StarForth

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Chapter 1

include/

Public headers for the hosted StarForth VM (src/). Kernel-only headers live under include/starkernel/.

Core VM

- vm.h — the VM struct and all core types (DictEntry, DictPhysics, stacks, dictionary state); the central header most other files include.
- vm_api.h — external VM API surface.
- vm_host.h, vm_debug.h, startup.h, version.h — host integration, debug utilities, startup sequencing, version string.
- cli.h, repl.h, io.h, log.h — CLI parsing, REPL loop, I/O, logging.
- word_registry.h — word registration system shared by every src/word_source/*.c file.
- compudynamics.h — the generic compudynamics module: tuning-word/config lookups (cd_tuning_word(), cd_tuning_vm()) consumed by ssm_jacquard.c.

Memory / blocks

- memory_management.h, dictionary_management.h — dictionary allocator and search.
- block_subsystem.h, blkcfg.h, blkio.h, blkio_factory.h — logical→ physical block mapper and pluggable block I/O backends (file/RAM).
- platform_alloc.h, platform_lock.h, platform_time.h — platform abstraction shims (hosted vs. kernel allocation/locking/timing).

Physics-driven adaptive runtime (7 feedback loops)

- physics_runtime.h — main physics coordinator.
- physics_hotwords_cache.h — Loop #1, execution-heat hot-words cache.
- physics_metadata.h — per-word DictPhysics metadata tracking.
- physics_pipelining_metrics.h — Loop #4, word-transition prediction.
- physics_execution_hooks.h — execution instrumentation hook points.

- rolling_window_of_truth.h, rolling_window_knobs.h — Loop #2 circular execution-history buffer and its tuning knobs.
- inference_engine.h — Loops #5/#6, window-width and decay-slope statistical inference.
- dictionary_heat_optimization.h — Loop #1 heat counters.
- ssm_jacquard.h — L8 Jacquard steady-state mode selector.
- doe_metrics.h — Design of Experiments (2^7 factorial) metrics.
- profiler.h — performance profiling hooks.

Arithmetic / codegen

- q48_16.h — Q48.16 deterministic fixed-point arithmetic (used instead of IEEE-754 float specifically to keep cross-architecture behavior bit-identical).
- math_portable.h — portable math helpers.
- arch_detect.h, starforth_config.h — architecture detection and the build-flag fallback-default layer (used when a .c file is compiled by hand without make).
- vm_asm_opt.h, vm_asm_opt_arm64.h, vm_asm_opt_riscv64.h, vm_inner_interp_asm.h, vm_inner_interp_arm64.h, vm_inner_interp_riscv64.h — per-architecture assembler-optimized inner interpreter (USE_ASM_OPT=1).

See include/starkernel/README.md for the bare-metal kernel headers.

Chapter 2

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Chapter 4

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Chapter 5

Topic Documentation

5.1 Architecture Detection

Automatic detection of target architecture and inclusion of optimization headers.

Automatic detection of target architecture and inclusion of optimization headers.

This module automatically detects the target architecture at compile time and includes the appropriate assembly optimization headers.

Supported architectures:

- x86_64 (AMD64, Intel 64)
- ARM64 (AArch64, ARMv8-A)

Unsupported architectures fall back to pure C implementations.

5.2 Unified API Wrappers

Consistent API macros across all architectures.

Consistent API macros across all architectures.

These macros provide a consistent API across all architectures by automatically dispatching to the appropriate optimized or fallback implementation based on the target architecture and available optimizations.

5.3 Runtime Architecture Detection

Runtime detection of CPU features.

Runtime detection of CPU features.

Functions for detecting available CPU features at runtime, such as SIMD support (SSE4.2, AVX, NEON) and other architecture-specific capabilities.

5.4 Build Information

Functions for querying build configuration.

Functions for querying build configuration.

Provides information about the build configuration, including target architecture, enabled optimizations, and threading model.

5.5 VM Input Operations

Public API for managing VM input operations including Terminal Input Buffer (TIB), input pointer (>IN), and input span (SPAN) handling.

Functions

- int vm_input_ensure (VM *vm)

  Ensure input buffers are allocated.
- unsigned char * vm_input_tib (VM *vm)

  Get pointer to terminal input buffer (TIB)
- cell_t * vm_input_in (VM *vm)

  Get pointer to input offset variable.
- cell_t * vm_input_span (VM *vm)

  Get pointer to input span variable.
- void vm_input_load_line (VM *vm, const char *src, size_t n)

  Load input line into TIB.
- void vm_input_source (VM *vm, cell_t *out_addr, cell_t *out_len)

  Get current input source buffer info.
- cell_t vm_addr_from_ptr (VM *vm, void *p)

  Convert native pointer to Forth memory address.

5.5.1 Detailed Description

Public API for managing VM input operations including Terminal Input Buffer (TIB), input pointer (>IN), and input span (SPAN) handling.

5.5.2 Function Documentation

5.5.2.1 vm_addr_from_ptr()

```
cell_t vm_addr_from_ptr (
            VM * vm,
            void * p )
```

Convert native pointer to Forth memory address.

Parameters

vm	VM instance
p	Native pointer to convert

Returns

Forth memory address (offset from VM memory base)

Converts a native C pointer to a Forth memory address by calculating offset from VM memory base. Returns 0 for invalid pointers.

References base, and VM::memory.

5.5.2.2 vm_input_ensure()

```
int vm_input_ensure (
            VM * vm )
```

Ensure input buffers are allocated.

Parameters

vm	VM instance

Returns

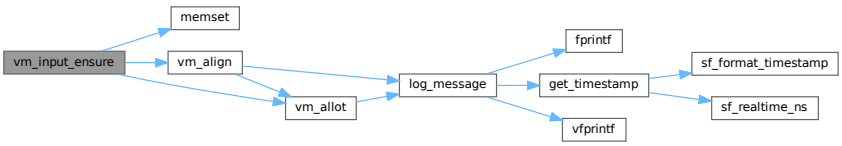
0 on success, 1 on error

Allocates TIB buffer and input variables if not already allocated

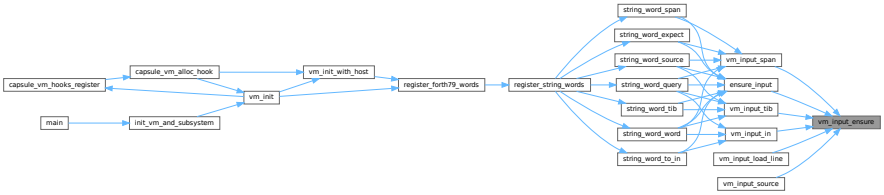
References VM::error, VM::in_var, INPUT_BUFFER_SIZE, memset(), VM::span_var, VM::tib_buf, VM::tib_cap, vm_align(), and vm_allot().

Referenced by ensure_input(), vm_input_in(), vm_input_load_line(), vm_input_source(), vm_input_span(), and vm_input_tib().

Here is the call graph for this function:



Here is the caller graph for this function:



5.5.2.3 vm_input_in()

```
cell_t * vm_input_in (
            VM * vm )
```

Get pointer to input offset variable.

Parameters

vm	VM instance

Returns

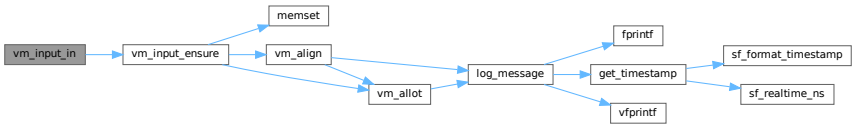
Pointer to input offset or NULL on error

Returns pointer to VM's input offset variable after ensuring it exists

References VM::in_var, and vm_input_ensure().

Referenced by string_word_query(), string_word_to_in(), and string_word_word().

Here is the call graph for this function:



Here is the caller graph for this function:

5.5.2.4 vm_input_load_line()

```
void vm_input_load_line (
            VM * vm,
            const char * src,
            size_t n )
```

Load input line into TIB.

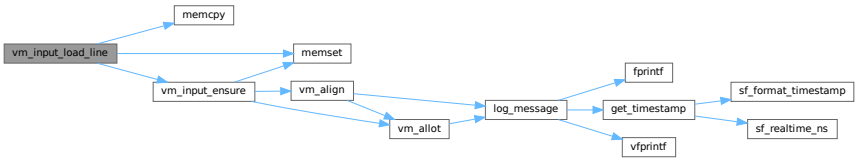
Parameters

vm	VM instance
src	Source string to load
n	Number of characters to load

Loads up to n characters from src into TIB, zero-pads remainder Resets input offset and updates span. Handles NULL src gracefully.

References VM::in_var, memcpy(), memset(), VM::span_var, VM::tib_buf, VM::tib_cap, and vm_input_ensure().

Here is the call graph for this function:



5.5.2.5 vm_input_source()

```
void vm_input_source (
            VM * vm,
            cell_t * out_addr,
            cell_t * out_len )
```

Get current input source buffer info.

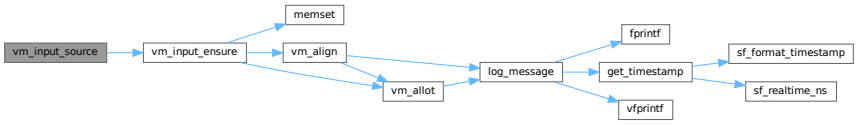
Parameters

vm	VM instance
out_addr	Output parameter for buffer address
out_len	Output parameter for buffer length

Returns current input buffer address and length through parameters Both parameters are optional (can be NULL)

References VM::span_var, VM::tib_buf, and vm_input_ensure().

Here is the call graph for this function:



5.5.2.6 vm_input_span()

```
cell_t * vm_input_span (
            VM * vm )
```

Get pointer to input span variable.

Parameters

vm	VM instance

Returns

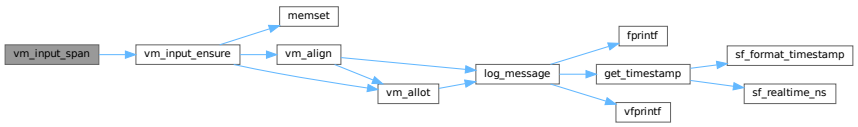
Pointer to span variable or NULL on error

Returns pointer to VM's input span variable after ensuring it exists

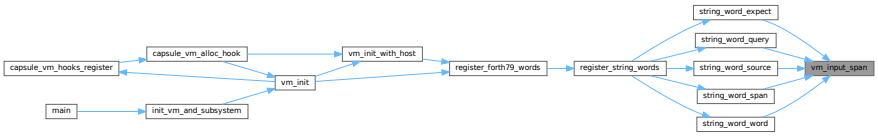
References VM::span_var, and vm_input_ensure().

Referenced by string_word_expect(), string_word_query(), string_word_source(), string_word_span(), and string_word_word().

Here is the call graph for this function:



Here is the caller graph for this function:



5.5.2.7 vm_input_tib()

```
unsigned char * vm_input_tib (
            VM * vm )
```

Get pointer to terminal input buffer (TIB)

Parameters

vm	VM instance

Returns

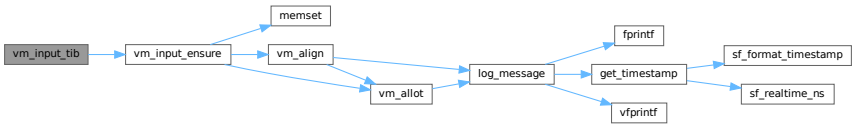
Pointer to TIB or NULL on error

Returns pointer to VM's terminal input buffer after ensuring it exists

References VM::tib_buf, and vm_input_ensure().

Referenced by string_word_query(), string_word_source(), string_word_tib(), and string_word_word().

Here is the call graph for this function:



Here is the caller graph for this function:

5.6 Stack Operations

Optimized stack manipulation operations.

Functions

- static void vm_push_asm (VM *vm, cell_t value)
  Optimized data stack push operation.
- static cell_t vm_pop_asm (VM *vm)
  Optimized data stack pop operation.
- static void vm_rpush_asm (VM *vm, cell_t value)
  Optimized return stack push operation.
- static cell_t vm_rpop_asm (VM *vm)
  Optimized return stack pop operation.
- static int vm_add_check_overflow (cell_t a, cell_t b, cell_t *result)
  Performs addition with hardware overflow detection.
- static int vm_sub_check_overflow (cell_t a, cell_t b, cell_t *result)
  Performs subtraction with hardware overflow detection.
- static void vm_mul_double (cell_t a, cell_t b, cell_t *hi, cell_t *lo)
  Performs double-width multiplication.
- static void vm_divmod (cell_t dividend, cell_t divisor, cell_t *quotient, cell_t *remainder)
  Performs division with remainder.
- static int vm_strcmp_asm (const char *s1, const char *s2, size_t len)
  Hardware-accelerated string comparison.
- static void vm_memcpy_asm (void *dest, const void *src, size_t len)
  Hardware-accelerated memory copy.
- static void vm_memzero_asm (void *dest, size_t len)
  Hardware-accelerated memory zero.
- static cell_t vm_min_asm (cell_t a, cell_t b)
  Branchless minimum calculation.
- static cell_t vm_max_asm (cell_t a, cell_t b)
  Branchless maximum calculation.
- static void vm_cpuid (uint32_t leaf, uint32_t *eax, uint32_t *ebx, uint32_t *ecx, uint32_t *edx)
  Wrapper for CPUID instruction.
- static int vm_has_sse42 (void)
  Checks for SSE4.2 support.

5.6.1 Detailed Description

Optimized stack manipulation operations.

Standard FORTH-79 stack manipulation words.

Critical optimizations for vm_push, vm_pop, vm_rpush, vm_rpop

Impact: EXTREME - These are called on nearly every Forth word execution

Benefits:

- Eliminates function call overhead (inline)
- Reduces branch mispredictions with conditional moves
- Keeps frequently-used values in registers
- Uses lea for pointer arithmetic (no flags affected)

L4Re Compatibility: YES - Pure computational code, no syscalls

The following FORTH words are implemented for stack manipulation:

- DROP (n –) Remove top stack item
- DUP (n – n n) Duplicate top stack item

- ?DUP (n – n n | n – 0) Duplicate if non-zero
- SWAP (n1 n2 – n2 n1) Exchange top two stack items
- OVER (n1 n2 – n1 n2 n1) Copy second stack item to top
- ROT (n1 n2 n3 – n2 n3 n1) Rotate top three stack items
- -ROT (n1 n2 n3 – n3 n1 n2) Reverse rotate top three items
- DEPTH (– n) Return number of stack items
- PICK (n – stack[n]) Copy nth stack item to top
- ROLL (n –) Move nth stack item to top

5.6.2 Function Documentation

5.6.2.1 vm_add_check_overflow()

```
static int vm_add_check_overflow (
            cell_t a,
            cell_t b,
            cell_t * result )  [inline], [static]
```

Performs addition with hardware overflow detection.

Parameters

a	First operand
b	Second operand
result	Pointer to store result

Returns

1 if overflow occurred, 0 otherwise

5.6.2.2 vm_cpuid()

```
static void vm_cpuid (
            uint32_t leaf,
            uint32_t * eax,
            uint32_t * ebx,
            uint32_t * ecx,
            uint32_t * edx )  [inline], [static]
```

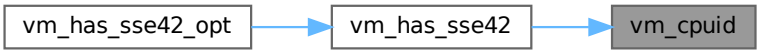
Wrapper for CPUID instruction.

Parameters

leaf	CPUID leaf number
eax	Pointer to store EAX result
ebx	Pointer to store EBX result
ecx	Pointer to store ECX result
edx	Pointer to store EDX result

Referenced by vm_has_sse42().

Here is the caller graph for this function:



5.6.2.3 vm_divmod()

```
static void vm_divmod (
             cell_t dividend,
             cell_t divisor,
             cell_t * quotient,
             cell_t * remainder )  [inline], [static]
```

Performs division with remainder.

Parameters

dividend	Dividend value
divisor	Divisor value
quotient	Pointer to store quotient
remainder	Pointer to store remainder

5.6.2.4 vm_has_sse42()

```
static int vm_has_sse42 (
             void  )  [inline], [static]
```

Checks for SSE4.2 support.

Returns

1 if SSE4.2 is supported, 0 otherwise

References vm_cpuid().

Referenced by vm_has_sse42_opt().

Here is the call graph for this function:

Here is the caller graph for this function:

5.6.2.5 vm_max_asm()

```
static cell_t vm_max_asm (
            cell_t a,
            cell_t b )  [inline], [static]
```

Branchless maximum calculation.

Parameters

a	First value
b	Second value

Returns

Larger of a and b

5.6.2.6 vm_memcpy_asm()

```
static void vm_memcpy_asm (
            void * dest,
```

```
            const void * src,
            size_t len )  [inline], [static]
```

Hardware-accelerated memory copy.

Parameters

dest	Destination buffer
src	Source buffer
len	Number of bytes to copy

5.6.2.7 vm_memzero_asm()

```
static void vm_memzero_asm (
            void * dest,
            size_t len )  [inline], [static]
```

Hardware-accelerated memory zero.

Parameters

dest	Buffer to zero
len	Number of bytes to zero

5.6.2.8 vm_min_asm()

```
static cell_t vm_min_asm (
            cell_t a,
            cell_t b )  [inline], [static]
```

Branchless minimum calculation.

Parameters

a	First value
b	Second value

Returns

Smaller of a and b

5.6.2.9 vm_mul_double()

```
static void vm_mul_double (
            cell_t a,
            cell_t b,
            cell_t * hi,
            cell_t * lo )  [inline], [static]
```

Performs double-width multiplication.

Parameters

a	First operand
b	Second operand
hi	Pointer to store high 64 bits
lo	Pointer to store low 64 bits

5.6.2.10 vm_pop_asm()

```
static cell_t vm_pop_asm (
            VM * vm )  [inline], [static]
```

Optimized data stack pop operation.

Parameters

vm	Pointer to VM context

Returns

Top value from stack, 0 on underflow

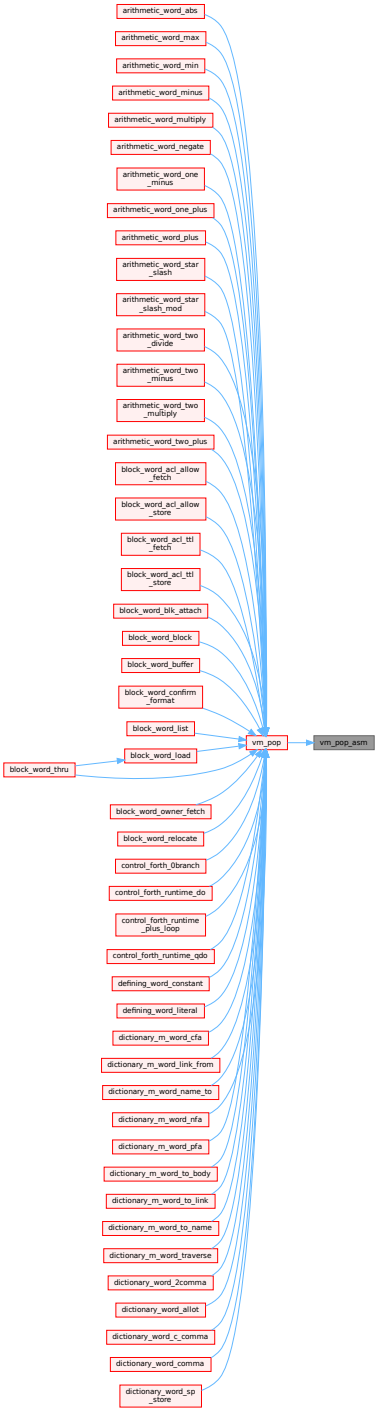
Note

Sets vm->error on stack underflow

References VM::data_stack, VM::dsp, and VM::error.

Referenced by vm_pop().

Here is the caller graph for this function:



5.6.2.11 vm_push_asm()

```
static void vm_push_asm (
            VM * vm,
            cell_t value )  [inline], [static]
```

Optimized data stack push operation.

Parameters

vm	Pointer to VM context
value	Value to push onto stack

Returns

void

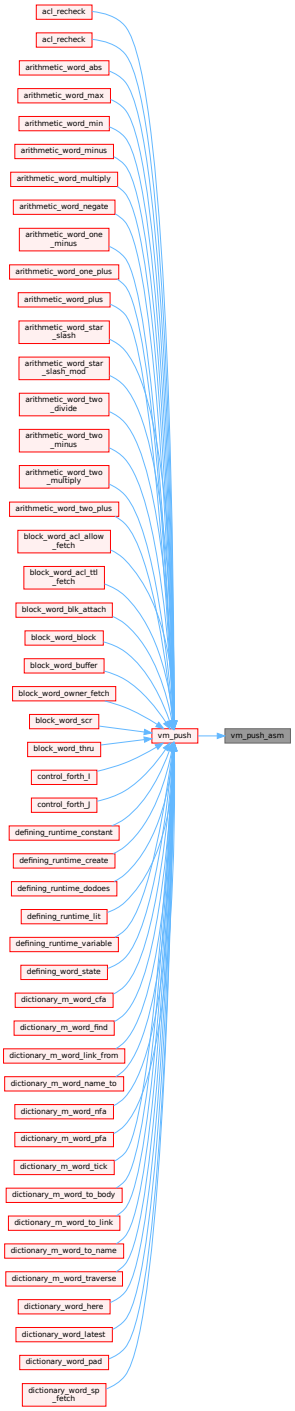
Note

Sets vm->error on stack overflow

References VM::data_stack, VM::dsp, and VM::error.

Referenced by vm_push().

Here is the caller graph for this function:



5.6.2.12 vm_rpop_asm()

```
static cell_t vm_rpop_asm (
            VM * vm )  [inline], [static]
```

Optimized return stack pop operation.

Parameters

vm	Pointer to VM context

Returns

Top value from return stack, 0 on underflow

Note

Sets vm->error on stack underflow

References VM::error, VM::return_stack, and VM::rsp.

Referenced by vm_rpop().

Here is the caller graph for this function:

5.6.2.13 vm_rpush_asm()

```
static void vm_rpush_asm (
            VM * vm,
            cell_t value )  [inline], [static]
```

Optimized return stack push operation.

Parameters

vm	Pointer to VM context
value	Value to push onto return stack

Returns

void

Note

Sets vm->error on stack overflow

References VM::error, VM::return_stack, and VM::rsp.

Referenced by vm_rpush().

Here is the caller graph for this function:

5.6.2.14 vm_strcmp_asm()

```
static int vm_strcmp_asm (
            const char * s1,
            const char * s2,
            size_t len )  [inline], [static]
```

Hardware-accelerated string comparison.

Parameters

s1	First string
s2	Second string
len	Length to compare

Returns

0 if equal, non-zero otherwise

5.6.2.15 vm_sub_check_overflow()

```
static int vm_sub_check_overflow (
            cell_t a,
            cell_t b,
            cell_t * result )  [inline], [static]
```

Performs subtraction with hardware overflow detection.

Parameters

a	First operand (minuend)
b	Second operand (subtrahend)
result	Pointer to store result

Returns

1 if overflow occurred, 0 otherwise

5.7 Fast Primitive Word Implementations

Register-based stack primitives optimized for ARM64.

Macros

- #define PRIM_DUP_ARM64()

  DUP primitive - duplicates top of stack item.
- #define PRIM_DROP_ARM64()
- #define PRIM_SWAP_ARM64()
- #define PRIM_OVER_ARM64()
- #define PRIM_ROT_ARM64()
- #define PRIM_PLUS_ARM64()
- #define PRIM_MINUS_ARM64()
- #define PRIM_STAR_ARM64()
- #define PRIM_SLASH_ARM64()
- #define PRIM_MOD_ARM64()
- #define PRIM_AND_ARM64()
- #define PRIM_OR_ARM64()
- #define PRIM_XOR_ARM64()
- #define PRIM_INVERT_ARM64()
- #define PRIM_NEGATE_ARM64()
- #define PRIM_FETCH_ARM64()
- #define PRIM_STORE_ARM64()
- #define PRIM_C_FETCH_ARM64()
- #define PRIM_C_STORE_ARM64()
- #define PRIM_TO_R_ARM64()
- #define PRIM_R_FROM_ARM64()
- #define PRIM_R_FETCH_ARM64()
- #define PRIM_2DUP_ARM64()
- #define PRIM_2DROP_ARM64()
- #define PRIM_ZERO_EQUALS_ARM64()
- #define PRIM_ZERO_LESS_ARM64()
- #define PRIM_EQUALS_ARM64()
- #define PRIM_LESS_ARM64()
- #define PRIM_GREATER_ARM64()
- #define PRIM_BRANCH_ARM64()
- #define PRIM_ZBRANCH_ARM64()
- #define PRIM_EXECUTE_ARM64()

5.7.1 Detailed Description

Register-based stack primitives optimized for ARM64.

Key optimization: TOS stays in x23, avoiding memory traffic

5.7.2 Macro Definition Documentation

5.7.2.1 PRIM_2DROP_ARM64

```
#define PRIM_2DROP_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x23, [x21, #-8]\n\t"     /* Load new TOS */ \
        "sub     x21, x21, #16\n\t"       /* DSP -= 2 */ \
        ::: "x21", "x23", "memory" \
    )
```

5.7.2.2 PRIM_2DUP_ARM64

```
#define PRIM_2DUP_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21]\n\t"           /* Load NOS */ \
        "stp     x0, x23, [x21, #8]\n\t"  /* Store pair */ \
        "add     x21, x21, #16\n\t"       /* DSP += 2 */ \
        ::: "x0", "x21", "memory" \
    )
```

5.7.2.3 PRIM_AND_ARM64

```
#define PRIM_AND_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t" \
        "and     x23, x23, x0\n\t" \
        ::: "x0", "x21", "x23" \
    )
```

5.7.2.4 PRIM_BRANCH_ARM64

```
#define PRIM_BRANCH_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x20]\n\t"           /* Load offset */ \
        "add     x20, x20, x0\n\t"        /* IP += offset */ \
        ::: "x0", "x20", "memory" \
    )
```

5.7.2.5 PRIM_C_FETCH_ARM64

```
#define PRIM_C_FETCH_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x19]\n\t" \
        "ldrb    w23, [x0, x23]\n\t"      /* Load byte, zero-extend */ \
        ::: "x0", "x23", "memory" \
    )
```

5.7.2.6 PRIM_C_STORE_ARM64

```
#define PRIM_C_STORE_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t" \
        "ldr     x1, [x19]\n\t" \
        "strb    w23, [x1, x0]\n\t"       /* Store byte */ \
        "ldr     x23, [x21]\n\t" \
        ::: "x0", "x1", "x21", "x23", "memory" \
    )
```

5.7.2.7 PRIM_DROP_ARM64

```
#define PRIM_DROP_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x23, [x21], #-8\n\t"     /* Load new TOS, decrement DSP */ \
        ::: "x21", "x23", "memory" \
    )
```

5.7.2.8 PRIM_DUP_ARM64

```
#define PRIM_DUP_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "str     x23, [x21, #8]!\n\t"     /* Store TOS, advance DSP */ \
        ::: "x21", "memory" \
    )
```

DUP primitive - duplicates top of stack item.

5.7.2.9 PRIM_EQUALS_ARM64

```
#define PRIM_EQUALS_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t" \
        "cmp     x0, x23\n\t" \
        "cset    x23, eq\n\t" \
        "neg     x23, x23\n\t" \
        ::: "x0", "x21", "x23", "cc" \
    )
```

5.7.2.10 PRIM_EXECUTE_ARM64

```
#define PRIM_EXECUTE_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x23, [x21], #-8\n\t"     /* Load new TOS */ \
        "br      x0\n\t"                  /* Branch to xt */ \
        ::: "x0", "x21", "x23", "memory" \
    )
```

5.7.2.11 PRIM_FETCH_ARM64

```
#define PRIM_FETCH_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x19]\n\t"           /* Load VM->memory */ \
        "ldr     x23, [x0, x23]\n\t"      /* TOS = memory[TOS] */ \
        ::: "x0", "x23", "memory" \
    )
```

5.7.2.12 PRIM_GREATER_ARM64

```
#define PRIM_GREATER_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t" \
        "cmp     x0, x23\n\t" \
        "cset    x23, gt\n\t" \
        "neg     x23, x23\n\t" \
        ::: "x0", "x21", "x23", "cc" \
    )
```

5.7.2.13 PRIM_INVERT_ARM64

```
#define PRIM_INVERT_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "mvn     x23, x23\n\t" \
        ::: "x23" \
    )
```

5.7.2.14 PRIM_LESS_ARM64

```
#define PRIM_LESS_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t" \
        "cmp     x0, x23\n\t" \
        "cset    x23, lt\n\t" \
        "neg     x23, x23\n\t" \
        ::: "x0", "x21", "x23", "cc" \
    )
```

5.7.2.15 PRIM_MINUS_ARM64

```
#define PRIM_MINUS_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t"      /* Load NOS, decrement DSP */ \
        "sub     x23, x0, x23\n\t"        /* TOS = NOS - TOS */ \
        ::: "x0", "x21", "x23" \
    )
```

5.7.2.16 PRIM_MOD_ARM64

```
#define PRIM_MOD_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t"      /* Load NOS, decrement DSP */ \
        "sdiv    x1, x0, x23\n\t"         /* quotient = NOS / TOS */ \
        "msub    x23, x1, x23, x0\n\t"    /* TOS = NOS - quotient * TOS */ \
        ::: "x0", "x1", "x21", "x23" \
    )
```

5.7.2.17 PRIM_NEGATE_ARM64

```
#define PRIM_NEGATE_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "neg     x23, x23\n\t" \
        ::: "x23" \
    )
```

5.7.2.18 PRIM_OR_ARM64

```
#define PRIM_OR_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t" \
        "orr     x23, x23, x0\n\t" \
        ::: "x0", "x21", "x23" \
    )
```

5.7.2.19 PRIM_OVER_ARM64

```
#define PRIM_OVER_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21]\n\t"           /* Load NOS */ \
        "str     x23, [x21, #8]!\n\t"     /* Store TOS, advance DSP */ \
        "mov     x23, x0\n\t"             /* TOS = NOS */ \
        ::: "x0", "x21", "x23", "memory" \
    )
```

5.7.2.20 PRIM_PLUS_ARM64

```
#define PRIM_PLUS_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t"      /* Load NOS, decrement DSP */ \
        "add     x23, x23, x0\n\t"        /* TOS = TOS + NOS */ \
        ::: "x0", "x21", "x23" \
    )
```

5.7.2.21 PRIM_R_FETCH_ARM64

```
#define PRIM_R_FETCH_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "str     x23, [x21, #8]!\n\t"     /* Store TOS, advance DSP */ \
        "ldr     x23, [x22, #-8]\n\t"     /* Load from RS (don't pop) */ \
        ::: "x21", "x23", "memory" \
    )
```

5.7.2.22 PRIM_R_FROM_ARM64

```
#define PRIM_R_FROM_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "str     x23, [x21, #8]!\n\t"     /* Store TOS, advance DSP */ \
        "ldr     x23, [x22, #-8]!\n\t"    /* Load from RS, decrement RSP */ \
        ::: "x21", "x22", "x23", "memory" \
    )
```

5.7.2.23 PRIM_ROT_ARM64

```
#define PRIM_ROT_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21]\n\t"           /* Load item2 */ \
        "ldr     x1, [x21, #-8]\n\t"      /* Load item3 */ \
        "str     x1, [x21]\n\t"           /* item3 -> NOS */ \
        "str     x23, [x21, #-8]\n\t"     /* TOS -> item3 */ \
        "mov     x23, x0\n\t"             /* item2 -> TOS */ \
        ::: "x0", "x1", "x23", "memory" \
    )
```

5.7.2.24 PRIM_SLASH_ARM64

```
#define PRIM_SLASH_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t"      /* Load NOS (dividend), decrement DSP */ \
        "sdiv    x23, x0, x23\n\t"        /* TOS = NOS / TOS */ \
        ::: "x0", "x21", "x23" \
    )
```

5.7.2.25 PRIM_STAR_ARM64

```
#define PRIM_STAR_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t"      /* Load NOS, decrement DSP */ \
        "mul     x23, x23, x0\n\t"        /* TOS = TOS * NOS */ \
        ::: "x0", "x21", "x23" \
    )
```

5.7.2.26 PRIM_STORE_ARM64

```
#define PRIM_STORE_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t"      /* Load address, decrement DSP */ \
        "ldr     x1, [x19]\n\t"           /* Load VM->memory */ \
        "str     x23, [x1, x0]\n\t"       /* memory[addr] = value */ \
        "ldr     x23, [x21]\n\t"          /* Load new TOS */ \
        ::: "x0", "x1", "x21", "x23", "memory" \
    )
```

5.7.2.27 PRIM_SWAP_ARM64

```
#define PRIM_SWAP_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21]\n\t"           /* Load NOS */ \
        "str     x23, [x21]\n\t"          /* Store TOS to NOS position */ \
        "mov     x23, x0\n\t"             /* TOS = old NOS */ \
        ::: "x0", "x23", "memory" \
    )
```

5.7.2.28 PRIM_TO_R_ARM64

```
#define PRIM_TO_R_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "str     x23, [x22], #8\n\t"      /* Store to RS, advance RSP */ \
        "ldr     x23, [x21], #-8\n\t"     /* Load new TOS, decrement DSP */ \
        ::: "x21", "x22", "x23", "memory" \
    )
```

5.7.2.29 PRIM_XOR_ARM64

```
#define PRIM_XOR_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x21], #-8\n\t" \
        "eor     x23, x23, x0\n\t" \
        ::: "x0", "x21", "x23" \
    )
```

5.7.2.30 PRIM_ZBRANCH_ARM64

```
#define PRIM_ZBRANCH_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x20]\n\t"           /* Load offset */ \
        "cmp     x23, #0\n\t" \
        "add     x1, x20, x0\n\t"         /* Calculate target */ \
        "add     x2, x20, #8\n\t"         /* Calculate skip */ \
        "csel    x20, x1, x2, eq\n\t"     /* Select target if zero */ \
        "ldr     x23, [x21], #-8\n\t"     /* Load new TOS */ \
        ::: "x0", "x1", "x2", "x20", "x21", "x23", "cc", "memory" \
    )
```

5.7.2.31 PRIM_ZERO_EQUALS_ARM64

```
#define PRIM_ZERO_EQUALS_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "cmp     x23, #0\n\t" \
        "cset    x23, eq\n\t"             /* Set to 1 if zero, else 0 */ \
        "neg     x23, x23\n\t"            /* Convert to -1 (true flag) */ \
        ::: "x23", "cc" \
    )
```

5.7.2.32 PRIM_ZERO_LESS_ARM64

```
#define PRIM_ZERO_LESS_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "cmp     x23, #0\n\t" \
        "cset    x23, lt\n\t" \
        "neg     x23, x23\n\t" \
        ::: "x23", "cc" \
    )
```

5.8 Control Flow Stack

Compile-time control flow stack for tracking branch targets and loop structures.

Functions

- static void cf_epoch_sync (VM *vm)
- static int cf_push_item (VM *vm, cf_tag_t tag, size_t mark)
- static int cf_pop_item (VM *vm, cf_item_t *out)
- static int cf_peek_item (VM *vm, cf_item_t *out)

5.8.1 Detailed Description

Compile-time control flow stack for tracking branch targets and loop structures.

The types (cf_tag_t, cf_item_t, ControlFlowState) and the CF_STACK_MAX constant live in include/vm.h and the storage itself lives per-VM at vm->cf, so two VMs compiling colon definitions concurrently never share nesting state (see include/vm.h's ControlFlowState comment).

5.8.2 Function Documentation

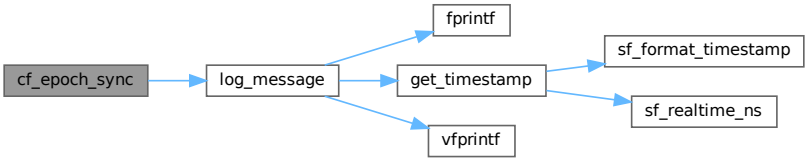
5.8.2.1 cf_epoch_sync()

```
static void cf_epoch_sync (
            VM * vm )  [inline], [static]
```

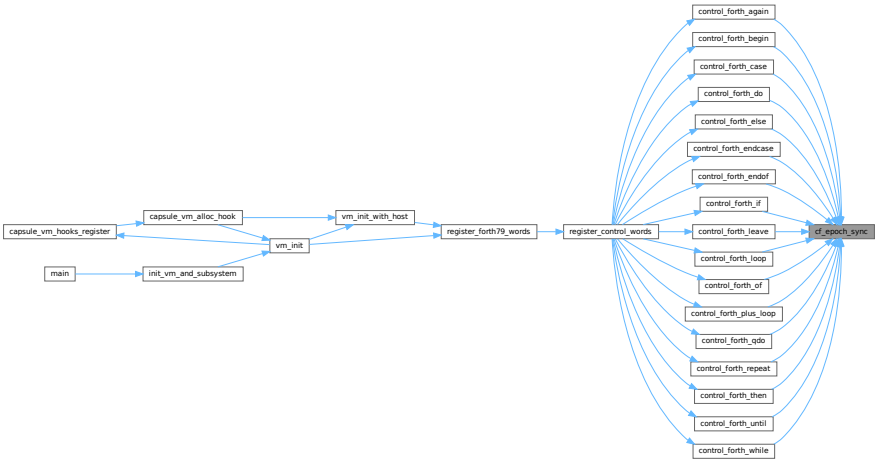
References VM::cf, ControlFlowState::cf_last_mode, ControlFlowState::cf_sp, LOG_DEBUG, log_message(), and VM::mode.

Referenced by control_forth_again(), control_forth_begin(), control_forth_case(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_if(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_then(), control_forth_until(), and control_forth_while().

Here is the call graph for this function:



Here is the caller graph for this function:



5.8.2.2 cf_peek_item()

```
static int cf_peek_item (
            VM * vm,
            cf_item_t * out )  [inline], [static]
```

References VM::cf, ControlFlowState::cf_sp, and ControlFlowState::cf_stack.

Referenced by control_forth_else(), control_forth_loop(), control_forth_plus_loop(), and control_forth_while().

Here is the caller graph for this function:

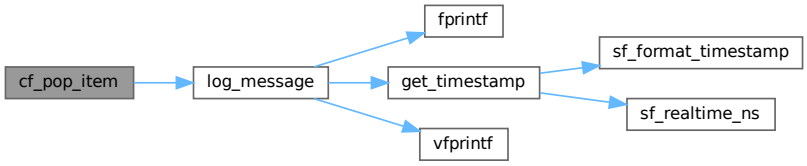
5.8.2.3 cf_pop_item()

```
static int cf_pop_item (
            VM * vm,
            cf_item_t * out )  [inline], [static]
```

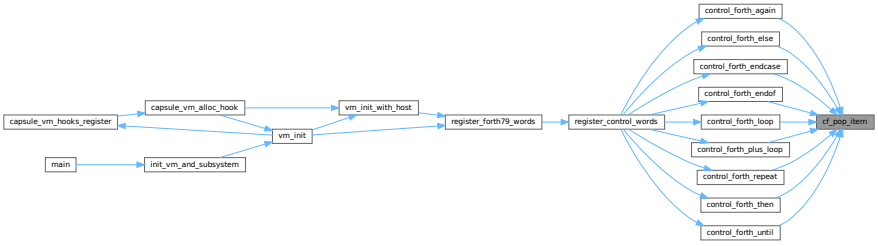
References VM::cf, ControlFlowState::cf_sp, ControlFlowState::cf_stack, LOG_ERROR, and log_message().

Referenced by control_forth_again(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_loop(), control_forth_plus_loop(), control_forth_repeat(), control_forth_then(), and control_forth_until().

Here is the call graph for this function:



Here is the caller graph for this function:



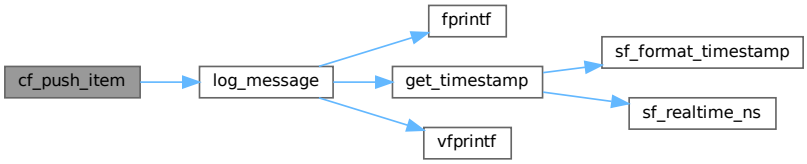
5.8.2.4 cf_push_item()

```
static int cf_push_item (
            VM * vm,
            cf_tag_t tag,
            size_t mark )  [inline], [static]
```

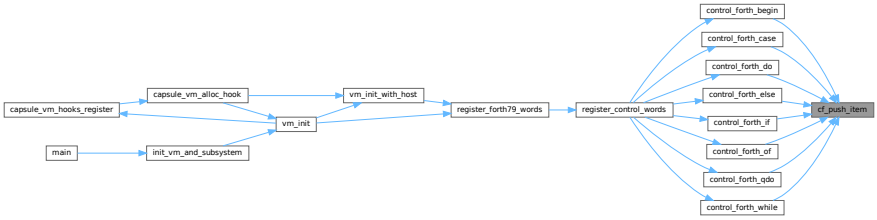
References cf_item_t::addr, VM::cf, ControlFlowState::cf_sp, ControlFlowState::cf_stack, CF_STACK_MAX, LOG_ERROR, log_message(), and cf_item_t::tag.

Referenced by control_forth_begin(), control_forth_case(), control_forth_do(), control_forth_else(), control_forth_if(), control_forth_of(), control_forth_qdo(), and control_forth_while().

Here is the call graph for this function:



Here is the caller graph for this function:



5.9 Runtime Branch Helpers

Runtime support for control flow operations.

Functions

- static void control_forth_UNLOOP (VM *vm)
- static void control_forth_if (VM *vm)
- static void control_forth_else (VM *vm)
- static void control_forth_then (VM *vm)
- static void control_forth_begin (VM *vm)
- static void control_forth_until (VM *vm)
- static void control_forth_again (VM *vm)
- static void control_forth_while (VM *vm)
- static void control_forth_repeat (VM *vm)
- static void control_forth_qdo (VM *vm)
- static void control_forth_do (VM *vm)
- static void control_forth_leave (VM *vm)
- static void control_forth_loop (VM *vm)
- static void control_forth_plus_loop (VM *vm)
- static void control_forth_case (VM *vm)
- static void control_forth_of (VM *vm)
- static void control_forth_endof (VM *vm)
- static void control_forth_endcase (VM *vm)
- void register_control_words (VM *vm)

  Registers all control flow words with the Forth virtual machine.

Internal Runtime Functions

Forward declarations for internal runtime helpers and control flow primitives

- static void control_forth_branch (VM *vm)
  Execute unconditional branch.
- static void control_forth_0branch (VM *vm)
  Execute conditional branch based on top of stack.
- static void control_forth_runtime_qdo (VM *vm)
  Runtime handler for ?DO loops.
- static void control_forth_runtime_do (VM *vm)
  Runtime handler for DO loops.
- static void control_forth_runtime_loop (VM *vm)
  Runtime handler for LOOP.
- static void control_forth_runtime_plus_loop (VM *vm)
  Runtime handler for +LOOP.
- static void control_forth_runtime_leave (VM *vm)
  Runtime handler for LEAVE.
- static void control_forth_I (VM *vm)
  Get current loop index.
- static void control_forth_J (VM *vm)
  Get outer loop index.
- static void control_forth_EXIT (VM *vm)
  Exit from current definition.

5.9.1 Detailed Description

Runtime support for control flow operations.

All functions operate on the per-step return IP (top of RS). All offsets are in BYTES.

5.9.2 Function Documentation

5.9.2.1 control_forth_0branch()

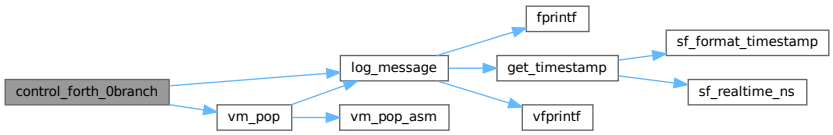
```
static void control_forth_0branch (
            VM * vm )  [static]
```

Execute conditional branch based on top of stack.

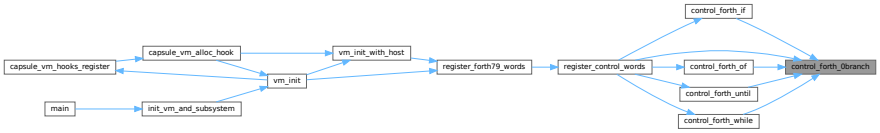
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, and vm_pop().

Referenced by control_forth_if(), control_forth_of(), control_forth_until(), control_forth_while(), and register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



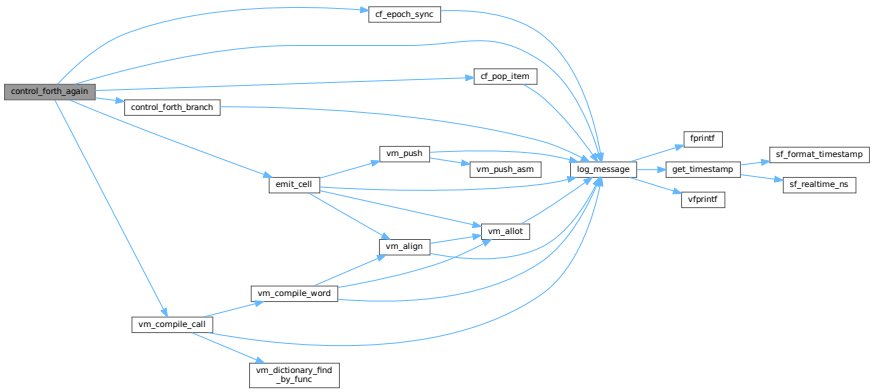
5.9.2.2 control_forth_again()

```
static void control_forth_again (
            VM * vm )  [static]
```

References cf_item_t::addr, CF_BEGIN, cf_epoch_sync(), cf_pop_item(), control_forth_branch(), emit_cell(), VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

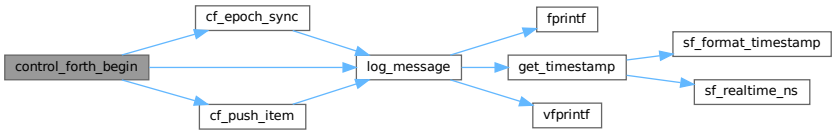
5.9.2.3 control_forth_begin()

```
static void control_forth_begin (
            VM * vm )  [static]
```

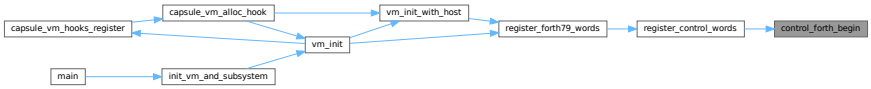
References CF_BEGIN, cf_epoch_sync(), cf_push_item(), VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, and MODE_COMPILE.

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



5.9.2.4 control_forth_branch()

```
static void control_forth_branch (
            VM * vm )  [static]
```

Execute unconditional branch.

Runtime unconditional branch.

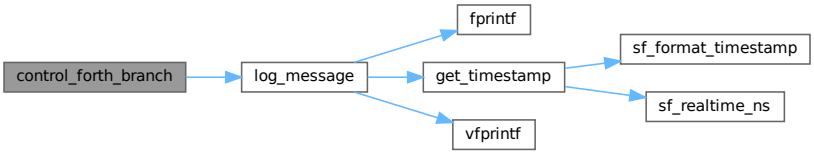
Parameters

vm	Virtual machine state

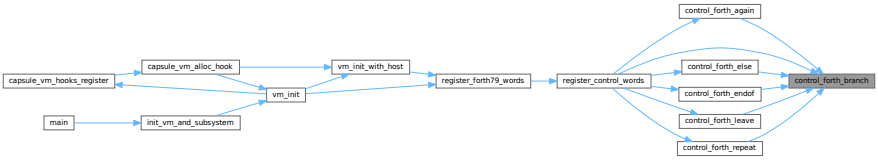
References VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::return_stack, and VM::rsp.

Referenced by control_forth_again(), control_forth_else(), control_forth_endof(), control_forth_leave(), control_forth_repeat(), and register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



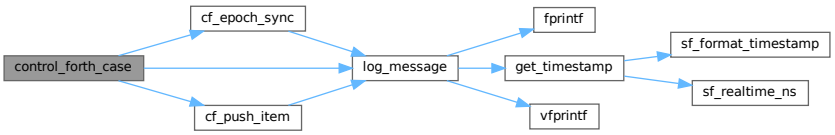
5.9.2.5 control_forth_case()

```
static void control_forth_case (
            VM * vm )  [static]
```

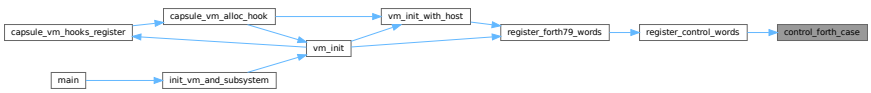
References VM::cf, CF_CASE, cf_epoch_sync(), cf_push_item(), CF_STACK_MAX, ControlFlowState::endof_mark_sp, ControlFlowState::endof_mark_stack, ControlFlowState::endof_sp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, and MODE_COMPILE.

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



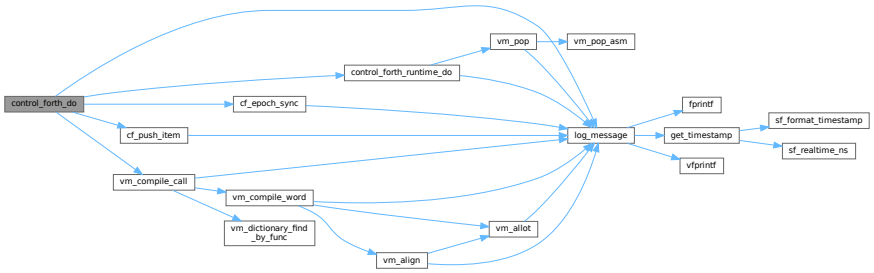
5.9.2.6 control_forth_do()

```
static void control_forth_do (
            VM * vm )  [static]
```

References VM::cf, CF_DO, cf_epoch_sync(), cf_push_item(), control_forth_runtime_do(), VM::error, VM::here, ControlFlowState::leave_mark_sp, ControlFlowState::leave_mark_stack, ControlFlowState::leave_sp, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

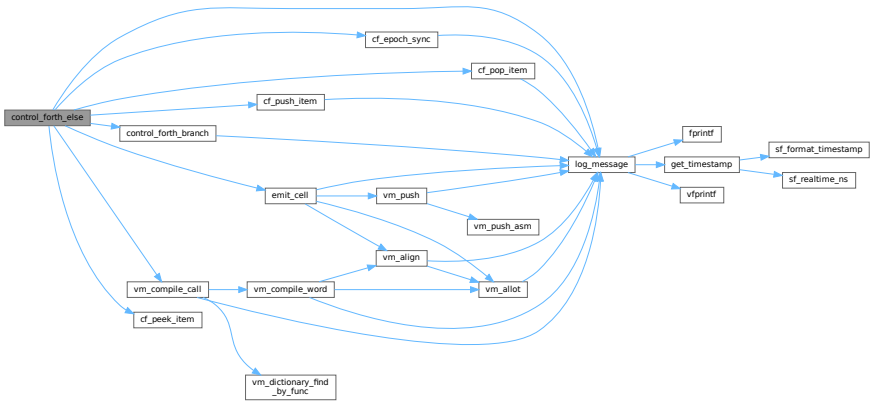
5.9.2.7 control_forth_else()

```
static void control_forth_else (
            VM * vm )  [static]
```

References cf_item_t::addr, CF_ELSE, cf_epoch_sync(), CF_IF, cf_peek_item(), cf_pop_item(), cf_push_item(), control_forth_branch(), emit_cell(), VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), VM::memory, VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

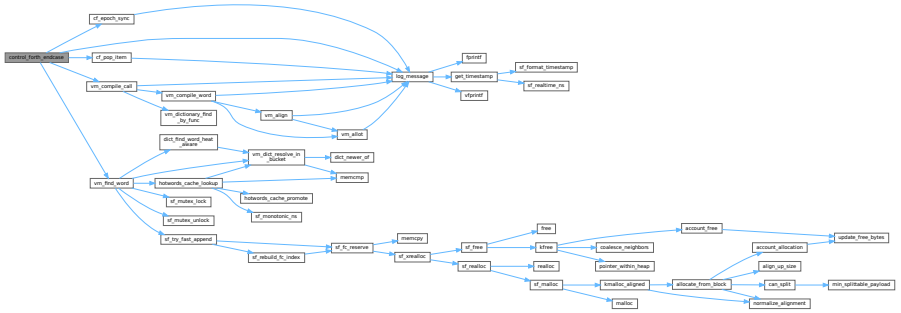
5.9.2.8 control_forth_endcase()

```
static void control_forth_endcase (
            VM * vm )  [static]
```

References VM::cf, CF_CASE, cf_epoch_sync(), cf_pop_item(), ControlFlowState::endof_addrs, ControlFlowState::endof_mark_sp, ControlFlowState::endof_mark_stack, ControlFlowState::endof_sp, VM::error, DictEntry::func, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), VM::memory, VM::mode, MODE_COMPILE, cf_item_t::tag, vm_compile_call(), and vm_find_word().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

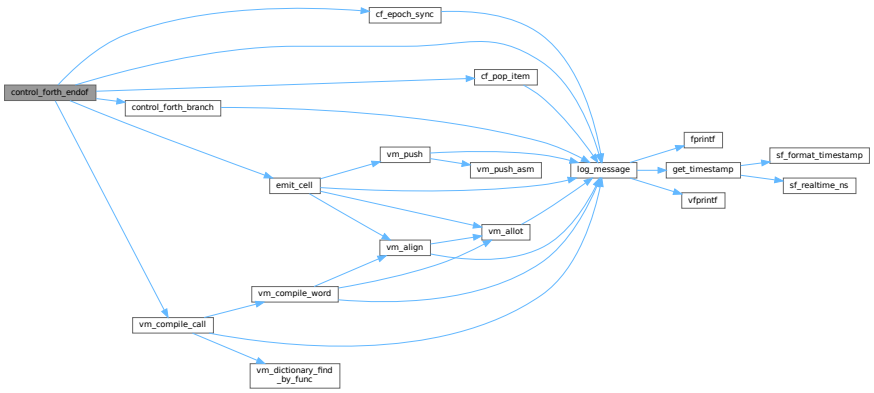
5.9.2.9 control_forth_endof()

```
static void control_forth_endof (
            VM * vm )  [static]
```

References cf_item_t::addr, VM::cf, cf_epoch_sync(), CF_OF, cf_pop_item(), CF_STACK_MAX, control_forth_branch(), emit_cell(), ControlFlowState::endof_addrs, ControlFlowState::endof_sp, VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), VM::memory, VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

5.9.2.10 control_forth_EXIT()

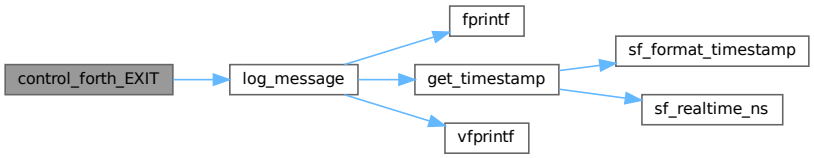
```
static void control_forth_EXIT (
            VM * vm )  [static]
```

Exit from current definition.

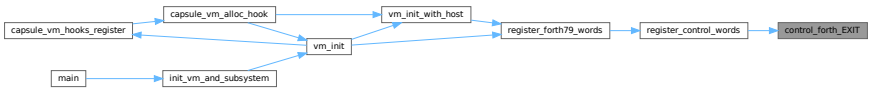
References VM::error, VM::exit_colon, LOG_DEBUG, LOG_ERROR, log_message(), and VM::rsp.

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



5.9.2.11 control_forth_I()

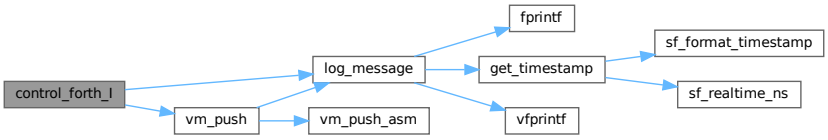
```
static void control_forth_I (
            VM * vm )  [static]
```

Get current loop index.

References VM::error, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, and vm_push().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

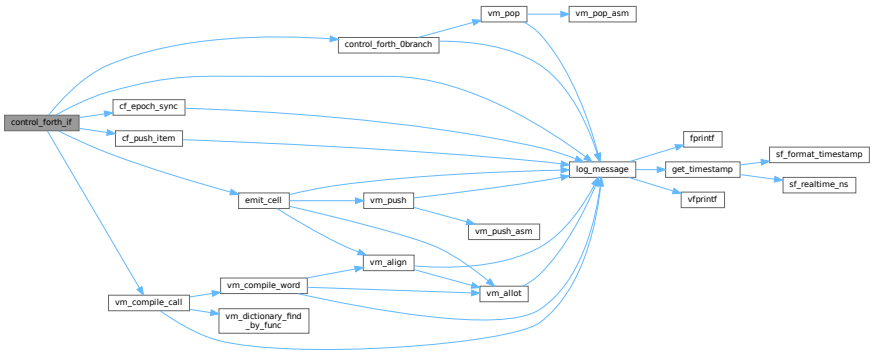
5.9.2.12 control_forth_if()

```
static void control_forth_if (
            VM * vm )  [static]
```

References cf_epoch_sync(), CF_IF, cf_push_item(), control_forth_0branch(), emit_cell(), VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

5.9.2.13 control_forth_J()

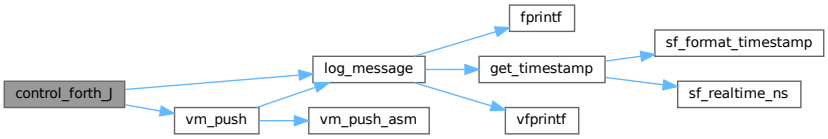
```
static void control_forth_J (
            VM * vm )  [static]
```

Get outer loop index.

References VM::error, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, and vm_push().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

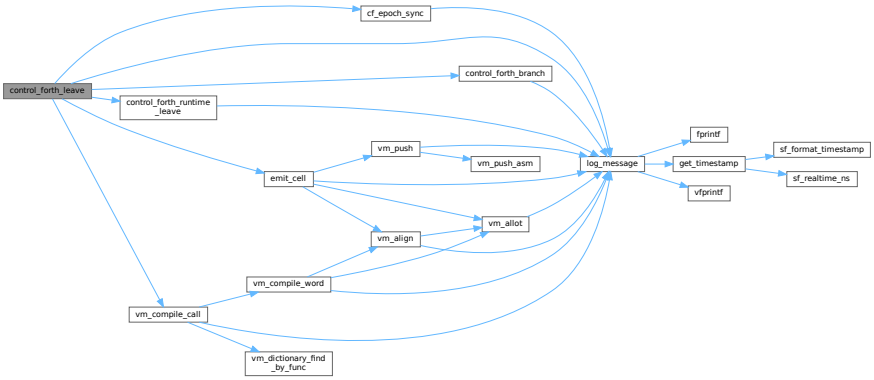
5.9.2.14 control_forth_leave()

```
static void control_forth_leave (
            VM * vm )  [static]
```

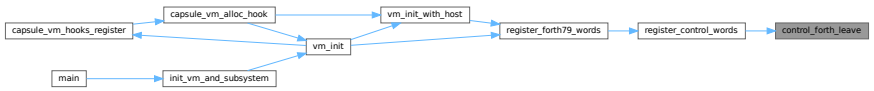
References VM::cf, CF_DO, cf_epoch_sync(), ControlFlowState::cf_sp, ControlFlowState::cf_stack, CF_STACK_MAX, control_forth_branch(), control_forth_runtime_leave(), emit_cell(), VM::error, ControlFlowState::leave_addrs, ControlFlowState::leave_mark_sp, ControlFlowState::leave_sp, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



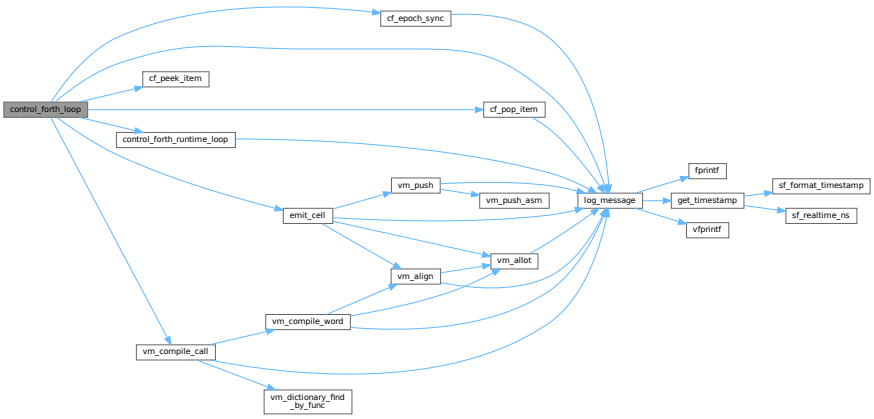
5.9.2.15 control_forth_loop()

```
static void control_forth_loop (
            VM * vm )  [static]
```

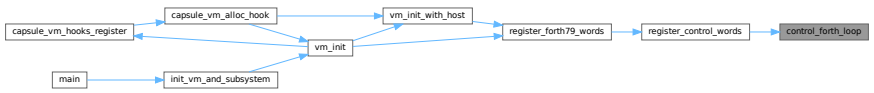
References cf_item_t::addr, VM::cf, CF_DO, cf_epoch_sync(), cf_peek_item(), cf_pop_item(), CF_WHILE, control_forth_runtime_loop(), emit_cell(), VM::error, VM::here, ControlFlowState::leave_addrs, ControlFlowState::leave_mark_sp, ControlFlowState::leave_mark_stack, ControlFlowState::leave_sp, LOG_DEBUG, LOG_ERROR, log_message(), VM::memory, VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



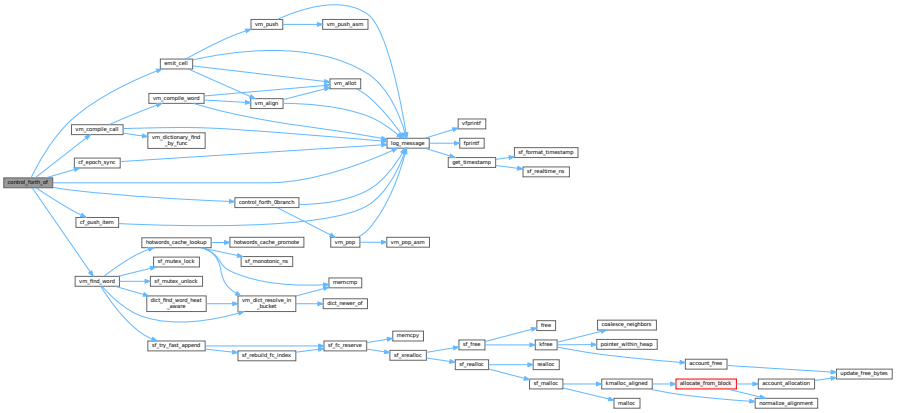
5.9.2.16 control_forth_of()

```
static void control_forth_of (
            VM * vm )  [static]
```

References VM::cf, CF_CASE, cf_epoch_sync(), CF_OF, cf_push_item(), ControlFlowState::cf_sp, ControlFlowState::cf_stack, control_forth_0branch(), emit_cell(), VM::error, DictEntry::func, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, cf_item_t::tag, vm_compile_call(), and vm_find_word().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

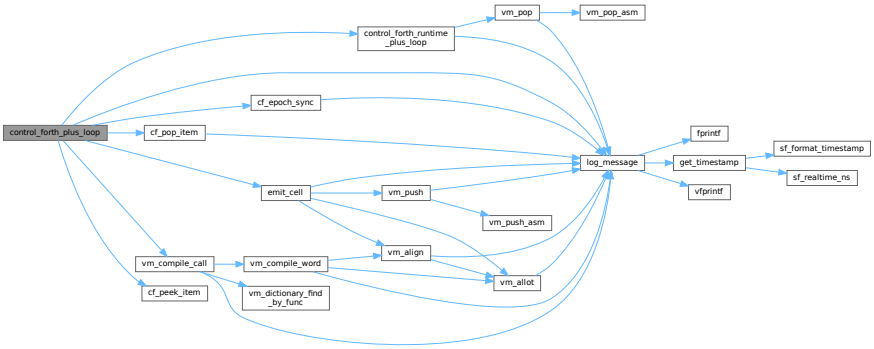
5.9.2.17 control_forth_plus_loop()

```
static void control_forth_plus_loop (
            VM * vm )  [static]
```

References cf_item_t::addr, VM::cf, CF_DO, cf_epoch_sync(), cf_peek_item(), cf_pop_item(), CF_WHILE, control_forth_runtime_plus_loop(), emit_cell(), VM::error, VM::here, ControlFlowState::leave_addrs, ControlFlowState::leave_mark_sp, ControlFlowState::leave_mark_stack, ControlFlowState::leave_sp, LOG_DEBUG, LOG_ERROR, log_message(), VM::memory, VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

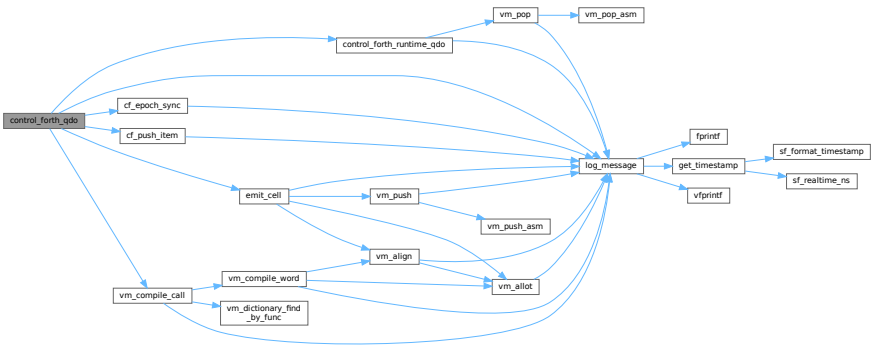
5.9.2.18 control_forth_qdo()

```
static void control_forth_qdo (
            VM * vm )  [static]
```

References VM::cf, CF_DO, cf_epoch_sync(), cf_push_item(), CF_WHILE, control_forth_runtime_qdo(), emit_cell(), VM::error, VM::here, ControlFlowState::leave_mark_sp, ControlFlowState::leave_mark_stack, ControlFlowState::leave_sp, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

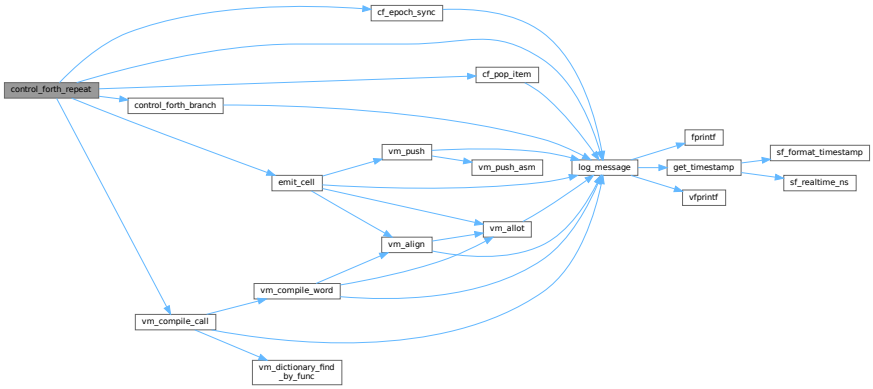
5.9.2.19 control_forth_repeat()

```
static void control_forth_repeat (
            VM * vm )  [static]
```

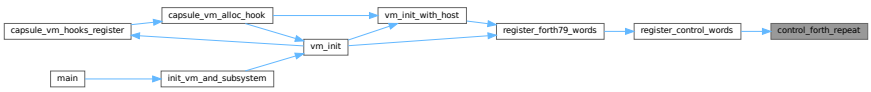
References cf_item_t::addr, CF_BEGIN, cf_epoch_sync(), cf_pop_item(), CF_WHILE, control_forth_branch(), emit_cell(), VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), VM::memory, VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



5.9.2.20 control_forth_runtime_do()

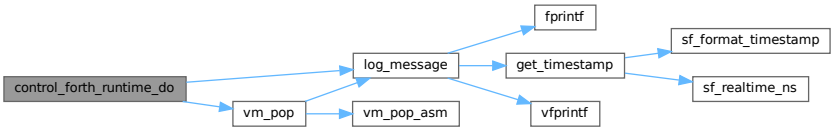
```
static void control_forth_runtime_do (
            VM * vm )  [static]
```

Runtime handler for DO loops.

References VM::dsp, VM::error, limit, LOG_DEBUG, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, STACK_SIZE, and vm_pop().

Referenced by control_forth_do(), and register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

5.9.2.21 control_forth_runtime_leave()

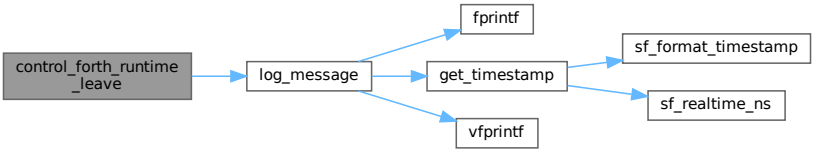
```
static void control_forth_runtime_leave (
            VM * vm )  [static]
```

Runtime handler for LEAVE.

References VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::return_stack, and VM::rsp.

Referenced by control_forth_leave(), and register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

5.9.2.22 control_forth_runtime_loop()

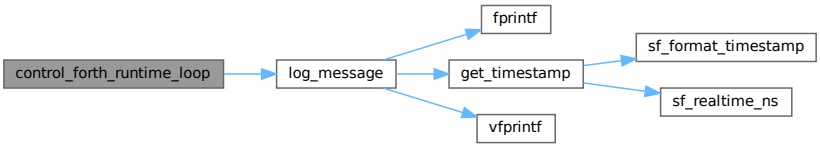
```
static void control_forth_runtime_loop (
            VM * vm )  [static]
```

Runtime handler for LOOP.

References VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::return_stack, and VM::rsp.

Referenced by control_forth_loop(), and register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

5.9.2.23 control_forth_runtime_plus_loop()

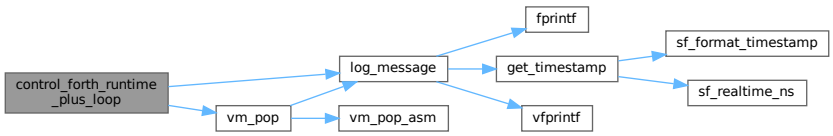
```
static void control_forth_runtime_plus_loop (
            VM * vm )  [static]
```

Runtime handler for +LOOP.

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, and vm_pop().

Referenced by control_forth_plus_loop(), and register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

5.9.2.24 control_forth_runtime_qdo()

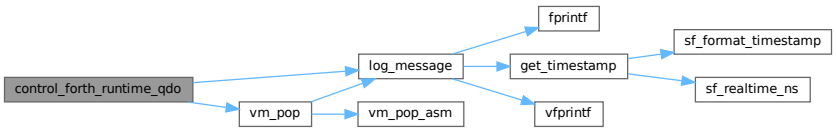
```
static void control_forth_runtime_qdo (
            VM * vm )  [static]
```

Runtime handler for ?DO loops.

References VM::dsp, VM::error, limit, LOG_DEBUG, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, STACK_SIZE, and vm_pop().

Referenced by control_forth_qdo(), and register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

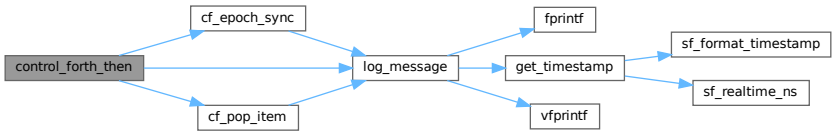
5.9.2.25 control_forth_then()

```
static void control_forth_then (
            VM * vm )  [static]
```

References cf_item_t::addr, CF_ELSE, cf_epoch_sync(), CF_IF, cf_pop_item(), VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), VM::memory, VM::mode, MODE_COMPILE, and cf_item_t::tag.

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

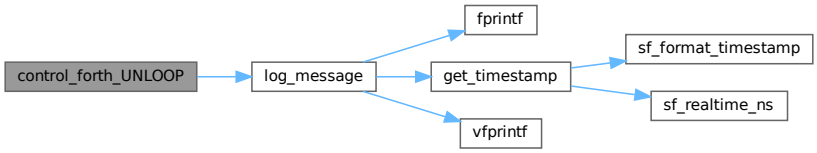
5.9.2.26 control_forth_UNLOOP()

```
static void control_forth_UNLOOP (
            VM * vm )  [static]
```

References VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::return_stack, and VM::rsp.

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:

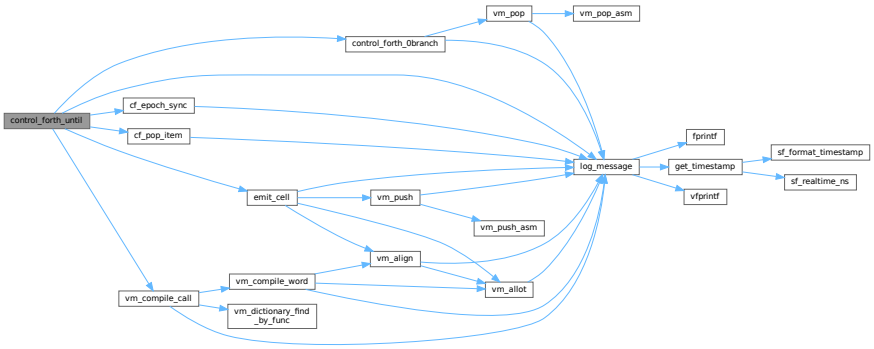
5.9.2.27 control_forth_until()

```
static void control_forth_until (
            VM * vm )  [static]
```

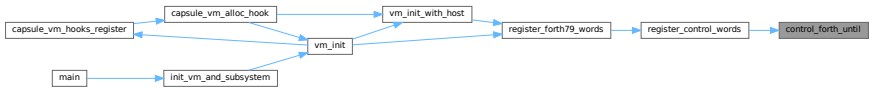
References cf_item_t::addr, CF_BEGIN, cf_epoch_sync(), cf_pop_item(), control_forth_0branch(), emit_cell(), VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



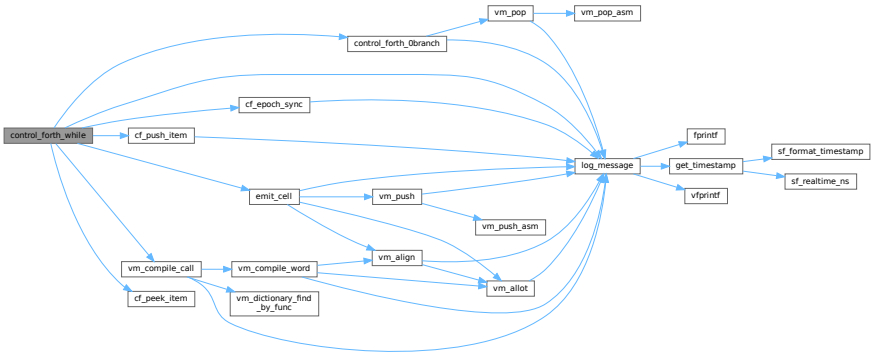
5.9.2.28 control_forth_while()

```
static void control_forth_while (
            VM * vm )  [static]
```

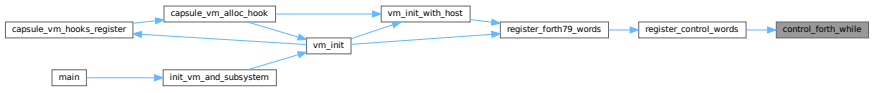
References CF_BEGIN, cf_epoch_sync(), cf_peek_item(), cf_push_item(), CF_WHILE, control_forth_0branch(), emit_cell(), VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, cf_item_t::tag, and vm_compile_call().

Referenced by register_control_words().

Here is the call graph for this function:



Here is the caller graph for this function:



5.9.2.29 register_control_words()

```
void register_control_words (
            VM * vm )
```

Registers all control flow words with the Forth virtual machine.

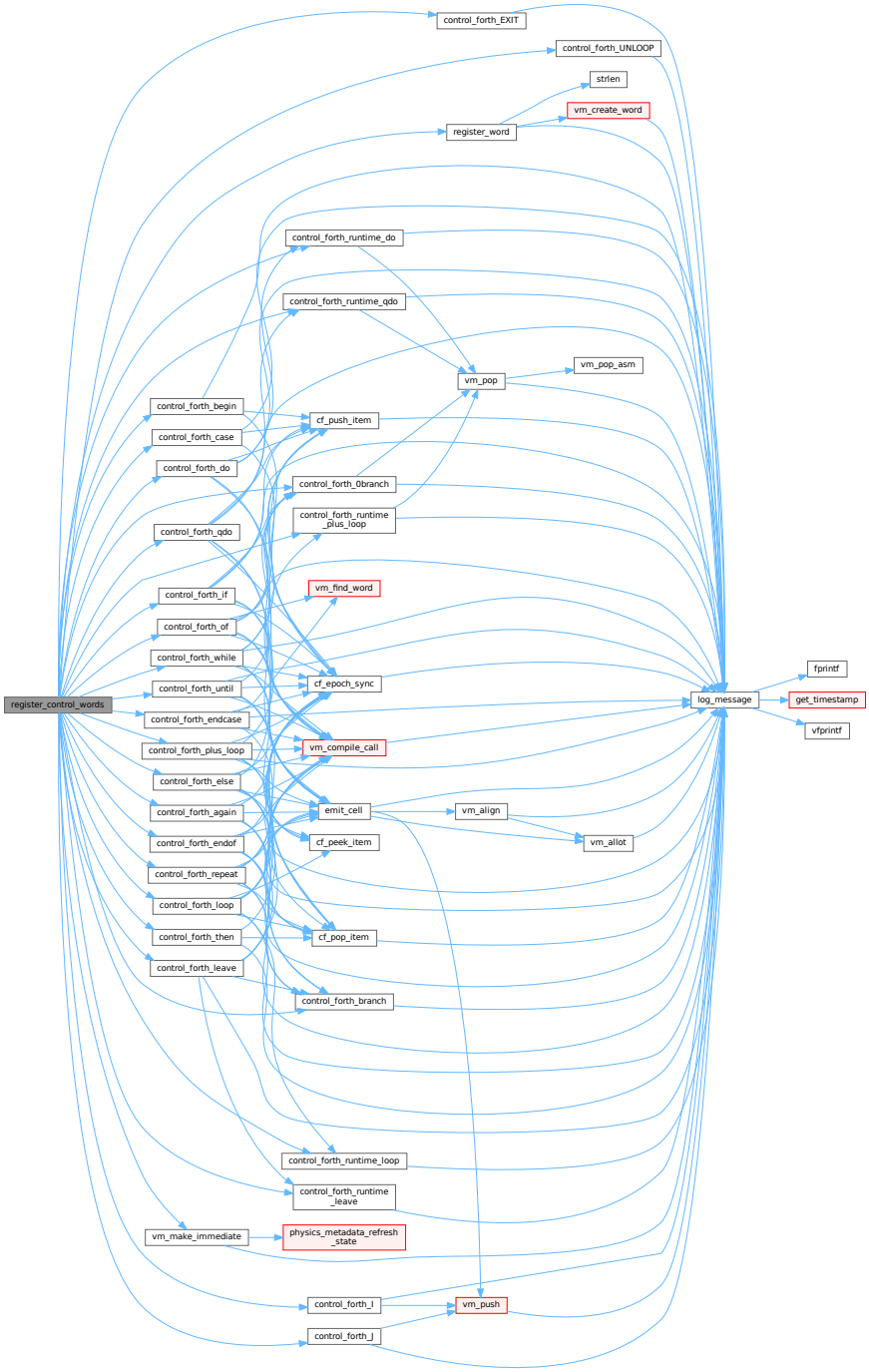
Parameters

vm	Pointer to the Forth virtual machine instance

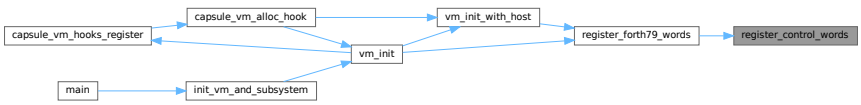
References control_forth_0branch(), control_forth_again(), control_forth_begin(), control_forth_branch(), control_forth_case(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_EXIT(), control_forth_I(), control_forth_if(), control_forth_J(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_runtime_do(), control_forth_runtime_leave(), control_forth_runtime_loop(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), control_forth_then(), control_forth_UNLOOP(), control_forth_until(), control_forth_while(), register_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



5.10 FORTH-79 Control Flow Words

Standard FORTH-79 control flow words implementation.

Standard FORTH-79 control flow words implementation.

5.11 FORTH-79 Defining Words

Standard FORTH-79 defining words.

Standard FORTH-79 defining words.

These words are used for creating new dictionary entries and defining words:

- : (–) Start colon definition
- ; (–) End colon definition
- CREATE (–) Create dictionary entry
- DOES> (–) Define runtime behavior
- <BUILDS (--) Create word with <BUILDS/DOES>
- CONSTANT (n –) Define constant
- VARIABLE (–) Define variable
- 2CONSTANT (d –) Define double constant
- 2VARIABLE (–) Define double variable
- USER (n –) Define user variable
- IMMEDIATE (–) Make most recent word immediate
- [COMPILE] (–) Force compilation of immediate word
- COMPILE (–) Compile inline code
- FORGET (–) Remove word and all after it

5.12 FORTH-79 Dictionary Manipulation Words

Standard FORTH-79 words for dictionary manipulation.

Standard FORTH-79 words for dictionary manipulation.

[(–)

Enter interpretation mode. Switches the system to interpret incoming words.

] (–)

Enter compilation mode. Switches the system to compile incoming words.

STATE (– addr)

Variable containing current compilation state. Returns address of STATE variable.

SMUDGE (–)

Toggle smudge bit of latest defined word. Used during word definition.

>BODY (xt – addr)

Convert execution token to parameter field address.

>NAME (xt – addr)

Convert execution token to name field address.

NAME> (addr – xt)

Convert name field address to execution token.

>LINK (addr – addr)

Get link field address from name field address.

LINK> (addr – addr)

Get next word's address from link field.

CFA (addr – xt)

Get code field address from name field address.

LFA (addr – addr)

Get link field address from name field address.

NFA (addr – addr)

Get name field address from any field address.

PFA (addr – addr)

Get parameter field address from name field address.

TRAVERSE (addr n – addr)

Move through name field by n characters.

INTERPRET (–)

Text interpreter - process input stream.

5.13 FORTH-79 Dictionary & Compilation Words

Dictionary and compilation words as defined in FORTH-79 Standard.

Dictionary and compilation words as defined in FORTH-79 Standard.

@word HERE (– addr) Returns address of next free dictionary space @word ALLOT (n –) Allocates n bytes in dictionary @word , (n –) Compiles n into dictionary @word C, (c –) Compiles character into dictionary @word 2, (d –) Compiles double into dictionary @word PAD (– addr) Returns address of temporary text buffer @word SP! (addr –) Sets data stack pointer @word SP@ (– addr) Gets data stack pointer @word LATEST (– addr) Returns address of most recent definition

5.14 FORTH-79 Line Editor Words

Line editor commands implementation.

Line editor commands implementation.

5.15 Framebuffer Words

Raw hardware-boundary FORTH words for the Console drawing fabric (FABRIC-0.md item 4.3.3).

Raw hardware-boundary FORTH words for the Console drawing fabric (FABRIC-0.md item 4.3.3).

Deliberately raster-native – no Cartesian awareness, no policy. That lives in capsules/fabric.4th instead, per the compose-in-FORTH-first rule.

Kernel-only: no-op on hosted builds (no framebuffer exists there).

PLOT (x y color –)

Write one pixel at raster coordinates (top-left origin, Y-down). Out-of-bounds writes are silently ignored (inherited from fb_put_pixel).

FB-WIDTH (– n)

FB-HEIGHT (– n)

Push the framebuffer's pixel width / height.

5.16 Keyboard Words

Raw hardware-boundary FORTH word for verifying the interrupt-driven keyboard path (FABRIC-0.md item 4.3.5).

Raw hardware-boundary FORTH word for verifying the interrupt-driven keyboard path (FABRIC-0.md item 4.3.5).

Deliberately a diagnostic peek at the raw scancode ring buffer – no set-2 translation, no REPL wiring. Those belong to the later REPL keyboard-input work noted in FABRIC-0.md.

Kernel-only, amd64-only today (i8042 is amd64 hardware); no-op elsewhere so dictionary parity across all three architectures is unaffected.

KBD-SCAN (– c -1 | 0)

Pop one raw scancode off the interrupt-fed ring buffer. Pushes the scancode and -1 (true) if one was available, or just 0 (false) if the buffer was empty.

KBD-DEBUG (– isr_count spurious_count)

Standing diagnostic: count of real keyboard IRQs serviced and count of LAPIC spurious-vector interrupts, both since boot.

VKBD-EVENT (– code value -1 | 0)

Items 4.3.5c (riscv64) / 4.3.5e (aarch64). Pop one decoded EV_KEY event (Linux input-event code/value pair) off the virtio-input interrupt-fed ring buffer. Kernel-only, riscv64/aarch64 (virtio-keyboard-pci); no-op on amd64 (i8042 hardware instead, see KBD-SCAN).

VKBD-DEBUG (– isr_count)

Standing diagnostic: count of virtio-input ISR invocations since boot.

KEY-EVENT (– keycode pressed -1 | 0)

Item 4.3.5f convergence checkpoint. One shared event shape across all three architectures: keycode in the Linux input keycode namespace (identical numbering to amd64's raw XT Set-1 scancode for the non-extended key range, by historical design, not translated arbitrarily – see the implementation's own doc comment), pressed is 1 or 0. This is the word the later REPL keyboard-input work (M8) is expected to build on; KBD-SCAN/VKBD-EVENT remain as lower-level per-device diagnostics.

ALT+TAB (–)

FABRIC-0.md item 4.4y-revised. Programmatic equivalent of the physical Alt+TAB graphics/text toggle – calls the same state-machine transition (console_fb_toggle_graphics() / vt100_toggle_graphics()) the keyboard interception in repl.c uses, so there is exactly one place the toggle actually happens.

5.17 Log Words

FORTH words for log-level control and structured string emission.

FORTH words for log-level control and structured string emission.

Level constants (– n)

Push the corresponding LogLevel integer onto the stack. LOG-ERROR (– 0) LOG-WARN (– 1) LOG-INFO (– 2) LOG-TEST (– 3) LOG-DEBUG (– 4)

LOG-LEVEL! (n –)

Set the current log level to n. Values outside 0–4 clamp to LOG-DEBUG.

LOG-LEVEL@ (– n)

Push the current log level.

LOG-INFO" ("ccc" --) IMMEDIATE @par LOG-WARN" ("ccc<quote>" –) IMMEDIATE

LOG-ERROR" ("ccc" --) IMMEDIATE @par LOG-TEST" ("ccc<quote>" –) IMMEDIATE

LOG-DEBUG" ("ccc" –) IMMEDIATE Parse the string literal up to the closing double-quote and emit it via log_message() at the corresponding level. W

DEBUG messages are free when the level is INFO.

LOG-INFO-STR (c-addr u –)

LOG-WARN-STR (c-addr u –)

LOG-ERROR-STR (c-addr u –)

LOG-TEST-STR (c-addr u –)

LOG-DEBUG-STR (c-addr u –)

Consume a counted string from the stack (as produced by S") and emit it via log_message() at the corresponding level. @par Runtime words (not for direct use) (do-log-error) (do-log-warn) (do-log-info) (do-log-test) (do-log-debug) Threaded-code runtime helpers compiled by the LOG-∗" immediates.

5.18 FORTH-79 Logical Operations

FORTH-79 Standard logical and comparison operations.

FORTH-79 Standard logical and comparison operations.

Implementation of the following FORTH-79 words:

- AND (n1 n2 – n3) Bitwise AND
- OR (n1 n2 – n3) Bitwise OR
- XOR (n1 n2 – n3) Bitwise XOR
- NOT (n1 – n2) Bitwise NOT
- 0= (n – flag) True if n is zero
- 0< (n – flag) True if n is negative
- 0> (n – flag) True if n is positive
- = (n1 n2 – flag) True if n1 equals n2
- < (n1 n2 – flag) True if n1 < n2
- > (n1 n2 – flag) True if n1 > n2
- U< (u1 u2 – flag) True if u1 < u2 (unsigned)
- U> (u1 u2 – flag) True if u1 > u2 (unsigned)
- WITHIN (n low high – flag) True if low <= n < high

5.19 FORTH-79 Memory Operations

Memory operation words defined in FORTH-79 standard.

Memory operation words defined in FORTH-79 standard.

Available operations:

- ! (n addr –) Store n at addr
- @ (addr – n) Fetch n from addr
- C! (c addr –) Store character at addr
- C@ (addr – c) Fetch character from addr
- +! (n addr –) Add n to value at addr
- 2! (d addr –) Store double at addr
- 2@ (addr – d) Fetch double from addr
- FILL (addr u c –) Fill u bytes at addr with c
- MOVE (addr1 addr2 u –) Move u bytes from addr1 to addr2
- CMOVE (addr1 addr2 u –) Move u bytes, low to high addresses
- CMOVE> (addr1 addr2 u –) Move u bytes, high to low addresses
- ERASE (addr u –) Fill u bytes at addr with zeros

5.20 FORTH-79 Return Stack Operations

5.21 REPL Scrollback Words

`SCROLL-BACK/SCROLL-FWD`, the REPL scrollback controls (FABRIC-0.md item 4.4q).

`SCROLL-BACK/SCROLL-FWD`, the REPL scrollback controls (FABRIC-0.md item 4.4q).

Kernel-only; no-op on hosted builds (no framebuffer console there).

SCROLL-BACK (n –)

Move the scrollback view back `n` lines (toward older output) and redraw. Clamped at the oldest stored line – no error on over-request, it just stops there.

SCROLL-FWD (n –)

Move the scrollback view forward `n` lines (toward live output) and redraw. Clamped at the live view.

5.22 FORTH-79 System & Environment Words

System and environment control words for FORTH-79.

System and environment control words for FORTH-79.

The following words provide system and environment control functionality:

COLD (–)

Performs a cold start of the system, reinitializing all system variables

WARM (–)

Performs a warm start of the system, preserving some system state

BYE (–)

Exits the FORTH system and returns to the host operating system

SAVE-SYSTEM (–)

Saves the current system image to disk

WORDS (–)

Lists all words in the current vocabulary

VLIST (–)

Lists all words in all vocabularies

?STACK (–)

Checks the stack depth and reports any stack errors

PAGE (–)

Clears the screen or outputs a form feed

NOP (–)

Performs no operation

79-STANDARD (–)

Ensures FORTH-79 standard compliance

5.23 TrueType Text Words

`TTF-TEXT`, the TrueType-backed text entry point (FABRIC-0.md item 4.3.7e).

`TTF-TEXT`, the TrueType-backed text entry point (FABRIC-0.md item 4.3.7e).

Kernel-only; no-op on hosted builds (no framebuffer/capsule system exists there).

TTF-TEXT (c-addr u x y size color –)

Render a UTF-8 string via the v1 default font capsule (`fonts:JetBrainsMono-Regular.ttf`, loaded and cached lazily on first use). (x,y) is raster pixel space (top-left origin, Y-down) – NOT capsules/fabric.4th's Cartesian Y-up convention used by the stroke font's `TEXT` (4.3.6f); the two are deliberately different coordinate systems, not interchangeable. (x,y) is the first glyph's baseline-left origin. `size` is capped at `TTF_CACHE_MAX_SIZE_PX` (see ttf.h). Advances proportionally per glyph via the font's real hmtx advance width, scaled to pixels.

5.24 FORTH-79 Vocabulary System Words

Standard vocabulary manipulation words.

Standard vocabulary manipulation words.

VOCABULARY (–)

Create new vocabulary

DEFINITIONS (–)

Set current vocabulary

CONTEXT (– addr)

Variable: search vocabulary pointer

CURRENT (– addr)

Variable: definition vocabulary pointer

FORTH (–)

Select FORTH vocabulary

ONLY (–)

Set minimal search order

ALSO (–)

Duplicate top of search order

ORDER (–)

Display search order

PREVIOUS (–)

Remove top of search order

(FIND) (addr – addr flag)

Find word in dictionary (primitive)

Chapter 6

Data Structure Documentation

6.1 __attribute__ Struct Reference

ioapic.c - I/O APIC driver (amd64)

Data Fields

- uint8_t signature [8]
- uint8_t checksum
- uint8_t oem_id [6]
- uint8_t revision
- uint32_t rsdt_address
- uint32_t length
- uint64_t xsdt_address
- uint8_t extended_checksum
- uint8_t reserved [3]
- uint8_t oem_table_id [8]
- uint32_t oem_revision
- uint32_t creator_id
- uint32_t creator_revision
- AcpiHeader hdr
- uint32_t local_apic_address
- uint32_t flags
- uint8_t type
- uint8_t length
- uint8_t io_apic_id
- uint32_t io_apic_address
- uint32_t gsi_base
- uint8_t bus
- uint8_t source
- uint32_t gsi
- uint16_t flags
- uint8_t address_space_id
- uint8_t register_bit_width
- uint8_t register_bit_offset
- uint8_t access_size
- uint64_t address
- uint64_t base_address
- uint16_t segment_group
- uint8_t start_bus
- uint8_t end_bus
- uint32_t reserved
- uint64_t reserved

6.1.1 Detailed Description

ioapic.c - I/O APIC driver (amd64)

Item 4.3.5 (FABRIC-0.md ?27.5). MADT parsing mirrors pci.c's RSDP -> XSDT -> table-by-signature walk (the two files don't share a header for this — same duplication pci.c already has relative to a hypothetical shared acpi.c, not introduced fresh here).

6.1.2 Field Documentation

6.1.2.1 access_size

```
uint8_t __attribute__::access_size
```

6.1.2.2 address

```
uint64_t __attribute__::address
```

6.1.2.3 address_space_id

```
uint8_t __attribute__::address_space_id
```

6.1.2.4 base_address

```
uint64_t __attribute__::base_address
```

6.1.2.5 bus

```
uint8_t __attribute__::bus
```

6.1.2.6 checksum

```
uint8_t __attribute__::checksum
```

6.1.2.7 creator_id

```
uint32_t __attribute__::creator_id
```

6.1.2.8 creator_revision

```
uint32_t __attribute__::creator_revision
```

6.1.2.9 end_bus

```
uint8_t __attribute__::end_bus
```

6.1.2.10 extended_checksum

```
uint8_t __attribute__::extended_checksum
```

6.1.2.11 flags [1/2]

```
uint32_t __attribute__::flags
```

6.1.2.12 flags [2/2]

```
uint16_t __attribute__::flags
```

6.1.2.13 gsi

```
uint32_t __attribute__::gsi
```

6.1.2.14 gsi_base

```
uint32_t __attribute__::gsi_base
```

6.1.2.15 hdr

```
AcpiHeader __attribute__::hdr
```

6.1.2.16 io_apic_address

```
uint32_t __attribute__::io_apic_address
```

6.1.2.17 io_apic_id

```
uint8_t __attribute__::io_apic_id
```

6.1.2.18 length [1/2]

```
uint32_t __attribute__::length
```

6.1.2.19 length [2/2]

```
uint8_t __attribute__::length
```

6.1.2.20 local_apic_address

```
uint32_t __attribute__::local_apic_address
```

6.1.2.21 oem_id

```
uint8_t __attribute__::oem_id
```

6.1.2.22 oem_revision

```
uint32_t __attribute__::oem_revision
```

6.1.2.23 oem_table_id

```
uint8_t __attribute__::oem_table_id
```

6.1.2.24 register_bit_offset

```
uint8_t __attribute__::register_bit_offset
```

6.1.2.25 register_bit_width

```
uint8_t __attribute__::register_bit_width
```

6.1.2.26 reserved [1/3]

```
uint8_t __attribute__::reserved
```

6.1.2.27 reserved [2/3]

```
uint32_t __attribute__::reserved
```

6.1.2.28 reserved [3/3]

```
uint64_t __attribute__::reserved
```

6.1.2.29 revision

```
uint8_t __attribute__::revision
```

6.1.2.30 rsdt_address

```
uint32_t __attribute__::rsdt_address
```

6.1.2.31 segment_group

```
uint16_t __attribute__::segment_group
```

6.1.2.32 signature

```
uint8_t __attribute__::signature
```

6.1.2.33 source

```
uint8_t __attribute__::source
```

6.1.2.34 start_bus

```
uint8_t __attribute__::start_bus
```

6.1.2.35 type

```
uint8_t __attribute__::type
```

6.1.2.36 xsdt_address

```
uint64_t __attribute__::xsdt_address
```

Referenced by fadt_find_pm_tmr_port(), and parse_madt().

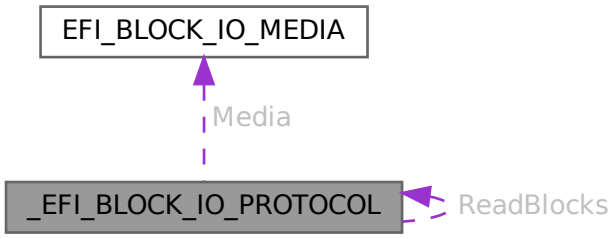
The documentation for this struct was generated from the following files:

- kernel/src/arch/amd64/ioapic.c
- kernel/src/arch/amd64/timer.c
- kernel/src/pci/pci.c

6.2 _EFI_BLOCK_IO_PROTOCOL Struct Reference

`#include <uefi.h>`

Collaboration diagram for _EFI_BLOCK_IO_PROTOCOL:



Data Fields

- UINT64 Revision
- EFI_BLOCK_IO_MEDIA * Media
- void * Reset
- EFI_BLOCK_READ ReadBlocks
- void * WriteBlocks
- void * FlushBlocks

6.2.1 Field Documentation

6.2.1.1 FlushBlocks

`void* _EFI_BLOCK_IO_PROTOCOL::FlushBlocks`

6.2.1.2 Media

`EFI_BLOCK_IO_MEDIA* _EFI_BLOCK_IO_PROTOCOL::Media`

6.2.1.3 ReadBlocks

`EFI_BLOCK_READ _EFI_BLOCK_IO_PROTOCOL::ReadBlocks`

6.2.1.4 Reset

`void* _EFI_BLOCK_IO_PROTOCOL::Reset`

6.2.1.5 Revision

```
UINT64 _EFI_BLOCK_IO_PROTOCOL::Revision
```

6.2.1.6 WriteBlocks

```
void* _EFI_BLOCK_IO_PROTOCOL::WriteBlocks
```

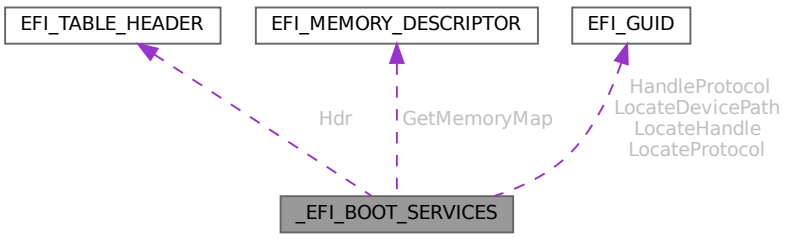
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.3 _EFI_BOOT_SERVICES Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for _EFI_BOOT_SERVICES:



Data Fields

- EFI_TABLE_HEADER Hdr
- EFI_RAISE_TPL RaiseTPL
- EFI_RESTORE_TPL RestoreTPL
- EFI_ALLOCATE_PAGES AllocatePages
- EFI_FREE_PAGES FreePages
- EFI_GET_MEMORY_MAP GetMemoryMap
- EFI_ALLOCATE_POOL AllocatePool
- EFI_FREE_POOL FreePool
- void * CreateEvent
- void * SetTimer
- void * WaitForEvent
- void * SignalEvent
- void * CloseEvent
- void * CheckEvent
- void * InstallProtocolInterface
- void * ReinstallProtocolInterface
- void * UninstallProtocolInterface

- EFI_HANDLE_PROTOCOL HandleProtocol
- void * Reserved
- void * RegisterProtocolNotify
- EFI_LOCATE_HANDLE LocateHandle
- EFI_LOCATE_DEVICE_PATH LocateDevicePath
- void * InstallConfigurationTable
- void * LoadImage
- void * StartImage
- void * Exit
- void * UnloadImage
- EFI_EXIT_BOOT_SERVICES ExitBootServices
- void * GetNextMonotonicCount
- EFI_STALL Stall
- void * SetWatchdogTimer
- void * ConnectController
- void * DisconnectController
- void * OpenProtocol
- void * CloseProtocol
- void * OpenProtocolInformation
- void * ProtocolsPerHandle
- void * LocateHandleBuffer
- EFI_LOCATE_PROTOCOL LocateProtocol

6.3.1 Field Documentation

6.3.1.1 AllocatePages

```
EFI_ALLOCATE_PAGES _EFI_BOOT_SERVICES::AllocatePages
```

Referenced by efi_main(), and load_kernel_from_esp().

6.3.1.2 AllocatePool

```
EFI_ALLOCATE_POOL _EFI_BOOT_SERVICES::AllocatePool
```

6.3.1.3 CheckEvent

```
void* _EFI_BOOT_SERVICES::CheckEvent
```

6.3.1.4 CloseEvent

```
void* _EFI_BOOT_SERVICES::CloseEvent
```

6.3.1.5 CloseProtocol

```
void* _EFI_BOOT_SERVICES::CloseProtocol
```

6.3.1.6 ConnectController

```
void* _EFI_BOOT_SERVICES::ConnectController
```

6.3.1.7 CreateEvent

```
void* _EFI_BOOT_SERVICES::CreateEvent
```

6.3.1.8 DisconnectController

```
void* _EFI_BOOT_SERVICES::DisconnectController
```

6.3.1.9 Exit

```
void* _EFI_BOOT_SERVICES::Exit
```

6.3.1.10 ExitBootServices

```
EFI_EXIT_BOOT_SERVICES _EFI_BOOT_SERVICES::ExitBootServices
```

Referenced by efi_main().

6.3.1.11 FreePages

```
EFI_FREE_PAGES _EFI_BOOT_SERVICES::FreePages
```

6.3.1.12 FreePool

```
EFI_FREE_POOL _EFI_BOOT_SERVICES::FreePool
```

6.3.1.13 GetMemoryMap

```
EFI_GET_MEMORY_MAP _EFI_BOOT_SERVICES::GetMemoryMap
```

Referenced by efi_main().

6.3.1.14 GetNextMonotonicCount

```
void* _EFI_BOOT_SERVICES::GetNextMonotonicCount
```

6.3.1.15 HandleProtocol

```
EFI_HANDLE_PROTOCOL _EFI_BOOT_SERVICES::HandleProtocol
```

Referenced by efi_main(), load_cfg_from_esp(), and load_kernel_from_esp().

6.3.1.16 Hdr

```
EFI_TABLE_HEADER _EFI_BOOT_SERVICES::Hdr
```

6.3.1.17 InstallConfigurationTable

```
void* _EFI_BOOT_SERVICES::InstallConfigurationTable
```

6.3.1.18 InstallProtocolInterface

```
void* _EFI_BOOT_SERVICES::InstallProtocolInterface
```

6.3.1.19 LoadImage

```
void* _EFI_BOOT_SERVICES::LoadImage
```

6.3.1.20 LocateDevicePath

```
EFI_LOCATE_DEVICE_PATH _EFI_BOOT_SERVICES::LocateDevicePath
```

6.3.1.21 LocateHandle

```
EFI_LOCATE_HANDLE _EFI_BOOT_SERVICES::LocateHandle
```

6.3.1.22 LocateHandleBuffer

```
void* _EFI_BOOT_SERVICES::LocateHandleBuffer
```

6.3.1.23 LocateProtocol

```
EFI_LOCATE_PROTOCOL _EFI_BOOT_SERVICES::LocateProtocol
```

Referenced by efi_main().

6.3.1.24 OpenProtocol

```
void* _EFI_BOOT_SERVICES::OpenProtocol
```

6.3.1.25 OpenProtocolInformation

```
void* _EFI_BOOT_SERVICES::OpenProtocolInformation
```

6.3.1.26 ProtocolsPerHandle

```
void* _EFI_BOOT_SERVICES::ProtocolsPerHandle
```

6.3.1.27 RaiseTPL

```
EFI_RAISE_TPL _EFI_BOOT_SERVICES::RaiseTPL
```

6.3.1.28 RegisterProtocolNotify

```
void* _EFI_BOOT_SERVICES::RegisterProtocolNotify
```

6.3.1.29 ReinstallProtocolInterface

```
void* _EFI_BOOT_SERVICES::ReinstallProtocolInterface
```

6.3.1.30 Reserved

```
void* _EFI_BOOT_SERVICES::Reserved
```

6.3.1.31 RestoreTPL

```
EFI_RESTORE_TPL _EFI_BOOT_SERVICES::RestoreTPL
```

6.3.1.32 SetTimer

```
void* _EFI_BOOT_SERVICES::SetTimer
```

6.3.1.33 SetWatchdogTimer

```
void* _EFI_BOOT_SERVICES::SetWatchdogTimer
```

6.3.1.34 SignalEvent

```
void* _EFI_BOOT_SERVICES::SignalEvent
```

6.3.1.35 Stall

```
EFI_STALL _EFI_BOOT_SERVICES::Stall
```

Referenced by debug_checkpoint().

6.3.1.36 StartImage

```
void* _EFI_BOOT_SERVICES::StartImage
```

6.3.1.37 UninstallProtocolInterface

```
void* _EFI_BOOT_SERVICES::UninstallProtocolInterface
```

6.3.1.38 UnloadImage

```
void* _EFI_BOOT_SERVICES::UnloadImage
```

6.3.1.39 WaitForEvent

```
void* _EFI_BOOT_SERVICES::WaitForEvent
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.4 _EFI_FILE_PROTOCOL Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for _EFI_FILE_PROTOCOL:

Data Fields

- UINT64 Revision
- EFI_FILE_OPEN Open
- EFI_FILE_CLOSE Close
- VOID * Delete
- EFI_FILE_READ Read
- VOID * Write
- VOID * GetPosition
- VOID * SetPosition
- EFI_FILE_GET_INFO GetInfo
- VOID * SetInfo
- VOID * Flush

6.4.1 Field Documentation

6.4.1.1 Close

```
EFI_FILE_CLOSE _EFI_FILE_PROTOCOL::Close
```

Referenced by load_cfg_from_esp(), and load_kernel_from_esp().

6.4.1.2 Delete

```
VOID* _EFI_FILE_PROTOCOL::Delete
```

6.4.1.3 Flush

```
VOID* _EFI_FILE_PROTOCOL::Flush
```

6.4.1.4 GetInfo

```
EFI_FILE_GET_INFO _EFI_FILE_PROTOCOL::GetInfo
```

Referenced by load_kernel_from_esp().

6.4.1.5 GetPosition

```
VOID* _EFI_FILE_PROTOCOL::GetPosition
```

6.4.1.6 Open

```
EFI_FILE_OPEN _EFI_FILE_PROTOCOL::Open
```

Referenced by load_cfg_from_esp(), and load_kernel_from_esp().

6.4.1.7 Read

```
EFI_FILE_READ _EFI_FILE_PROTOCOL::Read
```

Referenced by load_cfg_from_esp(), and load_kernel_from_esp().

6.4.1.8 Revision

```
UINT64 _EFI_FILE_PROTOCOL::Revision
```

6.4.1.9 SetInfo

```
VOID* _EFI_FILE_PROTOCOL::SetInfo
```

6.4.1.10 SetPosition

```
VOID* _EFI_FILE_PROTOCOL::SetPosition
```

6.4.1.11 Write

```
VOID* _EFI_FILE_PROTOCOL::Write
```

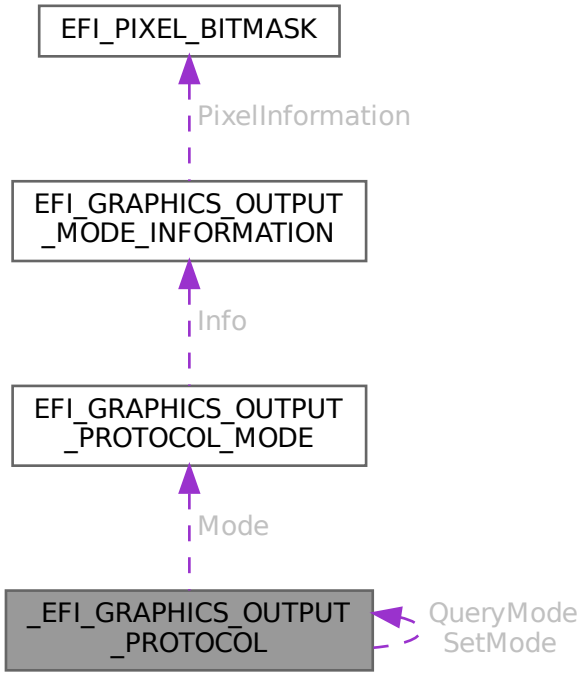
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.5 _EFI_GRAPHICS_OUTPUT_PROTOCOL Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for _EFI_GRAPHICS_OUTPUT_PROTOCOL:



Data Fields

- EFI_GRAPHICS_OUTPUT_PROTOCOL_QUERY_MODE QueryMode
- EFI_GRAPHICS_OUTPUT_PROTOCOL_SET_MODE SetMode
- void * Blt
- EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE * Mode

6.5.1 Field Documentation

6.5.1.1 Blt

```
void* _EFI_GRAPHICS_OUTPUT_PROTOCOL::Blt
```

6.5.1.2 Mode

```
EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE* _EFI_GRAPHICS_OUTPUT_PROTOCOL::Mode
```

Referenced by efi_main().

6.5.1.3 QueryMode

EFI_GRAPHICS_OUTPUT_PROTOCOL_QUERY_MODE _EFI_GRAPHICS_OUTPUT_PROTOCOL::QueryMode

6.5.1.4 SetMode

EFI_GRAPHICS_OUTPUT_PROTOCOL_SET_MODE _EFI_GRAPHICS_OUTPUT_PROTOCOL::SetMode

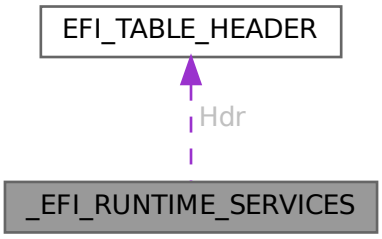
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.6 _EFI_RUNTIME_SERVICES Struct Reference

#include <uefi.h>

Collaboration diagram for _EFI_RUNTIME_SERVICES:



Data Fields

- EFI_TABLE_HEADER Hdr
- void * GetTime
- void * SetTime
- void * GetWakeupTime
- void * SetWakeupTime
- void * SetVirtualAddressMap
- void * ConvertPointer
- void * GetVariable
- void * GetNextVariableName
- void * SetVariable
- void * GetNextHighMonotonicCount
- void * ResetSystem

6.6.1 Field Documentation

6.6.1.1 ConvertPointer

```
void* _EFI_RUNTIME_SERVICES::ConvertPointer
```

6.6.1.2 GetNextHighMonotonicCount

```
void* _EFI_RUNTIME_SERVICES::GetNextHighMonotonicCount
```

6.6.1.3 GetNextVariableName

```
void* _EFI_RUNTIME_SERVICES::GetNextVariableName
```

6.6.1.4 GetTime

```
void* _EFI_RUNTIME_SERVICES::GetTime
```

6.6.1.5 GetVariable

```
void* _EFI_RUNTIME_SERVICES::GetVariable
```

Referenced by efi_main(), and system_word_reboot().

6.6.1.6 GetWakeupTime

```
void* _EFI_RUNTIME_SERVICES::GetWakeupTime
```

6.6.1.7 Hdr

```
EFI_TABLE_HEADER _EFI_RUNTIME_SERVICES::Hdr
```

6.6.1.8 ResetSystem

```
void* _EFI_RUNTIME_SERVICES::ResetSystem
```

Referenced by system_word_reboot().

6.6.1.9 SetTime

```
void* _EFI_RUNTIME_SERVICES::SetTime
```

6.6.1.10 SetVariable

```
void* _EFI_RUNTIME_SERVICES::SetVariable
```

Referenced by efi_main(), kernel_main_deep(), and system_word_reboot().

6.6.1.11 SetVirtualAddressMap

```
void* _EFI_RUNTIME_SERVICES::SetVirtualAddressMap
```

6.6.1.12 SetWakeupTime

```
void* _EFI_RUNTIME_SERVICES::SetWakeupTime
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.7 _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL:

Data Fields

- UINT64 Revision
- EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_OPEN_VOLUME OpenVolume

6.7.1 Field Documentation

6.7.1.1 OpenVolume

```
EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_OPEN_VOLUME _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL::OpenVolume
```

Referenced by load_cfg_from_esp(), and load_kernel_from_esp().

6.7.1.2 Revision

```
UINT64 _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL::Revision
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.8 _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL:

Data Fields

- EFI_TEXT_RESET Reset
- EFI_TEXT_STRING OutputString
- void * TestString
- void * QueryMode
- void * SetMode
- void * SetAttribute
- void * ClearScreen
- void * SetCursorPosition
- void * EnableCursor
- void * Mode

6.8.1 Field Documentation

6.8.1.1 ClearScreen

```
void* _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::ClearScreen
```

6.8.1.2 EnableCursor

```
void* _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::EnableCursor
```

6.8.1.3 Mode

```
void* _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::Mode
```

6.8.1.4 OutputString

```
EFI_TEXT_STRING _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::OutputString
```

Referenced by debug_checkpoint(), and efi_main().

6.8.1.5 QueryMode

```
void* _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::QueryMode
```

6.8.1.6 Reset

```
EFI_TEXT_RESET _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::Reset
```

Referenced by efi_main().

6.8.1.7 SetAttribute

```
void* _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::SetAttribute
```

6.8.1.8 SetCursorPosition

```
void* _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::SetCursorPosition
```

6.8.1.9 SetMode

```
void* _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::SetMode
```

6.8.1.10 TestString

```
void* _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::TestString
```

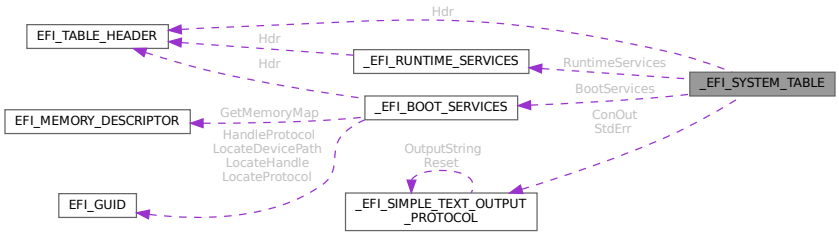
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.9 _EFI_SYSTEM_TABLE Struct Reference

`#include <uefi.h>`

Collaboration diagram for _EFI_SYSTEM_TABLE:



Data Fields

- EFI_TABLE_HEADER Hdr
- CHAR16 * FirmwareVendor
- UINT32 FirmwareRevision
- EFI_HANDLE ConsoleInHandle
- void * ConIn
- EFI_HANDLE ConsoleOutHandle
- EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL * ConOut
- EFI_HANDLE StandardErrorHandle
- EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL * StdErr
- EFI_RUNTIME_SERVICES * RuntimeServices
- EFI_BOOT_SERVICES * BootServices
- UINTN NumberOfTableEntries
- void * ConfigurationTable

6.9.1 Field Documentation

6.9.1.1 BootServices

```
EFI_BOOT_SERVICES* _EFI_SYSTEM_TABLE::BootServices
```

Referenced by debug_checkpoint(), and efi_main().

6.9.1.2 ConfigurationTable

```
void* _EFI_SYSTEM_TABLE::ConfigurationTable
```

Referenced by efi_main().

6.9.1.3 ConIn

```
void* _EFI_SYSTEM_TABLE::ConIn
```

6.9.1.4 ConOut

```
EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL* _EFI_SYSTEM_TABLE::ConOut
```

Referenced by debug_checkpoint(), and efi_main().

6.9.1.5 ConsoleInHandle

```
EFI_HANDLE _EFI_SYSTEM_TABLE::ConsoleInHandle
```

6.9.1.6 ConsoleOutHandle

```
EFI_HANDLE _EFI_SYSTEM_TABLE::ConsoleOutHandle
```

6.9.1.7 FirmwareRevision

```
UINT32 _EFI_SYSTEM_TABLE::FirmwareRevision
```

6.9.1.8 FirmwareVendor

```
CHAR16* _EFI_SYSTEM_TABLE::FirmwareVendor
```

6.9.1.9 Hdr

```
EFI_TABLE_HEADER _EFI_SYSTEM_TABLE::Hdr
```

6.9.1.10 NumberOfTableEntries

```
UINTN _EFI_SYSTEM_TABLE::NumberOfTableEntries
```

Referenced by efi_main().

6.9.1.11 RuntimeServices

```
EFI_RUNTIME_SERVICES* _EFI_SYSTEM_TABLE::RuntimeServices
```

Referenced by efi_main().

6.9.1.12 StandardErrorHandle

```
EFI_HANDLE _EFI_SYSTEM_TABLE::StandardErrorHandle
```

6.9.1.13 StdErr

```
EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL* _EFI_SYSTEM_TABLE::StdErr
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.10 artemis_sig_t Struct Reference

```
#include <artemis_sig.h>
```

Data Fields

- uint64_t magic
- uint8_t disk_uuid [16]
- uint64_t genesis_time_ns
- uint64_t metadata_devblocks
- uint32_t log_region_offset
- uint32_t log_region_devblocks
- uint64_t hdr_crc
- uint8_t _pad [4096 -(8+16+8+8+4+4+8)]

6.10.1 Field Documentation

6.10.1.1 _pad

```
uint8_t artemis_sig_t::_pad[4096 -( 8+ 16+ 8+ 8+ 4+4+ 8)]
```

6.10.1.2 disk_uuid

```
uint8_t artemis_sig_t::disk_uuid[16]
```

Referenced by artemis_sig_genesis_stamp().

6.10.1.3 genesis_time_ns

```
uint64_t artemis_sig_t::genesis_time_ns
```

Referenced by artemis_sig_genesis_stamp().

6.10.1.4 hdr_crc

```
uint64_t artemis_sig_t::hdr_crc
```

Referenced by artemis_sig_check(), and artemis_sig_genesis_stamp().

6.10.1.5 log_region_devblocks

```
uint32_t artemis_sig_t::log_region_devblocks
```

Referenced by artemis_sig_genesis_stamp().

6.10.1.6 log_region_offset

```
uint32_t artemis_sig_t::log_region_offset
```

Referenced by artemis_sig_genesis_stamp().

6.10.1.7 magic

```
uint64_t artemis_sig_t::magic
```

Referenced by artemis_sig_check(), and artemis_sig_genesis_stamp().

6.10.1.8 metadata_devblocks

```
uint64_t artemis_sig_t::metadata_devblocks
```

Referenced by artemis_sig_genesis_stamp().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/artemis_sig.h

6.11 BayesianLatencyPosterior Struct Reference

Bayesian statistics structure for inference and credible intervals All values stored in Q48.16 fixed-point (64-bit signed integer) representing nanoseconds with 2^-16 ≈ 0.0000153 ns precision.

```
#include <physics_hotwords_cache.h>
```

Data Fields

- int64_t mean_ns_q48
- int64_t stddev_ns_q48
- int64_t median_ns_q48
- int64_t credible_lower_95
- int64_t credible_upper_95
- int64_t credible_lower_99
- int64_t credible_upper_99
- uint64_t sample_count

6.11.1 Detailed Description

Bayesian statistics structure for inference and credible intervals All values stored in Q48.16 fixed-point (64-bit signed integer) representing nanoseconds with 2^-16 ≈ 0.0000153 ns precision.

6.11.2 Field Documentation

6.11.2.1 credible_lower_95

```
int64_t BayesianLatencyPosterior::credible_lower_95
```

Referenced by calculate_posterior(), and hotwords_bayesian_report().

6.11.2.2 credible_lower_99

```
int64_t BayesianLatencyPosterior::credible_lower_99
```

Referenced by calculate_posterior(), and hotwords_bayesian_report().

6.11.2.3 credible_upper_95

```
int64_t BayesianLatencyPosterior::credible_upper_95
```

Referenced by calculate_posterior(), and hotwords_bayesian_report().

6.11.2.4 credible_upper_99

```
int64_t BayesianLatencyPosterior::credible_upper_99
```

Referenced by calculate_posterior(), and hotwords_bayesian_report().

6.11.2.5 mean_ns_q48

```
int64_t BayesianLatencyPosterior::mean_ns_q48
```

Referenced by calculate_posterior(), hotwords_bayesian_report(), and hotwords_speedup_estimate().

6.11.2.6 median_ns_q48

```
int64_t BayesianLatencyPosterior::median_ns_q48
```

Referenced by calculate_posterior().

6.11.2.7 sample_count

```
uint64_t BayesianLatencyPosterior::sample_count
```

Referenced by calculate_posterior(), and hotwords_bayesian_report().

6.11.2.8 stddev_ns_q48

```
int64_t BayesianLatencyPosterior::stddev_ns_q48
```

Referenced by calculate_posterior(), hotwords_bayesian_report(), and hotwords_speedup_estimate().

The documentation for this struct was generated from the following file:

- v3/include/physics_hotwords_cache.h

6.12 blk_bam_entry_t Struct Reference

```
#include <block_subsystem.h>
```

Data Fields

- uint8_t allocated
- uint8_t dirty

6.12.1 Field Documentation

6.12.1.1 allocated

```
uint8_t blk_bam_entry_t::allocated
```

Referenced by bam_flush_to_disk(), bam_sync_from_disk(), blk_allocate(), blk_get_buffer(), blk_is_allocated(), blk_mark_allocated(), blk_mark_free(), blk_update(), and devblock_is_free().

6.12.1.2 dirty

```
uint8_t blk_bam_entry_t::dirty
```

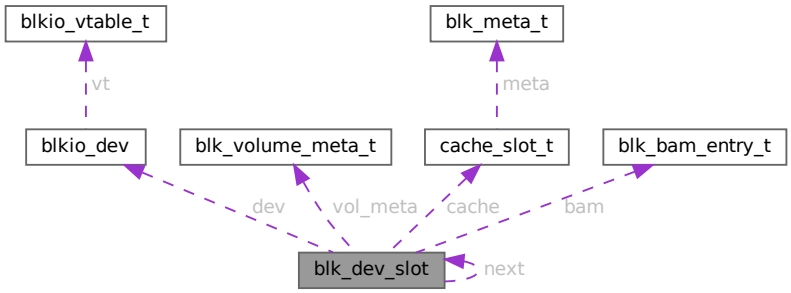
Referenced by blk_flush(), blk_get_buffer(), and blk_update().

The documentation for this struct was generated from the following file:

- v3/include/block_subsystem.h

6.13 blk_dev_slot Struct Reference

Collaboration diagram for blk_dev_slot:



Data Fields

- uint32_t start_lbn
- uint32_t user_blocks
- uint8_t * raw_base
- struct blkio_dev * dev
- uint32_t total_blkio_blocks_1k
- uint32_t devblock_base_4k
- blk_volume_meta_t vol_meta
- uint8_t vol_meta_dirty
- uint8_t bam_dirty
- uint8_t format_state
- cache_slot_t cache [8]
- blk_bam_entry_t * bam
- uint8_t has_ever_claimed
- uint32_t migration_scan_lbn
- blk_dev_slot_t * next

6.13.1 Field Documentation

6.13.1.1 bam

```
blk_bam_entry_t* blk_dev_slot::bam
```

Referenced by bam_flush_to_disk(), bam_sync_from_disk(), blk_allocate(), blk_flush(), blk_format_or_load_disk(), blk_get_buffer(), blk_is_allocated(), blk_mark_allocated(), blk_mark_free(), blk_subsys_add_raw_device(), blk_subsys_attach_device(), blk_subsys_detach_device(), blk_subsys_shutdown(), blk_update(), and devblock_is_free().

6.13.1.2 bam_dirty

```
uint8_t blk_dev_slot::bam_dirty
```

Referenced by bam_flush_to_disk(), bam_sync_from_disk(), blk_allocate(), blk_commit_format(), blk_mark_allocated(), blk_mark_free(), and blk_update().

6.13.1.3 cache

```
cache_slot_t blk_dev_slot::cache[8]
```

Referenced by blk_flush(), and cache_get_slot().

6.13.1.4 dev

```
struct blkio_dev* blk_dev_slot::dev
```

Referenced by bam_flush_to_disk(), bam_sync_from_disk(), blk_allocate(), blk_commit_format(), blk_flush(), blk_meta_zone_read(), blk_meta_zone_write(), blk_migration_idle_check(), blk_subsys_attach_device(), blk_subsys_confirm_format(), blk_subsys_detach_device(), blk_subsys_shutdown(), cache_writeback(), first_disk_slot(), read_devblock_4k(), read_header_4k(), reloc_flush_to_disk(), reloc_load_from_disk(), slot_by_dev(), write_devblock_4k(), and write_header_4k().

6.13.1.5 devblock_base_4k

```
uint32_t blk_dev_slot::devblock_base_4k
```

Referenced by blk_compute_fresh_geometry(), blk_format_or_load_disk(), and devblock4k_to_lba1k().

6.13.1.6 format_state

```
uint8_t blk_dev_slot::format_state
```

Referenced by blk_allocate(), blk_commit_format(), blk_format_or_load_disk(), blk_get_buffer(), blk_mark_allocated(), blk_mark_free(), blk_subsys_attach_device(), blk_subsys_shutdown(), and blk_update().

6.13.1.7 has_ever_claimed

```
uint8_t blk_dev_slot::has_ever_claimed
```

Referenced by blk_migration_idle_check_slot(), and blk_set_meta().

6.13.1.8 migration_scan_lbn

```
uint32_t blk_dev_slot::migration_scan_lbn
```

Referenced by blk_migration_idle_check_slot().

6.13.1.9 next

```
blk_dev_slot_t* blk_dev_slot::next
```

Referenced by blk_allocate(), blk_flush(), blk_migration_idle_check(), blk_subsys_detach_device(), blk_subsys_shutdown(), chain_append(), first_disk_slot(), lbn_to_slot(), and slot_by_dev().

6.13.1.10 raw_base

```
uint8_t* blk_dev_slot::raw_base
```

Referenced by blk_allocate(), blk_flush(), blk_get_buffer(), blk_get_device_free_blocks(), blk_get_meta(), blk_mark_allocated(), blk_mark_free(), blk_set_meta(), blk_subsys_add_raw_device(), and blk_update().

6.13.1.11 start_lbn

```
uint32_t blk_dev_slot::start_lbn
```

Referenced by blk_allocate(), blk_compute_fresh_geometry(), blk_firsttouch_claim(), blk_flush(), blk_get_buffer(), blk_get_device_range(), blk_get_first_disk_range(), blk_is_allocated(), blk_mark_allocated(), blk_mark_free(), blk_migration_idle_check_slot(), blk_owner_has_claim(), blk_subsys_add_raw_device(), blk_subsys_attach_device(), blk_subsys_detach_device(), blk_update(), devblock_claimed_by_lbn(), devblock_is_free(), lbn_to_slot(), and lbn_to_slot_pbn().

6.13.1.12 total_blkio_blocks_1k

```
uint32_t blk_dev_slot::total_blkio_blocks_1k
```

Referenced by blk_compute_fresh_geometry(), blk_format_or_load_disk(), blk_subsys_attach_device(), read_devblock_4k(), and write_devblock_4k().

6.13.1.13 user_blocks

```
uint32_t blk_dev_slot::user_blocks
```

Referenced by bam_flush_to_disk(), bam_pages_used(), bam_sync_from_disk(), blk_allocate(), blk_compute_fresh_geometry(), blk_firsttouch_claim(), blk_flush(), blk_format_or_load_disk(), blk_get_device_range(), blk_get_first_disk_range(), blk_migration_idle_check_slot(), blk_owner_has_claim(), blk_subsys_add_raw_device(), blk_subsys_attach_device(), blk_subsys_detach_device(), devblock_is_free(), and lbn_to_slot().

6.13.1.14 vol_meta

```
blk_volume_meta_t blk_dev_slot::vol_meta
```

Referenced by bam_flush_to_disk(), bam_pages_used(), bam_sync_from_disk(), blk_allocate(), blk_commit_format(), blk_compute_fresh_geometry(), blk_format_or_load_disk(), blk_get_device_free_blocks(), blk_get_volume_meta(), blk_mark_allocated(), blk_mark_free(), blk_meta_zone_read(), blk_meta_zone_write(), blk_set_volume_meta(), blk_subsys_attach_device(), blk_subsys_detach_device(), blk_subsys_shutdown(), blk_update(), reloc_flush_to_disk(), and reloc_load_from_disk().

6.13.1.15 vol_meta_dirty

```
uint8_t blk_dev_slot::vol_meta_dirty
```

Referenced by blk_allocate(), blk_mark_allocated(), blk_mark_free(), blk_set_volume_meta(), blk_subsys_attach_device(), blk_subsys_shutdown(), and blk_update().

The documentation for this struct was generated from the following file:

- v3/src/block_subsystem.c

6.14 blk_meta_t Struct Reference

`#include <block_subsystem.h>`

Data Fields

- uint64_t checksum
- uint64_t magic
- uint64_t created_time
- uint64_t modified_time
- uint64_t flags
- uint64_t write_count
- uint64_t content_type
- uint64_t encoding
- uint64_t content_length
- uint64_t reserved1
- uint64_t entropy [4]
- uint64_t hash [4]
- uint8_t owner_fp [8]
- uint8_t acl_allow
- uint32_t acl_ttl
- uint8_t acl_reserved [3]
- uint64_t reserved_future
- uint64_t prev_block
- uint64_t next_block
- uint64_t parent_block
- uint64_t chain_length
- uint64_t app_data [15]
- uint8_t padding [5]

6.14.1 Field Documentation

6.14.1.1 acl_allow

`uint8_t blk_meta_t::acl_allow`

Referenced by blk_meta_relocate_devblock().

6.14.1.2 acl_reserved

`uint8_t blk_meta_t::acl_reserved[3]`

6.14.1.3 acl_ttl

`uint32_t blk_meta_t::acl_ttl`

Referenced by blk_meta_relocate_devblock().

6.14.1.4 app_data

```
uint64_t blk_meta_t::app_data[15]
```

6.14.1.5 chain_length

```
uint64_t blk_meta_t::chain_length
```

6.14.1.6 checksum

```
uint64_t blk_meta_t::checksum
```

Referenced by blk_update().

6.14.1.7 content_length

```
uint64_t blk_meta_t::content_length
```

6.14.1.8 content_type

```
uint64_t blk_meta_t::content_type
```

6.14.1.9 created_time

```
uint64_t blk_meta_t::created_time
```

Referenced by blk_update().

6.14.1.10 encoding

```
uint64_t blk_meta_t::encoding
```

6.14.1.11 entropy

```
uint64_t blk_meta_t::entropy[4]
```

6.14.1.12 flags

```
uint64_t blk_meta_t::flags
```

Referenced by blk_meta_relocate_devblock(), and devblock_is_free().

6.14.1.13 hash

```
uint64_t blk_meta_t::hash[4]
```

6.14.1.14 magic

```
uint64_t blk_meta_t::magic
```

Referenced by blk_update(), and cache_load_devblock().

6.14.1.15 modified_time

```
uint64_t blk_meta_t::modified_time
```

Referenced by blk_update().

6.14.1.16 next_block

```
uint64_t blk_meta_t::next_block
```

6.14.1.17 owner_fp

```
uint8_t blk_meta_t::owner_fp[8]
```

Referenced by blk_meta_relocate_devblock(), and devblock_is_free().

6.14.1.18 padding

```
uint8_t blk_meta_t::padding[5]
```

6.14.1.19 parent_block

```
uint64_t blk_meta_t::parent_block
```

6.14.1.20 prev_block

```
uint64_t blk_meta_t::prev_block
```

6.14.1.21 reserved1

```
uint64_t blk_meta_t::reserved1
```

6.14.1.22 reserved_future

```
uint64_t blk_meta_t::reserved_future
```

6.14.1.23 write_count

```
uint64_t blk_meta_t::write_count
```

The documentation for this struct was generated from the following file:

- v3/include/block_subsystem.h

6.15 blk_reloc_entry_t Struct Reference

Data Fields

- uint32_t home_lbn
- uint32_t actual_lbn

6.15.1 Field Documentation

6.15.1.1 actual_lbn

```
uint32_t blk_reloc_entry_t::actual_lbn
```

Referenced by resolve_lbn().

6.15.1.2 home_lbn

```
uint32_t blk_reloc_entry_t::home_lbn
```

The documentation for this struct was generated from the following file:

- v3/src/block_subsystem.c

6.16 blk_volume_meta_t Struct Reference

```
#include <block_subsystem.h>
```

Data Fields

- uint32_t magic
- uint32_t version
- uint32_t total_volumes
- uint32_t flags
- char label [64]
- uint64_t total_devblocks
- uint32_t bam_start
- uint32_t bam_devblocks
- uint32_t devblock_base
- uint64_t tracked_blocks
- uint64_t total_blocks
- uint64_t free_blocks
- uint64_t first_free
- uint64_t last_allocated
- uint32_t reserved_disk_lo
- uint32_t reserved_ram_lo
- uint64_t created_time
- uint64_t mounted_time
- uint64_t hdr_crc
- uint32_t reloc_start
- uint32_t reloc_devblocks
- uint32_t meta_fence_blocks
- uint8_t _pad [4096 -(4+4+4+4+64+4+8+4+4+4+8+8+8+8+8+4+4+8+8+8+4+4+4)]

6.16.1 Field Documentation

6.16.1.1 _pad

```
uint8_t blk_volume_meta_t::_pad[4096 -( 4+4+ 4+4+64+ 4+ 8+ 4+4+4+ 8+8+8+ 8+8+ 4+4+ 8+8+ 8+
4+4+ 4)]
```

6.16.1.2 bam_devblocks

```
uint32_t blk_volume_meta_t::bam_devblocks
```

Referenced by bam_cover_devblocks(), bam_flush_to_disk(), bam_pages_used(), bam_sync_from_disk(), blk_commit_format(), blk_compute_fresh_geometry(), blk_format_or_load_disk(), blk_subsys_attach_device(), and compute_totals_from_B().

6.16.1.3 bam_start

```
uint32_t blk_volume_meta_t::bam_start
```

Referenced by bam_flush_to_disk(), bam_sync_from_disk(), blk_commit_format(), and blk_compute_fresh_geometry().

6.16.1.4 created_time

```
uint64_t blk_volume_meta_t::created_time
```

Referenced by blk_compute_fresh_geometry().

6.16.1.5 devblock_base

```
uint32_t blk_volume_meta_t::devblock_base
```

Referenced by blk_compute_fresh_geometry(), blk_format_or_load_disk(), and blk_subsys_attach_device().

6.16.1.6 first_free

```
uint64_t blk_volume_meta_t::first_free
```

Referenced by blk_allocate(), blk_compute_fresh_geometry(), and blk_mark_free().

6.16.1.7 flags

```
uint32_t blk_volume_meta_t::flags
```

Referenced by blk_firsttouch_claim(), blk_flags_get(), blk_flags_set(), blk_migration_idle_check_slot(), blk_owner_has_claim(), blk_set_meta(), and devblock_claimed_by_lbn().

6.16.1.8 free_blocks

```
uint64_t blk_volume_meta_t::free_blocks
```

Referenced by blk_allocate(), blk_compute_fresh_geometry(), blk_get_device_free_blocks(), blk_mark_allocated(), blk_mark_free(), blk_subsys_attach_device(), and blk_update().

6.16.1.9 hdr_crc

```
uint64_t blk_volume_meta_t::hdr_crc
```

6.16.1.10 label

```
char blk_volume_meta_t::label[64]
```

Referenced by blk_compute_fresh_geometry(), blk_subsys_attach_device(), and blk_subsys_detach_device().

6.16.1.11 last_allocated

```
uint64_t blk_volume_meta_t::last_allocated
```

Referenced by blk_allocate(), and blk_compute_fresh_geometry().

6.16.1.12 magic

```
uint32_t blk_volume_meta_t::magic
```

Referenced by blk_compute_fresh_geometry(), blk_format_or_load_disk(), and blk_get_meta().

6.16.1.13 meta_fence_blocks

```
uint32_t blk_volume_meta_t::meta_fence_blocks
```

Referenced by bam_cover_devblocks(), blk_compute_fresh_geometry(), blk_meta_zone_read(), blk_meta_zone_write(), blk_subsys_attach_device(), and compute_totals_from_B().

6.16.1.14 mounted_time

```
uint64_t blk_volume_meta_t::mounted_time
```

Referenced by blk_subsys_attach_device().

6.16.1.15 reloc_devblocks

```
uint32_t blk_volume_meta_t::reloc_devblocks
```

Referenced by bam_cover_devblocks(), blk_commit_format(), blk_compute_fresh_geometry(), compute_totals_from_B(), reloc_flush_to_disk(), and reloc_load_from_disk().

6.16.1.16 reloc_start

```
uint32_t blk_volume_meta_t::reloc_start
```

Referenced by blk_commit_format(), blk_compute_fresh_geometry(), reloc_flush_to_disk(), and reloc_load_from_disk().

6.16.1.17 reserved_disk_lo

```
uint32_t blk_volume_meta_t::reserved_disk_lo
```

Referenced by blk_compute_fresh_geometry().

6.16.1.18 reserved_ram_lo

```
uint32_t blk_volume_meta_t::reserved_ram_lo
```

Referenced by blk_compute_fresh_geometry().

6.16.1.19 total_blocks

```
uint64_t blk_volume_meta_t::total_blocks
```

Referenced by blk_compute_fresh_geometry(), blk_format_or_load_disk(), blk_get_device_free_blocks(), blk_subsys_attach_device(), and compute_totals_from_B().

6.16.1.20 total_devblocks

```
uint64_t blk_volume_meta_t::total_devblocks
```

Referenced by blk_compute_fresh_geometry(), blk_format_or_load_disk(), blk_meta_zone_read(), blk_meta_zone_write(), blk_subsys_attach_device(), and compute_totals_from_B().

6.16.1.21 total_volumes

```
uint32_t blk_volume_meta_t::total_volumes
```

Referenced by blk_compute_fresh_geometry().

6.16.1.22 tracked_blocks

```
uint64_t blk_volume_meta_t::tracked_blocks
```

Referenced by compute_totals_from_B().

6.16.1.23 version

```
uint32_t blk_volume_meta_t::version
```

Referenced by blk_compute_fresh_geometry(), and blk_format_or_load_disk().

The documentation for this struct was generated from the following file:

- v3/include/block_subsystem.h

6.17 blkcfg_t Struct Reference

```
#include <blkcfg.h>
```

Data Fields

- blkcfg_backend_t backend
- uint32_t fbs
- uint8_t read_only
- uint64_t size_bytes
- uint32_t blocks
- char file_path [4096]

6.17.1 Field Documentation

6.17.1.1 backend

```
blkcfg_backend_t blkcfg_t::backend
```

6.17.1.2 blocks

```
uint32_t blkcfg_t::blocks
```

6.17.1.3 fbs

```
uint32_t blkcfg_t::fbs
```

6.17.1.4 file_path

```
char blkcfg_t::file_path[4096]
```

6.17.1.5 read_only

```
uint8_t blkcfg_t::read_only
```

6.17.1.6 size_bytes

```
uint64_t blkcfg_t::size_bytes
```

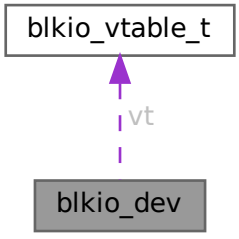
The documentation for this struct was generated from the following file:

- v3/include/blkcfg.h

6.18 blkio_dev Struct Reference

```
#include <blkio.h>
```

Collaboration diagram for blkio_dev:



Data Fields

- const blkio_vtable_t * vt
- uint32_t forth_block_size
- uint32_t total_blocks
- void * state
- uint8_t is_open

6.18.1 Field Documentation

6.18.1.1 forth_block_size

```
uint32_t blkio_dev::forth_block_size
```

Referenced by blkio_info(), blkio_open(), file_open(), gpt_read(), gpt_write_one(), part_open(), ram_open(), usb_blk_open(), and vblk_open().

6.18.1.2 is_open

```
uint8_t blkio_dev::is_open
```

Referenced by blkio_close(), blkio_flush(), blkio_info(), blkio_open(), blkio_read(), and blkio_write().

6.18.1.3 state

```
void* blkio_dev::state
```

Referenced by blkio_open(), file_close(), file_flush(), file_info(), file_open(), file_read(), file_write(), part_flush(), part_info(), part_open(), part_read(), part_write(), ram_close(), ram_info(), ram_open(), ram_read(), ram_write(), usb_blk_info(), usb_blk_open(), usb_blk_read(), usb_blk_write(), vblk_info(), vblk_open(), vblk_read(), and vblk_write().

6.18.1.4 total_blocks

```
uint32_t blkio_dev::total_blocks
```

Referenced by blkio_info(), blkio_open(), blkio_read(), blkio_write(), capsule_wirebind_overflow_idle_check(), file_open(), file_read(), file_write(), gpt_grow_last(), gpt_part_open(), gpt_read(), gpt_write_one(), part_open(), ram_open(), sk_v4_grow_stick(), sk_v4_identity_offer_wait(), usb_blk_open(), and vblk_open().

6.18.1.5 vt

```
const blkio_vtable_t* blkio_dev::vt
```

Referenced by blkio_close(), blkio_flush(), blkio_info(), blkio_open(), blkio_read(), blkio_write(), gpt_grow_last(), gpt_read(), gpt_write_one(), part_flush(), and part_info().

The documentation for this struct was generated from the following file:

- v3/include/blkio.h

6.19 blkio_file_state_t Struct Reference

Data Fields

- int fd
- char path [4096]
- uint32_t total_blocks
- uint32_t fbs
- uint8_t read_only

6.19.1 Field Documentation

6.19.1.1 fbs

```
uint32_t blkio_file_state_t::fbs
```

Referenced by blkio_file_init_state(), file_info(), file_open(), file_read(), and file_write().

6.19.1.2 fd

```
int blkio_file_state_t::fd
```

Referenced by blkio_file_init_state(), file_close(), file_flush(), file_info(), file_open(), file_read(), and file_write().

6.19.1.3 path

```
char blkio_file_state_t::path[4096]
```

Referenced by blkio_file_init_state(), and file_open().

6.19.1.4 read_only

```
uint8_t blkio_file_state_t::read_only
```

Referenced by blkio_file_init_state(), file_info(), file_open(), and file_write().

6.19.1.5 total_blocks

```
uint32_t blkio_file_state_t::total_blocks
```

Referenced by blkio_file_init_state(), file_info(), and file_open().

The documentation for this struct was generated from the following file:

- v3/src/blkio_file.c

6.20 blkio_info_t Struct Reference

`#include <blkio.h>`

Data Fields

- uint32_t forth_block_size
- uint32_t total_blocks
- uint32_t phys_sector_size
- uint64_t phys_size_bytes
- uint8_t read_only

6.20.1 Field Documentation

6.20.1.1 forth_block_size

`uint32_t blkio_info_t::forth_block_size`

Referenced by blkio_info(), file_info(), init_blkio(), ram_info(), usb_blk_info(), and vblk_info().

6.20.1.2 phys_sector_size

`uint32_t blkio_info_t::phys_sector_size`

Referenced by file_info(), gpt_read(), gpt_write_one(), ram_info(), usb_blk_info(), and vblk_info().

6.20.1.3 phys_size_bytes

`uint64_t blkio_info_t::phys_size_bytes`

Referenced by file_info(), init_blkio(), part_info(), ram_info(), usb_blk_info(), and vblk_info().

6.20.1.4 read_only

`uint8_t blkio_info_t::read_only`

Referenced by file_info(), init_blkio(), ram_info(), usb_blk_info(), and vblk_info().

6.20.1.5 total_blocks

`uint32_t blkio_info_t::total_blocks`

Referenced by artemis_sig_start_fblock(), blk_subsys_attach_device(), blkio_info(), file_info(), init_blkio(), part_info(), ram_info(), sk_v4_grow_artemis(), usb_blk_info(), and vblk_info().

The documentation for this struct was generated from the following file:

- v3/include/blkio.h

6.21 blkio_params_t Struct Reference

`#include <blkio.h>`

Data Fields

- uint32_t forth_block_size
- uint32_t total_blocks
- void * opaque

6.21.1 Field Documentation

6.21.1.1 forth_block_size

`uint32_t blkio_params_t::forth_block_size`

Referenced by blkio_factory_open(), blkio_open(), blkio_usb_open_msc(), capsule_mint_identity_scratch(), gpt_part_open(), and virtio_blk_find_artemis().

6.21.1.2 opaque

`void* blkio_params_t::opaque`

Referenced by blkio_usb_open_msc(), file_open(), gpt_part_open(), part_open(), ram_open(), usb_blk_open(), and virtio_blk_find_artemis().

6.21.1.3 total_blocks

`uint32_t blkio_params_t::total_blocks`

Referenced by blkio_open(), blkio_usb_open_msc(), gpt_part_open(), and virtio_blk_find_artemis().

The documentation for this struct was generated from the following file:

- v3/include/blkio.h

6.22 blkio_ram_state_t Struct Reference

Data Fields

- uint8_t * base
- uint32_t total_blocks
- uint32_t fbs
- uint8_t read_only

6.22.1 Field Documentation

6.22.1.1 base

```
uint8_t* blkio_ram_state_t::base
```

Referenced by blkio_ram_init_state(), ram_open(), ram_read(), and ram_write().

6.22.1.2 fbs

```
uint32_t blkio_ram_state_t::fbs
```

Referenced by blkio_ram_init_state(), ram_info(), ram_open(), ram_read(), and ram_write().

6.22.1.3 read_only

```
uint8_t blkio_ram_state_t::read_only
```

Referenced by blkio_ram_init_state(), ram_info(), and ram_write().

6.22.1.4 total_blocks

```
uint32_t blkio_ram_state_t::total_blocks
```

Referenced by blkio_ram_init_state(), in_bounds(), ram_info(), and ram_open().

The documentation for this struct was generated from the following file:

- v3/src/blkio_ram.c

6.23 blkio_vtable_t Struct Reference

```
#include <blkio.h>
```

Data Fields

- int(∗ open)(struct blkio_dev ∗dev, const blkio_params_t ∗p)
- int(∗ close)(struct blkio_dev ∗dev)
- int(∗ read)(struct blkio_dev ∗dev, uint32_t fblock, void ∗dst)
- int(∗ write)(struct blkio_dev ∗dev, uint32_t fblock, const void ∗src)
- int(∗ flush)(struct blkio_dev ∗dev)
- int(∗ info)(struct blkio_dev ∗dev, blkio_info_t ∗out)

6.23.1 Field Documentation

6.23.1.1 close

```
int(* blkio_vtable_t::close) (struct blkio_dev *dev)
```

Referenced by blkio_close(), and blkio_open().

6.23.1.2 flush

```
int(* blkio_vtable_t::flush) (struct blkio_dev *dev)
```

Referenced by blkio_flush(), blkio_open(), gpt_grow_last(), gpt_write_one(), and part_flush().

6.23.1.3 info

```
int(* blkio_vtable_t::info) (struct blkio_dev *dev, blkio_info_t *out)
```

Referenced by blkio_info(), blkio_open(), gpt_read(), gpt_write_one(), and part_info().

6.23.1.4 open

```
int(* blkio_vtable_t::open) (struct blkio_dev *dev, const blkio_params_t *p)
```

Referenced by blkio_open().

6.23.1.5 read

```
int(* blkio_vtable_t::read) (struct blkio_dev *dev, uint32_t fblock, void *dst)
```

Referenced by blkio_open(), and blkio_read().

6.23.1.6 write

```
int(* blkio_vtable_t::write) (struct blkio_dev *dev, uint32_t fblock, const void *src)
```

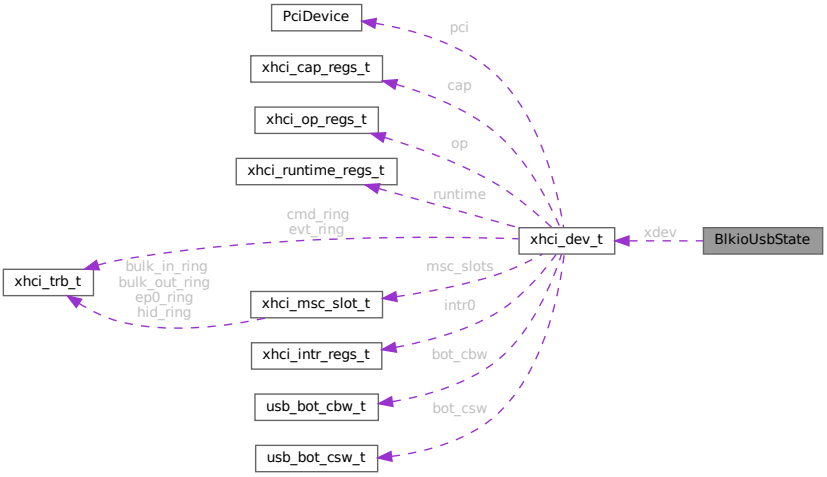
Referenced by blkio_open(), and blkio_write().

The documentation for this struct was generated from the following file:

- v3/include/blkio.h

6.24 BlkioUsbState Struct Reference

Collaboration diagram for BlkioUsbState:



Data Fields

- xhci_dev_t * xdev
- uint32_t slot_id
- uint32_t scsi_block_size
- uint32_t scsi_blocks_per_fblock
- uint32_t total_forth_blocks

6.24.1 Field Documentation

6.24.1.1 scsi_block_size

```
uint32_t BlkioUsbState::scsi_block_size
```

Referenced by blkio_usb_open_msc(), usb_blk_info(), usb_blk_read(), and usb_blk_write().

6.24.1.2 scsi_blocks_per_fblock

```
uint32_t BlkioUsbState::scsi_blocks_per_fblock
```

Referenced by blkio_usb_open_msc(), usb_blk_read(), and usb_blk_write().

6.24.1.3 slot_id

```
uint32_t BlkioUsbState::slot_id
```

Referenced by blkio_usb_open_msc(), usb_blk_read(), and usb_blk_write().

6.24.1.4 total_forth_blocks

```
uint32_t BlkioUsbState::total_forth_blocks
```

Referenced by blkio_usb_open_msc(), usb_blk_info(), usb_blk_open(), usb_blk_read(), and usb_blk_write().

6.24.1.5 xdev

```
xhci_dev_t* BlkioUsbState::xdev
```

Referenced by blkio_usb_open_msc(), usb_blk_read(), and usb_blk_write().

The documentation for this struct was generated from the following file:

- kernel/src/usb/blkio_usb.c

6.25 BlockBuffer Struct Reference

Block buffer structure maintaining buffer state.

```
#include <block_words.h>
```

Data Fields

- unsigned char data [1024]
  Block content buffer.
- int block_number
  Currently loaded block number (-1 = empty)
- int dirty
  Modified flag for write-back.
- int accessed
  LRU counter for buffer management.
- buffer_type_t type
  Buffer type for storage mechanism.
- uintptr_t hw_address
  Future: Hardware backing address.

6.25.1 Detailed Description

Block buffer structure maintaining buffer state.

6.25.2 Field Documentation

6.25.2.1 accessed

```
int BlockBuffer::accessed
```

LRU counter for buffer management.

6.25.2.2 block_number

```
int BlockBuffer::block_number
```

Currently loaded block number (-1 = empty)

6.25.2.3 data

```
unsigned char BlockBuffer::data[1024]
```

Block content buffer.

6.25.2.4 dirty

```
int BlockBuffer::dirty
```

Modified flag for write-back.

6.25.2.5 hw_address

```
uintptr_t BlockBuffer::hw_address
```

Future: Hardware backing address.

6.25.2.6 type

```
buffer_type_t BlockBuffer::type
```

Buffer type for storage mechanism.

The documentation for this struct was generated from the following file:

- v3/src/word_source/include/block_words.h

6.26 BootDisk Struct Reference

```
#include <uefi.h>
```

Data Fields

- uint8_t gpt
- uint8_t is_stick
- uint8_t disk_guid [16]

6.26.1 Field Documentation

6.26.1.1 disk_guid

```
uint8_t BootDisk::disk_guid[16]
```

Referenced by sk_v4_is_this_stick().

6.26.1.2 gpt

```
uint8_t BootDisk::gpt
```

6.26.1.3 is_stick

```
uint8_t BootDisk::is_stick
```

Referenced by kernel_main_deep(), and sk_v4_is_this_stick().

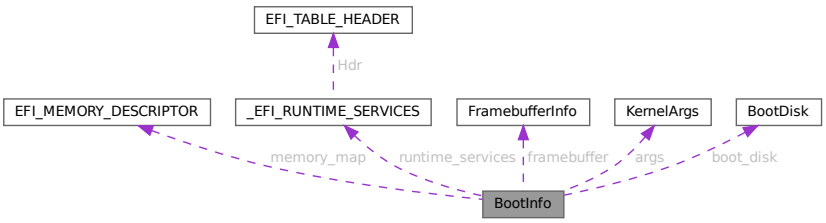
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.27 BootInfo Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for BootInfo:



Data Fields

- EFI_MEMORY_DESCRIPTOR * memory_map
- UINTN memory_map_size
- UINTN memory_map_descriptor_size
- EFI_RUNTIME_SERVICES * runtime_services
- void * acpi_table
- void * dtb
- FramebufferInfo framebuffer
- UINT8 uefi_boot_services_exited
- void * kernel_stack_base
- uint64_t kernel_stack_size
- KernelArgs args
- BootDisk boot_disk

6.27.1 Field Documentation

6.27.1.1 acpi_table

```
void* BootInfo::acpi_table
```

Referenced by efi_main(), kernel_main(), kernel_main_deep(), rpi5_native_boot(), running_under_hypervisor(), and timer_init().

6.27.1.2 args

```
KernelArgs BootInfo::args
```

Referenced by efi_main(), kernel_main(), kernel_main_deep(), and rpi5_native_boot().

6.27.1.3 boot_disk

```
BootDisk BootInfo::boot_disk
```

Referenced by efi_main(), and kernel_main_deep().

6.27.1.4 dtb

```
void* BootInfo::dtb
```

Referenced by apic_init(), efi_main(), kernel_main(), rpi5_native_boot(), running_under_hypervisor(), and timer_init().

6.27.1.5 framebuffer

```
FramebufferInfo BootInfo::framebuffer
```

Referenced by efi_main(), rpi5_native_boot(), and vmm_init().

6.27.1.6 kernel_stack_base

```
void* BootInfo::kernel_stack_base
```

Referenced by efi_main(), and rpi5_native_boot().

6.27.1.7 kernel_stack_size

```
uint64_t BootInfo::kernel_stack_size
```

Referenced by efi_main(), and rpi5_native_boot().

6.27.1.8 memory_map

```
EFI_MEMORY_DESCRIPTOR* BootInfo::memory_map
```

Referenced by efi_main(), pmm_init(), print_boot_info(), rpi5_native_boot(), and vmm_init().

6.27.1.9 memory_map_descriptor_size

```
UINTN BootInfo::memory_map_descriptor_size
```

Referenced by efi_main(), pmm_init(), print_boot_info(), rpi5_native_boot(), and vmm_init().

6.27.1.10 memory_map_size

```
UINTN BootInfo::memory_map_size
```

Referenced by efi_main(), pmm_init(), print_boot_info(), rpi5_native_boot(), and vmm_init().

6.27.1.11 runtime_services

```
EFI_RUNTIME_SERVICES* BootInfo::runtime_services
```

Referenced by efi_main(), kernel_main(), and rpi5_native_boot().

6.27.1.12 uefi_boot_services_exited

```
UINT8 BootInfo::uefi_boot_services_exited
```

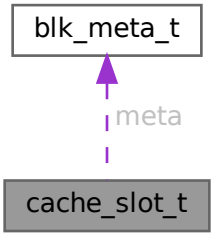
Referenced by efi_main(), and rpi5_native_boot().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.28 cache_slot_t Struct Reference

Collaboration diagram for cache_slot_t:



Data Fields

- uint32_t devblock
- uint8_t data [BLK_DEVICE_SECTOR]
- blk_meta_t meta [BLK_PACK_RATIO]
- uint8_t valid
- uint8_t loaded
- uint8_t dirty
- uint8_t meta_dirty

6.28.1 Field Documentation

6.28.1.1 data

```
uint8_t cache_slot_t::data[BLK_DEVICE_SECTOR]
```

Referenced by blk_get_buffer(), blk_update(), cache_load_devblock(), and cache_writeback().

6.28.1.2 devblock

```
uint32_t cache_slot_t::devblock
```

Referenced by blk_flush(), cache_get_slot(), and cache_writeback().

6.28.1.3 dirty

```
uint8_t cache_slot_t::dirty
```

Referenced by blk_flush(), blk_get_buffer(), blk_update(), and cache_writeback().

6.28.1.4 loaded

```
uint8_t cache_slot_t::loaded
```

Referenced by cache_load_devblock().

6.28.1.5 meta

```
blk_meta_t cache_slot_t::meta[BLK_PACK_RATIO]
```

Referenced by blk_get_meta(), blk_set_meta(), blk_update(), cache_load_devblock(), and cache_writeback().

6.28.1.6 meta_dirty

```
uint8_t cache_slot_t::meta_dirty
```

Referenced by blk_flush(), blk_set_meta(), blk_update(), and cache_writeback().

6.28.1.7 valid

```
uint8_t cache_slot_t::valid
```

Referenced by blk_flush(), and cache_get_slot().

The documentation for this struct was generated from the following file:

- v3/src/block_subsystem.c

6.29 CapsuleDirHeader Struct Reference

```
#include <capsule.h>
```

Data Fields

- uint64_t magic
- uint64_t arena_base
- uint64_t arena_size
- uint32_t desc_count
- uint32_t desc_capacity
- uint32_t name_count
- uint32_t reserved
- uint64_t dir_hash

6.29.1 Field Documentation

6.29.1.1 arena_base

```
uint64_t CapsuleDirHeader::arena_base
```

Referenced by capsule_console_birth(), capsule_runcap_birth(), and kernel_main_deep().

6.29.1.2 arena_size

```
uint64_t CapsuleDirHeader::arena_size
```

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_console_birth(), capsule_exec_init(), capsule_run_experiment(), capsule_runcap_birth(), and kernel_main_deep().

6.29.1.3 desc_capacity

```
uint32_t CapsuleDirHeader::desc_capacity
```

Referenced by capsule_console_birth(), capsule_runcap_birth(), and kernel_main_deep().

6.29.1.4 desc_count

```
uint32_t CapsuleDirHeader::desc_count
```

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_console_birth(), capsule_find_by_id(), capsule_find_by_name(), capsule_find_mama_init(), capsule_run_experiment(), capsule_runcap_birth(), and kernel_main_deep().

6.29.1.5 dir_hash

```
uint64_t CapsuleDirHeader::dir_hash
```

Referenced by capsule_console_birth(), capsule_runcap_birth(), and kernel_main_deep().

6.29.1.6 magic

```
uint64_t CapsuleDirHeader::magic
```

Referenced by capsule_console_birth(), capsule_runcap_birth(), and kernel_main_deep().

6.29.1.7 name_count

```
uint32_t CapsuleDirHeader::name_count
```

Referenced by capsule_console_birth(), capsule_runcap_birth(), and kernel_main_deep().

6.29.1.8 reserved

```
uint32_t CapsuleDirHeader::reserved
```

Referenced by kernel_main_deep().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/capsule.h

6.30 CapsuleNameEntry Struct Reference

```
#include <capsule.h>
```

Data Fields

- char name [512]

6.30.1 Field Documentation

6.30.1.1 name

```
char CapsuleNameEntry::name[512]
```

Referenced by capsule_console_birth(), and capsule_runcap_birth().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/capsule.h

6.31 CapsuleRunRecord Struct Reference

```
#include <capsule_run.h>
```

Data Fields

- uint64_t run_id
- VMUuid vm_id
- uint32_t reserved
- uint64_t capsule_id
- uint64_t capsule_hash
- uint64_t pre_dict_hash
- uint64_t post_dict_hash
- uint64_t started_ns
- uint64_t ended_ns
- uint32_t result_code
- uint32_t flags

6.31.1 Field Documentation

6.31.1.1 capsule_hash

```
uint64_t CapsuleRunRecord::capsule_hash
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.2 capsule_id

```
uint64_t CapsuleRunRecord::capsule_id
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.3 ended_ns

```
uint64_t CapsuleRunRecord::ended_ns
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.4 flags

```
uint32_t CapsuleRunRecord::flags
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.5 post_dict_hash

```
uint64_t CapsuleRunRecord::post_dict_hash
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.6 pre_dict_hash

```
uint64_t CapsuleRunRecord::pre_dict_hash
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.7 reserved

```
uint32_t CapsuleRunRecord::reserved
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.8 result_code

```
uint32_t CapsuleRunRecord::result_code
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.9 run_id

```
uint64_t CapsuleRunRecord::run_id
```

Referenced by capsule_run_experiment(), capsule_run_log_init(), and capsule_run_log_record().

6.31.1.10 started_ns

```
uint64_t CapsuleRunRecord::started_ns
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

6.31.1.11 vm_id

```
VMUuid CapsuleRunRecord::vm_id
```

Referenced by capsule_run_experiment(), and capsule_run_log_init().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/capsule_run.h

6.32 CapsuleSigEntry Struct Reference

```
#include <capsule.h>
```

Data Fields

- uint8_t sig [64]
- uint8_t has_sig
- uint8_t _pad [7]

6.32.1 Field Documentation

6.32.1.1 _pad

```
uint8_t CapsuleSigEntry::_pad[7]
```

6.32.1.2 has_sig

```
uint8_t CapsuleSigEntry::has_sig
```

6.32.1.3 sig

```
uint8_t CapsuleSigEntry::sig[64]
```

Referenced by capsule_verify_signature().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/capsule.h

6.33 CDConfigEntry Struct Reference

```
#include <compudynamics.h>
```

Data Fields

- uint8_t config_bits
- uint8_t has_prev
- uint8_t _pad [2]
- uint32_t benefit_score
- uint32_t tick_count
- uint32_t prev_window
- uint32_t prev_locality_q16

6.33.1 Field Documentation

6.33.1.1 _pad

```
uint8_t CDConfigEntry::_pad[2]
```

Referenced by cd_config_table_seed().

6.33.1.2 benefit_score

```
uint32_t CDConfigEntry::benefit_score
```

Referenced by cd_config_table_seed().

6.33.1.3 config_bits

```
uint8_t CDConfigEntry::config_bits
```

Referenced by cd_config_table_seed(), cd_config_table_tick(), ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), ssm_l8_update_table(), and vm_heartbeat_update_l8().

6.33.1.4 has_prev

```
uint8_t CDConfigEntry::has_prev
```

Referenced by cd_config_table_seed().

6.33.1.5 prev_locality_q16

```
uint32_t CDConfigEntry::prev_locality_q16
```

Referenced by cd_config_table_seed().

6.33.1.6 prev_window

```
uint32_t CDConfigEntry::prev_window
```

Referenced by cd_config_table_seed().

6.33.1.7 tick_count

```
uint32_t CDConfigEntry::tick_count
```

Referenced by cd_config_table_seed().

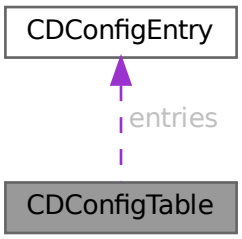
The documentation for this struct was generated from the following file:

- v3/include/compudynamics.h

6.34 CDConfigTable Struct Reference

```
#include <compudynamics.h>
```

Collaboration diagram for CDConfigTable:



Data Fields

- CDConfigEntry * entries
- uint32_t * regime_scores
- uint32_t * regime_ticks
- uint32_t * total_regime_ticks
- uint32_t num_configs
- uint32_t num_regimes
- uint8_t current_config
- uint8_t current_regime

6.34.1 Field Documentation

6.34.1.1 current_config

```
uint8_t CDConfigTable::current_config
```

Referenced by cd_config_table_force(), cd_config_table_seed(), cd_config_table_tick(), ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), ssm_l8_update_table(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.34.1.2 current_regime

```
uint8_t CDConfigTable::current_regime
```

Referenced by cd_config_table_seed(), cd_config_table_tick(), l8_regime_modulation_q16(), ssm_l8_tick_score_and_select(), ssm_l8_update_table(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.34.1.3 entries

```
CDConfigEntry* CDConfigTable::entries
```

Referenced by cd_config_table_force(), cd_config_table_free(), cd_config_table_init(), cd_config_table_seed(), cd_config_table_tick(), ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), ssm_l8_update_table(), and vm_heartbeat_update_l8().

6.34.1.4 num_configs

```
uint32_t CDConfigTable::num_configs
```

Referenced by cd_config_table_force(), cd_config_table_init(), cd_config_table_seed(), cd_config_table_tick(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.34.1.5 num_regimes

```
uint32_t CDConfigTable::num_regimes
```

Referenced by cd_config_table_init(), and cd_config_table_seed().

6.34.1.6 regime_scores

```
uint32_t* CDConfigTable::regime_scores
```

Referenced by cd_config_table_free(), cd_config_table_init(), cd_config_table_seed(), cd_config_table_tick(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.34.1.7 regime_ticks

```
uint32_t* CDConfigTable::regime_ticks
```

Referenced by cd_config_table_free(), cd_config_table_init(), cd_config_table_seed(), and cd_config_table_tick().

6.34.1.8 total_regime_ticks

```
uint32_t* CDConfigTable::total_regime_ticks
```

Referenced by cd_config_table_free(), cd_config_table_init(), cd_config_table_seed(), and cd_config_table_tick().

The documentation for this struct was generated from the following file:

- v3/include/compudynamics.h

6.35 CDRegimeMetrics Struct Reference

`#include <compudynamics.h>`

Data Fields

- uint32_t diversity_q16
- uint32_t volatility_q16
- uint32_t locality_q16

6.35.1 Field Documentation

6.35.1.1 diversity_q16

`uint32_t CDRegimeMetrics::diversity_q16`

Referenced by cd_classify_ids().

6.35.1.2 locality_q16

`uint32_t CDRegimeMetrics::locality_q16`

Referenced by cd_classify_ids(), and ssm_l8_update_table().

6.35.1.3 volatility_q16

`uint32_t CDRegimeMetrics::volatility_q16`

Referenced by cd_classify_ids().

The documentation for this struct was generated from the following file:

- v3/include/compudynamics.h

6.36 CDTuning Struct Reference

`#include <compudynamics.h>`

Data Fields

- uint32_t id_window_depth
- uint32_t locality_lookback
- uint32_t diversity_high_threshold_q16
- uint32_t volatility_high_threshold_q16
- uint32_t locality_high_threshold_q16
- uint32_t num_configs
- uint32_t num_regimes
- uint32_t score_max
- uint32_t score_min
- uint32_t score_decay_factor_q16
- uint32_t ucb_k
- uint32_t reward_gain
- uint32_t joint_weight_q16
- uint32_t anova_weight_q16

6.36.1 Field Documentation

6.36.1.1 anova_weight_q16

```
uint32_t CDTuning::anova_weight_q16
```

Referenced by cd_config_table_tick(), cd_tuning_vm(), and cd_tuning_word().

6.36.1.2 diversity_high_threshold_q16

```
uint32_t CDTuning::diversity_high_threshold_q16
```

Referenced by cd_tuning_vm(), and cd_tuning_word().

6.36.1.3 id_window_depth

```
uint32_t CDTuning::id_window_depth
```

Referenced by cd_tuning_vm(), cd_tuning_word(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.36.1.4 joint_weight_q16

```
uint32_t CDTuning::joint_weight_q16
```

Referenced by cd_config_table_tick(), cd_tuning_vm(), and cd_tuning_word().

6.36.1.5 locality_high_threshold_q16

```
uint32_t CDTuning::locality_high_threshold_q16
```

Referenced by cd_tuning_vm(), cd_tuning_word(), and ssm_l8_update_table().

6.36.1.6 locality_lookback

```
uint32_t CDTuning::locality_lookback
```

Referenced by cd_tuning_vm(), cd_tuning_word(), and ssm_l8_update_table().

6.36.1.7 num_configs

```
uint32_t CDTuning::num_configs
```

Referenced by cd_config_table_init(), cd_tuning_vm(), cd_tuning_word(), and ssm_l8_seed_from_doe().

6.36.1.8 num_regimes

```
uint32_t CDTuning::num_regimes
```

Referenced by cd_config_table_init(), cd_tuning_vm(), and cd_tuning_word().

6.36.1.9 reward_gain

```
uint32_t CDTuning::reward_gain
```

Referenced by cd_config_table_tick(), cd_tuning_vm(), and cd_tuning_word().

6.36.1.10 score_decay_factor_q16

```
uint32_t CDTuning::score_decay_factor_q16
```

Referenced by cd_config_table_tick(), cd_tuning_vm(), and cd_tuning_word().

6.36.1.11 score_max

```
uint32_t CDTuning::score_max
```

Referenced by cd_config_table_tick(), cd_tuning_vm(), cd_tuning_word(), and ssm_l8_seed_from_doe().

6.36.1.12 score_min

```
uint32_t CDTuning::score_min
```

Referenced by cd_config_table_tick(), cd_tuning_vm(), and cd_tuning_word().

6.36.1.13 ucb_k

```
uint32_t CDTuning::ucb_k
```

Referenced by cd_config_table_tick(), cd_tuning_vm(), and cd_tuning_word().

6.36.1.14 volatility_high_threshold_q16

```
uint32_t CDTuning::volatility_high_threshold_q16
```

Referenced by cd_tuning_vm(), and cd_tuning_word().

The documentation for this struct was generated from the following file:

- v3/include/compudynamics.h

6.37 cf_item_t Struct Reference

```
#include <vm.h>
```

Data Fields

- size_t addr
- cf_tag_t tag

6.37.1 Field Documentation

6.37.1.1 addr

```
size_t cf_item_t::addr
```

Referenced by cf_push_item(), control_forth_again(), control_forth_else(), control_forth_endof(), control_forth_loop(), control_forth_plus_loop(), control_forth_repeat(), control_forth_then(), and control_forth_until().

6.37.1.2 tag

```
cf_tag_t cf_item_t::tag
```

Referenced by cf_push_item(), control_forth_again(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_repeat(), control_forth_then(), control_forth_until(), and control_forth_while().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.38 CLIConfig Struct Reference

Configuration structure from command-line arguments Consolidates all parsed CLI options into a single, cleanly organized struct.

```
#include <cli.h>
```

Data Fields

- int run_tests
- int break_me
- int fail_fast
- int benchmark
- int benchmark_iterations
- int doe_experiment
- HeartbeatLogMode heartbeat_log_mode
- int script_mode
- LogLevel log_level
- int log_level_explicitly_set
- const char * disk_img_path
- uint32_t ram_disk_mb
- int run_tests_flag_observed

6.38.1 Detailed Description

Configuration structure from command-line arguments Consolidates all parsed CLI options into a single, cleanly organized struct.

6.38.2 Field Documentation

6.38.2.1 benchmark

```
int CLIConfig::benchmark
```

Referenced by cli_parse(), and main().

6.38.2.2 benchmark_iterations

```
int CLIConfig::benchmark_iterations
```

Referenced by cli_parse(), and run_benchmark_mode().

6.38.2.3 break_me

```
int CLIConfig::break_me
```

Referenced by cli_parse(), main(), and run_optional_tests().

6.38.2.4 disk_img_path

```
const char* CLIConfig::disk_img_path
```

Referenced by cli_parse(), and init_blkio().

6.38.2.5 doe_experiment

```
int CLIConfig::doe_experiment
```

Referenced by cli_parse(), and main().

6.38.2.6 fail_fast

```
int CLIConfig::fail_fast
```

Referenced by cli_parse(), and main().

6.38.2.7 heartbeat_log_mode

```
HeartbeatLogMode CLIConfig::heartbeat_log_mode
```

Referenced by cli_parse().

6.38.2.8 log_level

```
LogLevel CLIConfig::log_level
```

Referenced by cli_parse(), and main().

6.38.2.9 log_level_explicitly_set

```
int CLIConfig::log_level_explicitly_set
```

Referenced by cli_parse(), and main().

6.38.2.10 ram_disk_mb

```
uint32_t CLIConfig::ram_disk_mb
```

Referenced by cli_parse(), and init_blkio().

6.38.2.11 run_tests

```
int CLIConfig::run_tests
```

Referenced by cli_parse().

6.38.2.12 run_tests_flag_observed

```
int CLIConfig::run_tests_flag_observed
```

Referenced by cli_parse(), and main().

6.38.2.13 script_mode

```
int CLIConfig::script_mode
```

Referenced by cli_parse(), and main().

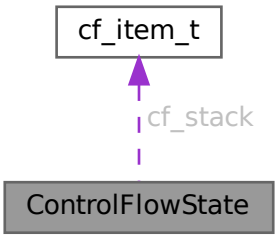
The documentation for this struct was generated from the following file:

- v3/include/cli.h

6.39 ControlFlowState Struct Reference

```
#include <vm.h>
```

Collaboration diagram for ControlFlowState:



Data Fields

- cf_item_t cf_stack [64]
- int cf_sp
- int cf_last_mode
- size_t leave_addrs [64]
- int leave_sp
- int leave_mark_stack [64]
- int leave_mark_sp
- size_t endof_addrs [64]
- int endof_sp
- int endof_mark_stack [64]
- int endof_mark_sp

6.39.1 Field Documentation

6.39.1.1 cf_last_mode

```
int ControlFlowState::cf_last_mode
```

Referenced by cf_epoch_sync(), vm_init(), and vm_init_with_host().

6.39.1.2 cf_sp

```
int ControlFlowState::cf_sp
```

Referenced by cf_epoch_sync(), cf_peek_item(), cf_pop_item(), cf_push_item(), control_forth_leave(), control_forth_of(), vm_init(), and vm_init_with_host().

6.39.1.3 cf_stack

```
cf_item_t ControlFlowState::cf_stack[64]
```

Referenced by cf_peek_item(), cf_pop_item(), cf_push_item(), control_forth_leave(), and control_forth_of().

6.39.1.4 endof_addrs

```
size_t ControlFlowState::endof_addrs[64]
```

Referenced by control_forth_endcase(), and control_forth_endof().

6.39.1.5 endof_mark_sp

```
int ControlFlowState::endof_mark_sp
```

Referenced by control_forth_case(), control_forth_endcase(), vm_init(), and vm_init_with_host().

6.39.1.6 endof_mark_stack

```
int ControlFlowState::endof_mark_stack[64]
```

Referenced by control_forth_case(), and control_forth_endcase().

6.39.1.7 endof_sp

```
int ControlFlowState::endof_sp
```

Referenced by control_forth_case(), control_forth_endcase(), control_forth_endof(), vm_init(), and vm_init_with_host().

6.39.1.8 leave_addrs

```
size_t ControlFlowState::leave_addrs[64]
```

Referenced by control_forth_leave(), control_forth_loop(), and control_forth_plus_loop().

6.39.1.9 leave_mark_sp

```
int ControlFlowState::leave_mark_sp
```

Referenced by control_forth_do(), control_forth_leave(), control_forth_loop(), control_forth_plus_loop(), control_forth_qdo(), vm_init(), and vm_init_with_host().

6.39.1.10 leave_mark_stack

```
int ControlFlowState::leave_mark_stack[64]
```

Referenced by control_forth_do(), control_forth_loop(), control_forth_plus_loop(), and control_forth_qdo().

6.39.1.11 leave_sp

```
int ControlFlowState::leave_sp
```

Referenced by control_forth_do(), control_forth_leave(), control_forth_loop(), control_forth_plus_loop(), control_forth_qdo(), vm_init(), and vm_init_with_host().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.40 der_span_t Struct Reference

Data Fields

- const uint8_t * p
- size_t len

6.40.1 Field Documentation

6.40.1.1 len

```
size_t der_span_t::len
```

Referenced by der_next(), x509_extract_ed25519_pubkey(), x509_extract_serial(), and x509_verify_signature().

6.40.1.2 p

```
const uint8_t* der_span_t::p
```

Referenced by der_next(), x509_extract_ed25519_pubkey(), x509_extract_serial(), and x509_verify_signature().

The documentation for this struct was generated from the following file:

- kernel/src/crypto/x509_ed25519.c

6.41 DiagEvent Struct Reference

Data Fields

- uint16_t code
- uint32_t value

6.41.1 Field Documentation

6.41.1.1 code

```
uint16_t DiagEvent::code
```

Referenced by diag_push(), and virtio_input_pop_event().

6.41.1.2 value

```
uint32_t DiagEvent::value
```

Referenced by diag_push(), and virtio_input_pop_event().

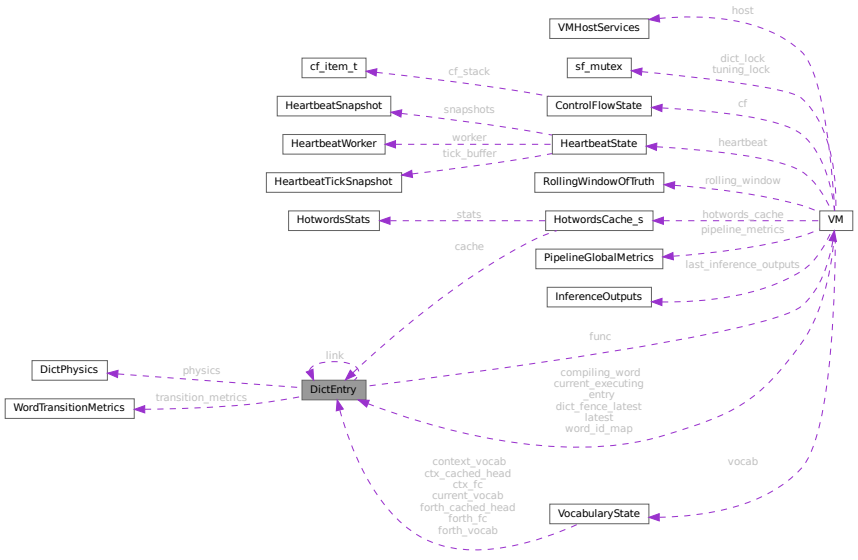
The documentation for this struct was generated from the following file:

- kernel/src/virtio/virtio_input.c

6.42 DictEntry Struct Reference

```
#include <vm.h>
```

Collaboration diagram for DictEntry:



Data Fields

- struct DictEntry * link
- word_func_t func
- cell_t flags
- uint8_t name_len
- cell_t execution_heat
- uint8_t acl_default
- uint32_t acl_ttl
- uint8_t acl_allow
- uint8_t acl_mode
- uint8_t acl_pinned
- uint32_t word_id
- DictPhysics physics
- WordTransitionMetrics * transition_metrics
- char name [ ]

6.42.1 Field Documentation

6.42.1.1 acl_allow

```
uint8_t DictEntry::acl_allow
```

Referenced by acl_inherit_entry(), dictionary_snapshot_acl_from_parent(), execute_colon_word(), forth_acl_allow_fetch(), forth_acl_allow_store(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_inherit(), test_acl_init_primitives(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_bypa and vm_exit_compile_mode().

6.42.1.2 acl_default

```
uint8_t DictEntry::acl_default
```

Referenced by sk_dict_canonical_hash().

6.42.1.3 acl_mode

```
uint8_t DictEntry::acl_mode
```

Referenced by acl_inherit_entry(), dictionary_snapshot_acl_from_parent(), forth_acl_mode_fetch(), forth_acl_mode_store(), kernel_main_deep(), test_acl_inherit(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), and test_acl_ttl_hot_path().

6.42.1.4 acl_pinned

```
uint8_t DictEntry::acl_pinned
```

Referenced by acl_inherit_entry(), dictionary_snapshot_acl_from_parent(), forth_acl_allow_store(), forth_acl_mode_store(), forth_acl_pin(), forth_acl_pinned_query(), forth_acl_ttl_store(), kernel_main_deep(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_inherit(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_blocks_shadow(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), and test_emergency_console_bypass().

6.42.1.5 acl_ttl

```
uint32_t DictEntry::acl_ttl
```

Referenced by acl_inherit_entry(), dictionary_snapshot_acl_from_parent(), execute_colon_word(), forth_acl_ttl_fetch(), forth_acl_ttl_store(), test_acl_deny_aborts(), test_acl_inherit(), test_acl_init_primitives(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_bypass(), and vm_exit_compile_mode().

6.42.1.6 execution_heat

```
cell_t DictEntry::execution_heat
```

Referenced by compare_dict_entry_heat_desc(), execute_colon_word(), forth_acl_heat_fetch(), forth_ALL_HEATS(), forth_PHYSICS_BURN(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_SHOW_FEEDBACK(), forth_PHYSICS_WORD_METR hotwords_cache_lookup(), infer_word_run(), physics_on_lookup(), physics_post_execute(), physics_pre_execute(), starforth_word_init(), test_acl_adaptive_ttl(), test_acl_read_accessors(), and vm_interpret_word().

6.42.1.7 flags

```
cell_t DictEntry::flags
```

Referenced by defining_word_immediate(), dictionary_m_word_hidden(), dictionary_word_forget(), forth_ALL_HEATS(), hotwords_cache_lookup(), sk_dict_canonical_hash(), system_word_vlist(), vm_dict_resolve_in_bucket(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_hide_word(), vm_interpret_word(), vm_make_immediate(), vm_pin_execution_heat(), vm_smudge_word(), vm_unpin_execution_heat(), vocab_find_word(), and vocabulary_word_paren_find().

6.42.1.8 func

```
word_func_t DictEntry::func
```

Referenced by acl_recheck(), acl_recheck(), control_forth_endcase(), control_forth_of(), defer_runtime(), defining_runtime_does_rt(), execute_colon_word(), forth_PHYSICS_BURN(), hash_colon_body(), sk_dict_canonical_hash(), starforth_word_init(), system_word_execute(), vm_create_word(), word_defer_fetch(), and word_is().

6.42.1.9 link

```
struct DictEntry* DictEntry::link
```

Referenced by dictionary_snapshot_acl_from_parent(), dictionary_word_forget(), find_entry_from_name(), infer_word_run(), sf_try_fast_append(), system_word_words(), vm_cleanup(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

6.42.1.10 name

```
char DictEntry::name[]
```

Referenced by defer_runtime(), defining_word_immediate(), dictionary_snapshot_acl_from_parent(), dictionary_word_forget(), execute_colon_word(), fc_rebuild(), forth_ALL_HEATS(), forth_PHYSICS_BURN(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_SHOW_FEEDBACK(), forth_PHYSICS_WORD_METRICS(), hotwords_cache_evict_name(), hotwords_cache_lookup(), sf_rebuild_fc_index(), sf_try_fast_append(), sk_dict_canonical_hash(), system_word_see(), vm_debug_dump_state(), vm_dict_resolve_in_bucket(), vm_exit_compile_mode(), vm_hide_word(), vm_make_immediate(), vm_smudge_word(), vocab_find_word(), and vocabulary_word_order().

6.42.1.11 name_len

```
uint8_t DictEntry::name_len
```

Referenced by defer_runtime(), defining_word_immediate(), dictionary_snapshot_acl_from_parent(), dictionary_word_forget(), execute_colon_word(), forth_ALL_HEATS(), hotwords_cache_evict_name(), hotwords_cache_lookup(), profiler_generate_report(), profiler_print_hotspots(), sk_dict_canonical_hash(), system_word_see(), system_word_vlist(), vm_dict_resolve_in_bucket(), vm_exit_compile_mode(), vm_hide_word(), vm_make_immediate(), vm_smudge_word(), vocab_find_word(), and vocabulary_word_order().

6.42.1.12 physics

```
DictPhysics DictEntry::physics
```

Referenced by execute_colon_word(), forth_PHYSICS_BURN(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_SHOW_FEEDBACK(), forth_PHYSICS_WORD_METRICS(), physics_on_lookup(), physics_pre_execute(), vm_interpret_word(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

6.42.1.13 transition_metrics

```
WordTransitionMetrics* DictEntry::transition_metrics
```

Referenced by dictionary_word_forget(), execute_colon_word(), physics_pre_execute(), rolling_window_seed_pipelining_context(), and vm_cleanup().

6.42.1.14 word_id

```
uint32_t DictEntry::word_id
```

Referenced by execute_colon_word(), forth_acl_word_id(), hash_colon_body(), physics_pre_execute(), sk_dict_canonical_hash(), sk_parity_collect(), test_acl_read_accessors(), vm_interpret_word(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.43 DictPhysics Struct Reference

```
#include <vm.h>
```

Data Fields

- uint16_t temperature_q8
- uint64_t last_active_ns
- uint64_t last_decay_ns
- uint64_t last_decay_tick
- uint32_t mass_bytes
- uint32_t avg_latency_ns
- uint8_t state_flags
- uint8_t acl_hint
- uint16_t pubsub_mask

6.43.1 Field Documentation

6.43.1.1 acl_hint

```
uint8_t DictPhysics::acl_hint
```

6.43.1.2 avg_latency_ns

```
uint32_t DictPhysics::avg_latency_ns
```

Referenced by forth_PHYSICS_SHOW_FEEDBACK(), and forth_PHYSICS_WORD_METRICS().

6.43.1.3 last_active_ns

```
uint64_t DictPhysics::last_active_ns
```

Referenced by execute_colon_word(), forth_PHYSICS_BURN(), forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_SHOW_FEEDBA
forth_PHYSICS_WORD_METRICS(), physics_on_lookup(), physics_pre_execute(), and vm_interpret_word().

6.43.1.4 last_decay_ns

```
uint64_t DictPhysics::last_decay_ns
```

Referenced by execute_colon_word(), physics_on_lookup(), physics_pre_execute(), vm_interpret_word(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

6.43.1.5 last_decay_tick

```
uint64_t DictPhysics::last_decay_tick
```

Referenced by execute_colon_word(), physics_on_lookup(), physics_pre_execute(), vm_interpret_word(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

6.43.1.6 mass_bytes

```
uint32_t DictPhysics::mass_bytes
```

Referenced by forth_PHYSICS_SHOW_FEEDBACK(), and forth_PHYSICS_WORD_METRICS().

6.43.1.7 pubsub_mask

```
uint16_t DictPhysics::pubsub_mask
```

6.43.1.8 state_flags

```
uint8_t DictPhysics::state_flags
```

6.43.1.9 temperature_q8

```
uint16_t DictPhysics::temperature_q8
```

Referenced by forth_PHYSICS_BURN(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_SHOW_FEEDBACK(), and forth_PHYSICS_WORD_METRICS().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.44 DoeMetrics Struct Reference

Complete metrics snapshot for a single DoE run.

```
#include <doe_metrics.h>
```

Data Fields

- uint32_t total_lookups
- uint64_t cache_hits
- double cache_hit_percent
- uint64_t bucket_hits
- double bucket_hit_percent
- int64_t cache_hit_latency_ns
- int64_t cache_hit_stddev_ns
- int64_t bucket_search_latency_ns
- int64_t bucket_search_stddev_ns
- uint64_t context_predictions_total
- uint64_t context_correct
- double context_accuracy_percent
- uint64_t cache_promotions
- uint64_t cache_demotions
- double window_diversity_percent
- uint32_t window_final_size_bytes
- uint32_t rolling_window_width
- uint32_t actual_window_size
- uint64_t total_executions
- uint64_t window_variance_q48
- double decay_slope
- uint64_t total_heat
- uint64_t hot_word_count
- uint64_t stale_word_count
- double stale_word_ratio
- double avg_word_heat
- uint64_t tick_count
- uint64_t tick_target_ns
- uint64_t inference_run_count
- uint64_t early_exit_count
- double prefetch_accuracy_percent
- uint64_t prefetch_attempts

- uint64_t prefetch_hits
- uint64_t window_tuning_checks
- uint32_t final_effective_window_size
- int64_t vm_workload_duration_ns_q48
- uint64_t total_runtime_ms
- uint64_t words_executed
- uint64_t dictionary_lookups
- uint64_t memory_allocated_bytes
- double speedup_vs_baseline
- double ci_lower_95
- double ci_upper_95
- int64_t cpu_temp_delta_c_q48
- int64_t cpu_freq_delta_mhz_q48
- uint32_t decay_rate_q16
- uint32_t decay_min_interval_ns
- uint32_t rolling_window_size
- uint32_t adaptive_shrink_rate
- uint32_t heat_cache_demotion_threshold
- int enable_loop_1_heat_tracking
- int enable_loop_2_rolling_window
- int enable_loop_3_linear_decay
- int enable_loop_4_pipelining
- int enable_loop_5_window_inference
- int enable_loop_6_decay_inference
- int enable_loop_7_adaptive_heartrate
- int enable_hotwords_cache
- int enable_pipelining

6.44.1 Detailed Description

Complete metrics snapshot for a single DoE run.

Represents all 35 metrics collected per test iteration, mirroring the CSV schema. All values extracted directly from VM structures (no string parsing).

6.44.2 Field Documentation

6.44.2.1 actual_window_size

```
uint32_t DoeMetrics::actual_window_size
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.2 adaptive_shrink_rate

```
uint32_t DoeMetrics::adaptive_shrink_rate
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.3 avg_word_heat

```
double DoeMetrics::avg_word_heat
```

Referenced by metrics_from_vm(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.4 bucket_hit_percent

```
double DoeMetrics::bucket_hit_percent
```

Referenced by extract_cache_metrics(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.5 bucket_hits

```
uint64_t DoeMetrics::bucket_hits
```

Referenced by extract_cache_metrics(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.6 bucket_search_latency_ns

```
int64_t DoeMetrics::bucket_search_latency_ns
```

Referenced by extract_cache_metrics(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.7 bucket_search_stddev_ns

```
int64_t DoeMetrics::bucket_search_stddev_ns
```

Referenced by extract_cache_metrics(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.8 cache_demotions

```
uint64_t DoeMetrics::cache_demotions
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.9 cache_hit_latency_ns

```
int64_t DoeMetrics::cache_hit_latency_ns
```

Referenced by extract_cache_metrics(), metrics_print_text(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.10 cache_hit_percent

```
double DoeMetrics::cache_hit_percent
```

Referenced by extract_cache_metrics(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.11 cache_hit_stddev_ns

```
int64_t DoeMetrics::cache_hit_stddev_ns
```

Referenced by extract_cache_metrics(), metrics_print_text(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.12 cache_hits

```
uint64_t DoeMetrics::cache_hits
```

Referenced by extract_cache_metrics(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.13 cache_promotions

```
uint64_t DoeMetrics::cache_promotions
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.14 ci_lower_95

```
double DoeMetrics::ci_lower_95
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.15 ci_upper_95

```
double DoeMetrics::ci_upper_95
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.16 context_accuracy_percent

```
double DoeMetrics::context_accuracy_percent
```

Referenced by metrics_from_vm(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.17 context_correct

```
uint64_t DoeMetrics::context_correct
```

Referenced by metrics_from_vm(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.18 context_predictions_total

```
uint64_t DoeMetrics::context_predictions_total
```

Referenced by metrics_from_vm(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.19 cpu_freq_delta_mhz_q48

```
int64_t DoeMetrics::cpu_freq_delta_mhz_q48
```

Referenced by metrics_from_vm(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.20 cpu_temp_delta_c_q48

```
int64_t DoeMetrics::cpu_temp_delta_c_q48
```

Referenced by metrics_from_vm(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.21 decay_min_interval_ns

```
uint32_t DoeMetrics::decay_min_interval_ns
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.22 decay_rate_q16

```
uint32_t DoeMetrics::decay_rate_q16
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.23 decay_slope

```
double DoeMetrics::decay_slope
```

Referenced by metrics_from_vm(), metrics_print_text(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.24 dictionary_lookups

```
uint64_t DoeMetrics::dictionary_lookups
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.25 early_exit_count

```
uint64_t DoeMetrics::early_exit_count
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.26 enable_hotwords_cache

```
int DoeMetrics::enable_hotwords_cache
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.27 enable_loop_1_heat_tracking

```
int DoeMetrics::enable_loop_1_heat_tracking
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.28 enable_loop_2_rolling_window

```
int DoeMetrics::enable_loop_2_rolling_window
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.29 enable_loop_3_linear_decay

```
int DoeMetrics::enable_loop_3_linear_decay
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.30 enable_loop_4_pipelining

```
int DoeMetrics::enable_loop_4_pipelining
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.31 enable_loop_5_window_inference

```
int DoeMetrics::enable_loop_5_window_inference
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.32 enable_loop_6_decay_inference

```
int DoeMetrics::enable_loop_6_decay_inference
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.33 enable_loop_7_adaptive_heartrate

```
int DoeMetrics::enable_loop_7_adaptive_heartrate
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.34 enable_pipelining

```
int DoeMetrics::enable_pipelining
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.35 final_effective_window_size

```
uint32_t DoeMetrics::final_effective_window_size
```

Referenced by metrics_from_vm(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.36 heat_cache_demotion_threshold

```
uint32_t DoeMetrics::heat_cache_demotion_threshold
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.37 hot_word_count

```
uint64_t DoeMetrics::hot_word_count
```

Referenced by metrics_from_vm(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.38 inference_run_count

```
uint64_t DoeMetrics::inference_run_count
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.39 memory_allocated_bytes

```
uint64_t DoeMetrics::memory_allocated_bytes
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.40 prefetch_accuracy_percent

```
double DoeMetrics::prefetch_accuracy_percent
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.41 prefetch_attempts

```
uint64_t DoeMetrics::prefetch_attempts
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.42 prefetch_hits

```
uint64_t DoeMetrics::prefetch_hits
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.43 rolling_window_size

```
uint32_t DoeMetrics::rolling_window_size
```

Referenced by metrics_from_vm(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.44 rolling_window_width

```
uint32_t DoeMetrics::rolling_window_width
```

Referenced by metrics_from_vm(), metrics_print_text(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.45 speedup_vs_baseline

```
double DoeMetrics::speedup_vs_baseline
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.46 stale_word_count

```
uint64_t DoeMetrics::stale_word_count
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.47 stale_word_ratio

```
double DoeMetrics::stale_word_ratio
```

Referenced by metrics_from_vm(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.48 tick_count

```
uint64_t DoeMetrics::tick_count
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.49 tick_target_ns

```
uint64_t DoeMetrics::tick_target_ns
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.50 total_executions

```
uint64_t DoeMetrics::total_executions
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.51 total_heat

```
uint64_t DoeMetrics::total_heat
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.52 total_lookups

```
uint32_t DoeMetrics::total_lookups
```

Referenced by metrics_from_vm(), metrics_print_text(), and metrics_write_csv_row().

6.44.2.53 total_runtime_ms

```
uint64_t DoeMetrics::total_runtime_ms
```

Referenced by metrics_from_vm(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.54 vm_workload_duration_ns_q48

```
int64_t DoeMetrics::vm_workload_duration_ns_q48
```

Referenced by metrics_from_vm(), metrics_print_text(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.55 window_diversity_percent

```
double DoeMetrics::window_diversity_percent
```

Referenced by metrics_from_vm(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

6.44.2.56 window_final_size_bytes

```
uint32_t DoeMetrics::window_final_size_bytes
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.57 window_tuning_checks

```
uint64_t DoeMetrics::window_tuning_checks
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.58 window_variance_q48

```
uint64_t DoeMetrics::window_variance_q48
```

Referenced by metrics_from_vm(), and metrics_write_csv_row().

6.44.2.59 words_executed

```
uint64_t DoeMetrics::words_executed
```

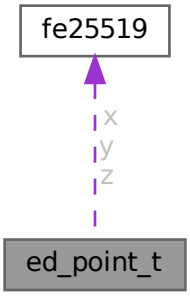
Referenced by metrics_from_vm(), metrics_write_csv_row(), and metrics_write_james_law_csv_row().

The documentation for this struct was generated from the following file:

- v3/include/doe_metrics.h

6.45 ed_point_t Struct Reference

Collaboration diagram for ed_point_t:



Data Fields

- fe25519 x
- fe25519 y
- fe25519 z

6.45.1 Field Documentation

6.45.1.1 x

```
fe25519 ed_point_t::x
```

Referenced by base_point(), ed25519_verify(), point_add(), point_compress(), point_decompress(), and point_identity().

6.45.1.2 y

```
fe25519 ed_point_t::y
```

Referenced by base_point(), ed25519_verify(), point_add(), point_compress(), point_decompress(), and point_identity().

6.45.1.3 z

```
fe25519 ed_point_t::z
```

Referenced by base_point(), ed25519_verify(), point_add(), point_compress(), point_decompress(), and point_identity().

The documentation for this struct was generated from the following file:

- kernel/src/crypto/ed25519.c

6.46 EFI_BLOCK_IO_MEDIA Struct Reference

```
#include <uefi.h>
```

Data Fields

- UINT32 MediaId
- BOOLEAN RemovableMedia
- BOOLEAN MediaPresent
- BOOLEAN LogicalPartition
- BOOLEAN ReadOnly
- BOOLEAN WriteCaching
- UINT32 BlockSize
- UINT32 IoAlign
- UINT64 LastBlock

6.46.1 Field Documentation

6.46.1.1 BlockSize

```
UINT32 EFI_BLOCK_IO_MEDIA::BlockSize
```

6.46.1.2 IoAlign

```
UINT32 EFI_BLOCK_IO_MEDIA::IoAlign
```

6.46.1.3 LastBlock

```
UINT64 EFI_BLOCK_IO_MEDIA::LastBlock
```

6.46.1.4 LogicalPartition

```
BOOLEAN EFI_BLOCK_IO_MEDIA::LogicalPartition
```

6.46.1.5 MediaId

```
UINT32 EFI_BLOCK_IO_MEDIA::MediaId
```

6.46.1.6 MediaPresent

```
BOOLEAN EFI_BLOCK_IO_MEDIA::MediaPresent
```

6.46.1.7 ReadOnly

```
BOOLEAN EFI_BLOCK_IO_MEDIA::ReadOnly
```

6.46.1.8 RemovableMedia

```
BOOLEAN EFI_BLOCK_IO_MEDIA::RemovableMedia
```

6.46.1.9 WriteCaching

```
BOOLEAN EFI_BLOCK_IO_MEDIA::WriteCaching
```

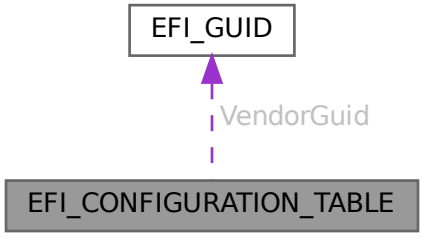
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.47 EFI_CONFIGURATION_TABLE Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for EFI_CONFIGURATION_TABLE:



Data Fields

- EFI_GUID VendorGuid
- void * VendorTable

6.47.1 Field Documentation

6.47.1.1 VendorGuid

```
EFI_GUID EFI_CONFIGURATION_TABLE::VendorGuid
```

6.47.1.2 VendorTable

```
void* EFI_CONFIGURATION_TABLE::VendorTable
```

Referenced by efi_main().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.48 EFI_DEVICE_PATH_PROTOCOL Struct Reference

```
#include <uefi.h>
```

Data Fields

- UINT8 Type
- UINT8 SubType
- UINT8 Length [2]

6.48.1 Field Documentation

6.48.1.1 Length

```
UINT8 EFI_DEVICE_PATH_PROTOCOL::Length[2]
```

6.48.1.2 SubType

```
UINT8 EFI_DEVICE_PATH_PROTOCOL::SubType
```

6.48.1.3 Type

```
UINT8 EFI_DEVICE_PATH_PROTOCOL::Type
```

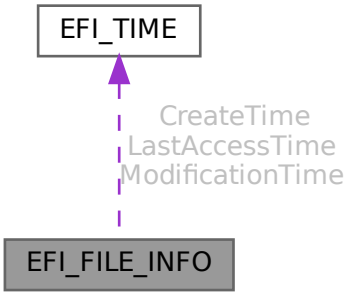
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.49 EFI_FILE_INFO Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for EFI_FILE_INFO:



Data Fields

- UINT64 Size
- UINT64 FileSize
- UINT64 PhysicalSize
- EFI_TIME CreateTime
- EFI_TIME LastAccessTime
- EFI_TIME ModificationTime
- UINT64 Attribute
- CHAR16 FileName [256]

6.49.1 Field Documentation

6.49.1.1 Attribute

```
UINT64 EFI_FILE_INFO::Attribute
```

6.49.1.2 CreateTime

```
EFI_TIME EFI_FILE_INFO::CreateTime
```

6.49.1.3 FileName

```
CHAR16 EFI_FILE_INFO::FileName[256]
```

6.49.1.4 FileSize

```
UINT64 EFI_FILE_INFO::FileSize
```

Referenced by load_kernel_from_esp().

6.49.1.5 LastAccessTime

```
EFI_TIME EFI_FILE_INFO::LastAccessTime
```

6.49.1.6 ModificationTime

```
EFI_TIME EFI_FILE_INFO::ModificationTime
```

6.49.1.7 PhysicalSize

```
UINT64 EFI_FILE_INFO::PhysicalSize
```

6.49.1.8 Size

```
UINT64 EFI_FILE_INFO::Size
```

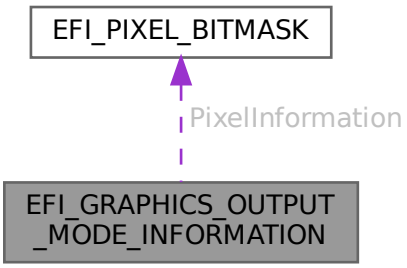
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.50 EFI_GRAPHICS_OUTPUT_MODE_INFORMATION Struct Reference

`#include <uefi.h>`

Collaboration diagram for EFI_GRAPHICS_OUTPUT_MODE_INFORMATION:



Data Fields

- UINT32 Version
- UINT32 HorizontalResolution
- UINT32 VerticalResolution
- EFI_GRAPHICS_PIXEL_FORMAT PixelFormat
- EFI_PIXEL_BITMASK PixelInformation
- UINT32 PixelsPerScanLine

6.50.1 Field Documentation

6.50.1.1 HorizontalResolution

```
UINT32 EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::HorizontalResolution
```

Referenced by efi_main().

6.50.1.2 PixelFormat

```
EFI_GRAPHICS_PIXEL_FORMAT EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::PixelFormat
```

Referenced by efi_main().

6.50.1.3 PixelInformation

```
EFI_PIXEL_BITMASK EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::PixelInformation
```

6.50.1.4 PixelsPerScanLine

```
UINT32 EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::PixelsPerScanLine
```

Referenced by efi_main().

6.50.1.5 Version

```
UINT32 EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::Version
```

6.50.1.6 VerticalResolution

```
UINT32 EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::VerticalResolution
```

Referenced by efi_main().

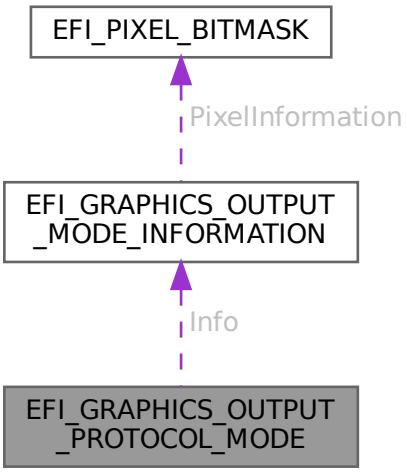
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.51 EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE Struct Reference

```
#include <uefi.h>
```

Collaboration diagram for EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE:



Data Fields

- UINT32 MaxMode
- UINT32 Mode
- EFI_GRAPHICS_OUTPUT_MODE_INFORMATION * Info
- UINTN SizeOfInfo
- EFI_PHYSICAL_ADDRESS FrameBufferBase
- UINTN FrameBufferSize

6.51.1 Field Documentation

6.51.1.1 FrameBufferBase

```
EFI_PHYSICAL_ADDRESS EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::FrameBufferBase
```

Referenced by efi_main().

6.51.1.2 FrameBufferSize

```
UINTN EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::FrameBufferSize
```

Referenced by efi_main().

6.51.1.3 Info

```
EFI_GRAPHICS_OUTPUT_MODE_INFORMATION* EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::Info
```

Referenced by efi_main().

6.51.1.4 MaxMode

```
UINT32 EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::MaxMode
```

6.51.1.5 Mode

```
UINT32 EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::Mode
```

6.51.1.6 SizeOfInfo

```
UINTN EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::SizeOfInfo
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.52 EFI_GUID Struct Reference

`#include <uefi.h>`

Data Fields

- UINT32 Data1
- UINT16 Data2
- UINT16 Data3
- UINT8 Data4 [8]

6.52.1 Field Documentation

6.52.1.1 Data1

`UINT32 EFI_GUID::Data1`

Referenced by guid_equals().

6.52.1.2 Data2

`UINT16 EFI_GUID::Data2`

Referenced by guid_equals().

6.52.1.3 Data3

`UINT16 EFI_GUID::Data3`

Referenced by guid_equals().

6.52.1.4 Data4

`UINT8 EFI_GUID::Data4[8]`

Referenced by guid_equals().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.53 EFI_LOADED_IMAGE_PROTOCOL Struct Reference

`#include <uefi.h>`

Data Fields

- UINT32 Revision
- EFI_HANDLE ParentHandle
- void * SystemTable
- EFI_HANDLE DeviceHandle
- VOID * FilePath
- VOID * Reserved
- UINT32 LoadOptionsSize
- VOID * LoadOptions
- VOID * ImageBase
- UINT64 ImageSize
- EFI_MEMORY_TYPE ImageCodeType
- EFI_MEMORY_TYPE ImageDataType
- VOID * Unload

6.53.1 Field Documentation

6.53.1.1 DeviceHandle

```
EFI_HANDLE EFI_LOADED_IMAGE_PROTOCOL::DeviceHandle
```

Referenced by load_cfg_from_esp(), and load_kernel_from_esp().

6.53.1.2 FilePath

```
VOID* EFI_LOADED_IMAGE_PROTOCOL::FilePath
```

6.53.1.3 ImageBase

```
VOID* EFI_LOADED_IMAGE_PROTOCOL::ImageBase
```

6.53.1.4 ImageCodeType

```
EFI_MEMORY_TYPE EFI_LOADED_IMAGE_PROTOCOL::ImageCodeType
```

6.53.1.5 ImageDataType

```
EFI_MEMORY_TYPE EFI_LOADED_IMAGE_PROTOCOL::ImageDataType
```

6.53.1.6 ImageSize

```
UINT64 EFI_LOADED_IMAGE_PROTOCOL::ImageSize
```

6.53.1.7 LoadOptions

```
VOID* EFI_LOADED_IMAGE_PROTOCOL::LoadOptions
```

Referenced by efi_main().

6.53.1.8 LoadOptionsSize

```
UINT32 EFI_LOADED_IMAGE_PROTOCOL::LoadOptionsSize
```

Referenced by efi_main().

6.53.1.9 ParentHandle

```
EFI_HANDLE EFI_LOADED_IMAGE_PROTOCOL::ParentHandle
```

6.53.1.10 Reserved

```
VOID* EFI_LOADED_IMAGE_PROTOCOL::Reserved
```

6.53.1.11 Revision

```
UINT32 EFI_LOADED_IMAGE_PROTOCOL::Revision
```

6.53.1.12 SystemTable

```
void* EFI_LOADED_IMAGE_PROTOCOL::SystemTable
```

6.53.1.13 Unload

```
VOID* EFI_LOADED_IMAGE_PROTOCOL::Unload
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.54 EFI_MEMORY_DESCRIPTOR Struct Reference

```
#include <uefi.h>
```

Data Fields

- UINT32 Type
- UINT64 PhysicalStart
- UINT64 VirtualStart
- UINT64 NumberOfPages
- UINT64 Attribute

6.54.1 Field Documentation

6.54.1.1 Attribute

```
UINT64 EFI_MEMORY_DESCRIPTOR::Attribute
```

Referenced by add_memmap_entry().

6.54.1.2 NumberOfPages

```
UINT64 EFI_MEMORY_DESCRIPTOR::NumberOfPages
```

Referenced by add_memmap_entry(), pmm_init(), print_boot_info(), and vmm_init().

6.54.1.3 PhysicalStart

```
UINT64 EFI_MEMORY_DESCRIPTOR::PhysicalStart
```

Referenced by add_memmap_entry(), pmm_init(), and vmm_init().

6.54.1.4 Type

```
UINT32 EFI_MEMORY_DESCRIPTOR::Type
```

Referenced by add_memmap_entry(), pmm_init(), print_boot_info(), and vmm_init().

6.54.1.5 VirtualStart

```
UINT64 EFI_MEMORY_DESCRIPTOR::VirtualStart
```

Referenced by add_memmap_entry().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.55 EFI_PIXEL_BITMASK Struct Reference

```
#include <uefi.h>
```

Data Fields

- UINT32 RedMask
- UINT32 GreenMask
- UINT32 BlueMask
- UINT32 ReservedMask

6.55.1 Field Documentation

6.55.1.1 BlueMask

```
UINT32 EFI_PIXEL_BITMASK::BlueMask
```

6.55.1.2 GreenMask

```
UINT32 EFI_PIXEL_BITMASK::GreenMask
```

6.55.1.3 RedMask

```
UINT32 EFI_PIXEL_BITMASK::RedMask
```

6.55.1.4 ReservedMask

```
UINT32 EFI_PIXEL_BITMASK::ReservedMask
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.56 EFI_TABLE_HEADER Struct Reference

```
#include <uefi.h>
```

Data Fields

- UINT64 Signature
- UINT32 Revision
- UINT32 HeaderSize
- UINT32 CRC32
- UINT32 Reserved

6.56.1 Field Documentation

6.56.1.1 CRC32

```
UINT32 EFI_TABLE_HEADER::CRC32
```

6.56.1.2 HeaderSize

```
UINT32 EFI_TABLE_HEADER::HeaderSize
```

6.56.1.3 Reserved

```
UINT32 EFI_TABLE_HEADER::Reserved
```

6.56.1.4 Revision

```
UINT32 EFI_TABLE_HEADER::Revision
```

6.56.1.5 Signature

```
UINT64 EFI_TABLE_HEADER::Signature
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.57 EFI_TIME Struct Reference

```
#include <uefi.h>
```

Data Fields

- UINT16 Year
- UINT8 Month
- UINT8 Day
- UINT8 Hour
- UINT8 Minute
- UINT8 Second
- UINT8 Pad1
- UINT32 Nanosecond
- INT16 TimeZone
- UINT8 Daylight
- UINT8 Pad2

6.57.1 Field Documentation

6.57.1.1 Day

```
UINT8 EFI_TIME::Day
```

6.57.1.2 Daylight

```
UINT8 EFI_TIME::Daylight
```

6.57.1.3 Hour

```
UINT8 EFI_TIME::Hour
```

6.57.1.4 Minute

```
UINT8 EFI_TIME::Minute
```

6.57.1.5 Month

```
UINT8 EFI_TIME::Month
```

6.57.1.6 Nanosecond

```
UINT32 EFI_TIME::Nanosecond
```

6.57.1.7 Pad1

```
UINT8 EFI_TIME::Pad1
```

6.57.1.8 Pad2

```
UINT8 EFI_TIME::Pad2
```

6.57.1.9 Second

```
UINT8 EFI_TIME::Second
```

6.57.1.10 TimeZone

```
INT16 EFI_TIME::TimeZone
```

6.57.1.11 Year

```
UINT16 EFI_TIME::Year
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.58 Elf64_Ehdr Struct Reference

```
#include <elf64.h>
```

Data Fields

- unsigned char e_ident [16]
- Elf64_Half e_type
- Elf64_Half e_machine
- Elf64_Word e_version
- Elf64_Addr e_entry
- Elf64_Off e_phoff
- Elf64_Off e_shoff
- Elf64_Word e_flags
- Elf64_Half e_ehsize
- Elf64_Half e_phentsize
- Elf64_Half e_phnum
- Elf64_Half e_shentsize
- Elf64_Half e_shnum
- Elf64_Half e_shstrndx

6.58.1 Field Documentation

6.58.1.1 e_ehsize

```
Elf64_Half Elf64_Ehdr::e_ehsize
```

6.58.1.2 e_entry

```
Elf64_Addr Elf64_Ehdr::e_entry
```

Referenced by elf_load_kernel().

6.58.1.3 e_flags

```
Elf64_Word Elf64_Ehdr::e_flags
```

6.58.1.4 e_ident

```
unsigned char Elf64_Ehdr::e_ident[16]
```

Referenced by elf_validate_header().

6.58.1.5 e_machine

```
Elf64_Half Elf64_Ehdr::e_machine
```

Referenced by elf_validate_header().

6.58.1.6 e_phentsize

```
Elf64_Half Elf64_Ehdr::e_phentsize
```

6.58.1.7 e_phnum

```
Elf64_Half Elf64_Ehdr::e_phnum
```

Referenced by elf_load_segments().

6.58.1.8 e_phoff

```
Elf64_Off Elf64_Ehdr::e_phoff
```

Referenced by elf_load_segments().

6.58.1.9 e_shentsize

```
Elf64_Half Elf64_Ehdr::e_shentsize
```

6.58.1.10 e_shnum

```
Elf64_Half Elf64_Ehdr::e_shnum
```

Referenced by elf_apply_relocations().

6.58.1.11 e_shoff

```
Elf64_Off Elf64_Ehdr::e_shoff
```

Referenced by elf_apply_relocations().

6.58.1.12 e_shstrndx

```
Elf64_Half Elf64_Ehdr::e_shstrndx
```

6.58.1.13 e_type

```
Elf64_Half Elf64_Ehdr::e_type
```

Referenced by elf_load_kernel(), and elf_validate_header().

6.58.1.14 e_version

```
Elf64_Word Elf64_Ehdr::e_version
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/elf64.h

6.59 Elf64_Phdr Struct Reference

```
#include <elf64.h>
```

Data Fields

- Elf64_Word p_type
- Elf64_Word p_flags
- Elf64_Off p_offset
- Elf64_Addr p_vaddr
- Elf64_Addr p_paddr
- Elf64_Xword p_filesz
- Elf64_Xword p_memsz
- Elf64_Xword p_align

6.59.1 Field Documentation

6.59.1.1 p_align

```
Elf64_Xword Elf64_Phdr::p_align
```

6.59.1.2 p_filesz

```
Elf64_Xword Elf64_Phdr::p_filesz
```

6.59.1.3 p_flags

```
Elf64_Word Elf64_Phdr::p_flags
```

6.59.1.4 p_memsz

```
Elf64_Xword Elf64_Phdr::p_memsz
```

6.59.1.5 p_offset

```
Elf64_Off Elf64_Phdr::p_offset
```

Referenced by elf_load_segments().

6.59.1.6 p_paddr

```
Elf64_Addr Elf64_Phdr::p_paddr
```

6.59.1.7 p_type

```
Elf64_Word Elf64_Phdr::p_type
```

6.59.1.8 p_vaddr

```
Elf64_Addr Elf64_Phdr::p_vaddr
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/elf64.h

6.60 Elf64_Rel Struct Reference

```
#include <elf64.h>
```

Data Fields

- Elf64_Addr r_offset
- Elf64_Xword r_info

6.60.1 Field Documentation

6.60.1.1 r_info

```
Elf64_Xword Elf64_Rel::r_info
```

6.60.1.2 r_offset

```
Elf64_Addr Elf64_Rel::r_offset
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/elf64.h

6.61 Elf64_Rela Struct Reference

```
#include <elf64.h>
```

Data Fields

- Elf64_Addr r_offset
- Elf64_Xword r_info
- Elf64_Sxword r_addend

6.61.1 Field Documentation

6.61.1.1 r_addend

```
Elf64_Sxword Elf64_Rela::r_addend
```

Referenced by elf_apply_relocations().

6.61.1.2 r_info

```
Elf64_Xword Elf64_Rela::r_info
```

6.61.1.3 r_offset

```
Elf64_Addr Elf64_Rela::r_offset
```

Referenced by elf_apply_relocations().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/elf64.h

6.62 Elf64_Shdr Struct Reference

```
#include <elf64.h>
```

Data Fields

- Elf64_Word sh_name
- Elf64_Word sh_type
- Elf64_Xword sh_flags
- Elf64_Addr sh_addr
- Elf64_Off sh_offset
- Elf64_Xword sh_size
- Elf64_Word sh_link
- Elf64_Word sh_info
- Elf64_Xword sh_addralign
- Elf64_Xword sh_entsize

6.62.1 Field Documentation

6.62.1.1 sh_addr

```
Elf64_Addr Elf64_Shdr::sh_addr
```

6.62.1.2 sh_addralign

```
Elf64_Xword Elf64_Shdr::sh_addralign
```

6.62.1.3 sh_entsize

```
Elf64_Xword Elf64_Shdr::sh_entsize
```

Referenced by elf_apply_relocations().

6.62.1.4 sh_flags

```
Elf64_Xword Elf64_Shdr::sh_flags
```

6.62.1.5 sh_info

```
Elf64_Word Elf64_Shdr::sh_info
```

6.62.1.6 sh_link

```
Elf64_Word Elf64_Shdr::sh_link
```

Referenced by elf_apply_relocations().

6.62.1.7 sh_name

```
Elf64_Word Elf64_Shdr::sh_name
```

6.62.1.8 sh_offset

```
Elf64_Off Elf64_Shdr::sh_offset
```

Referenced by elf_apply_relocations().

6.62.1.9 sh_size

```
Elf64_Xword Elf64_Shdr::sh_size
```

Referenced by elf_apply_relocations().

6.62.1.10 sh_type

```
Elf64_Word Elf64_Shdr::sh_type
```

Referenced by elf_apply_relocations().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/elf64.h

6.63 Elf64_Sym Struct Reference

```
#include <elf64.h>
```

Data Fields

- Elf64_Word st_name
- unsigned char st_info
- unsigned char st_other
- Elf64_Half st_shndx
- Elf64_Addr st_value
- Elf64_Xword st_size

6.63.1 Field Documentation

6.63.1.1 st_info

```
unsigned char Elf64_Sym::st_info
```

6.63.1.2 st_name

```
Elf64_Word Elf64_Sym::st_name
```

6.63.1.3 st_other

```
unsigned char Elf64_Sym::st_other
```

6.63.1.4 st_shndx

```
Elf64_Half Elf64_Sym::st_shndx
```

6.63.1.5 st_size

```
Elf64_Xword Elf64_Sym::st_size
```

6.63.1.6 st_value

```
Elf64_Addr Elf64_Sym::st_value
```

Referenced by elf_apply_relocations().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/elf64.h

6.64 ExecResult Struct Reference

```
#include <test_contracts.h>
```

Data Fields

- cell_t stack [1024]
- int dsp
- int rsp
- int error

6.64.1 Field Documentation

6.64.1.1 dsp

```
int ExecResult::dsp
```

Referenced by assert_heartbeat_safe(), capture_exec_result(), check_physics_transparent(), and exec_results_equal().

6.64.1.2 error

```
int ExecResult::error
```

Referenced by capture_exec_result(), and exec_results_equal().

6.64.1.3 rsp

```
int ExecResult::rsp
```

Referenced by assert_heartbeat_safe(), capture_exec_result(), and exec_results_equal().

6.64.1.4 stack

```
cell_t ExecResult::stack[1024]
```

Referenced by capture_exec_result(), and exec_results_equal().

The documentation for this struct was generated from the following file:

- v3/src/test_runner/include/test_contracts.h

6.65 FbState Struct Reference

Data Fields

- volatile uint32_t * base
- uint32_t stride
- uint32_t width
- uint32_t height
- FbPixelFormat fmt
- uint32_t scale
- int ready

6.65.1 Field Documentation

6.65.1.1 base

```
volatile uint32_t* FbState::base
```

Referenced by fb_draw_glyph(), fb_fill_rect(), fb_init(), fb_put_pixel(), fb_scroll_rect(), and fb_scroll_rows().

6.65.1.2 fmt

```
FbPixelFormat FbState::fmt
```

Referenced by fb_init(), and pack_pixel().

6.65.1.3 height

```
uint32_t FbState::height
```

Referenced by fb_draw_glyph(), fb_draw_orientation_test(), fb_fill_rect(), fb_height(), fb_init(), fb_put_pixel(), fb_scroll_rect(), and fb_scroll_rows().

6.65.1.4 ready

```
int FbState::ready
```

Referenced by fb_draw_glyph(), fb_draw_orientation_test(), fb_fill_rect(), fb_init(), fb_is_available(), fb_put_pixel(), fb_scroll_rect(), and fb_scroll_rows().

6.65.1.5 scale

```
uint32_t FbState::scale
```

Referenced by fb_cell_h(), fb_cell_w(), fb_draw_glyph(), and fb_init().

6.65.1.6 stride

```
uint32_t FbState::stride
```

Referenced by fb_draw_glyph(), fb_fill_rect(), fb_init(), fb_put_pixel(), fb_scroll_rect(), and fb_scroll_rows().

6.65.1.7 width

```
uint32_t FbState::width
```

Referenced by fb_draw_glyph(), fb_draw_orientation_test(), fb_fill_rect(), fb_init(), fb_put_pixel(), fb_scroll_rect(), fb_scroll_rows(), and fb_width().

The documentation for this struct was generated from the following file:

- kernel/src/hal/framebuffer.c

6.66 fdt_header_t Struct Reference

Data Fields

- uint32_t magic
- uint32_t totalsize
- uint32_t off_dt_struct
- uint32_t off_dt_strings
- uint32_t off_mem_rsvmap
- uint32_t version
- uint32_t last_comp_version
- uint32_t boot_cpuid_phys
- uint32_t size_dt_strings
- uint32_t size_dt_struct

6.66.1 Field Documentation

6.66.1.1 boot_cpuid_phys

```
uint32_t fdt_header_t::boot_cpuid_phys
```

6.66.1.2 last_comp_version

```
uint32_t fdt_header_t::last_comp_version
```

6.66.1.3 magic

```
uint32_t fdt_header_t::magic
```

Referenced by fdt_valid().

6.66.1.4 off_dt_strings

```
uint32_t fdt_header_t::off_dt_strings
```

Referenced by fdt_find_node_by_compatible(), fdt_find_node_by_device_type(), fdt_find_prop(), fdt_find_prop_in_node(), and fdt_valid().

6.66.1.5 off_dt_struct

```
uint32_t fdt_header_t::off_dt_struct
```

Referenced by fdt_complete(), fdt_find_child(), fdt_find_node_by_compatible(), fdt_find_node_by_device_type(), fdt_find_node_by_name(), fdt_find_prop(), fdt_find_prop_in_node(), fdt_next_child_node(), fdt_root_node(), and fdt_valid().

6.66.1.6 off_mem_rsvmap

```
uint32_t fdt_header_t::off_mem_rsvmap
```

6.66.1.7 size_dt_strings

```
uint32_t fdt_header_t::size_dt_strings
```

Referenced by fdt_valid().

6.66.1.8 size_dt_struct

```
uint32_t fdt_header_t::size_dt_struct
```

Referenced by fdt_complete(), fdt_find_child(), fdt_find_node_by_compatible(), fdt_find_node_by_device_type(), fdt_find_node_by_name(), fdt_find_prop(), fdt_find_prop_in_node(), fdt_next_child_node(), fdt_root_node(), and fdt_valid().

6.66.1.9 totalsize

```
uint32_t fdt_header_t::totalsize
```

Referenced by fdt_valid().

6.66.1.10 version

```
uint32_t fdt_header_t::version
```

The documentation for this struct was generated from the following file:

- kernel/src/hal/fdt.c

6.67 fdt_uart_t Struct Reference

```
#include <fdt_uart.h>
```

Data Fields

- int kind
  FDT_UART_∗.
- uint64_t base
  address of register 0, as the CPU sees it
- uint32_t reg_shift
  register n is at base + (n << reg_shift)
- uint32_t io_width
  bytes read or written at a time: 1 or 4

6.67.1 Field Documentation

6.67.1.1 base

```
uint64_t fdt_uart_t::base
```

address of register 0, as the CPU sees it

Referenced by console_attach_serial(), and fdt_console_uart().

6.67.1.2 io_width

```
uint32_t fdt_uart_t::io_width
```

bytes read or written at a time: 1 or 4

Referenced by console_attach_serial(), and fdt_console_uart().

6.67.1.3 kind

```
int fdt_uart_t::kind
```

FDT_UART_∗.

Referenced by console_attach_serial(), and fdt_console_uart().

6.67.1.4 reg_shift

```
uint32_t fdt_uart_t::reg_shift
```

register n is at base + (n << reg_shift)

Referenced by console_attach_serial(), and fdt_console_uart().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/fdt_uart.h

6.68 fe25519 Struct Reference

```
#include <fe25519.h>
```

Data Fields

- int64_t v [5]

6.68.1 Field Documentation

6.68.1.1 v

```
int64_t fe25519::v[5]
```

Referenced by fe25519_0(), fe25519_1(), fe25519_add(), fe25519_carry(), fe25519_mul(), fe25519_mul_small(), fe25519_pack(), fe25519_sub(), and fe25519_unpack().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/fe25519.h

6.69 FILE Struct Reference

```
#include <stdio.h>
```

Data Fields

- int _dummy

6.69.1 Field Documentation

6.69.1.1 _dummy

```
int FILE::_dummy
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/freestanding/stdio.h

6.70 FramebufferInfo Struct Reference

```
#include <uefi.h>
```

Data Fields

- void * base
- UINTN size
- UINT32 width
- UINT32 height
- UINT32 pixels_per_scanline
- UINT32 pixel_format

6.70.1 Field Documentation

6.70.1.1 base

```
void* FramebufferInfo::base
```

Referenced by console_fb_init(), efi_main(), fb_init(), rpi5_native_boot(), and vmm_init().

6.70.1.2 height

```
UINT32 FramebufferInfo::height
```

Referenced by efi_main(), fb_init(), and rpi5_native_boot().

6.70.1.3 pixel_format

```
UINT32 FramebufferInfo::pixel_format
```

Referenced by efi_main(), and rpi5_native_boot().

6.70.1.4 pixels_per_scanline

```
UINT32 FramebufferInfo::pixels_per_scanline
```

Referenced by efi_main(), fb_init(), and rpi5_native_boot().

6.70.1.5 size

```
UINTN FramebufferInfo::size
```

Referenced by efi_main(), rpi5_native_boot(), and vmm_init().

6.70.1.6 width

```
UINT32 FramebufferInfo::width
```

Referenced by efi_main(), fb_init(), and rpi5_native_boot().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/uefi.h

6.71 gdt_entry Struct Reference

arch.c (amd64) - Architecture abstractions for StarKernel on x86_64

Data Fields

- uint16_t limit_low
- uint16_t base_low
- uint8_t base_mid
- uint8_t access
- uint8_t granularity
- uint8_t base_high

6.71.1 Detailed Description

arch.c (amd64) - Architecture abstractions for StarKernel on x86_64

6.71.2 Field Documentation

6.71.2.1 access

```
uint8_t gdt_entry::access
```

6.71.2.2 base_high

```
uint8_t gdt_entry::base_high
```

6.71.2.3 base_low

```
uint16_t gdt_entry::base_low
```

6.71.2.4 base_mid

```
uint8_t gdt_entry::base_mid
```

6.71.2.5 granularity

```
uint8_t gdt_entry::granularity
```

6.71.2.6 limit_low

```
uint16_t gdt_entry::limit_low
```

The documentation for this struct was generated from the following file:

- kernel/src/arch/amd64/arch.c

6.72 gdtr Struct Reference

Data Fields

- uint16_t limit
- uint64_t base

6.72.1 Field Documentation

6.72.1.1 base

```
uint64_t gdtr::base
```

Referenced by gdt_init().

6.72.1.2 limit

```
uint16_t gdtr::limit
```

Referenced by gdt_init().

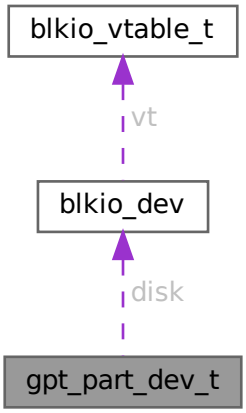
The documentation for this struct was generated from the following file:

- kernel/src/arch/amd64/arch.c

6.73 gpt_part_dev_t Struct Reference

```
#include <gpt.h>
```

Collaboration diagram for gpt_part_dev_t:



Data Fields

- blkio_dev_t * disk
- uint32_t first_fblock
- uint32_t fblocks

6.73.1 Field Documentation

6.73.1.1 disk

```
blkio_dev_t* gpt_part_dev_t::disk
```

Referenced by gpt_part_open(), part_flush(), part_info(), part_read(), and part_write().

6.73.1.2 fblocks

```
uint32_t gpt_part_dev_t::fblocks
```

Referenced by gpt_part_open(), part_info(), part_open(), part_read(), and part_write().

6.73.1.3 first_fblock

```
uint32_t gpt_part_dev_t::first_fblock
```

Referenced by gpt_part_open(), part_read(), and part_write().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/gpt.h

6.74 gpt_part_t Struct Reference

```
#include <gpt.h>
```

Data Fields

- uint8_t type [16]
- uint64_t first_lba
- uint64_t last_lba

6.74.1 Field Documentation

6.74.1.1 first_lba

```
uint64_t gpt_part_t::first_lba
```

Referenced by gpt_part_open(), gpt_read(), and sk_v4_grow_stick().

6.74.1.2 last_lba

```
uint64_t gpt_part_t::last_lba
```

Referenced by gpt_part_open(), and gpt_read().

6.74.1.3 type

```
uint8_t gpt_part_t::type[16]
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/gpt.h

6.75 heap_block Struct Reference

Collaboration diagram for heap_block:

Data Fields

- size_t size
- size_t requested
- int free
- struct heap_block * next
- struct heap_block * prev

6.75.1 Field Documentation

6.75.1.1 free

```
int heap_block::free
```

Referenced by allocate_from_block(), coalesce_neighbors(), kfree(), kmalloc_aligned(), kmalloc_debug_census(), kmalloc_debug_census_bytes(), and kmalloc_init().

6.75.1.2 next

```
struct heap_block* heap_block::next
```

Referenced by allocate_from_block(), coalesce_neighbors(), kmalloc_aligned(), kmalloc_debug_census(), kmalloc_debug_census_bytes(), and kmalloc_init().

6.75.1.3 prev

```
struct heap_block* heap_block::prev
```

Referenced by allocate_from_block(), coalesce_neighbors(), and kmalloc_init().

6.75.1.4 requested

```
size_t heap_block::requested
```

Referenced by allocate_from_block(), kfree(), and kmalloc_init().

6.75.1.5 size

```
size_t heap_block::size
```

Referenced by allocate_from_block(), coalesce_neighbors(), kmalloc_debug_census(), kmalloc_debug_census_bytes(), and kmalloc_init().

The documentation for this struct was generated from the following file:

- kernel/src/memory/kmalloc.c

6.76 HeartbeatSnapshot Struct Reference

```
#include <vm.h>
```

Data Fields

- uint64_t published_tick
- uint64_t published_ns
- uint32_t window_width
- uint32_t actual_window_size
- uint64_t decay_slope_q48
- uint64_t hot_word_count
- uint64_t stale_word_count
- uint64_t total_heat

6.76.1 Field Documentation

6.76.1.1 actual_window_size

```
uint32_t HeartbeatSnapshot::actual_window_size
```

Referenced by vm_heartbeat_publish_snapshot().

6.76.1.2 decay_slope_q48

```
uint64_t HeartbeatSnapshot::decay_slope_q48
```

Referenced by heartbeat_publish_snapshot(), and vm_heartbeat_publish_snapshot().

6.76.1.3 hot_word_count

```
uint64_t HeartbeatSnapshot::hot_word_count
```

Referenced by heartbeat_publish_snapshot(), and vm_heartbeat_publish_snapshot().

6.76.1.4 published_ns

```
uint64_t HeartbeatSnapshot::published_ns
```

Referenced by heartbeat_publish_snapshot(), and vm_heartbeat_publish_snapshot().

6.76.1.5 published_tick

```
uint64_t HeartbeatSnapshot::published_tick
```

Referenced by heartbeat_publish_snapshot(), and vm_heartbeat_publish_snapshot().

6.76.1.6 stale_word_count

```
uint64_t HeartbeatSnapshot::stale_word_count
```

Referenced by heartbeat_publish_snapshot(), and vm_heartbeat_publish_snapshot().

6.76.1.7 total_heat

```
uint64_t HeartbeatSnapshot::total_heat
```

Referenced by heartbeat_publish_snapshot(), and vm_heartbeat_publish_snapshot().

6.76.1.8 window_width

```
uint32_t HeartbeatSnapshot::window_width
```

Referenced by heartbeat_publish_snapshot(), and vm_heartbeat_publish_snapshot().

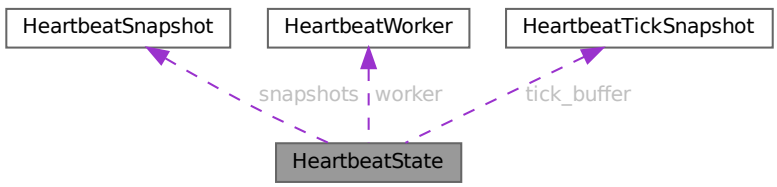
The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.77 HeartbeatState Struct Reference

```
#include <vm.h>
```

Collaboration diagram for HeartbeatState:



Data Fields

- uint64_t tick_count
- uint64_t last_inference_tick
- uint32_t check_counter
- int heartbeat_enabled
- uint64_t tick_target_ns
- volatile uint32_t snapshot_index
- HeartbeatSnapshot snapshots [2]
- HeartbeatWorker * worker
- uint64_t inference_run_count
- uint64_t early_exit_count
- uint64_t words_executed
- uint64_t dictionary_lookups
- HeartbeatTickSnapshot * tick_buffer
- uint32_t tick_buffer_size
- uint64_t tick_buffer_write_index
- uint64_t tick_count_total
- uint64_t run_start_ns
- uint32_t tick_number_offset
- double bucket_sum_K
- double bucket_sum_K_squared
- double bucket_sum_window_variance
- double bucket_sum_heat_variance
- uint64_t bucket_mode_transitions
- uint32_t bucket_collapse_flag
- uint32_t bucket_tick_count
- uint64_t m5_time_trust
- uint64_t m5_variance

6.77.1 Field Documentation

6.77.1.1 bucket_collapse_flag

```
uint32_t HeartbeatState::bucket_collapse_flag
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.2 bucket_mode_transitions

```
uint64_t HeartbeatState::bucket_mode_transitions
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.3 bucket_sum_heat_variance

```
double HeartbeatState::bucket_sum_heat_variance
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.4 bucket_sum_K

```
double HeartbeatState::bucket_sum_K
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.5 bucket_sum_K_squared

```
double HeartbeatState::bucket_sum_K_squared
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.6 bucket_sum_window_variance

```
double HeartbeatState::bucket_sum_window_variance
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.7 bucket_tick_count

```
uint32_t HeartbeatState::bucket_tick_count
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.8 check_counter

```
uint32_t HeartbeatState::check_counter
```

Referenced by execute_colon_word(), physics_post_execute(), vm_init(), vm_init_with_host(), and vm_interpret().

6.77.1.9 dictionary_lookups

```
uint64_t HeartbeatState::dictionary_lookups
```

Referenced by metrics_from_vm(), and vm_find_word().

6.77.1.10 early_exit_count

```
uint64_t HeartbeatState::early_exit_count
```

Referenced by heartbeat_capture_tick_snapshot(), metrics_from_vm(), and vm_tick_inference_engine().

6.77.1.11 heartbeat_enabled

```
int HeartbeatState::heartbeat_enabled
```

Referenced by vm_heartbeat_run_cycle(), vm_init(), vm_init_with_host(), vm_tick(), and vm_tick_inference_engine().

6.77.1.12 inference_run_count

```
uint64_t HeartbeatState::inference_run_count
```

Referenced by metrics_from_vm(), and vm_tick_inference_engine().

6.77.1.13 last_inference_tick

```
uint64_t HeartbeatState::last_inference_tick
```

Referenced by vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_tick(), and vm_tick_inference_engine().

6.77.1.14 m5_time_trust

```
uint64_t HeartbeatState::m5_time_trust
```

6.77.1.15 m5_variance

```
uint64_t HeartbeatState::m5_variance
```

6.77.1.16 run_start_ns

```
uint64_t HeartbeatState::run_start_ns
```

6.77.1.17 snapshot_index

```
volatile uint32_t HeartbeatState::snapshot_index
```

Referenced by heartbeat_publish_snapshot(), vm_heartbeat_publish_snapshot(), vm_init(), vm_init_with_host(), and vm_snapshot_read().

6.77.1.18 snapshots

```
HeartbeatSnapshot HeartbeatState::snapshots[2]
```

Referenced by heartbeat_publish_snapshot(), vm_heartbeat_publish_snapshot(), and vm_snapshot_read().

6.77.1.19 tick_buffer

```
HeartbeatTickSnapshot* HeartbeatState::tick_buffer
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.20 tick_buffer_size

```
uint32_t HeartbeatState::tick_buffer_size
```

6.77.1.21 tick_buffer_write_index

```
uint64_t HeartbeatState::tick_buffer_write_index
```

Referenced by metrics_write_james_law_csv_row().

6.77.1.22 tick_count

```
uint64_t HeartbeatState::tick_count
```

Referenced by block_word_block(), block_word_buffer(), block_word_update(), execute_colon_word(), heartbeat_capture_tick_snapsh heartbeat_publish_snapshot(), metrics_from_vm(), physics_on_lookup(), physics_pre_execute(), starforth_word_heartbeat_ticks(), vm_heartbeat_publish_snapshot(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_interpret_word(), vm_tick(), vm_tick_apply_background_decay(), vm_tick_apply_background_decay(), and vm_tick_inference_engine().

6.77.1.23 tick_count_total

```
uint64_t HeartbeatState::tick_count_total
```

6.77.1.24 tick_number_offset

```
uint32_t HeartbeatState::tick_number_offset
```

6.77.1.25 tick_target_ns

```
uint64_t HeartbeatState::tick_target_ns
```

Referenced by metrics_from_vm(), perturb_physics(), restore_physics(), save_physics(), vm_init(), vm_init_with_host(), and vm_tick_inference_engine().

6.77.1.26 words_executed

```
uint64_t HeartbeatState::words_executed
```

Referenced by execute_colon_word(), heartbeat_capture_tick_snapshot(), metrics_from_vm(), physics_post_execute(), and vm_interpret_word().

6.77.1.27 worker

```
HeartbeatWorker* HeartbeatState::worker
```

Referenced by execute_colon_word(), heartbeat_thread_main(), physics_post_execute(), vm_cleanup(), vm_heartbeat_start_thread(), vm_heartbeat_stop_thread(), vm_init(), vm_init_with_host(), vm_interpret(), and vm_tick_inference_engine().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.78 HeartbeatTickSnapshot Struct Reference

```
#include <vm.h>
```

Data Fields

- uint32_t tick_number
- uint64_t elapsed_ns
- uint64_t tick_interval_ns
- uint32_t cache_hits_delta
- uint32_t bucket_hits_delta
- uint32_t word_executions_delta
- uint64_t hot_word_count
- double avg_word_heat
- uint32_t window_width
- uint32_t actual_window_size
- uint32_t predicted_label_hits
- double estimated_jitter_ns
- uint8_t l8_mode

6.78.1 Field Documentation

6.78.1.1 actual_window_size

```
uint32_t HeartbeatTickSnapshot::actual_window_size
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.2 avg_word_heat

```
double HeartbeatTickSnapshot::avg_word_heat
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.3 bucket_hits_delta

```
uint32_t HeartbeatTickSnapshot::bucket_hits_delta
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.4 cache_hits_delta

```
uint32_t HeartbeatTickSnapshot::cache_hits_delta
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.5 elapsed_ns

```
uint64_t HeartbeatTickSnapshot::elapsed_ns
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.6 estimated_jitter_ns

```
double HeartbeatTickSnapshot::estimated_jitter_ns
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.7 hot_word_count

```
uint64_t HeartbeatTickSnapshot::hot_word_count
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.8 l8_mode

```
uint8_t HeartbeatTickSnapshot::l8_mode
```

Referenced by metrics_write_james_law_csv_row().

6.78.1.9 predicted_label_hits

```
uint32_t HeartbeatTickSnapshot::predicted_label_hits
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.10 tick_interval_ns

```
uint64_t HeartbeatTickSnapshot::tick_interval_ns
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.11 tick_number

```
uint32_t HeartbeatTickSnapshot::tick_number
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.12 window_width

```
uint32_t HeartbeatTickSnapshot::window_width
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

6.78.1.13 word_executions_delta

```
uint32_t HeartbeatTickSnapshot::word_executions_delta
```

Referenced by doe_log_tick_row(), heartbeat_capture_tick_snapshot(), and heartbeat_emit_tick_row().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.79 HeartbeatWorker Struct Reference

```
#include <vm_internal.h>
```

Data Fields

- uint64_t tick_ns
- int running
- int stop_requested

6.79.1 Field Documentation

6.79.1.1 running

```
int HeartbeatWorker::running
```

Referenced by heartbeat_thread_main().

6.79.1.2 stop_requested

```
int HeartbeatWorker::stop_requested
```

Referenced by heartbeat_thread_main(), vm_cleanup(), and vm_heartbeat_stop_thread().

6.79.1.3 tick_ns

```
uint64_t HeartbeatWorker::tick_ns
```

Referenced by heartbeat_thread_main(), vm_heartbeat_start_thread(), vm_init_with_host(), and vm_tick_inference_engine().

The documentation for this struct was generated from the following files:

- v3/src/vm_internal.h
- kernel/src/vm/vm_internal.h

6.80 homeblocks_sig_t Struct Reference

```
#include <homeblocks_sig.h>
```

Data Fields

- uint64_t magic
- uint8_t drive_uuid [16]
- uint64_t minted_time_ns
- uint64_t metadata_devblocks
- uint32_t cert_offset
- uint32_t cert_devblocks
- uint32_t identity_src_offset
- uint32_t identity_src_devblocks
- uint64_t hdr_crc
- uint8_t _pad [4096 -(8+16+8+8+4+4+4+4+8)]

6.80.1 Field Documentation

6.80.1.1 _pad

```
uint8_t homeblocks_sig_t::_pad[4096 -( 8+ 16+ 8+ 8+ 4+4+ 4+4+ 8)]
```

6.80.1.2 cert_devblocks

```
uint32_t homeblocks_sig_t::cert_devblocks
```

Referenced by capsule_mint_identity(), capsule_wirebind_try_attach(), and capsule_wirebind_verify_cert().

6.80.1.3 cert_offset

```
uint32_t homeblocks_sig_t::cert_offset
```

Referenced by capsule_mint_identity(), capsule_wirebind_try_attach(), and capsule_wirebind_verify_cert().

6.80.1.4 drive_uuid

```
uint8_t homeblocks_sig_t::drive_uuid[16]
```

Referenced by capsule_mint_identity(), and capsule_wirebind_verify_cert().

6.80.1.5 hdr_crc

```
uint64_t homeblocks_sig_t::hdr_crc
```

Referenced by capsule_mint_identity(), and homeblocks_sig_check().

6.80.1.6 identity_src_devblocks

```
uint32_t homeblocks_sig_t::identity_src_devblocks
```

Referenced by capsule_mint_identity(), capsule_runcap_birth(), capsule_wirebind_try_attach(), and capsule_zuse_boot_check_key().

6.80.1.7 identity_src_offset

```
uint32_t homeblocks_sig_t::identity_src_offset
```

Referenced by capsule_mint_identity(), capsule_runcap_birth(), capsule_wirebind_try_attach(), and capsule_zuse_boot_check_key().

6.80.1.8 magic

```
uint64_t homeblocks_sig_t::magic
```

Referenced by capsule_mint_identity(), and homeblocks_sig_check().

6.80.1.9 metadata_devblocks

```
uint64_t homeblocks_sig_t::metadata_devblocks
```

Referenced by capsule_mint_identity().

6.80.1.10 minted_time_ns

```
uint64_t homeblocks_sig_t::minted_time_ns
```

Referenced by capsule_mint_identity().

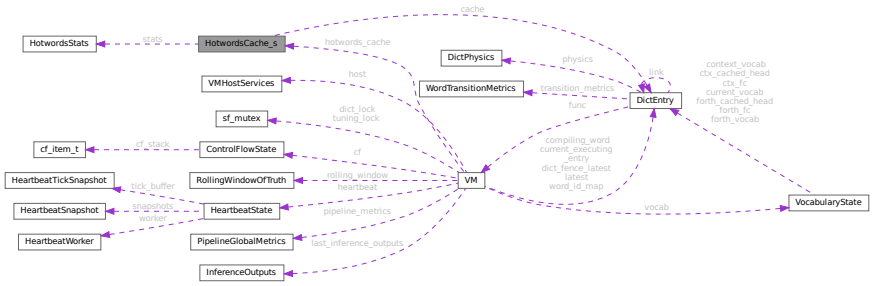
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/homeblocks_sig.h

6.81 HotwordsCache_s Struct Reference

`#include <physics_hotwords_cache.h>`

Collaboration diagram for HotwordsCache_s:



Data Fields

- DictEntry * cache [32]

  Cache entries (pointers to DictEntry)
- uint32_t cache_count

  Number of valid entries in cache.
- uint32_t lru_index

  LRU: last-used index for eviction.
- HotwordsStats stats

  Performance statistics.
- int enabled

  Enabled/disabled flag (runtime toggle)

6.81.1 Field Documentation

6.81.1.1 cache

```
DictEntry* HotwordsCache_s::cache[32]
```

Cache entries (pointers to DictEntry)

Referenced by forth_PHYSICS_CACHE_STATS(), hotwords_cache_evict_entry(), hotwords_cache_evict_name(), hotwords_cache_lookup(), hotwords_cache_promote(), and hotwords_cache_remove_at().

6.81.1.2 cache_count

```
uint32_t HotwordsCache_s::cache_count
```

Number of valid entries in cache.

Referenced by forth_PHYSICS_BUILD_INFO(), forth_PHYSICS_CACHE_STATS(), hotwords_cache_evict_entry(), hotwords_cache_evict_name(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_cache_promote(), and hotwords_cache_remove_at().

6.81.1.3 enabled

```
int HotwordsCache_s::enabled
```

Enabled/disabled flag (runtime toggle)

Referenced by forth_PHYSICS_BUILD_INFO(), forth_PHYSICS_TOGGLE_CACHE(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_cache_set_enabled(), metrics_from_vm(), and physics_pre_execute().

6.81.1.4 lru_index

```
uint32_t HotwordsCache_s::lru_index
```

LRU: last-used index for eviction.

Referenced by hotwords_cache_init(), hotwords_cache_promote(), and hotwords_cache_remove_at().

6.81.1.5 stats

```
HotwordsStats HotwordsCache_s::stats
```

Performance statistics.

Referenced by bucket_posterior(), cache_posterior(), extract_cache_metrics(), forth_BENCH_DICT_LOOKUP(), forth_PHYSICS_BAYESIAN_REPORT(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_RESET_STATS(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_cache_promote(), and metrics_from_vm().

The documentation for this struct was generated from the following file:

- v3/include/physics_hotwords_cache.h

6.82 HotwordsStats Struct Reference

```
#include <physics_hotwords_cache.h>
```

Data Fields

- uint64_t total_lookups

  Total lookups performed.
- uint64_t cache_hits

  Lookups that hit the hot-words cache.
- uint64_t bucket_hits

  Lookups that missed cache but found in bucket.
- uint64_t misses

  Lookups that failed (word not found)
- uint64_t evictions

  Words evicted from cache (LRU)
- uint64_t promotions

  Times a word was promoted to hot-words.
- uint64_t bucket_reorders

  Times bucket was reordered.
- int64_t cache_hit_total_ns_q48

  === 64-bit Fixed-Point Statistics (Q48.16 format) === Q48.16 = 48-bit integer + 16-bit fractional part Precision: 2^-16 ns ≈ 0.0000153 ns Range: ±140 trillion ns (≈ 4.4 years) Allows: Bayesian inference, precise averaging, statistical computation
- int64_t bucket_search_total_ns_q48

  Sum of bucket search latencies (64-bit fixed-point, Q48.16)
- uint64_t cache_hit_samples

  Number of cache hit samples (for averaging)
- uint64_t bucket_search_samples

  Number of bucket search samples (for averaging)
- int64_t min_cache_hit_ns

  Minimum cache hit latency (nanoseconds)
- int64_t max_cache_hit_ns

  Maximum cache hit latency (nanoseconds)
- int64_t min_bucket_search_ns

  Minimum bucket search latency (nanoseconds)
- int64_t max_bucket_search_ns

  Maximum bucket search latency (nanoseconds)
- int64_t cache_hit_variance_sum_q48

  Sum of squared cache hit latencies (for variance/stddev)
- int64_t bucket_search_variance_sum_q48

  Sum of squared bucket search latencies (for variance/stddev)

6.82.1 Field Documentation

6.82.1.1 bucket_hits

```
uint64_t HotwordsStats::bucket_hits
```

Lookups that missed cache but found in bucket.

Referenced by extract_cache_metrics(), forth_PHYSICS_BAYESIAN_REPORT(), hotwords_bayesian_report(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.2 bucket_reorders

```
uint64_t HotwordsStats::bucket_reorders
```

Times bucket was reordered.

Referenced by hotwords_cache_init(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.3 bucket_search_samples

```
uint64_t HotwordsStats::bucket_search_samples
```

Number of bucket search samples (for averaging)

Referenced by extract_cache_metrics(), forth_PHYSICS_BAYESIAN_REPORT(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_bucket_searches(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.4 bucket_search_total_ns_q48

```
int64_t HotwordsStats::bucket_search_total_ns_q48
```

Sum of bucket search latencies (64-bit fixed-point, Q48.16)

Referenced by extract_cache_metrics(), forth_PHYSICS_BAYESIAN_REPORT(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_bucket_searches(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.5 bucket_search_variance_sum_q48

```
int64_t HotwordsStats::bucket_search_variance_sum_q48
```

Sum of squared bucket search latencies (for variance/stddev)

Referenced by extract_cache_metrics(), forth_PHYSICS_BAYESIAN_REPORT(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_bucket_searches(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.6 cache_hit_samples

```
uint64_t HotwordsStats::cache_hit_samples
```

Number of cache hit samples (for averaging)

Referenced by extract_cache_metrics(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_cache_hits(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.7 cache_hit_total_ns_q48

```
int64_t HotwordsStats::cache_hit_total_ns_q48
```

=== 64-bit Fixed-Point Statistics (Q48.16 format) === Q48.16 = 48-bit integer + 16-bit fractional part Precision↩ : 2^-16 ns ≈ 0.0000153 ns Range: ±140 trillion ns (≈ 4.4 years) Allows: Bayesian inference, precise averaging, statistical computation

Sum of cache hit latencies (64-bit fixed-point, Q48.16)

Referenced by extract_cache_metrics(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_cache_hits(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.8 cache_hit_variance_sum_q48

```
int64_t HotwordsStats::cache_hit_variance_sum_q48
```

Sum of squared cache hit latencies (for variance/stddev)

Referenced by extract_cache_metrics(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_cache_hits(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.9 cache_hits

```
uint64_t HotwordsStats::cache_hits
```

Lookups that hit the hot-words cache.

Referenced by extract_cache_metrics(), forth_PHYSICS_BAYESIAN_REPORT(), hotwords_bayesian_report(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.10 evictions

```
uint64_t HotwordsStats::evictions
```

Words evicted from cache (LRU)

Referenced by hotwords_cache_init(), hotwords_cache_promote(), hotwords_stats_print(), hotwords_stats_reset(), and metrics_from_vm().

6.82.1.11 max_bucket_search_ns

```
int64_t HotwordsStats::max_bucket_search_ns
```

Maximum bucket search latency (nanoseconds)

Referenced by forth_PHYSICS_BAYESIAN_REPORT(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_bucket_searches(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.12 max_cache_hit_ns

```
int64_t HotwordsStats::max_cache_hit_ns
```

Maximum cache hit latency (nanoseconds)

Referenced by hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_cache_hits(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.13 min_bucket_search_ns

```
int64_t HotwordsStats::min_bucket_search_ns
```

Minimum bucket search latency (nanoseconds)

Referenced by forth_PHYSICS_BAYESIAN_REPORT(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_bucket_searches(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.14 min_cache_hit_ns

```
int64_t HotwordsStats::min_cache_hit_ns
```

Minimum cache hit latency (nanoseconds)

Referenced by hotwords_cache_init(), hotwords_cache_lookup(), hotwords_posterior_cache_hits(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.15 misses

```
uint64_t HotwordsStats::misses
```

Lookups that failed (word not found)

Referenced by hotwords_bayesian_report(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_stats_print(), and hotwords_stats_reset().

6.82.1.16 promotions

```
uint64_t HotwordsStats::promotions
```

Times a word was promoted to hot-words.

Referenced by hotwords_cache_init(), hotwords_cache_promote(), hotwords_stats_print(), hotwords_stats_reset(), and metrics_from_vm().

6.82.1.17 total_lookups

```
uint64_t HotwordsStats::total_lookups
```

Total lookups performed.

Referenced by extract_cache_metrics(), hotwords_cache_init(), hotwords_cache_lookup(), hotwords_stats_reset(), and metrics_from_vm().

The documentation for this struct was generated from the following file:

- v3/include/physics_hotwords_cache.h

6.83 idt_entry Struct Reference

Data Fields

- uint16_t offset_low
- uint16_t selector
- uint8_t ist
- uint8_t type_attr
- uint16_t offset_mid
- uint32_t offset_high
- uint32_t zero

6.83.1 Field Documentation

6.83.1.1 ist

```
uint8_t idt_entry::ist
```

Referenced by set_idt_entry().

6.83.1.2 offset_high

```
uint32_t idt_entry::offset_high
```

Referenced by set_idt_entry().

6.83.1.3 offset_low

```
uint16_t idt_entry::offset_low
```

Referenced by set_idt_entry().

6.83.1.4 offset_mid

```
uint16_t idt_entry::offset_mid
```

Referenced by set_idt_entry().

6.83.1.5 selector

```
uint16_t idt_entry::selector
```

Referenced by set_idt_entry().

6.83.1.6 type_attr

```
uint8_t idt_entry::type_attr
```

Referenced by set_idt_entry().

6.83.1.7 zero

```
uint32_t idt_entry::zero
```

Referenced by set_idt_entry().

The documentation for this struct was generated from the following file:

- kernel/src/arch/amd64/interrupts.c

6.84 idtr Struct Reference

Data Fields

- uint16_t limit
- uint64_t base

6.84.1 Field Documentation

6.84.1.1 base

```
uint64_t idtr::base
```

6.84.1.2 limit

```
uint16_t idtr::limit
```

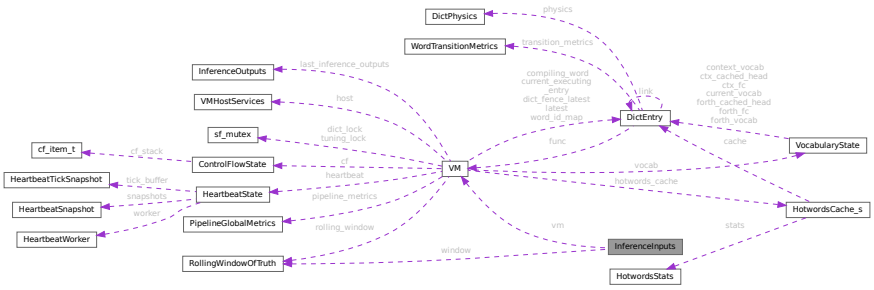
The documentation for this struct was generated from the following file:

- kernel/src/arch/amd64/interrupts.c

6.85 InferenceInputs Struct Reference

```
#include <inference_engine.h>
```

Collaboration diagram for InferenceInputs:



Data Fields

- VM * vm
- RollingWindowOfTruth * window
- uint64_t trajectory_length
- uint64_t prefetch_hits
- uint64_t prefetch_attempts
- uint64_t hot_word_count
- uint64_t stale_word_count
- uint64_t total_heat
- uint32_t word_count
- uint64_t last_total_heat
- uint64_t last_stale_count

6.85.1 Field Documentation

6.85.1.1 hot_word_count

```
uint64_t InferenceInputs::hot_word_count
```

Referenced by infer_word_run().

6.85.1.2 last_stale_count

```
uint64_t InferenceInputs::last_stale_count
```

Referenced by infer_word_run().

6.85.1.3 last_total_heat

```
uint64_t InferenceInputs::last_total_heat
```

Referenced by infer_word_run().

6.85.1.4 prefetch_attempts

```
uint64_t InferenceInputs::prefetch_attempts
```

Referenced by infer_word_run().

6.85.1.5 prefetch_hits

```
uint64_t InferenceInputs::prefetch_hits
```

Referenced by infer_word_run().

6.85.1.6 stale_word_count

```
uint64_t InferenceInputs::stale_word_count
```

Referenced by infer_word_run().

6.85.1.7 total_heat

```
uint64_t InferenceInputs::total_heat
```

Referenced by infer_word_run().

6.85.1.8 trajectory_length

```
uint64_t InferenceInputs::trajectory_length
```

Referenced by infer_word_run().

6.85.1.9 vm

```
VM* InferenceInputs::vm
```

Referenced by infer_word_run(), and inference_engine_run().

6.85.1.10 window

```
RollingWindowOfTruth* InferenceInputs::window
```

Referenced by infer_word_run(), inference_engine_run(), and vm_tick_inference_engine().

6.85.1.11 word_count

```
uint32_t InferenceInputs::word_count
```

Referenced by infer_word_run().

The documentation for this struct was generated from the following file:

- v3/include/inference_engine.h

6.86 InferenceOutputs Struct Reference

```
#include <inference_engine.h>
```

Data Fields

- uint32_t adaptive_window_width
- uint64_t adaptive_decay_slope
- uint64_t window_variance_q48
- uint64_t slope_fit_quality_q48
- uint32_t early_exited
- uint64_t last_check_tick

6.86.1 Field Documentation

6.86.1.1 adaptive_decay_slope

```
uint64_t InferenceOutputs::adaptive_decay_slope
```

Referenced by infer_word_decay_fetch(), inference_engine_run(), inference_outputs_to_string(), inference_outputs_validate(), and vm_tick_inference_engine().

6.86.1.2 adaptive_window_width

```
uint32_t InferenceOutputs::adaptive_window_width
```

Referenced by infer_word_window_fetch(), inference_engine_run(), inference_outputs_to_string(), inference_outputs_validate(), and vm_tick_inference_engine().

6.86.1.3 early_exited

```
uint32_t InferenceOutputs::early_exited
```

Referenced by infer_word_early_exit_fetch(), inference_engine_run(), inference_outputs_to_string(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), and vm_tick_inference_engine().

6.86.1.4 last_check_tick

```
uint64_t InferenceOutputs::last_check_tick
```

6.86.1.5 slope_fit_quality_q48

```
uint64_t InferenceOutputs::slope_fit_quality_q48
```

Referenced by infer_word_fit_fetch(), inference_engine_run(), inference_outputs_to_string(), inference_outputs_validate(), and vm_tick_inference_engine().

6.86.1.6 window_variance_q48

```
uint64_t InferenceOutputs::window_variance_q48
```

Referenced by infer_word_variance_fetch(), inference_engine_run(), inference_outputs_to_string(), metrics_from_vm(), and vm_tick_inference_engine().

The documentation for this struct was generated from the following file:

- v3/include/inference_engine.h

6.87 KernelArgs Struct Reference

```
#include <kernel_args.h>
```

Data Fields

- uint64_t stack_size
- uint64_t heap_size
- int run_doe
- int log_level
- int system
- int screen_boot
- char raw [512]

6.87.1 Field Documentation

6.87.1.1 heap_size

```
uint64_t KernelArgs::heap_size
```

Referenced by cmdline_parse_ascii(), and kernel_main().

6.87.1.2 log_level

```
int KernelArgs::log_level
```

Referenced by cmdline_parse_ascii().

6.87.1.3 raw

```
char KernelArgs::raw[512]
```

Referenced by cmdline_parse_ascii().

6.87.1.4 run_doe

```
int KernelArgs::run_doe
```

Referenced by cmdline_parse_ascii(), and kernel_main_deep().

6.87.1.5 screen_boot

```
int KernelArgs::screen_boot
```

Referenced by cmdline_parse_ascii().

6.87.1.6 stack_size

```
uint64_t KernelArgs::stack_size
```

Referenced by cmdline_parse_ascii(), and efi_main().

6.87.1.7 system

```
int KernelArgs::system
```

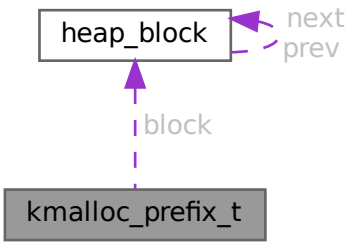
Referenced by cmdline_parse_ascii(), and kernel_main_deep().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/kernel_args.h

6.88 kmalloc_prefix_t Struct Reference

Collaboration diagram for kmalloc_prefix_t:



Data Fields

- uint32_t magic
- heap_block_t * block

6.88.1 Field Documentation

6.88.1.1 block

```
heap_block_t* kmalloc_prefix_t::block
```

Referenced by allocate_from_block(), and kfree().

6.88.1.2 magic

```
uint32_t kmalloc_prefix_t::magic
```

Referenced by allocate_from_block(), and kfree().

The documentation for this struct was generated from the following file:

- kernel/src/memory/kmalloc.c

6.89 kmalloc_stats_t Struct Reference

kmalloc.h - Kernel heap allocator interface

```
#include <kmalloc.h>
```

Data Fields

- uint64_t total_bytes
- uint64_t used_bytes
- uint64_t peak_bytes
- uint64_t free_bytes

6.89.1 Detailed Description

kmalloc.h - Kernel heap allocator interface

6.89.2 Field Documentation

6.89.2.1 free_bytes

```
uint64_t kmalloc_stats_t::free_bytes
```

Referenced by kmalloc_init(), print_heap_stats(), and update_free_bytes().

6.89.2.2 peak_bytes

```
uint64_t kmalloc_stats_t::peak_bytes
```

Referenced by account_allocation(), kmalloc_init(), print_heap_stats(), and sf_alloc_get_stats().

6.89.2.3 total_bytes

```
uint64_t kmalloc_stats_t::total_bytes
```

Referenced by kmalloc_init(), print_heap_stats(), sf_alloc_get_stats(), and update_free_bytes().

6.89.2.4 used_bytes

```
uint64_t kmalloc_stats_t::used_bytes
```

Referenced by account_allocation(), account_free(), kmalloc_init(), print_heap_stats(), sf_alloc_get_stats(), and update_free_bytes().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/kmalloc.h

6.90 log_region_ctrl_t Struct Reference

```
#include <log_region.h>
```

Data Fields

- uint64_t magic
- uint32_t devblocks
- uint32_t head_slot
- uint32_t tail_slot
- uint32_t record_count
- uint64_t hdr_crc
- uint8_t _pad [4096 -(8+4+4+4+4+8)]

6.90.1 Field Documentation

6.90.1.1 _pad

```
uint8_t log_region_ctrl_t::_pad[4096 -(8+4+4+4+4+8)]
```

6.90.1.2 devblocks

```
uint32_t log_region_ctrl_t::devblocks
```

Referenced by log_region_append(), log_region_ctrl_init_fresh(), and log_region_read_recent().

6.90.1.3 hdr_crc

```
uint64_t log_region_ctrl_t::hdr_crc
```

Referenced by log_region_ctrl_read(), and log_region_ctrl_write().

6.90.1.4 head_slot

```
uint32_t log_region_ctrl_t::head_slot
```

Referenced by log_region_append(), and log_region_ctrl_init_fresh().

6.90.1.5 magic

```
uint64_t log_region_ctrl_t::magic
```

Referenced by log_region_ctrl_init_fresh(), and log_region_ctrl_read().

6.90.1.6 record_count

```
uint32_t log_region_ctrl_t::record_count
```

Referenced by log_region_append(), log_region_ctrl_init_fresh(), and log_region_read_recent().

6.90.1.7 tail_slot

```
uint32_t log_region_ctrl_t::tail_slot
```

Referenced by log_region_append(), log_region_ctrl_init_fresh(), and log_region_read_recent().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/log_region.h

6.91 log_slot_t Struct Reference

```
#include <log_region.h>
```

Data Fields

- uint64_t timestamp
- uint16_t msg_len
- uint8_t level
- char source [16u]
- char msg [(1024u - 8u - 2u - 1u - 16u)]

6.91.1 Field Documentation

6.91.1.1 level

```
uint8_t log_slot_t::level
```

Referenced by log_region_append().

6.91.1.2 msg

```
char log_slot_t::msg[(1024u - 8u - 2u - 1u - 16u)]
```

Referenced by log_region_append().

6.91.1.3 msg_len

```
uint16_t log_slot_t::msg_len
```

Referenced by log_region_append().

6.91.1.4 source

```
char log_slot_t::source[16u]
```

Referenced by log_region_append().

6.91.1.5 timestamp

```
uint64_t log_slot_t::timestamp
```

Referenced by log_region_append().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/log_region.h

6.92 MemoryProfile Struct Reference

```
#include <profiler.h>
```

Data Fields

- uint64_t reads
- uint64_t writes
- uint64_t cache_hits
- uint64_t cache_misses
- uint64_t total_bytes_read
- uint64_t total_bytes_written

6.92.1 Field Documentation

6.92.1.1 cache_hits

```
uint64_t MemoryProfile::cache_hits
```

6.92.1.2 cache_misses

```
uint64_t MemoryProfile::cache_misses
```

6.92.1.3 reads

```
uint64_t MemoryProfile::reads
```

6.92.1.4 total_bytes_read

```
uint64_t MemoryProfile::total_bytes_read
```

6.92.1.5 total_bytes_written

```
uint64_t MemoryProfile::total_bytes_written
```

6.92.1.6 writes

```
uint64_t MemoryProfile::writes
```

The documentation for this struct was generated from the following file:

- v3/include/profiler.h

6.93 ParityPacket Struct Reference

ParityPacket - Summary of VM state for comparison.

```
#include <parity.h>
```

Data Fields

- uint32_t word_count
- uint32_t here_offset
- uint32_t latest_word_id
- uint64_t header_hash64
- uint32_t tests_total
- uint32_t tests_passed
- uint32_t tests_failed
- uint32_t tests_skipped
- uint32_t tests_errors
- uint64_t window_hash64
- int bootstrap_result

6.93.1 Detailed Description

ParityPacket - Summary of VM state for comparison.

M7.1a fields are sufficient for bootstrap validation. M7.1b fields are added for POST validation.

6.93.2 Field Documentation

6.93.2.1 bootstrap_result

```
int ParityPacket::bootstrap_result
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.2 header_hash64

```
uint64_t ParityPacket::header_hash64
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.3 here_offset

```
uint32_t ParityPacket::here_offset
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.4 latest_word_id

```
uint32_t ParityPacket::latest_word_id
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.5 tests_errors

```
uint32_t ParityPacket::tests_errors
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.6 tests_failed

```
uint32_t ParityPacket::tests_failed
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.7 tests_passed

```
uint32_t ParityPacket::tests_passed
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.8 tests_skipped

```
uint32_t ParityPacket::tests_skipped
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.9 tests_total

```
uint32_t ParityPacket::tests_total
```

Referenced by sk_parity_collect(), and sk_parity_print().

6.93.2.10 window_hash64

```
uint64_t ParityPacket::window_hash64
```

Referenced by sk_parity_collect().

6.93.2.11 word_count

```
uint32_t ParityPacket::word_count
```

Referenced by sk_parity_collect(), and sk_parity_print().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/vm/parity.h

6.94 PciDevice Struct Reference

```
#include <pci.h>
```

Data Fields

- uint8_t bus
- uint8_t device
- uint8_t function
- uint16_t vendor_id
- uint16_t device_id

6.94.1 Field Documentation

6.94.1.1 bus

```
uint8_t PciDevice::bus
```

Referenced by pci_find_class(), pci_find_first(), pci_read16(), pci_read32(), pci_read8(), pci_write16(), pci_write32(), and pci_write8().

6.94.1.2 device

```
uint8_t PciDevice::device
```

Referenced by pci_find_class(), pci_find_first(), pci_read16(), pci_read32(), pci_read8(), pci_write16(), pci_write32(), and pci_write8().

6.94.1.3 device_id

```
uint16_t PciDevice::device_id
```

Referenced by pci_find_class(), pci_find_first(), and xhci_find_and_map().

6.94.1.4 function

```
uint8_t PciDevice::function
```

Referenced by pci_find_class(), pci_find_first(), pci_read16(), pci_read32(), pci_read8(), pci_write16(), pci_write32(), and pci_write8().

6.94.1.5 vendor_id

```
uint16_t PciDevice::vendor_id
```

Referenced by pci_find_class(), pci_find_first(), and xhci_find_and_map().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/pci.h

6.95 physics_analytics_event_header Struct Reference

Event header written into the analytics ring buffer.

```
#include <physics_runtime.h>
```

Data Fields

- uint32_t channel
  Logical channel identifier.
- uint16_t payload_bytes
  Size of event payload.
- uint16_t reserved
  Reserved for alignment.
- uint64_t timestamp_ns
  Producer timestamp.

6.95.1 Detailed Description

Event header written into the analytics ring buffer.

6.95.2 Field Documentation

6.95.2.1 channel

```
uint32_t physics_analytics_event_header::channel
```

Logical channel identifier.

Referenced by physics_analytics_publish_event().

6.95.2.2 payload_bytes

```
uint16_t physics_analytics_event_header::payload_bytes
```

Size of event payload.

Referenced by physics_analytics_publish_event().

6.95.2.3 reserved

```
uint16_t physics_analytics_event_header::reserved
```

Reserved for alignment.

Referenced by physics_analytics_publish_event().

6.95.2.4 timestamp_ns

```
uint64_t physics_analytics_event_header::timestamp_ns
```

Producer timestamp.

Referenced by physics_analytics_publish_event().

The documentation for this struct was generated from the following file:

- v3/include/physics_runtime.h

6.96 physics_analytics_header Struct Reference

Analytics heap header seen by both producer (VM) and consumer (HOLA).

```
#include <physics_runtime.h>
```

Data Fields

- uint32_t magic
  HOLA_SHARED_MAGIC.
- uint16_t version_major
  Protocol major version.
- uint16_t version_minor
  Protocol minor version.
- uint32_t heap_bytes
  Total heap size.
- uint32_t ring_offset
  Offset to event ring.
- uint32_t ring_bytes
  Event ring length.
- uint32_t summary_offset
  Offset to summary/scratch region.
- uint32_t summary_bytes
  Summary region length.
- uint32_t scratch_offset
  Offset to reserved scratch area.
- uint32_t scratch_bytes
  Scratch area length.
- uint64_t produce_seq
  Monotonic sequence for producers.
- uint64_t consume_seq
  Consumer-visible sequence.
- uint32_t write_offset
  Producer write cursor.
- uint32_t read_offset
  Consumer read cursor.
- uint32_t dropped_events
  Count of dropped events.
- uint32_t flags
  Heap flags (see docs)

6.96.1 Detailed Description

Analytics heap header seen by both producer (VM) and consumer (HOLA).

6.96.2 Field Documentation

6.96.2.1 consume_seq

```
uint64_t physics_analytics_header::consume_seq
```

Consumer-visible sequence.

Referenced by analytics_heap_allocate().

6.96.2.2 dropped_events

```
uint32_t physics_analytics_header::dropped_events
```

Count of dropped events.

Referenced by analytics_heap_allocate(), and physics_analytics_publish_event().

6.96.2.3 flags

```
uint32_t physics_analytics_header::flags
```

Heap flags (see docs)

Referenced by analytics_heap_allocate().

6.96.2.4 heap_bytes

```
uint32_t physics_analytics_header::heap_bytes
```

Total heap size.

Referenced by analytics_heap_allocate().

6.96.2.5 magic

```
uint32_t physics_analytics_header::magic
```

HOLA_SHARED_MAGIC.

Referenced by analytics_heap_allocate().

6.96.2.6 produce_seq

```
uint64_t physics_analytics_header::produce_seq
```

Monotonic sequence for producers.

Referenced by analytics_heap_allocate(), and physics_analytics_publish_event().

6.96.2.7 read_offset

```
uint32_t physics_analytics_header::read_offset
```

Consumer read cursor.

Referenced by analytics_heap_allocate(), and analytics_ring_free().

6.96.2.8 ring_bytes

```
uint32_t physics_analytics_header::ring_bytes
```

Event ring length.

Referenced by analytics_heap_allocate(), analytics_ring_free(), and physics_analytics_publish_event().

6.96.2.9 ring_offset

```
uint32_t physics_analytics_header::ring_offset
```

Offset to event ring.

Referenced by analytics_heap_allocate().

6.96.2.10 scratch_bytes

```
uint32_t physics_analytics_header::scratch_bytes
```

Scratch area length.

Referenced by analytics_heap_allocate().

6.96.2.11 scratch_offset

```
uint32_t physics_analytics_header::scratch_offset
```

Offset to reserved scratch area.

Referenced by analytics_heap_allocate().

6.96.2.12 summary_bytes

```
uint32_t physics_analytics_header::summary_bytes
```

Summary region length.

Referenced by analytics_heap_allocate().

6.96.2.13 summary_offset

```
uint32_t physics_analytics_header::summary_offset
```

Offset to summary/scratch region.

Referenced by analytics_heap_allocate().

6.96.2.14 version_major

```
uint16_t physics_analytics_header::version_major
```

Protocol major version.

Referenced by analytics_heap_allocate().

6.96.2.15 version_minor

```
uint16_t physics_analytics_header::version_minor
```

Protocol minor version.

Referenced by analytics_heap_allocate().

6.96.2.16 write_offset

```
uint32_t physics_analytics_header::write_offset
```

Producer write cursor.

Referenced by analytics_heap_allocate(), analytics_ring_free(), and physics_analytics_publish_event().

The documentation for this struct was generated from the following file:

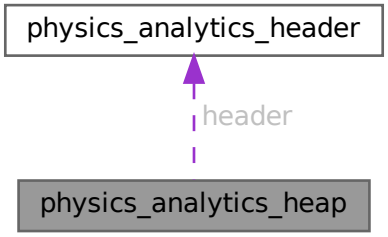
- v3/include/physics_runtime.h

6.97 physics_analytics_heap Struct Reference

Simple view onto the analytics heap layout.

```
#include <physics_runtime.h>
```

Collaboration diagram for physics_analytics_heap:



Data Fields

- uint8_t * base
  Base pointer (owned by runtime)
- size_t bytes
  Total bytes reserved.
- physics_analytics_header_t * header
  Shared header.
- uint8_t * ring
  Event ring base.
- size_t ring_bytes
  Event ring span.
- uint8_t * summary
  Summary/statistics region.
- size_t summary_bytes
  Summary region span.
- uint8_t * scratch
  Scratch/reserved region.
- size_t scratch_bytes
  Scratch region span.

6.97.1 Detailed Description

Simple view onto the analytics heap layout.

6.97.2 Field Documentation

6.97.2.1 base

```
uint8_t* physics_analytics_heap::base
```

Base pointer (owned by runtime)

Referenced by analytics_heap_allocate(), and analytics_heap_release().

6.97.2.2 bytes

```
size_t physics_analytics_heap::bytes
```

Total bytes reserved.

Referenced by analytics_heap_allocate().

6.97.2.3 header

```
physics_analytics_header_t* physics_analytics_heap::header
```

Shared header.

Referenced by analytics_heap_allocate(), and physics_analytics_publish_event().

6.97.2.4 ring

```
uint8_t* physics_analytics_heap::ring
```

Event ring base.

Referenced by analytics_heap_allocate(), and physics_analytics_publish_event().

6.97.2.5 ring_bytes

```
size_t physics_analytics_heap::ring_bytes
```

Event ring span.

Referenced by analytics_heap_allocate().

6.97.2.6 scratch

```
uint8_t* physics_analytics_heap::scratch
```

Scratch/reserved region.

Referenced by analytics_heap_allocate().

6.97.2.7 scratch_bytes

```
size_t physics_analytics_heap::scratch_bytes
```

Scratch region span.

Referenced by analytics_heap_allocate().

6.97.2.8 summary

```
uint8_t* physics_analytics_heap::summary
```

Summary/statistics region.

Referenced by analytics_heap_allocate().

6.97.2.9 summary_bytes

```
size_t physics_analytics_heap::summary_bytes
```

Summary region span.

Referenced by analytics_heap_allocate().

The documentation for this struct was generated from the following file:

- v3/include/physics_runtime.h

6.98 physics_host_snapshot Struct Reference

Snapshot of scheduler-adjacent host signals.

`#include <physics_runtime.h>`

Data Fields

- physics_host_backend_t backend
  Selected backend (POSIX/L4Re/other)
- uint32_t scheduler_policy
  OS-specific scheduler policy identifier.
- uint32_t scheduler_priority
  Nominal thread priority.
- uint32_t scheduler_quantum_ns
  Reported quantum in nanoseconds (0 if unknown)
- uint32_t runnable_threads
  Runnable entities on this CPU set (best effort)
- uint32_t cpu_count
  Online logical CPU count.
- uint32_t load_avg_milli
  Smoothed load average (×1000)
- uint32_t flags
  Backend-specific flags.
- uint32_t psi_cpu_some_avg10_milli
  CPU PSI some avg10 ×1000.
- uint32_t psi_cpu_some_avg60_milli
  CPU PSI some avg60 ×1000.
- uint32_t psi_cpu_some_avg300_milli
  CPU PSI some avg300 ×1000.
- uint32_t psi_cpu_full_avg10_milli
  CPU PSI full avg10 ×1000.
- uint32_t psi_cpu_full_avg60_milli
  CPU PSI full avg60 ×1000.
- uint32_t psi_cpu_full_avg300_milli
  CPU PSI full avg300 ×1000.
- uint32_t psi_io_some_avg10_milli
  IO PSI some avg10 ×1000.
- uint32_t psi_io_some_avg60_milli
  IO PSI some avg60 ×1000.
- uint32_t psi_io_some_avg300_milli
  IO PSI some avg300 ×1000.
- uint32_t psi_io_full_avg10_milli
  IO PSI full avg10 ×1000.
- uint32_t psi_io_full_avg60_milli
  IO PSI full avg60 ×1000.
- uint32_t psi_io_full_avg300_milli
  IO PSI full avg300 ×1000.
- uint32_t psi_mem_some_avg10_milli
  Memory PSI some avg10 ×1000.

- uint32_t psi_mem_some_avg60_milli
  Memory PSI some avg60 ×1000.
- uint32_t psi_mem_some_avg300_milli
  Memory PSI some avg300 ×1000.
- uint64_t monotonic_time_ns
  Monotonic clock reading.
- uint64_t realtime_ns
  Wall-clock timestamp (0 if unavailable)
- uint64_t backend_seq
  Backend-provided sequence counter.
- uint64_t cpu_total_jiffies
  /proc/stat total jiffies snapshot
- uint64_t cpu_idle_jiffies
  /proc/stat idle jiffies snapshot
- uint64_t cgroup_cpu_usage_us
  cgroup v2 cpu.stat usage_usec (0 if unavailable)
- uint64_t cgroup_memory_current_bytes
  cgroup v2 memory.current (0 if unavailable)

6.98.1 Detailed Description

Snapshot of scheduler-adjacent host signals.

Fields are intentionally fixed width to maximise portability and allow the governance repository to consume binary dumps without per-platform quirks.

6.98.2 Field Documentation

6.98.2.1 backend

```
physics_host_backend_t physics_host_snapshot::backend
```

Selected backend (POSIX/L4Re/other)

Referenced by snapshot_posix().

6.98.2.2 backend_seq

```
uint64_t physics_host_snapshot::backend_seq
```

Backend-provided sequence counter.

Referenced by snapshot_posix().

6.98.2.3 cgroup_cpu_usage_us

```
uint64_t physics_host_snapshot::cgroup_cpu_usage_us
```

cgroup v2 cpu.stat usage_usec (0 if unavailable)

Referenced by snapshot_posix().

6.98.2.4 cgroup_memory_current_bytes

```
uint64_t physics_host_snapshot::cgroup_memory_current_bytes
```

cgroup v2 memory.current (0 if unavailable)

Referenced by snapshot_posix().

6.98.2.5 cpu_count

```
uint32_t physics_host_snapshot::cpu_count
```

Online logical CPU count.

Referenced by snapshot_posix().

6.98.2.6 cpu_idle_jiffies

```
uint64_t physics_host_snapshot::cpu_idle_jiffies
```

/proc/stat idle jiffies snapshot

Referenced by snapshot_posix().

6.98.2.7 cpu_total_jiffies

```
uint64_t physics_host_snapshot::cpu_total_jiffies
```

/proc/stat total jiffies snapshot

Referenced by snapshot_posix().

6.98.2.8 flags

```
uint32_t physics_host_snapshot::flags
```

Backend-specific flags.

Referenced by snapshot_posix().

6.98.2.9 load_avg_milli

```
uint32_t physics_host_snapshot::load_avg_milli
```

Smoothed load average ($\times$1000)

Referenced by snapshot_posix().

6.98.2.10 monotonic_time_ns

```
uint64_t physics_host_snapshot::monotonic_time_ns
```

Monotonic clock reading.

Referenced by snapshot_posix().

6.98.2.11 psi_cpu_full_avg10_milli

```
uint32_t physics_host_snapshot::psi_cpu_full_avg10_milli
```

CPU PSI full avg10 ×1000.

Referenced by snapshot_posix().

6.98.2.12 psi_cpu_full_avg300_milli

```
uint32_t physics_host_snapshot::psi_cpu_full_avg300_milli
```

CPU PSI full avg300 ×1000.

Referenced by snapshot_posix().

6.98.2.13 psi_cpu_full_avg60_milli

```
uint32_t physics_host_snapshot::psi_cpu_full_avg60_milli
```

CPU PSI full avg60 ×1000.

Referenced by snapshot_posix().

6.98.2.14 psi_cpu_some_avg10_milli

```
uint32_t physics_host_snapshot::psi_cpu_some_avg10_milli
```

CPU PSI some avg10 ×1000.

Referenced by snapshot_posix().

6.98.2.15 psi_cpu_some_avg300_milli

```
uint32_t physics_host_snapshot::psi_cpu_some_avg300_milli
```

CPU PSI some avg300 ×1000.

Referenced by snapshot_posix().

6.98.2.16 psi_cpu_some_avg60_milli

```
uint32_t physics_host_snapshot::psi_cpu_some_avg60_milli
```

CPU PSI some avg60 ×1000.

Referenced by snapshot_posix().

6.98.2.17 psi_io_full_avg10_milli

```
uint32_t physics_host_snapshot::psi_io_full_avg10_milli
```

IO PSI full avg10 ×1000.

Referenced by snapshot_posix().

6.98.2.18 psi_io_full_avg300_milli

```
uint32_t physics_host_snapshot::psi_io_full_avg300_milli
```

IO PSI full avg300 ×1000.

Referenced by snapshot_posix().

6.98.2.19 psi_io_full_avg60_milli

```
uint32_t physics_host_snapshot::psi_io_full_avg60_milli
```

IO PSI full avg60 ×1000.

Referenced by snapshot_posix().

6.98.2.20 psi_io_some_avg10_milli

```
uint32_t physics_host_snapshot::psi_io_some_avg10_milli
```

IO PSI some avg10 ×1000.

Referenced by snapshot_posix().

6.98.2.21 psi_io_some_avg300_milli

```
uint32_t physics_host_snapshot::psi_io_some_avg300_milli
```

IO PSI some avg300 ×1000.

Referenced by snapshot_posix().

6.98.2.22 psi_io_some_avg60_milli

```
uint32_t physics_host_snapshot::psi_io_some_avg60_milli
```

IO PSI some avg60 ×1000.

Referenced by snapshot_posix().

6.98.2.23 psi_mem_some_avg10_milli

```
uint32_t physics_host_snapshot::psi_mem_some_avg10_milli
```

Memory PSI some avg10 ×1000.

Referenced by snapshot_posix().

6.98.2.24 psi_mem_some_avg300_milli

```
uint32_t physics_host_snapshot::psi_mem_some_avg300_milli
```

Memory PSI some avg300 ×1000.

Referenced by snapshot_posix().

6.98.2.25 psi_mem_some_avg60_milli

```
uint32_t physics_host_snapshot::psi_mem_some_avg60_milli
```

Memory PSI some avg60 ×1000.

Referenced by snapshot_posix().

6.98.2.26 realtime_ns

```
uint64_t physics_host_snapshot::realtime_ns
```

Wall-clock timestamp (0 if unavailable)

Referenced by snapshot_posix().

6.98.2.27 runnable_threads

```
uint32_t physics_host_snapshot::runnable_threads
```

Runnable entities on this CPU set (best effort)

Referenced by snapshot_posix().

6.98.2.28 scheduler_policy

```
uint32_t physics_host_snapshot::scheduler_policy
```

OS-specific scheduler policy identifier.

Referenced by snapshot_posix().

6.98.2.29 scheduler_priority

```
uint32_t physics_host_snapshot::scheduler_priority
```

Nominal thread priority.

Referenced by snapshot_posix().

6.98.2.30 scheduler_quantum_ns

```
uint32_t physics_host_snapshot::scheduler_quantum_ns
```

Reported quantum in nanoseconds (0 if unknown)

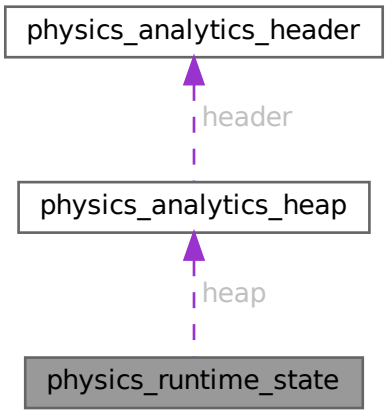
Referenced by snapshot_posix().

The documentation for this struct was generated from the following file:

- v3/include/physics_runtime.h

6.99 physics_runtime_state Struct Reference

Collaboration diagram for physics_runtime_state:



Data Fields

- physics_analytics_heap_t heap
- int heap_ready
- uint64_t backend_seq

6.99.1 Field Documentation

6.99.1.1 backend_seq

```
uint64_t physics_runtime_state::backend_seq
```

Referenced by analytics_heap_allocate(), analytics_heap_release(), and snapshot_posix().

6.99.1.2 heap

```
physics_analytics_heap_t physics_runtime_state::heap
```

Referenced by analytics_heap_allocate(), analytics_heap_release(), physics_analytics_heap_info(), and physics_analytics_publish_event().

6.99.1.3 heap_ready

```
int physics_runtime_state::heap_ready
```

Referenced by analytics_heap_allocate(), analytics_heap_release(), physics_analytics_heap_info(), physics_analytics_publish_event() and physics_host_snapshot().

The documentation for this struct was generated from the following file:

- v3/src/physics_runtime.c

6.100 physics_seed_definition Struct Reference

Data Fields

- const char * name
- uint16_t temperature_q8
- uint32_t avg_latency_ns
- uint8_t acl_hint
- uint8_t pubsub_mask

6.100.1 Field Documentation

6.100.1.1 acl_hint

```
uint8_t physics_seed_definition::acl_hint
```

6.100.1.2 avg_latency_ns

```
uint32_t physics_seed_definition::avg_latency_ns
```

6.100.1.3 name

```
const char* physics_seed_definition::name
```

Referenced by physics_metadata_apply_seed().

6.100.1.4 pubsub_mask

```
uint8_t physics_seed_definition::pubsub_mask
```

6.100.1.5 temperature_q8

```
uint16_t physics_seed_definition::temperature_q8
```

Referenced by physics_metadata_apply_seed().

The documentation for this struct was generated from the following file:

- v3/src/physics_metadata.c

6.101 PhysicsSnapshot Struct Reference

```
#include <test_contracts.h>
```

Data Fields

- uint64_t decay_slope_q48
- uint32_t eff_window_size
- uint64_t tick_target_ns
- cell_t heat_25th
- cell_t heat_50th
- cell_t heat_75th
- uint64_t prefetch_attempts
- uint64_t total_executions

6.101.1 Field Documentation

6.101.1.1 decay_slope_q48

```
uint64_t PhysicsSnapshot::decay_slope_q48
```

Referenced by restore_physics(), and save_physics().

6.101.1.2 eff_window_size

```
uint32_t PhysicsSnapshot::eff_window_size
```

Referenced by restore_physics(), and save_physics().

6.101.1.3 heat_25th

```
cell_t PhysicsSnapshot::heat_25th
```

Referenced by restore_physics(), and save_physics().

6.101.1.4 heat_50th

```
cell_t PhysicsSnapshot::heat_50th
```

Referenced by restore_physics(), and save_physics().

6.101.1.5 heat_75th

```
cell_t PhysicsSnapshot::heat_75th
```

Referenced by restore_physics(), and save_physics().

6.101.1.6 prefetch_attempts

```
uint64_t PhysicsSnapshot::prefetch_attempts
```

Referenced by restore_physics(), and save_physics().

6.101.1.7 tick_target_ns

```
uint64_t PhysicsSnapshot::tick_target_ns
```

Referenced by restore_physics(), and save_physics().

6.101.1.8 total_executions

```
uint64_t PhysicsSnapshot::total_executions
```

Referenced by restore_physics(), and save_physics().

The documentation for this struct was generated from the following file:

- v3/src/test_runner/include/test_contracts.h

6.102 PipelineGlobalMetrics Struct Reference

`#include <vm.h>`

Data Fields

- uint64_t prefetch_attempts
- uint64_t prefetch_hits
- uint64_t window_tuning_checks
- uint32_t last_checked_window_size
- double last_checked_accuracy
- uint32_t suggested_next_size

6.102.1 Field Documentation

6.102.1.1 last_checked_accuracy

`double PipelineGlobalMetrics::last_checked_accuracy`

Referenced by vm_init(), vm_init_with_host(), and vm_tick_window_tuner().

6.102.1.2 last_checked_window_size

`uint32_t PipelineGlobalMetrics::last_checked_window_size`

Referenced by vm_init(), vm_init_with_host(), and vm_tick_window_tuner().

6.102.1.3 prefetch_attempts

`uint64_t PipelineGlobalMetrics::prefetch_attempts`

Referenced by execute_colon_word(), forth_PHYSICS_RESET_STATS(), infer_word_run(), metrics_from_vm(), perturb_physics(), physics_pre_execute(), restore_physics(), save_physics(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_window_tuner().

6.102.1.4 prefetch_hits

`uint64_t PipelineGlobalMetrics::prefetch_hits`

Referenced by execute_colon_word(), forth_PHYSICS_RESET_STATS(), infer_word_run(), metrics_from_vm(), physics_pre_execute(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_window_tuner().

6.102.1.5 suggested_next_size

`uint32_t PipelineGlobalMetrics::suggested_next_size`

Referenced by vm_init(), and vm_init_with_host().

6.102.1.6 window_tuning_checks

```
uint64_t PipelineGlobalMetrics::window_tuning_checks
```

Referenced by forth_PHYSICS_RESET_STATS(), metrics_from_vm(), vm_init(), vm_init_with_host(), and vm_tick_window_tuner().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.103 pmm_stats_t Struct Reference

```
#include <pmm.h>
```

Data Fields

- uint64_t total_pages
- uint64_t used_pages
- uint64_t free_pages
- uint64_t total_bytes
- uint64_t used_bytes
- uint64_t free_bytes

6.103.1 Field Documentation

6.103.1.1 free_bytes

```
uint64_t pmm_stats_t::free_bytes
```

Referenced by pmm_get_stats(), and print_pmm_stats().

6.103.1.2 free_pages

```
uint64_t pmm_stats_t::free_pages
```

Referenced by pmm_get_stats(), and print_pmm_stats().

6.103.1.3 total_bytes

```
uint64_t pmm_stats_t::total_bytes
```

Referenced by pmm_get_stats(), and print_pmm_stats().

6.103.1.4 total_pages

```
uint64_t pmm_stats_t::total_pages
```

Referenced by pmm_get_stats(), and print_pmm_stats().

6.103.1.5 used_bytes

```
uint64_t pmm_stats_t::used_bytes
```

Referenced by pmm_get_stats(), and print_pmm_stats().

6.103.1.6 used_pages

```
uint64_t pmm_stats_t::used_pages
```

Referenced by pmm_get_stats(), and print_pmm_stats().

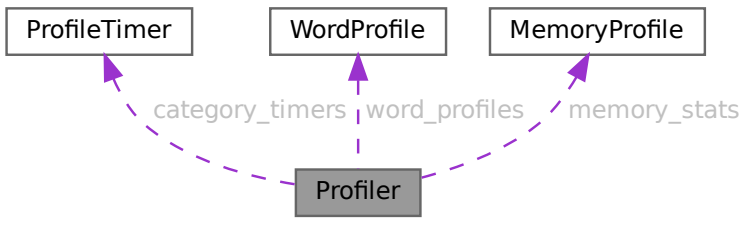
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/pmm.h

6.104 Profiler Struct Reference

```
#include <profiler.h>
```

Collaboration diagram for Profiler:



Data Fields

- ProfileLevel level
- uint64_t profiling_overhead
- uint64_t total_execution_time
- ProfileTimer category_timers [PROF_CATEGORY_COUNT]
- WordProfile * word_profiles
- size_t word_profile_count
- size_t word_profile_capacity
- MemoryProfile memory_stats
- uint64_t instruction_count
- uint64_t branch_count
- uint64_t loop_iterations
- struct {
  uint64_t vm_cycles
  uint64_t dict_lookups
  uint64_t stack_operations
  uint64_t memory_allocations
  uint64_t compile_operations
  } counters

6.104.1 Field Documentation

6.104.1.1 branch_count

```
uint64_t Profiler::branch_count
```

6.104.1.2 category_timers

```
ProfileTimer Profiler::category_timers[PROF_CATEGORY_COUNT]
```

6.104.1.3 compile_operations

```
uint64_t Profiler::compile_operations
```

6.104.1.4 [struct]

```
struct { ... } Profiler::counters
```

6.104.1.5 dict_lookups

```
uint64_t Profiler::dict_lookups
```

6.104.1.6 instruction_count

```
uint64_t Profiler::instruction_count
```

6.104.1.7 level

```
ProfileLevel Profiler::level
```

6.104.1.8 loop_iterations

```
uint64_t Profiler::loop_iterations
```

6.104.1.9 memory_allocations

```
uint64_t Profiler::memory_allocations
```

6.104.1.10 memory_stats

```
MemoryProfile Profiler::memory_stats
```

6.104.1.11 profiling_overhead

```
uint64_t Profiler::profiling_overhead
```

6.104.1.12 stack_operations

```
uint64_t Profiler::stack_operations
```

6.104.1.13 total_execution_time

```
uint64_t Profiler::total_execution_time
```

6.104.1.14 vm_cycles

```
uint64_t Profiler::vm_cycles
```

6.104.1.15 word_profile_capacity

```
size_t Profiler::word_profile_capacity
```

6.104.1.16 word_profile_count

```
size_t Profiler::word_profile_count
```

6.104.1.17 word_profiles

```
WordProfile* Profiler::word_profiles
```

The documentation for this struct was generated from the following file:

- v3/include/profiler.h

6.105 ProfileScope Struct Reference

```
#include <profiler.h>
```

Data Fields

- ProfileCategory category
- const char * word_name

6.105.1 Field Documentation

6.105.1.1 category

```
ProfileCategory ProfileScope::category
```

6.105.1.2 word_name

```
const char* ProfileScope::word_name
```

The documentation for this struct was generated from the following file:

- v3/include/profiler.h

6.106 ProfileTimer Struct Reference

Timer for measuring execution duration.

```
#include <profiler.h>
```

Data Fields

- uint64_t start_time
  Start timestamp.
- uint64_t total_time
  Accumulated execution time.
- uint64_t call_count
  Number of measurements.
- uint64_t min_time
  Minimum recorded time.
- uint64_t max_time
  Maximum recorded time.
- const char * name
  Timer identifier.

6.106.1 Detailed Description

Timer for measuring execution duration.

6.106.2 Field Documentation

6.106.2.1 call_count

```
uint64_t ProfileTimer::call_count
```

Number of measurements.

6.106.2.2 max_time

```
uint64_t ProfileTimer::max_time
```

Maximum recorded time.

6.106.2.3 min_time

```
uint64_t ProfileTimer::min_time
```

Minimum recorded time.

6.106.2.4 name

```
const char* ProfileTimer::name
```

Timer identifier.

6.106.2.5 start_time

```
uint64_t ProfileTimer::start_time
```

Start timestamp.

6.106.2.6 total_time

```
uint64_t ProfileTimer::total_time
```

Accumulated execution time.

The documentation for this struct was generated from the following file:

- v3/include/profiler.h

6.107 reloc_block Struct Reference

reloc_stub.c - Provide a minimal .reloc section for PE/COFF EFI loader

Data Fields

- uint32_t page_rva
- uint32_t block_size
- uint16_t entry

6.107.1 Detailed Description

reloc_stub.c - Provide a minimal .reloc section for PE/COFF EFI loader

Some firmware refuses to load images without a Base Relocation Directory. This stub supplies an empty relocation block to satisfy the loader.

PE/COFF Base Relocation Block header.

Mirrors the `IMAGE_BASE_RELOCATION` layout from the PE specification:

- `page_rva` — RVA of the 4 KB page that the following entries apply to.
- `block_size` — total byte size of this block including the header and all entries (minimum 8 bytes for the header alone).
- `entry` — one or more 16-bit relocation entries packed as TYPE (4 bits) | OFFSET (12 bits); TYPE=0 / OFFSET=0 is a no-op padding entry used to 32-bit-align the block.

Marked `packed` to suppress any padding the compiler might insert between fields; `aligned(4)` ensures the block sits on a 4-byte boundary as required by the PE loader.

6.107.2 Field Documentation

6.107.2.1 block_size

```
uint32_t reloc_block::block_size
```

6.107.2.2 entry

```
uint16_t reloc_block::entry
```

6.107.2.3 page_rva

```
uint32_t reloc_block::page_rva
```

Referenced by __attribute__().

The documentation for this struct was generated from the following file:

- kernel/src/boot/reloc_stub.c

6.108 rolling_window_view_t Struct Reference

Immutable snapshot view of a `RollingWindowOfTruth`.

Data Fields

- const uint32_t * history
- uint32_t window_pos
- uint64_t total_executions
- uint32_t effective_window_size
- int is_warm

6.108.1 Detailed Description

Immutable snapshot view of a `RollingWindowOfTruth`.

Provides a read-only window into one of the two double-buffered snapshot arrays. Reader threads (the heartbeat, pipelining, and diversity subsystems) obtain a `rolling_window_view_t` via `rolling_window_snapshot_view()` rather than accessing the live `RollingWindowOfTruth` fields directly; this avoids TOCTOU races with the writer thread that calls `rolling_window_record_execution()`.

Fields mirror the snapshot-time copies of the corresponding `RollingWindowOfTruth` members:

- `history` — pointer into `snapshot_buffers`[idx]; size `ROLLING_WINDOW_SIZE`.
- `window_pos` — write cursor at snapshot time.
- `total_executions` — monotonic execution count at snapshot time.
- `effective_window_size` — adaptive window width at snapshot time.
- `is_warm` — whether the window had reached $\geq$ 1024 executions at snapshot.

6.108.2 Field Documentation

6.108.2.1 effective_window_size

```
uint32_t rolling_window_view_t::effective_window_size
```

Referenced by rolling_window_measure_diversity_view(), and rolling_window_snapshot_view().

6.108.2.2 history

```
const uint32_t* rolling_window_view_t::history
```

Referenced by rolling_window_count_transition(), rolling_window_export_execution_history(), rolling_window_find_hottest_word(), rolling_window_get_recent_sequence(), rolling_window_measure_diversity_view(), rolling_window_pattern_capture_rate(), rolling_window_run_adaptive_pass(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), and rolling_window_snapshot_view().

6.108.2.3 is_warm

```
int rolling_window_view_t::is_warm
```

Referenced by rolling_window_count_transition(), rolling_window_find_hottest_word(), rolling_window_measure_diversity_view(), rolling_window_run_adaptive_pass(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), rolling_window_snapshot_view(), and rolling_window_stats_string().

6.108.2.4 total_executions

```
uint64_t rolling_window_view_t::total_executions
```

Referenced by rolling_window_export_execution_history(), rolling_window_get_recent_sequence(), rolling_window_measure_diversit rolling_window_pattern_capture_rate(), rolling_window_run_adaptive_pass(), rolling_window_snapshot_view(), and rolling_window_stats_string().

6.108.2.5 window_pos

```
uint32_t rolling_window_view_t::window_pos
```

Referenced by rolling_window_export_execution_history(), rolling_window_get_recent_sequence(), rolling_window_measure_diversit rolling_window_snapshot_view(), and rolling_window_stats_string().

The documentation for this struct was generated from the following file:

- v3/src/rolling_window_of_truth.c

6.109 RollingWindowOfTruth Struct Reference

```
#include <vm.h>
```

Data Fields

- uint32_t * execution_history
- uint32_t * snapshot_buffers [2]
- uint32_t window_pos
- uint64_t total_executions
- int is_warm
- uint32_t effective_window_size
- uint64_t last_pattern_diversity
- uint64_t pattern_diversity_check_count
- volatile uint32_t snapshot_index
- volatile uint32_t snapshot_pending
- uint32_t snapshot_window_pos [2]
- uint64_t snapshot_total_executions [2]
- uint32_t snapshot_effective_window_size [2]
- int snapshot_is_warm [2]
- uint32_t adaptive_check_accumulator
- volatile uint32_t adaptive_pending

6.109.1 Field Documentation

6.109.1.1 adaptive_check_accumulator

```
uint32_t RollingWindowOfTruth::adaptive_check_accumulator
```

Referenced by rolling_window_init(), and rolling_window_record_execution().

6.109.1.2 adaptive_pending

```
volatile uint32_t RollingWindowOfTruth::adaptive_pending
```

Referenced by rolling_window_check_adaptive_shrink(), rolling_window_init(), rolling_window_record_execution(), and rolling_window_service_internal().

6.109.1.3 effective_window_size

```
uint32_t RollingWindowOfTruth::effective_window_size
```

Referenced by extract_heat_trajectory(), heartbeat_capture_tick_snapshot(), heartbeat_publish_snapshot(), metrics_from_vm(), perturb_physics(), restore_physics(), rolling_window_init(), rolling_window_publish_snapshot(), rolling_window_run_adaptive_pass(), run_doe_experiment(), save_physics(), vm_heartbeat_publish_snapshot(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_window_tuner().

6.109.1.4 execution_history

```
uint32_t* RollingWindowOfTruth::execution_history
```

Referenced by rolling_window_cleanup(), rolling_window_init(), rolling_window_publish_snapshot(), rolling_window_record_execution and rolling_window_reset().

6.109.1.5 is_warm

```
int RollingWindowOfTruth::is_warm
```

Referenced by extract_heat_trajectory(), rolling_window_count_transition(), rolling_window_find_hottest_word(), rolling_window_init(), rolling_window_is_warm(), rolling_window_publish_snapshot(), rolling_window_record_execution(), rolling_window_reset(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), run_doe_experiment(), vm_tick_inference_engine(), and vm_tick_window_tuner().

6.109.1.6 last_pattern_diversity

```
uint64_t RollingWindowOfTruth::last_pattern_diversity
```

Referenced by rolling_window_init(), and rolling_window_run_adaptive_pass().

6.109.1.7 pattern_diversity_check_count

```
uint64_t RollingWindowOfTruth::pattern_diversity_check_count
```

Referenced by rolling_window_init(), and rolling_window_run_adaptive_pass().

6.109.1.8 snapshot_buffers

```
uint32_t* RollingWindowOfTruth::snapshot_buffers[2]
```

Referenced by rolling_window_cleanup(), rolling_window_init(), rolling_window_publish_snapshot(), and rolling_window_snapshot_view().

6.109.1.9 snapshot_effective_window_size

```
uint32_t RollingWindowOfTruth::snapshot_effective_window_size[2]
```

Referenced by rolling_window_init(), rolling_window_publish_snapshot(), and rolling_window_snapshot_view().

6.109.1.10 snapshot_index

```
volatile uint32_t RollingWindowOfTruth::snapshot_index
```

Referenced by rolling_window_init(), rolling_window_publish_snapshot(), and rolling_window_snapshot_view().

6.109.1.11 snapshot_is_warm

```
int RollingWindowOfTruth::snapshot_is_warm[2]
```

Referenced by rolling_window_init(), rolling_window_publish_snapshot(), and rolling_window_snapshot_view().

6.109.1.12 snapshot_pending

```
volatile uint32_t RollingWindowOfTruth::snapshot_pending
```

Referenced by rolling_window_init(), rolling_window_publish_snapshot(), rolling_window_publish_snapshot_if_needed(), rolling_window_record_execution(), and rolling_window_reset().

6.109.1.13 snapshot_total_executions

```
uint64_t RollingWindowOfTruth::snapshot_total_executions[2]
```

Referenced by rolling_window_init(), rolling_window_publish_snapshot(), and rolling_window_snapshot_view().

6.109.1.14 snapshot_window_pos

```
uint32_t RollingWindowOfTruth::snapshot_window_pos[2]
```

Referenced by rolling_window_init(), rolling_window_publish_snapshot(), and rolling_window_snapshot_view().

6.109.1.15 total_executions

```
uint64_t RollingWindowOfTruth::total_executions
```

Referenced by heartbeat_capture_tick_snapshot(), infer_word_run(), metrics_from_vm(), perturb_physics(), restore_physics(), rolling_window_init(), rolling_window_publish_snapshot(), rolling_window_record_execution(), rolling_window_reset(), run_doe_experiment(), save_physics(), vm_heartbeat_publish_snapshot(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), and vm_tick_inference_engine().

6.109.1.16 window_pos

```
uint32_t RollingWindowOfTruth::window_pos
```

Referenced by infer_word_run(), rolling_window_init(), rolling_window_publish_snapshot(), rolling_window_record_execution(), rolling_window_reset(), and vm_tick_inference_engine().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.110 rpi5_range_t Struct Reference

Data Fields

- uint64_t addr
- uint64_t size

6.110.1 Field Documentation

6.110.1.1 addr

```
uint64_t rpi5_range_t::addr
```

Referenced by collect_ram_regions(), collect_reserved_ranges(), emit_region_with_carveouts(), and sort_ranges_by_addr().

6.110.1.2 size

```
uint64_t rpi5_range_t::size
```

Referenced by collect_ram_regions(), collect_reserved_ranges(), and emit_region_with_carveouts().

The documentation for this struct was generated from the following file:

- kernel/src/arch/aarch64/rpi5_native_boot.c

6.111 Rpi5FramebufferInfo Struct Reference

rpi5_mailbox.h - VideoCore mailbox property-interface framebuffer setup, for the native (non-UEFI) Raspberry Pi 5 boot path (FABRIC-3.md ?IV.3 item 3).

```
#include <rpi5_mailbox.h>
```

Data Fields

- void * base
- uint64_t size
- uint32_t width
- uint32_t height
- uint32_t pixels_per_scanline
- uint32_t pixel_format

6.111.1 Detailed Description

rpi5_mailbox.h - VideoCore mailbox property-interface framebuffer setup, for the native (non-UEFI) Raspberry Pi 5 boot path (FABRIC-3.md ?IV.3 item 3).

Register layout, message/tag format, and property-tag IDs confirmed against multiple sources before writing `rpi5_mailbox.c` — see that file's own doc comment for exactly which, and what (if anything) remains unverified against real hardware (not in hand until 2026-09-17; this driver has never run on real silicon).

6.111.2 Field Documentation

6.111.2.1 base

```
void* Rpi5FramebufferInfo::base
```

Referenced by rpi5_mailbox_get_framebuffer(), and rpi5_native_boot().

6.111.2.2 height

```
uint32_t Rpi5FramebufferInfo::height
```

Referenced by rpi5_mailbox_get_framebuffer(), and rpi5_native_boot().

6.111.2.3 pixel_format

```
uint32_t Rpi5FramebufferInfo::pixel_format
```

Referenced by rpi5_mailbox_get_framebuffer(), and rpi5_native_boot().

6.111.2.4 pixels_per_scanline

```
uint32_t Rpi5FramebufferInfo::pixels_per_scanline
```

Referenced by rpi5_mailbox_get_framebuffer(), and rpi5_native_boot().

6.111.2.5 size

```
uint64_t Rpi5FramebufferInfo::size
```

Referenced by rpi5_mailbox_get_framebuffer(), and rpi5_native_boot().

6.111.2.6 width

```
uint32_t Rpi5FramebufferInfo::width
```

Referenced by rpi5_mailbox_get_framebuffer(), and rpi5_native_boot().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/rpi5_mailbox.h

6.112 sbiret_t Struct Reference

Data Fields

- long error
- long value

6.112.1 Field Documentation

6.112.1.1 error

```
long sbiret_t::error
```

Referenced by apic_timer_start(), sbi_call1(), and sbi_set_timer().

6.112.1.2 value

```
long sbiret_t::value
```

Referenced by apic_timer_start(), and sbi_call1().

The documentation for this struct was generated from the following file:

- kernel/src/arch/riscv64/apic.c

6.113 sf_alloc_stats Struct Reference

```
#include <platform_alloc.h>
```

Data Fields

- size_t total_bytes
- size_t used_bytes
- size_t peak_bytes
- size_t alloc_count
- size_t free_count

6.113.1 Field Documentation

6.113.1.1 alloc_count

```
size_t sf_alloc_stats::alloc_count
```

Referenced by sf_alloc_get_stats(), sf_alloc_init(), sf_calloc(), sf_malloc(), and sf_realloc().

6.113.1.2 free_count

```
size_t sf_alloc_stats::free_count
```

Referenced by sf_alloc_get_stats(), sf_alloc_init(), and sf_free().

6.113.1.3 peak_bytes

```
size_t sf_alloc_stats::peak_bytes
```

Referenced by sf_alloc_get_stats(), sf_alloc_init(), sf_calloc(), and sf_malloc().

6.113.1.4 total_bytes

```
size_t sf_alloc_stats::total_bytes
```

Referenced by sf_alloc_get_stats(), and sf_alloc_init().

6.113.1.5 used_bytes

```
size_t sf_alloc_stats::used_bytes
```

Referenced by sf_alloc_get_stats(), sf_alloc_init(), sf_calloc(), and sf_malloc().

The documentation for this struct was generated from the following file:

- v3/include/platform_alloc.h

6.114 sf_mutex Struct Reference

```
#include <platform_lock.h>
```

Data Fields

- pthread_mutex_t handle

6.114.1 Field Documentation

6.114.1.1 handle

```
pthread_mutex_t sf_mutex::handle
```

Referenced by sf_mutex_destroy(), sf_mutex_init(), sf_mutex_lock(), and sf_mutex_unlock().

The documentation for this struct was generated from the following file:

- v3/include/platform_lock.h

6.115 sf_time_backend_t Struct Reference

```
#include <platform_time.h>
```

Data Fields

- sf_time_ns_t(* get_monotonic_ns)(void)
  Get monotonic time (for performance measurement)
- sf_time_ns_t(* get_realtime_ns)(void)
  Get wall-clock time.
- int(* set_realtime_ns)(sf_time_ns_t ns_since_epoch)
  Set wall-clock time (may require privileges)
- int(* format_timestamp)(sf_time_ns_t ns_since_epoch, char *buf, int format_24h)
  Format timestamp as human-readable string.
- int(* has_rtc)(void)
  Check if real-time clock is available.

6.115.1 Field Documentation

6.115.1.1 format_timestamp

```
int(* sf_time_backend_t::format_timestamp) (sf_time_ns_t ns_since_epoch, char *buf, int format↩
_24h)
```

Format timestamp as human-readable string.

Parameters

ns_since_epoch	Nanoseconds since Unix epoch
buf	Output buffer (SF_TIME_STAMP_SIZE bytes)
format_24h	Use 24-hour format (1) or 12-hour (0)

Returns

0 on success, -1 on error

Referenced by sf_format_timestamp().

6.115.1.2 get_monotonic_ns

```
sf_time_ns_t(* sf_time_backend_t::get_monotonic_ns) (void)
```

Get monotonic time (for performance measurement)

Returns

Nanoseconds since system boot (never decreases)

Referenced by sf_monotonic_ns().

6.115.1.3 get_realtime_ns

```
sf_time_ns_t(* sf_time_backend_t::get_realtime_ns) (void)
```

Get wall-clock time.

Returns

Nanoseconds since Unix epoch (1970-01-01 00:00:00 UTC) Returns 0 if RTC unavailable

Referenced by sf_realtime_ns().

6.115.1.4 has_rtc

```
int(* sf_time_backend_t::has_rtc) (void)
```

Check if real-time clock is available.

Returns

1 if RTC available, 0 if not

Referenced by sf_has_rtc().

6.115.1.5 set_realtime_ns

```
int(* sf_time_backend_t::set_realtime_ns) (sf_time_ns_t ns_since_epoch)
```

Set wall-clock time (may require privileges)

Parameters

ns_since_epoch	Nanoseconds since Unix epoch

Returns

0 on success, -1 on error

Referenced by sf_set_realtime_ns().

The documentation for this struct was generated from the following file:

- v3/include/platform_time.h

6.116 sha512_ctx_t Struct Reference

`#include <sha512.h>`

Data Fields

- uint64_t state [8]
- uint64_t bitlen
- uint8_t buf [128]
- size_t buf_len

6.116.1 Field Documentation

6.116.1.1 bitlen

`uint64_t sha512_ctx_t::bitlen`

Referenced by sha512_final(), sha512_init(), and sha512_update().

6.116.1.2 buf

`uint8_t sha512_ctx_t::buf[128]`

Referenced by sha512_final(), and sha512_update().

6.116.1.3 buf_len

`size_t sha512_ctx_t::buf_len`

Referenced by sha512_final(), sha512_init(), and sha512_update().

6.116.1.4 state

```
uint64_t sha512_ctx_t::state[8]
```

Referenced by sha512_block(), sha512_final(), and sha512_init().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/sha512.h

6.117 sigaction Struct Reference

```
#include <signal.h>
```

Data Fields

- sighandler_t sa_handler
- int sa_flags

6.117.1 Field Documentation

6.117.1.1 sa_flags

```
int sigaction::sa_flags
```

Referenced by vm_debug_install_signal_handlers().

6.117.1.2 sa_handler

```
sighandler_t sigaction::sa_handler
```

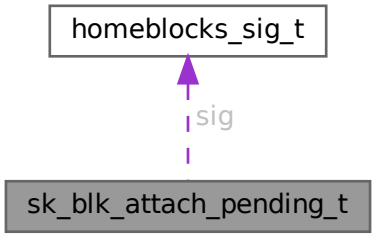
Referenced by vm_debug_install_signal_handlers().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/freestanding/signal.h

6.118 sk_blk_attach_pending_t Struct Reference

Collaboration diagram for sk_blk_attach_pending_t:



Data Fields

- int pending
- homeblocks_sig_result_t sig_rc
- homeblocks_sig_t sig
- int is_artemis

6.118.1 Field Documentation

6.118.1.1 is_artemis

```
int sk_blk_attach_pending_t::is_artemis
```

Referenced by sk_repl_idle(), and sk_word_blk_attach_ack().

6.118.1.2 pending

```
int sk_blk_attach_pending_t::pending
```

Referenced by sk_repl_idle(), and sk_word_blk_attach_ack().

6.118.1.3 sig

```
homeblocks_sig_t sk_blk_attach_pending_t::sig
```

Referenced by sk_repl_idle(), and sk_word_blk_attach_ack().

6.118.1.4 sig_rc

```
homeblocks_sig_result_t sk_blk_attach_pending_t::sig_rc
```

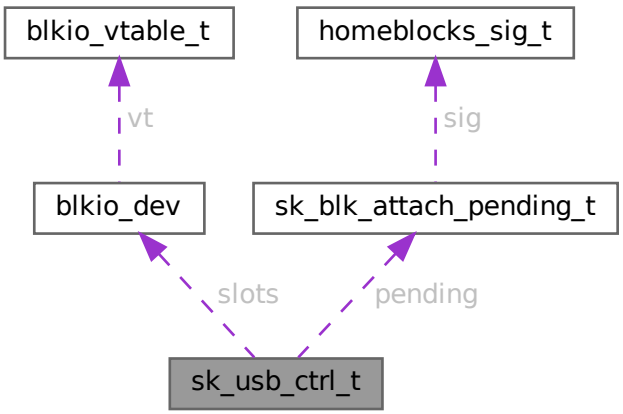
Referenced by sk_repl_idle(), and sk_word_blk_attach_ack().

The documentation for this struct was generated from the following file:

- kernel/src/repl.c

6.119 sk_usb_ctrl_t Struct Reference

Collaboration diagram for sk_usb_ctrl_t:



Data Fields

- blkio_dev_t * slots
- uint32_t count
- sk_blk_attach_pending_t * pending

6.119.1 Field Documentation

6.119.1.1 count

```
uint32_t sk_usb_ctrl_t::count
```

Referenced by sk_repl_idle(), and sk_word_blk_attach_ack().

6.119.1.2 pending

```
sk_blk_attach_pending_t* sk_usb_ctrl_t::pending
```

Referenced by sk_repl_idle(), and sk_word_blk_attach_ack().

6.119.1.3 slots

```
blkio_dev_t* sk_usb_ctrl_t::slots
```

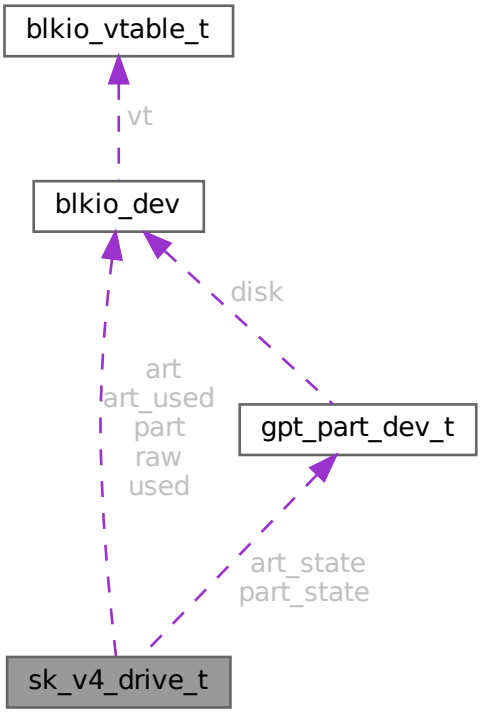
Referenced by sk_repl_idle().

The documentation for this struct was generated from the following file:

- kernel/src/repl.c

6.120 sk_v4_drive_t Struct Reference

Collaboration diagram for sk_v4_drive_t:



Data Fields

- blkio_dev_t raw
- blkio_dev_t part
- gpt_part_dev_t part_state
- blkio_dev_t * used
- blkio_dev_t art
- gpt_part_dev_t art_state
- blkio_dev_t * art_used

6.120.1 Field Documentation

6.120.1.1 art

```
blkio_dev_t sk_v4_drive_t::art
```

Referenced by sk_v4_drive_arrived(), and sk_v4_grow_stick().

6.120.1.2 art_state

```
gpt_part_dev_t sk_v4_drive_t::art_state
```

Referenced by sk_v4_drive_arrived(), and sk_v4_grow_stick().

6.120.1.3 art_used

```
blkio_dev_t* sk_v4_drive_t::art_used
```

Referenced by sk_v4_drive_arrived(), and sk_v4_drive_left().

6.120.1.4 part

```
blkio_dev_t sk_v4_drive_t::part
```

Referenced by sk_v4_drive_arrived(), and sk_v4_real_zuse_arrived().

6.120.1.5 part_state

```
gpt_part_dev_t sk_v4_drive_t::part_state
```

Referenced by sk_v4_drive_arrived(), and sk_v4_real_zuse_arrived().

6.120.1.6 raw

```
blkio_dev_t sk_v4_drive_t::raw
```

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), sk_v4_identity_offer_wait(), and sk_v4_real_zuse_arrived().

6.120.1.7 used

```
blkio_dev_t* sk_v4_drive_t::used
```

Referenced by sk_v4_drive_arrived(), sk_v4_drive_left(), and sk_v4_real_zuse_arrived().

The documentation for this struct was generated from the following file:

- kernel/src/v4/sk_v4_identity.c

6.121 sk_v4_marker_t Struct Reference

```
#include <sk_v4_marker.h>
```

Data Fields

- int present
- uint8_t proxy [32]
- int has_real
- uint8_t real [32]

6.121.1 Field Documentation

6.121.1.1 has_real

```
int sk_v4_marker_t::has_real
```

Referenced by sk_v4_drive_arrived(), sk_v4_drive_left(), sk_v4_marker_read(), sk_v4_marker_write(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

6.121.1.2 present

```
int sk_v4_marker_t::present
```

Referenced by sk_v4_drive_arrived(), sk_v4_drive_left(), sk_v4_genesis(), sk_v4_marker_read(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

6.121.1.3 proxy

```
uint8_t sk_v4_marker_t::proxy[32]
```

Referenced by sk_v4_drive_arrived(), sk_v4_genesis(), sk_v4_marker_read(), and sk_v4_marker_write().

6.121.1.4 real

```
uint8_t sk_v4_marker_t::real[32]
```

Referenced by sk_v4_marker_read(), sk_v4_marker_write(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/v4/sk_v4_marker.h

6.122 SpeedupEstimate Struct Reference

Calculate speedup estimate with credible interval All values in Q48.16 fixed-point format (64-bit signed integer) Probabilities are in range [0, Q48_SCALE] representing [0%, 100%].

```
#include <physics_hotwords_cache.h>
```

Data Fields

- int64_t speedup_factor_q48
- int64_t credible_lower_95_q48
- int64_t credible_upper_95_q48
- int64_t probability_gt_10pct_q48
- int64_t probability_gt_double_q48

6.122.1 Detailed Description

Calculate speedup estimate with credible interval All values in Q48.16 fixed-point format (64-bit signed integer) Probabilities are in range [0, Q48_SCALE] representing [0%, 100%].

6.122.2 Field Documentation

6.122.2.1 credible_lower_95_q48

```
int64_t SpeedupEstimate::credible_lower_95_q48
```

Referenced by hotwords_bayesian_report(), and hotwords_speedup_estimate().

6.122.2.2 credible_upper_95_q48

```
int64_t SpeedupEstimate::credible_upper_95_q48
```

Referenced by hotwords_bayesian_report(), and hotwords_speedup_estimate().

6.122.2.3 probability_gt_10pct_q48

```
int64_t SpeedupEstimate::probability_gt_10pct_q48
```

Referenced by hotwords_bayesian_report(), and hotwords_speedup_estimate().

6.122.2.4 probability_gt_double_q48

```
int64_t SpeedupEstimate::probability_gt_double_q48
```

Referenced by hotwords_bayesian_report(), and hotwords_speedup_estimate().

6.122.2.5 speedup_factor_q48

```
int64_t SpeedupEstimate::speedup_factor_q48
```

Referenced by hotwords_bayesian_report(), and hotwords_speedup_estimate().

The documentation for this struct was generated from the following file:

- v3/include/physics_hotwords_cache.h

6.123 ssm_config_t Struct Reference

```
#include <ssm_jacquard.h>
```

Data Fields

- int L1_heat_tracking
- int L2_rolling_window
- int L3_linear_decay
- int L4_pipelining
- int L5_window_inference
- int L6_decay_inference
- int L7_adaptive_heartrate

6.123.1 Field Documentation

6.123.1.1 L1_heat_tracking

```
int ssm_config_t::L1_heat_tracking
```

Referenced by ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.123.1.2 L2_rolling_window

```
int ssm_config_t::L2_rolling_window
```

Referenced by ssm_apply_mode(), ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.123.1.3 L3_linear_decay

```
int ssm_config_t::L3_linear_decay
```

Referenced by physics_metadata_apply_linear_decay(), ssm_apply_mode(), ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.123.1.4 L4_pipelining

```
int ssm_config_t::L4_pipelining
```

Referenced by physics_pre_execute(), ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.123.1.5 L5_window_inference

```
int ssm_config_t::L5_window_inference
```

Referenced by inference_engine_run(), ssm_apply_mode(), ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.123.1.6 L6_decay_inference

```
int ssm_config_t::L6_decay_inference
```

Referenced by inference_engine_run(), ssm_apply_mode(), ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.123.1.7 L7_adaptive_heartrate

```
int ssm_config_t::L7_adaptive_heartrate
```

Referenced by ssm_apply_mode_from_table(), ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

The documentation for this struct was generated from the following file:

- v3/include/ssm_jacquard.h

6.124 ssm_l8_metrics_t Struct Reference

`#include <ssm_jacquard.h>`

Data Fields

- double entropy
- double cv
- double temporal_decay
- double stability_score
- int inference_ran_this_tick
- int inference_early_exited

6.124.1 Field Documentation

6.124.1.1 cv

`double ssm_l8_metrics_t::cv`

Referenced by infer_word_l8_update(), ssm_l8_update(), ssm_l8_update_table(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.124.1.2 entropy

`double ssm_l8_metrics_t::entropy`

Referenced by infer_word_l8_update(), ssm_l8_update(), ssm_l8_update_table(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.124.1.3 inference_early_exited

`int ssm_l8_metrics_t::inference_early_exited`

Referenced by ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.124.1.4 inference_ran_this_tick

`int ssm_l8_metrics_t::inference_ran_this_tick`

Referenced by ssm_l8_tick_score_and_select(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.124.1.5 stability_score

`double ssm_l8_metrics_t::stability_score`

Referenced by infer_word_l8_update(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.124.1.6 temporal_decay

```
double ssm_l8_metrics_t::temporal_decay
```

Referenced by infer_word_l8_update(), ssm_l8_update(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

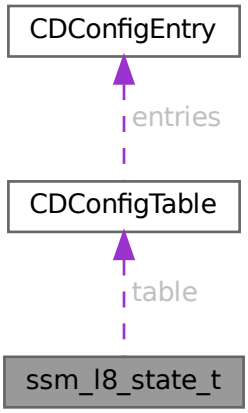
The documentation for this struct was generated from the following file:

- v3/include/ssm_jacquard.h

6.125 ssm_l8_state_t Struct Reference

```
#include <ssm_jacquard.h>
```

Collaboration diagram for ssm_l8_state_t:



Data Fields

- ssm_l8_mode_t current_mode
- uint32_t hysteresis_counter
- ssm_l8_mode_t pending_mode
- CDConfigTable * table

6.125.1 Field Documentation

6.125.1.1 current_mode

```
ssm_l8_mode_t ssm_l8_state_t::current_mode
```

Referenced by infer_word_l8_mode(), ssm_apply_mode(), ssm_l8_init(), ssm_l8_update(), ssm_l8_update_table(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

6.125.1.2 hysteresis_counter

```
uint32_t ssm_l8_state_t::hysteresis_counter
```

Referenced by ssm_l8_init(), and ssm_l8_update().

6.125.1.3 pending_mode

```
ssm_l8_mode_t ssm_l8_state_t::pending_mode
```

Referenced by ssm_l8_init(), and ssm_l8_update().

6.125.1.4 table

```
CDConfigTable* ssm_l8_state_t::table
```

Referenced by l8_regime_modulation_q16(), ssm_apply_mode_from_table(), ssm_l8_force_config(), ssm_l8_free_table(), ssm_l8_init(), ssm_l8_init_table(), ssm_l8_update_table(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

The documentation for this struct was generated from the following file:

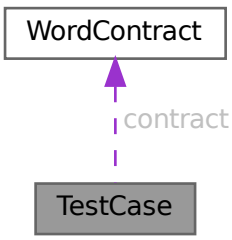
- v3/include/ssm_jacquard.h

6.126 TestCase Struct Reference

Structure representing a single test case.

```
#include <test_common.h>
```

Collaboration diagram for TestCase:



Data Fields

- const char * name
  Name of the test case.
- const char * input
  Input Forth code.
- const char * expected
  Expected output.
- TestType type
  Type of test case.
- int should_error
  Whether test should produce an error.
- int implemented
  Whether the functionality is implemented.
- WordContract contract
  Per-test contract override; zero = inherit from suite/module.

6.126.1 Detailed Description

Structure representing a single test case.

6.126.2 Field Documentation

6.126.2.1 contract

```
WordContract TestCase::contract
```

Per-test contract override; zero = inherit from suite/module.

Referenced by run_test_suite_m().

6.126.2.2 expected

```
const char* TestCase::expected
```

Expected output.

Referenced by run_single_test().

6.126.2.3 implemented

```
int TestCase::implemented
```

Whether the functionality is implemented.

Referenced by run_single_test(), run_test_suite(), and run_test_suite_m().

6.126.2.4 input

```
const char* TestCase::input
```

Input Forth code.

Referenced by run_single_test(), and run_test_suite_m().

6.126.2.5 name

```
const char* TestCase::name
```

Name of the test case.

Referenced by run_single_test(), run_test_suite(), and run_test_suite_m().

6.126.2.6 should_error

```
int TestCase::should_error
```

Whether test should produce an error.

Referenced by run_single_test(), and run_test_suite_m().

6.126.2.7 type

```
TestType TestCase::type
```

Type of test case.

Referenced by run_test_suite_m().

The documentation for this struct was generated from the following file:

- v3/src/test_runner/include/test_common.h

6.127 TestModule Struct Reference

Structure representing a test module.

```
#include <test_runner.h>
```

Data Fields

- const char * module_name
  Name of the test module.
- void * reserved
  Reserved for future use.
- int reserved_int
  Reserved integer value.
- void(* run_module_tests)(VM *vm)
  Function pointer to run module tests.

6.127.1 Detailed Description

Structure representing a test module.

6.127.2 Field Documentation

6.127.2.1 module_name

```
const char* TestModule::module_name
```

Name of the test module.

Referenced by run_all_tests(), run_module_tests(), and run_word_tests().

6.127.2.2 reserved

```
void* TestModule::reserved
```

Reserved for future use.

6.127.2.3 reserved_int

```
int TestModule::reserved_int
```

Reserved integer value.

6.127.2.4 run_module_tests

```
void(* TestModule::run_module_tests) (VM *vm)
```

Function pointer to run module tests.

Referenced by run_module_tests().

The documentation for this struct was generated from the following file:

- v3/src/test_runner/include/test_runner.h

6.128 TestStats Struct Reference

Structure holding test execution statistics.

`#include <test_runner.h>`

Data Fields

- int total_tests
  Total number of tests executed.
- int total_pass
  Number of passed tests.
- int total_fail
  Number of failed tests.
- int total_skip
  Number of skipped tests.
- int total_error
  Number of tests that resulted in errors.

6.128.1 Detailed Description

Structure holding test execution statistics.

6.128.2 Field Documentation

6.128.2.1 total_error

`int TestStats::total_error`

Number of tests that resulted in errors.

Referenced by run_all_tests(), run_stress_tests(), sk_parity_collect(), and test_stats_accumulate().

6.128.2.2 total_fail

`int TestStats::total_fail`

Number of failed tests.

Referenced by run_all_tests(), run_stress_tests(), sk_parity_collect(), and test_stats_accumulate().

6.128.2.3 total_pass

`int TestStats::total_pass`

Number of passed tests.

Referenced by run_all_tests(), run_stress_tests(), sk_parity_collect(), and test_stats_accumulate().

6.128.2.4 total_skip

```
int TestStats::total_skip
```

Number of skipped tests.

Referenced by run_all_tests(), run_stress_tests(), sk_parity_collect(), and test_stats_accumulate().

6.128.2.5 total_tests

```
int TestStats::total_tests
```

Total number of tests executed.

Referenced by run_all_tests(), run_break_me_tests(), run_stress_tests(), sk_parity_collect(), and test_stats_accumulate().

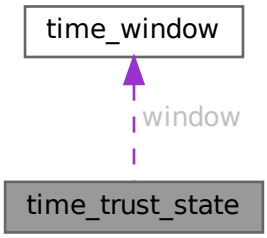
The documentation for this struct was generated from the following file:

- v3/src/test_runner/include/test_runner.h

6.129 time_trust_state Struct Reference

```
#include <timer.h>
```

Collaboration diagram for time_trust_state:



Data Fields

- volatile uint64_t ticks
- uint64_t last_tsc
- uint64_t expected_delta
- TimeWindow window
- q48_16_t variance
- q48_16_t trust
- uint64_t total_samples

6.129.1 Field Documentation

6.129.1.1 expected_delta

```
uint64_t time_trust_state::expected_delta
```

Referenced by heartbeat_init(), and heartbeat_service().

6.129.1.2 last_tsc

```
uint64_t time_trust_state::last_tsc
```

Referenced by heartbeat_init(), and heartbeat_service().

6.129.1.3 ticks

```
volatile uint64_t time_trust_state::ticks
```

Referenced by doe_log_tick_row(), heartbeat_init(), heartbeat_tick(), and heartbeat_ticks().

6.129.1.4 total_samples

```
uint64_t time_trust_state::total_samples
```

Referenced by heartbeat_init(), and heartbeat_service().

6.129.1.5 trust

```
q48_16_t time_trust_state::trust
```

Referenced by doe_log_tick_row(), heartbeat_init(), heartbeat_service(), and heartbeat_trust().

6.129.1.6 variance

```
q48_16_t time_trust_state::variance
```

Referenced by doe_log_tick_row(), heartbeat_init(), heartbeat_service(), and kernel_main_deep().

6.129.1.7 window

```
TimeWindow time_trust_state::window
```

Referenced by heartbeat_init(), and heartbeat_service().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/timer.h

6.130 time_window Struct Reference

`#include <timer.h>`

Data Fields

- int64_t deltas [64]
- uint32_t pos
- uint32_t count

6.130.1 Field Documentation

6.130.1.1 count

`uint32_t time_window::count`

Referenced by heartbeat_init().

6.130.1.2 deltas

`int64_t time_window::deltas[64]`

Referenced by heartbeat_init().

6.130.1.3 pos

`uint32_t time_window::pos`

Referenced by heartbeat_init().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/timer.h

6.131 timer_calibration_record Struct Reference

`#include <timer.h>`

Data Fields

- uint64_t hpet_hz
- uint64_t tsc_hz_mean
- uint64_t pit_hz_mean
- uint64_t cv_hpet_ppm
- uint64_t cv_pit_ppm
- uint64_t diff_ppm
- uint32_t windows_used
- uint8_t converged
- uint8_t vm_mode
- uint8_t trust
- uint8_t reserved [1]

6.131.1 Field Documentation

6.131.1.1 converged

```
uint8_t timer_calibration_record::converged
```

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), and timer_init().

6.131.1.2 cv_hpet_ppm

```
uint64_t timer_calibration_record::cv_hpet_ppm
```

Referenced by converge_tsc_bare_metal(), and init_timer_vm_mode().

6.131.1.3 cv_pit_ppm

```
uint64_t timer_calibration_record::cv_pit_ppm
```

Referenced by converge_tsc_bare_metal(), and init_timer_vm_mode().

6.131.1.4 diff_ppm

```
uint64_t timer_calibration_record::diff_ppm
```

Referenced by converge_tsc_bare_metal(), and init_timer_vm_mode().

6.131.1.5 hpet_hz

```
uint64_t timer_calibration_record::hpet_hz
```

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), and timer_init().

6.131.1.6 pit_hz_mean

```
uint64_t timer_calibration_record::pit_hz_mean
```

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), and timer_init().

6.131.1.7 reserved

```
uint8_t timer_calibration_record::reserved[1]
```

6.131.1.8 trust

```
uint8_t timer_calibration_record::trust
```

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), timer_init(), and timer_now_ns().

6.131.1.9 tsc_hz_mean

```
uint64_t timer_calibration_record::tsc_hz_mean
```

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), and timer_init().

6.131.1.10 vm_mode

```
uint8_t timer_calibration_record::vm_mode
```

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), timer_check_drift_now(), timer_init(), and timer_now_ns().

6.131.1.11 windows_used

```
uint32_t timer_calibration_record::windows_used
```

Referenced by converge_tsc_bare_metal(), and init_timer_vm_mode().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/timer.h

6.132 timespec Struct Reference

```
#include <time.h>
```

Data Fields

- time_t tv_sec
- long tv_nsec

6.132.1 Field Documentation

6.132.1.1 tv_nsec

```
long timespec::tv_nsec
```

Referenced by heartbeat_thread_main(), posix_get_monotonic_ns(), posix_get_realtime_ns(), posix_set_realtime_ns(), and snapshot_posix().

6.132.1.2 tv_sec

```
time_t timespec::tv_sec
```

Referenced by heartbeat_thread_main(), posix_get_monotonic_ns(), posix_get_realtime_ns(), posix_set_realtime_ns(), and snapshot_posix().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/freestanding/time.h

6.133 timeval Struct Reference

```
#include <time.h>
```

Data Fields

- time_t tv_sec
- suseconds_t tv_usec

6.133.1 Field Documentation

6.133.1.1 tv_sec

```
time_t timeval::tv_sec
```

Referenced by sf_terminal_ready().

6.133.1.2 tv_usec

```
suseconds_t timeval::tv_usec
```

Referenced by sf_terminal_ready().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/freestanding/sys/time.h

6.134 timezone Struct Reference

```
#include <time.h>
```

Data Fields

- int tz_minuteswest
- int tz_dsttime

6.134.1 Field Documentation

6.134.1.1 tz_dsttime

```
int timezone::tz_dsttime
```

6.134.1.2 tz_minuteswest

```
int timezone::tz_minuteswest
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/freestanding/sys/time.h

6.135 ttf_bitmap_t Struct Reference

A caller-owned 8-bit-per-pixel bitmap.

```
#include <ttf.h>
```

Data Fields

- uint8_t * pixels
- uint32_t width
- uint32_t height

6.135.1 Detailed Description

A caller-owned 8-bit-per-pixel bitmap.

`ttf_rasterize_glyph()` writes `fill_value` into covered pixels and leaves everything else untouched (it does not clear the buffer first — caller's job, so repeated rasterization into the same bitmap, e.g. for a text run, composites correctly without an extra clear between glyphs).

6.135.2 Field Documentation

6.135.2.1 height

```
uint32_t ttf_bitmap_t::height
```

Referenced by ttf_draw_glyph_cell().

6.135.2.2 pixels

```
uint8_t* ttf_bitmap_t::pixels
```

Referenced by ttf_draw_glyph_cell().

6.135.2.3 width

```
uint32_t ttf_bitmap_t::width
```

Referenced by ttf_draw_glyph_cell().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/ttf.h

6.136 ttf_flat_point_t Struct Reference

Data Fields

- q48_16_t x
- q48_16_t y

6.136.1 Field Documentation

6.136.1.1 x

```
q48_16_t ttf_flat_point_t::x
```

6.136.1.2 y

```
q48_16_t ttf_flat_point_t::y
```

The documentation for this struct was generated from the following file:

- kernel/src/hal/ttf.c

6.137 ttf_font_t Struct Reference

Parsed font handle.

```
#include <ttf.h>
```

Data Fields

- const uint8_t * data
- uint32_t size
- uint32_t head_off
- uint32_t maxp_off
- uint32_t loca_off
- uint32_t loca_len
- uint32_t glyf_off
- uint32_t glyf_len
- uint16_t units_per_em
- int16_t index_to_loc_format
- uint16_t num_glyphs
- uint32_t cmap_subtable_off
- int has_cmap
- uint32_t hmtx_off
- uint16_t num_h_metrics

6.137.1 Detailed Description

Parsed font handle.

Borrows the caller's buffer (does not copy or own it) — the buffer must outlive the ttf_font_t.

6.137.2 Field Documentation

6.137.2.1 cmap_subtable_off

```
uint32_t ttf_font_t::cmap_subtable_off
```

Referenced by ttf_codepoint_to_glyph(), and ttf_parse().

6.137.2.2 data

```
const uint8_t* ttf_font_t::data
```

Referenced by decode_composite_glyph(), decode_simple_glyph(), ttf_codepoint_to_glyph(), ttf_glyph_advance_width(), ttf_glyph_header(), and ttf_parse().

6.137.2.3 glyf_len

```
uint32_t ttf_font_t::glyf_len
```

Referenced by ttf_parse().

6.137.2.4 glyf_off

```
uint32_t ttf_font_t::glyf_off
```

Referenced by ttf_glyph_header(), and ttf_parse().

6.137.2.5 has_cmap

```
int ttf_font_t::has_cmap
```

Referenced by ttf_codepoint_to_glyph(), and ttf_parse().

6.137.2.6 head_off

```
uint32_t ttf_font_t::head_off
```

Referenced by ttf_parse().

6.137.2.7 hmtx_off

```
uint32_t ttf_font_t::hmtx_off
```

Referenced by ttf_glyph_advance_width(), and ttf_parse().

6.137.2.8 index_to_loc_format

```
int16_t ttf_font_t::index_to_loc_format
```

Referenced by ttf_glyph_header(), and ttf_parse().

6.137.2.9 loca_len

```
uint32_t ttf_font_t::loca_len
```

Referenced by ttf_parse().

6.137.2.10 loca_off

```
uint32_t ttf_font_t::loca_off
```

Referenced by ttf_glyph_header(), and ttf_parse().

6.137.2.11 maxp_off

```
uint32_t ttf_font_t::maxp_off
```

Referenced by ttf_parse().

6.137.2.12 num_glyphs

```
uint16_t ttf_font_t::num_glyphs
```

Referenced by ttf_glyph_header(), and ttf_parse().

6.137.2.13 num_h_metrics

```
uint16_t ttf_font_t::num_h_metrics
```

Referenced by ttf_glyph_advance_width(), and ttf_parse().

6.137.2.14 size

```
uint32_t ttf_font_t::size
```

Referenced by in_bounds(), and ttf_parse().

6.137.2.15 units_per_em

```
uint16_t ttf_font_t::units_per_em
```

Referenced by ttf_parse().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/ttf.h

6.138 ttf_glyph_header_t Struct Reference

Raw glyf record header, per ?27.6/4.3.7's "done when" clause.

```
#include <ttf.h>
```

Data Fields

- int16_t num_contours
- int16_t x_min
- int16_t y_min
- int16_t x_max
- int16_t y_max
- uint32_t glyf_offset
- uint32_t glyf_length

6.138.1 Detailed Description

Raw glyf record header, per ?27.6/4.3.7's "done when" clause.

6.138.2 Field Documentation

6.138.2.1 glyf_length

```
uint32_t ttf_glyph_header_t::glyf_length
```

Referenced by decode_glyph_r(), and ttf_glyph_header().

6.138.2.2 glyf_offset

```
uint32_t ttf_glyph_header_t::glyf_offset
```

Referenced by decode_composite_glyph(), decode_simple_glyph(), and ttf_glyph_header().

6.138.2.3 num_contours

```
int16_t ttf_glyph_header_t::num_contours
```

Referenced by decode_glyph_r(), decode_simple_glyph(), and ttf_glyph_header().

6.138.2.4 x_max

```
int16_t ttf_glyph_header_t::x_max
```

Referenced by ttf_glyph_header().

6.138.2.5 x_min

```
int16_t ttf_glyph_header_t::x_min
```

Referenced by ttf_glyph_header().

6.138.2.6 y_max

```
int16_t ttf_glyph_header_t::y_max
```

Referenced by ttf_glyph_header().

6.138.2.7 y_min

```
int16_t ttf_glyph_header_t::y_min
```

Referenced by ttf_glyph_header().

The documentation for this struct was generated from the following file:

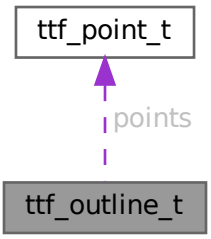
- kernel/include/starkernel/ttf.h

6.139 ttf_outline_t Struct Reference

Simple- and composite-glyph outline, flattened to one point list plus per-contour end indices (TrueType convention: contour_ends[c] is the index of the LAST point of contour c, inclusive; points are shared across contours only in the sense that contour c+1 starts right after contour_ends[c]).

`#include <ttf.h>`

Collaboration diagram for ttf_outline_t:



Data Fields

- ttf_point_t * points
- uint32_t max_points
- uint32_t point_count
- uint16_t * contour_ends
- uint32_t max_contours
- uint32_t contour_count

6.139.1 Detailed Description

Simple- and composite-glyph outline, flattened to one point list plus per-contour end indices (TrueType convention: contour_ends[c] is the index of the LAST point of contour c, inclusive; points are shared across contours only in the sense that contour c+1 starts right after contour_ends[c]).

Caller supplies both backing arrays — this module never allocates.

6.139.2 Field Documentation

6.139.2.1 contour_count

`uint32_t ttf_outline_t::contour_count`

Referenced by decode_simple_glyph(), and ttf_glyph_outline().

6.139.2.2 contour_ends

```
uint16_t* ttf_outline_t::contour_ends
```

Referenced by decode_simple_glyph().

6.139.2.3 max_contours

```
uint32_t ttf_outline_t::max_contours
```

Referenced by decode_simple_glyph().

6.139.2.4 max_points

```
uint32_t ttf_outline_t::max_points
```

Referenced by decode_simple_glyph().

6.139.2.5 point_count

```
uint32_t ttf_outline_t::point_count
```

Referenced by decode_composite_glyph(), decode_simple_glyph(), and ttf_glyph_outline().

6.139.2.6 points

```
ttf_point_t* ttf_outline_t::points
```

Referenced by decode_composite_glyph(), and decode_simple_glyph().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/ttf.h

6.140 ttf_point_t Struct Reference

One outline point, in raw font design units (NOT scaled by unitsPerEm — that's the caller's job, same convention as ttf_glyph_header_t's bbox), expressed in Q48.16.

```
#include <ttf.h>
```

Data Fields

- q48_16_t x
- q48_16_t y
- uint8_t on_curve

6.140.1 Detailed Description

One outline point, in raw font design units (NOT scaled by unitsPerEm — that's the caller's job, same convention as ttf_glyph_header_t's bbox), expressed in Q48.16.

Two's-complement negative values are expected and correct for q48_add/q48_sub and for q48_from_u64-style left-shift conversion; this module never calls q48_mul/q48_div on outline coordinates (see ttf.c's file header comment for why).

6.140.2 Field Documentation

6.140.2.1 on_curve

```
uint8_t ttf_point_t::on_curve
```

Referenced by decode_simple_glyph(), and flatten_contour().

6.140.2.2 x

```
q48_16_t ttf_point_t::x
```

Referenced by decode_composite_glyph(), decode_simple_glyph(), and flatten_contour().

6.140.2.3 y

```
q48_16_t ttf_point_t::y
```

Referenced by decode_composite_glyph(), decode_simple_glyph(), and flatten_contour().

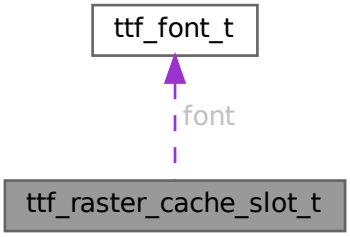
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/ttf.h

6.141 ttf_raster_cache_slot_t Struct Reference

```
#include <ttf.h>
```

Collaboration diagram for ttf_raster_cache_slot_t:



Data Fields

- int valid
- const ttf_font_t * font
- uint32_t codepoint
- uint32_t size_px
- uint32_t width
- uint32_t height
- uint32_t hits
- uint8_t pixels [((64+8 *2) *(64+8 *2))]

6.141.1 Field Documentation

6.141.1.1 codepoint

```
uint32_t ttf_raster_cache_slot_t::codepoint
```

6.141.1.2 font

```
const ttf_font_t* ttf_raster_cache_slot_t::font
```

6.141.1.3 height

```
uint32_t ttf_raster_cache_slot_t::height
```

6.141.1.4 hits

```
uint32_t ttf_raster_cache_slot_t::hits
```

6.141.1.5 pixels

```
uint8_t ttf_raster_cache_slot_t::pixels[((64+ 8 *2) *(64+ 8 *2))]
```

6.141.1.6 size_px

```
uint32_t ttf_raster_cache_slot_t::size_px
```

6.141.1.7 valid

```
int ttf_raster_cache_slot_t::valid
```

6.141.1.8 width

```
uint32_t ttf_raster_cache_slot_t::width
```

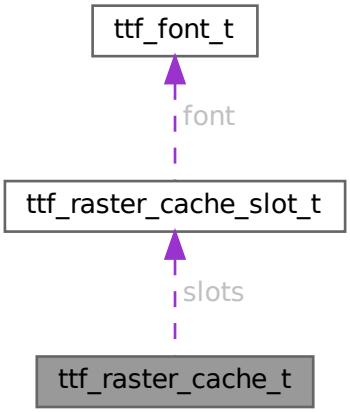
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/ttf.h

6.142 ttf_raster_cache_t Struct Reference

```
#include <ttf.h>
```

Collaboration diagram for ttf_raster_cache_t:



Data Fields

- ttf_raster_cache_slot_t * slots
- uint32_t slot_count
- uint32_t evict_next

6.142.1 Field Documentation

6.142.1.1 evict_next

```
uint32_t ttf_raster_cache_t::evict_next
```

Referenced by ttf_raster_cache_init().

6.142.1.2 slot_count

```
uint32_t ttf_raster_cache_t::slot_count
```

Referenced by ttf_raster_cache_init().

6.142.1.3 slots

```
ttf_raster_cache_slot_t* ttf_raster_cache_t::slots
```

Referenced by ttf_raster_cache_init().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/ttf.h

6.143 usb_bot_cbw_t Struct Reference

```
#include <xhci.h>
```

Data Fields

- uint32_t dCBWSignature
- uint32_t dCBWTag
- uint32_t dCBWDataTransferLength
- uint8_t bmCBWFlags
- uint8_t bCBWLUN
- uint8_t bCBWCBLength
- uint8_t CBWCB [16]

6.143.1 Field Documentation

6.143.1.1 bCBWCBLength

```
uint8_t usb_bot_cbw_t::bCBWCBLength
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), and xhci_bot_send_write10().

6.143.1.2 bCBWLUN

```
uint8_t usb_bot_cbw_t::bCBWLUN
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), and xhci_bot_send_write10().

6.143.1.3 bmCBWFlags

```
uint8_t usb_bot_cbw_t::bmCBWFlags
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), and xhci_bot_send_write10().

6.143.1.4 CBWCB

```
uint8_t usb_bot_cbw_t::CBWCB[16]
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), and xhci_bot_send_write10().

6.143.1.5 dCBWDataTransferLength

```
uint32_t usb_bot_cbw_t::dCBWDataTransferLength
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), and xhci_bot_send_write10().

6.143.1.6 dCBWSignature

```
uint32_t usb_bot_cbw_t::dCBWSignature
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), and xhci_bot_send_write10().

6.143.1.7 dCBWTag

```
uint32_t usb_bot_cbw_t::dCBWTag
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), and xhci_bot_send_write10().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.144 usb_bot_csw_t Struct Reference

```
#include <xhci.h>
```

Data Fields

- uint32_t dCSWSignature
- uint32_t dCSWTag
- uint32_t dCSWDataResidue
- uint8_t bCSWStatus

6.144.1 Field Documentation

6.144.1.1 bCSWStatus

```
uint8_t usb_bot_csw_t::bCSWStatus
```

Referenced by xhci_poll_one().

6.144.1.2 dCSWDataResidue

```
uint32_t usb_bot_csw_t::dCSWDataResidue
```

Referenced by xhci_poll_one().

6.144.1.3 dCSWSignature

```
uint32_t usb_bot_csw_t::dCSWSignature
```

Referenced by xhci_poll_one().

6.144.1.4 dCSWTag

```
uint32_t usb_bot_csw_t::dCSWTag
```

Referenced by xhci_poll_one().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.145 usb_setup_packet_t Struct Reference

```
#include <xhci.h>
```

Data Fields

- uint8_t bmRequestType
- uint8_t bRequest
- uint16_t wValue
- uint16_t wIndex
- uint16_t wLength

6.145.1 Field Documentation

6.145.1.1 bmRequestType

```
uint8_t usb_setup_packet_t::bmRequestType
```

Referenced by xhci_ep0_bot_mass_storage_reset(), xhci_ep0_control_read(), xhci_ep0_control_write_nodata(), xhci_ep0_hid_set_leds(), and xhci_ep0_hid_set_protocol().

6.145.1.2 bRequest

```
uint8_t usb_setup_packet_t::bRequest
```

6.145.1.3 wIndex

```
uint16_t usb_setup_packet_t::wIndex
```

6.145.1.4 wLength

```
uint16_t usb_setup_packet_t::wLength
```

6.145.1.5 wValue

```
uint16_t usb_setup_packet_t::wValue
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.146 user_identity_seed_t Struct Reference

```
#include <user_identity_seed.h>
```

Data Fields

- uint32_t magic
- uint32_t version
- uint8_t seed [32]
- uint8_t pubkey [32]
- char full_name [64u]
- char username [32u]
- char email [64u]
- char phone [24u]
- uint64_t crc
- uint8_t _pad [4096 -(4+4+32+32+64u+32u+64u+24u+8)]

6.146.1 Field Documentation

6.146.1.1 _pad

```
uint8_t user_identity_seed_t::_pad[4096 -(4+4+32+32+ 64u+ 32u+ 64u+ 24u+8)]
```

6.146.1.2 crc

```
uint64_t user_identity_seed_t::crc
```

Referenced by capsule_mint_identity(), capsule_wirebind_try_attach(), capsule_zuse_boot_check_key(), and verify_mint().

6.146.1.3 email

```
char user_identity_seed_t::email[64u]
```

Referenced by capsule_mint_identity().

6.146.1.4 full_name

```
char user_identity_seed_t::full_name[64u]
```

Referenced by capsule_mint_identity().

6.146.1.5 magic

```
uint32_t user_identity_seed_t::magic
```

Referenced by capsule_mint_identity(), capsule_wirebind_try_attach(), capsule_zuse_boot_check_key(), and verify_mint().

6.146.1.6 phone

```
char user_identity_seed_t::phone[24u]
```

Referenced by capsule_mint_identity().

6.146.1.7 pubkey

```
uint8_t user_identity_seed_t::pubkey[32]
```

Referenced by capsule_mint_identity(), and capsule_zuse_boot_check_key().

6.146.1.8 seed

```
uint8_t user_identity_seed_t::seed[32]
```

Referenced by capsule_mint_identity(), and capsule_zuse_boot_check_key().

6.146.1.9 username

```
char user_identity_seed_t::username[32u]
```

Referenced by capsule_mint_identity(), and capsule_wirebind_try_attach().

6.146.1.10 version

```
uint32_t user_identity_seed_t::version
```

Referenced by capsule_mint_identity(), capsule_wirebind_try_attach(), capsule_zuse_boot_check_key(), and verify_mint().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/user_identity_seed.h

6.147 VirtBlkReq Struct Reference

Data Fields

- uint32_t type
- uint32_t reserved
- uint64_t sector

6.147.1 Field Documentation

6.147.1.1 reserved

```
uint32_t VirtBlkReq::reserved
```

Referenced by vblk_io().

6.147.1.2 sector

```
uint64_t VirtBlkReq::sector
```

Referenced by vblk_io().

6.147.1.3 type

```
uint32_t VirtBlkReq::type
```

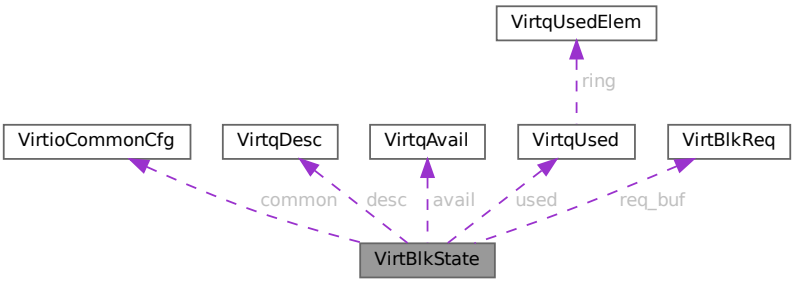
Referenced by vblk_io().

The documentation for this struct was generated from the following file:

- kernel/src/virtio/virtio_blk.c

6.148 VirtBlkState Struct Reference

Collaboration diagram for VirtBlkState:



Data Fields

- VirtioCommonCfg * common
- volatile uint16_t * notify
- uint32_t notify_off_mult
- uint16_t queue_notify_off
- VirtqDesc * desc
- VirtqAvail * avail
- VirtqUsed * used
- uint16_t avail_idx
- uint16_t last_used_idx
- uint64_t capacity_sectors
- uint32_t total_forth_blocks
- VirtBlkReq * req_buf
- uint8_t * data_buf
- uint8_t * status_buf

6.148.1 Field Documentation

6.148.1.1 avail

```
VirtqAvail* VirtBlkState::avail
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.2 avail_idx

```
uint16_t VirtBlkState::avail_idx
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.3 capacity_sectors

```
uint64_t VirtBlkState::capacity_sectors
```

Referenced by vblk_info(), and vblk_init_device().

6.148.1.4 common

```
VirtioCommonCfg* VirtBlkState::common
```

Referenced by vblk_init_device().

6.148.1.5 data_buf

```
uint8_t* VirtBlkState::data_buf
```

Referenced by vblk_init_device(), vblk_read(), and vblk_write().

6.148.1.6 desc

```
VirtqDesc* VirtBlkState::desc
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.7 last_used_idx

```
uint16_t VirtBlkState::last_used_idx
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.8 notify

```
volatile uint16_t* VirtBlkState::notify
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.9 notify_off_mult

```
uint32_t VirtBlkState::notify_off_mult
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.10 queue_notify_off

```
uint16_t VirtBlkState::queue_notify_off
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.11 req_buf

```
VirtBlkReq* VirtBlkState::req_buf
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.12 status_buf

```
uint8_t* VirtBlkState::status_buf
```

Referenced by vblk_init_device(), and vblk_io().

6.148.1.13 total_forth_blocks

```
uint32_t VirtBlkState::total_forth_blocks
```

Referenced by vblk_info(), vblk_init_device(), vblk_open(), vblk_read(), vblk_write(), and virtio_blk_find_artemis().

6.148.1.14 used

```
VirtqUsed* VirtBlkState::used
```

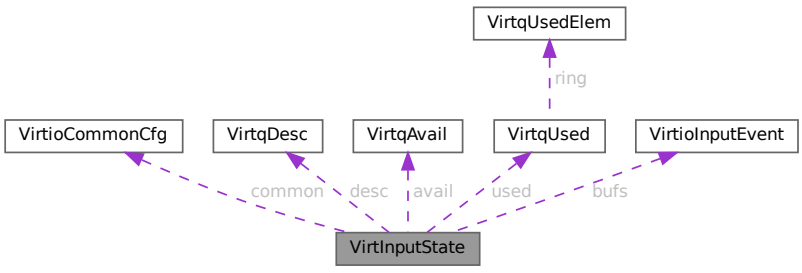
Referenced by vblk_init_device(), and vblk_io().

The documentation for this struct was generated from the following file:

- kernel/src/virtio/virtio_blk.c

6.149 VirtInputState Struct Reference

Collaboration diagram for VirtInputState:



Data Fields

- VirtioCommonCfg * common
- volatile uint16_t * notify
- uint32_t notify_off_mult
- uint16_t queue_notify_off
- volatile uint8_t * isr_status
- VirtqDesc * desc
- VirtqAvail * avail
- VirtqUsed * used
- VirtioInputEvent * bufs
- uint16_t avail_idx
- uint16_t last_used_idx

6.149.1 Field Documentation

6.149.1.1 avail

```
VirtqAvail* VirtInputState::avail
```

Referenced by vinput_init_device(), and virtio_input_isr().

6.149.1.2 avail_idx

```
uint16_t VirtInputState::avail_idx
```

Referenced by vinput_init_device(), and virtio_input_isr().

6.149.1.3 bufs

```
VirtioInputEvent* VirtInputState::bufs
```

Referenced by vinput_init_device(), and virtio_input_isr().

6.149.1.4 common

```
VirtioCommonCfg* VirtInputState::common
```

Referenced by vinput_init_device().

6.149.1.5 desc

```
VirtqDesc* VirtInputState::desc
```

Referenced by vinput_init_device().

6.149.1.6 isr_status

```
volatile uint8_t* VirtInputState::isr_status
```

Referenced by vinput_init_device(), and virtio_input_isr().

6.149.1.7 last_used_idx

```
uint16_t VirtInputState::last_used_idx
```

Referenced by vinput_init_device(), and virtio_input_isr().

6.149.1.8 notify

```
volatile uint16_t* VirtInputState::notify
```

Referenced by vinput_init_device(), and virtio_input_isr().

6.149.1.9 notify_off_mult

```
uint32_t VirtInputState::notify_off_mult
```

Referenced by vinput_init_device(), and virtio_input_isr().

6.149.1.10 queue_notify_off

```
uint16_t VirtInputState::queue_notify_off
```

Referenced by vinput_init_device(), and virtio_input_isr().

6.149.1.11 used

```
VirtqUsed* VirtInputState::used
```

Referenced by vinput_init_device(), and virtio_input_isr().

The documentation for this struct was generated from the following file:

- kernel/src/virtio/virtio_input.c

6.150 VirtioCommonCfg Struct Reference

Data Fields

- volatile uint32_t device_feature_select
- volatile uint32_t device_feature
- volatile uint32_t driver_feature_select
- volatile uint32_t driver_feature
- volatile uint16_t config_msix_vector
- volatile uint16_t num_queues
- volatile uint8_t device_status
- volatile uint8_t config_generation
- volatile uint16_t queue_select
- volatile uint16_t queue_size
- volatile uint16_t queue_msix_vector
- volatile uint16_t queue_enable
- volatile uint16_t queue_notify_off
- volatile uint64_t queue_desc
- volatile uint64_t queue_driver
- volatile uint64_t queue_device
- volatile uint16_t queue_notify_data
- volatile uint16_t queue_reset

6.150.1 Field Documentation

6.150.1.1 config_generation

```
volatile uint8_t VirtioCommonCfg::config_generation
```

6.150.1.2 config_msix_vector

```
volatile uint16_t VirtioCommonCfg::config_msix_vector
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.3 device_feature

```
volatile uint32_t VirtioCommonCfg::device_feature
```

6.150.1.4 device_feature_select

```
volatile uint32_t VirtioCommonCfg::device_feature_select
```

6.150.1.5 device_status

```
volatile uint8_t VirtioCommonCfg::device_status
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.6 driver_feature

```
volatile uint32_t VirtioCommonCfg::driver_feature
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.7 driver_feature_select

```
volatile uint32_t VirtioCommonCfg::driver_feature_select
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.8 num_queues

```
volatile uint16_t VirtioCommonCfg::num_queues
```

Referenced by vinput_init_device().

6.150.1.9 queue_desc

```
volatile uint64_t VirtioCommonCfg::queue_desc
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.10 queue_device

```
volatile uint64_t VirtioCommonCfg::queue_device
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.11 queue_driver

```
volatile uint64_t VirtioCommonCfg::queue_driver
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.12 queue_enable

```
volatile uint16_t VirtioCommonCfg::queue_enable
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.13 queue_msix_vector

```
volatile uint16_t VirtioCommonCfg::queue_msix_vector
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.14 queue_notify_data

```
volatile uint16_t VirtioCommonCfg::queue_notify_data
```

6.150.1.15 queue_notify_off

```
volatile uint16_t VirtioCommonCfg::queue_notify_off
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.16 queue_reset

```
volatile uint16_t VirtioCommonCfg::queue_reset
```

6.150.1.17 queue_select

```
volatile uint16_t VirtioCommonCfg::queue_select
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

6.150.1.18 queue_size

```
volatile uint16_t VirtioCommonCfg::queue_size
```

Referenced by vblk_init_device(), vinput_init_device(), and vrng_init_device().

The documentation for this struct was generated from the following files:

- kernel/src/virtio/virtio_blk.c
- kernel/src/virtio/virtio_input.c
- kernel/src/virtio/virtio_rng.c

6.151 VirtioInputEvent Struct Reference

```
#include <virtio_input.h>
```

Data Fields

- uint16_t type
- uint16_t code
- uint32_t value

6.151.1 Field Documentation

6.151.1.1 code

```
uint16_t VirtioInputEvent::code
```

Referenced by virtio_input_isr().

6.151.1.2 type

```
uint16_t VirtioInputEvent::type
```

Referenced by virtio_input_isr().

6.151.1.3 value

```
uint32_t VirtioInputEvent::value
```

Referenced by virtio_input_isr().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/virtio_input.h

6.152 VirtqAvail Struct Reference

Data Fields

- uint16_t flags
- uint16_t idx
- uint16_t ring [4u]
- uint16_t used_event

6.152.1 Field Documentation

6.152.1.1 flags

```
uint16_t VirtqAvail::flags
```

6.152.1.2 idx

```
uint16_t VirtqAvail::idx
```

Referenced by vblk_io(), vinput_init_device(), virtio_input_isr(), and vrng_request().

6.152.1.3 ring

```
uint16_t VirtqAvail::ring
```

Referenced by vblk_io(), vinput_init_device(), virtio_input_isr(), and vrng_request().

6.152.1.4 used_event

```
uint16_t VirtqAvail::used_event
```

The documentation for this struct was generated from the following files:

- kernel/src/virtio/virtio_blk.c
- kernel/src/virtio/virtio_input.c
- kernel/src/virtio/virtio_rng.c

6.153 VirtqDesc Struct Reference

Data Fields

- uint64_t addr
- uint32_t len
- uint16_t flags
- uint16_t next

6.153.1 Field Documentation

6.153.1.1 addr

```
uint64_t VirtqDesc::addr
```

Referenced by vblk_io(), vinput_init_device(), and vrng_request().

6.153.1.2 flags

```
uint16_t VirtqDesc::flags
```

Referenced by vblk_io(), vinput_init_device(), and vrng_request().

6.153.1.3 len

```
uint32_t VirtqDesc::len
```

Referenced by vblk_io(), vinput_init_device(), and vrng_request().

6.153.1.4 next

```
uint16_t VirtqDesc::next
```

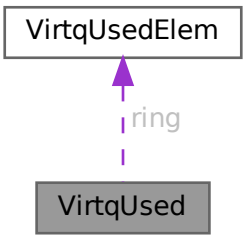
Referenced by vblk_io(), vinput_init_device(), and vrng_request().

The documentation for this struct was generated from the following files:

- kernel/src/virtio/virtio_blk.c
- kernel/src/virtio/virtio_input.c
- kernel/src/virtio/virtio_rng.c

6.154 VirtqUsed Struct Reference

Collaboration diagram for VirtqUsed:



Data Fields

- uint16_t flags
- uint16_t idx
- VirtqUsedElem ring [4u]
- uint16_t avail_event

6.154.1 Field Documentation

6.154.1.1 avail_event

```
uint16_t VirtqUsed::avail_event
```

6.154.1.2 flags

```
uint16_t VirtqUsed::flags
```

6.154.1.3 idx

```
uint16_t VirtqUsed::idx
```

Referenced by vblk_io(), virtio_input_isr(), and vrng_request().

6.154.1.4 ring

```
VirtqUsedElem VirtqUsed::ring
```

Referenced by virtio_input_isr(), and vrng_request().

The documentation for this struct was generated from the following files:

- kernel/src/virtio/virtio_blk.c
- kernel/src/virtio/virtio_input.c
- kernel/src/virtio/virtio_rng.c

6.155 VirtqUsedElem Struct Reference

Data Fields

- uint32_t id
- uint32_t len

6.155.1 Field Documentation

6.155.1.1 id

```
uint32_t VirtqUsedElem::id
```

Referenced by virtio_input_isr().

6.155.1.2 len

```
uint32_t VirtqUsedElem::len
```

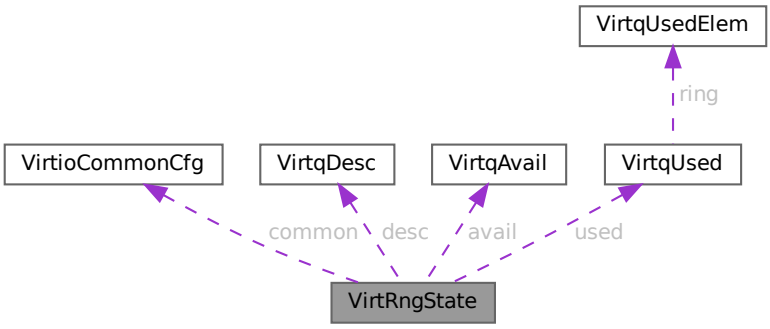
Referenced by vrng_request().

The documentation for this struct was generated from the following files:

- kernel/src/virtio/virtio_blk.c
- kernel/src/virtio/virtio_input.c
- kernel/src/virtio/virtio_rng.c

6.156 VirtRngState Struct Reference

Collaboration diagram for VirtRngState:



Data Fields

- VirtioCommonCfg * common
- volatile uint16_t * notify
- uint32_t notify_off_mult
- uint16_t queue_notify_off
- VirtqDesc * desc
- VirtqAvail * avail
- VirtqUsed * used
- uint16_t avail_idx
- uint16_t last_used_idx
- uint8_t * data_buf

6.156.1 Field Documentation

6.156.1.1 avail

```
VirtqAvail* VirtRngState::avail
```

Referenced by vrng_init_device(), and vrng_request().

6.156.1.2 avail_idx

```
uint16_t VirtRngState::avail_idx
```

Referenced by vrng_init_device(), and vrng_request().

6.156.1.3 common

```
VirtioCommonCfg* VirtRngState::common
```

Referenced by vrng_init_device().

6.156.1.4 data_buf

```
uint8_t* VirtRngState::data_buf
```

Referenced by virtio_rng_get_bytes(), vrng_init_device(), and vrng_request().

6.156.1.5 desc

```
VirtqDesc* VirtRngState::desc
```

Referenced by vrng_init_device(), and vrng_request().

6.156.1.6 last_used_idx

```
uint16_t VirtRngState::last_used_idx
```

Referenced by vrng_init_device(), and vrng_request().

6.156.1.7 notify

```
volatile uint16_t* VirtRngState::notify
```

Referenced by vrng_init_device(), and vrng_request().

6.156.1.8 notify_off_mult

```
uint32_t VirtRngState::notify_off_mult
```

Referenced by vrng_init_device(), and vrng_request().

6.156.1.9 queue_notify_off

```
uint16_t VirtRngState::queue_notify_off
```

Referenced by vrng_init_device(), and vrng_request().

6.156.1.10 used

```
VirtqUsed* VirtRngState::used
```

Referenced by vrng_init_device(), and vrng_request().

The documentation for this struct was generated from the following file:

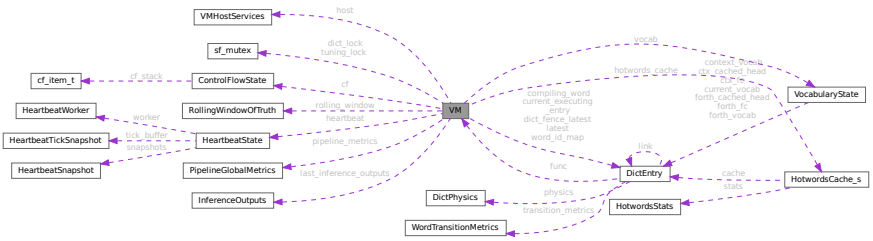
- kernel/src/virtio/virtio_rng.c

6.157 VM Struct Reference

Main virtual machine state container.

```
#include <vm.h>
```

Collaboration diagram for VM:



Data Fields

Stack Management

- cell_t data_stack [1024]
  Parameter stack storage.
- cell_t return_stack [1024]
  Return stack storage.
- int dsp
  Data stack pointer.
- int rsp
  Return stack pointer.
- int exit_colon
  Exit flag for colon definitions.
- int abort_requested
  ABORT flag for immediate termination.
- int ecw_nesting
  Depth of execute_colon_word call stack; >0 means inside a colon word.
- volatile int doe_row_printing
  Non-zero while EMIT-ROW assembles a row; heartbeat output must defer.
- uint8_t emergency_console
  1 = fault handler active; bypasses all ACL checks (C-only write)
- uint8_t zuse_session
  1 = zuse authenticated at console; shows zuse)ok> prompt
- uint8_t acl_skip

1 = skip all ACL hooks (Ananke enforcement VM; prevents recursion)

- uint8_t zuse_cert_installed

  1 = zuse_cert_seed/pubkey hold a real minted cert (one-time fuse)
- uint8_t zuse_cert_seed [32]

  Ed25519 seed, this instance's Zuse identity.
- uint8_t zuse_cert_pubkey [32]

  Ed25519 public key derived from the seed at mint time, cached here so callers don't need to re-derive it.
- uint8_t zuse_root_pubkey_known

  1 = zuse_root_pubkey holds a real value, loaded from the persistent genesis-marker fence (zuse_genesis_marker_t, capsule_zuse_boot_load_root_pubkey()) independently of whether Zuse's own thumbdrive is attached this boot.
- uint8_t zuse_root_pubkey [32]

  Ed25519 public key, loaded from the genesis-marker fence.

Dictionary Management

- const VMHostServices * host

  Host allocator/time services.
- uint8_t * memory

  Unified VM memory buffer.
- uintptr_t here

  Next free memory location (byte offset or absolute pointer if M7)
- DictEntry * latest

  Most recent word.
- DictEntry * word_id_map [1024]

  Stable ID → entry map for speculation.
- uint32_t recycled_word_ids [1024]

  Reusable ID stack for FORGET.
- uint32_t recycled_word_id_count

  Depth of recycled stack.
- uint32_t next_word_id

  Next fresh ID when recycle stack empty.
- DictEntry * dict_fence_latest
- size_t dict_fence_here
- sf_mutex_t dict_lock

  Protects dictionary structural mutations.
- char input_buffer [1025]
- size_t input_length
- size_t input_pos
- vm_mode_t mode
- DictEntry * compiling_word
- int interpreter_enabled
- char current_word_name [31+1]
- cell_t * compile_buffer
- size_t compile_pos
- size_t compile_size
- cell_t state_var
- DictEntry * current_executing_entry
- cell_t * ip
- int error
- int halted
- cell_t base
- unsigned char * tib_buf
- size_t tib_cap
- cell_t * in_var
- cell_t * span_var
- vaddr_t scr_addr
- vaddr_t state_addr
- vaddr_t base_addr
- vaddr_t hold_addr
- int hold_pos
- VocabularyState vocab

- ControlFlowState cf
- uint32_t blk_vm_lbn [4]
- uint8_t * blk_vm_cbuf [4]
- uint8_t blk_vm_dirty [4]
- int blk_vm_next
- uint64_t blk_vm_epoch

Physics Hot-Words Cache

- HotwordsCache * hotwords_cache
  Frequency-driven dictionary acceleration cache.

Rolling Window of Truth (Deterministic Metrics)

- RollingWindowOfTruth rolling_window
  Execution history for reproducible seeding.

Phase 2: Heat-Aware Dictionary Optimization

- cell_t heat_threshold_25th
  25th percentile heat (bucket search priority)
- cell_t heat_threshold_50th
  50th percentile heat
- cell_t heat_threshold_75th
  75th percentile heat
- uint64_t last_bucket_reorg_ns
  When we last reorganized buckets.
- int lookup_strategy
  0=naive, 1=heat-aware, 2=inference-reorg

VM Heartbeat (Loop #3 & #5 Coordination)

- HeartbeatState heartbeat
  Centralized time-driven tuning dispatcher.
- uint32_t heartbeat_decay_cursor_id
  Continuation cursor for background decay sweeps.

Pipelining Global Metrics (Loop #4 & #5 Feedback)

- PipelineGlobalMetrics pipeline_metrics
  Aggregated prefetch accuracy tracking.

Physics Loop #3: Adaptive Heat Decay Tuning

- uint64_t decay_slope_q48
  Current decay rate (Q48.16 fixed-point, starts at 2:1 = 131072)
- uint64_t last_decay_check_ns
  Timestamp of last decay effectiveness measurement.
- uint64_t total_heat_at_last_check
  Total dictionary heat at last check (for slope inference)
- uint64_t hot_word_count_at_check
  Hot words observed at last inference.
- uint64_t stale_word_count_at_check
  Stale words at last check (for trend analysis)
- uint32_t word_count_at_check
  Total word count at last check (for ratio calculation)

- int decay_slope_direction
  -1 = decrease slope, 0 = stable, +1 = increase slope (inference)
- sf_mutex_t tuning_lock
  Guards shared tuning knobs (slope, snapshots)

Unified Inference Engine (Phase 2: Replacing Loops #3 & #5)

- InferenceOutputs * last_inference_outputs
  Cached inference outputs (for ANOVA early-exit and tuning application)

SSM L8: Jacquard Mode Selector (Steady State Machine)

- void * ssm_l8_state
  Opaque pointer to ssm_l8_state_t (avoid circular include)
- void * ssm_config
  Opaque pointer to ssm_config_t (L3/L4 mode bits)

6.157.1 Detailed Description

Main virtual machine state container.

Contains all state information for a StarForth VM instance including stacks, dictionary, memory, and execution state.

6.157.2 Field Documentation

6.157.2.1 abort_requested

```
int VM::abort_requested
```

ABORT flag for immediate termination.

Referenced by block_word_next_block(), block_word_thru(), check_physics_transparent(), defining_runtime_dodoes(), exec_block_with_retry(), execute_colon_word(), restore_vm_state(), sk_repl_run(), sk_repl_step(), system_word_abort(), test_acl_deny_aborts(), vm_init(), vm_init_with_host(), vm_interpret(), and vm_repl().

6.157.2.2 acl_skip

```
uint8_t VM::acl_skip
```

1 = skip all ACL hooks (Ananke enforcement VM; prevents recursion)

6.157.2.3 base

```
cell_t VM::base
```

Referenced by current_base(), dbg_get_base(), vm_get_base(), vm_set_base(), and vm_set_base().

6.157.2.4 base_addr

```
vaddr_t VM::base_addr
```

Referenced by dbg_get_base(), format_word_base(), vm_get_base(), vm_init(), vm_init_with_host(), vm_set_base(), and vm_set_base().

6.157.2.5 blk_vm_cbuf

```
uint8_t* VM::blk_vm_cbuf[4]
```

Referenced by blk_vm_assign(), blk_vm_check_epoch(), blk_vm_evict(), blk_vm_find(), blk_vm_flush_all(), blk_vm_load(), block_word_empty_buffers(), and block_word_update().

6.157.2.6 blk_vm_dirty

```
uint8_t VM::blk_vm_dirty[4]
```

Referenced by blk_vm_assign(), blk_vm_check_epoch(), blk_vm_evict(), blk_vm_flush_all(), blk_vm_load(), block_word_empty_buffers(), and block_word_update().

6.157.2.7 blk_vm_epoch

```
uint64_t VM::blk_vm_epoch
```

Referenced by blk_vm_check_epoch().

6.157.2.8 blk_vm_lbn

```
uint32_t VM::blk_vm_lbn[4]
```

Referenced by blk_vm_assign(), blk_vm_check_epoch(), blk_vm_evict(), blk_vm_find(), blk_vm_flush_all(), blk_vm_is_cross_device_copy(), blk_vm_load(), and block_word_empty_buffers().

6.157.2.9 blk_vm_next

```
int VM::blk_vm_next
```

Referenced by blk_vm_evict().

6.157.2.10 cf

```
ControlFlowState VM::cf
```

Referenced by cf_epoch_sync(), cf_peek_item(), cf_pop_item(), cf_push_item(), control_forth_case(), control_forth_do(), control_forth_endcase(), control_forth_endof(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), vm_init(), and vm_init_with_host().

6.157.2.11 compile_buffer

```
cell_t* VM::compile_buffer
```

6.157.2.12 compile_pos

```
size_t VM::compile_pos
```

6.157.2.13 compile_size

```
size_t VM::compile_size
```

6.157.2.14 compiling_word

```
DictEntry* VM::compiling_word
```

Referenced by restore_vm_state(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_init(), and vm_init_with_host().

6.157.2.15 current_executing_entry

```
DictEntry* VM::current_executing_entry
```

Referenced by acl_recheck(), acl_recheck(), defer_runtime(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_variable(), execute_colon_word(), restore_vm_state(), starforth_word_init(), system_word_execute(), vm_debug_dump_state(), vm_docol_arm64(), vm_docol_asm(), vm_docol_rv64(), vm_init(), vm_init_with_host(), vm_interpret_word(), and vocabulary_select_runtime().

6.157.2.16 current_word_name

```
char VM::current_word_name[31+1]
```

Referenced by vm_enter_compile_mode().

6.157.2.17 data_stack

```
cell_t VM::data_stack[1024]
```

Parameter stack storage.

Referenced by assert_stack_top(), capture_exec_result(), double_word_2dup(), double_word_2over(), double_word_dabs(), format_word_dot_s(), format_word_hash_s(), forth_BENCH_DICT_LOOKUP(), forth_COMPARE_LOOKUPS(), forth_DECAY_RATE_FETCH(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_PERCENTILES(), forth_HEAT_STORE(), forth_LOOKUP_STRATEGY_FETCH(), forth_LOOKUP_STRATEGY_STORE(), forth_PHYSICS_BURN(), forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), io_word_emit(), io_word_key(), io_word_question_terminal(), io_word_spaces(), stack_word_depth(), stack_word_dup(), stack_word_minus_rot(), stack_word_over(), stack_word_pick(), stack_word_question_dup(), stack_word_roll(), stack_word_rot(), stack_word_swap(), vm_pop(), vm_pop_asm(), vm_pop_asm(), vm_pop_asm(), vm_pop_fast(), vm_push(), vm_push_asm(), vm_push_asm(), vm_push_asm(), vm_push_fast(), vm_save_registers(), vm_save_registers_arm64(), vm_save_registers_rv64(), vm_setup_registers(), vm_setup_registers_arm64(), vm_setup_registers_rv64(), and vocabulary_word_paren_find().

6.157.2.18 decay_slope_direction

```
int VM::decay_slope_direction
```

-1 = decrease slope, 0 = stable, +1 = increase slope (inference)

Referenced by vm_init(), vm_init_with_host(), and vm_tick_slope_validator().

6.157.2.19 decay_slope_q48

```
uint64_t VM::decay_slope_q48
```

Current decay rate (Q48.16 fixed-point, starts at 2:1 = 131072)

Referenced by heartbeat_publish_snapshot(), metrics_from_vm(), perturb_physics(), physics_decay_slope_load(), restore_physics(), save_physics(), vm_heartbeat_publish_snapshot(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_slope_validator().

6.157.2.20 dict_fence_here

```
size_t VM::dict_fence_here
```

Referenced by dictionary_word_fence(), dictionary_word_forget(), main(), vm_init(), and vm_init_with_host().

6.157.2.21 dict_fence_latest

```
DictEntry* VM::dict_fence_latest
```

Referenced by dictionary_word_fence(), dictionary_word_forget(), main(), vm_init(), and vm_init_with_host().

6.157.2.22 dict_lock

```
sf_mutex_t VM::dict_lock
```

Protects dictionary structural mutations.

Referenced by dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), dictionary_word_fence(), dictionary_word_forget(), extract_heat_trajectory(), infer_word_run(), metrics_from_vm(), physics_on_lookup(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), vm_cleanup(), vm_create_word(), vm_dict_entry_ok(), vm_find_word(), vm_init(), vm_init_with_host(), vm_interpret_word(), vm_tick_apply_background_decay(), vm_tick_apply_background_decay(), vm_tick_inference_engine(), and vm_tick_slope_validator().

6.157.2.23 doe_row_printing

```
volatile int VM::doe_row_printing
```

Non-zero while EMIT-ROW assembles a row; heartbeat output must defer.

6.157.2.24 dsp

```
int VM::dsp
```

Data stack pointer.

Referenced by arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), assert_stack_depth(), assert_stack_top(), block_word_acl_allow_fetch(), block_word_acl_allow_store(), block_word_acl_ttl_fetch(), block_word_acl_ttl_store(), block_word_blk_attach(), block_word_block(), block_word_buffer(), block_word_confirm_format(), block_word_list(), block_word_load(), block_word_owner_fetch(), block_word_relocate(), block_word_thru(), capture_exec_result(), check_physics_transparent(), control_forth_0branch(), control_forth_runtime_do(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), defining_word_constant(), defining_word_literal(), dictionary_m_word_cfa(), dictionary_m_word_link_from(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), dictionary_m_word_traverse(), dictionary_word_2comma(), dictionary_word_allot(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_sp_fetch(), dictionary_word_sp_store(), double_word_2drop(), double_word_2dup(), double_word_2over(), double_word_2rot(), double_word_2swap(), double_word_2to_r(), double_word_d_equals(), double_word_d_less(), double_word_d_minus(), double_word_d_plus(), double_word_d_two_slash(), double_word_d_two_star(), double_word_d_zero_equals(), double_word_d_zero_less(), double_word_dabs(), double_word_dmax(), double_word_dmin(), double_word_dnegate(), double_word_s_to_d(), editor_word_edit(), editor_word_l(), editor_word_s(), execute_colon_word(), fbw_plot(), format_word_d_dot(), format_word_d_dot_r(), format_word_dot(), format_word_dot_r(), format_word_dot_s(), format_word_dump(), format_word_end_conversion(), format_word_hash(), format_word_hash_s(), format_word_hold(), format_word_question(), format_word_sign(), format_word_u_dot(), format_word_u_dot_r(), forth_acl_allow_store(), forth_acl_inherit(), forth_acl_mode_store(), forth_acl_ttl_store(), forth_BENCH_DICT_LOOKUP(), forth_COMPARE_LOOKUPS(), forth_DECAY_RATE_FETCH(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_PERCENTILES(), forth_HEAT_STORE(), forth_LOOKUP_STRATEGY_FETCH(), forth_LOOKUP_STRATEGY_STORE(), forth_PHYSICS_BURN(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), io_word_emit(), io_word_key(), io_word_question_terminal(), io_word_spaces(), io_word_type(), log_str_emit(), log_word_set_level(), logical_word_and(), logical_word_equals(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), memory_word_2fetch(), memory_word_2store(), memory_word_cells(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), mixed_math_word_m_minus(), mixed_math_word_m_plus(), mixed_math_word_m_slash_mod(), mixed_math_word_m_star(), mixed_math_word_mod(), mixed_math_word_mod(), mixed_math_word_slash_mod(), mixed_math_word_star_slash(), mixed_math_word_star_slash_mod(), pop_xt(), reset_vm_state(), restore_vm_state(), return_stack_word_r_fetch(), return_stack_word_r_from(), return_stack_word_to_r(), runtime_abortq(), save_vm_state(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), stack_word_depth(), stack_word_drop(), stack_word_dup(), stack_word_minus_rot(), stack_word_over(), stack_word_pick(), stack_word_question_dup(), stack_word_roll(), stack_word_rot(), stack_word_swap(), starforth_word_execution_heat_fetch(), starforth_word_execution_heat_stor starforth_word_random(), starforth_word_seed(), starforth_word_top_words(), starforth_word_wait(), starforth_word_zuse_pubkey_fe string_word_blank(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_minus_trailing(), string_word_number(), string_word_scan(), string_word_search(), string_word_skip(), string_word_word(), system_word_abort_quote(), system_word_execute(), system_word_reboot(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_strict_mode(), test_emergency_console_bypass(), vm_debug_dump_state(), vm_init(), vm_init_with_host(), vm_interpret_word(), vm_pop(), vm_pop_asm(), vm_pop_asm(), vm_pop_asm(), vm_pop_fast(), vm_push(), vm_push_asm(), vm_push_asm(), vm_push_asm(), vm_push_fast(), vm_save_registers(), vm_save_registers_arm64(), vm_save_registers_rv64(), vm_setup_registers(), vm_setup_registers_arm64(), vm_setup_registers_rv64(), vocabulary_word_paren_find(), word_divide(), word_divmod(), and word_is().

6.157.2.25 ecw_nesting

```
int VM::ecw_nesting
```

Depth of execute_colon_word call stack; >0 means inside a colon word.

Referenced by double_word_2r_fetch(), double_word_2r_from(), double_word_2to_r(), execute_colon_word(), return_stack_word_r_fetch(), return_stack_word_r_from(), and return_stack_word_to_r().

6.157.2.26 emergency_console

```
uint8_t VM::emergency_console
```

1 = fault handler active; bypasses all ACL checks (C-only write)

Referenced by acl_recheck(), acl_recheck(), execute_colon_word(), run_acl_words_tests(), test_acl_deny_aborts(), test_acl_ttl_hot_path(), test_emergency_console_bypass(), and vm_interpret_word().

6.157.2.27 error

```
int VM::error
```

Referenced by acl_recheck(), acl_recheck(), arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), array_ptr(), assert_vm_error(), block_word_acl_allow_fetch(), block_word_acl_allow_store(), block_word_acl_ttl_fetch(), block_word_acl_ttl_store(), block_word_blk_attach(), block_word_block(), block_word_buffer(), block_word_confirm_format(), block_word_list(), block_word_load(), block_word_next_block(), block_word_owner_fetch(), block_word_relocate(), block_word_thru(), block_word_update(), capsule_vm_alloc_hook(), capture_exec_result(), check_physics_transparent(), control_forth_0branch(), control_forth_again(), control_forth_begin(), control_forth_branch(), control_forth_case(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_EXIT(), control_forth_I(), control_forth_if(), control_forth_J(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_runtime_do(), control_forth_runtime_leave(), control_forth_runtime_loop(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), control_forth_then(), control_forth_UNLOOP(), control_forth_until(), control_forth_while(), defer_runtime(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_does_rt(), defining_runtime_lit(), defining_runtime_variable(), defining_word_colon(), defining_word_compile(), defining_word_constant(), defining_word_create(), defining_word_does(), defining_word_immediate(), defining_word_literal(), defining_word_semicolon(), defining_word_variable(), dictionary_m_word_cfa(), dictionary_m_word_find(), dictionary_m_word_hidden(), dictionary_m_word_link_from(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_smudge(), dictionary_m_word_tick(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), dictionary_m_word_traverse(), dictionary_word_2comma(), dictionary_word_allot(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_forget(), dictionary_word_sp_store(), double_word_2drop(), double_word_2dup(), double_word_2over(), double_word_2r_fetch(), double_word_2r_from(), double_word_2rot(), double_word_2swap(), double_word_2to_r(), double_word_d_equals(), double_word_d_less(), double_word_d_minus(), double_word_d_plus(), double_word_d_two_slash(), double_word_d_two_star(), double_word_d_zero_equals(), double_word_d_zero_less(), double_word_dabs(), double_word_dmax(), double_word_dmin(), double_word_dnegate(), double_word_s_to_d(), editor_word_edit(), editor_word_l(), editor_word_s(), editor_word_show(), emit_cell(), ensure_input(), exec_block_with_retry(), execute_colon_word(), fbw_plot(), format_word_d_dot(), format_word_d_dot_r(), format_word_dot(), format_word_dot_r(), format_word_dump(), format_word_hash(), format_word_hash_s(), format_word_hold(), format_word_question(), format_word_sign(), format_word_u_dot(), format_word_u_dot_r(), forth_acl_allow_store(), forth_acl_inherit(), forth_acl_mode_store(), forth_acl_ttl_store(), forth_ALL_HEATS(), forth_BENCH_DICT_LOOKUP(), forth_COMPARE_LOOKUPS(), forth_DECAY_RATE_FETCH(), forth_FREEZE_CRITICAL(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(),

forth_HEAT_FETCH(), forth_HEAT_PERCENTILES(), forth_HEAT_STORE(), forth_LOOKUP_STRATEGY_FETCH(), forth_LOOKUP_STRATEGY_STORE(), forth_PHYSICS_BAYESIAN_REPORT(), forth_PHYSICS_BUILD_INFO(), forth_PHYSICS_BURN(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_RESET_STATS(), forth_PHYSICS_SHOW_FEEDBACK(), forth_PHYSICS_TOGGLE_CACHE(), forth_PHYSICS_WORD_METRICS(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), forth_REORG_BUCKETS(), forth_SHOW_HEAT(), forth_SHOW_HEAT_OPTIMIZATION(), forth_UNFREEZE_WORD(), infer_word_run(), init_vm_and_subsystem(), init_vocabulary_system(), io_runtime_do_string(), io_word_dot_quote(), io_word_emit(), io_word_key(), io_word_question_terminal(), io_word_spaces(), io_word_type(), kernel_main_deep(), log_do_emit(), log_emit_string(), log_str_emit(), log_word_set_level(), logical_word_and(), logical_word_equals(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), main(), memory_word_2fetch(), memory_word_2store(), memory_word_cells(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), mixed_math_word_m_minus(), mixed_math_word_m_plus(), mixed_math_word_m_slash_mod(), mixed_math_word_m_star(), mixed_math_word_mod(), mixed_math_word_mod(), mixed_math_word_slash_mod(), mixed_math_word_star_slash(), mixed_math_word_star_slash_mod(), pop_xt(), reset_vm_state(), restore_vm_state(), return_stack_word_r_fetch(), return_stack_word_r_from(), return_stack_word_to_r(), run_single_test(), runtime_abortq(), save_vm_state(), sk_repl_run(), sk_repl_step(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), stack_word_depth(), stack_word_drop(), stack_word_dup(), stack_word_minus_rot(), stack_word_over(), stack_word_pick(), stack_word_question_dup(), stack_word_roll(), stack_word_rot(), stack_word_swap(), starforth_word_execution_heat_fetch(), starforth_word_execution_heat_store(), starforth_word_init(), starforth_word_random(), starforth_word_seed(), starforth_word_top_words(), starforth_word_wait(), starforth_word_zuse_pubkey_fetch(), string_runtime_s_quote(), string_word_blank(), string_word_bracket_tick(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_minus_trailing(), string_word_number(), string_word_query(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), string_word_source(), string_word_span(), string_word_tib(), string_word_to_in(), string_word_word(), system_word_abort(), system_word_abort_quote(), system_word_execute(), system_word_quit(), system_word_reboot(), system_word_save_system(), system_word_see(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_blocks_shadow(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_bypass(), vm_align(), vm_allot(), vm_assert_interpreter_enabled(), vm_bootstrap_root_vocabulary(), vm_bootstrap_scr(), vm_compile_call(), vm_compile_exit(), vm_compile_literal(), vm_compile_word(), vm_create_word(), vm_debug_dump_state(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_init(), vm_init_with_host(), vm_input_ensure(), vm_interpret(), vm_interpret_word(), vm_load_cell(), vm_load_u8(), vm_make_immediate(), vm_pin_execution_heat(), vm_pop(), vm_pop_asm(), vm_pop_asm(), vm_pop_asm(), vm_push(), vm_push_asm(), vm_push_asm(), vm_push_asm(), vm_repl(), vm_rpop(), vm_rpop_asm(), vm_rpop_asm(), vm_rpop_asm(), vm_rpush(), vm_rpush_asm(), vm_rpush_asm(), vm_rpush_asm(), vm_smudge_word(), vm_store_cell(), vm_store_u8(), vm_unpin_execution_heat(), vocabulary_create_vocabulary_direct(), vocabulary_word_paren_find(), vocabulary_word_vocabulary(), word_defer(), word_defer_fetch(), word_divide(), word_divmod(), and word_is().

6.157.2.28 exit_colon

```
int VM::exit_colon
```

Exit flag for colon definitions.

Referenced by check_physics_transparent(), control_forth_EXIT(), defining_runtime_dodoes(), execute_colon_word(), restore_vm_state(), vm_init(), and vm_init_with_host().

6.157.2.29 halted

```
int VM::halted
```

Referenced by __attribute__(), capsule_vm_kill_all_nonmama(), kernel_main_deep(), sk_repl_run(), sk_repl_step(), starforth_word_init(), system_word_bye(), system_word_reboot(), vm_init(), vm_init_with_host(), and vm_repl().

6.157.2.30 heartbeat

```
HeartbeatState VM::heartbeat
```

Centralized time-driven tuning dispatcher.

Referenced by block_word_block(), block_word_buffer(), block_word_update(), execute_colon_word(), heartbeat_capture_tick_snapsh heartbeat_publish_snapshot(), heartbeat_thread_main(), metrics_from_vm(), metrics_write_james_law_csv_row(), perturb_physics(), physics_on_lookup(), physics_post_execute(), physics_pre_execute(), restore_physics(), save_physics(), starforth_word_heartbeat_ticks(), vm_cleanup(), vm_find_word(), vm_heartbeat_publish_snapshot(), vm_heartbeat_run_cycle(), vm_heartbeat_start_thread(), vm_heartbeat_stop_thread(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_interpret(), vm_interpret_word(), vm_snapshot_read(), vm_tick(), vm_tick_apply_background_decay(), vm_tick_apply_background_decay(), and vm_tick_inference_engine().

6.157.2.31 heartbeat_decay_cursor_id

```
uint32_t VM::heartbeat_decay_cursor_id
```

Continuation cursor for background decay sweeps.

Referenced by vm_init(), vm_init_with_host(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

6.157.2.32 heat_threshold_25th

```
cell_t VM::heat_threshold_25th
```

25th percentile heat (bucket search priority)

Referenced by dict_update_heat_percentiles(), forth_HEAT_PERCENTILES(), forth_SHOW_HEAT_OPTIMIZATION(), perturb_physics(), restore_physics(), and save_physics().

6.157.2.33 heat_threshold_50th

```
cell_t VM::heat_threshold_50th
```

50th percentile heat

Referenced by dict_update_heat_percentiles(), forth_HEAT_PERCENTILES(), forth_SHOW_HEAT_OPTIMIZATION(), perturb_physics(), restore_physics(), and save_physics().

6.157.2.34 heat_threshold_75th

```
cell_t VM::heat_threshold_75th
```

75th percentile heat

Referenced by dict_update_heat_percentiles(), forth_HEAT_PERCENTILES(), forth_SHOW_HEAT_OPTIMIZATION(), perturb_physics(), restore_physics(), and save_physics().

6.157.2.35 here

```
uintptr_t VM::here
```

Next free memory location (byte offset or absolute pointer if M7)

Referenced by control_forth_again(), control_forth_begin(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_loop(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_then(), control_forth_until(), defining_runtime_does_rt(), defining_word_create(), defining_word_variable(), dictionary_word_2comma(), dictionary_word_allot(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_fence(), dictionary_word_forget(), dictionary_word_here(), dictionary_word_latest(), main(), reset_vm_state(), restore_dict_state(), save_dict_state(), sk_parity_collect(), string_word_s_quote(), system_word_save_system(), vm_align(), vm_allot(), vm_cleanup(), vm_debug_dump_state(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_init(), vm_init_with_host(), and vocabulary_create_vocabulary_direct().

6.157.2.36 hold_addr

```
vaddr_t VM::hold_addr
```

Referenced by format_word_end_conversion(), vm_init(), and vm_init_with_host().

6.157.2.37 hold_pos

```
int VM::hold_pos
```

Referenced by format_word_begin_conversion(), format_word_end_conversion(), format_word_hold(), vm_init(), and vm_init_with_host().

6.157.2.38 host

```
const VMHostServices* VM::host
```

Host allocator/time services.

Referenced by vm_host(), vm_init_with_host(), and vm_reset_hosted_fake_ns().

6.157.2.39 hot_word_count_at_check

```
uint64_t VM::hot_word_count_at_check
```

Hot words observed at last inference.

Referenced by heartbeat_publish_snapshot(), vm_heartbeat_publish_snapshot(), and vm_tick_slope_validator().

6.157.2.40 hotwords_cache

```
HotwordsCache* VM::hotwords_cache
```

Frequency-driven dictionary acceleration cache.

Referenced by bucket_posterior(), cache_posterior(), execute_colon_word(), forth_BENCH_DICT_LOOKUP(), forth_PHYSICS_BAYESIAN_REPORT(), forth_PHYSICS_BUILD_INFO(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_RESET_STATS(), forth_PHYSICS_TOGGLE_CACHE(), metrics_from_vm(), physics_pre_execute(), rolling_window_seed_hotwords_cache(), vm_cleanup(), vm_create_word(), vm_dictionary_untrack_entry(), vm_exit_compile_mode(), vm_find_word(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_hide_word(), vm_init(), vm_init_with_host(), and vm_smudge_word().

6.157.2.41 in_var

```
cell_t* VM::in_var
```

Referenced by vm_input_ensure(), vm_input_in(), and vm_input_load_line().

6.157.2.42 input_buffer

```
char VM::input_buffer[1025]
```

Referenced by forth_backslash(), io_word_dot_quote(), log_emit_string(), starforth_word_paren_dash(), string_word_s_quote(), system_word_abort_quote(), vm_interpret(), and vm_parse_word().

6.157.2.43 input_length

```
size_t VM::input_length
```

Referenced by forth_backslash(), io_word_dot_quote(), log_emit_string(), starforth_word_paren_dash(), string_word_s_quote(), system_word_abort_quote(), vm_init(), vm_init_with_host(), vm_interpret(), and vm_parse_word().

6.157.2.44 input_pos

```
size_t VM::input_pos
```

Referenced by forth_backslash(), io_word_dot_quote(), log_emit_string(), starforth_word_paren_dash(), string_word_s_quote(), system_word_abort_quote(), vm_init(), vm_init_with_host(), vm_interpret(), and vm_parse_word().

6.157.2.45 interpreter_enabled

```
int VM::interpreter_enabled
```

Referenced by vm_assert_interpreter_enabled(), vm_enable_interpreter(), and vm_init_with_host().

6.157.2.46 ip

```
cell_t* VM::ip
```

Referenced by vm_debug_dump_state(), vm_save_registers(), vm_save_registers_arm64(), vm_save_registers_rv64(), vm_setup_registers(), vm_setup_registers_arm64(), and vm_setup_registers_rv64().

6.157.2.47 last_bucket_reorg_ns

```
uint64_t VM::last_bucket_reorg_ns
```

When we last reorganized buckets.

Referenced by dict_adaptive_optimization_pass(), dict_reorganize_buckets_by_heat(), vm_init(), and vm_init_with_host().

6.157.2.48 last_decay_check_ns

```
uint64_t VM::last_decay_check_ns
```

Timestamp of last decay effectiveness measurement.

Referenced by vm_init(), and vm_init_with_host().

6.157.2.49 last_inference_outputs

```
InferenceOutputs* VM::last_inference_outputs
```

Cached inference outputs (for ANOVA early-exit and tuning application)

Referenced by infer_word_decay_fetch(), infer_word_early_exit_fetch(), infer_word_fit_fetch(), infer_word_run(), infer_word_variance_fetch(), infer_word_window_fetch(), metrics_from_vm(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), and vm_tick_inference_engine().

6.157.2.50 latest

```
DictEntry* VM::latest
```

Most recent word.

Referenced by capsule_dict_hash_hook(), defining_runtime_does_rt(), defining_word_immediate(), dict_newer_of(), dict_update_heat_percentiles(), dictionary_m_word_hidden(), dictionary_snapshot_acl_from_parent(), dictionary_word_fence(), dictionary_word_forget(), find_entry_from_name(), forth_acl_init_primitives(), forth_ALL_HEATS(), forth_PHYSICS_BURN(), forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_SHOW_FEEDBACK(), forth_PHYSICS_WORD_METRICS(), forth_PIPELINING_RESET_ALL(), forth_PIPELINING_STATS(), heartbeat_capture_tick_snapshot(), infer_word_run(), init_vocabulary_system(), main(), metrics_from_vm(), restore_dict_state(), save_dict_state(), sf_rebuild_fc_index(), sf_try_fast_append(), sk_dict_canonical_hash(), sk_dict_word_count(), sk_parity_collect(), starforth_word_reset_execution_heat(), starforth_word_top_words(), starforth_word_word_execution_heat(), system_word_vlist(), system_word_words(), vm_cleanup(), vm_create_word(), vm_dict_entry_ok(), vm_dictionary_find_by_func(), vm_find_word(), vm_hide_word(), vm_init(), vm_init_with_host(), vm_make_immediate(), vm_pin_execution_heat(), vm_smudge_word(), vm_tick_apply_background_de vm_tick_apply_background_decay(), vm_tick_inference_engine(), vm_tick_slope_validator(), vm_unpin_execution_heat(), vocabulary_create_vocabulary_direct(), vocabulary_select_runtime(), and vocabulary_word_vocabulary().

6.157.2.51 lookup_strategy

```
int VM::lookup_strategy
```

0=naive, 1=heat-aware, 2=inference-reorg

Referenced by dict_adaptive_optimization_pass(), forth_COMPARE_LOOKUPS(), forth_LOOKUP_STRATEGY_FETCH(), forth_LOOKUP_STRATEGY_STORE(), forth_SHOW_HEAT_OPTIMIZATION(), vm_find_word(), vm_init(), and vm_init_with_host().

6.157.2.52 memory

```
uint8_t* VM::memory
```

Unified VM memory buffer.

Referenced by array_ptr(), blk_vm_assign(), blk_vm_evict(), blk_vm_flush_all(), blk_vm_load(), block_word_update(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_loop(), control_forth_plus_loop(), control_forth_repeat(), control_forth_then(), dbg_get_base(), defining_runtime_does_rt(), emit_cell(), extract_name(), hash_colon_body(), init_vocabulary_system(), io_init(), io_write_block(), log_str_emit(), runtime_abortq(), system_word_abort_quote(), system_word_save_system(), system_word_see(), vaddr_from_ptr(), vm_addr_from_ptr(), vm_addr_ok(), vm_addr_to_block(), vm_allot(), vm_bootstrap_scr(), vm_cleanup(), vm_debug_dump_state(), vm_get_block_addr(), vm_init(), vm_init_with_host(), vm_load_cell(), vm_ptr(), vm_store_cell(), vocab_sync_vm_vars(), vocabulary_create_vocabulary_direct(), and vocabulary_word_vocabulary().

6.157.2.53 mode

```
vm_mode_t VM::mode
```

Referenced by cf_epoch_sync(), control_forth_again(), control_forth_begin(), control_forth_case(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_if(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_then(), control_forth_until(), control_forth_while(), defining_word_colon(), defining_word_does(), defining_word_left_bracket(), defining_word_right_bracket(), defining_word_semicolon(), dictionary_m_word_hidden(), dictionary_m_word_interpret(), dictionary_m_word_smudge(), emit_cell(), exec_block_with_retry(), io_word_dot_quote(), log_emit_string(), reset_vm_state(), restore_vm_state(), save_vm_state(), string_word_bracket_tick(), string_word_s_quote(), system_word_abort_quote(), system_word_quit(), system_word_reboot(), vm_compile_call(), vm_compile_exit(), vm_compile_literal(), vm_compile_word(), vm_debug_dump_state(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_init(), vm_init_with_host(), and vm_interpret_word().

6.157.2.54 next_word_id

```
uint32_t VM::next_word_id
```

Next fresh ID when recycle stack empty.

Referenced by vm_dictionary_acquire_word_id(), vm_init(), and vm_init_with_host().

6.157.2.55 pipeline_metrics

```
PipelineGlobalMetrics VM::pipeline_metrics
```

Aggregated prefetch accuracy tracking.

Referenced by execute_colon_word(), forth_PHYSICS_RESET_STATS(), infer_word_run(), metrics_from_vm(), perturb_physics(), physics_pre_execute(), restore_physics(), save_physics(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_window_tuner().

6.157.2.56 recycled_word_id_count

```
uint32_t VM::recycled_word_id_count
```

Depth of recycled stack.

Referenced by vm_dictionary_acquire_word_id(), vm_dictionary_untrack_entry(), vm_init(), and vm_init_with_host().

6.157.2.57 recycled_word_ids

```
uint32_t VM::recycled_word_ids[1024]
```

Reusable ID stack for FORGET.

Referenced by vm_dictionary_acquire_word_id(), and vm_dictionary_untrack_entry().

6.157.2.58 return_stack

```
cell_t VM::return_stack[1024]
```

Return stack storage.

Referenced by control_forth_0branch(), control_forth_branch(), control_forth_I(), control_forth_J(), control_forth_runtime_do(), control_forth_runtime_leave(), control_forth_runtime_loop(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), control_forth_UNLOOP(), defining_runtime_dodoes(), defining_runtime_does_rt(), defining_runtime_lit(), double_word_2r_fetch(), double_word_2r_from(), double_word_2to_r(), io_runtime_do_string(), log_do_emit(), return_stack_word_r_fetch(), return_stack_word_r_from(), return_stack_word_to_r(), string_runtime_s_quote(), vm_rpop(), vm_rpop_asm(), vm_rpop_asm(), vm_rpop_asm(), vm_rpop_fast(), vm_rpush(), vm_rpush_asm(), vm_rpush_asm(), vm_rpush_asm(), vm_rpush_fast(), vm_save_registers(), vm_save_registers_arm64(), vm_save_registers_rv64(), vm_setup_registers(), vm_setup_registers_arm64(), and vm_setup_registers_rv64().

6.157.2.59 rolling_window

```
RollingWindowOfTruth VM::rolling_window
```

Execution history for reproducible seeding.

Referenced by dict_adaptive_optimization_pass(), execute_colon_word(), heartbeat_capture_tick_snapshot(), heartbeat_publish_snapshot(), infer_word_run(), infer_word_window_diversity(), metrics_from_vm(), perturb_physics(), physics_pre_execute(), restore_physics(), run_doe_experiment(), save_physics(), vm_cleanup(), vm_heartbeat_publish_snapshot(), vm_heartbeat_run_cycle(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_window_tuner().

6.157.2.60 rsp

```
int VM::rsp
```

Return stack pointer.

Referenced by capture_exec_result(), check_physics_transparent(), control_forth_0branch(), control_forth_branch(), control_forth_EXIT(), control_forth_I(), control_forth_J(), control_forth_runtime_do(), control_forth_runtime_leave(), control_forth_runtime_loop(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), control_forth_UNLOOP(), defining_runtime_dodoes(), defining_runtime_does_rt(), defining_runtime_lit(), double_word_2r_fetch(), double_word_2r_from(), double_word_2to_r(), execute_colon_word(), io_runtime_do_string(), log_do_emit(), reset_vm_state(), restore_vm_state(), return_stack_word_r_fetch(), return_stack_word_r_from(), return_stack_word_to_r(), save_vm_state(), string_runtime_s_quote(), system_word_quit(), vm_debug_dump_state(), vm_init(), vm_init_with_host(), vm_interpret_word(), vm_rpop(), vm_rpop_asm(), vm_rpop_asm(), vm_rpop_asm(), vm_rpop_fast(), vm_rpush(), vm_rpush_asm(), vm_rpush_asm(), vm_rpush_asm(), vm_rpush_fast(), vm_save_registers(), vm_save_registers_arm64(), vm_save_registers_rv64(), vm_setup_registers(), vm_setup_registers_arm64(), and vm_setup_registers_rv64().

6.157.2.61 scr_addr

```
vaddr_t VM::scr_addr
```

Referenced by block_word_next_block(), block_word_scr(), block_word_update(), current_scr(), editor_word_edit(), mark_buffer_dirty(), set_scr(), vm_bootstrap_scr(), vm_debug_dump_state(), and vm_init().

6.157.2.62 span_var

```
cell_t* VM::span_var
```

Referenced by vm_input_ensure(), vm_input_load_line(), vm_input_source(), and vm_input_span().

6.157.2.63 ssm_config

```
void* VM::ssm_config
```

Opaque pointer to ssm_config_t (L3/L4 mode bits)

Referenced by infer_word_l8_apply(), infer_word_l8_table_force(), inference_engine_run(), physics_metadata_apply_linear_decay(), physics_pre_execute(), vm_cleanup(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), and vm_init_with_host().

6.157.2.64 ssm_l8_state

```
void* VM::ssm_l8_state
```

Opaque pointer to ssm_l8_state_t (avoid circular include)

Referenced by infer_word_l8_apply(), infer_word_l8_mode(), infer_word_l8_table_force(), infer_word_l8_update(), l8_regime_modulation_q16(), vm_cleanup(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), and vm_init_with_host().

6.157.2.65 stale_word_count_at_check

```
uint64_t VM::stale_word_count_at_check
```

Stale words at last check (for trend analysis)

Referenced by heartbeat_publish_snapshot(), infer_word_run(), vm_heartbeat_publish_snapshot(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_slope_validator().

6.157.2.66 state_addr

```
vaddr_t VM::state_addr
```

Referenced by defining_word_left_bracket(), defining_word_right_bracket(), defining_word_state(), exec_block_with_retry(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_init(), and vm_init_with_host().

6.157.2.67 state_var

```
cell_t VM::state_var
```

Referenced by exec_block_with_retry(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_init(), and vm_init_with_host().

6.157.2.68 tib_buf

```
unsigned char* VM::tib_buf
```

Referenced by vm_input_ensure(), vm_input_load_line(), vm_input_source(), and vm_input_tib().

6.157.2.69 tib_cap

```
size_t VM::tib_cap
```

Referenced by vm_input_ensure(), and vm_input_load_line().

6.157.2.70 total_heat_at_last_check

```
uint64_t VM::total_heat_at_last_check
```

Total dictionary heat at last check (for slope inference)

Referenced by heartbeat_publish_snapshot(), infer_word_run(), vm_heartbeat_publish_snapshot(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_slope_validator().

6.157.2.71 tuning_lock

```
sf_mutex_t VM::tuning_lock
```

Guards shared tuning knobs (slope, snapshots)

Referenced by metrics_from_vm(), vm_cleanup(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_tick_inference_engine(), and vm_tick_slope_validator().

6.157.2.72 vocab

```
VocabularyState VM::vocab
```

Referenced by init_vocabulary_system(), vocab_find_word(), vocab_sync_vm_vars(), vocabulary_select_runtime(), vocabulary_word_context(), vocabulary_word_current(), vocabulary_word_definitions(), vocabulary_word_forth(), and vocabulary_word_order().

6.157.2.73 word_count_at_check

```
uint32_t VM::word_count_at_check
```

Total word count at last check (for ratio calculation)

Referenced by vm_tick_inference_engine(), and vm_tick_slope_validator().

6.157.2.74 word_id_map

```
DictEntry* VM::word_id_map[1024]
```

Stable ID → entry map for speculation.

Referenced by vm_dictionary_lookup_by_word_id(), vm_dictionary_track_entry(), and vm_dictionary_untrack_entry().

6.157.2.75 zuse_cert_installed

```
uint8_t VM::zuse_cert_installed
```

1 = zuse_cert_seed/pubkey hold a real minted cert (one-time fuse)

Referenced by capsule_mint_identity(), starforth_word_zuse_cert_installed_query(), and vm_zuse_cert_install().

6.157.2.76 zuse_cert_pubkey

```
uint8_t VM::zuse_cert_pubkey[32]
```

Ed25519 public key derived from the seed at mint time, cached here so callers don't need to re-derive it.

No FORTH word can write it – deliberately kept out of the dictionary so ACL-PIN's redefinition-only guarantee can't be bypassed via >BODY on a CONSTANT (see FABRIC-2.md). Read-only FORTH access via ZUSE-PUBKEY.

Referenced by starforth_word_zuse_pubkey_fetch(), and vm_zuse_cert_install().

6.157.2.77 zuse_cert_seed

```
uint8_t VM::zuse_cert_seed[32]
```

Ed25519 seed, this instance's Zuse identity.

C-only write via vm_zuse_cert_install(); no FORTH word can read or write it – the seed is the private key, never exposed past this struct.

Referenced by capsule_mint_identity(), and vm_zuse_cert_install().

6.157.2.78 zuse_root_pubkey

```
uint8_t VM::zuse_root_pubkey[32]
```

Ed25519 public key, loaded from the genesis-marker fence.

Same value zuse_cert_pubkey ends up holding once Zuse herself attaches – this is just available earlier and unconditionally.

Referenced by capsule_wirebind_verify_cert(), capsule_zuse_boot_load_root_pubkey(), and install_and_activate().

6.157.2.79 zuse_root_pubkey_known

```
uint8_t VM::zuse_root_pubkey_known
```

1 = zuse_root_pubkey holds a real value, loaded from the persistent genesis-marker fence (zuse_genesis_marker_t, capsule_zuse_boot_load_root_pubkey()) independently of whether Zuse's own thumbdrive is attached this boot.

Deliberately separate from zuse_cert_installed/zuse_cert_seed above – that pair is a one-way fuse gating MINT (needs her live private seed); this pair gates WIREBIND cert *verification* only (needs nothing but her already-public key), so a WIREBIND identity can be verified and attach without requiring Zuse's own live session this boot. Bob, 2026-09-09: "zuse is zuse, [each identity] is [itself]" – one identity's attach must not depend on another's live presence.

Referenced by capsule_wirebind_try_attach(), capsule_wirebind_verify_cert(), capsule_zuse_boot_load_root_pubkey(), and install_and_activate().

6.157.2.80 zuse_session

```
uint8_t VM::zuse_session
```

1 = zuse authenticated at console; shows zuse)ok> prompt

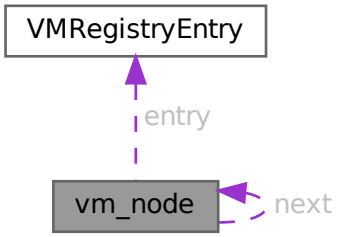
Referenced by capsule_zuse_boot_logout(), capsule_zuse_boot_try_attach(), sk_console_identity_present(), sk_console_user_prefix(), starforth_word_zuse_authenticate(), starforth_word_zuse_session(), vm_exit_compile_mode(), and vm_repl().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.158 vm_node Struct Reference

Collaboration diagram for vm_node:



Data Fields

- VMRegistryEntry entry
- struct vm_node * next

6.158.1 Field Documentation

6.158.1.1 entry

```
VMRegistryEntry vm_node::entry
```

Referenced by capsule_vm_find_by_name(), capsule_vm_find_by_name_nocase(), capsule_vm_kill(), capsule_vm_kill_all_nonmama capsule_vm_registry_get_by_index(), capsule_vm_registry_init(), vm_find_entry_ptr(), vm_registry_alloc(), and vm_registry_live_count().

6.158.1.2 next

```
struct vm_node* vm_node::next
```

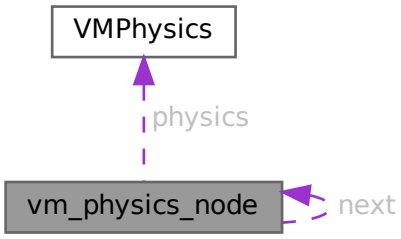
Referenced by capsule_vm_find_by_name(), capsule_vm_find_by_name_nocase(), capsule_vm_kill(), capsule_vm_kill_all_nonmama capsule_vm_registry_get_by_index(), capsule_vm_registry_init(), vm_find_entry_ptr(), vm_registry_alloc(), and vm_registry_live_count().

The documentation for this struct was generated from the following file:

- kernel/src/capsule/capsule_birth.c

6.159 vm_physics_node Struct Reference

Collaboration diagram for vm_physics_node:



Data Fields

- VMUuid vm_id
- VMPhysics physics
- struct vm_physics_node * next

6.159.1 Field Documentation

6.159.1.1 next

```
struct vm_physics_node* vm_physics_node::next
```

Referenced by vm_physics_find(), vm_physics_fleet_heat_sum(), vm_physics_init(), vm_physics_status(), and vm_physics_touch().

6.159.1.2 physics

```
VMPhysics vm_physics_node::physics
```

Referenced by vm_physics_fleet_heat_sum(), vm_physics_heat_of(), vm_physics_init(), vm_physics_retire(), vm_physics_status(), and vm_physics_touch().

6.159.1.3 vm_id

```
VMUuid vm_physics_node::vm_id
```

Referenced by vm_physics_find(), vm_physics_init(), and vm_physics_status().

The documentation for this struct was generated from the following file:

- kernel/src/capsule/capsule_vm_physics.c

6.160 VMFleetTouchSample Struct Reference

Data Fields

- uint64_t elapsed_ticks
- uint64_t amount
- int clamped

6.160.1 Field Documentation

6.160.1.1 amount

```
uint64_t VMFleetTouchSample::amount
```

Referenced by vm_physics_tick(), and vm_physics_touch().

6.160.1.2 clamped

```
int VMFleetTouchSample::clamped
```

Referenced by vm_physics_tick(), and vm_physics_touch().

6.160.1.3 elapsed_ticks

```
uint64_t VMFleetTouchSample::elapsed_ticks
```

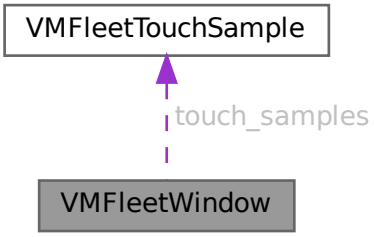
Referenced by vm_physics_tick(), and vm_physics_touch().

The documentation for this struct was generated from the following file:

- kernel/src/capsule/capsule_vm_physics.c

6.161 VMFleetWindow Struct Reference

Collaboration diagram for VMFleetWindow:



Data Fields

- VMFleetTouchSample touch_samples [64]
- uint32_t head
- uint32_t count
- int is_warm

6.161.1 Field Documentation

6.161.1.1 count

```
uint32_t VMFleetWindow::count
```

Referenced by vm_physics_touch().

6.161.1.2 head

```
uint32_t VMFleetWindow::head
```

Referenced by vm_physics_touch().

6.161.1.3 is_warm

```
int VMFleetWindow::is_warm
```

Referenced by vm_physics_status(), vm_physics_tick(), and vm_physics_touch().

6.161.1.4 touch_samples

```
VMFleetTouchSample VMFleetWindow::touch_samples[64]
```

Referenced by vm_physics_tick(), and vm_physics_touch().

The documentation for this struct was generated from the following file:

- kernel/src/capsule/capsule_vm_physics.c

6.162 VMHostServices Struct Reference

VMHostServices - pluggable host operations.

```
#include <vm_host.h>
```

Data Fields

- sk_alloc_fn alloc
- sk_free_fn free
- sk_time_fn monotonic_ns
- sk_mutex_init_fn mutex_init
- sk_mutex_lock_fn mutex_lock
- sk_mutex_unlock_fn mutex_unlock
- sk_mutex_destroy_fn mutex_destroy
- sk_puts_fn puts
- sk_putc_fn putc
- sk_xt_validate_fn is_executable_ptr
- sk_xt_entry_owns_fn owns_xt_entry
- sk_panic_fn panic
- int parity_mode
- int verbose

6.162.1 Detailed Description

VMHostServices - pluggable host operations.

Hosted builds point these at libc functions. Kernel builds point these at kernel implementations.

6.162.2 Field Documentation

6.162.2.1 alloc

```
sk_alloc_fn VMHostServices::alloc
```

Referenced by vm_host_alloc().

6.162.2.2 free

```
sk_free_fn VMHostServices::free
```

Referenced by vm_host_free().

6.162.2.3 is_executable_ptr

```
sk_xt_validate_fn VMHostServices::is_executable_ptr
```

Referenced by vm_bootstrap_root_vocabulary().

6.162.2.4 monotonic_ns

```
sk_time_fn VMHostServices::monotonic_ns
```

Referenced by vm_monotonic_ns().

6.162.2.5 mutex_destroy

sk_mutex_destroy_fn VMHostServices::mutex_destroy

6.162.2.6 mutex_init

sk_mutex_init_fn VMHostServices::mutex_init

6.162.2.7 mutex_lock

sk_mutex_lock_fn VMHostServices::mutex_lock

6.162.2.8 mutex_unlock

sk_mutex_unlock_fn VMHostServices::mutex_unlock

6.162.2.9 owns_xt_entry

sk_xt_entry_owns_fn VMHostServices::owns_xt_entry

6.162.2.10 panic

sk_panic_fn VMHostServices::panic

Referenced by vm_bootstrap_root_vocabulary().

6.162.2.11 parity_mode

int VMHostServices::parity_mode

6.162.2.12 putc

sk_putc_fn VMHostServices::putc

6.162.2.13 puts

sk_puts_fn VMHostServices::puts

6.162.2.14 verbose

```
int VMHostServices::verbose
```

The documentation for this struct was generated from the following file:

- v3/include/vm_host.h

6.163 vmm_page_info_t Struct Reference

```
#include <vmm.h>
```

Data Fields

- int present
- int writable
- int executable

6.163.1 Field Documentation

6.163.1.1 executable

```
int vmm_page_info_t::executable
```

Referenced by vmm_query_page().

6.163.1.2 present

```
int vmm_page_info_t::present
```

Referenced by vmm_query_page().

6.163.1.3 writable

```
int vmm_page_info_t::writable
```

Referenced by vmm_query_page().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/vmm.h

6.164 VMPhysics Struct Reference

Data Fields

- uint64_t execution_heat_q48
- uint64_t last_active_tick
- int touched
- int is_live

6.164.1 Field Documentation

6.164.1.1 execution_heat_q48

```
uint64_t VMPhysics::execution_heat_q48
```

Referenced by vm_physics_fleet_heat_sum(), vm_physics_heat_of(), vm_physics_init(), vm_physics_retire(), vm_physics_status(), vm_physics_touch(), and vm_physics_transfer().

6.164.1.2 is_live

```
int VMPhysics::is_live
```

Referenced by vm_physics_fleet_heat_sum(), vm_physics_heat_of(), vm_physics_init(), vm_physics_retire(), vm_physics_status(), and vm_physics_touch().

6.164.1.3 last_active_tick

```
uint64_t VMPhysics::last_active_tick
```

Referenced by vm_physics_init(), and vm_physics_touch().

6.164.1.4 touched

```
int VMPhysics::touched
```

Referenced by vm_physics_init(), and vm_physics_touch().

The documentation for this struct was generated from the following file:

- kernel/src/capsule/capsule_vm_physics.c

6.165 VMRegistryEntry Struct Reference

```
#include <capsule_run.h>
```

Data Fields

- VMUuid vm_id
- uint32_t state
- uint64_t birth_capsule_id
- uint64_t birth_timestamp_ns
- uint64_t birth_dict_hash
- uint32_t flags
- VMUuid parent_vm_id
- void * vm_ptr
- char name [64]
- size_t stadium_patron_cell
- int pending_reap

6.165.1 Field Documentation

6.165.1.1 birth_capsule_id

```
uint64_t VMRegistryEntry::birth_capsule_id
```

Referenced by capsule_birth_mama(), capsule_vm_registry_init(), and vm_registry_alloc().

6.165.1.2 birth_dict_hash

```
uint64_t VMRegistryEntry::birth_dict_hash
```

Referenced by capsule_birth_mama(), capsule_vm_registry_init(), and vm_registry_alloc().

6.165.1.3 birth_timestamp_ns

```
uint64_t VMRegistryEntry::birth_timestamp_ns
```

Referenced by capsule_vm_registry_init(), and vm_registry_alloc().

6.165.1.4 flags

```
uint32_t VMRegistryEntry::flags
```

Referenced by capsule_vm_registry_init(), and vm_registry_alloc().

6.165.1.5 name

```
char VMRegistryEntry::name[64]
```

Referenced by capsule_vm_find_by_name(), capsule_vm_find_by_name_nocase(), capsule_vm_kill(), capsule_vm_kill_all_nonmama
capsule_vm_registry_init(), doe_log_tick_row(), vm_registry_alloc(), and wirebind_teardown_console().

6.165.1.6 parent_vm_id

```
VMUuid VMRegistryEntry::parent_vm_id
```

Referenced by capsule_vm_registry_init(), vm_physics_find_root_id(), and vm_registry_alloc().

6.165.1.7 pending_reap

```
int VMRegistryEntry::pending_reap
```

6.165.1.8 stadium_patron_cell

```
size_t VMRegistryEntry::stadium_patron_cell
```

Referenced by capsule_vm_kill_all_nonmama(), capsule_vm_registry_init(), and vm_registry_alloc().

6.165.1.9 state

```
uint32_t VMRegistryEntry::state
```

Referenced by capsule_vm_kill_all_nonmama(), capsule_vm_registry_init(), capsule_wirebind_try_attach(), kernel_main_deep(), sk_repl_dispatch_line(), vm_registry_alloc(), vm_registry_live_count(), wirebind_resolve_attached(), and wirebind_teardown_console().

6.165.1.10 vm_id

```
VMUuid VMRegistryEntry::vm_id
```

Referenced by capsule_vm_kill_all_nonmama(), capsule_vm_registry_init(), doe_log_tick_row(), kernel_main_deep(), sk_repl_dispatch_line(), sk_word_blk_attach_ack(), vm_find_entry_ptr(), and vm_registry_alloc().

6.165.1.11 vm_ptr

```
void* VMRegistryEntry::vm_ptr
```

Referenced by capsule_birth_baby(), capsule_vm_kill_all_nonmama(), capsule_vm_registry_init(), kernel_main_deep(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), vm_registry_alloc(), and wirebind_teardown_console().

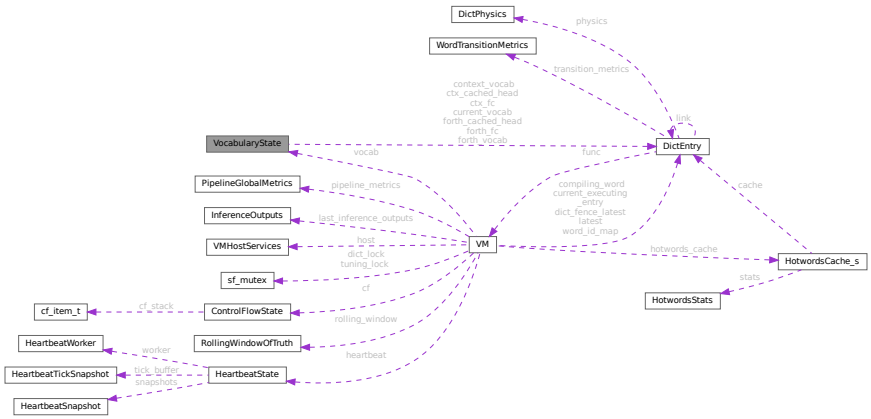
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/capsule_run.h

6.166 VocabularyState Struct Reference

`#include <vm.h>`

Collaboration diagram for VocabularyState:



Data Fields

- int initialized
- DictEntry * forth_vocab
- DictEntry * context_vocab
- DictEntry * current_vocab
- vaddr_t context_var_addr
- vaddr_t current_var_addr
- DictEntry ** ctx_fc [256]
- size_t ctx_n [256]
- DictEntry * ctx_cached_head
- DictEntry ** forth_fc [256]
- size_t forth_n [256]
- DictEntry * forth_cached_head

6.166.1 Field Documentation

6.166.1.1 context_var_addr

`vaddr_t VocabularyState::context_var_addr`

Referenced by init_vocabulary_system(), vocab_sync_vm_vars(), and vocabulary_word_context().

6.166.1.2 context_vocab

`DictEntry* VocabularyState::context_vocab`

Referenced by init_vocabulary_system(), vocab_find_word(), vocab_sync_vm_vars(), vocabulary_select_runtime(), vocabulary_word_definitions(), vocabulary_word_forth(), and vocabulary_word_order().

6.166.1.3 ctx_cached_head

```
DictEntry* VocabularyState::ctx_cached_head
```

Referenced by vocab_find_word().

6.166.1.4 ctx_fc

```
DictEntry** VocabularyState::ctx_fc[256]
```

Referenced by vocab_find_word().

6.166.1.5 ctx_n

```
size_t VocabularyState::ctx_n[256]
```

Referenced by vocab_find_word().

6.166.1.6 current_var_addr

```
vaddr_t VocabularyState::current_var_addr
```

Referenced by init_vocabulary_system(), vocab_sync_vm_vars(), and vocabulary_word_current().

6.166.1.7 current_vocab

```
DictEntry* VocabularyState::current_vocab
```

Referenced by init_vocabulary_system(), vocab_sync_vm_vars(), vocabulary_word_definitions(), and vocabulary_word_order().

6.166.1.8 forth_cached_head

```
DictEntry* VocabularyState::forth_cached_head
```

Referenced by vocab_find_word().

6.166.1.9 forth_fc

```
DictEntry** VocabularyState::forth_fc[256]
```

Referenced by vocab_find_word().

6.166.1.10 forth_n

```
size_t VocabularyState::forth_n[256]
```

Referenced by vocab_find_word().

6.166.1.11 forth_vocab

```
DictEntry* VocabularyState::forth_vocab
```

Referenced by init_vocabulary_system(), vocab_find_word(), vocabulary_word_forth(), and vocabulary_word_order().

6.166.1.12 initialized

```
int VocabularyState::initialized
```

Referenced by init_vocabulary_system().

The documentation for this struct was generated from the following file:

- v3/include/vm.h

6.167 VT100State Struct Reference

Data Fields

- uint32_t cols
- uint32_t rows
- uint32_t cx
- uint32_t cy
- uint32_t saved_cx
- uint32_t saved_cy
- uint32_t fg
- uint32_t bg
- uint32_t def_fg
- uint32_t def_bg
- int bold
- int underline
- int reverse
- ParseState state
- int32_t params [16]
- uint32_t param_count
- int param_has_value
- int initialized

6.167.1 Field Documentation

6.167.1.1 bg

```
uint32_t VT100State::bg
```

Referenced by apply_sgr(), eff_bg(), eff_fg(), erase_line_range(), and reset_attrs().

6.167.1.2 bold

```
int VT100State::bold
```

Referenced by apply_sgr(), draw_cursor_glyph(), and reset_attrs().

6.167.1.3 cols

```
uint32_t VT100State::cols
```

Referenced by advance_cursor(), dispatch_csi(), draw_cursor_glyph(), erase_display(), erase_line(), scroll_up(), scrollback_redraw(), set_cursor(), vt100_cols(), vt100_enable_ttf(), vt100_init(), vt100_putc(), and vt100_reset().

6.167.1.4 cx

```
uint32_t VT100State::cx
```

Referenced by advance_cursor(), dispatch_csi(), draw_cursor_glyph(), erase_display(), erase_line(), set_cursor(), vt100_draw_cursor(), vt100_enable_ttf(), vt100_erase_cursor(), vt100_init(), vt100_putc(), and vt100_reset().

6.167.1.5 cy

```
uint32_t VT100State::cy
```

Referenced by advance_cursor(), dispatch_csi(), draw_cursor_glyph(), erase_display(), erase_line(), set_cursor(), vt100_draw_cursor(), vt100_enable_ttf(), vt100_erase_cursor(), vt100_init(), vt100_putc(), and vt100_reset().

6.167.1.6 def_bg

```
uint32_t VT100State::def_bg
```

Referenced by apply_sgr(), erase_display(), reset_attrs(), scroll_up(), scrollback_redraw(), vt100_enable_ttf(), vt100_init(), vt100_putc(), vt100_reset(), and vt100_toggle_graphics().

6.167.1.7 def_fg

```
uint32_t VT100State::def_fg
```

Referenced by apply_sgr(), reset_attrs(), scrollback_redraw(), and vt100_init().

6.167.1.8 fg

```
uint32_t VT100State::fg
```

Referenced by apply_sgr(), eff_bg(), eff_fg(), and reset_attrs().

6.167.1.9 initialized

```
int VT100State::initialized
```

Referenced by vt100_enable_ttf(), vt100_init(), vt100_putc(), and vt100_reset().

6.167.1.10 param_count

```
uint32_t VT100State::param_count
```

Referenced by apply_sgr(), param(), reset_parser(), and vt100_putc().

6.167.1.11 param_has_value

```
int VT100State::param_has_value
```

Referenced by reset_parser(), and vt100_putc().

6.167.1.12 params

```
int32_t VT100State::params[16]
```

Referenced by param(), reset_parser(), and vt100_putc().

6.167.1.13 reverse

```
int VT100State::reverse
```

Referenced by apply_sgr(), eff_bg(), eff_fg(), and reset_attrs().

6.167.1.14 rows

```
uint32_t VT100State::rows
```

Referenced by advance_cursor(), dispatch_csi(), draw_cursor_glyph(), erase_display(), scroll_up(), scrollback_line_at(), scrollback_redraw(), set_cursor(), vt100_enable_ttf(), vt100_init(), vt100_putc(), vt100_reset(), and vt100_rows().

6.167.1.15 saved_cx

```
uint32_t VT100State::saved_cx
```

Referenced by dispatch_csi(), vt100_init(), vt100_putc(), and vt100_reset().

6.167.1.16 saved_cy

```
uint32_t VT100State::saved_cy
```

Referenced by dispatch_csi(), vt100_init(), vt100_putc(), and vt100_reset().

6.167.1.17 state

```
ParseState VT100State::state
```

Referenced by reset_parser(), and vt100_putc().

6.167.1.18 underline

```
int VT100State::underline
```

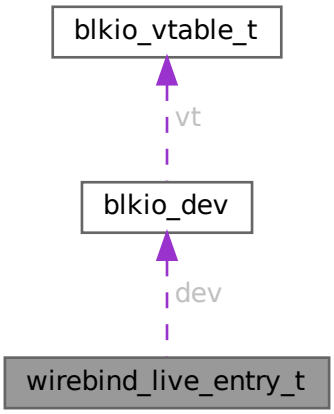
Referenced by apply_sgr(), draw_cursor_glyph(), and reset_attrs().

The documentation for this struct was generated from the following file:

- kernel/src/hal/vt100.c

6.168 wirebind_live_entry_t Struct Reference

Collaboration diagram for wirebind_live_entry_t:



Data Fields

- int in_use
- struct blkio_dev * dev
- VMUuid user_vm_id
- char username [32u]
- int switch_slot

6.168.1 Field Documentation

6.168.1.1 dev

```
struct blkio_dev* wirebind_live_entry_t::dev
```

Referenced by capsule_wirebind_try_attach(), and wirebind_live_remove().

6.168.1.2 in_use

```
int wirebind_live_entry_t::in_use
```

Referenced by capsule_wirebind_try_attach(), and wirebind_live_remove().

6.168.1.3 switch_slot

```
int wirebind_live_entry_t::switch_slot
```

Referenced by capsule_wirebind_try_attach(), and wirebind_live_remove().

6.168.1.4 user_vm_id

```
VMUuid wirebind_live_entry_t::user_vm_id
```

Referenced by capsule_wirebind_try_attach(), capsule_wirebind_unclean_detach(), and wirebind_live_remove().

6.168.1.5 username

```
char wirebind_live_entry_t::username[32u]
```

Referenced by capsule_wirebind_try_attach(), capsule_wirebind_unclean_detach(), and wirebind_live_remove().

The documentation for this struct was generated from the following file:

- kernel/src/capsule/capsule_wirebind.c

6.169 WordContract Struct Reference

```
#include <test_contracts.h>
```

Data Fields

- contract_flags_t flags
- int fuzz_rounds

6.169.1 Field Documentation

6.169.1.1 flags

```
contract_flags_t WordContract::flags
```

Referenced by resolve_contract(), and run_test_suite_m().

6.169.1.2 fuzz_rounds

```
int WordContract::fuzz_rounds
```

Referenced by run_test_suite_m().

The documentation for this struct was generated from the following file:

- v3/src/test_runner/include/test_contracts.h

6.170 WordProfile Struct Reference

Execution statistics for a single word.

```
#include <profiler.h>
```

Data Fields

- const char * word_name
  Name of the profiled word.
- uint64_t total_time
  Total execution time.
- uint64_t call_count
  Number of executions.
- uint64_t avg_time
  Average execution time.
- uint64_t min_time
  Minimum execution time.
- uint64_t max_time
  Maximum execution time.
- double percentage
  Percentage of total runtime.

6.170.1 Detailed Description

Execution statistics for a single word.

6.170.2 Field Documentation

6.170.2.1 avg_time

```
uint64_t WordProfile::avg_time
```

Average execution time.

6.170.2.2 call_count

```
uint64_t WordProfile::call_count
```

Number of executions.

6.170.2.3 max_time

```
uint64_t WordProfile::max_time
```

Maximum execution time.

6.170.2.4 min_time

```
uint64_t WordProfile::min_time
```

Minimum execution time.

6.170.2.5 percentage

```
double WordProfile::percentage
```

Percentage of total runtime.

6.170.2.6 total_time

```
uint64_t WordProfile::total_time
```

Total execution time.

6.170.2.7 word_name

```
const char* WordProfile::word_name
```

Name of the profiled word.

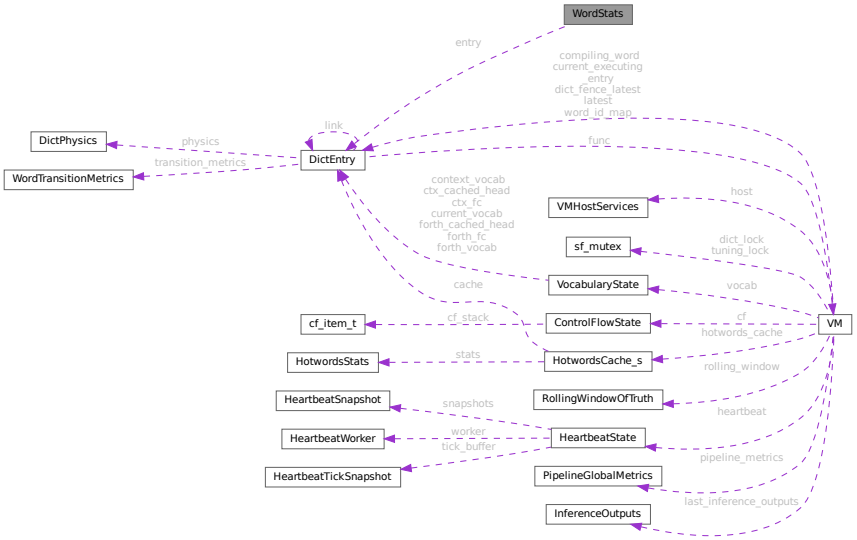
The documentation for this struct was generated from the following file:

- v3/include/profiler.h

6.171 WordStats Struct Reference

Statistics for individual word execution.

Collaboration diagram for WordStats:



Data Fields

- const DictEntry * entry

  Pointer to dictionary entry.
- uint64_t call_count

  Number of times word was called.
- uint64_t total_time_ns

  Total execution time in nanoseconds.
- uint64_t min_time_ns

  Minimum execution time in nanoseconds.
- uint64_t max_time_ns

  Maximum execution time in nanoseconds.

6.171.1 Detailed Description

Statistics for individual word execution.

6.171.2 Field Documentation

6.171.2.1 call_count

```
uint64_t WordStats::call_count
```

Number of times word was called.

Referenced by compare_by_calls(), get_word_stats(), profiler_generate_report(), profiler_print_hotspots(), profiler_word_count(), and profiler_word_exit().

6.171.2.2 entry

```
const DictEntry* WordStats::entry
```

Pointer to dictionary entry.

Referenced by get_word_stats(), profiler_generate_report(), and profiler_print_hotspots().

6.171.2.3 max_time_ns

```
uint64_t WordStats::max_time_ns
```

Maximum execution time in nanoseconds.

Referenced by get_word_stats(), profiler_generate_report(), and profiler_word_exit().

6.171.2.4 min_time_ns

```
uint64_t WordStats::min_time_ns
```

Minimum execution time in nanoseconds.

Referenced by get_word_stats(), and profiler_word_exit().

6.171.2.5 total_time_ns

```
uint64_t WordStats::total_time_ns
```

Total execution time in nanoseconds.

Referenced by compare_by_time(), get_word_stats(), profiler_generate_report(), and profiler_word_exit().

The documentation for this struct was generated from the following file:

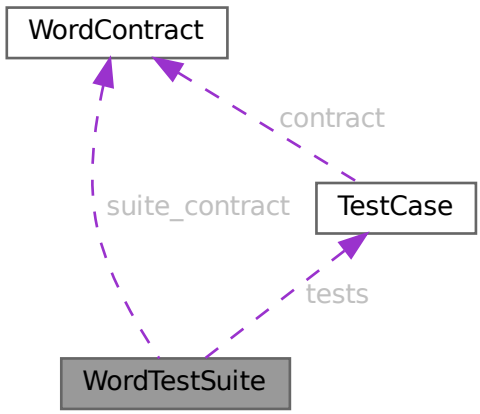
- v3/src/profiler.c

6.172 WordTestSuite Struct Reference

Collection of test cases for a single Forth word.

`#include <test_common.h>`

Collaboration diagram for WordTestSuite:



Data Fields

- const char * word_name
  Name of the Forth word being tested.
- TestCase tests [20]
  Array of test cases.
- int test_count
  Number of tests in the suite.
- WordContract suite_contract
  Suite-level contract; zero = inherit from module.

6.172.1 Detailed Description

Collection of test cases for a single Forth word.

6.172.2 Field Documentation

6.172.2.1 suite_contract

`WordContract WordTestSuite::suite_contract`

Suite-level contract; zero = inherit from module.

Referenced by run_test_suite_m().

6.172.2.2 test_count

```
int WordTestSuite::test_count
```

Number of tests in the suite.

Referenced by run_test_suite(), and run_test_suite_m().

6.172.2.3 tests

```
TestCase WordTestSuite::tests[20]
```

Array of test cases.

Referenced by run_test_suite(), and run_test_suite_m().

6.172.2.4 word_name

```
const char* WordTestSuite::word_name
```

Name of the Forth word being tested.

Referenced by run_arithmetic_words_tests(), run_block_words_tests(), run_control_words_tests(), run_defining_words_tests(), run_dictionary_manipulation_words_tests(), run_dictionary_words_tests(), run_double_words_tests(), run_format_words_tests(), run_inference_words_tests(), run_io_words_tests(), run_logical_words_tests(), run_mama_forth_words_tests(), run_memory_words_tests(), run_mixed_arithmetic_words_tests(), run_physics_freeze_words_tests(), run_q48_words_tests(), run_return_stack_words_tests(), run_stack_words_tests(), run_starforth_words_tests(), run_string_words_tests(), run_system_words_tests(), run_test_suite(), run_test_suite_m(), and run_vocabulary_words_tests().

The documentation for this struct was generated from the following file:

- v3/src/test_runner/include/test_common.h

6.173 WordTransitionMetrics Struct Reference

SPECULATION_THRESHOLD_Q48: Minimum probability (Q48.16) to speculate on a word transition.

```
#include <physics_pipelining_metrics.h>
```

Data Fields

- uint64_t * transition_heat

  transition_heat[i]: Number of times word with index i has been executed immediately after this word.
- uint64_t total_transitions

  Total number of transitions observed from this word.
- uint64_t prefetch_attempts

  Number of speculative prefetch attempts made for this word.
- uint64_t prefetch_hits

  Number of successful prefetch predictions (hits)
- uint64_t prefetch_misses

  Number of failed prefetch predictions (misses)
- int64_t prefetch_latency_saved_q48

  Total latency saved through successful prefetching (Q48.16 nanoseconds).
- int64_t misprediction_cost_q48

  Total latency cost from failed prefetch predictions (Q48.16 nanoseconds).
- int64_t max_transition_probability_q48

  Cached probability of most likely next word (for quick access).
- uint32_t most_likely_next_word_id

  Index (word id) of most likely next word.
- uint32_t * context_window

  Circular buffer of previous word IDs for context tracking.
- uint32_t context_window_pos

  Current position in context_window circular buffer.
- void * context_transitions

  Sparse hash table for context-based transitions.
- uint64_t total_context_transitions

  Total context-based transitions observed.
- uint32_t actual_window_size

  Actual window size for this word's metrics.

6.173.1 Detailed Description

SPECULATION_THRESHOLD_Q48: Minimum probability (Q48.16) to speculate on a word transition.

Range: 0.10 (very aggressive) to 0.95 (very conservative) Default: see starforth_config.h (STARFORTH↩ _CONFIG_SPECULATION_THRESHOLD_Q48_DEFAULT) Q48.16 encoding: 0.50 = 0x8000LL (1LL << 15) SPECULATION_DEPTH: How many words ahead to prefetch speculatively. Range: 1 (next word only) to 4 (very aggressive) Default: see starforth_config.h (STARFORTH_CONFIG_SPECULATION_DEPTH_DEFAULT) MIN_↩ SAMPLES_FOR_SPECULATION: Minimum number of transitions observed before making speculation decisions. Range: 1 (immediate) to 100 (very conservative) Default: see starforth_config.h (STARFORTH_CONFIG_MIN↩ _SAMPLES_FOR_SPECULATION_DEFAULT) MISPREDICTION_COST_Q48: Estimated cost (in nanoseconds, Q48.16 format) of recovering from wrong speculation. This is calibrated to the actual recovery time on target hardware. Range: 0 to 100 ns Default: see starforth_config.h (STARFORTH_CONFIG_MISPREDICTION_COST↩ _Q48_DEFAULT) Q48.16 encoding: 25 ns = 25 << 16 = 0x190000LL MINIMUM_PREFETCH_ROI: Minimum expected Return-On-Investment ratio for speculation to be worthwhile. Speculation succeeds only if: (prefetch↩ _latency_saved / total_attempts) > MINIMUM_PREFETCH_ROI Range: 1.0 (always speculate) to 2.0 (very selective) Default: see starforth_config.h (STARFORTH_CONFIG_MINIMUM_PREFETCH_ROI_DEFAULT) Q48.16 encoding: 1.10 = 1.10 * (1 << 16) = 0x1199AL TRANSITION_WINDOW_SIZE: Knob #6 - Execution context depth for prediction

How many previous words to remember when predicting next word. Larger window captures deeper patterns but uses more memory.

Window=1: Only immediate predecessor (A→B predictions) Window=2: Previous 2 words (A,B→C predictions) - good balance Window=4: Previous 4 words (captures multi-level patterns) Window=8: Very deep, expensive – see starforth_config.h for the actual shipped default

Binary Chop Search Space (Phase 2): Iteration 1: Try window=2 (baseline) Iteration 2: Try window=1 and window=4 Iteration 3: Narrow to optimal (1, 2, or 4) Converge: Pick size with highest prediction accuracy

Range: 1 to 8 Default: see starforth_config.h (STARFORTH_CONFIG_TRANSITION_WINDOW_SIZE_DEFAULT) Trade-off: Pattern depth vs. memory usage & complexity

Tuning: make TRANSITION_WINDOW_SIZE=1 (or 2, 4, 8)

6.173.2 Field Documentation

6.173.2.1 actual_window_size

```
uint32_t WordTransitionMetrics::actual_window_size
```

Actual window size for this word's metrics.

May differ from TRANSITION_WINDOW_SIZE if memory allocation failed. Phase 2 uses this to validate context data reliability.

Referenced by transition_metrics_context_accuracy_string(), transition_metrics_init(), transition_metrics_reset(), and transition_metrics_update_context_window().

6.173.2.2 context_transitions

```
void* WordTransitionMetrics::context_transitions
```

Sparse hash table for context-based transitions.

Maps: hash(context_window) → counts_array[DICTIONARY_SIZE]

Phase 1: Collect only (simple reference implementation) Phase 2: Analyze prediction accuracy by context depth Phase 3: Use for adaptive prefetching decisions

Opaque pointer - implementation is in transition_metrics.c

Referenced by transition_metrics_cleanup(), transition_metrics_init(), and transition_metrics_reset().

6.173.2.3 context_window

```
uint32_t* WordTransitionMetrics::context_window
```

Circular buffer of previous word IDs for context tracking.

Size = TRANSITION_WINDOW_SIZE (default 2) Used to build multi-word context patterns (e.g., A,B→C)

Example with WINDOW=2: context_window[0] = older word (2 steps back) context_window[1] = recent word (1 step back) Next word completes the pattern: (context_window[0], context_window[1]) → next

Referenced by transition_metrics_cleanup(), transition_metrics_init(), transition_metrics_reset(), and transition_metrics_update_conte

6.173.2.4 context_window_pos

```
uint32_t WordTransitionMetrics::context_window_pos
```

Current position in context_window circular buffer.

Points to slot where next word ID will be stored.

Referenced by transition_metrics_init(), and transition_metrics_reset().

6.173.2.5 max_transition_probability_q48

```
int64_t WordTransitionMetrics::max_transition_probability_q48
```

Cached probability of most likely next word (for quick access).

Updated periodically to avoid recomputation. Q48.16 format (0.0 to 1.0 == 0LL to 1LL<<16)

Referenced by forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), transition_metrics_init(), transition_metrics_reset(), transition_metrics_stats_string(), and transition_metrics_update_cache().

6.173.2.6 misprediction_cost_q48

```
int64_t WordTransitionMetrics::misprediction_cost_q48
```

Total latency cost from failed prefetch predictions (Q48.16 nanoseconds).

Negative value (cost) to be subtracted from savings.

Referenced by forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), transition_metrics_init(), transition_metrics_record_prefetch_miss(), transition_metrics_reset(), and transition_metrics_stats_string().

6.173.2.7 most_likely_next_word_id

```
uint32_t WordTransitionMetrics::most_likely_next_word_id
```

Index (word id) of most likely next word.

Used for fast prefetch without scanning transition_heat array.

Referenced by execute_colon_word(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), physics_pre_execute(), transition_metrics_init(), transition_metrics_reset(), transition_metrics_stats_string(), and transition_metrics_update_cache().

6.173.2.8 prefetch_attempts

```
uint64_t WordTransitionMetrics::prefetch_attempts
```

Number of speculative prefetch attempts made for this word.

Referenced by execute_colon_word(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_STATS(), physics_pre_execute(), transition_metrics_init(), transition_metrics_reset(), and transition_metrics_stats_string().

6.173.2.9 prefetch_hits

```
uint64_t WordTransitionMetrics::prefetch_hits
```

Number of successful prefetch predictions (hits)

Referenced by forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_STATS(), transition_metrics_init(), transition_metrics_record_prefetch_hit(), transition_metrics_reset(), and transition_metrics_stats_string().

6.173.2.10 prefetch_latency_saved_q48

```
int64_t WordTransitionMetrics::prefetch_latency_saved_q48
```

Total latency saved through successful prefetching (Q48.16 nanoseconds).

Positive value indicates net benefit from speculation.

Referenced by forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), transition_metrics_init(), transition_metrics_record_prefetch_hit(), transition_metrics_reset(), and transition_metrics_stats_string().

6.173.2.11 prefetch_misses

```
uint64_t WordTransitionMetrics::prefetch_misses
```

Number of failed prefetch predictions (misses)

Referenced by forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_STATS(), transition_metrics_init(), transition_metrics_record_prefetch_miss(), transition_metrics_reset(), and transition_metrics_stats_string().

6.173.2.12 total_context_transitions

```
uint64_t WordTransitionMetrics::total_context_transitions
```

Total context-based transitions observed.

Counter for Phase 2 analysis (accuracy measurement)

Referenced by transition_metrics_context_accuracy_string(), transition_metrics_init(), transition_metrics_record_context(), and transition_metrics_reset().

6.173.2.13 total_transitions

```
uint64_t WordTransitionMetrics::total_transitions
```

Total number of transitions observed from this word.

Referenced by forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRAN forth_PIPELINING_STATS(), transition_metrics_get_probability_q48(), transition_metrics_init(), transition_metrics_record(), transition_metrics_reset(), transition_metrics_should_speculate(), transition_metrics_stats_string(), and transition_metrics_update_ca

6.173.2.14 transition_heat

```
uint64_t* WordTransitionMetrics::transition_heat
```

transition_heat[i]: Number of times word with index i has been executed immediately after this word.

Dynamically allocated array of size DICTIONARY_SIZE. Initialized to NULL; allocated on first use to save memory for words that are never executed.

Referenced by forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), transition_metrics_cleanup(), transition_metrics_get_probability_q48(), transition_metrics_init(), transition_metrics_record(), transition_metrics_reset(), transition_metrics_should_speculate(), and transition_metrics_update_cache().

The documentation for this struct was generated from the following file:

- v3/include/physics_pipelining_metrics.h

6.174 xhci_cap_regs_t Struct Reference

```
#include <xhci.h>
```

Data Fields

- volatile uint8_t cap_length
- volatile uint8_t reserved0
- volatile uint16_t hci_version
- volatile uint32_t hcs_params1
- volatile uint32_t hcs_params2
- volatile uint32_t hcs_params3
- volatile uint32_t hcc_params1
- volatile uint32_t db_off
- volatile uint32_t rts_off
- volatile uint32_t hcc_params2

6.174.1 Field Documentation

6.174.1.1 cap_length

```
volatile uint8_t xhci_cap_regs_t::cap_length
```

Referenced by xhci_find_and_map().

6.174.1.2 db_off

```
volatile uint32_t xhci_cap_regs_t::db_off
```

Referenced by xhci_find_and_map().

6.174.1.3 hcc_params1

```
volatile uint32_t xhci_cap_regs_t::hcc_params1
```

Referenced by xhci_bringup(), xhci_ctx_bytes(), and xhci_take_from_bios().

6.174.1.4 hcc_params2

```
volatile uint32_t xhci_cap_regs_t::hcc_params2
```

6.174.1.5 hci_version

```
volatile uint16_t xhci_cap_regs_t::hci_version
```

6.174.1.6 hcs_params1

```
volatile uint32_t xhci_cap_regs_t::hcs_params1
```

Referenced by xhci_find_and_map().

6.174.1.7 hcs_params2

```
volatile uint32_t xhci_cap_regs_t::hcs_params2
```

Referenced by xhci_find_and_map().

6.174.1.8 hcs_params3

```
volatile uint32_t xhci_cap_regs_t::hcs_params3
```

6.174.1.9 reserved0

```
volatile uint8_t xhci_cap_regs_t::reserved0
```

6.174.1.10 rts_off

```
volatile uint32_t xhci_cap_regs_t::rts_off
```

Referenced by xhci_find_and_map().

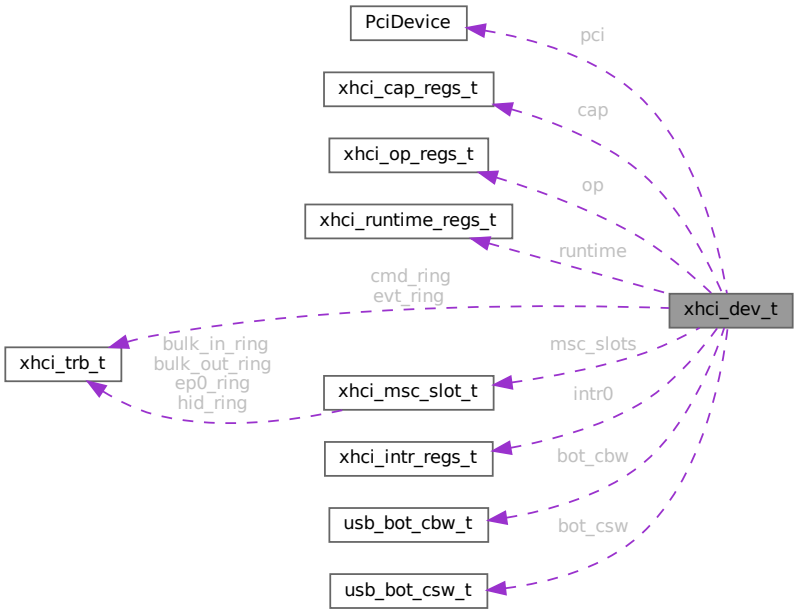
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.175 xhci_dev_t Struct Reference

`#include <xhci_driver.h>`

Collaboration diagram for xhci_dev_t:



Public Types

- enum {
  XHCI_CONN_IDLE = 0 , XHCI_CONN_AWAIT_PORT_RESET , XHCI_CONN_AWAIT_ENABLE_SLOT ,
  XHCI_CONN_AWAIT_ADDRESS_DEVICE ,
  XHCI_CONN_AWAIT_DISABLE_SLOT , XHCI_CONN_AWAIT_CONFIGURE_ENDPOINT , XHCI_CONN_AWAIT_RESET_EN
  , XHCI_CONN_AWAIT_SET_TR_DEQUEUE }
- enum {
  BOT_CMD_NONE = 0 , BOT_CMD_TEST_UNIT_READY , BOT_CMD_READ10 , BOT_CMD_READ_CAPACITY10
  ,
  BOT_CMD_WRITE10 }
- enum { BOT_STATUS_IDLE = 0 , BOT_STATUS_PASS , BOT_STATUS_FAILED , BOT_STATUS_TIMEOUT
  }
- enum { BOT_TUR_CHAIN_NONE = 0 , BOT_TUR_CHAIN_READ10 , BOT_TUR_CHAIN_READ_CAPACITY10
  , BOT_TUR_CHAIN_WRITE10 }

Data Fields

- PciDevice pci
- uint64_t bar0_phys
- xhci_cap_regs_t * cap
- xhci_op_regs_t * op
- xhci_runtime_regs_t * runtime

- xhci_doorbell_t * doorbell
- uint32_t max_slots
- uint32_t max_ports
- uint32_t max_intrs
- uint32_t max_scratchpad_bufs
- void * dcbaa
- void * scratchpad_arr
- xhci_trb_t * cmd_ring
- uint32_t cmd_ring_cycle
- uint32_t cmd_ring_enq
- xhci_trb_t * evt_ring
- void * evt_ring_seg_table
- uint32_t evt_ring_cycle
- uint32_t evt_ring_deq
- xhci_intr_regs_t * intr0
- uint32_t port_slot_id [32u]
- uint32_t pending_connect_port_id
- uint32_t pending_connect_speed
- struct {
  uint8_t valid
  uint8_t is_connect
  uint32_t port_id
  uint32_t portsc
  uint32_t slot_id
  } pending_events [32u]

- enum xhci_dev_t:: { ... } connect_state
- uint32_t pending_connect_slot_id
- uint32_t pending_disable_slot_id
- xhci_msc_slot_t * msc_slots
- usb_bot_cbw_t bot_cbw
- usb_bot_csw_t bot_csw
- uint32_t bot_next_tag
- uint32_t bot_last_tag
- uint8_t bot_data_buf [1024]
- uint32_t bot_expected_data_len
- enum xhci_dev_t:: { ... } bot_cmd_kind
- enum xhci_dev_t:: { ... } bot_last_status
- enum xhci_dev_t:: { ... } bot_tur_chain_target
- uint32_t bot_tur_retries
- uint32_t bot_read10_lba
- uint16_t bot_read10_num_blocks
- uint32_t bot_read10_block_size
- uint32_t bot_write10_lba
- uint16_t bot_write10_num_blocks
- uint32_t bot_write10_block_size
- uint32_t bot_cap_last_lba
- uint32_t bot_cap_block_size
- uint32_t bot_stall_recoveries
- uint32_t stall_dci
- uint8_t stall_ep_addr
- uint8_t bot_reset_clear_remaining
- uint32_t stall_retry_action

6.175.1 Member Enumeration Documentation

6.175.1.1 anonymous enum

anonymous enum

Enumerator

BOT_CMD_NONE	
BOT_CMD_TEST_UNIT_READY	
BOT_CMD_READ10	
BOT_CMD_READ_CAPACITY10	
BOT_CMD_WRITE10	

6.175.1.2 anonymous enum

anonymous enum

Enumerator

BOT_STATUS_IDLE	
BOT_STATUS_PASS	
BOT_STATUS_FAILED	
BOT_STATUS_TIMEOUT	

6.175.1.3 anonymous enum

anonymous enum

Enumerator

BOT_TUR_CHAIN_NONE	
BOT_TUR_CHAIN_READ10	
BOT_TUR_CHAIN_READ_CAPACITY10	
BOT_TUR_CHAIN_WRITE10	

6.175.1.4 anonymous enum

anonymous enum

Enumerator

XHCI_CONN_IDLE	
XHCI_CONN_AWAIT_PORT_RESET	
XHCI_CONN_AWAIT_ENABLE_SLOT	
XHCI_CONN_AWAIT_ADDRESS_DEVICE	

Enumerator

XHCI_CONN_AWAIT_DISABLE_SLOT	
XHCI_CONN_AWAIT_CONFIGURE_ENDPOINT	
XHCI_CONN_AWAIT_RESET_ENDPOINT	
XHCI_CONN_AWAIT_SET_TR_DEQUEUE	

6.175.2 Field Documentation

6.175.2.1 bar0_phys

```
uint64_t xhci_dev_t::bar0_phys
```

Referenced by xhci_find_and_map().

6.175.2.2 bot_cap_block_size

```
uint32_t xhci_dev_t::bot_cap_block_size
```

Referenced by blkio_usb_open_msc(), xhci_bringup(), and xhci_poll_one().

6.175.2.3 bot_cap_last_lba

```
uint32_t xhci_dev_t::bot_cap_last_lba
```

Referenced by blkio_usb_open_msc(), xhci_bringup(), and xhci_poll_one().

6.175.2.4 bot_cbw

```
usb_bot_cbw_t xhci_dev_t::bot_cbw
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), and xhci_bot_send_write10().

6.175.2.5 []

```
enum { ... } xhci_dev_t::bot_cmd_kind
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_wait_for_idle(), xhci_bringup(), xhci_handle_bulk_stall(), xhci_poll_one(), and xhci_stall_fail().

6.175.2.6 bot_csw

```
usb_bot_csw_t xhci_dev_t::bot_csw
```

Referenced by xhci_bot_receive_csw(), and xhci_poll_one().

6.175.2.7 bot_data_buf

```
uint8_t xhci_dev_t::bot_data_buf[1024]
```

Referenced by usb_blk_read(), usb_blk_write(), xhci_bot_read_block(), xhci_bot_read_data_in(), xhci_bot_send_read10(), xhci_bot_send_write10(), xhci_bot_write_block(), xhci_bot_write_data_out(), and xhci_poll_one().

6.175.2.8 bot_expected_data_len

```
uint32_t xhci_dev_t::bot_expected_data_len
```

Referenced by xhci_bot_read_data_in(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready xhci_bot_send_write10(), xhci_bot_write_data_out(), xhci_bringup(), and xhci_poll_one().

6.175.2.9 []

```
enum { ... } xhci_dev_t::bot_last_status
```

Referenced by xhci_bot_wait_for_idle(), xhci_bringup(), xhci_poll_one(), and xhci_stall_fail().

6.175.2.10 bot_last_tag

```
uint32_t xhci_dev_t::bot_last_tag
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bringup(), and xhci_poll_one().

6.175.2.11 bot_next_tag

```
uint32_t xhci_dev_t::bot_next_tag
```

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), and xhci_bringup().

6.175.2.12 bot_read10_block_size

```
uint32_t xhci_dev_t::bot_read10_block_size
```

Referenced by xhci_bot_read_block(), xhci_bringup(), and xhci_poll_one().

6.175.2.13 bot_read10_lba

```
uint32_t xhci_dev_t::bot_read10_lba
```

Referenced by xhci_bot_read_block(), xhci_bringup(), and xhci_poll_one().

6.175.2.14 bot_read10_num_blocks

```
uint16_t xhci_dev_t::bot_read10_num_blocks
```

Referenced by xhci_bot_read_block(), xhci_bringup(), and xhci_poll_one().

6.175.2.15 bot_reset_clear_remaining

```
uint8_t xhci_dev_t::bot_reset_clear_remaining
```

Referenced by xhci_poll_one(), and xhci_stall_fail().

6.175.2.16 bot_stall_recoveries

```
uint32_t xhci_dev_t::bot_stall_recoveries
```

Referenced by xhci_handle_bulk_stall().

6.175.2.17 []

```
enum { ... } xhci_dev_t::bot_tur_chain_target
```

Referenced by xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_write_block(), xhci_bringup(), and xhci_poll_one().

6.175.2.18 bot_tur_retries

```
uint32_t xhci_dev_t::bot_tur_retries
```

Referenced by xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_write_block(), xhci_bringup(), and xhci_poll_one().

6.175.2.19 bot_write10_block_size

```
uint32_t xhci_dev_t::bot_write10_block_size
```

Referenced by xhci_bot_write_block(), and xhci_poll_one().

6.175.2.20 bot_write10_lba

```
uint32_t xhci_dev_t::bot_write10_lba
```

Referenced by xhci_bot_write_block(), and xhci_poll_one().

6.175.2.21 bot_write10_num_blocks

```
uint16_t xhci_dev_t::bot_write10_num_blocks
```

Referenced by xhci_bot_write_block(), and xhci_poll_one().

6.175.2.22 cap

```
xhci_cap_regs_t* xhci_dev_t::cap
```

Referenced by xhci_bringup(), xhci_ctx_bytes(), xhci_find_and_map(), and xhci_take_from_bios().

6.175.2.23 cmd_ring

```
xhci_trb_t* xhci_dev_t::cmd_ring
```

Referenced by xhci_bringup(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), xhci_cmd_configure_hid_endpoint(), xhci_cmd_disable_slot(), xhci_cmd_enable_slot(), xhci_cmd_reset_endpoint(), xhci_cmd_set_tr_dequeue_pointer(), and xhci_submit_command().

6.175.2.24 cmd_ring_cycle

```
uint32_t xhci_dev_t::cmd_ring_cycle
```

Referenced by xhci_bringup(), and xhci_submit_command().

6.175.2.25 cmd_ring_enq

```
uint32_t xhci_dev_t::cmd_ring_enq
```

Referenced by xhci_bringup(), and xhci_submit_command().

6.175.2.26 []

```
enum { ... } xhci_dev_t::connect_state
```

Referenced by xhci_bringup(), xhci_drain_pending_event(), xhci_handle_bulk_stall(), xhci_handle_port_connected(), and xhci_poll_one().

6.175.2.27 dcbaa

```
void* xhci_dev_t::dcbaa
```

Referenced by xhci_bringup(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), xhci_cmd_configure_hid_endpoint(), and xhci_poll_one().

6.175.2.28 doorbell

```
xhci_doorbell_t* xhci_dev_t::doorbell
```

Referenced by xhci_bulk_in_enqueue_and_ring(), xhci_bulk_out_enqueue_and_ring(), xhci_ep0_bot_mass_storage_reset(), xhci_ep0_clear_endpoint_halt(), xhci_ep0_get_config_descriptor(), xhci_ep0_get_device_descriptor(), xhci_ep0_hid_set_leds(), xhci_ep0_hid_set_protocol(), xhci_ep0_set_configuration(), xhci_find_and_map(), xhci_hid_queue_report(), and xhci_submit_command().

6.175.2.29 evt_ring

```
xhci_trb_t* xhci_dev_t::evt_ring
```

Referenced by xhci_bringup(), and xhci_poll_one().

6.175.2.30 evt_ring_cycle

```
uint32_t xhci_dev_t::evt_ring_cycle
```

Referenced by xhci_bringup(), and xhci_poll_one().

6.175.2.31 evt_ring_deq

```
uint32_t xhci_dev_t::evt_ring_deq
```

Referenced by xhci_bringup(), and xhci_poll_one().

6.175.2.32 evt_ring_seg_table

```
void* xhci_dev_t::evt_ring_seg_table
```

Referenced by xhci_bringup().

6.175.2.33 intr0

```
xhci_intr_regs_t* xhci_dev_t::intr0
```

Referenced by xhci_bringup(), and xhci_poll_one().

6.175.2.34 is_connect

```
uint8_t xhci_dev_t::is_connect
```

Referenced by xhci_drain_pending_event(), and xhci_queue_pending_event().

6.175.2.35 max_intrs

```
uint32_t xhci_dev_t::max_intrs
```

Referenced by xhci_find_and_map().

6.175.2.36 max_ports

```
uint32_t xhci_dev_t::max_ports
```

Referenced by xhci_find_and_map(), xhci_port_regs(), and xhci_scan_ports_for_already_connected().

6.175.2.37 max_scratchpad_bufs

```
uint32_t xhci_dev_t::max_scratchpad_bufs
```

Referenced by xhci_bringup(), and xhci_find_and_map().

6.175.2.38 max_slots

```
uint32_t xhci_dev_t::max_slots
```

Referenced by sk_repl_idle(), sk_v4_idle(), usb_blk_state_for(), xhci_bringup(), xhci_find_and_map(), xhci_msc_slot_for(), and xhci_poll_one().

6.175.2.39 msc_slots

```
xhci_msc_slot_t* xhci_dev_t::msc_slots
```

Referenced by xhci_bringup(), and xhci_msc_slot_for().

6.175.2.40 op

```
xhci_op_regs_t* xhci_dev_t::op
```

Referenced by xhci_bringup(), xhci_find_and_map(), and xhci_port_regs().

6.175.2.41 pci

```
PciDevice xhci_dev_t::pci
```

Referenced by xhci_find_and_map().

6.175.2.42 pending_connect_port_id

```
uint32_t xhci_dev_t::pending_connect_port_id
```

Referenced by xhci_bringup(), xhci_handle_port_connected(), and xhci_poll_one().

6.175.2.43 pending_connect_slot_id

```
uint32_t xhci_dev_t::pending_connect_slot_id
```

Referenced by xhci_bringup(), and xhci_poll_one().

6.175.2.44 pending_connect_speed

```
uint32_t xhci_dev_t::pending_connect_speed
```

Referenced by xhci_bringup(), xhci_handle_port_connected(), and xhci_poll_one().

6.175.2.45 pending_disable_slot_id

```
uint32_t xhci_dev_t::pending_disable_slot_id
```

Referenced by xhci_bringup(), xhci_drain_pending_event(), and xhci_poll_one().

6.175.2.46 [struct]

```
struct { ... } xhci_dev_t::pending_events[ 32u ]
```

Referenced by xhci_bringup(), xhci_drain_pending_event(), and xhci_queue_pending_event().

6.175.2.47 port_id

```
uint32_t xhci_dev_t::port_id
```

Referenced by xhci_drain_pending_event(), and xhci_queue_pending_event().

6.175.2.48 port_slot_id

```
uint32_t xhci_dev_t::port_slot_id[32u]
```

Referenced by xhci_bringup(), and xhci_poll_one().

6.175.2.49 portsc

```
uint32_t xhci_dev_t::portsc
```

Referenced by xhci_drain_pending_event(), and xhci_queue_pending_event().

6.175.2.50 runtime

```
xhci_runtime_regs_t* xhci_dev_t::runtime
```

Referenced by xhci_bringup(), and xhci_find_and_map().

6.175.2.51 scratchpad_arr

```
void* xhci_dev_t::scratchpad_arr
```

Referenced by xhci_bringup().

6.175.2.52 slot_id

```
uint32_t xhci_dev_t::slot_id
```

Referenced by xhci_drain_pending_event(), and xhci_queue_pending_event().

6.175.2.53 stall_dci

```
uint32_t xhci_dev_t::stall_dci
```

Referenced by xhci_handle_bulk_stall().

6.175.2.54 stall_ep_addr

```
uint8_t xhci_dev_t::stall_ep_addr
```

Referenced by xhci_handle_bulk_stall(), and xhci_poll_one().

6.175.2.55 stall_retry_action

```
uint32_t xhci_dev_t::stall_retry_action
```

Referenced by xhci_handle_bulk_stall(), xhci_poll_one(), and xhci_stall_fail().

6.175.2.56 valid

```
uint8_t xhci_dev_t::valid
```

Referenced by xhci_bringup(), xhci_drain_pending_event(), and xhci_queue_pending_event().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci_driver.h

6.176 xhci_ep_ctx32_t Struct Reference

`#include <xhci.h>`

Data Fields

- volatile uint32_t dword0
- volatile uint32_t dword1
- volatile uint64_t tr_dequeue_ptr
- volatile uint32_t dword4
- volatile uint32_t reserved [3]

6.176.1 Field Documentation

6.176.1.1 dword0

`volatile uint32_t xhci_ep_ctx32_t::dword0`

Referenced by xhci_cmd_configure_hid_endpoint().

6.176.1.2 dword1

`volatile uint32_t xhci_ep_ctx32_t::dword1`

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

6.176.1.3 dword4

`volatile uint32_t xhci_ep_ctx32_t::dword4`

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

6.176.1.4 reserved

`volatile uint32_t xhci_ep_ctx32_t::reserved[3]`

6.176.1.5 tr_dequeue_ptr

`volatile uint64_t xhci_ep_ctx32_t::tr_dequeue_ptr`

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.177 xhci_input_ctrl_ctx32_t Struct Reference

`#include <xhci.h>`

Data Fields

- volatile uint32_t drop_flags
- volatile uint32_t add_flags
- volatile uint32_t reserved [5]
- volatile uint32_t config_word

6.177.1 Field Documentation

6.177.1.1 add_flags

`volatile uint32_t xhci_input_ctrl_ctx32_t::add_flags`

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

6.177.1.2 config_word

`volatile uint32_t xhci_input_ctrl_ctx32_t::config_word`

6.177.1.3 drop_flags

`volatile uint32_t xhci_input_ctrl_ctx32_t::drop_flags`

6.177.1.4 reserved

`volatile uint32_t xhci_input_ctrl_ctx32_t::reserved[5]`

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.178 xhci_intr_regs_t Struct Reference

`#include <xhci.h>`

Data Fields

- volatile uint32_t iman
- volatile uint32_t imod
- volatile uint32_t erstsz
- volatile uint32_t reserved0
- volatile uint64_t erstba
- volatile uint64_t erdp

6.178.1 Field Documentation

6.178.1.1 erdp

```
volatile uint64_t xhci_intr_regs_t::erdp
```

Referenced by xhci_bringup(), and xhci_poll_one().

6.178.1.2 erstba

```
volatile uint64_t xhci_intr_regs_t::erstba
```

Referenced by xhci_bringup().

6.178.1.3 erstsz

```
volatile uint32_t xhci_intr_regs_t::erstsz
```

Referenced by xhci_bringup().

6.178.1.4 iman

```
volatile uint32_t xhci_intr_regs_t::iman
```

6.178.1.5 imod

```
volatile uint32_t xhci_intr_regs_t::imod
```

6.178.1.6 reserved0

```
volatile uint32_t xhci_intr_regs_t::reserved0
```

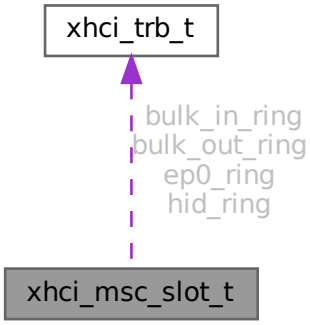
The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.179 xhci_msc_slot_t Struct Reference

`#include <xhci_driver.h>`

Collaboration diagram for xhci_msc_slot_t:



Data Fields

- uint32_t in_use
- void * input_ctx
- void * device_ctx
- xhci_trb_t * ep0_ring
- uint32_t ep0_ring_cycle
- uint32_t ep0_ring_enq
- uint8_t device_descriptor [18]
- uint8_t config_descriptor [128]
- uint16_t config_total_length
- uint8_t bulk_in_ep_addr
- uint16_t bulk_in_max_packet
- uint8_t bulk_out_ep_addr
- uint16_t bulk_out_max_packet
- xhci_trb_t * bulk_in_ring
- uint32_t bulk_in_ring_cycle
- uint32_t bulk_in_ring_enq
- xhci_trb_t * bulk_out_ring
- uint32_t bulk_out_ring_cycle
- uint32_t bulk_out_ring_enq
- uint8_t hid_kbd
- uint8_t hid_running
- uint8_t hid_iface
- uint8_t hid_ep_addr
- uint16_t hid_max_packet
- uint8_t hid_interval
- xhci_trb_t * hid_ring
- uint32_t hid_ring_cycle
- uint32_t hid_ring_enq

- uint8_t * hid_buf
- uint8_t hid_prev [8]
- uint8_t hid_leds_sent
- uint8_t bot_msc_attach_pending
- uint8_t bot_msc_attached
- uint8_t bot_msc_detach_pending
- xhci_transfer_purpose_t transfer_purpose
- xhci_next_action_t next_action
- uint16_t next_action_length
- uint8_t next_action_config_value

6.179.1 Field Documentation

6.179.1.1 bot_msc_attach_pending

```
uint8_t xhci_msc_slot_t::bot_msc_attach_pending
```

Referenced by sk_repl_idle(), sk_v4_idle(), and xhci_poll_one().

6.179.1.2 bot_msc_attached

```
uint8_t xhci_msc_slot_t::bot_msc_attached
```

Referenced by sk_v4_idle(), sk_word_blk_attach_ack(), and xhci_poll_one().

6.179.1.3 bot_msc_detach_pending

```
uint8_t xhci_msc_slot_t::bot_msc_detach_pending
```

Referenced by sk_repl_idle(), sk_v4_idle(), and xhci_poll_one().

6.179.1.4 bulk_in_ep_addr

```
uint8_t xhci_msc_slot_t::bulk_in_ep_addr
```

Referenced by xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_block(), xhci_bulk_in_enqueue_and_ring(), xhci_cmd_configure_endpoint(), xhci_handle_bulk_stall(), and xhci_poll_one().

6.179.1.5 bulk_in_max_packet

```
uint16_t xhci_msc_slot_t::bulk_in_max_packet
```

Referenced by xhci_cmd_configure_endpoint(), and xhci_poll_one().

6.179.1.6 bulk_in_ring

```
xhci_trb_t* xhci_msc_slot_t::bulk_in_ring
```

Referenced by xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_read_data_in(), xhci_bot_receive_csw(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_block(), xhci_bulk_in_enqueue_and_ring(), xhci_cmd_configure_endpoint(), and xhci_poll_one().

6.179.1.7 bulk_in_ring_cycle

```
uint32_t xhci_msc_slot_t::bulk_in_ring_cycle
```

Referenced by xhci_bulk_in_enqueue_and_ring(), xhci_cmd_configure_endpoint(), and xhci_poll_one().

6.179.1.8 bulk_in_ring_enq

```
uint32_t xhci_msc_slot_t::bulk_in_ring_enq
```

Referenced by xhci_bulk_in_enqueue_and_ring(), xhci_cmd_configure_endpoint(), and xhci_poll_one().

6.179.1.9 bulk_out_ep_addr

```
uint8_t xhci_msc_slot_t::bulk_out_ep_addr
```

Referenced by xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_block(), xhci_bulk_out_enqueue_and_ring(), xhci_cmd_configure_endpoint(), xhci_handle_bulk_stall(), and xhci_poll_one().

6.179.1.10 bulk_out_max_packet

```
uint16_t xhci_msc_slot_t::bulk_out_max_packet
```

Referenced by xhci_cmd_configure_endpoint(), and xhci_poll_one().

6.179.1.11 bulk_out_ring

```
xhci_trb_t* xhci_msc_slot_t::bulk_out_ring
```

Referenced by xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_block(), xhci_bot_write_data_out(), xhci_bulk_out_enqueue_and_ring(), xhci_cmd_configure_endpoint(), and xhci_poll_one().

6.179.1.12 bulk_out_ring_cycle

```
uint32_t xhci_msc_slot_t::bulk_out_ring_cycle
```

Referenced by xhci_bulk_out_enqueue_and_ring(), xhci_cmd_configure_endpoint(), and xhci_poll_one().

6.179.1.13 bulk_out_ring_enq

```
uint32_t xhci_msc_slot_t::bulk_out_ring_enq
```

Referenced by xhci_bulk_out_enqueue_and_ring(), xhci_cmd_configure_endpoint(), and xhci_poll_one().

6.179.1.14 config_descriptor

```
uint8_t xhci_msc_slot_t::config_descriptor[128]
```

Referenced by xhci_ep0_get_config_descriptor(), and xhci_poll_one().

6.179.1.15 config_total_length

```
uint16_t xhci_msc_slot_t::config_total_length
```

Referenced by xhci_poll_one().

6.179.1.16 device_ctx

```
void* xhci_msc_slot_t::device_ctx
```

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

6.179.1.17 device_descriptor

```
uint8_t xhci_msc_slot_t::device_descriptor[18]
```

Referenced by xhci_ep0_get_device_descriptor(), and xhci_poll_one().

6.179.1.18 ep0_ring

```
xhci_trb_t* xhci_msc_slot_t::ep0_ring
```

Referenced by xhci_cmd_address_device(), xhci_ep0_bot_mass_storage_reset(), xhci_ep0_clear_endpoint_halt(), xhci_ep0_enqueue_trb(), xhci_ep0_get_config_descriptor(), xhci_ep0_get_device_descriptor(), xhci_ep0_hid_set_leds(), xhci_ep0_hid_set_protocol(), and xhci_ep0_set_configuration().

6.179.1.19 ep0_ring_cycle

```
uint32_t xhci_msc_slot_t::ep0_ring_cycle
```

Referenced by xhci_cmd_address_device(), and xhci_ep0_enqueue_trb().

6.179.1.20 ep0_ring_enq

```
uint32_t xhci_msc_slot_t::ep0_ring_enq
```

Referenced by xhci_cmd_address_device(), and xhci_ep0_enqueue_trb().

6.179.1.21 hid_buf

```
uint8_t* xhci_msc_slot_t::hid_buf
```

Referenced by xhci_cmd_configure_hid_endpoint(), xhci_ep0_hid_set_leds(), xhci_hid_queue_report(), and xhci_poll_one().

6.179.1.22 hid_ep_addr

```
uint8_t xhci_msc_slot_t::hid_ep_addr
```

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_hid_endpoint(), xhci_hid_queue_report(), and xhci_poll_one().

6.179.1.23 hid_iface

```
uint8_t xhci_msc_slot_t::hid_iface
```

Referenced by xhci_ep0_hid_set_leds(), xhci_ep0_hid_set_protocol(), and xhci_poll_one().

6.179.1.24 hid_interval

```
uint8_t xhci_msc_slot_t::hid_interval
```

Referenced by xhci_cmd_configure_hid_endpoint(), and xhci_poll_one().

6.179.1.25 hid_kbd

```
uint8_t xhci_msc_slot_t::hid_kbd
```

Referenced by xhci_cmd_address_device(), and xhci_poll_one().

6.179.1.26 hid_leds_sent

```
uint8_t xhci_msc_slot_t::hid_leds_sent
```

Referenced by xhci_ep0_hid_set_leds(), and xhci_poll_one().

6.179.1.27 hid_max_packet

```
uint16_t xhci_msc_slot_t::hid_max_packet
```

Referenced by xhci_cmd_configure_hid_endpoint(), xhci_hid_queue_report(), and xhci_poll_one().

6.179.1.28 hid_prev

```
uint8_t xhci_msc_slot_t::hid_prev[8]
```

Referenced by xhci_poll_one().

6.179.1.29 hid_ring

```
xhci_trb_t* xhci_msc_slot_t::hid_ring
```

Referenced by xhci_cmd_configure_hid_endpoint(), and xhci_hid_queue_report().

6.179.1.30 hid_ring_cycle

```
uint32_t xhci_msc_slot_t::hid_ring_cycle
```

Referenced by xhci_cmd_configure_hid_endpoint(), and xhci_hid_queue_report().

6.179.1.31 hid_ring_enq

```
uint32_t xhci_msc_slot_t::hid_ring_enq
```

Referenced by xhci_cmd_configure_hid_endpoint(), and xhci_hid_queue_report().

6.179.1.32 hid_running

```
uint8_t xhci_msc_slot_t::hid_running
```

Referenced by xhci_cmd_address_device(), and xhci_poll_one().

6.179.1.33 in_use

```
uint32_t xhci_msc_slot_t::in_use
```

Referenced by xhci_cmd_address_device(), and xhci_poll_one().

6.179.1.34 input_ctx

```
void* xhci_msc_slot_t::input_ctx
```

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

6.179.1.35 next_action

```
xhci_next_action_t xhci_msc_slot_t::next_action
```

Referenced by xhci_handle_bulk_stall(), and xhci_poll_one().

6.179.1.36 next_action_config_value

```
uint8_t xhci_msc_slot_t::next_action_config_value
```

Referenced by xhci_poll_one().

6.179.1.37 next_action_length

```
uint16_t xhci_msc_slot_t::next_action_length
```

Referenced by xhci_poll_one().

6.179.1.38 transfer_purpose

```
xhci_transfer_purpose_t xhci_msc_slot_t::transfer_purpose
```

Referenced by xhci_bot_read_data_in(), xhci_bot_receive_csw(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_data_out(), xhci_ep0_bot_mass_storage_reset(), xhci_ep0_clear_endpoint_halt(), xhci_ep0_get_config_descriptor(), xhci_ep0_get_device_descriptor(), xhci_ep0_hid_set_leds(), xhci_ep0_hid_set_protocol(), xhci_ep0_set_configuration(), and xhci_poll_one().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci_driver.h

6.180 xhci_op_regs_t Struct Reference

```
#include <xhci.h>
```

Data Fields

- volatile uint32_t usb_cmd
- volatile uint32_t usb_sts
- volatile uint32_t page_size
- volatile uint32_t reserved0 [2]
- volatile uint32_t dn_ctrl
- volatile uint64_t crcr
- volatile uint32_t reserved1 [4]
- volatile uint64_t dcbaap
- volatile uint32_t config

6.180.1 Field Documentation

6.180.1.1 config

```
volatile uint32_t xhci_op_regs_t::config
```

Referenced by xhci_bringup().

6.180.1.2 crcr

```
volatile uint64_t xhci_op_regs_t::crcr
```

Referenced by xhci_bringup().

6.180.1.3 dcbaap

```
volatile uint64_t xhci_op_regs_t::dcbaap
```

Referenced by xhci_bringup().

6.180.1.4 dn_ctrl

```
volatile uint32_t xhci_op_regs_t::dn_ctrl
```

6.180.1.5 page_size

```
volatile uint32_t xhci_op_regs_t::page_size
```

Referenced by xhci_bringup().

6.180.1.6 reserved0

```
volatile uint32_t xhci_op_regs_t::reserved0[2]
```

6.180.1.7 reserved1

```
volatile uint32_t xhci_op_regs_t::reserved1[4]
```

6.180.1.8 usb_cmd

```
volatile uint32_t xhci_op_regs_t::usb_cmd
```

Referenced by xhci_bringup().

6.180.1.9 usb_sts

```
volatile uint32_t xhci_op_regs_t::usb_sts
```

Referenced by xhci_bringup().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.181 xhci_port_regs_t Struct Reference

```
#include <xhci.h>
```

Data Fields

- volatile uint32_t portsc
- volatile uint32_t portpmsc
- volatile uint32_t portli
- volatile uint32_t porthlpmc

6.181.1 Field Documentation

6.181.1.1 porthlpmc

```
volatile uint32_t xhci_port_regs_t::porthlpmc
```

6.181.1.2 portli

```
volatile uint32_t xhci_port_regs_t::portli
```

6.181.1.3 portpmsc

```
volatile uint32_t xhci_port_regs_t::portpmsc
```

6.181.1.4 portsc

```
volatile uint32_t xhci_port_regs_t::portsc
```

Referenced by xhci_handle_port_connected(), xhci_poll_one(), and xhci_scan_ports_for_already_connected().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.182 xhci_runtime_regs_t Struct Reference

`#include <xhci.h>`

Data Fields

- volatile uint32_t mf_index
- volatile uint32_t reserved0 [7]

6.182.1 Field Documentation

6.182.1.1 mf_index

`volatile uint32_t xhci_runtime_regs_t::mf_index`

6.182.1.2 reserved0

`volatile uint32_t xhci_runtime_regs_t::reserved0[7]`

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.183 xhci_slot_ctx32_t Struct Reference

`#include <xhci.h>`

Data Fields

- volatile uint32_t dword0
- volatile uint32_t dword1
- volatile uint32_t dword2
- volatile uint32_t dword3
- volatile uint32_t reserved [4]

6.183.1 Field Documentation

6.183.1.1 dword0

`volatile uint32_t xhci_slot_ctx32_t::dword0`

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

6.183.1.2 dword1

```
volatile uint32_t xhci_slot_ctx32_t::dword1
```

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

6.183.1.3 dword2

```
volatile uint32_t xhci_slot_ctx32_t::dword2
```

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

6.183.1.4 dword3

```
volatile uint32_t xhci_slot_ctx32_t::dword3
```

6.183.1.5 reserved

```
volatile uint32_t xhci_slot_ctx32_t::reserved[4]
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.184 xhci_trb_t Struct Reference

```
#include <xhci.h>
```

Data Fields

- volatile uint64_t parameter
- volatile uint32_t status
- volatile uint32_t control

6.184.1 Field Documentation

6.184.1.1 control

```
volatile uint32_t xhci_trb_t::control
```

Referenced by xhci_bringup(), xhci_bulk_in_enqueue_and_ring(), xhci_bulk_out_enqueue_and_ring(), xhci_cmd_address_device(), xhci_ep0_enqueue_trb(), xhci_hid_queue_report(), xhci_poll_one(), and xhci_submit_command().

6.184.1.2 parameter

```
volatile uint64_t xhci_trb_t::parameter
```

Referenced by xhci_bringup(), xhci_bulk_in_enqueue_and_ring(), xhci_bulk_out_enqueue_and_ring(), xhci_cmd_address_device(), xhci_ep0_enqueue_trb(), xhci_hid_queue_report(), xhci_poll_one(), and xhci_submit_command().

6.184.1.3 status

```
volatile uint32_t xhci_trb_t::status
```

Referenced by xhci_bringup(), xhci_bulk_in_enqueue_and_ring(), xhci_bulk_out_enqueue_and_ring(), xhci_cmd_address_device(), xhci_ep0_enqueue_trb(), xhci_hid_queue_report(), xhci_poll_one(), and xhci_submit_command().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xhci.h

6.185 XXHash64State Struct Reference

Streaming state structure.

```
#include <xxhash64.h>
```

Data Fields

- uint64_t total_len
- uint64_t v1
- uint64_t v2
- uint64_t v3
- uint64_t v4
- uint8_t buffer [32]
- uint32_t buffer_size
- uint64_t seed

6.185.1 Detailed Description

Streaming state structure.

6.185.2 Field Documentation

6.185.2.1 buffer

```
uint8_t XXHash64State::buffer[32]
```

Referenced by xxhash64_digest(), and xxhash64_update().

6.185.2.2 buffer_size

```
uint32_t XXHash64State::buffer_size
```

Referenced by xxhash64_digest(), xxhash64_reset(), and xxhash64_update().

6.185.2.3 seed

```
uint64_t XXHash64State::seed
```

Referenced by xxhash64_digest(), and xxhash64_reset().

6.185.2.4 total_len

```
uint64_t XXHash64State::total_len
```

Referenced by xxhash64_digest(), xxhash64_reset(), and xxhash64_update().

6.185.2.5 v1

```
uint64_t XXHash64State::v1
```

Referenced by xxhash64_digest(), xxhash64_reset(), and xxhash64_update().

6.185.2.6 v2

```
uint64_t XXHash64State::v2
```

Referenced by xxhash64_digest(), xxhash64_reset(), and xxhash64_update().

6.185.2.7 v3

```
uint64_t XXHash64State::v3
```

Referenced by xxhash64_digest(), xxhash64_reset(), and xxhash64_update().

6.185.2.8 v4

```
uint64_t XXHash64State::v4
```

Referenced by xxhash64_digest(), xxhash64_reset(), and xxhash64_update().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/xxhash64.h

6.186 zuse_cert_devblock_t Struct Reference

`#include <zuse_cert_devblock.h>`

Data Fields

- uint32_t magic
- uint32_t version
- uint8_t seed [32]
- uint8_t pubkey [32]
- uint64_t crc
- uint8_t _pad [4096 -(4+4+32+32+8)]

6.186.1 Field Documentation

6.186.1.1 _pad

```
uint8_t zuse_cert_devblock_t::_pad[4096 -(4+4+32+32+8)]
```

6.186.1.2 crc

```
uint64_t zuse_cert_devblock_t::crc
```

6.186.1.3 magic

```
uint32_t zuse_cert_devblock_t::magic
```

6.186.1.4 pubkey

```
uint8_t zuse_cert_devblock_t::pubkey[32]
```

6.186.1.5 seed

```
uint8_t zuse_cert_devblock_t::seed[32]
```

6.186.1.6 version

```
uint32_t zuse_cert_devblock_t::version
```

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/zuse_cert_devblock.h

6.187 zuse_genesis_marker_t Struct Reference

`#include <zuse_genesis_marker.h>`

Data Fields

- uint32_t magic
- uint32_t version
- uint8_t zuse_pubkey [32]
- uint64_t crc
- uint8_t _pad [4096 -(4+4+32+8)]

6.187.1 Field Documentation

6.187.1.1 _pad

`uint8_t zuse_genesis_marker_t::_pad[4096 -(4+4+32+8)]`

6.187.1.2 crc

`uint64_t zuse_genesis_marker_t::crc`

Referenced by capsule_zuse_boot_try_attach(), and genesis_marker_read().

6.187.1.3 magic

`uint32_t zuse_genesis_marker_t::magic`

Referenced by capsule_zuse_boot_try_attach(), and genesis_marker_read().

6.187.1.4 version

`uint32_t zuse_genesis_marker_t::version`

Referenced by capsule_zuse_boot_try_attach(), and genesis_marker_read().

6.187.1.5 zuse_pubkey

`uint8_t zuse_genesis_marker_t::zuse_pubkey[32]`

Referenced by capsule_zuse_boot_check(), capsule_zuse_boot_root_pubkey(), and capsule_zuse_boot_try_attach().

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/zuse_genesis_marker.h

6.188 zuse_genesis_marker_v2_t Struct Reference

`#include <zuse_genesis_marker.h>`

Data Fields

- uint32_t magic
- uint32_t version
- uint8_t proxy_pubkey [32]
- uint8_t real_pubkey [32]
- uint32_t has_real
- uint32_t _reserved
- uint64_t crc
- uint8_t _pad [4096 -(4+4+32+32+4+4+8)]

6.188.1 Field Documentation

6.188.1.1 _pad

`uint8_t zuse_genesis_marker_v2_t::_pad[4096 -(4+4+32+32+4+4+8)]`

6.188.1.2 _reserved

`uint32_t zuse_genesis_marker_v2_t::_reserved`

6.188.1.3 crc

`uint64_t zuse_genesis_marker_v2_t::crc`

6.188.1.4 has_real

`uint32_t zuse_genesis_marker_v2_t::has_real`

6.188.1.5 magic

`uint32_t zuse_genesis_marker_v2_t::magic`

6.188.1.6 proxy_pubkey

`uint8_t zuse_genesis_marker_v2_t::proxy_pubkey[32]`

6.188.1.7 real_pubkey

`uint8_t zuse_genesis_marker_v2_t::real_pubkey[32]`

6.188.1.8 version

`uint32_t zuse_genesis_marker_v2_t::version`

The documentation for this struct was generated from the following file:

- kernel/include/starkernel/zuse_genesis_marker.h

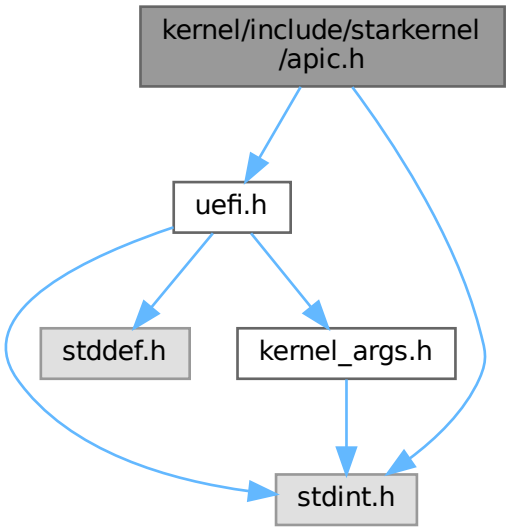
Chapter 7

File Documentation

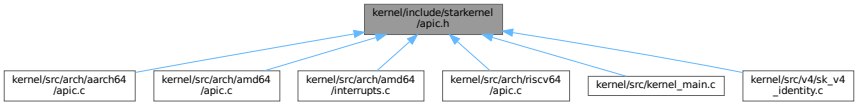
7.1 kernel/include/starkernel/apic.h File Reference

```
#include "uefi.h"
#include <stdint.h>
```

Include dependency graph for apic.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define APIC_TIMER_VECTOR 0x20

  apic.h - Local APIC interface
- #define APIC_SPURIOUS_VECTOR 0xFF

Functions

- int apic_init (BootInfo *boot_info)

  Initialise the GICv2 distributor and CPU interface (M4 milestone).
- uint8_t apic_id (void)

  Return this CPU's xAPIC ID.
- void apic_eoi (void)

  Signal End of Interrupt (common cross-ISA signature — see below).
- int apic_timer_init (uint64_t tsc_hz, uint32_t tick_hz)

  Compute the expected system-counter ticks per heartbeat period.
- void apic_timer_start (void)

  Start the APIC timer (enables periodic interrupts).
- void apic_timer_stop (void)

  Stop the APIC timer (disables periodic interrupts).
- void apic_timer_rearm (void)

  Re-arm the APIC timer at the current adaptive period (item 0.8, ?26).
- uint64_t apic_timer_period_tsc (void)

  Get the configured timer period in TSC ticks.

7.1.1 Macro Definition Documentation

7.1.1.1 APIC_SPURIOUS_VECTOR

```
#define APIC_SPURIOUS_VECTOR 0xFF
```

7.1.1.2 APIC_TIMER_VECTOR

```
#define APIC_TIMER_VECTOR 0x20
```

apic.h - Local APIC interface

7.1.2 Function Documentation

7.1.2.1 apic_eoi()

```
void apic_eoi (
            void  )
```

Signal End of Interrupt (common cross-ISA signature — see below).

The shared apic.h interface has no way to pass which interrupt is being completed, but GICv2's GICC↩ _EOIR needs the exact INTID GICC_IAR returned, not just "an" EOI. aarch64_irq_handler() calls apic_eoi_intid() directly with that value instead; this form exists only to satisfy the common call site and is not used on the interrupt path GIC brings up.

Signal End of Interrupt (common cross-ISA signature — see below).

Writes zero to APIC_REG_EOI (offset 0x0B0). This informs the APIC that the currently serviced interrupt has been handled so that the next interrupt in the vector's priority class can be delivered. Must be called at the end of every interrupt service routine before IRET; omitting the EOI stalls all future interrupt delivery at the same or lower priority.

For the APIC timer heartbeat path this is called inside isr_common_handler() immediately after heartbeat_tick().

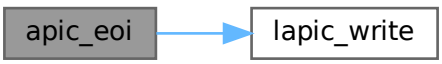
Signal End of Interrupt (common cross-ISA signature — see below).

On x86-64 this writes to the Local APIC EOI register. On RISC-V EOI is handled by reading the PLIC claim/complete register; that path is not yet wired. This stub is a no-op that satisfies the common interface.

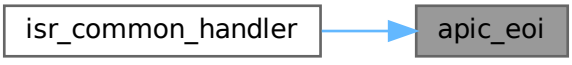
References APIC_REG_EOI, and lapic_write().

Referenced by isr_common_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.1.2.2 apic_id()

```
uint8_t apic_id (
            void  )
```

Return this CPU's xAPIC ID.

Reads `APIC_REG_ID` and extracts bits 31:24, the xAPIC ID field. Used by the I/O APIC driver (item 4.3.5) as the destination field when programming a redirection entry — interrupts routed to this ID are delivered to the current CPU's Local APIC.

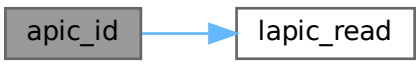
Returns

This CPU's 8-bit xAPIC ID.

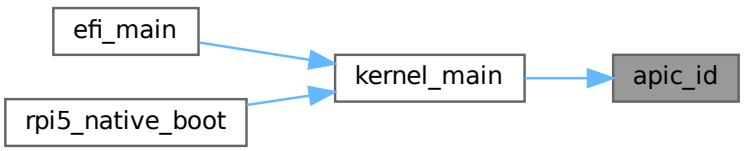
References APIC_REG_ID, and lapic_read().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.1.2.3 apic_init()

```
int apic_init (
            BootInfo * boot_info )
```

Initialise the GICv2 distributor and CPU interface (M4 milestone).

Enables exactly one interrupt source: the physical timer PPI for the exception level detected in item 0.4 (30 at EL1, 26 at EL2 — see `TIMER_PPI_EL1` / `TIMER_PPI_EL2` above). Sequence:

0. Try `gic_bases_from_dtb()` against `boot_info->dtb`; on success, `s_gicd_base` / `s_gicc_base` are overridden from the real hardware addresses. On failure (no DTB, e.g. this system's QEMU/UEFI firmware — see file header) they keep the QEMU constant defaults, exactly the behaviour this function had before this step existed.

1. Set this interrupt's priority (`GICD_IPRIORITYR`) below the CPU interface's priority mask, so it is never itself masked out.
2. Enable it in `GICD_ISENABLER0` (PPIs 16–31 live in the first word).
3. Enable the distributor, Group 0 only (`GICD_CTLR`) — this deployment has no GICv2 security-extension split in use.
4. Set the CPU interface priority mask to allow everything through (`GICC_PMR` = 0xFF) and enable the CPU interface (`GICC_CTLR`).

Deliberately not configured: `GICD_ICFGR` (trigger sensitivity). The ARM generic timer's PPI is architecturally level-sensitive; this is not a general GIC driver and item 0.6's own scope does not call for reconfiguring it.

Parameters

boot_info	Kernel `BootInfo`; `dtb` is consulted for real-hardware GIC base discovery as of the 2026-09-04 fix (previously unused — see file header), and, as of the same fix, for `aarch64_psci_conduit_init()`'s PSCI conduit discovery (arch.c) — bundled into this call for the same reason GIC discovery is: this is the one point in boot with `boot_info->dtb` already in hand.

Returns

0 always.

Initialise the GICv2 distributor and CPU interface (M4 milestone).

Called during M4 (interrupt controller init) before the IDT is loaded. Performs the following steps:

1. Reads `IA32_APIC_BASE_MSR` (0x1B) to determine the current APIC mode.
2. If x2APIC mode (bit 10) is active, clears it to switch to xAPIC MMIO mode while keeping the global-enable bit (bit 11) set, as required by Intel SDM Vol.3 ?10.12.5 (never clear both bits simultaneously).
3. If the global-enable bit (bit 11) was clear, sets it.
4. Software-enables the APIC via `APIC_REG_SIVR` (Spurious Interrupt Vector Register) and assigns spurious vector 0xFF.

5. Clears the Task Priority Register (TPR=0) so all interrupt priorities are delivered; a non-zero TPR left by UEFI would silently suppress all APIC interrupts at or below that priority level.
6. Issues a spurious EOI write to clear any stale in-service interrupt that UEFI may have left pending (specifically the APIC timer vector that fires just before `ExitBootServices`).

The `boot_info` parameter is reserved for future use (e.g., reading the ACPI MADT for the physical LAPIC base address); it is currently unused and the default identity-mapped address `LAPIC_DEFAULT_PHYS` = 0xFEE00000 is always used.

Parameters

boot_info	Pointer to kernel `BootInfo` (ACPI/memory-map data); currently unused, reserved for MADT-based LAPIC relocation.

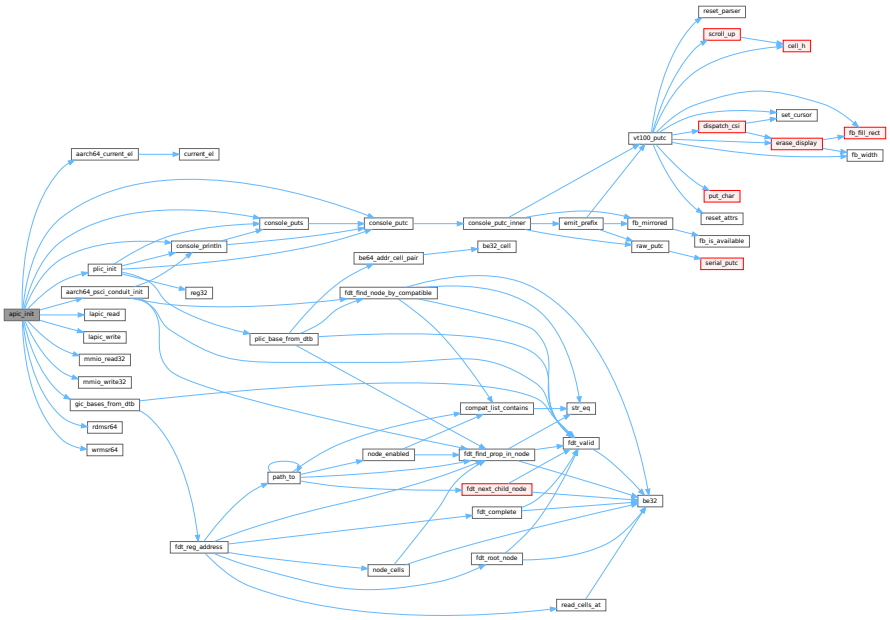
Returns

0 on success (always; the APIC is assumed to be present on x86-64).

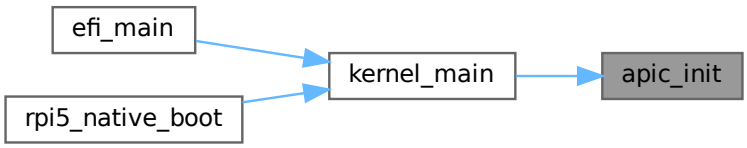
References aarch64_current_el(), aarch64_psci_conduit_init(), APIC_REG_EOI, APIC_REG_ISR_BASE, APIC_REG_SIVR, APIC_REG_TPR, console_println(), console_putc(), console_puts(), BootInfo::dtb, gic_bases_from_dtb(), GICC_CTLR, GICC_CTLR_ENABLE_GRP0, GICC_PMR, GICD_CTLR, GICD_CTLR_ENABLE_GRP0, GICD_IPRIORITYR, GICD_ISENABLER0, IA32_APIC_BASE_GLOBAL_EN, IA32_APIC_BASE_MSR, IA32_APIC_BASE_X2APIC_, lapic_base, LAPIC_DEFAULT_PHYS, lapic_phys_base, lapic_read(), LAPIC_VIRT_BASE, lapic_write(), mmio_read32(), mmio_write32(), plic_init(), PMR_ALLOW_ALL, rdmsr64(), s_gicc_base, s_gicd_base, s_timer_ppi, TIMER_PPI_EL1, TIMER_PPI_EL2, TIMER_PRIORITY, and wrmsr64().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.1.2.4 apic_timer_init()

```
int apic_timer_init (
            uint64_t tsc_hz,
            uint32_t tick_hz )
```

Compute the expected system-counter ticks per heartbeat period.

Computes `s_timer_period_tsc` (the expected number of `CNTPCT_EL0` ticks between heartbeats), used both by `heartbeat_init()` to seed the rolling-window `expected_delta` and by `apic_timer_start()` / `apic_timer_rearm()` (item 0.7) as the `TVAL` step written on every arm and re-arm.

If either `tsc_hz` or `tick_hz` is zero, a fallback of 10,000,000 ticks is stored (approximately 160 ms at 62.5 MHz, a safe non-zero sentinel that prevents division-by-zero in the heartbeat path).

Parameters

tsc_hz	System counter frequency from `timer_init()` (Hz).
tick_hz	Desired heartbeat rate (Hz); 0 → uses fallback.

Returns

0 always.

Compute the expected system-counter ticks per heartbeat period.

Calibrates the APIC timer frequency via `calibrate_apic_timer()` then programs the LVT Timer Register and Initial Count Register to deliver `APIC_TIMER_VECTOR` periodically at `tick_hz` interrupts per second. The timer is left **masked** after initialisation; call `apic_timer_start()` after the IDT is loaded and interrupts are enabled to begin delivery.

Derived quantities stored for later use:

- `timer_initial_count` — APIC ticks per heartbeat period (`apic_hz` / `tick_hz`), written to `APIC_REG_TIMER_ICR`.
- `timer_tick_hz` — requested tick rate (100 Hz default).
- `timer_period_tsc_ticks` — expected TSC ticks per heartbeat (`tsc_hz` / `tick_hz`), used by `heartbeat_tick()` to compute inter-tick variance for the TIME-TRUST Q48.16 metric.

If `tick_hz` is 0 it defaults to 100 Hz (10 ms period). If calibration returns 0 (no APIC timer detected or counter stuck) the function prints a diagnostic and returns -1 without programming the timer.

Parameters

tsc_hz	TSC frequency in Hz (from `timer_init()`); used to derive the 10 ms calibration window and `timer_period_tsc_ticks`. Pass 0 if TSC is not yet calibrated.
tick_hz	Desired interrupt rate in Hz; 0 → defaults to 100 Hz.

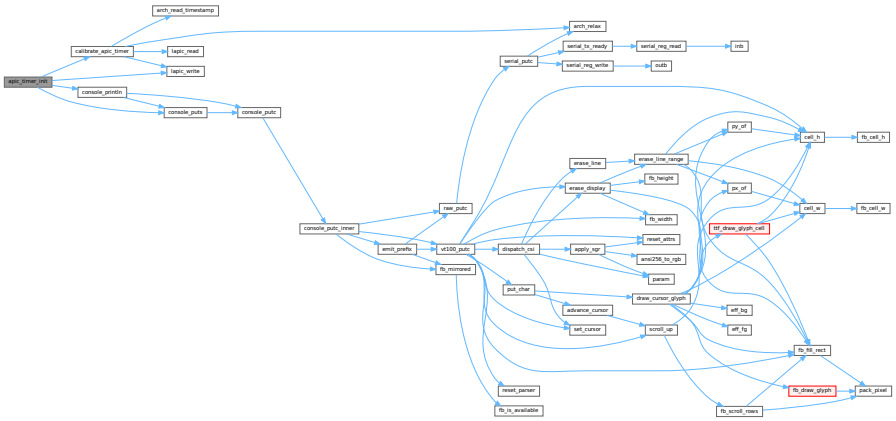
Returns

0 on success, -1 if APIC timer calibration failed.

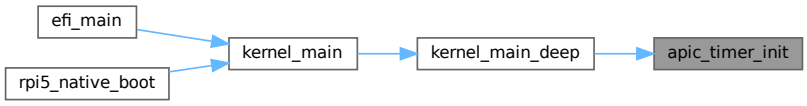
References APIC_REG_LVT_TIMER, APIC_REG_TIMER_DCR, APIC_REG_TIMER_ICR, APIC_TIMER_VECTOR, calibrate_apic_timer(), console_println(), console_puts(), lapic_write(), LVT_MASKED, LVT_MODE_PERIODIC, s_apic_hz, s_counter_hz_apic, s_time_hz, s_timer_period_tsc, TIMER_DIV_1, timer_initial_count, timer_period_tsc_ticks, and timer_tick_hz.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.1.2.5 apic_timer_period_tsc()

```
uint64_t apic_timer_period_tsc (
            void  )
```

Get the configured timer period in TSC ticks.

Get the configured timer period in TSC ticks.

Returns `s_timer_period_tsc`, set by `apic_timer_init()` as `tsc_hz / tick_hz`. This value is consumed by `heartbeat_init()` to seed the rolling-window `expected_delta` so that inter-tick deviation measurements are relative to the correct nominal interval.

Returns

Expected CNTPCT_EL0 ticks per heartbeat period; 10,000,000 if frequencies were not available at init time.

Get the configured timer period in TSC ticks.

Returns timer_period_tsc_ticks, computed by apic_timer_init() as tsc_hz / tick_hz. The value represents the ideal number of TSC ticks that should elapse between consecutive APIC_TIMER_VECTOR interrupts when the TSC runs at tsc_hz Hz and the heartbeat runs at tick_hz Hz.

Used by timer.c to seed the heartbeat rolling window with the nominal inter-tick interval so that the first few ticks produce meaningful variance estimates rather than comparing against zero. Returns 0 if tsc_hz was 0 at initialisation time (TSC unknown).

Returns

Expected TSC ticks per heartbeat period, or 0 if unavailable.

Get the configured timer period in TSC ticks.

Returns s_timer_period_tsc, set by apic_timer_init() as tsc_hz / tick_hz. Consumed by heartbeat_init() to seed the rolling-window expected_delta, and by apic_timer_start() / riscv64_timer_rearm() as the SBI deadline step.

Returns

Expected time-counter ticks per heartbeat period; 10,000,000 if frequencies were not available at init time.

References s_timer_period_tsc, and timer_period_tsc_ticks.

7.1.2.6 apic_timer_rearm()

```
void apic_timer_rearm (
            void  )
```

Re-arm the APIC timer at the current adaptive period (item 0.8, ?26).

Recomputes the initial count from heartbeat_next_period_ns() and writes it to the ICR; a periodic-mode ICR write restarts the countdown immediately at the new value. Called once per tick from the ISR, before heartbeat_tick().

Re-arm the APIC timer at the current adaptive period (item 0.8, ?26).

Writes a fresh TVAL — the entirety of a periodic re-arm, since TVAL is relative to "now" rather than an absolute deadline. Unlike riscv64's SBI re-arm (item 0.3), there is no drift-correction bookkeeping: each write means "@c s_timer_period_tsc ticks from this instant," so time spent servicing the interrupt before this call simply lengthens that one period rather than accumulating error across ticks.

This is the one call that must never be skipped. The ARM Generic Timer does not auto-reload: once TVAL crosses zero, CTL.ISTATUS latches and stays asserted — a level condition — until software writes a new TVAL or clears CTL.ENABLE. A return path that skips this leaves the interrupt permanently pending, which the GIC would deliver again the instant it is EOI'd: a real interrupt storm, not a hypothetical one (this is exactly the failure this driver was checked against during item 0.6's own verification, and confirmed absent there only because nothing armed the timer yet).

Called from aarch64_irq_handler() (interrupts.c) before heartbeat_tick() — same ordering discipline as riscv64_timer_rearm() (item 0.3): re-arm first, so a fault in the rest of the handler cannot also cost the next tick.

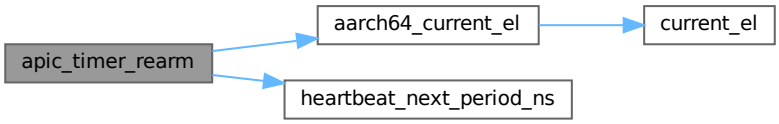
The step written is heartbeat_next_period_ns() (item 0.8, ?26) converted to CNTPCT_EL0 ticks via s_counter_hz_apic, not the fixed s_timer_period_tsc apic_timer_start() used for the very first arm – that value remains apic_timer_period_tsc()'s return for heartbeat_init()'s initial expected_delta, unchanged.

amd64's APIC timer runs in periodic mode: hardware auto-reloads APIC_REG_TIMER_ICR on every expiry with no software intervention, unlike riscv64's one-shot SBI deadline or aarch64's one-shot CNTP_TVAL_EL0 – neither of which needed a rearm function before this item for the same reason this one now exists. To make the period adaptive, this function recomputes timer_initial_count from heartbeat_next_period_ns() (?26) and s_apic_hz, then writes it to APIC_REG_TIMER_ICR. A periodic-mode ICR write takes effect immediately and restarts the countdown at the new value – the same mechanism apic_timer_start() already relies on to force QEMU TCG's emulated APIC to begin counting.

Called from isr_common_handler() on every APIC_TIMER_VECTOR interrupt, before heartbeat_tick() – same ordering discipline as riscv64/aarch64's rearm-before-heartbeat_tick(), so a fault in heartbeat_tick() cannot also cost the next tick.

References aarch64_current_el(), heartbeat_next_period_ns(), s_counter_hz_apic, and s_timer_period_tsc.

Here is the call graph for this function:



7.1.2.7 apic_timer_start()

```
void apic_timer_start (
            void  )
```

Start the APIC timer (enables periodic interrupts).

Call this after IDT and heartbeat handler are set up.

Start the APIC timer (enables periodic interrupts).

Writes CNTP_TVAL_EL0 (or CNTHP_TVAL_EL2 at EL2 — aarch64_current_el(), same EL-aware discipline as items 0.4–0.6) to s_timer_period_tsc, then sets CTL.ENABLE=1, CTL.IMASK=0.

TVAL is a signed 32-bit *relative* countdown — writing it sets "fire @c s_timer_period_tsc ticks from this instant," unlike riscv64's SBI interface (item 0.3), which takes an absolute deadline the caller must compute. No "now" reading is needed here at all.

The ISB after the CTL write is required, not decorative: per the architecture, and confirmed against Linux's own arch_timer_reg_write_cp15() (arch/arm64/include/asm/arch_timer.h), only the *control* register write

needs synchronising before the enable/mask state is guaranteed visible to the interrupt pipeline — `TVAL/CVAL writes` do not carry the same requirement, which is why `apic_timer_rearm()` below omits it.

`s_timer_period_tsc` must already be set by `apic_timer_init()`. If it is still 0, `TVAL=0` fires immediately and continuously until `apic_timer_rearm()` runs — a correctly-functioning if oddly-paced timer, not a hang.

Start the APIC timer (enables periodic interrupts).

Called after `arch_interrupts_init()` and `arch_enable_interrupts()` to start the 100 Hz heartbeat that drives `heartbeat_tick()`. The sequence is:

1. Read the current LVT Timer Register.
2. Clear the `LVT_MASKED` bit (bit 16) to unmask the interrupt.
3. Write the LVT register back.
4. Write `timer_initial_count` to `APIC_REG_TIMER_ICR` to (re-)arm the countdown. QEMU TCG requires an explicit ICR write after unmask — it does not auto-restart a previously masked periodic timer. On real hardware this is harmless and equally correct.
5. Reads back LVT and ICR values and prints them for boot-log verification.

Must be called exactly once per boot after the IDT is loaded. Calling it again restarts the countdown from the initial value without otherwise reconfiguring the timer.

Start the APIC timer (enables periodic interrupts).

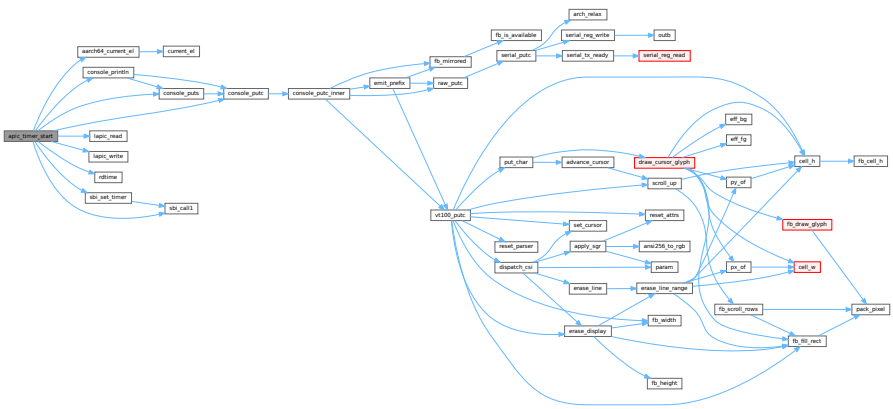
Probes for the TIME extension first. If the SEE does not provide it the timer is **not** armed and the condition is reported loudly rather than papered over with the legacy EID 0x00 call: a heartbeat that silently never ticks is far worse to diagnose than one that says why at boot.

On success: computes the first absolute deadline, arms it, and sets `sie.STIE`. Global delivery is gated separately by `sstatus.SIE`, which `arch_enable_interrupts()` sets.

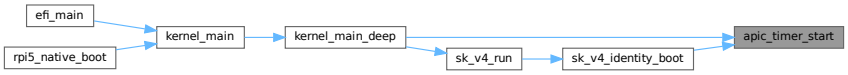
References aarch64_current_el(), APIC_REG_LVT_TIMER, APIC_REG_TIMER_ICR, console_println(), console_putc(), console_puts(), sbiret_t::error, lapic_read(), lapic_write(), rdtime(), s_next_deadline, s_sbi_time_ok, s_timer_period_tsc, SBI_BASE_FID_PROBE_EXT, sbi_call1(), SBI_EXT_BASE, SBI_EXT_TIME, sbi_set_timer(), SBI_SUCCESS, SIE_STIE, timer_initial_count, and sbiret_t::value.

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.1.2.8 apic_timer_stop()

```
void apic_timer_stop (
            void  )
```

Stop the APIC timer (disables periodic interrupts).

Stop the APIC timer (disables periodic interrupts).

Per the architecture, `ENABLE=0` unconditionally stops the count and de-asserts the interrupt condition regardless of `IMASK` — a single write is sufficient, no separate mask step needed.

Stop the APIC timer (disables periodic interrupts).

Sets the `LVT_MASKED` bit (bit 16) in the LVT Timer Register by performing a read-modify-write on `APIC_REG_LVT_TIMER`. The existing periodic-mode and vector configuration is preserved; only the mask bit changes. The APIC timer's internal countdown continues running but interrupt delivery is suppressed. Calling `apic_timer_start()` again after this function will unmask and re-arm the timer.

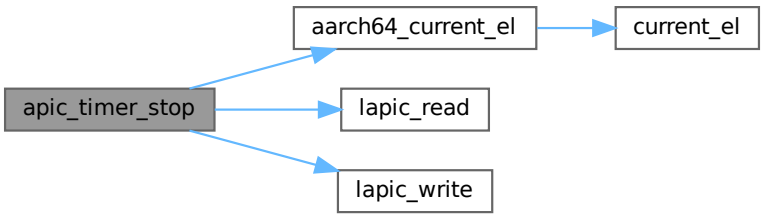
Used in the kernel panic path and during any critical section where heartbeat interrupts would corrupt shared state.

Stop the APIC timer (disables periodic interrupts).

The SBI timer cannot be cancelled outright — masking the enable bit is the supported way to stop delivery. Any deadline already programmed simply goes unserviced.

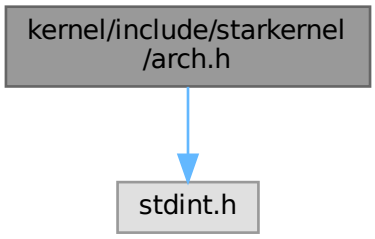
References aarch64_current_el(), APIC_REG_LVT_TIMER, lapic_read(), lapic_write(), LVT_MASKED, s_sbi_time_ok, and SIE_STIE.

Here is the call graph for this function:



7.2 kernel/include/starkernel/arch.h File Reference

`#include <stdint.h>`
Include dependency graph for arch.h:



This graph shows which files directly or indirectly include this file:

Functions

- void arch_early_init (void)

  arch.h - Architecture abstraction layer for StarKernel
- void arch_enable_interrupts (void)

  Enable IRQ delivery on the current core (AArch64 DAIFCLR).
- void arch_disable_interrupts (void)

  Disable IRQ delivery on the current core (AArch64 DAIFSET).
- void arch_interrupts_init (void)

  Install the AArch64 exception vector table (M4 milestone).
- void arch_halt (void)

  Halt the core until the next event (AArch64 WFI).
- void arch_cold_reset (void) __attribute__((noreturn))
- uint64_t arch_read_timestamp (void)

  Read the AArch64 system counter (CNTPCT_EL0).
- void arch_mmu_init (void)

  Initialise the AArch64 MMU (stub — deferred to a later milestone).
- static void arch_relax (void)

7.2.1 Function Documentation

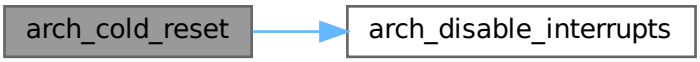
7.2.1.1 arch_cold_reset()

```
void arch_cold_reset (
            void  )
```

References arch_disable_interrupts(), and s_psci_use_smc.

Referenced by sk_v4_serve().

Here is the call graph for this function:



Here is the caller graph for this function:

7.2.1.2 arch_disable_interrupts()

```
void arch_disable_interrupts (
            void  )
```

Disable IRQ delivery on the current core (AArch64 DAIFSET).

Issues `MSR` DAIFSET, #2 which sets the `I` bit (IRQ mask) in the `DAIF` flags, masking IRQ exceptions. FIQ, SError, and Debug exceptions are unaffected. Used around critical sections in the single-threaded kernel where interrupt delivery would corrupt shared state.

The `memory` clobber acts as a compiler-level barrier; for a full hardware memory barrier use `DSB` before calling this function.

Disable IRQ delivery on the current core (AArch64 DAIFSET).

Issues the `CLI` instruction to clear the Interrupt Flag. Used around critical sections in the single-threaded kernel where interrupt delivery would corrupt shared state.

Disable IRQ delivery on the current core (AArch64 DAIFSET).

Issues `CSRCI sstatus, 0x2` which clears bit 1 (`SIE`) in `sstatus`, masking all supervisor-mode interrupts. Machine-mode interrupts are unaffected. Used around critical sections in the single-threaded kernel. The `memory` clobber acts as a compiler barrier; pair with a `FENCE` instruction for a hardware barrier.

Referenced by arch_cold_reset(), and arch_cold_reset().

Here is the caller graph for this function:

7.2.1.3 arch_early_init()

```
void arch_early_init (
            void  )
```

arch.h - Architecture abstraction layer for StarKernel

Provides a minimal interface used across early boot, interrupt control, low-power halting, timestamp reads, and MMU bring-up.

arch.h - Architecture abstraction layer for StarKernel

On x86-64 this function loads the GDT; AArch64 has no equivalent because privilege separation is provided by the exception-level architecture (EL0/EL1/EL2/EL3) rather than segment descriptors. The exception vector table is installed later in `arch_interrupts_init()` by calling `aarch64_install_vectors()` which writes `VBAR_EL1`.

This stub exists to satisfy the common `arch_early_init()` call site in `kernel_main()` so that the same milestone sequence compiles across all three supported ISAs (amd64 / aarch64 / riscv64).

arch.h - Architecture abstraction layer for StarKernel

Called immediately after the UEFI boot stub transfers control to the kernel, before the console or interrupt controller are available. Loads the minimal three-entry GDT via `gdt_init()` so that subsequent code has valid segment selectors. IDT setup is deferred until after the console is live (called separately via `arch_interrupts_init()`).

arch.h - Architecture abstraction layer for StarKernel

RISC-V has no GDT or IDT; privilege separation is handled by the machine/supervisor/user execution modes (M/S/U), and the trap vector table is installed by writing `stvec` in `arch_interrupts_init()` via `riscv64_install_vectors()`. This stub satisfies the common `arch_early_init()` call site in `kernel_main()` without any RISC-V-specific action.

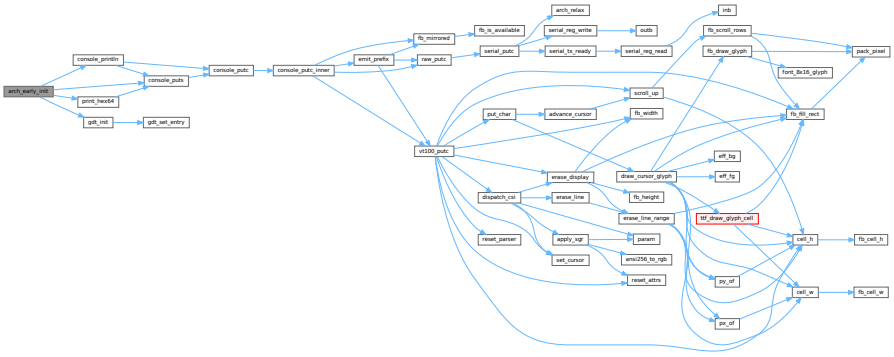
Correction, 2026-09-04 (FABRIC-3.md ?V.3 item 7's code audit). The unconditional Bare-mode switch this function used to perform was justified entirely by behaviour observed under this system's QEMU/EDK2 RISC-V firmware (`satp.MODE=10/Sv57`, kernel identity-mapped within it — see the comment on `print_hex64()` above). That observation cannot apply to the native boot path (U-Boot+OpenSBI, no EDK2 at all, FABRIC-3.md ?V.1) this kernel now also has, and OpenSBI's own S-mode handoff convention leaves `satp` already at 0 (Bare) in the common case — meaning the switch below was very likely running as a harmless no-op there, but on an unverified assumption rather than a checked one. Rather than build a general Sv39/Sv48/Sv57 page-table walker just to *prove* the running address is identity-mapped before switching (out of proportion to this item's real scope), the fix narrows

what actually needs the QEMU-specific safety argument: **skip the switch entirely when `satp` is already 0.** That is the expected case on both a from-Bare native boot and any firmware that already left translation off, and it needs no safety argument at all — there is nothing to switch away from. The unconditional-switch path still exists for the confirmed QEMU/EDK2 case (`mode` != 0), where the identity-mapping argument above remains the actual justification, unchanged.

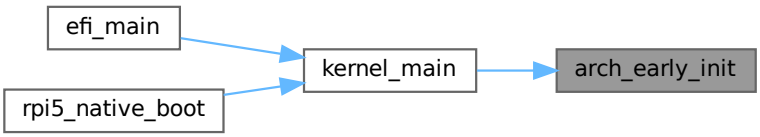
References __kernel_start, console_println(), console_puts(), gdt_init(), and print_hex64().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.2.1.4 arch_enable_interrupts()

```
void arch_enable_interrupts (
            void  )
```

Enable IRQ delivery on the current core (AArch64 DAIFCLR).

Issues `MSR` DAIFCLR, #2 which clears the `I` bit (IRQ mask) in the `DAIF` (Debug / Abort / IRQ / FIQ) flags of the current exception level. After this instruction the core will take IRQ exceptions from the GIC. The `memory` clobber prevents the compiler from reordering stores across the barrier.

Must be called after `arch_interrupts_init()` has installed the vector table in `VBAR_EL1` and the GIC timer driver has been configured.

Enable IRQ delivery on the current core (AArch64 DAIFCLR).

Issues the `STI` instruction to set the Interrupt Flag. Must be called after the IDT is loaded and the APIC is configured, otherwise the first interrupt will triple-fault.

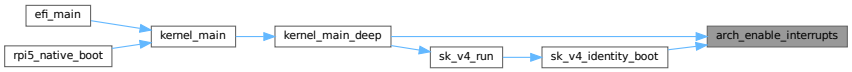
Enable IRQ delivery on the current core (AArch64 DAIFCLR).

Issues `CSRSI sstatus, 0x2` which sets bit 1 (`SIE` — Supervisor Interrupt Enable) in the `sstatus` CSR. While `SIE` = 1, pending supervisor-mode interrupts are taken. The `memory` clobber prevents the compiler from reordering stores across the barrier.

Must be called after `arch_interrupts_init()` has installed the `stvec` trap handler, and after the PLIC driver has been configured to forward the desired interrupt sources.

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the caller graph for this function:



7.2.1.5 arch_halt()

```
void arch_halt (
            void  )
```

Halt the core until the next event (AArch64 WFI).

Issues the `WFI` (Wait For Interrupt) instruction. The core enters a low-power standby state and resumes execution when an IRQ, FIQ, SError, debug event, or reset is detected. In the kernel panic path this is called inside an infinite loop with interrupts disabled (`DAIFSET`) to stop the processor permanently. In the idle path it reduces power consumption between heartbeat ticks.

The `memory` clobber prevents the compiler from sinking stores across the `WFI`.

Halt the core until the next event (AArch64 WFI).

Issues the `HLT` instruction. In the kernel panic path this is called in an infinite loop (interrupts disabled) to stop the processor permanently. In normal use it is called once per idle iteration to reduce power consumption.

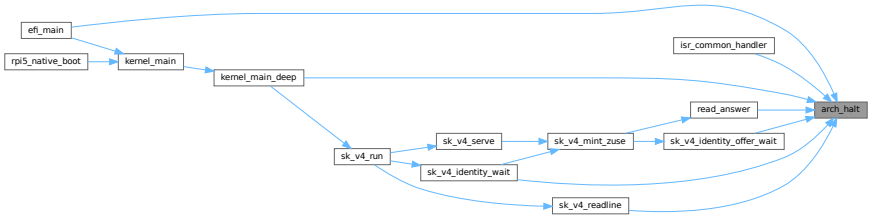
Halt the core until the next event (AArch64 WFI).

Issues the `WFI` (Wait For Interrupt) instruction in supervisor mode. The core enters a low-power state and resumes when a pending interrupt is detected (or after a platform-specific timeout). In the kernel panic path this is called inside an infinite loop with `SIE` cleared to stop the processor permanently. In the idle path it reduces power consumption between heartbeat ticks.

The `memory` clobber prevents store-sinking across the `WFI`.

Referenced by efi_main(), isr_common_handler(), kernel_main_deep(), read_answer(), sk_v4_identity_offer_wait(), sk_v4_identity_wait(), and sk_v4_readline().

Here is the caller graph for this function:



7.2.1.6 arch_interrupts_init()

```
void arch_interrupts_init (
            void  )
```

Install the AArch64 exception vector table (M4 milestone).

First reads and reports the exception level via aarch64_current_el() (punch-list item 0.4) — this is the earliest point in boot with both a working console (up since M1) and a genuine need for the answer (vector installation is the first EL-dependent operation). The read itself is cheap and safe far earlier than this; only the console print is gated on this call site.

Then calls aarch64_install_vectors() (defined in isr.S) which writes the address of the vector table base into VBAR_EL1 or VBAR_EL2 (Vector Base Address Register), whichever matches the exception level aarch64_current_el() just reported. After this instruction all exceptions at that level (synchronous, IRQ, FIQ, SError) dispatch through the 512-byte-aligned vector table assembled in isr.S.

Correction, 2026-09-04 (FABRIC-3.md ?IV.3 item 7's code audit): this doc comment and the runtime console message below previously claimed EL2 was "a known gap... @c VBAR_EL1 is written unconditionally regardless of the detected level," citing punch-list item 0.5 as the still-open work to fix it. Checked against isr.S's own aarch64_install_vectors() (the actual implementation, not this comment) and found that claim stale↩ : the assembly already branches on aarch64_current_el() and writes vbar_el2 at EL2 / vbar_el1 at EL1, threading the same answer through el2_mode_flag for the IRQ trampoline's ELR_ELx/SPSR_ELx selection too (see isr.S's own "EL selection" header comment). There never was a gap here to close — item 0.5's EL2 vector work was already done by the time this comment was written describing it as open; only the comment was wrong, not the code.

On AArch64 there is no IDT and no PIC to disable; the GIC replaces both. The arch_interrupts_init() name is kept identical across all ISAs so that kernel_main() can call the same symbol regardless of the target architecture.

Must be called after the kernel stack is established (so that the correct-EL SP is valid) and before arch_enable_interrupts().

Install the AArch64 exception vector table (M4 milestone).

Calls riscv64_install_vectors() (defined in isr.S) which writes the trap vector base address into stvec (Supervisor Trap Vector Base Address Register, CSR 0x105). The vector mode field (bits [1:0]) is set to 0 (Direct mode) so all traps dispatch to the single base address, or 1 (Vectored mode) so async interrupts dispatch to stvec + 4∗cause.

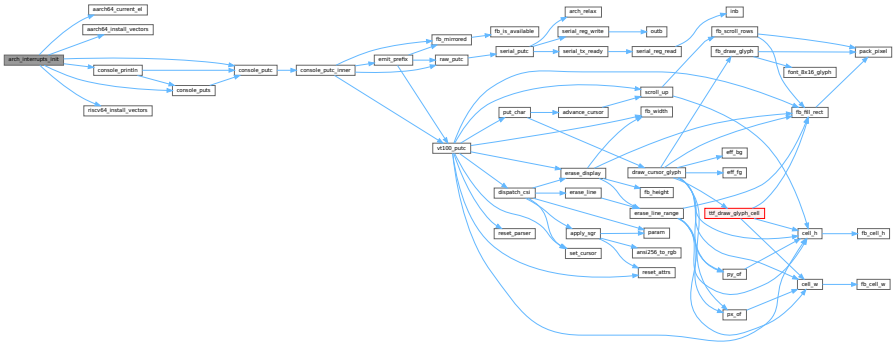
On RISC-V there is no IDT and no legacy PIC; the PLIC replaces both. The arch_interrupts_init() name is shared across all three ISAs so that kernel_main() calls the same symbol regardless of target.

Must be called after the supervisor stack (sp) is established and before arch_enable_interrupts().

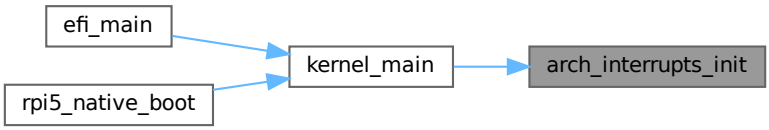
References aarch64_current_el(), aarch64_install_vectors(), console_println(), console_putc(), console_puts(), and riscv64_install_vectors().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.2.1.7 arch_mmu_init()

```
void arch_mmu_init (
            void  )
```

Initialise the AArch64 MMU (stub — deferred to a later milestone).

Full page-table setup (TTBR0/TTBR1, MAIR, TCR, SCTLR.M) is deferred to a later milestone. This stub exists to satisfy the common `arch_mmu_init()` call site shared across all three ISAs. The VMM subsystem (`vmm.c`) handles page-table management independently of this hook.

Initialise the AArch64 MMU (stub — deferred to a later milestone).

Full four-level page table setup is deferred; the VMM subsystem (`vmm.c`) handles page table management independently. This function exists as an architectural hook for future per-CPU MMU configuration that must run after GDT/IDT setup but before the first memory access through a non-identity-mapped virtual address.

Initialise the AArch64 MMU (stub — deferred to a later milestone).

Full Sv39/Sv48 page-table setup (SATP, PMP, etc.) is deferred to a later milestone. This stub satisfies the common `arch_mmu_init()` call site shared across all three supported ISAs. The VMM subsystem (`vmm.c`) handles page-table management independently of this hook.

7.2.1.8 arch_read_timestamp()

```
uint64_t arch_read_timestamp (
            void  )
```

Read the AArch64 system counter (CNTPCT_EL0).

Issues `MRS %0, cntpct_el0` to read the 64-bit physical system counter. On AArch64 the system counter is the architectural equivalent of the x86-64 TSC: a monotonically incrementing clock whose frequency is reported by `CNTFRQ_EL0` and set by firmware at boot.

Unlike `RDTSC` on x86-64, `CNTPCT_EL0` is fully synchronised across cores (no per-core skew), invariant across power-state changes, and does not require serialisation for most measurement use cases. It is used as the time base for `timer_now_ns()` and `heartbeat_tick()`.

Returns

Current 64-bit system counter value in counter ticks (frequency given by `CNTFRQ_EL0`, typically 10–62.5 MHz).

Read the AArch64 system counter (CNTPCT_EL0).

Executes `RDTSC` and combines `EDX:EAX` into a 64-bit value. Does not serialise instruction execution; use `RDTSCP` or a surrounding `CPUID` where ordering guarantees are required.

Returns

Current TSC value in CPU cycles.

Read the AArch64 system counter (CNTPCT_EL0).

Issues the `RDCYCLE` pseudo-instruction (a `CSRRS` on `cycle`, CSR 0xC00) to read the 64-bit hardware performance counter that counts elapsed clock cycles since reset. On RISC-V the cycle counter is the architectural equivalent of the x86-64 TSC.

Unlike the AArch64 `CNTPCT_EL0`, the RISC-V `cycle` register is a per-hart counter and is not architecturally guaranteed to be synchronised across harts. For single-core LithosAnanke this is not a concern. Frequency is not architecturally specified; `timer_init()` assumes 1 GHz for QEMU `virt` board compatibility.

Returns

Current 64-bit cycle counter value; frequency platform-dependent.

Referenced by calibrate_apic_timer().

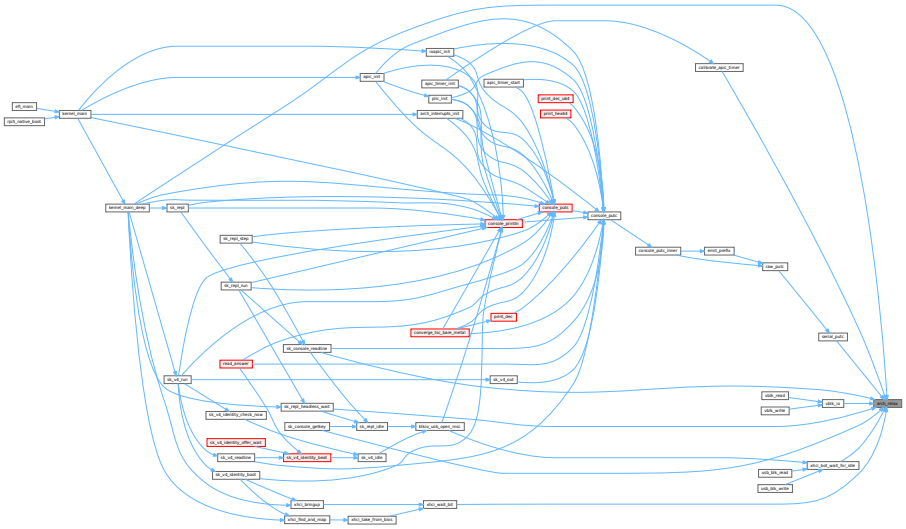
Here is the caller graph for this function:

7.2.1.9 arch_relax()

```
static void arch_relax (
            void  )  [inline], [static]
```

Referenced by calibrate_apic_timer(), kernel_main_deep(), serial_putc(), sk_console_getkey(), sk_console_readline(), sk_repl_headless_wait(), vblk_io(), xhci_bot_wait_for_idle(), and xhci_wait_bit().

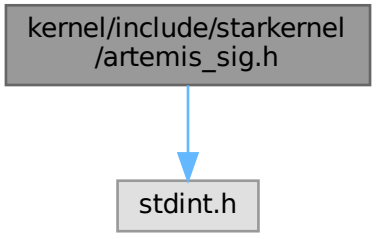
Here is the caller graph for this function:



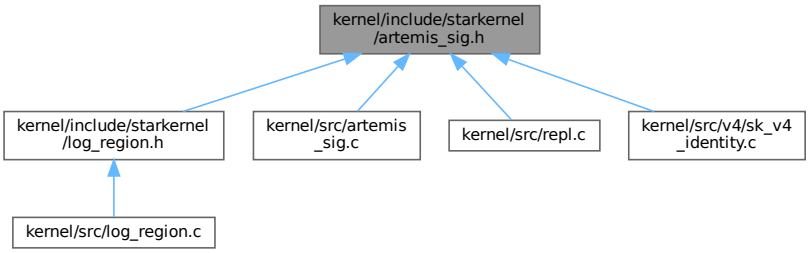
7.3 kernel/include/starkernel/artemis_sig.h File Reference

```
#include <stdint.h>
```

Include dependency graph for artemis_sig.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct artemis_sig_t

Macros

- #define ARTEMIS_SIG_MAGIC 0x4D545241ULL /* 'ARTM' */

  artemis_sig.h - Artemis disk signature format (FABRIC-3.md ?XXVI follow-on, 2026-09-13)
- #define ARTEMIS_SIG_VERSION_0 0
- #define ARTEMIS_SIG_PACK(ver) (ARTEMIS_SIG_MAGIC | ((uint64_t)(ver) << 32))
- #define ARTEMIS_SIG_GET_MAGIC(m) ((uint32_t)((m) & 0xFFFFFFFFULL))
- #define ARTEMIS_SIG_GET_VERSION(m) ((uint8_t)(((m) >> 32) & 0xFF))
- #define ARTEMIS_SIG_DEVBLOCK_FROM_TOP 64u

Typedefs

- typedef char artemis_sig_size_check[(sizeof(artemis_sig_t)==4096) ? 1 :-1]

Enumerations

- enum artemis_sig_result_t {
  ARTEMIS_SIG_OK = 0 , ARTEMIS_SIG_BLANK , ARTEMIS_SIG_BAD_VERSION , ARTEMIS_SIG_BAD_CRC
  ,
  ARTEMIS_SIG_READ_ERROR }

Functions

- artemis_sig_result_t artemis_sig_check (struct blkio_dev *dev, artemis_sig_t *out_sig)
- uint64_t artemis_sig_compute_crc (const artemis_sig_t *sig)

  artemis_sig.c - Artemis disk signature check (FABRIC-3.md ?XXVI follow-on).
- int artemis_sig_genesis_stamp (struct blkio_dev *dev)

7.3.1 Macro Definition Documentation

7.3.1.1 ARTEMIS_SIG_DEVBLOCK_FROM_TOP

```
#define ARTEMIS_SIG_DEVBLOCK_FROM_TOP 64u
```

7.3.1.2 ARTEMIS_SIG_GET_MAGIC

```
#define ARTEMIS_SIG_GET_MAGIC(
            m ) ((uint32_t)((m) & 0xFFFFFFFFULL))
```

7.3.1.3 ARTEMIS_SIG_GET_VERSION

```
#define ARTEMIS_SIG_GET_VERSION(
            m ) ((uint8_t)(((m) >> 32) & 0xFF))
```

7.3.1.4 ARTEMIS_SIG_MAGIC

```
#define ARTEMIS_SIG_MAGIC 0x4D545241ULL /* 'ARTM' */
```

artemis_sig.h - Artemis disk signature format (FABRIC-3.md ?XXVI follow-on, 2026-09-13)

Identifies Artemis's own disk, distinct from an identity thumbdrive's homeblocks_sig_t – needed once Artemis's disk stops being found by a hardcoded PCI virtio-blk vendor/device ID scan (QEMU-only; real hardware has no reason to expose a virtio-blk PCI device at all, since virtio is a paravirtualization standard, not something a physical storage controller speaks) and starts being discovered generically instead, the same way WIREBIND already discovers identity thumbdrives – by content signature, not by which bus happened to present the device. Without a distinct signature, generic discovery on real hardware (where an identity thumbdrive and Artemis's own disk could both be attached as USB-MSC devices simultaneously) would have no way to tell them apart.

Mirrors homeblocks_sig_t's own structural convention (magic + version + CRC, one 4KiB header) – a sibling format, not a field bolted onto homeblocks_sig_t itself: homeblocks_sig_t's own header comment already states it's "deliberately narrow in scope" (identity-drive fields only, no spare room), and Artemis's disk is conceptually a different kind of thing (one dedicated fleet-owned device, not one of many candidate identity drives), not a variant of the same one.

CORRECTION, same day: the first version of this format placed the header at a fixed bottom-of-device forth-block (4, i.e. devblock 1), copying homeblocks_sig_t's own devblock-1 convention. That convention is safe for an identity thumbdrive (raw, dedicated storage – capsule_mint.c writes directly, no block-subsystem format involved), but Artemis's disk is block_subsystem.c's own STFR/v2-formatted volume: devblock 0 holds that format's header (read_header_4k()/write_header_4k(), block_subsystem.c) and devblock 1 is the FIRST DEVBLOCK OF THE LIVE BAM (blk_compute_fresh_geometry(): bam_start = 1). Writing artemis_sig_t there would have overwritten Artemis's own live allocation map on the very first real boot this ran against – caught (via `git status/grep` cross-reference against block_subsystem.c, not against a live disk) before the genesis-stamp call site ever executed against the real image.

The header now lives at a fixed offset from the END of the device instead (ARTEMIS_SIG_DEVBLOCK↩ _FROM_TOP, see below) – the same "top-of-device, outside the user-addressable LBN pool" region block_subsystem.c's own meta_fence_blocks reservation (128 devblocks by default, BLK_META_FENCE_INIT) already carves out for exactly this kind of system metadata, and where Zuse's own genesis marker already lives (blk_meta_zone_read()/write(), devblock_from_top 0; 1-63 reserved, unused, since the eligibility list was removed 2026-10-14). This format deliberately does NOT go through blk_meta_zone_∗, though: that accessor requires

the device to already be blk_subsys_attach_device()'d and format-detected (first_disk_slot()) – exactly the state generic pre-attach discovery (repl.c's idle-loop USB-MSC scan) doesn't have yet, which is the entire reason this format exists. artemis_sig_check()/artemis_sig_genesis_stamp() instead compute the same top-of-device arithmetic independently via blkio_info(), so they work on a raw, not-yet-attached device exactly like homeblocks_sig_check() already does. ARTEMIS_SIG_DEVBLOCK_FROM_TOP is fixed well clear of Zuse's genesis marker (0) and the reserved, unused 1-63.

Reserves offset/size pointers to the growable per-VM log-persistence region (FABRIC-3.md ?XXVI follow-on's own log-record work), the same way homeblocks_sig_t reserves pointers to where the cert and identity source attach – this format doesn't need revisiting when that region's own internal layout is designed.

7.3.1.5 ARTEMIS_SIG_PACK

```
#define ARTEMIS_SIG_PACK(
              ver )  (ARTEMIS_SIG_MAGIC | ((uint64_t)(ver) << 32))
```

7.3.1.6 ARTEMIS_SIG_VERSION_0

```
#define ARTEMIS_SIG_VERSION_0 0
```

7.3.2 Typedef Documentation

7.3.2.1 artemis_sig_size_check

```
typedef char artemis_sig_size_check[(sizeof(artemis_sig_t)==4096) ?  1 :-1]
```

7.3.3 Enumeration Type Documentation

7.3.3.1 artemis_sig_result_t

```
enum artemis_sig_result_t
```

Enumerator

ARTEMIS_SIG_OK	
ARTEMIS_SIG_BLANK	
ARTEMIS_SIG_BAD_VERSION	
ARTEMIS_SIG_BAD_CRC	
ARTEMIS_SIG_READ_ERROR	

7.3.4 Function Documentation

7.3.4.1 artemis_sig_check()

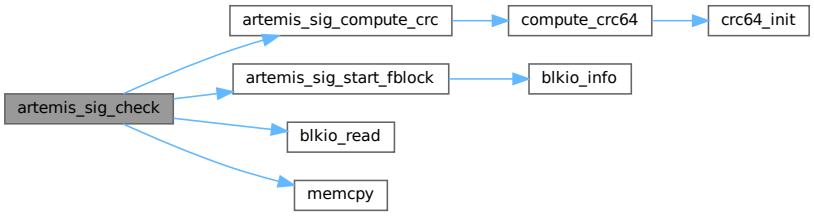
```
artemis_sig_result_t artemis_sig_check (
```

```
            struct blkio_dev * dev,
            artemis_sig_t * out_sig )
```

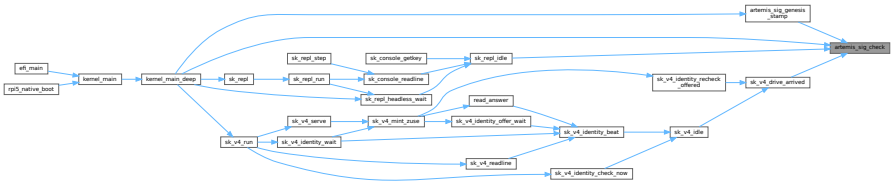
References ARTEMIS_SIG_BAD_CRC, ARTEMIS_SIG_BAD_VERSION, ARTEMIS_SIG_BLANK, artemis_sig_compute_crc(), ARTEMIS_SIG_GET_MAGIC, ARTEMIS_SIG_GET_VERSION, ARTEMIS_SIG_MAGIC, ARTEMIS_SIG_OK, ARTEMIS_SIG_READ_ERROR, artemis_sig_start_fblock(), ARTEMIS_SIG_VERSION_0, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_read(), artemis_sig_t::hdr_crc, artemis_sig_t::magic, and memcpy().

Referenced by artemis_sig_genesis_stamp(), kernel_main_deep(), sk_repl_idle(), and sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:



7.3.4.2 artemis_sig_compute_crc()

```
uint64_t artemis_sig_compute_crc (
            const artemis_sig_t * sig )
```

artemis_sig.c - Artemis disk signature check (FABRIC-3.md ?XXVI follow-on).

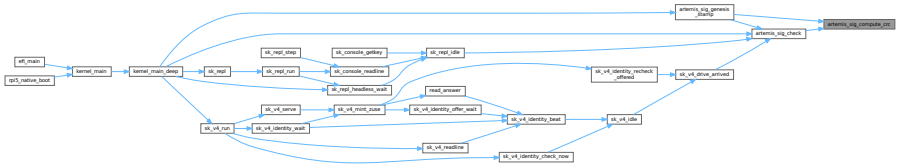
See starkernel/artemis_sig.h for the format and interface design.

References compute_crc64().

Referenced by artemis_sig_check(), and artemis_sig_genesis_stamp().

Here is the call graph for this function:

Here is the caller graph for this function:



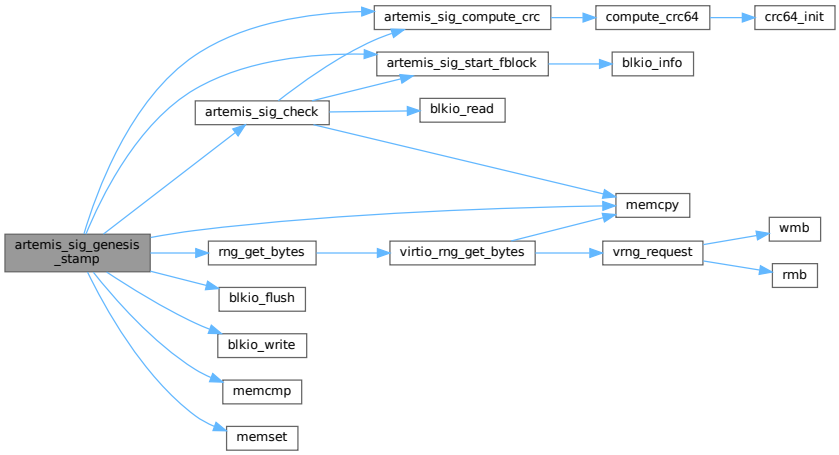
7.3.4.3 artemis_sig_genesis_stamp()

```
int artemis_sig_genesis_stamp (
            struct blkio_dev * dev )
```

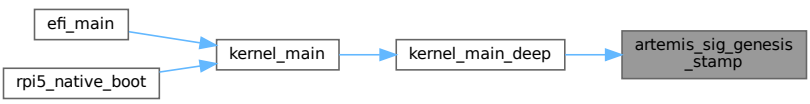
References artemis_sig_check(), artemis_sig_compute_crc(), ARTEMIS_SIG_OK, ARTEMIS_SIG_PACK, artemis_sig_start_fblock(), ARTEMIS_SIG_VERSION_0, blkio_flush(), BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_write(), artemis_sig_t::disk_uuid, artemis_sig_t::genesis_time_ns, artemis_sig_t::hdr_crc, artemis_sig_t::log_region_devblocks, artemis_sig_t::log_region_offset, artemis_sig_t::magic, memcmp(), memcpy(), memset(), artemis_sig_t::metadata_devblocks, and rng_get_bytes().

Referenced by kernel_main_deep().

Here is the call graph for this function:



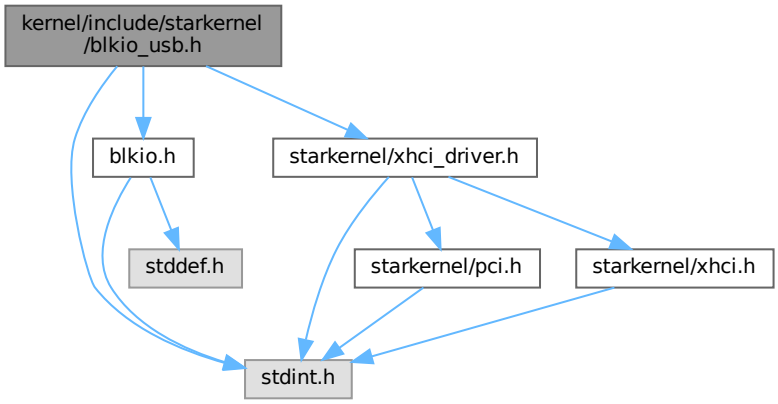
Here is the caller graph for this function:



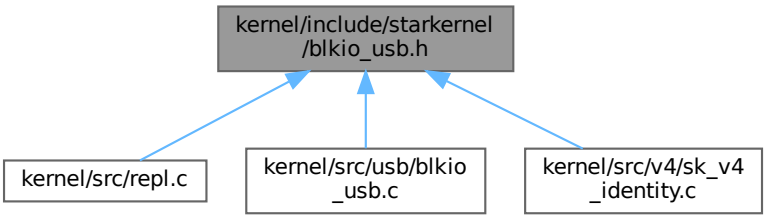
7.4 kernel/include/starkernel/blkio_usb.h File Reference

```
#include <stdint.h>
#include "blkio.h"
#include "starkernel/xhci_driver.h"
```

Include dependency graph for blkio_usb.h:



This graph shows which files directly or indirectly include this file:



Functions

- int blkio_usb_open_msc (blkio_dev_t *dev_out, xhci_dev_t *xdev, uint32_t slot_id)

7.4.1 Function Documentation

7.4.1.1 blkio_usb_open_msc()

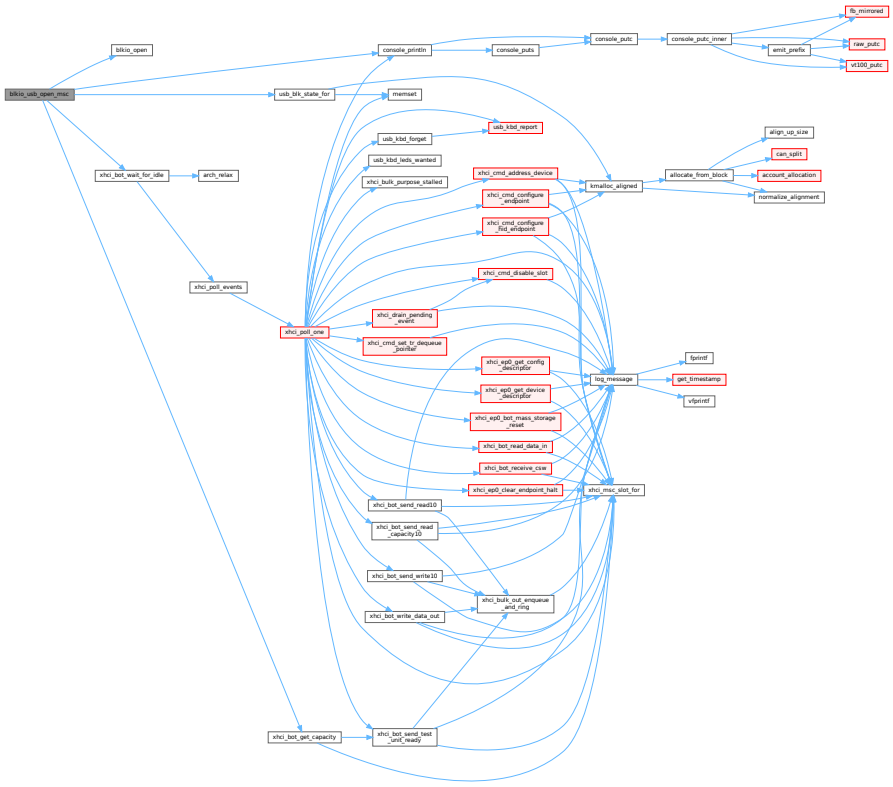
```
int blkio_usb_open_msc (
            blkio_dev_t * dev_out,
```

```
    xhci_dev_t * xdev,
    uint32_t slot_id )
```

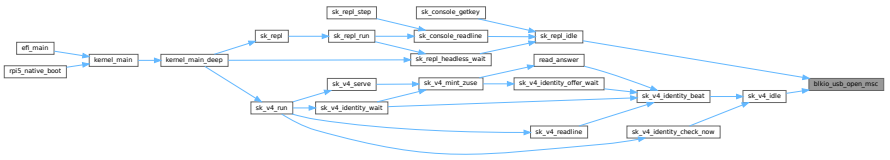
References BLKIO_FORTH_BLOCK_SIZE, blkio_open(), block_size, xhci_dev_t::bot_cap_block_size, xhci_dev_t::bot_cap_last_lba, console_println(), blkio_params_t::forth_block_size, g_usb_blk_vtable, blkio_params_t::opaque, BlkioUsbState::scsi_block_size, BlkioUsbState::scsi_blocks_per_fblock, BlkioUsbState::slot_id, blkio_params_t::total_blocks, BlkioUsbState::total_forth_blocks, usb_blk_state_for(), BlkioUsbState::xdev, xdev, xhci_bot_get_capacity(), and xhci_bot_wait_for_idle().

Referenced by sk_repl_idle(), and sk_v4_idle().

Here is the call graph for this function:

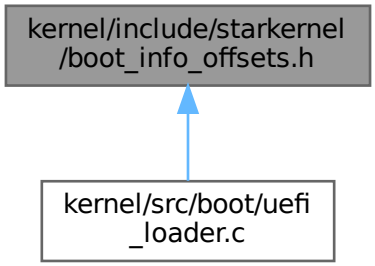


Here is the caller graph for this function:



7.5 kernel/include/starkernel/boot_info_offsets.h File Reference

This graph shows which files directly or indirectly include this file:



Macros

- #define BOOT_INFO_KERNEL_STACK_BASE_OFFSET 88
- #define BOOT_INFO_KERNEL_STACK_SIZE_OFFSET 96

7.5.1 Macro Definition Documentation

7.5.1.1 BOOT_INFO_KERNEL_STACK_BASE_OFFSET

```
#define BOOT_INFO_KERNEL_STACK_BASE_OFFSET 88
```

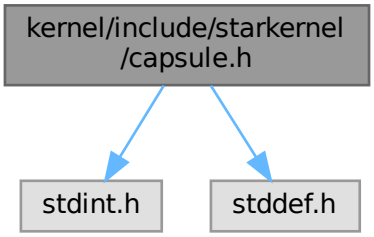
7.5.1.2 BOOT_INFO_KERNEL_STACK_SIZE_OFFSET

```
#define BOOT_INFO_KERNEL_STACK_SIZE_OFFSET 96
```

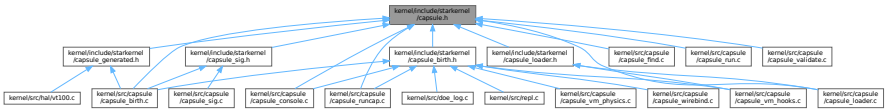
7.6 kernel/include/starkernel/capsule.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for capsule.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct CapsuleNameEntry
- struct CapsuleSigEntry
- struct CapsuleDirHeader

Macros

- #define CAPSULE_DESC_MAGIC 0x53504143ULL /* 'CAPS' little-endian */

  capsule.h - Init Capsule Architecture (M7.1)
- #define CAPSULE_DIR_MAGIC 0x44504143ULL /* 'CAPD' little-endian */
- #define CAPSULE_VERSION_0 0

  Version.
- #define CAPSULE_MAX_COUNT 256

  Limits.
- #define CAPSULE_NAME_MAX 512

  Maximum capsule name length (colon-separated path, null-terminated)
- #define CAPSULE_FLAG_ACTIVE 0x00000001 /* Eligible for use */

  State flags.
- #define CAPSULE_FLAG_REVOKED 0x00000002 /* Birth-blocked forever */
- #define CAPSULE_FLAG_DEPRECATED 0x00000004 /* Eligible but discouraged */
- #define CAPSULE_FLAG_PINNED 0x00000008 /* Immune to GC */
- #define CAPSULE_FLAG_PRODUCTION 0x00000010 /* (p) truth-bearing */

  Mode flags (D2: babies carry both)
- #define CAPSULE_FLAG_EXPERIMENT 0x00000020 /* (e) workload only */
- #define CAPSULE_FLAG_MAMA_INIT 0x00000040 /* (m) Mama's init */

Mama init flag (exactly one capsule must have this)

- #define CAPSULE_FLAG_CONTRIB 0x00000080 /* (c) contributor-submitted */

  Contributor capsule flag (FABRIC-2.md ?I.5, 2026-09-04) – path-match on capsules/contrib/, mirrors FLAG_MAMA↩ _INIT's own exact-match pattern in mkcapsule.c's flags_from_name().
- #define CAPSULE_MODE_VALID(f)

  Validate mode flags.
- #define CAPSULE_IS_MAMA_INIT(f) (((f) & CAPSULE_FLAG_MAMA_INIT) && ((f) & CAPSULE_FLAG_ACTIVE))

  Check if capsule is Mama's init.
- #define CAPSULE_BIRTH_ELIGIBLE(f)

  Birth eligibility: active and not revoked (flag type irrelevant — D2)
- #define CAPSULE_DOE_ELIGIBLE(f)

  DoE eligibility: experiment, active, not revoked.
- #define CAPSULE_MAGIC_PACK(ver, alg) (CAPSULE_DESC_MAGIC | ((uint64_t)(ver) << 32) | ((uint64↩ _t)(alg) << 40))
- #define CAPSULE_MAGIC_GET_SIG(m) ((uint32_t)((m) & 0xFFFFFFFFULL))
- #define CAPSULE_MAGIC_GET_VERSION(m) ((uint8_t)(((m) >> 32) & 0xFF))
- #define CAPSULE_MAGIC_GET_HASHALG(m) ((uint8_t)(((m) >> 40) & 0xFF))

Enumerations

- enum CapsuleHashAlg { CAPSULE_HASH_XXHASH64 = 0 , CAPSULE_HASH_SHA256 = 1 , CAPSULE_HASH_BLAKE3 = 2 }
- enum CapsuleValidateResult {
  CAPSULE_VALID = 0 , CAPSULE_ERR_BAD_MAGIC , CAPSULE_ERR_BAD_VERSION , CAPSULE_ERR_BAD_HASH_AL
  ,
  CAPSULE_ERR_BOUNDS , CAPSULE_ERR_MODE_INVALID , CAPSULE_ERR_REVOKED_ACTIVE ,
  CAPSULE_ERR_HASH_MISMATCH ,
  CAPSULE_ERR_NULL_PTR }

Functions

- struct __attribute__ ((aligned(64)))
- CapsuleValidateResult capsule_validate (const CapsuleDesc *desc, const uint8_t *arena_base, uint64_↩ t arena_size, int verify_hash)

  capsule_validate - Validate a capsule descriptor
- const char * capsule_validate_result_str (CapsuleValidateResult result)

  capsule_validate_result_str - Get string for validation result
- const CapsuleDesc * capsule_find_by_id (const CapsuleDirHeader *dir, const CapsuleDesc *descs, uint64_t id)

  capsule_find_by_id - Find capsule by content hash ID
- const CapsuleDesc * capsule_find_by_name (const CapsuleDirHeader *dir, const CapsuleDesc *descs, const CapsuleNameEntry *names, const char *name)

  capsule_find_by_name - Find capsule by colon-separated name
- const uint8_t * capsule_get_payload (const CapsuleDesc *desc, const uint8_t *arena_base)

  capsule_get_payload - Get pointer to capsule payload bytes
- const CapsuleDesc * capsule_find_mama_init (const CapsuleDirHeader *dir, const CapsuleDesc *descs)

  capsule_find_mama_init - Find the Mama init capsule

Variables

- CapsuleDesc

7.6.1 Macro Definition Documentation

7.6.1.1 CAPSULE_BIRTH_ELIGIBLE

```
#define CAPSULE_BIRTH_ELIGIBLE(
              f )
```

Value:

```
    (((f) & CAPSULE_FLAG_ACTIVE) && \
     !((f) & CAPSULE_FLAG_REVOKED))
```

Birth eligibility: active and not revoked (flag type irrelevant — D2)

7.6.1.2 CAPSULE_DESC_MAGIC

```
#define CAPSULE_DESC_MAGIC 0x53504143ULL /* 'CAPS' little-endian */
```

capsule.h - Init Capsule Architecture (M7.1)

Content-addressed, immutable init capsules for VM birth. See docs/reference/M7.1.md for full specification.

Key invariants:

- Exactly ONE production (p) INIT defines a baby VM
- capsule_id == content_hash (content-addressed)
- No shared/implicit base INITs
- DOMAIN is Mama-only, PERSONALITY is baby-only Magic signatures

7.6.1.3 CAPSULE_DIR_MAGIC

```
#define CAPSULE_DIR_MAGIC 0x44504143ULL /* 'CAPD' little-endian */
```

7.6.1.4 CAPSULE_DOE_ELIGIBLE

```
#define CAPSULE_DOE_ELIGIBLE(
              f )
```

Value:

```
    (((f) & CAPSULE_FLAG_EXPERIMENT) && \
     ((f) & CAPSULE_FLAG_ACTIVE) && \
     !((f) & CAPSULE_FLAG_REVOKED))
```

DoE eligibility: experiment, active, not revoked.

7.6.1.5 CAPSULE_FLAG_ACTIVE

```
#define CAPSULE_FLAG_ACTIVE 0x00000001 /* Eligible for use */
```

State flags.

7.6.1.6 CAPSULE_FLAG_CONTRIB

```
#define CAPSULE_FLAG_CONTRIB 0x00000080 /* (c) contributor-submitted */
```

Contributor capsule flag (FABRIC-2.md ?I.5, 2026-09-04) – path-match on capsules/contrib/, mirrors FLAG_↩ MAMA_INIT's own exact-match pattern in mkcapsule.c's flags_from_name().

Trust-tier enforcement (QEMU-vs- real-hardware, decided in conversation) is a runtime check in capsule_validate()'s callers, not encoded in this bit itself – the bit only marks "this capsule's provenance is a contributor, not this project's own source," same as CAPSULE_FLAG_PRODUCTION/_EXPERIMENT mark mode, not policy.

7.6.1.7 CAPSULE_FLAG_DEPRECATED

```
#define CAPSULE_FLAG_DEPRECATED 0x00000004 /* Eligible but discouraged */
```

7.6.1.8 CAPSULE_FLAG_EXPERIMENT

```
#define CAPSULE_FLAG_EXPERIMENT 0x00000020 /* (e) workload only */
```

7.6.1.9 CAPSULE_FLAG_MAMA_INIT

```
#define CAPSULE_FLAG_MAMA_INIT 0x00000040 /* (m) Mama's init */
```

Mama init flag (exactly one capsule must have this)

7.6.1.10 CAPSULE_FLAG_PINNED

```
#define CAPSULE_FLAG_PINNED 0x00000008 /* Immune to GC */
```

7.6.1.11 CAPSULE_FLAG_PRODUCTION

```
#define CAPSULE_FLAG_PRODUCTION 0x00000010 /* (p) truth-bearing */
```

Mode flags (D2: babies carry both)

7.6.1.12 CAPSULE_FLAG_REVOKED

```
#define CAPSULE_FLAG_REVOKED 0x00000002 /* Birth-blocked forever */
```

7.6.1.13 CAPSULE_IS_MAMA_INIT

```
#define CAPSULE_IS_MAMA_INIT(
              f )  (((f) & CAPSULE_FLAG_MAMA_INIT) && ((f) & CAPSULE_FLAG_ACTIVE))
```

Check if capsule is Mama's init.

7.6.1.14 CAPSULE_MAGIC_GET_HASHALG

```
#define CAPSULE_MAGIC_GET_HASHALG(
            m ) ((uint8_t)(((m) >> 40) & 0xFF))
```

7.6.1.15 CAPSULE_MAGIC_GET_SIG

```
#define CAPSULE_MAGIC_GET_SIG(
            m ) ((uint32_t)((m) & 0xFFFFFFFFULL))
```

7.6.1.16 CAPSULE_MAGIC_GET_VERSION

```
#define CAPSULE_MAGIC_GET_VERSION(
            m ) ((uint8_t)(((m) >> 32) & 0xFF))
```

7.6.1.17 CAPSULE_MAGIC_PACK

```
#define CAPSULE_MAGIC_PACK(
            ver,
            alg )  (CAPSULE_DESC_MAGIC | ((uint64_t)(ver) << 32) | ((uint64_t)(alg) << 40))
```

7.6.1.18 CAPSULE_MAX_COUNT

```
#define CAPSULE_MAX_COUNT 256
```

Limits.

7.6.1.19 CAPSULE_MODE_VALID

```
#define CAPSULE_MODE_VALID(
            f )
```

Value:

```
    ((((f) & CAPSULE_FLAG_MAMA_INIT) != 0) ? \
        (!((f) & (CAPSULE_FLAG_PRODUCTION | CAPSULE_FLAG_EXPERIMENT))) : \
        (((f) & CAPSULE_FLAG_PRODUCTION) || ((f) & CAPSULE_FLAG_EXPERIMENT)))
```

Validate mode flags.

Mama: neither (p) nor (e) may be set. Babies: at least one of (p) or (e) must be set (both is fine — D2).

7.6.1.20 CAPSULE_NAME_MAX

```
#define CAPSULE_NAME_MAX 512
```

Maximum capsule name length (colon-separated path, null-terminated)

7.6.1.21 CAPSULE_VERSION_0

```
#define CAPSULE_VERSION_0 0
```

Version.

7.6.2 Enumeration Type Documentation

7.6.2.1 CapsuleHashAlg

```
enum CapsuleHashAlg
```

Enumerator

CAPSULE_HASH_XXHASH64	
CAPSULE_HASH_SHA256	
CAPSULE_HASH_BLAKE3	

7.6.2.2 CapsuleValidateResult

```
enum CapsuleValidateResult
```

Enumerator

CAPSULE_VALID	
CAPSULE_ERR_BAD_MAGIC	
CAPSULE_ERR_BAD_VERSION	
CAPSULE_ERR_BAD_HASH_ALG	
CAPSULE_ERR_BOUNDS	
CAPSULE_ERR_MODE_INVALID	
CAPSULE_ERR_REVOKED_ACTIVE	
CAPSULE_ERR_HASH_MISMATCH	
CAPSULE_ERR_NULL_PTR	

7.6.3 Function Documentation

7.6.3.1 __attribute__()

```
struct __attribute__ (
            (aligned(64))  )
```

7.6.3.2 capsule_find_by_id()

```
const CapsuleDesc * capsule_find_by_id (
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            uint64_t id )
```

capsule_find_by_id - Find capsule by content hash ID

Parameters

dir	Directory header
descs	Descriptor array
id	Capsule ID (content hash) to find

Returns

Pointer to descriptor, or NULL if not found

References CapsuleDirHeader::desc_count.

7.6.3.3 capsule_find_by_name()

```
const CapsuleDesc * capsule_find_by_name (
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const char * name )
```

capsule_find_by_name - Find capsule by colon-separated name

Parameters

dir	Directory header
descs	Descriptor array
names	Name entry array (parallel to descs)
name	Colon-separated capsule name, e.g. "core:init.4th"

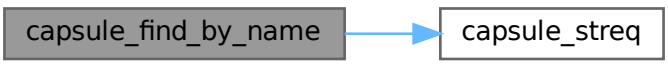
Returns

Pointer to descriptor, or NULL if not found

References capsule_streq(), CapsuleDirHeader::desc_count, and name.

Referenced by capsule_birth_baby(), capsule_exec_init(), and capsule_run_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

7.6.3.4 capsule_find_mama_init()

```
const CapsuleDesc * capsule_find_mama_init (
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs )
```

capsule_find_mama_init - Find the Mama init capsule

Searches the descriptor array for the capsule with CAPSULE_FLAG_MAMA_INIT. There must be exactly one such capsule.

Parameters

dir	Directory header
descs	Descriptor array

Returns

Pointer to Mama's init descriptor, or NULL if not found

References CAPSULE_IS_MAMA_INIT, CapsuleDirHeader::desc_count, and flags.

Referenced by capsule_birth_mama(), and kernel_main_deep().

Here is the caller graph for this function:

7.6.3.5 capsule_get_payload()

```
const uint8_t * capsule_get_payload (
            const CapsuleDesc * desc,
            const uint8_t * arena_base )
```

capsule_get_payload - Get pointer to capsule payload bytes

Parameters

desc	Capsule descriptor
arena_base	Base address of payload arena

Returns

Pointer to payload bytes, or NULL on error

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_exec_init(), and capsule_run_experiment().

Here is the caller graph for this function:

7.6.3.6 capsule_validate()

```
CapsuleValidateResult capsule_validate (
            const CapsuleDesc * desc,
            const uint8_t * arena_base,
            uint64_t arena_size,
            int verify_hash )
```

capsule_validate - Validate a capsule descriptor

Parameters

desc	Capsule descriptor to validate
arena_base	Base address of payload arena
arena_size	Size of payload arena in bytes
verify_hash	If true, recompute and compare content hash

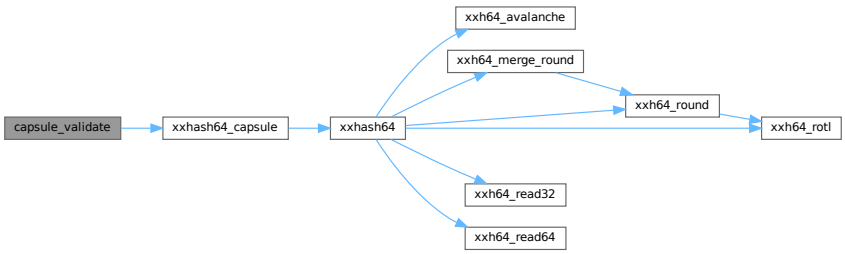
Returns

CAPSULE_VALID on success, error code otherwise

References CAPSULE_DESC_MAGIC, CAPSULE_ERR_BAD_HASH_ALG, CAPSULE_ERR_BAD_MAGIC, CAPSULE_ERR_BAD_VERSION, CAPSULE_ERR_BOUNDS, CAPSULE_ERR_HASH_MISMATCH, CAPSULE_ERR_MODE_INVA CAPSULE_ERR_NULL_PTR, CAPSULE_ERR_REVOKED_ACTIVE, CAPSULE_FLAG_ACTIVE, CAPSULE_FLAG_REVOKED, CAPSULE_HASH_BLAKE3, CAPSULE_HASH_XXHASH64, CAPSULE_MAGIC_GET_HASHALG, CAPSULE_MAGIC_GET_SIG, CAPSULE_MAGIC_GET_VERSION, CAPSULE_MODE_VALID, CAPSULE_VALID, CAPSULE_VERSION_0, and xxhash64_capsule().

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_exec_init(), and capsule_run_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

7.6.3.7 capsule_validate_result_str()

```
const char * capsule_validate_result_str (
            CapsuleValidateResult result )
```

capsule_validate_result_str - Get string for validation result

References validate_result_strings.

7.6.4 Variable Documentation

7.6.4.1 CapsuleDesc

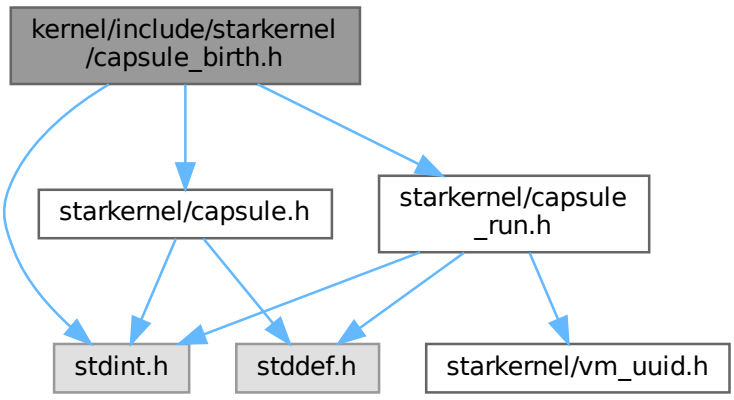
```
CapsuleDesc
```

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_console_birth(), capsule_exec_init(), capsule_run_experiment(), capsule_runcap_birth(), capsule_verify_signature(), find_and_cache_pubkey(), and kernel_main_deep().

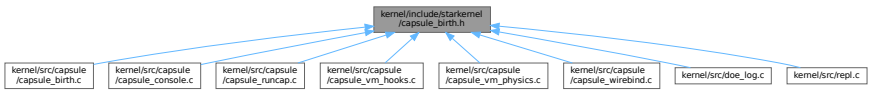
7.7 kernel/include/starkernel/capsule_birth.h File Reference

```
#include <stdint.h>
#include "starkernel/capsule.h"
#include "starkernel/capsule_run.h"
```

Include dependency graph for capsule_birth.h:



This graph shows which files directly or indirectly include this file:



Typedefs

- typedef int(∗ CapsuleExecFn) (void ∗vm_ctx, const char ∗code, uint64_t code_len)

  capsule_birth.h - VM Birth Protocol (M7.1)
- typedef uint64_t(∗ CapsuleDictHashFn) (void ∗vm_ctx)

  Dictionary hash function type.
- typedef void ∗(∗ CapsuleVMAllocFn) (void)

  VM allocation function type (for baby birth)

Functions

- void capsule_birth_set_hooks (CapsuleExecFn exec_fn, CapsuleDictHashFn dict_hash_fn, CapsuleVMAllocFn vm_alloc_fn)

  capsule_birth_set_hooks - Configure VM execution hooks
- CapsuleRunResult capsule_birth_mama (void ∗mama_vm, const CapsuleDirHeader ∗dir, const CapsuleDesc ∗descs, const CapsuleNameEntry ∗names, const uint8_t ∗arena)

  capsule_birth_mama - Execute Mama's init capsule
- CapsuleRunResult capsule_birth_baby (const char ∗capsule_name, const CapsuleDirHeader ∗dir, const CapsuleDesc ∗descs, const CapsuleNameEntry ∗names, const uint8_t ∗arena, VMUuid parent, int skip↩ _pki_sig, VMUuid ∗out_vm_id, void ∗∗out_vm_ctx)

  capsule_birth_baby - Birth a new VM from a named (p) capsule
- CapsuleRunResult capsule_run_experiment (void ∗mama_vm, const char ∗capsule_name, const CapsuleDirHeader ∗dir, const CapsuleDesc ∗descs, const CapsuleNameEntry ∗names, const uint8_t ∗arena, uint64_t ∗out_run_id)

  capsule_run_experiment - Execute a named (e) capsule on Mama
- void capsule_vm_hooks_register (void)

  capsule_vm_hooks_register - Wire concrete VM hooks into the capsule subsystem
- void capsule_vm_registry_init (void ∗mama_vm_ptr)

  capsule_vm_registry_init - Initialize VM registry
- int capsule_vm_kill (const char ∗name)

  capsule_vm_kill - Destroy a named VM and release all its resources
- int capsule_vm_registry_get (VMUuid vm_id, VMRegistryEntry ∗out)

  capsule_vm_registry_get - Get VM registry entry by ID
- uint32_t capsule_vm_registry_count (void)

  capsule_vm_registry_count - Get number of registered VMs
- int capsule_vm_registry_get_by_index (uint32_t index, VMRegistryEntry ∗out)

  capsule_vm_registry_get_by_index - Get registry entry by list position (birth order, stable within a boot session – the registry is append-only).
- int capsule_vm_find_by_name (const char ∗name, VMRegistryEntry ∗out)

  capsule_vm_find_by_name - Find VM registry entry by symbolic name
- int capsule_vm_find_by_name_nocase (const char ∗name, VMRegistryEntry ∗out)

  capsule_vm_find_by_name_nocase - Find VM registry entry by name (case-insensitive)
- void capsule_vm_set_state (VMUuid vm_id, uint32_t state)

capsule_vm_set_state - Update a VM's state in the registry

- void capsule_vm_set_pending_reap (VMUuid vm_id, int pending)

  capsule_vm_set_pending_reap - FABRIC-3.md ?XXVIII Stage 4 (2026-09-14): mark vm_id for deferred teardown once it is no longer worth resuming – see VMRegistryEntry.pending_reap's own doc comment for the full rationale.
- void capsule_vm_force_reap (VMUuid vm_id)

  capsule_vm_force_reap - FABRIC-3.md ?XXVIII Stage 4 (2026-09-14): unconditionally tear down vm_id regardless of VM_STATE_SWITCHED_OUT – the one caller allowed to bypass capsule_vm_kill()'s own refusal there, because this is called by the Stage 3 switcher itself (vm_core.c's checkpoint, on noticing pending_reap set), at the one point that genuinely knows the parked native-stack context will never be resumed.
- void capsule_vm_registry_set_name (VMUuid vm_id, const char *name)

  capsule_vm_registry_set_name - Assign a symbolic name to a registered VM
- void capsule_vm_kill_all_nonmama (void)

  capsule_vm_kill_all_nonmama - Kill every non-Mama VM in the registry.

7.7.1 Typedef Documentation

7.7.1.1 CapsuleDictHashFn

```
typedef uint64_t(* CapsuleDictHashFn) (void *vm_ctx)
```

Dictionary hash function type.

Parameters

vm_ctx	Opaque pointer to VM context

Returns

64-bit hash of dictionary state

7.7.1.2 CapsuleExecFn

```
typedef int(* CapsuleExecFn) (void *vm_ctx, const char *code, uint64_t code_len)
```

capsule_birth.h - VM Birth Protocol (M7.1)

Functions for birthing VMs from capsules:

- Mama init: Execute core/init.4th to establish Mama's PERSONALITY
- Baby birth: Create new VM from (p) capsule
- Experiment run: Execute (e) capsule on Mama VM execution function type

Parameters

vm_ctx	Opaque pointer to VM context
code	FORTH source code to execute
code_len	Length of code in bytes

Returns

0 on success, non-zero on error

7.7.1.3 CapsuleVMAllocFn

```
typedef void *(* CapsuleVMAllocFn) (void)
```

VM allocation function type (for baby birth)

Returns

Opaque pointer to new VM context, or NULL on failure

7.7.2 Function Documentation

7.7.2.1 capsule_birth_baby()

```
CapsuleRunResult capsule_birth_baby (
            const char * capsule_name,
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena,
            VMUuid parent,
            int skip_pki_sig,
            VMUuid * out_vm_id,
            void ** out_vm_ctx )
```

capsule_birth_baby - Birth a new VM from a named (p) capsule

Finds the capsule by colon-separated name, validates it, allocates a new VM, executes the capsule payload as IDENTITY, then (if present) executes unit.4th from the baby's block space as PERSONALITY.

Parameters

capsule_name	Colon-separated capsule name, e.g. "production:myvm.4th"
dir	Capsule directory header
descs	Capsule descriptor array
names	Capsule name entry array (parallel to descs)
arena	Capsule payload arena
parent	Who is birthing this VM (FABRIC-2.md ?H.12 step 7) – the caller's own VMUuid (e.g. vm->stadium_vm_id for a FORTH word handler), recorded on the new VM's Session.parent. Every current call site has one in scope, directly or one level up; traced live rather than assumed (checked all 6 call sites across mama_forth_words.c/capsule_console.c/ capsule_runcap.c/capsule_wirebind.c).
skip_pki_sig	0 for every build-time capsule (the normal case – checked against the compile-time-baked signature array via capsule_get_signatures()). Non-zero only for RUNCAP (FABRIC-2.md ?F.6/F.18): a heap-built, single-entry directory sourced from a user's own thumbdrive has no entry in that array at all – index 0 would silently compare against whatever real capsule happens to occupy slot 0, which is not a security check, just a guaranteed-wrong one. Trust for that content comes from CERTVERIFY (a separate root, the user's own Zuse-signed cert) already having run before RUNCAP is ever called, not from this flag – this only skips a check that was never meaningful for that content in the first place. Deliberately a plain flag, not a
	new entry point, so the policy is one call-site decision, trivially reversible.
out_vm_id	Output: assigned VM ID
out_vm_ctx	Output: new VM context

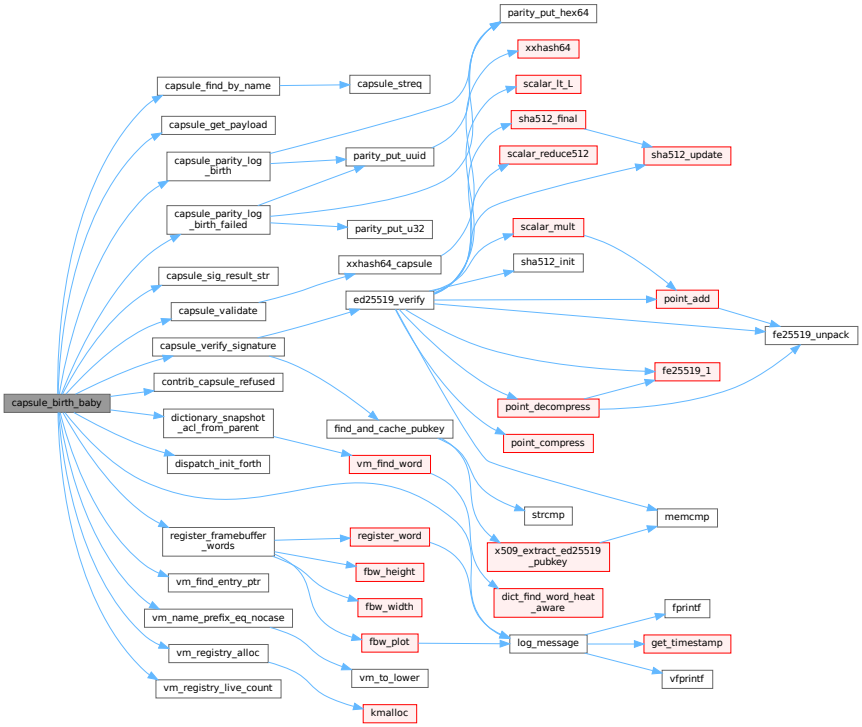
Returns

CAPSULE_RUN_OK on success, error code otherwise

References CapsuleDirHeader::arena_size, CAPSULE_BIRTH_ELIGIBLE, capsule_find_by_name(), capsule_get_payload(), capsule_parity_log_birth(), capsule_parity_log_birth_failed(), CAPSULE_RUN_ERR_EXEC_FAIL, CAPSULE_RUN_ERR_FLEET_FU CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_ERR_NOT_ELIGIBLE, CAPSULE_RUN_ERR_STILLBORN, CAPSULE_RUN_OK, CAPSULE_SIG_INVALID, CAPSULE_SIG_OK, capsule_sig_result_str(), CAPSULE_VALID, capsule_validate(), capsule_verify_signature(), CapsuleDesc, contrib_capsule_refused(), CapsuleDirHeader::desc_count, dictionary_snapshot_acl_from_parent(), dispatch_init_forth(), entry, log_message(), LOG_WARN, name, register_framebuffer_words(), vm_alloc_fn, vm_dict_hash_fn, vm_exec_fn, vm_find_entry_ptr(), vm_name_prefix_eq_nocase(), VMRegistryEntry::vm_ptr, vm_registry_alloc(), vm_registry_live_count(), VM_STATE_EMBRYO, VM_STATE_LIVE, and VM_STATE_STILLBORN.

Referenced by capsule_console_birth(), and capsule_runcap_birth().

Here is the call graph for this function:



Here is the caller graph for this function:

7.7.2.2 capsule_birth_mama()

```
CapsuleRunResult capsule_birth_mama (
            void * mama_vm,
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena )
```

capsule_birth_mama - Execute Mama's init capsule

Finds the MAMA_INIT capsule by flag, validates it, executes it on Mama's VM.

Parameters

mama_vm	Mama's VM context
dir	Capsule directory header
descs	Capsule descriptor array
names	Capsule name entry array (parallel to descs)
arena	Capsule payload arena

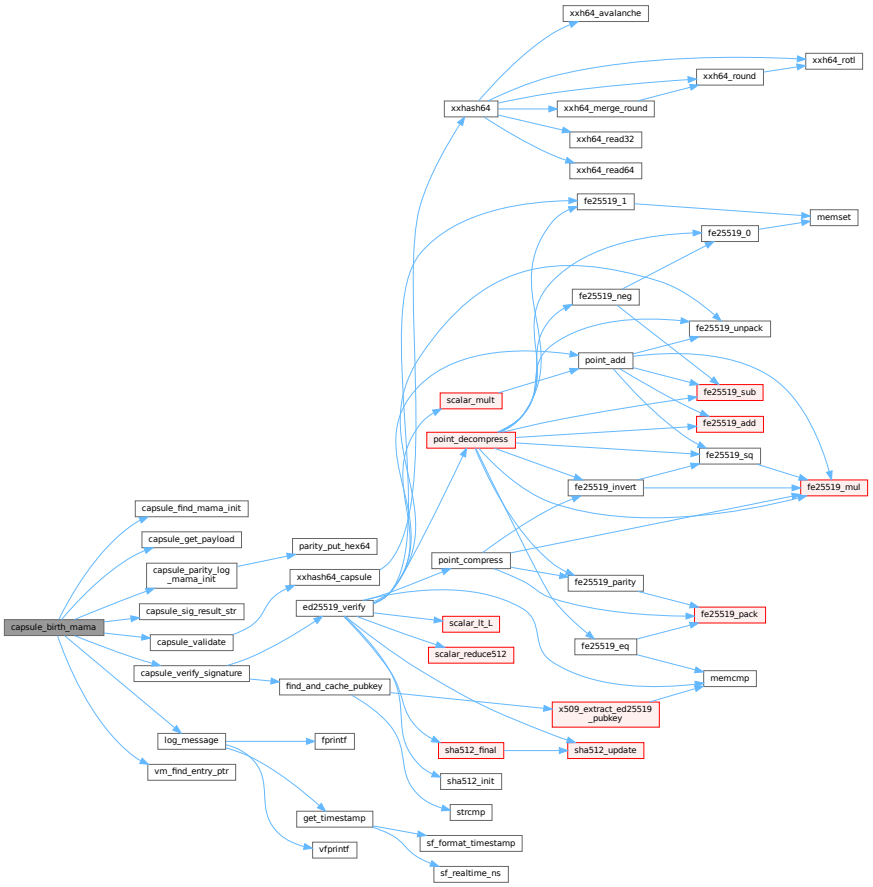
Returns

CAPSULE_RUN_OK on success, error code otherwise

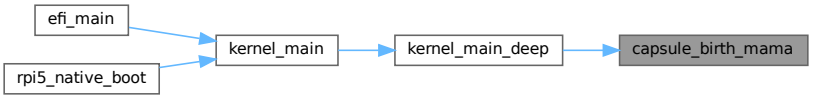
References CapsuleDirHeader::arena_size, VMRegistryEntry::birth_capsule_id, VMRegistryEntry::birth_dict_hash, capsule_find_mama_init(), capsule_get_payload(), capsule_parity_log_mama_init(), CAPSULE_RUN_ERR_EXEC_FAIL, CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_OK, CAPSULE_SIG_INVALID, CAPSULE_SIG_OK, capsule_sig_result_str(), CAPSULE_VALID, capsule_validate(), capsule_verify_signature(), CapsuleDesc, CapsuleDirHeader::desc_count, log_message(), LOG_WARN, name, vm_dict_hash_fn, vm_exec_fn, and vm_find_entry_ptr().

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.7.2.3 capsule_birth_set_hooks()

```
void capsule_birth_set_hooks (
            CapsuleExecFn exec_fn,
            CapsuleDictHashFn dict_hash_fn,
            CapsuleVMAllocFn vm_alloc_fn )
```

capsule_birth_set_hooks - Configure VM execution hooks

Must be called before any birth operations.

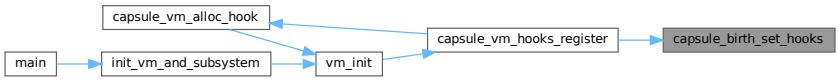
Parameters

exec_fn	Function to execute FORTH code on VM
dict_hash↩ _fn	Function to compute dictionary hash
vm_alloc_fn	Function to allocate new VM (for babies)

References vm_alloc_fn, vm_dict_hash_fn, and vm_exec_fn.

Referenced by capsule_vm_hooks_register().

Here is the caller graph for this function:



7.7.2.4 capsule_run_experiment()

```
CapsuleRunResult capsule_run_experiment (
            void * mama_vm,
            const char * capsule_name,
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena,
            uint64_t * out_run_id )
```

capsule_run_experiment - Execute a named (e) capsule on Mama

Finds the experiment capsule by colon-separated name, validates it, executes it on Mama's VM without creating a new VM.

Parameters

mama_vm	Mama's VM context
capsule_name	Colon-separated capsule name, e.g. "experiments:doe-l8:init-l8-stable.4th"
dir	Capsule directory header
descs	Capsule descriptor array
names	Capsule name entry array (parallel to descs)
arena	Capsule payload arena
out_run_id	Output: assigned run ID

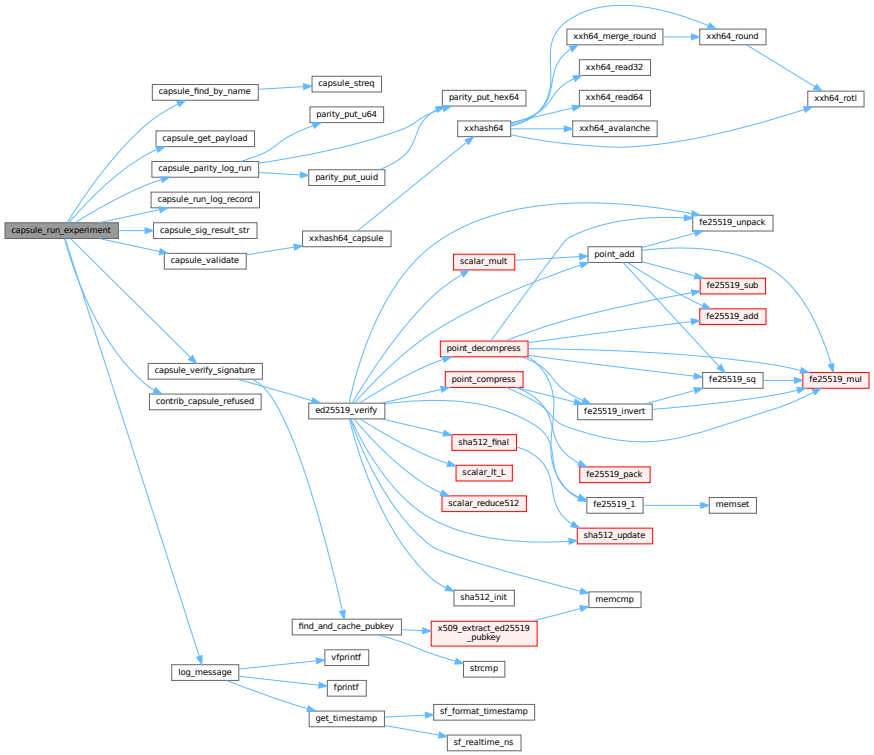
Returns

CAPSULE_RUN_OK on success, error code otherwise

References CapsuleDirHeader::arena_size, CAPSULE_DOE_ELIGIBLE, capsule_find_by_name(), capsule_get_payload(), CapsuleRunRecord::capsule_hash, CapsuleRunRecord::capsule_id, capsule_parity_log_run(), CAPSULE_RUN_ERR_EXEC_FAIL,

CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_ERR_NOT_ELIGIBLE, capsule_run_log_record(), CAPSULE_RUN_OK, CAPSULE_SIG_INVALID, CAPSULE_SIG_OK, capsule_sig_result_str(), CAPSULE_VALID, capsule_validate(), capsule_verify_signature(), CapsuleDesc, contrib_capsule_refused(), CapsuleDirHeader::desc_count, CapsuleRunRecord::ended_ns, CapsuleRunRecord::flags, log_message(), LOG_WARN, name, CapsuleRunRecord::post_dict_hash, CapsuleRunRecord::pre_dict_h, CapsuleRunRecord::reserved, CapsuleRunRecord::result_code, CapsuleRunRecord::run_id, CapsuleRunRecord::started_ns, vm_dict_hash_fn, vm_exec_fn, and CapsuleRunRecord::vm_id.

Here is the call graph for this function:



7.7.2.5 capsule_vm_find_by_name()

```
int capsule_vm_find_by_name (
            const char * name,
            VMRegistryEntry * out )
```

capsule_vm_find_by_name - Find VM registry entry by symbolic name

Case-sensitive. Returns the first match.

Parameters

name	Symbolic VM name, e.g. "Hermes"
out	Output: registry entry copy

Returns

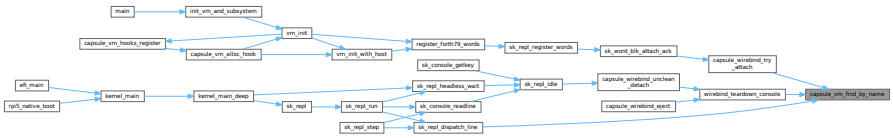
0 if found, -1 if not found

References vm_node::entry, VMRegistryEntry::name, name, vm_node::next, vm_name_eq(), and vm_registry_head.

Referenced by capsule_wirebind_try_attach(), sk_repl_dispatch_line(), and wirebind_teardown_console().

Here is the call graph for this function:

Here is the caller graph for this function:



7.7.2.6 capsule_vm_find_by_name_nocase()

```
int capsule_vm_find_by_name_nocase (
            const char * name,
            VMRegistryEntry * out )
```

capsule_vm_find_by_name_nocase - Find VM registry entry by name (case-insensitive)

Used by BIRTH for idempotency: prevents birthing a second VM with the same name regardless of case differences.

Parameters

name	Symbolic VM name (compared case-insensitively)
out	Output: registry entry copy

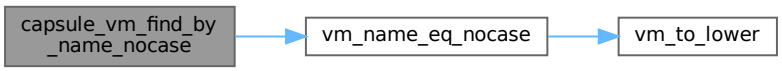
Returns

0 if found, -1 if not found

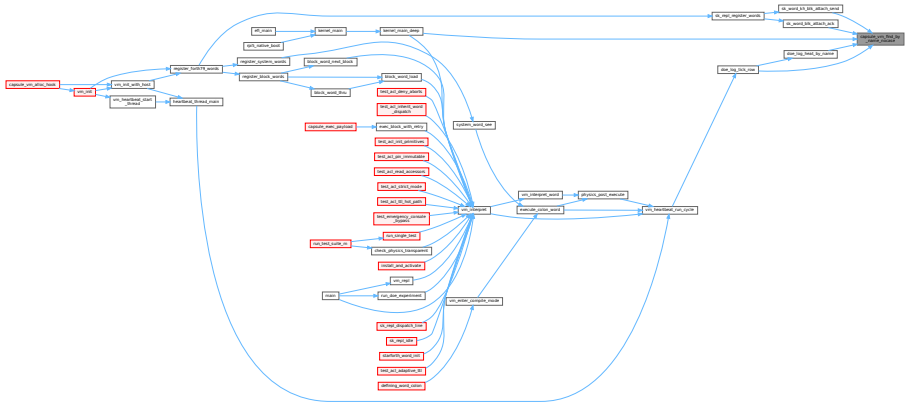
References vm_node::entry, VMRegistryEntry::name, name, vm_node::next, vm_name_eq_nocase(), and vm_registry_head.

Referenced by doe_log_heat_by_name(), doe_log_tick_row(), kernel_main_deep(), sk_word_blk_attach_ack(), and sk_word_kh_blk_attach_send().

Here is the call graph for this function:



Here is the caller graph for this function:



7.7.2.7 capsule_vm_force_reap()

```
void capsule_vm_force_reap (
            VMUuid vm_id )
```

capsule_vm_force_reap - FABRIC-3.md ?XXVIII Stage 4 (2026-09-14): unconditionally tear down vm_id regardless of VM_STATE_SWITCHED_OUT – the one caller allowed to bypass capsule_vm_kill()'s own refusal there, because this is called *by* the Stage 3 switcher itself (vm_core.c's checkpoint, on noticing pending_reap set), at the one point that genuinely knows the parked native-stack context will never be resumed.

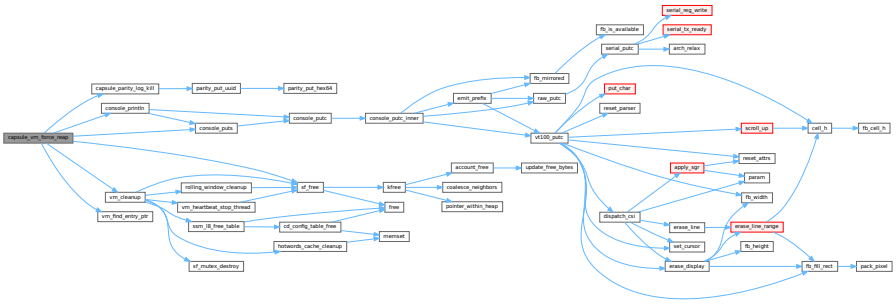
Also releases the VM's own switch-signal slot (sk_vm_switch_signal_unregister()) – generic cleanup, independent of whatever subsystem (WIREBIND today) set pending_reap in the first place. No-op if vm_id isn't registered or is already DEAD.

Parameters

vm_id	VM ID to reap.

References capsule_parity_log_kill(), console_println(), console_puts(), entry, sf_free(), vm_cleanup(), vm_find_entry_ptr(), VM_NAME_MAX, and VM_STATE_DEAD.

Here is the call graph for this function:



7.7.2.8 capsule_vm_hooks_register()

```
void capsule_vm_hooks_register (
            void  )
```

capsule_vm_hooks_register - Wire concrete VM hooks into the capsule subsystem

Registers capsule_exec_hook, capsule_dict_hash_hook, and capsule_vm_alloc_hook. Must be called after vm_init() on Mama's VM and before any birth operations.

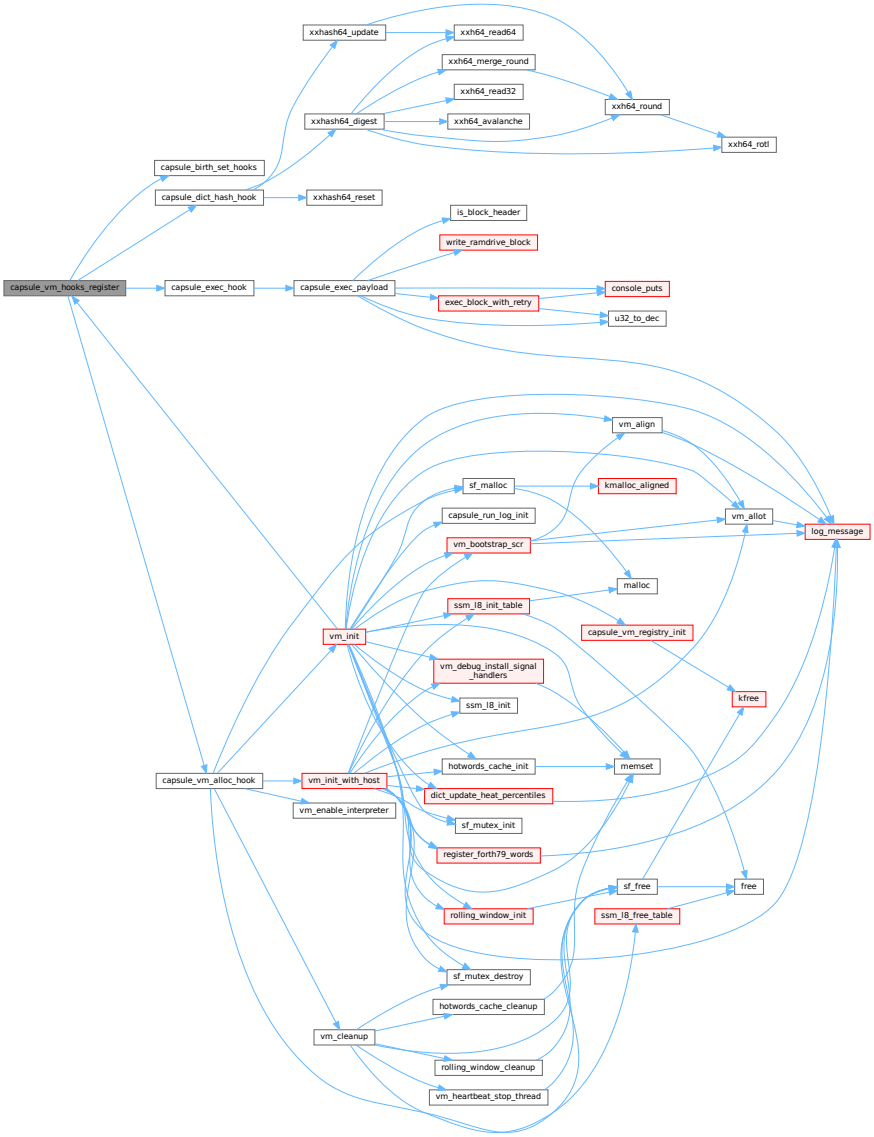
capsule_vm_hooks_register - Wire concrete VM hooks into the capsule subsystem

Must be called after vm_init() completes on Mama's VM, before any capsule birth or experiment operations.

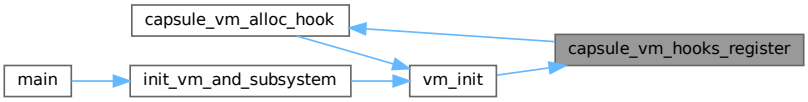
References capsule_birth_set_hooks(), capsule_dict_hash_hook(), capsule_exec_hook(), and capsule_vm_alloc_hook().

Referenced by vm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.7.2.9 capsule_vm_kill()

```
int capsule_vm_kill (
            const char * name )
```

capsule_vm_kill - Destroy a named VM and release all its resources

Looks up the VM by name (case-insensitive). Hera (VM 0) cannot be killed. If the VM is already DEAD the call is a no-op. On success: vm_cleanup + sf_free, state → VM_STATE_DEAD, name cleared.

Parameters

name	Symbolic name of the VM to kill (case-insensitive)

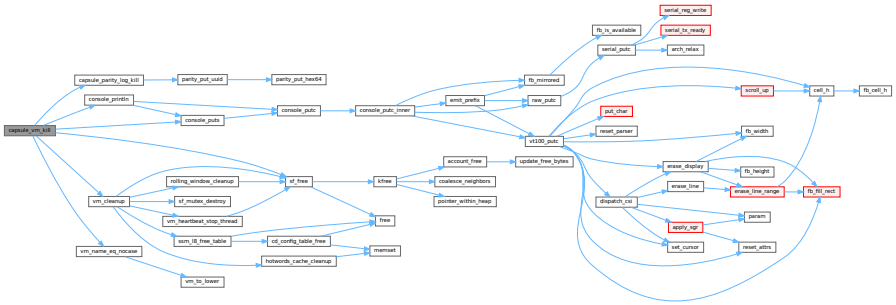
Returns

0 on success (or already dead), -1 if not found or refused

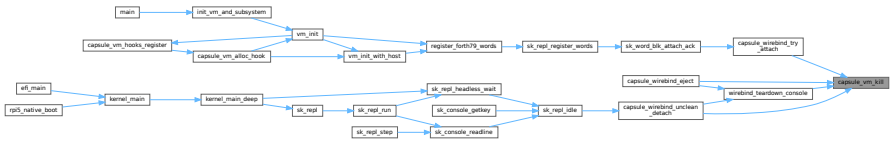
References capsule_parity_log_kill(), console_println(), console_puts(), entry, vm_node::entry, VMRegistryEntry::name, name, vm_node::next, sf_free(), vm_cleanup(), vm_name_eq_nocase(), VM_NAME_MAX, vm_registry_head, VM_STATE_DEAD, and VM_STATE_SWITCHED_OUT.

Referenced by capsule_wirebind_eject(), capsule_wirebind_try_attach(), capsule_wirebind_unclean_detach(), and wirebind_teardown_console().

Here is the call graph for this function:



Here is the caller graph for this function:



7.7.2.10 capsule_vm_kill_all_nonmama()

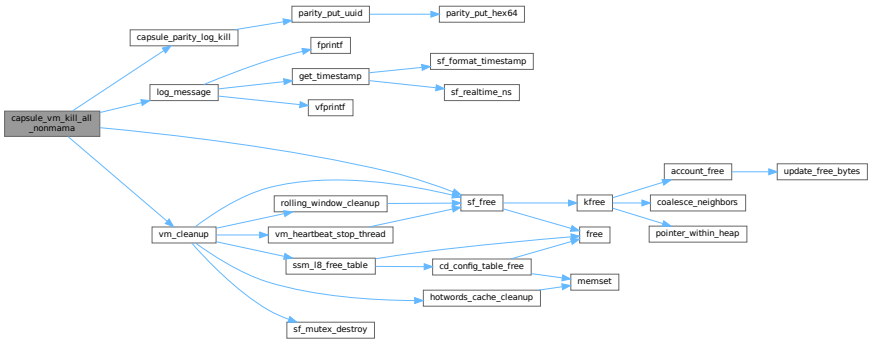
```
void capsule_vm_kill_all_nonmama (
            void  )
```

capsule_vm_kill_all_nonmama - Kill every non-Mama VM in the registry.

Sets halted, calls vm_cleanup + sf_free, marks state DEAD. Used by Hera's BYE immediately before arch_cold_reset() to reap all children.

References capsule_parity_log_kill(), vm_node::entry, VM::halted, log_message(), LOG_WARN, VMRegistryEntry::name, vm_node::next, sf_free(), VMRegistryEntry::stadium_patron_cell, VMRegistryEntry::state, vm_cleanup(), VMRegistryEntry::vm_id, VMRegistryEntry::vm_ptr, vm_registry_head, VM_STATE_DEAD, and VM_STATE_SWITCHED_OUT.

Here is the call graph for this function:



7.7.2.11 capsule_vm_registry_count()

```
uint32_t capsule_vm_registry_count (
            void  )
```

capsule_vm_registry_count - Get number of registered VMs

References vm_registry_count.

7.7.2.12 capsule_vm_registry_get()

```
int capsule_vm_registry_get (
            VMUuid vm_id,
            VMRegistryEntry * out )
```

capsule_vm_registry_get - Get VM registry entry by ID

Parameters

vm↩ _id	VM ID to look up
out	Output: registry entry copy

Returns

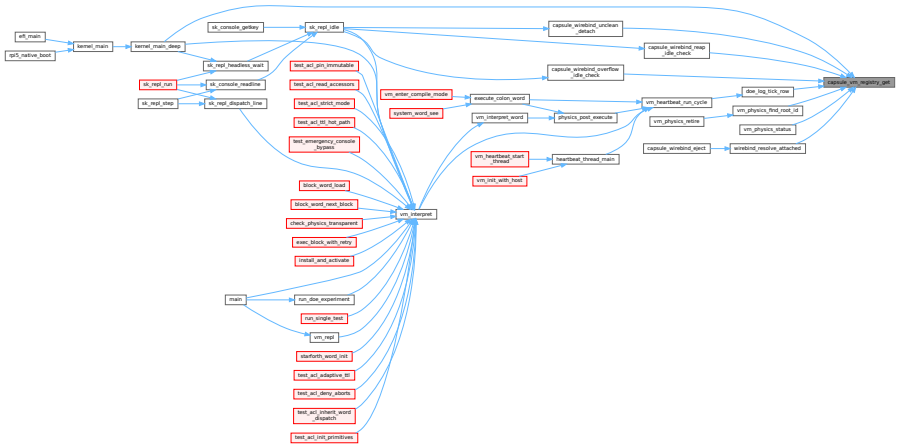
0 on success, -1 if not found

References entry, and vm_find_entry_ptr().

Referenced by capsule_wirebind_overflow_idle_check(), capsule_wirebind_reap_idle_check(), capsule_wirebind_unclean_detach(), doe_log_tick_row(), kernel_main_deep(), vm_physics_find_root_id(), vm_physics_status(), and wirebind_resolve_attached().

Here is the call graph for this function:

Here is the caller graph for this function:



7.7.2.13 capsule_vm_registry_get_by_index()

```
int capsule_vm_registry_get_by_index (
            uint32_t index,
            VMRegistryEntry * out )
```

capsule_vm_registry_get_by_index - Get registry entry by list position (birth order, stable within a boot session – the registry is append-only).

For enumeration (e.g. the idle-loop messaging pump, FABRIC-2.md Phase C, 2026-08-28), where no vm_id is known up front. Index range is [0, capsule_vm_registry_count()).

Parameters

index	Zero-based position in birth order
out	Output: registry entry copy

Returns

0 on success, -1 if index is out of range

References vm_node::entry, vm_node::next, and vm_registry_head.

7.7.2.14 capsule_vm_registry_init()

```
void capsule_vm_registry_init (
            void * mama_vm_ptr )
```

capsule_vm_registry_init - Initialize VM registry

Allocates Mama's registry node (VM 0, name "Hera") via kmalloc and stores mama_vm_ptr so KILL can guard against destroying Mama. Must be called after kmalloc_init().

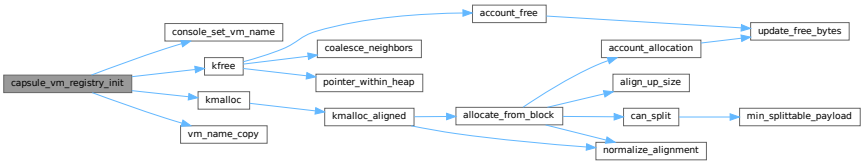
Parameters

mama_vm_ptr	Pointer to Mama's VM object (e.g. &sk_mama_vm)

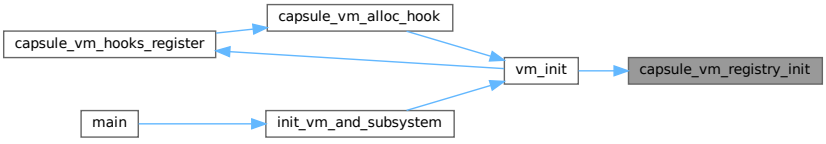
References VMRegistryEntry::birth_capsule_id, VMRegistryEntry::birth_dict_hash, VMRegistryEntry::birth_timestamp_ns, console_set_vm_name(), vm_node::entry, VMRegistryEntry::flags, kfree(), kmalloc(), VMRegistryEntry::name, vm_node::next, VMRegistryEntry::parent_vm_id, VMRegistryEntry::stadium_patron_cell, VMRegistryEntry::state, VMRegistryEntry::vm_id, vm_name_copy(), VM_NAME_MAX, VMRegistryEntry::vm_ptr, vm_registry_count, vm_registry_head, and VM_STATE_LIVE.

Referenced by vm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.7.2.15 capsule_vm_registry_set_name()

```
void capsule_vm_registry_set_name (
            VMUuid vm_id,
            const char * name )
```

capsule_vm_registry_set_name - Assign a symbolic name to a registered VM

Truncates to VM_NAME_MAX-1 characters. No-op if vm_id not found.

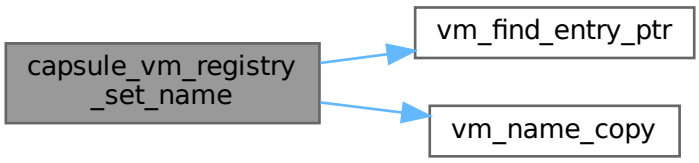
Parameters

vm↩ _id	VM ID to name
name	Symbolic name string

References entry, name, vm_find_entry_ptr(), and vm_name_copy().

Referenced by capsule_console_birth(), and capsule_runcap_birth().

Here is the call graph for this function:



Here is the caller graph for this function:

7.7.2.16 capsule_vm_set_pending_reap()

```
void capsule_vm_set_pending_reap (
            VMUuid vm_id,
            int pending )
```

capsule_vm_set_pending_reap - FABRIC-3.md ?XXVIII Stage 4 (2026-09-14): mark vm_id for deferred teardown once it is no longer worth resuming – see VMRegistryEntry.pending_reap's own doc comment for the full rationale.

No-op if vm_id isn't registered.

Parameters

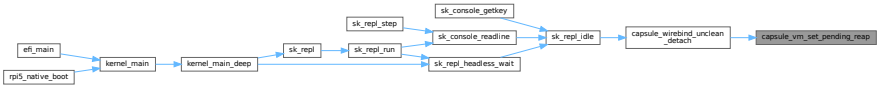
vm_id	VM ID to mark.
pending	1 to mark, 0 to clear (e.g. a re-attach of the same identity before the switcher ever reaped it).

References entry, and vm_find_entry_ptr().

Referenced by capsule_wirebind_unclean_detach().

Here is the call graph for this function:

Here is the caller graph for this function:



7.7.2.17 capsule_vm_set_state()

```
void capsule_vm_set_state (
            VMUuid vm_id,
            uint32_t state )
```

capsule_vm_set_state - Update a VM's state in the registry

Parameters

vm_id	VM ID to update
state	New VMState value

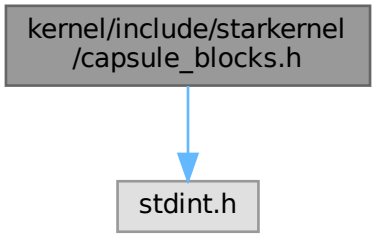
References entry, and vm_find_entry_ptr().

Here is the call graph for this function:

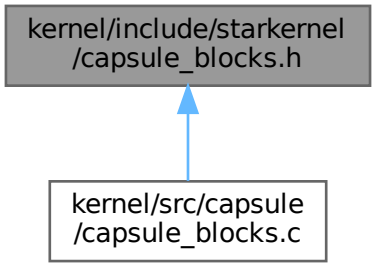
7.8 kernel/include/starkernel/capsule_blocks.h File Reference

```
#include <stdint.h>
```

Include dependency graph for capsule_blocks.h:



This graph shows which files directly or indirectly include this file:



Functions

- int capsule_block_header (const uint8_t *p, const uint8_t *end, uint32_t *out_num, const uint8_t **out_after)

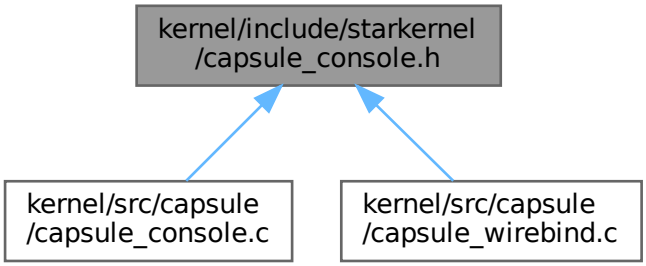
7.8.1 Function Documentation

7.8.1.1 capsule_block_header()

```
int capsule_block_header (
            const uint8_t * p,
            const uint8_t * end,
            uint32_t * out_num,
            const uint8_t ** out_after )
```

7.9 kernel/include/starkernel/capsule_console.h File Reference

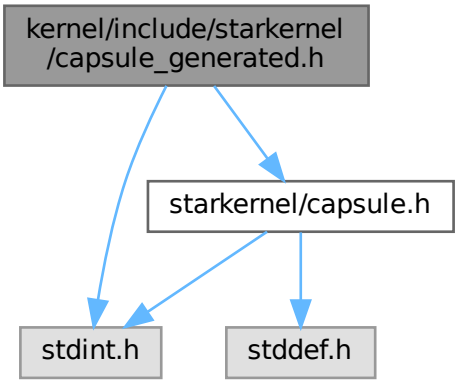
This graph shows which files directly or indirectly include this file:



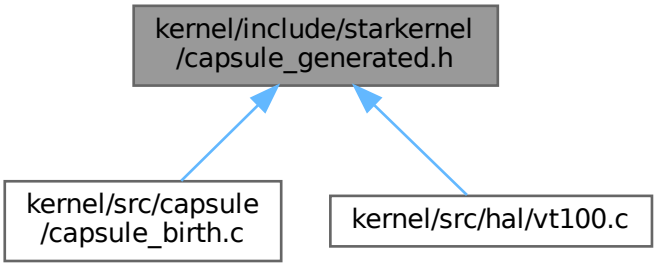
7.10 kernel/include/starkernel/capsule_generated.h File Reference

```
#include <stdint.h>
#include "starkernel/capsule.h"
```

Include dependency graph for capsule_generated.h:



This graph shows which files directly or indirectly include this file:



Functions

- __attribute__ ((visibility("hidden"))) extern const uint8_t capsule_arena[ ]
  capsule_generated.h - Declarations for mkcapsule-generated capsule store.

7.10.1 Function Documentation

7.10.1.1 __attribute__()

```
__attribute__ (
            (visibility("hidden"))  ) const
```

capsule_generated.h - Declarations for mkcapsule-generated capsule store.

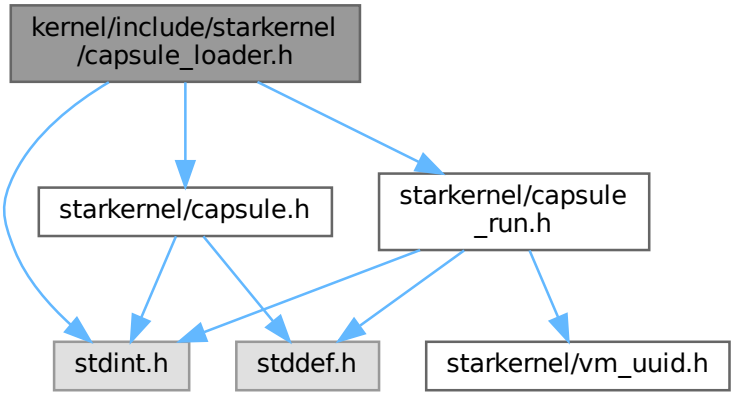
The matching capsule_generated.c is produced at build time by mkcapsule. These three arrays plus the directory header are compiled into .rodata.

7.11 kernel/include/starkernel/capsule_loader.h File Reference

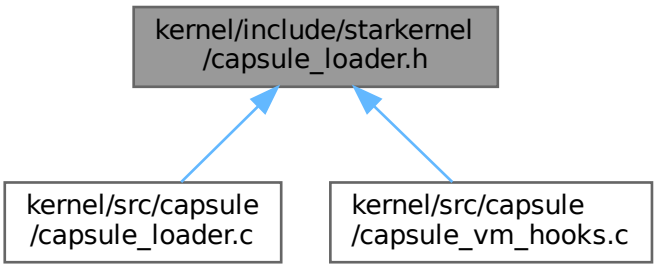
```
#include <stdint.h>
#include "starkernel/capsule.h"
```

```
#include "starkernel/capsule_run.h"
```

Include dependency graph for capsule_loader.h:



This graph shows which files directly or indirectly include this file:



Functions

- int capsule_load_blocks (const uint8_t *payload, uint64_t length, uint32_t *out_entry_block)

  capsule_loader.h - Block Capsule Loader and Executor (M7.1)
- void capsule_clear_blocks (const uint8_t *payload, uint64_t length)

  capsule_clear_blocks - Zero all ramdrive slots referenced in a capsule payload
- int capsule_exec_payload (void *vm_opaque, const uint8_t *payload, uint64_t length)

  capsule_exec_payload - Parse, populate block device, and execute a payload
- CapsuleRunResult capsule_exec_init (void *vm, const char *capsule_name, const CapsuleDirHeader *dir, const CapsuleDesc *descs, const CapsuleNameEntry *names, const uint8_t *arena)

  capsule_exec_init - Load and execute an init capsule

7.11.1 Function Documentation

7.11.1.1 capsule_clear_blocks()

```
void capsule_clear_blocks (
            const uint8_t * payload,
            uint64_t length )
```

capsule_clear_blocks - Zero all ramdrive slots referenced in a capsule payload

Re-parses the payload for "Block <num>" headers and zeros each corresponding 1024-byte ramdrive slot. NOT called by capsule_exec_init() (fixed 2026-09-10 – see its own doc comment): callers that specifically want a capsule's block range freed for reuse (e.g. kernel_main.c, right after Mama's own init.4th birth, to free that range for interactive block-editor use) call this themselves, explicitly, after exec returns.

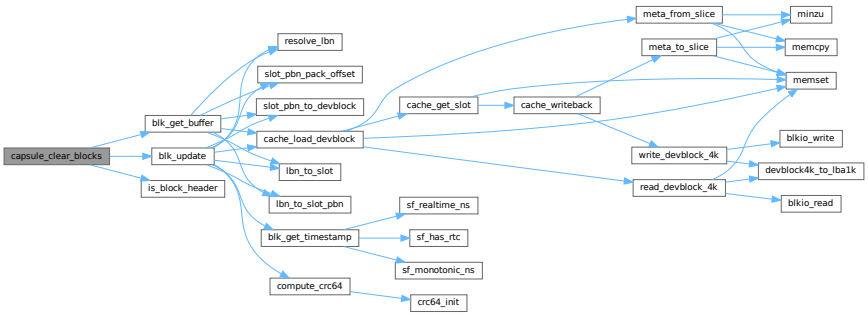
Parameters

payload	Raw capsule payload bytes
length	Payload length in bytes

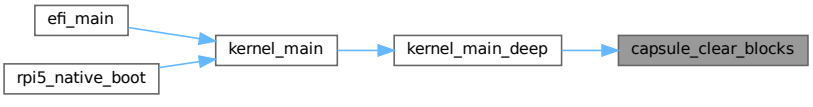
References blk_get_buffer(), blk_update(), is_block_header(), and LOADER_BLOCK_SIZE.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.11.1.2 capsule_exec_init()

```
CapsuleRunResult capsule_exec_init (
            void * vm,
            const char * capsule_name,
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena )
```

capsule_exec_init - Load and execute an init capsule

Full init sequence:

1. Locate capsule by colon-separated name in the capsule directory
2. Validate content hash
3. capsule_exec_payload: populate block device + execute content

Block content is NOT cleared afterward (fixed 2026-09-10): it stays resident in ramdrive storage so a subsequent Standard BLOCK/LOAD on the same block number reads back what EXEC just wrote, matching FORTH-79 block-persistence semantics. Callers that specifically want the old "free this capsule's block range" behavior (e.g. kernel_main.c freeing init.4th's range for later interactive block-editor use) call capsule_clear_blocks() themselves, explicitly, after this returns.

Parameters

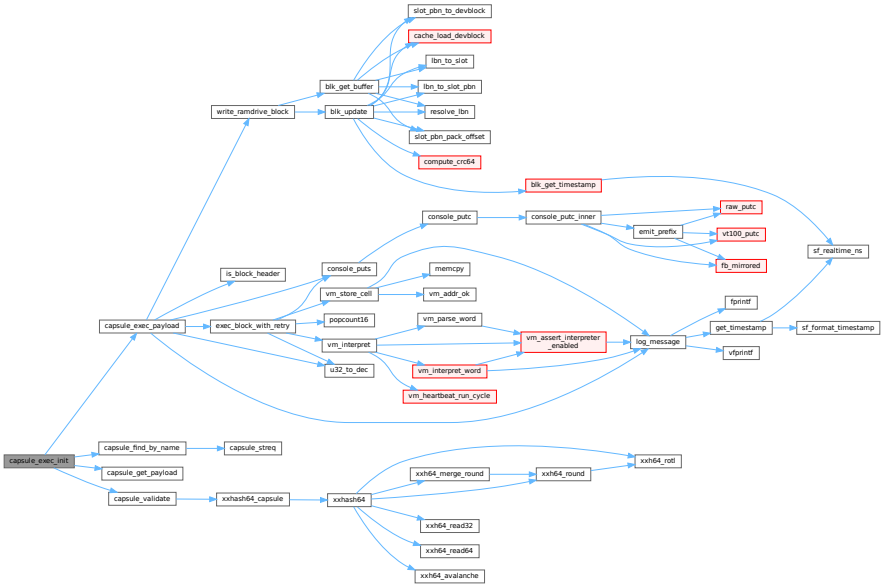
vm	VM to execute on
capsule_name	Colon-separated capsule name, e.g. "init.4th"
dir	Capsule directory header
descs	Capsule descriptor array
names	Capsule name entry array (parallel to descs)
arena	Capsule payload arena

Returns

CAPSULE_RUN_OK on success, error code otherwise

References CapsuleDirHeader::arena_size, capsule_exec_payload(), capsule_find_by_name(), capsule_get_payload(), CAPSULE_RUN_ERR_EXEC_FAIL, CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_OK, CAPSULE_VALID, capsule_validate(), and CapsuleDesc.

Here is the call graph for this function:



7.11.1.3 capsule_exec_payload()

```
int capsule_exec_payload (
            void * vm_opaque,
            const uint8_t * payload,
            uint64_t length )
```

capsule_exec_payload - Parse, populate block device, and execute a payload

For each "Block <num>" section: write content to block device (warn+truncate if > 1KB), then execute line-by-line via vm_interpret. No LOAD is injected.

Parameters

vm_opaque	VM to execute on
payload	Raw payload bytes
length	Payload length in bytes

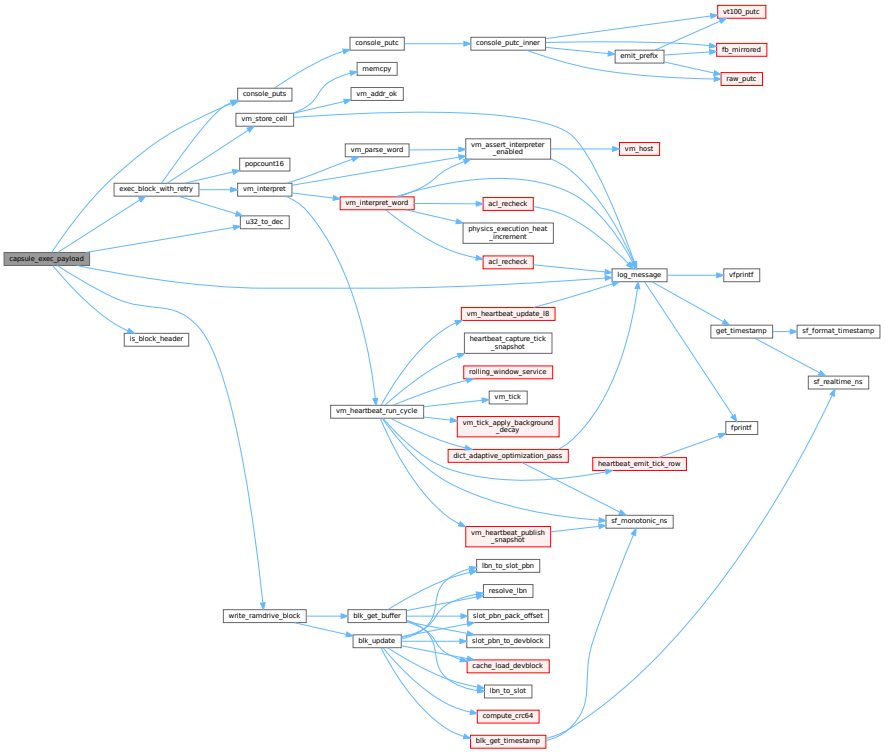
Returns

0 on success, -1 on execution error

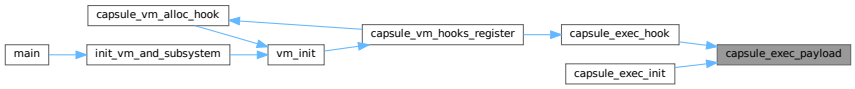
References console_puts(), exec_block_with_retry(), is_block_header(), LOADER_BLOCK_SIZE, LOG_INFO, log_message(), u32_to_dec(), and write_ramdrive_block().

Referenced by capsule_exec_hook(), and capsule_exec_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.11.1.4 capsule_load_blocks()

```
int capsule_load_blocks (
            const uint8_t * payload,
            uint64_t length,
            uint32_t * out_entry_block )
```

capsule_loader.h - Block Capsule Loader and Executor (M7.1)

Parses a capsule payload for "Block <num>" headers and writes each block's content into the correct ramdrive slot, then executes the entry block and zeros the ramdrive slots afterward.

Format: Block <decimal>
<content: up to 1024 bytes of FORTH source> Block <decimal>
...

Blocks may appear in any order; block numbers are arbitrary. Content exceeding 1024 bytes is truncated with a warning. capsule_load_blocks - Parse a capsule payload and write blocks to the ramdrive

For each "Block <num>" header found in the payload:

1. Zero the 1024-byte ramdrive slot for block <num>
2. Copy content bytes into the slot (excess beyond 1024 silently dropped)
3. Mark the slot dirty via blk_update()

Content between headers may be text or binary. Anything before the first "Block <num>" header is ignored.

Parameters

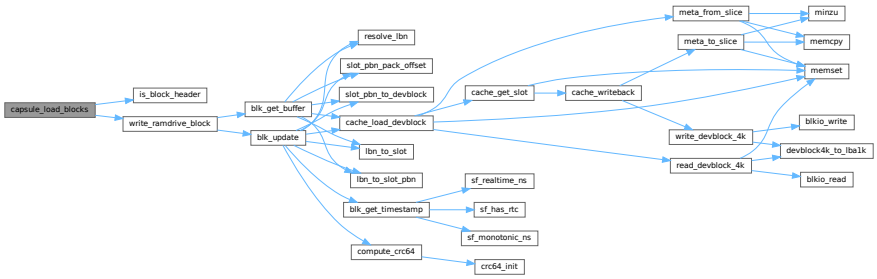
payload	Raw capsule payload bytes (not null-terminated)
length	Payload length in bytes
out_entry_block	If non-NULL, receives the first block number found (the execution entry point); set to 0 if no blocks found

Returns

Number of blocks written, or -1 on invalid input

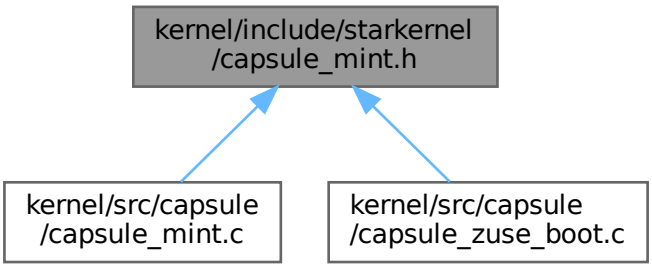
References is_block_header(), and write_ramdrive_block().

Here is the call graph for this function:



7.12 kernel/include/starkernel/capsule_mint.h File Reference

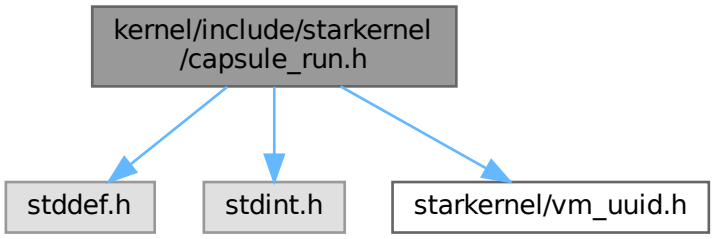
This graph shows which files directly or indirectly include this file:



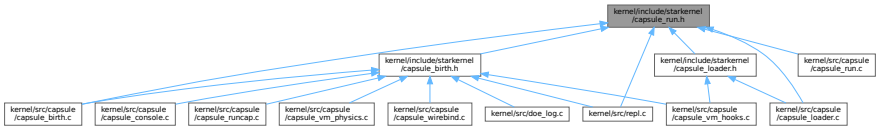
7.13 kernel/include/starkernel/capsule_run.h File Reference

```
#include <stddef.h>
#include <stdint.h>
#include "starkernel/vm_uuid.h"
```

Include dependency graph for capsule_run.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct CapsuleRunRecord
- struct VMRegistryEntry

Macros

- #define CAPSULE_MAX_RUN_RECORDS 1024

  capsule_run.h - DoE Run Logging (M7.1)
- #define VM_NAME_MAX 64

  Maximum length of a VM symbolic name, including null terminator.

Enumerations

- enum CapsuleRunResult {
  CAPSULE_RUN_OK = 0 , CAPSULE_RUN_ERR_INVALID , CAPSULE_RUN_ERR_NOT_ELIGIBLE ,
  CAPSULE_RUN_ERR_EXEC_FAIL ,
  CAPSULE_RUN_ERR_HASH_MISMATCH , CAPSULE_RUN_ERR_STILLBORN , CAPSULE_RUN_ERR_FLEET_FULL
  }
- enum VMState {
  VM_STATE_EMBRYO = 0 , VM_STATE_LIVE , VM_STATE_STOPPED , VM_STATE_STILLBORN ,
  VM_STATE_DEAD , VM_STATE_SWITCHED_OUT }

Functions

- void capsule_run_log_init (void)

  capsule_run_log_init - Initialize run log
- uint64_t capsule_run_log_record (const CapsuleRunRecord *record)

  capsule_run_log_record - Log a run record
- int capsule_run_log_get (uint64_t run_id, CapsuleRunRecord *out)

  capsule_run_log_get - Get a run record by ID
- uint32_t capsule_run_log_count (void)

  capsule_run_log_count - Get number of logged runs
- void capsule_parity_log_birth (VMUuid vm_id, uint64_t capsule_id, uint64_t capsule_hash, uint64_t dict_↩ hash)

  capsule_parity_log_birth - Log VM birth parity record
- void capsule_parity_log_birth_failed (VMUuid vm_id, uint64_t capsule_id, CapsuleRunResult error, uint64_t partial_dict_hash)

  capsule_parity_log_birth_failed - Log failed birth
- void capsule_parity_log_run (VMUuid vm_id, uint64_t run_id, uint64_t capsule_id, uint64_t pre_dict_hash, uint64_t post_dict_hash)

  capsule_parity_log_run - Log DoE run parity record
- void capsule_parity_log_mama_init (uint64_t capsule_id, uint64_t capsule_hash, uint64_t dict_hash)

  capsule_parity_log_mama_init - Log Mama init parity record
- void capsule_parity_log_kill (VMUuid vm_id, const char *name)

  capsule_parity_log_kill - Log VM kill parity record
- void capsule_parity_set_output (void(*putc_fn)(char), void(*puts_fn)(const char *))

  capsule_parity_set_output - Set output hooks for parity logging

7.13.1 Macro Definition Documentation

7.13.1.1 CAPSULE_MAX_RUN_RECORDS

```
#define CAPSULE_MAX_RUN_RECORDS 1024
```

capsule_run.h - DoE Run Logging (M7.1)

Structures for logging capsule execution runs and VM births. Supports provenance tracking and experiment reproducibility. Phase A: Fixed ring buffer size

7.13.1.2 VM_NAME_MAX

```
#define VM_NAME_MAX 64
```

Maximum length of a VM symbolic name, including null terminator.

7.13.2 Enumeration Type Documentation

7.13.2.1 CapsuleRunResult

```
enum CapsuleRunResult
```

Enumerator

CAPSULE_RUN_OK	
CAPSULE_RUN_ERR_INVALID	
CAPSULE_RUN_ERR_NOT_ELIGIBLE	
CAPSULE_RUN_ERR_EXEC_FAIL	
CAPSULE_RUN_ERR_HASH_MISMATCH	
CAPSULE_RUN_ERR_STILLBORN	
CAPSULE_RUN_ERR_FLEET_FULL	

7.13.2.2 VMState

```
enum VMState
```

Enumerator

VM_STATE_EMBRYO	
VM_STATE_LIVE	
VM_STATE_STOPPED	
VM_STATE_STILLBORN	
VM_STATE_DEAD	
VM_STATE_SWITCHED_OUT	

7.13.3 Function Documentation

7.13.3.1 capsule_parity_log_birth()

```
void capsule_parity_log_birth (
            VMUuid vm_id,
            uint64_t capsule_id,
            uint64_t capsule_hash,
            uint64_t dict_hash )
```

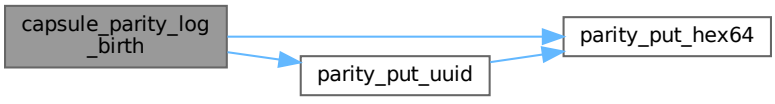
capsule_parity_log_birth - Log VM birth parity record

Output format: PARITY:BIRTH vm_id=N capsule_id=X mode=p capsule_hash=H dict_hash=D

References PARITY_EMIT, PARITY_HAVE_SINK, parity_put_hex64(), and parity_put_uuid().

Referenced by capsule_birth_baby().

Here is the call graph for this function:



Here is the caller graph for this function:

7.13.3.2 capsule_parity_log_birth_failed()

```
void capsule_parity_log_birth_failed (
            VMUuid vm_id,
            uint64_t capsule_id,
            CapsuleRunResult error,
            uint64_t partial_dict_hash )
```

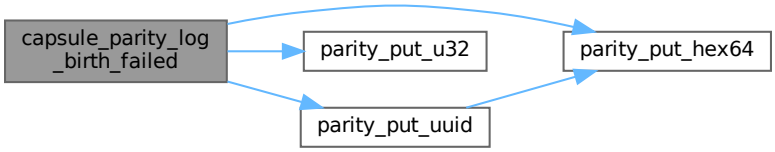
capsule_parity_log_birth_failed - Log failed birth

Output format: PARITY:BIRTH_FAILED vm_id=N capsule_id=X error=E partial_dict_hash=H

References PARITY_EMIT, PARITY_HAVE_SINK, parity_put_hex64(), parity_put_u32(), and parity_put_uuid().

Referenced by capsule_birth_baby().

Here is the call graph for this function:



Here is the caller graph for this function:

7.13.3.3 capsule_parity_log_kill()

```
void capsule_parity_log_kill (
            VMUuid vm_id,
            const char * name )
```

capsule_parity_log_kill - Log VM kill parity record

Output format: PARITY:KILL vm_id=N name=X

References name, PARITY_EMIT, PARITY_HAVE_SINK, and parity_put_uuid().

Referenced by capsule_vm_force_reap(), capsule_vm_kill(), and capsule_vm_kill_all_nonmama().

Here is the call graph for this function:

Here is the caller graph for this function:

7.13.3.4 capsule_parity_log_mama_init()

```
void capsule_parity_log_mama_init (
            uint64_t capsule_id,
            uint64_t capsule_hash,
            uint64_t dict_hash )
```

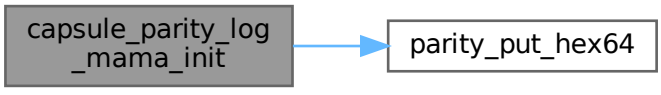
capsule_parity_log_mama_init - Log Mama init parity record

Output format: PARITY:MAMA_INIT capsule_id=X mode=m capsule_hash=H dict_hash=D

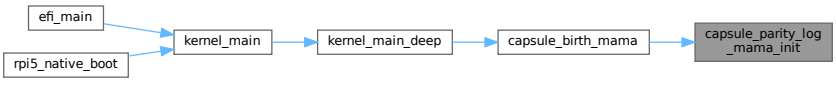
References PARITY_EMIT, PARITY_HAVE_SINK, and parity_put_hex64().

Referenced by capsule_birth_mama().

Here is the call graph for this function:



Here is the caller graph for this function:



7.13.3.5 capsule_parity_log_run()

```
void capsule_parity_log_run (
            VMUuid vm_id,
            uint64_t run_id,
            uint64_t capsule_id,
            uint64_t pre_dict_hash,
            uint64_t post_dict_hash )
```

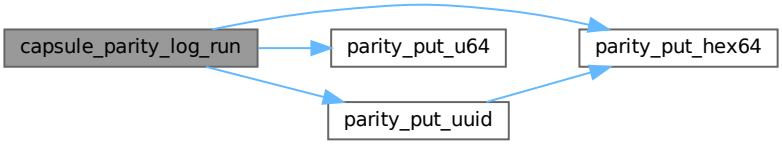
capsule_parity_log_run - Log DoE run parity record

Output format: PARITY:RUN vm_id=N run_id=R capsule_id=X mode=e pre_dict=P post_dict=Q

References PARITY_EMIT, PARITY_HAVE_SINK, parity_put_hex64(), parity_put_u64(), and parity_put_uuid().

Referenced by capsule_run_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

7.13.3.6 capsule_parity_set_output()

```
void capsule_parity_set_output (
            void(*)(char) putc_fn,
            void(*)(const char *) puts_fn )
```

capsule_parity_set_output - Set output hooks for parity logging

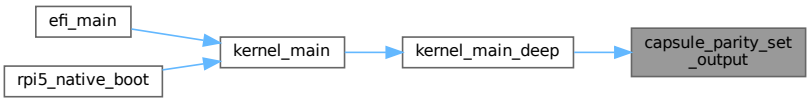
Parameters

putc_fn	Function to output a single character
puts_fn	Function to output a string

References parity_putc, and parity_puts.

Referenced by kernel_main_deep().

Here is the caller graph for this function:



7.13.3.7 capsule_run_log_count()

```
uint32_t capsule_run_log_count (
            void  )
```

capsule_run_log_count - Get number of logged runs

References run_log_count.

7.13.3.8 capsule_run_log_get()

```
int capsule_run_log_get (
            uint64_t run_id,
            CapsuleRunRecord * out )
```

capsule_run_log_get - Get a run record by ID

Parameters

run↩ _id	Run ID to retrieve
out	Output record

Returns

0 on success, -1 if not found

References CAPSULE_MAX_RUN_RECORDS, run_id_counter, and run_log.

7.13.3.9 capsule_run_log_init()

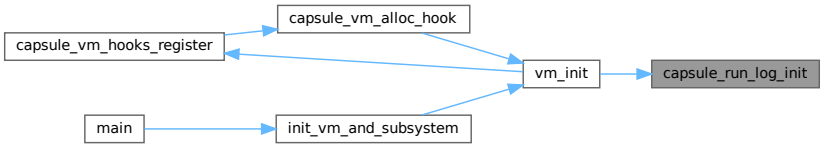
```
void capsule_run_log_init (
            void  )
```

capsule_run_log_init - Initialize run log

References CapsuleRunRecord::capsule_hash, CapsuleRunRecord::capsule_id, CAPSULE_MAX_RUN_RECORDS, CapsuleRunRecord::ended_ns, CapsuleRunRecord::flags, CapsuleRunRecord::post_dict_hash, CapsuleRunRecord::pre_dict_hash, CapsuleRunRecord::reserved, CapsuleRunRecord::result_code, CapsuleRunRecord::run_id, run_id_counter, run_log, run_log_count, run_log_head, CapsuleRunRecord::started_ns, and CapsuleRunRecord::vm_id.

Referenced by vm_init().

Here is the caller graph for this function:



7.13.3.10 capsule_run_log_record()

```
uint64_t capsule_run_log_record (
            const CapsuleRunRecord * record )
```

capsule_run_log_record - Log a run record

Parameters

record	Record to log

Returns

Run ID assigned, or 0 on failure

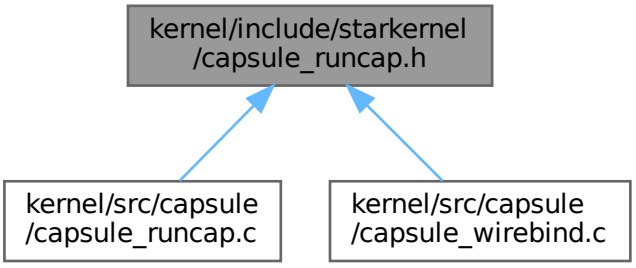
References CAPSULE_MAX_RUN_RECORDS, CapsuleRunRecord::run_id, run_id_counter, run_log, run_log_count, and run_log_head.

Referenced by capsule_run_experiment().

Here is the caller graph for this function:

7.14 kernel/include/starkernel/capsule_runcap.h File Reference

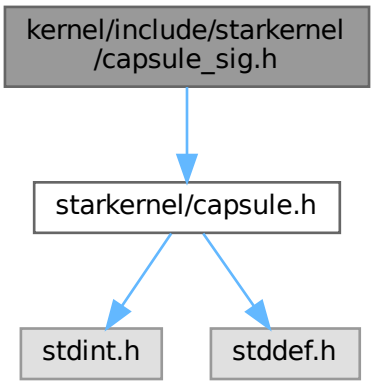
This graph shows which files directly or indirectly include this file:



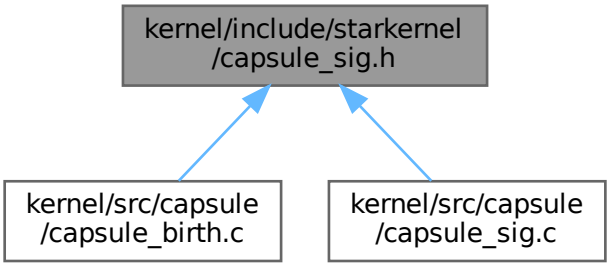
7.15 kernel/include/starkernel/capsule_sig.h File Reference

```
#include "starkernel/capsule.h"
```

Include dependency graph for capsule_sig.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define CAPSULE_SIGNING_CERT_NAME "pki:starshipos-intermediate.der"

Enumerations

- enum CapsuleSigResult { CAPSULE_SIG_OK = 0 , CAPSULE_SIG_MISSING , CAPSULE_SIG_INVALID , CAPSULE_SIG_NO_ROOT_KEY }

Functions

- CapsuleSigResult capsule_verify_signature (const CapsuleDesc *descs, const CapsuleNameEntry *names, const CapsuleSigEntry *sigs, const uint8_t *arena_base, uint32_t desc_count, int index)
- const char * capsule_sig_result_str (CapsuleSigResult result)

7.15.1 Macro Definition Documentation

7.15.1.1 CAPSULE_SIGNING_CERT_NAME

```
#define CAPSULE_SIGNING_CERT_NAME "pki:starshipos-intermediate.der"
```

7.15.2 Enumeration Type Documentation

7.15.2.1 CapsuleSigResult

```
enum CapsuleSigResult
```

Enumerator

CAPSULE_SIG_OK	
CAPSULE_SIG_MISSING	
CAPSULE_SIG_INVALID	
CAPSULE_SIG_NO_ROOT_KEY	

7.15.3 Function Documentation

7.15.3.1 capsule_sig_result_str()

```
const char * capsule_sig_result_str (
            CapsuleSigResult result )
```

References CAPSULE_SIG_INVALID, CAPSULE_SIG_MISSING, CAPSULE_SIG_NO_ROOT_KEY, and CAPSULE_SIG_OK.

Referenced by capsule_birth_baby(), capsule_birth_mama(), and capsule_run_experiment().

Here is the caller graph for this function:

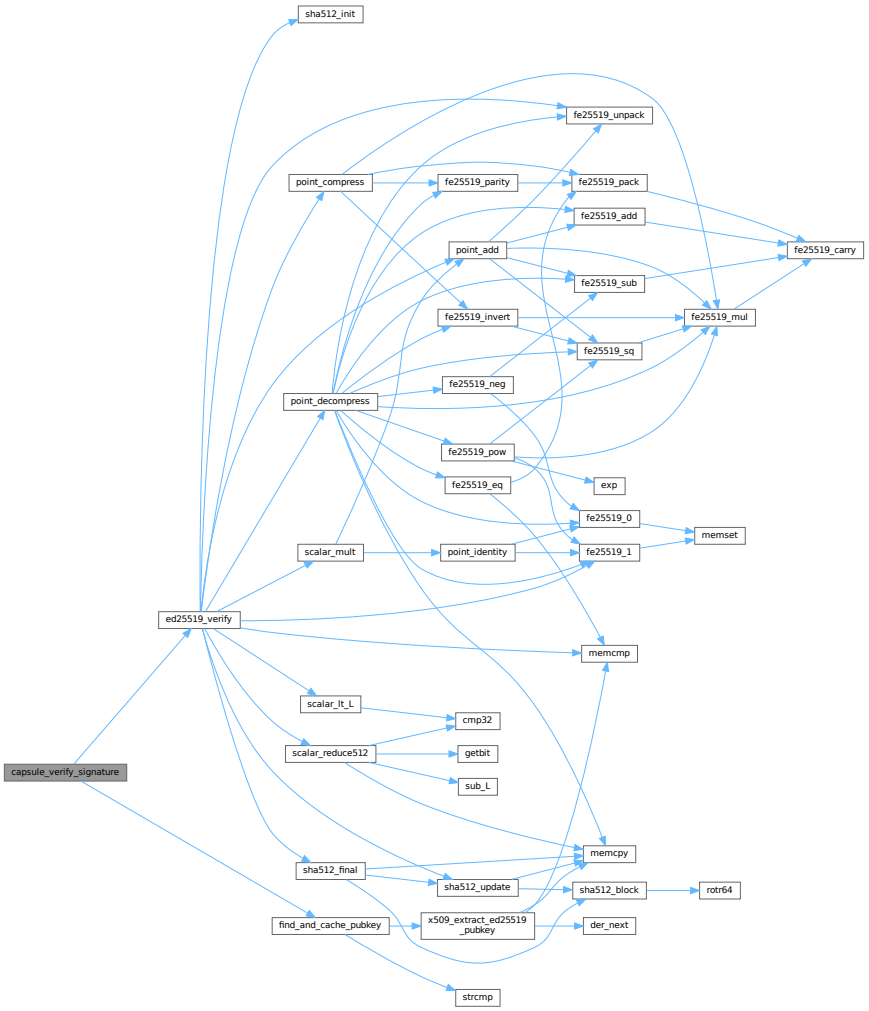
7.15.3.2 capsule_verify_signature()

```
CapsuleSigResult capsule_verify_signature (
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const CapsuleSigEntry * sigs,
            const uint8_t * arena_base,
            uint32_t desc_count,
            int index )
```

References cached_pubkey, CAPSULE_SIG_INVALID, CAPSULE_SIG_MISSING, CAPSULE_SIG_NO_ROOT_KEY, CAPSULE_SIG_OK, CapsuleDesc, ed25519_verify(), find_and_cache_pubkey(), and CapsuleSigEntry::sig.

Referenced by capsule_birth_baby(), capsule_birth_mama(), and capsule_run_experiment().

Here is the call graph for this function:

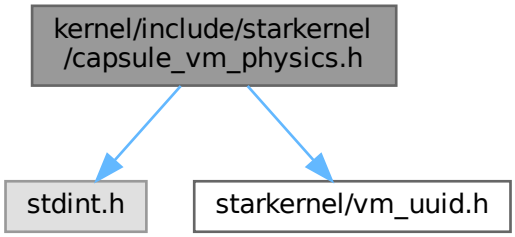


Here is the caller graph for this function:

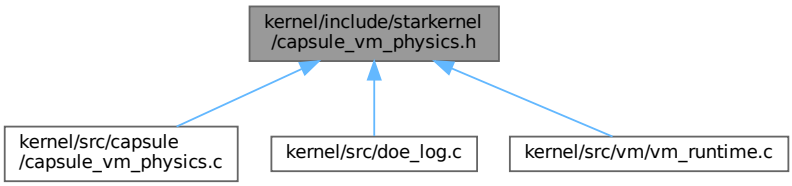
7.16 kernel/include/starkernel/capsule_vm_physics.h File Reference

```
#include <stdint.h>
#include "starkernel/vm_uuid.h"
```

Include dependency graph for capsule_vm_physics.h:



This graph shows which files directly or indirectly include this file:



Functions

- void vm_physics_init (VMUuid vm_id)

  capsule_vm_physics.h - Dynamic VM Fleet Physics
- void vm_physics_retire (VMUuid vm_id)

  vm_physics_retire - Remove a killed VM, returning its heat to Hera
- void vm_physics_touch (VMUuid vm_id)

  vm_physics_touch - Record real dispatch activity against a VM
- void vm_physics_tick (uint64_t now_ns)

  vm_physics_tick - Heartbeat-gated inference pass
- void vm_physics_heartbeat_tick (uint64_t now_ns)

  vm_physics_heartbeat_tick - Fleet-wide heartbeat, gates vm_physics_tick()
- uint64_t vm_physics_fleet_heat_sum (void)

  vm_physics_fleet_heat_sum - Sum of execution_heat_q48 over all LIVE VMs
- uint64_t vm_physics_heat_of (VMUuid vm_id)

  vm_physics_heat_of - Current execution_heat_q48 for one VM
- int vm_physics_conserved (void)

  vm_physics_conserved - Conservation check
- void vm_physics_status (void)

  vm_physics_status - Print a diagnostic status report

7.16.1 Function Documentation

7.16.1.1 vm_physics_conserved()

```
int vm_physics_conserved (
            void  )
```

vm_physics_conserved - Conservation check

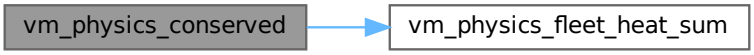
Returns

1 if $|$vm_physics_fleet_heat_sum() - Q.1$| <$ epsilon, else 0

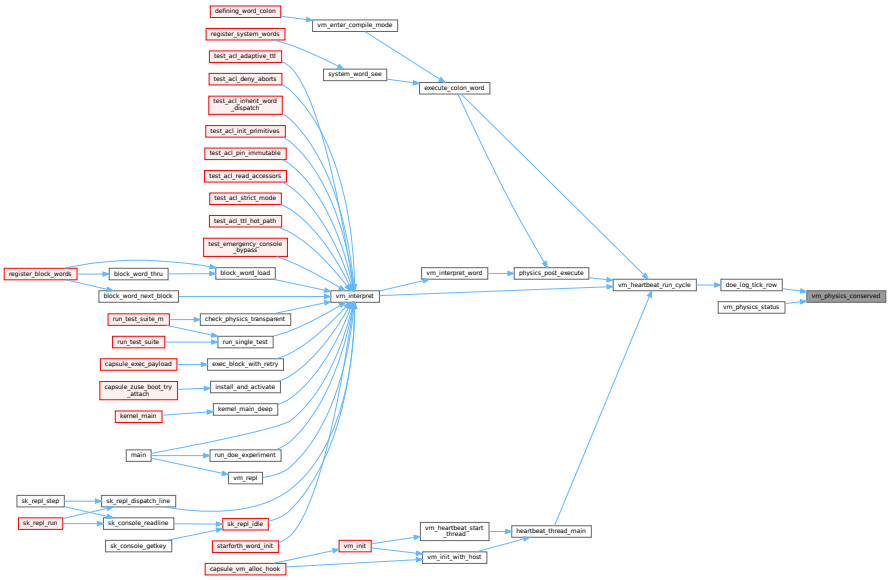
References Q48_ONE, VM_PHYSICS_EPSILON_Q48, and vm_physics_fleet_heat_sum().

Referenced by doe_log_tick_row(), and vm_physics_status().

Here is the call graph for this function:



Here is the caller graph for this function:



7.16.1.2 vm_physics_fleet_heat_sum()

```
uint64_t vm_physics_fleet_heat_sum (
            void  )
```

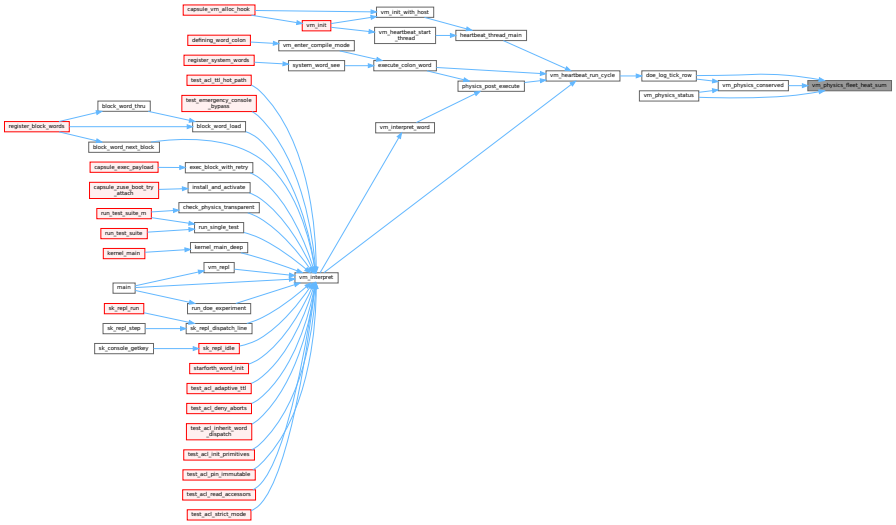
vm_physics_fleet_heat_sum - Sum of execution_heat_q48 over all LIVE VMs

Diagnostic / verification primitive. Should always read Q.1 (65536) if the conservation invariant holds.

References VMPhysics::execution_heat_q48, VMPhysics::is_live, vm_physics_node::next, vm_physics_node::physics, and vm_physics_head.

Referenced by doe_log_tick_row(), vm_physics_conserved(), and vm_physics_status().

Here is the caller graph for this function:



7.16.1.3 vm_physics_heartbeat_tick()

```
void vm_physics_heartbeat_tick (
            uint64_t now_ns )
```

vm_physics_heartbeat_tick - Fleet-wide heartbeat, gates vm_physics_tick()

Call from every VM's own vm_tick(), not just Hera's. Increments a single fleet-wide tick counter (distinct from any VM's own per-VM HeartbeatState.tick_count) and calls vm_physics_tick() once that shared counter has advanced by HEARTBEAT_INFERENCE_FREQUENCY since the last fit.

Fixes a real defect (VM-FLEET-ATTRACTOR-DESIGN-20260705.md rev k): gating this on Hera's own tick_count meant the inference pass almost never fired, because Hera-as-orchestrator mostly blocks on VM-EXEC/ VM-CALL dispatch – work that accrues to the *target* VM's own tick count, not hers. VM-PHYSICS-DYNAMIC-FLEET-DESIGN-20260705.md already specified the fix's direction: fleet_transfer_slope_q48 must be inferred "from aggregate fleet statistics... not one per VM" – the same principle applies to the readiness signal that gates computing it, not just the regression's own input trajectory.

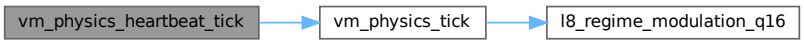
Parameters

now_ns	Current monotonic time in nanoseconds (of whichever VM is calling; unused by vm_physics_tick() today)

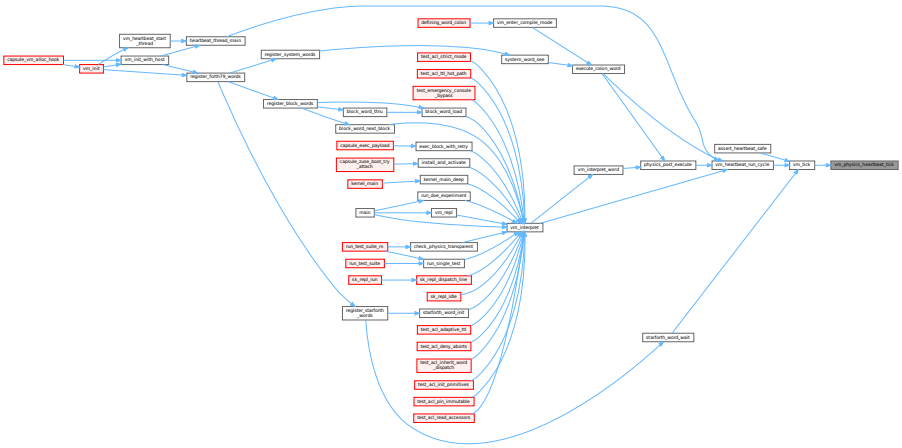
References fleet_heartbeat_tick_count, fleet_last_capacity_tick, STADIUM_CAPACITY_TICK, and vm_physics_tick().

Referenced by vm_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.16.1.4 vm_physics_heat_of()

```
uint64_t vm_physics_heat_of (
            VMUuid vm_id )
```

vm_physics_heat_of - Current execution_heat_q48 for one VM

Transparency primitive (VM-FLEET-ATTRACTOR-DESIGN-20260705.md): the fleet-wide conservation invariant always reads Q.1 by construction, so it carries no information about how heat is actually distributed among live VMs. This is the per-VM fact that sum alone can't provide.

Parameters

vm↩ _id	Registry VM ID

Returns

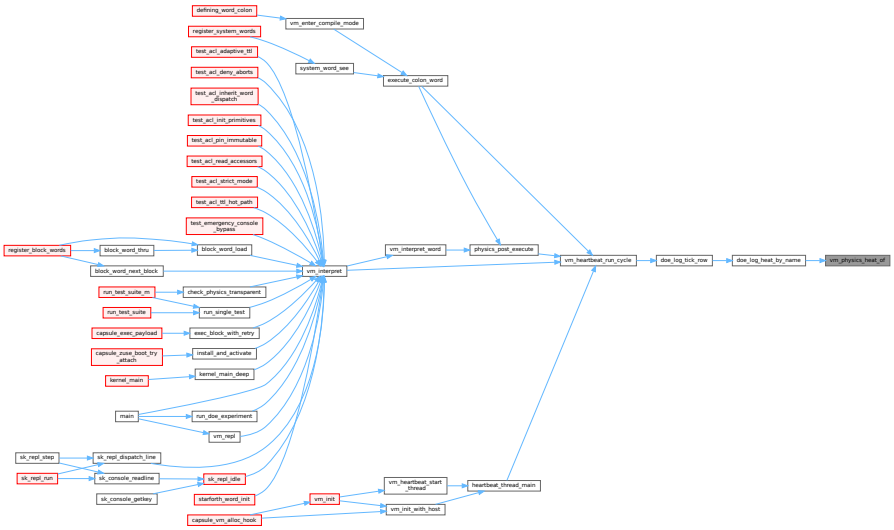
execution_heat_q48, or 0 if vm_id is unknown or not live

References VMPhysics::execution_heat_q48, VMPhysics::is_live, vm_physics_node::physics, and vm_physics_find().

Referenced by doe_log_heat_by_name().

Here is the call graph for this function:

Here is the caller graph for this function:



7.16.1.5 vm_physics_init()

```
void vm_physics_init (
            VMUuid vm_id )
```

capsule_vm_physics.h - Dynamic VM Fleet Physics

Structural parallel to the word-level physics engine (execution heat, decay, rolling-window history, regression-inferred slope) applied to VMs instead of dictionary words. Kernel-only: no hosted-build equivalent, since the hosted build has no multi-VM fleet.

sum(execution_heat_q48 for all LIVE VMs) == Q.1 is a conservation invariant, held by construction: every state change is a balanced transfer (see design doc VM-PHYSICS-DYNAMIC-FLEET-DESIGN-20260705.md).

This is a passive observer of VM activity, never a driver of it — there is no scheduler here. Recording happens only at existing dispatch points (BIRTH, KILL, VM-EXEC, VM-CALL, VM-STEP). vm_physics_init - Register a newly-born VM at zero heat

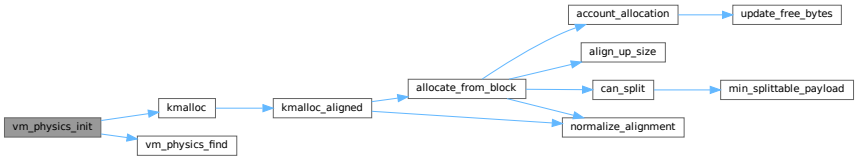
Called from mama_word_birth once a VM reaches VM_STATE_LIVE. Starts at execution_heat_q48 = 0, so conservation holds trivially — no fan-out from existing VMs is needed.

Parameters

vm↩_id	Registry VM ID assigned at birth

References VMPhysics::execution_heat_q48, VMPhysics::is_live, kmalloc(), VMPhysics::last_active_tick, vm_physics_node::next, vm_physics_node::physics, Q48_ONE, VMPhysics::touched, vm_physics_node::vm_id, vm_physics_find(), and vm_physics_head.

Here is the call graph for this function:



7.16.1.6 vm_physics_retire()

```
void vm_physics_retire (
            VMUuid vm_id )
```

vm_physics_retire - Remove a killed VM, returning its heat to Hera

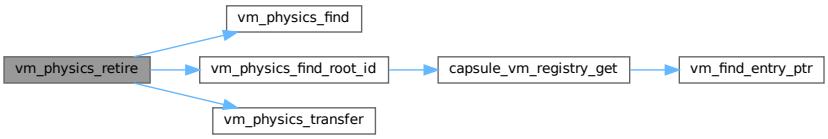
Called from mama_word_kill before the registry entry is torn down. The dying VM's entire remaining heat is transferred up its parent_vm_id chain (VMRegistryEntry, capsule_run.h) to the fleet's single structural root, Hera – no division, no per-survivor weighting. The chain walk tolerates already-dead intermediate parents (a parent's own parent_vm_id was set once at its birth and never rewritten, so the walk continues through it).

Parameters

vm↩_id	Registry VM ID of the VM being killed

References VMPhysics::execution_heat_q48, VMPhysics::is_live, vm_physics_node::physics, vm_physics_find(), vm_physics_find_root_id(), and vm_physics_transfer().

Here is the call graph for this function:



7.16.1.7 vm_physics_status()

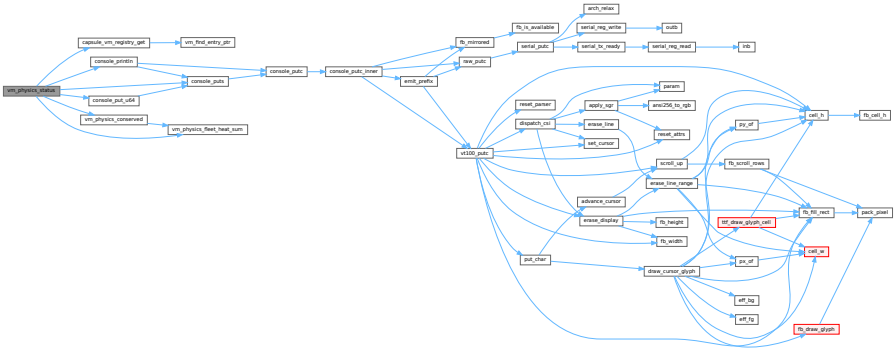
```
void vm_physics_status (
            void  )
```

vm_physics_status - Print a diagnostic status report

Replaces K-STATUS/VM-STATUS. Reports fleet heat sum, conservation verdict, and the current fleet-wide inferred slope / fit quality / warm-up state – the fleet-level analog of K-STATUS's per-VM report, adapted to a mechanism with no fixed VM count to enumerate.

References capsule_vm_registry_get(), console_println(), console_put_u64(), console_puts(), entry, VMPhysics::execution_heat_q48, fleet_transfer_slope_q48, fleet_window, VMPhysics::is_live, VMFleetWindow::is_warm, vm_physics_node::next, vm_physics_node::physics, slope_fit_quality_q48, vm_physics_node::vm_id, vm_physics_conserved(), vm_physics_fleet_heat_sum(), and vm_physics_head.

Here is the call graph for this function:



7.16.1.8 vm_physics_tick()

```
void vm_physics_tick (
            uint64_t now_ns )
```

vm_physics_tick - Heartbeat-gated inference pass

Mirrors vm_tick_inference_engine: when the fleet touch-history window is warm, replays it to re-fit fleet_transfer_↩ slope_q48 via the same closed-form log-linear OLS regression used for word-level decay. Skips the update (does not substitute a default) when unwarmed or when fit quality is not usable.

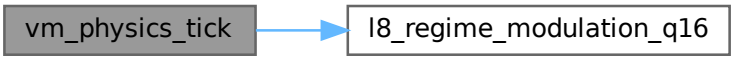
Parameters

now_ns	Current monotonic time in nanoseconds

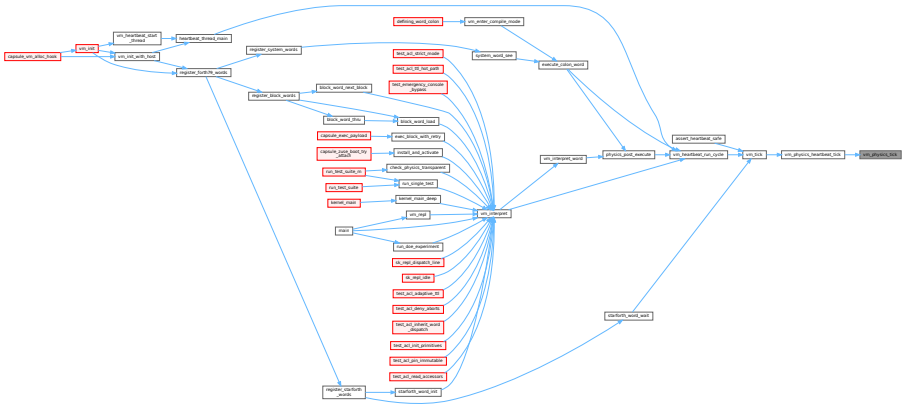
References VMFleetTouchSample::amount, VMFleetTouchSample::clamped, VMFleetTouchSample::elapsed_ticks, fleet_transfer_slope_q48, fleet_window, VMFleetWindow::is_warm, l8_regime_modulation_q16(), slope_fit_quality_q48, VMFleetWindow::touch_samples, VM_FLEET_WINDOW_DEPTH, and VM_PHYSICS_MIN_INFORMATIVE_SAMPLES.

Referenced by vm_physics_heartbeat_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.16.1.9 vm_physics_touch()

```
void vm_physics_touch (
            VMUuid vm_id )
```

vm_physics_touch - Record real dispatch activity against a VM

Called from the three existing dispatch primitives (VM-EXEC, VM-CALL, VM-STEP) at the point they've already confirmed the target VM is live. Pulls heat from the rest of the fleet toward the touched VM (amount = elapsed_ticks * fleet_transfer_slope_q48 >> 16) and appends vm_id to the fleet's rolling touch-history window.

Restated on the virtual tick (FABRIC-0.md item 2.1, 2026-08-04): no longer takes a wall-clock timestamp. Reads fleet_heartbeat_tick_count internally, which is execution-paced (advanced once per vm_tick() call, see vm_↩ physics_heartbeat_tick), so the transfer this produces is a deterministic function of the execution stream, not of wall time.

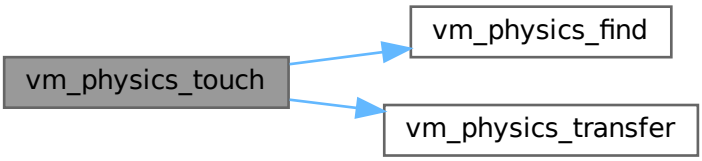
Parameters

vm↩ _id	Registry VM ID being dispatched to

References VMFleetTouchSample::amount, VMFleetTouchSample::clamped, VMFleetWindow::count, VMFleetTouchSample::elapsed, VMPhysics::execution_heat_q48, fleet_heartbeat_tick_count, fleet_transfer_slope_q48, fleet_window, VMFleetWindow::head, VMPhysics::is_live, VMFleetWindow::is_warm, VMPhysics::last_active_tick, vm_physics_node::next, vm_physics_node::physics,

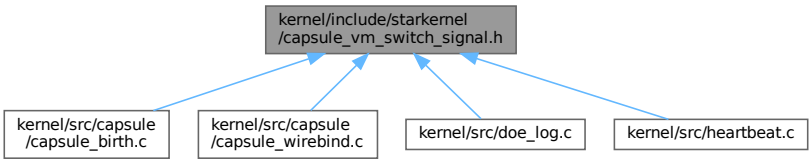
VMFleetWindow::touch_samples, VMPhysics::touched, VM_FLEET_WINDOW_DEPTH, vm_physics_find(), vm_physics_head, and vm_physics_transfer().

Here is the call graph for this function:



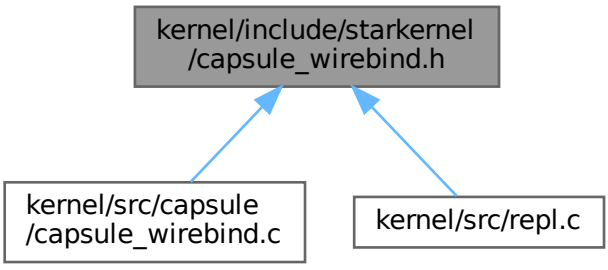
7.17 kernel/include/starkernel/capsule_vm_switch_signal.h File Reference

This graph shows which files directly or indirectly include this file:



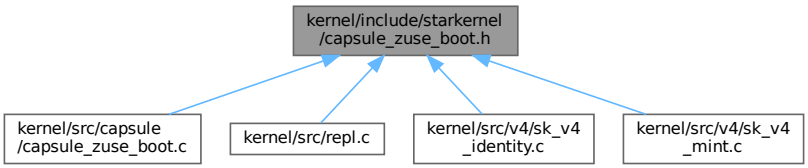
7.18 kernel/include/starkernel/capsule_wirebind.h File Reference

This graph shows which files directly or indirectly include this file:



7.19 kernel/include/starkernel/capsule_zuse_boot.h File Reference

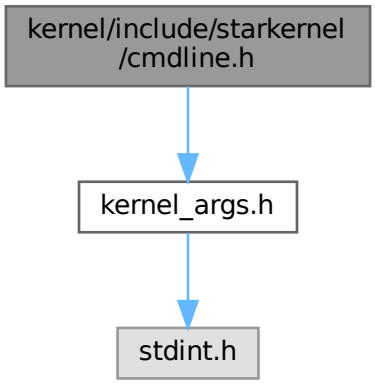
This graph shows which files directly or indirectly include this file:



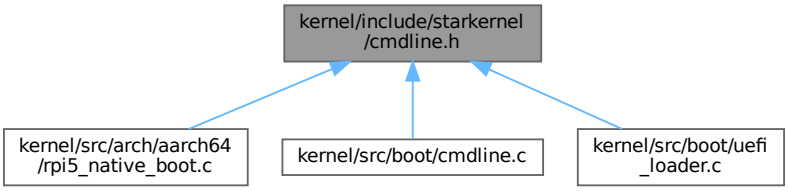
7.20 kernel/include/starkernel/cmdline.h File Reference

```
#include "kernel_args.h"
```

Include dependency graph for cmdline.h:



This graph shows which files directly or indirectly include this file:



Functions

- void cmdline_parse_ascii (const char *cmdline, KernelArgs *args)

  Parse a NUL-terminated ASCII command-line string into KernelArgs.
- uint64_t cmdline_parse_size (const char *s)

  Parse a decimal integer with optional K/M/G size suffix.

7.20.1 Function Documentation

7.20.1.1 cmdline_parse_ascii()

```
void cmdline_parse_ascii (
            const char * cmdline,
            KernelArgs * args )
```

Parse a NUL-terminated ASCII command-line string into KernelArgs.

Populates args from space-separated tokens in cmdline. Always initialises all fields to their defaults first (so partial or empty command lines produce safe values):

- stack_size = 0 (use BSS static stack)
- heap_size = 0 (use built-in kmalloc arena)
- run_doe = KARGS_DEFAULT_RUN_DOE
- log_level = KARGS_DEFAULT_LOG_LEVEL
- raw[0] = '\0'

Recognised flags:

- --doe — sets args->run_doe = 1.
- --log-level=<level> — sets args->log_level via parse_log_level().
- --stack=<size> — sets args->stack_size via cmdline_parse_size().
- --heap=<size> — sets args->heap_size via cmdline_parse_size().

Unknown flags are silently ignored for forward-compatibility with flags introduced in future kernel versions. The raw command-line string is copied verbatim into args->raw (truncated to KERNEL_ARGS_CMDLINE_MAX - 1) for diagnostic logging.

Called from efi_main() (in uefi_loader.c) after assembling the ASCII command line from the three priority sources: NVRAM variable, starforth.cfg on the ESP, and EFI LoadOptions.

Parameters

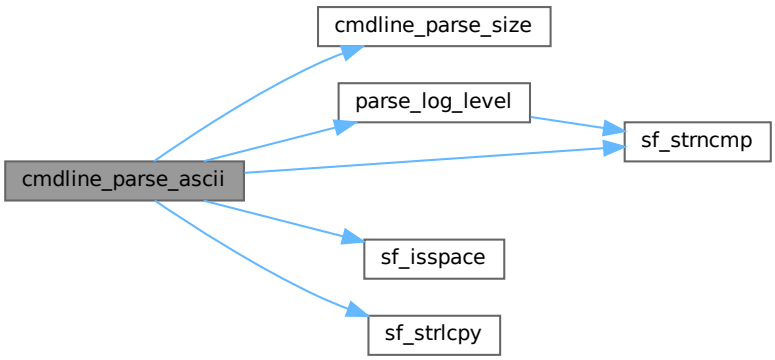
cmdline	NUL-terminated ASCII command line; may be NULL or empty.
args	Output KernelArgs structure; must not be NULL.

References cmdline_parse_size(), KernelArgs::heap_size, KARGS_DEFAULT_LOG_LEVEL, KARGS_DEFAULT_RUN_DOE,

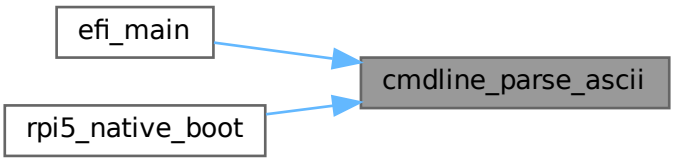
KARGS_SYSTEM_DEFAULT, KARGS_SYSTEM_V3, KARGS_SYSTEM_V4, KERNEL_ARGS_CMDLINE_MAX, KernelArgs::log_level, parse_log_level(), KernelArgs::raw, KernelArgs::run_doe, KernelArgs::screen_boot, sf_isspace(), sf_strlcpy(), sf_strncmp(), KernelArgs::stack_size, and KernelArgs::system.

Referenced by efi_main(), and rpi5_native_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.20.1.2 cmdline_parse_size()

```
uint64_t cmdline_parse_size (
            const char * s )
```

Parse a decimal integer with optional K/M/G size suffix.

Reads a non-negative decimal integer from `s` and multiplies it by:

- 1024 for 'K' or 'k' (kibibytes)
- 1024^2 for 'M' or 'm' (mebibytes)

- 1024^3 for 'G' or 'g' (gibibytes)
- 1 for any other or absent suffix

Returns 0 if `s` is NULL, empty, or does not begin with a digit. Overflow is not checked; caller must validate the resulting value is sensible for its intended use (stack size, heap size, etc.).

Used by `cmdline_parse_ascii()` to decode the `--stack=<size>` and `--heap=<size>` arguments from the boot command line.

Parameters

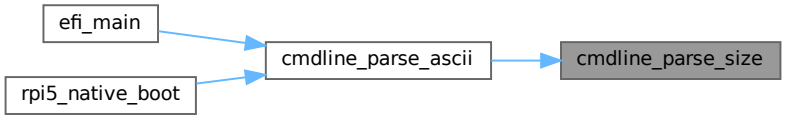
s	NUL-terminated string beginning with a decimal integer and optionally followed by a size suffix character.

Returns

Parsed byte count (0 on parse failure or zero input).

Referenced by cmdline_parse_ascii().

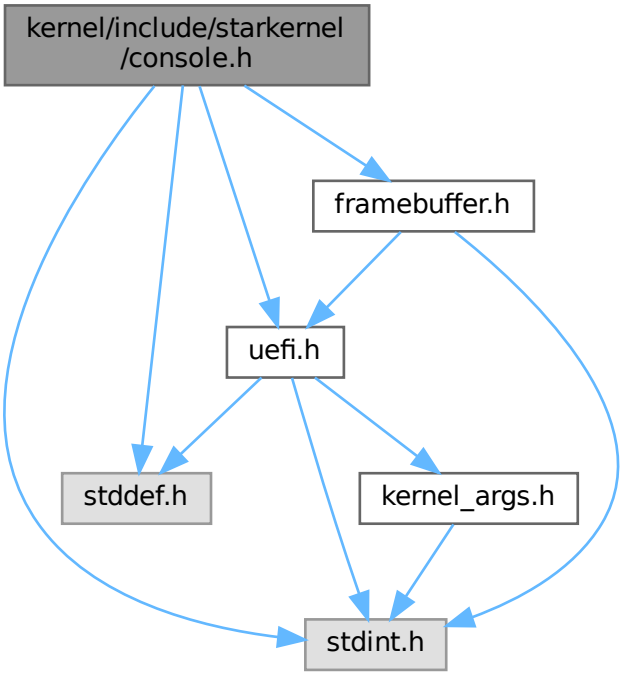
Here is the caller graph for this function:



7.21 kernel/include/starkernel/console.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "uefi.h"
#include "framebuffer.h"
```

Include dependency graph for console.h:



This graph shows which files directly or indirectly include this file:

Typedefs

- typedef const char ∗(∗ console_user_prefix_fn) (void)

  FABRIC-3.md SXXV follow-up (2026-09-13): the line prefix used to be a bare "[VMName] ", ambiguous between a console-proxy VM and the actual identity VM behind it (e.g.

Functions

- void console_attach_serial (const void ∗dtb)

  console.h - Serial console + framebuffer VT100 interface for StarKernel
- void console_init (void)

  Initialize serial console (UART).
- void console_describe_serial (void)

  Print one line saying which serial line the console found, or that there is none.
- void console_fb_init (const FramebufferInfo ∗info, FbPixelFormat fmt)

  Initialize the framebuffer VT100 terminal.
- void console_fb_enable_ttf (void)

FABRIC-0.md item 4.4j: switch the framebuffer console's glyph backend from font_8x16.c to TTF-TEXT's rasterizer.

- void console_fb_mirror (int on)
- void console_fb_clear (void)
- void console_fb_scroll_back (uint32_t n)

  FABRIC-0.md item 4.4q: thin wrappers over vt100_scroll_back()/ vt100_scroll_fwd() – see those functions' doc comments for the full contract.
- void console_fb_scroll_fwd (uint32_t n)
- void console_fb_toggle_graphics (void)

  FABRIC-0.md item 4.4y-revised: thin wrapper over vt100_toggle_graphics() – see that function's doc comment for the full contract (the Alt+TAB graphics/text state machine).
- void console_fb_draw_cursor (void)

  Thin wrapper over vt100_draw_cursor() – see that function's doc comment for the full contract (a static block cursor at the terminal's current position).
- void console_fb_erase_cursor (void)

  Thin wrapper over vt100_erase_cursor().
- void console_putc (char c)

  Write a single character to serial console.
- void console_puts (const char *s)

  Write a null-terminated string to serial console.
- void console_println (const char *s)

  Write a string with newline to serial console.
- void console_ensure_line_start (void)

  console_ensure_line_start - Make sure the next real output starts at the beginning of a fresh output line, closing off whatever is currently mid-line (e.g.
- void console_cancel_deferred_line_start (void)

  console_cancel_deferred_line_start - Discard a pending deferred newline from console_ensure_line_start() without ever emitting it.
- uint64_t console_tx_count (void)

  console_tx_count - Monotonic count of console_putc() calls delivered to either output (serial and/or framebuffer).
- int console_getc (void)

  Read a single character from serial console (non-blocking) Returns -1 if no character available.
- int console_poll (void)

  Check if character is available for reading.
- void console_set_vm_name (const char *name)

  Set the active VM name shown as [Name] prefix on each output line.
- const char * console_get_vm_name (void)
- void console_save_vm_name (char *out, size_t cap)

  console_save_vm_name - Copy the current active-VM name into the caller's own buffer, for a later console_set_vm_name() restore.
- void console_set_user_prefix_provider (console_user_prefix_fn fn)

Variables

- volatile const char * g_sk_fault_word

  interrupts.c (aarch64) - Exception vector setup and common handler

7.21.1 Typedef Documentation

7.21.1.1 console_user_prefix_fn

```
typedef const char *(* console_user_prefix_fn) (void)
```

FABRIC-3.md SXXV follow-up (2026-09-13): the line prefix used to be a bare "[VMName] ", ambiguous between a console-proxy VM and the actual identity VM behind it (e.g.

"rajames" the console vs. "rajames∼user" the real WIREBIND-restricted identity) – confirmed live to cause real confusion during testing. Unified to "[user@VMName] " when a user context is available, still "[VMName] " when not (unauthenticated/ pre-login, unchanged from today).

console.c is a clean HAL module with no dependency on capsule/WIREBIND logic (zuse_session, capsule_wirebind_attached_userna – pulling either in directly here would be a real layering violation, not just a style preference. This callback lets repl.c (which already computes exactly this for sk_print_prompt()) supply the "user" half without console.c knowing anything about VMs, sessions, or WIREBIND. Returns NULL/empty for "no user context" (falls back to the bare "[VMName] " form); the returned pointer must remain valid until the next call (matches console_get_vm_name()'s own single-buffer convention).

7.21.2 Function Documentation

7.21.2.1 console_attach_serial()

```
void console_attach_serial (
            const void * dtb )
```

console.h - Serial console + framebuffer VT100 interface for StarKernel

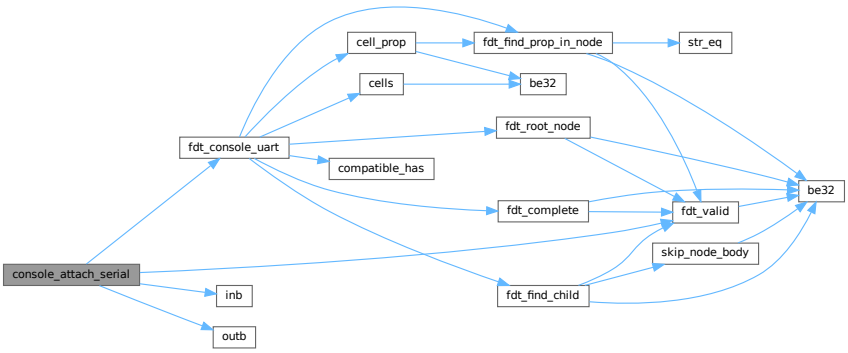
Output policy:

- Serial UART is always active (initialized by console_init).
- When console_fb_init() has been called and the framebuffer is ready, every character is also rendered through the VT100 terminal on screen.
- Both outputs are always live simultaneously; serial cannot be disabled. Find the board's serial console line. Must be called before anything is printed: until it is, and on a board with no such line, the console writes to no serial port and reads from none. On a PC it is COM1, if a UART answers there; elsewhere it is the UART the devicetree names as the console (/chosen/stdout-path); with no devicetree at all it is the UART of QEMU's virt machine. `dtb` may be NULL.

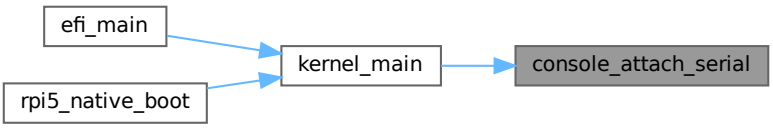
References fdt_uart_t::base, fdt_console_uart(), FDT_UART_PL011, fdt_valid(), g_serial_base, g_serial_from_dt, g_serial_kind, g_serial_shift, g_serial_width, inb(), fdt_uart_t::io_width, fdt_uart_t::kind, outb(), fdt_uart_t::reg_shift, SERIAL_MMIO16550, SERIAL_NONE, SERIAL_PL011, and SERIAL_PORT16550.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.21.2.2 console_cancel_deferred_line_start()

```
void console_cancel_deferred_line_start (
            void  )
```

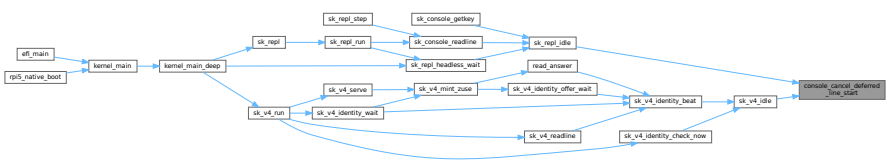
console_cancel_deferred_line_start - Discard a pending deferred newline from console_ensure_line_start() without ever emitting it.

No-op if no newline is currently deferred. Callers that speculatively deferred a line break before checking whether they actually have anything to print (sk_repl_idle()'s idle-beat check being the motivating case, FABRIC-2.md ?I.9) call this when the check comes back negative, so the console is left exactly as it was – no stray newline, no phantom blank line.

References g_pending_line_close.

Referenced by sk_repl_idle(), and sk_v4_idle().

Here is the caller graph for this function:



7.21.2.3 console_describe_serial()

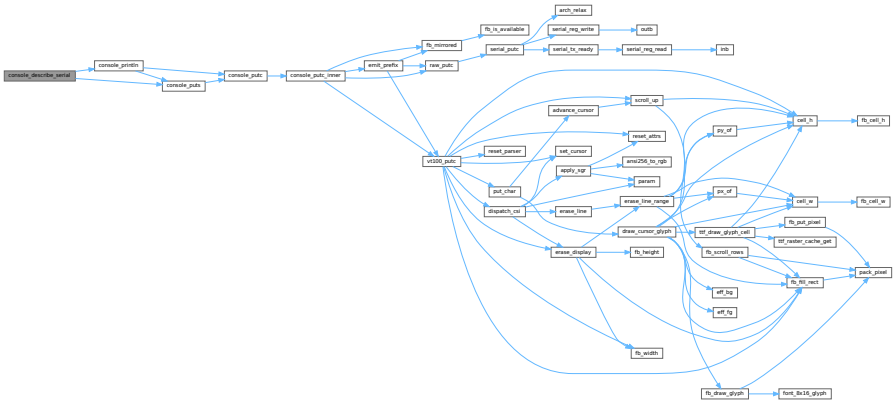
```
void console_describe_serial (
            void  )
```

Print one line saying which serial line the console found, or that there is none.

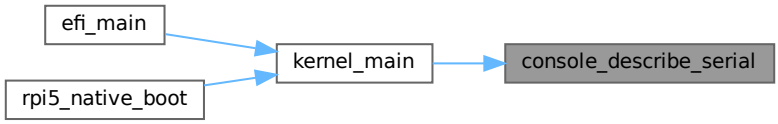
References console_println(), console_puts(), g_serial_base, g_serial_from_dt, g_serial_kind, SERIAL_NONE, SERIAL_PL011, and SERIAL_PORT16550.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.21.2.4 console_ensure_line_start()

```
void console_ensure_line_start (
            void  )
```

console_ensure_line_start - Make sure the *next real output* starts at the beginning of a fresh output line, closing off whatever is currently mid-line (e.g.

a dangling prompt). No-op if already at line start.

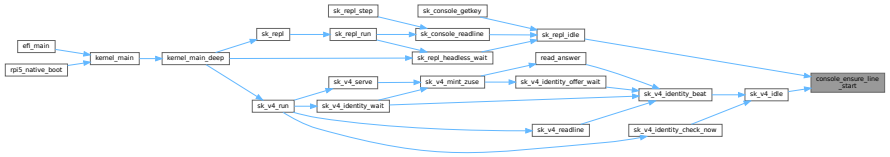
FABRIC-2.md ?I.9 fix, 2026-09-05: the newline is DEFERRED, not emitted immediately – it only actually reaches the console on the next real console_putc() call, and is silently dropped (never emitted at all) if

console_cancel_deferred_line_start() is called first instead. Before this fix, an immediate, unconditional newline here meant any caller invoking this function "just in case" (sk_repl_idle() being the one real caller) would visibly snap a bare, unfinished prompt line to a fresh blank line even when nothing was actually about to be printed – indistinguishable from Enter having already been pressed at that prompt. Deferring means a caller that turns out to have nothing to print can cancel cleanly, with zero visible effect, while a caller that does print gets the correct "close the old line first" behavior for free, still counted by console_tx_count() as real output (unlike the old always-silent inner form) since it is realized through the normal console_putc() path.

References g_line_start, and g_pending_line_close.

Referenced by sk_repl_idle(), and sk_v4_idle().

Here is the caller graph for this function:



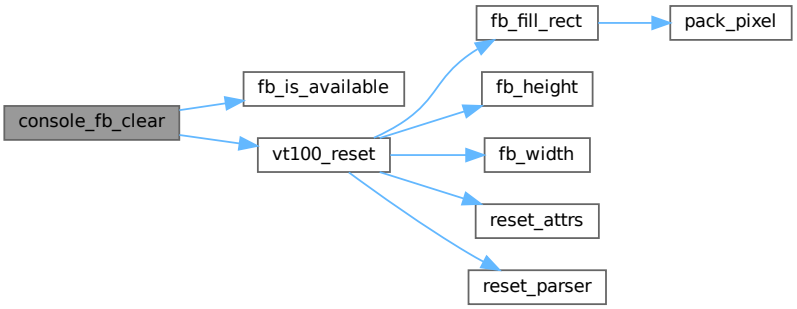
7.21.2.5 console_fb_clear()

```
void console_fb_clear (
            void  )
```

References fb_is_available(), and vt100_reset().

Referenced by sk_v4_drive_left(), sk_v4_fixed_screen(), and sk_v4_session_end().

Here is the call graph for this function:



Here is the caller graph for this function:

7.21.2.6 console_fb_draw_cursor()

```
void console_fb_draw_cursor (
            void  )
```

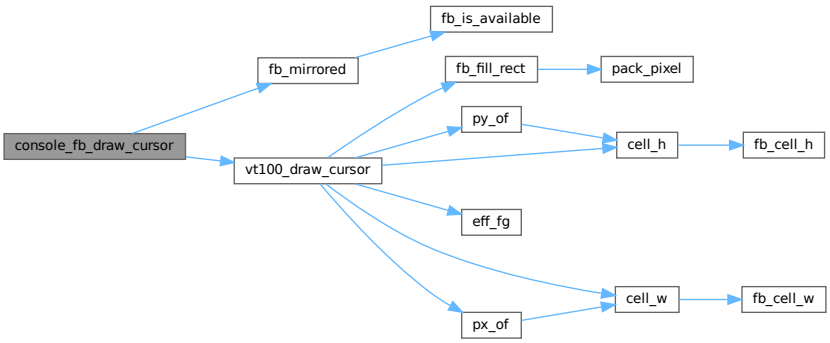
Thin wrapper over vt100_draw_cursor() – see that function's doc comment for the full contract (a static block cursor at the terminal's current position).

No-op if the framebuffer console was never initialized.

References fb_mirrored(), and vt100_draw_cursor().

Referenced by sk_console_readline(), sk_cursor_show(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:

7.21.2.7 console_fb_enable_ttf()

```
void console_fb_enable_ttf (
            void  )
```

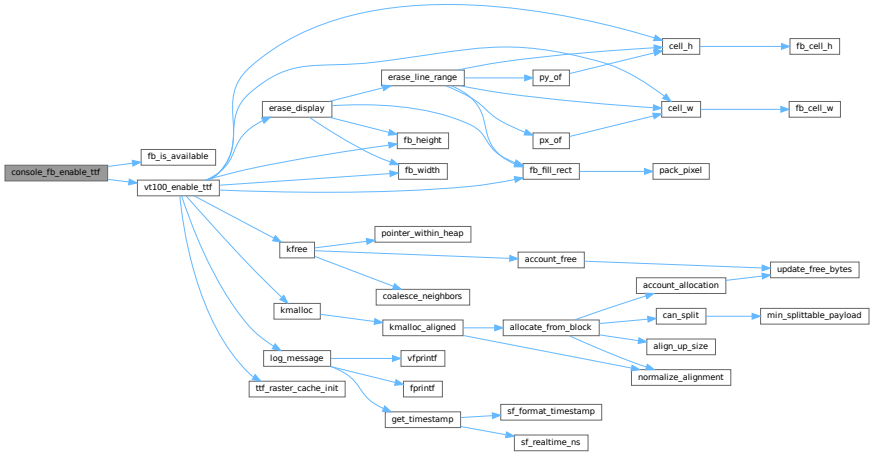
FABRIC-0.md item 4.4j: switch the framebuffer console's glyph backend from font_8x16.c to TTF-TEXT's rasterizer.

Thin wrapper over vt100_enable_ttf() – see that function's doc comment for the full contract (lazy font load, cell-geometry/cols/rows recompute, screen clear, one-shot). No-op if the framebuffer console was never initialized (console_fb_init() not called, or it no-op'd on a NULL framebuffer).

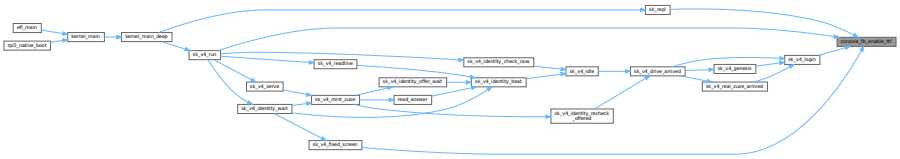
References fb_is_available(), and vt100_enable_ttf().

Referenced by sk_repl(), sk_v4_fixed_screen(), sk_v4_login(), and sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.21.2.8 console_fb_erase_cursor()

```
void console_fb_erase_cursor (
            void  )
```

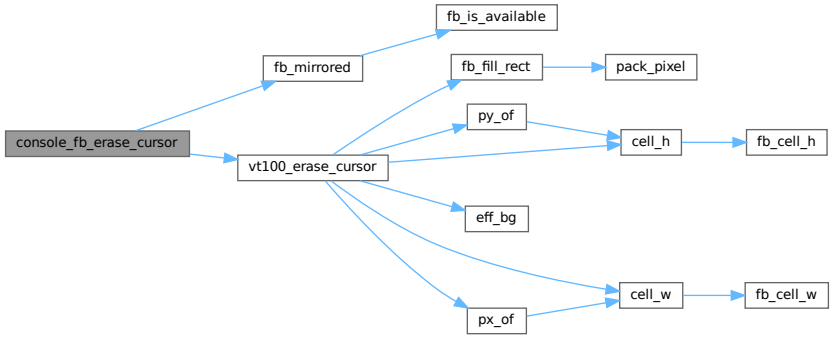
Thin wrapper over vt100_erase_cursor().

No-op if the framebuffer console was never initialized.

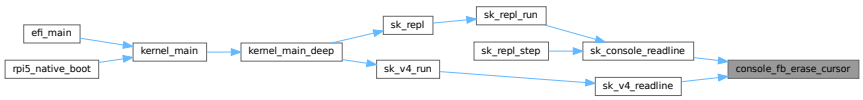
References fb_mirrored(), and vt100_erase_cursor().

Referenced by sk_console_readline(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:



7.21.2.9 console_fb_init()

```
void console_fb_init (
            const FramebufferInfo * info,
            FbPixelFormat fmt )
```

Initialize the framebuffer VT100 terminal.

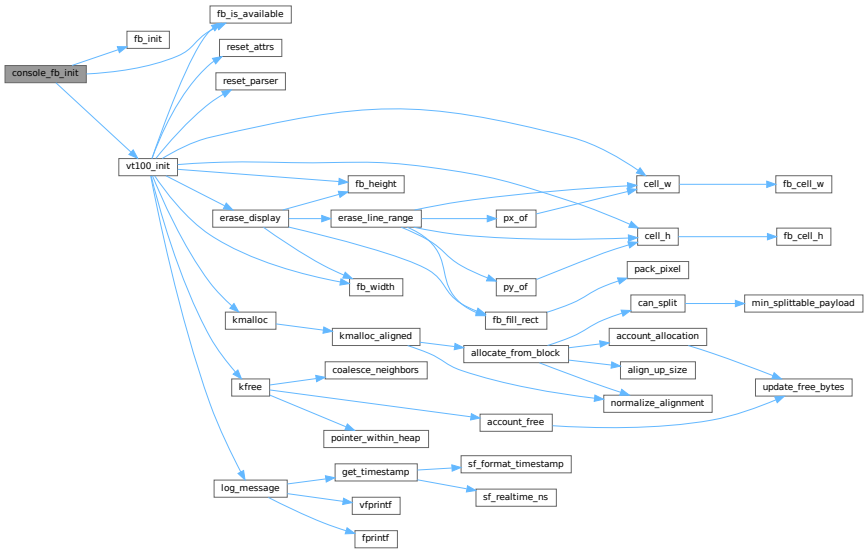
Call after UEFI boot services have been exited and the GOP framebuffer address is known (from BootInfo). Safe to call with info==NULL (no-op). fmt: FB_PIXEL_BGRX32 is correct for most QEMU / real hardware GOP.

Initialize the framebuffer VT100 terminal.

Safe to call with info == NULL or when the framebuffer base is zero (no-op). After this call every console_putc / console_puts output is mirrored to the screen; the serial UART continues to function concurrently.

References FramebufferInfo::base, fb_init(), fb_is_available(), and vt100_init().

Here is the call graph for this function:



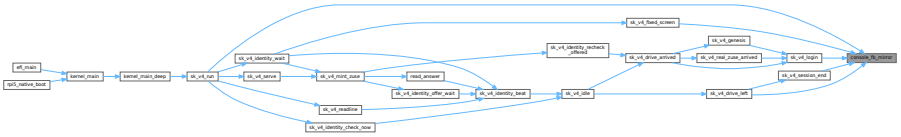
7.21.2.10 console_fb_mirror()

```
void console_fb_mirror (
            int on )
```

References g_fb_mirror.

Referenced by sk_v4_drive_left(), sk_v4_fixed_screen(), sk_v4_login(), sk_v4_run(), and sk_v4_session_end().

Here is the caller graph for this function:



7.21.2.11 console_fb_scroll_back()

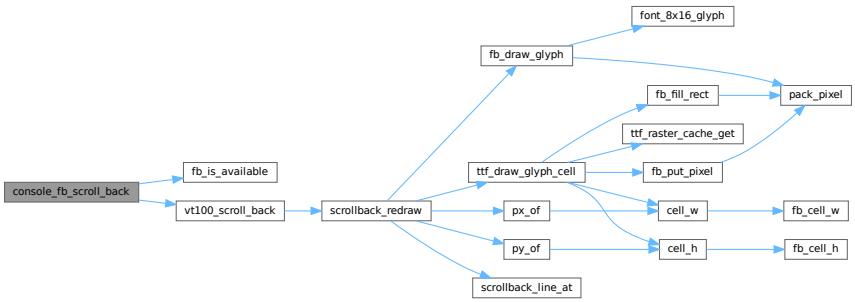
```
void console_fb_scroll_back (
            uint32_t n )
```

FABRIC-0.md item 4.4q: thin wrappers over vt100_scroll_back()/ vt100_scroll_fwd() – see those functions' doc comments for the full contract.

No-op if the framebuffer console was never initialized.

References fb_is_available(), and vt100_scroll_back().

Here is the call graph for this function:

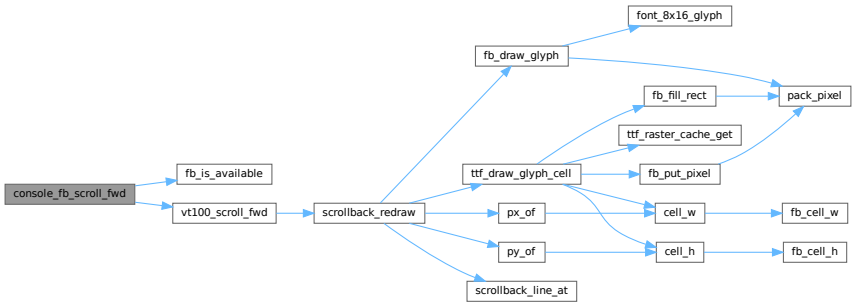


7.21.2.12 console_fb_scroll_fwd()

```
void console_fb_scroll_fwd (
            uint32_t n )
```

References fb_is_available(), and vt100_scroll_fwd().

Here is the call graph for this function:



7.21.2.13 console_fb_toggle_graphics()

```
void console_fb_toggle_graphics (
            void  )
```

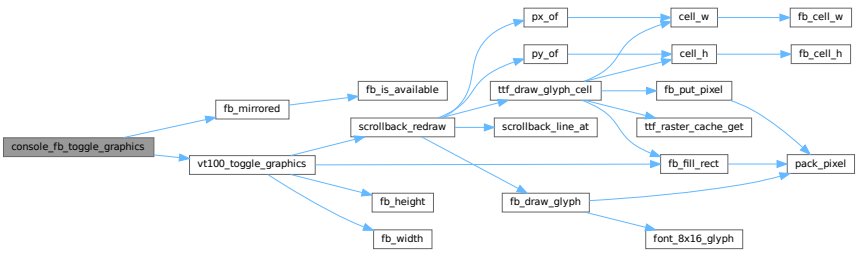
FABRIC-0.md item 4.4y-revised: thin wrapper over vt100_toggle_graphics() – see that function's doc comment for the full contract (the Alt+TAB graphics/text state machine).

No-op if the framebuffer console was never initialized.

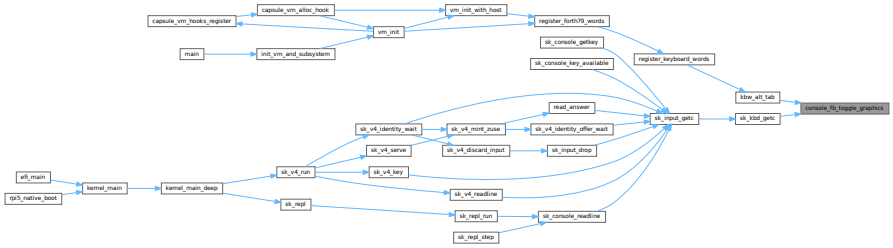
References fb_mirrored(), and vt100_toggle_graphics().

Referenced by kbw_alt_tab(), and sk_kbd_getc().

Here is the call graph for this function:



Here is the caller graph for this function:



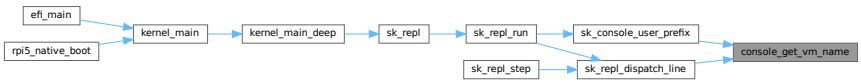
7.21.2.14 console_get_vm_name()

```
const char * console_get_vm_name (
            void  )
```

References g_active_vm_name.

Referenced by sk_console_user_prefix(), and sk_repl_dispatch_line().

Here is the caller graph for this function:



7.21.2.15 console_getc()

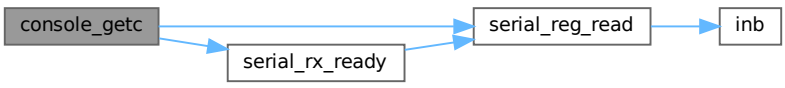
```
int console_getc (
            void  )
```

Read a single character from serial console (non-blocking) Returns -1 if no character available.

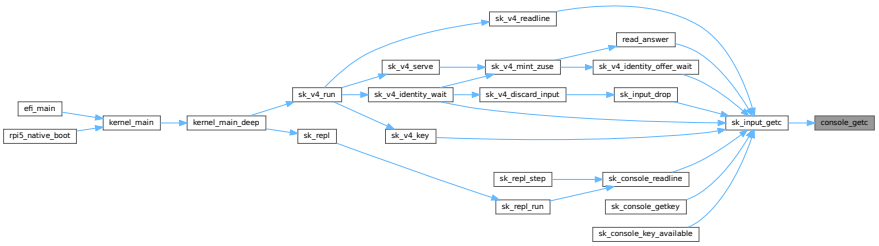
References serial_reg_read(), and serial_rx_ready().

Referenced by sk_input_getc().

Here is the call graph for this function:



Here is the caller graph for this function:



7.21.2.16 console_init()

```
void console_init (
            void  )
```

Initialize serial console (UART).

Must be called once during early kernel boot, after console_attach_serial().

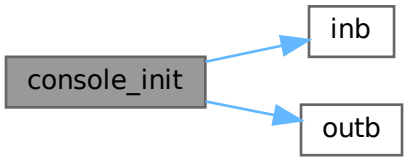
Initialize serial console (UART).

aarch64, riscv64: the line was set up by the firmware; nothing to do.

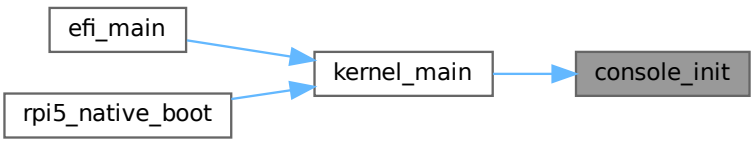
References g_serial_kind, inb(), outb(), SERIAL_NONE, and SERIAL_PORT16550.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.21.2.17 console_poll()

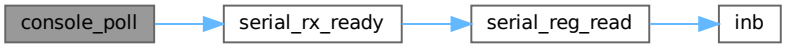
```
int console_poll (
            void  )
```

Check if character is available for reading.

Check if character is available for reading.

References serial_rx_ready().

Here is the call graph for this function:



7.21.2.18 console_println()

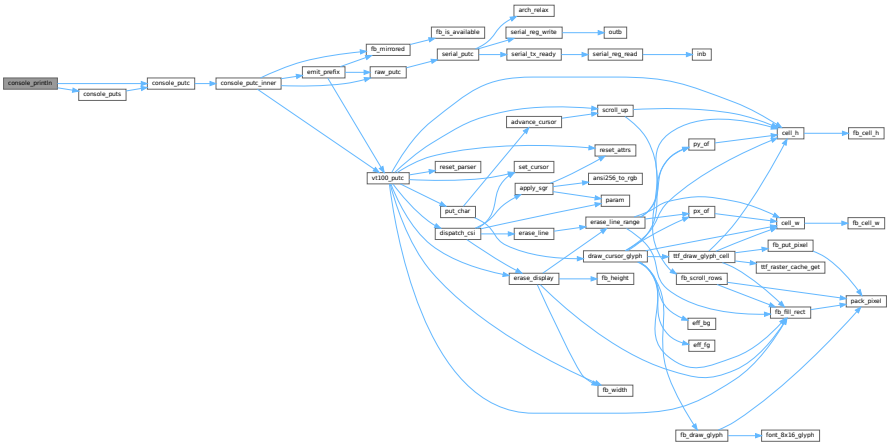
```
void console_println (
            const char * s )
```

Write a string with newline to serial console.

References console_putc(), and console_puts().

Referenced by aarch64_exception_handler(), aarch64_psci_conduit_init(), apic_init(), apic_timer_init(), apic_timer_start(), arch_early_init(), arch_interrupts_init(), blkio_usb_open_msc(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_wirebind_eject(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), capsule_wirebind_unclean_detac capsule_zuse_boot_logout(), capsule_zuse_boot_try_attach(), console_describe_serial(), converge_tsc_bare_metal(), decode_pf_error(), enable_interrupt_route(), failed(), gpt_read(), i8042_init(), init_timer_vm_mode(), ioapic_init(), isr_common_handler(), kernel_main(), kernel_main_deep(), pci_init(), plic_init(), print_banner(), print_boot_info(), print_heap_stats(), print_nl(), print_pmm_stats(), print_uint(), riscv64_exception_handler(), rng_init(), say_size(), sk_repl(), sk_repl_dispatch_line(), sk_repl_run(), sk_repl_step(), sk_v4_drive_arrived(), sk_v4_fixed_screen(), sk_v4_genesis(), sk_v4_grow_stick(), sk_v4_identity_boot(), sk_v4_login(), sk_v4_mint_zuse(), sk_v4_real_zuse_arrived(), sk_v4_run(), sk_v4_serve(), sk_v4_session_end(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), timer_fatal(), timer_init(), vblk_init_device(), vinput_init_device(), virtio_blk_find_artemis(), virtio_input_find_keyboard(), virtio_rng_init(), vm_bootstrap_root_vocabulary(), vm_init_with_host(), vm_physics_status(), vmm_init(), vmm_map_page(), vocab_sync_vm_vars(), vocabulary_create_vocabulary_direct(), vrng_init_device(), and xhci_poll_one().

Here is the call graph for this function:



7.21.2.19 console_putc()

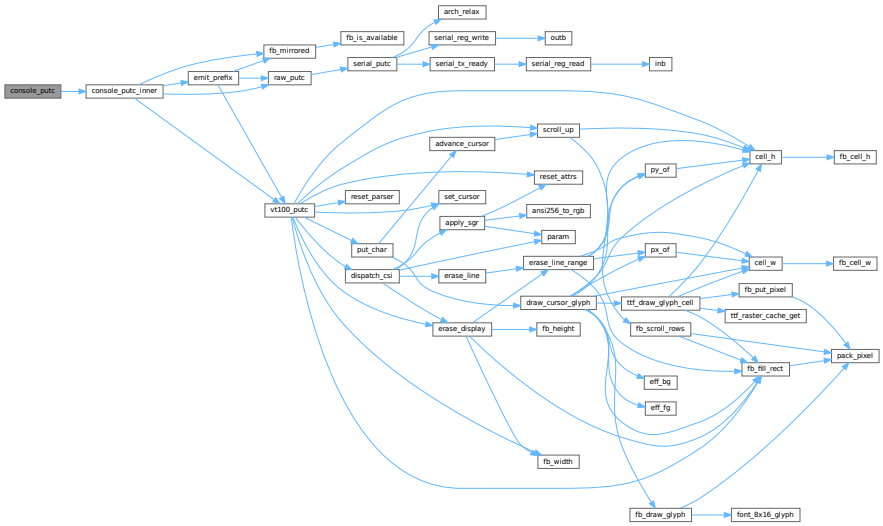
```
void console_putc (
            char c )
```

Write a single character to serial console.

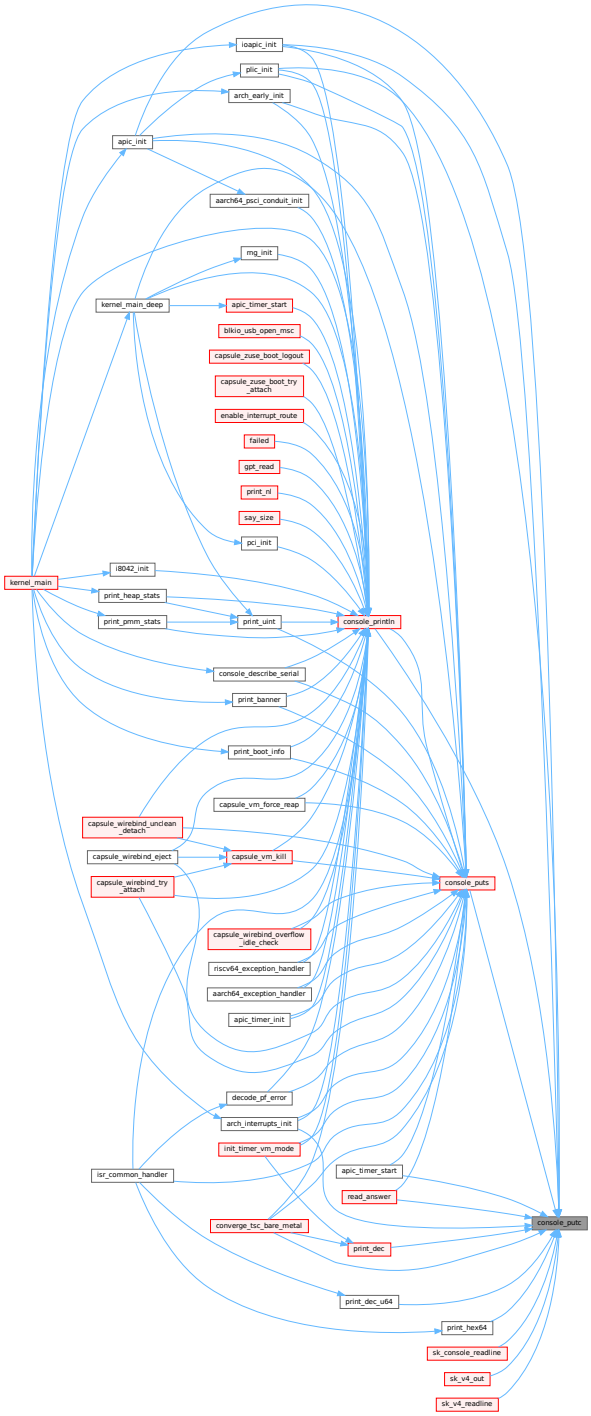
References console_putc_inner(), g_console_tx_count, and g_pending_line_close.

Referenced by apic_init(), apic_timer_start(), arch_interrupts_init(), console_println(), console_puts(), converge_tsc_bare_metal(), ioapic_init(), plic_init(), print_dec(), print_dec_u64(), print_hex64(), read_answer(), sk_console_readline(), sk_v4_out(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:



7.21.2.20 console_puts()

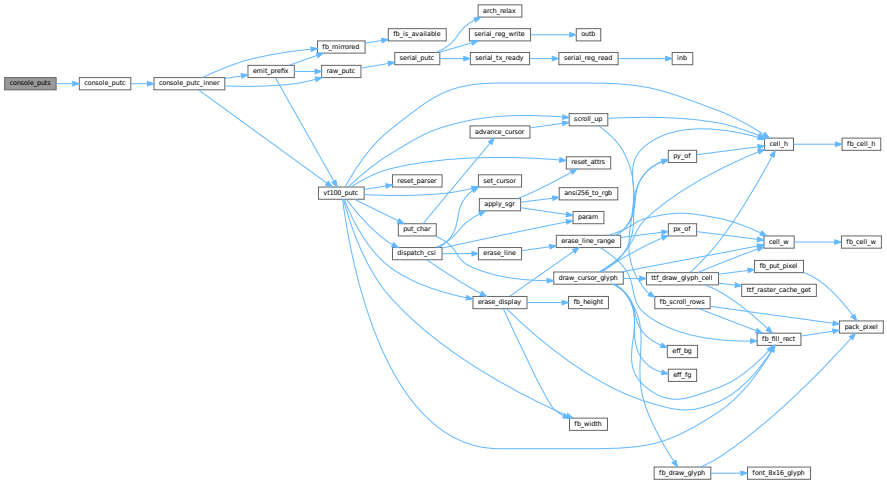
```
void console_puts (
            const char * s )
```

Write a null-terminated string to serial console.

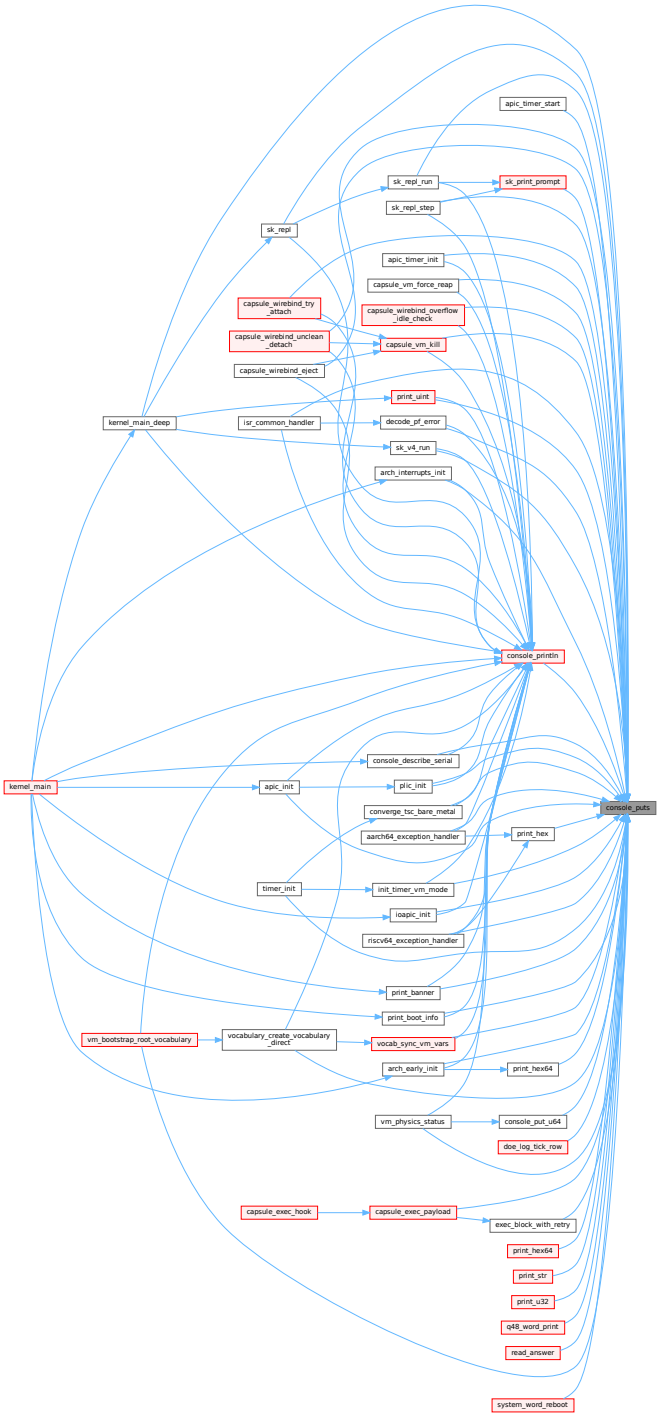
References console_putc().

Referenced by aarch64_exception_handler(), apic_init(), apic_timer_init(), apic_timer_start(), arch_early_init(), arch_interrupts_init(), capsule_exec_payload(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_wirebind_eject(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), capsule_wirebind_unclean_detach(), console_describe_serial(), console_println(), console_put_u64(), converge_tsc_bare_metal(), decode_pf_error(), doe_log_tick_row(), exec_block_with_retry(), init_timer_vm_mode(), ioapic_init(), isr_common_handler(), kernel_main_deep(), plic_init(), print_banner(), print_boot_info(), print_hex(), print_hex64(), print_hex64(), print_str(), print_u32(), print_uint(), q48_word_print(), read_answer(), riscv64_exception_handler(), sk_print_prompt(), sk_repl(), sk_repl_run(), sk_repl_step(), sk_v4_run(), system_word_reboot(), timer_init(), vm_bootstrap_root_vocabulary(), vm_physics_status(), vocab_sync_vm_vars(), and vocabulary_create_vocabulary_direct().

Here is the call graph for this function:



Here is the caller graph for this function:



7.21.2.21 console_save_vm_name()

```
void console_save_vm_name (
            char * out,
            size_t cap )
```

console_save_vm_name - Copy the current active-VM name into the caller's own buffer, for a later console_set_vm_name() restore.

console_get_vm_name() alone is NOT safe for save-then-restore: it returns a pointer into the single internal buffer console_set_vm_name() copies into, so an intervening console_set_vm_name() call (the normal "switch, do work, switch back" pattern every BIRTH/VM-EXEC/CONNECT-∗ call site uses) overwrites the very bytes the saved pointer points at before the restore ever runs – found live 2026-08-28, the restore silently no-ops. Copies at most cap-1 bytes plus a NUL terminator; writes "" if there was no active name (NULL) to save.

Parameters

out	Caller-owned buffer.
cap	Its size in bytes.

References g_active_vm_name.

7.21.2.22 console_set_user_prefix_provider()

```
void console_set_user_prefix_provider (
            console_user_prefix_fn fn )
```

References g_user_prefix_fn.

Referenced by sk_repl_run(), and sk_v4_login().

Here is the caller graph for this function:

7.21.2.23 console_set_vm_name()

```
void console_set_vm_name (
            const char * name )
```

Set the active VM name shown as [Name] prefix on each output line.

Pass NULL to suppress the prefix (kernel-only output before any VM). Copies into internal storage (FABRIC-2.md Phase F, 2026-08-28) – the caller's own pointer does not need to remain valid afterward.

References CONSOLE_VM_NAME_BUF, g_active_vm_name, g_active_vm_name_buf, and name.

Referenced by capsule_vm_registry_init(), and sk_v4_login().

Here is the caller graph for this function:

7.21.2.24 console_tx_count()

```
uint64_t console_tx_count (
            void  )
```

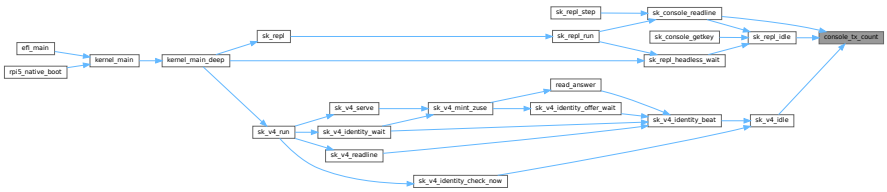
console_tx_count - Monotonic count of console_putc() calls delivered to either output (serial and/or framebuffer).

In use by the REPL to detect that an idle bottom half (heartbeat, USB attach/detach) wrote to the console while the top-level prompt was showing, so it can re-anchor the prompt afterward. Never decreases.

References g_console_tx_count.

Referenced by sk_console_readline(), sk_repl_idle(), and sk_v4_idle().

Here is the caller graph for this function:



7.21.3 Variable Documentation

7.21.3.1 g_sk_fault_word

```
volatile const char* g_sk_fault_word  [extern]
```

interrupts.c (aarch64) - Exception vector setup and common handler

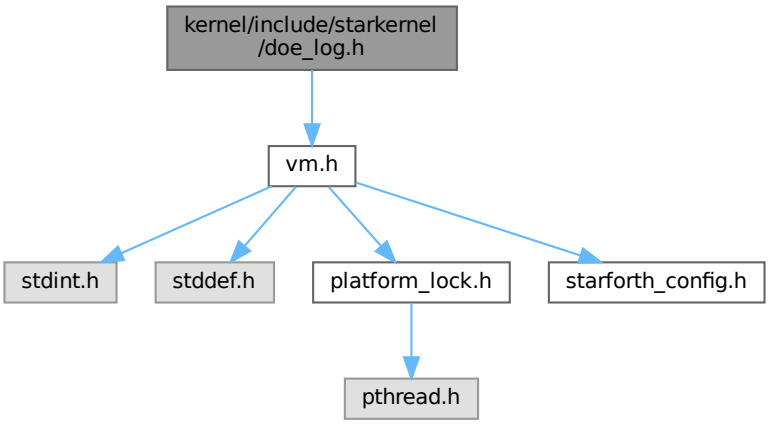
interrupts.c (aarch64) - Exception vector setup and common handler

Referenced by execute_colon_word(), isr_common_handler(), and vm_interpret_word().

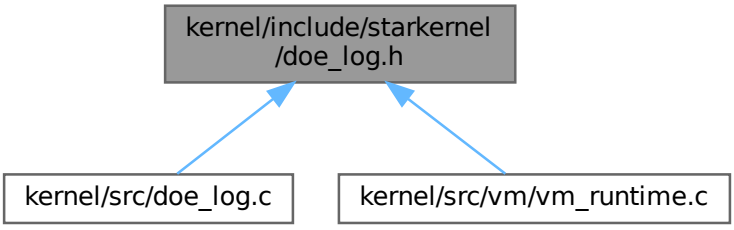
7.22 kernel/include/starkernel/doe_log.h File Reference

```
#include "vm.h"
```

Include dependency graph for doe_log.h:



This graph shows which files directly or indirectly include this file:



Functions

- void doe_log_tick_row (VM *vm, const HeartbeatTickSnapshot *snap)

  Emit one CSV row for the current heartbeat tick, unless g_doe_log_enabled is 0 (a no-op then).
- void register_doe_log_words (VM *vm)

  Registers HB-ON (–) and HB-OFF (–), which set g_doe_log_enabled to 1 and 0 respectively.

Variables

- int g_doe_log_enabled

  starkernel/doe_log.h — DoE (Design of Experiments) CSV logger

7.22.1 Function Documentation

7.22.1.1 doe_log_tick_row()

```
void doe_log_tick_row (
            VM * vm,
            const HeartbeatTickSnapshot * snap )
```

Emit one CSV row for the current heartbeat tick, unless g_doe_log_enabled is 0 (a no-op then).

Pulls APIC TimeTrustState via heartbeat_state(). Prints the column header once, before the first row ever emitted – not re-printed on every HB-ON, so a session toggled off and back on stays one continuous CSV rather than getting a second header embedded partway through.

Parameters

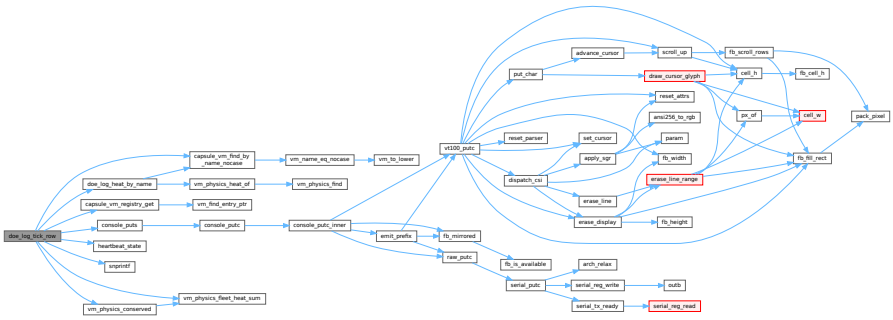
vm	VM instance (used for snapshot data)
snap	Populated HeartbeatTickSnapshot from heartbeat_capture_tick_snapshot()

References HeartbeatTickSnapshot::actual_window_size, HeartbeatTickSnapshot::avg_word_heat, HeartbeatTickSnapshot::bucket_
HeartbeatTickSnapshot::cache_hits_delta, capsule_vm_find_by_name_nocase(), capsule_vm_registry_get(),

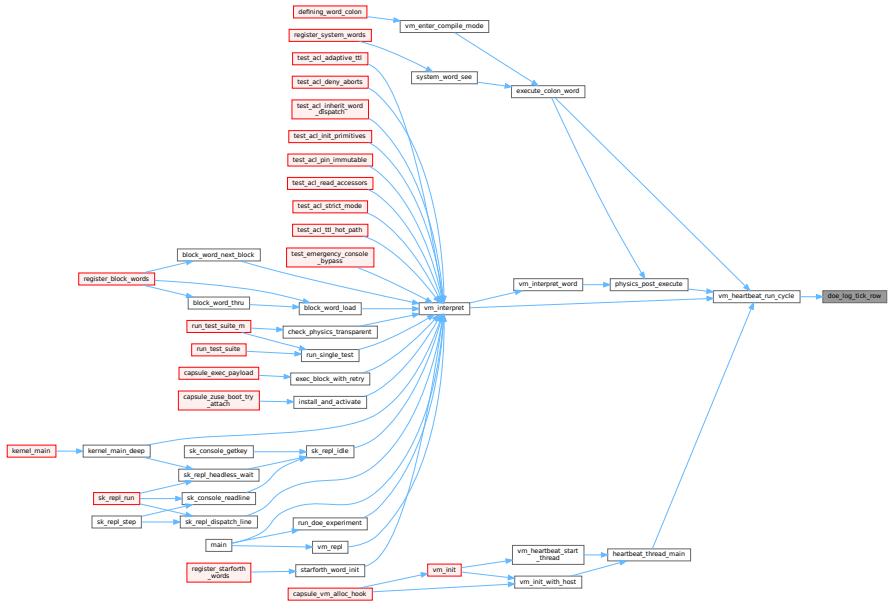
console_puts(), DOE_BUF_SIZE, doe_header, doe_log_heat_by_name(), DOE_PREFIX, HeartbeatTickSnapshot::elapsed_ns, HeartbeatTickSnapshot::estimated_jitter_ns, g_doe_log_enabled, heartbeat_state(), HeartbeatTickSnapshot::hot_word_count, VMRegistryEntry::name, HeartbeatTickSnapshot::predicted_label_hits, snprintf(), HeartbeatTickSnapshot::tick_interval_ns, HeartbeatTickSnapshot::tick_number, time_trust_state::ticks, time_trust_state::trust, time_trust_state::variance, VMRegistryEntry::vm_id, vm_physics_conserved(), vm_physics_fleet_heat_sum(), HeartbeatTickSnapshot::window_width, and HeartbeatTickSnapshot::word_executions_delta.

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.22.1.2 register_doe_log_words()

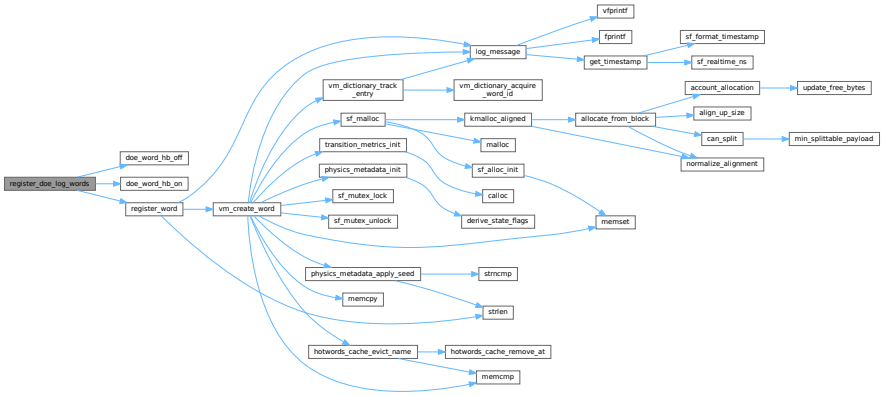
```
void register_doe_log_words (
            VM * vm )
```

Registers HB-ON (–) and HB-OFF (–), which set g_doe_log_enabled to 1 and 0 respectively.

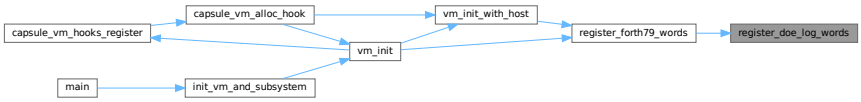
References doe_word_hb_off(), doe_word_hb_on(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.22.2 Variable Documentation

7.22.2.1 g_doe_log_enabled

```
int g_doe_log_enabled  [extern]
```

starkernel/doe_log.h — DoE (Design of Experiments) CSV logger

Emits per-heartbeat-tick CSV rows to the serial log, tagged with [HADES][DOE] so they can be grepped cleanly from the QEMU log.

Each row contains the 12 standard heartbeat snapshot fields plus 3 APIC timer fields from TimeTrustState: apic↩ _ticks, time_trust_q48, variance_q48

A header row is printed automatically before the first data row.

Always compiled in – gating moved from a build-time flag (HEARTBEAT_DOE_LOG) to a runtime one (g_doe_log↩ _enabled below) so the same build can run with or without per-tick instrumentation, toggled live via the HB-ON/HB-OFF FORTH words (register_doe_log_words()), no rebuild required. Runtime enable flag for doe_log_tick_row() below. Defaults to 1 (matches the old HEARTBEAT_DOE_LOG=1 default – instrumentation on unless explicitly turned off). Toggled by HB-ON/HB-OFF; read, not meant to be written directly outside those two words.

starkernel/doe_log.h — DoE (Design of Experiments) CSV logger

Emits CSV rows to the serial log once per heartbeat tick. Each row is prefixed with a cyan [HADES][DOE] tag so it can be extracted cleanly:

grep -aP '[HADES][DOE]' qemu-amd64-∗.log

Columns (in order): 0a. vm_name string — the emitting VM's own registry name (reverse lookup on vm->stadium↩ _vm_id, "?" if unregistered at this tick). Added 2026-09-16 for the multiuser/ multitasking DoE (FABRIC-3.md ?↩ XXXIII): every prior column already described *a* VM's state each row, but nothing said *which* VM emitted it, making concurrent-VM rows indistinguishable by source. 0b. vm_id_hex string — the emitting VM's own stadium_vm_↩ id as "hi-lo" hex, same format PARITY:BIRTH/PARITY:KILL already print. Names get reused across a trial's own KILL+rebirth cycles; this is the one column unique to a single birth instance.

1. tick_number uint32 — monotonic heartbeat counter
2. elapsed_ns uint64 — ns since run start
3. tick_interval_ns uint64 — actual interval from prior tick
4. cache_hits_delta uint32 — hot-words cache hits this tick (TODO: 0)
5. bucket_hits_delta uint32 — bucket hits this tick (TODO: 0)
6. word_executions_delta uint32 — words executed this tick (TODO: 0)
7. hot_word_count uint64 — words with heat >= threshold
8. avg_word_heat_q48 uint64 — mean execution heat as raw Q48.16 integer
9. window_width uint32 — rolling window effective size
10. actual_window_size uint32 — true analysis width: min(total_executions, effective_window_size)
11. predicted_label_hits uint32 — ANOVA early-exit confirmations per tick (L8 validation signal)
12. jitter_bits uint64 — estimated_jitter_ns IEEE 754 raw bits (union-punned)
13. apic_ticks uint64 — APIC timer monotonic tick count
14. time_trust_q48 uint64 — TIME-TRUST in Q48.16 format
15. variance_q48 uint64 — timing variance in Q48.16 format
16. hera_heat_q48 uint64 — VM fleet physics: Hera's execution_heat_q48
17. hermes_heat_q48 uint64 — VM fleet physics: Hermes's execution_heat_q48
18. artemis_heat_q48 uint64 — VM fleet physics: Artemis's execution_heat_q48
19. fleet_k_q48 uint64 — "K": vm_physics_fleet_heat_sum() over ALL live VMs (not just the 3 named Tripod members above – this is the genuine conservation invariant, which should read Q48_ONE (65536) whenever conservation holds). Requested 2026-09-12 alongside the 3x9 factorial analysis in experiments/std79-doe/ – columns 16-18 alone cannot reconstruct this since they omit every identity VM's own heat.
20. fleet_conserved uint32 — vm_physics_conserved() as 0/1: whether $|$fleet_k_q48 - Q48_ONE$|$ < VM_↩ PHYSICS_EPSILON_Q48 at the moment this row was captured.
21. switch_count_cumulative uint64 — Stage 3 preemptive-switch count, cumulative since boot (capsule_vm_switch_signal.c).
22. switch_current_slot uint32 — which registered switch-signal participant is executing at this tick (0=Hera,1=Hermes, 2=Artemis by current registration order; 0xFFFFFFFF = none/unregistered at this moment).
23. switch_hera_readiness uint32 — Hera's raw readiness accumulator (slot 0).
24. switch_hermes_readiness uint32 — Hermes's raw readiness accumulator (slot 1).

25. switch_artemis_readiness uint32 — Artemis's raw readiness accumulator (slot 2).
26. switch_ticks_since uint32 — ticks elapsed since the last real switch (capsule_vm_switch_signal.c); empirically verifies the fixed 50-tick threshold under real DoE load rather than assuming it.

Columns 21-26 (FABRIC-3.md ?XXVIII Stage 3 follow-on, 2026-09-13): added alongside Stage 3's timer-driven preemptive context switching – read-only exposure of state the switch-signal module already tracked internally for its own decision-making; no new measurement logic, just made observable. Slot readiness columns are hardcoded to the 3 known Tripod slots (same convention as columns 16-18) rather than a dynamic per-slot column set, for the same reason: this is a logging schema for the currently-known fleet, not the switch-signal mechanism itself (which stays slot-count-agnostic, headroom for up to 8 participants – see capsule_vm_switch_signal.h).

Note: avg_word_heat and estimated_jitter_ns are stored as double in the snapshot but the freestanding snprintf has no %f support. avg_word_heat is emitted as raw Q48.16 (multiply by 65536); jitter is union-punned to its IEEE 754 uint64 bit pattern to avoid UB from out-of-range cast.

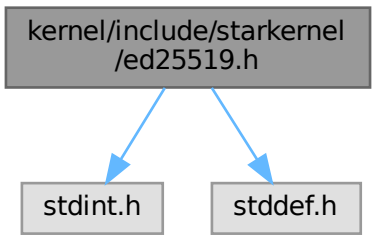
Columns 16-18 (VM-FLEET-ATTRACTOR-DESIGN-20260705.md, Phase 3): looked up by name each tick rather than by a fixed vm_id, since kill/rebirth (e.g. TRIPOD-TEST's K-soak) assigns a fresh vm_id on every rebirth. Fixed to the three known Tripod VMs, not a dynamic per-VM column set – this is a logging schema for a specific known fleet, not the physics mechanism itself (which stays genuinely VM-count-agnostic). Reads 0 for any VM not currently found in the registry (e.g. Hermes momentarily during its kill/rebirth window), which is a legitimate observation, not an error.

Referenced by doe_log_tick_row(), doe_word_hb_off(), and doe_word_hb_on().

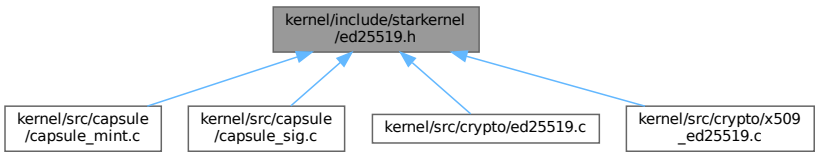
7.23 kernel/include/starkernel/ed25519.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for ed25519.h:



This graph shows which files directly or indirectly include this file:



Functions

- int ed25519_verify (const uint8_t pubkey[32], const uint8_t *msg, size_t msg_len, const uint8_t sig[64])
- void ed25519_keygen (const uint8_t seed[32], uint8_t pubkey_out[32])
- void ed25519_sign (const uint8_t seed[32], const uint8_t *msg, size_t msg_len, uint8_t sig_out[64])

7.23.1 Function Documentation

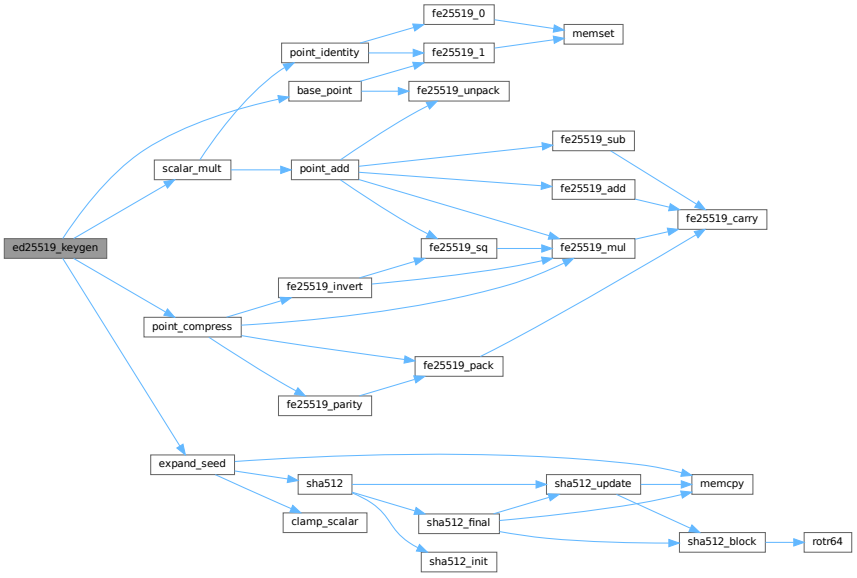
7.23.1.1 ed25519_keygen()

```
void ed25519_keygen (
            const uint8_t seed[32],
            uint8_t pubkey_out[32] )
```

References base_point(), expand_seed(), point_compress(), and scalar_mult().

Referenced by capsule_mint_identity().

Here is the call graph for this function:



Here is the caller graph for this function:

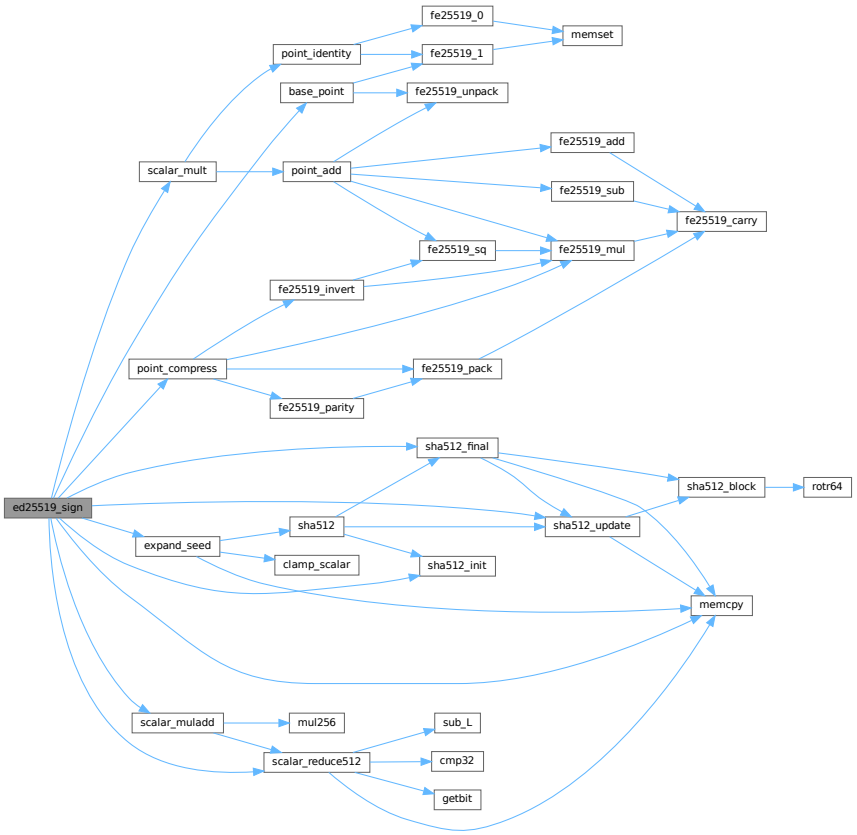
7.23.1.2 ed25519_sign()

```
void ed25519_sign (
            const uint8_t seed[32],
            const uint8_t * msg,
            size_t msg_len,
            uint8_t sig_out[64] )
```

References base_point(), expand_seed(), memcpy(), point_compress(), scalar_muladd(), scalar_mult(), scalar_reduce512(), sha512_final(), sha512_init(), and sha512_update().

Referenced by x509_build_user_cert().

Here is the call graph for this function:



Here is the caller graph for this function:

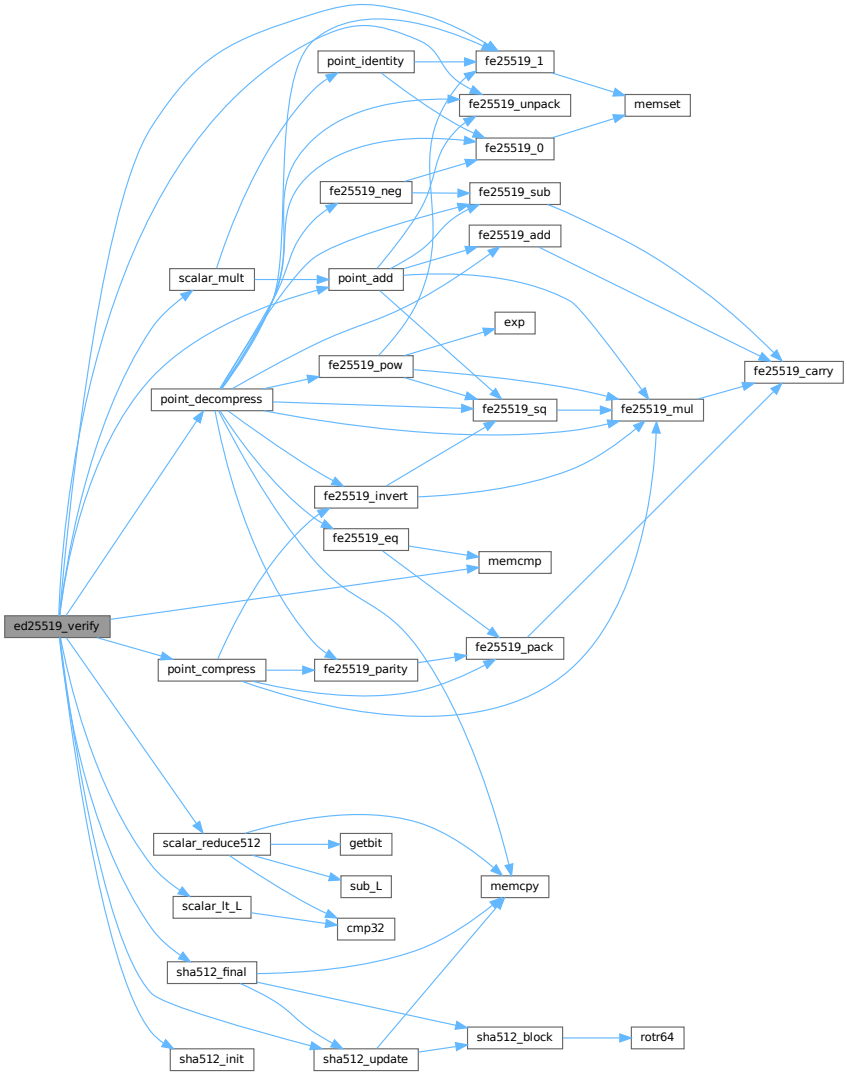
7.23.1.3 ed25519_verify()

```
int ed25519_verify (
            const uint8_t pubkey[32],
            const uint8_t * msg,
            size_t msg_len,
            const uint8_t sig[64] )
```

References BX_BYTES, BY_BYTES, fe25519_1(), fe25519_unpack(), memcmp(), point_add(), point_compress(), point_decompress(), scalar_lt_L(), scalar_mult(), scalar_reduce512(), sha512_final(), sha512_init(), sha512_update(), ed_point_t::x, ed_point_t::y, and ed_point_t::z.

Referenced by capsule_verify_signature(), and x509_verify_signature().

Here is the call graph for this function:

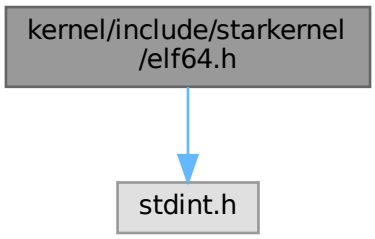


Here is the caller graph for this function:

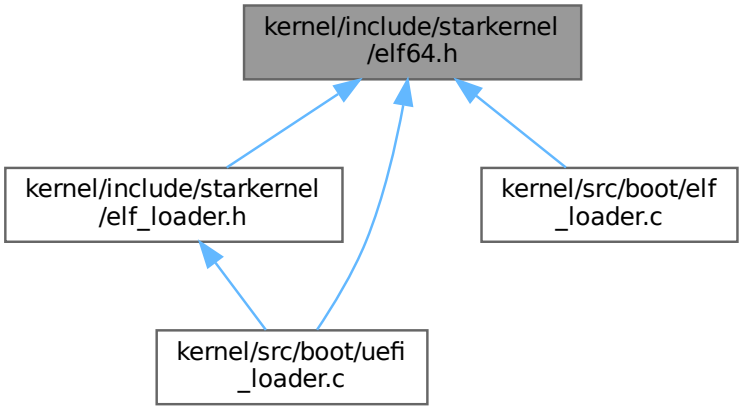
7.24 kernel/include/starkernel/elf64.h File Reference

```
#include <stdint.h>
```

Include dependency graph for elf64.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct Elf64_Ehdr

- struct Elf64_Phdr
- struct Elf64_Shdr
- struct Elf64_Rela
- struct Elf64_Sym
- struct Elf64_Rel

Macros

- #define EI_MAG0 0

  elf64.h - ELF64 structures for kernel loading Minimal ELF64 definitions for the UEFI loader
- #define EI_MAG1 1
- #define EI_MAG2 2
- #define EI_MAG3 3
- #define EI_CLASS 4
- #define EI_DATA 5
- #define EI_VERSION 6
- #define EI_OSABI 7
- #define EI_ABIVERSION 8
- #define EI_PAD 9
- #define EI_NIDENT 16
- #define ELFMAG0 0x7F
- #define ELFMAG1 'E'
- #define ELFMAG2 'L'
- #define ELFMAG3 'F'
- #define ELFCLASS32 1
- #define ELFCLASS64 2
- #define ELFDATA2LSB 1 /* Little-endian */
- #define ELFDATA2MSB 2 /* Big-endian */
- #define EV_CURRENT 1
- #define ELFOSABI_NONE 0 /* UNIX System V ABI */
- #define ET_NONE 0
- #define ET_REL 1
- #define ET_EXEC 2
- #define ET_DYN 3
- #define ET_CORE 4
- #define EM_X86_64 62 /* AMD x86-64 */
- #define EM_AARCH64 183 /* ARM AARCH64 */
- #define EM_RISCV 243 /* RISC-V */
- #define PT_NULL 0
- #define PT_LOAD 1
- #define PT_DYNAMIC 2
- #define PT_INTERP 3
- #define PT_NOTE 4
- #define PT_SHLIB 5
- #define PT_PHDR 6
- #define PT_TLS 7
- #define PF_X 0x1 /* Execute */
- #define PF_W 0x2 /* Write */
- #define PF_R 0x4 /* Read */
- #define SHT_NULL 0
- #define SHT_PROGBITS 1
- #define SHT_SYMTAB 2
- #define SHT_STRTAB 3
- #define SHT_RELA 4

- #define SHT_HASH 5
- #define SHT_DYNAMIC 6
- #define SHT_NOTE 7
- #define SHT_NOBITS 8
- #define SHT_REL 9
- #define SHT_SHLIB 10
- #define SHT_DYNSYM 11
- #define R_X86_64_NONE 0
- #define R_X86_64_64 1
- #define R_X86_64_PC32 2
- #define R_X86_64_RELATIVE 8
- #define R_X86_64_32 10
- #define R_X86_64_32S 11
- #define R_X86_64_PLT32 4
- #define R_AARCH64_NONE 0
- #define R_AARCH64_ABS64 257
- #define R_AARCH64_RELATIVE 1027
- #define R_RISCV_NONE 0
- #define R_RISCV_64 2
- #define R_RISCV_RELATIVE 3
- #define ELF64_R_SYM(i) ((i) >> 32)
- #define ELF64_R_TYPE(i) ((i) & 0xffffffffL)
- #define ELF64_R_INFO(s, t) (((Elf64_Xword)(s) << 32) + ((Elf64_Xword)(t) & 0xffffffffL))

Typedefs

- typedef uint64_t Elf64_Addr
- typedef uint64_t Elf64_Off
- typedef uint16_t Elf64_Half
- typedef uint32_t Elf64_Word
- typedef int32_t Elf64_Sword
- typedef uint64_t Elf64_Xword
- typedef int64_t Elf64_Sxword

7.24.1 Macro Definition Documentation

7.24.1.1 EI_ABIVERSION

```
#define EI_ABIVERSION 8
```

7.24.1.2 EI_CLASS

```
#define EI_CLASS 4
```

7.24.1.3 EI_DATA

```
#define EI_DATA 5
```

7.24.1.4 EI_MAG0

```
#define EI_MAG0 0
```

elf64.h - ELF64 structures for kernel loading Minimal ELF64 definitions for the UEFI loader

7.24.1.5 EI_MAG1

```
#define EI_MAG1 1
```

7.24.1.6 EI_MAG2

```
#define EI_MAG2 2
```

7.24.1.7 EI_MAG3

```
#define EI_MAG3 3
```

7.24.1.8 EI_NIDENT

```
#define EI_NIDENT 16
```

7.24.1.9 EI_OSABI

```
#define EI_OSABI 7
```

7.24.1.10 EI_PAD

```
#define EI_PAD 9
```

7.24.1.11 EI_VERSION

```
#define EI_VERSION 6
```

7.24.1.12 ELF64_R_INFO

```
#define ELF64_R_INFO(
              s,
              t ) (((Elf64_Xword)(s) << 32) + ((Elf64_Xword)(t) & 0xffffffffL))
```

7.24.1.13 ELF64_R_SYM

```
#define ELF64_R_SYM(
             i ) ((i) >> 32)
```

7.24.1.14 ELF64_R_TYPE

```
#define ELF64_R_TYPE(
             i ) ((i) & 0xffffffffL)
```

7.24.1.15 ELFCLASS32

```
#define ELFCLASS32 1
```

7.24.1.16 ELFCLASS64

```
#define ELFCLASS64 2
```

7.24.1.17 ELFDATA2LSB

```
#define ELFDATA2LSB 1 /* Little-endian */
```

7.24.1.18 ELFDATA2MSB

```
#define ELFDATA2MSB 2 /* Big-endian */
```

7.24.1.19 ELFMAG0

```
#define ELFMAG0 0x7F
```

7.24.1.20 ELFMAG1

```
#define ELFMAG1 'E'
```

7.24.1.21 ELFMAG2

```
#define ELFMAG2 'L'
```

7.24.1.22 ELFMAG3

```
#define ELFMAG3 'F'
```

7.24.1.23 ELFOSABI_NONE

```
#define ELFOSABI_NONE 0 /* UNIX System V ABI */
```

7.24.1.24 EM_AARCH64

```
#define EM_AARCH64 183 /* ARM AARCH64 */
```

7.24.1.25 EM_RISCV

```
#define EM_RISCV 243 /* RISC-V */
```

7.24.1.26 EM_X86_64

```
#define EM_X86_64 62 /* AMD x86-64 */
```

7.24.1.27 ET_CORE

```
#define ET_CORE 4
```

7.24.1.28 ET_DYN

```
#define ET_DYN 3
```

7.24.1.29 ET_EXEC

```
#define ET_EXEC 2
```

7.24.1.30 ET_NONE

```
#define ET_NONE 0
```

7.24.1.31 ET_REL

```
#define ET_REL 1
```

7.24.1.32 EV_CURRENT

```
#define EV_CURRENT 1
```

7.24.1.33 PF_R

```
#define PF_R 0x4 /* Read */
```

7.24.1.34 PF_W

```
#define PF_W 0x2 /* Write */
```

7.24.1.35 PF_X

```
#define PF_X 0x1 /* Execute */
```

7.24.1.36 PT_DYNAMIC

```
#define PT_DYNAMIC 2
```

7.24.1.37 PT_INTERP

```
#define PT_INTERP 3
```

7.24.1.38 PT_LOAD

```
#define PT_LOAD 1
```

7.24.1.39 PT_NOTE

```
#define PT_NOTE 4
```

7.24.1.40 PT_NULL

```
#define PT_NULL 0
```

7.24.1.41 PT_PHDR

```
#define PT_PHDR 6
```

7.24.1.42 PT_SHLIB

```
#define PT_SHLIB 5
```

7.24.1.43 PT_TLS

```
#define PT_TLS 7
```

7.24.1.44 R_AARCH64_ABS64

```
#define R_AARCH64_ABS64 257
```

7.24.1.45 R_AARCH64_NONE

```
#define R_AARCH64_NONE 0
```

7.24.1.46 R_AARCH64_RELATIVE

```
#define R_AARCH64_RELATIVE 1027
```

7.24.1.47 R_RISCV_64

```
#define R_RISCV_64 2
```

7.24.1.48 R_RISCV_NONE

```
#define R_RISCV_NONE 0
```

7.24.1.49 R_RISCV_RELATIVE

```
#define R_RISCV_RELATIVE 3
```

7.24.1.50 R_X86_64_32

```
#define R_X86_64_32 10
```

7.24.1.51 R_X86_64_32S

```
#define R_X86_64_32S 11
```

7.24.1.52 R_X86_64_64

```
#define R_X86_64_64 1
```

7.24.1.53 R_X86_64_NONE

```
#define R_X86_64_NONE 0
```

7.24.1.54 R_X86_64_PC32

```
#define R_X86_64_PC32 2
```

7.24.1.55 R_X86_64_PLT32

```
#define R_X86_64_PLT32 4
```

7.24.1.56 R_X86_64_RELATIVE

```
#define R_X86_64_RELATIVE 8
```

7.24.1.57 SHT_DYNAMIC

```
#define SHT_DYNAMIC 6
```

7.24.1.58 SHT_DYNSYM

```
#define SHT_DYNSYM 11
```

7.24.1.59 SHT_HASH

```
#define SHT_HASH 5
```

7.24.1.60 SHT_NOBITS

```
#define SHT_NOBITS 8
```

7.24.1.61 SHT_NOTE

```
#define SHT_NOTE 7
```

7.24.1.62 SHT_NULL

```
#define SHT_NULL 0
```

7.24.1.63 SHT_PROGBITS

```
#define SHT_PROGBITS 1
```

7.24.1.64 SHT_REL

```
#define SHT_REL 9
```

7.24.1.65 SHT_RELA

```
#define SHT_RELA 4
```

7.24.1.66 SHT_SHLIB

```
#define SHT_SHLIB 10
```

7.24.1.67 SHT_STRTAB

```
#define SHT_STRTAB 3
```

7.24.1.68 SHT_SYMTAB

```
#define SHT_SYMTAB 2
```

7.24.2 Typedef Documentation

7.24.2.1 Elf64_Addr

```
typedef uint64_t Elf64_Addr
```

7.24.2.2 Elf64_Half

```
typedef uint16_t Elf64_Half
```

7.24.2.3 Elf64_Off

```
typedef uint64_t Elf64_Off
```

7.24.2.4 Elf64_Sword

```
typedef int32_t Elf64_Sword
```

7.24.2.5 Elf64_Sxword

```
typedef int64_t Elf64_Sxword
```

7.24.2.6 Elf64_Word

```
typedef uint32_t Elf64_Word
```

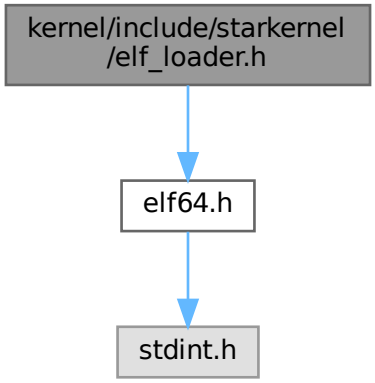
7.24.2.7 Elf64_Xword

```
typedef uint64_t Elf64_Xword
```

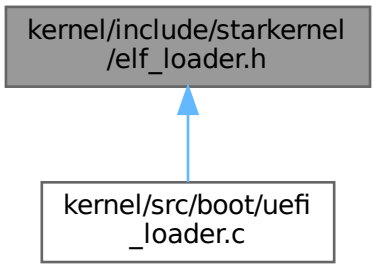
7.25 kernel/include/starkernel/elf_loader.h File Reference

```
#include "elf64.h"
```

Include dependency graph for elf_loader.h:



This graph shows which files directly or indirectly include this file:



Functions

- int elf_load_kernel (const uint8_t *elf_data, uint64_t elf_size, Elf64_Addr *entry_out)
  elf_loader.h - ELF64 kernel loader interface

7.25.1 Function Documentation

7.25.1.1 elf_load_kernel()

```
int elf_load_kernel (
            const uint8_t * elf_data,
            uint64_t elf_size,
            Elf64_Addr * entry_out )
```

elf_loader.h - ELF64 kernel loader interface

elf_loader.h - ELF64 kernel loader interface

Top-level ELF loader called by `efi_main()` (in the split-build path) after `ExitBootServices()`. Performs three operations in sequence:

1. **Header validation** via `elf_validate_header()` — checks magic, class, data encoding, version, type, and machine-specific architecture. Returns 0 immediately on failure.
2. **Segment loading** via `elf_load_segments()` — maps all `PT_LOAD` segments to their target addresses, initialises BSS to zero. The `load_base` is:
   - 0 for `ET_EXEC` (absolute-address kernel; typical for StarKernel).
   - 0x400000 (4 MB) for `ET_DYN` (position-independent kernel).
3. **Relocation processing** via `elf_apply_relocations()` — applies `SHT_RELA` sections to patch in the correct runtime addresses. Returns 0 on any relocation error.

On success, stores `load_base` + `e_entry` in `*entry_out` — the virtual address of the kernel's C entry function `kernel_main()` — and returns 1. The caller performs an indirect call to this address.

`elf_size` is currently unused (reserved for future bounds-checking of program-header and section-header offsets against the file boundary).

Parameters

elf_data	Pointer to the ELF64 file image in UEFI loader memory; must remain valid until after the call returns.
elf_size	Size of the ELF image in bytes (currently unchecked).
entry_out	Output: receives the kernel entry point address on success.

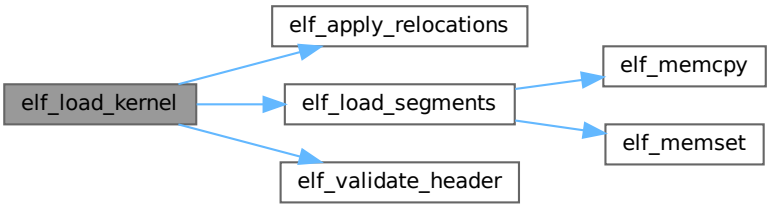
Returns

1 on success, 0 if validation, segment loading, or relocation fails.

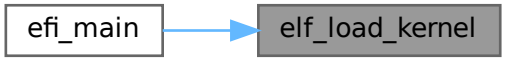
References Elf64_Ehdr::e_entry, Elf64_Ehdr::e_type, elf_apply_relocations(), elf_load_segments(), elf_validate_header(), ET_DYN, and ET_EXEC.

Referenced by efi_main().

Here is the call graph for this function:

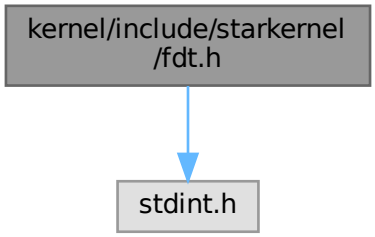


Here is the caller graph for this function:



7.26 kernel/include/starkernel/fdt.h File Reference

`#include <stdint.h>`
Include dependency graph for fdt.h:



This graph shows which files directly or indirectly include this file:

Functions

- int fdt_valid (const void *fdt)

  fdt.h - Minimal flattened-devicetree reader
- const void * fdt_find_prop (const void *fdt, const char *name, uint32_t *len_out)

  Find the first property with `name` anywhere in the tree.
- int fdt_prop_u32 (const void *fdt, const char *name, uint32_t *out)

  Read a single-cell (32-bit) property by name.
- const void * fdt_find_node_by_compatible (const void *fdt, const char *compatible)

  Find the first node whose "compatible" property matches `compatible`.
- const void * fdt_find_node_by_device_type (const void *fdt, const char *type)

  Find the first node whose "device_type" property equals `type`.
- const void * fdt_find_node_by_name (const void *fdt, const char *name)

  Find the first node whose own name matches `name`.
- const void * fdt_next_child_node (const void *fdt, const void *parent, const void *prev_child)

  Iterate the direct children of one node.
- const void * fdt_find_prop_in_node (const void *fdt, const void *node, const char *name, uint32_t *len_out)

  Find a property by name, scoped to one node.
- int fdt_complete (const void *fdt)

  Is the structure block whole? `fdt_valid()` checks the header; this checks also that the structure block ends with its end token, as a blob that has not been cut short does.
- const void * fdt_root_node (const void *fdt)

  The root node.
- const void * fdt_find_child (const void *fdt, const void *parent, const char *name, uint32_t name_len)

  Find a direct child of a node by its whole name.
- int fdt_reg_address (const void *fdt, const char *compatible, uint32_t index, uint64_t *out)

  The CPU's address for entry `index` of the `reg` of the first enabled node compatible with `compatible` (2026-10-14).

7.26.1 Function Documentation

7.26.1.1 fdt_complete()

```
int fdt_complete (
            const void * fdt )
```

Is the structure block whole? `fdt_valid()` checks the header; this checks also that the structure block ends with its end token, as a blob that has not been cut short does.

A reader that takes a property's absence to mean its default (a UART's "reg-shift") must not be handed half a tree.

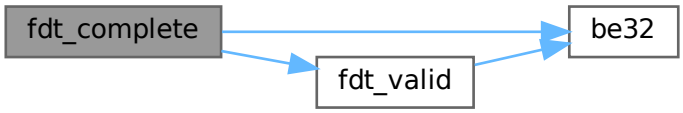
Returns

1 if `fdt` is valid and its structure block ends with FDT_END.

References be32(), FDT_END, fdt_valid(), fdt_header_t::off_dt_struct, and fdt_header_t::size_dt_struct.

Referenced by fdt_console_uart(), and fdt_reg_address().

Here is the call graph for this function:



Here is the caller graph for this function:

7.26.1.2 fdt_find_child()

```
const void * fdt_find_child (
            const void * fdt,
            const void * parent,
            const char * name,
            uint32_t name_len )
```

Find a direct child of a node by its whole name.

The name is matched exactly, unit address included ("serial@10000000" is not "serial"), and is given with its length so that one component of a path can be passed without copying it. Only `parent's` own children are looked at, never their descendants.

Parameters

fdt	Blob; checked with `fdt_valid()`.
parent	Node handle; NULL is safe and returns NULL.
name	The child's name; need not be NUL-terminated.
name_len	Its length in bytes.

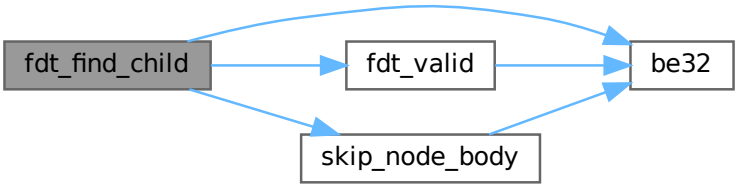
Returns

Handle to the child, or NULL if `parent` has none of that name.

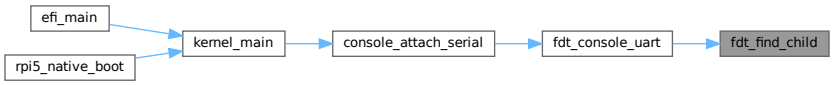
References be32(), FDT_BEGIN_NODE, FDT_NOP, FDT_PROP, fdt_valid(), name, name_len, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and skip_node_body().

Referenced by fdt_console_uart().

Here is the call graph for this function:



Here is the caller graph for this function:



7.26.1.3 fdt_find_node_by_compatible()

```
const void * fdt_find_node_by_compatible (
            const void * fdt,
            const char * compatible )
```

Find the first node whose "compatible" property matches `compatible`.

"compatible" is a NUL-separated list of strings (DT spec ?2.3.1) — matches if `compatible` equals any one entry in the list, not just the whole property verbatim. Scans the whole tree in document order; the first matching node wins if more than one exists.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
compatible	Compatible string to match, NUL-terminated.

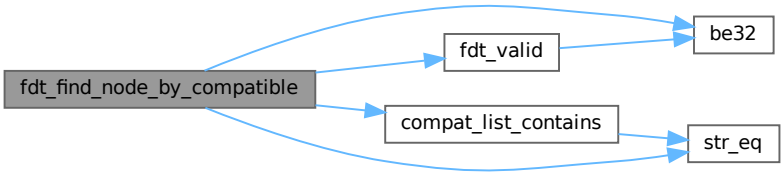
Returns

An opaque handle to the matched node, for use with `fdt_find_prop_in_node()` only (not a raw offset or a pointer to anything else meaningful) — or NULL if no node matches.

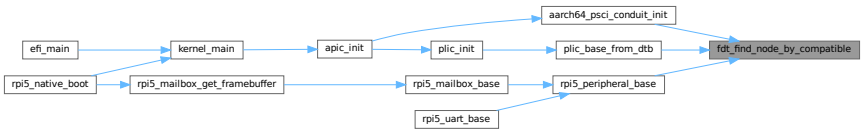
References base, be32(), compat_list_contains(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, FDT_PROP, fdt_valid(), fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and str_eq().

Referenced by aarch64_psci_conduit_init(), plic_base_from_dtb(), and rpi5_peripheral_base().

Here is the call graph for this function:



Here is the caller graph for this function:



7.26.1.4 fdt_find_node_by_device_type()

```
const void * fdt_find_node_by_device_type (
            const void * fdt,
            const char * type )
```

Find the first node whose "device_type" property equals `type`.

Some standard nodes (`/memory` per DT spec ?3.4) are identified by `device_type`, not `compatible` — unlike `compatible`, `device_type` is a single NUL-terminated string, not a list, so this matches the whole property value rather than scanning entries within it. Scans the whole tree in document order; the first matching node wins if more than one exists.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
type	device_type value to match, NUL-terminated.

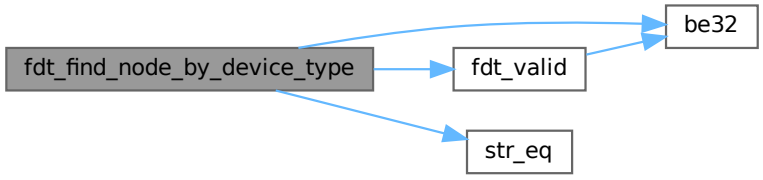
Returns

An opaque handle to the matched node, for use with `fdt_find_prop_in_node()` only — or NULL if no node matches.

References base, be32(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, FDT_PROP, fdt_valid(), fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and str_eq().

Referenced by collect_ram_regions(), and rpi5_mmu_map_ram().

Here is the call graph for this function:



Here is the caller graph for this function:

7.26.1.5 fdt_find_node_by_name()

```
const void * fdt_find_node_by_name (
            const void * fdt,
            const char * name )
```

Find the first node whose own name matches `name`.

Node names follow the DT spec ?2.2.1 `name[@unit-address]` convention — matches if `name` equals the node's name up to (not including) an `@` suffix, or the whole name if there is none. For a singleton node with no unit address (`/reserved-memory` being the concrete case this was added for), this is an exact match. Scans the whole tree in document order; the first matching node wins if more than one exists.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
name	Node name to match, NUL-terminated, no `@` suffix.

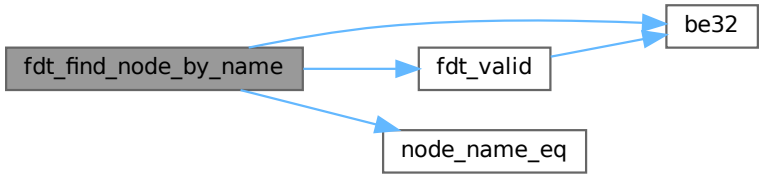
Returns

An opaque handle to the matched node, for use with `fdt_find_prop_in_node()` / `fdt_next_child_node()` only — or NULL if no node matches.

References base, be32(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, FDT_PROP, fdt_valid(), name, node_name_eq(), fdt_header_t::off_dt_struct, and fdt_header_t::size_dt_struct.

Referenced by collect_reserved_ranges().

Here is the call graph for this function:



Here is the caller graph for this function:

7.26.1.6 fdt_find_prop()

```
const void * fdt_find_prop (
             const void * fdt,
             const char * name,
             uint32_t * len_out )
```

Find the first property with `name` anywhere in the tree.

Scans the structure block in document order and returns the first match regardless of which node it belongs to. That is sufficient for properties which are uniform across a machine (timebase-frequency being the case this was written for) and is *not* sufficient for anything node-scoped.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
name	Property name, NUL-terminated.
len_out	Receives the property length in bytes; may be NULL.

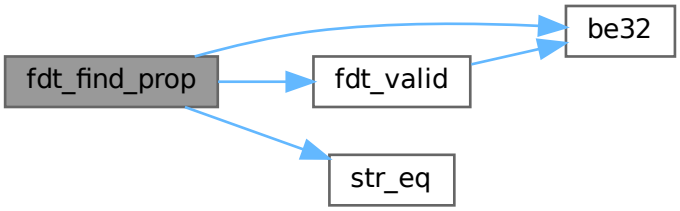
Returns

Pointer to the property value inside `fdt`, or NULL if not found. The value is big-endian as stored in the blob.

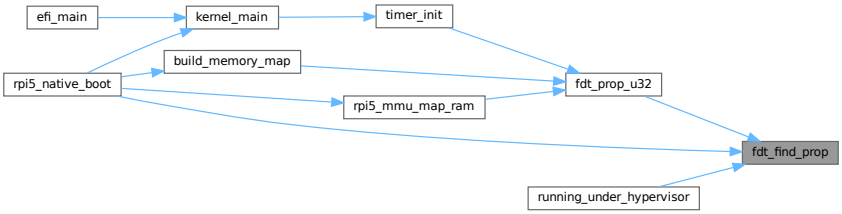
References base, be32(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, FDT_PROP, fdt_valid(), name, fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and str_eq().

Referenced by fdt_prop_u32(), rpi5_native_boot(), and running_under_hypervisor().

Here is the call graph for this function:



Here is the caller graph for this function:



7.26.1.7 fdt_find_prop_in_node()

```
const void * fdt_find_prop_in_node (
            const void * fdt,
            const void * node,
            const char * name,
            uint32_t * len_out )
```

Find a property by name, scoped to one node.

Like `fdt_find_prop()`, but scans only `node`'s own direct properties (as returned by `fdt_find_node_by_compatible()` — stops at the first child node or the end of `node`'s property list, never descends into children, never continues into a sibling. This is the difference that matters for a property name like "reg", which is not unique across the tree the way "timebase-frequency" (the whole reason `fdt_find_prop()` was originally sufficient) happens to be.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
node	Handle from `fdt_find_node_by_compatible()`; NULL is safe and returns NULL (propagates a failed node lookup without a separate caller-side check).
name	Property name, NUL-terminated.
len_out	Receives the property length in bytes; may be NULL.

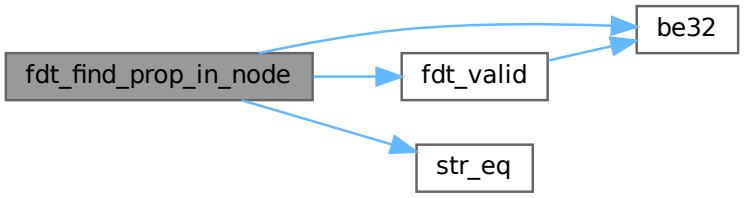
Returns

Pointer to the property value inside `fdt`, or NULL if not found (or if `node` is NULL). The value is big-endian as stored in the blob.

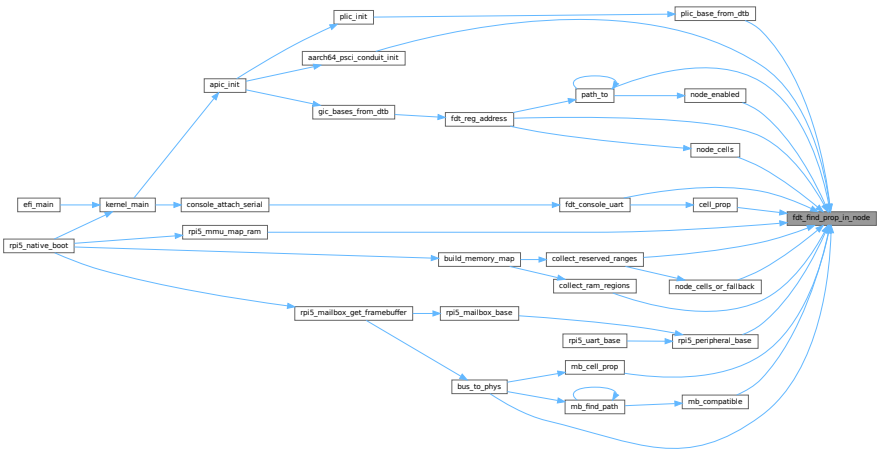
References be32(), FDT_NOP, FDT_PROP, fdt_valid(), name, fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and str_eq().

Referenced by aarch64_psci_conduit_init(), bus_to_phys(), cell_prop(), collect_ram_regions(), collect_reserved_ranges(), fdt_console_uart(), fdt_reg_address(), mb_cell_prop(), mb_compatible(), node_cells(), node_cells_or_fallback(), node_enabled(), path_to(), plic_base_from_dtb(), rpi5_mmu_map_ram(), and rpi5_peripheral_base().

Here is the call graph for this function:



Here is the caller graph for this function:



7.26.1.8 fdt_next_child_node()

```
const void * fdt_next_child_node (
            const void * fdt,
            const void * parent,
            const void * prev_child )
```

Iterate the direct children of one node.

Pass `prev_child` as NULL to get the first child; pass a previous result back in to get the next one. Stops (returns NULL) once there are no more children. Skips over each child's own descendants correctly (so a child with grandchildren doesn't confuse the scan), but does not itself descend into them — only direct children of `parent` are ever returned.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
parent	Handle from one of the `fdt_find_node_by_*()` functions.
prev_child	NULL for the first child, or a handle previously returned by this function for `parent` to continue from.

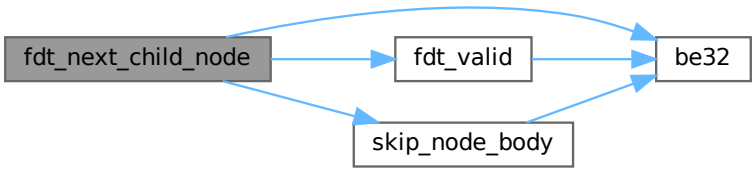
Returns

Handle to the next direct child, for use with `fdt_find_prop_in_node()` / `fdt_next_child_node()` only — or NULL once `parent`'s children are exhausted.

References be32(), FDT_BEGIN_NODE, FDT_NOP, FDT_PROP, fdt_valid(), fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and skip_node_body().

Referenced by collect_reserved_ranges(), mb_find_path(), and path_to().

Here is the call graph for this function:



Here is the caller graph for this function:

7.26.1.9 fdt_prop_u32()

```
int fdt_prop_u32 (
            const void * fdt,
            const char * name,
            uint32_t * out )
```

Read a single-cell (32-bit) property by name.

Convenience over `fdt_find_prop()` that also handles the big-endian conversion. Fails if the property is absent or not exactly 4 bytes.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
name	Property name, NUL-terminated.
out	Receives the host-order value on success; untouched on failure.

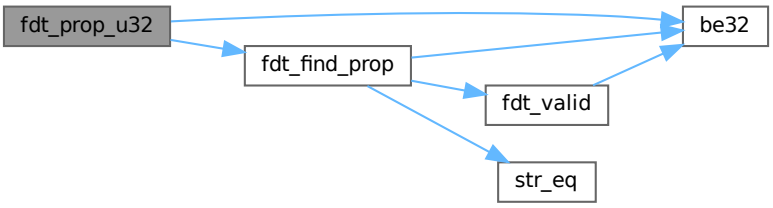
Returns

1 on success, 0 on failure.

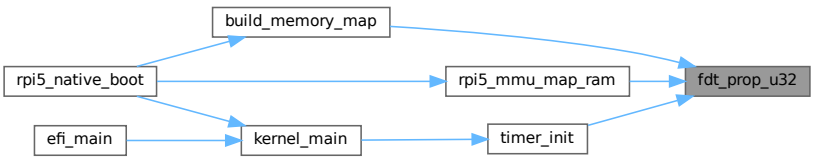
References be32(), fdt_find_prop(), and name.

Referenced by build_memory_map(), rpi5_mmu_map_ram(), and timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.26.1.10 fdt_reg_address()

```
int fdt_reg_address (
            const void * fdt,
            const char * compatible,
            uint32_t index,
            uint64_t * out )
```

The CPU's address for entry `index` of the `reg` of the first enabled node compatible with `compatible` (2026-10-14).

The entry is read in its parent's #address-cells/#size-cells and carried up through every bus's `ranges` to the root – an empty `ranges` keeps the address, a bus with no `ranges` has no way up. The Pi 5's GIC, for one, sits at 0x7fff9000 on /soc, which is 0x107fff9000 to the CPU.

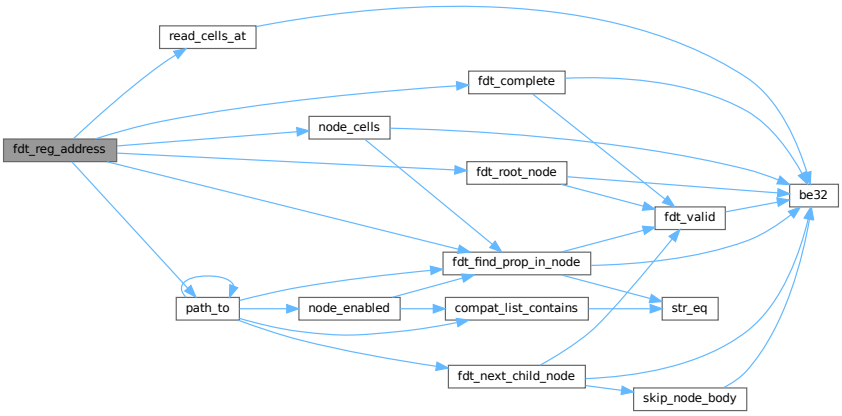
Returns

1 and the address in `out`, or 0 if there is no such node, entry or way up.

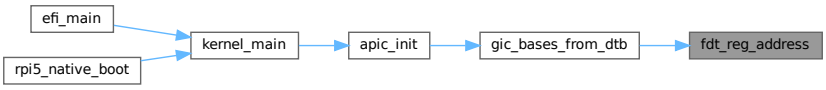
References entry, fdt_complete(), fdt_find_prop_in_node(), FDT_PATH_MAX, fdt_root_node(), node_cells(), path_to(), and read_cells_at().

Referenced by gic_bases_from_dtb().

Here is the call graph for this function:



Here is the caller graph for this function:



7.26.1.11 fdt_root_node()

```
const void * fdt_root_node (
            const void * fdt )
```

The root node.

Parameters

fdt	Blob; checked with `fdt_valid()`.

Returns

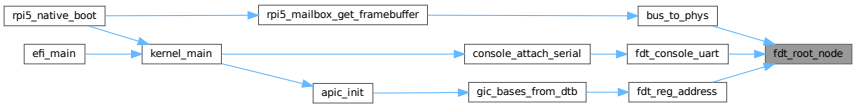
Handle to the root node, for `fdt_find_child()` and `fdt_find_prop_in_node()`, or NULL.

References be32(), FDT_BEGIN_NODE, FDT_NOP, fdt_valid(), fdt_header_t::off_dt_struct, and fdt_header_t::size_dt_struct.

Referenced by bus_to_phys(), fdt_console_uart(), and fdt_reg_address().

Here is the call graph for this function:

Here is the caller graph for this function:



7.26.1.12 fdt_valid()

```
int fdt_valid (
            const void * fdt )
```

fdt.h - Minimal flattened-devicetree reader

Just enough of the Devicetree Specification v0.4 ?5 to pull values out of the blob the UEFI firmware publishes under EFI_DTB_TABLE_GUID, or that a native (non-UEFI) boot entry passes directly. Read-only, no allocation, no tree construction — it walks the structure block each call, which is fine for the handful of boot-time lookups the kernel needs.

Deliberately not a general devicetree library. Added for punch-list item 0.3 (riscv64 timebase-frequency); extended (FABRIC-3.md ?IV.3/?V.3, 2026-09-04) with node-scoped lookup, for exactly the case this header originally flagged as a future need (item 0.6's aarch64 GIC) plus its real, concrete consumers as of this pass: the Raspberry Pi 5's UART/ mailbox register addresses (native boot, no ACPI) and the Milk-V Mars's real PLIC base address (currently hardcoded to QEMU-virt's own value, `arch/riscv64/plic.c`'s own doc comment already warned this isn't assumed stable across configurations).

Test whether `fdt` points at a valid flattened devicetree.

Checks the 0xd00dfeed magic and that the structure and strings blocks lie inside totalsize. Does not validate the token stream.

Parameters

fdt	Candidate blob; NULL is safe and returns 0.

Returns

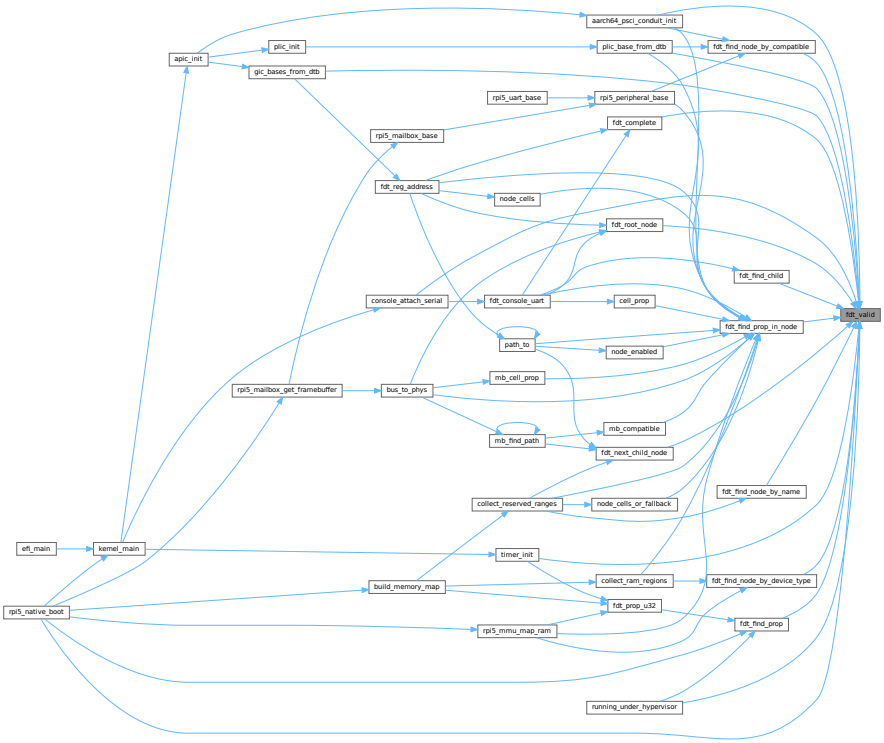
1 if the header is usable, 0 otherwise.

References be32(), FDT_MAGIC, fdt_header_t::magic, fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_strings, fdt_header_t::size_dt_struct, and fdt_header_t::totalsize.

Referenced by aarch64_psci_conduit_init(), console_attach_serial(), fdt_complete(), fdt_find_child(), fdt_find_node_by_compatible(), fdt_find_node_by_device_type(), fdt_find_node_by_name(), fdt_find_prop(), fdt_find_prop_in_node(), fdt_next_child_node(), fdt_root_node(), gic_bases_from_dtb(), plic_base_from_dtb(), rpi5_native_boot(), running_under_hypervisor(), and timer_init().

Here is the call graph for this function:

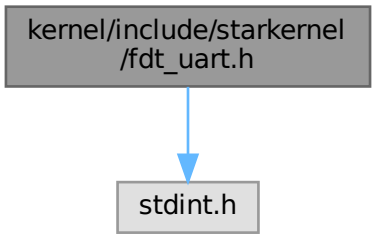
Here is the caller graph for this function:



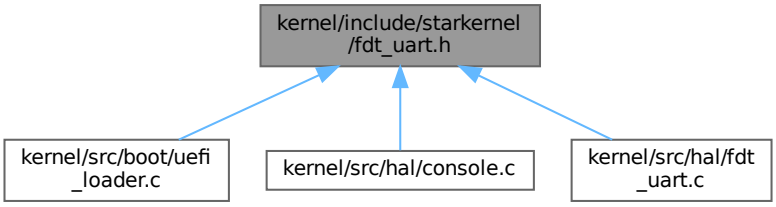
7.27 kernel/include/starkernel/fdt_uart.h File Reference

```
#include <stdint.h>
```

Include dependency graph for fdt_uart.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct fdt_uart_t

Enumerations

- enum { FDT_UART_NONE = 0 , FDT_UART_PL011 , FDT_UART_16550 }

  fdt_uart.h - the console's serial line, as a board's devicetree names it.

Functions

- int fdt_console_uart (const void *fdt, fdt_uart_t *out)

  Find the console's serial line in a devicetree.

7.27.1 Enumeration Type Documentation

7.27.1.1 anonymous enum

```
anonymous enum
```

fdt_uart.h - the console's serial line, as a board's devicetree names it.

A board has one serial line that is its console, and its devicetree says which: /chosen/stdout-path, either the path of a node or an alias for one (/aliases), with line settings after a colon that are not used here. The firmware that handed the devicetree over has already set that line up. This finds what kind of UART it is, where it is as the CPU addresses it, and how its registers are laid out.

Nothing is guessed. If the devicetree does not name a console, or names one this cannot place or has no driver for, there is no line.

Verified off the boards by tools/fdt_uart_test.c.

Enumerator

FDT_UART_NONE	no line
FDT_UART_PL011	ARM PL011: 32-bit registers, four bytes apart.
FDT_UART_16550	16550 and its kin (ns16550a, snps,dw-apb-uart), by memory

7.27.2 Function Documentation

7.27.2.1 fdt_console_uart()

```
int fdt_console_uart (
            const void * fdt,
            fdt_uart_t * out )
```

Find the console's serial line in a devicetree.

Parameters

fdt	Blob; NULL and what is not a devicetree are safe.
out	Receives the line; its kind is FDT_UART_NONE when 0 is returned.

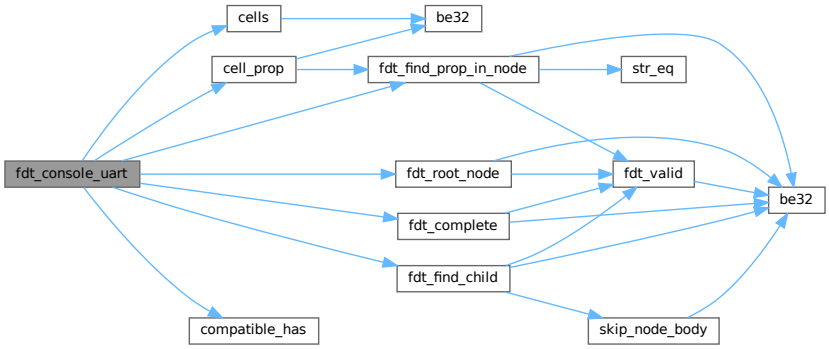
Returns

1 if the devicetree names a console UART that was found, placed and is of a kind listed above; 0 otherwise.

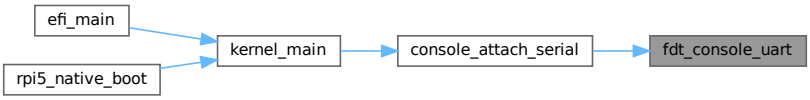
References fdt_uart_t::base, cell_prop(), cells(), compatible_has(), entry, fdt_complete(), fdt_find_child(), fdt_find_prop_in_node(), fdt_root_node(), FDT_UART_16550, FDT_UART_NONE, FDT_UART_PL011, fdt_uart_t::io_width, fdt_uart_t::kind, PATH_DEPTH, and fdt_uart_t::reg_shift.

Referenced by console_attach_serial().

Here is the call graph for this function:

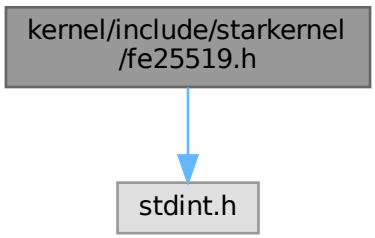


Here is the caller graph for this function:

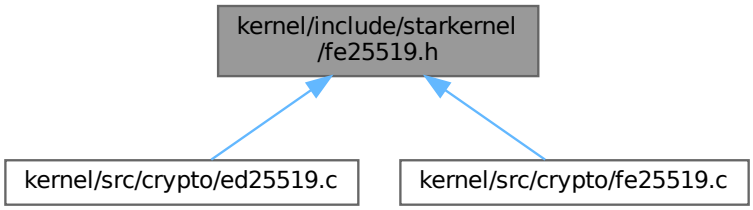


7.28 kernel/include/starkernel/fe25519.h File Reference

`#include <stdint.h>`
Include dependency graph for fe25519.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct fe25519

Functions

- void fe25519_0 (fe25519 *r)
- void fe25519_1 (fe25519 *r)
- void fe25519_copy (fe25519 *r, const fe25519 *a)
- void fe25519_add (fe25519 *r, const fe25519 *a, const fe25519 *b)
- void fe25519_sub (fe25519 *r, const fe25519 *a, const fe25519 *b)
- void fe25519_neg (fe25519 *r, const fe25519 *a)
- void fe25519_mul (fe25519 *r, const fe25519 *a, const fe25519 *b)
- void fe25519_sq (fe25519 *r, const fe25519 *a)
- void fe25519_invert (fe25519 *r, const fe25519 *a)
- void fe25519_mul_small (fe25519 *r, const fe25519 *a, uint32_t c)
- void fe25519_pack (uint8_t out[32], const fe25519 *a)
- void fe25519_unpack (fe25519 *r, const uint8_t in[32])
- int fe25519_eq (const fe25519 *a, const fe25519 *b)
- int fe25519_parity (const fe25519 *a)

7.28.1 Function Documentation

7.28.1.1 fe25519_0()

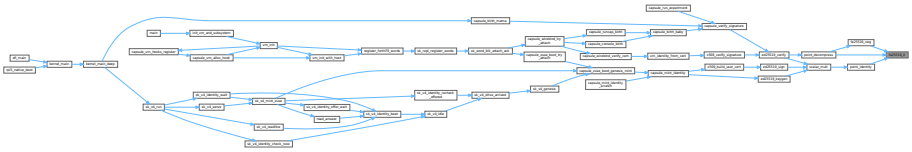
```
void fe25519_0 (
            fe25519 * r )
```

References memset(), and fe25519::v.

Referenced by fe25519_neg(), point_decompress(), and point_identity().

Here is the call graph for this function:

Here is the caller graph for this function:



7.28.1.2 fe25519_1()

```
void fe25519_1 (
            fe25519 * r )
```

References memset(), and fe25519::v.

Referenced by base_point(), ed25519_verify(), fe25519_pow(), point_decompress(), and point_identity().

Here is the call graph for this function:

Here is the caller graph for this function:

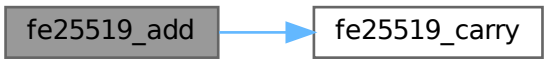
7.28.1.3 fe25519_add()

```
void fe25519_add (
              fe25519 * r,
              const fe25519 * a,
              const fe25519 * b )
```

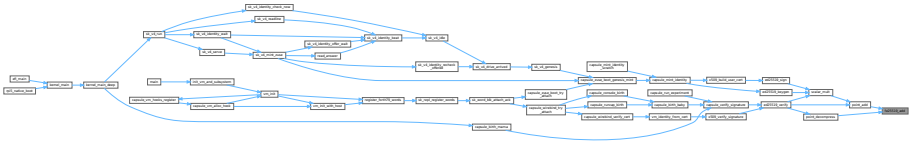
References fe25519_carry(), and fe25519::v.

Referenced by point_add(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:



7.28.1.4 fe25519_copy()

```
void fe25519_copy (
              fe25519 * r,
              const fe25519 * a )
```

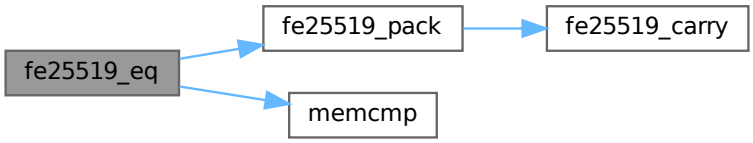
7.28.1.5 fe25519_eq()

```
int fe25519_eq (
              const fe25519 * a,
              const fe25519 * b )
```

References fe25519_pack(), and memcmp().

Referenced by point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

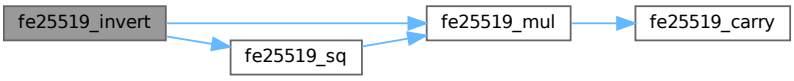
7.28.1.6 fe25519_invert()

```
void fe25519_invert (
            fe25519 * r,
            const fe25519 * a )
```

References fe25519_mul(), and fe25519_sq().

Referenced by point_compress(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

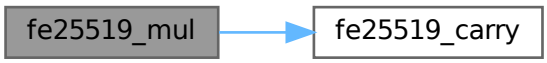
7.28.1.7 fe25519_mul()

```
void fe25519_mul (
             fe25519 * r,
             const fe25519 * a,
             const fe25519 * b )
```

References fe25519_carry(), MASK51, fe25519::v, and WBITS.

Referenced by fe25519_invert(), fe25519_pow(), fe25519_sq(), point_add(), point_compress(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

7.28.1.8 fe25519_mul_small()

```
void fe25519_mul_small (
             fe25519 * r,
             const fe25519 * a,
             uint32_t c )
```

References fe25519_carry(), MASK51, fe25519::v, and WBITS.

Here is the call graph for this function:

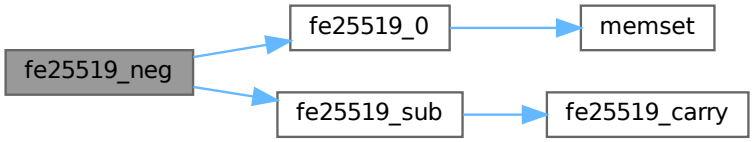
7.28.1.9 fe25519_neg()

```
void fe25519_neg (
            fe25519 * r,
            const fe25519 * a )
```

References fe25519_0(), fe25519_sub(), and zero.

Referenced by point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

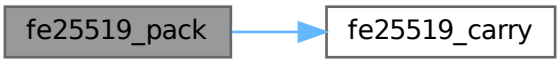
7.28.1.10 fe25519_pack()

```
void fe25519_pack (
            uint8_t out[32],
            const fe25519 * a )
```

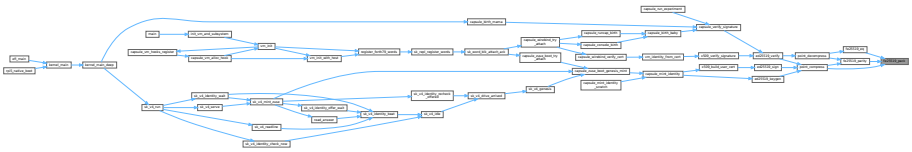
References fe25519_carry(), MASK51, fe25519::v, and WBITS.

Referenced by fe25519_eq(), fe25519_parity(), and point_compress().

Here is the call graph for this function:



Here is the caller graph for this function:



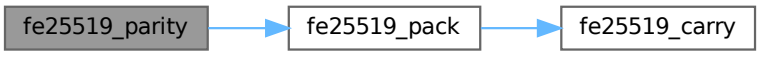
7.28.1.11 fe25519_parity()

```
int fe25519_parity (
            const fe25519 * a )
```

References fe25519_pack().

Referenced by point_compress(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

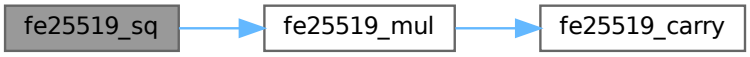
7.28.1.12 fe25519_sq()

```
void fe25519_sq (
            fe25519 * r,
            const fe25519 * a )
```

References fe25519_mul().

Referenced by fe25519_invert(), fe25519_pow(), point_add(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

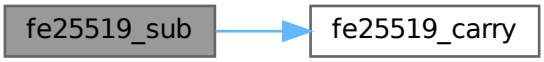
7.28.1.13 fe25519_sub()

```
void fe25519_sub (
            fe25519 * r,
            const fe25519 * a,
            const fe25519 * b )
```

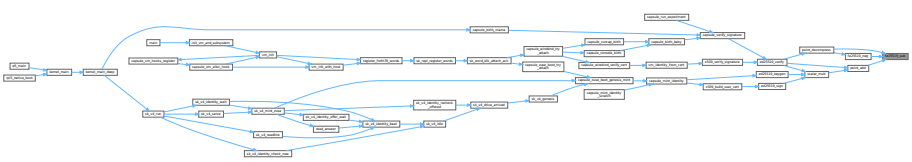
References fe25519_carry(), and fe25519::v.

Referenced by fe25519_neg(), point_add(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:



7.28.1.14 fe25519_unpack()

```
void fe25519_unpack (
            fe25519 * r,
            const uint8_t in[32] )
```

References MASK51, fe25519::v, and WBITS.

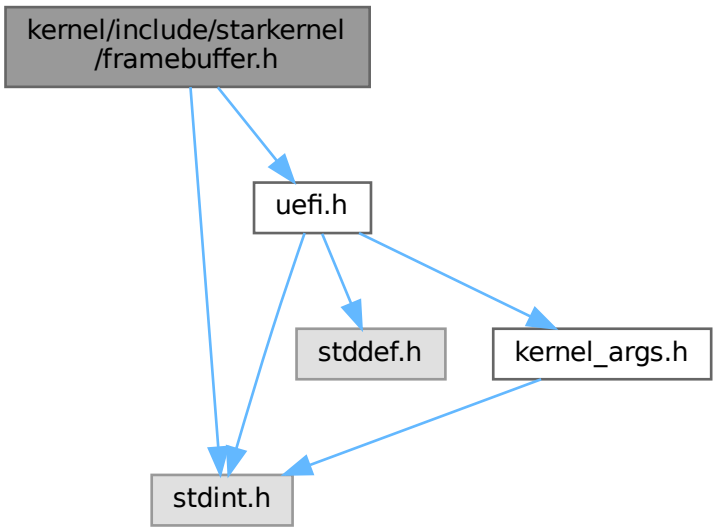
Referenced by base_point(), ed25519_verify(), point_add(), and point_decompress().

Here is the caller graph for this function:

7.29 kernel/include/starkernel/framebuffer.h File Reference

```
#include <stdint.h>
#include "uefi.h"
```

Include dependency graph for framebuffer.h:



This graph shows which files directly or indirectly include this file:

Macros

- #define FB_RGB(r, g, b) (((uint32_t)(r) << 16) | ((uint32_t)(g) << 8) | (uint32_t)(b))
- #define FB_R(c) (((uint32_t)(c) >> 16) & 0xFFu)
- #define FB_G(c) (((uint32_t)(c) >> 8) & 0xFFu)
- #define FB_B(c) ((uint32_t)(c) & 0xFFu)

Enumerations

- enum FbPixelFormat { FB_PIXEL_BGRX32 = 0 , FB_PIXEL_RGBX32 = 1 }

  framebuffer.h — UEFI GOP framebuffer driver interface

Functions

- const uint32_t FB_ANSI_PALETTE[16] __attribute__ ((visibility("hidden")))
- void fb_init (const FramebufferInfo *info, FbPixelFormat fmt)

  Initialize the framebuffer from UEFI bootloader GOP data.
- int fb_is_available (void)

  Returns 1 if the framebuffer has been successfully initialized.
- uint32_t fb_width (void)
- uint32_t fb_height (void)
- uint32_t fb_cell_w (void)

  Effective character cell width/height in pixels (8/16 × scale factor).
- uint32_t fb_cell_h (void)
- void fb_put_pixel (uint32_t x, uint32_t y, uint32_t rgb)

  Write a single pixel.
- void fb_fill_rect (uint32_t x, uint32_t y, uint32_t w, uint32_t h, uint32_t rgb)

  Fill a rectangle with a solid color.
- void fb_draw_glyph (uint32_t px, uint32_t py, uint8_t ch, uint32_t fg, uint32_t bg)

  Draw one 8×16 character glyph at pixel position (px, py).
- void fb_draw_orientation_test (void)

  One-time boot diagnostic (FABRIC-0.md item 4.3.1): fills each raster corner with a distinct solid color so a screendump reveals orientation.
- void fb_scroll_rows (uint32_t pixel_rows, uint32_t bg)

  Scroll the whole framebuffer up by `pixel_rows` pixel rows.
- void fb_scroll_rect (uint32_t x, uint32_t y, uint32_t w, uint32_t h, uint32_t pixel_rows, uint32_t bg)

  Scroll a sub-rectangle of the framebuffer up by `pixel_rows` pixel rows (FABRIC-0.md item 4.4t: box-confined REPL scrolling).

7.29.1 Macro Definition Documentation

7.29.1.1 FB_B

```
#define FB_B(
             c ) ( (uint32_t)(c) & 0xFFu)
```

7.29.1.2 FB_G

```
#define FB_G(
             c ) (((uint32_t)(c) >> 8) & 0xFFu)
```

7.29.1.3 FB_R

```
#define FB_R(
              c ) (((uint32_t)(c) >> 16) & 0xFFu)
```

7.29.1.4 FB_RGB

```
#define FB_RGB(
              r,
              g,
              b )  (((uint32_t)(r) << 16) | ((uint32_t)(g) << 8) | (uint32_t)(b))
```

7.29.2 Enumeration Type Documentation

7.29.2.1 FbPixelFormat

```
enum FbPixelFormat
```

framebuffer.h — UEFI GOP framebuffer driver interface

Pixel format: BGRX32 (PixelBlueGreenRedReserved8BitPerColor), the dominant format for QEMU virt GOP. RGBX32 is also supported.

Color values throughout this API are packed as 0x00RRGGBB.

Enumerator

FB_PIXEL_BGRX32	
FB_PIXEL_RGBX32	

7.29.3 Function Documentation

7.29.3.1 __attribute__()

```
const uint32_t FB_ANSI_PALETTE[16] __attribute__ (
             (visibility("hidden"))  )  [extern]
```

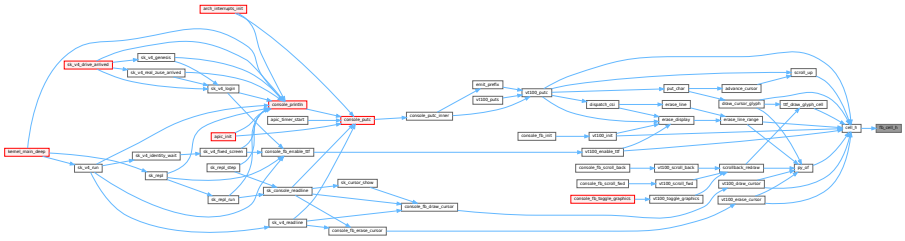
7.29.3.2 fb_cell_h()

```
uint32_t fb_cell_h (
             void  )
```

References g_fb, and FbState::scale.

Referenced by cell_h().

Here is the caller graph for this function:



7.29.3.3 fb_cell_w()

```
uint32_t fb_cell_w (
            void  )
```

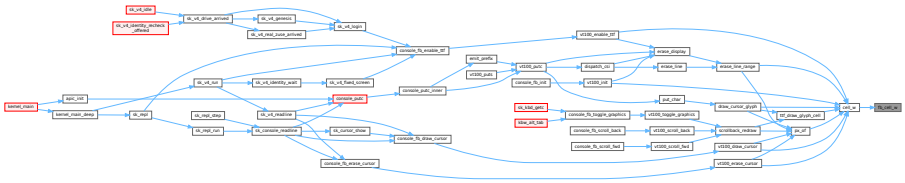
Effective character cell width/height in pixels (8/16 × scale factor).

Effective character cell width/height in pixels (8/16 × scale factor).

References g_fb, and FbState::scale.

Referenced by cell_w().

Here is the caller graph for this function:



7.29.3.4 fb_draw_glyph()

```
void fb_draw_glyph (
            uint32_t px,
            uint32_t py,
            uint8_t ch,
            uint32_t fg,
            uint32_t bg )
```

Draw one 8×16 character glyph at pixel position (px, py).

fg / bg are packed 0x00RRGGBB colors.

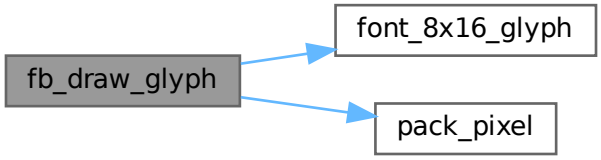
Draw one 8×16 character glyph at pixel position (px, py).

Scales by g_fb.scale so the same font works at any resolution.

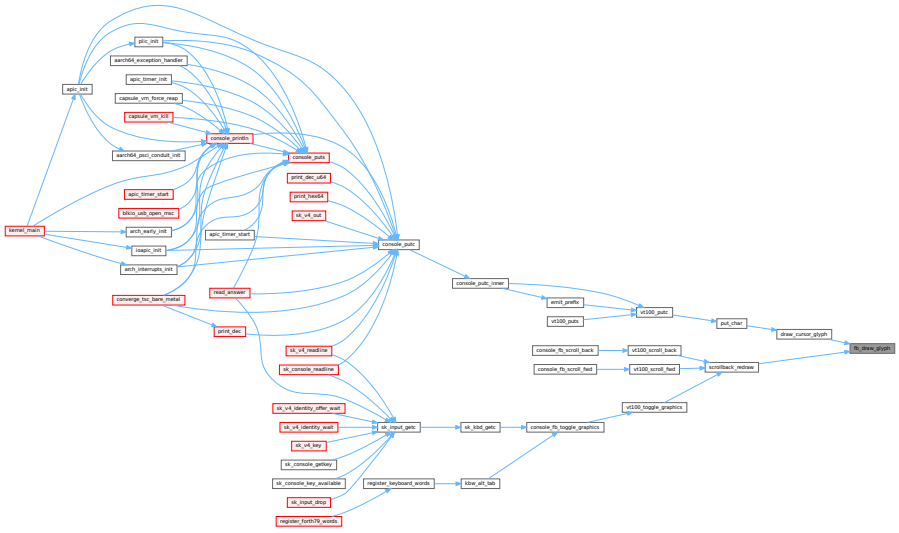
References FbState::base, font_8x16_glyph(), g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::scale, FbState::stride, and FbState::width.

Referenced by draw_cursor_glyph(), and scrollback_redraw().

Here is the call graph for this function:



Here is the caller graph for this function:



7.29.3.5 fb_draw_orientation_test()

```
void fb_draw_orientation_test (
            void  )
```

One-time boot diagnostic (FABRIC-0.md item 4.3.1): fills each raster corner with a distinct solid color so a screen-dump reveals orientation.

Not part of the Console drawing fabric – diagnostic-only.

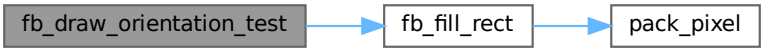
One-time boot diagnostic (FABRIC-0.md item 4.3.1): fills each raster corner with a distinct solid color so a screen-dump reveals orientation.

Fills each raster corner with a distinct solid color so a screendump immediately reveals whether the image is flipped or rotated. Not part of the Console drawing fabric itself – diagnostic-only, analogous to item 4.2's self-test scaffolding.

Corner colors (raster/top-left-origin coordinates, pre-Cartesian-flip): top-left RED top-right GREEN bottom-left BLUE bottom-right YELLOW

References fb_fill_rect(), FB_RGB, g_fb, FbState::height, FbState::ready, and FbState::width.

Here is the call graph for this function:



7.29.3.6 fb_fill_rect()

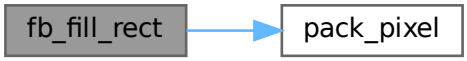
```
void fb_fill_rect (
            uint32_t x,
            uint32_t y,
            uint32_t w,
            uint32_t h,
            uint32_t rgb )
```

Fill a rectangle with a solid color.

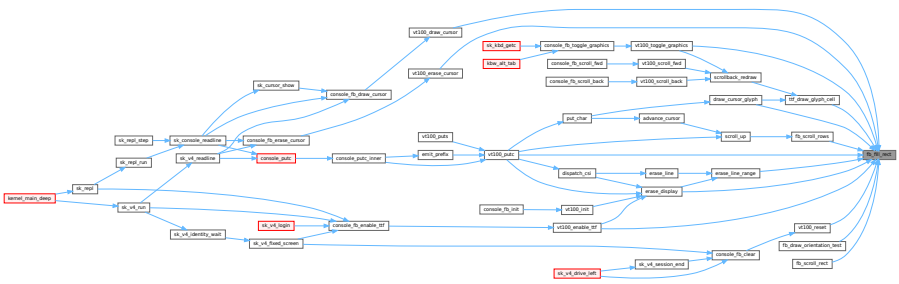
References FbState::base, g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::stride, and FbState::width.

Referenced by draw_cursor_glyph(), erase_display(), erase_line_range(), fb_draw_orientation_test(), fb_scroll_rect(), fb_scroll_rows(), ttf_draw_glyph_cell(), vt100_draw_cursor(), vt100_enable_ttf(), vt100_erase_cursor(), vt100_putc(), vt100_reset(), and vt100_toggle_graphics().

Here is the call graph for this function:



Here is the caller graph for this function:



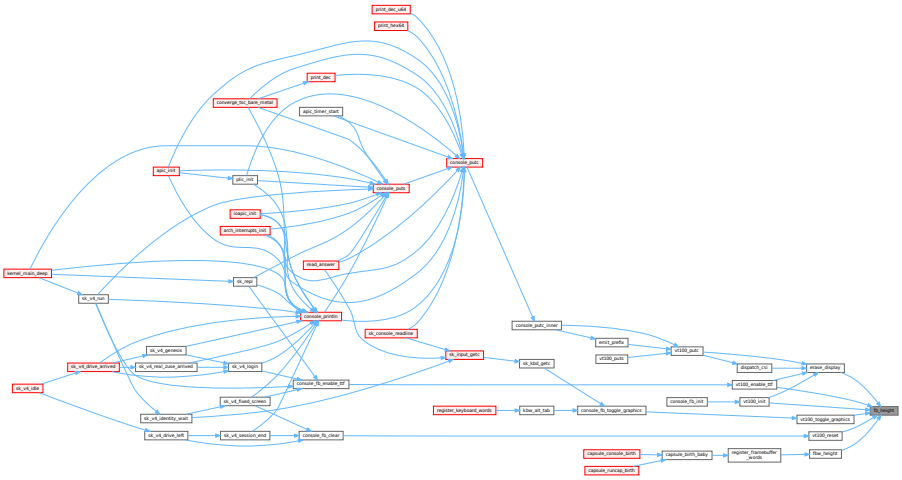
7.29.3.7 fb_height()

```
uint32_t fb_height (
            void  )
```

References g_fb, and FbState::height.

Referenced by erase_display(), fbw_height(), vt100_enable_ttf(), vt100_init(), vt100_reset(), and vt100_toggle_graphics().

Here is the caller graph for this function:



7.29.3.8 fb_init()

```
void fb_init (
            const FramebufferInfo * info,
            FbPixelFormat fmt )
```

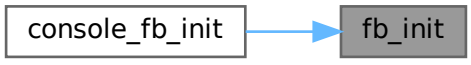
Initialize the framebuffer from UEFI bootloader GOP data.

Must be called before any other fb_∗ function. fmt: pixel layout reported by GOP (default FB_PIXEL_BGRX32).

References FramebufferInfo::base, FbState::base, FbState::fmt, g_fb, FramebufferInfo::height, FbState::height, FramebufferInfo::pixels_per_scanline, FbState::ready, FbState::scale, FbState::stride, FramebufferInfo::width, and FbState::width.

Referenced by console_fb_init().

Here is the caller graph for this function:



7.29.3.9 fb_is_available()

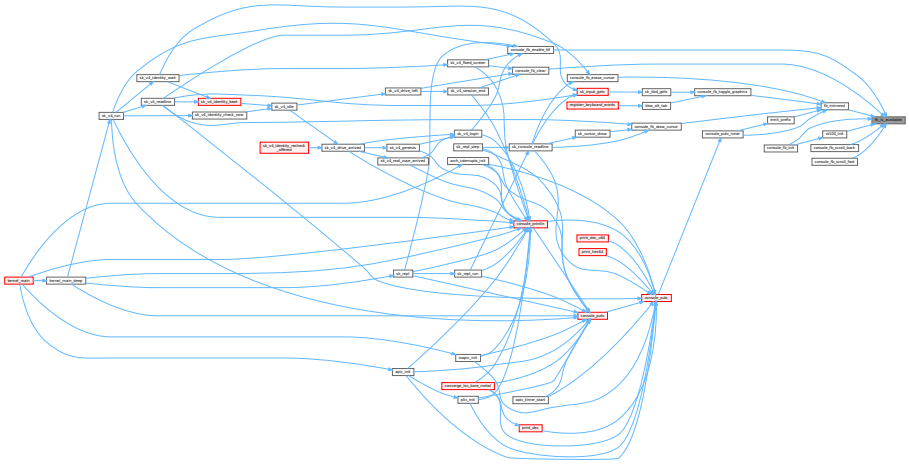
```
int fb_is_available (
            void  )
```

Returns 1 if the framebuffer has been successfully initialized.

References g_fb, and FbState::ready.

Referenced by console_fb_clear(), console_fb_enable_ttf(), console_fb_init(), console_fb_scroll_back(), console_fb_scroll_fwd(), fb_mirrored(), and vt100_init().

Here is the caller graph for this function:



7.29.3.10 fb_put_pixel()

```
void fb_put_pixel (
            uint32_t x,
            uint32_t y,
            uint32_t rgb )
```

Write a single pixel.

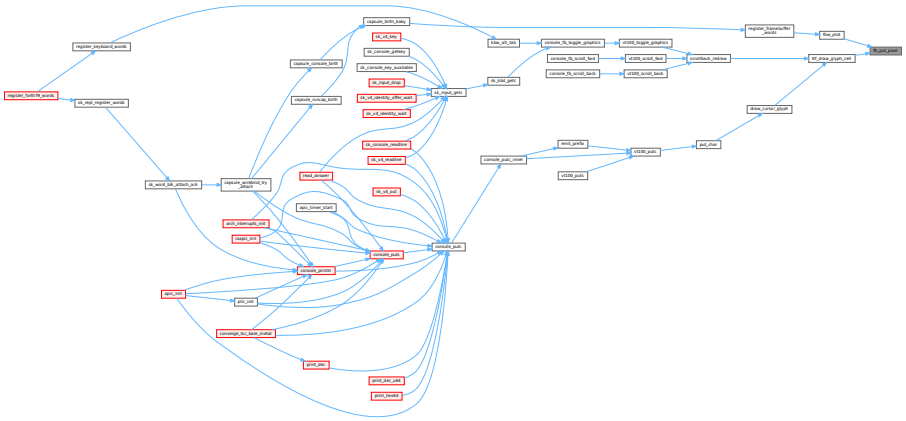
Out-of-bounds writes are silently ignored.

References FbState::base, g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::stride, and FbState::width.

Referenced by fbw_plot(), and ttf_draw_glyph_cell().

Here is the call graph for this function:

Here is the caller graph for this function:



7.29.3.11 fb_scroll_rect()

```
void fb_scroll_rect (
            uint32_t x,
            uint32_t y,
            uint32_t w,
            uint32_t h,
            uint32_t pixel_rows,
            uint32_t bg )
```

Scroll a sub-rectangle of the framebuffer up by `pixel_rows` pixel rows (FABRIC-0.md item 4.4t: box-confined REPL scrolling).

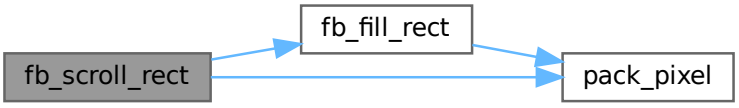
Unlike fb_scroll_rows() (whole-framebuffer), this is bounded to [x, x+w) x [y, y+h). Both take an explicit pixel-row count so callers with a non-8x16 cell height (e.g. TTF mode) pass their own cell height directly. Pixels outside the rect are untouched. The vacated rows at the bottom of the rect are filled with bg.

Scroll a sub-rectangle of the framebuffer up by `pixel_rows` pixel rows (FABRIC-0.md item 4.4t: box-confined REPL scrolling).

Same non-volatile bulk-copy rationale as fb_scroll_rows() above, but bounded to a caller-supplied rectangle instead of the whole framebuffer – needed once REPL text is confined to the 4.4o CANVAS box, since a whole-framebuffer scroll would drag pixels from outside the box (e.g. a future 4.4r border) into the text area. Takes pixel_rows directly rather than char_rows ∗ a hardcoded cell height, since TTF mode's cell height (24px) differs from bitmap mode's (16px ∗ scale).

References FbState::base, fb_fill_rect(), g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::stride, and FbState::width.

Here is the call graph for this function:



7.29.3.12 fb_scroll_rows()

```
void fb_scroll_rows (
            uint32_t pixel_rows,
            uint32_t bg )
```

Scroll the whole framebuffer up by `pixel_rows` pixel rows.

The vacated rows at the bottom are filled with bg. Takes an explicit pixel-row count (not a hardcoded 8x16-cell assumption) so callers with a non-8x16 cell height (e.g. TTF mode, 24px) pass their own cell height directly – same convention fb_scroll_rect() below already uses, for the same reason (a caller-computed char_rows $*$ fixed-16px assumption drifts out of sync with the text model's own row height in TTF mode, and that drift compounds with every scroll).

Scroll the whole framebuffer up by `pixel_rows` pixel rows.

The vacated rows at the bottom are filled with bg.

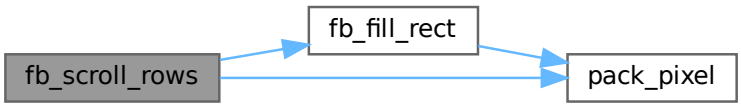
Takes a pixel-row count directly rather than a character-row count scaled by a hardcoded 16px cell height: the caller (vt100.c's scroll_up()) knows the actual active glyph cell height (16 $\times$ scale for bitmap mode, 24 for TTF mode), and a mismatch between the height this function scrolls by and the height the text model actually draws rows at compounds by the gap on every single scroll – a few scrolls barely show it, but enough scrolls (or scrolling quickly) accumulates visible pixel overlap between rows.

Copies through non-volatile pointers (FABRIC-0.md item 4.4g performance fix, 2026-08-11): the GOP framebuffer is mapped write-back, not cache-disabled MMIO (vmm.c:350-363 – "QEMU's VGA emulation is coherent and UC-mapping causes #GP"), so it behaves as ordinary RAM and does not need per-word volatile access. `g_fb.base` stays `volatile` for single-pixel writes elsewhere in this file (draw calls that must not be reordered relative to other framebuffer state), but that qualifier forced this copy into one un-batchable 4-byte access per element with no compiler vectorization – catastrophic once boot output exceeds one screen ($\sim$10^10 volatile accesses for an 18,000-line boot transcript under TCG). Casting away volatile here for the bulk copy/fill lets the compiler batch these loops normally.

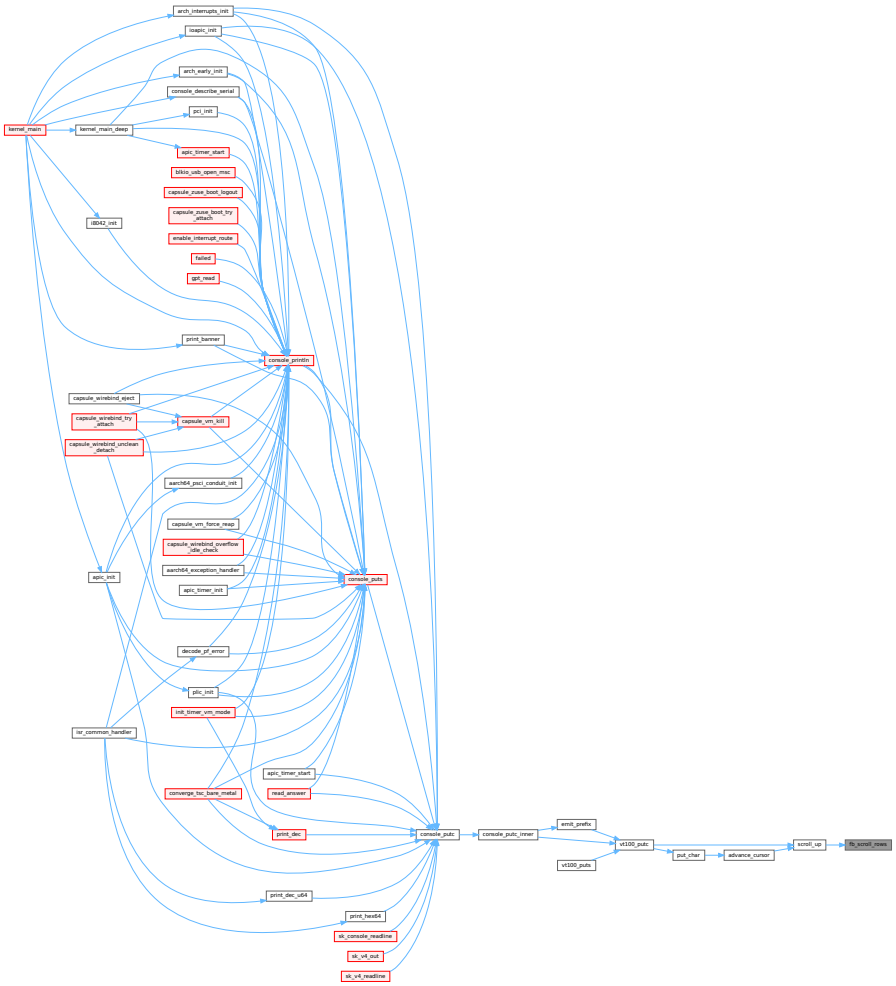
References FbState::base, fb_fill_rect(), g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::stride, and FbState::width.

Referenced by scroll_up().

Here is the call graph for this function:



Here is the caller graph for this function:



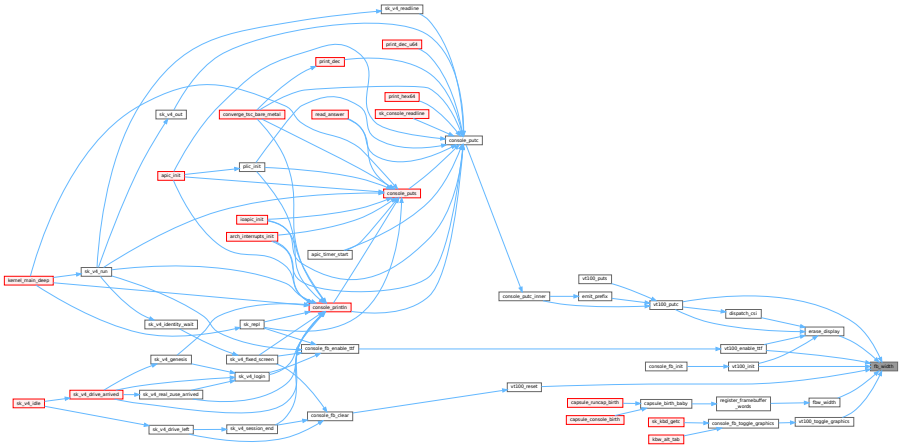
7.29.3.13 fb_width()

```
uint32_t fb_width (
            void  )
```

References g_fb, and FbState::width.

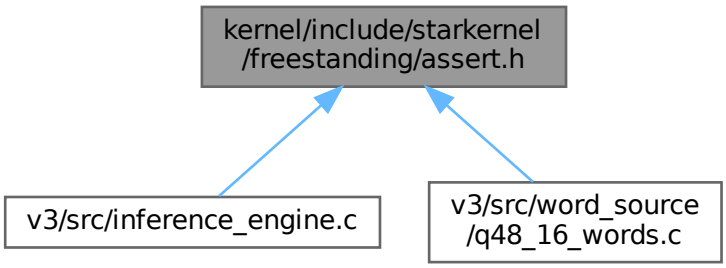
Referenced by erase_display(), fbw_width(), vt100_enable_ttf(), vt100_init(), vt100_putc(), vt100_reset(), and vt100_toggle_graphics().

Here is the caller graph for this function:



7.30 kernel/include/starkernel/freestanding/assert.h File Reference

This graph shows which files directly or indirectly include this file:



Macros

- #define assert(expr) ((void)(expr))
- #define static_assert _Static_assert

7.30.1 Macro Definition Documentation

7.30.1.1 assert

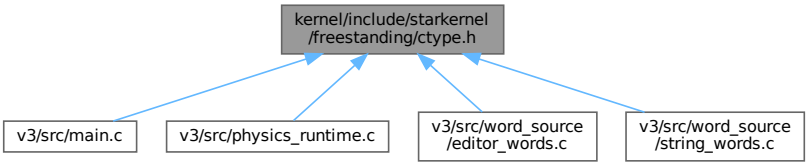
```
#define assert(
              expr ) ((void)(expr))
```

7.30.1.2 static_assert

```
#define static_assert _Static_assert
```

7.31 kernel/include/starkernel/freestanding/ctype.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- static int isdigit (int c)
- static int isspace (int c)
- static int isalpha (int c)
- static int isalnum (int c)
- static int isupper (int c)
- static int islower (int c)
- static int isprint (int c)
- static int isxdigit (int c)
- static int toupper (int c)
- static int tolower (int c)
- static int ispunct (int c)
- static int iscntrl (int c)

7.31.1 Function Documentation

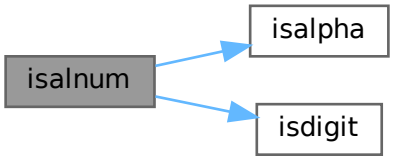
7.31.1.1 isalnum()

```
static int isalnum (
            int c )  [inline], [static]
```

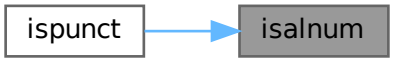
References isalpha(), and isdigit().

Referenced by ispunct().

Here is the call graph for this function:



Here is the caller graph for this function:

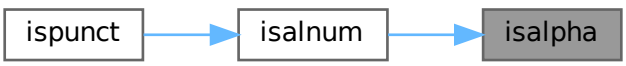


7.31.1.2 isalpha()

```
static int isalpha (
            int c )  [inline], [static]
```

Referenced by isalnum().

Here is the caller graph for this function:



7.31.1.3 iscntrl()

```
static int iscntrl (
            int c )  [inline], [static]
```

7.31.1.4 isdigit()

```
static int isdigit (
            int c )  [inline], [static]
```

Referenced by editor_word_edit(), isalnum(), and isxdigit().

Here is the caller graph for this function:

7.31.1.5 islower()

```
static int islower (
            int c )  [inline], [static]
```

Referenced by toupper().

Here is the caller graph for this function:

7.31.1.6 isprint()

```
static int isprint (
            int c )  [inline], [static]
```

Referenced by ispunct().

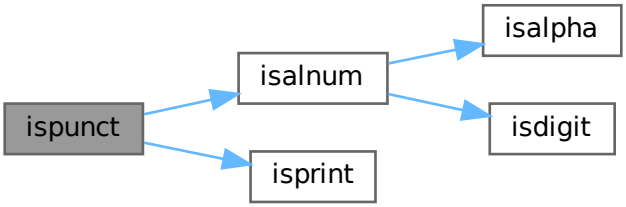
Here is the caller graph for this function:

7.31.1.7 ispunct()

```
static int ispunct (
            int c )  [inline], [static]
```

References isalnum(), and isprint().

Here is the call graph for this function:



7.31.1.8 isspace()

```
static int isspace (
            int c )  [inline], [static]
```

Referenced by editor_word_edit().

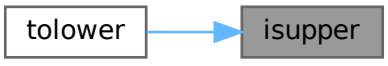
Here is the caller graph for this function:

7.31.1.9 isupper()

```
static int isupper (
            int c )  [inline], [static]
```

Referenced by tolower().

Here is the caller graph for this function:



7.31.1.10 isxdigit()

```
static int isxdigit (
            int c )  [inline], [static]
```

References isdigit().

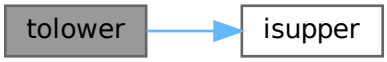
Here is the call graph for this function:

7.31.1.11 tolower()

```
static int tolower (
            int c )  [inline], [static]
```

References isupper().

Here is the call graph for this function:



7.31.1.12 toupper()

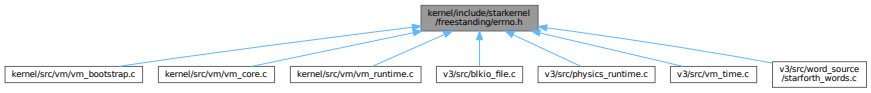
```
static int toupper (
            int c )  [inline], [static]
```

References islower().

Here is the call graph for this function:

7.32 kernel/include/starkernel/freestanding/errno.h File Reference

This graph shows which files directly or indirectly include this file:



Macros

- #define errno _freestanding_errno
- #define EPERM 1
- #define ENOENT 2
- #define EINVAL 22
- #define ENOMEM 12

Variables

- static int _freestanding_errno = 0

7.32.1 Macro Definition Documentation

7.32.1.1 EINVAL

```
#define EINVAL 22
```

7.32.1.2 ENOENT

```
#define ENOENT 2
```

7.32.1.3 ENOMEM

```
#define ENOMEM 12
```

7.32.1.4 EPERM

```
#define EPERM 1
```

7.32.1.5 errno

```
#define errno _freestanding_errno
```

7.32.2 Variable Documentation

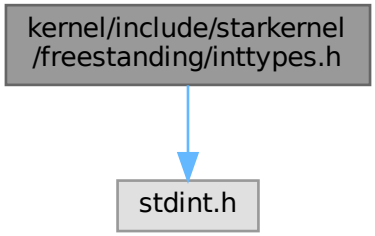
7.32.2.1 _freestanding_errno

```
int _freestanding_errno = 0  [static]
```

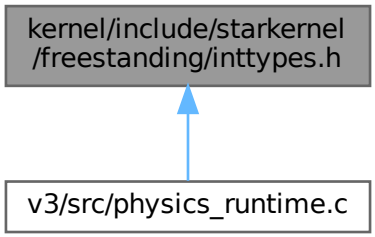
7.33 kernel/include/starkernel/freestanding/inttypes.h File Reference

```
#include <stdint.h>
```

Include dependency graph for inttypes.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define PRId8 "d"
- #define PRId16 "d"
- #define PRId32 "d"
- #define PRId64 "lld"
- #define PRIu8 "u"

- #define PRIu16 "u"
- #define PRIu32 "u"
- #define PRIu64 "llu"
- #define PRIx8 "x"
- #define PRIx16 "x"
- #define PRIx32 "x"
- #define PRIx64 "llx"
- #define PRIX8 "X"
- #define PRIX16 "X"
- #define PRIX32 "X"
- #define PRIX64 "llX"
- #define PRIi8 "d"
- #define PRIi16 "d"
- #define PRIi32 "d"
- #define PRIi64 "lld"

7.33.1 Macro Definition Documentation

7.33.1.1 PRId16

```
#define PRId16 "d"
```

7.33.1.2 PRId32

```
#define PRId32 "d"
```

7.33.1.3 PRId64

```
#define PRId64 "lld"
```

7.33.1.4 PRId8

```
#define PRId8 "d"
```

7.33.1.5 PRIi16

```
#define PRIi16 "d"
```

7.33.1.6 PRIi32

```
#define PRIi32 "d"
```

7.33.1.7 PRIi64

```
#define PRIi64 "lld"
```

7.33.1.8 PRIi8

```
#define PRIi8 "d"
```

7.33.1.9 PRIu16

```
#define PRIu16 "u"
```

7.33.1.10 PRIu32

```
#define PRIu32 "u"
```

7.33.1.11 PRIu64

```
#define PRIu64 "llu"
```

7.33.1.12 PRIu8

```
#define PRIu8 "u"
```

7.33.1.13 PRIx16

```
#define PRIx16 "x"
```

7.33.1.14 PRIX16

```
#define PRIX16 "X"
```

7.33.1.15 PRIx32

```
#define PRIx32 "x"
```

7.33.1.16 PRIX32

```
#define PRIX32 "X"
```

7.33.1.17 PRIx64

```
#define PRIx64 "llx"
```

7.33.1.18 PRIX64

```
#define PRIX64 "llX"
```

7.33.1.19 PRIx8

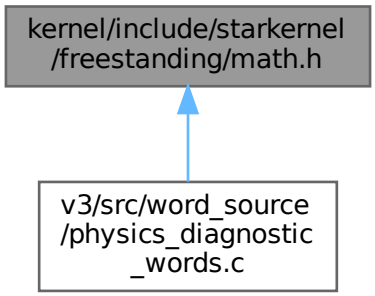
```
#define PRIx8 "x"
```

7.33.1.20 PRIX8

```
#define PRIX8 "X"
```

7.34 kernel/include/starkernel/freestanding/math.h File Reference

This graph shows which files directly or indirectly include this file:



Macros

- #define HUGE_VAL __builtin_huge_val()
- #define NAN __builtin_nanf("")
- #define INFINITY __builtin_inff()

Functions

- double sqrt (double x)
- double pow (double base, double exp)
- double fabs (double x)
- double ceil (double x)
- double floor (double x)
- double log (double x)
- double exp (double x)
- double sin (double x)
- double cos (double x)
- double atan2 (double y, double x)

7.34.1 Macro Definition Documentation

7.34.1.1 HUGE_VAL

```
#define HUGE_VAL __builtin_huge_val()
```

7.34.1.2 INFINITY

```
#define INFINITY __builtin_inff()
```

7.34.1.3 NAN

```
#define NAN __builtin_nanf("")
```

7.34.2 Function Documentation

7.34.2.1 atan2()

```
double atan2 (
            double y,
            double x )
```

7.34.2.2 ceil()

```
double ceil (
            double x )
```

7.34.2.3 cos()

```
double cos (
            double x )
```

7.34.2.4 exp()

```
double exp (
            double x )
```

Referenced by fe25519_pow().

Here is the caller graph for this function:

7.34.2.5 fabs()

```
double fabs (
            double x )
```

7.34.2.6 floor()

```
double floor (
            double x )
```

7.34.2.7 log()

```
double log (
            double x )
```

7.34.2.8 pow()

```
double pow (
            double base,
            double exp )
```

7.34.2.9 sin()

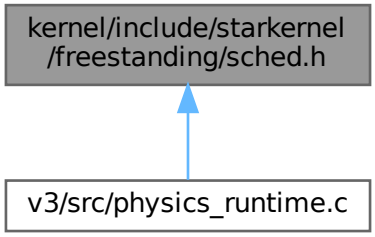
```
double sin (
            double x )
```

7.34.2.10 sqrt()

```
double sqrt (
            double x )
```

7.35 kernel/include/starkernel/freestanding/sched.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- static int sched_yield (void)

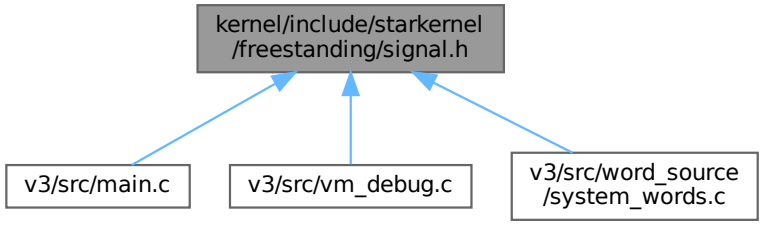
7.35.1 Function Documentation

7.35.1.1 sched_yield()

```
static int sched_yield (
            void  )  [inline], [static]
```

7.36 kernel/include/starkernel/freestanding/signal.h File Reference

This graph shows which files directly or indirectly include this file:



Data Structures

- struct sigaction

Macros

- #define SIGINT 2
- #define SIGABRT 6
- #define SIGSEGV 11
- #define SIGTERM 15
- #define SIG_DFL ((sighandler_t)0)
- #define SIG_IGN ((sighandler_t)1)
- #define SA_RESETHAND 0

Typedefs

- typedef void(∗ sighandler_t) (int)

Functions

- static sighandler_t signal (int sig, sighandler_t handler)
- static int sigaction (int sig, const struct sigaction *act, struct sigaction *old)

7.36.1 Macro Definition Documentation

7.36.1.1 SA_RESETHAND

```
#define SA_RESETHAND 0
```

7.36.1.2 SIG_DFL

```
#define SIG_DFL ((sighandler_t)0)
```

7.36.1.3 SIG_IGN

```
#define SIG_IGN ((sighandler_t)1)
```

7.36.1.4 SIGABRT

```
#define SIGABRT 6
```

7.36.1.5 SIGINT

```
#define SIGINT 2
```

7.36.1.6 SIGSEGV

```
#define SIGSEGV 11
```

7.36.1.7 SIGTERM

```
#define SIGTERM 15
```

7.36.2 Typedef Documentation

7.36.2.1 sighandler_t

```
typedef void(* sighandler_t) (int)
```

7.36.3 Function Documentation

7.36.3.1 sigaction()

```
static int sigaction (
            int sig,
            const struct sigaction * act,
            struct sigaction * old )  [inline], [static]
```

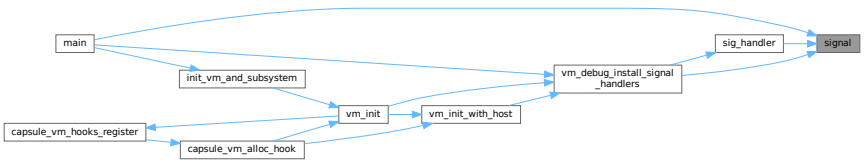
7.36.3.2 signal()

```
static sighandler_t signal (
            int sig,
            sighandler_t handler )  [inline], [static]
```

References SIG_DFL.

Referenced by main(), sig_handler(), and vm_debug_install_signal_handlers().

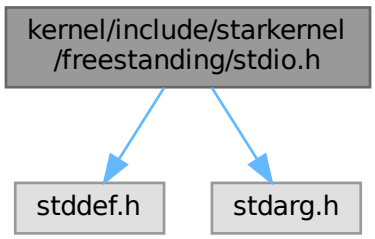
Here is the caller graph for this function:



7.37 kernel/include/starkernel/freestanding/stdio.h File Reference

```
#include <stddef.h>
#include <stdarg.h>
```

Include dependency graph for stdio.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct FILE

Macros

- #define stderr ((FILE *)0)
- #define stdout ((FILE *)1)
- #define stdin ((FILE *)2)
- #define SEEK_SET 0
- #define SEEK_CUR 1
- #define SEEK_END 2

Functions

- int printf (const char *fmt,...)
- int fprintf (FILE *stream, const char *fmt,...)
- int vfprintf (FILE *stream, const char *fmt, va_list args)
- int snprintf (char *buf, size_t n, const char *fmt,...)
- int vsnprintf (char *buf, size_t n, const char *fmt, va_list args)
- int puts (const char *s)
- int fputs (const char *s, FILE *stream)
- int fflush (FILE *stream)
- int putchar (int c)
- int fseek (FILE *stream, long offset, int whence)
- long ftell (FILE *stream)
- int sscanf (const char *str, const char *fmt,...)
- int getchar (void)
- int fgetc (FILE *stream)
- int fputc (int c, FILE *stream)
- char * fgets (char *s, int n, FILE *stream)
- FILE * fopen (const char *path, const char *mode)
- int fclose (FILE *stream)
- size_t fread (void *ptr, size_t size, size_t nmemb, FILE *stream)
- size_t fwrite (const void *ptr, size_t size, size_t nmemb, FILE *stream)
- int fscanf (FILE *stream, const char *fmt,...)
- void rewind (FILE *stream)

7.37.1 Macro Definition Documentation

7.37.1.1 SEEK_CUR

```
#define SEEK_CUR 1
```

7.37.1.2 SEEK_END

```
#define SEEK_END 2
```

7.37.1.3 SEEK_SET

```
#define SEEK_SET 0
```

7.37.1.4 stderr

```
#define stderr ((FILE *)0)
```

7.37.1.5 stdin

```
#define stdin ((FILE *)2)
```

7.37.1.6 stdout

```
#define stdout ((FILE *)1)
```

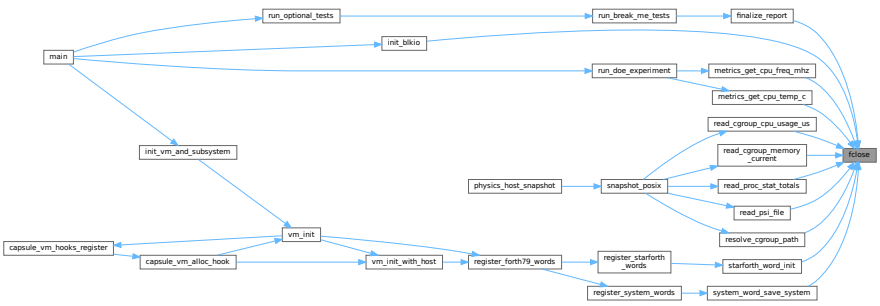
7.37.2 Function Documentation

7.37.2.1 fclose()

```
int fclose (
            FILE * stream )
```

Referenced by finalize_report(), init_blkio(), metrics_get_cpu_freq_mhz(), metrics_get_cpu_temp_c(), read_cgroup_cpu_usage_us(), read_cgroup_memory_current(), read_proc_stat_totals(), read_psi_file(), resolve_cgroup_path(), starforth_word_init(), and system_word_save_system().

Here is the caller graph for this function:

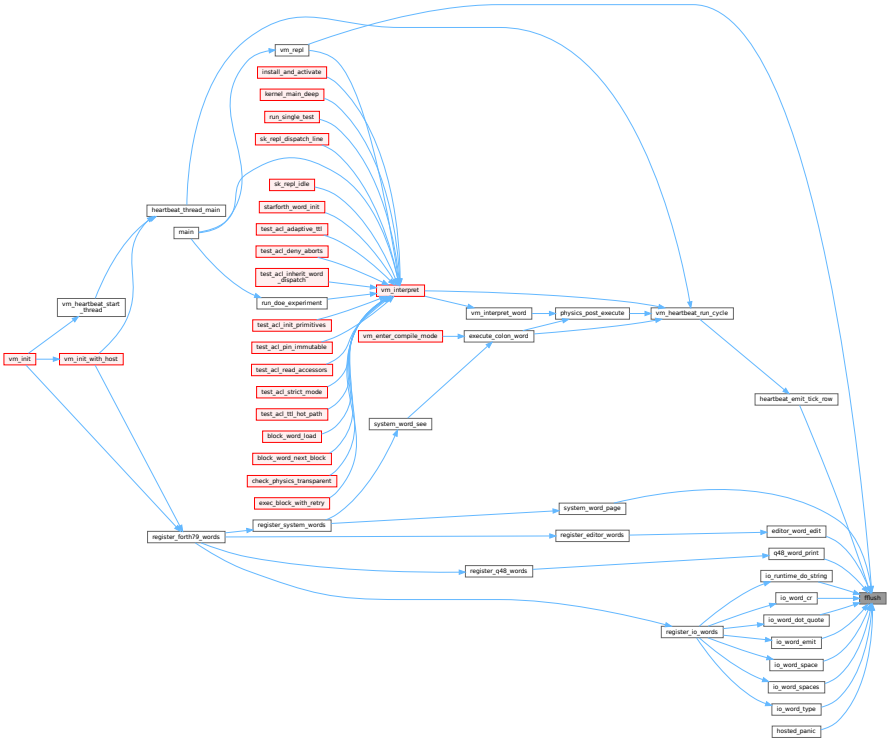


7.37.2.2 fflush()

```
int fflush (
            FILE * stream )
```

Referenced by editor_word_edit(), heartbeat_emit_tick_row(), hosted_panic(), io_runtime_do_string(), io_word_cr(), io_word_dot_quote(), io_word_emit(), io_word_space(), io_word_spaces(), io_word_type(), q48_word_print(), system_word_page(), and vm_repl().

Here is the caller graph for this function:



7.37.2.3 fgetc()

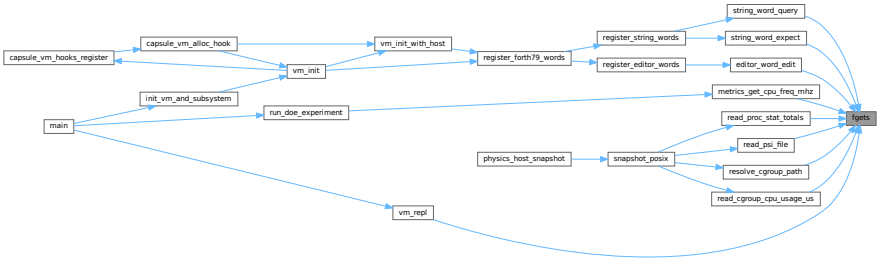
```
int fgetc (
            FILE * stream )
```

7.37.2.4 fgets()

```
char * fgets (
            char * s,
            int n,
            FILE * stream )
```

Referenced by editor_word_edit(), metrics_get_cpu_freq_mhz(), read_cgroup_cpu_usage_us(), read_proc_stat_totals(), read_psi_file(), resolve_cgroup_path(), string_word_expect(), string_word_query(), and vm_repl().

Here is the caller graph for this function:

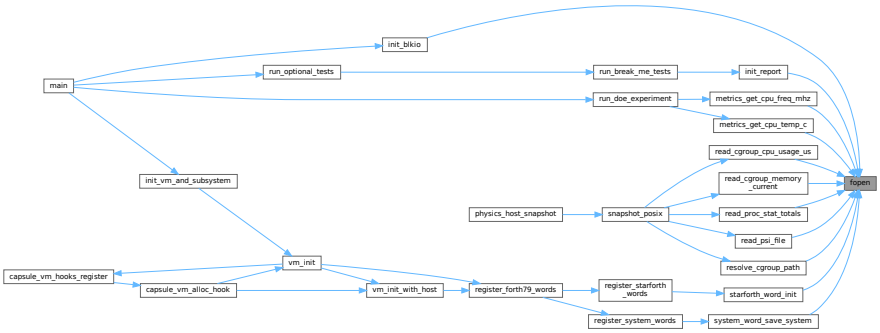


7.37.2.5 fopen()

```
FILE * fopen (
            const char * path,
            const char * mode )
```

Referenced by init_blkio(), init_report(), metrics_get_cpu_freq_mhz(), metrics_get_cpu_temp_c(), read_cgroup_cpu_usage_us(), read_cgroup_memory_current(), read_proc_stat_totals(), read_psi_file(), resolve_cgroup_path(), starforth_word_init(), and system_word_save_system().

Here is the caller graph for this function:

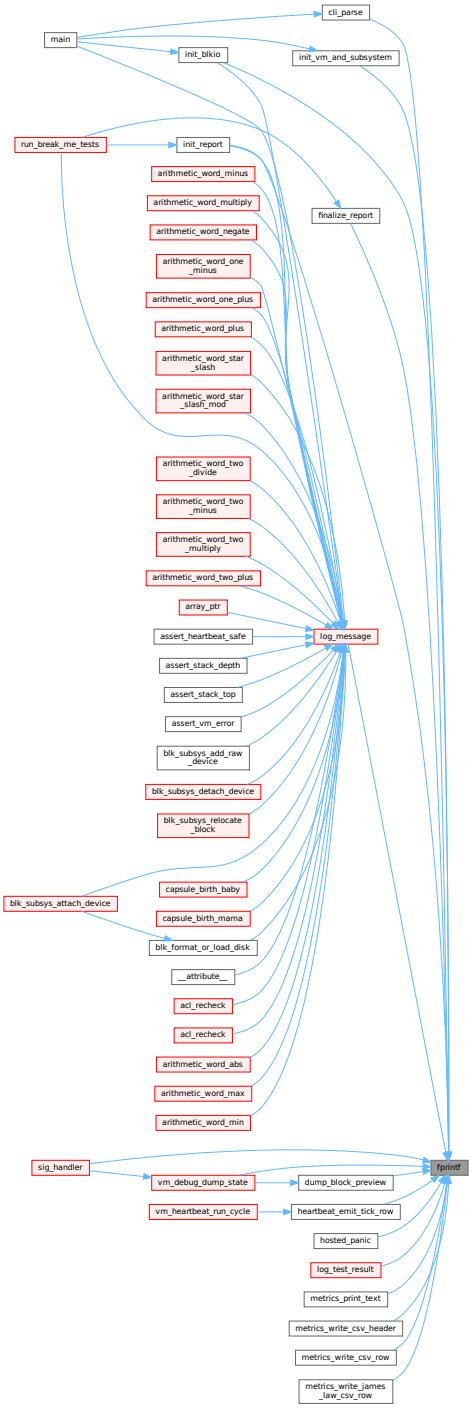


7.37.2.6 fprintf()

```
int fprintf (
            FILE * stream,
            const char * fmt,
             ...  )
```

Referenced by cli_parse(), dump_block_preview(), finalize_report(), heartbeat_emit_tick_row(), hosted_panic(), init_blkio(), init_report(), init_vm_and_subsystem(), log_message(), log_test_result(), metrics_print_text(), metrics_write_csv_header(), metrics_write_csv_row(), metrics_write_james_law_csv_row(), sig_handler(), and vm_debug_dump_state().

Here is the caller graph for this function:



7.37.2.7 fputc()

```
int fputc (
            int c,
            FILE * stream )
```

Referenced by hosted_putc(), runtime_abortq(), system_word_abort_quote(), and system_word_reboot().

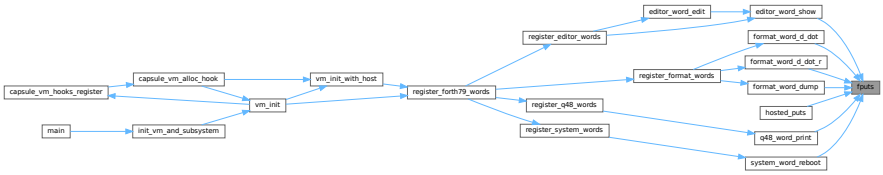
Here is the caller graph for this function:

7.37.2.8 fputs()

```
int fputs (
            const char * s,
            FILE * stream )
```

Referenced by editor_word_show(), format_word_d_dot(), format_word_d_dot_r(), format_word_dump(), hosted_puts(), q48_word_print(), and system_word_reboot().

Here is the caller graph for this function:

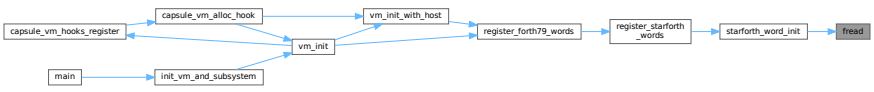


7.37.2.9 fread()

```
size_t fread (
            void * ptr,
            size_t size,
            size_t nmemb,
            FILE * stream )
```

Referenced by starforth_word_init().

Here is the caller graph for this function:

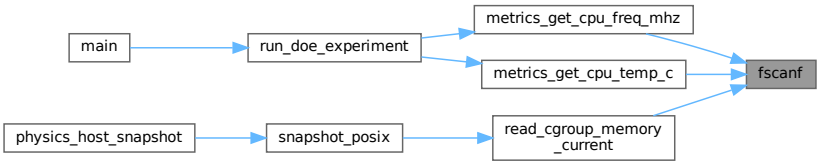


7.37.2.10 fscanf()

```
int fscanf (
            FILE * stream,
            const char * fmt,
             ...  )
```

Referenced by metrics_get_cpu_freq_mhz(), metrics_get_cpu_temp_c(), and read_cgroup_memory_current().

Here is the caller graph for this function:



7.37.2.11 fseek()

```
int fseek (
            FILE * stream,
            long offset,
            int whence )
```

Referenced by starforth_word_init().

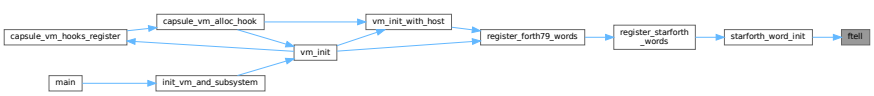
Here is the caller graph for this function:

7.37.2.12 ftell()

```
long ftell (
            FILE * stream )
```

Referenced by starforth_word_init().

Here is the caller graph for this function:

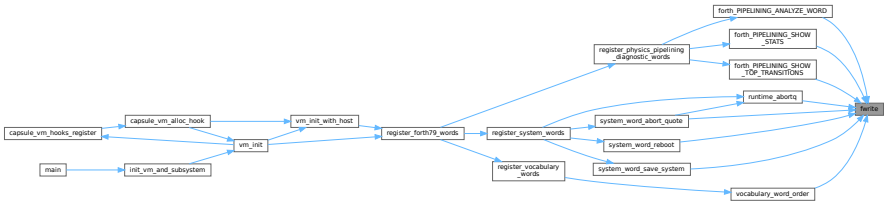


7.37.2.13 fwrite()

```
size_t fwrite (
            const void * ptr,
            size_t size,
            size_t nmemb,
            FILE * stream )
```

Referenced by forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRAN runtime_abortq(), system_word_abort_quote(), system_word_reboot(), system_word_save_system(), and vocabulary_word_order().

Here is the caller graph for this function:

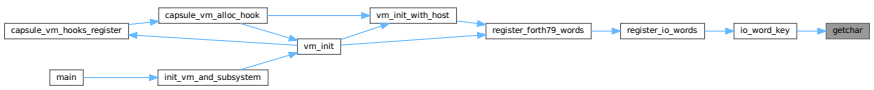


7.37.2.14 getchar()

```
int getchar (
            void  )
```

Referenced by io_word_key().

Here is the caller graph for this function:



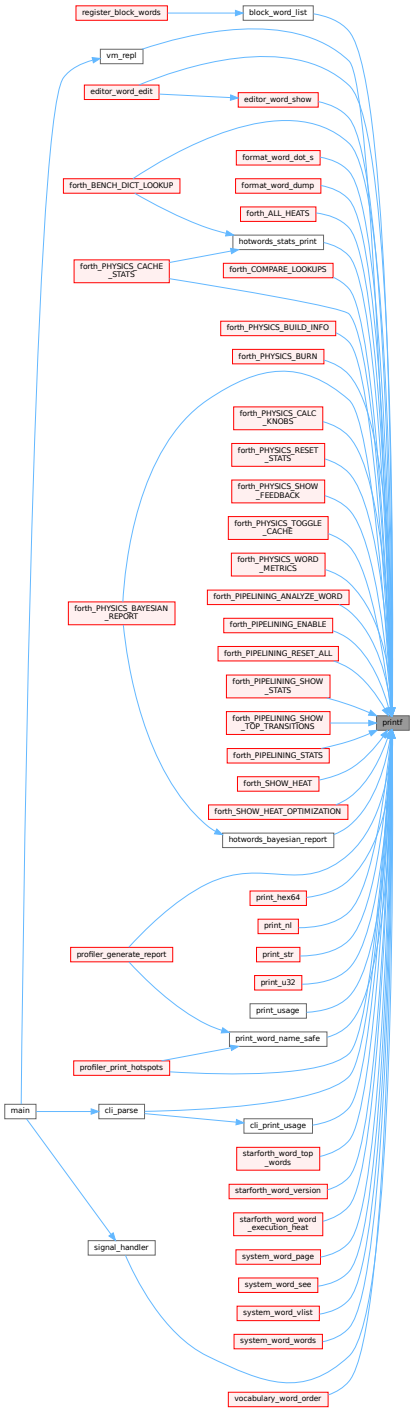
7.37.2.15 printf()

```
int printf (
            const char * fmt,
             ...  )
```

Referenced by block_word_list(), cli_parse(), cli_print_usage(), editor_word_edit(), editor_word_show(), format_word_dot_s(), format_word_dump(), forth_ALL_HEATS(), forth_BENCH_DICT_LOOKUP(), forth_COMPARE_LOOKUPS(), forth_PHYSICS_BAYESIAN_REPORT(), forth_PHYSICS_BUILD_INFO(), forth_PHYSICS_BURN(), forth_PHYSICS_CACHE_STATS forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_RESET_STATS(), forth_PHYSICS_SHOW_FEEDBACK(), forth_PHYSICS_TOGGLE_CACHE(), forth_PHYSICS_WORD_METRICS(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_ENABLE(), forth_PIPELINING_RESET_ALL(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_ forth_PIPELINING_STATS(), forth_SHOW_HEAT(), forth_SHOW_HEAT_OPTIMIZATION(), hotwords_bayesian_report(),

hotwords_stats_print(), print_hex64(), print_nl(), print_str(), print_u32(), print_usage(), print_word_name_safe(), profiler_generate_report(), profiler_print_hotspots(), signal_handler(), starforth_word_top_words(), starforth_word_version(), starforth_word_word_execution_heat(), system_word_page(), system_word_see(), system_word_vlist(), system_word_words(), vm_repl(), and vocabulary_word_order().

Here is the caller graph for this function:



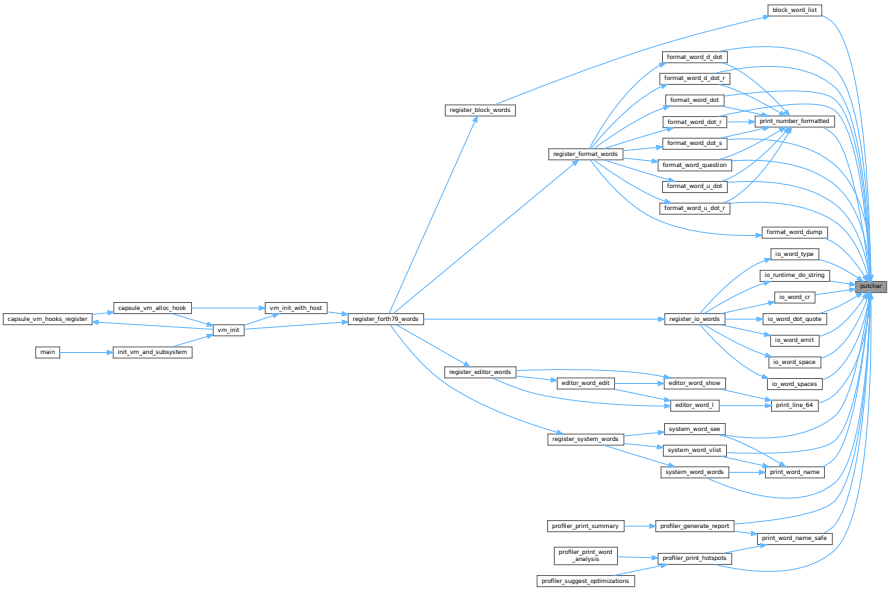
7.37.2.16 putchar()

```
int putchar (
```

```
            int c )
```

Referenced by block_word_list(), format_word_d_dot(), format_word_d_dot_r(), format_word_dot(), format_word_dot_r(), format_word_dot_s(), format_word_dump(), format_word_question(), format_word_u_dot(), format_word_u_dot_r(), io_runtime_do_string(), io_word_cr(), io_word_dot_quote(), io_word_emit(), io_word_space(), io_word_spaces(), io_word_type(), print_line_64(), print_number_formatted(), print_word_name(), print_word_name_safe(), profiler_generate_report(), profiler_print_hotspots(), system_word_see(), system_word_vlist(), and system_word_words().

Here is the caller graph for this function:

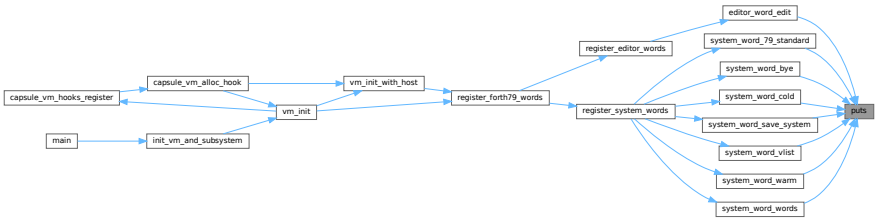


7.37.2.17 puts()

```
int puts (
            const char * s )
```

Referenced by editor_word_edit(), system_word_79_standard(), system_word_bye(), system_word_cold(), system_word_save_system(), system_word_vlist(), system_word_warm(), and system_word_words().

Here is the caller graph for this function:



7.37.2.18 rewind()

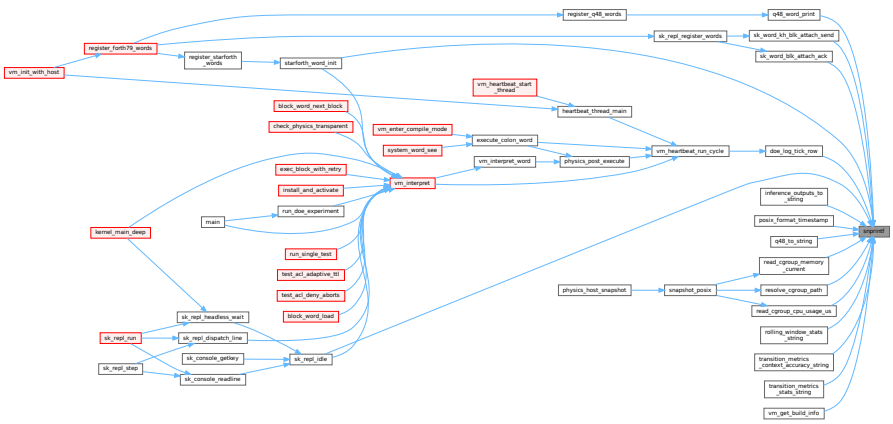
```
void rewind (
            FILE * stream )
```

7.37.2.19 snprintf()

```
int snprintf (
            char * buf,
            size_t n,
            const char * fmt,
             ...  )
```

Referenced by doe_log_tick_row(), inference_outputs_to_string(), posix_format_timestamp(), q48_to_string(), q48_word_print(), read_cgroup_cpu_usage_us(), read_cgroup_memory_current(), resolve_cgroup_path(), rolling_window_stats_string(), sk_repl_idle(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), starforth_word_init(), transition_metrics_context_accuracy_string(), transition_metrics_stats_string(), and vm_get_build_info().

Here is the caller graph for this function:

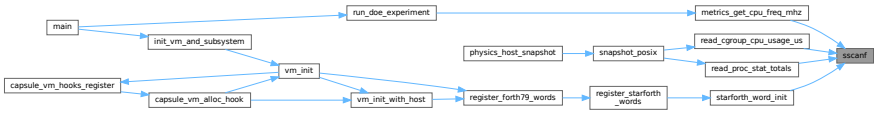


7.37.2.20 sscanf()

```
int sscanf (
            const char * str,
            const char * fmt,
             ...  )
```

Referenced by metrics_get_cpu_freq_mhz(), read_cgroup_cpu_usage_us(), read_proc_stat_totals(), and starforth_word_init().

Here is the caller graph for this function:

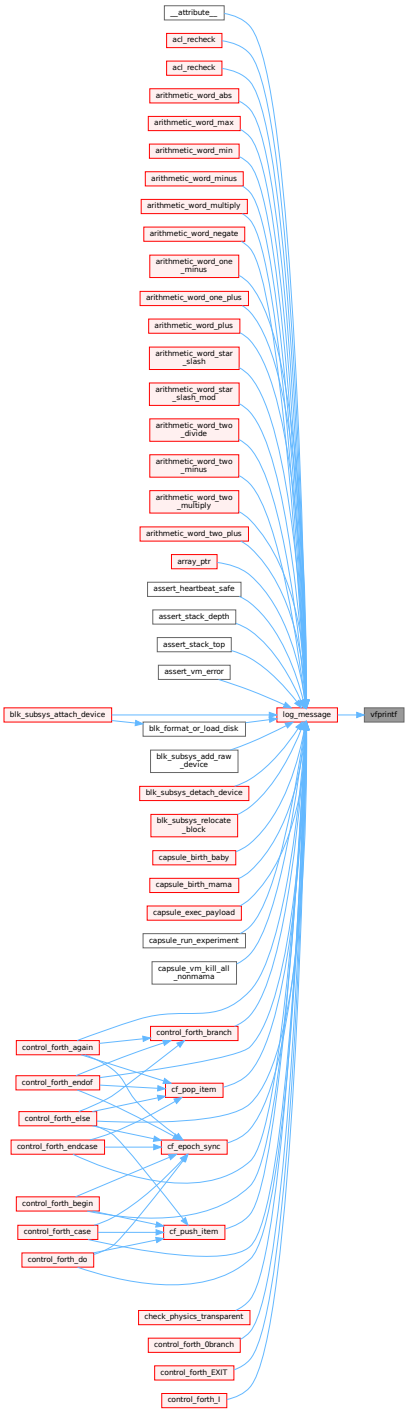


7.37.2.21 vfprintf()

```
int vfprintf (
            FILE * stream,
            const char * fmt,
            va_list args )
```

Referenced by log_message().

Here is the caller graph for this function:

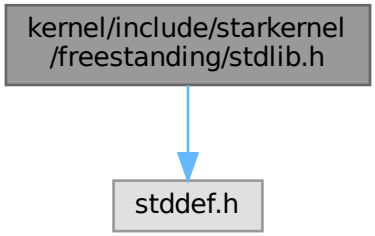


7.37.2.22 vsnprintf()

```
int vsnprintf (
              char * buf,
              size_t n,
              const char * fmt,
              va_list args )
```

7.38 kernel/include/starkernel/freestanding/stdlib.h File Reference

`#include <stddef.h>`
Include dependency graph for stdlib.h:



This graph shows which files directly or indirectly include this file:

Functions

- void ∗ malloc (size_t size)
- void free (void ∗ptr)
- void ∗ calloc (size_t n, size_t size)
- void ∗ realloc (void ∗ptr, size_t size)
- void abort (void)
- void qsort (void ∗base, size_t nmemb, size_t size, int(∗compar)(const void ∗, const void ∗))
- long strtol (const char ∗str, char ∗∗endptr, int base)
- unsigned long strtoul (const char ∗str, char ∗∗endptr, int base)
- long long strtoll (const char ∗str, char ∗∗endptr, int base)
- int atoi (const char ∗str)
- long atol (const char ∗str)

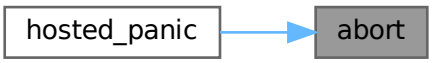
7.38.1 Function Documentation

7.38.1.1 abort()

```
void abort (
            void  )
```

Referenced by hosted_panic().

Here is the caller graph for this function:

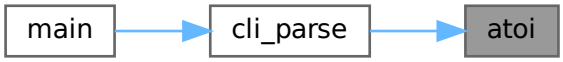


7.38.1.2 atoi()

```
int atoi (
            const char * str )
```

Referenced by cli_parse().

Here is the caller graph for this function:



7.38.1.3 atol()

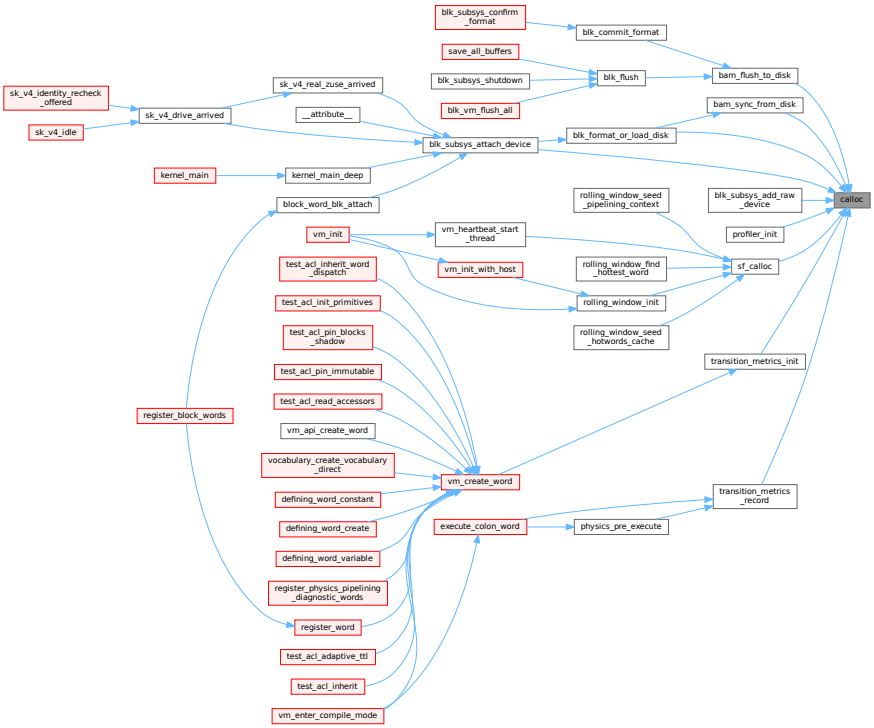
```
long atol (
            const char * str )
```

7.38.1.4 calloc()

```
void * calloc (
            size_t n,
            size_t size )
```

Referenced by bam_flush_to_disk(), bam_sync_from_disk(), blk_format_or_load_disk(), blk_subsys_add_raw_device(), blk_subsys_attach_device(), profiler_init(), sf_calloc(), transition_metrics_init(), and transition_metrics_record().

Here is the caller graph for this function:

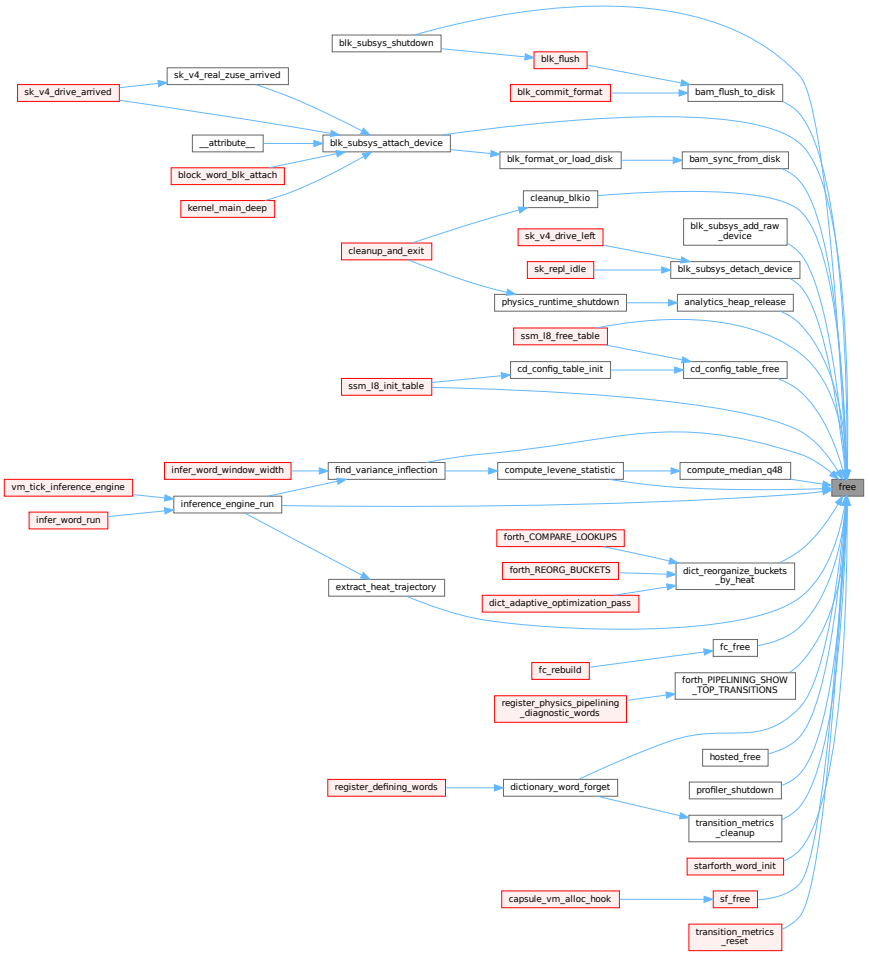


7.38.1.5 free()

```
void free (
            void * ptr )
```

Referenced by analytics_heap_release(), bam_flush_to_disk(), bam_sync_from_disk(), blk_subsys_add_raw_device(), blk_subsys_attach_device(), blk_subsys_detach_device(), blk_subsys_shutdown(), cd_config_table_free(), cleanup_blkio(), compute_levene_statistic(), compute_median_q48(), dict_reorganize_buckets_by_heat(), dictionary_word_forget(), extract_heat_trajectory(), fc_free(), find_variance_inflection(), forth_PIPELINING_SHOW_TOP_TRANSITIC hosted_free(), inference_engine_run(), profiler_shutdown(), sf_free(), ssm_l8_free_table(), ssm_l8_init_table(), starforth_word_init(), transition_metrics_cleanup(), and transition_metrics_reset().

Here is the caller graph for this function:

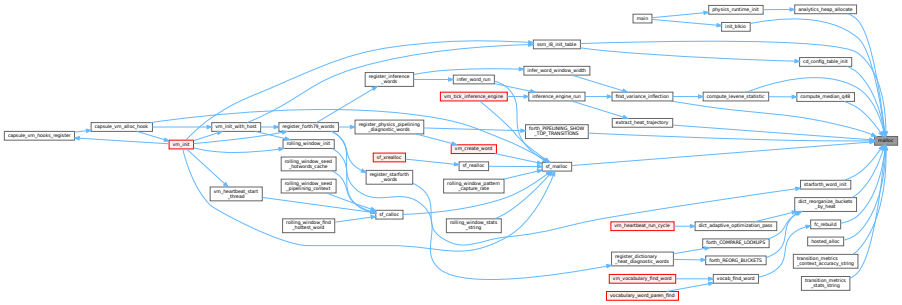


7.38.1.6 malloc()

```
void * malloc (
            size_t size )
```

Referenced by analytics_heap_allocate(), cd_config_table_init(), compute_levene_statistic(), compute_median_q48(), dict_reorganize_buckets_by_heat(), extract_heat_trajectory(), fc_rebuild(), find_variance_inflection(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), hosted_alloc(), init_blkio(), sf_malloc(), ssm_l8_init_table(), starforth_word_init(), transition_metrics_context_accuracy_string(), and transition_metrics_stats_string().

Here is the caller graph for this function:

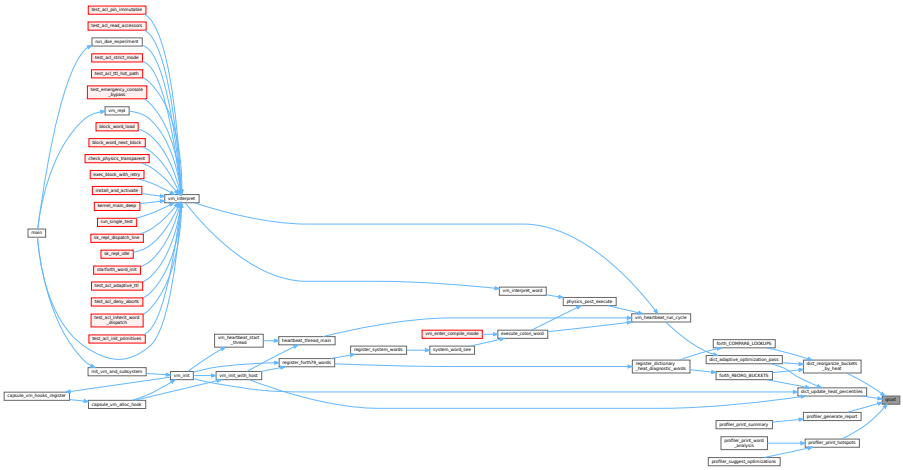


7.38.1.7 qsort()

```
void qsort (
            void * base,
            size_t nmemb,
            size_t size,
            int(*)(const void *, const void *) compar )
```

Referenced by dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), profiler_generate_report(), and profiler_print_hotspots().

Here is the caller graph for this function:

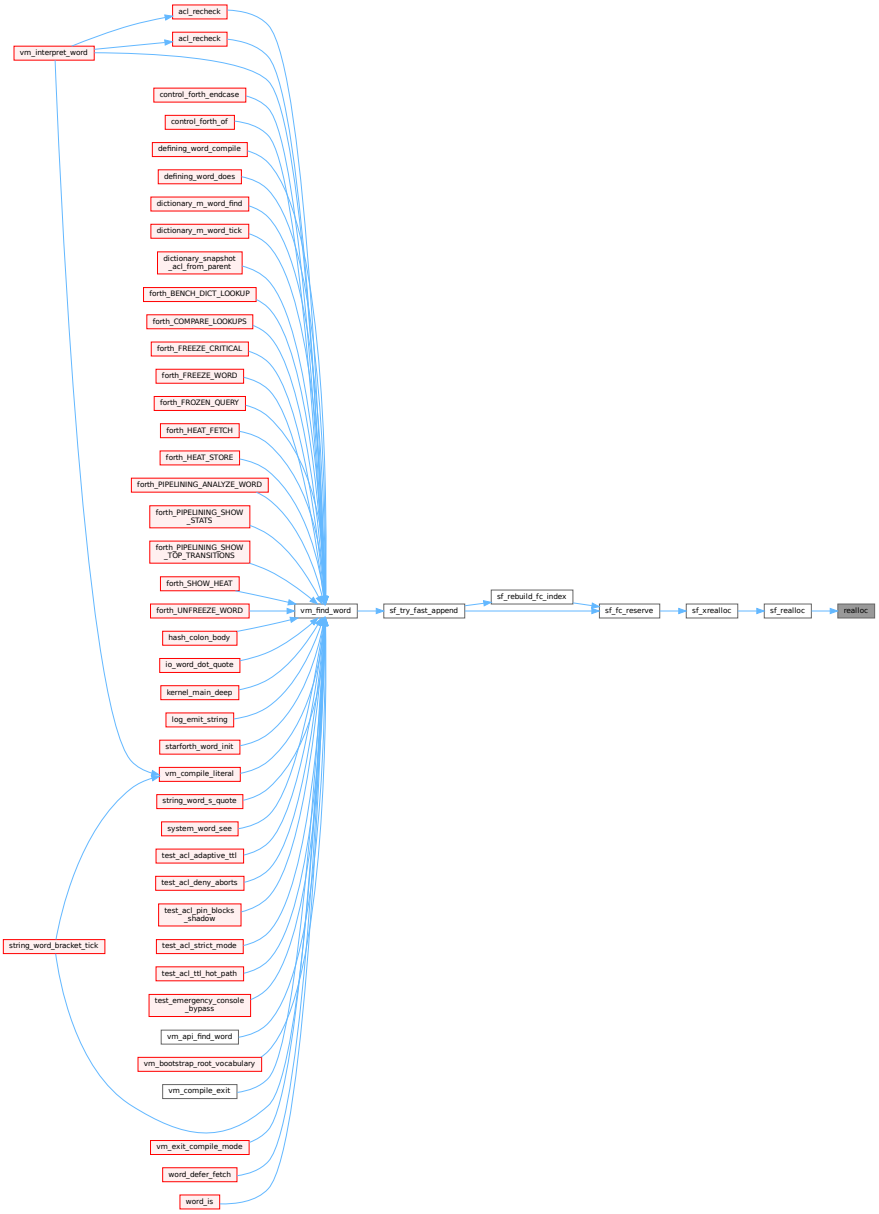


7.38.1.8 realloc()

```
void * realloc (
            void * ptr,
            size_t size )
```

Referenced by sf_realloc().

Here is the caller graph for this function:



7.38.1.9 strtol()

```
long strtol (
            const char * str,
            char ** endptr,
            int base )
```

Referenced by convert_string_to_number().

Here is the caller graph for this function:

7.38.1.10 strtoll()

```
long long strtoll (
            const char * str,
            char ** endptr,
            int base )
```

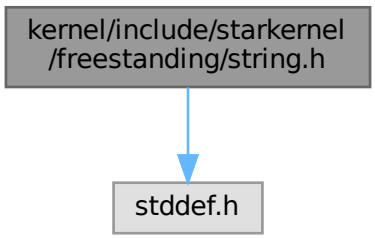
7.38.1.11 strtoul()

```
unsigned long strtoul (
            const char * str,
            char ** endptr,
            int base )
```

7.39 kernel/include/starkernel/freestanding/string.h File Reference

```
#include <stddef.h>
```

Include dependency graph for string.h:



Functions

- void ∗ memcpy (void ∗dest, const void ∗src, size_t n)
- void ∗ memmove (void ∗dest, const void ∗src, size_t n)
- void ∗ memset (void ∗s, int c, size_t n)
- int memcmp (const void ∗s1, const void ∗s2, size_t n)
- void ∗ memchr (const void ∗s, int c, size_t n)

- size_t strlen (const char *s)
- char * strcpy (char *dest, const char *src)
- char * strncpy (char *dest, const char *src, size_t n)
- int strcmp (const char *s1, const char *s2)
- int strncmp (const char *s1, const char *s2, size_t n)
- char * strchr (const char *s, int c)
- char * strrchr (const char *s, int c)
- char * strerror (int errnum)

7.39.1 Function Documentation

7.39.1.1 memchr()

```
void * memchr (
            const void * s,
            int c,
            size_t n )
```

Referenced by block_word_next_block().

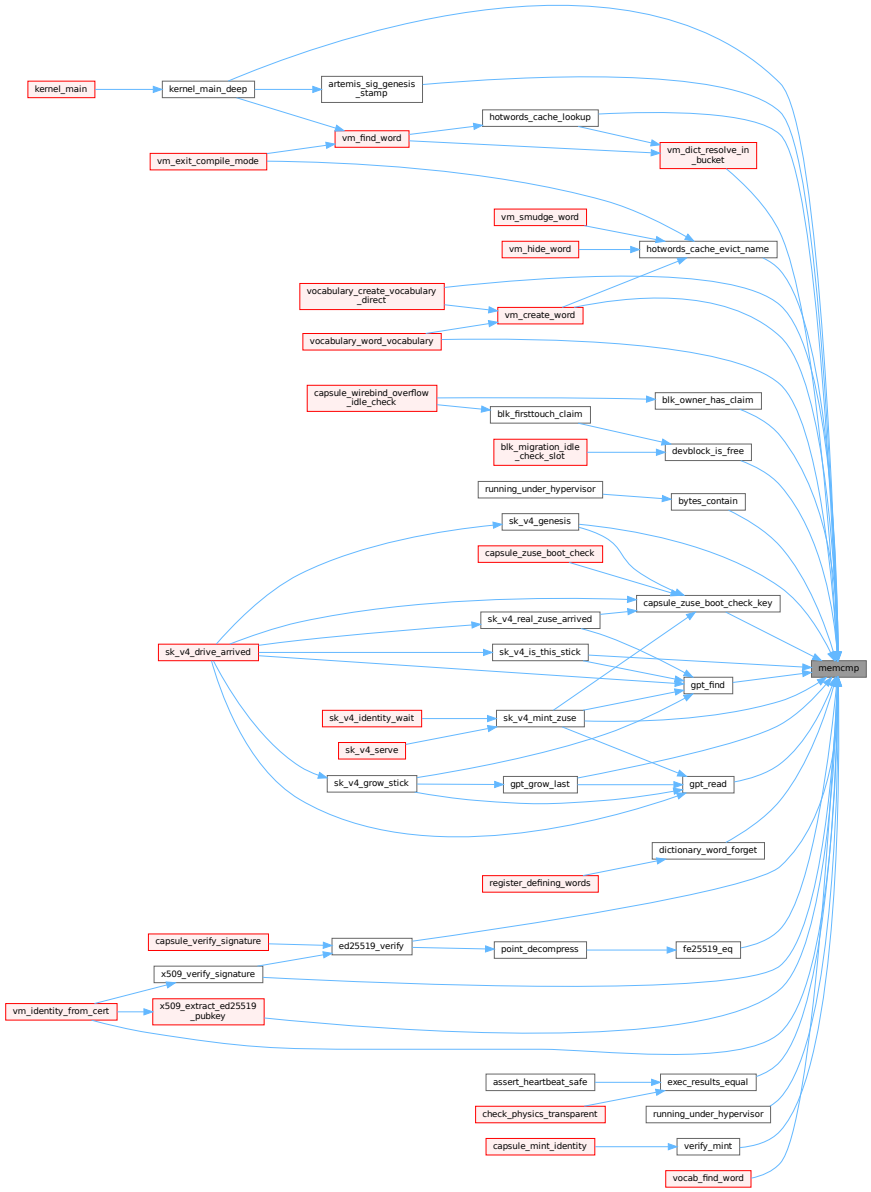
Here is the caller graph for this function:

7.39.1.2 memcmp()

```
int memcmp (
            const void * s1,
            const void * s2,
            size_t n )
```

Referenced by artemis_sig_genesis_stamp(), blk_owner_has_claim(), bytes_contain(), capsule_zuse_boot_check_key(), devblock_is_free(), dictionary_word_forget(), ed25519_verify(), exec_results_equal(), fe25519_eq(), gpt_find(), gpt_grow_last(), gpt_read(), hotwords_cache_evict_name(), hotwords_cache_lookup(), kernel_main_deep(), running_under_hypervisor(), sk_v4_genesis(), sk_v4_is_this_stick(), sk_v4_mint_zuse(), verify_mint(), vm_create_word(), vm_dict_resolve_in_bucket(), vm_identity_from_cert(), vocab_find_word(), vocabulary_create_vocabulary_direct(), vocabulary_word_vocabulary(), x509_extract_ed25519_pubkey(), and x509_verify_signature().

Here is the caller graph for this function:



7.39.1.3 memcpy()

```
void * memcpy (
            void * dest,
            const void * src,
            size_t n )
```

Referenced by artemis_sig_check(), artemis_sig_genesis_stamp(), blk_firsttouch_claim(), blk_meta_relocate_devblock(), blk_owner_fp_get(), blk_owner_fp_set(), blk_subsys_relocate_block(), blk_vm_evict(), blk_vm_flush_all(), blk_vm_load(), block_word_load(), block_word_next_block(), block_word_owner_fetch(), block_word_update(), capsule_console_birth(), capsule_mint_identity(), capsule_mint_identity_scratch(), capsule_runcap_birth(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), capsule_zuse_boot_check_key(),

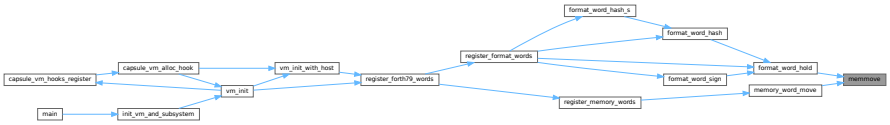
capsule_zuse_boot_root_pubkey(), capsule_zuse_boot_try_attach(), capture_exec_result(), compute_median_q48(), convert_string_to_number(), defining_runtime_does_rt(), der_put_tlv(), der_put_uint_integer(), dict_reorganize_buckets_by_heat(), ed25519_sign(), editor_word_edit(), editor_word_s(), expand_seed(), extract_name(), gpt_disk_guid(), gpt_grow_last(), gpt_read(), gpt_write_one(), homeblocks_sig_check(), install_and_activate(), io_write_block(), kernel_main_deep(), log_region_append(), log_region_read_slot(), log_region_write_slot(), meta_from_slice(), meta_to_slice(), physics_analytics_publish_event(), point_decompress(), put_sectors(), ram_read(), ram_write(), reloc_flush_to_disk(), reloc_load_from_disk(), rolling_window_export_execution_history(), rolling_window_publish_snapshot(), say_size(), scalar_reduce512(), sf_fc_reserve(), sha512_final(), sha512_update(), sk_repl_dispatch_line(), sk_v4_drive_arrived(), sk_v4_genesis(), sk_v4_login(), sk_v4_marker_read(), sk_v4_marker_write(), sk_v4_mint_zuse(), starforth_word_init(), string_word_word(), system_word_abort_quote(), usb_blk_read(), usb_blk_write(), vblk_read(), vblk_write(), virtio_rng_get_bytes(), vm_create_word(), vm_enter_compile_mode(), vm_identity_from_cert(), vm_input_load_line(), vm_load_cell(), vm_store_cell(), vm_zuse_cert_install(), vocabulary_create_vocabulary_direct(), volmeta_from_buf(), volmeta_to_buf(), x509_build_user_cert(), x509_extract_ed25519_pubkey(), x509_extract_serial(), xhci_ep0_bot_mass_storage_rese xhci_ep0_control_read(), xhci_ep0_control_write_nodata(), xhci_ep0_hid_set_leds(), and xhci_ep0_hid_set_protocol().

7.39.1.4 memmove()

```
void * memmove (
            void * dest,
            const void * src,
            size_t n )
```

Referenced by format_word_hold(), and memory_word_move().

Here is the caller graph for this function:



7.39.1.5 memset()

```
void * memset (
            void * s,
            int c,
            size_t n )
```

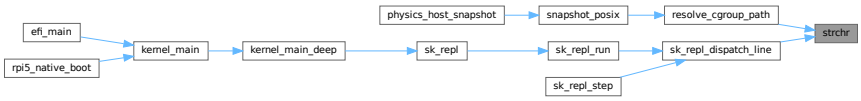
Referenced by analytics_heap_allocate(), artemis_sig_genesis_stamp(), bam_flush_to_disk(), bam_sync_from_disk(), blk_compute_fresh_geometry(), blk_flush(), blk_get_empty_buffer(), blk_get_meta(), blk_meta_relocate_devblock(), blk_subsys_init(), blk_subsys_shutdown(), blk_vm_assign(), blkio_file_init_state(), bucket_posterior(), cache_get_slot(), cache_load_devblock(), cache_posterior(), capsule_console_birth(), capsule_mint_identity(), capsule_mint_identity_scratch(), capsule_runcap_birth(), capsule_wirebind_verify_cert(), capsule_zuse_boot_try_attach(), capture_exec_result(), cd_classify_ids(), cd_config_table_free(), cd_config_table_init(), editor_word_edit(), editor_word_s(), empty_all_buffers(), fe25519_0(), fe25519_1(), format_word_begin_conversion(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), gpt_read(), gpt_write_one(), hotwords_cache_cleanup(), hotwords_cache_init(), infer_word_run(), io_init(), log_region_append(), log_region_ctrl_init_fresh(), log_region_write_slot(), memory_word_erase(), memory_word_fill(), meta_from_slice(), meta_to_slice(), physics_analytics_publish_event(), read_devblock_4k(), read_header_4k(), reloc_load_from_disk(), rolling_window_reset(), rolling_window_snapshot_view(), sf_alloc_init(), sk_repl_idle(), sk_v4_drive_left(), sk_v4_genesis(), sk_v4_idle(), sk_v4_marker_read(), sk_v4_marker_write(), sk_v4_mint_zuse(), sk_v4_real_zuse_arrived(), snapshot_posix(), starforth_word_init(), transition_metrics_reset(), usb_blk_state_for(), vblk_init_device(), vinput_init_device(), vm_create_word(), vm_debug_install_signal_handlers(), vm_host_calloc(), vm_init(), vm_init_with_host(), vm_input_ensure(), vm_input_load_line(), vm_tick_inference_engine(), volmeta_from_buf(), volmeta_to_buf(), vrng_init_device(), xhci_bringup(), and xhci_poll_one().

7.39.1.6 strchr()

```
char * strchr (
            const char * s,
            int c )
```

Referenced by resolve_cgroup_path(), and sk_repl_dispatch_line().

Here is the caller graph for this function:

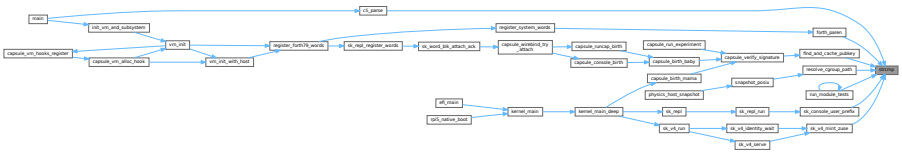


7.39.1.7 strcmp()

```
int strcmp (
            const char * s1,
            const char * s2 )
```

Referenced by cli_parse(), find_and_cache_pubkey(), forth_paren(), resolve_cgroup_path(), run_module_tests(), sk_console_user_prefix(), and sk_v4_mint_zuse().

Here is the caller graph for this function:



7.39.1.8 strcpy()

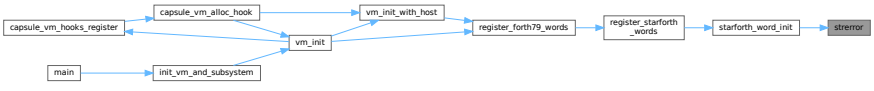
```
char * strcpy (
            char * dest,
            const char * src )
```

7.39.1.9 strerror()

```
char * strerror (
            int errnum )
```

Referenced by starforth_word_init().

Here is the caller graph for this function:

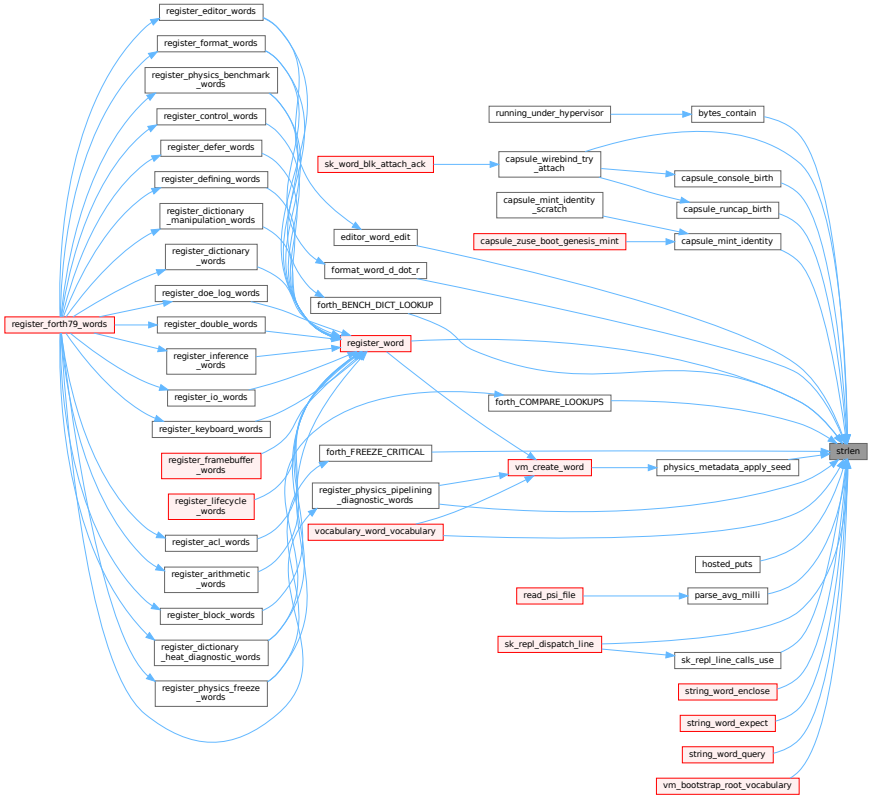


7.39.1.10 strlen()

```
size_t strlen (
            const char * s )
```

Referenced by bytes_contain(), capsule_console_birth(), capsule_mint_identity(), capsule_runcap_birth(), capsule_wirebind_try_attach(), editor_word_edit(), format_word_d_dot_r(), forth_BENCH_DICT_LOOKUP(), forth_COMPARE_LOOKUPS(), forth_FREEZE_CRITICAL(), hosted_puts(), parse_avg_milli(), physics_metadata_apply_seed(), register_physics_pipelining_diagnostic_words(), register_word(), sk_repl_dispatch_line(), sk_repl_line_calls_use(), string_word_enclose(), string_word_expect(), string_word_query(), vm_bootstrap_root_vocabulary(), and vocabulary_word_vocabulary().

Here is the caller graph for this function:

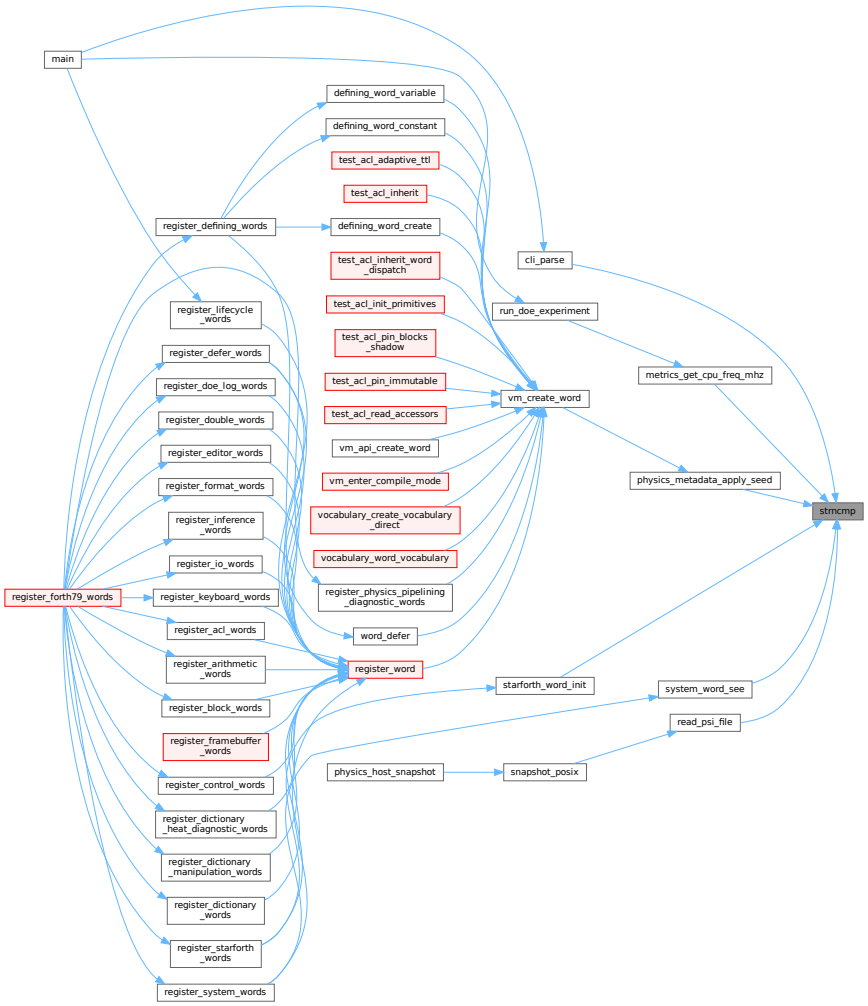


7.39.1.11 strncmp()

```
int strncmp (
            const char * s1,
            const char * s2,
            size_t n )
```

Referenced by cli_parse(), metrics_get_cpu_freq_mhz(), physics_metadata_apply_seed(), read_psi_file(), starforth_word_init(), and system_word_see().

Here is the caller graph for this function:



7.39.1.12 strncpy()

```
char * strncpy (
            char * dest,
            const char * src,
            size_t n )
```

Referenced by blk_compute_fresh_geometry(), and posix_format_timestamp().

Here is the caller graph for this function:

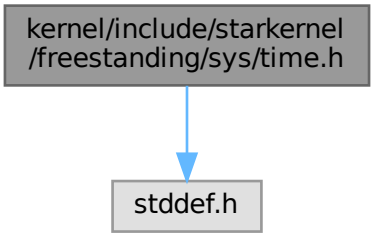
7.39.1.13 strrchr()

```
char * strrchr (
            const char * s,
            int c )
```

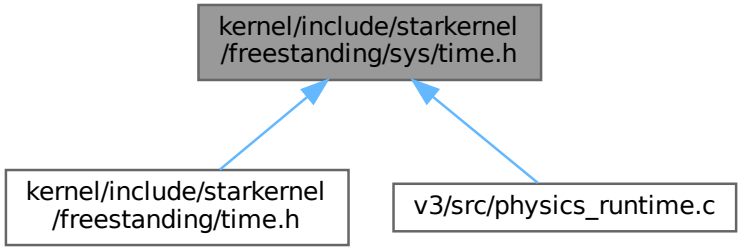
7.40 kernel/include/starkernel/freestanding/sys/time.h File Reference

```
#include <stddef.h>
```

Include dependency graph for time.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct timeval
- struct timezone

Typedefs

- typedef long time_t
- typedef long suseconds_t

Functions

- static int gettimeofday (struct timeval *tv, struct timezone *tz)

7.40.1 Typedef Documentation

7.40.1.1 suseconds_t

```
typedef long suseconds_t
```

7.40.1.2 time_t

```
typedef long time_t
```

7.40.2 Function Documentation

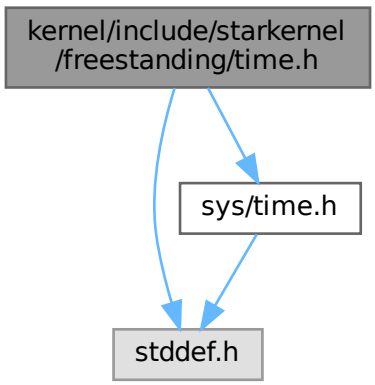
7.40.2.1 gettimeofday()

```
static int gettimeofday (
            struct timeval * tv,
            struct timezone * tz )  [inline], [static]
```

7.41 kernel/include/starkernel/freestanding/time.h File Reference

```
#include <stddef.h>
#include "sys/time.h"
```

Include dependency graph for time.h:



Data Structures

- struct timespec

Functions

- int nanosleep (const struct timespec *req, struct timespec *rem)

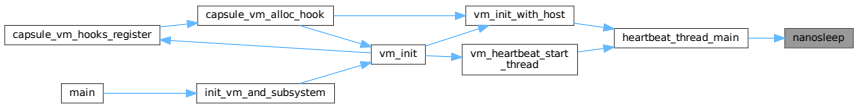
7.41.1 Function Documentation

7.41.1.1 nanosleep()

```
int nanosleep (
            const struct timespec * req,
            struct timespec * rem )
```

Referenced by heartbeat_thread_main().

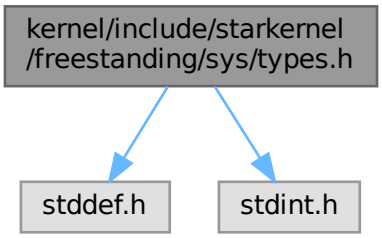
Here is the caller graph for this function:



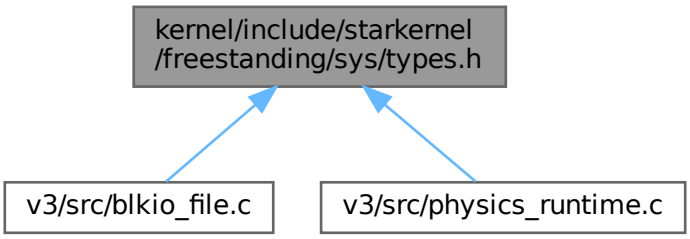
7.42 kernel/include/starkernel/freestanding/sys/types.h File Reference

```
#include <stddef.h>
#include <stdint.h>
```

Include dependency graph for types.h:



This graph shows which files directly or indirectly include this file:



Typedefs

- typedef long ssize_t
- typedef long off_t
- typedef unsigned int mode_t
- typedef unsigned int uid_t
- typedef unsigned int gid_t
- typedef int pid_t

7.42.1 Typedef Documentation

7.42.1.1 gid_t

```
typedef unsigned int gid_t
```

7.42.1.2 mode_t

```
typedef unsigned int mode_t
```

7.42.1.3 off_t

```
typedef long off_t
```

7.42.1.4 pid_t

```
typedef int pid_t
```

7.42.1.5 ssize_t

```
typedef long ssize_t
```

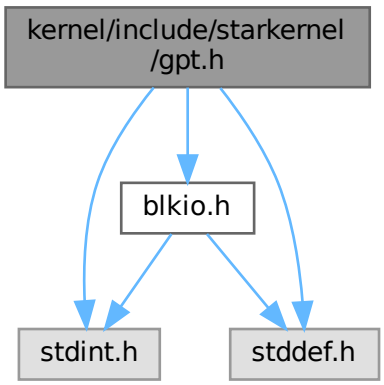
7.42.1.6 uid_t

```
typedef unsigned int uid_t
```

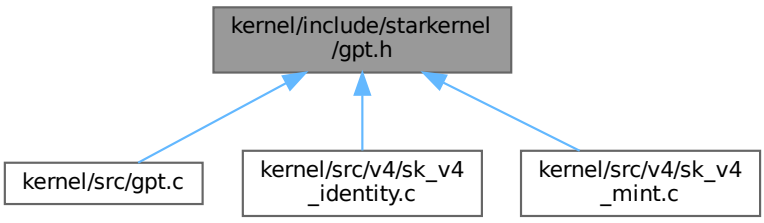
7.43 kernel/include/starkernel/gpt.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "blkio.h"
```

Include dependency graph for gpt.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct gpt_part_t
- struct gpt_part_dev_t

Macros

- #define GPT_OK 0 /* a valid GPT */
- #define GPT_NONE 1 /* not a GPT disk -- no protective MBR -- (or one whose sectors are not 512 bytes): read it raw */
- #define GPT_BAD 2 /* a protective MBR, but its header or entry array does not check out: not used */
- #define GPT_EIO 3 /* its first block could not be read: not used */

Functions

- int gpt_read (blkio_dev_t *disk, gpt_part_t *parts, unsigned max, unsigned *count)
- void gpt_disk_guid (uint8_t guid[16])
- uint64_t gpt_alternate_lba (void)
- int gpt_grow_last (blkio_dev_t *disk, const uint8_t type[16], uint64_t max_part_sectors, uint64_t *new_last_lba)
- int gpt_write_one (blkio_dev_t *disk, const uint8_t type[16], uint64_t part_sectors, uint8_t disk_guid[16])
- int gpt_find (const gpt_part_t *parts, unsigned count, const uint8_t type[16])
- int gpt_part_open (blkio_dev_t *dev, gpt_part_dev_t *st, blkio_dev_t *disk, const gpt_part_t *p)
- uint32_t gpt_crc32 (const void *buf, size_t len)

Variables

- const uint8_t gpt_type_starship_identity [16]
- const uint8_t gpt_type_starship_artemis [16]

7.43.1 Macro Definition Documentation

7.43.1.1 GPT_BAD

```
#define GPT_BAD 2 /* a protective MBR, but its header or entry array does not check out:  not used */
```

7.43.1.2 GPT_EIO

```
#define GPT_EIO 3 /* its first block could not be read:  not used */
```

7.43.1.3 GPT_NONE

```
#define GPT_NONE 1 /* not a GPT disk -- no protective MBR -- (or one whose sectors are not 512 bytes):  read it raw */
```

7.43.1.4 GPT_OK

```
#define GPT_OK 0 /* a valid GPT */
```

7.43.2 Function Documentation

7.43.2.1 gpt_alternate_lba()

```
uint64_t gpt_alternate_lba (
            void  )
```

References g_gpt_alternate_lba.

Referenced by sk_v4_grow_stick().

Here is the caller graph for this function:

7.43.2.2 gpt_crc32()

```
uint32_t gpt_crc32 (
            const void * buf,
            size_t len )
```

Referenced by gpt_grow_last(), gpt_read(), and gpt_write_one().

Here is the caller graph for this function:

7.43.2.3 gpt_disk_guid()

```
void gpt_disk_guid (
            uint8_t guid[16] )
```

References g_gpt_disk_guid, and memcpy().

Referenced by sk_v4_is_this_stick().

Here is the call graph for this function:

Here is the caller graph for this function:

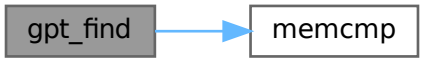
7.43.2.4 gpt_find()

```
int gpt_find (
            const gpt_part_t * parts,
            unsigned count,
            const uint8_t type[16] )
```

References count, and memcmp().

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), sk_v4_is_this_stick(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

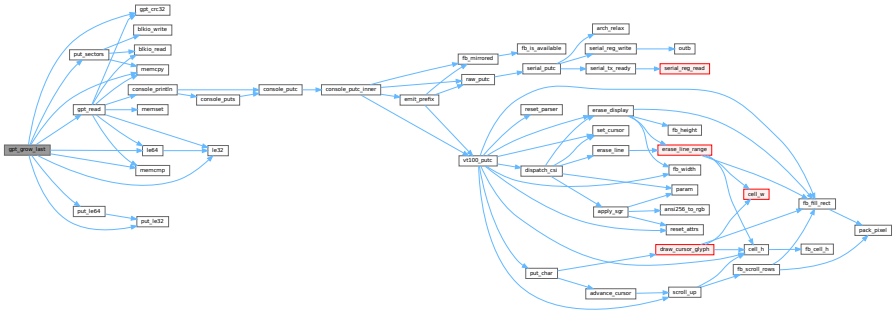
7.43.2.5 gpt_grow_last()

```
int gpt_grow_last (
            blkio_dev_t * disk,
            const uint8_t type[16],
            uint64_t max_part_sectors,
            uint64_t * new_last_lba )
```

References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, count, blkio_vtable_t::flush, g_gpt_entries, g_gpt_hdr_block, GPT_BAD, gpt_crc32(), GPT_EIO, GPT_NONE, GPT_OK, gpt_read(), GPT_SECTOR, le32(), le64(), memcmp(), memcpy(), put_le32(), put_le64(), put_sectors(), blkio_dev::total_blocks, blkio_dev::vt, and zero.

Referenced by sk_v4_grow_stick().

Here is the call graph for this function:



Here is the caller graph for this function:

7.43.2.6 gpt_part_open()

```
int gpt_part_open (
            blkio_dev_t * dev,
            gpt_part_dev_t * st,
            blkio_dev_t * disk,
            const gpt_part_t * p )
```

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, blkio_open(), gpt_part_dev_t::disk, gpt_part_dev_t::fblocks, gpt_part_dev_t::first_fblock, gpt_part_t::first_lba, blkio_params_t::forth_block_size, g_part_vt, gpt_part_t::last_lba, blkio_params_t::opaque, blkio_params_t::total_blocks, and blkio_dev::total_blocks.

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

Here is the call graph for this function:

Here is the caller graph for this function:

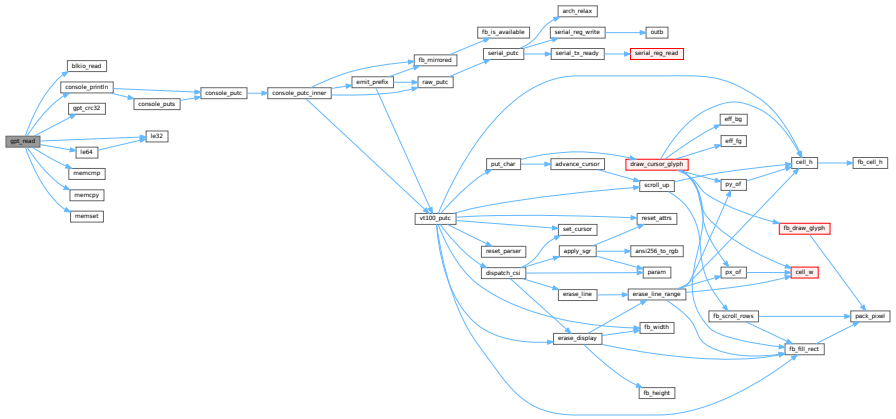
7.43.2.7 gpt_read()

```
int gpt_read (
            blkio_dev_t * disk,
            gpt_part_t * parts,
            unsigned max,
            unsigned * count )
```

References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_read(), console_println(), count, gpt_part_t::first_lba, blkio_dev::forth_block_size, g_gpt_alternate_lba, g_gpt_disk_guid, g_gpt_entries, g_gpt_hdr_block, GPT_BAD, gpt_crc32(), GPT_EIO, GPT_ENTRIES_MAX, GPT_NONE, GPT_OK, GPT_SECTOR, blkio_vtable_t::info, gpt_part_t::last_lba, le32(), le64(), memcmp(), memcpy(), memset(), blkio_info_t::phys_sector_size, blkio_dev::total_blocks, blkio_dev::vt, and zero.

Referenced by gpt_grow_last(), sk_v4_drive_arrived(), sk_v4_grow_stick(), and sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

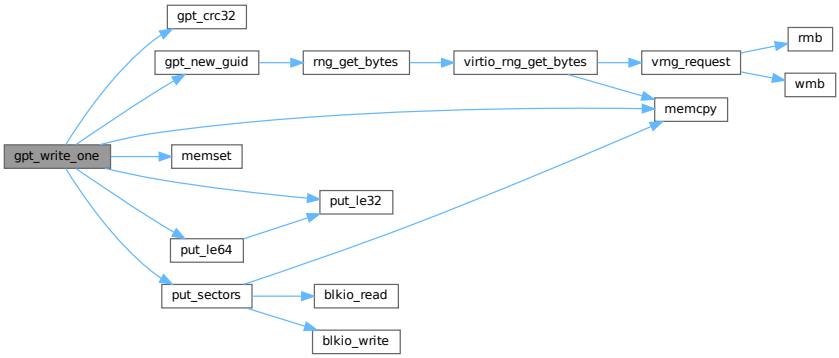
7.43.2.8 gpt_write_one()

```
int gpt_write_one (
            blkio_dev_t * disk,
            const uint8_t type[16],
            uint64_t part_sectors,
            uint8_t disk_guid[16] )
```

References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_vtable_t::flush, blkio_dev::forth_block_size, g_gpt_new_entries, GPT_BAD, gpt_crc32(), GPT_EIO, GPT_ENT_SECTORS, GPT_ESIZE, GPT_NENT, gpt_new_guid(), GPT_OK, GPT_SECTOR, blkio_vtable_t::info, memcpy(), memset(), name, blkio_info_t::phys_sector_size, put_le32(), put_le64(), put_sectors(), blkio_dev::total_blocks, blkio_dev::vt, and zero.

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

7.43.3 Variable Documentation

7.43.3.1 gpt_type_starship_artemis

```
const uint8_t gpt_type_starship_artemis[16]  [extern]
```

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), and sk_v4_is_this_stick().

7.43.3.2 gpt_type_starship_identity

```
const uint8_t gpt_type_starship_identity[16]  [extern]
```

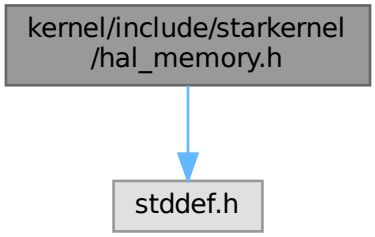
Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), sk_v4_is_this_stick(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

7.44 kernel/include/starkernel/hal/hal.h File Reference

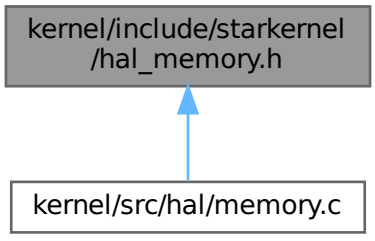
7.45 kernel/include/starkernel/hal_memory.h File Reference

```
#include <stddef.h>
```

Include dependency graph for hal_memory.h:



This graph shows which files directly or indirectly include this file:



Functions

- void * hal_mem_alloc (size_t size)

  hal_memory.h - HAL memory allocation wrappers
- void * hal_mem_alloc_aligned (size_t size, size_t align)
- void hal_mem_free (void *ptr)

7.45.1 Function Documentation

7.45.1.1 hal_mem_alloc()

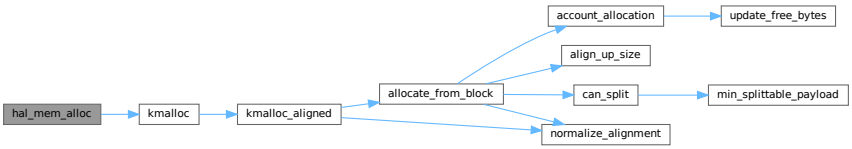
```
void * hal_mem_alloc (
            size_t size )
```

hal_memory.h - HAL memory allocation wrappers

hal_memory.h - HAL memory allocation wrappers

References kmalloc().

Here is the call graph for this function:

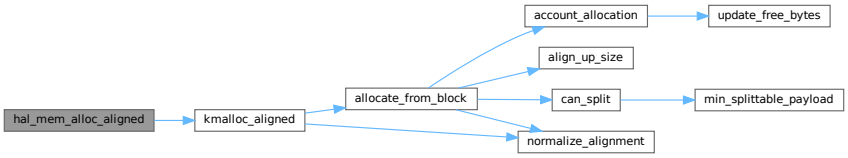


7.45.1.2 hal_mem_alloc_aligned()

```
void * hal_mem_alloc_aligned (
            size_t size,
            size_t align )
```

References kmalloc_aligned().

Here is the call graph for this function:

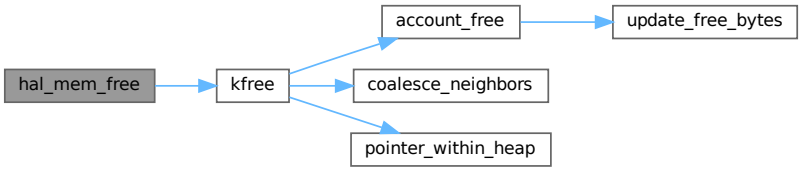


7.45.1.3 hal_mem_free()

```
void hal_mem_free (
            void * ptr )
```

References kfree().

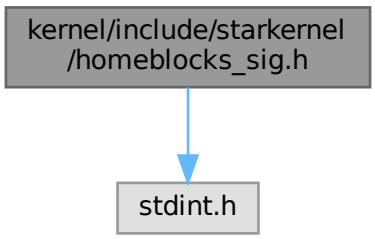
Here is the call graph for this function:



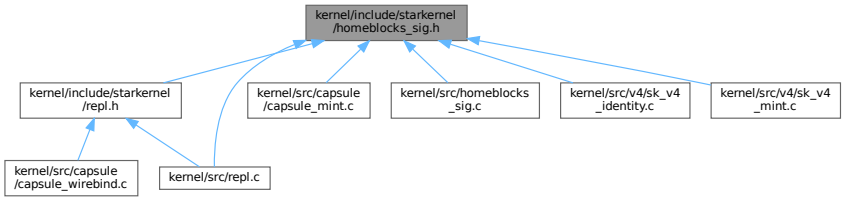
7.46 kernel/include/starkernel/homeblocks_sig.h File Reference

```
#include <stdint.h>
```

Include dependency graph for homeblocks_sig.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct homeblocks_sig_t

Macros

- #define HOMEBLOCKS_SIG_MAGIC

  homeblocks_sig.h - Home-blocks drive signature format (FABRIC-2.md, Milestone 4, Phase 8 kickoff; relocated + GPT dropped ?F.13/?F.8, 2026-08-28)
- #define HOMEBLOCKS_SIG_VERSION_0 0
- #define HOMEBLOCKS_SIG_PACK(ver) (HOMEBLOCKS_SIG_MAGIC | ((uint64_t)(ver) << 32))
- #define HOMEBLOCKS_SIG_GET_MAGIC(m) ((uint32_t)((m) & 0xFFFFFFFFULL))
- #define HOMEBLOCKS_SIG_GET_VERSION(m) ((uint8_t)(((m) >> 32) & 0xFF))
- #define HOMEBLOCKS_SIG_START_FBLOCK 4u

Typedefs

- typedef char homeblocks_sig_size_check[(sizeof(homeblocks_sig_t)==4096) ? 1 :-1]

Enumerations

- enum homeblocks_sig_result_t {
  HOMEBLOCKS_SIG_OK = 0 , HOMEBLOCKS_SIG_BLANK , HOMEBLOCKS_SIG_BAD_VERSION ,
  HOMEBLOCKS_SIG_BAD_CRC ,
  HOMEBLOCKS_SIG_READ_ERROR }

Functions

- homeblocks_sig_result_t homeblocks_sig_check (struct blkio_dev *dev, uint32_t sig_start_fblock, homeblocks_sig_t *out_sig)
- uint64_t homeblocks_sig_compute_crc (const homeblocks_sig_t *sig)

  homeblocks_sig.c - Drive signature check (FABRIC-2.md, Milestone 4).

7.46.1 Macro Definition Documentation

7.46.1.1 HOMEBLOCKS_SIG_GET_MAGIC

```
#define HOMEBLOCKS_SIG_GET_MAGIC(
            m ) ((uint32_t)((m) & 0xFFFFFFFFULL))
```

7.46.1.2 HOMEBLOCKS_SIG_GET_VERSION

```
#define HOMEBLOCKS_SIG_GET_VERSION(
            m ) ((uint8_t)(((m) >> 32) & 0xFF))
```

7.46.1.3 HOMEBLOCKS_SIG_MAGIC

```
#define HOMEBLOCKS_SIG_MAGIC
```

Value:

```
0x4248414CULL /* 'LAHB', same little-endian ASCII
* packing as CAPSULE_DESC_MAGIC's 'CAPS' */
```

homeblocks_sig.h - Home-blocks drive signature format (FABRIC-2.md, Milestone 4, Phase 8 kickoff; relocated + GPT dropped ?F.13/?F.8, 2026-08-28)

Identifies and authenticates a physical thumb drive as a legitimate LithosAnanke home-blocks drive, before any write path touches it. Lives at forth-block HOMEBLOCKS_SIG_START_FBLOCK (devblock 1) of the raw device – GPT partitioning was decided against permanently (?F.8): this is the real, final on-disk location, not an interim stand-in. Devblock 0 is left alone for the block-subsystem's own generic 'STFR'/v2 volume header (block_subsystem.h) – the two formats would otherwise collide (?F.13, found while scoping BMAPREAD).

Mirrors two existing precedents exactly, not invented fresh:

- CAPSULE_MAGIC_PACK's bit-packed magic (starkernel/capsule.h)
- blk_volume_meta_t's magic+version+fields+pad-to-4096 structural convention (block_subsystem.h)

Deliberately narrow in scope: this header identifies/authenticates the DRIVE only. It reserves offset/size pointers to where the cert (CERTVERIFY, ?F.7) and this identity's own personality/init source (RUNCAP/MINT, ?F.6/?F.8) attach, so this format doesn't need revisiting when those get built – it does not itself decide their content.

7.46.1.4 HOMEBLOCKS_SIG_PACK

```
#define HOMEBLOCKS_SIG_PACK(
              ver )   (HOMEBLOCKS_SIG_MAGIC | ((uint64_t)(ver) << 32))
```

7.46.1.5 HOMEBLOCKS_SIG_START_FBLOCK

```
#define HOMEBLOCKS_SIG_START_FBLOCK 4u
```

7.46.1.6 HOMEBLOCKS_SIG_VERSION_0

```
#define HOMEBLOCKS_SIG_VERSION_0 0
```

7.46.2 Typedef Documentation

7.46.2.1 homeblocks_sig_size_check

```
typedef char homeblocks_sig_size_check[(sizeof(homeblocks_sig_t)==4096) ?  1 :-1]
```

7.46.3 Enumeration Type Documentation

7.46.3.1 homeblocks_sig_result_t

```
enum homeblocks_sig_result_t
```

Enumerator

HOMEBLOCKS_SIG_OK	
HOMEBLOCKS_SIG_BLANK	
HOMEBLOCKS_SIG_BAD_VERSION	
HOMEBLOCKS_SIG_BAD_CRC	
HOMEBLOCKS_SIG_READ_ERROR	

7.46.4 Function Documentation

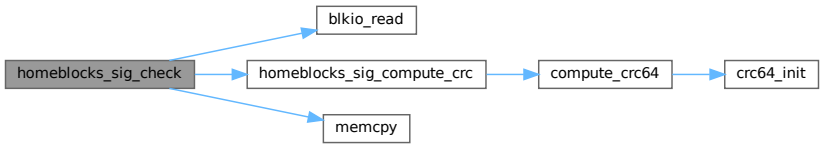
7.46.4.1 homeblocks_sig_check()

```
homeblocks_sig_result_t homeblocks_sig_check (
            struct blkio_dev * dev,
            uint32_t sig_start_fblock,
            homeblocks_sig_t * out_sig )
```

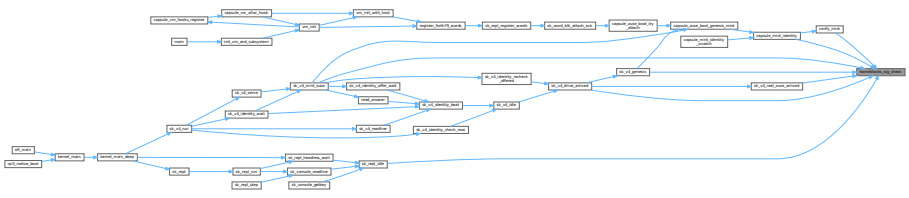
References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_read(), homeblocks_sig_t::hdr_crc, HOMEBLOCKS_SIG_BAD_CRC, HOMEBLOCKS_SIG_BAD_VERSION, HOMEBLOCKS_SIG_BLANK, homeblocks_sig_compute_crc(), HOMEBLOCKS_SIG_GET_M HOMEBLOCKS_SIG_GET_VERSION, HOMEBLOCKS_SIG_MAGIC, HOMEBLOCKS_SIG_OK, HOMEBLOCKS_SIG_READ_ERRO HOMEBLOCKS_SIG_VERSION_0, homeblocks_sig_t::magic, and memcpy().

Referenced by capsule_mint_identity(), sk_repl_idle(), sk_v4_drive_arrived(), sk_v4_genesis(), sk_v4_mint_zuse(), sk_v4_real_zuse_arrived(), and verify_mint().

Here is the call graph for this function:



Here is the caller graph for this function:



7.46.4.2 homeblocks_sig_compute_crc()

```
uint64_t homeblocks_sig_compute_crc (
            const homeblocks_sig_t * sig )
```

homeblocks_sig.c - Drive signature check (FABRIC-2.md, Milestone 4).

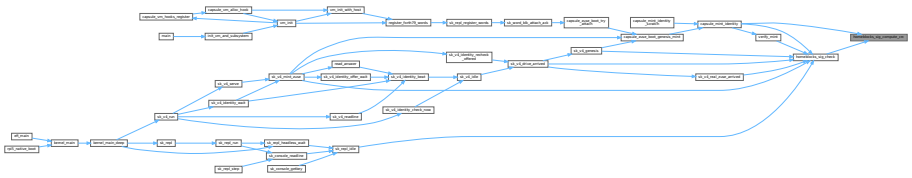
See starkernel/homeblocks_sig.h for the format and interface design.

References compute_crc64().

Referenced by capsule_mint_identity(), and homeblocks_sig_check().

Here is the call graph for this function:

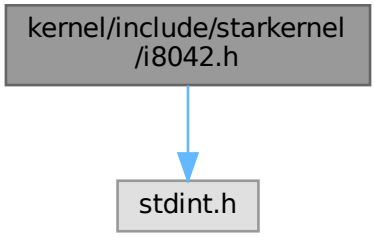
Here is the caller graph for this function:



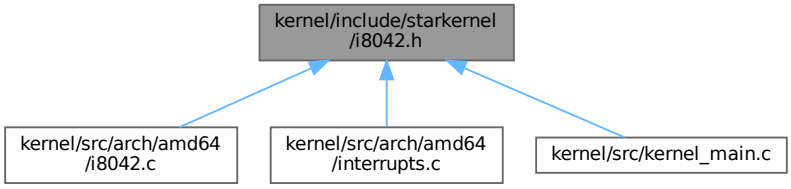
7.47 kernel/include/starkernel/i8042.h File Reference

```
#include <stdint.h>
```

Include dependency graph for i8042.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define I8042_KEYBOARD_VECTOR 0x21

  i8042.h - PS/2 keyboard controller interface (amd64 only)

Functions

- void i8042_init (void)

  Enable IRQ1 delivery in the i8042 controller's command byte.
- void i8042_drain_stale (void)

  Drain any byte sitting in the output buffer right before unmasking IRQ1.
- void i8042_handle_irq (void)

  Called from the keyboard IRQ dispatch path (interrupts.c) on every I8042_KEYBOARD_VECTOR interrupt.
- int i8042_pop_scancode (uint8_t *out)

  Pop one raw scancode off the ring buffer, from non-interrupt context.

Variables

- volatile uint32_t g_i8042_isr_count

7.47.1 Macro Definition Documentation

7.47.1.1 I8042_KEYBOARD_VECTOR

```
#define I8042_KEYBOARD_VECTOR 0x21
```

i8042.h - PS/2 keyboard controller interface (amd64 only)

Item 4.3.5 (FABRIC-0.md ?27.5). Interrupt-driven only — no polling of the status port (0x64) anywhere in this path. Groundwork only: this captures and prints raw scancodes. Scancode-to-keycode translation and a consumer API belong to the REPL keyboard-input work noted in FABRIC-0.md, not here.

7.47.2 Function Documentation

7.47.2.1 i8042_drain_stale()

```
void i8042_drain_stale (
            void  )
```

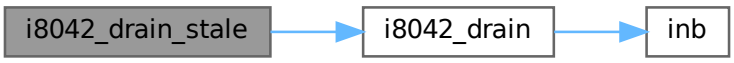
Drain any byte sitting in the output buffer right before unmasking IRQ1.

Edge-triggered lines only assert on a rising edge; if OBF is already set (from real wall-clock time elapsing between i8042_init() and unmask while OBF was already high), there is no edge left to fire on, ever.

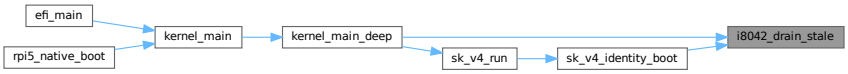
References g_i8042_present, and i8042_drain().

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.47.2.2 i8042_handle_irq()

```
void i8042_handle_irq (
            void  )
```

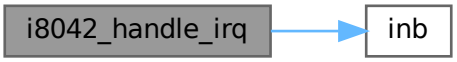
Called from the keyboard IRQ dispatch path (interrupts.c) on every I8042_KEYBOARD_VECTOR interrupt.

Trivial by design: reads the scancode from port 0x60 (must always be read, or the controller never clears OBF and stops delivering further interrupts) and pushes it onto a small ring buffer. No printing, no translation, no other work — that all happens outside interrupt context via i8042_pop_scancode(). Does not issue apic_eoi() — the caller does.

References g_i8042_isr_count, I8042_DATA_PORT, inb(), ring, ring_head, RING_SIZE, and ring_tail.

Referenced by isr_common_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

7.47.2.3 i8042_init()

```
void i8042_init (
            void  )
```

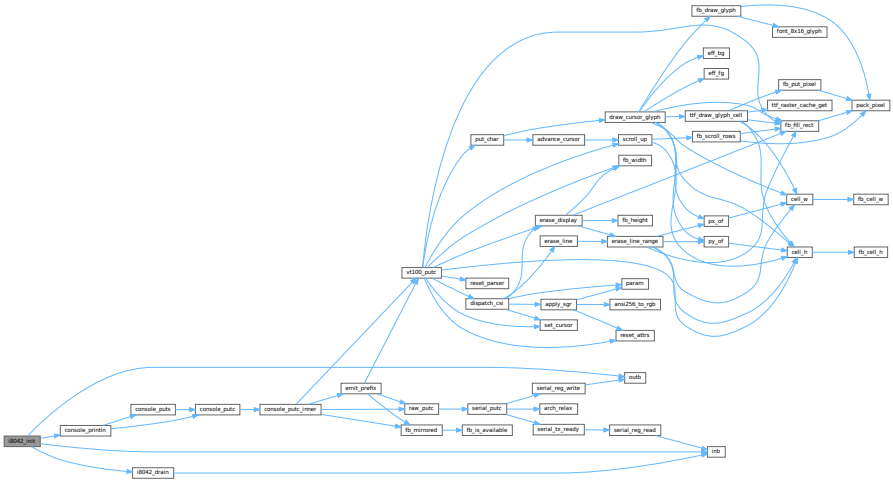
Enable IRQ1 delivery in the i8042 controller's command byte.

Assumes the controller was already brought up by firmware (OVMF) — does not run the 0xAA self-test or the full two-port init sequence, since that is more than this item's scope requires.

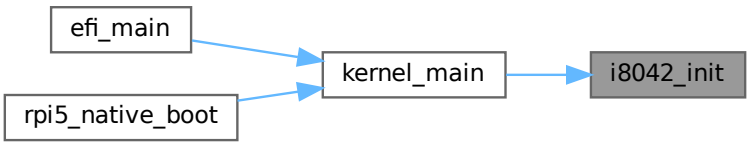
References console_println(), g_i8042_present, I8042_CMD_PORT, I8042_CMD_READ_CONFIG, I8042_CMD_WRITE_CONFIG, I8042_CONFIG_IRQ1_ENABLE, I8042_DATA_PORT, I8042_DEV_ACK, I8042_DEV_CMD_ENABLE_SCANNING, i8042_drain(), I8042_INIT_WAIT_ITERS, I8042_STATUS_INPUT_FULL, I8042_STATUS_OUTPUT_FULL, I8042_STATUS_PORT, inb(), and outb().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.47.2.4 i8042_pop_scancode()

```
int i8042_pop_scancode (
            uint8_t * out )
```

Pop one raw scancode off the ring buffer, from non-interrupt context.

Single producer (the ISR), single reader (this function) — same shape already established safe on one hart elsewhere in this tree (?21.1).

Parameters

out	Written with the popped scancode on success.

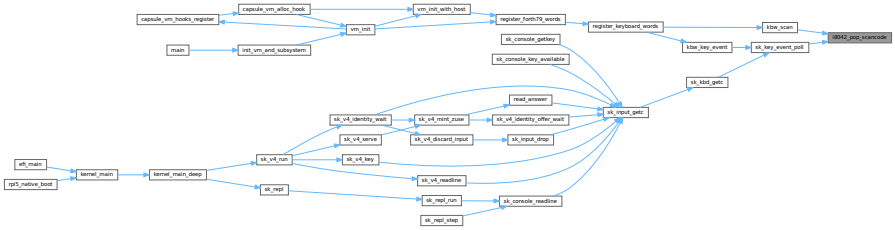
Returns

1 if a scancode was popped, 0 if the buffer was empty.

References ring, ring_head, RING_SIZE, and ring_tail.

Referenced by kbw_scan(), and sk_key_event_poll().

Here is the caller graph for this function:



7.47.3 Variable Documentation

7.47.3.1 g_i8042_isr_count

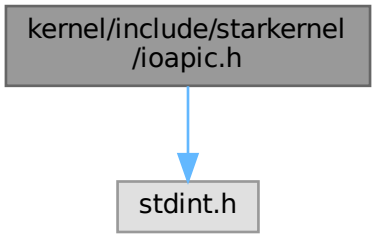
```
volatile uint32_t g_i8042_isr_count  [extern]
```

Referenced by i8042_handle_irq().

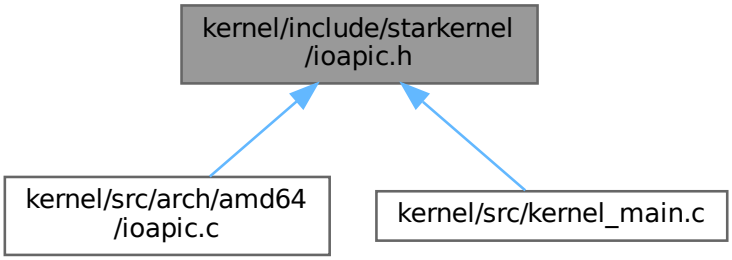
7.48 kernel/include/starkernel/ioapic.h File Reference

```
#include <stdint.h>
```

Include dependency graph for ioapic.h:



This graph shows which files directly or indirectly include this file:



Functions

- int ioapic_init (void *acpi_rsdp)

  ioapic.h - I/O APIC interface (amd64 only)
- int ioapic_route_legacy_irq (uint8_t isa_irq, uint8_t vector, uint8_t dest_apic_id)

  Program a redirection entry for a legacy ISA IRQ, initially masked.
- void ioapic_unmask_legacy_irq (uint8_t isa_irq)

  Clear the mask bit on a previously routed legacy IRQ's redirection entry.

7.48.1 Function Documentation

7.48.1.1 ioapic_init()

```
int ioapic_init (
            void * acpi_rsdp )
```

ioapic.h - I/O APIC interface (amd64 only)

Item 4.3.5 (FABRIC-0.md ?27.5): no I/O APIC driver existed anywhere in this tree before this item. The Local APIC (apic.h) self-interrupts for the timer and needs no routing; any *legacy* IRQ (i8042 keyboard's IRQ1 included) requires the I/O APIC to redirect it to a Local APIC vector. Locate and map the I/O APIC via the ACPI MADT (parsed from `acpi_rsdp`). Also captures any Interrupt Source Override entries so legacy ISA IRQs with a non-default GSI/polarity/trigger mapping route correctly.

Parameters

acpi_rsdp	BootInfo->acpi_table (RSDP), or NULL.

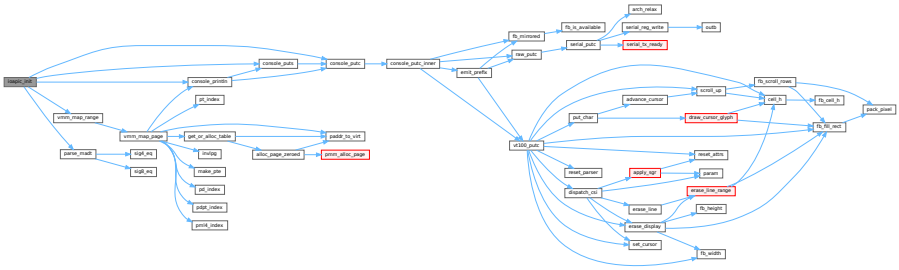
Returns

0 on success, -1 if no MADT/I/O APIC entry was found.

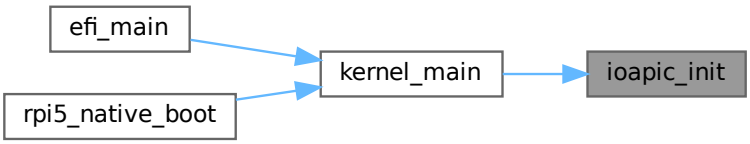
References console_println(), console_putc(), console_puts(), flags, g_ioapic_base, g_ioapic_gsi_base, g_ioapic_ready, g_override_count, g_overrides, parse_madt(), VMM_FLAG_CACHE_DISABLE, VMM_FLAG_WRITABLE, and vmm_map_range().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.48.1.2 ioapic_route_legacy_irq()

```
int ioapic_route_legacy_irq (
            uint8_t isa_irq,
            uint8_t vector,
            uint8_t dest_apic_id )
```

Program a redirection entry for a legacy ISA IRQ, initially masked.

Honors an Interrupt Source Override for `isa_irq` if the MADT had one (different GSI, polarity, or trigger mode); otherwise uses the ISA default (GSI == isa_irq, active-high, edge-triggered) per the ACPI specification's "conforms to bus" default.

Parameters

isa_irq	Legacy IRQ number (0-15).
vector	IDT vector to deliver (e.g. 0x21).
dest_apic↩ _id	Destination Local APIC ID (see apic_id()).

Returns

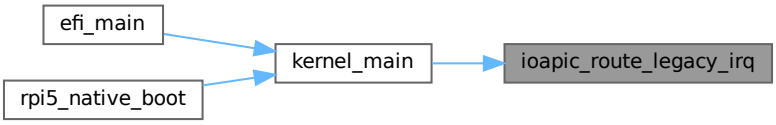
0 on success, -1 if ioapic_init() has not succeeded.

References flags, g_ioapic_gsi_base, g_ioapic_ready, g_override_count, g_overrides, g_redir_low, g_redir_valid, ioapic_write(), ISO_POLARITY_LOW, ISO_POLARITY_MASK, ISO_TRIGGER_LEVEL, ISO_TRIGGER_MASK, and MAX_REDIR_ENTRIES.

Referenced by kernel_main().

Here is the call graph for this function:

Here is the caller graph for this function:



7.48.1.3 ioapic_unmask_legacy_irq()

```
void ioapic_unmask_legacy_irq (
            uint8_t isa_irq )
```

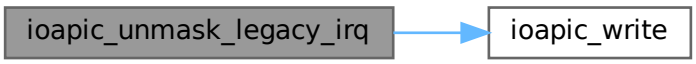
Clear the mask bit on a previously routed legacy IRQ's redirection entry.

Call only after ioapic_route_legacy_irq() has programmed it.

References g_ioapic_gsi_base, g_ioapic_ready, g_override_count, g_overrides, g_redir_low, g_redir_valid, ioapic_write(), and MAX_REDIR_ENTRIES.

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

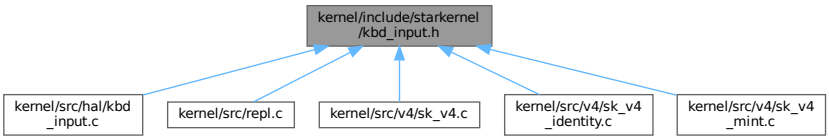
Here is the call graph for this function:



Here is the caller graph for this function:

7.49 kernel/include/starkernel/kbd_input.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- int sk_input_getc (void)
- void sk_input_drop (void)

7.49.1 Function Documentation

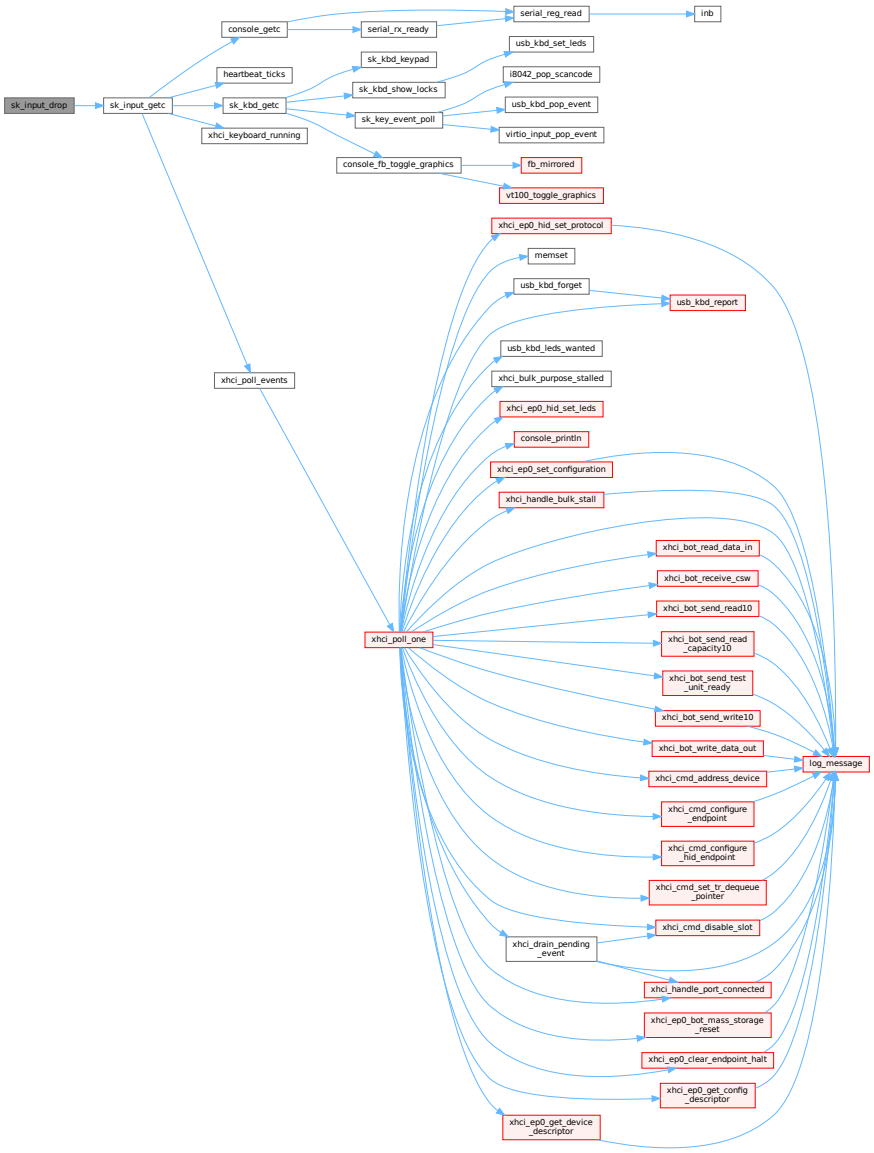
7.49.1.1 sk_input_drop()

```
void sk_input_drop (
            void  )
```

References sk_input_getc().

Referenced by sk_v4_discard_input().

Here is the call graph for this function:



Here is the caller graph for this function:

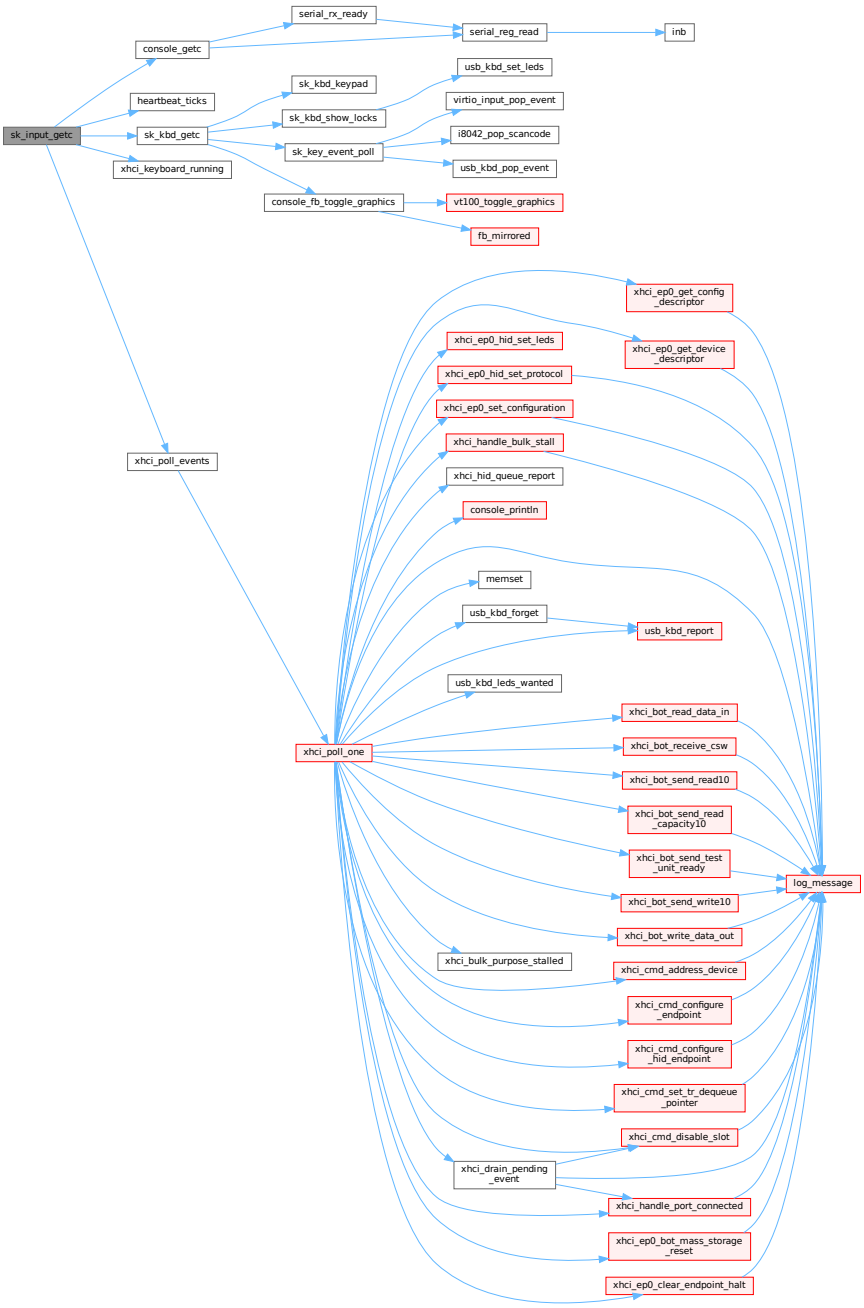
7.49.1.2 sk_input_getc()

```
int sk_input_getc (
            void  )
```

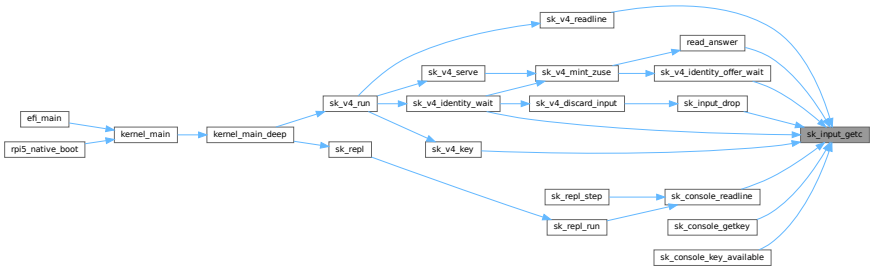
References console_getc(), g_kbd_poll_tick, heartbeat_ticks(), sk_kbd_getc(), xhci_keyboard_running(), and xhci_poll_events().

Referenced by read_answer(), sk_console_getkey(), sk_console_key_available(), sk_console_readline(), sk_input_drop(), sk_v4_identity_offer_wait(), sk_v4_identity_wait(), sk_v4_key(), and sk_v4_readline().

Here is the call graph for this function:

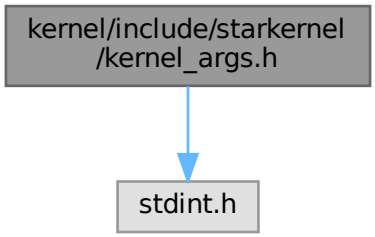


Here is the caller graph for this function:



7.50 kernel/include/starkernel/kernel_args.h File Reference

`#include <stdint.h>`
Include dependency graph for kernel_args.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct KernelArgs

Macros

- #define KERNEL_ARGS_CMDLINE_MAX 512
- #define KARGS_DEFAULT_STACK_SIZE (2ULL ∗ 1024ULL ∗ 1024ULL) /∗ 2 MB ∗/
- #define KARGS_DEFAULT_HEAP_SIZE (2ULL ∗ 1024ULL ∗ 1024ULL ∗ 1024ULL) /∗ 2 GB ∗/
- #define KARGS_DEFAULT_LOG_LEVEL 2 /∗ warn — quiet by default; --log-level=info/debug re-enables ECW word-execution tracing ∗/

- #define KARGS_DEFAULT_RUN_DOE 0
- #define KARGS_SYSTEM_DEFAULT 0
- #define KARGS_SYSTEM_V3 3
- #define KARGS_SYSTEM_V4 4
- #define KARGS_LOG_DEBUG 0
- #define KARGS_LOG_INFO 1
- #define KARGS_LOG_WARN 2
- #define KARGS_LOG_ERROR 3
- #define REBOOT_MAX_TRIES 3

7.50.1 Macro Definition Documentation

7.50.1.1 KARGS_DEFAULT_HEAP_SIZE

```
#define KARGS_DEFAULT_HEAP_SIZE (2ULL * 1024ULL * 1024ULL * 1024ULL) /* 2 GB */
```

7.50.1.2 KARGS_DEFAULT_LOG_LEVEL

```
#define KARGS_DEFAULT_LOG_LEVEL 2 /* warn -- quiet by default; --log-level=info/debug re-enables
ECW word-execution tracing */
```

7.50.1.3 KARGS_DEFAULT_RUN_DOE

```
#define KARGS_DEFAULT_RUN_DOE 0
```

7.50.1.4 KARGS_DEFAULT_STACK_SIZE

```
#define KARGS_DEFAULT_STACK_SIZE (2ULL * 1024ULL * 1024ULL) /* 2 MB */
```

7.50.1.5 KARGS_LOG_DEBUG

```
#define KARGS_LOG_DEBUG 0
```

7.50.1.6 KARGS_LOG_ERROR

```
#define KARGS_LOG_ERROR 3
```

7.50.1.7 KARGS_LOG_INFO

```
#define KARGS_LOG_INFO 1
```

7.50.1.8 KARGS_LOG_WARN

```
#define KARGS_LOG_WARN 2
```

7.50.1.9 KARGS_SYSTEM_DEFAULT

```
#define KARGS_SYSTEM_DEFAULT 0
```

7.50.1.10 KARGS_SYSTEM_V3

```
#define KARGS_SYSTEM_V3 3
```

7.50.1.11 KARGS_SYSTEM_V4

```
#define KARGS_SYSTEM_V4 4
```

7.50.1.12 KERNEL_ARGS_CMDLINE_MAX

```
#define KERNEL_ARGS_CMDLINE_MAX 512
```

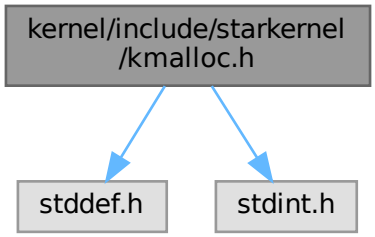
7.50.1.13 REBOOT_MAX_TRIES

```
#define REBOOT_MAX_TRIES 3
```

7.51 kernel/include/starkernel/kmalloc.h File Reference

```
#include <stddef.h>
#include <stdint.h>
```

Include dependency graph for kmalloc.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct kmalloc_stats_t

  kmalloc.h - Kernel heap allocator interface

Functions

- int kmalloc_init (uint64_t heap_size_bytes)
- int kmalloc_is_initialized (void)
- void * kmalloc (size_t size)
- void * kmalloc_aligned (size_t size, size_t align)
- void kfree (void *ptr)
- kmalloc_stats_t kmalloc_get_stats (void)
- uintptr_t kmalloc_heap_base_addr (void)
- uintptr_t kmalloc_heap_end_addr (void)
- void kmalloc_debug_census (size_t *out_largest_free, size_t *out_free_count, size_t *out_used_count, size_t *out_total_blocks)
- void kmalloc_debug_census_bytes (size_t *out_total_free_bytes, size_t *out_total_used_bytes)

7.51.1 Function Documentation

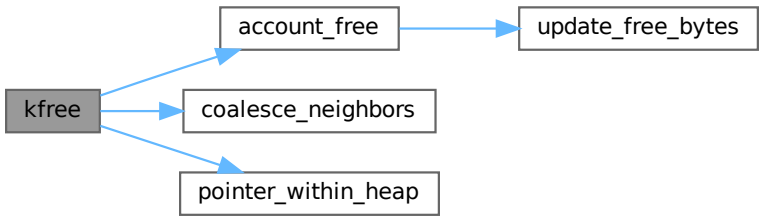
7.51.1.1 kfree()

```
void kfree (
            void * ptr )
```

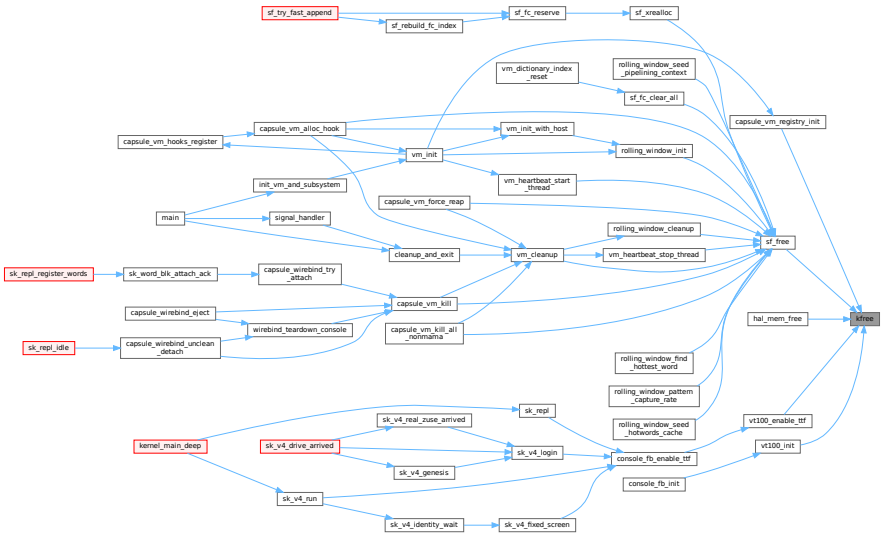
References account_free(), kmalloc_prefix_t::block, coalesce_neighbors(), heap_block::free, heap_initialized, KMALLOC_MAGIC, kmalloc_prefix_t::magic, pointer_within_heap(), and heap_block::requested.

Referenced by capsule_vm_registry_init(), hal_mem_free(), sf_free(), vt100_enable_ttf(), and vt100_init().

Here is the call graph for this function:



Here is the caller graph for this function:



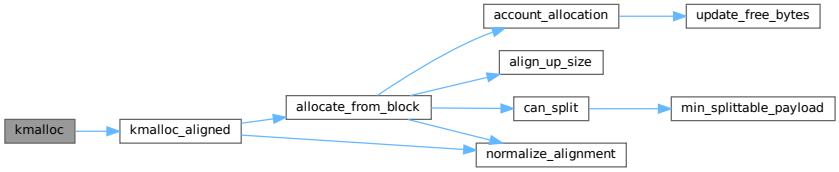
7.51.1.2 kmalloc()

```
void * kmalloc (
            size_t size )
```

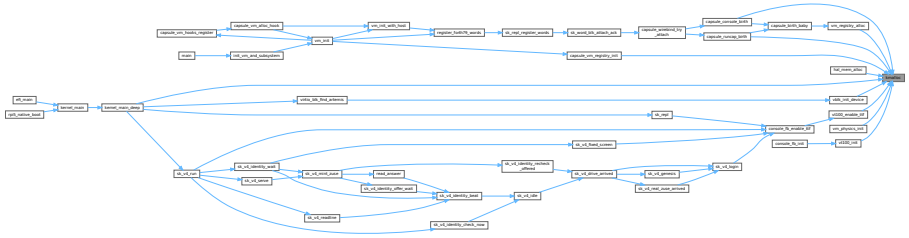
References kmalloc_aligned(), and KMALLOC_MIN_ALIGN.

Referenced by capsule_console_birth(), capsule_runcap_birth(), capsule_vm_registry_init(), hal_mem_alloc(), kernel_main_deep(), vblk_init_device(), vm_physics_init(), vm_registry_alloc(), vt100_enable_ttf(), and vt100_init().

Here is the call graph for this function:



Here is the caller graph for this function:



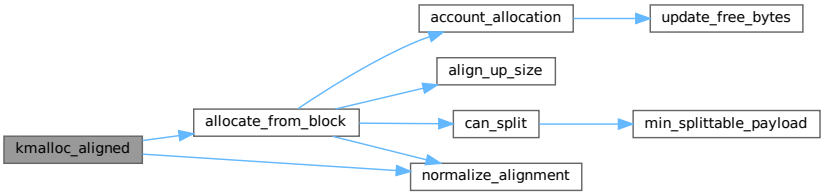
7.51.1.3 kmalloc_aligned()

```
void * kmalloc_aligned (
            size_t size,
            size_t align )
```

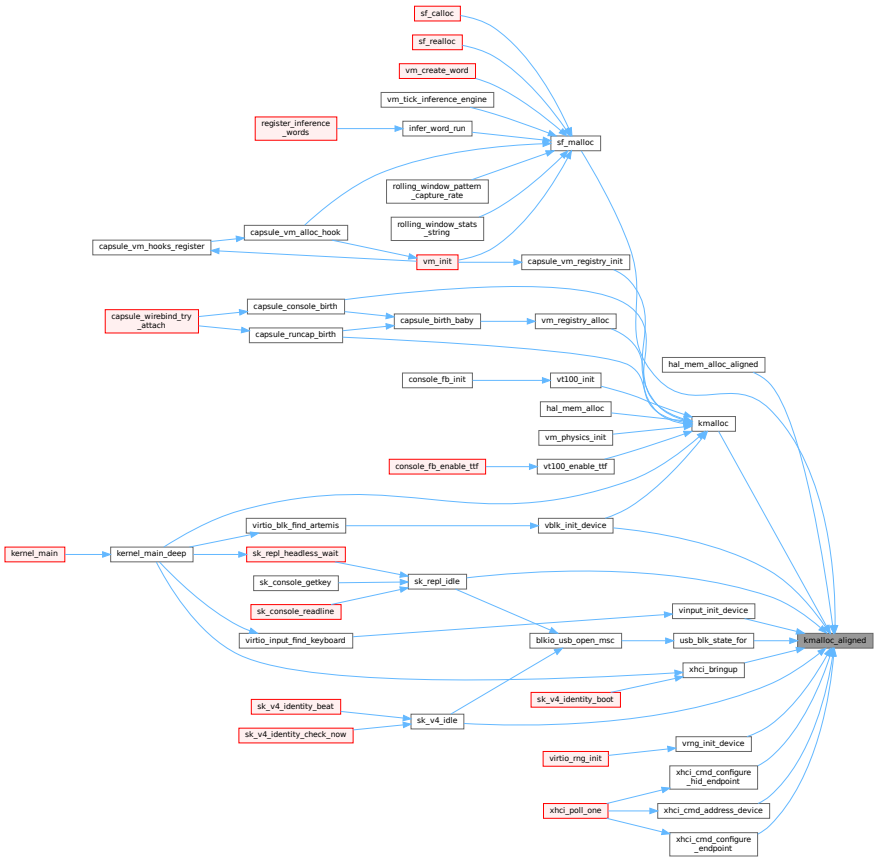
References allocate_from_block(), heap_block::free, heap_head, heap_initialized, heap_block::next, and normalize_alignment().

Referenced by hal_mem_alloc_aligned(), kmalloc(), sf_malloc(), sk_repl_idle(), sk_v4_idle(), usb_blk_state_for(), vblk_init_device(), vinput_init_device(), vrng_init_device(), xhci_bringup(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint and xhci_cmd_configure_hid_endpoint().

Here is the call graph for this function:



Here is the caller graph for this function:



7.51.1.4 kmalloc_debug_census()

```
void kmalloc_debug_census (
            size_t * out_largest_free,
            size_t * out_free_count,
            size_t * out_used_count,
            size_t * out_total_blocks )
```

References heap_block::free, heap_head, heap_block::next, and heap_block::size.

7.51.1.5 kmalloc_debug_census_bytes()

```
void kmalloc_debug_census_bytes (
            size_t * out_total_free_bytes,
            size_t * out_total_used_bytes )
```

References heap_block::free, heap_head, heap_block::next, and heap_block::size.

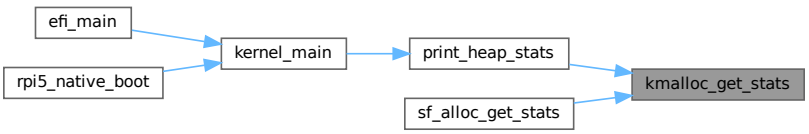
7.51.1.6 kmalloc_get_stats()

```
kmalloc_stats_t kmalloc_get_stats (
            void  )
```

References heap_stats.

Referenced by print_heap_stats(), and sf_alloc_get_stats().

Here is the caller graph for this function:



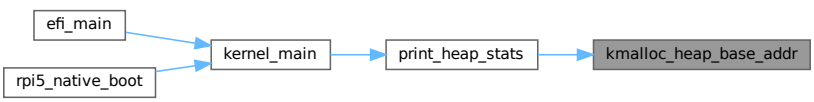
7.51.1.7 kmalloc_heap_base_addr()

```
uintptr_t kmalloc_heap_base_addr (
            void  )
```

References heap_base.

Referenced by print_heap_stats().

Here is the caller graph for this function:



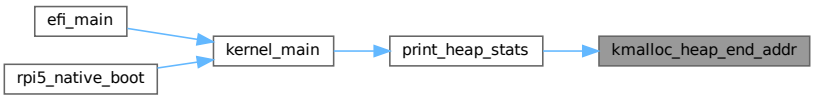
7.51.1.8 kmalloc_heap_end_addr()

```
uintptr_t kmalloc_heap_end_addr (
            void  )
```

References heap_base, and heap_size.

Referenced by print_heap_stats().

Here is the caller graph for this function:



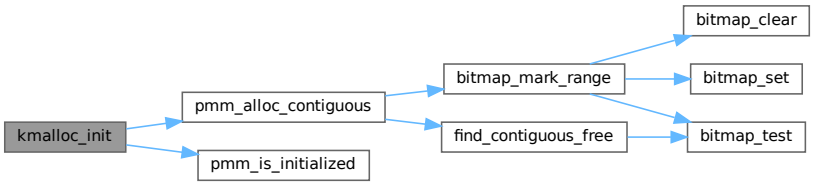
7.51.1.9 kmalloc_init()

```
int kmalloc_init (
            uint64_t heap_size_bytes )
```

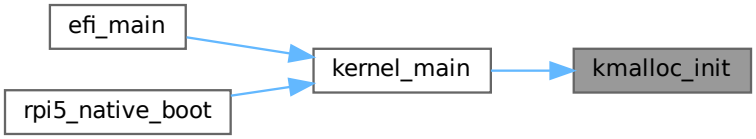
References heap_block::free, kmalloc_stats_t::free_bytes, heap_base, heap_head, heap_initialized, heap_size, heap_stats, KMALLOC_DEFAULT_HEAP_SIZE, KMALLOC_MIN_PAGES, heap_block::next, kmalloc_stats_t::peak_bytes, pmm_alloc_contiguous(), pmm_is_initialized(), PMM_PAGE_SIZE, heap_block::prev, heap_block::requested, heap_block::size, kmalloc_stats_t::total_bytes, and kmalloc_stats_t::used_bytes.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.51.1.10 kmalloc_is_initialized()

```
int kmalloc_is_initialized (
            void  )
```

References heap_initialized.

7.52 kernel/include/starkernel/log_attrib.h File Reference

Functions

- struct VM * vm_log_attributed_vm (void)

7.52.1 Function Documentation

7.52.1.1 vm_log_attributed_vm()

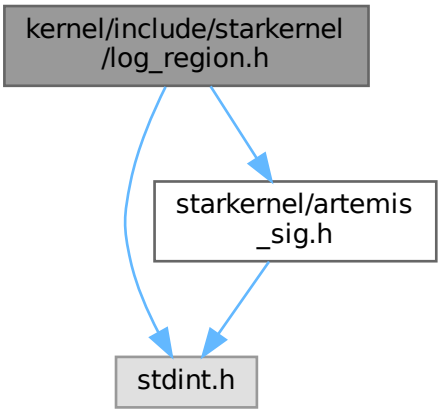
```
struct VM * vm_log_attributed_vm (
            void  )
```

References g_log_attrib_vm.

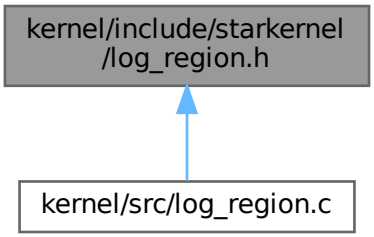
7.53 kernel/include/starkernel/log_region.h File Reference

```
#include <stdint.h>
#include "starkernel/artemis_sig.h"
```

Include dependency graph for log_region.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct log_region_ctrl_t
- struct log_slot_t

Macros

- #define LOG_REGION_DEVBLOCK_FROM_TOP_BASE (ARTEMIS_SIG_DEVBLOCK_FROM_TOP + 1u) /* 65 */

  log_region.h - Growable per-VM log-persistence ring on Artemis's own disk (FABRIC-3.md ?XXVI follow-on, Step 4, 2026-09-13)
- #define LOG_REGION_INITIAL_DEVBLOCKS 4u /* slot devblocks at first use, excludes control header */
- #define LOG_REGION_GROWTH_INCREMENT 4u
- #define LOG_REGION_MAX_DEVBLOCKS 32u /* ceiling -- devblock_from_top stays within [66,96] */
- #define LOG_REGION_PROTECTED_MAX_LEVEL 1u /* LOG_WARN and below (ERROR, WARN) */
- #define LOG_SLOTS_PER_DEVBLOCK 4u /* 4 x 1 KiB forth-blocks per 4 KiB devblock */
- #define LOG_SLOT_SIZE 1024u
- #define LOG_REGION_MAGIC 0x474C474Cull /* 'LGLG' */
- #define LOG_REGION_VERSION_0 0
- #define LOG_REGION_PACK(ver) (LOG_REGION_MAGIC | ((uint64_t)(ver) << 32))
- #define LOG_REGION_GET_MAGIC(m) ((uint32_t)((m) & 0xFFFFFFFFull))
- #define LOG_REGION_GET_VERSION(m) ((uint8_t)(((m) >> 32) & 0xFF))
- #define LOG_SLOT_SOURCE_MAX 16u /* NUL-padded VM/source tag, e.g. "Hera", "HADES" */
- #define LOG_SLOT_MSG_MAX (LOG_SLOT_SIZE - 8u - 2u - 1u - LOG_SLOT_SOURCE_MAX) /* 997 */

Typedefs

- typedef char log_region_ctrl_size_check[(sizeof(log_region_ctrl_t)==4096) ? 1 :-1]
- typedef char log_slot_size_check[(sizeof(log_slot_t)==1024u) ? 1 :-1]

Functions

- int log_region_append (uint8_t level, uint64_t timestamp, const char *source, uint32_t source_len, const char *msg, uint32_t msg_len)
- int log_region_read_recent (uint32_t back, log_slot_t *out)

  log_region_read_recent - read one record back (2026-10-14, for LOG-SHOW).

7.53.1 Macro Definition Documentation

7.53.1.1 LOG_REGION_DEVBLOCK_FROM_TOP_BASE

```
#define LOG_REGION_DEVBLOCK_FROM_TOP_BASE (ARTEMIS_SIG_DEVBLOCK_FROM_TOP + 1u) /* 65 */
```

log_region.h - Growable per-VM log-persistence ring on Artemis's own disk (FABRIC-3.md ?XXVI follow-on, Step 4, 2026-09-13)

Records real log_message() output (INFO and above, independent of the console's own current_level filter) so a run survives past the QEMU serial log – the motivating case is comparing bare-metal and QEMU results directly as a DoE factor once bare-metal boot lands, where the only artifact both platforms share is whatever got persisted to disk.

Lives in the SAME top-of-device system-metadata fence artemis_sig_t and Zuse's genesis marker already uses (block_subsystem.h's blk_meta_zone_read()/write(), devblock_from_top addressing) – reached the SAME way, deliberately NOT through artemis_sig.c's own independent blkio_info()-based arithmetic. That arithmetic exists only because artemis_sig_t must be discoverable on a device that isn't attached yet (bus-agnostic discovery, repl.c's idle-loop USB-MSC scan); this ring is only ever read or written once Artemis's disk is already attached and formatted (LOG-APPEND runs inside Artemis's own already-live dictionary context, dispatched by a sender's MSG-SEND/↩ MSG-TICK), so blk_meta_zone_∗() – which requires exactly that already-attached state – is the correct, simpler, already-tested tool, not a limitation to work around.

Fixed devblock_from_top allocation (NOT persisted in artemis_sig_t's own log_region_offset/log_region_devblocks fields – those stay at their genesis-time value of 0/0, "informational only, control header below is authoritative," documented in artemis_sig.h; two writers of the same fact was rejected as unnecessary drift risk): 64 – artemis_sig_t itself (ARTEMIS_SIG_DEVBLOCK_FROM_TOP) 65 – this ring's control header (LOG_REGION_DEVBLOCK_↩ FROM_TOP_BASE) 66-96 – this ring's slot devblocks, growable up to LOG_REGION_MAX_DEVBLOCKS Chosen clear of Zuse's genesis marker (devblock_from_top=0) and of devblocks 1-63, reserved and unused since Zuse's eligibility list was removed (2026-10-14, FABRIC-3.md SXXXVII).

Ring granularity is one whole devblock-quarter (LOG_SLOT_SIZE, 1024 bytes = exactly one blkio forth-block) per record – avoids any partial-forth-block read-modify-write for the write itself (a slot write is one aligned blkio_write()-equivalent-sized unit); the surrounding devblock (4 slots) still needs a read-modify-write via blk_meta_zone_read()/write() since that accessor's own unit is one full 4 KiB devblock, but that cost is the same regardless of slot size. Records are truncated to fit one slot rather than spanning multiple – simple, real, and sufficient for what's actually persisted (see vm_log_buffer.h's own tighter caps, chosen to fit a whole batch of several records inside one VM-EXEC/MSG-SEND line, INPUT_BUFFER_SIZE=1025).

7.53.1.2 LOG_REGION_GET_MAGIC

```
#define LOG_REGION_GET_MAGIC(
              m ) ((uint32_t)((m) & 0xFFFFFFFFull))
```

7.53.1.3 LOG_REGION_GET_VERSION

```
#define LOG_REGION_GET_VERSION(
              m ) ((uint8_t)(((m) >> 32) & 0xFF))
```

7.53.1.4 LOG_REGION_GROWTH_INCREMENT

```
#define LOG_REGION_GROWTH_INCREMENT 4u
```

7.53.1.5 LOG_REGION_INITIAL_DEVBLOCKS

```
#define LOG_REGION_INITIAL_DEVBLOCKS 4u /* slot devblocks at first use, excludes control header
*/
```

7.53.1.6 LOG_REGION_MAGIC

```
#define LOG_REGION_MAGIC 0x474C474Cull /* 'LGLG' */
```

7.53.1.7 LOG_REGION_MAX_DEVBLOCKS

```
#define LOG_REGION_MAX_DEVBLOCKS 32u /* ceiling -- devblock_from_top stays within [66,96] */
```

7.53.1.8 LOG_REGION_PACK

```
#define LOG_REGION_PACK(
             ver )  (LOG_REGION_MAGIC | ((uint64_t)(ver) << 32))
```

7.53.1.9 LOG_REGION_PROTECTED_MAX_LEVEL

```
#define LOG_REGION_PROTECTED_MAX_LEVEL 1u /* LOG_WARN and below (ERROR, WARN) */
```

7.53.1.10 LOG_REGION_VERSION_0

```
#define LOG_REGION_VERSION_0 0
```

7.53.1.11 LOG_SLOT_MSG_MAX

```
#define LOG_SLOT_MSG_MAX (LOG_SLOT_SIZE - 8u - 2u - 1u - LOG_SLOT_SOURCE_MAX) /* 997 */
```

7.53.1.12 LOG_SLOT_SIZE

```
#define LOG_SLOT_SIZE 1024u
```

7.53.1.13 LOG_SLOT_SOURCE_MAX

```
#define LOG_SLOT_SOURCE_MAX 16u /* NUL-padded VM/source tag, e.g.  "Hera", "HADES" */
```

7.53.1.14 LOG_SLOTS_PER_DEVBLOCK

```
#define LOG_SLOTS_PER_DEVBLOCK 4u /* 4 x 1 KiB forth-blocks per 4 KiB devblock */
```

7.53.2 Typedef Documentation

7.53.2.1 log_region_ctrl_size_check

```
typedef char log_region_ctrl_size_check[(sizeof(log_region_ctrl_t)==4096) ?  1 :-1]
```

7.53.2.2 log_slot_size_check

```
typedef char log_slot_size_check[(sizeof(log_slot_t)== 1024u) ?  1 :-1]
```

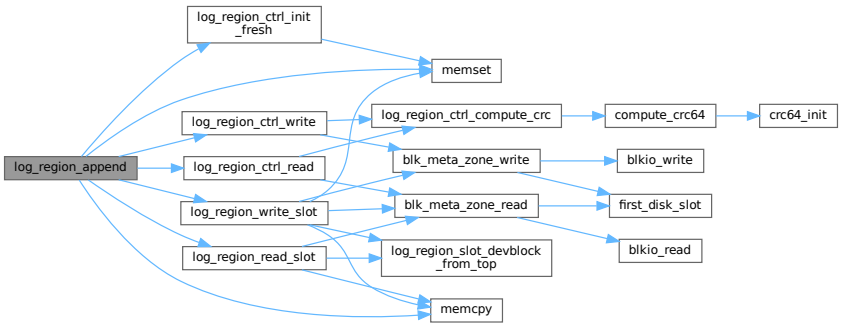
7.53.3 Function Documentation

7.53.3.1 log_region_append()

```
int log_region_append (
            uint8_t level,
            uint64_t timestamp,
            const char * source,
            uint32_t source_len,
            const char * msg,
            uint32_t msg_len )
```

References log_region_ctrl_t::devblocks, log_region_ctrl_t::head_slot, log_slot_t::level, level, log_region_ctrl_init_fresh(), log_region_ctrl_read(), log_region_ctrl_write(), LOG_REGION_GROWTH_INCREMENT, LOG_REGION_MAX_DEVBLOCKS, LOG_REGION_PROTECTED_MAX_LEVEL, log_region_read_slot(), log_region_write_slot(), LOG_SLOT_MSG_MAX, LOG_SLOT_SOURCE_MAX, LOG_SLOTS_PER_DEVBLOCK, memcpy(), memset(), log_slot_t::msg, log_slot_t::msg_len, log_region_ctrl_t::record_count, log_slot_t::source, log_region_ctrl_t::tail_slot, and log_slot_t::timestamp.

Here is the call graph for this function:



7.53.3.2 log_region_read_recent()

```
int log_region_read_recent (
            uint32_t back,
            log_slot_t * out )
```

log_region_read_recent - read one record back (2026-10-14, for LOG-SHOW).

Parameters

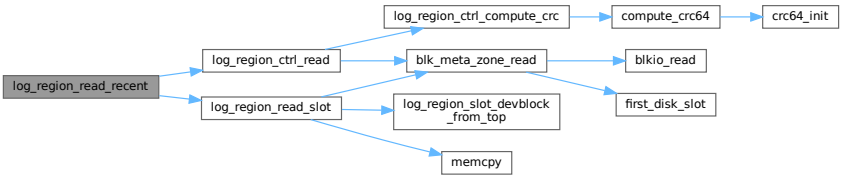
back	0 for the newest record, 1 for the one before it, ...
out	Filled with the record.

Returns

0 on success, 1 if there is no such record (the ring holds fewer than back+1, or none at all), -1 on a read failure or no ring.

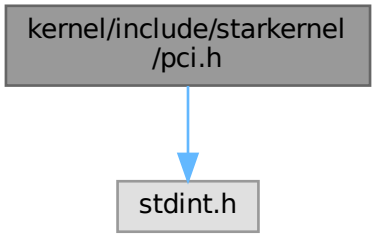
References log_region_ctrl_t::devblocks, log_region_ctrl_read(), log_region_read_slot(), LOG_SLOTS_PER_DEVBLOCK, log_region_ctrl_t::record_count, and log_region_ctrl_t::tail_slot.

Here is the call graph for this function:

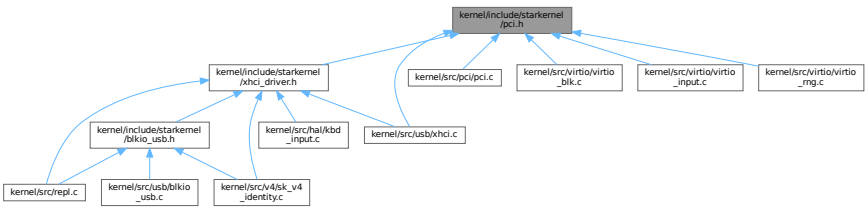


7.54 kernel/include/starkernel/pci.h File Reference

`#include <stdint.h>`
Include dependency graph for pci.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct PciDevice

Macros

- #define PCI_CFG_VENDOR_ID 0x00
- #define PCI_CFG_DEVICE_ID 0x02
- #define PCI_CFG_COMMAND 0x04
- #define PCI_CFG_STATUS 0x06
- #define PCI_CFG_CLASS_REV 0x08
- #define PCI_CFG_HEADER_TYPE 0x0E
- #define PCI_CFG_BAR0 0x10
- #define PCI_CFG_BAR1 0x14
- #define PCI_CFG_BAR2 0x18
- #define PCI_CFG_BAR3 0x1C
- #define PCI_CFG_BAR4 0x20
- #define PCI_CFG_BAR5 0x24
- #define PCI_CFG_CAP_PTR 0x34
- #define PCI_CFG_INT_LINE 0x3C
- #define PCI_CFG_INT_PIN 0x3D /∗ 0=none, 1=INTA .. 4=INTD (item 4.3.5c/4.3.5d) ∗/
- #define PCI_CMD_IO_SPACE (1u << 0)
- #define PCI_CMD_MEM_SPACE (1u << 1)
- #define PCI_CMD_BUS_MASTER (1u << 2)
- #define PCI_CMD_INTX_DISABLE
- #define PCI_BAR_TYPE_MASK 0x1u
- #define PCI_BAR_IO 0x1u
- #define PCI_BAR_MEM_64 0x4u /∗ bits [2:1] == 10 in memory BAR ∗/

Functions

- int pci_init (void ∗rsdp)
- int pci_find_first (uint16_t vendor_id, uint16_t device_id, PciDevice ∗out)
- int pci_find_class (uint8_t class_code, uint8_t subclass, uint8_t prog_if, unsigned index, PciDevice ∗out)
- uint32_t pci_read32 (const PciDevice ∗d, uint16_t offset)
- uint16_t pci_read16 (const PciDevice ∗d, uint16_t offset)
- uint8_t pci_read8 (const PciDevice ∗d, uint16_t offset)
- void pci_write32 (const PciDevice ∗d, uint16_t offset, uint32_t val)
- void pci_write16 (const PciDevice ∗d, uint16_t offset, uint16_t val)
- void pci_write8 (const PciDevice ∗d, uint16_t offset, uint8_t val)
- void pci_enable (const PciDevice ∗d)
- uint64_t pci_bar (const PciDevice ∗d, int bar_idx)
- uint64_t pci_bar_size (const PciDevice ∗d, int bar_idx)
- int pci_map_bar (uint64_t phys_addr, uint64_t size)

7.54.1 Macro Definition Documentation

7.54.1.1 PCI_BAR_IO

```
#define PCI_BAR_IO 0x1u
```

7.54.1.2 PCI_BAR_MEM_64

```
#define PCI_BAR_MEM_64 0x4u /* bits [2:1] == 10 in memory BAR */
```

7.54.1.3 PCI_BAR_TYPE_MASK

```
#define PCI_BAR_TYPE_MASK 0x1u
```

7.54.1.4 PCI_CFG_BAR0

```
#define PCI_CFG_BAR0 0x10
```

7.54.1.5 PCI_CFG_BAR1

```
#define PCI_CFG_BAR1 0x14
```

7.54.1.6 PCI_CFG_BAR2

```
#define PCI_CFG_BAR2 0x18
```

7.54.1.7 PCI_CFG_BAR3

```
#define PCI_CFG_BAR3 0x1C
```

7.54.1.8 PCI_CFG_BAR4

```
#define PCI_CFG_BAR4 0x20
```

7.54.1.9 PCI_CFG_BAR5

```
#define PCI_CFG_BAR5 0x24
```

7.54.1.10 PCI_CFG_CAP_PTR

```
#define PCI_CFG_CAP_PTR 0x34
```

7.54.1.11 PCI_CFG_CLASS_REV

```
#define PCI_CFG_CLASS_REV 0x08
```

7.54.1.12 PCI_CFG_COMMAND

```
#define PCI_CFG_COMMAND 0x04
```

7.54.1.13 PCI_CFG_DEVICE_ID

```
#define PCI_CFG_DEVICE_ID 0x02
```

7.54.1.14 PCI_CFG_HEADER_TYPE

```
#define PCI_CFG_HEADER_TYPE 0x0E
```

7.54.1.15 PCI_CFG_INT_LINE

```
#define PCI_CFG_INT_LINE 0x3C
```

7.54.1.16 PCI_CFG_INT_PIN

```
#define PCI_CFG_INT_PIN 0x3D /* 0=none, 1=INTA ..  4=INTD (item 4.3.5c/4.3.5d) */
```

7.54.1.17 PCI_CFG_STATUS

```
#define PCI_CFG_STATUS 0x06
```

7.54.1.18 PCI_CFG_VENDOR_ID

```
#define PCI_CFG_VENDOR_ID 0x00
```

7.54.1.19 PCI_CMD_BUS_MASTER

```
#define PCI_CMD_BUS_MASTER (1u << 2)
```

7.54.1.20 PCI_CMD_INTX_DISABLE

```
#define PCI_CMD_INTX_DISABLE
```

Value:

```
(1u « 10)  /* item 4.3.5c/4.3.5e: pci_enable() never
* clears this -- if firmware left it set,
* INTx never asserts. Check explicitly. */
```

7.54.1.21 PCI_CMD_IO_SPACE

```
#define PCI_CMD_IO_SPACE (1u << 0)
```

7.54.1.22 PCI_CMD_MEM_SPACE

```
#define PCI_CMD_MEM_SPACE (1u << 1)
```

7.54.2 Function Documentation

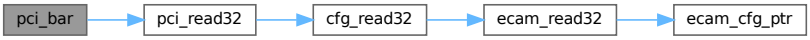
7.54.2.1 pci_bar()

```
uint64_t pci_bar (
            const PciDevice * d,
            int bar_idx )
```

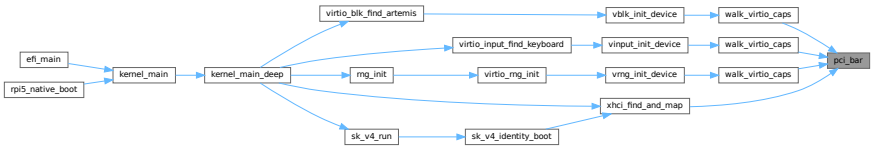
References PCI_BAR_MEM_64, PCI_BAR_TYPE_MASK, PCI_CFG_BAR0, and pci_read32().

Referenced by walk_virtio_caps(), walk_virtio_caps(), walk_virtio_caps(), and xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:



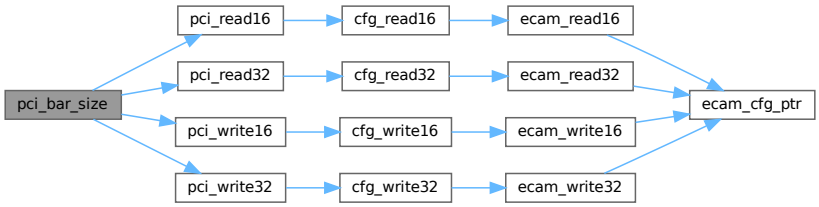
7.54.2.2 pci_bar_size()

```
uint64_t pci_bar_size (
            const PciDevice * d,
            int bar_idx )
```

References PCI_BAR_MEM_64, PCI_BAR_TYPE_MASK, PCI_CFG_BAR0, PCI_CFG_COMMAND, PCI_CMD_MEM_SPACE, pci_read16(), pci_read32(), pci_write16(), and pci_write32().

Referenced by xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:

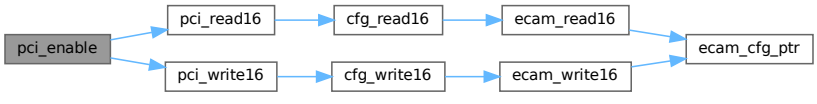
7.54.2.3 pci_enable()

```
void pci_enable (
            const PciDevice * d )
```

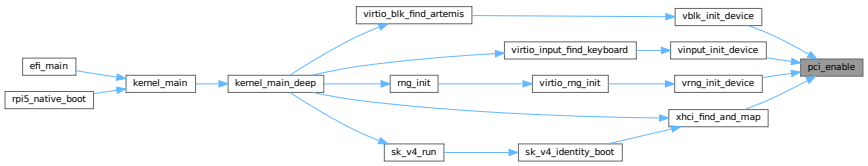
References PCI_CFG_COMMAND, PCI_CMD_BUS_MASTER, PCI_CMD_IO_SPACE, PCI_CMD_MEM_SPACE, pci_read16(), and pci_write16().

Referenced by vblk_init_device(), vinput_init_device(), vrng_init_device(), and xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:



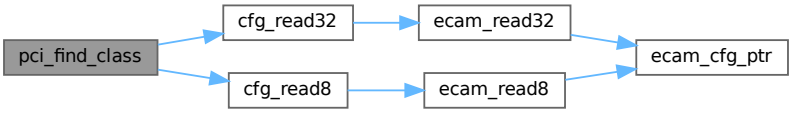
7.54.2.4 pci_find_class()

```
int pci_find_class (
            uint8_t class_code,
            uint8_t subclass,
            uint8_t prog_if,
            unsigned index,
            PciDevice * out )
```

References PciDevice::bus, cfg_read32(), cfg_read8(), PciDevice::device, PciDevice::device_id, PciDevice::function, g_bus_first, g_bus_last, g_ecam_base, PCI_CFG_CLASS_REV, PCI_CFG_HEADER_TYPE, PCI_CFG_VENDOR_ID, and PciDevice::vendor_id.

Referenced by xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:

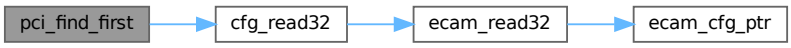
7.54.2.5 pci_find_first()

```
int pci_find_first (
            uint16_t vendor_id,
            uint16_t device_id,
            PciDevice * out )
```

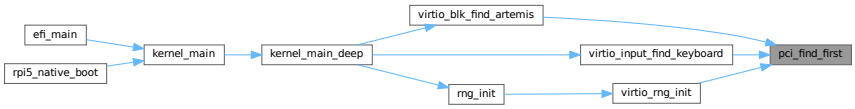
References PciDevice::bus, cfg_read32(), PciDevice::device, PciDevice::device_id, PciDevice::function, PCI_CFG_VENDOR_ID, and PciDevice::vendor_id.

Referenced by virtio_blk_find_artemis(), virtio_input_find_keyboard(), and virtio_rng_init().

Here is the call graph for this function:



Here is the caller graph for this function:



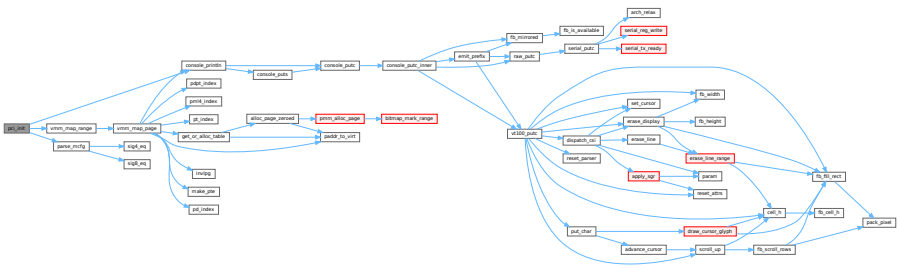
7.54.2.6 pci_init()

```
int pci_init (
            void * rsdp )
```

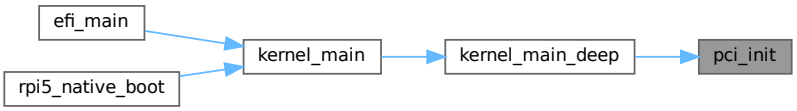
References console_println(), g_ecam_base, parse_mcfg(), VMM_FLAG_CACHE_DISABLE, VMM_FLAG_WRITABLE, and vmm_map_range().

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



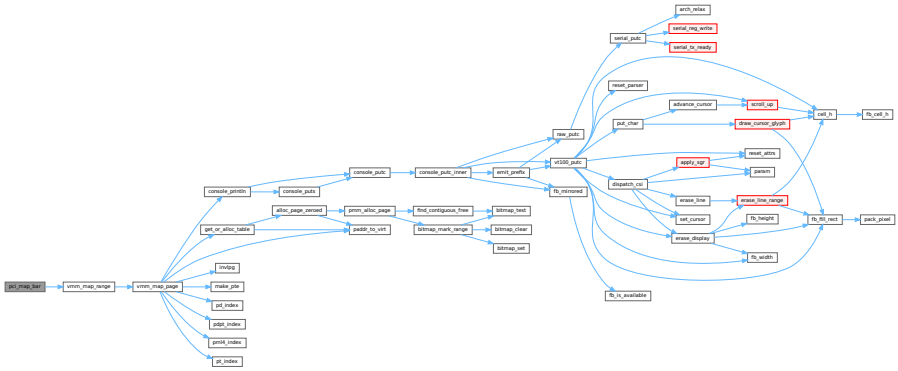
7.54.2.7 pci_map_bar()

```
int pci_map_bar (
            uint64_t phys_addr,
            uint64_t size )
```

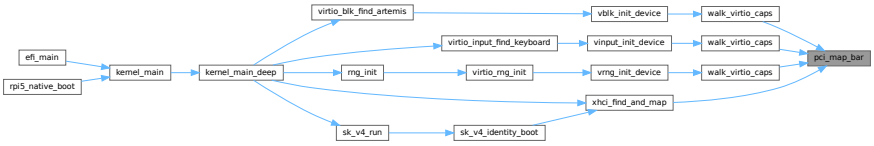
References VMM_FLAG_CACHE_DISABLE, VMM_FLAG_WRITABLE, and vmm_map_range().

Referenced by walk_virtio_caps(), walk_virtio_caps(), walk_virtio_caps(), and xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:



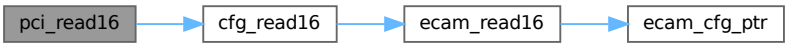
7.54.2.8 pci_read16()

```
uint16_t pci_read16 (
            const PciDevice * d,
            uint16_t offset )
```

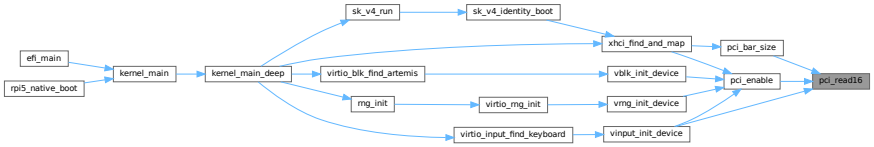
References PciDevice::bus, cfg_read16(), PciDevice::device, and PciDevice::function.

Referenced by pci_bar_size(), pci_enable(), and vinput_init_device().

Here is the call graph for this function:



Here is the caller graph for this function:



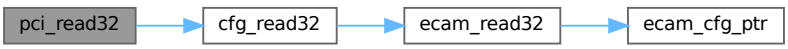
7.54.2.9 pci_read32()

```
uint32_t pci_read32 (
            const PciDevice * d,
            uint16_t offset )
```

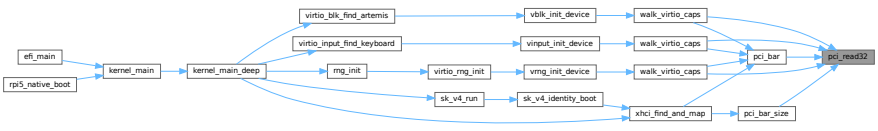
References PciDevice::bus, cfg_read32(), PciDevice::device, and PciDevice::function.

Referenced by pci_bar(), pci_bar_size(), walk_virtio_caps(), walk_virtio_caps(), and walk_virtio_caps().

Here is the call graph for this function:



Here is the caller graph for this function:



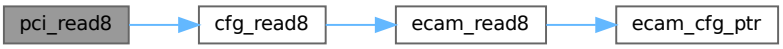
7.54.2.10 pci_read8()

```
uint8_t pci_read8 (
            const PciDevice * d,
            uint16_t offset )
```

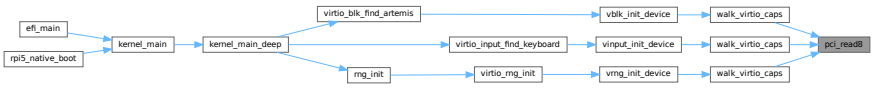
References PciDevice::bus, cfg_read8(), PciDevice::device, and PciDevice::function.

Referenced by walk_virtio_caps(), walk_virtio_caps(), and walk_virtio_caps().

Here is the call graph for this function:



Here is the caller graph for this function:



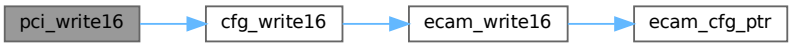
7.54.2.11 pci_write16()

```
void pci_write16 (
            const PciDevice * d,
            uint16_t offset,
            uint16_t val )
```

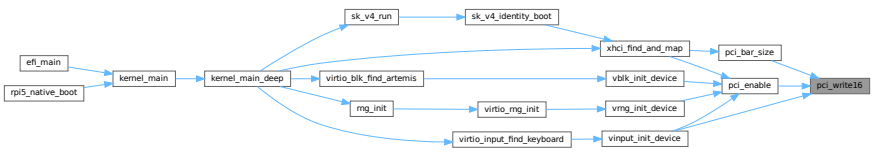
References PciDevice::bus, cfg_write16(), PciDevice::device, and PciDevice::function.

Referenced by pci_bar_size(), pci_enable(), and vinput_init_device().

Here is the call graph for this function:



Here is the caller graph for this function:



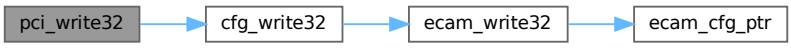
7.54.2.12 pci_write32()

```
void pci_write32 (
            const PciDevice * d,
            uint16_t offset,
            uint32_t val )
```

References PciDevice::bus, cfg_write32(), PciDevice::device, and PciDevice::function.

Referenced by pci_bar_size().

Here is the call graph for this function:



Here is the caller graph for this function:

7.54.2.13 pci_write8()

```
void pci_write8 (
            const PciDevice * d,
            uint16_t offset,
            uint8_t val )
```

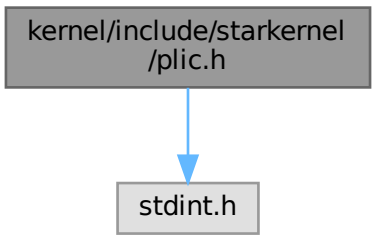
References PciDevice::bus, cfg_write8(), PciDevice::device, and PciDevice::function.

Here is the call graph for this function:

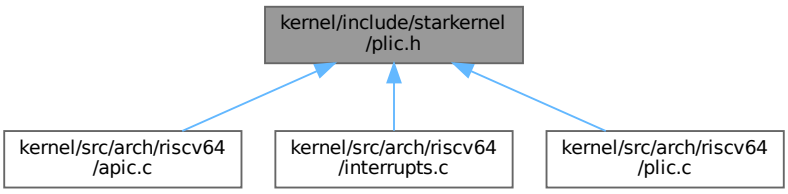
7.55 kernel/include/starkernel/pie_hidden.h File Reference

7.56 kernel/include/starkernel/plic.h File Reference

`#include <stdint.h>`
Include dependency graph for plic.h:



This graph shows which files directly or indirectly include this file:



Functions

- int plic_init (const void *dtb)

  plic.h - Platform-Level Interrupt Controller interface (riscv64 only)
- void plic_set_priority (uint32_t irq, uint32_t priority)

  Set a source's interrupt priority (1-7; 0 means "never interrupt").
- void plic_enable (uint32_t irq)

  Enable a source for the S-mode hart-0 context.
- void plic_disable (uint32_t irq)

  Disable a source for the S-mode hart-0 context.
- uint32_t plic_claim (void)

  Claim the highest-priority pending interrupt for the S-mode hart-0 context.
- void plic_complete (uint32_t irq)

  Signal completion of the source previously returned by plic_claim().

7.56.1 Function Documentation

7.56.1.1 plic_claim()

```
uint32_t plic_claim (
            void  )
```

Claim the highest-priority pending interrupt for the S-mode hart-0 context.

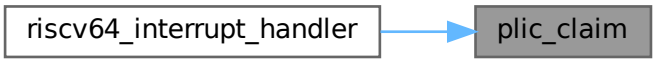
Returns the source ID, or 0 if none is pending.

References PLIC_CLAIM, PLIC_CONTEXT_S, and reg32().

Referenced by riscv64_interrupt_handler().

Here is the call graph for this function:

Here is the caller graph for this function:



7.56.1.2 plic_complete()

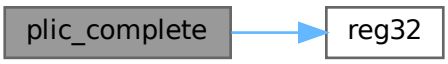
```
void plic_complete (
            uint32_t irq )
```

Signal completion of the source previously returned by plic_claim().

References PLIC_CLAIM, PLIC_CONTEXT_S, and reg32().

Referenced by riscv64_interrupt_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

7.56.1.3 plic_disable()

```
void plic_disable (
            uint32_t irq )
```

Disable a source for the S-mode hart-0 context.

References PLIC_CONTEXT_S, PLIC_ENABLE, and reg32().

Here is the call graph for this function:

7.56.1.4 plic_enable()

```
void plic_enable (
            uint32_t irq )
```

Enable a source for the S-mode hart-0 context.

References PLIC_CONTEXT_S, PLIC_ENABLE, and reg32().

Here is the call graph for this function:

7.56.1.5 plic_init()

```
int plic_init (
            const void * dtb )
```

plic.h - Platform-Level Interrupt Controller interface (riscv64 only)

Item 4.3.5a (FABRIC-0.md ?27.5): Phase 0 (0.2/0.3) only ever enabled the S-mode *timer* interrupt (sie.STIE). External interrupts (sie.SEIE) were never touched, and the PLIC – the only external-interrupt path on RISC-V, there is no legacy PIC or I/O APIC equivalent – had no driver at all before this item. Pure substrate: this item wires the mechanism (claim/dispatch/complete) with no permanent source enabled by default; a real consumer (4.3.5b, virtio-keyboard) enables its own source later.

`plic_init()` takes the boot DTB as of FABRIC-3.md ?V.3 item 3's fix, 2026-09-05: the base address was previously a QEMU-virt-specific hardcoded constant, unconditionally wrong on the Milk-V Mars's real JH7110 PLIC. See `plic.c`'s file header for the discovery mechanism. Map the PLIC and set the S-mode hart-0 context's priority threshold to 0 (maximally permissive – safe because nothing is enabled at any source by default; enabling a source is what actually lets it reach claim()). Also sets sie.SEIE. Does not touch sstatus.SIE – arch_enable_interrupts() still owns that, same as the timer.

Parameters

dtb	Candidate devicetree blob (`BootInfo->dtb`); NULL-safe. When a real `"sifive,plic-1.0.0"` node is found, the PLIC base address is read from its `reg` property; otherwise falls back to the QEMU-virt-machine constant, unchanged from this function's previous unconditional behaviour.

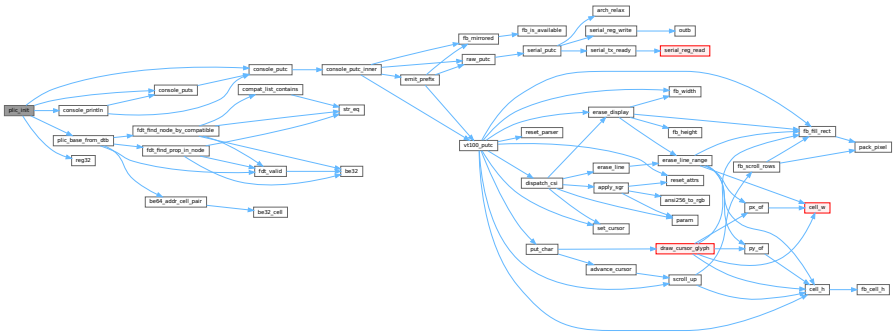
Returns

0 on success.

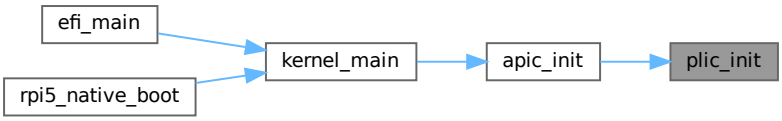
References console_println(), console_putc(), console_puts(), plic_base_from_dtb(), PLIC_CONTEXT_S, PLIC_THRESHOLD, reg32(), and s_plic_base.

Referenced by apic_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.56.1.6 plic_set_priority()

```
void plic_set_priority (
            uint32_t irq,
            uint32_t priority )
```

Set a source's interrupt priority (1-7; 0 means "never interrupt").

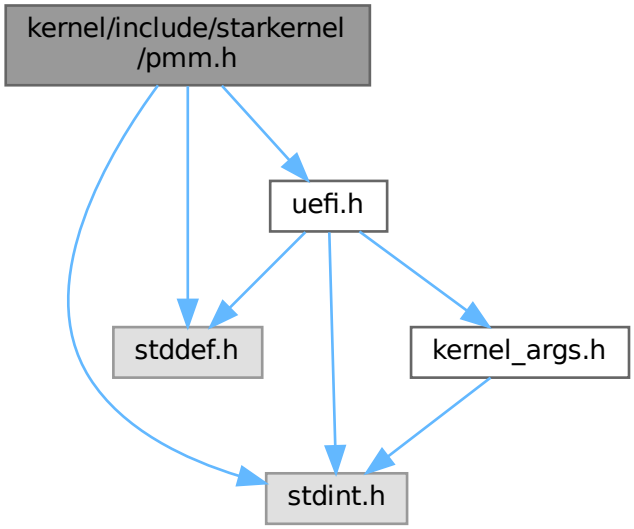
References PLIC_PRIORITY, and reg32().

Here is the call graph for this function:

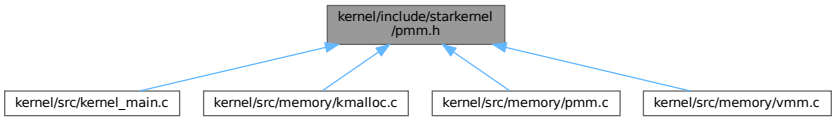
7.57 kernel/include/starkernel/pmm.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "uefi.h"
```

Include dependency graph for pmm.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct pmm_stats_t

Macros

- #define PMM_PAGE_SIZE 4096u

  pmm.h - Physical Memory Manager interface for StarKernel

Functions

- int pmm_init (BootInfo *boot_info)
- int pmm_is_initialized (void)
- uint64_t pmm_alloc_page (void)
- uint64_t pmm_alloc_contiguous (uint64_t num_pages)
- void pmm_free_page (uint64_t paddr)
- void pmm_free_contiguous (uint64_t paddr, uint64_t num_pages)
- pmm_stats_t pmm_get_stats (void)

7.57.1 Macro Definition Documentation

7.57.1.1 PMM_PAGE_SIZE

```
#define PMM_PAGE_SIZE 4096u
```

pmm.h - Physical Memory Manager interface for StarKernel

Bitmap-based allocator for 4KB physical pages. Initialization parses the UEFI memory map provided in BootInfo and exposes simple allocation and statistics helpers for early kernel bring-up.

7.57.2 Function Documentation

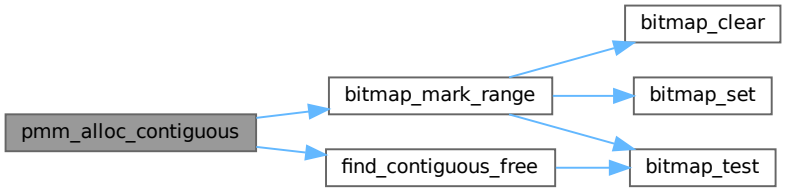
7.57.2.1 pmm_alloc_contiguous()

```
uint64_t pmm_alloc_contiguous (
            uint64_t num_pages )
```

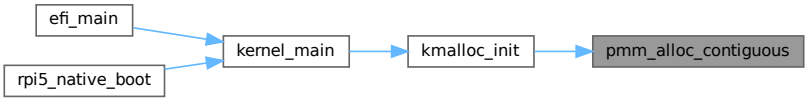
References bitmap_mark_range(), find_contiguous_free(), pmm_initialized, and PMM_PAGE_SIZE.

Referenced by kmalloc_init().

Here is the call graph for this function:



Here is the caller graph for this function:



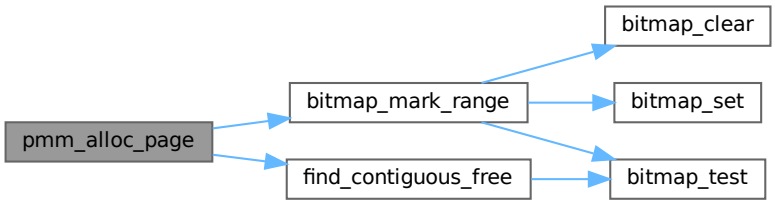
7.57.2.2 pmm_alloc_page()

```
uint64_t pmm_alloc_page (
            void  )
```

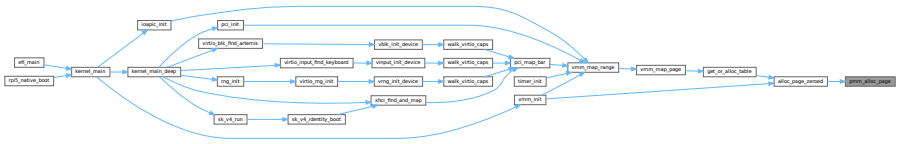
References bitmap_mark_range(), find_contiguous_free(), pmm_initialized, and PMM_PAGE_SIZE.

Referenced by alloc_page_zeroed().

Here is the call graph for this function:



Here is the caller graph for this function:



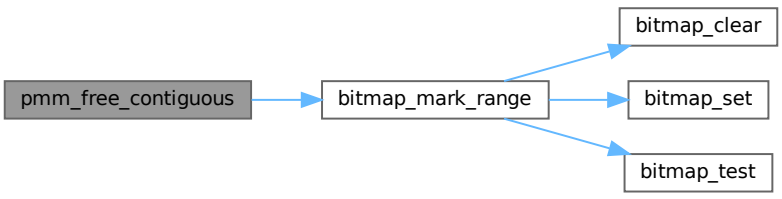
7.57.2.3 pmm_free_contiguous()

```
void pmm_free_contiguous (
            uint64_t paddr,
            uint64_t num_pages )
```

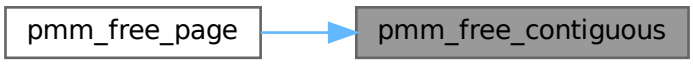
References bitmap_mark_range(), pmm_initialized, PMM_PAGE_SIZE, and pmm_tracked_pages.

Referenced by pmm_free_page().

Here is the call graph for this function:



Here is the caller graph for this function:

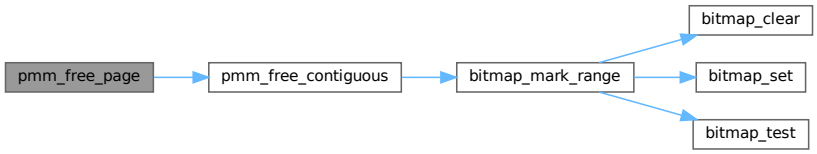


7.57.2.4 pmm_free_page()

```
void pmm_free_page (
            uint64_t paddr )
```

References pmm_free_contiguous(), pmm_initialized, and PMM_PAGE_SIZE.

Here is the call graph for this function:



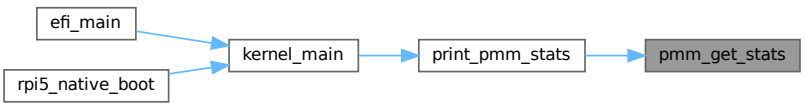
7.57.2.5 pmm_get_stats()

```
pmm_stats_t pmm_get_stats (
            void  )
```

References pmm_stats_t::free_bytes, pmm_stats_t::free_pages, pmm_free_pages, PMM_PAGE_SIZE, pmm_total_pages, pmm_stats_t::total_bytes, pmm_stats_t::total_pages, pmm_stats_t::used_bytes, and pmm_stats_t::used_pages.

Referenced by print_pmm_stats().

Here is the caller graph for this function:



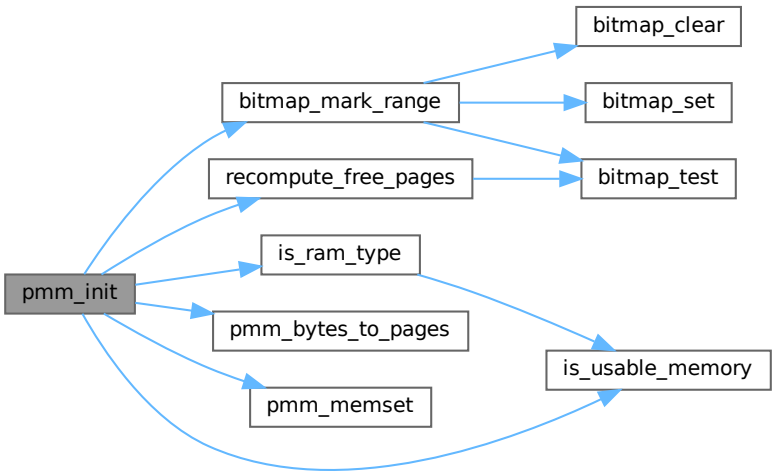
7.57.2.6 pmm_init()

```
int pmm_init (
            BootInfo * boot_info )
```

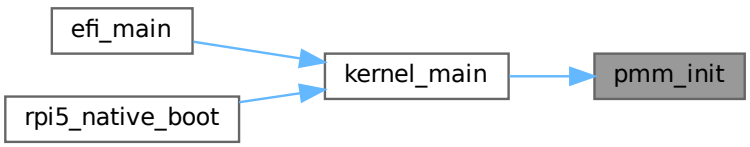
References __kernel_end, __kernel_start, bitmap_mark_range(), is_ram_type(), is_usable_memory(), BootInfo::memory_map, BootInfo::memory_map_descriptor_size, BootInfo::memory_map_size, EFI_MEMORY_DESCRIPTOR::NumberOfPages, EFI_MEMORY_DESCRIPTOR::PhysicalStart, pmm_alloc_floor_page, pmm_bitmap, PMM_BITMAP_BITS, pmm_bytes_to_pages(), pmm_free_pages, pmm_initialized, pmm_memset(), PMM_PAGE_SIZE, pmm_total_pages, pmm_tracked_pages, recompute_free_pages(), and EFI_MEMORY_DESCRIPTOR::Type.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



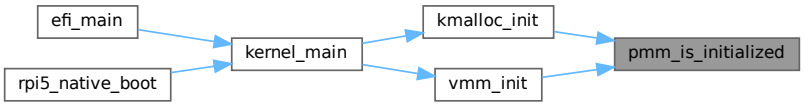
7.57.2.7 pmm_is_initialized()

```
int pmm_is_initialized (
            void  )
```

References pmm_initialized.

Referenced by kmalloc_init(), and vmm_init().

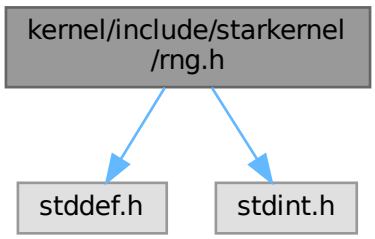
Here is the caller graph for this function:



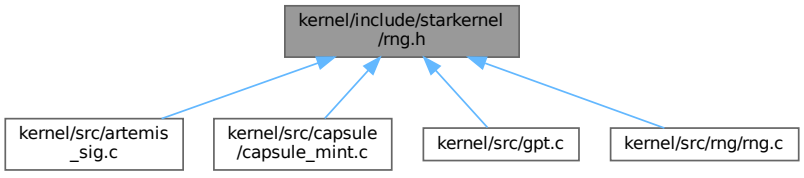
7.58 kernel/include/starkernel/rng.h File Reference

```
#include <stddef.h>
#include <stdint.h>
```

Include dependency graph for rng.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define RNG_ERR_NO_BACKEND (-1) /∗ rng_init() found no working entropy source ∗/

Functions

- int rng_init (void)
- int rng_ready (void)
- int rng_get_bytes (uint8_t ∗buf, size_t n)

7.58.1 Macro Definition Documentation

7.58.1.1 RNG_ERR_NO_BACKEND

```
#define RNG_ERR_NO_BACKEND (-1) /* rng_init() found no working entropy source */
```

7.58.2 Function Documentation

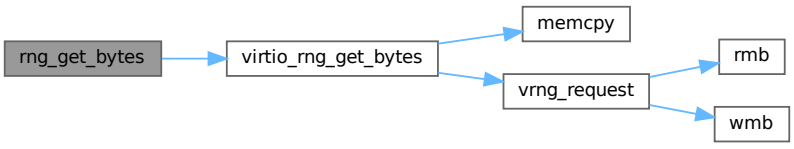
7.58.2.1 rng_get_bytes()

```
int rng_get_bytes (
            uint8_t * buf,
            size_t n )
```

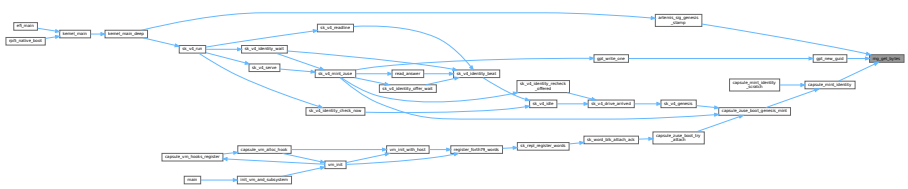
References g_rng_backend, RNG_BACKEND_VIRTIO, RNG_ERR_NO_BACKEND, and virtio_rng_get_bytes().

Referenced by artemis_sig_genesis_stamp(), capsule_mint_identity(), and gpt_new_guid().

Here is the call graph for this function:



Here is the caller graph for this function:



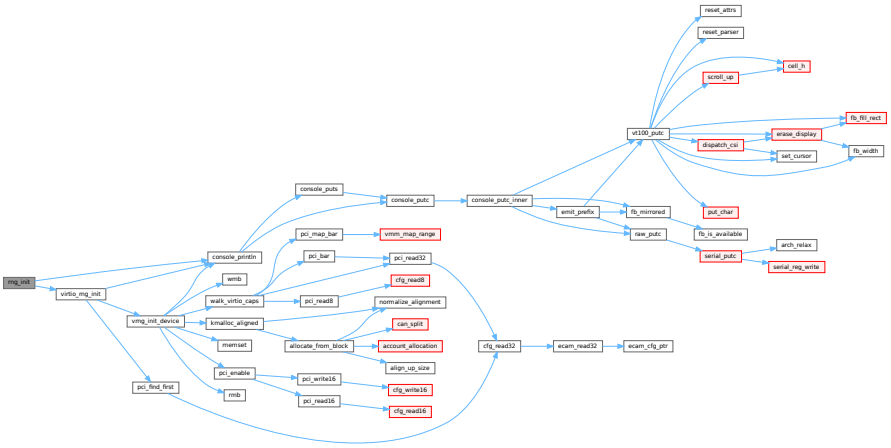
7.58.2.2 rng_init()

```
int rng_init (
              void  )
```

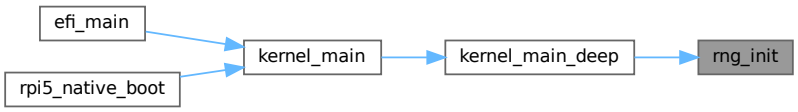
References console_println(), g_rng_backend, RNG_BACKEND_NONE, RNG_BACKEND_VIRTIO, and virtio_rng_init().

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.58.2.3 rng_ready()

```
int rng_ready (
              void  )
```

References g_rng_backend, and RNG_BACKEND_NONE.

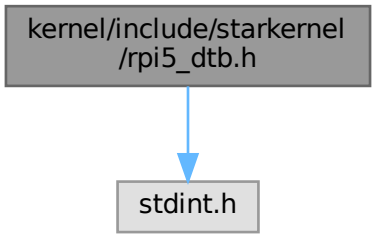
Referenced by capsule_mint_identity().

Here is the caller graph for this function:

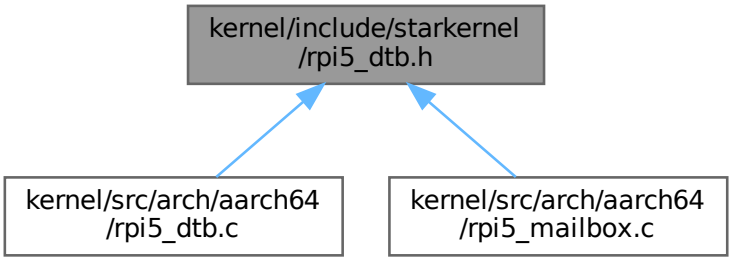
7.59 kernel/include/starkernel/rpi5_dtb.h File Reference

```
#include <stdint.h>
```

Include dependency graph for rpi5_dtb.h:



This graph shows which files directly or indirectly include this file:



Functions

- uint64_t rpi5_uart_base (const void *dtb)

  rpi5_dtb.h - Raspberry Pi 5 (BCM2712) devicetree-based peripheral discovery, for the native (non-UEFI) boot path (FABRIC-3.md ?IV.3).
- uint64_t rpi5_mailbox_base (const void *dtb)

  Find the VideoCore mailbox property interface's CPU-physical base address from the DTB.

7.59.1 Function Documentation

7.59.1.1 rpi5_mailbox_base()

```
uint64_t rpi5_mailbox_base (
            const void * dtb )
```

Find the VideoCore mailbox property interface's CPU-physical base address from the DTB.

Parameters

dtb	Devicetree blob; NULL is safe.

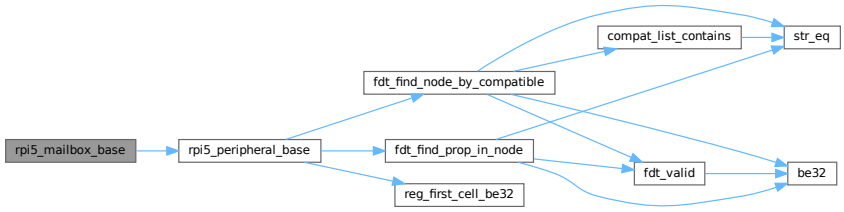
Returns

Final CPU-physical MMIO base address, or 0 if the node is absent, malformed, or `dtb` is invalid.

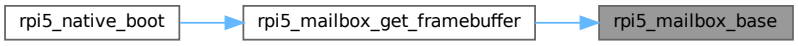
References rpi5_peripheral_base().

Referenced by rpi5_mailbox_get_framebuffer().

Here is the call graph for this function:



Here is the caller graph for this function:



7.59.1.2 rpi5_uart_base()

```
uint64_t rpi5_uart_base (
            const void * dtb )
```

rpi5_dtb.h - Raspberry Pi 5 (BCM2712) devicetree-based peripheral discovery, for the native (non-UEFI) boot path (FABRIC-3.md ?IV.3).

Two lookups: the PL011 UART (early console) and the VideoCore mailbox property interface (framebuffer setup, ?IV.3 item 3). Both peripherals live under BCM2712's own devicetree "soc" simple-bus node, which applies one fixed address translation to every child `reg` value — see `rpi5_dtb.c`'s own doc comment for the confirmed offset and where it was verified. `fdt.c`'s reader deliberately does not do general `ranges`-property translation (it is "not a general devicetree library"); this file applies the one, fixed, SoC-wide offset by name instead of teaching `fdt.c` a general mechanism for a single known hardware fact.

Find the PL011 UART's CPU-physical base address from the DTB.

Parameters

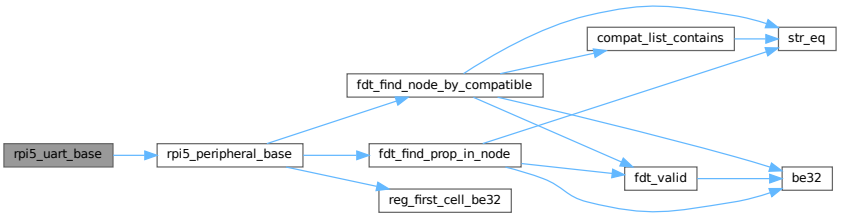
dtb	Devicetree blob, as passed to the native boot entry (or `BootInfo->dtb`); NULL is safe.

Returns

Final CPU-physical MMIO base address, or 0 if the node is absent, malformed, or `dtb` is invalid.

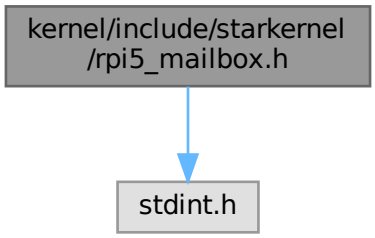
References rpi5_peripheral_base().

Here is the call graph for this function:

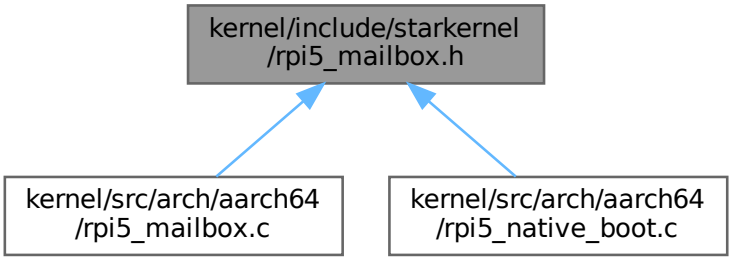


7.60 kernel/include/starkernel/rpi5_mailbox.h File Reference

`#include <stdint.h>`
Include dependency graph for rpi5_mailbox.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct Rpi5FramebufferInfo

  rpi5_mailbox.h - VideoCore mailbox property-interface framebuffer setup, for the native (non-UEFI) Raspberry Pi 5 boot path (FABRIC-3.md ?IV.3 item 3).

Functions

- int rpi5_mailbox_get_framebuffer (const void *dtb, uint32_t width, uint32_t height, uint32_t bpp, Rpi5FramebufferInfo *out)

  Request a framebuffer from the VideoCore firmware via the mailbox property interface, at the requested resolution/depth.

7.60.1 Function Documentation

7.60.1.1 rpi5_mailbox_get_framebuffer()

```
int rpi5_mailbox_get_framebuffer (
            const void * dtb,
            uint32_t width,
            uint32_t height,
            uint32_t bpp,
            Rpi5FramebufferInfo * out )
```

Request a framebuffer from the VideoCore firmware via the mailbox property interface, at the requested resolution/depth.

Sends one buffer with all six setup tags (physical size, virtual size, depth, pixel order, virtual offset, allocate) plus a get-pitch tag, in one request/response round trip.

Parameters

dtb	Devicetree blob (passed to `rpi5_mailbox_base()`).
width	Requested physical+virtual width, pixels.
height	Requested physical+virtual height, pixels.
bpp	Requested bits per pixel (32 is the only depth this driver has been designed against; others are not refused outright but are unverified).
out	Populated on success; untouched on failure.

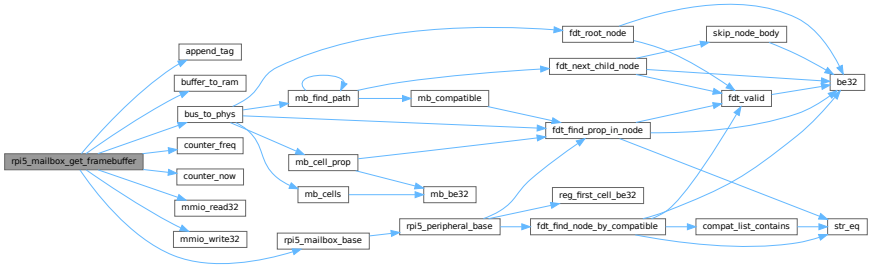
Returns

0 on success, negative on failure: -2 no mailbox node in the DTB, -3 the VC firmware rejected the request, -4 a response came back empty, -5 no answer within one second (every wait is bounded), -6 the devicetree's dma-ranges cannot place the framebuffer's bus address.

References append_tag(), Rpi5FramebufferInfo::base, base, buffer_to_ram(), bus_to_phys(), counter_freq(), counter_now(), Rpi5FramebufferInfo::height, limit, MBOX_CH_PROPERTY, MBOX_CODE_REQUEST, MBOX_CODE_RESPONSE_, MBOX_EMPTY, MBOX_FULL, MBOX_OFF_READ, MBOX_OFF_STATUS0, MBOX_OFF_STATUS1, MBOX_OFF_WRITE, mmio_read32(), mmio_write32(), Rpi5FramebufferInfo::pixel_format, PIXEL_ORDER_RGB, Rpi5FramebufferInfo::pixels_per_scanline, rpi5_mailbox_base(), Rpi5FramebufferInfo::size, TAG_ALLOCATE_BUFFER, TAG_END, TAG_GET_PITCH, TAG_SET_DEPTH, TAG_SET_PHYS_SIZE, TAG_SET_PIXEL_ORDER, TAG_SET_VIRT_SIZE, TAG_SET_VIRTUAL_OFFS, v2, and Rpi5FramebufferInfo::width.

Referenced by rpi5_native_boot().

Here is the call graph for this function:

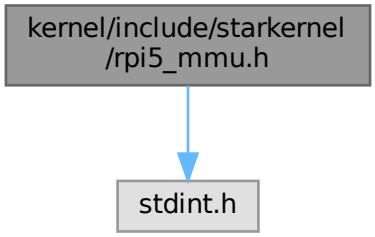


Here is the caller graph for this function:

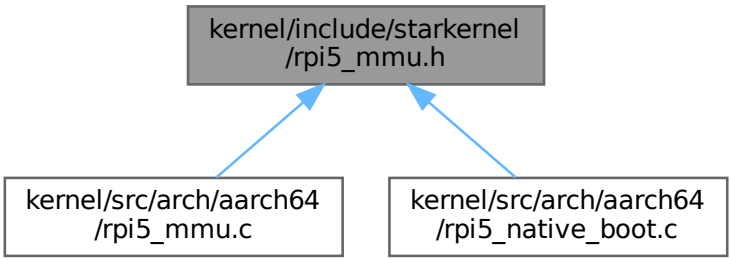
7.61 kernel/include/starkernel/rpi5_mmu.h File Reference

```
#include <stdint.h>
```

Include dependency graph for rpi5_mmu.h:



This graph shows which files directly or indirectly include this file:



Functions

- int rpi5_mmu_map_ram (const void *dtb)

  rpi5_mmu.h - the Pi 5 native path's identity map, once C runs (rpi5_mmu.c; native_rpi5_entry.S turns the MMU on).
- int rpi5_mmu_uncached (uint64_t addr, uint64_t size)

7.61.1 Function Documentation

7.61.1.1 rpi5_mmu_map_ram()

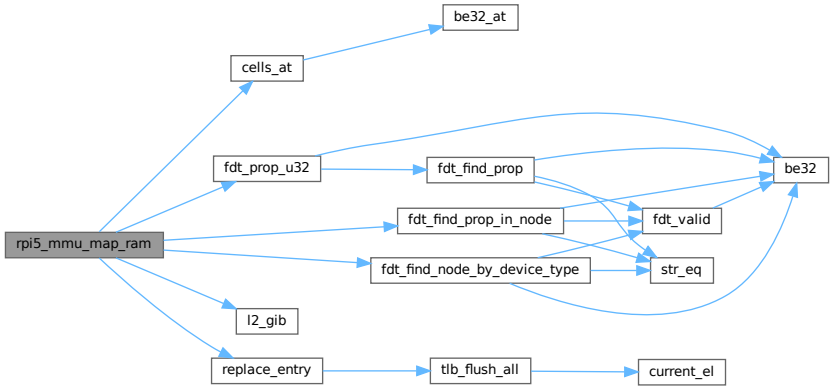
```
int rpi5_mmu_map_ram (
            const void * dtb )
```

rpi5_mmu.h - the Pi 5 native path's identity map, once C runs (rpi5_mmu.c; native_rpi5_entry.S turns the MMU on).

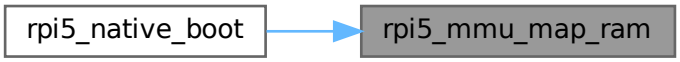
References BLOCK_NORMAL_WB, cells_at(), entry, fdt_find_node_by_device_type(), fdt_find_prop_in_node(), fdt_prop_u32(), g_rpi5_l1, GIB, l2_gib(), and replace_entry().

Referenced by rpi5_native_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



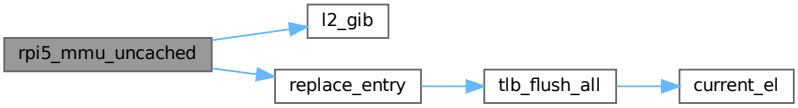
7.61.1.2 rpi5_mmu_uncached()

```
int rpi5_mmu_uncached (
            uint64_t addr,
            uint64_t size )
```

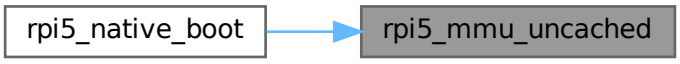
References __kernel_end, __kernel_start, BLOCK_NORMAL_NC, g_rpi5_l1, g_rpi5_l2, l2_gib(), MIB2, and replace_entry().

Referenced by rpi5_native_boot().

Here is the call graph for this function:

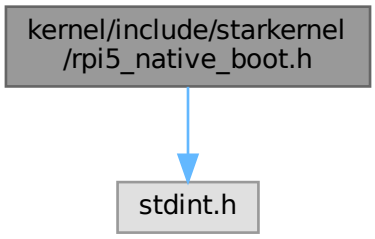


Here is the caller graph for this function:

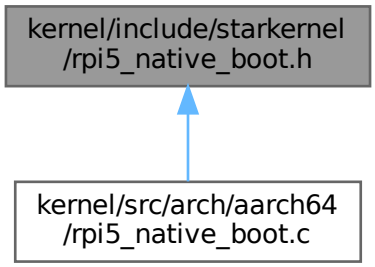


7.62 kernel/include/starkernel/rpi5_native_boot.h File Reference

`#include <stdint.h>`
Include dependency graph for rpi5_native_boot.h:



This graph shows which files directly or indirectly include this file:



Functions

- void rpi5_native_boot (uint64_t dtb) __attribute__((noreturn))
  rpi5_native_boot.h - Raspberry Pi 5 DTB->BootInfo constructor (FABRIC-3.md ?IV.3 item 2).

7.62.1 Function Documentation

7.62.1.1 rpi5_native_boot()

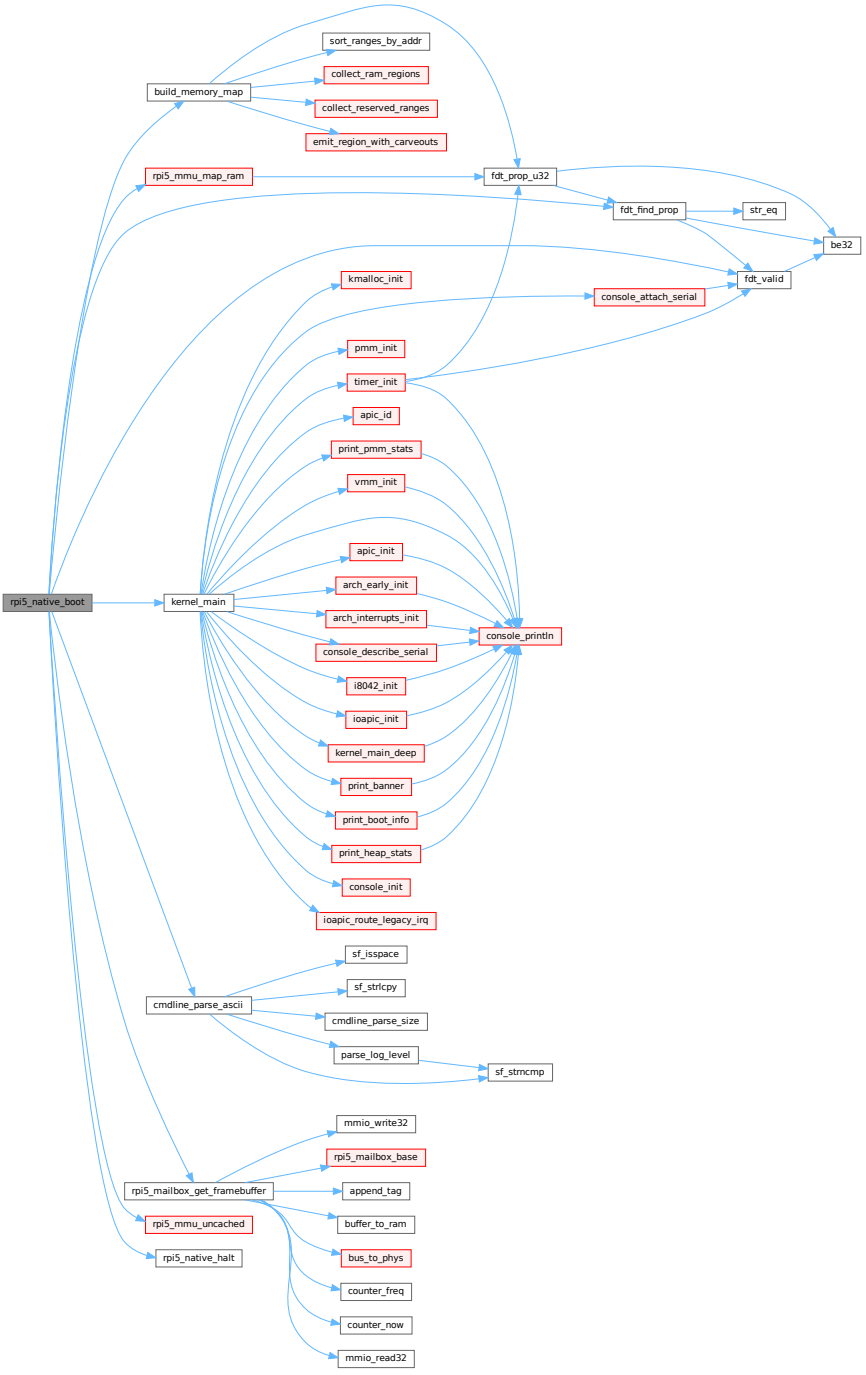
```
void rpi5_native_boot (
            uint64_t dtb )
```

rpi5_native_boot.h - Raspberry Pi 5 DTB->BootInfo constructor (FABRIC-3.md ?IV.3 item 2).

`native_rpi5_entry.S`'s `rpi5_native_start` tail-calls `rpi5_native_boot()` with the masked DTB pointer it captured. This function builds the *existing*, unmodified `BootInfo` struct (`include/starkernel/uefi.h`) from the devicetree instead of UEFI protocols, then calls the *existing*, unmodified `kernel_main()` — see this file's own `.c` for exactly what is and is not populated, and why.

References BootInfo::acpi_table, BootInfo::args, Rpi5FramebufferInfo::base, FramebufferInfo::base, build_memory_map(), cmdline_parse_ascii(), BootInfo::dtb, fdt_find_prop(), fdt_valid(), BootInfo::framebuffer, g_rpi5_boot_info, g_rpi5_memmap, Rpi5FramebufferInfo::height, FramebufferInfo::height, kernel_main(), BootInfo::kernel_stack_base, BootInfo::kernel_stack_size, BootInfo::memory_map, BootInfo::memory_map_descriptor_size, BootInfo::memory_map_size, Rpi5FramebufferInfo::pixel_format, FramebufferInfo::pixel_format, Rpi5FramebufferInfo::pixels_per_scanline, FramebufferInfo::pixels_per_scanline, RPI5_FB_DEFAULT_BPP, RPI5_FB_DEFAULT_HEIGHT, RPI5_FB_DEFAULT_WIDTH, rpi5_mailbox_get_framebuffer(), rpi5_mmu_map_ram(), rpi5_mmu_uncached(), rpi5_native_halt(), BootInfo::runtime_services, Rpi5FramebufferInfo::size, FramebufferInfo::size, BootInfo::uefi_boot_services_exited, Rpi5FramebufferInfo::width, and FramebufferInfo::width.

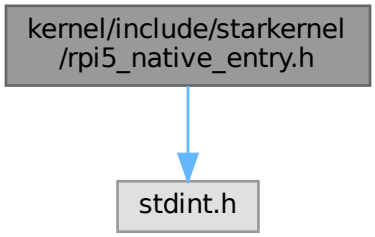
Here is the call graph for this function:



7.63 kernel/include/starkernel/rpi5_native_entry.h File Reference

```
#include <stdint.h>
```

Include dependency graph for rpi5_native_entry.h:



Variables

- uint64_t g_rpi5_dtb_ptr

  rpi5_native_entry.h - Raspberry Pi 5 native (non-UEFI) boot entry point (FABRIC-3.md ?IV.3 item 1).

7.63.1 Variable Documentation

7.63.1.1 g_rpi5_dtb_ptr

```
uint64_t g_rpi5_dtb_ptr  [extern]
```

rpi5_native_entry.h - Raspberry Pi 5 native (non-UEFI) boot entry point (FABRIC-3.md ?IV.3 item 1).

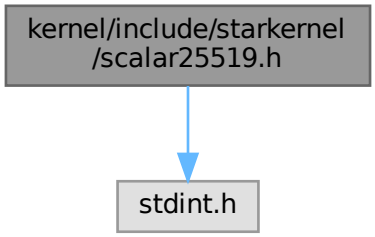
`native_rpi5_entry.S`'s `rpi5_native_start` is the very first code that runs on this path – entered directly by Pi 5 firmware, no UEFI, no ACPI, none of `boot/uefi_loader.c`'s PE-loader shape applies. It masks the firmware's raw entry register down to the documented 32-bit DTB pointer (?IV.1: upper 32 bits of the 64-bit register are unspecified) and stores it here, then establishes its own dedicated stack (this path has no EDK2 boot stack to inherit) and halts.

`g_rpi5_dtb_ptr` is this stub's one real output – the still-open DTB->BootInfo constructor (?IV.3 item 2) reads it from here once it exists; nothing calls that constructor yet, so `rpi5_native_start` halts rather than tail-calling into a function that isn't real.

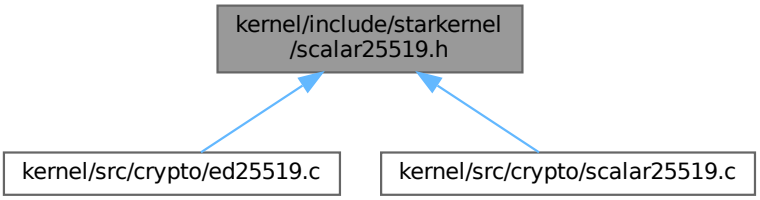
7.64 kernel/include/starkernel/scalar25519.h File Reference

```
#include <stdint.h>
```

Include dependency graph for scalar25519.h:



This graph shows which files directly or indirectly include this file:



Functions

- void scalar_reduce512 (uint8_t out[32], const uint8_t in[64])
- int scalar_lt_L (const uint8_t s[32])
- void scalar_muladd (uint8_t out[32], const uint8_t a[32], const uint8_t b[32], const uint8_t c[32])

7.64.1 Function Documentation

7.64.1.1 scalar_lt_L()

```
int scalar_lt_L (
            const uint8_t s[32] )
```

References cmp32(), and L_BYTES.

Referenced by ed25519_verify().

Here is the call graph for this function:

Here is the caller graph for this function:

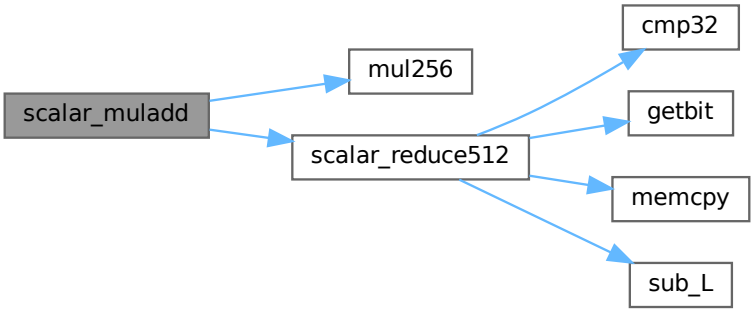
7.64.1.2 scalar_muladd()

```
void scalar_muladd (
            uint8_t out[32],
            const uint8_t a[32],
            const uint8_t b[32],
            const uint8_t c[32] )
```

References mul256(), and scalar_reduce512().

Referenced by ed25519_sign().

Here is the call graph for this function:



Here is the caller graph for this function:

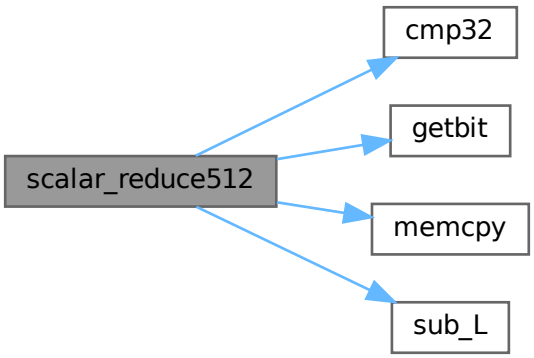
7.64.1.3 scalar_reduce512()

```
void scalar_reduce512 (
            uint8_t out[32],
            const uint8_t in[64] )
```

References cmp32(), getbit(), L_BYTES, memcpy(), and sub_L().

Referenced by ed25519_sign(), ed25519_verify(), and scalar_muladd().

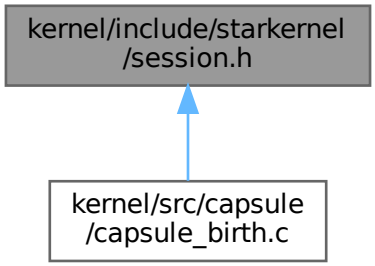
Here is the call graph for this function:



Here is the caller graph for this function:

7.65 kernel/include/starkernel/session.h File Reference

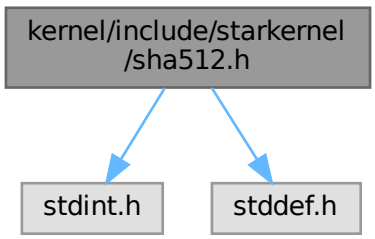
This graph shows which files directly or indirectly include this file:



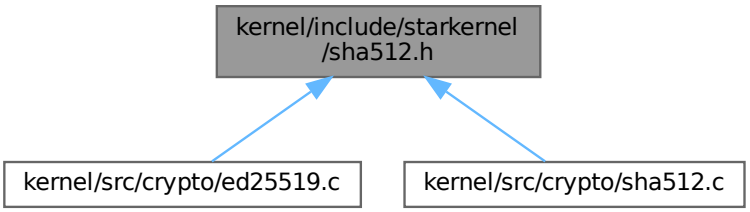
7.66 kernel/include/starkernel/sha512.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for sha512.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct sha512_ctx_t

Functions

- void sha512_init (sha512_ctx_t *ctx)
- void sha512_update (sha512_ctx_t *ctx, const uint8_t *data, size_t len)
- void sha512_final (sha512_ctx_t *ctx, uint8_t out[64])
- void sha512 (const uint8_t *data, size_t len, uint8_t out[64])

7.66.1 Function Documentation

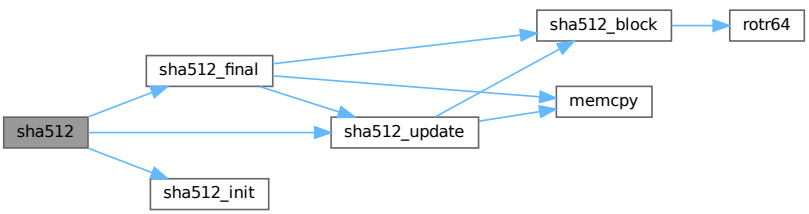
7.66.1.1 sha512()

```
void sha512 (
            const uint8_t * data,
            size_t len,
            uint8_t out[64] )
```

References sha512_final(), sha512_init(), and sha512_update().

Referenced by expand_seed().

Here is the call graph for this function:



Here is the caller graph for this function:

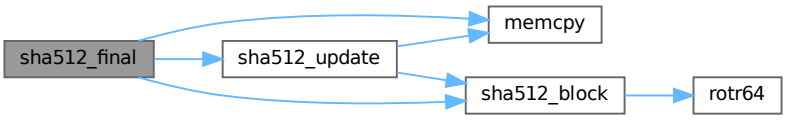
7.66.1.2 sha512_final()

```
void sha512_final (
            sha512_ctx_t * ctx,
            uint8_t out[64] )
```

References sha512_ctx_t::bitlen, sha512_ctx_t::buf, sha512_ctx_t::buf_len, memcpy(), sha512_block(), sha512_update(), sha512_ctx_t::state, and zero.

Referenced by ed25519_sign(), ed25519_verify(), and sha512().

Here is the call graph for this function:



Here is the caller graph for this function:

7.66.1.3 sha512_init()

```
void sha512_init (
            sha512_ctx_t * ctx )
```

References sha512_ctx_t::bitlen, sha512_ctx_t::buf_len, and sha512_ctx_t::state.

Referenced by ed25519_sign(), ed25519_verify(), and sha512().

Here is the caller graph for this function:

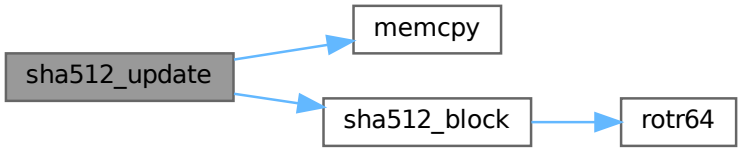
7.66.1.4 sha512_update()

```
void sha512_update (
            sha512_ctx_t * ctx,
            const uint8_t * data,
            size_t len )
```

References sha512_ctx_t::bitlen, sha512_ctx_t::buf, sha512_ctx_t::buf_len, memcpy(), and sha512_block().

Referenced by ed25519_sign(), ed25519_verify(), sha512(), and sha512_final().

Here is the call graph for this function:

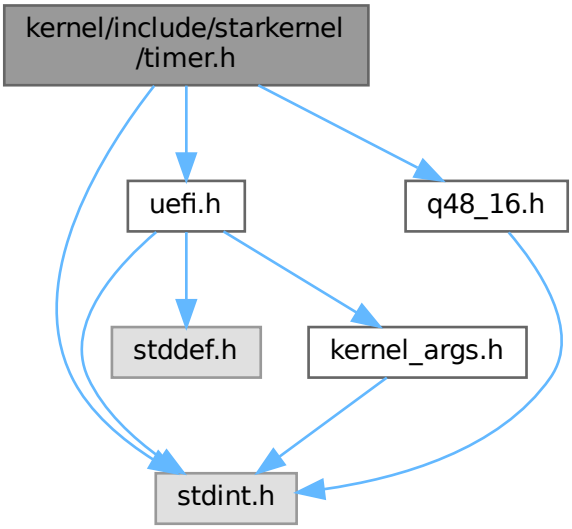


Here is the caller graph for this function:

7.67 kernel/include/starkernel/timer.h File Reference

```
#include <stdint.h>
#include "uefi.h"
#include "q48_16.h"
```

Include dependency graph for timer.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct time_window
- struct time_trust_state
- struct timer_calibration_record

Macros

- #define TIME_WINDOW_SIZE 64
- #define TIME_TRUST_HIGH Q48_ONE /∗ 1.0 = full confidence ∗/
- #define TIME_TRUST_LOW (Q48_ONE >> 2) /∗ 0.25 = low confidence ∗/

Typedefs

- typedef q48_16_t time_trust_t

  timer.h - Timer and Heartbeat Interface
- typedef struct time_window TimeWindow
- typedef struct time_trust_state TimeTrustState
- typedef enum timer_trust_level timer_trust_level_t
- typedef struct timer_calibration_record timer_calibration_record_t

Enumerations

- enum timer_trust_level { TIMER_TRUST_NONE = 0 , TIMER_TRUST_RELATIVE = 1 , TIMER_TRUST_ABSOLUTE = 2 }

Functions

- int timer_init (BootInfo *boot_info)

  Initialise the kernel timer subsystem (M5).
- uint64_t timer_tsc_hz (void)

  Return the system counter frequency in Hz.
- uint64_t timer_now_ns (void)

  Return a monotonic nanosecond timestamp.
- int timer_check_drift_now (void)

  Check for timer drift (AArch64 stub — always returns 0).
- const timer_calibration_record_t * timer_calibration_record (void)

  Return a pointer to the timer calibration record.
- void heartbeat_init (uint64_t tsc_hz, uint64_t tick_hz)

  Initialise the M5 heartbeat / TIME-TRUST subsystem.
- void heartbeat_tick (void)

  Top half.
- void heartbeat_service (void)

  Bottom half (punch-list item 0.8).
- uint64_t heartbeat_read_counter (void)

  Read the raw hardware counter this architecture's heartbeat is paced against – the same clock `timer_now_ns()` and calibration already use internally (rdtsc on amd64, the `time` CSR on riscv64, CNTPCT_EL0 on aarch64), not a separate/different source.
- uint64_t heartbeat_ticks (void)

  Get current TIME-TICKS (monotonic heartbeat count).
- time_trust_t heartbeat_trust (void)

  Get current TIME-TRUST (Q48.16 confidence metric).
- const TimeTrustState * heartbeat_state (void)

  Get pointer to full heartbeat state (for diagnostics).
- void heartbeat_set_adaptive_period_ns (uint64_t ns)

  Set the adaptive re-arm period, in nanoseconds (punch-list item 0.8, FABRIC-0.md ?26).
- uint64_t heartbeat_next_period_ns (void)

  Read the period the next hardware re-arm should use.

7.67.1 Macro Definition Documentation

7.67.1.1 TIME_TRUST_HIGH

```
#define TIME_TRUST_HIGH Q48_ONE /* 1.0 = full confidence */
```

7.67.1.2 TIME_TRUST_LOW

```
#define TIME_TRUST_LOW (Q48_ONE >> 2) /* 0.25 = low confidence */
```

7.67.1.3 TIME_WINDOW_SIZE

```
#define TIME_WINDOW_SIZE 64
```

7.67.2 Typedef Documentation

7.67.2.1 time_trust_t

```
typedef q48_16_t time_trust_t
```

timer.h - Timer and Heartbeat Interface

M5 Time Model:

- TIME-TICKS (Q64.0): Monotonic heartbeat counter, never decreases
- TIME-TRUST (Q48.16): Continuous confidence metric [0.0, 1.0]
- No discrete modes (NONE/REL/ABS are legacy, being phased out)
- Trust is a measurement, never gates execution

7.67.2.2 timer_calibration_record_t

```
typedef struct timer_calibration_record timer_calibration_record_t
```

7.67.2.3 timer_trust_level_t

```
typedef enum timer_trust_level timer_trust_level_t
```

7.67.2.4 TimeTrustState

```
typedef struct time_trust_state TimeTrustState
```

7.67.2.5 TimeWindow

```
typedef struct time_window TimeWindow
```

7.67.3 Enumeration Type Documentation

7.67.3.1 timer_trust_level

```
enum timer_trust_level
```

Enumerator

TIMER_TRUST_NONE	
TIMER_TRUST_RELATIVE	
TIMER_TRUST_ABSOLUTE	

7.67.4 Function Documentation

7.67.4.1 heartbeat_init()

```
void heartbeat_init (
            uint64_t tsc_hz,
            uint64_t tick_hz )
```

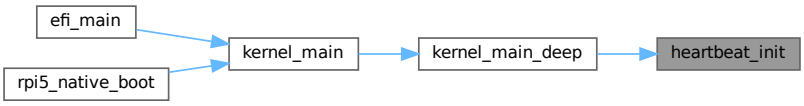
Initialise the M5 heartbeat / TIME-TRUST subsystem.

Shared across all three architectures – the fallback and calibration formula never differed between them, only what heartbeat_service() does with the resulting window did.

References time_window::count, time_window::deltas, time_trust_state::expected_delta, g_adaptive_period_ns, g_heartbeat, g_pending_valid, HEARTBEAT_BASE_PERIOD_NS, time_trust_state::last_tsc, time_window::pos, Q48_ONE, time_trust_state::ticks, TIME_WINDOW_SIZE, time_trust_state::total_samples, time_trust_state::trust, time_trust_state::variance, and time_trust_state::window.

Referenced by kernel_main_deep().

Here is the caller graph for this function:



7.67.4.2 heartbeat_next_period_ns()

```
uint64_t heartbeat_next_period_ns (
            void  )
```

Read the period the next hardware re-arm should use.

Called from interrupt context by each architecture's re-arm function in place of a fixed constant.

Called from interrupt context by each architecture's re-arm function (apic_timer_rearm(), riscv64_timer_rearm(), the AArch64 equivalent) in place of the fixed constant those functions used before item 0.8.

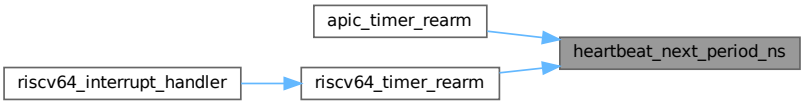
Returns

Current adaptive period in nanoseconds.

References g_adaptive_period_ns.

Referenced by apic_timer_rearm(), and riscv64_timer_rearm().

Here is the caller graph for this function:



7.67.4.3 heartbeat_read_counter()

```
uint64_t heartbeat_read_counter (
            void  )
```

Read the raw hardware counter this architecture's heartbeat is paced against – the same clock `timer_now_ns()` and calibration already use internally (rdtsc on amd64, the `time` CSR on riscv64, CNTPCT_EL0 on aarch64), not a separate/different source.

Implemented once per architecture in that architecture's timer.c; consumed only by `heartbeat_tick()` in the shared heartbeat.c.

Read the raw hardware counter this architecture's heartbeat is paced against – the same clock `timer_now_ns()` and calibration already use internally (rdtsc on amd64, the `time` CSR on riscv64, CNTPCT_EL0 on aarch64), not a separate/different source.

Item 0.8 (FABRIC-0.md ?25.1): the shared heartbeat.c now owns heartbeat_init()/heartbeat_tick()/heartbeat_↩service()/heartbeat_ticks()/ heartbeat_trust()/heartbeat_state() and the per-arch `g_heartbeat` state that used to live in this file. This is the one piece that stays per-architecture – the same `CNTPCT_EL0` the rest of this file's calibration already reads via `cntpct_read()`.

Returns

Current `CNTPCT_EL0` value.

Read the raw hardware counter this architecture's heartbeat is paced against – the same clock `timer_now_ns()` and calibration already use internally (rdtsc on amd64, the `time` CSR on riscv64, CNTPCT_EL0 on aarch64), not a separate/different source.

Item 0.8 (FABRIC-0.md ?25.1): the shared heartbeat.c owns heartbeat_init()/heartbeat_tick()/heartbeat_↩service()/heartbeat_ticks()/ heartbeat_trust()/heartbeat_state() and the variance/trust math that used to live in this file. This is the one piece that stays per-architecture – the same `rdtsc()` the rest of this file's TSC calibration already uses, not a separate/different source.

Returns

Current TSC value.

Read the raw hardware counter this architecture's heartbeat is paced against – the same clock `timer_now_ns()` and calibration already use internally (rdtsc on amd64, the `time` CSR on riscv64, CNTPCT_EL0 on aarch64), not a separate/different source.

Item 0.8 (FABRIC-0.md ?25.1): the shared heartbeat.c now owns heartbeat_init()/heartbeat_tick()/heartbeat_↩ service()/heartbeat_ticks()/ heartbeat_trust()/heartbeat_state(). This is the one piece that stays per-architecture – the same `rdtime()` the timer deadline is armed against, not `rdcycle()` or any other source. Must read the same counter the deadline was programmed against: `expected_delta` is derived from timebase-frequency and is therefore in `time` units; measuring the interval with `cycle` instead would difference two unrelated clocks.

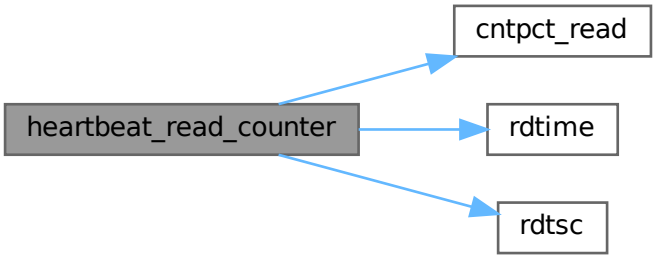
Returns

Current `time` CSR value.

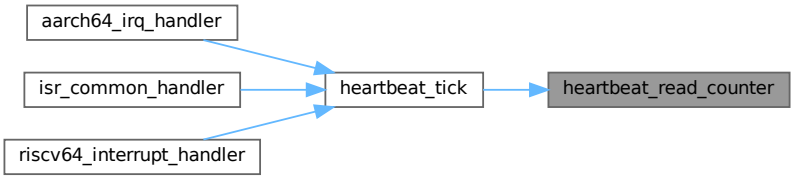
References cntpct_read(), rdtime(), and rdtsc().

Referenced by heartbeat_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.67.4.4 heartbeat_service()

```
void heartbeat_service (
            void  )
```

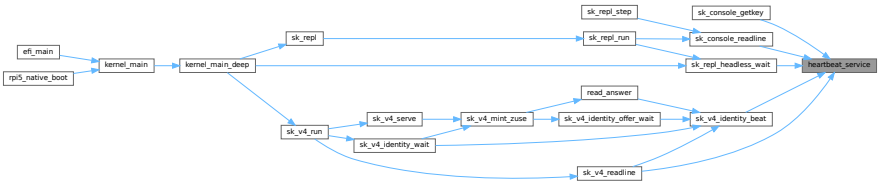
Bottom half (punch-list item 0.8).

Services one pending sample if `heartbeat_tick()` has latched one since the last call: computes the inter-tick deviation, updates the rolling window, and (architecture permitting – see `heartbeat.c`) recomputes variance and TIME-TRUST. Never runs in interrupt context. Call from the mainline, as frequently as convenient – a stale/skipped service call degrades the window's fidelity but affects nothing else, since TIME-TRUST is diagnostic only and never gates execution.

References time_trust_state::expected_delta, g_heartbeat, g_pending_counter, g_pending_valid, time_trust_state::last_tsc, Q48_ONE, time_trust_state::total_samples, time_trust_state::trust, time_trust_state::variance, and time_trust_state::window.

Referenced by sk_console_getkey(), sk_console_readline(), sk_repl_headless_wait(), sk_v4_identity_beat(), and sk_v4_readline().

Here is the caller graph for this function:



7.67.4.5 heartbeat_set_adaptive_period_ns()

```
void heartbeat_set_adaptive_period_ns (
            uint64_t ns )
```

Set the adaptive re-arm period, in nanoseconds (punch-list item 0.8, FABRIC-0.md ?26).

Called from the mainline execution path only (Loop #7's site in vm_runtime.c) – never from interrupt context. Clamped to [1/4x, 4x] of the kernel's base period internally; a caller need not pre-clamp.

Set the adaptive re-arm period, in nanoseconds (punch-list item 0.8, FABRIC-0.md ?26).

Called from vm_runtime.c's Loop #7 site on the mainline execution path (never interrupt context) with a value already rescaled to this file's HEARTBEAT_BASE_PERIOD_NS. Clamped defensively to the same [1/4x, 4x] band Loop #7 itself enforces around its own base, so a caller forwarding an unclamped or wrongly-scaled value cannot run the ISR away.

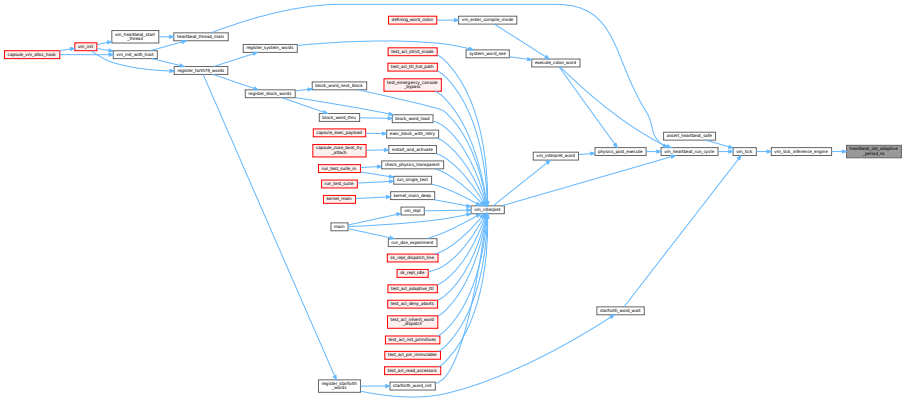
Parameters

ns	Desired period in nanoseconds for the next re-arm.

References g_adaptive_period_ns, and HEARTBEAT_BASE_PERIOD_NS.

Referenced by vm_tick_inference_engine().

Here is the caller graph for this function:



7.67.4.6 heartbeat_state()

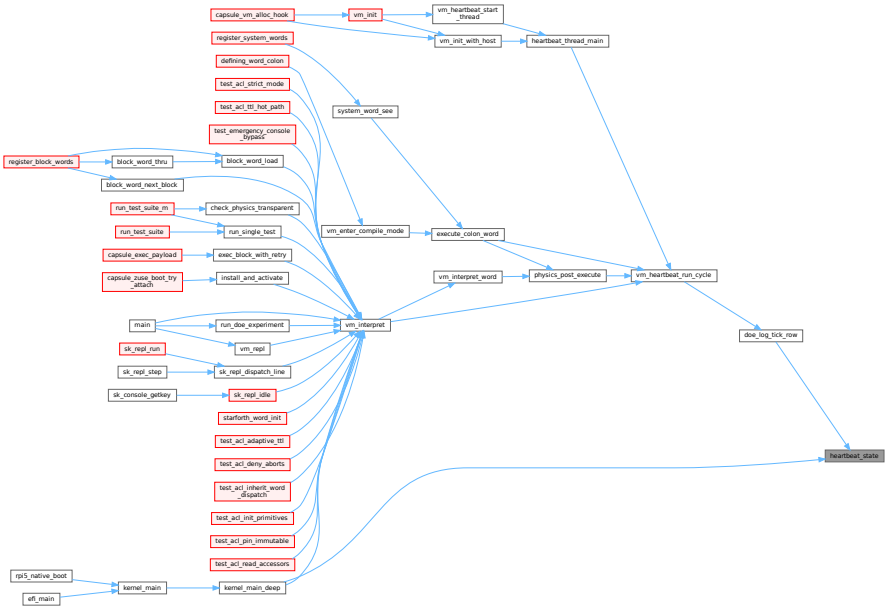
```
const TimeTrustState * heartbeat_state (
            void  )
```

Get pointer to full heartbeat state (for diagnostics).

References g_heartbeat.

Referenced by doe_log_tick_row(), and kernel_main_deep().

Here is the caller graph for this function:



7.67.4.7 heartbeat_tick()

```
void heartbeat_tick (
            void  )
```

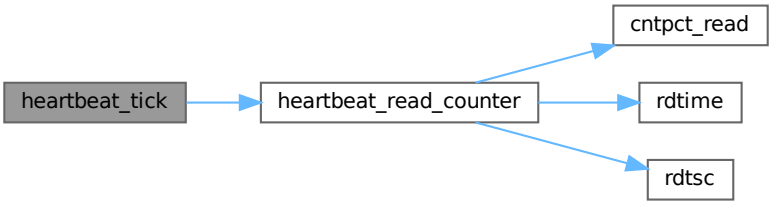
Top half.

Called directly from each architecture's ISR (punch-list item 0.8) – one call site per architecture, unchanged from before this item. Does exactly three things: reads the raw counter via `heartbeat_read_counter()`, increments TIME-TICKS, and latches the sample for `heartbeat_service()` to pick up. No window math, no variance, no loops – this must stay cheap enough for interrupt context.

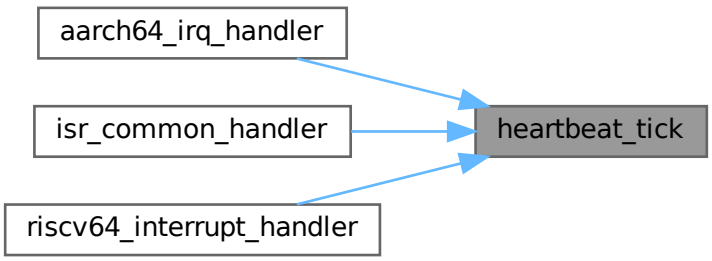
References g_heartbeat, g_pending_counter, g_pending_valid, heartbeat_read_counter(), and time_trust_state::ticks.

Referenced by aarch64_irq_handler(), isr_common_handler(), and riscv64_interrupt_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.67.4.8 heartbeat_ticks()

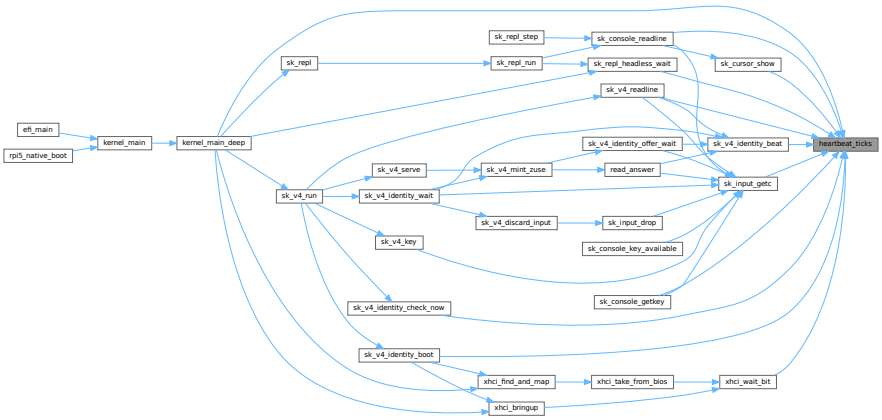
```
uint64_t heartbeat_ticks (
            void  )
```

Get current TIME-TICKS (monotonic heartbeat count).

References g_heartbeat, and time_trust_state::ticks.

Referenced by kernel_main_deep(), sk_console_getkey(), sk_console_readline(), sk_cursor_show(), sk_input_getc(), sk_repl_headless_wait(), sk_v4_identity_beat(), sk_v4_identity_boot(), sk_v4_identity_check_now(), sk_v4_readline(), and xhci_wait_bit().

Here is the caller graph for this function:



7.67.4.9 heartbeat_trust()

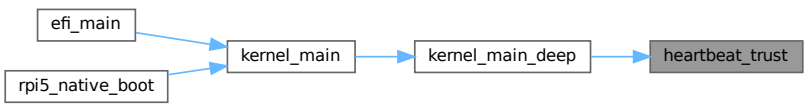
```
time_trust_t heartbeat_trust (
            void  )
```

Get current TIME-TRUST (Q48.16 confidence metric).

References g_heartbeat, and time_trust_state::trust.

Referenced by kernel_main_deep().

Here is the caller graph for this function:



7.67.4.10 timer_calibration_record()

```
const timer_calibration_record_t * timer_calibration_record (
            void  )
```

Return a pointer to the timer calibration record.

Returns `&s_cal` which is populated by `timer_init()` with:

- `tsc_hz_mean` = `CNTFRQ_EL0` (or 62.5 MHz fallback)
- `hpet_hz` = 0 (no HPET on AArch64)
- `pit_hz_mean` = 0 (no PIT on AArch64)
- `converged` = 1 (Generic Timer is already calibrated by firmware)
- `vm_mode` = real hypervisor-vs-hardware detection as of 2026-09-04 (ACPI RSDP OEM ID check, running_under_hypervisor() above) – the Generic Timer itself works identically either way, so this field's *timing* meaning here is purely informational, unlike amd64 where vm_mode gates a real calibration-path choice
- `trust` = `TIMER_TRUST_ABSOLUTE`

The record is exposed to `kernel_main()` and `timer.h` consumers for boot-log reporting and for the heartbeat subsystem's trust initialisation.

Returns

Pointer to the module-static calibration record; valid for the lifetime of the kernel.

Return a pointer to the timer calibration record.

Provides read-only access to the `calib_record` populated by `timer_init()`. Callers can inspect fields such as `trust`, `tsc_hz_mean`, `cv_hpet_ppm`, and `converged` for diagnostic output or to determine whether absolute timing guarantees are available.

Returns

Pointer to the static `timer_calibration_record_t` (never NULL).

Returns `&s_cal`, populated by `timer_init()` with the discovered (or fallback) frequency and the corresponding trust level — `TIMER_TRUST_ABSOLUTE` when `timebase-frequency` came from the devicetree, `TIMER_TRUST_RELATIVE` on the fallback. Consumed by `kernel_main()` for boot-log reporting and by the heartbeat subsystem's trust init.

Returns

Pointer to the module-static calibration record; valid for the lifetime of the kernel.

References calib_record, and s_cal.

7.67.4.11 timer_check_drift_now()

```
int timer_check_drift_now (
            void  )
```

Check for timer drift (AArch64 stub — always returns 0).

On x86-64 this function cross-checks the TSC against the HPET or PM Timer to detect frequency drift. The AArch64 Generic Timer is architecturally invariant and synchronised across all cores in the system; it cannot drift against itself. This stub always returns 0 (no drift detected) to satisfy the common `timer_check_drift_now()` call site.

Returns

0 always.

Check for timer drift (AArch64 stub — always returns 0).

In bare-metal mode delegates to `timer_drift_check_bare_metal()`. In VM mode returns 0 immediately: VM drift checking requires a VM-friendly reference (such as pvclock) that is not yet implemented.

Returns

0 if drift is acceptable or in VM mode, -1 on bare-metal measurement failure.

Check for timer drift (AArch64 stub — always returns 0).

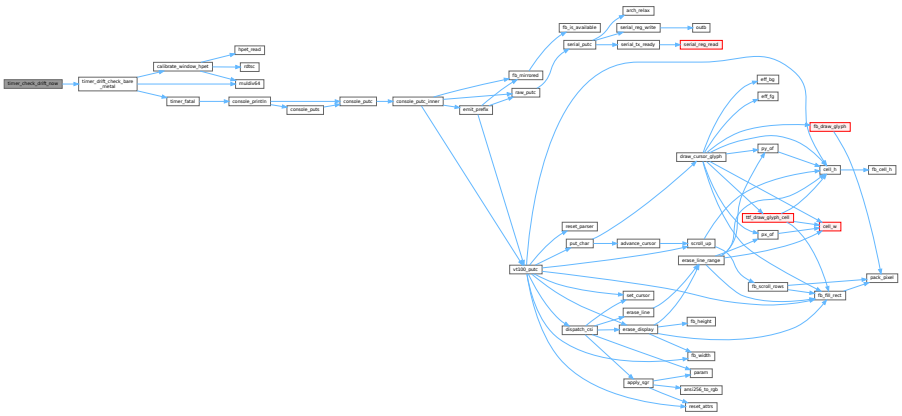
On x86-64 this cross-checks the TSC against the HPET. The RISC-V `time` counter has no independent reference to check against at this milestone — and per the privileged spec it is architecturally required to be a fixed, synchronised rate across harts, unlike `cycle`. Always returns 0 (no drift) to satisfy the common call site.

Returns

0 always.

References calib_record, timer_drift_check_bare_metal(), and timer_calibration_record::vm_mode.

Here is the call graph for this function:



7.67.4.12 timer_init()

```
int timer_init (
            BootInfo * boot_info )
```

Initialise the kernel timer subsystem (M5).

Detects the execution environment (bare metal vs. hypervisor) and follows the appropriate calibration path:

- **VM** / **hypervisor path** (CPUID.1:ECX[31] set): calls `init_timer_vm_mode()` — HPET MMIO disabled, TSC from CPUID/PM Timer.
- **Bare metal path**: maps HPET MMIO, enables the counter, optionally probes the PIT, then calls `converge_tsc_bare_metal()` until TSC Hz converges within `CV_EPSILON_PPM` ppm. Calls `timer_fatal()` on any hard failure.

On success, `tsc_hz_locked` holds the calibrated TSC frequency and `calib_record` is fully populated. `timer_now_ns()` is safe to call after this function returns.

Parameters

boot_info	BootInfo pointer from the UEFI loader; `acpi_table` is used to discover the ACPI PM_TMR_BLK port at runtime (see `fadt_find_pm_tmr_port()`) rather than assuming a fixed machine type's legacy address.

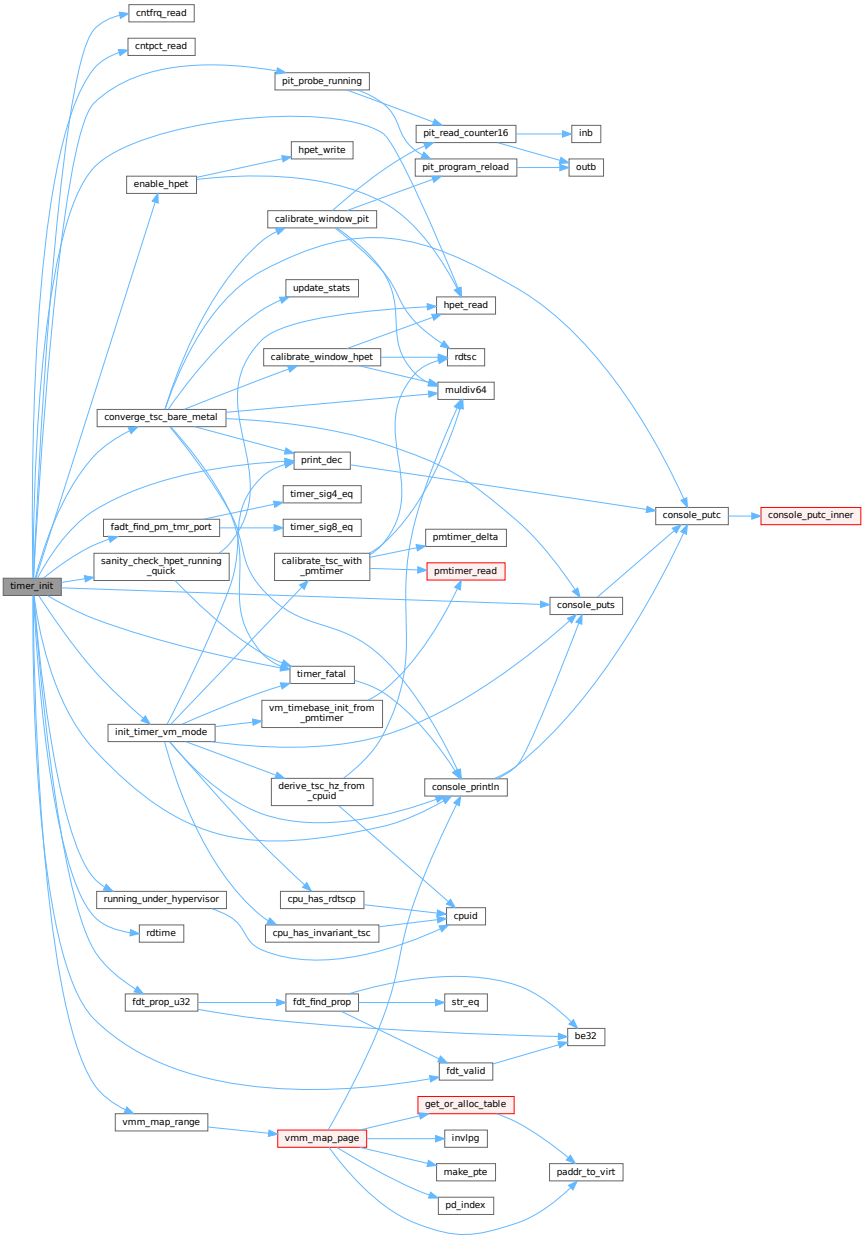
Returns

0 on success; calls `timer_fatal()` (never returns) on hard failure.

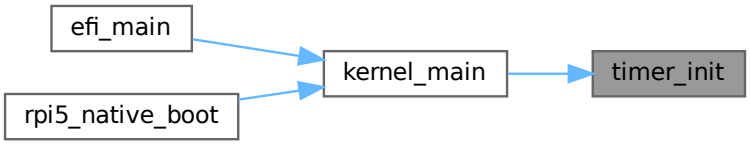
References BootInfo::acpi_table, calib_record, cntfrq_read(), cntpct_read(), console_println(), console_puts(), converge_tsc_bare_metal(), timer_calibration_record::converged, BootInfo::dtb, enable_hpet(), fadt_find_pm_tmr_port(), fdt_prop_u32(), fdt_valid(), hpet_freq_hz, HPET_GEN_CAP_ID, timer_calibration_record::hpet_hz, HPET_PHYS_BASE, hpet_read(), hpet_regs, HPET_VIRT_BASE, init_timer_vm_mode(), pit_available, timer_calibration_record::pit_hz_mean, pit_probe_running(), pit_tsc_hz_mean, pmtimer_port, print_dec(), rdtime(), running_under_hypervisor(), s_base_count, s_base_ns, s_cal, s_counter_hz, s_ns_per_tick, sanity_check_hpet_running_quick(), timer_fatal(), TIMER_REQUIRE_PIT, TIMER_TRUST_ABSOLUTE, TIMER_TRUST_NONE, TIMER_TRUST_RELATIVE, timer_calibration_record::trust, tsc_hz_locked, timer_calibration_record::tsc_hz_mean, timer_calibration_record::vm_mode, VMM_FLAG_WRITABLE, and vmm_map_range().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.67.4.13 timer_now_ns()

```
uint64_t timer_now_ns (
            void  )
```

Return a monotonic nanosecond timestamp.

Reads CNTPCT_EL0, computes the delta from s_base_count (captured at timer_init()), and converts to nanoseconds using the Q16.16 fixed-point s_ns_per_tick:
ns = s_base_ns + ((delta * s_ns_per_tick) » 16)

The multiplication uses 64-bit arithmetic; at typical counter frequencies ($\leq$ 100 MHz) and reasonable uptime intervals (days to weeks) there is no overflow risk in the delta-to-ns conversion.

Returns

Monotonic nanosecond count since timer_init(), starting at 0.

Return a monotonic nanosecond timestamp.

Selects the best available time source based on the calibration record:

- TIMER_TRUST_NONE: returns 0 (no time base yet).
- VM mode + trust $<$ TIMER_TRUST_ABSOLUTE: returns PM Timer relative ns.
- Absolute mode (tsc_hz_locked $>$ 0): reads TSC (RDTSCP if supported, else RDTSC) and converts to ns via muldiv64().

Called by the HAL (sk_hal_time_ns()) to feed the physics engine.

Returns

Nanoseconds since boot, or 0 if the timer is not yet calibrated.

Reads rdtime(), computes the elapsed delta from s_base_count (captured at timer_init()), and converts to nanoseconds using the Q16.16 fixed-point s_ns_per_tick:
ns = s_base_ns + ((delta * s_ns_per_tick) » 16)

The 64-bit product of delta $\times$ s_ns_per_tick wraps once elapsed real time reaches 2^48 ns ($\sim$3.26 days) — this bound is **independent of s_counter_hz**, since s_ns_per_tick scales inversely with frequency and the two effects cancel. Verified by direct computation, not carried over from the earlier cycle-based comment here, which claimed "$\sim$18 seconds" and did not match the arithmetic either. Beyond $\sim$3.26 days uptime timer_now_ns() wraps and produces incorrect values — a theoretical concern only for this single-hart POST-only kernel.

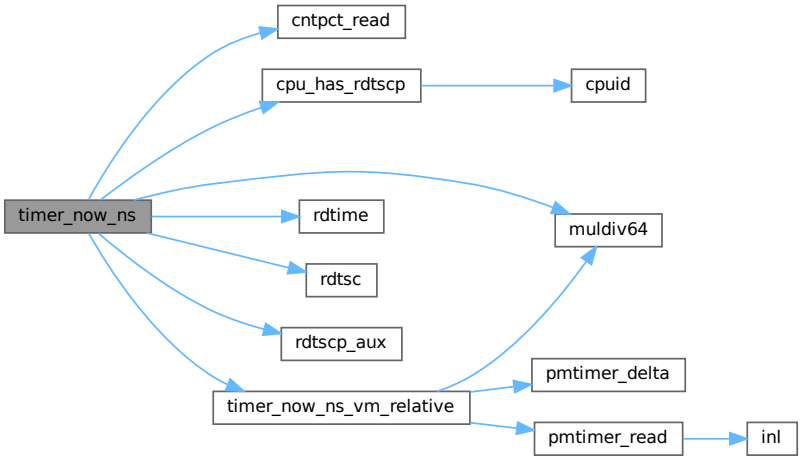
Returns

Monotonic nanosecond count since `timer_init()`, starting at 0.

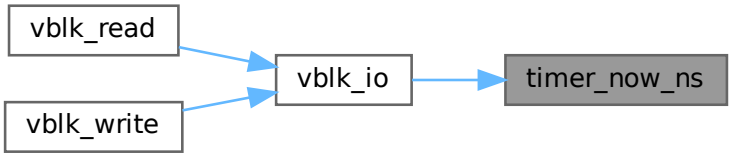
References calib_record, cntpct_read(), cpu_has_rdtscp(), muldiv64(), rdtime(), rdtsc(), rdtscp_aux(), s_base_count, s_base_ns, s_ns_per_tick, timer_now_ns_vm_relative(), TIMER_TRUST_ABSOLUTE, TIMER_TRUST_NONE, timer_calibration_record::trust, tsc_hz_locked, and timer_calibration_record::vm_mode.

Referenced by vblk_io().

Here is the call graph for this function:



Here is the caller graph for this function:



7.67.4.14 timer_tsc_hz()

```
uint64_t timer_tsc_hz (
            void  )
```

Return the system counter frequency in Hz.

Returns `s_counter_hz` as set from `CNTFRQ_EL0` by `timer_init()`. If `timer_init()` has not been called yet (or firmware reported 0 and the fallback was not applied), returns 62,500,000 Hz as a safe default.

Used by `apic_timer_init()` to compute `s_timer_period_tsc` and by the shim time backend to convert counter ticks to nanoseconds before the full timer subsystem is available.

Returns

System counter frequency in Hz; at least 62,500,000.

Return the system counter frequency in Hz.

Returns the value established by `timer_init()`. Zero means calibration has not completed or failed to derive a TSC frequency (PM Timer relative mode only).

Returns

TSC frequency in Hz, or 0 if unknown.

Return the system counter frequency in Hz.

Returns `s_counter_hz` — discovered from the devicetree's `timebase-frequency` when available, otherwise `RISCV_TIMEBASE_HZ_FALLBACK`. Used by `apic_timer_init()` to compute the expected inter-tick period and by the shim time backend to convert `time` counts to nanoseconds.

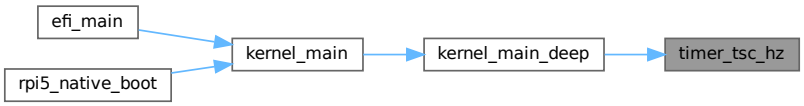
Returns

`time` counter frequency in Hz.

References s_counter_hz, and tsc_hz_locked.

Referenced by kernel_main_deep().

Here is the caller graph for this function:

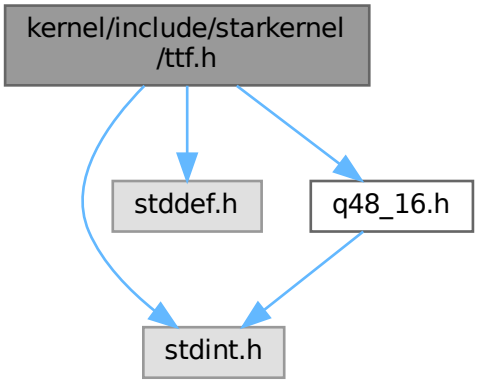


7.68 kernel/include/starkernel/ttf.h File Reference

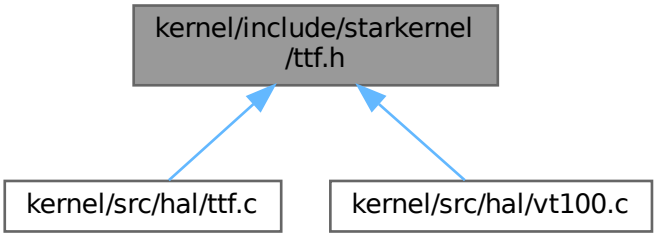
```
#include <stdint.h>
#include <stddef.h>
```

```
#include "q48_16.h"
```

Include dependency graph for ttf.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct ttf_font_t

  Parsed font handle.
- struct ttf_glyph_header_t

  Raw glyf record header, per ?27.6/4.3.7's "done when" clause.
- struct ttf_point_t

  One outline point, in raw font design units (NOT scaled by unitsPerEm — that's the caller's job, same convention as ttf_glyph_header_t's bbox), expressed in Q48.16.
- struct ttf_outline_t

  Simple- and composite-glyph outline, flattened to one point list plus per-contour end indices (TrueType convention: contour_ends[c] is the index of the LAST point of contour c, inclusive; points are shared across contours only in the sense that contour c+1 starts right after contour_ends[c]).
- struct ttf_bitmap_t

  A caller-owned 8-bit-per-pixel bitmap.
- struct ttf_raster_cache_slot_t
- struct ttf_raster_cache_t

Macros

- #define TTF_OK 0

  ttf.h - TrueType font parser core (Freestanding)
- #define TTF_ERR_BAD_SFNT -1
- #define TTF_ERR_TABLE_MISSING -2
- #define TTF_ERR_BAD_TABLE -3
- #define TTF_ERR_BAD_GLYPH_INDEX -4
- #define TTF_ERR_OUT_OF_BOUNDS -5
- #define TTF_ERR_TOO_MANY_POINTS -6
- #define TTF_ERR_TOO_MANY_CONTOURS -7
- #define TTF_ERR_TOO_DEEP -8 /∗ composite glyph nesting exceeded TTF_MAX_COMPOSITE_DEPTH ∗/
- #define TTF_ERR_UNSUPPORTED
- #define TTF_MAX_COMPOSITE_DEPTH 8
- #define TTF_GLYPH_MISSING 0

  Glyph index returned for "no mapping" by ttf_codepoint_to_glyph().
- #define TTF_CACHE_MAX_SIZE_PX 64
- #define TTF_CACHE_MARGIN 8
- #define TTF_CACHE_BITMAP_DIM (TTF_CACHE_MAX_SIZE_PX + TTF_CACHE_MARGIN ∗ 2)
- #define TTF_CACHE_BITMAP_BYTES (TTF_CACHE_BITMAP_DIM ∗ TTF_CACHE_BITMAP_DIM)

Functions

- int ttf_parse (const uint8_t ∗data, uint32_t size, ttf_font_t ∗out)

  ttf_parse - Locate and validate the sfnt directory and the head/maxp/ loca/glyf tables (cmap is optional; ttf_codepoint_to_glyph() fails cleanly if absent).
- uint32_t ttf_codepoint_to_glyph (const ttf_font_t ∗font, uint32_t codepoint)

  ttf_codepoint_to_glyph - Resolve a Unicode codepoint via the font's format-4 cmap subtable.
- int ttf_glyph_header (const ttf_font_t ∗font, uint32_t glyph_index, ttf_glyph_header_t ∗out)

  ttf_glyph_header - Read a glyph's outline header (contour count, bounding box) via loca + glyf.
- uint16_t ttf_glyph_advance_width (const ttf_font_t ∗font, uint32_t glyph_index)

  ttf_glyph_advance_width - Horizontal advance width via hmtx, in raw font design units (NOT scaled by unitsPerEm – caller's job, e.g.
- int ttf_glyph_outline (const ttf_font_t ∗font, uint32_t glyph_index, ttf_outline_t ∗out)

  ttf_glyph_outline - Extract a glyph's outline (simple or composite, recursively resolving composite components) into caller-supplied buffers.
- int ttf_rasterize_glyph (const ttf_font_t ∗font, uint32_t glyph_index, q48_16_t scale, q48_16_t origin_↩ x, q48_16_t origin_y, uint8_t fill_value, ttf_bitmap_t ∗out)

  ttf_rasterize_glyph - Flatten a glyph's outline (quadratic Bezier contours, fixed segment count per curve — see ttf.c's file header comment) and fill it into `out` using the even-odd rule (FABRIC-0.md item 4.3.7c; see that item's completion note for why even-odd rather than nonzero winding — correct for the v1 glyph repertoire's non-self- intersecting nested contours, not necessarily for an arbitrary font).
- void ttf_raster_cache_init (ttf_raster_cache_t ∗cache, ttf_raster_cache_slot_t ∗slots, uint32_t slot_count)

  ttf_raster_cache_init - Bind a caller-supplied slot array to `cache` and mark every slot empty.
- int ttf_raster_cache_get (ttf_raster_cache_t ∗cache, const ttf_font_t ∗font, uint32_t codepoint, uint32_t size↩ _px, ttf_bitmap_t ∗out, int ∗was_hit)

  ttf_raster_cache_get - Look up (font, codepoint, size_px); on a miss, rasterize and insert (evicting round-robin if every slot is full).

7.68.1 Macro Definition Documentation

7.68.1.1 TTF_CACHE_BITMAP_BYTES

```
#define TTF_CACHE_BITMAP_BYTES (TTF_CACHE_BITMAP_DIM * TTF_CACHE_BITMAP_DIM)
```

7.68.1.2 TTF_CACHE_BITMAP_DIM

```
#define TTF_CACHE_BITMAP_DIM (TTF_CACHE_MAX_SIZE_PX + TTF_CACHE_MARGIN * 2)
```

7.68.1.3 TTF_CACHE_MARGIN

```
#define TTF_CACHE_MARGIN 8
```

7.68.1.4 TTF_CACHE_MAX_SIZE_PX

```
#define TTF_CACHE_MAX_SIZE_PX 64
```

7.68.1.5 TTF_ERR_BAD_GLYPH_INDEX

```
#define TTF_ERR_BAD_GLYPH_INDEX -4
```

7.68.1.6 TTF_ERR_BAD_SFNT

```
#define TTF_ERR_BAD_SFNT -1
```

7.68.1.7 TTF_ERR_BAD_TABLE

```
#define TTF_ERR_BAD_TABLE -3
```

7.68.1.8 TTF_ERR_OUT_OF_BOUNDS

```
#define TTF_ERR_OUT_OF_BOUNDS -5
```

7.68.1.9 TTF_ERR_TABLE_MISSING

```
#define TTF_ERR_TABLE_MISSING -2
```

7.68.1.10 TTF_ERR_TOO_DEEP

```
#define TTF_ERR_TOO_DEEP -8 /* composite glyph nesting exceeded TTF_MAX_COMPOSITE_DEPTH */
```

7.68.1.11 TTF_ERR_TOO_MANY_CONTOURS

```
#define TTF_ERR_TOO_MANY_CONTOURS -7
```

7.68.1.12 TTF_ERR_TOO_MANY_POINTS

```
#define TTF_ERR_TOO_MANY_POINTS -6
```

7.68.1.13 TTF_ERR_UNSUPPORTED

```
#define TTF_ERR_UNSUPPORTED
```

Value:

```
-9 /* e.g. a non-identity composite transform or point-matched
* component args -- see ttf.c's file header comment; not a
* malformed font, just a code path this parser doesn't
* implement yet */
```

7.68.1.14 TTF_GLYPH_MISSING

```
#define TTF_GLYPH_MISSING 0
```

Glyph index returned for "no mapping" by ttf_codepoint_to_glyph().

7.68.1.15 TTF_MAX_COMPOSITE_DEPTH

```
#define TTF_MAX_COMPOSITE_DEPTH 8
```

7.68.1.16 TTF_OK

```
#define TTF_OK 0
```

ttf.h - TrueType font parser core (Freestanding)

FABRIC-0.md item 4.3.7. Reads a TTF's sfnt directory plus head/maxp/loca/ glyf/cmap tables, resolving a Unicode codepoint to a glyph index and its outline header (contour count, bounding box). Does NOT extract outline points or rasterize — that is 4.3.7a/4.3.7c. No floating point; all fields read here are raw integers straight from the font's own big-endian on-disk format (see FABRIC-0.md ?27.7 decision #2 for why the Q48.16-vs-float call was made, and why it doesn't bind this file, which never scales anything).

cmap: only format 4 (Windows/Unicode BMP) subtables are resolved. This covers ASCII and all of the BMP, which is what the v1 glyph repertoire (?27.6.4) needs. Format 12 (supplementary planes) is deferred — no v1 glyph requires it.

7.68.2 Function Documentation

7.68.2.1 ttf_codepoint_to_glyph()

```
uint32_t ttf_codepoint_to_glyph (
            const ttf_font_t * font,
            uint32_t codepoint )
```

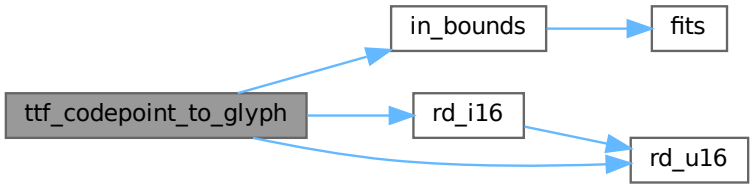
ttf_codepoint_to_glyph - Resolve a Unicode codepoint via the font's format-4 cmap subtable.

Returns

glyph index, or TTF_GLYPH_MISSING if unmapped or no cmap

References ttf_font_t::cmap_subtable_off, ttf_font_t::data, ttf_font_t::has_cmap, in_bounds(), rd_i16(), rd_u16(), and TTF_GLYPH_MISSING.

Here is the call graph for this function:



7.68.2.2 ttf_glyph_advance_width()

```
uint16_t ttf_glyph_advance_width (
            const ttf_font_t * font,
            uint32_t glyph_index )
```

ttf_glyph_advance_width - Horizontal advance width via hmtx, in raw font design units (NOT scaled by unitsPerEm – caller's job, e.g.

`q48_mul(q48_from_u64(width), scale)`; always non-negative, so the shared q48_mul is fine here unlike the signed cases documented in ttf.c's rasterizer). Glyphs past hmtx's numberOfHMetrics entries share the last entry's width, per spec.

Parameters

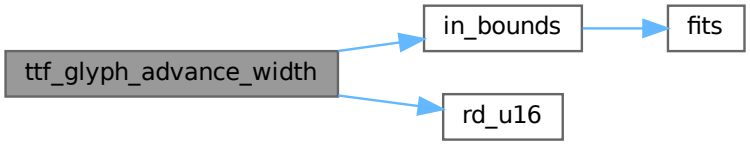
glyph_index	As returned by ttf_codepoint_to_glyph()

Returns

advance width, or 0 if glyph_index is out of range

References ttf_font_t::data, ttf_font_t::hmtx_off, in_bounds(), ttf_font_t::num_h_metrics, and rd_u16().

Here is the call graph for this function:



7.68.2.3 ttf_glyph_header()

```
int ttf_glyph_header (
            const ttf_font_t * font,
            uint32_t glyph_index,
            ttf_glyph_header_t * out )
```

ttf_glyph_header - Read a glyph's outline header (contour count, bounding box) via loca + glyf.

Does not extract contour points.

Parameters

glyph_index	As returned by ttf_codepoint_to_glyph()
out	Header to populate

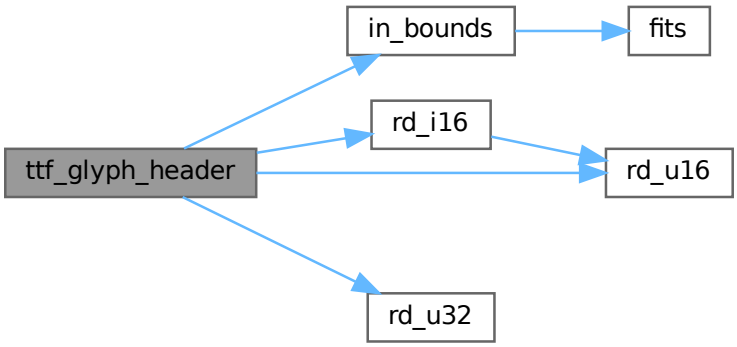
Returns

TTF_OK, or a TTF_ERR_∗ code

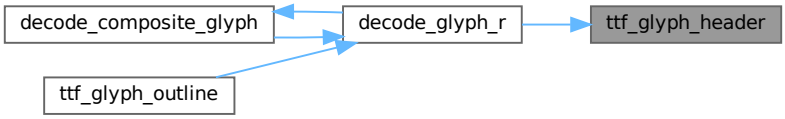
References ttf_font_t::data, ttf_glyph_header_t::glyf_length, ttf_font_t::glyf_off, ttf_glyph_header_t::glyf_offset, in_bounds(), ttf_font_t::index_to_loc_format, ttf_font_t::loca_off, ttf_glyph_header_t::num_contours, ttf_font_t::num_glyphs, rd_i16(), rd_u16(), rd_u32(), TTF_ERR_BAD_GLYPH_INDEX, TTF_ERR_BAD_TABLE, TTF_ERR_OUT_OF_BOUNDS, TTF_OK, ttf_glyph_header_t::x_max, ttf_glyph_header_t::x_min, ttf_glyph_header_t::y_max, and ttf_glyph_header_t::y_min.

Referenced by decode_glyph_r().

Here is the call graph for this function:



Here is the caller graph for this function:



7.68.2.4 ttf_glyph_outline()

```
int ttf_glyph_outline (
            const ttf_font_t * font,
            uint32_t glyph_index,
            ttf_outline_t * out )
```

ttf_glyph_outline - Extract a glyph's outline (simple or composite, recursively resolving composite components) into caller-supplied buffers.

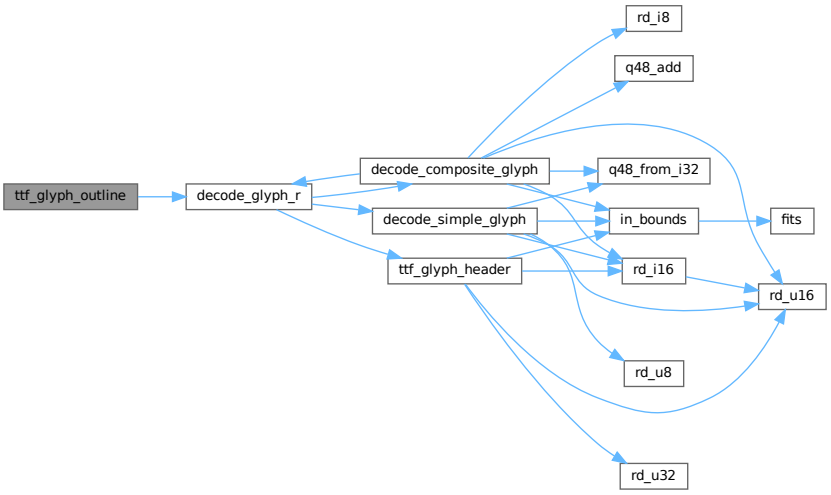
Composite components with a non-identity transform (any scale/rotation/ skew, i.e. anything but a pure (dx,dy) translation) or with point-matched (rather than xy-offset) placement args return TTF_ERR_UNSUPPORTED rather than silently producing a wrong outline — see ttf.c's file header comment for why, and check that limitation before relying on this for an arbitrary font.

Returns

TTF_OK, or a TTF_ERR_∗ code (including TTF_ERR_TOO_MANY_POINTS/ _CONTOURS if a caller buffer is too small, and TTF_ERR_TOO_DEEP if composite nesting exceeds TTF_MAX_COMPOSITE_DEPTH)

References ttf_outline_t::contour_count, decode_glyph_r(), ttf_outline_t::point_count, and TTF_ERR_BAD_TABLE.

Here is the call graph for this function:



7.68.2.5 ttf_parse()

```
int ttf_parse (
            const uint8_t * data,
            uint32_t size,
            ttf_font_t * out )
```

ttf_parse - Locate and validate the sfnt directory and the head/maxp/ loca/glyf tables (cmap is optional; ttf_codepoint_to_glyph() fails cleanly if absent).

Does not copy `data` — `out` borrows it.

Parameters

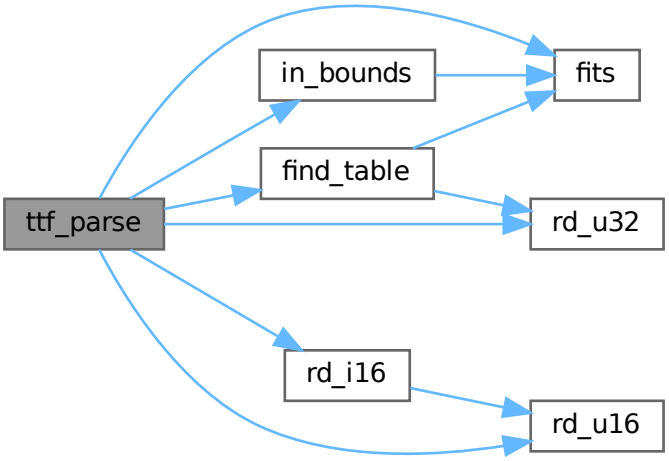
data	Whole .ttf file contents
size	Length of data in bytes
out	Parsed handle to populate

Returns

TTF_OK, or a TTF_ERR_∗ code

References ttf_font_t::cmap_subtable_off, ttf_font_t::data, find_table(), fits(), ttf_font_t::glyf_len, ttf_font_t::glyf_off, ttf_font_t::has_cmap, ttf_font_t::head_off, ttf_font_t::hmtx_off, in_bounds(), ttf_font_t::index_to_loc_format, ttf_font_t::loca_len, ttf_font_t::loca_off, ttf_font_t::maxp_off, ttf_font_t::num_glyphs, ttf_font_t::num_h_metrics, rd_i16(), rd_u16(), rd_u32(), ttf_font_t::size, TAG, TTF_ERR_BAD_SFNT, TTF_ERR_BAD_TABLE, TTF_ERR_OUT_OF_BOUNDS, TTF_OK, and ttf_font_t::units_per_em.

Here is the call graph for this function:



7.68.2.6 ttf_raster_cache_get()

```
int ttf_raster_cache_get (
            ttf_raster_cache_t * cache,
            const ttf_font_t * font,
            uint32_t codepoint,
            uint32_t size_px,
            ttf_bitmap_t * out,
            int * was_hit )
```

ttf_raster_cache_get - Look up (font, codepoint, size_px); on a miss, rasterize and insert (evicting round-robin if every slot is full).

`out` borrows the winning slot's buffer directly – valid until that slot is evicted by a later call.

Parameters

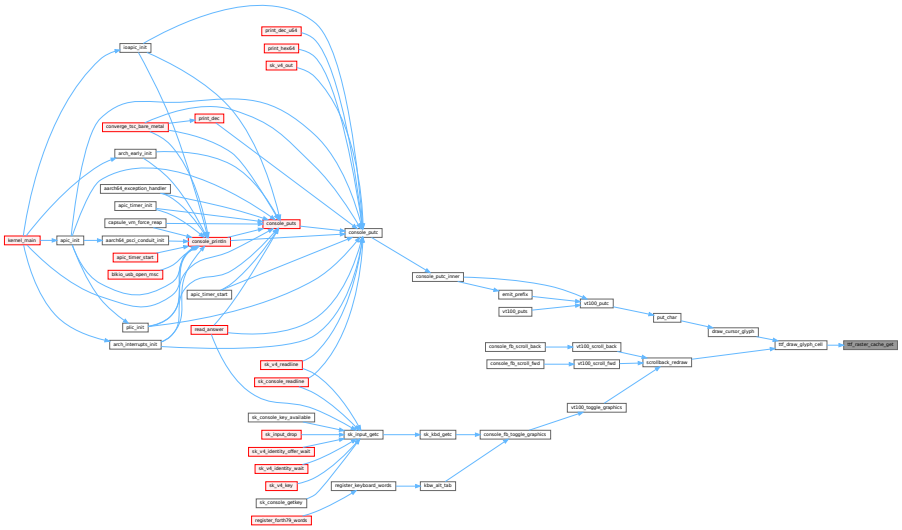
was_hit	If non-NULL, set to 1 on a cache hit, 0 if this call rasterized and inserted

Returns

TTF_OK, TTF_ERR_UNSUPPORTED if size_px > TTF_CACHE_MAX_SIZE_PX, or a ttf_rasterize_glyph() TTF_ERR_∗ code on a miss that failed to rasterize

Referenced by ttf_draw_glyph_cell().

Here is the caller graph for this function:



7.68.2.7 ttf_raster_cache_init()

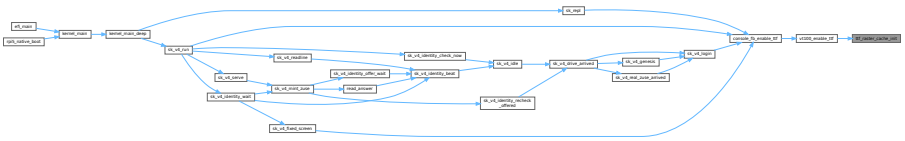
```
void ttf_raster_cache_init (
            ttf_raster_cache_t * cache,
            ttf_raster_cache_slot_t * slots,
            uint32_t slot_count )
```

ttf_raster_cache_init - Bind a caller-supplied slot array to `cache` and mark every slot empty.

References ttf_raster_cache_t::evict_next, ttf_raster_cache_t::slot_count, ttf_raster_cache_t::slots, and slots.

Referenced by vt100_enable_ttf().

Here is the caller graph for this function:



7.68.2.8 ttf_rasterize_glyph()

```
int ttf_rasterize_glyph (
            const ttf_font_t * font,
            uint32_t glyph_index,
            q48_16_t scale,
            q48_16_t origin_x,
            q48_16_t origin_y,
```

```
            uint8_t fill_value,
            ttf_bitmap_t * out )
```

ttf_rasterize_glyph - Flatten a glyph's outline (quadratic Bezier contours, fixed segment count per curve — see ttf.c's file header comment) and fill it into `out` using the even-odd rule (FABRIC-0.md item 4.3.7c; see that item's completion note for why even-odd rather than nonzero winding — correct for the v1 glyph repertoire's non-self-intersecting nested contours, not necessarily for an arbitrary font).

No antialiasing (explicitly deferred, per 4.3.7c's own "done when" clause). Never allocates — flattening uses a fixed-size local buffer bounded by TTF_RASTER_MAX_POINTS/TTF_RASTER_MAX_CONTOURS.

Parameters

scale	Font-design-units-to-pixels scale, Q48.16, e.g. q48_div(q48_from_u64(size_px), q48_from_u64(font->units_per_em))
origin_x	Pixel-space X (Q48.16) of the glyph's (0,0) font origin within `out`
origin_y	Pixel-space Y (Q48.16) of the glyph's baseline (font y=0) within `out`; font Y-up is flipped to raster Y-down internally

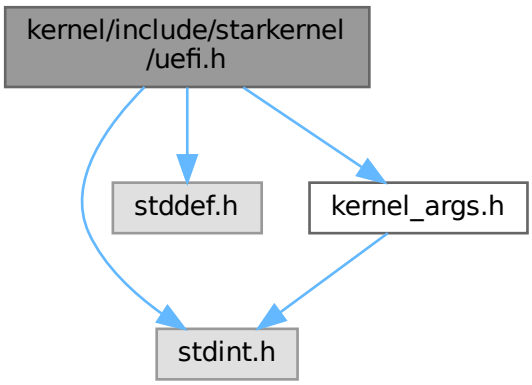
Returns

TTF_OK, or a TTF_ERR_* code (including TTF_ERR_TOO_MANY_POINTS/ _CONTOURS if the flattened outline exceeds the local buffer)

7.69 kernel/include/starkernel/uefi.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "kernel_args.h"
```

Include dependency graph for uefi.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct EFI_GUID
- struct EFI_MEMORY_DESCRIPTOR
- struct EFI_TABLE_HEADER
- struct _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL
- struct EFI_DEVICE_PATH_PROTOCOL
- struct _EFI_BOOT_SERVICES
- struct _EFI_RUNTIME_SERVICES
- struct _EFI_SYSTEM_TABLE
- struct EFI_CONFIGURATION_TABLE
- struct EFI_PIXEL_BITMASK
- struct EFI_GRAPHICS_OUTPUT_MODE_INFORMATION
- struct EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE
- struct _EFI_GRAPHICS_OUTPUT_PROTOCOL
- struct FramebufferInfo
- struct EFI_BLOCK_IO_MEDIA
- struct _EFI_BLOCK_IO_PROTOCOL
- struct _EFI_FILE_PROTOCOL
- struct _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL
- struct EFI_TIME
- struct EFI_FILE_INFO
- struct EFI_LOADED_IMAGE_PROTOCOL
- struct BootDisk
- struct BootInfo

Macros

- #define TRUE ((BOOLEAN)1)
- #define FALSE ((BOOLEAN)0)
- #define TPL_APPLICATION 4
- #define TPL_CALLBACK 8
- #define TPL_NOTIFY 16
- #define TPL_HIGH_LEVEL 31
- #define EFIAPI
- #define EFI_SUCCESS 0
- #define EFI_LOAD_ERROR (1 | (1ULL << 63))
- #define EFI_INVALID_PARAMETER (2 | (1ULL << 63))
- #define EFI_UNSUPPORTED (3 | (1ULL << 63))
- #define EFI_BAD_BUFFER_SIZE (4 | (1ULL << 63))
- #define EFI_BUFFER_TOO_SMALL (5 | (1ULL << 63))
- #define EFI_NOT_READY (6 | (1ULL << 63))
- #define EFI_DEVICE_ERROR (7 | (1ULL << 63))
- #define EFI_WRITE_PROTECTED (8 | (1ULL << 63))
- #define EFI_OUT_OF_RESOURCES (9 | (1ULL << 63))
- #define EFI_NOT_FOUND (14 | (1ULL << 63))
- #define EFI_ABORTED (21 | (1ULL << 63))

- #define EFI_MEMORY_UC 0x0000000000000001ULL
- #define EFI_MEMORY_WC 0x0000000000000002ULL
- #define EFI_MEMORY_WT 0x0000000000000004ULL
- #define EFI_MEMORY_WB 0x0000000000000008ULL
- #define EFI_MEMORY_UCE 0x0000000000000010ULL
- #define EFI_MEMORY_WP 0x0000000000001000ULL
- #define EFI_MEMORY_RP 0x0000000000002000ULL
- #define EFI_MEMORY_XP 0x0000000000004000ULL
- #define EFI_MEMORY_RUNTIME 0x8000000000000000ULL
- #define EFI_DEVICE_PATH_TYPE_MEDIA 0x04
- #define EFI_DEVICE_PATH_SUBTYPE_HARDDRIVE 0x01
- #define EFI_DEVICE_PATH_TYPE_END 0x7F
- #define EFI_DEVICE_PATH_SUBTYPE_END_ENTIRE 0xFF
- #define EFI_FILE_MODE_READ 0x0000000000000001ULL
- #define EFI_VARIABLE_NON_VOLATILE 0x00000001U
- #define EFI_VARIABLE_BOOTSERVICE_ACCESS 0x00000002U
- #define EFI_VARIABLE_RUNTIME_ACCESS 0x00000004U
- #define STARFORTH_VENDOR_GUID
- #define SF_VAR_BOOT_ARGS L"StarForthBootArgs"
- #define SF_VAR_REBOOT_TRIES L"StarForthRebootTries"
- #define SF_VAR_ZUSE_CERT

Typedefs

- typedef uint64_t UINTN

  uefi.h - UEFI definitions for StarKernel Minimal UEFI interface for bare-metal boot
- typedef int64_t INTN
- typedef uint8_t UINT8
- typedef uint16_t UINT16
- typedef uint32_t UINT32
- typedef uint64_t UINT64
- typedef int8_t INT8
- typedef int16_t INT16
- typedef int32_t INT32
- typedef int64_t INT64
- typedef uint8_t BOOLEAN
- typedef void VOID
- typedef uint16_t CHAR16
- typedef UINTN EFI_TPL
- typedef UINTN EFI_STATUS
- typedef void * EFI_HANDLE
- typedef UINT64 EFI_PHYSICAL_ADDRESS
- typedef EFI_STATUS(* EFI_TEXT_STRING) (struct _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL *This, CHAR16 *String)
- typedef EFI_STATUS(* EFI_TEXT_RESET) (struct _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL *This, BOOLEAN ExtendedVerification)
- typedef struct _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL
- typedef EFI_STATUS(* EFI_GET_MEMORY_MAP) (UINTN *MemoryMapSize, EFI_MEMORY_DESCRIPTOR *MemoryMap, UINTN *MapKey, UINTN *DescriptorSize, UINT32 *DescriptorVersion)
- typedef EFI_STATUS(* EFI_EXIT_BOOT_SERVICES) (EFI_HANDLE ImageHandle, UINTN MapKey)
- typedef EFI_STATUS(* EFI_ALLOCATE_POOL) (EFI_MEMORY_TYPE PoolType, UINTN Size, void **Buffer)
- typedef EFI_STATUS(* EFI_FREE_POOL) (void *Buffer)

- typedef EFI_STATUS(∗ EFI_ALLOCATE_PAGES) (EFI_ALLOCATE_TYPE Type, EFI_MEMORY_TYPE MemoryType, UINTN Pages, EFI_PHYSICAL_ADDRESS ∗Memory)
- typedef EFI_STATUS(∗ EFI_FREE_PAGES) (EFI_PHYSICAL_ADDRESS Memory, UINTN Pages)
- typedef EFI_STATUS(∗ EFI_HANDLE_PROTOCOL) (EFI_HANDLE Handle, EFI_GUID ∗Protocol, void ∗∗Interface)
- typedef EFI_STATUS(∗ EFI_STALL) (UINTN Microseconds)
- typedef EFI_STATUS(∗ EFI_LOCATE_HANDLE) (EFI_LOCATE_SEARCH_TYPE SearchType, EFI_GUID ∗Protocol, void ∗SearchKey, UINTN ∗BufferSize, EFI_HANDLE ∗Buffer)
- typedef EFI_STATUS(∗ EFI_LOCATE_PROTOCOL) (EFI_GUID ∗Protocol, void ∗Registration, void ∗∗Interface)
- typedef EFI_STATUS(∗ EFI_LOCATE_DEVICE_PATH) (EFI_GUID ∗Protocol, EFI_DEVICE_PATH_PROTOCOL ∗∗DevicePath, EFI_HANDLE ∗Device)
- typedef EFI_TPL(∗ EFI_RAISE_TPL) (EFI_TPL NewTpl)
- typedef void(∗ EFI_RESTORE_TPL) (EFI_TPL OldTpl)
- typedef struct _EFI_BOOT_SERVICES EFI_BOOT_SERVICES
- typedef struct _EFI_RUNTIME_SERVICES EFI_RUNTIME_SERVICES
- typedef struct _EFI_SYSTEM_TABLE EFI_SYSTEM_TABLE
- typedef EFI_STATUS(∗ EFI_GRAPHICS_OUTPUT_PROTOCOL_QUERY_MODE) (struct _EFI_GRAPHICS_OUTPUT_PROTO ∗This, UINT32 ModeNumber, UINTN ∗SizeOfInfo, EFI_GRAPHICS_OUTPUT_MODE_INFORMATION ∗∗Info)
- typedef EFI_STATUS(∗ EFI_GRAPHICS_OUTPUT_PROTOCOL_SET_MODE) (struct _EFI_GRAPHICS_OUTPUT_PROTOCO ∗This, UINT32 ModeNumber)
- typedef struct _EFI_GRAPHICS_OUTPUT_PROTOCOL EFI_GRAPHICS_OUTPUT_PROTOCOL
- typedef EFI_STATUS(∗ EFI_BLOCK_READ) (struct _EFI_BLOCK_IO_PROTOCOL ∗This, UINT32 MediaId, UINT64 Lba, UINTN BufferSize, void ∗Buffer)
- typedef struct _EFI_BLOCK_IO_PROTOCOL EFI_BLOCK_IO_PROTOCOL
- typedef EFI_STATUS(∗ EFI_FILE_OPEN) (struct _EFI_FILE_PROTOCOL ∗This, struct _EFI_FILE_PROTOCOL ∗∗NewHandle, CHAR16 ∗FileName, UINT64 OpenMode, UINT64 Attributes)
- typedef EFI_STATUS(∗ EFI_FILE_CLOSE) (struct _EFI_FILE_PROTOCOL ∗This)
- typedef EFI_STATUS(∗ EFI_FILE_READ) (struct _EFI_FILE_PROTOCOL ∗This, UINTN ∗BufferSize, VOID ∗Buffer)
- typedef EFI_STATUS(∗ EFI_FILE_GET_INFO) (struct _EFI_FILE_PROTOCOL ∗This, EFI_GUID ∗InformationType, UINTN ∗BufferSize, VOID ∗Buffer)
- typedef struct _EFI_FILE_PROTOCOL EFI_FILE_PROTOCOL
- typedef EFI_STATUS(∗ EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_OPEN_VOLUME) (struct _EFI_SIMPLE_FILE_SYSTEM_ ∗This, EFI_FILE_PROTOCOL ∗∗Root)
- typedef struct _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL EFI_SIMPLE_FILE_SYSTEM_PROTOCOL
- typedef EFI_STATUS(∗ EFI_GET_VARIABLE) (CHAR16 ∗VariableName, EFI_GUID ∗VendorGuid, UINT32 ∗Attributes, UINTN ∗DataSize, void ∗Data)
- typedef EFI_STATUS(∗ EFI_SET_VARIABLE) (CHAR16 ∗VariableName, EFI_GUID ∗VendorGuid, UINT32 Attributes, UINTN DataSize, void ∗Data)
- typedef void(∗ EFI_RESET_SYSTEM) (EFI_RESET_TYPE ResetType, EFI_STATUS ResetStatus, UINTN DataSize, void ∗ResetData)

Enumerations

- enum EFI_ALLOCATE_TYPE { AllocateAnyPages , AllocateMaxAddress , AllocateAddress , MaxAllocateType }
- enum EFI_MEMORY_TYPE { EfiReservedMemoryType , EfiLoaderCode , EfiLoaderData , EfiBootServicesCode , EfiBootServicesData , EfiRuntimeServicesCode , EfiRuntimeServicesData , EfiConventionalMemory , EfiUnusableMemory , EfiACPIReclaimMemory , EfiACPIMemoryNVS , EfiMemoryMappedIO , EfiMemoryMappedIOPortSpace , EfiPalCode , EfiPersistentMemory , EfiMaxMemoryType }
- enum EFI_LOCATE_SEARCH_TYPE { AllHandles , ByRegisterNotify , ByProtocol }

- enum EFI_GRAPHICS_PIXEL_FORMAT { PixelRedGreenBlueReserved8BitPerColor , PixelBlueGreenRedReserved8BitPerColor , PixelBitMask , PixelBltOnly , PixelFormatMax }
- enum EFI_RESET_TYPE { EfiResetCold , EfiResetWarm , EfiResetShutdown }

Variables

- static const EFI_GUID EFI_ACPI_20_TABLE_GUID = {0x8868e871,0xe4f1,0x11d3,{0xbc,0x22,0x00,0x80,0xc7,0x3c,0x88,0x8
- static const EFI_GUID EFI_ACPI_TABLE_GUID = {0xeb9d2d30,0x2d88,0x11d3,{0x9a,0x16,0x00,0x90,0x27,0x3f,0xc1,0x4d}}
- static const EFI_GUID EFI_DTB_TABLE_GUID
- static const EFI_GUID EFI_GRAPHICS_OUTPUT_PROTOCOL_GUID
- static const EFI_GUID EFI_LOADED_IMAGE_PROTOCOL_GUID
- static const EFI_GUID EFI_DEVICE_PATH_PROTOCOL_GUID
- static const EFI_GUID EFI_BLOCK_IO_PROTOCOL_GUID
- static const EFI_GUID EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_GUID
- static const EFI_GUID EFI_FILE_INFO_GUID

7.69.1 Macro Definition Documentation

7.69.1.1 EFI_ABORTED

```
#define EFI_ABORTED (21 | (1ULL << 63))
```

7.69.1.2 EFI_BAD_BUFFER_SIZE

```
#define EFI_BAD_BUFFER_SIZE (4 | (1ULL << 63))
```

7.69.1.3 EFI_BUFFER_TOO_SMALL

```
#define EFI_BUFFER_TOO_SMALL (5 | (1ULL << 63))
```

7.69.1.4 EFI_DEVICE_ERROR

```
#define EFI_DEVICE_ERROR (7 | (1ULL << 63))
```

7.69.1.5 EFI_DEVICE_PATH_SUBTYPE_END_ENTIRE

```
#define EFI_DEVICE_PATH_SUBTYPE_END_ENTIRE 0xFF
```

7.69.1.6 EFI_DEVICE_PATH_SUBTYPE_HARDDRIVE

```
#define EFI_DEVICE_PATH_SUBTYPE_HARDDRIVE 0x01
```

7.69.1.7 EFI_DEVICE_PATH_TYPE_END

```
#define EFI_DEVICE_PATH_TYPE_END 0x7F
```

7.69.1.8 EFI_DEVICE_PATH_TYPE_MEDIA

```
#define EFI_DEVICE_PATH_TYPE_MEDIA 0x04
```

7.69.1.9 EFI_FILE_MODE_READ

```
#define EFI_FILE_MODE_READ 0x0000000000000001ULL
```

7.69.1.10 EFI_INVALID_PARAMETER

```
#define EFI_INVALID_PARAMETER (2 | (1ULL << 63))
```

7.69.1.11 EFI_LOAD_ERROR

```
#define EFI_LOAD_ERROR (1 | (1ULL << 63))
```

7.69.1.12 EFI_MEMORY_RP

```
#define EFI_MEMORY_RP 0x0000000000002000ULL
```

7.69.1.13 EFI_MEMORY_RUNTIME

```
#define EFI_MEMORY_RUNTIME 0x8000000000000000ULL
```

7.69.1.14 EFI_MEMORY_UC

```
#define EFI_MEMORY_UC 0x0000000000000001ULL
```

7.69.1.15 EFI_MEMORY_UCE

```
#define EFI_MEMORY_UCE 0x0000000000000010ULL
```

7.69.1.16 EFI_MEMORY_WB

```
#define EFI_MEMORY_WB 0x0000000000000008ULL
```

7.69.1.17 EFI_MEMORY_WC

```
#define EFI_MEMORY_WC 0x0000000000000002ULL
```

7.69.1.18 EFI_MEMORY_WP

```
#define EFI_MEMORY_WP 0x0000000000001000ULL
```

7.69.1.19 EFI_MEMORY_WT

```
#define EFI_MEMORY_WT 0x0000000000000004ULL
```

7.69.1.20 EFI_MEMORY_XP

```
#define EFI_MEMORY_XP 0x0000000000004000ULL
```

7.69.1.21 EFI_NOT_FOUND

```
#define EFI_NOT_FOUND (14 | (1ULL << 63))
```

7.69.1.22 EFI_NOT_READY

```
#define EFI_NOT_READY (6 | (1ULL << 63))
```

7.69.1.23 EFI_OUT_OF_RESOURCES

```
#define EFI_OUT_OF_RESOURCES (9 | (1ULL << 63))
```

7.69.1.24 EFI_SUCCESS

```
#define EFI_SUCCESS 0
```

7.69.1.25 EFI_UNSUPPORTED

```
#define EFI_UNSUPPORTED (3 | (1ULL << 63))
```

7.69.1.26 EFI_VARIABLE_BOOTSERVICE_ACCESS

```
#define EFI_VARIABLE_BOOTSERVICE_ACCESS 0x00000002U
```

7.69.1.27 EFI_VARIABLE_NON_VOLATILE

```
#define EFI_VARIABLE_NON_VOLATILE 0x00000001U
```

7.69.1.28 EFI_VARIABLE_RUNTIME_ACCESS

```
#define EFI_VARIABLE_RUNTIME_ACCESS 0x00000004U
```

7.69.1.29 EFI_WRITE_PROTECTED

```
#define EFI_WRITE_PROTECTED (8 | (1ULL << 63))
```

7.69.1.30 EFIAPI

```
#define EFIAPI
```

7.69.1.31 FALSE

```
#define FALSE ((BOOLEAN)0)
```

7.69.1.32 SF_VAR_BOOT_ARGS

```
#define SF_VAR_BOOT_ARGS L"StarForthBootArgs"
```

7.69.1.33 SF_VAR_REBOOT_TRIES

```
#define SF_VAR_REBOOT_TRIES L"StarForthRebootTries"
```

7.69.1.34 SF_VAR_ZUSE_CERT

```
#define SF_VAR_ZUSE_CERT
```

Value:

```
L"StarForthZuseCert" /* 64 bytes: 32-byte Ed25519
* seed || 32-byte pubkey.
* Written exactly once
* (Phase 8 first-boot mint,
* see FABRIC-2.md) --
* presence means the fuse
* is already blown. */
```

7.69.1.35 STARFORTH_VENDOR_GUID

```
#define STARFORTH_VENDOR_GUID
```

Value:

```
    {0xb7e42c1aU, 0x4f3dU, 0x4e8bU, \
     {0x9cU, 0x5aU, 0x1dU, 0x2fU, 0x6aU, 0x8bU, 0x3eU, 0x70U}}
```

7.69.1.36 TPL_APPLICATION

```
#define TPL_APPLICATION 4
```

7.69.1.37 TPL_CALLBACK

```
#define TPL_CALLBACK 8
```

7.69.1.38 TPL_HIGH_LEVEL

```
#define TPL_HIGH_LEVEL 31
```

7.69.1.39 TPL_NOTIFY

```
#define TPL_NOTIFY 16
```

7.69.1.40 TRUE

```
#define TRUE ((BOOLEAN)1)
```

7.69.2 Typedef Documentation

7.69.2.1 BOOLEAN

```
typedef uint8_t BOOLEAN
```

7.69.2.2 CHAR16

```
typedef uint16_t CHAR16
```

7.69.2.3 EFI_ALLOCATE_PAGES

```
typedef EFI_STATUS( * EFI_ALLOCATE_PAGES) (EFI_ALLOCATE_TYPE Type, EFI_MEMORY_TYPE MemoryType,
UINTN Pages, EFI_PHYSICAL_ADDRESS *Memory)
```

7.69.2.4 EFI_ALLOCATE_POOL

```
typedef EFI_STATUS( * EFI_ALLOCATE_POOL) (EFI_MEMORY_TYPE PoolType, UINTN Size, void **Buffer)
```

7.69.2.5 EFI_BLOCK_IO_PROTOCOL

```
typedef struct _EFI_BLOCK_IO_PROTOCOL EFI_BLOCK_IO_PROTOCOL
```

7.69.2.6 EFI_BLOCK_READ

```
typedef EFI_STATUS( * EFI_BLOCK_READ) (struct _EFI_BLOCK_IO_PROTOCOL *This, UINT32 MediaId,
UINT64 Lba, UINTN BufferSize, void *Buffer)
```

7.69.2.7 EFI_BOOT_SERVICES

```
typedef struct _EFI_BOOT_SERVICES EFI_BOOT_SERVICES
```

7.69.2.8 EFI_EXIT_BOOT_SERVICES

```
typedef EFI_STATUS( * EFI_EXIT_BOOT_SERVICES) (EFI_HANDLE ImageHandle, UINTN MapKey)
```

7.69.2.9 EFI_FILE_CLOSE

```
typedef EFI_STATUS( * EFI_FILE_CLOSE) (struct _EFI_FILE_PROTOCOL *This)
```

7.69.2.10 EFI_FILE_GET_INFO

```
typedef EFI_STATUS( * EFI_FILE_GET_INFO) (struct _EFI_FILE_PROTOCOL *This, EFI_GUID *Information↩
Type, UINTN *BufferSize, VOID *Buffer)
```

7.69.2.11 EFI_FILE_OPEN

```
typedef EFI_STATUS( * EFI_FILE_OPEN) (struct _EFI_FILE_PROTOCOL *This, struct _EFI_FILE_PROTOCOL
**NewHandle, CHAR16 *FileName, UINT64 OpenMode, UINT64 Attributes)
```

7.69.2.12 EFI_FILE_PROTOCOL

```
typedef struct _EFI_FILE_PROTOCOL EFI_FILE_PROTOCOL
```

7.69.2.13 EFI_FILE_READ

```
typedef EFI_STATUS( * EFI_FILE_READ) (struct _EFI_FILE_PROTOCOL *This, UINTN *BufferSize, VOID
*Buffer)
```

7.69.2.14 EFI_FREE_PAGES

```
typedef EFI_STATUS( * EFI_FREE_PAGES) (EFI_PHYSICAL_ADDRESS Memory, UINTN Pages)
```

7.69.2.15 EFI_FREE_POOL

```
typedef EFI_STATUS( * EFI_FREE_POOL) (void *Buffer)
```

7.69.2.16 EFI_GET_MEMORY_MAP

```
typedef EFI_STATUS( * EFI_GET_MEMORY_MAP) (UINTN *MemoryMapSize, EFI_MEMORY_DESCRIPTOR *Memory↩
Map, UINTN *MapKey, UINTN *DescriptorSize, UINT32 *DescriptorVersion)
```

7.69.2.17 EFI_GET_VARIABLE

```
typedef EFI_STATUS( * EFI_GET_VARIABLE) (CHAR16 *VariableName, EFI_GUID *VendorGuid, UINT32
*Attributes, UINTN *DataSize, void *Data)
```

7.69.2.18 EFI_GRAPHICS_OUTPUT_PROTOCOL

```
typedef struct _EFI_GRAPHICS_OUTPUT_PROTOCOL EFI_GRAPHICS_OUTPUT_PROTOCOL
```

7.69.2.19 EFI_GRAPHICS_OUTPUT_PROTOCOL_QUERY_MODE

```
typedef EFI_STATUS( * EFI_GRAPHICS_OUTPUT_PROTOCOL_QUERY_MODE) (struct _EFI_GRAPHICS_OUTPUT_PROTOCOL
*This, UINT32 ModeNumber, UINTN *SizeOfInfo, EFI_GRAPHICS_OUTPUT_MODE_INFORMATION **Info)
```

7.69.2.20 EFI_GRAPHICS_OUTPUT_PROTOCOL_SET_MODE

```
typedef EFI_STATUS( * EFI_GRAPHICS_OUTPUT_PROTOCOL_SET_MODE) (struct _EFI_GRAPHICS_OUTPUT_PROTOCOL
*This, UINT32 ModeNumber)
```

7.69.2.21 EFI_HANDLE

```
typedef void* EFI_HANDLE
```

7.69.2.22 EFI_HANDLE_PROTOCOL

```
typedef EFI_STATUS( * EFI_HANDLE_PROTOCOL) (EFI_HANDLE Handle, EFI_GUID *Protocol, void **Interface)
```

7.69.2.23 EFI_LOCATE_DEVICE_PATH

```
typedef EFI_STATUS( * EFI_LOCATE_DEVICE_PATH) (EFI_GUID *Protocol, EFI_DEVICE_PATH_PROTOCOL
**DevicePath, EFI_HANDLE *Device)
```

7.69.2.24 EFI_LOCATE_HANDLE

```
typedef EFI_STATUS( * EFI_LOCATE_HANDLE) (EFI_LOCATE_SEARCH_TYPE SearchType, EFI_GUID *Protocol,
void *SearchKey, UINTN *BufferSize, EFI_HANDLE *Buffer)
```

7.69.2.25 EFI_LOCATE_PROTOCOL

```
typedef EFI_STATUS( * EFI_LOCATE_PROTOCOL) (EFI_GUID *Protocol, void *Registration, void **Interface)
```

7.69.2.26 EFI_PHYSICAL_ADDRESS

```
typedef UINT64 EFI_PHYSICAL_ADDRESS
```

7.69.2.27 EFI_RAISE_TPL

```
typedef EFI_TPL( * EFI_RAISE_TPL) (EFI_TPL NewTpl)
```

7.69.2.28 EFI_RESET_SYSTEM

```
typedef void( * EFI_RESET_SYSTEM) (EFI_RESET_TYPE ResetType, EFI_STATUS ResetStatus, UINTN
DataSize, void *ResetData)
```

7.69.2.29 EFI_RESTORE_TPL

```
typedef void( * EFI_RESTORE_TPL) (EFI_TPL OldTpl)
```

7.69.2.30 EFI_RUNTIME_SERVICES

```
typedef struct _EFI_RUNTIME_SERVICES EFI_RUNTIME_SERVICES
```

7.69.2.31 EFI_SET_VARIABLE

```
typedef EFI_STATUS( * EFI_SET_VARIABLE) (CHAR16 *VariableName, EFI_GUID *VendorGuid, UINT32
Attributes, UINTN DataSize, void *Data)
```

7.69.2.32 EFI_SIMPLE_FILE_SYSTEM_PROTOCOL

```
typedef struct _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL EFI_SIMPLE_FILE_SYSTEM_PROTOCOL
```

7.69.2.33 EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_OPEN_VOLUME

```
typedef EFI_STATUS( * EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_OPEN_VOLUME) (struct _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL
*This, EFI_FILE_PROTOCOL **Root)
```

7.69.2.34 EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL

```
typedef struct _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL
```

7.69.2.35 EFI_STALL

```
typedef EFI_STATUS( * EFI_STALL) (UINTN Microseconds)
```

7.69.2.36 EFI_STATUS

```
typedef UINTN EFI_STATUS
```

7.69.2.37 EFI_SYSTEM_TABLE

```
typedef struct _EFI_SYSTEM_TABLE EFI_SYSTEM_TABLE
```

7.69.2.38 EFI_TEXT_RESET

```
typedef EFI_STATUS( * EFI_TEXT_RESET) (struct _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL *This, BOOLEAN
ExtendedVerification)
```

7.69.2.39 EFI_TEXT_STRING

```
typedef EFI_STATUS( * EFI_TEXT_STRING) (struct _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL *This, CHAR16
*String)
```

7.69.2.40 EFI_TPL

```
typedef UINTN EFI_TPL
```

7.69.2.41 INT16

```
typedef int16_t INT16
```

7.69.2.42 INT32

```
typedef int32_t INT32
```

7.69.2.43 INT64

```
typedef int64_t INT64
```

7.69.2.44 INT8

```
typedef int8_t INT8
```

7.69.2.45 INTN

```
typedef int64_t INTN
```

7.69.2.46 UINT16

```
typedef uint16_t UINT16
```

7.69.2.47 UINT32

```
typedef uint32_t UINT32
```

7.69.2.48 UINT64

```
typedef uint64_t UINT64
```

7.69.2.49 UINT8

```
typedef uint8_t UINT8
```

7.69.2.50 UINTN

```
typedef uint64_t UINTN
```

uefi.h - UEFI definitions for StarKernel Minimal UEFI interface for bare-metal boot

7.69.2.51 VOID

```
typedef void VOID
```

7.69.3 Enumeration Type Documentation

7.69.3.1 EFI_ALLOCATE_TYPE

```
enum EFI_ALLOCATE_TYPE
```

Enumerator

AllocateAnyPages	
AllocateMaxAddress	
AllocateAddress	
MaxAllocateType	

7.69.3.2 EFI_GRAPHICS_PIXEL_FORMAT

enum EFI_GRAPHICS_PIXEL_FORMAT

Enumerator

PixelRedGreenBlueReserved8BitPerColor	
PixelBlueGreenRedReserved8BitPerColor	
PixelBitMask	
PixelBltOnly	
PixelFormatMax	

7.69.3.3 EFI_LOCATE_SEARCH_TYPE

enum EFI_LOCATE_SEARCH_TYPE

Enumerator

AllHandles	
ByRegisterNotify	
ByProtocol	

7.69.3.4 EFI_MEMORY_TYPE

enum EFI_MEMORY_TYPE

Enumerator

EfiReservedMemoryType	
EfiLoaderCode	
EfiLoaderData	
EfiBootServicesCode	
EfiBootServicesData	
EfiRuntimeServicesCode	
EfiRuntimeServicesData	
EfiConventionalMemory	
EfiUnusableMemory	
EfiACPIReclaimMemory	
EfiACPIMemoryNVS	
EfiMemoryMappedIO	
EfiMemoryMappedIOPortSpace	
EfiPalCode	
EfiPersistentMemory	
EfiMaxMemoryType	

7.69.3.5 EFI_RESET_TYPE

```
enum EFI_RESET_TYPE
```

Enumerator

EfiResetCold	
EfiResetWarm	
EfiResetShutdown	

7.69.4 Variable Documentation

7.69.4.1 EFI_ACPI_20_TABLE_GUID

```
const EFI_GUID EFI_ACPI_20_TABLE_GUID = {0x8868e871,0xe4f1,0x11d3,{0xbc,0x22,0x00,0x80,0xc7,0x3c,0x88,0x81}}
[static]
```

Referenced by efi_main().

7.69.4.2 EFI_ACPI_TABLE_GUID

```
const EFI_GUID EFI_ACPI_TABLE_GUID = {0xeb9d2d30,0x2d88,0x11d3,{0x9a,0x16,0x00,0x90,0x27,0x3f,0xc1,0x4d}}
[static]
```

Referenced by efi_main().

7.69.4.3 EFI_BLOCK_IO_PROTOCOL_GUID

```
const EFI_GUID EFI_BLOCK_IO_PROTOCOL_GUID  [static]
```

Initial value:

```
=
    {0x964e5b21,0x6459,0x11d2, {0x8e,0x39,0x00,0xa0,0xc9,0x69,0x72,0x3b}}
```

7.69.4.4 EFI_DEVICE_PATH_PROTOCOL_GUID

```
const EFI_GUID EFI_DEVICE_PATH_PROTOCOL_GUID  [static]
```

Initial value:

```
=
    {0x09576e91,0x6d3f,0x11d2, {0x8e,0x39,0x00,0xa0,0xc9,0x69,0x72,0x3b}}
```

7.69.4.5 EFI_DTB_TABLE_GUID

```
const EFI_GUID EFI_DTB_TABLE_GUID  [static]
```

Initial value:

```
= {
    0xb1b621d5, 0xf19c, 0x41a5, {0x83, 0x0b, 0xd9, 0x15, 0x2c, 0x69, 0xaa, 0xe0}
}
```

Referenced by efi_main().

7.69.4.6 EFI_FILE_INFO_GUID

```
const EFI_GUID EFI_FILE_INFO_GUID  [static]
```

Initial value:

```
=
    {0x09576e92,0x6d3f,0x11d2, {0x8e,0x39,0x00,0xa0,0xc9,0x69,0x72,0x3b}}
```

Referenced by load_kernel_from_esp().

7.69.4.7 EFI_GRAPHICS_OUTPUT_PROTOCOL_GUID

```
const EFI_GUID EFI_GRAPHICS_OUTPUT_PROTOCOL_GUID  [static]
```

Initial value:

```
=
    {0x9042a9de, 0x23dc, 0x4a38, {0x96, 0xfb, 0x7a, 0xde, 0xd0, 0x80, 0x51, 0x6a}}
```

Referenced by efi_main().

7.69.4.8 EFI_LOADED_IMAGE_PROTOCOL_GUID

```
const EFI_GUID EFI_LOADED_IMAGE_PROTOCOL_GUID  [static]
```

Initial value:

```
=
    {0x5B1B31A1,0x9562,0x11d2, {0x8E,0x3F,0x00,0xA0,0xC9,0x69,0x72,0x3B}}
```

Referenced by efi_main(), load_cfg_from_esp(), and load_kernel_from_esp().

7.69.4.9 EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_GUID

```
const EFI_GUID EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_GUID  [static]
```

Initial value:

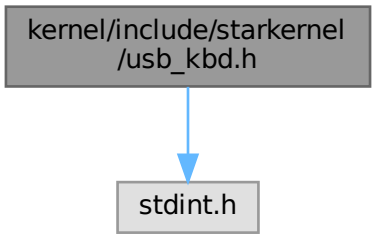
```
=
    {0x0964e5b22,0x6459,0x11d2, {0x8e,0x39,0x00,0xa0,0xc9,0x69,0x72,0x3b}}
```

Referenced by load_cfg_from_esp(), and load_kernel_from_esp().

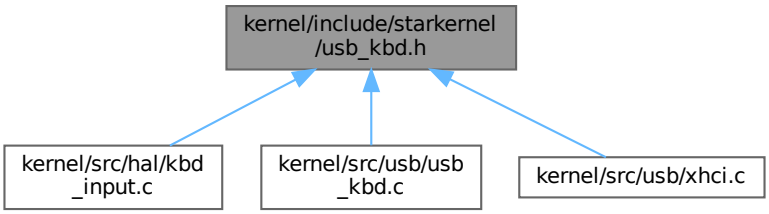
7.70 kernel/include/starkernel/usb_kbd.h File Reference

```
#include <stdint.h>
```

Include dependency graph for usb_kbd.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define USB_KBD_LED_NUM 0x01u
- #define USB_KBD_LED_CAPS 0x02u
- #define USB_KBD_LED_SCROLL 0x04u

Functions

- void usb_kbd_report (uint8_t prev[8], const uint8_t *report, uint32_t len)

  usb_kbd.h - a USB boot-protocol keyboard's keys, as key events (2026-10-14, boards/BRINGUP.md A3; usb_kbd.c).
- void usb_kbd_forget (uint8_t prev[8])
- int usb_kbd_pop_event (uint16_t *keycode, int *pressed)
- void usb_kbd_set_leds (uint8_t leds)
- uint8_t usb_kbd_leds_wanted (void)

7.70.1 Macro Definition Documentation

7.70.1.1 USB_KBD_LED_CAPS

```
#define USB_KBD_LED_CAPS 0x02u
```

7.70.1.2 USB_KBD_LED_NUM

```
#define USB_KBD_LED_NUM 0x01u
```

7.70.1.3 USB_KBD_LED_SCROLL

```
#define USB_KBD_LED_SCROLL 0x04u
```

7.70.2 Function Documentation

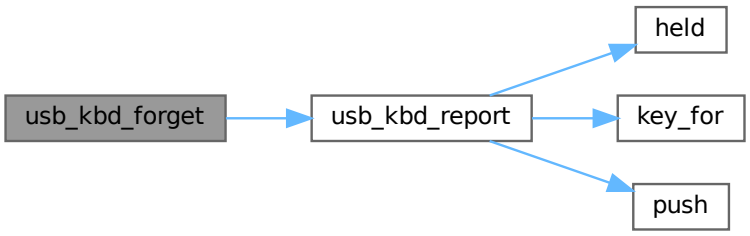
7.70.2.1 usb_kbd_forget()

```
void usb_kbd_forget (
            uint8_t prev[8] )
```

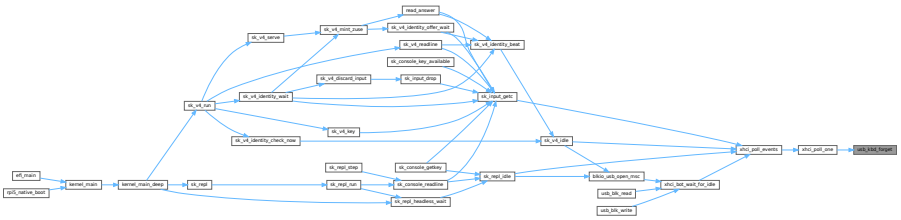
References usb_kbd_report().

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



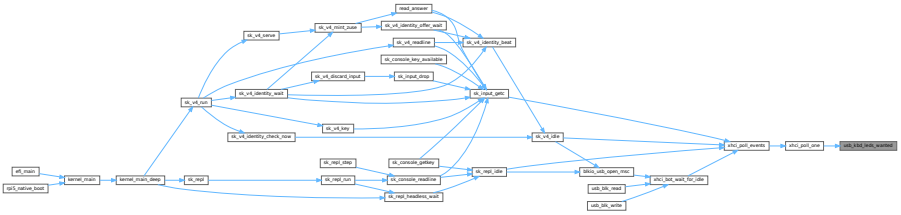
7.70.2.2 usb_kbd_leds_wanted()

```
uint8_t usb_kbd_leds_wanted (
            void  )
```

References g_leds_want.

Referenced by xhci_poll_one().

Here is the caller graph for this function:



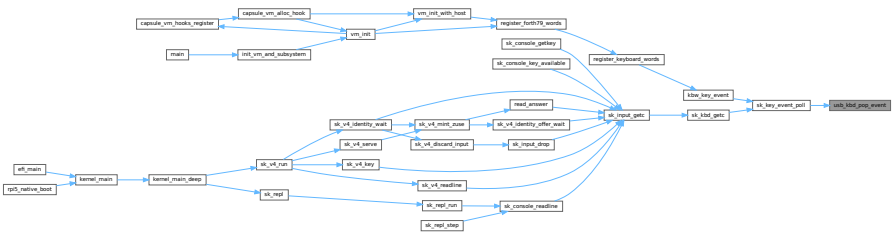
7.70.2.3 usb_kbd_pop_event()

```
int usb_kbd_pop_event (
            uint16_t * keycode,
            int * pressed )
```

References g_count, g_events, g_head, KBD_EVENTS, keycode, and pressed.

Referenced by sk_key_event_poll().

Here is the caller graph for this function:



7.70.2.4 usb_kbd_report()

```
void usb_kbd_report (
            uint8_t prev[8],
            const uint8_t * report,
            uint32_t len )
```

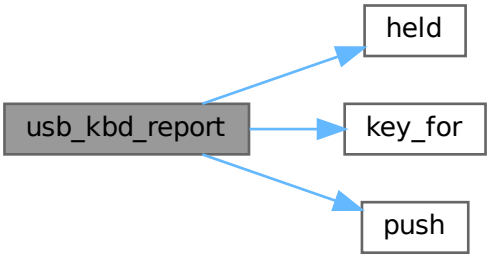
usb_kbd.h - a USB boot-protocol keyboard's keys, as key events (2026-10-14, boards/BRINGUP.md A3; usb_kbd.c).

The xHCI driver hands each 8-byte boot report here; the keys pressed and released since the report before come out as Linux input keycodes, the namespace every keyboard in this kernel already speaks (sk_key_event_poll(), keyboard_words.c).

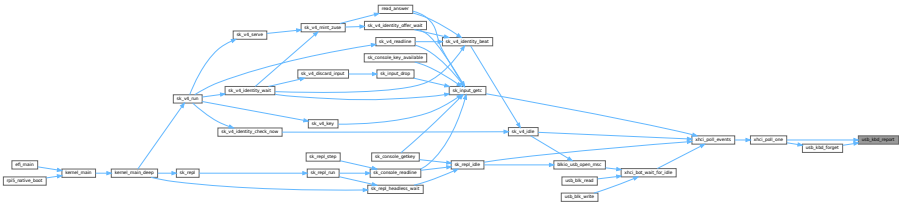
References held(), key_for(), modifier_key, and push().

Referenced by usb_kbd_forget(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



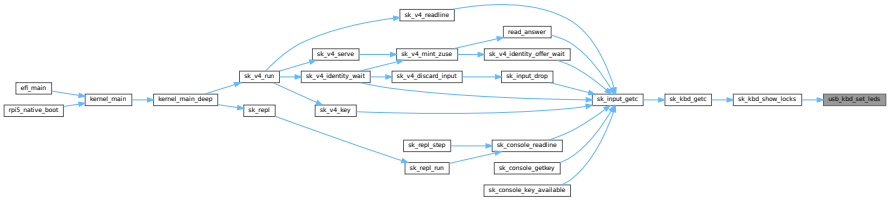
7.70.2.5 usb_kbd_set_leds()

```
void usb_kbd_set_leds (
            uint8_t leds )
```

References g_leds_want.

Referenced by sk_kbd_show_locks().

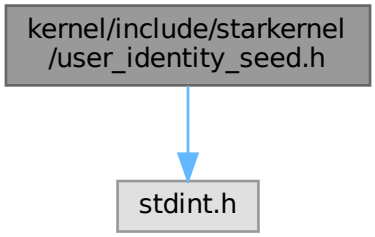
Here is the caller graph for this function:



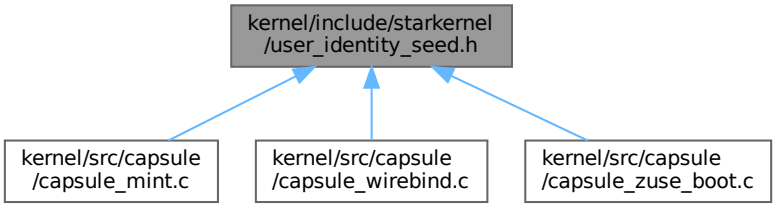
7.71 kernel/include/starkernel/user_identity_seed.h File Reference

```
#include <stdint.h>
```

Include dependency graph for user_identity_seed.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct user_identity_seed_t

Macros

- #define USER_IDENTITY_SEED_MAGIC ((uint32_t)'U' | ((uint32_t)'I' << 8) | ((uint32_t)'D' << 16) | ((uint32_t)'S' << 24))
- #define USER_IDENTITY_SEED_VERSION 2u
- #define USER_IDENTITY_FULL_NAME_MAX 64u
- #define USER_IDENTITY_USERNAME_MAX 32u
- #define USER_IDENTITY_EMAIL_MAX 64u
- #define USER_IDENTITY_PHONE_MAX 24u

Typedefs

- typedef char user_identity_seed_size_check[(sizeof(user_identity_seed_t)==4096) ? 1 :-1]

7.71.1 Macro Definition Documentation

7.71.1.1 USER_IDENTITY_EMAIL_MAX

```
#define USER_IDENTITY_EMAIL_MAX 64u
```

7.71.1.2 USER_IDENTITY_FULL_NAME_MAX

```
#define USER_IDENTITY_FULL_NAME_MAX 64u
```

7.71.1.3 USER_IDENTITY_PHONE_MAX

```
#define USER_IDENTITY_PHONE_MAX 24u
```

7.71.1.4 USER_IDENTITY_SEED_MAGIC

```
#define USER_IDENTITY_SEED_MAGIC  ((uint32_t)'U' | ((uint32_t)'I' << 8) | ((uint32_t)'D' <<
16) | ((uint32_t)'S' << 24))
```

7.71.1.5 USER_IDENTITY_SEED_VERSION

```
#define USER_IDENTITY_SEED_VERSION 2u
```

7.71.1.6 USER_IDENTITY_USERNAME_MAX

```
#define USER_IDENTITY_USERNAME_MAX 32u
```

7.71.2 Typedef Documentation

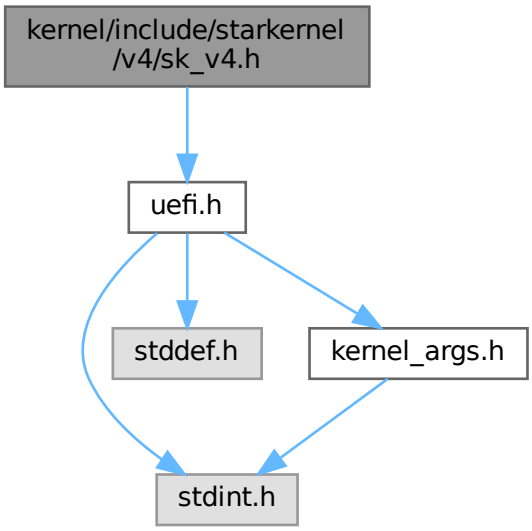
7.71.2.1 user_identity_seed_size_check

```
typedef char user_identity_seed_size_check[(sizeof(user_identity_seed_t)==4096) ?  1 :-1]
```

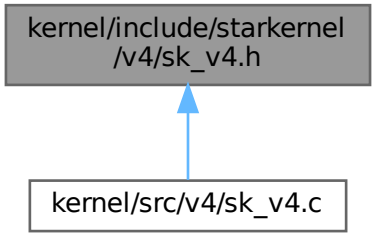
7.72 kernel/include/starkernel/v4/sk_v4.h File Reference

```
#include "uefi.h"
```

Include dependency graph for sk_v4.h:



This graph shows which files directly or indirectly include this file:



Functions

- void sk_v4_run (void(∗chain)(void), const BootDisk ∗boot_disk)

7.72.1 Function Documentation

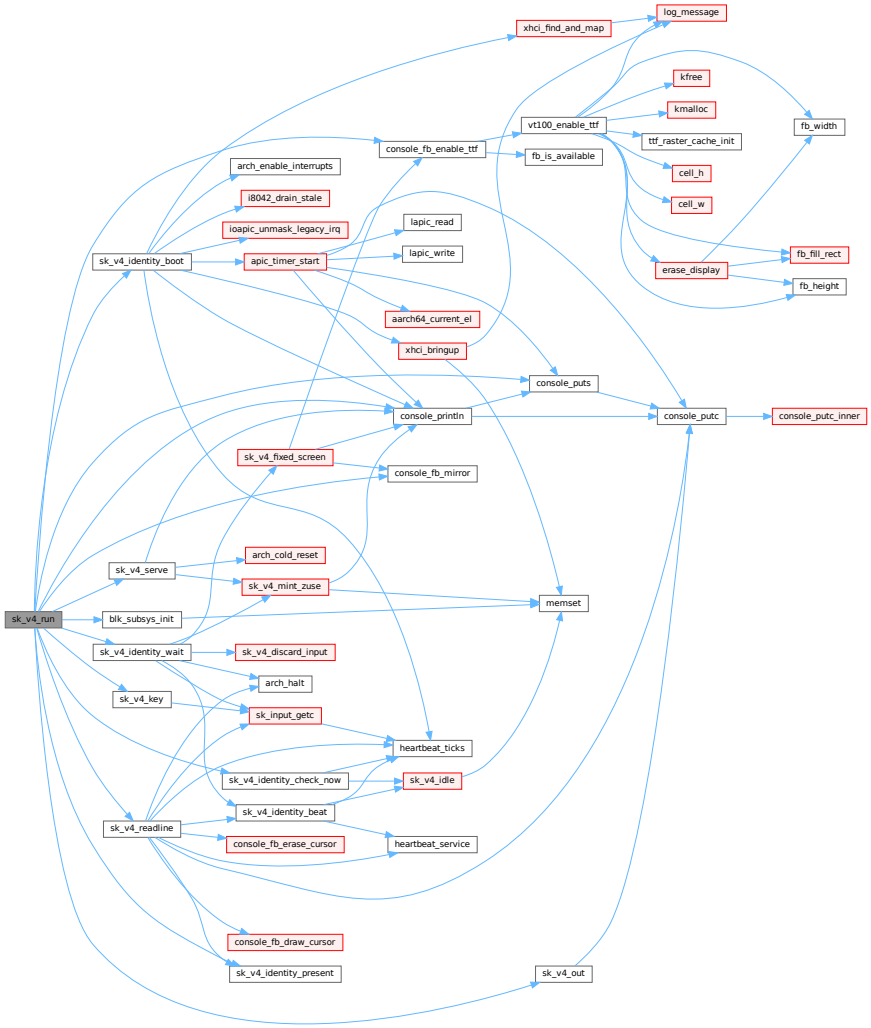
7.72.1.1 sk_v4_run()

```
void sk_v4_run (
            void(*)(void) chain,
            const BootDisk * boot_disk )
```

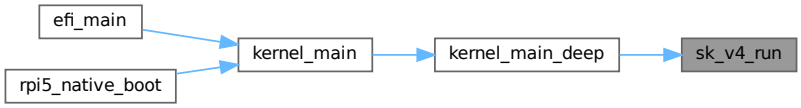
References blk_subsys_init(), console_fb_enable_ttf(), console_fb_mirror(), console_println(), console_puts(), sk_v4_es, sk_v4_heat, sk_v4_identity_boot(), sk_v4_identity_check_now(), sk_v4_identity_present(), sk_v4_identity_wait(), sk_v4_image, sk_v4_key(), sk_v4_node, sk_v4_out(), sk_v4_post_blk_ram, SK_V4_PROMPT, sk_v4_readline(), sk_v4_serve(), sk_v4_text, and sk_v4_words.

Referenced by kernel_main_deep().

Here is the call graph for this function:



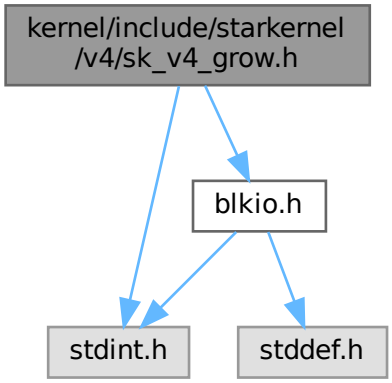
Here is the caller graph for this function:



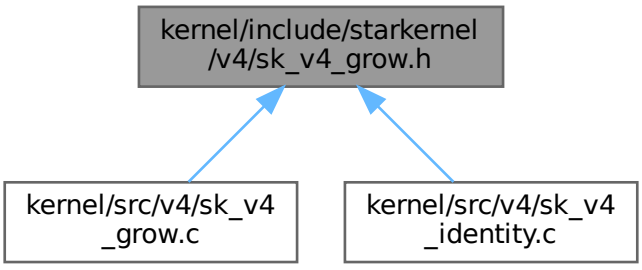
7.73 kernel/include/starkernel/v4/sk_v4_grow.h File Reference

```
#include <stdint.h>
#include "blkio.h"
```

Include dependency graph for sk_v4_grow.h:



This graph shows which files directly or indirectly include this file:



Functions

- uint64_t sk_v4_grow_cap_sectors (blkio_dev_t *art, uint64_t cap_sectors)
- int sk_v4_grow_artemis (blkio_dev_t *art)

7.73.1 Function Documentation

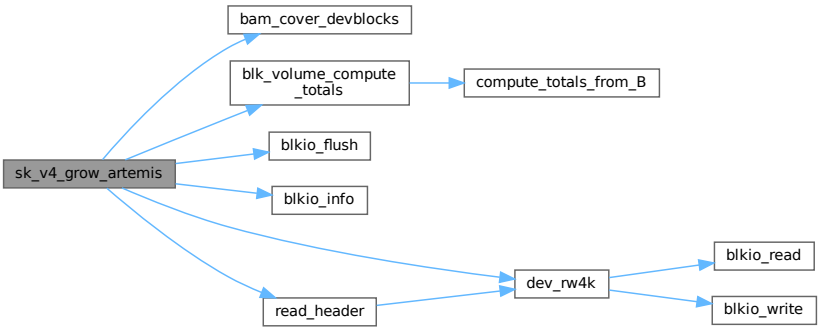
7.73.1.1 sk_v4_grow_artemis()

```
int sk_v4_grow_artemis (
            blkio_dev_t * art )
```

References bam_cover_devblocks(), blk_volume_compute_totals(), blkio_flush(), blkio_info(), BLKIO_OK, dev_rw4k(), g_hdr, g_move, read_header(), and blkio_info_t::total_blocks.

Referenced by sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

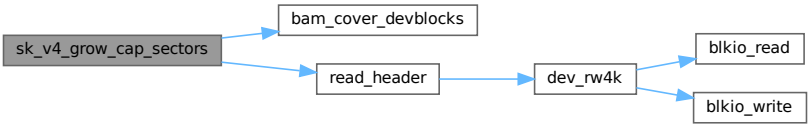
7.73.1.2 sk_v4_grow_cap_sectors()

```
uint64_t sk_v4_grow_cap_sectors (
            blkio_dev_t * art,
            uint64_t cap_sectors )
```

References bam_cover_devblocks(), g_hdr, and read_header().

Referenced by sk_v4_grow_stick().

Here is the call graph for this function:

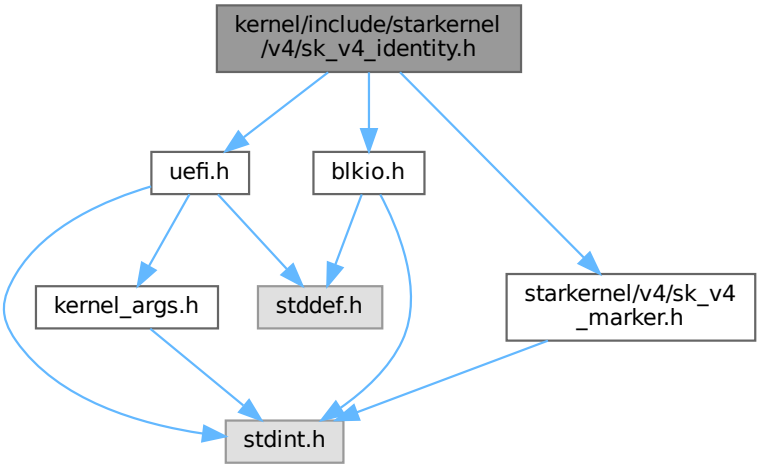


Here is the caller graph for this function:

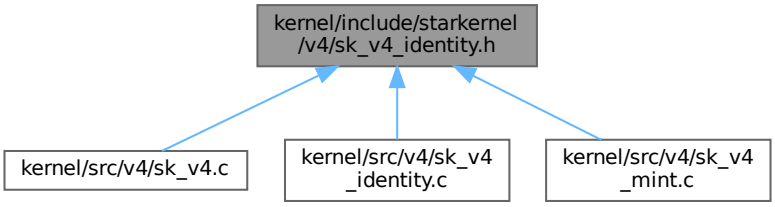
7.74 kernel/include/starkernel/v4/sk_v4_identity.h File Reference

```
#include "uefi.h"
#include "blkio.h"
#include "starkernel/v4/sk_v4_marker.h"
```

Include dependency graph for sk_v4_identity.h:



This graph shows which files directly or indirectly include this file:



Functions

- void sk_v4_identity_boot (const BootDisk *boot_disk)
- int sk_v4_identity_present (void)
- void sk_v4_identity_beat (void)
- void sk_v4_identity_check_now (void)
- int sk_v4_identity_offer_wait (blkio_dev_t **raw, uint64_t *bytes)
- int sk_v4_identity_stick_in (void)
- int sk_v4_identity_offered_present (void)
- void sk_v4_identity_release_offered (void)
- const sk_v4_marker_t * sk_v4_identity_marker (void)
- void sk_v4_identity_set_marker (const sk_v4_marker_t *m)
- void sk_v4_identity_recheck_offered (void)
- void sk_v4_identity_wait (void)

7.74.1 Function Documentation

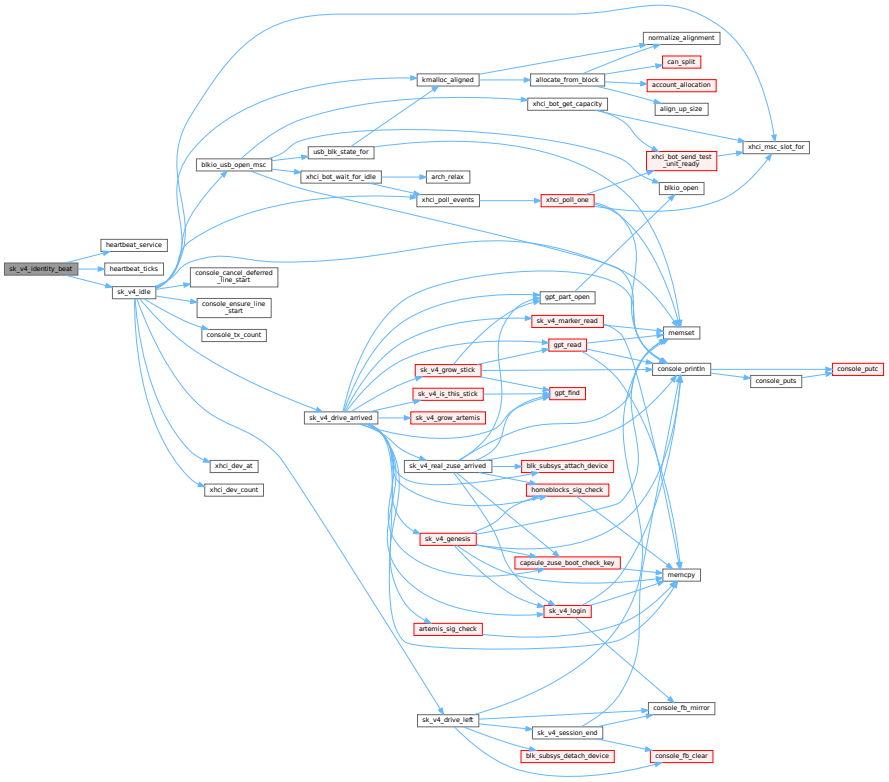
7.74.1.1 sk_v4_identity_beat()

```
void sk_v4_identity_beat (
            void  )
```

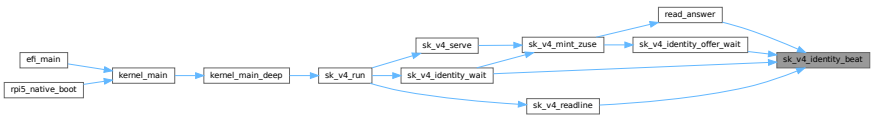
References g_last_beat, heartbeat_service(), heartbeat_ticks(), sk_v4_idle(), and SK_V4_IDLE_BEAT.

Referenced by read_answer(), sk_v4_identity_offer_wait(), sk_v4_identity_wait(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:



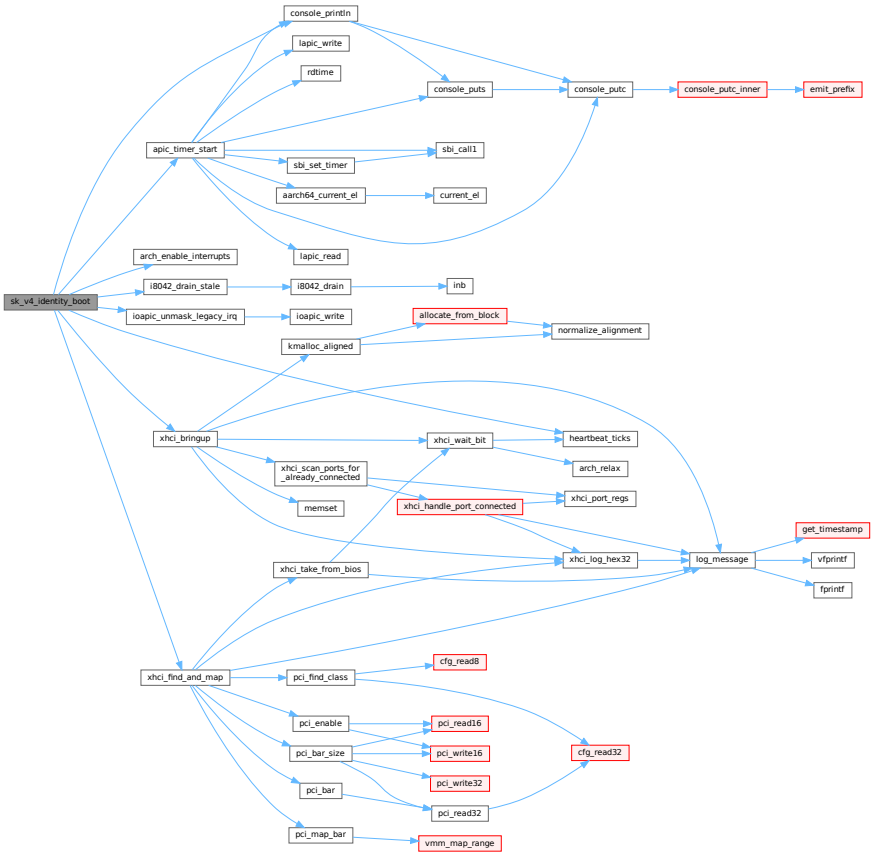
7.74.1.2 sk_v4_identity_boot()

```
void sk_v4_identity_boot (
            const BootDisk * boot_disk )
```

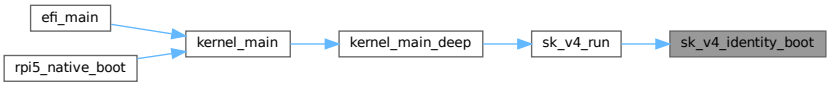
References apic_timer_start(), arch_enable_interrupts(), console_println(), g_boot_disk, g_last_beat, heartbeat_ticks(), i8042_drain_stale(), ioapic_unmask_legacy_irq(), xhci_bringup(), xhci_find_and_map(), and XHCI_MAX_CONTROLLERS.

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



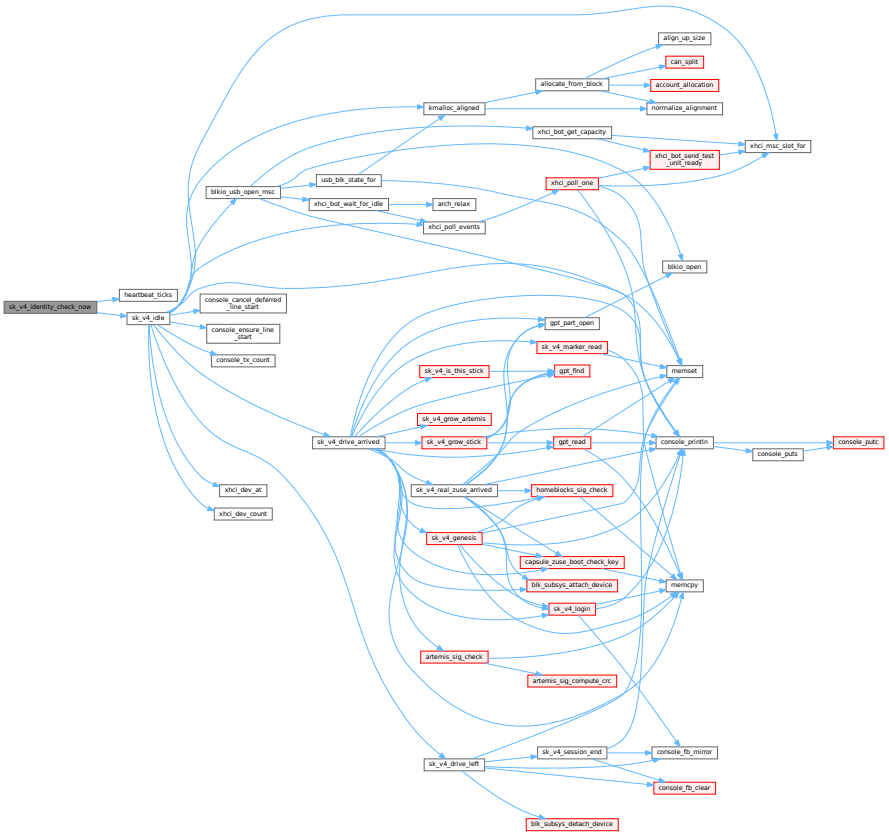
7.74.1.3 sk_v4_identity_check_now()

```
void sk_v4_identity_check_now (
            void  )
```

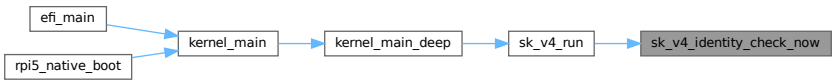
References g_last_beat, heartbeat_ticks(), and sk_v4_idle().

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.74.1.4 sk_v4_identity_marker()

```
const sk_v4_marker_t * sk_v4_identity_marker (
            void  )
```

References g_marker.

Referenced by sk_v4_mint_zuse().

Here is the caller graph for this function:

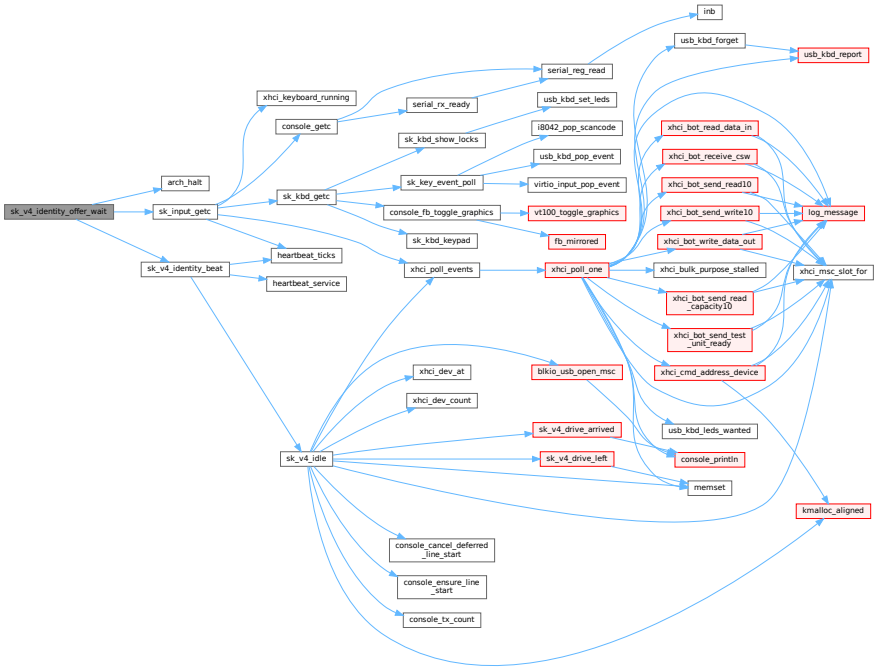
7.74.1.5 sk_v4_identity_offer_wait()

```
int sk_v4_identity_offer_wait (
            blkio_dev_t ** raw,
            uint64_t * bytes )
```

References arch_halt(), BLKIO_FORTH_BLOCK_SIZE, bytes, g_mint_waiting, g_offered, g_spare, g_stick_in, sk_v4_drive_t::raw, sk_input_getc(), sk_v4_identity_beat(), and blkio_dev::total_blocks.

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

7.74.1.6 sk_v4_identity_offered_present()

```
int sk_v4_identity_offered_present (
            void  )
```

References g_offered.

Referenced by read_answer(), and sk_v4_mint_zuse().

Here is the caller graph for this function:

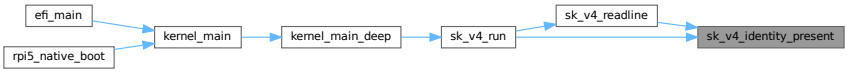
7.74.1.7 sk_v4_identity_present()

```
int sk_v4_identity_present (
            void  )
```

References g_zuse_session.

Referenced by sk_v4_readline(), and sk_v4_run().

Here is the caller graph for this function:



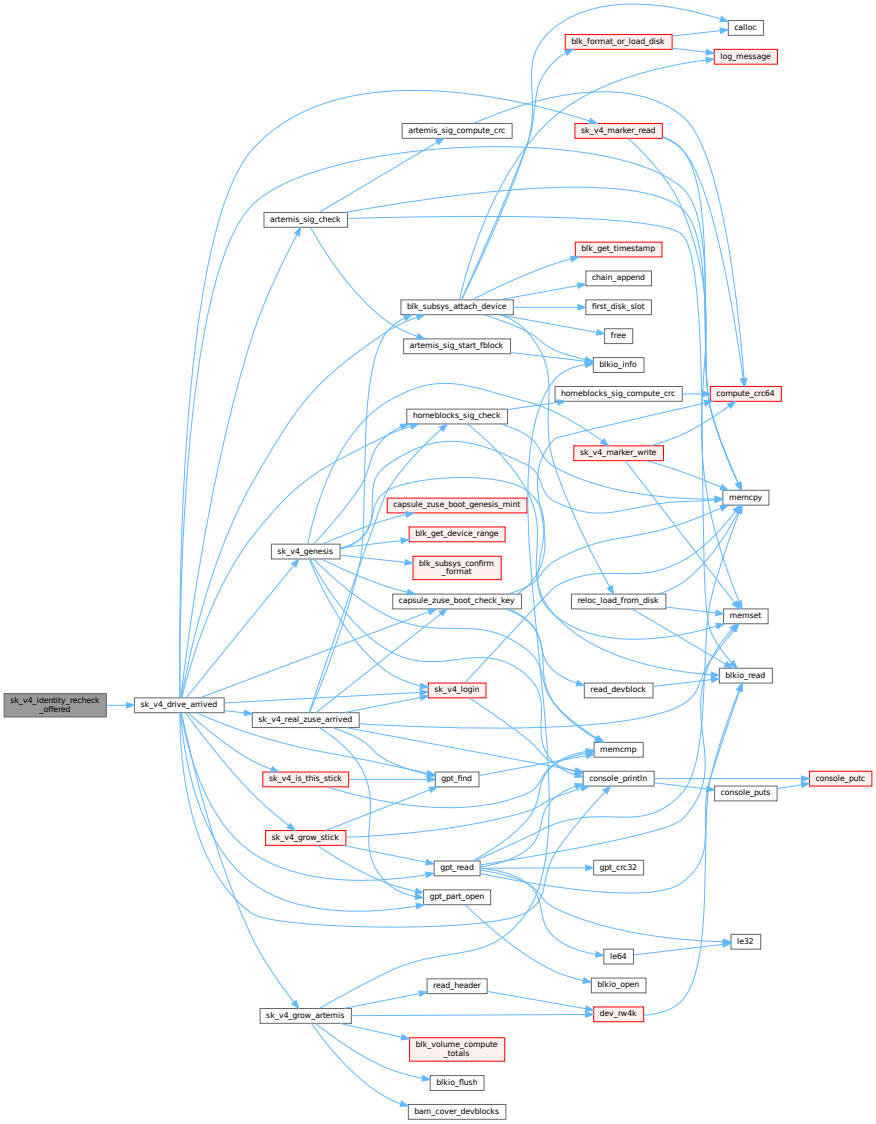
7.74.1.8 sk_v4_identity_recheck_offered()

```
void sk_v4_identity_recheck_offered (
            void  )
```

References g_offered, and sk_v4_drive_arrived().

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

7.74.1.9 sk_v4_identity_release_offered()

```
void sk_v4_identity_release_offered (
            void  )
```

References g_offered, and g_spare.

Referenced by failed(), and sk_v4_mint_zuse().

Here is the caller graph for this function:

7.74.1.10 sk_v4_identity_set_marker()

```
void sk_v4_identity_set_marker (
            const sk_v4_marker_t * m )
```

References g_marker.

Referenced by sk_v4_mint_zuse().

Here is the caller graph for this function:

7.74.1.11 sk_v4_identity_stick_in()

```
int sk_v4_identity_stick_in (
            void  )
```

References g_stick_in.

Referenced by read_answer().

Here is the caller graph for this function:

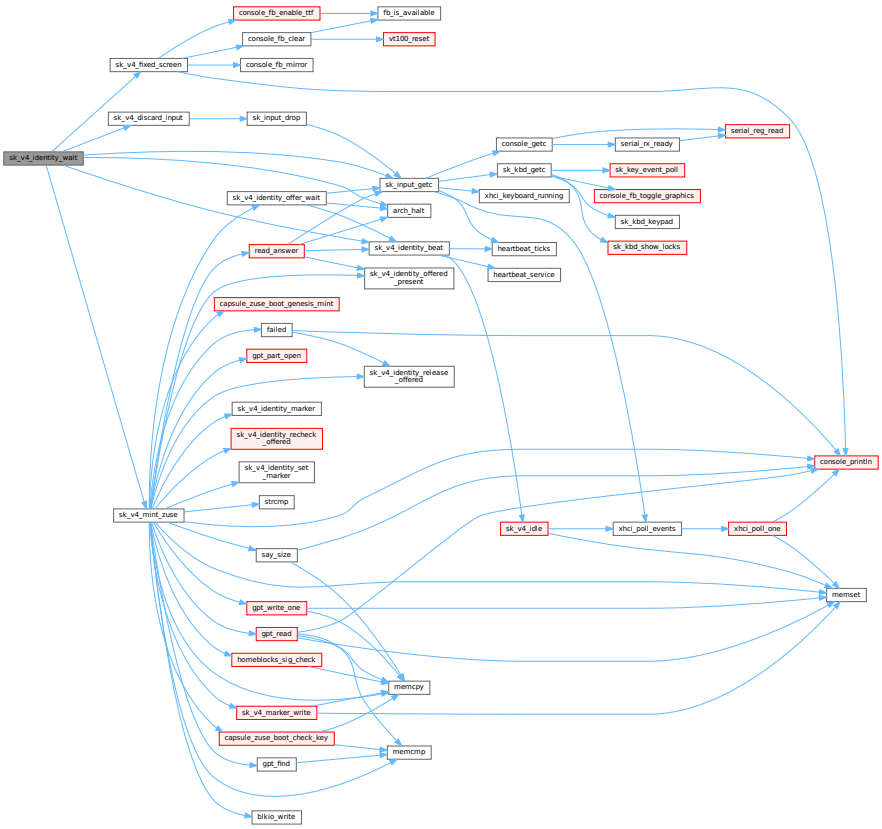
7.74.1.12 sk_v4_identity_wait()

```
void sk_v4_identity_wait (
            void  )
```

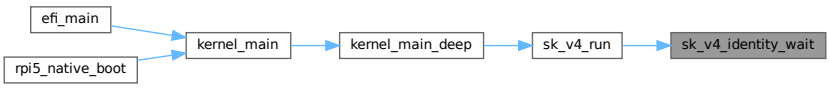
References arch_halt(), g_proxy_fallback, g_zuse_session, sk_input_getc(), sk_v4_discard_input(), sk_v4_fixed_screen(), sk_v4_identity_beat(), and sk_v4_mint_zuse().

Referenced by sk_v4_run().

Here is the call graph for this function:



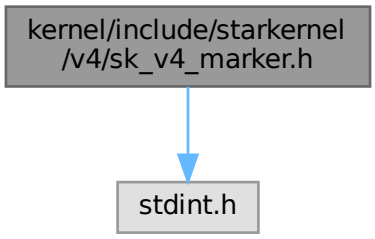
Here is the caller graph for this function:



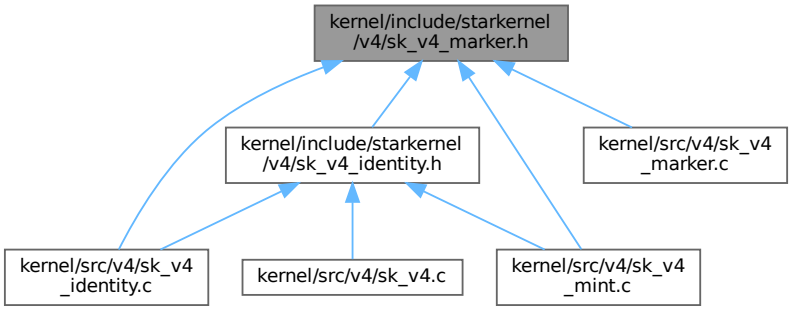
7.75 kernel/include/starkernel/v4/sk_v4_marker.h File Reference

```
#include <stdint.h>
```

Include dependency graph for sk_v4_marker.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct sk_v4_marker_t

Functions

- int sk_v4_marker_read (sk_v4_marker_t *m)
- int sk_v4_marker_write (const sk_v4_marker_t *m)

7.75.1 Function Documentation

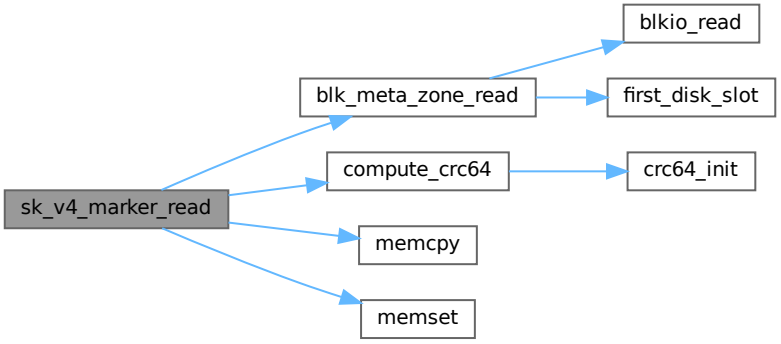
7.75.1.1 sk_v4_marker_read()

```
int sk_v4_marker_read (
            sk_v4_marker_t * m )
```

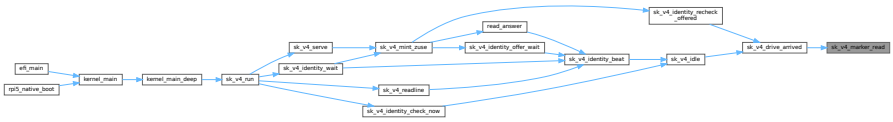
References blk_meta_zone_read(), compute_crc64(), g_buf, sk_v4_marker_t::has_real, memcpy(), memset(), sk_v4_marker_t::present, sk_v4_marker_t::proxy, sk_v4_marker_t::real, ZUSE_GENESIS_MARKER_MAGIC, ZUSE_GENESIS_MARKER_VERSION, and ZUSE_GENESIS_MARKER_VERSION_2.

Referenced by sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:



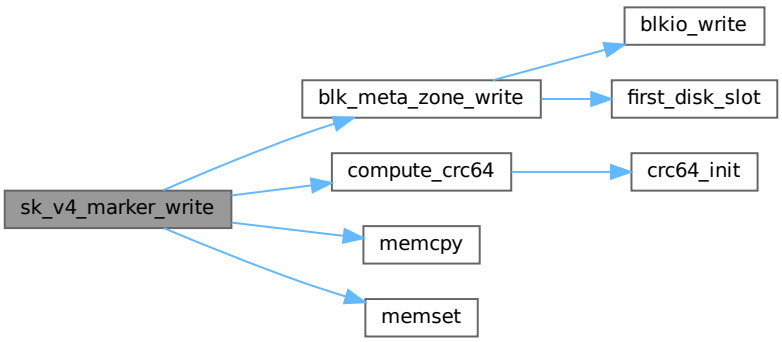
7.75.1.2 sk_v4_marker_write()

```
int sk_v4_marker_write (
            const sk_v4_marker_t * m )
```

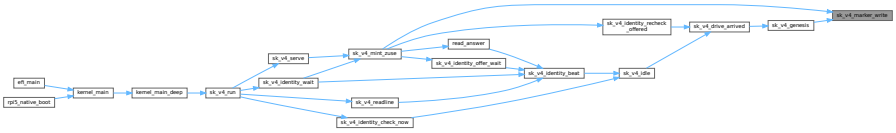
References blk_meta_zone_write(), compute_crc64(), g_buf, sk_v4_marker_t::has_real, memcpy(), memset(), sk_v4_marker_t::proxy, sk_v4_marker_t::real, ZUSE_GENESIS_MARKER_MAGIC, and ZUSE_GENESIS_MARKER_VERSION_2.

Referenced by sk_v4_genesis(), and sk_v4_mint_zuse().

Here is the call graph for this function:

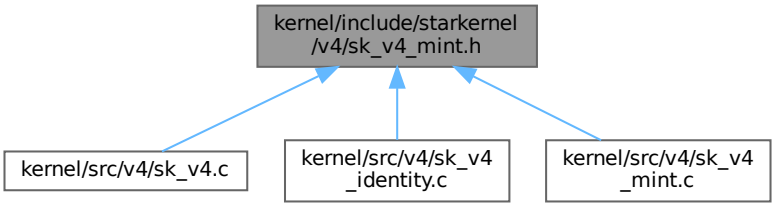


Here is the caller graph for this function:



7.76 kernel/include/starkernel/v4/sk_v4_mint.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- int sk_v4_mint_zuse (void)

7.76.1 Function Documentation

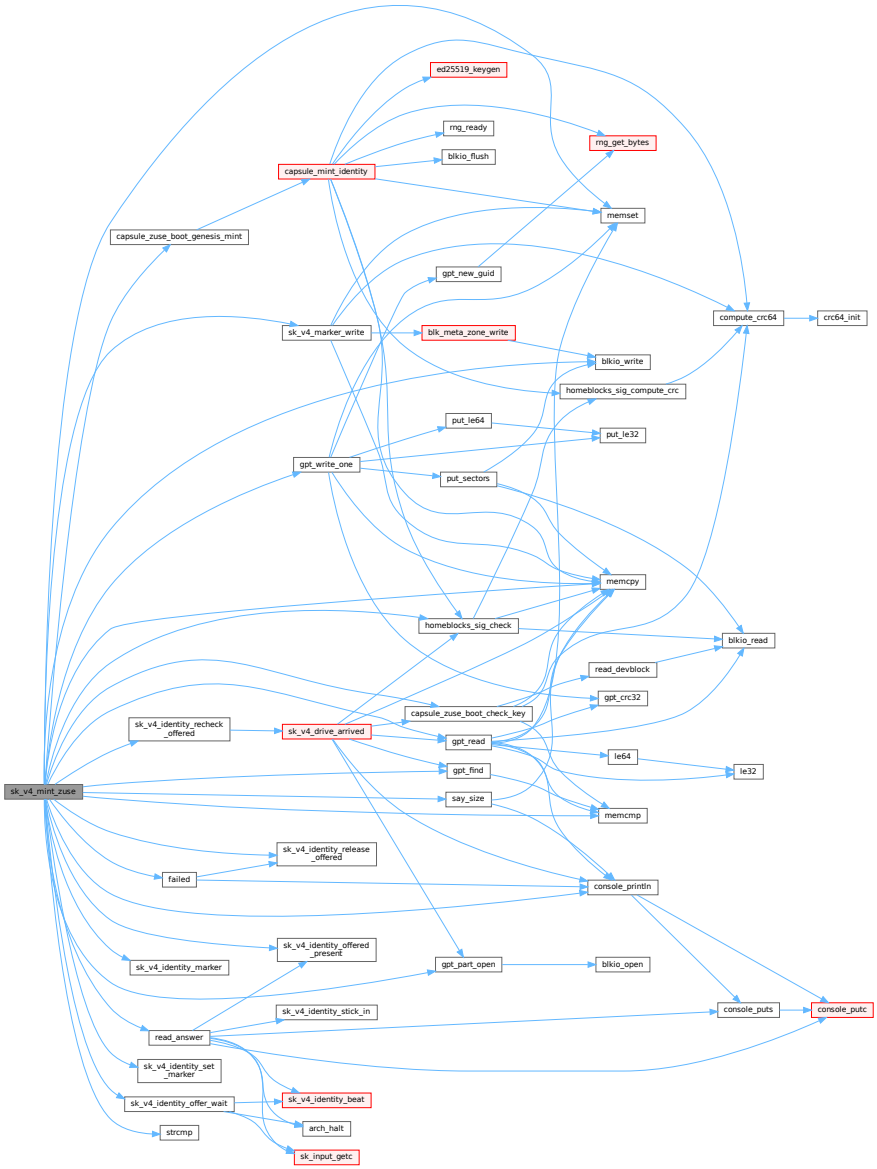
7.76.1.1 sk_v4_mint_zuse()

```
int sk_v4_mint_zuse (
            void  )
```

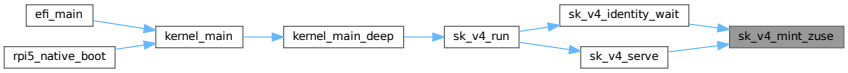
References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_write(), bytes, capsule_zuse_boot_check_key(), capsule_zuse_boot_genesis_mint(), console_println(), failed(), GPT_BAD, gpt_find(), GPT_OK, gpt_part_open(), gpt_read(), gpt_type_starship_identity, gpt_write_one(), sk_v4_marker_t::has_real, homeblocks_sig_check(), HOMEBLOCKS_SIG_START_FBLOCK, memcmp(), memcpy(), memset(), MINT_IDENT_SECTORS, MINT_MIN_BYTES, MINT_ZERO_FBLOCKS, sk_v4_marker_t::present, read_answer(), sk_v4_marker_t::real, say_size(), sk_v4_identity_marker(), sk_v4_identity_offer_wait(), sk_v4_identity_offered_present(), sk_v4_identity_recheck_offered(), sk_v4_identity_release_offered(), sk_v4_identity_set_marker(), sk_v4_marker_write(), strcmp(), and zero.

Referenced by sk_v4_identity_wait(), and sk_v4_serve().

Here is the call graph for this function:



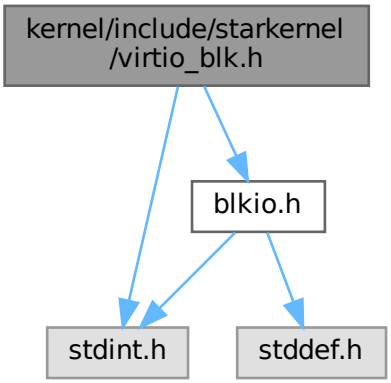
Here is the caller graph for this function:



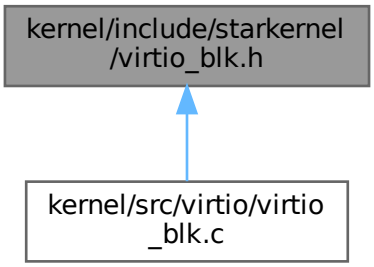
7.77 kernel/include/starkernel/virtio_blk.h File Reference

```
#include <stdint.h>
#include "blkio.h"
```

Include dependency graph for virtio_blk.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define VBLK_SECTOR_SIZE 512u
- #define VBLK_SECTORS_PER_BLOK 2u /* 1 KiB Forth block = 2 × 512-byte sectors */
- #define VBLK_ARTEMIS_SECTORS 61440u /* 30 MB */
- #define VIRTIO_PCI_VENDOR_ID 0x1AF4u
- #define VIRTIO_BLK_DEVICE_MODERN 0x1042u
- #define VIRTIO_BLK_DEVICE_LEGACY 0x1001u
- #define VIRTIO_BLK_T_IN 0u
- #define VIRTIO_BLK_T_OUT 1u
- #define VIRTIO_BLK_S_OK 0u
- #define VIRTIO_BLK_S_IOERR 1u
- #define VIRTIO_BLK_S_UNSUPP 2u

Functions

- int virtio_blk_find_artemis (blkio_dev_t *dev_out)

7.77.1 Macro Definition Documentation

7.77.1.1 VBLK_ARTEMIS_SECTORS

```
#define VBLK_ARTEMIS_SECTORS 61440u /* 30 MB */
```

7.77.1.2 VBLK_SECTOR_SIZE

```
#define VBLK_SECTOR_SIZE 512u
```

7.77.1.3 VBLK_SECTORS_PER_BLOK

```
#define VBLK_SECTORS_PER_BLOK 2u /* 1 KiB Forth block = 2 × 512-byte sectors */
```

7.77.1.4 VIRTIO_BLK_DEVICE_LEGACY

```
#define VIRTIO_BLK_DEVICE_LEGACY 0x1001u
```

7.77.1.5 VIRTIO_BLK_DEVICE_MODERN

```
#define VIRTIO_BLK_DEVICE_MODERN 0x1042u
```

7.77.1.6 VIRTIO_BLK_S_IOERR

```
#define VIRTIO_BLK_S_IOERR 1u
```

7.77.1.7 VIRTIO_BLK_S_OK

```
#define VIRTIO_BLK_S_OK 0u
```

7.77.1.8 VIRTIO_BLK_S_UNSUPP

```
#define VIRTIO_BLK_S_UNSUPP 2u
```

7.77.1.9 VIRTIO_BLK_T_IN

```
#define VIRTIO_BLK_T_IN 0u
```

7.77.1.10 VIRTIO_BLK_T_OUT

```
#define VIRTIO_BLK_T_OUT 1u
```

7.77.1.11 VIRTIO_PCI_VENDOR_ID

```
#define VIRTIO_PCI_VENDOR_ID 0x1AF4u
```

7.77.2 Function Documentation

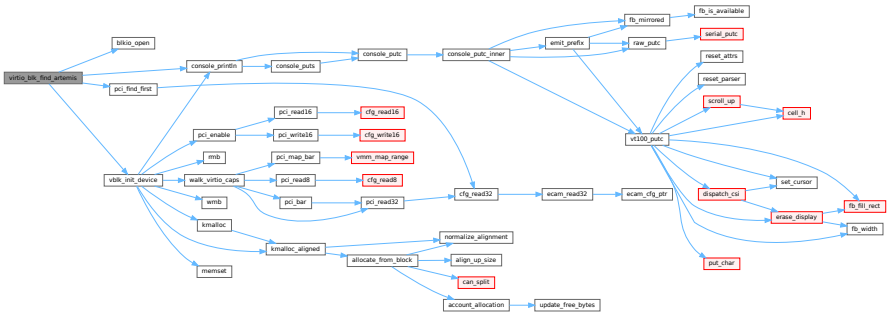
7.77.2.1 virtio_blk_find_artemis()

```
int virtio_blk_find_artemis (
            blkio_dev_t * dev_out )
```

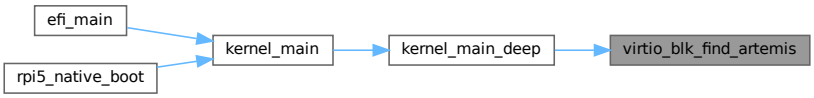
References BLKIO_FORTH_BLOCK_SIZE, blkio_open(), console_println(), blkio_params_t::forth_block_size, g_vblk, g_vblk_ready, g_vblk_vtable, blkio_params_t::opaque, pci_find_first(), blkio_params_t::total_blocks, VirtBlkState::total_forth_blocks, vblk_init_device(), VIRTIO_BLK_DEVICE_LEGACY, VIRTIO_BLK_DEVICE_MODERN, and VIRTIO_PCI_VENDOR_ID.

Referenced by kernel_main_deep().

Here is the call graph for this function:



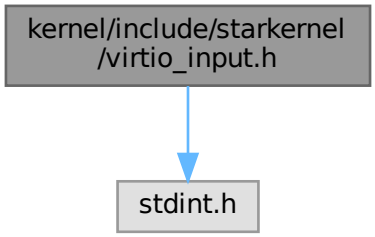
Here is the caller graph for this function:



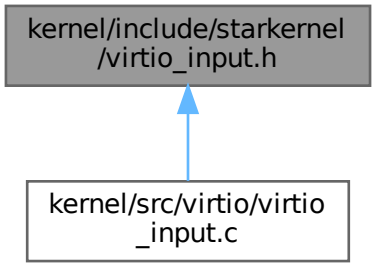
7.78 kernel/include/starkernel/virtio_input.h File Reference

```
#include <stdint.h>
```

Include dependency graph for virtio_input.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct VirtioInputEvent

Macros

- #define VIRTIO_INPUT_PCI_VENDOR_ID 0x1AF4u
- #define VIRTIO_INPUT_PCI_DEVICE_ID 0x1052u
- #define VIRTIO_INPUT_EV_KEY 0x01u

Functions

- int virtio_input_find_keyboard (void)
- void virtio_input_isr (void)
- int virtio_input_pop_event (uint16_t *code, uint32_t *value)

7.78.1 Macro Definition Documentation

7.78.1.1 VIRTIO_INPUT_EV_KEY

```
#define VIRTIO_INPUT_EV_KEY 0x01u
```

7.78.1.2 VIRTIO_INPUT_PCI_DEVICE_ID

```
#define VIRTIO_INPUT_PCI_DEVICE_ID 0x1052u
```

7.78.1.3 VIRTIO_INPUT_PCI_VENDOR_ID

```
#define VIRTIO_INPUT_PCI_VENDOR_ID 0x1AF4u
```

7.78.2 Function Documentation

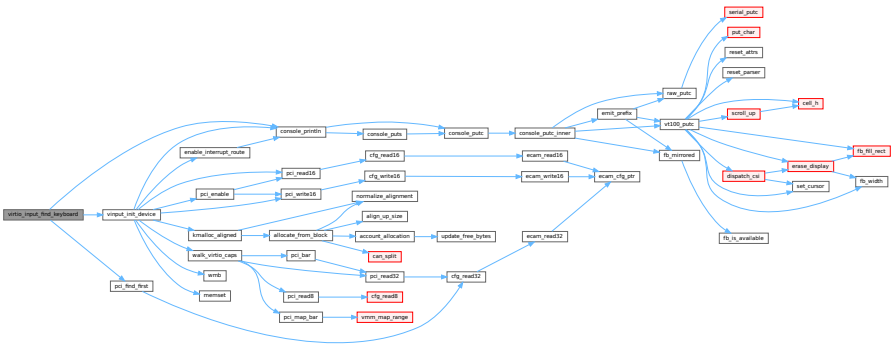
7.78.2.1 virtio_input_find_keyboard()

```
int virtio_input_find_keyboard (
            void  )
```

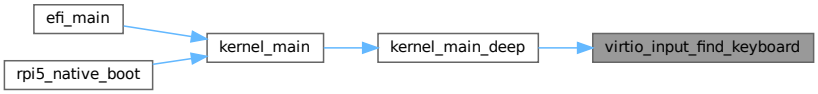
References console_println(), g_vinput_ready, pci_find_first(), vinput_init_device(), VIRTIO_INPUT_PCI_DEVICE_ID, and VIRTIO_INPUT_PCI_VENDOR_ID.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:

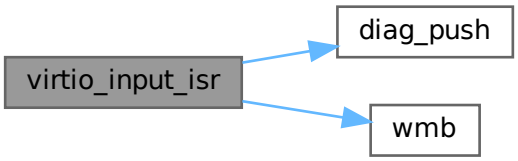


7.78.2.2 virtio_input_isr()

```
void virtio_input_isr (
            void  )
```

References VirtInputState::avail, VirtInputState::avail_idx, VirtInputState::bufs, VirtioInputEvent::code, diag_push(), EVENTQ_SIZE, g_vinput, g_vinput_ready, g_virtio_input_isr_count, VirtqUsedElem::id, VirtqAvail::idx, VirtqUsed::idx, VirtInputState::isr_status, VirtInputState::last_used_idx, VirtInputState::notify, VirtInputState::notify_off_mult, VirtInputState::queue_notify_off, VirtqAvail::ring, VirtqUsed::ring, VirtioInputEvent::type, VirtInputState::used, VirtioInputEvent::value, VIRTIO_INPUT_EV_KEY, and wmb().

Here is the call graph for this function:



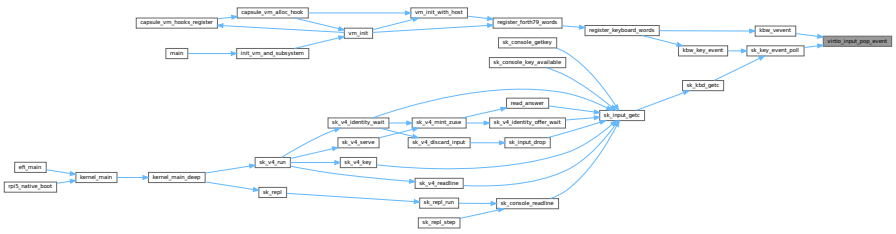
7.78.2.3 virtio_input_pop_event()

```
int virtio_input_pop_event (
            uint16_t * code,
            uint32_t * value )
```

References DiagEvent::code, DIAG_RING_SIZE, g_diag_head, g_diag_ring, g_diag_tail, and DiagEvent::value.

Referenced by kbw_vevent(), and sk_key_event_poll().

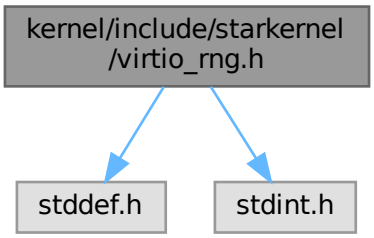
Here is the caller graph for this function:



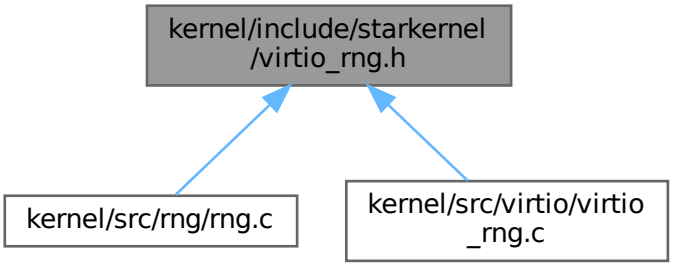
7.79 kernel/include/starkernel/virtio_rng.h File Reference

```
#include <stddef.h>
#include <stdint.h>
```

Include dependency graph for virtio_rng.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define VIRTIO_RNG_PCI_VENDOR_ID 0x1AF4u
- #define VIRTIO_RNG_DEVICE_MODERN 0x1044u
- #define VIRTIO_RNG_DEVICE_LEGACY 0x1005u

Functions

- int virtio_rng_init (void)
- int virtio_rng_ready (void)
- int virtio_rng_get_bytes (uint8_t *buf, size_t n)

7.79.1 Macro Definition Documentation

7.79.1.1 VIRTIO_RNG_DEVICE_LEGACY

```
#define VIRTIO_RNG_DEVICE_LEGACY 0x1005u
```

7.79.1.2 VIRTIO_RNG_DEVICE_MODERN

```
#define VIRTIO_RNG_DEVICE_MODERN 0x1044u
```

7.79.1.3 VIRTIO_RNG_PCI_VENDOR_ID

```
#define VIRTIO_RNG_PCI_VENDOR_ID 0x1AF4u
```

7.79.2 Function Documentation

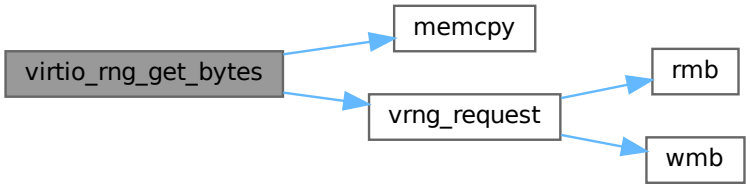
7.79.2.1 virtio_rng_get_bytes()

```
int virtio_rng_get_bytes (
            uint8_t * buf,
            size_t n )
```

References VirtRngState::data_buf, g_vrng, g_vrng_ready, memcpy(), and vrng_request().

Referenced by rng_get_bytes().

Here is the call graph for this function:



Here is the caller graph for this function:

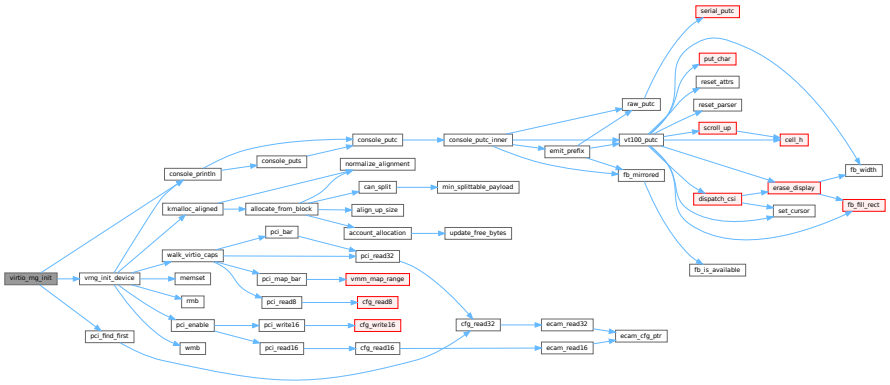
7.79.2.2 virtio_rng_init()

```
int virtio_rng_init (
            void  )
```

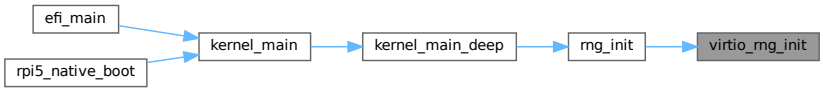
References console_println(), g_vrng_ready, pci_find_first(), VIRTIO_RNG_DEVICE_LEGACY, VIRTIO_RNG_DEVICE_MODERN, VIRTIO_RNG_PCI_VENDOR_ID, and vrng_init_device().

Referenced by rng_init().

Here is the call graph for this function:



Here is the caller graph for this function:



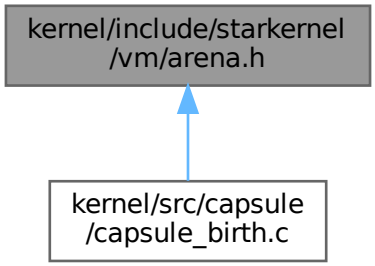
7.79.2.3 virtio_rng_ready()

```
int virtio_rng_ready (
            void  )
```

References g_vrng_ready.

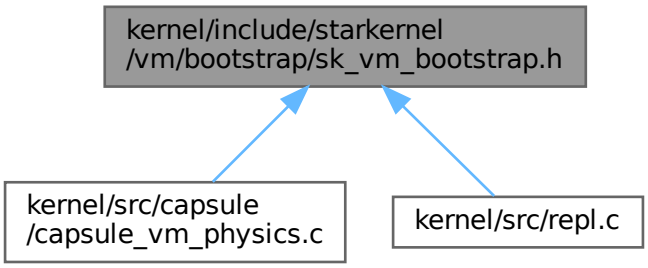
7.80 kernel/include/starkernel/vm/arena.h File Reference

This graph shows which files directly or indirectly include this file:



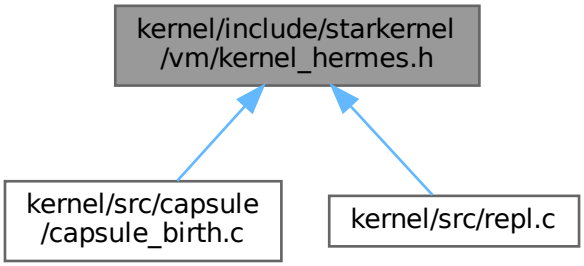
7.81 kernel/include/starkernel/vm/bootstrap/sk_vm_bootstrap.h File Reference

This graph shows which files directly or indirectly include this file:



7.82 kernel/include/starkernel/vm/kernel_hermes.h File Reference

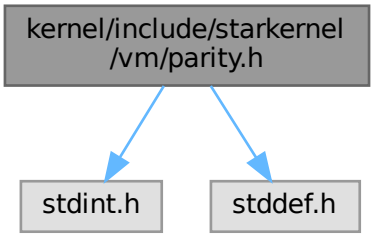
This graph shows which files directly or indirectly include this file:



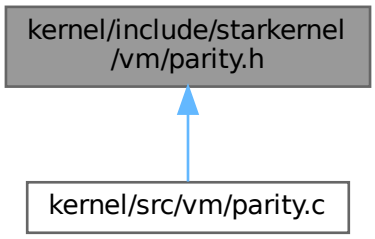
7.83 kernel/include/starkernel/vm/parity.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for parity.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct ParityPacket

  ParityPacket - Summary of VM state for comparison.

Macros

- #define SK_BOOTSTRAP_OK 0

  parity.h - Parity packet for VM validation
- #define SK_BOOTSTRAP_ARENA_FAIL 1
- #define SK_BOOTSTRAP_INIT_FAIL 2
- #define SK_BOOTSTRAP_DICT_FAIL 3
- #define FNV1A_64_OFFSET_BASIS 0xCBF29CE484222325ULL

  FNV-1a constants.
- #define FNV1A_64_PRIME 0x100000001B3ULL

Functions

- void sk_parity_collect (struct VM ∗vm, ParityPacket ∗out)

  Collect M7 parity data from the VM into a `ParityPacket`.
- void sk_parity_print (const ParityPacket ∗pkt)

  Print a `ParityPacket` to the kernel console or stdout.
- uint64_t sk_dict_canonical_hash (struct VM ∗vm)

  Compute the canonical FNV-1a 64-bit hash of the VM dictionary.
- uint32_t sk_dict_word_count (struct VM ∗vm)

  Count the number of entries in the VM dictionary.
- uint64_t fnv1a_64 (const uint8_t ∗data, size_t len, uint64_t hash)

  FNV-1a 64-bit incremental hash over a byte buffer.

7.83.1 Macro Definition Documentation

7.83.1.1 FNV1A_64_OFFSET_BASIS

```
#define FNV1A_64_OFFSET_BASIS 0xCBF29CE484222325ULL
```

FNV-1a constants.

7.83.1.2 FNV1A_64_PRIME

```
#define FNV1A_64_PRIME 0x100000001B3ULL
```

7.83.1.3 SK_BOOTSTRAP_ARENA_FAIL

```
#define SK_BOOTSTRAP_ARENA_FAIL 1
```

7.83.1.4 SK_BOOTSTRAP_DICT_FAIL

```
#define SK_BOOTSTRAP_DICT_FAIL 3
```

7.83.1.5 SK_BOOTSTRAP_INIT_FAIL

```
#define SK_BOOTSTRAP_INIT_FAIL 2
```

7.83.1.6 SK_BOOTSTRAP_OK

```
#define SK_BOOTSTRAP_OK 0
```

parity.h - Parity packet for VM validation

Defines structures and functions for comparing hosted vs kernel VM state. Parity is verified via canonical dictionary hash, not raw memory comparison.

M7 Normative Rules:

- word_id is monotonic creation index starting at 0
- Dictionary traversal is creation order (oldest to newest)
- Hash excludes pointers, padding, runtime fields
- Colon bodies are hashed as word_id sequences, not addresses Bootstrap result codes

7.83.2 Function Documentation

7.83.2.1 fnv1a_64()

```
uint64_t fnv1a_64 (
            const uint8_t * data,
            size_t len,
            uint64_t hash )
```

FNV-1a 64-bit incremental hash over a byte buffer.

Updates a running FNV-1a hash by folding `len` bytes from `data` into `hash`. The caller supplies the current hash state so that multiple buffers can be chained: pass `FNV1A_64_OFFSET_BASIS` for the first call and the returned value as `hash` for subsequent calls.

Algorithm: for each byte `b`, `hash` ^= b then `hash` *= FNV1A_64_PRIME.

Parameters

data	Pointer to the byte buffer to hash.
len	Number of bytes to consume.
hash	Running hash state; seed with `FNV1A_64_OFFSET_BASIS`.

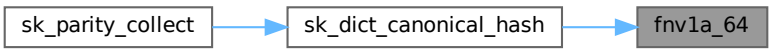
Returns

Updated hash state after processing all `len` bytes.

References FNV1A_64_PRIME.

Referenced by sk_dict_canonical_hash().

Here is the caller graph for this function:



7.83.2.2 sk_dict_canonical_hash()

```
uint64_t sk_dict_canonical_hash (
            struct VM * vm )
```

Compute the canonical FNV-1a 64-bit hash of the VM dictionary.

Implements M7 Rule 3: dictionary traversal is in creation order (oldest word first). Because `vm->latest` is the newest word, the function first builds a reverse array of entries and then hashes them in reverse-array order (oldest → newest).

For each entry the following structural fields are folded into the hash:

1. `flags` (1 byte)
2. `name_len` (1 byte)
3. `name` (name_len bytes)
4. `acl_default` (1 byte)
5. `word_id` (4 bytes, little-endian)
6. Colon body (via `hash_colon_body()`) if `WORD_COMPILED` is set

Pointer-valued fields (`func`, `link`) are intentionally excluded so the hash is stable across different build addresses and address-space layouts.

Traversal is capped at `MAX_DICT_ENTRIES` (2048) entries to guard against corruption.

Parameters

vm	Active VM whose dictionary will be hashed; returns 0 if NULL.

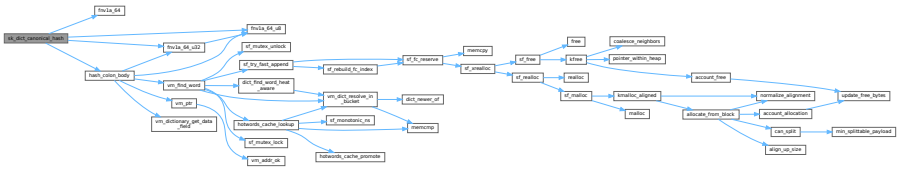
Returns

64-bit FNV-1a canonical hash of the dictionary structure.

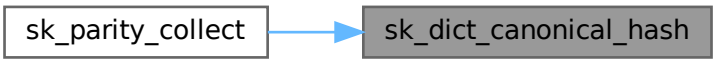
References DictEntry::acl_default, count, DictEntry::flags, fnv1a_64(), FNV1A_64_OFFSET_BASIS, fnv1a_64_u32(), fnv1a_64_u8(), DictEntry::func, hash_colon_body(), VM::latest, MAX_DICT_ENTRIES, DictEntry::name, DictEntry::name_len, sk_parity_debug_check_ptr, sk_parity_debug_log_msg, WORD_COMPILED, and DictEntry::word_id.

Referenced by sk_parity_collect().

Here is the call graph for this function:



Here is the caller graph for this function:



7.83.2.3 sk_dict_word_count()

```
uint32_t sk_dict_word_count (
            struct VM * vm )
```

Count the number of entries in the VM dictionary.

Walks the linked list starting at `vm->latest`, following each entry's `link` pointer until `NULL`. Stops early and returns `MAX_DICT_ENTRIES` if the list exceeds that limit, preventing runaway traversal on a corrupt dictionary.

Parameters

vm	Active VM whose dictionary will be counted; returns 0 if NULL.

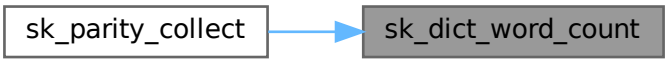
Returns

Number of dictionary entries found, capped at `MAX_DICT_ENTRIES`.

References count, VM::latest, and MAX_DICT_ENTRIES.

Referenced by sk_parity_collect().

Here is the caller graph for this function:



7.83.2.4 sk_parity_collect()

```
void sk_parity_collect (
            struct VM * vm,
            ParityPacket * out )
```

Collect M7 parity data from the VM into a `ParityPacket`.

Populates `out` with a snapshot of the VM's structural state for offline determinism verification. The packet contains:

- M7.1a fields: `word_count`, `here_offset`, `latest_word_id`, and the canonical dictionary hash (`header_hash64`) computed by `sk_dict_canonical_hash()`.
- M7.1b fields: test result counters (`tests_total` / `tests_passed` / `tests_failed` / `tests_skipped` / `tests_errors`) populated from `global_test_stats` when `STARFORTH_ENABLE_TESTS` is defined.

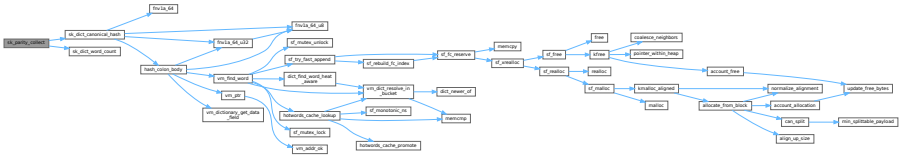
If `vm` is `NULL`, sets `out->bootstrap_result` to `SK_BOOTSTRAP_INIT_FAIL` and returns with all other fields zeroed. If `out` is `NULL` the function is a no-op.

Parameters

vm	Active VM to collect parity data from; may be `NULL`.
out	Output `ParityPacket` to fill; caller must allocate.

References ParityPacket::bootstrap_result, global_test_stats, ParityPacket::header_hash64, VM::here, ParityPacket::here_offset, VM::latest, ParityPacket::latest_word_id, SK_BOOTSTRAP_INIT_FAIL, SK_BOOTSTRAP_OK, sk_dict_canonical_hash(), sk_dict_word_count(), sk_parity_debug_log_msg, ParityPacket::tests_errors, ParityPacket::tests_failed, ParityPacket::tests_passed, ParityPacket::tests_skipped, ParityPacket::tests_total, TestStats::total_error, TestStats::total_fail, TestStats::total_pass, TestStats::total_skip, TestStats::total_tests, ParityPacket::window_hash64, ParityPacket::word_count, and DictEntry::word_id.

Here is the call graph for this function:



7.83.2.5 sk_parity_print()

```
void sk_parity_print (
            const ParityPacket * pkt )
```

Print a `ParityPacket` to the kernel console or stdout.

Emits two or three structured lines that can be captured in the QEMU serial log for offline determinism verification:

- `"PARITY:M7.1a word_count=N here=0xH latest_id=N hash=0xH"` — always emitted; contains the structural dictionary fingerprint.
- `"PARITY:M7.1b tests=N pass=N fail=N skip=N err=N"` — emitted only when `pkt->tests_total` > 0; contains POST result counts.
- `"PARITY:OK"` or `"PARITY:FAIL code=N"` — result verdict line.

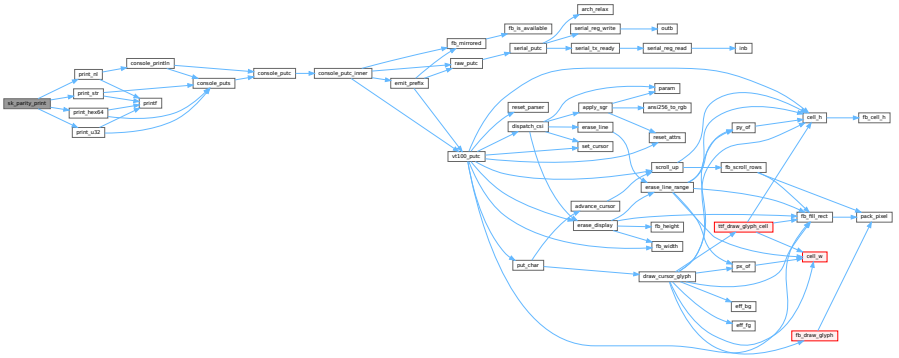
All output goes through `print_str()` / `print_u32()` / `print_hex64()` / `print_nl()` so the function compiles cleanly in both kernel and hosted builds. No-op if `pkt` is `NULL`.

Parameters

pkt	Pointer to the `ParityPacket` to display; may be `NULL`.

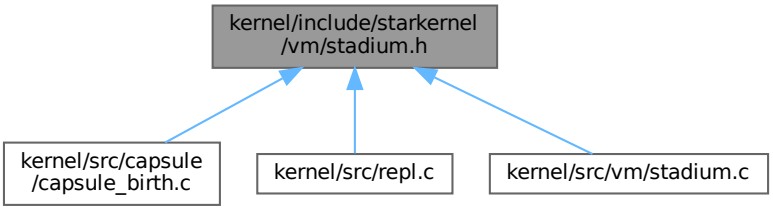
References ParityPacket::bootstrap_result, ParityPacket::header_hash64, ParityPacket::here_offset, ParityPacket::latest_word_id, print_hex64(), print_nl(), print_str(), print_u32(), SK_BOOTSTRAP_OK, ParityPacket::tests_errors, ParityPacket::tests_failed, ParityPacket::tests_passed, ParityPacket::tests_skipped, ParityPacket::tests_total, and ParityPacket::word_count.

Here is the call graph for this function:



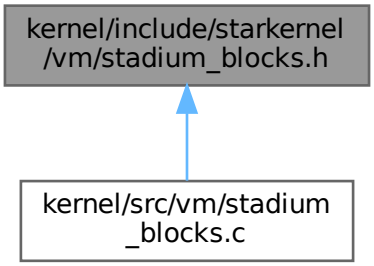
7.84 kernel/include/starkernel/vm/stadium.h File Reference

This graph shows which files directly or indirectly include this file:



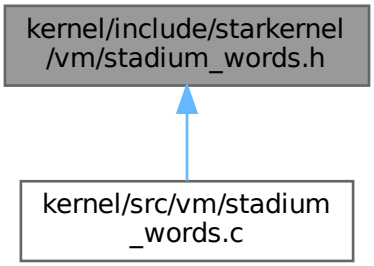
7.85 kernel/include/starkernel/vm/stadium_blocks.h File Reference

This graph shows which files directly or indirectly include this file:



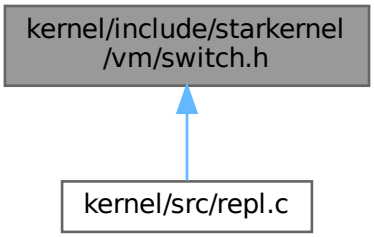
7.86 kernel/include/starkernel/vm/stadium_words.h File Reference

This graph shows which files directly or indirectly include this file:



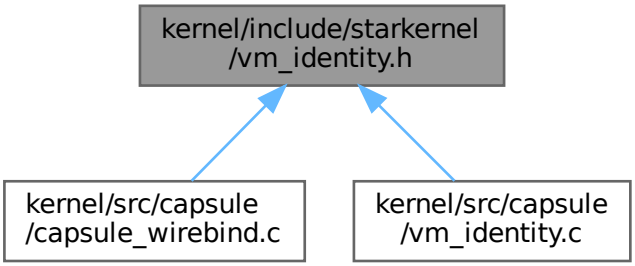
7.87 kernel/include/starkernel/vm/switch.h File Reference

This graph shows which files directly or indirectly include this file:



7.88 kernel/include/starkernel/vm_identity.h File Reference

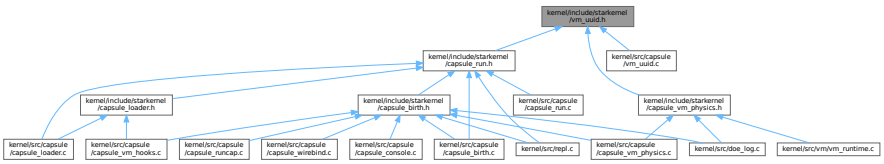
This graph shows which files directly or indirectly include this file:



7.89 kernel/include/starkernel/vm_log_buffer.h File Reference

7.90 kernel/include/starkernel/vm_uuid.h File Reference

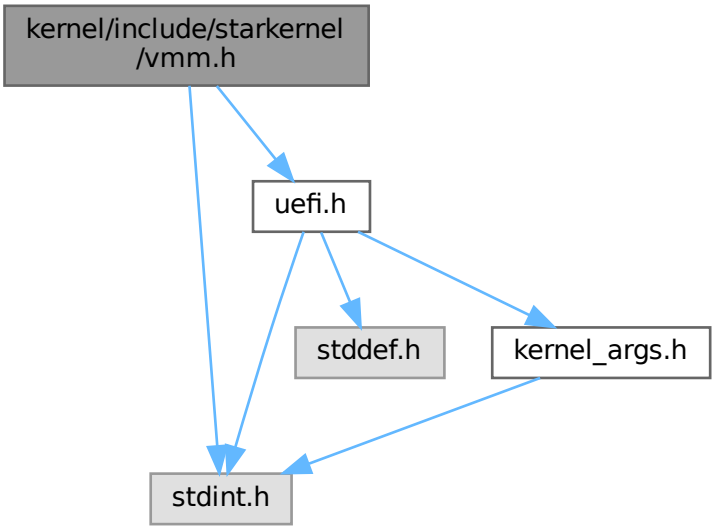
This graph shows which files directly or indirectly include this file:



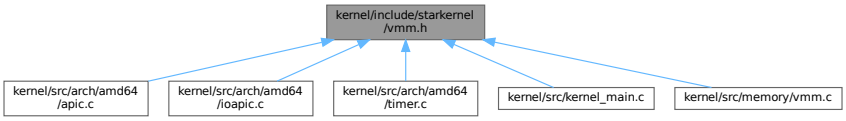
7.91 kernel/include/starkernel/vmm.h File Reference

```
#include <stdint.h>
#include "uefi.h"
```

Include dependency graph for vmm.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct vmm_page_info_t

Macros

- #define VMM_PAGE_SIZE 4096ull

  vmm.h - Virtual Memory Manager interface (x86_64 4-level paging)
- #define VMM_FLAG_PRESENT (1ull << 0)
- #define VMM_FLAG_WRITABLE (1ull << 1)
- #define VMM_FLAG_USER (1ull << 2)
- #define VMM_FLAG_CACHE_DISABLE (1ull << 4) /* maps to PTE_PCD — required for MMIO */
- #define VMM_FLAG_NX (1ull << 63)

Functions

- int vmm_init (BootInfo *boot_info)
- int vmm_map_page (uint64_t vaddr, uint64_t paddr, uint64_t flags)
- int vmm_unmap_page (uint64_t vaddr)
- uint64_t vmm_get_paddr (uint64_t vaddr)
- int vmm_map_range (uint64_t vaddr, uint64_t paddr, uint64_t size, uint64_t flags)
- int vmm_query_page (uint64_t vaddr, vmm_page_info_t *info)

7.91.1 Macro Definition Documentation

7.91.1.1 VMM_FLAG_CACHE_DISABLE

```
#define VMM_FLAG_CACHE_DISABLE (1ull << 4) /* maps to PTE_PCD -- required for MMIO */
```

7.91.1.2 VMM_FLAG_NX

```
#define VMM_FLAG_NX (1ull << 63)
```

7.91.1.3 VMM_FLAG_PRESENT

```
#define VMM_FLAG_PRESENT (1ull << 0)
```

7.91.1.4 VMM_FLAG_USER

```
#define VMM_FLAG_USER (1ull << 2)
```

7.91.1.5 VMM_FLAG_WRITABLE

```
#define VMM_FLAG_WRITABLE (1ull << 1)
```

7.91.1.6 VMM_PAGE_SIZE

```
#define VMM_PAGE_SIZE 4096ull
```

vmm.h - Virtual Memory Manager interface (x86_64 4-level paging)

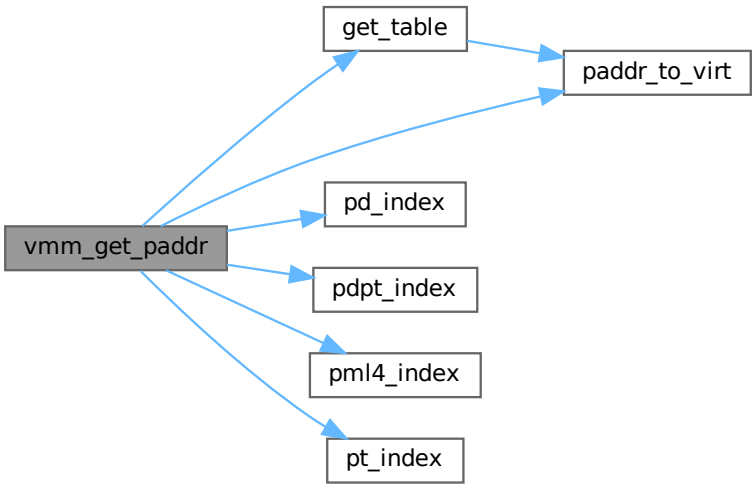
7.91.2 Function Documentation

7.91.2.1 vmm_get_paddr()

```
uint64_t vmm_get_paddr (
            uint64_t vaddr )
```

References ADDR_MASK, get_table(), paddr_to_virt(), pd_index(), pdpt_index(), pml4_index(), pt_index(), PTE_PRESENT, and vmm_root_pml4_phys.

Here is the call graph for this function:



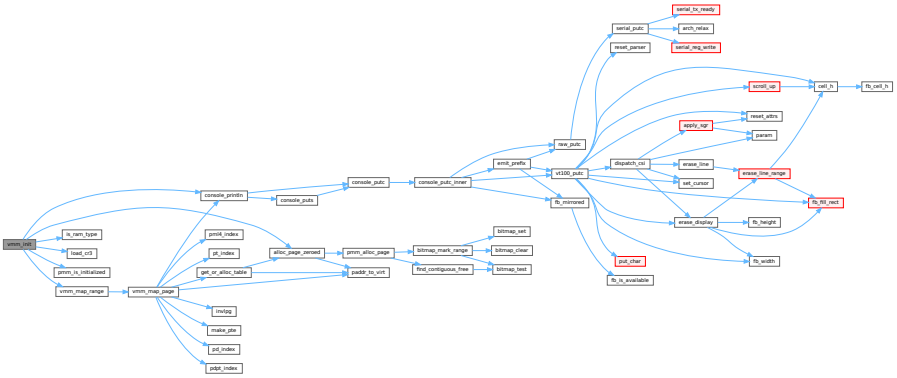
7.91.2.2 vmm_init()

```
int vmm_init (
            BootInfo * boot_info )
```

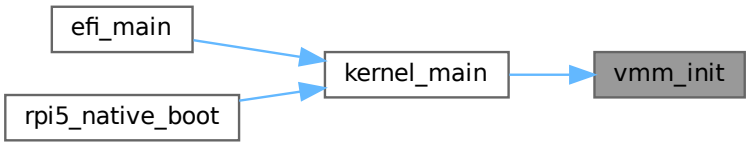
References alloc_page_zeroed(), FramebufferInfo::base, console_println(), BootInfo::framebuffer, hpet_phys_base, is_ram_type(), lapic_phys_base, load_cr3(), BootInfo::memory_map, BootInfo::memory_map_descriptor_size, BootInfo::memory_map_size, EFI_MEMORY_DESCRIPTOR::NumberOfPages, EFI_MEMORY_DESCRIPTOR::PhysicalStart, pmm_is_initialized(), FramebufferInfo::size, EFI_MEMORY_DESCRIPTOR::Type, VMM_FLAG_CACHE_DISABLE, VMM_FLAG_WRITABLE, vmm_map_range(), VMM_PAGE_SIZE, and vmm_root_pml4_phys.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



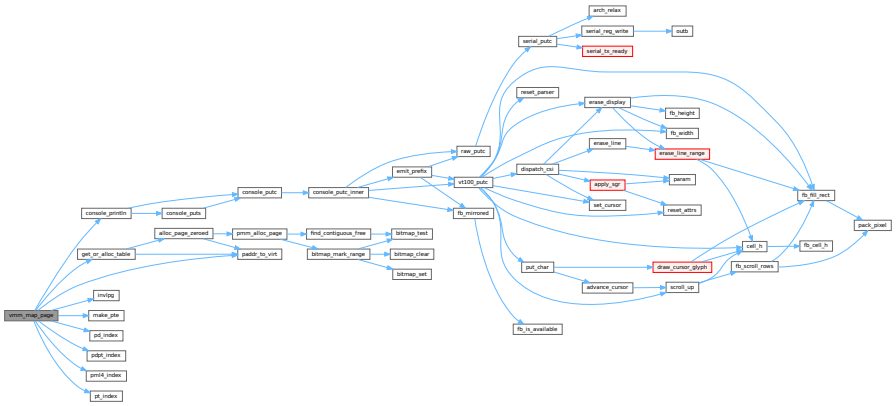
7.91.2.3 vmm_map_page()

```
int vmm_map_page (
            uint64_t vaddr,
            uint64_t paddr,
            uint64_t flags )
```

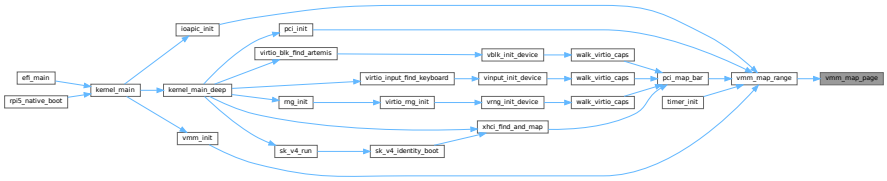
References ADDR_MASK, console_println(), flags, get_or_alloc_table(), invlpg(), make_pte(), paddr_to_virt(), pd_index(), pdpt_index(), pml4_index(), pt_index(), PTE_PRESENT, PTE_WRITABLE, VMM_FLAG_PRESENT, and vmm_root_pml4_phys.

Referenced by vmm_map_range().

Here is the call graph for this function:



Here is the caller graph for this function:



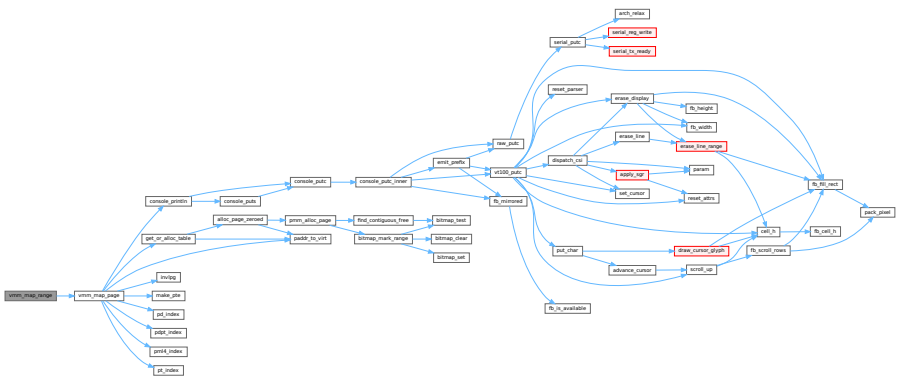
7.91.2.4 vmm_map_range()

```
int vmm_map_range (
            uint64_t vaddr,
            uint64_t paddr,
            uint64_t size,
            uint64_t flags )
```

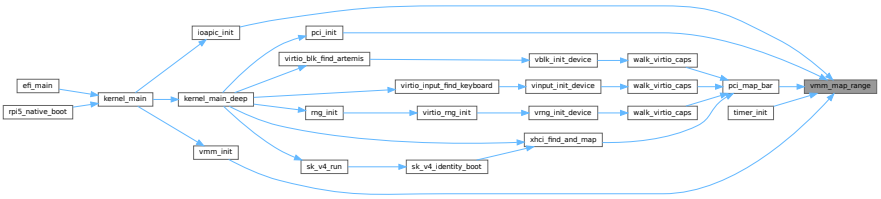
References flags, vmm_map_page(), and VMM_PAGE_SIZE.

Referenced by ioapic_init(), pci_init(), pci_map_bar(), timer_init(), and vmm_init().

Here is the call graph for this function:



Here is the caller graph for this function:

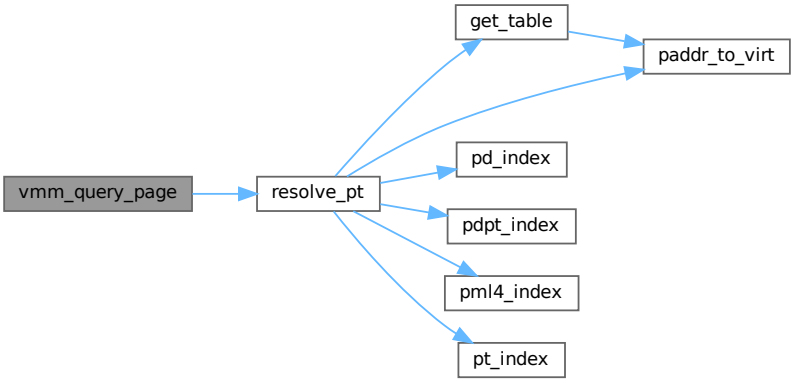


7.91.2.5 vmm_query_page()

```
int vmm_query_page (
            uint64_t vaddr,
            vmm_page_info_t * info )
```

References entry, vmm_page_info_t::executable, vmm_page_info_t::present, PTE_NX, PTE_PRESENT, PTE_WRITABLE, resolve_pt(), and vmm_page_info_t::writable.

Here is the call graph for this function:

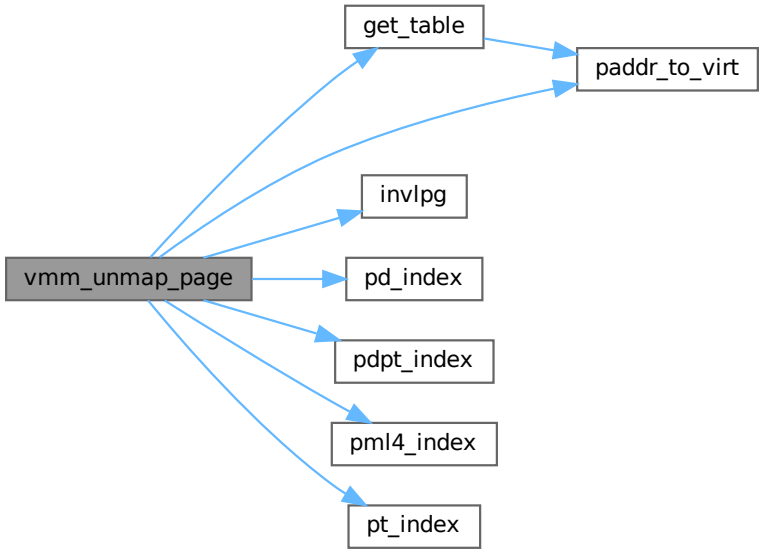


7.91.2.6 vmm_unmap_page()

```
int vmm_unmap_page (
            uint64_t vaddr )
```

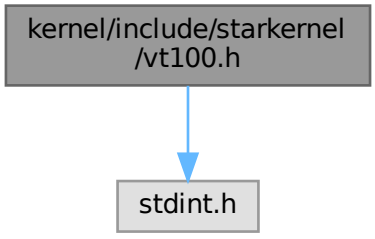
References get_table(), invlpg(), paddr_to_virt(), pd_index(), pdpt_index(), pml4_index(), pt_index(), PTE_PRESENT, and vmm_root_pml4_phys.

Here is the call graph for this function:

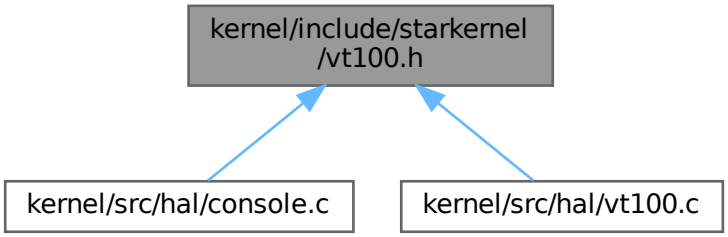


7.92 kernel/include/starkernel/vt100.h File Reference

`#include <stdint.h>`
Include dependency graph for vt100.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define VT100_DEFAULT_FG FB_RGB(0xAA, 0xAA, 0xAA) /∗ light gray ∗/

  vt100.h — Full-color ANSI / VT100 terminal state machine
- #define VT100_DEFAULT_BG FB_RGB(0x00, 0x00, 0x00) /∗ black ∗/

Functions

- void vt100_init (void)

  Initialize the VT100 terminal.
- void vt100_enable_ttf (void)

  FABRIC-0.md item 4.4j: switch the glyph-draw backend from font_8x16.c to TTF-TEXT's rasterizer for everything drawn from this call onward – boot/POST output before this call stays font_8x16.c, unaffected.
- void vt100_scroll_back (uint32_t n)

  FABRIC-0.md item 4.4q: move the REPL scrollback view back/forward by n lines and redraw.
- void vt100_scroll_fwd (uint32_t n)
- void vt100_putc (char c)

  Feed one byte into the terminal (handles escape sequences transparently).
- void vt100_puts (const char ∗s)

  Feed a null-terminated string.
- void vt100_toggle_graphics (void)

  FABRIC-0.md item 4.4y-revised: toggle the full-screen vt100 terminal between visible (normal operation) and hidden (graphics mode – the terminal stops drawing, letting direct framebuffer/TTF-TEXT calls show through undisturbed).
- void vt100_reset (void)
- void vt100_draw_cursor (void)

  Draw a solid block cursor at the terminal's current position.
- void vt100_erase_cursor (void)

  Erases whatever vt100_draw_cursor() last drew, restoring the cell to plain background.
- uint32_t vt100_cols (void)

  Terminal width in character columns.
- uint32_t vt100_rows (void)

  Terminal height in character rows.

7.92.1 Macro Definition Documentation

7.92.1.1 VT100_DEFAULT_BG

```
#define VT100_DEFAULT_BG FB_RGB(0x00, 0x00, 0x00) /* black */
```

7.92.1.2 VT100_DEFAULT_FG

```
#define VT100_DEFAULT_FG FB_RGB(0xAA, 0xAA, 0xAA) /* light gray */
```

vt100.h — Full-color ANSI / VT100 terminal state machine

Sits on top of the framebuffer driver. Call vt100_init() once the framebuffer is ready, then route all character output through vt100_putc().

Supported escape sequences ——————— Cursor movement ESC[H ESC[n;mH ESC[nA ESC[nB ESC[nC ESC[nD Cursor save/restore ESC[s ESC[u (also ESC7 / ESC8) Erase ESC[2J ESC[K ESC[0K ESC[1K ESC[2K SGR attributes ESC[...m (see below)

SGR codes ——— 0 reset all attributes 1 bold (doubles fg brightness) 4 underline 7 reverse video 22 normal intensity 24 underline off 27 reverse off 30–37 set fg to standard ANSI color 0–7 38;2;r;g;b set fg to 24-bit RGB truecolor 38;5;n set fg to 256-color index 39 reset fg to default 40–47 set bg to standard ANSI color 0–7 48;2;r;g;b set bg to 24-bit RGB truecolor 48;5;n set bg to 256-color index 49 reset bg to default 90–97 set fg to bright ANSI color 8–15 100–107 set bg to bright ANSI color 8–15

7.92.2 Function Documentation

7.92.2.1 vt100_cols()

```
uint32_t vt100_cols (
            void  )
```

Terminal width in character columns.

References VT100State::cols, and g_vt.

7.92.2.2 vt100_draw_cursor()

```
void vt100_draw_cursor (
            void  )
```

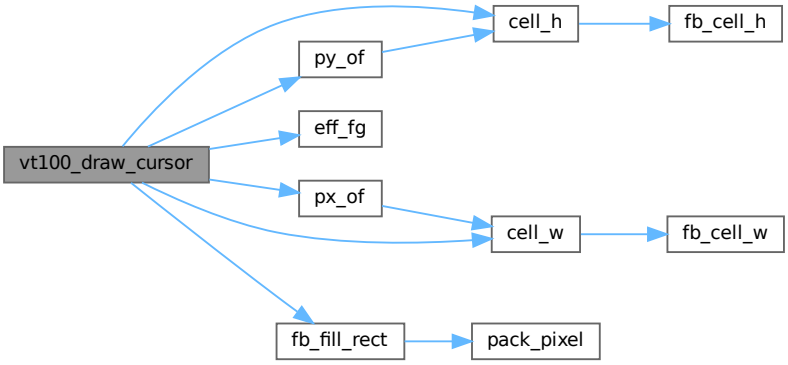
Draw a solid block cursor at the terminal's current position.

Static, not blinking. Idempotent – safe to call after every keystroke, since whatever gets typed next naturally overwrites it. No-op before TTF mode is active or while in graphics mode (vt100_toggle_graphics()).

References cell_h(), cell_w(), VT100State::cx, VT100State::cy, eff_fg(), fb_fill_rect(), g_glyph_mode, g_terminal_visible, g_vt, px_of(), py_of(), and VT_GLYPH_TTF.

Referenced by console_fb_draw_cursor().

Here is the call graph for this function:



Here is the caller graph for this function:

7.92.2.3 vt100_enable_ttf()

```
void vt100_enable_ttf (
            void  )
```

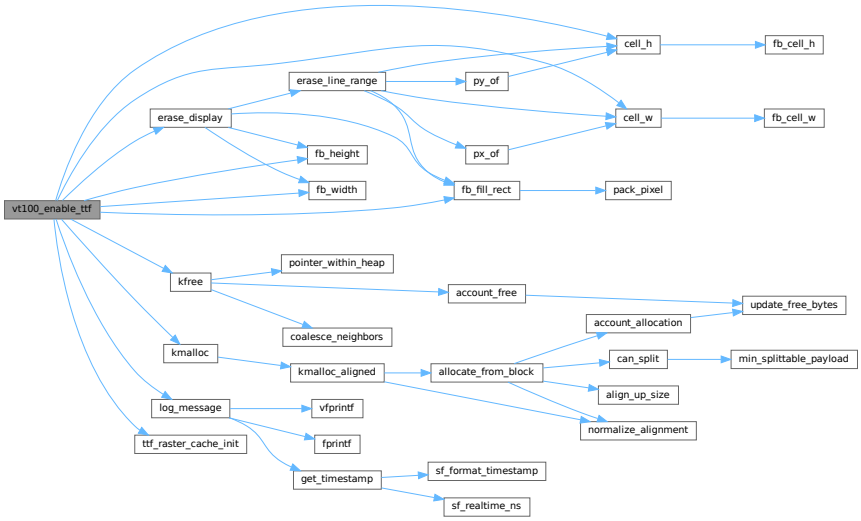
FABRIC-0.md item 4.4j: switch the glyph-draw backend from font_8x16.c to TTF-TEXT's rasterizer for everything drawn from this call onward – boot/POST output before this call stays font_8x16.c, unaffected.

Lazily loads the font capsule and its raster cache on first call (no-op on later calls). Recomputes cols/rows for the new cell size and clears the screen, since the two glyph backends use different cell dimensions. TTF point size/cell dimensions decided final by FABRIC-0.md item 4.4m (20px text, 96px REPL strip). No-op if the font capsule fails to load (stays on font_8x16.c; logged, not fatal).

References cell_h(), cell_w(), VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, erase_display(), fb_fill_rect(), fb_height(), fb_width(), g_boot_line_stride, g_boot_ring, g_boot_ring_cap, g_boot_ring_count, g_boot_ring_head, g_boot_rows, g_boot_shadow, g_glyph_mode, g_line_stride, g_ring, g_ring_cap, g_ring_count, g_ring_head, g_scroll_offset, g_shadow, g_ttf_cache, g_ttf_font, g_ttf_ready, g_vt, VT100State::initialized, kfree(), kmalloc(), LOG_ERROR, log_message(), VT100State::rows, slots, TTF_OK, ttf_raster_cache_init(), VT100_SCROLLBACK_MAX_LINES, VT100_TTF_CACHE_SLOTS, VT100_TTF_FONT_CAPSULE, and VT_GLYPH_TTF.

Referenced by console_fb_enable_ttf().

Here is the call graph for this function:



Here is the caller graph for this function:

7.92.2.4 vt100_erase_cursor()

```
void vt100_erase_cursor (
            void  )
```

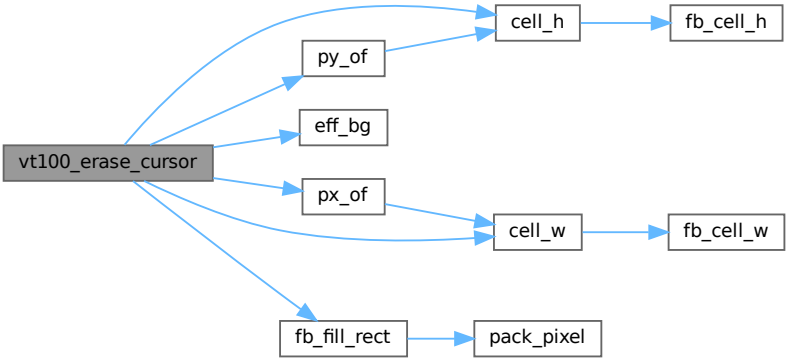
Erases whatever vt100_draw_cursor() last drew, restoring the cell to plain background.

Call before moving away from a cursor-drawn cell without also drawing a character there (e.g. Enter/newline). No-op before TTF mode is active or while in graphics mode.

References cell_h(), cell_w(), VT100State::cx, VT100State::cy, eff_bg(), fb_fill_rect(), g_glyph_mode, g_terminal_visible, g_vt, px_of(), py_of(), and VT_GLYPH_TTF.

Referenced by console_fb_erase_cursor().

Here is the call graph for this function:



Here is the caller graph for this function:

7.92.2.5 vt100_init()

```
void vt100_init (
            void  )
```

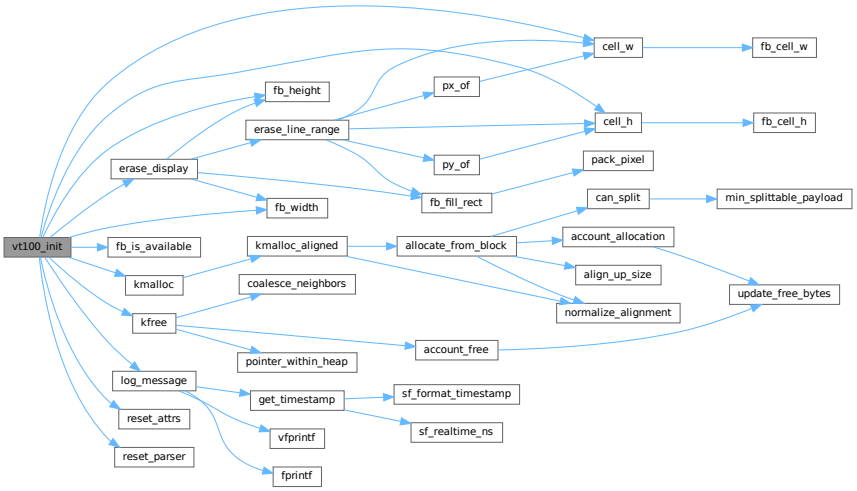
Initialize the VT100 terminal.

Must be called after fb_init(). Clears the screen and homes the cursor.

References cell_h(), cell_w(), VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, VT100State::def_fg, erase_display(), fb_height(), fb_is_available(), fb_width(), g_line_stride, g_ring, g_ring_cap, g_ring_count, g_ring_head, g_shadow, g_vt, VT100State::initialized, kfree(), kmalloc(), LOG_ERROR, log_message(), reset_attrs(), reset_parser(), VT100State::rows, VT100State::saved_cx, VT100State::saved_cy, VT100_BOOT_SCROLLBACK_MAX_LINES, VT100_DEFAULT_BG, and VT100_DEFAULT_FG.

Referenced by console_fb_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.92.2.6 vt100_putc()

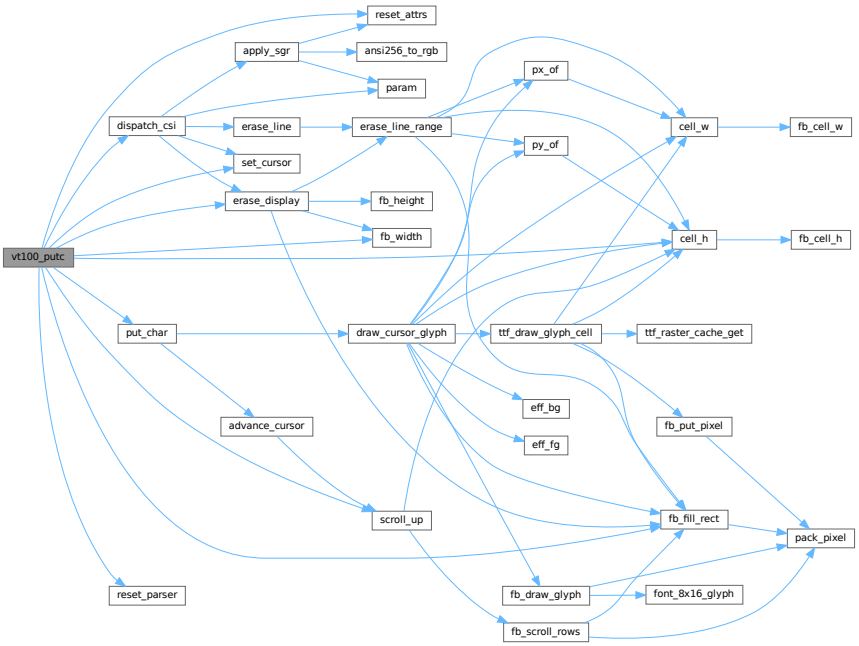
```
void vt100_putc (
            char c )
```

Feed one byte into the terminal (handles escape sequences transparently).

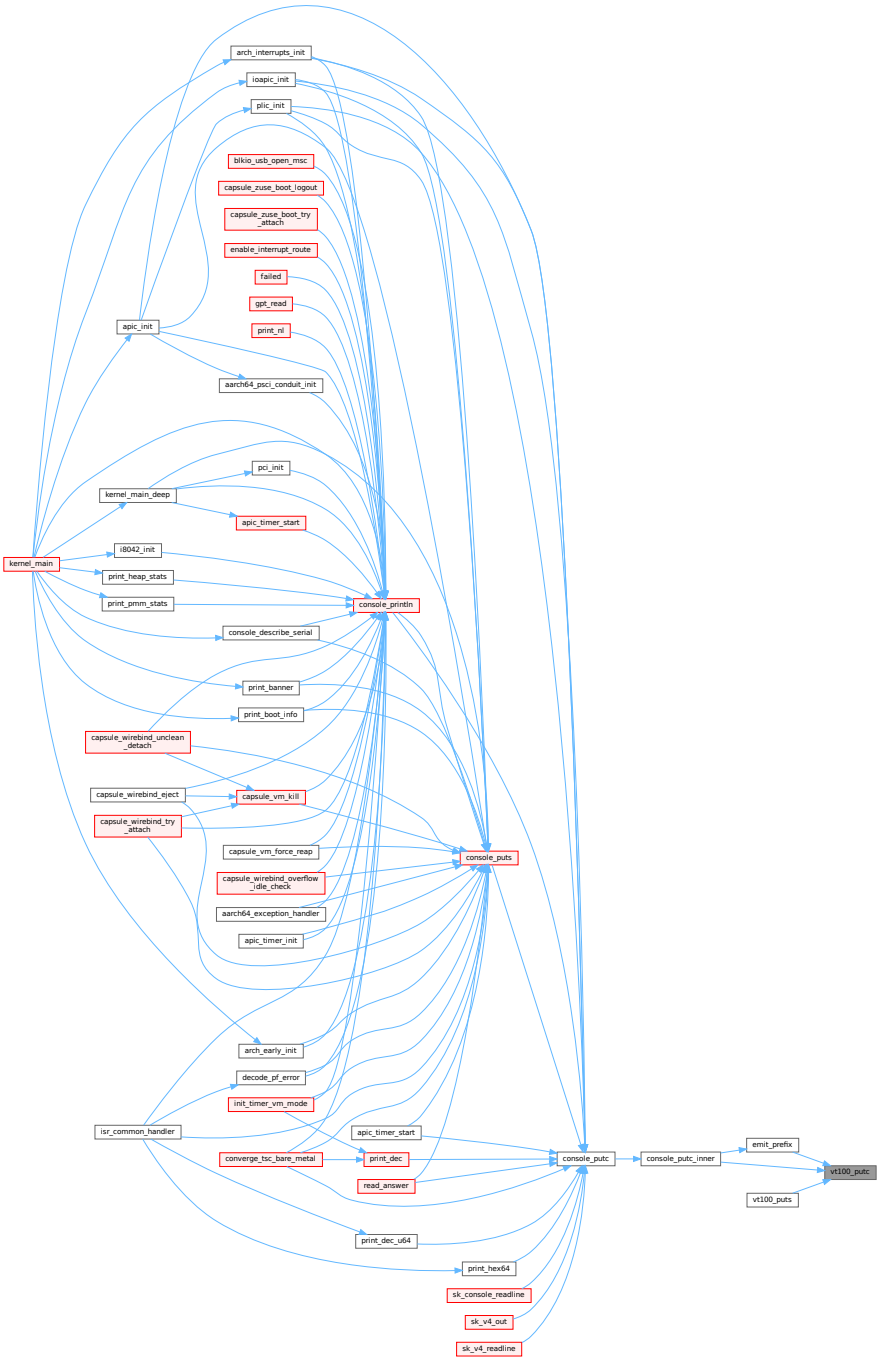
References cell_h(), VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, dispatch_csi(), erase_display(), fb_fill_rect(), fb_width(), g_vt, VT100State::initialized, VT100State::param_count, VT100State::param_has_value, VT100State::params, put_char(), reset_attrs(), reset_parser(), VT100State::rows, VT100State::saved_cx, VT100State::saved_cy, scroll_up(), set_cursor(), ST_CSI, ST_ESC, ST_ESC_CHAR, ST_ESC_HASH, ST_NORMAL, VT100State::state, and VT100_MAX_PARAMS.

Referenced by console_putc_inner(), emit_prefix(), and vt100_puts().

Here is the call graph for this function:



Here is the caller graph for this function:



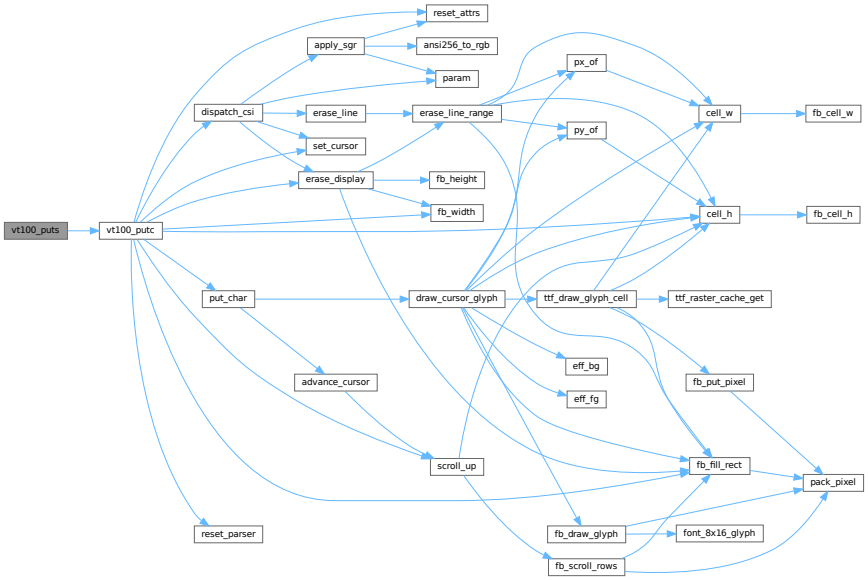
7.92.2.7 vt100_puts()

```
void vt100_puts (
            const char * s )
```

Feed a null-terminated string.

References vt100_putc().

Here is the call graph for this function:



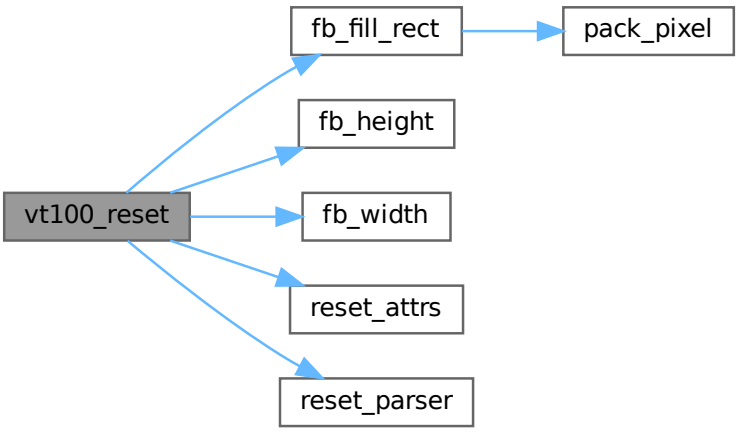
7.92.2.8 vt100_reset()

```
void vt100_reset (
            void  )
```

References VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, fb_fill_rect(), fb_height(), fb_width(), g_boot_ring_count, g_boot_rows, g_line_stride, g_ring_count, g_ring_head, g_scroll_offset, g_shadow, g_terminal_visible, g_vt, VT100State::initialized, reset_attrs(), reset_parser(), VT100State::rows, VT100State::saved_cx, and VT100State::saved_cy.

Referenced by console_fb_clear().

Here is the call graph for this function:



Here is the caller graph for this function:

7.92.2.9 vt100_rows()

```
uint32_t vt100_rows (
            void  )
```

Terminal height in character rows.

References g_vt, and VT100State::rows.

7.92.2.10 vt100_scroll_back()

```
void vt100_scroll_back (
            uint32_t n )
```

FABRIC-0.md item 4.4q: move the REPL scrollback view back/forward by `n` lines and redraw.

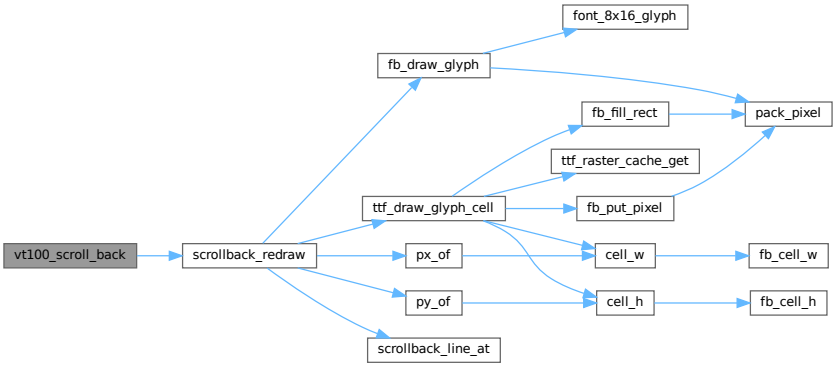
Offset 0 (the default, and where every call eventually returns to) is the live view – the same content already on screen. Clamped at both ends: back cannot pass the oldest stored line, forward cannot pass the live view. No-op (including no redraw) if the scrollback buffers failed to allocate at vt100_enable_ttf() time, or before TTF mode is active at all.

Known limitation: redraw uses the terminal's current default fg/bg, not each line's original SGR color state at the time it was printed (colors aren't stored per-cell) – text content is recovered exactly, color is not.

References g_boot_ring_count, g_boot_rows, g_ring, g_ring_count, g_scroll_offset, g_shadow, and scrollback_redraw().

Referenced by console_fb_scroll_back().

Here is the call graph for this function:



Here is the caller graph for this function:

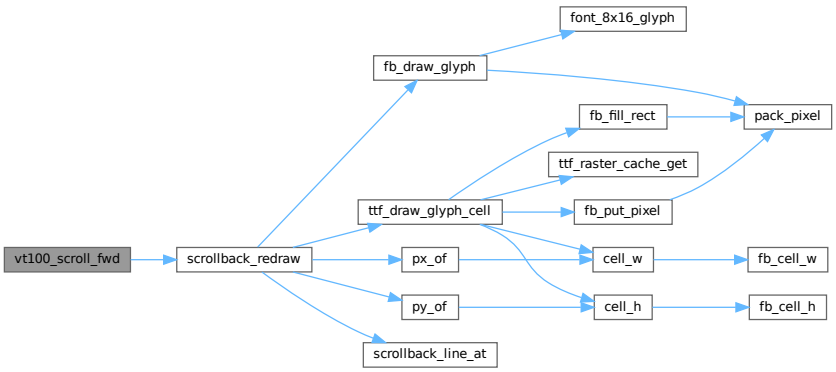
7.92.2.11 vt100_scroll_fwd()

```
void vt100_scroll_fwd (
            uint32_t n )
```

References g_ring, g_scroll_offset, g_shadow, and scrollback_redraw().

Referenced by console_fb_scroll_fwd().

Here is the call graph for this function:



Here is the caller graph for this function:

7.92.2.12 vt100_toggle_graphics()

```
void vt100_toggle_graphics (
            void  )
```

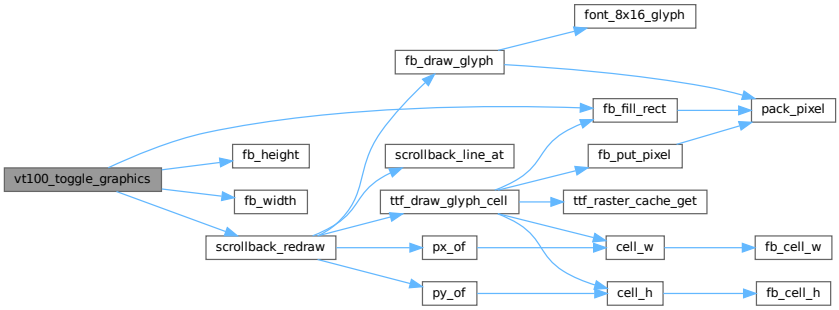
FABRIC-0.md item 4.4y-revised: toggle the full-screen vt100 terminal between visible (normal operation) and hidden (graphics mode – the terminal stops drawing, letting direct framebuffer/TTF-TEXT calls show through undisturbed).

Toggling back to visible does a full redraw of the terminal's current on-screen content, restoring it exactly as it was. No-op before TTF mode is active.

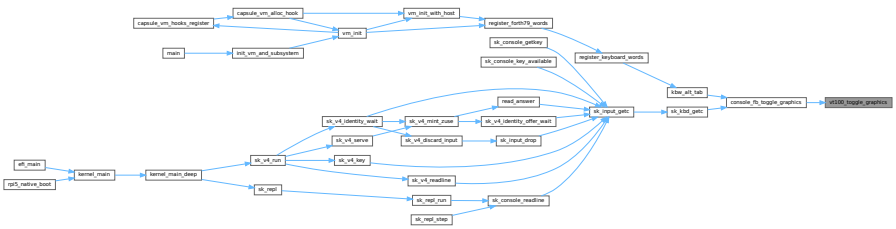
References VT100State::def_bg, fb_fill_rect(), fb_height(), fb_width(), g_glyph_mode, g_terminal_visible, g_ttf_ready, g_vt, scrollback_redraw(), and VT_GLYPH_TTF.

Referenced by console_fb_toggle_graphics().

Here is the call graph for this function:



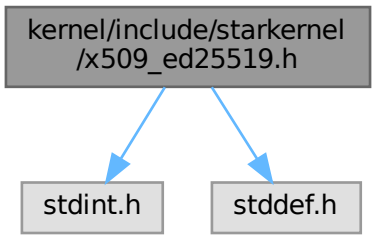
Here is the caller graph for this function:



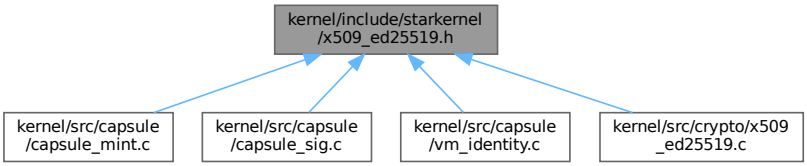
7.93 kernel/include/starkernel/x509_ed25519.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for x509_ed25519.h:



This graph shows which files directly or indirectly include this file:



Functions

- int x509_extract_ed25519_pubkey (const uint8_t *der, size_t der_len, uint8_t pubkey_out[32])
- int x509_verify_signature (const uint8_t *der, size_t der_len, const uint8_t issuer_pubkey[32])
- int x509_extract_serial (const uint8_t *der, size_t der_len, uint8_t *serial_out, size_t serial_out_cap, size_t *serial_len_out)
- size_t x509_build_user_cert (uint8_t *out, size_t out_cap, const uint8_t subject_pubkey[32], const uint8_t serial[16], const uint8_t issuer_seed[32])

7.93.1 Function Documentation

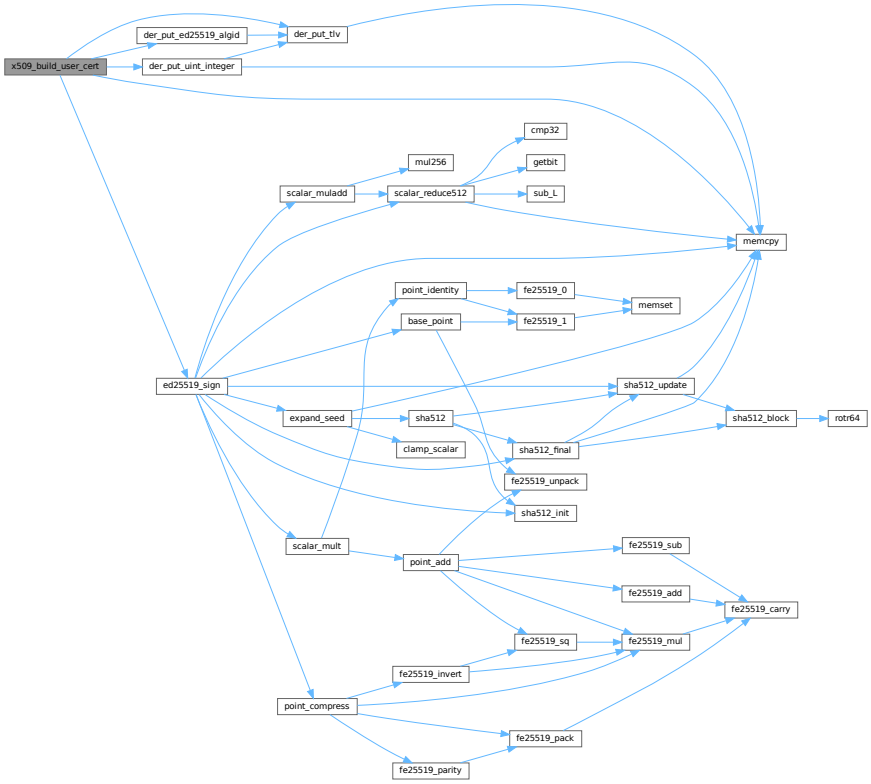
7.93.1.1 x509_build_user_cert()

```
size_t x509_build_user_cert (
            uint8_t * out,
            size_t out_cap,
            const uint8_t subject_pubkey[32],
            const uint8_t serial[16],
            const uint8_t issuer_seed[32] )
```

References der_put_ed25519_algid(), der_put_tlv(), der_put_uint_integer(), ed25519_sign(), and memcpy().

Referenced by capsule_mint_identity().

Here is the call graph for this function:



Here is the caller graph for this function:

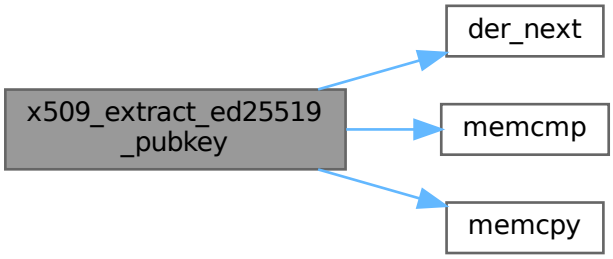
7.93.1.2 x509_extract_ed25519_pubkey()

```
int x509_extract_ed25519_pubkey (
            const uint8_t * der,
            size_t der_len,
            uint8_t pubkey_out[32] )
```

References der_next(), der_span_t::len, memcmp(), memcpy(), and der_span_t::p.

Referenced by find_and_cache_pubkey(), and vm_identity_from_cert().

Here is the call graph for this function:



Here is the caller graph for this function:

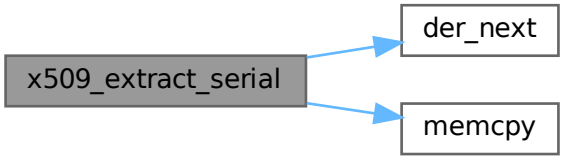
7.93.1.3 x509_extract_serial()

```
int x509_extract_serial (
            const uint8_t * der,
            size_t der_len,
            uint8_t * serial_out,
            size_t serial_out_cap,
            size_t * serial_len_out )
```

References der_next(), der_span_t::len, memcpy(), and der_span_t::p.

Referenced by vm_identity_from_cert().

Here is the call graph for this function:



Here is the caller graph for this function:

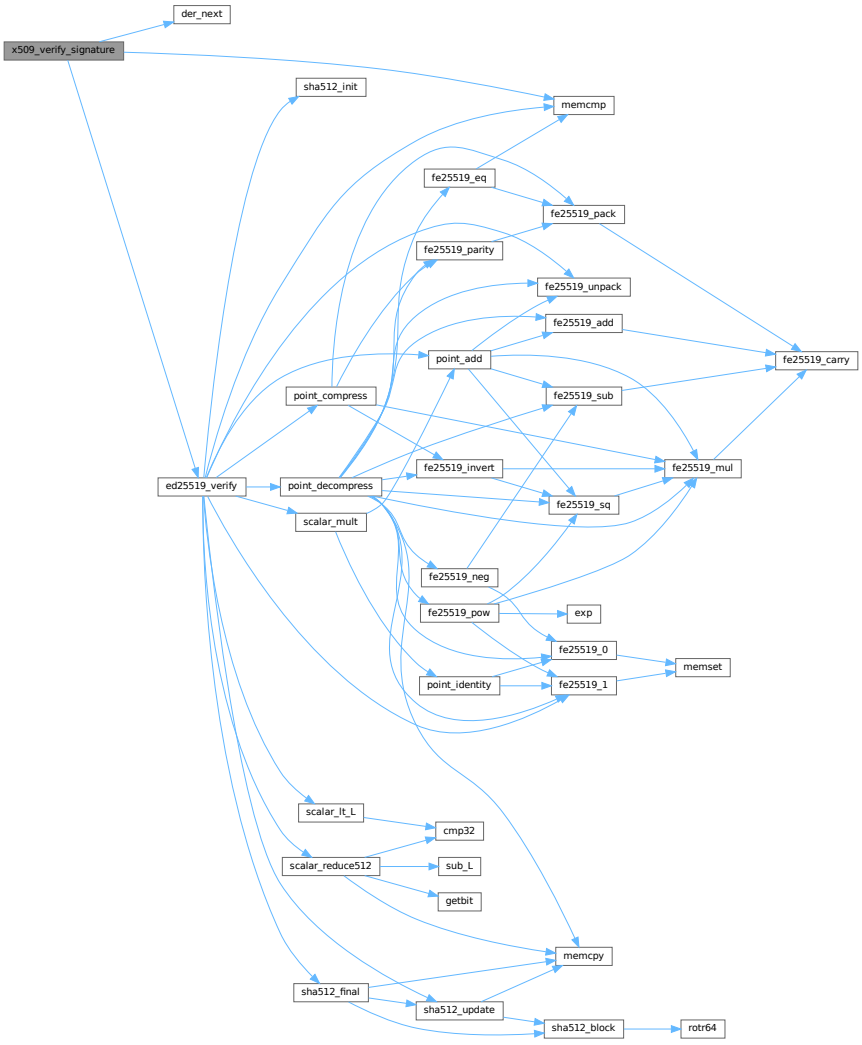
7.93.1.4 x509_verify_signature()

```
int x509_verify_signature (
            const uint8_t * der,
            size_t der_len,
            const uint8_t issuer_pubkey[32] )
```

References der_next(), ed25519_verify(), der_span_t::len, memcmp(), and der_span_t::p.

Referenced by vm_identity_from_cert().

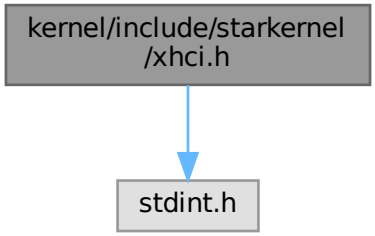
Here is the call graph for this function:



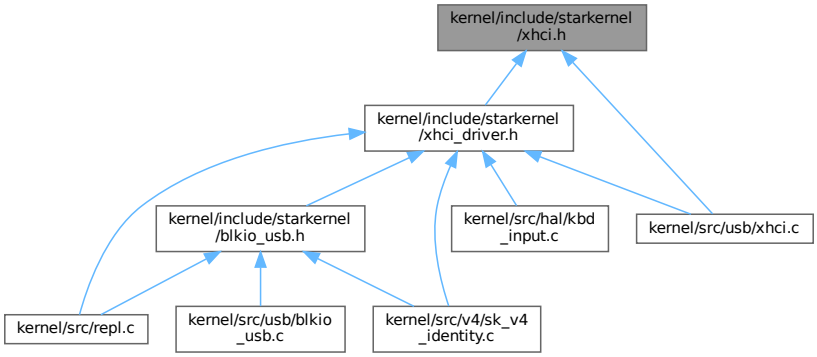
Here is the caller graph for this function:

7.94 kernel/include/starkernel/xhci.h File Reference

`#include <stdint.h>`
Include dependency graph for xhci.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct xhci_cap_regs_t
- struct xhci_op_regs_t
- struct xhci_port_regs_t
- struct xhci_intr_regs_t
- struct xhci_runtime_regs_t

- struct xhci_trb_t
- struct usb_setup_packet_t
- struct usb_bot_cbw_t
- struct usb_bot_csw_t
- struct xhci_slot_ctx32_t
- struct xhci_ep_ctx32_t
- struct xhci_input_ctrl_ctx32_t

Macros

- #define XHCI_HCSPARAMS1_MAX_SLOTS(v) ((uint32_t)(v) & 0xFFu)
- #define XHCI_HCSPARAMS1_MAX_INTRS(v) (((uint32_t)(v) >> 8) & 0x7FFu)
- #define XHCI_HCSPARAMS1_MAX_PORTS(v) (((uint32_t)(v) >> 24) & 0xFFu)
- #define XHCI_HCSPARAMS2_MAX_SCRATCHPAD_BUFS(v) ((((uint32_t)(v) >> 21) & 0x1Fu) << 5 | (((uint32_t)(v) >> 27) & 0x1Fu))
- #define XHCI_HCCPARAMS1_CSZ(v) (((uint32_t)(v) >> 2) & 0x1u)
- #define XHCI_USBCMD_RUN (1u << 0) /* Run/Stop: 1 = run */
- #define XHCI_USBCMD_HCRST (1u << 1) /* HC Reset */
- #define XHCI_USBCMD_INTE (1u << 2) /* Interrupter Enable */
- #define XHCI_USBCMD_HSEE (1u << 3) /* Host System Error Enable */
- #define XHCI_USBSTS_HCH (1u << 0) /* HC Halted */
- #define XHCI_USBSTS_HSE (1u << 2) /* Host System Error */
- #define XHCI_USBSTS_EINT (1u << 3) /* Event Interrupt */
- #define XHCI_USBSTS_PCD (1u << 4) /* Port Change Detect */
- #define XHCI_USBSTS_CNR (1u << 11) /* Controller Not Ready */
- #define XHCI_USBSTS_HCE (1u << 12) /* Host Controller Error */
- #define XHCI_CRCR_RCS (1ull << 0) /* Ring Cycle State */
- #define XHCI_CRCR_CS (1ull << 1) /* Command Stop */
- #define XHCI_CRCR_CA (1ull << 2) /* Command Abort */
- #define XHCI_CRCR_CRR (1ull << 3) /* Command Ring Running (read-only) */
- #define XHCI_CRCR_PTR_MASK (~0x3Full) /* pointer must be 64-byte aligned */
- #define XHCI_CONFIG_MAX_SLOTS_EN(n) ((uint32_t)(n) & 0xFFu)
- #define XHCI_PORT_REGS_OFFSET 0x400u
- #define XHCI_PORTSC_CCS (1u << 0) /* Current Connect Status */
- #define XHCI_PORTSC_PED (1u << 1) /* Port Enabled/Disabled */
- #define XHCI_PORTSC_PR (1u << 4) /* Port Reset */
- #define XHCI_PORTSC_PLS_MASK (0xFu << 5) /* Port Link State */
- #define XHCI_PORTSC_PP (1u << 9) /* Port Power */
- #define XHCI_PORTSC_SPEED_MASK (0xFu << 10)
- #define XHCI_PORTSC_SPEED(v) (((uint32_t)(v) >> 10) & 0xFu) /* xHCI 1.2 spec table 7-13 speed IDs */
- #define XHCI_PORTSC_CSC (1u << 17) /* Connect Status Change */
- #define XHCI_PORTSC_PEC (1u << 18) /* Port Enabled/Disabled Change */
- #define XHCI_PORTSC_PRC (1u << 21) /* Port Reset Change */
- #define XHCI_IMAN_IP (1u << 0) /* Interrupt Pending */
- #define XHCI_IMAN_IE (1u << 1) /* Interrupt Enable */
- #define XHCI_ERDP_EHB (1ull << 3) /* Event Handler Busy */
- #define XHCI_ERDP_PTR_MASK (~0xFull) /* pointer occupies bits[63:4] */
- #define XHCI_DB_TARGET(ep) ((uint32_t)(ep) & 0xFFu) /* 0 = command ring */
- #define XHCI_DB_STREAM_ID(sid) (((uint32_t)(sid) & 0xFFFFu) << 16)
- #define XHCI_TRB_CONTROL_CYCLE (1u << 0) /* Cycle bit */
- #define XHCI_TRB_CONTROL_TYPE_SHIFT 10
- #define XHCI_TRB_CONTROL_TYPE_MASK (0x3Fu << XHCI_TRB_CONTROL_TYPE_SHIFT)
- #define XHCI_TRB_TYPE(ctrl) (((ctrl) & XHCI_TRB_CONTROL_TYPE_MASK) >> XHCI_TRB_CONTROL_TYPE_SHIFT)
- #define XHCI_TRB_TYPE_NORMAL 1 /* Transfer Ring, bulk/interrupt/isoch -- not EP0 */

- #define XHCI_TRB_TYPE_LINK 6 /* ring-wraparound marker, Command/Transfer Rings only */
- #define XHCI_TRB_TYPE_ENABLE_SLOT_CMD 9
- #define XHCI_TRB_TYPE_DISABLE_SLOT_CMD 10
- #define XHCI_TRB_TYPE_ADDRESS_DEVICE_CMD 11
- #define XHCI_TRB_TYPE_CONFIGURE_ENDPOINT_CMD 12
- #define XHCI_TRB_TYPE_RESET_ENDPOINT_CMD 14
- #define XHCI_TRB_TYPE_SET_TR_DEQUEUE_POINTER_CMD 16
- #define XHCI_TRB_TYPE_SETUP_STAGE 2 /* Transfer Ring, control transfers only */
- #define XHCI_TRB_TYPE_DATA_STAGE 3
- #define XHCI_TRB_TYPE_STATUS_STAGE 4
- #define XHCI_TRB_TYPE_TRANSFER_EVENT 32
- #define XHCI_TRB_TYPE_COMMAND_COMPLETION_EVT 33
- #define XHCI_TRB_TYPE_PORT_STATUS_CHANGE_EVT 34
- #define XHCI_TRB_CONTROL_TC (1u << 1) /* Toggle Cycle */
- #define XHCI_TRB_CONTROL_IDT (1u << 6)
- #define XHCI_TRB_CONTROL_IOC (1u << 5) /* Interrupt On Completion */
- #define XHCI_TRB_CONTROL_DIR_IN (1u << 16) /* Data/Status Stage: 1=IN, 0=OUT */
- #define XHCI_SETUP_TRT_NO_DATA 0u
- #define XHCI_SETUP_TRT_OUT_DATA 2u
- #define XHCI_SETUP_TRT_IN_DATA 3u
- #define XHCI_TRB_CONTROL_TRT_SHIFT 16 /* Setup Stage TRB only; Data/Status Stage overlays DIR at the same bit */
- #define USB_REQ_GET_DESCRIPTOR 6u
- #define USB_REQ_SET_CONFIGURATION 9u
- #define USB_REQ_CLEAR_FEATURE 1u
- #define USB_DESC_TYPE_DEVICE 1u
- #define USB_DESC_TYPE_CONFIG 2u
- #define USB_DIR_DEVICE_TO_HOST 0x80u
- #define USB_DIR_HOST_TO_DEVICE 0x00u
- #define USB_REQ_TYPE_STANDARD 0u
- #define USB_REQ_TYPE_CLASS 1u
- #define USB_RECIP_DEVICE 0u
- #define USB_RECIP_INTERFACE 1u
- #define USB_RECIP_ENDPOINT 2u
- #define USB_FEATURE_ENDPOINT_HALT 0u
- #define USB_BOT_MASS_STORAGE_RESET 0xFFu
- #define USB_DESC_OFF_LENGTH 0u
- #define USB_DESC_OFF_TYPE 1u
- #define USB_CONFIG_OFF_TOTAL_LENGTH 2u /* wTotalLength, 2 bytes, Configuration descriptor only */
- #define USB_CONFIG_OFF_CONFIG_VALUE 5u /* bConfigurationValue -- the value SET_CONFIGURATION needs in wValue */
- #define USB_DESC_TYPE_INTERFACE 4u
- #define USB_IFACE_OFF_CLASS 5u
- #define USB_IFACE_OFF_SUBCLASS 6u
- #define USB_IFACE_OFF_PROTOCOL 7u
- #define USB_CLASS_MASS_STORAGE 0x08u
- #define USB_SUBCLASS_SCSI 0x06u /* SCSI transparent command set */
- #define USB_PROTOCOL_BOT 0x50u /* Bulk-Only Transport */
- #define USB_IFACE_OFF_NUMBER 2u /* bInterfaceNumber */
- #define USB_CLASS_HID 0x03u
- #define USB_SUBCLASS_HID_BOOT 0x01u
- #define USB_PROTOCOL_HID_KEYBOARD 0x01u
- #define USB_HID_REQ_SET_PROTOCOL 0x0Bu /* class, interface recipient */
- #define USB_HID_PROTOCOL_BOOT 0u
- #define USB_DESC_TYPE_ENDPOINT 5u

- #define USB_EP_OFF_ADDRESS 2u /* bEndpointAddress: bit 7 = direction, bits 3:0 = number */
- #define USB_EP_OFF_ATTRIBUTES 3u /* bmAttributes: bits 1:0 = transfer type */
- #define USB_EP_OFF_MAX_PACKET_SIZE 4u /* wMaxPacketSize, 2 bytes */
- #define USB_EP_ADDR_DIR_MASK 0x80u
- #define USB_EP_ADDR_NUM_MASK 0x0Fu
- #define USB_EP_ATTR_TYPE_MASK 0x03u
- #define USB_EP_TYPE_BULK 0x02u
- #define USB_EP_TYPE_INTERRUPT 0x03u
- #define USB_EP_OFF_INTERVAL 6u /* bInterval */
- #define USB_BOT_CBW_SIGNATURE 0x43425355u /* "USBC", wire byte order U,S,B,C as an LE dword */
- #define USB_BOT_CBW_LENGTH 31u
- #define USB_BOT_CBW_FLAG_DATA_IN 0x80u /* bmCBWFlags: device-to-host data stage */
- #define USB_BOT_CBW_LUN_DEFAULT 0u /* no multi-LUN support -- single-LUN devices only */
- #define SCSI_CMD_READ10 0x28u
- #define SCSI_CDB_LEN_READ10 10u
- #define SCSI_CMD_WRITE10 0x2Au
- #define SCSI_CDB_LEN_WRITE10 10u
- #define SCSI_CMD_TEST_UNIT_READY 0x00u
- #define SCSI_CDB_LEN_TEST_UNIT_READY 6u
- #define XHCI_BOT_TUR_MAX_RETRIES 3u
- #define XHCI_BOT_STALL_MAX_RECOVERIES 2u
- #define SCSI_CMD_READ_CAPACITY10 0x25u
- #define SCSI_CDB_LEN_READ_CAPACITY10 10u
- #define SCSI_READ_CAPACITY10_DATA_LEN 8u
- #define USB_BOT_CSW_SIGNATURE 0x53425355u /* "USBS", wire byte order U,S,B,S as an LE dword */
- #define USB_BOT_CSW_LENGTH 13u
- #define USB_BOT_CSW_STATUS_PASS 0u
- #define USB_BOT_CSW_STATUS_FAILED 1u
- #define USB_BOT_CSW_STATUS_PHASE_ERROR 2u
- #define XHCI_EVT_COMPLETION_CODE(status) (((uint32_t)(status) >> 24) & 0xFFu)
- #define XHCI_EVT_SLOT_ID(control) (((uint32_t)(control) >> 24) & 0xFFu)
- #define XHCI_COMPLETION_CODE_SUCCESS 1u
- #define XHCI_COMPLETION_CODE_STALL_ERROR 6u
- #define XHCI_COMPLETION_CODE_SHORT_PACKET 13u
- #define XHCI_EVT_EP_ID(control) (((uint32_t)(control) >> 16) & 0x1Fu)
- #define XHCI_PSC_EVT_PORT_ID(parameter) (((uint32_t)(parameter) >> 24) & 0xFFu)
- #define XHCI_SLOT_CTX_SPEED_SHIFT 20
- #define XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT 27
- #define XHCI_SLOT_CTX_ROOT_PORT_SHIFT 16
- #define XHCI_SLOT_CTX_INTR_TARGET_SHIFT 22
- #define XHCI_EP_CTX_TYPE_SHIFT 3
- #define XHCI_EP_CTX_TYPE_CONTROL_BIDI 4u /* EP0 */
- #define XHCI_EP_CTX_TYPE_BULK_OUT 2u /* xHCI 1.2 spec table 6-9 */
- #define XHCI_EP_CTX_TYPE_BULK_IN 6u
- #define XHCI_EP_CTX_TYPE_INTERRUPT_IN 7u
- #define XHCI_EP_CTX_INTERVAL_SHIFT 16 /* dword0: period 2^Interval x 125 us */
- #define XHCI_EP_CTX_CERR_SHIFT 1
- #define XHCI_EP_CTX_MAX_PACKET_SHIFT 16
- #define XHCI_EP_ADDR_TO_DCI(addr)
- #define XHCI_INPUT_CTRL_ADD_SLOT (1u << 0)
- #define XHCI_INPUT_CTRL_ADD_EP0 (1u << 1)
- #define XHCI_RING_TRB_COUNT 256u
- #define XHCI_RING_BYTES (XHCI_RING_TRB_COUNT * sizeof(xhci_trb_t))
- #define XHCI_EVT_RING_MAX_DRAIN XHCI_RING_TRB_COUNT
- #define XHCI_MAX_TRACKED_PORTS 32u

Typedefs

- typedef volatile uint32_t xhci_doorbell_t

7.94.1 Macro Definition Documentation

7.94.1.1 SCSI_CDB_LEN_READ10

```
#define SCSI_CDB_LEN_READ10 10u
```

7.94.1.2 SCSI_CDB_LEN_READ_CAPACITY10

```
#define SCSI_CDB_LEN_READ_CAPACITY10 10u
```

7.94.1.3 SCSI_CDB_LEN_TEST_UNIT_READY

```
#define SCSI_CDB_LEN_TEST_UNIT_READY 6u
```

7.94.1.4 SCSI_CDB_LEN_WRITE10

```
#define SCSI_CDB_LEN_WRITE10 10u
```

7.94.1.5 SCSI_CMD_READ10

```
#define SCSI_CMD_READ10 0x28u
```

7.94.1.6 SCSI_CMD_READ_CAPACITY10

```
#define SCSI_CMD_READ_CAPACITY10 0x25u
```

7.94.1.7 SCSI_CMD_TEST_UNIT_READY

```
#define SCSI_CMD_TEST_UNIT_READY 0x00u
```

7.94.1.8 SCSI_CMD_WRITE10

```
#define SCSI_CMD_WRITE10 0x2Au
```

7.94.1.9 SCSI_READ_CAPACITY10_DATA_LEN

```
#define SCSI_READ_CAPACITY10_DATA_LEN 8u
```

7.94.1.10 USB_BOT_CBW_FLAG_DATA_IN

```
#define USB_BOT_CBW_FLAG_DATA_IN 0x80u /* bmCBWFlags:  device-to-host data stage */
```

7.94.1.11 USB_BOT_CBW_LENGTH

```
#define USB_BOT_CBW_LENGTH 31u
```

7.94.1.12 USB_BOT_CBW_LUN_DEFAULT

```
#define USB_BOT_CBW_LUN_DEFAULT 0u /* no multi-LUN support -- single-LUN devices only */
```

7.94.1.13 USB_BOT_CBW_SIGNATURE

```
#define USB_BOT_CBW_SIGNATURE 0x43425355u /* "USBC", wire byte order U,S,B,C as an LE dword */
```

7.94.1.14 USB_BOT_CSW_LENGTH

```
#define USB_BOT_CSW_LENGTH 13u
```

7.94.1.15 USB_BOT_CSW_SIGNATURE

```
#define USB_BOT_CSW_SIGNATURE 0x53425355u /* "USBS", wire byte order U,S,B,S as an LE dword */
```

7.94.1.16 USB_BOT_CSW_STATUS_FAILED

```
#define USB_BOT_CSW_STATUS_FAILED 1u
```

7.94.1.17 USB_BOT_CSW_STATUS_PASS

```
#define USB_BOT_CSW_STATUS_PASS 0u
```

7.94.1.18 USB_BOT_CSW_STATUS_PHASE_ERROR

```
#define USB_BOT_CSW_STATUS_PHASE_ERROR 2u
```

7.94.1.19 USB_BOT_MASS_STORAGE_RESET

```
#define USB_BOT_MASS_STORAGE_RESET 0xFFu
```

7.94.1.20 USB_CLASS_HID

```
#define USB_CLASS_HID 0x03u
```

7.94.1.21 USB_CLASS_MASS_STORAGE

```
#define USB_CLASS_MASS_STORAGE 0x08u
```

7.94.1.22 USB_CONFIG_OFF_CONFIG_VALUE

```
#define USB_CONFIG_OFF_CONFIG_VALUE 5u /* bConfigurationValue -- the value SET_CONFIGURATION
needs in wValue */
```

7.94.1.23 USB_CONFIG_OFF_TOTAL_LENGTH

```
#define USB_CONFIG_OFF_TOTAL_LENGTH 2u /* wTotalLength, 2 bytes, Configuration descriptor only
*/
```

7.94.1.24 USB_DESC_OFF_LENGTH

```
#define USB_DESC_OFF_LENGTH 0u
```

7.94.1.25 USB_DESC_OFF_TYPE

```
#define USB_DESC_OFF_TYPE 1u
```

7.94.1.26 USB_DESC_TYPE_CONFIG

```
#define USB_DESC_TYPE_CONFIG 2u
```

7.94.1.27 USB_DESC_TYPE_DEVICE

```
#define USB_DESC_TYPE_DEVICE 1u
```

7.94.1.28 USB_DESC_TYPE_ENDPOINT

```
#define USB_DESC_TYPE_ENDPOINT 5u
```

7.94.1.29 USB_DESC_TYPE_INTERFACE

```
#define USB_DESC_TYPE_INTERFACE 4u
```

7.94.1.30 USB_DIR_DEVICE_TO_HOST

```
#define USB_DIR_DEVICE_TO_HOST 0x80u
```

7.94.1.31 USB_DIR_HOST_TO_DEVICE

```
#define USB_DIR_HOST_TO_DEVICE 0x00u
```

7.94.1.32 USB_EP_ADDR_DIR_MASK

```
#define USB_EP_ADDR_DIR_MASK 0x80u
```

7.94.1.33 USB_EP_ADDR_NUM_MASK

```
#define USB_EP_ADDR_NUM_MASK 0x0Fu
```

7.94.1.34 USB_EP_ATTR_TYPE_MASK

```
#define USB_EP_ATTR_TYPE_MASK 0x03u
```

7.94.1.35 USB_EP_OFF_ADDRESS

```
#define USB_EP_OFF_ADDRESS 2u /* bEndpointAddress:  bit 7 = direction, bits 3:0 = number */
```

7.94.1.36 USB_EP_OFF_ATTRIBUTES

```
#define USB_EP_OFF_ATTRIBUTES 3u /* bmAttributes:  bits 1:0 = transfer type */
```

7.94.1.37 USB_EP_OFF_INTERVAL

```
#define USB_EP_OFF_INTERVAL 6u /* bInterval */
```

7.94.1.38 USB_EP_OFF_MAX_PACKET_SIZE

```
#define USB_EP_OFF_MAX_PACKET_SIZE 4u /* wMaxPacketSize, 2 bytes */
```

7.94.1.39 USB_EP_TYPE_BULK

```
#define USB_EP_TYPE_BULK 0x02u
```

7.94.1.40 USB_EP_TYPE_INTERRUPT

```
#define USB_EP_TYPE_INTERRUPT 0x03u
```

7.94.1.41 USB_FEATURE_ENDPOINT_HALT

```
#define USB_FEATURE_ENDPOINT_HALT 0u
```

7.94.1.42 USB_HID_PROTOCOL_BOOT

```
#define USB_HID_PROTOCOL_BOOT 0u
```

7.94.1.43 USB_HID_REQ_SET_PROTOCOL

```
#define USB_HID_REQ_SET_PROTOCOL 0x0Bu /* class, interface recipient */
```

7.94.1.44 USB_IFACE_OFF_CLASS

```
#define USB_IFACE_OFF_CLASS 5u
```

7.94.1.45 USB_IFACE_OFF_NUMBER

```
#define USB_IFACE_OFF_NUMBER 2u /* bInterfaceNumber */
```

7.94.1.46 USB_IFACE_OFF_PROTOCOL

```
#define USB_IFACE_OFF_PROTOCOL 7u
```

7.94.1.47 USB_IFACE_OFF_SUBCLASS

```
#define USB_IFACE_OFF_SUBCLASS 6u
```

7.94.1.48 USB_PROTOCOL_BOT

```
#define USB_PROTOCOL_BOT 0x50u /* Bulk-Only Transport */
```

7.94.1.49 USB_PROTOCOL_HID_KEYBOARD

```
#define USB_PROTOCOL_HID_KEYBOARD 0x01u
```

7.94.1.50 USB_RECIP_DEVICE

```
#define USB_RECIP_DEVICE 0u
```

7.94.1.51 USB_RECIP_ENDPOINT

```
#define USB_RECIP_ENDPOINT 2u
```

7.94.1.52 USB_RECIP_INTERFACE

```
#define USB_RECIP_INTERFACE 1u
```

7.94.1.53 USB_REQ_CLEAR_FEATURE

```
#define USB_REQ_CLEAR_FEATURE 1u
```

7.94.1.54 USB_REQ_GET_DESCRIPTOR

```
#define USB_REQ_GET_DESCRIPTOR 6u
```

7.94.1.55 USB_REQ_SET_CONFIGURATION

```
#define USB_REQ_SET_CONFIGURATION 9u
```

7.94.1.56 USB_REQ_TYPE_CLASS

```
#define USB_REQ_TYPE_CLASS 1u
```

7.94.1.57 USB_REQ_TYPE_STANDARD

```
#define USB_REQ_TYPE_STANDARD 0u
```

7.94.1.58 USB_SUBCLASS_HID_BOOT

```
#define USB_SUBCLASS_HID_BOOT 0x01u
```

7.94.1.59 USB_SUBCLASS_SCSI

```
#define USB_SUBCLASS_SCSI 0x06u /* SCSI transparent command set */
```

7.94.1.60 XHCI_BOT_STALL_MAX_RECOVERIES

```
#define XHCI_BOT_STALL_MAX_RECOVERIES 2u
```

7.94.1.61 XHCI_BOT_TUR_MAX_RETRIES

```
#define XHCI_BOT_TUR_MAX_RETRIES 3u
```

7.94.1.62 XHCI_COMPLETION_CODE_SHORT_PACKET

```
#define XHCI_COMPLETION_CODE_SHORT_PACKET 13u
```

7.94.1.63 XHCI_COMPLETION_CODE_STALL_ERROR

```
#define XHCI_COMPLETION_CODE_STALL_ERROR 6u
```

7.94.1.64 XHCI_COMPLETION_CODE_SUCCESS

```
#define XHCI_COMPLETION_CODE_SUCCESS 1u
```

7.94.1.65 XHCI_CONFIG_MAX_SLOTS_EN

```
#define XHCI_CONFIG_MAX_SLOTS_EN(
              n ) ((uint32_t)(n) & 0xFFu)
```

7.94.1.66 XHCI_CRCR_CA

```
#define XHCI_CRCR_CA (1ull << 2) /* Command Abort */
```

7.94.1.67 XHCI_CRCR_CRR

```
#define XHCI_CRCR_CRR (1ull << 3) /* Command Ring Running (read-only) */
```

7.94.1.68 XHCI_CRCR_CS

```
#define XHCI_CRCR_CS (1ull << 1) /* Command Stop */
```

7.94.1.69 XHCI_CRCR_PTR_MASK

```
#define XHCI_CRCR_PTR_MASK (~0x3Full) /* pointer must be 64-byte aligned */
```

7.94.1.70 XHCI_CRCR_RCS

```
#define XHCI_CRCR_RCS (1ull << 0) /* Ring Cycle State */
```

7.94.1.71 XHCI_DB_STREAM_ID

```
#define XHCI_DB_STREAM_ID(
              sid ) (((uint32_t)(sid) & 0xFFFFu) << 16)
```

7.94.1.72 XHCI_DB_TARGET

```
#define XHCI_DB_TARGET(
              ep ) ((uint32_t)(ep) & 0xFFu) /* 0 = command ring */
```

7.94.1.73 XHCI_EP_ADDR_TO_DCI

```
#define XHCI_EP_ADDR_TO_DCI(
              addr )
```

Value:

```
    ((2u * ((uint32_t)(addr) & USB_EP_ADDR_NUM_MASK)) + \
     (((uint32_t)(addr) & USB_EP_ADDR_DIR_MASK) ? 1u : 0u))
```

7.94.1.74 XHCI_EP_CTX_CERR_SHIFT

```
#define XHCI_EP_CTX_CERR_SHIFT 1
```

7.94.1.75 XHCI_EP_CTX_INTERVAL_SHIFT

```
#define XHCI_EP_CTX_INTERVAL_SHIFT 16 /* dword0:  period 2^Interval x 125 us */
```

7.94.1.76 XHCI_EP_CTX_MAX_PACKET_SHIFT

```
#define XHCI_EP_CTX_MAX_PACKET_SHIFT 16
```

7.94.1.77 XHCI_EP_CTX_TYPE_BULK_IN

```
#define XHCI_EP_CTX_TYPE_BULK_IN 6u
```

7.94.1.78 XHCI_EP_CTX_TYPE_BULK_OUT

```
#define XHCI_EP_CTX_TYPE_BULK_OUT 2u /* xHCI 1.2 spec table 6-9 */
```

7.94.1.79 XHCI_EP_CTX_TYPE_CONTROL_BIDI

```
#define XHCI_EP_CTX_TYPE_CONTROL_BIDI 4u /* EP0 */
```

7.94.1.80 XHCI_EP_CTX_TYPE_INTERRUPT_IN

```
#define XHCI_EP_CTX_TYPE_INTERRUPT_IN 7u
```

7.94.1.81 XHCI_EP_CTX_TYPE_SHIFT

```
#define XHCI_EP_CTX_TYPE_SHIFT 3
```

7.94.1.82 XHCI_ERDP_EHB

```
#define XHCI_ERDP_EHB (1ull << 3) /* Event Handler Busy */
```

7.94.1.83 XHCI_ERDP_PTR_MASK

```
#define XHCI_ERDP_PTR_MASK (~0xFull) /* pointer occupies bits[63:4] */
```

7.94.1.84 XHCI_EVT_COMPLETION_CODE

```
#define XHCI_EVT_COMPLETION_CODE(
             status ) (((uint32_t)(status) >> 24) & 0xFFu)
```

7.94.1.85 XHCI_EVT_EP_ID

```
#define XHCI_EVT_EP_ID(
             control ) (((uint32_t)(control) >> 16) & 0x1Fu)
```

7.94.1.86 XHCI_EVT_RING_MAX_DRAIN

```
#define XHCI_EVT_RING_MAX_DRAIN XHCI_RING_TRB_COUNT
```

7.94.1.87 XHCI_EVT_SLOT_ID

```
#define XHCI_EVT_SLOT_ID(
             control ) (((uint32_t)(control) >> 24) & 0xFFu)
```

7.94.1.88 XHCI_HCCPARAMS1_CSZ

```
#define XHCI_HCCPARAMS1_CSZ(
             v ) (((uint32_t)(v) >> 2) & 0x1u)
```

7.94.1.89 XHCI_HCSPARAMS1_MAX_INTRS

```
#define XHCI_HCSPARAMS1_MAX_INTRS(
             v ) (((uint32_t)(v) >> 8) & 0x7FFu)
```

7.94.1.90 XHCI_HCSPARAMS1_MAX_PORTS

```
#define XHCI_HCSPARAMS1_MAX_PORTS(
             v ) (((uint32_t)(v) >> 24) & 0xFFu)
```

7.94.1.91 XHCI_HCSPARAMS1_MAX_SLOTS

```
#define XHCI_HCSPARAMS1_MAX_SLOTS(
             v ) ((uint32_t)(v) & 0xFFu)
```

7.94.1.92 XHCI_HCSPARAMS2_MAX_SCRATCHPAD_BUFS

```
#define XHCI_HCSPARAMS2_MAX_SCRATCHPAD_BUFS(
             v )  ((((uint32_t)(v) >> 21) & 0x1Fu) << 5 | (((uint32_t)(v) >> 27) & 0x1Fu))
```

7.94.1.93 XHCI_IMAN_IE

```
#define XHCI_IMAN_IE (1u << 1) /* Interrupt Enable */
```

7.94.1.94 XHCI_IMAN_IP

```
#define XHCI_IMAN_IP (1u << 0) /* Interrupt Pending */
```

7.94.1.95 XHCI_INPUT_CTRL_ADD_EP0

```
#define XHCI_INPUT_CTRL_ADD_EP0 (1u << 1)
```

7.94.1.96 XHCI_INPUT_CTRL_ADD_SLOT

```
#define XHCI_INPUT_CTRL_ADD_SLOT (1u << 0)
```

7.94.1.97 XHCI_MAX_TRACKED_PORTS

```
#define XHCI_MAX_TRACKED_PORTS 32u
```

7.94.1.98 XHCI_PORT_REGS_OFFSET

```
#define XHCI_PORT_REGS_OFFSET 0x400u
```

7.94.1.99 XHCI_PORTSC_CCS

```
#define XHCI_PORTSC_CCS (1u << 0) /* Current Connect Status */
```

7.94.1.100 XHCI_PORTSC_CSC

```
#define XHCI_PORTSC_CSC (1u << 17) /* Connect Status Change */
```

7.94.1.101 XHCI_PORTSC_PEC

```
#define XHCI_PORTSC_PEC (1u << 18) /* Port Enabled/Disabled Change */
```

7.94.1.102 XHCI_PORTSC_PED

```
#define XHCI_PORTSC_PED (1u << 1) /* Port Enabled/Disabled */
```

7.94.1.103 XHCI_PORTSC_PLS_MASK

```
#define XHCI_PORTSC_PLS_MASK (0xFu << 5) /* Port Link State */
```

7.94.1.104 XHCI_PORTSC_PP

```
#define XHCI_PORTSC_PP (1u << 9) /* Port Power */
```

7.94.1.105 XHCI_PORTSC_PR

```
#define XHCI_PORTSC_PR (1u << 4) /* Port Reset */
```

7.94.1.106 XHCI_PORTSC_PRC

```
#define XHCI_PORTSC_PRC (1u << 21) /* Port Reset Change */
```

7.94.1.107 XHCI_PORTSC_SPEED

```
#define XHCI_PORTSC_SPEED(
             v ) (((uint32_t)(v) >> 10) & 0xFu) /* xHCI 1.2 spec table 7-13 speed IDs */
```

7.94.1.108 XHCI_PORTSC_SPEED_MASK

```
#define XHCI_PORTSC_SPEED_MASK (0xFu << 10)
```

7.94.1.109 XHCI_PSC_EVT_PORT_ID

```
#define XHCI_PSC_EVT_PORT_ID(
             parameter ) (((uint32_t)(parameter) >> 24) & 0xFFu)
```

7.94.1.110 XHCI_RING_BYTES

```
#define XHCI_RING_BYTES (XHCI_RING_TRB_COUNT * sizeof(xhci_trb_t))
```

7.94.1.111 XHCI_RING_TRB_COUNT

```
#define XHCI_RING_TRB_COUNT 256u
```

7.94.1.112 XHCI_SETUP_TRT_IN_DATA

```
#define XHCI_SETUP_TRT_IN_DATA 3u
```

7.94.1.113 XHCI_SETUP_TRT_NO_DATA

```
#define XHCI_SETUP_TRT_NO_DATA 0u
```

7.94.1.114 XHCI_SETUP_TRT_OUT_DATA

```
#define XHCI_SETUP_TRT_OUT_DATA 2u
```

7.94.1.115 XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT

```
#define XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT 27
```

7.94.1.116 XHCI_SLOT_CTX_INTR_TARGET_SHIFT

```
#define XHCI_SLOT_CTX_INTR_TARGET_SHIFT 22
```

7.94.1.117 XHCI_SLOT_CTX_ROOT_PORT_SHIFT

```
#define XHCI_SLOT_CTX_ROOT_PORT_SHIFT 16
```

7.94.1.118 XHCI_SLOT_CTX_SPEED_SHIFT

```
#define XHCI_SLOT_CTX_SPEED_SHIFT 20
```

7.94.1.119 XHCI_TRB_CONTROL_CYCLE

```
#define XHCI_TRB_CONTROL_CYCLE (1u << 0) /* Cycle bit */
```

7.94.1.120 XHCI_TRB_CONTROL_DIR_IN

```
#define XHCI_TRB_CONTROL_DIR_IN (1u << 16) /* Data/Status Stage:  1=IN, 0=OUT */
```

7.94.1.121 XHCI_TRB_CONTROL_IDT

```
#define XHCI_TRB_CONTROL_IDT (1u << 6)
```

7.94.1.122 XHCI_TRB_CONTROL_IOC

```
#define XHCI_TRB_CONTROL_IOC (1u << 5) /* Interrupt On Completion */
```

7.94.1.123 XHCI_TRB_CONTROL_TC

```
#define XHCI_TRB_CONTROL_TC (1u << 1) /* Toggle Cycle */
```

7.94.1.124 XHCI_TRB_CONTROL_TRT_SHIFT

```
#define XHCI_TRB_CONTROL_TRT_SHIFT 16 /* Setup Stage TRB only; Data/Status Stage overlays DIR
at the same bit */
```

7.94.1.125 XHCI_TRB_CONTROL_TYPE_MASK

```
#define XHCI_TRB_CONTROL_TYPE_MASK (0x3Fu << XHCI_TRB_CONTROL_TYPE_SHIFT)
```

7.94.1.126 XHCI_TRB_CONTROL_TYPE_SHIFT

```
#define XHCI_TRB_CONTROL_TYPE_SHIFT 10
```

7.94.1.127 XHCI_TRB_TYPE

```
#define XHCI_TRB_TYPE(
             ctrl ) (((ctrl) & XHCI_TRB_CONTROL_TYPE_MASK) >> XHCI_TRB_CONTROL_TYPE_SHIFT)
```

7.94.1.128 XHCI_TRB_TYPE_ADDRESS_DEVICE_CMD

```
#define XHCI_TRB_TYPE_ADDRESS_DEVICE_CMD 11
```

7.94.1.129 XHCI_TRB_TYPE_COMMAND_COMPLETION_EVT

```
#define XHCI_TRB_TYPE_COMMAND_COMPLETION_EVT 33
```

7.94.1.130 XHCI_TRB_TYPE_CONFIGURE_ENDPOINT_CMD

```
#define XHCI_TRB_TYPE_CONFIGURE_ENDPOINT_CMD 12
```

7.94.1.131 XHCI_TRB_TYPE_DATA_STAGE

```
#define XHCI_TRB_TYPE_DATA_STAGE 3
```

7.94.1.132 XHCI_TRB_TYPE_DISABLE_SLOT_CMD

```
#define XHCI_TRB_TYPE_DISABLE_SLOT_CMD 10
```

7.94.1.133 XHCI_TRB_TYPE_ENABLE_SLOT_CMD

```
#define XHCI_TRB_TYPE_ENABLE_SLOT_CMD 9
```

7.94.1.134 XHCI_TRB_TYPE_LINK

```
#define XHCI_TRB_TYPE_LINK 6 /* ring-wraparound marker, Command/Transfer Rings only */
```

7.94.1.135 XHCI_TRB_TYPE_NORMAL

```
#define XHCI_TRB_TYPE_NORMAL 1 /* Transfer Ring, bulk/interrupt/isoch -- not EP0 */
```

7.94.1.136 XHCI_TRB_TYPE_PORT_STATUS_CHANGE_EVT

```
#define XHCI_TRB_TYPE_PORT_STATUS_CHANGE_EVT 34
```

7.94.1.137 XHCI_TRB_TYPE_RESET_ENDPOINT_CMD

```
#define XHCI_TRB_TYPE_RESET_ENDPOINT_CMD 14
```

7.94.1.138 XHCI_TRB_TYPE_SET_TR_DEQUEUE_POINTER_CMD

```
#define XHCI_TRB_TYPE_SET_TR_DEQUEUE_POINTER_CMD 16
```

7.94.1.139 XHCI_TRB_TYPE_SETUP_STAGE

```
#define XHCI_TRB_TYPE_SETUP_STAGE 2 /* Transfer Ring, control transfers only */
```

7.94.1.140 XHCI_TRB_TYPE_STATUS_STAGE

```
#define XHCI_TRB_TYPE_STATUS_STAGE 4
```

7.94.1.141 XHCI_TRB_TYPE_TRANSFER_EVENT

```
#define XHCI_TRB_TYPE_TRANSFER_EVENT 32
```

7.94.1.142 XHCI_USBCMD_HCRST

```
#define XHCI_USBCMD_HCRST (1u << 1) /* HC Reset */
```

7.94.1.143 XHCI_USBCMD_HSEE

```
#define XHCI_USBCMD_HSEE (1u << 3) /* Host System Error Enable */
```

7.94.1.144 XHCI_USBCMD_INTE

```
#define XHCI_USBCMD_INTE (1u << 2) /* Interrupter Enable */
```

7.94.1.145 XHCI_USBCMD_RUN

```
#define XHCI_USBCMD_RUN (1u << 0) /* Run/Stop:  1 = run */
```

7.94.1.146 XHCI_USBSTS_CNR

```
#define XHCI_USBSTS_CNR (1u << 11) /* Controller Not Ready */
```

7.94.1.147 XHCI_USBSTS_EINT

```
#define XHCI_USBSTS_EINT (1u << 3) /* Event Interrupt */
```

7.94.1.148 XHCI_USBSTS_HCE

```
#define XHCI_USBSTS_HCE (1u << 12) /* Host Controller Error */
```

7.94.1.149 XHCI_USBSTS_HCH

```
#define XHCI_USBSTS_HCH (1u << 0) /* HC Halted */
```

7.94.1.150 XHCI_USBSTS_HSE

```
#define XHCI_USBSTS_HSE (1u << 2) /* Host System Error */
```

7.94.1.151 XHCI_USBSTS_PCD

```
#define XHCI_USBSTS_PCD (1u << 4) /* Port Change Detect */
```

7.94.2 Typedef Documentation

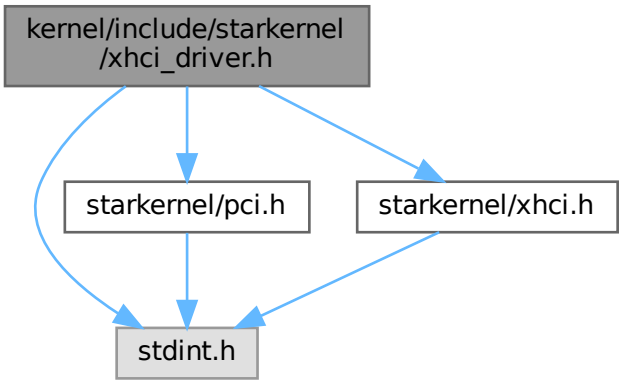
7.94.2.1 xhci_doorbell_t

```
typedef volatile uint32_t xhci_doorbell_t
```

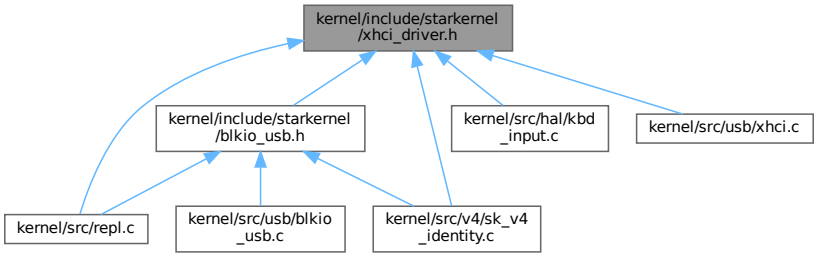
7.95 kernel/include/starkernel/xhci_driver.h File Reference

```
#include <stdint.h>
#include "starkernel/pci.h"
#include "starkernel/xhci.h"
```

Include dependency graph for xhci_driver.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct xhci_msc_slot_t
- struct xhci_dev_t

Macros

- #define XHCI_MAX_CONTROLLERS 8u

Enumerations

- enum xhci_transfer_purpose_t {
  XHCI_XFER_NONE = 0 , XHCI_XFER_DEVICE_DESC , XHCI_XFER_CONFIG_DESC_SHORT ,
  XHCI_XFER_CONFIG_DESC_FULL ,
  XHCI_XFER_SET_CONFIG , XHCI_XFER_CBW_SENT , XHCI_XFER_BOT_DATA_IN , XHCI_XFER_BOT_DATA_OUT
  ,
  XHCI_XFER_CSW_RECEIVED , XHCI_XFER_CLEAR_HALT , XHCI_XFER_BOT_RESET , XHCI_XFER_HID_SET_PROTOC
  ,
  XHCI_XFER_HID_SET_LEDS }
- enum xhci_next_action_t {
  XHCI_NEXT_ACTION_NONE = 0 , XHCI_NEXT_ACTION_GET_DEVICE_DESC , XHCI_NEXT_ACTION_GET_CONFIG_DES
  , XHCI_NEXT_ACTION_CONFIGURE_ENDPOINT ,
  XHCI_NEXT_ACTION_SET_CONFIG , XHCI_NEXT_ACTION_BOT_DATA_IN , XHCI_NEXT_ACTION_BOT_DATA_OUT
  , XHCI_NEXT_ACTION_BOT_CSW_RECEIVE ,
  XHCI_NEXT_ACTION_BOT_SEND_TUR , XHCI_NEXT_ACTION_BOT_SEND_READ10 , XHCI_NEXT_ACTION_BOT_SEND
  , XHCI_NEXT_ACTION_BOT_SEND_WRITE10 ,
  XHCI_NEXT_ACTION_CLEAR_HALT , XHCI_NEXT_ACTION_BOT_RESET , XHCI_NEXT_ACTION_HID_SET_PROTOCOL
  , XHCI_NEXT_ACTION_HID_POLL }

Functions

- int xhci_find_and_map (xhci_dev_t *dev, unsigned index)
- int xhci_bringup (xhci_dev_t *dev)
- uint32_t xhci_dev_count (void)
- xhci_dev_t * xhci_dev_at (uint32_t i)
- xhci_msc_slot_t * xhci_msc_slot_for (xhci_dev_t *dev, uint32_t slot_id)
- void xhci_poll_events (void)

- int xhci_cmd_enable_slot (xhci_dev_t *dev)
- int xhci_cmd_disable_slot (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_cmd_address_device (xhci_dev_t *dev, uint32_t slot_id, uint32_t port_id, uint32_t speed)
- int xhci_cmd_configure_endpoint (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_cmd_configure_hid_endpoint (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_ep0_hid_set_protocol (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_keyboard_running (void)
- int xhci_cmd_reset_endpoint (xhci_dev_t *dev, uint32_t slot_id, uint32_t ep_id)
- int xhci_cmd_set_tr_dequeue_pointer (xhci_dev_t *dev, uint32_t slot_id, uint32_t ep_id, uint64_t new_↩ dequeue, uint32_t dcs)
- int xhci_bot_send_read10 (xhci_dev_t *dev, uint32_t slot_id, uint32_t lba, uint16_t num_blocks, uint32_↩ t block_size)
- int xhci_bot_send_write10 (xhci_dev_t *dev, uint32_t slot_id, uint32_t lba, uint16_t num_blocks, uint32_↩ t block_size)
- int xhci_bot_send_test_unit_ready (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_read_block (xhci_dev_t *dev, uint32_t slot_id, uint32_t lba, uint16_t num_blocks, uint32_↩ t block_size)
- int xhci_bot_write_block (xhci_dev_t *dev, uint32_t slot_id, uint32_t lba, uint16_t num_blocks, uint32_↩ t block_size)
- int xhci_bot_send_read_capacity10 (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_get_capacity (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_wait_for_idle (xhci_dev_t *dev, uint32_t max_iters)
- int xhci_bot_read_data_in (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_write_data_out (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_receive_csw (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_ep0_get_device_descriptor (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_ep0_get_config_descriptor (xhci_dev_t *dev, uint32_t slot_id, uint16_t length)
- int xhci_ep0_set_configuration (xhci_dev_t *dev, uint32_t slot_id, uint8_t config_value)
- int xhci_ep0_clear_endpoint_halt (xhci_dev_t *dev, uint32_t slot_id, uint8_t ep_addr)
- int xhci_ep0_bot_mass_storage_reset (xhci_dev_t *dev, uint32_t slot_id)

7.95.1 Macro Definition Documentation

7.95.1.1 XHCI_MAX_CONTROLLERS

```
#define XHCI_MAX_CONTROLLERS 8u
```

7.95.2 Enumeration Type Documentation

7.95.2.1 xhci_next_action_t

```
enum xhci_next_action_t
```

Enumerator

XHCI_NEXT_ACTION_NONE	
XHCI_NEXT_ACTION_GET_DEVICE_DESC	
XHCI_NEXT_ACTION_GET_CONFIG_DESC	
XHCI_NEXT_ACTION_CONFIGURE_ENDPOINT	
XHCI_NEXT_ACTION_SET_CONFIG	
XHCI_NEXT_ACTION_BOT_DATA_IN	

Enumerator

XHCI_NEXT_ACTION_BOT_DATA_OUT	
XHCI_NEXT_ACTION_BOT_CSW_RECEIVE	
XHCI_NEXT_ACTION_BOT_SEND_TUR	
XHCI_NEXT_ACTION_BOT_SEND_READ10	
XHCI_NEXT_ACTION_BOT_SEND_READ_CAPACITY10	
XHCI_NEXT_ACTION_BOT_SEND_WRITE10	
XHCI_NEXT_ACTION_CLEAR_HALT	
XHCI_NEXT_ACTION_BOT_RESET	
XHCI_NEXT_ACTION_HID_SET_PROTOCOL	
XHCI_NEXT_ACTION_HID_POLL	

7.95.2.2 xhci_transfer_purpose_t

```
enum xhci_transfer_purpose_t
```

Enumerator

XHCI_XFER_NONE	
XHCI_XFER_DEVICE_DESC	
XHCI_XFER_CONFIG_DESC_SHORT	
XHCI_XFER_CONFIG_DESC_FULL	
XHCI_XFER_SET_CONFIG	
XHCI_XFER_CBW_SENT	
XHCI_XFER_BOT_DATA_IN	
XHCI_XFER_BOT_DATA_OUT	
XHCI_XFER_CSW_RECEIVED	
XHCI_XFER_CLEAR_HALT	
XHCI_XFER_BOT_RESET	
XHCI_XFER_HID_SET_PROTOCOL	
XHCI_XFER_HID_SET_LEDS	

7.95.3 Function Documentation

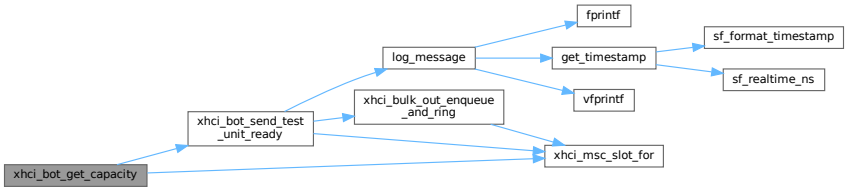
7.95.3.1 xhci_bot_get_capacity()

```
int xhci_bot_get_capacity (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

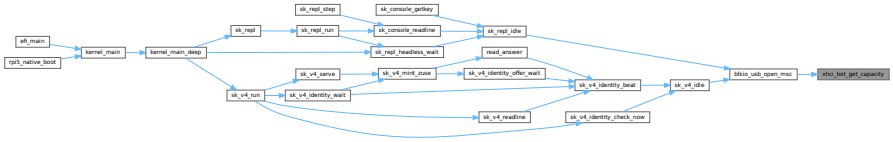
References xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, xhci_bot_send_test_unit_ready(), and xhci_msc_slot_for().

Referenced by blkio_usb_open_msc().

Here is the call graph for this function:



Here is the caller graph for this function:



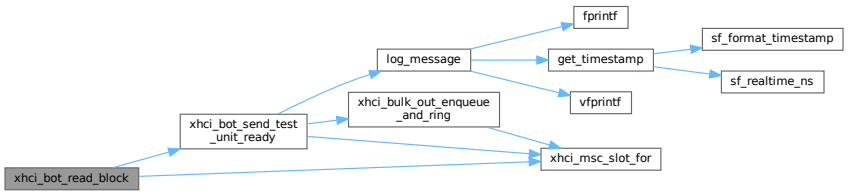
7.95.3.2 xhci_bot_read_block()

```
int xhci_bot_read_block (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t lba,
            uint16_t num_blocks,
            uint32_t block_size )
```

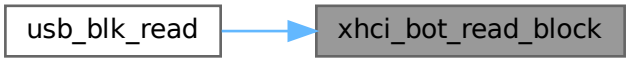
References block_size, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_read10_block_size, xhci_dev_t::bot_read10_lba, xhci_dev_t::bot_read10_num_blocks, xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_msc_slot_t::bulk_in_ep_adc xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, xhci_bot_send_test_unit_ready() and xhci_msc_slot_for().

Referenced by usb_blk_read().

Here is the call graph for this function:



Here is the caller graph for this function:



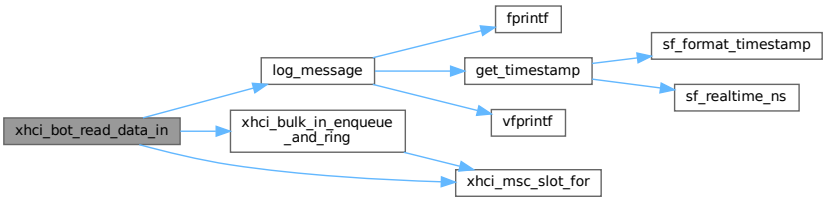
7.95.3.3 xhci_bot_read_data_in()

```
int xhci_bot_read_data_in (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

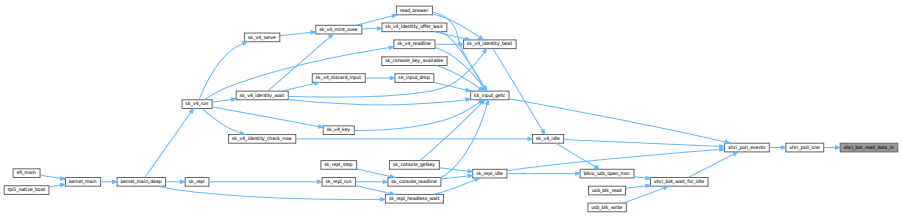
References xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_msc_slot_t::bulk_in_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, xhci_bulk_in_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_BOT_DATA_IN.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



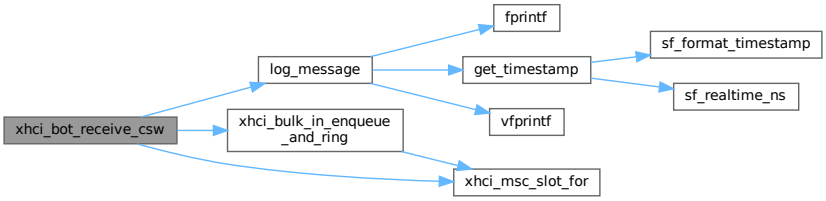
7.95.3.4 xhci_bot_receive_csw()

```
int xhci_bot_receive_csw (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

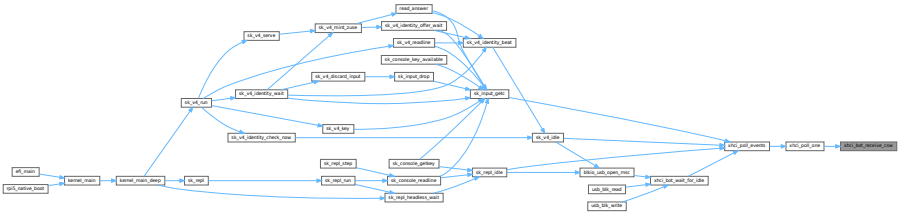
References xhci_dev_t::bot_csw, xhci_msc_slot_t::bulk_in_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_BOT_CSW_LENGTH, xhci_bulk_in_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CSW_RECEIVED.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



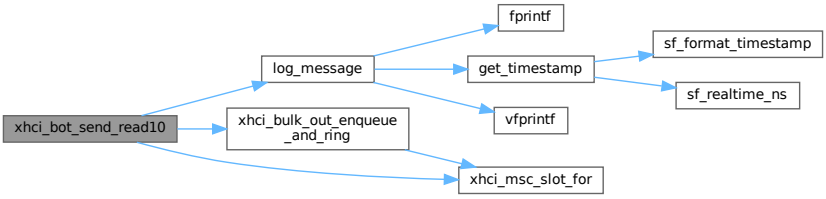
7.95.3.5 xhci_bot_send_read10()

```
int xhci_bot_send_read10 (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t lba,
            uint16_t num_blocks,
            uint32_t block_size )
```

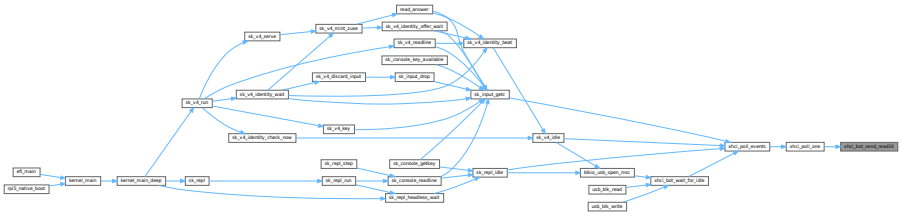
References usb_bot_cbw_t::bCBWCBLength, usb_bot_cbw_t::bCBWLUN, block_size, usb_bot_cbw_t::bmCBWFlags, xhci_dev_t::bot_cbw, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, usb_bot_cbw_t::CBWCB, usb_bot_cbw_t::dCBWDataTransferLe usb_bot_cbw_t::dCBWSignature, usb_bot_cbw_t::dCBWTag, LOG_DEBUG, log_message(), SCSI_CDB_LEN_READ10, SCSI_CMD_READ10, xhci_msc_slot_t::transfer_purpose, USB_BOT_CBW_FLAG_DATA_IN, USB_BOT_CBW_LENGTH, USB_BOT_CBW_LUN_DEFAULT, USB_BOT_CBW_SIGNATURE, xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CBW_SENT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



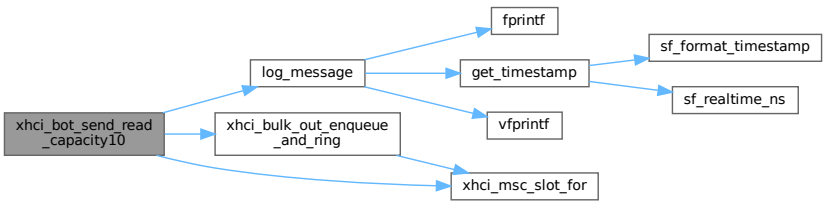
7.95.3.6 xhci_bot_send_read_capacity10()

```
int xhci_bot_send_read_capacity10 (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

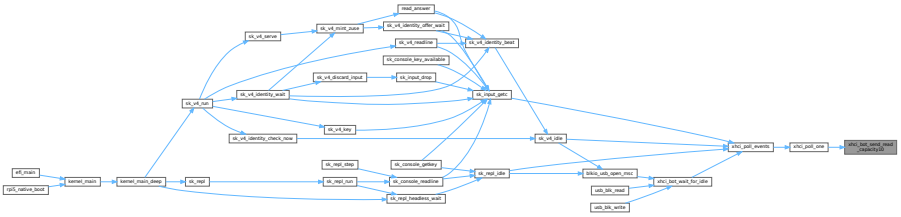
References usb_bot_cbw_t::bCBWCBLength, usb_bot_cbw_t::bCBWLUN, usb_bot_cbw_t::bmCBWFlags, xhci_dev_t::bot_cbw, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, usb_bot_cbw_t::CBWCB, usb_bot_cbw_t::dCBWDataTransferLength, usb_bot_cbw_t::dCBWSignatu usb_bot_cbw_t::dCBWTag, LOG_DEBUG, log_message(), SCSI_CDB_LEN_READ_CAPACITY10, SCSI_CMD_READ_CAPACITY1 SCSI_READ_CAPACITY10_DATA_LEN, xhci_msc_slot_t::transfer_purpose, USB_BOT_CBW_FLAG_DATA_IN, USB_BOT_CBW_LENGTH, USB_BOT_CBW_LUN_DEFAULT, USB_BOT_CBW_SIGNATURE, xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CBW_SENT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



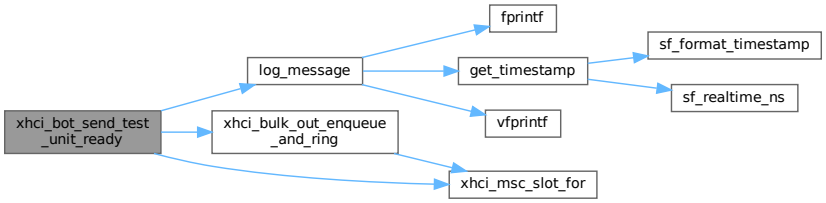
7.95.3.7 xhci_bot_send_test_unit_ready()

```
int xhci_bot_send_test_unit_ready (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

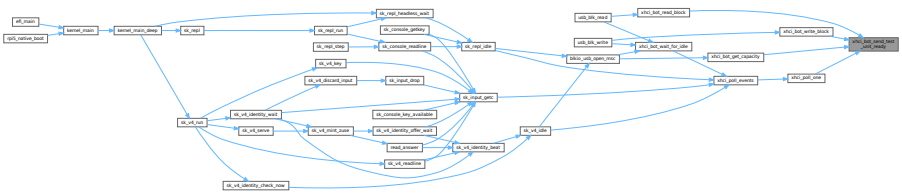
References usb_bot_cbw_t::bCBWCBLength, usb_bot_cbw_t::bCBWLUN, usb_bot_cbw_t::bmCBWFlags, xhci_dev_t::bot_cbw, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, usb_bot_cbw_t::CBWCB, usb_bot_cbw_t::dCBWDataTransferLength, usb_bot_cbw_t::dCBWSignatu usb_bot_cbw_t::dCBWTag, LOG_DEBUG, log_message(), SCSI_CDB_LEN_TEST_UNIT_READY, SCSI_CMD_TEST_UNIT_READ xhci_msc_slot_t::transfer_purpose, USB_BOT_CBW_LENGTH, USB_BOT_CBW_LUN_DEFAULT, USB_BOT_CBW_SIGNATURE, xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CBW_SENT.

Referenced by xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_write_block(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



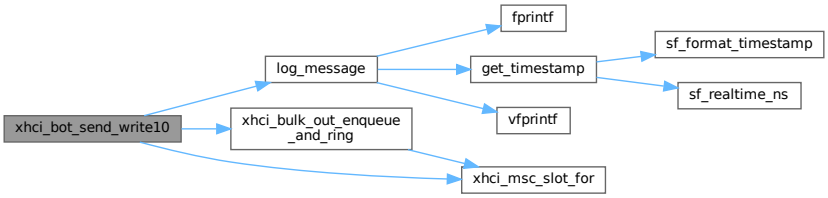
7.95.3.8 xhci_bot_send_write10()

```
int xhci_bot_send_write10 (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t lba,
            uint16_t num_blocks,
            uint32_t block_size )
```

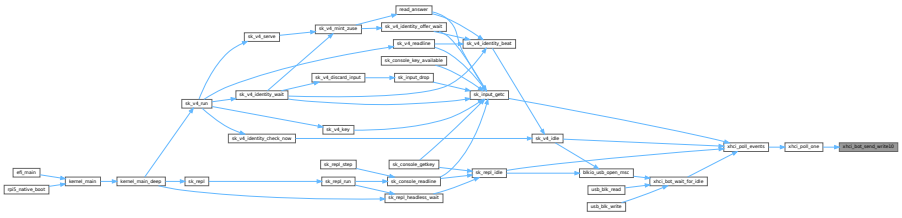
References usb_bot_cbw_t::bCBWCBLength, usb_bot_cbw_t::bCBWLUN, block_size, usb_bot_cbw_t::bmCBWFlags, xhci_dev_t::bot_cbw, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, usb_bot_cbw_t::CBWCB, usb_bot_cbw_t::dCBWDataTransferLe usb_bot_cbw_t::dCBWSignature, usb_bot_cbw_t::dCBWTag, LOG_DEBUG, log_message(), SCSI_CDB_LEN_WRITE10, SCSI_CMD_WRITE10, xhci_msc_slot_t::transfer_purpose, USB_BOT_CBW_LENGTH, USB_BOT_CBW_LUN_DEFAULT, USB_BOT_CBW_SIGNATURE, xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CBW_SENT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



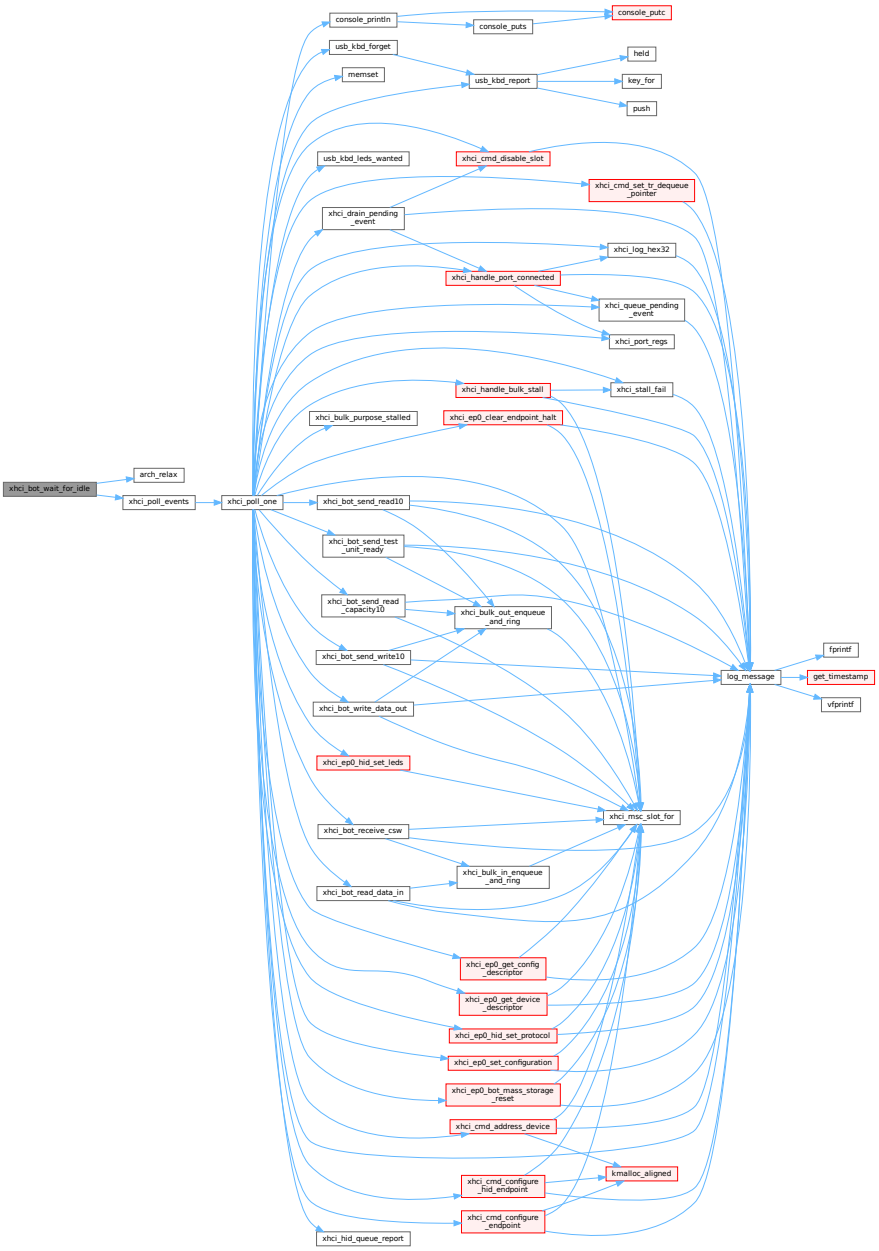
7.95.3.9 xhci_bot_wait_for_idle()

```
int xhci_bot_wait_for_idle (
            xhci_dev_t * dev,
            uint32_t max_iters )
```

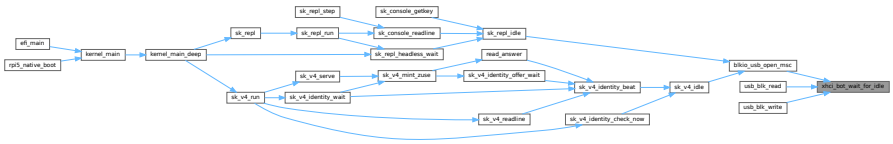
References arch_relax(), xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_last_status, and xhci_poll_events().

Referenced by blkio_usb_open_msc(), usb_blk_read(), and usb_blk_write().

Here is the call graph for this function:



Here is the caller graph for this function:



7.95.3.10 xhci_bot_write_block()

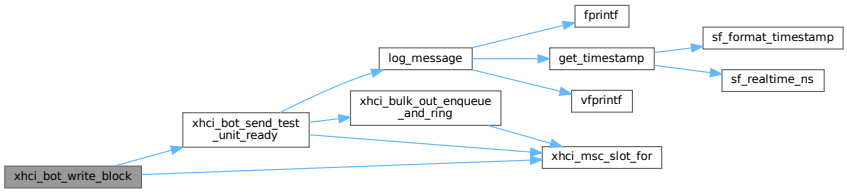
```
int xhci_bot_write_block (
```

```
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t lba,
            uint16_t num_blocks,
            uint32_t block_size )
```

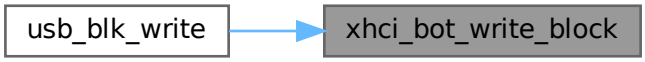
References block_size, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_dev_t::bot_write10_block_size, xhci_dev_t::bot_write10_lba, xhci_dev_t::bot_write10_num_blocks, xhci_msc_slot_t::bulk_in_ep, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, xhci_bot_send_test_unit_ready(), and xhci_msc_slot_for().

Referenced by usb_blk_write().

Here is the call graph for this function:



Here is the caller graph for this function:



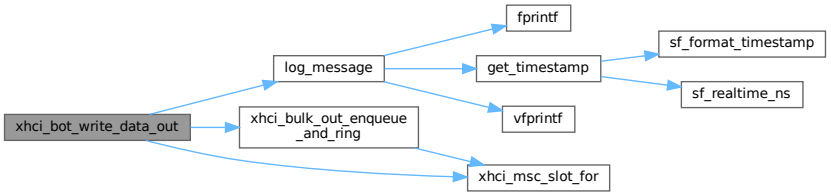
7.95.3.11 xhci_bot_write_data_out()

```
int xhci_bot_write_data_out (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

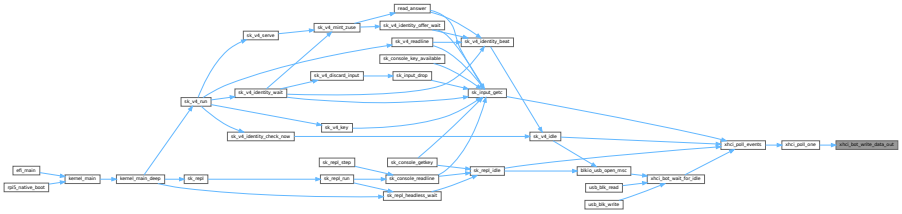
References xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_msc_slot_t::bulk_out_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_BOT_DATA_O

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



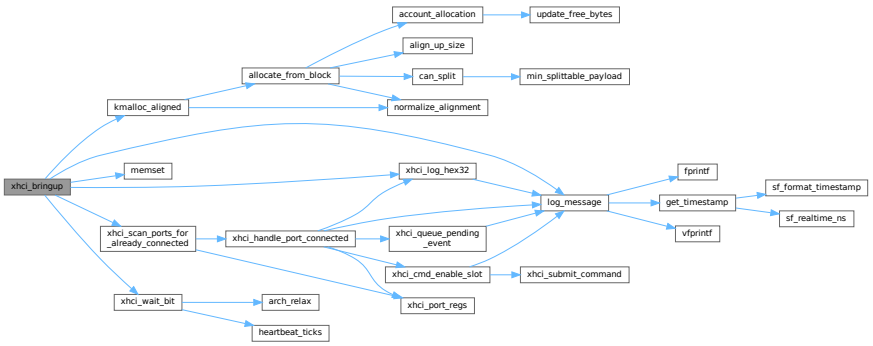
7.95.3.12 xhci_bringup()

```
int xhci_bringup (
            xhci_dev_t * dev )
```

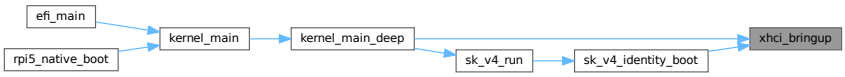
References xhci_dev_t::bot_cap_block_size, xhci_dev_t::bot_cap_last_lba, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_expected_dat xhci_dev_t::bot_last_status, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_dev_t::bot_read10_block_size, xhci_dev_t::bot_read10_lba, xhci_dev_t::bot_read10_num_blocks, xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_dev_t::cap, xhci_dev_t::cmd_ring, xhci_dev_t::cmd_ring_cycle, xhci_dev_t::cmd_ring_enq, xhci_op_regs_t::config, xhci_dev_t::connect_state, xhci_trb_t::control, xhci_op_regs_t::crcr, xhci_dev_t::dcbaa, xhci_op_regs_t::dcbaap, xhci_intr_regs_t::erdp, xhci_intr_regs_t::erstba, xhci_intr_regs_t::erstsz, xhci_dev_t::evt_ring, xhci_dev_t::evt_ring_cycle, xhci_dev_t::evt_ring_deq, xhci_dev_t::evt_ring_seg_table, g_xhci_dev_count, g_xhci_devs, xhci_cap_regs_t::hcc_params1, xhci_dev_t::intr0, kmalloc_aligned(), LOG_DEBUG, LOG_ERROR, log_message(), xhci_dev_t::max_scratchpad_bufs, xhci_dev_t::max_slots, memset(), xhci_dev_t::msc_slots, xhci_dev_t::op, xhci_op_regs_t::page_size, xhci_trb_t::parameter, xhci_dev_t::pending_connect_port_id, xhci_dev_t::pending_connect_slot_id, xhci_dev_t::pending_connect_speed, xhci_dev_t::pending_disable_slot_id, xhci_dev_t::pending_events, xhci_dev_t::port_slot_id, xhci_dev_t::runtime, xhci_dev_t::scratchpad_arr, xhci_trb_t::status, xhci_op_regs_t::usb_cmd, xhci_op_regs_t::usb_sts, xhci_dev_t::valid, XHCI_CONFIG_MAX_SLOTS_EN, XHCI_CRCR_PTR_MASK, XHCI_CRCR_RCS, XHCI_ERDP_PTR_MASK, XHCI_HCCPARAMS1_CSZ, xhci_log_hex32(), XHCI_MAX_CONTROLLERS, XHCI_MAX_TRACKED_PORTS, XHCI_RING_BYTES, XHCI_RING_TRB_COUNT, xhci_scan_ports_for_already_connected(), XHCI_TRB_CONTROL_CYCLE, XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_LINK, XHCI_USBCMD_HCRST, XHCI_USBCMD_RUN, XHCI_USBSTS_CNR, XHCI_USBSTS_HCH, and xhci_wait_bit().

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



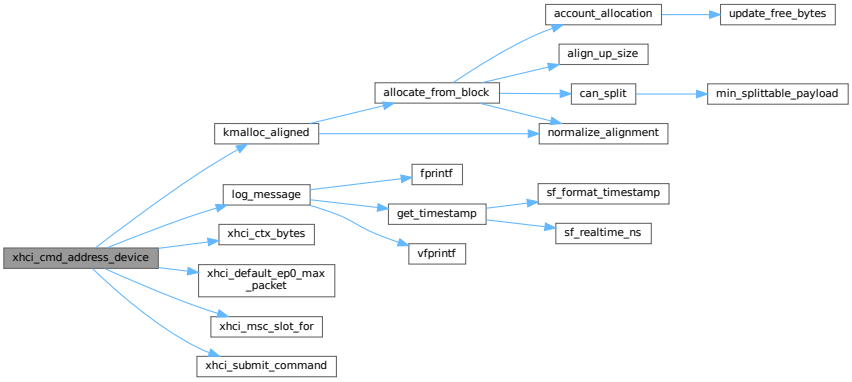
7.95.3.13 xhci_cmd_address_device()

```
int xhci_cmd_address_device (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t port_id,
            uint32_t speed )
```

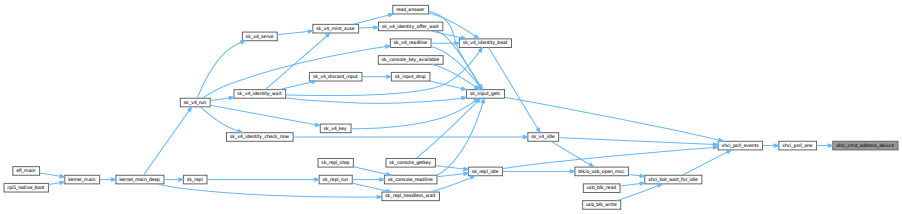
References xhci_input_ctrl_ctx32_t::add_flags, xhci_dev_t::cmd_ring, xhci_trb_t::control, xhci_dev_t::dcbaa, xhci_msc_slot_t::device_ctx, xhci_slot_ctx32_t::dword0, xhci_slot_ctx32_t::dword1, xhci_ep_ctx32_t::dword1, xhci_slot_ctx32_t::dword2, xhci_ep_ctx32_t::dword4, xhci_msc_slot_t::ep0_ring, xhci_msc_slot_t::ep0_ring_cycle, xhci_msc_slot_t::ep0_ring_enq, xhci_msc_slot_t::hid_ep_addr, xhci_msc_slot_t::hid_kbd, xhci_msc_slot_t::hid_running, xhci_msc_slot_t::in_use, xhci_msc_slot_t::input_ctx, kmalloc_aligned(), LOG_DEBUG, log_message(), xhci_trb_t::parameter, xhci_trb_t::status, xhci_ep_ctx32_t::tr_dequeue_ptr, xhci_ctx_bytes(), xhci_default_ep0_max_packet(), XHCI_EP_CTX_CERR_SHIF XHCI_EP_CTX_MAX_PACKET_SHIFT, XHCI_EP_CTX_TYPE_CONTROL_BIDI, XHCI_EP_CTX_TYPE_SHIFT, XHCI_INPUT_CTRL_ADD_EP0, XHCI_INPUT_CTRL_ADD_SLOT, xhci_msc_slot_for(), XHCI_RING_BYTES, XHCI_RING_TRB_COUNT, XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT, XHCI_SLOT_CTX_INTR_TARGET_SHIFT, XHCI_SLOT_CTX_ROOT_PORT_SHIFT, XHCI_SLOT_CTX_SPEED_SHIFT, xhci_submit_command(), XHCI_TRB_CONTROL_CY XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_ADDRESS_DEVICE_CMD, and XHCI_TRB_TYPE_LINK.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



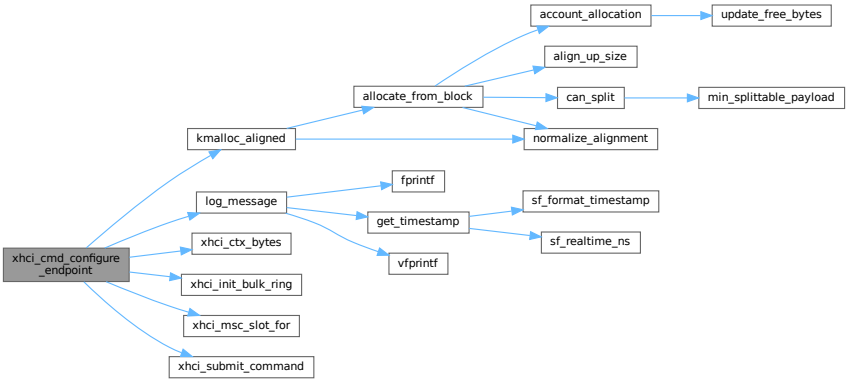
7.95.3.14 xhci_cmd_configure_endpoint()

```
int xhci_cmd_configure_endpoint (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

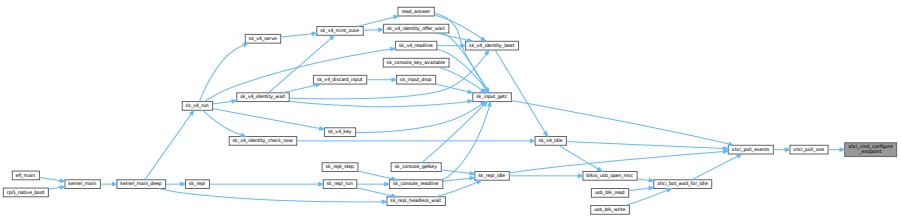
References xhci_input_ctrl_ctx32_t::add_flags, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_max_packet, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_in_ring_cycle, xhci_msc_slot_t::bulk_in_ring_enq, xhci_msc_slot_t::bulk_out_ep, xhci_msc_slot_t::bulk_out_max_packet, xhci_msc_slot_t::bulk_out_ring, xhci_msc_slot_t::bulk_out_ring_cycle, xhci_msc_slot_t::bulk_out_ring_enq, xhci_dev_t::cmd_ring, xhci_dev_t::dcbaa, xhci_msc_slot_t::device_ctx, xhci_slot_ctx32_t::dword0, xhci_slot_ctx32_t::dword1, xhci_ep_ctx32_t::dword1, xhci_slot_ctx32_t::dword2, xhci_ep_ctx32_t::dword4, xhci_msc_slot_t::input_ctx, kmalloc_aligned(), LOG_DEBUG, log_message(), xhci_ep_ctx32_t::tr_dequeue_ptr, xhci_ctx_bytes(), XHCI_EP_ADDR_TO_DCI, XHCI_EP_CTX_CERR_SHIFT, XHCI_EP_CTX_MAX_PACKET_SHIFT, XHCI_EP_CTX_TYPE_BULK_IN, XHCI_EP_CTX_TYPE_BULK_OUT, XHCI_EP_CTX_TYPE_SHIFT, xhci_init_bulk_ring(), XHCI_INPUT_CTRL_ADD_SLOT, xhci_msc_slot_for(), XHCI_RING_BYTES, XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT, xhci_submit_command(), and XHCI_TRB_TYPE_CONFIGU

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



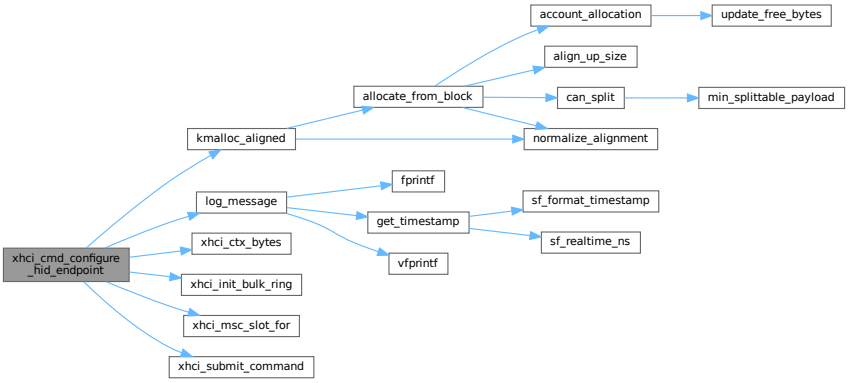
7.95.3.15 xhci_cmd_configure_hid_endpoint()

```
int xhci_cmd_configure_hid_endpoint (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

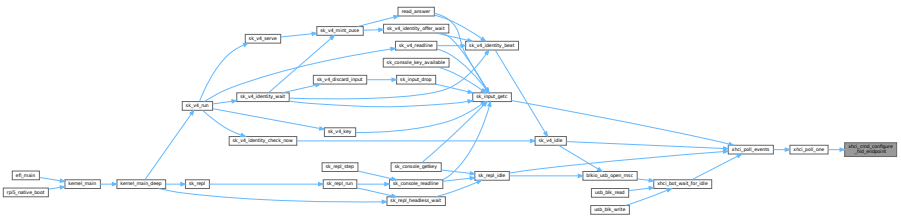
References xhci_input_ctrl_ctx32_t::add_flags, xhci_dev_t::cmd_ring, xhci_dev_t::dcbaa, xhci_msc_slot_t::device_ctx, xhci_slot_ctx32_t::dword0, xhci_ep_ctx32_t::dword0, xhci_slot_ctx32_t::dword1, xhci_ep_ctx32_t::dword1, xhci_slot_ctx32_t::dword2, xhci_ep_ctx32_t::dword4, xhci_msc_slot_t::hid_buf, xhci_msc_slot_t::hid_ep_addr, xhci_msc_slot_t::hid_interval, xhci_msc_slot_t::hid_max_packet, xhci_msc_slot_t::hid_ring, xhci_msc_slot_t::hid_ring_cycle, xhci_msc_slot_t::hid_ring_enq, xhci_msc_slot_t::input_ctx, kmalloc_aligned(), LOG_DEBUG, log_message(), xhci_ep_ctx32_t::tr_dequeue_ptr, xhci_ctx_bytes(), XHCI_EP_ADDR_TO_DCI, XHCI_EP_CTX_CERR_SHIFT, XHCI_EP_CTX_INTERVAL_SHIFT, XHCI_EP_CTX_MAX_PACKET_SHIFT, XHCI_EP_CTX_TYPE_INTERRUPT_IN, XHCI_EP_CTX_TYPE_SHIFT, xhci_init_bulk_ring(), XHCI_INPUT_CTRL_ADD_SLOT, xhci_msc_slot_for(), XHCI_RING_BYTES, XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT, XHCI_SLOT_CTX_SPEED_SHIFT, xhci_submit_command(), and XHCI_TRB_TYPE_CONFIGURE_ENDPOINT_CMD.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



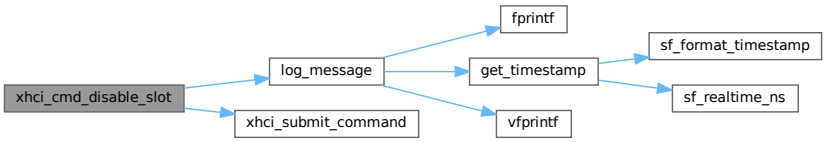
7.95.3.16 xhci_cmd_disable_slot()

```
int xhci_cmd_disable_slot (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

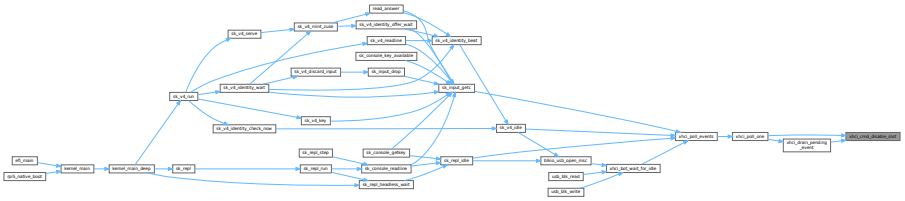
References xhci_dev_t::cmd_ring, LOG_DEBUG, log_message(), xhci_submit_command(), and XHCI_TRB_TYPE_DISABLE_SLOT

Referenced by xhci_drain_pending_event(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



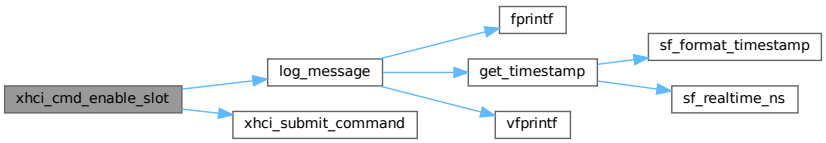
7.95.3.17 xhci_cmd_enable_slot()

```
int xhci_cmd_enable_slot (
            xhci_dev_t * dev )
```

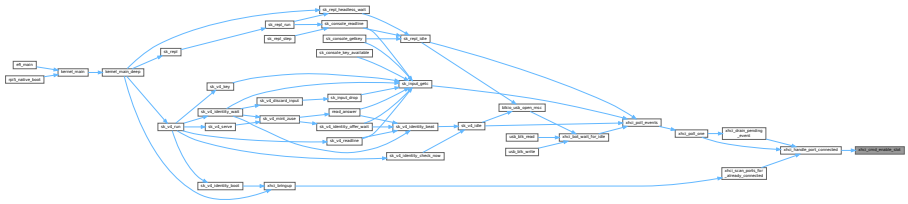
References xhci_dev_t::cmd_ring, LOG_DEBUG, log_message(), xhci_submit_command(), and XHCI_TRB_TYPE_ENABLE_SLOT_

Referenced by xhci_handle_port_connected().

Here is the call graph for this function:



Here is the caller graph for this function:



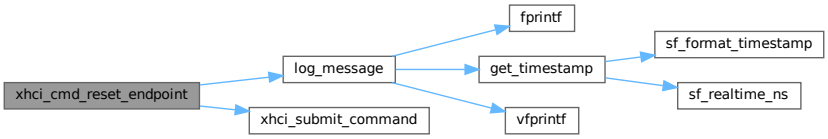
7.95.3.18 xhci_cmd_reset_endpoint()

```
int xhci_cmd_reset_endpoint (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t ep_id )
```

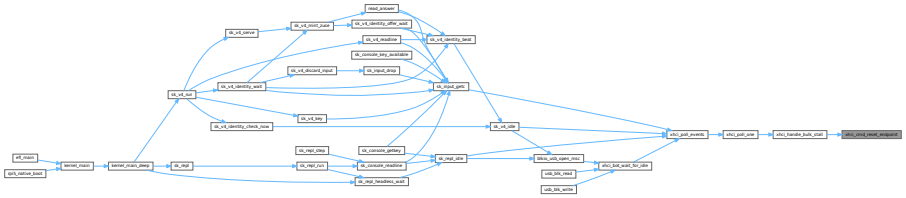
References xhci_dev_t::cmd_ring, LOG_DEBUG, log_message(), XHCI_EP_ADDR_TO_DCI, xhci_submit_command(), and XHCI_TRB_TYPE_RESET_ENDPOINT_CMD.

Referenced by xhci_handle_bulk_stall().

Here is the call graph for this function:



Here is the caller graph for this function:



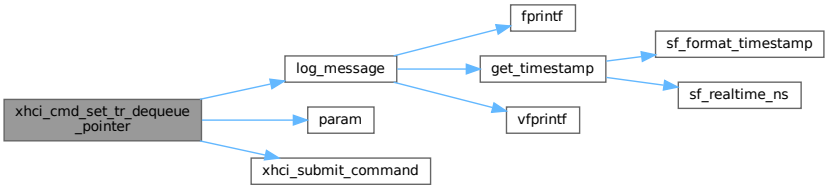
7.95.3.19 xhci_cmd_set_tr_dequeue_pointer()

```
int xhci_cmd_set_tr_dequeue_pointer (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t ep_id,
            uint64_t new_dequeue,
            uint32_t dcs )
```

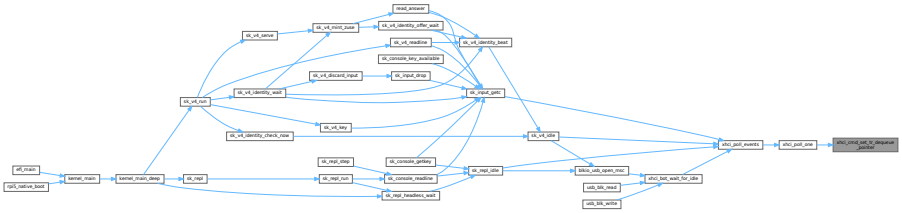
References xhci_dev_t::cmd_ring, LOG_DEBUG, log_message(), param(), xhci_submit_command(), and XHCI_TRB_TYPE_SET_TR_DEQUEUE_POINTER_CMD.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



7.95.3.20 xhci_dev_at()

```
xhci_dev_t * xhci_dev_at (
            uint32_t i )
```

References g_xhci_dev_count, and g_xhci_devs.

Referenced by sk_repl_idle(), sk_v4_idle(), and sk_word_blk_attach_ack().

Here is the caller graph for this function:

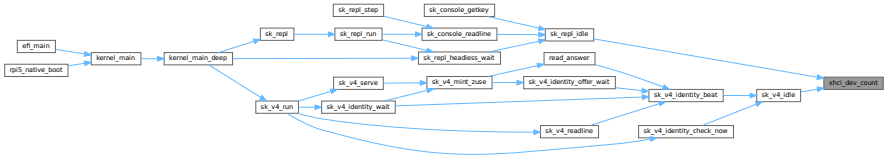
7.95.3.21 xhci_dev_count()

```
uint32_t xhci_dev_count (
            void  )
```

References g_xhci_dev_count.

Referenced by sk_repl_idle(), and sk_v4_idle().

Here is the caller graph for this function:



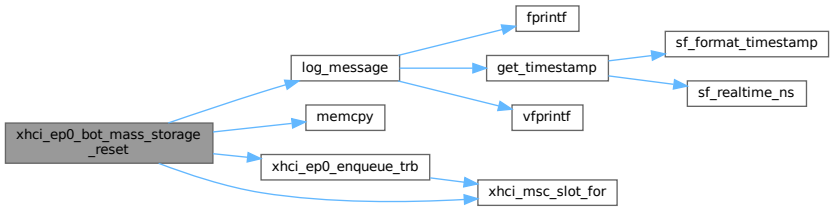
7.95.3.22 xhci_ep0_bot_mass_storage_reset()

```
int xhci_ep0_bot_mass_storage_reset (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

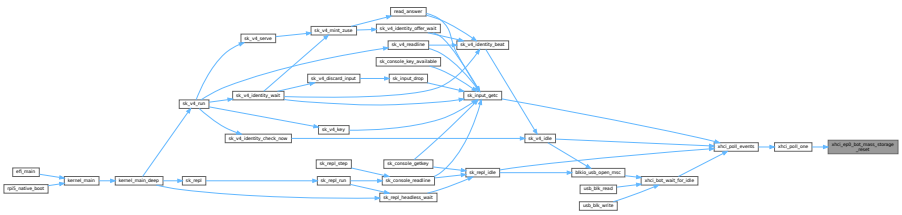
References usb_setup_packet_t::bmRequestType, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), memcpy(), xhci_msc_slot_t::transfer_purpose, USB_BOT_MASS_STORAGE_RESET, USB_RECIP_INTERFACE, USB_REQ_TYPE_CLASS, XHCI_DB_TARGET, xhci_ep0_enqueue_trb(), xhci_msc_slot_for(), XHCI_SETUP_TRT_NO_DATA, XHCI_TRB_CONTROL_DIR_IN, XHCI_TRB_CONTROL_IDT, XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TRT_SHIFT, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_SETUP_STAGE, XHCI_TRB_TYPE_STATUS_STAGE, and XHCI_XFER_BOT_RESET.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



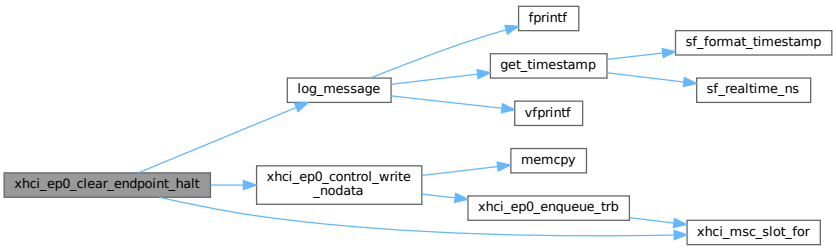
7.95.3.23 xhci_ep0_clear_endpoint_halt()

```
int xhci_ep0_clear_endpoint_halt (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint8_t ep_addr )
```

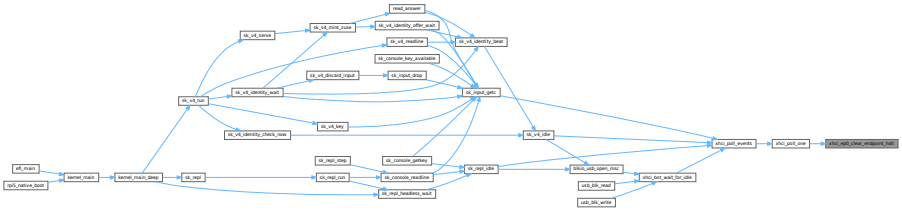
References xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_FEATURE_ENDPOINT_HALT, USB_REQ_CLEAR_FEATURE, XHCI_DB_TARGET, xhci_ep0_control_write_nodata(), xhci_msc_slot_for(), and XHCI_XFER_CLEAR_HALT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



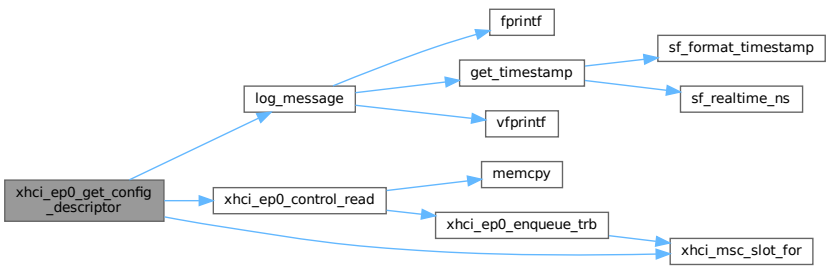
7.95.3.24 xhci_ep0_get_config_descriptor()

```
int xhci_ep0_get_config_descriptor (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint16_t length )
```

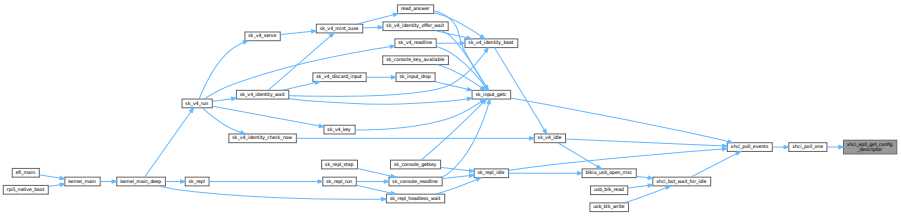
References xhci_msc_slot_t::config_descriptor, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_DESC_TYPE_CONFIG, USB_REQ_GET_DESCRIPTOR, XHCI_DB_TARGET, xhci_ep0_control_read(), xhci_msc_slot_for(), XHCI_XFER_CONFIG_DESC_FULL, and XHCI_XFER_CONFIG_DESC_SHORT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



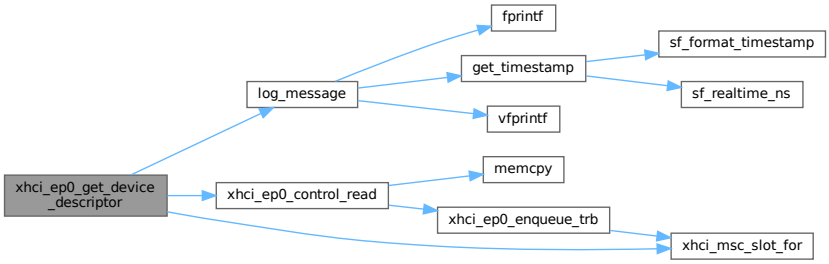
7.95.3.25 xhci_ep0_get_device_descriptor()

```
int xhci_ep0_get_device_descriptor (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

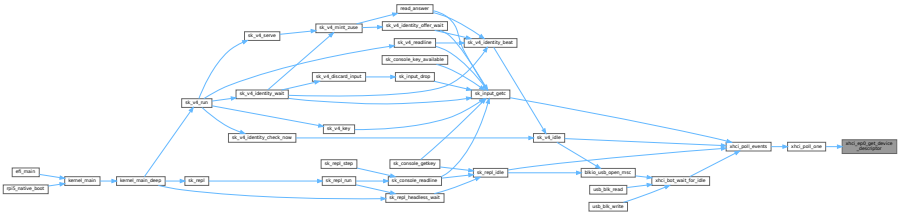
References xhci_msc_slot_t::device_descriptor, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_DESC_TYPE_DEVICE, USB_REQ_GET_DESCRIPTOR, XHCI_DB_TARGET, xhci_ep0_control_read(), xhci_msc_slot_for(), and XHCI_XFER_DEVICE_DESC.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



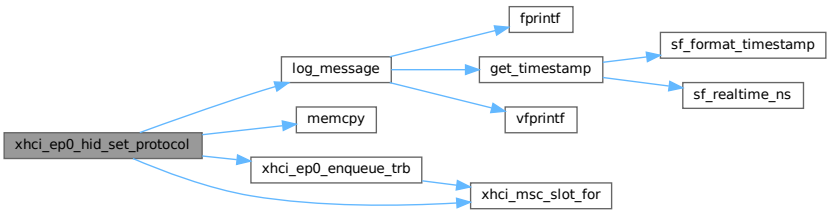
7.95.3.26 xhci_ep0_hid_set_protocol()

```
int xhci_ep0_hid_set_protocol (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

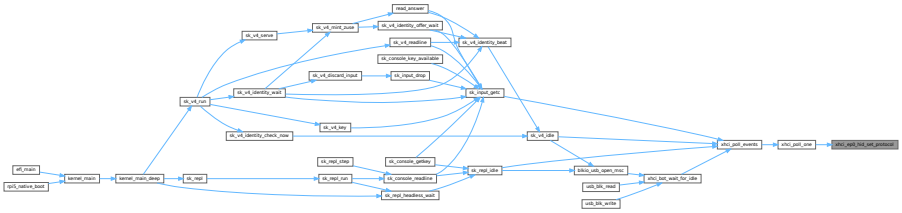
References usb_setup_packet_t::bmRequestType, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, xhci_msc_slot_t::hid_iface, LOG_DEBUG, log_message(), memcpy(), xhci_msc_slot_t::transfer_purpose, USB_HID_PROTOCOL_BOOT, USB_HID_REQ_SET_PROTOCOL, USB_RECIP_INTERFACE, USB_REQ_TYPE_CLASS, XHCI_DB_TARGET, xhci_ep0_enqueue_trb(), xhci_msc_slot_for(), XHCI_SETUP_TRT_NO_DATA, XHCI_TRB_CONTROL_DIR_IN, XHCI_TRB_CONTROL_IDT, XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TRT_SHIFT, XHCI_TRB_CONTROL_TYPE_SH XHCI_TRB_TYPE_SETUP_STAGE, XHCI_TRB_TYPE_STATUS_STAGE, and XHCI_XFER_HID_SET_PROTOCOL.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



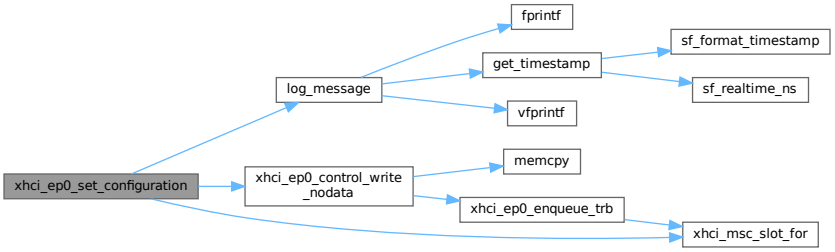
7.95.3.27 xhci_ep0_set_configuration()

```
int xhci_ep0_set_configuration (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint8_t config_value )
```

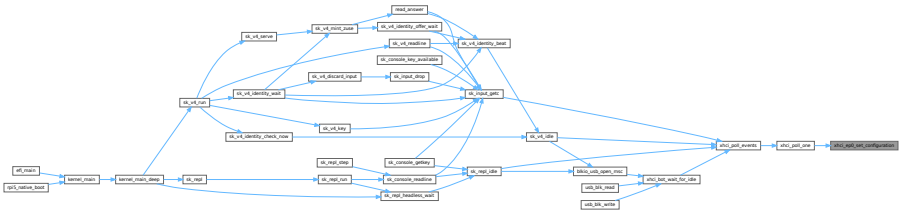
References xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_REQ_SET_CONFIGURATION, XHCI_DB_TARGET, xhci_ep0_control_write_nodata(), xhci_msc_slot_for(), and XHCI_XFER_SET_CONFIG.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



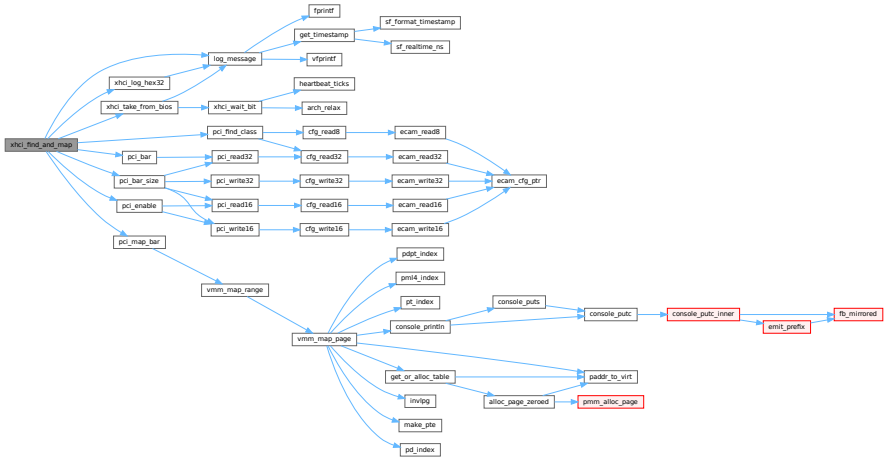
7.95.3.28 xhci_find_and_map()

```
int xhci_find_and_map (
            xhci_dev_t * dev,
            unsigned index )
```

References xhci_dev_t::bar0_phys, xhci_dev_t::cap, xhci_cap_regs_t::cap_length, xhci_cap_regs_t::db_off, PciDevice::device_id, xhci_dev_t::doorbell, xhci_cap_regs_t::hcs_params1, xhci_cap_regs_t::hcs_params2, LOG_DEBUG, LOG_ERROR, log_message(), xhci_dev_t::max_intrs, xhci_dev_t::max_ports, xhci_dev_t::max_scratchpad_bufs, xhci_dev_t::max_slots, xhci_dev_t::op, xhci_dev_t::pci, pci_bar(), pci_bar_size(), pci_enable(), pci_find_class(), pci_map_bar(), xhci_cap_regs_t::rts_off, xhci_dev_t::runtime, PciDevice::vendor_id, XHCI_BAR0_MIN_MAP_SIZE, XHCI_HCSPARAMS1_MAX_INTRS, XHCI_HCSPARAMS1_MAX_PORTS, XHCI_HCSPARAMS1_MAX_SLOTS, XHCI_HCSPARAMS2_MAX_SCRATCHPAD_BUFS, xhci_log_hex32(), XHCI_PCI_CLASS, XHCI_PCI_PROG_IF, XHCI_PCI_SUBCLASS, and xhci_take_from_bios().

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:

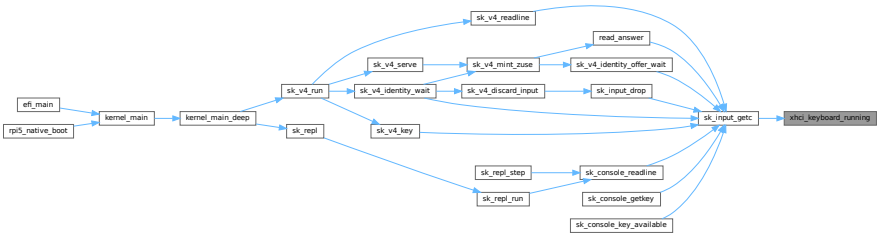
7.95.3.29 xhci_keyboard_running()

```
int xhci_keyboard_running (
            void  )
```

References g_xhci_keyboards.

Referenced by sk_input_getc().

Here is the caller graph for this function:



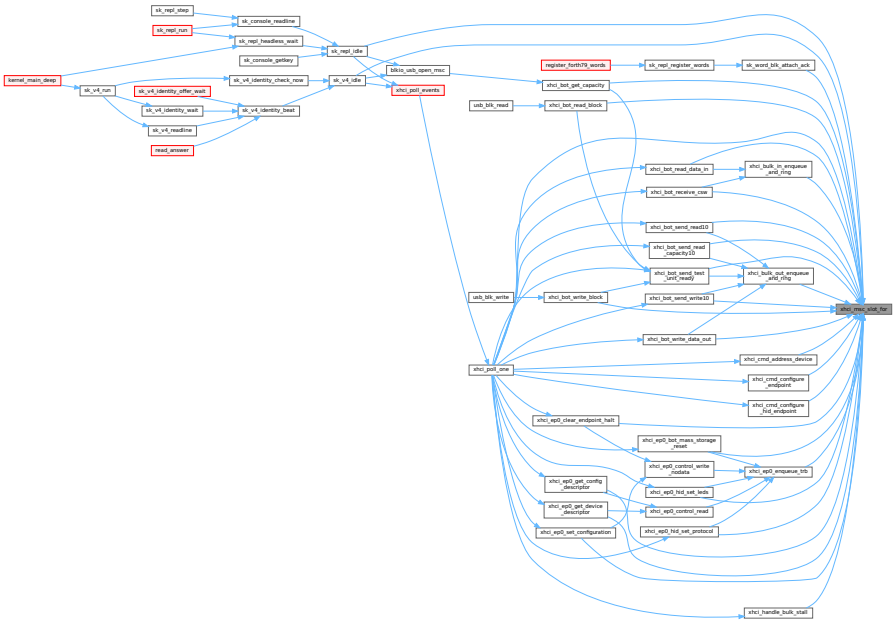
7.95.3.30 xhci_msc_slot_for()

```
xhci_msc_slot_t * xhci_msc_slot_for (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

References xhci_dev_t::max_slots, and xhci_dev_t::msc_slots.

Referenced by sk_repl_idle(), sk_v4_idle(), sk_word_blk_attach_ack(), xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_read_data_in(), xhci_bot_receive_csw(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_block(), xhci_bot_write_data_out(), xhci_bulk_in_enqueue_and_ring(), xhci_bulk_out_enqueue_and_ring(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), xhci_cmd_configure_hid_endpoint(), xhci_ep0_bot_mass_storage_reset(), xhci_ep0_clear_endpoint_halt(), xhci_ep0_enqueue_trb(), xhci_ep0_get_config_descriptor(), xhci_ep0_get_device_descriptor(), xhci_ep0_hid_set_leds(), xhci_ep0_hid_set_protocol(), xhci_ep0_set_configuration(), xhci_handle_bulk_stall(), and xhci_poll_one().

Here is the caller graph for this function:



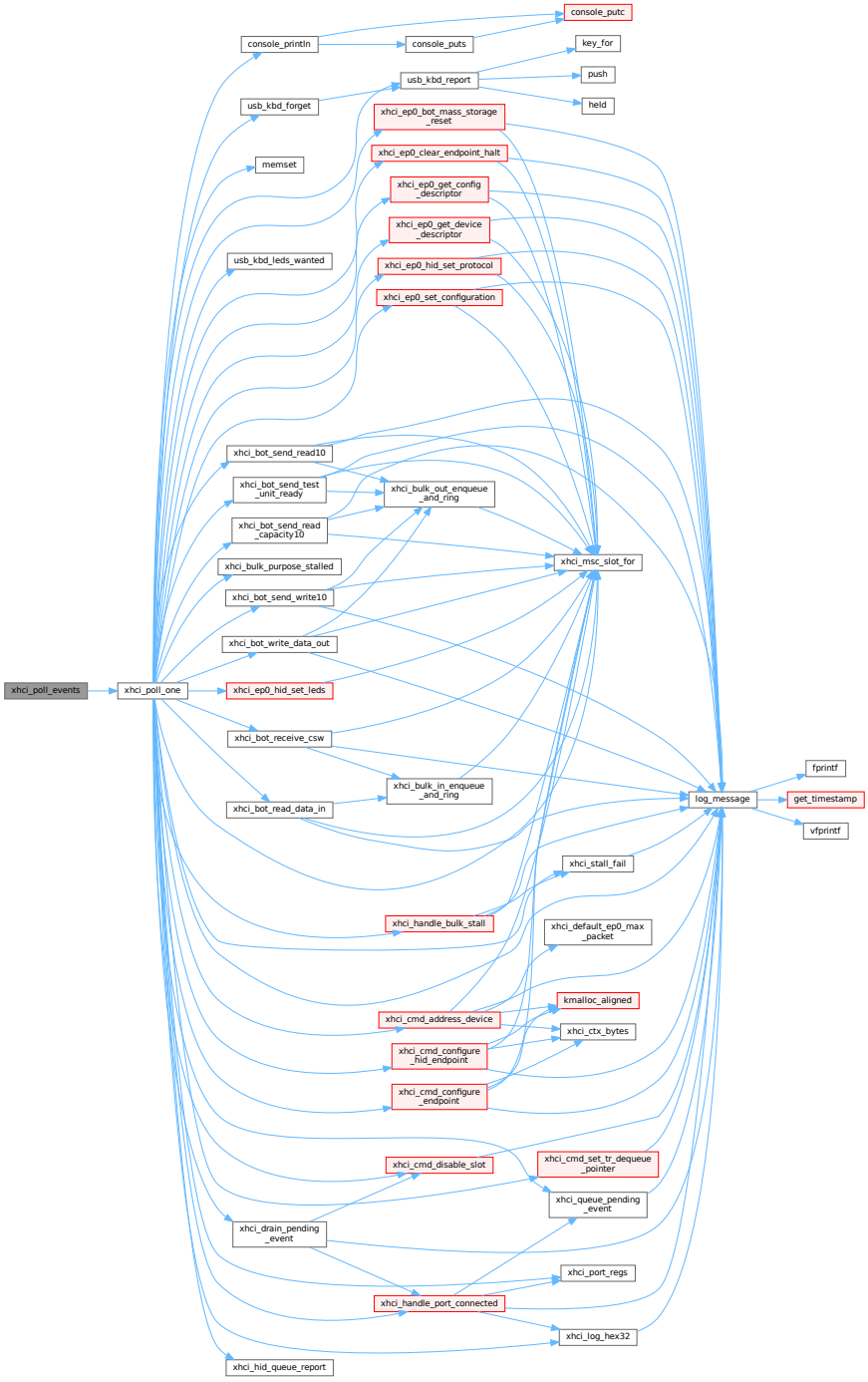
7.95.3.31 xhci_poll_events()

```
void xhci_poll_events (
            void  )
```

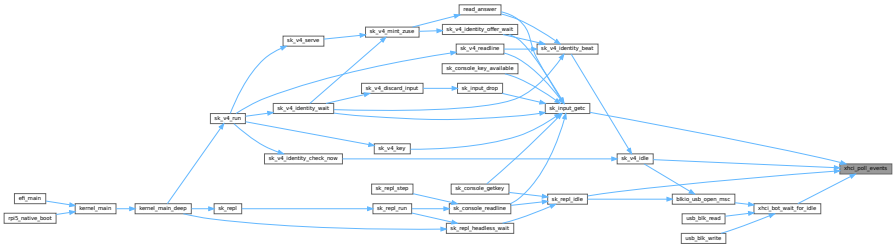
References g_xhci_dev_count, g_xhci_devs, and xhci_poll_one().

Referenced by sk_input_getc(), sk_repl_idle(), sk_v4_idle(), and xhci_bot_wait_for_idle().

Here is the call graph for this function:



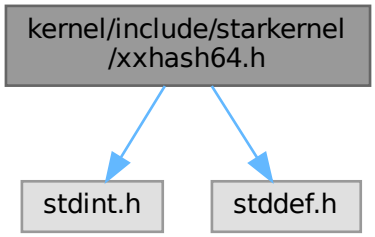
Here is the caller graph for this function:



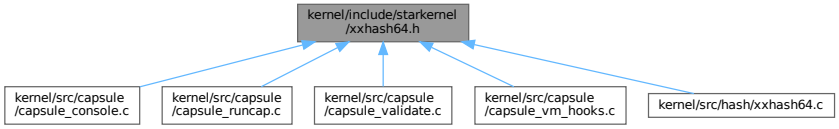
7.96 kernel/include/starkernel/xxhash64.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for xxhash64.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct XXHash64State

  Streaming state structure.

Macros

- #define XXHASH64_CAPSULE_SEED 0ULL

  xxhash64.h - xxHash64 Implementation (Freestanding)

Functions

- uint64_t xxhash64 (const void *data, size_t len, uint64_t seed)

  xxhash64 - Compute xxHash64 of a buffer
- static uint64_t xxhash64_capsule (const void *data, size_t len)

  xxhash64_capsule - Hash capsule payload with standard seed
- void xxhash64_reset (XXHash64State *state, uint64_t seed)

  xxhash64_reset - Initialize streaming state
- void xxhash64_update (XXHash64State *state, const void *data, size_t len)

  xxhash64_update - Feed data into streaming hash
- uint64_t xxhash64_digest (const XXHash64State *state)

  xxhash64_digest - Finalize and get hash value

7.96.1 Macro Definition Documentation

7.96.1.1 XXHASH64_CAPSULE_SEED

```
#define XXHASH64_CAPSULE_SEED 0ULL
```

xxhash64.h - xxHash64 Implementation (Freestanding)

Fast, deterministic 64-bit hash function for capsule content addressing. No libc dependency - works in kernel context.

Based on xxHash by Yann Collet (BSD-2-Clause license). https://github.com/Cyan4973/xxHash
Default seed for capsule hashing (deterministic)

7.96.2 Function Documentation

7.96.2.1 xxhash64()

```
uint64_t xxhash64 (
            const void * data,
            size_t len,
            uint64_t seed )
```

xxhash64 - Compute xxHash64 of a buffer

Parameters

data	Input data
len	Length in bytes
seed	Hash seed (use XXHASH64_CAPSULE_SEED for capsules)

Returns

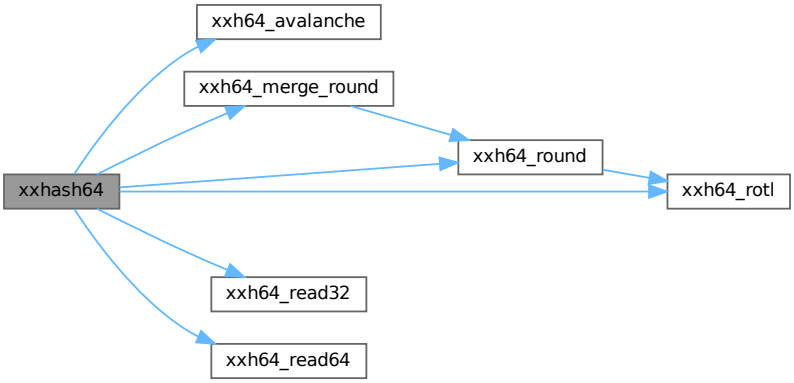
64-bit hash value

References limit, v1, v2, xxh64_avalanche(), xxh64_merge_round(), xxh64_read32(), xxh64_read64(), xxh64_rotl(),

xxh64_round(), XXHASH64_PRIME1, XXHASH64_PRIME2, XXHASH64_PRIME3, XXHASH64_PRIME4, and XXHASH64_PRIME5.

Referenced by xxhash64_capsule().

Here is the call graph for this function:



Here is the caller graph for this function:

7.96.2.2 xxhash64_capsule()

```
static uint64_t xxhash64_capsule (
            const void * data,
            size_t len )  [inline], [static]
```

xxhash64_capsule - Hash capsule payload with standard seed

Convenience wrapper using XXHASH64_CAPSULE_SEED.

Parameters

data	Capsule payload bytes
len	Payload length

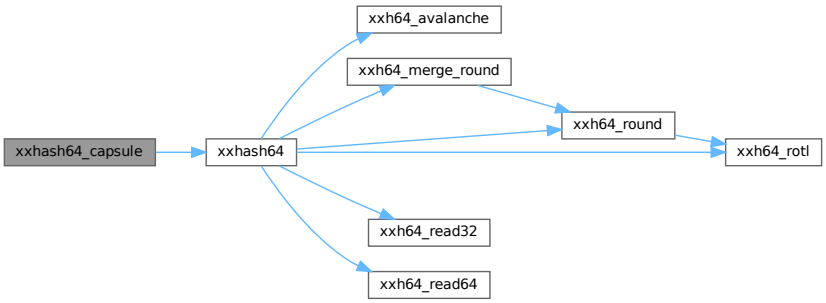
Returns

Content hash (capsule_id)

References xxhash64(), and XXHASH64_CAPSULE_SEED.

Referenced by capsule_console_birth(), capsule_runcap_birth(), and capsule_validate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.96.2.3 xxhash64_digest()

```
uint64_t xxhash64_digest (
            const XXHash64State * state )
```

xxhash64_digest - Finalize and get hash value

Parameters

state	Streaming state

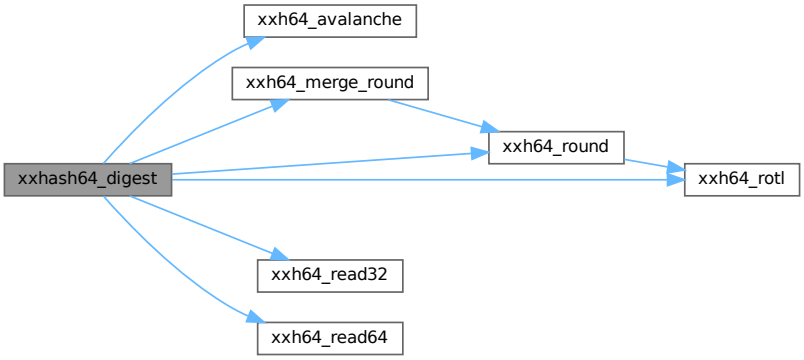
Returns

64-bit hash value

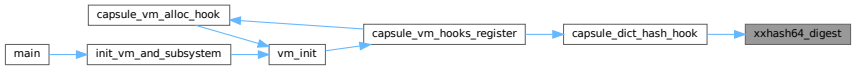
References XXHash64State::buffer, XXHash64State::buffer_size, XXHash64State::seed, XXHash64State::total_len, XXHash64State::v1, XXHash64State::v2, XXHash64State::v3, XXHash64State::v4, xxh64_avalanche(), xxh64_merge_round(), xxh64_read32(), xxh64_read64(), xxh64_rotl(), xxh64_round(), XXHASH64_PRIME1, XXHASH64_PRIME2, XXHASH64_PRIME3, XXHASH64_PRIME4, and XXHASH64_PRIME5.

Referenced by capsule_dict_hash_hook().

Here is the call graph for this function:



Here is the caller graph for this function:



7.96.2.4 xxhash64_reset()

```
void xxhash64_reset (
            XXHash64State * state,
            uint64_t seed )
```

xxhash64_reset - Initialize streaming state

Parameters

state	State to initialize
seed	Hash seed

References XXHash64State::buffer_size, XXHash64State::seed, XXHash64State::total_len, XXHash64State::v1, XXHash64State::v2, XXHash64State::v3, XXHash64State::v4, XXHASH64_PRIME1, and XXHASH64_PRIME2.

Referenced by capsule_dict_hash_hook().

Here is the caller graph for this function:

7.96.2.5 xxhash64_update()

```
void xxhash64_update (
            XXHash64State * state,
            const void * data,
            size_t len )
```

xxhash64_update - Feed data into streaming hash

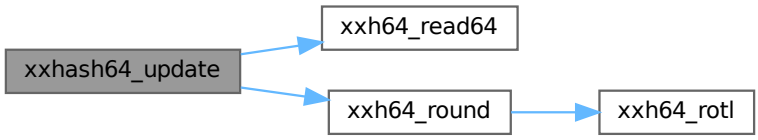
Parameters

state	Streaming state
data	Input data
len	Length in bytes

References XXHash64State::buffer, XXHash64State::buffer_size, limit, XXHash64State::total_len, XXHash64State::v1, XXHash64State::v2, XXHash64State::v3, XXHash64State::v4, xxh64_read64(), and xxh64_round().

Referenced by capsule_dict_hash_hook().

Here is the call graph for this function:

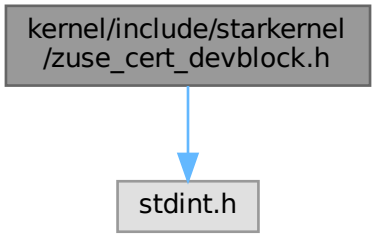


Here is the caller graph for this function:

7.97 kernel/include/starkernel/zuse_cert_devblock.h File Reference

```
#include <stdint.h>
```

Include dependency graph for zuse_cert_devblock.h:



Data Structures

- struct zuse_cert_devblock_t

Macros

- #define ZUSE_CERT_DEVBLOCK_MAGIC ((uint32_t)'Z' | ((uint32_t)'U' << 8) | ((uint32_t)'S' << 16) | ((uint32_t)'E' << 24))
- #define ZUSE_CERT_DEVBLOCK_VERSION 1u

7.97.1 Macro Definition Documentation

7.97.1.1 ZUSE_CERT_DEVBLOCK_MAGIC

```
#define ZUSE_CERT_DEVBLOCK_MAGIC  ((uint32_t)'Z' | ((uint32_t)'U' << 8) | ((uint32_t)'S' << 16) | ((uint32_t)'E' << 24))
```

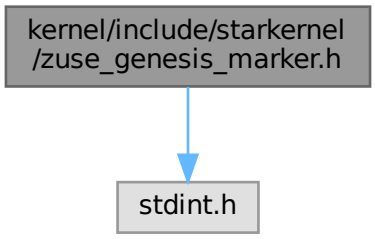
7.97.1.2 ZUSE_CERT_DEVBLOCK_VERSION

```
#define ZUSE_CERT_DEVBLOCK_VERSION 1u
```

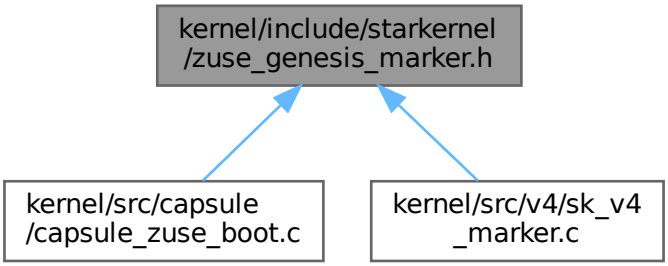
7.98 kernel/include/starkernel/zuse_genesis_marker.h File Reference

```
#include <stdint.h>
```

Include dependency graph for zuse_genesis_marker.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct zuse_genesis_marker_t
- struct zuse_genesis_marker_v2_t

Macros

- #define ZUSE_GENESIS_MARKER_MAGIC ((uint32_t)'Z' | ((uint32_t)'G' << 8) | ((uint32_t)'E' << 16) | ((uint32_t)'N' << 24))
- #define ZUSE_GENESIS_MARKER_VERSION 1u
- #define ZUSE_GENESIS_MARKER_VERSION_2 2u

7.98.1 Macro Definition Documentation

7.98.1.1 ZUSE_GENESIS_MARKER_MAGIC

```
#define ZUSE_GENESIS_MARKER_MAGIC  ((uint32_t)'Z' | ((uint32_t)'G' << 8) | ((uint32_t)'E' <<
16) | ((uint32_t)'N' << 24))
```

7.98.1.2 ZUSE_GENESIS_MARKER_VERSION

```
#define ZUSE_GENESIS_MARKER_VERSION 1u
```

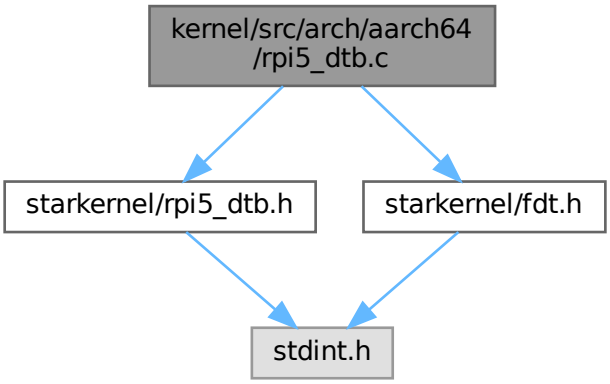
7.98.1.3 ZUSE_GENESIS_MARKER_VERSION_2

```
#define ZUSE_GENESIS_MARKER_VERSION_2 2u
```

7.99 kernel/src/arch/aarch64/rpi5_dtb.c File Reference

```
#include "starkernel/rpi5_dtb.h"
#include "starkernel/fdt.h"
```

Include dependency graph for rpi5_dtb.c:



Macros

- #define BCM2712_SOC_RANGES_OFFSET 0x1000000000ULL

  rpi5_dtb.c - Raspberry Pi 5 (BCM2712) devicetree-based peripheral discovery (FABRIC-3.md ?IV.3, 2026-09-04).

Functions

- static uint32_t reg_first_cell_be32 (const unsigned char *b)

  Read a devicetree `reg` property's first cell as big-endian.
- static uint64_t rpi5_peripheral_base (const void *dtb, const char *compatible)

  Find `compatible's` node, read its `reg` base address, and apply the one fixed BCM2712 `soc`-node translation offset.
- uint64_t rpi5_uart_base (const void *dtb)

  rpi5_dtb.h - Raspberry Pi 5 (BCM2712) devicetree-based peripheral discovery, for the native (non-UEFI) boot path (FABRIC-3.md ?IV.3).
- uint64_t rpi5_mailbox_base (const void *dtb)

  Find the VideoCore mailbox property interface's CPU-physical base address from the DTB.

7.99.1 Macro Definition Documentation

7.99.1.1 BCM2712_SOC_RANGES_OFFSET

```
#define BCM2712_SOC_RANGES_OFFSET 0x1000000000ULL
```

rpi5_dtb.c - Raspberry Pi 5 (BCM2712) devicetree-based peripheral discovery (FABRIC-3.md ?IV.3, 2026-09-04).

Confirmed directly against `bcm2712.dtsi` (raspberrypi/linux, rpi-6.12.y) before writing this, not assumed:

soc: soc@107c000000 { compatible = "simple-bus"; ranges = <0x0 0x10 0x0 0x80000000>; #address-cells = <1>; #size-cells = <1>; ... uart10: serial@7d001000 { compatible = "arm,pl011", "arm,primecell"; reg = <0x7d001000 0x200>; }; mailbox: mailbox@7c013880 { compatible = "brcm,bcm2835-mbox"; reg = <0x7c013880 0x40>; }; };

Every peripheral this file cares about lives under this one "soc" node, which applies exactly one translation to every child `reg` value: child address 0 maps to parent (CPU-physical) address 0x10_0000_0000 (`ranges`'s own `<0x0 0x10 0x0 ...>` — child cell 0, parent cells `0x10 0x0`, i.e. `0x10 << 32`). The child side's own `#address-cells = <1>` confirms each `reg` value's first cell is the whole child address (32-bit, no cell-splitting needed) before adding the offset. `fdt.c`'s reader deliberately does not parse `ranges` generally (it is "not a general devicetree library," per its own header comment) — this one, fixed, SoC-wide offset is applied here by name instead, since it is a single known hardware fact, not a general mechanism this codebase needs elsewhere yet.

7.99.2 Function Documentation

7.99.2.1 reg_first_cell_be32()

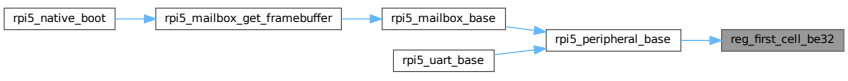
```
static uint32_t reg_first_cell_be32 (
            const unsigned char * b )  [static]
```

Read a devicetree `reg` property's first cell as big-endian.

`fdt.c` keeps its own `be32()` helper file-local (freestanding, no shared byte-swap utility to reuse) – duplicated here rather than exposing it, same "a few lines is simpler than a new shared dependency" precedent `tools/pkcs8_ed25519.c` already set in this codebase.

Referenced by rpi5_peripheral_base().

Here is the caller graph for this function:



7.99.2.2 rpi5_mailbox_base()

```
uint64_t rpi5_mailbox_base (
            const void * dtb )
```

Find the VideoCore mailbox property interface's CPU-physical base address from the DTB.

Parameters

dtb	Devicetree blob; NULL is safe.

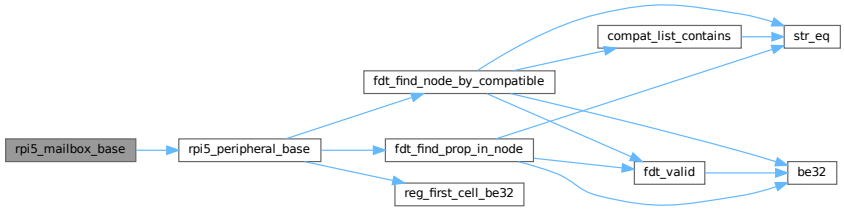
Returns

Final CPU-physical MMIO base address, or 0 if the node is absent, malformed, or `dtb` is invalid.

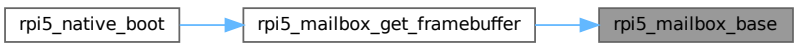
References rpi5_peripheral_base().

Referenced by rpi5_mailbox_get_framebuffer().

Here is the call graph for this function:



Here is the caller graph for this function:



7.99.2.3 rpi5_peripheral_base()

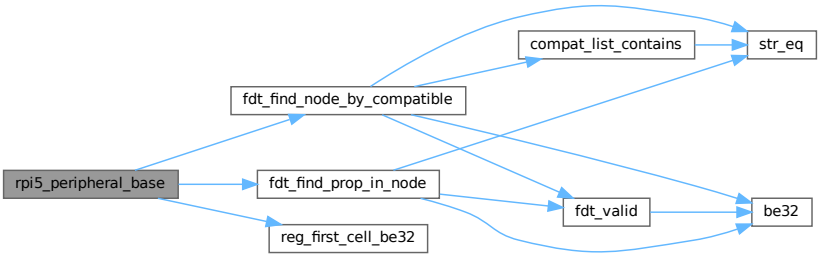
```
static uint64_t rpi5_peripheral_base (
            const void * dtb,
            const char * compatible )  [static]
```

Find `compatible`'s node, read its `reg` base address, and apply the one fixed BCM2712 `soc`-node translation offset.

References BCM2712_SOC_RANGES_OFFSET, fdt_find_node_by_compatible(), fdt_find_prop_in_node(), and reg_first_cell_be32().

Referenced by rpi5_mailbox_base(), and rpi5_uart_base().

Here is the call graph for this function:



Here is the caller graph for this function:

7.99.2.4 rpi5_uart_base()

```
uint64_t rpi5_uart_base (
            const void * dtb )
```

rpi5_dtb.h - Raspberry Pi 5 (BCM2712) devicetree-based peripheral discovery, for the native (non-UEFI) boot path (FABRIC-3.md ?IV.3).

Two lookups: the PL011 UART (early console) and the VideoCore mailbox property interface (framebuffer setup, ?IV.3 item 3). Both peripherals live under BCM2712's own devicetree "soc" simple-bus node, which applies one fixed address translation to every child `reg` value — see `rpi5_dtb.c`'s own doc comment for the confirmed offset and where it was verified. `fdt.c`'s reader deliberately does not do general `ranges`-property translation (it is "not a general devicetree library"); this file applies the one, fixed, SoC-wide offset by name instead of teaching `fdt.c` a general mechanism for a single known hardware fact.

Find the PL011 UART's CPU-physical base address from the DTB.

Parameters

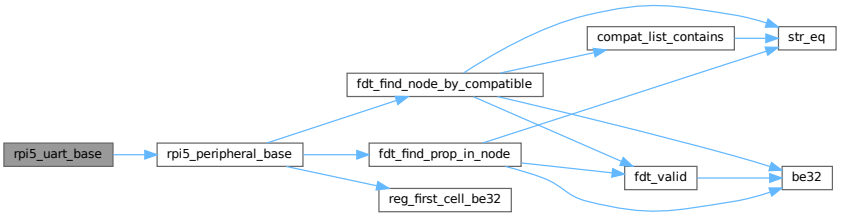
dtb	Devicetree blob, as passed to the native boot entry (or `BootInfo->dtb`); NULL is safe.

Returns

Final CPU-physical MMIO base address, or 0 if the node is absent, malformed, or `dtb` is invalid.

References rpi5_peripheral_base().

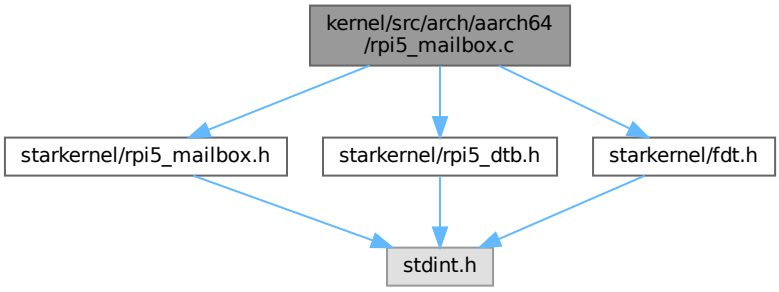
Here is the call graph for this function:



7.100 kernel/src/arch/aarch64/rpi5_mailbox.c File Reference

```
#include "starkernel/rpi5_mailbox.h"
#include "starkernel/rpi5_dtb.h"
#include "starkernel/fdt.h"
```

Include dependency graph for rpi5_mailbox.c:



Macros

- #define MBOX_OFF_READ 0x00u

  rpi5_mailbox.c - VideoCore mailbox property-interface framebuffer setup (FABRIC-3.md ?IV.3 item 3, 2026-09-04).
- #define MBOX_OFF_STATUS0 0x18u
- #define MBOX_OFF_WRITE 0x20u
- #define MBOX_OFF_STATUS1 0x38u
- #define MBOX_FULL 0x80000000u
- #define MBOX_EMPTY 0x40000000u
- #define MBOX_CH_PROPERTY 8u
- #define MBOX_CODE_REQUEST 0x00000000u
- #define MBOX_CODE_RESPONSE_OK 0x80000000u
- #define TAG_SET_PHYS_SIZE 0x00048003u
- #define TAG_SET_VIRT_SIZE 0x00048004u
- #define TAG_SET_DEPTH 0x00048005u
- #define TAG_SET_PIXEL_ORDER 0x00048006u
- #define TAG_SET_VIRTUAL_OFFS 0x00048009u
- #define TAG_ALLOCATE_BUFFER 0x00040001u
- #define TAG_GET_PITCH 0x00040008u
- #define TAG_END 0x00000000u
- #define PIXEL_ORDER_RGB 1u /∗ per the wiki's own tag doc: 0=BGR, 1=RGB ∗/

Functions

- static uint32_t g_mbox_buf[40] __attribute__ ((aligned(16)))
- static void mmio_write32 (uint64_t addr, uint32_t val)
- static uint32_t mmio_read32 (uint64_t addr)
- static uint64_t counter_now (void)
- static uint64_t counter_freq (void)
- static void buffer_to_ram (void)
- static uint32_t mb_be32 (const unsigned char *p)
- static uint64_t mb_cells (const unsigned char *p, uint32_t n)
- static uint32_t mb_cell_prop (const void *dtb, const void *node, const char *name, uint32_t otherwise)
- static int mb_compatible (const void *dtb, const void *node, const char *want)
- static int mb_find_path (const void *dtb, const void *node, const char *want, const void **path, int depth, int max)
- static int bus_to_phys (const void *dtb, uint64_t bus, uint64_t *phys)
- static void append_tag (uint32_t *idx, uint32_t tag_id, uint32_t value_bytes, const uint32_t *values, uint32_t nvalues)
- int rpi5_mailbox_get_framebuffer (const void *dtb, uint32_t width, uint32_t height, uint32_t bpp, Rpi5FramebufferInfo *out)

  Request a framebuffer from the VideoCore firmware via the mailbox property interface, at the requested resolution/depth.

7.100.1 Macro Definition Documentation

7.100.1.1 MBOX_CH_PROPERTY

```
#define MBOX_CH_PROPERTY 8u
```

7.100.1.2 MBOX_CODE_REQUEST

```
#define MBOX_CODE_REQUEST 0x00000000u
```

7.100.1.3 MBOX_CODE_RESPONSE_OK

```
#define MBOX_CODE_RESPONSE_OK 0x80000000u
```

7.100.1.4 MBOX_EMPTY

```
#define MBOX_EMPTY 0x40000000u
```

7.100.1.5 MBOX_FULL

```
#define MBOX_FULL 0x80000000u
```

7.100.1.6 MBOX_OFF_READ

```
#define MBOX_OFF_READ 0x00u
```

rpi5_mailbox.c - VideoCore mailbox property-interface framebuffer setup (FABRIC-3.md ?IV.3 item 3, 2026-09-04).

Never run on real hardware — the Pi 5 isn't in hand until 2026-09-17 (FABRIC-3.md ?II). Everything below is built from real, cited sources rather than assumed, but is compile-only-verified.

Register layout (offsets from `rpi5_mailbox_base()`, i.e. the `mailbox` devicetree node's own translated base address — `rpi5_dtb.c` already confirmed `0x107C013880` on real Pi 5 hardware, matching a Pi-5-specific bare-metal reference (main.lv/writeup/raspberry5_baremetal_framebuffer.md) independently confirming the same `0x107C000000` SoC base + `0x13880` mailbox offset this codebase's own devicetree-driven lookup already produces — two independent sources agreeing is why this offset is trusted, not just cited once):

+0x00 MBOX0_READ (receive: VC -> ARM) +0x18 MBOX0_STATUS (bit30 MBOX_EMPTY: nothing to read) +0x20 MBOX1_WRITE (send: ARM -> VC) +0x38 MBOX1_STATUS (bit31 MBOX_FULL: cannot write yet)

(`+0x20/+0x38` per the same Pi-5-specific reference above, which treats MBOX0/MBOX1 as two structurally identical 0x20-byte blocks back to back — a real difference from older-chip tutorials, which often describe a single shared status register at `+0x18` for both directions. Trusted here because it's the one source actually confirmed against Pi 5 hardware, not an older SoC.)

Message encoding (official wiki: github.com/raspberrypi/firmware/wiki/Mailbox-property-interface, channel and buffer format; property tag IDs/lengths from the same page): write `(buffer_addr & ~0xF) | channel` to MBOX1_WRITE; read back the same encoded value from MBOX0_READ once available, confirming it before trusting the buffer (the response overwrites the request in place — same shared buffer, not a separate response buffer). No bus-address translation applied to the buffer pointer itself (confirmed against the same Pi-5-specific reference: it writes the plain masked pointer, no added GPU-bus-alias bit, unlike the classic 32-bit-Pi convention some older tutorials describe) — genuinely different per-SoC-generation behavior, not an oversight.

Buffer/tag format (official wiki, same page): u32 total size, u32 request(0)/response(0x80000000|len) code, tags..., u32 end-tag(0). Each tag: u32 id, u32 value-buffer size, u32 req-size/resp-flag, value bytes padded to 4-byte alignment. Buffer itself must be 16-byte aligned (only the upper 28 bits of its address travel through the mailbox).

7.100.1.7 MBOX_OFF_STATUS0

```
#define MBOX_OFF_STATUS0 0x18u
```

7.100.1.8 MBOX_OFF_STATUS1

```
#define MBOX_OFF_STATUS1 0x38u
```

7.100.1.9 MBOX_OFF_WRITE

```
#define MBOX_OFF_WRITE 0x20u
```

7.100.1.10 PIXEL_ORDER_RGB

```
#define PIXEL_ORDER_RGB 1u /* per the wiki's own tag doc:  0=BGR, 1=RGB */
```

7.100.1.11 TAG_ALLOCATE_BUFFER

```
#define TAG_ALLOCATE_BUFFER 0x00040001u
```

7.100.1.12 TAG_END

```
#define TAG_END 0x00000000u
```

7.100.1.13 TAG_GET_PITCH

```
#define TAG_GET_PITCH 0x00040008u
```

7.100.1.14 TAG_SET_DEPTH

```
#define TAG_SET_DEPTH 0x00048005u
```

7.100.1.15 TAG_SET_PHYS_SIZE

```
#define TAG_SET_PHYS_SIZE 0x00048003u
```

7.100.1.16 TAG_SET_PIXEL_ORDER

```
#define TAG_SET_PIXEL_ORDER 0x00048006u
```

7.100.1.17 TAG_SET_VIRT_SIZE

```
#define TAG_SET_VIRT_SIZE 0x00048004u
```

7.100.1.18 TAG_SET_VIRTUAL_OFFS

```
#define TAG_SET_VIRTUAL_OFFS 0x00048009u
```

7.100.2 Function Documentation

7.100.2.1 __attribute__()

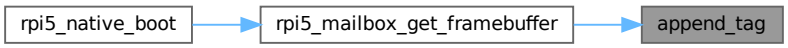
```
static uint32_t g_mbox_buf[40] __attribute__ (
            (aligned(16))  )  [static]
```

7.100.2.2 append_tag()

```
static void append_tag (
             uint32_t * idx,
             uint32_t tag_id,
             uint32_t value_bytes,
             const uint32_t * values,
             uint32_t nvalues )  [static]
```

Referenced by rpi5_mailbox_get_framebuffer().

Here is the caller graph for this function:

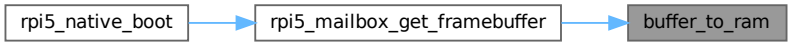


7.100.2.3 buffer_to_ram()

```
static void buffer_to_ram (
             void  )  [static]
```

Referenced by rpi5_mailbox_get_framebuffer().

Here is the caller graph for this function:



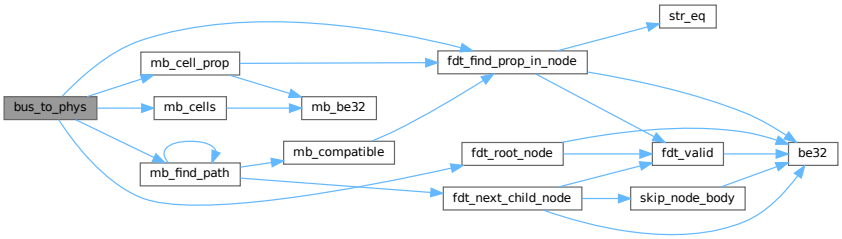
7.100.2.4 bus_to_phys()

```
static int bus_to_phys (
             const void * dtb,
             uint64_t bus,
             uint64_t * phys )  [static]
```

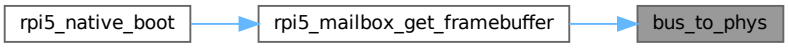
References entry, fdt_find_prop_in_node(), fdt_root_node(), mb_cell_prop(), mb_cells(), and mb_find_path().

Referenced by rpi5_mailbox_get_framebuffer().

Here is the call graph for this function:



Here is the caller graph for this function:

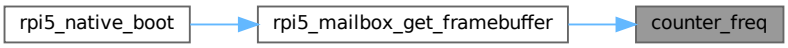


7.100.2.5 counter_freq()

```
static uint64_t counter_freq (
            void  )  [static]
```

Referenced by rpi5_mailbox_get_framebuffer().

Here is the caller graph for this function:

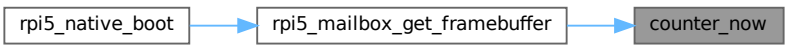


7.100.2.6 counter_now()

```
static uint64_t counter_now (
            void  )  [static]
```

Referenced by rpi5_mailbox_get_framebuffer().

Here is the caller graph for this function:

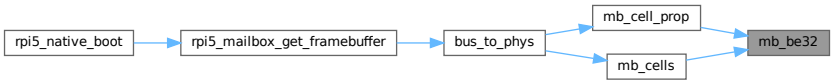


7.100.2.7 mb_be32()

```
static uint32_t mb_be32 (
            const unsigned char * p )  [static]
```

Referenced by mb_cell_prop(), and mb_cells().

Here is the caller graph for this function:



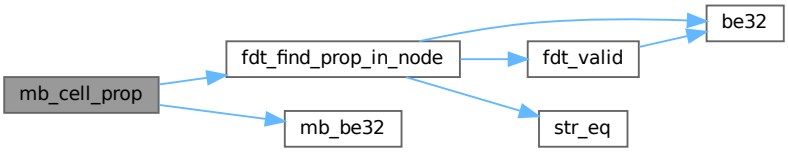
7.100.2.8 mb_cell_prop()

```
static uint32_t mb_cell_prop (
            const void * dtb,
            const void * node,
            const char * name,
            uint32_t otherwise )  [static]
```

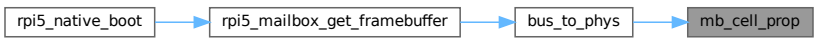
References fdt_find_prop_in_node(), mb_be32(), and name.

Referenced by bus_to_phys().

Here is the call graph for this function:



Here is the caller graph for this function:



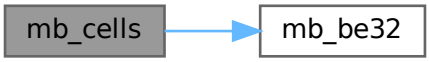
7.100.2.9 mb_cells()

```
static uint64_t mb_cells (
            const unsigned char * p,
            uint32_t n )  [static]
```

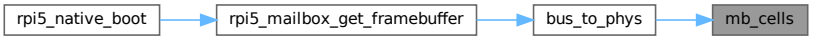
References mb_be32().

Referenced by bus_to_phys().

Here is the call graph for this function:



Here is the caller graph for this function:



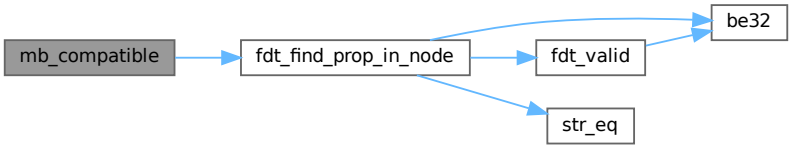
7.100.2.10 mb_compatible()

```
static int mb_compatible (
            const void * dtb,
            const void * node,
            const char * want )  [static]
```

References fdt_find_prop_in_node().

Referenced by mb_find_path().

Here is the call graph for this function:



Here is the caller graph for this function:

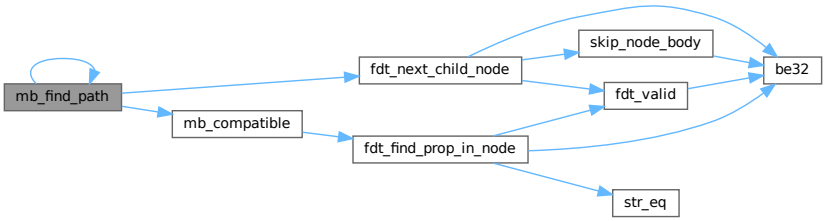
7.100.2.11 mb_find_path()

```
static int mb_find_path (
            const void * dtb,
            const void * node,
            const char * want,
            const void ** path,
            int depth,
            int max )  [static]
```

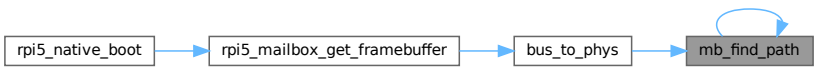
References fdt_next_child_node(), mb_compatible(), and mb_find_path().

Referenced by bus_to_phys(), and mb_find_path().

Here is the call graph for this function:



Here is the caller graph for this function:

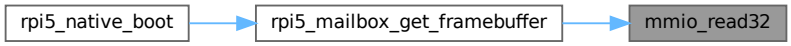


7.100.2.12 mmio_read32()

```
static uint32_t mmio_read32 (
            uint64_t addr )  [inline], [static]
```

Referenced by rpi5_mailbox_get_framebuffer().

Here is the caller graph for this function:

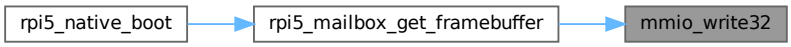


7.100.2.13 mmio_write32()

```
static void mmio_write32 (
            uint64_t addr,
            uint32_t val )  [inline], [static]
```

Referenced by rpi5_mailbox_get_framebuffer().

Here is the caller graph for this function:



7.100.2.14 rpi5_mailbox_get_framebuffer()

```
int rpi5_mailbox_get_framebuffer (
            const void * dtb,
            uint32_t width,
            uint32_t height,
            uint32_t bpp,
            Rpi5FramebufferInfo * out )
```

Request a framebuffer from the VideoCore firmware via the mailbox property interface, at the requested resolution/depth.

Sends one buffer with all six setup tags (physical size, virtual size, depth, pixel order, virtual offset, allocate) plus a get-pitch tag, in one request/response round trip.

Parameters

dtb	Devicetree blob (passed to `rpi5_mailbox_base()`).
width	Requested physical+virtual width, pixels.
height	Requested physical+virtual height, pixels.
bpp	Requested bits per pixel (32 is the only depth this driver has been designed against; others are not refused outright but are unverified).
out	Populated on success; untouched on failure.

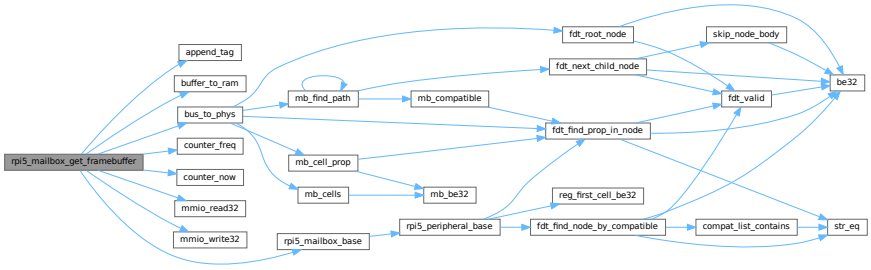
Returns

0 on success, negative on failure: -2 no mailbox node in the DTB, -3 the VC firmware rejected the request, -4 a response came back empty, -5 no answer within one second (every wait is bounded), -6 the devicetree's dma-ranges cannot place the framebuffer's bus address.

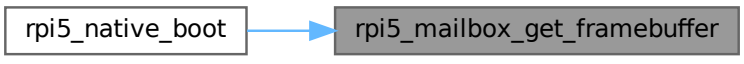
References append_tag(), Rpi5FramebufferInfo::base, base, buffer_to_ram(), bus_to_phys(), counter_freq(), counter_now(), Rpi5FramebufferInfo::height, limit, MBOX_CH_PROPERTY, MBOX_CODE_REQUEST, MBOX_CODE_RESPONSE_, MBOX_EMPTY, MBOX_FULL, MBOX_OFF_READ, MBOX_OFF_STATUS0, MBOX_OFF_STATUS1, MBOX_OFF_WRITE, mmio_read32(), mmio_write32(), Rpi5FramebufferInfo::pixel_format, PIXEL_ORDER_RGB, Rpi5FramebufferInfo::pixels_per_scanline, rpi5_mailbox_base(), Rpi5FramebufferInfo::size, TAG_ALLOCATE_BUFFER, TAG_END, TAG_GET_PITCH, TAG_SET_DEPTH, TAG_SET_PHYS_SIZE, TAG_SET_PIXEL_ORDER, TAG_SET_VIRT_SIZE, TAG_SET_VIRTUAL_OFFS, v2, and Rpi5FramebufferInfo::width.

Referenced by rpi5_native_boot().

Here is the call graph for this function:



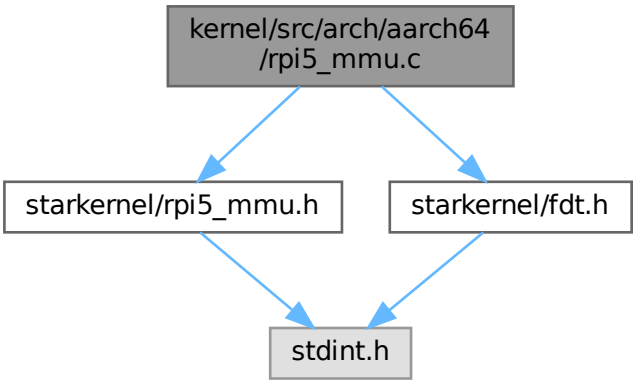
Here is the caller graph for this function:



7.101 kernel/src/arch/aarch64/rpi5_mmu.c File Reference

```
#include "starkernel/rpi5_mmu.h"
#include "starkernel/fdt.h"
```

Include dependency graph for rpi5_mmu.c:



Macros

- #define GIB (1ull << 30)
- #define MIB2 (1ull << 21)
- #define BLOCK_NORMAL_WB 0x701ull /* AF, SH inner, AttrIndx 0 */
- #define BLOCK_NORMAL_NC 0x709ull /* AF, SH inner, AttrIndx 2 */

Functions

- static uint64_t l2_gib (void)
- static uint32_t current_el (void)
- static void tlb_flush_all (void)
- static void replace_entry (volatile uint64_t *entry, uint64_t value)
- static uint32_t be32_at (const unsigned char *p)
- static uint64_t cells_at (const unsigned char *p, uint32_t n)
- int rpi5_mmu_map_ram (const void *dtb)

  rpi5_mmu.h - the Pi 5 native path's identity map, once C runs (rpi5_mmu.c; native_rpi5_entry.S turns the MMU on).
- int rpi5_mmu_uncached (uint64_t addr, uint64_t size)

Variables

- uint64_t g_rpi5_l1 [512]

  rpi5_mmu.c - the Pi 5 native path's identity map, once C runs (2026-10-14; boards/BRINGUP.md R2).
- uint64_t g_rpi5_l2 [512]
- char __kernel_start [ ]
- char __kernel_end [ ]

7.101.1 Macro Definition Documentation

7.101.1.1 BLOCK_NORMAL_NC

```
#define BLOCK_NORMAL_NC 0x709ull /* AF, SH inner, AttrIndx 2 */
```

7.101.1.2 BLOCK_NORMAL_WB

```
#define BLOCK_NORMAL_WB 0x701ull /* AF, SH inner, AttrIndx 0 */
```

7.101.1.3 GIB

```
#define GIB (1ull << 30)
```

7.101.1.4 MIB2

```
#define MIB2 (1ull << 21)
```

7.101.2 Function Documentation

7.101.2.1 be32_at()

```
static uint32_t be32_at (
            const unsigned char * p )  [static]
```

Referenced by cells_at().

Here is the caller graph for this function:

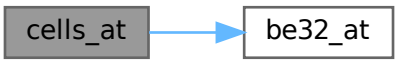
7.101.2.2 cells_at()

```
static uint64_t cells_at (
            const unsigned char * p,
            uint32_t n )  [static]
```

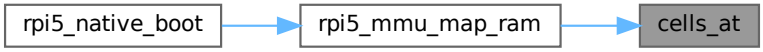
References be32_at().

Referenced by rpi5_mmu_map_ram().

Here is the call graph for this function:



Here is the caller graph for this function:

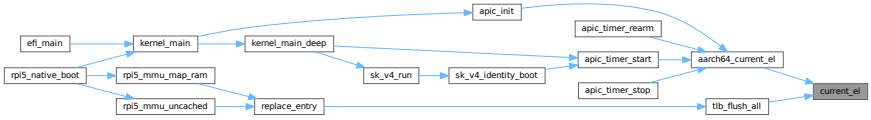


7.101.2.3 current_el()

```
static uint32_t current_el (
            void  )  [static]
```

Referenced by aarch64_current_el(), and tlb_flush_all().

Here is the caller graph for this function:



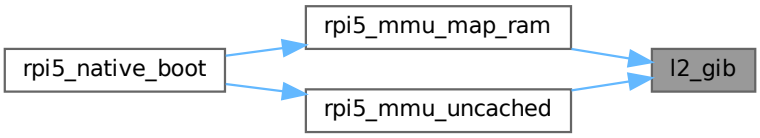
7.101.2.4 l2_gib()

```
static uint64_t l2_gib (
            void  )  [static]
```

References __kernel_start.

Referenced by rpi5_mmu_map_ram(), and rpi5_mmu_uncached().

Here is the caller graph for this function:



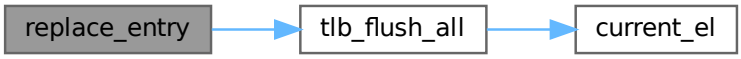
7.101.2.5 replace_entry()

```
static void replace_entry (
            volatile uint64_t * entry,
            uint64_t value )  [static]
```

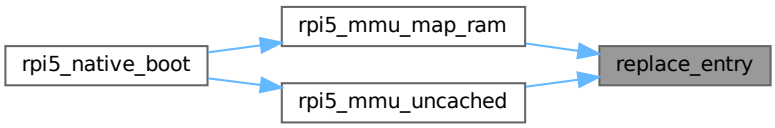
References entry, and tlb_flush_all().

Referenced by rpi5_mmu_map_ram(), and rpi5_mmu_uncached().

Here is the call graph for this function:



Here is the caller graph for this function:



7.101.2.6 rpi5_mmu_map_ram()

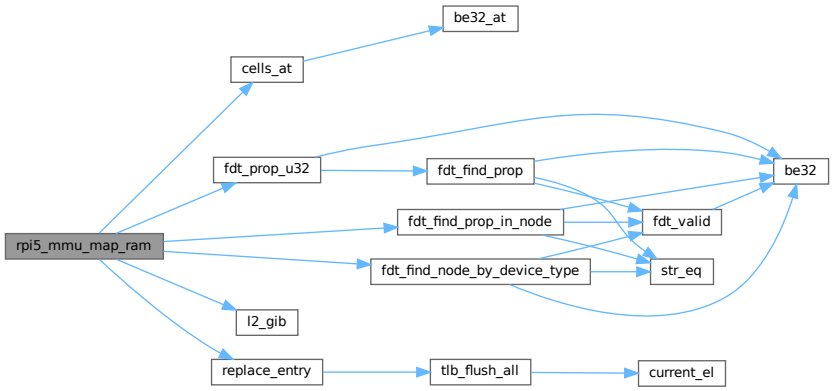
```
int rpi5_mmu_map_ram (
            const void * dtb )
```

rpi5_mmu.h - the Pi 5 native path's identity map, once C runs (rpi5_mmu.c; native_rpi5_entry.S turns the MMU on).

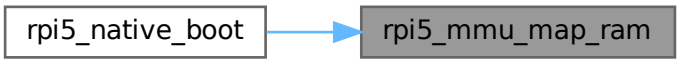
References BLOCK_NORMAL_WB, cells_at(), entry, fdt_find_node_by_device_type(), fdt_find_prop_in_node(), fdt_prop_u32(), g_rpi5_l1, GIB, l2_gib(), and replace_entry().

Referenced by rpi5_native_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



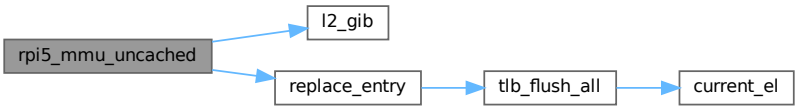
7.101.2.7 rpi5_mmu_uncached()

```
int rpi5_mmu_uncached (
            uint64_t addr,
            uint64_t size )
```

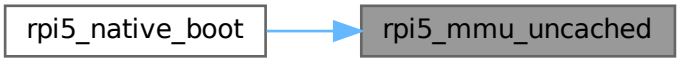
References __kernel_end, __kernel_start, BLOCK_NORMAL_NC, g_rpi5_l1, g_rpi5_l2, l2_gib(), MIB2, and replace_entry().

Referenced by rpi5_native_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.101.2.8 tlb_flush_all()

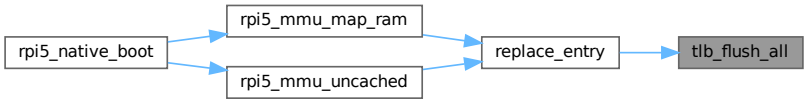
```
static void tlb_flush_all (
            void  )  [static]
```

References current_el().

Referenced by replace_entry().

Here is the call graph for this function:

Here is the caller graph for this function:



7.101.3 Variable Documentation

7.101.3.1 __kernel_end

```
char __kernel_end[]
```

Referenced by pmm_init(), and rpi5_mmu_uncached().

7.101.3.2 __kernel_start

```
char __kernel_start[]  [extern]
```

Referenced by l2_gib(), and rpi5_mmu_uncached().

7.101.3.3 g_rpi5_l1

```
uint64_t g_rpi5_l1[512]  [extern]
```

rpi5_mmu.c - the Pi 5 native path's identity map, once C runs (2026-10-14; boards/BRINGUP.md R2).

native_rpi5_entry.S turns the MMU and caches on before any C: the GiB the image is in Normal write-back in 2 MiB blocks (g_rpi5_l2) – GiB 0 on the Pi 5 – everything else Device, 1 GiB blocks (g_rpi5_l1). From here:

- rpi5_mmu_map_ram() makes every further GiB the devicetree's /memory covers entirely Normal write-back, so RAM past the first GiB is cached and can hold unaligned data – a GiB only partly RAM stays Device rather than let the CPU speculate into what is not RAM;
- rpi5_mmu_uncached() makes a range Normal non-cacheable, for the framebuffer, which the display reads straight from RAM. Each change breaks before it makes (invalid entry, TLB flush, new entry), as the architecture requires for a change of memory type.

Never run on real hardware yet. Rehearsed on QEMU's virt machine at EL2 (FABRIC-3.md ?XXXIX).

Referenced by rpi5_mmu_map_ram(), and rpi5_mmu_uncached().

7.101.3.4 g_rpi5_l2

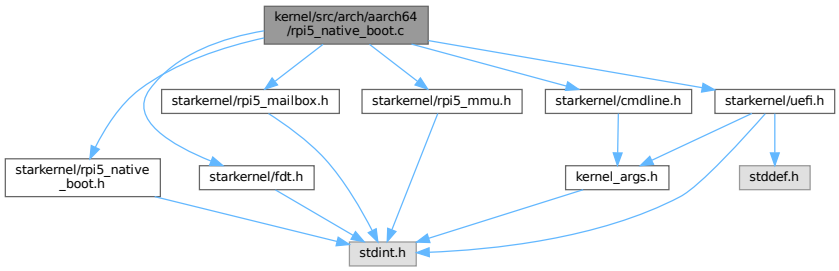
```
uint64_t g_rpi5_l2[512]  [extern]
```

Referenced by rpi5_mmu_uncached().

7.102 kernel/src/arch/aarch64/rpi5_native_boot.c File Reference

```
#include "starkernel/rpi5_native_boot.h"
#include "starkernel/fdt.h"
#include "starkernel/rpi5_mailbox.h"
#include "starkernel/rpi5_mmu.h"
#include "starkernel/cmdline.h"
#include "starkernel/uefi.h"
```

Include dependency graph for rpi5_native_boot.c:



Data Structures

- struct rpi5_range_t

Macros

- #define RPI5_FB_DEFAULT_WIDTH 1920u

  rpi5_native_boot.c - Raspberry Pi 5 DTB->BootInfo constructor (FABRIC-3.md ?IV.3 item 2, 2026-09-04).
- #define RPI5_FB_DEFAULT_HEIGHT 1080u
- #define RPI5_FB_DEFAULT_BPP 32u
- #define RPI5_MAX_RAM_REGIONS 4
- #define RPI5_MAX_RESERVED_RANGES 16
- #define RPI5_MAX_MEMMAP_ENTRIES (RPI5_MAX_RAM_REGIONS ∗ (2 ∗ RPI5_MAX_RESERVED_RANGES + 1))

Functions

- void kernel_main (BootInfo ∗boot_info)

  Main kernel entry point after UEFI handoff — executes milestones M0–M6.
- static uint32_t be32_at (const unsigned char ∗p)
- static uint64_t read_cells (const unsigned char ∗p, uint32_t ncells)

  Read one big-endian cell group (1 or 2 u32 cells) as a uint64_t.
- static void rpi5_native_halt (void)

  Halt this core.
- static uint32_t collect_ram_regions (const void ∗dtb, uint32_t acells, uint32_t scells, rpi5_range_t ∗out, uint32_t max)

  Parse `/memory`'s `reg` into raw (addr, size) ranges, honoring the root's own `#address-cells`/`#size-cells` (NOT the `soc` node's – see this file's own doc comment; `/memory` is a direct child of root).

- static uint32_t node_cells_or_fallback (const void *dtb, const void *node, const char *prop_name, uint32_t fallback)

  Read one node-scoped `#address-cells/#size-cells`-style u32 property, falling back to `fallback` if the node doesn't declare its own (DT spec ?3.5.4's own inheritance rule for `/reserved-memory`).
- static uint32_t collect_reserved_ranges (const void *dtb, uint32_t root_acells, uint32_t root_scells, rpi5_range_t *out, uint32_t max)

  Collect every `/reserved-memory` child's static `reg` range(s).
- static void sort_ranges_by_addr (rpi5_range_t *arr, uint32_t n)

  Insertion sort – small, fixed N; no libc qsort in freestanding.
- static void add_memmap_entry (uint32_t *idx, uint32_t max_entries, uint32_t type, uint64_t addr, uint64_t size)
- static void emit_region_with_carveouts (uint64_t ram_addr, uint64_t ram_size, const rpi5_range_t *reserved, uint32_t reserved_count, uint32_t *idx, uint32_t max_entries)

  Emit one RAM region as alternating conventional/reserved descriptors, clipping `reserved` (already sorted by address) to the region's own bounds.
- static uint32_t build_memory_map (const void *dtb)

  Build `g_rpi5_memmap` from `/memory` with `/reserved-memory`'s static children carved out.
- void rpi5_native_boot (uint64_t dtb)

  rpi5_native_boot.h - Raspberry Pi 5 DTB->BootInfo constructor (FABRIC-3.md ?IV.3 item 2).

Variables

- static BootInfo g_rpi5_boot_info = {0}
- static EFI_MEMORY_DESCRIPTOR g_rpi5_memmap [(4 *(2 *16+1))]

7.102.1 Macro Definition Documentation

7.102.1.1 RPI5_FB_DEFAULT_BPP

```
#define RPI5_FB_DEFAULT_BPP 32u
```

7.102.1.2 RPI5_FB_DEFAULT_HEIGHT

```
#define RPI5_FB_DEFAULT_HEIGHT 1080u
```

7.102.1.3 RPI5_FB_DEFAULT_WIDTH

```
#define RPI5_FB_DEFAULT_WIDTH 1920u
```

rpi5_native_boot.c - Raspberry Pi 5 DTB->BootInfo constructor (FABRIC-3.md ?IV.3 item 2, 2026-09-04).

Never run on real hardware – the Pi 5 isn't in hand until 2026-09-17 (FABRIC-3.md ?II). Compile-only-verified; 3-arch QEMU boot confirms this compiles and links, and does not disturb the existing UEFI/ACPI path – it cannot exercise a single line of this function, since nothing in that path calls it (same caveat as `rpi5_dtb.c`/`rpi5_mailbox.c`/`native_rpi5_entry.S` before it).

`rpi5_native_start` (`native_rpi5_entry.S`) tail-calls this function with the masked DTB pointer it captured. This builds the *existing*, unmodified `BootInfo` struct from the devicetree instead of UEFI protocols, then calls the *existing*, unmodified `kernel_main()` – this is the crux of why most of M1-M9 stays shared between the UEFI and native boot paths.

/memory's own reg (root #address-cells/#size-cells, confirmed against bcm2712.dtsi's actual root node – <2>/<2> – not assumed) is turned into EfiConventionalMemory descriptors, with /reserved-memory children that carry a static reg (brcm,bcm2712-ds.dtsi's real reserved-memory node has one, atf@0, confirmed by fetching that file rather than assumed) carved out as EfiReservedMemoryType descriptors instead of being silently left inside a conventional range. Children with no reg (linux,cma, which uses size/alloc-ranges – a dynamic reservation with no fixed address, confirmed against the same file) have nothing fixed to carve and are skipped – there is no allocator this early to service a dynamic reservation against anyway. no-map/reusable flags are not distinguished: every static reservation is excluded from EfiConventionalMemory regardless of which flag it carries, since this pass has no different treatment for either. /reserved-memory itself may declare its own #address-cells/#size-cells different from the root's (confirmed: bcm2712-ds.dtsi's does – <2>/<1>, not <2>/<2>) – read from the node itself, falling back to root's only if absent, per DT spec ?3.5.4's own inheritance rule.

What this deliberately does NOT do yet, named honestly rather than silently skipped:

- **The mailbox framebuffer request uses a fixed 1920x1080x32 default**, not real display negotiation (no EDID query exists in this codebase). Flagged, not guessed past this comment – revisit once real hardware and a real attached display are in hand.
- **Root and /reserved-memory #address-cells/#size-cells must each be exactly 1 or 2** – other widths halt rather than guess.

7.102.1.4 RPI5_MAX_MEMMAP_ENTRIES

```
#define RPI5_MAX_MEMMAP_ENTRIES (RPI5_MAX_RAM_REGIONS * (2 * RPI5_MAX_RESERVED_RANGES + 1))
```

7.102.1.5 RPI5_MAX_RAM_REGIONS

```
#define RPI5_MAX_RAM_REGIONS 4
```

7.102.1.6 RPI5_MAX_RESERVED_RANGES

```
#define RPI5_MAX_RESERVED_RANGES 16
```

7.102.2 Function Documentation

7.102.2.1 add_memmap_entry()

```
static void add_memmap_entry (
            uint32_t * idx,
            uint32_t max_entries,
            uint32_t type,
            uint64_t addr,
            uint64_t size )  [static]
```

References EFI_MEMORY_DESCRIPTOR::Attribute, g_rpi5_memmap, EFI_MEMORY_DESCRIPTOR::NumberOfPages, EFI_MEMORY_DESCRIPTOR::PhysicalStart, EFI_MEMORY_DESCRIPTOR::Type, and EFI_MEMORY_DESCRIPTOR::VirtualStart

Referenced by emit_region_with_carveouts().

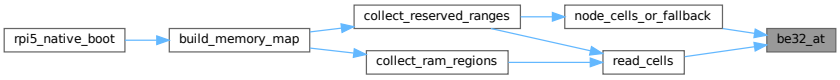
Here is the caller graph for this function:

7.102.2.2 be32_at()

```
static uint32_t be32_at (
            const unsigned char * p )  [static]
```

Referenced by node_cells_or_fallback(), and read_cells().

Here is the caller graph for this function:



7.102.2.3 build_memory_map()

```
static uint32_t build_memory_map (
            const void * dtb )  [static]
```

Build `g_rpi5_memmap` from `/memory` with `/reserved-memory`'s static children carved out.

See this file's own top doc comment for exactly what is and is not handled.

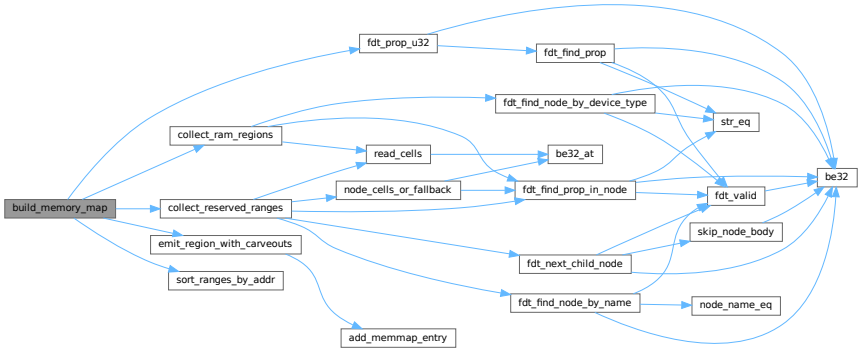
Returns

Number of entries written (0 on any failure – absence of `/reserved-memory` itself is not a failure, just zero carve-outs).

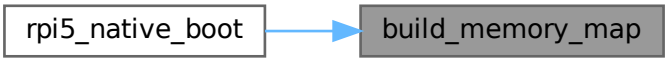
References collect_ram_regions(), collect_reserved_ranges(), emit_region_with_carveouts(), fdt_prop_u32(), RPI5_MAX_MEMMAP_ENTRIES, RPI5_MAX_RAM_REGIONS, RPI5_MAX_RESERVED_RANGES, and sort_ranges_by_addr().

Referenced by rpi5_native_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.102.2.4 collect_ram_regions()

```
static uint32_t collect_ram_regions (
            const void * dtb,
            uint32_t acells,
            uint32_t scells,
            rpi5_range_t * out,
            uint32_t max )  [static]
```

Parse `/memory`'s `reg` into raw (addr, size) ranges, honoring the root's own `#address-cells`/`#size-cells` (NOT the `soc` node's – see this file's own doc comment; `/memory` is a direct child of root).

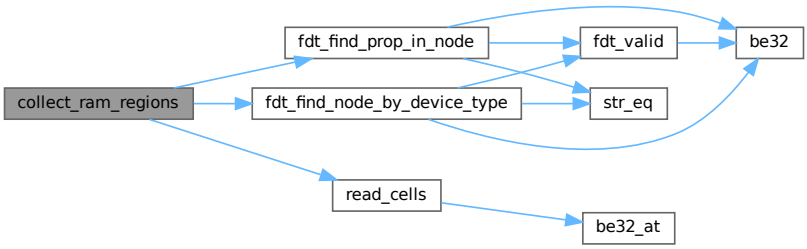
Returns

Number of ranges written (0 on any failure).

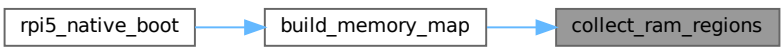
References rpi5_range_t::addr, count, fdt_find_node_by_device_type(), fdt_find_prop_in_node(), read_cells(), and rpi5_range_t::size.

Referenced by build_memory_map().

Here is the call graph for this function:



Here is the caller graph for this function:



7.102.2.5 collect_reserved_ranges()

```
static uint32_t collect_reserved_ranges (
            const void * dtb,
            uint32_t root_acells,
            uint32_t root_scells,
            rpi5_range_t * out,
            uint32_t max )  [static]
```

Collect every `/reserved-memory` child's static `reg` range(s).

Children with no `reg` (dynamic reservations – `size/alloc-ranges` only) are skipped: there is no allocator this early to service a dynamic reservation against, and nothing fixed to carve either way.

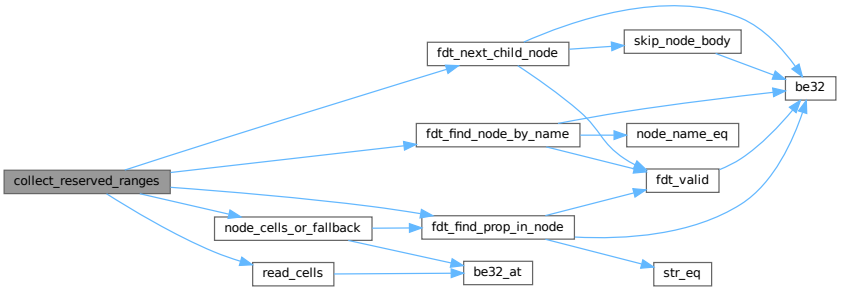
Returns

Number of ranges written (0 if `/reserved-memory` is absent or empty of static reservations – not an error, just nothing to carve).

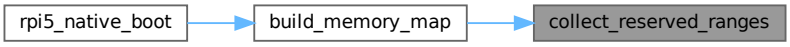
References rpi5_range_t::addr, count, fdt_find_node_by_name(), fdt_find_prop_in_node(), fdt_next_child_node(), node_cells_or_fallback(), read_cells(), and rpi5_range_t::size.

Referenced by build_memory_map().

Here is the call graph for this function:



Here is the caller graph for this function:



7.102.2.6 emit_region_with_carveouts()

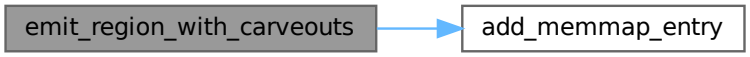
```
static void emit_region_with_carveouts (
            uint64_t ram_addr,
            uint64_t ram_size,
            const rpi5_range_t * reserved,
            uint32_t reserved_count,
            uint32_t * idx,
            uint32_t max_entries )  [static]
```

Emit one RAM region as alternating conventional/reserved descriptors, clipping `reserved` (already sorted by address) to the region's own bounds.

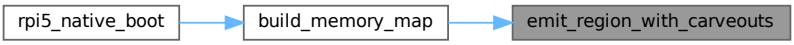
References add_memmap_entry(), rpi5_range_t::addr, EfiConventionalMemory, EfiReservedMemoryType, ram_size, and rpi5_range_t::size.

Referenced by build_memory_map().

Here is the call graph for this function:



Here is the caller graph for this function:



7.102.2.7 kernel_main()

```
void kernel_main (
            BootInfo * boot_info )  [extern]
```

Main kernel entry point after UEFI handoff — executes milestones M0–M6.

On amd64 and riscv64, `kernel_entry.S` switches the stack from UEFI's default to a 2 MiB zero-initialised BSS stack and tail-calls this function as `kernel_main_impl`. On aarch64 the assembly trampoline is not yet implemented and the UEFI loader calls `kernel_main` directly.

Milestone sequence:

- **M0 — Architecture early init** (`arch_early_init()`): On amd64, installs a minimal GDT with a proper 64-bit code segment at selector 0x08 and reloads CS via `lretq`. Without this, UEFI's 64-bit segment at 0x38 is in scope and the ISR's `INT` gate (which expects CS 0x08) would fault silently.

- **M1 — Console** (`console_init()`): brings up UART 16550 at 115200 8N1 and the framebuffer VT100 terminal. Then prints banner and memory map.
- **M2 — PMM** (`pmm_init()`): initialises the physical memory manager's 4 KiB page bitmap from the EFI memory map.
- **M3 — VMM** (`vmm_init()`): builds 4-level x86-64 page tables, maps all conventional RAM at the kernel virtual base, and loads CR3.
- **M4 — IDT + APIC** (`arch_interrupts_init()` + `apic_init()`): programs the 64-entry IDT, masks the legacy 8259A PIC, and initialises the Local APIC in xAPIC MMIO mode at 0xFEE00000.
- **M5 — Timer** (`timer_init()`): calibrates the TSC and HPET.
- **M6 — Heap** (`kmalloc_init()`): initialises the kernel slab allocator with `heap_size` from the boot args or `KARGS_DEFAULT_HEAP_SIZE` (2 GiB).

Stashes `boot_info->runtime_services` in `g_sk_runtime_services` for later use by kernel FORTH words (e.g. `REBOOT`). Then tail-calls `kernel_main_deep()` for M7 and the REPL.

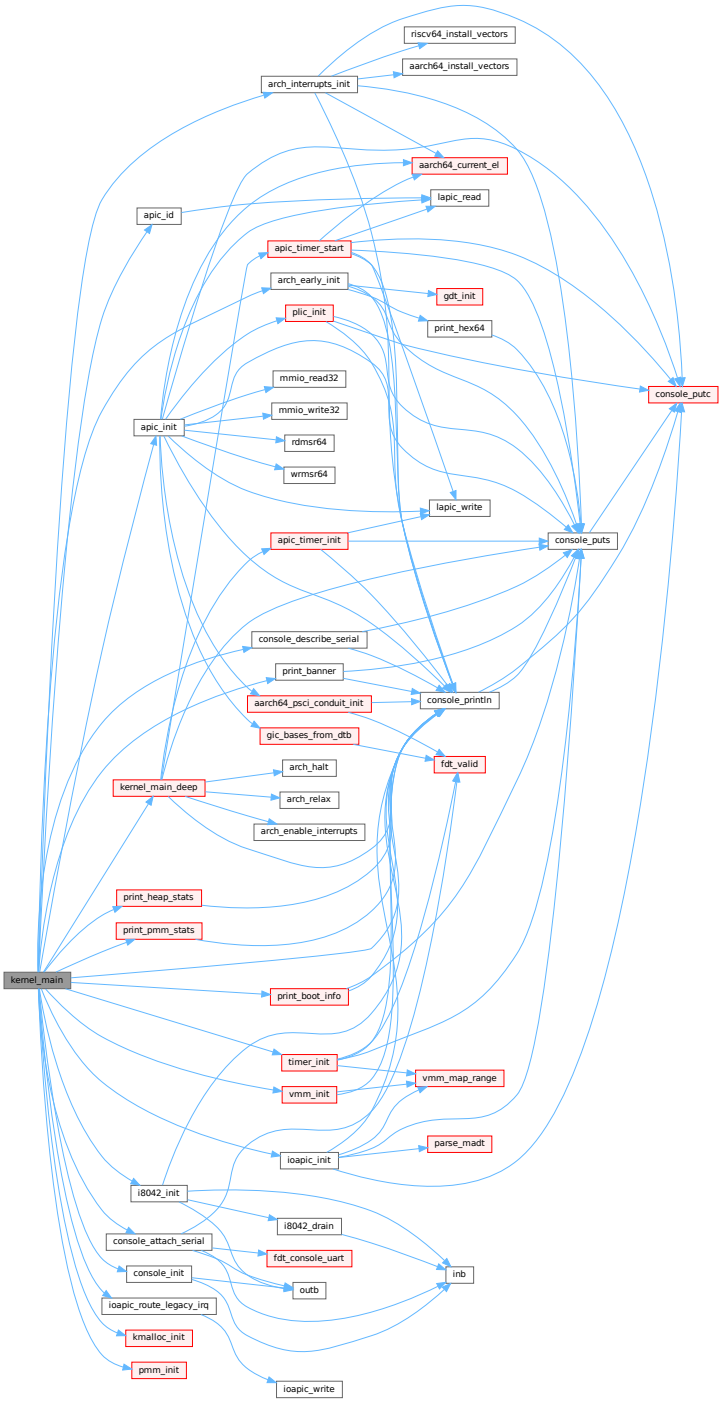
Parameters

boot_info	`BootInfo` populated by `uefi_loader.c` before `ExitBootServices()`; provides the memory map, ACPI pointer, framebuffer descriptor, runtime services pointer, and parsed kernel command-line arguments.

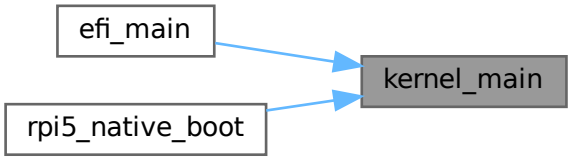
References BootInfo::acpi_table, apic_id(), apic_init(), arch_early_init(), arch_interrupts_init(), BootInfo::args, console_attach_serial(), console_describe_serial(), console_init(), console_println(), BootInfo::dtb, g_sk_runtime_services, KernelArgs::heap_size, i8042_init(), I8042_KEYBOARD_VECTOR, ioapic_init(), ioapic_route_legacy_irq(), KARGS_DEFAULT_HEAP_SIZE, kernel_main_deep(), kmalloc_init(), pmm_init(), print_banner(), print_boot_info(), print_heap_stats(), print_pmm_stats(), BootInfo::runtime_services, timer_init(), and vmm_init().

Referenced by efi_main(), and rpi5_native_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.102.2.8 node_cells_or_fallback()

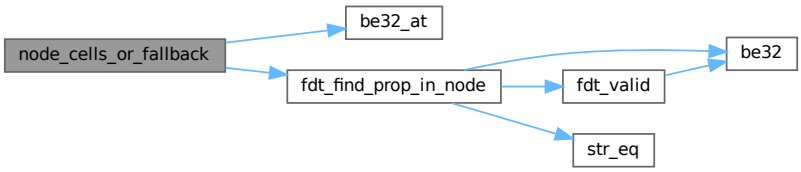
```
static uint32_t node_cells_or_fallback (
            const void * dtb,
            const void * node,
            const char * prop_name,
            uint32_t fallback )  [static]
```

Read one node-scoped `#address-cells`/`#size-cells`-style u32 property, falling back to `fallback` if the node doesn't declare its own (DT spec ?3.5.4's own inheritance rule for `/reserved-memory`).

References be32_at(), and fdt_find_prop_in_node().

Referenced by collect_reserved_ranges().

Here is the call graph for this function:



Here is the caller graph for this function:

7.102.2.9 read_cells()

```
static uint64_t read_cells (
            const unsigned char * p,
            uint32_t ncells )  [static]
```

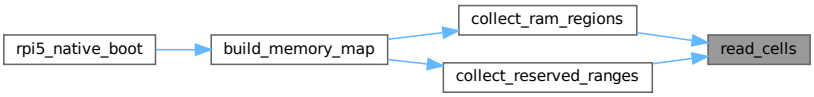
Read one big-endian cell group (1 or 2 u32 cells) as a uint64_t.

References be32_at().

Referenced by collect_ram_regions(), and collect_reserved_ranges().

Here is the call graph for this function:

Here is the caller graph for this function:



7.102.2.10 rpi5_native_boot()

```
void rpi5_native_boot (
            uint64_t dtb )
```

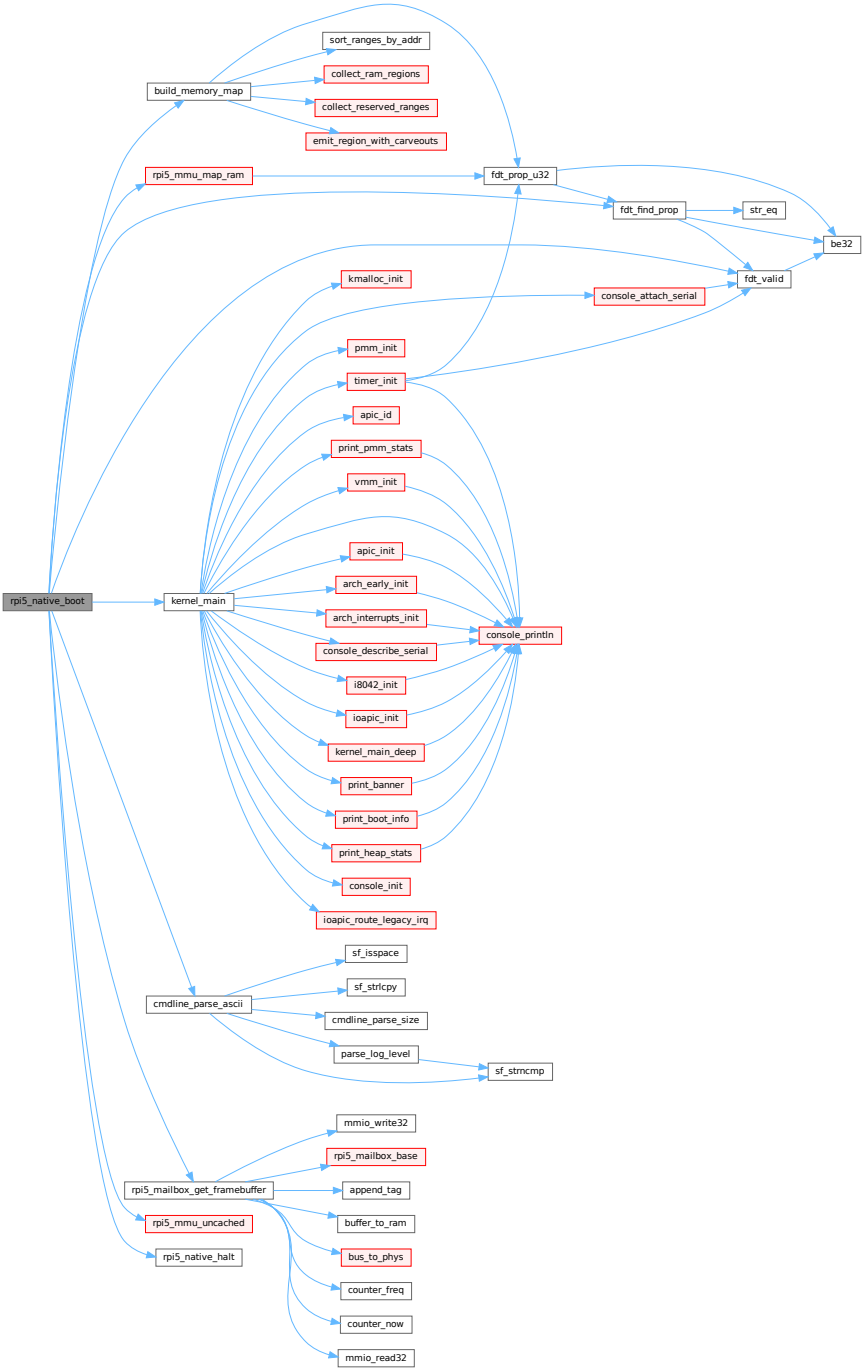
rpi5_native_boot.h - Raspberry Pi 5 DTB->BootInfo constructor (FABRIC-3.md ?IV.3 item 2).

`native_rpi5_entry.S`'s `rpi5_native_start` tail-calls `rpi5_native_boot()` with the masked DTB pointer it captured. This function builds the *existing*, unmodified `BootInfo` struct (`include/starkernel/uefi.h`) from the devicetree instead of UEFI protocols, then calls the *existing*, unmodified `kernel_main()` — see this file's own `.c` for exactly what is and is not populated, and why.

References BootInfo::acpi_table, BootInfo::args, Rpi5FramebufferInfo::base, FramebufferInfo::base, build_memory_map(), cmdline_parse_ascii(), BootInfo::dtb, fdt_find_prop(), fdt_valid(), BootInfo::framebuffer, g_rpi5_boot_info, g_rpi5_memmap, Rpi5FramebufferInfo::height, FramebufferInfo::height, kernel_main(), BootInfo::kernel_stack_base, BootInfo::kernel_stack_size, BootInfo::memory_map, BootInfo::memory_map_descriptor_size, BootInfo::memory_map_size, Rpi5FramebufferInfo::pixel_format, FramebufferInfo::pixel_format, Rpi5FramebufferInfo::pixels_per_scanline, FramebufferInfo::pixels_per_scanline, RPI5_FB_DEFAULT_BPP, RPI5_FB_DEFAULT_HEIGHT, RPI5_FB_DEFAULT_WIDTH, rpi5_mailbox_get_framebuffer(), rpi5_mmu_map_ram(), rpi5_mmu_uncached(), rpi5_native_halt(), BootInfo::runtime_services,

Rpi5FramebufferInfo::size, FramebufferInfo::size, BootInfo::uefi_boot_services_exited, Rpi5FramebufferInfo::width, and FramebufferInfo::width.

Here is the call graph for this function:



7.102.2.11 rpi5_native_halt()

```
static void rpi5_native_halt (
            void  )  [static]
```

Halt this core.

No console exists yet (M1 hasn't run) and there is nowhere safe to report failure – this is the same halt shape `native_rpi5_entry.S` itself uses before this function existed.

Referenced by rpi5_native_boot().

Here is the caller graph for this function:

7.102.2.12 sort_ranges_by_addr()

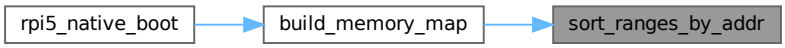
```
static void sort_ranges_by_addr (
            rpi5_range_t * arr,
            uint32_t n )  [static]
```

Insertion sort – small, fixed N; no libc qsort in freestanding.

References rpi5_range_t::addr.

Referenced by build_memory_map().

Here is the caller graph for this function:



7.102.3 Variable Documentation

7.102.3.1 g_rpi5_boot_info

```
BootInfo g_rpi5_boot_info = {0}  [static]
```

Referenced by rpi5_native_boot().

7.102.3.2 g_rpi5_memmap

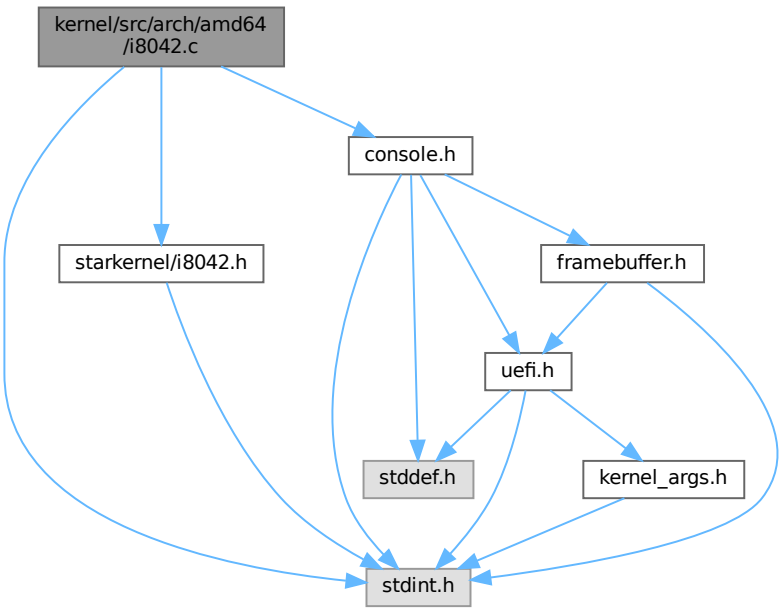
```
EFI_MEMORY_DESCRIPTOR g_rpi5_memmap[(4 *(2 * 16+1))]  [static]
```

Referenced by add_memmap_entry(), and rpi5_native_boot().

7.103 kernel/src/arch/amd64/i8042.c File Reference

```
#include <stdint.h>
#include "starkernel/i8042.h"
#include "console.h"
```

Include dependency graph for i8042.c:



Macros

- #define I8042_DATA_PORT 0x60

  i8042.c - PS/2 keyboard controller driver (amd64)
- #define I8042_STATUS_PORT 0x64
- #define I8042_CMD_PORT 0x64
- #define I8042_STATUS_OUTPUT_FULL (1u << 0)
- #define I8042_STATUS_INPUT_FULL (1u << 1)
- #define I8042_CMD_READ_CONFIG 0x20
- #define I8042_CMD_WRITE_CONFIG 0x60
- #define I8042_CONFIG_IRQ1_ENABLE (1u << 0)
- #define I8042_DEV_CMD_ENABLE_SCANNING 0xF4
- #define I8042_DEV_ACK 0xFA
- #define I8042_INIT_WAIT_ITERS 100000
- #define RING_SIZE 32

Functions

- static void outb (uint16_t port, uint8_t val)
- static uint8_t inb (uint16_t port)
- static void i8042_drain (void)

- void i8042_init (void)

  Enable IRQ1 delivery in the i8042 controller's command byte.
- void i8042_drain_stale (void)

  Drain any byte sitting in the output buffer right before unmasking IRQ1.
- void i8042_handle_irq (void)

  Called from the keyboard IRQ dispatch path (interrupts.c) on every I8042_KEYBOARD_VECTOR interrupt.
- int i8042_pop_scancode (uint8_t *out)

  Pop one raw scancode off the ring buffer, from non-interrupt context.

Variables

- static int g_i8042_present
- static volatile uint8_t ring [32]
- static volatile uint8_t ring_head = 0
- static volatile uint8_t ring_tail = 0
- volatile uint32_t g_i8042_isr_count = 0

7.103.1 Macro Definition Documentation

7.103.1.1 I8042_CMD_PORT

```
#define I8042_CMD_PORT 0x64
```

7.103.1.2 I8042_CMD_READ_CONFIG

```
#define I8042_CMD_READ_CONFIG 0x20
```

7.103.1.3 I8042_CMD_WRITE_CONFIG

```
#define I8042_CMD_WRITE_CONFIG 0x60
```

7.103.1.4 I8042_CONFIG_IRQ1_ENABLE

```
#define I8042_CONFIG_IRQ1_ENABLE (1u << 0)
```

7.103.1.5 I8042_DATA_PORT

```
#define I8042_DATA_PORT 0x60
```

i8042.c - PS/2 keyboard controller driver (amd64)

Item 4.3.5 (FABRIC-0.md ?27.5).

7.103.1.6 I8042_DEV_ACK

```
#define I8042_DEV_ACK 0xFA
```

7.103.1.7 I8042_DEV_CMD_ENABLE_SCANNING

```
#define I8042_DEV_CMD_ENABLE_SCANNING 0xF4
```

7.103.1.8 I8042_INIT_WAIT_ITERS

```
#define I8042_INIT_WAIT_ITERS 100000
```

7.103.1.9 I8042_STATUS_INPUT_FULL

```
#define I8042_STATUS_INPUT_FULL (1u << 1)
```

7.103.1.10 I8042_STATUS_OUTPUT_FULL

```
#define I8042_STATUS_OUTPUT_FULL (1u << 0)
```

7.103.1.11 I8042_STATUS_PORT

```
#define I8042_STATUS_PORT 0x64
```

7.103.1.12 RING_SIZE

```
#define RING_SIZE 32
```

7.103.2 Function Documentation

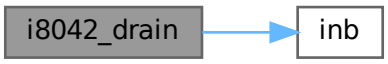
7.103.2.1 i8042_drain()

```
static void i8042_drain (
            void  )  [static]
```

References I8042_DATA_PORT, I8042_STATUS_OUTPUT_FULL, I8042_STATUS_PORT, and inb().

Referenced by i8042_drain_stale(), and i8042_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.103.2.2 i8042_drain_stale()

```
void i8042_drain_stale (
            void  )
```

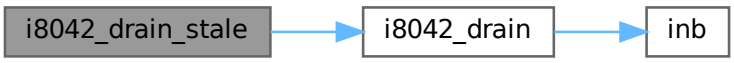
Drain any byte sitting in the output buffer right before unmasking IRQ1.

Edge-triggered lines only assert on a rising edge; if OBF is already set (from real wall-clock time elapsing between i8042_init() and unmask while OBF was already high), there is no edge left to fire on, ever.

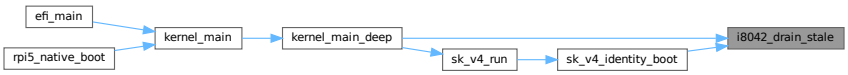
References g_i8042_present, and i8042_drain().

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.103.2.3 i8042_handle_irq()

```
void i8042_handle_irq (
            void  )
```

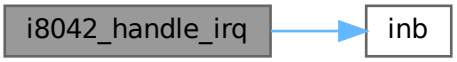
Called from the keyboard IRQ dispatch path (interrupts.c) on every I8042_KEYBOARD_VECTOR interrupt.

Trivial by design: reads the scancode from port 0x60 (must always be read, or the controller never clears OBF and stops delivering further interrupts) and pushes it onto a small ring buffer. No printing, no translation, no other work — that all happens outside interrupt context via i8042_pop_scancode(). Does not issue apic_eoi() — the caller does.

References g_i8042_isr_count, I8042_DATA_PORT, inb(), ring, ring_head, RING_SIZE, and ring_tail.

Referenced by isr_common_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

7.103.2.4 i8042_init()

```
void i8042_init (
            void  )
```

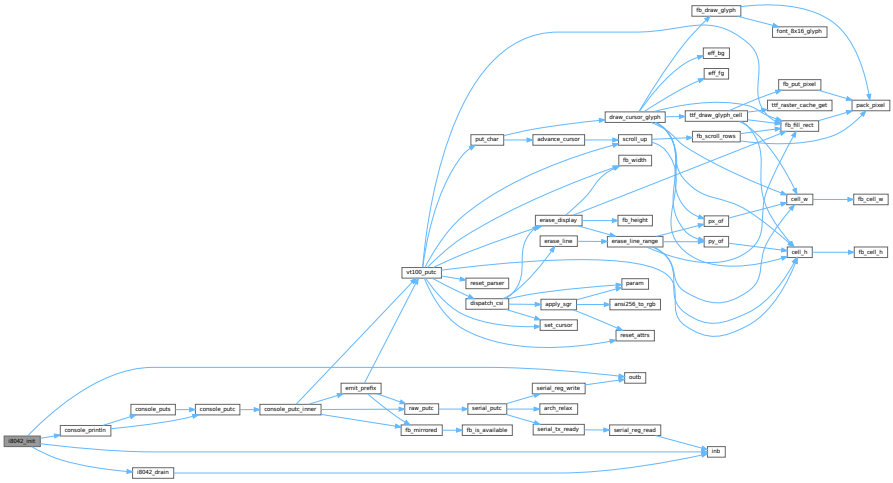
Enable IRQ1 delivery in the i8042 controller's command byte.

Assumes the controller was already brought up by firmware (OVMF) — does not run the 0xAA self-test or the full two-port init sequence, since that is more than this item's scope requires.

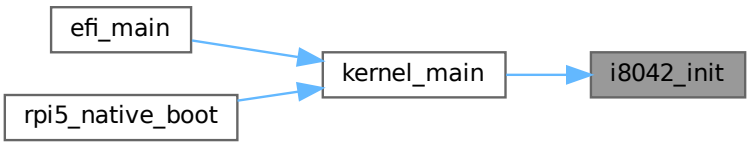
References console_println(), g_i8042_present, I8042_CMD_PORT, I8042_CMD_READ_CONFIG, I8042_CMD_WRITE_CONFIG, I8042_CONFIG_IRQ1_ENABLE, I8042_DATA_PORT, I8042_DEV_ACK, I8042_DEV_CMD_ENABLE_SCANNING, i8042_drain(), I8042_INIT_WAIT_ITERS, I8042_STATUS_INPUT_FULL, I8042_STATUS_OUTPUT_FULL, I8042_STATUS_PORT, inb(), and outb().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.103.2.5 i8042_pop_scancode()

```
int i8042_pop_scancode (
            uint8_t * out )
```

Pop one raw scancode off the ring buffer, from non-interrupt context.

Single producer (the ISR), single reader (this function) — same shape already established safe on one hart elsewhere in this tree (?21.1).

Parameters

out	Written with the popped scancode on success.

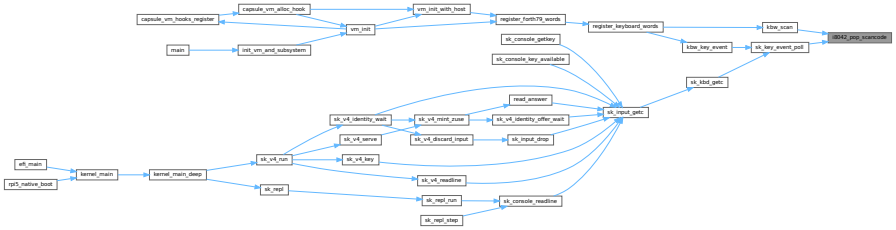
Returns

1 if a scancode was popped, 0 if the buffer was empty.

References ring, ring_head, RING_SIZE, and ring_tail.

Referenced by kbw_scan(), and sk_key_event_poll().

Here is the caller graph for this function:

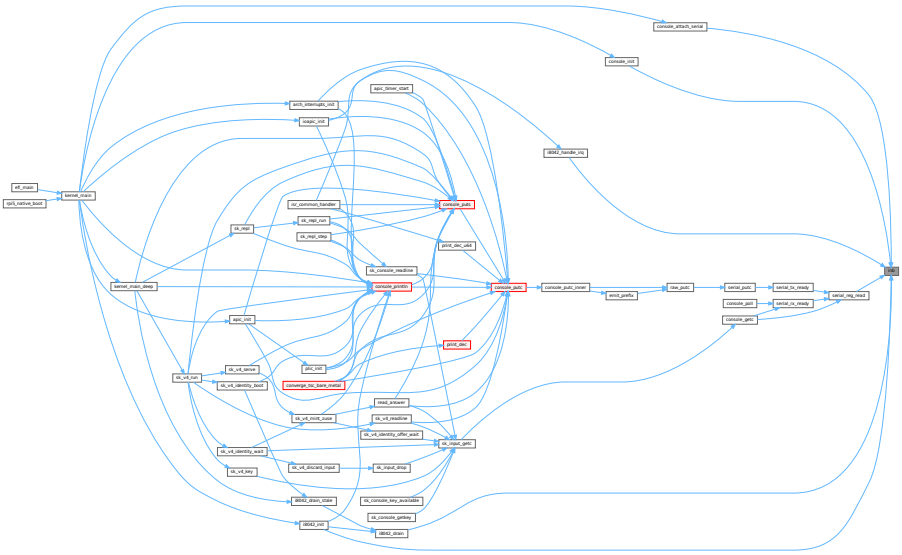


7.103.2.6 inb()

```
static uint8_t inb (
            uint16_t port )  [inline], [static]
```

Referenced by console_attach_serial(), console_init(), i8042_drain(), i8042_handle_irq(), i8042_init(), and serial_reg_read().

Here is the caller graph for this function:

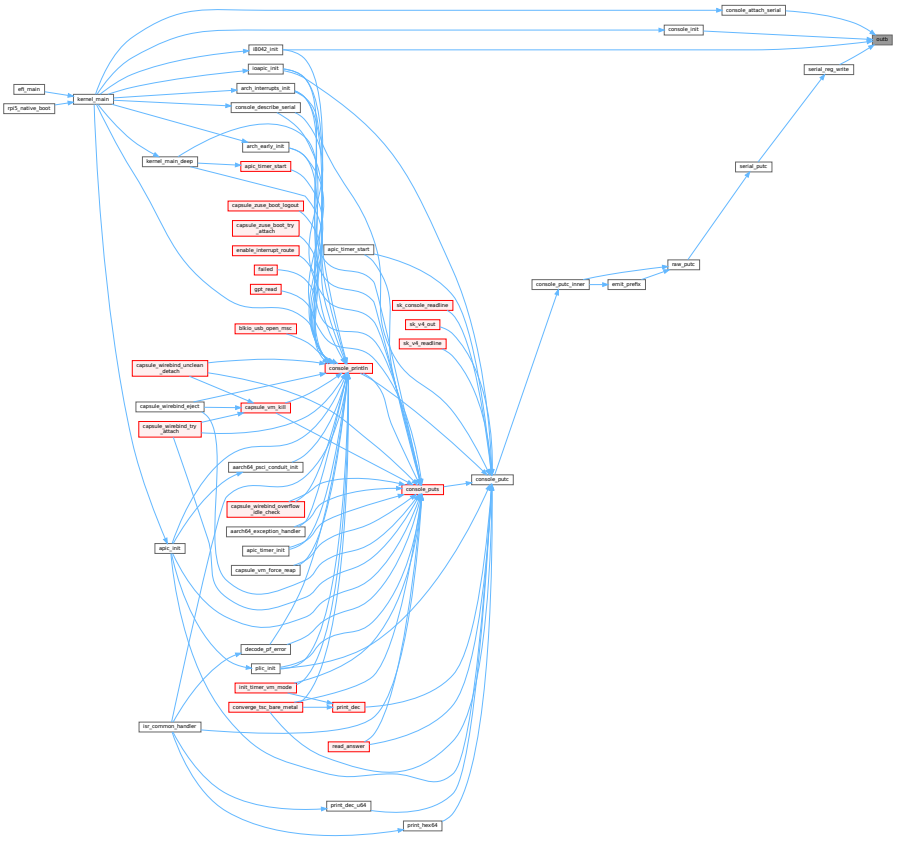


7.103.2.7 outb()

```
static void outb (
            uint16_t port,
            uint8_t val )  [inline], [static]
```

Referenced by console_attach_serial(), console_init(), i8042_init(), and serial_reg_write().

Here is the caller graph for this function:



7.103.3 Variable Documentation

7.103.3.1 g_i8042_isr_count

```
volatile uint32_t g_i8042_isr_count = 0
```

Referenced by i8042_handle_irq(), and kbw_debug().

7.103.3.2 g_i8042_present

```
int g_i8042_present  [static]
```

Referenced by i8042_drain_stale(), and i8042_init().

7.103.3.3 ring

```
volatile uint8_t ring[32]  [static]
```

Referenced by i8042_handle_irq(), i8042_pop_scancode(), physics_analytics_publish_event(), and xhci_init_bulk_ring().

7.103.3.4 ring_head

```
volatile uint8_t ring_head = 0  [static]
```

Referenced by i8042_handle_irq(), and i8042_pop_scancode().

7.103.3.5 ring_tail

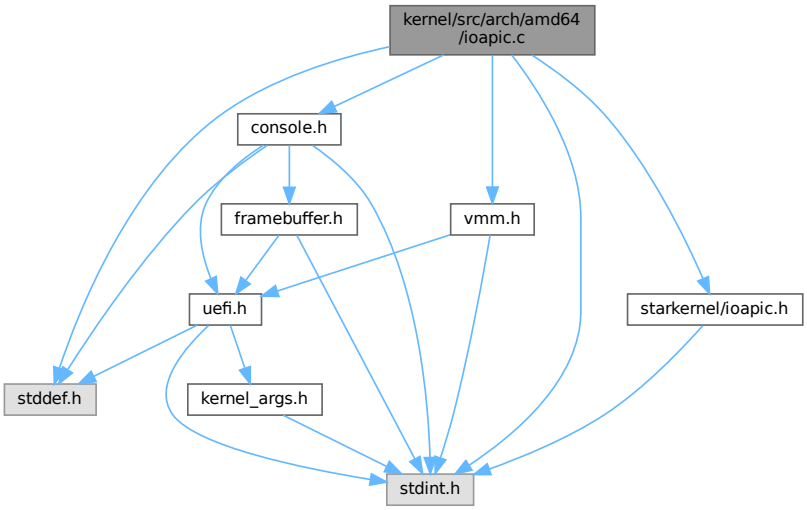
```
volatile uint8_t ring_tail = 0  [static]
```

Referenced by i8042_handle_irq(), and i8042_pop_scancode().

7.104 kernel/src/arch/amd64/ioapic.c File Reference

```
#include <stddef.h>
#include <stdint.h>
#include "starkernel/ioapic.h"
#include "console.h"
#include "vmm.h"
```

Include dependency graph for ioapic.c:



Data Structures

- struct __attribute__

  ioapic.c - I/O APIC driver (amd64)

Macros

- #define MADT_TYPE_IOAPIC 1
- #define MADT_TYPE_INT_SRC 2
- #define ISO_POLARITY_MASK 0x3u
- #define ISO_POLARITY_HIGH 0x1u
- #define ISO_POLARITY_LOW 0x3u
- #define ISO_TRIGGER_MASK 0xCu
- #define ISO_TRIGGER_EDGE 0x4u
- #define ISO_TRIGGER_LEVEL 0xCu
- #define MAX_OVERRIDES 16
- #define MAX_REDIR_ENTRIES 24

Functions

- static void ioapic_write (uint8_t reg, uint32_t val)
- static int sig4_eq (const uint8_t ∗p, const char ∗s)
- static int sig8_eq (const uint8_t ∗p, const char ∗s)
- static int parse_madt (void ∗rsdp)
- int ioapic_init (void ∗acpi_rsdp)

  ioapic.h - I/O APIC interface (amd64 only)
- int ioapic_route_legacy_irq (uint8_t isa_irq, uint8_t vector, uint8_t dest_apic_id)

  Program a redirection entry for a legacy ISA IRQ, initially masked.
- void ioapic_unmask_legacy_irq (uint8_t isa_irq)

  Clear the mask bit on a previously routed legacy IRQ's redirection entry.

Variables

- static uint64_t g_ioapic_base = 0
- static uint32_t g_ioapic_gsi_base = 0
- static int g_ioapic_ready = 0
- static MadtIntSrcOverride g_overrides [16]
- static int g_override_count = 0
- static uint32_t g_redir_low [24]
- static int g_redir_valid [24]

7.104.1 Macro Definition Documentation

7.104.1.1 ISO_POLARITY_HIGH

```
#define ISO_POLARITY_HIGH 0x1u
```

7.104.1.2 ISO_POLARITY_LOW

```
#define ISO_POLARITY_LOW 0x3u
```

7.104.1.3 ISO_POLARITY_MASK

```
#define ISO_POLARITY_MASK 0x3u
```

7.104.1.4 ISO_TRIGGER_EDGE

```
#define ISO_TRIGGER_EDGE 0x4u
```

7.104.1.5 ISO_TRIGGER_LEVEL

```
#define ISO_TRIGGER_LEVEL 0xCu
```

7.104.1.6 ISO_TRIGGER_MASK

```
#define ISO_TRIGGER_MASK 0xCu
```

7.104.1.7 MADT_TYPE_INT_SRC

```
#define MADT_TYPE_INT_SRC 2
```

7.104.1.8 MADT_TYPE_IOAPIC

```
#define MADT_TYPE_IOAPIC 1
```

7.104.1.9 MAX_OVERRIDES

```
#define MAX_OVERRIDES 16
```

7.104.1.10 MAX_REDIR_ENTRIES

```
#define MAX_REDIR_ENTRIES 24
```

7.104.2 Function Documentation

7.104.2.1 ioapic_init()

```
int ioapic_init (
            void * acpi_rsdp )
```

ioapic.h - I/O APIC interface (amd64 only)

Item 4.3.5 (FABRIC-0.md ?27.5): no I/O APIC driver existed anywhere in this tree before this item. The Local APIC (apic.h) self-interrupts for the timer and needs no routing; any *legacy* IRQ (i8042 keyboard's IRQ1 included) requires the I/O APIC to redirect it to a Local APIC vector. Locate and map the I/O APIC via the ACPI MADT (parsed from `acpi_rsdp`). Also captures any Interrupt Source Override entries so legacy ISA IRQs with a non-default GSI/polarity/trigger mapping route correctly.

Parameters

acpi_rsdp	BootInfo->acpi_table (RSDP), or NULL.

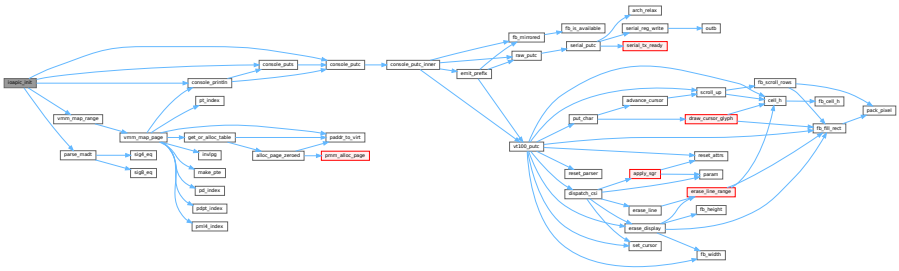
Returns

0 on success, -1 if no MADT/I/O APIC entry was found.

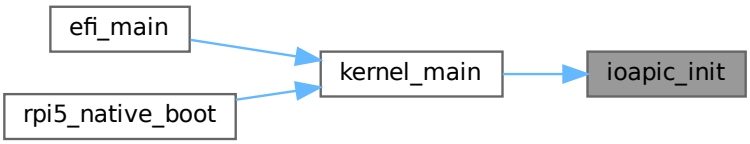
References console_println(), console_putc(), console_puts(), flags, g_ioapic_base, g_ioapic_gsi_base, g_ioapic_ready, g_override_count, g_overrides, parse_madt(), VMM_FLAG_CACHE_DISABLE, VMM_FLAG_WRITABLE, and vmm_map_range().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.104.2.2 ioapic_route_legacy_irq()

```
int ioapic_route_legacy_irq (
            uint8_t isa_irq,
            uint8_t vector,
            uint8_t dest_apic_id )
```

Program a redirection entry for a legacy ISA IRQ, initially masked.

Honors an Interrupt Source Override for `isa_irq` if the MADT had one (different GSI, polarity, or trigger mode); otherwise uses the ISA default (GSI == isa_irq, active-high, edge-triggered) per the ACPI specification's "conforms to bus" default.

Parameters

isa_irq	Legacy IRQ number (0-15).
vector	IDT vector to deliver (e.g. 0x21).
dest_apic↩ _id	Destination Local APIC ID (see apic_id()).

Returns

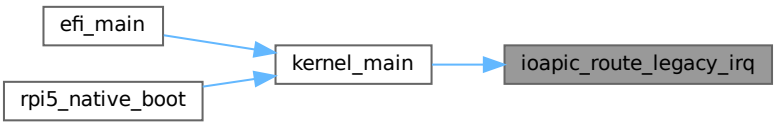
0 on success, -1 if ioapic_init() has not succeeded.

References flags, g_ioapic_gsi_base, g_ioapic_ready, g_override_count, g_overrides, g_redir_low, g_redir_valid, ioapic_write(), ISO_POLARITY_LOW, ISO_POLARITY_MASK, ISO_TRIGGER_LEVEL, ISO_TRIGGER_MASK, and MAX_REDIR_ENTRIES.

Referenced by kernel_main().

Here is the call graph for this function:

Here is the caller graph for this function:



7.104.2.3 ioapic_unmask_legacy_irq()

```
void ioapic_unmask_legacy_irq (
            uint8_t isa_irq )
```

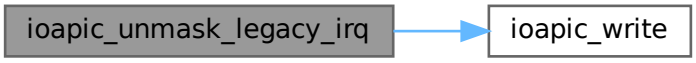
Clear the mask bit on a previously routed legacy IRQ's redirection entry.

Call only after ioapic_route_legacy_irq() has programmed it.

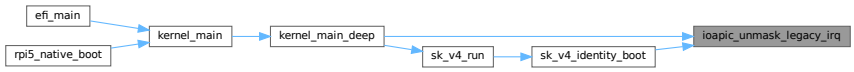
References g_ioapic_gsi_base, g_ioapic_ready, g_override_count, g_overrides, g_redir_low, g_redir_valid, ioapic_write(), and MAX_REDIR_ENTRIES.

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.104.2.4 ioapic_write()

```
static void ioapic_write (
            uint8_t reg,
            uint32_t val )  [static]
```

References g_ioapic_base.

Referenced by ioapic_route_legacy_irq(), and ioapic_unmask_legacy_irq().

Here is the caller graph for this function:

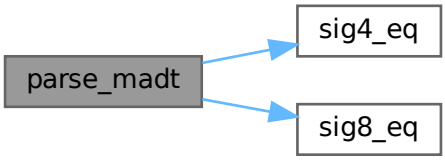
7.104.2.5 parse_madt()

```
static int parse_madt (
            void * rsdp )  [static]
```

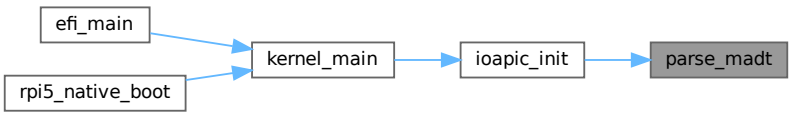
References g_ioapic_base, g_ioapic_gsi_base, g_override_count, g_overrides, MADT_TYPE_INT_SRC, MADT_TYPE_IOAPIC, MAX_OVERRIDES, sig4_eq(), sig8_eq(), and __attribute__::xsdt_address.

Referenced by ioapic_init().

Here is the call graph for this function:



Here is the caller graph for this function:

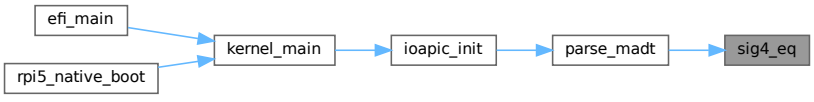


7.104.2.6 sig4_eq()

```
static int sig4_eq (
            const uint8_t * p,
            const char * s )  [static]
```

Referenced by parse_madt().

Here is the caller graph for this function:

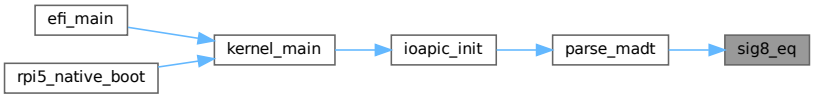


7.104.2.7 sig8_eq()

```
static int sig8_eq (
            const uint8_t * p,
            const char * s )  [static]
```

Referenced by parse_madt().

Here is the caller graph for this function:



7.104.3 Variable Documentation

7.104.3.1 g_ioapic_base

```
uint64_t g_ioapic_base = 0  [static]
```

Referenced by ioapic_init(), ioapic_write(), and parse_madt().

7.104.3.2 g_ioapic_gsi_base

```
uint32_t g_ioapic_gsi_base = 0  [static]
```

Referenced by ioapic_init(), ioapic_route_legacy_irq(), ioapic_unmask_legacy_irq(), and parse_madt().

7.104.3.3 g_ioapic_ready

```
int g_ioapic_ready = 0  [static]
```

Referenced by ioapic_init(), ioapic_route_legacy_irq(), and ioapic_unmask_legacy_irq().

7.104.3.4 g_override_count

```
int g_override_count = 0  [static]
```

Referenced by ioapic_init(), ioapic_route_legacy_irq(), ioapic_unmask_legacy_irq(), and parse_madt().

7.104.3.5 g_overrides

```
MadtIntSrcOverride g_overrides[16]  [static]
```

Referenced by ioapic_init(), ioapic_route_legacy_irq(), ioapic_unmask_legacy_irq(), and parse_madt().

7.104.3.6 g_redir_low

```
uint32_t g_redir_low[24]  [static]
```

Referenced by ioapic_route_legacy_irq(), and ioapic_unmask_legacy_irq().

7.104.3.7 g_redir_valid

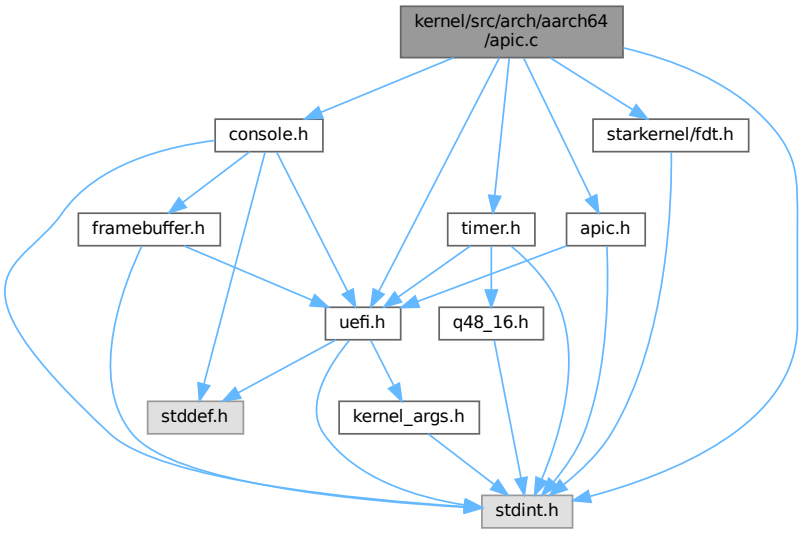
```
int g_redir_valid[24]  [static]
```

Referenced by ioapic_route_legacy_irq(), and ioapic_unmask_legacy_irq().

7.105 kernel/src/arch/aarch64/apic.c File Reference

```
#include "apic.h"
#include "uefi.h"
#include "console.h"
#include "timer.h"
#include "starkernel/fdt.h"
#include <stdint.h>
```

Include dependency graph for apic.c:



Macros

- #define GICD_BASE_PA_QEMU_DEFAULT 0x08000000UL
- #define GICC_BASE_PA_QEMU_DEFAULT 0x08010000UL
- #define TIMER_PPI_EL1 30u
- #define TIMER_PPI_EL2 26u
- #define GICD_CTLR 0x000

- #define GICD_ISENABLER0 0x100
- #define GICD_IPRIORITYR 0x400
- #define GICD_ITARGETSR 0x800 /∗ item 4.3.5d -- SPI target-CPU byte array ∗/
- #define GICD_ICFGR 0xC00
- #define GICD_ISPENDR 0x200 /∗ item 4.3.5d -- software set-pending, SPIs only ∗/
- #define GICC_CTLR 0x00
- #define GICC_PMR 0x04
- #define GICC_IAR 0x0C
- #define GICC_EOIR 0x10
- #define GICD_CTLR_ENABLE_GRP0 (1u << 0)
- #define GICC_CTLR_ENABLE_GRP0 (1u << 0)
- #define TIMER_PRIORITY 0x80u
- #define PMR_ALLOW_ALL 0xFFu

Functions

- int aarch64_current_el (void)

  apic.c (aarch64) - Minimal GICv2 driver + ARM Generic Timer (items 0.6/0.7/ 4.3.5d).
- void aarch64_psci_conduit_init (const void ∗dtb)

  Discover the real PSCI conduit ("smc" vs "hvc") from the DTB.
- static void mmio_write32 (uintptr_t base, uint32_t offset, uint32_t val)
- static uint32_t mmio_read32 (uintptr_t base, uint32_t offset)
- static int gic_bases_from_dtb (const void ∗dtb, uintptr_t ∗gicd_out, uintptr_t ∗gicc_out)

  Try to discover the real GICD/GICC base addresses from the DTB.
- int apic_init (BootInfo ∗boot_info)

  Initialise the GICv2 distributor and CPU interface (M4 milestone).
- void apic_spi_enable (uint32_t intid)

  Enable and route one SPI (item 4.3.5d).
- uint32_t apic_read_iar (void)

  Read the GIC CPU interface's Interrupt Acknowledge Register.
- uint32_t apic_timer_ppi (void)

  Return the timer PPI this build is watching for.
- void apic_eoi_intid (uint32_t intid)

  Signal End of Interrupt to the GIC CPU interface.
- void apic_eoi (void)

  Signal End of Interrupt (common cross-ISA signature — see below).
- int apic_timer_init (uint64_t tsc_hz, uint32_t tick_hz)

  Compute the expected system-counter ticks per heartbeat period.
- void apic_timer_start (void)

  Arm the ARM Generic Timer and enable its interrupt (item 0.7).
- void apic_timer_rearm (void)

  Re-arm the ARM Generic Timer for the next period (item 0.7).
- void apic_timer_stop (void)

  Stop timer delivery by clearing CTL.ENABLE (item 0.7).
- uint64_t apic_timer_period_tsc (void)

  Return the expected system-counter ticks per heartbeat period.

Variables

- static uintptr_t s_gicd_base = 0x08000000UL
- static uintptr_t s_gicc_base = 0x08010000UL
- static uint32_t s_timer_ppi = 30u
- static uint64_t s_timer_period_tsc = 0
- static uint64_t s_counter_hz_apic = 0

7.105.1 Macro Definition Documentation

7.105.1.1 GICC_BASE_PA_QEMU_DEFAULT

```
#define GICC_BASE_PA_QEMU_DEFAULT 0x08010000UL
```

7.105.1.2 GICC_CTLR

```
#define GICC_CTLR 0x00
```

7.105.1.3 GICC_CTLR_ENABLE_GRP0

```
#define GICC_CTLR_ENABLE_GRP0 (1u << 0)
```

7.105.1.4 GICC_EOIR

```
#define GICC_EOIR 0x10
```

7.105.1.5 GICC_IAR

```
#define GICC_IAR 0x0C
```

7.105.1.6 GICC_PMR

```
#define GICC_PMR 0x04
```

7.105.1.7 GICD_BASE_PA_QEMU_DEFAULT

```
#define GICD_BASE_PA_QEMU_DEFAULT 0x08000000UL
```

7.105.1.8 GICD_CTLR

```
#define GICD_CTLR 0x000
```

7.105.1.9 GICD_CTLR_ENABLE_GRP0

```
#define GICD_CTLR_ENABLE_GRP0 (1u << 0)
```

7.105.1.10 GICD_ICFGR

```
#define GICD_ICFGR 0xC00
```

7.105.1.11 GICD_IPRIORITYR

```
#define GICD_IPRIORITYR 0x400
```

7.105.1.12 GICD_ISENABLER0

```
#define GICD_ISENABLER0 0x100
```

7.105.1.13 GICD_ISPENDR

```
#define GICD_ISPENDR 0x200 /* item 4.3.5d -- software set-pending, SPIs only */
```

7.105.1.14 GICD_ITARGETSR

```
#define GICD_ITARGETSR 0x800 /* item 4.3.5d -- SPI target-CPU byte array */
```

7.105.1.15 PMR_ALLOW_ALL

```
#define PMR_ALLOW_ALL 0xFFu
```

7.105.1.16 TIMER_PPI_EL1

```
#define TIMER_PPI_EL1 30u
```

7.105.1.17 TIMER_PPI_EL2

```
#define TIMER_PPI_EL2 26u
```

7.105.1.18 TIMER_PRIORITY

```
#define TIMER_PRIORITY 0x80u
```

7.105.2 Function Documentation

7.105.2.1 aarch64_current_el()

```
int aarch64_current_el (
            void  )  [extern]
```

apic.c (aarch64) - Minimal GICv2 driver + ARM Generic Timer (items 0.6/0.7/ 4.3.5d).

"Minimal" is deliberate and stays deliberate: item 0.6 enabled exactly one PPI (the timer); item 4.3.5d adds the ability to enable exactly one SPI (for virtio-keyboard-pci, item 4.3.5e), still by explicit per-INTID call, not a general GIC driver – no SGI support, no GICv3/ITS, no SPI beyond the one 4.3.5e will actually enable.

GICD/GICC base addresses – DTB-discovered when a DTB is present, QEMU virt-machine constants otherwise (FABRIC-3.md ?IV.3 item 7, 2026-09-04 fix; originally recorded as a deliberate hardcode, FABRIC-0.md item 0.6 GAP-B1 follow-up, because `fdt_valid(boot_info->dtb)` fails on this system's QEMU aarch64 firmware – qemu-efi-aarch64 2025.11-3ubuntu7 does not forward a devicetree to the guest, confirmed live rather than assumed). That reasoning covered the QEMU/UEFI path correctly but never covered the native Pi 5 boot path (`rpi5_native_boot.c`), which receives a real DTB directly and calls this same, unmodified `apic_init()` – audited 2026-09-04, found still hardcoding the QEMU addresses unconditionally, which blocks reaching `ok>` on real BCM2712 hardware (its real GIC-400 sits at `0x10_7fff9000`, nowhere near QEMU's `0x08000000`). `gic_bases_from_dtb()` below closes that gap: tries DTB discovery first, falls back to the QEMU constants only when no DTB is present or the GIC node isn't found there – so the QEMU/UEFI path's existing, working behaviour is unchanged.

QEMU's own values were not recalled from memory either – they were read out of QEMU 10.2.1's own internal devicetree (`qemu-system-aarch64 -machine virt,dumpdtb=...`, decoded with this tree's own fdt.c reader) and are therefore correct for this exact QEMU version, though not guaranteed stable across others. Register *offsets* within each block (GICD_CTLR, GICC_IAR, etc.) are fixed by the GICv2 architecture, not the board, and were cross-checked against Linux's own driver header (linux/irqchip/arm-gic.h, from the linux-headers package installed on the build host) rather than recalled either.

apic.c (aarch64) - Minimal GICv2 driver + ARM Generic Timer (items 0.6/0.7/ 4.3.5d).

Reads `CurrentEL` (bits [3:2] hold the EL number, [1:0] are RES0) on first call and caches the result; every later call returns the cached value. Safe to call at any point in boot, including before `console_init()` — the read itself has no dependency, only the printing of it does (see `arch_interrupts_init()` in `interrupts.c`, the earliest point at which both this and a working console are available).

EDK2 on QEMU's aarch64 `virt` machine has been observed to leave the kernel at either EL1 or EL2 depending on firmware build; nothing in this tree may assume one over the other (FABRIC-0.md ?25.7.1 GAP-B3). Every EL-dependent choice — `VBAR_EL1` vs `VBAR_EL2`, the `ELR_ELx` / `SPSR_ELx` saved-state pair, and `CNTP_*_EL0` vs `CNTHP_*_EL2` — must read this accessor rather than hardcode a level.

Returns

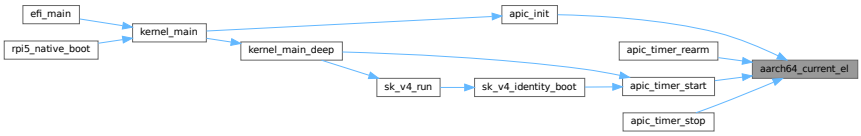
1 or 2. Never 0 or 3: a UEFI application that survived far enough to reach this call cannot be running at EL0 (unprivileged) or EL3 (secure monitor — QEMU's virt firmware runs the kernel at EL1/EL2).

References current_el(), and s_current_el.

Referenced by apic_init(), apic_timer_rearm(), apic_timer_start(), and apic_timer_stop().

Here is the call graph for this function:

Here is the caller graph for this function:



7.105.2.2 aarch64_psci_conduit_init()

```
void aarch64_psci_conduit_init (
            const void * dtb )  [extern]
```

Discover the real PSCI conduit ("smc" vs "hvc") from the DTB.

Looks up the devicetree's PSCI firmware node and reads its `method` property. BCM2712's own `/psci` node declares `compatible = "arm,psci-1.0", "arm,psci-0.2", "arm,psci"` and `method = "smc"` – confirmed directly against `bcm2712.dtsi`, not assumed. `fdt_find_node_by_compatible()` matches any entry in a node's compatible list, so searching for just the first (most specific) string is sufficient; the other two exist for older PSCI-spec-version consumers, not because this node might be tagged differently.

Leaves `s_psci_use_smc` at its default (0, HVC) if `dtb` is not a valid FDT, no PSCI node is found, or `method` is anything other than exactly `"smc"` – including the explicit `"hvc"` case, and the "property absent" case, both of which should keep the existing HVC behaviour rather than guess.

Called once from `apic_init()` (`arch/aarch64/apic.c`), the one point in boot that already has `boot_info->dtb` in hand at the right time for this kind of discovery (same rationale as that file's own GIC-base lookup) – collocated here in `arch.c`, not there, because `arch_cold_reset()` is this function's actual consumer and has no `boot_info` of its own to probe with by the time it runs (called from deep in VM execution, via `BYE`). Same extern-in-place convention this file and apic.c already use for `aarch64_current_el()`.

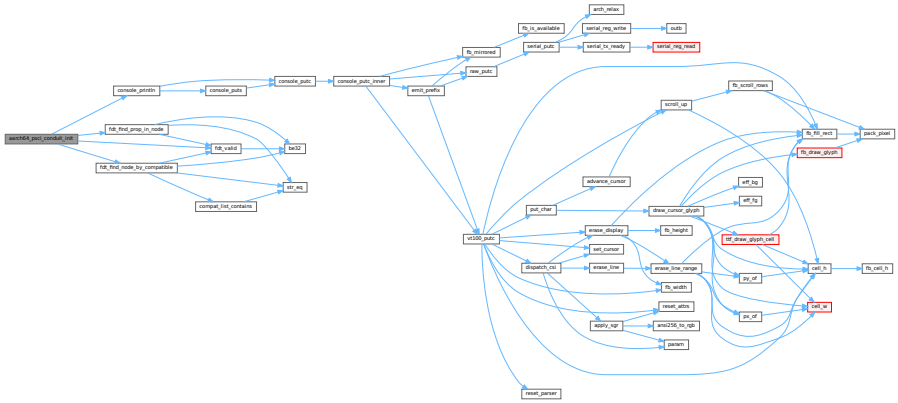
Parameters

dtb	Candidate devicetree blob (`BootInfo->dtb`); NULL-safe.

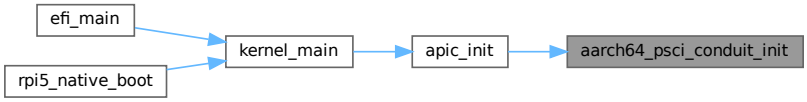
References console_println(), fdt_find_node_by_compatible(), fdt_find_prop_in_node(), fdt_valid(), and s_psci_use_smc.

Referenced by apic_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.105.2.3 apic_eoi()

```
void apic_eoi (
            void  )
```

Signal End of Interrupt (common cross-ISA signature — see below).

The shared `apic.h` interface has no way to pass which interrupt is being completed, but GICv2's `GICC_EOIR` needs the exact INTID `GICC_IAR` returned, not just "an" EOI. `aarch64_irq_handler()` calls `apic_eoi_intid()` directly with that value instead; this form exists only to satisfy the common call site and is not used on the interrupt path GIC brings up.

7.105.2.4 apic_eoi_intid()

```
void apic_eoi_intid (
            uint32_t intid )
```

Signal End of Interrupt to the GIC CPU interface.

Writes `intid` back to `GICC_EOIR`, matching the value `GICC_IAR` returned in `aarch64_irq_handler()`. Required after every acknowledged interrupt or the GIC considers it permanently active and will not re-signal it.

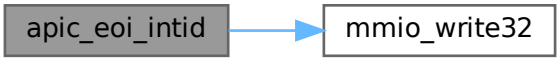
Parameters

intid	INTID as read from `GICC_IAR` (10 bits used by GICv2).

References GICC_EOIR, mmio_write32(), and s_gicc_base.

Referenced by aarch64_irq_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

7.105.2.5 apic_init()

```
int apic_init (
            BootInfo * boot_info )
```

Initialise the GICv2 distributor and CPU interface (M4 milestone).

Enables exactly one interrupt source: the physical timer PPI for the exception level detected in item 0.4 (30 at EL1, 26 at EL2 — see `TIMER_PPI_EL1` / `TIMER_PPI_EL2` above). Sequence:

0. Try `gic_bases_from_dtb()` against `boot_info->dtb`; on success, `s_gicd_base` / `s_gicc_base` are overridden from the real hardware addresses. On failure (no DTB, e.g. this system's QEMU/UEFI firmware — see file header) they keep the QEMU constant defaults, exactly the behaviour this function had before this step existed.

1. Set this interrupt's priority (`GICD_IPRIORITYR`) below the CPU interface's priority mask, so it is never itself masked out.
2. Enable it in `GICD_ISENABLER0` (PPIs 16–31 live in the first word).
3. Enable the distributor, Group 0 only (`GICD_CTLR`) — this deployment has no GICv2 security-extension split in use.
4. Set the CPU interface priority mask to allow everything through (`GICC_PMR` = 0xFF) and enable the CPU interface (`GICC_CTLR`).

Deliberately not configured: `GICD_ICFGR` (trigger sensitivity). The ARM generic timer's PPI is architecturally level-sensitive; this is not a general GIC driver and item 0.6's own scope does not call for reconfiguring it.

Parameters

boot_info	Kernel `BootInfo`; `dtb` is consulted for real-hardware GIC base discovery as of the 2026-09-04 fix (previously unused — see file header), and, as of the same fix, for `aarch64_psci_conduit_init()`'s PSCI conduit discovery (arch.c) — bundled into this call for the same reason GIC discovery is: this is the one point in boot with `boot_info->dtb` already in hand.

Returns

0 always.

7.105.2.6 apic_read_iar()

```
uint32_t apic_read_iar (
            void  )
```

Read the GIC CPU interface's Interrupt Acknowledge Register.

Reading `GICC_IAR` returns the INTID of the highest-priority pending interrupt and simultaneously moves it to the active state — this is the GICv2 acknowledgement step. Called from `aarch64_irq_handler()` in `interrupts.c` to identify which interrupt fired; the matching `apic_eoi_intid()` call below completes it.

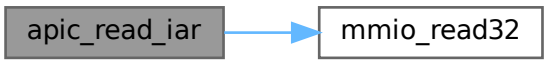
Returns

INTID (10 bits used by GICv2).

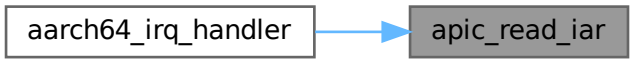
References GICC_IAR, mmio_read32(), and s_gicc_base.

Referenced by aarch64_irq_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.105.2.7 apic_spi_enable()

```
void apic_spi_enable (
            uint32_t intid )
```

Enable and route one SPI (item 4.3.5d).

Extends item 0.6's PPI-only init just far enough to bring up one Shared Peripheral Interrupt – still not a general GIC driver, still one explicit INTID per call, same bounded-scope posture 0.6 used.

Programs, for `intid` (expected range: SPIs, INTID >= 32):

1. `GICD_IPRIORITYR` (byte-indexed, same pattern `apic_init()` already uses for the timer PPI) – `TIMER_PRIORITY`, below `PMR_ALLOW_ALL`.
2. `GICD_ISENABLER` at `0x100` + 4*(intid/32) – PPIs/SGIs (0-31) live in word 0 (`GICD_ISENABLER0`); SPIs beyond use word `intid/32`, same architecture layout, not board-specific.
3. `GICD_ITARGETSR` (byte-indexed like IPRIORITYR) – routes to CPU 0 only; this target has no `-smp`, so no other bit is ever valid.
4. `GICD_ICFGR` is read back, not written, unless the readback disagrees with the expected level-triggered configuration – FABRIC-0.md ?27.5.1's decoded QEMU `interrupt-map` says PCI legacy INTx on this board already is level-triggered by default, so this keeps item 0.6's "don't touch ICFGR unless forced to" posture rather than writing it unconditionally.

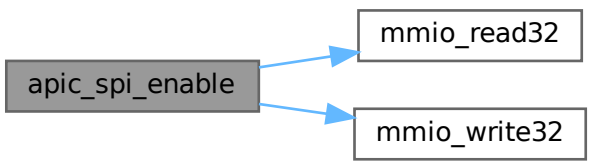
Does **not** touch `GICD_CTLR` or `GICC_CTLR/PMR` – `apic_init()` already enabled the distributor and CPU interface for the timer PPI, and those are global, not per-INTID; nothing here needs to repeat that.

Parameters

intid	Target SPI's INTID (32 + GIC SPI number).

References GICD_ICFGR, GICD_IPRIORITYR, GICD_ISENABLER0, GICD_ITARGETSR, mmio_read32(), mmio_write32(), s_gicd_base, and TIMER_PRIORITY.

Here is the call graph for this function:



7.105.2.8 apic_timer_init()

```
int apic_timer_init (
```

```
            uint64_t tsc_hz,
            uint32_t tick_hz )
```

Compute the expected system-counter ticks per heartbeat period.

Computes s_timer_period_tsc (the expected number of CNTPCT_EL0 ticks between heartbeats), used both by heartbeat_init() to seed the rolling-window expected_delta and by apic_timer_start() / apic_timer_rearm() (item 0.7) as the TVAL step written on every arm and re-arm.

If either tsc_hz or tick_hz is zero, a fallback of 10,000,000 ticks is stored (approximately 160 ms at 62.5 MHz, a safe non-zero sentinel that prevents division-by-zero in the heartbeat path).

Parameters

tsc_hz	System counter frequency from timer_init() (Hz).
tick_hz	Desired heartbeat rate (Hz); 0 → uses fallback.

Returns

0 always.

7.105.2.9 apic_timer_period_tsc()

```
uint64_t apic_timer_period_tsc (
            void  )
```

Return the expected system-counter ticks per heartbeat period.

Get the configured timer period in TSC ticks.

Returns s_timer_period_tsc, set by apic_timer_init() as tsc_hz / tick_hz. This value is consumed by heartbeat_init() to seed the rolling-window expected_delta so that inter-tick deviation measurements are relative to the correct nominal interval.

Returns

Expected CNTPCT_EL0 ticks per heartbeat period; 10,000,000 if frequencies were not available at init time.

7.105.2.10 apic_timer_ppi()

```
uint32_t apic_timer_ppi (
            void  )
```

Return the timer PPI this build is watching for.

Set once in apic_init() from aarch64_current_el() (30 at EL1, 26 at EL2). aarch64_irq_handler() compares apic_read_iar() 's result against this rather than a hardcoded constant.

References s_timer_ppi.

Referenced by aarch64_irq_handler().

Here is the caller graph for this function:

7.105.2.11 apic_timer_rearm()

```
void apic_timer_rearm (
            void  )
```

Re-arm the ARM Generic Timer for the next period (item 0.7).

Re-arm the APIC timer at the current adaptive period (item 0.8, ?26).

Writes a fresh `TVAL` — the entirety of a periodic re-arm, since `TVAL` is relative to "now" rather than an absolute deadline. Unlike riscv64's SBI re-arm (item 0.3), there is no drift-correction bookkeeping: each write means "@c s_timer_period_tsc ticks from this instant," so time spent servicing the interrupt before this call simply lengthens that one period rather than accumulating error across ticks.

This is the one call that must never be skipped. The ARM Generic Timer does not auto-reload: once `TVAL` crosses zero, `CTL.ISTATUS` latches and stays asserted — a level condition — until software writes a new `TVAL` or clears `CTL.ENABLE`. A return path that skips this leaves the interrupt permanently pending, which the GIC would deliver again the instant it is EOI'd: a real interrupt storm, not a hypothetical one (this is exactly the failure this driver was checked against during item 0.6's own verification, and confirmed absent there only because nothing armed the timer yet).

Called from `aarch64_irq_handler()` (interrupts.c) before `heartbeat_tick()` — same ordering discipline as `riscv64_timer_rearm()` (item 0.3): re-arm first, so a fault in the rest of the handler cannot also cost the next tick.

The step written is `heartbeat_next_period_ns()` (item 0.8, ?26) converted to `CNTPCT_EL0` ticks via `s_counter_hz_apic`, not the fixed `s_timer_period_tsc` `apic_timer_start()` used for the very first arm – that value remains `apic_timer_period_tsc()'s` return for `heartbeat_init()'s` initial `expected_delta`, unchanged.

7.105.2.12 apic_timer_start()

```
void apic_timer_start (
            void  )
```

Arm the ARM Generic Timer and enable its interrupt (item 0.7).

Start the APIC timer (enables periodic interrupts).

Writes `CNTP_TVAL_EL0` (or `CNTHP_TVAL_EL2` at EL2 — `aarch64_current_el()`, same EL-aware discipline as items 0.4–0.6) to `s_timer_period_tsc`, then sets `CTL.ENABLE=1`, `CTL.IMASK=0`.

TVAL is a signed 32-bit *relative* countdown — writing it sets "fire @c s_timer_period_tsc ticks from this instant," unlike riscv64's SBI interface (item 0.3), which takes an absolute deadline the caller must compute. No "now" reading is needed here at all.

The ISB after the CTL write is required, not decorative: per the architecture, and confirmed against Linux's own arch_timer_reg_write_cp15() (arch/arm64/include/asm/arch_timer.h), only the *control* register write needs synchronising before the enable/mask state is guaranteed visible to the interrupt pipeline — TVAL/CVAL writes do not carry the same requirement, which is why apic_timer_rearm() below omits it.

s_timer_period_tsc must already be set by apic_timer_init(). If it is still 0, TVAL=0 fires immediately and continuously until apic_timer_rearm() runs — a correctly-functioning if oddly-paced timer, not a hang.

7.105.2.13 apic_timer_stop()

```
void apic_timer_stop (
            void  )
```

Stop timer delivery by clearing CTL.ENABLE (item 0.7).

Stop the APIC timer (disables periodic interrupts).

Per the architecture, ENABLE=0 unconditionally stops the count and de-asserts the interrupt condition regardless of IMASK — a single write is sufficient, no separate mask step needed.

7.105.2.14 gic_bases_from_dtb()

```
static int gic_bases_from_dtb (
            const void * dtb,
            uintptr_t * gicd_out,
            uintptr_t * gicc_out )  [static]
```

Try to discover the real GICD/GICC base addresses from the DTB.

Looks up the "arm,gic-400" node and reads its reg property's first two entries. Returns 0 (leaving gicd_out / gicc_out untouched) if dtb is not a valid FDT, no matching node exists, or the reg property is shorter than two entries – callers must keep their own QEMU-constant default in that case, exactly as before this function existed (FABRIC-3.md ?IV.3 item 7 fix, 2026-09-04; see file header for why this is needed on the native Pi 5 path specifically).

Parameters

dtb	Candidate devicetree blob (BootInfo->dtb); NULL-safe.
gicd_out	Receives the distributor base address on success.
gicc_out	Receives the CPU interface 0 base address on success.

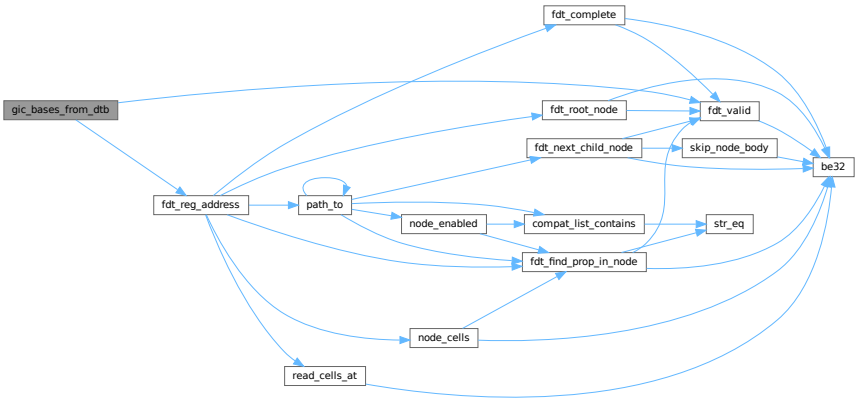
Returns

1 on success, 0 if discovery failed for any reason.

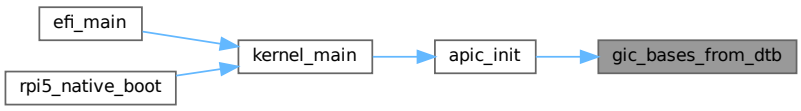
References fdt_reg_address(), and fdt_valid().

Referenced by apic_init().

Here is the call graph for this function:



Here is the caller graph for this function:



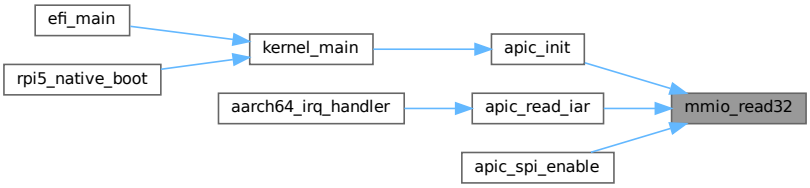
7.105.2.15 mmio_read32()

```
static uint32_t mmio_read32 (
            uintptr_t base,
            uint32_t offset )  [inline], [static]
```

References base.

Referenced by apic_init(), apic_read_iar(), and apic_spi_enable().

Here is the caller graph for this function:



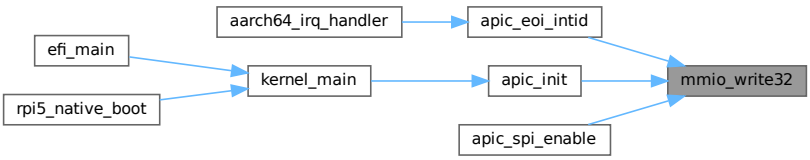
7.105.2.16 mmio_write32()

```
static void mmio_write32 (
            uintptr_t base,
            uint32_t offset,
            uint32_t val )  [inline], [static]
```

References base.

Referenced by apic_eoi_intid(), apic_init(), and apic_spi_enable().

Here is the caller graph for this function:



7.105.3 Variable Documentation

7.105.3.1 s_counter_hz_apic

```
uint64_t s_counter_hz_apic = 0  [static]
```

Referenced by apic_timer_init(), and apic_timer_rearm().

7.105.3.2 s_gicc_base

```
uintptr_t s_gicc_base = 0x08010000UL  [static]
```

Referenced by apic_eoi_intid(), apic_init(), and apic_read_iar().

7.105.3.3 s_gicd_base

```
uintptr_t s_gicd_base = 0x08000000UL  [static]
```

Referenced by apic_init(), and apic_spi_enable().

7.105.3.4 s_timer_period_tsc

```
uint64_t s_timer_period_tsc = 0  [static]
```

Referenced by apic_timer_init(), apic_timer_period_tsc(), apic_timer_rearm(), apic_timer_start(), and riscv64_timer_rearm().

7.105.3.5 s_timer_ppi

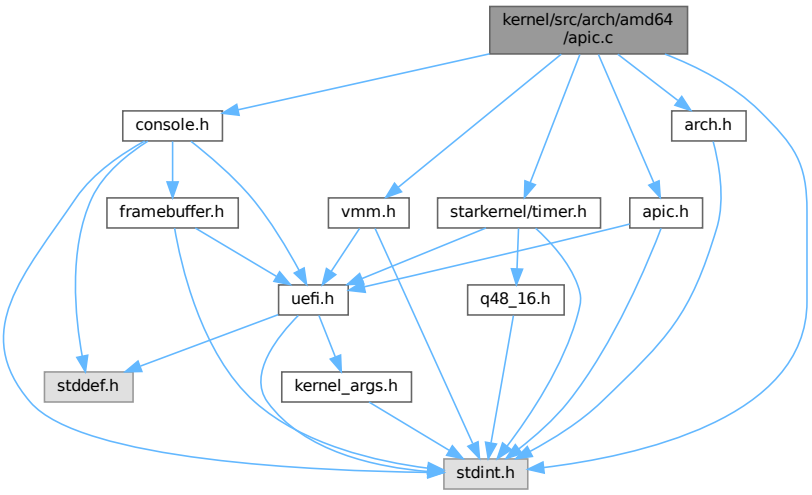
```
uint32_t s_timer_ppi = 30u  [static]
```

Referenced by apic_init(), and apic_timer_ppi().

7.106 kernel/src/arch/amd64/apic.c File Reference

```
#include <stdint.h>
#include "apic.h"
#include "console.h"
#include "vmm.h"
#include "arch.h"
#include "starkernel/timer.h"
```

Include dependency graph for apic.c:



Macros

- #define LAPIC_DEFAULT_PHYS 0xFEE00000u

  apic.c - Local APIC and Timer (amd64)
- #define LAPIC_VIRT_BASE 0xFEE00000u /* identity-mapped */
- #define IA32_APIC_BASE_MSR 0x1Bu
- #define IA32_APIC_BASE_GLOBAL_EN (1ull << 11) /* Global APIC hardware enable */
- #define IA32_APIC_BASE_X2APIC_EN (1ull << 10) /* x2APIC mode enable */
- #define APIC_REG_ID 0x020 /* APIC ID */
- #define APIC_REG_TPR 0x080 /* Task Priority Register */
- #define APIC_REG_EOI 0x0B0 /* End of Interrupt */
- #define APIC_REG_SIVR 0x0F0 /* Spurious Interrupt Vector Register */
- #define APIC_REG_LVT_TIMER 0x320 /* LVT Timer Register */
- #define APIC_REG_TIMER_ICR 0x380 /* Timer Initial Count Register */
- #define APIC_REG_TIMER_CCR 0x390 /* Timer Current Count Register */
- #define APIC_REG_TIMER_DCR 0x3E0 /* Timer Divide Configuration Register */

- #define LVT_MASKED (1u << 16) /* Interrupt masked */
- #define LVT_MODE_PERIODIC (1u << 17) /* Periodic mode */
- #define LVT_MODE_ONESHOT 0 /* One-shot mode (default) */
- #define TIMER_DIV_1 0x0B /* Divide by 1 */
- #define TIMER_DIV_2 0x00 /* Divide by 2 */
- #define TIMER_DIV_4 0x01 /* Divide by 4 */
- #define TIMER_DIV_8 0x02 /* Divide by 8 */
- #define TIMER_DIV_16 0x03 /* Divide by 16 */
- #define TIMER_DIV_32 0x08 /* Divide by 32 */
- #define TIMER_DIV_64 0x09 /* Divide by 64 */
- #define TIMER_DIV_128 0x0A /* Divide by 128 */
- #define APIC_REG_ISR_BASE 0x100

Functions

- static uint64_t rdmsr64 (uint32_t msr)

  Read a 64-bit Model Specific Register via `RDMSR`.
- static void wrmsr64 (uint32_t msr, uint64_t val)

  Write a 64-bit value to a Model Specific Register via `WRMSR`.
- static void lapic_write (uint32_t reg, uint32_t val)

  Write a 32-bit value to a Local APIC MMIO register.
- static uint32_t lapic_read (uint32_t reg)

  Read a 32-bit value from a Local APIC MMIO register.
- int apic_init (BootInfo *boot_info)

  Initialise the Local APIC in xAPIC MMIO mode.
- void apic_eoi (void)

  Signal End of Interrupt to the Local APIC.
- uint8_t apic_id (void)

  Return this CPU's xAPIC ID.
- static uint32_t calibrate_apic_timer (uint64_t tsc_hz)

  Calibrate the APIC timer against the TSC to determine its frequency.
- int apic_timer_init (uint64_t tsc_hz, uint32_t tick_hz)

  Initialise and configure the APIC timer for periodic heartbeat delivery.
- void apic_timer_start (void)

  Unmask and re-arm the APIC timer to begin periodic interrupt delivery.
- void apic_timer_stop (void)

  Mask the APIC timer to suppress further periodic interrupts.
- void apic_timer_rearm (void)

  Re-arm the APIC timer at the current adaptive period (item 0.8, ?26).
- uint64_t apic_timer_period_tsc (void)

  Return the expected TSC-tick count per APIC heartbeat period.

Variables

- static volatile uint32_t * lapic_base = (volatile uint32_t *)(uintptr_t) 0xFEE00000u
- static uint64_t lapic_phys_base = 0xFEE00000u
- static uint32_t timer_initial_count = 0
- static uint64_t timer_period_tsc_ticks = 0
- static uint32_t timer_tick_hz = 0
- static uint32_t s_apic_hz = 0

7.106.1 Macro Definition Documentation

7.106.1.1 APIC_REG_EOI

```
#define APIC_REG_EOI 0x0B0 /* End of Interrupt */
```

7.106.1.2 APIC_REG_ID

```
#define APIC_REG_ID 0x020 /* APIC ID */
```

7.106.1.3 APIC_REG_ISR_BASE

```
#define APIC_REG_ISR_BASE 0x100
```

7.106.1.4 APIC_REG_LVT_TIMER

```
#define APIC_REG_LVT_TIMER 0x320 /* LVT Timer Register */
```

7.106.1.5 APIC_REG_SIVR

```
#define APIC_REG_SIVR 0x0F0 /* Spurious Interrupt Vector Register */
```

7.106.1.6 APIC_REG_TIMER_CCR

```
#define APIC_REG_TIMER_CCR 0x390 /* Timer Current Count Register */
```

7.106.1.7 APIC_REG_TIMER_DCR

```
#define APIC_REG_TIMER_DCR 0x3E0 /* Timer Divide Configuration Register */
```

7.106.1.8 APIC_REG_TIMER_ICR

```
#define APIC_REG_TIMER_ICR 0x380 /* Timer Initial Count Register */
```

7.106.1.9 APIC_REG_TPR

```
#define APIC_REG_TPR 0x080 /* Task Priority Register */
```

7.106.1.10 IA32_APIC_BASE_GLOBAL_EN

```
#define IA32_APIC_BASE_GLOBAL_EN (1ull << 11) /* Global APIC hardware enable */
```

7.106.1.11 IA32_APIC_BASE_MSR

```
#define IA32_APIC_BASE_MSR 0x1Bu
```

7.106.1.12 IA32_APIC_BASE_X2APIC_EN

```
#define IA32_APIC_BASE_X2APIC_EN (1ull << 10) /* x2APIC mode enable */
```

7.106.1.13 LAPIC_DEFAULT_PHYS

```
#define LAPIC_DEFAULT_PHYS 0xFEE00000u
```

apic.c - Local APIC and Timer (amd64)

Provides:

- APIC initialization
- APIC timer for periodic heartbeat interrupts

7.106.1.14 LAPIC_VIRT_BASE

```
#define LAPIC_VIRT_BASE 0xFEE00000u /* identity-mapped */
```

7.106.1.15 LVT_MASKED

```
#define LVT_MASKED (1u << 16) /* Interrupt masked */
```

7.106.1.16 LVT_MODE_ONESHOT

```
#define LVT_MODE_ONESHOT 0 /* One-shot mode (default) */
```

7.106.1.17 LVT_MODE_PERIODIC

```
#define LVT_MODE_PERIODIC (1u << 17) /* Periodic mode */
```

7.106.1.18 TIMER_DIV_1

```
#define TIMER_DIV_1 0x0B /* Divide by 1 */
```

7.106.1.19 TIMER_DIV_128

```
#define TIMER_DIV_128 0x0A /* Divide by 128 */
```

7.106.1.20 TIMER_DIV_16

```
#define TIMER_DIV_16 0x03 /* Divide by 16 */
```

7.106.1.21 TIMER_DIV_2

```
#define TIMER_DIV_2 0x00 /* Divide by 2 */
```

7.106.1.22 TIMER_DIV_32

```
#define TIMER_DIV_32 0x08 /* Divide by 32 */
```

7.106.1.23 TIMER_DIV_4

```
#define TIMER_DIV_4 0x01 /* Divide by 4 */
```

7.106.1.24 TIMER_DIV_64

```
#define TIMER_DIV_64 0x09 /* Divide by 64 */
```

7.106.1.25 TIMER_DIV_8

```
#define TIMER_DIV_8 0x02 /* Divide by 8 */
```

7.106.2 Function Documentation

7.106.2.1 apic_eoi()

```
void apic_eoi (
            void  )
```

Signal End of Interrupt to the Local APIC.

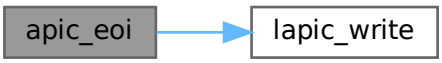
Signal End of Interrupt (common cross-ISA signature — see below).

Writes zero to `APIC_REG_EOI` (offset 0x0B0). This informs the APIC that the currently serviced interrupt has been handled so that the next interrupt in the vector's priority class can be delivered. Must be called at the end of every interrupt service routine before `IRET`; omitting the EOI stalls all future interrupt delivery at the same or lower priority.

For the APIC timer heartbeat path this is called inside `isr_common_handler()` immediately after `heartbeat_tick()`.

References APIC_REG_EOI, and lapic_write().

Here is the call graph for this function:



7.106.2.2 apic_id()

```
uint8_t apic_id (
            void  )
```

Return this CPU's xAPIC ID.

Reads `APIC_REG_ID` and extracts bits 31:24, the xAPIC ID field. Used by the I/O APIC driver (item 4.3.5) as the destination field when programming a redirection entry — interrupts routed to this ID are delivered to the current CPU's Local APIC.

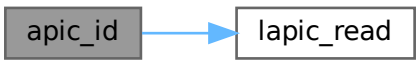
Returns

This CPU's 8-bit xAPIC ID.

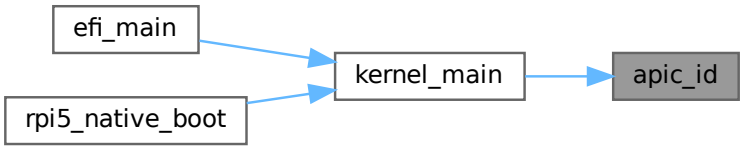
References APIC_REG_ID, and lapic_read().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.106.2.3 apic_init()

```
int apic_init (
            BootInfo * boot_info )
```

Initialise the Local APIC in xAPIC MMIO mode.

Initialise the GICv2 distributor and CPU interface (M4 milestone).

Called during M4 (interrupt controller init) before the IDT is loaded. Performs the following steps:

1. Reads IA32_APIC_BASE_MSR (0x1B) to determine the current APIC mode.
2. If x2APIC mode (bit 10) is active, clears it to switch to xAPIC MMIO mode while keeping the global-enable bit (bit 11) set, as required by Intel SDM Vol.3 ?10.12.5 (never clear both bits simultaneously).
3. If the global-enable bit (bit 11) was clear, sets it.
4. Software-enables the APIC via APIC_REG_SIVR (Spurious Interrupt Vector Register) and assigns spurious vector 0xFF.
5. Clears the Task Priority Register (TPR=0) so all interrupt priorities are delivered; a non-zero TPR left by UEFI would silently suppress all APIC interrupts at or below that priority level.
6. Issues a spurious EOI write to clear any stale in-service interrupt that UEFI may have left pending (specifically the APIC timer vector that fires just before ExitBootServices).

The boot_info parameter is reserved for future use (e.g., reading the ACPI MADT for the physical LAPIC base address); it is currently unused and the default identity-mapped address LAPIC_DEFAULT_PHYS = 0xFEE00000 is always used.

Parameters

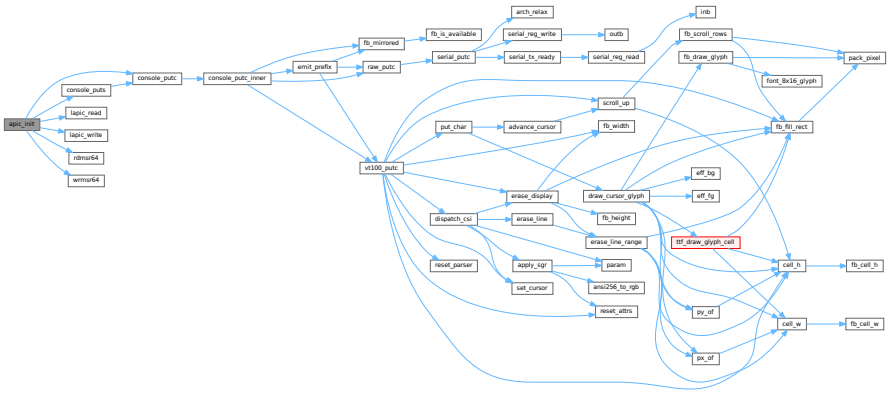
boot_info	Pointer to kernel BootInfo (ACPI/memory-map data); currently unused, reserved for MADT-based LAPIC relocation.

Returns

0 on success (always; the APIC is assumed to be present on x86-64).

References APIC_REG_EOI, APIC_REG_ISR_BASE, APIC_REG_SIVR, APIC_REG_TPR, console_putc(), console_puts(), IA32_APIC_BASE_GLOBAL_EN, IA32_APIC_BASE_MSR, IA32_APIC_BASE_X2APIC_EN, lapic_base, LAPIC_DEFAULT_PHYS, lapic_phys_base, lapic_read(), LAPIC_VIRT_BASE, lapic_write(), rdmsr64(), and wrmsr64().

Here is the call graph for this function:



7.106.2.4 apic_timer_init()

```
int apic_timer_init (
            uint64_t tsc_hz,
            uint32_t tick_hz )
```

Initialise and configure the APIC timer for periodic heartbeat delivery.

Compute the expected system-counter ticks per heartbeat period.

Calibrates the APIC timer frequency via `calibrate_apic_timer()` then programs the LVT Timer Register and Initial Count Register to deliver `APIC_TIMER_VECTOR` periodically at `tick_hz` interrupts per second. The timer is left **masked** after initialisation; call `apic_timer_start()` after the IDT is loaded and interrupts are enabled to begin delivery.

Derived quantities stored for later use:

- `timer_initial_count` — APIC ticks per heartbeat period (`apic_hz` / `tick_hz`), written to `APIC_REG_TIMER_ICR`.
- `timer_tick_hz` — requested tick rate (100 Hz default).
- `timer_period_tsc_ticks` — expected TSC ticks per heartbeat (`tsc_hz` / `tick_hz`), used by `heartbeat_tick()` to compute inter-tick variance for the TIME-TRUST Q48.16 metric.

If `tick_hz` is 0 it defaults to 100 Hz (10 ms period). If calibration returns 0 (no APIC timer detected or counter stuck) the function prints a diagnostic and returns -1 without programming the timer.

Parameters

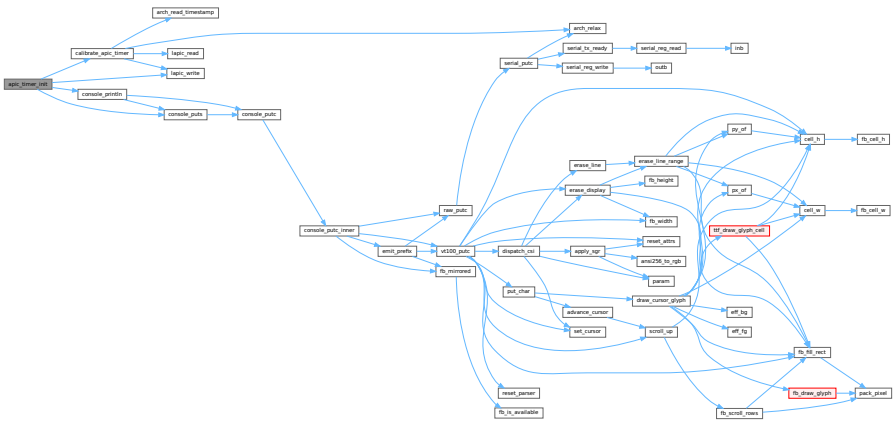
tsc_hz	TSC frequency in Hz (from `timer_init()`); used to derive the 10 ms calibration window and `timer_period_tsc_ticks`. Pass 0 if TSC is not yet calibrated.
tick_hz	Desired interrupt rate in Hz; 0 → defaults to 100 Hz.

Returns

0 on success, -1 if APIC timer calibration failed.

References APIC_REG_LVT_TIMER, APIC_REG_TIMER_DCR, APIC_REG_TIMER_ICR, APIC_TIMER_VECTOR, calibrate_apic_timer(), console_println(), console_puts(), lapic_write(), LVT_MASKED, LVT_MODE_PERIODIC, s_apic_hz, TIMER_DIV_1, timer_initial_count, timer_period_tsc_ticks, and timer_tick_hz.

Here is the call graph for this function:



7.106.2.5 apic_timer_period_tsc()

```
uint64_t apic_timer_period_tsc (
            void  )
```

Return the expected TSC-tick count per APIC heartbeat period.

Get the configured timer period in TSC ticks.

Returns `timer_period_tsc_ticks`, computed by `apic_timer_init()` as `tsc_hz` / `tick_hz`. The value represents the ideal number of TSC ticks that should elapse between consecutive `APIC_TIMER_VECTOR` interrupts when the TSC runs at `tsc_hz` Hz and the heartbeat runs at `tick_hz` Hz.

Used by `timer.c` to seed the heartbeat rolling window with the nominal inter-tick interval so that the first few ticks produce meaningful variance estimates rather than comparing against zero. Returns 0 if `tsc_hz` was 0 at initialisation time (TSC unknown).

Returns

Expected TSC ticks per heartbeat period, or 0 if unavailable.

References timer_period_tsc_ticks.

7.106.2.6 apic_timer_rearm()

```
void apic_timer_rearm (
            void  )
```

Re-arm the APIC timer at the current adaptive period (item 0.8, ?26).

Re-arm the ARM Generic Timer for the next period (item 0.7).

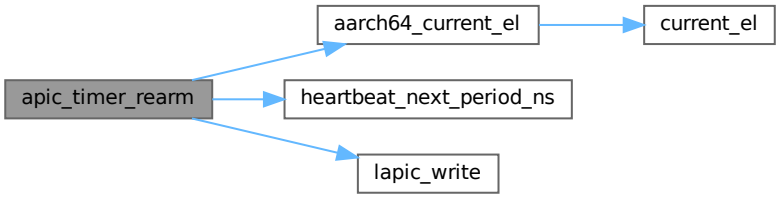
amd64's APIC timer runs in periodic mode: hardware auto-reloads `APIC_REG_TIMER_ICR` on every expiry with no software intervention, unlike riscv64's one-shot SBI deadline or aarch64's one-shot `CNTP_TVAL_EL0` – neither of which needed a rearm function before this item for the same reason this one now exists. To make the period adaptive, this function recomputes `timer_initial_count` from `heartbeat_next_period_ns()` (?26) and `s_apic_hz`, then writes it to `APIC_REG_TIMER_ICR`. A periodic-mode ICR write takes effect immediately and restarts the countdown at the new value – the same mechanism `apic_timer_start()` already relies on to force QEMU TCG's emulated APIC to begin counting.

Called from `isr_common_handler()` on every `APIC_TIMER_VECTOR` interrupt, before `heartbeat_tick()` – same ordering discipline as riscv64/aarch64's rearm-before-heartbeat_tick(), so a fault in `heartbeat_tick()` cannot also cost the next tick.

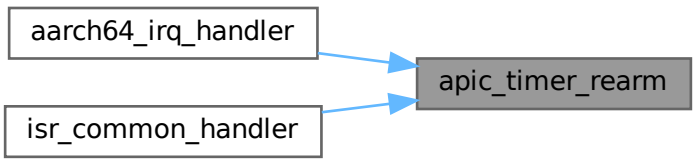
References aarch64_current_el(), APIC_REG_TIMER_ICR, heartbeat_next_period_ns(), lapic_write(), s_apic_hz, s_counter_hz_apic, s_timer_period_tsc, and timer_initial_count.

Referenced by aarch64_irq_handler(), and isr_common_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.106.2.7 apic_timer_start()

```
void apic_timer_start (
            void  )
```

Unmask and re-arm the APIC timer to begin periodic interrupt delivery.

Start the APIC timer (enables periodic interrupts).

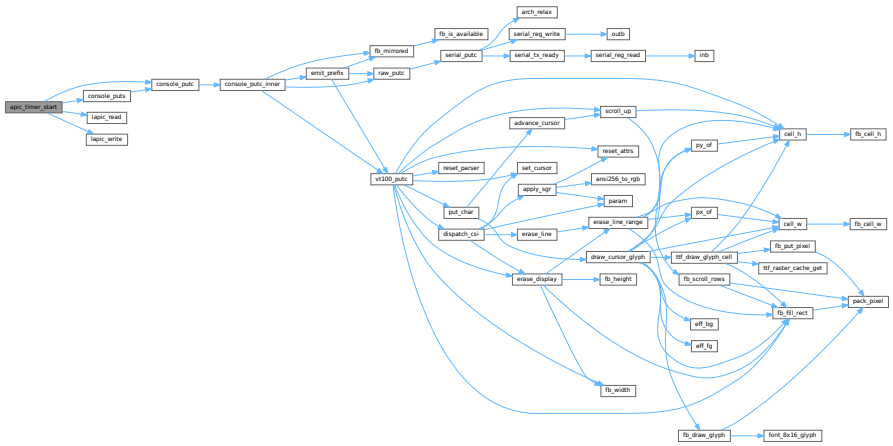
Called after `arch_interrupts_init()` and `arch_enable_interrupts()` to start the 100 Hz heartbeat that drives `heartbeat_tick()`. The sequence is:

1. Read the current LVT Timer Register.
2. Clear the `LVT_MASKED` bit (bit 16) to unmask the interrupt.
3. Write the LVT register back.
4. Write `timer_initial_count` to `APIC_REG_TIMER_ICR` to (re-)arm the countdown. QEMU TCG requires an explicit ICR write after unmask — it does not auto-restart a previously masked periodic timer. On real hardware this is harmless and equally correct.
5. Reads back LVT and ICR values and prints them for boot-log verification.

Must be called exactly once per boot after the IDT is loaded. Calling it again restarts the countdown from the initial value without otherwise reconfiguring the timer.

References APIC_REG_LVT_TIMER, APIC_REG_TIMER_ICR, console_putc(), console_puts(), lapic_read(), lapic_write(), and timer_initial_count.

Here is the call graph for this function:



7.106.2.8 apic_timer_stop()

```
void apic_timer_stop (
            void  )
```

Mask the APIC timer to suppress further periodic interrupts.

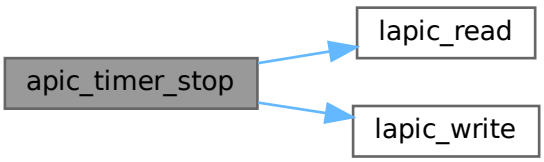
Stop the APIC timer (disables periodic interrupts).

Sets the LVT_MASKED bit (bit 16) in the LVT Timer Register by performing a read-modify-write on APIC↩ _REG_LVT_TIMER. The existing periodic-mode and vector configuration is preserved; only the mask bit changes. The APIC timer's internal countdown continues running but interrupt delivery is suppressed. Calling apic_timer_start() again after this function will unmask and re-arm the timer.

Used in the kernel panic path and during any critical section where heartbeat interrupts would corrupt shared state.

References APIC_REG_LVT_TIMER, lapic_read(), lapic_write(), and LVT_MASKED.

Here is the call graph for this function:



7.106.2.9 calibrate_apic_timer()

```
static uint32_t calibrate_apic_timer (
            uint64_t tsc_hz ) [static]
```

Calibrate the APIC timer against the TSC to determine its frequency.

The APIC timer runs from an internal bus-clock-derived source that has no fixed architectural relationship to the TSC. This function measures the APIC timer frequency empirically using a TSC-timed spin loop:

1. Configures the APIC timer DCR (Divide Configuration Register) to divisor 1 for maximum resolution.
2. Masks the LVT timer entry so no interrupt fires during calibration.
3. Loads the maximum initial count (0xFFFFFFFF) so the counter does not wrap during the measurement window.
4. Spins for a calibration window of `tsc_hz/100` TSC ticks (≈ 10 ms) using `arch_read_timestamp()`. Falls back to 10,000,000 cycles if `tsc_hz` is not yet known.
5. Reads `APIC_REG_TIMER_CCR` and subtracts from 0xFFFFFFFF to get the number of APIC ticks that elapsed in the window.
6. Scales by `tsc_hz` / calibration_tsc_ticks to obtain APIC Hz.

If `tsc_hz` is 0 (TSC not yet calibrated), the APIC count is multiplied by 100 as a rough fallback (assumes the 10M-cycle window was ≈ 10 ms on a 1 GHz core — good enough for initial bringup on QEMU TCG).

Parameters

tsc_hz	TSC frequency in Hz from `timer_init()`; 0 if not yet known.

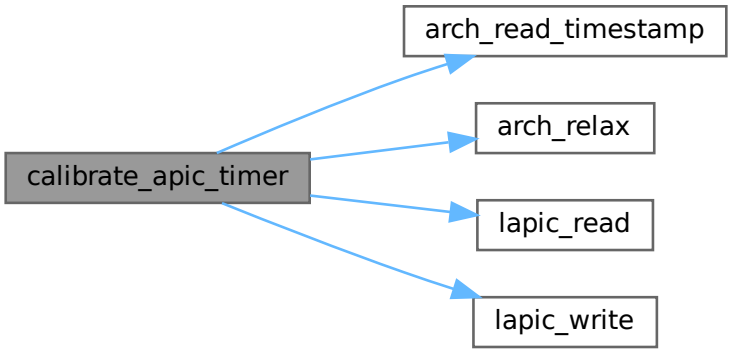
Returns

Measured APIC timer frequency in ticks per second (APIC Hz), or 0 if calibration could not produce a meaningful result.

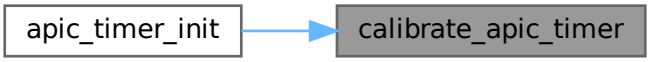
References APIC_REG_LVT_TIMER, APIC_REG_TIMER_CCR, APIC_REG_TIMER_DCR, APIC_REG_TIMER_ICR, arch_read_timestamp(), arch_relax(), lapic_read(), lapic_write(), LVT_MASKED, and TIMER_DIV_1.

Referenced by apic_timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.106.2.10 lapic_read()

```
static uint32_t lapic_read (
            uint32_t reg )  [static]
```

Read a 32-bit value from a Local APIC MMIO register.

Performs a `volatile` 32-bit MMIO load from the register at byte offset `reg` within the LAPIC page. The `volatile` qualifier on `lapic_base` prevents the compiler from caching the value across reads, which is essential for registers that change asynchronously (e.g., `APIC_REG_TIMER_CCR` which counts down independently of the CPU instruction stream).

Parameters

reg	Byte offset of the APIC register (e.g., `APIC_REG_TIMER_CCR`).

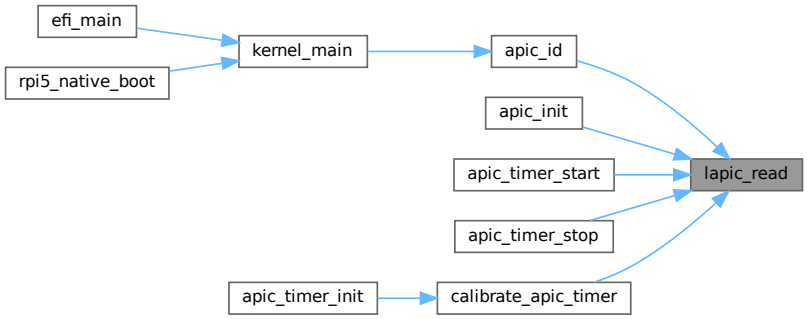
Returns

Current 32-bit value of the register.

References lapic_base.

Referenced by apic_id(), apic_init(), apic_timer_start(), apic_timer_stop(), and calibrate_apic_timer().

Here is the caller graph for this function:



7.106.2.11 lapic_write()

```
static void lapic_write (
            uint32_t reg,
            uint32_t val )  [static]
```

Write a 32-bit value to a Local APIC MMIO register.

All xAPIC registers are 32-bit wide and 16-byte aligned within the 4 KB MMIO page at `lapic_base`. The register offset `reg` is a byte offset (e.g., `APIC_REG_EOI` = 0x0B0); dividing by 4 converts it to a `uint32_t` array index. Writes must be 32-bit aligned and must not be merged or reordered by the compiler, hence the `volatile` qualifier on `lapic_base`.

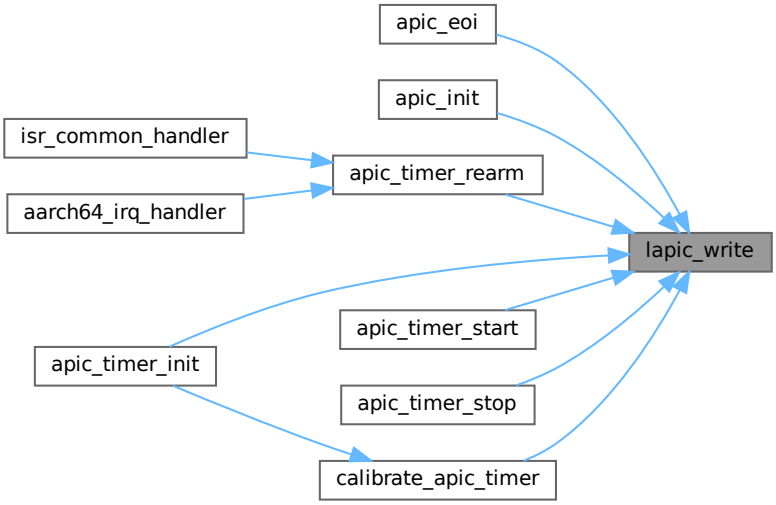
Parameters

reg	Byte offset of the APIC register (e.g., `APIC_REG_EOI`).
val	32-bit value to write.

References lapic_base.

Referenced by apic_eoi(), apic_init(), apic_timer_init(), apic_timer_rearm(), apic_timer_start(), apic_timer_stop(), and calibrate_apic_timer().

Here is the caller graph for this function:



7.106.2.12 rdmsr64()

```
static uint64_t rdmsr64 (
            uint32_t msr )  [static]
```

Read a 64-bit Model Specific Register via `RDMSR`.

Executes the `RDMSR` instruction with `msr` in `ECX`. The processor returns the high 32 bits in `EDX` and the low 32 bits in `EAX`; this function combines them into a single 64-bit value. Must run at CPL 0 (ring 0); a #GP fault results if executed in user mode or if `msr` denotes a reserved or non-existent register.

Parameters

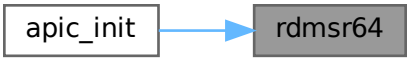
msr	32-bit MSR index (e.g., `IA32_APIC_BASE_MSR` = 0x1B).

Returns

Current 64-bit value of the specified MSR.

Referenced by apic_init().

Here is the caller graph for this function:



7.106.2.13 wrmsr64()

```
static void wrmsr64 (
            uint32_t msr,
            uint64_t val )  [static]
```

Write a 64-bit value to a Model Specific Register via `WRMSR`.

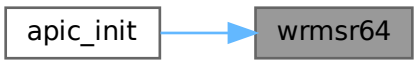
Executes the `WRMSR` instruction with `msr` in `ECX`, the high 32 bits of `val` in `EDX`, and the low 32 bits in `EAX`. Must run at CPL 0; a #GP results for reserved, non-existent, or read-only MSRs, or for writes that set reserved bits. Used here exclusively to manipulate `IA32_APIC_BASE_MSR` to switch from x2APIC to xAPIC mode and to assert the global hardware-enable bit.

Parameters

msr	32-bit MSR index.
val	64-bit value to write.

Referenced by apic_init().

Here is the caller graph for this function:



7.106.3 Variable Documentation

7.106.3.1 lapic_base

```
volatile uint32_t* lapic_base = (volatile uint32_t *)(uintptr_t) 0xFEE00000u  [static]
```

Referenced by apic_init(), lapic_read(), and lapic_write().

7.106.3.2 lapic_phys_base

```
uint64_t lapic_phys_base = 0xFEE00000u  [static]
```

Referenced by apic_init().

7.106.3.3 s_apic_hz

```
uint32_t s_apic_hz = 0  [static]
```

Referenced by apic_timer_init(), and apic_timer_rearm().

7.106.3.4 timer_initial_count

```
uint32_t timer_initial_count = 0  [static]
```

Referenced by apic_timer_init(), apic_timer_rearm(), and apic_timer_start().

7.106.3.5 timer_period_tsc_ticks

```
uint64_t timer_period_tsc_ticks = 0  [static]
```

Referenced by apic_timer_init(), and apic_timer_period_tsc().

7.106.3.6 timer_tick_hz

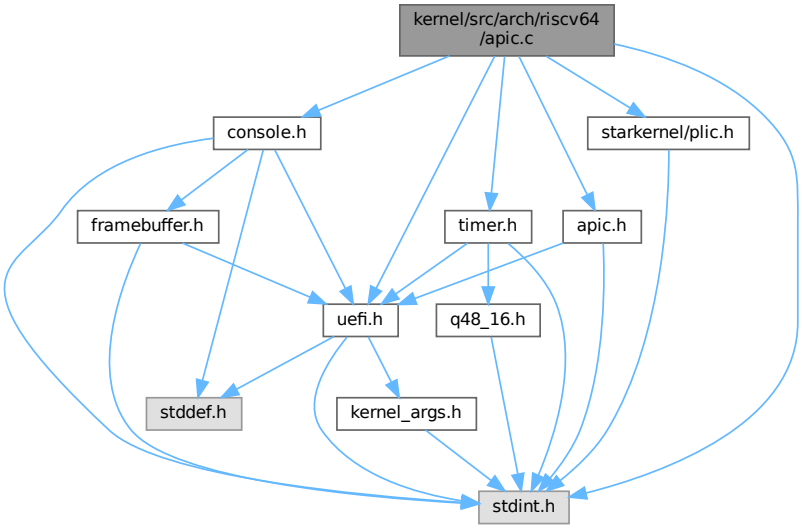
```
uint32_t timer_tick_hz = 0  [static]
```

Referenced by apic_timer_init().

7.107 kernel/src/arch/riscv64/apic.c File Reference

```
#include "apic.h"
#include "uefi.h"
#include "console.h"
#include "timer.h"
#include "starkernel/plic.h"
#include <stdint.h>
```

Include dependency graph for apic.c:



Data Structures

- struct sbiret_t

Macros

- #define SBI_EXT_BASE 0x10UL
- #define SBI_BASE_FID_PROBE_EXT 3UL
- #define SBI_EXT_TIME 0x54494D45UL /* "TIME" */
- #define SBI_TIME_FID_SET_TIMER 0UL
- #define SBI_SUCCESS 0L
- #define SIE_STIE (1UL << 5)

Functions

- static sbiret_t sbi_call1 (unsigned long eid, unsigned long fid, unsigned long arg0)

  Issue an SBI ECALL with one argument.
- static uint64_t rdtime (void)

  Read the RISC-V `time` CSR.
- static int sbi_set_timer (uint64_t deadline)

Arm the SBI timer for `deadline`.

- void riscv64_timer_rearm (void)

  Re-arm the one-shot SBI timer and account the tick.

- int apic_init (BootInfo *boot_info)

  Initialise the GICv2 distributor and CPU interface (M4 milestone).

- void apic_eoi (void)

  Signal End of Interrupt to the interrupt controller (RISC-V stub).

- int apic_timer_init (uint64_t tsc_hz, uint32_t tick_hz)

  Compute the expected system-counter ticks per heartbeat period.

- void apic_timer_start (void)

  Start timer delivery via the SBI TIME extension.

- void apic_timer_stop (void)

  Stop timer delivery by masking `sie.STIE`.

- uint64_t apic_timer_period_tsc (void)

  Return the expected `time`-counter ticks per heartbeat period.

Variables

- static uint64_t s_timer_period_tsc = 0

  apic.c (riscv64) - APIC stub.

- static uint64_t s_time_hz = 0
- static int s_sbi_time_ok = 0
- static uint64_t s_next_deadline = 0

7.107.1 Macro Definition Documentation

7.107.1.1 SBI_BASE_FID_PROBE_EXT

```
#define SBI_BASE_FID_PROBE_EXT 3UL
```

7.107.1.2 SBI_EXT_BASE

```
#define SBI_EXT_BASE 0x10UL
```

7.107.1.3 SBI_EXT_TIME

```
#define SBI_EXT_TIME 0x54494D45UL /* "TIME" */
```

7.107.1.4 SBI_SUCCESS

```
#define SBI_SUCCESS 0L
```

7.107.1.5 SBI_TIME_FID_SET_TIMER

```
#define SBI_TIME_FID_SET_TIMER 0UL
```

7.107.1.6 SIE_STIE

```
#define SIE_STIE (1UL << 5)
```

7.107.2 Function Documentation

7.107.2.1 apic_eoi()

```
void apic_eoi (
            void  )
```

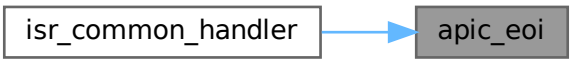
Signal End of Interrupt to the interrupt controller (RISC-V stub).

Signal End of Interrupt (common cross-ISA signature — see below).

On x86-64 this writes to the Local APIC EOI register. On RISC-V EOI is handled by reading the PLIC claim/complete register; that path is not yet wired. This stub is a no-op that satisfies the common interface.

Referenced by isr_common_handler().

Here is the caller graph for this function:



7.107.2.2 apic_init()

```
int apic_init (
            BootInfo * boot_info )
```

Initialise the GICv2 distributor and CPU interface (M4 milestone).

Enables exactly one interrupt source: the physical timer PPI for the exception level detected in item 0.4 (30 at EL1, 26 at EL2 — see `TIMER_PPI_EL1` / `TIMER_PPI_EL2` above). Sequence:

0. Try `gic_bases_from_dtb()` against `boot_info->dtb`; on success, `s_gicd_base` / `s_gicc_base` are overridden from the real hardware addresses. On failure (no DTB, e.g. this system's QEMU/UEFI firmware — see file header) they keep the QEMU constant defaults, exactly the behaviour this function had before this step existed.

1. Set this interrupt's priority (`GICD_IPRIORITYR`) below the CPU interface's priority mask, so it is never itself masked out.
2. Enable it in `GICD_ISENABLER0` (PPIs 16–31 live in the first word).
3. Enable the distributor, Group 0 only (`GICD_CTLR`) — this deployment has no GICv2 security-extension split in use.
4. Set the CPU interface priority mask to allow everything through (`GICC_PMR` = 0xFF) and enable the CPU interface (`GICC_CTLR`).

Deliberately not configured: `GICD_ICFGR` (trigger sensitivity). The ARM generic timer's PPI is architecturally level-sensitive; this is not a general GIC driver and item 0.6's own scope does not call for reconfiguring it.

Parameters

boot_info	Kernel `BootInfo`; `dtb` is consulted for real-hardware GIC base discovery as of the 2026-09-04 fix (previously unused — see file header), and, as of the same fix, for `aarch64_psci_conduit_init()`'s PSCI conduit discovery (arch.c) — bundled into this call for the same reason GIC discovery is: this is the one point in boot with `boot_info->dtb` already in hand.

Returns

0 always.

Initialise the GICv2 distributor and CPU interface (M4 milestone).

Called during M4 (interrupt controller init) before the IDT is loaded. Performs the following steps:

1. Reads `IA32_APIC_BASE_MSR` (0x1B) to determine the current APIC mode.
2. If x2APIC mode (bit 10) is active, clears it to switch to xAPIC MMIO mode while keeping the global-enable bit (bit 11) set, as required by Intel SDM Vol.3 ?10.12.5 (never clear both bits simultaneously).
3. If the global-enable bit (bit 11) was clear, sets it.
4. Software-enables the APIC via `APIC_REG_SIVR` (Spurious Interrupt Vector Register) and assigns spurious vector 0xFF.
5. Clears the Task Priority Register (TPR=0) so all interrupt priorities are delivered; a non-zero TPR left by UEFI would silently suppress all APIC interrupts at or below that priority level.
6. Issues a spurious EOI write to clear any stale in-service interrupt that UEFI may have left pending (specifically the APIC timer vector that fires just before `ExitBootServices`).

The `boot_info` parameter is reserved for future use (e.g., reading the ACPI MADT for the physical LAPIC base address); it is currently unused and the default identity-mapped address `LAPIC_DEFAULT_PHYS` = 0xFEE00000 is always used.

Parameters

boot_info	Pointer to kernel `BootInfo` (ACPI/memory-map data); currently unused, reserved for MADT-based LAPIC relocation.

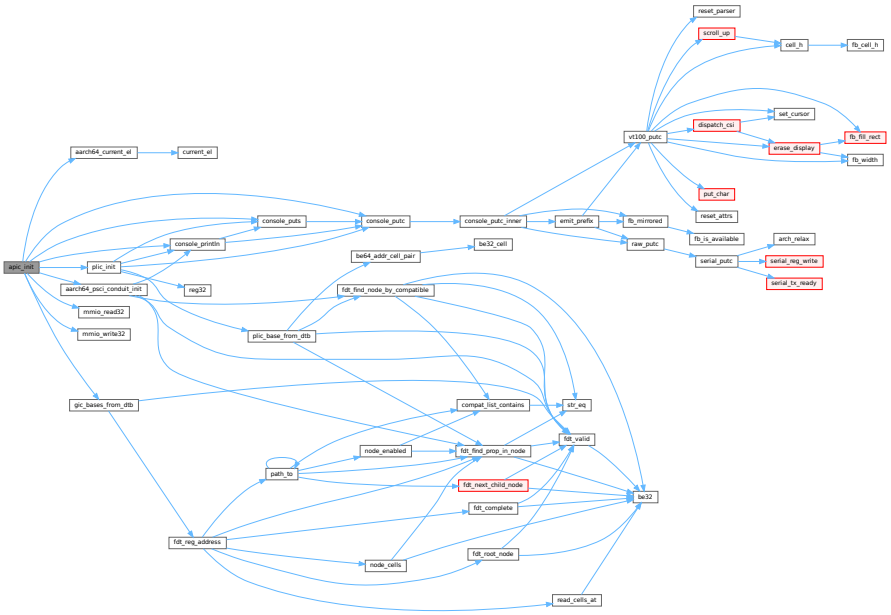
Returns

0 on success (always; the APIC is assumed to be present on x86-64).

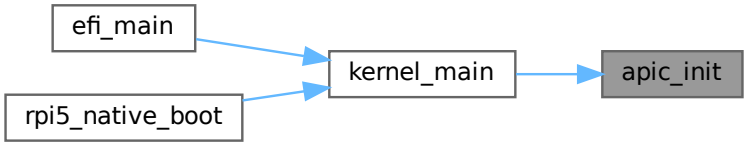
References aarch64_current_el(), aarch64_psci_conduit_init(), console_println(), console_putc(), console_puts(), BootInfo::dtb, gic_bases_from_dtb(), GICC_CTLR, GICC_CTLR_ENABLE_GRP0, GICC_PMR, GICD_CTLR, GICD_CTLR_ENABLE_GRP0, GICD_IPRIORITYR, GICD_ISENABLER0, mmio_read32(), mmio_write32(), plic_init(), PMR_ALLOW_ALL, s_gicc_base, s_gicd_base, s_timer_ppi, TIMER_PPI_EL1, TIMER_PPI_EL2, and TIMER_PRIORITY.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.107.2.3 apic_timer_init()

```
int apic_timer_init (
            uint64_t tsc_hz,
            uint32_t tick_hz )
```

Compute the expected system-counter ticks per heartbeat period.

Computes `s_timer_period_tsc` (the expected number of `CNTPCT_EL0` ticks between heartbeats), used both by `heartbeat_init()` to seed the rolling-window `expected_delta` and by `apic_timer_start()` / `apic_timer_rearm()` (item 0.7) as the `TVAL` step written on every arm and re-arm.

If either `tsc_hz` or `tick_hz` is zero, a fallback of 10,000,000 ticks is stored (approximately 160 ms at 62.5 MHz, a safe non-zero sentinel that prevents division-by-zero in the heartbeat path).

Parameters

tsc_hz	System counter frequency from `timer_init()` (Hz).
tick_hz	Desired heartbeat rate (Hz); 0 → uses fallback.

Returns

0 always.

Compute the expected system-counter ticks per heartbeat period.

Calibrates the APIC timer frequency via `calibrate_apic_timer()` then programs the LVT Timer Register and Initial Count Register to deliver `APIC_TIMER_VECTOR` periodically at `tick_hz` interrupts per second. The timer is left **masked** after initialisation; call `apic_timer_start()` after the IDT is loaded and interrupts are enabled to begin delivery.

Derived quantities stored for later use:

- `timer_initial_count` — APIC ticks per heartbeat period (`apic_hz` / `tick_hz`), written to `APIC_REG_TIMER_ICR`.
- `timer_tick_hz` — requested tick rate (100 Hz default).
- `timer_period_tsc_ticks` — expected TSC ticks per heartbeat (`tsc_hz` / `tick_hz`), used by `heartbeat_tick()` to compute inter-tick variance for the TIME-TRUST Q48.16 metric.

If `tick_hz` is 0 it defaults to 100 Hz (10 ms period). If calibration returns 0 (no APIC timer detected or counter stuck) the function prints a diagnostic and returns -1 without programming the timer.

Parameters

tsc_hz	TSC frequency in Hz (from `timer_init()`); used to derive the 10 ms calibration window and `timer_period_tsc_ticks`. Pass 0 if TSC is not yet calibrated.
tick_hz	Desired interrupt rate in Hz; 0 → defaults to 100 Hz.

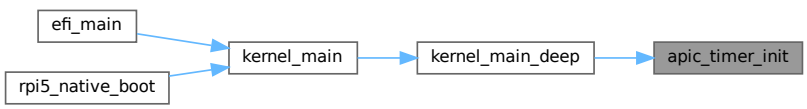
Returns

0 on success, -1 if APIC timer calibration failed.

References s_counter_hz_apic, s_time_hz, and s_timer_period_tsc.

Referenced by kernel_main_deep().

Here is the caller graph for this function:



7.107.2.4 apic_timer_period_tsc()

```
uint64_t apic_timer_period_tsc (
            void  )
```

Return the expected `time`-counter ticks per heartbeat period.

Get the configured timer period in TSC ticks.

Returns `s_timer_period_tsc`, set by `apic_timer_init()` as `tsc_hz` / `tick_hz`. Consumed by `heartbeat_init()` to seed the rolling-window `expected_delta`, and by `apic_timer_start()` / `riscv64_timer_rearm()` as the SBI deadline step.

Returns

Expected `time`-counter ticks per heartbeat period; 10,000,000 if frequencies were not available at init time.

References s_timer_period_tsc.

7.107.2.5 apic_timer_start()

```
void apic_timer_start (
            void  )
```

Start timer delivery via the SBI TIME extension.

Start the APIC timer (enables periodic interrupts).

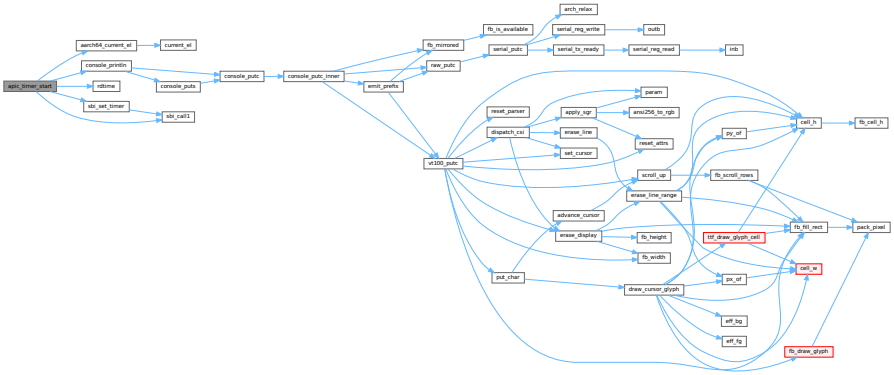
Probes for the TIME extension first. If the SEE does not provide it the timer is **not** armed and the condition is reported loudly rather than papered over with the legacy EID 0x00 call: a heartbeat that silently never ticks is far worse to diagnose than one that says why at boot.

On success: computes the first absolute deadline, arms it, and sets `sie.STIE`. Global delivery is gated separately by `sstatus.SIE`, which `arch_enable_interrupts()` sets.

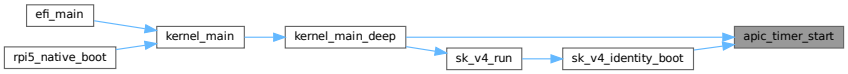
References aarch64_current_el(), console_println(), sbiret_t::error, rdtime(), s_next_deadline, s_sbi_time_ok, s_timer_period_tsc, SBI_BASE_FID_PROBE_EXT, sbi_call1(), SBI_EXT_BASE, SBI_EXT_TIME, sbi_set_timer(), SBI_SUCCESS, SIE_STIE, and sbiret_t::value.

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.107.2.6 apic_timer_stop()

```
void apic_timer_stop (
            void  )
```

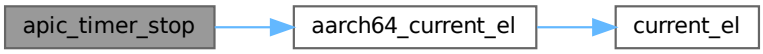
Stop timer delivery by masking `sie.STIE`.

Stop the APIC timer (disables periodic interrupts).

The SBI timer cannot be cancelled outright — masking the enable bit is the supported way to stop delivery. Any deadline already programmed simply goes unserviced.

References aarch64_current_el(), s_sbi_time_ok, and SIE_STIE.

Here is the call graph for this function:



7.107.2.7 rdtime()

```
static uint64_t rdtime (
            void  )  [inline], [static]
```

Read the RISC-V `time` CSR.

Deadlines handed to `sbi_set_timer()` are absolute values on this counter. `arch/riscv64/timer.c` keeps its own copy of this accessor; duplicating four instructions is preferable to widening `timer.h` with an architecture-specific accessor that only these two files can use.

Referenced by apic_timer_start(), and riscv64_timer_rearm().

Here is the caller graph for this function:

7.107.2.8 riscv64_timer_rearm()

```
void riscv64_timer_rearm (
            void  )
```

Re-arm the one-shot SBI timer and account the tick.

The SBI timer is one-shot by nature. Servicing a timer interrupt without programming the next deadline leaves the heartbeat stopped permanently, with no error anywhere — the single most likely silent failure of this driver. Every path out of a timer interrupt must reach this function.

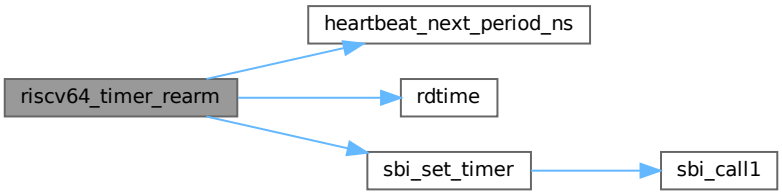
The step is `heartbeat_next_period_ns()` (item 0.8, ?26) converted to `time`-counter ticks via `s_time_hz`, not the fixed `s_timer_period_tsc` used to seed the very first deadline in `apic_timer_start()` – the latter remains `apic_timer_period_tsc()'s` return value for `heartbeat_init()'s` initial `expected_delta`, unchanged.

Called from `riscv64_interrupt_handler()` in `interrupts.c` on `scause` cause 5.

References heartbeat_next_period_ns(), rdtime(), s_next_deadline, s_sbi_time_ok, s_time_hz, s_timer_period_tsc, and sbi_set_timer().

Referenced by riscv64_interrupt_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

7.107.2.9 sbi_call1()

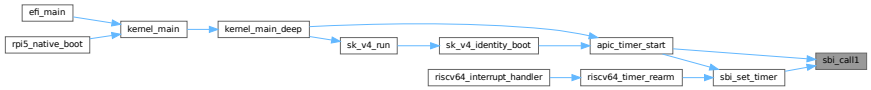
```
static sbiret_t sbi_call1 (
            unsigned long eid,
            unsigned long fid,
            unsigned long arg0 )  [static]
```

Issue an SBI ECALL with one argument.

References sbiret_t::error, and sbiret_t::value.

Referenced by apic_timer_start(), and sbi_set_timer().

Here is the caller graph for this function:



7.107.2.10 sbi_set_timer()

```
static int sbi_set_timer (
            uint64_t deadline )  [static]
```

Arm the SBI timer for `deadline`.

Returns

1 on success, 0 if the SEE rejected the call.

References sbiret_t::error, sbi_call1(), SBI_EXT_TIME, SBI_SUCCESS, and SBI_TIME_FID_SET_TIMER.

Referenced by apic_timer_start(), and riscv64_timer_rearm().

Here is the call graph for this function:

Here is the caller graph for this function:

7.107.3 Variable Documentation

7.107.3.1 s_next_deadline

```
uint64_t s_next_deadline = 0  [static]
```

Referenced by apic_timer_start(), and riscv64_timer_rearm().

7.107.3.2 s_sbi_time_ok

```
int s_sbi_time_ok = 0  [static]
```

Referenced by apic_timer_start(), apic_timer_stop(), and riscv64_timer_rearm().

7.107.3.3 s_time_hz

```
uint64_t s_time_hz = 0  [static]
```

Referenced by apic_timer_init(), and riscv64_timer_rearm().

7.107.3.4 s_timer_period_tsc

```
uint64_t s_timer_period_tsc = 0  [static]
```

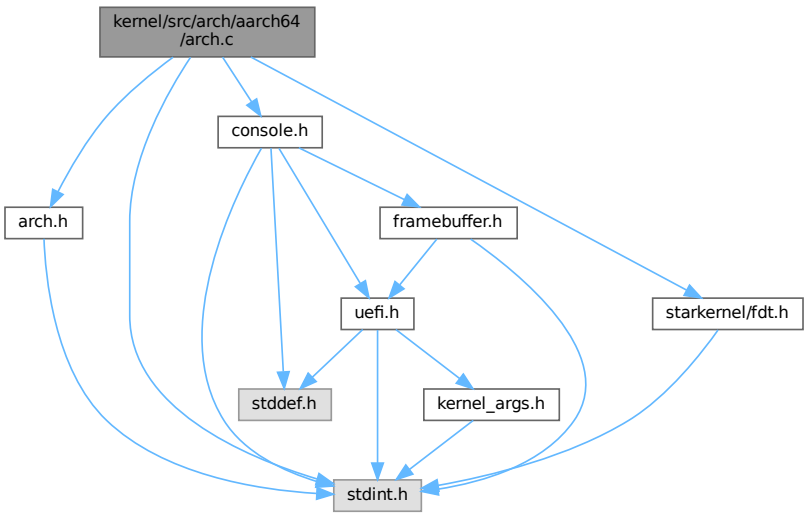
apic.c (riscv64) - APIC stub.

No Local APIC on RISC-V; interrupt controller is PLIC (Platform-Level Interrupt Controller). apic_init() calls into plic.c for the real PLIC bring-up (item 4.3.5b); apic_eoi() stays a no-op since PLIC completion happens per-source in the trap handler (claim/complete), not via a single shared EOI register.

7.108 kernel/src/arch/aarch64/arch.c File Reference

```
#include "arch.h"
#include "console.h"
#include "starkernel/fdt.h"
#include <stdint.h>
```

Include dependency graph for arch.c:



Functions

- void aarch64_install_vectors (void)

  arch.c (aarch64) - Architecture abstractions for StarKernel on AArch64
- int aarch64_current_el (void)

  Return the AArch64 exception level the kernel is running at.
- void arch_early_init (void)

  Perform the earliest AArch64 architecture initialisation (no-op).
- void arch_enable_interrupts (void)

  Enable IRQ delivery on the current core (AArch64 DAIFCLR).
- void arch_disable_interrupts (void)

  Disable IRQ delivery on the current core (AArch64 DAIFSET).
- void arch_halt (void)

  Halt the core until the next event (AArch64 WFI).
- void aarch64_psci_conduit_init (const void *dtb)

  Discover the real PSCI conduit ("smc" vs "hvc") from the DTB.
- void arch_cold_reset (void)
- uint64_t arch_read_timestamp (void)

  Read the AArch64 system counter (CNTPCT_EL0).
- void arch_mmu_init (void)

  Initialise the AArch64 MMU (stub — deferred to a later milestone).

Variables

- static int s_current_el = -1
- static int s_psci_use_smc = 0

7.108.1 Function Documentation

7.108.1.1 aarch64_current_el()

```
int aarch64_current_el (
            void  )
```

Return the AArch64 exception level the kernel is running at.

apic.c (aarch64) - Minimal GICv2 driver + ARM Generic Timer (items 0.6/0.7/ 4.3.5d).

Reads `CurrentEL` (bits [3:2] hold the EL number, [1:0] are RES0) on first call and caches the result; every later call returns the cached value. Safe to call at any point in boot, including before `console_init()` — the read itself has no dependency, only the printing of it does (see `arch_interrupts_init()` in `interrupts.c`, the earliest point at which both this and a working console are available).

EDK2 on QEMU's aarch64 `virt` machine has been observed to leave the kernel at either EL1 or EL2 depending on firmware build; nothing in this tree may assume one over the other (FABRIC-0.md ?25.7.1 GAP-B3). Every EL-dependent choice — `VBAR_EL1` vs `VBAR_EL2`, the `ELR_ELx` / `SPSR_ELx` saved-state pair, and `CNTP_*_EL0` vs `CNTHP_*_EL2` — must read this accessor rather than hardcode a level.

Returns

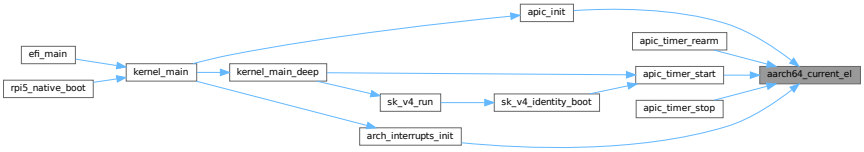
1 or 2. Never 0 or 3: a UEFI application that survived far enough to reach this call cannot be running at EL0 (unprivileged) or EL3 (secure monitor — QEMU's virt firmware runs the kernel at EL1/EL2).

References current_el(), and s_current_el.

Referenced by apic_init(), apic_timer_rearm(), apic_timer_start(), apic_timer_stop(), and arch_interrupts_init().

Here is the call graph for this function:

Here is the caller graph for this function:



7.108.1.2 aarch64_install_vectors()

```
void aarch64_install_vectors (
            void  )  [extern]
```

arch.c (aarch64) - Architecture abstractions for StarKernel on AArch64

7.108.1.3 aarch64_psci_conduit_init()

```
void aarch64_psci_conduit_init (
            const void * dtb )
```

Discover the real PSCI conduit ("smc" vs "hvc") from the DTB.

Looks up the devicetree's PSCI firmware node and reads its `method` property. BCM2712's own `/psci` node declares `compatible = "arm,psci-1.0", "arm,psci-0.2", "arm,psci"` and `method = "smc"` – confirmed directly against `bcm2712.dtsi`, not assumed. `fdt_find_node_by_compatible()` matches any entry in a node's compatible list, so searching for just the first (most specific) string is sufficient; the other two exist for older PSCI-spec-version consumers, not because this node might be tagged differently.

Leaves `s_psci_use_smc` at its default (0, HVC) if `dtb` is not a valid FDT, no PSCI node is found, or `method` is anything other than exactly `"smc"` – including the explicit `"hvc"` case, and the "property absent" case, both of which should keep the existing HVC behaviour rather than guess.

Called once from `apic_init()` (`arch/aarch64/apic.c`), the one point in boot that already has `boot_info->dtb` in hand at the right time for this kind of discovery (same rationale as that file's own GIC-base lookup) – collocated here in `arch.c`, not there, because `arch_cold_reset()` is this function's actual consumer and has no `boot_info` of its own to probe with by the time it runs (called from deep in VM execution, via `BYE`). Same extern-in-place convention this file and apic.c already use for `aarch64_current_el()`.

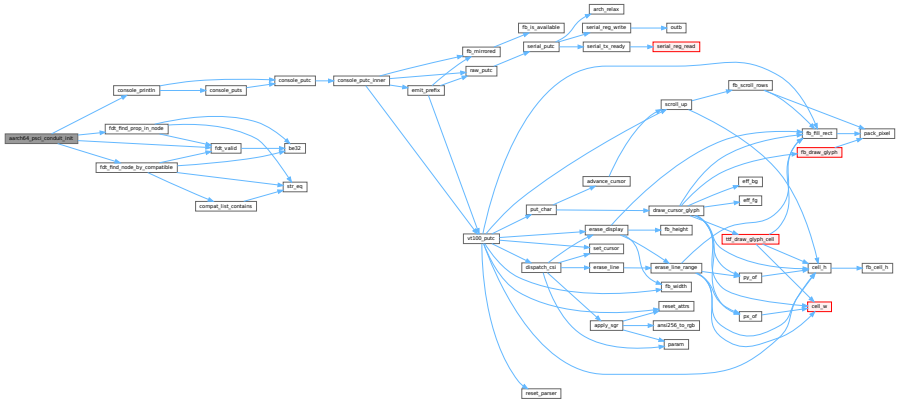
Parameters

dtb	Candidate devicetree blob (`BootInfo->dtb`); NULL-safe.

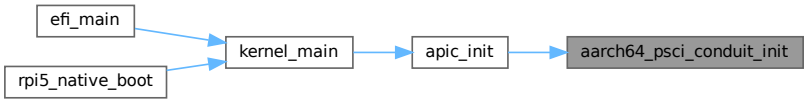
References console_println(), fdt_find_node_by_compatible(), fdt_find_prop_in_node(), fdt_valid(), and s_psci_use_smc.

Referenced by apic_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.108.1.4 arch_cold_reset()

```
void arch_cold_reset (
            void  )
```

7.108.1.5 arch_disable_interrupts()

```
void arch_disable_interrupts (
            void  )
```

Disable IRQ delivery on the current core (AArch64 DAIFSET).

Issues `MSR` DAIFSET, #2 which sets the `I` bit (IRQ mask) in the `DAIF` flags, masking IRQ exceptions. FIQ, SError, and Debug exceptions are unaffected. Used around critical sections in the single-threaded kernel where interrupt delivery would corrupt shared state.

The memory clobber acts as a compiler-level barrier; for a full hardware memory barrier use DSB before calling this function.

Referenced by arch_cold_reset(), and arch_cold_reset().

Here is the caller graph for this function:

7.108.1.6 arch_early_init()

```
void arch_early_init (
            void  )
```

Perform the earliest AArch64 architecture initialisation (no-op).

arch.h - Architecture abstraction layer for StarKernel

On x86-64 this function loads the GDT; AArch64 has no equivalent because privilege separation is provided by the exception-level architecture (EL0/EL1/EL2/EL3) rather than segment descriptors. The exception vector table is installed later in arch_interrupts_init() by calling aarch64_install_vectors() which writes VBAR_EL1.

This stub exists to satisfy the common arch_early_init() call site in kernel_main() so that the same milestone sequence compiles across all three supported ISAs (amd64 / aarch64 / riscv64).

7.108.1.7 arch_enable_interrupts()

```
void arch_enable_interrupts (
            void  )
```

Enable IRQ delivery on the current core (AArch64 DAIFCLR).

Issues MSR DAIFCLR, #2 which clears the I bit (IRQ mask) in the DAIF (Debug / Abort / IRQ / FIQ) flags of the current exception level. After this instruction the core will take IRQ exceptions from the GIC. The memory clobber prevents the compiler from reordering stores across the barrier.

Must be called after arch_interrupts_init() has installed the vector table in VBAR_EL1 and the GIC timer driver has been configured.

7.108.1.8 arch_halt()

```
void arch_halt (
            void  )
```

Halt the core until the next event (AArch64 WFI).

Issues the WFI (Wait For Interrupt) instruction. The core enters a low-power standby state and resumes execution when an IRQ, FIQ, SError, debug event, or reset is detected. In the kernel panic path this is called inside an infinite loop with interrupts disabled (DAIFSET) to stop the processor permanently. In the idle path it reduces power consumption between heartbeat ticks.

The memory clobber prevents the compiler from sinking stores across the WFI.

7.108.1.9 arch_mmu_init()

```
void arch_mmu_init (
            void  )
```

Initialise the AArch64 MMU (stub — deferred to a later milestone).

Full page-table setup (TTBR0/TTBR1, MAIR, TCR, SCTLR.M) is deferred to a later milestone. This stub exists to satisfy the common `arch_mmu_init()` call site shared across all three ISAs. The VMM subsystem (`vmm.c`) handles page-table management independently of this hook.

7.108.1.10 arch_read_timestamp()

```
uint64_t arch_read_timestamp (
            void  )
```

Read the AArch64 system counter (CNTPCT_EL0).

Issues `MRS %0, cntpct_el0` to read the 64-bit physical system counter. On AArch64 the system counter is the architectural equivalent of the x86-64 TSC: a monotonically incrementing clock whose frequency is reported by `CNTFRQ_EL0` and set by firmware at boot.

Unlike `RDTSC` on x86-64, `CNTPCT_EL0` is fully synchronised across cores (no per-core skew), invariant across power-state changes, and does not require serialisation for most measurement use cases. It is used as the time base for `timer_now_ns()` and `heartbeat_tick()`.

Returns

Current 64-bit system counter value in counter ticks (frequency given by `CNTFRQ_EL0`, typically 10–62.5 MHz).

7.108.2 Variable Documentation

7.108.2.1 s_current_el

```
int s_current_el = -1  [static]
```

Referenced by aarch64_current_el().

7.108.2.2 s_psci_use_smc

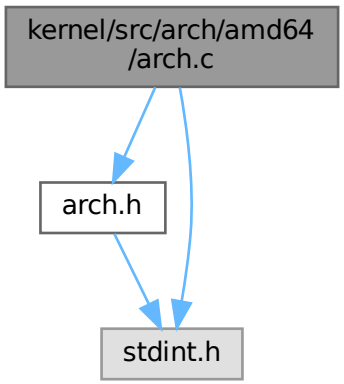
```
int s_psci_use_smc = 0  [static]
```

Referenced by aarch64_psci_conduit_init(), and arch_cold_reset().

7.109 kernel/src/arch/amd64/arch.c File Reference

```
#include "arch.h"
#include <stdint.h>
```

Include dependency graph for arch.c:



Data Structures

- struct gdt_entry

  arch.c (amd64) - Architecture abstractions for StarKernel on x86_64
- struct gdtr

Functions

- struct gdt_entry __attribute__ ((packed))
- static struct gdt_entry gdt[3] __attribute__ ((aligned(16)))
- static void gdt_set_entry (int index, uint8_t access, uint8_t granularity)

  Populate a GDT entry with limit 0xFFFF and a zero base.
- static void gdt_init (void)

  Initialise and load the minimal 3-entry GDT required for long mode.
- void arch_early_init (void)

  Perform the earliest x86-64 architecture initialisation.
- void arch_enable_interrupts (void)

  Enable hardware interrupts on the current CPU core (x86-64 STI).
- void arch_disable_interrupts (void)

  Disable hardware interrupts on the current CPU core (x86-64 CLI).
- void arch_halt (void)

  Halt the CPU until the next interrupt (x86-64 HLT).
- void arch_cold_reset (void)
- uint64_t arch_read_timestamp (void)

  Read the x86-64 Time Stamp Counter (RDTSC).
- void arch_mmu_init (void)

  Initialise the x86-64 MMU (stub — deferred to a later milestone).

Variables

- uint16_t limit_low
- uint16_t base_low
- uint8_t base_mid
- uint8_t access
- uint8_t granularity
- uint8_t base_high
- uint16_t limit
- uint64_t base

7.109.1 Function Documentation

7.109.1.1 __attribute__() [1/2]

```
static struct gdt_entry gdt[3] __attribute__ (
             (aligned(16))  )  [static]
```

7.109.1.2 __attribute__() [2/2]

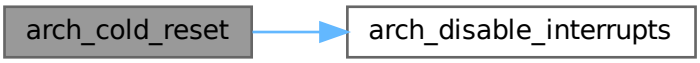
```
struct gdt_entry __attribute__ (
             (packed)  )
```

7.109.1.3 arch_cold_reset()

```
void arch_cold_reset (
             void  )
```

References arch_disable_interrupts().

Here is the call graph for this function:



7.109.1.4 arch_disable_interrupts()

```
void arch_disable_interrupts (
             void  )
```

Disable hardware interrupts on the current CPU core (x86-64 CLI).

Disable IRQ delivery on the current core (AArch64 DAIFSET).

Issues the `CLI` instruction to clear the Interrupt Flag. Used around critical sections in the single-threaded kernel where interrupt delivery would corrupt shared state.

7.109.1.5 arch_early_init()

```
void arch_early_init (
            void  )
```

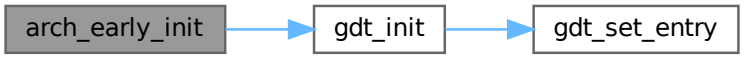
Perform the earliest x86-64 architecture initialisation.

arch.h - Architecture abstraction layer for StarKernel

Called immediately after the UEFI boot stub transfers control to the kernel, before the console or interrupt controller are available. Loads the minimal three-entry GDT via `gdt_init()` so that subsequent code has valid segment selectors. IDT setup is deferred until after the console is live (called separately via `arch_interrupts_init()`).

References gdt_init().

Here is the call graph for this function:



7.109.1.6 arch_enable_interrupts()

```
void arch_enable_interrupts (
            void  )
```

Enable hardware interrupts on the current CPU core (x86-64 STI).

Enable IRQ delivery on the current core (AArch64 DAIFCLR).

Issues the `STI` instruction to set the Interrupt Flag. Must be called after the IDT is loaded and the APIC is configured, otherwise the first interrupt will triple-fault.

7.109.1.7 arch_halt()

```
void arch_halt (
            void  )
```

Halt the CPU until the next interrupt (x86-64 HLT).

Halt the core until the next event (AArch64 WFI).

Issues the `HLT` instruction. In the kernel panic path this is called in an infinite loop (interrupts disabled) to stop the processor permanently. In normal use it is called once per idle iteration to reduce power consumption.

7.109.1.8 arch_mmu_init()

```
void arch_mmu_init (
            void  )
```

Initialise the x86-64 MMU (stub — deferred to a later milestone).

Initialise the AArch64 MMU (stub — deferred to a later milestone).

Full four-level page table setup is deferred; the VMM subsystem (vmm.c) handles page table management independently. This function exists as an architectural hook for future per-CPU MMU configuration that must run after GDT/IDT setup but before the first memory access through a non-identity-mapped virtual address.

7.109.1.9 arch_read_timestamp()

```
uint64_t arch_read_timestamp (
            void  )
```

Read the x86-64 Time Stamp Counter (RDTSC).

Read the AArch64 system counter (CNTPCT_EL0).

Executes RDTSC and combines EDX:EAX into a 64-bit value. Does not serialise instruction execution; use RDTSCP or a surrounding CPUID where ordering guarantees are required.

Returns

Current TSC value in CPU cycles.

7.109.1.10 gdt_init()

```
static void gdt_init (
            void  )  [static]
```

Initialise and load the minimal 3-entry GDT required for long mode.

Builds three GDT entries in the gdt[] array and loads the descriptor via LGDT followed by a far-return sequence to reload CS to selector 0x08 and all other segment registers to 0x10:

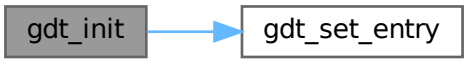
- Slot 0 (0x00): Null descriptor — all fields zero.
- Slot 1 (0x08): 64-bit kernel code (access=0x9A, granularity=0x20).
- Slot 2 (0x10): Kernel data (access=0x92, granularity=0x00).

Must be called before `arch_interrupts_init()` because the IDT uses selector 0x08 for all gate descriptors.

References gdtr::base, gdt_set_entry(), and gdtr::limit.

Referenced by arch_early_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.109.1.11 gdt_set_entry()

```
static void gdt_set_entry (
            int index,
            uint8_t access,
            uint8_t granularity )  [static]
```

Populate a GDT entry with limit 0xFFFF and a zero base.

In 64-bit long mode the base and limit fields of code/data segment descriptors are ignored by the processor; only the `access` and `granularity` flag bytes are architecturally significant. This helper writes the canonical long-mode descriptor layout: limit = 0xFFFF, all base bytes = 0, then stores the provided access and granularity values.

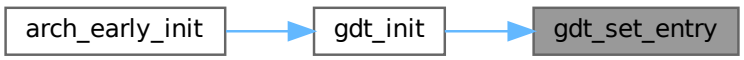
Parameters

index	Index into the `gdt[]` array (0 = null, 1 = code, 2 = data).
access	Access byte (e.g., 0x9A for kernel code, 0x92 for data).
granularity	Granularity/flags byte (e.g., 0x20 sets the L-bit for 64-bit code).

References access, and granularity.

Referenced by gdt_init().

Here is the caller graph for this function:



7.109.2 Variable Documentation

7.109.2.1 access

```
uint8_t access
```

Referenced by gdt_set_entry().

7.109.2.2 base

```
uint64_t base
```

Referenced by analytics_heap_allocate(), blk_vm_assign(), blk_vm_evict(), blk_vm_flush_all(), blk_vm_load(), blkio_ram_init_state(), block_word_update(), dev_rw4k(), div_ud_by_base(), erf_q48(), fdt_find_node_by_compatible(), fdt_find_node_by_device_type(), fdt_find_node_by_name(), fdt_find_prop(), format_word_hash(), itoa_simple(), mmio_read32(), mmio_write32(), print_number_formatted(), read_devblock(), read_devblock(), read_devblock(), read_devblock_4k(), rpi5_mailbox_get_framebuffer(), vm_addr_from_ptr(), vm_create_word(), vm_debug_dump_state(), vm_dictionary_get_data_field(), vm_parse_number(), vm_parse_number(), vocab_sync_vm_vars(), write_devblock(), and write_devblock_4k().

7.109.2.3 base_high

```
uint8_t base_high
```

7.109.2.4 base_low

```
uint16_t base_low
```

7.109.2.5 base_mid

```
uint8_t base_mid
```

7.109.2.6 granularity

```
uint8_t granularity
```

Referenced by gdt_set_entry().

7.109.2.7 limit

```
uint16_t limit
```

Referenced by blk_allocate(), control_forth_runtime_do(), control_forth_runtime_qdo(), der_next(), der_put_ed25519_algid(), der_put_tlv(), der_put_uint_integer(), profiler_generate_report(), profiler_print_hotspots(), rpi5_mailbox_get_framebuffer(), string_word_search(), walk_virtio_caps(), walk_virtio_caps(), walk_virtio_caps(), xxhash64(), and xxhash64_update().

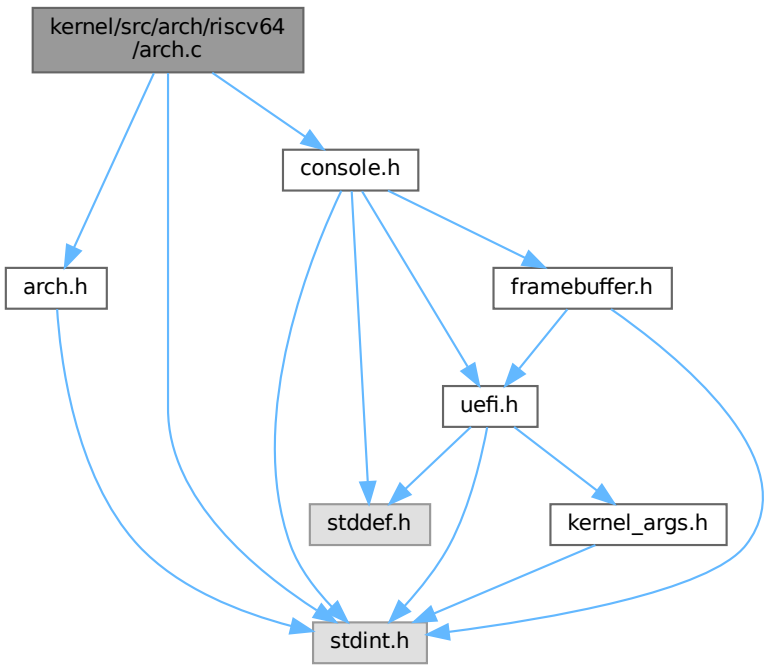
7.109.2.8 limit_low

```
uint16_t limit_low
```

7.110 kernel/src/arch/riscv64/arch.c File Reference

```
#include "arch.h"
#include "console.h"
#include <stdint.h>
```

Include dependency graph for arch.c:



Functions

- void riscv64_install_vectors (void)

  arch.c (riscv64) - Architecture abstractions for StarKernel on RISC-V 64-bit
- static void print_hex64 (uint64_t val)
- void arch_early_init (void)

  Perform the earliest RISC-V architecture initialisation (no-op).
- void arch_enable_interrupts (void)

  Enable supervisor-mode interrupts (RISC-V CSRSI sstatus).
- void arch_disable_interrupts (void)

  Disable supervisor-mode interrupts (RISC-V CSRCI sstatus).
- void arch_halt (void)

  Halt the core until the next interrupt (RISC-V WFI).
- void arch_cold_reset (void)
- uint64_t arch_read_timestamp (void)

  Read the RISC-V CPU cycle counter (`rdcycle`).
- void arch_mmu_init (void)

  Initialise the RISC-V MMU (stub — deferred to a later milestone).

Variables

- char __kernel_start [ ]

7.110.1 Function Documentation

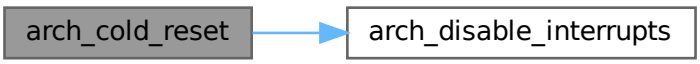
7.110.1.1 arch_cold_reset()

```
void arch_cold_reset (
            void  )
```

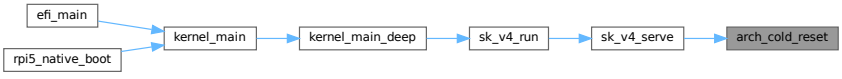
References arch_disable_interrupts(), and s_psci_use_smc.

Referenced by sk_v4_serve().

Here is the call graph for this function:



Here is the caller graph for this function:



7.110.1.2 arch_disable_interrupts()

```
void arch_disable_interrupts (
            void  )
```

Disable supervisor-mode interrupts (RISC-V CSRCI sstatus).

Disable IRQ delivery on the current core (AArch64 DAIFSET).

Issues `CSRCI sstatus, 0x2` which clears bit 1 (`SIE`) in `sstatus`, masking all supervisor-mode interrupts. Machine-mode interrupts are unaffected. Used around critical sections in the single-threaded kernel. The `memory` clobber acts as a compiler barrier; pair with a `FENCE` instruction for a hardware barrier.

7.110.1.3 arch_early_init()

```
void arch_early_init (
            void  )
```

Perform the earliest RISC-V architecture initialisation (no-op).

arch.h - Architecture abstraction layer for StarKernel

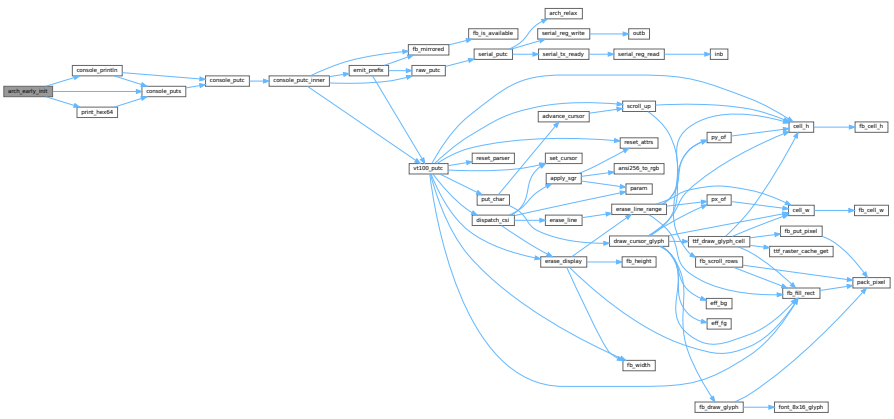
RISC-V has no GDT or IDT; privilege separation is handled by the machine/supervisor/user execution modes (M/S/U), and the trap vector table is installed by writing `stvec` in `arch_interrupts_init()` via `riscv64_install_vectors()`. This stub satisfies the common `arch_early_init()` call site in `kernel_main()` without any RISC-V-specific action.

Correction, 2026-09-04 (FABRIC-3.md ?V.3 item 7's code audit). The unconditional Bare-mode switch this function used to perform was justified entirely by behaviour observed under this system's QEMU/EDK2 RISC-V firmware (`satp.MODE=10/Sv57`, kernel identity-mapped within it — see the comment on `print_hex64()` above). That observation cannot apply to the native boot path (U-Boot+OpenSBI, no EDK2 at all, FABRIC-3.md ?V.1) this kernel now also has, and OpenSBI's own S-mode handoff convention leaves `satp` already at 0 (Bare) in the common case — meaning the switch below was very likely running as a harmless no-op there, but on an unverified assumption rather than a checked one. Rather than build a general Sv39/Sv48/Sv57 page-table walker just to *prove* the running address is identity-mapped before switching (out of proportion to this item's real scope), the fix narrows what actually needs the QEMU-specific safety argument: `**skip the switch entirely when satp is already 0.**` That is the expected case on both a from-Bare native boot and any firmware that already left translation off, and it needs no safety argument at all — there is nothing to switch away from. The unconditional-switch path still exists for the confirmed QEMU/EDK2 case (`mode != 0`), where the identity-mapping argument above remains the actual justification, unchanged.

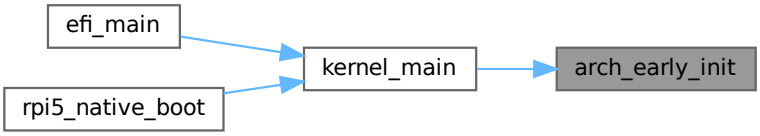
References __kernel_start, console_println(), console_puts(), and print_hex64().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.110.1.4 arch_enable_interrupts()

```
void arch_enable_interrupts (
            void  )
```

Enable supervisor-mode interrupts (RISC-V CSRSI sstatus).

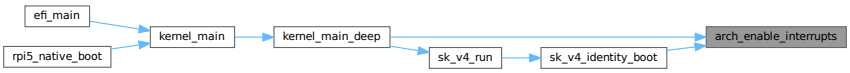
Enable IRQ delivery on the current core (AArch64 DAIFCLR).

Issues `CSRSI sstatus, 0x2` which sets bit 1 (`SIE` — Supervisor Interrupt Enable) in the `sstatus` CSR. While `SIE` = 1, pending supervisor-mode interrupts are taken. The `memory` clobber prevents the compiler from reordering stores across the barrier.

Must be called after `arch_interrupts_init()` has installed the `stvec` trap handler, and after the PLIC driver has been configured to forward the desired interrupt sources.

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the caller graph for this function:



7.110.1.5 arch_halt()

```
void arch_halt (
            void  )
```

Halt the core until the next interrupt (RISC-V WFI).

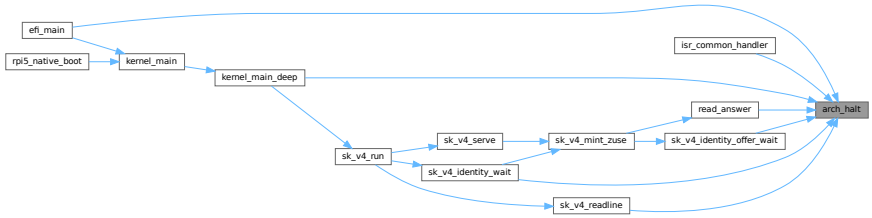
Halt the core until the next event (AArch64 WFI).

Issues the `WFI` (Wait For Interrupt) instruction in supervisor mode. The core enters a low-power state and resumes when a pending interrupt is detected (or after a platform-specific timeout). In the kernel panic path this is called inside an infinite loop with `SIE` cleared to stop the processor permanently. In the idle path it reduces power consumption between heartbeat ticks.

The `memory` clobber prevents store-sinking across the `WFI`.

Referenced by efi_main(), isr_common_handler(), kernel_main_deep(), read_answer(), sk_v4_identity_offer_wait(), sk_v4_identity_wait(), and sk_v4_readline().

Here is the caller graph for this function:



7.110.1.6 arch_mmu_init()

```
void arch_mmu_init (
            void  )
```

Initialise the RISC-V MMU (stub — deferred to a later milestone).

Initialise the AArch64 MMU (stub — deferred to a later milestone).

Full Sv39/Sv48 page-table setup (SATP, PMP, etc.) is deferred to a later milestone. This stub satisfies the common `arch_mmu_init()` call site shared across all three supported ISAs. The VMM subsystem (`vmm.c`) handles page-table management independently of this hook.

7.110.1.7 arch_read_timestamp()

```
uint64_t arch_read_timestamp (
            void  )
```

Read the RISC-V CPU cycle counter (`rdcycle`).

Read the AArch64 system counter (CNTPCT_EL0).

Issues the `RDCYCLE` pseudo-instruction (a `CSRRS` on `cycle`, CSR 0xC00) to read the 64-bit hardware performance counter that counts elapsed clock cycles since reset. On RISC-V the cycle counter is the architectural equivalent of the x86-64 TSC.

Unlike the AArch64 `CNTPCT_EL0`, the RISC-V `cycle` register is a per-hart counter and is not architecturally guaranteed to be synchronised across harts. For single-core LithosAnanke this is not a concern. Frequency is not architecturally specified; `timer_init()` assumes 1 GHz for QEMU `virt` board compatibility.

Returns

Current 64-bit cycle counter value; frequency platform-dependent.

Referenced by calibrate_apic_timer().

Here is the caller graph for this function:

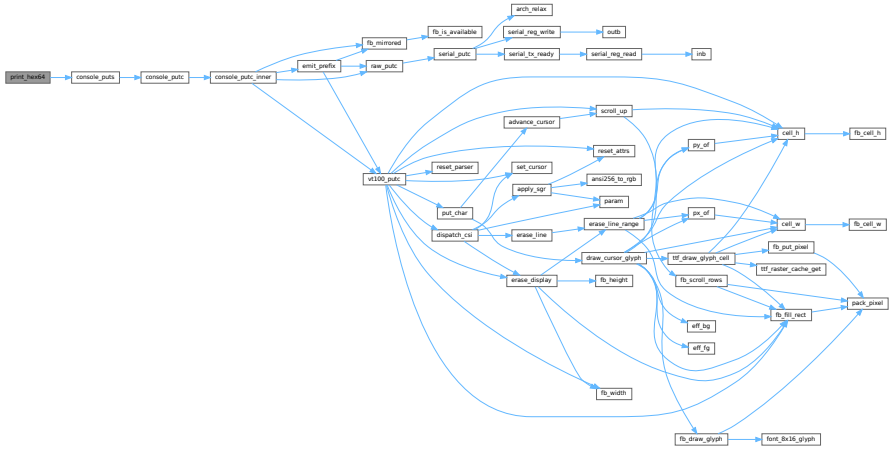
7.110.1.8 print_hex64()

```
static void print_hex64 (
            uint64_t val )  [static]
```

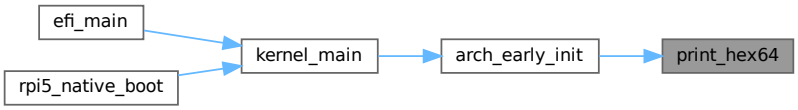
References console_puts().

Referenced by arch_early_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.110.1.9 riscv64_install_vectors()

```
void riscv64_install_vectors (
            void  )  [extern]
```

arch.c (riscv64) - Architecture abstractions for StarKernel on RISC-V 64-bit

7.110.2 Variable Documentation

7.110.2.1 __kernel_start

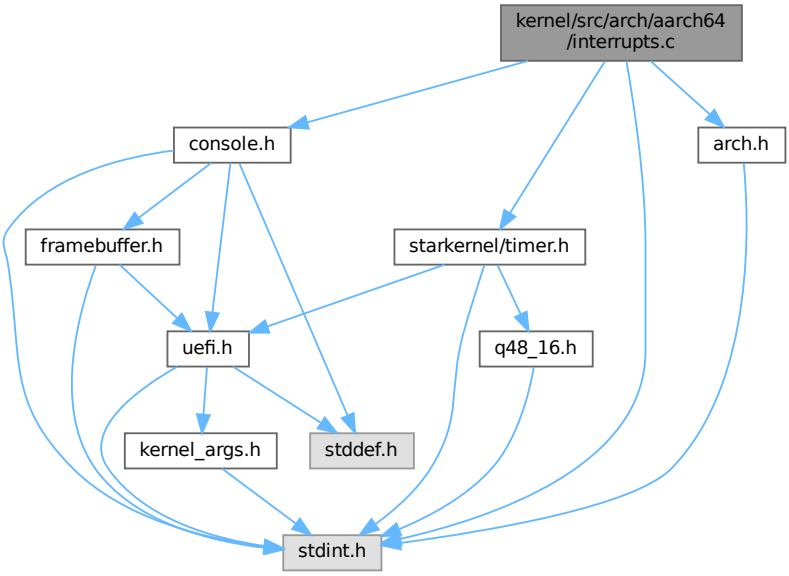
```
char __kernel_start[]  [extern]
```

Referenced by arch_early_init().

7.111 kernel/src/arch/aarch64/interrupts.c File Reference

```
#include <stdint.h>
#include "arch.h"
#include "console.h"
#include "starkernel/timer.h"
```

Include dependency graph for interrupts.c:



Macros

- #define GIC_INTID_SPURIOUS 1023u

Functions

- void aarch64_install_vectors (void)
- int aarch64_current_el (void)

  Return the AArch64 exception level the kernel is running at.
- uint32_t apic_read_iar (void)

  Read the GIC CPU interface's Interrupt Acknowledge Register.
- uint32_t apic_timer_ppi (void)

  Return the timer PPI this build is watching for.
- void apic_eoi_intid (uint32_t intid)

  Signal End of Interrupt to the GIC CPU interface.
- void apic_timer_rearm (void)

  Re-arm the ARM Generic Timer for the next period (item 0.7).
- void virtio_input_isr (void)
- void aarch64_irq_handler (void)

  Dispatch an IRQ taken at current-EL with SPx (punch-list item 0.7).
- static void print_hex (uint64_t val)

Print a 64-bit value as "0xNNNNNNNNNNNNNNNN" to the kernel console.

- void aarch64_exception_handler (void)

  AArch64 common exception handler — print diagnostic and spin.

- void arch_interrupts_init (void)

  Install the AArch64 exception vector table (M4 milestone).

Variables

- volatile const char * g_sk_fault_word = (void *)0

  interrupts.c (aarch64) - Exception vector setup and common handler

- uint32_t g_virtio_input_gic_intid

7.111.1 Macro Definition Documentation

7.111.1.1 GIC_INTID_SPURIOUS

```
#define GIC_INTID_SPURIOUS 1023u
```

7.111.2 Function Documentation

7.111.2.1 aarch64_current_el()

```
int aarch64_current_el (
            void  )  [extern]
```

Return the AArch64 exception level the kernel is running at.

apic.c (aarch64) - Minimal GICv2 driver + ARM Generic Timer (items 0.6/0.7/ 4.3.5d).

Reads `CurrentEL` (bits [3:2] hold the EL number, [1:0] are RES0) on first call and caches the result; every later call returns the cached value. Safe to call at any point in boot, including before `console_init()` — the read itself has no dependency, only the printing of it does (see `arch_interrupts_init()` in `interrupts.c`, the earliest point at which both this and a working console are available).

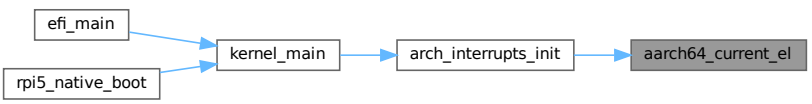
EDK2 on QEMU's aarch64 `virt` machine has been observed to leave the kernel at either EL1 or EL2 depending on firmware build; nothing in this tree may assume one over the other (FABRIC-0.md ?25.7.1 GAP-B3). Every EL-dependent choice — `VBAR_EL1` vs `VBAR_EL2`, the `ELR_ELx` / `SPSR_ELx` saved-state pair, and `CNTP_*_EL0` vs `CNTHP_*_EL2` — must read this accessor rather than hardcode a level.

Returns

1 or 2. Never 0 or 3: a UEFI application that survived far enough to reach this call cannot be running at EL0 (unprivileged) or EL3 (secure monitor — QEMU's virt firmware runs the kernel at EL1/EL2).

Referenced by arch_interrupts_init().

Here is the caller graph for this function:



7.111.2.2 aarch64_exception_handler()

```
void aarch64_exception_handler (
            void  )
```

AArch64 common exception handler — print diagnostic and spin.

Called from the `isr.S` exception vector table stubs for all exception types (synchronous, IRQ, FIQ, SError) that are not handled by a specific driver. Reads the four key EL1 exception system registers directly:

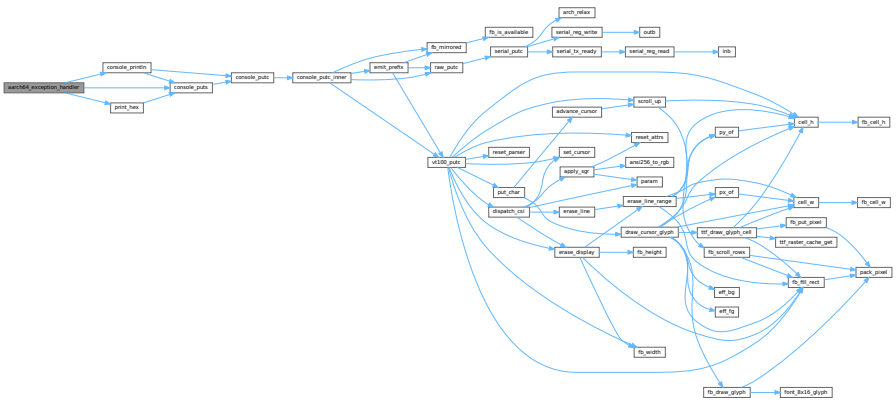
- `ESR_EL1` — Exception Syndrome Register: encodes the exception class (EC, bits [31:26]) and instruction-specific syndrome (ISS, bits [24:0]). The EC identifies the cause (e.g., 0x21 = data abort from EL1, 0x25 = data abort from EL0, 0x15 = SVC64).
- `ELR_EL1` — Exception Link Register: the PC of the instruction that caused the exception (or the instruction after, for IRQ/FIQ/SError).
- `FAR_EL1` — Fault Address Register: the virtual address that triggered a Data Abort or Instruction Abort; undefined for other exception types.
- `SPSR_EL1` — Saved Program Status Register: the PSTATE at the time of exception, including the mode field and interrupt-mask bits.

Prints all four values to the kernel console then enters an infinite `WFE` loop to halt the affected core permanently. All exceptions that reach this handler are fatal — there is no recovery path.

The global `g_sk_fault_word` is set by the VM FORTH dispatcher just before calling each word's function pointer; it names the word executing at the time of the fault, aiding post-mortem analysis from the serial log. (Currently logged only on the amd64 #GP path; future AArch64 diagnostic expansion can include it here.)

References console_println(), console_puts(), and print_hex().

Here is the call graph for this function:

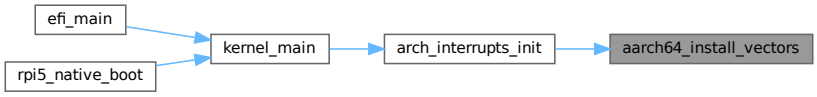


7.111.2.3 aarch64_install_vectors()

```
void aarch64_install_vectors (
            void  )  [extern]
```

Referenced by arch_interrupts_init().

Here is the caller graph for this function:



7.111.2.4 aarch64_irq_handler()

```
void aarch64_irq_handler (
            void  )
```

Dispatch an IRQ taken at current-EL with SPx (punch-list item 0.7).

Called from `irq_spx_trampoline` in `isr.S`, which has already saved the full caller-saved integer and FP/SIMD register sets plus `ELR_ELx` / `SPSR_ELx`, and will restore all of it and `ERET` after this function returns — unlike `aarch64_exception_handler()`, this path is designed to return normally.

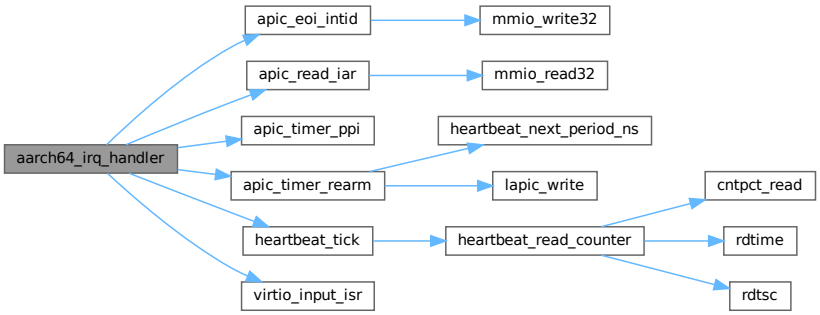
Reads `GICC_IAR` once (the GICv2 acknowledgement step — this also moves the interrupt to the active state), dispatches on the returned INTID, and always completes with the matching `GICC_EOIR` write, spurious or not: a spurious read must still not be treated as "nothing to clean up," and an unrecognised real INTID still needs the CPU interface unblocked for the next one.

For the timer PPI (`apic_timer_ppi()` — 30 at EL1, 26 at EL2, decided once in `apic_init()`: `apic_timer_rearm()` runs **first**, before `heartbeat_tick()` — the ARM Generic Timer does not auto-reload, so skipping this leaves the interrupt condition permanently latched (see `apic_timer_rearm()`'s own doc comment). Ordering the re-arm ahead of the rest of the dispatch means a fault in `heartbeat_tick()` cannot also cost the next tick — same discipline as `riscv64_timer_rearm()` (item 0.3).

virtio-input (item 4.3.5e, `g_virtio_input_gic_intid`): dispatched **before** the `GICC_EOIR` write below, not after — the ISR itself is what deasserts the device's (level-triggered) interrupt line by reading its ISR-status capability; EOI'ing first would let the GIC immediately re-signal a still-asserted line. Same claim-dispatch-complete ordering `riscv64_interrupt_handler()` uses for its own PLIC-routed devices.

References apic_eoi_intid(), apic_read_iar(), apic_timer_ppi(), apic_timer_rearm(), g_virtio_input_gic_intid, GIC_INTID_SPURIOUS, heartbeat_tick(), and virtio_input_isr().

Here is the call graph for this function:



7.111.2.5 apic_eoi_intid()

```
void apic_eoi_intid (
            uint32_t intid )  [extern]
```

Signal End of Interrupt to the GIC CPU interface.

Writes `intid` back to `GICC_EOIR`, matching the value `GICC_IAR` returned in `aarch64_irq_handler()`. Required after every acknowledged interrupt or the GIC considers it permanently active and will not re-signal it.

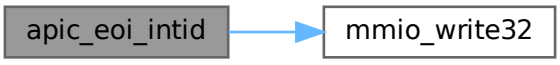
Parameters

intid	INTID as read from `GICC_IAR` (10 bits used by GICv2).

References GICC_EOIR, mmio_write32(), and s_gicc_base.

Referenced by aarch64_irq_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

7.111.2.6 apic_read_iar()

```
uint32_t apic_read_iar (
            void  )  [extern]
```

Read the GIC CPU interface's Interrupt Acknowledge Register.

Reading `GICC_IAR` returns the INTID of the highest-priority pending interrupt and simultaneously moves it to the active state — this is the GICv2 acknowledgement step. Called from `aarch64_irq_handler()` in `interrupts.c` to identify which interrupt fired; the matching `apic_eoi_intid()` call below completes it.

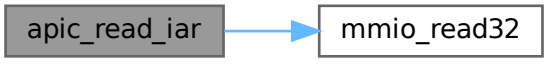
Returns

INTID (10 bits used by GICv2).

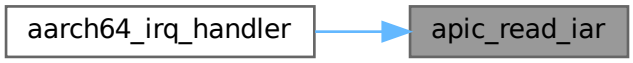
References GICC_IAR, mmio_read32(), and s_gicc_base.

Referenced by aarch64_irq_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.111.2.7 apic_timer_ppi()

```
uint32_t apic_timer_ppi (
            void  )  [extern]
```

Return the timer PPI this build is watching for.

Set once in `apic_init()` from `aarch64_current_el()` (30 at EL1, 26 at EL2). `aarch64_irq_handler()` compares `apic_read_iar()`'s result against this rather than a hardcoded constant.

References s_timer_ppi.

Referenced by aarch64_irq_handler().

Here is the caller graph for this function:

7.111.2.8 apic_timer_rearm()

```
void apic_timer_rearm (
            void  )  [extern]
```

Re-arm the ARM Generic Timer for the next period (item 0.7).

Re-arm the APIC timer at the current adaptive period (item 0.8, ?26).

Writes a fresh `TVAL` — the entirety of a periodic re-arm, since `TVAL` is relative to "now" rather than an absolute deadline. Unlike riscv64's SBI re-arm (item 0.3), there is no drift-correction bookkeeping: each write means "@c s_timer_period_tsc ticks from this instant," so time spent servicing the interrupt before this call simply lengthens that one period rather than accumulating error across ticks.

This is the one call that must never be skipped. The ARM Generic Timer does not auto-reload: once `TVAL` crosses zero, `CTL.ISTATUS` latches and stays asserted — a level condition — until software writes a new `TVAL` or clears `CTL.ENABLE`. A return path that skips this leaves the interrupt permanently pending, which the GIC would deliver again the instant it is EOI'd: a real interrupt storm, not a hypothetical one (this is exactly the failure this driver was checked against during item 0.6's own verification, and confirmed absent there only because nothing armed the timer yet).

Called from `aarch64_irq_handler()` (interrupts.c) before `heartbeat_tick()` — same ordering discipline as `riscv64_timer_rearm()` (item 0.3): re-arm first, so a fault in the rest of the handler cannot also cost the next tick.

The step written is `heartbeat_next_period_ns()` (item 0.8, ?26) converted to `CNTPCT_EL0` ticks via `s_counter_hz_apic`, not the fixed `s_timer_period_tsc` `apic_timer_start()` used for the very first arm – that value remains `apic_timer_period_tsc()`'s return for `heartbeat_init()`'s initial `expected_delta`, unchanged.

Re-arm the ARM Generic Timer for the next period (item 0.7).

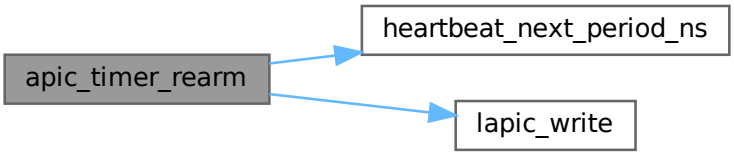
amd64's APIC timer runs in periodic mode: hardware auto-reloads `APIC_REG_TIMER_ICR` on every expiry with no software intervention, unlike riscv64's one-shot SBI deadline or aarch64's one-shot `CNTP_TVAL_EL0` – neither of which needed a rearm function before this item for the same reason this one now exists. To make the period adaptive, this function recomputes `timer_initial_count` from `heartbeat_next_period_ns()` (?26) and `s_apic_hz`, then writes it to `APIC_REG_TIMER_ICR`. A periodic-mode ICR write takes effect immediately and restarts the countdown at the new value – the same mechanism `apic_timer_start()` already relies on to force QEMU TCG's emulated APIC to begin counting.

Called from `isr_common_handler()` on every `APIC_TIMER_VECTOR` interrupt, before `heartbeat_tick()` – same ordering discipline as riscv64/aarch64's rearm-before-heartbeat_tick(), so a fault in `heartbeat_tick()` cannot also cost the next tick.

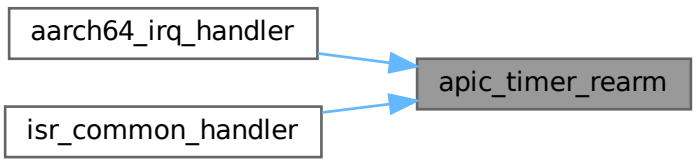
References APIC_REG_TIMER_ICR, heartbeat_next_period_ns(), lapic_write(), s_apic_hz, and timer_initial_count.

Referenced by aarch64_irq_handler(), and isr_common_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.111.2.9 arch_interrupts_init()

```
void arch_interrupts_init (
            void  )
```

Install the AArch64 exception vector table (M4 milestone).

First reads and reports the exception level via aarch64_current_el() (punch-list item 0.4) — this is the earliest point in boot with both a working console (up since M1) and a genuine need for the answer (vector installation is the first EL-dependent operation). The read itself is cheap and safe far earlier than this; only the console print is gated on this call site.

Then calls aarch64_install_vectors() (defined in isr.S) which writes the address of the vector table base into VBAR_EL1 or VBAR_EL2 (Vector Base Address Register), whichever matches the exception level aarch64_current_el() just reported. After this instruction all exceptions at that level (synchronous, IRQ, FIQ, SError) dispatch through the 512-byte-aligned vector table assembled in isr.S.

Correction, 2026-09-04 (FABRIC-3.md ?IV.3 item 7's code audit): this doc comment and the runtime console message below previously claimed EL2 was "a known gap... @c VBAR_EL1 is written unconditionally regardless of the detected level," citing punch-list item 0.5 as the still-open work to fix it. Checked against isr.S's own aarch64_install_vectors() (the actual implementation, not this comment) and found that claim stale↩ : the assembly already branches on aarch64_current_el() and writes vbar_el2 at EL2 / vbar_el1 at EL1, threading the same answer through el2_mode_flag for the IRQ trampoline's ELR_ELx/SPSR_ELx selection too (see isr.S's own "EL selection" header comment). There never was a gap here to close — item 0.5's EL2 vector work was already done by the time this comment was written describing it as open; only the comment was wrong, not the code.

On AArch64 there is no IDT and no PIC to disable; the GIC replaces both. The arch_interrupts_init() name is kept identical across all ISAs so that kernel_main() can call the same symbol regardless of the target architecture.

Must be called after the kernel stack is established (so that the correct-EL SP is valid) and before arch_enable_interrupts().

7.111.2.10 print_hex()

```
static void print_hex (
             uint64_t val )  [static]
```

Print a 64-bit value as "0xNNNNNNNNNNNNNNNN" to the kernel console.

Formats val as a 16-nibble lowercase hex string preceded by "0x" into a 19-byte stack buffer (including null terminator) then emits it via console_puts(). Used by aarch64_exception_handler() to print ESR_EL1, ELR_EL1, FAR_EL1, and SPSR_EL1 in the exception diagnostic dump. No heap allocation or libc dependency.

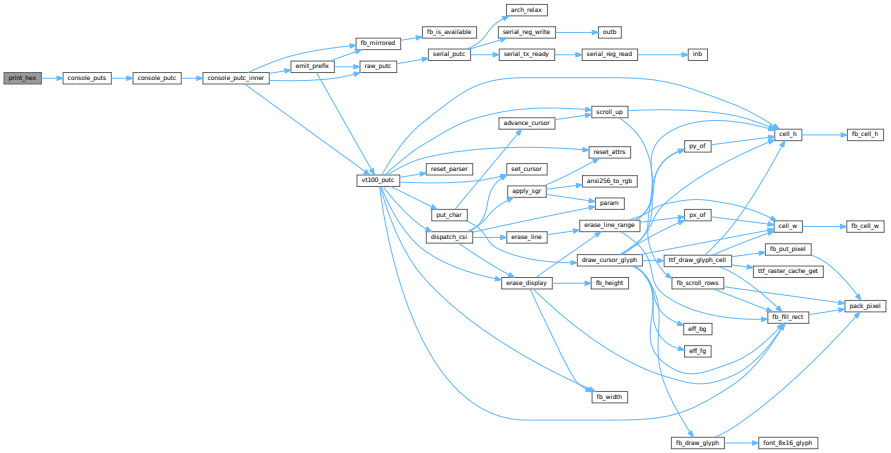
Parameters

val	64-bit value to format.

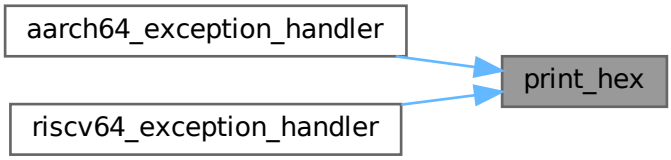
References console_puts().

Referenced by aarch64_exception_handler(), and riscv64_exception_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

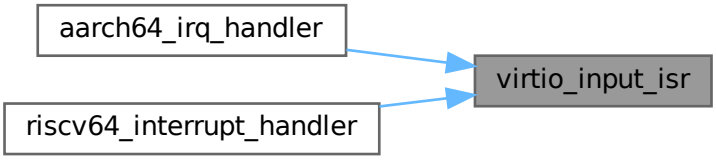


7.111.2.11 virtio_input_isr()

```
void virtio_input_isr (
            void  )  [extern]
```

Referenced by aarch64_irq_handler(), and riscv64_interrupt_handler().

Here is the caller graph for this function:



7.111.3 Variable Documentation

7.111.3.1 g_sk_fault_word

```
volatile const char* g_sk_fault_word = (void *)0
```

interrupts.c (aarch64) - Exception vector setup and common handler

Referenced by isr_common_handler().

7.111.3.2 g_virtio_input_gic_intid

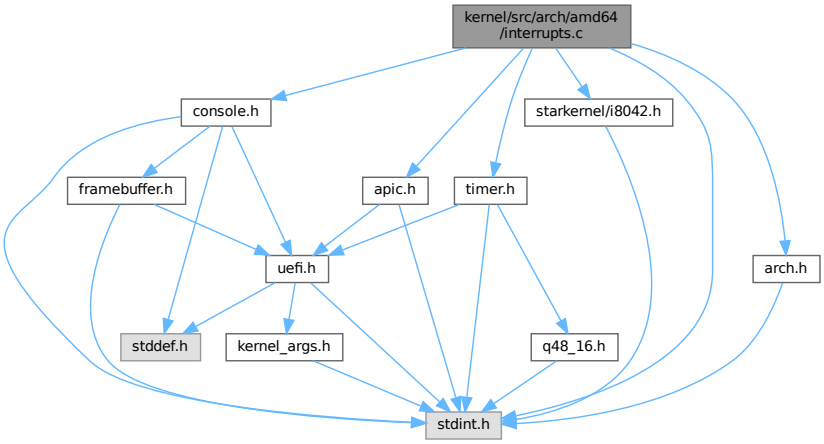
```
uint32_t g_virtio_input_gic_intid  [extern]
```

Referenced by aarch64_irq_handler().

7.112 kernel/src/arch/amd64/interrupts.c File Reference

```
#include <stdint.h>
#include "arch.h"
#include "console.h"
#include "apic.h"
#include "timer.h"
#include "starkernel/i8042.h"
```

Include dependency graph for interrupts.c:



Data Structures

- struct idt_entry
- struct idtr

Macros

- #define IDT_ENTRIES 256
- #define INTERRUPT_GATE 0x8E

Functions

- static void outb (uint16_t port, uint8_t val)

  Write a single byte to an x86 I/O port via `OUT`.
- struct idt_entry __attribute__ ((packed))
- void ∗isr_stub_table[256] __attribute__ ((visibility("hidden")))
- void isr_common_handler (uint64_t vector, uint64_t error_code, uint64_t rip, uint64_t cs, uint64_t rflags, uint64_t cr2, uint64_t stack_frame_ptr)

  Unified C-level interrupt and exception handler.
- static void set_idt_entry (int vector, void ∗isr)

  Write a single 64-bit interrupt gate descriptor into the IDT.
- static void lidt (struct idtr ∗idtr_desc)

  Load the Interrupt Descriptor Table register (`LIDT`).
- static void print_hex64 (uint64_t value)

  Print a 64-bit value as 16 lowercase hex digits to the kernel console.
- static void print_dec_u64 (uint64_t v)

  Print a 64-bit unsigned integer in decimal to the kernel console.
- static void pic_disable (void)

  Fully mask the legacy 8259A PIC to suppress all legacy IRQs.
- static void decode_pf_error (uint64_t ec)

  Decode and print the x86-64 Page Fault error code to the kernel console.
- void isr_stub0 (void)

  Initialise the x86-64 IDT and disable the legacy 8259 PIC (M4).

Variables

- volatile const char ∗ g_sk_fault_word = (void ∗)0

  interrupts.c (amd64) - Interrupt setup and exception/IRQ handling
- volatile uint32_t g_spurious_count = 0
- uint16_t offset_low
- uint16_t selector
- uint8_t ist
- uint8_t type_attr
- uint16_t offset_mid
- uint32_t offset_high
- uint32_t zero
- uint16_t limit
- uint64_t base
- static struct idt_entry idt [256]

7.112.1 Macro Definition Documentation

7.112.1.1 IDT_ENTRIES

```
#define IDT_ENTRIES 256
```

7.112.1.2 INTERRUPT_GATE

```
#define INTERRUPT_GATE 0x8E
```

7.112.2 Function Documentation

7.112.2.1 __attribute__() [1/2]

```
struct idt_entry __attribute__ (
             (packed)  )
```

7.112.2.2 __attribute__() [2/2]

```
void *isr_stub_table[256] __attribute__ (
             (visibility("hidden"))  )  [extern]
```

7.112.2.3 decode_pf_error()

```
static void decode_pf_error (
             uint64_t ec )  [static]
```

Decode and print the x86-64 Page Fault error code to the kernel console.

The processor pushes a 32-bit error code onto the stack for a #PF (vector 14). Each bit encodes information about the faulting access:

- bit 0 (P): 0 = page not present; 1 = protection violation.
- bit 1 (W/R): 0 = read access; 1 = write access.
- bit 2 (U/S): 0 = supervisor mode access; 1 = user mode access.
- bit 3 (RSVD): 1 = fault caused by a reserved bit set in a PTE.
- bit 4 (I/D): 1 = instruction fetch (no-execute violation).
- bit 5 (PK): 1 = protection-key violation (if PKRU is active).
- bit 6 (SS): 1 = shadow-stack access violation (CET).
- bit 15 (SGX): 1 = SGX enclave access violation.

Prints each active flag as a short tag to the kernel console followed by a newline. The CR2 register (captured by the ISR stub) holds the faulting linear address and is printed separately by `isr_common_handler()`.

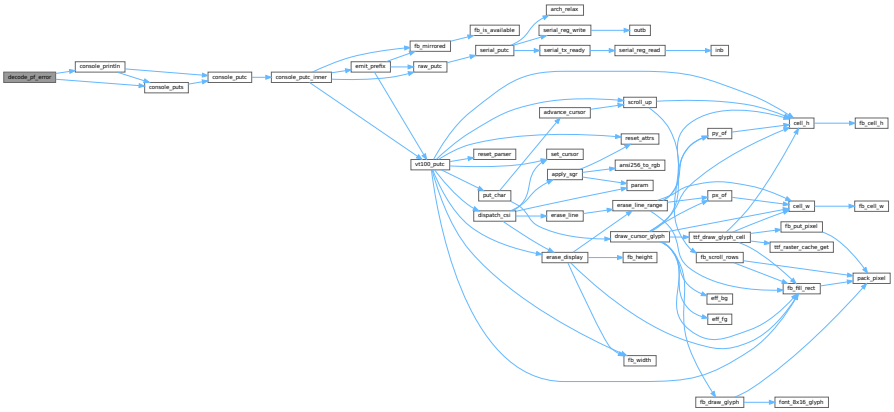
Parameters

ec	64-bit page fault error code (upper 32 bits are always zero on current x86-64 hardware; tested up to bit 15 per SDM).

References console_println(), and console_puts().

Referenced by isr_common_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

7.112.2.4 isr_common_handler()

```
void isr_common_handler (
            uint64_t vector,
            uint64_t error_code,
            uint64_t rip,
            uint64_t cs,
            uint64_t rflags,
            uint64_t cr2,
            uint64_t stack_frame_ptr )  [extern]
```

Unified C-level interrupt and exception handler.

All 256 IDT entries funnel through a common assembly trampoline in `isr.S` which captures caller-saved registers, reads `CR2` (the page-fault linear address), normalises the error code to 0 for vectors that do not push one, and then calls this function with six arguments reconstructed from the interrupt stack frame.

APIC timer path (vector == `APIC_TIMER_VECTOR`): Calls `heartbeat_tick()` to update the rolling window of inter-tick TSC deviations, then issues `apic_eoi()` and returns. This is the hot path — it executes at 100 Hz during normal kernel operation and must be kept brief.

Exception path (all other vectors): Prints a structured diagnostic to the kernel console:

- Vector number (decimal and hex)
- Error code (hex)
- RIP (hex) — faulting instruction pointer
- CR2 (hex) — page-fault linear address (meaningful only for vector 14)
- RSP (derived from `stack_frame_ptr` + 160, covering the ISR stub's pushed register block)
- RBP (read from the saved-register block at `stack_frame_ptr` + 64)
- Return address (first quadword at the derived RSP)
- Vector-specific decoding: `#DE` (0), `#GP` (13) with the active FORTH word name from `g_sk_fault_word`, `#PF` (14) with `decode_pf_error()`. Then halts the CPU in an infinite `HLT` loop — exceptions are fatal.

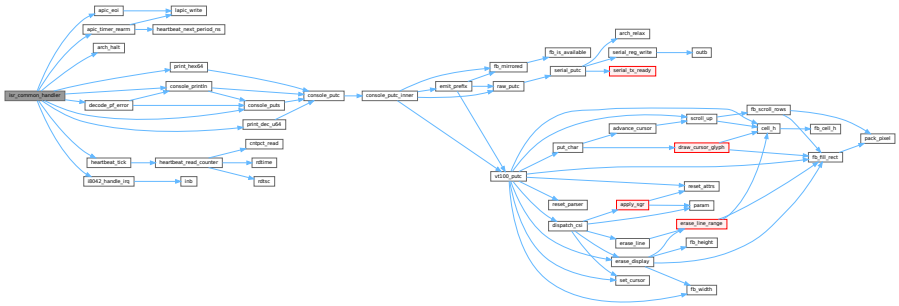
The `cs` and `rflags` parameters are currently unused (suppressed with (void) casts) but retained in the signature for future use (e.g., printing privilege level on #GP).

Parameters

vector	IDT vector that fired [0, 255].
error_code	Error code from the CPU stack (0 if not applicable).
rip	Faulting or interrupted instruction pointer.
cs	Code segment selector at the time of the interrupt.
rflags	RFLAGS at the time of the interrupt.
cr2	Value of `CR2` (page-fault linear address; only architecturally meaningful for vector 14).
stack_frame_ptr	Address of the ISR stub's saved-register block on the stack; used to reconstruct RSP and RBP for the diagnostic dump.

References apic_eoi(), APIC_SPURIOUS_VECTOR, apic_timer_rearm(), APIC_TIMER_VECTOR, arch_halt(), console_println(), console_puts(), decode_pf_error(), g_sk_fault_word, g_spurious_count, heartbeat_tick(), i8042_handle_irq(), I8042_KEYBOARD_VECTOR, print_dec_u64(), and print_hex64().

Here is the call graph for this function:



7.112.2.5 isr_stub0()

```
void isr_stub0 (
            void  )  [extern]
```

Initialise the x86-64 IDT and disable the legacy 8259 PIC (M4).

This is the M4 milestone function called from kernel_main() after the GDT is live (arch_early_init()) and before arch_enable_interrupts(). It performs three operations:

1. **Relocation fixup for the ISR stub table.** isr.S exports isr_stub_table[], a 256-entry table of link-time function pointers assembled at their expected virtual addresses. In a UEFI PE32+ image the UEFI loader places the image at an arbitrary base; pointer-sized relocations in .data are not applied by the PE loader (only code-relative relocations in .text are). The fixup computes the runtime delta between isr_stub0's runtime address and its link-time address stored in isr_stub_table[0], then applies that delta to every entry before installing it in the IDT.
2. **Fill all 256 IDT entries.** Calls set_idt_entry() for each vector with the corrected stub address, selector 0x08, IST 0, and type_attr INTERRUPT_GATE (0x8E).
3. **Load the IDT and mask the PIC.** Calls lidt() with the fully populated idt[] array, then calls pic_disable() to mask both PIC1 and PIC2 before STI is issued. This prevents spurious legacy PIC IRQs from reaching the IDT before the Local APIC takes over.

Must be called after gdt_init() (for selector 0x08) and before apic_init() / apic_timer_init() / arch_enable_interrupts().

7.112.2.6 lidt()

```
static void lidt (
            struct idtr * idtr_desc )  [static]
```

Load the Interrupt Descriptor Table register (LIDT).

Executes the LIDT instruction with the descriptor at idtr_desc, which contains the 16-bit limit (byte size of the IDT minus 1) and the 64-bit linear base address of the IDT array. After this instruction the CPU uses the new IDT for all exception and interrupt dispatch.

Must be called after all 256 entries in idt[] have been filled by set_idt_entry(). Called at the end of arch_interrupts_init().

Parameters

idtr_desc	Pointer to an idtr struct containing limit and base.

7.112.2.7 outb()

```
static void outb (
            uint16_t port,
            uint8_t val )  [inline], [static]
```

Write a single byte to an x86 I/O port via OUT.

Issues the OUT instruction to port port with data byte val. Used exclusively to program the legacy 8259 PIC's interrupt-mask registers during pic_disable(). In a kernel that uses the Local APIC for all interrupt delivery the PIC must be fully masked before enabling CPU interrupts; otherwise spurious IRQ0 from the PIC timer can corrupt the APIC timer ISR path.

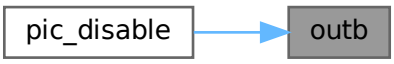
The "Nd" constraint allows the assembler to emit the short-form OUT imm8 encoding for constants in [0, 255] and the register form OUT DX otherwise.

Parameters

port	16-bit I/O port number (e.g., 0x21 = PIC1 data, 0xA1 = PIC2 data).
val	Byte value to write to the port.

Referenced by pic_disable().

Here is the caller graph for this function:



7.112.2.8 pic_disable()

```
static void pic_disable (
            void  )  [static]
```

Fully mask the legacy 8259A PIC to suppress all legacy IRQs.

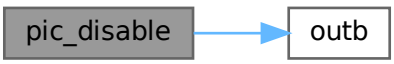
Writes 0xFF to PIC1's interrupt-mask register (port 0x21) and PIC2's interrupt-mask register (port 0xA1). When all bits are set every IRQ line (IRQ0–IRQ15) is masked and the PIC will not assert INTR to the CPU.

This is necessary because UEFI firmware initialises the 8259 PIC in compatibility mode with IRQ0 (timer) running at 18.2 Hz. After `ExitBootServices()` the firmware no longer handles these IRQs; if the PIC is not masked before `STI`, spurious PIC interrupts are delivered to the kernel's IDT at legacy vectors 0x20–0x2F, most of which have not been set up as ISRs and will triple-fault.

Called from `arch_interrupts_init()` after the IDT is loaded but before `arch_enable_interrupts()`.

References outb().

Here is the call graph for this function:



7.112.2.9 print_dec_u64()

```
static void print_dec_u64 (
            uint64_t v )  [static]
```

Print a 64-bit unsigned integer in decimal to the kernel console.

Converts `v` to a decimal ASCII string using a 32-byte stack buffer (digit reversal technique) and emits each character via `console_putc()`. Prints "0" for a zero value. Used by `isr_common_handler()` to print the exception vector number in decimal alongside its hex representation. No allocation or libc dependency.

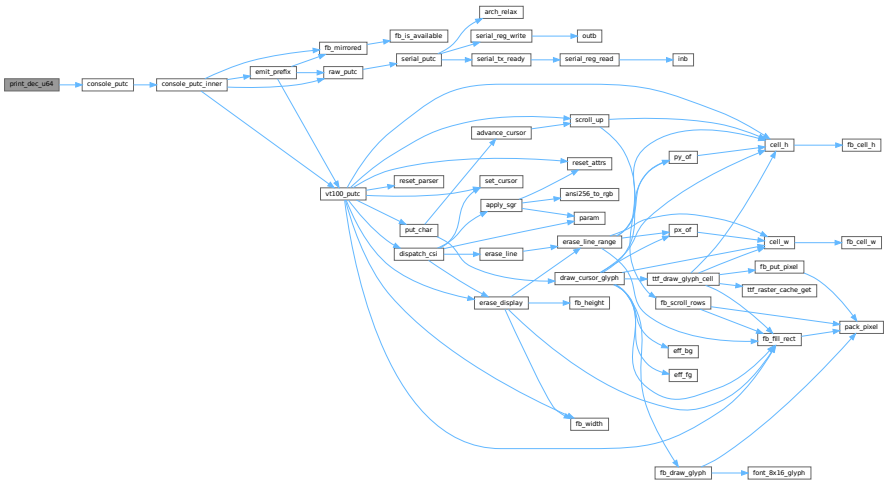
Parameters

v	64-bit unsigned integer to print.

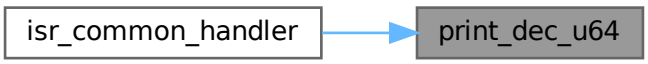
References console_putc().

Referenced by isr_common_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.112.2.10 print_hex64()

```
static void print_hex64 (
            uint64_t value )  [static]
```

Print a 64-bit value as 16 lowercase hex digits to the kernel console.

Emits exactly 16 nibbles (no `0x` prefix, no separators) by iterating from bit 60 down to bit 0 in steps of 4. Used exclusively by `isr_common_handler()` to print register values (RIP, CR2, RSP, RBP, return address) in the exception diagnostic dump. No allocation or libc dependency.

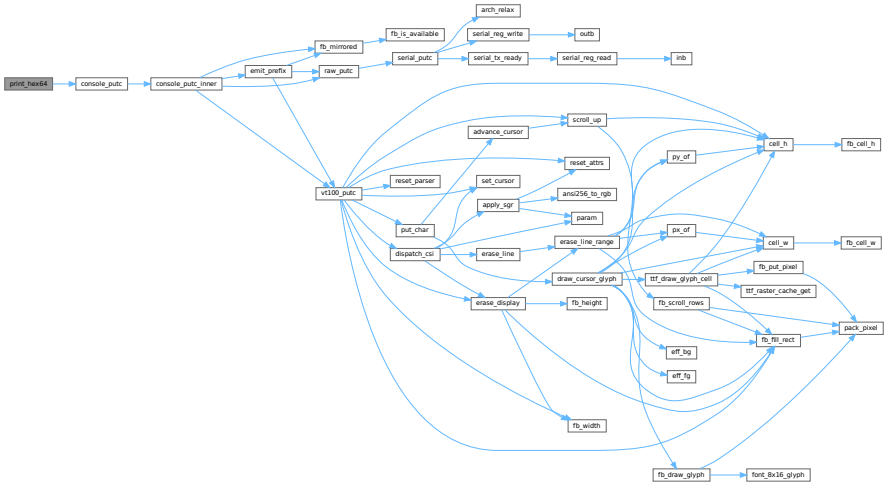
Parameters

value	64-bit value to format as lowercase hex.

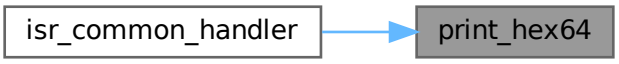
References console_putc().

Referenced by isr_common_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.112.2.11 set_idt_entry()

```
static void set_idt_entry (
            int vector,
            void * isr )  [static]
```

Write a single 64-bit interrupt gate descriptor into the IDT.

Fills `idt[vector]` with an x86-64 interrupt gate (type 0x8E):

- `offset_low` / `offset_mid` / `offset_high` — three parts of the ISR handler address `isr` split across the 16-byte descriptor layout.

- `selector` = 0x08 — kernel code segment (GDT slot 1).
- `ist` = 0 — no interrupt stack table; uses the current RSP.
- `type_attr` = `INTERRUPT_GATE` (0x8E) — P=1, DPL=0, 64-bit interrupt gate; the CPU automatically clears RFLAGS.IF on entry.
- `zero` = 0 — upper reserved dword must be zero.

Called once per vector inside `arch_interrupts_init()`'s loop after the relocation offset has been applied to the stub address from `isr_stub_table`.

Parameters

vector	IDT vector index [0, 255].
isr	Runtime address of the per-vector assembly stub in `isr.S`.

References idt, INTERRUPT_GATE, idt_entry::ist, idt_entry::offset_high, idt_entry::offset_low, idt_entry::offset_mid, idt_entry::selector, idt_entry::type_attr, and idt_entry::zero.

7.112.3 Variable Documentation

7.112.3.1 base

```
uint64_t base
```

7.112.3.2 g_sk_fault_word

```
volatile const char* g_sk_fault_word = (void *)0
```

interrupts.c (amd64) - Interrupt setup and exception/IRQ handling

interrupts.c (aarch64) - Exception vector setup and common handler

7.112.3.3 g_spurious_count

```
volatile uint32_t g_spurious_count = 0
```

Referenced by isr_common_handler(), and kbw_debug().

7.112.3.4 idt

```
struct idt_entry idt[256]  [static]
```

Referenced by set_idt_entry().

7.112.3.5 ist

```
uint8_t ist
```

7.112.3.6 limit

```
uint16_t limit
```

7.112.3.7 offset_high

```
uint32_t offset_high
```

7.112.3.8 offset_low

```
uint16_t offset_low
```

7.112.3.9 offset_mid

```
uint16_t offset_mid
```

7.112.3.10 selector

```
uint16_t selector
```

7.112.3.11 type_attr

```
uint8_t type_attr
```

7.112.3.12 zero

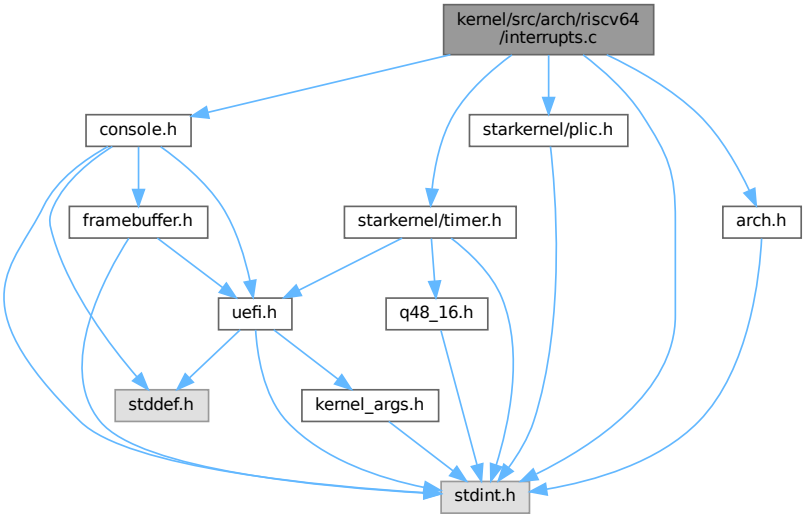
```
uint32_t zero
```

Referenced by bucket_posterior(), cache_posterior(), fe25519_neg(), gpt_grow_last(), gpt_read(), gpt_write_one(), point_decompress(), q48_from_double(), sha512_final(), and sk_v4_mint_zuse().

7.113 kernel/src/arch/riscv64/interrupts.c File Reference

```
#include <stdint.h>
#include "arch.h"
#include "console.h"
#include "starkernel/timer.h"
#include "starkernel/plic.h"
```

Include dependency graph for interrupts.c:



Macros

- #define SCAUSE_INTERRUPT_BIT (1ULL << 63)
- #define SCAUSE_S_TIMER 5ULL
- #define SCAUSE_S_EXTERNAL 9ULL

Functions

- void riscv64_install_vectors (void)
- void riscv64_timer_rearm (void)

  Re-arm the one-shot SBI timer and account the tick.
- void virtio_input_isr (void)
- void riscv64_interrupt_handler (uint64_t scause)

  Dispatch an asynchronous supervisor interrupt.
- static void print_hex (uint64_t val)

  Print a 64-bit value as "0xNNNNNNNNNNNNNNNN" to the kernel console.
- void riscv64_exception_handler (void)

  RISC-V common trap handler — print diagnostic and spin.
- void arch_interrupts_init (void)

  Install the RISC-V supervisor trap vector table (M4 milestone).

Variables

- volatile const char * g_sk_fault_word = (void *)0

  interrupts.c (riscv64) - Trap vector setup and common exception handler
- uint32_t g_virtio_input_plic_source
- volatile uint32_t g_plic_claim_count = 0

7.113.1 Macro Definition Documentation

7.113.1.1 SCAUSE_INTERRUPT_BIT

```
#define SCAUSE_INTERRUPT_BIT (1ULL << 63)
```

7.113.1.2 SCAUSE_S_EXTERNAL

```
#define SCAUSE_S_EXTERNAL 9ULL
```

7.113.1.3 SCAUSE_S_TIMER

```
#define SCAUSE_S_TIMER 5ULL
```

7.113.2 Function Documentation

7.113.2.1 arch_interrupts_init()

```
void arch_interrupts_init (
            void  )
```

Install the RISC-V supervisor trap vector table (M4 milestone).

Install the AArch64 exception vector table (M4 milestone).

Calls `riscv64_install_vectors()` (defined in `isr.S`) which writes the trap vector base address into `stvec` (Supervisor Trap Vector Base Address Register, CSR 0x105). The vector mode field (bits [1:0]) is set to `0` (Direct mode) so all traps dispatch to the single base address, or `1` (Vectored mode) so async interrupts dispatch to `stvec` + 4*cause.

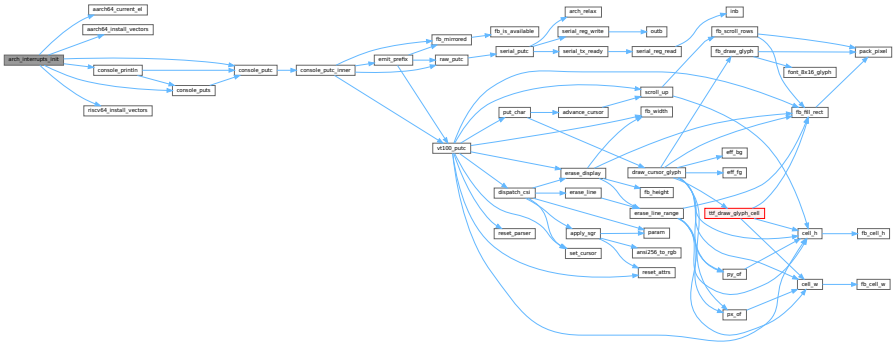
On RISC-V there is no IDT and no legacy PIC; the PLIC replaces both. The `arch_interrupts_init()` name is shared across all three ISAs so that `kernel_main()` calls the same symbol regardless of target.

Must be called after the supervisor stack (`sp`) is established and before `arch_enable_interrupts()`.

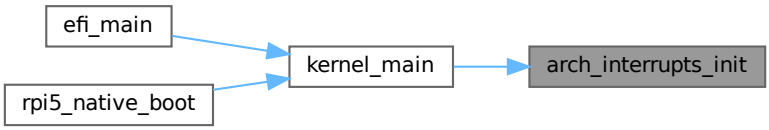
References aarch64_current_el(), aarch64_install_vectors(), console_println(), console_putc(), console_puts(), and riscv64_install_vectors().

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.113.2.2 print_hex()

```
static void print_hex (
            uint64_t val )  [static]
```

Print a 64-bit value as "0xNNNNNNNNNNNNNNNN" to the kernel console.

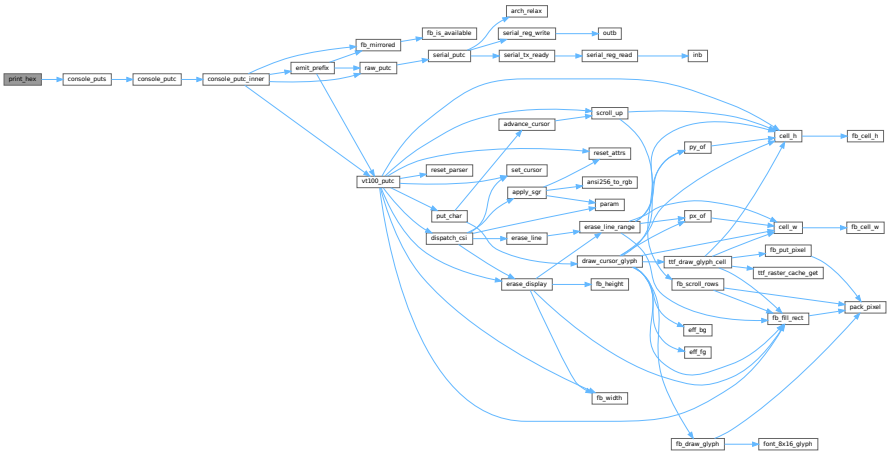
Formats `val` as a 16-nibble lowercase hex string preceded by "0x" into a 19-byte stack buffer (including null terminator) and emits it via `console_puts()`. Used by `riscv64_exception_handler()` to print `scause`, `sepc`, and `stval` in the exception diagnostic dump. No heap allocation or libc dependency.

Parameters

val	64-bit value to format.

References console_puts().

Here is the call graph for this function:



7.113.2.3 riscv64_exception_handler()

```
void riscv64_exception_handler (
            void  )
```

RISC-V common trap handler — print diagnostic and spin.

Called from the `isr.S` trap vector for all synchronous exceptions and asynchronous interrupts that are not handled by a specific driver. Reads three supervisor-mode CSRs directly:

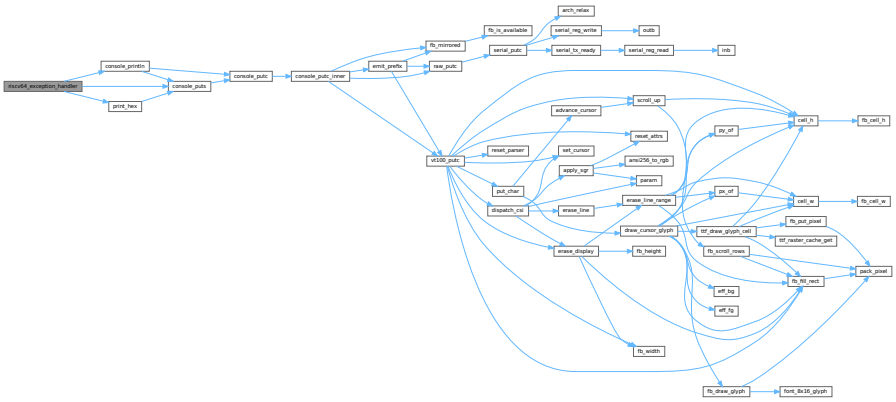
- `scause` — Supervisor Cause Register. Bit 63 distinguishes interrupts (1) from exceptions (0); bits [62:0] encode the cause code (e.g., 0 = instruction address misaligned, 2 = illegal instruction, 5 = load access fault, 13 = store page fault, 8 = ecall from U-mode). See RISC-V Privileged Spec ?4.1.9.
- `sepc` — Supervisor Exception Program Counter. The PC of the instruction that caused the trap (or the return address for interrupt handlers); execution resumes from `sepc` on SRET.
- `stval` — Supervisor Trap Value. For load/store page faults this holds the faulting virtual address; for illegal instruction faults it holds the faulting instruction encoding; zero for other causes.

Prints all three values to the kernel console then enters an infinite `WFI` loop to halt the core permanently. All exceptions that reach this handler are fatal in the current single-hart kernel.

`g_sk_fault_word` is set by the VM FORTH dispatcher and names the word executing at the time of the trap, aiding post-mortem serial log analysis.

References console_println(), console_puts(), and print_hex().

Here is the call graph for this function:

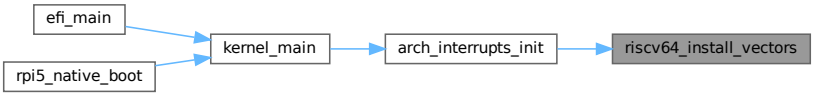


7.113.2.4 riscv64_install_vectors()

```
void riscv64_install_vectors (
            void  )  [extern]
```

Referenced by arch_interrupts_init().

Here is the caller graph for this function:



7.113.2.5 riscv64_interrupt_handler()

```
void riscv64_interrupt_handler (
            uint64_t scause )
```

Dispatch an asynchronous supervisor interrupt.

Called from `riscv64_trap_entry` in `isr.S` when `scause` has bit 63 set. Unlike `riscv64_exception_handler()` this **returns** — the trap entry restores the caller-saved register set and issues `SRET`.

Supervisor timer (cause 5) re-arms the one-shot SBI timer and then accounts the tick. **Re-arm comes first**: the SBI timer fires once per programmed deadline, so any return path that skips the re-arm stops the heartbeat permanently and silently. Ordering it ahead of `heartbeat_tick()` means a fault in the bookkeeping cannot also cost the next tick.

Supervisor external (cause 9): claim/dispatch/complete through the PLIC (substrate, item 4.3.5b). Source 10 (UART) stays unclaimed by anything here – 4.3.5b's own synthetic-interrupt self-test that used it was run once and reverted, not a standing consumer. virtio-input (item 4.3.5c) is the first real per-source dispatch, the same shape as i8042's keyboard branch in amd64's isr_common_handler().

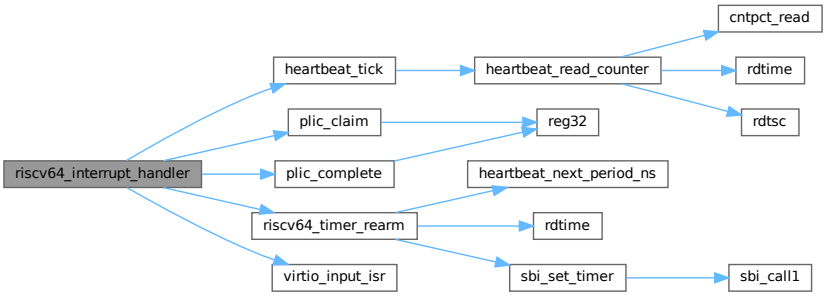
Any other cause is ignored rather than fatal: an unexpected-but-harmless asynchronous interrupt should not take the kernel down.

Parameters

scause	Raw `scause` value, interrupt bit still set.

References g_plic_claim_count, g_virtio_input_plic_source, heartbeat_tick(), plic_claim(), plic_complete(), riscv64_timer_rearm(), SCAUSE_S_EXTERNAL, SCAUSE_S_TIMER, and virtio_input_isr().

Here is the call graph for this function:



7.113.2.6 riscv64_timer_rearm()

```
void riscv64_timer_rearm (
            void  )  [extern]
```

Re-arm the one-shot SBI timer and account the tick.

The SBI timer is one-shot by nature. Servicing a timer interrupt without programming the next deadline leaves the heartbeat stopped permanently, with no error anywhere — the single most likely silent failure of this driver. Every path out of a timer interrupt must reach this function.

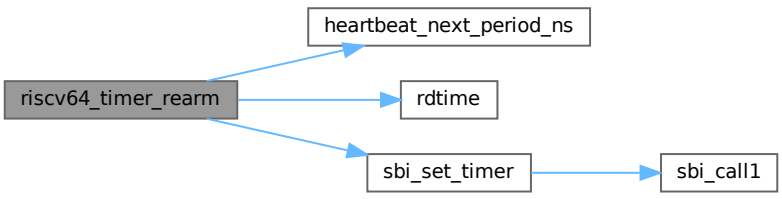
The step is `heartbeat_next_period_ns()` (item 0.8, ?26) converted to `time`-counter ticks via `s_time_hz`, not the fixed `s_timer_period_tsc` used to seed the very first deadline in `apic_timer_start()` – the latter remains `apic_timer_period_tsc()`'s return value for `heartbeat_init()`'s initial `expected_delta`, unchanged.

Called from `riscv64_interrupt_handler()` in `interrupts.c` on `scause` cause 5.

References heartbeat_next_period_ns(), rdtime(), s_next_deadline, s_sbi_time_ok, s_time_hz, s_timer_period_tsc, and sbi_set_timer().

Referenced by riscv64_interrupt_handler().

Here is the call graph for this function:



Here is the caller graph for this function:

7.113.2.7 virtio_input_isr()

```
void virtio_input_isr (
            void  )  [extern]
```

7.113.3 Variable Documentation

7.113.3.1 g_plic_claim_count

```
volatile uint32_t g_plic_claim_count = 0
```

Referenced by riscv64_interrupt_handler().

7.113.3.2 g_sk_fault_word

```
volatile const char* g_sk_fault_word = (void *)0
```

interrupts.c (riscv64) - Trap vector setup and common exception handler

interrupts.c (aarch64) - Exception vector setup and common handler

Referenced by execute_colon_word(), and vm_interpret_word().

7.113.3.3 g_virtio_input_plic_source

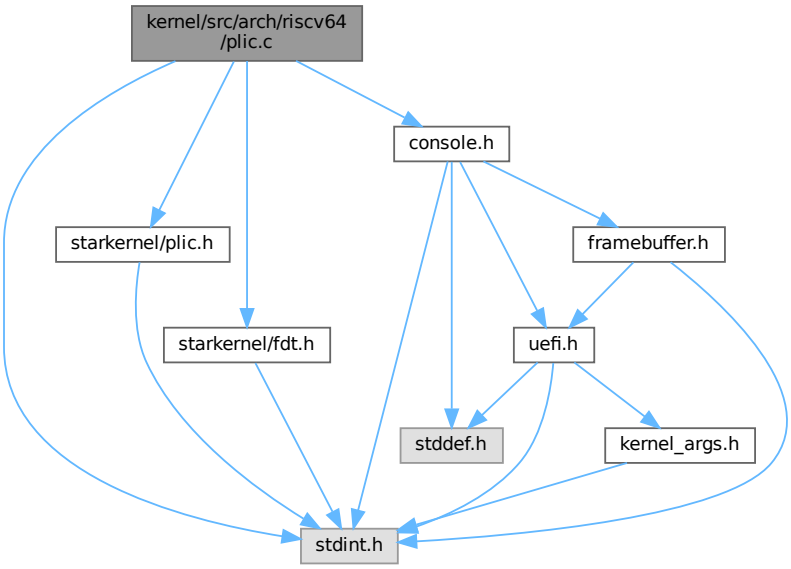
```
uint32_t g_virtio_input_plic_source  [extern]
```

Referenced by riscv64_interrupt_handler().

7.114 kernel/src/arch/riscv64/plic.c File Reference

```
#include <stdint.h>
#include "starkernel/plic.h"
#include "starkernel/fdt.h"
#include "console.h"
```

Include dependency graph for plic.c:



Macros

- #define PLIC_BASE_QEMU_DEFAULT 0x0C000000UL

  plic.c (riscv64) - Platform-Level Interrupt Controller driver
- #define PLIC_CONTEXT_S 1u /* S-mode, hart 0 -- verified, see file header */
- #define PLIC_PRIORITY(irq) (s_plic_base + 4u * (irq))
- #define PLIC_ENABLE(ctx) (s_plic_base + 0x2000u + 0x80u * (ctx))
- #define PLIC_THRESHOLD(ctx) (s_plic_base + 0x200000u + 0x1000u * (ctx))
- #define PLIC_CLAIM(ctx) (s_plic_base + 0x200004u + 0x1000u * (ctx))

Functions

- static volatile uint32_t * reg32 (uintptr_t addr)
- static uint32_t be32_cell (const unsigned char *b)

  Read one big-endian 32-bit cell from a devicetree property blob.
- static uint64_t be64_addr_cell_pair (const unsigned char *b)

  Read one two-cell (64-bit) big-endian address from a `reg` entry.
- static int plic_base_from_dtb (const void *dtb, uintptr_t *base_out)

  Try to discover the real PLIC base address from the DTB.
- int plic_init (const void *dtb)

  plic.h - Platform-Level Interrupt Controller interface (riscv64 only)

- void plic_set_priority (uint32_t irq, uint32_t priority)

  Set a source's interrupt priority (1-7; 0 means "never interrupt").
- void plic_enable (uint32_t irq)

  Enable a source for the S-mode hart-0 context.
- void plic_disable (uint32_t irq)

  Disable a source for the S-mode hart-0 context.
- uint32_t plic_claim (void)

  Claim the highest-priority pending interrupt for the S-mode hart-0 context.
- void plic_complete (uint32_t irq)

  Signal completion of the source previously returned by plic_claim().

Variables

- static uintptr_t s_plic_base = 0x0C000000UL

7.114.1 Macro Definition Documentation

7.114.1.1 PLIC_BASE_QEMU_DEFAULT

```
#define PLIC_BASE_QEMU_DEFAULT 0x0C000000UL
```

plic.c (riscv64) - Platform-Level Interrupt Controller driver

Item 4.3.5b. Register layout (priority/pending/enable/threshold/claim- complete) is the standard SiFive PLIC-1.0.0 layout QEMU implements – architectural, not board-specific, same status as the GICD/GICC register *offsets* item 0.6 cross-checked against the Linux arm-gic header.

PLIC_BASE_QEMU_DEFAULT and PLIC_CONTEXT_S are QEMU-virt-specific and were NOT hardcoded from memory: verified 2026-08-08 via `qemu-system-riscv64 -machine virt,dumpdtb=...`, decoded with a script using this tree's own fdt.c parsing logic (not dtc, which is not installed). The real devicetree shows: soc/plic@c000000: compatible = "sifive,plic-1.0.0","riscv,plic0", reg = <0x0 0xc000000 0x0 0x600000>, riscv,ndev = 95 soc/plic@c000000: interrupts-extended = <&cpu0-intc 11 &cpu0-intc 9> – two contexts for hart 0: context 0 feeds cause 11 (MEIE, M-mode external), context 1 feeds cause 9 (SEIE, S-mode external). Context index is position in this list, confirmed rather than assumed. soc/serial@10000000 (ns16550a): interrupts = <10>, interrupt-parent = &plic – PLIC source 10, matching console.c's existing NS16550_BASE. Confirmed for this exact QEMU 10.2.1 build; not assumed stable across versions, same caveat item 0.6 recorded for its own dumped values.

DTB-discovered base address, as of FABRIC-3.md ?V.3 item 3's fix, 2026-09-05: the node-scoped ("reg" is not globally unique the way "timebase-frequency" is) devicetree lookup this file's own comment previously flagged as "a bigger addition than this item's stated scope" was subsequently built anyway – `fdt_find_node_by_compatible()` + `fdt_find_prop_in_node()` (`fdt.c`/`fdt.h`), added for the aarch64 GIC base fix (FABRIC-3.md ?IV.3 item 7) and reused here unchanged. `plic_base_from_dtb()` below tries `"sifive,plic-1.0.0"` first; on failure (no DTB, e.g. this system's QEMU/UEFI firmware – same `fdt_valid()` failure mode apic.c's GIC discovery already documents) it falls back to the QEMU constant above, unchanged from this function's previous unconditional behaviour. Not yet confirmed against the Milk-V Mars's real DTB – the compatible string is architectural (SiFive PLIC-1.0.0 is the standard binding), not board-specific, but the actual JH7110 `reg` value is unverified until real hardware arrives (2026-09-17).

7.114.1.2 PLIC_CLAIM

```
#define PLIC_CLAIM(
              ctx ) (s_plic_base + 0x200004u + 0x1000u * (ctx))
```

7.114.1.3 PLIC_CONTEXT_S

```
#define PLIC_CONTEXT_S 1u /* S-mode, hart 0 -- verified, see file header */
```

7.114.1.4 PLIC_ENABLE

```
#define PLIC_ENABLE(
            ctx ) (s_plic_base + 0x2000u + 0x80u * (ctx))
```

7.114.1.5 PLIC_PRIORITY

```
#define PLIC_PRIORITY(
            irq ) (s_plic_base + 4u * (irq))
```

7.114.1.6 PLIC_THRESHOLD

```
#define PLIC_THRESHOLD(
            ctx ) (s_plic_base + 0x200000u + 0x1000u * (ctx))
```

7.114.2 Function Documentation

7.114.2.1 be32_cell()

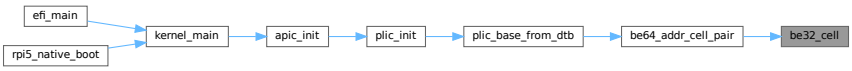
```
static uint32_t be32_cell (
            const unsigned char * b )  [static]
```

Read one big-endian 32-bit cell from a devicetree property blob.

Duplicated from aarch64 apic.c's identical helper rather than shared – same "a few lines is simpler than a new shared dependency" precedent that file's own comment already set for this exact situation.

Referenced by be64_addr_cell_pair().

Here is the caller graph for this function:



7.114.2.2 be64_addr_cell_pair()

```
static uint64_t be64_addr_cell_pair (
            const unsigned char * b )  [static]
```

Read one two-cell (64-bit) big-endian address from a `reg` entry.

QEMU-virt's `plic` node's own dumped `reg = <0x0 0xc000000 0x0 0x600000>` (see file header) is address(2 cells) + size(2 cells) = 4 cells total, same shape as aarch64's `gicv2` node – reads only the two address cells, ignoring the size pair that follows.

References be32_cell().

Referenced by plic_base_from_dtb().

Here is the call graph for this function:

Here is the caller graph for this function:

7.114.2.3 plic_base_from_dtb()

```
static int plic_base_from_dtb (
            const void * dtb,
            uintptr_t * base_out )  [static]
```

Try to discover the real PLIC base address from the DTB.

Looks up the "`sifive,plic-1.0.0`" node and reads its `reg` property's first (address) cell pair. Returns 0 (leaving `base_out` untouched) if `dtb` is not a valid FDT, no matching node exists, or `reg` is shorter than one address-cell pair – the caller keeps the QEMU constant default in that case, exactly as before this function existed.

Parameters

dtb	Candidate devicetree blob (`BootInfo->dtb`); NULL-safe.
base_out	Receives the PLIC base address on success.

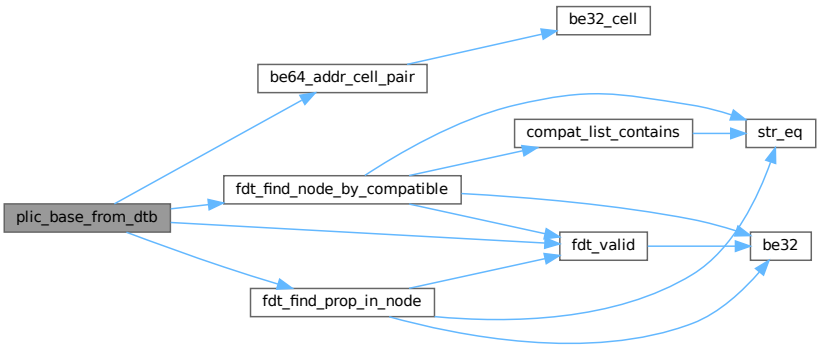
Returns

1 on success, 0 if discovery failed for any reason.

References be64_addr_cell_pair(), fdt_find_node_by_compatible(), fdt_find_prop_in_node(), and fdt_valid().

Referenced by plic_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.114.2.4 plic_claim()

```
uint32_t plic_claim (
            void  )
```

Claim the highest-priority pending interrupt for the S-mode hart-0 context.

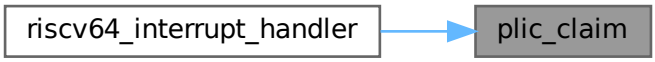
Returns the source ID, or 0 if none is pending.

References PLIC_CLAIM, PLIC_CONTEXT_S, and reg32().

Referenced by riscv64_interrupt_handler().

Here is the call graph for this function:

Here is the caller graph for this function:



7.114.2.5 plic_complete()

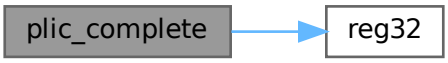
```
void plic_complete (
            uint32_t irq )
```

Signal completion of the source previously returned by plic_claim().

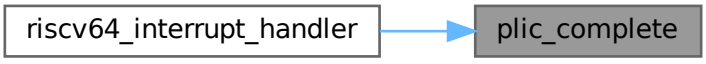
References PLIC_CLAIM, PLIC_CONTEXT_S, and reg32().

Referenced by riscv64_interrupt_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.114.2.6 plic_disable()

```
void plic_disable (
            uint32_t irq )
```

Disable a source for the S-mode hart-0 context.

References PLIC_CONTEXT_S, PLIC_ENABLE, and reg32().

Here is the call graph for this function:

7.114.2.7 plic_enable()

```
void plic_enable (
            uint32_t irq )
```

Enable a source for the S-mode hart-0 context.

References PLIC_CONTEXT_S, PLIC_ENABLE, and reg32().

Here is the call graph for this function:

7.114.2.8 plic_init()

```
int plic_init (
            const void * dtb )
```

plic.h - Platform-Level Interrupt Controller interface (riscv64 only)

Item 4.3.5a (FABRIC-0.md ?27.5): Phase 0 (0.2/0.3) only ever enabled the S-mode *timer* interrupt (sie.STIE). External interrupts (sie.SEIE) were never touched, and the PLIC – the only external-interrupt path on RISC-V, there is no legacy PIC or I/O APIC equivalent – had no driver at all before this item. Pure substrate: this item wires

the mechanism (claim/dispatch/complete) with no permanent source enabled by default; a real consumer (4.3.5b, virtio-keyboard) enables its own source later.

plic_init() takes the boot DTB as of FABRIC-3.md ?V.3 item 3's fix, 2026-09-05: the base address was previously a QEMU-virt-specific hardcoded constant, unconditionally wrong on the Milk-V Mars's real JH7110 PLIC. See plic.c's file header for the discovery mechanism. Map the PLIC and set the S-mode hart-0 context's priority threshold to 0 (maximally permissive – safe because nothing is enabled at any source by default; enabling a source is what actually lets it reach claim()). Also sets sie.SEIE. Does not touch sstatus.SIE – arch_enable_interrupts() still owns that, same as the timer.

Parameters

dtb	Candidate devicetree blob (`BootInfo->dtb`); NULL-safe. When a real `"sifive,plic-1.0.0"` node is found, the PLIC base address is read from its `reg` property; otherwise falls back to the QEMU-virt-machine constant, unchanged from this function's previous unconditional behaviour.

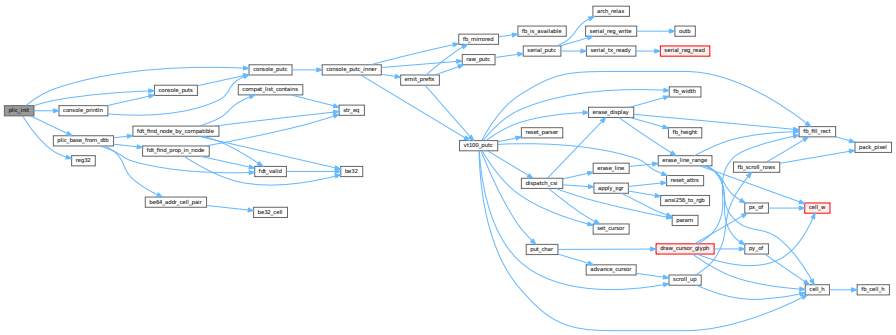
Returns

0 on success.

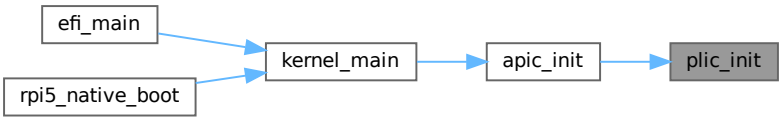
References console_println(), console_putc(), console_puts(), plic_base_from_dtb(), PLIC_CONTEXT_S, PLIC_THRESHOLD, reg32(), and s_plic_base.

Referenced by apic_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.114.2.9 plic_set_priority()

```
void plic_set_priority (
            uint32_t irq,
            uint32_t priority )
```

Set a source's interrupt priority (1-7; 0 means "never interrupt").

References PLIC_PRIORITY, and reg32().

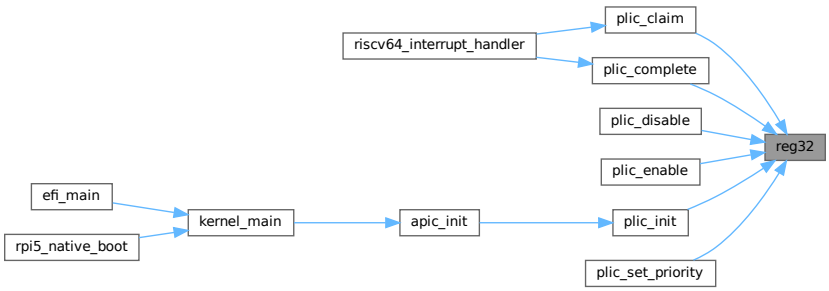
Here is the call graph for this function:

7.114.2.10 reg32()

```
static volatile uint32_t * reg32 (
            uintptr_t addr )  [inline], [static]
```

Referenced by plic_claim(), plic_complete(), plic_disable(), plic_enable(), plic_init(), and plic_set_priority().

Here is the caller graph for this function:



7.114.3 Variable Documentation

7.114.3.1 s_plic_base

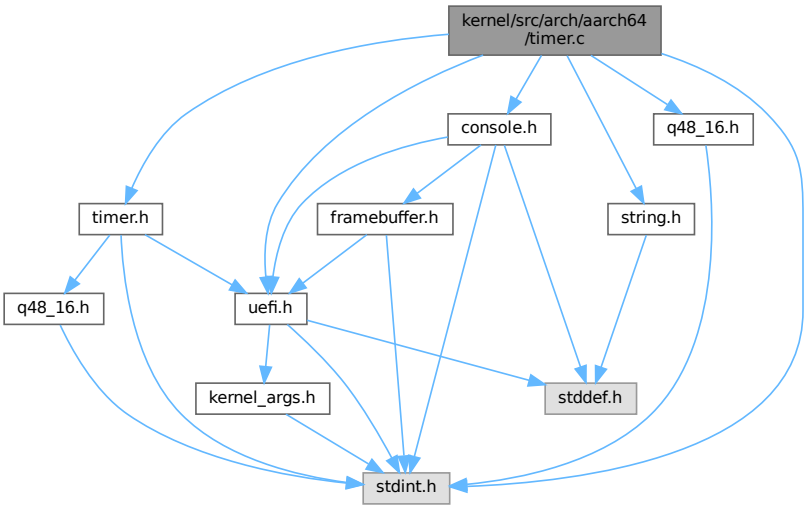
```
uintptr_t s_plic_base = 0x0C000000UL  [static]
```

Referenced by plic_init().

7.115 kernel/src/arch/aarch64/timer.c File Reference

```
#include "timer.h"
#include "console.h"
#include "q48_16.h"
#include "uefi.h"
#include <stdint.h>
#include <string.h>
```

Include dependency graph for timer.c:



Functions

- static int running_under_hypervisor (BootInfo *boot_info)

  timer.c (aarch64) - Timer subsystem using ARM Generic Timer (CNTPCT_EL0)
- static uint64_t cntpct_read (void)

  Read the AArch64 Physical System Counter with ISB serialisation.
- static uint64_t cntfrq_read (void)

  Read the AArch64 Counter Frequency Register (`CNTFRQ_EL0`).
- int timer_init (BootInfo *boot_info)
- uint64_t timer_tsc_hz (void)

  Return the system counter frequency in Hz.
- uint64_t timer_now_ns (void)

  Return a monotonic nanosecond timestamp.
- int timer_check_drift_now (void)

  Check for timer drift (AArch64 stub — always returns 0).
- const timer_calibration_record_t * timer_calibration_record (void)

  Return a pointer to the timer calibration record.
- uint64_t heartbeat_read_counter (void)

  Read the raw counter the aarch64 heartbeat is paced against.

Variables

- static uint64_t s_counter_hz = 0
- static uint64_t s_ns_per_tick = 0
- static uint64_t s_base_count = 0
- static uint64_t s_base_ns = 0
- static timer_calibration_record_t s_cal

7.115.1 Function Documentation

7.115.1.1 cntfrq_read()

```
static uint64_t cntfrq_read (
            void  )  [inline], [static]
```

Read the AArch64 Counter Frequency Register (CNTFRQ_EL0).

CNTFRQ_EL0 is a read-only EL0-accessible register whose value is written by EL3/EL2 firmware at boot to advertise the system counter frequency in Hz. It is the architectural way to discover CNTPCT_EL0's tick rate without out-of-band knowledge of the board.

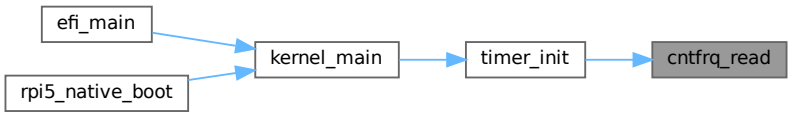
QEMU's SBSA/virt machine models typically set this to 62,500,000 Hz (62.5 MHz) for Cortex-A57 compatibility. Real hardware varies widely (10 MHz on Raspberry Pi 4, 24 MHz on Cortex-A53 dev boards, etc.). timer_init() falls back to 62,500,000 if the register reads zero.

Returns

Counter frequency in Hz as set by firmware; 0 if firmware did not initialise the register (uncommon but possible in bare-metal bring-up without a proper firmware stack).

Referenced by timer_init().

Here is the caller graph for this function:



7.115.1.2 cntpct_read()

```
static uint64_t cntpct_read (
            void  )  [inline], [static]
```

Read the AArch64 Physical System Counter with ISB serialisation.

Issues an `ISB` (Instruction Synchronisation Barrier) before reading `CNTPCT_EL0` to ensure all preceding instructions have completed before the counter value is sampled. This prevents the counter read from being speculated ahead of a preceding store or flag update, which would produce an erroneously early timestamp.

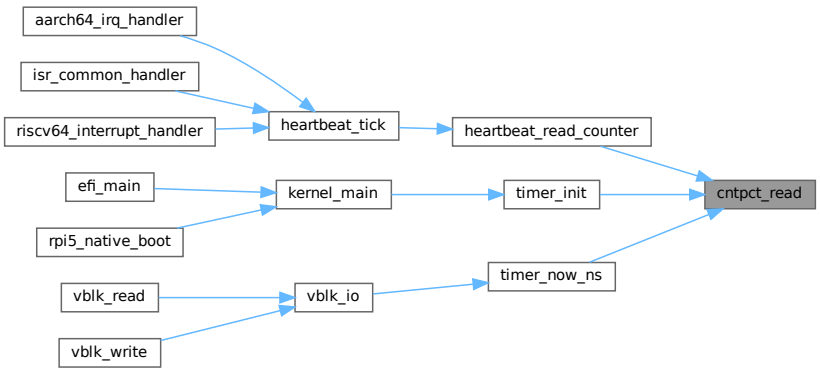
The ISB is heavier than strictly necessary for most timing uses but provides the same ordering guarantee as `RDTSCP` on x86-64. For interval measurements where start and end reads are in the same path, the overhead (1–3 cycles) is negligible.

Returns

Current 64-bit `CNTPCT_EL0` counter value in system-counter ticks.

Referenced by heartbeat_read_counter(), timer_init(), and timer_now_ns().

Here is the caller graph for this function:



7.115.1.3 heartbeat_read_counter()

```
uint64_t heartbeat_read_counter (
            void  )
```

Read the raw counter the aarch64 heartbeat is paced against.

Read the raw hardware counter this architecture's heartbeat is paced against – the same clock `timer_now_ns()` and calibration already use internally (rdtsc on amd64, the `time` CSR on riscv64, CNTPCT_EL0 on aarch64), not a separate/different source.

Item 0.8 (FABRIC-0.md ?25.1): the shared heartbeat.c now owns heartbeat_init()/heartbeat_tick()/heartbeat_service()/heartbeat_ticks()/ heartbeat_trust()/heartbeat_state() and the per-arch `g_heartbeat` state that used to live in this file. This is the one piece that stays per-architecture – the same `CNTPCT_EL0` the rest of this file's calibration already reads via `cntpct_read()`.

Returns

Current `CNTPCT_EL0` value.

7.115.1.4 running_under_hypervisor()

```
static int running_under_hypervisor (
            BootInfo * boot_info )  [static]
```

timer.c (aarch64) - Timer subsystem using ARM Generic Timer (CNTPCT_EL0)

Uses the 64-bit system counter available as CNTPCT_EL0. The counter frequency is read from CNTFRQ_EL0 (set by firmware).

References BootInfo::acpi_table, and memcmp().

Here is the call graph for this function:

7.115.1.5 timer_calibration_record()

```
const timer_calibration_record_t * timer_calibration_record (
            void  )
```

Return a pointer to the timer calibration record.

Returns `&s_cal` which is populated by `timer_init()` with:

- `tsc_hz_mean` = `CNTFRQ_EL0` (or 62.5 MHz fallback)
- `hpet_hz` = 0 (no HPET on AArch64)
- `pit_hz_mean` = 0 (no PIT on AArch64)
- `converged` = 1 (Generic Timer is already calibrated by firmware)
- `vm_mode` = real hypervisor-vs-hardware detection as of 2026-09-04 (ACPI RSDP OEM ID check, running_under_hypervisor() above) – the Generic Timer itself works identically either way, so this field's *timing* meaning here is purely informational, unlike amd64 where vm_mode gates a real calibration-path choice
- `trust` = `TIMER_TRUST_ABSOLUTE`

The record is exposed to `kernel_main()` and `timer.h` consumers for boot-log reporting and for the heartbeat subsystem's trust initialisation.

Returns

Pointer to the module-static calibration record; valid for the lifetime of the kernel.

7.115.1.6 timer_check_drift_now()

```
int timer_check_drift_now (
            void  )
```

Check for timer drift (AArch64 stub — always returns 0).

On x86-64 this function cross-checks the TSC against the HPET or PM Timer to detect frequency drift. The AArch64 Generic Timer is architecturally invariant and synchronised across all cores in the system; it cannot drift against itself. This stub always returns 0 (no drift detected) to satisfy the common `timer_check_drift_now()` call site.

Returns

0 always.

7.115.1.7 timer_init()

```
int timer_init (
            BootInfo * boot_info )
```

7.115.1.8 timer_now_ns()

```
uint64_t timer_now_ns (
            void  )
```

Return a monotonic nanosecond timestamp.

Reads `CNTPCT_EL0`, computes the delta from `s_base_count` (captured at `timer_init()`), and converts to nanoseconds using the Q16.16 fixed-point `s_ns_per_tick`:

```
ns = s_base_ns + ((delta * s_ns_per_tick) » 16)
```

The multiplication uses 64-bit arithmetic; at typical counter frequencies ($\leq$ 100 MHz) and reasonable uptime intervals (days to weeks) there is no overflow risk in the delta-to-ns conversion.

Returns

Monotonic nanosecond count since `timer_init()`, starting at 0.

7.115.1.9 timer_tsc_hz()

```
uint64_t timer_tsc_hz (
            void  )
```

Return the system counter frequency in Hz.

Returns `s_counter_hz` as set from `CNTFRQ_EL0` by `timer_init()`. If `timer_init()` has not been called yet (or firmware reported 0 and the fallback was not applied), returns 62,500,000 Hz as a safe default.

Used by `apic_timer_init()` to compute `s_timer_period_tsc` and by the shim time backend to convert counter ticks to nanoseconds before the full timer subsystem is available.

Returns

System counter frequency in Hz; at least 62,500,000.

7.115.2 Variable Documentation

7.115.2.1 s_base_count

```
uint64_t s_base_count = 0  [static]
```

Referenced by timer_init(), and timer_now_ns().

7.115.2.2 s_base_ns

```
uint64_t s_base_ns = 0  [static]
```

Referenced by timer_init(), and timer_now_ns().

7.115.2.3 s_cal

```
timer_calibration_record_t s_cal  [static]
```

Referenced by timer_calibration_record(), and timer_init().

7.115.2.4 s_counter_hz

```
uint64_t s_counter_hz = 0  [static]
```

Referenced by timer_init(), and timer_tsc_hz().

7.115.2.5 s_ns_per_tick

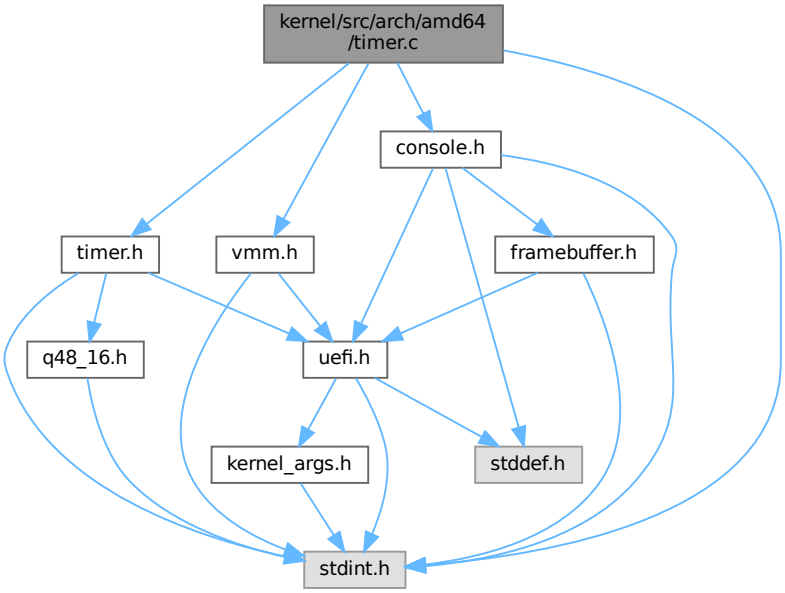
```
uint64_t s_ns_per_tick = 0  [static]
```

Referenced by timer_init(), and timer_now_ns().

7.116 kernel/src/arch/amd64/timer.c File Reference

```
#include <stdint.h>
#include "timer.h"
#include "console.h"
#include "vmm.h"
```

Include dependency graph for timer.c:



Data Structures

- struct __attribute__

  ioapic.c - I/O APIC driver (amd64)

Macros

- #define HPET_GEN_CAP_ID 0x000

  timer.c - Timer policy + TSC calibration (amd64)
- #define HPET_GEN_CONFIG 0x010
- #define HPET_MAIN_COUNTER 0x0F0
- #define HPET_PHYS_BASE 0xFED00000ull
- #define HPET_VIRT_BASE 0xFED00000ull /∗ identity-mapped in this setup ∗/
- #define PIT_CHANNEL0_DATA 0x40
- #define PIT_COMMAND 0x43
- #define PIT_FREQ_HZ 1193182u
- #define PMTIMER_IO_PORT_DEFAULT 0x408
- #define PMTIMER_FREQ_HZ 3579545ull
- #define PMTIMER_WIDTH_BITS 24
- #define PMTIMER_MASK ((1ull << PMTIMER_WIDTH_BITS) - 1ull)
- #define WARMUP_WINDOWS 2

- #define SAMPLE_WINDOWS 8
- #define WINDOW_TICKS_HPET 10000ull /∗ ∼1ms at 10MHz nominal ∗/
- #define WINDOW_TICKS_PIT 4000u /∗ ∼3.3ms nominal ∗/
- #define CV_EPSILON_PPM 1000ull /∗ 0.1% ∗/
- #define CV_STABLE_COUNT 6
- #define DRIFT_EPSILON_PPM 2000ull
- #define TIMER_REQUIRE_PIT 0
- #define TIMER_VM_STRICT_INVARIANT_TSC 0

Functions

- static uint64_t muldiv64 (uint64_t a, uint64_t b, uint64_t c)

  Compute (a × b) / c using 128-bit intermediate precision.
- static void print_dec (uint64_t val)

  Print a `uint64_t` value as decimal digits to the kernel console.
- static uint64_t rdtsc (void)

  Read the x86-64 Time Stamp Counter without serialisation (RDTSC).
- static uint64_t rdtscp_aux (uint32_t ∗aux)

  Read TSC and processor ID with weak serialisation (RDTSCP).
- static void cpuid (uint32_t leaf, uint32_t subleaf, uint32_t ∗a, uint32_t ∗b, uint32_t ∗c, uint32_t ∗d)

  Execute the x86-64 `CPUID` instruction and capture all output registers.
- static void outb (uint16_t port, uint8_t val)

  Write a byte to an x86 I/O port (OUT instruction).
- static uint8_t inb (uint16_t port)

  Read a byte from an x86 I/O port (IN instruction).
- static uint32_t inl (uint16_t port)

  Read a 32-bit dword from an x86 I/O port (INL instruction).
- static uint64_t hpet_read (uint32_t offset)

  Read a 64-bit HPET register at `offset` bytes from the HPET base.
- static void hpet_write (uint32_t offset, uint64_t val)

  Write a 64-bit value to an HPET register at `offset` bytes from base.
- static void timer_fatal (const char ∗msg)

  Emit a fatal timer error message and halt the processor permanently.
- static int cpu_has_invariant_tsc (void)

  Test whether the processor supports Invariant TSC (non-stop TSC).
- static int cpu_has_rdtscp (void)

  Test whether the processor supports the RDTSCP instruction.
- static int running_under_hypervisor (void)

  Detect whether the kernel is running under a hypervisor.
- static int timer_sig4_eq (const uint8_t ∗p, const char ∗s)
- static int timer_sig8_eq (const uint8_t ∗p, const char ∗s)
- static uint16_t fadt_find_pm_tmr_port (void ∗rsdp)

  Look up the ACPI PM_TMR_BLK I/O port from the FADT ("FACP" table).
- static uint32_t pmtimer_read (void)

  Read the raw ACPI PM Timer counter from I/O port `pmtimer_port`.
- static uint64_t pmtimer_delta (uint32_t start, uint32_t cur)

  Compute elapsed PM Timer ticks from `start` to `cur`, handling wrap-around.
- static uint64_t calibrate_tsc_with_pmtimer (void)

  Calibrate TSC frequency using the ACPI PM Timer as reference.
- static void vm_timebase_init_from_pmtimer (void)

  Initialise the VM relative-time base anchored to the PM Timer.

- static void enable_hpet (void)

  Enable the HPET main counter by setting the ENABLE_CNF bit.
- static void sanity_check_hpet_running_quick (void)

  Verify the HPET main counter is advancing (quick sanity check).
- static void pit_program_reload (uint16_t reload)

  Programme the 8253/8254 PIT Channel 0 with a 16-bit reload value.
- static uint16_t pit_read_counter16 (void)

  Read the current 16-bit counter value from PIT Channel 0.
- static int pit_probe_running (void)

  Probe whether the PIT is available and counting.
- static void update_stats (const uint64_t *samples, uint32_t count, uint64_t *mean, uint64_t *stddev)

  Compute mean and standard deviation of an array of `uint64_t` samples.
- static uint64_t calibrate_window_hpet (uint64_t target_ticks)

  Measure TSC frequency over a fixed HPET tick window.
- static uint64_t calibrate_window_pit (uint32_t target_ticks)

  Measure TSC frequency over a fixed PIT tick window.
- static int converge_tsc_bare_metal (uint64_t *locked_hz, uint64_t *pit_mean_out)

  Converge TSC frequency on bare metal using HPET + optional PIT cross-check.
- static uint64_t derive_tsc_hz_from_cpuid (void)

  Derive TSC frequency from CPUID leaves 0x15 and 0x16.
- static void init_timer_vm_mode (void)

  Initialise the timer subsystem in VM (hypervisor-present) mode.
- int timer_init (BootInfo *boot_info)

  Initialise the kernel timer subsystem (M5).
- uint64_t timer_tsc_hz (void)

  Return the locked TSC frequency in Hz.
- static uint64_t timer_now_ns_vm_relative (void)

  Return nanoseconds since boot using the ACPI PM Timer (VM relative mode).
- uint64_t timer_now_ns (void)

  Return the current monotonic time in nanoseconds.
- static int timer_drift_check_bare_metal (void)

  Check TSC drift against the HPET reference on bare metal.
- int timer_check_drift_now (void)

  Perform a runtime TSC drift check (no-op in VM mode).
- const timer_calibration_record_t * timer_calibration_record (void)

  Return a pointer to the current timer calibration record.
- uint64_t heartbeat_read_counter (void)

  Read the raw counter the amd64 heartbeat is paced against.

Variables

- static uint16_t pmtimer_port = 0x408
- static volatile uint64_t * hpet_regs = 0
- static uint64_t hpet_freq_hz = 0
- static uint64_t tsc_hz_locked = 0
- static uint64_t pit_tsc_hz_mean = 0
- static uint32_t windows_used = 0
- static timer_calibration_record_t calib_record = {0}
- static int pit_available = 0
- static uint32_t vm_pm_start = 0
- static uint64_t vm_ns_base = 0

7.116.1 Macro Definition Documentation

7.116.1.1 CV_EPSILON_PPM

```
#define CV_EPSILON_PPM 1000ull /* 0.1% */
```

7.116.1.2 CV_STABLE_COUNT

```
#define CV_STABLE_COUNT 6
```

7.116.1.3 DRIFT_EPSILON_PPM

```
#define DRIFT_EPSILON_PPM 2000ull
```

7.116.1.4 HPET_GEN_CAP_ID

```
#define HPET_GEN_CAP_ID 0x000
```

timer.c - Timer policy + TSC calibration (amd64)

The kernel will always run with the best time source available, but will only make determinism claims when the hardware contract is provably satisfied.

Policy split:

- VM path: avoid HPET MMIO. Prefer invariant TSC for ABSOLUTE time. Derive TSC Hz from CPUID leaves (0x15/0x16) when available; otherwise fall back to ACPI PM Timer (port I/O, stable under QEMU/KVM) to obtain TSC Hz. If invariant TSC is absent, kernel continues in RELATIVE time mode (PM Timer-based), unless strict mode is enabled.
- Bare metal path: calibrate TSC using HPET as primary reference, with optional PIT cross-check. Fail hard on non-convergence.

Failure mode: PANIC/HALT when invariants are not met.

Strict VM policy: -DTIMER_VM_STRICT_INVARIANT_TSC=1 enforces invariant TSC in VM mode (fail-hard).

7.116.1.5 HPET_GEN_CONFIG

```
#define HPET_GEN_CONFIG 0x010
```

7.116.1.6 HPET_MAIN_COUNTER

```
#define HPET_MAIN_COUNTER 0x0F0
```

7.116.1.7 HPET_PHYS_BASE

```
#define HPET_PHYS_BASE 0xFED00000ull
```

7.116.1.8 HPET_VIRT_BASE

```
#define HPET_VIRT_BASE 0xFED00000ull /* identity-mapped in this setup */
```

7.116.1.9 PIT_CHANNEL0_DATA

```
#define PIT_CHANNEL0_DATA 0x40
```

7.116.1.10 PIT_COMMAND

```
#define PIT_COMMAND 0x43
```

7.116.1.11 PIT_FREQ_HZ

```
#define PIT_FREQ_HZ 1193182u
```

7.116.1.12 PMTIMER_FREQ_HZ

```
#define PMTIMER_FREQ_HZ 3579545ull
```

7.116.1.13 PMTIMER_IO_PORT_DEFAULT

```
#define PMTIMER_IO_PORT_DEFAULT 0x408
```

7.116.1.14 PMTIMER_MASK

```
#define PMTIMER_MASK ((1ull << PMTIMER_WIDTH_BITS) - 1ull)
```

7.116.1.15 PMTIMER_WIDTH_BITS

```
#define PMTIMER_WIDTH_BITS 24
```

7.116.1.16 SAMPLE_WINDOWS

```
#define SAMPLE_WINDOWS 8
```

7.116.1.17 TIMER_REQUIRE_PIT

```
#define TIMER_REQUIRE_PIT 0
```

7.116.1.18 TIMER_VM_STRICT_INVARIANT_TSC

```
#define TIMER_VM_STRICT_INVARIANT_TSC 0
```

7.116.1.19 WARMUP_WINDOWS

```
#define WARMUP_WINDOWS 2
```

7.116.1.20 WINDOW_TICKS_HPET

```
#define WINDOW_TICKS_HPET 10000ull /* ~1ms at 10MHz nominal */
```

7.116.1.21 WINDOW_TICKS_PIT

```
#define WINDOW_TICKS_PIT 4000u /* ~3.3ms nominal */
```

7.116.2 Function Documentation

7.116.2.1 calibrate_tsc_with_pmtimer()

```
static uint64_t calibrate_tsc_with_pmtimer (
            void  )  [static]
```

Calibrate TSC frequency using the ACPI PM Timer as reference.

Waits for 1000 PM Timer ticks (~279 ?s at 3.58 MHz), measures the TSC delta over the same interval, then converts to Hz using `muldiv64()`. Includes a 5-million-iteration timeout to avoid hanging under TCG or broken PM Timer implementations.

Used by the VM path when CPUID leaves 0x15/0x16 do not provide a TSC frequency. The PM Timer is port I/O-based and does not cause VM-exits on most hypervisors (unlike HPET MMIO), making it suitable for VM calibration.

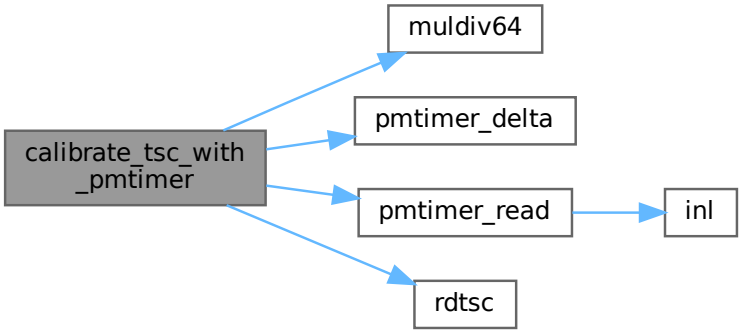
Returns

TSC frequency in Hz, or 0 if calibration timed out or produced an invalid result.

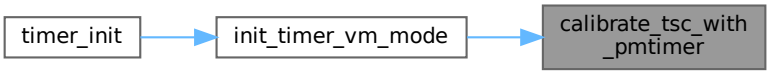
References muldiv64(), pmtimer_delta(), PMTIMER_FREQ_HZ, PMTIMER_MASK, pmtimer_read(), and rdtsc().

Referenced by init_timer_vm_mode().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.2 calibrate_window_hpet()

```
static uint64_t calibrate_window_hpet (
            uint64_t target_ticks )  [static]
```

Measure TSC frequency over a fixed HPET tick window.

Spins until the HPET main counter advances by `target_ticks` ticks, measuring the TSC delta over the same interval. Converts the result to Hz via `muldiv64()`. Returns 0 if the elapsed nanoseconds are zero (which indicates an invalid HPET frequency or overflow).

Used exclusively on the bare-metal path; the tight spin loop would cause excessive VM-exits if called under a hypervisor.

Parameters

target_ticks	HPET ticks to wait (~1 ms at 10 MHz HPET).

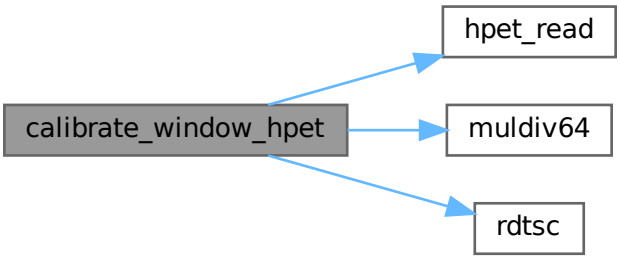
Returns

Estimated TSC frequency in Hz, or 0 on error.

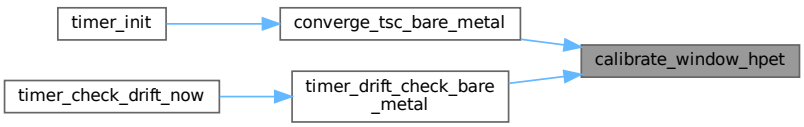
References hpet_freq_hz, HPET_MAIN_COUNTER, hpet_read(), muldiv64(), and rdtsc().

Referenced by converge_tsc_bare_metal(), and timer_drift_check_bare_metal().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.3 calibrate_window_pit()

```
static uint64_t calibrate_window_pit (
            uint32_t target_ticks )  [static]
```

Measure TSC frequency over a fixed PIT tick window.

Programs Channel 0 with reload 0xFFFF and polls until `target_ticks` PIT ticks have elapsed (up to 200,000 poll iterations). Returns the TSC Hz measured over the interval, or 0 if `pit_available` is false or the poll timed out.

Parameters

target_ticks	Number of PIT ticks to measure over (~3.3 ms at 1.19 MHz).

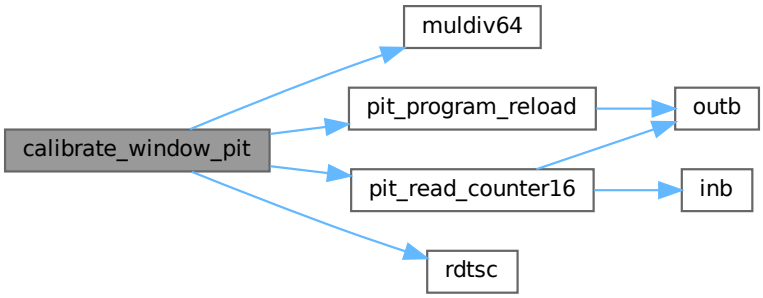
Returns

Estimated TSC frequency in Hz, or 0 if PIT is unavailable or timed out.

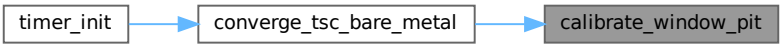
References muldiv64(), pit_available, PIT_FREQ_HZ, pit_program_reload(), pit_read_counter16(), and rdtsc().

Referenced by converge_tsc_bare_metal().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.4 converge_tsc_bare_metal()

```
static int converge_tsc_bare_metal (
            uint64_t * locked_hz,
            uint64_t * pit_mean_out )  [static]
```

Converge TSC frequency on bare metal using HPET + optional PIT cross-check.

Runs WARMUP_WINDOWS (2) warm-up windows then up to SAMPLE_WINDOWS (8) measurement windows, alternating HPET and PIT samples. Declares convergence when CV_STABLE_COUNT (6) consecutive windows all have CV below CV_EPSILON_PPM (1000 ppm). If both HPET and PIT are active the inter-source drift must also be < CV_EPSILON_PPM before the stable counter increments.

Fills calib_record on success. Calls timer_fatal() — never returns — on any hard error (HPET window failure, PIT required but unavailable).

Parameters

locked_hz	Output: converged TSC frequency in Hz.
pit_mean_out	Output: mean PIT-derived TSC Hz (0 if PIT disabled).

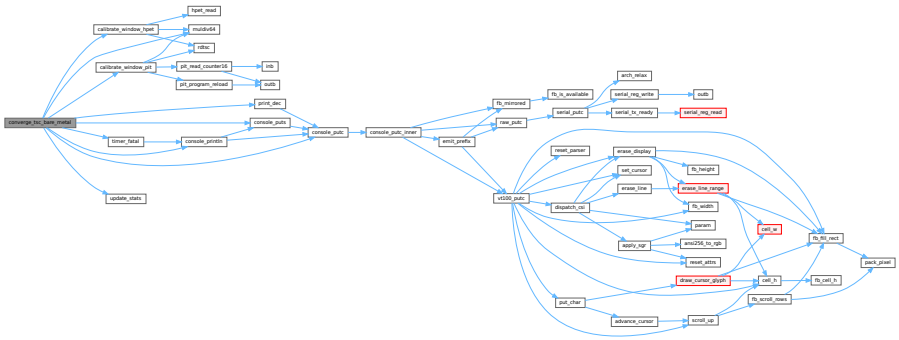
Returns

0 on successful convergence, -1 if the sample limit was exhausted.

References calib_record, calibrate_window_hpet(), calibrate_window_pit(), console_println(), console_putc(), console_puts(), timer_calibration_record::converged, CV_EPSILON_PPM, timer_calibration_record::cv_hpet_ppm, timer_calibration_record::cv_pit_ppm, CV_STABLE_COUNT, timer_calibration_record::diff_ppm, hpet_freq_hz, timer_calibration_record::hpet_hz, muldiv64(), pit_available, timer_calibration_record::pit_hz_mean, print_dec(), SAMPLE_WINDOWS, timer_fatal(), TIMER_REQUIRE_PIT, TIMER_TRUST_ABSOLUTE, timer_calibration_record::trust, timer_calibration_record::tsc_hz_mean, update_stats(), timer_calibration_record::vm_mode, WARMUP_WINDOWS, WINDOW_TICKS_HPET, WINDOW_TICKS_PIT, timer_calibration_record::windows_used, and windows_used.

Referenced by timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.116.2.5 cpu_has_invariant_tsc()

```
static int cpu_has_invariant_tsc (
            void  )  [static]
```

Test whether the processor supports Invariant TSC (non-stop TSC).

Reads `CPUID.80000007H`:EDX[8]. Invariant TSC means the TSC counts at a constant rate regardless of CPU frequency scaling or sleep states — a requirement for using RDTSC as a reliable nanosecond source.

Returns

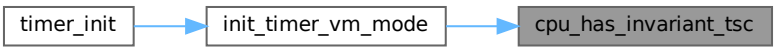
1 if invariant TSC is supported, 0 otherwise.

References cpuid().

Referenced by init_timer_vm_mode().

Here is the call graph for this function:

Here is the caller graph for this function:



7.116.2.6 cpu_has_rdtscp()

```
static int cpu_has_rdtscp (
            void  )  [static]
```

Test whether the processor supports the RDTSCP instruction.

Reads `CPUID.80000001H`:EDX[27]. RDTSCP provides weak serialisation and simultaneously reads both the TSC and the `IA32_TSC_AUX` MSR (which the OS programs to hold a per-CPU/socket identifier). Used in `timer_now_ns()` to prefer RDTSCP over the non-serialising RDTSC when available.

Returns

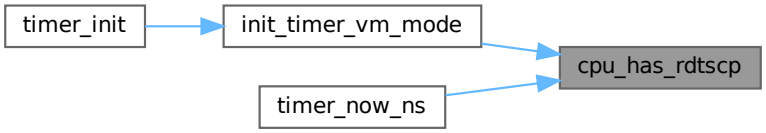
1 if RDTSCP is supported, 0 otherwise.

References cpuid().

Referenced by init_timer_vm_mode(), and timer_now_ns().

Here is the call graph for this function:

Here is the caller graph for this function:



7.116.2.7 cpuid()

```
static void cpuid (
            uint32_t leaf,
            uint32_t subleaf,
            uint32_t * a,
            uint32_t * b,
            uint32_t * c,
            uint32_t * d )  [inline], [static]
```

Execute the x86-64 `CPUID` instruction and capture all output registers.

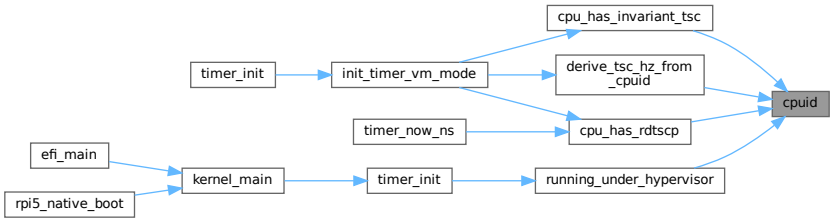
Passes `leaf` in `EAX` and `subleaf` in `ECX` before executing `CPUID`. Any of the output pointers may be `NULL`; the corresponding register value is then discarded.

Parameters

leaf	CPUID function leaf (EAX input).
subleaf	CPUID sub-leaf (ECX input, for structured extended leaves).
a	If non-NULL, receives `EAX` on return.
b	If non-NULL, receives `EBX` on return.
c	If non-NULL, receives `ECX` on return.
d	If non-NULL, receives `EDX` on return.

Referenced by cpu_has_invariant_tsc(), cpu_has_rdtscp(), derive_tsc_hz_from_cpuid(), and running_under_hypervisor().

Here is the caller graph for this function:



7.116.2.8 derive_tsc_hz_from_cpuid()

```
static uint64_t derive_tsc_hz_from_cpuid (
            void  )  [static]
```

Derive TSC frequency from CPUID leaves 0x15 and 0x16.

Checks leaf 0x15 (TSC/Crystal Ratio):

- If EAX, EBX, and ECX are all non-zero: $hz = ECX * EBX / EAX$.

Falls back to leaf 0x16 (base frequency in MHz) if leaf 0x15 gives 0.

Both leaves are available on Broadwell and later Intel CPUs; older CPUs and AMD processors may return 0. Under QEMU/KVM, leaf 0x15 is usually populated; under QEMU/TCG it often is not.

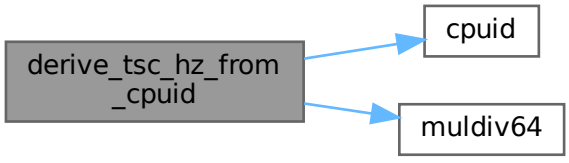
Returns

TSC frequency in Hz if derivable, 0 otherwise.

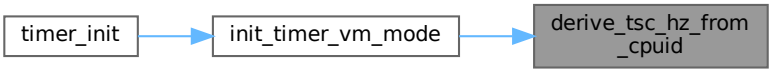
References cpuid(), and muldiv64().

Referenced by init_timer_vm_mode().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.9 enable_hpet()

```
static void enable_hpet (
            void  )  [static]
```

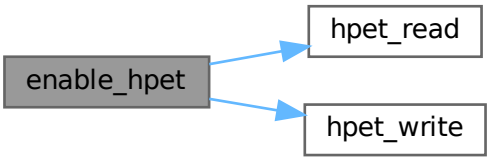
Enable the HPET main counter by setting the ENABLE_CNF bit.

Reads the `HPET_GEN_CONFIG` register, sets bit 0 (ENABLE_CNF), and writes it back. Must be called before the main counter is used for calibration. The HPET must be identity-mapped at `HPET_VIRT_BASE` before this function is called.

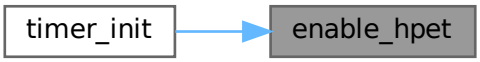
References HPET_GEN_CONFIG, hpet_read(), and hpet_write().

Referenced by timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.10 fadt_find_pm_tmr_port()

```
static uint16_t fadt_find_pm_tmr_port (
            void * rsdp )  [static]
```

Look up the ACPI PM_TMR_BLK I/O port from the FADT ("FACP" table).

Walks RSDP -> XSDT -> FADT exactly like pci.c's MCFG lookup. Prefers the ACPI 2.0+ X_PM_TMR_BLK Generic Address Structure (offset 208) when it names a valid SystemIO address; falls back to the legacy 32-bit PM_TMR_↩ BLK field (offset 76) otherwise. This port is machine-type dependent – QEMU's i440fx puts it at 0x408, Q35's ICH9 LPC at 0x608 – so it must be discovered rather than assumed.

Parameters

rsdp	BootInfo->acpi_table pointer from the UEFI configuration table (ACPI 2.0 GUID), or NULL.

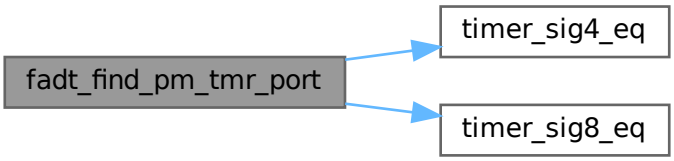
Returns

The discovered I/O port, or 0 if the FADT/XSDT/RSDP could not be parsed (caller should keep its hardcoded fallback in that case).

References timer_sig4_eq(), timer_sig8_eq(), and __attribute__::xsdt_address.

Referenced by timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.116.2.11 heartbeat_read_counter()

```
uint64_t heartbeat_read_counter (
            void  )
```

Read the raw counter the amd64 heartbeat is paced against.

Read the raw hardware counter this architecture's heartbeat is paced against – the same clock `timer_now_ns()` and calibration already use internally (rdtsc on amd64, the `time` CSR on riscv64, CNTPCT_EL0 on aarch64), not a separate/different source.

Item 0.8 (FABRIC-0.md ?25.1): the shared heartbeat.c owns heartbeat_init()/heartbeat_tick()/heartbeat_↩ service()/heartbeat_ticks()/ heartbeat_trust()/heartbeat_state() and the variance/trust math that used to live in this file. This is the one piece that stays per-architecture – the same `rdtsc()` the rest of this file's TSC calibration already uses, not a separate/different source.

Returns

Current TSC value.

References rdtsc().

Here is the call graph for this function:

7.116.2.12 hpet_read()

```
static uint64_t hpet_read (
            uint32_t offset )  [inline], [static]
```

Read a 64-bit HPET register at `offset` bytes from the HPET base.

Accesses `hpet_regs`[] (the identity-mapped MMIO region) using a naturally-aligned 64-bit read. `offset` must be a multiple of 8.

Parameters

offset	Byte offset of the target register (e.g., `HPET_MAIN_COUNTER` = 0x0F0).

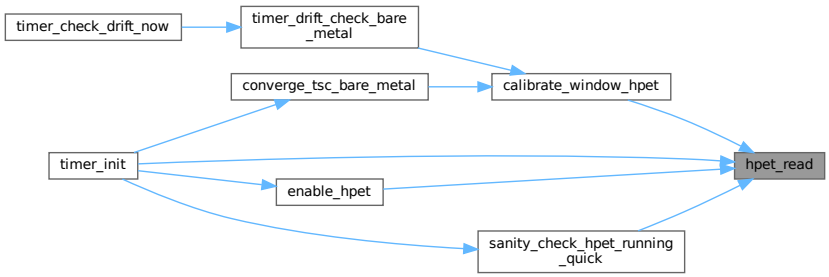
Returns

64-bit register value.

References hpet_regs.

Referenced by calibrate_window_hpet(), enable_hpet(), sanity_check_hpet_running_quick(), and timer_init().

Here is the caller graph for this function:



7.116.2.13 hpet_write()

```
static void hpet_write (
            uint32_t offset,
            uint64_t val )  [inline], [static]
```

Write a 64-bit value to an HPET register at `offset` bytes from base.

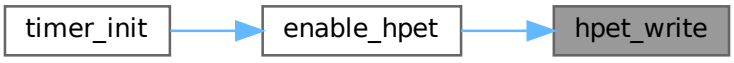
Parameters

offset	Byte offset of the target register (must be a multiple of 8).
val	64-bit value to write.

References hpet_regs.

Referenced by enable_hpet().

Here is the caller graph for this function:



7.116.2.14 inb()

```
static uint8_t inb (
            uint16_t port )  [inline], [static]
```

Read a byte from an x86 I/O port (IN instruction).

Parameters

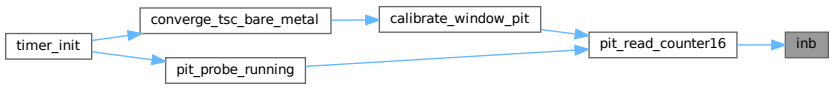
port	I/O port address.

Returns

Byte value read from the port.

Referenced by pit_read_counter16().

Here is the caller graph for this function:



7.116.2.15 init_timer_vm_mode()

```
static void init_timer_vm_mode (
            void  )  [static]
```

Initialise the timer subsystem in VM (hypervisor-present) mode.

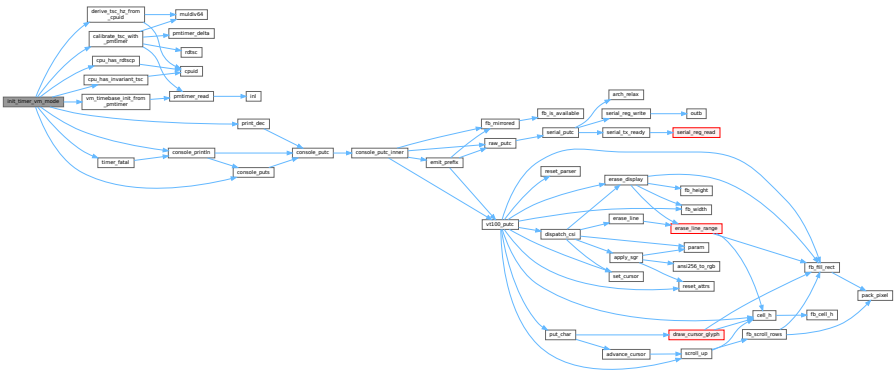
Skips HPET MMIO entirely (VM-exits would corrupt timing measurements). Instead:

1. Checks for invariant TSC. If absent and `TIMER_VM_STRICT_INVARIANT_TSC` is set, calls `timer_fatal()`. Otherwise logs a warning and uses `TIMER_TRUST_RELATIVE` mode.
2. Attempts to derive TSC Hz from CPUID leaves 0x15/0x16.
3. Falls back to `calibrate_tsc_with_pmtimer()` if CPUID yields 0.
4. If TSC Hz is still 0, logs a warning and forces `TIMER_TRUST_RELATIVE` (PM Timer only; no TSC→ns conversion).
5. Calls `vm_timebase_init_from_pmtimer()` to anchor relative time.
6. Fills `calib_record` with `vm_mode` = 1.

References calib_record, calibrate_tsc_with_pmtimer(), console_println(), console_puts(), timer_calibration_record::converged, cpu_has_invariant_tsc(), cpu_has_rdtscp(), timer_calibration_record::cv_hpet_ppm, timer_calibration_record::cv_pit_ppm, derive_tsc_hz_from_cpuid(), timer_calibration_record::diff_ppm, timer_calibration_record::hpet_hz, timer_calibration_record::pit_hz_r print_dec(), timer_fatal(), TIMER_TRUST_ABSOLUTE, TIMER_TRUST_RELATIVE, TIMER_VM_STRICT_INVARIANT_TSC, timer_calibration_record::trust, tsc_hz_locked, timer_calibration_record::tsc_hz_mean, timer_calibration_record::vm_mode, vm_timebase_init_from_pmtimer(), and timer_calibration_record::windows_used.

Referenced by timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.116.2.16 inl()

```
static uint32_t inl (
            uint16_t port )  [inline], [static]
```

Read a 32-bit dword from an x86 I/O port (INL instruction).

Used to read the ACPI PM Timer register which is a 24-bit counter accessed as a 32-bit I/O port.

Parameters

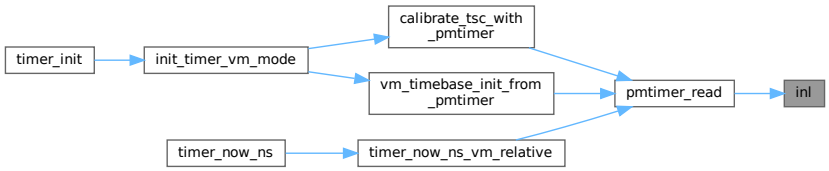
port	I/O port address.

Returns

32-bit value read from the port.

Referenced by pmtimer_read().

Here is the caller graph for this function:



7.116.2.17 muldiv64()

```
static uint64_t muldiv64 (
            uint64_t a,
            uint64_t b,
            uint64_t c )  [inline], [static]
```

Compute (a × b) / c using 128-bit intermediate precision.

Uses the x86-64 `MUL` instruction to produce a 128-bit product in `RDX:RAX`, then `DIV` to produce a 64-bit quotient. This avoids the overflow that would occur with a 64-bit-only intermediate when `a` and `b` are both large (e.g., nanosecond conversion of multi-GHz tick counts). No libgcc dependency — pure inline assembly.

FABRIC-0.md item 4.5d, 2026-08-11: this asm previously declared `RDX` as a plain output (`"=d"(hi)`), which tells GCC only "I want to read RDX's value after this block" — nothing told it that `mulq` writes RDX *before* `divq` needs to read a *different* value (the divisor `c`) out of it. Nothing stopped the register allocator from placing `c` itself in RDX, which `mulq` then overwrote with the product's high 64 bits before `divq` ever read it. At `-O0` this happened not to manifest; at `-O2`, GCC's more aggressive allocation actually did it, and for a product like `1000 * 1000000000` (fits entirely in the low 64 bits, so mulq's high-word output is 0), that corrupted the intended divisor to 0 – a genuine #DE (divide error) confirmed via QEMU `-d int` tracing, cascading to a double fault and then a triple fault (silently exited by `-no-reboot`, which is why this looked like an infinite hang rather than a crash at first). A `unsigned __int128` rewrite was tried first but needs libgcc's `__udivti3` for the general 128÷64 DIVISION case, undefined in this freestanding, `-nostdlib` build — not viable for that reason specifically. (Confirmed narrower during the Ed25519 crypto work, 2026-08-22: `__int128` multiply/add/shift-by-constant DO compile cleanly with zero undefined symbols on all three target toolchains — it's only division, needing a multi-instruction libgcc routine the compiler won't inline, that's unavailable here. Don't read this comment as "avoid __↩ int128 entirely" — src/starkernel/crypto/fe25519.c uses it safely for exactly that reason.) Fixed instead the way the Linux kernel's own `mul_u64_u64_div_u64` does it: declare `rdx` as a pure *clobber*, not an output. A clobber tells GCC the register is used internally by the whole asm block and must never be allocated to any input or output operand for its duration — exactly the guarantee the previous constraint list was missing.

Undefined behaviour if `a` × b / c overflows `uint64_t` (i.e., the true quotient exceeds `UINT64_MAX`). Callers must ensure this cannot happen with their inputs.

Parameters

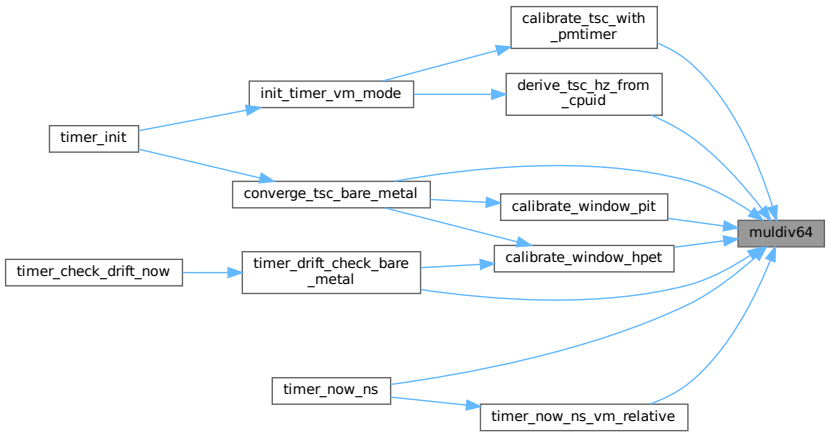
a	Multiplicand.
b	Multiplier.
c	Divisor (must be non-zero; division by zero causes a #DE fault).

Returns

Exact quotient (a ∗ b) / c, truncated toward zero.

Referenced by calibrate_tsc_with_pmtimer(), calibrate_window_hpet(), calibrate_window_pit(), converge_tsc_bare_metal(), derive_tsc_hz_from_cpuid(), timer_drift_check_bare_metal(), timer_now_ns(), and timer_now_ns_vm_relative().

Here is the caller graph for this function:



7.116.2.18 outb()

```
static void outb (
            uint16_t port,
            uint8_t val )  [inline], [static]
```

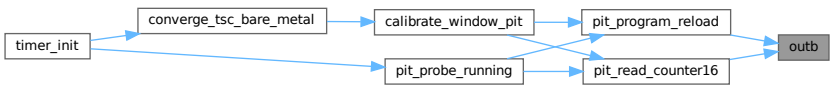
Write a byte to an x86 I/O port (OUT instruction).

Parameters

port	I/O port address.
val	Byte value to write.

Referenced by pit_program_reload(), and pit_read_counter16().

Here is the caller graph for this function:



7.116.2.19 pit_probe_running()

```
static int pit_probe_running (
            void  )  [static]
```

Probe whether the PIT is available and counting.

Programs the PIT with reload value 0xFFFF and polls up to 20,000 times for a counter change. Returns 1 if the counter advances (PIT running), 0 if it never changes (PIT absent, frozen, or emulation disabled). Used on the bare-metal path to decide whether to enable the PIT cross-check for TSC convergence.

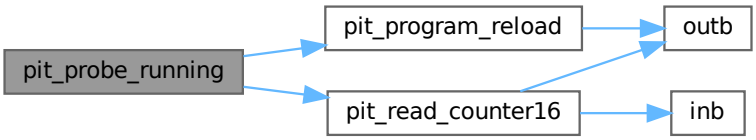
Returns

1 if the PIT is running, 0 if it is unavailable.

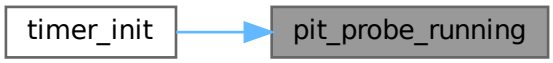
References pit_program_reload(), and pit_read_counter16().

Referenced by timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.20 pit_program_reload()

```
static void pit_program_reload (
            uint16_t reload )  [static]
```

Programme the 8253/8254 PIT Channel 0 with a 16-bit reload value.

Issues the mode command byte (0x34 = channel 0, lo/hi access, mode 2 rate generator) followed by the low and high bytes of `reload` to the PIT data port. After this call the PIT downcounts at `PIT_FREQ_HZ` (1193182 Hz) and reloads automatically.

Parameters

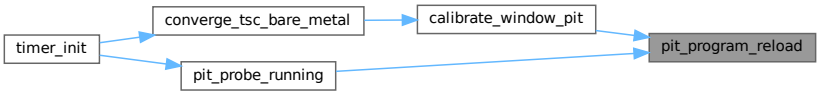
reload	16-bit initial counter value (higher = longer period).

References outb(), PIT_CHANNEL0_DATA, and PIT_COMMAND.

Referenced by calibrate_window_pit(), and pit_probe_running().

Here is the call graph for this function:

Here is the caller graph for this function:



7.116.2.21 pit_read_counter16()

```
static uint16_t pit_read_counter16 (
            void  )  [static]
```

Read the current 16-bit counter value from PIT Channel 0.

Sends a latch command (0x00) to the PIT command port to atomically snap the current count, then reads the low and high bytes from the Channel 0 data port in two `INB` instructions. Returns the counter as a 16-bit value; note the PIT counter counts down from the reload value.

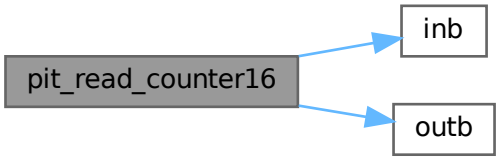
Returns

Current PIT Channel 0 counter value (decreasing, wraps at 0).

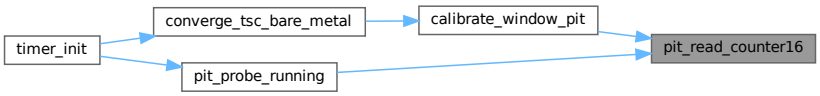
References inb(), outb(), PIT_CHANNEL0_DATA, and PIT_COMMAND.

Referenced by calibrate_window_pit(), and pit_probe_running().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.22 pmtimer_delta()

```
static uint64_t pmtimer_delta (
            uint32_t start,
            uint32_t cur )  [static]
```

Compute elapsed PM Timer ticks from `start` to `cur`, handling wrap-around.

Masks both values to `PMTIMER_WIDTH_BITS` (24 bits) before comparison. When the counter wraps — i.e., `cur` < `start` after masking — the function returns the distance through the wrap: (MASK - start + 1 + cur).

Parameters

start	PM Timer value at the beginning of the interval (unmasked).
cur	PM Timer value at the end of the interval (unmasked).

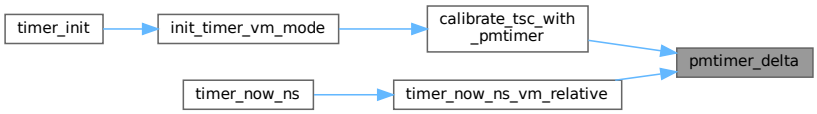
Returns

Number of PM Timer ticks elapsed, accounting for a single wrap.

References PMTIMER_MASK.

Referenced by calibrate_tsc_with_pmtimer(), and timer_now_ns_vm_relative().

Here is the caller graph for this function:



7.116.2.23 pmtimer_read()

```
static uint32_t pmtimer_read (
            void  )  [inline], [static]
```

Read the raw ACPI PM Timer counter from I/O port `pmtimer_port`.

The PM Timer runs at 3.579545 MHz and is a 24-bit counter (bits [23:0]) in most systems. The returned 32-bit value may contain non-zero bits above bit 23 on 32-bit PM Timer implementations; callers must mask with `PMTIMER_MASK` before use.

Returns

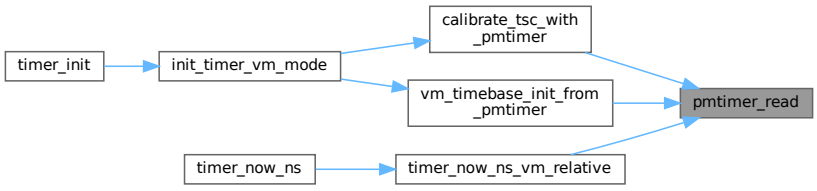
Raw 32-bit PM Timer register value.

References inl(), and pmtimer_port.

Referenced by calibrate_tsc_with_pmtimer(), timer_now_ns_vm_relative(), and vm_timebase_init_from_pmtimer().

Here is the call graph for this function:

Here is the caller graph for this function:



7.116.2.24 print_dec()

```
static void print_dec (
            uint64_t val )  [static]
```

Print a `uint64_t` value as decimal digits to the kernel console.

Uses a local reverse-digit buffer and `console_putc()`; no libc or heap allocation required. Prints `"0"` for a zero value. Used throughout the timer subsystem to emit calibration results without depending on `printf()`.

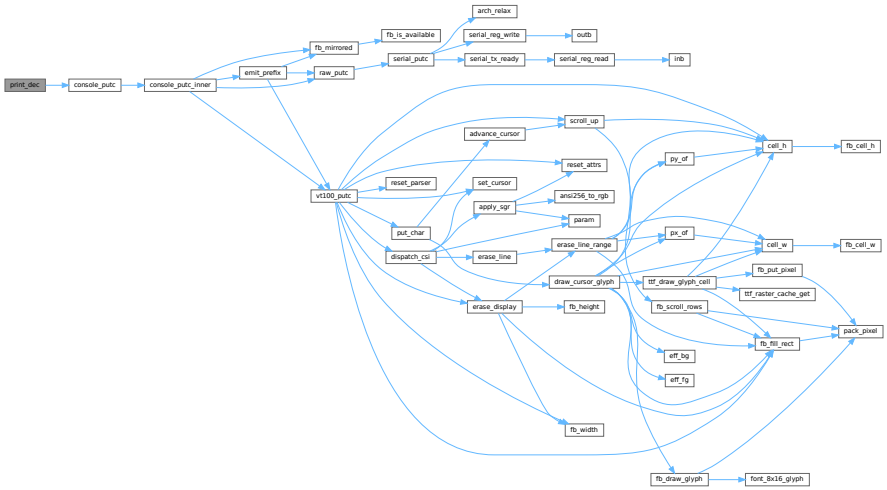
Parameters

val	Value to print in decimal.

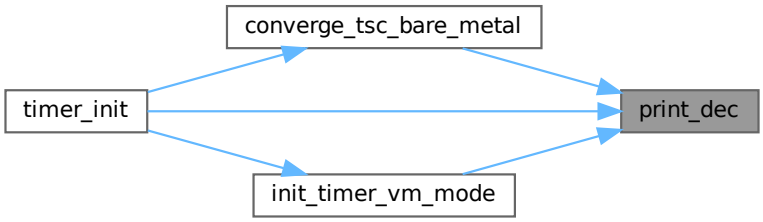
References console_putc().

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), and timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.25 rdtsc()

```
static uint64_t rdtsc (
            void  )  [inline], [static]
```

Read the x86-64 Time Stamp Counter without serialisation (RDTSC).

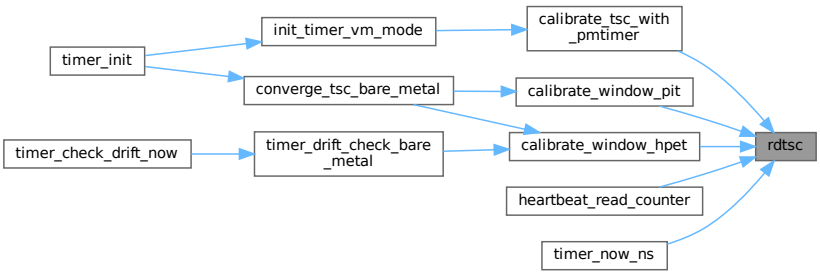
Executes the `RDTSC` instruction and combines `EDX:EAX` into a 64-bit result. May be reordered relative to surrounding instructions by the out-of-order execution unit; use `rdtscp_aux()` where ordering matters.

Returns

Current TSC value in CPU cycles.

Referenced by calibrate_tsc_with_pmtimer(), calibrate_window_hpet(), calibrate_window_pit(), heartbeat_read_counter(), and timer_now_ns().

Here is the caller graph for this function:



7.116.2.26 rdtscp_aux()

```
static uint64_t rdtscp_aux (
            uint32_t * aux )  [inline], [static]
```

Read TSC and processor ID with weak serialisation (RDTSCP).

`RDTSCP` is weakly serialising: all prior loads are complete before the read, but it does not wait for prior stores. Optionally captures the `IA32_TSC_AUX` MSR value (processor ID / NUMA node) in `aux`. Falls back to `rdtsc()` at call sites that check `cpu_has_rdtscp()` first.

Parameters

aux	If non-NULL, receives the `ECX` value from `RDTSCP` (processor/socket ID programmed by the OS or hypervisor).

Returns

Current TSC value in CPU cycles.

Referenced by timer_now_ns().

Here is the caller graph for this function:

7.116.2.27 running_under_hypervisor()

```
static int running_under_hypervisor (
            void  )  [static]
```

Detect whether the kernel is running under a hypervisor.

Reads `CPUID.1`:ECX[31] (Hypervisor Present bit). When set, the kernel switches to VM mode: HPET MMIO calibration is disabled (VM-exits would poison timing), and TSC frequency is derived from CPUID leaves 0x15/0x16 or the ACPI PM Timer instead.

Returns

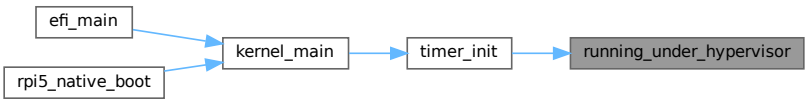
1 if a hypervisor is present (including QEMU/TCG), 0 on bare metal.

References cpuid().

Referenced by timer_init().

Here is the call graph for this function:

Here is the caller graph for this function:



7.116.2.28 sanity_check_hpet_running_quick()

```
static void sanity_check_hpet_running_quick (
            void ) [static]
```

Verify the HPET main counter is advancing (quick sanity check).

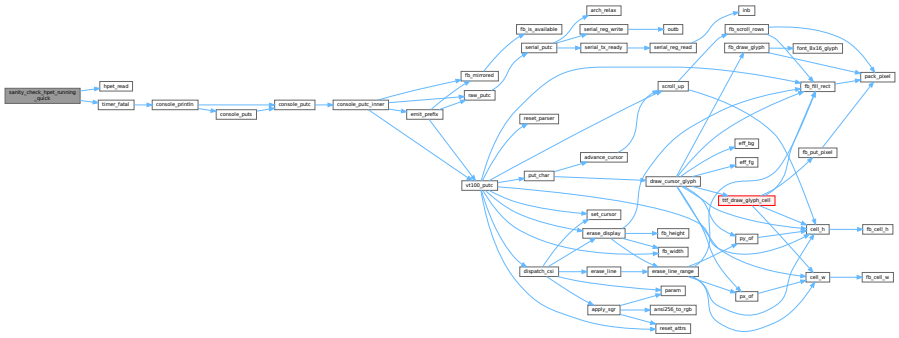
Reads the HPET_MAIN_COUNTER repeatedly up to 200,000 times. If the counter value changes at least once, the check passes silently. If the counter never changes — indicating a hardware fault, frozen HPET, or mapping error — calls timer_fatal() which halts the processor.

Only used on the bare-metal path; skipped in VM mode.

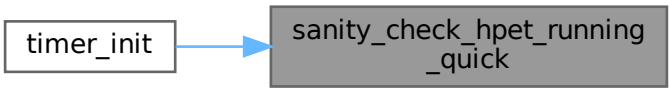
References HPET_MAIN_COUNTER, hpet_read(), and timer_fatal().

Referenced by timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.29 timer_calibration_record()

```
const timer_calibration_record_t * timer_calibration_record (
            void )
```

Return a pointer to the current timer calibration record.

Return a pointer to the timer calibration record.

Provides read-only access to the calib_record populated by timer_init(). Callers can inspect fields such as trust, tsc_hz_mean, cv_hpet_ppm, and converged for diagnostic output or to determine whether absolute timing guarantees are available.

Returns

Pointer to the static timer_calibration_record_t (never NULL).

References calib_record.

7.116.2.30 timer_check_drift_now()

```
int timer_check_drift_now (
            void  )
```

Perform a runtime TSC drift check (no-op in VM mode).

Check for timer drift (AArch64 stub — always returns 0).

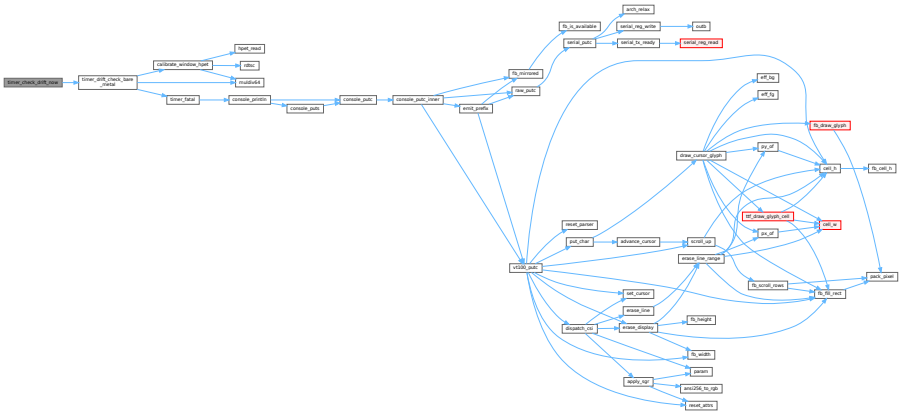
In bare-metal mode delegates to `timer_drift_check_bare_metal()`. In VM mode returns 0 immediately: VM drift checking requires a VM-friendly reference (such as pvclock) that is not yet implemented.

Returns

0 if drift is acceptable or in VM mode, -1 on bare-metal measurement failure.

References calib_record, timer_drift_check_bare_metal(), and timer_calibration_record::vm_mode.

Here is the call graph for this function:



7.116.2.31 timer_drift_check_bare_metal()

```
static int timer_drift_check_bare_metal (
            void  )  [static]
```

Check TSC drift against the HPET reference on bare metal.

Takes a single HPET calibration window and compares the measured TSC Hz to `tsc_hz_locked`. If the drift exceeds `DRIFT_EPSILON_PPM` (2000 ppm), calls `timer_fatal()` — never returns. Returns -1 if either reading is invalid.

Skipped in VM mode (`timer_check_drift_now()` returns 0 immediately).

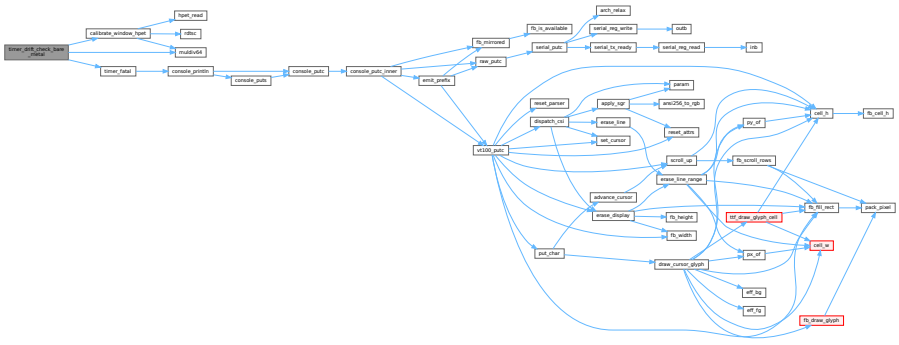
Returns

0 if drift is within bound, -1 on measurement failure.

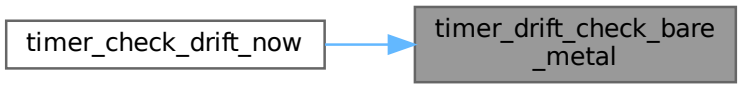
References calibrate_window_hpet(), DRIFT_EPSILON_PPM, muldiv64(), timer_fatal(), tsc_hz_locked, and WINDOW_TICKS_HPET.

Referenced by timer_check_drift_now().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.32 timer_fatal()

```
static void timer_fatal (
            const char * msg )  [static]
```

Emit a fatal timer error message and halt the processor permanently.

Prints `msg` followed by `"Timer subsystem fatal.  Halting."` to the kernel console, then enters an infinite `HLT` loop. Never returns. Called when a hard timer invariant cannot be satisfied (e.g., HPET counter not advancing, TSC calibration failed to converge).

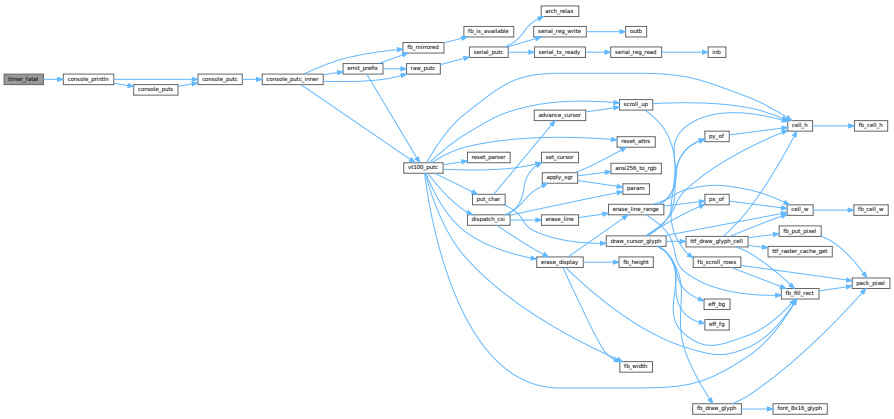
Parameters

msg	Null-terminated error description to print before halting.

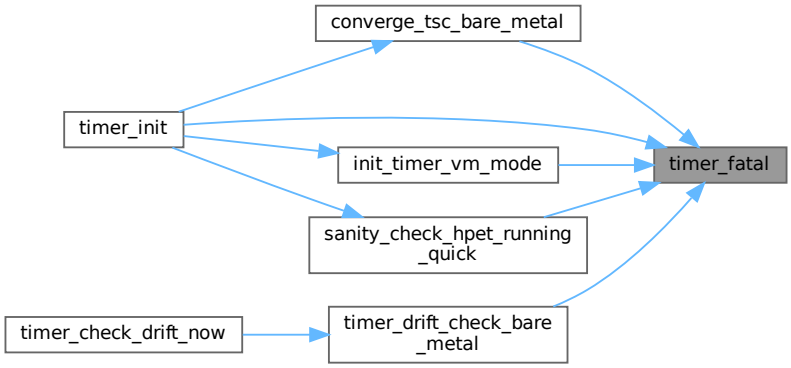
References console_println().

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), sanity_check_hpet_running_quick(), timer_drift_check_bare_meta and timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.2.33 timer_init()

```
int timer_init (
            BootInfo * boot_info )
```

Initialise the kernel timer subsystem (M5).

Detects the execution environment (bare metal vs. hypervisor) and follows the appropriate calibration path:

- **VM / hypervisor path** (CPUID.1:ECX[31] set): calls `init_timer_vm_mode()` — HPET MMIO disabled, TSC from CPUID/PM Timer.
- **Bare metal path**: maps HPET MMIO, enables the counter, optionally probes the PIT, then calls `converge_tsc_bare_metal()` until TSC Hz converges within `CV_EPSILON_PPM` ppm. Calls `timer_fatal()` on any hard failure.

On success, `tsc_hz_locked` holds the calibrated TSC frequency and `calib_record` is fully populated. `timer_now_ns()` is safe to call after this function returns.

Parameters

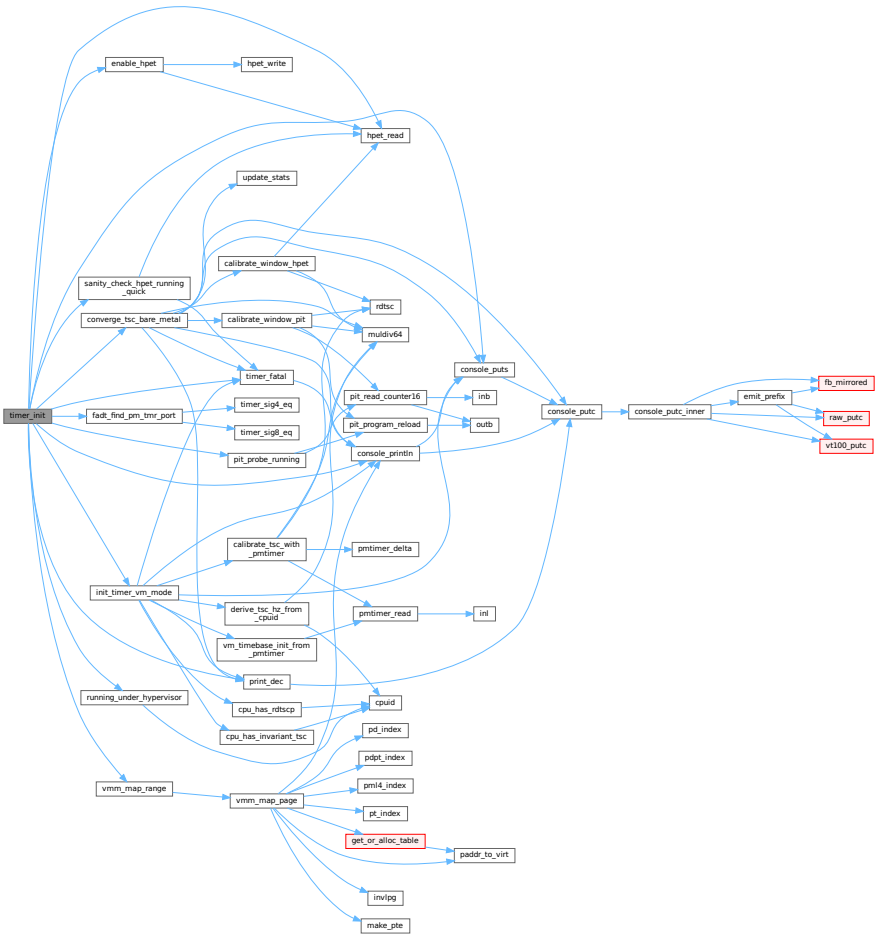
boot_info	BootInfo pointer from the UEFI loader; `acpi_table` is used to discover the ACPI PM_TMR_BLK port at runtime (see `fadt_find_pm_tmr_port()`) rather than assuming a fixed machine type's legacy address.

Returns

0 on success; calls `timer_fatal()` (never returns) on hard failure.

References BootInfo::acpi_table, calib_record, console_println(), console_puts(), converge_tsc_bare_metal(), timer_calibration_record::converged, enable_hpet(), fadt_find_pm_tmr_port(), hpet_freq_hz, HPET_GEN_CAP_ID, HPET_PHYS_BASE, hpet_read(), hpet_regs, HPET_VIRT_BASE, init_timer_vm_mode(), pit_available, pit_probe_running(), pit_tsc_hz_mean, pmtimer_port, print_dec(), running_under_hypervisor(), sanity_check_hpet_running_quick(), timer_fatal(), TIMER_REQUIRE_PIT, TIMER_TRUST_NONE, timer_calibration_record::trust, tsc_hz_locked, timer_calibration_record::vm_mode, VMM_FLAG_WRITABLE, and vmm_map_range().

Here is the call graph for this function:



7.116.2.34 timer_now_ns()

```
uint64_t timer_now_ns (
            void  )
```

Return the current monotonic time in nanoseconds.

Return a monotonic nanosecond timestamp.

Selects the best available time source based on the calibration record:

- `TIMER_TRUST_NONE`: returns 0 (no time base yet).
- VM mode + trust < `TIMER_TRUST_ABSOLUTE`: returns PM Timer relative ns.
- Absolute mode (`tsc_hz_locked` > 0): reads TSC (RDTSCP if supported, else RDTSC) and converts to ns via `muldiv64()`.

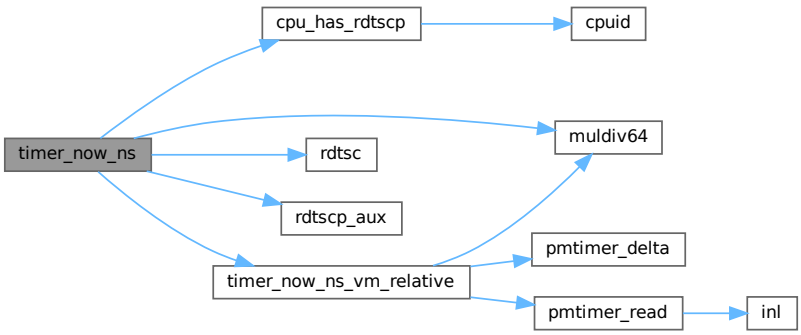
Called by the HAL (`sk_hal_time_ns()`) to feed the physics engine.

Returns

Nanoseconds since boot, or 0 if the timer is not yet calibrated.

References calib_record, cpu_has_rdtscp(), muldiv64(), rdtsc(), rdtscp_aux(), timer_now_ns_vm_relative(), TIMER_TRUST_ABSOLUTE, TIMER_TRUST_NONE, timer_calibration_record::trust, tsc_hz_locked, and timer_calibration_record::vm_mode.

Here is the call graph for this function:



7.116.2.35 timer_now_ns_vm_relative()

```
static uint64_t timer_now_ns_vm_relative (
            void  )  [static]
```

Return nanoseconds since boot using the ACPI PM Timer (VM relative mode).

Reads the current PM Timer counter, computes ticks elapsed since `vm_pm_start` (set by `vm_timebase_init_from_pmtime` converts to nanoseconds via `muldiv64()`, and adds `vm_ns_base`. Used when the calibration record shows `vm_mode` = 1 and `trust` < TIMER_TRUST_ABSOLUTE.

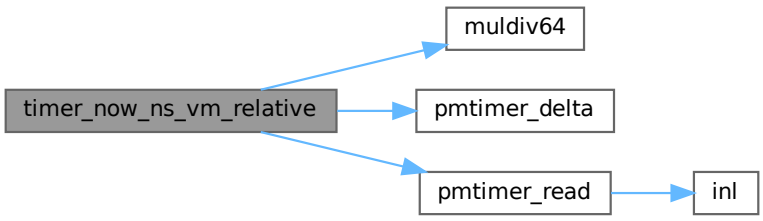
Returns

Nanoseconds elapsed since `vm_timebase_init_from_pmtimer()` was called.

References muldiv64(), pmtimer_delta(), PMTIMER_FREQ_HZ, PMTIMER_MASK, pmtimer_read(), vm_ns_base, and vm_pm_start.

Referenced by timer_now_ns().

Here is the call graph for this function:



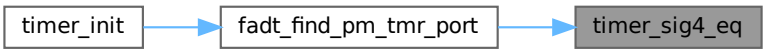
Here is the caller graph for this function:

7.116.2.36 timer_sig4_eq()

```
static int timer_sig4_eq (
            const uint8_t * p,
            const char * s )  [static]
```

Referenced by fadt_find_pm_tmr_port().

Here is the caller graph for this function:

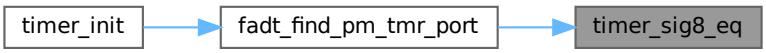


7.116.2.37 timer_sig8_eq()

```
static int timer_sig8_eq (
            const uint8_t * p,
            const char * s )  [static]
```

Referenced by fadt_find_pm_tmr_port().

Here is the caller graph for this function:



7.116.2.38 timer_tsc_hz()

```
uint64_t timer_tsc_hz (
            void  )
```

Return the locked TSC frequency in Hz.

Return the system counter frequency in Hz.

Returns the value established by `timer_init()`. Zero means calibration has not completed or failed to derive a TSC frequency (PM Timer relative mode only).

Returns

TSC frequency in Hz, or 0 if unknown.

References tsc_hz_locked.

7.116.2.39 update_stats()

```
static void update_stats (
             const uint64_t * samples,
             uint32_t count,
             uint64_t * mean,
             uint64_t * stddev )  [static]
```

Compute mean and standard deviation of an array of `uint64_t` samples.

Uses 64-bit integer arithmetic throughout. For TSC-frequency samples (∼3 GHz) with ≤16 windows, both the sum and variance accumulator remain within `uint64_t` range so long as deviations are below ∼1 MHz (which is well within the `CV_EPSILON_PPM` = 1000 ppm convergence bound).

Standard deviation is approximated via integer Newton-Raphson square root (10 iterations) over the variance.

Sets `*mean` = `*stddev` = 0 when `count` is 0.

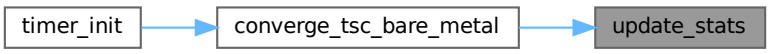
Parameters

samples	Array of `count` frequency samples in Hz.
count	Number of valid samples.
mean	Output: arithmetic mean of `samples`.
stddev	Output: population standard deviation of `samples`.

References count.

Referenced by converge_tsc_bare_metal().

Here is the caller graph for this function:



7.116.2.40 vm_timebase_init_from_pmtimer()

```
static void vm_timebase_init_from_pmtimer (
             void  )  [static]
```

Initialise the VM relative-time base anchored to the PM Timer.

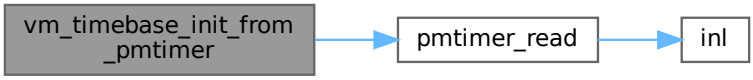
Records the current PM Timer counter value in `vm_pm_start` and resets `vm_ns_base` to zero. Subsequent calls to `timer_now_ns_vm_relative()` compute elapsed nanoseconds from this anchor point.

Called during `init_timer_vm_mode()` after the calibration phase, so the first call to `timer_now_ns()` returns a small positive value rather than a large absolute-time offset.

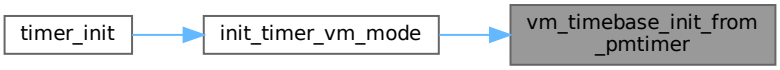
References PMTIMER_MASK, pmtimer_read(), vm_ns_base, and vm_pm_start.

Referenced by init_timer_vm_mode().

Here is the call graph for this function:



Here is the caller graph for this function:



7.116.3 Variable Documentation

7.116.3.1 calib_record

```
timer_calibration_record_t calib_record = {0}  [static]
```

Referenced by converge_tsc_bare_metal(), init_timer_vm_mode(), timer_calibration_record(), timer_check_drift_now(), timer_init(), and timer_now_ns().

7.116.3.2 hpet_freq_hz

```
uint64_t hpet_freq_hz = 0  [static]
```

Referenced by calibrate_window_hpet(), converge_tsc_bare_metal(), and timer_init().

7.116.3.3 hpet_regs

```
volatile uint64_t* hpet_regs = 0  [static]
```

Referenced by hpet_read(), hpet_write(), and timer_init().

7.116.3.4 pit_available

```
int pit_available = 0  [static]
```

Referenced by calibrate_window_pit(), converge_tsc_bare_metal(), and timer_init().

7.116.3.5 pit_tsc_hz_mean

```
uint64_t pit_tsc_hz_mean = 0  [static]
```

Referenced by timer_init().

7.116.3.6 pmtimer_port

```
uint16_t pmtimer_port = 0x408  [static]
```

Referenced by pmtimer_read(), and timer_init().

7.116.3.7 tsc_hz_locked

```
uint64_t tsc_hz_locked = 0  [static]
```

Referenced by init_timer_vm_mode(), timer_drift_check_bare_metal(), timer_init(), timer_now_ns(), and timer_tsc_hz().

7.116.3.8 vm_ns_base

```
uint64_t vm_ns_base = 0  [static]
```

Referenced by timer_now_ns_vm_relative(), and vm_timebase_init_from_pmtimer().

7.116.3.9 vm_pm_start

```
uint32_t vm_pm_start = 0  [static]
```

Referenced by timer_now_ns_vm_relative(), and vm_timebase_init_from_pmtimer().

7.116.3.10 windows_used

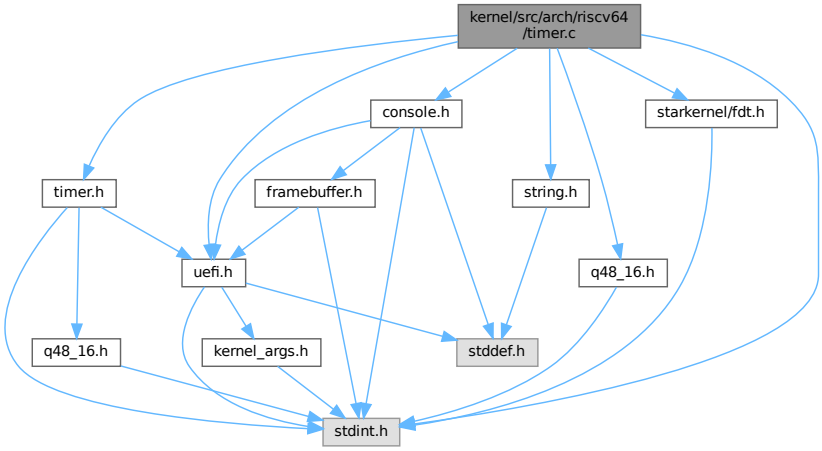
```
uint32_t windows_used = 0  [static]
```

Referenced by converge_tsc_bare_metal().

7.117 kernel/src/arch/riscv64/timer.c File Reference

```
#include "timer.h"
#include "console.h"
#include "q48_16.h"
#include "uefi.h"
#include "starkernel/fdt.h"
#include <stdint.h>
#include <string.h>
```

Include dependency graph for timer.c:



Macros

- #define RISCV_TIMEBASE_HZ_FALLBACK 10000000ULL

Functions

- static int bytes_contain (const uint8_t *hay, uint32_t haylen, const char *needle)

  timer.c (riscv64) - Timer using the `time` CSR.
- static int running_under_hypervisor (BootInfo *boot_info)
- static uint64_t rdtime (void)

  Read the RISC-V wall-clock counter (`rdtime`, CSR `time` 0xC01).
- static void print_dec (uint64_t val)

  Print `val` in decimal via `console_putc()`.
- int timer_init (BootInfo *boot_info)

  Initialise the kernel timer subsystem (M5).
- uint64_t timer_tsc_hz (void)

  Return the `time` counter frequency in Hz.
- uint64_t timer_now_ns (void)

  Return a monotonic nanosecond timestamp.
- int timer_check_drift_now (void)

  Check for `time` counter drift (RISC-V stub — always returns 0).
- const timer_calibration_record_t * timer_calibration_record (void)

  Return a pointer to the timer calibration record.
- uint64_t heartbeat_read_counter (void)

  Read the raw counter the riscv64 heartbeat is paced against.

Variables

- static uint64_t s_counter_hz = 10000000ULL
- static uint64_t s_ns_per_tick = 0
- static uint64_t s_base_count = 0
- static uint64_t s_base_ns = 0
- static timer_calibration_record_t s_cal

7.117.1 Macro Definition Documentation

7.117.1.1 RISCV_TIMEBASE_HZ_FALLBACK

```
#define RISCV_TIMEBASE_HZ_FALLBACK 10000000ULL
```

7.117.2 Function Documentation

7.117.2.1 bytes_contain()

```
static int bytes_contain (
            const uint8_t * hay,
            uint32_t haylen,
            const char * needle )  [static]
```

timer.c (riscv64) - Timer using the `time` CSR.

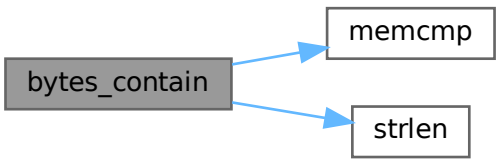
RISC-V provides `cycle` (per-hart clock cycles) and `time` (fixed-frequency wall clock). The primary timestamp source is `time`, read via rdtime, and its rate comes from the devicetree property timebase-frequency.

This was `cycle` at an assumed 1 GHz until punch-list item 0.3. Two things forced the change: the SBI TIME extension arms deadlines against `time`, so mixing the two counters would compare unrelated clocks; and `cycle` has no discoverable frequency, so every heartbeat variance and TIME-TRUST figure riscv64 produced before this was measured against a wrong expected interval (FABRIC-0.md ?16.2). Figures from before and after are not comparable.

References memcmp(), and strlen().

Referenced by running_under_hypervisor().

Here is the call graph for this function:



Here is the caller graph for this function:

7.117.2.2 heartbeat_read_counter()

```
uint64_t heartbeat_read_counter (
            void  )
```

Read the raw counter the riscv64 heartbeat is paced against.

Read the raw hardware counter this architecture's heartbeat is paced against – the same clock `timer_now_ns()` and calibration already use internally (rdtsc on amd64, the `time` CSR on riscv64, CNTPCT_EL0 on aarch64), not a separate/different source.

Item 0.8 (FABRIC-0.md ?25.1): the shared heartbeat.c now owns heartbeat_init()/heartbeat_tick()/heartbeat_↩ service()/heartbeat_ticks()/ heartbeat_trust()/heartbeat_state(). This is the one piece that stays per-architecture – the same `rdtime()` the timer deadline is armed against, not `rdcycle()` or any other source. Must read the same counter the deadline was programmed against: `expected_delta` is derived from timebase-frequency and is therefore in `time` units; measuring the interval with `cycle` instead would difference two unrelated clocks.

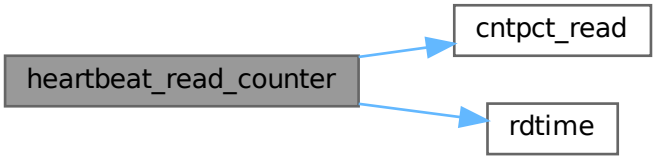
Returns

Current `time` CSR value.

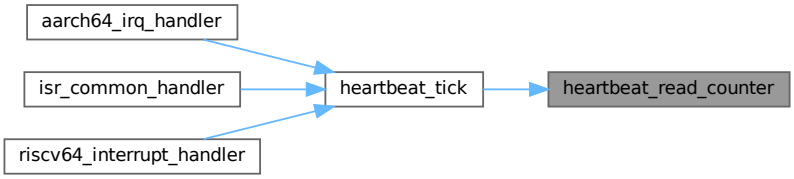
References cntpct_read(), and rdtime().

Referenced by heartbeat_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.117.2.3 print_dec()

```
static void print_dec (
            uint64_t val )  [static]
```

Print `val` in decimal via `console_putc()`.

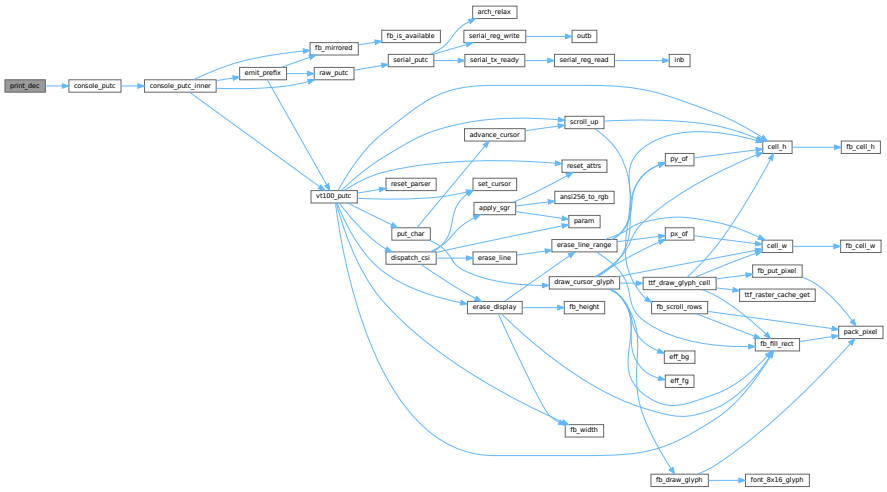
Same shape as the file-local helper in `arch/amd64/timer.c` — there is no shared decimal printer in `console.h`, and the freestanding build has no `printf()`. Prints "0" for zero.

Parameters

val	Value to print.

References console_putc().

Here is the call graph for this function:



7.117.2.4 rdtime()

```
static uint64_t rdtime (
            void  )  [inline], [static]
```

Read the RISC-V wall-clock counter (`rdtime`, CSR `time` 0xC01).

`time` is the memory-mapped real-time counter mandated by the privileged spec: fixed frequency, common to all harts, and — unlike `cycle` — its rate is discoverable, published by firmware as the devicetree property `timebase-frequency`.

This replaces the earlier `rdcycle()` source. Two reasons, and the first is not optional:

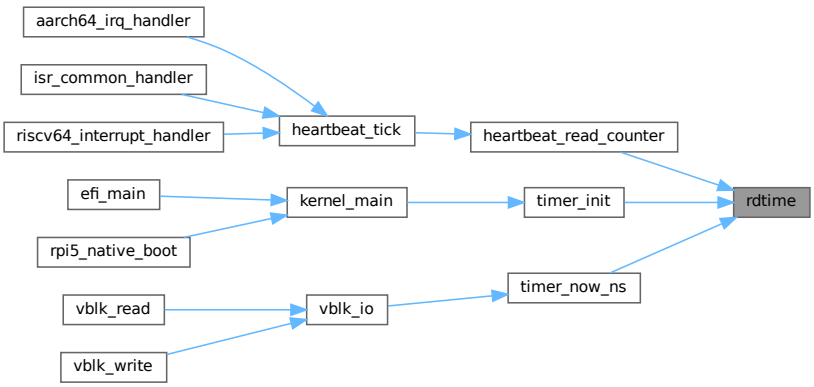
- **The SBI TIME extension is defined against `time`.** `sbi_set_timer()` takes an absolute value on this counter, so arming a timer from a `cycle` reading would compare two unrelated clocks.
- **`cycle`'s frequency is not discoverable**, which is why the previous implementation hardcoded an assumed 1 GHz. Every heartbeat variance and TIME-TRUST figure riscv64 has produced was therefore computed against a wrong expected interval.

Returns

Current 64-bit `time` value.

Referenced by heartbeat_read_counter(), timer_init(), and timer_now_ns().

Here is the caller graph for this function:

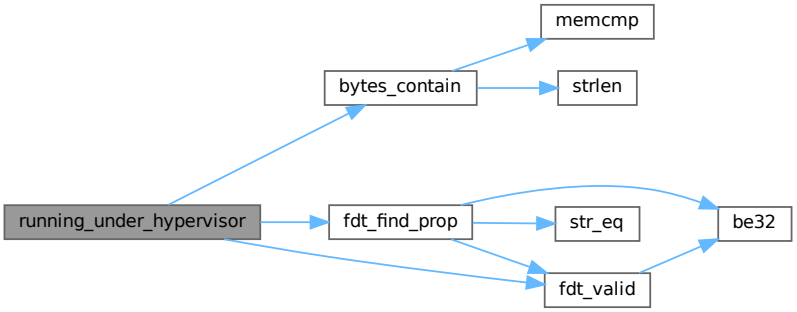


7.117.2.5 running_under_hypervisor()

```
static int running_under_hypervisor (
            BootInfo * boot_info )  [static]
```

References bytes_contain(), BootInfo::dtb, fdt_find_prop(), and fdt_valid().

Here is the call graph for this function:



7.117.2.6 timer_calibration_record()

```
const timer_calibration_record_t * timer_calibration_record (
            void  )
```

Return a pointer to the timer calibration record.

Returns `&s_cal`, populated by `timer_init()` with the discovered (or fallback) frequency and the corresponding trust level — `TIMER_TRUST_ABSOLUTE` when `timebase-frequency` came from the devicetree, `TIMER_TRUST_RELATIVE` on the fallback. Consumed by `kernel_main()` for boot-log reporting and by the heartbeat subsystem's trust init.

Returns

Pointer to the module-static calibration record; valid for the lifetime of the kernel.

References s_cal.

7.117.2.7 timer_check_drift_now()

```
int timer_check_drift_now (
            void  )
```

Check for `time` counter drift (RISC-V stub — always returns 0).

Check for timer drift (AArch64 stub — always returns 0).

On x86-64 this cross-checks the TSC against the HPET. The RISC-V `time` counter has no independent reference to check against at this milestone — and per the privileged spec it is architecturally required to be a fixed, synchronised rate across harts, unlike `cycle`. Always returns 0 (no drift) to satisfy the common call site.

Returns

0 always.

7.117.2.8 timer_init()

```
int timer_init (
            BootInfo * boot_info )
```

Initialise the kernel timer subsystem (M5).

Detects the execution environment (bare metal vs. hypervisor) and follows the appropriate calibration path:

- **VM / hypervisor path** (CPUID.1:ECX[31] set): calls `init_timer_vm_mode()` — HPET MMIO disabled, TSC from CPUID/PM Timer.
- **Bare metal path**: maps HPET MMIO, enables the counter, optionally probes the PIT, then calls `converge_tsc_bare_metal()` until TSC Hz converges within `CV_EPSILON_PPM` ppm. Calls `timer_fatal()` on any hard failure.

On success, `tsc_hz_locked` holds the calibrated TSC frequency and `calib_record` is fully populated. `timer_now_ns()` is safe to call after this function returns.

Parameters

boot_info	BootInfo pointer from the UEFI loader; `acpi_table` is used to discover the ACPI PM_TMR_BLK port at runtime (see `fadt_find_pm_tmr_port()`) rather than assuming a fixed machine type's legacy address.

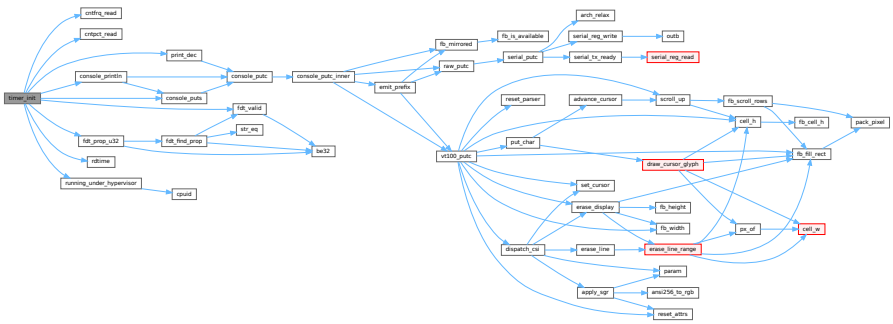
Returns

0 on success; calls `timer_fatal()` (never returns) on hard failure.

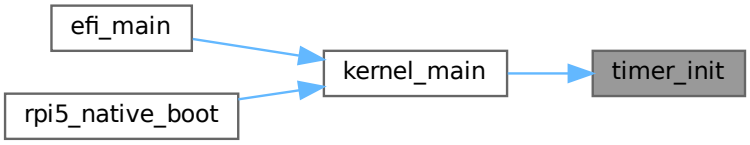
References cntfrq_read(), cntpct_read(), console_println(), console_puts(), timer_calibration_record::converged, BootInfo::dtb, fdt_prop_u32(), fdt_valid(), timer_calibration_record::hpet_hz, timer_calibration_record::pit_hz_mean, print_dec(), rdtime(), running_under_hypervisor(), s_base_count, s_base_ns, s_cal, s_counter_hz, s_ns_per_tick, TIMER_TRUST_ABSOLUTE, TIMER_TRUST_RELATIVE, timer_calibration_record::trust, timer_calibration_record::tsc_hz_mean, and timer_calibration_record::vm_mode.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.117.2.9 timer_now_ns()

```
uint64_t timer_now_ns (
            void  )
```

Return a monotonic nanosecond timestamp.

Reads `rdtime()`, computes the elapsed delta from `s_base_count` (captured at `timer_init()`), and converts to nanoseconds using the Q16.16 fixed-point `s_ns_per_tick`:

```
ns = s_base_ns + ((delta * s_ns_per_tick) » 16)
```

The 64-bit product of `delta` × `s_ns_per_tick` wraps once elapsed real time reaches 2^48 ns (~3.26 days) — this bound is **independent of `s_counter_hz`**, since `s_ns_per_tick` scales inversely with frequency and the two effects cancel. Verified by direct computation, not carried over from the earlier `cycle-based` comment here, which claimed "~18 seconds" and did not match the arithmetic either. Beyond ~3.26 days uptime `timer_now_ns()` wraps and produces incorrect values — a theoretical concern only for this single-hart POST-only kernel.

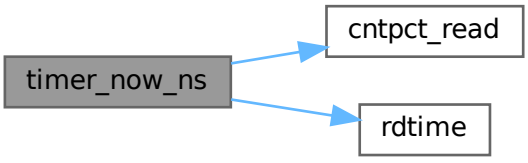
Returns

Monotonic nanosecond count since `timer_init()`, starting at 0.

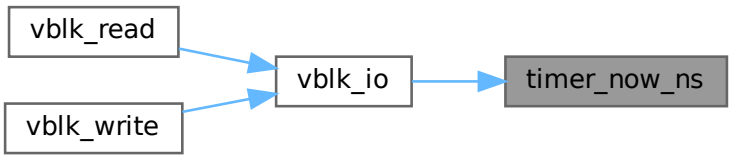
References cntpct_read(), rdtime(), s_base_count, s_base_ns, and s_ns_per_tick.

Referenced by vblk_io().

Here is the call graph for this function:



Here is the caller graph for this function:



7.117.2.10 timer_tsc_hz()

```
uint64_t timer_tsc_hz (
            void  )
```

Return the `time` counter frequency in Hz.

Return the system counter frequency in Hz.

Returns `s_counter_hz` — discovered from the devicetree's `timebase-frequency` when available, otherwise `RISCV_TIMEBASE_HZ_FALLBACK`. Used by `apic_timer_init()` to compute the expected inter-tick period and by the shim time backend to convert `time` counts to nanoseconds.

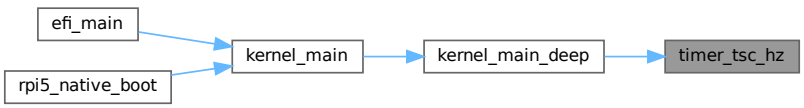
Returns

`time` counter frequency in Hz.

References s_counter_hz.

Referenced by kernel_main_deep().

Here is the caller graph for this function:



7.117.3 Variable Documentation

7.117.3.1 s_base_count

```
uint64_t s_base_count = 0  [static]
```

7.117.3.2 s_base_ns

```
uint64_t s_base_ns = 0  [static]
```

7.117.3.3 s_cal

```
timer_calibration_record_t s_cal  [static]
```

7.117.3.4 s_counter_hz

```
uint64_t s_counter_hz = 10000000ULL  [static]
```

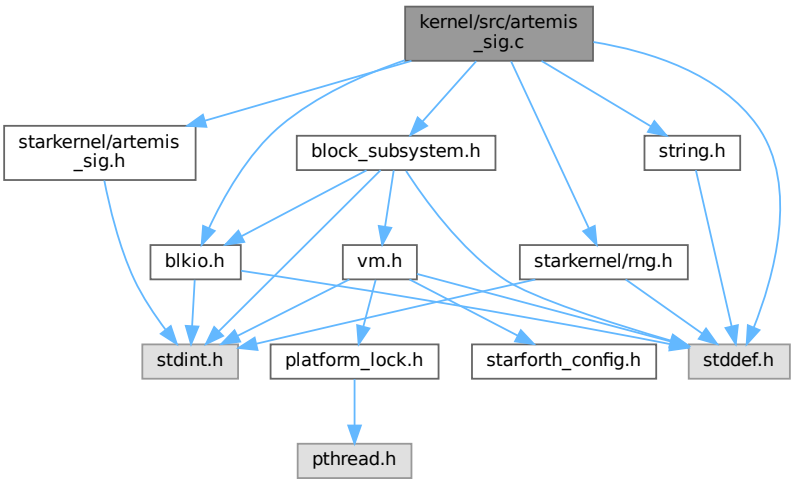
7.117.3.5 s_ns_per_tick

```
uint64_t s_ns_per_tick = 0  [static]
```

7.118 kernel/src/artemis_sig.c File Reference

```
#include "starkernel/artemis_sig.h"
#include <stddef.h>
#include <string.h>
#include "blkio.h"
#include "block_subsystem.h"
#include "starkernel/rng.h"
```

Include dependency graph for artemis_sig.c:



Functions

- uint64_t artemis_sig_compute_crc (const artemis_sig_t *sig)

  artemis_sig.c - Artemis disk signature check (FABRIC-3.md ?XXVI follow-on).
- static int artemis_sig_start_fblock (struct blkio_dev *dev, uint32_t *out_fblock)
- artemis_sig_result_t artemis_sig_check (struct blkio_dev *dev, artemis_sig_t *out_sig)
- int artemis_sig_genesis_stamp (struct blkio_dev *dev)

7.118.1 Function Documentation

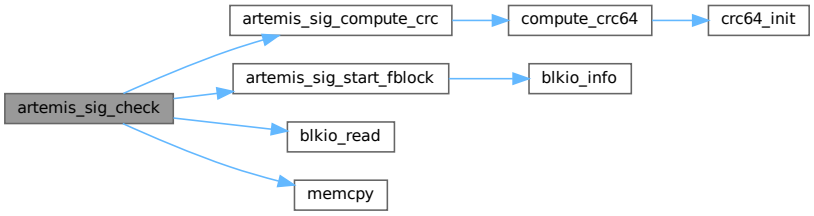
7.118.1.1 artemis_sig_check()

```
artemis_sig_result_t artemis_sig_check (
            struct blkio_dev * dev,
            artemis_sig_t * out_sig )
```

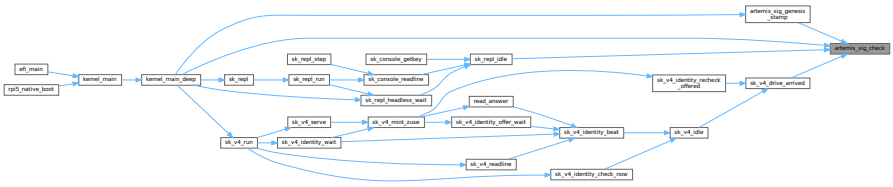
References ARTEMIS_SIG_BAD_CRC, ARTEMIS_SIG_BAD_VERSION, ARTEMIS_SIG_BLANK, artemis_sig_compute_crc(), ARTEMIS_SIG_GET_MAGIC, ARTEMIS_SIG_GET_VERSION, ARTEMIS_SIG_MAGIC, ARTEMIS_SIG_OK, ARTEMIS_SIG_READ_ERROR, artemis_sig_start_fblock(), ARTEMIS_SIG_VERSION_0, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_read(), artemis_sig_t::hdr_crc, artemis_sig_t::magic, and memcpy().

Referenced by artemis_sig_genesis_stamp(), kernel_main_deep(), sk_repl_idle(), and sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:



7.118.1.2 artemis_sig_compute_crc()

```
uint64_t artemis_sig_compute_crc (
            const artemis_sig_t * sig )
```

artemis_sig.c - Artemis disk signature check (FABRIC-3.md ?XXVI follow-on).

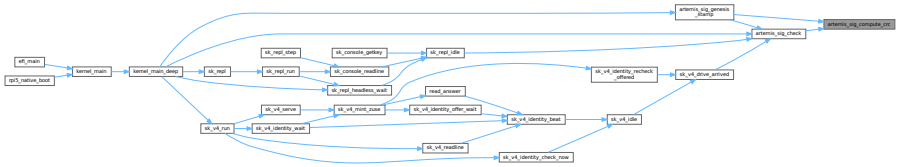
See starkernel/artemis_sig.h for the format and interface design.

References compute_crc64().

Referenced by artemis_sig_check(), and artemis_sig_genesis_stamp().

Here is the call graph for this function:

Here is the caller graph for this function:



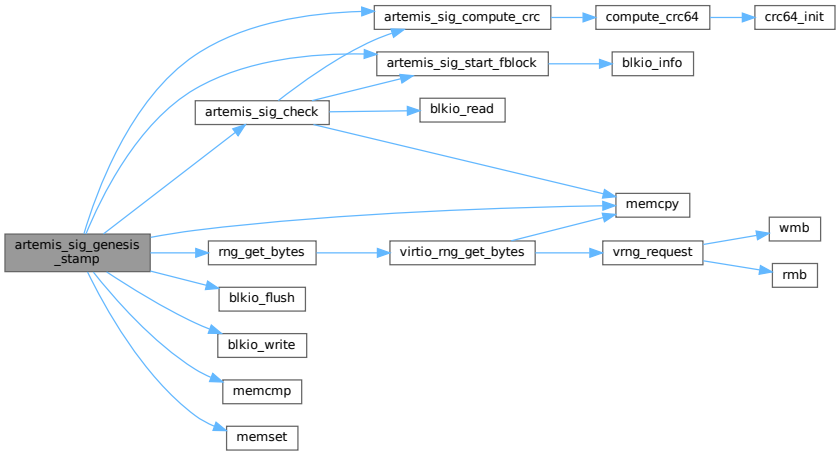
7.118.1.3 artemis_sig_genesis_stamp()

```
int artemis_sig_genesis_stamp (
            struct blkio_dev * dev )
```

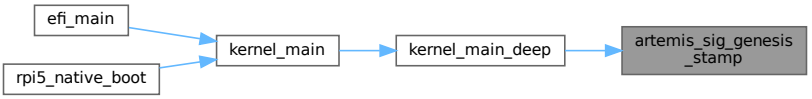
References artemis_sig_check(), artemis_sig_compute_crc(), ARTEMIS_SIG_OK, ARTEMIS_SIG_PACK, artemis_sig_start_fblock(), ARTEMIS_SIG_VERSION_0, blkio_flush(), BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_write(), artemis_sig_t::disk_uuid, artemis_sig_t::genesis_time_ns, artemis_sig_t::hdr_crc, artemis_sig_t::log_region_devblocks, artemis_sig_t::log_region_offset, artemis_sig_t::magic, memcmp(), memcpy(), memset(), artemis_sig_t::metadata_devblocks, and rng_get_bytes().

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.118.1.4 artemis_sig_start_fblock()

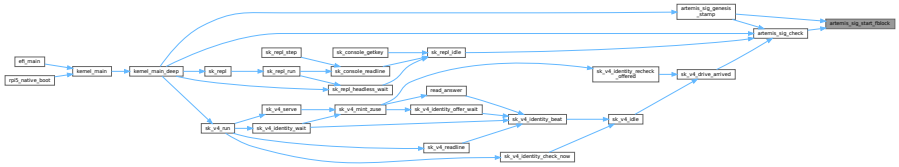
```
static int artemis_sig_start_fblock (
            struct blkio_dev * dev,
            uint32_t * out_fblock )  [static]
```

References ARTEMIS_SIG_DEVBLOCK_FROM_TOP, blkio_info(), BLKIO_OK, and blkio_info_t::total_blocks.

Referenced by artemis_sig_check(), and artemis_sig_genesis_stamp().

Here is the call graph for this function:

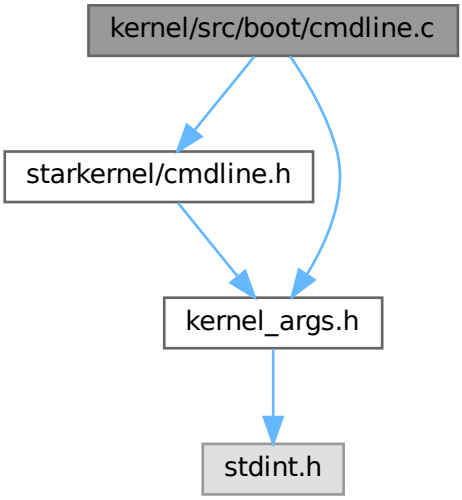
Here is the caller graph for this function:



7.119 kernel/src/boot/cmdline.c File Reference

```
#include "starkernel/cmdline.h"
#include "starkernel/kernel_args.h"
```

Include dependency graph for cmdline.c:



Functions

- static int sf_isspace (char c)

  Test whether a character is ASCII whitespace.
- static int sf_strncmp (const char *a, const char *b, unsigned int n)

  Compare at most `n` characters of two strings (freestanding).
- static void sf_strlcpy (char *dst, const char *src, unsigned int n)

  Copy a string into a fixed-size buffer with guaranteed NUL termination.
- uint64_t cmdline_parse_size (const char *s)

  Parse a decimal integer with optional K/M/G size suffix.
- static int parse_log_level (const char *s)

  Map a log-level name string to a `KARGS_LOG_*` constant.
- void cmdline_parse_ascii (const char *cmdline, KernelArgs *args)

  Parse a NUL-terminated ASCII command-line string into `KernelArgs`.

7.119.1 Function Documentation

7.119.1.1 cmdline_parse_ascii()

```
void cmdline_parse_ascii (
            const char * cmdline,
            KernelArgs * args )
```

Parse a NUL-terminated ASCII command-line string into KernelArgs.

Populates args from space-separated tokens in cmdline. Always initialises all fields to their defaults first (so partial or empty command lines produce safe values):

- stack_size = 0 (use BSS static stack)
- heap_size = 0 (use built-in kmalloc arena)
- run_doe = KARGS_DEFAULT_RUN_DOE
- log_level = KARGS_DEFAULT_LOG_LEVEL
- raw[0] = '\0'

Recognised flags:

- --doe — sets args->run_doe = 1.
- --log-level=<level> — sets args->log_level via parse_log_level().
- --stack=<size> — sets args->stack_size via cmdline_parse_size().
- --heap=<size> — sets args->heap_size via cmdline_parse_size().

Unknown flags are silently ignored for forward-compatibility with flags introduced in future kernel versions. The raw command-line string is copied verbatim into args->raw (truncated to KERNEL_ARGS_CMDLINE_MAX - 1) for diagnostic logging.

Called from efi_main() (in uefi_loader.c) after assembling the ASCII command line from the three priority sources: NVRAM variable, starforth.cfg on the ESP, and EFI LoadOptions.

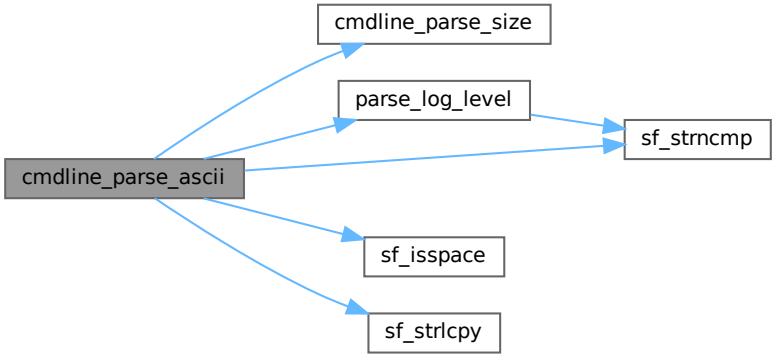
Parameters

cmdline	NUL-terminated ASCII command line; may be NULL or empty.
args	Output KernelArgs structure; must not be NULL.

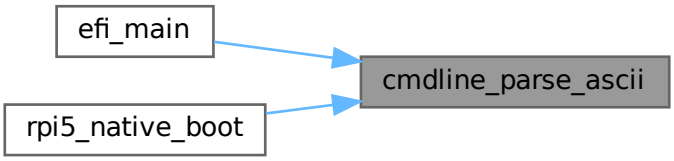
References cmdline_parse_size(), KernelArgs::heap_size, KARGS_DEFAULT_LOG_LEVEL, KARGS_DEFAULT_RUN_DOE, KARGS_SYSTEM_DEFAULT, KARGS_SYSTEM_V3, KARGS_SYSTEM_V4, KERNEL_ARGS_CMDLINE_MAX, KernelArgs::log_level, parse_log_level(), KernelArgs::raw, KernelArgs::run_doe, KernelArgs::screen_boot, sf_isspace(), sf_strlcpy(), sf_strncmp(), KernelArgs::stack_size, and KernelArgs::system.

Referenced by efi_main(), and rpi5_native_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.119.1.2 cmdline_parse_size()

```
uint64_t cmdline_parse_size (
            const char * s )
```

Parse a decimal integer with optional K/M/G size suffix.

Reads a non-negative decimal integer from `s` and multiplies it by:

- 1024 for 'K' or 'k' (kibibytes)
- 1024^2 for 'M' or 'm' (mebibytes)
- 1024^3 for 'G' or 'g' (gibibytes)
- 1 for any other or absent suffix

Returns 0 if `s` is NULL, empty, or does not begin with a digit. Overflow is not checked; caller must validate the resulting value is sensible for its intended use (stack size, heap size, etc.).

Used by `cmdline_parse_ascii()` to decode the `--stack=<size>` and `--heap=<size>` arguments from the boot command line.

Parameters

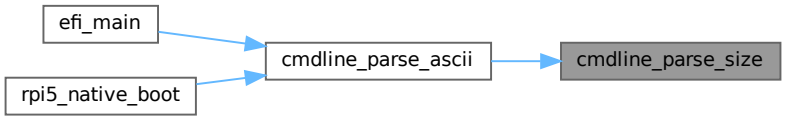
s	NUL-terminated string beginning with a decimal integer and optionally followed by a size suffix character.

Returns

Parsed byte count (0 on parse failure or zero input).

Referenced by cmdline_parse_ascii().

Here is the caller graph for this function:



7.119.1.3 parse_log_level()

```
static int parse_log_level (
            const char * s )  [static]
```

Map a log-level name string to a KARGS_LOG_* constant.

Performs case-insensitive prefix matching against the known level names:

- "debug" / "DEBUG" → KARGS_LOG_DEBUG
- "info" / "INFO" → KARGS_LOG_INFO
- "warn" / "WARN" → KARGS_LOG_WARN
- "error" / "ERROR" → KARGS_LOG_ERROR

Any unrecognised string (including empty) maps to KARGS_LOG_INFO as a safe default. Called from cmdline_parse_ascii() after recognising the --log-level= prefix.

Parameters

s	String beginning at the first character of the level name (i.e., after the "=" separator has been skipped by the caller).

Returns

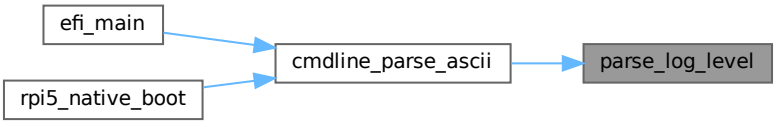
One of the KARGS_LOG_* constants defined in kernel_args.h; defaults to KARGS_LOG_INFO for unknown input.

References KARGS_LOG_DEBUG, KARGS_LOG_ERROR, KARGS_LOG_INFO, KARGS_LOG_WARN, and sf_strncmp().

Referenced by cmdline_parse_ascii().

Here is the call graph for this function:

Here is the caller graph for this function:



7.119.1.4 sf_isspace()

```
static int sf_isspace (
            char c )  [static]
```

Test whether a character is ASCII whitespace.

Returns non-zero for space (' '), horizontal tab ('\t'), carriage return ('\r'), and line feed ('\n'). Used by `cmdline_parse_ascii()` to skip inter-token whitespace and by `load_cfg_from_esp()` to strip trailing CR/LF from the config file. Replaces the libc `isspace()` which is not available in a freestanding build; this version does not consider locale.

Parameters

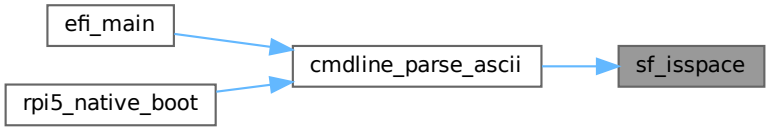
c	Character to test.

Returns

Non-zero if `c` is ASCII whitespace, 0 otherwise.

Referenced by cmdline_parse_ascii().

Here is the caller graph for this function:



7.119.1.5 sf_strlcpy()

```
static void sf_strlcpy (
            char * dst,
            const char * src,
            unsigned int n )  [static]
```

Copy a string into a fixed-size buffer with guaranteed NUL termination.

Copies at most `n-1` bytes from `src` into `dst` and always writes a NUL terminator at `dst[n-1]` (if `n` > 0). This is the BSD `strlcpy()` semantics without returning the source length. If `n` is 0 the function is a no-op (no write, no UB).

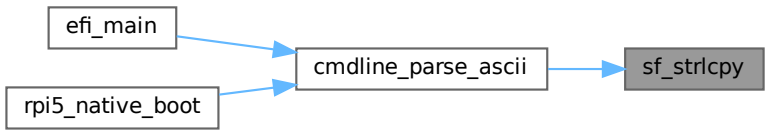
Used by `cmdline_parse_ascii()` to copy the raw command-line string into `KernelArgs.raw` with a guaranteed NUL, avoiding the truncation risk of `strncpy()`.

Parameters

dst	Destination buffer; receives at most `n-1` bytes of `src` followed by a NUL terminator.
src	NUL-terminated source string.
n	Size of `dst` in bytes (including the NUL slot).

Referenced by cmdline_parse_ascii().

Here is the caller graph for this function:



7.119.1.6 sf_strncmp()

```
static int sf_strncmp (
            const char * a,
            const char * b,
            unsigned int n )  [static]
```

Compare at most `n` characters of two strings (freestanding).

Iterates up to `n` bytes, stopping at the first differing character or when either string's null terminator is reached. Returns 0 if the first `n` characters are equal (or both strings end before `n`), positive if `a` is lexicographically greater, negative if `b` is. Comparison is on `unsigned char` values per C standard convention.

Used exclusively by `cmdline_parse_ascii()` and `parse_log_level()` to match fixed-length flag prefixes without a libc dependency.

Parameters

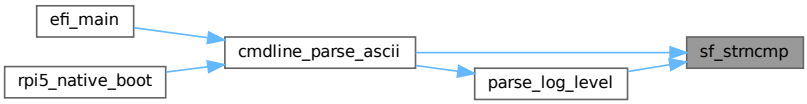
a	First string.
b	Second string.
n	Maximum number of characters to compare.

Returns

0 if equal, positive if `a` > `b`, negative if `a` < `b`.

Referenced by cmdline_parse_ascii(), and parse_log_level().

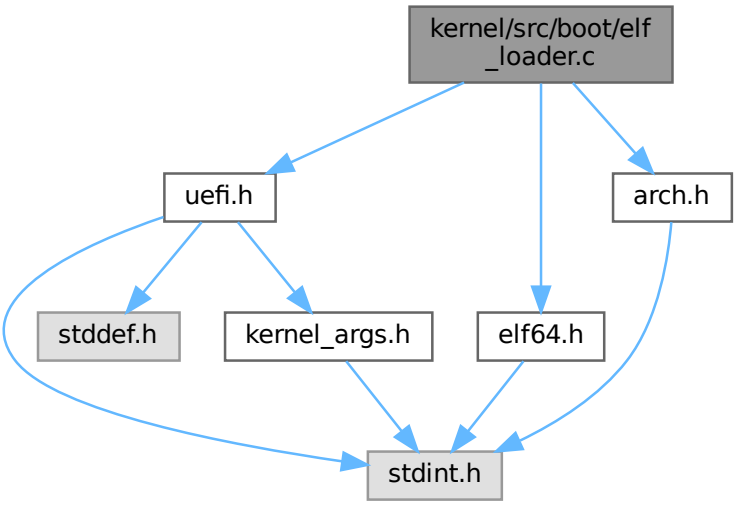
Here is the caller graph for this function:



7.120 kernel/src/boot/elf_loader.c File Reference

```
#include "uefi.h"
#include "elf64.h"
#include "arch.h"
```

Include dependency graph for elf_loader.c:



Functions

- static void * elf_memset (void *s, int c, uint64_t n)

  elf_loader.c - ELF64 kernel loader for StarKernel
- static void * elf_memcpy (void *dest, const void *src, uint64_t n)

  Copy a non-overlapping memory region (freestanding memcpy).
- static int elf_validate_header (const Elf64_Ehdr *ehdr)

  Validate an ELF64 header for the current target architecture.
- static int elf_load_segments (const uint8_t *elf_data, Elf64_Addr load_base)

  Map all PT_LOAD segments from an ELF64 image into memory.
- static int elf_apply_relocations (const uint8_t *elf_data, Elf64_Addr load_base)

  Apply all RELA relocation sections from an ELF64 image.
- int elf_load_kernel (const uint8_t *elf_data, uint64_t elf_size, Elf64_Addr *entry_out)

  Load, relocate, and return the entry point of a StarKernel ELF64 binary.

7.120.1 Function Documentation

7.120.1.1 elf_apply_relocations()

```
static int elf_apply_relocations (
            const uint8_t * elf_data,
            Elf64_Addr load_base )  [static]
```

Apply all RELA relocation sections from an ELF64 image.

Scans the section header table for sections of type `SHT_RELA`. For each such section, resolves the associated symbol table (via `sh_link`) and applies every relocation entry to the loaded image.

Supported relocation types are ISA-specific and compile-time selected:

- **amd64 (`ARCH_AMD64`)**:
  - `R_X86_64_NONE` — no-op.
  - `R_X86_64_RELATIVE` — absolute address = `load_base` + `r_addend`.
  - `R_X86_64_64` — `load_base` + symbol value + `r_addend` (64-bit).
  - `R_X86_64_32` / `R_X86_64_32S` — same, truncated to 32 bits.
  - `R_X86_64_PC32` / `R_X86_64_PLT32` — `symbol` + `r_addend` - P (PC-relative, 32 bits), where P is the relocation's own runtime address; PLT32 has no real PLT indirection in this static, non-PIE link, so it resolves the same as PC32.
- **aarch64 (`ARCH_AARCH64`)**:
  - `R_AARCH64_NONE` — no-op.
  - `R_AARCH64_RELATIVE` — `load_base` + `r_addend`.
  - `R_AARCH64_ABS64` — `load_base` + symbol + `r_addend`.
- **riscv64 (`ARCH_RISCV64`)**:
  - `R_RISCV_NONE` — no-op.
  - `R_RISCV_RELATIVE` — `load_base` + `r_addend`.
  - `R_RISCV_64` — `load_base` + symbol + `r_addend`.

Returns 0 (failure) if a symbol index in a relocation entry is out of bounds, if the symbol table entry size is zero, or if an unknown relocation type is encountered. Returns 1 on success.

Parameters

elf_data	Pointer to the ELF64 file image.
load_base	Load base address applied during `elf_load_segments()`.

Returns

1 on success, 0 on any relocation error.

References Elf64_Ehdr::e_shnum, Elf64_Ehdr::e_shoff, ELF64_R_SYM, ELF64_R_TYPE, R_AARCH64_ABS64, R_AARCH64_NONE, R_AARCH64_RELATIVE, Elf64_Rela::r_addend, Elf64_Rela::r_offset, R_RISCV_64, R_RISCV_NONE, R_RISCV_RELATIVE, R_X86_64_32, R_X86_64_32S, R_X86_64_64, R_X86_64_NONE, R_X86_64_PC32, R_X86_64_PLT32, R_X86_64_RELATIVE, Elf64_Shdr::sh_entsize, Elf64_Shdr::sh_link, Elf64_Shdr::sh_offset, Elf64_Shdr::sh_size, Elf64_Shdr::sh_type, SHT_RELA, and Elf64_Sym::st_value.

Referenced by elf_load_kernel().

Here is the caller graph for this function:

7.120.1.2 elf_load_kernel()

```
int elf_load_kernel (
            const uint8_t * elf_data,
            uint64_t elf_size,
            Elf64_Addr * entry_out )
```

Load, relocate, and return the entry point of a StarKernel ELF64 binary.

elf_loader.h - ELF64 kernel loader interface

Top-level ELF loader called by `efi_main()` (in the split-build path) after `ExitBootServices()`. Performs three operations in sequence:

1. **Header validation** via `elf_validate_header()` — checks magic, class, data encoding, version, type, and machine-specific architecture. Returns 0 immediately on failure.
2. **Segment loading** via `elf_load_segments()` — maps all `PT_LOAD` segments to their target addresses, initialises BSS to zero. The `load_base` is:
   - 0 for `ET_EXEC` (absolute-address kernel; typical for StarKernel).
   - 0x400000 (4 MB) for `ET_DYN` (position-independent kernel).
3. **Relocation processing** via `elf_apply_relocations()` — applies `SHT_RELA` sections to patch in the correct runtime addresses. Returns 0 on any relocation error.

On success, stores `load_base` + `e_entry` in `*entry_out` — the virtual address of the kernel's C entry function `kernel_main()` — and returns 1. The caller performs an indirect call to this address.

`elf_size` is currently unused (reserved for future bounds-checking of program-header and section-header offsets against the file boundary).

Parameters

elf_data	Pointer to the ELF64 file image in UEFI loader memory; must remain valid until after the call returns.
elf_size	Size of the ELF image in bytes (currently unchecked).
entry_out	Output: receives the kernel entry point address on success.

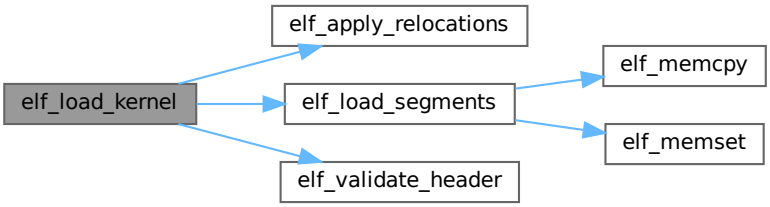
Returns

1 on success, 0 if validation, segment loading, or relocation fails.

References Elf64_Ehdr::e_entry, Elf64_Ehdr::e_type, elf_apply_relocations(), elf_load_segments(), elf_validate_header(), ET_DYN, and ET_EXEC.

Referenced by efi_main().

Here is the call graph for this function:



Here is the caller graph for this function:

7.120.1.3 elf_load_segments()

```
static int elf_load_segments (
             const uint8_t * elf_data,
             Elf64_Addr load_base )  [static]
```

Map all PT_LOAD segments from an ELF64 image into memory.

Iterates the program header table (`e_phnum` entries starting at offset `e_phoff`) and processes every entry with `p_type` == `PT_LOAD`:

1. Computes the destination address as `load_base` + `p_vaddr`.
2. Copies `p_filesz` bytes from `elf_data` + `p_offset` using `elf_memcpy()`.
3. If `p_memsz` > `p_filesz`, zero-fills the remaining (`p_memsz` - `p_filesz`) bytes with `elf_memset()` to initialise the BSS region within the segment.

The function does not check for address-range overlaps or that destination memory is physically available; the UEFI loader is responsible for allocating pages before calling `elf_load_kernel()`.

Parameters

elf_data	Pointer to the start of the ELF64 file in memory.
load_base	Base address at which to load the ELF image (0 for `ET_EXEC`, 0x400000 for `ET_DYN`).

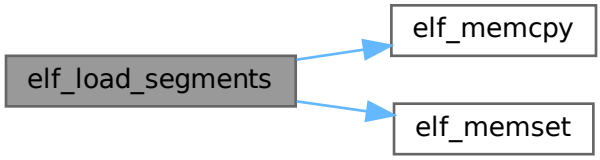
Returns

1 always (errors are silently ignored at this milestone; a future revision should return 0 on a failed memory access).

References Elf64_Ehdr::e_phnum, Elf64_Ehdr::e_phoff, elf_memcpy(), elf_memset(), Elf64_Phdr::p_offset, and PT_LOAD.

Referenced by elf_load_kernel().

Here is the call graph for this function:



Here is the caller graph for this function:

7.120.1.4 elf_memcpy()

```
static void * elf_memcpy (
            void * dest,
            const void * src,
            uint64_t n )  [static]
```

Copy a non-overlapping memory region (freestanding memcpy).

Copies `n` bytes from `src` to `dest` using a byte-at-a-time loop. Behaviour is undefined if the source and destination ranges overlap. Used by `elf_load_segments()` to copy each PT_LOAD segment's `p_filesz` bytes from the ELF image in memory to its load address.

Parameters

dest	Destination buffer; must not overlap with `src`.
src	Source buffer.
n	Number of bytes to copy.

Returns

`dest` (matches standard `memcpy` signature).

Referenced by elf_load_segments().

Here is the caller graph for this function:

7.120.1.5 elf_memset()

```
static void * elf_memset (
            void * s,
            int c,
            uint64_t n )  [static]
```

elf_loader.c - ELF64 kernel loader for StarKernel

Loads the StarKernel ELF binary from ESP, parses segments, applies relocations, and jumps to entry point.

Fill a memory region with a byte value (freestanding memset).

Writes `n` copies of the low byte of `c` to the memory starting at `s`. Used by `elf_load_segments()` to zero-fill BSS regions (`p_memsz` > `p_filesz`) without a libc dependency. The byte loop is correct for all sizes; a future optimisation could use SIMD or word-width stores for large BSS regions.

Parameters

s	Pointer to the start of the destination region.
c	Value to fill (only the low 8 bits are used).
n	Number of bytes to write.

Returns

`s` (matches standard `memset` signature).

Referenced by elf_load_segments().

Here is the caller graph for this function:

7.120.1.6 elf_validate_header()

```
static int elf_validate_header (
            const Elf64_Ehdr * ehdr )  [static]
```

Validate an ELF64 header for the current target architecture.

Checks the following fields in the ELF identification block and header:

- Magic bytes `e_ident`[0..3]: must be `0x7F` 'E' 'L' 'F'.
- Class `e_ident`[EI_CLASS]: must be `ELFCLASS64` (64-bit).
- Data encoding `e_ident`[EI_DATA]: must be `ELFDATA2LSB` (little-endian, the only byte order used by all three supported ISAs).
- Version `e_ident`[EI_VERSION]: must be `EV_CURRENT` (1).
- Type `e_type`: must be `ET_EXEC` (statically linked) or `ET_DYN` (position-independent executable).
- Machine `e_machine`: must match the build target — `EM_X86_64` for `ARCH_AMD64`, `EM_AARCH64` for `ARCH_AARCH64`, `EM_RISCV` for `ARCH_RISCV64`.

Parameters

ehdr	Pointer to the ELF64 header at the start of the image.

Returns

1 if the header is valid for this architecture, 0 otherwise.

References Elf64_Ehdr::e_ident, Elf64_Ehdr::e_machine, Elf64_Ehdr::e_type, EI_CLASS, EI_DATA, EI_MAG0, EI_MAG1, EI_MAG2, EI_MAG3, EI_VERSION, ELFCLASS64, ELFDATA2LSB, ELFMAG0, ELFMAG1, ELFMAG2, ELFMAG3, EM_AARCH64, EM_RISCV, EM_X86_64, ET_DYN, ET_EXEC, and EV_CURRENT.

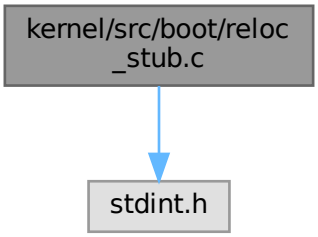
Referenced by elf_load_kernel().

Here is the caller graph for this function:

7.121 kernel/src/boot/reloc_stub.c File Reference

```
#include <stdint.h>
```

Include dependency graph for reloc_stub.c:



Data Structures

- struct reloc_block

  reloc_stub.c - Provide a minimal .reloc section for PE/COFF EFI loader

Functions

- struct reloc_block __attribute__ ((packed, aligned(4)))
- __attribute__ ((section(".reloc"), used))

  Minimal .reloc section stub to satisfy UEFI firmware loaders.

Variables

- uint32_t page_rva
- uint32_t block_size
- uint16_t entry

7.121.1 Function Documentation

7.121.1.1 __attribute__() [1/2]

```
struct reloc_block __attribute__ (
            (packed, aligned(4))  )
```

7.121.1.2 __attribute__() [2/2]

```
__attribute__ (
            (section(".reloc"), used)  )
```

Minimal .reloc section stub to satisfy UEFI firmware loaders.

Some UEFI implementations (notably certain hardware vendor firmware and strict OVMF builds) refuse to load a PE32+ image that lacks a Base Relocation Directory entry in the optional-header Data Directory. Even for monolithic position-independent images that require no run-time fix-ups, the presence of the .reloc section with a well-formed (but empty) relocation block is required to pass the firmware's image validation.

This single statically-allocated `reloc_block` satisfies the requirement:

- `page_rva` = 0 — applies to the first 4 KB page (convention for stubs).
- `block_size` = sizeof(reloc_block) — minimal well-formed block (8 bytes
  - 2 bytes for the single no-op entry = 10 bytes).
- `entry` = 0 — TYPE=0 (absolute, no-op) / OFFSET=0; ignored by the loader.

The `used` attribute prevents the compiler/linker from discarding the symbol as unreferenced; the `section`(".↩ reloc") attribute places it in the named PE section so the linker emits the correct Data Directory.

References entry, and reloc_block::page_rva.

7.121.2 Variable Documentation

7.121.2.1 block_size

```
uint32_t block_size
```

Referenced by blkio_usb_open_msc(), xhci_bot_read_block(), xhci_bot_send_read10(), xhci_bot_send_write10(), and xhci_bot_write_block().

7.121.2.2 entry

```
uint16_t entry
```

Referenced by __attribute__(), acl_recheck(), acl_recheck(), bus_to_phys(), capsule_birth_baby(), capsule_dict_hash_hook(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_vm_registry_get(), capsule_vm_registry_set_name(), capsule_vm_set_pending_reap(), capsule_vm_set_state(), capsule_wirebind_eject(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_reap_idle_check(), capsule_wirebind_unclean_detach(), cd_config_table_tick(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_variable(), defining_word_compile(), defining_word_constant(), defining_word_create(), defining_word_variable(), derive_state_flags(), dictionary_m_word_cfa(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), doe_log_heat_by_name(), execute_colon_word(), extract_heat_trajectory(), fdt_console_uart(), fdt_reg_address(), find_entry_from_name(), forth_FREEZE_CRITICAL(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_STORE(), forth_PIPELINING_ANALYZE_W forth_PIPELINING_RESET_ALL(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), forth_PIPELINING_STATS(), forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), get_body_address(), get_name_field(), get_or_alloc_table(), get_table(), get_word_stats(), hash_colon_body(), heartbeat_capture_tick_snapshot(), kernel_main_deep(), physics_execution_heat_increment(), physics_execution_heat_load(), physics_metadata_apply_linear_decay(),

physics_metadata_apply_seed(), physics_metadata_init(), physics_metadata_record_latency(), physics_metadata_refresh_state(), physics_metadata_set_mass(), physics_metadata_touch(), physics_on_lookup(), pop_xt(), print_word_name(), print_word_name_safe(), profiler_word_count(), profiler_word_enter(), profiler_word_exit(), register_word(), replace_entry(), rolling_window_seed_hotwords_cache(), rpi5_mmu_map_ram(), starforth_word_execution_heat_fetch(), starforth_word_execution_heat_store(), starforth_word_reset_execution_heat(), starforth_word_top_words(), starforth_word_word_execution_heat(), system_word_execute(), system_word_see(), vm_bootstrap_root_vocabulary(), vm_compile_call(), vm_compile_word(), vm_create_word(), vm_dictionary_get_data_field(), vm_dictionary_track_entry(), vm_dictionary_untrack_entry(), vm_docol_arm64(), vm_docol_asm(), vm_docol_rv64(), vm_interpret_word(), vm_physics_find_root_id(), vm_physics_status(), vmm_query_page(), vocabulary_create_vocabulary_direct(), and vocabulary_word_vocabulary().

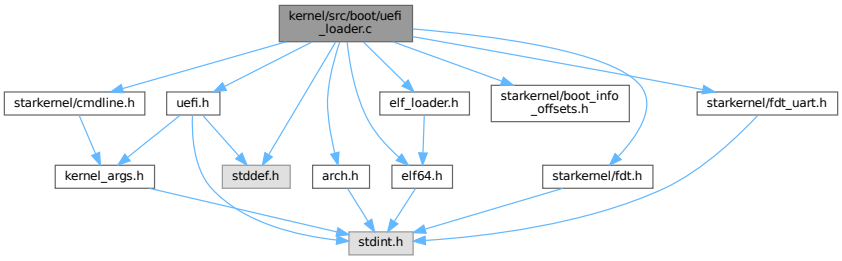
7.121.2.3 page_rva

```
uint32_t page_rva
```

7.122 kernel/src/boot/uefi_loader.c File Reference

```
#include "uefi.h"
#include "arch.h"
#include "elf_loader.h"
#include "elf64.h"
#include "starkernel/cmdline.h"
#include "starkernel/boot_info_offsets.h"
#include "starkernel/fdt.h"
#include "starkernel/fdt_uart.h"
#include <stddef.h>
```

Include dependency graph for uefi_loader.c:



Macros

- #define RAW_LOG(str) ((void)0)

  uefi_loader.c - UEFI boot loader for StarKernel
- #define UEFI_DEBUG_CHECKPOINTS 1
- #define DEBUG_CHECKPOINT_STALL_US (2u * 1000u * 1000u)
- #define KERNEL_MAX_SIZE (8 * 1024 * 1024)

Typedefs

- typedef void(* KernelEntry) (BootInfo *boot_info)

Functions

- static void debug_checkpoint (EFI_SYSTEM_TABLE *SystemTable, UINT32 id, const CHAR16 *label)
- static int guid_equals (const EFI_GUID *a, const EFI_GUID *b)

  Compare two EFI GUIDs for equality.
- static int load_cfg_from_esp (EFI_HANDLE ImageHandle, EFI_BOOT_SERVICES *BS, char *buf, UINTN buflen)

  Read `/starforth.cfg` from the EFI System Partition.
- static EFI_STATUS load_kernel_from_esp (EFI_HANDLE ImageHandle, EFI_BOOT_SERVICES *BS)

  Load `kernel.elf` from the ESP into UEFI-allocated memory (split build).
- EFI_STATUS EFIAPI efi_main (EFI_HANDLE ImageHandle, EFI_SYSTEM_TABLE *SystemTable)

  UEFI application entry point — boot loader for StarKernel.

Variables

- static BootInfo g_boot_info = {0}
- static uint8_t * kernel_elf_buffer = NULL
- static uint64_t kernel_elf_size = 0

7.122.1 Macro Definition Documentation

7.122.1.1 DEBUG_CHECKPOINT_STALL_US

```
#define DEBUG_CHECKPOINT_STALL_US (2u * 1000u * 1000u)
```

7.122.1.2 KERNEL_MAX_SIZE

```
#define KERNEL_MAX_SIZE (8 * 1024 * 1024)
```

7.122.1.3 RAW_LOG

```
#define RAW_LOG(
              str ) ((void)0)
```

uefi_loader.c - UEFI boot loader for StarKernel

This loader loads the StarKernel ELF binary from the ESP, parses it, loads segments, applies relocations, and jumps to entry.

7.122.1.4 UEFI_DEBUG_CHECKPOINTS

```
#define UEFI_DEBUG_CHECKPOINTS 1
```

7.122.2 Typedef Documentation

7.122.2.1 KernelEntry

```
typedef void(* KernelEntry) (BootInfo *boot_info)
```

7.122.3 Function Documentation

7.122.3.1 debug_checkpoint()

```
static void debug_checkpoint (
            EFI_SYSTEM_TABLE * SystemTable,
            UINT32 id,
            const CHAR16 * label )  [static]
```

References _EFI_SYSTEM_TABLE::BootServices, _EFI_SYSTEM_TABLE::ConOut, DEBUG_CHECKPOINT_STALL_US, _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::OutputString, and _EFI_BOOT_SERVICES::Stall.

Referenced by efi_main().

Here is the caller graph for this function:

7.122.3.2 efi_main()

```
EFI_STATUS EFIAPI efi_main (
            EFI_HANDLE ImageHandle,
            EFI_SYSTEM_TABLE * SystemTable )
```

UEFI application entry point — boot loader for StarKernel.

`efi_main()` is the UEFI PE32+ entry point called by the firmware immediately after the image is loaded and validated. It drives the full boot sequence in two phases:

Phase A — UEFI Boot Services are active:

A-0. Resets the UEFI ConOut console and emits an identification banner. On amd64, initialises COM1 via `raw_serial_init()` for raw-serial boot logging (`RAW_LOG()` macro).

A-1. Assembles the ASCII kernel command line from three sources in priority order:

1. `StarForthBootArgs` NVRAM variable (one-shot, set by REBOOT word; immediately cleared after reading to prevent re-use on next boot).
2. `/starforth`.cfg on the ESP (installer / build-time config).
3. `LoadOptions` from the UEFI boot manager (typically the EFI shell command line or boot entry options). Parses the result via `cmdline_parse_ascii()` into `g_boot_info.args`.

A-2. If `--stack=<size>` was given, allocates `stack_size` bytes of `EfiLoaderData` pages for the kernel stack and stores the base address and size in `g_boot_info`.

A-3. Pre-fills non-EBS-dependent `BootInfo` fields: runtime services pointer, ACPI table (found in `ConfigurationTable` by GUID), and GOP framebuffer geometry.

A-4. (Split build only) Loads `kernel.elf` from the ESP via `load_kernel_from_esp()` into the pre-allocated 8 MB buffer.

Phase B — ExitBootServices:

Calls `GetMemoryMap()` to obtain the current map key, then immediately calls `ExitBootServices()`. Retries up to 16 times on `EFI_INVALID_PARAMETER` (map key stale) as required by the UEFI spec. No UEFI Boot Services calls are made between `GetMemoryMap` and `ExitBootServices` — this is the UEFI "golden path" requirement.

Phase C — Post-ExitBootServices:

- **Monolithic build**: calls `kernel_main(&g_boot_info)` directly (kernel is linked into the same PE image).
- **Split build**: parses and loads the kernel ELF via `elf_load_kernel()`, then performs an indirect call to the resolved `kernel_main()` entry point address.

If the kernel returns (which it must not), `efi_main()` halts the processor in an infinite `arch_halt()` loop.

Parameters

ImageHandle	UEFI handle for this loaded application image.
SystemTable	Pointer to the UEFI system table (Boot/Runtime Services, ConOut, ConfigurationTable, etc.).

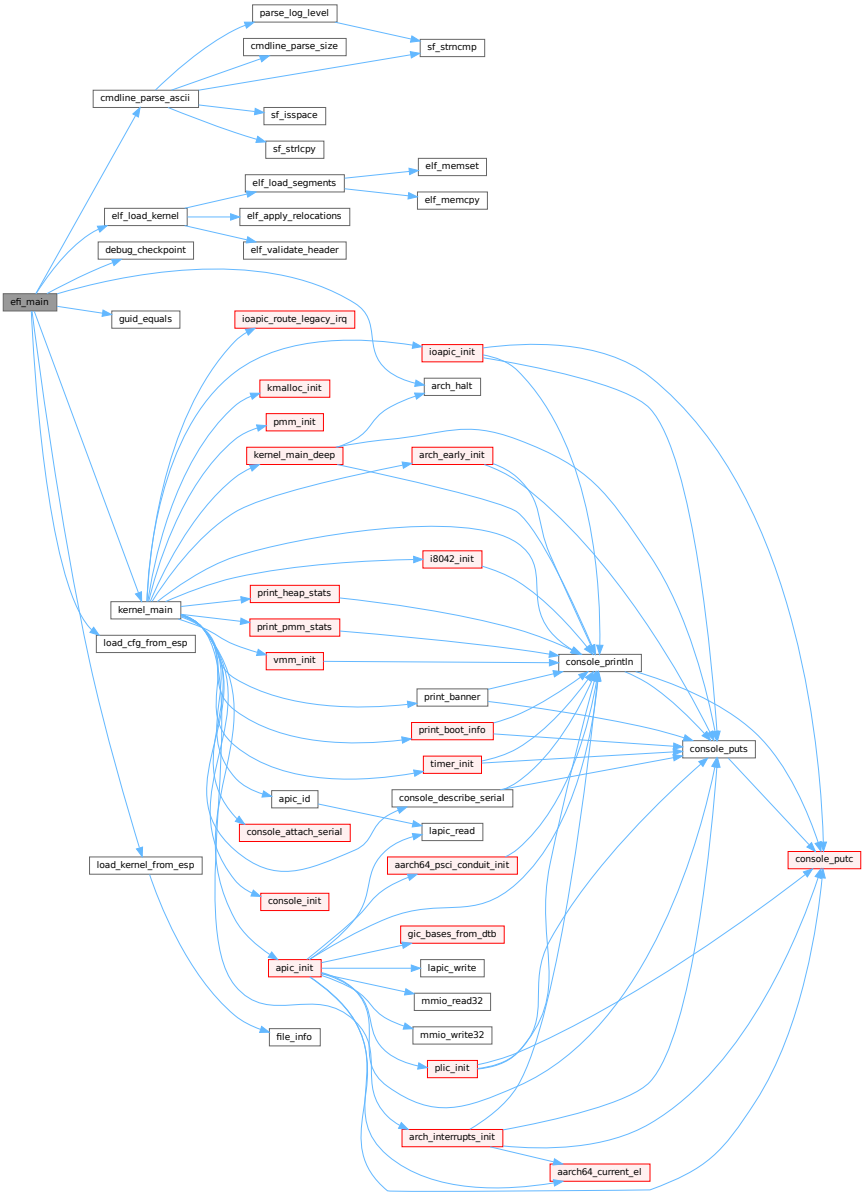
Returns

`EFI_SUCCESS` if the sequence completes without a fatal error before `ExitBootServices` (in practice, control never returns here because the kernel takes over permanently).

References BootInfo::acpi_table, AllocateAnyPages, _EFI_BOOT_SERVICES::AllocatePages, arch_halt(), BootInfo::args, FramebufferInfo::base, BootInfo::boot_disk, _EFI_SYSTEM_TABLE::BootServices, cmdline_parse_ascii(), _EFI_SYSTEM_TABLE::ConfigurationTable, _EFI_SYSTEM_TABLE::ConOut, debug_checkpoint(), BootInfo::dtb, EFI_ACPI_20_TABLE_GUID, EFI_ACPI_TABLE_GUID, EFI_BUFFER_TOO_SMALL, EFI_DTB_TABLE_GUID, EFI_GRAPHICS_OUTPUT_PROTOCOL_GUID, EFI_INVALID_PARAMETER, EFI_LOADED_IMAGE_PROTOCOL_GUID, EFI_SUCCESS, EFI_VARIABLE_BOOTSERVICE_ACCESS, EFI_VARIABLE_NON_VOLATILE, EFI_VARIABLE_RUNTIME_ACCES EfiLoaderData, elf_load_kernel(), _EFI_BOOT_SERVICES::ExitBootServices, FALSE, BootInfo::framebuffer, EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::FrameBufferBase, EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::FrameBufferS g_boot_info, _EFI_BOOT_SERVICES::GetMemoryMap, _EFI_RUNTIME_SERVICES::GetVariable, guid_equals(), _EFI_BOOT_SERVICES::HandleProtocol, FramebufferInfo::height, EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::HorizontalR EFI_GRAPHICS_OUTPUT_PROTOCOL_MODE::Info, KERNEL_ARGS_CMDLINE_MAX, kernel_elf_buffer, kernel_elf_size, kernel_main(), BootInfo::kernel_stack_base, BootInfo::kernel_stack_size, load_cfg_from_esp(), load_kernel_from_esp(), EFI_LOADED_IMAGE_PROTOCOL::LoadOptions, EFI_LOADED_IMAGE_PROTOCOL::LoadOptionsSize, _EFI_BOOT_SERVICES::LocateProtocol, BootInfo::memory_map, BootInfo::memory_map_descriptor_size, BootInfo::memory_map_size, _EFI_GRAPHICS_OUTPUT_PROTOCOL::Mode, _EFI_SYSTEM_TABLE::NumberOfTableEntries, _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::OutputString, FramebufferInfo::pixel_format, PixelBltOnly, EFI_GRAPHICS_OUTPUT_ FramebufferInfo::pixels_per_scanline, EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::PixelsPerScanLine, RAW_LOG, _EFI_SIMPLE_TEXT_OUTPUT_PROTOCOL::Reset, BootInfo::runtime_services, _EFI_SYSTEM_TABLE::RuntimeServ

_EFI_RUNTIME_SERVICES::SetVariable, SF_VAR_BOOT_ARGS, FramebufferInfo::size, KernelArgs::stack_size, STARFORTH_VENDOR_GUID, BootInfo::uefi_boot_services_exited, EFI_CONFIGURATION_TABLE::VendorTable, EFI_GRAPHICS_OUTPUT_MODE_INFORMATION::VerticalResolution, and FramebufferInfo::width.

Here is the call graph for this function:



7.122.3.3 guid_equals()

```
static int guid_equals (
            const EFI_GUID * a,
            const EFI_GUID * b )  [static]
```

Compare two EFI GUIDs for equality.

Compares all 128 bits of the two GUIDs field by field: `Data1` (32-bit), `Data2` (16-bit), `Data3` (16-bit), and all 8 bytes of `Data4`. Returns non-zero only if every field matches.

Used by `efi_main()` to search the UEFI `ConfigurationTable` for the ACPI 2.0 and ACPI 1.0 table GUIDs (`EFI_ACPI_20_TABLE_GUID` and `EFI_ACPI_TABLE_GUID`) to populate `g_boot_info.acpi_table` before calling `ExitBootServices()`.

Parameters

a	Pointer to the first EFI GUID.
b	Pointer to the second EFI GUID.

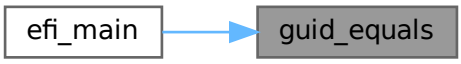
Returns

Non-zero if the GUIDs are equal, 0 otherwise.

References EFI_GUID::Data1, EFI_GUID::Data2, EFI_GUID::Data3, and EFI_GUID::Data4.

Referenced by efi_main().

Here is the caller graph for this function:



7.122.3.4 load_cfg_from_esp()

```
static int load_cfg_from_esp (
             EFI_HANDLE ImageHandle,
             EFI_BOOT_SERVICES * BS,
             char * buf,
             UINTN buflen )  [static]
```

Read `/starforth.cfg` from the EFI System Partition.

Opens the ESP root directory using `EFI_SIMPLE_FILE_SYSTEM_PROTOCOL` via the device handle of the loaded image, then reads the file `"starforth.cfg"` into `buf`. On success, `buf` contains a NUL-terminated ASCII command-line string (at most `buflen` - 1 bytes) with trailing CR and LF characters stripped.

This is the second-priority command-line source in `efi_main()` (after the NVRAM one-shot variable `StarForthBootArgs`). It is intended for installer-supplied or build-time-configured boot options that persist across reboots, unlike the ephemeral NVRAM variable.

Both `MONOLITHIC_BUILD` and split-build paths call this function; it is not gated by a preprocessor condition.

Parameters

ImageHandle	UEFI image handle for the current application; used to retrieve EFI_LOADED_IMAGE_PROTOCOL.
BS	UEFI Boot Services table pointer; must not be NULL.
buf	Caller-supplied buffer; receives the NUL-terminated ASCII config string on success.
buflen	Size of buf in bytes; at most buflen−1 bytes of the file are read.

Returns

1 if the file was read and contained non-empty content; 0 on any UEFI error or if the file is empty after stripping.

References _EFI_FILE_PROTOCOL::Close, EFI_LOADED_IMAGE_PROTOCOL::DeviceHandle, EFI_FILE_MODE_READ, EFI_LOADED_IMAGE_PROTOCOL_GUID, EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_GUID, EFI_SUCCESS, _EFI_BOOT_SERVICES::HandleProtocol, _EFI_FILE_PROTOCOL::Open, _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL::OpenVolum and _EFI_FILE_PROTOCOL::Read.

Referenced by efi_main().

Here is the caller graph for this function:

7.122.3.5 load_kernel_from_esp()

```
static EFI_STATUS load_kernel_from_esp (
            EFI_HANDLE ImageHandle,
            EFI_BOOT_SERVICES * BS )  [static]
```

Load kernel.elf from the ESP into UEFI-allocated memory (split build).

Used only in the split-build path (!MONOLITHIC_BUILD) where the kernel is a separate ELF file on the EFI System Partition rather than being linked directly into the loader image. Execution order:

1. Allocates KERNEL_MAX_SIZE (8 MB) of EfiLoaderData pages via AllocatePages. Stores the result in the module-static kernel_elf_buffer pointer.
2. Retrieves EFI_LOADED_IMAGE_PROTOCOL from ImageHandle to obtain the boot device handle.
3. Opens EFI_SIMPLE_FILE_SYSTEM_PROTOCOL on the device handle and opens the ESP volume root directory.
4. Opens "kernel.elf" for read-only access.
5. Queries file size via EFI_FILE_INFO; returns EFI_BUFFER_TOO_SMALL if the file exceeds KERNEL↩ _MAX_SIZE.
6. Reads the entire file into kernel_elf_buffer and stores the byte count in kernel_elf_size.

Must be called before ExitBootServices() — file system access via Boot Services is unavailable after EBS. The allocated buffer and size are then passed to elf_load_kernel() in Phase C.

Only compiled when MONOLITHIC_BUILD is not defined.

Parameters

ImageHandle	UEFI image handle for the current application.
BS	UEFI Boot Services table pointer.

Returns

`EFI_SUCCESS` on success, or a UEFI status code on failure.

References AllocateAnyPages, _EFI_BOOT_SERVICES::AllocatePages, _EFI_FILE_PROTOCOL::Close, EFI_LOADED_IMAGE_PROTOCOL::DeviceHandle, EFI_ABORTED, EFI_BUFFER_TOO_SMALL, EFI_FILE_INFO_GUID, EFI_FILE_MODE_READ, EFI_LOADED_IMAGE_PROTOCOL_GUID, EFI_SIMPLE_FILE_SYSTEM_PROTOCOL_GUID, EFI_SUCCESS, EfiLoaderData, file_info(), EFI_FILE_INFO::FileSize, _EFI_FILE_PROTOCOL::GetInfo, _EFI_BOOT_SERVICES::HandleProtocol, kernel_elf_buffer, kernel_elf_size, KERNEL_MAX_SIZE, _EFI_FILE_PROTOCOL::Open, _EFI_SIMPLE_FILE_SYSTEM_PROTOCOL::OpenVolume, RAW_LOG, and _EFI_FILE_PROTOCOL::Read.

Referenced by efi_main().

Here is the call graph for this function:

Here is the caller graph for this function:

7.122.4 Variable Documentation

7.122.4.1 g_boot_info

```
BootInfo g_boot_info = {0}  [static]
```

Referenced by efi_main().

7.122.4.2 kernel_elf_buffer

```
uint8_t* kernel_elf_buffer = NULL  [static]
```

Referenced by efi_main(), and load_kernel_from_esp().

7.122.4.3 kernel_elf_size

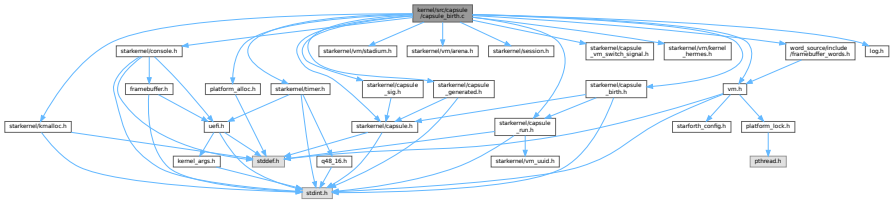
```
uint64_t kernel_elf_size = 0  [static]
```

Referenced by efi_main(), and load_kernel_from_esp().

7.123 kernel/src/capsule/capsule_birth.c File Reference

```
#include "starkernel/capsule_birth.h"
#include "starkernel/capsule.h"
#include "starkernel/capsule_run.h"
#include "starkernel/capsule_generated.h"
#include "starkernel/capsule_sig.h"
#include "starkernel/kmalloc.h"
#include "starkernel/console.h"
#include "starkernel/vm/stadium.h"
#include "starkernel/vm/arena.h"
#include "starkernel/session.h"
#include "starkernel/timer.h"
#include "starkernel/capsule_vm_switch_signal.h"
#include "starkernel/vm/kernel_hermes.h"
#include "word_source/include/framebuffer_words.h"
#include "vm.h"
#include "platform_alloc.h"
#include "log.h"
```

Include dependency graph for capsule_birth.c:



Data Structures

- struct vm_node

Typedefs

- typedef struct vm_node vm_node_t

Functions

- void capsule_birth_set_hooks (CapsuleExecFn exec_fn, CapsuleDictHashFn dict_hash_fn, CapsuleVMAllocFn vm_alloc_fn_arg)

  capsule_birth_set_hooks - Configure VM execution hooks
- static void vm_name_copy (char *dst, const char *src)
- static int vm_name_eq (const char *a, const char *b)
- static VMRegistryEntry * vm_find_entry_ptr (VMUuid vm_id)
- static void dictionary_snapshot_acl_from_parent (VM *child, VM *parent)
- void capsule_vm_registry_init (void *mama_vm_ptr)

  capsule_vm_registry_init - Initialize VM registry
- static VMRegistryEntry * vm_registry_alloc (void)
- int capsule_vm_registry_get (VMUuid vm_id, VMRegistryEntry *out)

  capsule_vm_registry_get - Get VM registry entry by ID
- uint32_t capsule_vm_registry_count (void)

  capsule_vm_registry_count - Get number of registered VMs
- int capsule_vm_registry_get_by_index (uint32_t index, VMRegistryEntry *out)

  capsule_vm_registry_get_by_index - Get registry entry by list position (birth order, stable within a boot session – the registry is append-only).
- static uint32_t vm_registry_live_count (void)
- int capsule_vm_find_by_name (const char *name, VMRegistryEntry *out)

  capsule_vm_find_by_name - Find VM registry entry by symbolic name
- static char vm_to_lower (char c)
- static int vm_name_eq_nocase (const char *a, const char *b)
- static int vm_name_prefix_eq_nocase (const char *str, const char *prefix)
- int capsule_vm_find_by_name_nocase (const char *name, VMRegistryEntry *out)

  capsule_vm_find_by_name_nocase - Find VM registry entry by name (case-insensitive)
- void capsule_vm_set_state (VMUuid vm_id, uint32_t state)

  capsule_vm_set_state - Update a VM's state in the registry
- void capsule_vm_set_pending_reap (VMUuid vm_id, int pending)

  capsule_vm_set_pending_reap - FABRIC-3.md ?XXVIII Stage 4 (2026-09-14): mark vm_id for deferred teardown once it is no longer worth resuming – see VMRegistryEntry.pending_reap's own doc comment for the full rationale.
- void capsule_vm_force_reap (VMUuid vm_id)

  capsule_vm_force_reap - FABRIC-3.md ?XXVIII Stage 4 (2026-09-14): unconditionally tear down vm_id regardless of VM_STATE_SWITCHED_OUT – the one caller allowed to bypass capsule_vm_kill()'s own refusal there, because this is called by the Stage 3 switcher itself (vm_core.c's checkpoint, on noticing pending_reap set), at the one point that genuinely knows the parked native-stack context will never be resumed.
- void capsule_vm_registry_set_name (VMUuid vm_id, const char *name)

  capsule_vm_registry_set_name - Assign a symbolic name to a registered VM
- static void dispatch_init_forth (void *vm_ctx)
- int capsule_vm_kill (const char *name)

  capsule_vm_kill - Destroy a named VM and release all its resources
- void capsule_vm_kill_all_nonmama (void)

  capsule_vm_kill_all_nonmama - Kill every non-Mama VM in the registry.
- static int contrib_capsule_refused (uint32_t flags, CapsuleSigResult sr)
- CapsuleRunResult capsule_birth_mama (void *mama_vm, const CapsuleDirHeader *dir, const CapsuleDesc *descs, const CapsuleNameEntry *names, const uint8_t *arena)

  capsule_birth_mama - Execute Mama's init capsule
- CapsuleRunResult capsule_birth_baby (const char *capsule_name, const CapsuleDirHeader *dir, const CapsuleDesc *descs, const CapsuleNameEntry *names, const uint8_t *arena, VMUuid parent, int skip↩ _pki_sig, VMUuid *out_vm_id, void **out_vm_ctx)

  capsule_birth_baby - Birth a new VM from a named (p) capsule
- CapsuleRunResult capsule_run_experiment (void *mama_vm, const char *capsule_name, const CapsuleDirHeader *dir, const CapsuleDesc *descs, const CapsuleNameEntry *names, const uint8_t *arena, uint64_t *out_run_id)

  capsule_run_experiment - Execute a named (e) capsule on Mama

Variables

- static CapsuleExecFn vm_exec_fn = 0

  capsule_birth.c - VM Birth Protocol Implementation (M7.1)
- static CapsuleDictHashFn vm_dict_hash_fn = 0
- static CapsuleVMAllocFn vm_alloc_fn = 0
- static vm_node_t * vm_registry_head = (void *)0
- static uint32_t vm_registry_count = 0

7.123.1 Typedef Documentation

7.123.1.1 vm_node_t

```
typedef struct vm_node vm_node_t
```

7.123.2 Function Documentation

7.123.2.1 capsule_birth_baby()

```
CapsuleRunResult capsule_birth_baby (
            const char * capsule_name,
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena,
            VMUuid parent,
            int skip_pki_sig,
            VMUuid * out_vm_id,
            void ** out_vm_ctx )
```

capsule_birth_baby - Birth a new VM from a named (p) capsule

Finds the capsule by colon-separated name, validates it, allocates a new VM, executes the capsule payload as IDENTITY, then (if present) executes unit.4th from the baby's block space as PERSONALITY.

Parameters

capsule_name	Colon-separated capsule name, e.g. "production:myvm.4th"
dir	Capsule directory header
descs	Capsule descriptor array
names	Capsule name entry array (parallel to descs)
arena	Capsule payload arena
parent	Who is birthing this VM (FABRIC-2.md ?H.12 step 7) – the caller's own VMUuid (e.g. vm->stadium_vm_id for a FORTH word handler), recorded on the new VM's Session.parent. Every current call site has one in scope, directly or one level up; traced live rather than assumed (checked all 6 call sites across mama_forth_words.c/capsule_console.c/ capsule_runcap.c/capsule_wirebind.c).

Parameters

skip_pki_sig	0 for every build-time capsule (the normal case – checked against the compile-time-baked signature array via capsule_get_signatures()). Non-zero only for RUNCAP (FABRIC-2.md ?F.6/F.18): a heap-built, single-entry directory sourced from a user's own thumbdrive has no entry in that array at all – index 0 would silently compare against whatever real capsule happens to occupy slot 0, which is not a security check, just a guaranteed-wrong one. Trust for that content comes from CERTVERIFY (a separate root, the user's own Zuse-signed cert) already having run before RUNCAP is ever called, not from this flag – this only skips a check that was never meaningful for that content in the first place. Deliberately a plain flag, not a new entry point, so the policy is one call-site decision, trivially reversible.
out_vm_id	Output: assigned VM ID
out_vm_ctx	Output: new VM context

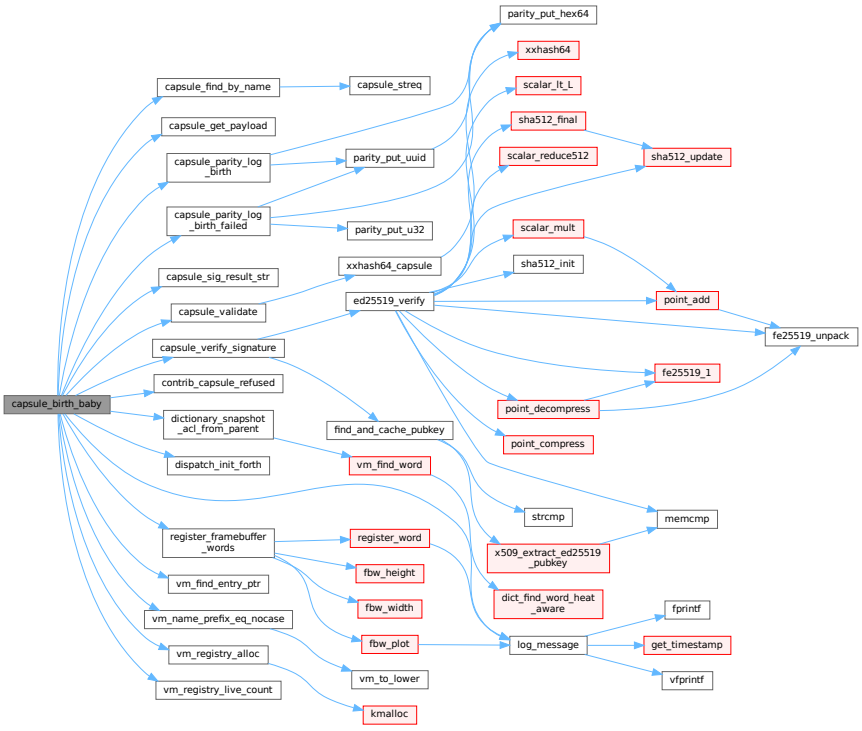
Returns

CAPSULE_RUN_OK on success, error code otherwise

References CapsuleDirHeader::arena_size, CAPSULE_BIRTH_ELIGIBLE, capsule_find_by_name(), capsule_get_payload(), capsule_parity_log_birth(), capsule_parity_log_birth_failed(), CAPSULE_RUN_ERR_EXEC_FAIL, CAPSULE_RUN_ERR_FLEET_FU CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_ERR_NOT_ELIGIBLE, CAPSULE_RUN_ERR_STILLBORN, CAPSULE_RUN_OK, CAPSULE_SIG_INVALID, CAPSULE_SIG_OK, capsule_sig_result_str(), CAPSULE_VALID, capsule_validate(), capsule_verify_signature(), CapsuleDesc, contrib_capsule_refused(), CapsuleDirHeader::desc_count, dictionary_snapshot_acl_from_parent(), dispatch_init_forth(), entry, log_message(), LOG_WARN, name, register_framebuffer_words(), vm_alloc_fn, vm_dict_hash_fn, vm_exec_fn, vm_find_entry_ptr(), vm_name_prefix_eq_nocase(), VMRegistryEntry::vm_ptr, vm_registry_alloc(), vm_registry_live_count(), VM_STATE_EMBRYO, VM_STATE_LIVE, and VM_STATE_STILLBORN.

Referenced by capsule_console_birth(), and capsule_runcap_birth().

Here is the call graph for this function:



Here is the caller graph for this function:

7.123.2.2 capsule_birth_mama()

```
CapsuleRunResult capsule_birth_mama (
            void * mama_vm,
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena )
```

capsule_birth_mama - Execute Mama's init capsule

Finds the MAMA_INIT capsule by flag, validates it, executes it on Mama's VM.

Parameters

mama_vm	Mama's VM context
dir	Capsule directory header
descs	Capsule descriptor array
names	Capsule name entry array (parallel to descs)
arena	Capsule payload arena

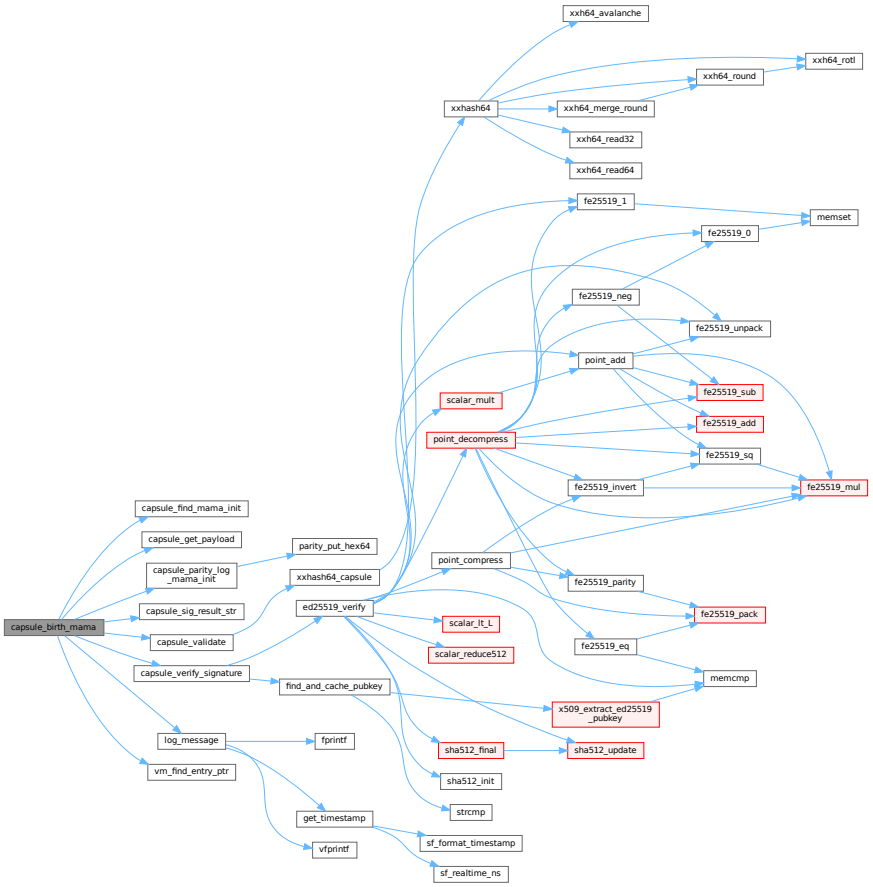
Returns

CAPSULE_RUN_OK on success, error code otherwise

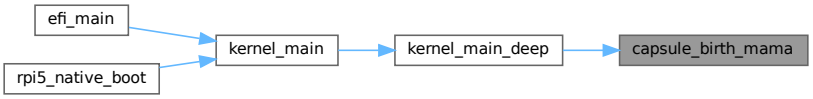
References CapsuleDirHeader::arena_size, VMRegistryEntry::birth_capsule_id, VMRegistryEntry::birth_dict_hash, capsule_find_mama_init(), capsule_get_payload(), capsule_parity_log_mama_init(), CAPSULE_RUN_ERR_EXEC_FAIL, CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_OK, CAPSULE_SIG_INVALID, CAPSULE_SIG_OK, capsule_sig_result_str(), CAPSULE_VALID, capsule_validate(), capsule_verify_signature(), CapsuleDesc, CapsuleDirHeader::desc_count, log_message(), LOG_WARN, name, vm_dict_hash_fn, vm_exec_fn, and vm_find_entry_ptr().

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.123.2.3 capsule_birth_set_hooks()

```
void capsule_birth_set_hooks (
            CapsuleExecFn exec_fn,
            CapsuleDictHashFn dict_hash_fn,
            CapsuleVMAllocFn vm_alloc_fn )
```

capsule_birth_set_hooks - Configure VM execution hooks

Must be called before any birth operations.

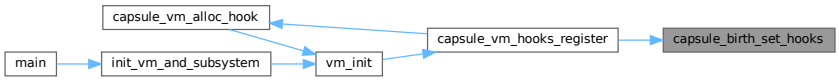
Parameters

exec_fn	Function to execute FORTH code on VM
dict_hash↩ _fn	Function to compute dictionary hash
vm_alloc_fn	Function to allocate new VM (for babies)

References vm_alloc_fn, vm_dict_hash_fn, and vm_exec_fn.

Referenced by capsule_vm_hooks_register().

Here is the caller graph for this function:



7.123.2.4 capsule_run_experiment()

```
CapsuleRunResult capsule_run_experiment (
            void * mama_vm,
            const char * capsule_name,
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena,
            uint64_t * out_run_id )
```

capsule_run_experiment - Execute a named (e) capsule on Mama

Finds the experiment capsule by colon-separated name, validates it, executes it on Mama's VM without creating a new VM.

Parameters

mama_vm	Mama's VM context
capsule_name	Colon-separated capsule name, e.g. "experiments:doe-l8:init-l8-stable.4th"
dir	Capsule directory header
descs	Capsule descriptor array
names	Capsule name entry array (parallel to descs)
arena	Capsule payload arena
out_run_id	Output: assigned run ID

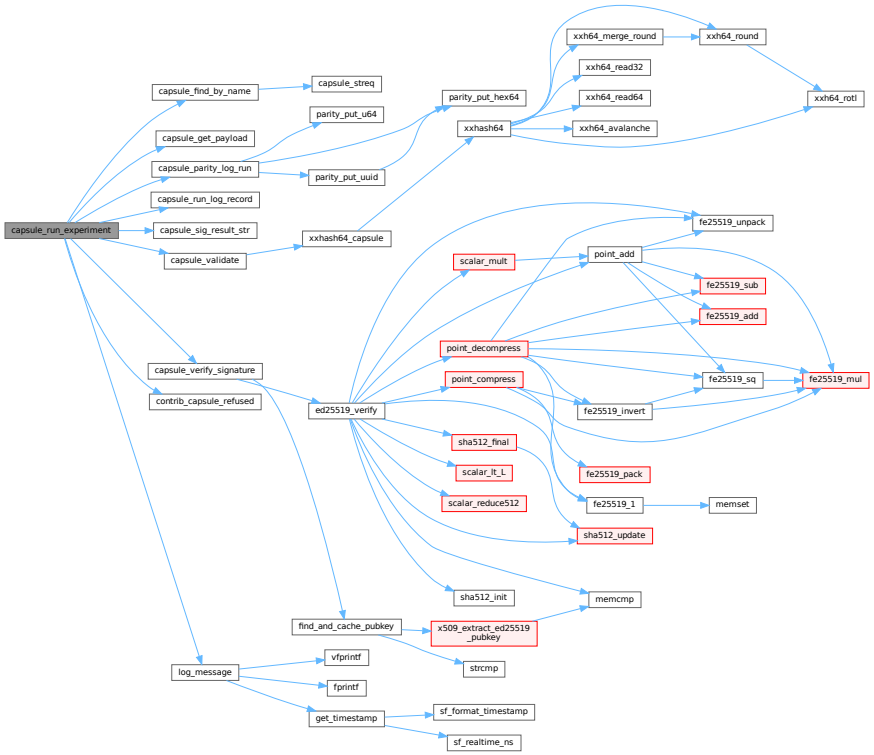
Returns

CAPSULE_RUN_OK on success, error code otherwise

References CapsuleDirHeader::arena_size, CAPSULE_DOE_ELIGIBLE, capsule_find_by_name(), capsule_get_payload(), CapsuleRunRecord::capsule_hash, CapsuleRunRecord::capsule_id, capsule_parity_log_run(), CAPSULE_RUN_ERR_EXEC_FAIL,

CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_ERR_NOT_ELIGIBLE, capsule_run_log_record(), CAPSULE_RUN_OK, CAPSULE_SIG_INVALID, CAPSULE_SIG_OK, capsule_sig_result_str(), CAPSULE_VALID, capsule_validate(), capsule_verify_signature(), CapsuleDesc, contrib_capsule_refused(), CapsuleDirHeader::desc_count, CapsuleRunRecord::ended_ns, CapsuleRunRecord::flags, log_message(), LOG_WARN, name, CapsuleRunRecord::post_dict_hash, CapsuleRunRecord::pre_dict_h, CapsuleRunRecord::reserved, CapsuleRunRecord::result_code, CapsuleRunRecord::run_id, CapsuleRunRecord::started_ns, vm_dict_hash_fn, vm_exec_fn, and CapsuleRunRecord::vm_id.

Here is the call graph for this function:



7.123.2.5 capsule_vm_find_by_name()

```
int capsule_vm_find_by_name (
            const char * name,
            VMRegistryEntry * out )
```

capsule_vm_find_by_name - Find VM registry entry by symbolic name

Case-sensitive. Returns the first match.

Parameters

name	Symbolic VM name, e.g. "Hermes"
out	Output: registry entry copy

Returns

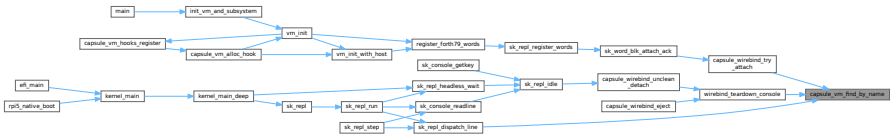
0 if found, -1 if not found

References vm_node::entry, VMRegistryEntry::name, name, vm_node::next, vm_name_eq(), and vm_registry_head.

Referenced by capsule_wirebind_try_attach(), sk_repl_dispatch_line(), and wirebind_teardown_console().

Here is the call graph for this function:

Here is the caller graph for this function:



7.123.2.6 capsule_vm_find_by_name_nocase()

```
int capsule_vm_find_by_name_nocase (
            const char * name,
            VMRegistryEntry * out )
```

capsule_vm_find_by_name_nocase - Find VM registry entry by name (case-insensitive)

Used by BIRTH for idempotency: prevents birthing a second VM with the same name regardless of case differences.

Parameters

name	Symbolic VM name (compared case-insensitively)
out	Output: registry entry copy

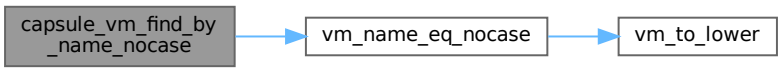
Returns

0 if found, -1 if not found

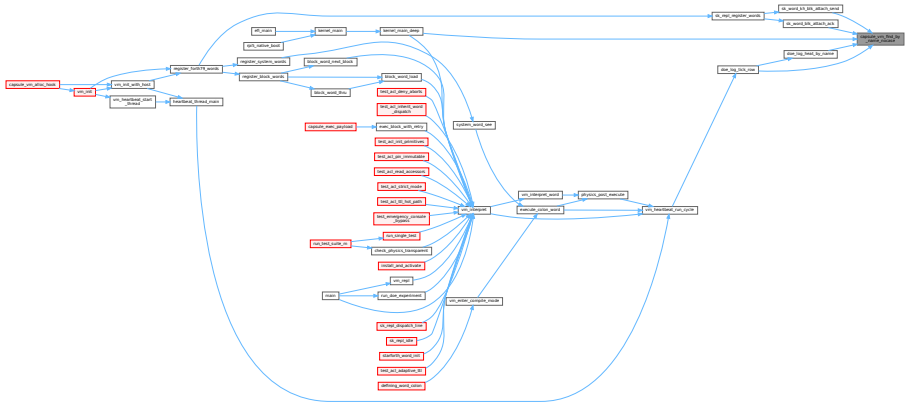
References vm_node::entry, VMRegistryEntry::name, name, vm_node::next, vm_name_eq_nocase(), and vm_registry_head.

Referenced by doe_log_heat_by_name(), doe_log_tick_row(), kernel_main_deep(), sk_word_blk_attach_ack(), and sk_word_kh_blk_attach_send().

Here is the call graph for this function:



Here is the caller graph for this function:



7.123.2.7 capsule_vm_force_reap()

```
void capsule_vm_force_reap (
            VMUuid vm_id )
```

capsule_vm_force_reap - FABRIC-3.md ?XXVIII Stage 4 (2026-09-14): unconditionally tear down vm_id regardless of VM_STATE_SWITCHED_OUT – the one caller allowed to bypass capsule_vm_kill()'s own refusal there, because this is called *by* the Stage 3 switcher itself (vm_core.c's checkpoint, on noticing pending_reap set), at the one point that genuinely knows the parked native-stack context will never be resumed.

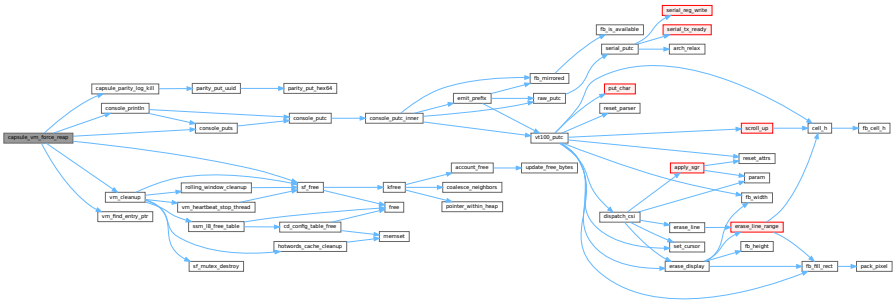
Also releases the VM's own switch-signal slot (sk_vm_switch_signal_unregister()) – generic cleanup, independent of whatever subsystem (WIREBIND today) set pending_reap in the first place. No-op if vm_id isn't registered or is already DEAD.

Parameters

vm_id	VM ID to reap.

References capsule_parity_log_kill(), console_println(), console_puts(), entry, sf_free(), vm_cleanup(), vm_find_entry_ptr(), VM_NAME_MAX, and VM_STATE_DEAD.

Here is the call graph for this function:



7.123.2.8 capsule_vm_kill()

```
int capsule_vm_kill (
            const char * name )
```

capsule_vm_kill - Destroy a named VM and release all its resources

Looks up the VM by name (case-insensitive). Hera (VM 0) cannot be killed. If the VM is already DEAD the call is a no-op. On success: vm_cleanup + sf_free, state → VM_STATE_DEAD, name cleared.

Parameters

name	Symbolic name of the VM to kill (case-insensitive)

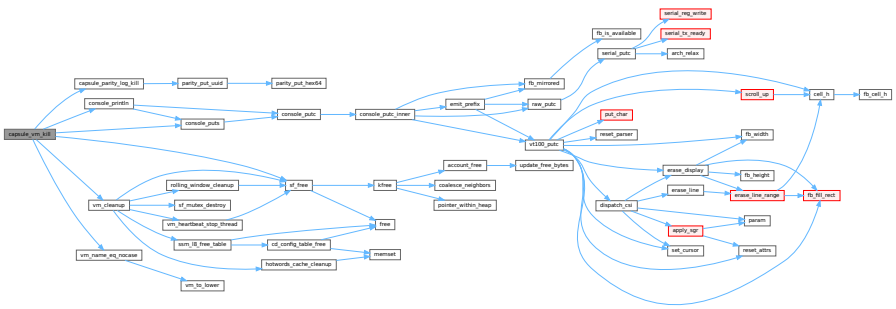
Returns

0 on success (or already dead), -1 if not found or refused

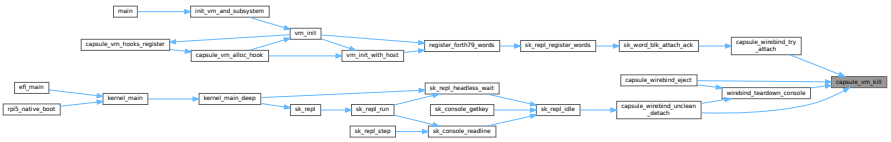
References capsule_parity_log_kill(), console_println(), console_puts(), entry, vm_node::entry, VMRegistryEntry::name, name, vm_node::next, sf_free(), vm_cleanup(), vm_name_eq_nocase(), VM_NAME_MAX, vm_registry_head, VM_STATE_DEAD, and VM_STATE_SWITCHED_OUT.

Referenced by capsule_wirebind_eject(), capsule_wirebind_try_attach(), capsule_wirebind_unclean_detach(), and wirebind_teardown_console().

Here is the call graph for this function:



Here is the caller graph for this function:



7.123.2.9 capsule_vm_kill_all_nonmama()

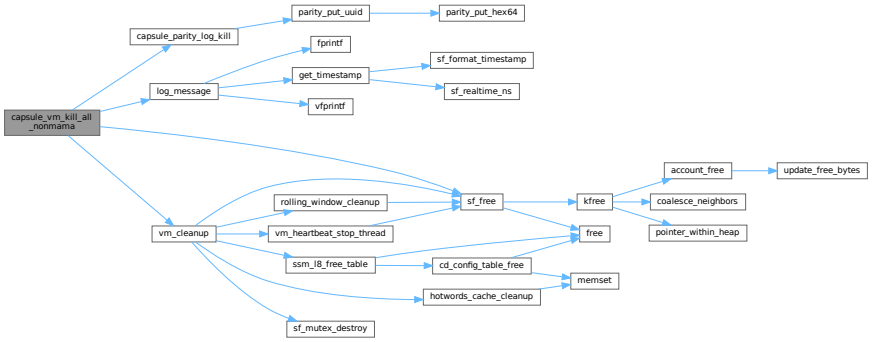
```
void capsule_vm_kill_all_nonmama (
            void  )
```

capsule_vm_kill_all_nonmama - Kill every non-Mama VM in the registry.

Sets halted, calls vm_cleanup + sf_free, marks state DEAD. Used by Hera's BYE immediately before arch_cold_reset() to reap all children.

References capsule_parity_log_kill(), vm_node::entry, VM::halted, log_message(), LOG_WARN, VMRegistryEntry::name, vm_node::next, sf_free(), VMRegistryEntry::stadium_patron_cell, VMRegistryEntry::state, vm_cleanup(), VMRegistryEntry::vm_id, VMRegistryEntry::vm_ptr, vm_registry_head, VM_STATE_DEAD, and VM_STATE_SWITCHED_OUT.

Here is the call graph for this function:



7.123.2.10 capsule_vm_registry_count()

```
uint32_t capsule_vm_registry_count (
            void  )
```

capsule_vm_registry_count - Get number of registered VMs

References vm_registry_count.

7.123.2.11 capsule_vm_registry_get()

```
int capsule_vm_registry_get (
            VMUuid vm_id,
            VMRegistryEntry * out )
```

capsule_vm_registry_get - Get VM registry entry by ID

Parameters

vm↩ _id	VM ID to look up
out	Output: registry entry copy

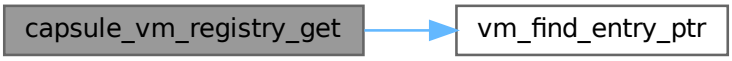
Returns

0 on success, -1 if not found

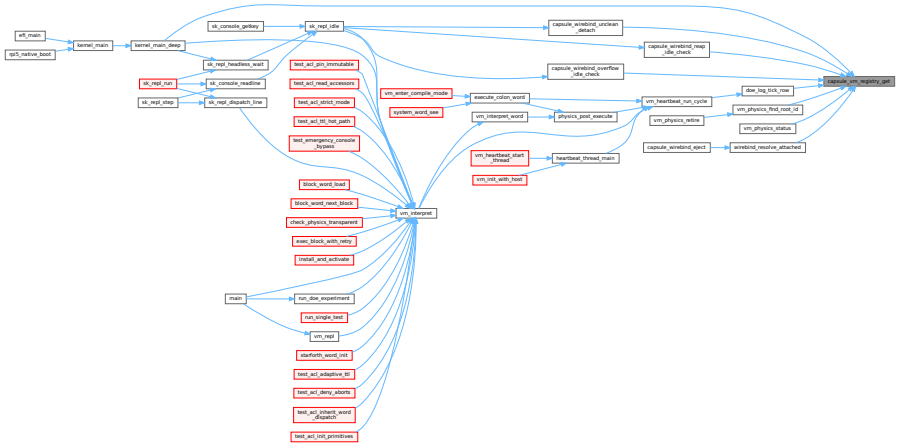
References entry, and vm_find_entry_ptr().

Referenced by capsule_wirebind_overflow_idle_check(), capsule_wirebind_reap_idle_check(), capsule_wirebind_unclean_detach(), doe_log_tick_row(), kernel_main_deep(), vm_physics_find_root_id(), vm_physics_status(), and wirebind_resolve_attached().

Here is the call graph for this function:



Here is the caller graph for this function:



7.123.2.12 capsule_vm_registry_get_by_index()

```
int capsule_vm_registry_get_by_index (
            uint32_t index,
            VMRegistryEntry * out )
```

capsule_vm_registry_get_by_index - Get registry entry by list position (birth order, stable within a boot session – the registry is append-only).

For enumeration (e.g. the idle-loop messaging pump, FABRIC-2.md Phase C, 2026-08-28), where no vm_id is known up front. Index range is [0, capsule_vm_registry_count()).

Parameters

index	Zero-based position in birth order
out	Output: registry entry copy

Returns

0 on success, -1 if index is out of range

References vm_node::entry, vm_node::next, and vm_registry_head.

7.123.2.13 capsule_vm_registry_init()

```
void capsule_vm_registry_init (
            void * mama_vm_ptr )
```

capsule_vm_registry_init - Initialize VM registry

Allocates Mama's registry node (VM 0, name "Hera") via kmalloc and stores mama_vm_ptr so KILL can guard against destroying Mama. Must be called after kmalloc_init().

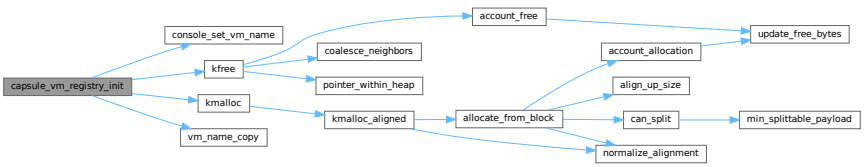
Parameters

mama_vm_ptr	Pointer to Mama's VM object (e.g. &sk_mama_vm)

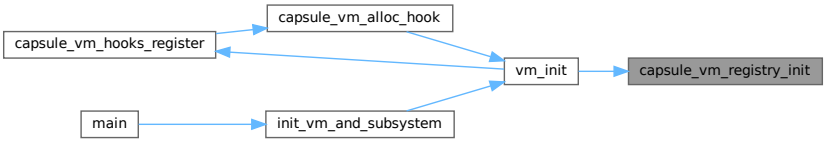
References VMRegistryEntry::birth_capsule_id, VMRegistryEntry::birth_dict_hash, VMRegistryEntry::birth_timestamp_ns, console_set_vm_name(), vm_node::entry, VMRegistryEntry::flags, kfree(), kmalloc(), VMRegistryEntry::name, vm_node::next, VMRegistryEntry::parent_vm_id, VMRegistryEntry::stadium_patron_cell, VMRegistryEntry::state, VMRegistryEntry::vm_id, vm_name_copy(), VM_NAME_MAX, VMRegistryEntry::vm_ptr, vm_registry_count, vm_registry_head, and VM_STATE_LIVE.

Referenced by vm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.123.2.14 capsule_vm_registry_set_name()

```
void capsule_vm_registry_set_name (
            VMUuid vm_id,
            const char * name )
```

capsule_vm_registry_set_name - Assign a symbolic name to a registered VM

Truncates to VM_NAME_MAX-1 characters. No-op if vm_id not found.

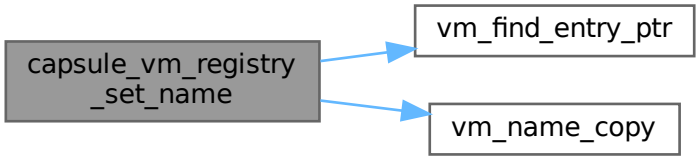
Parameters

vm↩ _id	VM ID to name
name	Symbolic name string

References entry, name, vm_find_entry_ptr(), and vm_name_copy().

Referenced by capsule_console_birth(), and capsule_runcap_birth().

Here is the call graph for this function:



Here is the caller graph for this function:

7.123.2.15 capsule_vm_set_pending_reap()

```
void capsule_vm_set_pending_reap (
            VMUuid vm_id,
            int pending )
```

capsule_vm_set_pending_reap - FABRIC-3.md ?XXVIII Stage 4 (2026-09-14): mark vm_id for deferred teardown once it is no longer worth resuming – see VMRegistryEntry.pending_reap's own doc comment for the full rationale.

No-op if vm_id isn't registered.

Parameters

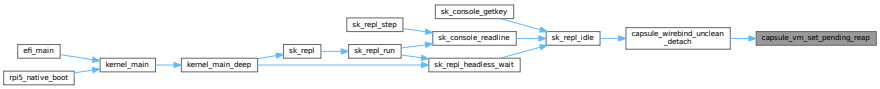
vm_id	VM ID to mark.
pending	1 to mark, 0 to clear (e.g. a re-attach of the same identity before the switcher ever reaped it).

References entry, and vm_find_entry_ptr().

Referenced by capsule_wirebind_unclean_detach().

Here is the call graph for this function:

Here is the caller graph for this function:



7.123.2.16 capsule_vm_set_state()

```
void capsule_vm_set_state (
            VMUuid vm_id,
            uint32_t state )
```

capsule_vm_set_state - Update a VM's state in the registry

Parameters

vm_id	VM ID to update
state	New VMState value

References entry, and vm_find_entry_ptr().

Here is the call graph for this function:

7.123.2.17 contrib_capsule_refused()

```
static int contrib_capsule_refused (
            uint32_t flags,
            CapsuleSigResult sr )  [static]
```

References CAPSULE_FLAG_CONTRIB, CAPSULE_SIG_OK, and flags.

Referenced by capsule_birth_baby(), and capsule_run_experiment().

Here is the caller graph for this function:

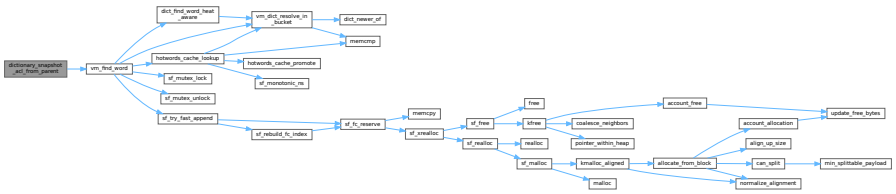
7.123.2.18 dictionary_snapshot_acl_from_parent()

```
static void dictionary_snapshot_acl_from_parent (
            VM * child,
            VM * parent )  [static]
```

References DictEntry::acl_allow, DictEntry::acl_mode, DictEntry::acl_pinned, DictEntry::acl_ttl, VM::latest, DictEntry::link, DictEntry::name, DictEntry::name_len, and vm_find_word().

Referenced by capsule_birth_baby().

Here is the call graph for this function:



Here is the caller graph for this function:

7.123.2.19 dispatch_init_forth()

```
static void dispatch_init_forth (
            void * vm_ctx )  [static]
```

Referenced by capsule_birth_baby().

Here is the caller graph for this function:

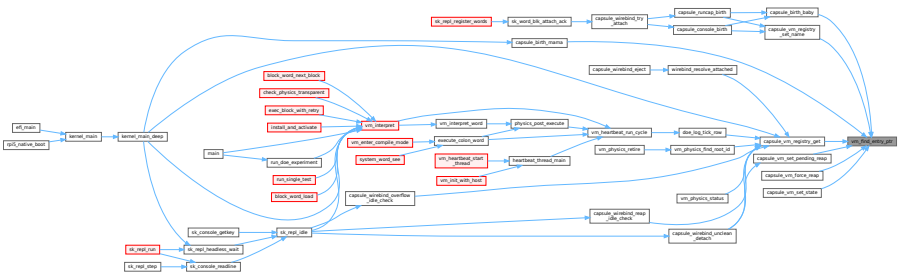
7.123.2.20 vm_find_entry_ptr()

```
static VMRegistryEntry * vm_find_entry_ptr (
            VMUuid vm_id )  [static]
```

References vm_node::entry, vm_node::next, VMRegistryEntry::vm_id, and vm_registry_head.

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_vm_force_reap(), capsule_vm_registry_get(), capsule_vm_registry_set_name(), capsule_vm_set_pending_reap(), and capsule_vm_set_state().

Here is the caller graph for this function:



7.123.2.21 vm_name_copy()

```
static void vm_name_copy (
            char * dst,
            const char * src )  [static]
```

References VM_NAME_MAX.

Referenced by capsule_vm_registry_init(), and capsule_vm_registry_set_name().

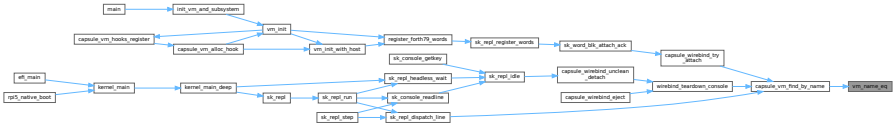
Here is the caller graph for this function:

7.123.2.22 vm_name_eq()

```
static int vm_name_eq (
            const char * a,
            const char * b )  [static]
```

Referenced by capsule_vm_find_by_name().

Here is the caller graph for this function:



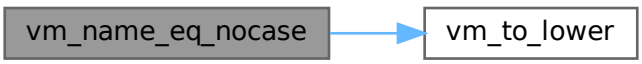
7.123.2.23 vm_name_eq_nocase()

```
static int vm_name_eq_nocase (
            const char * a,
            const char * b )  [static]
```

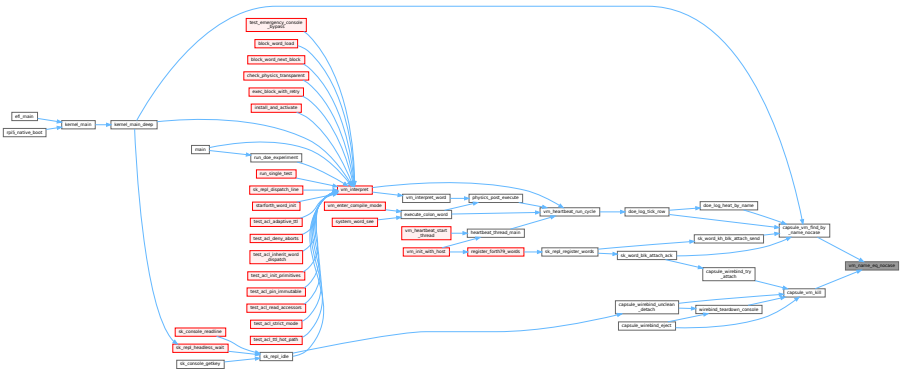
References vm_to_lower().

Referenced by capsule_vm_find_by_name_nocase(), and capsule_vm_kill().

Here is the call graph for this function:



Here is the caller graph for this function:



7.123.2.24 vm_name_prefix_eq_nocase()

```
static int vm_name_prefix_eq_nocase (
            const char * str,
            const char * prefix )  [static]
```

References vm_to_lower().

Referenced by capsule_birth_baby().

Here is the call graph for this function:

Here is the caller graph for this function:

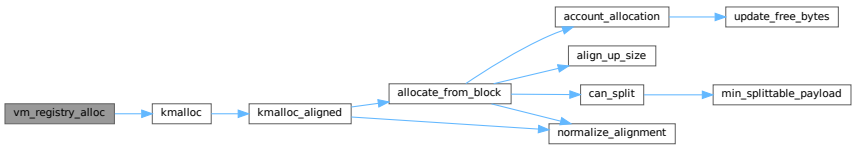
7.123.2.25 vm_registry_alloc()

```
static VMRegistryEntry * vm_registry_alloc (
            void  )  [static]
```

References VMRegistryEntry::birth_capsule_id, VMRegistryEntry::birth_dict_hash, VMRegistryEntry::birth_timestamp_ns, vm_node::entry, VMRegistryEntry::flags, kmalloc(), VMRegistryEntry::name, vm_node::next, VMRegistryEntry::parent_vm_id, VMRegistryEntry::stadium_patron_cell, VMRegistryEntry::state, VMRegistryEntry::vm_id, VM_NAME_MAX, VMRegistryEntry::vm_ptr, vm_registry_count, vm_registry_head, and VM_STATE_EMBRYO.

Referenced by capsule_birth_baby().

Here is the call graph for this function:



Here is the caller graph for this function:

7.123.2.26 vm_registry_live_count()

```
static uint32_t vm_registry_live_count (
            void  )  [static]
```

References vm_node::entry, vm_node::next, VMRegistryEntry::state, vm_registry_head, and VM_STATE_LIVE.

Referenced by capsule_birth_baby().

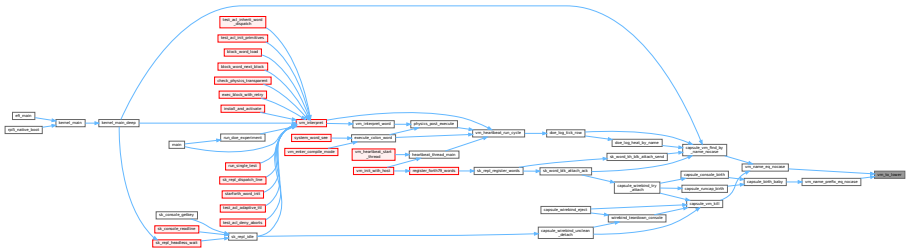
Here is the caller graph for this function:

7.123.2.27 vm_to_lower()

```
static char vm_to_lower (
            char c )  [static]
```

Referenced by vm_name_eq_nocase(), and vm_name_prefix_eq_nocase().

Here is the caller graph for this function:



7.123.3 Variable Documentation

7.123.3.1 vm_alloc_fn

```
CapsuleVMAllocFn vm_alloc_fn = 0  [static]
```

Referenced by capsule_birth_baby(), and capsule_birth_set_hooks().

7.123.3.2 vm_dict_hash_fn

```
CapsuleDictHashFn vm_dict_hash_fn = 0  [static]
```

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_birth_set_hooks(), and capsule_run_experiment().

7.123.3.3 vm_exec_fn

```
CapsuleExecFn vm_exec_fn = 0  [static]
```

capsule_birth.c - VM Birth Protocol Implementation (M7.1)

Mama init, baby birth, and experiment execution. Freestanding - no libc dependency.

Birth sequence for a baby VM:

1. Find capsule by name (capsule_find_by_name)
2. Assert CAPSULE_BIRTH_ELIGIBLE
3. Validate content hash
4. vm_alloc_hook() — fresh VM
5. vm_exec_hook(payload) — IDENTITY (init capsule from Hera's store)
6. vm_exec_hook("1 LOAD") — PERSONALITY (baby's personal init.4th from block 1, if present)
7. Log parity record

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_birth_set_hooks(), and capsule_run_experiment().

7.123.3.4 vm_registry_count

```
uint32_t vm_registry_count = 0  [static]
```

Referenced by capsule_vm_registry_count(), capsule_vm_registry_init(), and vm_registry_alloc().

7.123.3.5 vm_registry_head

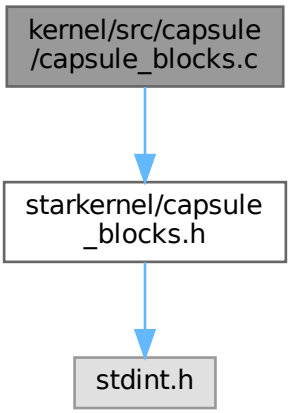
```
vm_node_t* vm_registry_head = (void *)0  [static]
```

Referenced by capsule_vm_find_by_name(), capsule_vm_find_by_name_nocase(), capsule_vm_kill(), capsule_vm_kill_all_nonmama capsule_vm_registry_get_by_index(), capsule_vm_registry_init(), vm_find_entry_ptr(), vm_registry_alloc(), and vm_registry_live_count().

7.124 kernel/src/capsule/capsule_blocks.c File Reference

```
#include "starkernel/capsule_blocks.h"
```

Include dependency graph for capsule_blocks.c:



Functions

- int capsule_block_header (const uint8_t *p, const uint8_t *end, uint32_t *out_num, const uint8_t **out_after)

7.124.1 Function Documentation

7.124.1.1 capsule_block_header()

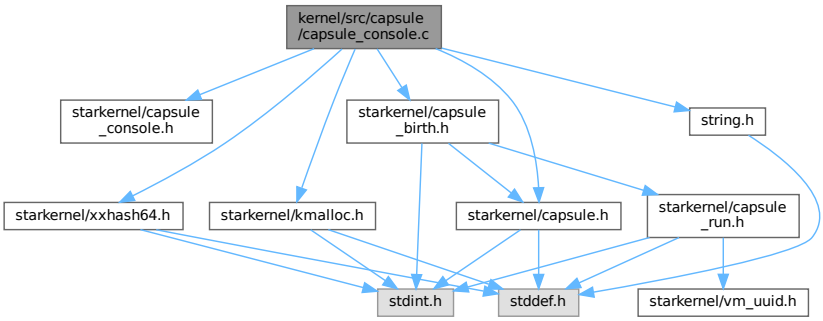
```
int capsule_block_header (
            const uint8_t * p,
            const uint8_t * end,
            uint32_t * out_num,
            const uint8_t ** out_after )
```

7.125 kernel/src/capsule/capsule_console.c File Reference

```
#include "starkernel/capsule_console.h"
#include "starkernel/capsule.h"
#include "starkernel/capsule_birth.h"
#include "starkernel/xxhash64.h"
#include "starkernel/kmalloc.h"
```

```
#include <string.h>
```

Include dependency graph for capsule_console.c:



Functions

- CapsuleRunResult capsule_console_birth (const char ∗console_name, VMUuid parent, VMUuid ∗out_vm_id, void ∗∗out_vm_ctx)

Variables

- static const char CONSOLE_IDENTITY_SRC [ ]

7.125.1 Function Documentation

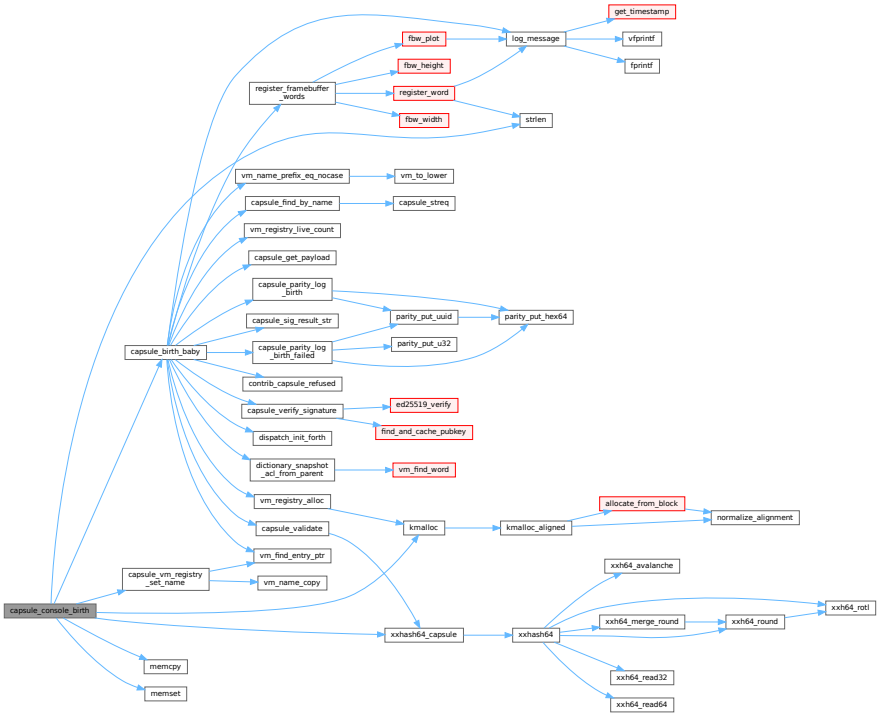
7.125.1.1 capsule_console_birth()

```
CapsuleRunResult capsule_console_birth (
            const char * console_name,
            VMUuid parent,
            VMUuid * out_vm_id,
            void ** out_vm_ctx )
```

References CapsuleDirHeader::arena_base, CapsuleDirHeader::arena_size, capsule_birth_baby(), CAPSULE_DIR_MAGIC, CAPSULE_FLAG_ACTIVE, CAPSULE_FLAG_PRODUCTION, CAPSULE_HASH_XXHASH64, CAPSULE_MAGIC_PACK, CAPSULE_NAME_MAX, CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_ERR_STILLBORN, CAPSULE_RUN_OK, CAPSULE_VERSION_0, capsule_vm_registry_set_name(), CapsuleDesc, CONSOLE_IDENTITY_SRC, CapsuleDirHeader::desc_capacity, CapsuleDirHeader::desc_count, CapsuleDirHeader::dir_hash, kmalloc(), CapsuleDirHeader::magic, memcpy(), memset(), CapsuleNameEntry::name, CapsuleDirHeader::name_count, strlen(), and xxhash64_capsule().

Referenced by capsule_wirebind_try_attach().

Here is the call graph for this function:



Here is the caller graph for this function:

7.125.2 Variable Documentation

7.125.2.1 CONSOLE_IDENTITY_SRC

```
const char CONSOLE_IDENTITY_SRC[]  [static]
```

Initial value:

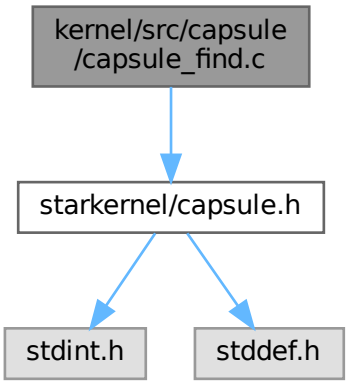
```
=
    "Block 4997\n"
```

Referenced by capsule_console_birth().

7.126 kernel/src/capsule/capsule_find.c File Reference

```
#include "starkernel/capsule.h"
```

Include dependency graph for capsule_find.c:



Functions

- static int capsule_streq (const char *a, const char *b)

  capsule_find.c - Capsule Lookup (M7.1)
- const CapsuleDesc * capsule_find_by_id (const CapsuleDirHeader *dir, const CapsuleDesc *descs, uint64_t id)

  capsule_find_by_id - Find capsule by content hash ID
- const CapsuleDesc * capsule_find_by_name (const CapsuleDirHeader *dir, const CapsuleDesc *descs, const CapsuleNameEntry *names, const char *name)

  capsule_find_by_name - Find capsule by colon-separated name
- const CapsuleDesc * capsule_find_mama_init (const CapsuleDirHeader *dir, const CapsuleDesc *descs)

  capsule_find_mama_init - Find the Mama init capsule
- const uint8_t * capsule_get_payload (const CapsuleDesc *desc, const uint8_t *arena_base)

  capsule_get_payload - Get pointer to capsule payload bytes

7.126.1 Function Documentation

7.126.1.1 capsule_find_by_id()

```
const CapsuleDesc * capsule_find_by_id (
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            uint64_t id )
```

capsule_find_by_id - Find capsule by content hash ID

Parameters

dir	Directory header
descs	Descriptor array
id	Capsule ID (content hash) to find

Returns

Pointer to descriptor, or NULL if not found

References CapsuleDirHeader::desc_count.

7.126.1.2 capsule_find_by_name()

```
const CapsuleDesc * capsule_find_by_name (
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const char * name )
```

capsule_find_by_name - Find capsule by colon-separated name

Parameters

dir	Directory header
descs	Descriptor array
names	Name entry array (parallel to descs)
name	Colon-separated capsule name, e.g. "core:init.4th"

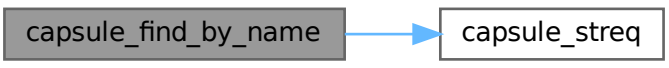
Returns

Pointer to descriptor, or NULL if not found

References capsule_streq(), CapsuleDirHeader::desc_count, and name.

Referenced by capsule_birth_baby(), capsule_exec_init(), and capsule_run_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

7.126.1.3 capsule_find_mama_init()

```
const CapsuleDesc * capsule_find_mama_init (
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs )
```

capsule_find_mama_init - Find the Mama init capsule

Searches the descriptor array for the capsule with CAPSULE_FLAG_MAMA_INIT. There must be exactly one such capsule.

Parameters

dir	Directory header
descs	Descriptor array

Returns

Pointer to Mama's init descriptor, or NULL if not found

References CAPSULE_IS_MAMA_INIT, CapsuleDirHeader::desc_count, and flags.

Referenced by capsule_birth_mama(), and kernel_main_deep().

Here is the caller graph for this function:

7.126.1.4 capsule_get_payload()

```
const uint8_t * capsule_get_payload (
            const CapsuleDesc * desc,
            const uint8_t * arena_base )
```

capsule_get_payload - Get pointer to capsule payload bytes

Parameters

desc	Capsule descriptor
arena_base	Base address of payload arena

Returns

Pointer to payload bytes, or NULL on error

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_exec_init(), and capsule_run_experiment().

Here is the caller graph for this function:

7.126.1.5 capsule_streq()

```
static int capsule_streq (
            const char * a,
            const char * b )  [static]
```

capsule_find.c - Capsule Lookup (M7.1)

Lookup functions for capsule descriptors by ID, name, and role. Freestanding - no libc dependency.

Referenced by capsule_find_by_name().

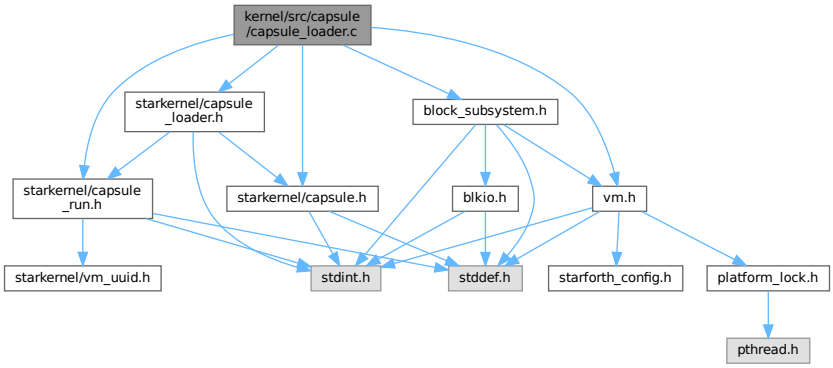
Here is the caller graph for this function:

7.127 kernel/src/capsule/capsule_loader.c File Reference

```
#include "starkernel/capsule_loader.h"
#include "starkernel/capsule.h"
#include "starkernel/capsule_run.h"
#include "block_subsystem.h"
```

```
#include "vm.h"
```

Include dependency graph for capsule_loader.c:



Macros

- #define CAPSULE_RAM_OFFSET 2048u

  capsule_loader.c - Block Capsule Loader and Executor (M7.1)
- #define LOADER_BLOCK_SIZE 1024u
- #define CAPSULE_BLOCK_LINES 16
- #define CAPSULE_LINE_COLS 64
- #define CAPSULE_EXEC_LINE_MAX 256
- #define CAPSULE_MAX_DEFERRED CAPSULE_BLOCK_LINES

Functions

- static int is_block_header (const uint8_t *p, const uint8_t *end, uint32_t *out_num, const uint8_t **out_after)
- static void write_ramdrive_block (uint32_t block_num, const uint8_t *content, uint32_t content_len)
- static size_t u32_to_dec (uint32_t val, char *buf, size_t size)
- int capsule_load_blocks (const uint8_t *payload, uint64_t length, uint32_t *out_entry_block)

  capsule_loader.h - Block Capsule Loader and Executor (M7.1)
- static int popcount16 (uint16_t v)
- static int exec_block_with_retry (VM *vm, const uint8_t *block_start, size_t block_len, uint32_t block_num)
- int capsule_exec_payload (void *vm_opaque, const uint8_t *payload, uint64_t length)

  capsule_exec_payload - Parse, populate block device, and execute a payload
- void capsule_clear_blocks (const uint8_t *payload, uint64_t length)

  capsule_clear_blocks - Zero all ramdrive slots referenced in a capsule payload
- CapsuleRunResult capsule_exec_init (void *vm_opaque, const char *capsule_name, const CapsuleDirHeader *dir, const CapsuleDesc *descs, const CapsuleNameEntry *names, const uint8_t *arena)

  capsule_exec_init - Load and execute an init capsule

7.127.1 Macro Definition Documentation

7.127.1.1 CAPSULE_BLOCK_LINES

```
#define CAPSULE_BLOCK_LINES 16
```

7.127.1.2 CAPSULE_EXEC_LINE_MAX

```
#define CAPSULE_EXEC_LINE_MAX 256
```

7.127.1.3 CAPSULE_LINE_COLS

```
#define CAPSULE_LINE_COLS 64
```

7.127.1.4 CAPSULE_MAX_DEFERRED

```
#define CAPSULE_MAX_DEFERRED CAPSULE_BLOCK_LINES
```

7.127.1.5 CAPSULE_RAM_OFFSET

```
#define CAPSULE_RAM_OFFSET 2048u
```

capsule_loader.c - Block Capsule Loader and Executor (M7.1)

Parses a capsule payload for "Block <num>" headers and implements the full init sequence:

1. Write blocks to ramdrive (2048+) — establishes device content so FORTH can call LOAD N later if needed.
2. Execute each block directly from payload bytes via exec_block_with_retry. exec_block_with_retry receives a C pointer into the payload; it does NOT use the block device, so no dedicated-RAM copy is needed here.
3. Zero dedicated RAM slots so userspace can reuse them.

The ramdrive (2048+) is the fallback device when no physical block device is mounted.

7.127.1.6 LOADER_BLOCK_SIZE

```
#define LOADER_BLOCK_SIZE 1024u
```

7.127.2 Function Documentation

7.127.2.1 capsule_clear_blocks()

```
void capsule_clear_blocks (
            const uint8_t * payload,
            uint64_t length )
```

capsule_clear_blocks - Zero all ramdrive slots referenced in a capsule payload

Re-parses the payload for "Block <num>" headers and zeros each corresponding 1024-byte ramdrive slot. NOT called by capsule_exec_init() (fixed 2026-09-10 – see its own doc comment): callers that specifically want a capsule's block range freed for reuse (e.g. kernel_main.c, right after Mama's own init.4th birth, to free that range for interactive block-editor use) call this themselves, explicitly, after exec returns.

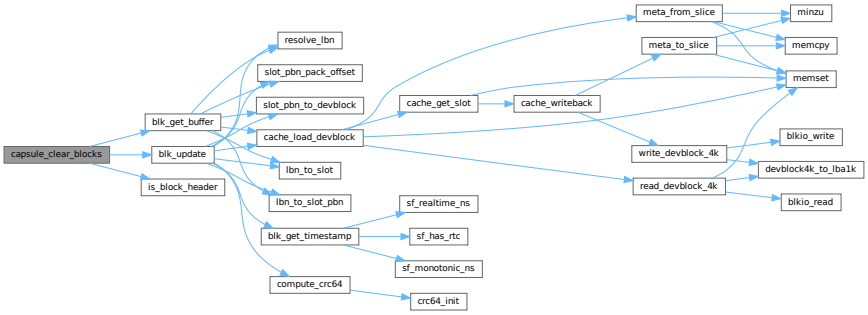
Parameters

payload	Raw capsule payload bytes
length	Payload length in bytes

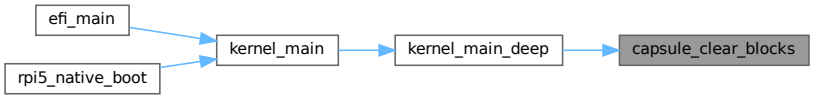
References blk_get_buffer(), blk_update(), is_block_header(), and LOADER_BLOCK_SIZE.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.127.2.2 capsule_exec_init()

```
CapsuleRunResult capsule_exec_init (
            void * vm,
            const char * capsule_name,
            const CapsuleDirHeader * dir,
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena )
```

capsule_exec_init - Load and execute an init capsule

Full init sequence:

1. Locate capsule by colon-separated name in the capsule directory
2. Validate content hash

3. capsule_exec_payload: populate block device + execute content

Block content is NOT cleared afterward (fixed 2026-09-10): it stays resident in ramdrive storage so a subsequent Standard BLOCK/LOAD on the same block number reads back what EXEC just wrote, matching FORTH-79 block-persistence semantics. Callers that specifically want the old "free this capsule's block range" behavior (e.g. kernel_main.c freeing init.4th's range for later interactive block-editor use) call capsule_clear_blocks() themselves, explicitly, after this returns.

Parameters

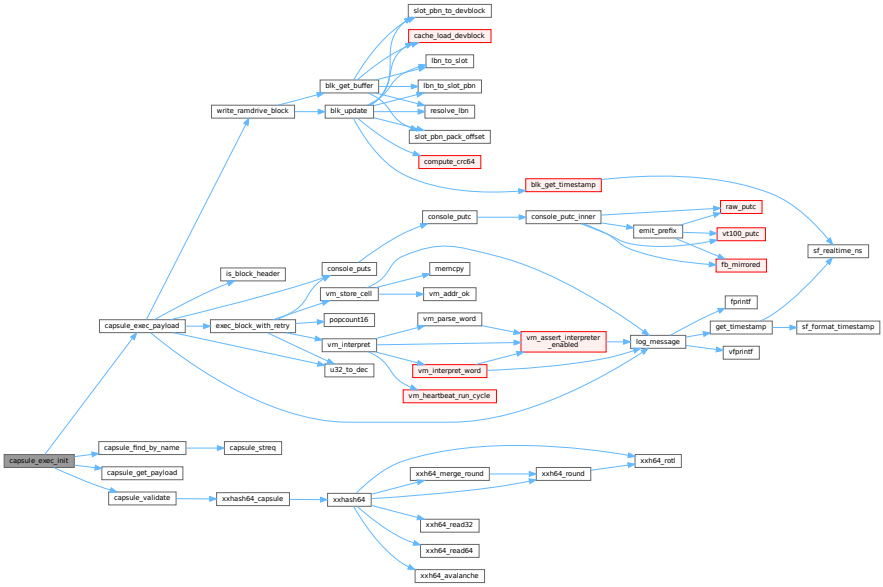
vm	VM to execute on
capsule_name	Colon-separated capsule name, e.g. "init.4th"
dir	Capsule directory header
descs	Capsule descriptor array
names	Capsule name entry array (parallel to descs)
arena	Capsule payload arena

Returns

CAPSULE_RUN_OK on success, error code otherwise

References CapsuleDirHeader::arena_size, capsule_exec_payload(), capsule_find_by_name(), capsule_get_payload(), CAPSULE_RUN_ERR_EXEC_FAIL, CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_OK, CAPSULE_VALID, capsule_validate(), and CapsuleDesc.

Here is the call graph for this function:



7.127.2.3 capsule_exec_payload()

```
int capsule_exec_payload (
            void * vm_opaque,
            const uint8_t * payload,
            uint64_t length )
```

capsule_exec_payload - Parse, populate block device, and execute a payload

For each "Block <num>" section: write content to block device (warn+truncate if > 1KB), then execute line-by-line via vm_interpret. No LOAD is injected.

Parameters

vm_opaque	VM to execute on
payload	Raw payload bytes
length	Payload length in bytes

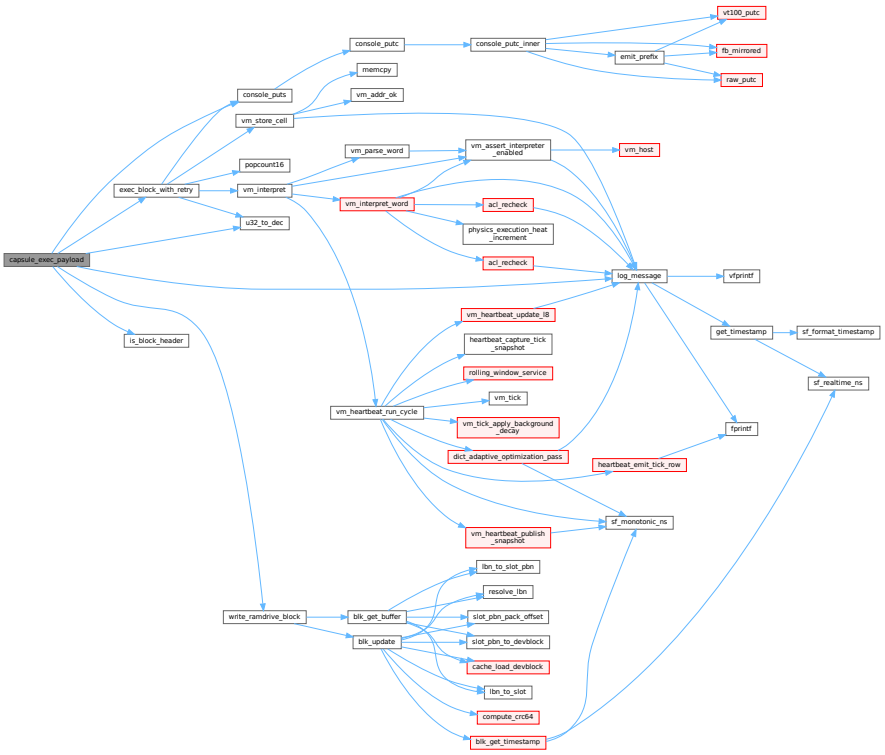
Returns

0 on success, -1 on execution error

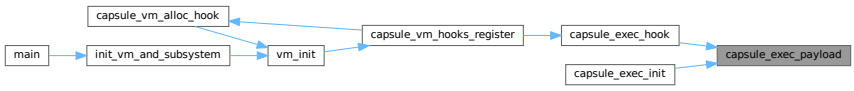
References console_puts(), exec_block_with_retry(), is_block_header(), LOADER_BLOCK_SIZE, LOG_INFO, log_message(), u32_to_dec(), and write_ramdrive_block().

Referenced by capsule_exec_hook(), and capsule_exec_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.127.2.4 capsule_load_blocks()

```
int capsule_load_blocks (
            const uint8_t * payload,
            uint64_t length,
            uint32_t * out_entry_block )
```

capsule_loader.h - Block Capsule Loader and Executor (M7.1)

Parses a capsule payload for "Block <num>" headers and writes each block's content into the correct ramdrive slot, then executes the entry block and zeros the ramdrive slots afterward.

Format: Block <decimal>
<content: up to 1024 bytes of FORTH source> Block <decimal>
...

Blocks may appear in any order; block numbers are arbitrary. Content exceeding 1024 bytes is truncated with a warning. capsule_load_blocks - Parse a capsule payload and write blocks to the ramdrive

For each "Block <num>" header found in the payload:

1. Zero the 1024-byte ramdrive slot for block <num>
2. Copy content bytes into the slot (excess beyond 1024 silently dropped)
3. Mark the slot dirty via blk_update()

Content between headers may be text or binary. Anything before the first "Block <num>" header is ignored.

Parameters

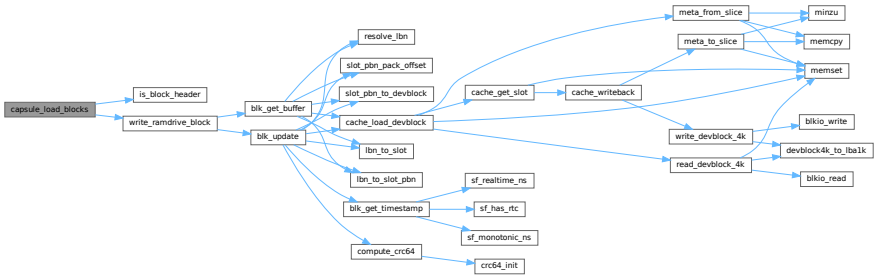
payload	Raw capsule payload bytes (not null-terminated)
length	Payload length in bytes
out_entry_block	If non-NULL, receives the first block number found (the execution entry point); set to 0 if no blocks found

Returns

Number of blocks written, or -1 on invalid input

References is_block_header(), and write_ramdrive_block().

Here is the call graph for this function:



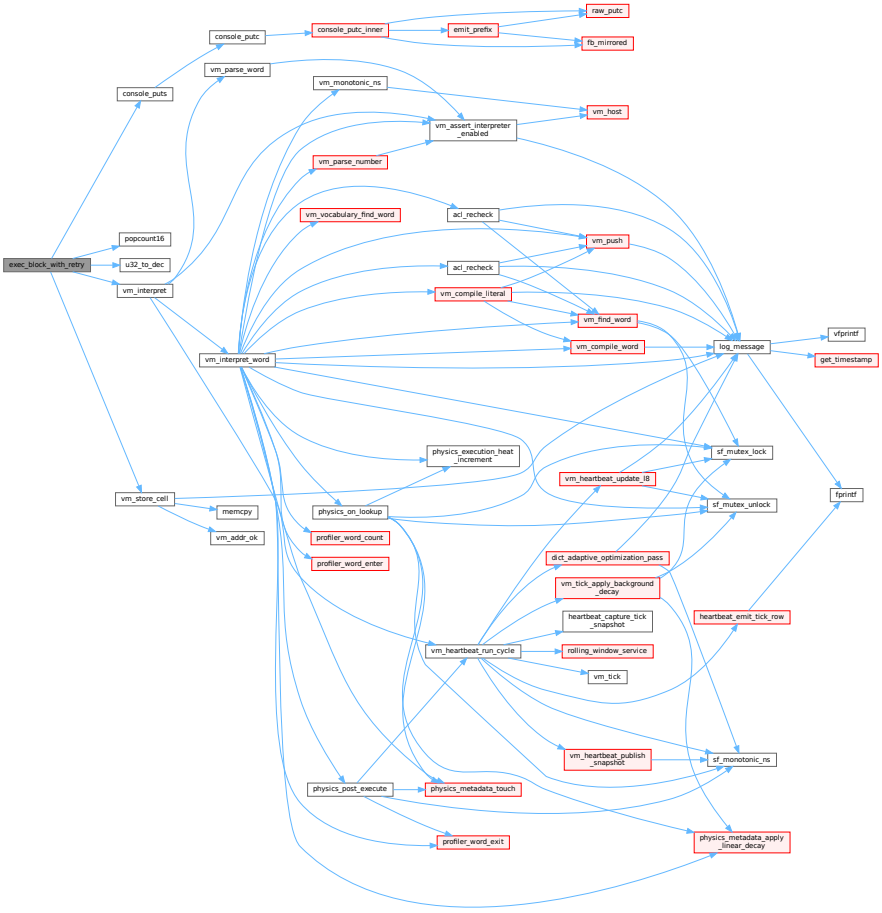
7.127.2.5 exec_block_with_retry()

```
static int exec_block_with_retry (
            VM * vm,
            const uint8_t * block_start,
            size_t block_len,
            uint32_t block_num )  [static]
```

References VM::abort_requested, CAPSULE_BLOCK_LINES, CAPSULE_EXEC_LINE_MAX, CAPSULE_LINE_COLS, console_puts(), VM::error, VM::mode, MODE_INTERPRET, popcount16(), VM::state_addr, VM::state_var, u32_to_dec(), vm_interpret(), and vm_store_cell().

Referenced by capsule_exec_payload().

Here is the call graph for this function:



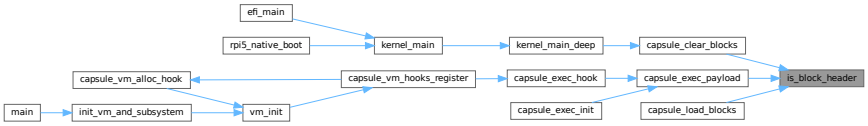
Here is the caller graph for this function:

7.127.2.6 is_block_header()

```
static int is_block_header (
            const uint8_t * p,
            const uint8_t * end,
            uint32_t * out_num,
            const uint8_t ** out_after )  [static]
```

Referenced by capsule_clear_blocks(), capsule_exec_payload(), and capsule_load_blocks().

Here is the caller graph for this function:

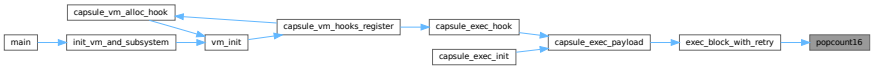


7.127.2.7 popcount16()

```
static int popcount16 (
            uint16_t v )  [static]
```

Referenced by exec_block_with_retry().

Here is the caller graph for this function:

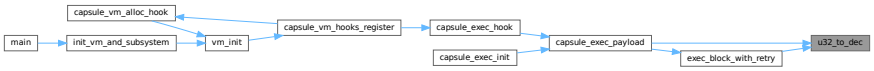


7.127.2.8 u32_to_dec()

```
static size_t u32_to_dec (
            uint32_t val,
            char * buf,
            size_t size )  [static]
```

Referenced by capsule_exec_payload(), and exec_block_with_retry().

Here is the caller graph for this function:



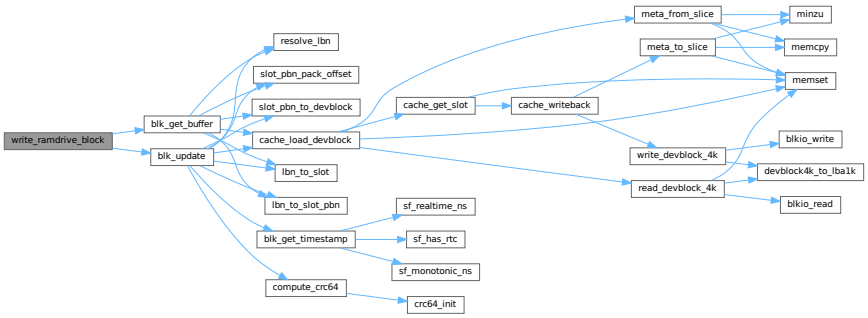
7.127.2.9 write_ramdrive_block()

```
static void write_ramdrive_block (
            uint32_t block_num,
            const uint8_t * content,
            uint32_t content_len )  [static]
```

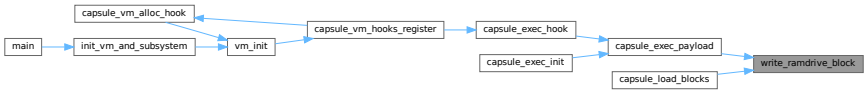
References blk_get_buffer(), blk_update(), and LOADER_BLOCK_SIZE.

Referenced by capsule_exec_payload(), and capsule_load_blocks().

Here is the call graph for this function:



Here is the caller graph for this function:

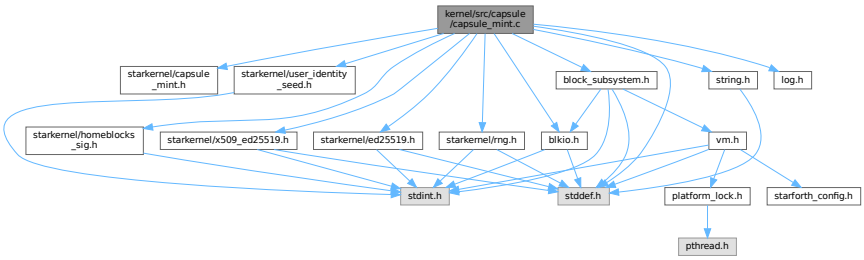


7.128 kernel/src/capsule/capsule_mint.c File Reference

```
#include "starkernel/capsule_mint.h"
#include "starkernel/homeblocks_sig.h"
#include "starkernel/user_identity_seed.h"
#include "starkernel/x509_ed25519.h"
#include "starkernel/ed25519.h"
#include "starkernel/rng.h"
#include "block_subsystem.h"
#include "blkio.h"
#include "log.h"
#include <string.h>
```

```
#include <stddef.h>
```

Include dependency graph for capsule_mint.c:



Macros

- #define MINT_CERT_DEVBLOCK 2u
- #define MINT_CERT_DEVBLOCKS 1u
- #define MINT_IDENTITY_SRC_OFFSET 3u
- #define MINT_IDENTITY_SRC_DEVBLOCKS 2u /∗ 1 seed record + 1 personality source ∗/
- #define MINT_METADATA_DEVBLOCKS 5u /∗ devblocks 0..4 reserved ∗/

Functions

- size_t blkio_ram_state_size (void)

  Return the byte size required for a `blkio_ram_state_t`.
- const blkio_vtable_t ∗ blkio_ram_vtable (void)

  Return the vtable for the RAM block I/O backend.
- int blkio_ram_init_state (void ∗state_mem, size_t state_len, uint8_t ∗base, uint32_t total_blocks, uint32_t fbs, uint8_t read_only, void ∗∗out_opaque)

  Initialise a `blkio_ram_state_t` in caller-provided memory.
- static int write_devblock (struct blkio_dev ∗dev, uint32_t devblock, const uint8_t ∗buf4096)
- static int read_devblock (struct blkio_dev ∗dev, uint32_t devblock, uint8_t ∗buf4096)
- static int verify_mint (struct blkio_dev ∗dev, uint32_t identity_src_offset, const user_identity_seed_t ∗written↩ _idrec)
- MintResult capsule_mint_identity (struct blkio_dev ∗dev, VM ∗issuer_vm, const char ∗full_name, const char ∗username, const char ∗email, const char ∗phone, uint8_t out_pubkey[32], uint8_t out_seed[32], Mint↩ Personality personality, int drive_known_blank)
- MintResult capsule_mint_identity_scratch (VM ∗issuer_vm, const char ∗full_name, const char ∗username, const char ∗email, const char ∗phone, MintPersonality personality, uint8_t out_uuid[16], uint8_t out_↩ cert[4096])

Variables

- static const char MINT_DEFAULT_PERSONALITY [ ]
- static const char MINT_RESTRICTED_PERSONALITY [ ]

7.128.1 Macro Definition Documentation

7.128.1.1 MINT_CERT_DEVBLOCK

```
#define MINT_CERT_DEVBLOCK 2u
```

7.128.1.2 MINT_CERT_DEVBLOCKS

```
#define MINT_CERT_DEVBLOCKS 1u
```

7.128.1.3 MINT_IDENTITY_SRC_DEVBLOCKS

```
#define MINT_IDENTITY_SRC_DEVBLOCKS 2u /* 1 seed record + 1 personality source */
```

7.128.1.4 MINT_IDENTITY_SRC_OFFSET

```
#define MINT_IDENTITY_SRC_OFFSET 3u
```

7.128.1.5 MINT_METADATA_DEVBLOCKS

```
#define MINT_METADATA_DEVBLOCKS 5u /* devblocks 0..4 reserved */
```

7.128.2 Function Documentation

7.128.2.1 blkio_ram_init_state()

```
int blkio_ram_init_state (
            void * state_mem,
            size_t state_len,
            uint8_t * base,
            uint32_t total_blocks,
            uint32_t fbs,
            uint8_t read_only,
            void ** out_opaque )  [extern]
```

Initialise a `blkio_ram_state_t` in caller-provided memory.

Stores `base`, `total_blocks`, `fbs` (defaulting to `BLKIO_FORTH_BLOCK_SIZE` if zero), and `read_only` into the state struct at `state_mem`. Sets `*out_opaque` to point to the state. The caller owns the `base` memory and must ensure it remains valid for the device lifetime.

Parameters

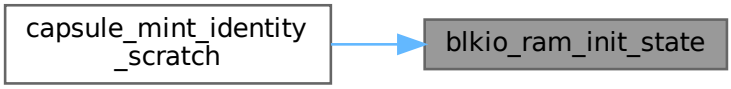
state_mem	Caller-allocated buffer (must be >= blkio_ram_state_size())
state_len	Size of `state_mem` in bytes
base	Pointer to the RAM block array
total_blocks	Number of FORTH blocks in `base`
fbs	FORTH block size in bytes (0 = use default)
read_only	1 = deny writes, 0 = allow reads and writes
out_opaque	Output: set to `state_mem` on success

Returns

`BLKIO_OK` on success, `BLKIO_EINVAL` on bad arguments

Referenced by capsule_mint_identity_scratch().

Here is the caller graph for this function:



7.128.2.2 blkio_ram_state_size()

```
size_t blkio_ram_state_size (
            void  )  [extern]
```

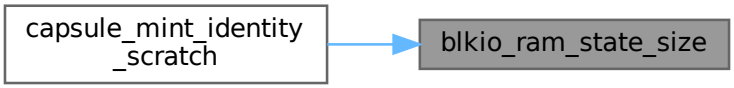
Return the byte size required for a `blkio_ram_state_t`.

Returns

sizeof(blkio_ram_state_t)

Referenced by capsule_mint_identity_scratch().

Here is the caller graph for this function:



7.128.2.3 blkio_ram_vtable()

```
const blkio_vtable_t * blkio_ram_vtable (
            void  )  [extern]
```

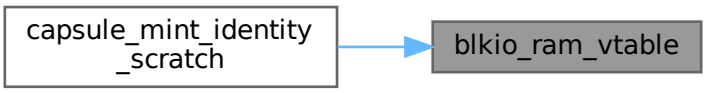
Return the vtable for the RAM block I/O backend.

Returns

Pointer to the static `blkio_vtable_t` for RAM devices

Referenced by capsule_mint_identity_scratch().

Here is the caller graph for this function:



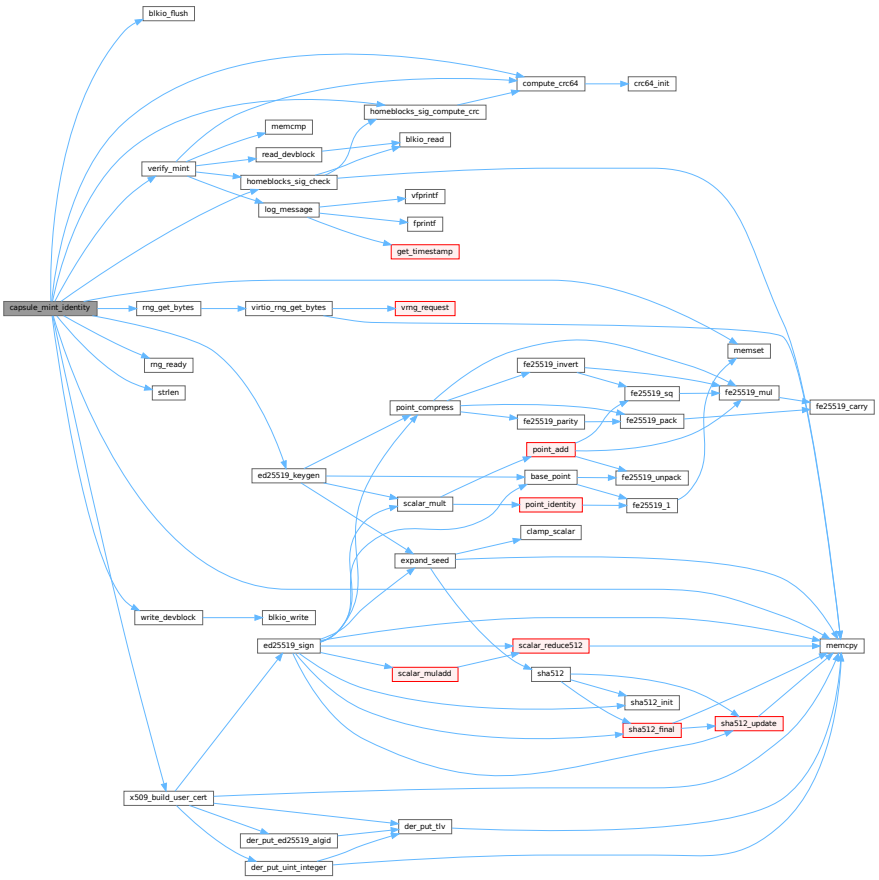
7.128.2.4 capsule_mint_identity()

```
MintResult capsule_mint_identity (
              struct blkio_dev * dev,
              VM * issuer_vm,
              const char * full_name,
              const char * username,
              const char * email,
              const char * phone,
              uint8_t out_pubkey[32],
              uint8_t out_seed[32],
              MintPersonality personality,
              int drive_known_blank )
```

References blkio_flush(), homeblocks_sig_t::cert_devblocks, homeblocks_sig_t::cert_offset, compute_crc64(), user_identity_seed_t::crc, homeblocks_sig_t::drive_uuid, ed25519_keygen(), user_identity_seed_t::email, user_identity_seed_t::full_name, homeblocks_sig_t::hdr_crc, homeblocks_sig_check(), homeblocks_sig_compute_crc(), HOMEBLOCKS_SIG_OK, HOMEBLOCKS_SIG_PACK, HOMEBLOCKS_SIG_START_FBLOCK, HOMEBLOCKS_SIG_VERSION_0, homeblocks_sig_t::identity_src_devblocks, homeblocks_sig_t::identity_src_offset, homeblocks_sig_t::magic, user_identity_seed_t::magic, memcpy(), memset(), homeblocks_sig_t::metadata_devblocks, MINT_CERT_DEVBLOCK, MINT_CERT_DEVBLOCKS, MINT_DEFAULT_PERSONALITY, MINT_IDENTITY_SRC_DEVBLOCKS, MINT_IDENTITY_SRC_OFF MINT_METADATA_DEVBLOCKS, MINT_RESTRICTED_PERSONALITY, homeblocks_sig_t::minted_time_ns, user_identity_seed_t::phone, user_identity_seed_t::pubkey, rng_get_bytes(), rng_ready(), user_identity_seed_t::seed, strlen(), USER_IDENTITY_EMAIL_MAX, USER_IDENTITY_FULL_NAME_MAX, USER_IDENTITY_PHONE_MAX, USER_IDENTITY_SEED_MAGIC, USER_IDENTITY_SEED_VERSION, USER_IDENTITY_USERNAME_MAX, user_identity_seed_t::username, verify_mint(), user_identity_seed_t::version, write_devblock(), x509_build_user_cert(), VM::zuse_cert_installed, and VM::zuse_cert_seed.

Referenced by capsule_mint_identity_scratch(), and capsule_zuse_boot_genesis_mint().

Here is the call graph for this function:



Here is the caller graph for this function:

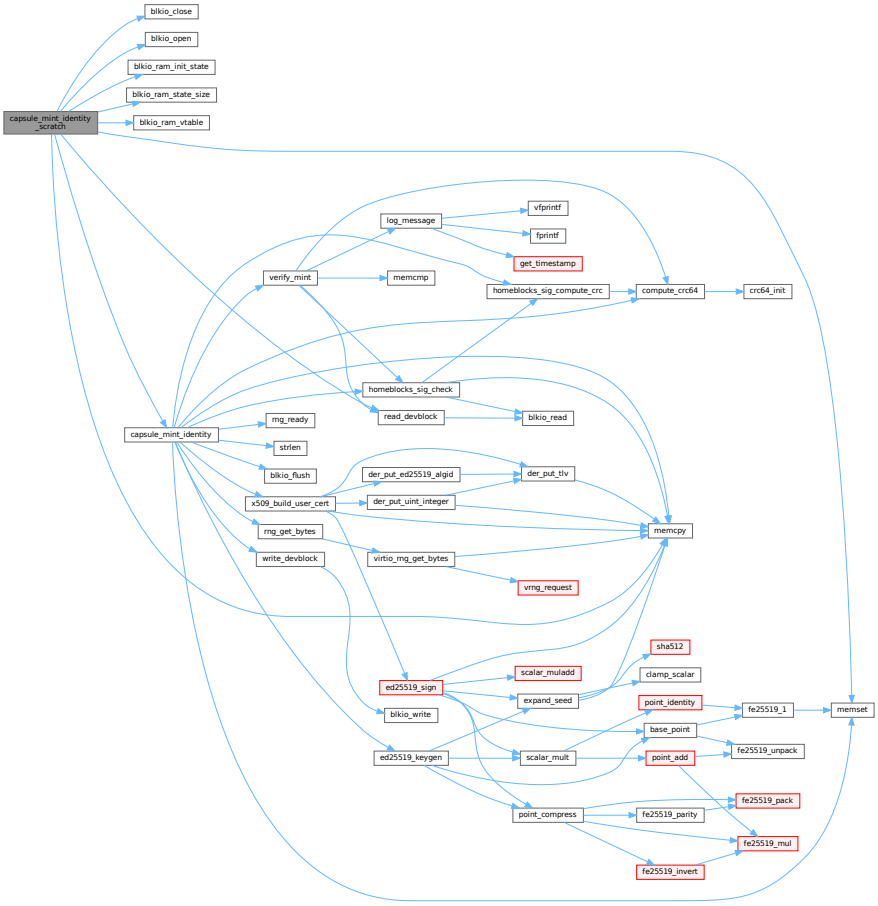
7.128.2.5 capsule_mint_identity_scratch()

```
MintResult capsule_mint_identity_scratch (
            VM * issuer_vm,
            const char * full_name,
            const char * username,
            const char * email,
            const char * phone,
            MintPersonality personality,
```

```
            uint8_t out_uuid[16],
            uint8_t out_cert[4096] )
```

References blkio_close(), BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_open(), blkio_ram_init_state(), blkio_ram_state_size(), blkio_ram_vtable(), capsule_mint_identity(), blkio_params_t::forth_block_size, HOMEBLOCKS_SIG_START_, memcpy(), memset(), MINT_CERT_DEVBLOCK, MINT_METADATA_DEVBLOCKS, and read_devblock().

Here is the call graph for this function:



7.128.2.6 read_devblock()

```
static int read_devblock (
            struct blkio_dev * dev,
            uint32_t devblock,
            uint8_t * buf4096 )  [static]
```

References base, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, and blkio_read().

Referenced by capsule_mint_identity_scratch(), and verify_mint().

Here is the call graph for this function:

Here is the caller graph for this function:

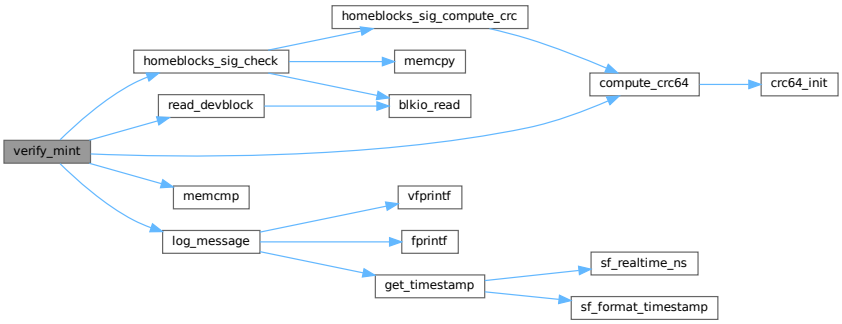
7.128.2.7 verify_mint()

```
static int verify_mint (
            struct blkio_dev * dev,
            uint32_t identity_src_offset,
            const user_identity_seed_t * written_idrec )  [static]
```

References compute_crc64(), user_identity_seed_t::crc, homeblocks_sig_check(), HOMEBLOCKS_SIG_OK, HOMEBLOCKS_SIG_START_FBLOCK, LOG_ERROR, LOG_INFO, log_message(), user_identity_seed_t::magic, memcmp(), read_devblock(), and user_identity_seed_t::version.

Referenced by capsule_mint_identity().

Here is the call graph for this function:



Here is the caller graph for this function:

7.128.2.8 write_devblock()

```
static int write_devblock (
            struct blkio_dev * dev,
            uint32_t devblock,
            const uint8_t * buf4096 )  [static]
```

References base, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, and blkio_write().

Referenced by capsule_mint_identity().

Here is the call graph for this function:

Here is the caller graph for this function:

7.128.3 Variable Documentation

7.128.3.1 MINT_DEFAULT_PERSONALITY

```
const char MINT_DEFAULT_PERSONALITY[]  [static]
```

Initial value:

```
=
    "Block 4999\n"
    ": WELCOME ( -- ) .\" Minted identity -- default personality\" CR ;\n"
    "WELCOME\n"
```

Referenced by capsule_mint_identity().

7.128.3.2 MINT_RESTRICTED_PERSONALITY

```
const char MINT_RESTRICTED_PERSONALITY[]  [static]
```

Initial value:

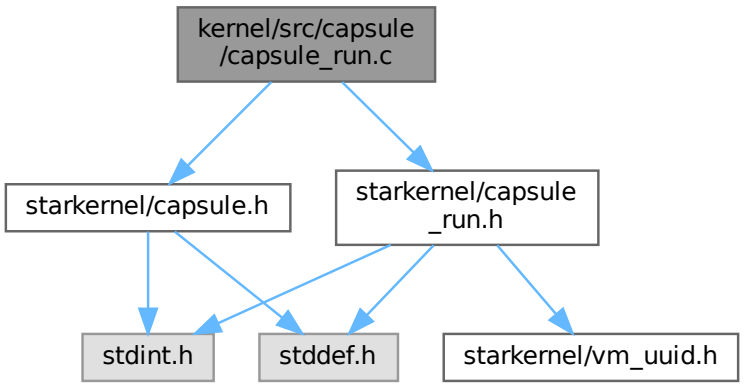
```
=
    "Block 4998\n"
    "S\" acl-std79.4th\" EXEC\n"
    "ACL-LOCKDOWN-STD79\n"
    ": WELCOME ( -- ) .\" Minted identity -- FORTH-79/83 standard words only\" CR ;\n"
    "WELCOME\n"
```

Referenced by capsule_mint_identity().

7.129 kernel/src/capsule/capsule_run.c File Reference

```
#include "starkernel/capsule_run.h"
#include "starkernel/capsule.h"
```

Include dependency graph for capsule_run.c:



Macros

- #define PARITY_HAVE_SINK (parity_puts != 0)

  capsule_run.c - DoE Run Logging and Parity (M7.1)
- #define PARITY_EMIT(s) do { if (parity_puts) parity_puts(s); } while (0)

Functions

- void capsule_run_log_init (void)

  capsule_run_log_init - Initialize run log
- uint64_t capsule_run_log_record (const CapsuleRunRecord *record)

  capsule_run_log_record - Log a run record
- int capsule_run_log_get (uint64_t run_id, CapsuleRunRecord *out)

  capsule_run_log_get - Get a run record by ID

- uint32_t capsule_run_log_count (void)

  capsule_run_log_count - Get number of logged runs
- void capsule_parity_set_output (void(*putc_fn)(char), void(*puts_fn)(const char *))

  capsule_parity_set_output - Set output hooks for parity logging
- static void parity_put_hex64 (uint64_t val)
- static void parity_put_uuid (VMUuid id)
- static void parity_put_u32 (uint32_t val)
- static void parity_put_u64 (uint64_t val)
- void capsule_parity_log_birth (VMUuid vm_id, uint64_t capsule_id, uint64_t capsule_hash, uint64_t dict_↩ hash)

  capsule_parity_log_birth - Log VM birth parity record
- void capsule_parity_log_birth_failed (VMUuid vm_id, uint64_t capsule_id, CapsuleRunResult error, uint64_t partial_dict_hash)

  capsule_parity_log_birth_failed - Log failed birth
- void capsule_parity_log_run (VMUuid vm_id, uint64_t run_id, uint64_t capsule_id, uint64_t pre_dict_hash, uint64_t post_dict_hash)

  capsule_parity_log_run - Log DoE run parity record
- void capsule_parity_log_mama_init (uint64_t capsule_id, uint64_t capsule_hash, uint64_t dict_hash)

  capsule_parity_log_mama_init - Log Mama init parity record
- void capsule_parity_log_kill (VMUuid vm_id, const char *name)

  capsule_parity_log_kill - Log VM kill parity record

Variables

- static CapsuleRunRecord run_log [1024]
- static uint32_t run_log_head = 0
- static uint32_t run_log_count = 0
- static uint64_t run_id_counter = 0
- static void(* parity_putc)(char c)=0
- static void(* parity_puts)(const char *s)=0

7.129.1 Macro Definition Documentation

7.129.1.1 PARITY_EMIT

```
#define PARITY_EMIT(
              s ) do { if (parity_puts) parity_puts(s); } while (0)
```

7.129.1.2 PARITY_HAVE_SINK

```
#define PARITY_HAVE_SINK (parity_puts != 0)
```

capsule_run.c - DoE Run Logging and Parity (M7.1)

Ring buffer for capsule execution logging and parity record emission. Freestanding - no libc dependency except for console output hooks.

7.129.2 Function Documentation

7.129.2.1 capsule_parity_log_birth()

```
void capsule_parity_log_birth (
            VMUuid vm_id,
            uint64_t capsule_id,
            uint64_t capsule_hash,
            uint64_t dict_hash )
```

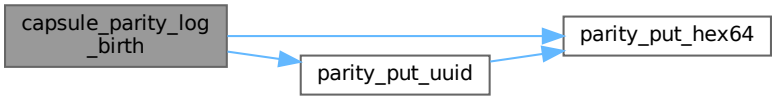
capsule_parity_log_birth - Log VM birth parity record

Output format: PARITY:BIRTH vm_id=N capsule_id=X mode=p capsule_hash=H dict_hash=D

References PARITY_EMIT, PARITY_HAVE_SINK, parity_put_hex64(), and parity_put_uuid().

Referenced by capsule_birth_baby().

Here is the call graph for this function:



Here is the caller graph for this function:

7.129.2.2 capsule_parity_log_birth_failed()

```
void capsule_parity_log_birth_failed (
            VMUuid vm_id,
            uint64_t capsule_id,
            CapsuleRunResult error,
            uint64_t partial_dict_hash )
```

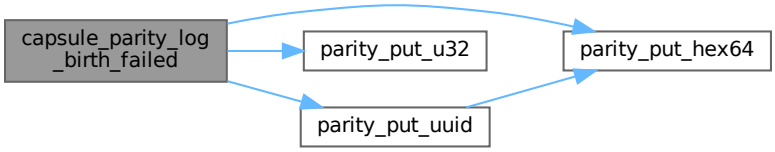
capsule_parity_log_birth_failed - Log failed birth

Output format: PARITY:BIRTH_FAILED vm_id=N capsule_id=X error=E partial_dict_hash=H

References PARITY_EMIT, PARITY_HAVE_SINK, parity_put_hex64(), parity_put_u32(), and parity_put_uuid().

Referenced by capsule_birth_baby().

Here is the call graph for this function:



Here is the caller graph for this function:

7.129.2.3 capsule_parity_log_kill()

```
void capsule_parity_log_kill (
            VMUuid vm_id,
            const char * name )
```

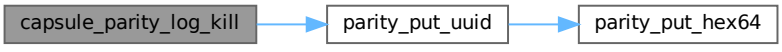
capsule_parity_log_kill - Log VM kill parity record

Output format: PARITY:KILL vm_id=N name=X

References name, PARITY_EMIT, PARITY_HAVE_SINK, and parity_put_uuid().

Referenced by capsule_vm_force_reap(), capsule_vm_kill(), and capsule_vm_kill_all_nonmama().

Here is the call graph for this function:



Here is the caller graph for this function:

7.129.2.4 capsule_parity_log_mama_init()

```
void capsule_parity_log_mama_init (
            uint64_t capsule_id,
            uint64_t capsule_hash,
            uint64_t dict_hash )
```

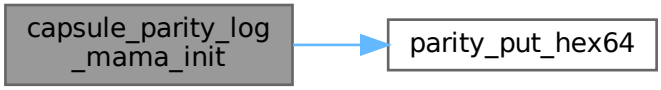
capsule_parity_log_mama_init - Log Mama init parity record

Output format: PARITY:MAMA_INIT capsule_id=X mode=m capsule_hash=H dict_hash=D

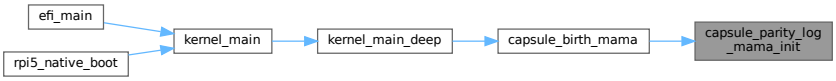
References PARITY_EMIT, PARITY_HAVE_SINK, and parity_put_hex64().

Referenced by capsule_birth_mama().

Here is the call graph for this function:



Here is the caller graph for this function:



7.129.2.5 capsule_parity_log_run()

```
void capsule_parity_log_run (
            VMUuid vm_id,
            uint64_t run_id,
            uint64_t capsule_id,
            uint64_t pre_dict_hash,
            uint64_t post_dict_hash )
```

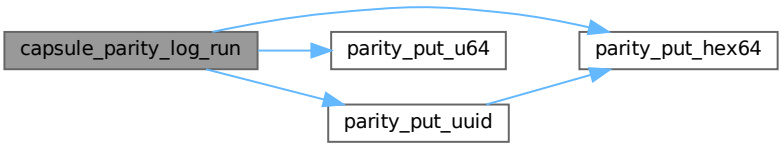
capsule_parity_log_run - Log DoE run parity record

Output format: PARITY:RUN vm_id=N run_id=R capsule_id=X mode=e pre_dict=P post_dict=Q

References PARITY_EMIT, PARITY_HAVE_SINK, parity_put_hex64(), parity_put_u64(), and parity_put_uuid().

Referenced by capsule_run_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

7.129.2.6 capsule_parity_set_output()

```
void capsule_parity_set_output (
            void(*)(char) putc_fn,
            void(*)(const char *) puts_fn )
```

capsule_parity_set_output - Set output hooks for parity logging

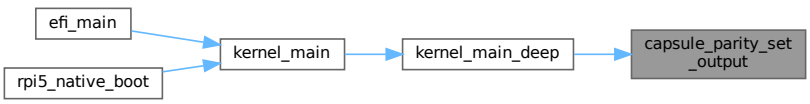
Parameters

putc↩ _fn	Function to output a single character
puts↩ _fn	Function to output a string

References parity_putc, and parity_puts.

Referenced by kernel_main_deep().

Here is the caller graph for this function:



7.129.2.7 capsule_run_log_count()

```
uint32_t capsule_run_log_count (
            void  )
```

capsule_run_log_count - Get number of logged runs

References run_log_count.

7.129.2.8 capsule_run_log_get()

```
int capsule_run_log_get (
            uint64_t run_id,
            CapsuleRunRecord * out )
```

capsule_run_log_get - Get a run record by ID

Parameters

run↩ _id	Run ID to retrieve
out	Output record

Returns

0 on success, -1 if not found

References CAPSULE_MAX_RUN_RECORDS, run_id_counter, and run_log.

7.129.2.9 capsule_run_log_init()

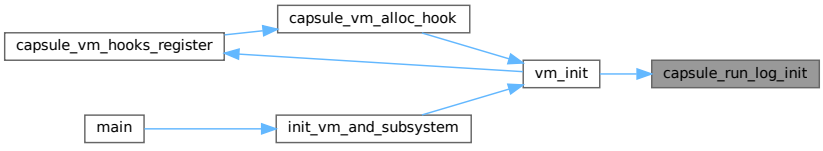
```
void capsule_run_log_init (
            void  )
```

capsule_run_log_init - Initialize run log

References CapsuleRunRecord::capsule_hash, CapsuleRunRecord::capsule_id, CAPSULE_MAX_RUN_RECORDS, CapsuleRunRecord::ended_ns, CapsuleRunRecord::flags, CapsuleRunRecord::post_dict_hash, CapsuleRunRecord::pre_dict_hash, CapsuleRunRecord::reserved, CapsuleRunRecord::result_code, CapsuleRunRecord::run_id, run_id_counter, run_log, run_log_count, run_log_head, CapsuleRunRecord::started_ns, and CapsuleRunRecord::vm_id.

Referenced by vm_init().

Here is the caller graph for this function:



7.129.2.10 capsule_run_log_record()

```
uint64_t capsule_run_log_record (
            const CapsuleRunRecord * record )
```

capsule_run_log_record - Log a run record

Parameters

record	Record to log

Returns

Run ID assigned, or 0 on failure

References CAPSULE_MAX_RUN_RECORDS, CapsuleRunRecord::run_id, run_id_counter, run_log, run_log_count, and run_log_head.

Referenced by capsule_run_experiment().

Here is the caller graph for this function:

7.129.2.11 parity_put_hex64()

```
static void parity_put_hex64 (
            uint64_t val )  [static]
```

References PARITY_EMIT.

Referenced by capsule_parity_log_birth(), capsule_parity_log_birth_failed(), capsule_parity_log_mama_init(), capsule_parity_log_run(), and parity_put_uuid().

Here is the caller graph for this function:

7.129.2.12 parity_put_u32()

```
static void parity_put_u32 (
            uint32_t val )  [static]
```

References PARITY_EMIT.

Referenced by capsule_parity_log_birth_failed().

Here is the caller graph for this function:

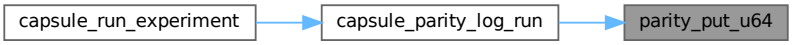
7.129.2.13 parity_put_u64()

```
static void parity_put_u64 (
            uint64_t val )  [static]
```

References PARITY_EMIT.

Referenced by capsule_parity_log_run().

Here is the caller graph for this function:



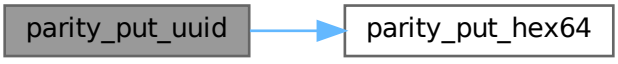
7.129.2.14 parity_put_uuid()

```
static void parity_put_uuid (
            VMUuid id )  [static]
```

References PARITY_EMIT, and parity_put_hex64().

Referenced by capsule_parity_log_birth(), capsule_parity_log_birth_failed(), capsule_parity_log_kill(), and capsule_parity_log_run().

Here is the call graph for this function:



Here is the caller graph for this function:

7.129.3 Variable Documentation

7.129.3.1 parity_putc

```
void(* parity_putc) (char c)=0 (
            char c )  [static]
```

Referenced by capsule_parity_set_output().

7.129.3.2 parity_puts

```
void(* parity_puts) (const char *s)=0 (
            const char * s )  [static]
```

Referenced by capsule_parity_set_output().

7.129.3.3 run_id_counter

```
uint64_t run_id_counter = 0  [static]
```

Referenced by capsule_run_log_get(), capsule_run_log_init(), and capsule_run_log_record().

7.129.3.4 run_log

```
CapsuleRunRecord run_log[1024]  [static]
```

Referenced by capsule_run_log_get(), capsule_run_log_init(), and capsule_run_log_record().

7.129.3.5 run_log_count

```
uint32_t run_log_count = 0  [static]
```

Referenced by capsule_run_log_count(), capsule_run_log_init(), and capsule_run_log_record().

7.129.3.6 run_log_head

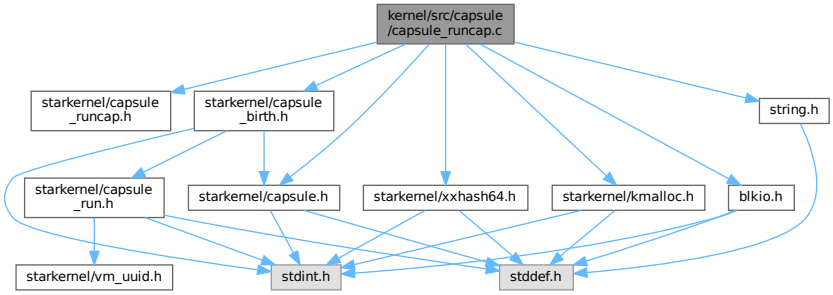
```
uint32_t run_log_head = 0  [static]
```

Referenced by capsule_run_log_init(), and capsule_run_log_record().

7.130 kernel/src/capsule/capsule_runcap.c File Reference

```
#include "starkernel/capsule_runcap.h"
#include "starkernel/capsule.h"
#include "starkernel/capsule_birth.h"
#include "starkernel/xxhash64.h"
#include "starkernel/kmalloc.h"
#include "blkio.h"
#include <string.h>
```

Include dependency graph for capsule_runcap.c:



Functions

- CapsuleRunResult capsule_runcap_birth (struct blkio_dev *dev, const homeblocks_sig_t *sig, const char *vm_name, VMUuid parent, VMUuid *out_vm_id, void **out_vm_ctx)

7.130.1 Function Documentation

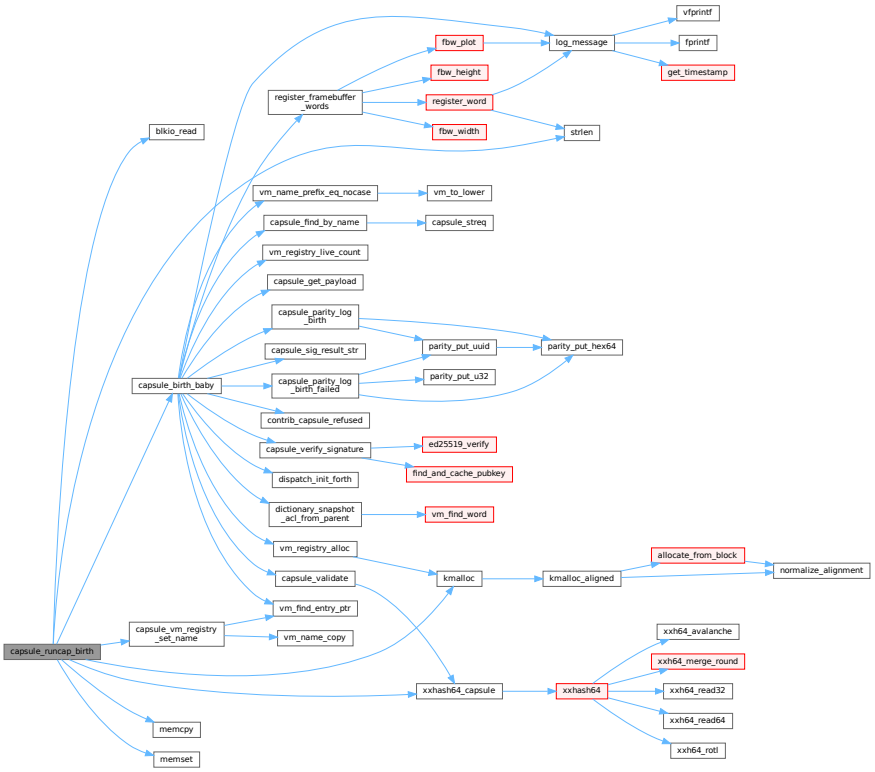
7.130.1.1 capsule_runcap_birth()

```
CapsuleRunResult capsule_runcap_birth (
            struct blkio_dev * dev,
            const homeblocks_sig_t * sig,
            const char * vm_name,
            VMUuid parent,
            VMUuid * out_vm_id,
            void ** out_vm_ctx )
```

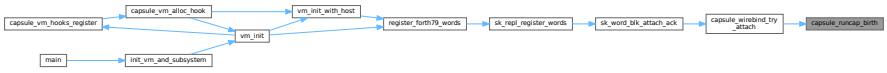
References CapsuleDirHeader::arena_base, CapsuleDirHeader::arena_size, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_read(), capsule_birth_baby(), CAPSULE_DIR_MAGIC, CAPSULE_FLAG_ACTIVE, CAPSULE_FLAG_PRODUCTI CAPSULE_HASH_XXHASH64, CAPSULE_MAGIC_PACK, CAPSULE_NAME_MAX, CAPSULE_RUN_ERR_INVALID, CAPSULE_RUN_ERR_STILLBORN, CAPSULE_RUN_OK, CAPSULE_VERSION_0, capsule_vm_registry_set_name(), CapsuleDesc, CapsuleDirHeader::desc_capacity, CapsuleDirHeader::desc_count, CapsuleDirHeader::dir_hash, homeblocks_sig_t::identity_src_devblocks, homeblocks_sig_t::identity_src_offset, kmalloc(), CapsuleDirHeader::magic, memcpy(), memset(), CapsuleNameEntry::name, CapsuleDirHeader::name_count, strlen(), and xxhash64_capsule().

Referenced by capsule_wirebind_try_attach().

Here is the call graph for this function:



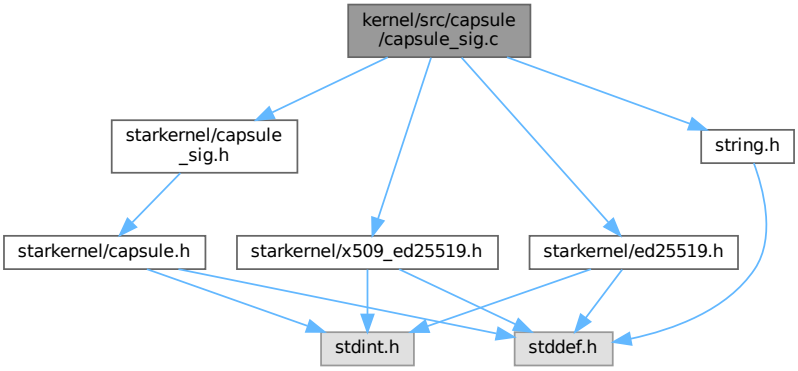
Here is the caller graph for this function:



7.131 kernel/src/capsule/capsule_sig.c File Reference

```
#include "starkernel/capsule_sig.h"
#include "starkernel/x509_ed25519.h"
#include "starkernel/ed25519.h"
#include <string.h>
```

Include dependency graph for capsule_sig.c:



Functions

- static int find_and_cache_pubkey (const CapsuleDesc *descs, const CapsuleNameEntry *names, const uint8_t *arena_base, uint32_t desc_count)
- CapsuleSigResult capsule_verify_signature (const CapsuleDesc *descs, const CapsuleNameEntry *names, const CapsuleSigEntry *sigs, const uint8_t *arena_base, uint32_t desc_count, int index)
- const char * capsule_sig_result_str (CapsuleSigResult result)

Variables

- static int pubkey_state = -1
- static uint8_t cached_pubkey [32]

7.131.1 Function Documentation

7.131.1.1 capsule_sig_result_str()

```
const char * capsule_sig_result_str (
            CapsuleSigResult result )
```

References CAPSULE_SIG_INVALID, CAPSULE_SIG_MISSING, CAPSULE_SIG_NO_ROOT_KEY, and CAPSULE_SIG_OK.

Referenced by capsule_birth_baby(), capsule_birth_mama(), and capsule_run_experiment().

Here is the caller graph for this function:

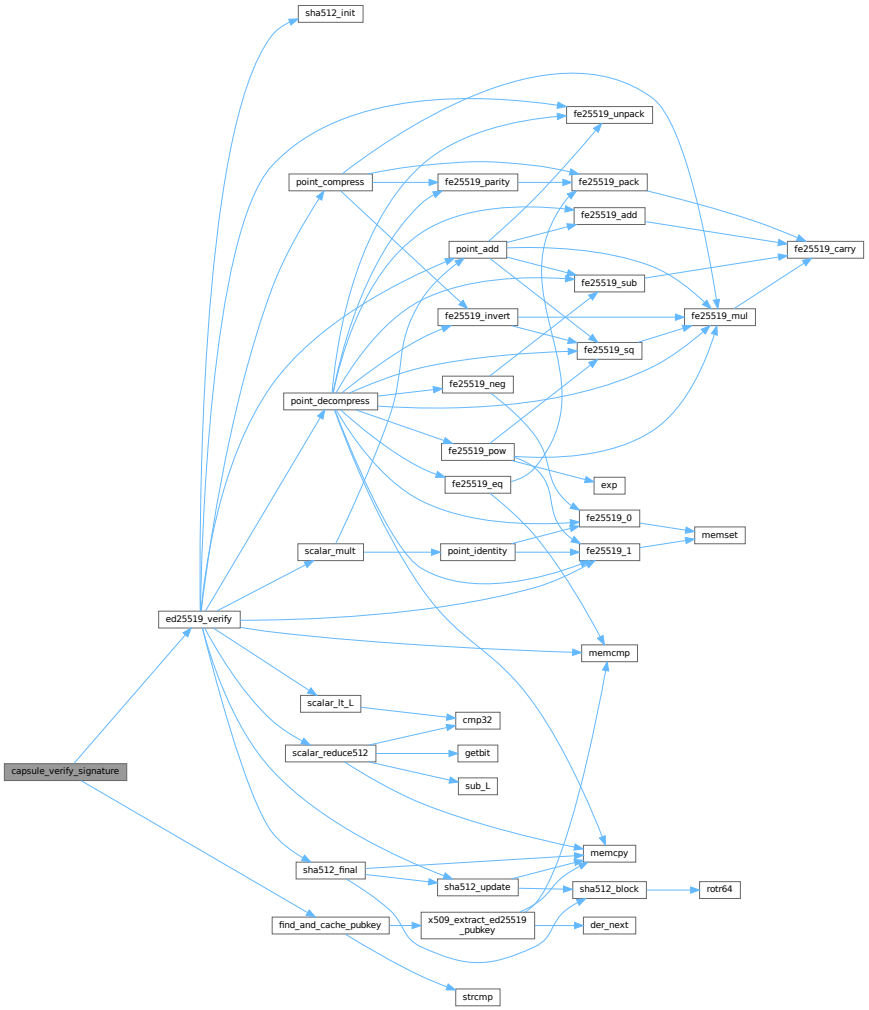
7.131.1.2 capsule_verify_signature()

```
CapsuleSigResult capsule_verify_signature (
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const CapsuleSigEntry * sigs,
            const uint8_t * arena_base,
            uint32_t desc_count,
            int index )
```

References cached_pubkey, CAPSULE_SIG_INVALID, CAPSULE_SIG_MISSING, CAPSULE_SIG_NO_ROOT_KEY, CAPSULE_SIG_OK, CapsuleDesc, ed25519_verify(), find_and_cache_pubkey(), and CapsuleSigEntry::sig.

Referenced by capsule_birth_baby(), capsule_birth_mama(), and capsule_run_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

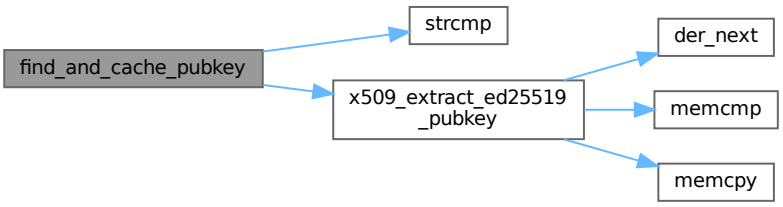
7.131.1.3 find_and_cache_pubkey()

```
static int find_and_cache_pubkey (
            const CapsuleDesc * descs,
            const CapsuleNameEntry * names,
            const uint8_t * arena_base,
            uint32_t desc_count )  [static]
```

References cached_pubkey, CAPSULE_SIGNING_CERT_NAME, CapsuleDesc, name, pubkey_state, strcmp(), and x509_extract_ed25519_pubkey().

Referenced by capsule_verify_signature().

Here is the call graph for this function:



Here is the caller graph for this function:

7.131.2 Variable Documentation

7.131.2.1 cached_pubkey

```
uint8_t cached_pubkey[32]  [static]
```

Referenced by capsule_verify_signature(), and find_and_cache_pubkey().

7.131.2.2 pubkey_state

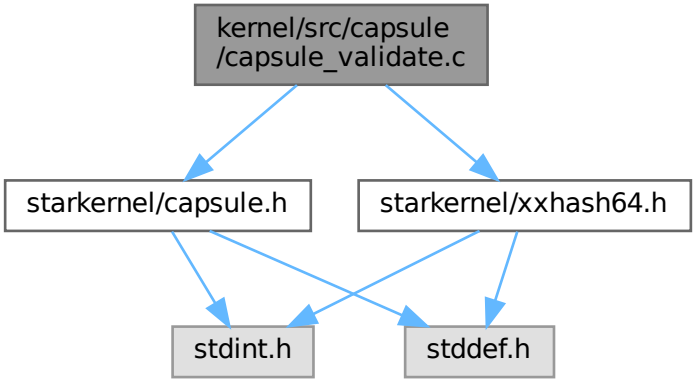
```
int pubkey_state = -1  [static]
```

Referenced by find_and_cache_pubkey().

7.132 kernel/src/capsule/capsule_validate.c File Reference

```
#include "starkernel/capsule.h"
#include "starkernel/xxhash64.h"
```

Include dependency graph for capsule_validate.c:



Functions

- const char * capsule_validate_result_str (CapsuleValidateResult result)

  capsule_validate_result_str - Get string for validation result
- CapsuleValidateResult capsule_validate (const CapsuleDesc *desc, const uint8_t *arena_base, uint64_t arena_size, int verify_hash)

  capsule_validate - Validate a capsule descriptor

Variables

- static const char * validate_result_strings [ ]

  capsule_validate.c - Capsule Validation (M7.1)

7.132.1 Function Documentation

7.132.1.1 capsule_validate()

```
CapsuleValidateResult capsule_validate (
            const CapsuleDesc * desc,
            const uint8_t * arena_base,
            uint64_t arena_size,
            int verify_hash )
```

capsule_validate - Validate a capsule descriptor

Parameters

desc	Capsule descriptor to validate
arena_base	Base address of payload arena
arena_size	Size of payload arena in bytes
verify_hash	If true, recompute and compare content hash

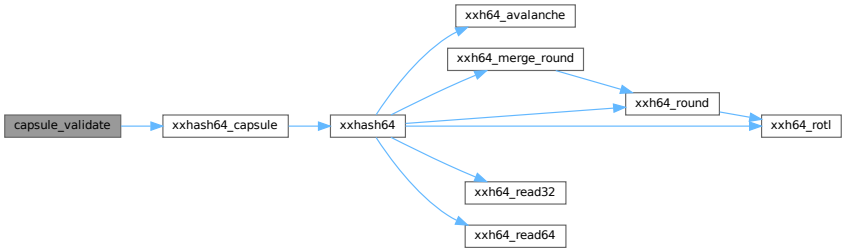
Returns

CAPSULE_VALID on success, error code otherwise

References CAPSULE_DESC_MAGIC, CAPSULE_ERR_BAD_HASH_ALG, CAPSULE_ERR_BAD_MAGIC, CAPSULE_ERR_BAD_VERSION, CAPSULE_ERR_BOUNDS, CAPSULE_ERR_HASH_MISMATCH, CAPSULE_ERR_MODE_INVA CAPSULE_ERR_NULL_PTR, CAPSULE_ERR_REVOKED_ACTIVE, CAPSULE_FLAG_ACTIVE, CAPSULE_FLAG_REVOKED, CAPSULE_HASH_BLAKE3, CAPSULE_HASH_XXHASH64, CAPSULE_MAGIC_GET_HASHALG, CAPSULE_MAGIC_GET_SIG, CAPSULE_MAGIC_GET_VERSION, CAPSULE_MODE_VALID, CAPSULE_VALID, CAPSULE_VERSION_0, and xxhash64_capsule().

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_exec_init(), and capsule_run_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

7.132.1.2 capsule_validate_result_str()

```
const char * capsule_validate_result_str (
            CapsuleValidateResult result )
```

capsule_validate_result_str - Get string for validation result

References validate_result_strings.

7.132.2 Variable Documentation

7.132.2.1 validate_result_strings

```
const char* validate_result_strings[]  [static]
```

Initial value:

```
= {
    "valid",
    "bad magic",
    "bad version",
    "bad hash algorithm",
    "bounds error",
    "mode invalid",
    "revoked but active",
    "hash mismatch",
    "null pointer",
}
```

capsule_validate.c - Capsule Validation (M7.1)

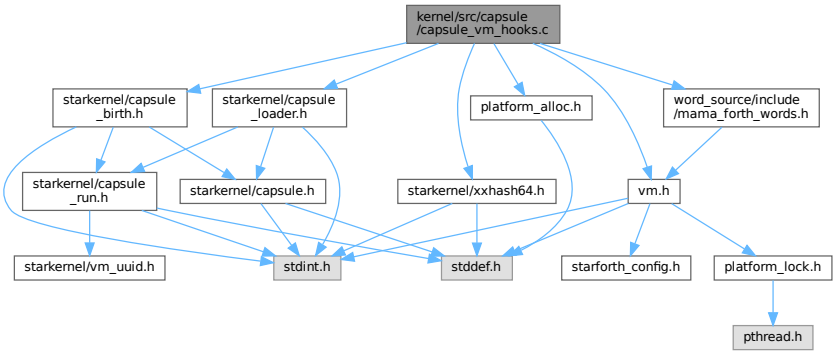
Validates capsule descriptors for structural integrity and content hash. Freestanding - no libc dependency.

Referenced by capsule_validate_result_str().

7.133 kernel/src/capsule/capsule_vm_hooks.c File Reference

```
#include "starkernel/capsule_birth.h"
#include "starkernel/capsule_loader.h"
#include "starkernel/xxhash64.h"
#include "vm.h"
#include "platform_alloc.h"
#include "word_source/include/mama_forth_words.h"
```

Include dependency graph for capsule_vm_hooks.c:



Functions

- static int capsule_exec_hook (void *vm_ctx, const char *code, uint64_t code_len)

  capsule_vm_hooks.c - VM Hook Implementations for Capsule Birth (M7.1)
- static uint64_t capsule_dict_hash_hook (void *vm_ctx)
- static void * capsule_vm_alloc_hook (void)
- void capsule_vm_hooks_register (void)

  capsule_vm_hooks_register - Wire the three hooks into the capsule subsystem.

7.133.1 Function Documentation

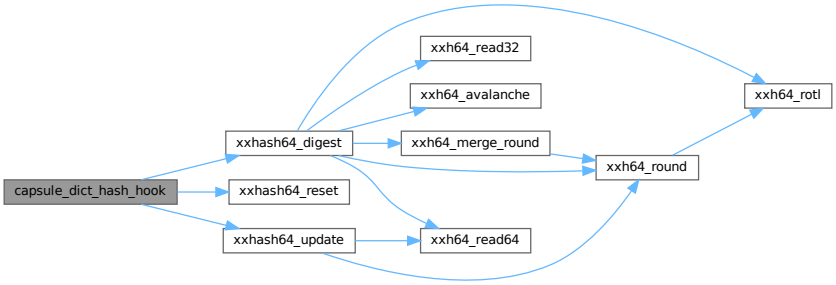
7.133.1.1 capsule_dict_hash_hook()

```
static uint64_t capsule_dict_hash_hook (
            void * vm_ctx )  [static]
```

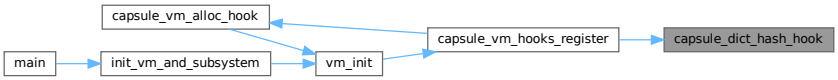
References entry, VM::latest, xxhash64_digest(), xxhash64_reset(), and xxhash64_update().

Referenced by capsule_vm_hooks_register().

Here is the call graph for this function:



Here is the caller graph for this function:



7.133.1.2 capsule_exec_hook()

```
static int capsule_exec_hook (
            void * vm_ctx,
            const char * code,
            uint64_t code_len )  [static]
```

capsule_vm_hooks.c - VM Hook Implementations for Capsule Birth (M7.1)

Concrete implementations of the three function pointers required by capsule_birth_set_hooks():

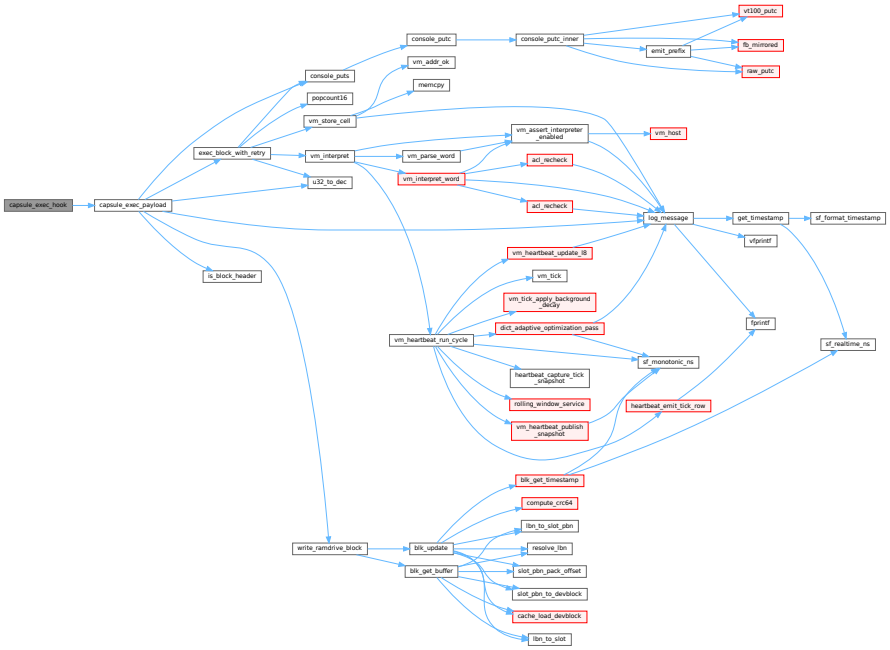
capsule_exec_hook – wraps vm_interpret() capsule_dict_hash_hook – xxhash64 walk of the live dictionary capsule_vm_alloc_hook – allocates and initialises a fresh VM

Call capsule_vm_hooks_register() once during VM bootstrap (after register_forth79_words) to wire everything up.

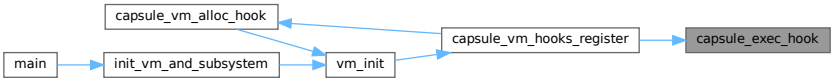
References capsule_exec_payload().

Referenced by capsule_vm_hooks_register().

Here is the call graph for this function:



Here is the caller graph for this function:



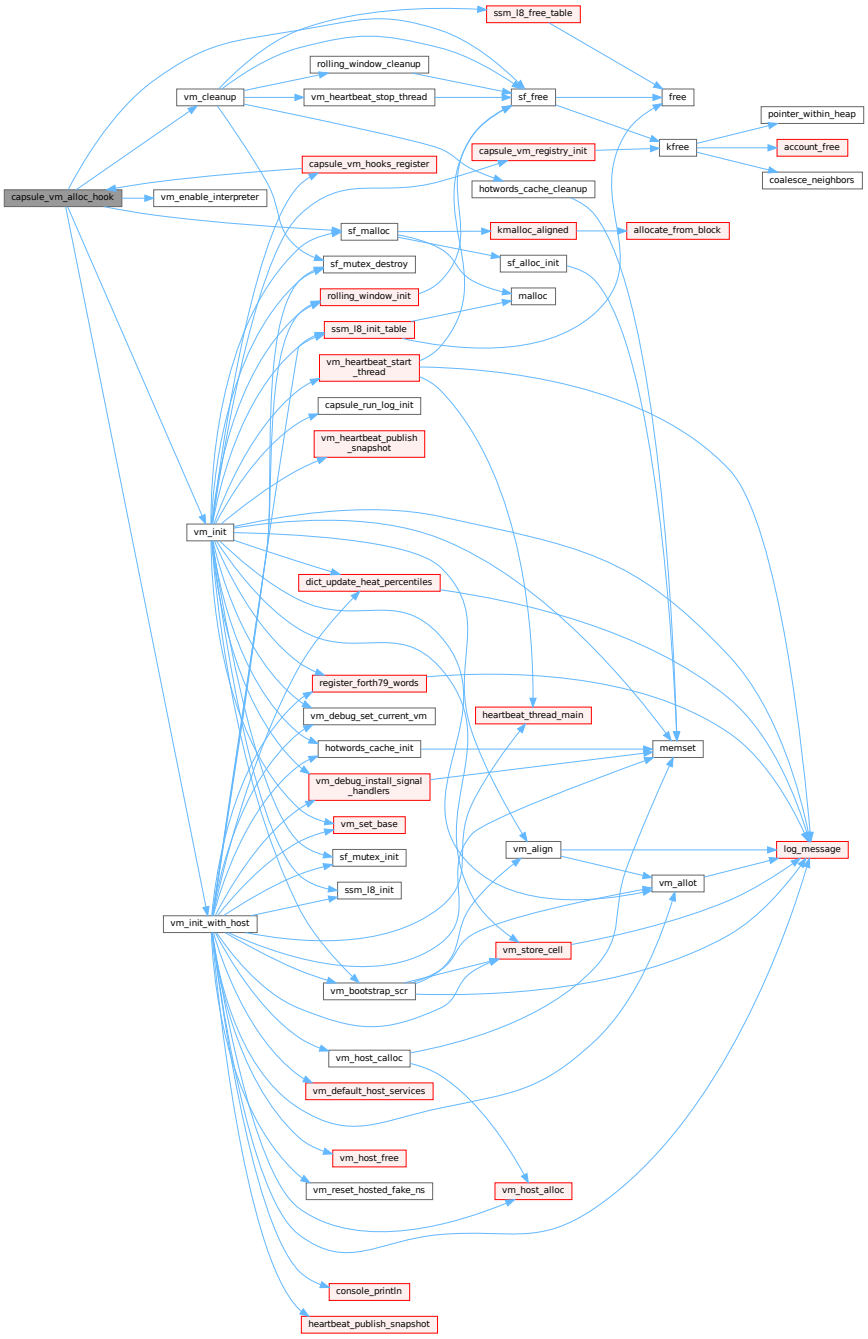
7.133.1.3 capsule_vm_alloc_hook()

```
static void * capsule_vm_alloc_hook (
            void  )  [static]
```

References VM::error, sf_free(), sf_malloc(), vm_cleanup(), vm_enable_interpreter(), vm_init(), and vm_init_with_host().

Referenced by capsule_vm_hooks_register().

Here is the call graph for this function:



Here is the caller graph for this function:

7.133.1.4 capsule_vm_hooks_register()

```
void capsule_vm_hooks_register (
            void  )
```

capsule_vm_hooks_register - Wire the three hooks into the capsule subsystem.

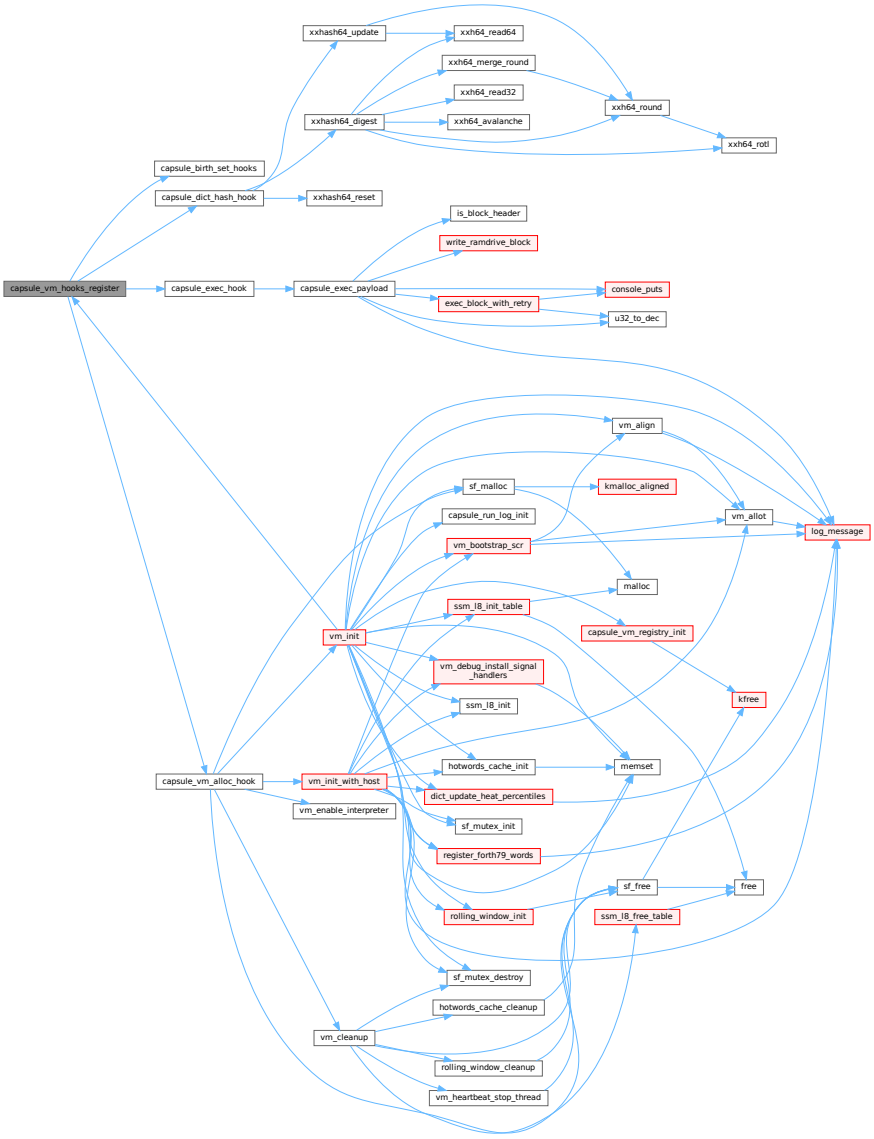
capsule_vm_hooks_register - Wire concrete VM hooks into the capsule subsystem

Must be called after vm_init() completes on Mama's VM, before any capsule birth or experiment operations.

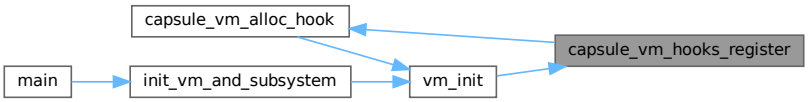
References capsule_birth_set_hooks(), capsule_dict_hash_hook(), capsule_exec_hook(), and capsule_vm_alloc_hook().

Referenced by vm_init().

Here is the call graph for this function:



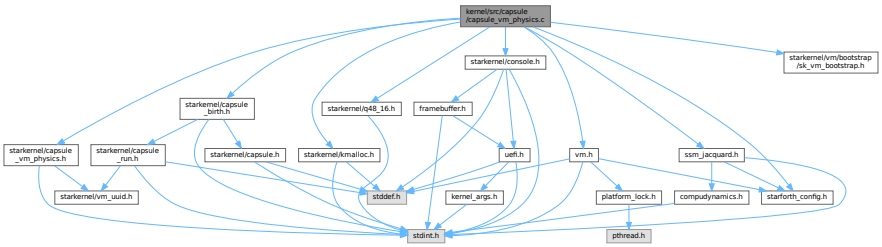
Here is the caller graph for this function:



7.134 kernel/src/capsule/capsule_vm_physics.c File Reference

```
#include "starkernel/capsule_vm_physics.h"
#include "starkernel/capsule_birth.h"
#include "starkernel/kmalloc.h"
#include "starkernel/q48_16.h"
#include "starkernel/console.h"
#include "starforth_config.h"
#include "starkernel/vm/bootstrap/sk_vm_bootstrap.h"
#include "vm.h"
#include "ssm_jacquard.h"
```

Include dependency graph for capsule_vm_physics.c:



Data Structures

- struct VMPhysics
- struct vm_physics_node
- struct VMFleetTouchSample
- struct VMFleetWindow

Macros

- #define VM_FLEET_WINDOW_DEPTH 64

  capsule_vm_physics.c - Dynamic VM Fleet Physics Implementation
- #define VM_PHYSICS_EPSILON_Q48 3277ULL
- #define VM_PHYSICS_MIN_INFORMATIVE_SAMPLES 8

Typedefs

- typedef struct vm_physics_node vm_physics_node_t

Functions

- static vm_physics_node_t * vm_physics_find (VMUuid vm_id)
- static void vm_physics_transfer (VMPhysics *from, VMPhysics *to, uint64_t amount_q48)

  vm_physics_transfer - The one conservative primitive everything else is a special case of.
- void vm_physics_init (VMUuid vm_id)

  capsule_vm_physics.h - Dynamic VM Fleet Physics
- static VMUuid vm_physics_find_root_id (VMUuid vm_id)

  vm_physics_find_root_id - Walk parent_vm_id edges up to Hera
- void vm_physics_retire (VMUuid vm_id)

  vm_physics_retire - Remove a killed VM, returning its heat to Hera
- void vm_physics_touch (VMUuid vm_id)

  vm_physics_touch - Record real dispatch activity against a VM
- static uint32_t l8_regime_modulation_q16 (void)

  l8_regime_modulation_q16 - Read-only Q16 multiplier from Hera's own L8
- void vm_physics_tick (uint64_t now_ns)

  vm_physics_tick - Heartbeat-gated inference pass
- void vm_physics_heartbeat_tick (uint64_t now_ns)

  vm_physics_heartbeat_tick - Fleet-wide heartbeat, gates vm_physics_tick()
- uint64_t vm_physics_fleet_heat_sum (void)

  vm_physics_fleet_heat_sum - Sum of execution_heat_q48 over all LIVE VMs
- int vm_physics_conserved (void)

  vm_physics_conserved - Conservation check
- uint64_t vm_physics_heat_of (VMUuid vm_id)

  vm_physics_heat_of - Current execution_heat_q48 for one VM
- static void console_put_u64 (uint64_t val)
- void vm_physics_status (void)

  vm_physics_status - Print a diagnostic status report

Variables

- static vm_physics_node_t * vm_physics_head = (void *)0
- static VMFleetWindow fleet_window = { { { 0, 0, 0 } }, 0, 0, 0 }
- static uint64_t fleet_transfer_slope_q48 = 65536ULL / 3
- static uint64_t slope_fit_quality_q48 = 0
- static uint64_t fleet_heartbeat_tick_count = 0
- static uint64_t fleet_last_capacity_tick = 0

7.134.1 Macro Definition Documentation

7.134.1.1 VM_FLEET_WINDOW_DEPTH

```
#define VM_FLEET_WINDOW_DEPTH 64
```

capsule_vm_physics.c - Dynamic VM Fleet Physics Implementation

See capsule_vm_physics.h and docs/working/architecture/VM-PHYSICS-DYNAMIC-FLEET-DESIGN-20260705.↩
md for the full design rationale.

Concurrency: no locking. The only interrupt-driven kernel path (heartbeat_tick, from the timer ISR) touches only its own isolated TimeTrustState and never calls into mama_word_*, vm_interpret, or any capsule/dictionary state. HEARTBEAT_THREAD_ENABLED=0 means no separate OS thread runs physics logic either. BIRTH/KILL/↩
VM-EXEC/VM-CALL/ VM-STEP all execute synchronously in Hera's single interpreter context with nothing able to preempt them mid-transfer.

L8 coupling (rev q): the only place this file reaches outside its own VMPhysics/VMFleetWindow state is l8_regime_modulation_q16(), a read-only look at Hera's own ssm_l8_state via sk_get_mama_vm() – modulating the fleet's empirically-recovered transfer rate uniformly, never deciding which VM receives heat. Still a passive observer: this changes how fast the fleet's own rate estimate responds, not who runs or who gets touched.

7.134.1.2 VM_PHYSICS_EPSILON_Q48

```
#define VM_PHYSICS_EPSILON_Q48 3277ULL
```

7.134.1.3 VM_PHYSICS_MIN_INFORMATIVE_SAMPLES

```
#define VM_PHYSICS_MIN_INFORMATIVE_SAMPLES 8
```

7.134.2 Typedef Documentation

7.134.2.1 vm_physics_node_t

```
typedef struct vm_physics_node vm_physics_node_t
```

7.134.3 Function Documentation

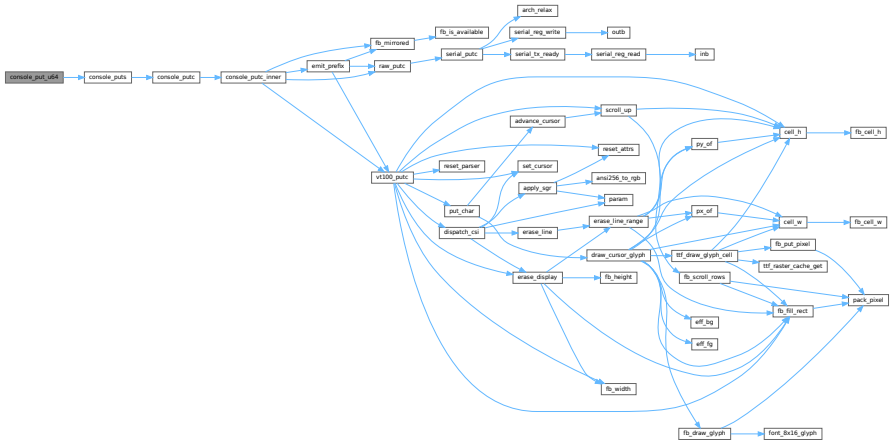
7.134.3.1 console_put_u64()

```
static void console_put_u64 (
            uint64_t val )  [static]
```

References console_puts().

Referenced by vm_physics_status().

Here is the call graph for this function:



Here is the caller graph for this function:

7.134.3.2 l8_regime_modulation_q16()

```
static uint32_t l8_regime_modulation_q16 (
            void  )  [static]
```

l8_regime_modulation_q16 - Read-only Q16 multiplier from Hera's own L8

Gives L8 a real, passive-observer-respecting causal channel into the fleet's transfer rate (rev q, VM-FLEET-↩ ATTRACTOR-DESIGN-20260705.md): previously nothing L8 did could affect fleet dynamics at all (rev j's architectural diagnosis for its null DoE result). Reuses Hera's adaptive table's current_regime – the same 3-bit entropy/cv/temporal classification the bandit already stratifies its own scores by, rather than inventing a new signal – as a proxy for fleet-wide dispatch activity, since all VM-EXEC/VM-CALL flows through her.

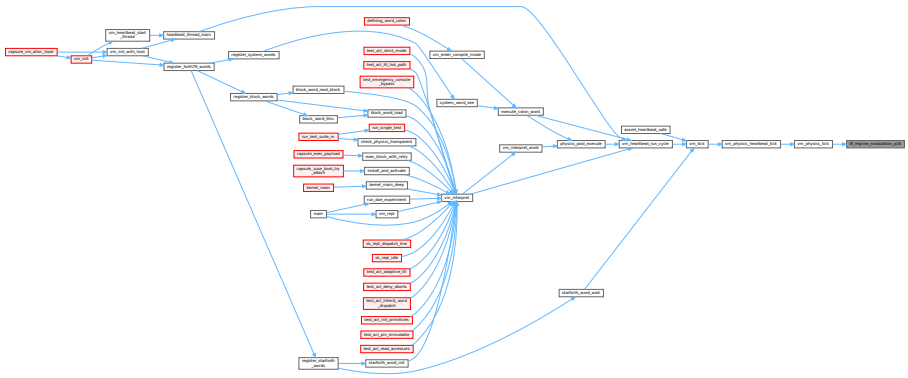
modulation = (popcount(regime) + 1) ∗ 0.5, i.e. 0.5x-2.0x: more of the three high-signal bits active scales the fleet's already-recovered rate up (track change more aggressively), fewer scales it down (damp toward the raw empirical rate). No per-VM favoritism – this scales whatever vm_physics_tick() already computed uniformly, it doesn't decide who receives heat.

Returns Q16 65536 (neutral 1.0x) if Hera or her adaptive table isn't available, so a missing signal never blocks or corrupts the estimate this multiplies.

References CDConfigTable::current_regime, VM::ssm_l8_state, and ssm_l8_state_t::table.

Referenced by vm_physics_tick().

Here is the caller graph for this function:



7.134.3.3 vm_physics_conserved()

```
int vm_physics_conserved (
            void  )
```

vm_physics_conserved - Conservation check

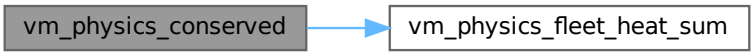
Returns

1 if $|$vm_physics_fleet_heat_sum() - Q.1$|$ $<$ epsilon, else 0

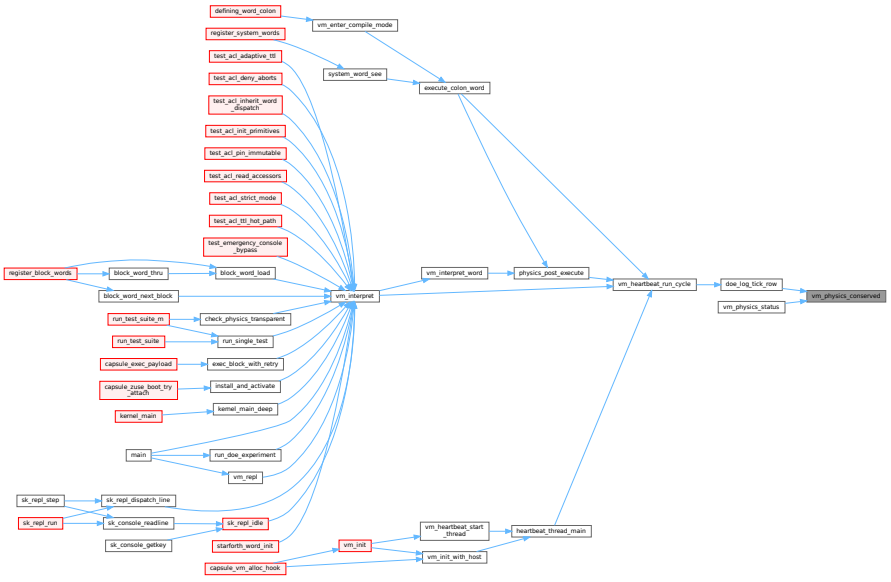
References Q48_ONE, VM_PHYSICS_EPSILON_Q48, and vm_physics_fleet_heat_sum().

Referenced by doe_log_tick_row(), and vm_physics_status().

Here is the call graph for this function:



Here is the caller graph for this function:



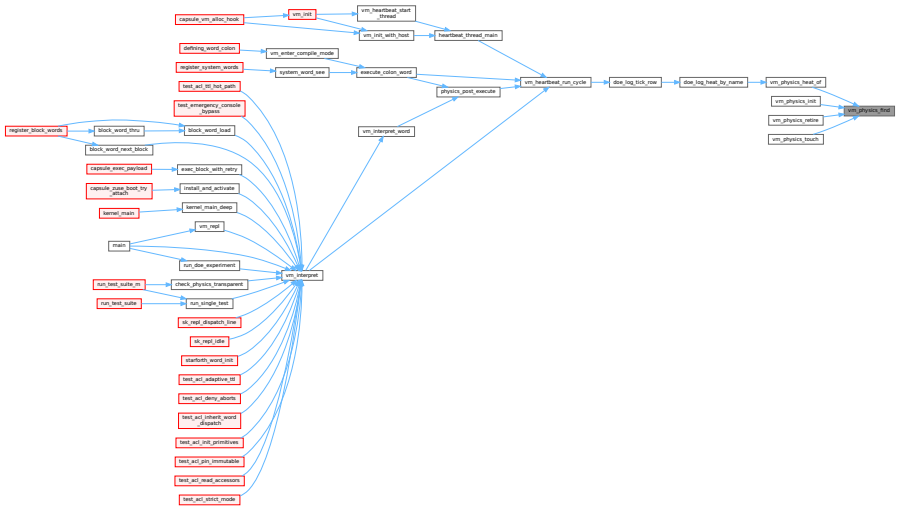
7.134.3.4 vm_physics_find()

```
static vm_physics_node_t * vm_physics_find (
            VMUuid vm_id )  [static]
```

References vm_physics_node::next, vm_physics_node::vm_id, and vm_physics_head.

Referenced by vm_physics_heat_of(), vm_physics_init(), vm_physics_retire(), and vm_physics_touch().

Here is the caller graph for this function:



7.134.3.5 vm_physics_find_root_id()

```
static VMUuid vm_physics_find_root_id (
            VMUuid vm_id )  [static]
```

vm_physics_find_root_id - Walk parent_vm_id edges up to Hera

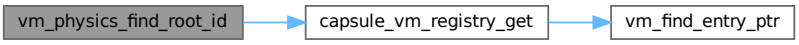
Every VM's parent_vm_id (VMRegistryEntry, capsule_run.h) is set once at its own birth and never rewritten – including a dead VM's, so the walk continues correctly through an already-killed intermediate parent without any special dead-parent handling. Hera's own entry is self-referential (parent_vm_id == vm_id == vm_uuid_hera()), which is what stops the walk: she is the only node with no outbound edge.

The 64-hop guard is defensive only – a well-formed chain terminates in O(fleet depth) hops, nowhere near 64. It exists so a corrupted chain (which should never happen) returns the starting vm_id instead of spinning.

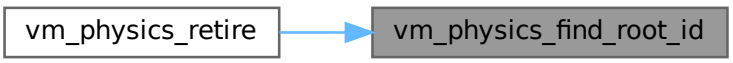
References capsule_vm_registry_get(), entry, and VMRegistryEntry::parent_vm_id.

Referenced by vm_physics_retire().

Here is the call graph for this function:



Here is the caller graph for this function:



7.134.3.6 vm_physics_fleet_heat_sum()

```
uint64_t vm_physics_fleet_heat_sum (
            void  )
```

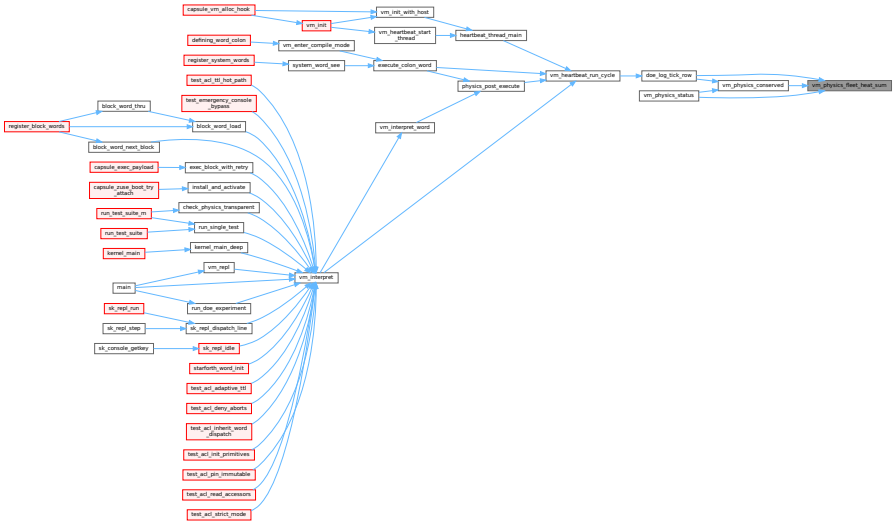
vm_physics_fleet_heat_sum - Sum of execution_heat_q48 over all LIVE VMs

Diagnostic / verification primitive. Should always read Q.1 (65536) if the conservation invariant holds.

References VMPhysics::execution_heat_q48, VMPhysics::is_live, vm_physics_node::next, vm_physics_node::physics, and vm_physics_head.

Referenced by doe_log_tick_row(), vm_physics_conserved(), and vm_physics_status().

Here is the caller graph for this function:



7.134.3.7 vm_physics_heartbeat_tick()

```
void vm_physics_heartbeat_tick (
            uint64_t now_ns )
```

vm_physics_heartbeat_tick - Fleet-wide heartbeat, gates vm_physics_tick()

Call from every VM's own vm_tick(), not just Hera's. Increments a single fleet-wide tick counter (distinct from any VM's own per-VM HeartbeatState.tick_count) and calls vm_physics_tick() once that shared counter has advanced by HEARTBEAT_INFERENCE_FREQUENCY since the last fit.

Fixes a real defect (VM-FLEET-ATTRACTOR-DESIGN-20260705.md rev k): gating this on Hera's own tick_count meant the inference pass almost never fired, because Hera-as-orchestrator mostly blocks on VM-EXEC/ VM-CALL dispatch – work that accrues to the *target* VM's own tick count, not hers. VM-PHYSICS-DYNAMIC-FLEET-DESIGN-20260705.md already specified the fix's direction: fleet_transfer_slope_q48 must be inferred "from aggregate fleet statistics... not one per VM" – the same principle applies to the readiness signal that gates computing it, not just the regression's own input trajectory.

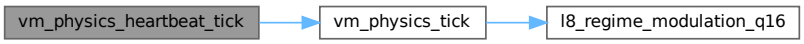
Parameters

now_ns	Current monotonic time in nanoseconds (of whichever VM is calling; unused by vm_physics_tick() today)

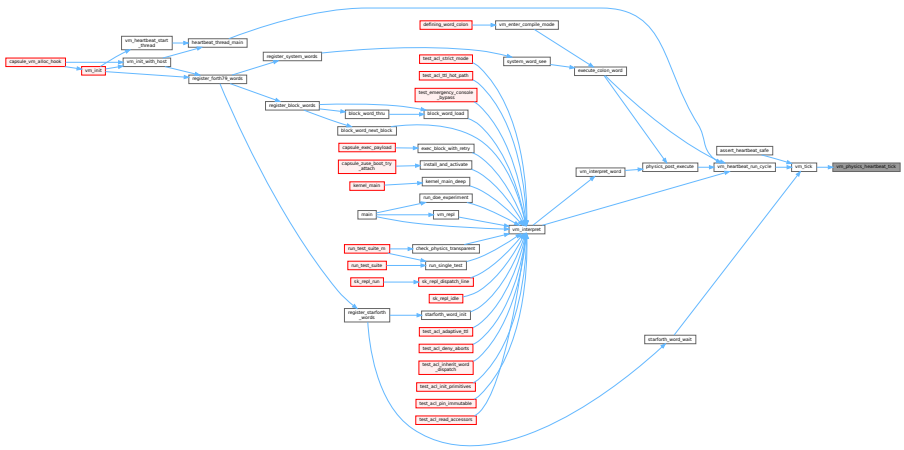
References fleet_heartbeat_tick_count, fleet_last_capacity_tick, STADIUM_CAPACITY_TICK, and vm_physics_tick().

Referenced by vm_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.134.3.8 vm_physics_heat_of()

```
uint64_t vm_physics_heat_of (
            VMUuid vm_id )
```

vm_physics_heat_of - Current execution_heat_q48 for one VM

Transparency primitive (VM-FLEET-ATTRACTOR-DESIGN-20260705.md): the fleet-wide conservation invariant always reads Q.1 by construction, so it carries no information about how heat is actually distributed among live VMs. This is the per-VM fact that sum alone can't provide.

Parameters

vm↩ _id	Registry VM ID

Returns

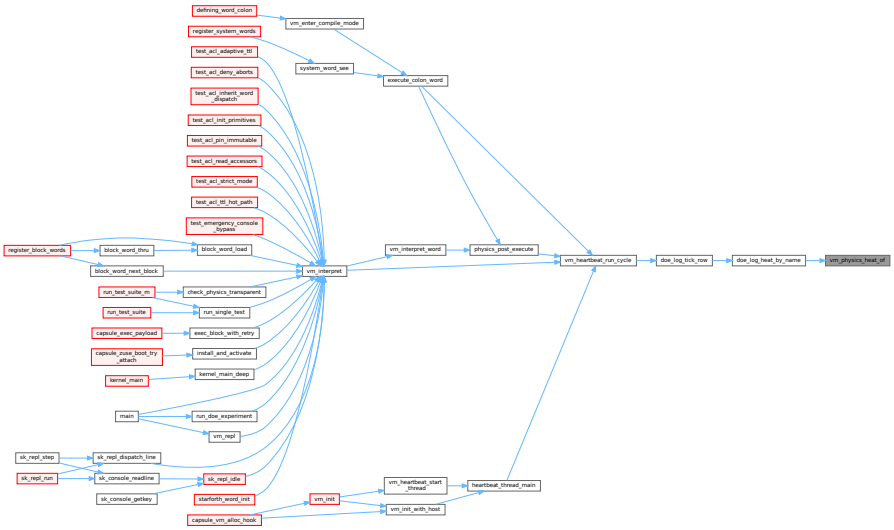
execution_heat_q48, or 0 if vm_id is unknown or not live

References VMPhysics::execution_heat_q48, VMPhysics::is_live, vm_physics_node::physics, and vm_physics_find().

Referenced by doe_log_heat_by_name().

Here is the call graph for this function:

Here is the caller graph for this function:



7.134.3.9 vm_physics_init()

```
void vm_physics_init (
            VMUuid vm_id )
```

capsule_vm_physics.h - Dynamic VM Fleet Physics

Structural parallel to the word-level physics engine (execution heat, decay, rolling-window history, regression-inferred slope) applied to VMs instead of dictionary words. Kernel-only: no hosted-build equivalent, since the hosted build has no multi-VM fleet.

sum(execution_heat_q48 for all LIVE VMs) == Q.1 is a conservation invariant, held by construction: every state change is a balanced transfer (see design doc VM-PHYSICS-DYNAMIC-FLEET-DESIGN-20260705.md).

This is a passive observer of VM activity, never a driver of it — there is no scheduler here. Recording happens only at existing dispatch points (BIRTH, KILL, VM-EXEC, VM-CALL, VM-STEP). vm_physics_init - Register a newly-born VM at zero heat

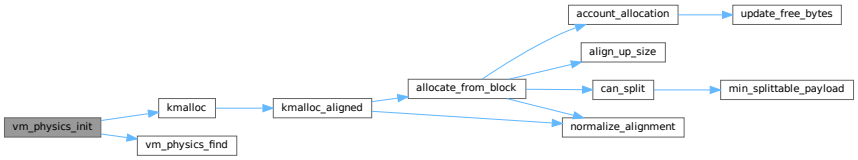
Called from mama_word_birth once a VM reaches VM_STATE_LIVE. Starts at execution_heat_q48 = 0, so conservation holds trivially — no fan-out from existing VMs is needed.

Parameters

vm↩_id	Registry VM ID assigned at birth

References VMPhysics::execution_heat_q48, VMPhysics::is_live, kmalloc(), VMPhysics::last_active_tick, vm_physics_node::next, vm_physics_node::physics, Q48_ONE, VMPhysics::touched, vm_physics_node::vm_id, vm_physics_find(), and vm_physics_head.

Here is the call graph for this function:



7.134.3.10 vm_physics_retire()

```
void vm_physics_retire (
            VMUuid vm_id )
```

vm_physics_retire - Remove a killed VM, returning its heat to Hera

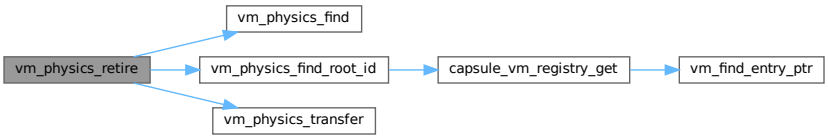
Called from mama_word_kill before the registry entry is torn down. The dying VM's entire remaining heat is transferred up its parent_vm_id chain (VMRegistryEntry, capsule_run.h) to the fleet's single structural root, Hera – no division, no per-survivor weighting. The chain walk tolerates already-dead intermediate parents (a parent's own parent_vm_id was set once at its birth and never rewritten, so the walk continues through it).

Parameters

vm↩_id	Registry VM ID of the VM being killed

References VMPhysics::execution_heat_q48, VMPhysics::is_live, vm_physics_node::physics, vm_physics_find(), vm_physics_find_root_id(), and vm_physics_transfer().

Here is the call graph for this function:



7.134.3.11 vm_physics_status()

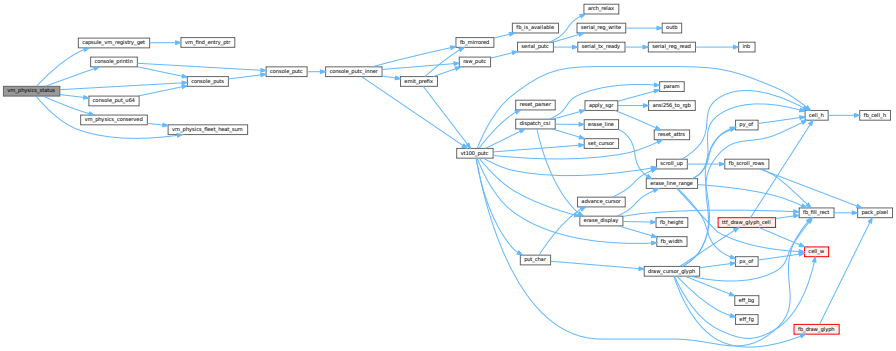
```
void vm_physics_status (
            void  )
```

vm_physics_status - Print a diagnostic status report

Replaces K-STATUS/VM-STATUS. Reports fleet heat sum, conservation verdict, and the current fleet-wide inferred slope / fit quality / warm-up state – the fleet-level analog of K-STATUS's per-VM report, adapted to a mechanism with no fixed VM count to enumerate.

References capsule_vm_registry_get(), console_println(), console_put_u64(), console_puts(), entry, VMPhysics::execution_heat_q48, fleet_transfer_slope_q48, fleet_window, VMPhysics::is_live, VMFleetWindow::is_warm, vm_physics_node::next, vm_physics_node::physics, slope_fit_quality_q48, vm_physics_node::vm_id, vm_physics_conserved(), vm_physics_fleet_heat_sum(), and vm_physics_head.

Here is the call graph for this function:



7.134.3.12 vm_physics_tick()

```
void vm_physics_tick (
            uint64_t now_ns )
```

vm_physics_tick - Heartbeat-gated inference pass

Mirrors vm_tick_inference_engine: when the fleet touch-history window is warm, replays it to re-fit fleet_transfer_↩ slope_q48 via the same closed-form log-linear OLS regression used for word-level decay. Skips the update (does not substitute a default) when unwarmed or when fit quality is not usable.

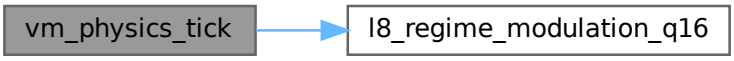
Parameters

now_ns	Current monotonic time in nanoseconds

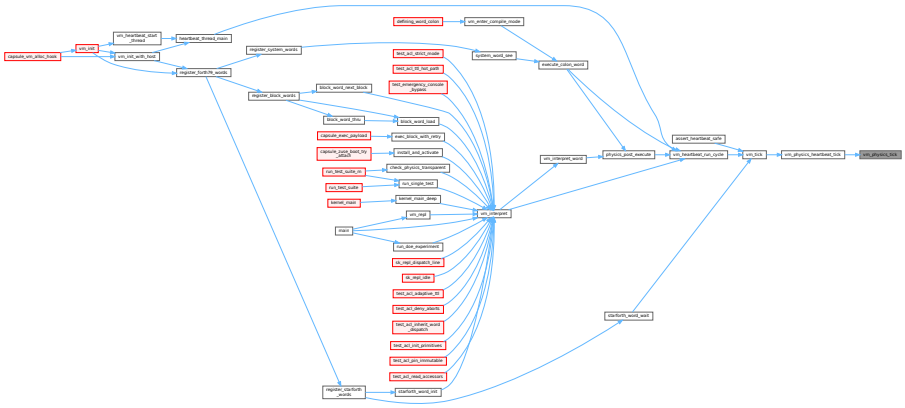
References VMFleetTouchSample::amount, VMFleetTouchSample::clamped, VMFleetTouchSample::elapsed_ticks, fleet_transfer_slope_q48, fleet_window, VMFleetWindow::is_warm, l8_regime_modulation_q16(), slope_fit_quality_q48, VMFleetWindow::touch_samples, VM_FLEET_WINDOW_DEPTH, and VM_PHYSICS_MIN_INFORMATIVE_SAMPLES.

Referenced by vm_physics_heartbeat_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.134.3.13 vm_physics_touch()

```
void vm_physics_touch (
            VMUuid vm_id )
```

vm_physics_touch - Record real dispatch activity against a VM

Called from the three existing dispatch primitives (VM-EXEC, VM-CALL, VM-STEP) at the point they've already confirmed the target VM is live. Pulls heat from the rest of the fleet toward the touched VM (amount = elapsed_ticks ∗ fleet_transfer_slope_q48 >> 16) and appends vm_id to the fleet's rolling touch-history window.

Restated on the virtual tick (FABRIC-0.md item 2.1, 2026-08-04): no longer takes a wall-clock timestamp. Reads fleet_heartbeat_tick_count internally, which is execution-paced (advanced once per vm_tick() call, see vm_↩ physics_heartbeat_tick), so the transfer this produces is a deterministic function of the execution stream, not of wall time.

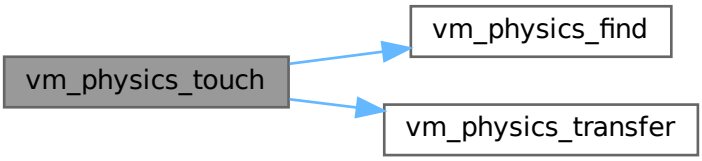
Parameters

vm↩ _id	Registry VM ID being dispatched to

References VMFleetTouchSample::amount, VMFleetTouchSample::clamped, VMFleetWindow::count, VMFleetTouchSample::elapsed, VMPhysics::execution_heat_q48, fleet_heartbeat_tick_count, fleet_transfer_slope_q48, fleet_window, VMFleetWindow::head, VMPhysics::is_live, VMFleetWindow::is_warm, VMPhysics::last_active_tick, vm_physics_node::next, vm_physics_node::physics,

VMFleetWindow::touch_samples, VMPhysics::touched, VM_FLEET_WINDOW_DEPTH, vm_physics_find(), vm_physics_head, and vm_physics_transfer().

Here is the call graph for this function:



7.134.3.14 vm_physics_transfer()

```
static void vm_physics_transfer (
            VMPhysics * from,
            VMPhysics * to,
            uint64_t amount_q48 )  [static]
```

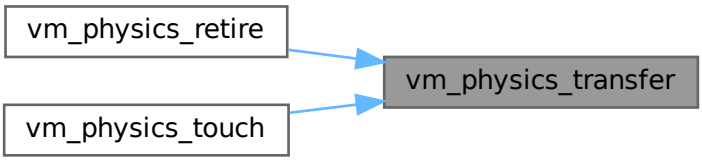
vm_physics_transfer - The one conservative primitive everything else is a special case of.

Subtracts amount from from (clamped at 0) and adds the same amount to to. Nothing is created or destroyed: sum(execution_heat for all LIVE VMs) is invariant across any call.

References VMPhysics::execution_heat_q48.

Referenced by vm_physics_retire(), and vm_physics_touch().

Here is the caller graph for this function:



7.134.4 Variable Documentation

7.134.4.1 fleet_heartbeat_tick_count

```
uint64_t fleet_heartbeat_tick_count = 0  [static]
```

Referenced by vm_physics_heartbeat_tick(), and vm_physics_touch().

7.134.4.2 fleet_last_capacity_tick

```
uint64_t fleet_last_capacity_tick = 0  [static]
```

Referenced by vm_physics_heartbeat_tick().

7.134.4.3 fleet_transfer_slope_q48

```
uint64_t fleet_transfer_slope_q48 = 65536ULL / 3  [static]
```

Referenced by vm_physics_status(), vm_physics_tick(), and vm_physics_touch().

7.134.4.4 fleet_window

```
VMFleetWindow fleet_window = { { { 0, 0, 0 } }, 0, 0, 0 }  [static]
```

Referenced by vm_physics_status(), vm_physics_tick(), and vm_physics_touch().

7.134.4.5 slope_fit_quality_q48

```
uint64_t slope_fit_quality_q48 = 0  [static]
```

Referenced by vm_physics_status(), and vm_physics_tick().

7.134.4.6 vm_physics_head

```
vm_physics_node_t* vm_physics_head = (void *)0  [static]
```

Referenced by vm_physics_find(), vm_physics_fleet_heat_sum(), vm_physics_init(), vm_physics_status(), and vm_physics_touch().

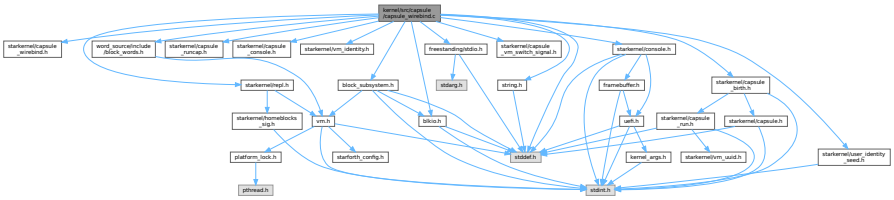
7.135 kernel/src/capsule/capsule_vm_switch_signal.c File Reference

7.136 kernel/src/capsule/capsule_wirebind.c File Reference

```
#include "starkernel/capsule_wirebind.h"
#include "starkernel/capsule_birth.h"
#include "starkernel/capsule_runcap.h"
#include "starkernel/capsule_console.h"
#include "starkernel/vm_identity.h"
#include "starkernel/user_identity_seed.h"
#include "starkernel/console.h"
#include "starkernel/repl.h"
#include "starkernel/capsule_vm_switch_signal.h"
#include "blkio.h"
#include "block_subsystem.h"
#include "word_source/include/block_words.h"
```

```
#include "freestanding/stdio.h"
#include <string.h>
#include <stddef.h>
```

Include dependency graph for capsule_wirebind.c:



Data Structures

- struct wirebind_live_entry_t

Macros

- #define WIREBIND_MAX_LIVE 13u
- #define WIREBIND_CERT_MAX_DEVBLOCKS 4u
- #define WIREBIND_OVERFLOW_FREE_THRESHOLD_PCT 10u
- #define WIREBIND_OVERFLOW_CLAIM_DEVBLOCKS 8u

Functions

- static wirebind_live_entry_t * wirebind_live_find_by_dev (struct blkio_dev *dev)
- static wirebind_live_entry_t * wirebind_live_alloc (void)
- static int read_devblock (struct blkio_dev *dev, uint32_t devblock, uint8_t *buf4096)
- int capsule_wirebind_verify_cert (struct blkio_dev *dev, const homeblocks_sig_t *sig, VM *mama_vm, VMIdentity *out)
- void capsule_wirebind_try_attach (struct blkio_dev *dev, const homeblocks_sig_t *sig, VM *mama_vm)
- static int wirebind_resolve_attached (VMRegistryEntry *out)
- static void wirebind_teardown_console (const char *username)
- static void wirebind_live_remove (wirebind_live_entry_t *e)
- int capsule_wirebind_eject (void)
- void capsule_wirebind_unclean_detach (struct blkio_dev *dev)
- void capsule_wirebind_reap_idle_check (void)
- const char * capsule_wirebind_attached_username (void)
- void capsule_wirebind_overflow_idle_check (void)

Variables

- static VMUuid g_wirebind_attached_vm_id
- static int g_wirebind_attached_valid = 0
- static char g_wirebind_attached_username [32u] = {0}
- static struct blkio_dev * g_wirebind_attached_dev = (struct blkio_dev *) 0
- static wirebind_live_entry_t g_wirebind_live [13u]

7.136.1 Macro Definition Documentation

7.136.1.1 WIREBIND_CERT_MAX_DEVBLOCKS

```
#define WIREBIND_CERT_MAX_DEVBLOCKS 4u
```

7.136.1.2 WIREBIND_MAX_LIVE

```
#define WIREBIND_MAX_LIVE 13u
```

7.136.1.3 WIREBIND_OVERFLOW_CLAIM_DEVBLOCKS

```
#define WIREBIND_OVERFLOW_CLAIM_DEVBLOCKS 8u
```

7.136.1.4 WIREBIND_OVERFLOW_FREE_THRESHOLD_PCT

```
#define WIREBIND_OVERFLOW_FREE_THRESHOLD_PCT 10u
```

7.136.2 Function Documentation

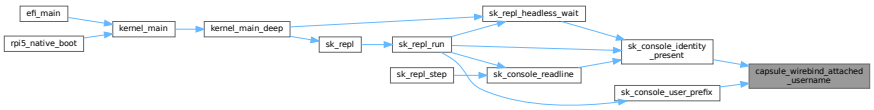
7.136.2.1 capsule_wirebind_attached_username()

```
const char * capsule_wirebind_attached_username (
            void  )
```

References g_wirebind_attached_username, and g_wirebind_attached_valid.

Referenced by sk_console_identity_present(), and sk_console_user_prefix().

Here is the caller graph for this function:

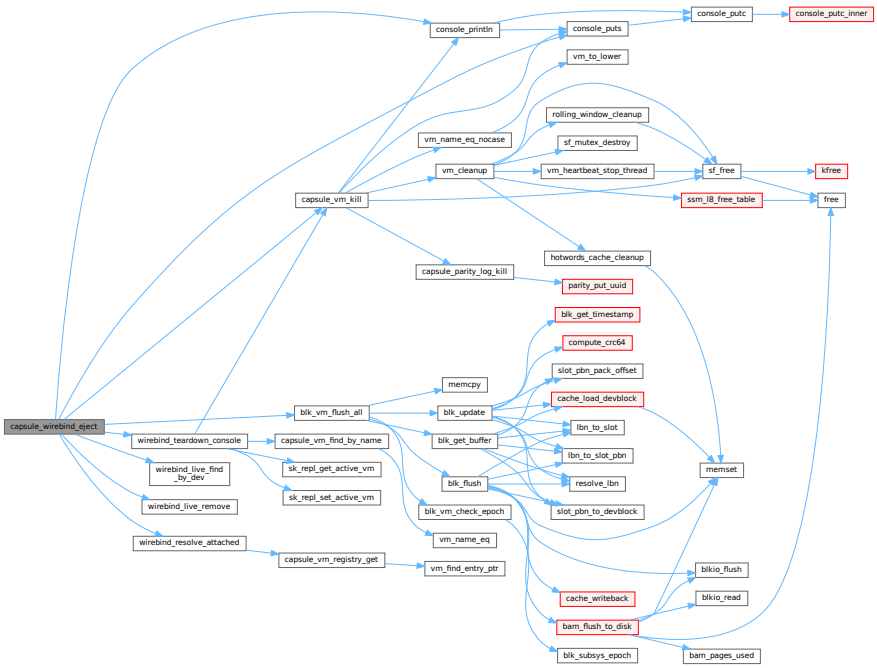


7.136.2.2 capsule_wirebind_eject()

```
int capsule_wirebind_eject (
            void  )
```

References blk_vm_flush_all(), capsule_vm_kill(), console_println(), console_puts(), entry, g_wirebind_attached_dev, g_wirebind_attached_username, g_wirebind_attached_valid, wirebind_live_find_by_dev(), wirebind_live_remove(), wirebind_resolve_attached(), and wirebind_teardown_console().

Here is the call graph for this function:



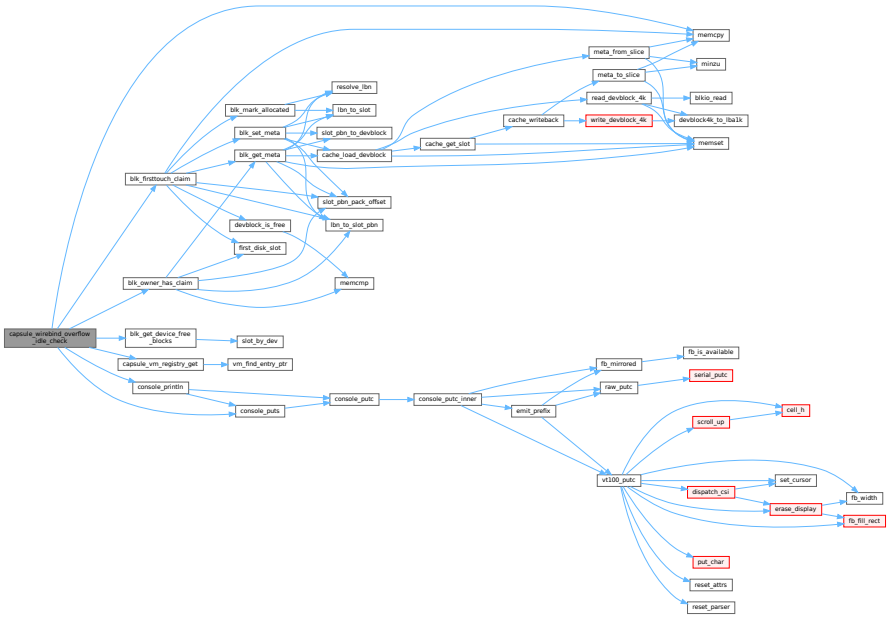
7.136.2.3 capsule_wirebind_overflow_idle_check()

```
void capsule_wirebind_overflow_idle_check (
            void  )
```

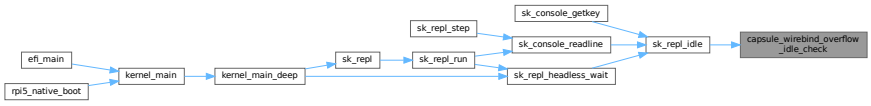
References blk_firsttouch_claim(), blk_get_device_free_blocks(), BLK_OK, blk_owner_has_claim(), capsule_vm_registry_get(), console_println(), console_puts(), entry, g_wirebind_attached_dev, g_wirebind_attached_username, g_wirebind_attached_valid, g_wirebind_attached_vm_id, memcpy(), blkio_dev::total_blocks, VM_STATE_LIVE, WIREBIND_OVERFLOW_CLAIM_DEVBLOCKS, and WIREBIND_OVERFLOW_FREE_THRESHOLD_PCT.

Referenced by sk_repl_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



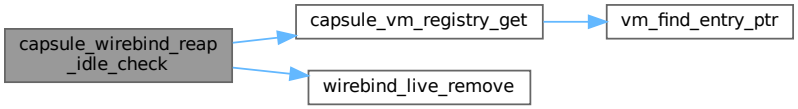
7.136.2.4 capsule_wirebind_reap_idle_check()

```
void capsule_wirebind_reap_idle_check (
            void  )
```

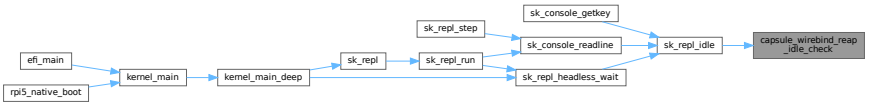
References capsule_vm_registry_get(), entry, g_wirebind_live, VM_STATE_DEAD, wirebind_live_remove(), and WIREBIND_MAX_LIVE.

Referenced by sk_repl_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



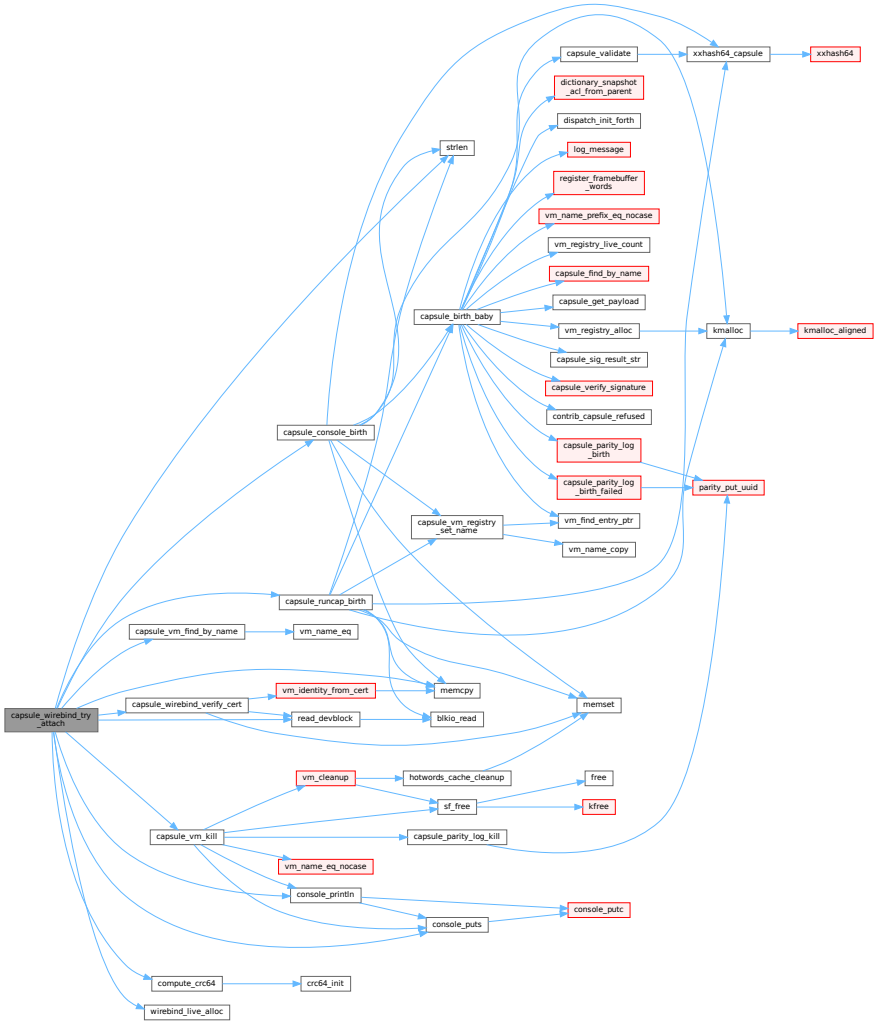
7.136.2.5 capsule_wirebind_try_attach()

```
void capsule_wirebind_try_attach (
            struct blkio_dev * dev,
            const homeblocks_sig_t * sig,
            VM * mama_vm )
```

References capsule_console_birth(), CAPSULE_RUN_OK, capsule_runcap_birth(), capsule_vm_find_by_name(), capsule_vm_kill(), capsule_wirebind_verify_cert(), homeblocks_sig_t::cert_devblocks, homeblocks_sig_t::cert_offset, compute_crc64(), console_println(), console_puts(), user_identity_seed_t::crc, wirebind_live_entry_t::dev, g_wirebind_attached_dev, g_wirebind_attached_username, g_wirebind_attached_valid, g_wirebind_attached_vm_id, homeblocks_sig_t::identity_src_devblocks, homeblocks_sig_t::identity_src_offset, wirebind_live_entry_t::in_use, user_identity_seed_t::magic, memcpy(), read_devblock(), VMRegistryEntry::state, strlen(), wirebind_live_entry_t::switch_slot, USER_IDENTITY_SEED_MAGIC, USER_IDENTITY_SEED_VERSION, USER_IDENTITY_USERNAME_MAX, wirebind_live_entry_t::user_vm_id, user_identity_seed_t::username, wirebind_live_entry_t::username, user_identity_seed_t::version, VM_STATE_LIVE, wirebind_live_alloc(), and VM::zuse_root_pubkey_known.

Referenced by sk_word_blk_attach_ack().

Here is the call graph for this function:



Here is the caller graph for this function:

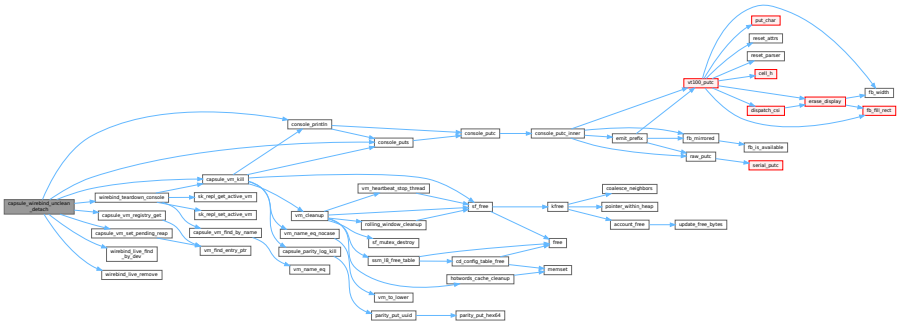
7.136.2.6 capsule_wirebind_unclean_detach()

```
void capsule_wirebind_unclean_detach (
            struct blkio_dev * dev )
```

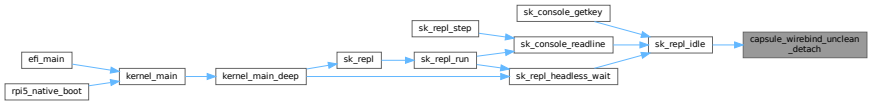
References capsule_vm_kill(), capsule_vm_registry_get(), capsule_vm_set_pending_reap(), console_println(), console_puts(), entry, g_wirebind_attached_dev, g_wirebind_attached_username, g_wirebind_attached_valid, wirebind_live_entry_t::user_vm_id, wirebind_live_entry_t::username, VM_STATE_DEAD, VM_STATE_STILLBORN, wirebind_live_find_by_dev(), wirebind_live_remove(), and wirebind_teardown_console().

Referenced by sk_repl_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



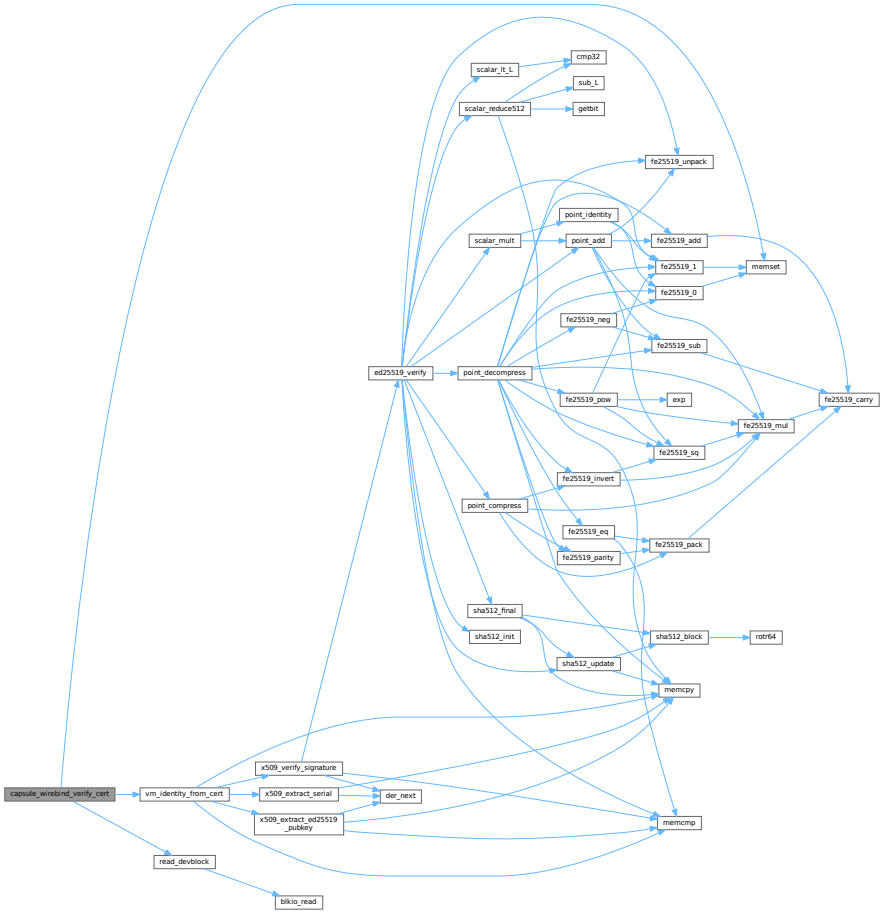
7.136.2.7 capsule_wirebind_verify_cert()

```
int capsule_wirebind_verify_cert (
            struct blkio_dev * dev,
            const homeblocks_sig_t * sig,
            VM * mama_vm,
            VMIdentity * out )
```

References homeblocks_sig_t::cert_devblocks, homeblocks_sig_t::cert_offset, homeblocks_sig_t::drive_uuid, memset(), read_devblock(), vm_identity_from_cert(), WIREBIND_CERT_MAX_DEVBLOCKS, VM::zuse_root_pubkey, and VM::zuse_root_pubkey_known.

Referenced by capsule_wirebind_try_attach().

Here is the call graph for this function:



Here is the caller graph for this function:

7.136.2.8 read_devblock()

```
static int read_devblock (
            struct blkio_dev * dev,
            uint32_t devblock,
            uint8_t * buf4096 )  [static]
```

References base, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, and blkio_read().

Referenced by capsule_wirebind_try_attach(), and capsule_wirebind_verify_cert().

Here is the call graph for this function:

Here is the caller graph for this function:

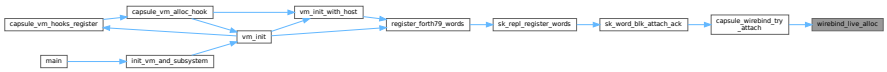
7.136.2.9 wirebind_live_alloc()

```
static wirebind_live_entry_t * wirebind_live_alloc (
            void  )  [static]
```

References g_wirebind_live, and WIREBIND_MAX_LIVE.

Referenced by capsule_wirebind_try_attach().

Here is the caller graph for this function:



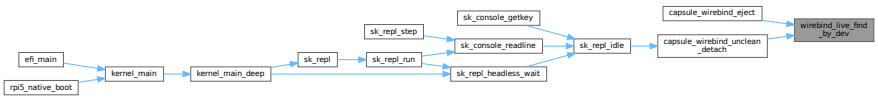
7.136.2.10 wirebind_live_find_by_dev()

```
static wirebind_live_entry_t * wirebind_live_find_by_dev (
            struct blkio_dev * dev )  [static]
```

References g_wirebind_live, and WIREBIND_MAX_LIVE.

Referenced by capsule_wirebind_eject(), and capsule_wirebind_unclean_detach().

Here is the caller graph for this function:



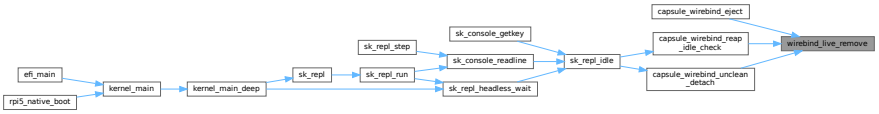
7.136.2.11 wirebind_live_remove()

```
static void wirebind_live_remove (
            wirebind_live_entry_t * e )  [static]
```

References wirebind_live_entry_t::dev, wirebind_live_entry_t::in_use, wirebind_live_entry_t::switch_slot, wirebind_live_entry_t::user_ and wirebind_live_entry_t::username.

Referenced by capsule_wirebind_eject(), capsule_wirebind_reap_idle_check(), and capsule_wirebind_unclean_detach().

Here is the caller graph for this function:



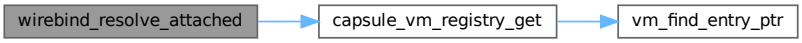
7.136.2.12 wirebind_resolve_attached()

```
static int wirebind_resolve_attached (
            VMRegistryEntry * out )  [static]
```

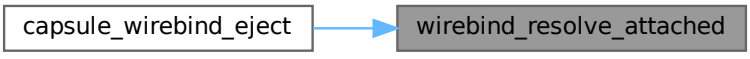
References capsule_vm_registry_get(), g_wirebind_attached_username, g_wirebind_attached_valid, g_wirebind_attached_vm_id, VMRegistryEntry::state, and VM_STATE_LIVE.

Referenced by capsule_wirebind_eject().

Here is the call graph for this function:



Here is the caller graph for this function:



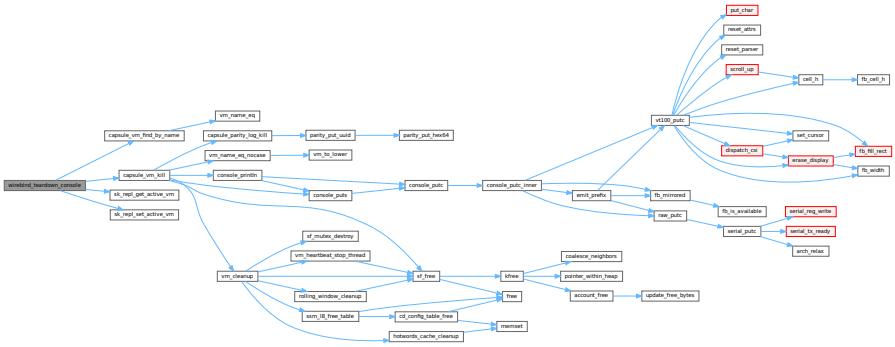
7.136.2.13 wirebind_teardown_console()

```
static void wirebind_teardown_console (
            const char * username )  [static]
```

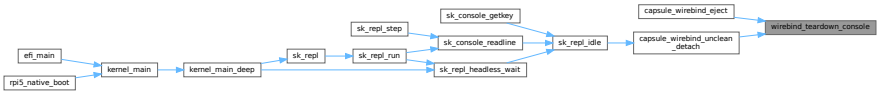
References capsule_vm_find_by_name(), capsule_vm_kill(), VMRegistryEntry::name, sk_repl_get_active_vm(), sk_repl_set_active_vm(), VMRegistryEntry::state, VMRegistryEntry::vm_ptr, and VM_STATE_LIVE.

Referenced by capsule_wirebind_eject(), and capsule_wirebind_unclean_detach().

Here is the call graph for this function:



Here is the caller graph for this function:



7.136.3 Variable Documentation

7.136.3.1 g_wirebind_attached_dev

```
struct blkio_dev* g_wirebind_attached_dev = (struct blkio_dev *) 0  [static]
```

Referenced by capsule_wirebind_eject(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), and capsule_wirebind_unclean_detach().

7.136.3.2 g_wirebind_attached_username

```
char g_wirebind_attached_username[32u] = {0}  [static]
```

Referenced by capsule_wirebind_attached_username(), capsule_wirebind_eject(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), capsule_wirebind_unclean_detach(), and wirebind_resolve_attached().

7.136.3.3 g_wirebind_attached_valid

```
int g_wirebind_attached_valid = 0  [static]
```

Referenced by capsule_wirebind_attached_username(), capsule_wirebind_eject(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), capsule_wirebind_unclean_detach(), and wirebind_resolve_attached().

7.136.3.4 g_wirebind_attached_vm_id

```
VMUuid g_wirebind_attached_vm_id  [static]
```

Referenced by capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), and wirebind_resolve_attached().

7.136.3.5 g_wirebind_live

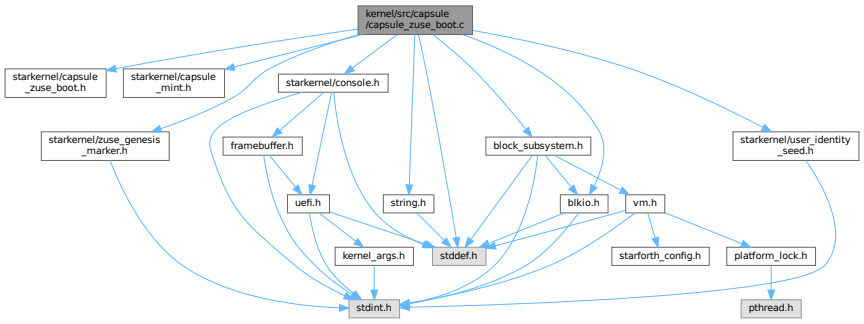
```
wirebind_live_entry_t g_wirebind_live[13u]  [static]
```

Referenced by capsule_wirebind_reap_idle_check(), wirebind_live_alloc(), and wirebind_live_find_by_dev().

7.137 kernel/src/capsule/capsule_zuse_boot.c File Reference

```
#include "starkernel/capsule_zuse_boot.h"
#include "starkernel/capsule_mint.h"
#include "starkernel/zuse_genesis_marker.h"
#include "starkernel/user_identity_seed.h"
#include "starkernel/console.h"
#include "block_subsystem.h"
#include "blkio.h"
#include <string.h>
#include <stddef.h>
```

Include dependency graph for capsule_zuse_boot.c:



Functions

- static int read_devblock (struct blkio_dev ∗dev, uint32_t devblock, uint8_t ∗buf4096)
- static int genesis_marker_read (zuse_genesis_marker_t ∗out)
- static void install_and_activate (VM ∗mama_vm, struct blkio_dev ∗dev, const uint8_t seed[32], const uint8_t pubkey[32])
- zuse_drive_t capsule_zuse_boot_check_key (struct blkio_dev ∗dev, homeblocks_sig_result_t sig_rc, const homeblocks_sig_t ∗sig, const uint8_t want[32], uint8_t seed[32], uint8_t pubkey[32])
- zuse_drive_t capsule_zuse_boot_check (struct blkio_dev ∗dev, homeblocks_sig_result_t sig_rc, const homeblocks_sig_t ∗sig, uint8_t seed[32], uint8_t pubkey[32])
- int capsule_zuse_boot_genesis_mint (struct blkio_dev ∗dev, uint8_t seed[32], uint8_t pubkey[32])
- int capsule_zuse_boot_root_pubkey (uint8_t pubkey[32])
- void capsule_zuse_boot_try_attach (struct blkio_dev ∗dev, homeblocks_sig_result_t sig_rc, const homeblocks_sig_t ∗sig, VM ∗mama_vm)
- void capsule_zuse_boot_logout (VM ∗mama_vm, struct blkio_dev ∗dev)
- struct blkio_dev ∗ capsule_zuse_boot_attached_dev (void)
- void capsule_zuse_boot_load_root_pubkey (VM ∗mama_vm)

Variables

- static int g_zuse_attached_this_device = 0
- static struct blkio_dev ∗ g_zuse_attached_dev = (struct blkio_dev ∗) 0

7.137.1 Function Documentation

7.137.1.1 capsule_zuse_boot_attached_dev()

```
struct blkio_dev * capsule_zuse_boot_attached_dev (
            void  )
```

References g_zuse_attached_dev, and g_zuse_attached_this_device.

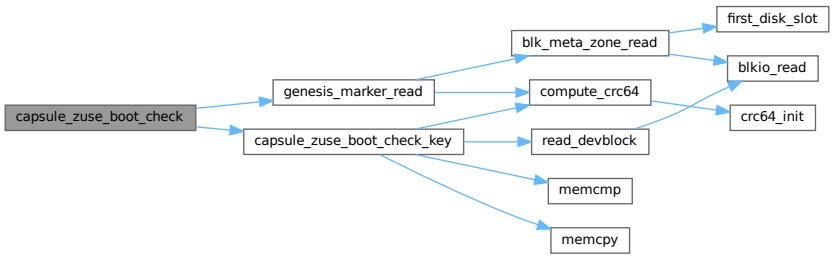
7.137.1.2 capsule_zuse_boot_check()

```
zuse_drive_t capsule_zuse_boot_check (
            struct blkio_dev * dev,
            homeblocks_sig_result_t sig_rc,
            const homeblocks_sig_t * sig,
            uint8_t seed[32],
            uint8_t pubkey[32] )
```

References capsule_zuse_boot_check_key(), genesis_marker_read(), HOMEBLOCKS_SIG_BLANK, and zuse_genesis_marker_t::zuse_pubkey.

Referenced by capsule_zuse_boot_try_attach().

Here is the call graph for this function:



Here is the caller graph for this function:

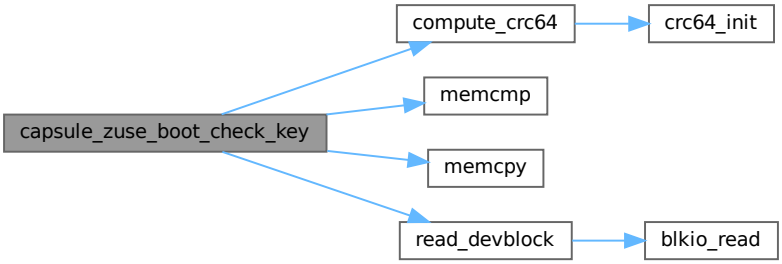
7.137.1.3 capsule_zuse_boot_check_key()

```
zuse_drive_t capsule_zuse_boot_check_key (
            struct blkio_dev * dev,
            homeblocks_sig_result_t sig_rc,
            const homeblocks_sig_t * sig,
            const uint8_t want[32],
            uint8_t seed[32],
            uint8_t pubkey[32] )
```

References compute_crc64(), user_identity_seed_t::crc, HOMEBLOCKS_SIG_OK, homeblocks_sig_t::identity_src_devblocks, homeblocks_sig_t::identity_src_offset, user_identity_seed_t::magic, memcmp(), memcpy(), user_identity_seed_t::pubkey, read_devblock(), user_identity_seed_t::seed, USER_IDENTITY_SEED_MAGIC, USER_IDENTITY_SEED_VERSION, and user_identity_seed_t::version.

Referenced by capsule_zuse_boot_check(), sk_v4_drive_arrived(), sk_v4_genesis(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

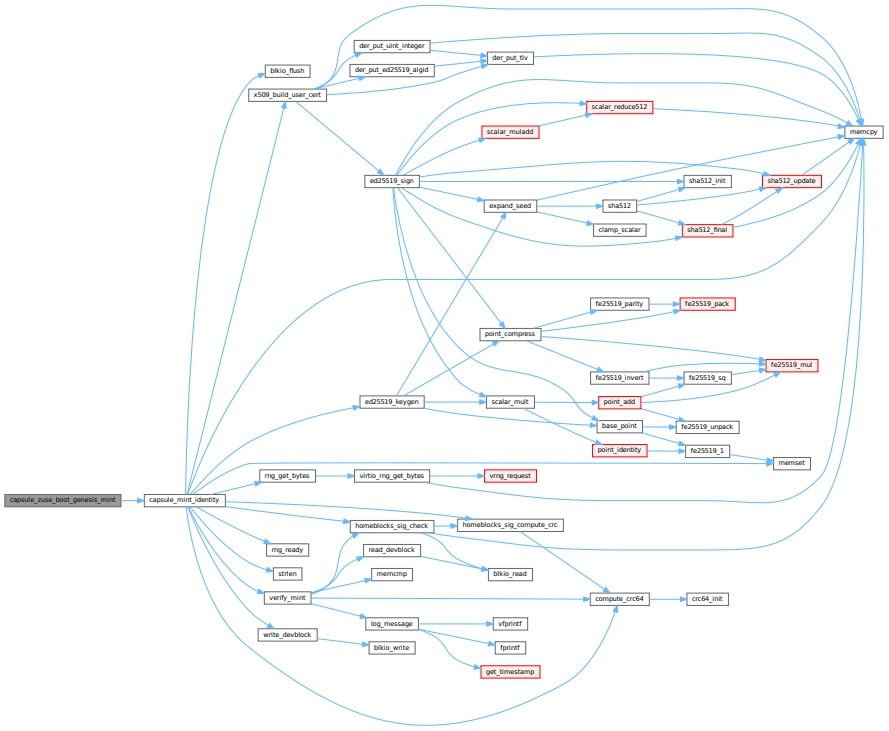
7.137.1.4 capsule_zuse_boot_genesis_mint()

```
int capsule_zuse_boot_genesis_mint (
            struct blkio_dev * dev,
            uint8_t seed[32],
            uint8_t pubkey[32] )
```

References capsule_mint_identity().

Referenced by capsule_zuse_boot_try_attach(), sk_v4_genesis(), and sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

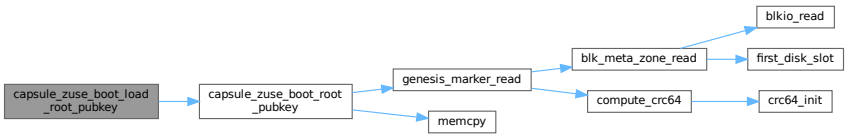
7.137.1.5 capsule_zuse_boot_load_root_pubkey()

```
void capsule_zuse_boot_load_root_pubkey (
            VM * mama_vm )
```

References capsule_zuse_boot_root_pubkey(), VM::zuse_root_pubkey, and VM::zuse_root_pubkey_known.

Referenced by kernel_main_deep(), and sk_word_blk_attach_ack().

Here is the call graph for this function:



Here is the caller graph for this function:

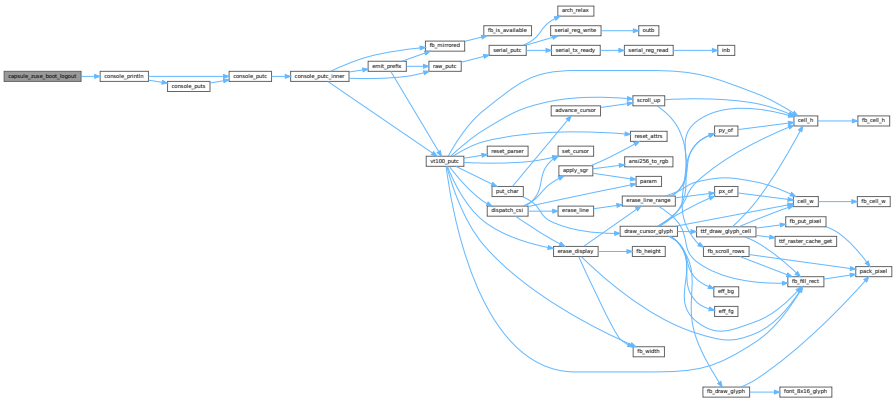
7.137.1.6 capsule_zuse_boot_logout()

```
void capsule_zuse_boot_logout (
            VM * mama_vm,
            struct blkio_dev * dev )
```

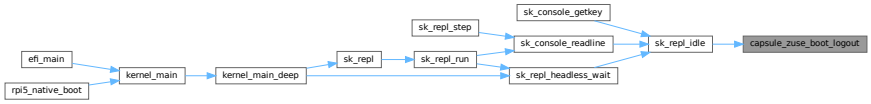
References console_println(), g_zuse_attached_dev, g_zuse_attached_this_device, and VM::zuse_session.

Referenced by sk_repl_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



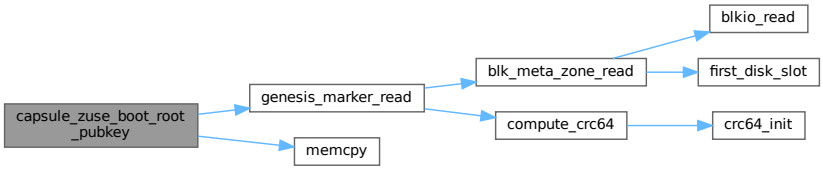
7.137.1.7 capsule_zuse_boot_root_pubkey()

```
int capsule_zuse_boot_root_pubkey (
            uint8_t pubkey[32] )
```

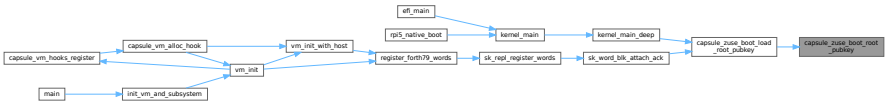
References genesis_marker_read(), memcpy(), and zuse_genesis_marker_t::zuse_pubkey.

Referenced by capsule_zuse_boot_load_root_pubkey().

Here is the call graph for this function:



Here is the caller graph for this function:



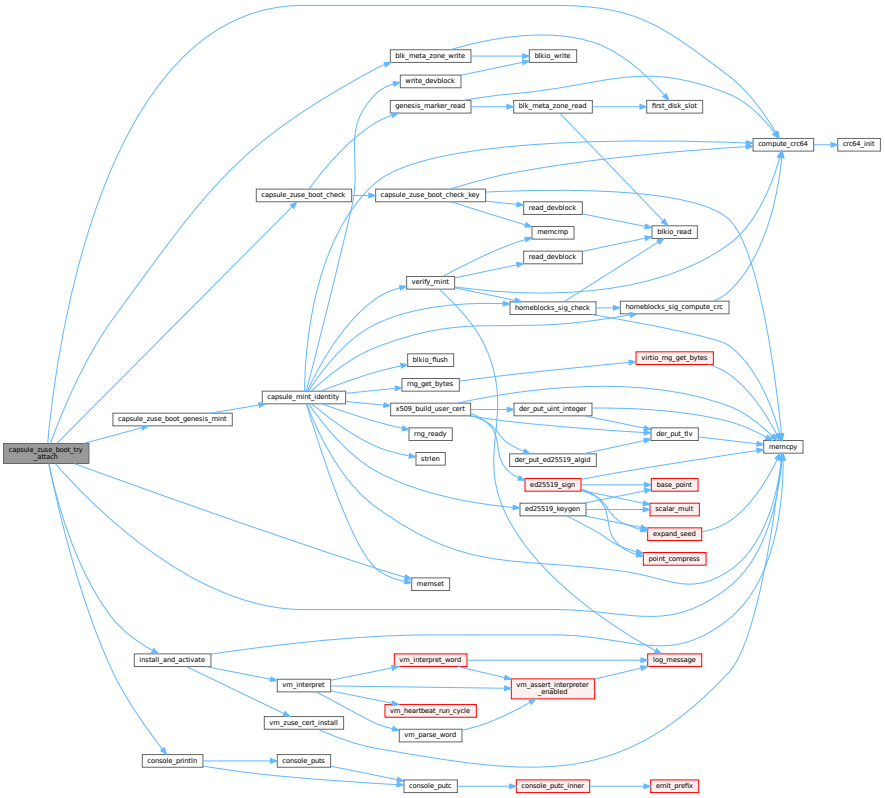
7.137.1.8 capsule_zuse_boot_try_attach()

```
void capsule_zuse_boot_try_attach (
            struct blkio_dev * dev,
            homeblocks_sig_result_t sig_rc,
            const homeblocks_sig_t * sig,
            VM * mama_vm )
```

References blk_meta_zone_write(), capsule_zuse_boot_check(), capsule_zuse_boot_genesis_mint(), compute_crc64(), console_println(), zuse_genesis_marker_t::crc, install_and_activate(), zuse_genesis_marker_t::magic, memcpy(), memset(), zuse_genesis_marker_t::version, ZUSE_GENESIS_MARKER_MAGIC, ZUSE_GENESIS_MARKER_VERSION, zuse_genesis_marker_t::zuse_pubkey, and VM::zuse_session.

Referenced by sk_word_blk_attach_ack().

Here is the call graph for this function:



Here is the caller graph for this function:

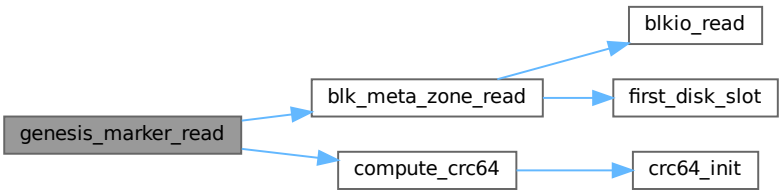
7.137.1.9 genesis_marker_read()

```
static int genesis_marker_read (
            zuse_genesis_marker_t * out )  [static]
```

References blk_meta_zone_read(), compute_crc64(), zuse_genesis_marker_t::crc, zuse_genesis_marker_t::magic, zuse_genesis_marker_t::version, ZUSE_GENESIS_MARKER_MAGIC, and ZUSE_GENESIS_MARKER_VERSION.

Referenced by capsule_zuse_boot_check(), and capsule_zuse_boot_root_pubkey().

Here is the call graph for this function:



Here is the caller graph for this function:

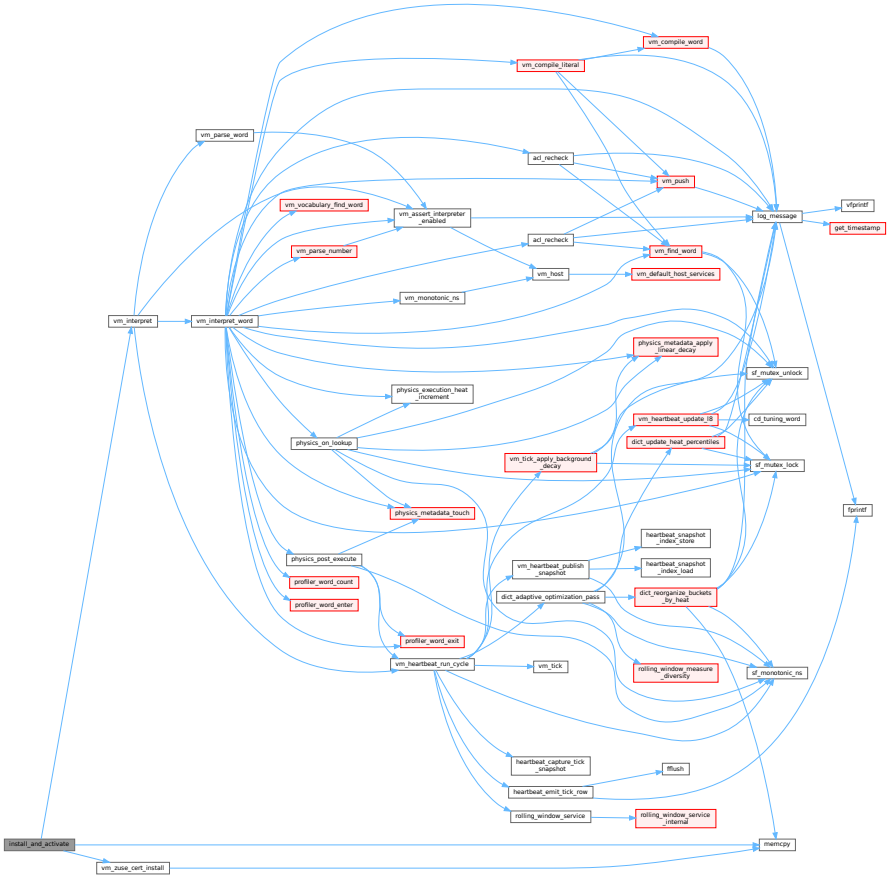
7.137.1.10 install_and_activate()

```
static void install_and_activate (
            VM * mama_vm,
            struct blkio_dev * dev,
            const uint8_t seed[32],
            const uint8_t pubkey[32] )  [static]
```

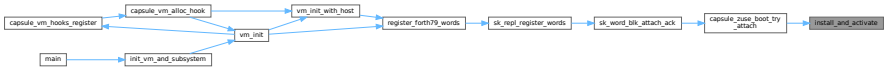
References g_zuse_attached_dev, g_zuse_attached_this_device, memcpy(), vm_interpret(), vm_zuse_cert_install(), VM::zuse_root_pubkey, and VM::zuse_root_pubkey_known.

Referenced by capsule_zuse_boot_try_attach().

Here is the call graph for this function:



Here is the caller graph for this function:



7.137.1.11 read_devblock()

```
static int read_devblock (
            struct blkio_dev * dev,
            uint32_t devblock,
            uint8_t * buf4096 )  [static]
```

References base, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, and blkio_read().

Referenced by capsule_zuse_boot_check_key().

Here is the call graph for this function:

Here is the caller graph for this function:

7.137.2 Variable Documentation

7.137.2.1 g_zuse_attached_dev

```
struct blkio_dev* g_zuse_attached_dev = (struct blkio_dev *) 0  [static]
```

Referenced by capsule_zuse_boot_attached_dev(), capsule_zuse_boot_logout(), and install_and_activate().

7.137.2.2 g_zuse_attached_this_device

```
int g_zuse_attached_this_device = 0  [static]
```

Referenced by capsule_zuse_boot_attached_dev(), capsule_zuse_boot_logout(), and install_and_activate().

7.138 kernel/src/capsule/mama_forth_words.c File Reference

Mama FORTH vocabulary implementation for kernel capsule system (M7.1)

7.138.1 Detailed Description

Mama FORTH vocabulary implementation for kernel capsule system (M7.1)

Implements the MAMA vocabulary - kernel-only words for the LithosAnanke capsule birth protocol. This file is ONLY compiled for **STARKERNEL** builds.

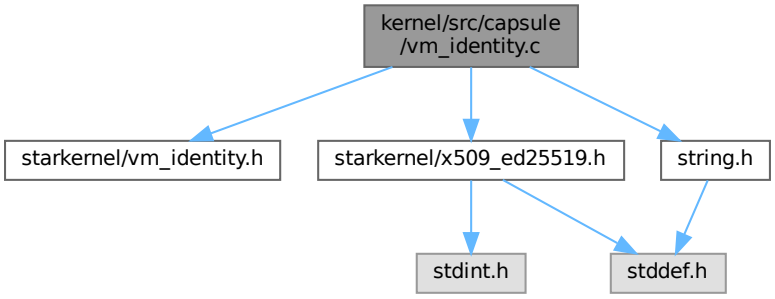
The MAMA vocabulary provides:

- Capsule directory enumeration
- Baby VM birth from production capsules
- Experiment execution on Mama
- VM registry queries

7.139 kernel/src/capsule/vm_identity.c File Reference

```
#include "starkernel/vm_identity.h"
#include "starkernel/x509_ed25519.h"
#include <string.h>
```

Include dependency graph for vm_identity.c:



Functions

- int vm_identity_has_cap (const VMIdentity *id, uint32_t cap)
- int vm_identity_from_cert (VMIdentity *out, const uint8_t *der, size_t der_len, const uint8_t issuer_↩ pubkey[32], const uint8_t drive_uuid[16], uint32_t acl_caps)

7.139.1 Function Documentation

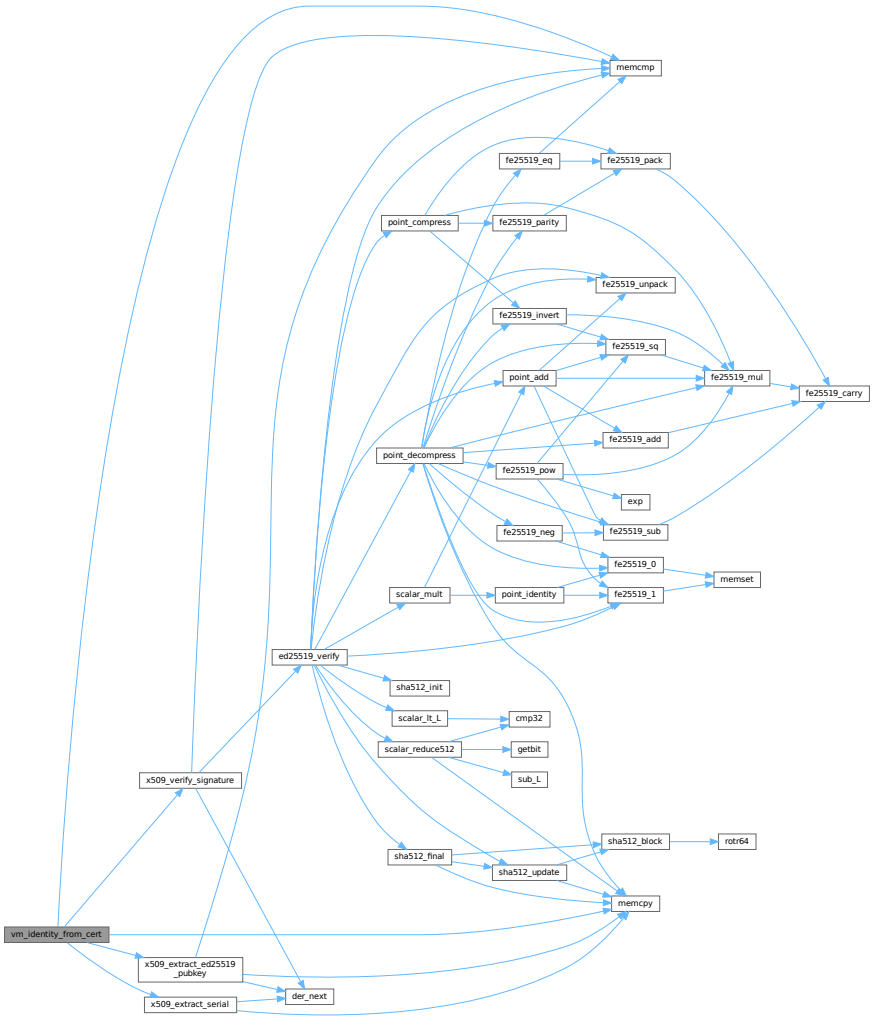
7.139.1.1 vm_identity_from_cert()

```
int vm_identity_from_cert (
            VMIdentity * out,
            const uint8_t * der,
            size_t der_len,
            const uint8_t issuer_pubkey[32],
            const uint8_t drive_uuid[16],
            uint32_t acl_caps )
```

References memcmp(), memcpy(), x509_extract_ed25519_pubkey(), x509_extract_serial(), and x509_verify_signature().

Referenced by capsule_wirebind_verify_cert().

Here is the call graph for this function:



Here is the caller graph for this function:

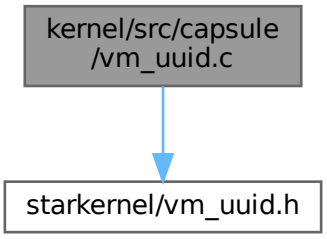
7.139.1.2 vm_identity_has_cap()

```
int vm_identity_has_cap (
            const VMIdentity * id,
            uint32_t cap )
```

7.140 kernel/src/capsule/vm_uuid.c File Reference

```
#include "starkernel/vm_uuid.h"
```

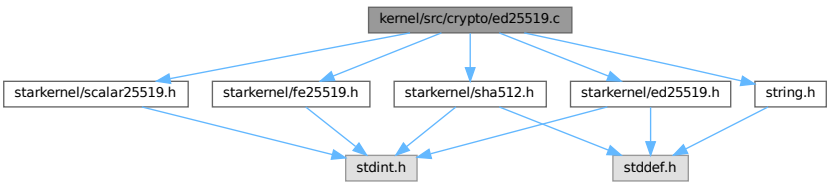
Include dependency graph for vm_uuid.c:



7.141 kernel/src/crypto/ed25519.c File Reference

```
#include "starkernel/ed25519.h"
#include "starkernel/fe25519.h"
#include "starkernel/scalar25519.h"
#include "starkernel/sha512.h"
#include <string.h>
```

Include dependency graph for ed25519.c:



Data Structures

- struct ed_point_t

Functions

- static void fe25519_pow (fe25519 *r, const fe25519 *a, const uint8_t exp[32])
- static void point_identity (ed_point_t *p)
- static void point_add (ed_point_t *r, const ed_point_t *p1, const ed_point_t *p2)
- static void scalar_mult (ed_point_t *r, const uint8_t scalar[32], const ed_point_t *p)
- static int point_decompress (ed_point_t *p, const uint8_t in[32])

- static void point_compress (uint8_t out[32], const ed_point_t *p)
- static void clamp_scalar (uint8_t a[32])
- static void expand_seed (const uint8_t seed[32], uint8_t a[32], uint8_t prefix[32])
- static void base_point (ed_point_t *b)
- void ed25519_keygen (const uint8_t seed[32], uint8_t pubkey_out[32])
- void ed25519_sign (const uint8_t seed[32], const uint8_t *msg, size_t msg_len, uint8_t sig_out[64])
- int ed25519_verify (const uint8_t pubkey[32], const uint8_t *msg, size_t msg_len, const uint8_t sig[64])

Variables

- static const uint8_t D_BYTES [32]
- static const uint8_t BX_BYTES [32]
- static const uint8_t BY_BYTES [32]
- static const uint8_t SQRTM1_BYTES [32]
- static const uint8_t POW_2252M2_EXP [32]

7.141.1 Function Documentation

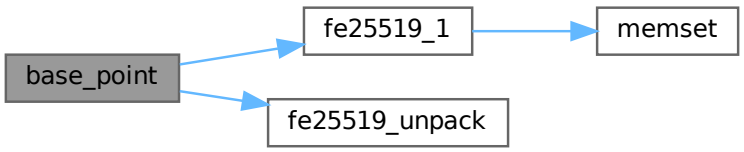
7.141.1.1 base_point()

```
static void base_point (
            ed_point_t * b )  [static]
```

References BX_BYTES, BY_BYTES, fe25519_1(), fe25519_unpack(), ed_point_t::x, ed_point_t::y, and ed_point_t::z.

Referenced by ed25519_keygen(), and ed25519_sign().

Here is the call graph for this function:



Here is the caller graph for this function:

7.141.1.2 clamp_scalar()

```
static void clamp_scalar (
            uint8_t a[32] )  [static]
```

Referenced by expand_seed().

Here is the caller graph for this function:

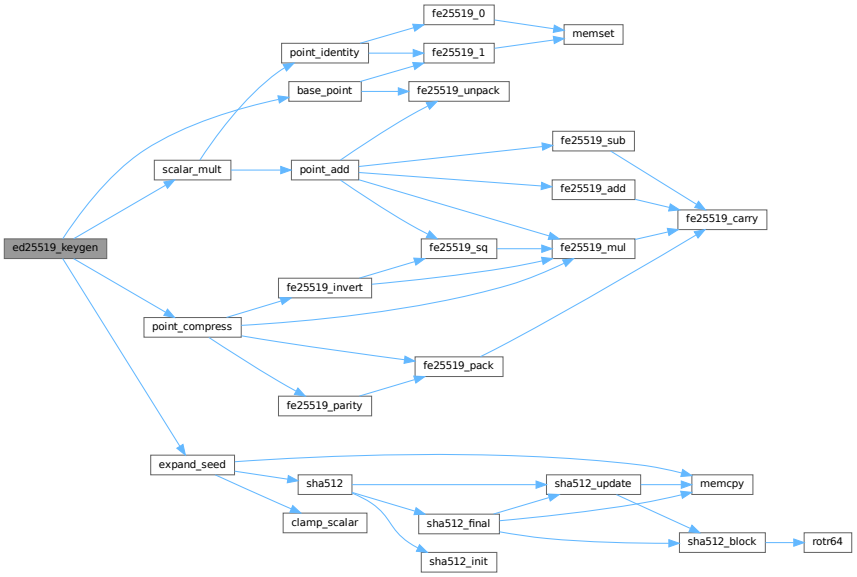
7.141.1.3 ed25519_keygen()

```
void ed25519_keygen (
            const uint8_t seed[32],
            uint8_t pubkey_out[32] )
```

References base_point(), expand_seed(), point_compress(), and scalar_mult().

Referenced by capsule_mint_identity().

Here is the call graph for this function:



Here is the caller graph for this function:

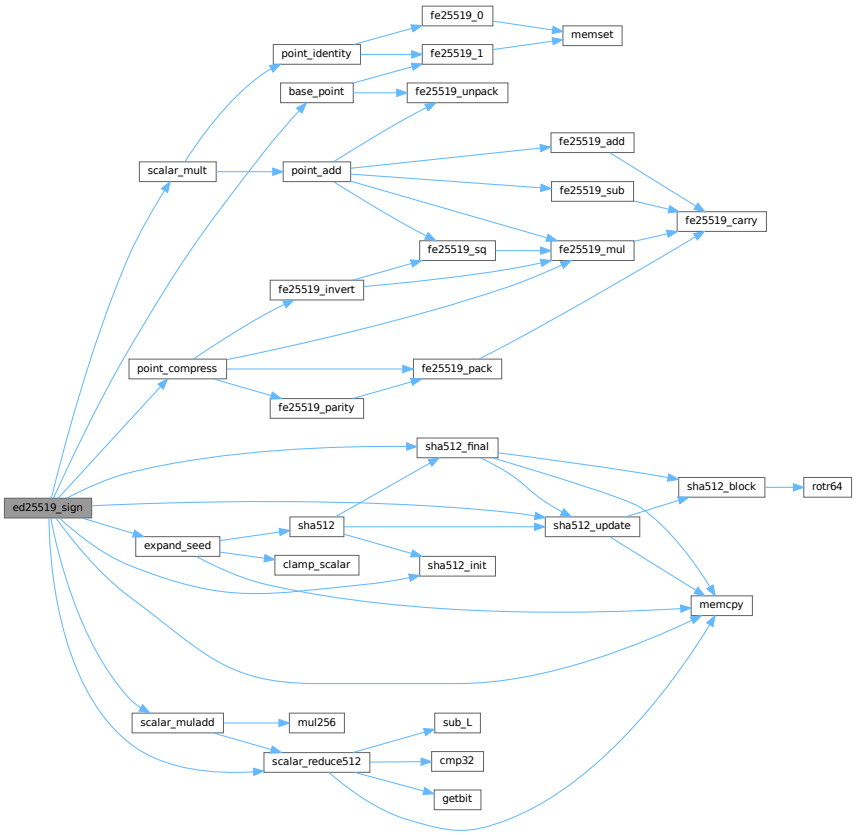
7.141.1.4 ed25519_sign()

```
void ed25519_sign (
            const uint8_t seed[32],
            const uint8_t * msg,
            size_t msg_len,
            uint8_t sig_out[64] )
```

References base_point(), expand_seed(), memcpy(), point_compress(), scalar_muladd(), scalar_mult(), scalar_reduce512(), sha512_final(), sha512_init(), and sha512_update().

Referenced by x509_build_user_cert().

Here is the call graph for this function:



Here is the caller graph for this function:

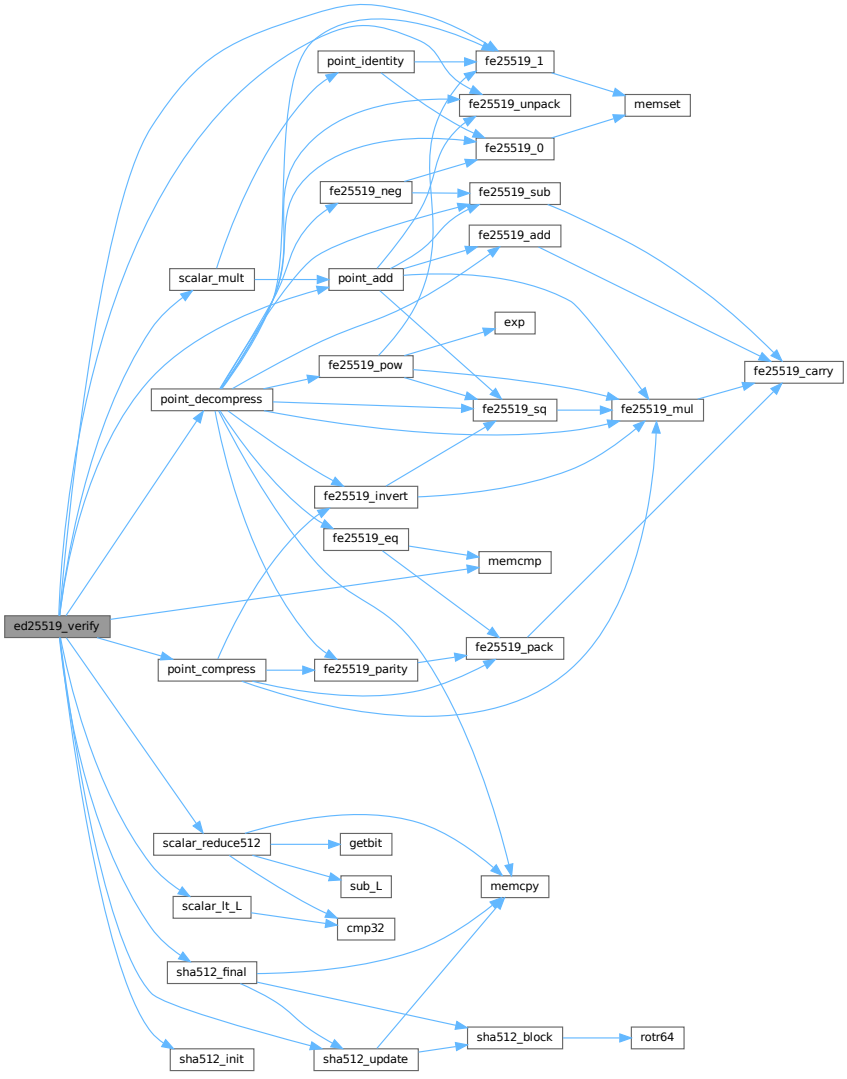
7.141.1.5 ed25519_verify()

```
int ed25519_verify (
            const uint8_t pubkey[32],
            const uint8_t * msg,
            size_t msg_len,
            const uint8_t sig[64] )
```

References BX_BYTES, BY_BYTES, fe25519_1(), fe25519_unpack(), memcmp(), point_add(), point_compress(), point_decompress(), scalar_lt_L(), scalar_mult(), scalar_reduce512(), sha512_final(), sha512_init(), sha512_update(), ed_point_t::x, ed_point_t::y, and ed_point_t::z.

Referenced by capsule_verify_signature(), and x509_verify_signature().

Here is the call graph for this function:



Here is the caller graph for this function:

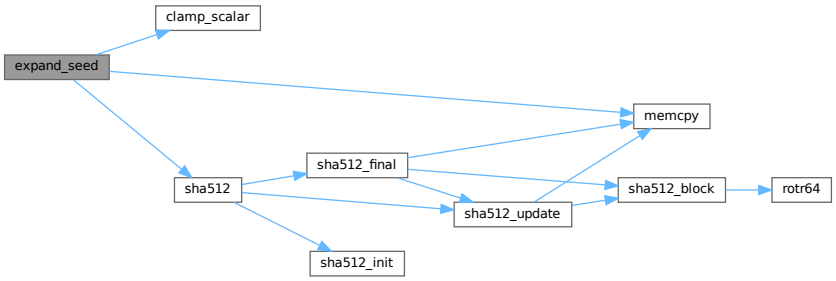
7.141.1.6 expand_seed()

```
static void expand_seed (
            const uint8_t seed[32],
            uint8_t a[32],
            uint8_t prefix[32] )  [static]
```

References clamp_scalar(), memcpy(), and sha512().

Referenced by ed25519_keygen(), and ed25519_sign().

Here is the call graph for this function:



Here is the caller graph for this function:

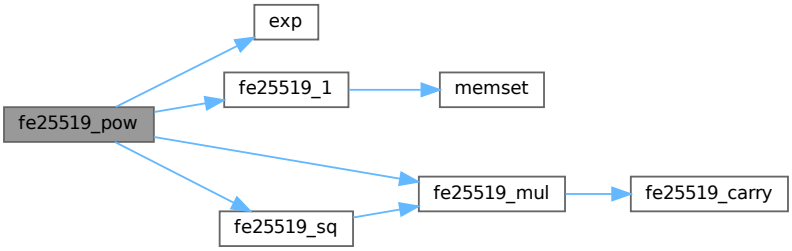
7.141.1.7 fe25519_pow()

```
static void fe25519_pow (
            fe25519 * r,
            const fe25519 * a,
            const uint8_t exp[32] )  [static]
```

References exp(), fe25519_1(), fe25519_mul(), and fe25519_sq().

Referenced by point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

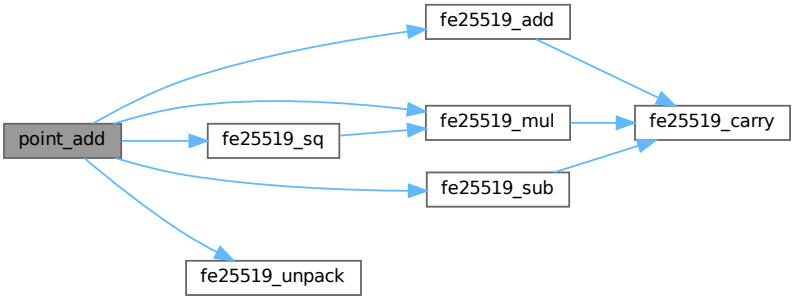
7.141.1.8 point_add()

```
static void point_add (
            ed_point_t * r,
            const ed_point_t * p1,
            const ed_point_t * p2 )  [static]
```

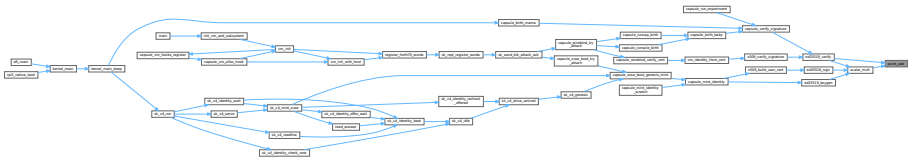
References D_BYTES, fe25519_add(), fe25519_mul(), fe25519_sq(), fe25519_sub(), fe25519_unpack(), ed_point_t::x, ed_point_t::y, and ed_point_t::z.

Referenced by ed25519_verify(), and scalar_mult().

Here is the call graph for this function:



Here is the caller graph for this function:



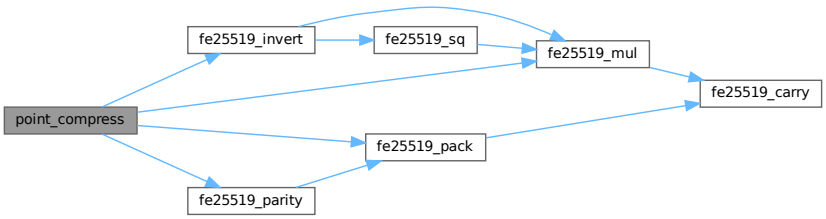
7.141.1.9 point_compress()

```
static void point_compress (
            uint8_t out[32],
            const ed_point_t * p )  [static]
```

References fe25519_invert(), fe25519_mul(), fe25519_pack(), fe25519_parity(), ed_point_t::x, ed_point_t::y, and ed_point_t::z.

Referenced by ed25519_keygen(), ed25519_sign(), and ed25519_verify().

Here is the call graph for this function:



Here is the caller graph for this function:

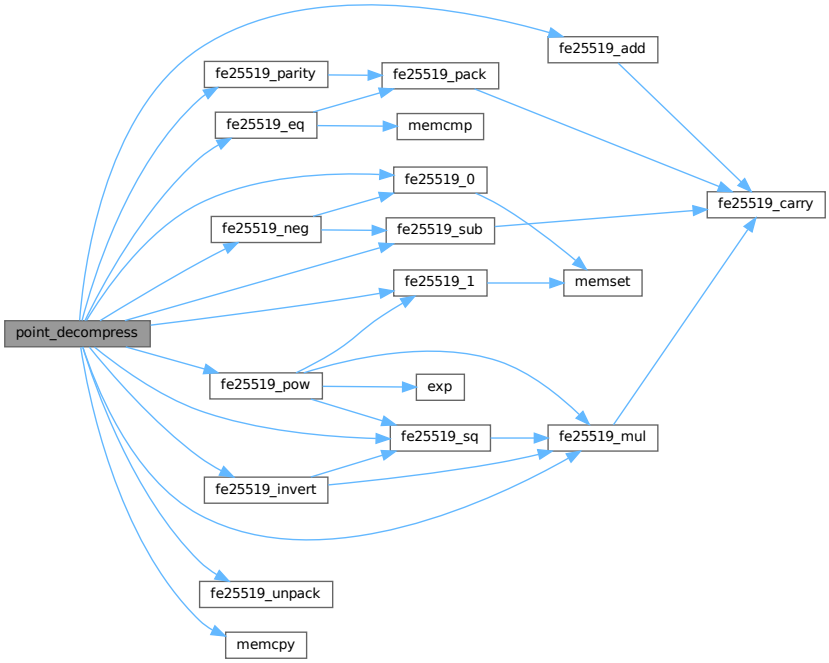
7.141.1.10 point_decompress()

```
static int point_decompress (
            ed_point_t * p,
            const uint8_t in[32] )  [static]
```

References D_BYTES, fe25519_0(), fe25519_1(), fe25519_add(), fe25519_eq(), fe25519_invert(), fe25519_mul(), fe25519_neg(), fe25519_parity(), fe25519_pow(), fe25519_sq(), fe25519_sub(), fe25519_unpack(), memcpy(), POW_2252M2_EXP, SQRTM1_BYTES, ed_point_t::x, ed_point_t::y, ed_point_t::z, and zero.

Referenced by ed25519_verify().

Here is the call graph for this function:



Here is the caller graph for this function:

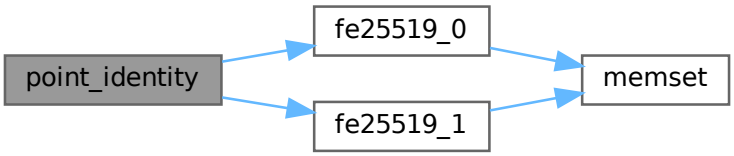
7.141.1.11 point_identity()

```
static void point_identity (
            ed_point_t * p )  [static]
```

References fe25519_0(), fe25519_1(), ed_point_t::x, ed_point_t::y, and ed_point_t::z.

Referenced by scalar_mult().

Here is the call graph for this function:



Here is the caller graph for this function:

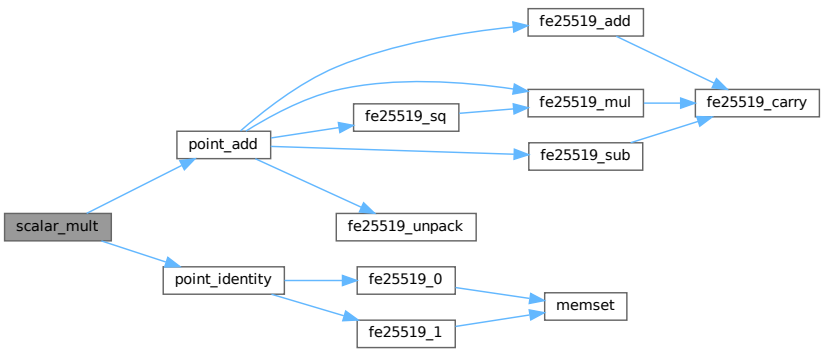
7.141.1.12 scalar_mult()

```
static void scalar_mult (
            ed_point_t * r,
            const uint8_t scalar[32],
            const ed_point_t * p )  [static]
```

References point_add(), and point_identity().

Referenced by ed25519_keygen(), ed25519_sign(), and ed25519_verify().

Here is the call graph for this function:



Here is the caller graph for this function:

7.141.2 Variable Documentation

7.141.2.1 BX_BYTES

```
const uint8_t BX_BYTES[32]  [static]
```

Initial value:

```
= {
    0x1a, 0xd5, 0x25, 0x8f, 0x60, 0x2d, 0x56, 0xc9,
    0xb2, 0xa7, 0x25, 0x95, 0x60, 0xc7, 0x2c, 0x69,
    0x5c, 0xdc, 0xd6, 0xfd, 0x31, 0xe2, 0xa4, 0xc0,
    0xfe, 0x53, 0x6e, 0xcd, 0xd3, 0x36, 0x69, 0x21,
}
```

Referenced by base_point(), and ed25519_verify().

7.141.2.2 BY_BYTES

```
const uint8_t BY_BYTES[32]  [static]
```

Initial value:

```
= {
    0x58, 0x66, 0x66, 0x66, 0x66, 0x66, 0x66, 0x66,
    0x66, 0x66, 0x66, 0x66, 0x66, 0x66, 0x66, 0x66,
    0x66, 0x66, 0x66, 0x66, 0x66, 0x66, 0x66, 0x66,
    0x66, 0x66, 0x66, 0x66, 0x66, 0x66, 0x66, 0x66,
}
```

Referenced by base_point(), and ed25519_verify().

7.141.2.3 D_BYTES

```
const uint8_t D_BYTES[32]  [static]
```

Initial value:

```
= {
    0xa3, 0x78, 0x59, 0x13, 0xca, 0x4d, 0xeb, 0x75,
    0xab, 0xd8, 0x41, 0x41, 0x4d, 0x0a, 0x70, 0x00,
    0x98, 0xe8, 0x79, 0x77, 0x79, 0x40, 0xc7, 0x8c,
    0x73, 0xfe, 0x6f, 0x2b, 0xee, 0x6c, 0x03, 0x52,
}
```

Referenced by point_add(), and point_decompress().

7.141.2.4 POW_2252M2_EXP

```
const uint8_t POW_2252M2_EXP[32]  [static]
```

Initial value:

```
= {
    0xfe, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
    0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
    0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
    0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0x0f,
}
```

Referenced by point_decompress().

7.141.2.5 SQRTM1_BYTES

```
const uint8_t SQRTM1_BYTES[32]  [static]
```

Initial value:

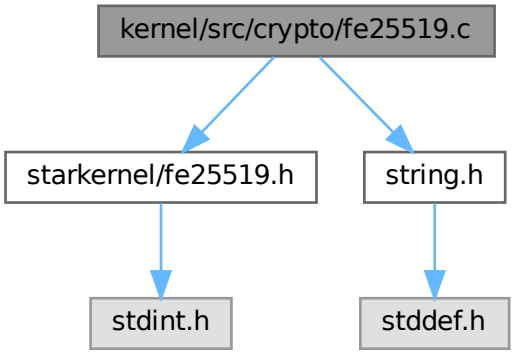
```
= {
    0xb0, 0xa0, 0x0e, 0x4a, 0x27, 0x1b, 0xee, 0xc4,
    0x78, 0xe4, 0x2f, 0xad, 0x06, 0x18, 0x43, 0x2f,
    0xa7, 0xd7, 0xfb, 0x3d, 0x99, 0x00, 0x4d, 0x2b,
    0x0b, 0xdf, 0xc1, 0x4f, 0x80, 0x24, 0x83, 0x2b,
}
```

Referenced by point_decompress().

7.142 kernel/src/crypto/fe25519.c File Reference

```
#include "starkernel/fe25519.h"
#include <string.h>
```

Include dependency graph for fe25519.c:



Macros

- #define WBITS 51
- #define MASK51 (((int64_t)1 << WBITS) - 1)

Typedefs

- typedef unsigned __int128 u128

Functions

- void fe25519_0 (fe25519 *r)
- void fe25519_1 (fe25519 *r)
- void fe25519_copy (fe25519 *r, const fe25519 *a)
- static void fe25519_carry (fe25519 *r)
- void fe25519_add (fe25519 *r, const fe25519 *a, const fe25519 *b)
- void fe25519_sub (fe25519 *r, const fe25519 *a, const fe25519 *b)
- void fe25519_neg (fe25519 *r, const fe25519 *a)
- void fe25519_mul (fe25519 *r, const fe25519 *a, const fe25519 *b)
- void fe25519_sq (fe25519 *r, const fe25519 *a)
- void fe25519_mul_small (fe25519 *r, const fe25519 *a, uint32_t c)
- void fe25519_invert (fe25519 *r, const fe25519 *a)
- void fe25519_pack (uint8_t out[32], const fe25519 *a)
- void fe25519_unpack (fe25519 *r, const uint8_t in[32])
- int fe25519_eq (const fe25519 *a, const fe25519 *b)
- int fe25519_parity (const fe25519 *a)

7.142.1 Macro Definition Documentation

7.142.1.1 MASK51

```
#define MASK51 (((int64_t)1 << WBITS) - 1)
```

7.142.1.2 WBITS

```
#define WBITS 51
```

7.142.2 Typedef Documentation

7.142.2.1 u128

```
typedef unsigned __int128 u128
```

7.142.3 Function Documentation

7.142.3.1 fe25519_0()

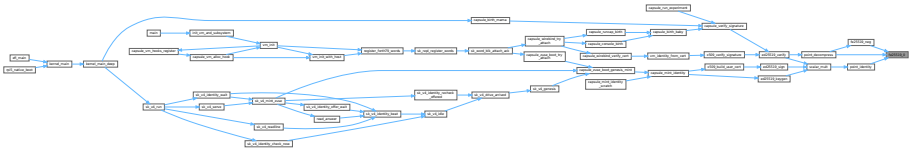
```
void fe25519_0 (
            fe25519 * r )
```

References memset(), and fe25519::v.

Referenced by fe25519_neg(), point_decompress(), and point_identity().

Here is the call graph for this function:

Here is the caller graph for this function:



7.142.3.2 fe25519_1()

```
void fe25519_1 (
            fe25519 * r )
```

References memset(), and fe25519::v.

Referenced by base_point(), ed25519_verify(), fe25519_pow(), point_decompress(), and point_identity().

Here is the call graph for this function:

Here is the caller graph for this function:

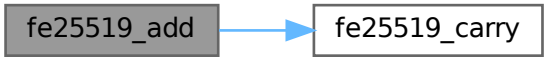
7.142.3.3 fe25519_add()

```
void fe25519_add (
            fe25519 * r,
            const fe25519 * a,
            const fe25519 * b )
```

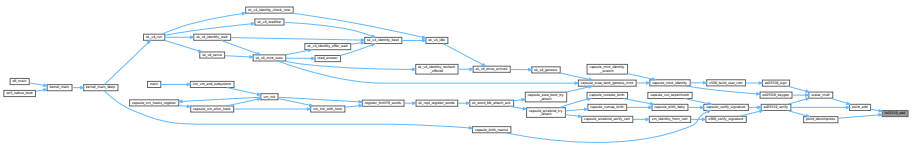
References fe25519_carry(), and fe25519::v.

Referenced by point_add(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:



7.142.3.4 fe25519_carry()

```
static void fe25519_carry (
            fe25519 * r )  [static]
```

References fe25519::v, and WBITS.

Referenced by fe25519_add(), fe25519_mul(), fe25519_mul_small(), fe25519_pack(), and fe25519_sub().

Here is the caller graph for this function:

7.142.3.5 fe25519_copy()

```
void fe25519_copy (
            fe25519 * r,
            const fe25519 * a )
```

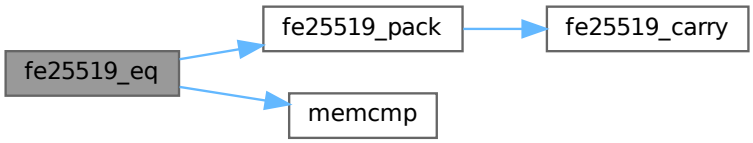
7.142.3.6 fe25519_eq()

```
int fe25519_eq (
            const fe25519 * a,
            const fe25519 * b )
```

References fe25519_pack(), and memcmp().

Referenced by point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

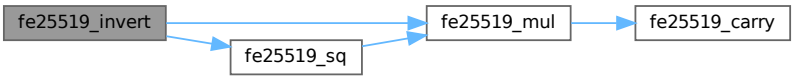
7.142.3.7 fe25519_invert()

```
void fe25519_invert (
            fe25519 * r,
            const fe25519 * a )
```

References fe25519_mul(), and fe25519_sq().

Referenced by point_compress(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

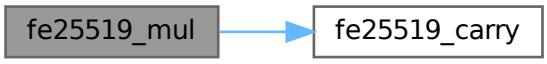
7.142.3.8 fe25519_mul()

```
void fe25519_mul (
            fe25519 * r,
            const fe25519 * a,
            const fe25519 * b )
```

References fe25519_carry(), MASK51, fe25519::v, and WBITS.

Referenced by fe25519_invert(), fe25519_pow(), fe25519_sq(), point_add(), point_compress(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

7.142.3.9 fe25519_mul_small()

```
void fe25519_mul_small (
            fe25519 * r,
            const fe25519 * a,
            uint32_t c )
```

References fe25519_carry(), MASK51, fe25519::v, and WBITS.

Here is the call graph for this function:

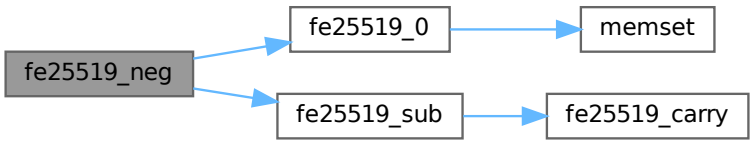
7.142.3.10 fe25519_neg()

```
void fe25519_neg (
            fe25519 * r,
            const fe25519 * a )
```

References fe25519_0(), fe25519_sub(), and zero.

Referenced by point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

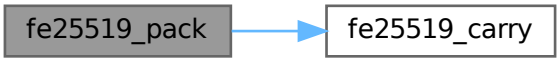
7.142.3.11 fe25519_pack()

```
void fe25519_pack (
            uint8_t out[32],
            const fe25519 * a )
```

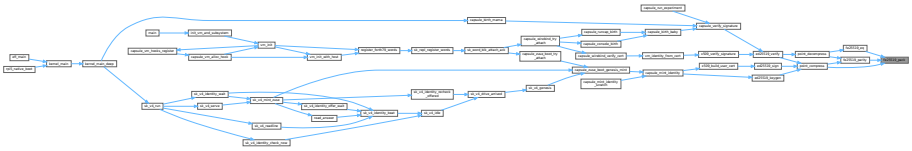
References fe25519_carry(), MASK51, fe25519::v, and WBITS.

Referenced by fe25519_eq(), fe25519_parity(), and point_compress().

Here is the call graph for this function:



Here is the caller graph for this function:



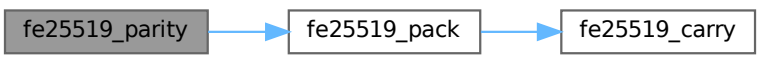
7.142.3.12 fe25519_parity()

```
int fe25519_parity (
            const fe25519 * a )
```

References fe25519_pack().

Referenced by point_compress(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

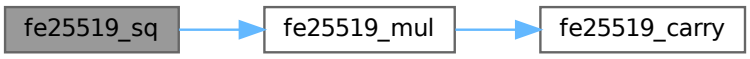
7.142.3.13 fe25519_sq()

```
void fe25519_sq (
             fe25519 * r,
             const fe25519 * a )
```

References fe25519_mul().

Referenced by fe25519_invert(), fe25519_pow(), point_add(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:

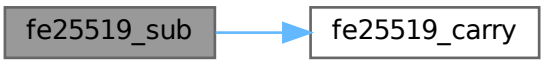
7.142.3.14 fe25519_sub()

```
void fe25519_sub (
             fe25519 * r,
             const fe25519 * a,
             const fe25519 * b )
```

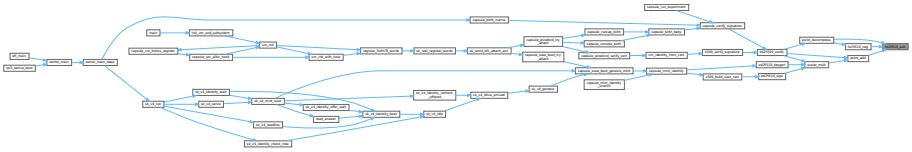
References fe25519_carry(), and fe25519::v.

Referenced by fe25519_neg(), point_add(), and point_decompress().

Here is the call graph for this function:



Here is the caller graph for this function:



7.142.3.15 fe25519_unpack()

```
void fe25519_unpack (
            fe25519 * r,
            const uint8_t in[32] )
```

References MASK51, fe25519::v, and WBITS.

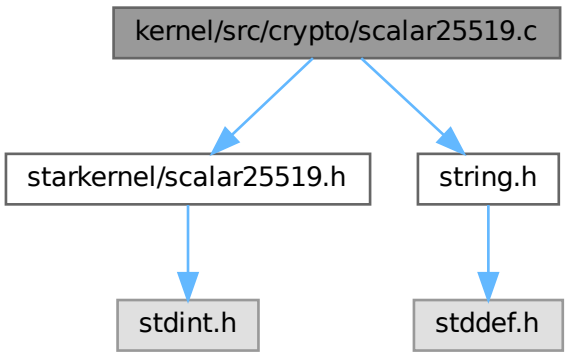
Referenced by base_point(), ed25519_verify(), point_add(), and point_decompress().

Here is the caller graph for this function:

7.143 kernel/src/crypto/scalar25519.c File Reference

```
#include "starkernel/scalar25519.h"
#include <string.h>
```

Include dependency graph for scalar25519.c:



Functions

- static int getbit (const uint8_t *big, int nbytes, int i)
- static void sub_L (uint8_t r[32])
- static int cmp32 (const uint8_t a[32], const uint8_t b[32])
- int scalar_lt_L (const uint8_t s[32])
- void scalar_reduce512 (uint8_t out[32], const uint8_t in[64])
- static void mul256 (uint32_t out_limbs[16], const uint8_t a[32], const uint8_t b[32])
- void scalar_muladd (uint8_t out[32], const uint8_t a[32], const uint8_t b[32], const uint8_t c[32])

Variables

- static const uint8_t L_BYTES [32]

7.143.1 Function Documentation

7.143.1.1 cmp32()

```
static int cmp32 (
            const uint8_t a[32],
            const uint8_t b[32] )  [static]
```

Referenced by scalar_lt_L(), and scalar_reduce512().

Here is the caller graph for this function:

7.143.1.2 getbit()

```
static int getbit (
            const uint8_t * big,
            int nbytes,
            int i )  [static]
```

Referenced by scalar_reduce512().

Here is the caller graph for this function:

7.143.1.3 mul256()

```
static void mul256 (
            uint32_t out_limbs[16],
            const uint8_t a[32],
            const uint8_t b[32] )  [static]
```

Referenced by scalar_muladd().

Here is the caller graph for this function:

7.143.1.4 scalar_lt_L()

```
int scalar_lt_L (
            const uint8_t s[32] )
```

References cmp32(), and L_BYTES.

Referenced by ed25519_verify().

Here is the call graph for this function:

Here is the caller graph for this function:

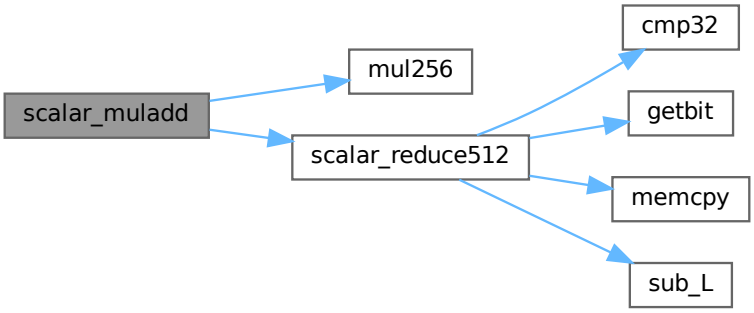
7.143.1.5 scalar_muladd()

```
void scalar_muladd (
            uint8_t out[32],
            const uint8_t a[32],
            const uint8_t b[32],
            const uint8_t c[32] )
```

References mul256(), and scalar_reduce512().

Referenced by ed25519_sign().

Here is the call graph for this function:



Here is the caller graph for this function:

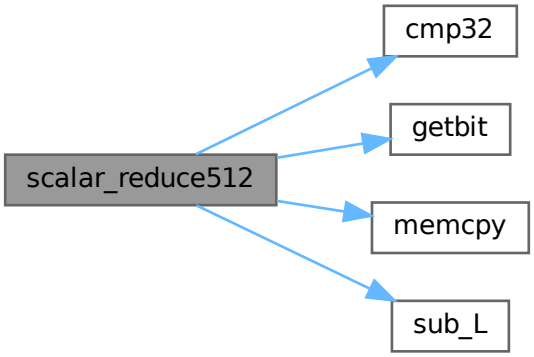
7.143.1.6 scalar_reduce512()

```
void scalar_reduce512 (
            uint8_t out[32],
            const uint8_t in[64] )
```

References cmp32(), getbit(), L_BYTES, memcpy(), and sub_L().

Referenced by ed25519_sign(), ed25519_verify(), and scalar_muladd().

Here is the call graph for this function:



Here is the caller graph for this function:

7.143.1.7 sub_L()

```
static void sub_L (
            uint8_t r[32] )  [static]
```

References L_BYTES.

Referenced by scalar_reduce512().

Here is the caller graph for this function:

7.143.2 Variable Documentation

7.143.2.1 L_BYTES

```
const uint8_t L_BYTES[32]  [static]
```

Initial value:

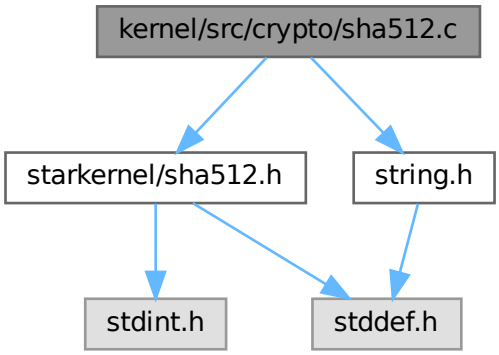
```
= {
    0xed, 0xd3, 0xf5, 0x5c, 0x1a, 0x63, 0x12, 0x58,
    0xd6, 0x9c, 0xf7, 0xa2, 0xde, 0xf9, 0xde, 0x14,
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x10
}
```

Referenced by scalar_lt_L(), scalar_reduce512(), and sub_L().

7.144 kernel/src/crypto/sha512.c File Reference

```
#include "starkernel/sha512.h"
#include <string.h>
```

Include dependency graph for sha512.c:



Functions

- static uint64_t rotr64 (uint64_t x, int n)
- static void sha512_block (sha512_ctx_t *ctx, const uint8_t block[128])
- void sha512_init (sha512_ctx_t *ctx)
- void sha512_update (sha512_ctx_t *ctx, const uint8_t *data, size_t len)
- void sha512_final (sha512_ctx_t *ctx, uint8_t out[64])
- void sha512 (const uint8_t *data, size_t len, uint8_t out[64])

Variables

- static const uint64_t K [80]

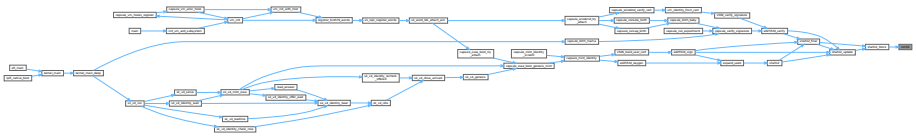
7.144.1 Function Documentation

7.144.1.1 rotr64()

```
static uint64_t rotr64 (
            uint64_t x,
            int n )  [inline], [static]
```

Referenced by sha512_block().

Here is the caller graph for this function:



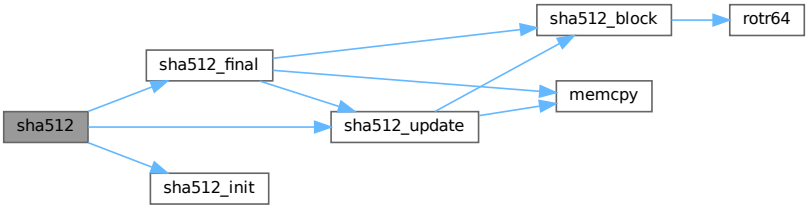
7.144.1.2 sha512()

```
void sha512 (
            const uint8_t * data,
            size_t len,
            uint8_t out[64] )
```

References sha512_final(), sha512_init(), and sha512_update().

Referenced by expand_seed().

Here is the call graph for this function:



Here is the caller graph for this function:

7.144.1.3 sha512_block()

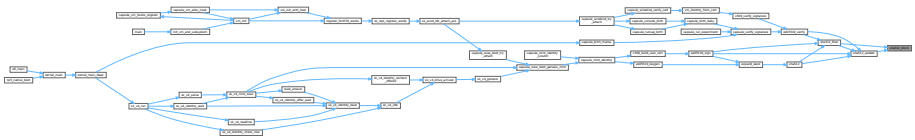
```
static void sha512_block (
            sha512_ctx_t * ctx,
            const uint8_t block[128] )  [static]
```

References g, K, rotr64(), and sha512_ctx_t::state.

Referenced by sha512_final(), and sha512_update().

Here is the call graph for this function:

Here is the caller graph for this function:



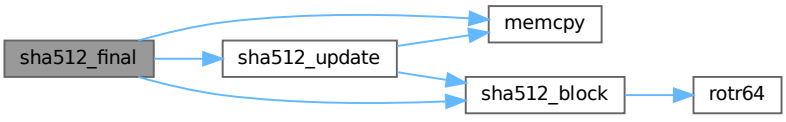
7.144.1.4 sha512_final()

```
void sha512_final (
            sha512_ctx_t * ctx,
            uint8_t out[64] )
```

References sha512_ctx_t::bitlen, sha512_ctx_t::buf, sha512_ctx_t::buf_len, memcpy(), sha512_block(), sha512_update(), sha512_ctx_t::state, and zero.

Referenced by ed25519_sign(), ed25519_verify(), and sha512().

Here is the call graph for this function:



Here is the caller graph for this function:

7.144.1.5 sha512_init()

```
void sha512_init (
            sha512_ctx_t * ctx )
```

References sha512_ctx_t::bitlen, sha512_ctx_t::buf_len, and sha512_ctx_t::state.

Referenced by ed25519_sign(), ed25519_verify(), and sha512().

Here is the caller graph for this function:

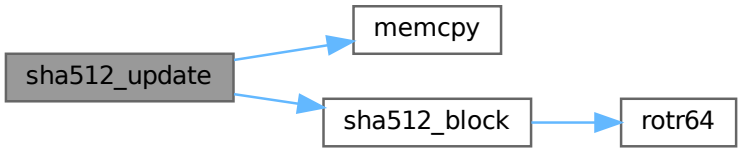
7.144.1.6 sha512_update()

```
void sha512_update (
            sha512_ctx_t * ctx,
            const uint8_t * data,
            size_t len )
```

References sha512_ctx_t::bitlen, sha512_ctx_t::buf, sha512_ctx_t::buf_len, memcpy(), and sha512_block().

Referenced by ed25519_sign(), ed25519_verify(), sha512(), and sha512_final().

Here is the call graph for this function:



Here is the caller graph for this function:

7.144.2 Variable Documentation

7.144.2.1 K

```
const uint64_t K[80]  [static]
```

Initial value:

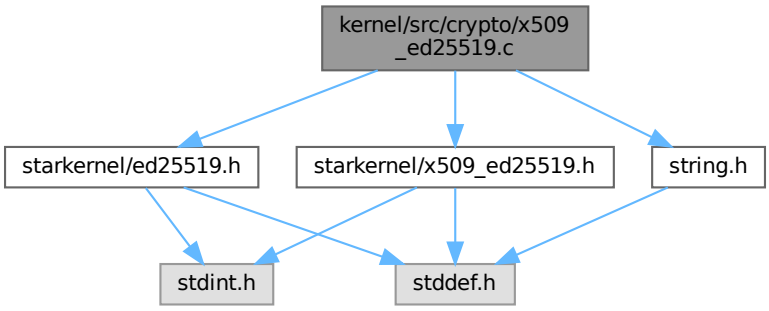
```
= {
    0x428a2f98d728ae22ULL, 0x7137449123ef65cdULL, 0xb5c0fbcfec4d3b2fULL, 0xe9b5dba58189dbbcULL,
    0x3956c25bf348b538ULL, 0x59f111f1b605d019ULL, 0x923f82a4af194f9bULL, 0xab1c5ed5da6d8118ULL,
    0xd807aa98a3030242ULL, 0x12835b0145706fbeULL, 0x243185be4ee4b28cULL, 0x550c7dc3d5ffb4e2ULL,
    0x72be5d74f27b896fULL, 0x80deb1fe3b1696b1ULL, 0x9bdc06a725c71235ULL, 0xc19bf174cf692694ULL,
    0xe49b69c19ef14ad2ULL, 0xefbe4786384f25e3ULL, 0x0fc19dc68b8cd5b5ULL, 0x240ca1cc77ac9c65ULL,
    0x2de92c6f592b0275ULL, 0x4a7484aa6ea6e483ULL, 0x5cb0a9dcbd41fbd4ULL, 0x76f988da831153b5ULL,
    0x983e5152ee66dfabULL, 0xa831c66d2db43210ULL, 0xb00327c898fb213fULL, 0xbf597fc7beef0ee4ULL,
    0xc6e00bf33da88fc2ULL, 0xd5a79147930aa725ULL, 0x06ca6351e003826fULL, 0x142929670a0e6e70ULL,
    0x27b70a8546d22ffcULL, 0x2e1b21385c26c926ULL, 0x4d2c6dfc5ac42aedULL, 0x53380d139d95b3dfULL,
    0x650a73548baf63deULL, 0x766a0abb3c77b2a8ULL, 0x81c2c92e47edaee6ULL, 0x92722c851482353bULL,
    0xa2bfe8a14cf10364ULL, 0xa81a664bbc423001ULL, 0xc24b8b70d0f89791ULL, 0xc76c51a30654be30ULL,
    0xd192e819d6ef5218ULL, 0xd69906245565a910ULL, 0xf40e35855771202aULL, 0x106aa07032bbd1b8ULL,
    0x19a4c116b8d2d0c8ULL, 0x1e376c085141ab53ULL, 0x2748774cdf8eeb99ULL, 0x34b0bcb5e19b48a8ULL,
    0x391c0cb3c5c95a63ULL, 0x4ed8aa4ae3418acbULL, 0x5b9cca4f7763e373ULL, 0x682e6ff3d6b2b8a3ULL,
    0x748f82ee5defb2fcULL, 0x78a5636f43172f60ULL, 0x84c87814a1f0ab72ULL, 0x8cc702081a6439ecULL,
    0x90befffa23631e28ULL, 0xa4506cebde82bde9ULL, 0xbef9a3f7b2c67915ULL, 0xc67178f2e372532bULL,
    0xca273eceea26619cULL, 0xd186b8c721c0c207ULL, 0xeada7dd6cde0eb1eULL, 0xf57d4f7fee6ed178ULL,
    0x06f067aa72176fbaULL, 0x0a637dc5a2c898a6ULL, 0x113f9804bef90daeULL, 0x1b710b35131c471bULL,
    0x28db77f523047d84ULL, 0x32caab7b40c72493ULL, 0x3c9ebe0a15c9bebcULL, 0x431d67c49c100d4cULL,
    0x4cc5d4becb3e42b6ULL, 0x597f299cfc657e2aULL, 0x5fcb6fab3ad6faecULL, 0x6c44198c4a475817ULL
}
```

Referenced by sha512_block().

7.145 kernel/src/crypto/x509_ed25519.c File Reference

```
#include "starkernel/x509_ed25519.h"
#include "starkernel/ed25519.h"
#include <string.h>
```

Include dependency graph for x509_ed25519.c:



Data Structures

- struct der_span_t

Functions

- static int der_next (const uint8_t **cursor, const uint8_t *limit, uint8_t *tag_out, der_span_t *content_out)
- int x509_extract_ed25519_pubkey (const uint8_t *der, size_t der_len, uint8_t pubkey_out[32])
- int x509_verify_signature (const uint8_t *der, size_t der_len, const uint8_t issuer_pubkey[32])
- int x509_extract_serial (const uint8_t *der, size_t der_len, uint8_t *serial_out, size_t serial_out_cap, size_t *serial_len_out)
- static int der_put_tlv (uint8_t **pos, uint8_t *limit, uint8_t tag, const uint8_t *content, size_t content_len)
- static int der_put_ed25519_algid (uint8_t **pos, uint8_t *limit)
- static int der_put_uint_integer (uint8_t **pos, uint8_t *limit, const uint8_t *val, size_t val_len)
- size_t x509_build_user_cert (uint8_t *out, size_t out_cap, const uint8_t subject_pubkey[32], const uint8_t serial[16], const uint8_t issuer_seed[32])

7.145.1 Function Documentation

7.145.1.1 der_next()

```
static int der_next (
            const uint8_t ** cursor,
            const uint8_t * limit,
            uint8_t * tag_out,
            der_span_t * content_out )  [static]
```

References der_span_t::len, limit, and der_span_t::p.

Referenced by x509_extract_ed25519_pubkey(), x509_extract_serial(), and x509_verify_signature().

Here is the caller graph for this function:

7.145.1.2 der_put_ed25519_algid()

```
static int der_put_ed25519_algid (
            uint8_t ** pos,
            uint8_t * limit )  [static]
```

References der_put_tlv(), and limit.

Referenced by x509_build_user_cert().

Here is the call graph for this function:

Here is the caller graph for this function:

7.145.1.3 der_put_tlv()

```
static int der_put_tlv (
            uint8_t ** pos,
            uint8_t * limit,
            uint8_t tag,
            const uint8_t * content,
            size_t content_len )  [static]
```

References limit, and memcpy().

Referenced by der_put_ed25519_algid(), der_put_uint_integer(), and x509_build_user_cert().

Here is the call graph for this function:

Here is the caller graph for this function:

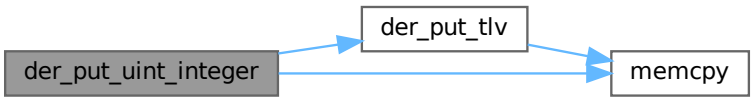
7.145.1.4 der_put_uint_integer()

```
static int der_put_uint_integer (
            uint8_t ** pos,
            uint8_t * limit,
            const uint8_t * val,
            size_t val_len )  [static]
```

References der_put_tlv(), limit, and memcpy().

Referenced by x509_build_user_cert().

Here is the call graph for this function:



Here is the caller graph for this function:

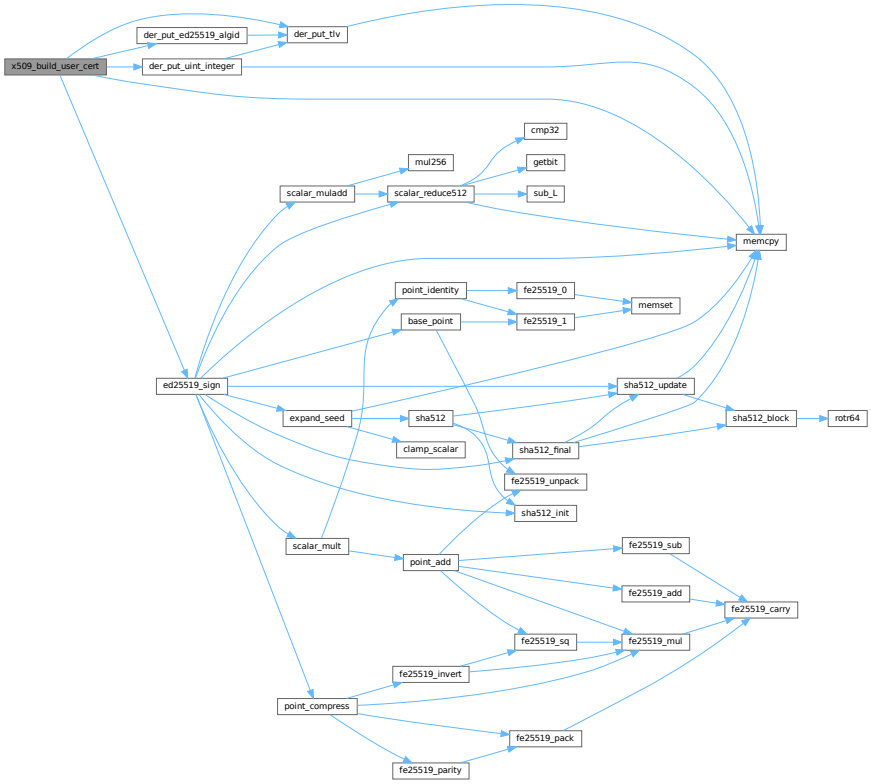
7.145.1.5 x509_build_user_cert()

```
size_t x509_build_user_cert (
            uint8_t * out,
            size_t out_cap,
            const uint8_t subject_pubkey[32],
            const uint8_t serial[16],
            const uint8_t issuer_seed[32] )
```

References der_put_ed25519_algid(), der_put_tlv(), der_put_uint_integer(), ed25519_sign(), and memcpy().

Referenced by capsule_mint_identity().

Here is the call graph for this function:



Here is the caller graph for this function:

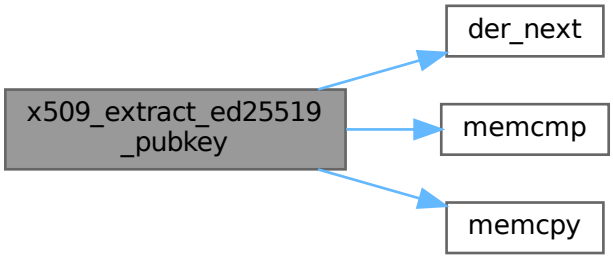
7.145.1.6 x509_extract_ed25519_pubkey()

```
int x509_extract_ed25519_pubkey (
            const uint8_t * der,
            size_t der_len,
            uint8_t pubkey_out[32] )
```

References der_next(), der_span_t::len, memcmp(), memcpy(), and der_span_t::p.

Referenced by find_and_cache_pubkey(), and vm_identity_from_cert().

Here is the call graph for this function:



Here is the caller graph for this function:

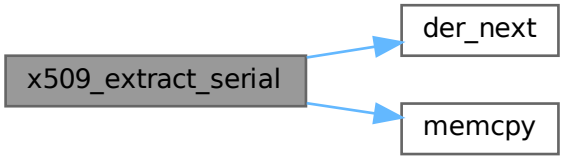
7.145.1.7 x509_extract_serial()

```
int x509_extract_serial (
            const uint8_t * der,
            size_t der_len,
            uint8_t * serial_out,
            size_t serial_out_cap,
            size_t * serial_len_out )
```

References der_next(), der_span_t::len, memcpy(), and der_span_t::p.

Referenced by vm_identity_from_cert().

Here is the call graph for this function:



Here is the caller graph for this function:

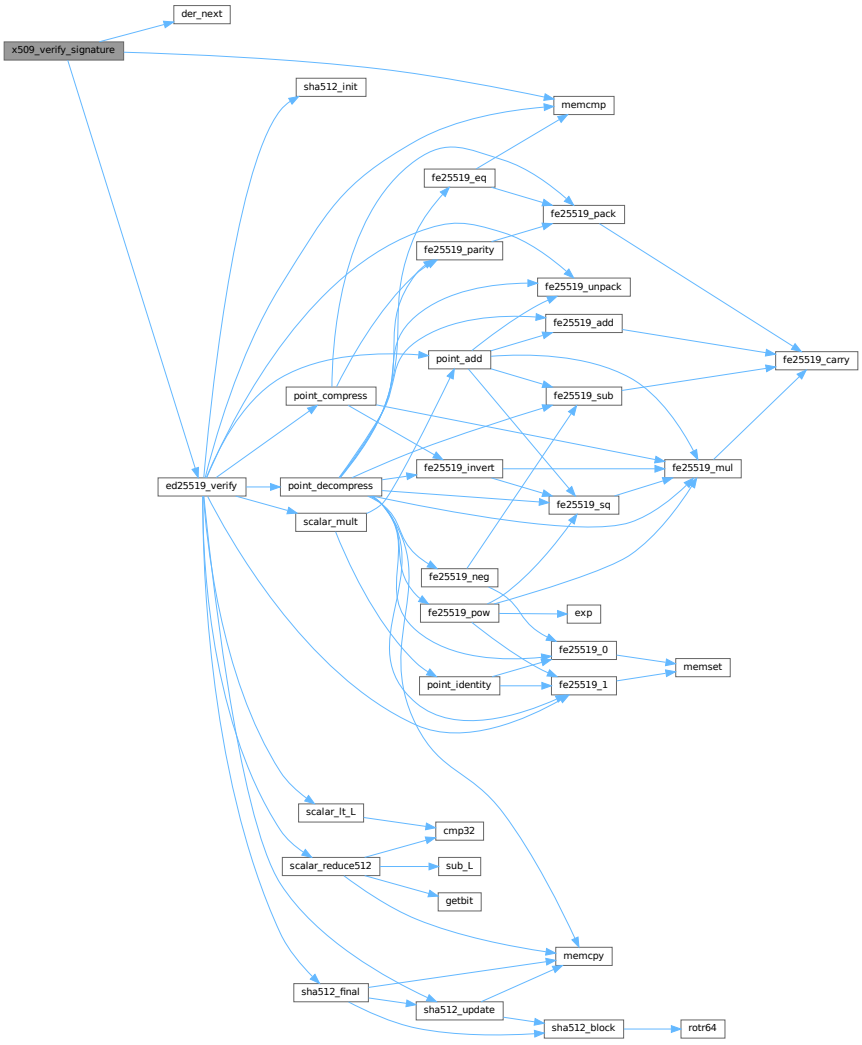
7.145.1.8 x509_verify_signature()

```
int x509_verify_signature (
            const uint8_t * der,
            size_t der_len,
            const uint8_t issuer_pubkey[32] )
```

References der_next(), ed25519_verify(), der_span_t::len, memcmp(), and der_span_t::p.

Referenced by vm_identity_from_cert().

Here is the call graph for this function:

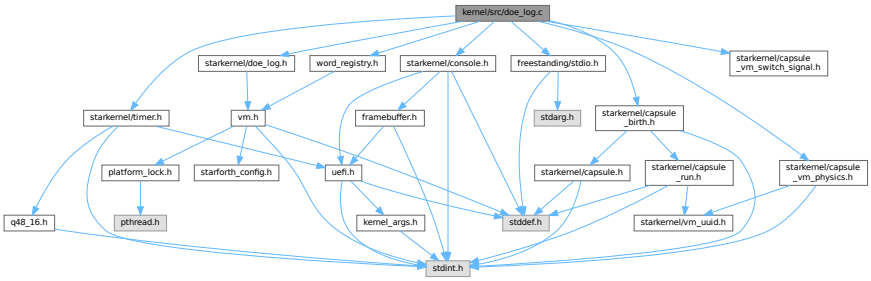


Here is the caller graph for this function:

7.146 kernel/src/doe_log.c File Reference

```
#include "starkernel/doe_log.h"
#include "starkernel/console.h"
#include "starkernel/timer.h"
#include "starkernel/capsule_birth.h"
#include "starkernel/capsule_vm_physics.h"
#include "starkernel/capsule_vm_switch_signal.h"
#include "freestanding/stdio.h"
#include "word_registry.h"
```

Include dependency graph for doe_log.c:



Macros

- #define DOE_PREFIX "\x1b[36m[HADES][DOE]\x1b[0m "
- #define DOE_BUF_SIZE 512

Functions

- static uint64_t doe_log_heat_by_name (const char *name)
- void doe_log_tick_row (VM *vm, const HeartbeatTickSnapshot *snap)

  Emit one CSV row for the current heartbeat tick, unless g_doe_log_enabled is 0 (a no-op then).
- static void doe_word_hb_on (VM *vm)
- static void doe_word_hb_off (VM *vm)
- void register_doe_log_words (VM *vm)

  Registers HB-ON (–) and HB-OFF (–), which set g_doe_log_enabled to 1 and 0 respectively.

Variables

- int g_doe_log_enabled = 0

  doe_log.c — DoE CSV logger for the LithosAnanke kernel
- static const char * doe_header

7.146.1 Macro Definition Documentation

7.146.1.1 DOE_BUF_SIZE

```
#define DOE_BUF_SIZE 512
```

7.146.1.2 DOE_PREFIX

```
#define DOE_PREFIX "\x1b[36m[HADES][DOE ]\x1b[0m "
```

7.146.2 Function Documentation

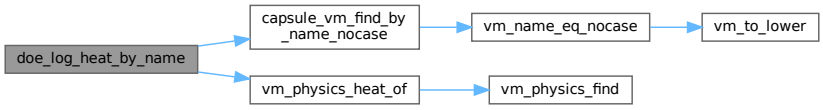
7.146.2.1 doe_log_heat_by_name()

```
static uint64_t doe_log_heat_by_name (
            const char * name )  [static]
```

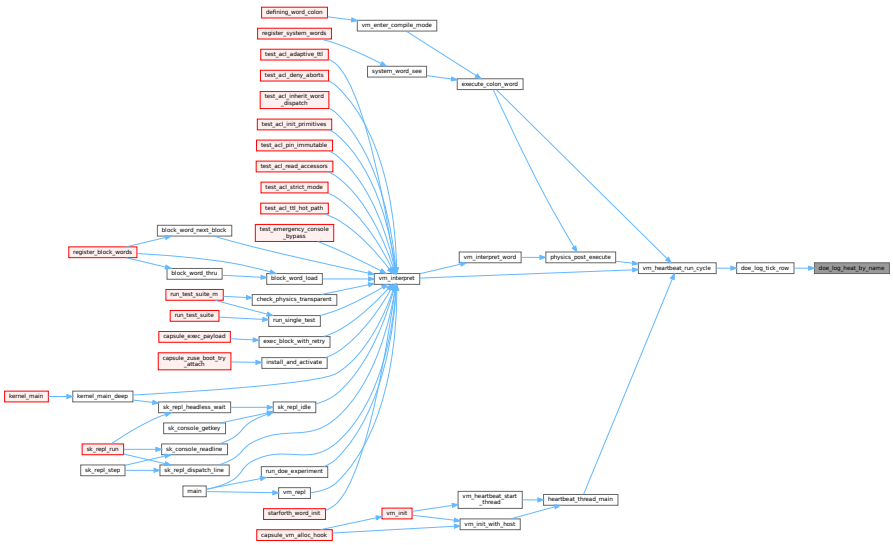
References capsule_vm_find_by_name_nocase(), entry, name, and vm_physics_heat_of().

Referenced by doe_log_tick_row().

Here is the call graph for this function:



Here is the caller graph for this function:



7.146.2.2 doe_log_tick_row()

```
void doe_log_tick_row (
            VM * vm,
            const HeartbeatTickSnapshot * snap )
```

Emit one CSV row for the current heartbeat tick, unless g_doe_log_enabled is 0 (a no-op then).

Pulls APIC TimeTrustState via heartbeat_state(). Prints the column header once, before the first row ever emitted – not re-printed on every HB-ON, so a session toggled off and back on stays one continuous CSV rather than getting a second header embedded partway through.

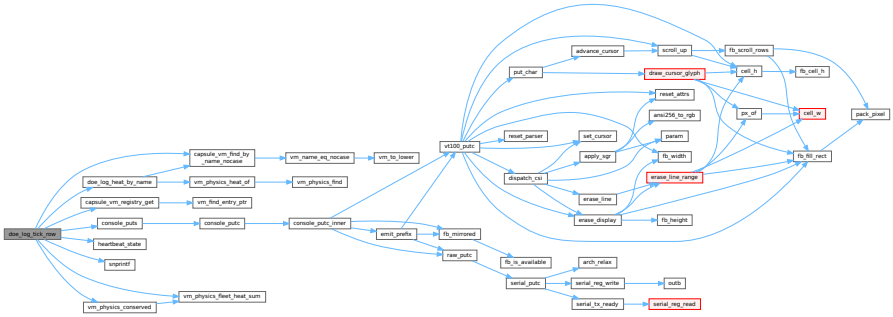
Parameters

vm	VM instance (used for snapshot data)
snap	Populated HeartbeatTickSnapshot from heartbeat_capture_tick_snapshot()

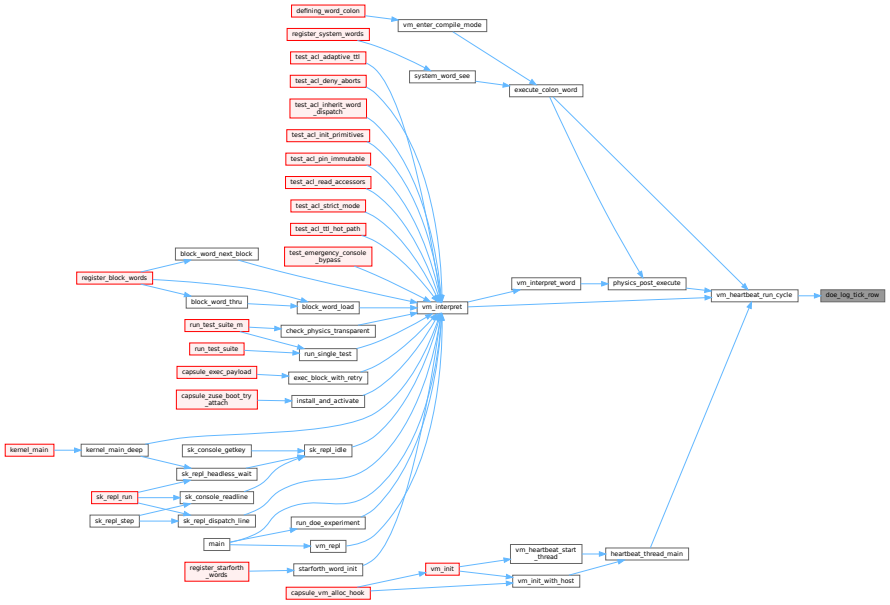
References HeartbeatTickSnapshot::actual_window_size, HeartbeatTickSnapshot::avg_word_heat, HeartbeatTickSnapshot::bucket_, HeartbeatTickSnapshot::cache_hits_delta, capsule_vm_find_by_name_nocase(), capsule_vm_registry_get(), console_puts(), DOE_BUF_SIZE, doe_header, doe_log_heat_by_name(), DOE_PREFIX, HeartbeatTickSnapshot::elapsed_ns, HeartbeatTickSnapshot::estimated_jitter_ns, g_doe_log_enabled, heartbeat_state(), HeartbeatTickSnapshot::hot_word_count, VMRegistryEntry::name, HeartbeatTickSnapshot::predicted_label_hits, snprintf(), HeartbeatTickSnapshot::tick_interval_ns, HeartbeatTickSnapshot::tick_number, time_trust_state::ticks, time_trust_state::trust, time_trust_state::variance, VMRegistryEntry::vm_id, vm_physics_conserved(), vm_physics_fleet_heat_sum(), HeartbeatTickSnapshot::window_width, and HeartbeatTickSnapshot::word_executions_delta.

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.146.2.3 doe_word_hb_off()

```
static void doe_word_hb_off (
            VM * vm )  [static]
```

References g_doe_log_enabled.

Referenced by register_doe_log_words().

Here is the caller graph for this function:

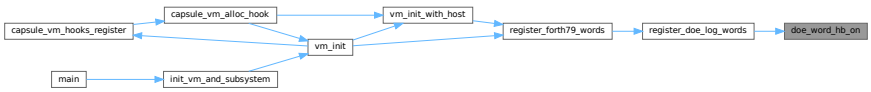
7.146.2.4 doe_word_hb_on()

```
static void doe_word_hb_on (
            VM * vm )  [static]
```

References g_doe_log_enabled.

Referenced by register_doe_log_words().

Here is the caller graph for this function:



7.146.2.5 register_doe_log_words()

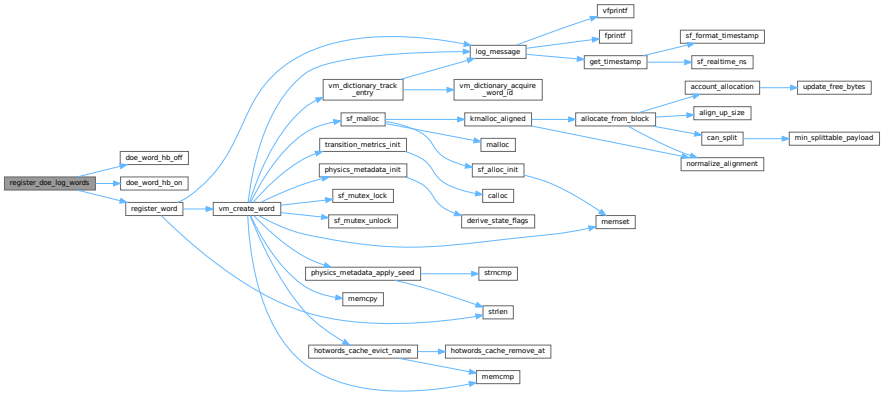
```
void register_doe_log_words (
            VM * vm )
```

Registers HB-ON (–) and HB-OFF (–), which set g_doe_log_enabled to 1 and 0 respectively.

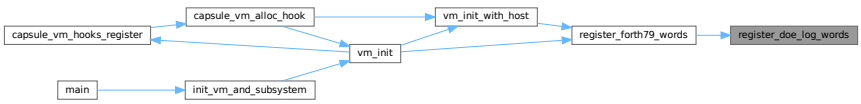
References doe_word_hb_off(), doe_word_hb_on(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.146.3 Variable Documentation

7.146.3.1 doe_header

```
const char* doe_header  [static]
```

Initial value:

```
=
     "\x1b[36m[HADES][DOE ]\x1b[0m "
    "vm_name,vm_id_hex,"
    "tick_number,elapsed_ns,tick_interval_ns,"
    "cache_hits_delta,bucket_hits_delta,word_executions_delta,"
    "hot_word_count,avg_word_heat_q48,"
    "window_width,actual_window_size,predicted_label_hits,jitter_bits,"
    "apic_ticks,time_trust_q48,variance_q48,vm_call_depth_max,"
    "hera_heat_q48,hermes_heat_q48,artemis_heat_q48,"
    "fleet_k_q48,fleet_conserved,"
    "switch_count_cumulative,switch_current_slot,"
    "switch_hera_readiness,switch_hermes_readiness,switch_artemis_readiness,"
    "switch_ticks_since"
```

Referenced by doe_log_tick_row().

7.146.3.2 g_doe_log_enabled

```
int g_doe_log_enabled = 0
```

doe_log.c — DoE CSV logger for the LithosAnanke kernel

starkernel/doe_log.h — DoE (Design of Experiments) CSV logger

Emits CSV rows to the serial log once per heartbeat tick. Each row is prefixed with a cyan [HADES][DOE] tag so it can be extracted cleanly:

grep -aP '[HADES][DOE]' qemu-amd64-∗.log

Columns (in order): 0a. vm_name string — the emitting VM's own registry name (reverse lookup on vm->stadium↩ _vm_id, "?" if unregistered at this tick). Added 2026-09-16 for the multiuser/ multitasking DoE (FABRIC-3.md ?↩ XXXIII): every prior column already described *a* VM's state each row, but nothing said *which* VM emitted it, making concurrent-VM rows indistinguishable by source. 0b. vm_id_hex string — the emitting VM's own stadium_vm_↩ id as "hi-lo" hex, same format PARITY:BIRTH/PARITY:KILL already print. Names get reused across a trial's own KILL+rebirth cycles; this is the one column unique to a single birth instance.

1. tick_number uint32 — monotonic heartbeat counter
2. elapsed_ns uint64 — ns since run start
3. tick_interval_ns uint64 — actual interval from prior tick
4. cache_hits_delta uint32 — hot-words cache hits this tick (TODO: 0)
5. bucket_hits_delta uint32 — bucket hits this tick (TODO: 0)
6. word_executions_delta uint32 — words executed this tick (TODO: 0)
7. hot_word_count uint64 — words with heat >= threshold
8. avg_word_heat_q48 uint64 — mean execution heat as raw Q48.16 integer
9. window_width uint32 — rolling window effective size
10. actual_window_size uint32 — true analysis width: min(total_executions, effective_window_size)
11. predicted_label_hits uint32 — ANOVA early-exit confirmations per tick (L8 validation signal)
12. jitter_bits uint64 — estimated_jitter_ns IEEE 754 raw bits (union-punned)
13. apic_ticks uint64 — APIC timer monotonic tick count
14. time_trust_q48 uint64 — TIME-TRUST in Q48.16 format
15. variance_q48 uint64 — timing variance in Q48.16 format
16. hera_heat_q48 uint64 — VM fleet physics: Hera's execution_heat_q48
17. hermes_heat_q48 uint64 — VM fleet physics: Hermes's execution_heat_q48
18. artemis_heat_q48 uint64 — VM fleet physics: Artemis's execution_heat_q48
19. fleet_k_q48 uint64 — "K": vm_physics_fleet_heat_sum() over ALL live VMs (not just the 3 named Tripod members above – this is the genuine conservation invariant, which should read Q48_ONE (65536) whenever conservation holds). Requested 2026-09-12 alongside the 3x9 factorial analysis in experiments/std79-doe/ – columns 16-18 alone cannot reconstruct this since they omit every identity VM's own heat.
20. fleet_conserved uint32 — vm_physics_conserved() as 0/1: whether |fleet_k_q48 - Q48_ONE| < VM_↩ PHYSICS_EPSILON_Q48 at the moment this row was captured.
21. switch_count_cumulative uint64 — Stage 3 preemptive-switch count, cumulative since boot (capsule_vm_switch_signal.c).

22. switch_current_slot uint32 — which registered switch-signal participant is executing at this tick (0=Hera,1=Hermes, 2=Artemis by current registration order; 0xFFFFFFFF = none/unregistered at this moment).
23. switch_hera_readiness uint32 — Hera's raw readiness accumulator (slot 0).
24. switch_hermes_readiness uint32 — Hermes's raw readiness accumulator (slot 1).
25. switch_artemis_readiness uint32 — Artemis's raw readiness accumulator (slot 2).
26. switch_ticks_since uint32 — ticks elapsed since the last real switch (capsule_vm_switch_signal.c); empirically verifies the fixed 50-tick threshold under real DoE load rather than assuming it.

Columns 21-26 (FABRIC-3.md ?XXVIII Stage 3 follow-on, 2026-09-13): added alongside Stage 3's timer-driven preemptive context switching – read-only exposure of state the switch-signal module already tracked internally for its own decision-making; no new measurement logic, just made observable. Slot readiness columns are hardcoded to the 3 known Tripod slots (same convention as columns 16-18) rather than a dynamic per-slot column set, for the same reason: this is a logging schema for the currently-known fleet, not the switch-signal mechanism itself (which stays slot-count-agnostic, headroom for up to 8 participants – see capsule_vm_switch_signal.h).

Note: avg_word_heat and estimated_jitter_ns are stored as double in the snapshot but the freestanding snprintf has no %f support. avg_word_heat is emitted as raw Q48.16 (multiply by 65536); jitter is union-punned to its IEEE 754 uint64 bit pattern to avoid UB from out-of-range cast.

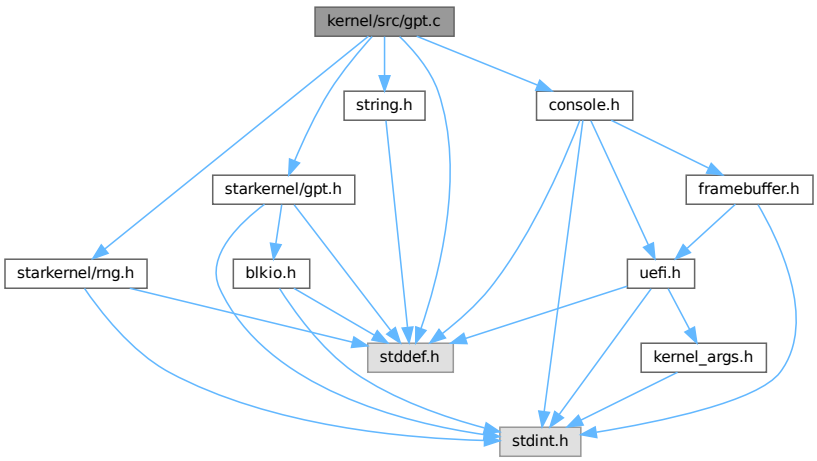
Columns 16-18 (VM-FLEET-ATTRACTOR-DESIGN-20260705.md, Phase 3): looked up by name each tick rather than by a fixed vm_id, since kill/rebirth (e.g. TRIPOD-TEST's K-soak) assigns a fresh vm_id on every rebirth. Fixed to the three known Tripod VMs, not a dynamic per-VM column set – this is a logging schema for a specific known fleet, not the physics mechanism itself (which stays genuinely VM-count-agnostic). Reads 0 for any VM not currently found in the registry (e.g. Hermes momentarily during its kill/rebirth window), which is a legitimate observation, not an error.

Referenced by doe_log_tick_row(), doe_word_hb_off(), and doe_word_hb_on().

7.147 kernel/src/gpt.c File Reference

```
#include "starkernel/gpt.h"
#include "starkernel/rng.h"
#include "console.h"
#include <stddef.h>
#include <string.h>
```

Include dependency graph for gpt.c:



Macros

- #define GPT_SECTOR 512u
- #define GPT_ENTRIES_MAX (32u ∗ 1024u) /∗ the entry array read, at most (128 entries of 128 bytes is 16 KiB) ∗/
- #define GPT_NENT 128u
- #define GPT_ESIZE 128u
- #define GPT_ENT_SECTORS ((GPT_NENT ∗ GPT_ESIZE) / GPT_SECTOR) /∗ 32 ∗/

Functions

- uint32_t gpt_crc32 (const void ∗buf, size_t len)
- static uint32_t le32 (const uint8_t ∗p)
- static uint64_t le64 (const uint8_t ∗p)
- int gpt_read (blkio_dev_t ∗disk, gpt_part_t ∗parts, unsigned max, unsigned ∗count)
- void gpt_disk_guid (uint8_t guid[16])
- int gpt_find (const gpt_part_t ∗parts, unsigned count, const uint8_t type[16])
- static void put_le32 (uint8_t ∗p, uint32_t v)
- static void put_le64 (uint8_t ∗p, uint64_t v)
- static int put_sectors (blkio_dev_t ∗disk, uint64_t lba, const uint8_t ∗src, uint32_t n)
- uint64_t gpt_alternate_lba (void)
- int gpt_grow_last (blkio_dev_t ∗disk, const uint8_t type[16], uint64_t max_part_sectors, uint64_t ∗new_last↩ _lba)
- static int gpt_new_guid (uint8_t g[16])
- int gpt_write_one (blkio_dev_t ∗disk, const uint8_t type[16], uint64_t part_sectors, uint8_t disk_guid[16])
- static int part_open (blkio_dev_t ∗dev, const blkio_params_t ∗p)
- static int part_close (blkio_dev_t ∗dev)
- static int part_read (blkio_dev_t ∗dev, uint32_t fblock, void ∗dst)
- static int part_write (blkio_dev_t ∗dev, uint32_t fblock, const void ∗src)
- static int part_flush (blkio_dev_t ∗dev)
- static int part_info (blkio_dev_t ∗dev, blkio_info_t ∗out)
- int gpt_part_open (blkio_dev_t ∗dev, gpt_part_dev_t ∗st, blkio_dev_t ∗disk, const gpt_part_t ∗p)

Variables

- const uint8_t gpt_type_starship_identity [16]
- const uint8_t gpt_type_starship_artemis [16]
- static uint8_t g_gpt_hdr_block [1024u]
- static uint8_t g_gpt_entries [(32u ∗1024u)]
- static uint8_t g_gpt_disk_guid [16]
- static uint64_t g_gpt_alternate_lba
- static uint8_t g_gpt_rmw [1024u]
- static uint8_t g_gpt_new_entries [128u ∗128u]
- static const blkio_vtable_t g_part_vt = { part_open, part_close, part_read, part_write, part_flush, part_info }

7.147.1 Macro Definition Documentation

7.147.1.1 GPT_ENT_SECTORS

```
#define GPT_ENT_SECTORS ((GPT_NENT * GPT_ESIZE) / GPT_SECTOR) /* 32 */
```

7.147.1.2 GPT_ENTRIES_MAX

```
#define GPT_ENTRIES_MAX (32u * 1024u) /* the entry array read, at most (128 entries of 128
bytes is 16 KiB) */
```

7.147.1.3 GPT_ESIZE

```
#define GPT_ESIZE 128u
```

7.147.1.4 GPT_NENT

```
#define GPT_NENT 128u
```

7.147.1.5 GPT_SECTOR

```
#define GPT_SECTOR 512u
```

7.147.2 Function Documentation

7.147.2.1 gpt_alternate_lba()

```
uint64_t gpt_alternate_lba (
            void  )
```

References g_gpt_alternate_lba.

Referenced by sk_v4_grow_stick().

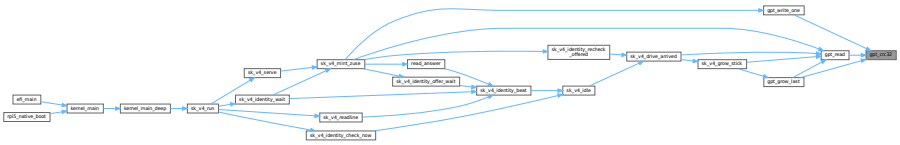
Here is the caller graph for this function:

7.147.2.2 gpt_crc32()

```
uint32_t gpt_crc32 (
            const void * buf,
            size_t len )
```

Referenced by gpt_grow_last(), gpt_read(), and gpt_write_one().

Here is the caller graph for this function:



7.147.2.3 gpt_disk_guid()

```
void gpt_disk_guid (
            uint8_t guid[16] )
```

References g_gpt_disk_guid, and memcpy().

Referenced by sk_v4_is_this_stick().

Here is the call graph for this function:

Here is the caller graph for this function:

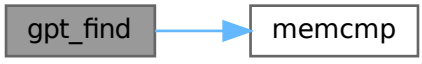
7.147.2.4 gpt_find()

```
int gpt_find (
            const gpt_part_t * parts,
            unsigned count,
            const uint8_t type[16] )
```

References count, and memcmp().

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), sk_v4_is_this_stick(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

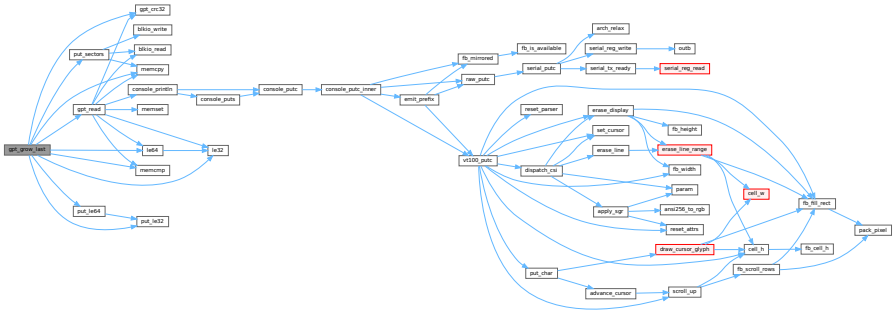
7.147.2.5 gpt_grow_last()

```
int gpt_grow_last (
            blkio_dev_t * disk,
            const uint8_t type[16],
            uint64_t max_part_sectors,
            uint64_t * new_last_lba )
```

References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, count, blkio_vtable_t::flush, g_gpt_entries, g_gpt_hdr_block, GPT_BAD, gpt_crc32(), GPT_EIO, GPT_NONE, GPT_OK, gpt_read(), GPT_SECTOR, le32(), le64(), memcmp(), memcpy(), put_le32(), put_le64(), put_sectors(), blkio_dev::total_blocks, blkio_dev::vt, and zero.

Referenced by sk_v4_grow_stick().

Here is the call graph for this function:



Here is the caller graph for this function:

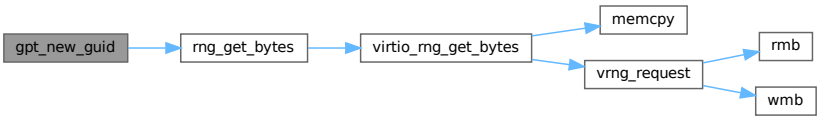
7.147.2.6 gpt_new_guid()

```
static int gpt_new_guid (
            uint8_t g[16] )  [static]
```

References g, and rng_get_bytes().

Referenced by gpt_write_one().

Here is the call graph for this function:



Here is the caller graph for this function:

7.147.2.7 gpt_part_open()

```
int gpt_part_open (
            blkio_dev_t * dev,
            gpt_part_dev_t * st,
            blkio_dev_t * disk,
            const gpt_part_t * p )
```

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, blkio_open(), gpt_part_dev_t::disk, gpt_part_dev_t::fblocks, gpt_part_dev_t::first_fblock, gpt_part_t::first_lba, blkio_params_t::forth_block_size, g_part_vt, gpt_part_t::last_lba, blkio_params_t::opaque, blkio_params_t::total_blocks, and blkio_dev::total_blocks.

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

Here is the call graph for this function:

Here is the caller graph for this function:

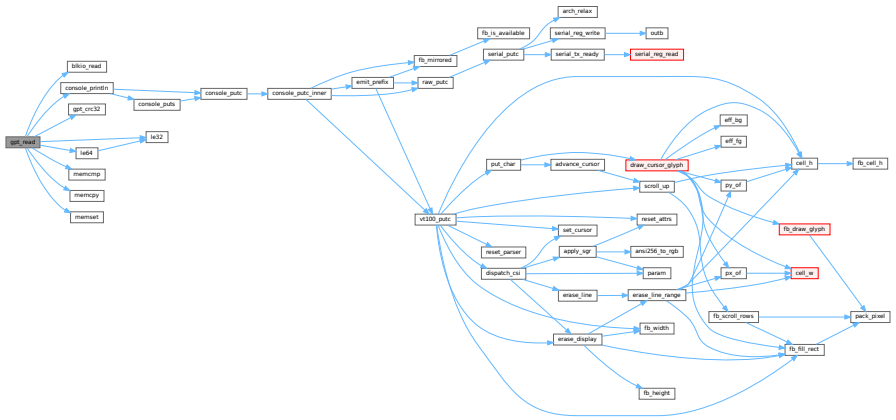
7.147.2.8 gpt_read()

```
int gpt_read (
            blkio_dev_t * disk,
            gpt_part_t * parts,
            unsigned max,
            unsigned * count )
```

References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_read(), console_println(), count, gpt_part_t::first_lba, blkio_dev::forth_block_size, g_gpt_alternate_lba, g_gpt_disk_guid, g_gpt_entries, g_gpt_hdr_block, GPT_BAD, gpt_crc32(), GPT_EIO, GPT_ENTRIES_MAX, GPT_NONE, GPT_OK, GPT_SECTOR, blkio_vtable_t::info, gpt_part_t::last_lba, le32(), le64(), memcmp(), memcpy(), memset(), blkio_info_t::phys_sector_size, blkio_dev::total_blocks, blkio_dev::vt, and zero.

Referenced by gpt_grow_last(), sk_v4_drive_arrived(), sk_v4_grow_stick(), and sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

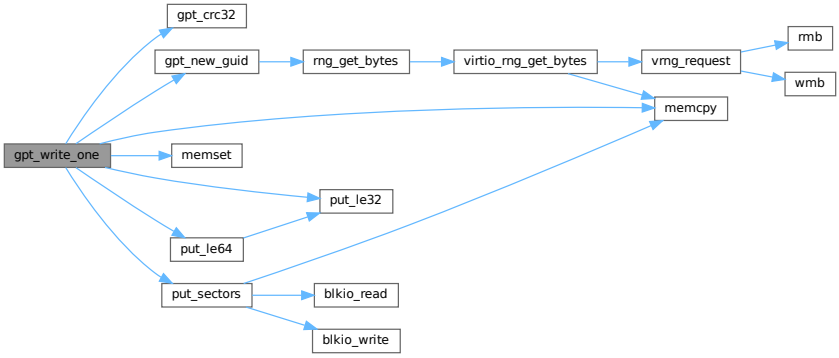
7.147.2.9 gpt_write_one()

```
int gpt_write_one (
            blkio_dev_t * disk,
            const uint8_t type[16],
            uint64_t part_sectors,
            uint8_t disk_guid[16] )
```

References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_vtable_t::flush, blkio_dev::forth_block_size, g_gpt_new_entries, GPT_BAD, gpt_crc32(), GPT_EIO, GPT_ENT_SECTORS, GPT_ESIZE, GPT_NENT, gpt_new_guid(), GPT_OK, GPT_SECTOR, blkio_vtable_t::info, memcpy(), memset(), name, blkio_info_t::phys_sector_size, put_le32(), put_le64(), put_sectors(), blkio_dev::total_blocks, blkio_dev::vt, and zero.

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

7.147.2.10 le32()

```
static uint32_t le32 (
            const uint8_t * p )  [static]
```

Referenced by gpt_grow_last(), gpt_read(), and le64().

Here is the caller graph for this function:

7.147.2.11 le64()

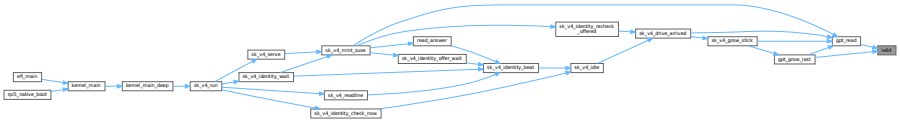
```
static uint64_t le64 (
            const uint8_t * p )  [static]
```

References le32().

Referenced by gpt_grow_last(), and gpt_read().

Here is the call graph for this function:

Here is the caller graph for this function:



7.147.2.12 part_close()

```
static int part_close (
            blkio_dev_t * dev )  [static]
```

References BLKIO_OK.

7.147.2.13 part_flush()

```
static int part_flush (
            blkio_dev_t * dev )  [static]
```

References gpt_part_dev_t::disk, blkio_vtable_t::flush, blkio_dev::state, and blkio_dev::vt.

7.147.2.14 part_info()

```
static int part_info (
            blkio_dev_t * dev,
            blkio_info_t * out )  [static]
```

References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, gpt_part_dev_t::disk, gpt_part_dev_t::fblocks, blkio_vtable_t::info, blkio_info_t::phys_size_bytes, blkio_dev::state, blkio_info_t::total_blocks, and blkio_dev::vt.

7.147.2.15 part_open()

```
static int part_open (
            blkio_dev_t * dev,
            const blkio_params_t * p )  [static]
```

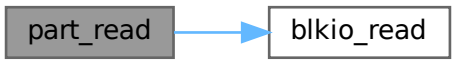
References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, gpt_part_dev_t::fblocks, blkio_dev::forth_block_size, blkio_params_t::opaque, blkio_dev::state, and blkio_dev::total_blocks.

7.147.2.16 part_read()

```
static int part_read (
            blkio_dev_t * dev,
            uint32_t fblock,
            void * dst )  [static]
```

References BLKIO_EINVAL, blkio_read(), gpt_part_dev_t::disk, gpt_part_dev_t::fblocks, gpt_part_dev_t::first_fblock, and blkio_dev::state.

Here is the call graph for this function:

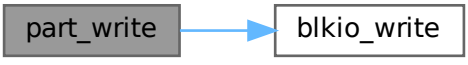


7.147.2.17 part_write()

```
static int part_write (
            blkio_dev_t * dev,
            uint32_t fblock,
            const void * src )  [static]
```

References BLKIO_EINVAL, blkio_write(), gpt_part_dev_t::disk, gpt_part_dev_t::fblocks, gpt_part_dev_t::first_fblock, and blkio_dev::state.

Here is the call graph for this function:



7.147.2.18 put_le32()

```
static void put_le32 (
            uint8_t * p,
            uint32_t v )  [static]
```

Referenced by gpt_grow_last(), gpt_write_one(), and put_le64().

Here is the caller graph for this function:

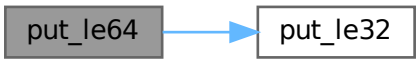
7.147.2.19 put_le64()

```
static void put_le64 (
            uint8_t * p,
            uint64_t v )  [static]
```

References put_le32().

Referenced by gpt_grow_last(), and gpt_write_one().

Here is the call graph for this function:



Here is the caller graph for this function:

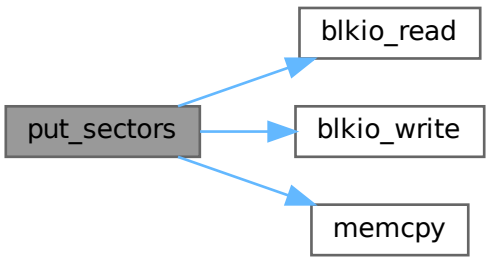
7.147.2.20 put_sectors()

```
static int put_sectors (
            blkio_dev_t * disk,
            uint64_t lba,
            const uint8_t * src,
            uint32_t n )  [static]
```

References BLKIO_OK, blkio_read(), blkio_write(), g_gpt_rmw, GPT_SECTOR, and memcpy().

Referenced by gpt_grow_last(), and gpt_write_one().

Here is the call graph for this function:



Here is the caller graph for this function:

7.147.3 Variable Documentation

7.147.3.1 g_gpt_alternate_lba

```
uint64_t g_gpt_alternate_lba  [static]
```

Referenced by gpt_alternate_lba(), and gpt_read().

7.147.3.2 g_gpt_disk_guid

```
uint8_t g_gpt_disk_guid[16]  [static]
```

Referenced by gpt_disk_guid(), and gpt_read().

7.147.3.3 g_gpt_entries

```
uint8_t g_gpt_entries[(32u *1024u)]  [static]
```

Referenced by gpt_grow_last(), and gpt_read().

7.147.3.4 g_gpt_hdr_block

```
uint8_t g_gpt_hdr_block[1024u]  [static]
```

Referenced by gpt_grow_last(), and gpt_read().

7.147.3.5 g_gpt_new_entries

```
uint8_t g_gpt_new_entries[128u * 128u]  [static]
```

Referenced by gpt_write_one().

7.147.3.6 g_gpt_rmw

```
uint8_t g_gpt_rmw[1024u]  [static]
```

Referenced by put_sectors().

7.147.3.7 g_part_vt

```
const blkio_vtable_t g_part_vt = { part_open, part_close, part_read, part_write, part_flush,
part_info }  [static]
```

Referenced by gpt_part_open().

7.147.3.8 gpt_type_starship_artemis

```
const uint8_t gpt_type_starship_artemis[16]
```

Initial value:

```
= {
    0x86, 0xB5, 0xD7, 0xBC, 0x8E, 0x1C, 0xEF, 0x4E,
    0x86, 0xA3, 0x27, 0x3A, 0x8D, 0x8E, 0xE6, 0x24
}
```

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), and sk_v4_is_this_stick().

7.147.3.9 gpt_type_starship_identity

```
const uint8_t gpt_type_starship_identity[16]
```

Initial value:

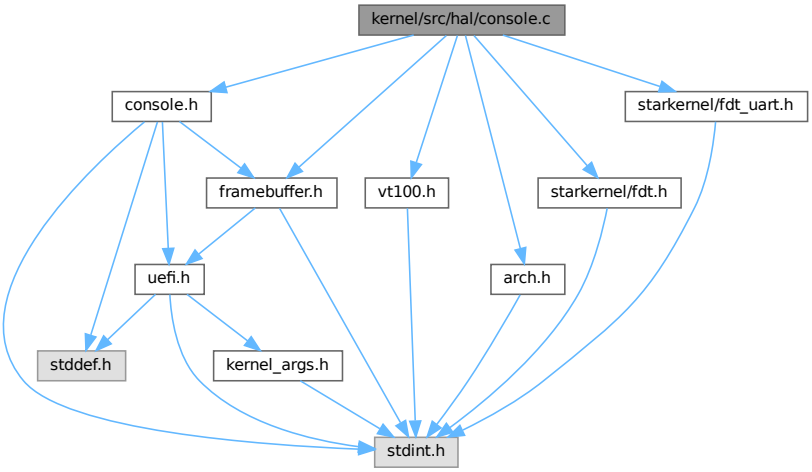
```
= {
    0xE1, 0xBF, 0xBE, 0x23, 0x17, 0x48, 0xF3, 0x4C,
    0xA5, 0x37, 0x90, 0x69, 0xBF, 0x15, 0x97, 0x88
}
```

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), sk_v4_is_this_stick(), sk_v4_mint_zuse(), and sk_v4_real_zuse_arrived().

7.148 kernel/src/hal/console.c File Reference

```
#include "console.h"
#include "framebuffer.h"
#include "vt100.h"
#include "arch.h"
#include "starkernel/fdt.h"
#include "starkernel/fdt_uart.h"
```

Include dependency graph for console.c:



Macros

- #define SERIAL_TX_MAX_SPIN 4000000u
- #define UART16550_LSR 5u
- #define UART16550_LSR_DR (1u << 0)
- #define UART16550_LSR_THRE (1u << 5)
- #define PL011_FR 6u
- #define PL011_FR_RXFE (1u << 4)
- #define PL011_FR_TXFF (1u << 5)
- #define CONSOLE_VM_NAME_BUF 64

Enumerations

- enum { SERIAL_NONE = 0 , SERIAL_PORT16550 , SERIAL_MMIO16550 , SERIAL_PL011 }

  console.c - Serial console implementation (UART 16550) Supports amd64 via I/O ports

Functions

- static uint32_t serial_reg_read (unsigned n)
- static void serial_reg_write (unsigned n, uint32_t v)
- static int serial_tx_ready (void)
- static int serial_rx_ready (void)

- static void serial_putc (char c)
- void console_attach_serial (const void *dtb)

  console.h - Serial console + framebuffer VT100 interface for StarKernel
- void console_init (void)

  Initialize serial console x86: programs the 16550 at COM1, if console_attach_serial() found one.
- void console_describe_serial (void)

  Print one line saying which serial line the console found, or that there is none.
- static int fb_mirrored (void)
- void console_fb_mirror (int on)
- void console_fb_clear (void)
- void console_set_vm_name (const char *name)

  Set the active VM name shown as [Name] prefix on each output line.
- const char * console_get_vm_name (void)
- void console_set_user_prefix_provider (console_user_prefix_fn fn)
- void console_save_vm_name (char *out, size_t cap)

  console_save_vm_name - Copy the current active-VM name into the caller's own buffer, for a later console_set_vm_name() restore.
- static void raw_putc (char c)
- static void emit_prefix (void)
- static void console_putc_inner (char c)

  Write a single character to serial console.
- void console_putc (char c)

  Write a single character to serial console.
- void console_puts (const char *s)

  Write a null-terminated string to serial console.
- uint64_t console_tx_count (void)

  console_tx_count - Monotonic count of console_putc() calls delivered to either output (serial and/or framebuffer).
- void console_ensure_line_start (void)

  console_ensure_line_start - Make sure the next real output starts at the beginning of a fresh output line, closing off whatever is currently mid-line (e.g.
- void console_cancel_deferred_line_start (void)

  console_cancel_deferred_line_start - Discard a pending deferred newline from console_ensure_line_start() without ever emitting it.
- void console_println (const char *s)

  Write a string with newline to serial console.
- int console_poll (void)

  Check if data is available to read.
- void console_fb_init (const FramebufferInfo *info, FbPixelFormat fmt)

  Initialize the framebuffer VT100 terminal and attach it to the console.
- void console_fb_enable_ttf (void)

  FABRIC-0.md item 4.4j: switch the framebuffer console's glyph backend from font_8x16.c to TTF-TEXT's rasterizer.
- void console_fb_scroll_back (uint32_t n)

  FABRIC-0.md item 4.4q: thin wrappers over vt100_scroll_back()/ vt100_scroll_fwd() – see those functions' doc comments for the full contract.
- void console_fb_scroll_fwd (uint32_t n)
- void console_fb_toggle_graphics (void)

  FABRIC-0.md item 4.4y-revised: thin wrapper over vt100_toggle_graphics() – see that function's doc comment for the full contract (the Alt+TAB graphics/text state machine).
- void console_fb_draw_cursor (void)

  Thin wrapper over vt100_draw_cursor() – see that function's doc comment for the full contract (a static block cursor at the terminal's current position).
- void console_fb_erase_cursor (void)

  Thin wrapper over vt100_erase_cursor().
- int console_getc (void)

  Read a single character from serial console (non-blocking) Returns -1 if no character available.

Variables

- static int g_serial_kind
- static uintptr_t g_serial_base
- static unsigned g_serial_shift
- static unsigned g_serial_width
- static int g_serial_from_dt
- static char g_active_vm_name_buf [64]
- static const char * g_active_vm_name = (void *)0
- static int g_line_start = 1
- static int g_fb_mirror = 1
- static uint64_t g_console_tx_count
- static console_user_prefix_fn g_user_prefix_fn = (void *)0
- static int g_pending_line_close = 0

7.148.1 Macro Definition Documentation

7.148.1.1 CONSOLE_VM_NAME_BUF

```
#define CONSOLE_VM_NAME_BUF 64
```

7.148.1.2 PL011_FR

```
#define PL011_FR 6u
```

7.148.1.3 PL011_FR_RXFE

```
#define PL011_FR_RXFE (1u << 4)
```

7.148.1.4 PL011_FR_TXFF

```
#define PL011_FR_TXFF (1u << 5)
```

7.148.1.5 SERIAL_TX_MAX_SPIN

```
#define SERIAL_TX_MAX_SPIN 4000000u
```

7.148.1.6 UART16550_LSR

```
#define UART16550_LSR 5u
```

7.148.1.7 UART16550_LSR_DR

```
#define UART16550_LSR_DR (1u << 0)
```

7.148.1.8 UART16550_LSR_THRE

```
#define UART16550_LSR_THRE (1u << 5)
```

7.148.2 Enumeration Type Documentation

7.148.2.1 anonymous enum

```
anonymous enum
```

console.c - Serial console implementation (UART 16550) Supports amd64 via I/O ports

Enumerator

SERIAL_NONE	
SERIAL_PORT16550	
SERIAL_MMIO16550	
SERIAL_PL011	

7.148.3 Function Documentation

7.148.3.1 console_attach_serial()

```
void console_attach_serial (
            const void * dtb )
```

console.h - Serial console + framebuffer VT100 interface for StarKernel

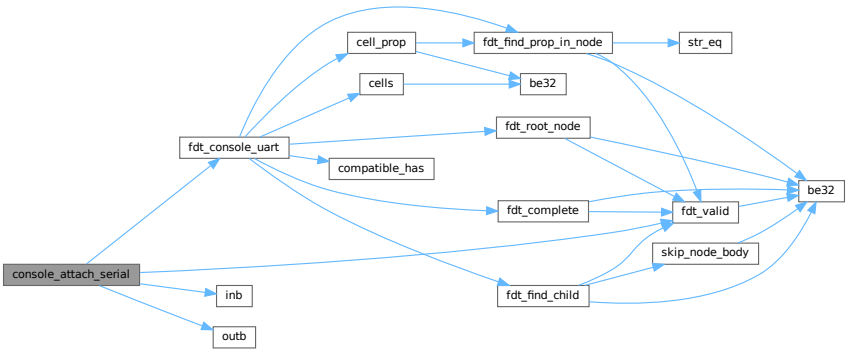
Output policy:

- Serial UART is always active (initialized by console_init).
- When console_fb_init() has been called and the framebuffer is ready, every character is also rendered through the VT100 terminal on screen.
- Both outputs are always live simultaneously; serial cannot be disabled. Find the board's serial console line. Must be called before anything is printed: until it is, and on a board with no such line, the console writes to no serial port and reads from none. On a PC it is COM1, if a UART answers there; elsewhere it is the UART the devicetree names as the console (/chosen/stdout-path); with no devicetree at all it is the UART of QEMU's virt machine. `dtb` may be NULL.

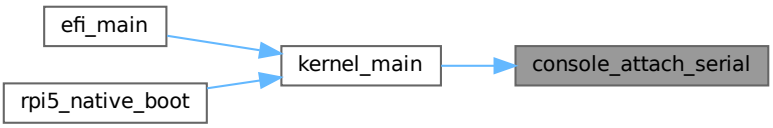
References fdt_uart_t::base, fdt_console_uart(), FDT_UART_PL011, fdt_valid(), g_serial_base, g_serial_from_dt, g_serial_kind, g_serial_shift, g_serial_width, inb(), fdt_uart_t::io_width, fdt_uart_t::kind, outb(), fdt_uart_t::reg_shift, SERIAL_MMIO16550, SERIAL_NONE, SERIAL_PL011, and SERIAL_PORT16550.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.2 console_cancel_deferred_line_start()

```
void console_cancel_deferred_line_start (
            void  )
```

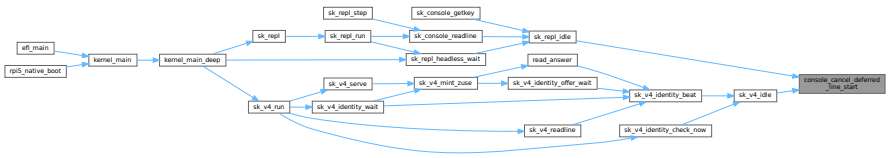
console_cancel_deferred_line_start - Discard a pending deferred newline from console_ensure_line_start() without ever emitting it.

No-op if no newline is currently deferred. Callers that speculatively deferred a line break before checking whether they actually have anything to print (sk_repl_idle()'s idle-beat check being the motivating case, FABRIC-2.md ?I.9) call this when the check comes back negative, so the console is left exactly as it was – no stray newline, no phantom blank line.

References g_pending_line_close.

Referenced by sk_repl_idle(), and sk_v4_idle().

Here is the caller graph for this function:



7.148.3.3 console_describe_serial()

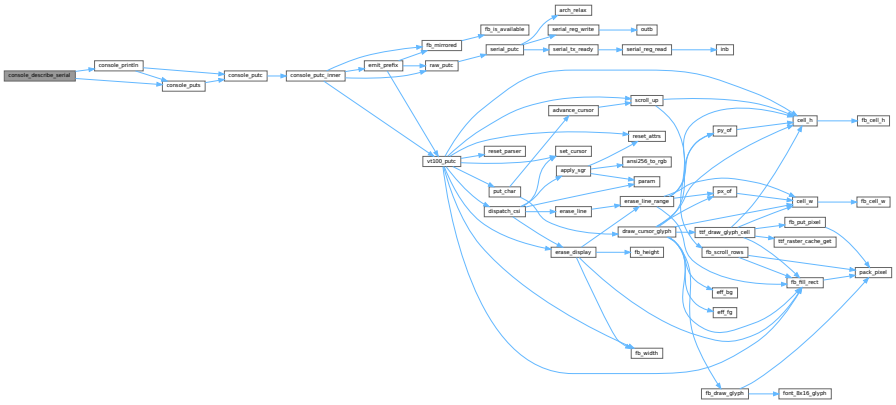
```
void console_describe_serial (
            void  )
```

Print one line saying which serial line the console found, or that there is none.

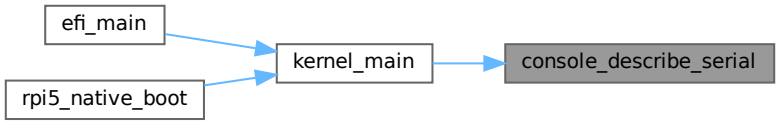
References console_println(), console_puts(), g_serial_base, g_serial_from_dt, g_serial_kind, SERIAL_NONE, SERIAL_PL011, and SERIAL_PORT16550.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.4 console_ensure_line_start()

```
void console_ensure_line_start (
            void  )
```

console_ensure_line_start - Make sure the *next real output* starts at the beginning of a fresh output line, closing off whatever is currently mid-line (e.g.

a dangling prompt). No-op if already at line start.

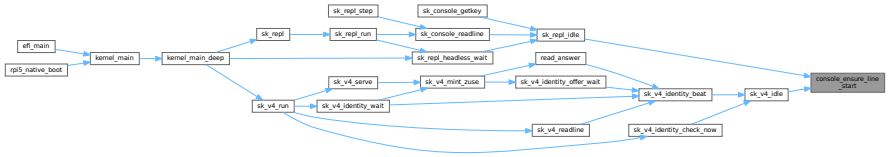
FABRIC-2.md ?I.9 fix, 2026-09-05: the newline is DEFERRED, not emitted immediately – it only actually reaches the console on the next real console_putc() call, and is silently dropped (never emitted at all) if

console_cancel_deferred_line_start() is called first instead. Before this fix, an immediate, unconditional newline here meant any caller invoking this function "just in case" (sk_repl_idle() being the one real caller) would visibly snap a bare, unfinished prompt line to a fresh blank line even when nothing was actually about to be printed – indistinguishable from Enter having already been pressed at that prompt. Deferring means a caller that turns out to have nothing to print can cancel cleanly, with zero visible effect, while a caller that does print gets the correct "close the old line first" behavior for free, still counted by console_tx_count() as real output (unlike the old always-silent inner form) since it is realized through the normal console_putc() path.

References g_line_start, and g_pending_line_close.

Referenced by sk_repl_idle(), and sk_v4_idle().

Here is the caller graph for this function:



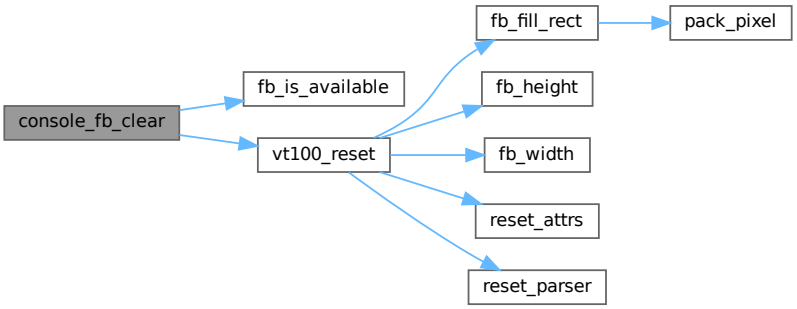
7.148.3.5 console_fb_clear()

```
void console_fb_clear (
            void  )
```

References fb_is_available(), and vt100_reset().

Referenced by sk_v4_drive_left(), sk_v4_fixed_screen(), and sk_v4_session_end().

Here is the call graph for this function:



Here is the caller graph for this function:

7.148.3.6 console_fb_draw_cursor()

```
void console_fb_draw_cursor (
            void  )
```

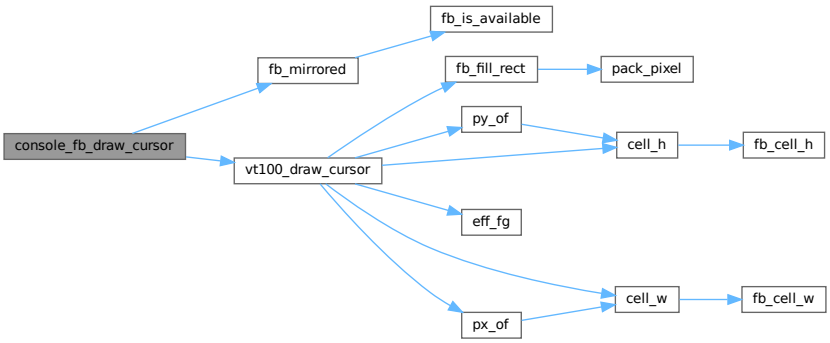
Thin wrapper over vt100_draw_cursor() – see that function's doc comment for the full contract (a static block cursor at the terminal's current position).

No-op if the framebuffer console was never initialized.

References fb_mirrored(), and vt100_draw_cursor().

Referenced by sk_console_readline(), sk_cursor_show(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:

7.148.3.7 console_fb_enable_ttf()

```
void console_fb_enable_ttf (
            void  )
```

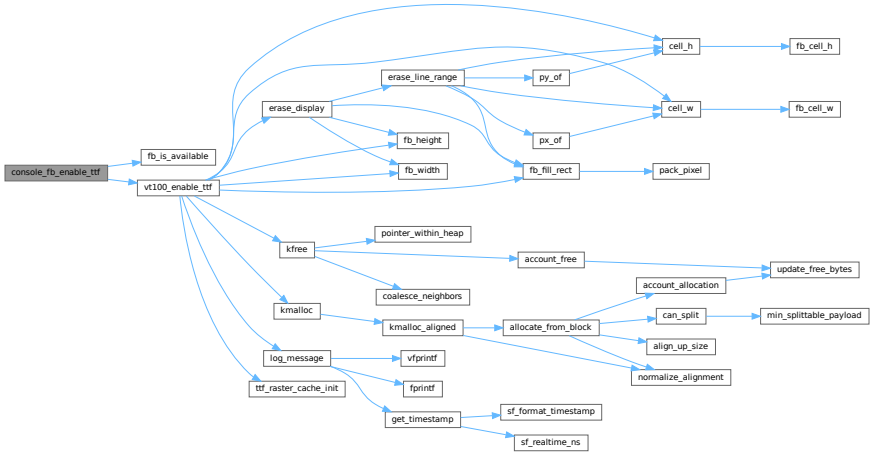
FABRIC-0.md item 4.4j: switch the framebuffer console's glyph backend from font_8x16.c to TTF-TEXT's rasterizer.

Thin wrapper over vt100_enable_ttf() – see that function's doc comment for the full contract (lazy font load, cell-geometry/cols/rows recompute, screen clear, one-shot). No-op if the framebuffer console was never initialized (console_fb_init() not called, or it no-op'd on a NULL framebuffer).

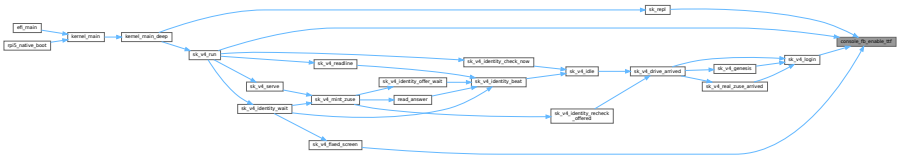
References fb_is_available(), and vt100_enable_ttf().

Referenced by sk_repl(), sk_v4_fixed_screen(), sk_v4_login(), and sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.8 console_fb_erase_cursor()

```
void console_fb_erase_cursor (
            void  )
```

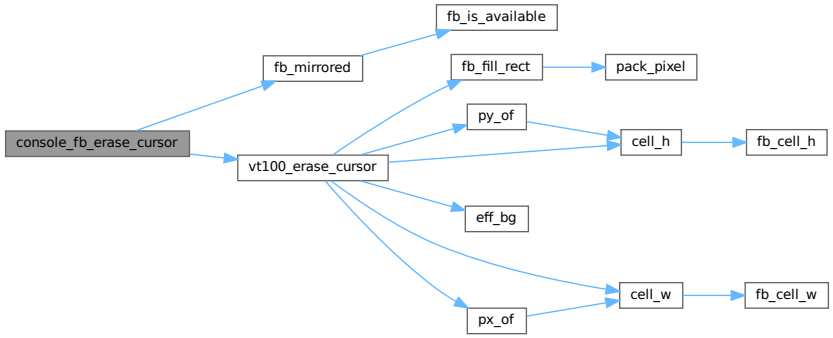
Thin wrapper over vt100_erase_cursor().

No-op if the framebuffer console was never initialized.

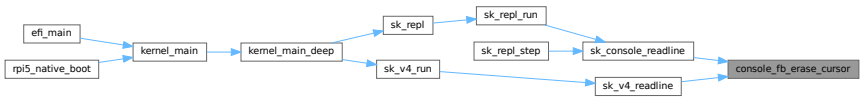
References fb_mirrored(), and vt100_erase_cursor().

Referenced by sk_console_readline(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.9 console_fb_init()

```
void console_fb_init (
            const FramebufferInfo * info,
            FbPixelFormat fmt )
```

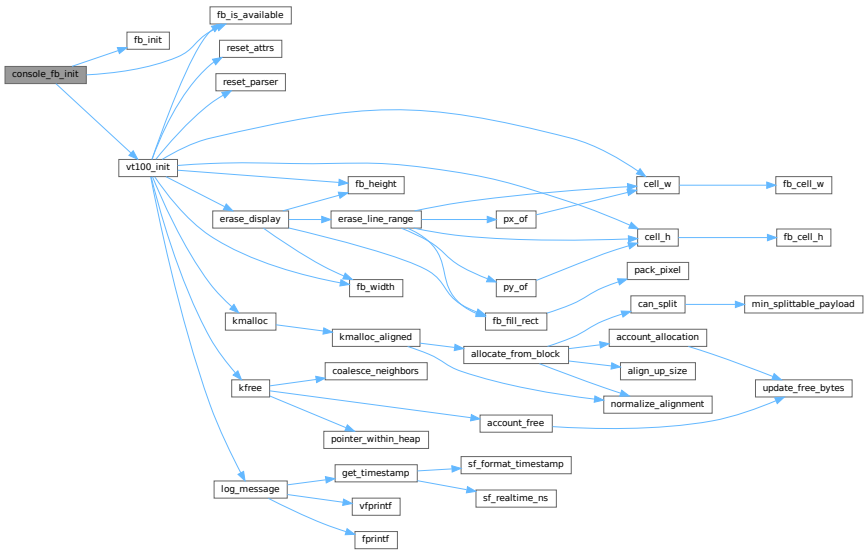
Initialize the framebuffer VT100 terminal and attach it to the console.

Initialize the framebuffer VT100 terminal.

Safe to call with info == NULL or when the framebuffer base is zero (no-op). After this call every console_putc / console_puts output is mirrored to the screen; the serial UART continues to function concurrently.

References FramebufferInfo::base, fb_init(), fb_is_available(), and vt100_init().

Here is the call graph for this function:



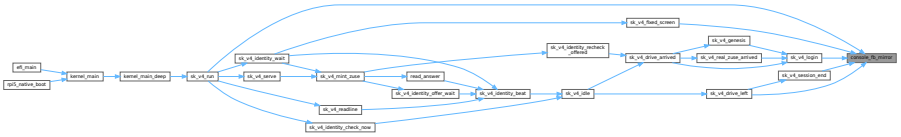
7.148.3.10 console_fb_mirror()

```
void console_fb_mirror (
            int on )
```

References g_fb_mirror.

Referenced by sk_v4_drive_left(), sk_v4_fixed_screen(), sk_v4_login(), sk_v4_run(), and sk_v4_session_end().

Here is the caller graph for this function:



7.148.3.11 console_fb_scroll_back()

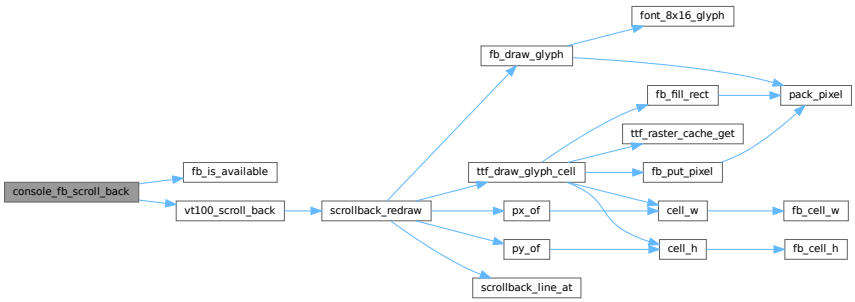
```
void console_fb_scroll_back (
            uint32_t n )
```

FABRIC-0.md item 4.4q: thin wrappers over vt100_scroll_back()/ vt100_scroll_fwd() – see those functions' doc comments for the full contract.

No-op if the framebuffer console was never initialized.

References fb_is_available(), and vt100_scroll_back().

Here is the call graph for this function:

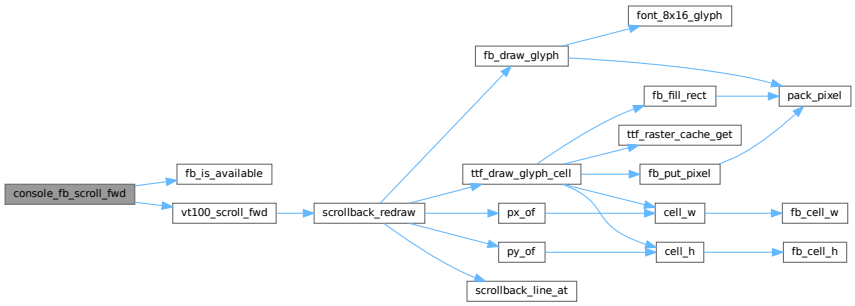


7.148.3.12 console_fb_scroll_fwd()

```
void console_fb_scroll_fwd (
            uint32_t n )
```

References fb_is_available(), and vt100_scroll_fwd().

Here is the call graph for this function:



7.148.3.13 console_fb_toggle_graphics()

```
void console_fb_toggle_graphics (
            void  )
```

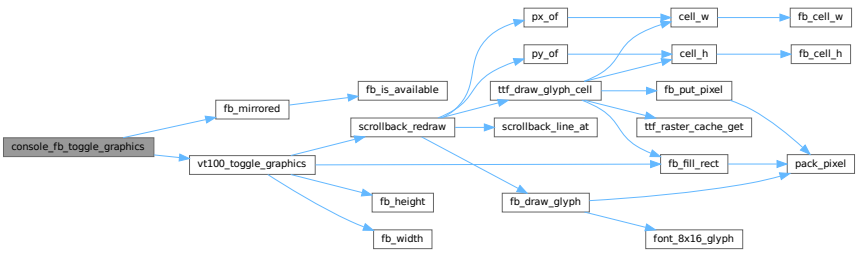
FABRIC-0.md item 4.4y-revised: thin wrapper over vt100_toggle_graphics() – see that function's doc comment for the full contract (the Alt+TAB graphics/text state machine).

No-op if the framebuffer console was never initialized.

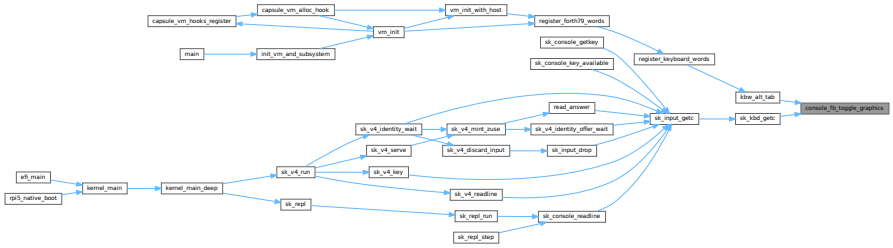
References fb_mirrored(), and vt100_toggle_graphics().

Referenced by kbw_alt_tab(), and sk_kbd_getc().

Here is the call graph for this function:



Here is the caller graph for this function:



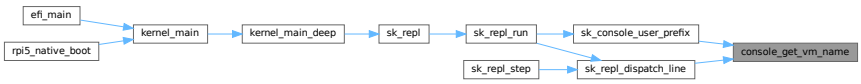
7.148.3.14 console_get_vm_name()

```
const char * console_get_vm_name (
            void  )
```

References g_active_vm_name.

Referenced by sk_console_user_prefix(), and sk_repl_dispatch_line().

Here is the caller graph for this function:



7.148.3.15 console_getc()

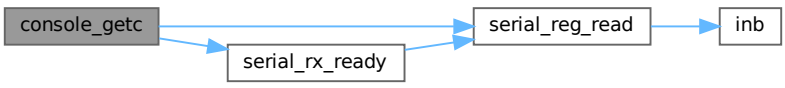
```
int console_getc (
            void  )
```

Read a single character from serial console (non-blocking) Returns -1 if no character available.

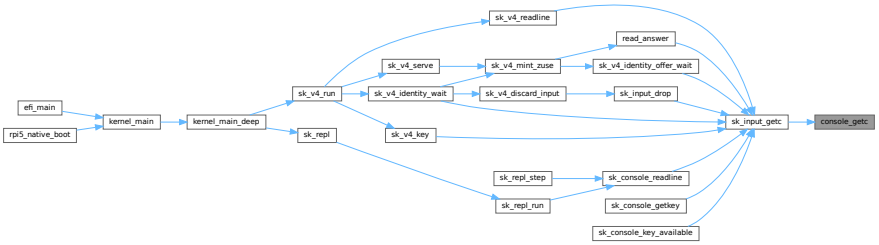
References serial_reg_read(), and serial_rx_ready().

Referenced by sk_input_getc().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.16 console_init()

```
void console_init (
            void  )
```

Initialize serial console x86: programs the 16550 at COM1, if console_attach_serial() found one.

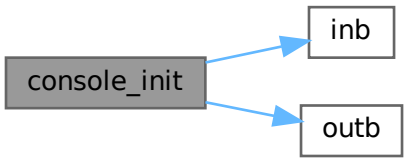
Initialize serial console (UART).

aarch64, riscv64: the line was set up by the firmware; nothing to do.

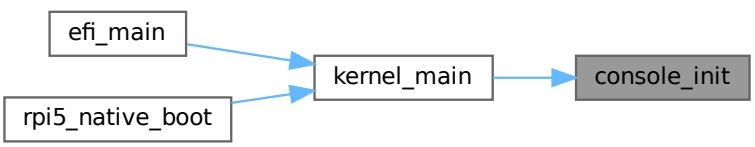
References g_serial_kind, inb(), outb(), SERIAL_NONE, and SERIAL_PORT16550.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.17 console_poll()

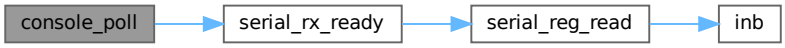
```
int console_poll (
            void  )
```

Check if data is available to read.

Check if character is available for reading.

References serial_rx_ready().

Here is the call graph for this function:



7.148.3.18 console_println()

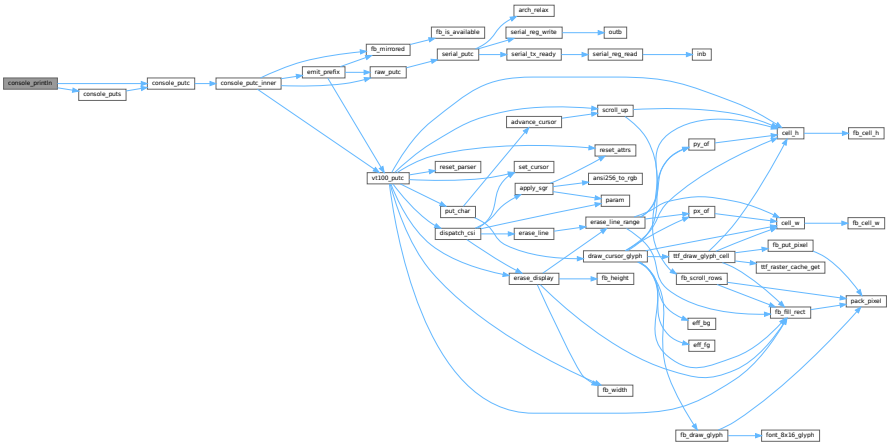
```
void console_println (
            const char * s )
```

Write a string with newline to serial console.

References console_putc(), and console_puts().

Referenced by aarch64_exception_handler(), aarch64_psci_conduit_init(), apic_init(), apic_timer_init(), apic_timer_start(), arch_early_init(), arch_interrupts_init(), blkio_usb_open_msc(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_wirebind_eject(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), capsule_wirebind_unclean_detac capsule_zuse_boot_logout(), capsule_zuse_boot_try_attach(), console_describe_serial(), converge_tsc_bare_metal(), decode_pf_error(), enable_interrupt_route(), failed(), gpt_read(), i8042_init(), init_timer_vm_mode(), ioapic_init(), isr_common_handler(), kernel_main(), kernel_main_deep(), pci_init(), plic_init(), print_banner(), print_boot_info(), print_heap_stats(), print_nl(), print_pmm_stats(), print_uint(), riscv64_exception_handler(), rng_init(), say_size(), sk_repl(), sk_repl_dispatch_line(), sk_repl_run(), sk_repl_step(), sk_v4_drive_arrived(), sk_v4_fixed_screen(), sk_v4_genesis(), sk_v4_grow_stick(), sk_v4_identity_boot(), sk_v4_login(), sk_v4_mint_zuse(), sk_v4_real_zuse_arrived(), sk_v4_run(), sk_v4_serve(), sk_v4_session_end(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), timer_fatal(), timer_init(), vblk_init_device(), vinput_init_device(), virtio_blk_find_artemis(), virtio_input_find_keyboard(), virtio_rng_init(), vm_bootstrap_root_vocabulary(), vm_init_with_host(), vm_physics_status(), vmm_init(), vmm_map_page(), vocab_sync_vm_vars(), vocabulary_create_vocabulary_direct(), vrng_init_device(), and xhci_poll_one().

Here is the call graph for this function:



7.148.3.19 console_putc()

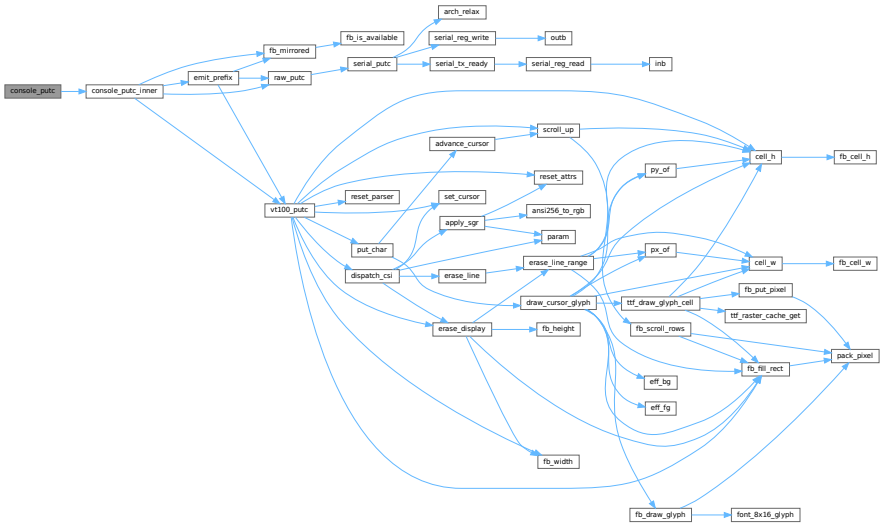
```
void console_putc (
            char c )
```

Write a single character to serial console.

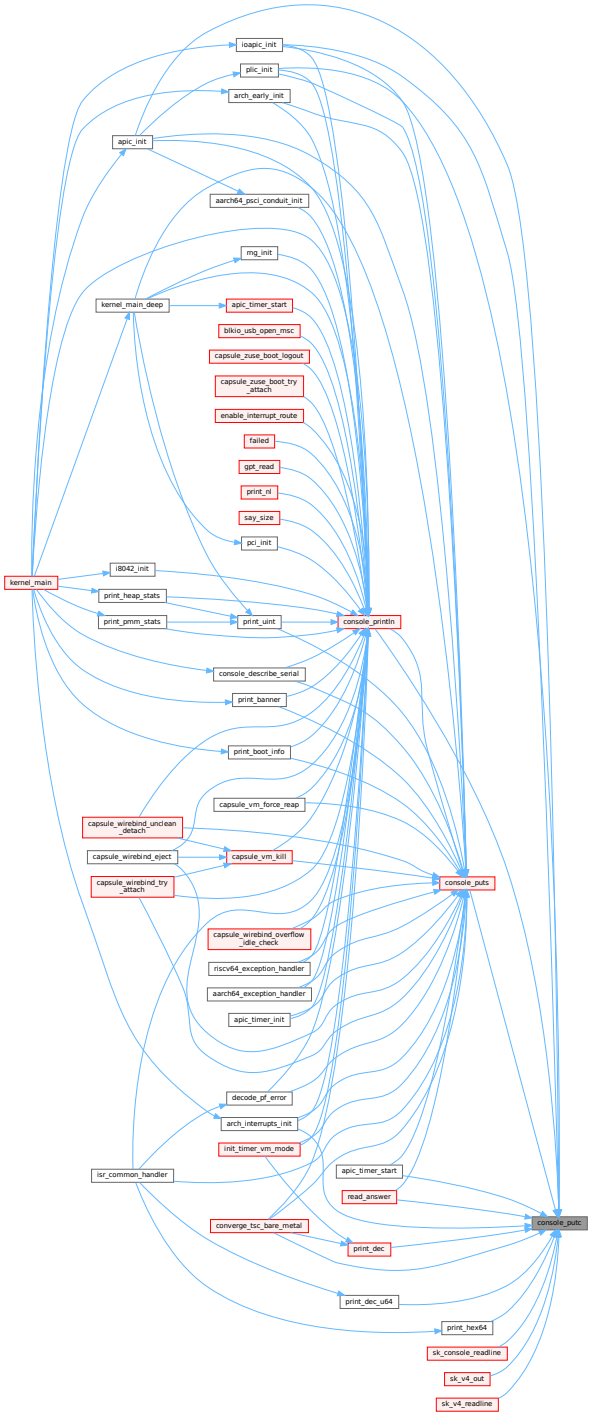
References console_putc_inner(), g_console_tx_count, and g_pending_line_close.

Referenced by apic_init(), apic_timer_start(), arch_interrupts_init(), console_println(), console_puts(), converge_tsc_bare_metal(), ioapic_init(), plic_init(), print_dec(), print_dec_u64(), print_hex64(), read_answer(), sk_console_readline(), sk_v4_out(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.20 console_putc_inner()

```
static void console_putc_inner (
            char c )  [static]
```

Write a single character to serial console.

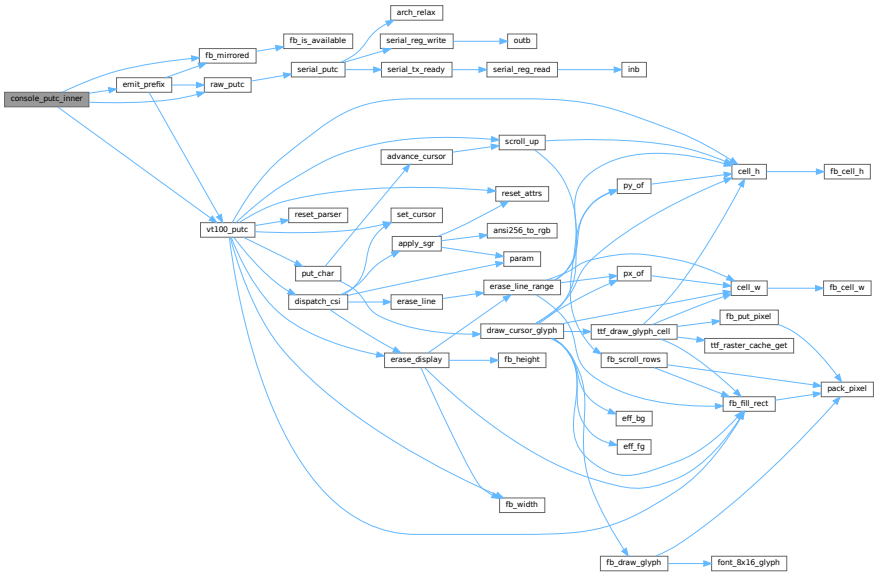
Emits "[VMName] " at the start of each new line when a VM name is set. Also mirrors output to the framebuffer VT100 terminal when available. Serial output is ALWAYS active regardless of framebuffer state.

console_putc_inner(): the same body minus the tx-counter increment – used internally for the newline console_putc() itself realizes out of g_pending_line_close below (see console_ensure_line_start()), so that one real character write emits at most one counted "start" (the '
' plus the character together read as a single unit of real output, not two, to console_tx_count()'s callers).

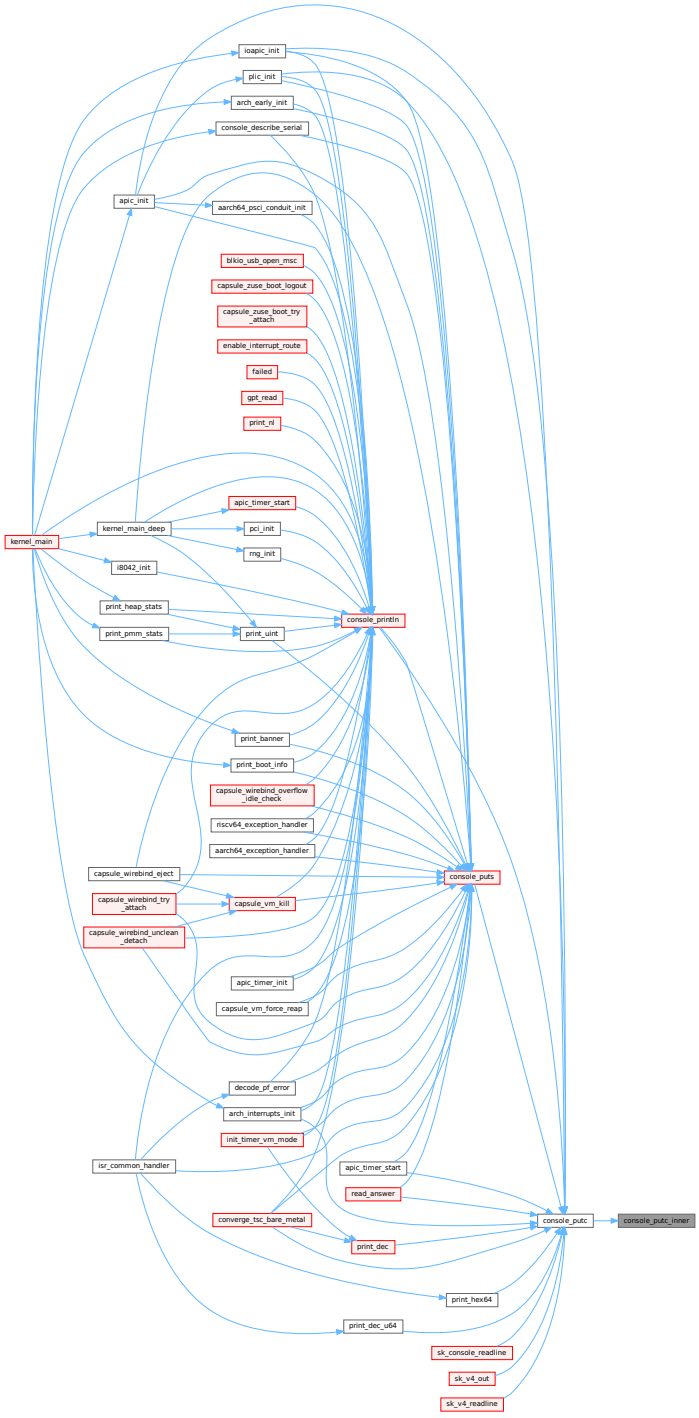
References emit_prefix(), fb_mirrored(), g_active_vm_name, g_line_start, raw_putc(), and vt100_putc().

Referenced by console_putc().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.21 console_puts()

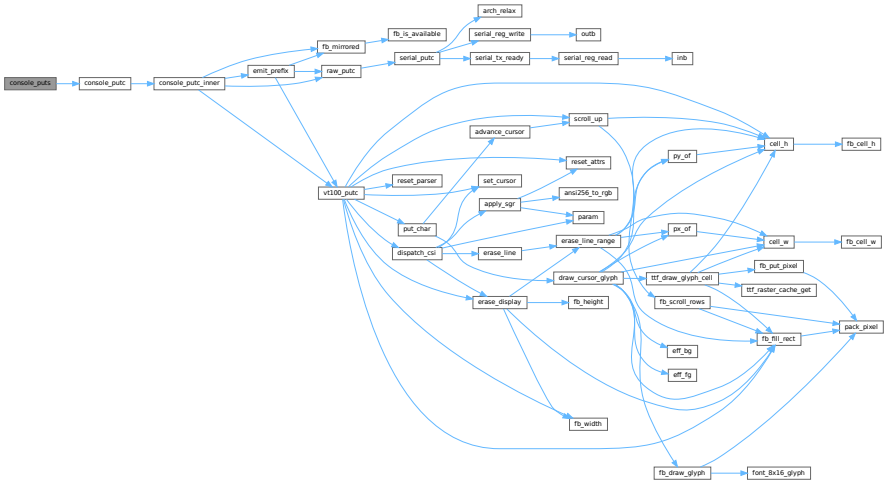
```
void console_puts (
            const char * s )
```

Write a null-terminated string to serial console.

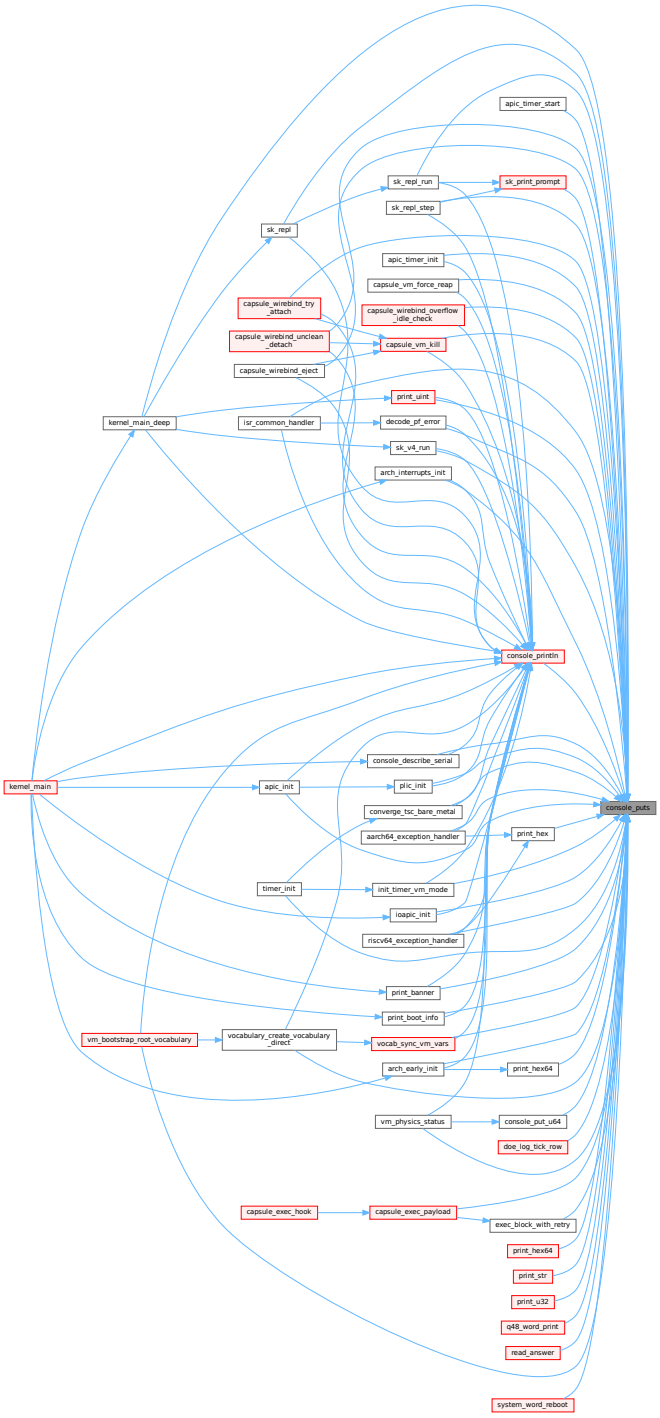
References console_putc().

Referenced by aarch64_exception_handler(), apic_init(), apic_timer_init(), apic_timer_start(), arch_early_init(), arch_interrupts_init(), capsule_exec_payload(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_wirebind_eject(), capsule_wirebind_overflow_idle_check(), capsule_wirebind_try_attach(), capsule_wirebind_unclean_detach(), console_describe_serial(), console_println(), console_put_u64(), converge_tsc_bare_metal(), decode_pf_error(), doe_log_tick_row(), exec_block_with_retry(), init_timer_vm_mode(), ioapic_init(), isr_common_handler(), kernel_main_deep(), plic_init(), print_banner(), print_boot_info(), print_hex(), print_hex64(), print_hex64(), print_str(), print_u32(), print_uint(), q48_word_print(), read_answer(), riscv64_exception_handler(), sk_print_prompt(), sk_repl(), sk_repl_run(), sk_repl_step(), sk_v4_run(), system_word_reboot(), timer_init(), vm_bootstrap_root_vocabulary(), vm_physics_status(), vocab_sync_vm_vars(), and vocabulary_create_vocabulary_direct().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.22 console_save_vm_name()

```
void console_save_vm_name (
            char * out,
            size_t cap )
```

console_save_vm_name - Copy the current active-VM name into the caller's own buffer, for a later console_set_vm_name() restore.

console_get_vm_name() alone is NOT safe for save-then-restore: it returns a pointer into the single internal buffer console_set_vm_name() copies into, so an intervening console_set_vm_name() call (the normal "switch, do work, switch back" pattern every BIRTH/VM-EXEC/CONNECT-∗ call site uses) overwrites the very bytes the saved pointer points at before the restore ever runs – found live 2026-08-28, the restore silently no-ops. Copies at most cap-1 bytes plus a NUL terminator; writes "" if there was no active name (NULL) to save.

Parameters

out	Caller-owned buffer.
cap	Its size in bytes.

References g_active_vm_name.

7.148.3.23 console_set_user_prefix_provider()

```
void console_set_user_prefix_provider (
            console_user_prefix_fn fn )
```

References g_user_prefix_fn.

Referenced by sk_repl_run(), and sk_v4_login().

Here is the caller graph for this function:

7.148.3.24 console_set_vm_name()

```
void console_set_vm_name (
            const char * name )
```

Set the active VM name shown as [Name] prefix on each output line.

Pass NULL to suppress the prefix (kernel-only output before any VM). Copies into internal storage (FABRIC-2.md Phase F, 2026-08-28) – the caller's own pointer does not need to remain valid afterward.

References CONSOLE_VM_NAME_BUF, g_active_vm_name, g_active_vm_name_buf, and name.

Referenced by capsule_vm_registry_init(), and sk_v4_login().

Here is the caller graph for this function:

7.148.3.25 console_tx_count()

```
uint64_t console_tx_count (
            void  )
```

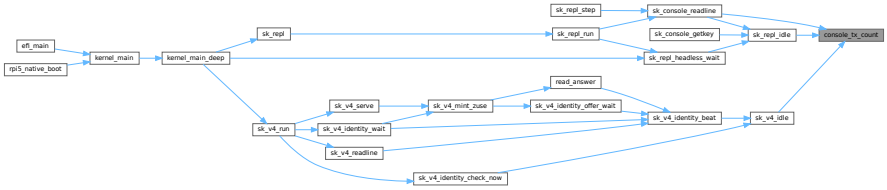
console_tx_count - Monotonic count of console_putc() calls delivered to either output (serial and/or framebuffer).

In use by the REPL to detect that an idle bottom half (heartbeat, USB attach/detach) wrote to the console while the top-level prompt was showing, so it can re-anchor the prompt afterward. Never decreases.

References g_console_tx_count.

Referenced by sk_console_readline(), sk_repl_idle(), and sk_v4_idle().

Here is the caller graph for this function:



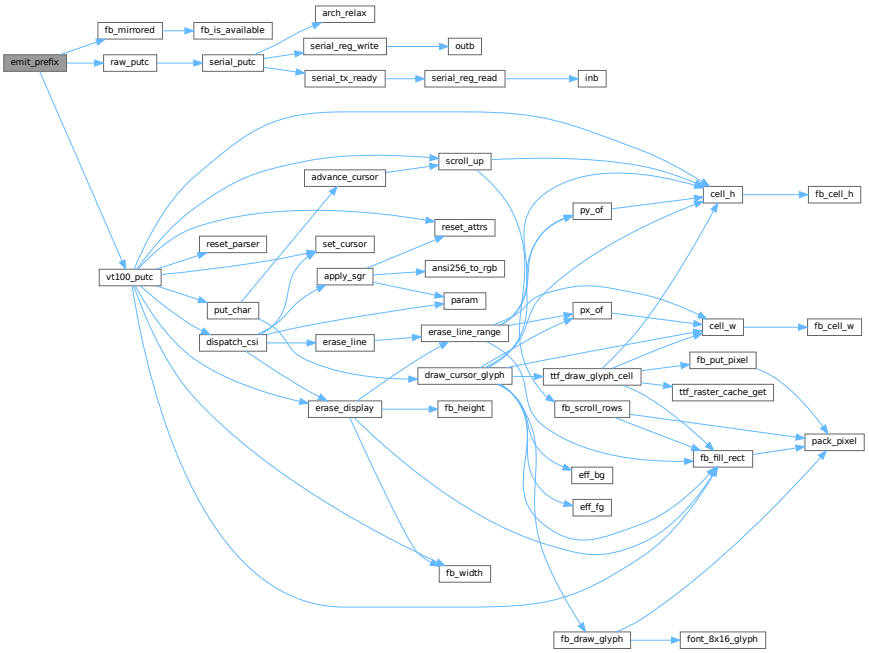
7.148.3.26 emit_prefix()

```
static void emit_prefix (
            void  )  [static]
```

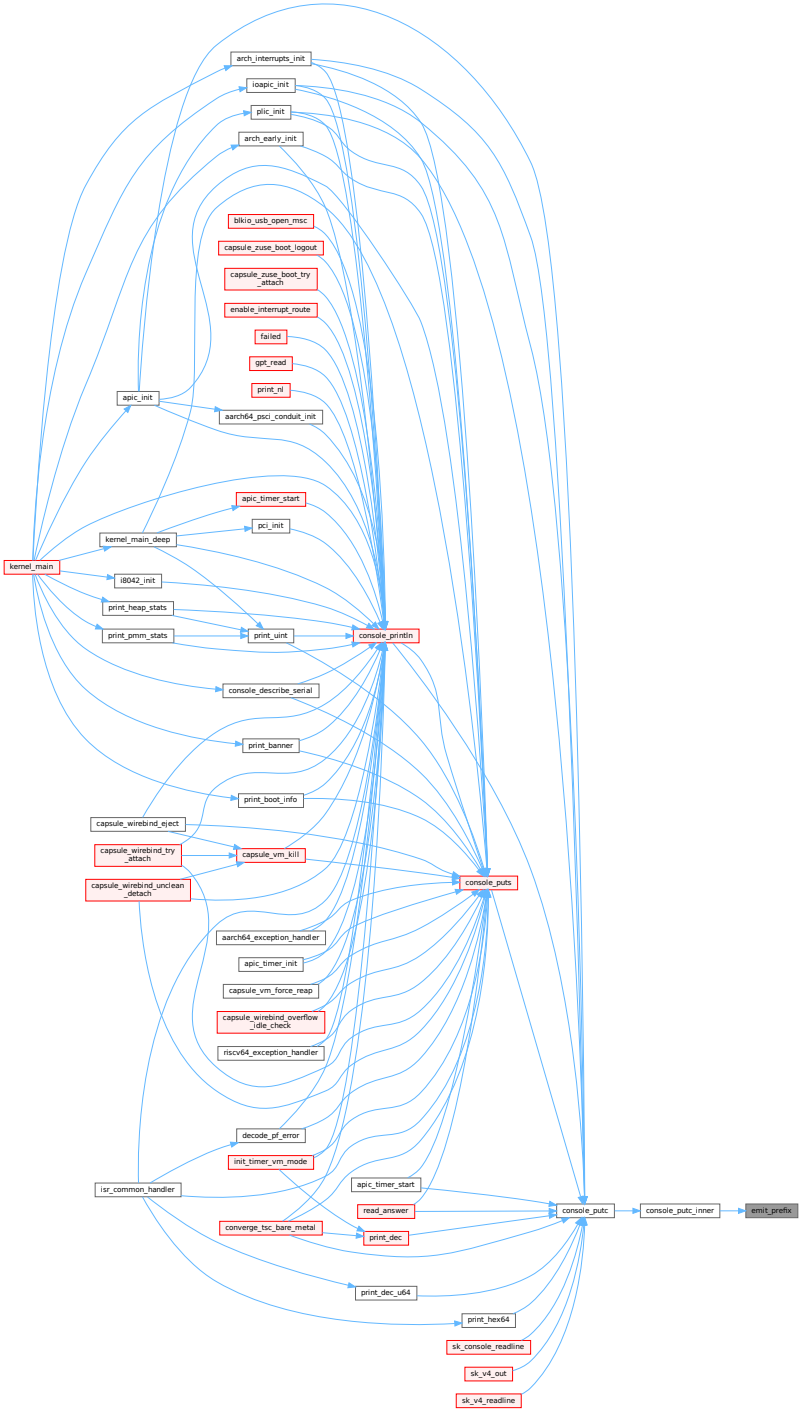
References fb_mirrored(), g_active_vm_name, g_user_prefix_fn, raw_putc(), and vt100_putc().

Referenced by console_putc_inner().

Here is the call graph for this function:



Here is the caller graph for this function:



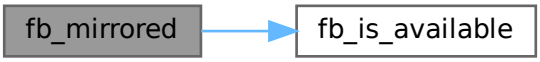
7.148.3.27 fb_mirrored()

```
static int fb_mirrored (
            void  )  [static]
```

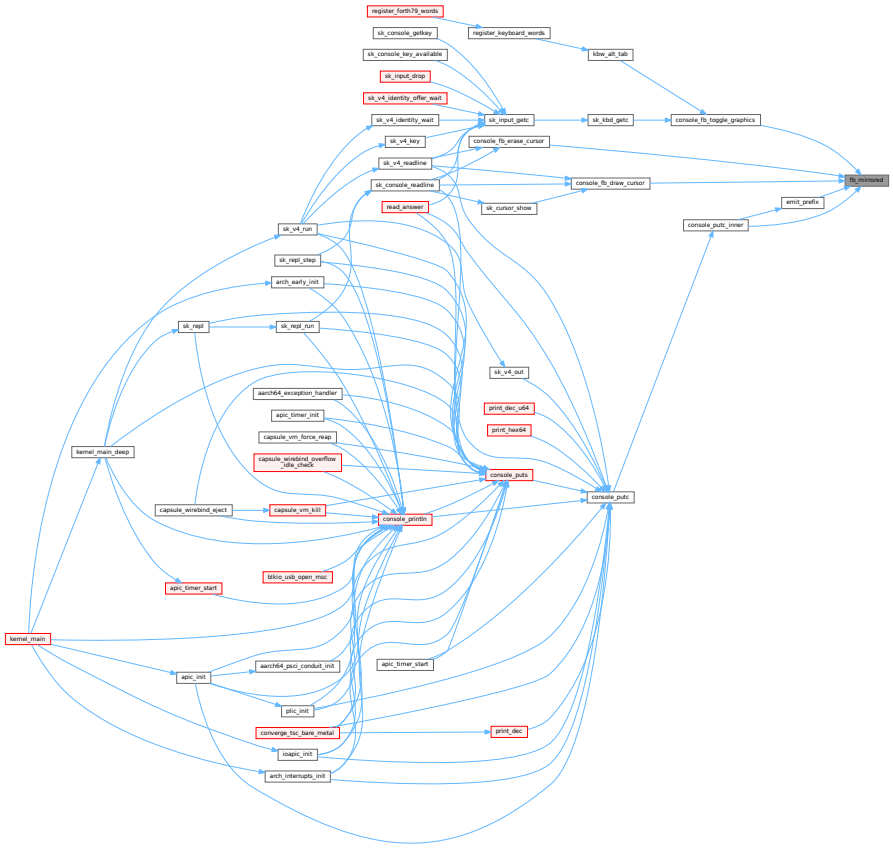
References fb_is_available(), and g_fb_mirror.

Referenced by console_fb_draw_cursor(), console_fb_erase_cursor(), console_fb_toggle_graphics(), console_putc_inner(), and emit_prefix().

Here is the call graph for this function:



Here is the caller graph for this function:



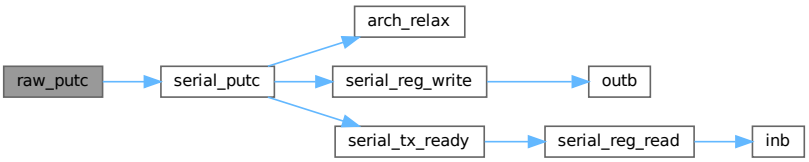
7.148.3.28 raw_putc()

```
static void raw_putc (
            char c )  [static]
```

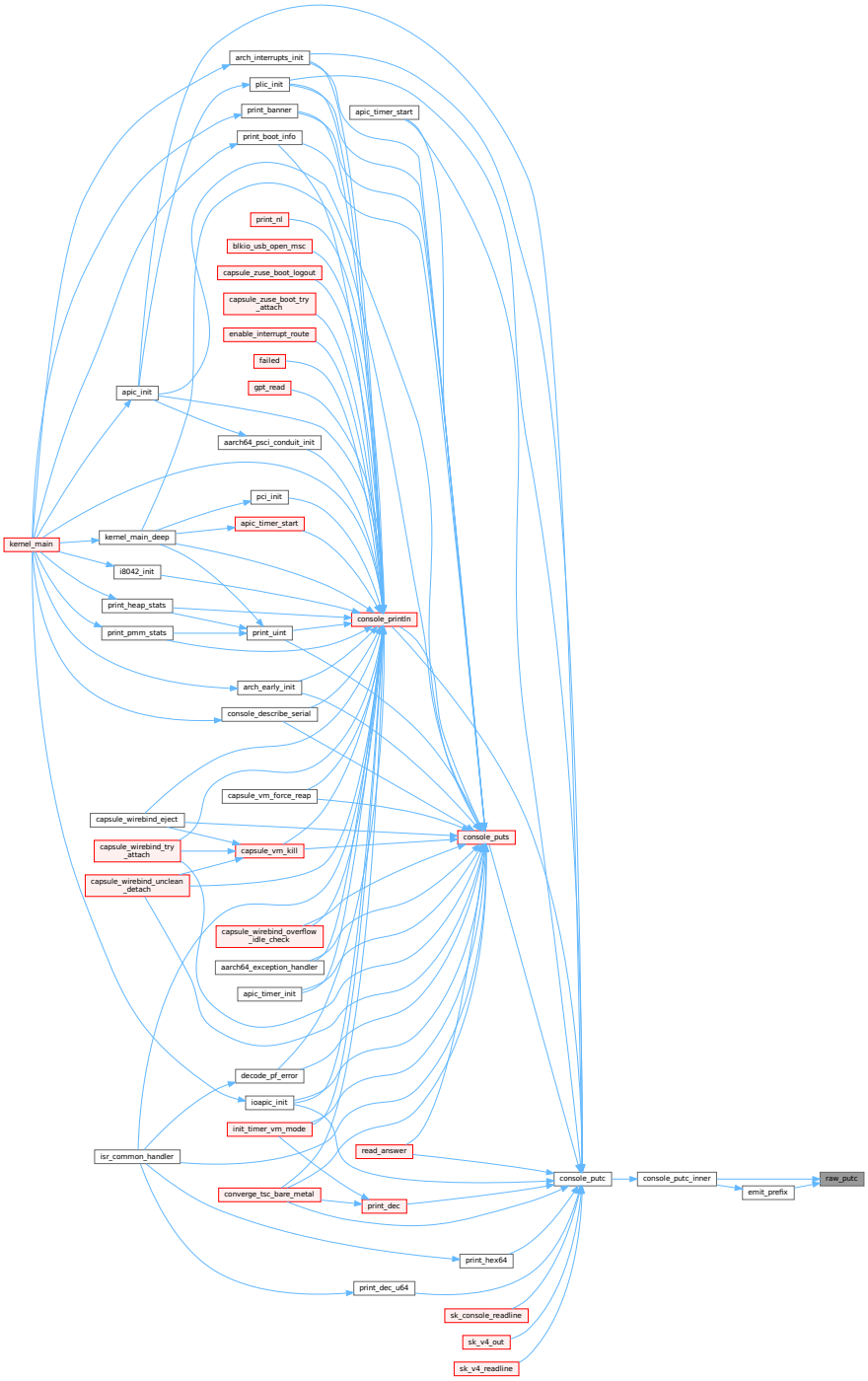
References serial_putc().

Referenced by console_putc_inner(), and emit_prefix().

Here is the call graph for this function:



Here is the caller graph for this function:



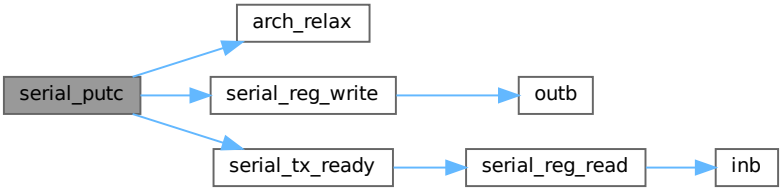
7.148.3.29 serial_putc()

```
static void serial_putc (
            char c )  [static]
```

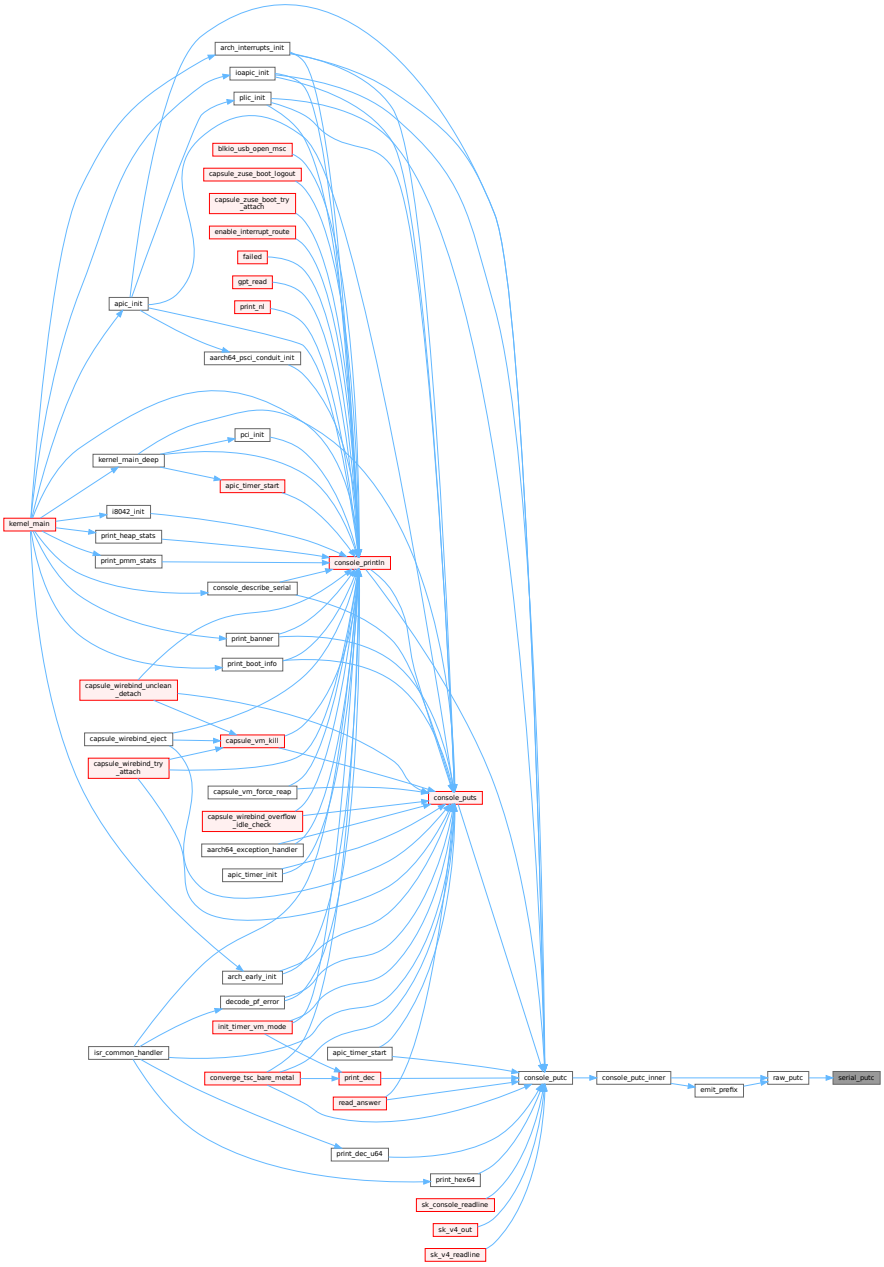
References arch_relax(), g_serial_kind, SERIAL_NONE, serial_reg_write(), SERIAL_TX_MAX_SPIN, and serial_tx_ready().

Referenced by raw_putc().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.3.30 serial_reg_read()

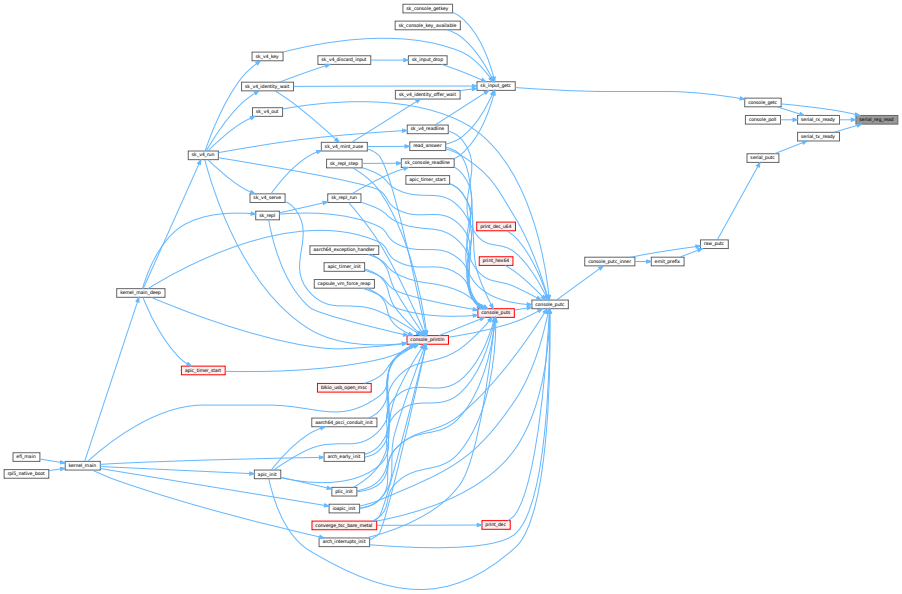
```
static uint32_t serial_reg_read (
            unsigned n )  [static]
```

References g_serial_base, g_serial_kind, g_serial_shift, g_serial_width, inb(), and SERIAL_PORT16550.

Referenced by console_getc(), serial_rx_ready(), and serial_tx_ready().

Here is the call graph for this function:

Here is the caller graph for this function:



7.148.3.31 serial_reg_write()

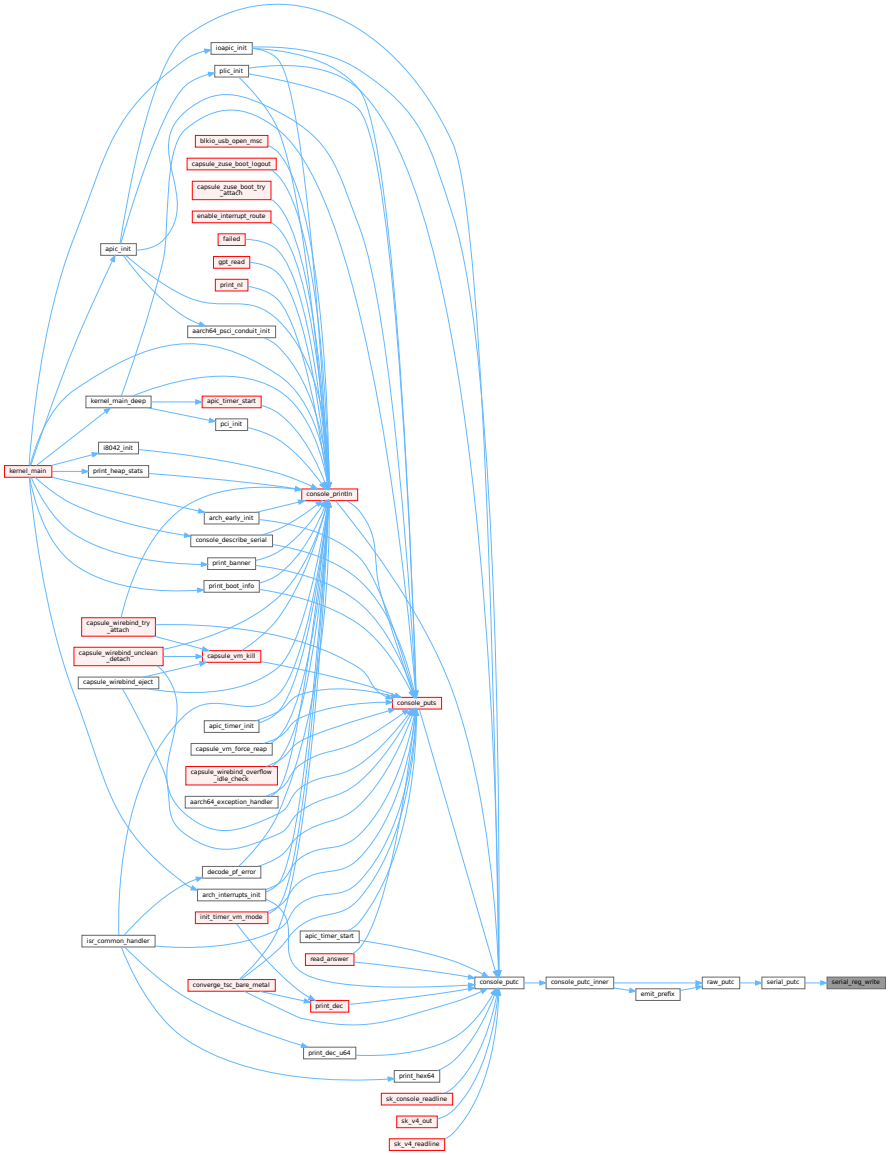
```
static void serial_reg_write (
            unsigned n,
            uint32_t v )  [static]
```

References g_serial_base, g_serial_kind, g_serial_shift, g_serial_width, outb(), and SERIAL_PORT16550.

Referenced by serial_putc().

Here is the call graph for this function:

Here is the caller graph for this function:



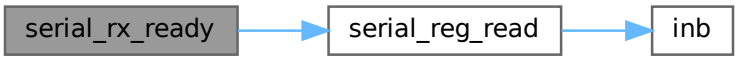
7.148.3.32 serial_rx_ready()

```
static int serial_rx_ready (
            void  )  [static]
```

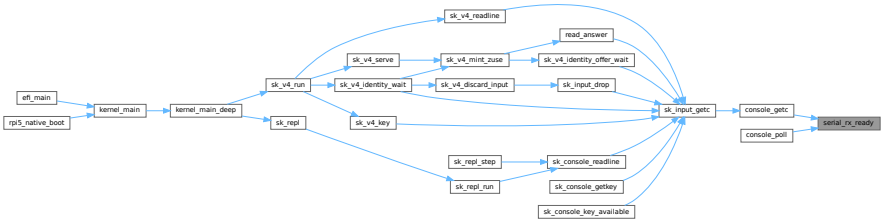
References g_serial_kind, PL011_FR, PL011_FR_RXFE, SERIAL_NONE, SERIAL_PL011, serial_reg_read(), UART16550_LSR, and UART16550_LSR_DR.

Referenced by console_getc(), and console_poll().

Here is the call graph for this function:



Here is the caller graph for this function:



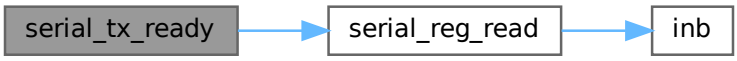
7.148.3.33 serial_tx_ready()

```
static int serial_tx_ready (
            void  )  [static]
```

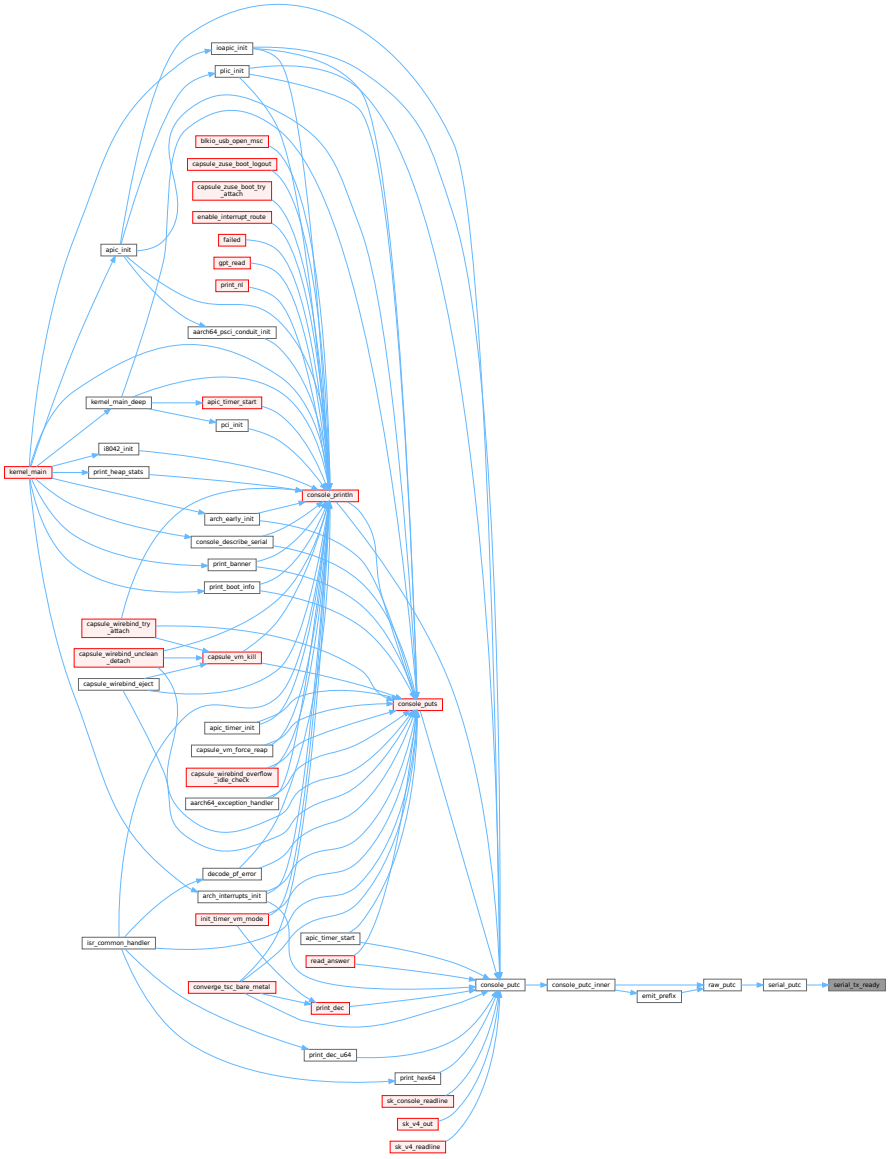
References g_serial_kind, PL011_FR, PL011_FR_TXFF, SERIAL_PL011, serial_reg_read(), UART16550_LSR, and UART16550_LSR_THRE.

Referenced by serial_putc().

Here is the call graph for this function:



Here is the caller graph for this function:



7.148.4 Variable Documentation

7.148.4.1 g_active_vm_name

```
const char* g_active_vm_name = (void *)0  [static]
```

Referenced by console_get_vm_name(), console_putc_inner(), console_save_vm_name(), console_set_vm_name(), and emit_prefix().

7.148.4.2 g_active_vm_name_buf

```
char g_active_vm_name_buf[64]  [static]
```

Referenced by console_set_vm_name().

7.148.4.3 g_console_tx_count

```
uint64_t g_console_tx_count  [static]
```

Referenced by console_putc(), and console_tx_count().

7.148.4.4 g_fb_mirror

```
int g_fb_mirror = 1  [static]
```

Referenced by console_fb_mirror(), and fb_mirrored().

7.148.4.5 g_line_start

```
int g_line_start = 1  [static]
```

Referenced by console_ensure_line_start(), and console_putc_inner().

7.148.4.6 g_pending_line_close

```
int g_pending_line_close = 0  [static]
```

Referenced by console_cancel_deferred_line_start(), console_ensure_line_start(), and console_putc().

7.148.4.7 g_serial_base

```
uintptr_t g_serial_base  [static]
```

Referenced by console_attach_serial(), console_describe_serial(), serial_reg_read(), and serial_reg_write().

7.148.4.8 g_serial_from_dt

```
int g_serial_from_dt  [static]
```

Referenced by console_attach_serial(), and console_describe_serial().

7.148.4.9 g_serial_kind

```
int g_serial_kind  [static]
```

Referenced by console_attach_serial(), console_describe_serial(), console_init(), serial_putc(), serial_reg_read(), serial_reg_write(), serial_rx_ready(), and serial_tx_ready().

7.148.4.10 g_serial_shift

```
unsigned g_serial_shift  [static]
```

Referenced by console_attach_serial(), serial_reg_read(), and serial_reg_write().

7.148.4.11 g_serial_width

```
unsigned g_serial_width  [static]
```

Referenced by console_attach_serial(), serial_reg_read(), and serial_reg_write().

7.148.4.12 g_user_prefix_fn

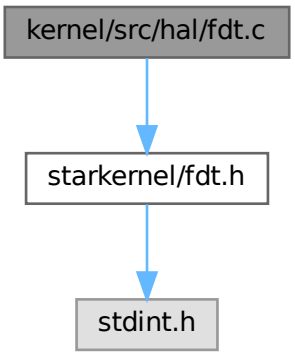
```
console_user_prefix_fn g_user_prefix_fn = (void *)0  [static]
```

Referenced by console_set_user_prefix_provider(), and emit_prefix().

7.149 kernel/src/hal/fdt.c File Reference

```
#include "starkernel/fdt.h"
```

Include dependency graph for fdt.c:



Data Structures

- struct fdt_header_t

Macros

- #define FDT_BEGIN_NODE 0x00000001u

  fdt.c - Minimal flattened-devicetree reader
- #define FDT_END_NODE 0x00000002u
- #define FDT_PROP 0x00000003u
- #define FDT_NOP 0x00000004u
- #define FDT_END 0x00000009u
- #define FDT_MAGIC 0xd00dfeedu
- #define FDT_PATH_MAX 12u

Functions

- static uint32_t be32 (const void *p)

  Byte-swap a big-endian 32-bit field from the blob.
- static int str_eq (const char *a, const char *b)

  Freestanding string compare; returns 1 when equal.
- int fdt_valid (const void *fdt)

  fdt.h - Minimal flattened-devicetree reader
- const void * fdt_find_prop (const void *fdt, const char *name, uint32_t *len_out)

  Find the first property with `name` anywhere in the tree.
- int fdt_prop_u32 (const void *fdt, const char *name, uint32_t *out)

  Read a single-cell (32-bit) property by name.
- static int compat_list_contains (const char *list, uint32_t len, const char *want)

  Test whether NUL-separated string list `list` (length `len`) contains `want` as one of its entries.
- const void * fdt_find_node_by_compatible (const void *fdt, const char *compatible)

  Find the first node whose "compatible" property matches `compatible`.
- const void * fdt_find_node_by_device_type (const void *fdt, const char *type)

  Find the first node whose "device_type" property equals `type`.
- static int node_name_eq (const char *node_name, const char *want)

  Test whether a node-name string (blob text, possibly followed by an `@unit-address`) matches `want` up to that boundary.
- const void * fdt_find_node_by_name (const void *fdt, const char *name)

  Find the first node whose own name matches `name`.
- static const unsigned char * skip_node_body (const unsigned char *p, const unsigned char *end)

  Advance `p` past one complete node body (properties, then every descendant, recursively via a depth counter) starting just inside it (i.e.
- const void * fdt_next_child_node (const void *fdt, const void *parent, const void *prev_child)

  Iterate the direct children of one node.
- int fdt_complete (const void *fdt)

  Is the structure block whole? `fdt_valid()` checks the header; this checks also that the structure block ends with its end token, as a blob that has not been cut short does.
- const void * fdt_root_node (const void *fdt)

  The root node.
- const void * fdt_find_child (const void *fdt, const void *parent, const char *name, uint32_t name_len)

  Find a direct child of a node by its whole name.
- const void * fdt_find_prop_in_node (const void *fdt, const void *node, const char *name, uint32_t *len_out)

  Find a property by name, scoped to one node.
- static uint32_t node_cells (const void *fdt, const void *node, const char *name, uint32_t otherwise)
- static uint64_t read_cells_at (const unsigned char *p, uint32_t n)
- static int node_enabled (const void *fdt, const void *node)
- static uint32_t path_to (const void *fdt, const void *node, const char *want, const void **path, uint32_t depth)
- int fdt_reg_address (const void *fdt, const char *compatible, uint32_t index, uint64_t *out)

  The CPU's address for entry `index` of the `reg` of the first enabled node compatible with `compatible` (2026-10-14).

7.149.1 Macro Definition Documentation

7.149.1.1 FDT_BEGIN_NODE

```
#define FDT_BEGIN_NODE 0x00000001u
```

fdt.c - Minimal flattened-devicetree reader

Devicetree Specification v0.4 ?5. Everything in the blob is big-endian; the kernel targets are little-endian, so every field goes through be32().

7.149.1.2 FDT_END

```
#define FDT_END 0x00000009u
```

7.149.1.3 FDT_END_NODE

```
#define FDT_END_NODE 0x00000002u
```

7.149.1.4 FDT_MAGIC

```
#define FDT_MAGIC 0xd00dfeedu
```

7.149.1.5 FDT_NOP

```
#define FDT_NOP 0x00000004u
```

7.149.1.6 FDT_PATH_MAX

```
#define FDT_PATH_MAX 12u
```

7.149.1.7 FDT_PROP

```
#define FDT_PROP 0x00000003u
```

7.149.2 Function Documentation

7.149.2.1 be32()

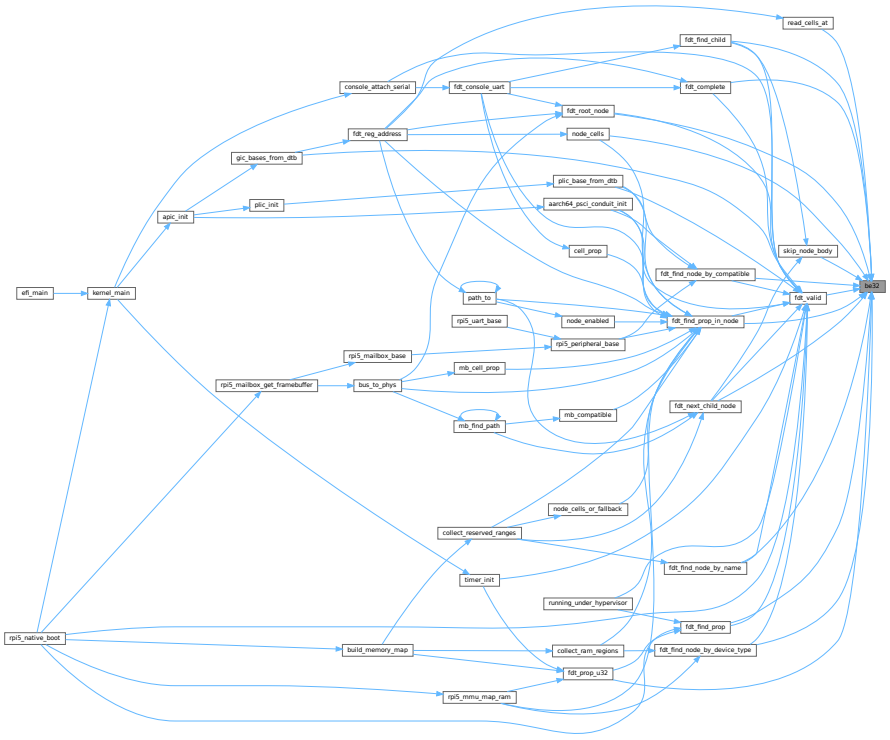
```
static uint32_t be32 (
            const void * p )  [static]
```

Byte-swap a big-endian 32-bit field from the blob.

Read bytewise rather than as a `uint32_t` load: structure-block tokens are only guaranteed 4-byte aligned relative to the block start, and property values carry no alignment guarantee at all.

Referenced by fdt_complete(), fdt_find_child(), fdt_find_node_by_compatible(), fdt_find_node_by_device_type(), fdt_find_node_by_name(), fdt_find_prop(), fdt_find_prop_in_node(), fdt_next_child_node(), fdt_prop_u32(), fdt_root_node(), fdt_valid(), node_cells(), read_cells_at(), and skip_node_body().

Here is the caller graph for this function:



7.149.2.2 compat_list_contains()

```
static int compat_list_contains (
            const char * list,
            uint32_t len,
            const char * want )  [static]
```

Test whether NUL-separated string list `list` (length `len`) contains `want` as one of its entries.

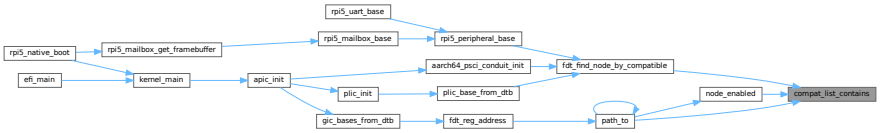
"compatible" properties are formatted as one or more NUL-terminated strings concatenated (DT spec ?2.3.1) – each entry's own embedded NUL is real property data, not synthesized, so str_eq() (which walks until either side's NUL) terminates correctly at each entry's real boundary.

References str_eq().

Referenced by fdt_find_node_by_compatible(), node_enabled(), and path_to().

Here is the call graph for this function:

Here is the caller graph for this function:



7.149.2.3 fdt_complete()

```
int fdt_complete (
            const void * fdt )
```

Is the structure block whole? `fdt_valid()` checks the header; this checks also that the structure block ends with its end token, as a blob that has not been cut short does.

A reader that takes a property's absence to mean its default (a UART's "reg-shift") must not be handed half a tree.

Returns

1 if `fdt` is valid and its structure block ends with FDT_END.

References be32(), FDT_END, fdt_valid(), fdt_header_t::off_dt_struct, and fdt_header_t::size_dt_struct.

Referenced by fdt_console_uart(), and fdt_reg_address().

Here is the call graph for this function:

Here is the caller graph for this function:

7.149.2.4 fdt_find_child()

```
const void * fdt_find_child (
            const void * fdt,
            const void * parent,
            const char * name,
            uint32_t name_len )
```

Find a direct child of a node by its whole name.

The name is matched exactly, unit address included ("serial@10000000" is not "serial"), and is given with its length so that one component of a path can be passed without copying it. Only `parent`'s own children are looked at, never their descendants.

Parameters

fdt	Blob; checked with `fdt_valid()`.
parent	Node handle; NULL is safe and returns NULL.
name	The child's name; need not be NUL-terminated.
name_len	Its length in bytes.

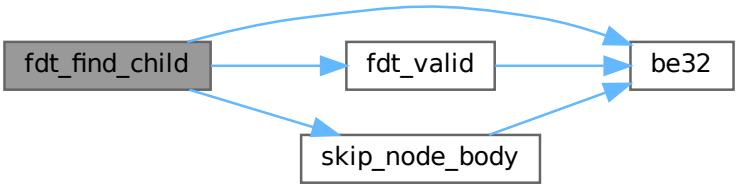
Returns

Handle to the child, or NULL if `parent` has none of that name.

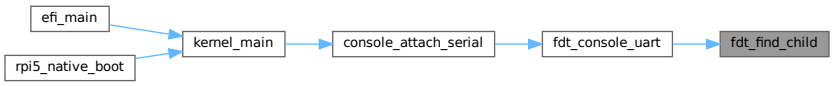
References be32(), FDT_BEGIN_NODE, FDT_NOP, FDT_PROP, fdt_valid(), name, name_len, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and skip_node_body().

Referenced by fdt_console_uart().

Here is the call graph for this function:



Here is the caller graph for this function:



7.149.2.5 fdt_find_node_by_compatible()

```
const void * fdt_find_node_by_compatible (
             const void * fdt,
             const char * compatible )
```

Find the first node whose "compatible" property matches `compatible`.

"compatible" is a NUL-separated list of strings (DT spec ?2.3.1) — matches if `compatible` equals any one entry in the list, not just the whole property verbatim. Scans the whole tree in document order; the first matching node wins if more than one exists.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
compatible	Compatible string to match, NUL-terminated.

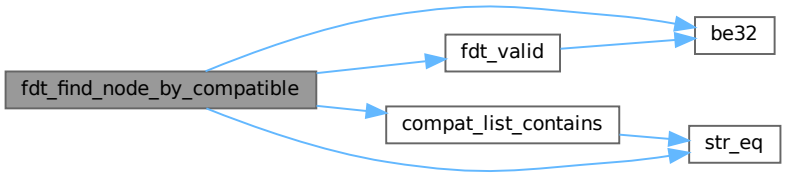
Returns

An opaque handle to the matched node, for use with `fdt_find_prop_in_node()` only (not a raw offset or a pointer to anything else meaningful) — or NULL if no node matches.

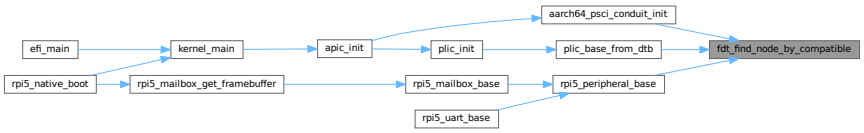
References base, be32(), compat_list_contains(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, FDT_PROP, fdt_valid(), fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and str_eq().

Referenced by aarch64_psci_conduit_init(), plic_base_from_dtb(), and rpi5_peripheral_base().

Here is the call graph for this function:



Here is the caller graph for this function:



7.149.2.6 fdt_find_node_by_device_type()

```
const void * fdt_find_node_by_device_type (
            const void * fdt,
            const char * type )
```

Find the first node whose "device_type" property equals `type`.

Some standard nodes (`/memory` per DT spec ?3.4) are identified by `device_type`, not `compatible` — unlike `compatible`, `device_type` is a single NUL-terminated string, not a list, so this matches the whole property value rather than scanning entries within it. Scans the whole tree in document order; the first matching node wins if more than one exists.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
type	device_type value to match, NUL-terminated.

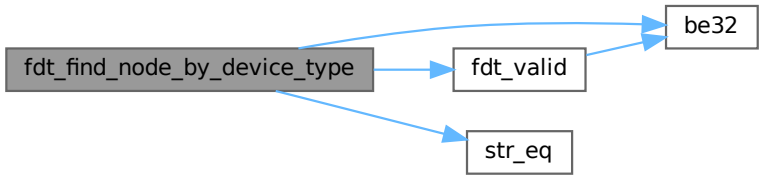
Returns

An opaque handle to the matched node, for use with `fdt_find_prop_in_node()` only — or NULL if no node matches.

References base, be32(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, FDT_PROP, fdt_valid(), fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and str_eq().

Referenced by collect_ram_regions(), and rpi5_mmu_map_ram().

Here is the call graph for this function:



Here is the caller graph for this function:

7.149.2.7 fdt_find_node_by_name()

```
const void * fdt_find_node_by_name (
            const void * fdt,
            const char * name )
```

Find the first node whose own name matches `name`.

Node names follow the DT spec ?2.2.1 `name[@unit-address]` convention — matches if `name` equals the node's name up to (not including) an `@` suffix, or the whole name if there is none. For a singleton node with no unit address (`/reserved-memory` being the concrete case this was added for), this is an exact match. Scans the whole tree in document order; the first matching node wins if more than one exists.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
name	Node name to match, NUL-terminated, no `@` suffix.

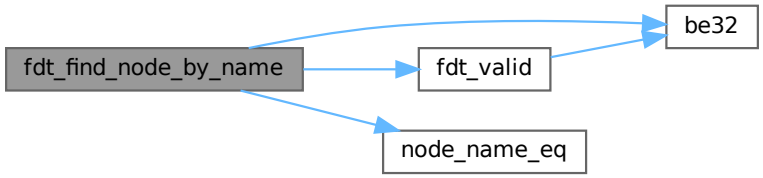
Returns

An opaque handle to the matched node, for use with `fdt_find_prop_in_node()` / `fdt_next_child_node()` only — or NULL if no node matches.

References base, be32(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, FDT_PROP, fdt_valid(), name, node_name_eq(), fdt_header_t::off_dt_struct, and fdt_header_t::size_dt_struct.

Referenced by collect_reserved_ranges().

Here is the call graph for this function:



Here is the caller graph for this function:

7.149.2.8 fdt_find_prop()

```
const void * fdt_find_prop (
             const void * fdt,
             const char * name,
             uint32_t * len_out )
```

Find the first property with `name` anywhere in the tree.

Scans the structure block in document order and returns the first match regardless of which node it belongs to. That is sufficient for properties which are uniform across a machine (timebase-frequency being the case this was written for) and is *not* sufficient for anything node-scoped.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
name	Property name, NUL-terminated.
len_out	Receives the property length in bytes; may be NULL.

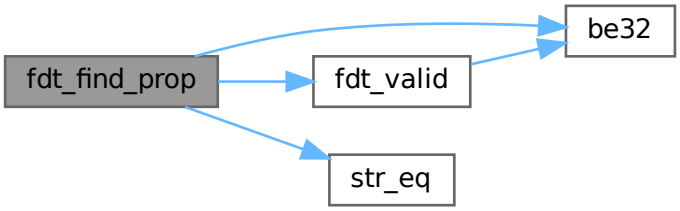
Returns

Pointer to the property value inside `fdt`, or NULL if not found. The value is big-endian as stored in the blob.

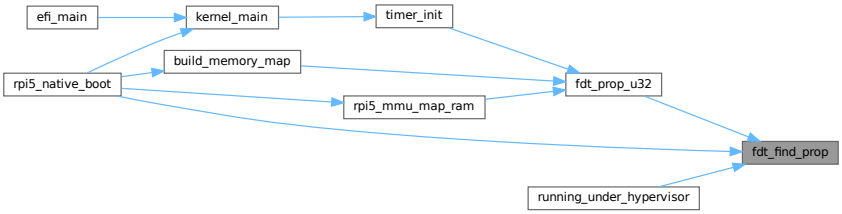
References base, be32(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, FDT_PROP, fdt_valid(), name, fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and str_eq().

Referenced by fdt_prop_u32(), rpi5_native_boot(), and running_under_hypervisor().

Here is the call graph for this function:



Here is the caller graph for this function:



7.149.2.9 fdt_find_prop_in_node()

```
const void * fdt_find_prop_in_node (
            const void * fdt,
            const void * node,
            const char * name,
            uint32_t * len_out )
```

Find a property by name, scoped to one node.

Like `fdt_find_prop()`, but scans only `node`'s own direct properties (as returned by `fdt_find_node_by_compatible()` — stops at the first child node or the end of `node`'s property list, never descends into children, never continues into a sibling. This is the difference that matters for a property name like "reg", which is not unique across the tree the way "timebase-frequency" (the whole reason `fdt_find_prop()` was originally sufficient) happens to be.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
node	Handle from `fdt_find_node_by_compatible()`; NULL is safe and returns NULL (propagates a failed node lookup without a separate caller-side check).
name	Property name, NUL-terminated.
len_out	Receives the property length in bytes; may be NULL.

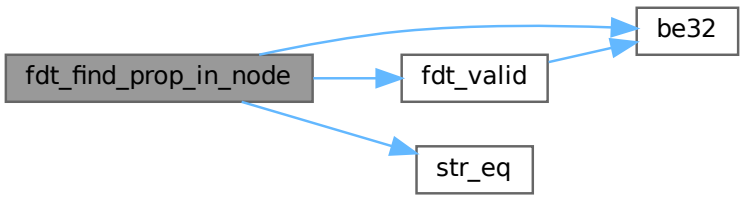
Returns

Pointer to the property value inside `fdt`, or NULL if not found (or if `node` is NULL). The value is big-endian as stored in the blob.

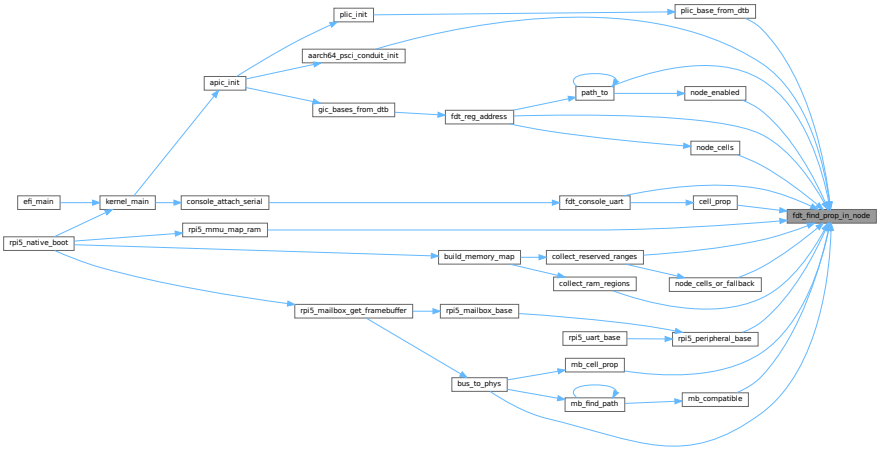
References be32(), FDT_NOP, FDT_PROP, fdt_valid(), name, fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and str_eq().

Referenced by aarch64_psci_conduit_init(), bus_to_phys(), cell_prop(), collect_ram_regions(), collect_reserved_ranges(), fdt_console_uart(), fdt_reg_address(), mb_cell_prop(), mb_compatible(), node_cells(), node_cells_or_fallback(), node_enabled(), path_to(), plic_base_from_dtb(), rpi5_mmu_map_ram(), and rpi5_peripheral_base().

Here is the call graph for this function:



Here is the caller graph for this function:



7.149.2.10 fdt_next_child_node()

```
const void * fdt_next_child_node (
            const void * fdt,
            const void * parent,
            const void * prev_child )
```

Iterate the direct children of one node.

Pass `prev_child` as NULL to get the first child; pass a previous result back in to get the next one. Stops (returns NULL) once there are no more children. Skips over each child's own descendants correctly (so a child with grandchildren doesn't confuse the scan), but does not itself descend into them — only direct children of `parent` are ever returned.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
parent	Handle from one of the `fdt_find_node_by_*()` functions.
prev_child	NULL for the first child, or a handle previously returned by this function for `parent` to continue from.

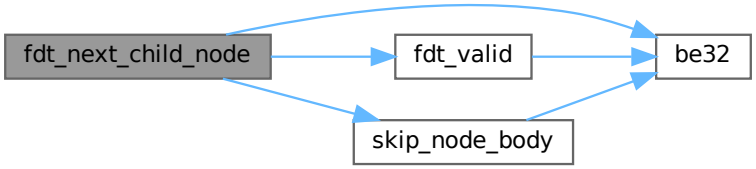
Returns

Handle to the next direct child, for use with `fdt_find_prop_in_node()` / `fdt_next_child_node()` only — or NULL once `parent`'s children are exhausted.

References be32(), FDT_BEGIN_NODE, FDT_NOP, FDT_PROP, fdt_valid(), fdt_header_t::off_dt_struct, fdt_header_t::size_dt_struct, and skip_node_body().

Referenced by collect_reserved_ranges(), mb_find_path(), and path_to().

Here is the call graph for this function:



Here is the caller graph for this function:

7.149.2.11 fdt_prop_u32()

```
int fdt_prop_u32 (
            const void * fdt,
            const char * name,
            uint32_t * out )
```

Read a single-cell (32-bit) property by name.

Convenience over `fdt_find_prop()` that also handles the big-endian conversion. Fails if the property is absent or not exactly 4 bytes.

Parameters

fdt	Blob, already checked with `fdt_valid()`.
name	Property name, NUL-terminated.
out	Receives the host-order value on success; untouched on failure.

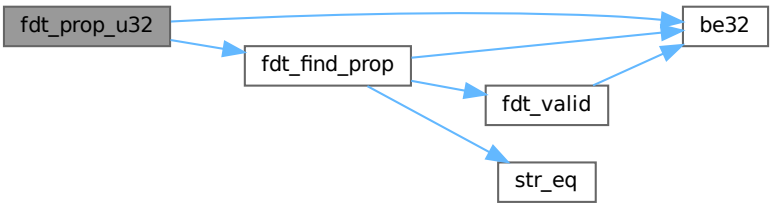
Returns

1 on success, 0 on failure.

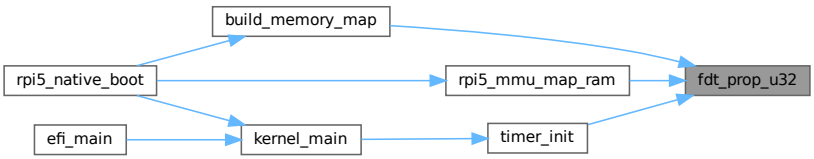
References be32(), fdt_find_prop(), and name.

Referenced by build_memory_map(), rpi5_mmu_map_ram(), and timer_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.149.2.12 fdt_reg_address()

```
int fdt_reg_address (
            const void * fdt,
            const char * compatible,
            uint32_t index,
            uint64_t * out )
```

The CPU's address for entry `index` of the `reg` of the first enabled node compatible with `compatible` (2026-10-14).

The entry is read in its parent's #address-cells/#size-cells and carried up through every bus's `ranges` to the root – an empty `ranges` keeps the address, a bus with no `ranges` has no way up. The Pi 5's GIC, for one, sits at 0x7fff9000 on /soc, which is 0x107fff9000 to the CPU.

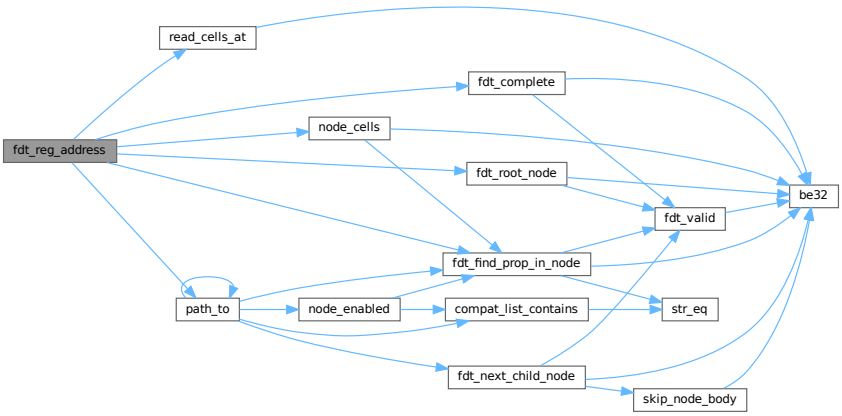
Returns

1 and the address in `out`, or 0 if there is no such node, entry or way up.

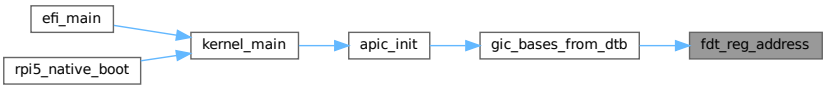
References entry, fdt_complete(), fdt_find_prop_in_node(), FDT_PATH_MAX, fdt_root_node(), node_cells(), path_to(), and read_cells_at().

Referenced by gic_bases_from_dtb().

Here is the call graph for this function:



Here is the caller graph for this function:



7.149.2.13 fdt_root_node()

```
const void * fdt_root_node (
            const void * fdt )
```

The root node.

Parameters

fdt	Blob; checked with `fdt_valid()`.

Returns

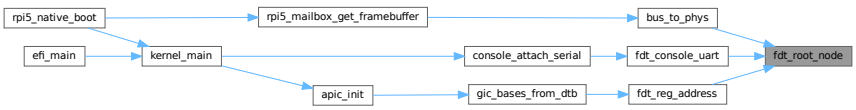
Handle to the root node, for `fdt_find_child()` and `fdt_find_prop_in_node()`, or NULL.

References be32(), FDT_BEGIN_NODE, FDT_NOP, fdt_valid(), fdt_header_t::off_dt_struct, and fdt_header_t::size_dt_struct.

Referenced by bus_to_phys(), fdt_console_uart(), and fdt_reg_address().

Here is the call graph for this function:

Here is the caller graph for this function:



7.149.2.14 fdt_valid()

```
int fdt_valid (
            const void * fdt )
```

fdt.h - Minimal flattened-devicetree reader

Just enough of the Devicetree Specification v0.4 ?5 to pull values out of the blob the UEFI firmware publishes under EFI_DTB_TABLE_GUID, or that a native (non-UEFI) boot entry passes directly. Read-only, no allocation, no tree construction — it walks the structure block each call, which is fine for the handful of boot-time lookups the kernel needs.

Deliberately not a general devicetree library. Added for punch-list item 0.3 (riscv64 timebase-frequency); extended (FABRIC-3.md ?IV.3/?V.3, 2026-09-04) with node-scoped lookup, for exactly the case this header originally flagged as a future need (item 0.6's aarch64 GIC) plus its real, concrete consumers as of this pass: the Raspberry Pi 5's UART/ mailbox register addresses (native boot, no ACPI) and the Milk-V Mars's real PLIC base address (currently hardcoded to QEMU-virt's own value, `arch/riscv64/plic.c`'s own doc comment already warned this isn't assumed stable across configurations).

Test whether `fdt` points at a valid flattened devicetree.

Checks the 0xd00dfeed magic and that the structure and strings blocks lie inside totalsize. Does not validate the token stream.

Parameters

fdt	Candidate blob; NULL is safe and returns 0.

Returns

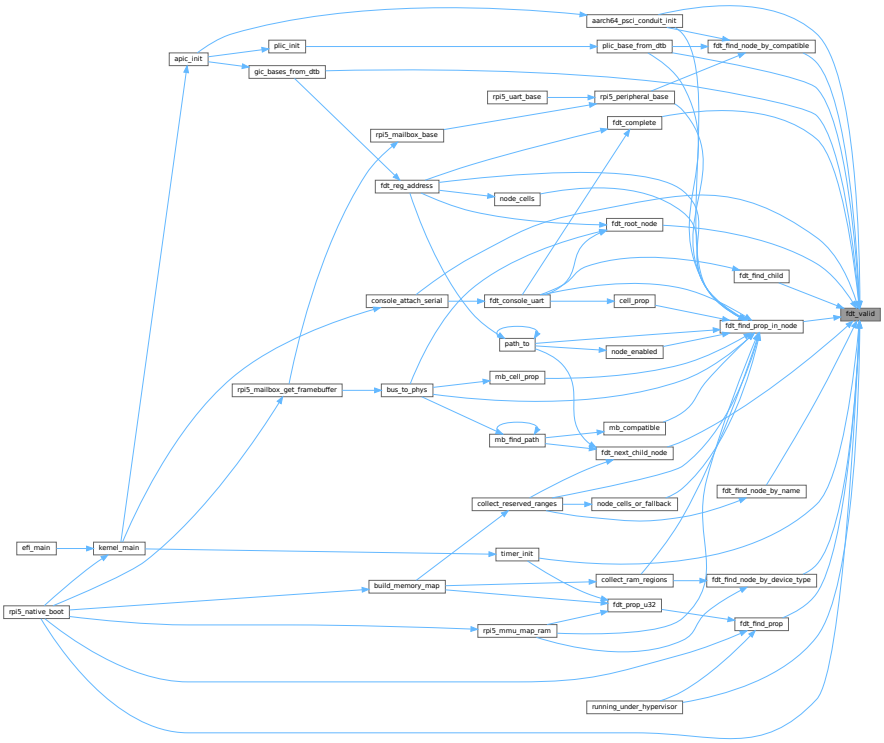
1 if the header is usable, 0 otherwise.

References be32(), FDT_MAGIC, fdt_header_t::magic, fdt_header_t::off_dt_strings, fdt_header_t::off_dt_struct, fdt_header_t::size_dt_strings, fdt_header_t::size_dt_struct, and fdt_header_t::totalsize.

Referenced by aarch64_psci_conduit_init(), console_attach_serial(), fdt_complete(), fdt_find_child(), fdt_find_node_by_compatible(), fdt_find_node_by_device_type(), fdt_find_node_by_name(), fdt_find_prop(), fdt_find_prop_in_node(), fdt_next_child_node(), fdt_root_node(), gic_bases_from_dtb(), plic_base_from_dtb(), rpi5_native_boot(), running_under_hypervisor(), and timer_init().

Here is the call graph for this function:

Here is the caller graph for this function:



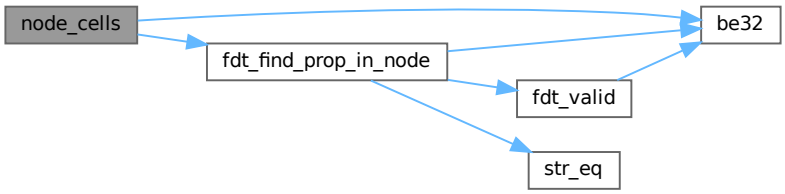
7.149.2.15 node_cells()

```
static uint32_t node_cells (
            const void * fdt,
            const void * node,
            const char * name,
            uint32_t otherwise )  [static]
```

References be32(), fdt_find_prop_in_node(), and name.

Referenced by fdt_reg_address().

Here is the call graph for this function:



Here is the caller graph for this function:

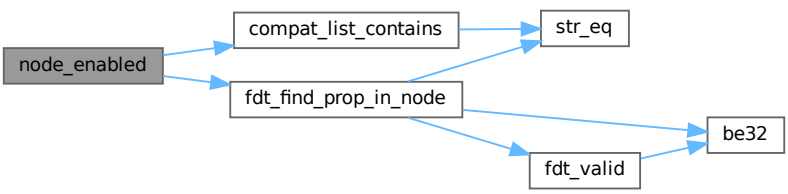
7.149.2.16 node_enabled()

```
static int node_enabled (
            const void * fdt,
            const void * node )  [static]
```

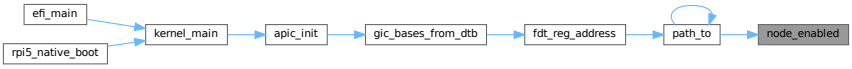
References compat_list_contains(), and fdt_find_prop_in_node().

Referenced by path_to().

Here is the call graph for this function:



Here is the caller graph for this function:



7.149.2.17 node_name_eq()

```
static int node_name_eq (
            const char * node_name,
            const char * want )  [static]
```

Test whether a node-name string (blob text, possibly followed by an `@unit-address`) matches `want` up to that boundary.

Referenced by fdt_find_node_by_name().

Here is the caller graph for this function:

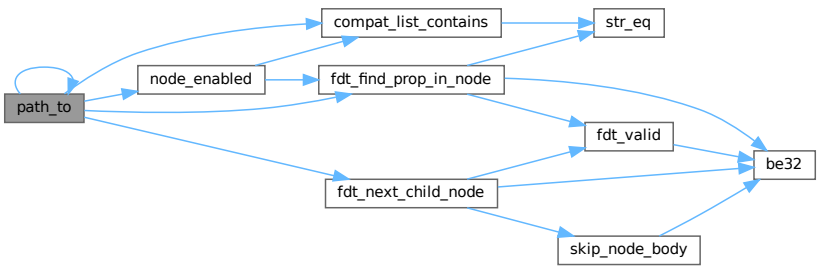
7.149.2.18 path_to()

```
static uint32_t path_to (
            const void * fdt,
            const void * node,
            const char * want,
            const void ** path,
            uint32_t depth )  [static]
```

References compat_list_contains(), fdt_find_prop_in_node(), fdt_next_child_node(), FDT_PATH_MAX, node_enabled(), and path_to().

Referenced by fdt_reg_address(), and path_to().

Here is the call graph for this function:



Here is the caller graph for this function:

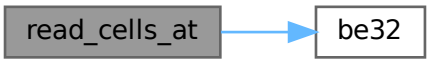
7.149.2.19 read_cells_at()

```
static uint64_t read_cells_at (
            const unsigned char * p,
            uint32_t n )  [static]
```

References be32().

Referenced by fdt_reg_address().

Here is the call graph for this function:



Here is the caller graph for this function:

7.149.2.20 skip_node_body()

```
static const unsigned char * skip_node_body (
            const unsigned char * p,
            const unsigned char * end )  [static]
```

Advance p past one complete node body (properties, then every descendant, recursively via a depth counter) starting just inside it (i.e.

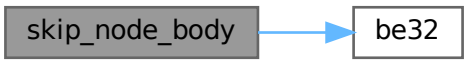
p is a node handle, right after its own FDT_BEGIN_NODE name), stopping just after the matching FDT_END_↩ NODE.

Internal to `fdt_next_child_node()` — a node handle's own children may have further descendants even though this reader's public node-lookup functions never return anything but direct-child handles, so finding the *next sibling* after a child still requires skipping past whatever that child itself contains.

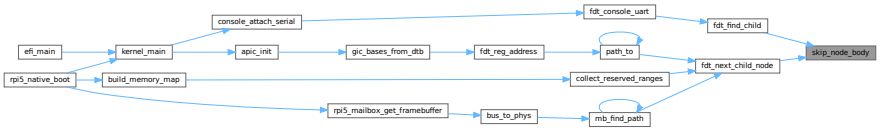
References be32(), FDT_BEGIN_NODE, FDT_END_NODE, FDT_NOP, and FDT_PROP.

Referenced by fdt_find_child(), and fdt_next_child_node().

Here is the call graph for this function:



Here is the caller graph for this function:



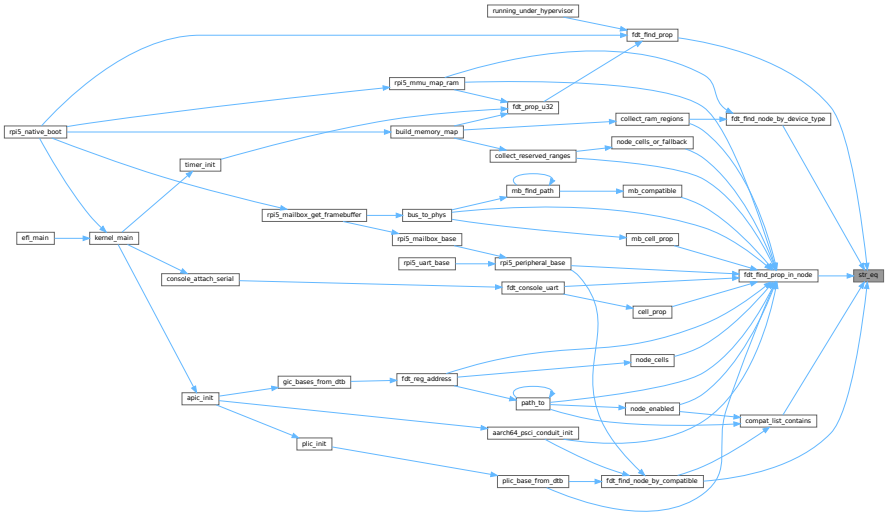
7.149.2.21 str_eq()

```
static int str_eq (
            const char * a,
            const char * b )  [static]
```

Freestanding string compare; returns 1 when equal.

Referenced by compat_list_contains(), fdt_find_node_by_compatible(), fdt_find_node_by_device_type(), fdt_find_prop(), and fdt_find_prop_in_node().

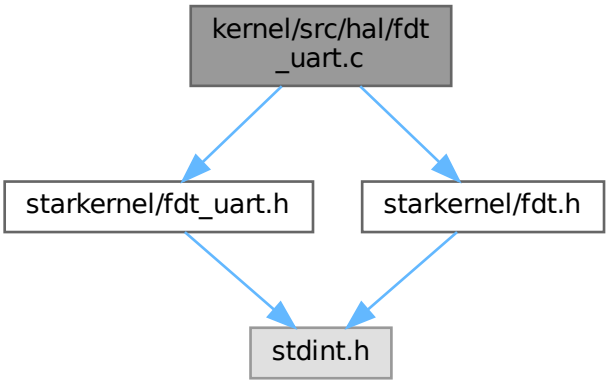
Here is the caller graph for this function:



7.150 kernel/src/hal/fdt_uart.c File Reference

```
#include "starkernel/fdt_uart.h"
#include "starkernel/fdt.h"
```

Include dependency graph for fdt_uart.c:



Macros

- #define PATH_DEPTH 8 /∗ nodes from the root to the UART, the root counted ∗/

  fdt_uart.c - the console's serial line, as a board's devicetree names it.

Functions

- static uint32_t be32 (const unsigned char ∗b)
- static uint32_t cell_prop (const void ∗fdt, const void ∗node, const char ∗name, uint32_t otherwise)
- static uint64_t cells (const unsigned char ∗p, uint32_t n)
- static int compatible_has (const char ∗list, uint32_t len, const char ∗want)
- int fdt_console_uart (const void ∗fdt, fdt_uart_t ∗out)

  Find the console's serial line in a devicetree.

7.150.1 Macro Definition Documentation

7.150.1.1 PATH_DEPTH

```
#define PATH_DEPTH 8 /* nodes from the root to the UART, the root counted */
```

fdt_uart.c - the console's serial line, as a board's devicetree names it.

See fdt_uart.h.

The node is reached a component of its path at a time from the root, so that each bus on the way is in hand: a node's "reg" is an address on its parent's bus, and is carried up to the CPU's own addresses through the "ranges" of every bus above it (DT spec 2.3.8). A bus with an empty "ranges" passes addresses on unchanged; one with none at all has no mapping, and the line is not found.

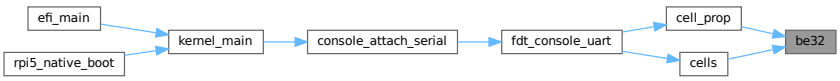
7.150.2 Function Documentation

7.150.2.1 be32()

```
static uint32_t be32 (
            const unsigned char * b )  [static]
```

Referenced by cell_prop(), and cells().

Here is the caller graph for this function:



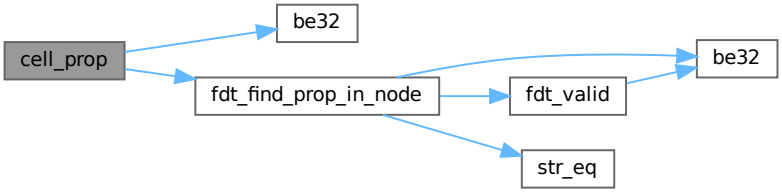
7.150.2.2 cell_prop()

```
static uint32_t cell_prop (
            const void * fdt,
            const void * node,
            const char * name,
            uint32_t otherwise )  [static]
```

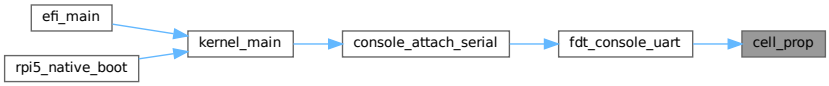
References be32(), fdt_find_prop_in_node(), and name.

Referenced by fdt_console_uart().

Here is the call graph for this function:



Here is the caller graph for this function:



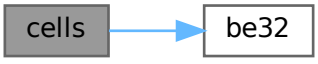
7.150.2.3 cells()

```
static uint64_t cells (
            const unsigned char * p,
            uint32_t n )  [static]
```

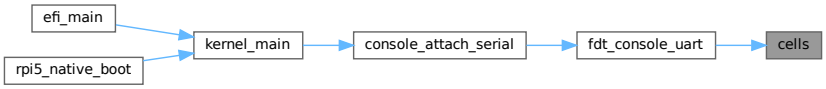
References be32().

Referenced by fdt_console_uart().

Here is the call graph for this function:



Here is the caller graph for this function:

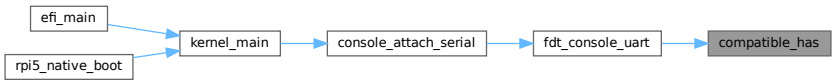


7.150.2.4 compatible_has()

```
static int compatible_has (
            const char * list,
            uint32_t len,
            const char * want )  [static]
```

Referenced by fdt_console_uart().

Here is the caller graph for this function:



7.150.2.5 fdt_console_uart()

```
int fdt_console_uart (
            const void * fdt,
            fdt_uart_t * out )
```

Find the console's serial line in a devicetree.

Parameters

fdt	Blob; NULL and what is not a devicetree are safe.
out	Receives the line; its kind is FDT_UART_NONE when 0 is returned.

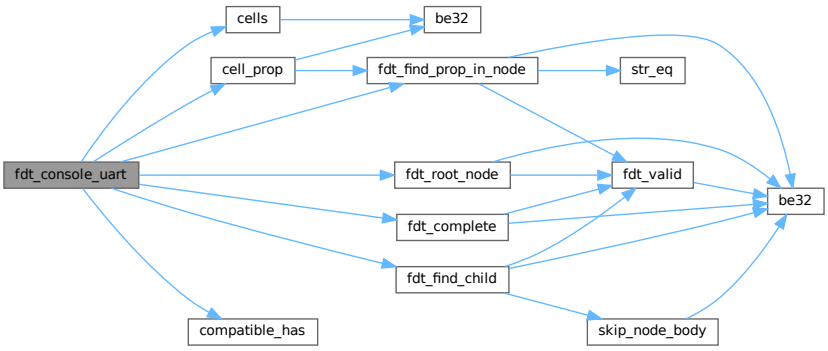
Returns

1 if the devicetree names a console UART that was found, placed and is of a kind listed above; 0 otherwise.

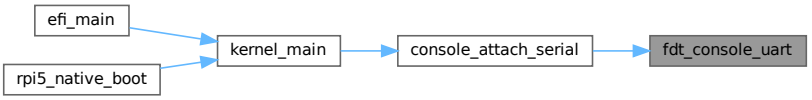
References fdt_uart_t::base, cell_prop(), cells(), compatible_has(), entry, fdt_complete(), fdt_find_child(), fdt_find_prop_in_node(), fdt_root_node(), FDT_UART_16550, FDT_UART_NONE, FDT_UART_PL011, fdt_uart_t::io_width, fdt_uart_t::kind, PATH_DEPTH, and fdt_uart_t::reg_shift.

Referenced by console_attach_serial().

Here is the call graph for this function:

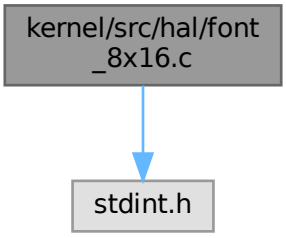


Here is the caller graph for this function:



7.151 kernel/src/hal/font_8x16.c File Reference

`#include <stdint.h>`
Include dependency graph for font_8x16.c:



Functions

- const uint8_t * font_8x16_glyph (uint8_t ch)

  Return pointer to the 16-byte glyph bitmap for character ch.

Variables

- const uint8_t font_8x16_data [256 ∗16]

  font_8x16.c — Embedded IBM CP437 VGA 8× 16 bitmap font (256 glyphs × 16 bytes)

7.151.1 Function Documentation

7.151.1.1 font_8x16_glyph()

```
const uint8_t * font_8x16_glyph (
            uint8_t ch )
```

Return pointer to the 16-byte glyph bitmap for character ch.

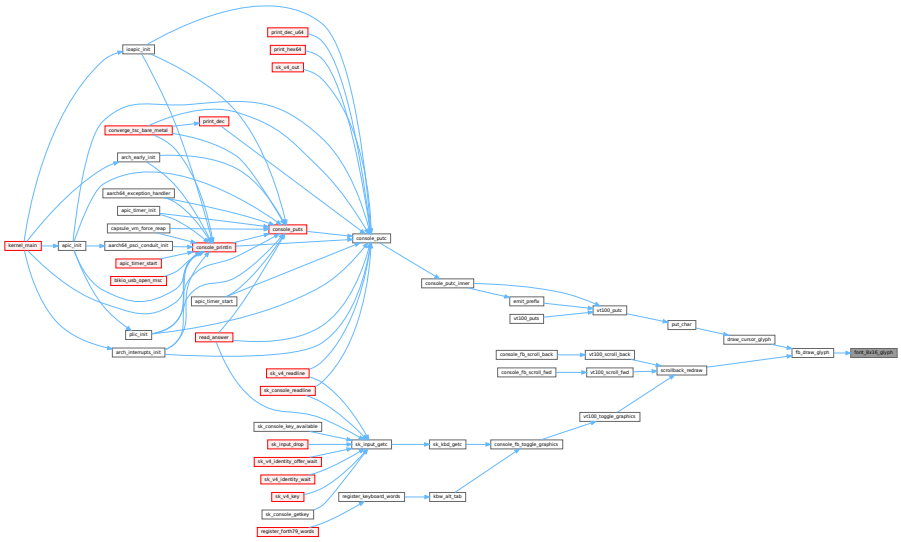
framebuffer.c — UEFI GOP framebuffer pixel driver

Caller must not modify the returned data.

References font_8x16_data.

Referenced by fb_draw_glyph().

Here is the caller graph for this function:



7.151.2 Variable Documentation

7.151.2.1 font_8x16_data

```
const uint8_t font_8x16_data[256 ∗16]
```

font_8x16.c — Embedded IBM CP437 VGA 8×16 bitmap font (256 glyphs × 16 bytes)

Format: one byte per scanline, MSB = leftmost pixel. Glyph for character N starts at byte N∗16.

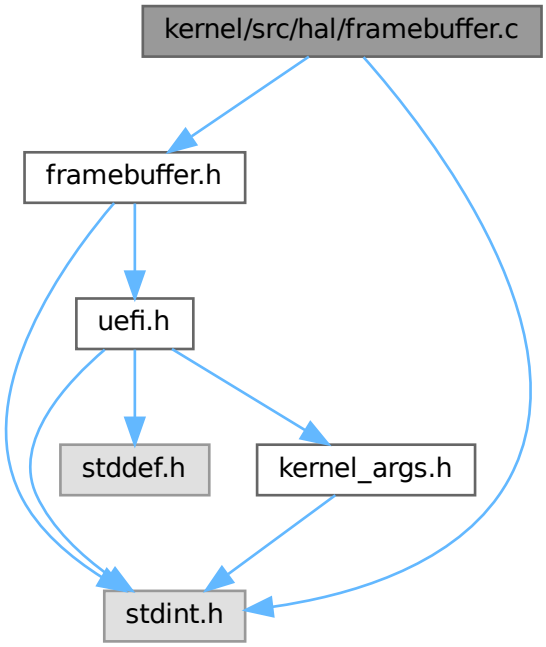
Derived from the IBM PC BIOS ROM font, which is in the public domain.

Referenced by font_8x16_glyph().

7.152 kernel/src/hal/framebuffer.c File Reference

```
#include "framebuffer.h"
#include <stdint.h>
```

Include dependency graph for framebuffer.c:



Data Structures

- struct FbState

Functions

- const uint8_t * font_8x16_glyph (uint8_t ch)

  framebuffer.c — UEFI GOP framebuffer pixel driver
- const uint32_t FB_ANSI_PALETTE[16] __attribute__ ((visibility("hidden")))
- static uint32_t pack_pixel (uint32_t rgb)
- void fb_init (const FramebufferInfo *info, FbPixelFormat fmt)

  Initialize the framebuffer from UEFI bootloader GOP data.
- int fb_is_available (void)

  Returns 1 if the framebuffer has been successfully initialized.
- uint32_t fb_width (void)
- uint32_t fb_height (void)
- uint32_t fb_cell_w (void)

  Effective character cell dimensions in pixels (accounts for scale).
- uint32_t fb_cell_h (void)

- void fb_put_pixel (uint32_t x, uint32_t y, uint32_t rgb)

  Write a single pixel.
- void fb_fill_rect (uint32_t x, uint32_t y, uint32_t w, uint32_t h, uint32_t rgb)

  Fill a rectangle with a solid color.
- void fb_draw_glyph (uint32_t px, uint32_t py, uint8_t ch, uint32_t fg, uint32_t bg)

  Draw one 8×16 glyph at pixel position (px, py).
- void fb_draw_orientation_test (void)

  fb_draw_orientation_test — one-time boot diagnostic (FABRIC-0.md item 4.3.1).
- void fb_scroll_rows (uint32_t pixel_rows, uint32_t bg)

  Scroll the framebuffer up by `pixel_rows` pixel rows.
- void fb_scroll_rect (uint32_t x, uint32_t y, uint32_t w, uint32_t h, uint32_t pixel_rows, uint32_t bg)

  fb_scroll_rect — box-confined scroll (FABRIC-0.md item 4.4t).

Variables

- static FbState g_fb

7.152.1 Function Documentation

7.152.1.1 __attribute__()

```
const uint32_t FB_ANSI_PALETTE[16] __attribute__ (
            (visibility("hidden"))  )
```

References FB_RGB.

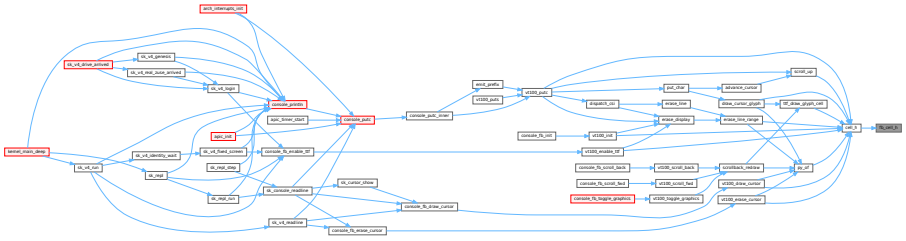
7.152.1.2 fb_cell_h()

```
uint32_t fb_cell_h (
            void  )
```

References g_fb, and FbState::scale.

Referenced by cell_h().

Here is the caller graph for this function:



7.152.1.3 fb_cell_w()

```
uint32_t fb_cell_w (
            void  )
```

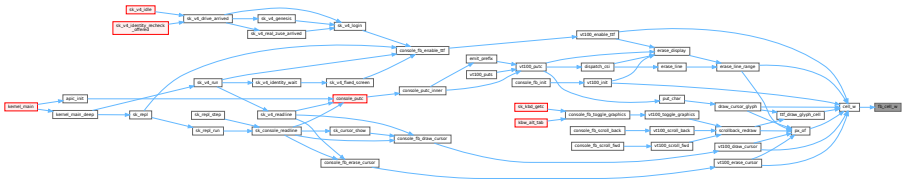
Effective character cell dimensions in pixels (accounts for scale).

Effective character cell width/height in pixels (8/16 × scale factor).

References g_fb, and FbState::scale.

Referenced by cell_w().

Here is the caller graph for this function:



7.152.1.4 fb_draw_glyph()

```
void fb_draw_glyph (
            uint32_t px,
            uint32_t py,
            uint8_t ch,
            uint32_t fg,
            uint32_t bg )
```

Draw one 8×16 glyph at pixel position (px, py).

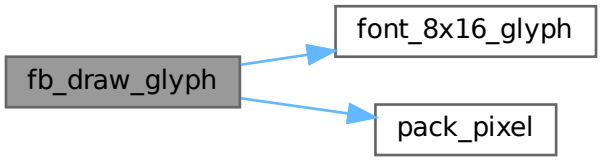
Draw one 8×16 character glyph at pixel position (px, py).

Scales by g_fb.scale so the same font works at any resolution.

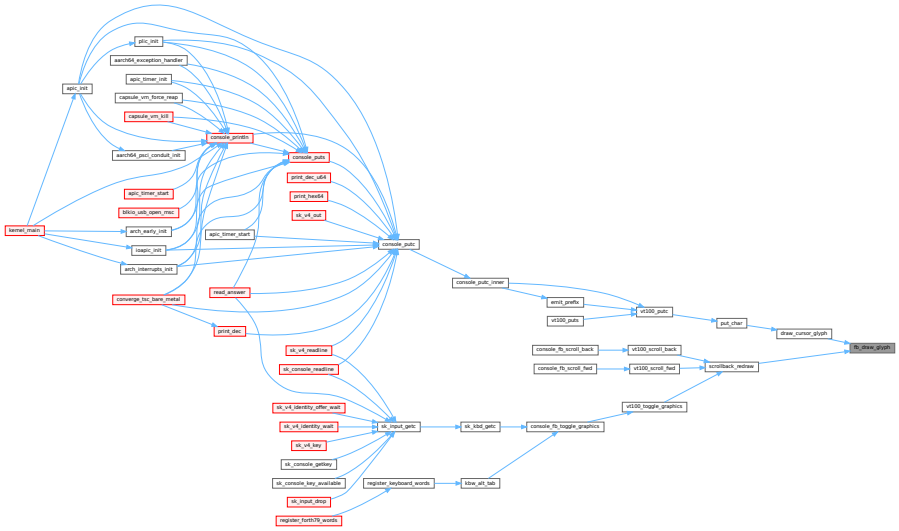
References FbState::base, font_8x16_glyph(), g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::scale, FbState::stride, and FbState::width.

Referenced by draw_cursor_glyph(), and scrollback_redraw().

Here is the call graph for this function:



Here is the caller graph for this function:



7.152.1.5 fb_draw_orientation_test()

```
void fb_draw_orientation_test (
            void  )
```

fb_draw_orientation_test — one-time boot diagnostic (FABRIC-0.md item 4.3.1).

One-time boot diagnostic (FABRIC-0.md item 4.3.1): fills each raster corner with a distinct solid color so a screendump reveals orientation.

Fills each raster corner with a distinct solid color so a screendump immediately reveals whether the image is flipped or rotated. Not part of the Console drawing fabric itself – diagnostic-only, analogous to item 4.2's self-test scaffolding.

Corner colors (raster/top-left-origin coordinates, pre-Cartesian-flip): top-left RED top-right GREEN bottom-left BLUE bottom-right YELLOW

References fb_fill_rect(), FB_RGB, g_fb, FbState::height, FbState::ready, and FbState::width.

Here is the call graph for this function:

7.152.1.6 fb_fill_rect()

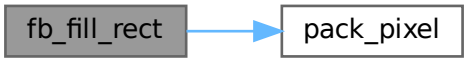
```
void fb_fill_rect (
            uint32_t x,
            uint32_t y,
            uint32_t w,
            uint32_t h,
            uint32_t rgb )
```

Fill a rectangle with a solid color.

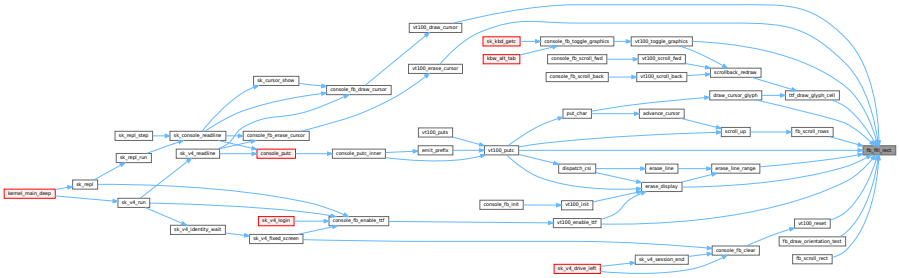
References FbState::base, g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::stride, and FbState::width.

Referenced by draw_cursor_glyph(), erase_display(), erase_line_range(), fb_draw_orientation_test(), fb_scroll_rect(), fb_scroll_rows(), ttf_draw_glyph_cell(), vt100_draw_cursor(), vt100_enable_ttf(), vt100_erase_cursor(), vt100_putc(), vt100_reset(), and vt100_toggle_graphics().

Here is the call graph for this function:



Here is the caller graph for this function:



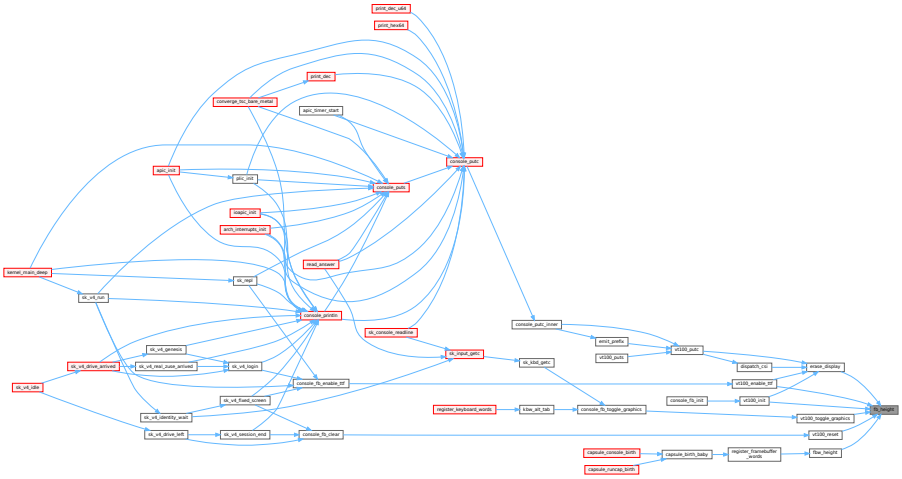
7.152.1.7 fb_height()

```
uint32_t fb_height (
            void  )
```

References g_fb, and FbState::height.

Referenced by erase_display(), fbw_height(), vt100_enable_ttf(), vt100_init(), vt100_reset(), and vt100_toggle_graphics().

Here is the caller graph for this function:



7.152.1.8 fb_init()

```
void fb_init (
            const FramebufferInfo * info,
            FbPixelFormat fmt )
```

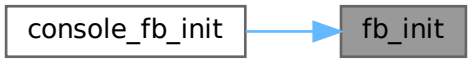
Initialize the framebuffer from UEFI bootloader GOP data.

Must be called before any other fb_∗ function. fmt: pixel layout reported by GOP (default FB_PIXEL_BGRX32).

References FramebufferInfo::base, FbState::base, FbState::fmt, g_fb, FramebufferInfo::height, FbState::height, FramebufferInfo::pixels_per_scanline, FbState::ready, FbState::scale, FbState::stride, FramebufferInfo::width, and FbState::width.

Referenced by console_fb_init().

Here is the caller graph for this function:



7.152.1.9 fb_is_available()

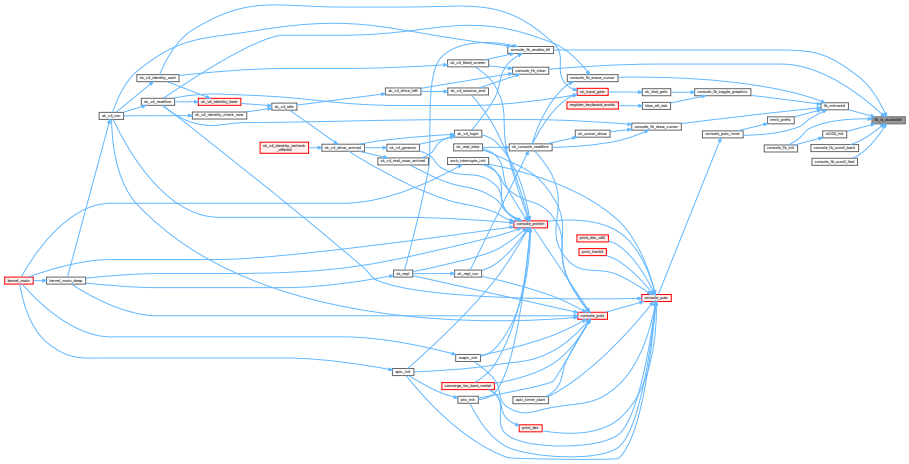
```
int fb_is_available (
            void  )
```

Returns 1 if the framebuffer has been successfully initialized.

References g_fb, and FbState::ready.

Referenced by console_fb_clear(), console_fb_enable_ttf(), console_fb_init(), console_fb_scroll_back(), console_fb_scroll_fwd(), fb_mirrored(), and vt100_init().

Here is the caller graph for this function:



7.152.1.10 fb_put_pixel()

```
void fb_put_pixel (
            uint32_t x,
            uint32_t y,
            uint32_t rgb )
```

Write a single pixel.

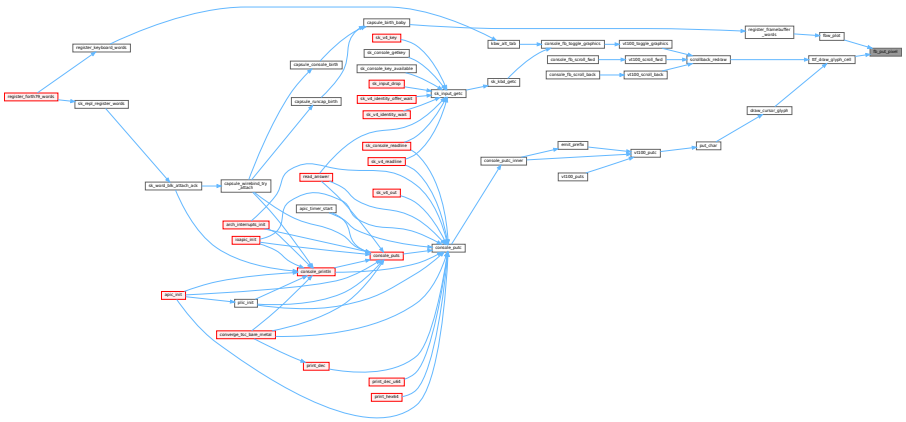
Out-of-bounds writes are silently ignored.

References FbState::base, g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::stride, and FbState::width.

Referenced by fbw_plot(), and ttf_draw_glyph_cell().

Here is the call graph for this function:

Here is the caller graph for this function:



7.152.1.11 fb_scroll_rect()

```
void fb_scroll_rect (
            uint32_t x,
            uint32_t y,
            uint32_t w,
            uint32_t h,
            uint32_t pixel_rows,
            uint32_t bg )
```

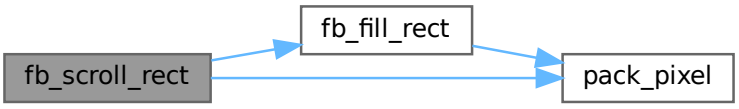
fb_scroll_rect — box-confined scroll (FABRIC-0.md item 4.4t).

Scroll a sub-rectangle of the framebuffer up by `pixel_rows` pixel rows (FABRIC-0.md item 4.4t: box-confined REPL scrolling).

Same non-volatile bulk-copy rationale as fb_scroll_rows() above, but bounded to a caller-supplied rectangle instead of the whole framebuffer – needed once REPL text is confined to the 4.4o CANVAS box, since a whole-framebuffer scroll would drag pixels from outside the box (e.g. a future 4.4r border) into the text area. Takes pixel_rows directly rather than char_rows ∗ a hardcoded cell height, since TTF mode's cell height (24px) differs from bitmap mode's (16px ∗ scale).

References FbState::base, fb_fill_rect(), g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::stride, and FbState::width.

Here is the call graph for this function:



7.152.1.12 fb_scroll_rows()

```
void fb_scroll_rows (
            uint32_t pixel_rows,
            uint32_t bg )
```

Scroll the framebuffer up by `pixel_rows` pixel rows.

Scroll the whole framebuffer up by `pixel_rows` pixel rows.

The vacated rows at the bottom are filled with bg.

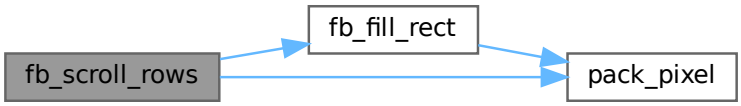
Takes a pixel-row count directly rather than a character-row count scaled by a hardcoded 16px cell height: the caller (vt100.c's scroll_up()) knows the actual active glyph cell height (16 × scale for bitmap mode, 24 for TTF mode), and a mismatch between the height this function scrolls by and the height the text model actually draws rows at compounds by the gap on every single scroll – a few scrolls barely show it, but enough scrolls (or scrolling quickly) accumulates visible pixel overlap between rows.

Copies through non-volatile pointers (FABRIC-0.md item 4.4g performance fix, 2026-08-11): the GOP framebuffer is mapped write-back, not cache-disabled MMIO (vmm.c:350-363 – "QEMU's VGA emulation is coherent and UC-mapping causes #GP"), so it behaves as ordinary RAM and does not need per-word volatile access. `g_fb.base` stays `volatile` for single-pixel writes elsewhere in this file (draw calls that must not be reordered relative to other framebuffer state), but that qualifier forced this copy into one un-batchable 4-byte access per element with no compiler vectorization – catastrophic once boot output exceeds one screen (~10^10 volatile accesses for an 18,000-line boot transcript under TCG). Casting away volatile here for the bulk copy/fill lets the compiler batch these loops normally.

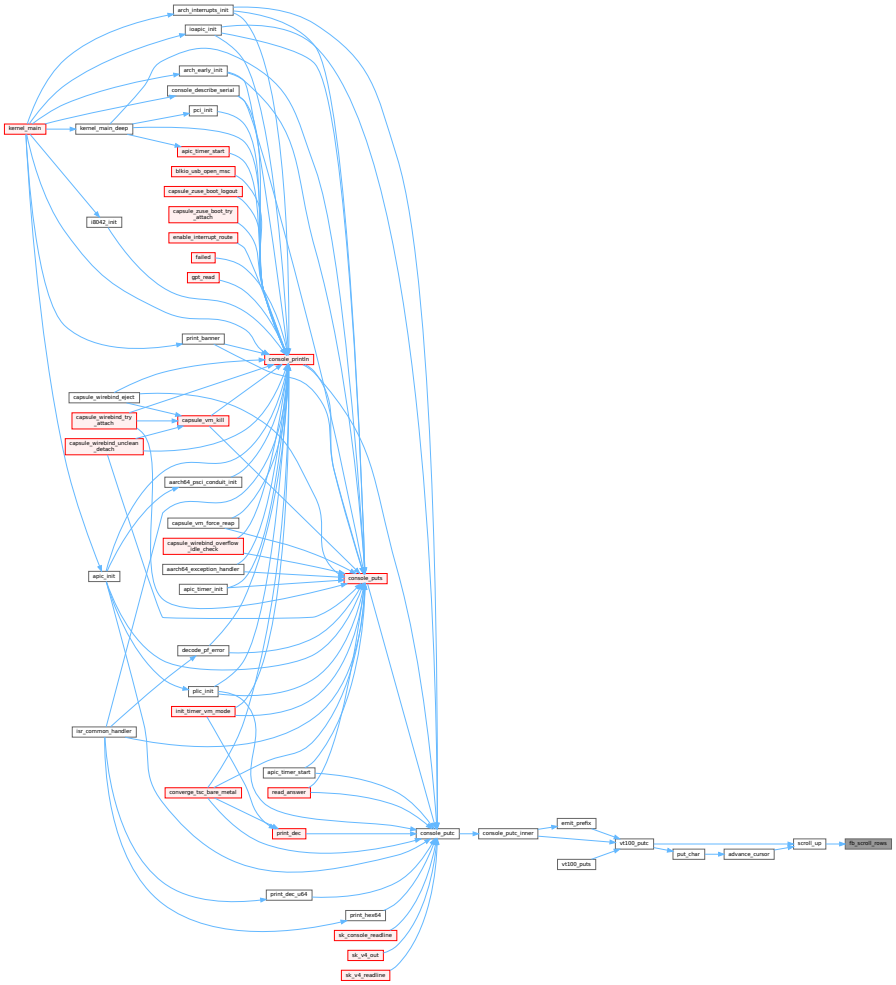
References FbState::base, fb_fill_rect(), g_fb, FbState::height, pack_pixel(), FbState::ready, FbState::stride, and FbState::width.

Referenced by scroll_up().

Here is the call graph for this function:



Here is the caller graph for this function:



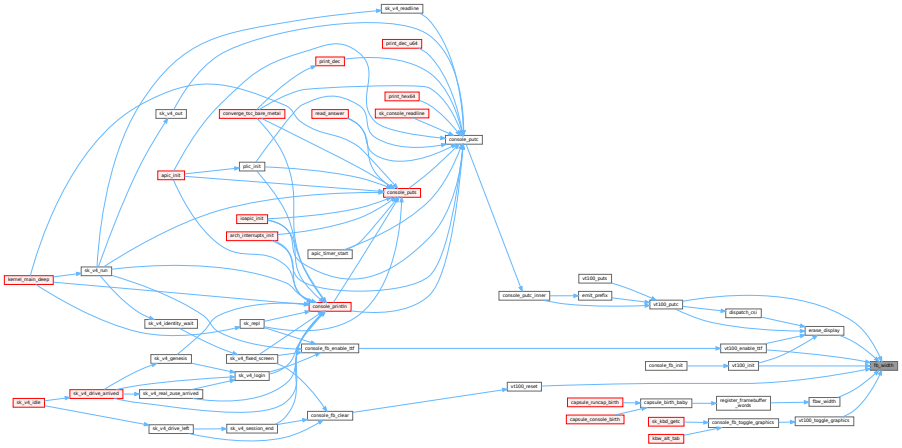
7.152.1.13 fb_width()

```
uint32_t fb_width (
            void  )
```

References g_fb, and FbState::width.

Referenced by erase_display(), fbw_width(), vt100_enable_ttf(), vt100_init(), vt100_putc(), vt100_reset(), and vt100_toggle_graphics().

Here is the caller graph for this function:



7.152.1.14 font_8x16_glyph()

```
const uint8_t * font_8x16_glyph (
            uint8_t ch )  [extern]
```

framebuffer.c — UEFI GOP framebuffer pixel driver

Supports BGRX32 and RGBX32 pixel formats. Pixel scale factor allows 1×/2×/4× rendering for hi-res displays.

Hi-res mode: 1080p (1920×1080) @ scale=1 → 240 cols × 67 rows (8×16 cells) 1080p (1920×1080) @ scale=2 → 120 cols × 33 rows (16×32 cells) 4K (3840×2160) @ scale=2 → 240 cols × 67 rows (16×32 cells) 4K (3840×2160) @ scale=4 → 120 cols × 33 rows (32×64 cells)

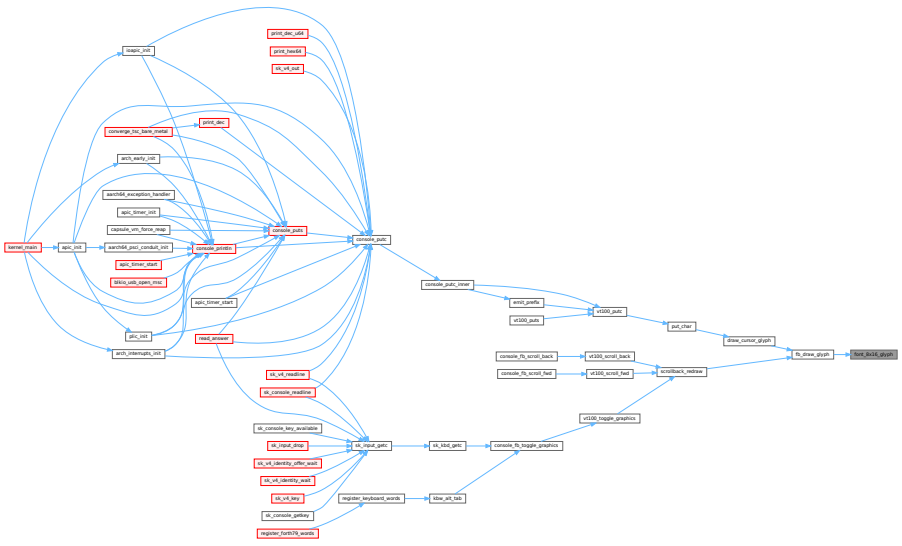
framebuffer.c — UEFI GOP framebuffer pixel driver

Caller must not modify the returned data.

References font_8x16_data.

Referenced by fb_draw_glyph().

Here is the caller graph for this function:



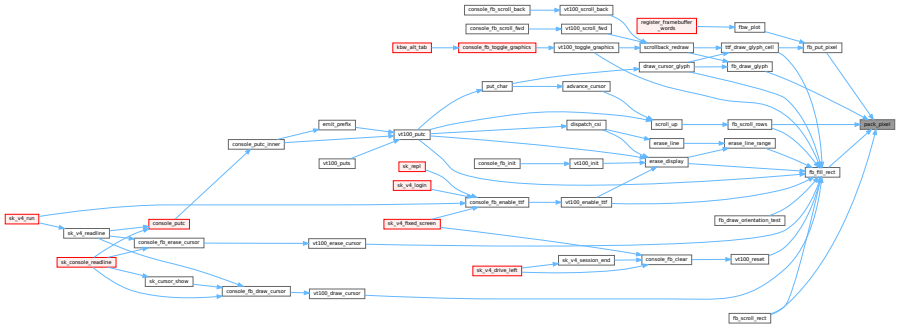
7.152.1.15 pack_pixel()

```
static uint32_t pack_pixel (
            uint32_t rgb )  [static]
```

References FB_B, FB_G, FB_PIXEL_RGBX32, FB_R, FbState::fmt, g, and g_fb.

Referenced by fb_draw_glyph(), fb_fill_rect(), fb_put_pixel(), fb_scroll_rect(), and fb_scroll_rows().

Here is the caller graph for this function:



7.152.2 Variable Documentation

7.152.2.1 g_fb

```
FbState g_fb  [static]
```

Referenced by fb_cell_h(), fb_cell_w(), fb_draw_glyph(), fb_draw_orientation_test(), fb_fill_rect(), fb_height(), fb_init(), fb_is_available(), fb_put_pixel(), fb_scroll_rect(), fb_scroll_rows(), fb_width(), and pack_pixel().

7.153 kernel/src/hal/hal.c File Reference

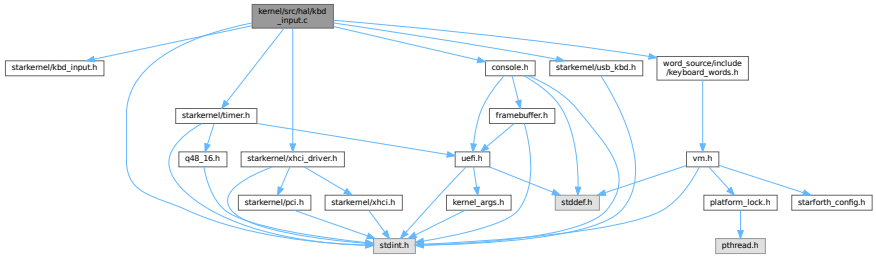
7.154 kernel/src/hal/host_services.c File Reference

7.155 kernel/src/hal/kbd_input.c File Reference

```
#include "starkernel/kbd_input.h"
#include "console.h"
#include "starkernel/timer.h"
#include "starkernel/xhci_driver.h"
#include "starkernel/usb_kbd.h"
#include "word_source/include/keyboard_words.h"
```

```
#include <stdint.h>
```

Include dependency graph for kbd_input.c:



Macros

- #define SK_KBD_TABLE_SIZE 98u /∗ highest keycode used below is KEY_RIGHTCTRL=97 ∗/
- #define SK_KEY_BACKSPACE 14u
- #define SK_KEY_TAB 15u
- #define SK_KEY_ENTER 28u
- #define SK_KEY_LEFTSHIFT 42u
- #define SK_KEY_RIGHTSHIFT 54u
- #define SK_KEY_LEFTALT 56u
- #define SK_KEY_RIGHTALT 100u
- #define SK_KEY_CAPSLOCK 58u
- #define SK_KEY_NUMLOCK 69u
- #define SK_KEY_KPENTER 96u
- #define SK_KEY_KPSLASH 98u
- #define SK_KEY_102ND 86u

Functions

- static void sk_kbd_show_locks (void)
- static int sk_kbd_keypad (uint16_t keycode)
- static int sk_kbd_getc (void)
- int sk_input_getc (void)
- void sk_input_drop (void)

Variables

- static const char sk_kbd_unshifted [98u]
- static const char sk_kbd_shifted [98u]
- static int g_kbd_shift_down
- static int g_kbd_alt_down
- static int g_kbd_caps_lock
- static int g_kbd_num_lock = 1
- static uint64_t g_kbd_poll_tick

7.155.1 Macro Definition Documentation

7.155.1.1 SK_KBD_TABLE_SIZE

```
#define SK_KBD_TABLE_SIZE 98u /* highest keycode used below is KEY_RIGHTCTRL=97 */
```

7.155.1.2 SK_KEY_102ND

```
#define SK_KEY_102ND 86u
```

7.155.1.3 SK_KEY_BACKSPACE

```
#define SK_KEY_BACKSPACE 14u
```

7.155.1.4 SK_KEY_CAPSLOCK

```
#define SK_KEY_CAPSLOCK 58u
```

7.155.1.5 SK_KEY_ENTER

```
#define SK_KEY_ENTER 28u
```

7.155.1.6 SK_KEY_KPENTER

```
#define SK_KEY_KPENTER 96u
```

7.155.1.7 SK_KEY_KPSLASH

```
#define SK_KEY_KPSLASH 98u
```

7.155.1.8 SK_KEY_LEFTALT

```
#define SK_KEY_LEFTALT 56u
```

7.155.1.9 SK_KEY_LEFTSHIFT

```
#define SK_KEY_LEFTSHIFT 42u
```

7.155.1.10 SK_KEY_NUMLOCK

```
#define SK_KEY_NUMLOCK 69u
```

7.155.1.11 SK_KEY_RIGHTALT

```
#define SK_KEY_RIGHTALT 100u
```

7.155.1.12 SK_KEY_RIGHTSHIFT

```
#define SK_KEY_RIGHTSHIFT 54u
```

7.155.1.13 SK_KEY_TAB

```
#define SK_KEY_TAB 15u
```

7.155.2 Function Documentation

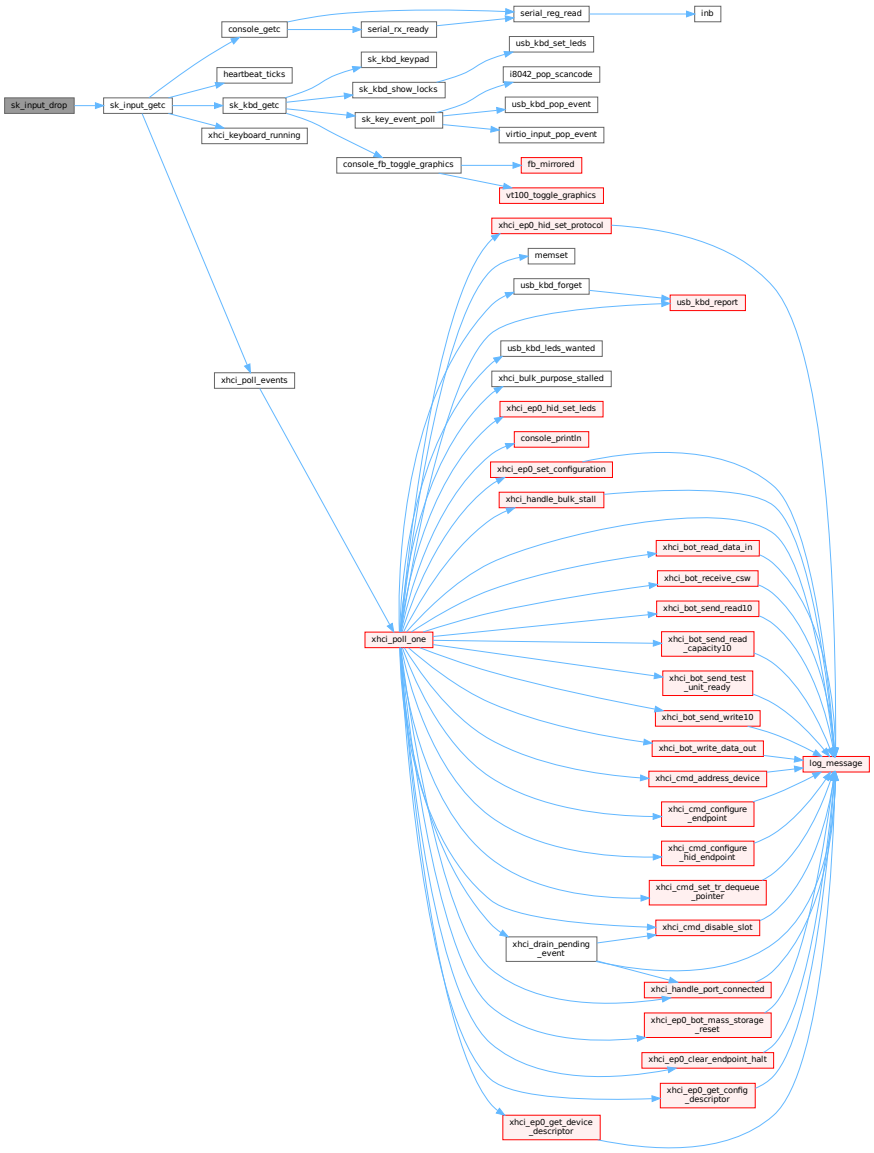
7.155.2.1 sk_input_drop()

```
void sk_input_drop (
            void  )
```

References sk_input_getc().

Referenced by sk_v4_discard_input().

Here is the call graph for this function:



Here is the caller graph for this function:

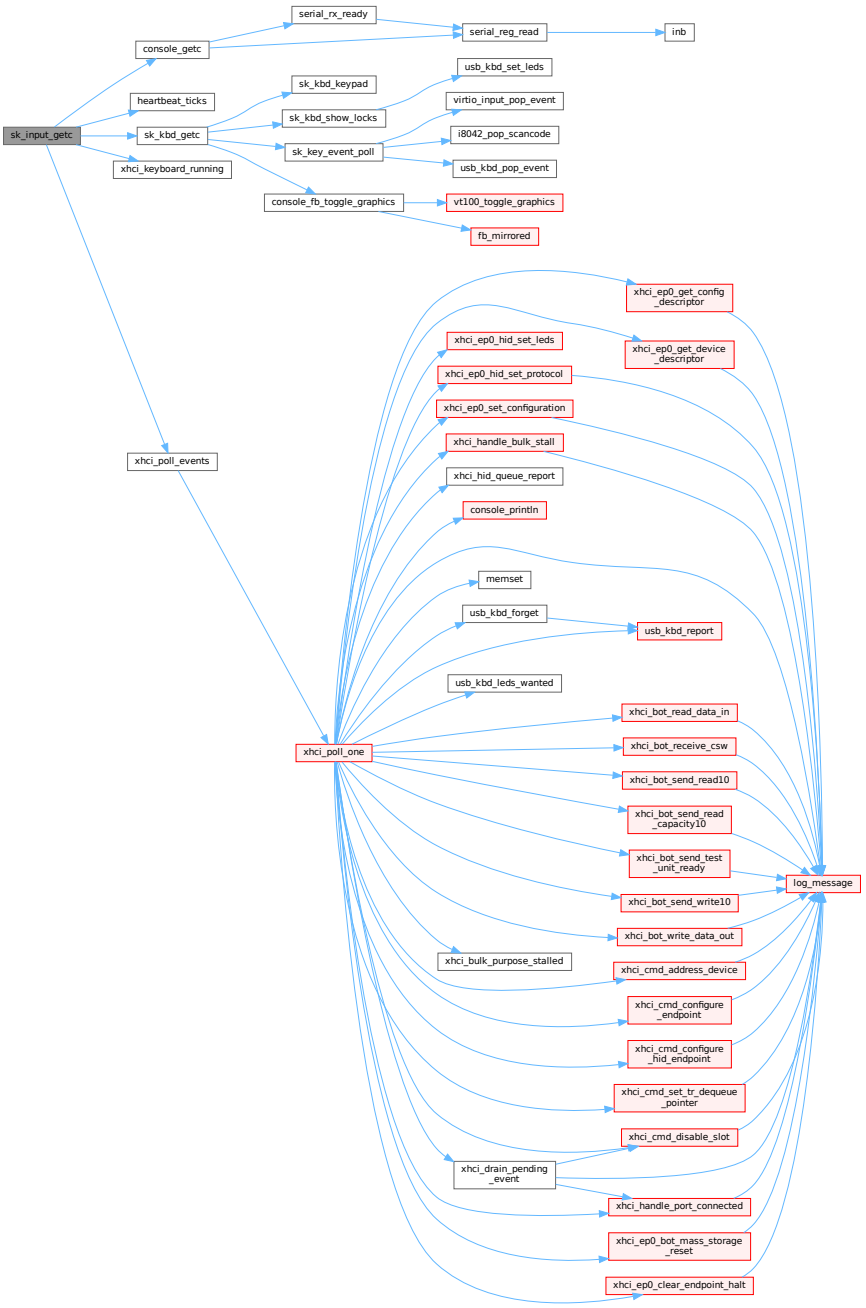
7.155.2.2 sk_input_getc()

```
int sk_input_getc (
            void  )
```

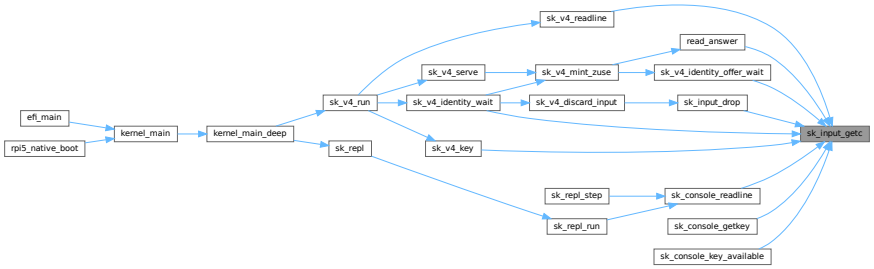
References console_getc(), g_kbd_poll_tick, heartbeat_ticks(), sk_kbd_getc(), xhci_keyboard_running(), and xhci_poll_events().

Referenced by read_answer(), sk_console_getkey(), sk_console_key_available(), sk_console_readline(), sk_input_drop(), sk_v4_identity_offer_wait(), sk_v4_identity_wait(), sk_v4_key(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:



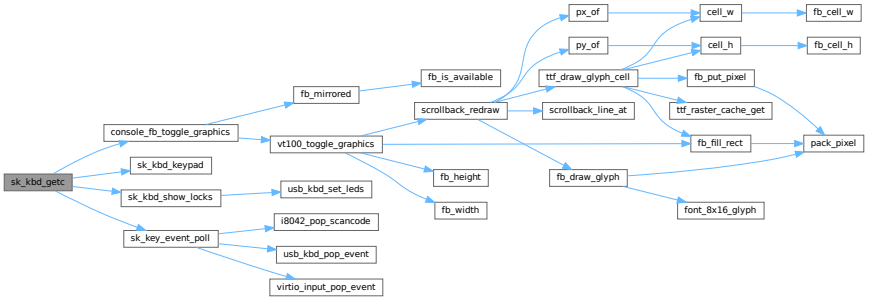
7.155.2.3 sk_kbd_getc()

```
static int sk_kbd_getc (
            void  )  [static]
```

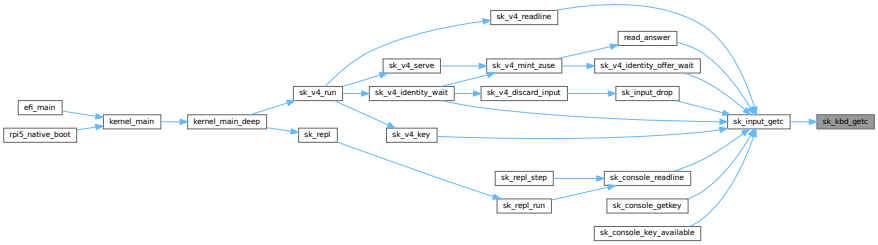
References console_fb_toggle_graphics(), g_kbd_alt_down, g_kbd_caps_lock, g_kbd_num_lock, g_kbd_shift_down, keycode, pressed, sk_kbd_keypad(), sk_kbd_shifted, sk_kbd_show_locks(), SK_KBD_TABLE_SIZE, sk_kbd_unshifted, SK_KEY_102ND, SK_KEY_BACKSPACE, SK_KEY_CAPSLOCK, SK_KEY_ENTER, sk_key_event_poll(), SK_KEY_LEFTALT, SK_KEY_LEFTSHIFT, SK_KEY_NUMLOCK, SK_KEY_RIGHTALT, SK_KEY_RIGHTSHIFT, and SK_KEY_TAB.

Referenced by sk_input_getc().

Here is the call graph for this function:



Here is the caller graph for this function:



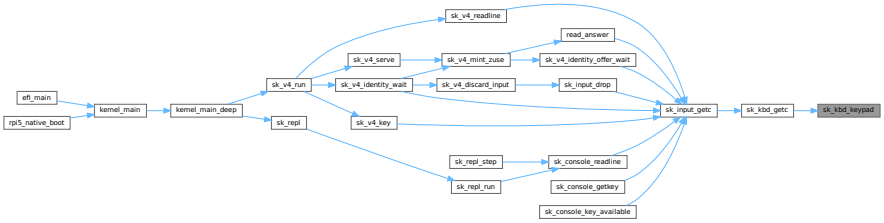
7.155.2.4 sk_kbd_keypad()

```
static int sk_kbd_keypad (
            uint16_t keycode )  [static]
```

References g_kbd_num_lock, keycode, SK_KEY_KPENTER, and SK_KEY_KPSLASH.

Referenced by sk_kbd_getc().

Here is the caller graph for this function:



7.155.2.5 sk_kbd_show_locks()

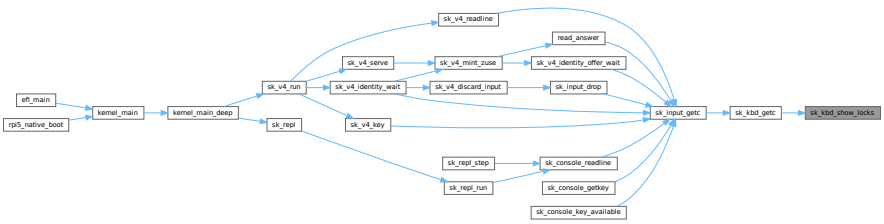
```
static void sk_kbd_show_locks (
            void  )  [static]
```

References g_kbd_caps_lock, g_kbd_num_lock, USB_KBD_LED_CAPS, USB_KBD_LED_NUM, and usb_kbd_set_leds().

Referenced by sk_kbd_getc().

Here is the call graph for this function:

Here is the caller graph for this function:



7.155.3 Variable Documentation

7.155.3.1 g_kbd_alt_down

```
int g_kbd_alt_down  [static]
```

Referenced by sk_kbd_getc().

7.155.3.2 g_kbd_caps_lock

```
int g_kbd_caps_lock  [static]
```

Referenced by sk_kbd_getc(), and sk_kbd_show_locks().

7.155.3.3 g_kbd_num_lock

```
int g_kbd_num_lock = 1  [static]
```

Referenced by sk_kbd_getc(), sk_kbd_keypad(), and sk_kbd_show_locks().

7.155.3.4 g_kbd_poll_tick

```
uint64_t g_kbd_poll_tick  [static]
```

Referenced by sk_input_getc().

7.155.3.5 g_kbd_shift_down

```
int g_kbd_shift_down  [static]
```

Referenced by sk_kbd_getc().

7.155.3.6 sk_kbd_shifted

```
const char sk_kbd_shifted[98u]  [static]
```

Initial value:

```
= {
    [2]='!',[3]='@',[4]='#',[5]='$',[6]='%',[7]='^',[8]='&',[9]='*',[10]='(',[11]=')',
    [12]='_',[13]='+',
    [16]='Q',[17]='W',[18]='E',[19]='R',[20]='T',[21]='Y',[22]='U',[23]='I',[24]='O',[25]='P',
    [26]='{',[27]='}',
    [30]='A',[31]='S',[32]='D',[33]='F',[34]='G',[35]='H',[36]='J',[37]='K',[38]='L',
    [39]=':',[40]='"',[41]='~',[43]='|',
    [44]='Z',[45]='X',[46]='C',[47]='V',[48]='B',[49]='N',[50]='M',
    [51]='<',[52]='>',[53]='?',
    [57]=' ',
}
```

Referenced by sk_kbd_getc().

7.155.3.7 sk_kbd_unshifted

```
const char sk_kbd_unshifted[98u]  [static]
```

Initial value:

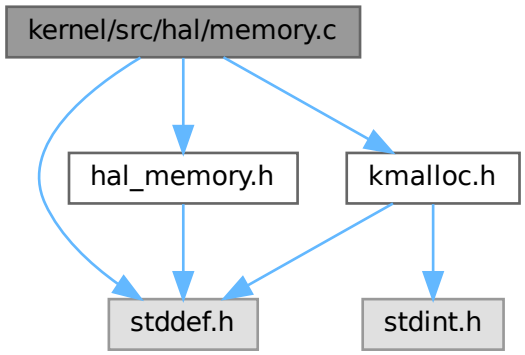
```
= {
    [2]='1',[3]='2',[4]='3',[5]='4',[6]='5',[7]='6',[8]='7',[9]='8',[10]='9',[11]='0',
    [12]='-',[13]='=',
    [16]='q',[17]='w',[18]='e',[19]='r',[20]='t',[21]='y',[22]='u',[23]='i',[24]='o',[25]='p',
    [26]='[',[27]=']',
    [30]='a',[31]='s',[32]='d',[33]='f',[34]='g',[35]='h',[36]='j',[37]='k',[38]='l',
    [39]=';',[40]='\"',[41]='`',[43]='\\',
    [44]='z',[45]='x',[46]='c',[47]='v',[48]='b',[49]='n',[50]='m',
    [51]=',',[52]='.',[53]='/',
    [57]=' ',
}
```

Referenced by sk_kbd_getc().

7.156 kernel/src/hal/memory.c File Reference

```
#include <stddef.h>
#include "hal_memory.h"
#include "kmalloc.h"
```

Include dependency graph for memory.c:



Functions

- void * hal_mem_alloc (size_t size)

  memory.c - HAL memory wrappers
- void * hal_mem_alloc_aligned (size_t size, size_t align)
- void hal_mem_free (void *ptr)

7.156.1 Function Documentation

7.156.1.1 hal_mem_alloc()

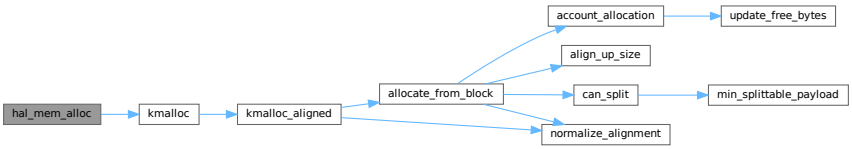
```
void * hal_mem_alloc (
            size_t size )
```

memory.c - HAL memory wrappers

hal_memory.h - HAL memory allocation wrappers

References kmalloc().

Here is the call graph for this function:

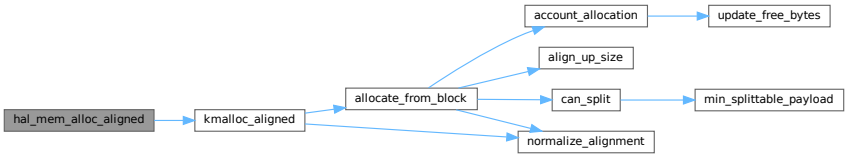


7.156.1.2 hal_mem_alloc_aligned()

```
void * hal_mem_alloc_aligned (
            size_t size,
            size_t align )
```

References kmalloc_aligned().

Here is the call graph for this function:

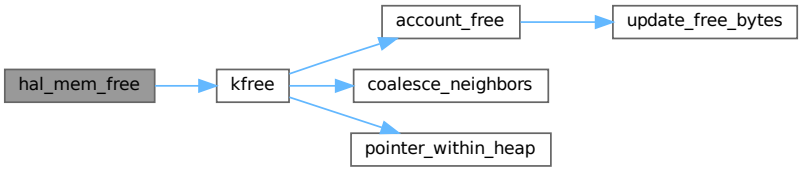


7.156.1.3 hal_mem_free()

```
void hal_mem_free (
            void * ptr )
```

References kfree().

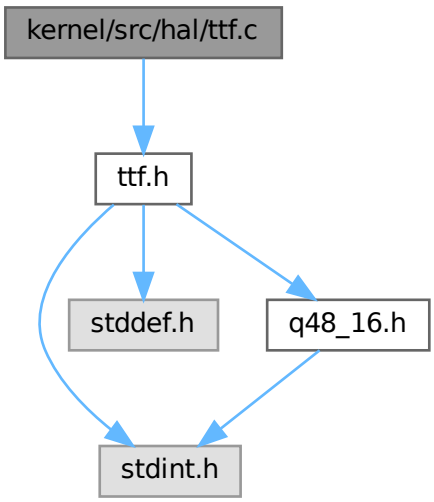
Here is the call graph for this function:



7.157 kernel/src/hal/ttf.c File Reference

```
#include "ttf.h"
```

Include dependency graph for ttf.c:



Data Structures

- struct ttf_flat_point_t

Macros

- #define TAG(a, b, c, d) (((uint32_t)(a) << 24) | ((uint32_t)(b) << 16) | ((uint32_t)(c) << 8) | (uint32_t)(d))

  ttf.c — TrueType font parser core (FABRIC-0.md items 4.3.7, 4.3.7a)
- #define TTF_FLAG_ON_CURVE 0x01
- #define TTF_FLAG_X_SHORT 0x02
- #define TTF_FLAG_Y_SHORT 0x04
- #define TTF_FLAG_REPEAT 0x08
- #define TTF_FLAG_X_SAME_OR_POS 0x10
- #define TTF_FLAG_Y_SAME_OR_POS 0x20
- #define TTF_MAX_SIMPLE_POINTS 512
- #define TTF_COMP_ARGS_ARE_WORDS 0x0001
- #define TTF_COMP_ARGS_ARE_XY_VALUES 0x0002
- #define TTF_COMP_WE_HAVE_A_SCALE 0x0008
- #define TTF_COMP_MORE_COMPONENTS 0x0020
- #define TTF_COMP_WE_HAVE_XY_SCALE 0x0040
- #define TTF_COMP_WE_HAVE_2X2 0x0080
- #define TTF_F2DOT14_ONE 16384 /* 1.0 in F2Dot14 */
- #define TTF_QUAD_SEGMENTS
- #define TTF_RASTER_RAW_MAX_POINTS 256
- #define TTF_RASTER_RAW_MAX_CONTOURS 16
- #define TTF_RASTER_FLAT_MAX_POINTS (TTF_RASTER_RAW_MAX_POINTS * TTF_QUAD_SEGMENTS)
- #define TTF_RASTER_FLAT_MAX_CONTOURS TTF_RASTER_RAW_MAX_CONTOURS

Functions

- static int fits (uint32_t size, uint32_t off, uint32_t len)
- static int in_bounds (const ttf_font_t *f, uint32_t off, uint32_t len)
- static uint16_t rd_u16 (const uint8_t *d, uint32_t off)
- static int16_t rd_i16 (const uint8_t *d, uint32_t off)
- static uint32_t rd_u32 (const uint8_t *d, uint32_t off)
- static int find_table (const uint8_t *data, uint32_t size, uint16_t num_tables, uint32_t tag, uint32_t *tbl_off, uint32_t *tbl_len)
- int ttf_parse (const uint8_t *data, uint32_t size, ttf_font_t *out)

  ttf_parse - Locate and validate the sfnt directory and the head/maxp/ loca/glyf tables (cmap is optional; ttf_codepoint_to_glyph() fails cleanly if absent).
- uint32_t ttf_codepoint_to_glyph (const ttf_font_t *font, uint32_t codepoint)

  ttf_codepoint_to_glyph - Resolve a Unicode codepoint via the font's format-4 cmap subtable.
- int ttf_glyph_header (const ttf_font_t *font, uint32_t glyph_index, ttf_glyph_header_t *out)

  ttf_glyph_header - Read a glyph's outline header (contour count, bounding box) via loca + glyf.
- uint16_t ttf_glyph_advance_width (const ttf_font_t *font, uint32_t glyph_index)

  ttf_glyph_advance_width - Horizontal advance width via hmtx, in raw font design units (NOT scaled by unitsPerEm – caller's job, e.g.
- static uint8_t rd_u8 (const uint8_t *d, uint32_t off)
- static int8_t rd_i8 (const uint8_t *d, uint32_t off)
- static q48_16_t q48_from_i32 (int32_t v)
- static int decode_simple_glyph (const ttf_font_t *font, const ttf_glyph_header_t *hdr, ttf_outline_t *out)
- static int decode_glyph_r (const ttf_font_t *font, uint32_t glyph_index, ttf_outline_t *out, int depth)
- static int decode_composite_glyph (const ttf_font_t *font, const ttf_glyph_header_t *hdr, ttf_outline_t *out, int depth)
- int ttf_glyph_outline (const ttf_font_t *font, uint32_t glyph_index, ttf_outline_t *out)

  ttf_glyph_outline - Extract a glyph's outline (simple or composite, recursively resolving composite components) into caller-supplied buffers.

- static q48_16_t q48_smul (q48_16_t a, q48_16_t b)
- static q48_16_t q48_mid (q48_16_t a, q48_16_t b)
- static void raw_midpoint (const ttf_point_t *a, const ttf_point_t *b, ttf_point_t *out)
- static void to_pixel_space (q48_16_t fx, q48_16_t fy, q48_16_t scale, q48_16_t origin_x, q48_16_t origin_y, q48_16_t *px, q48_16_t *py)
- static void flat_push (ttf_flat_point_t *pts, uint32_t *count, uint32_t max, q48_16_t x, q48_16_t y, int *err)
- static void flatten_quad (ttf_flat_point_t *pts, uint32_t *count, uint32_t max, q48_16_t p0x, q48_16_t p0y, q48_16_t p1x, q48_16_t p1y, q48_16_t p2x, q48_16_t p2y, int *err)
- static void flatten_contour (const ttf_point_t *raw, uint32_t begin, uint32_t end, q48_16_t scale, q48_16_t origin_x, q48_16_t origin_y, ttf_flat_point_t *flat_pts, uint32_t *flat_count, uint32_t flat_max, int *err)
- int ttf_rasterize_glyph (const ttf_font_t *font, uint32_t glyph_index, q48_16_t scale, q48_16_t origin_x, q48_16_t origin_y, uint8_t fill_value, ttf_bitmap_t *out)

  ttf_rasterize_glyph - Flatten a glyph's outline (quadratic Bezier contours, fixed segment count per curve — see ttf.c's file header comment) and fill it into `out` using the even-odd rule (FABRIC-0.md item 4.3.7c; see that item's completion note for why even-odd rather than nonzero winding — correct for the v1 glyph repertoire's non-self- intersecting nested contours, not necessarily for an arbitrary font).
- void ttf_raster_cache_init (ttf_raster_cache_t *cache, ttf_raster_cache_slot_t *slots, uint32_t slot_count)

  ttf_raster_cache_init - Bind a caller-supplied slot array to `cache` and mark every slot empty.
- int ttf_raster_cache_get (ttf_raster_cache_t *cache, const ttf_font_t *font, uint32_t codepoint, uint32_t size_px, ttf_bitmap_t *out, int *was_hit)

  ttf_raster_cache_get - Look up (font, codepoint, size_px); on a miss, rasterize and insert (evicting round-robin if every slot is full).

7.157.1 Macro Definition Documentation

7.157.1.1 TAG

```
#define TAG(
              a,
              b,
              c,
              d )  (((uint32_t)(a) << 24) | ((uint32_t)(b) << 16) | ((uint32_t)(c) << 8) |
(uint32_t)(d))
```

ttf.c — TrueType font parser core (FABRIC-0.md items 4.3.7, 4.3.7a)

sfnt directory + head/maxp/loca/glyf/cmap(format 4) table parsing, plus simple- and composite-glyph outline extraction. All multi-byte fields in a TTF are big-endian; this file reads them by hand (no libc byteswap dependency) with bounds checks against the buffer length on every access, since the buffer is untrusted input.

Composite-glyph transforms: this file applies (dx,dy) TRANSLATION only. A composite component carrying a non-identity scale/rotation/skew (the WE_HAVE_A_SCALE/WE_HAVE_AN_X_AND_Y_SCALE/WE_HAVE_A_TWO_BY_TWO flags with a non-1.0/non-zero F2Dot14 value) is rejected with TTF_ERR_UNSUPPORTED rather than silently mis-rendered. Reason: applying such a transform needs a signed fixed-point multiply, and the shared q48_mul()/q48_div() in src/starkernel/math/q48_16.c are unsigned-only (q48_div saturates via an unsigned overflow check; q48_mul does a plain unsigned widen-multiply) — confirmed by reading that file, not assumed. Per this repo's rule against modifying a shared/tested module to "fix" it without being asked, that gap is reported (see FABRIC-0.md's 4.3.7a completion note), not patched here. No glyph in the v1 repertoire (?27.6.4) needs a non-identity composite transform — checked against fonts/JetBrainsMono-Regular.ttf before writing this, not assumed.

7.157.1.2 TTF_COMP_ARGS_ARE_WORDS

```
#define TTF_COMP_ARGS_ARE_WORDS 0x0001
```

7.157.1.3 TTF_COMP_ARGS_ARE_XY_VALUES

```
#define TTF_COMP_ARGS_ARE_XY_VALUES 0x0002
```

7.157.1.4 TTF_COMP_MORE_COMPONENTS

```
#define TTF_COMP_MORE_COMPONENTS 0x0020
```

7.157.1.5 TTF_COMP_WE_HAVE_2X2

```
#define TTF_COMP_WE_HAVE_2X2 0x0080
```

7.157.1.6 TTF_COMP_WE_HAVE_A_SCALE

```
#define TTF_COMP_WE_HAVE_A_SCALE 0x0008
```

7.157.1.7 TTF_COMP_WE_HAVE_XY_SCALE

```
#define TTF_COMP_WE_HAVE_XY_SCALE 0x0040
```

7.157.1.8 TTF_F2DOT14_ONE

```
#define TTF_F2DOT14_ONE 16384 /* 1.0 in F2Dot14 */
```

7.157.1.9 TTF_FLAG_ON_CURVE

```
#define TTF_FLAG_ON_CURVE 0x01
```

7.157.1.10 TTF_FLAG_REPEAT

```
#define TTF_FLAG_REPEAT 0x08
```

7.157.1.11 TTF_FLAG_X_SAME_OR_POS

```
#define TTF_FLAG_X_SAME_OR_POS 0x10
```

7.157.1.12 TTF_FLAG_X_SHORT

```
#define TTF_FLAG_X_SHORT 0x02
```

7.157.1.13 TTF_FLAG_Y_SAME_OR_POS

```
#define TTF_FLAG_Y_SAME_OR_POS 0x20
```

7.157.1.14 TTF_FLAG_Y_SHORT

```
#define TTF_FLAG_Y_SHORT 0x04
```

7.157.1.15 TTF_MAX_SIMPLE_POINTS

```
#define TTF_MAX_SIMPLE_POINTS 512
```

7.157.1.16 TTF_QUAD_SEGMENTS

```
#define TTF_QUAD_SEGMENTS
```

Value:

```
8 /* fixed subdivision count per quadratic curve --
* same fixed-segment-count approach as
* capsules/fabric.4th's CIRCLE/ELLIPSE (36 segs)
* and ARC (18 segs); no adaptive tessellation. */
```

7.157.1.17 TTF_RASTER_FLAT_MAX_CONTOURS

```
#define TTF_RASTER_FLAT_MAX_CONTOURS TTF_RASTER_RAW_MAX_CONTOURS
```

7.157.1.18 TTF_RASTER_FLAT_MAX_POINTS

```
#define TTF_RASTER_FLAT_MAX_POINTS (TTF_RASTER_RAW_MAX_POINTS * TTF_QUAD_SEGMENTS)
```

7.157.1.19 TTF_RASTER_RAW_MAX_CONTOURS

```
#define TTF_RASTER_RAW_MAX_CONTOURS 16
```

7.157.1.20 TTF_RASTER_RAW_MAX_POINTS

```
#define TTF_RASTER_RAW_MAX_POINTS 256
```

7.157.2 Function Documentation

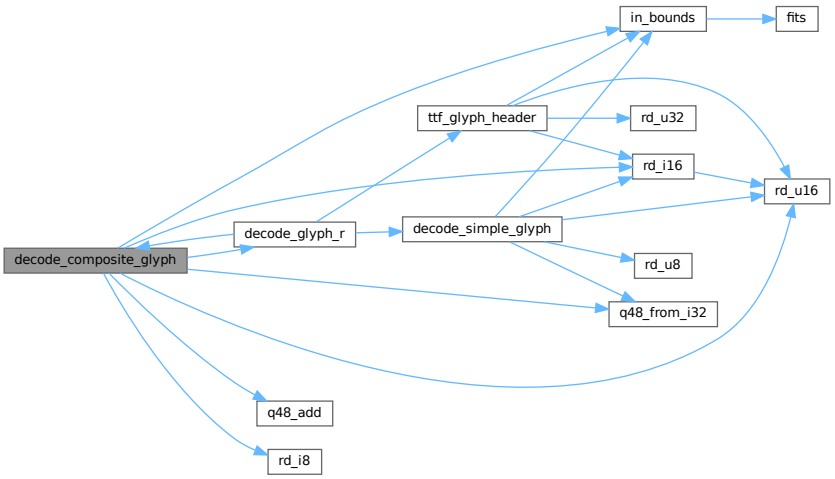
7.157.2.1 decode_composite_glyph()

```
static int decode_composite_glyph (
            const ttf_font_t * font,
            const ttf_glyph_header_t * hdr,
            ttf_outline_t * out,
            int depth )  [static]
```

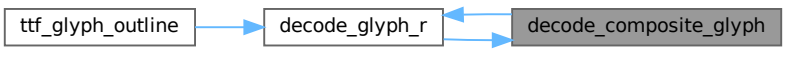
References ttf_font_t::data, decode_glyph_r(), flags, ttf_glyph_header_t::glyf_offset, in_bounds(), ttf_outline_t::point_count, ttf_outline_t::points, q48_add(), q48_from_i32(), rd_i16(), rd_i8(), rd_u16(), TTF_COMP_ARGS_ARE_WORDS, TTF_COMP_ARGS_ARE_XY_VALUES, TTF_COMP_MORE_COMPONENTS, TTF_COMP_WE_HAVE_2X2, TTF_COMP_WE_HAVE_A_SCALE, TTF_COMP_WE_HAVE_XY_SCALE, TTF_ERR_OUT_OF_BOUNDS, TTF_ERR_UNSUPPORTED, TTF_F2DOT14_ONE, TTF_OK, ttf_point_t::x, and ttf_point_t::y.

Referenced by decode_glyph_r().

Here is the call graph for this function:



Here is the caller graph for this function:



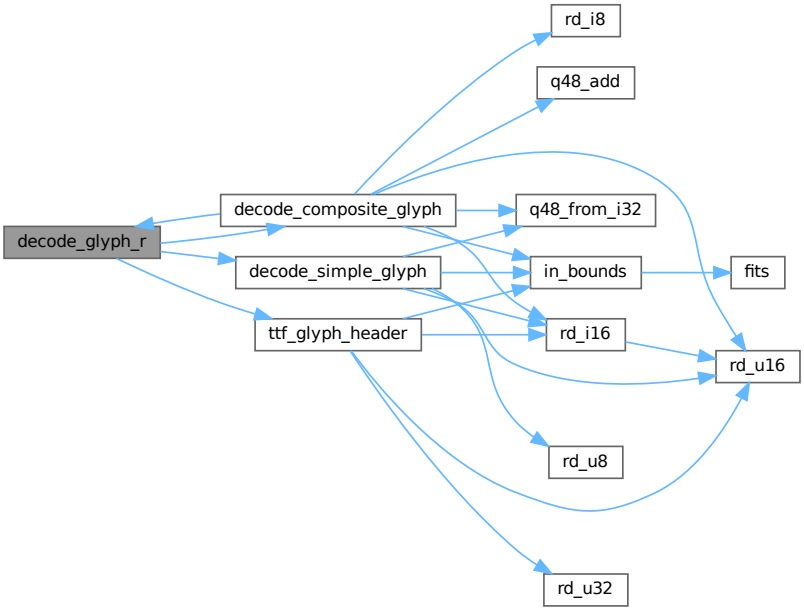
7.157.2.2 decode_glyph_r()

```
static int decode_glyph_r (
            const ttf_font_t * font,
            uint32_t glyph_index,
            ttf_outline_t * out,
            int depth )  [static]
```

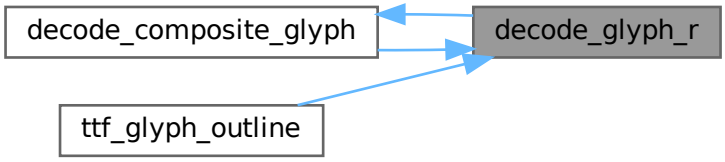
References decode_composite_glyph(), decode_simple_glyph(), ttf_glyph_header_t::glyf_length, ttf_glyph_header_t::num_contours, TTF_ERR_TOO_DEEP, ttf_glyph_header(), TTF_MAX_COMPOSITE_DEPTH, and TTF_OK.

Referenced by decode_composite_glyph(), and ttf_glyph_outline().

Here is the call graph for this function:



Here is the caller graph for this function:



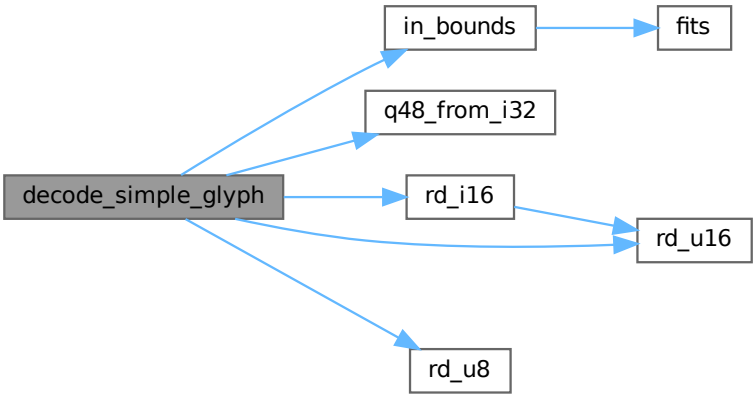
7.157.2.3 decode_simple_glyph()

```
static int decode_simple_glyph (
            const ttf_font_t * font,
            const ttf_glyph_header_t * hdr,
            ttf_outline_t * out )  [static]
```

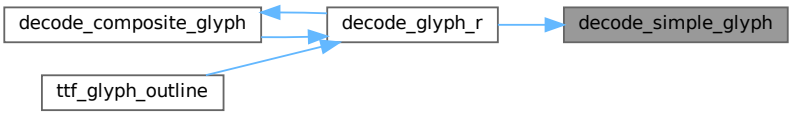
References ttf_outline_t::contour_count, ttf_outline_t::contour_ends, ttf_font_t::data, flags, ttf_glyph_header_t::glyf_offset, in_bounds(), ttf_outline_t::max_contours, ttf_outline_t::max_points, ttf_glyph_header_t::num_contours, ttf_point_t::on_curve, ttf_outline_t::point_count, ttf_outline_t::points, q48_from_i32(), rd_i16(), rd_u16(), rd_u8(), TTF_ERR_OUT_OF_BOUNDS, TTF_ERR_TOO_MANY_CONTOURS, TTF_ERR_TOO_MANY_POINTS, TTF_FLAG_ON_CURVE, TTF_FLAG_REPEAT, TTF_FLAG_X_SAME_OR_POS, TTF_FLAG_X_SHORT, TTF_FLAG_Y_SAME_OR_POS, TTF_FLAG_Y_SHORT, TTF_MAX_SIMPLE_POINTS, TTF_OK, ttf_point_t::x, and ttf_point_t::y.

Referenced by decode_glyph_r().

Here is the call graph for this function:



Here is the caller graph for this function:



7.157.2.4 find_table()

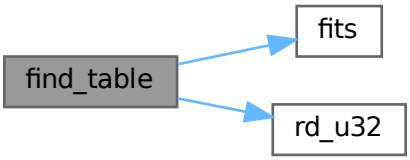
```
static int find_table (
            const uint8_t * data,
```

```
            uint32_t size,
            uint16_t num_tables,
            uint32_t tag,
            uint32_t * tbl_off,
            uint32_t * tbl_len )  [static]
```

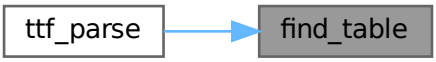
References fits(), rd_u32(), TTF_ERR_OUT_OF_BOUNDS, TTF_ERR_TABLE_MISSING, and TTF_OK.

Referenced by ttf_parse().

Here is the call graph for this function:



Here is the caller graph for this function:

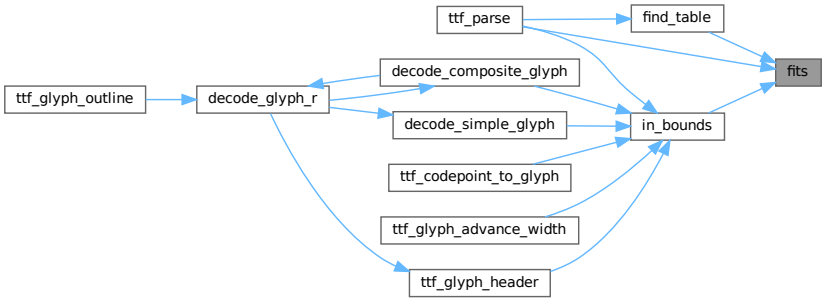


7.157.2.5 fits()

```
static int fits (
            uint32_t size,
            uint32_t off,
            uint32_t len )  [static]
```

Referenced by find_table(), in_bounds(), and ttf_parse().

Here is the caller graph for this function:



7.157.2.6 flat_push()

```
static void flat_push (
            ttf_flat_point_t * pts,
            uint32_t * count,
            uint32_t max,
            q48_16_t x,
            q48_16_t y,
            int * err )  [static]
```

Referenced by flatten_contour(), and flatten_quad().

Here is the caller graph for this function:

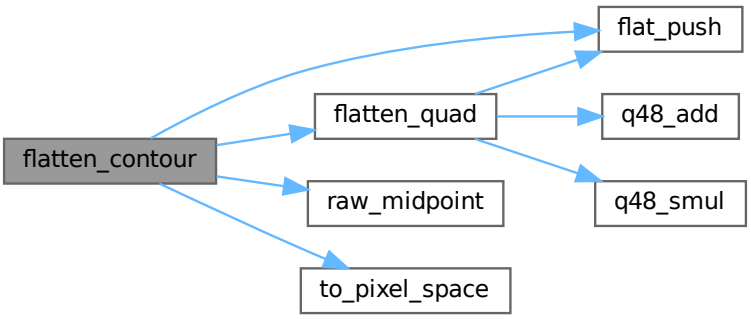
7.157.2.7 flatten_contour()

```
static void flatten_contour (
            const ttf_point_t * raw,
            uint32_t begin,
            uint32_t end,
            q48_16_t scale,
            q48_16_t origin_x,
            q48_16_t origin_y,
            ttf_flat_point_t * flat_pts,
            uint32_t * flat_count,
```

```
            uint32_t flat_max,
            int * err )  [static]
```

References flat_push(), flatten_quad(), ttf_point_t::on_curve, raw_midpoint(), to_pixel_space(), TTF_OK, ttf_point_t::x, and ttf_point_t::y.

Here is the call graph for this function:



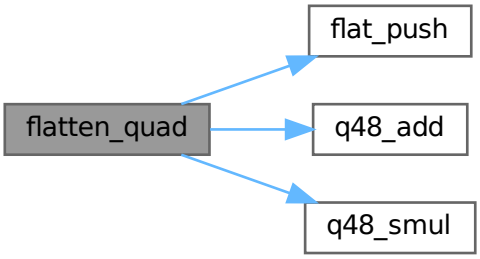
7.157.2.8 flatten_quad()

```
static void flatten_quad (
            ttf_flat_point_t * pts,
            uint32_t * count,
            uint32_t max,
            q48_16_t p0x,
            q48_16_t p0y,
            q48_16_t p1x,
            q48_16_t p1y,
            q48_16_t p2x,
            q48_16_t p2y,
            int * err )  [static]
```

References count, flat_push(), q48_add(), Q48_ONE, q48_smul(), and TTF_QUAD_SEGMENTS.

Referenced by flatten_contour().

Here is the call graph for this function:



Here is the caller graph for this function:

7.157.2.9 in_bounds()

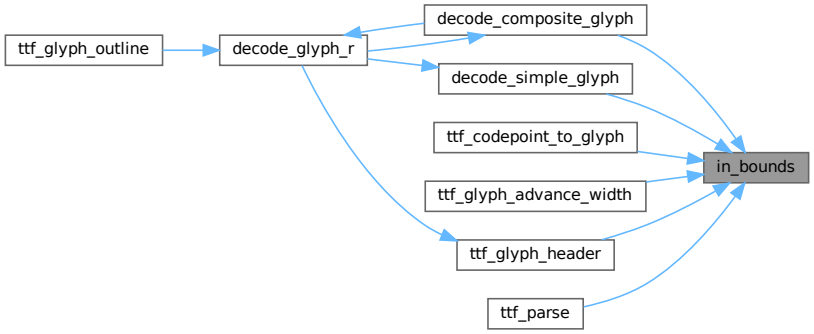
```
static int in_bounds (
            const ttf_font_t * f,
            uint32_t off,
            uint32_t len )  [static]
```

References fits(), and ttf_font_t::size.

Referenced by decode_composite_glyph(), decode_simple_glyph(), ttf_codepoint_to_glyph(), ttf_glyph_advance_width(), ttf_glyph_header(), and ttf_parse().

Here is the call graph for this function:

Here is the caller graph for this function:

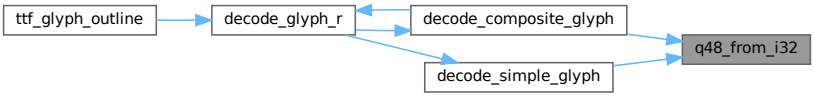


7.157.2.10 q48_from_i32()

```
static q48_16_t q48_from_i32 (
            int32_t v )  [static]
```

Referenced by decode_composite_glyph(), and decode_simple_glyph().

Here is the caller graph for this function:



7.157.2.11 q48_mid()

```
static q48_16_t q48_mid (
            q48_16_t a,
            q48_16_t b )  [static]
```

7.157.2.12 q48_smul()

```
static q48_16_t q48_smul (
            q48_16_t a,
            q48_16_t b )  [static]
```

Referenced by flatten_quad().

Here is the caller graph for this function:

7.157.2.13 raw_midpoint()

```
static void raw_midpoint (
            const ttf_point_t * a,
            const ttf_point_t * b,
            ttf_point_t * out )  [static]
```

Referenced by flatten_contour().

Here is the caller graph for this function:

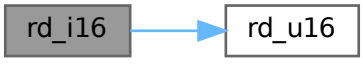
7.157.2.14 rd_i16()

```
static int16_t rd_i16 (
            const uint8_t * d,
            uint32_t off )  [static]
```

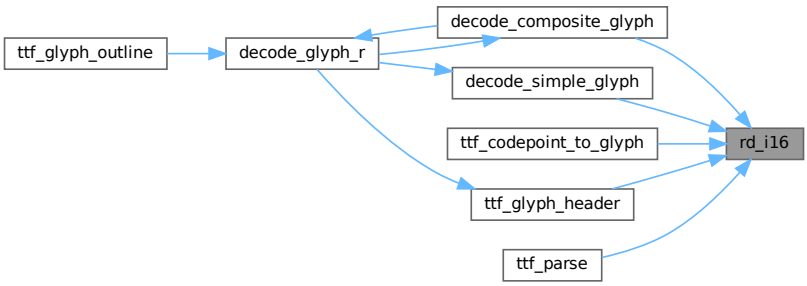
References rd_u16().

Referenced by decode_composite_glyph(), decode_simple_glyph(), ttf_codepoint_to_glyph(), ttf_glyph_header(), and ttf_parse().

Here is the call graph for this function:



Here is the caller graph for this function:



7.157.2.15 rd_i8()

```
static int8_t rd_i8 (
            const uint8_t * d,
            uint32_t off )  [static]
```

Referenced by decode_composite_glyph().

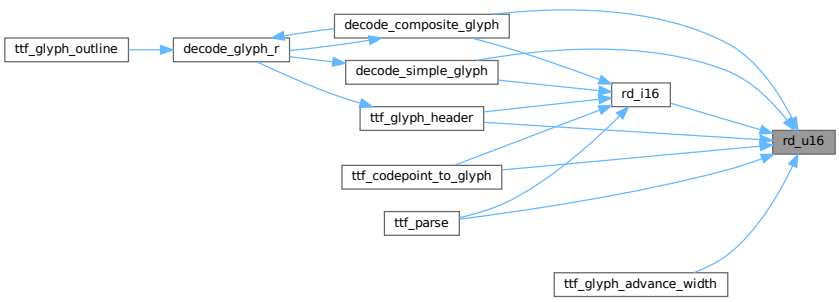
Here is the caller graph for this function:

7.157.2.16 rd_u16()

```
static uint16_t rd_u16 (
            const uint8_t * d,
            uint32_t off )  [static]
```

Referenced by decode_composite_glyph(), decode_simple_glyph(), rd_i16(), ttf_codepoint_to_glyph(), ttf_glyph_advance_width(), ttf_glyph_header(), and ttf_parse().

Here is the caller graph for this function:

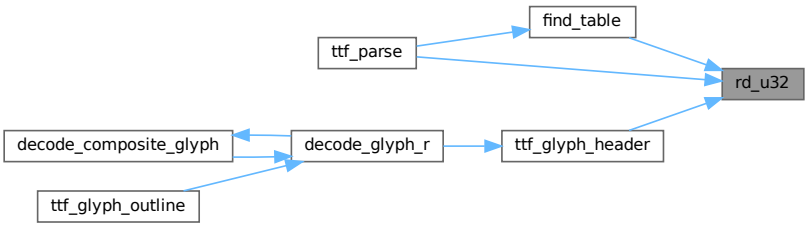


7.157.2.17 rd_u32()

```
static uint32_t rd_u32 (
            const uint8_t * d,
            uint32_t off )  [static]
```

Referenced by find_table(), ttf_glyph_header(), and ttf_parse().

Here is the caller graph for this function:

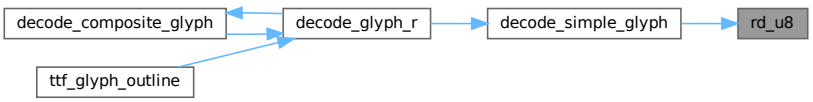


7.157.2.18 rd_u8()

```
static uint8_t rd_u8 (
            const uint8_t * d,
            uint32_t off )  [static]
```

Referenced by decode_simple_glyph().

Here is the caller graph for this function:

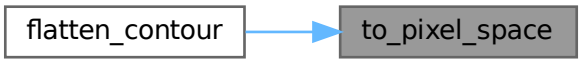


7.157.2.19 to_pixel_space()

```
static void to_pixel_space (
            q48_16_t fx,
            q48_16_t fy,
            q48_16_t scale,
            q48_16_t origin_x,
            q48_16_t origin_y,
            q48_16_t * px,
            q48_16_t * py )  [static]
```

Referenced by flatten_contour().

Here is the caller graph for this function:



7.157.2.20 ttf_codepoint_to_glyph()

```
uint32_t ttf_codepoint_to_glyph (
            const ttf_font_t * font,
            uint32_t codepoint )
```

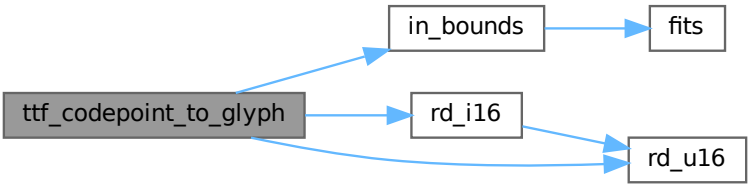
ttf_codepoint_to_glyph - Resolve a Unicode codepoint via the font's format-4 cmap subtable.

Returns

glyph index, or TTF_GLYPH_MISSING if unmapped or no cmap

References ttf_font_t::cmap_subtable_off, ttf_font_t::data, ttf_font_t::has_cmap, in_bounds(), rd_i16(), rd_u16(), and TTF_GLYPH_MISSING.

Here is the call graph for this function:



7.157.2.21 ttf_glyph_advance_width()

```
uint16_t ttf_glyph_advance_width (
            const ttf_font_t * font,
            uint32_t glyph_index )
```

ttf_glyph_advance_width - Horizontal advance width via hmtx, in raw font design units (NOT scaled by unitsPerEm – caller's job, e.g.

`q48_mul(q48_from_u64(width), scale)`; always non-negative, so the shared q48_mul is fine here unlike the signed cases documented in ttf.c's rasterizer). Glyphs past hmtx's numberOfHMetrics entries share the last entry's width, per spec.

Parameters

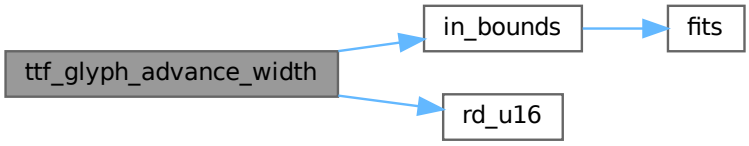
glyph_index	As returned by ttf_codepoint_to_glyph()

Returns

advance width, or 0 if glyph_index is out of range

References ttf_font_t::data, ttf_font_t::hmtx_off, in_bounds(), ttf_font_t::num_h_metrics, and rd_u16().

Here is the call graph for this function:



7.157.2.22 ttf_glyph_header()

```
int ttf_glyph_header (
            const ttf_font_t * font,
            uint32_t glyph_index,
            ttf_glyph_header_t * out )
```

ttf_glyph_header - Read a glyph's outline header (contour count, bounding box) via loca + glyf.

Does not extract contour points.

Parameters

glyph_index	As returned by ttf_codepoint_to_glyph()
out	Header to populate

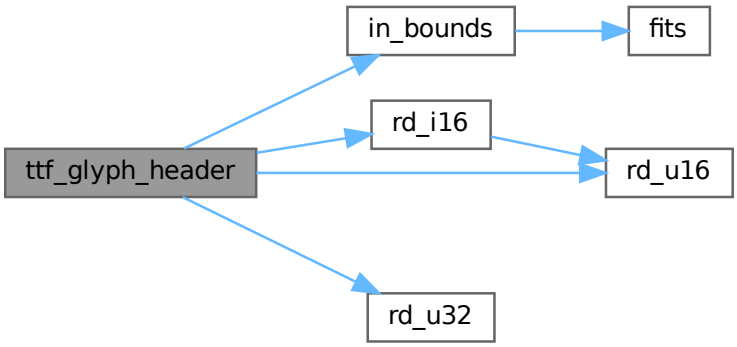
Returns

TTF_OK, or a TTF_ERR_∗ code

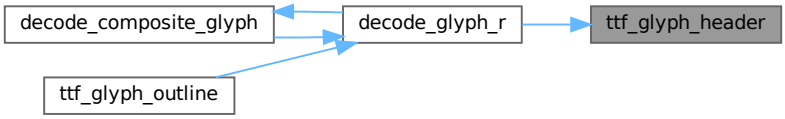
References ttf_font_t::data, ttf_glyph_header_t::glyf_length, ttf_font_t::glyf_off, ttf_glyph_header_t::glyf_offset, in_bounds(), ttf_font_t::index_to_loc_format, ttf_font_t::loca_off, ttf_glyph_header_t::num_contours, ttf_font_t::num_glyphs, rd_i16(), rd_u16(), rd_u32(), TTF_ERR_BAD_GLYPH_INDEX, TTF_ERR_BAD_TABLE, TTF_ERR_OUT_OF_BOUNDS, TTF_OK, ttf_glyph_header_t::x_max, ttf_glyph_header_t::x_min, ttf_glyph_header_t::y_max, and ttf_glyph_header_t::y_min.

Referenced by decode_glyph_r().

Here is the call graph for this function:



Here is the caller graph for this function:



7.157.2.23 ttf_glyph_outline()

```
int ttf_glyph_outline (
            const ttf_font_t * font,
            uint32_t glyph_index,
            ttf_outline_t * out )
```

ttf_glyph_outline - Extract a glyph's outline (simple or composite, recursively resolving composite components) into caller-supplied buffers.

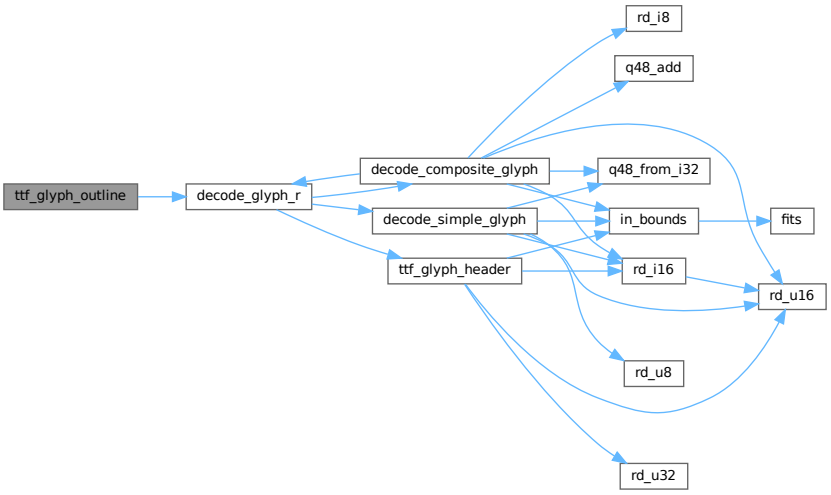
Composite components with a non-identity transform (any scale/rotation/ skew, i.e. anything but a pure (dx,dy) translation) or with point-matched (rather than xy-offset) placement args return TTF_ERR_UNSUPPORTED rather than silently producing a wrong outline — see ttf.c's file header comment for why, and check that limitation before relying on this for an arbitrary font.

Returns

TTF_OK, or a TTF_ERR_∗ code (including TTF_ERR_TOO_MANY_POINTS/ _CONTOURS if a caller buffer is too small, and TTF_ERR_TOO_DEEP if composite nesting exceeds TTF_MAX_COMPOSITE_DEPTH)

References ttf_outline_t::contour_count, decode_glyph_r(), ttf_outline_t::point_count, and TTF_ERR_BAD_TABLE.

Here is the call graph for this function:



7.157.2.24 ttf_parse()

```
int ttf_parse (
            const uint8_t * data,
            uint32_t size,
            ttf_font_t * out )
```

ttf_parse - Locate and validate the sfnt directory and the head/maxp/ loca/glyf tables (cmap is optional; ttf_codepoint_to_glyph() fails cleanly if absent).

Does not copy `data` — `out` borrows it.

Parameters

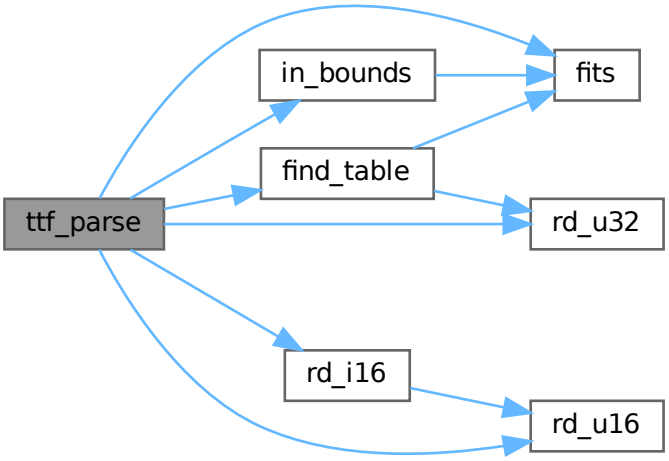
data	Whole .ttf file contents
size	Length of data in bytes
out	Parsed handle to populate

Returns

TTF_OK, or a TTF_ERR_∗ code

References ttf_font_t::cmap_subtable_off, ttf_font_t::data, find_table(), fits(), ttf_font_t::glyf_len, ttf_font_t::glyf_off, ttf_font_t::has_cmap, ttf_font_t::head_off, ttf_font_t::hmtx_off, in_bounds(), ttf_font_t::index_to_loc_format, ttf_font_t::loca_len, ttf_font_t::loca_off, ttf_font_t::maxp_off, ttf_font_t::num_glyphs, ttf_font_t::num_h_metrics, rd_i16(), rd_u16(), rd_u32(), ttf_font_t::size, TAG, TTF_ERR_BAD_SFNT, TTF_ERR_BAD_TABLE, TTF_ERR_OUT_OF_BOUNDS, TTF_OK, and ttf_font_t::units_per_em.

Here is the call graph for this function:



7.157.2.25 ttf_raster_cache_get()

```
int ttf_raster_cache_get (
            ttf_raster_cache_t * cache,
            const ttf_font_t * font,
            uint32_t codepoint,
            uint32_t size_px,
            ttf_bitmap_t * out,
            int * was_hit )
```

ttf_raster_cache_get - Look up (font, codepoint, size_px); on a miss, rasterize and insert (evicting round-robin if every slot is full).

`out` borrows the winning slot's buffer directly – valid until that slot is evicted by a later call.

Parameters

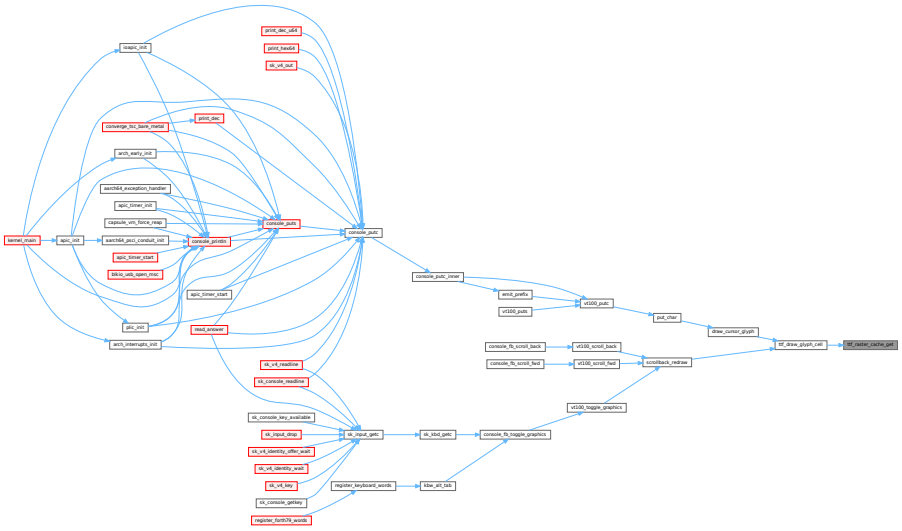
was_hit	If non-NULL, set to 1 on a cache hit, 0 if this call rasterized and inserted

Returns

TTF_OK, TTF_ERR_UNSUPPORTED if size_px > TTF_CACHE_MAX_SIZE_PX, or a ttf_rasterize_glyph() TTF_ERR_* code on a miss that failed to rasterize

Referenced by ttf_draw_glyph_cell().

Here is the caller graph for this function:



7.157.2.26 ttf_raster_cache_init()

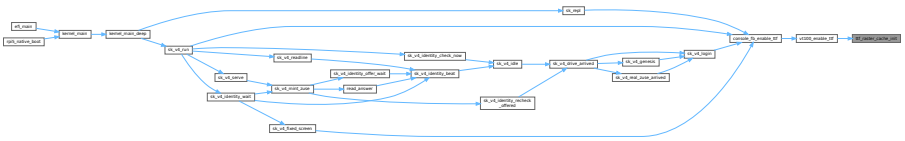
```
void ttf_raster_cache_init (
            ttf_raster_cache_t * cache,
            ttf_raster_cache_slot_t * slots,
            uint32_t slot_count )
```

ttf_raster_cache_init - Bind a caller-supplied slot array to `cache` and mark every slot empty.

References ttf_raster_cache_t::evict_next, ttf_raster_cache_t::slot_count, ttf_raster_cache_t::slots, and slots.

Referenced by vt100_enable_ttf().

Here is the caller graph for this function:



7.157.2.27 ttf_rasterize_glyph()

```
int ttf_rasterize_glyph (
            const ttf_font_t * font,
            uint32_t glyph_index,
            q48_16_t scale,
            q48_16_t origin_x,
            q48_16_t origin_y,
```

```
        uint8_t fill_value,
        ttf_bitmap_t * out )
```

ttf_rasterize_glyph - Flatten a glyph's outline (quadratic Bezier contours, fixed segment count per curve — see ttf.c's file header comment) and fill it into `out` using the even-odd rule (FABRIC-0.md item 4.3.7c; see that item's completion note for why even-odd rather than nonzero winding — correct for the v1 glyph repertoire's non-self-intersecting nested contours, not necessarily for an arbitrary font).

No antialiasing (explicitly deferred, per 4.3.7c's own "done when" clause). Never allocates — flattening uses a fixed-size local buffer bounded by TTF_RASTER_MAX_POINTS/TTF_RASTER_MAX_CONTOURS.

Parameters

scale	Font-design-units-to-pixels scale, Q48.16, e.g. q48_div(q48_from_u64(size_px), q48_from_u64(font->units_per_em))
origin_x	Pixel-space X (Q48.16) of the glyph's (0,0) font origin within `out`
origin_y	Pixel-space Y (Q48.16) of the glyph's baseline (font y=0) within `out`; font Y-up is flipped to raster Y-down internally

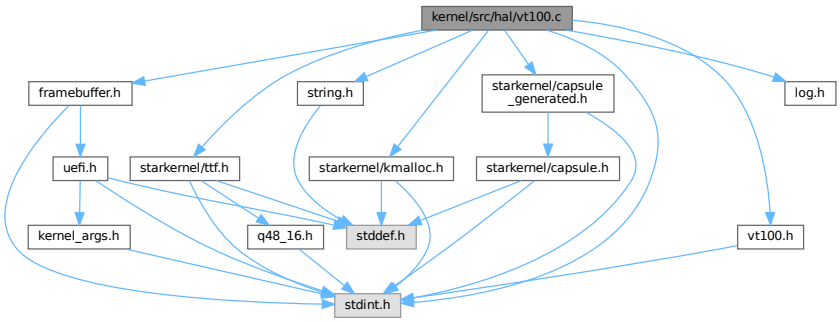
Returns

TTF_OK, or a TTF_ERR_* code (including TTF_ERR_TOO_MANY_POINTS/ _CONTOURS if the flattened outline exceeds the local buffer)

7.158 kernel/src/hal/vt100.c File Reference

```
#include "vt100.h"
#include "framebuffer.h"
#include "starkernel/ttf.h"
#include "starkernel/capsule_generated.h"
#include "starkernel/kmalloc.h"
#include "log.h"
#include <stdint.h>
#include <string.h>
```

Include dependency graph for vt100.c:



Data Structures

- struct VT100State

Macros

- #define VT100_MAX_PARAMS 16

  vt100.c — Full-color ANSI / VT100 terminal state machine
- #define UNDERLINE_ROW 14u
- #define VT100_TTF_SIZE_PX 20u
- #define VT100_TTF_CELL_W_PX 12u /∗ 600/1000 ∗ VT100_TTF_SIZE_PX ∗/
- #define VT100_TTF_CELL_H_PX 24u /∗ provisional: size + 4px leading/descender ∗/
- #define VT100_TTF_CACHE_SLOTS 96u /∗ covers all 95 printable ASCII, no thrash ∗/
- #define VT100_TTF_FONT_CAPSULE "fonts:JetBrainsMono-Regular.ttf"
- #define VT100_SCROLLBACK_MAX_LINES 1000u
- #define VT100_BOOT_SCROLLBACK_MAX_LINES 4096u

Enumerations

- enum vt_glyph_mode_t { VT_GLYPH_BITMAP = 0 , VT_GLYPH_TTF = 1 }
- enum ParseState {
  ST_NORMAL = 0 , ST_ESC , ST_CSI , ST_ESC_HASH ,
  ST_ESC_CHAR }

Functions

- static void put_char (uint8_t ch)
- static void advance_cursor (void)
- static void scroll_up (uint32_t lines)
- static void erase_display (int mode)
- static void erase_line (int mode)
- static void set_cursor (uint32_t row, uint32_t col)
- static void apply_sgr (void)
- static uint32_t cell_w (void)
- static uint32_t cell_h (void)
- static uint32_t px_of (uint32_t col)
- static uint32_t py_of (uint32_t row)
- static uint32_t eff_fg (void)
- static uint32_t eff_bg (void)
- static void ttf_draw_glyph_cell (uint32_t cell_px, uint32_t cell_py, uint8_t ch, uint32_t fg, uint32_t bg)
- static void draw_cursor_glyph (uint8_t ch)
- void vt100_draw_cursor (void)

  Draw a solid block cursor at the terminal's current position.
- void vt100_erase_cursor (void)

  Erases whatever vt100_draw_cursor() last drew, restoring the cell to plain background.
- static void reset_attrs (void)
- static void reset_parser (void)
- static int32_t param (uint32_t n, int32_t def)
- void vt100_init (void)

  Initialize the VT100 terminal.
- void vt100_enable_ttf (void)

  FABRIC-0.md item 4.4j: switch the glyph-draw backend from font_8x16.c to TTF-TEXT's rasterizer for everything drawn from this call onward – boot/POST output before this call stays font_8x16.c, unaffected.
- static const char ∗ scrollback_line_at (uint32_t idx)
- static void scrollback_redraw (void)
- void vt100_reset (void)
- void vt100_toggle_graphics (void)

FABRIC-0.md item 4.4y-revised: toggle the full-screen vt100 terminal between visible (normal operation) and hidden (graphics mode – the terminal stops drawing, letting direct framebuffer/TTF-TEXT calls show through undisturbed).

- void vt100_scroll_back (uint32_t n)

  FABRIC-0.md item 4.4q: move the REPL scrollback view back/forward by `n` lines and redraw.
- void vt100_scroll_fwd (uint32_t n)
- uint32_t vt100_cols (void)

  Terminal width in character columns.
- uint32_t vt100_rows (void)

  Terminal height in character rows.
- static void erase_line_range (uint32_t row, uint32_t c0, uint32_t c1)
- static uint32_t ansi256_to_rgb (uint32_t idx)
- static void dispatch_csi (char final)
- void vt100_putc (char raw)

  Feed one byte into the terminal (handles escape sequences transparently).
- void vt100_puts (const char *s)

  Feed a null-terminated string.

Variables

- static vt_glyph_mode_t g_glyph_mode = VT_GLYPH_BITMAP
- static ttf_font_t g_ttf_font
- static int g_ttf_ready = 0
- static ttf_raster_cache_t g_ttf_cache
- static int g_terminal_visible = 1
- static char * g_shadow = (void *)0
- static char * g_ring = (void *)0
- static uint32_t g_line_stride = 0
- static uint32_t g_ring_count = 0
- static uint32_t g_ring_head = 0
- static uint32_t g_ring_cap = 0
- static uint32_t g_scroll_offset = 0
- static char * g_boot_shadow = (void *)0
- static char * g_boot_ring = (void *)0
- static uint32_t g_boot_line_stride = 0
- static uint32_t g_boot_ring_count = 0
- static uint32_t g_boot_ring_head = 0
- static uint32_t g_boot_ring_cap = 0
- static uint32_t g_boot_rows = 0
- static VT100State g_vt

7.158.1 Macro Definition Documentation

7.158.1.1 UNDERLINE_ROW

```
#define UNDERLINE_ROW 14u
```

7.158.1.2 VT100_BOOT_SCROLLBACK_MAX_LINES

```
#define VT100_BOOT_SCROLLBACK_MAX_LINES 4096u
```

7.158.1.3 VT100_MAX_PARAMS

```
#define VT100_MAX_PARAMS 16
```

vt100.c — Full-color ANSI / VT100 terminal state machine

Parser states ————————- NORMAL plain text characters ESC received 0x1B, waiting for next byte CSI received ESC [, accumulating parameter digits / intermediates ESC_HASH received ESC # (line attributes — we ignore, eat next byte) ESC_CHAR received ESC (or ESC) (charset designation — ignored)

Supported CSI sequences ———————————— CUU A cursor up CUD B cursor down CUF C cursor forward CUB D cursor back CUP H cursor position (row ; col) ED J erase display (0=below 1=above 2=all) EL K erase line (0=right 1=left 2=all) SGR m select graphic rendition (see header) SCP s save cursor position RCP u restore cursor position

ESC sequences (2-char) ESC 7 save cursor (DEC) ESC 8 restore cursor (DEC) ESC M reverse index (scroll down) ESC c full reset

7.158.1.4 VT100_SCROLLBACK_MAX_LINES

```
#define VT100_SCROLLBACK_MAX_LINES 1000u
```

7.158.1.5 VT100_TTF_CACHE_SLOTS

```
#define VT100_TTF_CACHE_SLOTS 96u /* covers all 95 printable ASCII, no thrash */
```

7.158.1.6 VT100_TTF_CELL_H_PX

```
#define VT100_TTF_CELL_H_PX 24u /* provisional:  size + 4px leading/descender */
```

7.158.1.7 VT100_TTF_CELL_W_PX

```
#define VT100_TTF_CELL_W_PX 12u /* 600/1000 * VT100_TTF_SIZE_PX */
```

7.158.1.8 VT100_TTF_FONT_CAPSULE

```
#define VT100_TTF_FONT_CAPSULE "fonts:JetBrainsMono-Regular.ttf"
```

7.158.1.9 VT100_TTF_SIZE_PX

```
#define VT100_TTF_SIZE_PX 20u
```

7.158.2 Enumeration Type Documentation

7.158.2.1 ParseState

```
enum ParseState
```

Enumerator

ST_NORMAL	
ST_ESC	
ST_CSI	
ST_ESC_HASH	
ST_ESC_CHAR	

7.158.2.2 vt_glyph_mode_t

```
enum vt_glyph_mode_t
```

Enumerator

VT_GLYPH_BITMAP	
VT_GLYPH_TTF	

7.158.3 Function Documentation

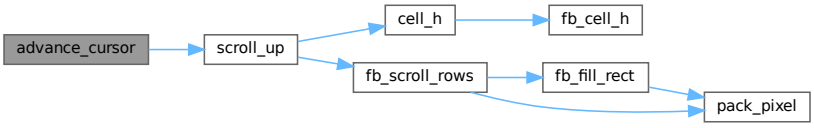
7.158.3.1 advance_cursor()

```
static void advance_cursor (
            void  )  [static]
```

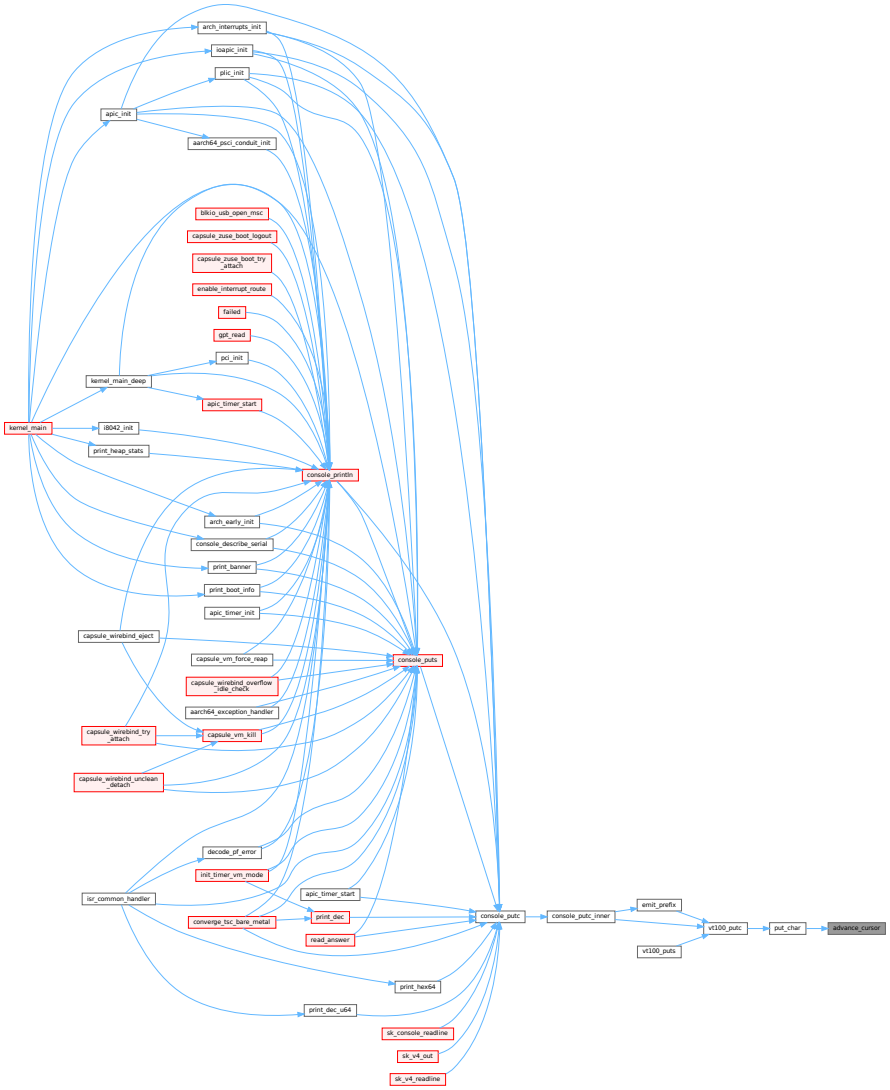
References VT100State::cols, VT100State::cx, VT100State::cy, g_vt, VT100State::rows, and scroll_up().

Referenced by put_char().

Here is the call graph for this function:



Here is the caller graph for this function:



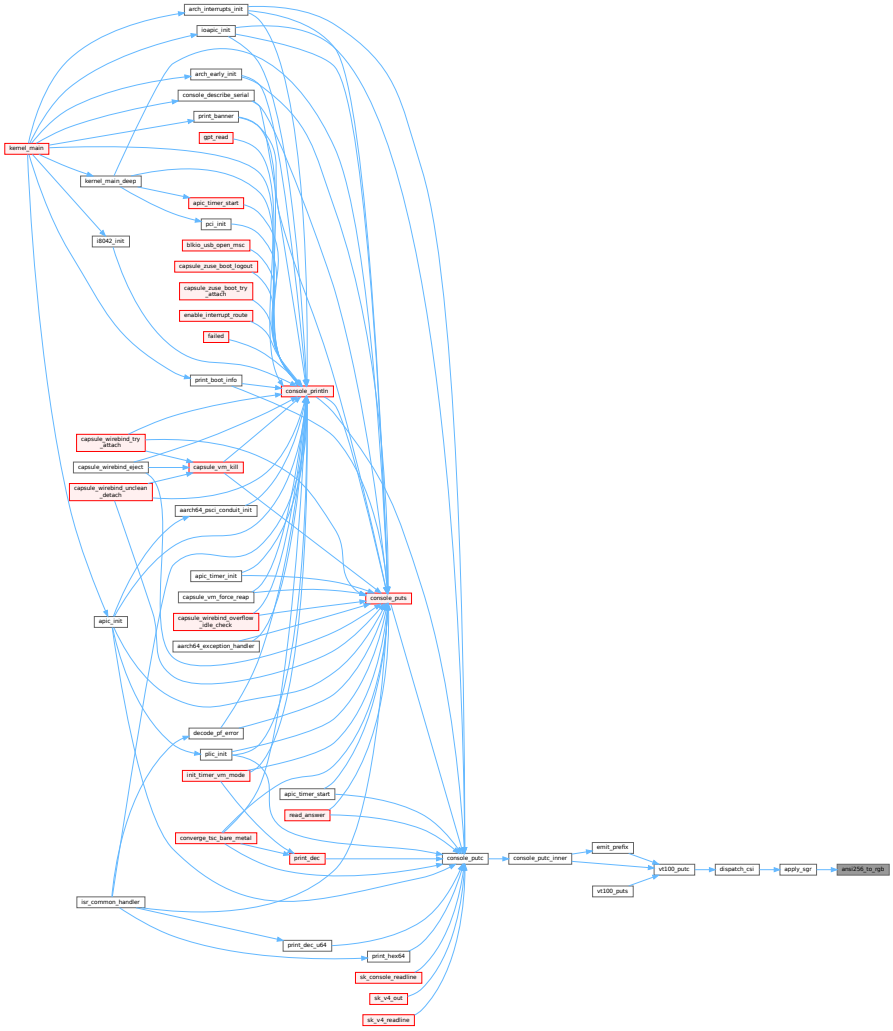
7.158.3.2 ansi256_to_rgb()

```
static uint32_t ansi256_to_rgb (
            uint32_t idx )  [static]
```

References FB_RGB, and g.

Referenced by apply_sgr().

Here is the caller graph for this function:



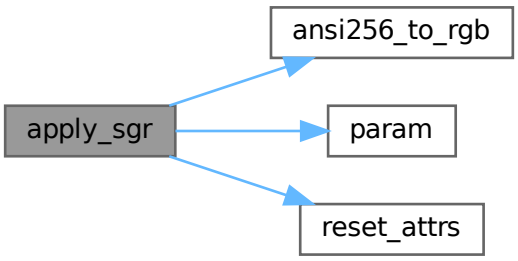
7.158.3.3 apply_sgr()

```
static void apply_sgr (
            void  )  [static]
```

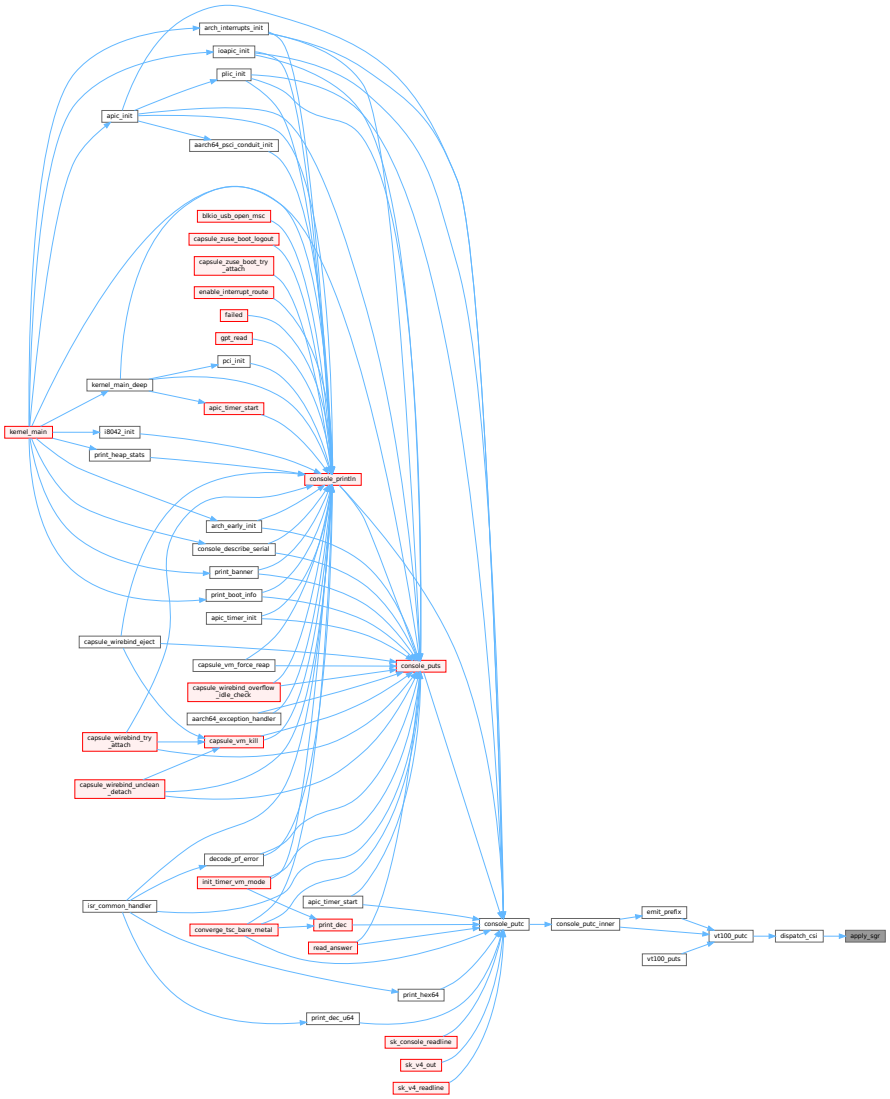
References ansi256_to_rgb(), VT100State::bg, VT100State::bold, VT100State::def_bg, VT100State::def_fg, FB_RGB, VT100State::fg, g, g_vt, param(), VT100State::param_count, reset_attrs(), VT100State::reverse, and VT100State::underline.

Referenced by dispatch_csi().

Here is the call graph for this function:



Here is the caller graph for this function:



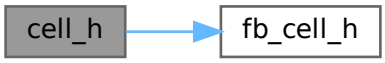
7.158.3.4 cell_h()

```
static uint32_t cell_h (
            void  )  [static]
```

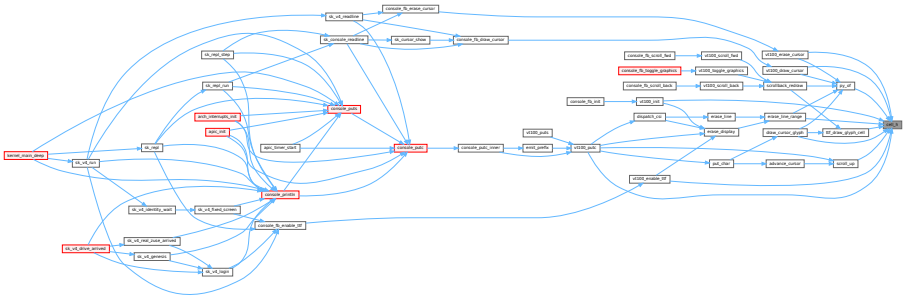
References fb_cell_h(), g_glyph_mode, VT100_TTF_CELL_H_PX, and VT_GLYPH_TTF.

Referenced by draw_cursor_glyph(), erase_line_range(), py_of(), scroll_up(), ttf_draw_glyph_cell(), vt100_draw_cursor(), vt100_enable_ttf(), vt100_erase_cursor(), vt100_init(), and vt100_putc().

Here is the call graph for this function:



Here is the caller graph for this function:



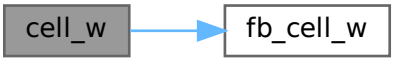
7.158.3.5 cell_w()

```
static uint32_t cell_w (
            void  )  [static]
```

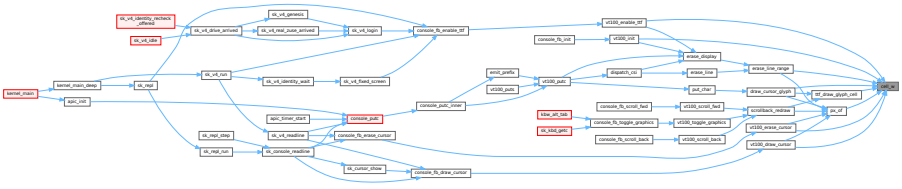
References fb_cell_w(), g_glyph_mode, VT100_TTF_CELL_W_PX, and VT_GLYPH_TTF.

Referenced by draw_cursor_glyph(), erase_line_range(), px_of(), ttf_draw_glyph_cell(), vt100_draw_cursor(), vt100_enable_ttf(), vt100_erase_cursor(), and vt100_init().

Here is the call graph for this function:



Here is the caller graph for this function:



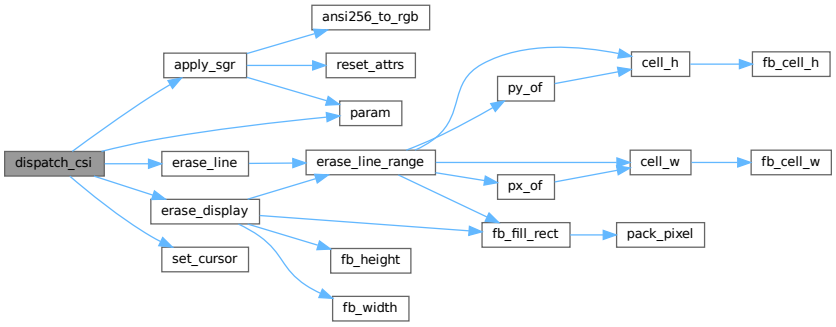
7.158.3.6 dispatch_csi()

```
static void dispatch_csi (
            char final )  [static]
```

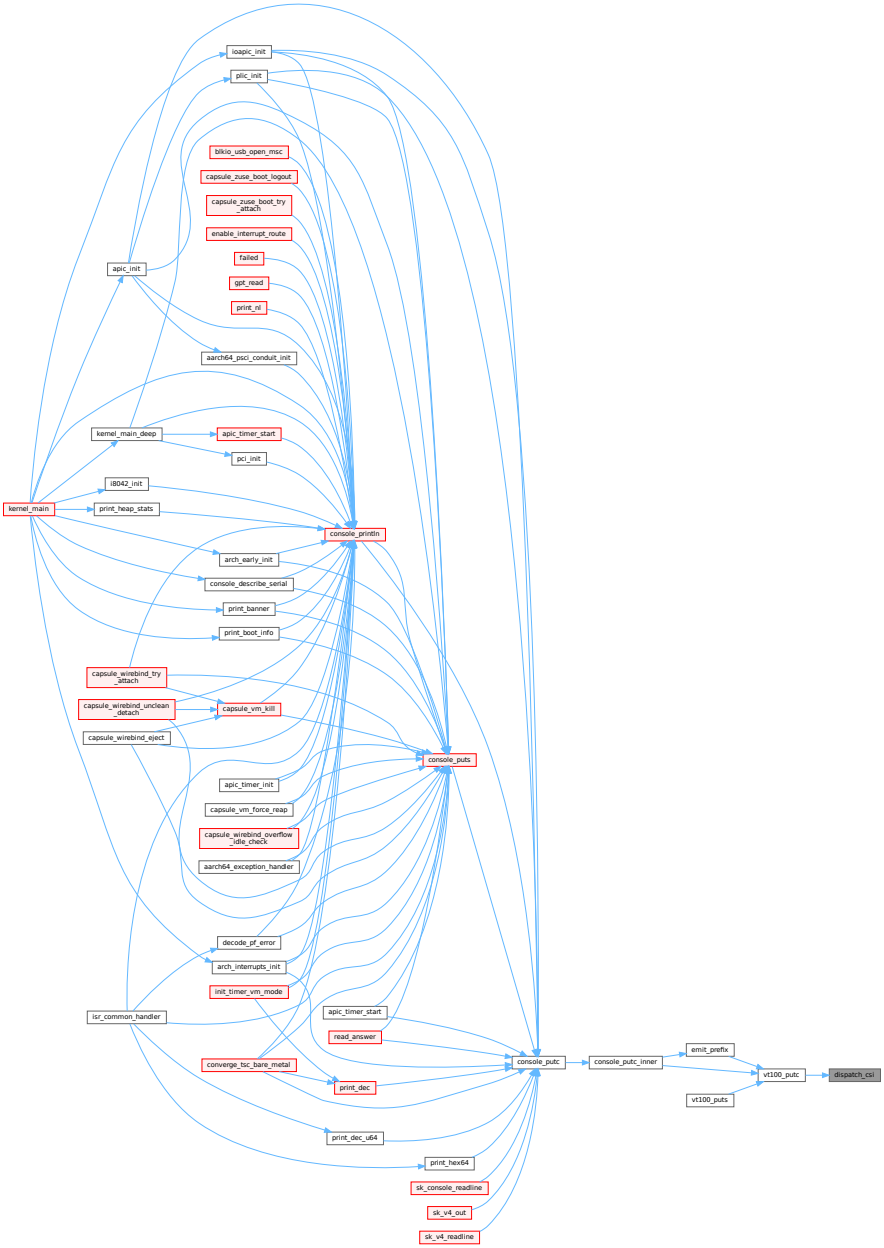
References apply_sgr(), VT100State::cols, VT100State::cx, VT100State::cy, erase_display(), erase_line(), g_vt, param(), VT100State::rows, VT100State::saved_cx, VT100State::saved_cy, and set_cursor().

Referenced by vt100_putc().

Here is the call graph for this function:



Here is the caller graph for this function:



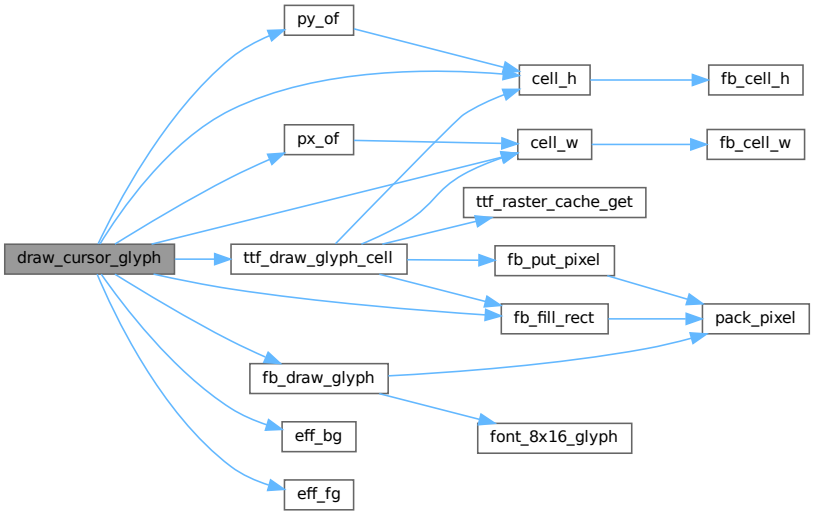
7.158.3.7 draw_cursor_glyph()

```
static void draw_cursor_glyph (
            uint8_t ch )  [static]
```

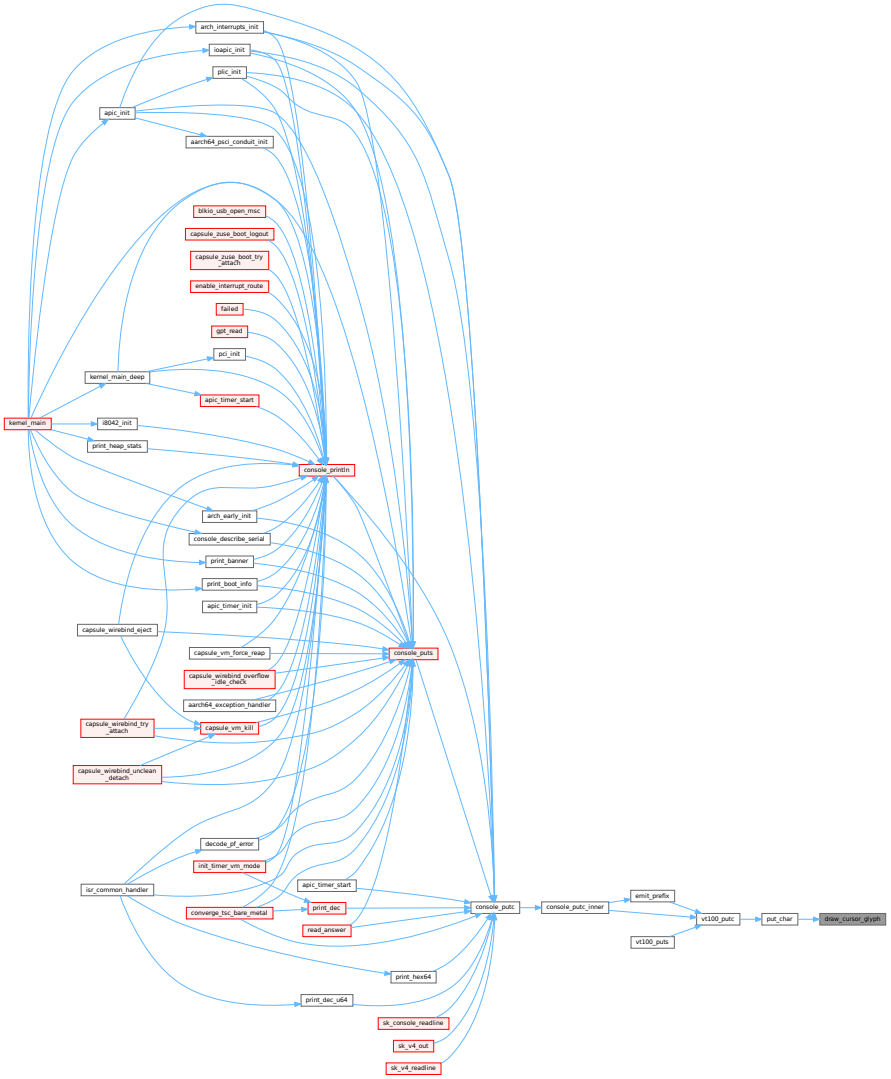
References VT100State::bold, cell_h(), cell_w(), VT100State::cols, VT100State::cx, VT100State::cy, eff_bg(), eff_fg(), FB_B, fb_draw_glyph(), fb_fill_rect(), FB_G, FB_R, FB_RGB, g, g_glyph_mode, g_line_stride, g_shadow, g_terminal_visible, g_vt, px_of(), py_of(), VT100State::rows, ttf_draw_glyph_cell(), VT100State::underline, UNDERLINE_ROW, VT100_TTF_SIZE_PX, and VT_GLYPH_TTF.

Referenced by put_char().

Here is the call graph for this function:



Here is the caller graph for this function:



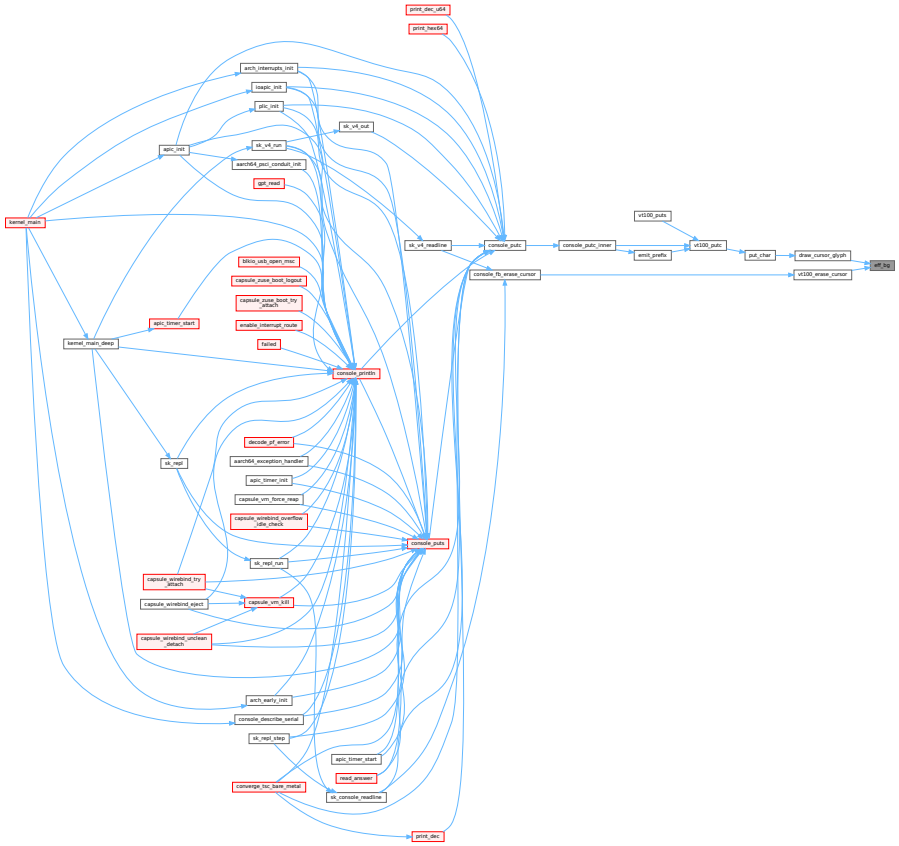
7.158.3.8 eff_bg()

```
static uint32_t eff_bg (
            void  )  [static]
```

References VT100State::bg, VT100State::fg, g_vt, and VT100State::reverse.

Referenced by draw_cursor_glyph(), and vt100_erase_cursor().

Here is the caller graph for this function:



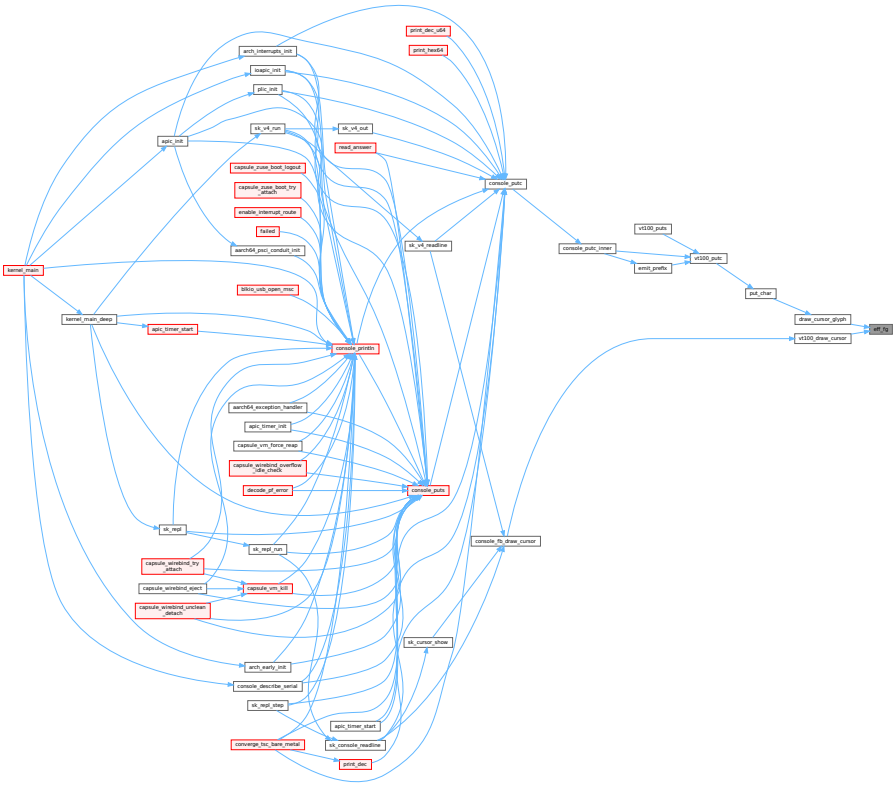
7.158.3.9 eff_fg()

```
static uint32_t eff_fg (
            void  )  [static]
```

References VT100State::bg, VT100State::fg, g_vt, and VT100State::reverse.

Referenced by draw_cursor_glyph(), and vt100_draw_cursor().

Here is the caller graph for this function:



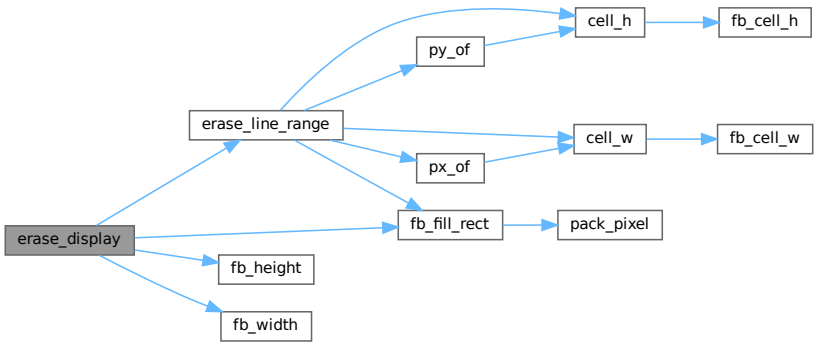
7.158.3.10 erase_display()

```
static void erase_display (
            int mode )  [static]
```

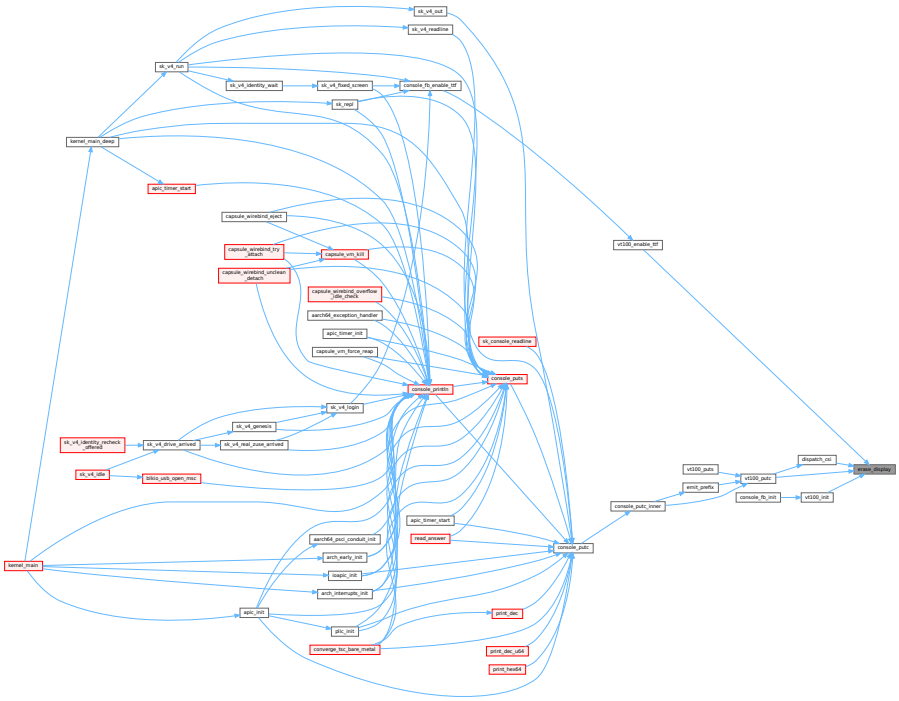
References VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, erase_line_range(), fb_fill_rect(), fb_height(), fb_width(), g_terminal_visible, g_vt, and VT100State::rows.

Referenced by dispatch_csi(), vt100_enable_ttf(), vt100_init(), and vt100_putc().

Here is the call graph for this function:



Here is the caller graph for this function:



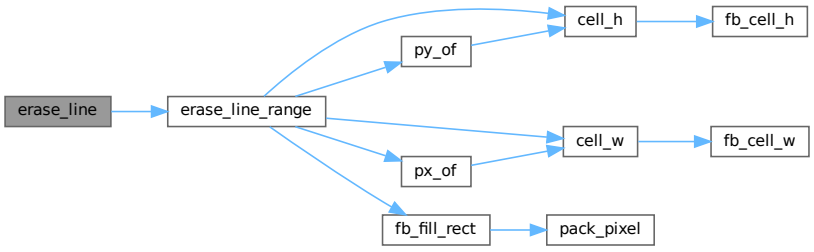
7.158.3.11 erase_line()

```
static void erase_line (
            int mode )  [static]
```

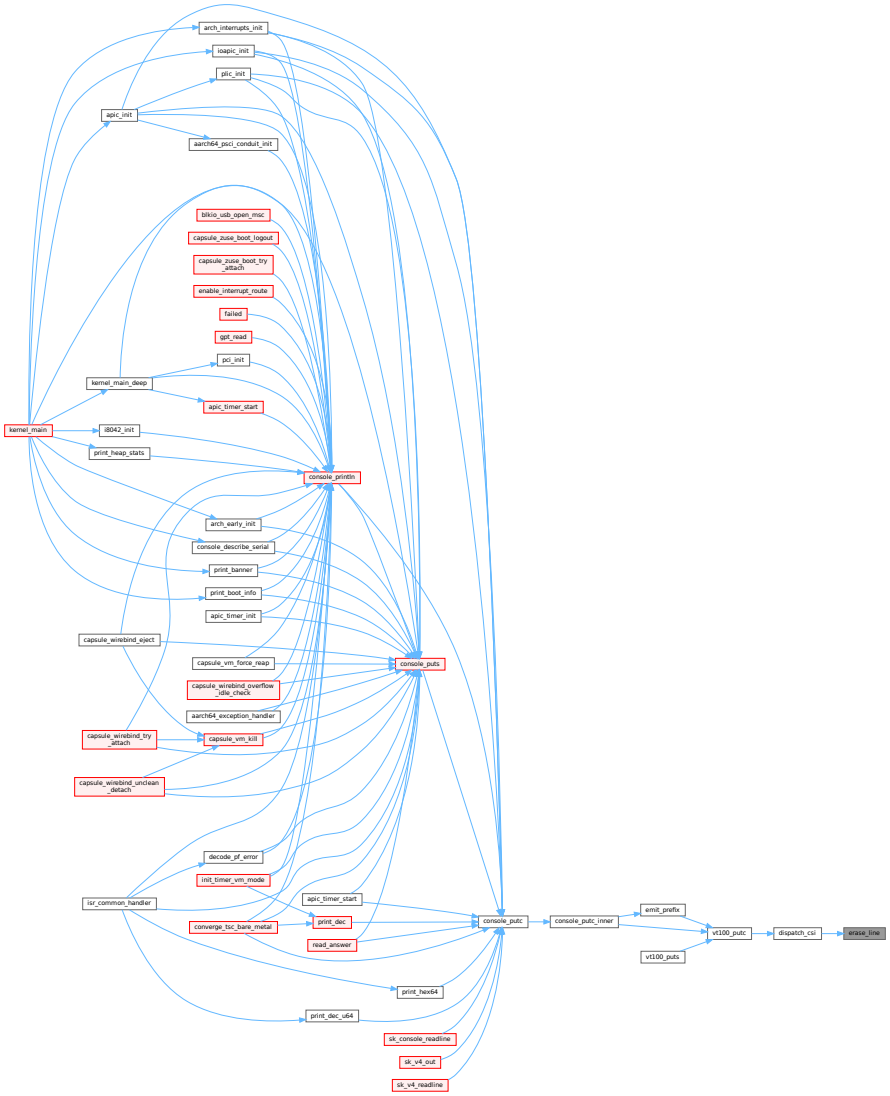
References VT100State::cols, VT100State::cx, VT100State::cy, erase_line_range(), and g_vt.

Referenced by dispatch_csi().

Here is the call graph for this function:



Here is the caller graph for this function:



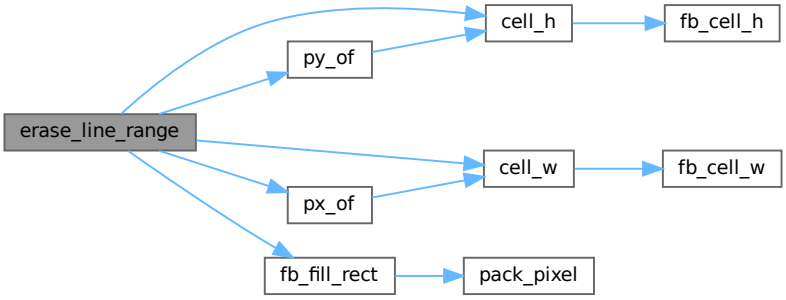
7.158.3.12 erase_line_range()

```
static void erase_line_range (
            uint32_t row,
            uint32_t c0,
            uint32_t c1 )  [static]
```

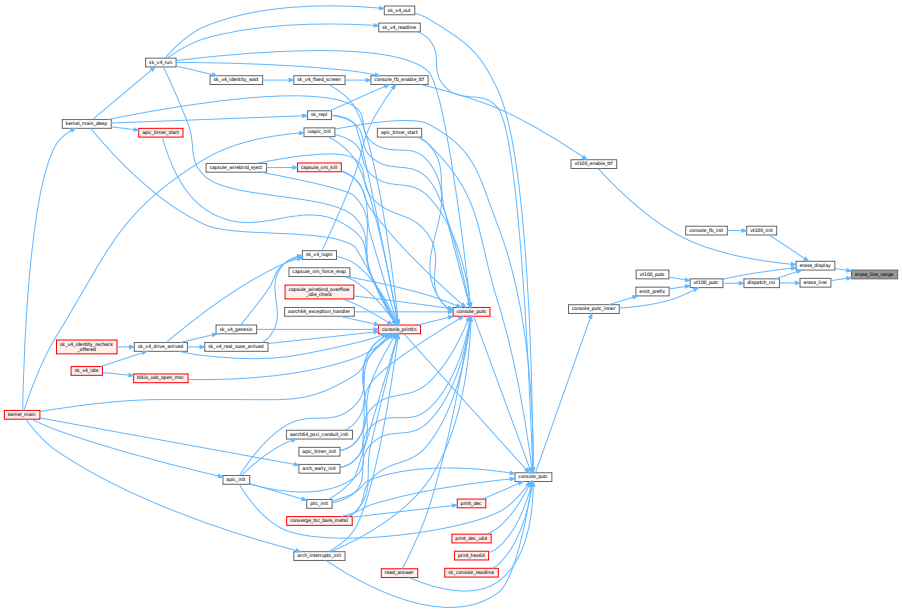
References VT100State::bg, cell_h(), cell_w(), fb_fill_rect(), g_terminal_visible, g_vt, px_of(), and py_of().

Referenced by erase_display(), and erase_line().

Here is the call graph for this function:



Here is the caller graph for this function:



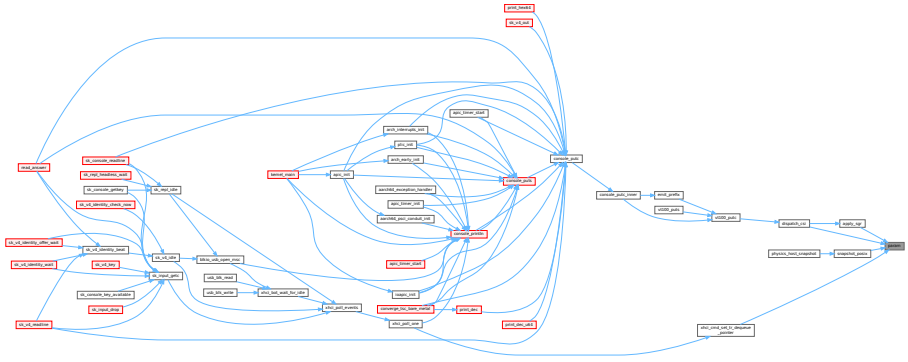
7.158.3.13 param()

```
static int32_t param (
            uint32_t n,
            int32_t def )  [static]
```

References g_vt, VT100State::param_count, and VT100State::params.

Referenced by apply_sgr(), dispatch_csi(), snapshot_posix(), and xhci_cmd_set_tr_dequeue_pointer().

Here is the caller graph for this function:



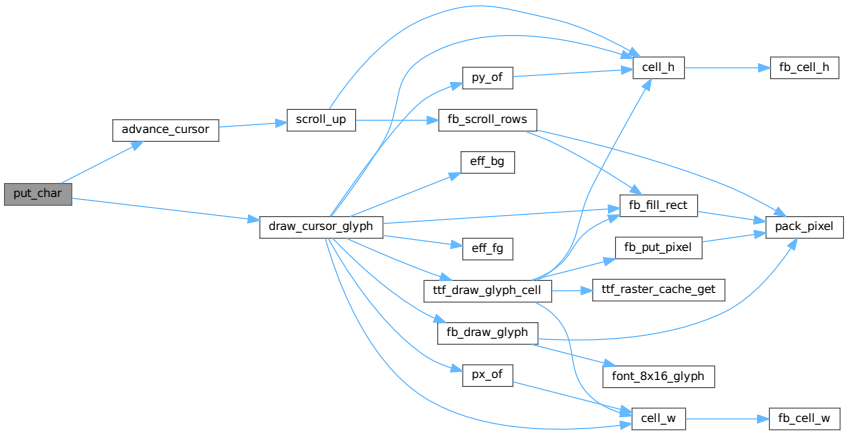
7.158.3.14 put_char()

```
static void put_char (
            uint8_t ch )  [static]
```

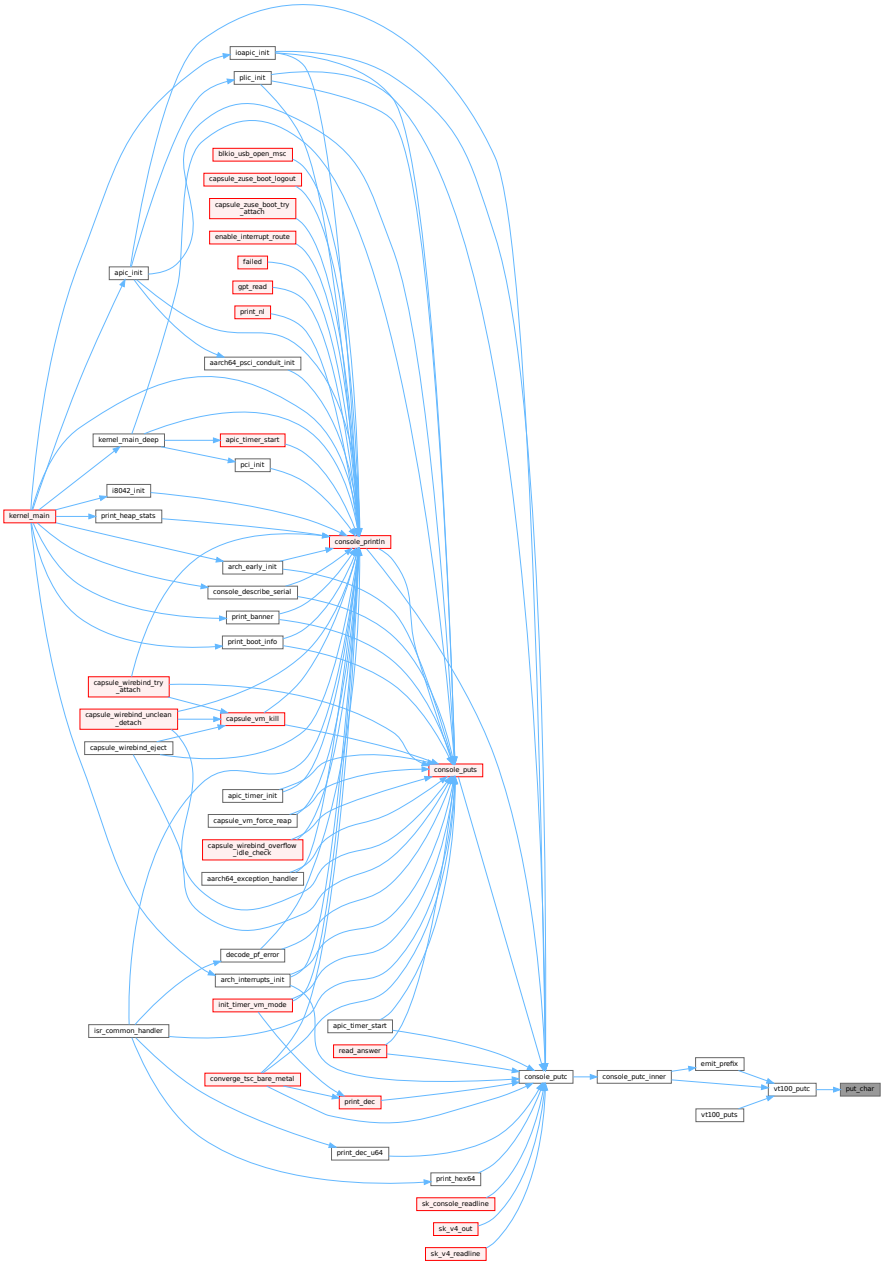
References advance_cursor(), and draw_cursor_glyph().

Referenced by vt100_putc().

Here is the call graph for this function:



Here is the caller graph for this function:



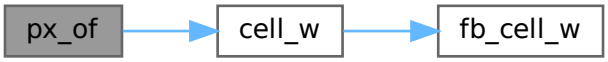
7.158.3.15 px_of()

```
static uint32_t px_of (
            uint32_t col )  [static]
```

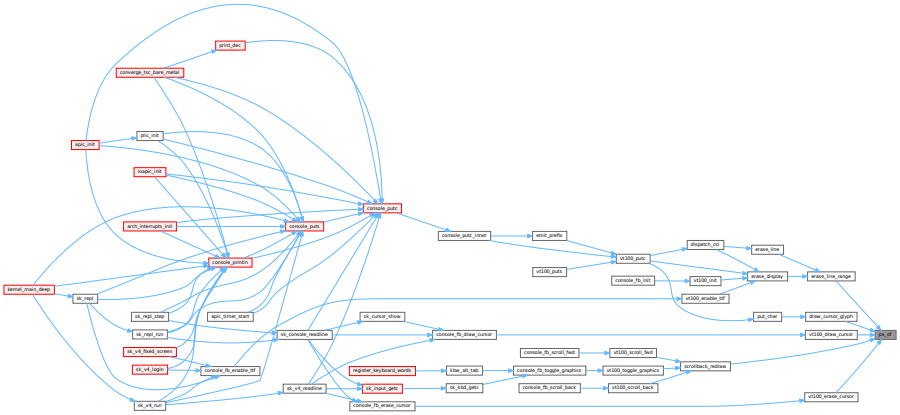
References cell_w().

Referenced by draw_cursor_glyph(), erase_line_range(), scrollback_redraw(), vt100_draw_cursor(), and vt100_erase_cursor().

Here is the call graph for this function:



Here is the caller graph for this function:



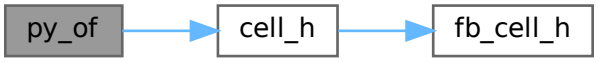
7.158.3.16 py_of()

```
static uint32_t py_of (
            uint32_t row )  [static]
```

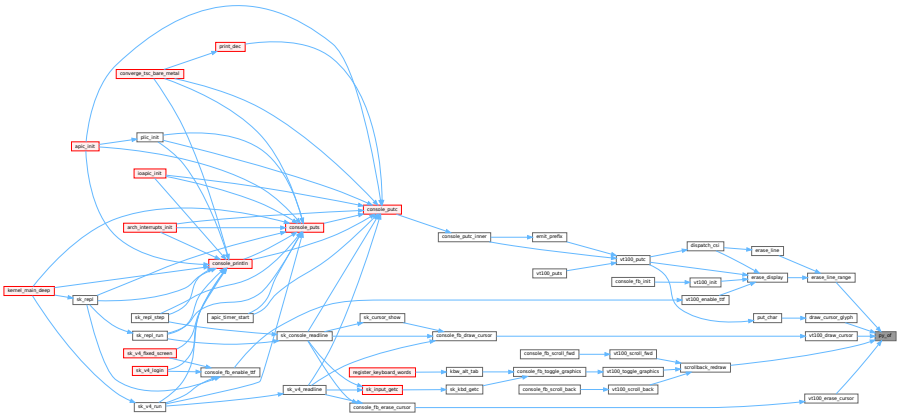
References cell_h().

Referenced by draw_cursor_glyph(), erase_line_range(), scrollback_redraw(), vt100_draw_cursor(), and vt100_erase_cursor().

Here is the call graph for this function:



Here is the caller graph for this function:



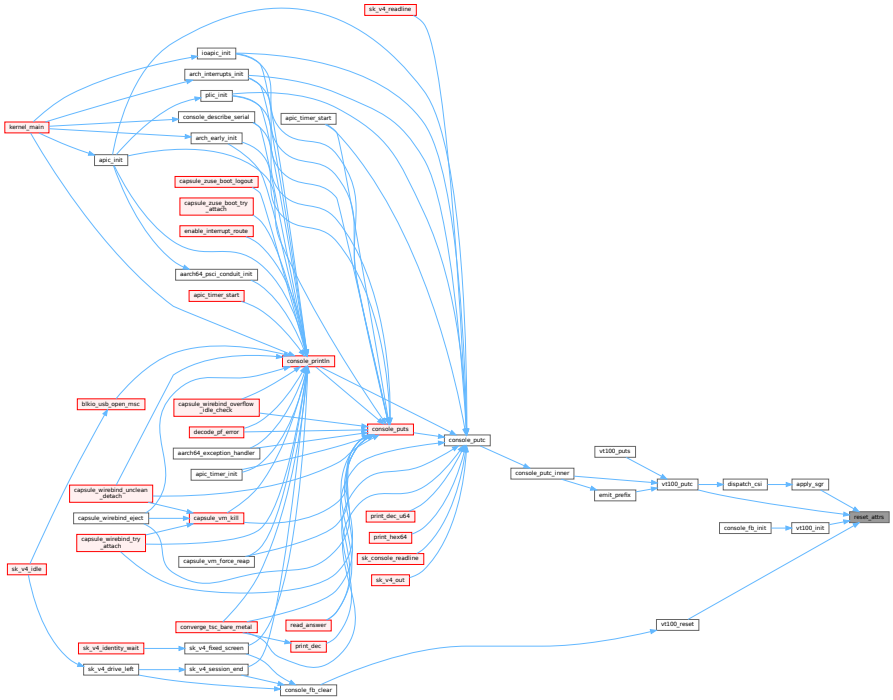
7.158.3.17 reset_attrs()

```
static void reset_attrs (
            void  )  [static]
```

References VT100State::bg, VT100State::bold, VT100State::def_bg, VT100State::def_fg, VT100State::fg, g_vt, VT100State::reverse, and VT100State::underline.

Referenced by apply_sgr(), vt100_init(), vt100_putc(), and vt100_reset().

Here is the caller graph for this function:



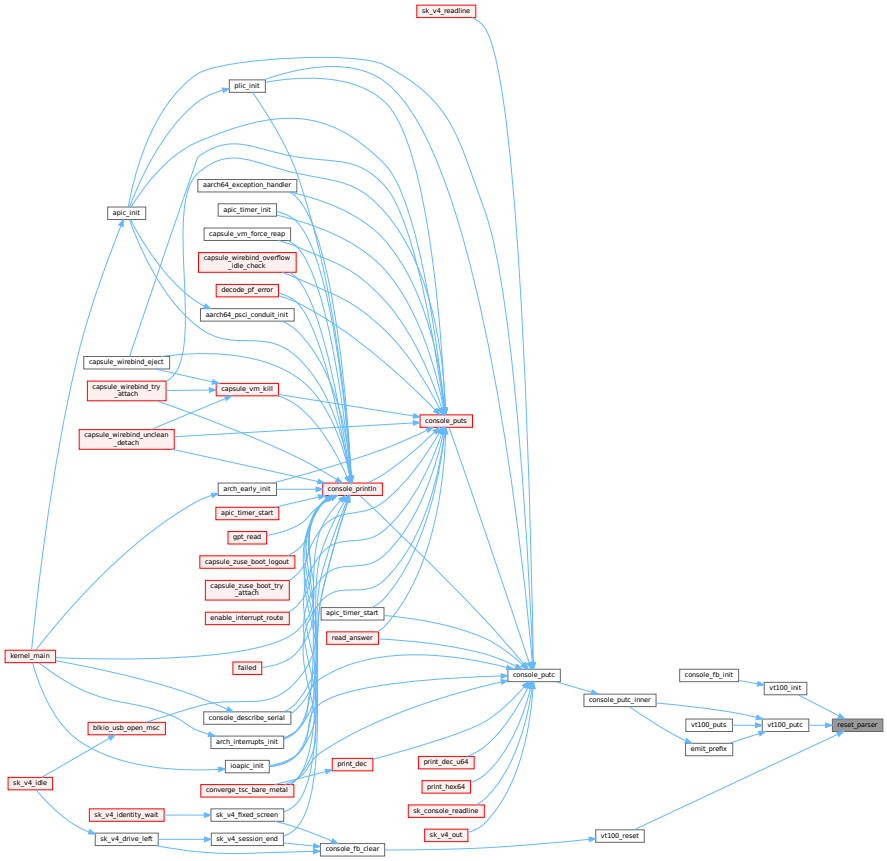
7.158.3.18 reset_parser()

```
static void reset_parser (
            void  )  [static]
```

References g_vt, VT100State::param_count, VT100State::param_has_value, VT100State::params, ST_NORMAL, VT100State::state, and VT100_MAX_PARAMS.

Referenced by vt100_init(), vt100_putc(), and vt100_reset().

Here is the caller graph for this function:



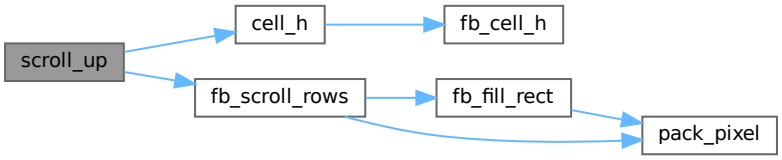
7.158.3.19 scroll_up()

```
static void scroll_up (
            uint32_t lines )  [static]
```

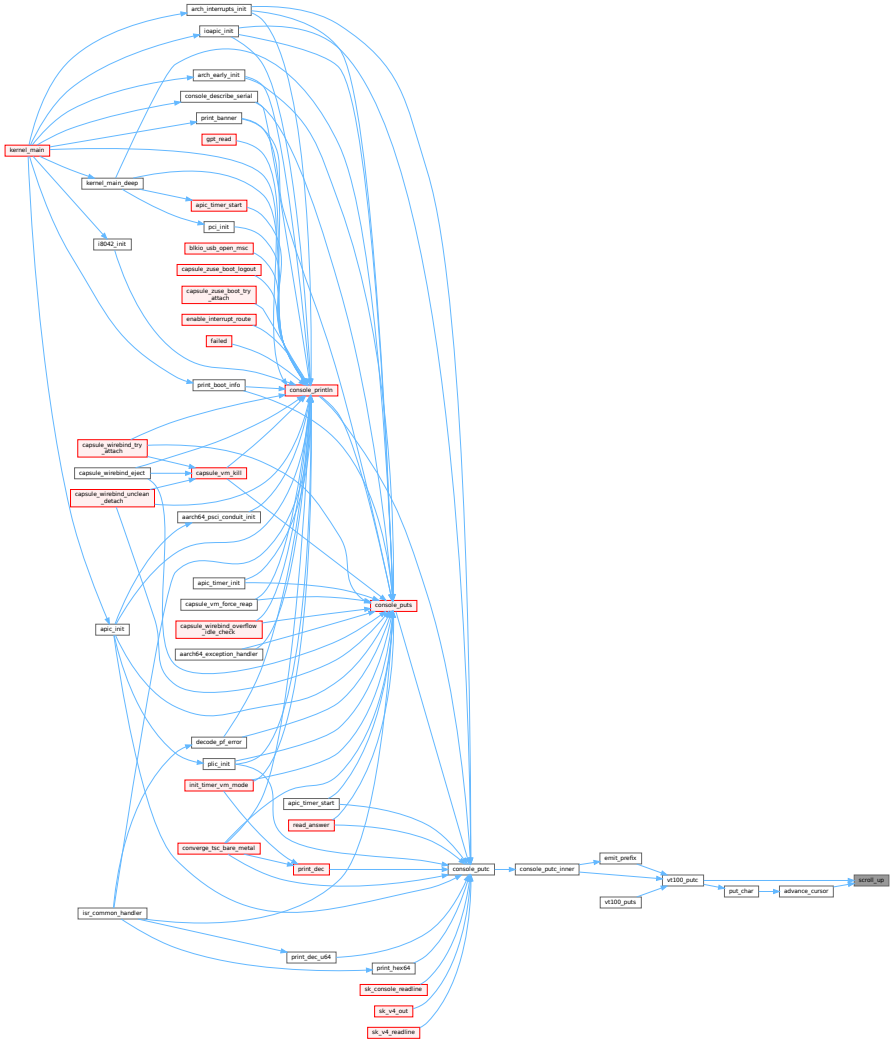
References cell_h(), VT100State::cols, VT100State::def_bg, fb_scroll_rows(), g_line_stride, g_ring, g_ring_cap, g_ring_count, g_ring_head, g_shadow, g_terminal_visible, g_vt, and VT100State::rows.

Referenced by advance_cursor(), and vt100_putc().

Here is the call graph for this function:



Here is the caller graph for this function:



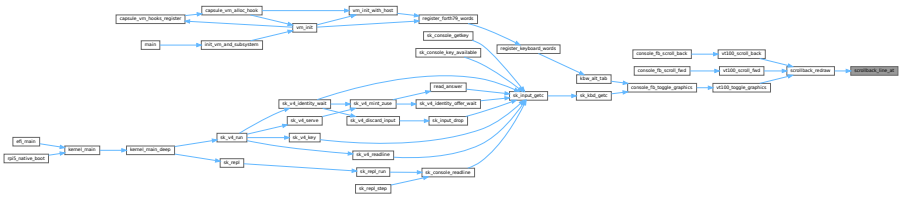
7.158.3.20 scrollback_line_at()

```
static const char * scrollback_line_at (
            uint32_t idx )  [static]
```

References g_boot_line_stride, g_boot_ring, g_boot_ring_cap, g_boot_ring_count, g_boot_ring_head, g_boot_rows, g_boot_shadow, g_line_stride, g_ring, g_ring_cap, g_ring_count, g_ring_head, g_shadow, g_vt, and VT100State::rows.

Referenced by scrollback_redraw().

Here is the caller graph for this function:



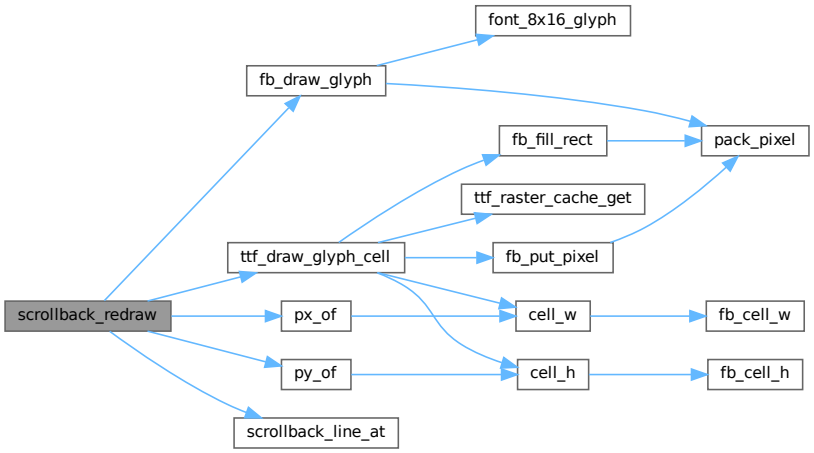
7.158.3.21 scrollback_redraw()

```
static void scrollback_redraw (
            void  )  [static]
```

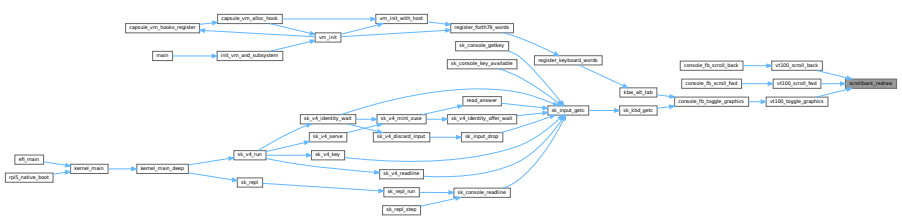
References VT100State::cols, VT100State::def_bg, VT100State::def_fg, fb_draw_glyph(), g_boot_ring_count, g_boot_rows, g_glyph_mode, g_ring_count, g_scroll_offset, g_vt, px_of(), py_of(), VT100State::rows, scrollback_line_at(), ttf_draw_glyph_cell(), and VT_GLYPH_TTF.

Referenced by vt100_scroll_back(), vt100_scroll_fwd(), and vt100_toggle_graphics().

Here is the call graph for this function:



Here is the caller graph for this function:



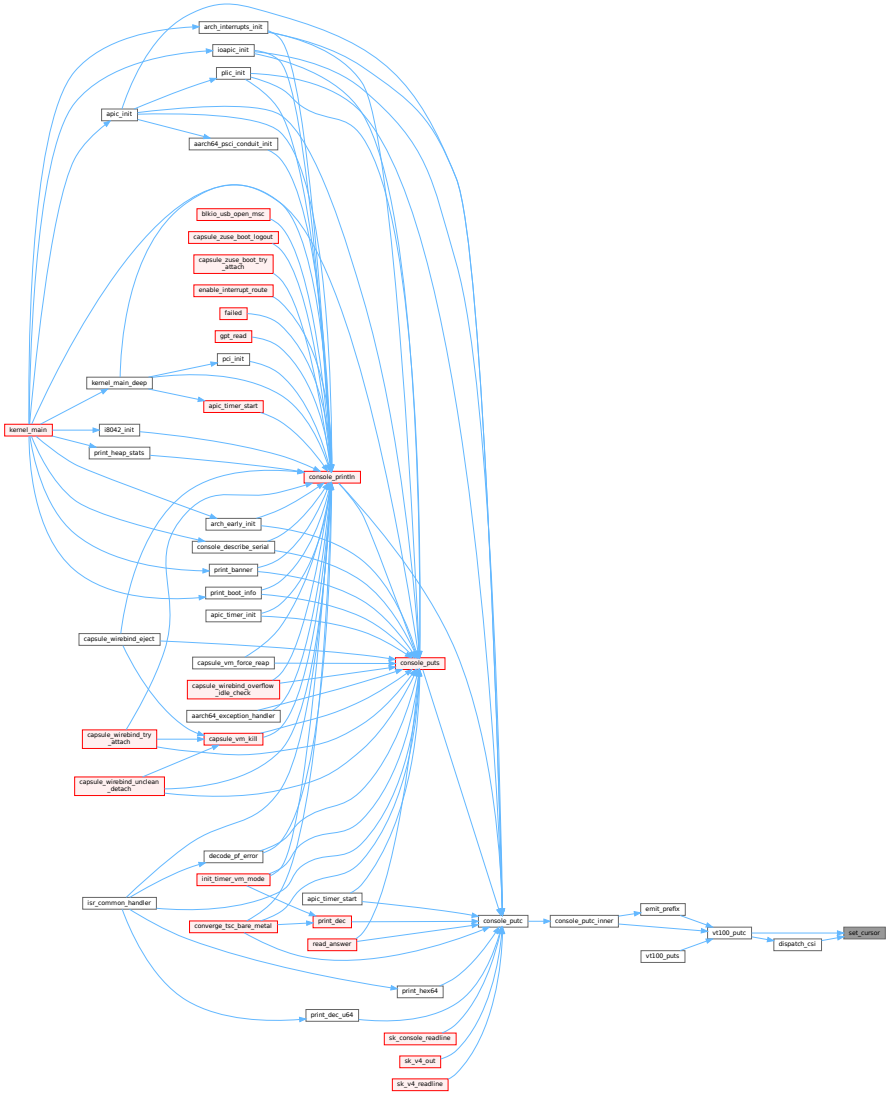
7.158.3.22 set_cursor()

```
static void set_cursor (
            uint32_t row,
            uint32_t col )  [static]
```

References VT100State::cols, VT100State::cx, VT100State::cy, g_vt, and VT100State::rows.

Referenced by dispatch_csi(), and vt100_putc().

Here is the caller graph for this function:



7.158.3.23 ttf_draw_glyph_cell()

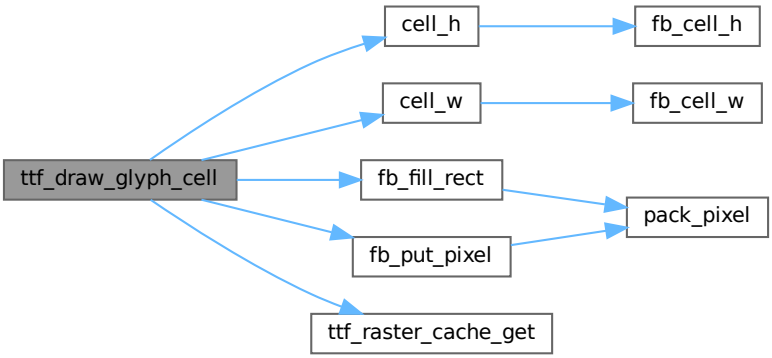
```
static void ttf_draw_glyph_cell (
            uint32_t cell_px,
            uint32_t cell_py,
```

```
    uint8_t ch,
    uint32_t fg,
    uint32_t bg )  [static]
```

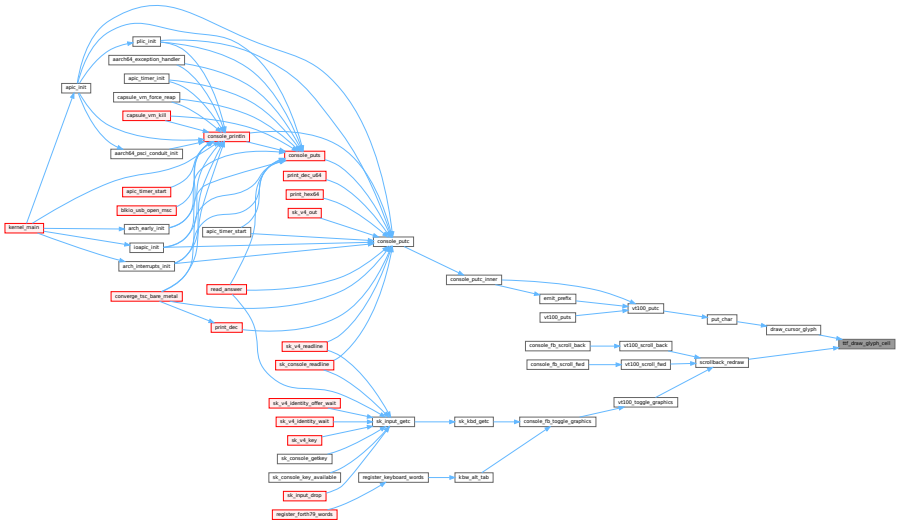
References cell_h(), cell_w(), fb_fill_rect(), fb_put_pixel(), g_ttf_cache, g_ttf_font, g_ttf_ready, ttf_bitmap_t::height, ttf_bitmap_t::pixels, TTF_CACHE_MARGIN, TTF_OK, ttf_raster_cache_get(), VT100_TTF_SIZE_PX, and ttf_bitmap_t::width.

Referenced by draw_cursor_glyph(), and scrollback_redraw().

Here is the call graph for this function:



Here is the caller graph for this function:



7.158.3.24 vt100_cols()

```
uint32_t vt100_cols (
            void  )
```

Terminal width in character columns.

References VT100State::cols, and g_vt.

7.158.3.25 vt100_draw_cursor()

```
void vt100_draw_cursor (
            void  )
```

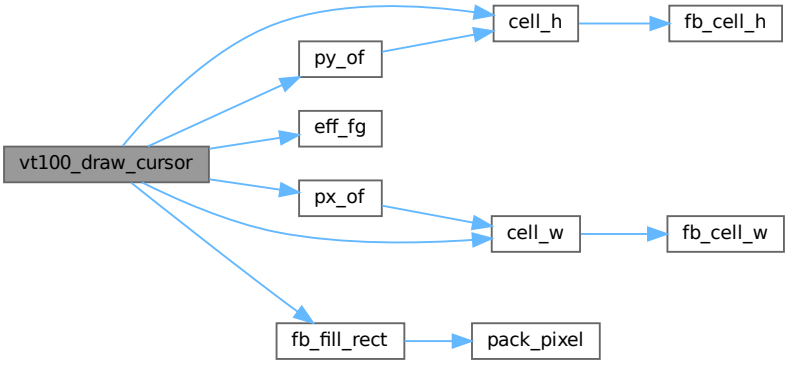
Draw a solid block cursor at the terminal's current position.

Static, not blinking. Idempotent – safe to call after every keystroke, since whatever gets typed next naturally overwrites it. No-op before TTF mode is active or while in graphics mode (vt100_toggle_graphics()).

References cell_h(), cell_w(), VT100State::cx, VT100State::cy, eff_fg(), fb_fill_rect(), g_glyph_mode, g_terminal_visible, g_vt, px_of(), py_of(), and VT_GLYPH_TTF.

Referenced by console_fb_draw_cursor().

Here is the call graph for this function:



Here is the caller graph for this function:

7.158.3.26 vt100_enable_ttf()

```
void vt100_enable_ttf (
            void  )
```

FABRIC-0.md item 4.4j: switch the glyph-draw backend from font_8x16.c to TTF-TEXT's rasterizer for everything drawn from this call onward – boot/POST output before this call stays font_8x16.c, unaffected.

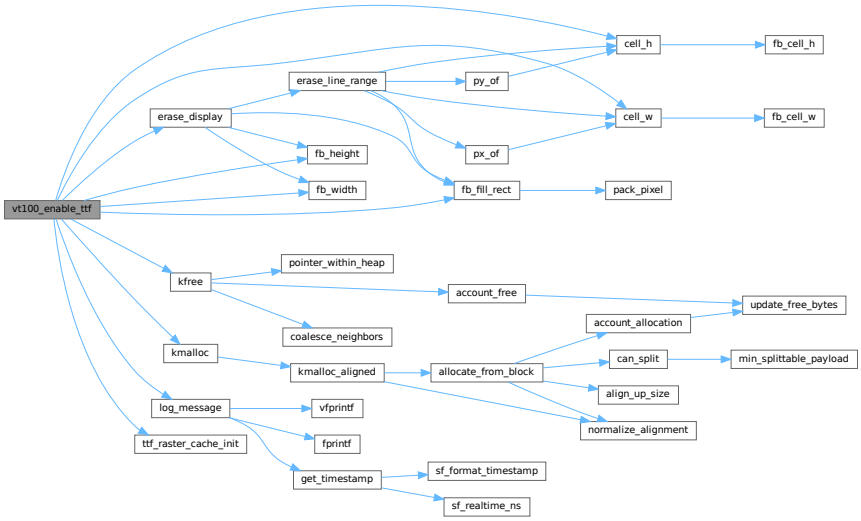
Lazily loads the font capsule and its raster cache on first call (no-op on later calls). Recomputes cols/rows for the new cell size and clears the screen, since the two glyph backends use different cell dimensions. TTF point size/cell

dimensions decided final by FABRIC-0.md item 4.4m (20px text, 96px REPL strip). No-op if the font capsule fails to load (stays on font_8x16.c; logged, not fatal).

References cell_h(), cell_w(), VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, erase_display(), fb_fill_rect(), fb_height(), fb_width(), g_boot_line_stride, g_boot_ring, g_boot_ring_cap, g_boot_ring_count, g_boot_ring_head, g_boot_rows, g_boot_shadow, g_glyph_mode, g_line_stride, g_ring, g_ring_cap, g_ring_count, g_ring_head, g_scroll_offset, g_shadow, g_ttf_cache, g_ttf_font, g_ttf_ready, g_vt, VT100State::initialized, kfree(), kmalloc(), LOG_ERROR, log_message(), VT100State::rows, slots, TTF_OK, ttf_raster_cache_init(), VT100_SCROLLBACK_MAX_LINES, VT100_TTF_CACHE_SLOTS, VT100_TTF_FONT_CAPSULE, and VT_GLYPH_TTF.

Referenced by console_fb_enable_ttf().

Here is the call graph for this function:



Here is the caller graph for this function:

7.158.3.27 vt100_erase_cursor()

```
void vt100_erase_cursor (
            void  )
```

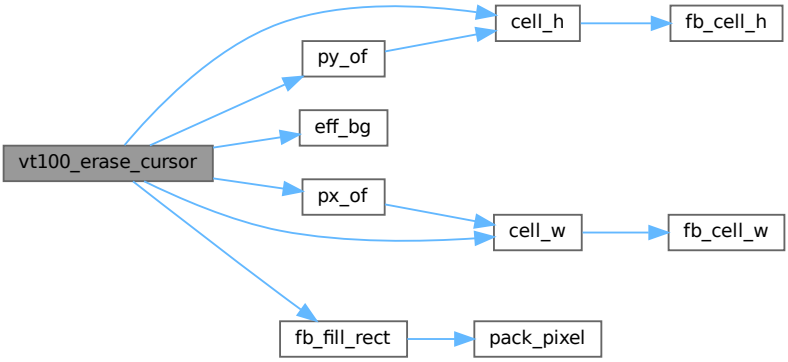
Erases whatever vt100_draw_cursor() last drew, restoring the cell to plain background.

Call before moving away from a cursor-drawn cell without also drawing a character there (e.g. Enter/newline). No-op before TTF mode is active or while in graphics mode.

References cell_h(), cell_w(), VT100State::cx, VT100State::cy, eff_bg(), fb_fill_rect(), g_glyph_mode, g_terminal_visible, g_vt, px_of(), py_of(), and VT_GLYPH_TTF.

Referenced by console_fb_erase_cursor().

Here is the call graph for this function:



Here is the caller graph for this function:

7.158.3.28 vt100_init()

```
void vt100_init (
            void  )
```

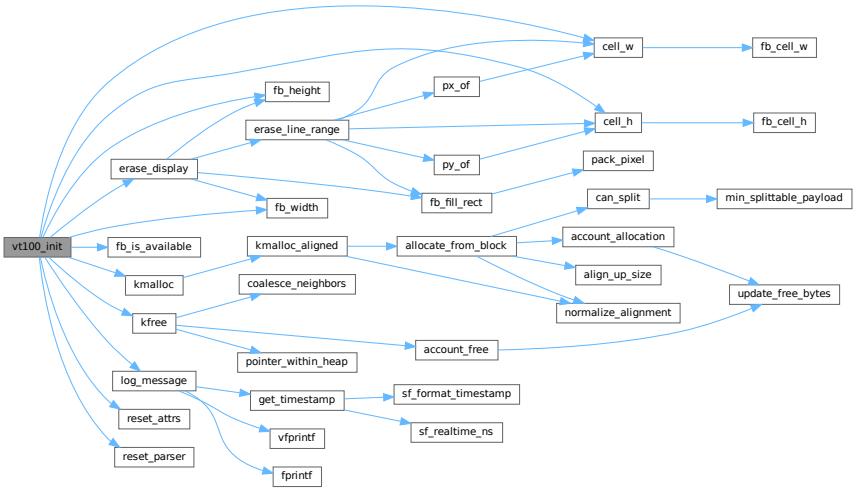
Initialize the VT100 terminal.

Must be called after fb_init(). Clears the screen and homes the cursor.

References cell_h(), cell_w(), VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, VT100State::def_fg, erase_display(), fb_height(), fb_is_available(), fb_width(), g_line_stride, g_ring, g_ring_cap, g_ring_count, g_ring_head, g_shadow, g_vt, VT100State::initialized, kfree(), kmalloc(), LOG_ERROR, log_message(), reset_attrs(), reset_parser(), VT100State::rows, VT100State::saved_cx, VT100State::saved_cy, VT100_BOOT_SCROLLBACK_MAX_LINES, VT100_DEFAULT_BG, and VT100_DEFAULT_FG.

Referenced by console_fb_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.158.3.29 vt100_putc()

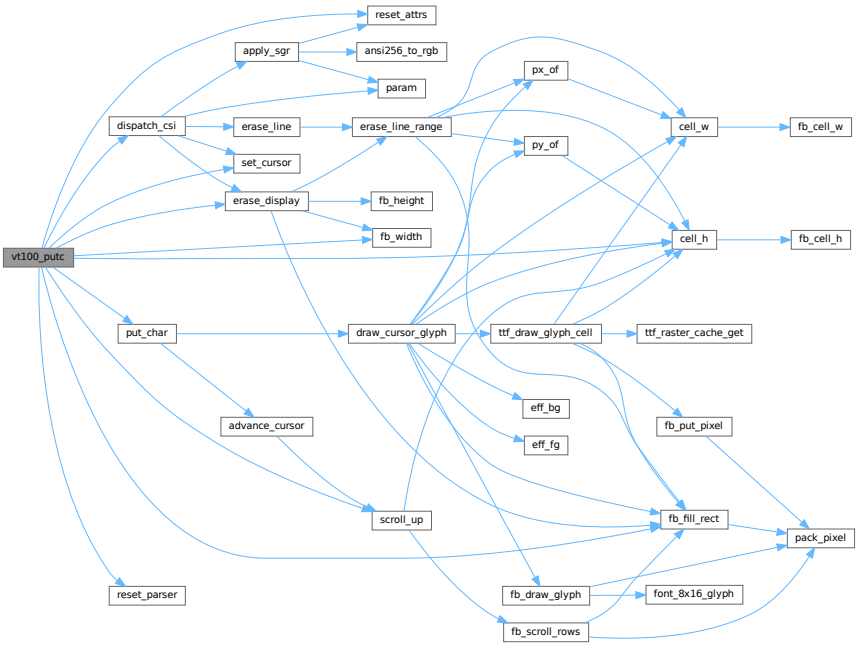
```
void vt100_putc (
            char raw )
```

Feed one byte into the terminal (handles escape sequences transparently).

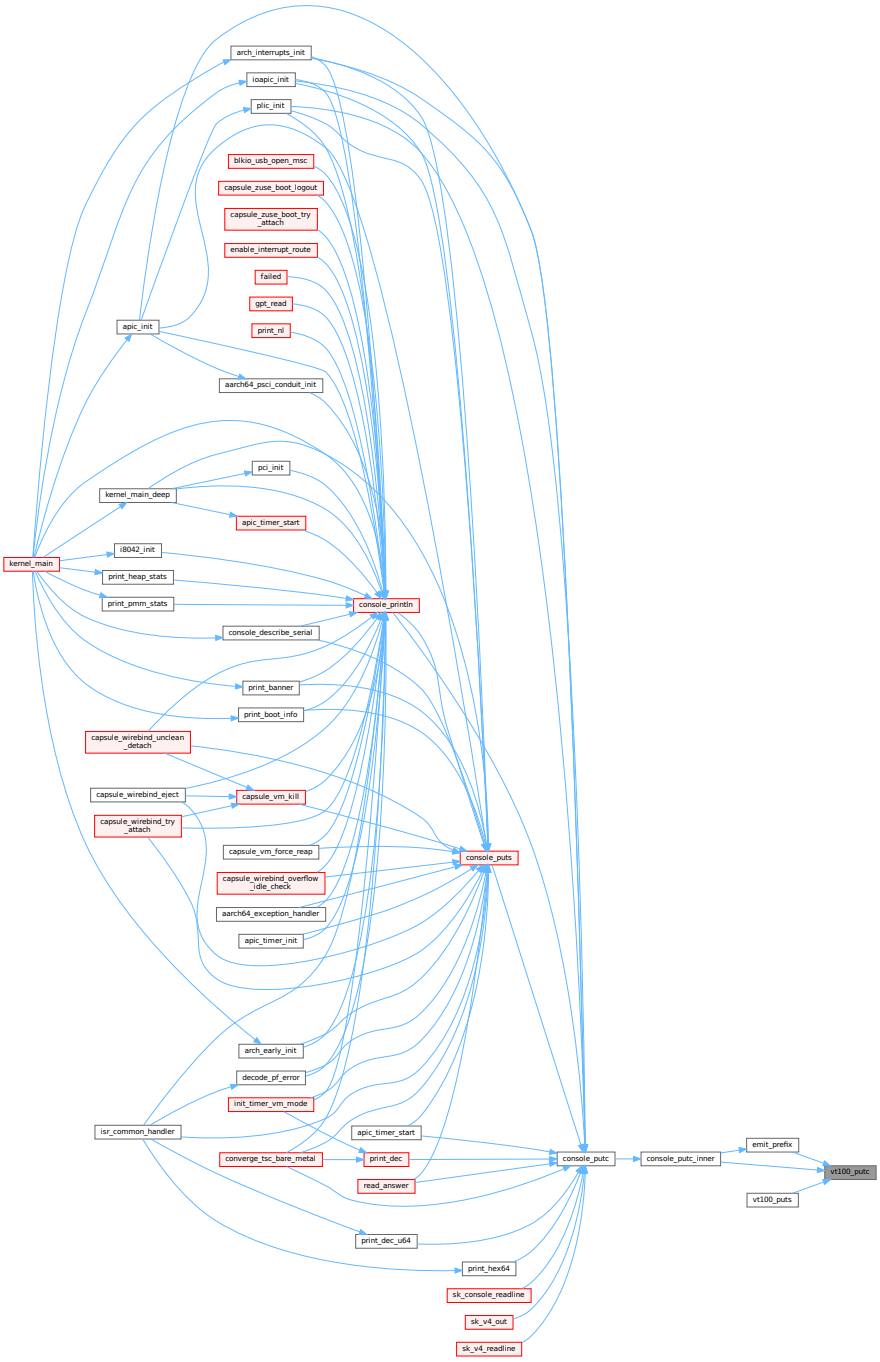
References cell_h(), VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, dispatch_csi(), erase_display(), fb_fill_rect(), fb_width(), g_vt, VT100State::initialized, VT100State::param_count, VT100State::param_has_value, VT100State::params, put_char(), reset_attrs(), reset_parser(), VT100State::rows, VT100State::saved_cx, VT100State::saved_cy, scroll_up(), set_cursor(), ST_CSI, ST_ESC, ST_ESC_CHAR, ST_ESC_HASH, ST_NORMAL, VT100State::state, and VT100_MAX_PARAMS.

Referenced by console_putc_inner(), emit_prefix(), and vt100_puts().

Here is the call graph for this function:



Here is the caller graph for this function:



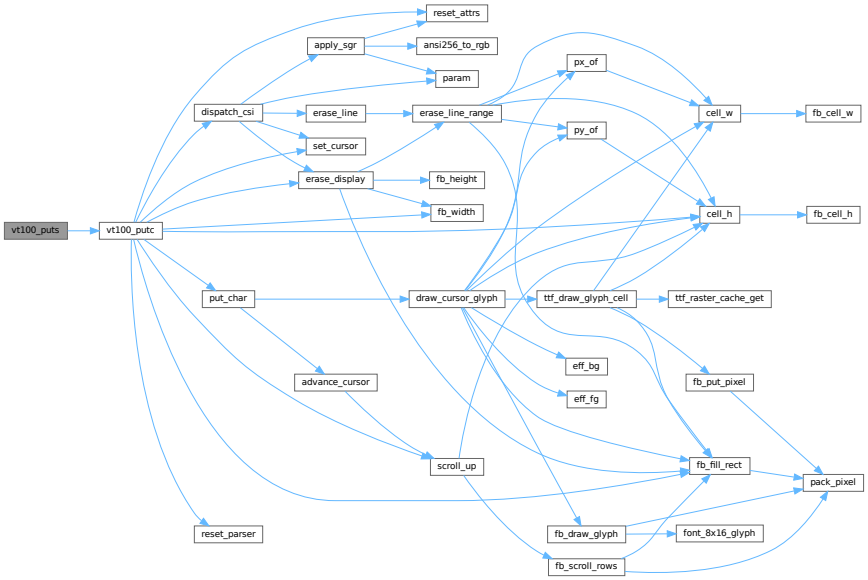
7.158.3.30 vt100_puts()

```
void vt100_puts (
            const char * s )
```

Feed a null-terminated string.

References vt100_putc().

Here is the call graph for this function:



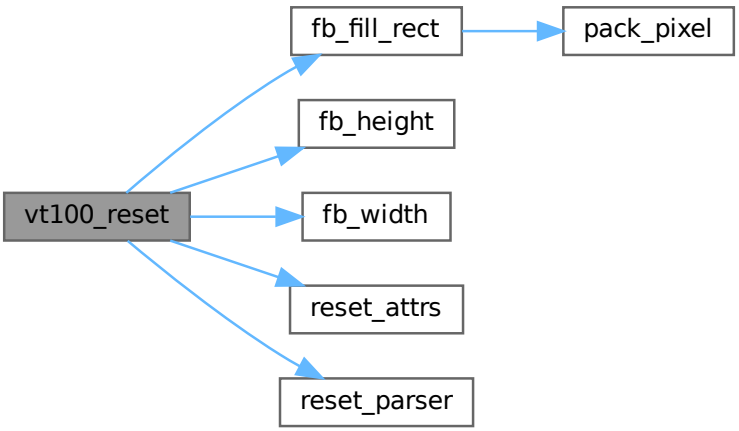
7.158.3.31 vt100_reset()

```
void vt100_reset (
            void  )
```

References VT100State::cols, VT100State::cx, VT100State::cy, VT100State::def_bg, fb_fill_rect(), fb_height(), fb_width(), g_boot_ring_count, g_boot_rows, g_line_stride, g_ring_count, g_ring_head, g_scroll_offset, g_shadow, g_terminal_visible, g_vt, VT100State::initialized, reset_attrs(), reset_parser(), VT100State::rows, VT100State::saved_cx, and VT100State::saved_cy.

Referenced by console_fb_clear().

Here is the call graph for this function:



Here is the caller graph for this function:

7.158.3.32 vt100_rows()

```
uint32_t vt100_rows (
            void  )
```

Terminal height in character rows.

References g_vt, and VT100State::rows.

7.158.3.33 vt100_scroll_back()

```
void vt100_scroll_back (
            uint32_t n )
```

FABRIC-0.md item 4.4q: move the REPL scrollback view back/forward by `n` lines and redraw.

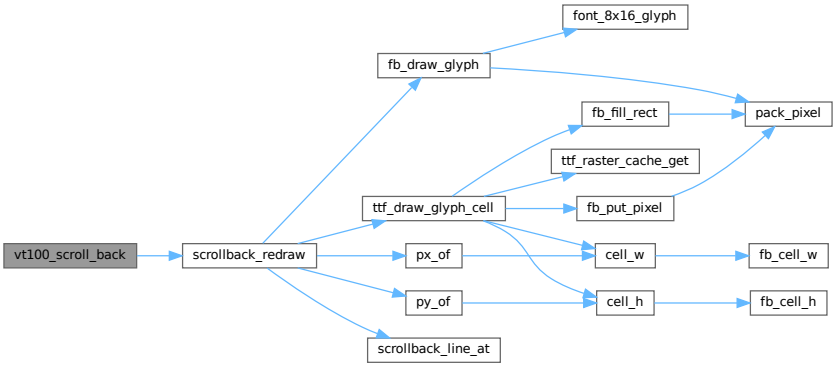
Offset 0 (the default, and where every call eventually returns to) is the live view – the same content already on screen. Clamped at both ends: back cannot pass the oldest stored line, forward cannot pass the live view. No-op (including no redraw) if the scrollback buffers failed to allocate at vt100_enable_ttf() time, or before TTF mode is active at all.

Known limitation: redraw uses the terminal's current default fg/bg, not each line's original SGR color state at the time it was printed (colors aren't stored per-cell) – text content is recovered exactly, color is not.

References g_boot_ring_count, g_boot_rows, g_ring, g_ring_count, g_scroll_offset, g_shadow, and scrollback_redraw().

Referenced by console_fb_scroll_back().

Here is the call graph for this function:



Here is the caller graph for this function:

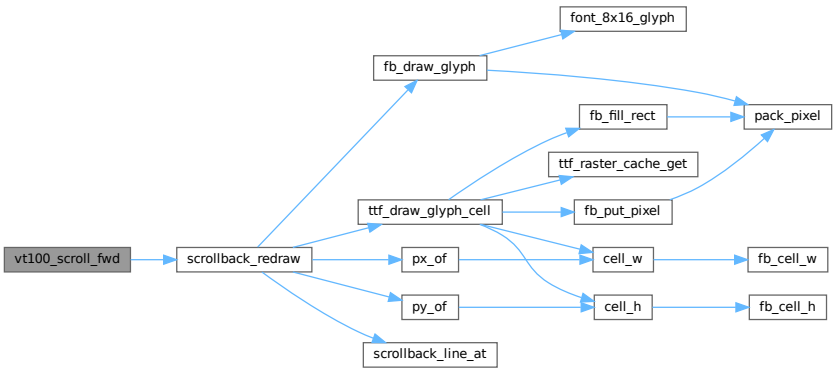
7.158.3.34 vt100_scroll_fwd()

```
void vt100_scroll_fwd (
            uint32_t n )
```

References g_ring, g_scroll_offset, g_shadow, and scrollback_redraw().

Referenced by console_fb_scroll_fwd().

Here is the call graph for this function:



Here is the caller graph for this function:

7.158.3.35 vt100_toggle_graphics()

```
void vt100_toggle_graphics (
            void  )
```

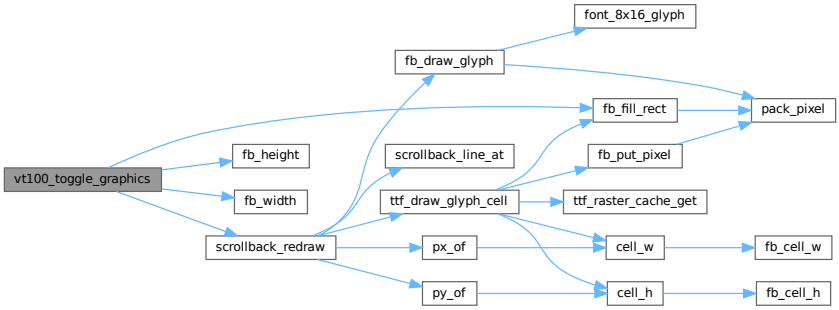
FABRIC-0.md item 4.4y-revised: toggle the full-screen vt100 terminal between visible (normal operation) and hidden (graphics mode – the terminal stops drawing, letting direct framebuffer/TTF-TEXT calls show through undisturbed).

Toggling back to visible does a full redraw of the terminal's current on-screen content, restoring it exactly as it was. No-op before TTF mode is active.

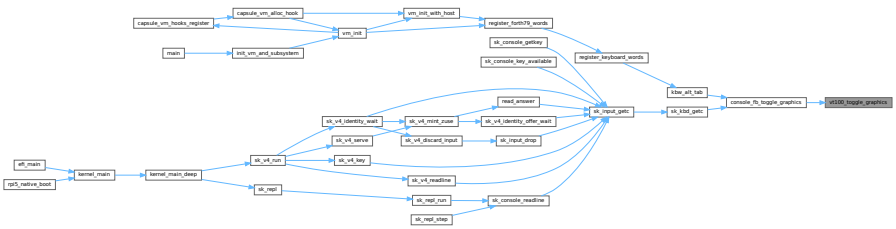
References VT100State::def_bg, fb_fill_rect(), fb_height(), fb_width(), g_glyph_mode, g_terminal_visible, g_ttf_ready, g_vt, scrollback_redraw(), and VT_GLYPH_TTF.

Referenced by console_fb_toggle_graphics().

Here is the call graph for this function:



Here is the caller graph for this function:



7.158.4 Variable Documentation

7.158.4.1 g_boot_line_stride

```
uint32_t g_boot_line_stride = 0  [static]
```

Referenced by scrollback_line_at(), and vt100_enable_ttf().

7.158.4.2 g_boot_ring

```
char* g_boot_ring = (void *)0  [static]
```

Referenced by scrollback_line_at(), and vt100_enable_ttf().

7.158.4.3 g_boot_ring_cap

```
uint32_t g_boot_ring_cap = 0  [static]
```

Referenced by scrollback_line_at(), and vt100_enable_ttf().

7.158.4.4 g_boot_ring_count

```
uint32_t g_boot_ring_count = 0  [static]
```

Referenced by scrollback_line_at(), scrollback_redraw(), vt100_enable_ttf(), vt100_reset(), and vt100_scroll_back().

7.158.4.5 g_boot_ring_head

```
uint32_t g_boot_ring_head = 0  [static]
```

Referenced by scrollback_line_at(), and vt100_enable_ttf().

7.158.4.6 g_boot_rows

```
uint32_t g_boot_rows = 0  [static]
```

Referenced by scrollback_line_at(), scrollback_redraw(), vt100_enable_ttf(), vt100_reset(), and vt100_scroll_back().

7.158.4.7 g_boot_shadow

```
char* g_boot_shadow = (void *)0  [static]
```

Referenced by scrollback_line_at(), and vt100_enable_ttf().

7.158.4.8 g_glyph_mode

```
vt_glyph_mode_t g_glyph_mode = VT_GLYPH_BITMAP  [static]
```

Referenced by cell_h(), cell_w(), draw_cursor_glyph(), scrollback_redraw(), vt100_draw_cursor(), vt100_enable_ttf(), vt100_erase_cursor(), and vt100_toggle_graphics().

7.158.4.9 g_line_stride

```
uint32_t g_line_stride = 0  [static]
```

Referenced by draw_cursor_glyph(), scroll_up(), scrollback_line_at(), vt100_enable_ttf(), vt100_init(), and vt100_reset().

7.158.4.10 g_ring

```
char* g_ring = (void *)0  [static]
```

Referenced by scroll_up(), scrollback_line_at(), vt100_enable_ttf(), vt100_init(), vt100_scroll_back(), and vt100_scroll_fwd().

7.158.4.11 g_ring_cap

```
uint32_t g_ring_cap = 0  [static]
```

Referenced by scroll_up(), scrollback_line_at(), vt100_enable_ttf(), and vt100_init().

7.158.4.12 g_ring_count

```
uint32_t g_ring_count = 0  [static]
```

Referenced by scroll_up(), scrollback_line_at(), scrollback_redraw(), vt100_enable_ttf(), vt100_init(), vt100_reset(), and vt100_scroll_back().

7.158.4.13 g_ring_head

```
uint32_t g_ring_head = 0  [static]
```

Referenced by scroll_up(), scrollback_line_at(), vt100_enable_ttf(), vt100_init(), and vt100_reset().

7.158.4.14 g_scroll_offset

```
uint32_t g_scroll_offset = 0  [static]
```

Referenced by scrollback_redraw(), vt100_enable_ttf(), vt100_reset(), vt100_scroll_back(), and vt100_scroll_fwd().

7.158.4.15 g_shadow

```
char* g_shadow = (void *)0  [static]
```

Referenced by draw_cursor_glyph(), scroll_up(), scrollback_line_at(), vt100_enable_ttf(), vt100_init(), vt100_reset(), vt100_scroll_back(), and vt100_scroll_fwd().

7.158.4.16 g_terminal_visible

```
int g_terminal_visible = 1  [static]
```

Referenced by draw_cursor_glyph(), erase_display(), erase_line_range(), scroll_up(), vt100_draw_cursor(), vt100_erase_cursor(), vt100_reset(), and vt100_toggle_graphics().

7.158.4.17 g_ttf_cache

```
ttf_raster_cache_t g_ttf_cache  [static]
```

Referenced by ttf_draw_glyph_cell(), and vt100_enable_ttf().

7.158.4.18 g_ttf_font

```
ttf_font_t g_ttf_font  [static]
```

Referenced by ttf_draw_glyph_cell(), and vt100_enable_ttf().

7.158.4.19 g_ttf_ready

```
int g_ttf_ready = 0  [static]
```

Referenced by ttf_draw_glyph_cell(), vt100_enable_ttf(), and vt100_toggle_graphics().

7.158.4.20 g_vt

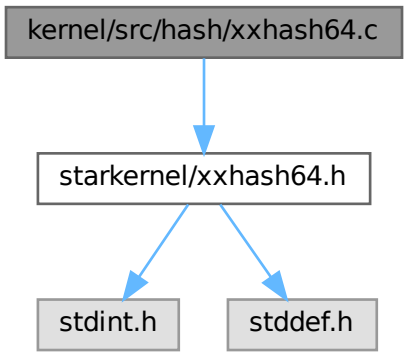
```
VT100State g_vt  [static]
```

Referenced by advance_cursor(), apply_sgr(), dispatch_csi(), draw_cursor_glyph(), eff_bg(), eff_fg(), erase_display(), erase_line(), erase_line_range(), param(), reset_attrs(), reset_parser(), scroll_up(), scrollback_line_at(), scrollback_redraw(), set_cursor(), vt100_cols(), vt100_draw_cursor(), vt100_enable_ttf(), vt100_erase_cursor(), vt100_init(), vt100_putc(), vt100_reset(), vt100_rows(), and vt100_toggle_graphics().

7.159 kernel/src/hash/xxhash64.c File Reference

```
#include "starkernel/xxhash64.h"
```

Include dependency graph for xxhash64.c:



Macros

- #define XXHASH64_PRIME1 0x9E3779B185EBCA87ULL
  xxhash64.c - Freestanding xxHash64 Implementation
- #define XXHASH64_PRIME2 0xC2B2AE3D27D4EB4FULL
- #define XXHASH64_PRIME3 0x165667B19E3779F9ULL
- #define XXHASH64_PRIME4 0x85EBCA77C2B2AE63ULL
- #define XXHASH64_PRIME5 0x27D4EB2F165667C5ULL

Functions

- static uint64_t xxh64_rotl (uint64_t x, int r)
  Rotate left 64-bit.
- static uint64_t xxh64_read64 (const uint8_t *p)
  Read 64-bit little-endian (unaligned safe)
- static uint32_t xxh64_read32 (const uint8_t *p)
  Read 32-bit little-endian (unaligned safe)
- static uint64_t xxh64_round (uint64_t acc, uint64_t input)
  Round function.
- static uint64_t xxh64_merge_round (uint64_t acc, uint64_t val)
  Merge accumulator.
- static uint64_t xxh64_avalanche (uint64_t h)
  Avalanche finalization.
- uint64_t xxhash64 (const void *data, size_t len, uint64_t seed)
  xxhash64 - Compute xxHash64 of a buffer
- void xxhash64_reset (XXHash64State *state, uint64_t seed)
  xxhash64_reset - Initialize streaming state
- void xxhash64_update (XXHash64State *state, const void *data, size_t len)
  xxhash64_update - Feed data into streaming hash
- uint64_t xxhash64_digest (const XXHash64State *state)
  xxhash64_digest - Finalize and get hash value

7.159.1 Macro Definition Documentation

7.159.1.1 XXHASH64_PRIME1

```
#define XXHASH64_PRIME1 0x9E3779B185EBCA87ULL
```

xxhash64.c - Freestanding xxHash64 Implementation

Based on xxHash by Yann Collet (BSD-2-Clause). Adapted for freestanding kernel use - no libc dependency.

xxHash is an extremely fast non-cryptographic hash algorithm. https://github.com/Cyan4973/xx↩Hash

7.159.1.2 XXHASH64_PRIME2

```
#define XXHASH64_PRIME2 0xC2B2AE3D27D4EB4FULL
```

7.159.1.3 XXHASH64_PRIME3

```
#define XXHASH64_PRIME3 0x165667B19E3779F9ULL
```

7.159.1.4 XXHASH64_PRIME4

```
#define XXHASH64_PRIME4 0x85EBCA77C2B2AE63ULL
```

7.159.1.5 XXHASH64_PRIME5

```
#define XXHASH64_PRIME5 0x27D4EB2F165667C5ULL
```

7.159.2 Function Documentation

7.159.2.1 xxh64_avalanche()

```
static uint64_t xxh64_avalanche (
            uint64_t h )  [inline], [static]
```

Avalanche finalization.

References XXHASH64_PRIME2, and XXHASH64_PRIME3.

Referenced by xxhash64(), and xxhash64_digest().

Here is the caller graph for this function:

7.159.2.2 xxh64_merge_round()

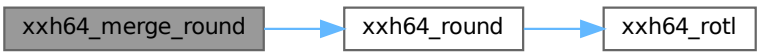
```
static uint64_t xxh64_merge_round (
            uint64_t acc,
            uint64_t val )  [inline], [static]
```

Merge accumulator.

References xxh64_round(), XXHASH64_PRIME1, and XXHASH64_PRIME4.

Referenced by xxhash64(), and xxhash64_digest().

Here is the call graph for this function:



Here is the caller graph for this function:

7.159.2.3 xxh64_read32()

```
static uint32_t xxh64_read32 (
            const uint8_t * p )  [inline], [static]
```

Read 32-bit little-endian (unaligned safe)

Referenced by xxhash64(), and xxhash64_digest().

Here is the caller graph for this function:

7.159.2.4 xxh64_read64()

```
static uint64_t xxh64_read64 (
            const uint8_t * p )  [inline], [static]
```

Read 64-bit little-endian (unaligned safe)

Referenced by xxhash64(), xxhash64_digest(), and xxhash64_update().

Here is the caller graph for this function:

7.159.2.5 xxh64_rotl()

```
static uint64_t xxh64_rotl (
            uint64_t x,
            int r )  [inline], [static]
```

Rotate left 64-bit.

Referenced by xxh64_round(), xxhash64(), and xxhash64_digest().

Here is the caller graph for this function:

7.159.2.6 xxh64_round()

```
static uint64_t xxh64_round (
            uint64_t acc,
            uint64_t input )  [inline], [static]
```

Round function.

References xxh64_rotl(), XXHASH64_PRIME1, and XXHASH64_PRIME2.

Referenced by xxh64_merge_round(), xxhash64(), xxhash64_digest(), and xxhash64_update().

Here is the call graph for this function:

Here is the caller graph for this function:

7.159.2.7 xxhash64()

```
uint64_t xxhash64 (
            const void * data,
            size_t len,
            uint64_t seed )
```

xxhash64 - Compute xxHash64 of a buffer

Parameters

data	Input data
len	Length in bytes
seed	Hash seed (use XXHASH64_CAPSULE_SEED for capsules)

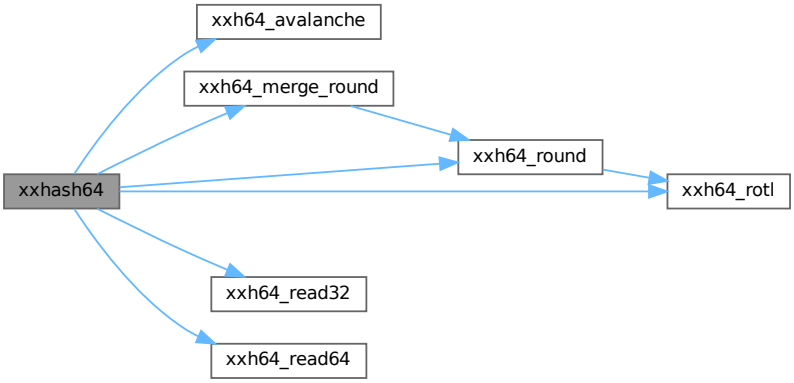
Returns

64-bit hash value

References limit, v1, v2, xxh64_avalanche(), xxh64_merge_round(), xxh64_read32(), xxh64_read64(), xxh64_rotl(), xxh64_round(), XXHASH64_PRIME1, XXHASH64_PRIME2, XXHASH64_PRIME3, XXHASH64_PRIME4, and XXHASH64_PRIME5.

Referenced by xxhash64_capsule().

Here is the call graph for this function:



Here is the caller graph for this function:

7.159.2.8 xxhash64_digest()

```
uint64_t xxhash64_digest (
            const XXHash64State * state )
```

xxhash64_digest - Finalize and get hash value

Parameters

state	Streaming state

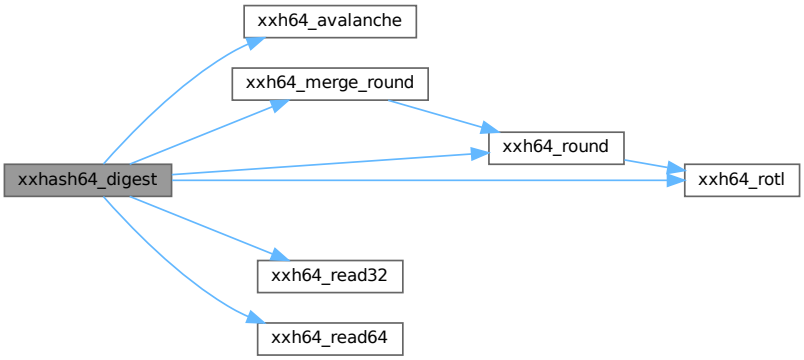
Returns

64-bit hash value

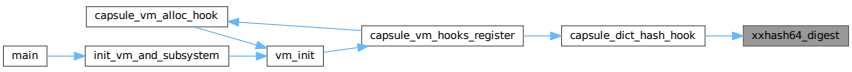
References XXHash64State::buffer, XXHash64State::buffer_size, XXHash64State::seed, XXHash64State::total_len, XXHash64State::v1, XXHash64State::v2, XXHash64State::v3, XXHash64State::v4, xxh64_avalanche(), xxh64_merge_round(), xxh64_read32(), xxh64_read64(), xxh64_rotl(), xxh64_round(), XXHASH64_PRIME1, XXHASH64_PRIME2, XXHASH64_PRIME3, XXHASH64_PRIME4, and XXHASH64_PRIME5.

Referenced by capsule_dict_hash_hook().

Here is the call graph for this function:



Here is the caller graph for this function:



7.159.2.9 xxhash64_reset()

```
void xxhash64_reset (
            XXHash64State * state,
            uint64_t seed )
```

xxhash64_reset - Initialize streaming state

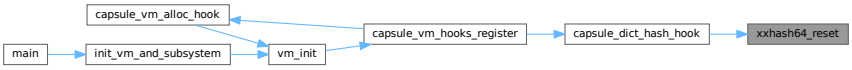
Parameters

state	State to initialize
seed	Hash seed

References XXHash64State::buffer_size, XXHash64State::seed, XXHash64State::total_len, XXHash64State::v1, XXHash64State::v2, XXHash64State::v3, XXHash64State::v4, XXHASH64_PRIME1, and XXHASH64_PRIME2.

Referenced by capsule_dict_hash_hook().

Here is the caller graph for this function:



7.159.2.10 xxhash64_update()

```
void xxhash64_update (
            XXHash64State * state,
            const void * data,
            size_t len )
```

xxhash64_update - Feed data into streaming hash

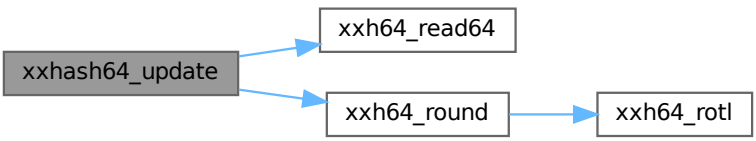
Parameters

state	Streaming state
data	Input data
len	Length in bytes

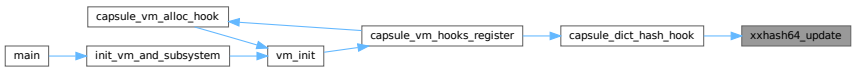
References XXHash64State::buffer, XXHash64State::buffer_size, limit, XXHash64State::total_len, XXHash64State::v1, XXHash64State::v2, XXHash64State::v3, XXHash64State::v4, xxh64_read64(), and xxh64_round().

Referenced by capsule_dict_hash_hook().

Here is the call graph for this function:



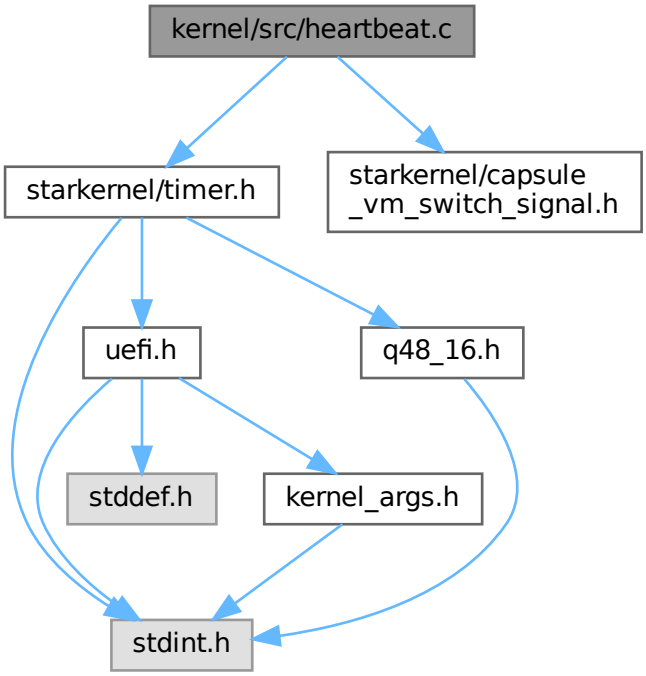
Here is the caller graph for this function:



7.160 kernel/src/heartbeat.c File Reference

```
#include "starkernel/timer.h"
#include "starkernel/capsule_vm_switch_signal.h"
```

Include dependency graph for heartbeat.c:



Macros

- #define HEARTBEAT_HAS_VARIANCE 0

  heartbeat.c - Shared M5 heartbeat / TIME-TRUST engine (punch-list item 0.8)
- #define HEARTBEAT_BASE_PERIOD_NS 10000000ULL

Functions

- void heartbeat_init (uint64_t tsc_hz, uint64_t tick_hz)

  Initialise the M5 heartbeat / TIME-TRUST subsystem.
- void heartbeat_tick (void)

  Top half.
- void heartbeat_service (void)

  Bottom half (punch-list item 0.8).
- uint64_t heartbeat_ticks (void)

  Get current TIME-TICKS (monotonic heartbeat count).
- time_trust_t heartbeat_trust (void)

  Get current TIME-TRUST (Q48.16 confidence metric).
- const TimeTrustState * heartbeat_state (void)

  Get pointer to full heartbeat state (for diagnostics).
- void heartbeat_set_adaptive_period_ns (uint64_t ns)

  Set the adaptive re-arm period (FABRIC-0.md ?26).
- uint64_t heartbeat_next_period_ns (void)

  Read the period the next hardware re-arm should use.

Variables

- static TimeTrustState g_heartbeat
- static volatile uint64_t g_pending_counter
- static volatile int g_pending_valid
- static volatile uint64_t g_adaptive_period_ns = 10000000ULL

7.160.1 Macro Definition Documentation

7.160.1.1 HEARTBEAT_BASE_PERIOD_NS

```
#define HEARTBEAT_BASE_PERIOD_NS 10000000ULL
```

7.160.1.2 HEARTBEAT_HAS_VARIANCE

```
#define HEARTBEAT_HAS_VARIANCE 0
```

heartbeat.c - Shared M5 heartbeat / TIME-TRUST engine (punch-list item 0.8)

One implementation of heartbeat_init()/heartbeat_ticks()/heartbeat_trust()/ heartbeat_state(), shared by all three architectures. Each architecture's timer.c contributes only heartbeat_read_counter() — the one thing that is genuinely per-ISA (rdtsc / rdtime / CNTPCT_EL0).

Top half / bottom half split (FABRIC-0.md ?25.1 item 0.8, per the GAP-A1 ruling in ?16.4/?18.4): heartbeat_tick() is called from interrupt context and does nothing but read the counter, bump TIME-TICKS, and latch a pending sample. heartbeat_service() runs on the mainline (the REPL idle loop) and does the window/variance/trust work. Neither one feeds patron state — the engine stays on the virtual tick per ?18.4, unchanged by this file.

Adaptive re-arm period (FABRIC-0.md ?26, ruled 2026-08-03): Loop #7 (vm_runtime.c) computes an execution-derived stable/volatile signal and calls heartbeat_set_adaptive_period_ns() with it, rescaled to this file's kernel-appropriate base (10 ms, matching the 100 Hz rate item 0.1-0.7 configured) rather than the hosted 10 ?s HEARTBEAT_TICK_NS base. Each architecture's re-arm function reads heartbeat_next_period_ns() and converts it to raw counter units instead of using a fixed constant. Single writer (mainline, via vm_tick()'s Loop #7 site), single reader (the ISR's re-arm call) — no lock needed, per ?21.1's finding that nothing here is actually concurrent on one hart.

7.160.2 Function Documentation

7.160.2.1 heartbeat_init()

```
void heartbeat_init (
            uint64_t tsc_hz,
            uint64_t tick_hz )
```

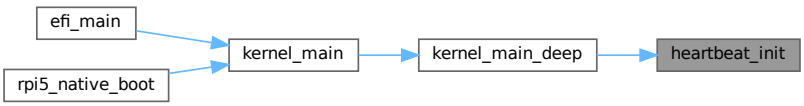
Initialise the M5 heartbeat / TIME-TRUST subsystem.

Shared across all three architectures – the fallback and calibration formula never differed between them, only what heartbeat_service() does with the resulting window did.

References time_window::count, time_window::deltas, time_trust_state::expected_delta, g_adaptive_period_ns, g_heartbeat, g_pending_valid, HEARTBEAT_BASE_PERIOD_NS, time_trust_state::last_tsc, time_window::pos, Q48_ONE, time_trust_state::ticks, TIME_WINDOW_SIZE, time_trust_state::total_samples, time_trust_state::trust, time_trust_state::variance, and time_trust_state::window.

Referenced by kernel_main_deep().

Here is the caller graph for this function:



7.160.2.2 heartbeat_next_period_ns()

```
uint64_t heartbeat_next_period_ns (
            void  )
```

Read the period the next hardware re-arm should use.

Called from interrupt context by each architecture's re-arm function (apic_timer_rearm(), riscv64_timer_rearm(), the AArch64 equivalent) in place of the fixed constant those functions used before item 0.8.

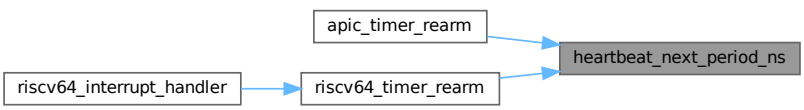
Returns

Current adaptive period in nanoseconds.

References g_adaptive_period_ns.

Referenced by apic_timer_rearm(), and riscv64_timer_rearm().

Here is the caller graph for this function:



7.160.2.3 heartbeat_service()

```
void heartbeat_service (
            void  )
```

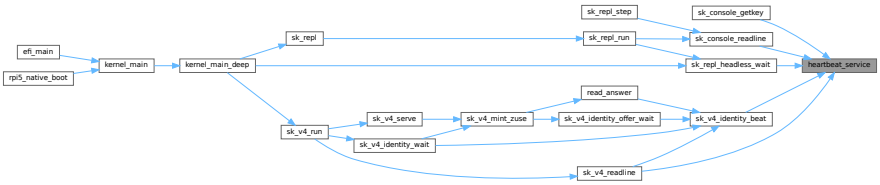
Bottom half (punch-list item 0.8).

Services one pending sample if `heartbeat_tick()` has latched one since the last call: computes the inter-tick deviation, updates the rolling window, and (architecture permitting – see `heartbeat.c`) recomputes variance and TIME-TRUST. Never runs in interrupt context. Call from the mainline, as frequently as convenient – a stale/skipped service call degrades the window's fidelity but affects nothing else, since TIME-TRUST is diagnostic only and never gates execution.

References time_trust_state::expected_delta, g_heartbeat, g_pending_counter, g_pending_valid, time_trust_state::last_tsc, Q48_ONE, time_trust_state::total_samples, time_trust_state::trust, time_trust_state::variance, and time_trust_state::window.

Referenced by sk_console_getkey(), sk_console_readline(), sk_repl_headless_wait(), sk_v4_identity_beat(), and sk_v4_readline().

Here is the caller graph for this function:



7.160.2.4 heartbeat_set_adaptive_period_ns()

```
void heartbeat_set_adaptive_period_ns (
            uint64_t ns )
```

Set the adaptive re-arm period (FABRIC-0.md ?26).

Set the adaptive re-arm period, in nanoseconds (punch-list item 0.8, FABRIC-0.md ?26).

Called from vm_runtime.c's Loop #7 site on the mainline execution path (never interrupt context) with a value already rescaled to this file's HEARTBEAT_BASE_PERIOD_NS. Clamped defensively to the same [1/4x, 4x] band Loop #7 itself enforces around its own base, so a caller forwarding an unclamped or wrongly-scaled value cannot run the ISR away.

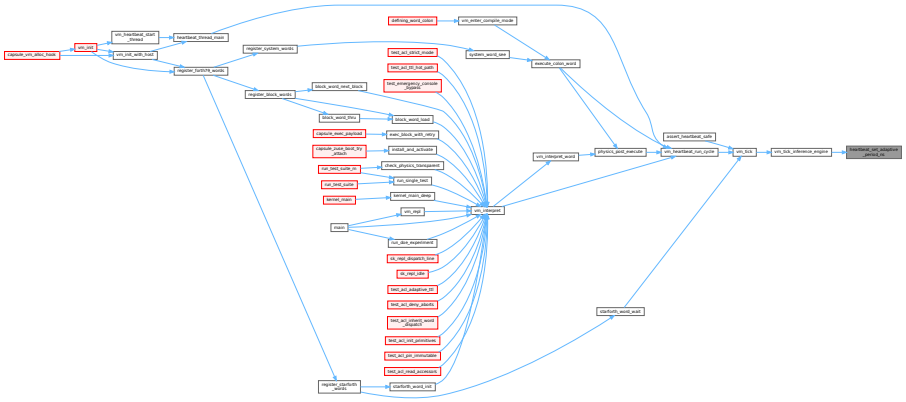
Parameters

ns	Desired period in nanoseconds for the next re-arm.

References g_adaptive_period_ns, and HEARTBEAT_BASE_PERIOD_NS.

Referenced by vm_tick_inference_engine().

Here is the caller graph for this function:



7.160.2.5 heartbeat_state()

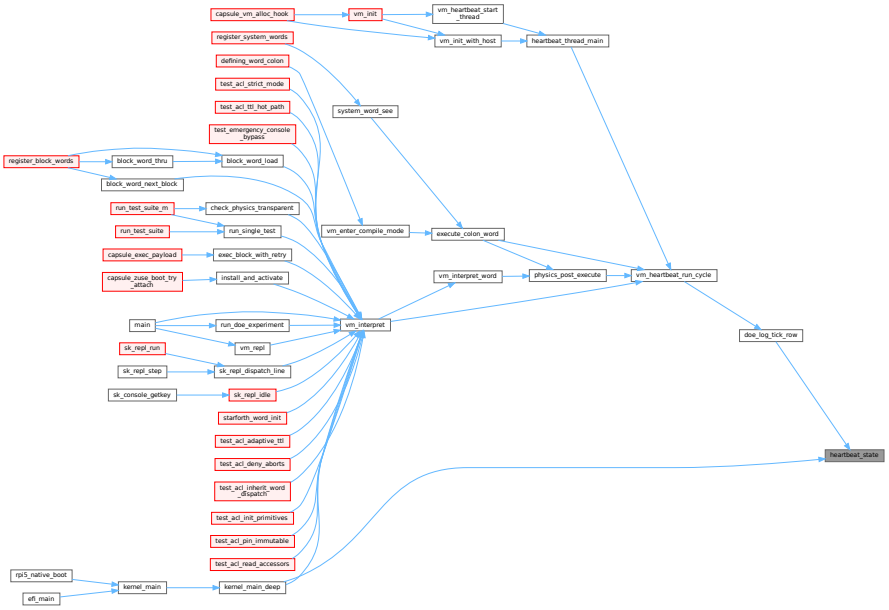
```
const TimeTrustState * heartbeat_state (
            void  )
```

Get pointer to full heartbeat state (for diagnostics).

References g_heartbeat.

Referenced by doe_log_tick_row(), and kernel_main_deep().

Here is the caller graph for this function:



7.160.2.6 heartbeat_tick()

```
void heartbeat_tick (
            void  )
```

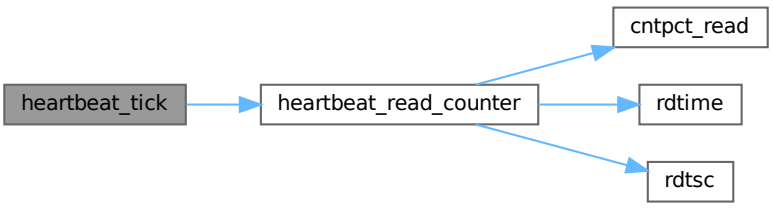
Top half.

Called directly from each architecture's ISR (punch-list item 0.8) – one call site per architecture, unchanged from before this item. Does exactly three things: reads the raw counter via `heartbeat_read_counter()`, increments TIME-TICKS, and latches the sample for `heartbeat_service()` to pick up. No window math, no variance, no loops – this must stay cheap enough for interrupt context.

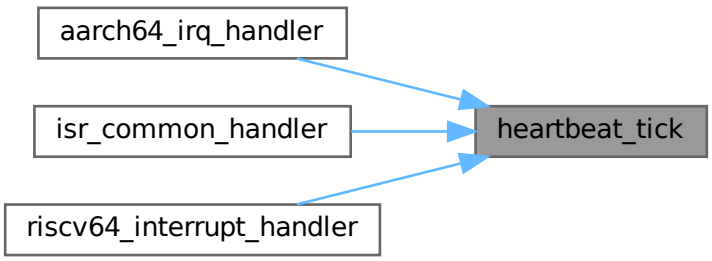
References g_heartbeat, g_pending_counter, g_pending_valid, heartbeat_read_counter(), and time_trust_state::ticks.

Referenced by aarch64_irq_handler(), isr_common_handler(), and riscv64_interrupt_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.160.2.7 heartbeat_ticks()

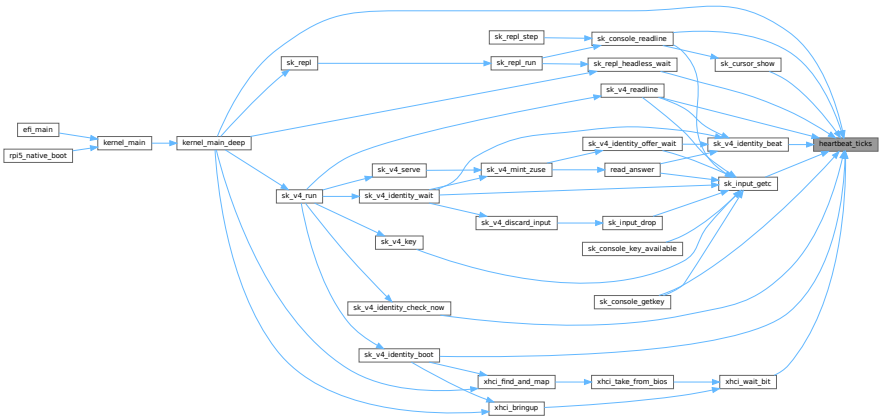
```
uint64_t heartbeat_ticks (
            void  )
```

Get current TIME-TICKS (monotonic heartbeat count).

References g_heartbeat, and time_trust_state::ticks.

Referenced by kernel_main_deep(), sk_console_getkey(), sk_console_readline(), sk_cursor_show(), sk_input_getc(), sk_repl_headless_wait(), sk_v4_identity_beat(), sk_v4_identity_boot(), sk_v4_identity_check_now(), sk_v4_readline(), and xhci_wait_bit().

Here is the caller graph for this function:



7.160.2.8 heartbeat_trust()

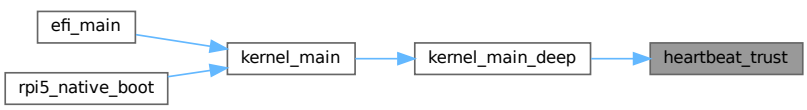
```
time_trust_t heartbeat_trust (
            void  )
```

Get current TIME-TRUST (Q48.16 confidence metric).

References g_heartbeat, and time_trust_state::trust.

Referenced by kernel_main_deep().

Here is the caller graph for this function:



7.160.3 Variable Documentation

7.160.3.1 g_adaptive_period_ns

```
volatile uint64_t g_adaptive_period_ns = 10000000ULL  [static]
```

Referenced by heartbeat_init(), heartbeat_next_period_ns(), and heartbeat_set_adaptive_period_ns().

7.160.3.2 g_heartbeat

```
TimeTrustState g_heartbeat  [static]
```

Referenced by heartbeat_init(), heartbeat_service(), heartbeat_state(), heartbeat_tick(), heartbeat_ticks(), and heartbeat_trust().

7.160.3.3 g_pending_counter

```
volatile uint64_t g_pending_counter  [static]
```

Referenced by heartbeat_service(), and heartbeat_tick().

7.160.3.4 g_pending_valid

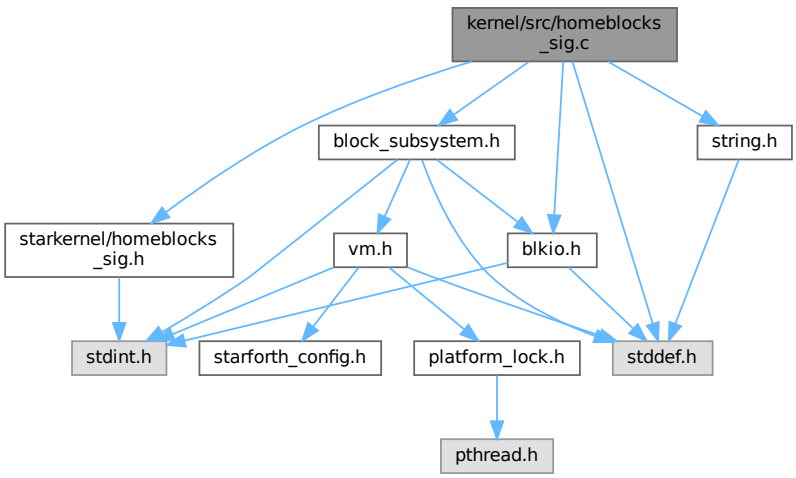
```
volatile int g_pending_valid  [static]
```

Referenced by heartbeat_init(), heartbeat_service(), and heartbeat_tick().

7.161 kernel/src/homeblocks_sig.c File Reference

```
#include "starkernel/homeblocks_sig.h"
#include <stddef.h>
#include <string.h>
#include "blkio.h"
#include "block_subsystem.h"
```

Include dependency graph for homeblocks_sig.c:



Functions

- uint64_t homeblocks_sig_compute_crc (const homeblocks_sig_t *sig)

  homeblocks_sig.c - Drive signature check (FABRIC-2.md, Milestone 4).
- homeblocks_sig_result_t homeblocks_sig_check (struct blkio_dev *dev, uint32_t sig_start_fblock, homeblocks_sig_t *out_sig)

7.161.1 Function Documentation

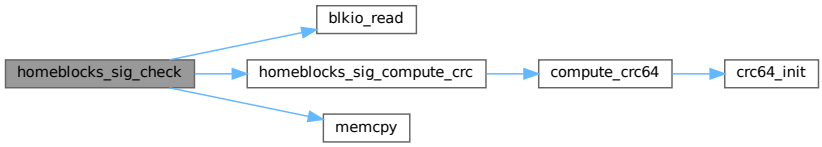
7.161.1.1 homeblocks_sig_check()

```
homeblocks_sig_result_t homeblocks_sig_check (
            struct blkio_dev * dev,
            uint32_t sig_start_fblock,
            homeblocks_sig_t * out_sig )
```

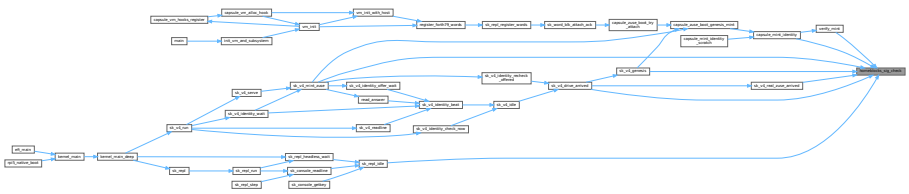
References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_read(), homeblocks_sig_t::hdr_crc, HOMEBLOCKS_SIG_BAD_CRC, HOMEBLOCKS_SIG_BAD_VERSION, HOMEBLOCKS_SIG_BLANK, homeblocks_sig_compute_crc(), HOMEBLOCKS_SIG_GET_M HOMEBLOCKS_SIG_GET_VERSION, HOMEBLOCKS_SIG_MAGIC, HOMEBLOCKS_SIG_OK, HOMEBLOCKS_SIG_READ_ERR HOMEBLOCKS_SIG_VERSION_0, homeblocks_sig_t::magic, and memcpy().

Referenced by capsule_mint_identity(), sk_repl_idle(), sk_v4_drive_arrived(), sk_v4_genesis(), sk_v4_mint_zuse(), sk_v4_real_zuse_arrived(), and verify_mint().

Here is the call graph for this function:



Here is the caller graph for this function:



7.161.1.2 homeblocks_sig_compute_crc()

```
uint64_t homeblocks_sig_compute_crc (
            const homeblocks_sig_t * sig )
```

homeblocks_sig.c - Drive signature check (FABRIC-2.md, Milestone 4).

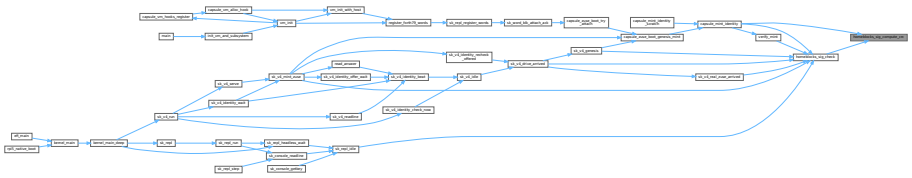
See starkernel/homeblocks_sig.h for the format and interface design.

References compute_crc64().

Referenced by capsule_mint_identity(), and homeblocks_sig_check().

Here is the call graph for this function:

Here is the caller graph for this function:

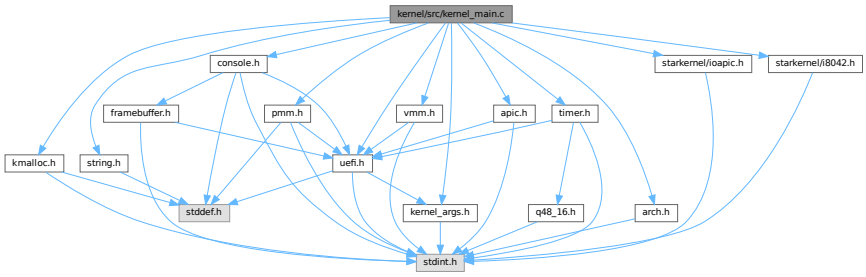


7.162 kernel/src/kernel_main.c File Reference

```
#include <string.h>
#include "uefi.h"
#include "console.h"
#include "arch.h"
#include "pmm.h"
#include "vmm.h"
#include "apic.h"
#include "timer.h"
#include "starkernel/ioapic.h"
#include "starkernel/i8042.h"
#include "kmalloc.h"
```

```
#include "starkernel/kernel_args.h"
```

Include dependency graph for kernel_main.c:



Functions

- static void kernel_main_deep (BootInfo *boot_info)

  Deep kernel initialisation — M5 heartbeat, M7 VM bootstrap, and REPL.
- static int is_ram_type (uint32_t type)

  Return non-zero if the EFI memory type represents usable or reclaimable RAM.
- static void itoa_simple (uint64_t value, char *buf, int base)

  Convert a `uint64_t` to a NUL-terminated string in the given base.
- static void print_uint (const char *label, uint64_t value)

  Print an optional label followed by a `uint64_t` in decimal to the console.
- static void print_boot_info (BootInfo *boot_info)

  Print a boot-information summary from the UEFI memory map to the console.
- static void print_pmm_stats (void)

  Print Physical Memory Manager statistics to the kernel console.
- static void print_heap_stats (void)

  Print kernel heap (kmalloc) statistics to the kernel console.
- static void print_banner (void)

  Print the StarKernel ASCII-art banner and build metadata to the console.
- void kernel_main (BootInfo *boot_info)

  Main kernel entry point after UEFI handoff — executes milestones M0–M6.

Variables

- EFI_RUNTIME_SERVICES * g_sk_runtime_services = NULL

  kernel_main.c - StarKernel main entry point (LithosAnanke branch)

7.162.1 Function Documentation

7.162.1.1 is_ram_type()

```
static int is_ram_type (
            uint32_t type )  [static]
```

Return non-zero if the EFI memory type represents usable or reclaimable RAM.

Covers all UEFI memory types that either are immediately usable by the PMM or can be reclaimed once Boot Services have exited:

- EfiConventionalMemory — general purpose RAM.
- EfiLoaderCode / EfiLoaderData — UEFI loader pages (reclaimed post-EBS).
- EfiBootServicesCode / EfiBootServicesData — boot-service pages (reclaimed post-EBS).
- EfiRuntimeServicesCode / EfiRuntimeServicesData — pages the firmware still uses for runtime calls (kept mapped, counted as physical RAM).
- EfiACPIReclaimMemory — ACPI tables; may be freed after OS has parsed them.
- EfiACPIMemoryNVS — non-volatile ACPI storage; kept reserved but is RAM.

Returns 0 for all device-memory, MMIO, persistent-memory, and special types. Used by print_boot_info() to compute the total physical RAM visible in the EFI memory map.

Parameters

type	EFI_MEMORY_TYPE value from an EFI_MEMORY_DESCRIPTOR.

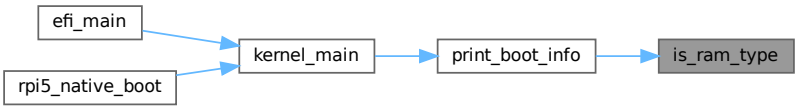
Returns

Non-zero if the type is RAM; 0 otherwise.

References EfiACPIMemoryNVS, EfiACPIReclaimMemory, EfiBootServicesCode, EfiBootServicesData, EfiConventionalMemory, EfiLoaderCode, EfiLoaderData, EfiRuntimeServicesCode, and EfiRuntimeServicesData.

Referenced by print_boot_info().

Here is the caller graph for this function:



7.162.1.2 itoa_simple()

```
static void itoa_simple (
            uint64_t value,
            char * buf,
            int base )  [static]
```

Convert a uint64_t to a NUL-terminated string in the given base.

Produces a freestanding (no libc) integer-to-string conversion for the kernel console paths. Handles bases 2–16; digits above 9 are lowercase alphabetic ('a'-'f' for hex). Special case: value == 0 writes the string "0" and returns immediately.

The algorithm builds the digit string in reverse order into a 64-byte local temp[] buffer, then reverses it into buf. buf must be at least 65 bytes to hold a 64-bit binary string plus NUL; in practice all callers pass 64-byte buffers and use base 10 or 16, where the maximum length is 20 or 16 digits respectively.

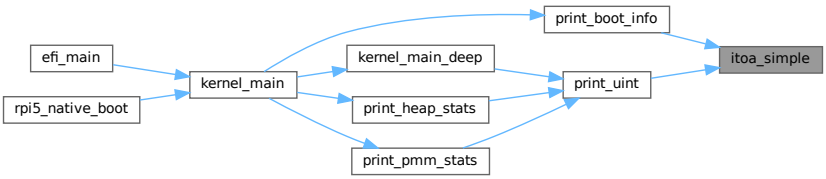
Parameters

value	Non-negative integer to convert.
buf	Caller-allocated output buffer (minimum 65 bytes for binary).
base	Numeric base (2–16).

References base.

Referenced by print_boot_info(), and print_uint().

Here is the caller graph for this function:



7.162.1.3 kernel_main()

```
void kernel_main (
            BootInfo * boot_info )
```

Main kernel entry point after UEFI handoff — executes milestones M0–M6.

On amd64 and riscv64, `kernel_entry.S` switches the stack from UEFI's default to a 2 MiB zero-initialised BSS stack and tail-calls this function as `kernel_main_impl`. On aarch64 the assembly trampoline is not yet implemented and the UEFI loader calls `kernel_main` directly.

Milestone sequence:

- **M0 — Architecture early init** (`arch_early_init()`): On amd64, installs a minimal GDT with a proper 64-bit code segment at selector 0x08 and reloads CS via `lretq`. Without this, UEFI's 64-bit segment at 0x38 is in scope and the ISR's `INT` gate (which expects CS 0x08) would fault silently.
- **M1 — Console** (`console_init()`): brings up UART 16550 at 115200 8N1 and the framebuffer VT100 terminal. Then prints banner and memory map.
- **M2 — PMM** (`pmm_init()`): initialises the physical memory manager's 4 KiB page bitmap from the EFI memory map.
- **M3 — VMM** (`vmm_init()`): builds 4-level x86-64 page tables, maps all conventional RAM at the kernel virtual base, and loads CR3.
- **M4 — IDT + APIC** (`arch_interrupts_init()` + `apic_init()`): programs the 64-entry IDT, masks the legacy 8259A PIC, and initialises the Local APIC in xAPIC MMIO mode at 0xFEE00000.
- **M5 — Timer** (`timer_init()`): calibrates the TSC and HPET.
- **M6 — Heap** (`kmalloc_init()`): initialises the kernel slab allocator with `heap_size` from the boot args or `KARGS_DEFAULT_HEAP_SIZE` (2 GiB).

Stashes `boot_info->runtime_services` in `g_sk_runtime_services` for later use by kernel FORTH words (e.g. `REBOOT`). Then tail-calls `kernel_main_deep()` for M7 and the REPL.

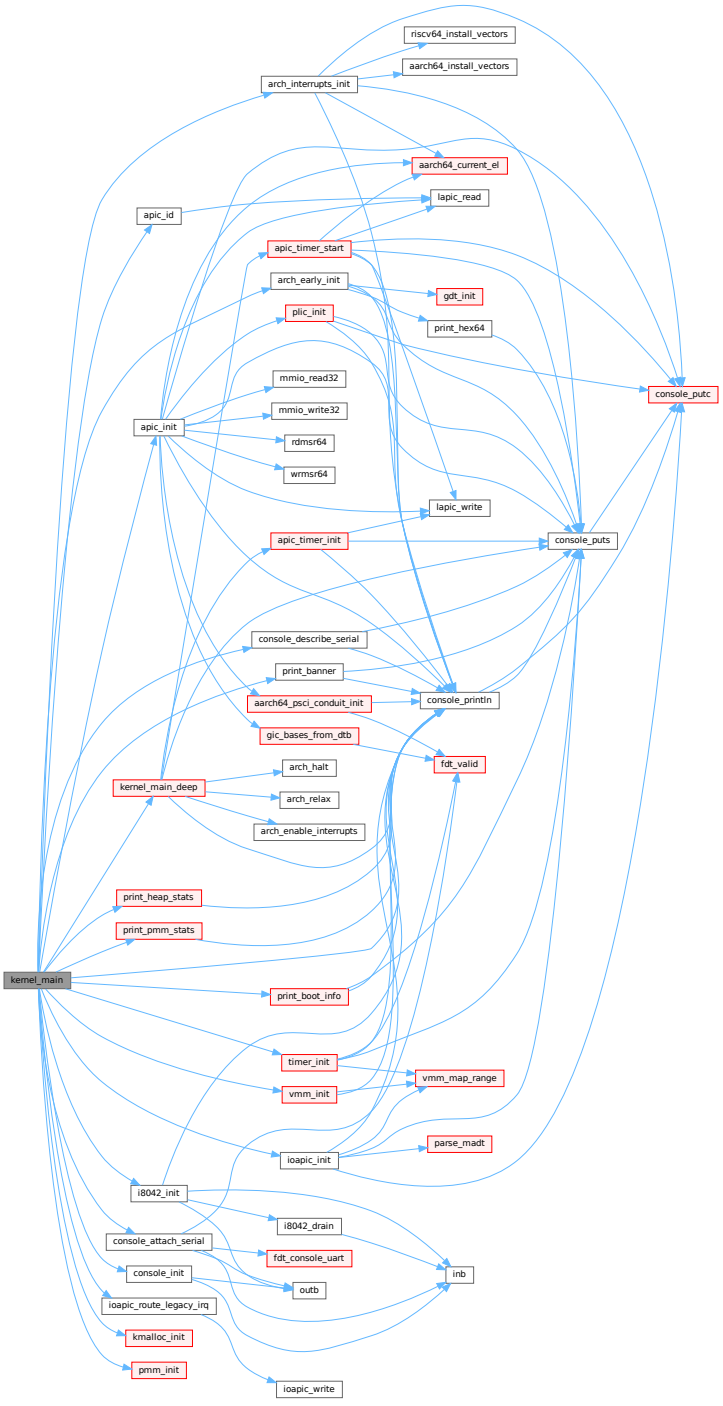
Parameters

boot_info	`BootInfo` populated by `uefi_loader.c` before `ExitBootServices()`; provides the memory map, ACPI pointer, framebuffer descriptor, runtime services pointer, and parsed kernel command-line arguments.

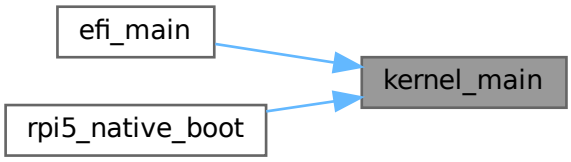
References BootInfo::acpi_table, apic_id(), apic_init(), arch_early_init(), arch_interrupts_init(), BootInfo::args, console_attach_serial(), console_describe_serial(), console_init(), console_println(), BootInfo::dtb, g_sk_runtime_services, KernelArgs::heap_size, i8042_init(), I8042_KEYBOARD_VECTOR, ioapic_init(), ioapic_route_legacy_irq(), KARGS_DEFAULT_HEAP_SIZE, kernel_main_deep(), kmalloc_init(), pmm_init(), print_banner(), print_boot_info(), print_heap_stats(), print_pmm_stats(), BootInfo::runtime_services, timer_init(), and vmm_init().

Referenced by efi_main(), and rpi5_native_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.162.1.4 kernel_main_deep()

```
static void kernel_main_deep (
            BootInfo * boot_info )  [static]
```

Deep kernel initialisation — M5 heartbeat, M7 VM bootstrap, and REPL.

Called as the final act of `kernel_main_impl()` / `kernel_main()` after all hardware milestones M0–M6 are complete. Runs on the 2 MiB BSS stack on amd64 (set up by `kernel_entry.S` before `kernel_main_impl()` was called) or the UEFI-provided stack on aarch64 and riscv64.

M5 — Heartbeat subsystem: Calls `apic_timer_init(tsc_hz, 100)` to configure the APIC timer for 100 Hz periodic delivery to vector 32, then `heartbeat_init(tsc_hz, 100)` to initialise the rolling-window heartbeat state.

M7 — VM bootstrap (when `STARFORTH_ENABLE_VM` is defined):

1. `sk_vm_bootstrap_parity()` — allocates the Mama VM and validates the capsule directory parity.
2. Allocates 1 MiB `blk_ram_buf` (LBN 0–991) and 1 MiB `krd_buf` (LBN 2048–3071 = capsule ramdrive) from `kmalloc`, then calls `capsule_blk_init()` to wire them into the Mama VM's block subsystem.
3. Copies the read-only `capsule_arena` to heap and calls `capsule_exec_init()` to load and execute `init.4th`.
4. Pins `CAPSULE-BIRTH` and `BIRTH` with `ACL_MODE_STRICT` via `vm_find_word()` so that ACL policy cannot downgrade them.

After M7, the APIC timer is started via `apic_timer_start()` and `arch_enable_interrupts()` enables IRQs.

REPL (when `STARFORTH_ENABLE_VM` is defined):

- If `boot_info->args.run_doe` is set, injects `"12345 3 EXEC-DOE BYE"` before the interactive REPL.
- If `SK_STARTUP_FORTH` is defined at build time, executes it as a compile-time startup script (lowest priority — overridden by `--doe`).
- Activates the framebuffer VT100 terminal (if the framebuffer descriptor is valid) so the REPL output appears on screen as well as the serial port.
- Clears the `StarForthRebootTries` NVRAM variable to signal a clean boot.
- Calls `sk_repl()` — the interactive FORTH REPL loop. Returns when the user executes `BYE` or `vm->halted` is set.

Terminates with an infinite `arch_halt()` idle loop regardless of the `STARFORTH_ENABLE_VM` build configuration.

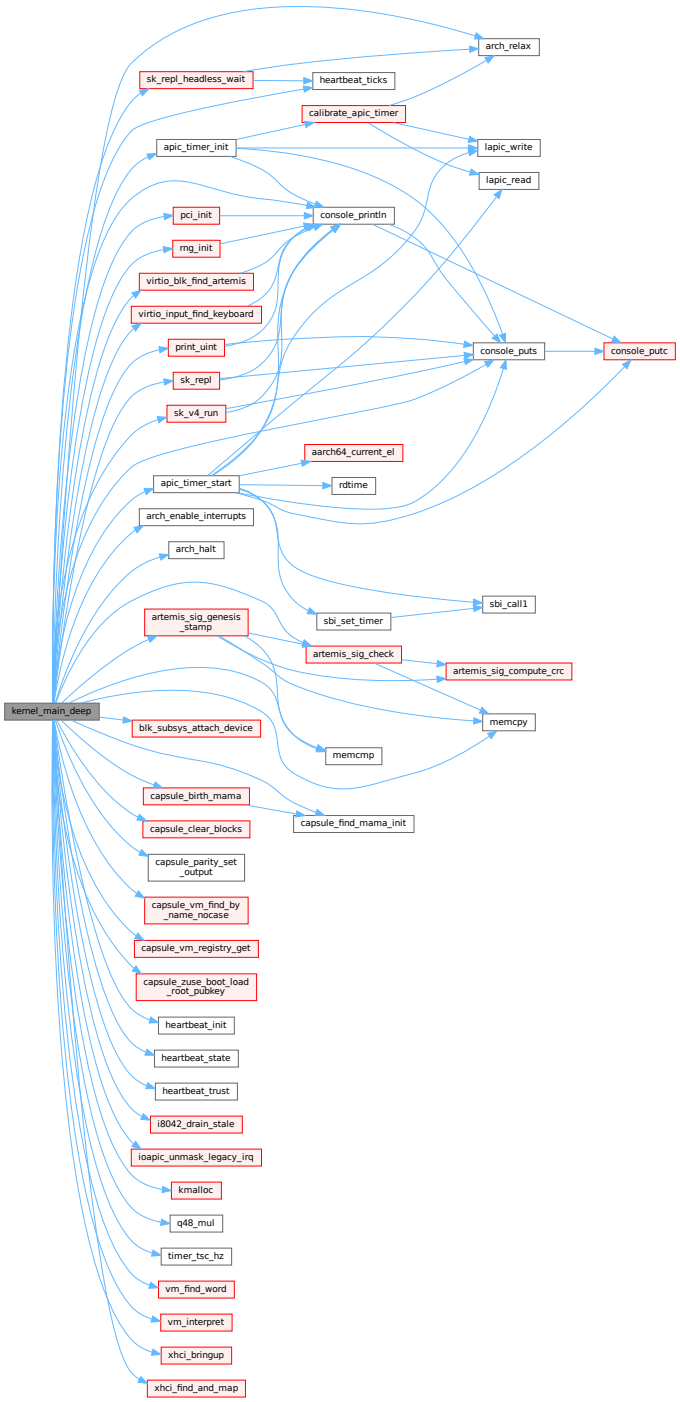
Parameters

boot_info	The `BootInfo` passed from `kernel_main_impl()`.

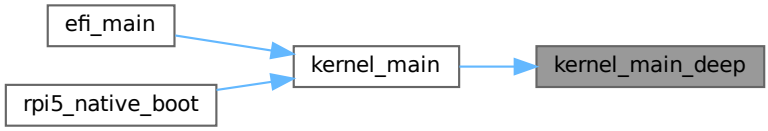
References DictEntry::acl_mode, ACL_MODE_STRICT, DictEntry::acl_pinned, BootInfo::acpi_table, apic_timer_init(), apic_timer_start(), arch_enable_interrupts(), arch_halt(), arch_relax(), CapsuleDirHeader::arena_base, CapsuleDirHeader::arena_siz BootInfo::args, ARTEMIS_SIG_BLANK, artemis_sig_check(), artemis_sig_genesis_stamp(), blk_subsys_attach_device(), BootInfo::boot_disk, capsule_birth_mama(), capsule_clear_blocks(), capsule_find_mama_init(), capsule_parity_set_output(), CAPSULE_RUN_OK, capsule_vm_find_by_name_nocase(), capsule_vm_registry_get(), capsule_zuse_boot_load_root_pubkey(), CapsuleDesc, console_println(), console_puts(), CapsuleDirHeader::desc_capacity, CapsuleDirHeader::desc_count, CapsuleDirHeader::dir_hash, EFI_VARIABLE_BOOTSERVICE_ACCESS, EFI_VARIABLE_NON_VOLATILE, EFI_VARIABLE_RUNTIME_ACCESS, entry, VM::error, g_sk_runtime_services, VM::halted, heartbeat_init(), heartbeat_state(), heartbeat_ticks(), heartbeat_trust(), i8042_drain_stale(), ioapic_unmask_legacy_irq(), BootDisk::is_stick, KARGS_SYSTEM_DEFAULT, KARGS_SYSTEM_V3, KARGS_SYSTEM_V4, kmalloc(), CapsuleDirHeader::magic, memcmp(), memcpy(), CapsuleDirHeader::name_count, pci_init(), print_uint(), q48_mul(), Q48_ONE, CapsuleDirHeader::reserved, rng_init(), KernelArgs::run_doe, _EFI_RUNTIME_SERVICES::SetVariable, SF_VAR_REBOOT_TRIES, sk_repl(), sk_repl_headless_wait(), sk_v4_run(), STARFORTH_VENDOR_GUID, VMRegistryEntry::state, KernelArgs::system, timer_tsc_hz(), time_trust_state::variance, virtio_blk_find_artemis(), virtio_input_find_keyboard(), vm_find_word(), VMRegistryEntry::vm_id, vm_interpret(), VMRegistryEntry::vm_ptr, VM_STATE_LIVE, xhci_bringup(), xhci_find_and_map(), and XHCI_MAX_CONTROLLERS.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.162.1.5 print_banner()

```
static void print_banner (
            void  )  [static]
```

Print the StarKernel ASCII-art banner and build metadata to the console.

Emits:

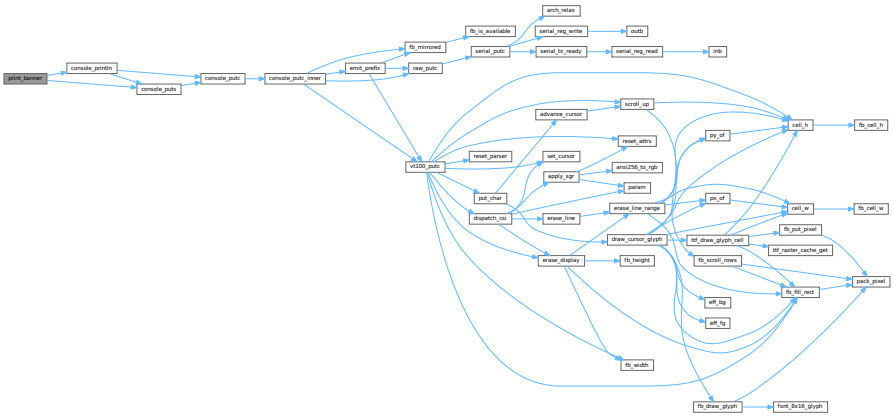
- The "StarKernel" ASCII-art logotype (six-line block font).
- `LITHOS_VERSION_STR` — the `LithosAnanke` version string from `version.h`.
- Target ISA: "amd64", "aarch64", "riscv64", or "unknown", selected by compile-time `ARCH_*` / `__riscv` preprocessor guards.
- Build date and time from `__DATE__` / `__TIME__` (compiler intrinsics).
- "UEFI BootServices: EXITED" — confirmation that the kernel is running after `ExitBootServices()` and owns all hardware.

Called first in `kernel_main_impl()` / `kernel_main()` after `console_init()` so the banner is the first visible output on the serial port, matching the `QEMU_BASELINE.log` reference.

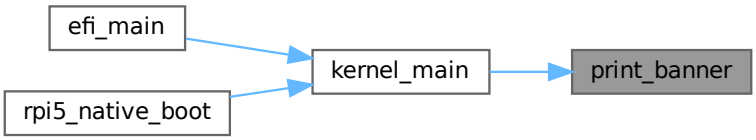
References console_println(), console_puts(), and LITHOS_VERSION_STR.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.162.1.6 print_boot_info()

```
static void print_boot_info (
            BootInfo * boot_info )  [static]
```

Print a boot-information summary from the UEFI memory map to the console.

Iterates over every EFI_MEMORY_DESCRIPTOR in boot_info->memory_map and accumulates:

- total_memory — sum of page sizes for all RAM-type regions (via is_ram_type()).
- usable_memory — sum of page sizes for EfiConventionalMemory only.

Emits a three-field report box to the kernel serial console:

- "Memory map entries: N"
- "Total memory: N MB" (rounds down to whole MiB)
- "Usable memory: N MB"

Called from kernel_main_impl() / kernel_main() immediately after M1 console initialisation, so the memory map must still be intact (it always is — the map was captured by uefi_loader.c before ExitBoot↩Services()).

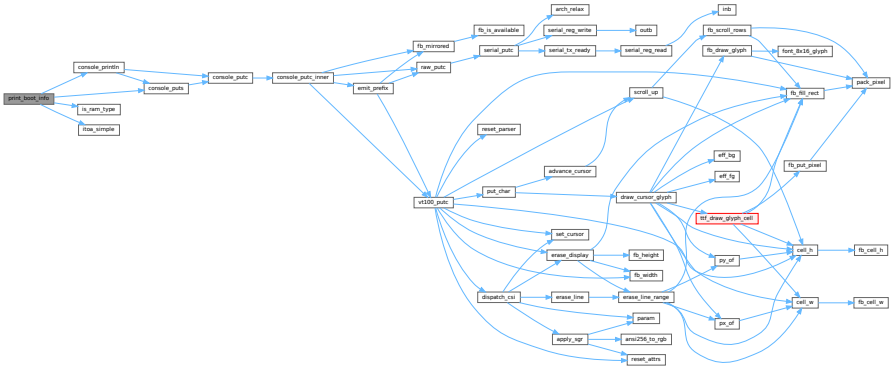
Parameters

boot_info	BootInfo structure populated by uefi_loader.c; provides memory_map, memory_map_size, and memory_map_descriptor_size.

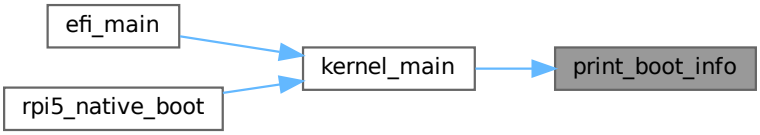
References console_println(), console_puts(), EfiConventionalMemory, is_ram_type(), itoa_simple(), BootInfo::memory_map, BootInfo::memory_map_descriptor_size, BootInfo::memory_map_size, EFI_MEMORY_DESCRIPTOR::NumberOfPages, and EFI_MEMORY_DESCRIPTOR::Type.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.162.1.7 print_heap_stats()

```
static void print_heap_stats (
            void  )  [static]
```

Print kernel heap (kmalloc) statistics to the kernel console.

Calls `kmalloc_get_stats()` to obtain a `kmalloc_stats_t` snapshot and emits four lines via `print_uint()`:

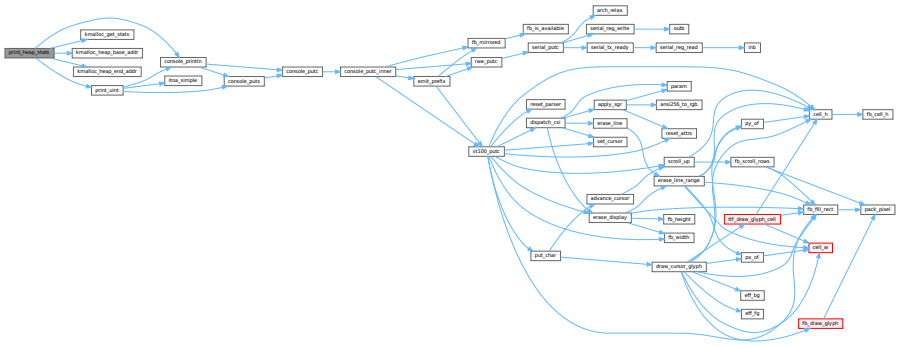
- Total bytes allocated to the heap arena.
- Free bytes currently available.
- Used bytes currently allocated by callers.
- Peak bytes — the high-water mark since `kmalloc_init()`.

Called from `kernel_main_impl()` / `kernel_main()` immediately after `kmalloc_init()` (M6) to confirm that the heap was sized correctly from the `--heap=` boot argument or its 2 GiB default.

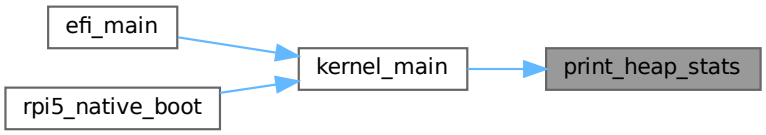
References console_println(), kmalloc_stats_t::free_bytes, kmalloc_get_stats(), kmalloc_heap_base_addr(), kmalloc_heap_end_addr(), kmalloc_stats_t::peak_bytes, print_uint(), kmalloc_stats_t::total_bytes, and kmalloc_stats_t::used_bytes.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.162.1.8 print_pmm_stats()

```
static void print_pmm_stats (
            void  )  [static]
```

Print Physical Memory Manager statistics to the kernel console.

Calls `pmm_get_stats()` to obtain a `pmm_stats_t` snapshot and then emits six lines via `print_uint()`:

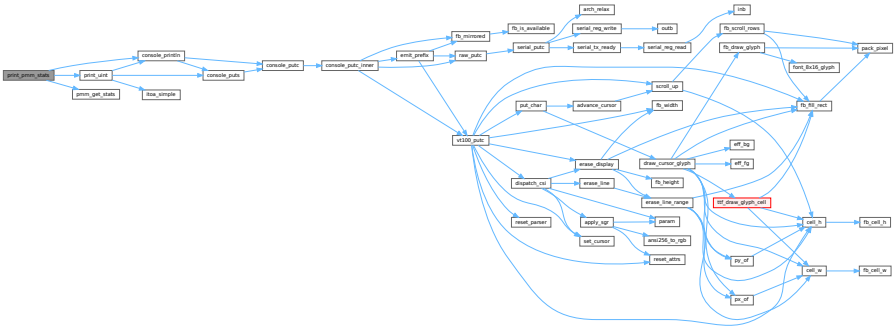
- Total pages, free pages, used pages (in 4 KiB page units).
- Total MB, free MB, used MB (bytes ÷ 1 MiB, truncated).

Called from `kernel_main_impl()` / `kernel_main()` immediately after `pmm_init()` completes (M2), providing a sanity check that the PMM saw the expected quantity of physical RAM.

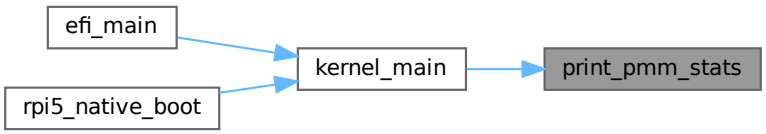
References console_putln(), pmm_stats_t::free_bytes, pmm_stats_t::free_pages, pmm_get_stats(), print_uint(), pmm_stats_t::total_bytes, pmm_stats_t::total_pages, pmm_stats_t::used_bytes, and pmm_stats_t::used_pages.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.162.1.9 print_uint()

```
static void print_uint (
            const char * label,
            uint64_t value )  [static]
```

Print an optional label followed by a `uint64_t` in decimal to the console.

Converts `value` to a decimal string via `itoa_simple()` and emits it with a trailing newline via `console_println()`. If `label` is non-NULL, it is emitted first via `console_puts()` (no newline between label and value). Used by `print_pmm_stats()` and `print_heap_stats()` to avoid repeating the convert-and-print pattern for each statistic line.

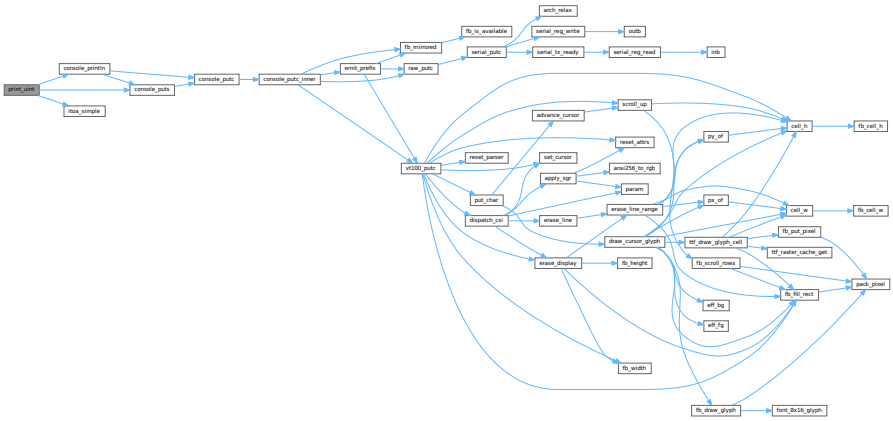
Parameters

label	Optional NUL-terminated prefix string; NULL to omit.
value	64-bit unsigned integer to display in decimal.

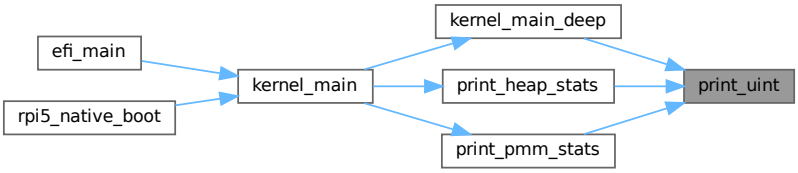
References console_println(), console_puts(), and itoa_simple().

Referenced by kernel_main_deep(), print_heap_stats(), and print_pmm_stats().

Here is the call graph for this function:



Here is the caller graph for this function:



7.162.2 Variable Documentation

7.162.2.1 g_sk_runtime_services

```
EFI_RUNTIME_SERVICES* g_sk_runtime_services = NULL
```

kernel_main.c - StarKernel main entry point (LithosAnanke branch)

Milestone status: M0-M5: Complete (build, boot, PMM, VMM, interrupts, timer) M6: Infrastructure present (kmalloc exists, validation deferred) M7: Not started (VM integration pending)

UEFI Runtime Services pointer — set once at M6 init, valid for kernel lifetime.

Populated from `boot_info->runtime_services` just before the kernel heap is initialised (between the M5 timer init and `kernel_main_deep()`). Declared `extern` in the UEFI header so kernel FORTH words (e.g. `REBOOT`) can access it without including the full `kernel_main.c` translation unit.

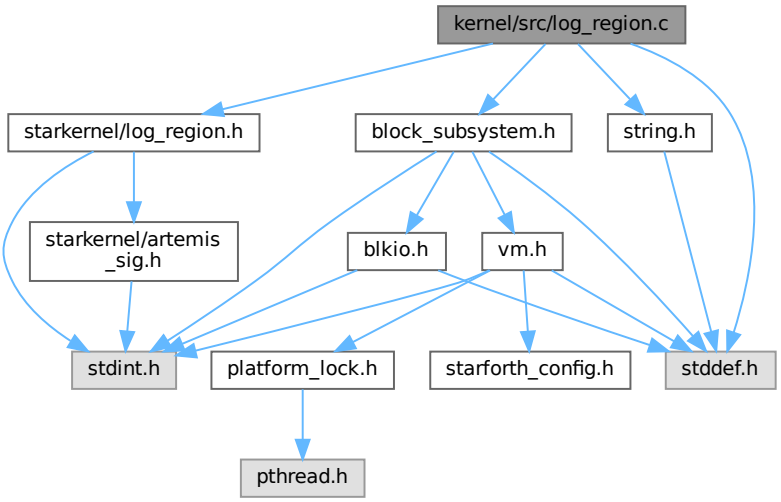
Validity note: UEFI Runtime Services remain valid in physical mode after `ExitBootServices()`. This kernel does not call `SetVirtualAddressMap()`, so the pointer is the raw physical address returned by firmware. On QEMU/OVMF this is always usable; on real hardware it is valid as long as the CPU is in physical mode (identity-mapped) — which it is for the duration of LithosAnanke, since the VMM uses a separate TTBR/CR3 but does not remap the EFI reserved regions.

Referenced by kernel_main(), kernel_main_deep(), and system_word_reboot().

7.163 kernel/src/log_region.c File Reference

```
#include "starkernel/log_region.h"
#include <stddef.h>
#include <string.h>
#include "block_subsystem.h"
```

Include dependency graph for log_region.c:



Functions

- static uint64_t log_region_ctrl_compute_crc (const log_region_ctrl_t ∗ctrl)

  log_region.c - Growable per-VM log-persistence ring on Artemis's disk.
- static int log_region_ctrl_read (log_region_ctrl_t ∗out)
- static int log_region_ctrl_write (log_region_ctrl_t ∗ctrl)
- static void log_region_ctrl_init_fresh (log_region_ctrl_t ∗ctrl)
- static uint32_t log_region_slot_devblock_from_top (uint32_t slot_index)
- static int log_region_read_slot (uint32_t slot_index, log_slot_t ∗out)
- static int log_region_write_slot (uint32_t slot_index, const log_slot_t ∗slot)
- int log_region_append (uint8_t level, uint64_t timestamp, const char ∗source, uint32_t source_len, const char ∗msg, uint32_t msg_len)
- int log_region_read_recent (uint32_t back, log_slot_t ∗out)

  log_region_read_recent - read one record back (2026-10-14, for LOG-SHOW).

7.163.1 Function Documentation

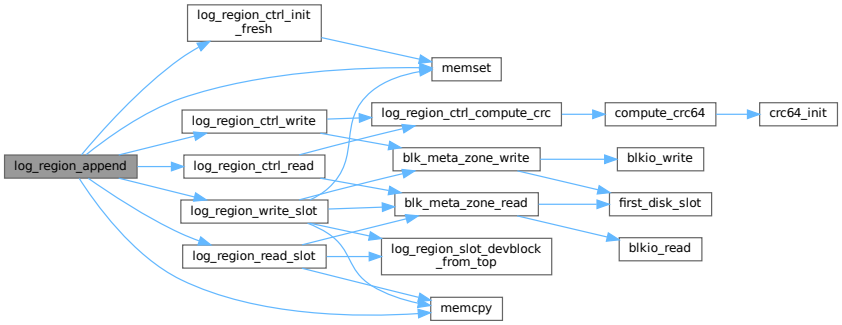
7.163.1.1 log_region_append()

```
int log_region_append (
            uint8_t level,
            uint64_t timestamp,
```

```
            const char * source,
            uint32_t source_len,
            const char * msg,
            uint32_t msg_len )
```

References log_region_ctrl_t::devblocks, log_region_ctrl_t::head_slot, log_slot_t::level, level, log_region_ctrl_init_fresh(), log_region_ctrl_read(), log_region_ctrl_write(), LOG_REGION_GROWTH_INCREMENT, LOG_REGION_MAX_DEVBLOCKS, LOG_REGION_PROTECTED_MAX_LEVEL, log_region_read_slot(), log_region_write_slot(), LOG_SLOT_MSG_MAX, LOG_SLOT_SOURCE_MAX, LOG_SLOTS_PER_DEVBLOCK, memcpy(), memset(), log_slot_t::msg, log_slot_t::msg_len, log_region_ctrl_t::record_count, log_slot_t::source, log_region_ctrl_t::tail_slot, and log_slot_t::timestamp.

Here is the call graph for this function:



7.163.1.2 log_region_ctrl_compute_crc()

```
static uint64_t log_region_ctrl_compute_crc (
            const log_region_ctrl_t * ctrl )  [static]
```

log_region.c - Growable per-VM log-persistence ring on Artemis's disk.

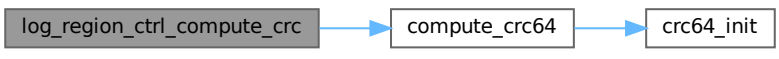
See starkernel/log_region.h for the format/interface design.

Deliberately never calls log_message() (or anything documented to call it) – this runs inside Artemis's own dictionary context during message delivery (LOG-APPEND, dispatched by a sender's MSG-SEND/MSG-TICK); a log call here would append to Artemis's own buffer and eventually flush back through this same path.

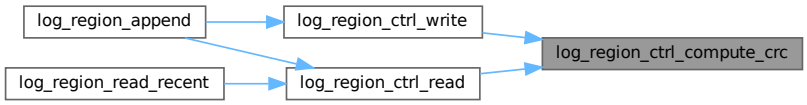
References compute_crc64().

Referenced by log_region_ctrl_read(), and log_region_ctrl_write().

Here is the call graph for this function:



Here is the caller graph for this function:



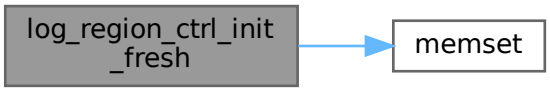
7.163.1.3 log_region_ctrl_init_fresh()

```
static void log_region_ctrl_init_fresh (
            log_region_ctrl_t * ctrl )  [static]
```

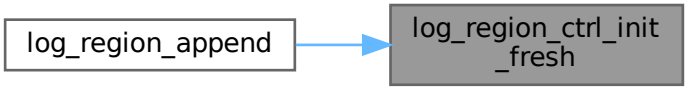
References log_region_ctrl_t::devblocks, log_region_ctrl_t::head_slot, LOG_REGION_INITIAL_DEVBLOCKS, LOG_REGION_PACK, LOG_REGION_VERSION_0, log_region_ctrl_t::magic, memset(), log_region_ctrl_t::record_count, and log_region_ctrl_t::tail_slot.

Referenced by log_region_append().

Here is the call graph for this function:



Here is the caller graph for this function:



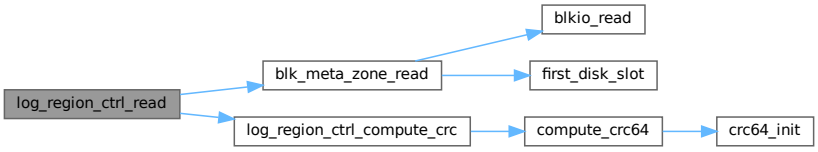
7.163.1.4 log_region_ctrl_read()

```
static int log_region_ctrl_read (
            log_region_ctrl_t * out )  [static]
```

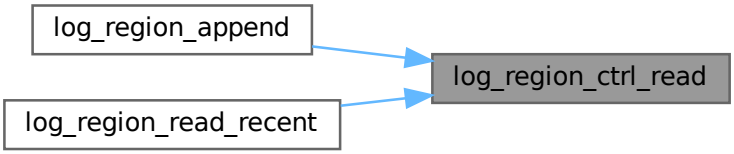
References blk_meta_zone_read(), log_region_ctrl_t::hdr_crc, log_region_ctrl_compute_crc(), LOG_REGION_DEVBLOCK_FROM_T LOG_REGION_GET_MAGIC, LOG_REGION_GET_VERSION, LOG_REGION_MAGIC, LOG_REGION_VERSION_0, and log_region_ctrl_t::magic.

Referenced by log_region_append(), and log_region_read_recent().

Here is the call graph for this function:



Here is the caller graph for this function:



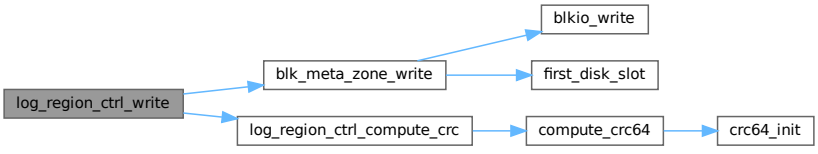
7.163.1.5 log_region_ctrl_write()

```
static int log_region_ctrl_write (
            log_region_ctrl_t * ctrl )  [static]
```

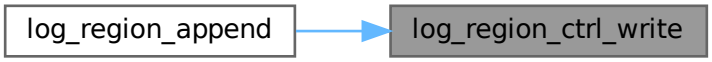
References blk_meta_zone_write(), log_region_ctrl_t::hdr_crc, log_region_ctrl_compute_crc(), and LOG_REGION_DEVBLOCK_FRO

Referenced by log_region_append().

Here is the call graph for this function:



Here is the caller graph for this function:



7.163.1.6 log_region_read_recent()

```
int log_region_read_recent (
            uint32_t back,
            log_slot_t * out )
```

log_region_read_recent - read one record back (2026-10-14, for LOG-SHOW).

Parameters

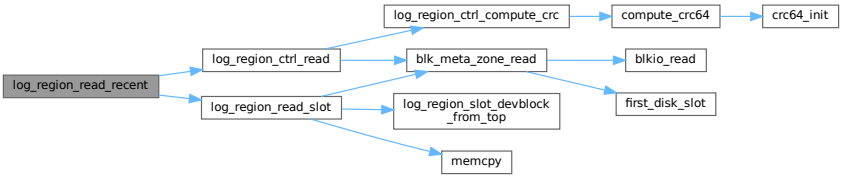
back	0 for the newest record, 1 for the one before it, ...
out	Filled with the record.

Returns

0 on success, 1 if there is no such record (the ring holds fewer than back+1, or none at all), -1 on a read failure or no ring.

References log_region_ctrl_t::devblocks, log_region_ctrl_read(), log_region_read_slot(), LOG_SLOTS_PER_DEVBLOCK, log_region_ctrl_t::record_count, and log_region_ctrl_t::tail_slot.

Here is the call graph for this function:



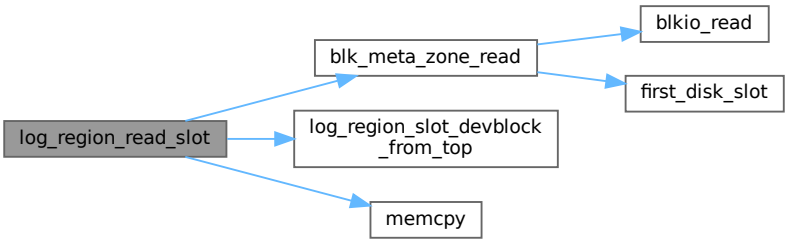
7.163.1.7 log_region_read_slot()

```
static int log_region_read_slot (
            uint32_t slot_index,
            log_slot_t * out )  [static]
```

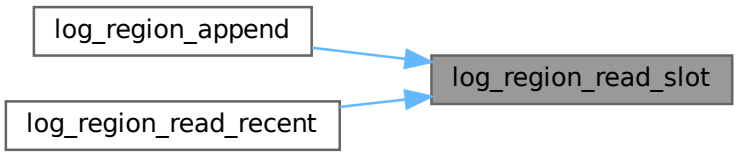
References blk_meta_zone_read(), log_region_slot_devblock_from_top(), LOG_SLOT_SIZE, LOG_SLOTS_PER_DEVBLOCK, and memcpy().

Referenced by log_region_append(), and log_region_read_recent().

Here is the call graph for this function:



Here is the caller graph for this function:



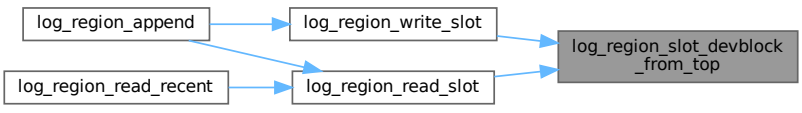
7.163.1.8 log_region_slot_devblock_from_top()

```
static uint32_t log_region_slot_devblock_from_top (
            uint32_t slot_index )  [static]
```

References LOG_REGION_DEVBLOCK_FROM_TOP_BASE, and LOG_SLOTS_PER_DEVBLOCK.

Referenced by log_region_read_slot(), and log_region_write_slot().

Here is the caller graph for this function:



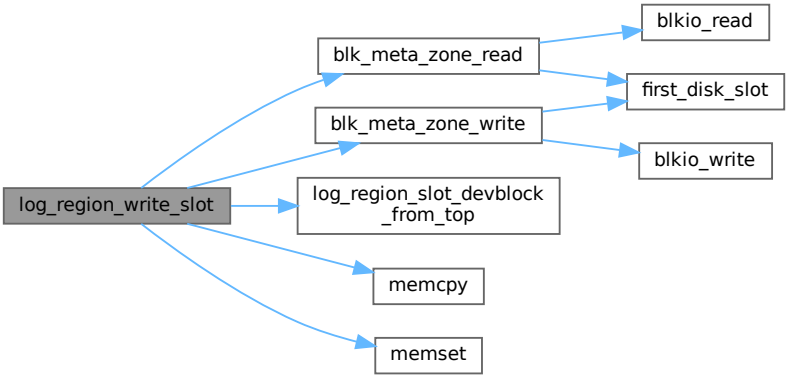
7.163.1.9 log_region_write_slot()

```
static int log_region_write_slot (
            uint32_t slot_index,
            const log_slot_t * slot )  [static]
```

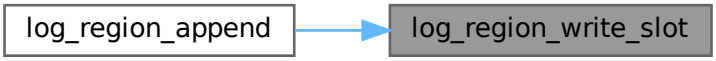
References blk_meta_zone_read(), blk_meta_zone_write(), log_region_slot_devblock_from_top(), LOG_SLOT_SIZE, LOG_SLOTS_PER_DEVBLOCK, memcpy(), and memset().

Referenced by log_region_append().

Here is the call graph for this function:



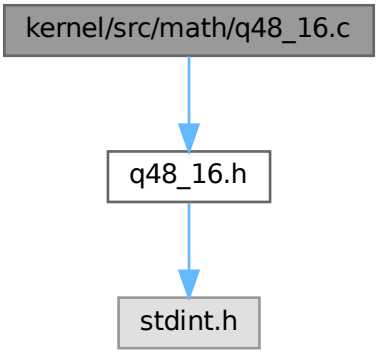
Here is the caller graph for this function:



7.164 kernel/src/math/q48_16.c File Reference

```
#include "q48_16.h"
```

Include dependency graph for q48_16.c:



Functions

- q48_16_t q48_mul (q48_16_t a, q48_16_t b)

  q48_16.c - Q48.16 Fixed-Point Arithmetic for StarKernel
- q48_16_t q48_div (q48_16_t a, q48_16_t b)

  Divide two Q48.16 fixed-point values.
- q48_16_t q48_exp_approx (q48_16_t q)

  Compute an approximation of `e^q` in Q48.16 format (Taylor series).
- q48_16_t q48_log_approx (q48_16_t x)

  Compute an approximation of `ln(x)` in Q48.16 format (integer-only).
- q48_16_t q48_sqrt_approx (q48_16_t q)

  Compute an approximation of `sqrt(q)` in Q48.16 format (Newton-Raphson).
- static int64_t q48_reduce_angle (int64_t x)
- q48_16_t q48_sin_approx (q48_16_t q)

  Compute an approximation of `sin(q)` in Q48.16 format (radians).
- q48_16_t q48_cos_approx (q48_16_t q)

  Compute an approximation of `cos(q)` in Q48.16 format (radians).

7.164.1 Function Documentation

7.164.1.1 q48_cos_approx()

```
q48_16_t q48_cos_approx (
            q48_16_t q )
```

Compute an approximation of `cos(q)` in Q48.16 format (radians).

Range-reduces into [-pi, pi] via `q48_reduce_angle()`, then sums the Taylor series `1` - x^2/2! + x^4/4! - ... for terms n = 2,4,6,8,10, with an early exit when a term falls below 10. Cosine is even (`cos`(-x) = cos(x)), so no sign correction is needed – `x^2` already absorbs the sign of `x`.

Parameters

q	Angle in Q48.16 format (radians, any magnitude)

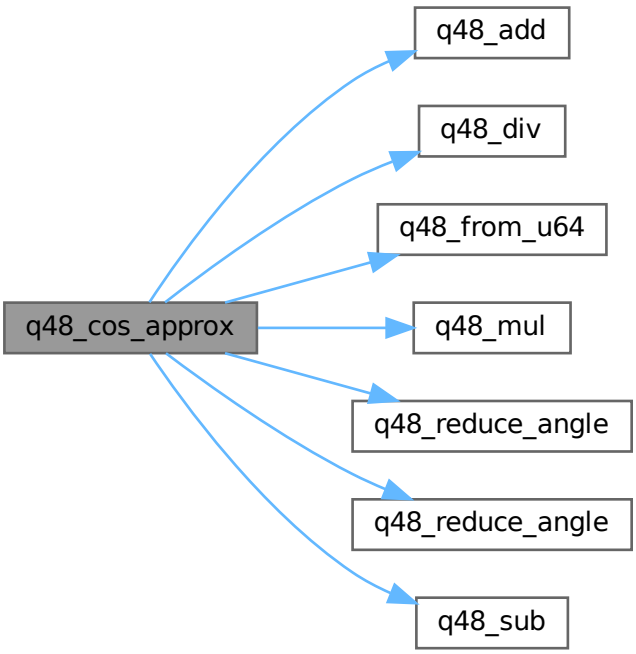
Returns

`cos(q)` in Q48.16 format

References q48_add(), q48_div(), q48_from_u64(), q48_mul(), Q48_ONE, q48_reduce_angle(), q48_reduce_angle(), and q48_sub().

Referenced by q48_word_cos().

Here is the call graph for this function:



Here is the caller graph for this function:

7.164.1.2 q48_div()

```
q48_16_t q48_div (
            q48_16_t a,
            q48_16_t b )
```

Divide two Q48.16 fixed-point values.

Computes (a << 16) / b. Returns 0 if b == 0 (safe, but callers should guard). Returns UINT64_MAX as a saturation sentinel when a exceeds 2^48, which would overflow the 16-bit left-shift.

Parameters

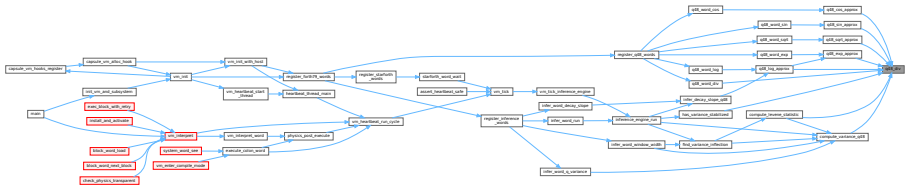
a	Dividend in Q48.16 format
b	Divisor in Q48.16 format; 0 returns 0

Returns

Quotient in Q48.16 format, or UINT64_MAX on saturation

Referenced by compute_levene_statistic(), compute_variance_q48(), has_variance_stabilized(), q48_cos_approx(), q48_exp_approx(), q48_log_approx(), q48_sin_approx(), q48_sqrt_approx(), and q48_word_div().

Here is the caller graph for this function:



7.164.1.3 q48_exp_approx()

```
q48_16_t q48_exp_approx (
            q48_16_t q )
```

Compute an approximation of e^q in Q48.16 format (Taylor series).

Supporting function for q48_log_approx() Newton iterations. Uses the Taylor series 1 + x + x^2/2! + ... up to 10 terms, with an early-exit when a term falls below 50 (sub-LSB in Q48.16). Handles negative q by computing e^|q| then returning 1/result. Returns 1.0 (65536) for q == 0, UINT64_MAX for q >= 16.0, and 0 for q <= -16.0.

Parameters

q	Exponent in Q48.16 format (signed interpretation)

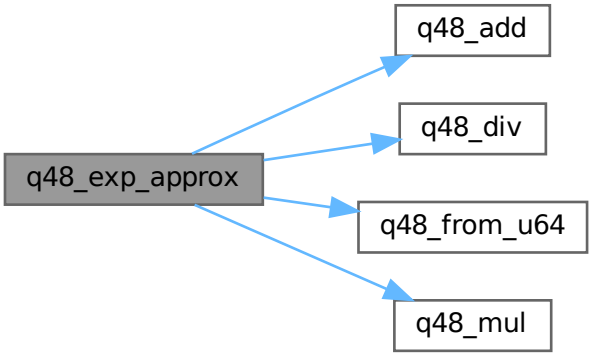
Returns

e^q in Q48.16 format

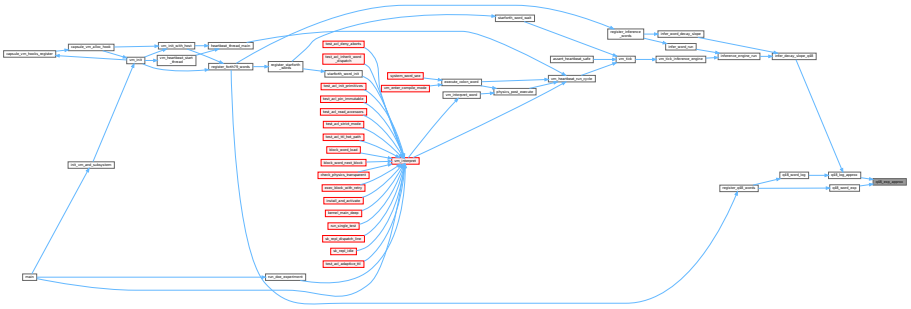
References q48_add(), q48_div(), q48_from_u64(), q48_mul(), and Q48_ONE.

Referenced by q48_log_approx(), and q48_word_exp().

Here is the call graph for this function:



Here is the caller graph for this function:



7.164.1.4 q48_log_approx()

```
q48_16_t q48_log_approx (
            q48_16_t x )
```

Compute an approximation of ln(x) in Q48.16 format (integer-only).

Used by infer_decay_slope_q48() (Loop #6) for log-linear OLS regression. Algorithm: range-reduces x to the interval [1, 2) by tracking the exponent k (so x = 2^k * m), applies 6 Newton-Raphson iterations on e^y = m starting from the first-order approximation y_0 = m - 1, then assembles the result as ln(x) = k*ln(2) + ln(m). Returns 0 for x == 0 (ln undefined) and for x == 65536 (ln(1.0) == 0.0 exactly). LN2_Q48 = 45426 (0.693147... × 65536).

Parameters

x	Input value in Q48.16 format (uint64_t; value of 65536 = 1.0)

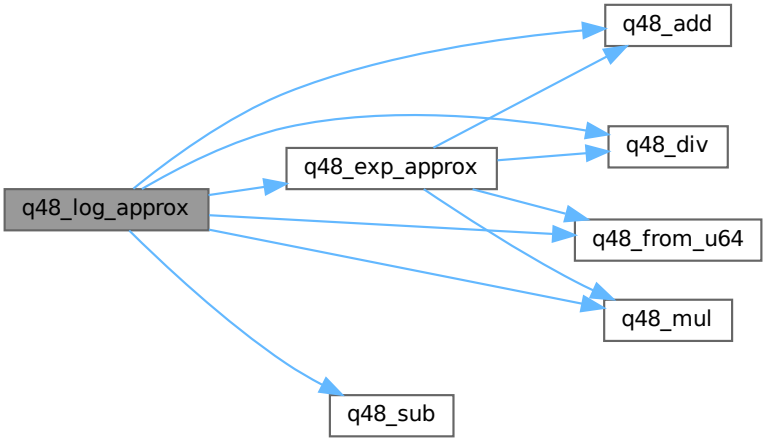
Returns

`ln(x)` in Q48.16 format, or 0 for x==0 or x==65536

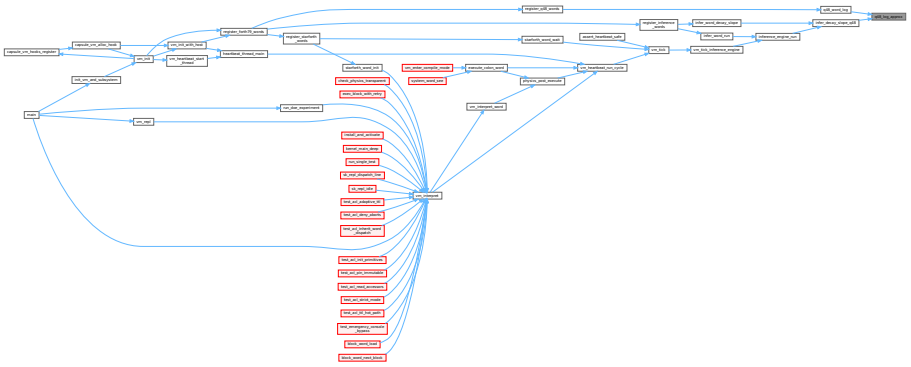
References q48_add(), q48_div(), q48_exp_approx(), q48_from_u64(), q48_mul(), Q48_ONE, and q48_sub().

Referenced by infer_decay_slope_q48(), and q48_word_log().

Here is the call graph for this function:



Here is the caller graph for this function:



7.164.1.5 q48_mul()

```
q48_16_t q48_mul (
            q48_16_t a,
            q48_16_t b )
```

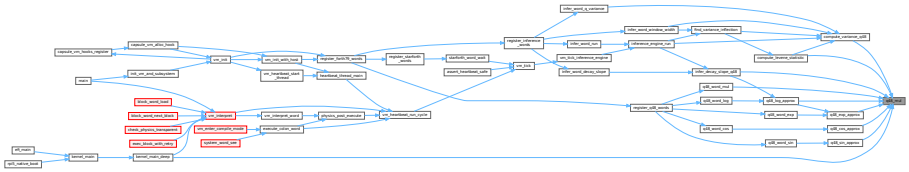
q48_16.c - Q48.16 Fixed-Point Arithmetic for StarKernel

Multiply two Q48.16 fixed-point values.

Freestanding implementation: no libc, no floating-point.

Referenced by compute_levene_statistic(), compute_variance_q48(), infer_decay_slope_q48(), kernel_main_deep(), q48_cos_approx(), q48_exp_approx(), q48_log_approx(), q48_sin_approx(), and q48_word_mul().

Here is the caller graph for this function:



7.164.1.6 q48_reduce_angle()

```
static int64_t q48_reduce_angle (
            int64_t x )  [static]
```

Referenced by q48_cos_approx(), and q48_sin_approx().

Here is the caller graph for this function:

7.164.1.7 q48_sin_approx()

```
q48_16_t q48_sin_approx (
            q48_16_t q )
```

Compute an approximation of `sin(q)` in Q48.16 format (radians).

Range-reduces into [-pi, pi] via `q48_reduce_angle()`, then sums the Taylor series `x` - x^3/3! + x^5/5! - ... for terms n = 3,5,7,9,11, with an early exit when a term falls below 10 (sub-LSB in Q48.16). Sine is odd (`sin`(-x) = -sin(x)), so the sign is factored out before the series and reapplied to the result.

Parameters

q	Angle in Q48.16 format (radians, any magnitude)

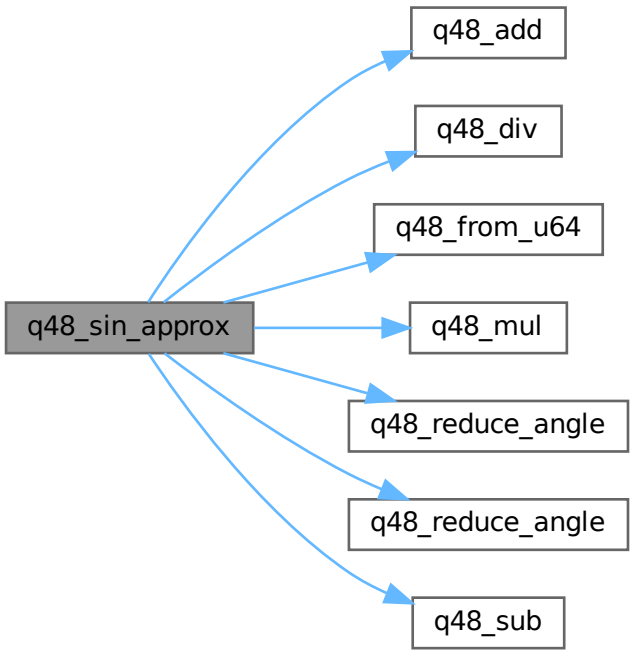
Returns

`sin(q)` in Q48.16 format

References q48_add(), q48_div(), q48_from_u64(), q48_mul(), q48_reduce_angle(), q48_reduce_angle(), and q48_sub().

Referenced by q48_word_sin().

Here is the call graph for this function:



Here is the caller graph for this function:

7.164.1.8 q48_sqrt_approx()

```
q48_16_t q48_sqrt_approx (
            q48_16_t q )
```

Compute an approximation of `sqrt(q)` in Q48.16 format (Newton-Raphson).

Iterates `x_{n+1}` = (x_n + q/x_n) / 2 starting from (q >> 1) + 16384, for up to 8 iterations. Terminates early when the delta between successive estimates falls below 10 (approximately 0.00015 in Q48.16). Used for R^2 computation in the inference engine. Returns 0 for `q` == 0, and 1.0 (65536) for `q` == 65536.

Parameters

q	Input value in Q48.16 format

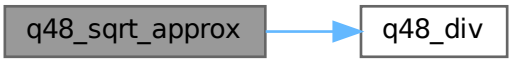
Returns

`sqrt(q)` in Q48.16 format

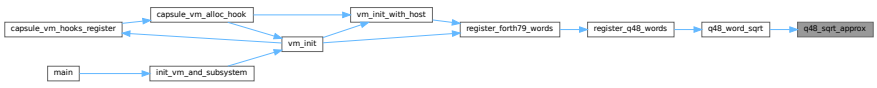
References q48_div(), and Q48_ONE.

Referenced by q48_word_sqrt().

Here is the call graph for this function:



Here is the caller graph for this function:

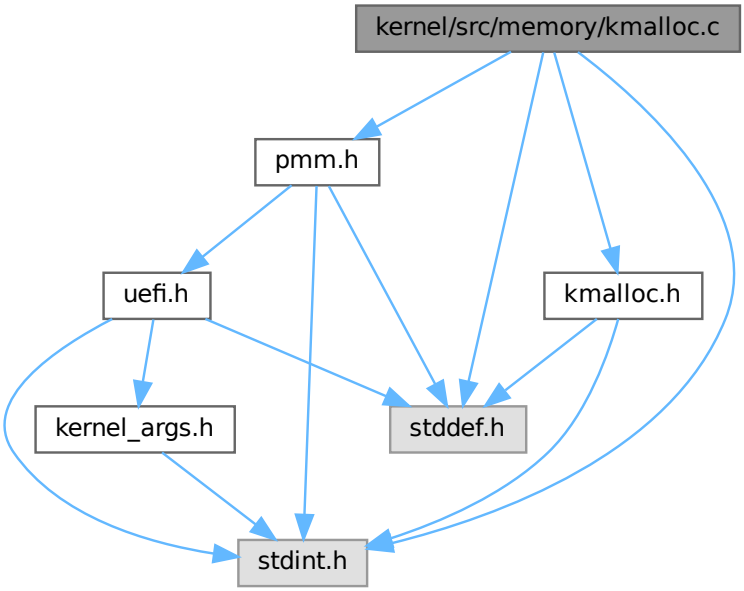


7.165 kernel/src/memory/kmalloc.c File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "kmalloc.h"
```

```
#include "pmm.h"
```

Include dependency graph for kmalloc.c:



Data Structures

- struct heap_block
- struct kmalloc_prefix_t

Macros

- #define KMALLOC_DEFAULT_HEAP_SIZE (2ULL ∗ 1024ULL ∗ 1024ULL ∗ 1024ULL) /∗ 2 GiB — floor for 256+ baby VMs ∗/

  kmalloc.c - Simple kernel heap allocator
- #define KMALLOC_MIN_ALIGN 16u
- #define KMALLOC_MAGIC 0x4B4D414Cu /∗ 'KMAL' ∗/
- #define KMALLOC_MIN_PAGES ((64u ∗ 1024u ∗ 1024u) / PMM_PAGE_SIZE)

Typedefs

- typedef struct heap_block heap_block_t

Functions

- uintptr_t kmalloc_heap_base_addr (void)
- uintptr_t kmalloc_heap_end_addr (void)
- static size_t align_up_size (size_t value, size_t align)
- static size_t normalize_alignment (size_t align)
- static void update_free_bytes (void)
- static void account_allocation (size_t requested)
- static void account_free (size_t requested)
- static int pointer_within_heap (const void *ptr)
- static void coalesce_neighbors (heap_block_t *block)
- static size_t min_splittable_payload (void)
- static int can_split (size_t remainder)
- static void * allocate_from_block (heap_block_t *block, size_t requested, size_t align)
- int kmalloc_init (uint64_t heap_size_bytes)
- int kmalloc_is_initialized (void)
- void * kmalloc (size_t size)
- void * kmalloc_aligned (size_t size, size_t align)
- void kfree (void *ptr)
- kmalloc_stats_t kmalloc_get_stats (void)
- void kmalloc_debug_census (size_t *out_largest_free, size_t *out_free_count, size_t *out_used_count, size_t *out_total_blocks)
- void kmalloc_debug_census_bytes (size_t *out_total_free_bytes, size_t *out_total_used_bytes)

Variables

- static uint8_t * heap_base = NULL
- static uint64_t heap_size = 0
- static heap_block_t * heap_head = NULL
- static kmalloc_stats_t heap_stats = {0}
- static int heap_initialized = 0

7.165.1 Macro Definition Documentation

7.165.1.1 KMALLOC_DEFAULT_HEAP_SIZE

```
#define KMALLOC_DEFAULT_HEAP_SIZE (2ULL * 1024ULL * 1024ULL * 1024ULL) /* 2 GiB -- floor for
256+ baby VMs */
```

kmalloc.c - Simple kernel heap allocator

Reserves a fixed heap from PMM and serves aligned allocations with a doubly-linked free list plus coalescing. The allocator avoids libc helpers and keeps metadata inside the heap itself.

7.165.1.2 KMALLOC_MAGIC

```
#define KMALLOC_MAGIC 0x4B4D414Cu /* 'KMAL' */
```

7.165.1.3 KMALLOC_MIN_ALIGN

```
#define KMALLOC_MIN_ALIGN 16u
```

7.165.1.4 KMALLOC_MIN_PAGES

```
#define KMALLOC_MIN_PAGES ((64u * 1024u * 1024u) / PMM_PAGE_SIZE)
```

7.165.2 Typedef Documentation

7.165.2.1 heap_block_t

```
typedef struct heap_block heap_block_t
```

7.165.3 Function Documentation

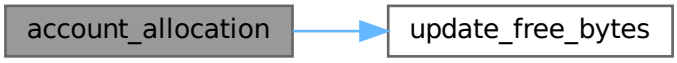
7.165.3.1 account_allocation()

```
static void account_allocation (
            size_t requested )  [static]
```

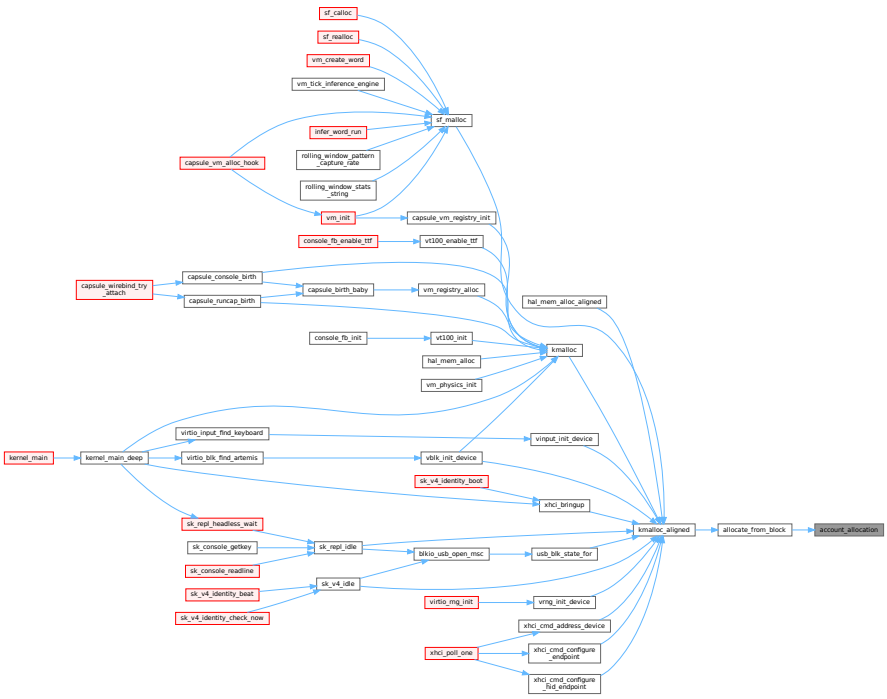
References heap_stats, kmalloc_stats_t::peak_bytes, update_free_bytes(), and kmalloc_stats_t::used_bytes.

Referenced by allocate_from_block().

Here is the call graph for this function:



Here is the caller graph for this function:



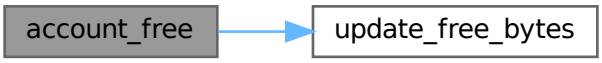
7.165.3.2 account_free()

```
static void account_free (
            size_t requested )  [static]
```

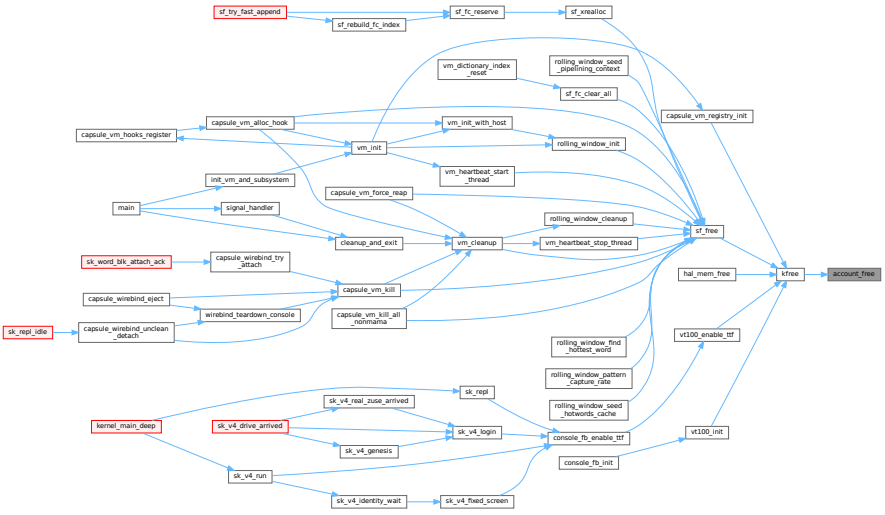
References heap_stats, update_free_bytes(), and kmalloc_stats_t::used_bytes.

Referenced by kfree().

Here is the call graph for this function:



Here is the caller graph for this function:

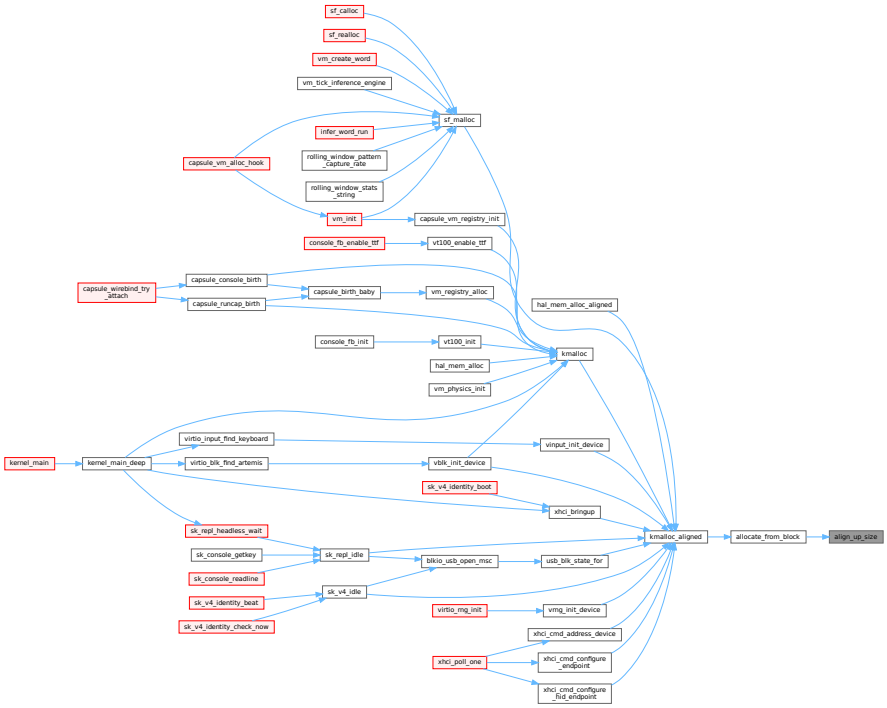


7.165.3.3 align_up_size()

```
static size_t align_up_size (
            size_t value,
            size_t align )  [static]
```

Referenced by allocate_from_block().

Here is the caller graph for this function:



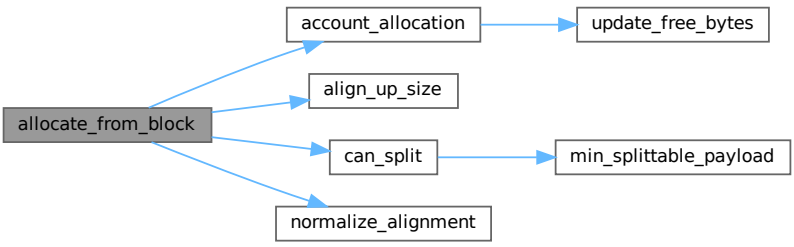
7.165.3.4 allocate_from_block()

```
static void * allocate_from_block (
            heap_block_t * block,
            size_t requested,
            size_t align )  [static]
```

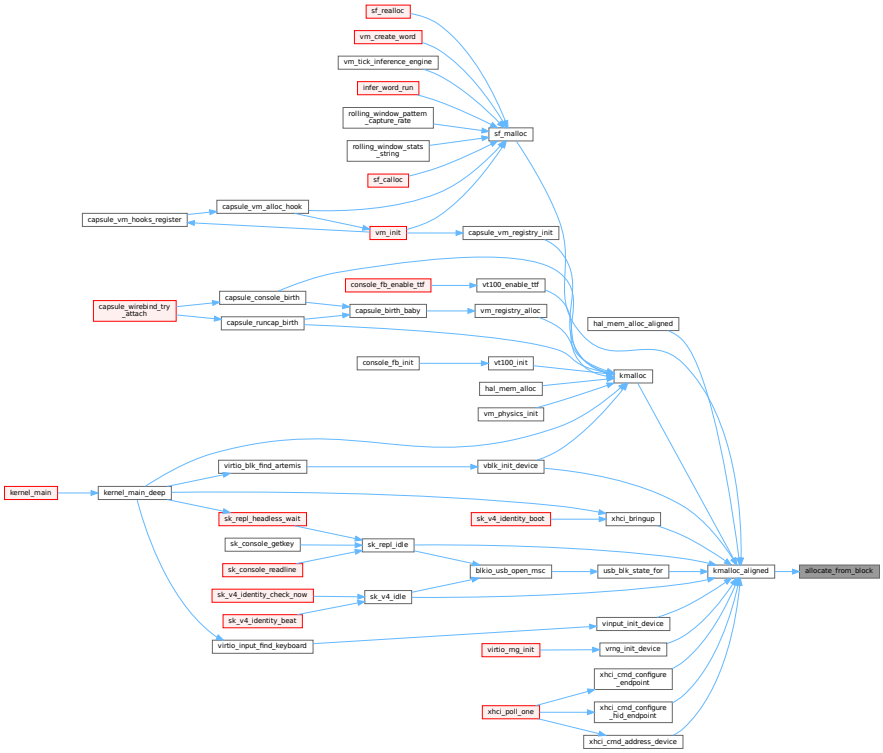
References account_allocation(), align_up_size(), kmalloc_prefix_t::block, can_split(), heap_block::free, KMALLOC_MAGIC, KMALLOC_MIN_ALIGN, kmalloc_prefix_t::magic, heap_block::next, normalize_alignment(), heap_block::prev, heap_block::requested, and heap_block::size.

Referenced by kmalloc_aligned().

Here is the call graph for this function:



Here is the caller graph for this function:



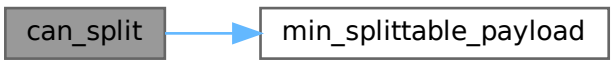
7.165.3.5 can_split()

```
static int can_split (
            size_t remainder )  [static]
```

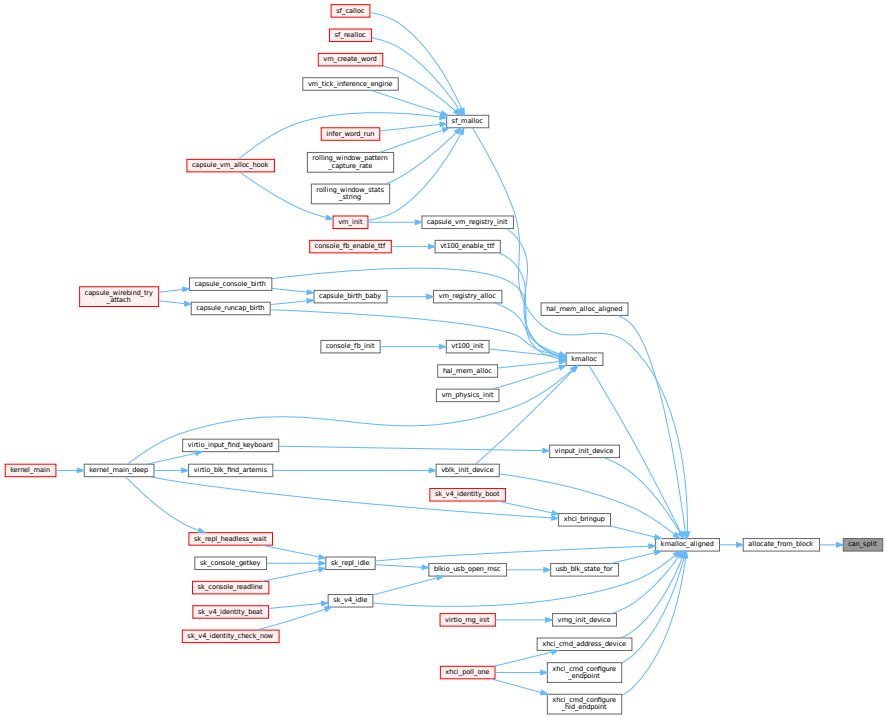
References min_splittable_payload().

Referenced by allocate_from_block().

Here is the call graph for this function:



Here is the caller graph for this function:



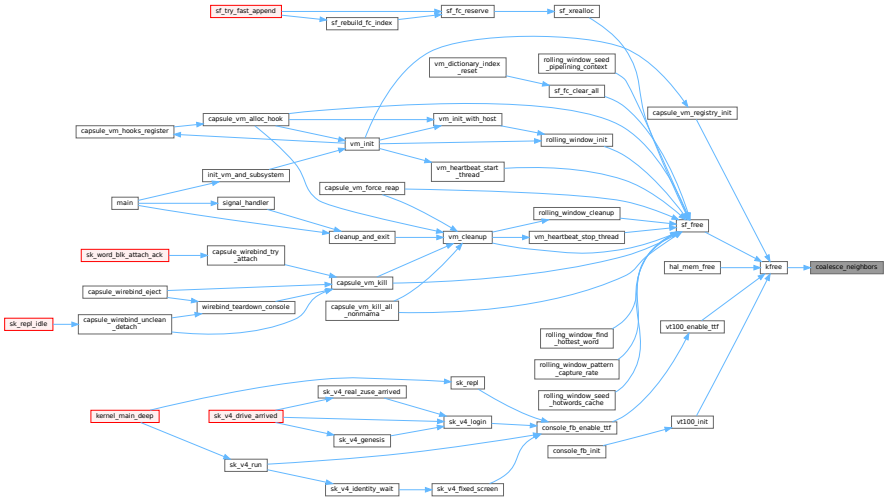
7.165.3.6 coalesce_neighbors()

```
static void coalesce_neighbors (
            heap_block_t * block )  [static]
```

References heap_block::free, heap_head, heap_block::next, heap_block::prev, and heap_block::size.

Referenced by kfree().

Here is the caller graph for this function:



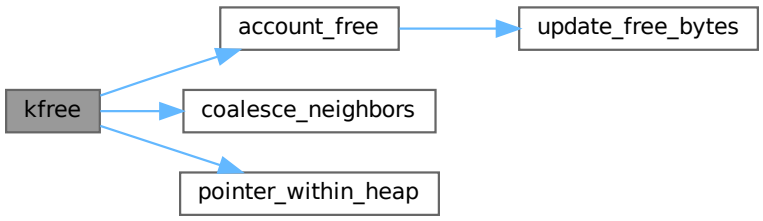
7.165.3.7 kfree()

```
void kfree (
            void * ptr )
```

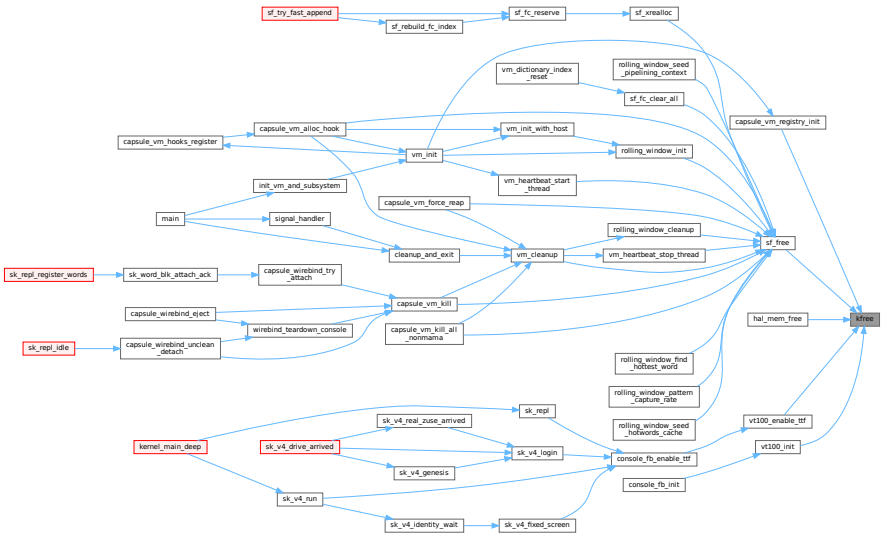
References account_free(), kmalloc_prefix_t::block, coalesce_neighbors(), heap_block::free, heap_initialized, KMALLOC_MAGIC, kmalloc_prefix_t::magic, pointer_within_heap(), and heap_block::requested.

Referenced by capsule_vm_registry_init(), hal_mem_free(), sf_free(), vt100_enable_ttf(), and vt100_init().

Here is the call graph for this function:



Here is the caller graph for this function:



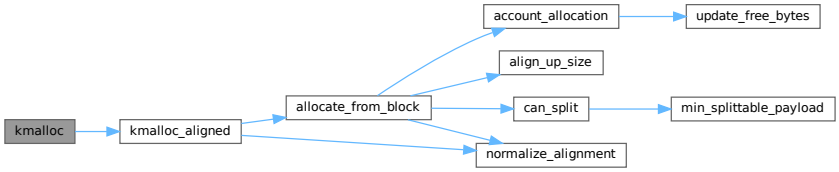
7.165.3.8 kmalloc()

```
void * kmalloc (
            size_t size )
```

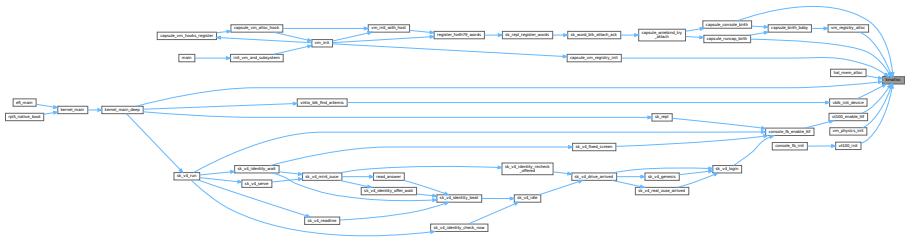
References kmalloc_aligned(), and KMALLOC_MIN_ALIGN.

Referenced by capsule_console_birth(), capsule_runcap_birth(), capsule_vm_registry_init(), hal_mem_alloc(), kernel_main_deep(), vblk_init_device(), vm_physics_init(), vm_registry_alloc(), vt100_enable_ttf(), and vt100_init().

Here is the call graph for this function:



Here is the caller graph for this function:



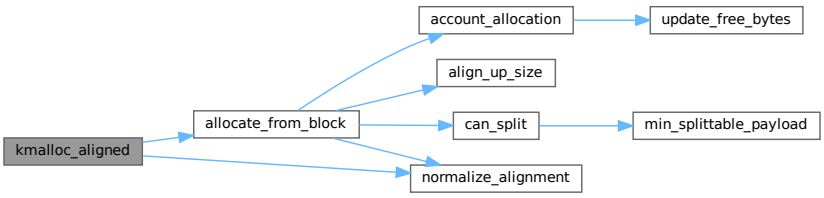
7.165.3.9 kmalloc_aligned()

```
void * kmalloc_aligned (
            size_t size,
            size_t align )
```

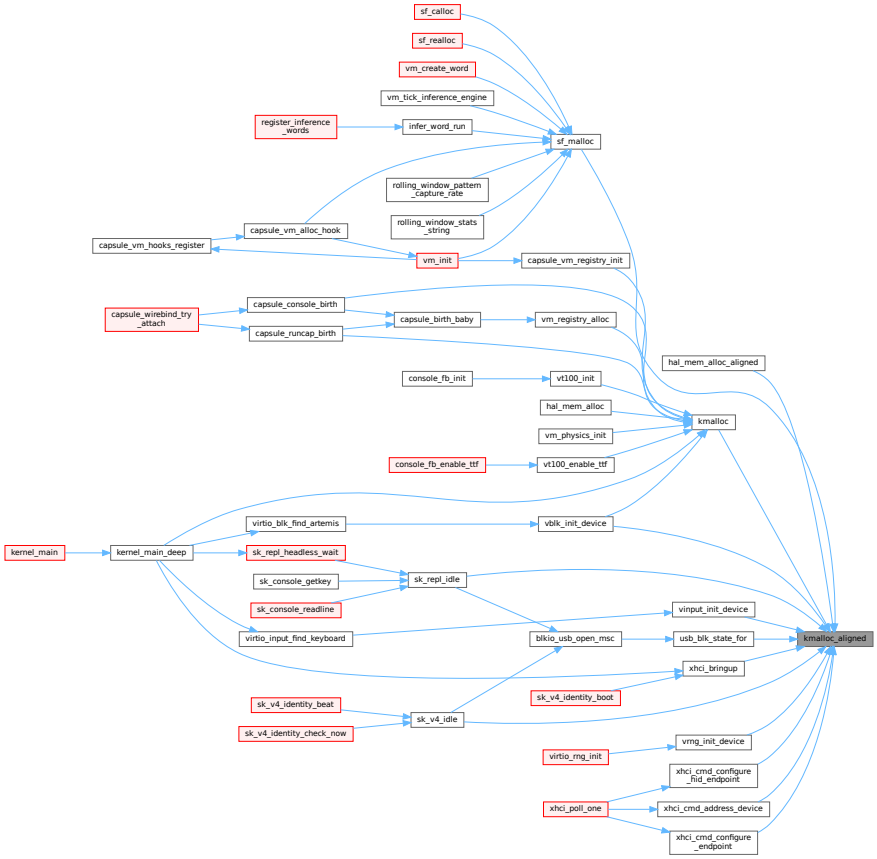
References allocate_from_block(), heap_block::free, heap_head, heap_initialized, heap_block::next, and normalize_alignment().

Referenced by hal_mem_alloc_aligned(), kmalloc(), sf_malloc(), sk_repl_idle(), sk_v4_idle(), usb_blk_state_for(), vblk_init_device(), vinput_init_device(), vrng_init_device(), xhci_bringup(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

Here is the call graph for this function:



Here is the caller graph for this function:



7.165.3.10 kmalloc_debug_census()

```
void kmalloc_debug_census (
            size_t * out_largest_free,
            size_t * out_free_count,
            size_t * out_used_count,
            size_t * out_total_blocks )
```

References heap_block::free, heap_head, heap_block::next, and heap_block::size.

7.165.3.11 kmalloc_debug_census_bytes()

```
void kmalloc_debug_census_bytes (
            size_t * out_total_free_bytes,
            size_t * out_total_used_bytes )
```

References heap_block::free, heap_head, heap_block::next, and heap_block::size.

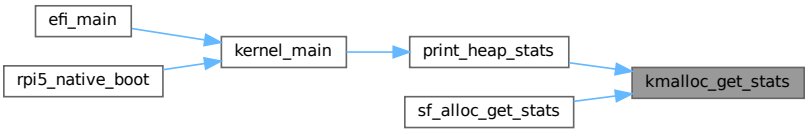
7.165.3.12 kmalloc_get_stats()

```
kmalloc_stats_t kmalloc_get_stats (
            void  )
```

References heap_stats.

Referenced by print_heap_stats(), and sf_alloc_get_stats().

Here is the caller graph for this function:



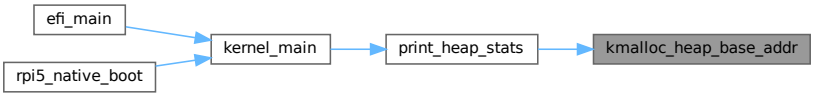
7.165.3.13 kmalloc_heap_base_addr()

```
uintptr_t kmalloc_heap_base_addr (
            void  )
```

References heap_base.

Referenced by print_heap_stats().

Here is the caller graph for this function:



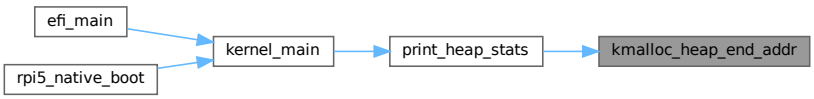
7.165.3.14 kmalloc_heap_end_addr()

```
uintptr_t kmalloc_heap_end_addr (
            void  )
```

References heap_base, and heap_size.

Referenced by print_heap_stats().

Here is the caller graph for this function:



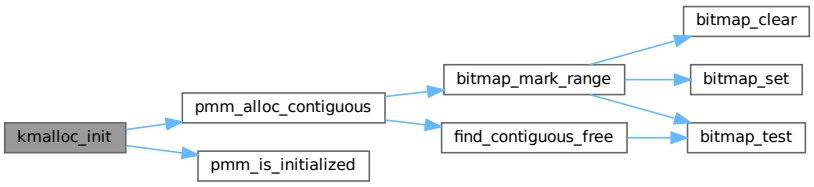
7.165.3.15 kmalloc_init()

```
int kmalloc_init (
            uint64_t heap_size_bytes )
```

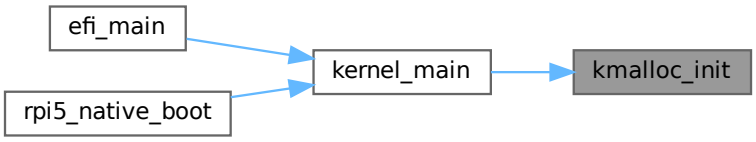
References heap_block::free, kmalloc_stats_t::free_bytes, heap_base, heap_head, heap_initialized, heap_size, heap_stats, KMALLOC_DEFAULT_HEAP_SIZE, KMALLOC_MIN_PAGES, heap_block::next, kmalloc_stats_t::peak_bytes, pmm_alloc_contiguous(), pmm_is_initialized(), PMM_PAGE_SIZE, heap_block::prev, heap_block::requested, heap_block::size, kmalloc_stats_t::total_bytes, and kmalloc_stats_t::used_bytes.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.165.3.16 kmalloc_is_initialized()

```
int kmalloc_is_initialized (
            void  )
```

References heap_initialized.

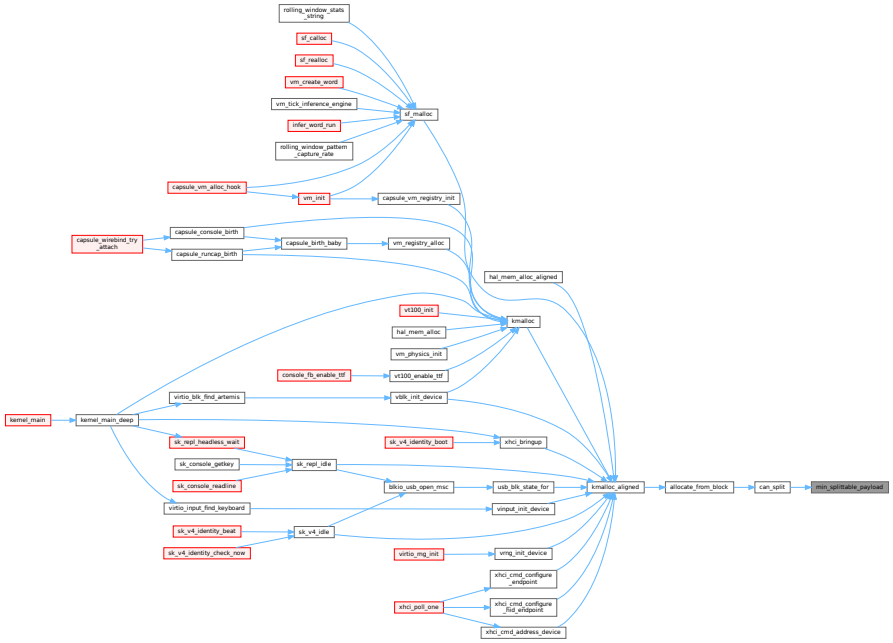
7.165.3.17 min_splittable_payload()

```
static size_t min_splittable_payload (
            void  )  [static]
```

References KMALLOC_MIN_ALIGN.

Referenced by can_split().

Here is the caller graph for this function:



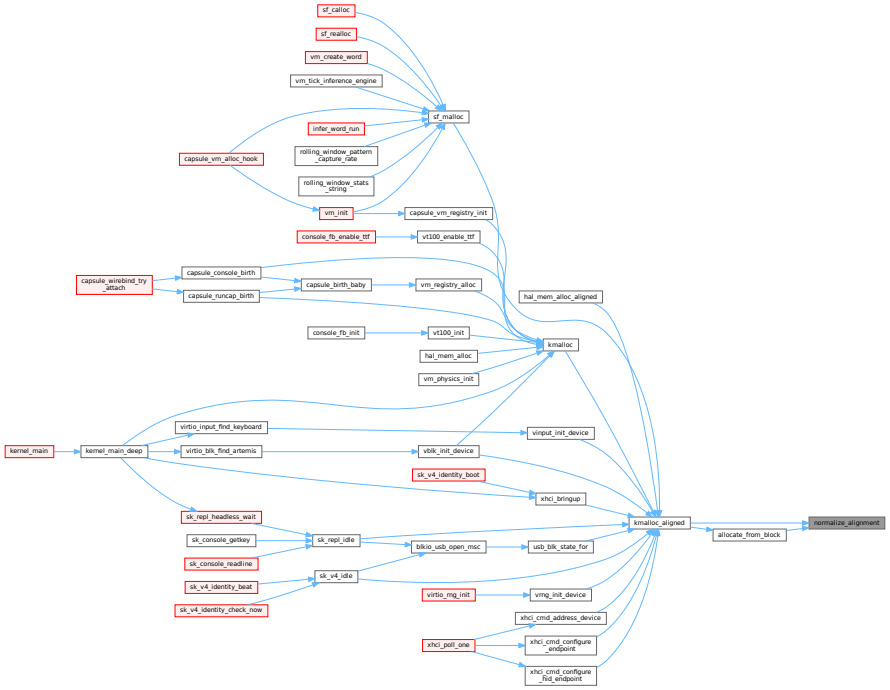
7.165.3.18 normalize_alignment()

```
static size_t normalize_alignment (
            size_t align )  [static]
```

References KMALLOC_MIN_ALIGN.

Referenced by allocate_from_block(), and kmalloc_aligned().

Here is the caller graph for this function:



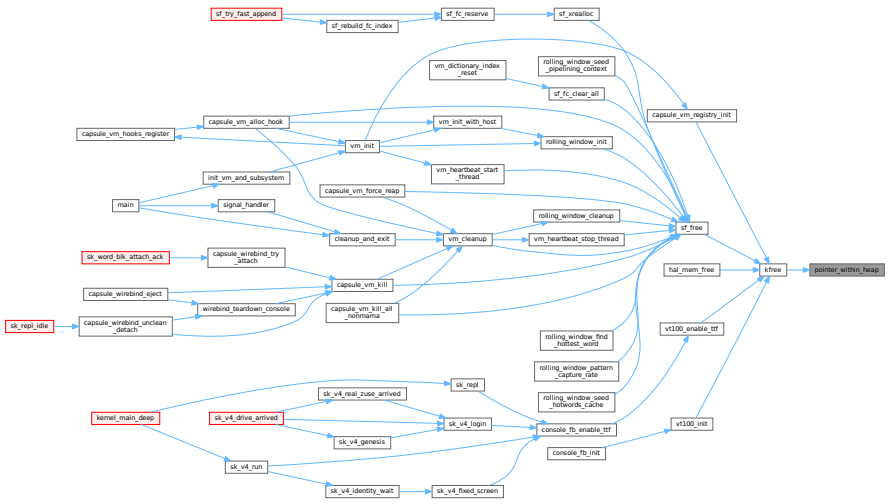
7.165.3.19 pointer_within_heap()

```
static int pointer_within_heap (
            const void * ptr )  [static]
```

References heap_base, and heap_size.

Referenced by kfree().

Here is the caller graph for this function:



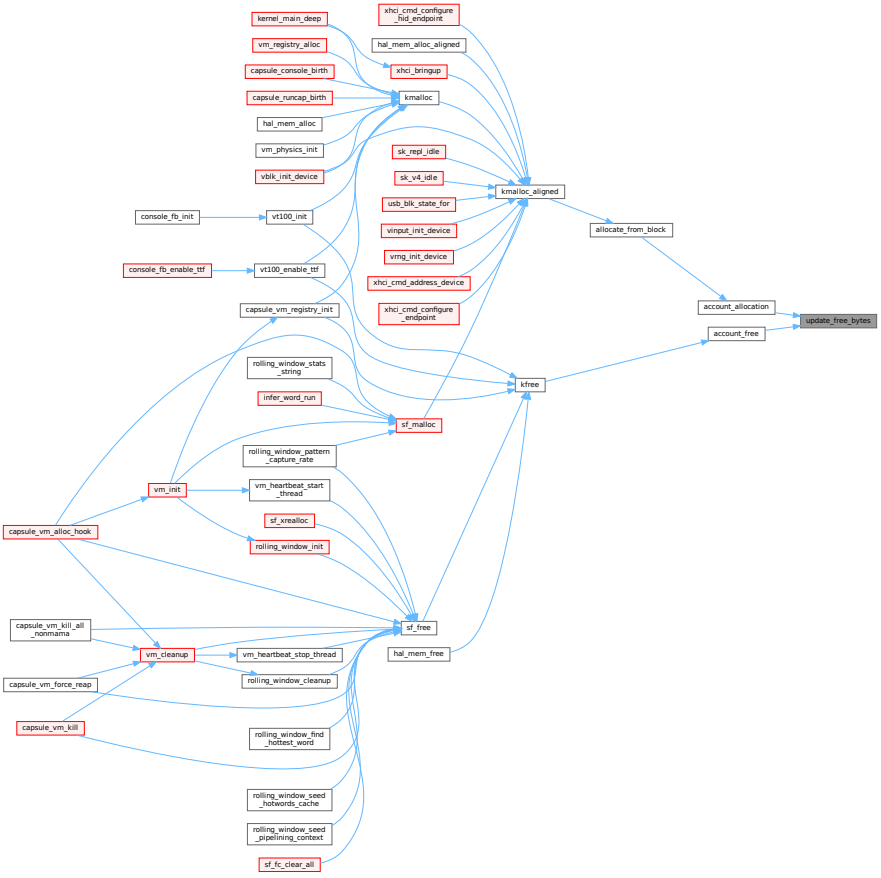
7.165.3.20 update_free_bytes()

```
static void update_free_bytes (
            void  )  [static]
```

References kmalloc_stats_t::free_bytes, heap_stats, kmalloc_stats_t::total_bytes, and kmalloc_stats_t::used_bytes.

Referenced by account_allocation(), and account_free().

Here is the caller graph for this function:



7.165.4 Variable Documentation

7.165.4.1 heap_base

```
uint8_t* heap_base = NULL  [static]
```

Referenced by kmalloc_heap_base_addr(), kmalloc_heap_end_addr(), kmalloc_init(), and pointer_within_heap().

7.165.4.2 heap_head

```
heap_block_t* heap_head = NULL  [static]
```

Referenced by coalesce_neighbors(), kmalloc_aligned(), kmalloc_debug_census(), kmalloc_debug_census_bytes(), and kmalloc_init().

7.165.4.3 heap_initialized

```
int heap_initialized = 0  [static]
```

Referenced by kfree(), kmalloc_aligned(), kmalloc_init(), and kmalloc_is_initialized().

7.165.4.4 heap_size

```
uint64_t heap_size = 0  [static]
```

Referenced by kmalloc_heap_end_addr(), kmalloc_init(), and pointer_within_heap().

7.165.4.5 heap_stats

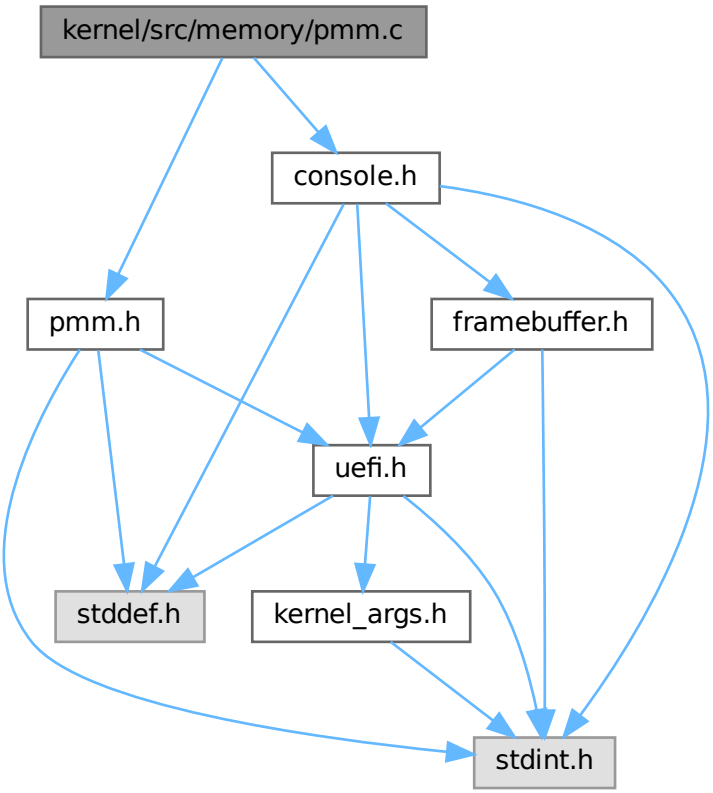
```
kmalloc_stats_t heap_stats = {0}  [static]
```

Referenced by account_allocation(), account_free(), kmalloc_get_stats(), kmalloc_init(), and update_free_bytes().

7.166 kernel/src/memory/pmm.c File Reference

```
#include "pmm.h"
#include "console.h"
```

Include dependency graph for pmm.c:



Macros

- #define PMM_MAX_BITMAP_BYTES (2u ∗ 1024u ∗ 1024u) /∗ Tracks up to ∼64 GiB ∗/

  pmm.c - Physical Memory Manager (bitmap allocator)
- #define PMM_BITMAP_BITS (PMM_MAX_BITMAP_BYTES ∗ 8ull)

Functions

- static void pmm_memset (void ∗dst, uint8_t value, size_t size)
- static uint64_t pmm_bytes_to_pages (uint64_t bytes)
- static void bitmap_set (uint64_t bit)
- static void bitmap_clear (uint64_t bit)
- static int bitmap_test (uint64_t bit)
- static void bitmap_mark_range (uint64_t start_page, uint64_t page_count, int used)
- static uint64_t find_contiguous_free (uint64_t pages_needed)
- static int is_usable_memory (uint32_t type)
- static int is_ram_type (uint32_t type)
- static void recompute_free_pages (void)
- int pmm_init (BootInfo ∗boot_info)
- int pmm_is_initialized (void)
- uint64_t pmm_alloc_page (void)
- uint64_t pmm_alloc_contiguous (uint64_t num_pages)
- void pmm_free_page (uint64_t paddr)
- void pmm_free_contiguous (uint64_t paddr, uint64_t num_pages)
- pmm_stats_t pmm_get_stats (void)

Variables

- static const uint64_t pmm_alloc_floor_page = 0x100000u / PMM_PAGE_SIZE
- static uint8_t pmm_bitmap [(2u ∗1024u ∗1024u)]
- static uint64_t pmm_total_pages = 0
- static uint64_t pmm_free_pages = 0
- static int pmm_initialized = 0
- static uint64_t pmm_tracked_pages = 0
- char __kernel_start [ ]
- char __kernel_end [ ]

7.166.1 Macro Definition Documentation

7.166.1.1 PMM_BITMAP_BITS

```
#define PMM_BITMAP_BITS (PMM_MAX_BITMAP_BYTES ∗ 8ull)
```

7.166.1.2 PMM_MAX_BITMAP_BYTES

```
#define PMM_MAX_BITMAP_BYTES (2u ∗ 1024u ∗ 1024u) /∗ Tracks up to ∼64 GiB ∗/
```

pmm.c - Physical Memory Manager (bitmap allocator)

Builds a 1-bit-per-page bitmap from the UEFI memory map and provides primitive page allocation for early kernel bring-up. The allocator favors simplicity and debuggability; performance tuning can happen once paging and interrupts are in place.

7.166.2 Function Documentation

7.166.2.1 bitmap_clear()

```
static void bitmap_clear (
            uint64_t bit )  [inline], [static]
```

References pmm_bitmap.

Referenced by bitmap_mark_range().

Here is the caller graph for this function:

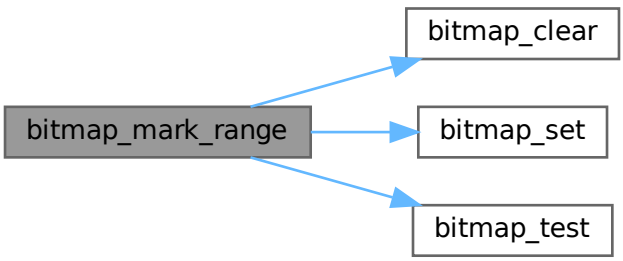
7.166.2.2 bitmap_mark_range()

```
static void bitmap_mark_range (
            uint64_t start_page,
            uint64_t page_count,
            int used )  [static]
```

References bitmap_clear(), bitmap_set(), bitmap_test(), pmm_free_pages, and pmm_tracked_pages.

Referenced by pmm_alloc_contiguous(), pmm_alloc_page(), pmm_free_contiguous(), and pmm_init().

Here is the call graph for this function:



Here is the caller graph for this function:

7.166.2.3 bitmap_set()

```
static void bitmap_set (
            uint64_t bit )  [inline], [static]
```

References pmm_bitmap.

Referenced by bitmap_mark_range().

Here is the caller graph for this function:

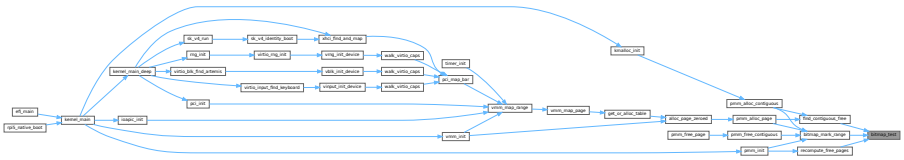
7.166.2.4 bitmap_test()

```
static int bitmap_test (
            uint64_t bit )  [inline], [static]
```

References pmm_bitmap.

Referenced by bitmap_mark_range(), find_contiguous_free(), and recompute_free_pages().

Here is the caller graph for this function:



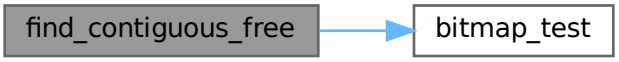
7.166.2.5 find_contiguous_free()

```
static uint64_t find_contiguous_free (
            uint64_t pages_needed )  [static]
```

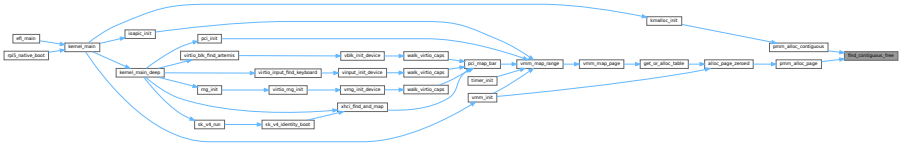
References bitmap_test(), pmm_alloc_floor_page, and pmm_tracked_pages.

Referenced by pmm_alloc_contiguous(), and pmm_alloc_page().

Here is the call graph for this function:



Here is the caller graph for this function:



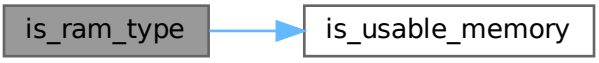
7.166.2.6 is_ram_type()

```
static int is_ram_type (
            uint32_t type ) [static]
```

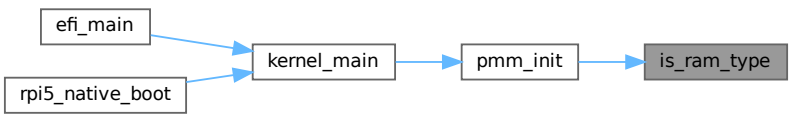
References EfiACPIMemoryNVS, EfiACPIReclaimMemory, EfiRuntimeServicesCode, EfiRuntimeServicesData, and is_usable_memory().

Referenced by pmm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



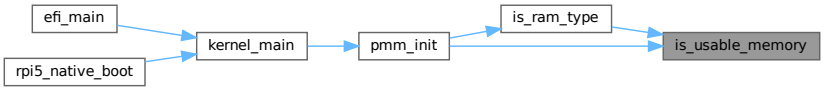
7.166.2.7 is_usable_memory()

```
static int is_usable_memory (
            uint32_t type )  [static]
```

References EfiConventionalMemory.

Referenced by is_ram_type(), and pmm_init().

Here is the caller graph for this function:



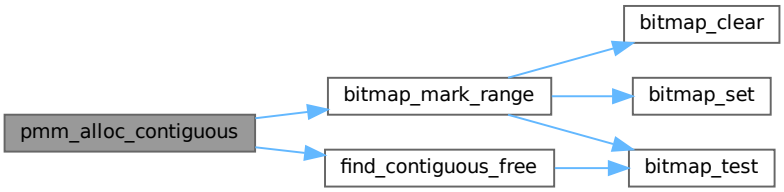
7.166.2.8 pmm_alloc_contiguous()

```
uint64_t pmm_alloc_contiguous (
            uint64_t num_pages )
```

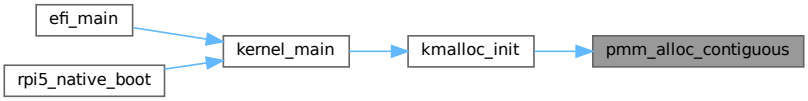
References bitmap_mark_range(), find_contiguous_free(), pmm_initialized, and PMM_PAGE_SIZE.

Referenced by kmalloc_init().

Here is the call graph for this function:



Here is the caller graph for this function:



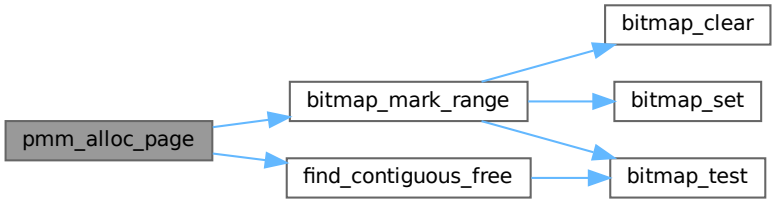
7.166.2.9 pmm_alloc_page()

```
uint64_t pmm_alloc_page (
            void  )
```

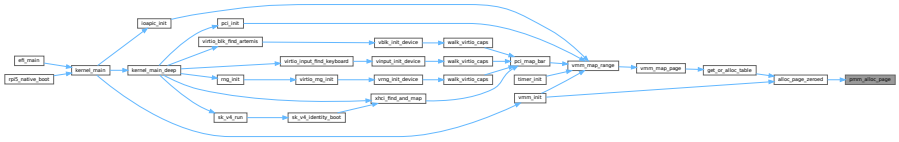
References bitmap_mark_range(), find_contiguous_free(), pmm_initialized, and PMM_PAGE_SIZE.

Referenced by alloc_page_zeroed().

Here is the call graph for this function:



Here is the caller graph for this function:



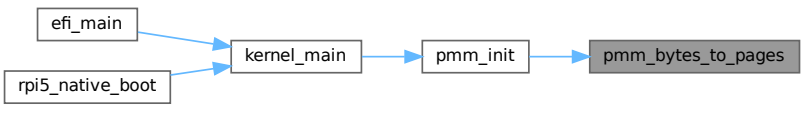
7.166.2.10 pmm_bytes_to_pages()

```
static uint64_t pmm_bytes_to_pages (
            uint64_t bytes )  [inline], [static]
```

References bytes, and PMM_PAGE_SIZE.

Referenced by pmm_init().

Here is the caller graph for this function:



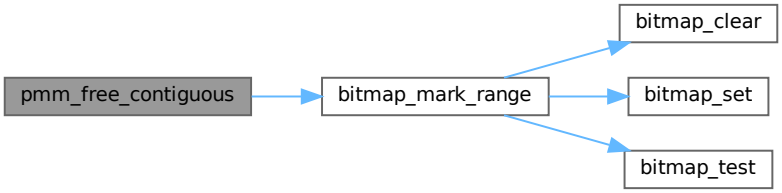
7.166.2.11 pmm_free_contiguous()

```
void pmm_free_contiguous (
            uint64_t paddr,
            uint64_t num_pages )
```

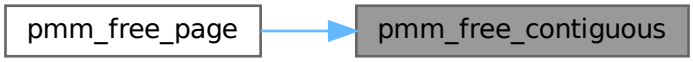
References bitmap_mark_range(), pmm_initialized, PMM_PAGE_SIZE, and pmm_tracked_pages.

Referenced by pmm_free_page().

Here is the call graph for this function:



Here is the caller graph for this function:

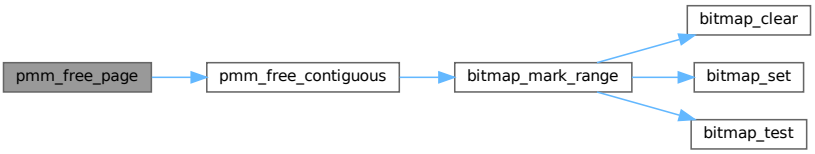


7.166.2.12 pmm_free_page()

```
void pmm_free_page (
            uint64_t paddr )
```

References pmm_free_contiguous(), pmm_initialized, and PMM_PAGE_SIZE.

Here is the call graph for this function:



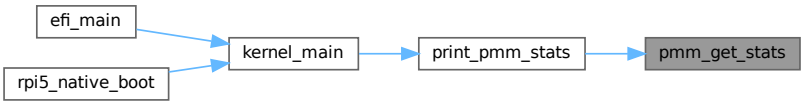
7.166.2.13 pmm_get_stats()

```
pmm_stats_t pmm_get_stats (
            void  )
```

References pmm_stats_t::free_bytes, pmm_stats_t::free_pages, pmm_free_pages, PMM_PAGE_SIZE, pmm_total_pages, pmm_stats_t::total_bytes, pmm_stats_t::total_pages, pmm_stats_t::used_bytes, and pmm_stats_t::used_pages.

Referenced by print_pmm_stats().

Here is the caller graph for this function:



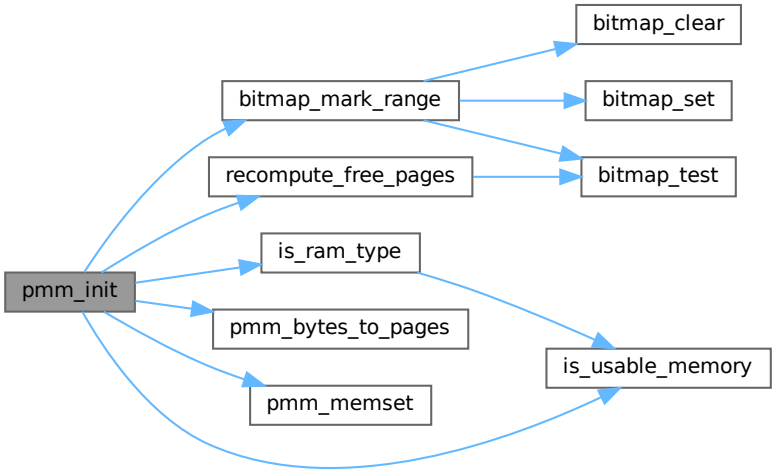
7.166.2.14 pmm_init()

```
int pmm_init (
            BootInfo * boot_info )
```

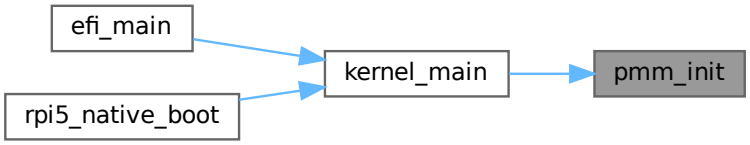
References __kernel_end, __kernel_start, bitmap_mark_range(), is_ram_type(), is_usable_memory(), BootInfo::memory_map, BootInfo::memory_map_descriptor_size, BootInfo::memory_map_size, EFI_MEMORY_DESCRIPTOR::NumberOfPages, EFI_MEMORY_DESCRIPTOR::PhysicalStart, pmm_alloc_floor_page, pmm_bitmap, PMM_BITMAP_BITS, pmm_bytes_to_pages(), pmm_free_pages, pmm_initialized, pmm_memset(), PMM_PAGE_SIZE, pmm_total_pages, pmm_tracked_pages, recompute_free_pages(), and EFI_MEMORY_DESCRIPTOR::Type.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



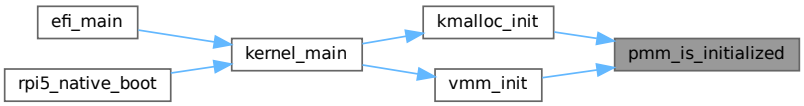
7.166.2.15 pmm_is_initialized()

```
int pmm_is_initialized (
            void  )
```

References pmm_initialized.

Referenced by kmalloc_init(), and vmm_init().

Here is the caller graph for this function:

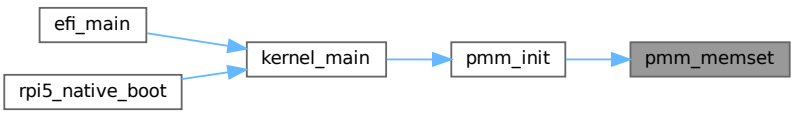


7.166.2.16 pmm_memset()

```
static void pmm_memset (
            void * dst,
            uint8_t value,
            size_t size )  [static]
```

Referenced by pmm_init().

Here is the caller graph for this function:



7.166.2.17 recompute_free_pages()

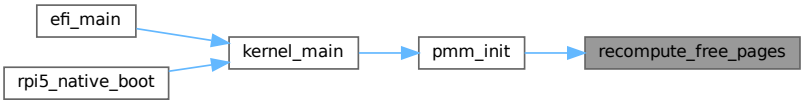
```
static void recompute_free_pages (
            void  )  [static]
```

References bitmap_test(), pmm_free_pages, and pmm_tracked_pages.

Referenced by pmm_init().

Here is the call graph for this function:

Here is the caller graph for this function:



7.166.3 Variable Documentation

7.166.3.1 __kernel_end

```
char __kernel_end[]  [extern]
```

Referenced by pmm_init(), and rpi5_mmu_uncached().

7.166.3.2 __kernel_start

```
char __kernel_start[]  [extern]
```

Referenced by pmm_init().

7.166.3.3 pmm_alloc_floor_page

```
const uint64_t pmm_alloc_floor_page = 0x100000u / PMM_PAGE_SIZE  [static]
```

Referenced by find_contiguous_free(), and pmm_init().

7.166.3.4 pmm_bitmap

```
uint8_t pmm_bitmap[(2u *1024u *1024u)]  [static]
```

Referenced by bitmap_clear(), bitmap_set(), bitmap_test(), and pmm_init().

7.166.3.5 pmm_free_pages

```
uint64_t pmm_free_pages = 0  [static]
```

Referenced by bitmap_mark_range(), pmm_get_stats(), pmm_init(), and recompute_free_pages().

7.166.3.6 pmm_initialized

```
int pmm_initialized = 0  [static]
```

Referenced by pmm_alloc_contiguous(), pmm_alloc_page(), pmm_free_contiguous(), pmm_free_page(), pmm_init(), and pmm_is_initialized().

7.166.3.7 pmm_total_pages

```
uint64_t pmm_total_pages = 0  [static]
```

Referenced by pmm_get_stats(), and pmm_init().

7.166.3.8 pmm_tracked_pages

```
uint64_t pmm_tracked_pages = 0  [static]
```

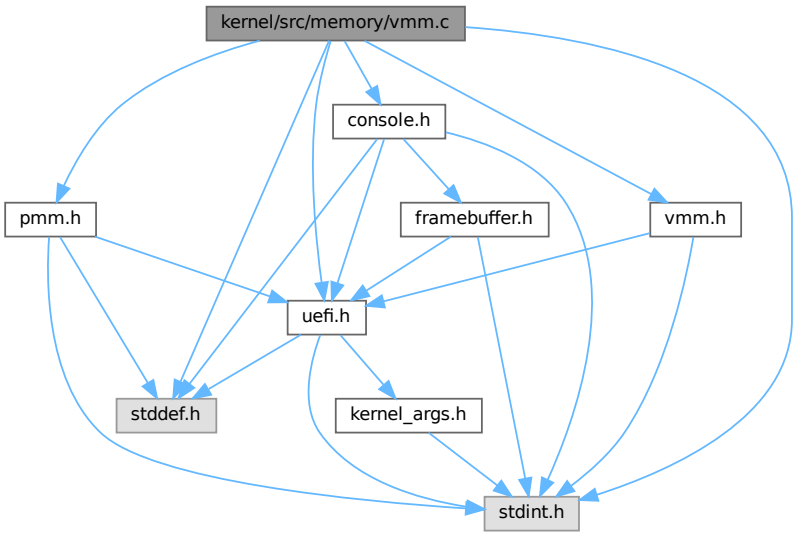
Referenced by bitmap_mark_range(), find_contiguous_free(), pmm_free_contiguous(), pmm_init(), and recompute_free_pages().

7.167 kernel/src/memory/vmm.c File Reference

```
#include <stddef.h>
#include <stdint.h>
#include "vmm.h"
#include "pmm.h"
#include "console.h"
```

```
#include "uefi.h"
```

Include dependency graph for vmm.c:



Macros

- #define PTE_PRESENT (1ull << 0)

  vmm.c - 4-level paging Virtual Memory Manager (x86_64)
- #define PTE_WRITABLE (1ull << 1)
- #define PTE_USER (1ull << 2)
- #define PTE_PWT (1ull << 3)
- #define PTE_PCD (1ull << 4)
- #define PTE_ACCESSED (1ull << 5)
- #define PTE_DIRTY (1ull << 6)
- #define PTE_PS (1ull << 7)
- #define PTE_GLOBAL (1ull << 8)
- #define PTE_NX (1ull << 63)
- #define ADDR_MASK 0x000FFFFFFFFFF000ull

Functions

- static int is_ram_type (uint32_t type)
- static uint64_t * paddr_to_virt (uint64_t paddr)
- static uint64_t alloc_page_zeroed (void)
- static uint16_t pml4_index (uint64_t vaddr)
- static uint16_t pdpt_index (uint64_t vaddr)
- static uint16_t pd_index (uint64_t vaddr)
- static uint16_t pt_index (uint64_t vaddr)
- static uint64_t * get_or_alloc_table (uint64_t *parent, uint16_t idx)
- static uint64_t * get_table (uint64_t *parent, uint16_t idx)
- static uint64_t make_pte (uint64_t paddr, uint64_t flags)
- static void invlpg (uint64_t vaddr)

- static void load_cr3 (uint64_t pml4_phys)
- static uint64_t * resolve_pt (uint64_t vaddr, uint16_t *idx_out)
- int vmm_map_page (uint64_t vaddr, uint64_t paddr, uint64_t flags)
- int vmm_unmap_page (uint64_t vaddr)
- uint64_t vmm_get_paddr (uint64_t vaddr)
- int vmm_map_range (uint64_t vaddr, uint64_t paddr, uint64_t size, uint64_t flags)
- int vmm_query_page (uint64_t vaddr, vmm_page_info_t *info)
- int vmm_init (BootInfo *boot_info)

Variables

- static uint64_t vmm_root_pml4_phys = 0
- static const uint64_t lapic_phys_base = 0xFEE00000ull
- static const uint64_t hpet_phys_base = 0xFED00000ull

7.167.1 Macro Definition Documentation

7.167.1.1 ADDR_MASK

```
#define ADDR_MASK 0x000FFFFFFFFFF000ull
```

7.167.1.2 PTE_ACCESSED

```
#define PTE_ACCESSED (1ull << 5)
```

7.167.1.3 PTE_DIRTY

```
#define PTE_DIRTY (1ull << 6)
```

7.167.1.4 PTE_GLOBAL

```
#define PTE_GLOBAL (1ull << 8)
```

7.167.1.5 PTE_NX

```
#define PTE_NX (1ull << 63)
```

7.167.1.6 PTE_PCD

```
#define PTE_PCD (1ull << 4)
```

7.167.1.7 PTE_PRESENT

```
#define PTE_PRESENT (1ull << 0)
```

vmm.c - 4-level paging Virtual Memory Manager (x86_64)

Minimal bring-up: identity maps the first 16 MiB, supports single-page map/unmap/query, and switches to the new page table root.

7.167.1.8 PTE_PS

```
#define PTE_PS (1ull << 7)
```

7.167.1.9 PTE_PWT

```
#define PTE_PWT (1ull << 3)
```

7.167.1.10 PTE_USER

```
#define PTE_USER (1ull << 2)
```

7.167.1.11 PTE_WRITABLE

```
#define PTE_WRITABLE (1ull << 1)
```

7.167.2 Function Documentation

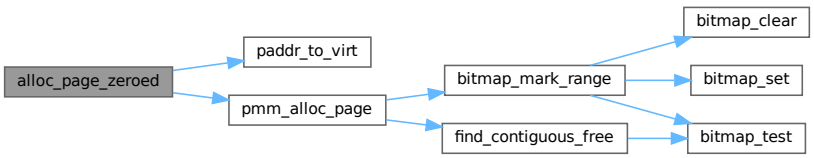
7.167.2.1 alloc_page_zeroed()

```
static uint64_t alloc_page_zeroed (
            void  )  [static]
```

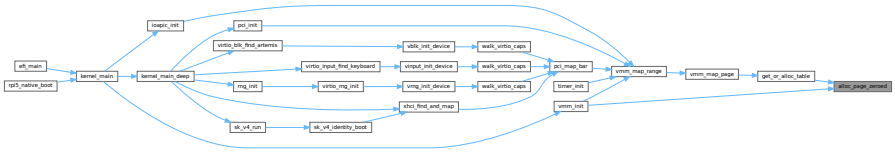
References paddr_to_virt(), pmm_alloc_page(), and VMM_PAGE_SIZE.

Referenced by get_or_alloc_table(), and vmm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



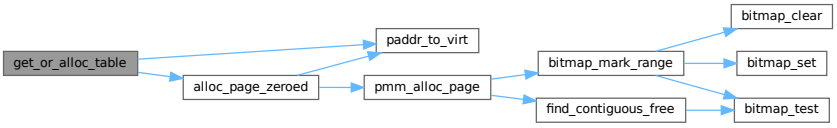
7.167.2.2 get_or_alloc_table()

```
static uint64_t * get_or_alloc_table (
            uint64_t * parent,
            uint16_t idx )  [static]
```

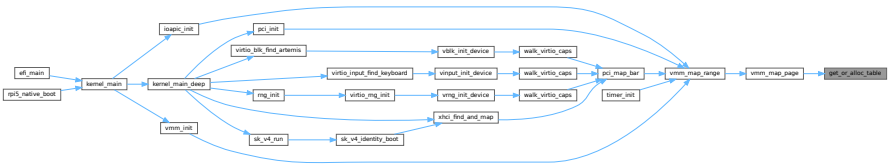
References ADDR_MASK, alloc_page_zeroed(), entry, paddr_to_virt(), PTE_PRESENT, and PTE_WRITABLE.

Referenced by vmm_map_page().

Here is the call graph for this function:



Here is the caller graph for this function:



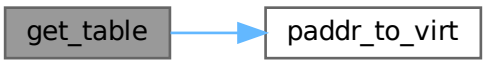
7.167.2.3 get_table()

```
static uint64_t * get_table (
            uint64_t * parent,
            uint16_t idx )  [static]
```

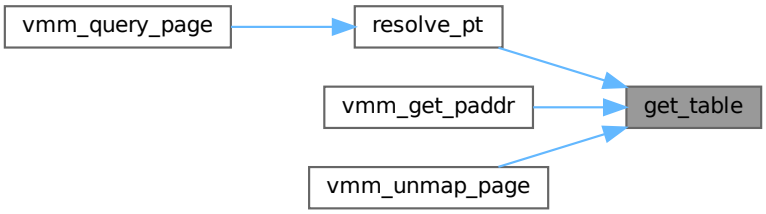
References ADDR_MASK, entry, paddr_to_virt(), and PTE_PRESENT.

Referenced by resolve_pt(), vmm_get_paddr(), and vmm_unmap_page().

Here is the call graph for this function:



Here is the caller graph for this function:

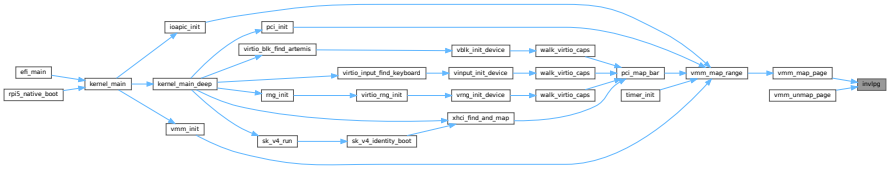


7.167.2.4 invlpg()

```
static void invlpg (
            uint64_t vaddr )  [inline], [static]
```

Referenced by vmm_map_page(), and vmm_unmap_page().

Here is the caller graph for this function:



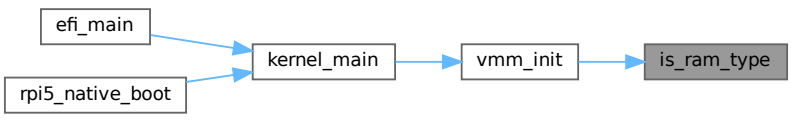
7.167.2.5 is_ram_type()

```
static int is_ram_type (
            uint32_t type )  [static]
```

References EfiACPIMemoryNVS, EfiACPIReclaimMemory, EfiBootServicesCode, EfiBootServicesData, EfiConventionalMemory, EfiLoaderCode, EfiLoaderData, EfiRuntimeServicesCode, and EfiRuntimeServicesData.

Referenced by vmm_init().

Here is the caller graph for this function:

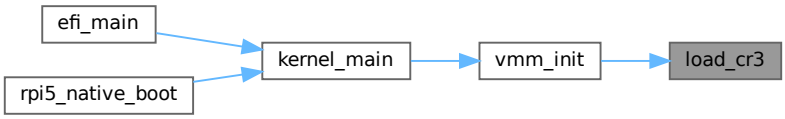


7.167.2.6 load_cr3()

```
static void load_cr3 (
            uint64_t pml4_phys )  [inline], [static]
```

Referenced by vmm_init().

Here is the caller graph for this function:



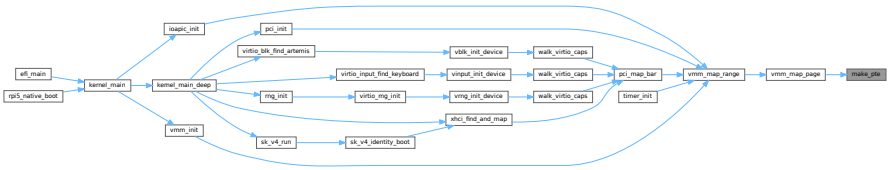
7.167.2.7 make_pte()

```
static uint64_t make_pte (
            uint64_t paddr,
            uint64_t flags )  [static]
```

References ADDR_MASK, flags, PTE_NX, PTE_PCD, PTE_PRESENT, PTE_USER, PTE_WRITABLE, VMM_FLAG_CACHE_DISABLE, VMM_FLAG_NX, VMM_FLAG_PRESENT, VMM_FLAG_USER, and VMM_FLAG_WRITABLE.

Referenced by vmm_map_page().

Here is the caller graph for this function:

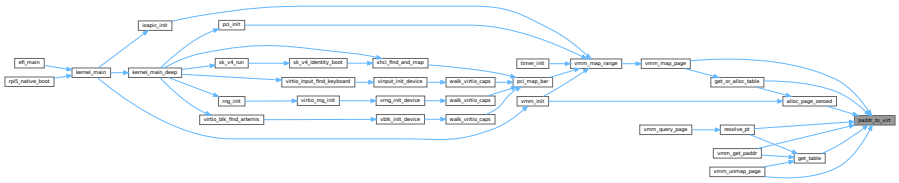


7.167.2.8 paddr_to_virt()

```
static uint64_t * paddr_to_virt (
            uint64_t paddr )  [inline], [static]
```

Referenced by alloc_page_zeroed(), get_or_alloc_table(), get_table(), resolve_pt(), vmm_get_paddr(), vmm_map_page(), and vmm_unmap_page().

Here is the caller graph for this function:

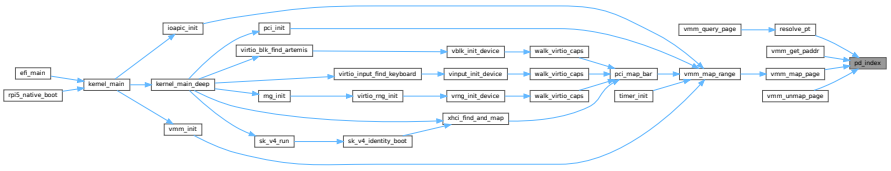


7.167.2.9 pd_index()

```
static uint16_t pd_index (
            uint64_t vaddr )  [inline], [static]
```

Referenced by resolve_pt(), vmm_get_paddr(), vmm_map_page(), and vmm_unmap_page().

Here is the caller graph for this function:

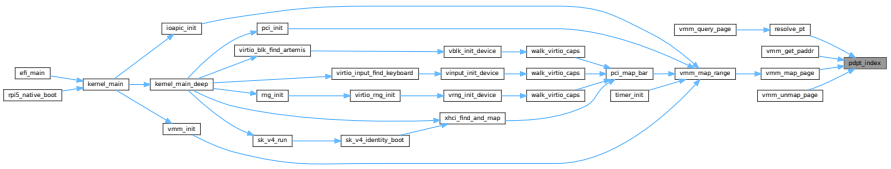


7.167.2.10 pdpt_index()

```
static uint16_t pdpt_index (
            uint64_t vaddr )  [inline], [static]
```

Referenced by resolve_pt(), vmm_get_paddr(), vmm_map_page(), and vmm_unmap_page().

Here is the caller graph for this function:

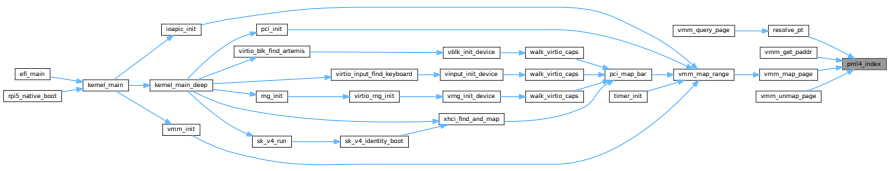


7.167.2.11 pml4_index()

```
static uint16_t pml4_index (
            uint64_t vaddr )  [inline], [static]
```

Referenced by resolve_pt(), vmm_get_paddr(), vmm_map_page(), and vmm_unmap_page().

Here is the caller graph for this function:

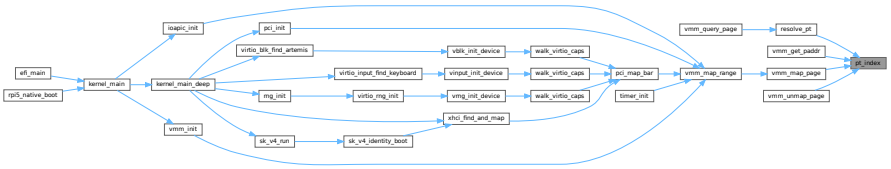


7.167.2.12 pt_index()

```
static uint16_t pt_index (
            uint64_t vaddr )  [inline], [static]
```

Referenced by resolve_pt(), vmm_get_paddr(), vmm_map_page(), and vmm_unmap_page().

Here is the caller graph for this function:



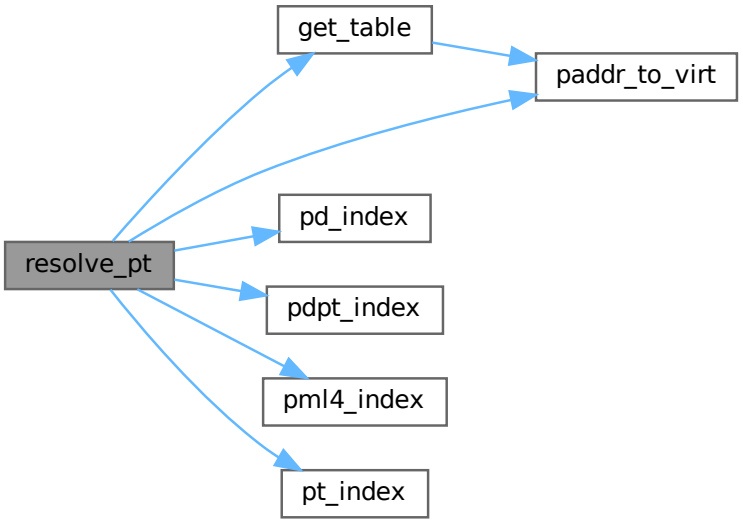
7.167.2.13 resolve_pt()

```
static uint64_t * resolve_pt (
            uint64_t vaddr,
            uint16_t * idx_out )  [static]
```

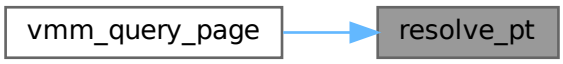
References get_table(), paddr_to_virt(), pd_index(), pdpt_index(), pml4_index(), pt_index(), and vmm_root_pml4_phys.

Referenced by vmm_query_page().

Here is the call graph for this function:



Here is the caller graph for this function:

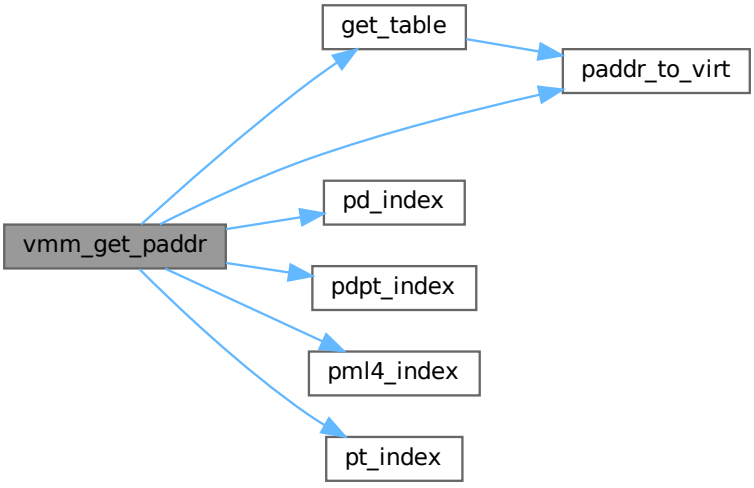


7.167.2.14 vmm_get_paddr()

```
uint64_t vmm_get_paddr (
            uint64_t vaddr )
```

References ADDR_MASK, get_table(), paddr_to_virt(), pd_index(), pdpt_index(), pml4_index(), pt_index(), PTE_PRESENT, and vmm_root_pml4_phys.

Here is the call graph for this function:



7.167.2.15 vmm_init()

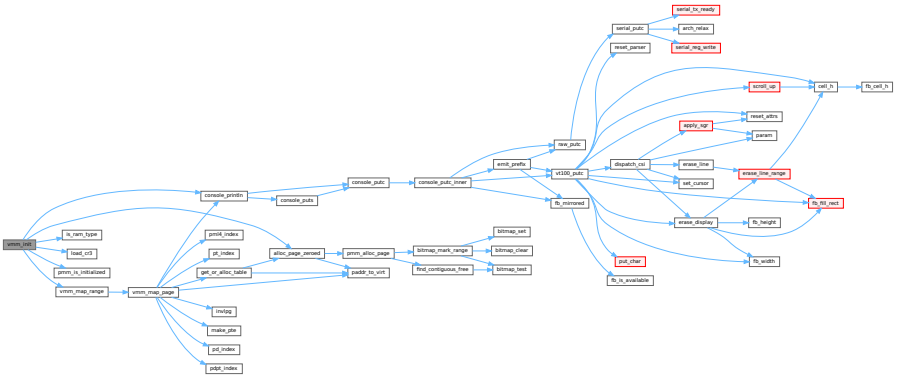
```
int vmm_init (
            BootInfo * boot_info )
```

References alloc_page_zeroed(), FramebufferInfo::base, console_println(), BootInfo::framebuffer, hpet_phys_base, is_ram_type(), lapic_phys_base, load_cr3(), BootInfo::memory_map, BootInfo::memory_map_descriptor_size, BootInfo::memory_map_size, EFI_MEMORY_DESCRIPTOR::NumberOfPages, EFI_MEMORY_DESCRIPTOR::PhysicalStart,

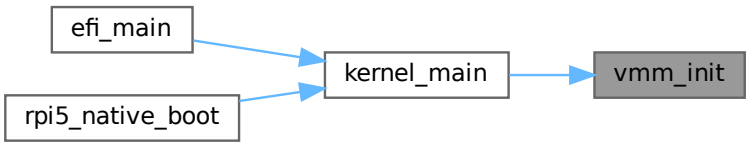
pmm_is_initialized(), FramebufferInfo::size, EFI_MEMORY_DESCRIPTOR::Type, VMM_FLAG_CACHE_DISABLE, VMM_FLAG_WRITABLE, vmm_map_range(), VMM_PAGE_SIZE, and vmm_root_pml4_phys.

Referenced by kernel_main().

Here is the call graph for this function:



Here is the caller graph for this function:



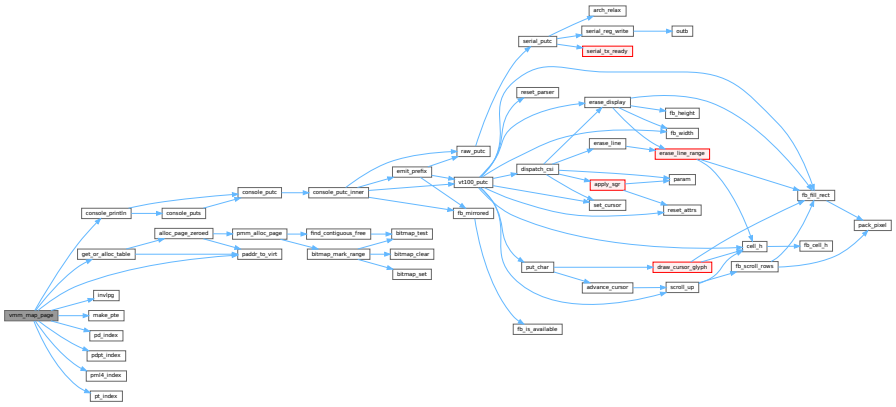
7.167.2.16 vmm_map_page()

```
int vmm_map_page (
            uint64_t vaddr,
            uint64_t paddr,
            uint64_t flags )
```

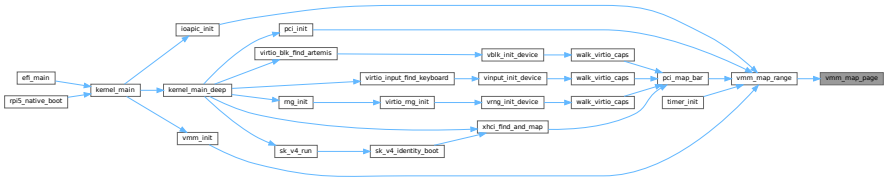
References ADDR_MASK, console_println(), flags, get_or_alloc_table(), invlpg(), make_pte(), paddr_to_virt(), pd_index(), pdpt_index(), pml4_index(), pt_index(), PTE_PRESENT, PTE_WRITABLE, VMM_FLAG_PRESENT, and vmm_root_pml4_phys.

Referenced by vmm_map_range().

Here is the call graph for this function:



Here is the caller graph for this function:



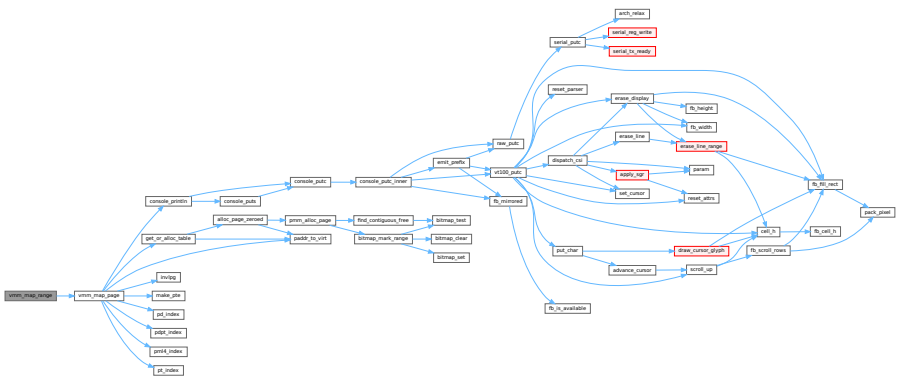
7.167.2.17 vmm_map_range()

```
int vmm_map_range (
            uint64_t vaddr,
            uint64_t paddr,
            uint64_t size,
            uint64_t flags )
```

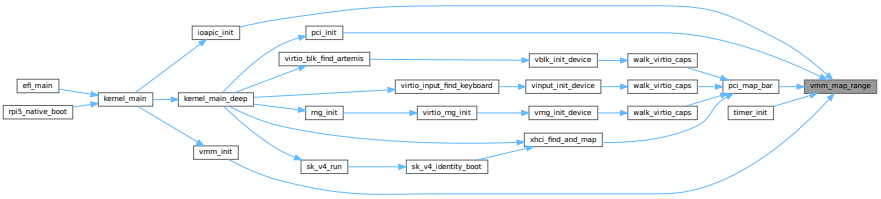
References flags, vmm_map_page(), and VMM_PAGE_SIZE.

Referenced by ioapic_init(), pci_init(), pci_map_bar(), timer_init(), and vmm_init().

Here is the call graph for this function:



Here is the caller graph for this function:

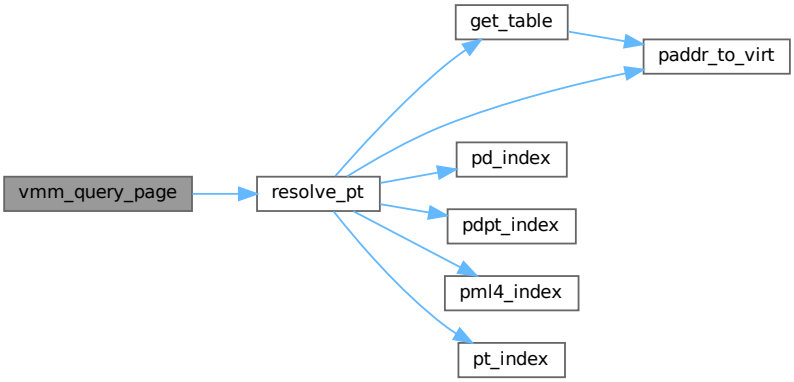


7.167.2.18 vmm_query_page()

```
int vmm_query_page (
            uint64_t vaddr,
            vmm_page_info_t * info )
```

References entry, vmm_page_info_t::executable, vmm_page_info_t::present, PTE_NX, PTE_PRESENT, PTE_WRITABLE, resolve_pt(), and vmm_page_info_t::writable.

Here is the call graph for this function:

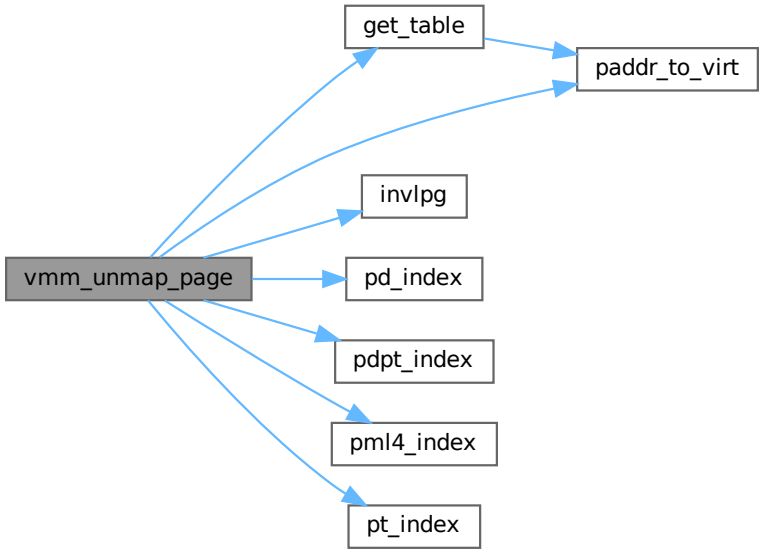


7.167.2.19 vmm_unmap_page()

```
int vmm_unmap_page (
            uint64_t vaddr )
```

References get_table(), invlpg(), paddr_to_virt(), pd_index(), pdpt_index(), pml4_index(), pt_index(), PTE_PRESENT, and vmm_root_pml4_phys.

Here is the call graph for this function:



7.167.3 Variable Documentation

7.167.3.1 hpet_phys_base

```
const uint64_t hpet_phys_base = 0xFED00000ull  [static]
```

Referenced by vmm_init().

7.167.3.2 lapic_phys_base

```
const uint64_t lapic_phys_base = 0xFEE00000ull  [static]
```

Referenced by vmm_init().

7.167.3.3 vmm_root_pml4_phys

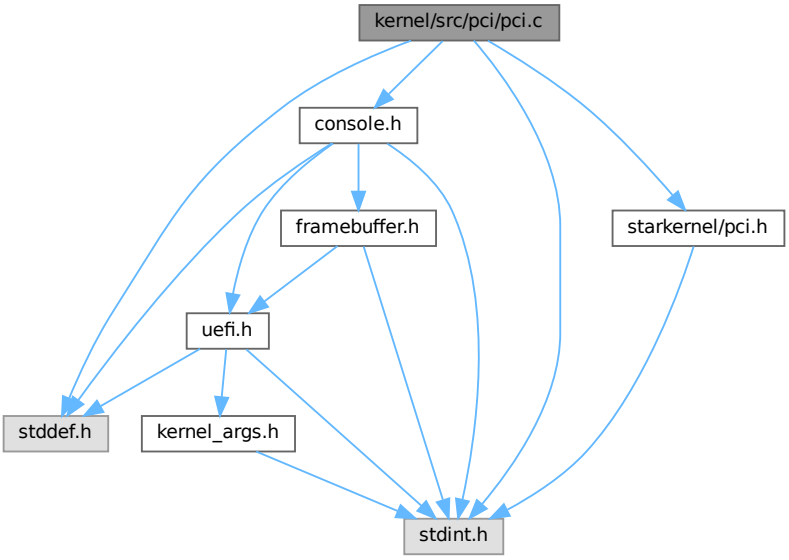
```
uint64_t vmm_root_pml4_phys = 0  [static]
```

Referenced by resolve_pt(), vmm_get_paddr(), vmm_init(), vmm_map_page(), and vmm_unmap_page().

7.168 kernel/src/pci/pci.c File Reference

```
#include <stddef.h>
#include <stdint.h>
#include "starkernel/pci.h"
#include "console.h"
```

Include dependency graph for pci.c:



Data Structures

- struct __attribute__

  ioapic.c - I/O APIC driver (amd64)

Functions

- static volatile uint32_t * ecam_cfg_ptr (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off)
- static uint32_t ecam_read32 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off)
- static uint16_t ecam_read16 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off)
- static uint8_t ecam_read8 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off)
- static void ecam_write32 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off, uint32_t v)
- static void ecam_write16 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off, uint16_t v)
- static void ecam_write8 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off, uint8_t v)
- static uint32_t cfg_read32 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off)
- static uint16_t cfg_read16 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off)
- static uint8_t cfg_read8 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off)
- static void cfg_write32 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off, uint32_t v)
- static void cfg_write16 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off, uint16_t v)
- static void cfg_write8 (uint8_t bus, uint8_t slot, uint8_t fn, uint16_t off, uint8_t v)
- static int sig4_eq (const uint8_t *p, const char *s)
- static int sig8_eq (const uint8_t *p, const char *s)

- static int parse_mcfg (void *rsdp)
- int pci_init (void *rsdp)
- int pci_find_first (uint16_t vendor_id, uint16_t device_id, PciDevice *out)
- int pci_find_class (uint8_t class_code, uint8_t subclass, uint8_t prog_if, unsigned index, PciDevice *out)
- uint32_t pci_read32 (const PciDevice *d, uint16_t off)
- uint16_t pci_read16 (const PciDevice *d, uint16_t off)
- uint8_t pci_read8 (const PciDevice *d, uint16_t off)
- void pci_write32 (const PciDevice *d, uint16_t off, uint32_t v)
- void pci_write16 (const PciDevice *d, uint16_t off, uint16_t v)
- void pci_write8 (const PciDevice *d, uint16_t off, uint8_t v)
- void pci_enable (const PciDevice *d)
- uint64_t pci_bar (const PciDevice *d, int bar_idx)
- uint64_t pci_bar_size (const PciDevice *d, int bar_idx)
- int pci_map_bar (uint64_t phys_addr, uint64_t size)

Variables

- static uint64_t g_ecam_base = 0
- static uint8_t g_bus_first = 0
- static uint8_t g_bus_last = 255

7.168.1 Function Documentation

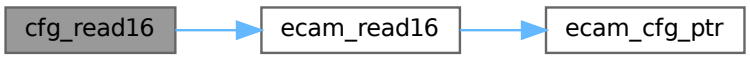
7.168.1.1 cfg_read16()

```
static uint16_t cfg_read16 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off )  [static]
```

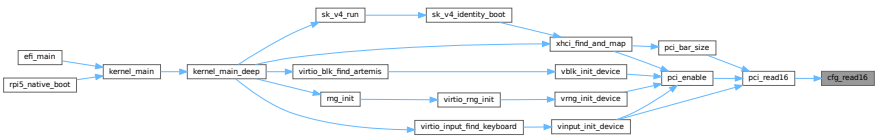
References ecam_read16().

Referenced by pci_read16().

Here is the call graph for this function:



Here is the caller graph for this function:



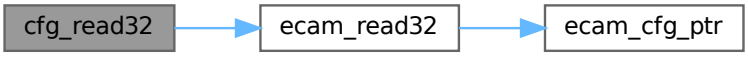
7.168.1.2 cfg_read32()

```
static uint32_t cfg_read32 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off )  [static]
```

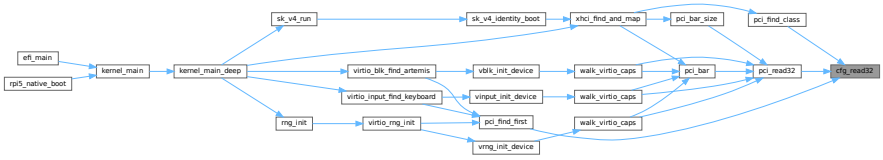
References ecam_read32().

Referenced by pci_find_class(), pci_find_first(), and pci_read32().

Here is the call graph for this function:



Here is the caller graph for this function:



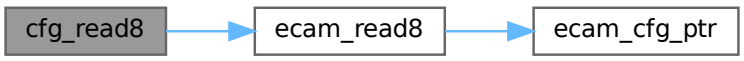
7.168.1.3 cfg_read8()

```
static uint8_t cfg_read8 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off )  [static]
```

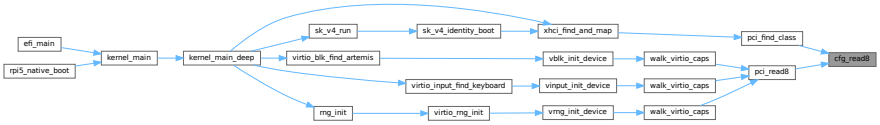
References ecam_read8().

Referenced by pci_find_class(), and pci_read8().

Here is the call graph for this function:



Here is the caller graph for this function:



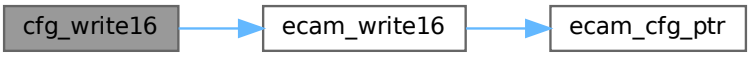
7.168.1.4 cfg_write16()

```
static void cfg_write16 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off,
            uint16_t v )  [static]
```

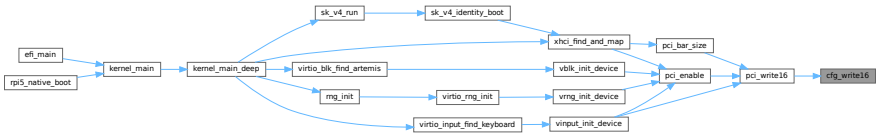
References ecam_write16().

Referenced by pci_write16().

Here is the call graph for this function:



Here is the caller graph for this function:



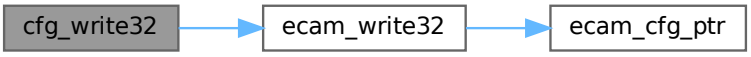
7.168.1.5 cfg_write32()

```
static void cfg_write32 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off,
            uint32_t v )  [static]
```

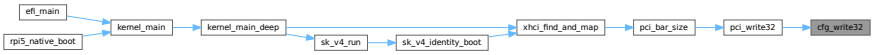
References ecam_write32().

Referenced by pci_write32().

Here is the call graph for this function:



Here is the caller graph for this function:



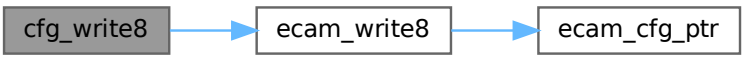
7.168.1.6 cfg_write8()

```
static void cfg_write8 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off,
            uint8_t v )  [static]
```

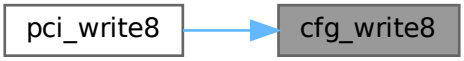
References ecam_write8().

Referenced by pci_write8().

Here is the call graph for this function:



Here is the caller graph for this function:



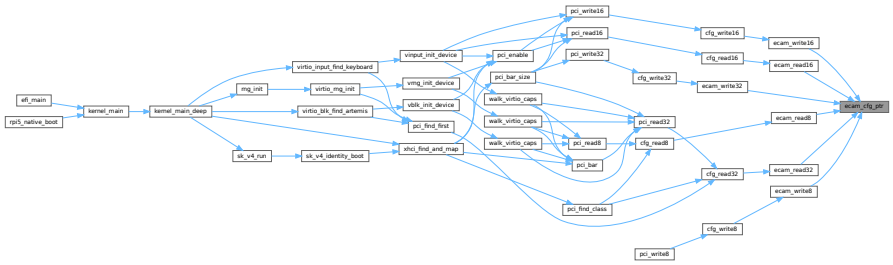
7.168.1.7 ecam_cfg_ptr()

```
static volatile uint32_t * ecam_cfg_ptr (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off )  [static]
```

References g_ecam_base.

Referenced by ecam_read16(), ecam_read32(), ecam_read8(), ecam_write16(), ecam_write32(), and ecam_write8().

Here is the caller graph for this function:



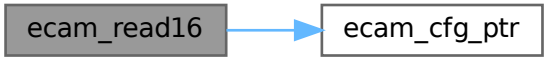
7.168.1.8 ecam_read16()

```
static uint16_t ecam_read16 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off )  [static]
```

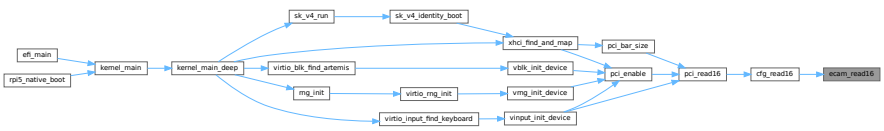
References ecam_cfg_ptr().

Referenced by cfg_read16().

Here is the call graph for this function:



Here is the caller graph for this function:



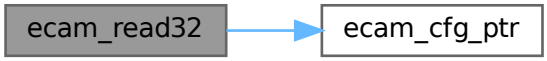
7.168.1.9 ecam_read32()

```
static uint32_t ecam_read32 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off )  [static]
```

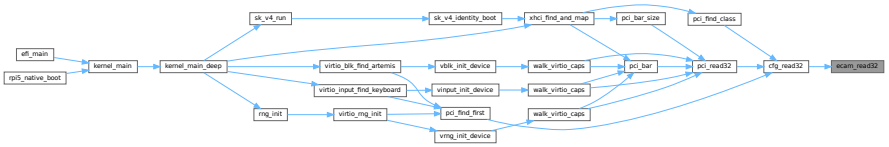
References ecam_cfg_ptr().

Referenced by cfg_read32().

Here is the call graph for this function:



Here is the caller graph for this function:



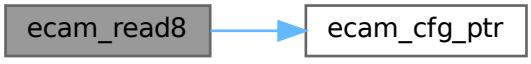
7.168.1.10 ecam_read8()

```
static uint8_t ecam_read8 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off )  [static]
```

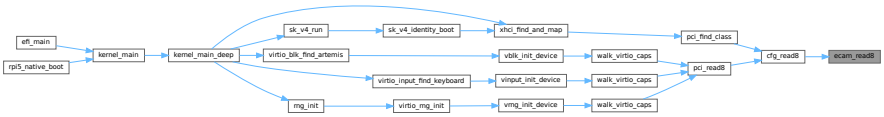
References ecam_cfg_ptr().

Referenced by cfg_read8().

Here is the call graph for this function:



Here is the caller graph for this function:



7.168.1.11 ecam_write16()

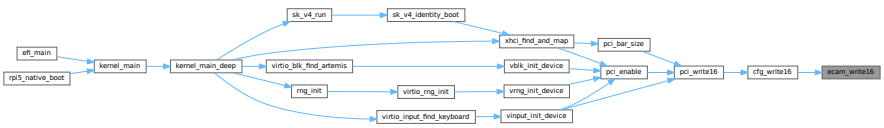
```
static void ecam_write16 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off,
            uint16_t v )  [static]
```

References ecam_cfg_ptr().

Referenced by cfg_write16().

Here is the call graph for this function:

Here is the caller graph for this function:



7.168.1.12 ecam_write32()

```
static void ecam_write32 (
            uint8_t bus,
            uint8_t slot,
            uint8_t fn,
            uint16_t off,
            uint32_t v )  [static]
```

References ecam_cfg_ptr().

Referenced by cfg_write32().

Here is the call graph for this function:

Here is the caller graph for this function:

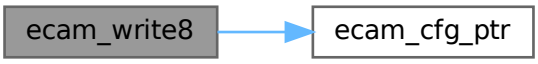
7.168.1.13 ecam_write8()

```
static void ecam_write8 (
             uint8_t bus,
             uint8_t slot,
             uint8_t fn,
             uint16_t off,
             uint8_t v )  [static]
```

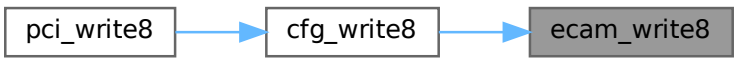
References ecam_cfg_ptr().

Referenced by cfg_write8().

Here is the call graph for this function:



Here is the caller graph for this function:



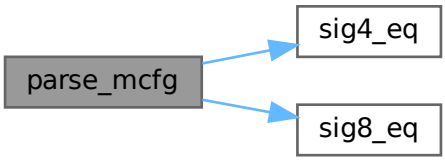
7.168.1.14 parse_mcfg()

```
static int parse_mcfg (
            void * rsdp )  [static]
```

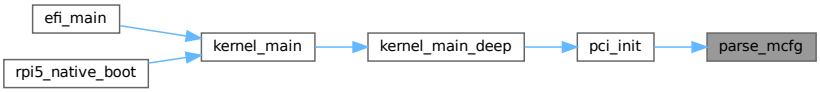
References g_bus_first, g_bus_last, g_ecam_base, sig4_eq(), and sig8_eq().

Referenced by pci_init().

Here is the call graph for this function:



Here is the caller graph for this function:



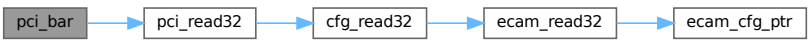
7.168.1.15 pci_bar()

```
uint64_t pci_bar (
            const PciDevice * d,
            int bar_idx )
```

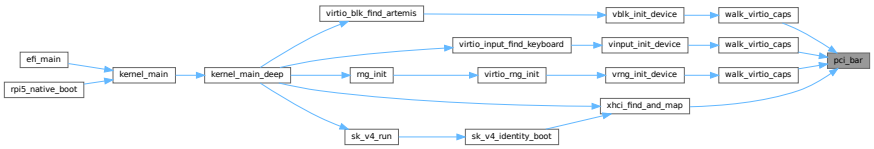
References PCI_BAR_MEM_64, PCI_BAR_TYPE_MASK, PCI_CFG_BAR0, and pci_read32().

Referenced by walk_virtio_caps(), walk_virtio_caps(), walk_virtio_caps(), and xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:



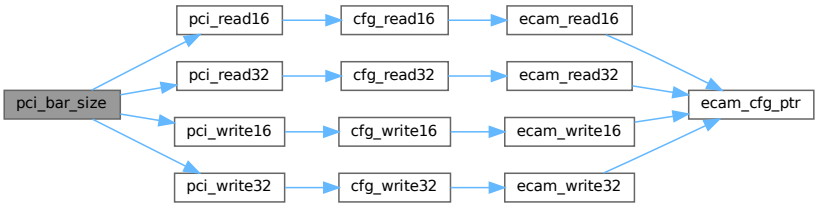
7.168.1.16 pci_bar_size()

```
uint64_t pci_bar_size (
            const PciDevice * d,
            int bar_idx )
```

References PCI_BAR_MEM_64, PCI_BAR_TYPE_MASK, PCI_CFG_BAR0, PCI_CFG_COMMAND, PCI_CMD_MEM_SPACE, pci_read16(), pci_read32(), pci_write16(), and pci_write32().

Referenced by xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:

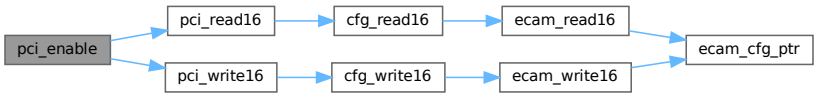
7.168.1.17 pci_enable()

```
void pci_enable (
            const PciDevice * d )
```

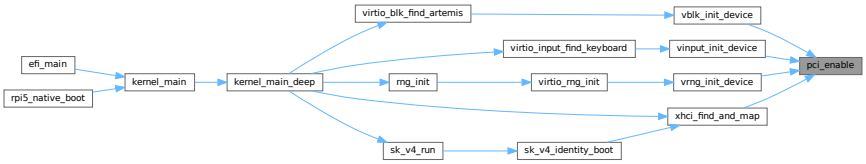
References PCI_CFG_COMMAND, PCI_CMD_BUS_MASTER, PCI_CMD_IO_SPACE, PCI_CMD_MEM_SPACE, pci_read16(), and pci_write16().

Referenced by vblk_init_device(), vinput_init_device(), vrng_init_device(), and xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:



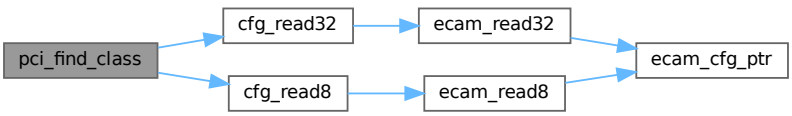
7.168.1.18 pci_find_class()

```
int pci_find_class (
            uint8_t class_code,
            uint8_t subclass,
            uint8_t prog_if,
            unsigned index,
            PciDevice * out )
```

References PciDevice::bus, cfg_read32(), cfg_read8(), PciDevice::device, PciDevice::device_id, PciDevice::function, g_bus_first, g_bus_last, g_ecam_base, PCI_CFG_CLASS_REV, PCI_CFG_HEADER_TYPE, PCI_CFG_VENDOR_ID, and PciDevice::vendor_id.

Referenced by xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:

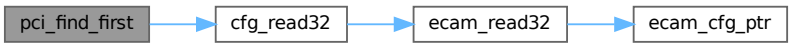
7.168.1.19 pci_find_first()

```
int pci_find_first (
            uint16_t vendor_id,
            uint16_t device_id,
            PciDevice * out )
```

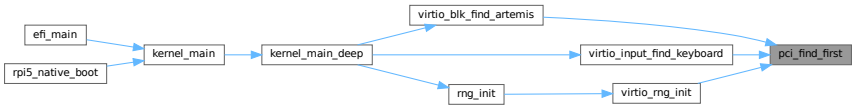
References PciDevice::bus, cfg_read32(), PciDevice::device, PciDevice::device_id, PciDevice::function, PCI_CFG_VENDOR_ID, and PciDevice::vendor_id.

Referenced by virtio_blk_find_artemis(), virtio_input_find_keyboard(), and virtio_rng_init().

Here is the call graph for this function:



Here is the caller graph for this function:

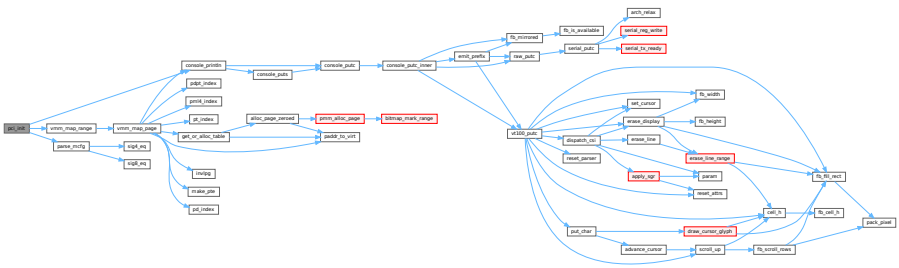


7.168.1.20 pci_init()

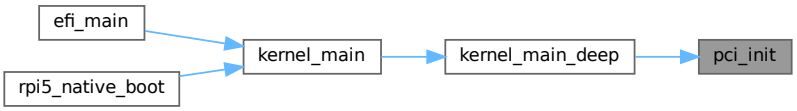
```
int pci_init (
            void * rsdp )
```

References console_println(), g_ecam_base, parse_mcfg(), VMM_FLAG_CACHE_DISABLE, VMM_FLAG_WRITABLE, and vmm_map_range().

Here is the call graph for this function:



Here is the caller graph for this function:



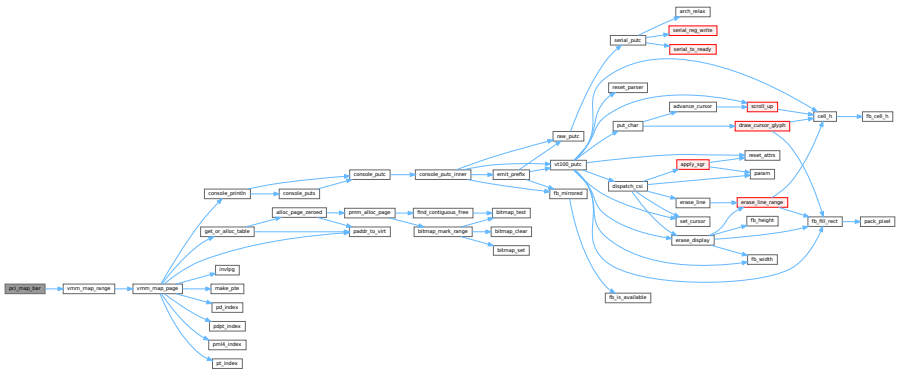
7.168.1.21 pci_map_bar()

```
int pci_map_bar (
            uint64_t phys_addr,
            uint64_t size )
```

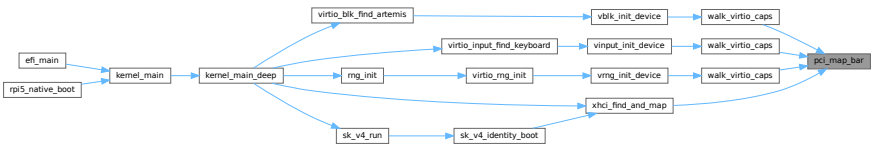
References VMM_FLAG_CACHE_DISABLE, VMM_FLAG_WRITABLE, and vmm_map_range().

Referenced by walk_virtio_caps(), walk_virtio_caps(), walk_virtio_caps(), and xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:



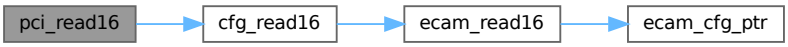
7.168.1.22 pci_read16()

```
uint16_t pci_read16 (
            const PciDevice * d,
            uint16_t off )
```

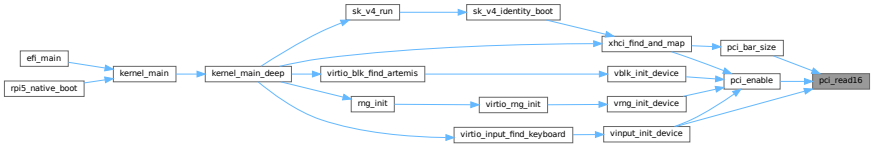
References PciDevice::bus, cfg_read16(), PciDevice::device, and PciDevice::function.

Referenced by pci_bar_size(), pci_enable(), and vinput_init_device().

Here is the call graph for this function:



Here is the caller graph for this function:



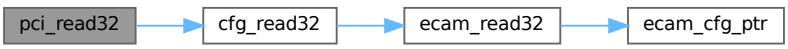
7.168.1.23 pci_read32()

```
uint32_t pci_read32 (
            const PciDevice * d,
            uint16_t off )
```

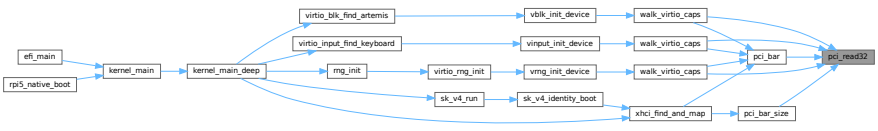
References PciDevice::bus, cfg_read32(), PciDevice::device, and PciDevice::function.

Referenced by pci_bar(), pci_bar_size(), walk_virtio_caps(), walk_virtio_caps(), and walk_virtio_caps().

Here is the call graph for this function:



Here is the caller graph for this function:



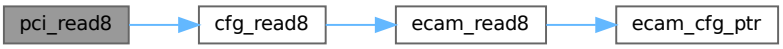
7.168.1.24 pci_read8()

```
uint8_t pci_read8 (
            const PciDevice * d,
            uint16_t off )
```

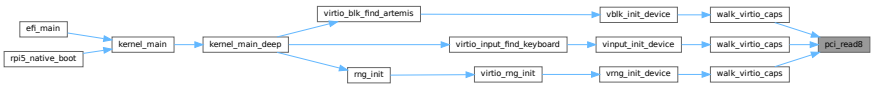
References PciDevice::bus, cfg_read8(), PciDevice::device, and PciDevice::function.

Referenced by walk_virtio_caps(), walk_virtio_caps(), and walk_virtio_caps().

Here is the call graph for this function:



Here is the caller graph for this function:



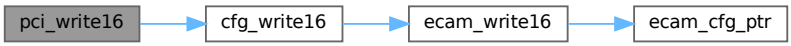
7.168.1.25 pci_write16()

```
void pci_write16 (
            const PciDevice * d,
            uint16_t off,
            uint16_t v )
```

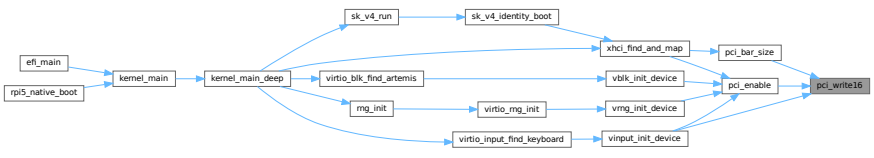
References PciDevice::bus, cfg_write16(), PciDevice::device, and PciDevice::function.

Referenced by pci_bar_size(), pci_enable(), and vinput_init_device().

Here is the call graph for this function:



Here is the caller graph for this function:



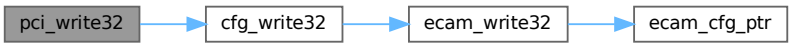
7.168.1.26 pci_write32()

```
void pci_write32 (
            const PciDevice * d,
            uint16_t off,
            uint32_t v )
```

References PciDevice::bus, cfg_write32(), PciDevice::device, and PciDevice::function.

Referenced by pci_bar_size().

Here is the call graph for this function:



Here is the caller graph for this function:

7.168.1.27 pci_write8()

```
void pci_write8 (
            const PciDevice * d,
            uint16_t off,
            uint8_t v )
```

References PciDevice::bus, cfg_write8(), PciDevice::device, and PciDevice::function.

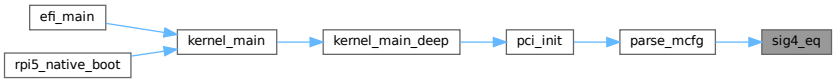
Here is the call graph for this function:

7.168.1.28 sig4_eq()

```
static int sig4_eq (
            const uint8_t * p,
            const char * s )  [static]
```

Referenced by parse_mcfg().

Here is the caller graph for this function:

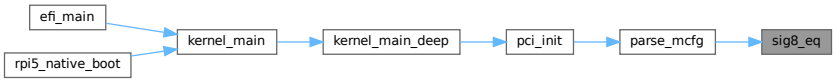


7.168.1.29 sig8_eq()

```
static int sig8_eq (
            const uint8_t * p,
            const char * s )  [static]
```

Referenced by parse_mcfg().

Here is the caller graph for this function:



7.168.2 Variable Documentation

7.168.2.1 g_bus_first

```
uint8_t g_bus_first = 0  [static]
```

Referenced by parse_mcfg(), and pci_find_class().

7.168.2.2 g_bus_last

```
uint8_t g_bus_last = 255  [static]
```

Referenced by parse_mcfg(), and pci_find_class().

7.168.2.3 g_ecam_base

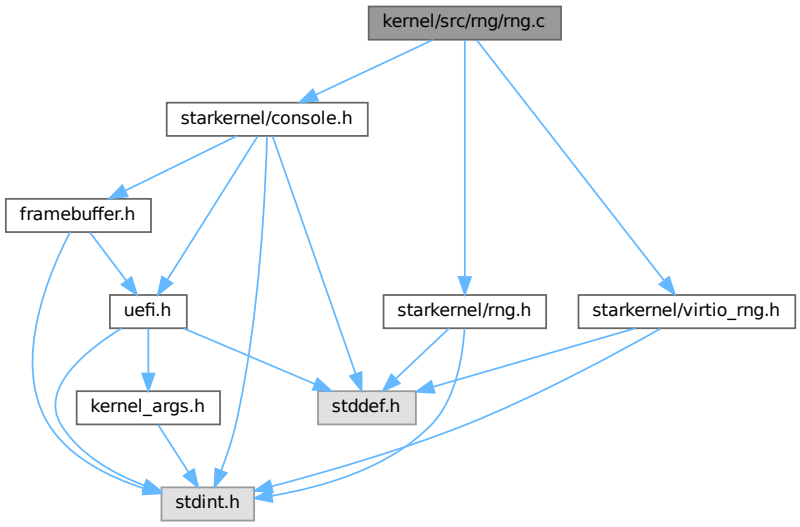
```
uint64_t g_ecam_base = 0  [static]
```

Referenced by ecam_cfg_ptr(), parse_mcfg(), pci_find_class(), and pci_init().

7.169 kernel/src/rng/rng.c File Reference

```
#include "starkernel/rng.h"
#include "starkernel/virtio_rng.h"
#include "starkernel/console.h"
```

Include dependency graph for rng.c:



Enumerations

- enum { RNG_BACKEND_NONE = 0 , RNG_BACKEND_VIRTIO }

Functions

- int rng_init (void)
- int rng_ready (void)
- int rng_get_bytes (uint8_t *buf, size_t n)

Variables

- static int g_rng_backend = RNG_BACKEND_NONE

7.169.1 Enumeration Type Documentation

7.169.1.1 anonymous enum

```
anonymous enum
```

Enumerator

RNG_BACKEND_NONE	
RNG_BACKEND_VIRTIO	

7.169.2 Function Documentation

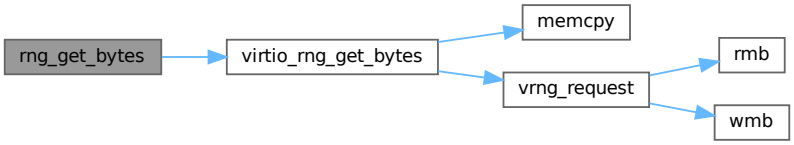
7.169.2.1 rng_get_bytes()

```
int rng_get_bytes (
            uint8_t * buf,
            size_t n )
```

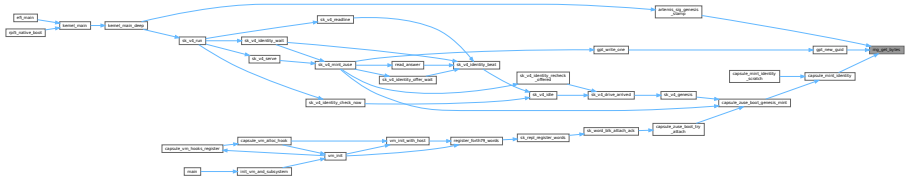
References g_rng_backend, RNG_BACKEND_VIRTIO, RNG_ERR_NO_BACKEND, and virtio_rng_get_bytes().

Referenced by artemis_sig_genesis_stamp(), capsule_mint_identity(), and gpt_new_guid().

Here is the call graph for this function:



Here is the caller graph for this function:



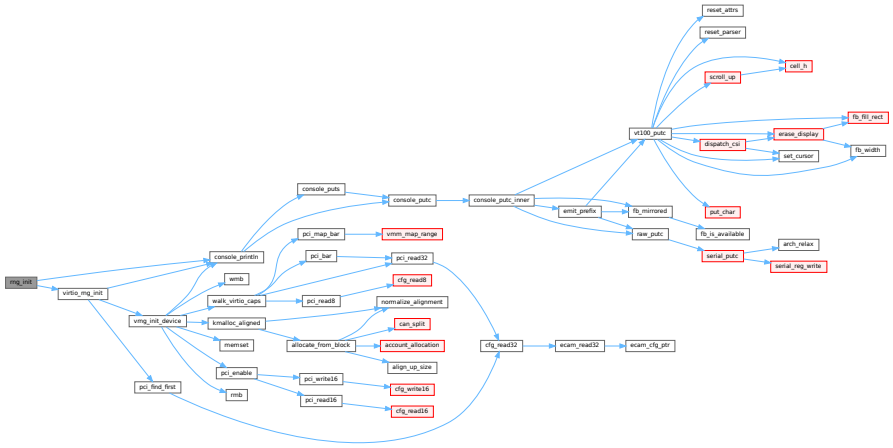
7.169.2.2 rng_init()

```
int rng_init (
            void  )
```

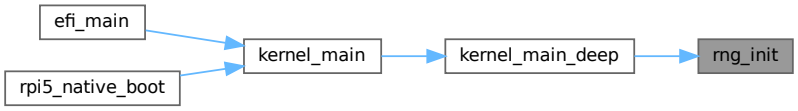
References console_println(), g_rng_backend, RNG_BACKEND_NONE, RNG_BACKEND_VIRTIO, and virtio_rng_init().

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.169.2.3 rng_ready()

```
int rng_ready (
            void  )
```

References g_rng_backend, and RNG_BACKEND_NONE.

Referenced by capsule_mint_identity().

Here is the caller graph for this function:

7.169.3 Variable Documentation

7.169.3.1 g_rng_backend

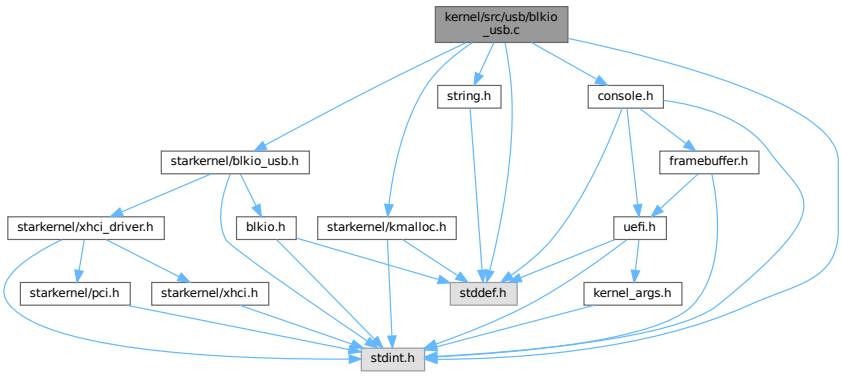
```
int g_rng_backend = RNG_BACKEND_NONE  [static]
```

Referenced by rng_get_bytes(), rng_init(), and rng_ready().

7.170 kernel/src/usb/blkio_usb.c File Reference

```
#include <stddef.h>
#include <stdint.h>
#include <string.h>
#include "starkernel/blkio_usb.h"
#include "starkernel/kmalloc.h"
#include "console.h"
```

Include dependency graph for blkio_usb.c:



Data Structures

- struct BlkioUsbState

Functions

- static BlkioUsbState * usb_blk_state_for (xhci_dev_t *xdev, uint32_t slot_id)
- static int usb_blk_open (blkio_dev_t *dev, const blkio_params_t *p)
- static int usb_blk_close (blkio_dev_t *dev)
- static int usb_blk_read (blkio_dev_t *dev, uint32_t fblock, void *dst)
- static int usb_blk_write (blkio_dev_t *dev, uint32_t fblock, const void *src)
- static int usb_blk_flush (blkio_dev_t *dev)
- static int usb_blk_info (blkio_dev_t *dev, blkio_info_t *out)
- int blkio_usb_open_msc (blkio_dev_t *dev_out, xhci_dev_t *xdev, uint32_t slot_id)

Variables

- struct {
  xhci_dev_t * xdev
  BlkioUsbState * slots
  uint32_t count
  } g_usb_blk [8u]

- static const blkio_vtable_t g_usb_blk_vtable

7.170.1 Function Documentation

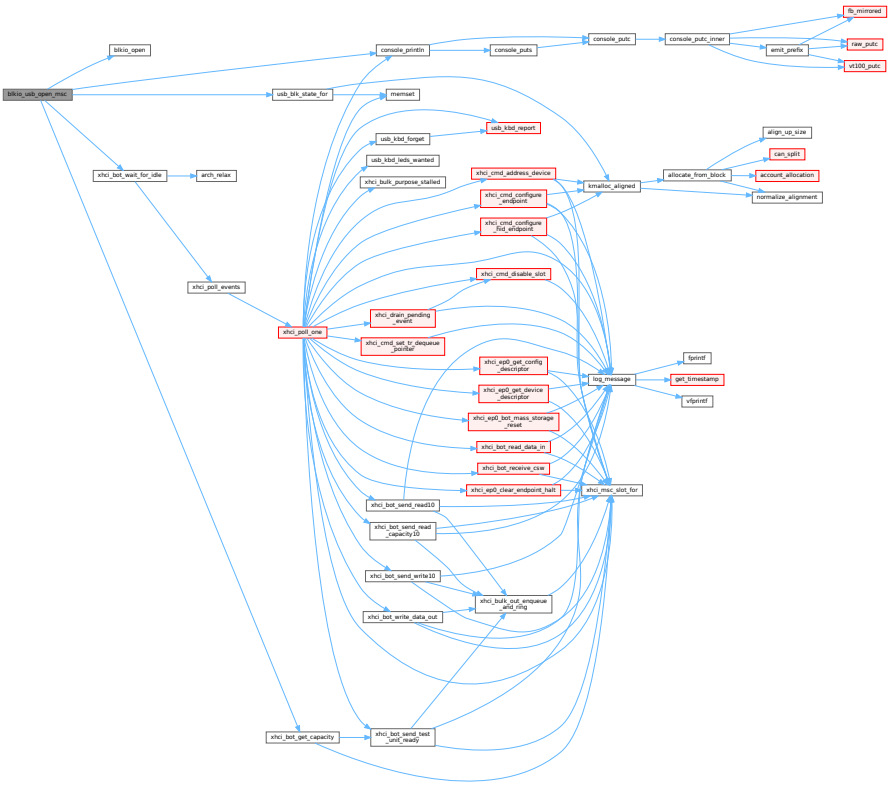
7.170.1.1 blkio_usb_open_msc()

```
int blkio_usb_open_msc (
            blkio_dev_t * dev_out,
            xhci_dev_t * xdev,
            uint32_t slot_id )
```

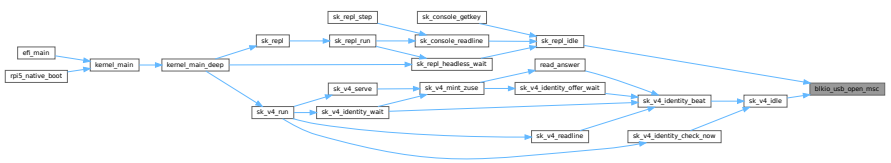
References BLKIO_FORTH_BLOCK_SIZE, blkio_open(), block_size, xhci_dev_t::bot_cap_block_size, xhci_dev_t::bot_cap_last_lba, console_println(), blkio_params_t::forth_block_size, g_usb_blk_vtable, blkio_params_t::opaque, BlkioUsbState::scsi_block_size, BlkioUsbState::scsi_blocks_per_fblock, BlkioUsbState::slot_id, blkio_params_t::total_blocks, BlkioUsbState::total_forth_blocks, usb_blk_state_for(), BlkioUsbState::xdev, xdev, xhci_bot_get_capacity(), and xhci_bot_wait_for_idle().

Referenced by sk_repl_idle(), and sk_v4_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.170.1.2 usb_blk_close()

```
static int usb_blk_close (
            blkio_dev_t * dev )  [static]
```

References BLKIO_OK.

7.170.1.3 usb_blk_flush()

```
static int usb_blk_flush (
            blkio_dev_t * dev )  [static]
```

References BLKIO_OK.

7.170.1.4 usb_blk_info()

```
static int usb_blk_info (
            blkio_dev_t * dev,
            blkio_info_t * out )  [static]
```

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_info_t::forth_block_size, blkio_info_t::phys_sector_size, blkio_info_t::phys_size_bytes, blkio_info_t::read_only, BlkioUsbState::scsi_block_size, blkio_dev::state, blkio_info_t::total_blocks, and BlkioUsbState::total_forth_blocks.

7.170.1.5 usb_blk_open()

```
static int usb_blk_open (
            blkio_dev_t * dev,
            const blkio_params_t * p )  [static]
```

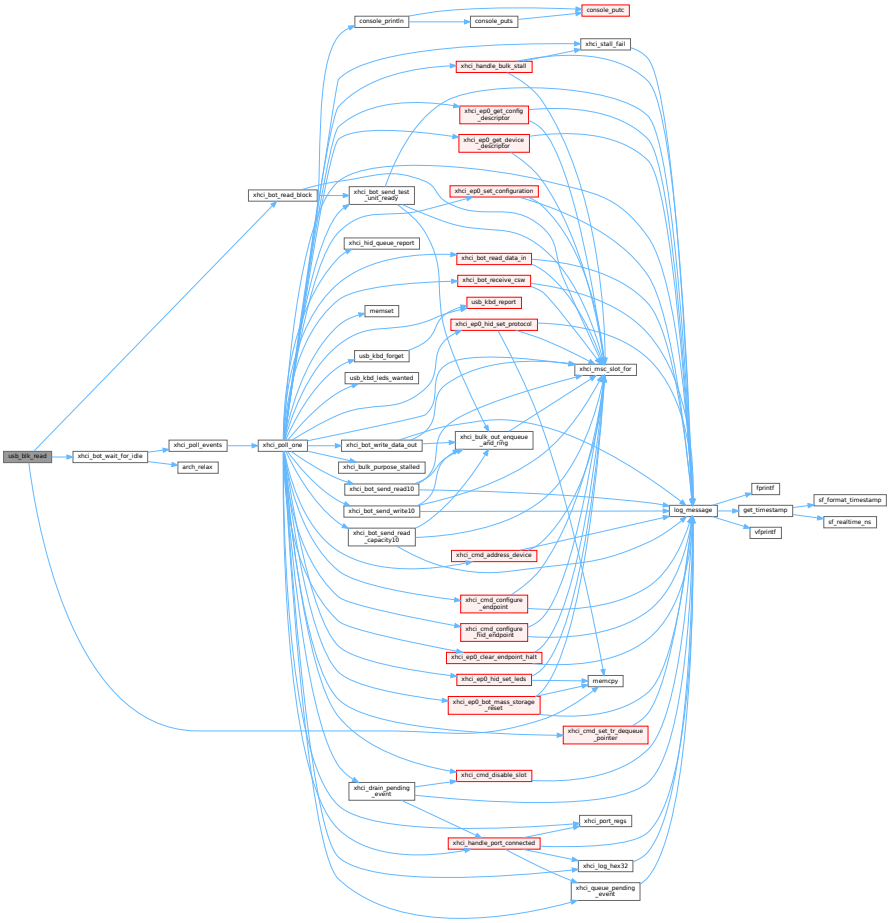
References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_dev::forth_block_size, blkio_params_t::opaque, blkio_dev::state, blkio_dev::total_blocks, and BlkioUsbState::total_forth_blocks.

7.170.1.6 usb_blk_read()

```
static int usb_blk_read (
            blkio_dev_t * dev,
            uint32_t fblock,
            void * dst )  [static]
```

References BLKIO_EINVAL, BLKIO_EIO, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, xhci_dev_t::bot_data_buf, memcpy(), BlkioUsbState::scsi_block_size, BlkioUsbState::scsi_blocks_per_fblock, BlkioUsbState::slot_id, blkio_dev::state, BlkioUsbState::total_forth_blocks, BlkioUsbState::xdev, xhci_bot_read_block(), and xhci_bot_wait_for_idle().

Here is the call graph for this function:



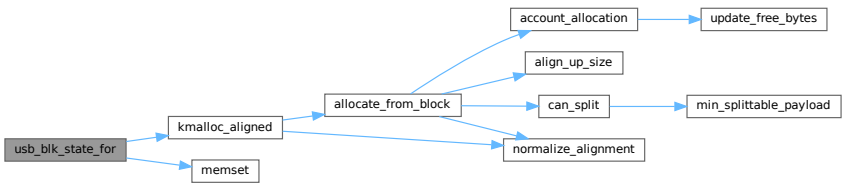
7.170.1.7 usb_blk_state_for()

```
static BlkioUsbState * usb_blk_state_for (
            xhci_dev_t * xdev,
            uint32_t slot_id )  [static]
```

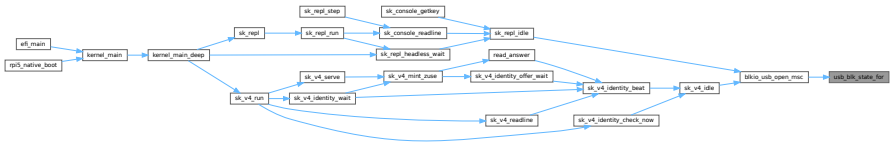
References bytes, g_usb_blk, kmalloc_aligned(), xhci_dev_t::max_slots, memset(), slots, xdev, and XHCI_MAX_CONTROLLERS.

Referenced by blkio_usb_open_msc().

Here is the call graph for this function:



Here is the caller graph for this function:

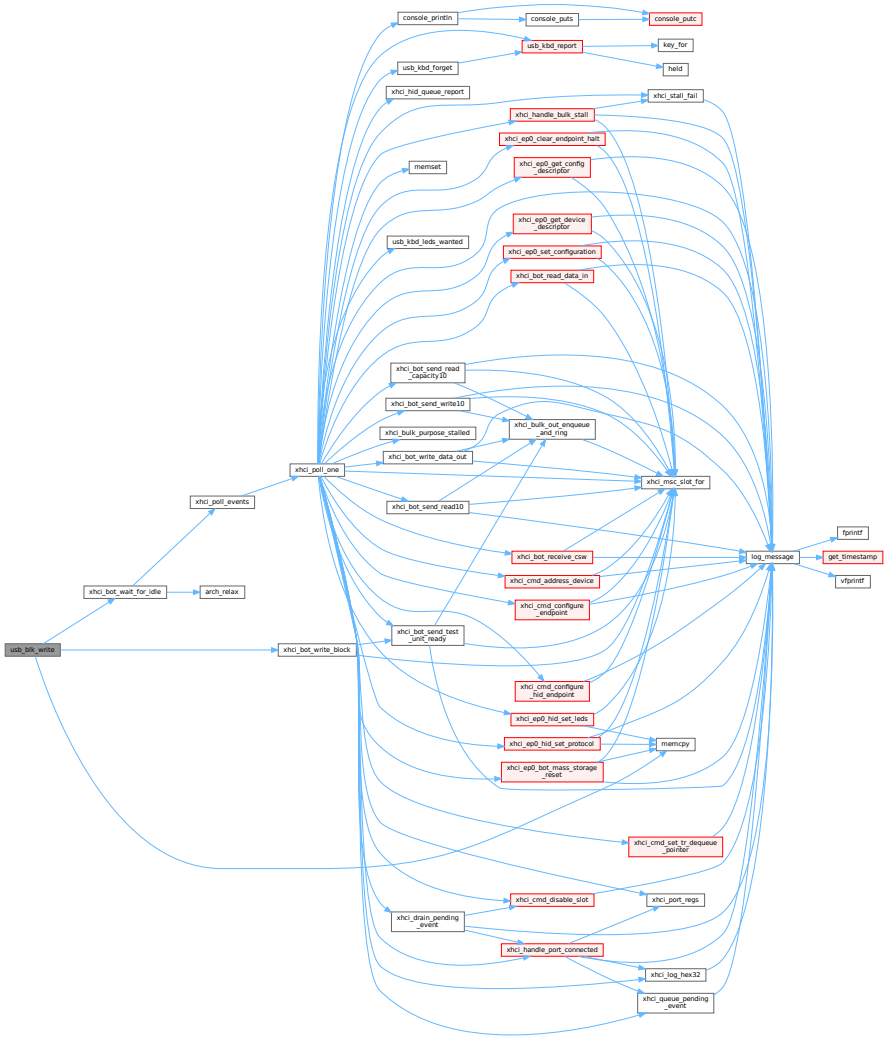


7.170.1.8 usb_blk_write()

```
static int usb_blk_write (
            blkio_dev_t * dev,
            uint32_t fblock,
            const void * src )  [static]
```

References BLKIO_EINVAL, BLKIO_EIO, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, xhci_dev_t::bot_data_buf, memcpy(), BlkioUsbState::scsi_block_size, BlkioUsbState::scsi_blocks_per_fblock, BlkioUsbState::slot_id, blkio_dev::state, BlkioUsbState::total_forth_blocks, BlkioUsbState::xdev, xhci_bot_wait_for_idle(), and xhci_bot_write_block().

Here is the call graph for this function:



7.170.2 Variable Documentation

7.170.2.1 count

```
uint32_t count
```

Referenced by blk_firsttouch_claim(), cd_classify_ids(), collect_ram_regions(), collect_reserved_ranges(), dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), flatten_quad(), forth_ALL_HEATS(), forth_PIPELINING_RESET_ALL(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), gpt_find(), gpt_grow_last(), gpt_read(), hotwords_bucket_reorder(), io_word_spaces(), io_word_type(), reloc_load_from_disk(), rolling_window_count_transition(), sf_calloc(), sk_dict_canonical_hash(), sk_dict_word_count(), string_word_count(), system_word_vlist(), system_word_words(), transition_metrics_get_probability_q48(), and update_stats().

7.170.2.2 [struct]

```
struct { ...  } g_usb_blk[ 8u ]  [static]
```

Referenced by usb_blk_state_for().

7.170.2.3 g_usb_blk_vtable

```
const blkio_vtable_t g_usb_blk_vtable  [static]
```

Initial value:

```
= {
    .open  = usb_blk_open,
    .close = usb_blk_close,
    .read  = usb_blk_read,
    .write = usb_blk_write,
    .flush = usb_blk_flush,
    .info  = usb_blk_info
}
```

Referenced by blkio_usb_open_msc().

7.170.2.4 slots

```
BlkioUsbState* slots
```

Referenced by sk_word_blk_attach_ack(), ttf_raster_cache_init(), usb_blk_state_for(), and vt100_enable_ttf().

7.170.2.5 xdev

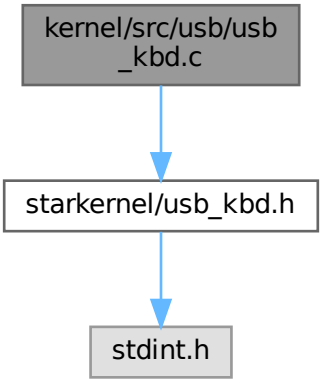
```
xhci_dev_t* xdev
```

Referenced by blkio_usb_open_msc(), sk_repl_idle(), sk_v4_idle(), sk_word_blk_attach_ack(), and usb_blk_state_for().

7.171 kernel/src/usb/usb_kbd.c File Reference

```
#include "starkernel/usb_kbd.h"
```

Include dependency graph for usb_kbd.c:



Macros

- #define KBD_EVENTS 64u

Functions

- static void push (uint16_t keycode, int pressed)
- static uint16_t key_for (uint8_t usage)
- static int held (const uint8_t *keys, uint32_t n, uint8_t usage)
- void usb_kbd_report (uint8_t prev[8], const uint8_t *report, uint32_t len)

  usb_kbd.h - a USB boot-protocol keyboard's keys, as key events (2026-10-14, boards/BRINGUP.md A3; usb_kbd.c).
- void usb_kbd_forget (uint8_t prev[8])
- void usb_kbd_set_leds (uint8_t leds)
- uint8_t usb_kbd_leds_wanted (void)
- int usb_kbd_pop_event (uint16_t *keycode, int *pressed)

Variables

- static const uint8_t usage_to_key [0x66]

  usb_kbd.c - a USB boot-protocol keyboard's reports, as key events (2026-10-14, boards/BRINGUP.md A3).
- static const uint8_t modifier_key [8] = { 29, 42, 56, 125, 97, 54, 100, 126 }
- struct {
  uint16_t keycode
  uint8_t pressed
  } g_events [64u]

- static uint32_t g_head
- static uint32_t g_count
- static uint8_t g_leds_want = 0x01u

7.171.1 Macro Definition Documentation

7.171.1.1 KBD_EVENTS

```
#define KBD_EVENTS 64u
```

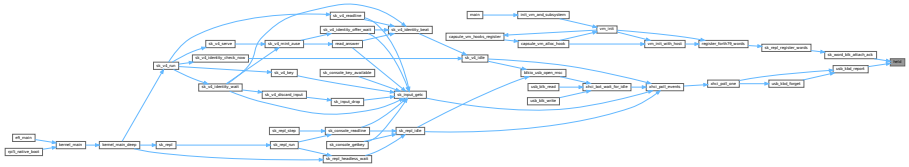
7.171.2 Function Documentation

7.171.2.1 held()

```
static int held (
            const uint8_t * keys,
            uint32_t n,
            uint8_t usage )  [static]
```

Referenced by sk_word_blk_attach_ack(), and usb_kbd_report().

Here is the caller graph for this function:



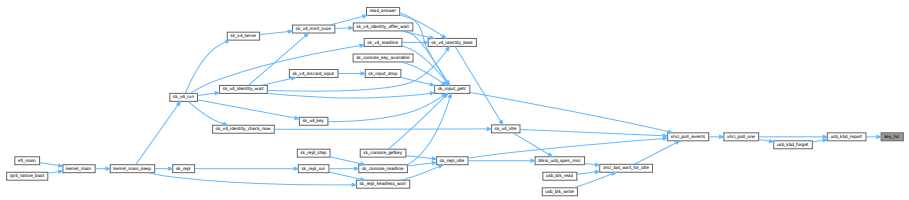
7.171.2.2 key_for()

```
static uint16_t key_for (
            uint8_t usage )  [static]
```

References usage_to_key.

Referenced by usb_kbd_report().

Here is the caller graph for this function:



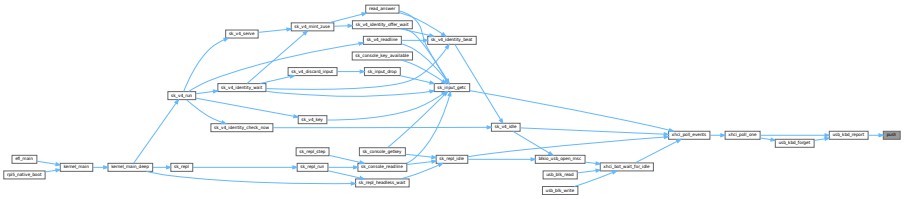
7.171.2.3 push()

```
static void push (
            uint16_t keycode,
            int pressed )  [static]
```

References g_count, g_events, g_head, KBD_EVENTS, keycode, and pressed.

Referenced by usb_kbd_report().

Here is the caller graph for this function:



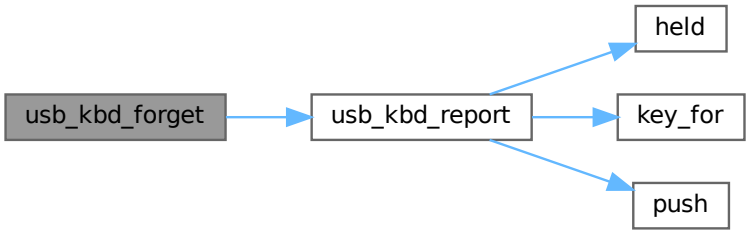
7.171.2.4 usb_kbd_forget()

```
void usb_kbd_forget (
            uint8_t prev[8] )
```

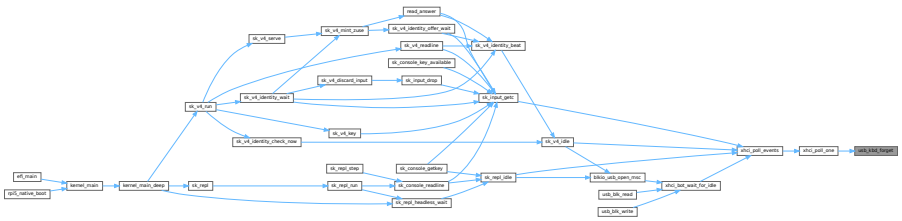
References usb_kbd_report().

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



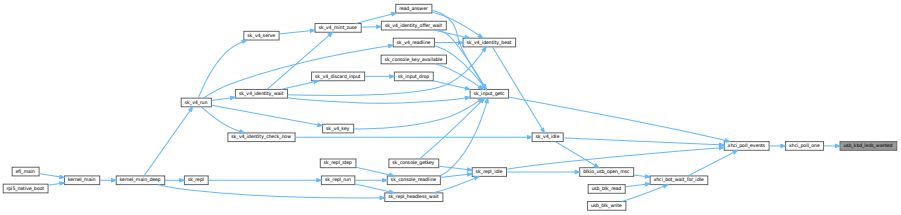
7.171.2.5 usb_kbd_leds_wanted()

```
uint8_t usb_kbd_leds_wanted (
            void  )
```

References g_leds_want.

Referenced by xhci_poll_one().

Here is the caller graph for this function:



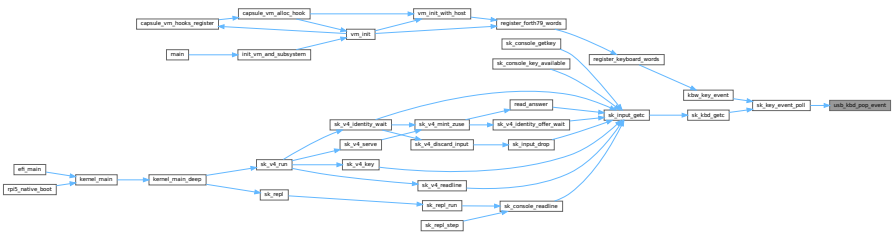
7.171.2.6 usb_kbd_pop_event()

```
int usb_kbd_pop_event (
            uint16_t * keycode,
            int * pressed )
```

References g_count, g_events, g_head, KBD_EVENTS, keycode, and pressed.

Referenced by sk_key_event_poll().

Here is the caller graph for this function:



7.171.2.7 usb_kbd_report()

```
void usb_kbd_report (
            uint8_t prev[8],
            const uint8_t * report,
            uint32_t len )
```

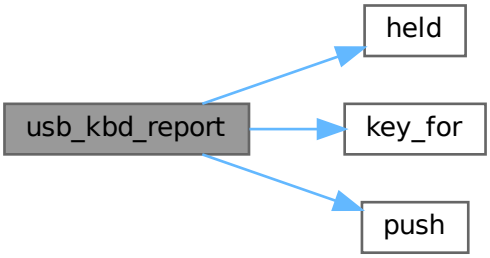
usb_kbd.h - a USB boot-protocol keyboard's keys, as key events (2026-10-14, boards/BRINGUP.md A3; usb_kbd.c).

The xHCI driver hands each 8-byte boot report here; the keys pressed and released since the report before come out as Linux input keycodes, the namespace every keyboard in this kernel already speaks (sk_key_event_poll(), keyboard_words.c).

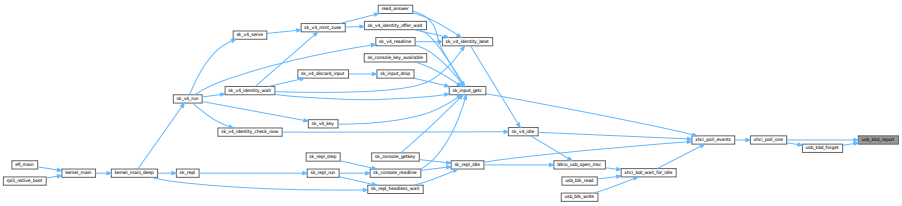
References held(), key_for(), modifier_key, and push().

Referenced by usb_kbd_forget(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



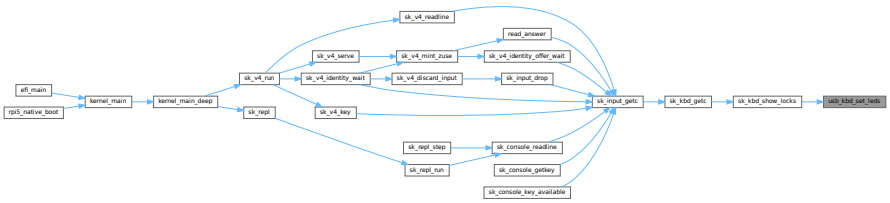
7.171.2.8 usb_kbd_set_leds()

```
void usb_kbd_set_leds (
            uint8_t leds )
```

References g_leds_want.

Referenced by sk_kbd_show_locks().

Here is the caller graph for this function:



7.171.3 Variable Documentation

7.171.3.1 g_count

```
uint32_t g_count  [static]
```

Referenced by push(), and usb_kbd_pop_event().

7.171.3.2 [struct]

```
struct { ...  } g_events[ 64u ]  [static]
```

Referenced by push(), and usb_kbd_pop_event().

7.171.3.3 g_head

```
uint32_t g_head  [static]
```

Referenced by push(), and usb_kbd_pop_event().

7.171.3.4 g_leds_want

```
uint8_t g_leds_want = 0x01u  [static]
```

Referenced by usb_kbd_leds_wanted(), and usb_kbd_set_leds().

7.171.3.5 keycode

```
uint16_t keycode
```

Referenced by kbw_key_event(), push(), sk_kbd_getc(), sk_kbd_keypad(), sk_key_event_poll(), and usb_kbd_pop_event().

7.171.3.6 modifier_key

```
const uint8_t modifier_key[8] = { 29, 42, 56, 125, 97, 54, 100, 126 }  [static]
```

Referenced by usb_kbd_report().

7.171.3.7 pressed

```
uint8_t pressed
```

Referenced by kbw_key_event(), push(), sk_kbd_getc(), sk_key_event_poll(), and usb_kbd_pop_event().

7.171.3.8 usage_to_key

```
const uint8_t usage_to_key[0x66]  [static]
```

Initial value:

```
= {
    [0x04] = 30, [0x05] = 48, [0x06] = 46, [0x07] = 32, [0x08] = 18,
    [0x09] = 33, [0x0A] = 34, [0x0B] = 35, [0x0C] = 23, [0x0D] = 36,
    [0x0E] = 37, [0x0F] = 38, [0x10] = 50, [0x11] = 49, [0x12] = 24,
    [0x13] = 25, [0x14] = 16, [0x15] = 19, [0x16] = 31, [0x17] = 20,
    [0x18] = 22, [0x19] = 47, [0x1A] = 17, [0x1B] = 45, [0x1C] = 21,
    [0x1D] = 44,
    [0x1E] = 2,  [0x1F] = 3,  [0x20] = 4,  [0x21] = 5,  [0x22] = 6,
    [0x23] = 7,  [0x24] = 8,  [0x25] = 9,  [0x26] = 10, [0x27] = 11,
    [0x28] = 28, [0x29] = 1,  [0x2A] = 14, [0x2B] = 15, [0x2C] = 57,
    [0x2D] = 12, [0x2E] = 13, [0x2F] = 26, [0x30] = 27, [0x31] = 43,
    [0x32] = 43, [0x33] = 39, [0x34] = 40, [0x35] = 41, [0x36] = 51,
    [0x37] = 52, [0x38] = 53, [0x39] = 58,
    [0x3A] = 59, [0x3B] = 60, [0x3C] = 61, [0x3D] = 62, [0x3E] = 63,
    [0x3F] = 64, [0x40] = 65, [0x41] = 66, [0x42] = 67, [0x43] = 68,
    [0x44] = 87, [0x45] = 88,
    [0x46] = 99,  [0x47] = 70,  [0x48] = 119,
    [0x49] = 110, [0x4A] = 102, [0x4B] = 104,
    [0x4C] = 111, [0x4D] = 107, [0x4E] = 109,
    [0x4F] = 106, [0x50] = 105, [0x51] = 108, [0x52] = 103,
    [0x53] = 69,
    [0x54] = 98,  [0x55] = 55,  [0x56] = 74,  [0x57] = 78,  [0x58] = 96,
    [0x59] = 79,  [0x5A] = 80,  [0x5B] = 81,  [0x5C] = 75,  [0x5D] = 76,
    [0x5E] = 77,  [0x5F] = 71,  [0x60] = 72,  [0x61] = 73,  [0x62] = 82,
    [0x63] = 83,  [0x64] = 86,  [0x65] = 127,
}
```

usb_kbd.c - a USB boot-protocol keyboard's reports, as key events (2026-10-14, boards/BRINGUP.md A3).

See usb_kbd.h.

A boot report says which keys are held now, not what changed: what was held in the report before and is not now has been released, and the other way round has been pressed. The eight modifier bits are keys too (left/right Ctrl, Shift, Alt, GUI). A report whose keys are all 0x01 is the keyboard's "too many keys" (ErrorRollOver) and changes nothing.

Usage IDs (HID Usage Tables 1.12, page 7) become Linux keycodes (input-event-codes.h) – the same numbers the PS/2 and virtio keyboards already give sk_key_event_poll(). Only the keys a console uses are mapped; others are dropped. The keyboard does not repeat a held key: held is held, and nothing here repeats it either.

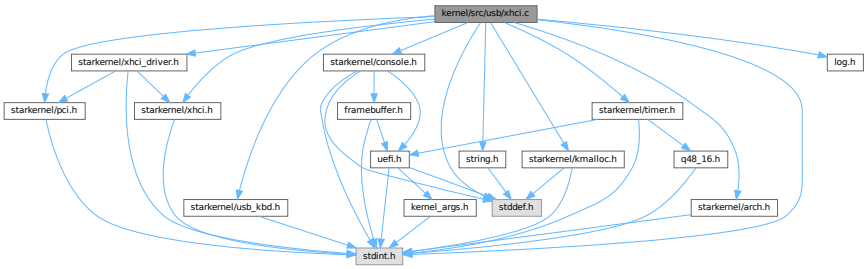
Referenced by key_for().

7.172 kernel/src/usb/xhci.c File Reference

```
#include <stddef.h>
#include <stdint.h>
#include <string.h>
#include "starkernel/pci.h"
#include "starkernel/xhci.h"
#include "starkernel/xhci_driver.h"
#include "starkernel/usb_kbd.h"
#include "starkernel/console.h"
#include "starkernel/kmalloc.h"
#include "starkernel/timer.h"
#include "starkernel/arch.h"
```

```
#include "log.h"
```

Include dependency graph for xhci.c:



Macros

- #define XHCI_BAR0_MIN_MAP_SIZE 0x10000ull
- #define XHCI_PCI_CLASS 0x0Cu
- #define XHCI_PCI_SUBCLASS 0x03u
- #define XHCI_PCI_PROG_IF 0x30u
- #define XHCI_XCAP_LEGACY 1u
- #define XHCI_LEGSUP_BIOS_OWNED (1u << 16)
- #define XHCI_LEGSUP_OS_OWNED (1u << 24)
- #define USB_HID_REQ_SET_REPORT 0x09u
- #define USB_HID_REPORT_OUTPUT 0x0200u /* wValue: report type Output (2), report ID 0 */

Functions

- static int xhci_wait_bit (volatile uint32_t *reg, uint32_t mask, int want_set, uint64_t max_ticks)
- static void xhci_log_hex32 (const char *prefix, uint32_t v)
- static void xhci_take_from_bios (xhci_dev_t *dev)
- int xhci_find_and_map (xhci_dev_t *dev, unsigned index)
- int xhci_cmd_enable_slot (xhci_dev_t *dev)
- int xhci_cmd_disable_slot (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_cmd_address_device (xhci_dev_t *dev, uint32_t slot_id, uint32_t port_id, uint32_t speed)
- int xhci_cmd_configure_endpoint (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_cmd_reset_endpoint (xhci_dev_t *dev, uint32_t slot_id, uint32_t ep_id)
- int xhci_cmd_set_tr_dequeue_pointer (xhci_dev_t *dev, uint32_t slot_id, uint32_t ep_id, uint64_t new_↩ dequeue, uint32_t dcs)
- int xhci_bot_send_read10 (xhci_dev_t *dev, uint32_t slot_id, uint32_t lba, uint16_t num_blocks, uint32_↩ t block_size)
- int xhci_bot_send_write10 (xhci_dev_t *dev, uint32_t slot_id, uint32_t lba, uint16_t num_blocks, uint32_↩ t block_size)
- int xhci_bot_send_test_unit_ready (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_send_read_capacity10 (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_get_capacity (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_read_data_in (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_write_data_out (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_bot_receive_csw (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_ep0_get_device_descriptor (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_ep0_get_config_descriptor (xhci_dev_t *dev, uint32_t slot_id, uint16_t length)
- int xhci_ep0_set_configuration (xhci_dev_t *dev, uint32_t slot_id, uint8_t config_value)
- static void xhci_scan_ports_for_already_connected (xhci_dev_t *dev)

- int xhci_bringup (xhci_dev_t *dev)
- uint32_t xhci_dev_count (void)
- xhci_dev_t * xhci_dev_at (uint32_t i)
- xhci_msc_slot_t * xhci_msc_slot_for (xhci_dev_t *dev, uint32_t slot_id)
- static void xhci_submit_command (xhci_dev_t *dev, uint64_t parameter, uint32_t status, uint32_t trb_type, uint32_t extra_control_bits)
- static uint32_t xhci_default_ep0_max_packet (uint32_t speed)
- static size_t xhci_ctx_bytes (const xhci_dev_t *dev)
- static void xhci_init_bulk_ring (xhci_trb_t *ring)
- int xhci_cmd_configure_hid_endpoint (xhci_dev_t *dev, uint32_t slot_id)
- static void xhci_bulk_out_enqueue_and_ring (xhci_dev_t *dev, uint32_t slot_id, uint64_t parameter, uint32_t status, uint32_t control_bits)
- int xhci_bot_read_block (xhci_dev_t *dev, uint32_t slot_id, uint32_t lba, uint16_t num_blocks, uint32_t block_size)
- int xhci_bot_write_block (xhci_dev_t *dev, uint32_t slot_id, uint32_t lba, uint16_t num_blocks, uint32_t block_size)
- int xhci_bot_wait_for_idle (xhci_dev_t *dev, uint32_t max_iters)
- static void xhci_bulk_in_enqueue_and_ring (xhci_dev_t *dev, uint32_t slot_id, uint64_t parameter, uint32_t status, uint32_t control_bits)
- static void xhci_ep0_enqueue_trb (xhci_dev_t *dev, uint32_t slot_id, uint64_t parameter, uint32_t status, uint32_t control_bits)
- static void xhci_ep0_control_read (xhci_dev_t *dev, uint32_t slot_id, uint8_t bRequest, uint16_t wValue, uint16_t wIndex, uint8_t *buf, uint16_t len)
- static void xhci_ep0_control_write_nodata (xhci_dev_t *dev, uint32_t slot_id, uint8_t bRequest, uint16_t wValue, uint16_t wIndex)
- int xhci_ep0_clear_endpoint_halt (xhci_dev_t *dev, uint32_t slot_id, uint8_t ep_addr)
- int xhci_ep0_bot_mass_storage_reset (xhci_dev_t *dev, uint32_t slot_id)
- int xhci_ep0_hid_set_protocol (xhci_dev_t *dev, uint32_t slot_id)
- static int xhci_ep0_hid_set_leds (xhci_dev_t *dev, uint32_t slot_id, uint8_t leds)
- static void xhci_hid_queue_report (xhci_dev_t *dev, uint32_t slot_id, xhci_msc_slot_t *ms)
- static xhci_port_regs_t * xhci_port_regs (xhci_dev_t *dev, uint32_t port_id)
- static void xhci_queue_pending_event (xhci_dev_t *dev, uint32_t port_id, int is_connect, uint32_t portsc, uint32_t slot_id)
- static void xhci_handle_port_connected (xhci_dev_t *dev, uint32_t port_id, uint32_t portsc)
- static void xhci_drain_pending_event (xhci_dev_t *dev)
- static void xhci_stall_fail (xhci_dev_t *dev)
- static int xhci_bulk_purpose_stalled (xhci_dev_t *dev, uint32_t purpose)
- static void xhci_handle_bulk_stall (xhci_dev_t *dev, uint32_t slot_id, uint32_t purpose)
- int xhci_keyboard_running (void)
- static void xhci_poll_one (xhci_dev_t *dev)
- void xhci_poll_events (void)

Variables

- static xhci_dev_t * g_xhci_devs [8u]
- static uint32_t g_xhci_dev_count
- static uint32_t g_xhci_keyboards

7.172.1 Macro Definition Documentation

7.172.1.1 USB_HID_REPORT_OUTPUT

```
#define USB_HID_REPORT_OUTPUT 0x0200u /* wValue:  report type Output (2), report ID 0 */
```

7.172.1.2 USB_HID_REQ_SET_REPORT

```
#define USB_HID_REQ_SET_REPORT 0x09u
```

7.172.1.3 XHCI_BAR0_MIN_MAP_SIZE

```
#define XHCI_BAR0_MIN_MAP_SIZE 0x10000ull
```

7.172.1.4 XHCI_LEGSUP_BIOS_OWNED

```
#define XHCI_LEGSUP_BIOS_OWNED (1u << 16)
```

7.172.1.5 XHCI_LEGSUP_OS_OWNED

```
#define XHCI_LEGSUP_OS_OWNED (1u << 24)
```

7.172.1.6 XHCI_PCI_CLASS

```
#define XHCI_PCI_CLASS 0x0Cu
```

7.172.1.7 XHCI_PCI_PROG_IF

```
#define XHCI_PCI_PROG_IF 0x30u
```

7.172.1.8 XHCI_PCI_SUBCLASS

```
#define XHCI_PCI_SUBCLASS 0x03u
```

7.172.1.9 XHCI_XCAP_LEGACY

```
#define XHCI_XCAP_LEGACY 1u
```

7.172.2 Function Documentation

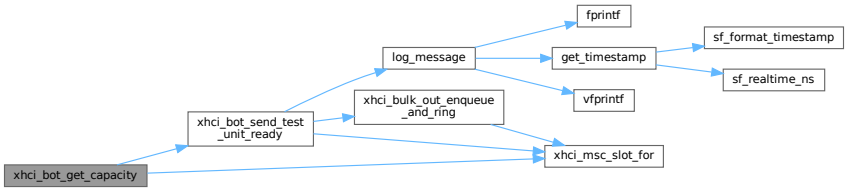
7.172.2.1 xhci_bot_get_capacity()

```
int xhci_bot_get_capacity (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

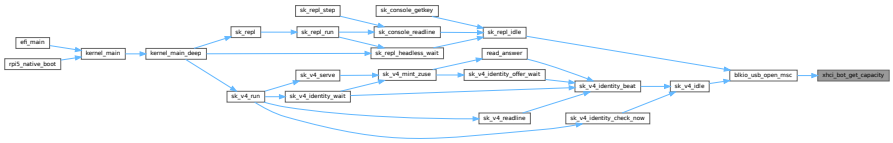
References xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, xhci_bot_send_test_unit_ready(), and xhci_msc_slot_for().

Referenced by blkio_usb_open_msc().

Here is the call graph for this function:



Here is the caller graph for this function:



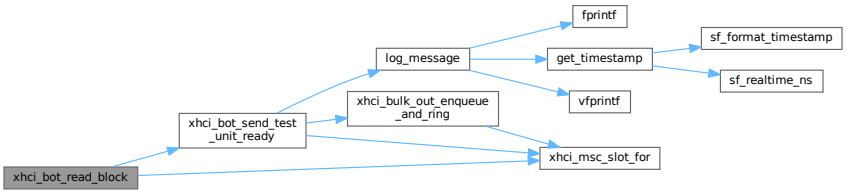
7.172.2.2 xhci_bot_read_block()

```
int xhci_bot_read_block (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t lba,
            uint16_t num_blocks,
            uint32_t block_size )
```

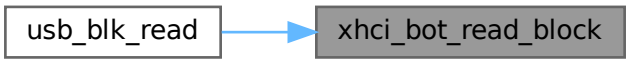
References block_size, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_read10_block_size, xhci_dev_t::bot_read10_lba, xhci_dev_t::bot_read10_num_blocks, xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, xhci_bot_send_test_unit_ready(), and xhci_msc_slot_for().

Referenced by usb_blk_read().

Here is the call graph for this function:



Here is the caller graph for this function:



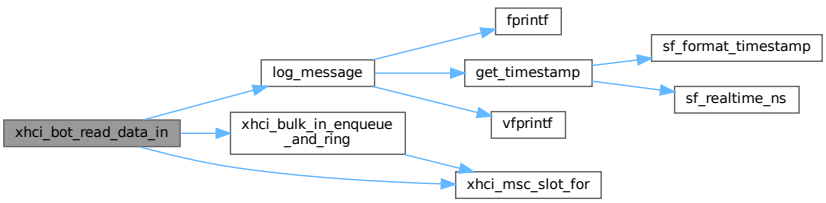
7.172.2.3 xhci_bot_read_data_in()

```
int xhci_bot_read_data_in (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

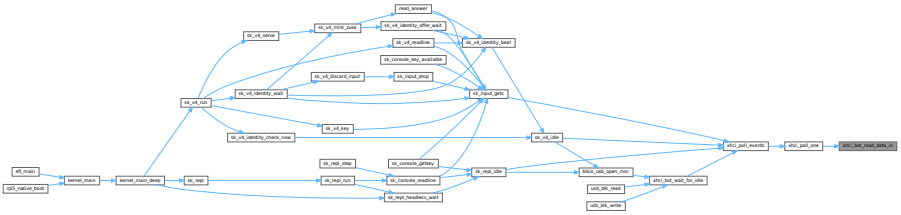
References xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_msc_slot_t::bulk_in_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, xhci_bulk_in_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_BOT_DATA_IN

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



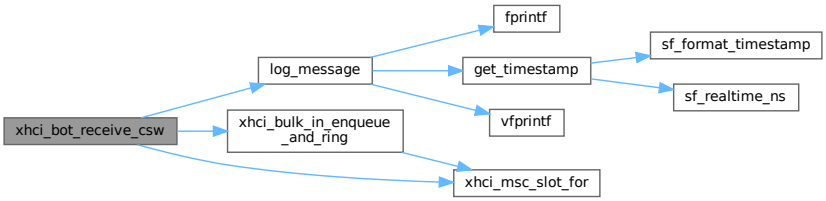
7.172.2.4 xhci_bot_receive_csw()

```
int xhci_bot_receive_csw (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

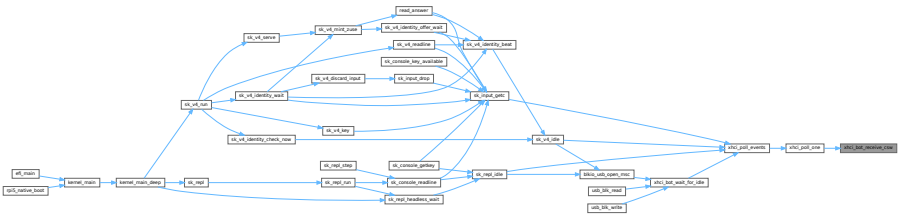
References xhci_dev_t::bot_csw, xhci_msc_slot_t::bulk_in_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_BOT_CSW_LENGTH, xhci_bulk_in_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CSW_RECEIVED.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



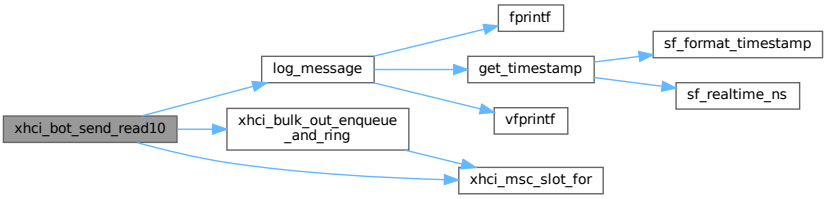
7.172.2.5 xhci_bot_send_read10()

```
int xhci_bot_send_read10 (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t lba,
            uint16_t num_blocks,
            uint32_t block_size )
```

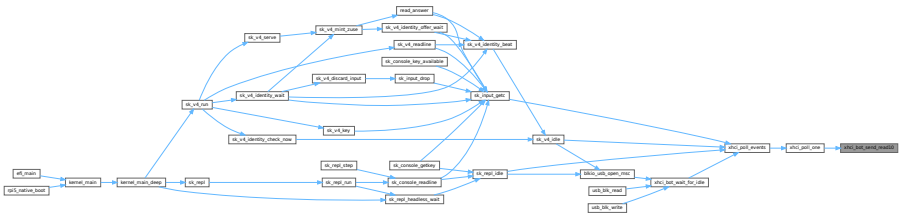
References usb_bot_cbw_t::bCBWCBLength, usb_bot_cbw_t::bCBWLUN, block_size, usb_bot_cbw_t::bmCBWFlags, xhci_dev_t::bot_cbw, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, usb_bot_cbw_t::CBWCB, usb_bot_cbw_t::dCBWDataTransferLe usb_bot_cbw_t::dCBWSignature, usb_bot_cbw_t::dCBWTag, LOG_DEBUG, log_message(), SCSI_CDB_LEN_READ10, SCSI_CMD_READ10, xhci_msc_slot_t::transfer_purpose, USB_BOT_CBW_FLAG_DATA_IN, USB_BOT_CBW_LENGTH, USB_BOT_CBW_LUN_DEFAULT, USB_BOT_CBW_SIGNATURE, xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CBW_SENT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



7.172.2.6 xhci_bot_send_read_capacity10()

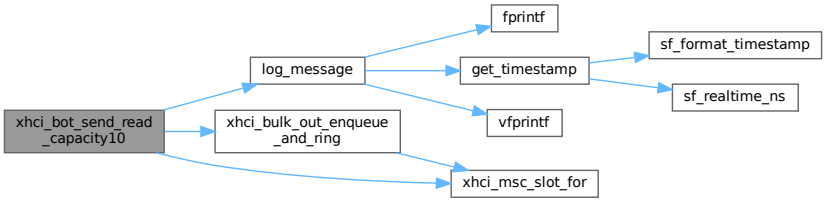
```
int xhci_bot_send_read_capacity10 (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

References usb_bot_cbw_t::bCBWCBLength, usb_bot_cbw_t::bCBWLUN, usb_bot_cbw_t::bmCBWFlags, xhci_dev_t::bot_cbw, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr,

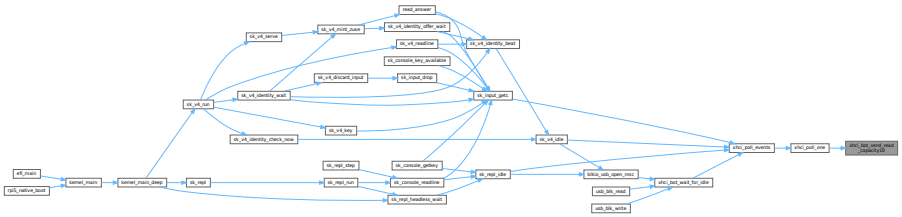
xhci_msc_slot_t::bulk_out_ring, usb_bot_cbw_t::CBWCB, usb_bot_cbw_t::dCBWDataTransferLength, usb_bot_cbw_t::dCBWSignatu
usb_bot_cbw_t::dCBWTag, LOG_DEBUG, log_message(), SCSI_CDB_LEN_READ_CAPACITY10, SCSI_CMD_READ_CAPACITY1
SCSI_READ_CAPACITY10_DATA_LEN, xhci_msc_slot_t::transfer_purpose, USB_BOT_CBW_FLAG_DATA_IN,
USB_BOT_CBW_LENGTH, USB_BOT_CBW_LUN_DEFAULT, USB_BOT_CBW_SIGNATURE, xhci_bulk_out_enqueue_and_ring(),
xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL,
and XHCI_XFER_CBW_SENT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



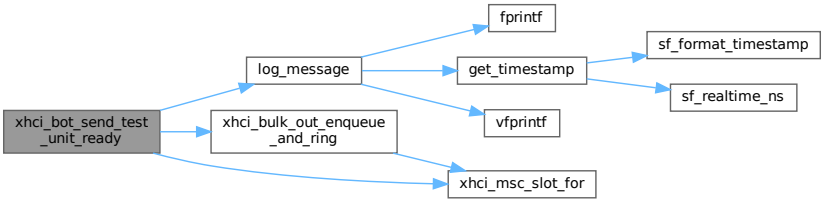
7.172.2.7 xhci_bot_send_test_unit_ready()

```
int xhci_bot_send_test_unit_ready (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

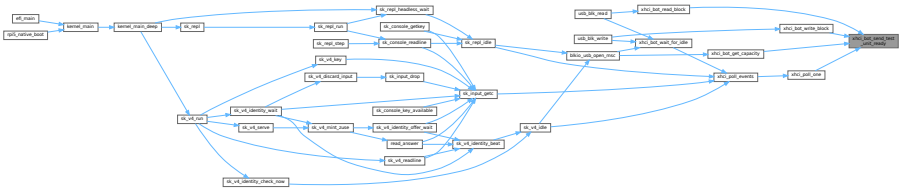
References usb_bot_cbw_t::bCBWCBLength, usb_bot_cbw_t::bCBWLUN, usb_bot_cbw_t::bmCBWFlags,
xhci_dev_t::bot_cbw, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_tag,
xhci_dev_t::bot_next_tag, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr,
xhci_msc_slot_t::bulk_out_ring, usb_bot_cbw_t::CBWCB, usb_bot_cbw_t::dCBWDataTransferLength, usb_bot_cbw_t::dCBWSignatu
usb_bot_cbw_t::dCBWTag, LOG_DEBUG, log_message(), SCSI_CDB_LEN_TEST_UNIT_READY, SCSI_CMD_TEST_UNIT_READ
xhci_msc_slot_t::transfer_purpose, USB_BOT_CBW_LENGTH, USB_BOT_CBW_LUN_DEFAULT, USB_BOT_CBW_SIGNATURE,
xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT,
XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CBW_SENT.

Referenced by xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_write_block(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



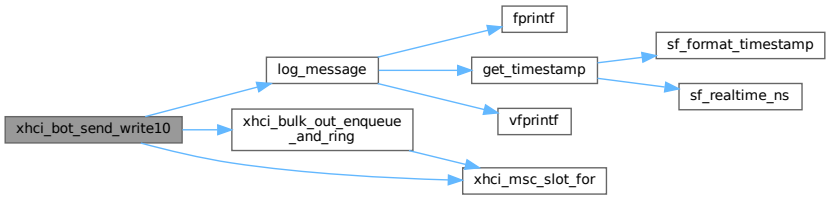
7.172.2.8 xhci_bot_send_write10()

```
int xhci_bot_send_write10 (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t lba,
            uint16_t num_blocks,
            uint32_t block_size )
```

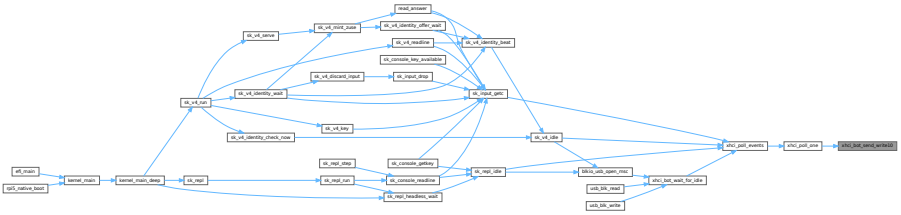
References usb_bot_cbw_t::bCBWCBLength, usb_bot_cbw_t::bCBWLUN, block_size, usb_bot_cbw_t::bmCBWFlags, xhci_dev_t::bot_cbw, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, usb_bot_cbw_t::CBWCB, usb_bot_cbw_t::dCBWDataTransferLe usb_bot_cbw_t::dCBWSignature, usb_bot_cbw_t::dCBWTag, LOG_DEBUG, log_message(), SCSI_CDB_LEN_WRITE10, SCSI_CMD_WRITE10, xhci_msc_slot_t::transfer_purpose, USB_BOT_CBW_LENGTH, USB_BOT_CBW_LUN_DEFAULT, USB_BOT_CBW_SIGNATURE, xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_CBW_SENT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



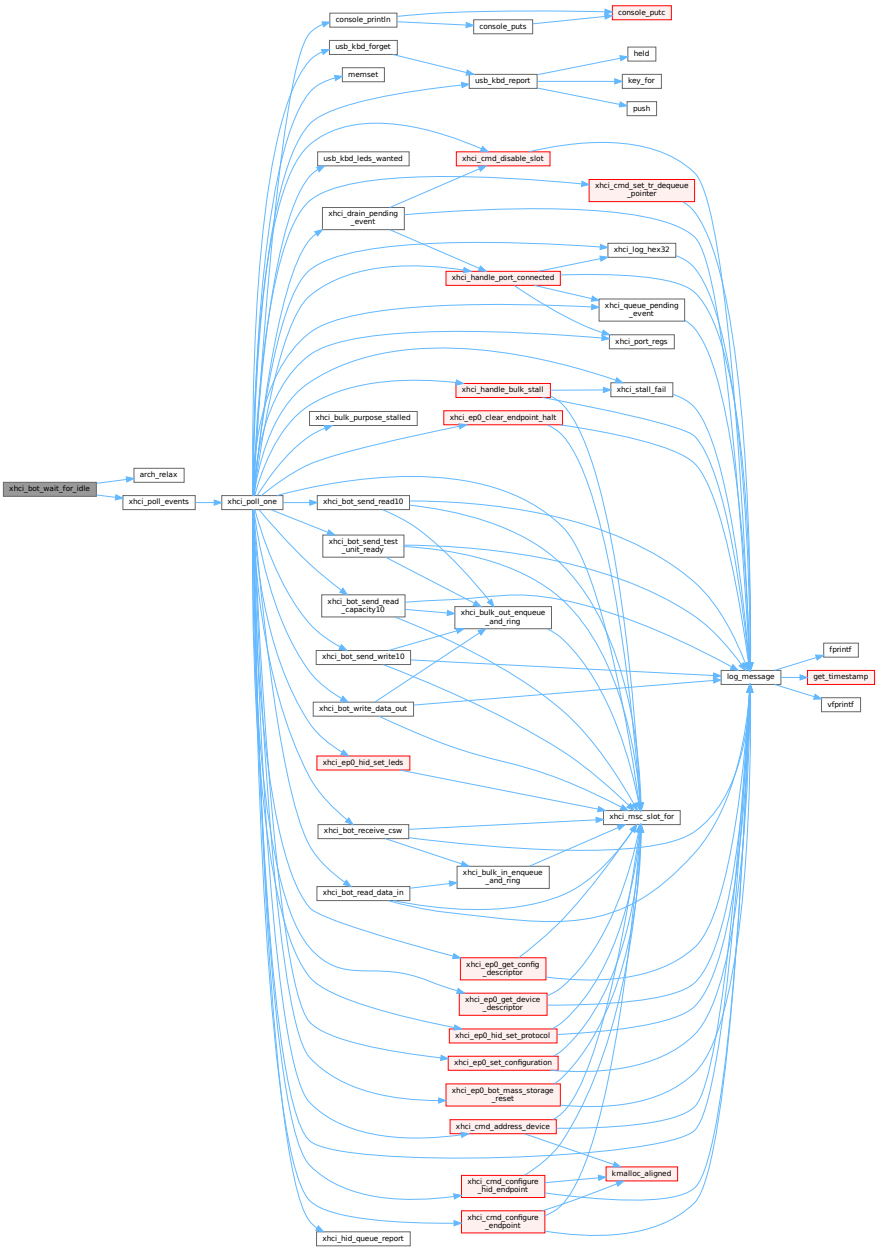
7.172.2.9 xhci_bot_wait_for_idle()

```
int xhci_bot_wait_for_idle (
            xhci_dev_t * dev,
            uint32_t max_iters )
```

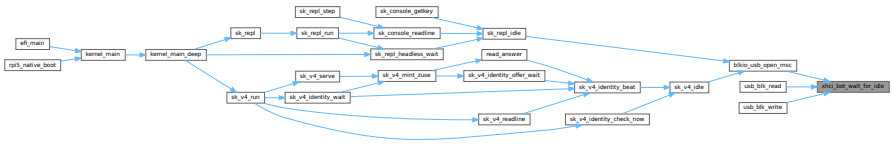
References arch_relax(), xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_last_status, and xhci_poll_events().

Referenced by blkio_usb_open_msc(), usb_blk_read(), and usb_blk_write().

Here is the call graph for this function:



Here is the caller graph for this function:



7.172.2.10 xhci_bot_write_block()

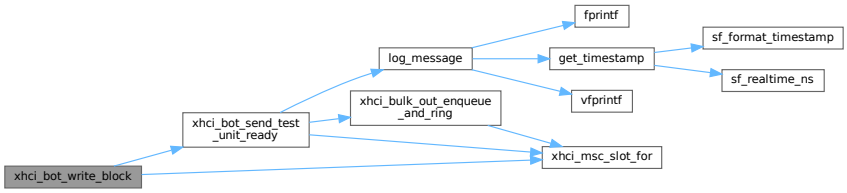
```
int xhci_bot_write_block (
```

```
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t lba,
            uint16_t num_blocks,
            uint32_t block_size )
```

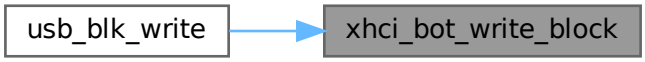
References block_size, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_dev_t::bot_write10_block_size, xhci_dev_t::bot_write10_lba, xhci_dev_t::bot_write10_num_blocks, xhci_msc_slot_t::bulk_in_ep, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, xhci_bot_send_test_unit_ready(), and xhci_msc_slot_for().

Referenced by usb_blk_write().

Here is the call graph for this function:



Here is the caller graph for this function:



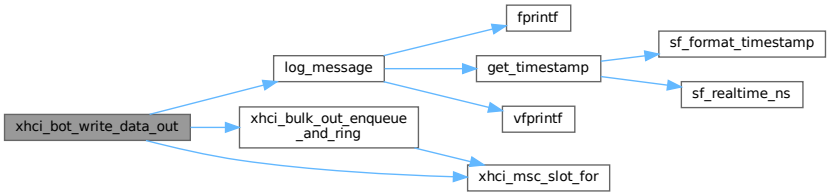
7.172.2.11 xhci_bot_write_data_out()

```
int xhci_bot_write_data_out (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

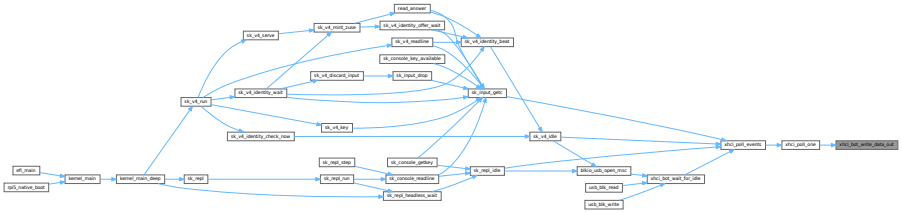
References xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_msc_slot_t::bulk_out_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, xhci_bulk_out_enqueue_and_ring(), xhci_msc_slot_for(), XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_NORMAL, and XHCI_XFER_BOT_DATA_O

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



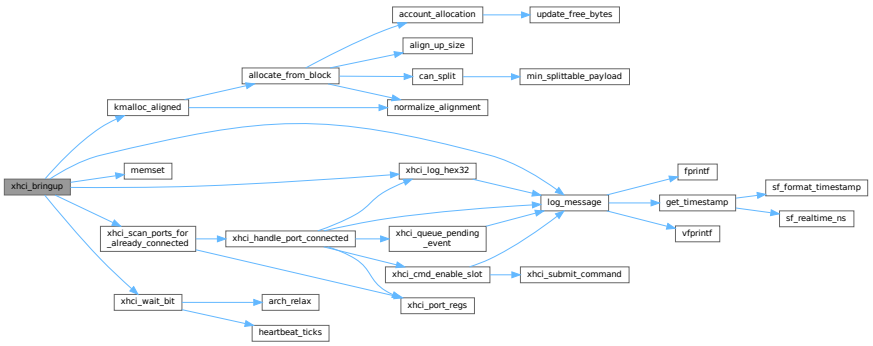
7.172.2.12 xhci_bringup()

```
int xhci_bringup (
            xhci_dev_t * dev )
```

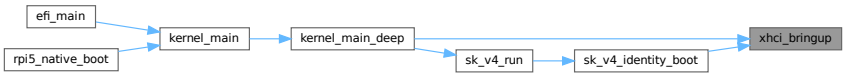
References xhci_dev_t::bot_cap_block_size, xhci_dev_t::bot_cap_last_lba, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_expected_dat xhci_dev_t::bot_last_status, xhci_dev_t::bot_last_tag, xhci_dev_t::bot_next_tag, xhci_dev_t::bot_read10_block_size, xhci_dev_t::bot_read10_lba, xhci_dev_t::bot_read10_num_blocks, xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_dev_t::cap, xhci_dev_t::cmd_ring, xhci_dev_t::cmd_ring_cycle, xhci_dev_t::cmd_ring_enq, xhci_op_regs_t::config, xhci_dev_t::connect_state, xhci_trb_t::control, xhci_op_regs_t::crcr, xhci_dev_t::dcbaa, xhci_op_regs_t::dcbaap, xhci_intr_regs_t::erdp, xhci_intr_regs_t::erstba, xhci_intr_regs_t::erstsz, xhci_dev_t::evt_ring, xhci_dev_t::evt_ring_cycle, xhci_dev_t::evt_ring_deq, xhci_dev_t::evt_ring_seg_table, g_xhci_dev_count, g_xhci_devs, xhci_cap_regs_t::hcc_params1, xhci_dev_t::intr0, kmalloc_aligned(), LOG_DEBUG, LOG_ERROR, log_message(), xhci_dev_t::max_scratchpad_bufs, xhci_dev_t::max_slots, memset(), xhci_dev_t::msc_slots, xhci_dev_t::op, xhci_op_regs_t::page_size, xhci_trb_t::parameter, xhci_dev_t::pending_connect_port_id, xhci_dev_t::pending_connect_slot_id, xhci_dev_t::pending_connect_speed, xhci_dev_t::pending_disable_slot_id, xhci_dev_t::pending_events, xhci_dev_t::port_slot_id, xhci_dev_t::runtime, xhci_dev_t::scratchpad_arr, xhci_trb_t::status, xhci_op_regs_t::usb_cmd, xhci_op_regs_t::usb_sts, xhci_dev_t::valid, XHCI_CONFIG_MAX_SLOTS_EN, XHCI_CRCR_PTR_MASK, XHCI_CRCR_RCS, XHCI_ERDP_PTR_MASK, XHCI_HCCPARAMS1_CSZ, xhci_log_hex32(), XHCI_MAX_CONTROLLERS, XHCI_MAX_TRACKED_PORTS, XHCI_RING_BYTES, XHCI_RING_TRB_COUNT, xhci_scan_ports_for_already_connected(), XHCI_TRB_CONTROL_CYCLE, XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_LINK, XHCI_USBCMD_HCRST, XHCI_USBCMD_RUN, XHCI_USBSTS_CNR, XHCI_USBSTS_HCH, and xhci_wait_bit().

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.172.2.13 xhci_bulk_in_enqueue_and_ring()

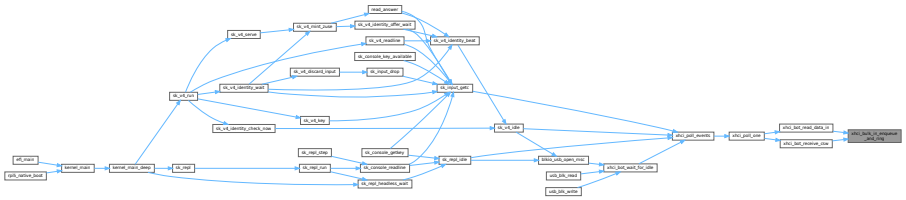
```
static void xhci_bulk_in_enqueue_and_ring (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint64_t parameter,
            uint32_t status,
            uint32_t control_bits )  [static]
```

References xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_in_ring_cycle, xhci_msc_slot_t::bulk_in_ring_enq, xhci_trb_t::control, xhci_dev_t::doorbell, xhci_trb_t::parameter, xhci_trb_t::status, XHCI_DB_TARGET, XHCI_EP_ADDR_TO_DCI, xhci_msc_slot_for(), XHCI_RING_TRB_COUNT, XHCI_TRB_CONTROL_CYCLE, XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, and XHCI_TRB_TYPE_LINK.

Referenced by xhci_bot_read_data_in(), and xhci_bot_receive_csw().

Here is the call graph for this function:

Here is the caller graph for this function:



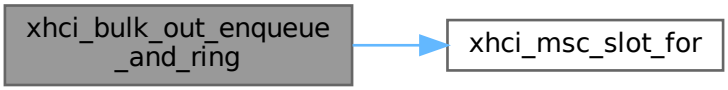
7.172.2.14 xhci_bulk_out_enqueue_and_ring()

```
static void xhci_bulk_out_enqueue_and_ring (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint64_t parameter,
            uint32_t status,
            uint32_t control_bits )  [static]
```

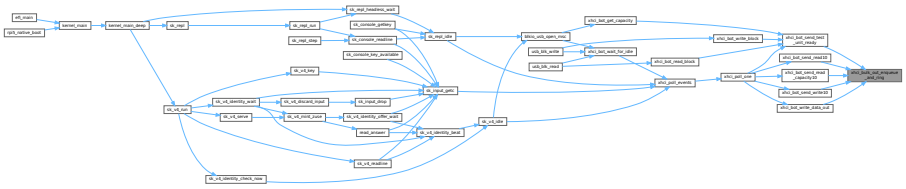
References xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_ring, xhci_msc_slot_t::bulk_out_ring_cycle, xhci_msc_slot_t::bulk_out_ring_enq, xhci_trb_t::control, xhci_dev_t::doorbell, xhci_trb_t::parameter, xhci_trb_t::status, XHCI_DB_TARGET, XHCI_EP_ADDR_TO_DCI, xhci_msc_slot_for(), XHCI_RING_TRB_COUNT, XHCI_TRB_CONTROL_CYCLE, XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, and XHCI_TRB_TYPE_LINK.

Referenced by xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), and xhci_bot_write_data_out().

Here is the call graph for this function:



Here is the caller graph for this function:



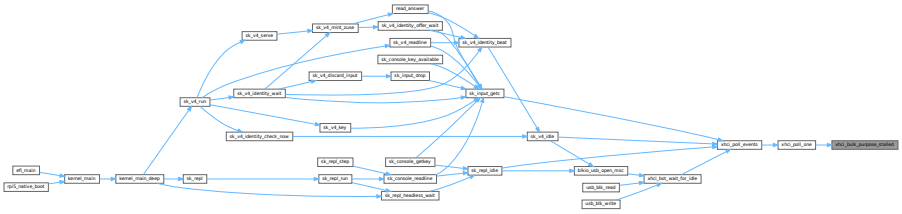
7.172.2.15 xhci_bulk_purpose_stalled()

```
static int xhci_bulk_purpose_stalled (
            xhci_dev_t * dev,
            uint32_t purpose )  [static]
```

References XHCI_XFER_BOT_DATA_IN, XHCI_XFER_BOT_DATA_OUT, XHCI_XFER_CBW_SENT, and XHCI_XFER_CSW_RECEIVED.

Referenced by xhci_poll_one().

Here is the caller graph for this function:



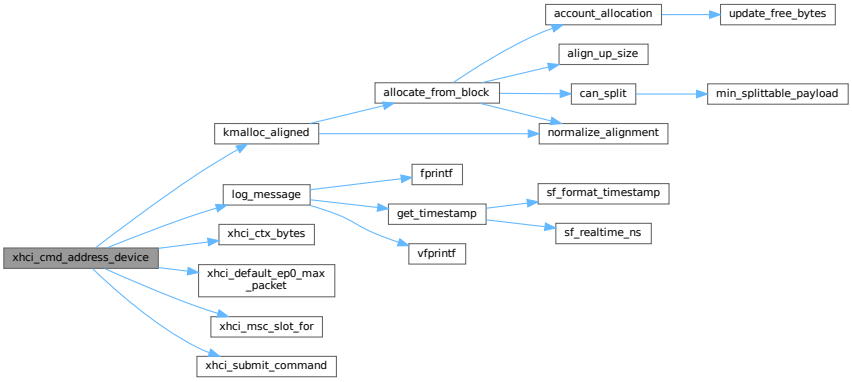
7.172.2.16 xhci_cmd_address_device()

```
int xhci_cmd_address_device (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t port_id,
            uint32_t speed )
```

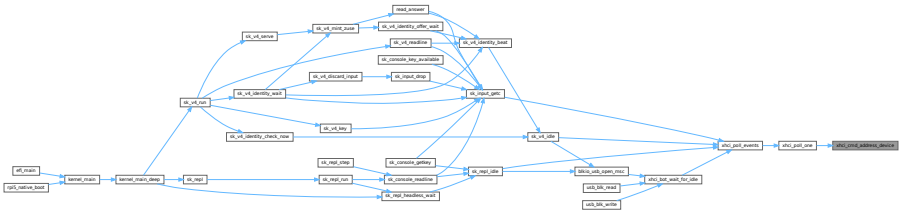
References xhci_input_ctrl_ctx32_t::add_flags, xhci_dev_t::cmd_ring, xhci_trb_t::control, xhci_dev_t::dcbaa, xhci_msc_slot_t::device_ctx, xhci_slot_ctx32_t::dword0, xhci_slot_ctx32_t::dword1, xhci_ep_ctx32_t::dword1, xhci_slot_ctx32_t::dword2, xhci_ep_ctx32_t::dword4, xhci_msc_slot_t::ep0_ring, xhci_msc_slot_t::ep0_ring_cycle, xhci_msc_slot_t::ep0_ring_enq, xhci_msc_slot_t::hid_ep_addr, xhci_msc_slot_t::hid_kbd, xhci_msc_slot_t::hid_running, xhci_msc_slot_t::in_use, xhci_msc_slot_t::input_ctx, kmalloc_aligned(), LOG_DEBUG, log_message(), xhci_trb_t::parameter, xhci_trb_t::status, xhci_ep_ctx32_t::tr_dequeue_ptr, xhci_ctx_bytes(), xhci_default_ep0_max_packet(), XHCI_EP_CTX_CERR_SHIF XHCI_EP_CTX_MAX_PACKET_SHIFT, XHCI_EP_CTX_TYPE_CONTROL_BIDI, XHCI_EP_CTX_TYPE_SHIFT, XHCI_INPUT_CTRL_ADD_EP0, XHCI_INPUT_CTRL_ADD_SLOT, xhci_msc_slot_for(), XHCI_RING_BYTES, XHCI_RING_TRB_COUNT, XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT, XHCI_SLOT_CTX_INTR_TARGET_SHIFT, XHCI_SLOT_CTX_ROOT_PORT_SHIFT, XHCI_SLOT_CTX_SPEED_SHIFT, xhci_submit_command(), XHCI_TRB_CONTROL_CY XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_ADDRESS_DEVICE_CMD, and XHCI_TRB_TYPE_LINK.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



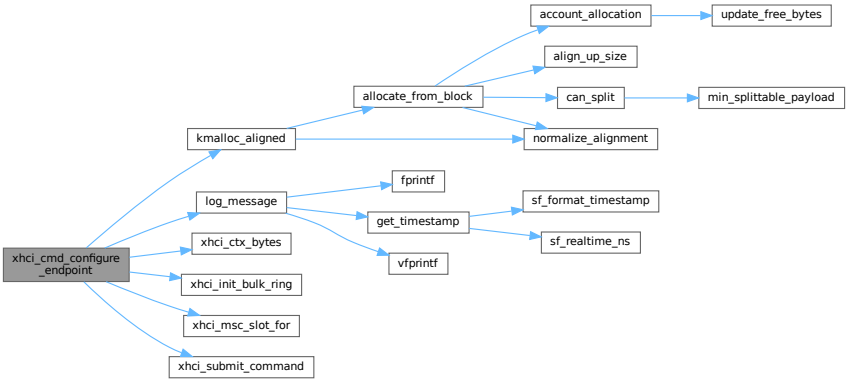
7.172.2.17 xhci_cmd_configure_endpoint()

```
int xhci_cmd_configure_endpoint (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

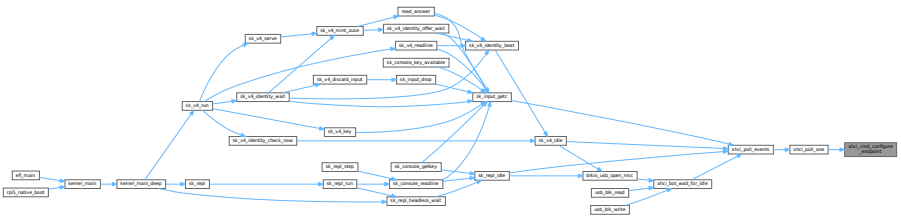
References xhci_input_ctrl_ctx32_t::add_flags, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_max_packet, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_in_ring_cycle, xhci_msc_slot_t::bulk_in_ring_enq, xhci_msc_slot_t::bulk_out_ep xhci_msc_slot_t::bulk_out_max_packet, xhci_msc_slot_t::bulk_out_ring, xhci_msc_slot_t::bulk_out_ring_cycle, xhci_msc_slot_t::bulk_out_ring_enq, xhci_dev_t::cmd_ring, xhci_dev_t::dcbaa, xhci_msc_slot_t::device_ctx, xhci_slot_ctx32_t::dword0, xhci_slot_ctx32_t::dword1, xhci_ep_ctx32_t::dword1, xhci_slot_ctx32_t::dword2, xhci_ep_ctx32_t::dword4, xhci_msc_slot_t::input_ctx, kmalloc_aligned(), LOG_DEBUG, log_message(), xhci_ep_ctx32_t::tr_dequeue_ptr, xhci_ctx_bytes(), XHCI_EP_ADDR_TO_DCI, XHCI_EP_CTX_CERR_SHIFT, XHCI_EP_CTX_MAX_PACKET_SHIFT, XHCI_EP_CTX_TYPE_BULK_IN, XHCI_EP_CTX_TYPE_BULK_OUT, XHCI_EP_CTX_TYPE_SHIFT, xhci_init_bulk_ring(), XHCI_INPUT_CTRL_ADD_SLOT, xhci_msc_slot_for(), XHCI_RING_BYTES, XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT, xhci_submit_command(), and XHCI_TRB_TYPE_CONFIGU

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



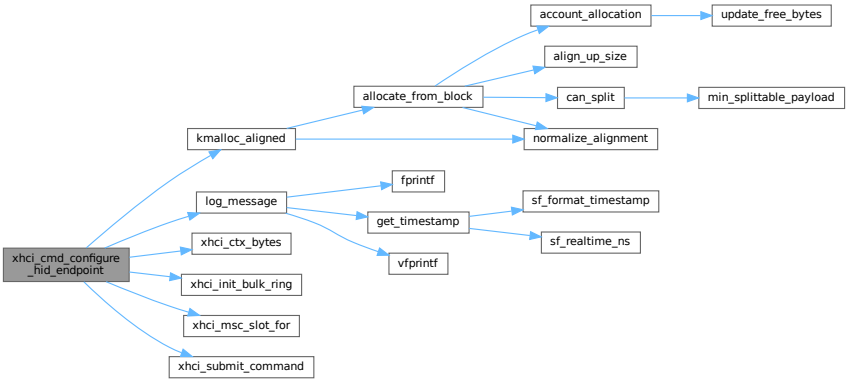
7.172.2.18 xhci_cmd_configure_hid_endpoint()

```
int xhci_cmd_configure_hid_endpoint (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

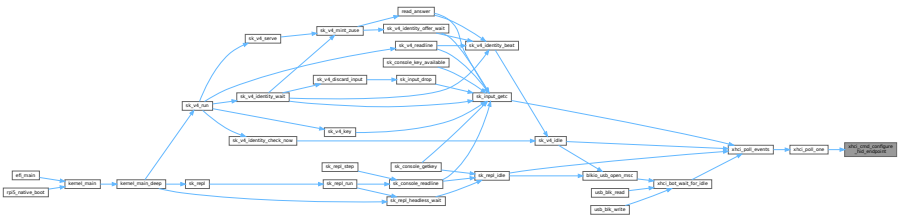
References xhci_input_ctrl_ctx32_t::add_flags, xhci_dev_t::cmd_ring, xhci_dev_t::dcbaa, xhci_msc_slot_t::device_ctx, xhci_slot_ctx32_t::dword0, xhci_ep_ctx32_t::dword0, xhci_slot_ctx32_t::dword1, xhci_ep_ctx32_t::dword1, xhci_slot_ctx32_t::dword2, xhci_ep_ctx32_t::dword4, xhci_msc_slot_t::hid_buf, xhci_msc_slot_t::hid_ep_addr, xhci_msc_slot_t::hid_interval, xhci_msc_slot_t::hid_max_packet, xhci_msc_slot_t::hid_ring, xhci_msc_slot_t::hid_ring_cycle, xhci_msc_slot_t::hid_ring_enq, xhci_msc_slot_t::input_ctx, kmalloc_aligned(), LOG_DEBUG, log_message(), xhci_ep_ctx32_t::tr_dequeue_ptr, xhci_ctx_bytes(), XHCI_EP_ADDR_TO_DCI, XHCI_EP_CTX_CERR_SHIFT, XHCI_EP_CTX_INTERVAL_SHIFT, XHCI_EP_CTX_MAX_PACKET_SHIFT, XHCI_EP_CTX_TYPE_INTERRUPT_IN, XHCI_EP_CTX_TYPE_SHIFT, xhci_init_bulk_ring(), XHCI_INPUT_CTRL_ADD_SLOT, xhci_msc_slot_for(), XHCI_RING_BYTES, XHCI_SLOT_CTX_CONTEXT_ENTRIES_SHIFT, XHCI_SLOT_CTX_SPEED_SHIFT, xhci_submit_command(), and XHCI_TRB_TYPE_CONFIGURE_ENDPOINT_CMD.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



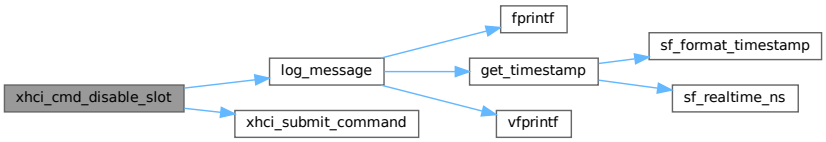
7.172.2.19 xhci_cmd_disable_slot()

```
int xhci_cmd_disable_slot (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

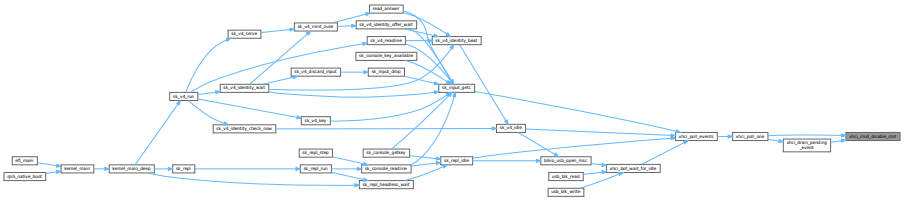
References xhci_dev_t::cmd_ring, LOG_DEBUG, log_message(), xhci_submit_command(), and XHCI_TRB_TYPE_DISABLE_SLOT.

Referenced by xhci_drain_pending_event(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



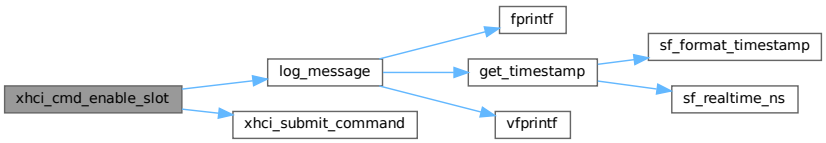
7.172.2.20 xhci_cmd_enable_slot()

```
int xhci_cmd_enable_slot (
            xhci_dev_t * dev )
```

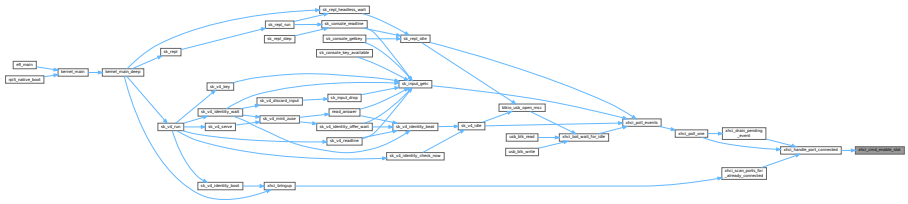
References xhci_dev_t::cmd_ring, LOG_DEBUG, log_message(), xhci_submit_command(), and XHCI_TRB_TYPE_ENABLE_SLOT_

Referenced by xhci_handle_port_connected().

Here is the call graph for this function:



Here is the caller graph for this function:



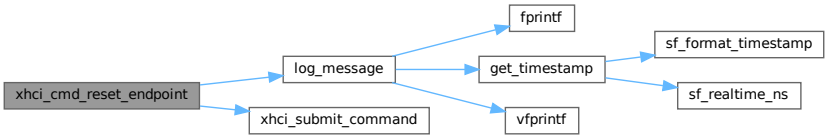
7.172.2.21 xhci_cmd_reset_endpoint()

```
int xhci_cmd_reset_endpoint (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t ep_id )
```

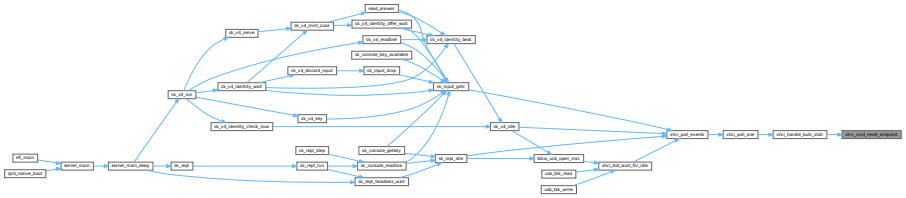
References xhci_dev_t::cmd_ring, LOG_DEBUG, log_message(), XHCI_EP_ADDR_TO_DCI, xhci_submit_command(), and XHCI_TRB_TYPE_RESET_ENDPOINT_CMD.

Referenced by xhci_handle_bulk_stall().

Here is the call graph for this function:



Here is the caller graph for this function:



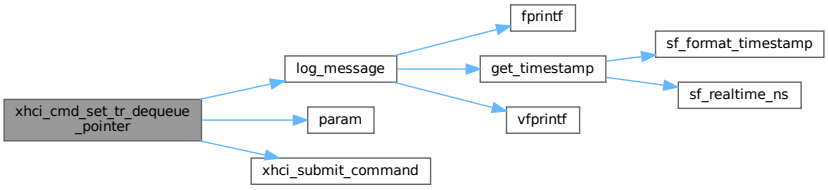
7.172.2.22 xhci_cmd_set_tr_dequeue_pointer()

```
int xhci_cmd_set_tr_dequeue_pointer (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t ep_id,
            uint64_t new_dequeue,
            uint32_t dcs )
```

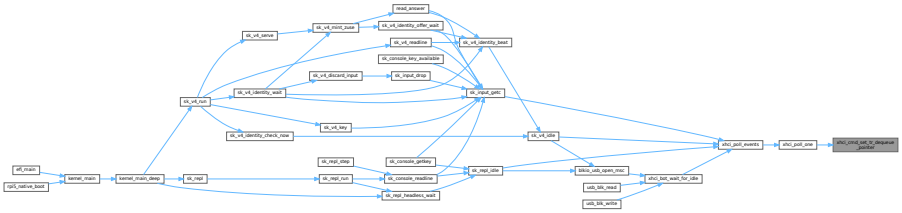
References xhci_dev_t::cmd_ring, LOG_DEBUG, log_message(), param(), xhci_submit_command(), and XHCI_TRB_TYPE_SET_TR_DEQUEUE_POINTER_CMD.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



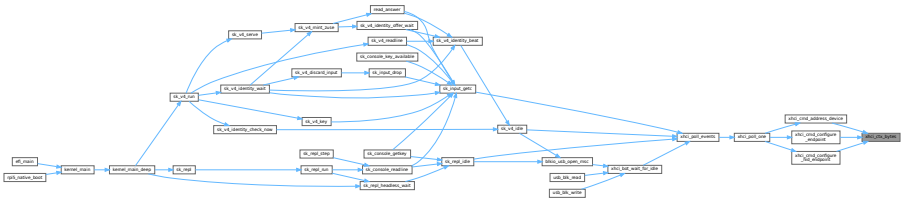
7.172.2.23 xhci_ctx_bytes()

```
static size_t xhci_ctx_bytes (
            const xhci_dev_t * dev )  [static]
```

References xhci_dev_t::cap, xhci_cap_regs_t::hcc_params1, and XHCI_HCCPARAMS1_CSZ.

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

Here is the caller graph for this function:

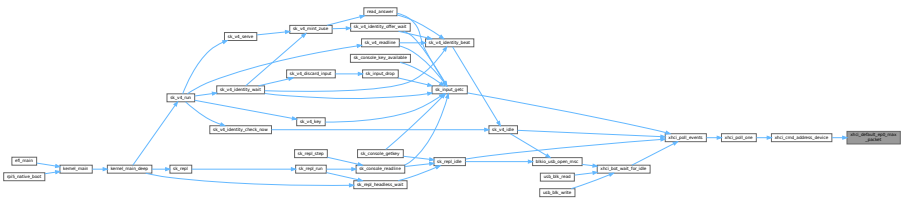


7.172.2.24 xhci_default_ep0_max_packet()

```
static uint32_t xhci_default_ep0_max_packet (
            uint32_t speed )  [static]
```

Referenced by xhci_cmd_address_device().

Here is the caller graph for this function:



7.172.2.25 xhci_dev_at()

```
xhci_dev_t * xhci_dev_at (
            uint32_t i )
```

References g_xhci_dev_count, and g_xhci_devs.

Referenced by sk_repl_idle(), sk_v4_idle(), and sk_word_blk_attach_ack().

Here is the caller graph for this function:

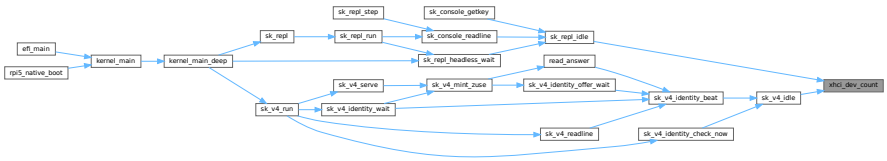
7.172.2.26 xhci_dev_count()

```
uint32_t xhci_dev_count (
            void  )
```

References g_xhci_dev_count.

Referenced by sk_repl_idle(), and sk_v4_idle().

Here is the caller graph for this function:



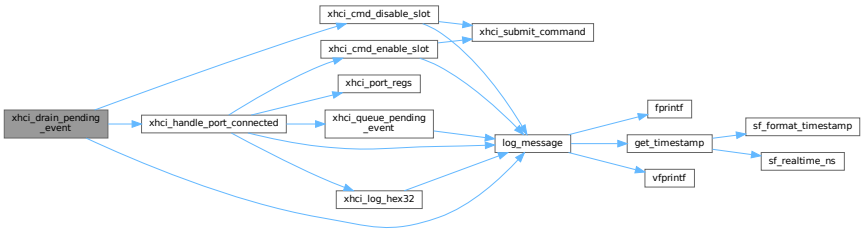
7.172.2.27 xhci_drain_pending_event()

```
static void xhci_drain_pending_event (
            xhci_dev_t * dev )  [static]
```

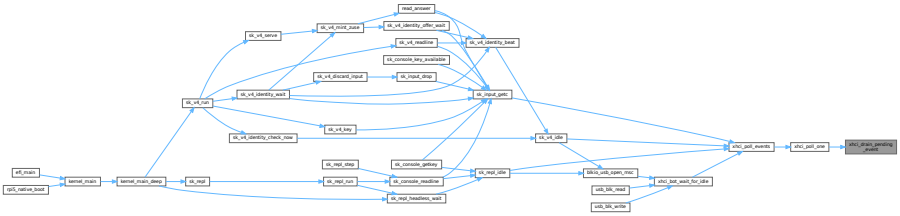
References xhci_dev_t::connect_state, xhci_dev_t::is_connect, LOG_DEBUG, log_message(), xhci_dev_t::pending_disable_slot_id, xhci_dev_t::pending_events, xhci_dev_t::port_id, xhci_dev_t::portsc, xhci_dev_t::slot_id, xhci_dev_t::valid, xhci_cmd_disable_slot(), xhci_handle_port_connected(), and XHCI_MAX_TRACKED_PORTS.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



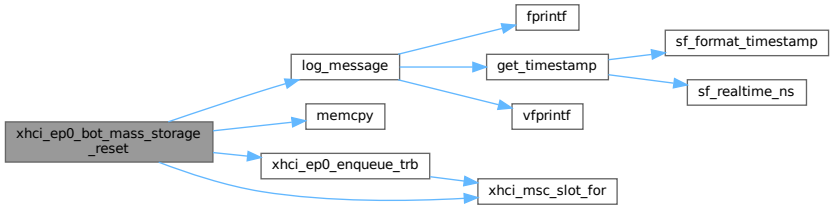
7.172.2.28 xhci_ep0_bot_mass_storage_reset()

```
int xhci_ep0_bot_mass_storage_reset (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

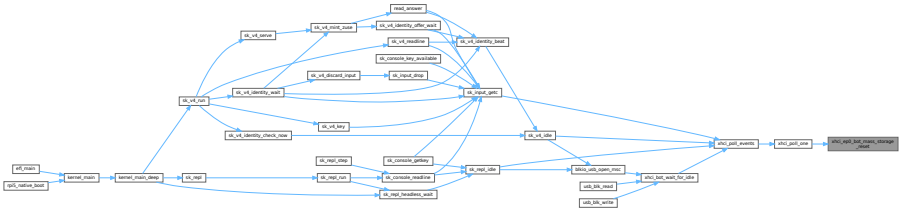
References usb_setup_packet_t::bmRequestType, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), memcpy(), xhci_msc_slot_t::transfer_purpose, USB_BOT_MASS_STORAGE_RESET, USB_RECIP_INTERFACE, USB_REQ_TYPE_CLASS, XHCI_DB_TARGET, xhci_ep0_enqueue_trb(), xhci_msc_slot_for(), XHCI_SETUP_TRT_NO_DATA, XHCI_TRB_CONTROL_DIR_IN, XHCI_TRB_CONTROL_IDT, XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TRT_SHIFT, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_SETUP_STAGE, XHCI_TRB_TYPE_STATUS_STAGE, and XHCI_XFER_BOT_RESET.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



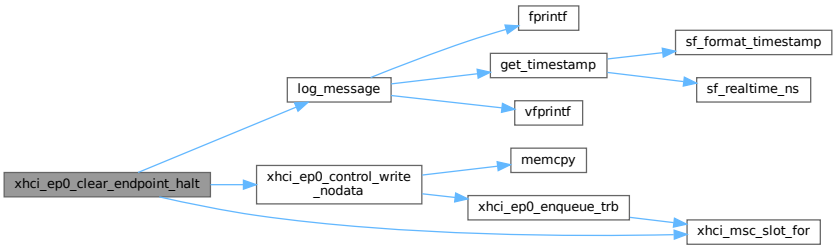
7.172.2.29 xhci_ep0_clear_endpoint_halt()

```
int xhci_ep0_clear_endpoint_halt (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint8_t ep_addr )
```

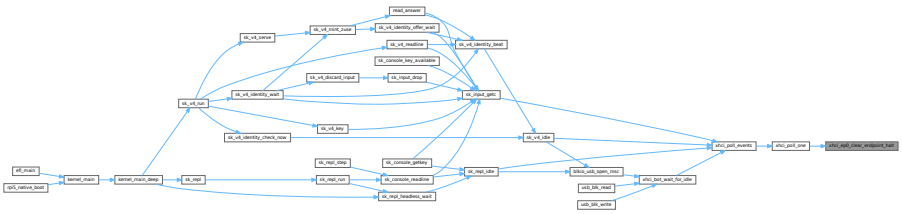
References xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_FEATURE_ENDPOINT_HALT, USB_REQ_CLEAR_FEATURE, XHCI_DB_TARGET, xhci_ep0_control_write_nodata(), xhci_msc_slot_for(), and XHCI_XFER_CLEAR_HALT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



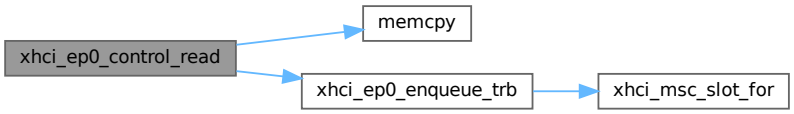
7.172.2.30 xhci_ep0_control_read()

```
static void xhci_ep0_control_read (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint8_t bRequest,
            uint16_t wValue,
            uint16_t wIndex,
            uint8_t * buf,
            uint16_t len )  [static]
```

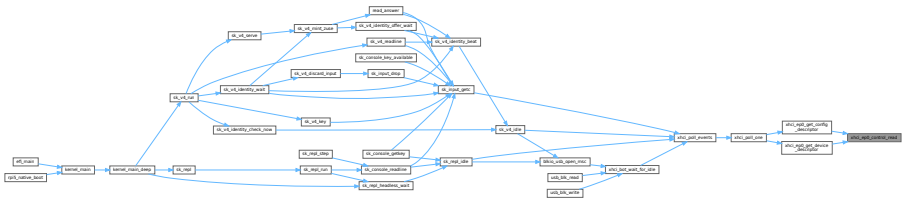
References usb_setup_packet_t::bmRequestType, memcpy(), USB_DIR_DEVICE_TO_HOST, xhci_ep0_enqueue_trb(), XHCI_SETUP_TRT_IN_DATA, XHCI_TRB_CONTROL_DIR_IN, XHCI_TRB_CONTROL_IDT, XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TRT_SHIFT, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_DATA_STAGE, XHCI_TRB_TYPE_SETUP_STAGE, and XHCI_TRB_TYPE_STATUS_STAGE.

Referenced by xhci_ep0_get_config_descriptor(), and xhci_ep0_get_device_descriptor().

Here is the call graph for this function:



Here is the caller graph for this function:



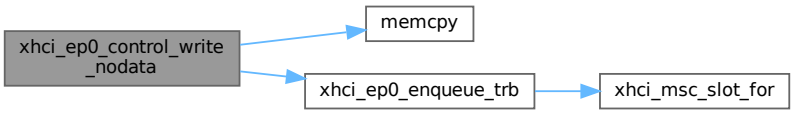
7.172.2.31 xhci_ep0_control_write_nodata()

```
static void xhci_ep0_control_write_nodata (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint8_t bRequest,
            uint16_t wValue,
            uint16_t wIndex )  [static]
```

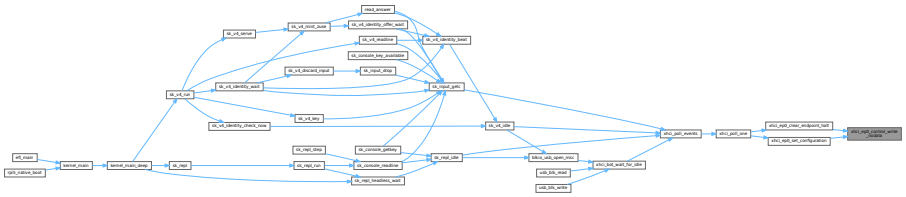
References usb_setup_packet_t::bmRequestType, memcpy(), USB_DIR_HOST_TO_DEVICE, xhci_ep0_enqueue_trb(), XHCI_SETUP_TRT_NO_DATA, XHCI_TRB_CONTROL_DIR_IN, XHCI_TRB_CONTROL_IDT, XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TRT_SHIFT, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_SETUP_STAGE, and XHCI_TRB_TYPE_STATUS_STAGE.

Referenced by xhci_ep0_clear_endpoint_halt(), and xhci_ep0_set_configuration().

Here is the call graph for this function:



Here is the caller graph for this function:



7.172.2.32 xhci_ep0_enqueue_trb()

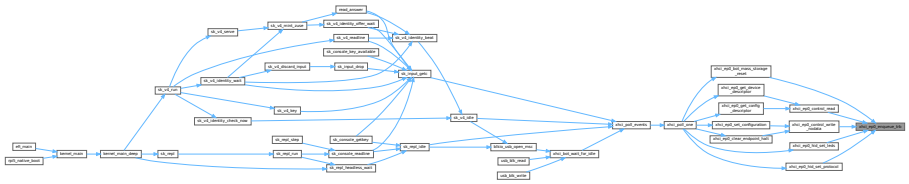
```
static void xhci_ep0_enqueue_trb (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint64_t parameter,
            uint32_t status,
            uint32_t control_bits )  [static]
```

References xhci_trb_t::control, xhci_msc_slot_t::ep0_ring, xhci_msc_slot_t::ep0_ring_cycle, xhci_msc_slot_t::ep0_ring_enq, xhci_trb_t::parameter, xhci_trb_t::status, xhci_msc_slot_for(), XHCI_RING_TRB_COUNT, XHCI_TRB_CONTROL_CYCLE, XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, and XHCI_TRB_TYPE_LINK.

Referenced by xhci_ep0_bot_mass_storage_reset(), xhci_ep0_control_read(), xhci_ep0_control_write_nodata(), xhci_ep0_hid_set_leds(), and xhci_ep0_hid_set_protocol().

Here is the call graph for this function:

Here is the caller graph for this function:



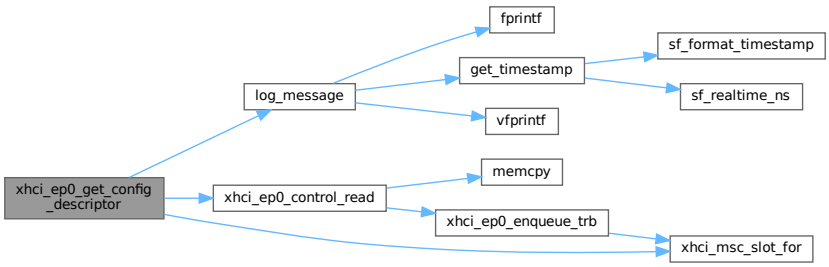
7.172.2.33 xhci_ep0_get_config_descriptor()

```
int xhci_ep0_get_config_descriptor (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint16_t length )
```

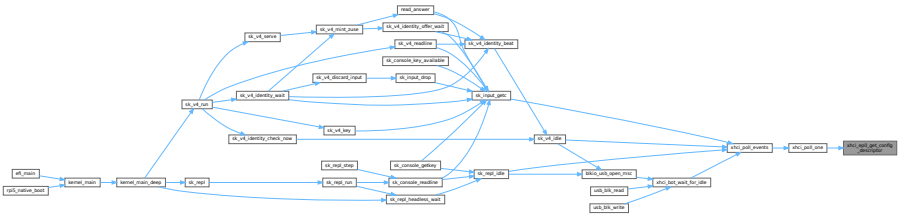
References xhci_msc_slot_t::config_descriptor, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_DESC_TYPE_CONFIG, USB_REQ_GET_DESCRIPTOR, XHCI_DB_TARGET, xhci_ep0_control_read(), xhci_msc_slot_for(), XHCI_XFER_CONFIG_DESC_FULL, and XHCI_XFER_CONFIG_DESC_SHORT.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



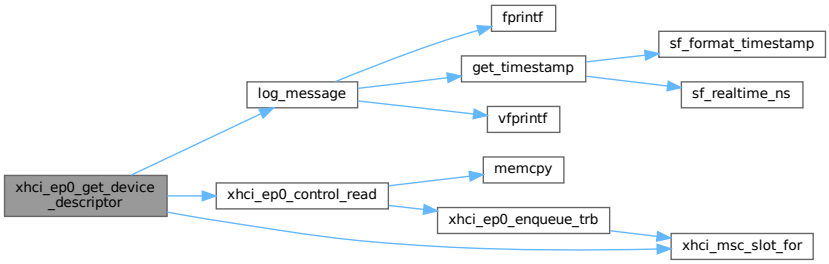
7.172.2.34 xhci_ep0_get_device_descriptor()

```
int xhci_ep0_get_device_descriptor (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

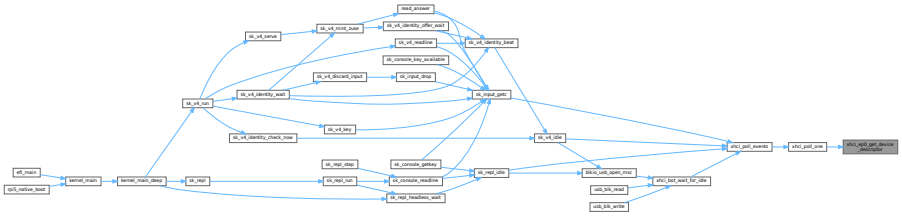
References xhci_msc_slot_t::device_descriptor, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_DESC_TYPE_DEVICE, USB_REQ_GET_DESCRIPTOR, XHCI_DB_TARGET, xhci_ep0_control_read(), xhci_msc_slot_for(), and XHCI_XFER_DEVICE_DESC.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



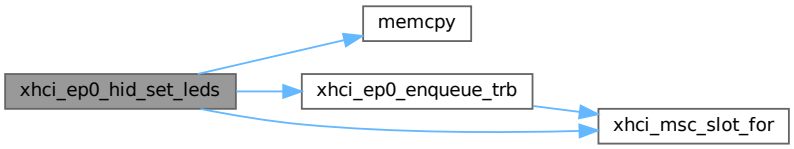
7.172.2.35 xhci_ep0_hid_set_leds()

```
static int xhci_ep0_hid_set_leds (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint8_t leds )  [static]
```

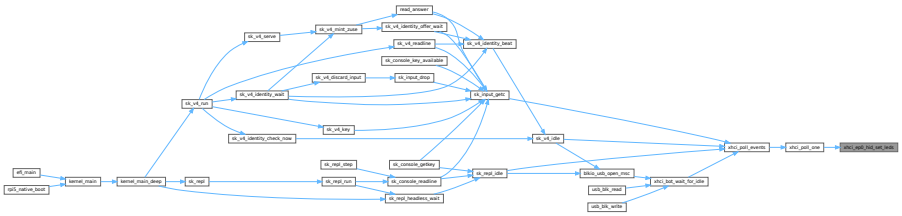
References usb_setup_packet_t::bmRequestType, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, xhci_msc_slot_t::hid_buf, xhci_msc_slot_t::hid_iface, xhci_msc_slot_t::hid_leds_sent, memcpy(), xhci_msc_slot_t::transfer_purpose, USB_HID_REPORT_OUTPUT, USB_HID_REQ_SET_REPORT, USB_RECIP_INTERFACE, USB_REQ_TYPE_CLASS, XHCI_DB_TARGET, xhci_ep0_enqueue_trb(), xhci_msc_slot_for(), XHCI_SETUP_TRT_OUT_DATA, XHCI_TRB_CONTROL_DIR_IN, XHCI_TRB_CONTROL_IDT, XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TRT_SHIFT, XHCI_TRB_CONTROL_TYPE_SH, XHCI_TRB_TYPE_DATA_STAGE, XHCI_TRB_TYPE_SETUP_STAGE, XHCI_TRB_TYPE_STATUS_STAGE, and XHCI_XFER_HID_SET_LEDS.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



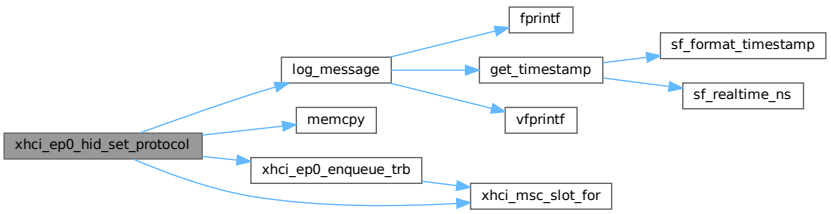
7.172.2.36 xhci_ep0_hid_set_protocol()

```
int xhci_ep0_hid_set_protocol (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

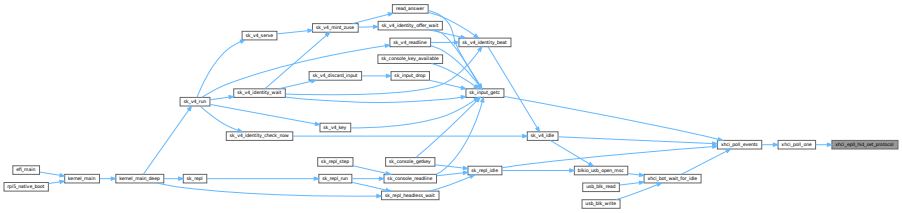
References usb_setup_packet_t::bmRequestType, xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, xhci_msc_slot_t::hid_iface, LOG_DEBUG, log_message(), memcpy(), xhci_msc_slot_t::transfer_purpose, USB_HID_PROTOCOL_BOOT, USB_HID_REQ_SET_PROTOCOL, USB_RECIP_INTERFACE, USB_REQ_TYPE_CLASS, XHCI_DB_TARGET, xhci_ep0_enqueue_trb(), xhci_msc_slot_for(), XHCI_SETUP_TRT_NO_DATA, XHCI_TRB_CONTROL_DIR_IN, XHCI_TRB_CONTROL_IDT, XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TRT_SHIFT, XHCI_TRB_CONTROL_TYPE_SH XHCI_TRB_TYPE_SETUP_STAGE, XHCI_TRB_TYPE_STATUS_STAGE, and XHCI_XFER_HID_SET_PROTOCOL.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



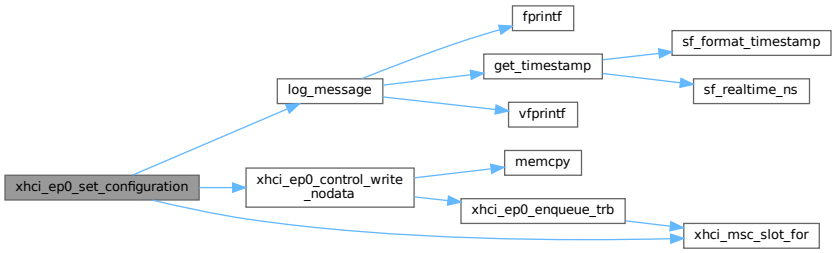
7.172.2.37 xhci_ep0_set_configuration()

```
int xhci_ep0_set_configuration (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint8_t config_value )
```

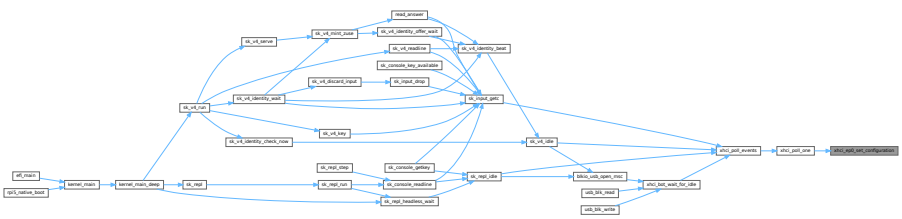
References xhci_dev_t::doorbell, xhci_msc_slot_t::ep0_ring, LOG_DEBUG, log_message(), xhci_msc_slot_t::transfer_purpose, USB_REQ_SET_CONFIGURATION, XHCI_DB_TARGET, xhci_ep0_control_write_nodata(), xhci_msc_slot_for(), and XHCI_XFER_SET_CONFIG.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



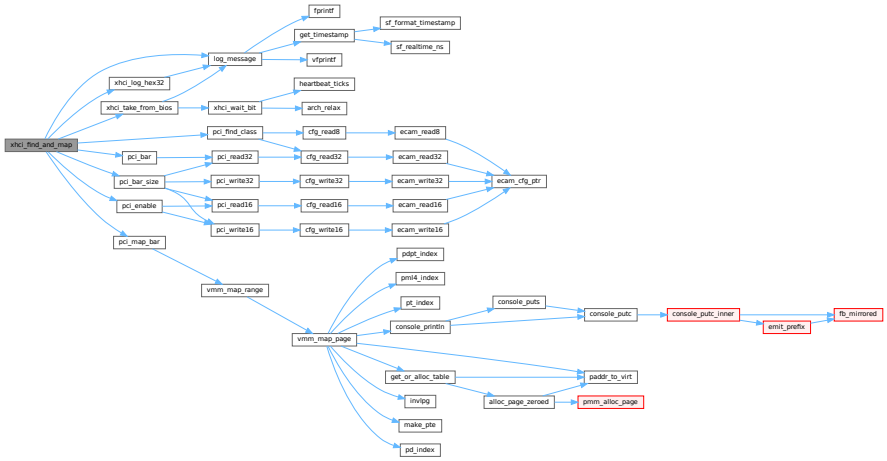
7.172.2.38 xhci_find_and_map()

```
int xhci_find_and_map (
            xhci_dev_t * dev,
            unsigned index )
```

References xhci_dev_t::bar0_phys, xhci_dev_t::cap, xhci_cap_regs_t::cap_length, xhci_cap_regs_t::db_off, PciDevice::device_id, xhci_dev_t::doorbell, xhci_cap_regs_t::hcs_params1, xhci_cap_regs_t::hcs_params2, LOG_DEBUG, LOG_ERROR, log_message(), xhci_dev_t::max_intrs, xhci_dev_t::max_ports, xhci_dev_t::max_scratchpad_bufs, xhci_dev_t::max_slots, xhci_dev_t::op, xhci_dev_t::pci, pci_bar(), pci_bar_size(), pci_enable(), pci_find_class(), pci_map_bar(), xhci_cap_regs_t::rts_off, xhci_dev_t::runtime, PciDevice::vendor_id, XHCI_BAR0_MIN_MAP_SIZE, XHCI_HCSPARAMS1_MAX_INTRS, XHCI_HCSPARAMS1_MAX_PORTS, XHCI_HCSPARAMS1_MAX_SLOTS, XHCI_HCSPARAMS2_MAX_SCRATCHPAD_BUFS, xhci_log_hex32(), XHCI_PCI_CLASS, XHCI_PCI_PROG_IF, XHCI_PCI_SUBCLASS, and xhci_take_from_bios().

Referenced by kernel_main_deep(), and sk_v4_identity_boot().

Here is the call graph for this function:



Here is the caller graph for this function:

7.172.2.39 xhci_handle_bulk_stall()

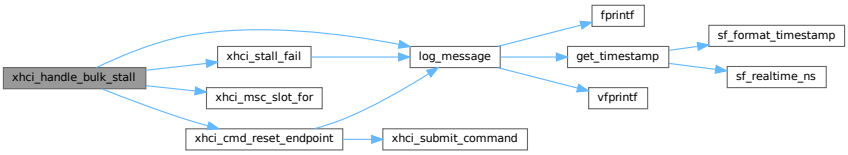
```
static void xhci_handle_bulk_stall (
            xhci_dev_t * dev,
            uint32_t slot_id,
            uint32_t purpose )  [static]
```

References xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_stall_recoveries, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_out_ep_addr, xhci_dev_t::connect_state, LOG_ERROR, log_message(), LOG_WARN,

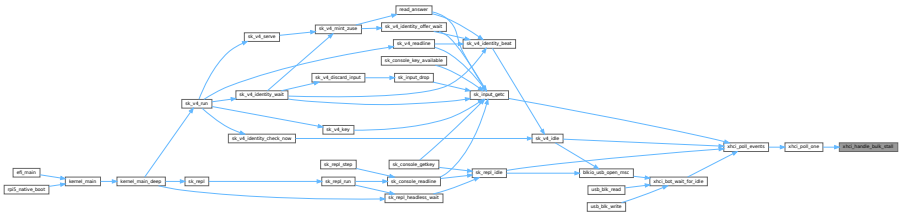
xhci_msc_slot_t::next_action, xhci_dev_t::stall_dci, xhci_dev_t::stall_ep_addr, xhci_dev_t::stall_retry_action, XHCI_BOT_STALL_MAX_RECOVERIES, xhci_cmd_reset_endpoint(), XHCI_EP_ADDR_TO_DCI, xhci_msc_slot_for(), XHCI_NEXT_ACTION_BOT_CSW_RECEIVE, XHCI_NEXT_ACTION_BOT_DATA_IN, XHCI_NEXT_ACTION_BOT_DATA_OUT, XHCI_NEXT_ACTION_BOT_RESET, XHCI_NEXT_ACTION_BOT_SEND_READ10, XHCI_NEXT_ACTION_BOT_SEND_READ_CA XHCI_NEXT_ACTION_BOT_SEND_TUR, XHCI_NEXT_ACTION_BOT_SEND_WRITE10, xhci_stall_fail(), XHCI_XFER_BOT_DATA_IN, XHCI_XFER_BOT_DATA_OUT, XHCI_XFER_CBW_SENT, and XHCI_XFER_CSW_RECEIVED.

Referenced by xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



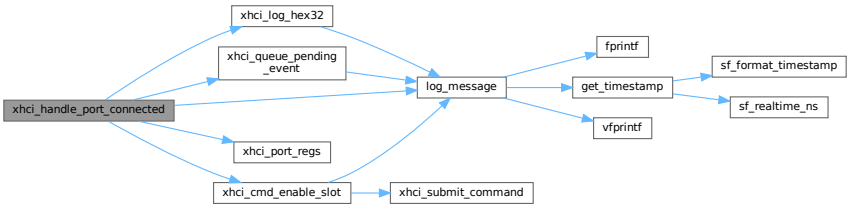
7.172.2.40 xhci_handle_port_connected()

```
static void xhci_handle_port_connected (
            xhci_dev_t * dev,
            uint32_t port_id,
            uint32_t portsc )  [static]
```

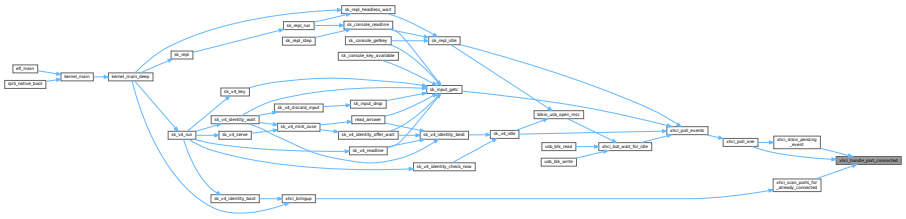
References xhci_dev_t::connect_state, LOG_DEBUG, log_message(), LOG_WARN, xhci_dev_t::pending_connect_port_id, xhci_dev_t::pending_connect_speed, xhci_port_regs_t::portsc, xhci_cmd_enable_slot(), xhci_log_hex32(), XHCI_MAX_TRACKED_PORTS, xhci_port_regs(), XHCI_PORTSC_PED, XHCI_PORTSC_PP, XHCI_PORTSC_PR, XHCI_PORTSC_SPEED, and xhci_queue_pending_event().

Referenced by xhci_drain_pending_event(), xhci_poll_one(), and xhci_scan_ports_for_already_connected().

Here is the call graph for this function:



Here is the caller graph for this function:



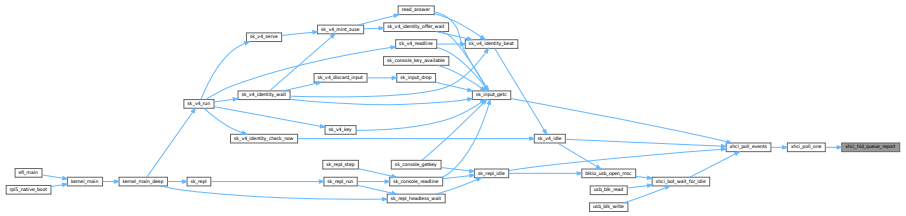
7.172.2.41 xhci_hid_queue_report()

```
static void xhci_hid_queue_report (
            xhci_dev_t * dev,
            uint32_t slot_id,
            xhci_msc_slot_t * ms )  [static]
```

References xhci_trb_t::control, xhci_dev_t::doorbell, xhci_msc_slot_t::hid_buf, xhci_msc_slot_t::hid_ep_addr, xhci_msc_slot_t::hid_max_packet, xhci_msc_slot_t::hid_ring, xhci_msc_slot_t::hid_ring_cycle, xhci_msc_slot_t::hid_ring_enq, xhci_trb_t::parameter, xhci_trb_t::status, XHCI_DB_TARGET, XHCI_EP_ADDR_TO_DCI, XHCI_RING_TRB_COUNT, XHCI_TRB_CONTROL_CYCLE, XHCI_TRB_CONTROL_IOC, XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, XHCI_TRB_TYPE_LINK, and XHCI_TRB_TYPE_NORMAL.

Referenced by xhci_poll_one().

Here is the caller graph for this function:



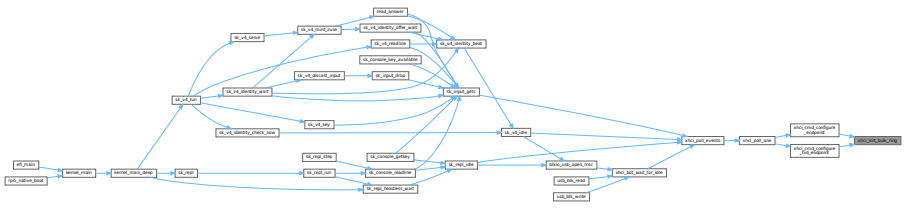
7.172.2.42 xhci_init_bulk_ring()

```
static void xhci_init_bulk_ring (
            xhci_trb_t * ring )  [static]
```

References ring, XHCI_RING_TRB_COUNT, XHCI_TRB_CONTROL_CYCLE, XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, and XHCI_TRB_TYPE_LINK.

Referenced by xhci_cmd_configure_endpoint(), and xhci_cmd_configure_hid_endpoint().

Here is the caller graph for this function:



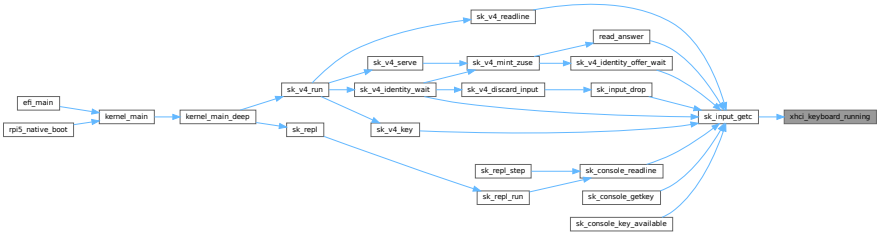
7.172.2.43 xhci_keyboard_running()

```
int xhci_keyboard_running (
            void  )
```

References g_xhci_keyboards.

Referenced by sk_input_getc().

Here is the caller graph for this function:



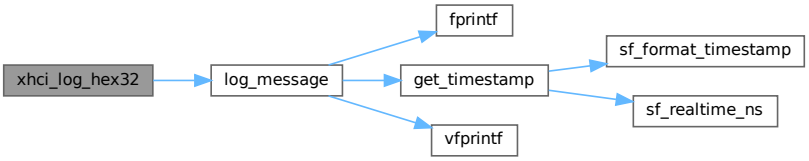
7.172.2.44 xhci_log_hex32()

```
static void xhci_log_hex32 (
            const char * prefix,
            uint32_t v )  [static]
```

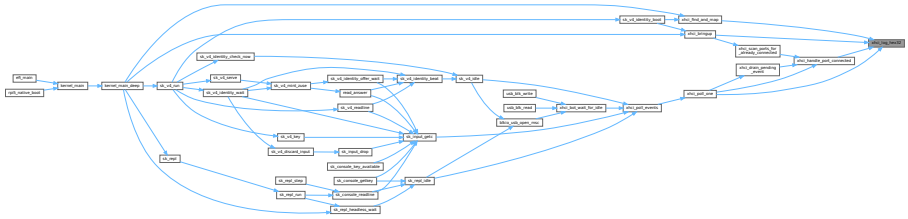
References LOG_DEBUG, and log_message().

Referenced by xhci_bringup(), xhci_find_and_map(), xhci_handle_port_connected(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



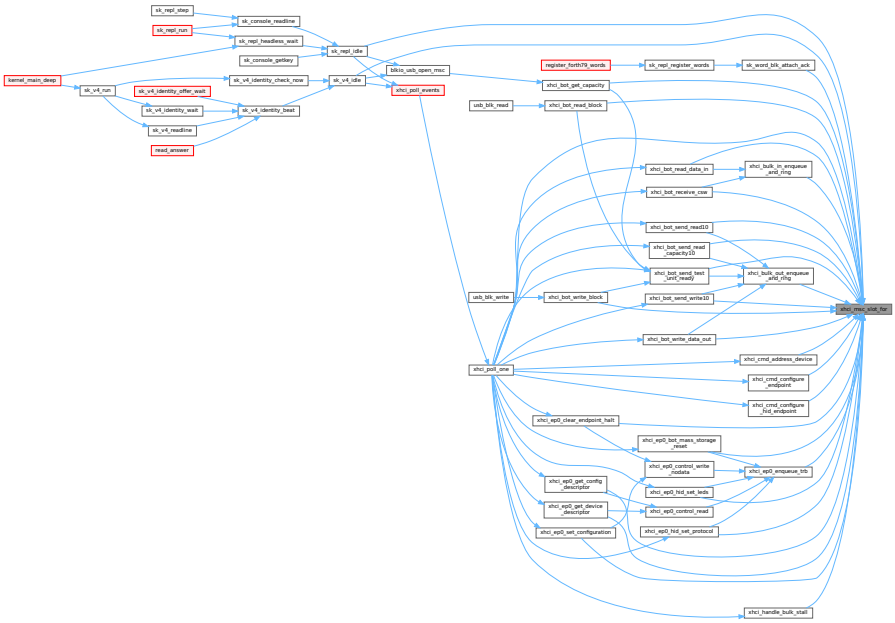
7.172.2.45 xhci_msc_slot_for()

```
xhci_msc_slot_t * xhci_msc_slot_for (
            xhci_dev_t * dev,
            uint32_t slot_id )
```

References xhci_dev_t::max_slots, and xhci_dev_t::msc_slots.

Referenced by sk_repl_idle(), sk_v4_idle(), sk_word_blk_attach_ack(), xhci_bot_get_capacity(), xhci_bot_read_block(), xhci_bot_read_data_in(), xhci_bot_receive_csw(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_block(), xhci_bot_write_data_out(), xhci_bulk_in_enqueue_and_ring(), xhci_bulk_out_enqueue_and_ring(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), xhci_cmd_configure_hid_endpoint(), xhci_ep0_bot_mass_storage_reset(), xhci_ep0_clear_endpoint_halt(), xhci_ep0_enqueue_trb(), xhci_ep0_get_config_descriptor(), xhci_ep0_get_device_descriptor(), xhci_ep0_hid_set_leds(), xhci_ep0_hid_set_protocol(), xhci_ep0_set_configuration(), xhci_handle_bulk_stall(), and xhci_poll_one().

Here is the caller graph for this function:



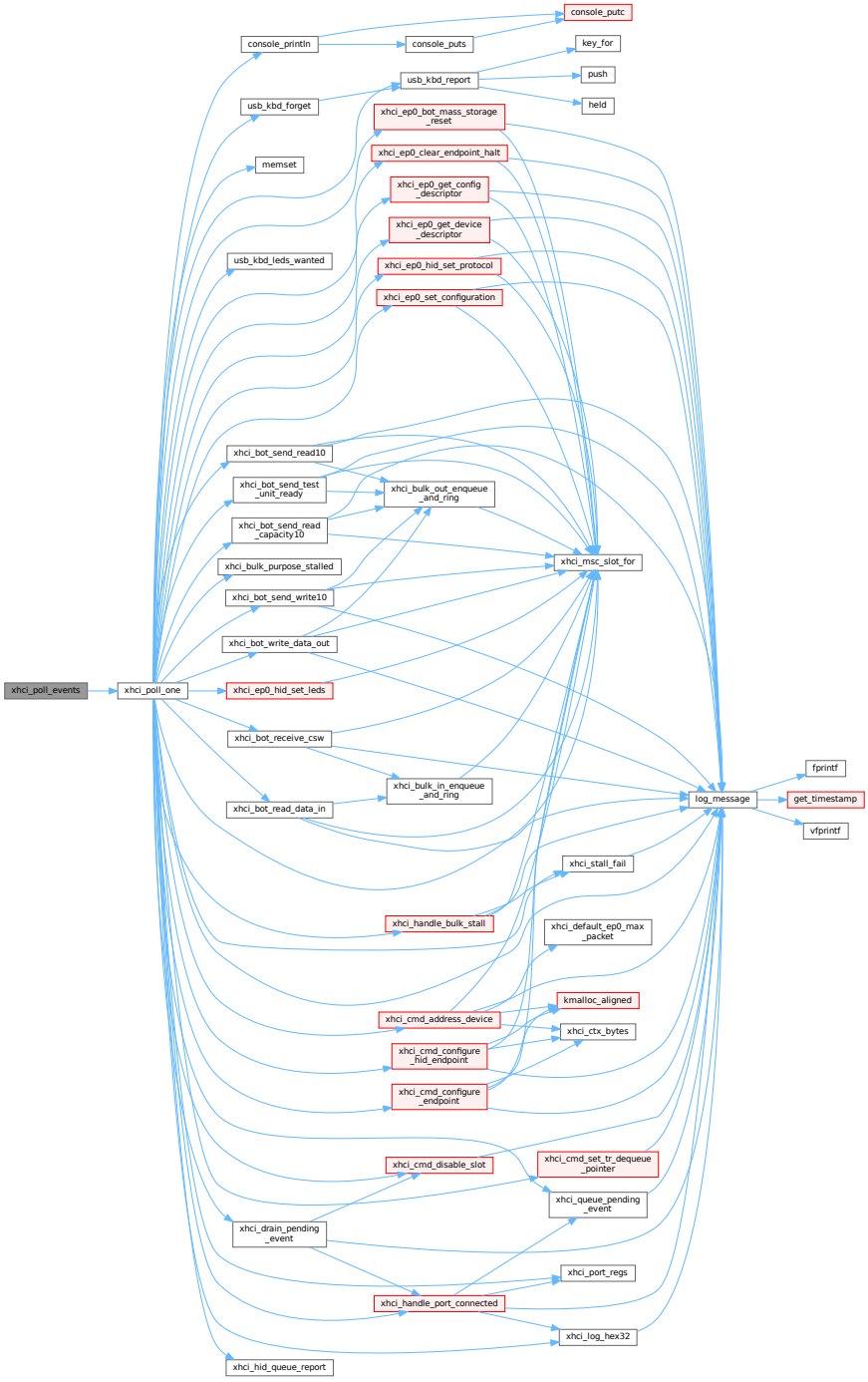
7.172.2.46 xhci_poll_events()

```
void xhci_poll_events (
            void  )
```

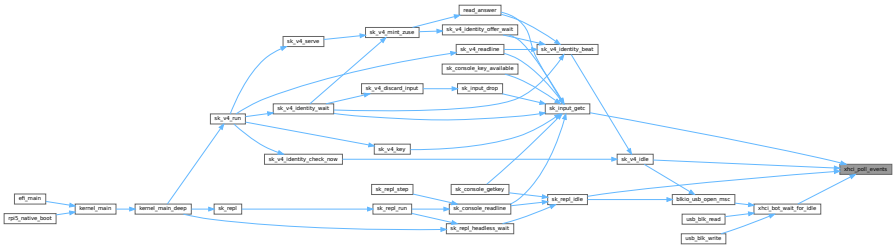
References g_xhci_dev_count, g_xhci_devs, and xhci_poll_one().

Referenced by sk_input_getc(), sk_repl_idle(), sk_v4_idle(), and xhci_bot_wait_for_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.172.2.47 xhci_poll_one()

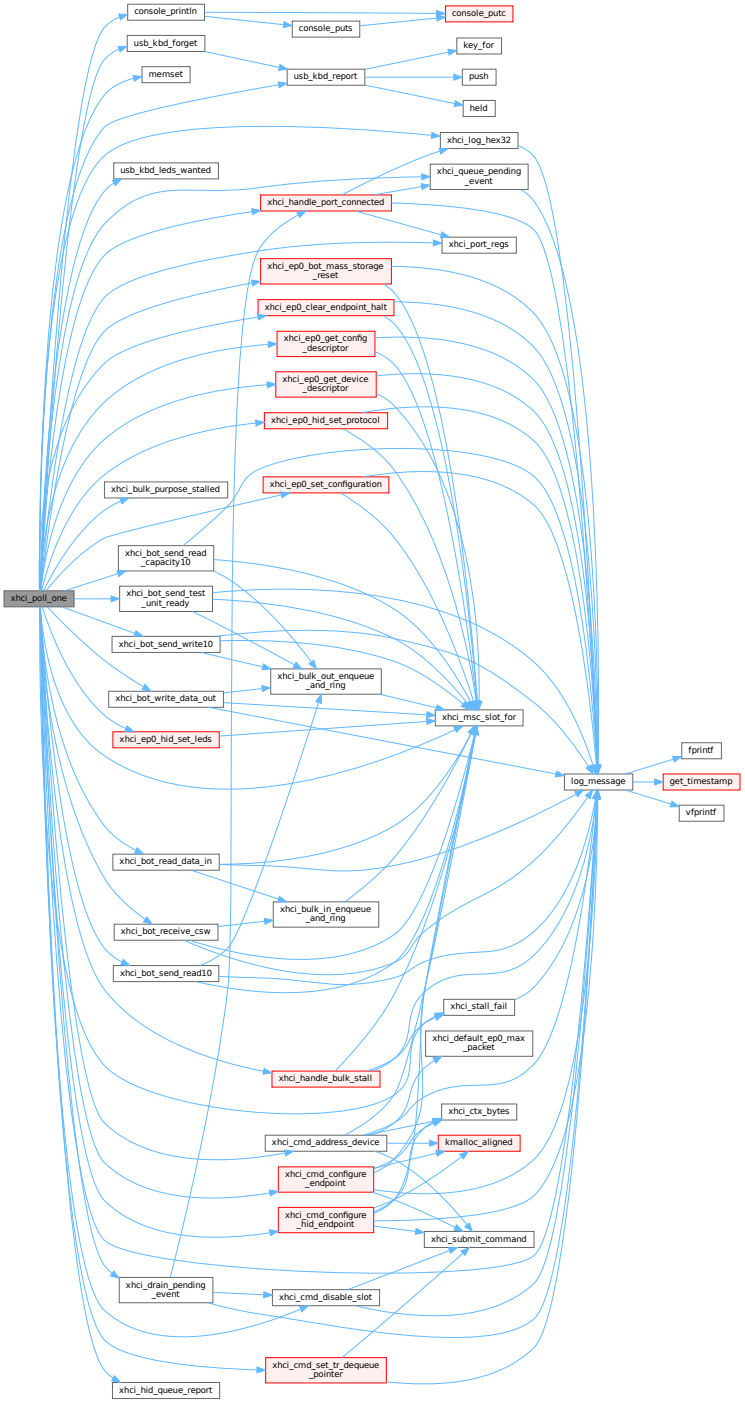
```
static void xhci_poll_one (
            xhci_dev_t * dev )  [static]
```

References usb_bot_csw_t::bCSWStatus, xhci_dev_t::bot_cap_block_size, xhci_dev_t::bot_cap_last_lba, xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_csw, xhci_dev_t::bot_data_buf, xhci_dev_t::bot_expected_data_len, xhci_dev_t::bot_last_status, xhci_dev_t::bot_last_tag, xhci_msc_slot_t::bot_msc_attach_pending, xhci_msc_slot_t::bot_msc_attache xhci_msc_slot_t::bot_msc_detach_pending, xhci_dev_t::bot_read10_block_size, xhci_dev_t::bot_read10_lba, xhci_dev_t::bot_read10_num_blocks, xhci_dev_t::bot_reset_clear_remaining, xhci_dev_t::bot_tur_chain_target, xhci_dev_t::bot_tur_retries, xhci_dev_t::bot_write10_block_size, xhci_dev_t::bot_write10_lba, xhci_dev_t::bot_write10_num_blocks, xhci_msc_slot_t::bulk_in_ep_addr, xhci_msc_slot_t::bulk_in_max_packet, xhci_msc_slot_t::bulk_in_ring, xhci_msc_slot_t::bulk_in_ri xhci_msc_slot_t::bulk_in_ring_enq, xhci_msc_slot_t::bulk_out_ep_addr, xhci_msc_slot_t::bulk_out_max_packet, xhci_msc_slot_t::bulk_out_ring, xhci_msc_slot_t::bulk_out_ring_cycle, xhci_msc_slot_t::bulk_out_ring_enq, xhci_msc_slot_t::config_descriptor, xhci_msc_slot_t::config_total_length, xhci_dev_t::connect_state, console_println(), xhci_trb_t::control, xhci_dev_t::dcbaa, usb_bot_csw_t::dCSWDataResidue, usb_bot_csw_t::dCSWSignature, usb_bot_csw_t::dCSWTag, xhci_msc_slot_t::device_descriptor, xhci_intr_regs_t::erdp, xhci_dev_t::evt_ring, xhci_dev_t::evt_ring_cycle, xhci_dev_t::evt_ring_deq, g_xhci_keyboards, xhci_msc_slot_t::hid_buf, xhci_msc_slot_t::hid_ep_addr, xhci_msc_slot_t::hid_iface, xhci_msc_slot_t::hid_interval, xhci_msc_slot_t::hid_kbd, xhci_msc_slot_t::hid_leds_sent, xhci_msc_slot_t::hid_max_packet, xhci_msc_slot_t::hid_prev, xhci_msc_slot_t::hid_running, xhci_msc_slot_t::in_use, xhci_dev_t::intr0, LOG_DEBUG, LOG_ERROR, LOG_INFO, log_message(), LOG_WARN, xhci_dev_t::max_slots, memset(), xhci_msc_slot_t::next_action, xhci_msc_slot_t::next_action_config_value, xhci_msc_slot_t::next_action_length, xhci_trb_t::parameter, xhci_dev_t::pending_connect_port_id, xhci_dev_t::pending_connect_slot_id, xhci_dev_t::pending_connect_sp xhci_dev_t::pending_disable_slot_id, xhci_dev_t::port_slot_id, xhci_port_regs_t::portsc, xhci_dev_t::stall_ep_addr, xhci_dev_t::stall_retry_action, xhci_trb_t::status, xhci_msc_slot_t::transfer_purpose, USB_BOT_CSW_SIGNATURE, USB_BOT_CSW_STATUS_FAILED, USB_BOT_CSW_STATUS_PASS, USB_CLASS_HID, USB_CLASS_MASS_STORAGE, USB_CONFIG_OFF_CONFIG_VALUE, USB_CONFIG_OFF_TOTAL_LENGTH, USB_DESC_OFF_LENGTH, USB_DESC_OFF_TYPE, USB_DESC_TYPE_ENDPOINT, USB_DESC_TYPE_INTERFACE, USB_EP_ADDR_DIR_MASK, USB_EP_ATTR_TYPE_MASK, USB_EP_OFF_ADDRESS, USB_EP_OFF_ATTRIBUTES, USB_EP_OFF_INTERVAL, USB_EP_OFF_MAX_PACKET_SIZE, USB_EP_TYPE_BULK, USB_EP_TYPE_INTERRUPT, USB_IFACE_OFF_CLASS, USB_IFACE_OFF_NUMBER, USB_IFACE_OFF_PROTOCOL, USB_IFACE_OFF_SUBCLASS, usb_kbd_forget(), usb_kbd_leds_wanted(), usb_kbd_report(), USB_PROTOCOL_BOT, USB_PROTOCOL_HID_KEYBOARD, USB_SUBCLASS_HID_BOOT, USB_SUBCLASS_SCSI, xhci_bot_read_data_in(), xhci_bot_receive_csw(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), XHCI_BOT_TUR_MAX_RETRIES, xhci_bot_write_data_out(), xhci_bulk_purpose_stalled(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), xhci_cmd_configure_hid_endpoint(), xhci_cmd_disable_slot(), xhci_cmd_set_tr_dequeue_pointer(), XHCI_COMPLETION_CODE_SHORT_PACKET, XHCI_COMPLETION_CODE_STALL_ERROR, XHCI_COMPLETION_CODE_SUC xhci_drain_pending_event(), xhci_ep0_bot_mass_storage_reset(), xhci_ep0_clear_endpoint_halt(), xhci_ep0_get_config_descriptor(xhci_ep0_get_device_descriptor(), xhci_ep0_hid_set_leds(), xhci_ep0_hid_set_protocol(), xhci_ep0_set_configuration(), XHCI_EP_ADDR_TO_DCI, XHCI_ERDP_EHB, XHCI_ERDP_PTR_MASK, XHCI_EVT_COMPLETION_CODE, XHCI_EVT_EP_ID, XHCI_EVT_RING_MAX_DRAIN, XHCI_EVT_SLOT_ID, xhci_handle_bulk_stall(), xhci_handle_port_connected() xhci_hid_queue_report(), xhci_log_hex32(), XHCI_MAX_TRACKED_PORTS, xhci_msc_slot_for(), XHCI_NEXT_ACTION_BOT_CSW XHCI_NEXT_ACTION_BOT_DATA_IN, XHCI_NEXT_ACTION_BOT_DATA_OUT, XHCI_NEXT_ACTION_BOT_RESET,

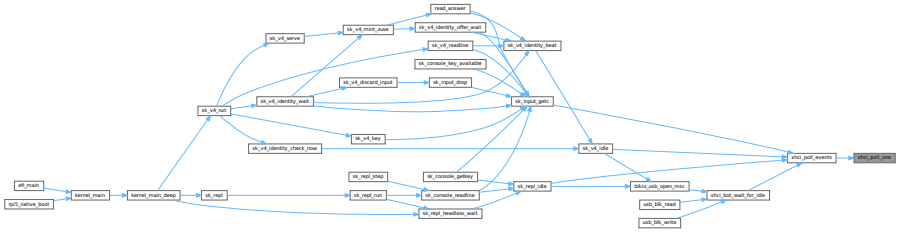
XHCI_NEXT_ACTION_BOT_SEND_READ10, XHCI_NEXT_ACTION_BOT_SEND_READ_CAPACITY10, XHCI_NEXT_ACTION_BO
XHCI_NEXT_ACTION_BOT_SEND_WRITE10, XHCI_NEXT_ACTION_CLEAR_HALT, XHCI_NEXT_ACTION_CONFIGURE_ENDPO
XHCI_NEXT_ACTION_GET_CONFIG_DESC, XHCI_NEXT_ACTION_GET_DEVICE_DESC, XHCI_NEXT_ACTION_HID_POLL,
XHCI_NEXT_ACTION_HID_SET_PROTOCOL, XHCI_NEXT_ACTION_NONE, XHCI_NEXT_ACTION_SET_CONFIG,
xhci_port_regs(), XHCI_PORTSC_CCS, XHCI_PORTSC_CSC, XHCI_PORTSC_PP, XHCI_PORTSC_PRC,
XHCI_PSC_EVT_PORT_ID, xhci_queue_pending_event(), XHCI_RING_TRB_COUNT, xhci_stall_fail(), XHCI_TRB_CONTROL_CYC
XHCI_TRB_TYPE, XHCI_TRB_TYPE_COMMAND_COMPLETION_EVT, XHCI_TRB_TYPE_PORT_STATUS_CHANGE_EVT,
XHCI_TRB_TYPE_TRANSFER_EVENT, XHCI_XFER_BOT_DATA_IN, XHCI_XFER_BOT_DATA_OUT, XHCI_XFER_BOT_RESET,
XHCI_XFER_CBW_SENT, XHCI_XFER_CLEAR_HALT, XHCI_XFER_CONFIG_DESC_FULL, XHCI_XFER_CONFIG_DESC_SHOR
XHCI_XFER_CSW_RECEIVED, XHCI_XFER_DEVICE_DESC, XHCI_XFER_HID_SET_LEDS, XHCI_XFER_HID_SET_PROTOCOL
XHCI_XFER_NONE, and XHCI_XFER_SET_CONFIG.

Referenced by xhci_poll_events().

Here is the call graph for this function:



Here is the caller graph for this function:



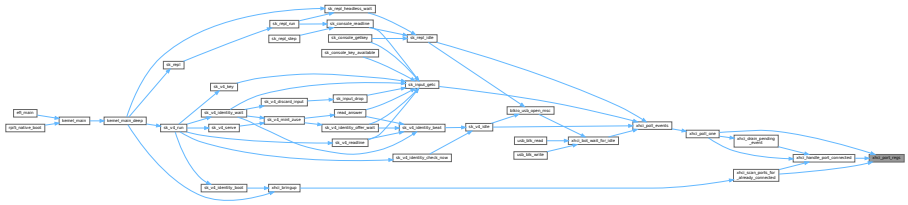
7.172.2.48 xhci_port_regs()

```
static xhci_port_regs_t * xhci_port_regs (
            xhci_dev_t * dev,
            uint32_t port_id )  [static]
```

References xhci_dev_t::max_ports, xhci_dev_t::op, and XHCI_PORT_REGS_OFFSET.

Referenced by xhci_handle_port_connected(), xhci_poll_one(), and xhci_scan_ports_for_already_connected().

Here is the caller graph for this function:



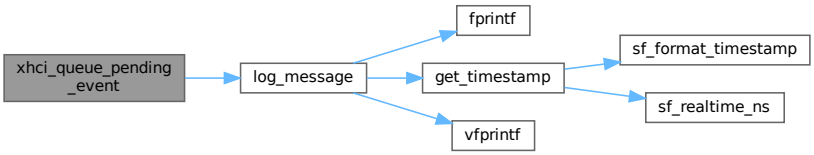
7.172.2.49 xhci_queue_pending_event()

```
static void xhci_queue_pending_event (
            xhci_dev_t * dev,
            uint32_t port_id,
            int is_connect,
            uint32_t portsc,
            uint32_t slot_id )  [static]
```

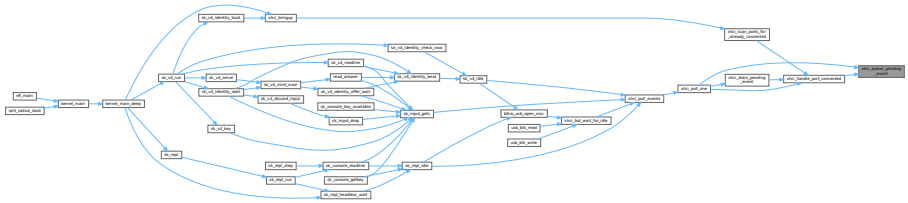
References xhci_dev_t::is_connect, LOG_DEBUG, log_message(), xhci_dev_t::pending_events, xhci_dev_t::port_id, xhci_dev_t::portsc, xhci_dev_t::slot_id, xhci_dev_t::valid, and XHCI_MAX_TRACKED_PORTS.

Referenced by xhci_handle_port_connected(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



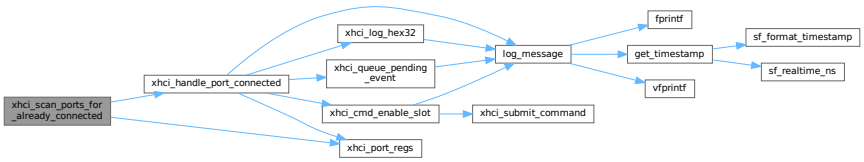
7.172.2.50 xhci_scan_ports_for_already_connected()

```
static void xhci_scan_ports_for_already_connected (
            xhci_dev_t * dev )  [static]
```

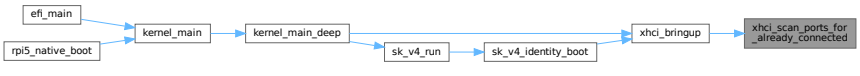
References xhci_dev_t::max_ports, xhci_port_regs_t::portsc, xhci_handle_port_connected(), XHCI_MAX_TRACKED_PORTS, xhci_port_regs(), XHCI_PORTSC_CCS, XHCI_PORTSC_CSC, XHCI_PORTSC_PP, and XHCI_PORTSC_PRC.

Referenced by xhci_bringup().

Here is the call graph for this function:



Here is the caller graph for this function:



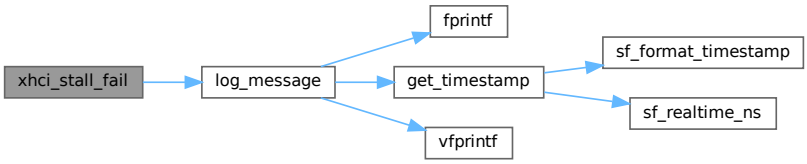
7.172.2.51 xhci_stall_fail()

```
static void xhci_stall_fail (
            xhci_dev_t * dev ) [static]
```

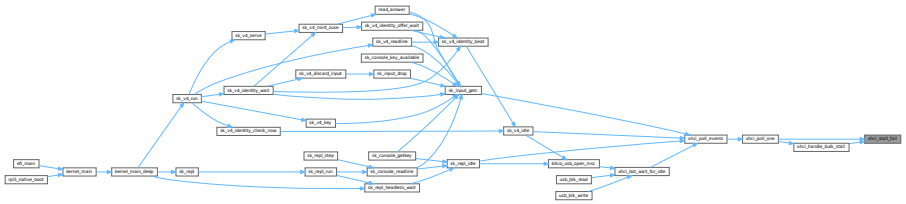
References xhci_dev_t::bot_cmd_kind, xhci_dev_t::bot_last_status, xhci_dev_t::bot_reset_clear_remaining, LOG_ERROR, log_message(), xhci_dev_t::stall_retry_action, and XHCI_NEXT_ACTION_NONE.

Referenced by xhci_handle_bulk_stall(), and xhci_poll_one().

Here is the call graph for this function:



Here is the caller graph for this function:



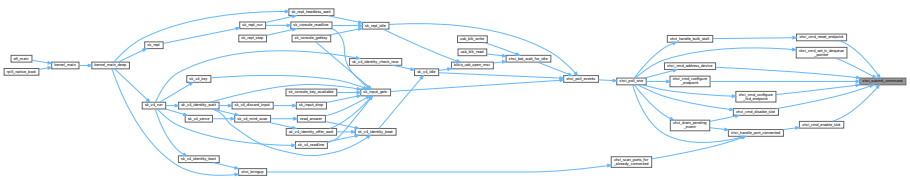
7.172.2.52 xhci_submit_command()

```
static void xhci_submit_command (
            xhci_dev_t * dev,
            uint64_t parameter,
            uint32_t status,
            uint32_t trb_type,
            uint32_t extra_control_bits ) [static]
```

References xhci_dev_t::cmd_ring, xhci_dev_t::cmd_ring_cycle, xhci_dev_t::cmd_ring_enq, xhci_trb_t::control, xhci_dev_t::doorbell, xhci_trb_t::parameter, xhci_trb_t::status, XHCI_DB_TARGET, XHCI_RING_TRB_COUNT, XHCI_TRB_CONTROL_CYCLE, XHCI_TRB_CONTROL_TC, XHCI_TRB_CONTROL_TYPE_SHIFT, and XHCI_TRB_TYPE_LINK.

Referenced by xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), xhci_cmd_configure_hid_endpoint(), xhci_cmd_disable_slot(), xhci_cmd_enable_slot(), xhci_cmd_reset_endpoint(), and xhci_cmd_set_tr_dequeue_pointer().

Here is the caller graph for this function:



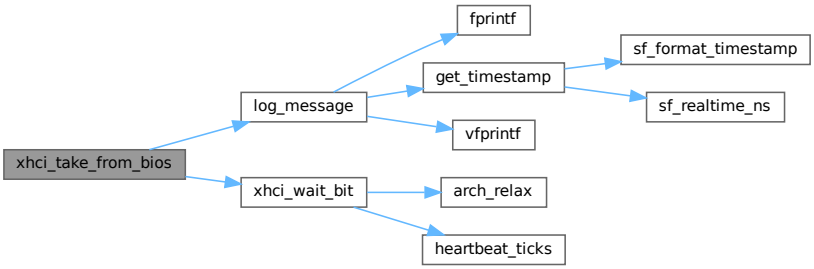
7.172.2.53 xhci_take_from_bios()

```
static void xhci_take_from_bios (
            xhci_dev_t * dev )  [static]
```

References xhci_dev_t::cap, xhci_cap_regs_t::hcc_params1, LOG_DEBUG, log_message(), LOG_WARN, XHCI_LEGSUP_BIOS_OWNED, XHCI_LEGSUP_OS_OWNED, xhci_wait_bit(), and XHCI_XCAP_LEGACY.

Referenced by xhci_find_and_map().

Here is the call graph for this function:



Here is the caller graph for this function:

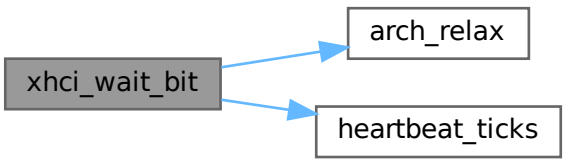
7.172.2.54 xhci_wait_bit()

```
static int xhci_wait_bit (
            volatile uint32_t * reg,
            uint32_t mask,
            int want_set,
            uint64_t max_ticks )  [static]
```

References arch_relax(), and heartbeat_ticks().

Referenced by xhci_bringup(), and xhci_take_from_bios().

Here is the call graph for this function:



Here is the caller graph for this function:

7.172.3 Variable Documentation

7.172.3.1 g_xhci_dev_count

```
uint32_t g_xhci_dev_count  [static]
```

Referenced by xhci_bringup(), xhci_dev_at(), xhci_dev_count(), and xhci_poll_events().

7.172.3.2 g_xhci_devs

```
xhci_dev_t* g_xhci_devs[8u]  [static]
```

Referenced by xhci_bringup(), xhci_dev_at(), and xhci_poll_events().

7.172.3.3 g_xhci_keyboards

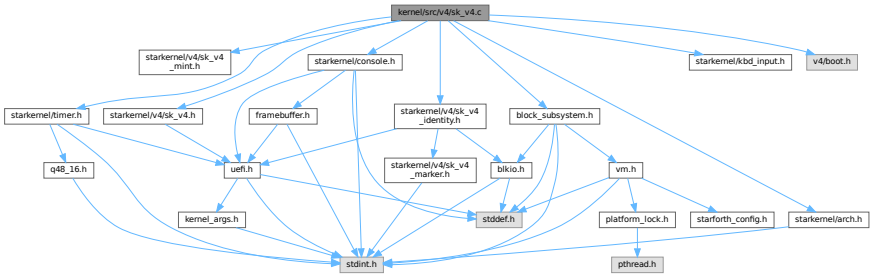
```
uint32_t g_xhci_keyboards  [static]
```

Referenced by xhci_keyboard_running(), and xhci_poll_one().

7.173 kernel/src/v4/sk_v4.c File Reference

```
#include "starkernel/v4/sk_v4_mint.h"
#include "starkernel/v4/sk_v4.h"
#include "starkernel/v4/sk_v4_identity.h"
#include "starkernel/kbd_input.h"
#include "starkernel/console.h"
#include "starkernel/arch.h"
#include "starkernel/timer.h"
#include "v4/boot.h"
#include "block_subsystem.h"
```

Include dependency graph for sk_v4.c:



Macros

- #define SK_V4_LINE 1024u /∗ what the line editor here takes: a line, as the boot takes one (v4/system/boot.c) ∗/
- #define SK_V4_PROMPT "\x1b[38;2;85;255;255mok> \x1b[39m"
- #define SK_V4_CURSOR_BLINK 50u /∗ ticks between blinks, as v3's (500 ms at 100 Hz) ∗/

Functions

- static void sk_v4_out (const char ∗text, unsigned len)
- static int sk_v4_key (void)
- static void sk_v4_serve (v4_node ∗node, unsigned request)
- static int sk_v4_readline (void)
- void sk_v4_run (void(∗chain)(void), const BootDisk ∗boot_disk)

Variables

- static v4_node sk_v4_node
- static v4_exec_state sk_v4_es
- static v4_heat sk_v4_heat
- static v4_image sk_v4_image
- static char sk_v4_text [1024u+1u]
- static uint8_t sk_v4_post_blk_ram [2080u ∗1024u]
- static const char ∗const sk_v4_words [ ] = { "BYE", "MINT-ZUSE" }

7.173.1 Macro Definition Documentation

7.173.1.1 SK_V4_CURSOR_BLINK

```
#define SK_V4_CURSOR_BLINK 50u /* ticks between blinks, as v3's (500 ms at 100 Hz) */
```

7.173.1.2 SK_V4_LINE

```
#define SK_V4_LINE 1024u /* what the line editor here takes:  a line, as the boot takes one
(v4/system/boot.c) */
```

7.173.1.3 SK_V4_PROMPT

```
#define SK_V4_PROMPT "\x1b[38;2;85;255;255mok> \x1b[39m"
```

7.173.2 Function Documentation

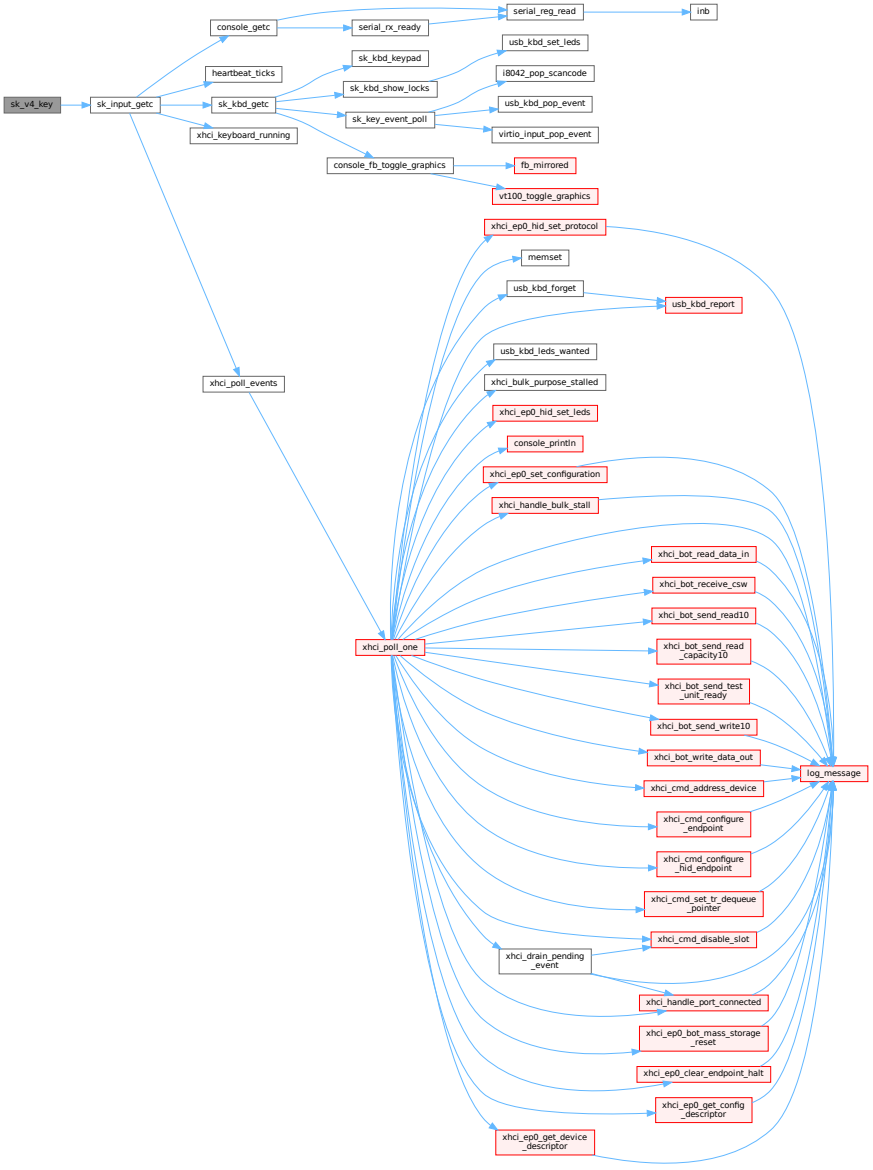
7.173.2.1 sk_v4_key()

```
static int sk_v4_key (
            void  )  [static]
```

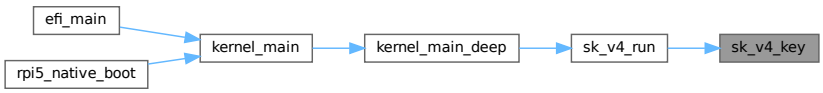
References sk_input_getc().

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



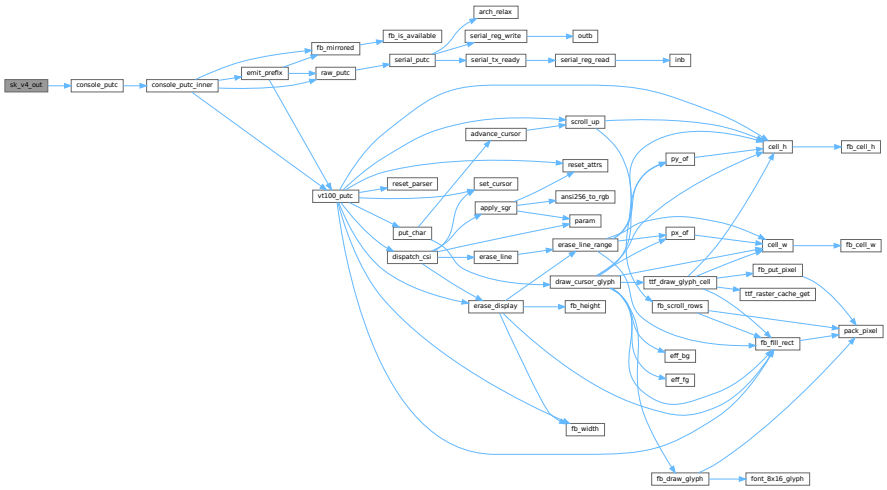
7.173.2.2 sk_v4_out()

```
static void sk_v4_out (
            const char * text,
            unsigned len )  [static]
```

References console_putc().

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:

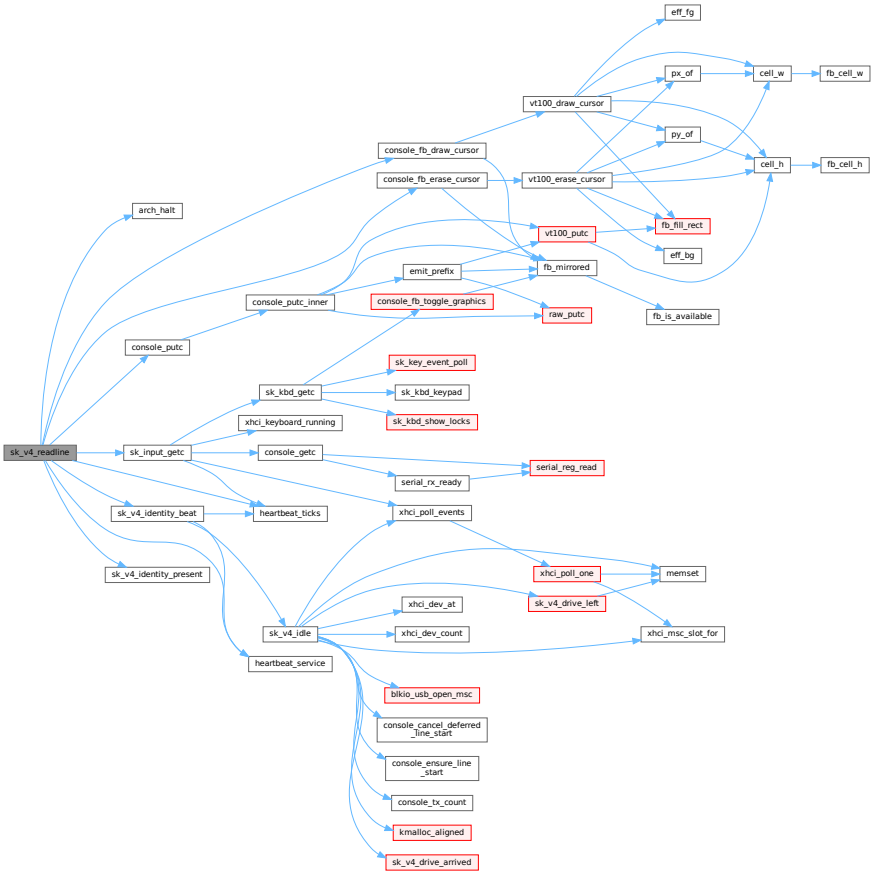
7.173.2.3 sk_v4_readline()

```
static int sk_v4_readline (
            void  )  [static]
```

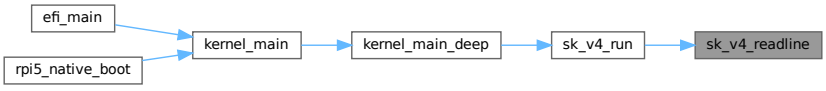
References arch_halt(), console_fb_draw_cursor(), console_fb_erase_cursor(), console_putc(), heartbeat_service(), heartbeat_ticks(), sk_input_getc(), SK_V4_CURSOR_BLINK, sk_v4_identity_beat(), sk_v4_identity_present(), SK_V4_LINE, and sk_v4_text.

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



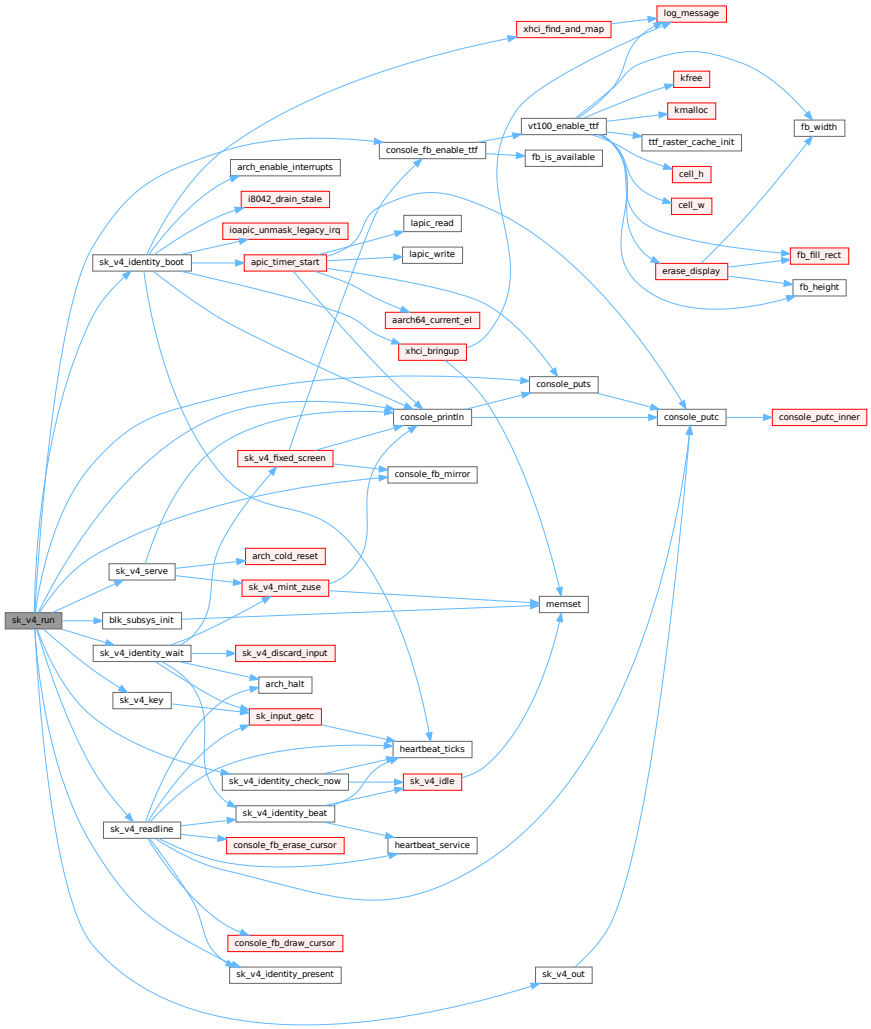
7.173.2.4 sk_v4_run()

```
void sk_v4_run (
            void(*)(void) chain,
            const BootDisk * boot_disk )
```

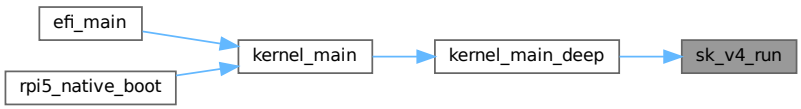
References blk_subsys_init(), console_fb_enable_ttf(), console_fb_mirror(), console_println(), console_puts(), sk_v4_es, sk_v4_heat, sk_v4_identity_boot(), sk_v4_identity_check_now(), sk_v4_identity_present(), sk_v4_identity_wait(), sk_v4_image, sk_v4_key(), sk_v4_node, sk_v4_out(), sk_v4_post_blk_ram, SK_V4_PROMPT, sk_v4_readline(), sk_v4_serve(), sk_v4_text, and sk_v4_words.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



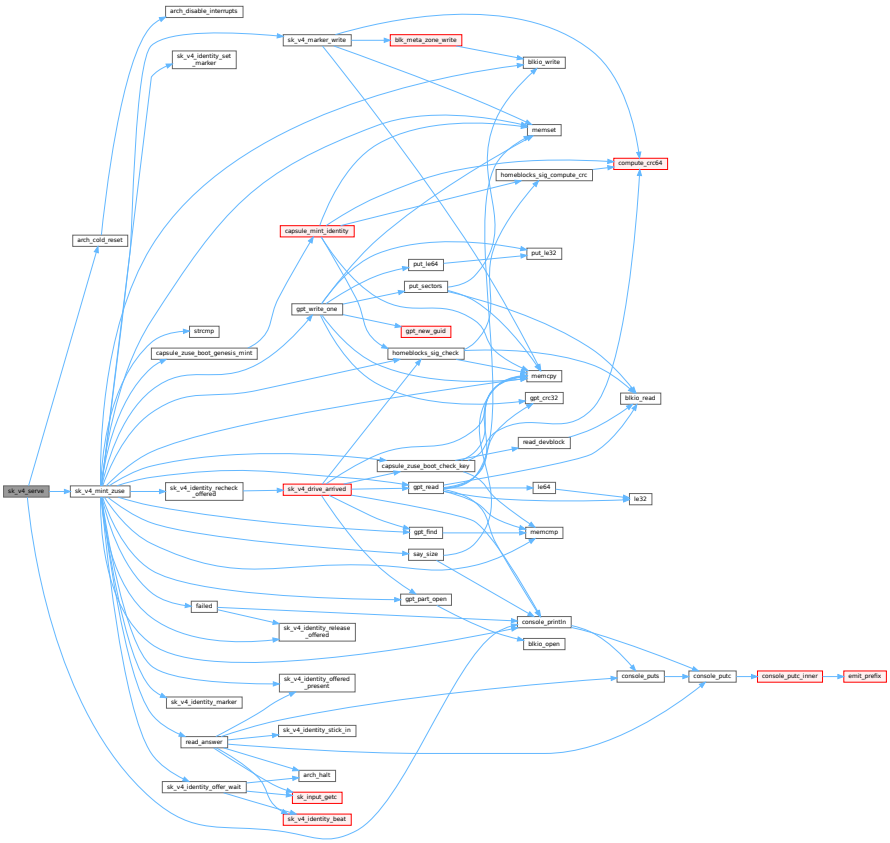
7.173.2.5 sk_v4_serve()

```
static void sk_v4_serve (
            v4_node * node,
            unsigned request )  [static]
```

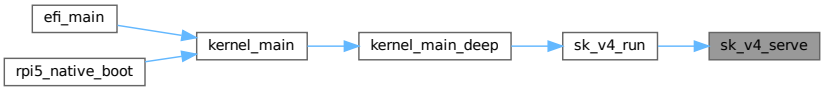
References arch_cold_reset(), console_println(), and sk_v4_mint_zuse().

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.173.3 Variable Documentation

7.173.3.1 sk_v4_es

```
v4_exec_state sk_v4_es  [static]
```

Referenced by sk_v4_run().

7.173.3.2 sk_v4_heat

```
v4_heat sk_v4_heat  [static]
```

Referenced by sk_v4_run().

7.173.3.3 sk_v4_image

```
v4_image sk_v4_image  [static]
```

Referenced by sk_v4_run().

7.173.3.4 sk_v4_node

```
v4_node sk_v4_node  [static]
```

Referenced by sk_v4_run().

7.173.3.5 sk_v4_post_blk_ram

```
uint8_t sk_v4_post_blk_ram[2080u * 1024u]  [static]
```

Referenced by sk_v4_run().

7.173.3.6 sk_v4_text

```
char sk_v4_text[1024u+1u]  [static]
```

Referenced by sk_v4_readline(), and sk_v4_run().

7.173.3.7 sk_v4_words

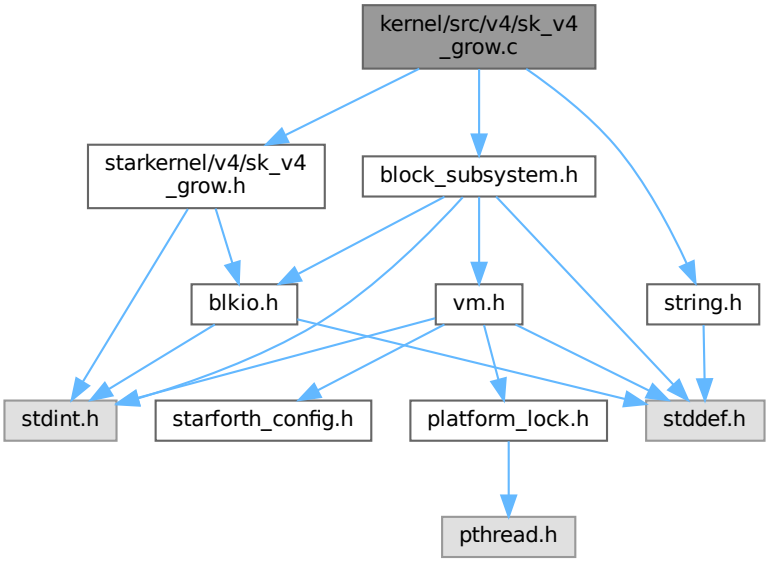
```
const char* const sk_v4_words[] = { "BYE", "MINT-ZUSE" }  [static]
```

Referenced by sk_v4_run().

7.174 kernel/src/v4/sk_v4_grow.c File Reference

```
#include "starkernel/v4/sk_v4_grow.h"
#include "block_subsystem.h"
#include <string.h>
```

Include dependency graph for sk_v4_grow.c:



Functions

- static int dev_rw4k (blkio_dev_t *dev, uint64_t devblock, uint8_t *buf, int write)
- static int read_header (blkio_dev_t *art)
- static uint64_t bam_cover_devblocks (const blk_volume_meta_t *m)
- uint64_t sk_v4_grow_cap_sectors (blkio_dev_t *art, uint64_t cap_sectors)
- int sk_v4_grow_artemis (blkio_dev_t *art)

Variables

- union {
    uint8_t bytes [4096]
    blk_volume_meta_t meta
  } g_hdr

- static uint8_t g_move [4096]

7.174.1 Function Documentation

7.174.1.1 bam_cover_devblocks()

```
static uint64_t bam_cover_devblocks (
            const blk_volume_meta_t * m )  [static]
```

References blk_volume_meta_t::bam_devblocks, blk_volume_meta_t::meta_fence_blocks, and blk_volume_meta_t::reloc_devblocks.

Referenced by sk_v4_grow_artemis(), and sk_v4_grow_cap_sectors().

Here is the caller graph for this function:

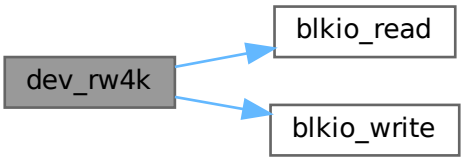
7.174.1.2 dev_rw4k()

```
static int dev_rw4k (
            blkio_dev_t * dev,
            uint64_t devblock,
            uint8_t * buf,
            int write )  [static]
```

References base, BLKIO_OK, blkio_read(), and blkio_write().

Referenced by read_header(), and sk_v4_grow_artemis().

Here is the call graph for this function:



Here is the caller graph for this function:

7.174.1.3 read_header()

```
static int read_header (
            blkio_dev_t * art )  [static]
```

References dev_rw4k(), and g_hdr.

Referenced by sk_v4_grow_artemis(), and sk_v4_grow_cap_sectors().

Here is the call graph for this function:

Here is the caller graph for this function:

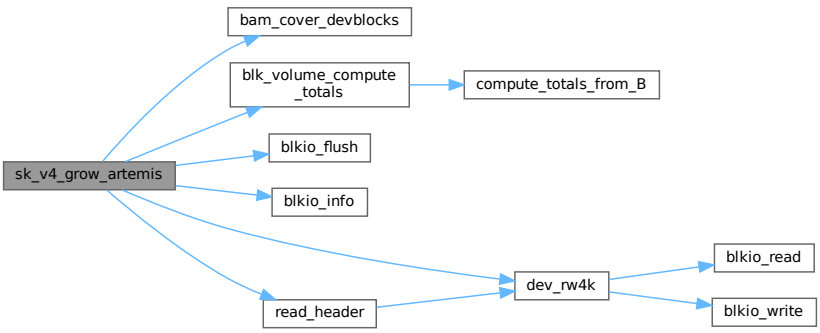
7.174.1.4 sk_v4_grow_artemis()

```
int sk_v4_grow_artemis (
            blkio_dev_t * art )
```

References bam_cover_devblocks(), blk_volume_compute_totals(), blkio_flush(), blkio_info(), BLKIO_OK, dev_rw4k(), g_hdr, g_move, read_header(), and blkio_info_t::total_blocks.

Referenced by sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

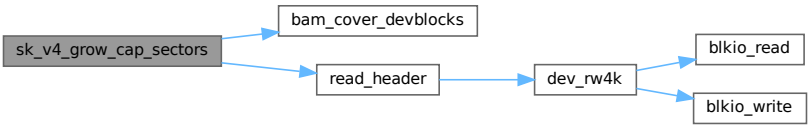
7.174.1.5 sk_v4_grow_cap_sectors()

```
uint64_t sk_v4_grow_cap_sectors (
            blkio_dev_t * art,
            uint64_t cap_sectors )
```

References bam_cover_devblocks(), g_hdr, and read_header().

Referenced by sk_v4_grow_stick().

Here is the call graph for this function:



Here is the caller graph for this function:

7.174.2 Variable Documentation

7.174.2.1 bytes

```
uint8_t bytes[4096]
```

Referenced by analytics_heap_allocate(), array_ptr(), hosted_xt_entry_owned(), pmm_bytes_to_pages(), profiler_memory_alloc(), profiler_memory_read(), profiler_memory_write(), say_size(), sk_repl_idle(), sk_v4_identity_offer_wait(), sk_v4_idle(), sk_v4_mint_zuse(), usb_blk_state_for(), vm_align(), and vm_allot().

7.174.2.2 [union]

```
union { ... } g_hdr [static]
```

Referenced by read_header(), sk_v4_grow_artemis(), and sk_v4_grow_cap_sectors().

7.174.2.3 g_move

```
uint8_t g_move[4096] [static]
```

Referenced by sk_v4_grow_artemis().

7.174.2.4 meta

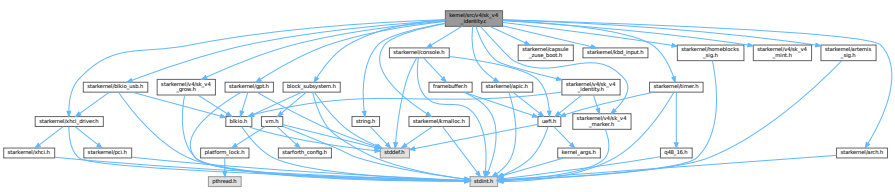
```
blk_volume_meta_t meta
```

Referenced by blk_acl_allow_get(), blk_acl_allow_set(), blk_acl_ttl_get(), blk_acl_ttl_set(), blk_firsttouch_claim(), blk_flags_get(), blk_flags_set(), blk_get_meta(), blk_get_volume_meta(), blk_migration_idle_check_slot(), blk_owner_fp_get(), blk_owner_fp_set(), blk_owner_has_claim(), blk_set_meta(), blk_set_volume_meta(), and devblock_claimed_by_lbn().

7.175 kernel/src/v4/sk_v4_identity.c File Reference

```
#include "starkernel/v4/sk_v4_identity.h"
#include "starkernel/console.h"
#include "starkernel/arch.h"
#include "starkernel/apic.h"
#include "starkernel/timer.h"
#include "starkernel/kmalloc.h"
#include "starkernel/xhci_driver.h"
#include "starkernel/blkio_usb.h"
#include "starkernel/homeblocks_sig.h"
#include "starkernel/artemis_sig.h"
#include "starkernel/capsule_zuse_boot.h"
#include "starkernel/kbd_input.h"
#include "starkernel/gpt.h"
#include "starkernel/v4/sk_v4_marker.h"
#include "starkernel/v4/sk_v4_grow.h"
#include "starkernel/v4/sk_v4_mint.h"
#include "block_subsystem.h"
#include <string.h>
```

Include dependency graph for sk_v4_identity.c:



Data Structures

- struct sk_v4_drive_t

Macros

- #define SK_V4_IDLE_BEAT 100u /∗ ticks between idle beats, v3's SK_IDLE_BEAT_INTERVAL (1 s at 100 Hz) ∗/
- #define SK_V4_GPT_PARTS 16u
- #define SK_V4_GROW_MIN_BYTES STICK_GROW_MIN_BYTES
- #define SK_V4_CAP_SECTORS (STICK_ARTEMIS_CAP_GIB ∗ 2097152ULL)

Functions

- static const char ∗ sk_v4_user_prefix (void)
- int sk_v4_identity_present (void)
- void sk_v4_identity_boot (const BootDisk ∗boot_disk)
- static int sk_v4_is_this_stick (unsigned nparts)
- static int sk_v4_grow_stick (sk_v4_drive_t ∗d, unsigned ∗nparts)
- static void sk_v4_login (blkio_dev_t ∗dev, const uint8_t seed[32], const uint8_t pubkey[32], const char ∗line)
- static int sk_v4_genesis (blkio_dev_t ∗dev, blkio_dev_t ∗art)
- static int sk_v4_real_zuse_arrived (sk_v4_drive_t ∗d, unsigned nparts)
- static int sk_v4_drive_arrived (sk_v4_drive_t ∗d)
- static void sk_v4_session_end (void)
- static void sk_v4_drive_left (sk_v4_drive_t ∗d)
- static void sk_v4_idle (void)
- void sk_v4_identity_beat (void)
- void sk_v4_identity_check_now (void)
- int sk_v4_identity_offer_wait (blkio_dev_t ∗∗raw, uint64_t ∗bytes)
- int sk_v4_identity_stick_in (void)
- int sk_v4_identity_offered_present (void)
- void sk_v4_identity_release_offered (void)
- const sk_v4_marker_t ∗ sk_v4_identity_marker (void)
- void sk_v4_identity_set_marker (const sk_v4_marker_t ∗m)
- void sk_v4_identity_recheck_offered (void)
- static void sk_v4_discard_input (void)
- static void sk_v4_fixed_screen (void)
- void sk_v4_identity_wait (void)

Variables

- static int g_zuse_session
- static int g_zuse_cert_installed
- static uint8_t g_zuse_seed [32]
- static uint8_t g_zuse_pubkey [32]
- static uint8_t g_zuse_root_pubkey [32]
- static int g_zuse_root_known
- static struct blkio_dev ∗ g_zuse_dev
- static sk_v4_marker_t g_marker
- static int g_proxy_fallback

- struct {
  sk_v4_drive_t * slots
  uint32_t count
  } g_usb [8u]

- static gpt_part_t g_gpt_parts [16u]
- static uint64_t g_last_beat
- static int g_mint_waiting
- static sk_v4_drive_t * g_offered
- static sk_v4_drive_t * g_spare
- static sk_v4_drive_t * g_pending_real
- static sk_v4_drive_t * g_real_drive
- static const BootDisk * g_boot_disk
- static int g_stick_in

7.175.1 Macro Definition Documentation

7.175.1.1 SK_V4_CAP_SECTORS

```
#define SK_V4_CAP_SECTORS (STICK_ARTEMIS_CAP_GIB * 2097152ULL)
```

7.175.1.2 SK_V4_GPT_PARTS

```
#define SK_V4_GPT_PARTS 16u
```

7.175.1.3 SK_V4_GROW_MIN_BYTES

```
#define SK_V4_GROW_MIN_BYTES STICK_GROW_MIN_BYTES
```

7.175.1.4 SK_V4_IDLE_BEAT

```
#define SK_V4_IDLE_BEAT 100u /* ticks between idle beats, v3's SK_IDLE_BEAT_INTERVAL (1 s at
100 Hz) */
```

7.175.2 Function Documentation

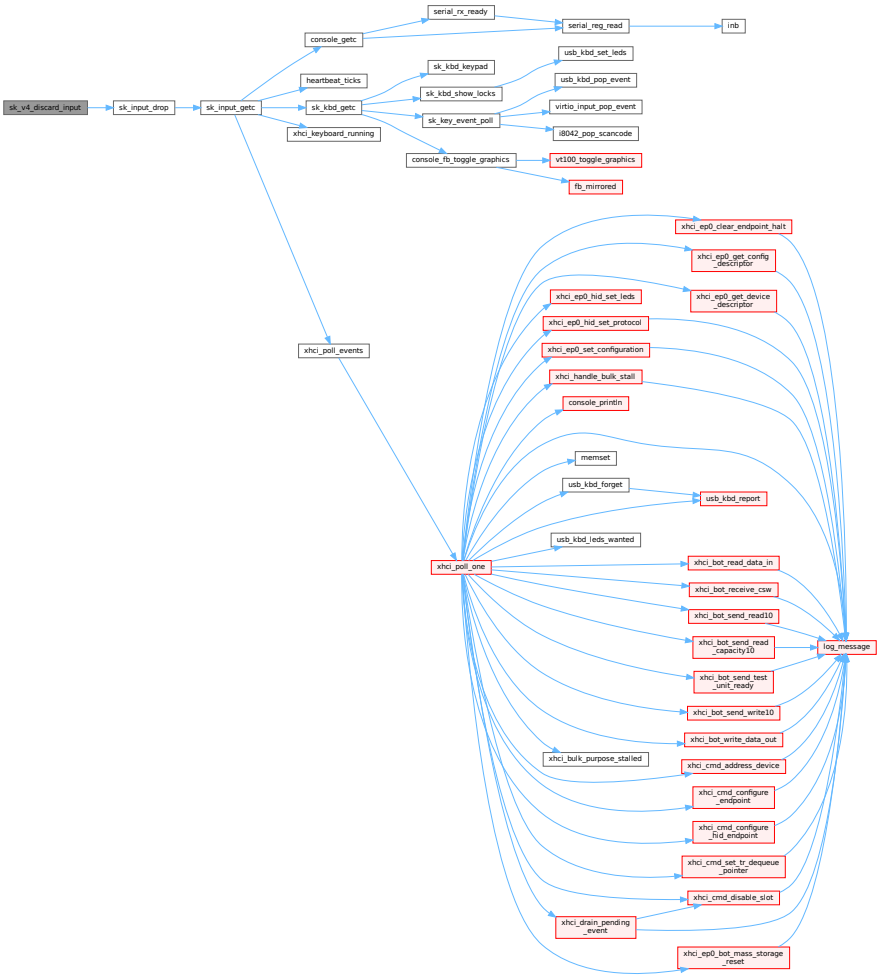
7.175.2.1 sk_v4_discard_input()

```
static void sk_v4_discard_input (
            void  )  [static]
```

References sk_input_drop().

Referenced by sk_v4_identity_wait().

Here is the call graph for this function:



Here is the caller graph for this function:

7.175.2.2 sk_v4_drive_arrived()

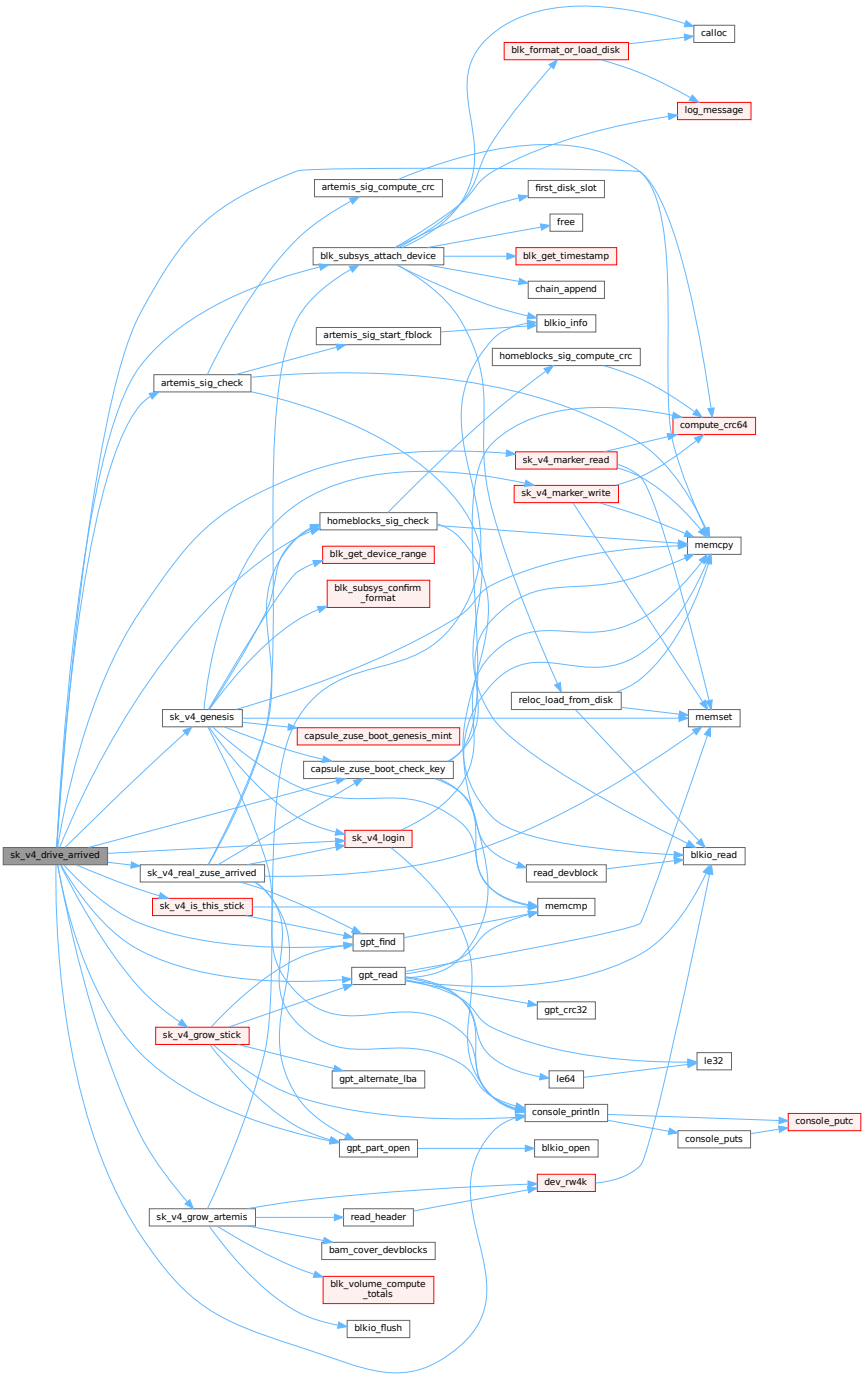
```
static int sk_v4_drive_arrived (
            sk_v4_drive_t * d )  [static]
```

References sk_v4_drive_t::art, sk_v4_drive_t::art_state, sk_v4_drive_t::art_used, artemis_sig_check(), ARTEMIS_SIG_OK, BLK_OK, blk_subsys_attach_device(), BLKIO_OK, capsule_zuse_boot_check_key(), console_println(), g, g_gpt_parts, g_marker, g_mint_waiting, g_offered, g_pending_real, g_proxy_fallback, g_spare, g_stick_in, g_zuse_root_known, g_zuse_root_pubkey, g_zuse_session, GPT_BAD, GPT_EIO, gpt_find(), GPT_OK, gpt_part_open(), gpt_read(), gpt_type_starship_artemis, gpt_type_starship_identity, sk_v4_marker_t::has_real,

HOMEBLOCKS_SIG_BLANK, homeblocks_sig_check(), HOMEBLOCKS_SIG_START_FBLOCK, memcpy(), sk_v4_drive_t::part, sk_v4_drive_t::part_state, sk_v4_marker_t::present, sk_v4_marker_t::proxy, sk_v4_drive_t::raw, sk_v4_genesis(), SK_V4_GPT_PARTS, sk_v4_grow_artemis(), sk_v4_grow_stick(), sk_v4_is_this_stick(), sk_v4_login(), sk_v4_marker_read(), sk_v4_real_zuse_arrived(), and sk_v4_drive_t::used.

Referenced by sk_v4_identity_recheck_offered(), and sk_v4_idle().

Here is the call graph for this function:



Here is the caller graph for this function:

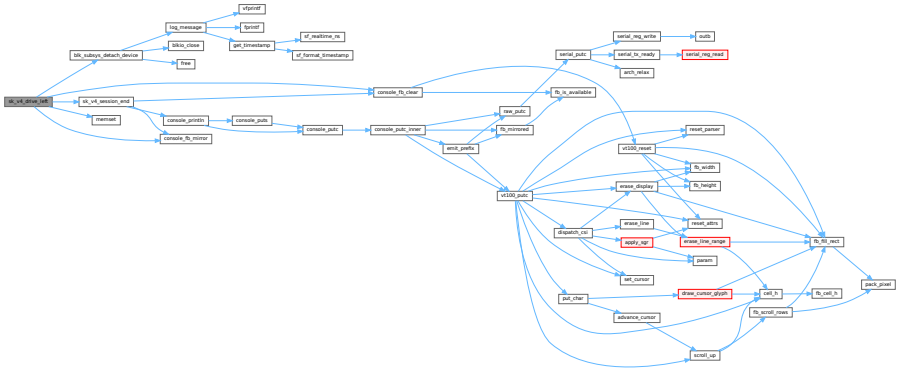
7.175.2.3 sk_v4_drive_left()

```
static void sk_v4_drive_left (
            sk_v4_drive_t * d )  [static]
```

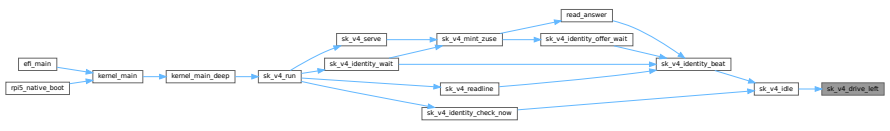
References sk_v4_drive_t::art_used, blk_subsys_detach_device(), console_fb_clear(), console_fb_mirror(), g_marker, g_offered, g_pending_real, g_proxy_fallback, g_real_drive, g_spare, g_stick_in, g_zuse_dev, sk_v4_marker_t::has_real, memset(), sk_v4_marker_t::present, sk_v4_session_end(), and sk_v4_drive_t::used.

Referenced by sk_v4_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



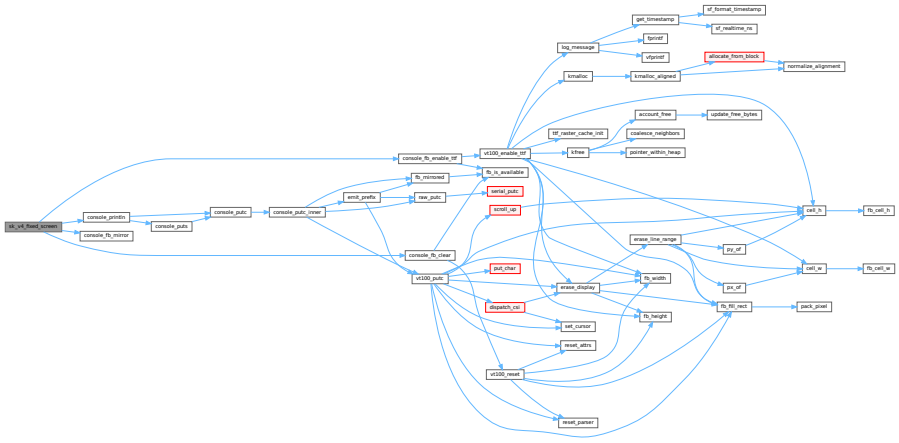
7.175.2.4 sk_v4_fixed_screen()

```
static void sk_v4_fixed_screen (
            void  )  [static]
```

References console_fb_clear(), console_fb_enable_ttf(), console_fb_mirror(), and console_println().

Referenced by sk_v4_identity_wait().

Here is the call graph for this function:



Here is the caller graph for this function:

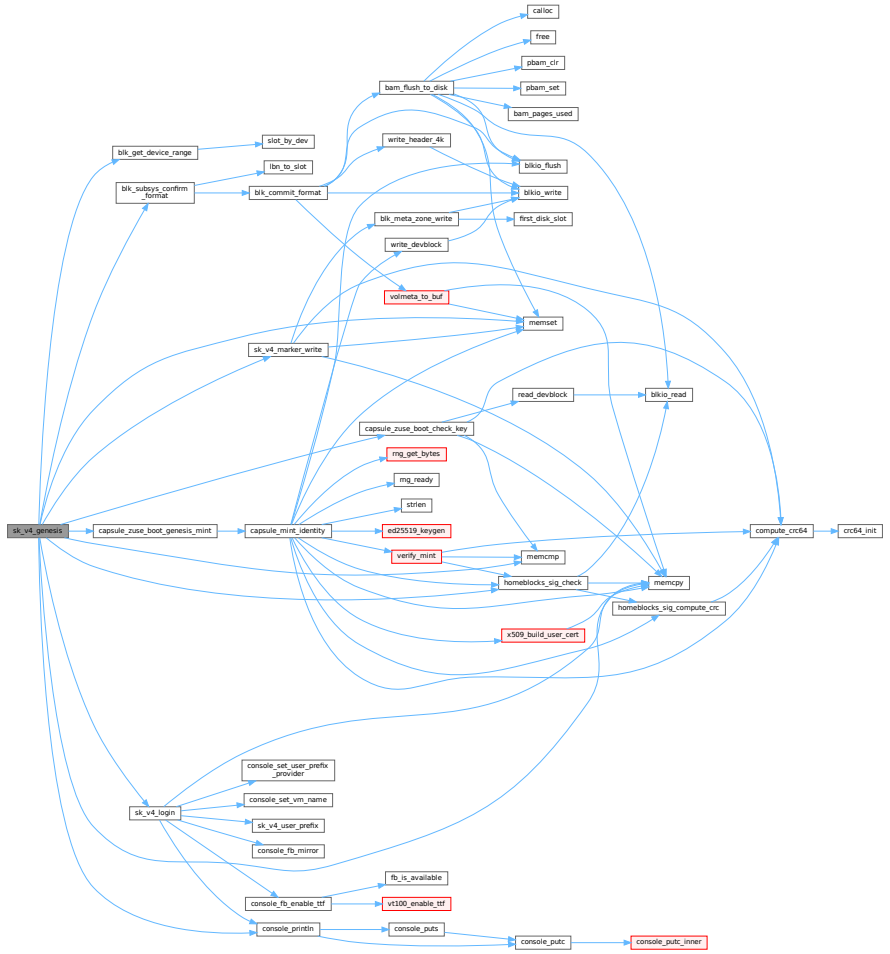
7.175.2.5 sk_v4_genesis()

```
static int sk_v4_genesis (
            blkio_dev_t * dev,
            blkio_dev_t * art )  [static]
```

References blk_get_device_range(), BLK_OK, blk_subsys_confirm_format(), capsule_zuse_boot_check_key(), capsule_zuse_boot_genesis_mint(), console_println(), g_marker, homeblocks_sig_check(), HOMEBLOCKS_SIG_START_FBLOCK, memcmp(), memcpy(), memset(), sk_v4_marker_t::present, sk_v4_marker_t::proxy, sk_v4_login(), and sk_v4_marker_write().

Referenced by sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

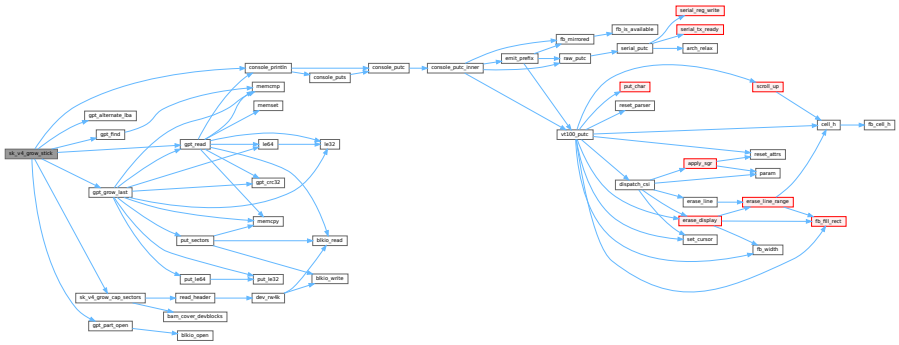
7.175.2.6 sk_v4_grow_stick()

```
static int sk_v4_grow_stick (
            sk_v4_drive_t * d,
            unsigned * nparts )  [static]
```

References sk_v4_drive_t::art, sk_v4_drive_t::art_state, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, console_println(), gpt_part_t::first_lba, g_gpt_parts, gpt_alternate_lba(), gpt_find(), gpt_grow_last(), GPT_OK, gpt_part_open(), gpt_read(), gpt_type_starship_artemis, gpt_type_starship_identity, sk_v4_drive_t::raw, SK_V4_CAP_SECTORS, SK_V4_GPT_PARTS, sk_v4_grow_cap_sectors(), SK_V4_GROW_MIN_BYTES, and blkio_dev::total_blocks.

Referenced by sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

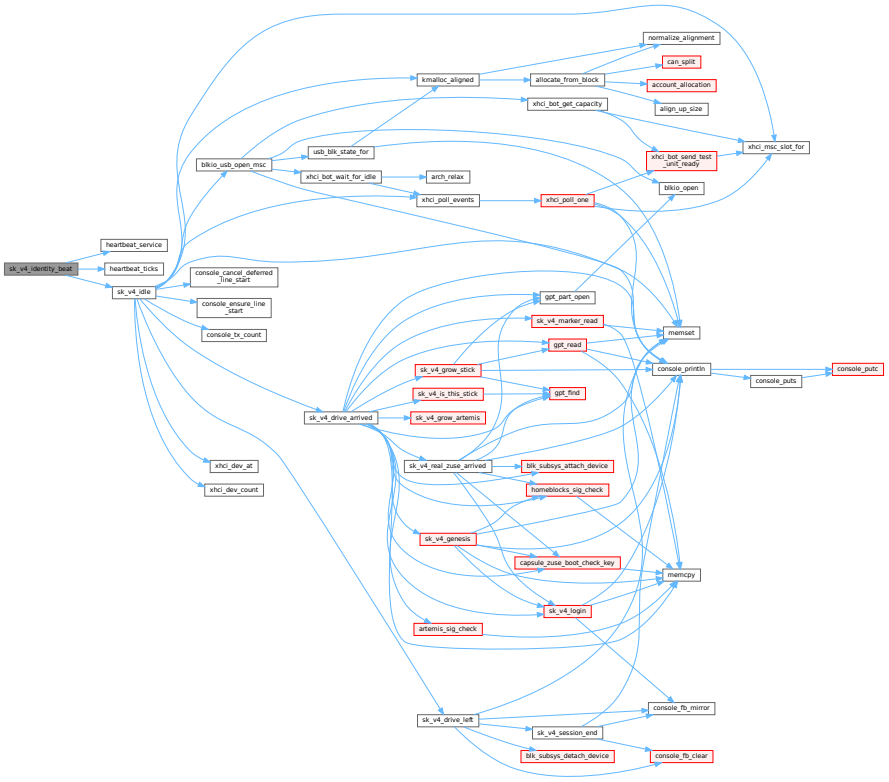
7.175.2.7 sk_v4_identity_beat()

```
void sk_v4_identity_beat (
            void  )
```

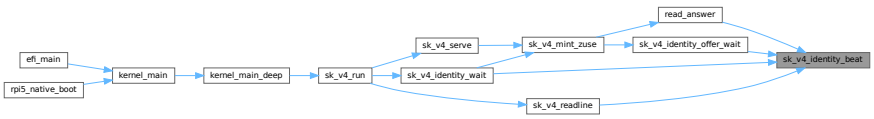
References g_last_beat, heartbeat_service(), heartbeat_ticks(), sk_v4_idle(), and SK_V4_IDLE_BEAT.

Referenced by read_answer(), sk_v4_identity_offer_wait(), sk_v4_identity_wait(), and sk_v4_readline().

Here is the call graph for this function:



Here is the caller graph for this function:



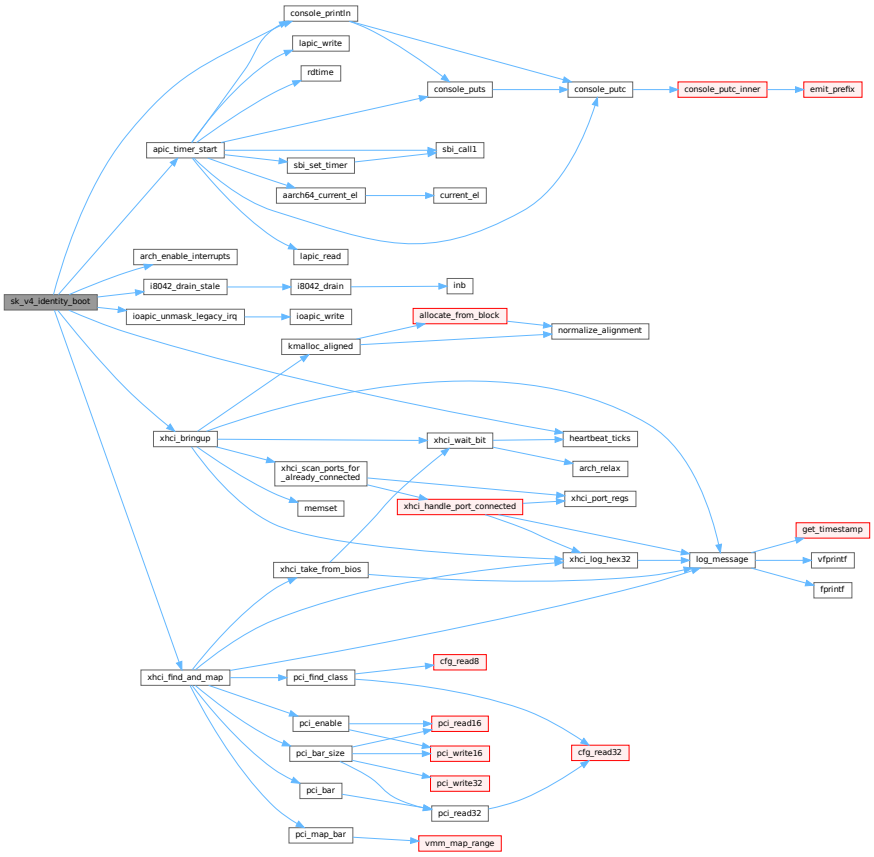
7.175.2.8 sk_v4_identity_boot()

```
void sk_v4_identity_boot (
            const BootDisk * boot_disk )
```

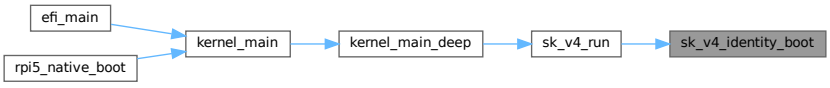
References apic_timer_start(), arch_enable_interrupts(), console_println(), g_boot_disk, g_last_beat, heartbeat_ticks(), i8042_drain_stale(), ioapic_unmask_legacy_irq(), xhci_bringup(), xhci_find_and_map(), and XHCI_MAX_CONTROLLERS.

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



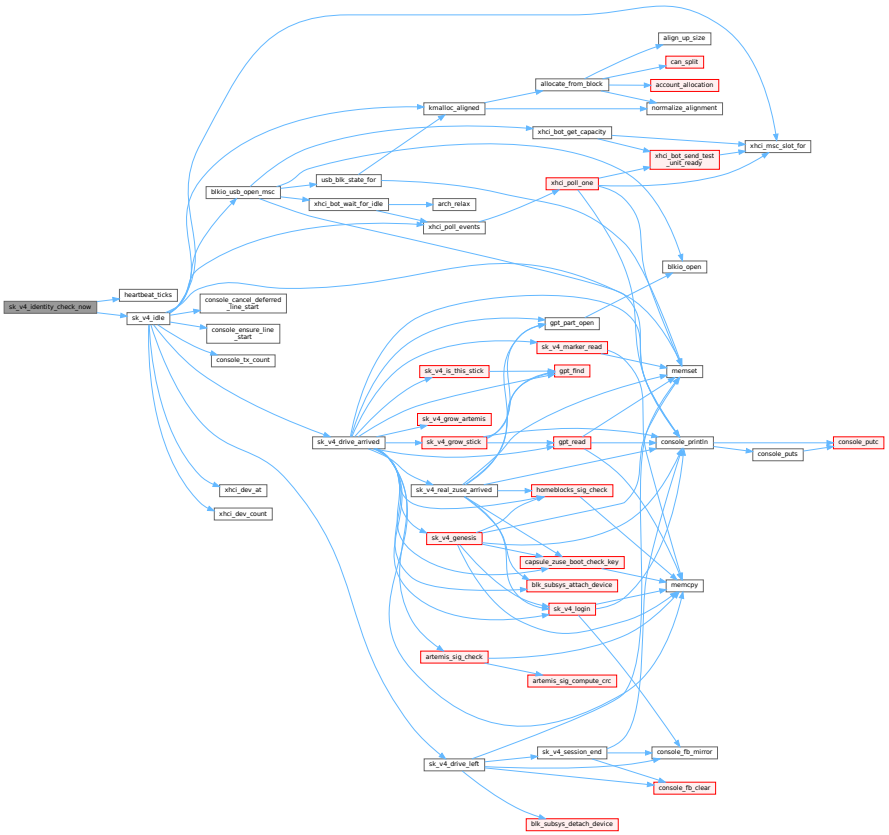
7.175.2.9 sk_v4_identity_check_now()

```
void sk_v4_identity_check_now (
            void  )
```

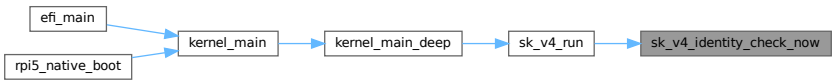
References g_last_beat, heartbeat_ticks(), and sk_v4_idle().

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.175.2.10 sk_v4_identity_marker()

```
const sk_v4_marker_t * sk_v4_identity_marker (
            void  )
```

References g_marker.

Referenced by sk_v4_mint_zuse().

Here is the caller graph for this function:

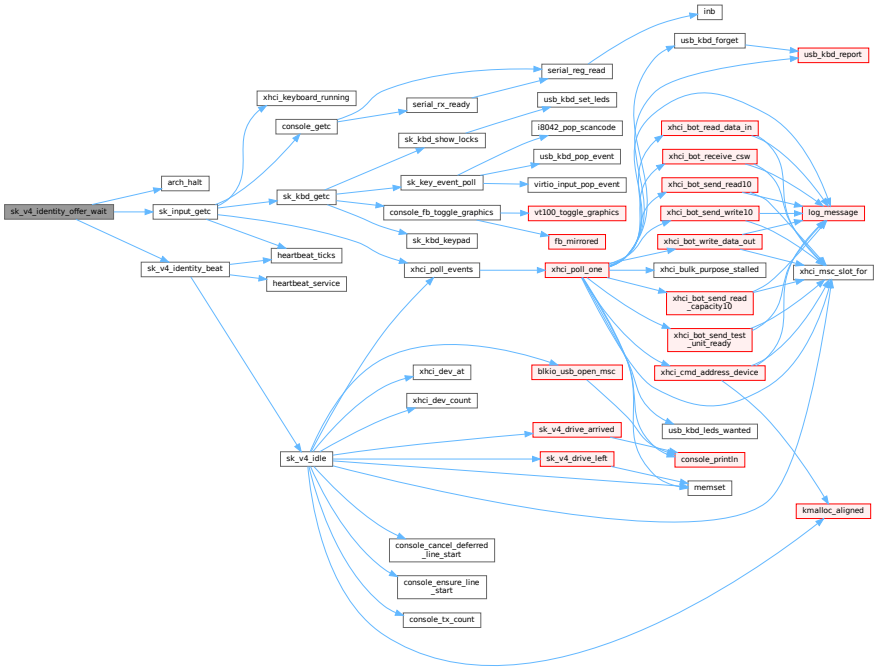
7.175.2.11 sk_v4_identity_offer_wait()

```
int sk_v4_identity_offer_wait (
            blkio_dev_t ** raw,
            uint64_t * bytes )
```

References arch_halt(), BLKIO_FORTH_BLOCK_SIZE, bytes, g_mint_waiting, g_offered, g_spare, g_stick_in, sk_v4_drive_t::raw, sk_input_getc(), sk_v4_identity_beat(), and blkio_dev::total_blocks.

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

7.175.2.12 sk_v4_identity_offered_present()

```
int sk_v4_identity_offered_present (
            void  )
```

References g_offered.

Referenced by read_answer(), and sk_v4_mint_zuse().

Here is the caller graph for this function:

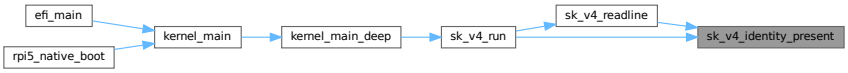
7.175.2.13 sk_v4_identity_present()

```
int sk_v4_identity_present (
            void  )
```

References g_zuse_session.

Referenced by sk_v4_readline(), and sk_v4_run().

Here is the caller graph for this function:



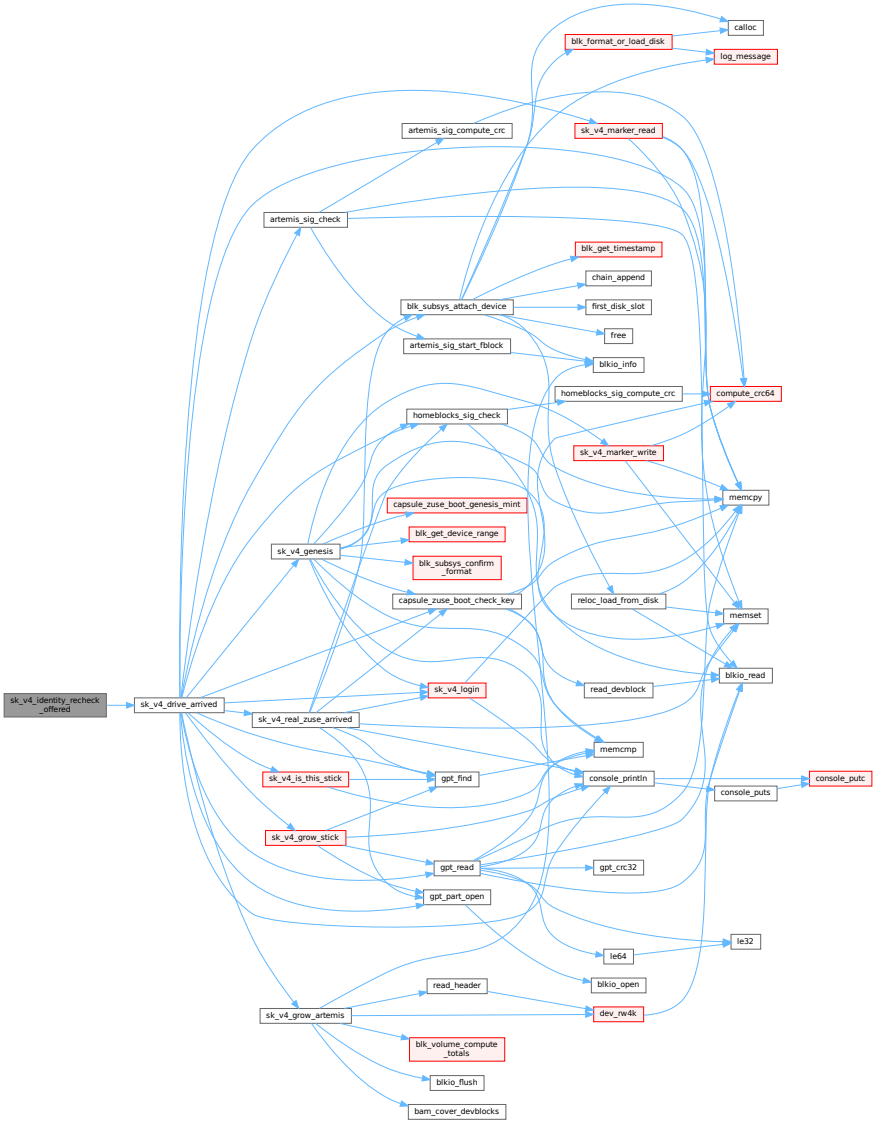
7.175.2.14 sk_v4_identity_recheck_offered()

```
void sk_v4_identity_recheck_offered (
            void  )
```

References g_offered, and sk_v4_drive_arrived().

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

7.175.2.15 sk_v4_identity_release_offered()

```
void sk_v4_identity_release_offered (
            void  )
```

References g_offered, and g_spare.

Referenced by failed(), and sk_v4_mint_zuse().

Here is the caller graph for this function:

7.175.2.16 sk_v4_identity_set_marker()

```
void sk_v4_identity_set_marker (
            const sk_v4_marker_t * m )
```

References g_marker.

Referenced by sk_v4_mint_zuse().

Here is the caller graph for this function:

7.175.2.17 sk_v4_identity_stick_in()

```
int sk_v4_identity_stick_in (
            void  )
```

References g_stick_in.

Referenced by read_answer().

Here is the caller graph for this function:

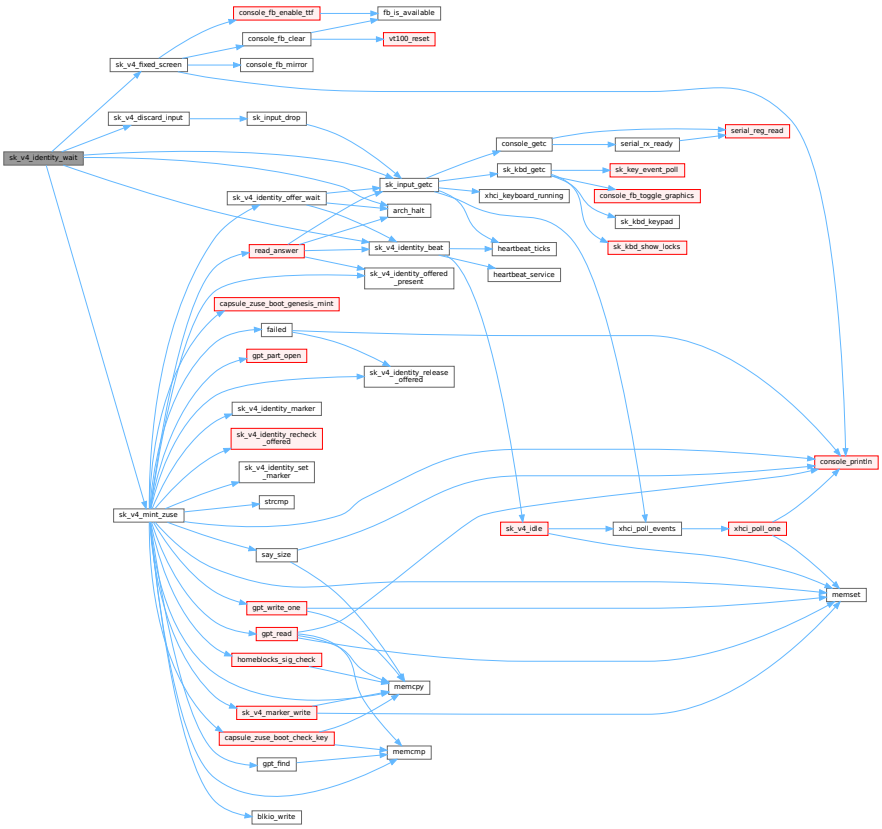
7.175.2.18 sk_v4_identity_wait()

```
void sk_v4_identity_wait (
            void  )
```

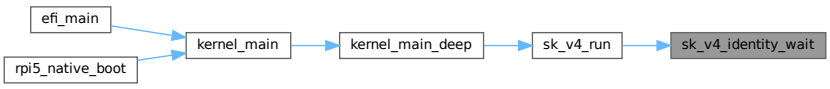
References arch_halt(), g_proxy_fallback, g_zuse_session, sk_input_getc(), sk_v4_discard_input(), sk_v4_fixed_screen(), sk_v4_identity_beat(), and sk_v4_mint_zuse().

Referenced by sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



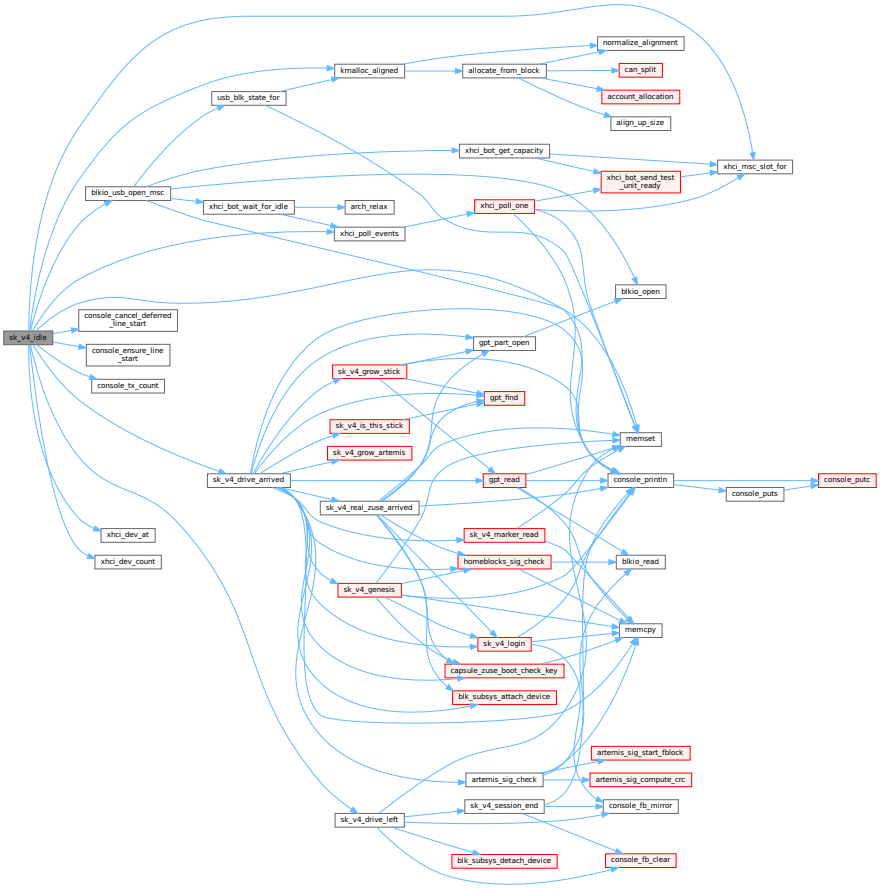
7.175.2.19 sk_v4_idle()

```
static void sk_v4_idle (
            void  )  [static]
```

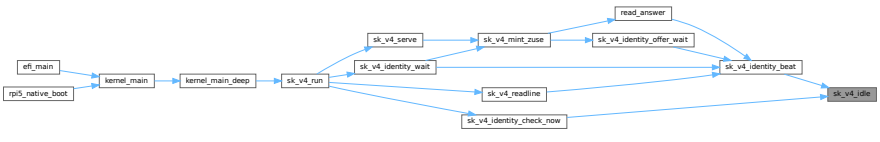
References blkio_usb_open_msc(), xhci_msc_slot_t::bot_msc_attach_pending, xhci_msc_slot_t::bot_msc_attached, xhci_msc_slot_t::bot_msc_detach_pending, bytes, console_cancel_deferred_line_start(), console_ensure_line_start(), console_tx_count(), g_usb, kmalloc_aligned(), xhci_dev_t::max_slots, memset(), sk_v4_drive_arrived(), sk_v4_drive_left(), slots, xdev, xhci_dev_at(), xhci_dev_count(), XHCI_MAX_CONTROLLERS, xhci_msc_slot_for(), and xhci_poll_events().

Referenced by sk_v4_identity_beat(), and sk_v4_identity_check_now().

Here is the call graph for this function:



Here is the caller graph for this function:



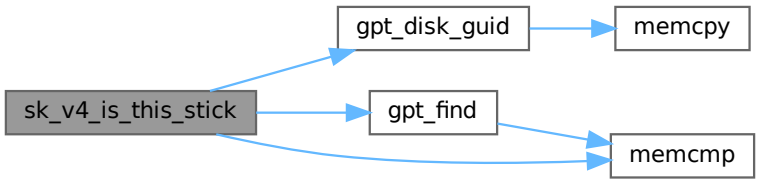
7.175.2.20 sk_v4_is_this_stick()

```
static int sk_v4_is_this_stick (
            unsigned nparts )  [static]
```

References BootDisk::disk_guid, g_boot_disk, g_gpt_parts, g_stick_in, gpt_disk_guid(), gpt_find(), gpt_type_starship_artemis, gpt_type_starship_identity, BootDisk::is_stick, and memcmp().

Referenced by sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

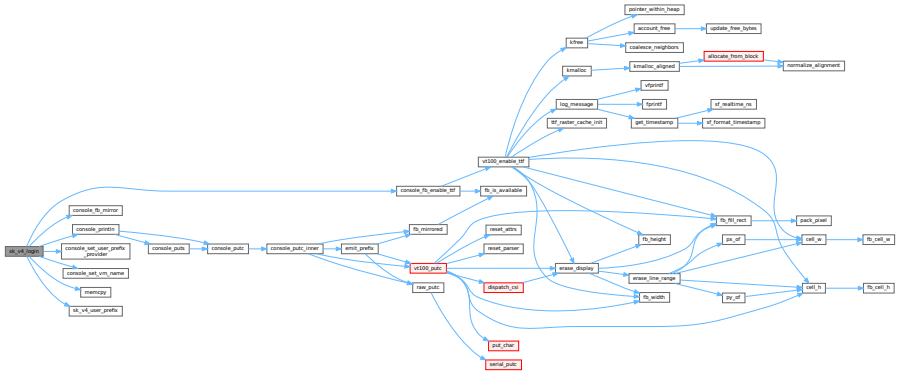
7.175.2.21 sk_v4_login()

```
static void sk_v4_login (
            blkio_dev_t * dev,
            const uint8_t seed[32],
            const uint8_t pubkey[32],
            const char * line )  [static]
```

References console_fb_enable_ttf(), console_fb_mirror(), console_println(), console_set_user_prefix_provider(), console_set_vm_name(), g_zuse_cert_installed, g_zuse_dev, g_zuse_pubkey, g_zuse_root_known, g_zuse_root_pubkey, g_zuse_seed, g_zuse_session, memcpy(), and sk_v4_user_prefix().

Referenced by sk_v4_drive_arrived(), sk_v4_genesis(), and sk_v4_real_zuse_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

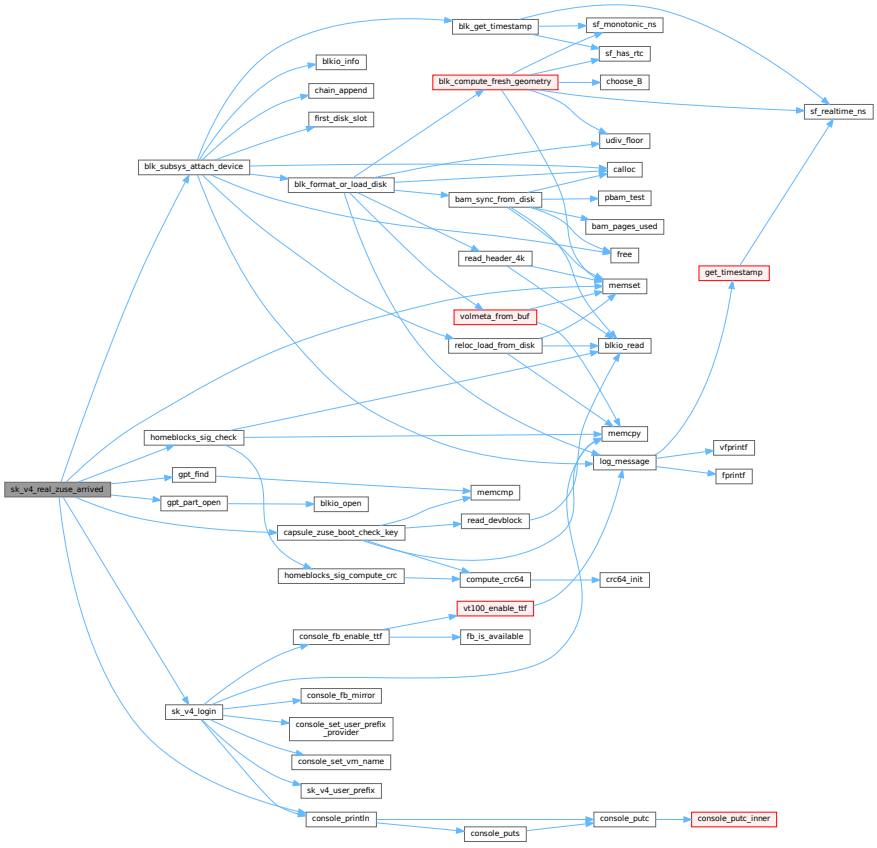
7.175.2.22 sk_v4_real_zuse_arrived()

```
static int sk_v4_real_zuse_arrived (
            sk_v4_drive_t * d,
            unsigned nparts )  [static]
```

References BLK_OK, blk_subsys_attach_device(), BLKIO_OK, capsule_zuse_boot_check_key(), console_println(), g_gpt_parts, g_marker, g_proxy_fallback, g_real_drive, gpt_find(), gpt_part_open(), gpt_type_starship_identity, sk_v4_marker_t::has_real, homeblocks_sig_check(), HOMEBLOCKS_SIG_START_FBLOCK, memset(), sk_v4_drive_t::part, sk_v4_drive_t::part_state, sk_v4_marker_t::present, sk_v4_drive_t::raw, sk_v4_marker_t::real, sk_v4_login(), and sk_v4_drive_t::used.

Referenced by sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

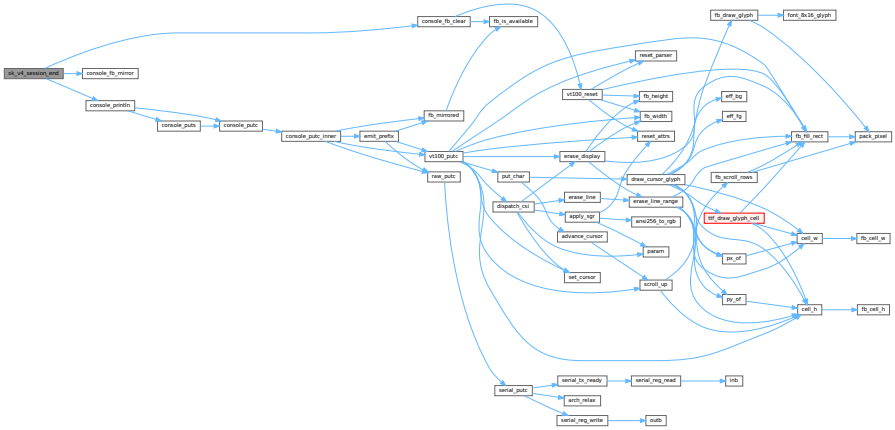
7.175.2.23 sk_v4_session_end()

```
static void sk_v4_session_end (
            void  )  [static]
```

References console_fb_clear(), console_fb_mirror(), console_println(), g_zuse_dev, and g_zuse_session.

Referenced by sk_v4_drive_left().

Here is the call graph for this function:



Here is the caller graph for this function:

7.175.2.24 sk_v4_user_prefix()

```
static const char * sk_v4_user_prefix (
            void  )  [static]
```

References g_zuse_session.

Referenced by sk_v4_login().

Here is the caller graph for this function:

7.175.3 Variable Documentation

7.175.3.1 count

```
uint32_t count
```

7.175.3.2 g_boot_disk

```
const BootDisk* g_boot_disk  [static]
```

Referenced by sk_v4_identity_boot(), and sk_v4_is_this_stick().

7.175.3.3 g_gpt_parts

```
gpt_part_t g_gpt_parts[16u]  [static]
```

Referenced by sk_v4_drive_arrived(), sk_v4_grow_stick(), sk_v4_is_this_stick(), and sk_v4_real_zuse_arrived().

7.175.3.4 g_last_beat

```
uint64_t g_last_beat  [static]
```

Referenced by sk_v4_identity_beat(), sk_v4_identity_boot(), and sk_v4_identity_check_now().

7.175.3.5 g_marker

```
sk_v4_marker_t g_marker  [static]
```

Referenced by sk_v4_drive_arrived(), sk_v4_drive_left(), sk_v4_genesis(), sk_v4_identity_marker(), sk_v4_identity_set_marker(), and sk_v4_real_zuse_arrived().

7.175.3.6 g_mint_waiting

```
int g_mint_waiting  [static]
```

Referenced by sk_v4_drive_arrived(), and sk_v4_identity_offer_wait().

7.175.3.7 g_offered

```
sk_v4_drive_t* g_offered  [static]
```

Referenced by sk_v4_drive_arrived(), sk_v4_drive_left(), sk_v4_identity_offer_wait(), sk_v4_identity_offered_present(), sk_v4_identity_recheck_offered(), and sk_v4_identity_release_offered().

7.175.3.8 g_pending_real

```
sk_v4_drive_t* g_pending_real  [static]
```

Referenced by sk_v4_drive_arrived(), and sk_v4_drive_left().

7.175.3.9 g_proxy_fallback

```
int g_proxy_fallback  [static]
```

Referenced by sk_v4_drive_arrived(), sk_v4_drive_left(), sk_v4_identity_wait(), and sk_v4_real_zuse_arrived().

7.175.3.10 g_real_drive

```
sk_v4_drive_t* g_real_drive  [static]
```

Referenced by sk_v4_drive_left(), and sk_v4_real_zuse_arrived().

7.175.3.11 g_spare

```
sk_v4_drive_t* g_spare  [static]
```

Referenced by sk_v4_drive_arrived(), sk_v4_drive_left(), sk_v4_identity_offer_wait(), and sk_v4_identity_release_offered().

7.175.3.12 g_stick_in

```
int g_stick_in  [static]
```

Referenced by sk_v4_drive_arrived(), sk_v4_drive_left(), sk_v4_identity_offer_wait(), sk_v4_identity_stick_in(), and sk_v4_is_this_stick().

7.175.3.13 [struct]

```
struct { ...  } g_usb[ 8u ]  [static]
```

Referenced by sk_v4_idle().

7.175.3.14 g_zuse_cert_installed

```
int g_zuse_cert_installed  [static]
```

Referenced by sk_v4_login().

7.175.3.15 g_zuse_dev

```
struct blkio_dev* g_zuse_dev  [static]
```

Referenced by sk_v4_drive_left(), sk_v4_login(), and sk_v4_session_end().

7.175.3.16 g_zuse_pubkey

```
uint8_t g_zuse_pubkey[32]  [static]
```

Referenced by sk_v4_login().

7.175.3.17 g_zuse_root_known

```
int g_zuse_root_known  [static]
```

Referenced by sk_v4_drive_arrived(), and sk_v4_login().

7.175.3.18 g_zuse_root_pubkey

```
uint8_t g_zuse_root_pubkey[32]  [static]
```

Referenced by sk_v4_drive_arrived(), and sk_v4_login().

7.175.3.19 g_zuse_seed

```
uint8_t g_zuse_seed[32]  [static]
```

Referenced by sk_v4_login().

7.175.3.20 g_zuse_session

```
int g_zuse_session  [static]
```

Referenced by sk_v4_drive_arrived(), sk_v4_identity_present(), sk_v4_identity_wait(), sk_v4_login(), sk_v4_session_end(), and sk_v4_user_prefix().

7.175.3.21 slots

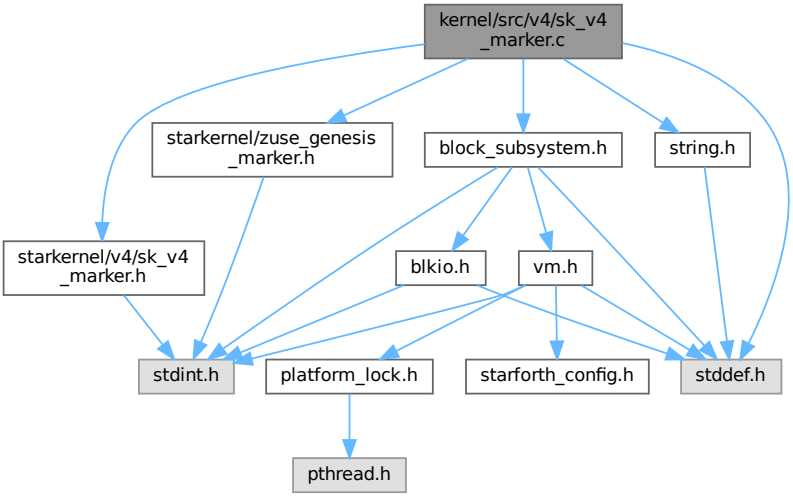
```
sk_v4_drive_t* slots
```

Referenced by sk_v4_idle().

7.176 kernel/src/v4/sk_v4_marker.c File Reference

```
#include "starkernel/v4/sk_v4_marker.h"
#include "starkernel/zuse_genesis_marker.h"
#include "block_subsystem.h"
#include <stddef.h>
#include <string.h>
```

Include dependency graph for sk_v4_marker.c:



Functions

- int sk_v4_marker_read (sk_v4_marker_t *m)
- int sk_v4_marker_write (const sk_v4_marker_t *m)

Variables

- union {
  uint8_t bytes [4096]
  zuse_genesis_marker_t v1
  zuse_genesis_marker_v2_t v2
  } g_buf

7.176.1 Function Documentation

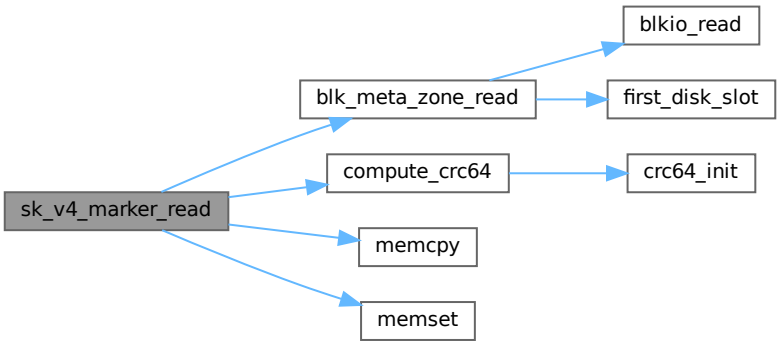
7.176.1.1 sk_v4_marker_read()

```
int sk_v4_marker_read (
            sk_v4_marker_t * m )
```

References blk_meta_zone_read(), compute_crc64(), g_buf, sk_v4_marker_t::has_real, memcpy(), memset(), sk_v4_marker_t::present, sk_v4_marker_t::proxy, sk_v4_marker_t::real, ZUSE_GENESIS_MARKER_MAGIC, ZUSE_GENESIS_MARKER_VERSION, and ZUSE_GENESIS_MARKER_VERSION_2.

Referenced by sk_v4_drive_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

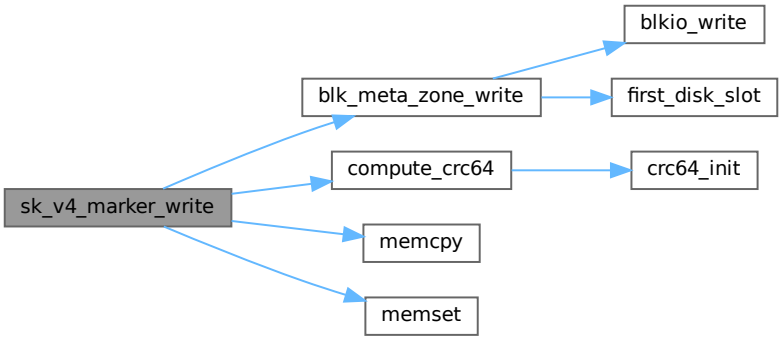
7.176.1.2 sk_v4_marker_write()

```
int sk_v4_marker_write (
            const sk_v4_marker_t * m )
```

References blk_meta_zone_write(), compute_crc64(), g_buf, sk_v4_marker_t::has_real, memcpy(), memset(), sk_v4_marker_t::proxy, sk_v4_marker_t::real, ZUSE_GENESIS_MARKER_MAGIC, and ZUSE_GENESIS_MARKER_VERSION_2.

Referenced by sk_v4_genesis(), and sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

7.176.2 Variable Documentation

7.176.2.1 bytes

```
uint8_t bytes[4096]
```

7.176.2.2 [union]

```
union { ... } g_buf [static]
```

Referenced by sk_v4_marker_read(), and sk_v4_marker_write().

7.176.2.3 v1

```
zuse_genesis_marker_t v1
```

Referenced by xxhash64().

7.176.2.4 v2

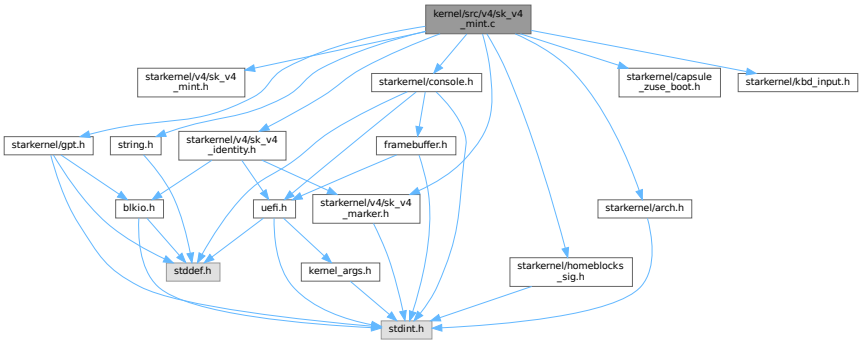
```
zuse_genesis_marker_v2_t v2
```

Referenced by rpi5_mailbox_get_framebuffer(), and xxhash64().

7.177 kernel/src/v4/sk_v4_mint.c File Reference

```
#include "starkernel/v4/sk_v4_mint.h"
#include "starkernel/v4/sk_v4_identity.h"
#include "starkernel/v4/sk_v4_marker.h"
#include "starkernel/capsule_zuse_boot.h"
#include "starkernel/homeblocks_sig.h"
#include "starkernel/kbd_input.h"
#include "starkernel/console.h"
#include "starkernel/arch.h"
#include "starkernel/gpt.h"
#include <string.h>
```

Include dependency graph for sk_v4_mint.c:



Macros

- #define MINT_MIN_BYTES (64ULL ∗ 1024ULL ∗ 1024ULL) /∗ a stick under 64 MiB is refused ∗/
- #define MINT_IDENT_SECTORS (500ULL ∗ 2048ULL) /∗ the identity partition: 500 MiB ∗/
- #define MINT_ZERO_FBLOCKS 32u /∗ its first 8 devblocks, zeroed ∗/

Functions

- static void say_size (uint64_t bytes)
- static int read_answer (char ∗buf, int max)
- static int failed (void)
- int sk_v4_mint_zuse (void)

7.177.1 Macro Definition Documentation

7.177.1.1 MINT_IDENT_SECTORS

```
#define MINT_IDENT_SECTORS (500ULL * 2048ULL) /* the identity partition:  500 MiB */
```

7.177.1.2 MINT_MIN_BYTES

```
#define MINT_MIN_BYTES (64ULL * 1024ULL * 1024ULL) /* a stick under 64 MiB is refused */
```

7.177.1.3 MINT_ZERO_FBLOCKS

```
#define MINT_ZERO_FBLOCKS 32u /* its first 8 devblocks, zeroed */
```

7.177.2 Function Documentation

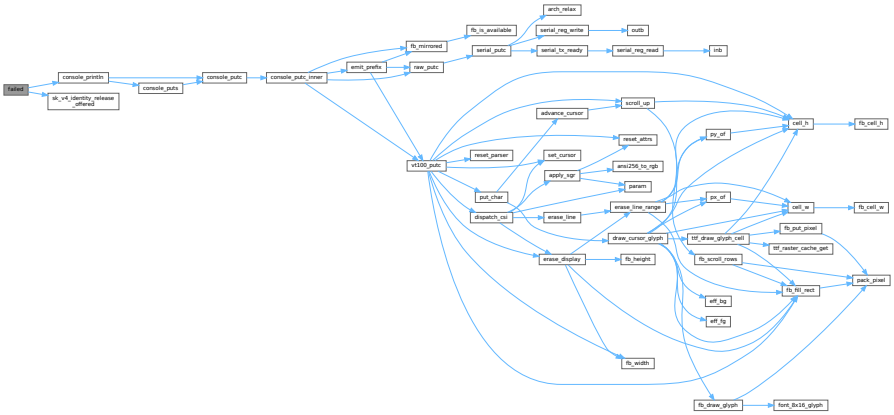
7.177.2.1 failed()

```
static int failed (
            void  )  [static]
```

References console_println(), and sk_v4_identity_release_offered().

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

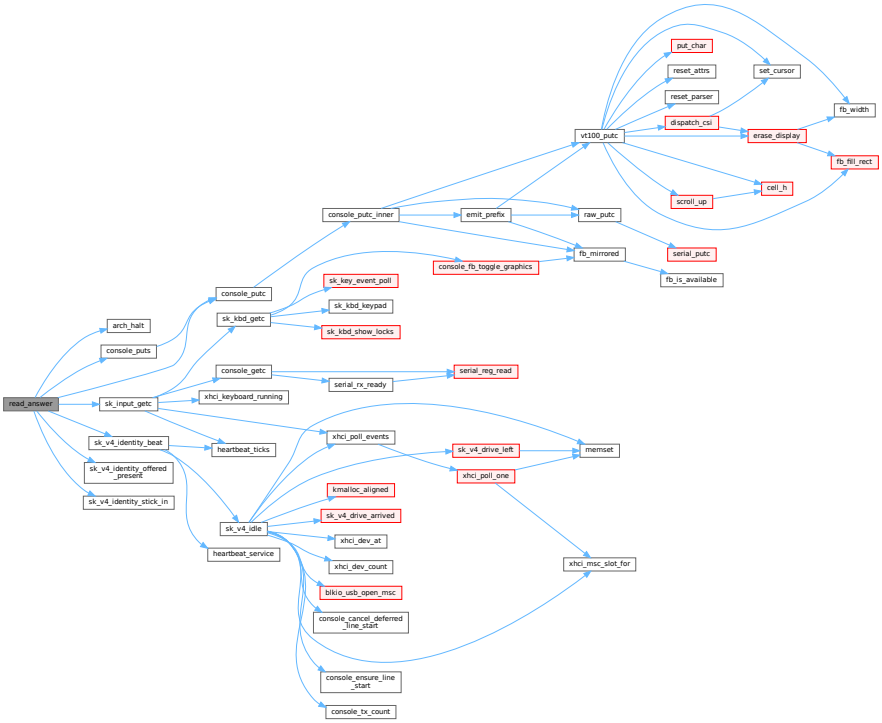
7.177.2.2 read_answer()

```
static int read_answer (
            char * buf,
            int max )  [static]
```

References arch_halt(), console_putc(), console_puts(), sk_input_getc(), sk_v4_identity_beat(), sk_v4_identity_offered_present(), and sk_v4_identity_stick_in().

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

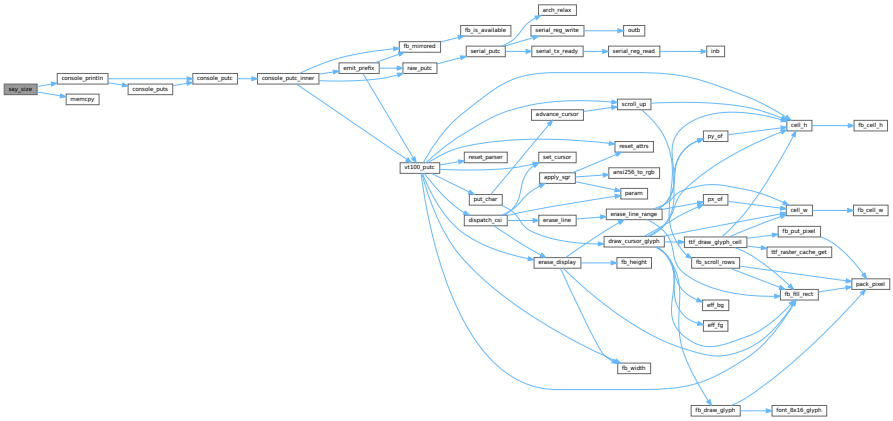
7.177.2.3 say_size()

```
static void say_size (
            uint64_t bytes )  [static]
```

References bytes, console_println(), and memcpy().

Referenced by sk_v4_mint_zuse().

Here is the call graph for this function:



Here is the caller graph for this function:

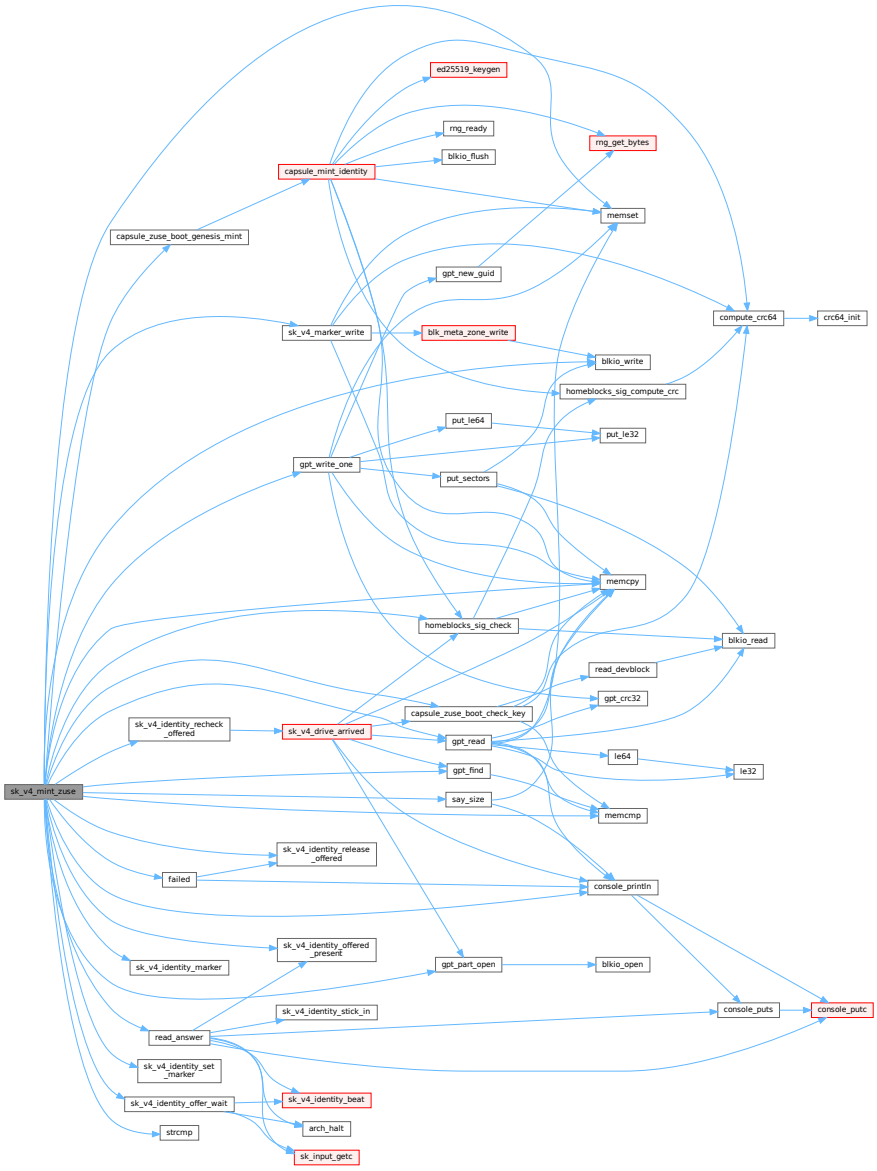
7.177.2.4 sk_v4_mint_zuse()

```
int sk_v4_mint_zuse (
            void  )
```

References BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_write(), bytes, capsule_zuse_boot_check_key(), capsule_zuse_boot_genesis_mint(), console_println(), failed(), GPT_BAD, gpt_find(), GPT_OK, gpt_part_open(), gpt_read(), gpt_type_starship_identity, gpt_write_one(), sk_v4_marker_t::has_real, homeblocks_sig_check(), HOMEBLOCKS_SIG_START_FBLOCK, memcmp(), memcpy(), memset(), MINT_IDENT_SECTORS, MINT_MIN_BYTES, MINT_ZERO_FBLOCKS, sk_v4_marker_t::present, read_answer(), sk_v4_marker_t::real, say_size(), sk_v4_identity_marker(), sk_v4_identity_offer_wait(), sk_v4_identity_offered_present(), sk_v4_identity_recheck_offered(), sk_v4_identity_release_offered(), sk_v4_identity_set_marker(), sk_v4_marker_write(), strcmp(), and zero.

Referenced by sk_v4_identity_wait(), and sk_v4_serve().

Here is the call graph for this function:



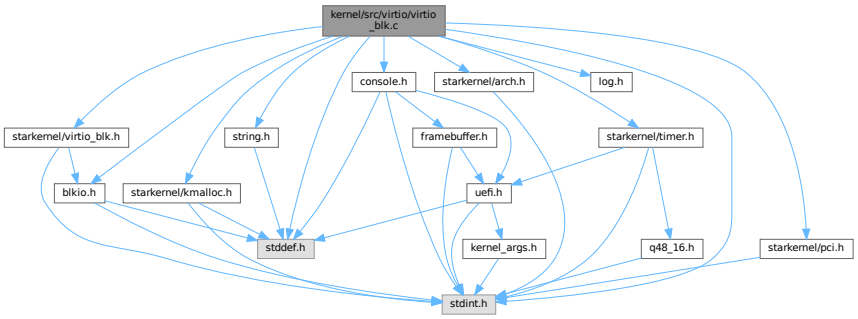
Here is the caller graph for this function:

7.178 kernel/src/virtio/virtio_blk.c File Reference

```
#include <stddef.h>
#include <stdint.h>
```

```
#include <string.h>
#include "starkernel/pci.h"
#include "starkernel/virtio_blk.h"
#include "starkernel/kmalloc.h"
#include "console.h"
#include "blkio.h"
#include "log.h"
#include "starkernel/arch.h"
#include "starkernel/timer.h"
```

Include dependency graph for virtio_blk.c:



Data Structures

- struct VirtioCommonCfg
- struct VirtqDesc
- struct VirtqAvail
- struct VirtqUsedElem
- struct VirtqUsed
- struct VirtBlkReq
- struct VirtBlkState

Macros

- #define VIRTIO_PCI_CAP_VENDOR_ID 0x09u
- #define VIRTIO_PCI_CAP_COMMON_CFG 1u
- #define VIRTIO_PCI_CAP_NOTIFY_CFG 2u
- #define VIRTIO_PCI_CAP_ISR_CFG 3u
- #define VIRTIO_PCI_CAP_DEVICE_CFG 4u
- #define VCAP_OFF_CAP_VNDR 0u
- #define VCAP_OFF_CAP_NEXT 1u
- #define VCAP_OFF_CAP_LEN 2u
- #define VCAP_OFF_CFG_TYPE 3u
- #define VCAP_OFF_BAR 4u
- #define VCAP_OFF_OFFSET 8u
- #define VCAP_OFF_LENGTH 12u
- #define VCAP_OFF_NOTIFY_MULT 16u
- #define VIRTIO_STATUS_ACKNOWLEDGE 0x01u
- #define VIRTIO_STATUS_DRIVER 0x02u
- #define VIRTIO_STATUS_DRIVER_OK 0x04u
- #define VIRTIO_STATUS_FEATURES_OK 0x08u

- #define VIRTIO_STATUS_FAILED 0x80u
- #define VIRTIO_F_VERSION_1 (1ULL << 32)
- #define VQUEUE_SIZE 4u /* power of 2; ≥ 3 for one in-flight chain */
- #define VRING_DESC_F_NEXT 1u
- #define VRING_DESC_F_WRITE 2u
- #define VBLK_IO_TIMEOUT_NS 5000000000ULL

Functions

- static void * walk_virtio_caps (const PciDevice *d, uint8_t cap_type, uint32_t *extra_out)
- static void wmb (void)
- static void rmb (void)
- static int vblk_io (int write, uint64_t sector, void *buf, uint32_t nbytes)
- static int vblk_open (blkio_dev_t *dev, const blkio_params_t *p)
- static int vblk_close (blkio_dev_t *dev)
- static int vblk_read (blkio_dev_t *dev, uint32_t fblock, void *dst)
- static int vblk_write (blkio_dev_t *dev, uint32_t fblock, const void *src)
- static int vblk_flush (blkio_dev_t *dev)
- static int vblk_info (blkio_dev_t *dev, blkio_info_t *out)
- static int vblk_init_device (const PciDevice *pci)
- int virtio_blk_find_artemis (blkio_dev_t *dev_out)

Variables

- static VirtBlkState g_vblk
- static int g_vblk_ready = 0
- static int g_vblk_dead = 0
- static const blkio_vtable_t g_vblk_vtable

7.178.1 Macro Definition Documentation

7.178.1.1 VBLK_IO_TIMEOUT_NS

```
#define VBLK_IO_TIMEOUT_NS 5000000000ULL
```

7.178.1.2 VCAP_OFF_BAR

```
#define VCAP_OFF_BAR 4u
```

7.178.1.3 VCAP_OFF_CAP_LEN

```
#define VCAP_OFF_CAP_LEN 2u
```

7.178.1.4 VCAP_OFF_CAP_NEXT

```
#define VCAP_OFF_CAP_NEXT 1u
```

7.178.1.5 VCAP_OFF_CAP_VNDR

```
#define VCAP_OFF_CAP_VNDR 0u
```

7.178.1.6 VCAP_OFF_CFG_TYPE

```
#define VCAP_OFF_CFG_TYPE 3u
```

7.178.1.7 VCAP_OFF_LENGTH

```
#define VCAP_OFF_LENGTH 12u
```

7.178.1.8 VCAP_OFF_NOTIFY_MULT

```
#define VCAP_OFF_NOTIFY_MULT 16u
```

7.178.1.9 VCAP_OFF_OFFSET

```
#define VCAP_OFF_OFFSET 8u
```

7.178.1.10 VIRTIO_F_VERSION_1

```
#define VIRTIO_F_VERSION_1 (1ULL << 32)
```

7.178.1.11 VIRTIO_PCI_CAP_COMMON_CFG

```
#define VIRTIO_PCI_CAP_COMMON_CFG 1u
```

7.178.1.12 VIRTIO_PCI_CAP_DEVICE_CFG

```
#define VIRTIO_PCI_CAP_DEVICE_CFG 4u
```

7.178.1.13 VIRTIO_PCI_CAP_ISR_CFG

```
#define VIRTIO_PCI_CAP_ISR_CFG 3u
```

7.178.1.14 VIRTIO_PCI_CAP_NOTIFY_CFG

```
#define VIRTIO_PCI_CAP_NOTIFY_CFG 2u
```

7.178.1.15 VIRTIO_PCI_CAP_VENDOR_ID

```
#define VIRTIO_PCI_CAP_VENDOR_ID 0x09u
```

7.178.1.16 VIRTIO_STATUS_ACKNOWLEDGE

```
#define VIRTIO_STATUS_ACKNOWLEDGE 0x01u
```

7.178.1.17 VIRTIO_STATUS_DRIVER

```
#define VIRTIO_STATUS_DRIVER 0x02u
```

7.178.1.18 VIRTIO_STATUS_DRIVER_OK

```
#define VIRTIO_STATUS_DRIVER_OK 0x04u
```

7.178.1.19 VIRTIO_STATUS_FAILED

```
#define VIRTIO_STATUS_FAILED 0x80u
```

7.178.1.20 VIRTIO_STATUS_FEATURES_OK

```
#define VIRTIO_STATUS_FEATURES_OK 0x08u
```

7.178.1.21 VQUEUE_SIZE

```
#define VQUEUE_SIZE 4u /* power of 2; ≥ 3 for one in-flight chain */
```

7.178.1.22 VRING_DESC_F_NEXT

```
#define VRING_DESC_F_NEXT 1u
```

7.178.1.23 VRING_DESC_F_WRITE

```
#define VRING_DESC_F_WRITE 2u
```

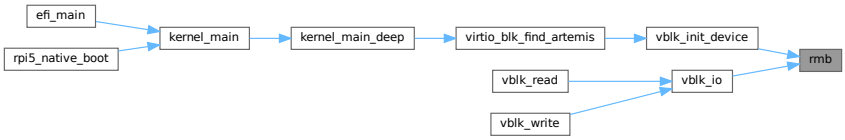
7.178.2 Function Documentation

7.178.2.1 rmb()

```
static void rmb (
            void  )  [inline], [static]
```

Referenced by vblk_init_device(), and vblk_io().

Here is the caller graph for this function:



7.178.2.2 vblk_close()

```
static int vblk_close (
            blkio_dev_t * dev )  [static]
```

References BLKIO_OK.

7.178.2.3 vblk_flush()

```
static int vblk_flush (
            blkio_dev_t * dev )  [static]
```

References BLKIO_OK.

7.178.2.4 vblk_info()

```
static int vblk_info (
            blkio_dev_t * dev,
            blkio_info_t * out )  [static]
```

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, VirtBlkState::capacity_sectors, blkio_info_t::forth_block_size, blkio_info_t::phys_sector_size, blkio_info_t::phys_size_bytes, blkio_info_t::read_only, blkio_dev::state, blkio_info_t::total_blocks, VirtBlkState::total_forth_blocks, and VBLK_SECTOR_SIZE.

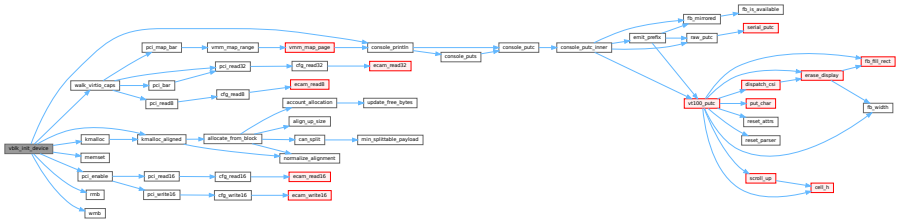
7.178.2.5 vblk_init_device()

```
static int vblk_init_device (
            const PciDevice * pci )  [static]
```

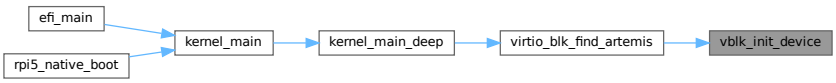
References VirtBlkState::avail, VirtBlkState::avail_idx, BLKIO_FORTH_BLOCK_SIZE, VirtBlkState::capacity_sectors, VirtBlkState::common, VirtioCommonCfg::config_msix_vector, console_println(), VirtBlkState::data_buf, VirtBlkState::desc, VirtioCommonCfg::device_status, VirtioCommonCfg::driver_feature, VirtioCommonCfg::driver_feature_select, g_vblk, kmalloc(), kmalloc_aligned(), VirtBlkState::last_used_idx, memset(), VirtBlkState::notify, VirtBlkState::notify_off_mult, pci_enable(), VirtioCommonCfg::queue_desc, VirtioCommonCfg::queue_device, VirtioCommonCfg::queue_driver, VirtioCommonCfg::queue_enable, VirtioCommonCfg::queue_msix_vector, VirtioCommonCfg::queue_notify_off, VirtBlkState::queue_notify_off, VirtioCommonCfg::queue_select, VirtioCommonCfg::queue_size, VirtBlkState::req_buf, rmb(), VirtBlkState::status_buf, VirtBlkState::total_forth_blocks, VirtBlkState::used, VBLK_ARTEMIS_SECTORS, VBLK_SECTORS_PER_BLOK, VIRTIO_F_VERSION_1, VIRTIO_PCI_CAP_COMMON_CFG, VIRTIO_PCI_CAP_DEVICE_CFG, VIRTIO_PCI_CAP_NOTIFY_CFG, VIRTIO_STATUS_ACKNOWLEDGE, VIRTIO_STATUS_DRIVER, VIRTIO_STATUS_DRIVER_OK, VIRTIO_STATUS_FAILED, VIRTIO_STATUS_FEATURES_OK, VQUEUE_SIZE, walk_virtio_caps(), and wmb().

Referenced by virtio_blk_find_artemis().

Here is the call graph for this function:



Here is the caller graph for this function:



7.178.2.6 vblk_io()

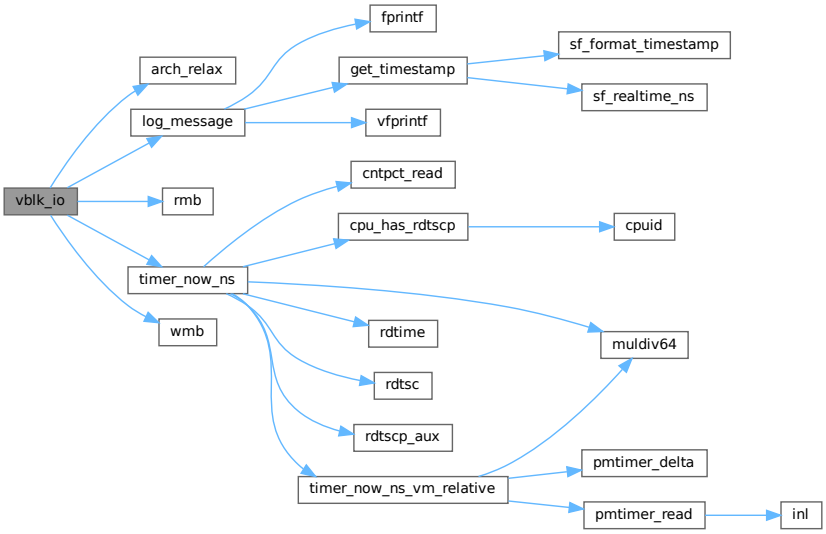
```
static int vblk_io (
            int write,
            uint64_t sector,
            void * buf,
            uint32_t nbytes )  [static]
```

References VirtqDesc::addr, arch_relax(), VirtBlkState::avail, VirtBlkState::avail_idx, BLKIO_EIO, BLKIO_OK, VirtBlkState::desc, VirtqDesc::flags, g_vblk, g_vblk_dead, VirtqAvail::idx, VirtqUsed::idx, VirtBlkState::last_used_idx, VirtqDesc::len, LOG_ERROR, log_message(), VirtqDesc::next, VirtBlkState::notify, VirtBlkState::notify_off_mult, VirtBlkState::queue_notify_off, VirtBlkState::req_buf, VirtBlkReq::reserved, VirtqAvail::ring, rmb(), VirtBlkReq::sector, VirtBlkState::status_buf, timer_now_ns(), VirtBlkReq::type, VirtBlkState::used, VBLK_IO_TIMEOUT_NS,

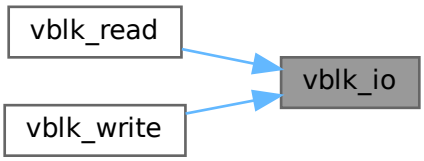
VIRTIO_BLK_S_OK, VIRTIO_BLK_T_IN, VIRTIO_BLK_T_OUT, VQUEUE_SIZE, VRING_DESC_F_NEXT, VRING_DESC_F_WRITE, and wmb().

Referenced by vblk_read(), and vblk_write().

Here is the call graph for this function:



Here is the caller graph for this function:



7.178.2.7 vblk_open()

```
static int vblk_open (
            blkio_dev_t * dev,
            const blkio_params_t * p )  [static]
```

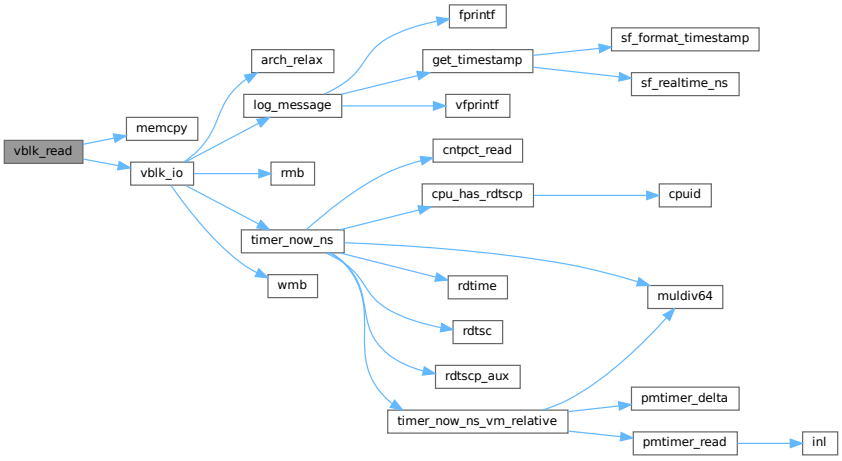
References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_dev::forth_block_size, g_vblk, blkio_dev::state, blkio_dev::total_blocks, and VirtBlkState::total_forth_blocks.

7.178.2.8 vblk_read()

```
static int vblk_read (
            blkio_dev_t * dev,
            uint32_t fblock,
            void * dst )  [static]
```

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, VirtBlkState::data_buf, memcpy(), blkio_dev::state, VirtBlkState::total_forth_blocks, vblk_io(), and VBLK_SECTORS_PER_BLOK.

Here is the call graph for this function:

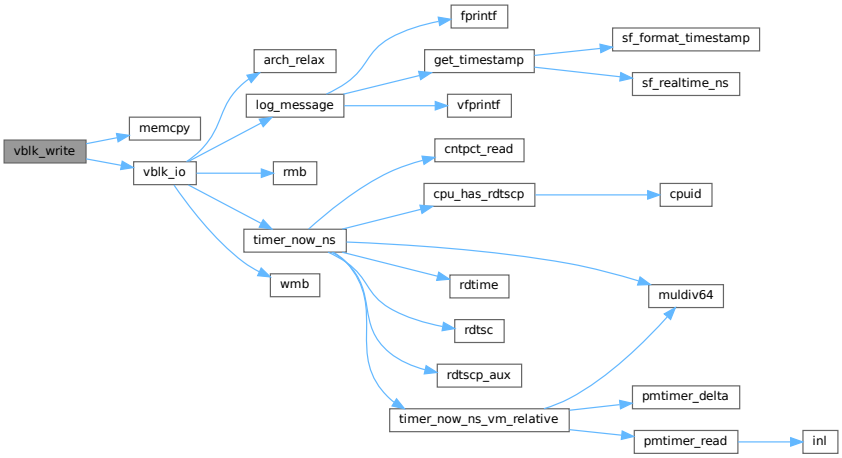


7.178.2.9 vblk_write()

```
static int vblk_write (
            blkio_dev_t * dev,
            uint32_t fblock,
            const void * src )  [static]
```

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, VirtBlkState::data_buf, memcpy(), blkio_dev::state, VirtBlkState::total_forth_blocks, vblk_io(), and VBLK_SECTORS_PER_BLOK.

Here is the call graph for this function:



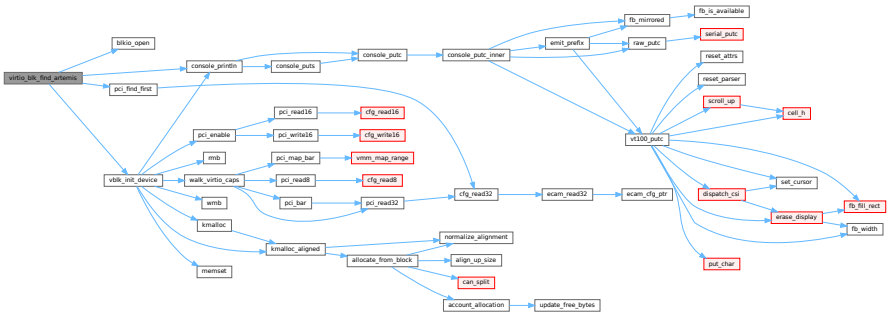
7.178.2.10 virtio_blk_find_artemis()

```
int virtio_blk_find_artemis (
            blkio_dev_t * dev_out )
```

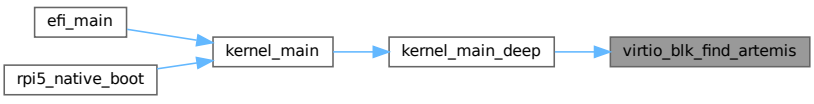
References BLKIO_FORTH_BLOCK_SIZE, blkio_open(), console_println(), blkio_params_t::forth_block_size, g_vblk, g_vblk_ready, g_vblk_vtable, blkio_params_t::opaque, pci_find_first(), blkio_params_t::total_blocks, VirtBlkState::total_forth_blocks, vblk_init_device(), VIRTIO_BLK_DEVICE_LEGACY, VIRTIO_BLK_DEVICE_MODERN, and VIRTIO_PCI_VENDOR_ID.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



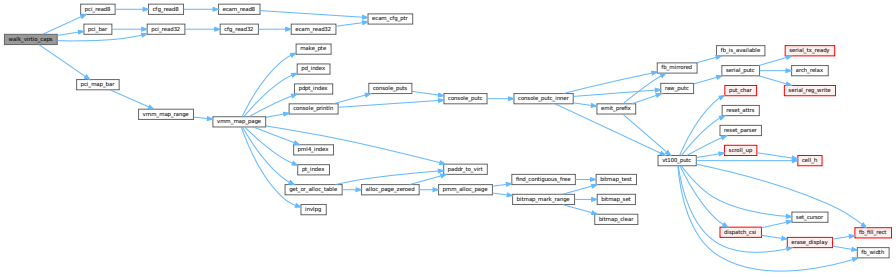
7.178.2.11 walk_virtio_caps()

```
static void * walk_virtio_caps (
            const PciDevice * d,
            uint8_t cap_type,
            uint32_t * extra_out )  [static]
```

References limit, pci_bar(), PCI_CFG_CAP_PTR, pci_map_bar(), pci_read32(), pci_read8(), VCAP_OFF_BAR, VCAP_OFF_CAP_NEXT, VCAP_OFF_CAP_VNDR, VCAP_OFF_CFG_TYPE, VCAP_OFF_LENGTH, VCAP_OFF_NOTIFY_MULT, VCAP_OFF_OFFSET, VIRTIO_PCI_CAP_NOTIFY_CFG, and VIRTIO_PCI_CAP_VENDOR_ID.

Referenced by vblk_init_device().

Here is the call graph for this function:



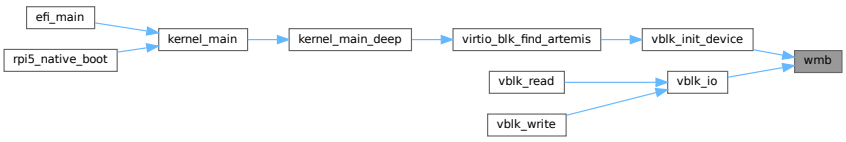
Here is the caller graph for this function:

7.178.2.12 wmb()

```
static void wmb (
            void  )  [inline], [static]
```

Referenced by vblk_init_device(), and vblk_io().

Here is the caller graph for this function:



7.178.3 Variable Documentation

7.178.3.1 g_vblk

```
VirtBlkState g_vblk  [static]
```

Referenced by vblk_init_device(), vblk_io(), vblk_open(), and virtio_blk_find_artemis().

7.178.3.2 g_vblk_dead

```
int g_vblk_dead = 0  [static]
```

Referenced by vblk_io().

7.178.3.3 g_vblk_ready

```
int g_vblk_ready = 0  [static]
```

Referenced by virtio_blk_find_artemis().

7.178.3.4 g_vblk_vtable

```
const blkio_vtable_t g_vblk_vtable  [static]
```

Initial value:

```
= {
    .open  = vblk_open,
    .close = vblk_close,
    .read  = vblk_read,
    .write = vblk_write,
    .flush = vblk_flush,
    .info  = vblk_info
}
```

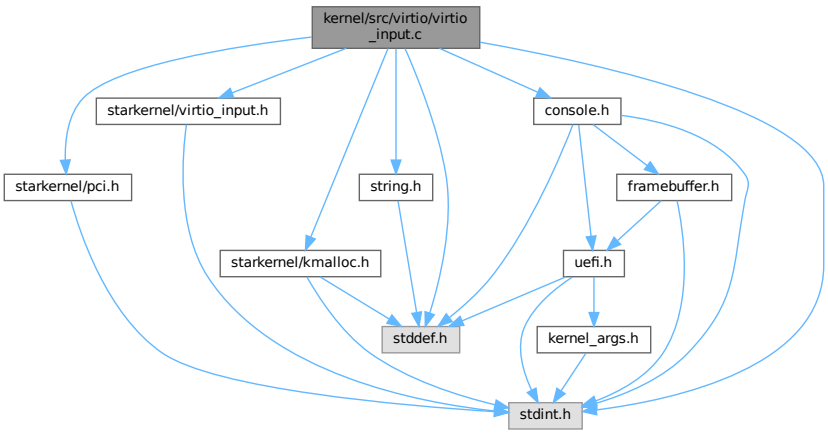
Referenced by virtio_blk_find_artemis().

7.179 kernel/src/virtio/virtio_input.c File Reference

```
#include <stddef.h>
#include <stdint.h>
#include <string.h>
#include "starkernel/pci.h"
#include "starkernel/virtio_input.h"
#include "starkernel/kmalloc.h"
```

```
#include "console.h"
```

Include dependency graph for virtio_input.c:



Data Structures

- struct VirtioCommonCfg
- struct VirtqDesc
- struct VirtqAvail
- struct VirtqUsedElem
- struct VirtqUsed
- struct DiagEvent
- struct VirtInputState

Macros

- #define VIRTIO_PCI_CAP_VENDOR_ID 0x09u
- #define VIRTIO_PCI_CAP_COMMON_CFG 1u
- #define VIRTIO_PCI_CAP_NOTIFY_CFG 2u
- #define VIRTIO_PCI_CAP_ISR_CFG 3u
- #define VCAP_OFF_CAP_VNDR 0u
- #define VCAP_OFF_CAP_NEXT 1u
- #define VCAP_OFF_CFG_TYPE 3u
- #define VCAP_OFF_BAR 4u
- #define VCAP_OFF_OFFSET 8u
- #define VCAP_OFF_LENGTH 12u
- #define VCAP_OFF_NOTIFY_MULT 16u
- #define VIRTIO_STATUS_ACKNOWLEDGE 0x01u
- #define VIRTIO_STATUS_DRIVER 0x02u
- #define VIRTIO_STATUS_DRIVER_OK 0x04u
- #define VIRTIO_STATUS_FEATURES_OK 0x08u
- #define VIRTIO_STATUS_FAILED 0x80u
- #define VIRTIO_F_VERSION_1 (1ULL << 32)
- #define EVENTQ_SIZE 8u /* power of 2; headroom for several queued events */
- #define VRING_DESC_F_WRITE 2u
- #define DIAG_RING_SIZE 16u

Functions

- static void diag_push (uint16_t code, uint32_t value)
- int virtio_input_pop_event (uint16_t *code, uint32_t *value)
- static void * walk_virtio_caps (const PciDevice *d, uint8_t cap_type, uint32_t *extra_out)
- static void wmb (void)
- static int enable_interrupt_route (const PciDevice *pci)
- static int vinput_init_device (const PciDevice *pci)
- int virtio_input_find_keyboard (void)
- void virtio_input_isr (void)

Variables

- static DiagEvent g_diag_ring [16u]
- static volatile uint32_t g_diag_head = 0
- static volatile uint32_t g_diag_tail = 0
- volatile uint32_t g_virtio_input_isr_count = 0
- static VirtInputState g_vinput
- static int g_vinput_ready = 0
- uint32_t g_virtio_input_plic_source = 0
- uint32_t g_virtio_input_gic_intid = 0

7.179.1 Macro Definition Documentation

7.179.1.1 DIAG_RING_SIZE

```
#define DIAG_RING_SIZE 16u
```

7.179.1.2 EVENTQ_SIZE

```
#define EVENTQ_SIZE 8u /* power of 2; headroom for several queued events */
```

7.179.1.3 VCAP_OFF_BAR

```
#define VCAP_OFF_BAR 4u
```

7.179.1.4 VCAP_OFF_CAP_NEXT

```
#define VCAP_OFF_CAP_NEXT 1u
```

7.179.1.5 VCAP_OFF_CAP_VNDR

```
#define VCAP_OFF_CAP_VNDR 0u
```

7.179.1.6 VCAP_OFF_CFG_TYPE

```
#define VCAP_OFF_CFG_TYPE 3u
```

7.179.1.7 VCAP_OFF_LENGTH

```
#define VCAP_OFF_LENGTH 12u
```

7.179.1.8 VCAP_OFF_NOTIFY_MULT

```
#define VCAP_OFF_NOTIFY_MULT 16u
```

7.179.1.9 VCAP_OFF_OFFSET

```
#define VCAP_OFF_OFFSET 8u
```

7.179.1.10 VIRTIO_F_VERSION_1

```
#define VIRTIO_F_VERSION_1 (1ULL << 32)
```

7.179.1.11 VIRTIO_PCI_CAP_COMMON_CFG

```
#define VIRTIO_PCI_CAP_COMMON_CFG 1u
```

7.179.1.12 VIRTIO_PCI_CAP_ISR_CFG

```
#define VIRTIO_PCI_CAP_ISR_CFG 3u
```

7.179.1.13 VIRTIO_PCI_CAP_NOTIFY_CFG

```
#define VIRTIO_PCI_CAP_NOTIFY_CFG 2u
```

7.179.1.14 VIRTIO_PCI_CAP_VENDOR_ID

```
#define VIRTIO_PCI_CAP_VENDOR_ID 0x09u
```

7.179.1.15 VIRTIO_STATUS_ACKNOWLEDGE

```
#define VIRTIO_STATUS_ACKNOWLEDGE 0x01u
```

7.179.1.16 VIRTIO_STATUS_DRIVER

```
#define VIRTIO_STATUS_DRIVER 0x02u
```

7.179.1.17 VIRTIO_STATUS_DRIVER_OK

```
#define VIRTIO_STATUS_DRIVER_OK 0x04u
```

7.179.1.18 VIRTIO_STATUS_FAILED

```
#define VIRTIO_STATUS_FAILED 0x80u
```

7.179.1.19 VIRTIO_STATUS_FEATURES_OK

```
#define VIRTIO_STATUS_FEATURES_OK 0x08u
```

7.179.1.20 VRING_DESC_F_WRITE

```
#define VRING_DESC_F_WRITE 2u
```

7.179.2 Function Documentation

7.179.2.1 diag_push()

```
static void diag_push (
            uint16_t code,
            uint32_t value )  [static]
```

References DiagEvent::code, DIAG_RING_SIZE, g_diag_head, g_diag_ring, g_diag_tail, and DiagEvent::value.

Referenced by virtio_input_isr().

Here is the caller graph for this function:

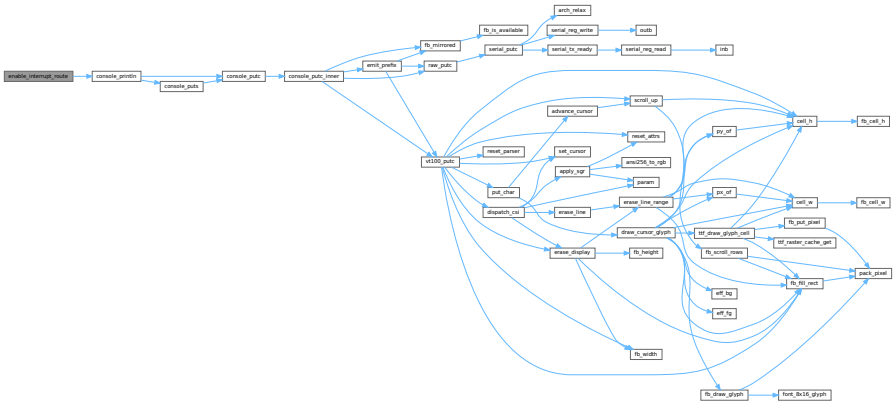
7.179.2.2 enable_interrupt_route()

```
static int enable_interrupt_route (
            const PciDevice * pci )  [static]
```

References console_println().

Referenced by vinput_init_device().

Here is the call graph for this function:



Here is the caller graph for this function:

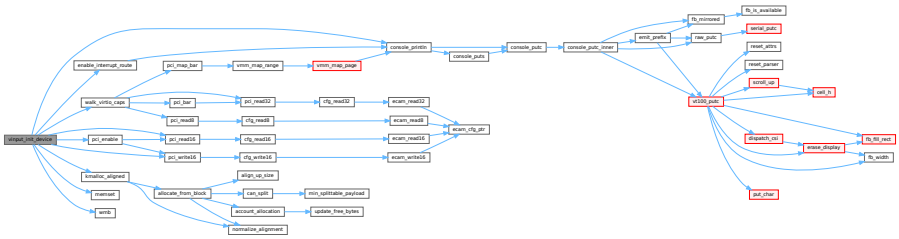
7.179.2.3 vinput_init_device()

```
static int vinput_init_device (
            const PciDevice * pci )  [static]
```

References VirtqDesc::addr, VirtInputState::avail, VirtInputState::avail_idx, VirtInputState::bufs, VirtInputState::common, VirtioCommonCfg::config_msix_vector, console_println(), VirtInputState::desc, VirtioCommonCfg::device_status, VirtioCommonCfg::driver_feature, VirtioCommonCfg::driver_feature_select, enable_interrupt_route(), EVENTQ_SIZE, VirtqDesc::flags, g_vinput, VirtqAvail::idx, VirtInputState::isr_status, kmalloc_aligned(), VirtInputState::last_used_idx, VirtqDesc::len, memset(), VirtqDesc::next, VirtInputState::notify, VirtInputState::notify_off_mult, VirtioCommonCfg::num_queues, PCI_CFG_COMMAND, PCI_CMD_INTX_DISABLE, pci_enable(), pci_read16(), pci_write16(), VirtioCommonCfg::queue_desc, VirtioCommonCfg::queue_device, VirtioCommonCfg::queue_driver, VirtioCommonCfg::queue_enable, VirtioCommonCfg::queue_ms VirtioCommonCfg::queue_notify_off, VirtInputState::queue_notify_off, VirtioCommonCfg::queue_select, VirtioCommonCfg::queue_si VirtqAvail::ring, VirtInputState::used, VIRTIO_F_VERSION_1, VIRTIO_PCI_CAP_COMMON_CFG, VIRTIO_PCI_CAP_ISR_CFG, VIRTIO_PCI_CAP_NOTIFY_CFG, VIRTIO_STATUS_ACKNOWLEDGE, VIRTIO_STATUS_DRIVER, VIRTIO_STATUS_DRIVER_OK, VIRTIO_STATUS_FAILED, VIRTIO_STATUS_FEATURES_OK, VRING_DESC_F_WRITE, walk_virtio_caps(), and wmb().

Referenced by virtio_input_find_keyboard().

Here is the call graph for this function:



Here is the caller graph for this function:

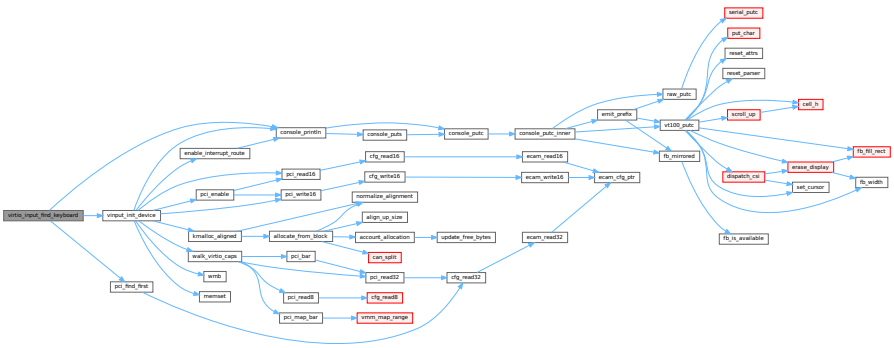
7.179.2.4 virtio_input_find_keyboard()

```
int virtio_input_find_keyboard (
            void  )
```

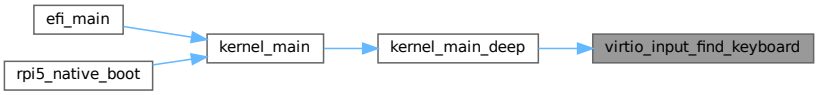
References console_println(), g_vinput_ready, pci_find_first(), vinput_init_device(), VIRTIO_INPUT_PCI_DEVICE_ID, and VIRTIO_INPUT_PCI_VENDOR_ID.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



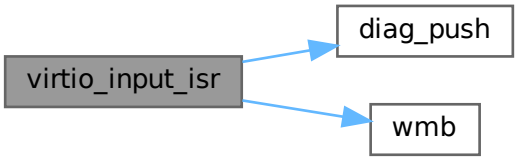
7.179.2.5 virtio_input_isr()

```
void virtio_input_isr (
            void  )
```

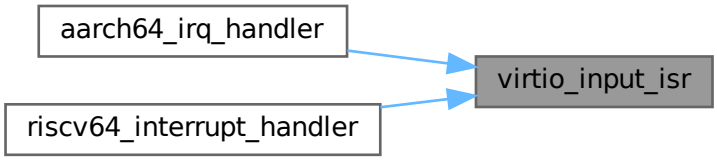
References VirtInputState::avail, VirtInputState::avail_idx, VirtInputState::bufs, VirtioInputEvent::code, diag_push(), EVENTQ_SIZE, g_vinput, g_vinput_ready, g_virtio_input_isr_count, VirtqUsedElem::id, VirtqAvail::idx, VirtqUsed::idx, VirtInputState::isr_status, VirtInputState::last_used_idx, VirtInputState::notify, VirtInputState::notify_off_mult, VirtInputState::queue_notify_off, VirtqAvail::ring, VirtqUsed::ring, VirtioInputEvent::type, VirtInputState::used, VirtioInputEvent::value, VIRTIO_INPUT_EV_KEY, and wmb().

Referenced by aarch64_irq_handler(), and riscv64_interrupt_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



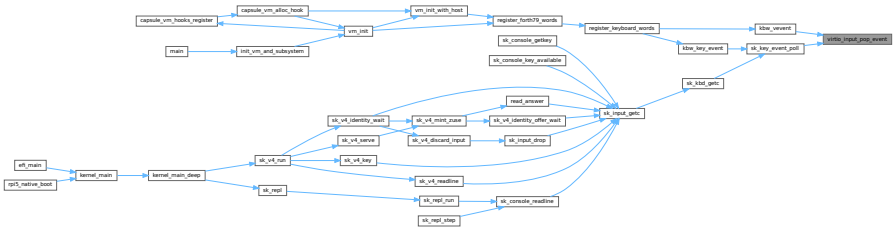
7.179.2.6 virtio_input_pop_event()

```
int virtio_input_pop_event (
            uint16_t * code,
            uint32_t * value )
```

References DiagEvent::code, DIAG_RING_SIZE, g_diag_head, g_diag_ring, g_diag_tail, and DiagEvent::value.

Referenced by kbw_vevent(), and sk_key_event_poll().

Here is the caller graph for this function:



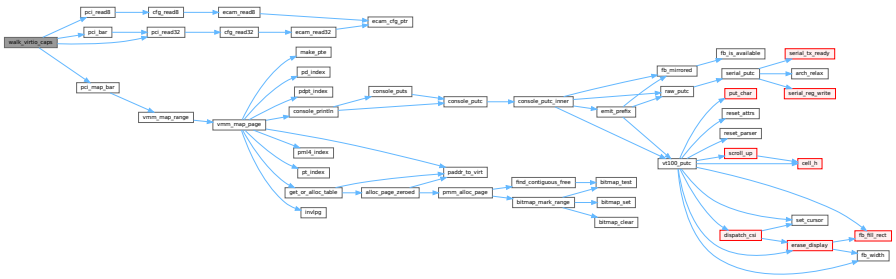
7.179.2.7 walk_virtio_caps()

```
static void * walk_virtio_caps (
            const PciDevice * d,
            uint8_t cap_type,
            uint32_t * extra_out )  [static]
```

References limit, pci_bar(), PCI_CFG_CAP_PTR, pci_map_bar(), pci_read32(), pci_read8(), VCAP_OFF_BAR, VCAP_OFF_CAP_NEXT, VCAP_OFF_CAP_VNDR, VCAP_OFF_CFG_TYPE, VCAP_OFF_LENGTH, VCAP_OFF_NOTIFY_MULT, VCAP_OFF_OFFSET, VIRTIO_PCI_CAP_NOTIFY_CFG, and VIRTIO_PCI_CAP_VENDOR_ID.

Referenced by vinput_init_device().

Here is the call graph for this function:



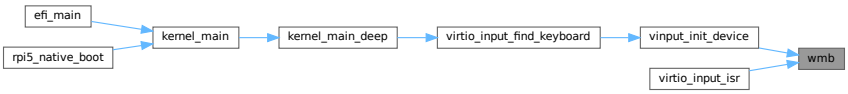
Here is the caller graph for this function:

7.179.2.8 wmb()

```
static void wmb (
            void  )  [inline], [static]
```

Referenced by vinput_init_device(), and virtio_input_isr().

Here is the caller graph for this function:



7.179.3 Variable Documentation

7.179.3.1 g_diag_head

```
volatile uint32_t g_diag_head = 0  [static]
```

Referenced by diag_push(), and virtio_input_pop_event().

7.179.3.2 g_diag_ring

```
DiagEvent g_diag_ring[16u]  [static]
```

Referenced by diag_push(), and virtio_input_pop_event().

7.179.3.3 g_diag_tail

```
volatile uint32_t g_diag_tail = 0  [static]
```

Referenced by diag_push(), and virtio_input_pop_event().

7.179.3.4 g_vinput

```
VirtInputState g_vinput  [static]
```

Referenced by vinput_init_device(), and virtio_input_isr().

7.179.3.5 g_vinput_ready

```
int g_vinput_ready = 0  [static]
```

Referenced by virtio_input_find_keyboard(), and virtio_input_isr().

7.179.3.6 g_virtio_input_gic_intid

```
uint32_t g_virtio_input_gic_intid = 0
```

Referenced by aarch64_irq_handler().

7.179.3.7 g_virtio_input_isr_count

```
volatile uint32_t g_virtio_input_isr_count = 0
```

Referenced by kbw_vdebug(), and virtio_input_isr().

7.179.3.8 g_virtio_input_plic_source

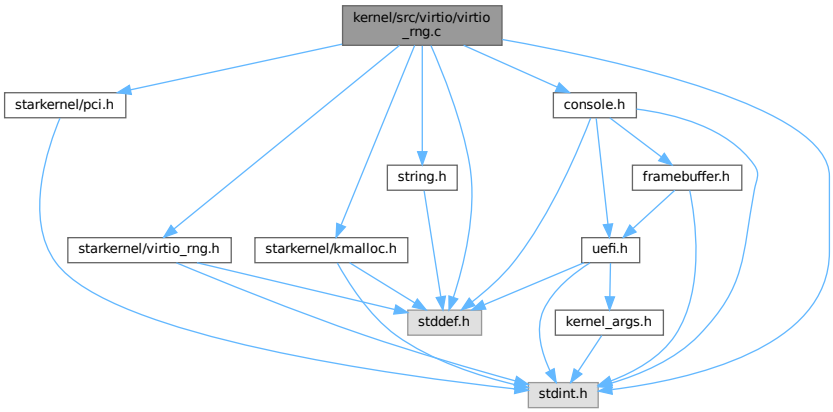
```
uint32_t g_virtio_input_plic_source = 0
```

Referenced by riscv64_interrupt_handler().

7.180 kernel/src/virtio/virtio_rng.c File Reference

```
#include <stddef.h>
#include <stdint.h>
#include <string.h>
#include "starkernel/pci.h"
#include "starkernel/virtio_rng.h"
#include "starkernel/kmalloc.h"
#include "console.h"
```

Include dependency graph for virtio_rng.c:



Data Structures

- struct VirtioCommonCfg
- struct VirtqDesc
- struct VirtqAvail
- struct VirtqUsedElem
- struct VirtqUsed
- struct VirtRngState

Macros

- #define VIRTIO_PCI_CAP_VENDOR_ID 0x09u
- #define VIRTIO_PCI_CAP_COMMON_CFG 1u
- #define VIRTIO_PCI_CAP_NOTIFY_CFG 2u
- #define VCAP_OFF_CAP_VNDR 0u
- #define VCAP_OFF_CAP_NEXT 1u
- #define VCAP_OFF_CFG_TYPE 3u
- #define VCAP_OFF_BAR 4u
- #define VCAP_OFF_OFFSET 8u
- #define VCAP_OFF_LENGTH 12u
- #define VCAP_OFF_NOTIFY_MULT 16u
- #define VIRTIO_STATUS_ACKNOWLEDGE 0x01u
- #define VIRTIO_STATUS_DRIVER 0x02u
- #define VIRTIO_STATUS_DRIVER_OK 0x04u
- #define VIRTIO_STATUS_FEATURES_OK 0x08u
- #define VIRTIO_STATUS_FAILED 0x80u
- #define VIRTIO_F_VERSION_1 (1ULL << 32)
- #define VQUEUE_SIZE 1u
- #define VRING_DESC_F_WRITE 2u
- #define VRNG_BUF_SIZE 64u /* bytes requested from the device per round */

Functions

- static void * walk_virtio_caps (const PciDevice *d, uint8_t cap_type, uint32_t *extra_out)
- static void wmb (void)
- static void rmb (void)
- static int vrng_request (uint32_t *bytes_out)
- static int vrng_init_device (const PciDevice *pci)
- int virtio_rng_init (void)
- int virtio_rng_ready (void)
- int virtio_rng_get_bytes (uint8_t *buf, size_t n)

Variables

- static VirtRngState g_vrng
- static int g_vrng_ready = 0

7.180.1 Macro Definition Documentation

7.180.1.1 VCAP_OFF_BAR

```
#define VCAP_OFF_BAR 4u
```

7.180.1.2 VCAP_OFF_CAP_NEXT

```
#define VCAP_OFF_CAP_NEXT 1u
```

7.180.1.3 VCAP_OFF_CAP_VNDR

```
#define VCAP_OFF_CAP_VNDR 0u
```

7.180.1.4 VCAP_OFF_CFG_TYPE

```
#define VCAP_OFF_CFG_TYPE 3u
```

7.180.1.5 VCAP_OFF_LENGTH

```
#define VCAP_OFF_LENGTH 12u
```

7.180.1.6 VCAP_OFF_NOTIFY_MULT

```
#define VCAP_OFF_NOTIFY_MULT 16u
```

7.180.1.7 VCAP_OFF_OFFSET

```
#define VCAP_OFF_OFFSET 8u
```

7.180.1.8 VIRTIO_F_VERSION_1

```
#define VIRTIO_F_VERSION_1 (1ULL << 32)
```

7.180.1.9 VIRTIO_PCI_CAP_COMMON_CFG

```
#define VIRTIO_PCI_CAP_COMMON_CFG 1u
```

7.180.1.10 VIRTIO_PCI_CAP_NOTIFY_CFG

```
#define VIRTIO_PCI_CAP_NOTIFY_CFG 2u
```

7.180.1.11 VIRTIO_PCI_CAP_VENDOR_ID

```
#define VIRTIO_PCI_CAP_VENDOR_ID 0x09u
```

7.180.1.12 VIRTIO_STATUS_ACKNOWLEDGE

```
#define VIRTIO_STATUS_ACKNOWLEDGE 0x01u
```

7.180.1.13 VIRTIO_STATUS_DRIVER

```
#define VIRTIO_STATUS_DRIVER 0x02u
```

7.180.1.14 VIRTIO_STATUS_DRIVER_OK

```
#define VIRTIO_STATUS_DRIVER_OK 0x04u
```

7.180.1.15 VIRTIO_STATUS_FAILED

```
#define VIRTIO_STATUS_FAILED 0x80u
```

7.180.1.16 VIRTIO_STATUS_FEATURES_OK

```
#define VIRTIO_STATUS_FEATURES_OK 0x08u
```

7.180.1.17 VQUEUE_SIZE

```
#define VQUEUE_SIZE 1u
```

7.180.1.18 VRING_DESC_F_WRITE

```
#define VRING_DESC_F_WRITE 2u
```

7.180.1.19 VRNG_BUF_SIZE

```
#define VRNG_BUF_SIZE 64u /* bytes requested from the device per round */
```

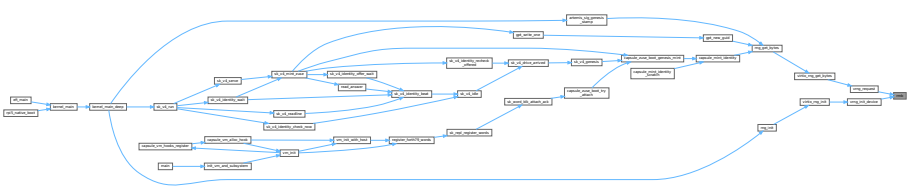
7.180.2 Function Documentation

7.180.2.1 rmb()

```
static void rmb (
            void  )  [inline], [static]
```

Referenced by vrng_init_device(), and vrng_request().

Here is the caller graph for this function:



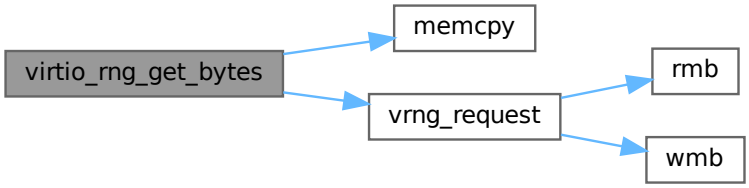
7.180.2.2 virtio_rng_get_bytes()

```
int virtio_rng_get_bytes (
            uint8_t * buf,
            size_t n )
```

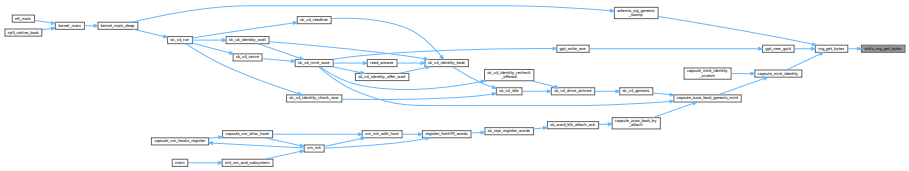
References VirtRngState::data_buf, g_vrng, g_vrng_ready, memcpy(), and vrng_request().

Referenced by rng_get_bytes().

Here is the call graph for this function:



Here is the caller graph for this function:



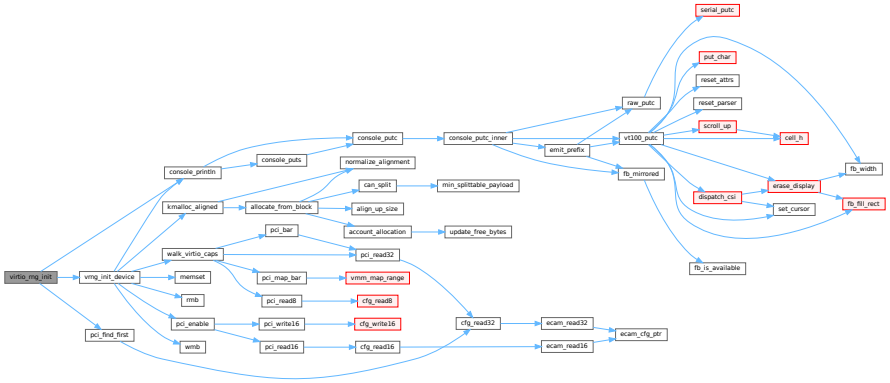
7.180.2.3 virtio_rng_init()

```
int virtio_rng_init (
            void  )
```

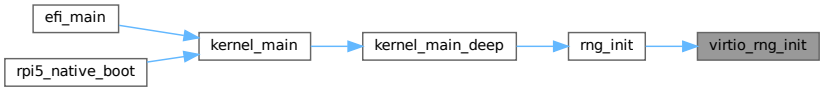
References console_println(), g_vrng_ready, pci_find_first(), VIRTIO_RNG_DEVICE_LEGACY, VIRTIO_RNG_DEVICE_MODERN, VIRTIO_RNG_PCI_VENDOR_ID, and vrng_init_device().

Referenced by rng_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.180.2.4 virtio_rng_ready()

```
int virtio_rng_ready (
            void  )
```

References g_vrng_ready.

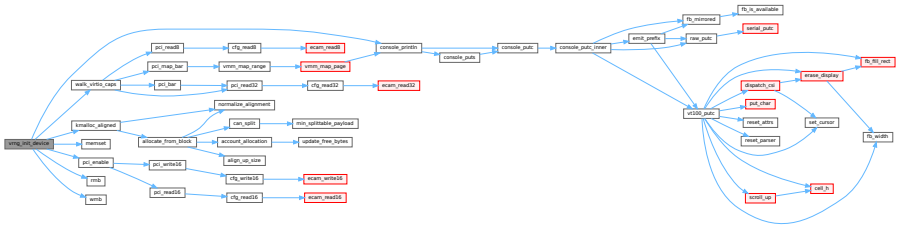
7.180.2.5 vrng_init_device()

```
static int vrng_init_device (
            const PciDevice * pci )  [static]
```

References VirtRngState::avail, VirtRngState::avail_idx, VirtRngState::common, VirtioCommonCfg::config_msix_vector, console_println(), VirtRngState::data_buf, VirtRngState::desc, VirtioCommonCfg::device_status, VirtioCommonCfg::driver_feature, VirtioCommonCfg::driver_feature_select, g_vrng, kmalloc_aligned(), VirtRngState::last_used_idx, memset(), VirtRngState::notify, VirtRngState::notify_off_mult, pci_enable(), VirtioCommonCfg::queue_desc, VirtioCommonCfg::queue_device, VirtioCommonCfg::queue_driver, VirtioCommonCfg::queue_enable, VirtioCommonCfg::queue_msix_vector, VirtioCommonCfg::queue_notify_off, VirtRngState::queue_notify_off, VirtioCommonCfg::queue_select, VirtioCommonCfg::queue_siz rmb(), VirtRngState::used, VIRTIO_F_VERSION_1, VIRTIO_PCI_CAP_COMMON_CFG, VIRTIO_PCI_CAP_NOTIFY_CFG, VIRTIO_STATUS_ACKNOWLEDGE, VIRTIO_STATUS_DRIVER, VIRTIO_STATUS_DRIVER_OK, VIRTIO_STATUS_FAILED, VIRTIO_STATUS_FEATURES_OK, VQUEUE_SIZE, VRNG_BUF_SIZE, walk_virtio_caps(), and wmb().

Referenced by virtio_rng_init().

Here is the call graph for this function:



Here is the caller graph for this function:

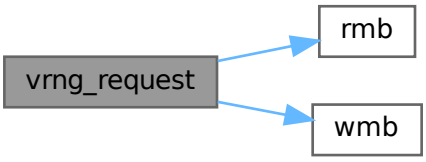
7.180.2.6 vrng_request()

```
static int vrng_request (
            uint32_t * bytes_out ) [static]
```

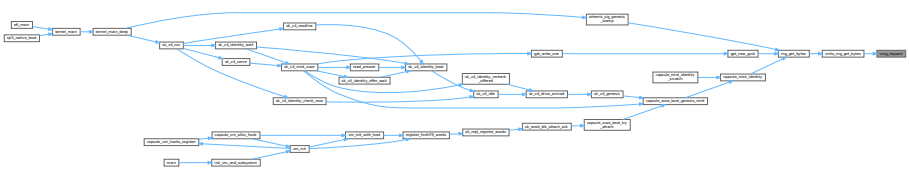
References VirtqDesc::addr, VirtRngState::avail, VirtRngState::avail_idx, VirtRngState::data_buf, VirtRngState::desc, VirtqDesc::flags, g_vrng, VirtqAvail::idx, VirtqUsed::idx, VirtRngState::last_used_idx, VirtqDesc::len, VirtqUsedElem::len, VirtqDesc::next, VirtRngState::notify, VirtRngState::notify_off_mult, VirtRngState::queue_notify_off, VirtqAvail::ring, VirtqUsed::ring, rmb(), VirtRngState::used, VQUEUE_SIZE, VRING_DESC_F_WRITE, VRNG_BUF_SIZE, and wmb().

Referenced by virtio_rng_get_bytes().

Here is the call graph for this function:



Here is the caller graph for this function:



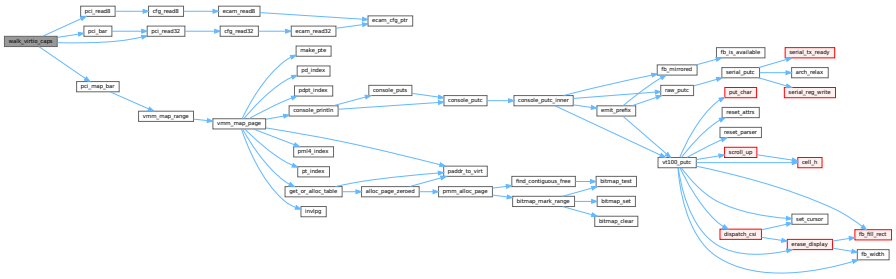
7.180.2.7 walk_virtio_caps()

```
static void * walk_virtio_caps (
            const PciDevice * d,
            uint8_t cap_type,
            uint32_t * extra_out )  [static]
```

References limit, pci_bar(), PCI_CFG_CAP_PTR, pci_map_bar(), pci_read32(), pci_read8(), VCAP_OFF_BAR, VCAP_OFF_CAP_NEXT, VCAP_OFF_CAP_VNDR, VCAP_OFF_CFG_TYPE, VCAP_OFF_LENGTH, VCAP_OFF_NOTIFY_MULT, VCAP_OFF_OFFSET, VIRTIO_PCI_CAP_NOTIFY_CFG, and VIRTIO_PCI_CAP_VENDOR_ID.

Referenced by vrng_init_device().

Here is the call graph for this function:



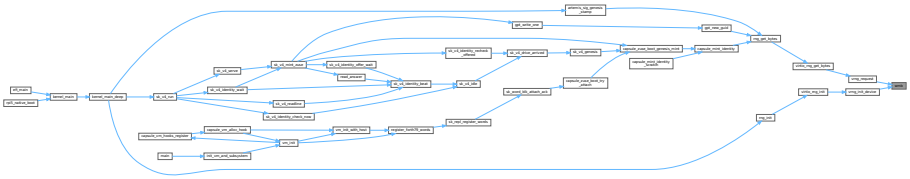
Here is the caller graph for this function:

7.180.2.8 wmb()

```
static void wmb (
            void  )  [inline], [static]
```

Referenced by vrng_init_device(), and vrng_request().

Here is the caller graph for this function:



7.180.3 Variable Documentation

7.180.3.1 g_vrng

```
VirtRngState g_vrng  [static]
```

Referenced by virtio_rng_get_bytes(), vrng_init_device(), and vrng_request().

7.180.3.2 g_vrng_ready

```
int g_vrng_ready = 0  [static]
```

Referenced by virtio_rng_get_bytes(), virtio_rng_init(), and virtio_rng_ready().

7.181 kernel/src/vm/arena.c File Reference

7.182 kernel/src/vm/bootstrap/sk_vm_bootstrap.c File Reference

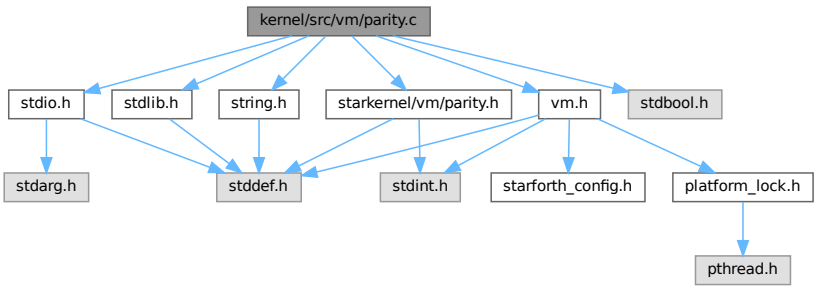
7.183 kernel/src/vm/host/shim.c File Reference

7.184 kernel/src/vm/kernel_hermes.c File Reference

7.185 kernel/src/vm/parity.c File Reference

```
#include "starkernel/vm/parity.h"
#include "vm.h"
#include <stdio.h>
#include <stdlib.h>
#include <stdbool.h>
#include <string.h>
```

Include dependency graph for parity.c:



Macros

- #define SK_PARITY_DEBUG 0

  parity.c - Parity packet collection and canonical hash
- #define sk_parity_debug_log_msg(msg) do { (void)(msg); } while (0)
- #define sk_parity_debug_check_ptr(vm, label, entry, idx, hptr, xt, ptr) do { (void)(vm); (void)(label); (void)(entry); (void)(idx); (void)(hptr); (void)(xt); (void)(ptr); } while (0)
- #define MAX_DICT_ENTRIES 2048

Functions

- static void print_u32 (uint32_t val)

  Print a `uint32_t` value as decimal to the kernel console or stdout.
- static void print_hex64 (uint64_t val)

  Print a `uint64_t` value as a 16-digit hex string with "0x" prefix.
- static void print_str (const char *s)

  Print a null-terminated string to the kernel console or stdout.
- static void print_nl (void)

  Print a newline to the kernel console or stdout.
- uint64_t fnv1a_64 (const uint8_t *data, size_t len, uint64_t hash)

  FNV-1a 64-bit incremental hash over a byte buffer.
- static uint64_t fnv1a_64_u8 (uint8_t byte, uint64_t hash)

  FNV-1a 64-bit incremental hash over a single byte.
- static uint64_t fnv1a_64_u32 (uint32_t val, uint64_t hash)

  FNV-1a 64-bit incremental hash over a 32-bit value (little-endian).
- uint32_t sk_dict_word_count (struct VM *vm)

  Count the number of entries in the VM dictionary.
- static uint64_t hash_colon_body (struct VM *vm, DictEntry *entry, uint32_t word_index, uint64_t hash)

  Hash the compiled body of a colon definition as a sequence of word IDs.
- uint64_t sk_dict_canonical_hash (struct VM *vm)

  Compute the canonical FNV-1a 64-bit hash of the VM dictionary.
- void sk_parity_collect (struct VM *vm, ParityPacket *out)

  Collect M7 parity data from the VM into a `ParityPacket`.
- void sk_parity_print (const ParityPacket *pkt)

  Print a `ParityPacket` to the kernel console or stdout.

7.185.1 Macro Definition Documentation

7.185.1.1 MAX_DICT_ENTRIES

```
#define MAX_DICT_ENTRIES 2048
```

7.185.1.2 SK_PARITY_DEBUG

```
#define SK_PARITY_DEBUG 0
```

parity.c - Parity packet collection and canonical hash

Implements M7 parity validation for hosted vs kernel comparison.

M7 Normative Rules enforced here:

- Rule 1: word_id is monotonic creation index
- Rule 2: Colon bodies hashed as word_id sequence
- Rule 3: Dictionary traversal in creation order

7.185.1.3 sk_parity_debug_check_ptr

```
#define sk_parity_debug_check_ptr(
              vm,
              label,
              entry,
              idx,
              hptr,
              xt,
              ptr )  do { (void)(vm); (void)(label); (void)(entry); (void)(idx); (void)(hptr);
(void)(xt); (void)(ptr); } while (0)
```

7.185.1.4 sk_parity_debug_log_msg

```
#define sk_parity_debug_log_msg(
              msg ) do { (void)(msg); } while (0)
```

7.185.2 Function Documentation

7.185.2.1 fnv1a_64()

```
uint64_t fnv1a_64 (
             const uint8_t * data,
             size_t len,
             uint64_t hash )
```

FNV-1a 64-bit incremental hash over a byte buffer.

Updates a running FNV-1a hash by folding `len` bytes from `data` into `hash`. The caller supplies the current hash state so that multiple buffers can be chained: pass `FNV1A_64_OFFSET_BASIS` for the first call and the returned value as `hash` for subsequent calls.

Algorithm: for each byte `b`, `hash` ^= b then `hash` *= FNV1A_64_PRIME.

Parameters

data	Pointer to the byte buffer to hash.
len	Number of bytes to consume.
hash	Running hash state; seed with `FNV1A_64_OFFSET_BASIS`.

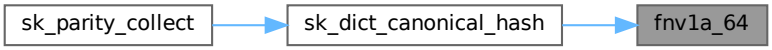
Returns

Updated hash state after processing all `len` bytes.

References FNV1A_64_PRIME.

Referenced by sk_dict_canonical_hash().

Here is the caller graph for this function:



7.185.2.2 fnv1a_64_u32()

```
static uint64_t fnv1a_64_u32 (
            uint32_t val,
            uint64_t hash )  [static]
```

FNV-1a 64-bit incremental hash over a 32-bit value (little-endian).

Folds all four bytes of `val` into `hash` in little-endian order (least-significant byte first) via four `fnv1a_64_u8()` calls. Used to hash `word_id` fields — which are `uint32_t` — into the canonical dictionary hash in a byte-order-stable way.

Parameters

val	32-bit value to hash.
hash	Running FNV-1a hash state.

Returns

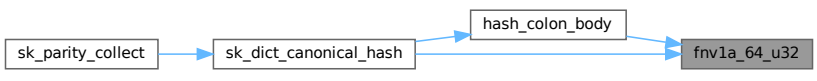
Updated hash state after consuming all four bytes.

References fnv1a_64_u8().

Referenced by hash_colon_body(), and sk_dict_canonical_hash().

Here is the call graph for this function:

Here is the caller graph for this function:



7.185.2.3 fnv1a_64_u8()

```
static uint64_t fnv1a_64_u8 (
            uint8_t byte,
            uint64_t hash )  [static]
```

FNV-1a 64-bit incremental hash over a single byte.

Convenience wrapper for folding one byte into a running FNV-1a hash state. Used by `fnv1a_64_u32()` to hash multi-byte values byte-by-byte in a defined endian order.

Parameters

byte	Single byte to fold into the hash.
hash	Running hash state.

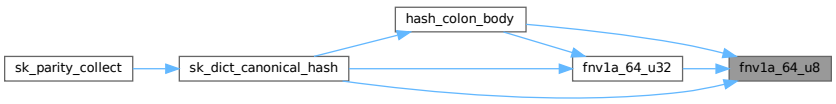
Returns

Updated hash state.

References FNV1A_64_PRIME.

Referenced by fnv1a_64_u32(), hash_colon_body(), and sk_dict_canonical_hash().

Here is the caller graph for this function:



7.185.2.4 hash_colon_body()

```
static uint64_t hash_colon_body (
            struct VM * vm,
            DictEntry * entry,
            uint32_t word_index,
            uint64_t hash )  [static]
```

Hash the compiled body of a colon definition as a sequence of word IDs.

Implements M7 Rule 2: colon bodies are hashed as their `word_id` sequence, not as raw code pointers, ensuring the hash is stable across address-space layout changes (ASLR, relocation, different build addresses).

Traversal reads each cell from the threaded body in order:

- A non-NULL `DictEntry` pointer → its `word_id` is hashed.
- An `EXIT` entry → its `word_id` is hashed and traversal stops.
- A `LIT` entry → its `word_id` is hashed and the following cell (the literal value) is hashed as eight individual bytes (little-endian).
- A `NULL` cell → traversal stops (end-of-body sentinel).

Returns `hash` unchanged if `entry` lacks the `WORD_COMPILED` flag or has no valid data-field. Capped at 1024 cells per body as a safety limit.

Parameters

vm	Active VM instance.
entry	Dictionary entry whose body will be hashed; must have `WORD_COMPILED` set.
word_index	Creation-order ordinal of `entry` (used by debug mode).
hash	Running FNV-1a hash state from the caller.

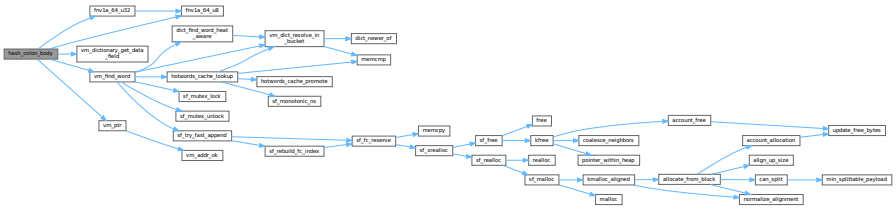
Returns

Updated hash state after processing the colon body.

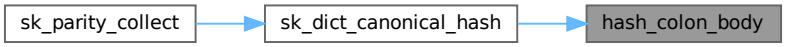
References entry, fnv1a_64_u32(), fnv1a_64_u8(), DictEntry::func, VM::memory, sk_parity_debug_check_ptr, sk_parity_debug_log_msg, vm_dictionary_get_data_field(), vm_find_word(), VM_MEMORY_SIZE, vm_ptr(), WORD_COMPILED, and DictEntry::word_id.

Referenced by sk_dict_canonical_hash().

Here is the call graph for this function:



Here is the caller graph for this function:



7.185.2.5 print_hex64()

```
static void print_hex64 (
            uint64_t val )  [static]
```

Print a `uint64_t` value as a 16-digit hex string with "0x" prefix.

Formats `val` as "0xNNNNNNNNNNNNNNNN" using a fixed-size local buffer (no libc required) and emits it via `console_puts()` in kernel builds or `printf()` in hosted builds. Used by `sk_parity_print()` to format hash and address fields in parity output lines.

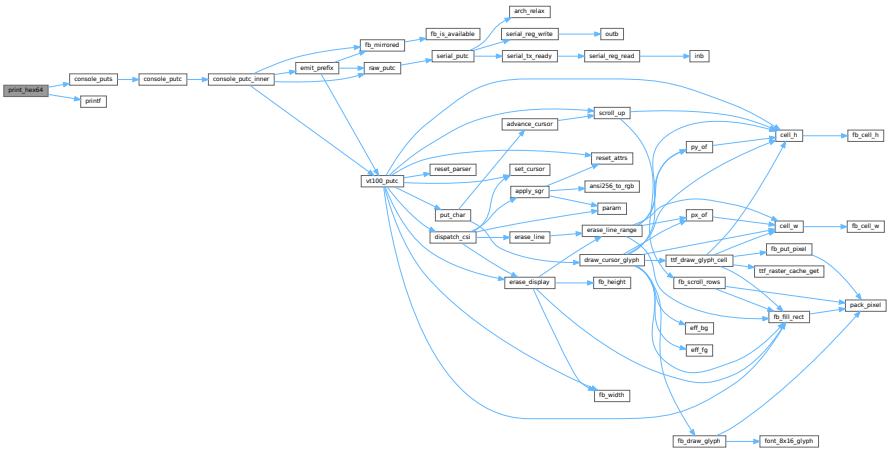
Parameters

val	64-bit value to print as lowercase hex.

References console_puts(), and printf().

Referenced by sk_parity_print().

Here is the call graph for this function:



Here is the caller graph for this function:

7.185.2.6 print_nl()

```
static void print_nl (
            void  )  [static]
```

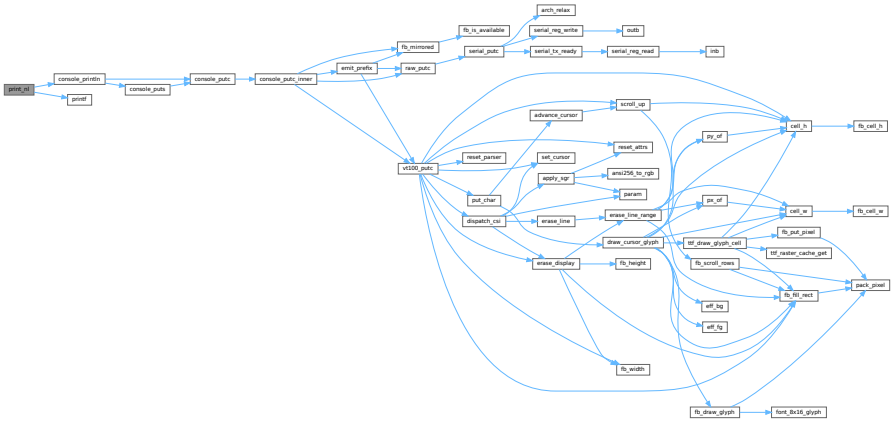
Print a newline to the kernel console or stdout.

Emits a line terminator via `console_println("")` in kernel builds or `printf("\n")` in hosted builds. Paired with `print_str()` to avoid scattering `ifdef` guards through parity formatting code.

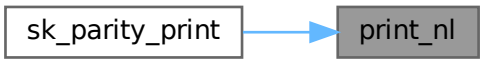
References console_println(), and printf().

Referenced by sk_parity_print().

Here is the call graph for this function:



Here is the caller graph for this function:



7.185.2.7 print_str()

```
static void print_str (
            const char * s )  [static]
```

Print a null-terminated string to the kernel console or stdout.

Emits `s` via `console_puts()` in kernel builds or `printf()` in hosted builds. Serves as a single dispatch point so parity output compiles cleanly in both environments without scattering `ifdef` guards through the formatting code.

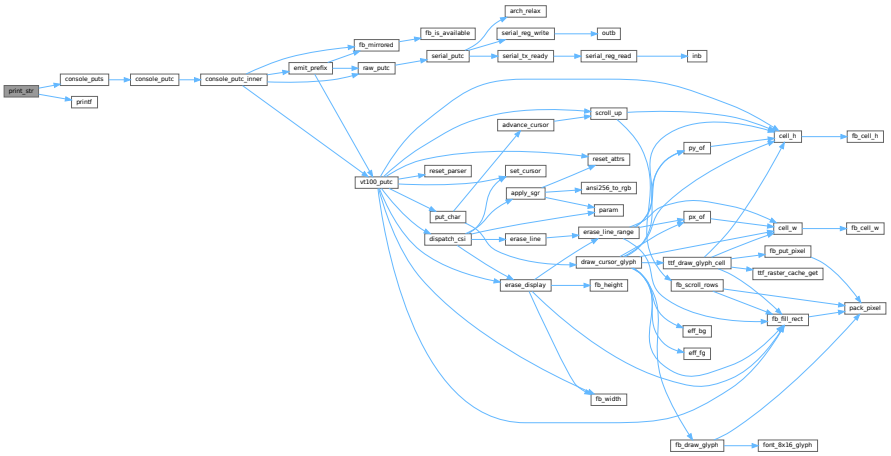
Parameters

s	Null-terminated string to print.

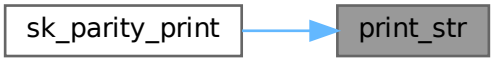
References console_puts(), and printf().

Referenced by sk_parity_print().

Here is the call graph for this function:



Here is the caller graph for this function:



7.185.2.8 print_u32()

```
static void print_u32 (
            uint32_t val )  [static]
```

Print a `uint32_t` value as decimal to the kernel console or stdout.

Converts `val` to a decimal ASCII string using a local buffer (no libc required) and emits it via `console_puts()` in kernel builds or `printf()` in hosted builds. Used by `sk_parity_print()` to format count and ID fields in parity output lines.

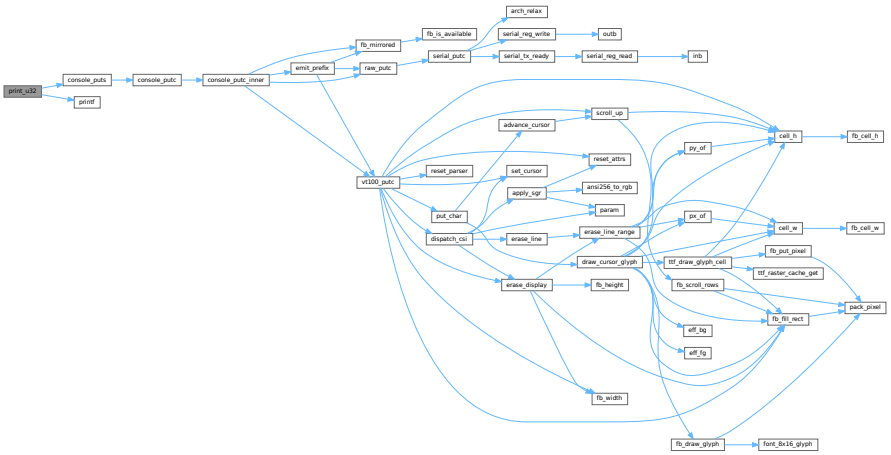
Parameters

val	32-bit unsigned value to print.

References console_puts(), and printf().

Referenced by sk_parity_print().

Here is the call graph for this function:



Here is the caller graph for this function:

7.185.2.9 sk_dict_canonical_hash()

```
uint64_t sk_dict_canonical_hash (
            struct VM * vm )
```

Compute the canonical FNV-1a 64-bit hash of the VM dictionary.

Implements M7 Rule 3: dictionary traversal is in creation order (oldest word first). Because `vm->latest` is the newest word, the function first builds a reverse array of entries and then hashes them in reverse-array order (oldest → newest).

For each entry the following structural fields are folded into the hash:

1. `flags` (1 byte)
2. `name_len` (1 byte)
3. `name` (name_len bytes)
4. `acl_default` (1 byte)
5. `word_id` (4 bytes, little-endian)
6. Colon body (via `hash_colon_body()`) if `WORD_COMPILED` is set

Pointer-valued fields (`func`, `link`) are intentionally excluded so the hash is stable across different build addresses and address-space layouts.

Traversal is capped at `MAX_DICT_ENTRIES` (2048) entries to guard against corruption.

Parameters

vm	Active VM whose dictionary will be hashed; returns 0 if NULL.

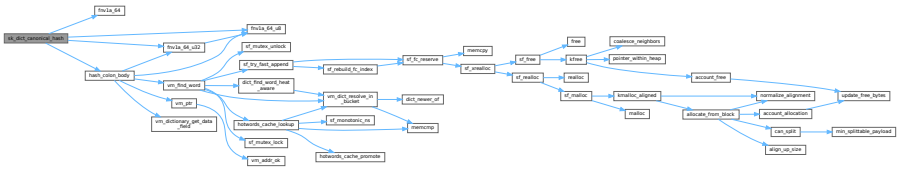
Returns

64-bit FNV-1a canonical hash of the dictionary structure.

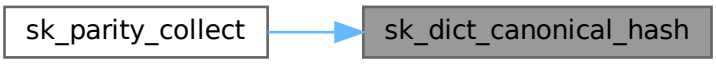
References DictEntry::acl_default, count, DictEntry::flags, fnv1a_64(), FNV1A_64_OFFSET_BASIS, fnv1a_64_u32(), fnv1a_64_u8(), DictEntry::func, hash_colon_body(), VM::latest, MAX_DICT_ENTRIES, DictEntry::name, DictEntry::name_len, sk_parity_debug_check_ptr, sk_parity_debug_log_msg, WORD_COMPILED, and DictEntry::word_id.

Referenced by sk_parity_collect().

Here is the call graph for this function:



Here is the caller graph for this function:



7.185.2.10 sk_dict_word_count()

```
uint32_t sk_dict_word_count (
            struct VM * vm )
```

Count the number of entries in the VM dictionary.

Walks the linked list starting at `vm->latest`, following each entry's `link` pointer until `NULL`. Stops early and returns `MAX_DICT_ENTRIES` if the list exceeds that limit, preventing runaway traversal on a corrupt dictionary.

Parameters

vm	Active VM whose dictionary will be counted; returns 0 if NULL.

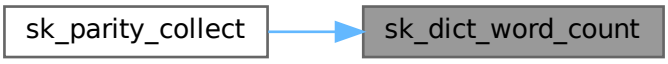
Returns

Number of dictionary entries found, capped at `MAX_DICT_ENTRIES`.

References count, VM::latest, and MAX_DICT_ENTRIES.

Referenced by sk_parity_collect().

Here is the caller graph for this function:



7.185.2.11 sk_parity_collect()

```
void sk_parity_collect (
            struct VM * vm,
            ParityPacket * out )
```

Collect M7 parity data from the VM into a `ParityPacket`.

Populates `out` with a snapshot of the VM's structural state for offline determinism verification. The packet contains:

- M7.1a fields: `word_count`, `here_offset`, `latest_word_id`, and the canonical dictionary hash (`header_hash64`) computed by `sk_dict_canonical_hash()`.
- M7.1b fields: test result counters (`tests_total` / `tests_passed` / `tests_failed` / `tests_skipped` / `tests_errors`) populated from `global_test_stats` when `STARFORTH_ENABLE_TESTS` is defined.

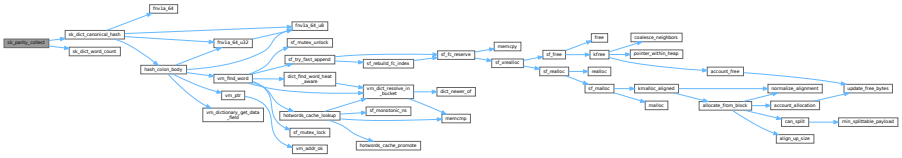
If `vm` is `NULL`, sets `out->bootstrap_result` to `SK_BOOTSTRAP_INIT_FAIL` and returns with all other fields zeroed. If `out` is `NULL` the function is a no-op.

Parameters

vm	Active VM to collect parity data from; may be `NULL`.
out	Output `ParityPacket` to fill; caller must allocate.

References ParityPacket::bootstrap_result, global_test_stats, ParityPacket::header_hash64, VM::here, ParityPacket::here_offset, VM::latest, ParityPacket::latest_word_id, SK_BOOTSTRAP_INIT_FAIL, SK_BOOTSTRAP_OK, sk_dict_canonical_hash(), sk_dict_word_count(), sk_parity_debug_log_msg, ParityPacket::tests_errors, ParityPacket::tests_failed, ParityPacket::tests_passed, ParityPacket::tests_skipped, ParityPacket::tests_total, TestStats::total_error, TestStats::total_fail, TestStats::total_pass, TestStats::total_skip, TestStats::total_tests, ParityPacket::window_hash64, ParityPacket::word_count, and DictEntry::word_id.

Here is the call graph for this function:



7.185.2.12 sk_parity_print()

```
void sk_parity_print (
            const ParityPacket * pkt )
```

Print a ParityPacket to the kernel console or stdout.

Emits two or three structured lines that can be captured in the QEMU serial log for offline determinism verification:

- "PARITY:M7.1a word_count=N here=0xH latest_id=N hash=0xH" — always emitted; contains the structural dictionary fingerprint.
- "PARITY:M7.1b tests=N pass=N fail=N skip=N err=N" — emitted only when pkt->tests_total > 0; contains POST result counts.
- "PARITY:OK" or "PARITY:FAIL code=N" — result verdict line.

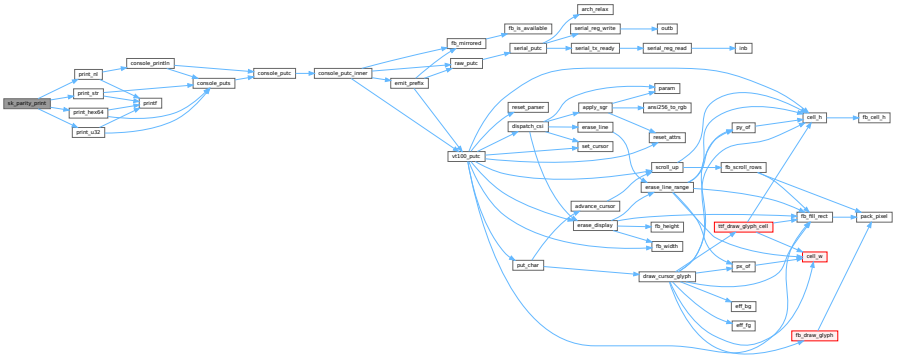
All output goes through print_str() / print_u32() / print_hex64() / print_nl() so the function compiles cleanly in both kernel and hosted builds. No-op if pkt is NULL.

Parameters

pkt	Pointer to the ParityPacket to display; may be NULL.

References ParityPacket::bootstrap_result, ParityPacket::header_hash64, ParityPacket::here_offset, ParityPacket::latest_word_id, print_hex64(), print_nl(), print_str(), print_u32(), SK_BOOTSTRAP_OK, ParityPacket::tests_errors, ParityPacket::tests_failed, ParityPacket::tests_passed, ParityPacket::tests_skipped, ParityPacket::tests_total, and ParityPacket::word_count.

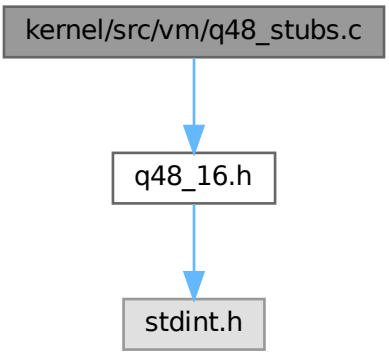
Here is the call graph for this function:



7.186 kernel/src/vm/q48_stubs.c File Reference

```
#include "q48_16.h"
```

Include dependency graph for q48_stubs.c:



Functions

- q48_16_t q48_from_double (double d)
  Convert a `double` to Q48.16 format.
- double q48_to_double (q48_16_t q)
  Convert a Q48.16 value to `double`.

7.186.1 Function Documentation

7.186.1.1 q48_from_double()

```
q48_16_t q48_from_double (
            double d )
```

Convert a `double` to Q48.16 format.

Multiplies `d` by 65536.0 and rounds to nearest. Intended for testing and diagnostics only — not called in the inference engine hot path to avoid floating-point dependency.

Parameters

d	Value to convert

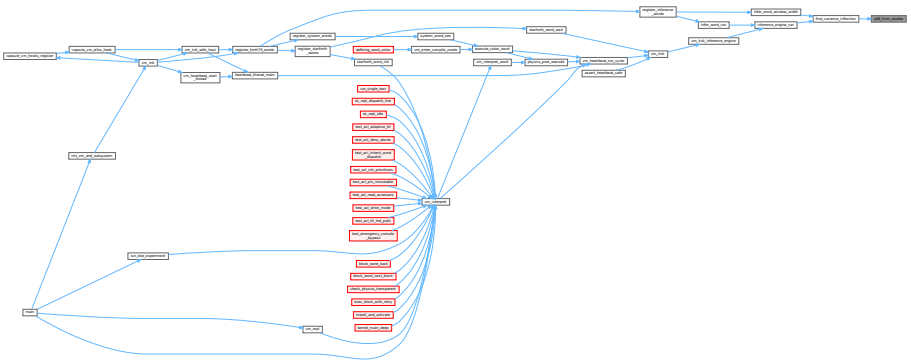
Returns

Nearest Q48.16 representation of `d`

References zero.

Referenced by find_variance_inflection().

Here is the caller graph for this function:



7.186.1.2 q48_to_double()

```
double q48_to_double (
            q48_16_t q )
```

Convert a Q48.16 value to `double`.

Divides `q` by 65536.0. Used for logging and RStudio dashboard output; not called in the inference engine hot path.

Parameters

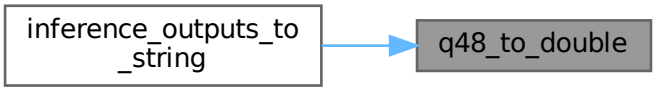
q	Value in Q48.16 format

Returns

Equivalent `double` value

Referenced by inference_outputs_to_string().

Here is the caller graph for this function:

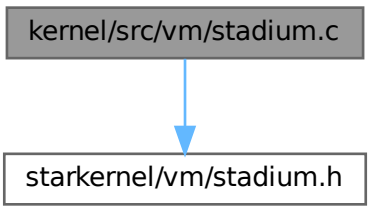


7.187 kernel/src/vm/session.c File Reference

7.188 kernel/src/vm/stadium.c File Reference

```
#include "starkernel/vm/stadium.h"
```

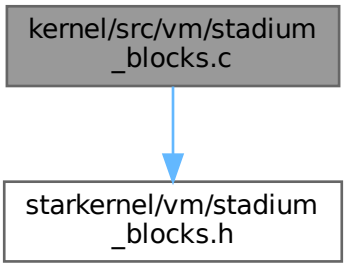
Include dependency graph for stadium.c:



7.189 kernel/src/vm/stadium_blocks.c File Reference

```
#include "starkernel/vm/stadium_blocks.h"
```

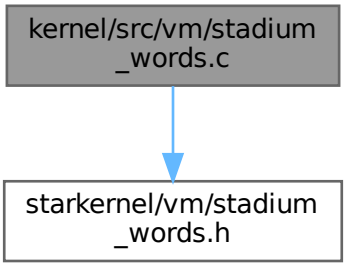
Include dependency graph for stadium_blocks.c:



7.190 kernel/src/vm/stadium_words.c File Reference

```
#include "starkernel/vm/stadium_words.h"
```

Include dependency graph for stadium_words.c:



7.191 kernel/src/vm/switch.c File Reference

7.192 kernel/src/vm/vm_core.c File Reference

```
#include "../../../v3/include/vm.h"
#include "../../../v3/include/inference_engine.h"
#include "../../../v3/include/log.h"
#include "../../../v3/include/word_registry.h"
#include "../../../v3/include/vm_debug.h"
#include "../../../v3/include/profiler.h"
#include "../../../v3/include/platform_time.h"
#include "../../../v3/include/physics_metadata.h"
#include "../../../v3/include/physics_hotwords_cache.h"
#include "../../../v3/include/physics_pipelining_metrics.h"
#include "../../../v3/include/rolling_window_of_truth.h"
#include "../../../v3/include/dictionary_heat_optimization.h"
#include "../../../v3/include/ssm_jacquard.h"
#include "../../../v3/include/vm_host.h"
#include "word_source/include/vocabulary_words.h"
#include "vm_internal.h"
#include <stdlib.h>
#include <errno.h>
#include <time.h>
#include <stdio.h>
#include <string.h>
#include <stdint.h>
```

Include dependency graph for vm_core.c:

Macros

- #define vm_check_arena(tag) ((void)0)

Functions

- static void * hosted_alloc (size_t size, size_t align)
- static void hosted_free (void *ptr)
- static uint64_t hosted_time_ns (void)
- static int hosted_mutex_init (void *mutex)
- static int hosted_mutex_lock (void *mutex)
- static int hosted_mutex_unlock (void *mutex)
- static void hosted_mutex_destroy (void *mutex)
- static int hosted_puts (const char *str)
- static int hosted_putc (int c)
- static void hosted_panic (const char *message)
- static bool hosted_xt_is_executable (const void *ptr)
- static bool hosted_xt_entry_owned (const void *ptr, size_t bytes)
- void vm_reset_hosted_fake_ns (VM *vm)
- static void vm_assert_interpreter_enabled (VM *vm, const char *caller)
- void vm_enable_interpreter (VM *vm)
- const VMHostServices * vm_default_host_services (void)
- const VMHostServices * vm_host (const VM *vm)
- void * vm_host_alloc (VM *vm, size_t size, size_t align)
- void * vm_host_calloc (VM *vm, size_t n, size_t size)
- void vm_host_free (VM *vm, void *ptr)
- uint64_t vm_monotonic_ns (VM *vm)
- unsigned vm_get_base (const VM *vm)

  Read the current number base from the VM.
- void vm_set_base (VM *vm, unsigned b)

  Set the VM number base and update both the cell and the host mirror.
- int vm_zuse_cert_install (VM *vm, const uint8_t seed[32], const uint8_t pubkey[32])

  One-time write of the Zuse cert (seed + derived pubkey) – blows the fuse.
- void vm_cleanup (VM *vm)

  Clean up and free VM resources.
- int vm_parse_word (VM *vm, char *word, size_t max_len)

  Parse the next whitespace-delimited token from the input buffer.
- int vm_parse_number (VM *vm, const char *s, cell_t *out)

  Attempt to parse a string as an integer in the current number base.
- void vm_enter_compile_mode (VM *vm, const char *name, size_t len)

  Begin a colon definition and switch the VM to compile mode.
- void vm_compile_word (VM *vm, DictEntry *entry)

  Append a word reference (DictEntry) to the current threaded body.*
- void vm_compile_literal (VM *vm, cell_t value)

  Compile a literal value into the current threaded body (or push it).
- void vm_compile_call (VM *vm, word_func_t func)

  Compile a call to a word identified by its C function pointer.
- void vm_compile_exit (VM *vm)

  Compile an `EXIT` reference into the current threaded body.
- void vm_exit_compile_mode (VM *vm)

  Finalise a colon definition and return to interpret mode.
- static void acl_recheck (VM *vm, DictEntry *entry)

- void execute_colon_word (VM *vm)

  Inner interpreter for threaded colon definitions.
- void vm_interpret_word (VM *vm, const char *word_str, size_t len)

  Interpret or compile a single word token.
- VM * vm_log_attributed_vm (void)
- int sk_vm_at_outermost_interpret (void)
- void vm_interpret (VM *vm, const char *input)
- int vm_addr_ok (struct VM *vm, vaddr_t addr, size_t len)

  Validate that a VM address range lies within `vm->memory`.
- uint8_t * vm_ptr (struct VM *vm, vaddr_t addr)

  Return a host C pointer into VM memory at `addr`.
- uint8_t vm_load_u8 (struct VM *vm, vaddr_t addr)

  Load an unsigned byte from VM memory.
- void vm_store_u8 (struct VM *vm, vaddr_t addr, uint8_t v)

  Store an unsigned byte to VM memory.
- cell_t vm_load_cell (struct VM *vm, vaddr_t addr)

  Load an aligned cell from VM memory.
- void vm_store_cell (struct VM *vm, vaddr_t addr, cell_t v)

  Store an aligned cell to VM memory.
- void vm_make_immediate (VM *vm)

  Mark the most recently created word as IMMEDIATE (FORTH-79).

Variables

- static uint64_t hosted_fake_ns = 0
- static const VMHostServices hosted_services
- static VM * g_log_attrib_vm
- static int g_vm_interpret_depth

7.192.1 Macro Definition Documentation

7.192.1.1 vm_check_arena

```
#define vm_check_arena(
             tag ) ((void)0)
```

7.192.2 Function Documentation

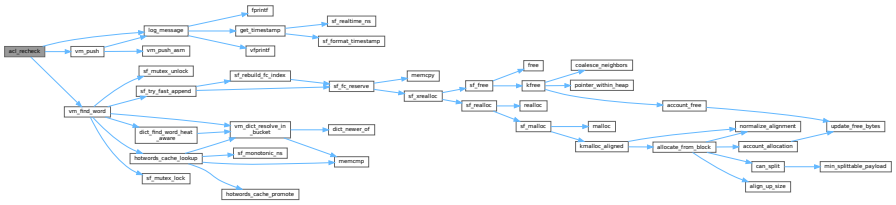
7.192.2.1 acl_recheck()

```
static void acl_recheck (
            VM * vm,
            DictEntry * entry )  [static]
```

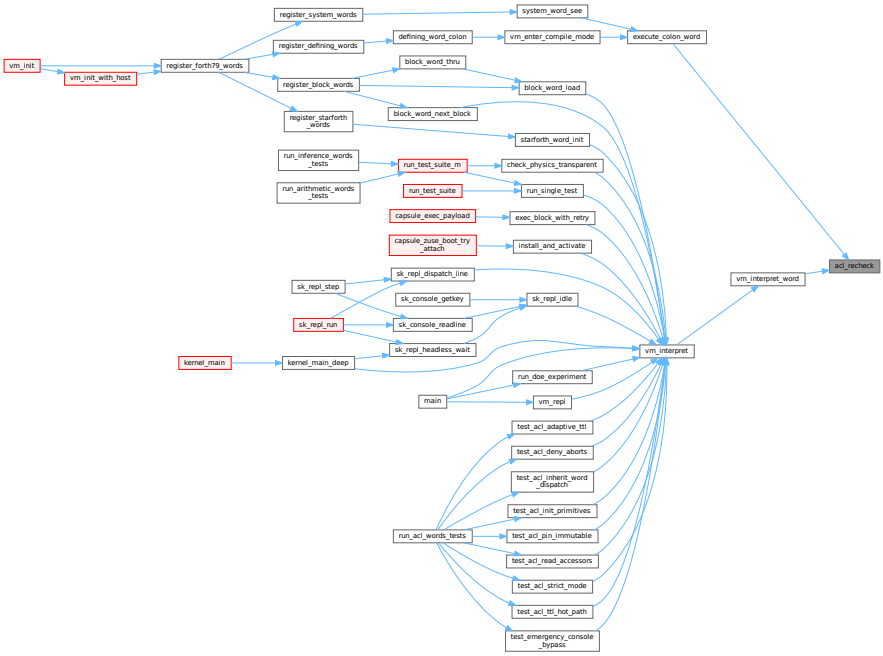
References ACL_TTL_OPEN, VM::current_executing_entry, VM::emergency_console, entry, VM::error, DictEntry::func, log_message(), LOG_WARN, vm_find_word(), and vm_push().

Referenced by execute_colon_word(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.2 execute_colon_word()

```
void execute_colon_word (
            VM * vm )
```

Inner interpreter for threaded colon definitions.

Runs the body of a colon-defined word whose `DictEntry` points to a sequence of `DictEntry*` cells in VM memory (indirect threaded code). The interpreter pointer (IP) is maintained on the return stack so that runtime control-flow words ((BRANCH), (0BRANCH), (DO), etc.) can redirect execution by modifying the top-of-return-stack IP.

Execution loop per iteration:

1. Read `DictEntry* w` from `*ip`.
2. Run physics pre-execute hooks (heat, decay, pipelining).

3. ACL hot-path check (decrement TTL; call `acl_recheck()` on zero).
4. Push `ip+1` onto the return stack as the resume point.
5. Call `w->func(vm)`.
6. Run physics post-execute hooks.
7. Check `vm->exit_colon` (set by `EXIT`): pop and discard the saved IP, then return to caller.
8. Check `vm->abort_requested`: unwind and return immediately.
9. Pop the (possibly modified) IP from the return stack and repeat.

`vm->ecw_nesting` is incremented on entry and decremented on every return path to enable recursive colon calls.

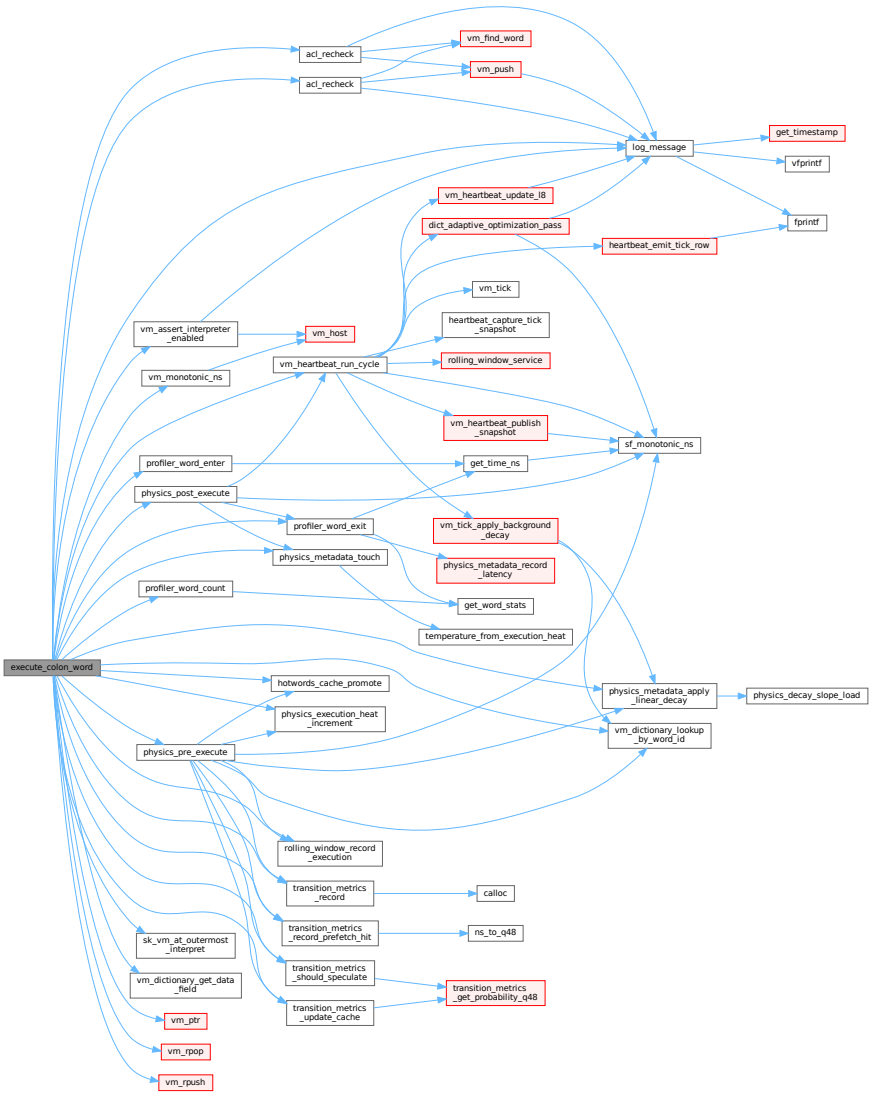
Parameters

vm	VM instance; `vm->current_executing_entry` must point to the `DictEntry` being executed.

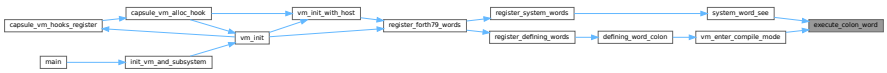
References VM::abort_requested, DictEntry::acl_allow, acl_recheck(), acl_recheck(), DictEntry::acl_ttl, HeartbeatState::check_counte VM::current_executing_entry, DICTIONARY_SIZE, VM::dsp, VM::ecw_nesting, VM::emergency_console, ENABLE_HOTWORDS_CACHE, ENABLE_PIPELINING, entry, VM::error, DictEntry::execution_heat, VM::exit_colon, DictEntry::func, g_sk_fault_word, VM::heartbeat, HEARTBEAT_CHECK_FREQUENCY, VM::hotwords_cache, hotwords_cache_promote(), HOTWORDS_EXECUTION_HEAT_THRESHOLD, DictPhysics::last_active_ns, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, WordTransitionMetrics::most_likely_next_word_id, DictEntry::name, DictEntry::name_len, DictEntry::physics, physics_execution_heat_increment(), physics_metadata_apply_linear_decay(), physics_metadata_touch(), physics_post_execute(), physics_pre_execute(), VM::pipeline_metrics, WordTransitionMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, profiler_word_count(), profiler_word_enter(), profiler_word_exit(), VM::rolling_window, rolling_window_record_execution(), VM::rsp, sk_vm_at_outermost_interpret(), HeartbeatState::tick_count, DictEntry::transition_metrics, transition_metrics_record(), transition_metrics_record_prefetch_hit(), transition_metrics_should_speculate(), transition_metrics_update_cache(), vm_assert_interpreter_enabled(), vm_dictionary_get_data_field(), vm_dictionary_lookup_by_word_id(), vm_heartbeat_run_cycle(), vm_monotonic_ns(), vm_ptr(), vm_rpop(), vm_rpush(), word_id, DictEntry::word_id, HeartbeatState::words_executed, and HeartbeatState::worker.

Referenced by system_word_see(), and vm_enter_compile_mode().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.3 hosted_alloc()

```
static void * hosted_alloc (
            size_t size,
            size_t align )  [static]
```

References malloc().

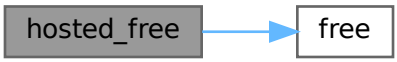
Here is the call graph for this function:

7.192.2.4 hosted_free()

```
static void hosted_free (
            void * ptr )  [static]
```

References free().

Here is the call graph for this function:



7.192.2.5 hosted_mutex_destroy()

```
static void hosted_mutex_destroy (
            void * mutex )  [static]
```

References sf_mutex_destroy().

Here is the call graph for this function:

7.192.2.6 hosted_mutex_init()

```
static int hosted_mutex_init (
            void * mutex )  [static]
```

References sf_mutex_init().

Here is the call graph for this function:

7.192.2.7 hosted_mutex_lock()

```
static int hosted_mutex_lock (
            void * mutex )  [static]
```

References sf_mutex_lock().

Here is the call graph for this function:

7.192.2.8 hosted_mutex_unlock()

```
static int hosted_mutex_unlock (
            void * mutex )  [static]
```

References sf_mutex_unlock().

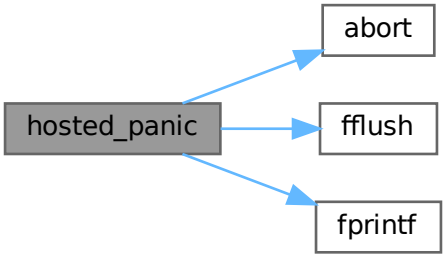
Here is the call graph for this function:

7.192.2.9 hosted_panic()

```
static void hosted_panic (
            const char * message )  [static]
```

References abort(), fflush(), fprintf(), and stderr.

Here is the call graph for this function:



7.192.2.10 hosted_putc()

```
static int hosted_putc (
            int c )  [static]
```

References fputc(), and stdout.

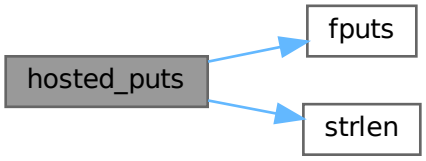
Here is the call graph for this function:

7.192.2.11 hosted_puts()

```
static int hosted_puts (
            const char * str )  [static]
```

References fputs(), stdout, and strlen().

Here is the call graph for this function:

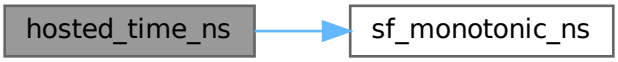


7.192.2.12 hosted_time_ns()

```
static uint64_t hosted_time_ns (
            void  )  [static]
```

References hosted_fake_ns, and sf_monotonic_ns().

Here is the call graph for this function:



7.192.2.13 hosted_xt_entry_owned()

```
static bool hosted_xt_entry_owned (
            const void * ptr,
            size_t bytes )  [static]
```

References bytes.

7.192.2.14 hosted_xt_is_executable()

```
static bool hosted_xt_is_executable (
            const void * ptr )  [static]
```

7.192.2.15 sk_vm_at_outermost_interpret()

```
int sk_vm_at_outermost_interpret (
            void  )
```

References g_vm_interpret_depth.

Referenced by execute_colon_word().

Here is the caller graph for this function:

7.192.2.16 vm_addr_ok()

```
int vm_addr_ok (
            struct VM * vm,
            vaddr_t addr,
            size_t len )
```

Validate that a VM address range lies within `vm->memory`.

Checks that [addr, addr+len) is fully contained within the `VM_MEMORY_SIZE`-byte flat address space. The check is done with unsigned arithmetic to avoid UB on overflow: if `len` alone exceeds `VM_MEMORY_SIZE` the range is immediately rejected.

Parameters

vm	VM instance; returns 0 if NULL or memory not allocated.
addr	Start of the range (inclusive).
len	Number of bytes in the range.

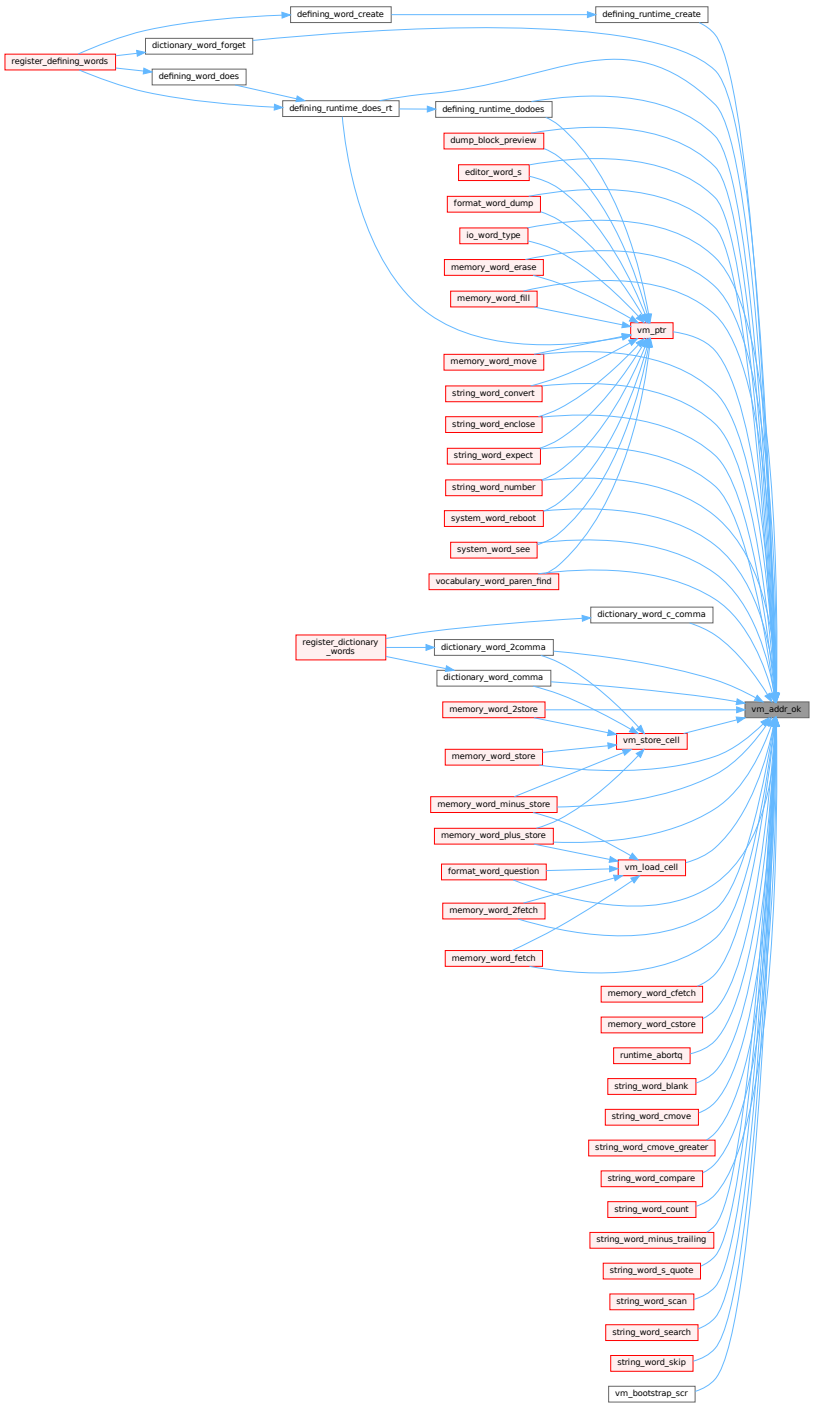
Returns

1 if the full range [addr, addr+len) is in bounds; 0 otherwise.

References VM::memory, and VM_MEMORY_SIZE.

Referenced by defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_does_rt(), dictionary_word_2comma(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_forget(), dump_block_preview(), editor_word_s(), format_word_dump(), format_word_question(), io_word_type(), memory_word_2fetch(), memory_word_2store(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), runtime_abortq(), string_word_blank(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_minus_trailing(), string_word_number(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), system_word_reboot(), system_word_see(), vm_bootstrap_scr(), vm_load_cell(), vm_ptr(), vm_store_cell(), and vocabulary_word_paren_find().

Here is the caller graph for this function:



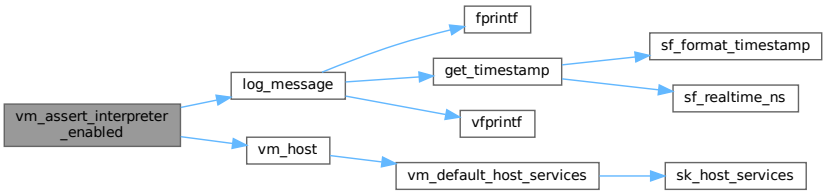
7.192.2.17 vm_assert_interpreter_enabled()

```
static void vm_assert_interpreter_enabled (
            VM * vm,
            const char * caller )  [static]
```

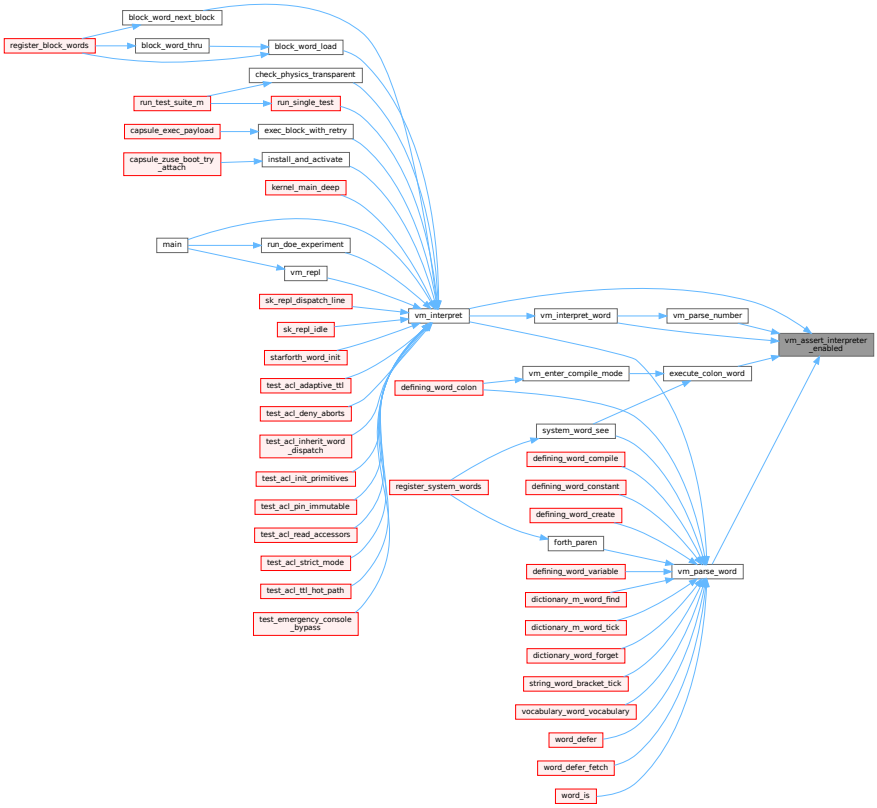
References VM::error, VM::interpreter_enabled, LOG_ERROR, log_message(), and vm_host().

Referenced by execute_colon_word(), vm_interpret(), vm_interpret_word(), vm_parse_number(), and vm_parse_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.18 vm_cleanup()

```
void vm_cleanup (
            VM * vm )
```

Clean up and free VM resources.

Frees allocated memory and resets VM state.

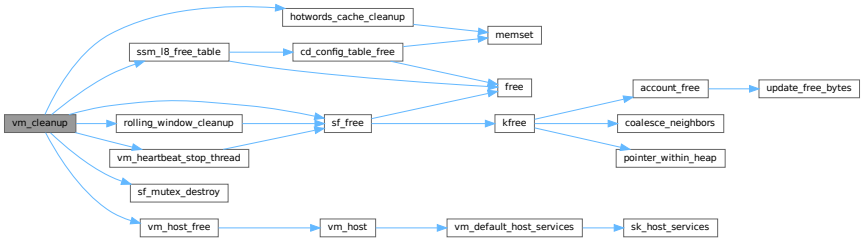
Parameters

vm	Pointer to VM structure to clean up

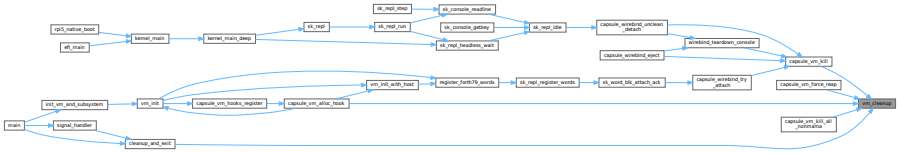
References VM::dict_lock, VM::heartbeat, VM::here, VM::hotwords_cache, hotwords_cache_cleanup(), VM::latest, DictEntry::link, VM::memory, VM::rolling_window, rolling_window_cleanup(), sf_free(), sf_mutex_destroy(), VM::ssm_config, ssm_l8_free_table(), VM::ssm_l8_state, HeartbeatWorker::stop_requested, DictEntry::transition_metrics, VM::tuning_lock, vm_heartbeat_stop_thread(), vm_host_free(), and HeartbeatState::worker.

Referenced by capsule_vm_alloc_hook(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_vm_kill_all_nonmama(), and cleanup_and_exit().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.19 vm_compile_call()

```
void vm_compile_call (
            VM * vm,
            word_func_t func )
```

Compile a call to a word identified by its C function pointer.

Looks up the `DictEntry` whose `func` field matches `func` via `vm_dictionary_find_by_func()`, then delegates to `vm_compile_word()`. Used by generating words (e.g., `DOES>`) that need to embed a specific runtime routine into a compiled definition without knowing its name.

Sets `vm->error` if not in compile mode or if no matching entry is found.

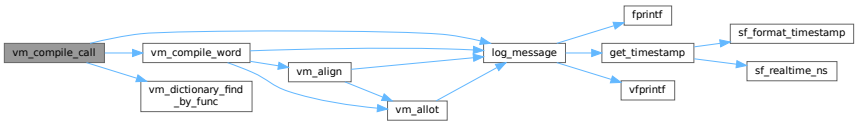
Parameters

vm	VM instance in compile mode.
func	C function pointer identifying the word to compile.

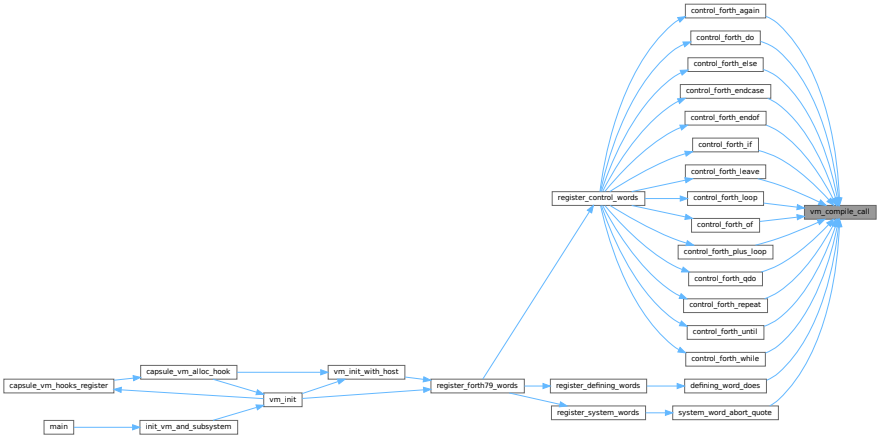
References entry, VM::error, func, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_compile_word(), and vm_dictionary_find_by_func().

Referenced by control_forth_again(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_if(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_until(), control_forth_while(), defining_word_does(), and system_word_abort_quote().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.20 vm_compile_exit()

```
void vm_compile_exit (
            VM * vm )
```

Compile an `EXIT` reference into the current threaded body.

Appends the `EXIT` word entry so that when the threaded body is executed, `execute_colon_word()` sets `vm->exit_colon` and unwinds the inner loop. Used by control-flow generating words (e.g., `IF` optimisation paths) that need an explicit early-return.

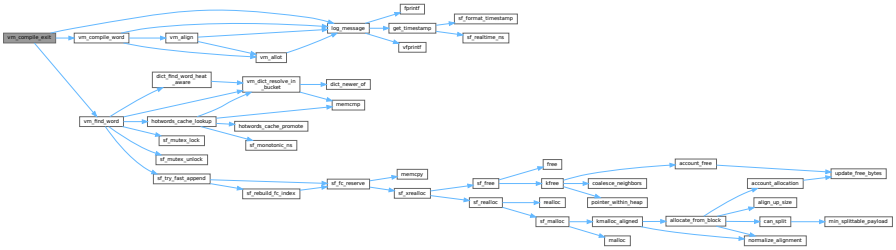
Sets `vm->error` if not in compile mode or if `EXIT` is not found.

Parameters

vm	VM instance in compile mode.

References VM::error, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_compile_word(), and vm_find_word().

Here is the call graph for this function:



7.192.2.21 vm_compile_literal()

```
void vm_compile_literal (
            VM * vm,
            cell_t value )
```

Compile a literal value into the current threaded body (or push it).

In compile mode, appends the `LIT` word reference followed by the literal value so the inner interpreter will push `value` at runtime. In interpret mode, pushes `value` directly onto the data stack.

Sets `vm->error` if `LIT` cannot be found in the dictionary.

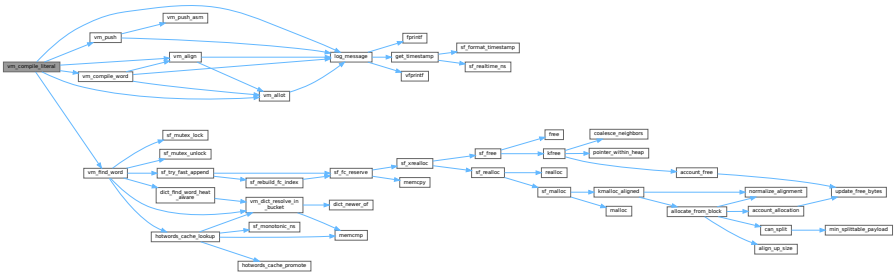
Parameters

vm	VM instance.
value	Cell value to compile or push.

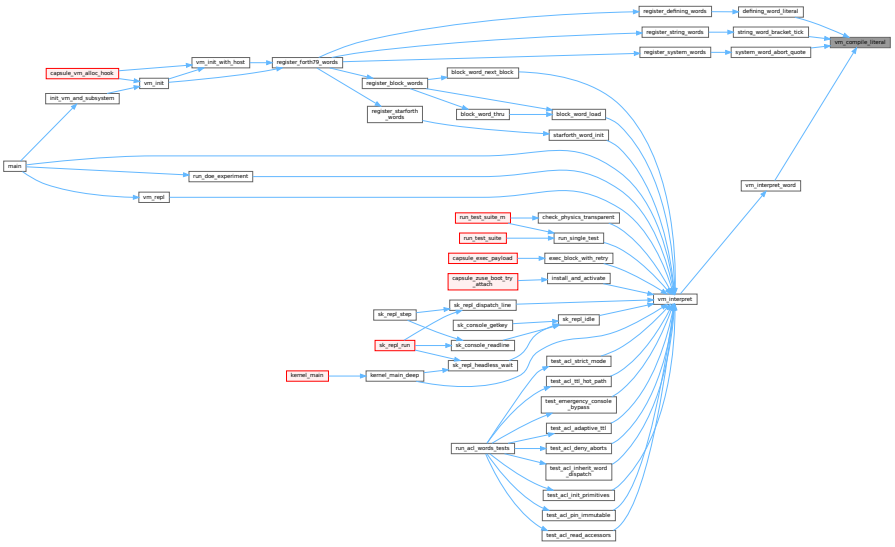
References VM::error, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_align(), vm_allot(), vm_compile_word(), vm_find_word(), and vm_push().

Referenced by defining_word_literal(), string_word_bracket_tick(), system_word_abort_quote(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.22 vm_compile_word()

```
void vm_compile_word (
            VM * vm,
            DictEntry * entry )
```

Append a word reference (DictEntry*) to the current threaded body.

Aligns `HERE`, then allots one `cell_t` slot and stores the `DictEntry*` as a cell. This is the fundamental compilation step used by the inner interpreter: each slot in the threaded body is a pointer to the `DictEntry` of the word to call.

Sets `vm->error` if the VM is not in compile mode, `entry` is NULL, or allotment fails.

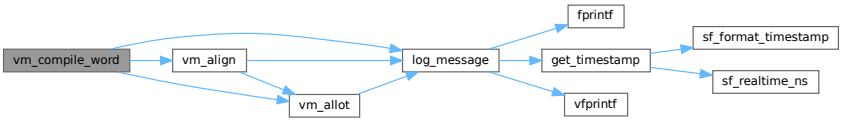
Parameters

vm	VM instance in compile mode.
entry	Dictionary entry of the word to compile; must not be NULL.

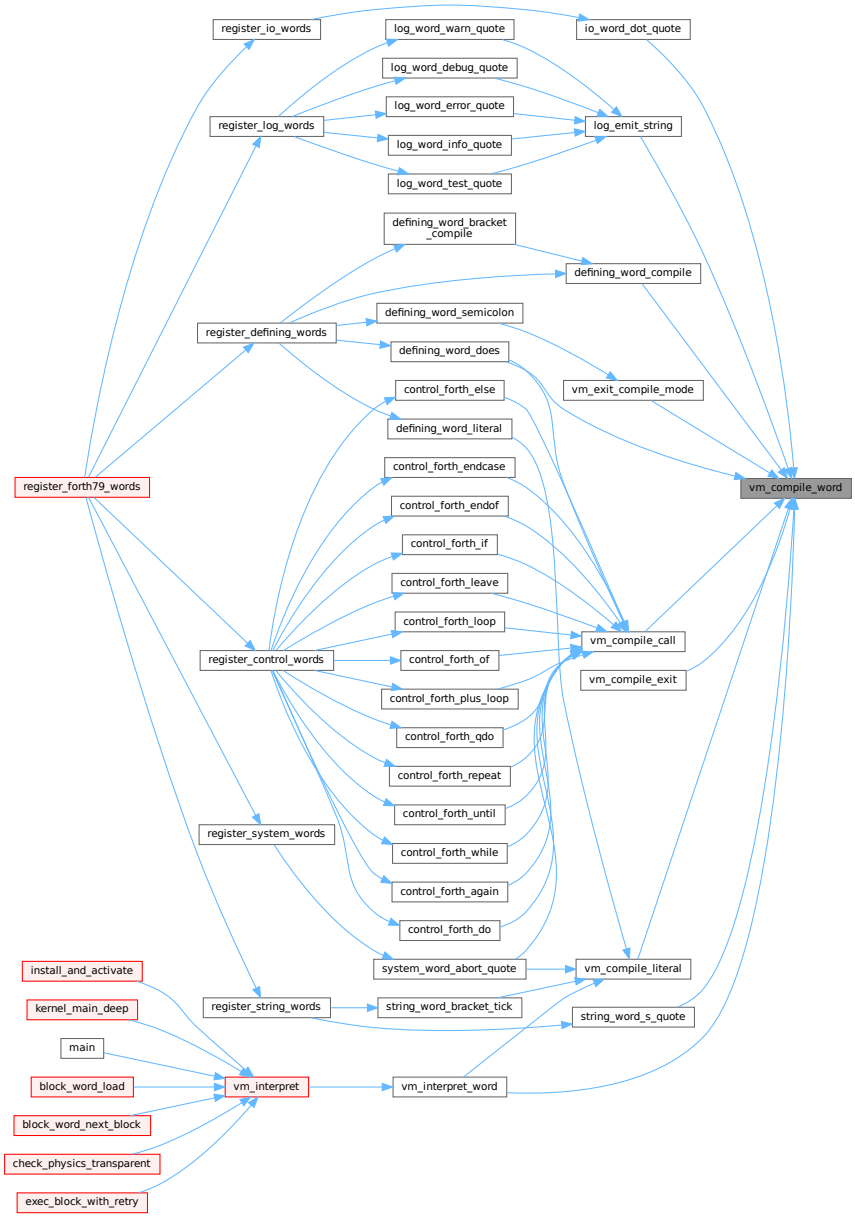
References entry, VM::error, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_align(), and vm_allot().

Referenced by defining_word_compile(), defining_word_does(), io_word_dot_quote(), log_emit_string(), string_word_s_quote(), vm_compile_call(), vm_compile_exit(), vm_compile_literal(), vm_exit_compile_mode(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



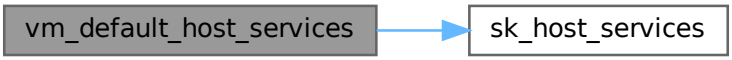
7.192.2.23 vm_default_host_services()

```
const VMHostServices * vm_default_host_services (
            void  )
```

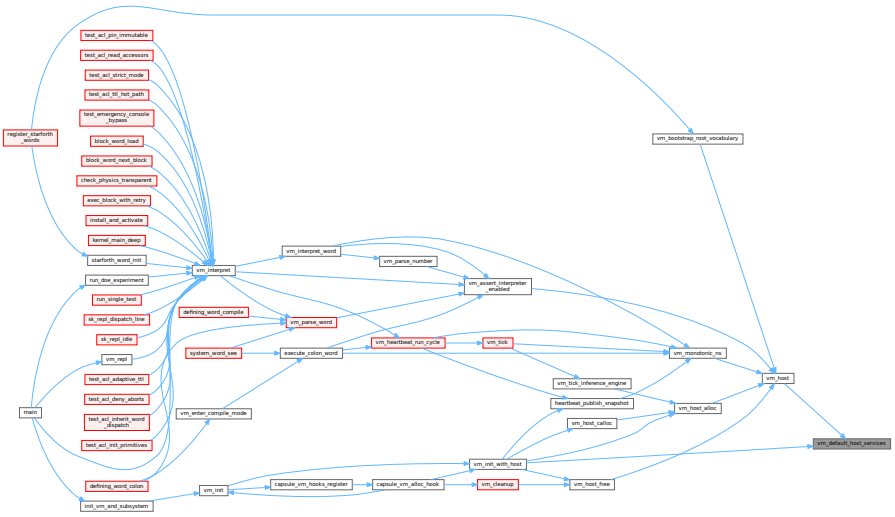
References hosted_services, and sk_host_services().

Referenced by vm_host(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



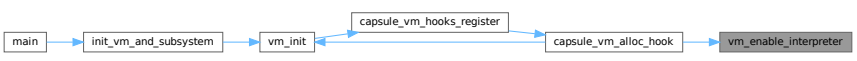
7.192.2.24 vm_enable_interpreter()

```
void vm_enable_interpreter (
            VM * vm )
```

References VM::interpreter_enabled.

Referenced by capsule_vm_alloc_hook().

Here is the caller graph for this function:



7.192.2.25 vm_enter_compile_mode()

```
void vm_enter_compile_mode (
            VM * vm,
            const char * name,
            size_t len )
```

Begin a colon definition and switch the VM to compile mode.

Creates a new dictionary entry for `name` via `vm_create_word()`, marks it `WORD_SMUDGED` so it is invisible to lookups during compilation, sets the VM mode to `MODE_COMPILE`, and writes the current `HERE` address into the entry's data field as the start of the threaded body.

The SMUDGE flag is cleared by `vm_exit_compile_mode()` when the semicolon is encountered.

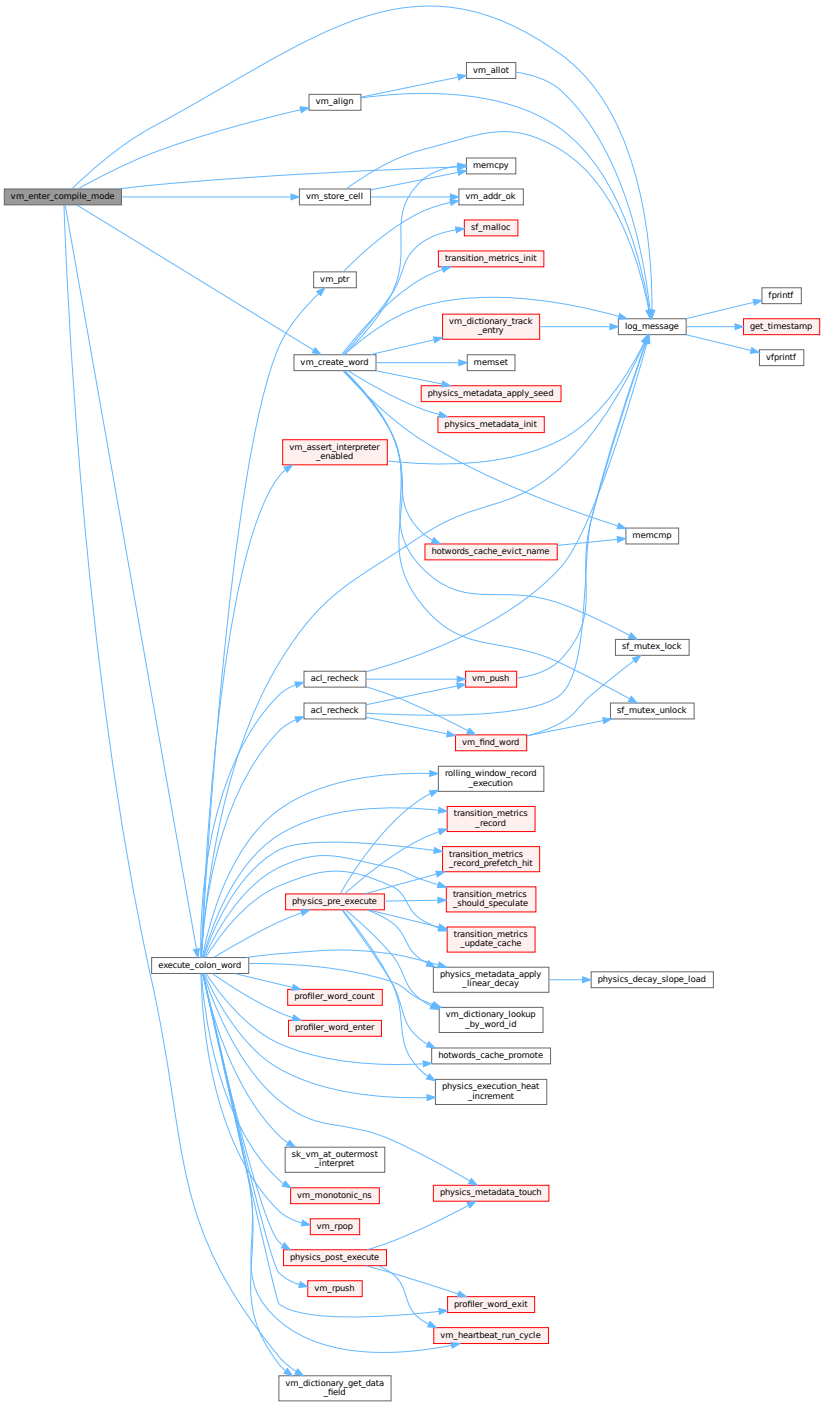
Parameters

vm	VM instance.
name	Word name string (does not need to be NUL-terminated).
len	Length of `name`; clamped to `WORD_NAME_MAX`.

References VM::compiling_word, VM::current_word_name, VM::error, execute_colon_word(), DictEntry::flags, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), memcpy(), VM::mode, MODE_COMPILE, name, VM::state_addr, VM::state_var, vm_align(), vm_create_word(), vm_dictionary_get_data_field(), vm_store_cell(), WORD_NAME_MAX, and WORD_SMUDGED.

Referenced by defining_word_colon().

Here is the call graph for this function:



Here is the caller graph for this function:

7.192.2.26 vm_exit_compile_mode()

```
void vm_exit_compile_mode (
            VM * vm )
```

Finalise a colon definition and return to interpret mode.

Appends a final `EXIT` reference, clears the `WORD_SMUDGED` flag so the new word becomes visible in the dictionary, and sets `WORD_COMPILED`. Also computes the word's mass (header + body bytes) for the physics engine and calls `physics_metadata_refresh_state()`.

Resets `vm->mode` to `MODE_INTERPRET`, clears `vm->state_var`, and NULLs `vm->compiling_word`.

Sets `vm->error` if `vm` has no active `compiling_word` or if `EXIT` cannot be found.

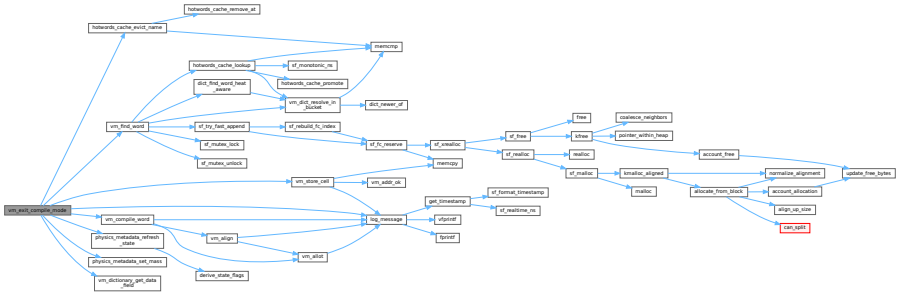
Parameters

vm	VM instance currently in compile mode.

References DictEntry::acl_allow, DictEntry::acl_ttl, ACL_TTL_OPEN, VM::compiling_word, VM::error, DictEntry::flags, VM::here, VM::hotwords_cache, hotwords_cache_evict_name(), LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_INTERPRET, DictEntry::name, DictEntry::name_len, physics_metadata_refresh_state(), physics_metadata_set_mass(), VM::state_addr, VM::state_var, vm_compile_word(), vm_dictionary_get_data_field(), vm_find_word(), vm_store_cell(), WORD_COMPILED, and VM::zuse_session.

Referenced by defining_word_semicolon().

Here is the call graph for this function:



Here is the caller graph for this function:

7.192.2.27 vm_get_base()

```
unsigned vm_get_base (
            const VM * vm )
```

Read the current number base from the VM.

Prefers the cell stored at `vm->base_addr` (the canonical FORTH `BASE` variable) if it is aligned and in the valid range [2, 36]. Falls back to the host-mirror `vm->base` if the cell is out of range, and finally returns 10 if both are invalid or `vm` is NULL.

The double-read (cell + mirror) keeps the VM consistent when C code modifies `vm->base` directly without going through `vm_set_base()`.

Parameters

vm	VM instance to query (may be NULL; returns 10 in that case).

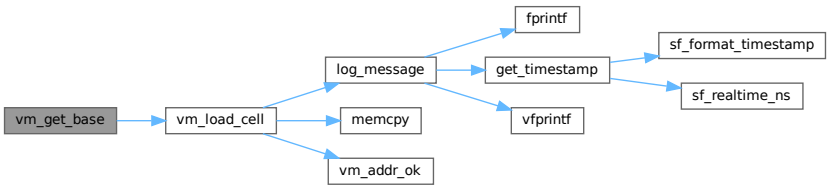
Returns

Current number base in range [2, 36].

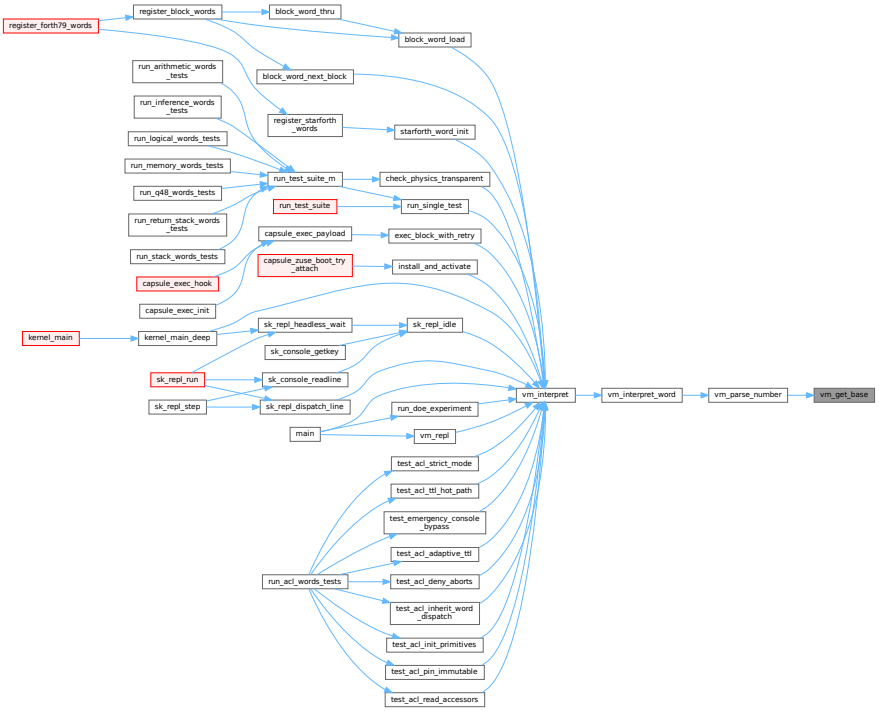
References VM::base, VM::base_addr, vm_load_cell(), and VM_MEMORY_SIZE.

Referenced by vm_parse_number().

Here is the call graph for this function:



Here is the caller graph for this function:



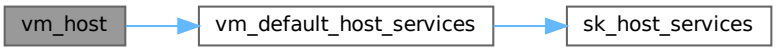
7.192.2.28 vm_host()

```
const VMHostServices * vm_host (
            const VM * vm )
```

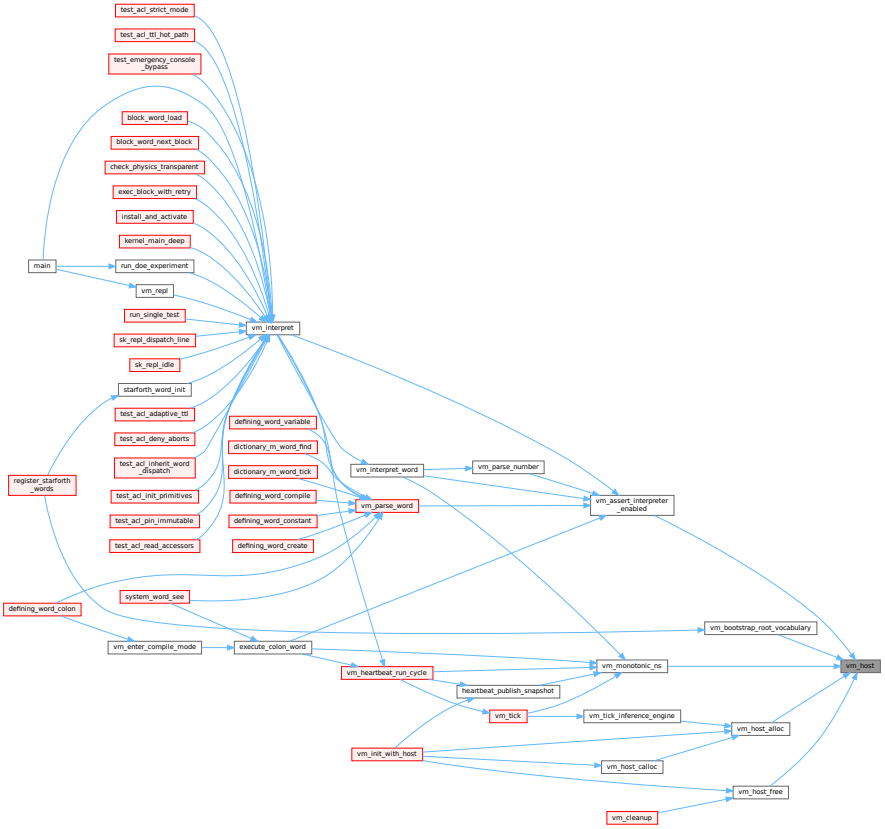
References VM::host, and vm_default_host_services().

Referenced by vm_assert_interpreter_enabled(), vm_bootstrap_root_vocabulary(), vm_host_alloc(), vm_host_free(), and vm_monotonic_ns().

Here is the call graph for this function:



Here is the caller graph for this function:



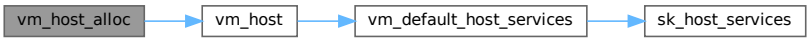
7.192.2.29 vm_host_alloc()

```
void * vm_host_alloc (
            VM * vm,
            size_t size,
            size_t align )
```

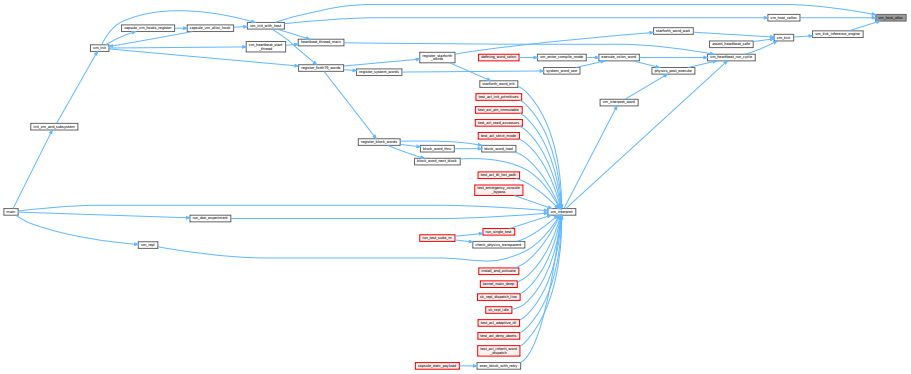
References VMHostServices::alloc, and vm_host().

Referenced by vm_host_calloc(), vm_init_with_host(), and vm_tick_inference_engine().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.30 vm_host_calloc()

```
void * vm_host_calloc (
            VM * vm,
            size_t n,
            size_t size )
```

References memset(), and vm_host_alloc().

Referenced by vm_init_with_host().

Here is the call graph for this function:

Here is the caller graph for this function:

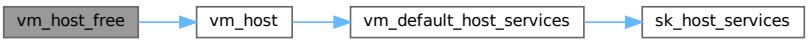
7.192.2.31 vm_host_free()

```
void vm_host_free (
            VM * vm,
            void * ptr )
```

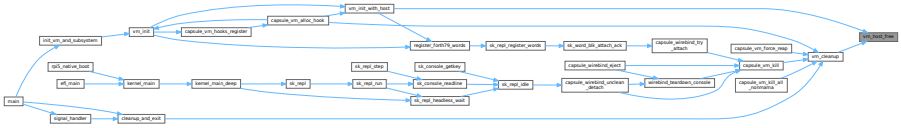
References VMHostServices::free, and vm_host().

Referenced by vm_cleanup(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



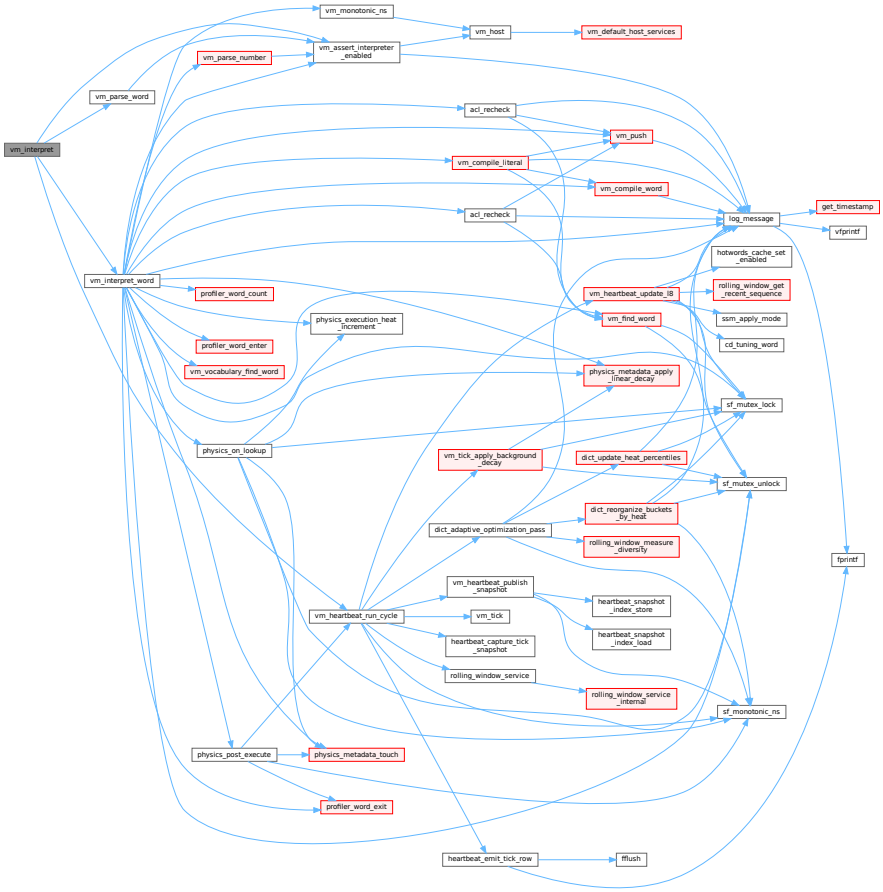
7.192.2.32 vm_interpret()

```
void vm_interpret (
            VM * vm,
            const char * input )
```

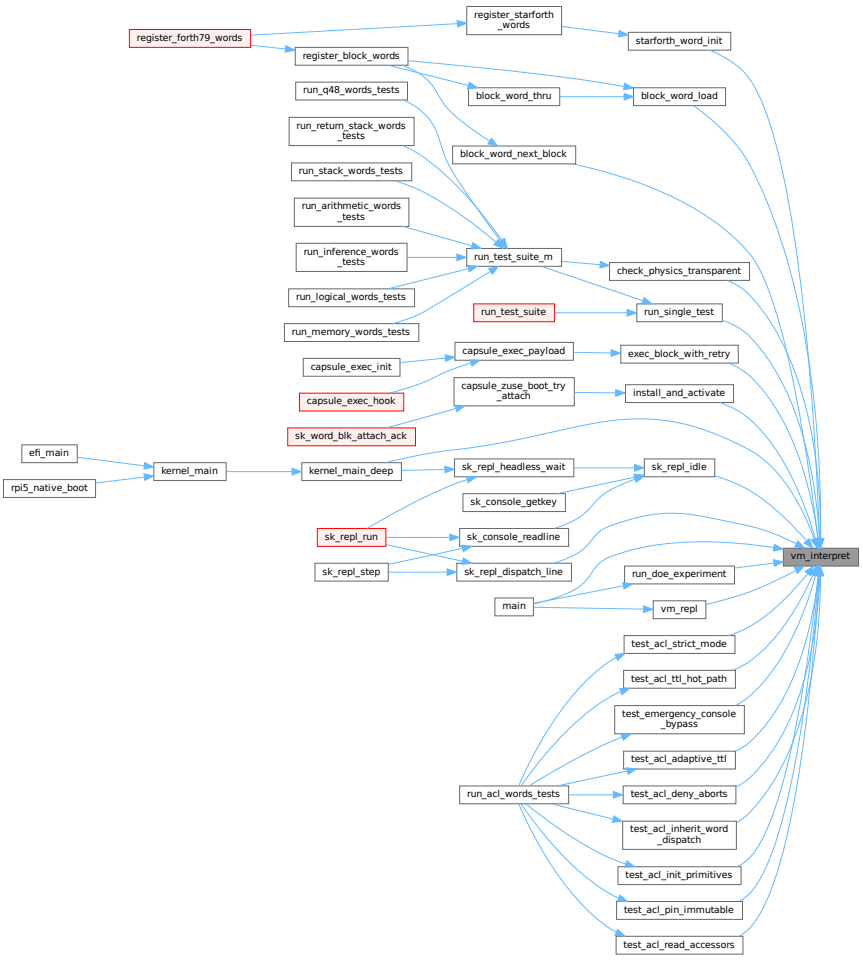
References VM::abort_requested, HeartbeatState::check_counter, VM::error, g_log_attrib_vm, g_vm_interpret_depth, g_vm_interpret_depth, VM::heartbeat, HEARTBEAT_CHECK_FREQUENCY, VM::input_buffer, INPUT_BUFFER_SIZE, VM::input_length, VM::input_pos, vm_assert_interpreter_enabled(), vm_heartbeat_run_cycle(), vm_interpret_word(), vm_parse_word(), and HeartbeatState::worker.

Referenced by block_word_load(), block_word_next_block(), check_physics_transparent(), exec_block_with_retry(), install_and_activate(), kernel_main_deep(), main(), run_doe_experiment(), run_single_test(), sk_repl_dispatch_line(), sk_repl_idle(), starforth_word_init(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_bypass(), and vm_repl().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.33 vm_interpret_word()

```
void vm_interpret_word (
            VM * vm,
            const char * word_str,
            size_t len )
```

Interpret or compile a single word token.

This is the outer interpreter's per-token dispatch:

1. **Dictionary lookup**: vocabulary-aware search, falling back to the canonical flat dictionary. Physics heat is recorded via `physics_on_lookup()`.
2. **Compile mode, non-immediate**: append the entry to the current threaded body via `vm_compile_word()`.
3. **Interpret mode, or immediate in compile mode**: ACL check (hot-path TTL decrement / cold-path `acl_recheck()`), then call `entry->func()`.
4. **Number literal**: if no dictionary match, attempt `vm_parse_number()`. In compile mode, compile as a literal; in interpret mode, push directly.
5. **Error**: unknown token — sets `vm->error`.

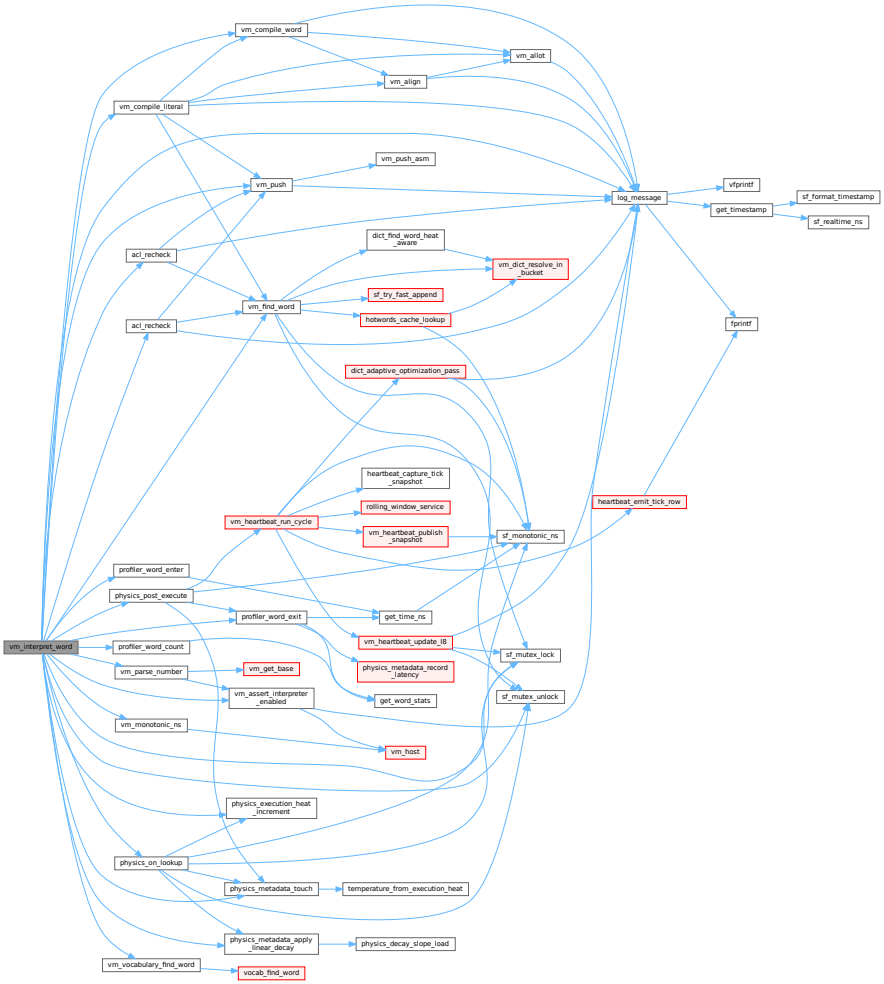
Parameters

vm	VM instance.
word_str	Token string (need not be NUL-terminated).
len	Length of `word_str` in bytes.

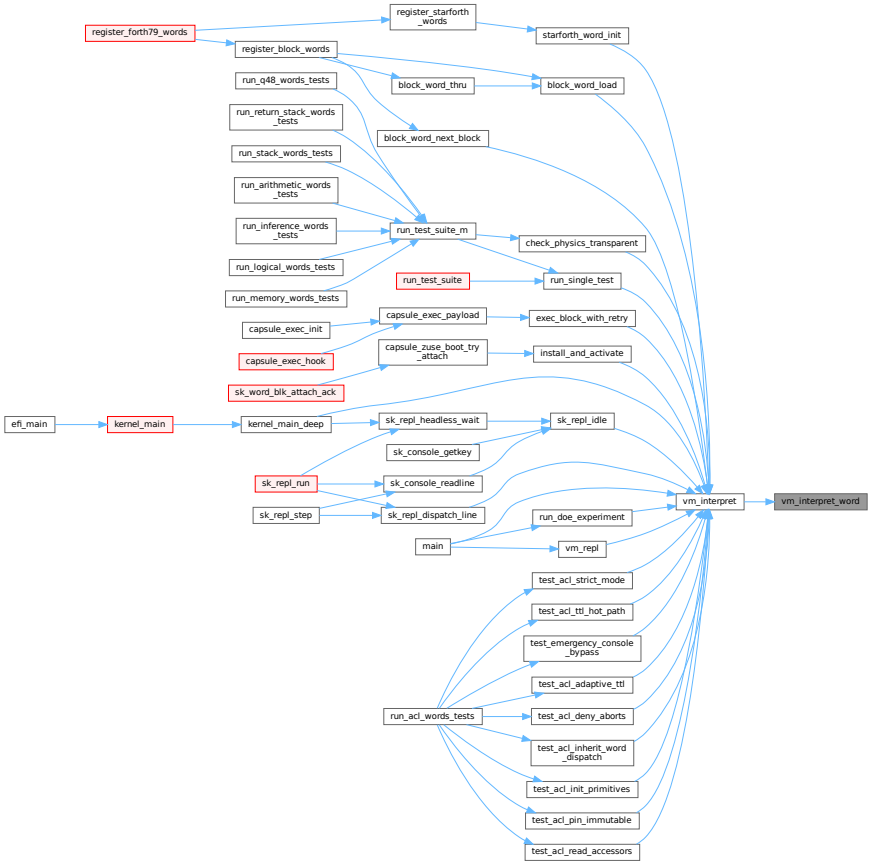
References acl_recheck(), acl_recheck(), VM::current_executing_entry, VM::dict_lock, VM::dsp, VM::emergency_console, entry, VM::error, DictEntry::execution_heat, DictEntry::flags, g_sk_fault_word, VM::heartbeat, DictPhysics::last_active_ns, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, VM::mode, MODE_COMPILE, name, DictEntry::physics, physics_execution_heat_increment(), physics_metadata_apply_linear_decay(), physics_metadata_touch(), physics_on_lookup(), physics_post_execute(), profiler_word_count(), profiler_word_enter(), profiler_word_exit(), VM::rsp, sf_mutex_lock(), sf_mutex_unlock(), HeartbeatState::tick_count, vm_assert_interpreter_enabled(), vm_compile_literal(), vm_compile_word(), vm_find_word(), vm_monotonic_ns(), vm_parse_number(), vm_push(), vm_vocabulary_find_word(), DictEntry::word_id, WORD_IMMEDIATE, and HeartbeatState::words_executed.

Referenced by vm_interpret().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.34 vm_load_cell()

```
cell_t vm_load_cell (
            struct VM * vm,
            vaddr_t addr )
```

Load an aligned cell from VM memory.

Validates that `addr` is within bounds for a full `cell_t` read and that it is naturally aligned (addr % sizeof(cell_t) == 0). Uses `memcpy()` rather than a direct pointer dereference to avoid strict aliasing and alignment UB. Sets `vm->error` and returns 0 on failure.

Parameters

vm	VM instance.
addr	Aligned VM byte offset to read.

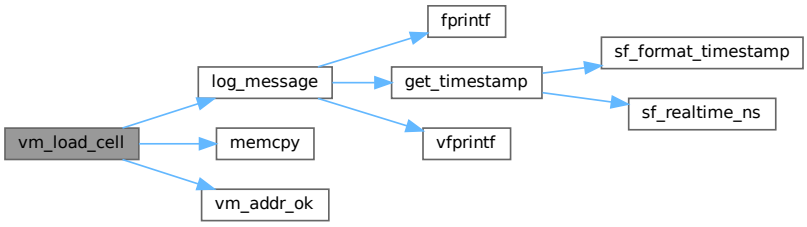
Returns

Cell value at `addr`, or 0 on alignment or bounds error.

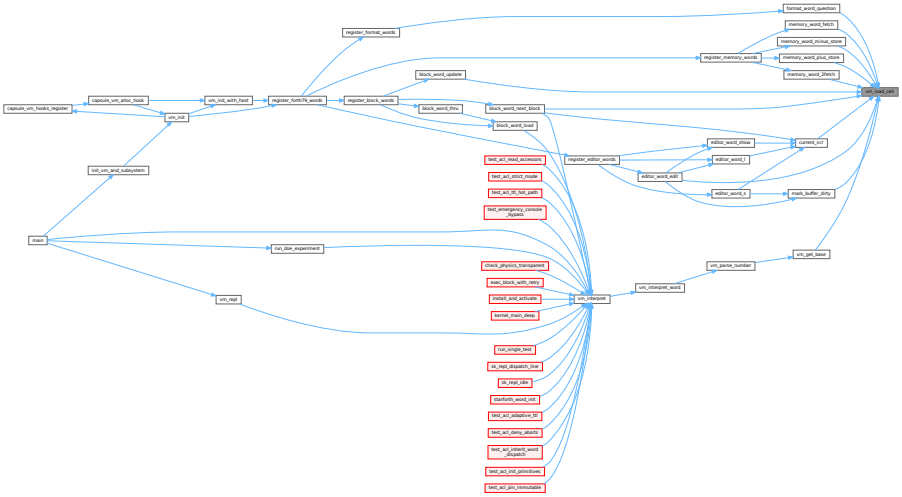
References VM::error, LOG_ERROR, log_message(), memcpy(), VM::memory, and vm_addr_ok().

Referenced by block_word_next_block(), block_word_update(), current_scr(), editor_word_edit(), format_word_question(), mark_buffer_dirty(), memory_word_2fetch(), memory_word_fetch(), memory_word_minus_store(), memory_word_plus_store(), and vm_get_base().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.35 vm_load_u8()

```
uint8_t vm_load_u8 (
            struct VM * vm,
            vaddr_t addr )
```

Load an unsigned byte from VM memory.

Resolves `addr` via `vm_ptr()`. Sets `vm->error` and returns 0 if the address is out of bounds.

Parameters

vm	VM instance.
addr	VM byte offset to read.

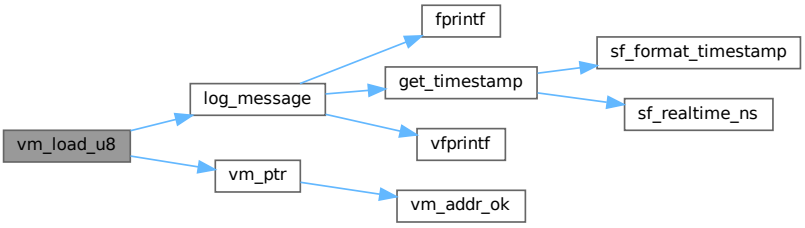
Returns

Byte value at `addr`, or 0 on error.

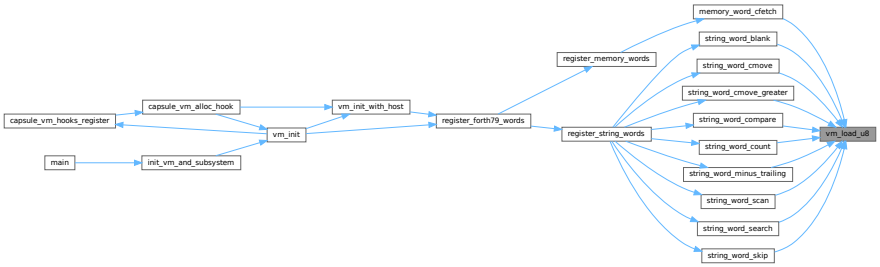
References VM::error, LOG_ERROR, log_message(), and vm_ptr().

Referenced by memory_word_cfetch(), string_word_blank(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_count(), string_word_minus_trailing(), string_word_scan(), string_word_search(), and string_word_skip().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.36 vm_log_attributed_vm()

```
VM * vm_log_attributed_vm (
            void  )
```

References g_log_attrib_vm.

7.192.2.37 vm_make_immediate()

```
void vm_make_immediate (
            VM * vm )
```

Mark the most recently created word as IMMEDIATE (FORTH-79).

Sets `WORD_IMMEDIATE` on `vm->latest` so the word executes during compilation rather than being compiled into the current definition. Also calls `physics_metadata_refresh_state()` to update the physics engine's record of the entry's flags.

Sets `vm->error` if `vm` has no `latest` entry (i.e., the dictionary is empty or no word has been created yet).

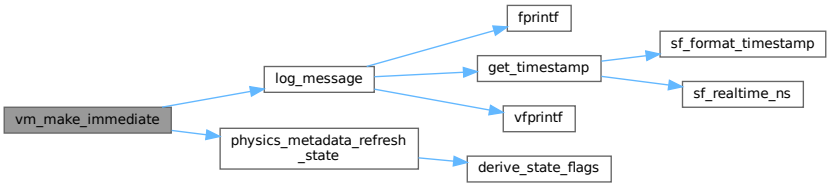
Parameters

vm	VM instance.

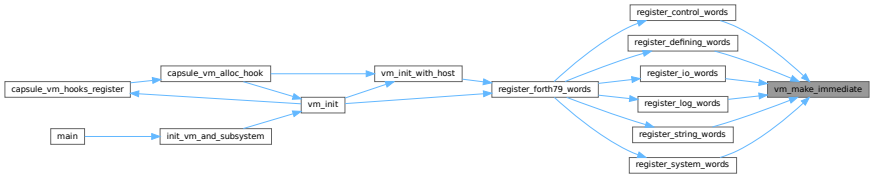
References VM::error, DictEntry::flags, VM::latest, LOG_DEBUG, LOG_ERROR, log_message(), DictEntry::name, DictEntry::name_len, physics_metadata_refresh_state(), and WORD_IMMEDIATE.

Referenced by register_control_words(), register_defining_words(), register_io_words(), register_log_words(), register_string_words(), and register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:



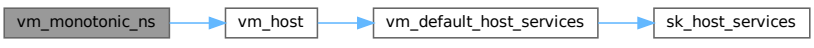
7.192.2.38 vm_monotonic_ns()

```
uint64_t vm_monotonic_ns (
            VM * vm )
```

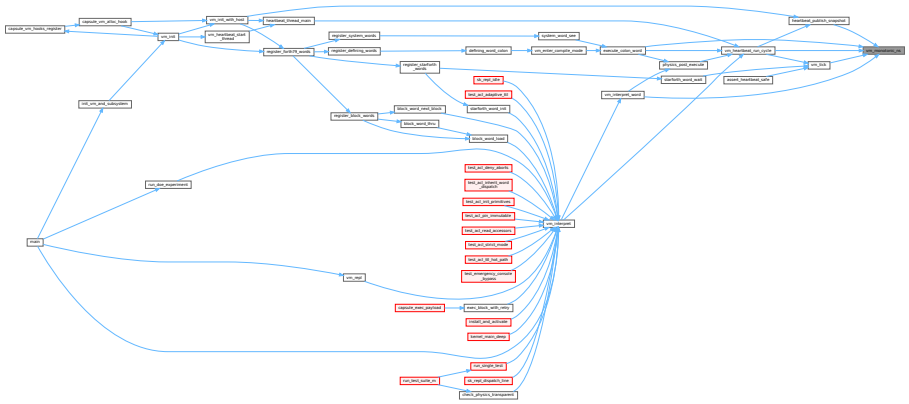
References VMHostServices::monotonic_ns, and vm_host().

Referenced by execute_colon_word(), heartbeat_publish_snapshot(), vm_heartbeat_run_cycle(), vm_interpret_word(), and vm_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.39 vm_parse_number()

```
int vm_parse_number (
            VM * vm,
            const char * s,
            cell_t * out )
```

Attempt to parse a string as an integer in the current number base.

Reads the current base from `vm_get_base()`, then converts each character of `s` (case-insensitive, digits 0–9 and letters A–Z/a–z) to a digit value. Returns 0 immediately on any character that is not a valid digit in the current base, or on an empty string after the optional sign.

Handles an optional leading `'+'` or `'-'` sign. The result is a full-width `cell_t` (sign extended for negative values).

Parameters

vm	VM instance (used for base only; may be NULL, in which case base defaults to 10).
s	NUL-terminated string to parse.
out	Pointer to receive the parsed value on success.

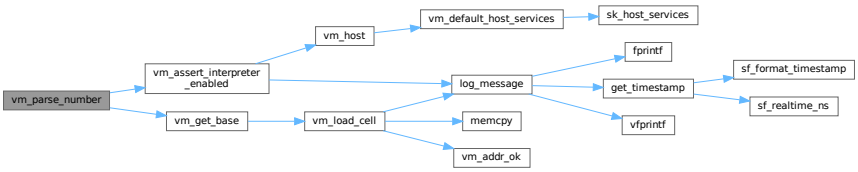
Returns

1 on successful parse, 0 on any parse failure.

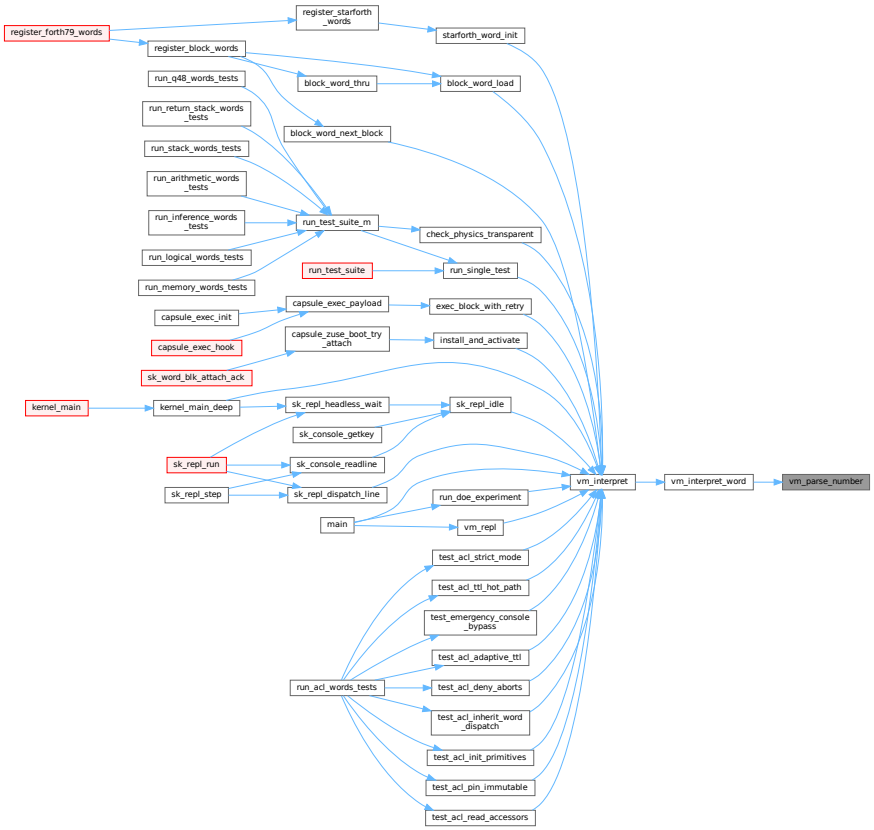
References base, vm_assert_interpreter_enabled(), and vm_get_base().

Referenced by vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.40 vm_parse_word()

```
int vm_parse_word (
            VM * vm,
            char * word,
            size_t max_len )
```

Parse the next whitespace-delimited token from the input buffer.

Skips leading whitespace (space, tab, CR, LF), then extracts characters until the next whitespace or end of buffer, storing up to `max_len` ? 1 characters in `word` followed by a NUL terminator. Advances `vm->input_pos` past the consumed token.

Parameters

vm	VM instance; `vm->input_buffer` / `input_pos` / `input_length` must be populated (typically by `vm_interpret()`).
word	Output buffer for the parsed token.
max_len	Size of `word` in bytes (including NUL terminator).

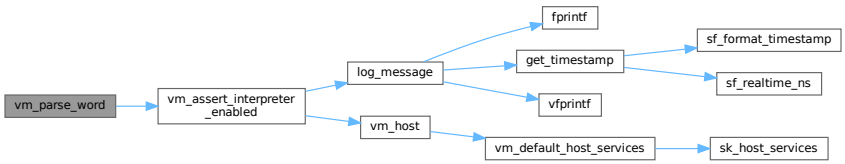
Returns

Number of characters written (excluding NUL), or 0 if the buffer is exhausted or `vm` / `word` is NULL.

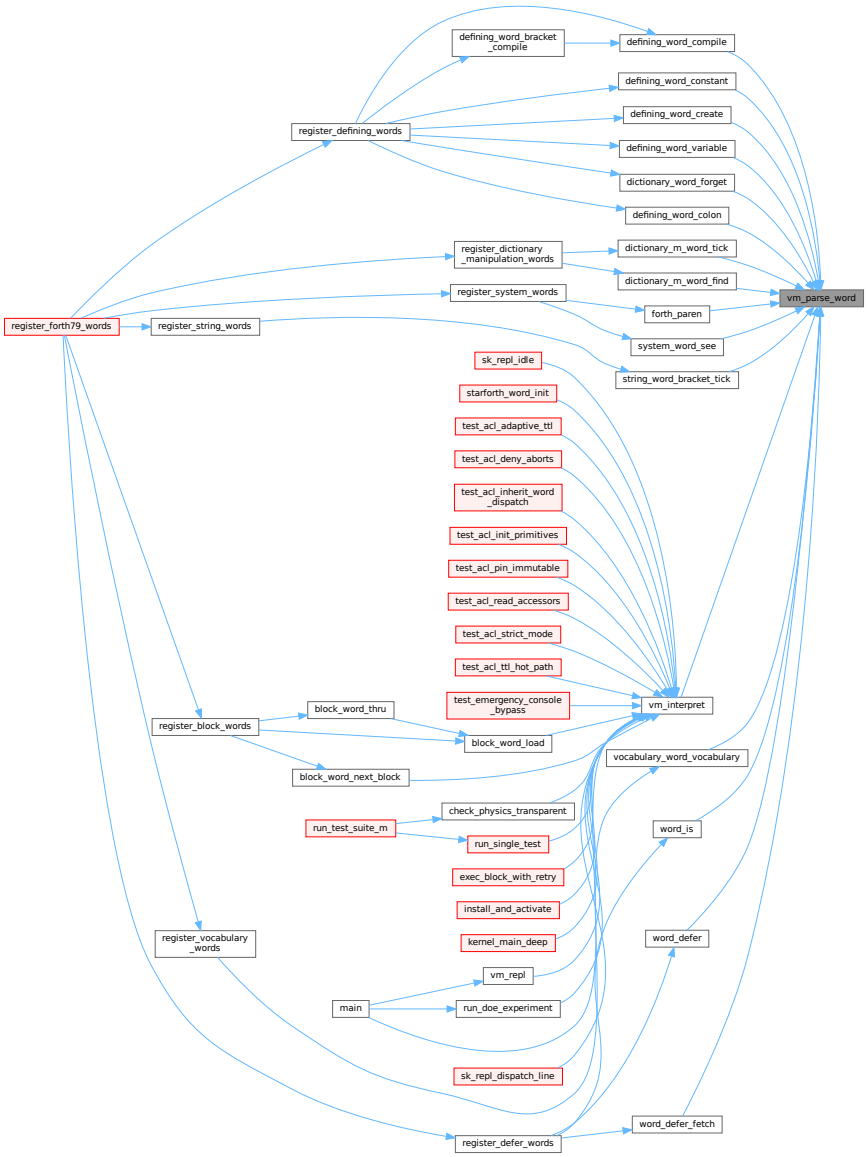
References VM::input_buffer, VM::input_length, VM::input_pos, and vm_assert_interpreter_enabled().

Referenced by defining_word_colon(), defining_word_compile(), defining_word_constant(), defining_word_create(), defining_word_variable(), dictionary_m_word_find(), dictionary_m_word_tick(), dictionary_word_forget(), forth_paren(), string_word_bracket_tick(), system_word_see(), vm_interpret(), vocabulary_word_vocabulary(), word_defer(), word_defer_fetch(), and word_is().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.41 vm_ptr()

```
uint8_t * vm_ptr (
            struct VM * vm,
            vaddr_t addr )
```

Return a host C pointer into VM memory at `addr`.

Validates the address with `vm_addr_ok()` (minimum 1-byte range) and returns `NULL` if the address is out of bounds or `vm` is uninitialised. The returned pointer is valid for at least one byte; callers that need multi-byte access should perform their own range check first.

Parameters

vm	VM instance.
addr	VM byte offset to dereference.

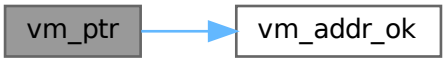
Returns

Host pointer into `vm->memory`, or NULL on bounds failure.

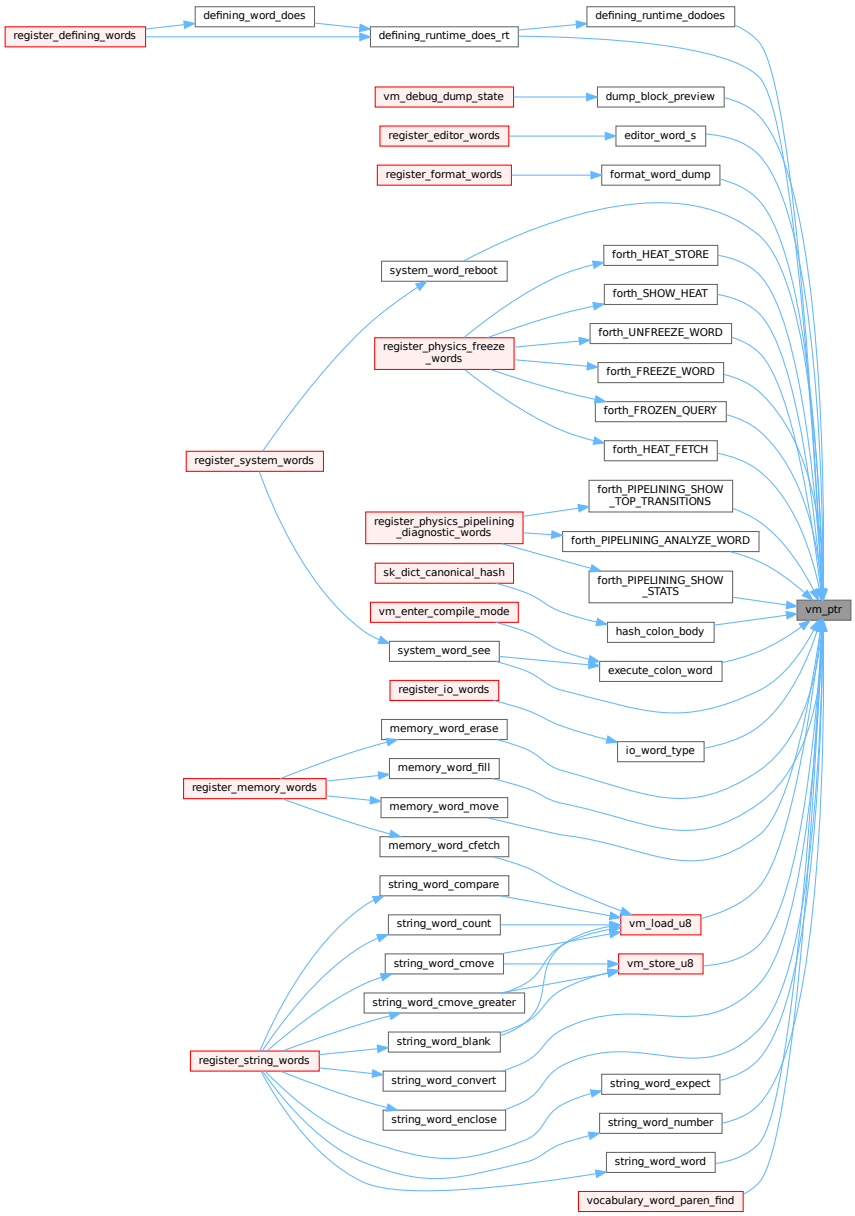
References VM::memory, and vm_addr_ok().

Referenced by defining_runtime_dodoes(), defining_runtime_does_rt(), dump_block_preview(), editor_word_s(), execute_colon_word(), format_word_dump(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_STORE(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TO forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), hash_colon_body(), io_word_type(), memory_word_erase(), memory_word_fill(), memory_word_move(), string_word_convert(), string_word_enclose(), string_word_expect(), string_word_number(), string_word_word(), system_word_reboot(), system_word_see(), vm_load_u8(), vm_store_u8(), and vocabulary_word_paren_find().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.42 vm_reset_hosted_fake_ns()

```
void vm_reset_hosted_fake_ns (
            VM * vm )
```

References VM::host, hosted_fake_ns, hosted_services, and PARITY_MODE.

Referenced by vm_init_with_host().

Here is the caller graph for this function:

7.192.2.43 vm_set_base()

```
void vm_set_base (
            VM * vm,
            unsigned b )
```

Set the VM number base and update both the cell and the host mirror.

Clamps `b` to [2, 36] (replacing out-of-range values with 10), then writes to the FORTH `BASE` variable cell at `vm->base_addr` and to the host-mirror field `vm->base` so both sources agree.

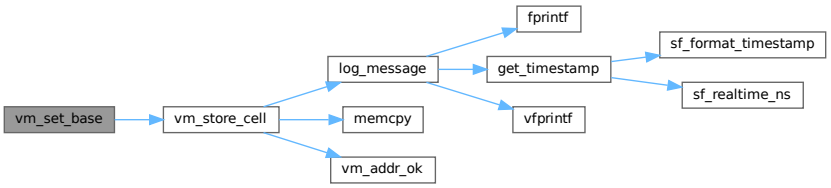
Parameters

vm	VM instance to update.
b	Desired number base; clamped to [2, 36].

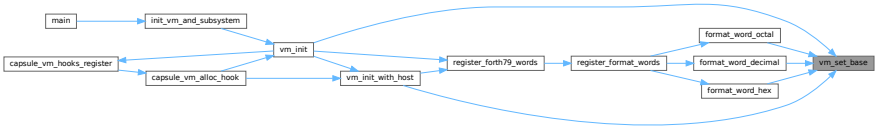
References VM::base, VM::base_addr, and vm_store_cell().

Referenced by format_word_decimal(), format_word_hex(), format_word_octal(), vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.44 vm_store_cell()

```
void vm_store_cell (
            struct VM * vm,
            vaddr_t addr,
            cell_t v )
```

Store an aligned cell to VM memory.

Validates alignment and bounds, then copies `v` into VM memory via `memcpy()`. Sets `vm->error` on alignment or bounds failure.

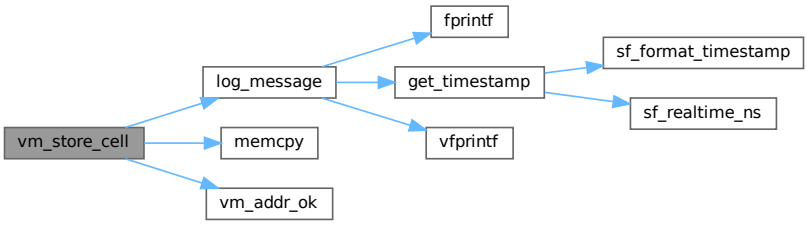
Parameters

vm	VM instance.
addr	Aligned VM byte offset to write.
v	Cell value to store.

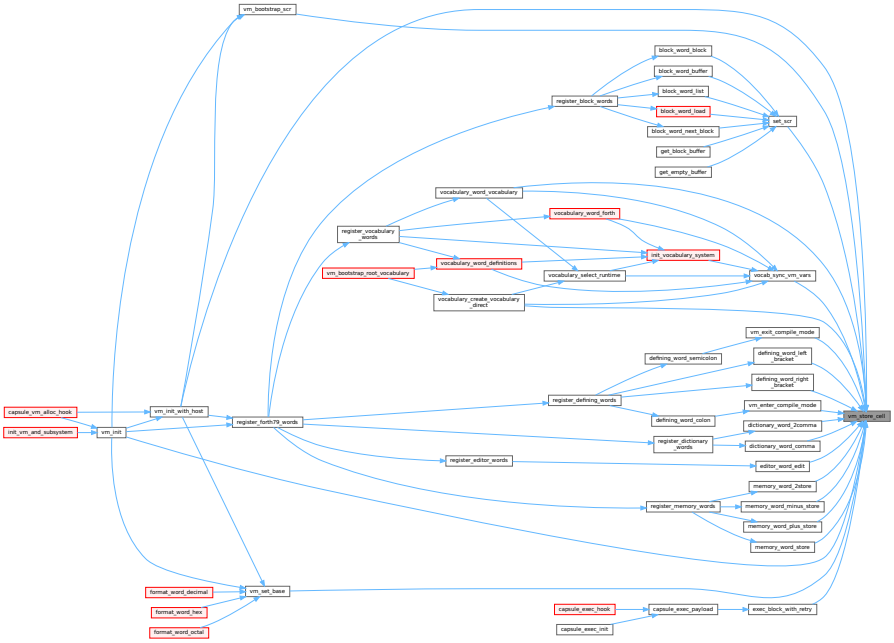
References VM::error, LOG_ERROR, log_message(), memcpy(), VM::memory, and vm_addr_ok().

Referenced by defining_word_left_bracket(), defining_word_right_bracket(), dictionary_word_2comma(), dictionary_word_comma(), editor_word_edit(), exec_block_with_retry(), memory_word_2store(), memory_word_minus_store(), memory_word_plus_store(), memory_word_store(), set_scr(), vm_bootstrap_scr(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_init(), vm_init_with_host(), vm_set_base(), vocab_sync_vm_vars(), vocabulary_create_vocabulary_dire and vocabulary_word_vocabulary().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.45 vm_store_u8()

```
void vm_store_u8 (
            struct VM * vm,
            vaddr_t addr,
            uint8_t v )
```

Store an unsigned byte to VM memory.

Resolves `addr` via `vm_ptr()`. Sets `vm->error` if the address is out of bounds; otherwise writes `v`.

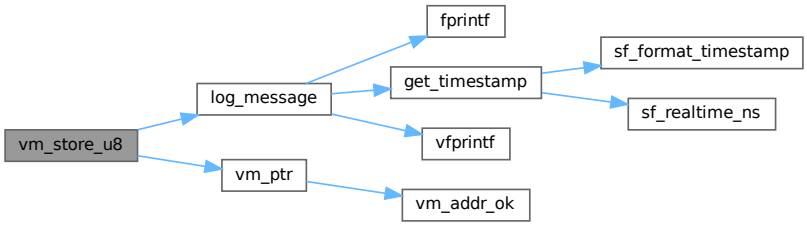
Parameters

vm	VM instance.
addr	VM byte offset to write.
v	Byte value to store.

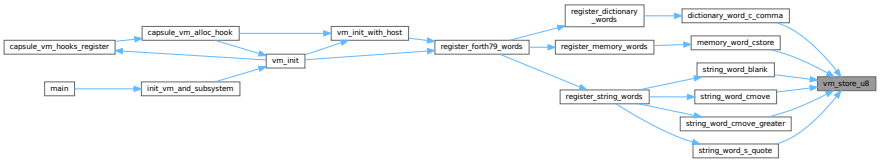
References VM::error, LOG_ERROR, log_message(), and vm_ptr().

Referenced by dictionary_word_c_comma(), memory_word_cstore(), string_word_blank(), string_word_cmove(), string_word_cmove_greater(), and string_word_s_quote().

Here is the call graph for this function:



Here is the caller graph for this function:



7.192.2.46 vm_zuse_cert_install()

```
int vm_zuse_cert_install (
            VM * vm,
            const uint8_t seed[32],
            const uint8_t pubkey[32] )
```

One-time write of the Zuse cert (seed + derived pubkey) – blows the fuse.

Deliberately not backed by a dictionary CONSTANT: ACL-PIN only blocks redefinition (vm_create_word shadowing), not a >BODY-then-store on the word's data field, so a pinned CONSTANT is not actually immutable against FORTH-level tampering. Keeping the value in a VM struct field with no corresponding FORTH store word closes that path entirely – see FABRIC-2.md's Milestone 4 mint-then-pin writeup for the finding.

Parameters

vm	VM instance.
seed	Ed25519 seed, 32 bytes (the private identity).
pubkey	Ed25519 public key derived from seed, 32 bytes.

Returns

0 on success; -1 if already installed (fuse already blown).

References memcpy(), VM::zuse_cert_installed, VM::zuse_cert_pubkey, and VM::zuse_cert_seed.

Referenced by install_and_activate().

Here is the call graph for this function:

Here is the caller graph for this function:

7.192.3 Variable Documentation

7.192.3.1 g_log_attrib_vm

```
VM* g_log_attrib_vm  [static]
```

Referenced by vm_interpret(), and vm_log_attributed_vm().

7.192.3.2 g_vm_interpret_depth

```
int g_vm_interpret_depth  [static]
```

Referenced by sk_vm_at_outermost_interpret(), and vm_interpret().

7.192.3.3 hosted_fake_ns

```
uint64_t hosted_fake_ns = 0  [static]
```

Referenced by hosted_time_ns(), and vm_reset_hosted_fake_ns().

7.192.3.4 hosted_services

```
const VMHostServices hosted_services  [static]
```

Initial value:

```
= {
    .alloc = hosted_alloc,
    .free = hosted_free,
    .monotonic_ns = hosted_time_ns,
    .mutex_init = hosted_mutex_init,
    .mutex_lock = hosted_mutex_lock,
    .mutex_unlock = hosted_mutex_unlock,
    .mutex_destroy = hosted_mutex_destroy,
    .puts = hosted_puts,
    .putc = hosted_putc,
    .is_executable_ptr = hosted_xt_is_executable,
    .owns_xt_entry = hosted_xt_entry_owned,
    .panic = hosted_panic,
    .parity_mode =  0 ,
    .verbose = 0
}
```

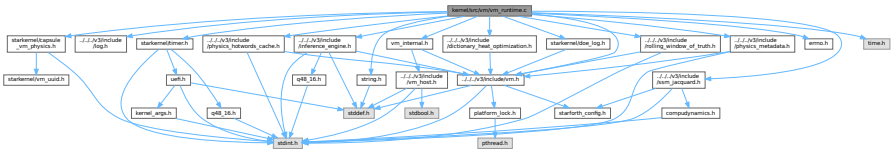
Referenced by vm_default_host_services(), and vm_reset_hosted_fake_ns().

7.193 kernel/src/vm/vm_log_buffer.c File Reference

7.194 kernel/src/vm/vm_runtime.c File Reference

```
#include "../../../v3/include/vm.h"
#include "../../../v3/include/log.h"
#include "../../../v3/include/rolling_window_of_truth.h"
#include "../../../v3/include/dictionary_heat_optimization.h"
#include "../../../v3/include/inference_engine.h"
#include "../../../v3/include/physics_metadata.h"
#include "../../../v3/include/physics_hotwords_cache.h"
#include "starkernel/doe_log.h"
#include "../../../v3/include/ssm_jacquard.h"
#include "vm_internal.h"
#include "starkernel/capsule_vm_physics.h"
#include "starkernel/timer.h"
#include <errno.h>
#include <string.h>
#include <time.h>
```

Include dependency graph for vm_runtime.c:



Functions

- uint32_t heartbeat_snapshot_index_load (const volatile uint32_t *ptr)
- void heartbeat_snapshot_index_store (volatile uint32_t *ptr, uint32_t value)
- void heartbeat_publish_snapshot (VM *vm)
- void vm_tick (VM *vm)

  Central heartbeat dispatcher for time-driven tuning operations.
- void vm_tick_window_tuner (VM *vm)

  Loop #5: Context-aware window tuning via binary chop search.
- void vm_tick_slope_validator (VM *vm)

  Loop #3: Heat decay slope validation via periodic measurement.
- static void vm_tick_apply_background_decay (VM *vm, uint64_t now_ns)
- static void vm_heartbeat_update_l8 (VM *vm)

  L8 FINAL INTEGRATION: Jacquard mode selector heartbeat update.
- void vm_heartbeat_run_cycle (VM *vm)
- void * heartbeat_thread_main (void *arg)
- void vm_snapshot_read (const VM *vm, HeartbeatSnapshot *out_snapshot)
- void vm_tick_inference_engine (VM *vm)

  Phase 2: Unified Inference Engine - Adaptive Window & Decay Slope Tuning.

7.194.1 Function Documentation

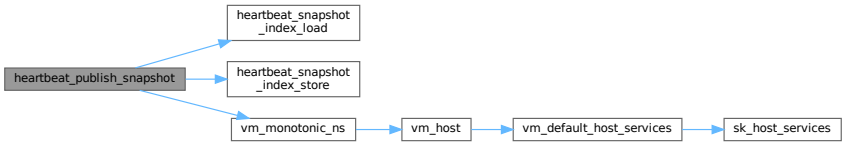
7.194.1.1 heartbeat_publish_snapshot()

```
void heartbeat_publish_snapshot (
            VM * vm )
```

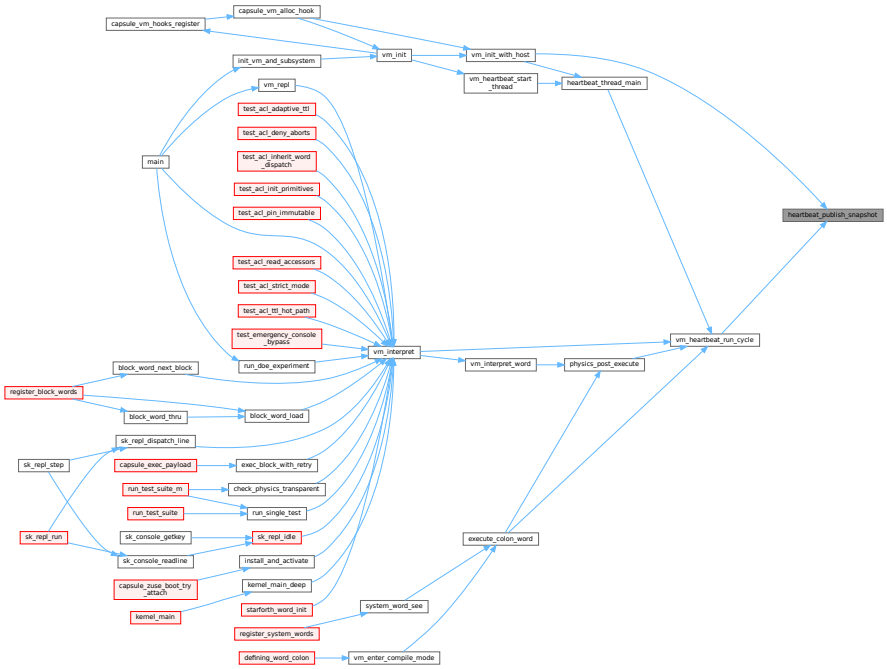
References HeartbeatSnapshot::decay_slope_q48, VM::decay_slope_q48, RollingWindowOfTruth::effective_window_size, VM::heartbeat, heartbeat_snapshot_index_load(), heartbeat_snapshot_index_store(), HeartbeatSnapshot::hot_word_count, VM::hot_word_count_at_check, HeartbeatSnapshot::published_ns, HeartbeatSnapshot::published_tick, VM::rolling_window, HeartbeatState::snapshot_index, HeartbeatState::snapshots, HeartbeatSnapshot::stale_word_count, VM::stale_word_count_at_chec HeartbeatState::tick_count, HeartbeatSnapshot::total_heat, VM::total_heat_at_last_check, vm_monotonic_ns(), and HeartbeatSnapshot::window_width.

Referenced by vm_heartbeat_run_cycle(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:

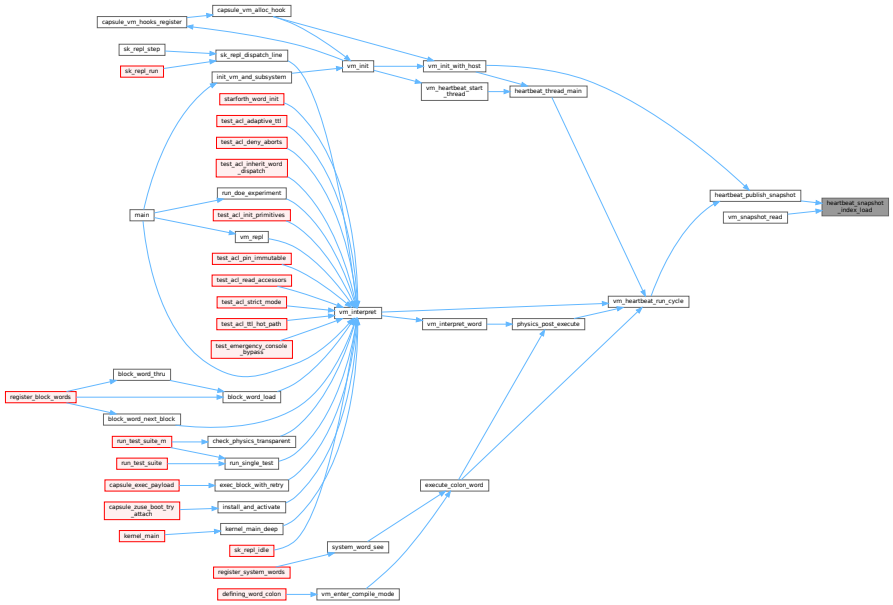


7.194.1.2 heartbeat_snapshot_index_load()

```
uint32_t heartbeat_snapshot_index_load (
            const volatile uint32_t * ptr )
```

Referenced by heartbeat_publish_snapshot(), and vm_snapshot_read().

Here is the caller graph for this function:

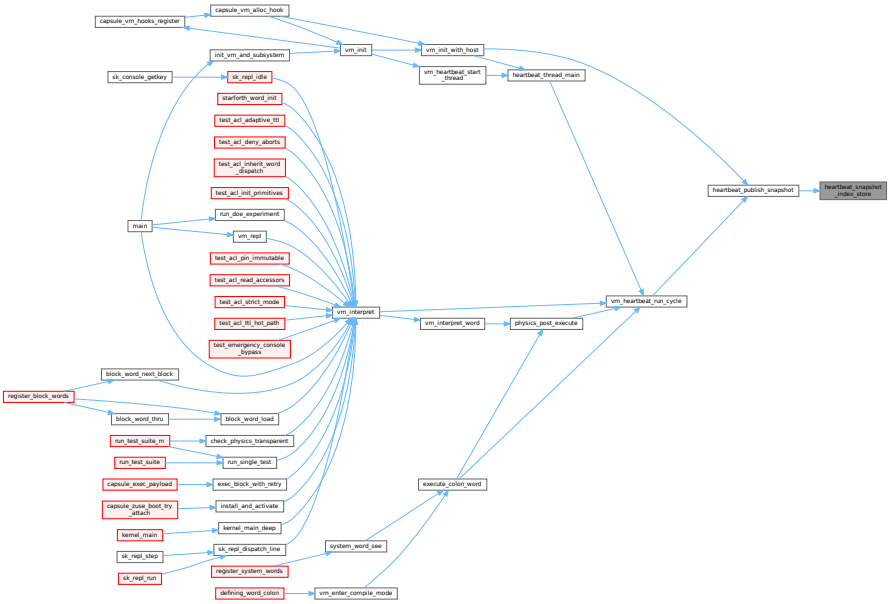


7.194.1.3 heartbeat_snapshot_index_store()

```
void heartbeat_snapshot_index_store (
            volatile uint32_t * ptr,
            uint32_t value )
```

Referenced by heartbeat_publish_snapshot().

Here is the caller graph for this function:



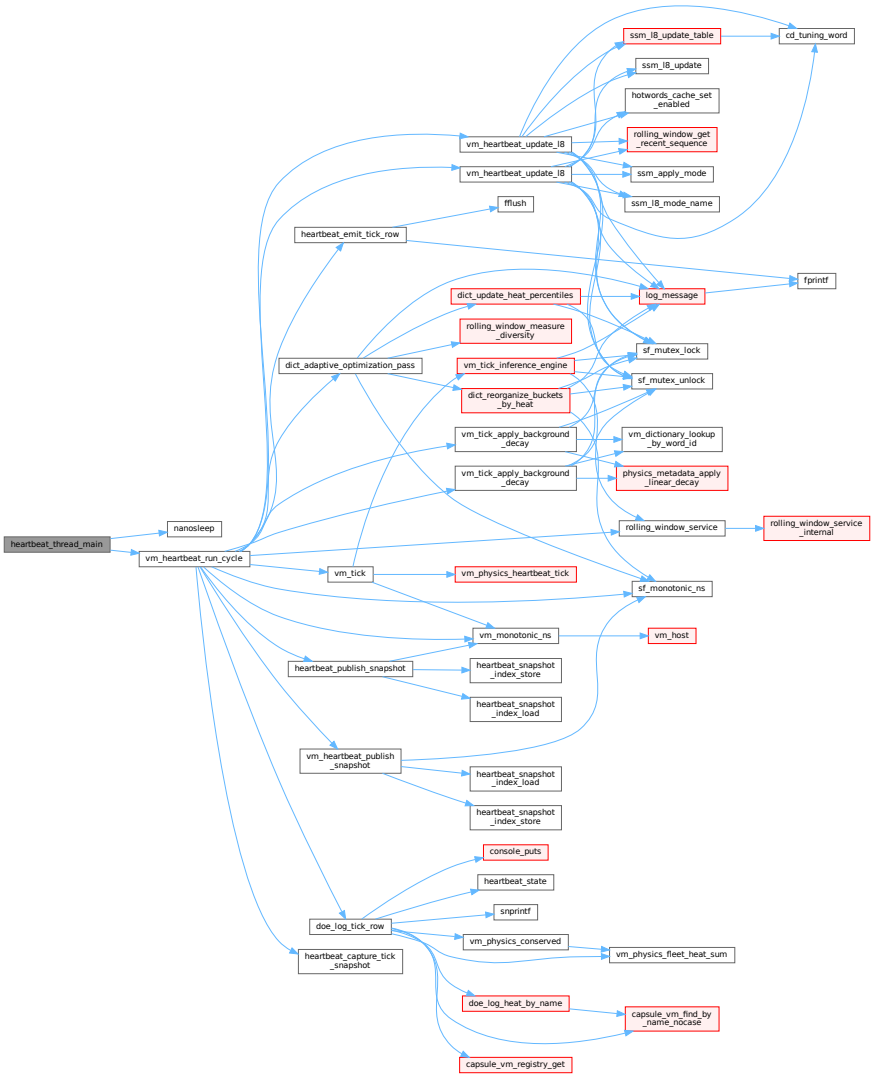
7.194.1.4 heartbeat_thread_main()

```
void * heartbeat_thread_main (
            void * arg )
```

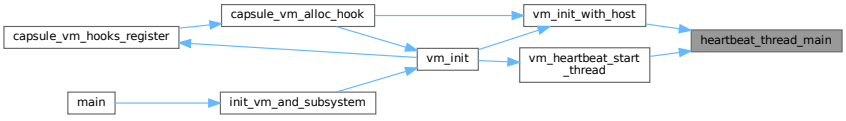
References errno, VM::heartbeat, HEARTBEAT_TICK_NS, nanosleep(), HeartbeatWorker::running, HeartbeatWorker::stop_requeste
HeartbeatWorker::tick_ns, timespec::tv_nsec, timespec::tv_sec, vm_heartbeat_run_cycle(), and HeartbeatState::worker.

Referenced by vm_heartbeat_start_thread(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



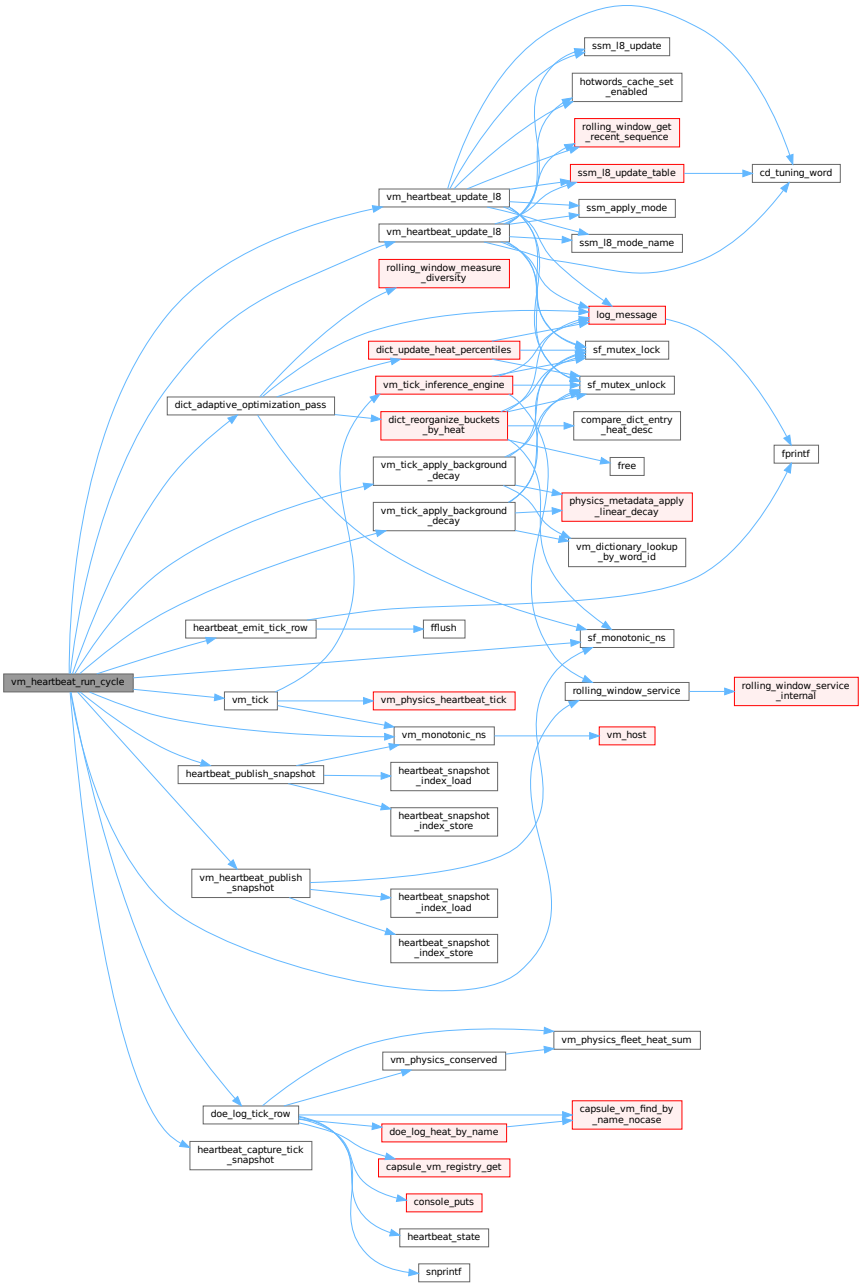
7.194.1.5 vm_heartbeat_run_cycle()

```
void vm_heartbeat_run_cycle (
            VM * vm )
```

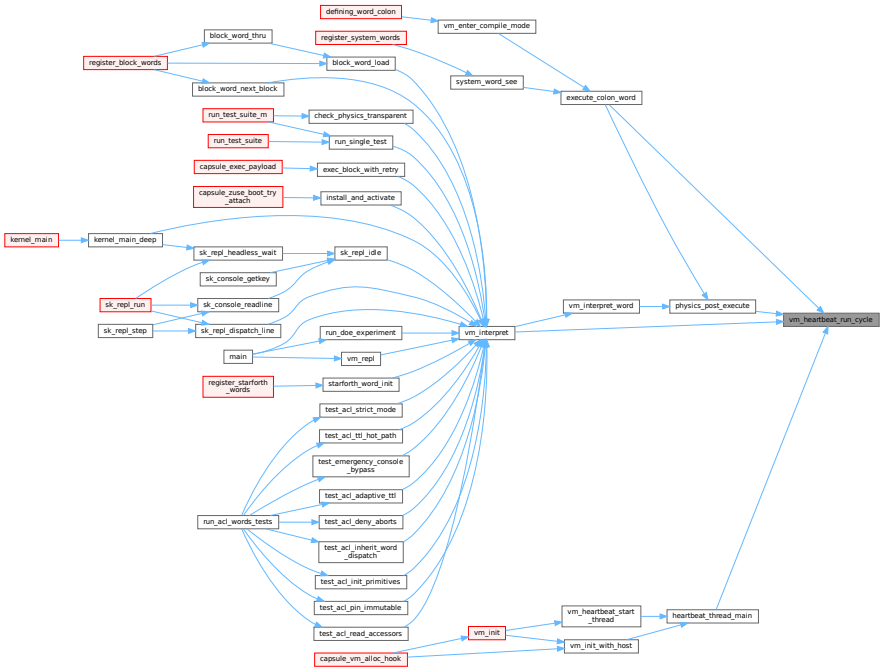
References dict_adaptive_optimization_pass(), doe_log_tick_row(), VM::heartbeat, heartbeat_capture_tick_snapshot(), heartbeat_emit_tick_row(), HeartbeatState::heartbeat_enabled, heartbeat_publish_snapshot(), VM::rolling_window, rolling_window_service(), sf_monotonic_ns(), vm_heartbeat_publish_snapshot(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_monotonic_ns(), vm_tick(), vm_tick_apply_background_decay(), and vm_tick_apply_background_dec

Referenced by execute_colon_word(), heartbeat_thread_main(), physics_post_execute(), and vm_interpret().

Here is the call graph for this function:



Here is the caller graph for this function:



7.194.1.6 vm_heartbeat_update_l8()

```
static void vm_heartbeat_update_l8 (
            VM * vm )  [static]
```

L8 FINAL INTEGRATION: Jacquard mode selector heartbeat update.

Collects metrics from L1-L7 physics layers and feeds them to the L8 Jacquard mode selector. L8 then chooses the optimal configuration mode based on workload characteristics and applies it to the runtime.

This is the SOLE policy engine - all adaptive decisions flow through L8.

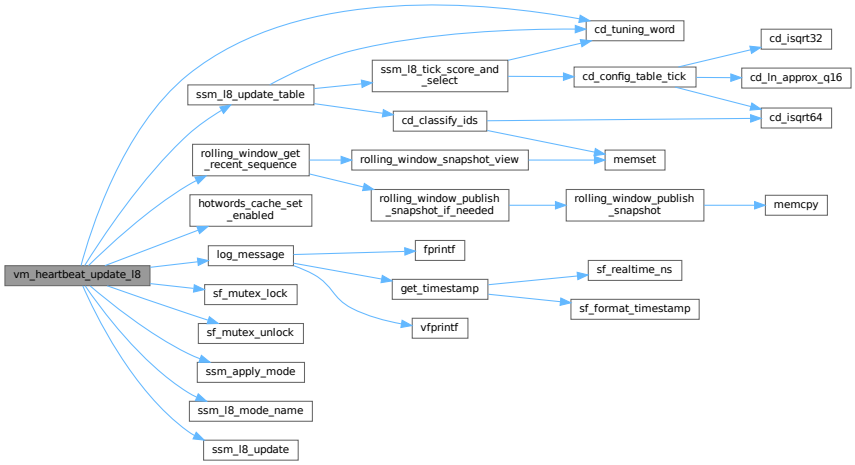
Parameters

vm	Pointer to VM instance

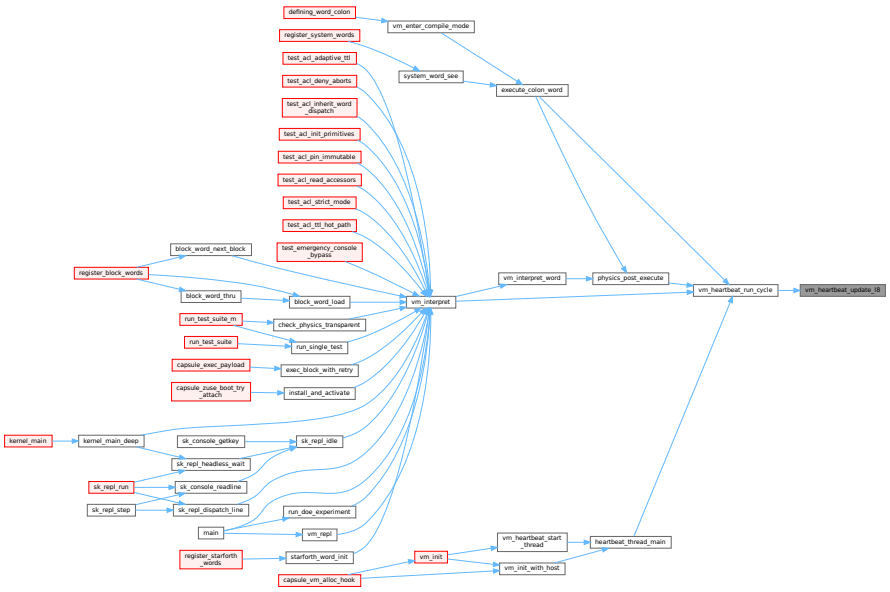
References CD_MAX_CLASSIFY_DEPTH, cd_tuning_word(), CDConfigTable::current_config, ssm_l8_state_t::current_mode, CDConfigTable::current_regime, ssm_l8_metrics_t::cv, VM::decay_slope_q48, InferenceOutputs::early_exited, RollingWindowOfTruth::effective_window_size, ssm_l8_metrics_t::entropy, VM::heartbeat, VM::hotwords_cache, hotwords_cache_set_enabled(), CDTuning::id_window_depth, ssm_l8_metrics_t::inference_early_exited, ssm_l8_metrics_t::inference, ssm_config_t::L1_heat_tracking, ssm_config_t::L2_rolling_window, ssm_config_t::L3_linear_decay, ssm_config_t::L4_pipelining, ssm_config_t::L5_window_inference, ssm_config_t::L6_decay_inference, ssm_config_t::L7_adaptive_heartrate, VM::last_inference_outputs, HeartbeatState::last_inference_tick, LOG_INFO, log_message(), CDConfigTable::num_configs, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, CDConfigTable::regime_scores, VM::rolling_window, rolling_window_get_recent_sequence(), ROLLING_WINDOW_SIZE, sf_mutex_lock(), sf_mutex_unlock(), ssm_apply_mode(), VM::ssm_config, ssm_l8_mode_name(), VM::ssm_l8_state, ssm_l8_update(), ssm_l8_update_table(), ssm_l8_metrics_t::stability_score, ssm_l8_state_t::table, ssm_l8_metrics_t::temporal_decay, HeartbeatState::tick_count, RollingWindowOfTruth::total_executions, and VM::tuning_lock.

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:

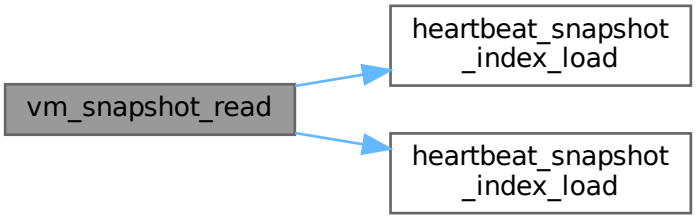


7.194.1.7 vm_snapshot_read()

```
void vm_snapshot_read (
            const VM * vm,
            HeartbeatSnapshot * out_snapshot )
```

References VM::heartbeat, heartbeat_snapshot_index_load(), heartbeat_snapshot_index_load(), HeartbeatState::snapshot_index, and HeartbeatState::snapshots.

Here is the call graph for this function:



7.194.1.8 vm_tick()

```
void vm_tick (
            VM * vm )
```

Central heartbeat dispatcher for time-driven tuning operations.

Aggregates all periodic optimization tasks (Loop #3 and Loop #5) into one place. Designed as plugin architecture - new tuning operations can be added as plugins.

Options for integration:

- Synchronous (now): Called from main execution loop, every N executions
- Background thread (future): Runs in separate thread, decoupled from VM execution

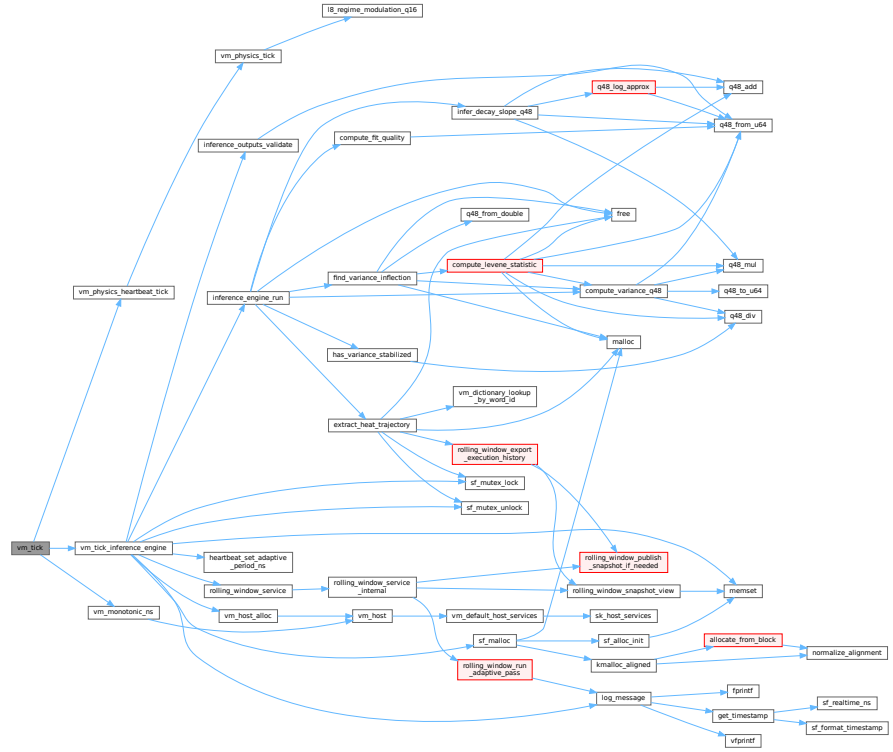
Parameters

vm	Pointer to VM instance

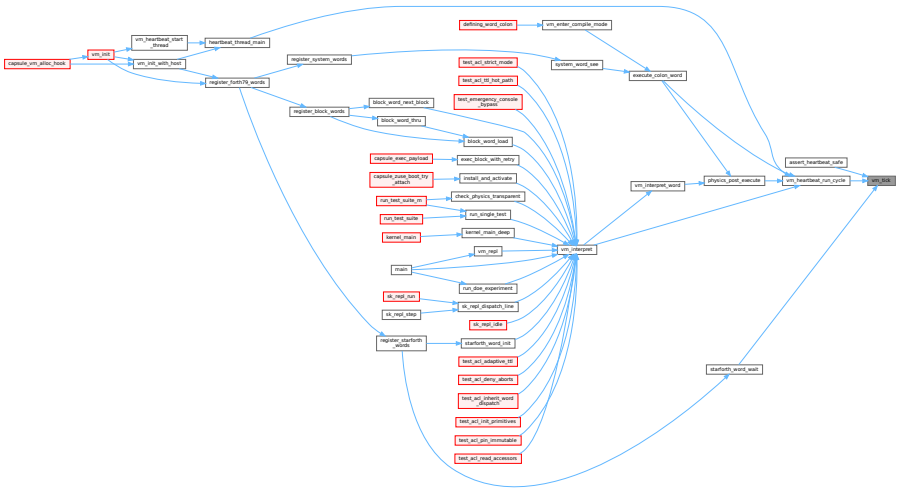
References VM::heartbeat, HeartbeatState::heartbeat_enabled, HEARTBEAT_INFERENCE_FREQUENCY, HeartbeatState::last_inference_tick, HeartbeatState::tick_count, vm_monotonic_ns(), vm_physics_heartbeat_tick(), and vm_tick_inference_engine().

Referenced by assert_heartbeat_safe(), starforth_word_wait(), and vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



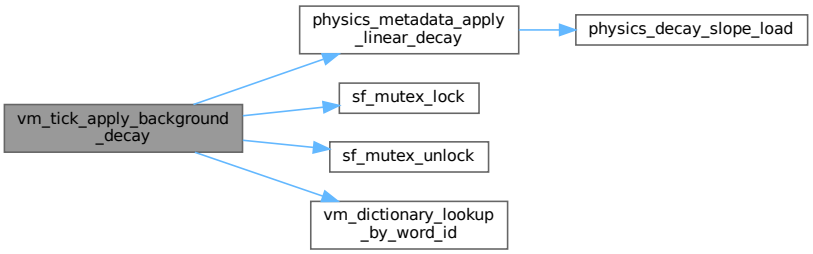
7.194.1.9 vm_tick_apply_background_decay()

```
static void vm_tick_apply_background_decay (
            VM * vm,
            uint64_t now_ns )  [static]
```

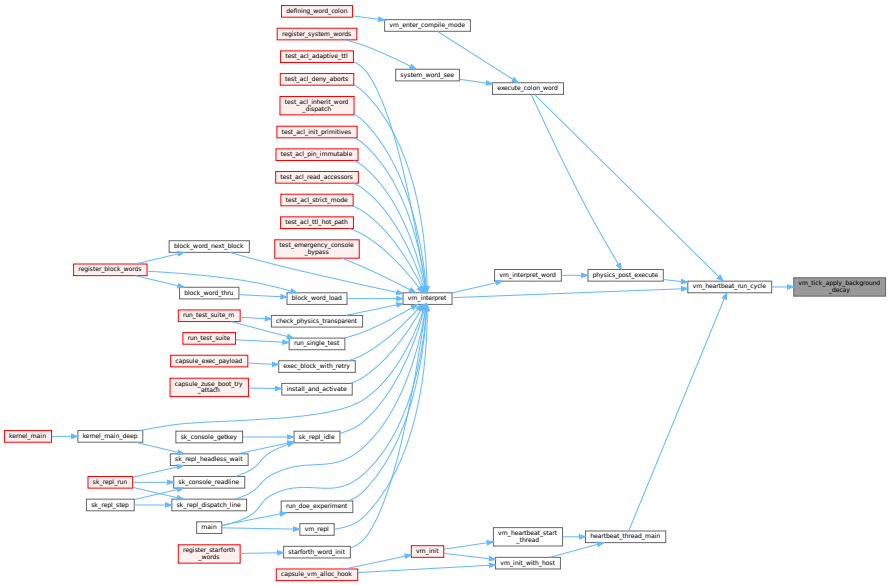
References VM::dict_lock, VM::heartbeat, HEARTBEAT_DECAY_BATCH, VM::heartbeat_decay_cursor_id, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, VM::latest, DictEntry::link, DictEntry::physics, physics_metadata_apply_line sf_mutex_lock(), sf_mutex_unlock(), HeartbeatState::tick_count, vm_dictionary_lookup_by_word_id(), DictEntry::word_id, and WORD_ID_INVALID.

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.194.1.10 vm_tick_inference_engine()

```
void vm_tick_inference_engine (
            VM * vm )
```

Phase 2: Unified Inference Engine - Adaptive Window & Decay Slope Tuning.

Coordinates inference on rolling window of truth to determine:

- Optimal adaptive window width (via variance inflection detection)
- Optimal decay slope (via exponential regression on heat trajectory)

Uses ANOVA early-exit to skip full inference when variance is stable (<5% change). All math uses Q48.16 fixed-point (integer-only, no floating-point).

Replaces legacy vm_tick_window_tuner() and vm_tick_slope_validator().

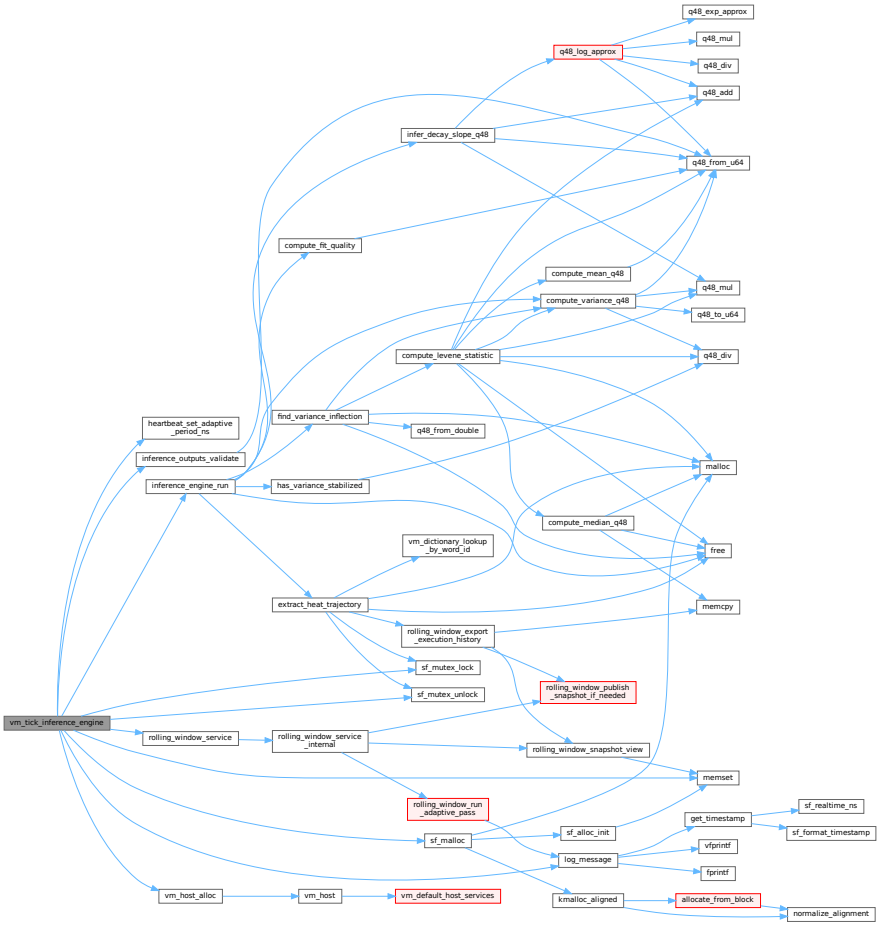
Parameters

vm	Pointer to VM instance

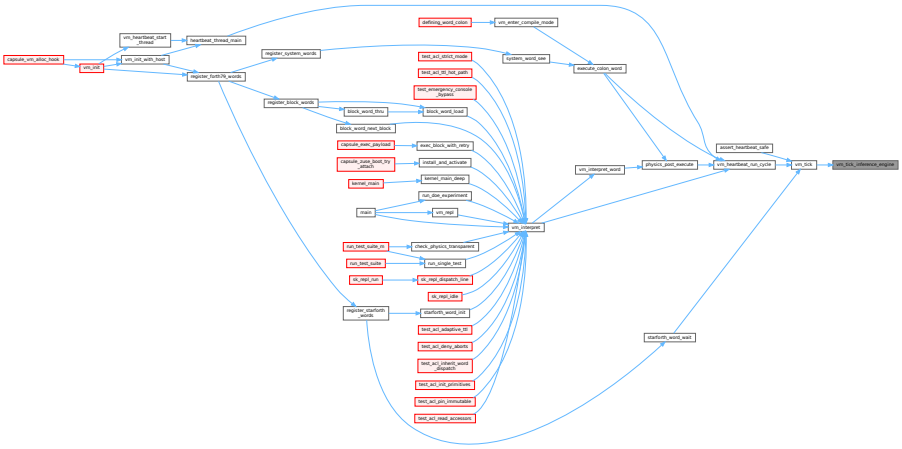
References InferenceOutputs::adaptive_decay_slope, InferenceOutputs::adaptive_window_width, VM::decay_slope_q48, VM::dict_lock, HeartbeatState::early_exit_count, InferenceOutputs::early_exited, RollingWindowOfTruth::effective_window_size, VM::heartbeat, HeartbeatState::heartbeat_enabled, heartbeat_set_adaptive_period_ns(), HEARTBEAT_TICK_NS, HOTWORDS_EXECUTION_HEAT_THRESHOLD, inference_engine_run(), inference_outputs_validate(), HeartbeatState::inference_, RollingWindowOfTruth::is_warm, VM::last_inference_outputs, HeartbeatState::last_inference_tick, VM::latest, LOG_DEBUG, LOG_ERROR, LOG_INFO, log_message(), memset(), VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempt, PipelineGlobalMetrics::prefetch_hits, VM::rolling_window, rolling_window_service(), sf_malloc(), sf_mutex_lock(), sf_mutex_unlock(), InferenceOutputs::slope_fit_quality_q48, VM::stale_word_count_at_check, HeartbeatState::tick_count, HeartbeatWorker::tick_ns, HeartbeatState::tick_target_ns, RollingWindowOfTruth::total_executions, VM::total_heat_at_last_check, VM::tuning_lock, vm_host_alloc(), InferenceInputs::window, RollingWindowOfTruth::window_pos, InferenceOutputs::window_variance, word_count, VM::word_count_at_check, and HeartbeatState::worker.

Referenced by vm_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.194.1.11 vm_tick_slope_validator()

```
void vm_tick_slope_validator (
```

```
VM * vm )
```

Loop #3: Heat decay slope validation via periodic measurement.

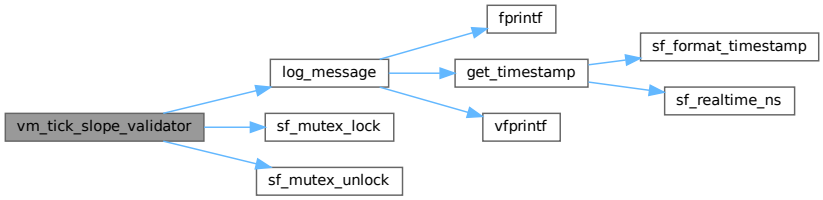
Validates that linear decay is actually helping optimize dictionary caching. Measures stale word ratio, hot word count, and average heat distribution.

Parameters

vm	Pointer to VM instance

References VM::decay_slope_direction, VM::decay_slope_q48, VM::dict_lock, VM::hot_word_count_at_check, HOTWORDS_EXECUTION_HEAT_THRESHOLD, VM::latest, LOG_DEBUG, LOG_INFO, log_message(), sf_mutex_lock(), sf_mutex_unlock(), VM::stale_word_count_at_check, VM::total_heat_at_last_check, VM::tuning_lock, word_count, and VM::word_count_at_check.

Here is the call graph for this function:



7.194.1.12 vm_tick_window_tuner()

```
void vm_tick_window_tuner (
VM * vm )
```

Loop #5: Context-aware window tuning via binary chop search.

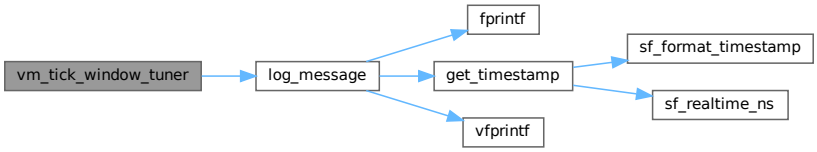
Uses prefetch accuracy to guide window size adaptation. Binary search converges on optimal effective_window_↩ size for current workload.

Parameters

vm	Pointer to VM instance

References ADAPTIVE_MIN_WINDOW_SIZE, RollingWindowOfTruth::effective_window_size, ENABLE_PIPELINING, RollingWindowOfTruth::is_warm, PipelineGlobalMetrics::last_checked_accuracy, PipelineGlobalMetrics::last_checked_window_size, LOG_DEBUG, LOG_INFO, log_message(), VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::rolling_window, ROLLING_WINDOW_SIZE, and PipelineGlobalMetrics::window_tuning_ch

Here is the call graph for this function:

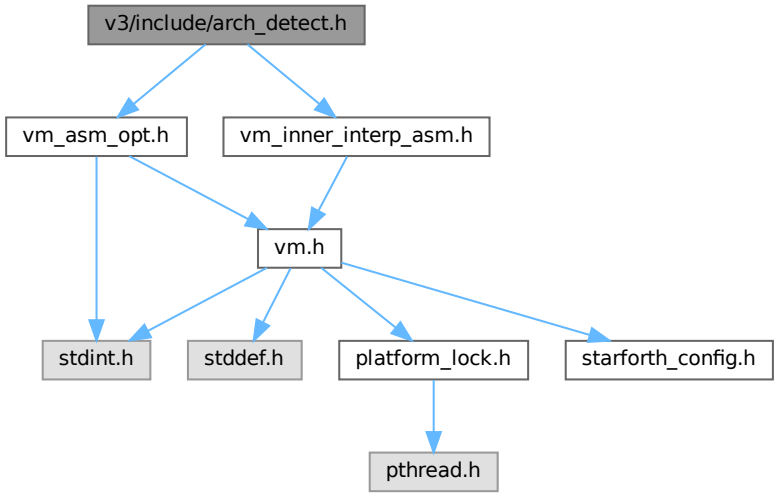


7.195 v3/include/arch_detect.h File Reference

Architecture Detection and Unified API for StarForth.

```
#include "vm_asm_opt.h"
#include "vm_inner_interp_asm.h"
```

Include dependency graph for arch_detect.h:



Macros

- #define ARCH_X86_64 0
- #define ARCH_ARM64 0
- #define ARCH_RISCV64 0
- #define ARCH_NAME "Unknown"
- #define vm_push_opt(vm, val) vm_push_asm(vm, val)
- #define vm_pop_opt(vm) vm_pop_asm(vm)
- #define vm_rpush_opt(vm, val) vm_rpush_asm(vm, val)
- #define vm_rpop_opt(vm) vm_rpop_asm(vm)
- #define vm_add_overflow_opt(a, b, res) vm_add_check_overflow(a, b, res)

- #define vm_sub_overflow_opt(a, b, res) vm_sub_check_overflow(a, b, res)
- #define vm_mul_double_opt(a, b, hi, lo) vm_mul_double(a, b, hi, lo)
- #define vm_divmod_opt(dividend, divisor, quot, rem) vm_divmod(dividend, divisor, quot, rem)
- #define vm_strcmp_opt(s1, s2, len) vm_strcmp_asm(s1, s2, len)
- #define vm_memcpy_opt(dst, src, len) vm_memcpy_asm(dst, src, len)
- #define vm_memzero_opt(dst, len) vm_memzero_asm(dst, len)
- #define vm_min_opt(a, b) vm_min_asm(a, b)
- #define vm_max_opt(a, b) vm_max_asm(a, b)
- #define vm_abs_opt(a) vm_abs_asm(a)
- #define vm_clz_opt(x) vm_clz(x)
- #define vm_ctz_opt(x) vm_ctz(x)
- #define vm_popcnt_opt(x) vm_popcnt(x)
- #define vm_prefetch_opt(addr) vm_prefetch(addr)
- #define vm_prefetch_stream_opt(addr) vm_prefetch_stream(addr)
- #define NEXT_OPT() NEXT_ASM()
- #define vm_setup_registers_opt(vm) vm_setup_registers(vm)
- #define vm_save_registers_opt(vm) vm_save_registers(vm)
- #define PRIM_DUP_OPT() PRIM_DUP()
- #define PRIM_DROP_OPT() PRIM_DROP()
- #define PRIM_SWAP_OPT() PRIM_SWAP()
- #define PRIM_PLUS_OPT() PRIM_PLUS()
- #define PRIM_MINUS_OPT() PRIM_MINUS()
- #define PRIM_STAR_OPT() PRIM_STAR()
- #define PRIM_FETCH_OPT() PRIM_FETCH()
- #define PRIM_STORE_OPT() PRIM_STORE()
- #define PRIM_TO_R_OPT() PRIM_TO_R()
- #define PRIM_R_FROM_OPT() PRIM_R_FROM()
- #define PRIM_R_FETCH_OPT() PRIM_R_FETCH()
- #define PRIM_BRANCH_OPT() PRIM_BRANCH()
- #define PRIM_ZBRANCH_OPT() PRIM_ZBRANCH()

Functions

- static int vm_has_sse42_opt (void)
- static const char * vm_get_arch_name (void)
- static int vm_has_asm_opt (void)
- static int vm_has_direct_threading (void)
- static const char * vm_get_build_info (void)

7.195.1 Detailed Description

Architecture Detection and Unified API for StarForth.

Automatically selects x86_64 or ARM64 optimizations and provides a unified interface for architecture-specific optimizations.

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7.195.2 Macro Definition Documentation

7.195.2.1 ARCH_ARM64

```
#define ARCH_ARM64 0
```

7.195.2.2 ARCH_NAME

```
#define ARCH_NAME "Unknown"
```

7.195.2.3 ARCH_RISCV64

```
#define ARCH_RISCV64 0
```

7.195.2.4 ARCH_X86_64

```
#define ARCH_X86_64 0
```

7.195.2.5 NEXT_OPT

```
#define NEXT_OPT( ) NEXT_ASM()
```

7.195.2.6 PRIM_BRANCH_OPT

```
#define PRIM_BRANCH_OPT( ) PRIM_BRANCH()
```

7.195.2.7 PRIM_DROP_OPT

```
#define PRIM_DROP_OPT( ) PRIM_DROP()
```

7.195.2.8 PRIM_DUP_OPT

```
#define PRIM_DUP_OPT( ) PRIM_DUP()
```

7.195.2.9 PRIM_FETCH_OPT

```
#define PRIM_FETCH_OPT( ) PRIM_FETCH()
```

7.195.2.10 PRIM_MINUS_OPT

```
#define PRIM_MINUS_OPT( ) PRIM_MINUS()
```

7.195.2.11 PRIM_PLUS_OPT

```
#define PRIM_PLUS_OPT( ) PRIM_PLUS()
```

7.195.2.12 PRIM_R_FETCH_OPT

```
#define PRIM_R_FETCH_OPT( ) PRIM_R_FETCH()
```

7.195.2.13 PRIM_R_FROM_OPT

```
#define PRIM_R_FROM_OPT( ) PRIM_R_FROM()
```

7.195.2.14 PRIM_STAR_OPT

```
#define PRIM_STAR_OPT( ) PRIM_STAR()
```

7.195.2.15 PRIM_STORE_OPT

```
#define PRIM_STORE_OPT( ) PRIM_STORE()
```

7.195.2.16 PRIM_SWAP_OPT

```
#define PRIM_SWAP_OPT( ) PRIM_SWAP()
```

7.195.2.17 PRIM_TO_R_OPT

```
#define PRIM_TO_R_OPT( ) PRIM_TO_R()
```

7.195.2.18 PRIM_ZBRANCH_OPT

```
#define PRIM_ZBRANCH_OPT( ) PRIM_ZBRANCH()
```

7.195.2.19 vm_abs_opt

```
#define vm_abs_opt(
              a ) vm_abs_asm(a)
```

7.195.2.20 vm_add_overflow_opt

```
#define vm_add_overflow_opt(
              a,
              b,
              res ) vm_add_check_overflow(a, b, res)
```

7.195.2.21 vm_clz_opt

```
#define vm_clz_opt(
              x ) vm_clz(x)
```

7.195.2.22 vm_ctz_opt

```
#define vm_ctz_opt(
              x ) vm_ctz(x)
```

7.195.2.23 vm_divmod_opt

```
#define vm_divmod_opt(
              dividend,
              divisor,
              quot,
              rem ) vm_divmod(dividend, divisor, quot, rem)
```

7.195.2.24 vm_max_opt

```
#define vm_max_opt(
              a,
              b ) vm_max_asm(a, b)
```

7.195.2.25 vm_memcpy_opt

```
#define vm_memcpy_opt(
              dst,
              src,
              len ) vm_memcpy_asm(dst, src, len)
```

7.195.2.26 vm_memzero_opt

```
#define vm_memzero_opt(
              dst,
              len ) vm_memzero_asm(dst, len)
```

7.195.2.27 vm_min_opt

```
#define vm_min_opt(
              a,
              b ) vm_min_asm(a, b)
```

7.195.2.28 vm_mul_double_opt

```
#define vm_mul_double_opt(
              a,
              b,
              hi,
              lo ) vm_mul_double(a, b, hi, lo)
```

7.195.2.29 vm_pop_opt

```
#define vm_pop_opt(
              vm ) vm_pop_asm(vm)
```

7.195.2.30 vm_popcnt_opt

```
#define vm_popcnt_opt(
              x ) vm_popcnt(x)
```

7.195.2.31 vm_prefetch_opt

```
#define vm_prefetch_opt(
              addr ) vm_prefetch(addr)
```

7.195.2.32 vm_prefetch_stream_opt

```
#define vm_prefetch_stream_opt(
              addr ) vm_prefetch_stream(addr)
```

7.195.2.33 vm_push_opt

```
#define vm_push_opt(
              vm,
              val ) vm_push_asm(vm, val)
```

7.195.2.34 vm_rpop_opt

```
#define vm_rpop_opt(
              vm ) vm_rpop_asm(vm)
```

7.195.2.35 vm_rpush_opt

```
#define vm_rpush_opt(
              vm,
              val ) vm_rpush_asm(vm, val)
```

7.195.2.36 vm_save_registers_opt

```
#define vm_save_registers_opt(
              vm ) vm_save_registers(vm)
```

7.195.2.37 vm_setup_registers_opt

```
#define vm_setup_registers_opt(
              vm ) vm_setup_registers(vm)
```

7.195.2.38 vm_strcmp_opt

```
#define vm_strcmp_opt(
              s1,
              s2,
              len ) vm_strcmp_asm(s1, s2, len)
```

7.195.2.39 vm_sub_overflow_opt

```
#define vm_sub_overflow_opt(
              a,
              b,
              res ) vm_sub_check_overflow(a, b, res)
```

7.195.3 Function Documentation

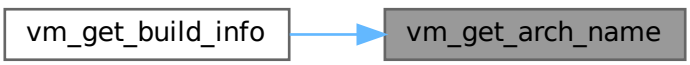
7.195.3.1 vm_get_arch_name()

```
static const char * vm_get_arch_name (
            void  )  [inline], [static]
```

References ARCH_NAME.

Referenced by vm_get_build_info().

Here is the caller graph for this function:

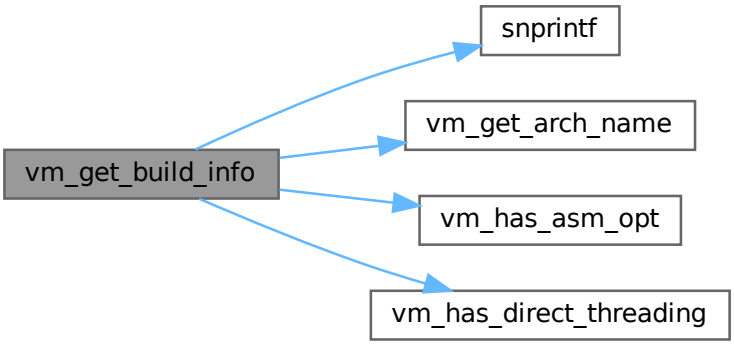


7.195.3.2 vm_get_build_info()

```
static const char * vm_get_build_info (
            void  )  [inline], [static]
```

References snprintf(), vm_get_arch_name(), vm_has_asm_opt(), and vm_has_direct_threading().

Here is the call graph for this function:



7.195.3.3 vm_has_asm_opt()

```
static int vm_has_asm_opt (
            void  )  [inline], [static]
```

Referenced by vm_get_build_info().

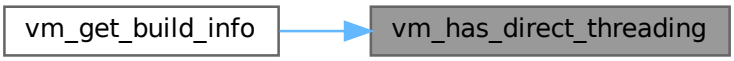
Here is the caller graph for this function:

7.195.3.4 vm_has_direct_threading()

```
static int vm_has_direct_threading (
            void  )  [inline], [static]
```

Referenced by vm_get_build_info().

Here is the caller graph for this function:

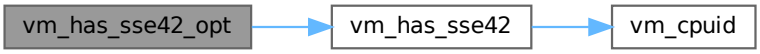


7.195.3.5 vm_has_sse42_opt()

```
static int vm_has_sse42_opt (
            void  )  [inline], [static]
```

References vm_has_sse42().

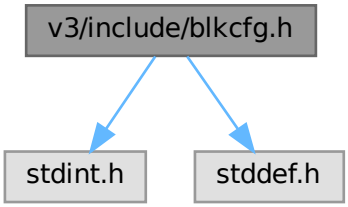
Here is the call graph for this function:



7.196 v3/include/blkcfg.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for blkcfg.h:



Data Structures

- struct blkcfg_t

Macros

- #define BLKCFG_DEFAULT_FBS 1024u /* default Forth Block Size in bytes */
- #define BLKCFG_PATH_MAX 4096

Enumerations

- enum blkcfg_backend_t { BLKCFG_BACKEND_NONE = 0 , BLKCFG_BACKEND_FILE = 1 , BLKCFG_BACKEND_RAM = 2 }

Functions

- int blkcfg_init_from_options (blkcfg_t *cfg, const char *disk_img_path, uint64_t ram_mb, uint32_t fbs, uint8_t read_only)

  Initialize a block configuration from CLI-style options.
- int blkcfg_format_summary (const blkcfg_t *cfg, char *dst, size_t dst_cap)

  Format a single-line summary into 'dst' (capacity 'dst_cap' bytes).

Variables

- blkcfg_t g_blkcfg

7.196.1 Macro Definition Documentation

7.196.1.1 BLKCFG_DEFAULT_FBS

```
#define BLKCFG_DEFAULT_FBS 1024u /* default Forth Block Size in bytes */
```

7.196.1.2 BLKCFG_PATH_MAX

```
#define BLKCFG_PATH_MAX 4096
```

7.196.2 Enumeration Type Documentation

7.196.2.1 blkcfg_backend_t

```
enum blkcfg_backend_t
```

Enumerator

BLKCFG_BACKEND_NONE	
BLKCFG_BACKEND_FILE	
BLKCFG_BACKEND_RAM	

7.196.3 Function Documentation

7.196.3.1 blkcfg_format_summary()

```
int blkcfg_format_summary (
            const blkcfg_t * cfg,
            char * dst,
            size_t dst_cap )
```

Format a single-line summary into 'dst' (capacity 'dst_cap' bytes).

Example: "backend=FILE path=./disks/os.img fbs=1024 ro=0" "backend=RAM size=1024MB fbs=1024 blocks=1048576 ro=0"

Returns number of bytes that would have been written (like snprintf).

7.196.3.2 blkcfg_init_from_options()

```
int blkcfg_init_from_options (
            blkcfg_t * cfg,
            const char * disk_img_path,
            uint64_t ram_mb,
            uint32_t fbs,
            uint8_t read_only )
```

Initialize a block configuration from CLI-style options.

Inputs:

- disk_img_path: if non-NULL and non-empty => choose FILE backend
- ram_mb: megabytes for RAM fallback (only used if no disk image)
- fbs: forth block size (bytes). If 0 => BLKCFG_DEFAULT_FBS
- read_only: intended read-only flag (advisory)

Behavior:

- FILE: record path, set blocks/size_bytes = 0 (unknown until attached)
- RAM : compute size_bytes = ram_mb∗MiB; blocks = size_bytes/fbs (floored)

Returns: 0 on success; -1 on invalid args.

7.196.4 Variable Documentation

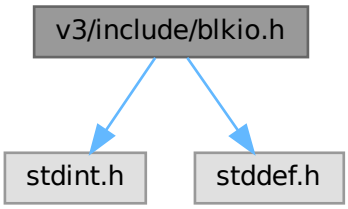
7.196.4.1 g_blkcfg

```
blkcfg_t g_blkcfg  [extern]
```

7.197 v3/include/blkio.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for blkio.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct blkio_params_t
- struct blkio_info_t
- struct blkio_vtable_t
- struct blkio_dev

Macros

- #define BLKIO_FORTH_BLOCK_SIZE 1024u

Typedefs

- typedef struct blkio_dev blkio_dev_t

Enumerations

- enum {
  BLKIO_OK = 0 , BLKIO_EINVAL = -1 , BLKIO_ENOSUP = -2 , BLKIO_EIO = -3 ,
  BLKIO_ENOSPACE = -4 , BLKIO_ECLOSED = -5 }

Functions

- static int blkio_open (blkio_dev_t *dev, const blkio_vtable_t *vt, const blkio_params_t *p)
- static int blkio_close (blkio_dev_t *dev)
- static int blkio_read (blkio_dev_t *dev, uint32_t fblock, void *dst)
- static int blkio_write (blkio_dev_t *dev, uint32_t fblock, const void *src)
- static int blkio_flush (blkio_dev_t *dev)
- static int blkio_info (blkio_dev_t *dev, blkio_info_t *out)
- static void blkio_bzero (void *p, uint32_t fbs)

7.197.1 Macro Definition Documentation

7.197.1.1 BLKIO_FORTH_BLOCK_SIZE

```
#define BLKIO_FORTH_BLOCK_SIZE 1024u
```

7.197.2 Typedef Documentation

7.197.2.1 blkio_dev_t

```
typedef struct blkio_dev blkio_dev_t
```

7.197.3 Enumeration Type Documentation

7.197.3.1 anonymous enum

```
anonymous enum
```

Enumerator

BLKIO_OK	
BLKIO_EINVAL	
BLKIO_ENOSUP	
BLKIO_EIO	
BLKIO_ENOSPACE	
BLKIO_ECLOSED	

7.197.4 Function Documentation

7.197.4.1 blkio_bzero()

```
static void blkio_bzero (
            void * p,
            uint32_t fbs )  [inline], [static]
```

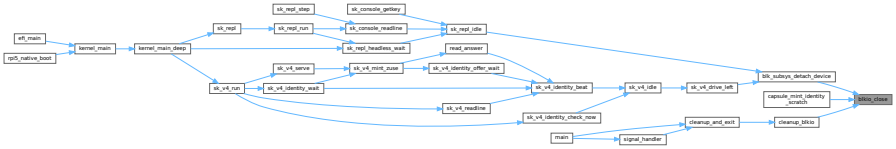
7.197.4.2 blkio_close()

```
static int blkio_close (
            blkio_dev_t * dev )  [inline], [static]
```

References BLKIO_ECLOSED, blkio_vtable_t::close, blkio_dev::is_open, and blkio_dev::vt.

Referenced by blk_subsys_detach_device(), capsule_mint_identity_scratch(), and cleanup_blkio().

Here is the caller graph for this function:



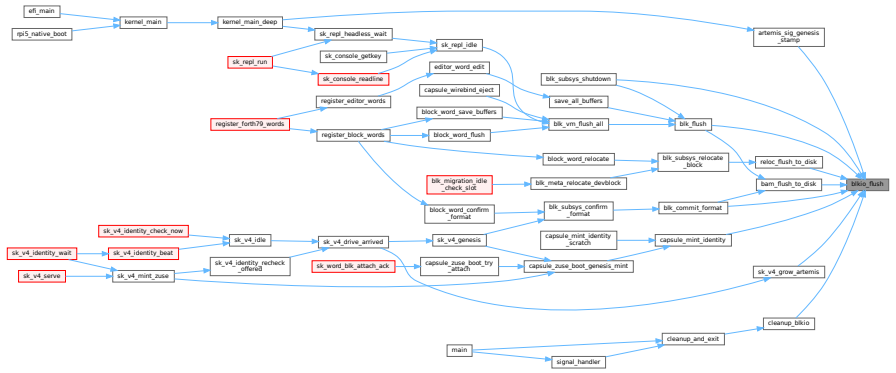
7.197.4.3 blkio_flush()

```
static int blkio_flush (
            blkio_dev_t * dev )  [inline], [static]
```

References BLKIO_ECLOSED, blkio_vtable_t::flush, blkio_dev::is_open, and blkio_dev::vt.

Referenced by artemis_sig_genesis_stamp(), bam_flush_to_disk(), blk_commit_format(), blk_flush(), blk_subsys_shutdown(), capsule_mint_identity(), cleanup_blkio(), reloc_flush_to_disk(), and sk_v4_grow_artemis().

Here is the caller graph for this function:



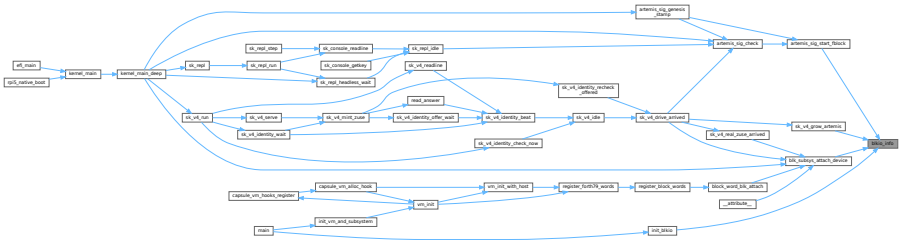
7.197.4.4 blkio_info()

```
static int blkio_info (
            blkio_dev_t * dev,
            blkio_info_t * out )  [inline], [static]
```

References BLKIO_EINVAL, BLKIO_OK, blkio_info_t::forth_block_size, blkio_dev::forth_block_size, blkio_vtable_t::info, blkio_dev::is_open, blkio_info_t::total_blocks, blkio_dev::total_blocks, and blkio_dev::vt.

Referenced by artemis_sig_start_fblock(), blk_subsys_attach_device(), init_blkio(), and sk_v4_grow_artemis().

Here is the caller graph for this function:



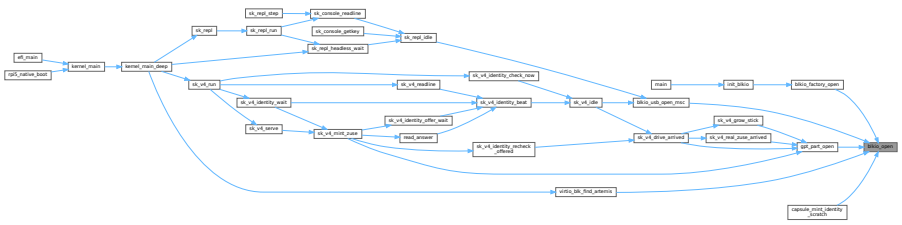
7.197.4.5 blkio_open()

```
static int blkio_open (
            blkio_dev_t * dev,
            const blkio_vtable_t * vt,
            const blkio_params_t * p )  [inline], [static]
```

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_vtable_t::close, blkio_vtable_t::flush, blkio_params_t::forth_block_size, blkio_dev::forth_block_size, blkio_vtable_t::info, blkio_dev::is_open, blkio_vtable_t::open, blkio_vtable_t::read, blkio_dev::state, blkio_params_t::total_blocks, blkio_dev::total_blocks, blkio_dev::vt, and blkio_vtable_t::write.

Referenced by blkio_factory_open(), blkio_usb_open_msc(), capsule_mint_identity_scratch(), gpt_part_open(), and virtio_blk_find_artemis().

Here is the caller graph for this function:



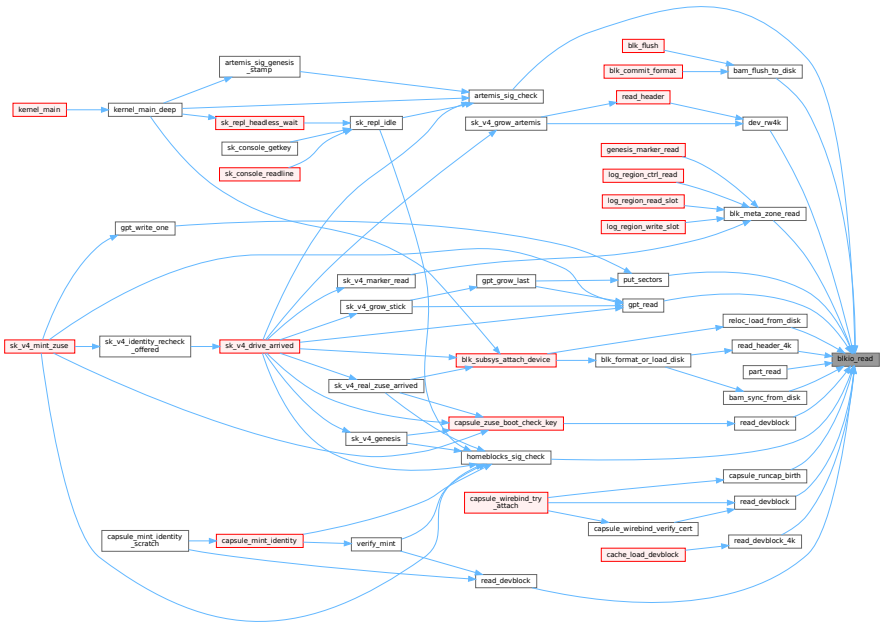
7.197.4.6 blkio_read()

```
static int blkio_read (
            blkio_dev_t * dev,
            uint32_t fblock,
            void * dst )  [inline], [static]
```

References BLKIO_EINVAL, blkio_dev::is_open, blkio_vtable_t::read, blkio_dev::total_blocks, and blkio_dev::vt.

Referenced by artemis_sig_check(), bam_flush_to_disk(), bam_sync_from_disk(), blk_meta_zone_read(), capsule_runcap_birth(), dev_rw4k(), gpt_read(), homeblocks_sig_check(), part_read(), put_sectors(), read_devblock(), read_devblock(), read_devblock_4k(), read_header_4k(), and reloc_load_from_disk().

Here is the caller graph for this function:



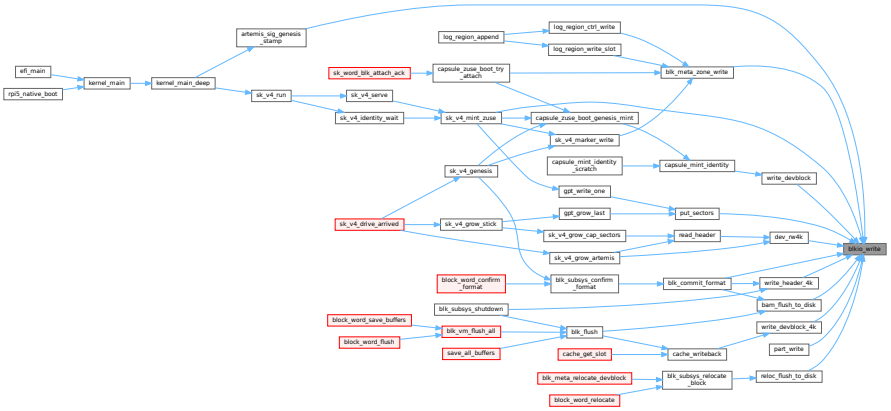
7.197.4.7 blkio_write()

```
static int blkio_write (
            blkio_dev_t * dev,
            uint32_t fblock,
            const void * src )  [inline], [static]
```

References BLKIO_EINVAL, blkio_dev::is_open, blkio_dev::total_blocks, blkio_dev::vt, and blkio_vtable_t::write.

Referenced by artemis_sig_genesis_stamp(), bam_flush_to_disk(), blk_commit_format(), blk_meta_zone_write(), dev_rw4k(), part_write(), put_sectors(), reloc_flush_to_disk(), sk_v4_mint_zuse(), write_devblock(), write_devblock_4k(), and write_header_4k().

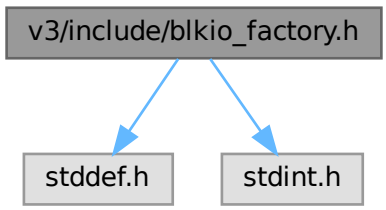
Here is the caller graph for this function:



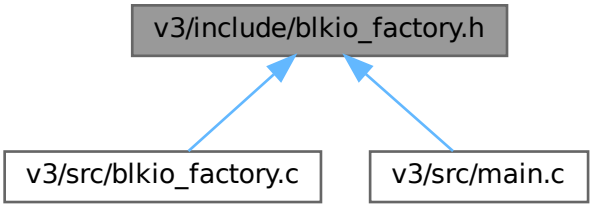
7.198 v3/include/blkio_factory.h File Reference

```
#include <stddef.h>
#include <stdint.h>
```

Include dependency graph for blkio_factory.h:



This graph shows which files directly or indirectly include this file:



Functions

- int blkio_factory_open (struct blkio_dev *dev, const char *disk_img_path, uint8_t read_only, uint32_t total_blocks, uint32_t fbs, void *state_mem, size_t state_len, uint8_t *ram_base, uint32_t ram_blocks, uint8_t *out_used_file)

  Open a block device using either a file-backed image (if disk_img_path is non-empty) or a RAM-backed buffer (fallback).

7.198.1 Function Documentation

7.198.1.1 blkio_factory_open()

```
int blkio_factory_open (
            blkio_dev_t * dev,
            const char * disk_img_path,
            uint8_t read_only,
            uint32_t total_blocks,
            uint32_t fbs,
            void * state_mem,
            size_t state_len,
            uint8_t * ram_base,
            uint32_t ram_blocks,
            uint8_t * out_used_file )
```

Open a block device using either a file-backed image (if disk_img_path is non-empty) or a RAM-backed buffer (fallback).

Parameters:

- dev : output device object (caller-allocated)
- disk_img_path : path to raw image; if NULL/empty => RAM fallback
- read_only : 1 = open read-only; 0 = read/write
- total_blocks : FILE: 0 => derive from file size; >0 => size hint RAM : must match ram_blocks
- fbs : forth block size in bytes (0 => default per blkio.h)
- state_mem : caller-provided backend state buffer (opaque to caller)
- state_len : size of state_mem in bytes
- ram_base : RAM storage base pointer (RAM backend only)
- ram_blocks : number of Forth blocks in ram_base (RAM backend only)
- out_used_file : optional; set to 1 if FILE backend selected, else 0

Returns: 0 on success; negative blkio error code on failure.

Open a block device using either a file-backed image (if disk_img_path is non-empty) or a RAM-backed buffer (fallback).

Selects the file backend when `disk_img_path` is non-empty, otherwise falls back to the RAM backend using `ram_base` / `ram_blocks`.

File backend behaviour:

- Creates the file if it does not exist (unless `read_only` is set).
- Derives `total_blocks` from the file size when `total_blocks` == 0.
- Sets `*out_used_file` = 1 on success.

RAM backend behaviour:

- `ram_base` must point to at least `ram_blocks * fbs` bytes of caller-owned memory that outlives the device.

Parameters

dev	Output device handle to populate
disk_img_path	Path to disk image file, or NULL/empty for RAM
read_only	1 = open read-only, 0 = read-write
total_blocks	Desired block count (0 = derive from file size)
fbs	FORTH block size in bytes (0 = use `BLKIO_FORTH_BLOCK_SIZE`)
state_mem	Caller-allocated state buffer (must be large enough)
state_len	Size of `state_mem` in bytes
ram_base	Base of RAM block array (used only when no disk path)
ram_blocks	Number of blocks in `ram_base`
out_used_file	Optional output: set to 1 if the file backend was used

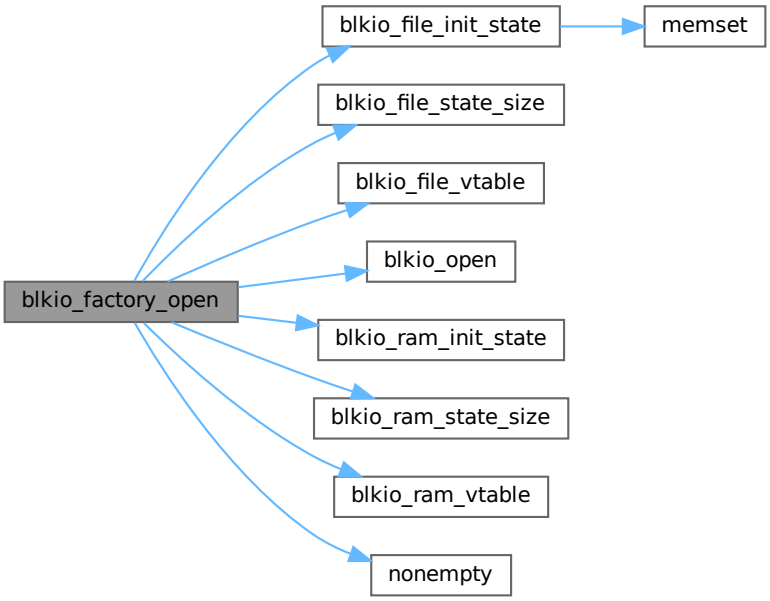
Returns

`BLKIO_OK` on success, or a `BLKIO_E*` error code

References BLKIO_EINVAL, BLKIO_ENOSPACE, blkio_file_init_state(), blkio_file_state_size(), blkio_file_vtable(), BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_open(), blkio_ram_init_state(), blkio_ram_state_size(), blkio_ram_vtable(), blkio_params_t::forth_block_size, nonempty(), and ram_base.

Referenced by init_blkio().

Here is the call graph for this function:

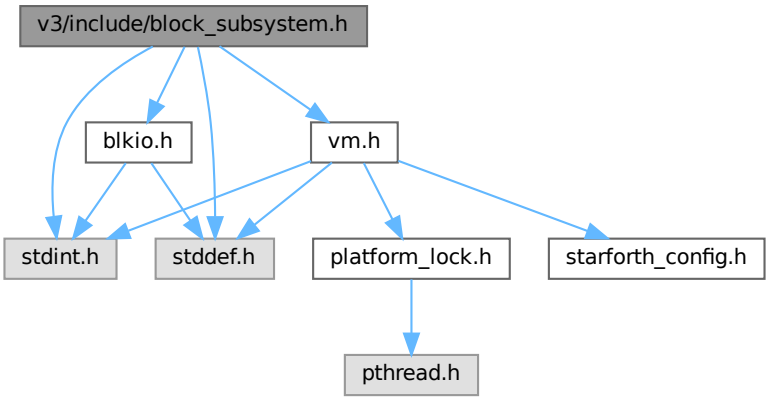


Here is the caller graph for this function:

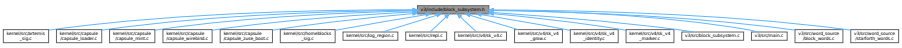
7.199 v3/include/block_subsystem.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "vm.h"
#include "blkio.h"
```

Include dependency graph for block_subsystem.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct blk_volume_meta_t
- struct blk_meta_t
- struct blk_bam_entry_t

Macros

- #define BLK_FORTH_SIZE 1024u /∗ Forth block size ∗/
- #define BLK_RAM_BLOCKS 2080u /∗ Physical RAM blocks (user-visible LBN 0..2047) ∗/
- #define BLK_DISK_START 2080u /∗ Device-backed Forth blocks start at LBN 2080 ∗/
- #define BLK_DEVICE_SECTOR 4096u /∗ Physical “devblock” size (4×1 KiB blkio units) ∗/
- #define BLK_PACK_RATIO 3u /∗ 3× 1 KiB data per 4 KiB devblock (plus 1 KiB metadata) ∗/
- #define BLK_META_TOTAL 1024u /∗ Last 1 KiB in a 4 KiB devblock is metadata ∗/
- #define BLK_META_PER_BLOCK 341u /∗ 341×3 ∼= 1023, padded to 1024 ∗/
- #define BLK_FORTH_SYS_RESERVED 32u /∗ RAM physical blocks 0..31 hidden; user LBN 0 = PBN 32 ∗/
- #define BLK_DISK_SYS_RESERVED 32u /∗ First 32 blocks of each disk reserved (byte-aligned BAM offset) ∗/
- #define BLK_META_FENCE_INIT
- #define BLK_FLAG_CLAIMED (1ull << 0) /∗ owned, per BMAPFMT's owner_fp ∗/
- #define BLK_FLAG_MIGRATING (1ull << 1) /∗ mid-migration; serves MIGSM ∗/
- #define BLK_FLAG_STALE (1ull << 2) /∗ interrupted flush; serves UNCLEAN ∗/

Enumerations

- enum {
  BLK_OK = 0 , BLK_EINVAL = -1 , BLK_ERANGE = -2 , BLK_EIO = -3 ,
  BLK_ENODEV = -4 , BLK_ERESERVED = -5 , BLK_EDIRTY = -6 , BLK_ENOMEM = -7 ,
  BLK_ENOSPC = -8 }
- enum { BLK_FMT_FORMATTED = 0 , BLK_FMT_PROVISIONAL = 1 }

Functions

- int blk_subsys_init (uint8_t *ram_base, size_t ram_size)
- int blk_subsys_attach_device (struct blkio_dev *dev)
- int blk_subsys_detach_device (struct blkio_dev *dev)
- uint64_t blk_subsys_epoch (void)
- int blk_subsys_relocate_block (uint32_t home_lbn, uint32_t target_lbn)
- int blk_get_device_range (struct blkio_dev *dev, uint32_t *out_start_lbn, uint32_t *out_count)
- const void * blk_lbn_device_handle (uint32_t lbn)
- int blk_get_device_free_blocks (struct blkio_dev *dev, uint64_t *out_free, uint64_t *out_total)
- int blk_get_first_disk_range (uint32_t *out_start_lbn, uint32_t *out_count)
- int blk_firsttouch_claim (const uint8_t owner_fp[8], uint32_t count, uint32_t *out_chain_head)
- int blk_owner_has_claim (const uint8_t owner_fp[8])
- int blk_meta_relocate_devblock (uint32_t home_devblock, uint32_t target_devblock)
- void blk_migration_idle_check (void)
- int blk_subsys_shutdown (void)
- uint8_t * blk_get_buffer (uint32_t block_num, int writable)
- uint8_t * blk_get_empty_buffer (uint32_t block_num)
- int blk_flush (uint32_t block_num)
- int blk_update (uint32_t block_num)
- int blk_get_volume_meta (blk_volume_meta_t *meta)
- int blk_set_volume_meta (const blk_volume_meta_t *meta)
- int blk_meta_zone_read (uint32_t devblock_from_top, uint8_t buf[4096])
- int blk_meta_zone_write (uint32_t devblock_from_top, const uint8_t buf[4096])
- uint64_t compute_crc64 (const uint8_t *data, size_t len)
- int blk_is_valid (uint32_t block_num)
- uint32_t blk_get_total_blocks (void)
- int blk_get_meta (uint32_t block_num, blk_meta_t *meta)
- int blk_set_meta (uint32_t block_num, const blk_meta_t *meta)
- int blk_owner_fp_get (uint32_t block_num, uint8_t out_fp[8])
- int blk_owner_fp_set (uint32_t block_num, const uint8_t fp[8])
- int blk_acl_allow_get (uint32_t block_num, uint8_t *out_allow)
- int blk_acl_allow_set (uint32_t block_num, uint8_t allow)
- int blk_acl_ttl_get (uint32_t block_num, uint32_t *out_ttl)
- int blk_acl_ttl_set (uint32_t block_num, uint32_t ttl)
- int blk_flags_get (uint32_t block_num, uint64_t *out_flags)
- int blk_flags_set (uint32_t block_num, uint64_t flags)
- int blk_is_allocated (uint32_t block_num)
- int blk_mark_allocated (uint32_t block_num)
- int blk_mark_free (uint32_t block_num)
- int blk_allocate (uint32_t *block_num)
- int blk_subsys_add_raw_device (uint8_t *buf, uint32_t nblocks)
- int blk_subsys_confirm_format (uint32_t lbn)
- void blk_volume_compute_totals (blk_volume_meta_t *m)
- void blk_subsys_set_format_bam_for (uint64_t total_devblocks)

7.199.1 Macro Definition Documentation

7.199.1.1 BLK_DEVICE_SECTOR

```
#define BLK_DEVICE_SECTOR 4096u /* Physical "devblock" size (4×1 KiB blkio units) */
```

7.199.1.2 BLK_DISK_START

```
#define BLK_DISK_START 2080u /* Device-backed Forth blocks start at LBN 2080 */
```

7.199.1.3 BLK_DISK_SYS_RESERVED

```
#define BLK_DISK_SYS_RESERVED 32u /* First 32 blocks of each disk reserved (byte-aligned BAM
offset) */
```

7.199.1.4 BLK_FLAG_CLAIMED

```
#define BLK_FLAG_CLAIMED (1ull << 0) /* owned, per BMAPFMT's owner_fp */
```

7.199.1.5 BLK_FLAG_MIGRATING

```
#define BLK_FLAG_MIGRATING (1ull << 1) /* mid-migration; serves MIGSM */
```

7.199.1.6 BLK_FLAG_STALE

```
#define BLK_FLAG_STALE (1ull << 2) /* interrupted flush; serves UNCLEAN */
```

7.199.1.7 BLK_FORTH_SIZE

```
#define BLK_FORTH_SIZE 1024u /* Forth block size */
```

7.199.1.8 BLK_FORTH_SYS_RESERVED

```
#define BLK_FORTH_SYS_RESERVED 32u /* RAM physical blocks 0..31 hidden; user LBN 0 = PBN 32 */
```

7.199.1.9 BLK_META_FENCE_INIT

```
#define BLK_META_FENCE_INIT
```

Value:

```
128u  /* Starting size (4 KiB devblocks -- 512 KiB) of the
* top-of-device system-metadata fence, grows downward
* from here. */
```

7.199.1.10 BLK_META_PER_BLOCK

```
#define BLK_META_PER_BLOCK 341u /* 341×3 ∼= 1023, padded to 1024 */
```

7.199.1.11 BLK_META_TOTAL

```
#define BLK_META_TOTAL 1024u /* Last 1 KiB in a 4 KiB devblock is metadata */
```

7.199.1.12 BLK_PACK_RATIO

```
#define BLK_PACK_RATIO 3u /* 3× 1 KiB data per 4 KiB devblock (plus 1 KiB metadata) */
```

7.199.1.13 BLK_RAM_BLOCKS

```
#define BLK_RAM_BLOCKS 2080u /* Physical RAM blocks (user-visible LBN 0..2047) */
```

7.199.2 Enumeration Type Documentation

7.199.2.1 anonymous enum

```
anonymous enum
```

Enumerator

BLK_OK	
BLK_EINVAL	
BLK_ERANGE	
BLK_EIO	
BLK_ENODEV	
BLK_ERESERVED	
BLK_EDIRTY	
BLK_ENOMEM	
BLK_ENOSPC	

7.199.2.2 anonymous enum

```
anonymous enum
```

Enumerator

BLK_FMT_FORMATTED	
BLK_FMT_PROVISIONAL	

7.199.3 Function Documentation

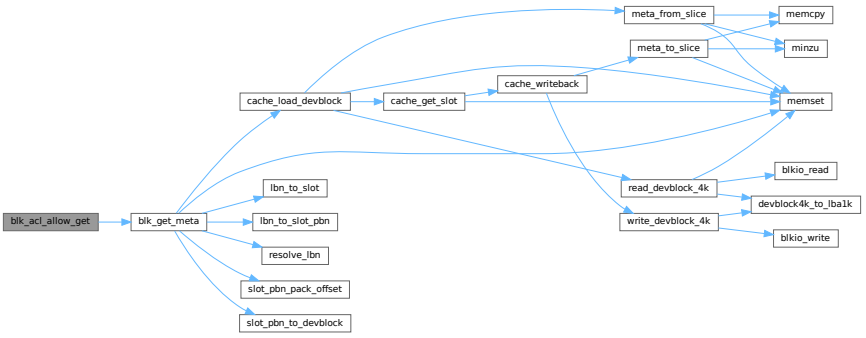
7.199.3.1 blk_acl_allow_get()

```
int blk_acl_allow_get (
            uint32_t block_num,
            uint8_t * out_allow )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, and meta.

Referenced by block_word_acl_allow_fetch().

Here is the call graph for this function:



Here is the caller graph for this function:

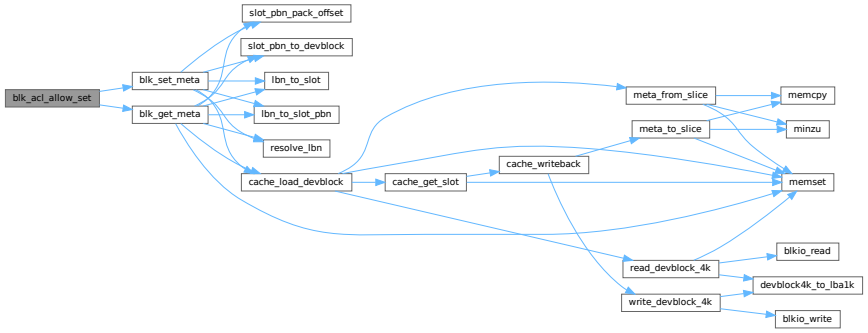
7.199.3.2 blk_acl_allow_set()

```
int blk_acl_allow_set (
            uint32_t block_num,
            uint8_t allow )
```

References blk_get_meta(), BLK_OK, blk_set_meta(), and meta.

Referenced by block_word_acl_allow_store().

Here is the call graph for this function:



Here is the caller graph for this function:

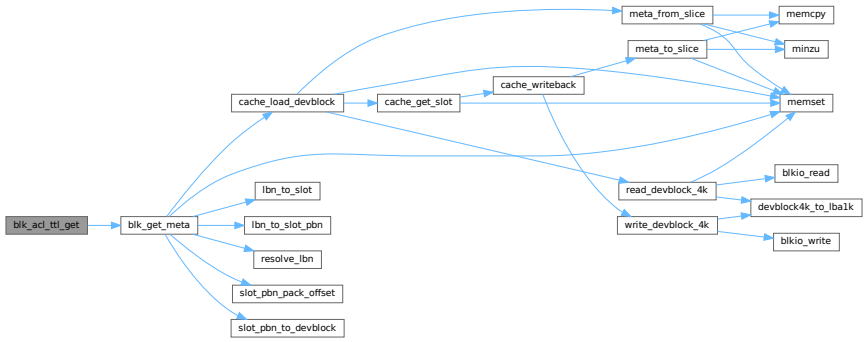
7.199.3.3 blk_acl_ttl_get()

```
int blk_acl_ttl_get (
            uint32_t block_num,
            uint32_t * out_ttl )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, and meta.

Referenced by block_word_acl_ttl_fetch().

Here is the call graph for this function:



Here is the caller graph for this function:

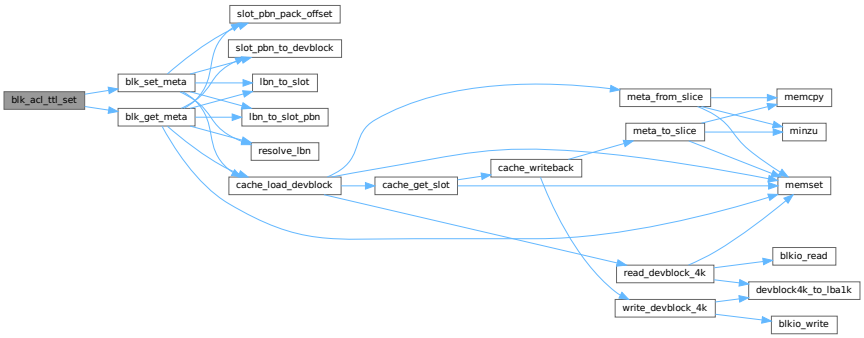
7.199.3.4 blk_acl_ttl_set()

```
int blk_acl_ttl_set (
            uint32_t block_num,
            uint32_t ttl )
```

References blk_get_meta(), BLK_OK, blk_set_meta(), and meta.

Referenced by block_word_acl_ttl_store().

Here is the call graph for this function:



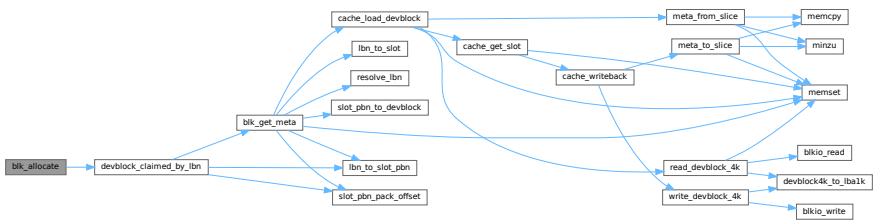
Here is the caller graph for this function:

7.199.3.5 blk_allocate()

```
int blk_allocate (
            uint32_t * block_num )
```

References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_dev_slot::bam_dirty, BLK_EINVAL, BLK_ENODEV, BLK_ERANGE, BLK_FMT_PROVISIONAL, BLK_OK, blk_dev_slot::dev, devblock_claimed_by_lbn(), blk_volume_meta_t::first_free, blk_dev_slot::format_state, blk_volume_meta_t::free_blocks, g, blk_volume_meta_t::last_allocated, limit, blk_dev_slot::next, blk_dev_slot::raw_base, blk_dev_slot::start_lbn, blk_dev_slot::user_blocks, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Here is the call graph for this function:



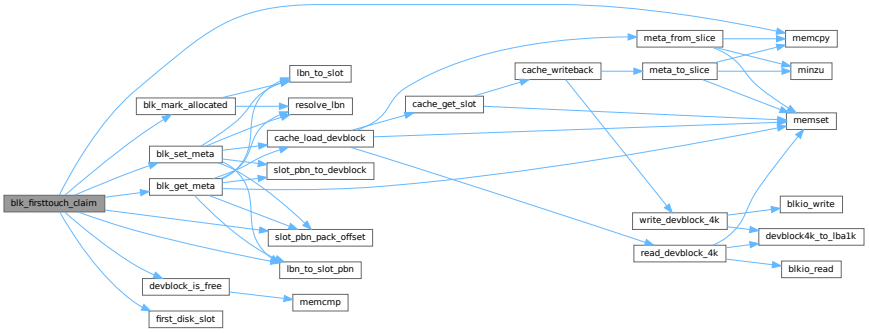
7.199.3.6 blk_firsttouch_claim()

```
int blk_firsttouch_claim (
            const uint8_t owner_fp[8],
            uint32_t count,
            uint32_t * out_chain_head )
```

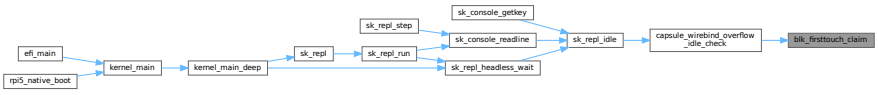
References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ENOSPC, BLK_FIRSTTOUCH_MAX_CLAIM, BLK_FLAG_CLAIMED, blk_get_meta(), blk_mark_allocated(), BLK_OK, BLK_PACK_RATIO, blk_set_meta(), count, devblock_is_free(), first_disk_slot(), blk_volume_meta_t::flags, lbn_to_slot_pbn(), memcpy(), meta, slot_pbn_pack_offset(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by capsule_wirebind_overflow_idle_check().

Here is the call graph for this function:



Here is the caller graph for this function:

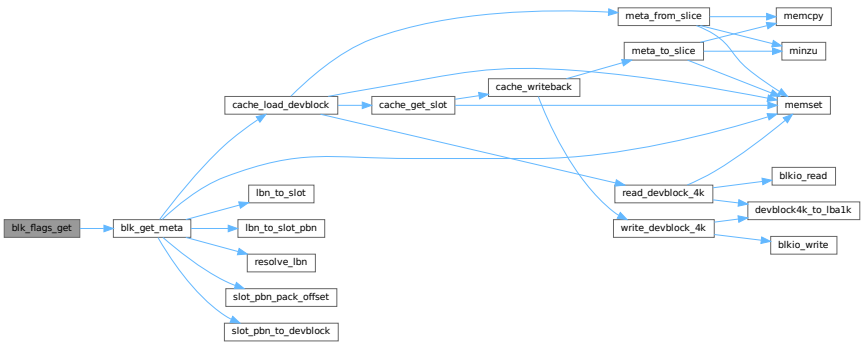


7.199.3.7 blk_flags_get()

```
int blk_flags_get (
            uint32_t block_num,
            uint64_t * out_flags )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, blk_volume_meta_t::flags, and meta.

Here is the call graph for this function:

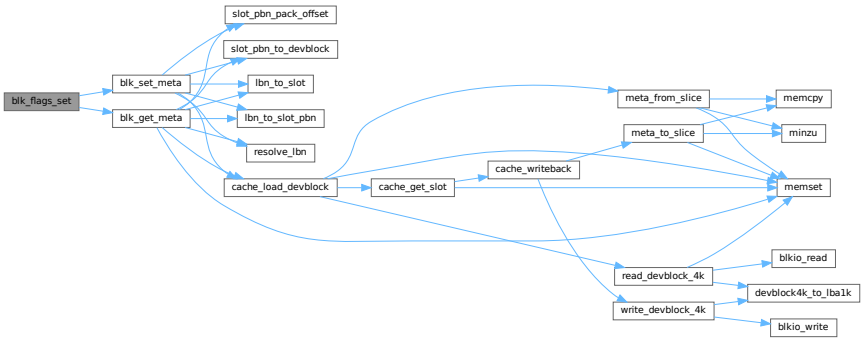


7.199.3.8 blk_flags_set()

```
int blk_flags_set (
            uint32_t block_num,
            uint64_t flags )
```

References blk_get_meta(), BLK_OK, blk_set_meta(), blk_volume_meta_t::flags, flags, and meta.

Here is the call graph for this function:



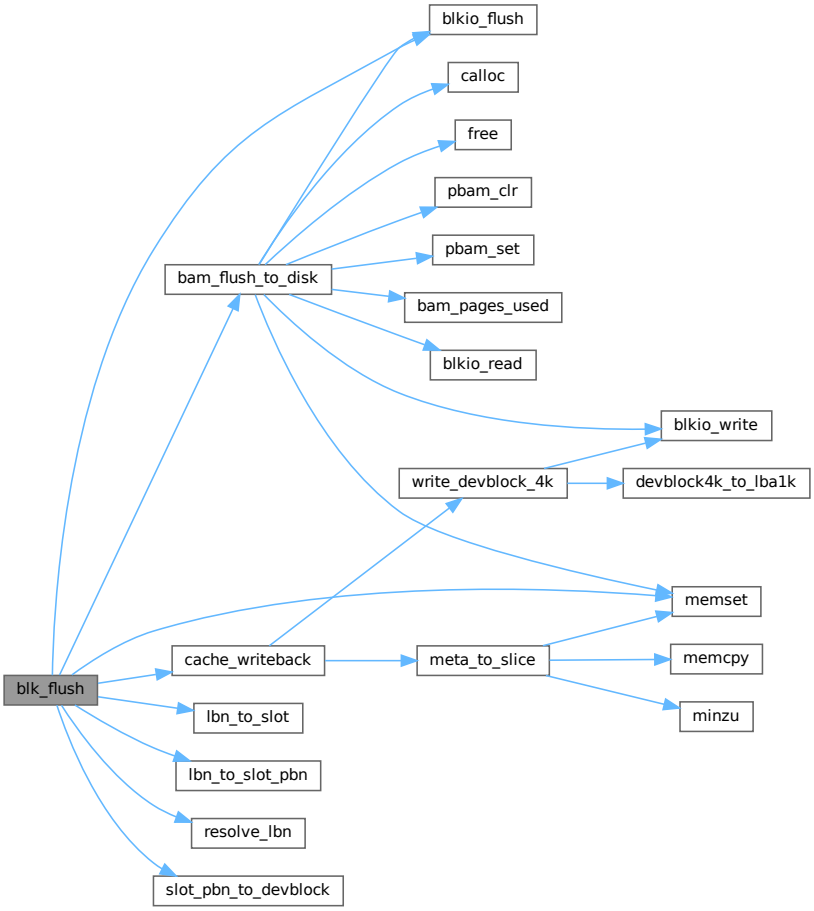
7.199.3.9 blk_flush()

```
int blk_flush (
            uint32_t block_num )
```

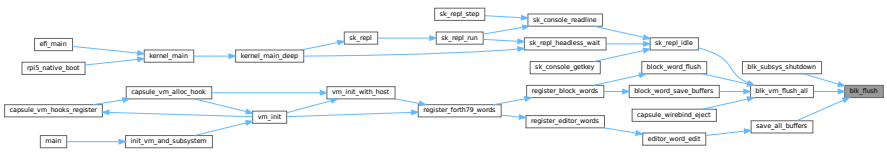
References blk_dev_slot::bam, bam_flush_to_disk(), BLK_ENODEV, BLK_ERANGE, BLK_FORTH_SYS_RESERVED, BLK_OK, BLK_RAM_BLOCKS, blkio_flush(), blk_dev_slot::cache, cache_writeback(), blk_dev_slot::dev, cache_slot_t::devblock, blk_bam_entry_t::dirty, cache_slot_t::dirty, DISK_CACHE_SLOTS, g, lbn_to_slot(), lbn_to_slot_pbn(), memset(), cache_slot_t::meta_dirty, blk_dev_slot::next, blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_to_devblock(), blk_dev_slot::start_lbn, blk_dev_slot::user_blocks, and cache_slot_t::valid.

Referenced by blk_subsys_shutdown(), blk_vm_flush_all(), and save_all_buffers().

Here is the call graph for this function:



Here is the caller graph for this function:



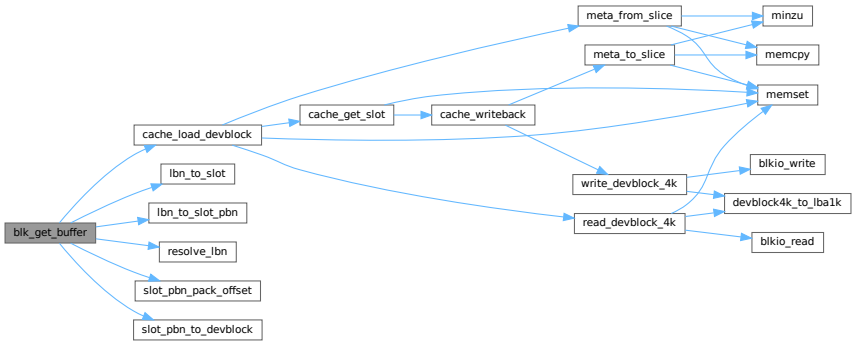
7.199.3.10 blk_get_buffer()

```
uint8_t * blk_get_buffer (
            uint32_t block_num,
            int writable )
```

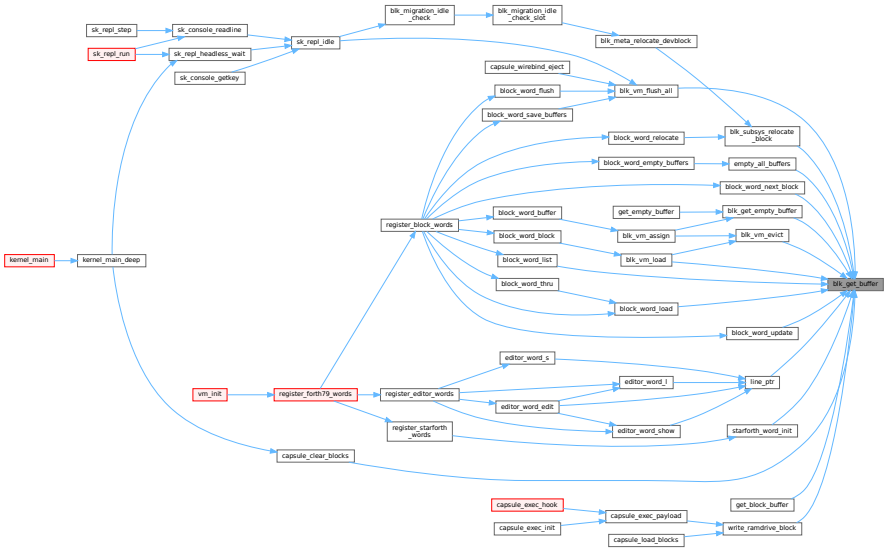
References blk_bam_entry_t::allocated, blk_dev_slot::bam, BLK_FMT_PROVISIONAL, BLK_FORTH_SIZE, BLK_FORTH_SYS_RESERVED, BLK_RAM_BLOCKS, cache_load_devblock(), cache_slot_t::data, blk_bam_entry_t::dirty, cache_slot_t::dirty, blk_dev_slot::format_state, g, lbn_to_slot(), lbn_to_slot_pbn(), blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_pack_offset(), slot_pbn_to_devblock(), and blk_dev_slot::start_lbn.

Referenced by blk_get_empty_buffer(), blk_subsys_relocate_block(), blk_vm_evict(), blk_vm_flush_all(), blk_vm_load(), block_word_list(), block_word_load(), block_word_next_block(), block_word_update(), capsule_clear_blocks(), empty_all_buffers(), get_block_buffer(), line_ptr(), starforth_word_init(), and write_ramdrive_block().

Here is the call graph for this function:



Here is the caller graph for this function:



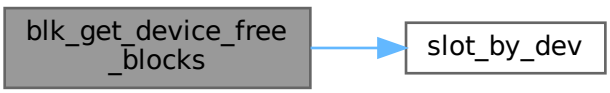
7.199.3.11 blk_get_device_free_blocks()

```
int blk_get_device_free_blocks (
            struct blkio_dev * dev,
            uint64_t * out_free,
            uint64_t * out_total )
```

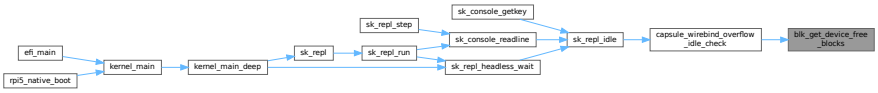
References BLK_EINVAL, BLK_ENODEV, BLK_OK, blk_volume_meta_t::free_blocks, blk_dev_slot::raw_base, slot_by_dev(), blk_volume_meta_t::total_blocks, and blk_dev_slot::vol_meta.

Referenced by capsule_wirebind_overflow_idle_check().

Here is the call graph for this function:



Here is the caller graph for this function:



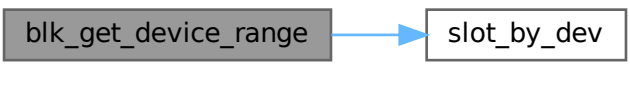
7.199.3.12 blk_get_device_range()

```
int blk_get_device_range (
            struct blkio_dev * dev,
            uint32_t * out_start_lbn,
            uint32_t * out_count )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, slot_by_dev(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by sk_v4_genesis().

Here is the call graph for this function:



Here is the caller graph for this function:

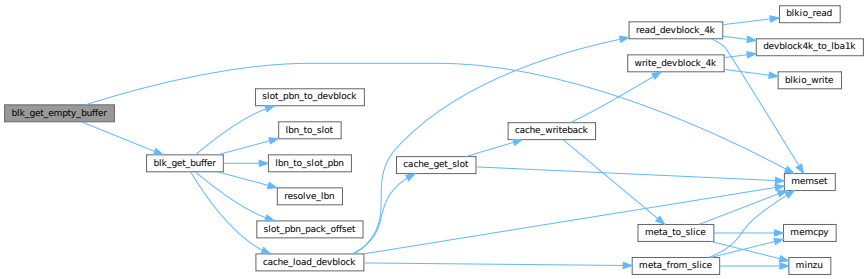
7.199.3.13 blk_get_empty_buffer()

```
uint8_t * blk_get_empty_buffer (
            uint32_t block_num )
```

References BLK_FORTH_SIZE, blk_get_buffer(), and memset().

Referenced by blk_vm_assign(), and get_empty_buffer().

Here is the call graph for this function:



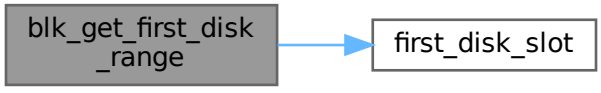
Here is the caller graph for this function:

7.199.3.14 blk_get_first_disk_range()

```
int blk_get_first_disk_range (
            uint32_t * out_start_lbn,
            uint32_t * out_count )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, first_disk_slot(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Here is the call graph for this function:



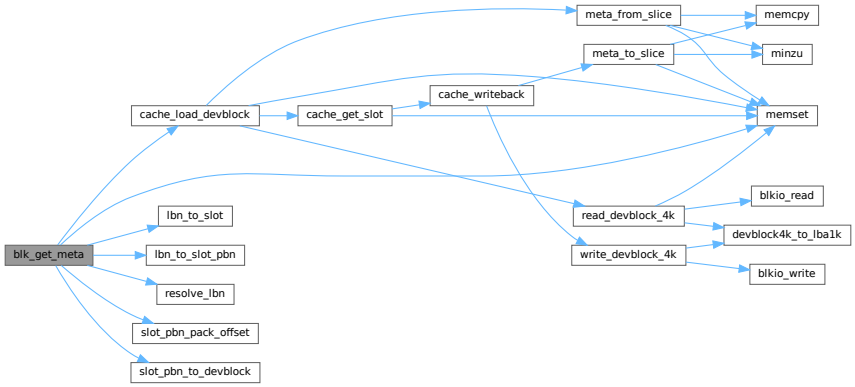
7.199.3.15 blk_get_meta()

```
int blk_get_meta (
            uint32_t block_num,
            blk_meta_t * meta )
```

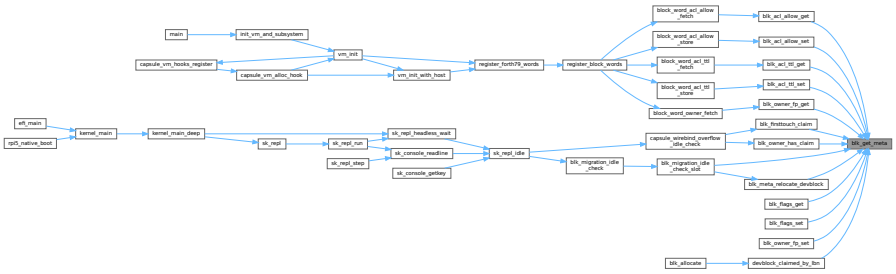
References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ERANGE, BLK_OK, cache_load_devblock(), g, lbn_to_slot(), lbn_to_slot_pbn(), blk_volume_meta_t::magic, memset(), meta, cache_slot_t::meta, blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_pack_offset(), and slot_pbn_to_devblock().

Referenced by blk_acl_allow_get(), blk_acl_allow_set(), blk_acl_ttl_get(), blk_acl_ttl_set(), blk_firsttouch_claim(), blk_flags_get(), blk_flags_set(), blk_meta_relocate_devblock(), blk_migration_idle_check_slot(), blk_owner_fp_get(), blk_owner_fp_set(), blk_owner_has_claim(), and devblock_claimed_by_lbn().

Here is the call graph for this function:



Here is the caller graph for this function:



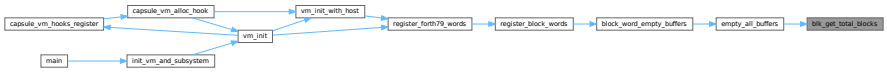
7.199.3.16 blk_get_total_blocks()

```
uint32_t blk_get_total_blocks (
            void  )
```

References g.

Referenced by empty_all_buffers().

Here is the caller graph for this function:

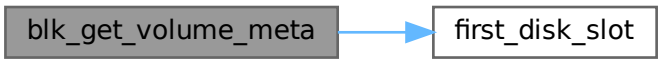


7.199.3.17 blk_get_volume_meta()

```
int blk_get_volume_meta (
            blk_volume_meta_t * meta )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, first_disk_slot(), meta, and blk_dev_slot::vol_meta.

Here is the call graph for this function:

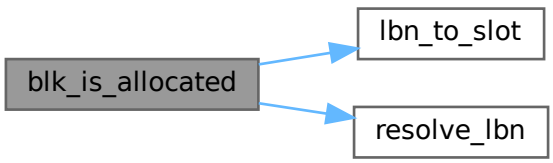


7.199.3.18 blk_is_allocated()

```
int blk_is_allocated (
            uint32_t block_num )
```

References blk_bam_entry_t::allocated, blk_dev_slot::bam, BLK_EINVAL, BLK_ENODEV, g, lbn_to_slot(), resolve_lbn(), and blk_dev_slot::start_lbn.

Here is the call graph for this function:



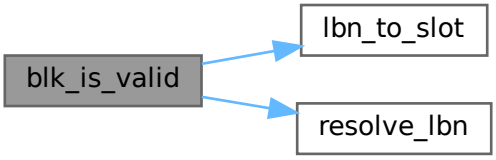
7.199.3.19 blk_is_valid()

```
int blk_is_valid (
            uint32_t block_num )
```

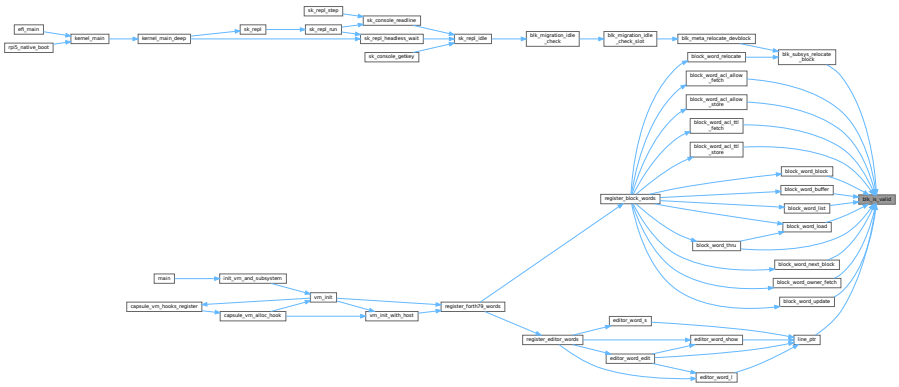
References g, lbn_to_slot(), and resolve_lbn().

Referenced by blk_subsys_relocate_block(), block_word_acl_allow_fetch(), block_word_acl_allow_store(), block_word_acl_ttl_fetch(), block_word_acl_ttl_store(), block_word_block(), block_word_buffer(), block_word_list(), block_word_load(), block_word_next_block(), block_word_owner_fetch(), block_word_thru(), block_word_update(), and line_ptr().

Here is the call graph for this function:



Here is the caller graph for this function:



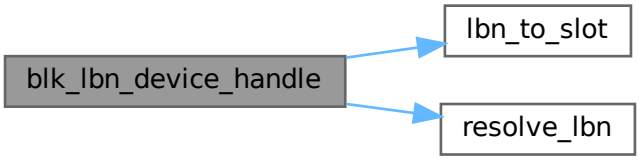
7.199.3.20 blk_lbn_device_handle()

```
const void * blk_lbn_device_handle (
            uint32_t lbn )
```

References lbn_to_slot(), and resolve_lbn().

Referenced by blk_vm_is_cross_device_copy().

Here is the call graph for this function:



Here is the caller graph for this function:

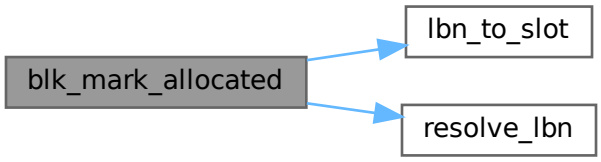
7.199.3.21 blk_mark_allocated()

```
int blk_mark_allocated (
            uint32_t block_num )
```

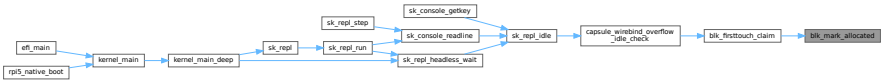
References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_dev_slot::bam_dirty, BLK_EINVAL, BLK_ENODEV, BLK_ERANGE, BLK_ERESERVED, BLK_FMT_PROVISIONAL, BLK_OK, blk_dev_slot::format_state, blk_volume_meta_t::free_blocg, lbn_to_slot(), blk_dev_slot::raw_base, resolve_lbn(), blk_dev_slot::start_lbn, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Referenced by blk_firsttouch_claim().

Here is the call graph for this function:



Here is the caller graph for this function:



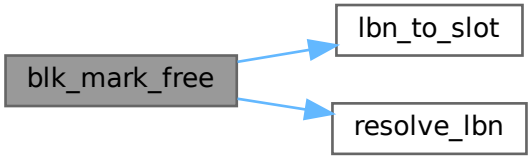
7.199.3.22 blk_mark_free()

```
int blk_mark_free (
            uint32_t block_num )
```

References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_dev_slot::bam_dirty, BLK_EINVAL, BLK_ENODEV, BLK_ERANGE, BLK_ERESERVED, BLK_FMT_PROVISIONAL, BLK_OK, blk_volume_meta_t::first_free, blk_dev_slot::format_state, blk_volume_meta_t::free_blocks, g, lbn_to_slot(), blk_dev_slot::raw_base, resolve_lbn(), blk_dev_slot::start_lbn, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Referenced by blk_subsys_relocate_block().

Here is the call graph for this function:



Here is the caller graph for this function:

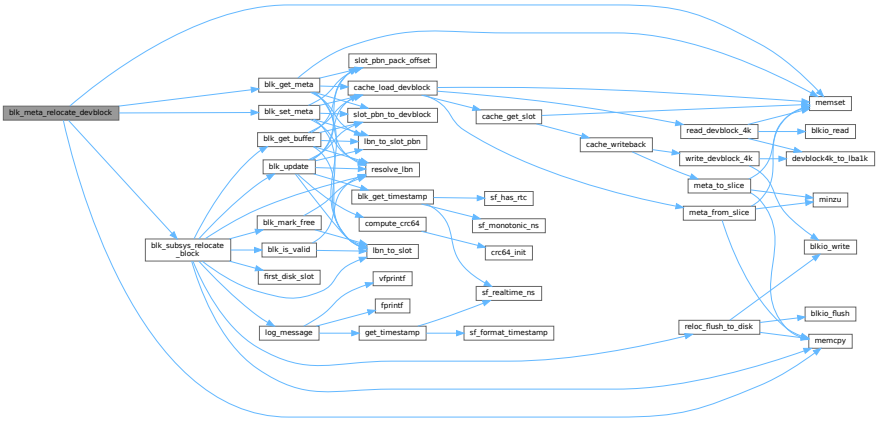
7.199.3.23 blk_meta_relocate_devblock()

```
int blk_meta_relocate_devblock (
            uint32_t home_devblock,
            uint32_t target_devblock )
```

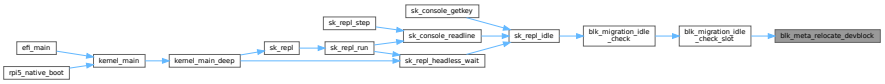
References blk_meta_t::acl_allow, blk_meta_t::acl_ttl, BLK_EINVAL, BLK_EIO, BLK_FLAG_CLAIMED, BLK_FLAG_MIGRATING, blk_get_meta(), BLK_OK, BLK_PACK_RATIO, blk_set_meta(), blk_subsys_relocate_block(), blk_meta_t::flags, memcpy(), memset(), and blk_meta_t::owner_fp.

Referenced by blk_migration_idle_check_slot().

Here is the call graph for this function:



Here is the caller graph for this function:



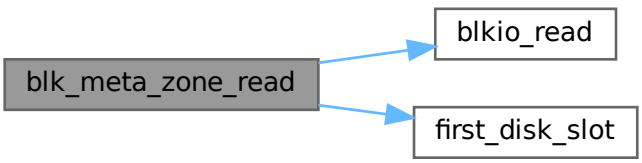
7.199.3.24 blk_meta_zone_read()

```
int blk_meta_zone_read (
            uint32_t devblock_from_top,
            uint8_t buf[4096] )
```

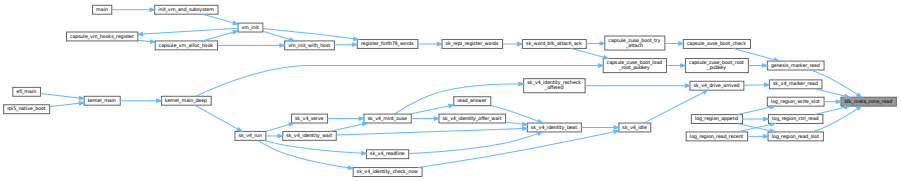
References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_OK, BLKIO_OK, blkio_read(), blk_dev_slot::dev, first_disk_slot(), blk_volume_meta_t::meta_fence_blocks, blk_volume_meta_t::total_devblocks, and blk_dev_slot::vol_meta.

Referenced by genesis_marker_read(), log_region_ctrl_read(), log_region_read_slot(), log_region_write_slot(), and sk_v4_marker_read().

Here is the call graph for this function:



Here is the caller graph for this function:



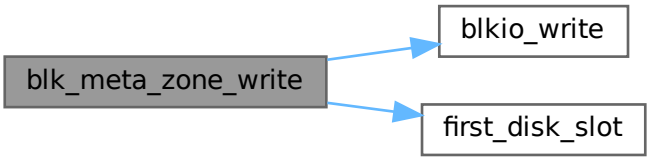
7.199.3.25 blk_meta_zone_write()

```
int blk_meta_zone_write (
            uint32_t devblock_from_top,
            const uint8_t buf[4096] )
```

References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_OK, BLKIO_OK, blkio_write(), blk_dev_slot::dev, first_disk_slot(), blk_volume_meta_t::meta_fence_blocks, blk_volume_meta_t::total_devblocks, and blk_dev_slot::vol_meta.

Referenced by capsule_zuse_boot_try_attach(), log_region_ctrl_write(), log_region_write_slot(), and sk_v4_marker_write().

Here is the call graph for this function:



Here is the caller graph for this function:

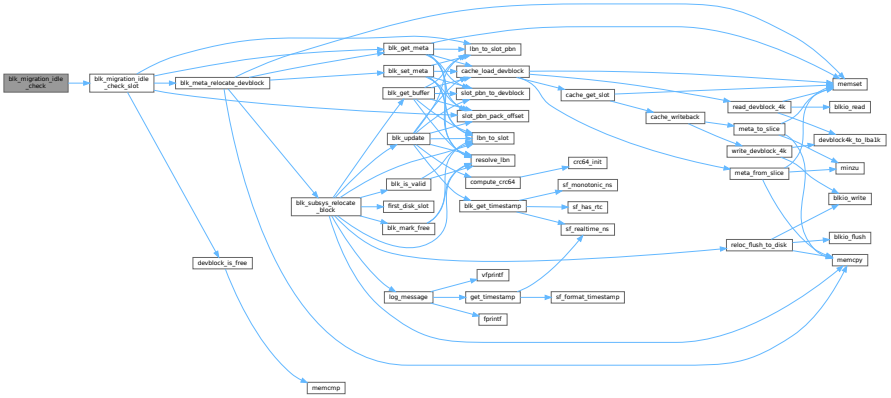
7.199.3.26 blk_migration_idle_check()

```
void blk_migration_idle_check (
            void  )
```

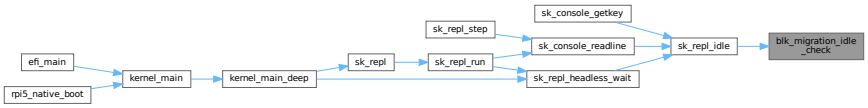
References blk_migration_idle_check_slot(), blk_dev_slot::dev, g, and blk_dev_slot::next.

Referenced by sk_repl_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



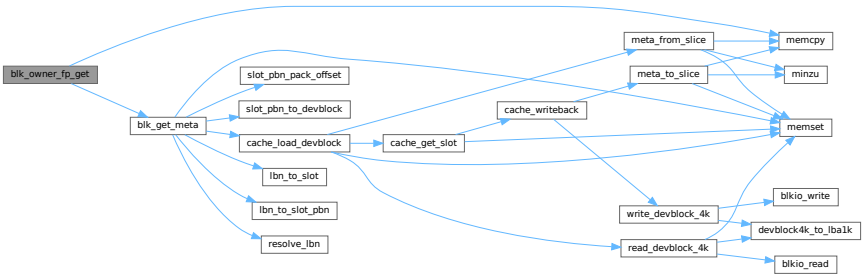
7.199.3.27 blk_owner_fp_get()

```
int blk_owner_fp_get (
            uint32_t block_num,
            uint8_t out_fp[8] )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, memcpy(), and meta.

Referenced by block_word_owner_fetch().

Here is the call graph for this function:



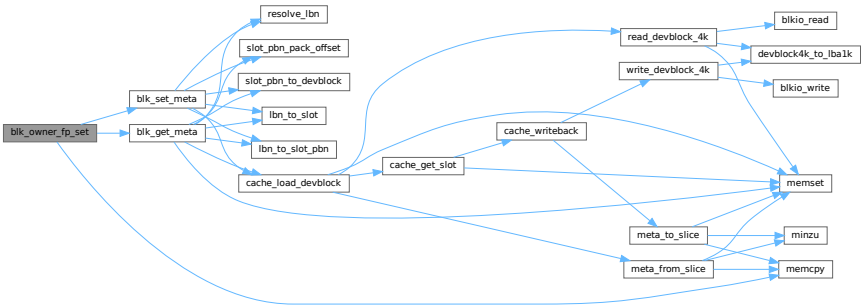
Here is the caller graph for this function:

7.199.3.28 blk_owner_fp_set()

```
int blk_owner_fp_set (
            uint32_t block_num,
            const uint8_t fp[8] )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, blk_set_meta(), memcpy(), and meta.

Here is the call graph for this function:



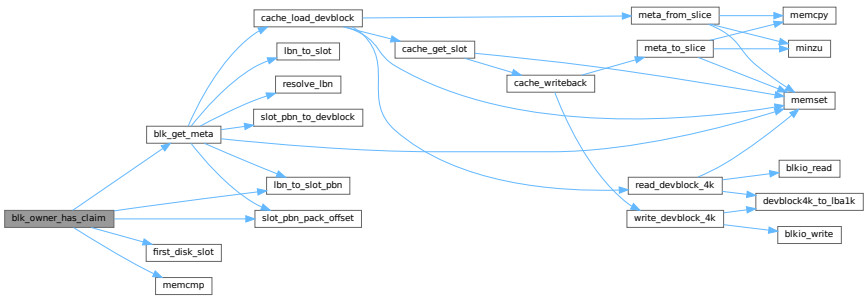
7.199.3.29 blk_owner_has_claim()

```
int blk_owner_has_claim (
            const uint8_t owner_fp[8] )
```

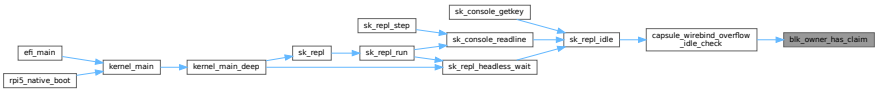
References BLK_FLAG_CLAIMED, blk_get_meta(), BLK_OK, first_disk_slot(), blk_volume_meta_t::flags, lbn_to_slot_pbn(), memcmp(), meta, slot_pbn_pack_offset(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by capsule_wirebind_overflow_idle_check().

Here is the call graph for this function:



Here is the caller graph for this function:



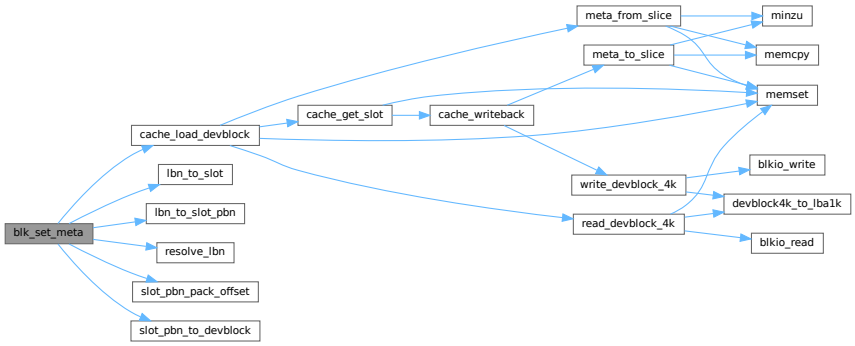
7.199.3.30 blk_set_meta()

```
int blk_set_meta (
            uint32_t block_num,
            const blk_meta_t * meta )
```

References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ERANGE, BLK_FLAG_CLAIMED, BLK_OK, cache_load_devblock(), blk_volume_meta_t::flags, g, blk_dev_slot::has_ever_claimed, lbn_to_slot(), lbn_to_slot_pbn(), meta, cache_slot_t::meta, cache_slot_t::meta_dirty, blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_pack_offset(), and slot_pbn_to_devblock().

Referenced by blk_acl_allow_set(), blk_acl_ttl_set(), blk_firsttouch_claim(), blk_flags_set(), blk_meta_relocate_devblock(), and blk_owner_fp_set().

Here is the call graph for this function:



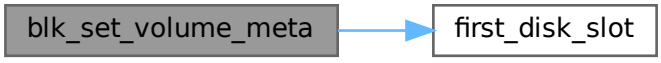
Here is the caller graph for this function:

7.199.3.31 blk_set_volume_meta()

```
int blk_set_volume_meta (
            const blk_volume_meta_t * meta )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, first_disk_slot(), meta, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Here is the call graph for this function:

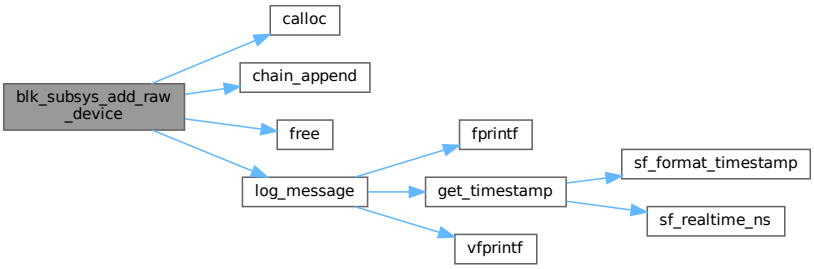


7.199.3.32 blk_subsys_add_raw_device()

```
int blk_subsys_add_raw_device (
            uint8_t * buf,
            uint32_t nblocks )
```

References blk_dev_slot::bam, BLK_EINVAL, BLK_ENODEV, BLK_ENOMEM, BLK_OK, calloc(), chain_append(), free(), g, LOG_INFO, log_message(), blk_dev_slot::raw_base, blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Here is the call graph for this function:



7.199.3.33 blk_subsys_attach_device()

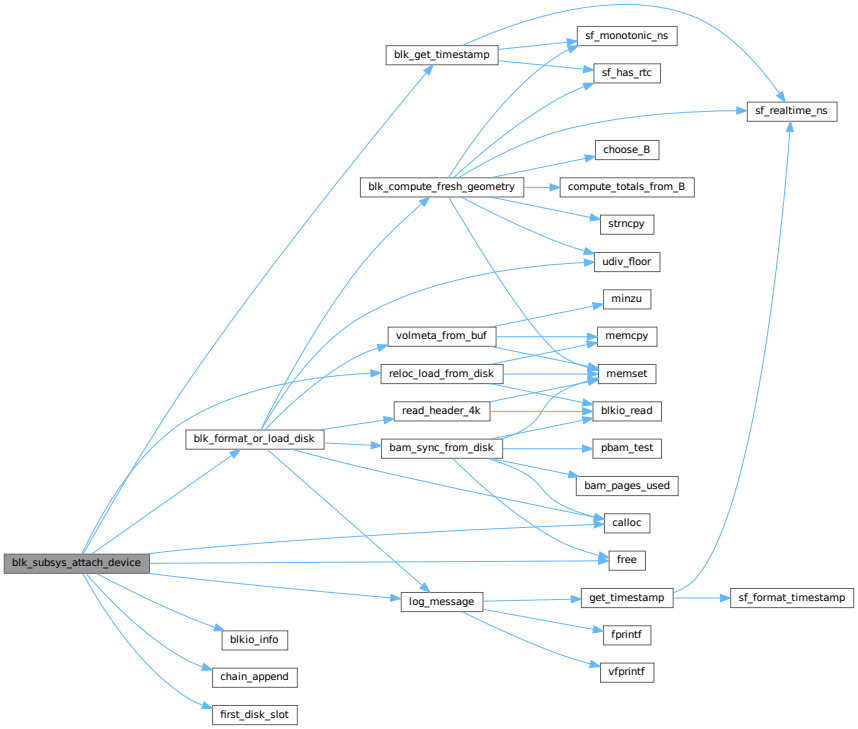
```
int blk_subsys_attach_device (
            struct blkio_dev * dev )
```

References blk_dev_slot::bam, blk_volume_meta_t::bam_devblocks, BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ENOMEM, BLK_FMT_FORMATTED, blk_format_or_load_disk(), blk_get_timestamp(), BLK_OK, blkio_info(),

BLKIO_OK, calloc(), chain_append(), blk_dev_slot::dev, blk_volume_meta_t::devblock_base, first_disk_slot(), blk_dev_slot::format_state, free(), blk_volume_meta_t::free_blocks, g, blk_volume_meta_t::label, LOG_INFO, log_message(), blk_volume_meta_t::meta_fence_blocks, blk_volume_meta_t::mounted_time, reloc_load_from_disk(), blk_dev_slot::start_lbn, blk_dev_slot::total_blkio_blocks_1k, blkio_info_t::total_blocks, blk_volume_meta_t::total_blocks, blk_volume_meta_t::total_devblocks, blk_dev_slot::user_blocks, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Referenced by __attribute__(), block_word_blk_attach(), kernel_main_deep(), sk_v4_drive_arrived(), and sk_v4_real_zuse_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

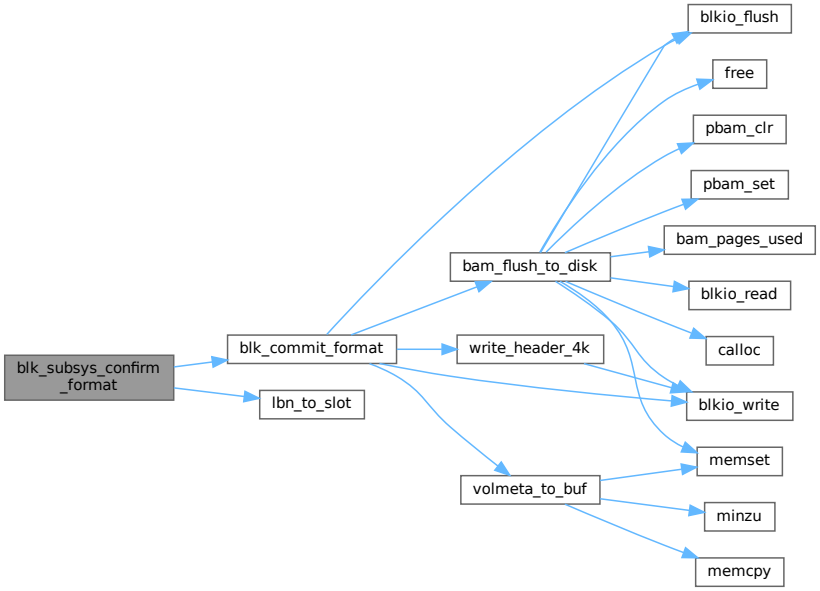
7.199.3.34 blk_subsys_confirm_format()

```
int blk_subsys_confirm_format (
            uint32_t lbn )
```

References blk_commit_format(), BLK_ENODEV, BLK_ERANGE, blk_dev_slot::dev, g, and lbn_to_slot().

Referenced by block_word_confirm_format(), and sk_v4_genesis().

Here is the call graph for this function:



Here is the caller graph for this function:

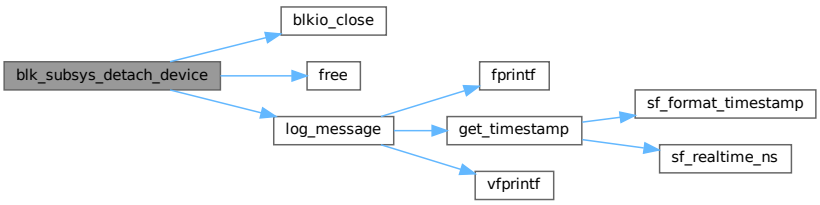
7.199.3.35 blk_subsys_detach_device()

```
int blk_subsys_detach_device (
            struct blkio_dev * dev )
```

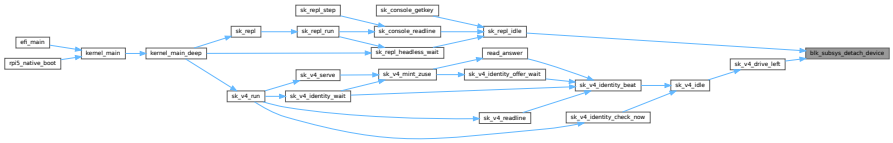
References blk_dev_slot::bam, BLK_EINVAL, BLK_ENODEV, BLK_OK, blkio_close(), blk_dev_slot::dev, free(), g, blk_volume_meta_t::label, LOG_INFO, log_message(), LOG_WARN, blk_dev_slot::next, blk_dev_slot::start_lbn, blk_dev_slot::user_blocks, and blk_dev_slot::vol_meta.

Referenced by sk_repl_idle(), and sk_v4_drive_left().

Here is the call graph for this function:



Here is the caller graph for this function:



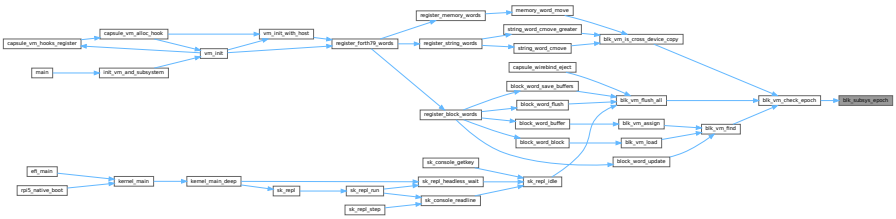
7.199.3.36 blk_subsys_epoch()

```
uint64_t blk_subsys_epoch (
            void  )
```

References g.

Referenced by blk_vm_check_epoch().

Here is the caller graph for this function:



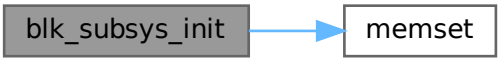
7.199.3.37 blk_subsys_init()

```
int blk_subsys_init (
            uint8_t * ram_base,
            size_t ram_size )
```

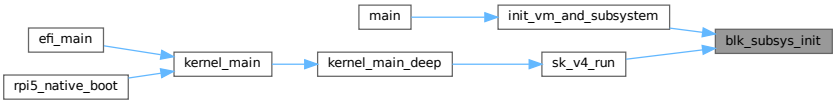
References BLK_EINVAL, BLK_FORTH_SIZE, BLK_FORTH_SYS_RESERVED, BLK_OK, BLK_RAM_BLOCKS, g, memset(), ram_base, and ram_size.

Referenced by init_vm_and_subsystem(), and sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



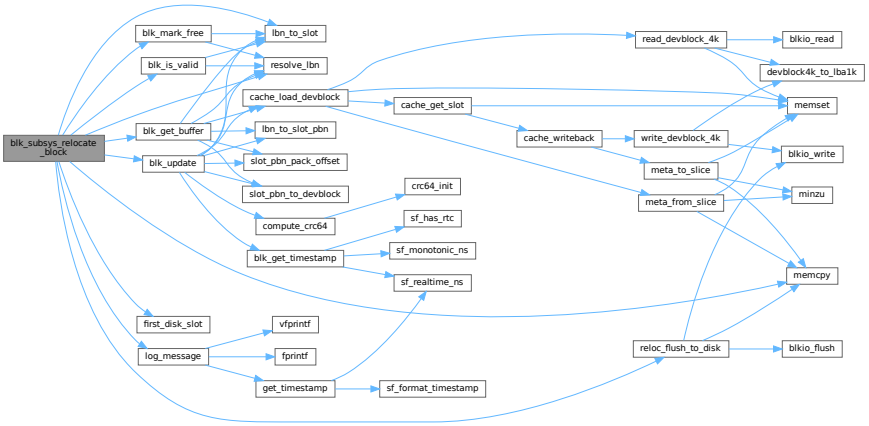
7.199.3.38 blk_subsys_relocate_block()

```
int blk_subsys_relocate_block (
            uint32_t home_lbn,
            uint32_t target_lbn )
```

References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ENOMEM, BLK_ERANGE, BLK_FORTH_SIZE, blk_get_buffer(), blk_is_valid(), blk_mark_free(), BLK_OK, BLK_RELOC_MAX_ENTRIES, blk_update(), first_disk_slot(), g, lbn_to_slot(), LOG_INFO, log_message(), LOG_WARN, memcpy(), reloc_flush_to_disk(), and resolve_lbn().

Referenced by blk_meta_relocate_devblock(), and block_word_relocate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.199.3.39 blk_subsys_set_format_bam_for()

```
void blk_subsys_set_format_bam_for (
            uint64_t total_devblocks )
```

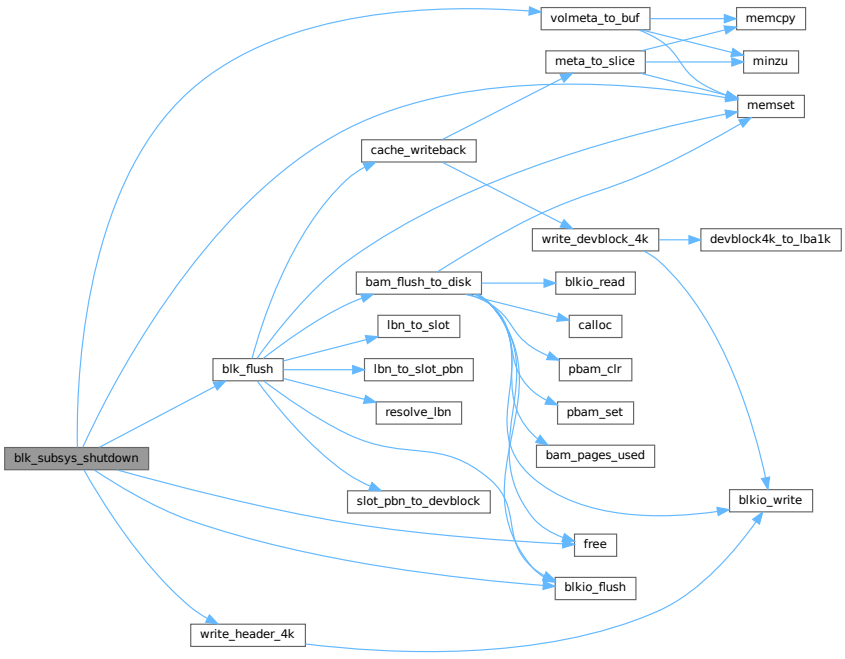
References g_format_bam_for.

7.199.3.40 blk_subsys_shutdown()

```
int blk_subsys_shutdown (
            void  )
```

References blk_dev_slot::bam, BLK_DEVICE_SECTOR, blk_flush(), BLK_FMT_FORMATTED, BLK_OK, blkio_flush(), blk_dev_slot::dev, blk_dev_slot::format_state, free(), g, memset(), blk_dev_slot::next, blk_dev_slot::vol_meta, blk_dev_slot::vol_meta_dirty, volmeta_to_buf(), and write_header_4k().

Here is the call graph for this function:



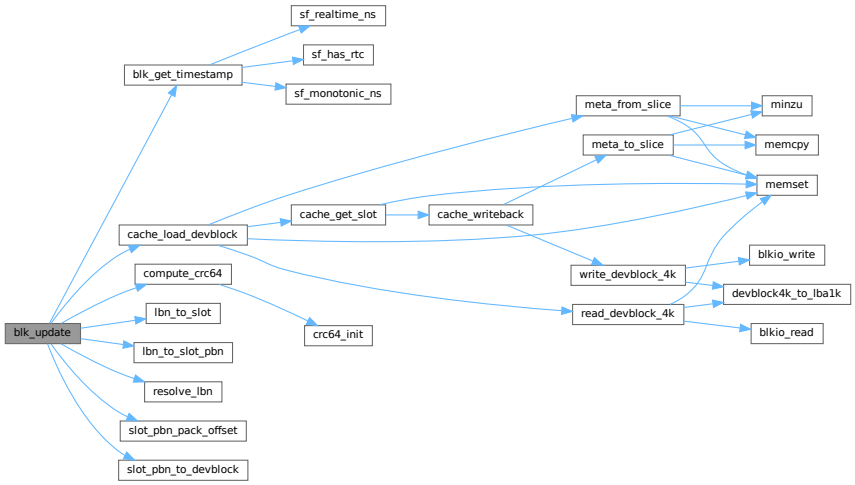
7.199.3.41 blk_update()

```
int blk_update (
            uint32_t block_num )
```

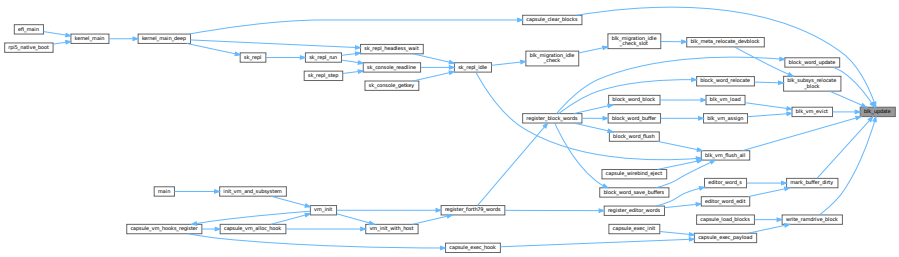
References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_dev_slot::bam_dirty, BLK_EIO, BLK_ENODEV, BLK_ERANGE, BLK_ERESERVED, BLK_FMT_PROVISIONAL, BLK_FORTH_SIZE, BLK_FORTH_SYS_RESERVED, blk_get_timestamp(), BLK_OK, BLK_RAM_BLOCKS, cache_load_devblock(), blk_meta_t::checksum, compute_crc64(), blk_meta_t::created_time, cache_slot_t::data, blk_bam_entry_t::dirty, cache_slot_t::dirty, blk_dev_slot::format_state, blk_volume_meta_t::free_blocks, g, lbn_to_slot(), lbn_to_slot_pbn(), blk_meta_t::magic, cache_slot_t::meta, cache_slot_t::meta_dirty, blk_meta_t::modified_time, blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_pack_offset(), slot_pbn_to_devblock(), blk_dev_slot::start_lbn, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Referenced by blk_subsys_relocate_block(), blk_vm_evict(), blk_vm_flush_all(), block_word_update(), capsule_clear_blocks(), mark_buffer_dirty(), and write_ramdrive_block().

Here is the call graph for this function:



Here is the caller graph for this function:



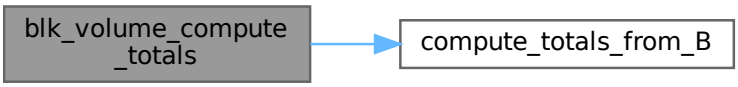
7.199.3.42 blk_volume_compute_totals()

```
void blk_volume_compute_totals (
            blk_volume_meta_t * m )
```

References compute_totals_from_B().

Referenced by sk_v4_grow_artemis().

Here is the call graph for this function:



Here is the caller graph for this function:

7.199.3.43 compute_crc64()

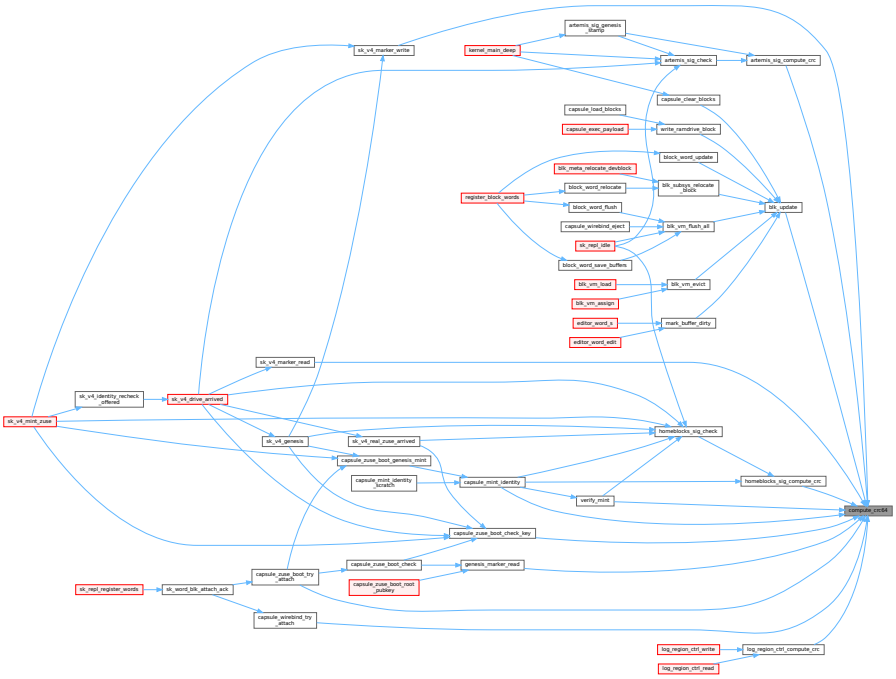
```
uint64_t compute_crc64 (
            const uint8_t * data,
            size_t len )
```

References crc64_init(), crc64_inited, and crc64_table.

Referenced by artemis_sig_compute_crc(), blk_update(), capsule_mint_identity(), capsule_wirebind_try_attach(), capsule_zuse_boot_check_key(), capsule_zuse_boot_try_attach(), genesis_marker_read(), homeblocks_sig_compute_crc(), log_region_ctrl_compute_crc(), sk_v4_marker_read(), sk_v4_marker_write(), and verify_mint().

Here is the call graph for this function:

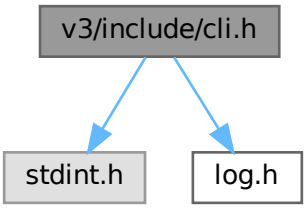
Here is the caller graph for this function:



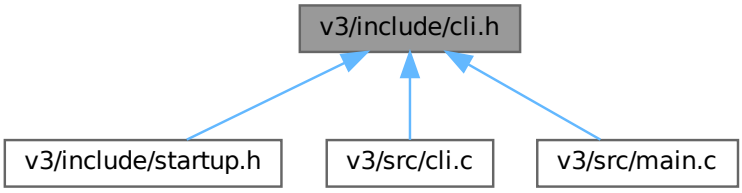
7.200 v3/include/cli.h File Reference

```
#include <stdint.h>
#include "log.h"
```

Include dependency graph for cli.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct CLIConfig

  Configuration structure from command-line arguments Consolidates all parsed CLI options into a single, cleanly organized struct.

Enumerations

- enum HeartbeatLogMode { HEARTBEAT_LOG_OFF = 0 , HEARTBEAT_LOG_SUMMARY = 1 , HEARTBEAT_LOG_FULL = 2 }

  Heartbeat logging modes for DoE experiments.

Functions

- CLIConfig cli_parse (int argc, char ∗argv[ ])

  Parse command-line arguments into CLIConfig.
- void cli_print_usage (const char ∗program_name)

  Print usage/help information.

7.200.1 Enumeration Type Documentation

7.200.1.1 HeartbeatLogMode

```
enum HeartbeatLogMode
```

Heartbeat logging modes for DoE experiments.

Enumerator

HEARTBEAT_LOG_OFF	
HEARTBEAT_LOG_SUMMARY	
HEARTBEAT_LOG_FULL	

7.200.2 Function Documentation

7.200.2.1 cli_parse()

```
CLIConfig cli_parse (
            int argc,
            char * argv[] )
```

Parse command-line arguments into CLIConfig.

Parameters

argc	Argument count
argv	Argument vector

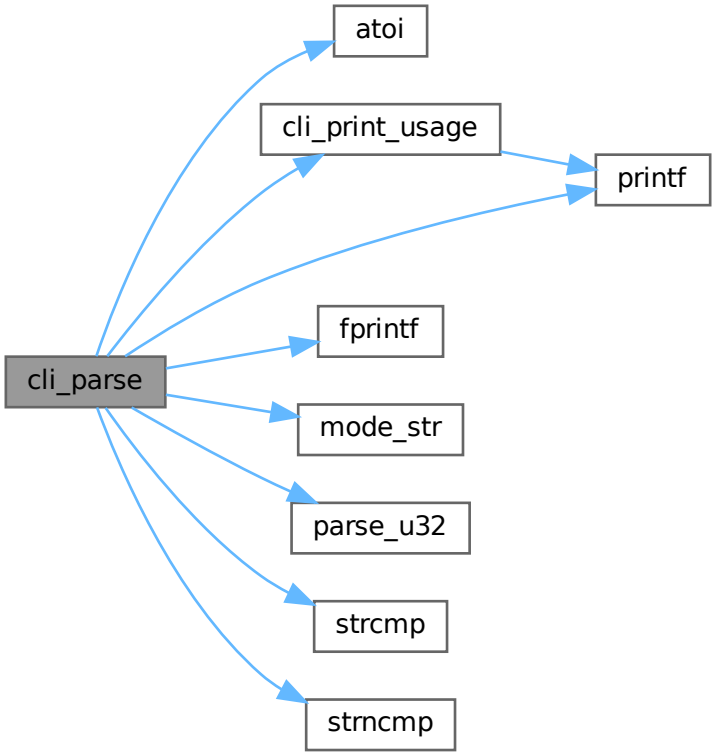
Returns

CLIConfig struct with parsed options, or exits on –version/–help

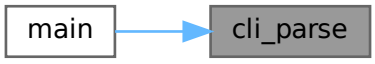
References atoi(), CLIConfig::benchmark, CLIConfig::benchmark_iterations, CLIConfig::break_me, cli_print_usage(), CLIConfig::disk_img_path, CLIConfig::doe_experiment, CLIConfig::fail_fast, fprintf(), HEARTBEAT_LOG_FULL, CLIConfig::heartbeat_log_mode, HEARTBEAT_LOG_OFF, HEARTBEAT_LOG_SUMMARY, LOG_DEBUG, LOG_ERROR, LOG_INFO, CLIConfig::log_level, CLIConfig::log_level_explicitly_set, LOG_NONE, LOG_TEST, LOG_WARN, mode_str(), parse_u32(), printf(), CLIConfig::ram_disk_mb, CLIConfig::run_tests, CLIConfig::run_tests_flag_observed, CLIConfig::script_mode, STARFORTH_VERSION_FULL, stderr, strcmp(), and strncmp().

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.200.2.2 cli_print_usage()

```
void cli_print_usage (
            const char * program_name )
```

Print usage/help information.

Parameters

program_name	Name of the executable

References printf().

Referenced by cli_parse().

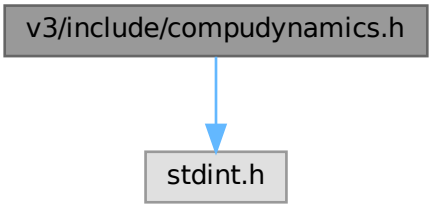
Here is the call graph for this function:

Here is the caller graph for this function:

7.201 v3/include/compudynamics.h File Reference

```
#include <stdint.h>
```

Include dependency graph for compudynamics.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct CDRegimeMetrics
- struct CDTuning
- struct CDConfigEntry
- struct CDConfigTable

Macros

- #define CD_MAX_CLASSIFY_DEPTH 64u

Functions

- CDRegimeMetrics cd_classify_ids (const uint32_t *ids, uint32_t count, uint32_t locality_lookback)

  Classify a recent entity-ID touch sequence into diversity/volatility/ locality, purely from execution counts – no wall-clock input anywhere.
- CDTuning cd_tuning_word (void)
- CDTuning cd_tuning_vm (void)
- int cd_config_table_init (CDConfigTable *table, const CDTuning *tuning)

  Allocate a config table sized for tuning->num_configs / num_regimes.
- void cd_config_table_free (CDConfigTable *table)

  Free all memory owned by a config table.
- void cd_config_table_seed (CDConfigTable *table, const CDTuning *tuning, const uint32_t *initial_scores, uint8_t initial_config)

  Seed every (regime, config) score with initial_scores[config], and set the starting active config to initial_config.
- uint8_t cd_config_table_tick (CDConfigTable *table, const CDTuning *tuning, uint8_t regime, uint32_t anova_stability_q16, int use_joint_convergence, uint32_t current_window, uint32_t current_locality_q16)

  Score the currently-active config from this tick's outcome and UCB1-reselect this tick's config, for the given regime.
- void cd_config_table_force (CDConfigTable *table, uint8_t config_idx)

  Force the table onto an externally-chosen config (as if UCB1 had picked it).

7.201.1 Macro Definition Documentation

7.201.1.1 CD_MAX_CLASSIFY_DEPTH

```
#define CD_MAX_CLASSIFY_DEPTH 64u
```

7.201.2 Function Documentation

7.201.2.1 cd_classify_ids()

```
CDRegimeMetrics cd_classify_ids (
            const uint32_t * ids,
            uint32_t count,
            uint32_t locality_lookback )
```

Classify a recent entity-ID touch sequence into diversity/volatility/ locality, purely from execution counts – no wall-clock input anywhere.

Parameters

ids	Recent entity IDs, oldest first, chronological order
count	Number of valid entries in ids (clamped internally to CD_MAX_CLASSIFY_DEPTH)
locality_lookback	How many preceding touches count as "recent" for the locality measure (clamped to count)

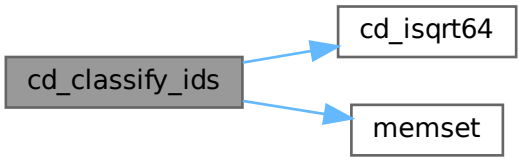
Returns

Classified regime metrics; all-zero if count == 0

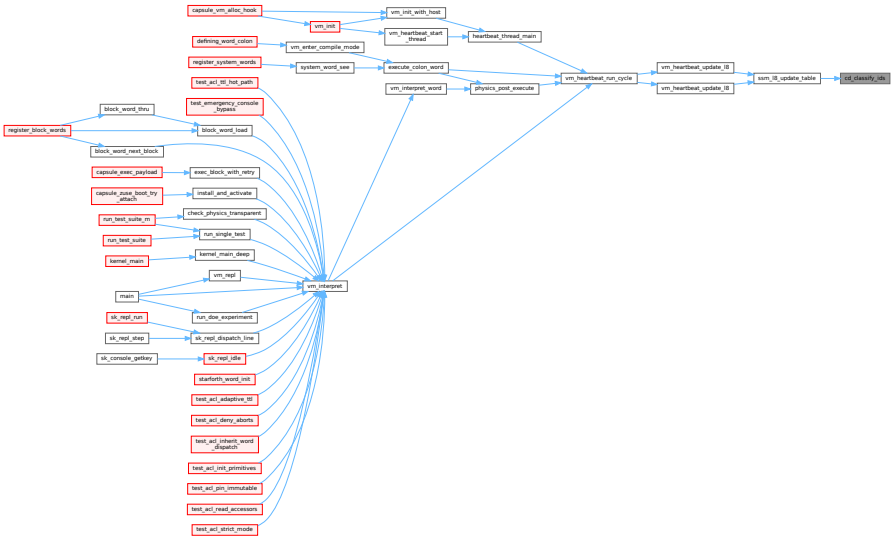
References cd_isqrt64(), CD_MAX_CLASSIFY_DEPTH, count, CDRegimeMetrics::diversity_q16, CDRegimeMetrics::locality_q16, memset(), and CDRegimeMetrics::volatility_q16.

Referenced by ssm_l8_update_table().

Here is the call graph for this function:



Here is the caller graph for this function:



7.201.2.2 cd_config_table_force()

```
void cd_config_table_force (
            CDConfigTable * table,
            uint8_t config_idx )
```

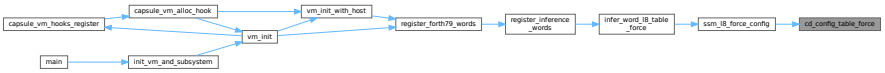
Force the table onto an externally-chosen config (as if UCB1 had picked it).

One-tick nudge, not a hold – see ssm_l8_force_config().

References CDConfigTable::current_config, CDConfigTable::entries, and CDConfigTable::num_configs.

Referenced by ssm_l8_force_config().

Here is the caller graph for this function:



7.201.2.3 cd_config_table_free()

```
void cd_config_table_free (
            CDConfigTable * table )
```

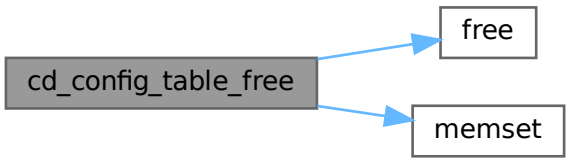
Free all memory owned by a config table.

Safe on a zeroed table.

References CDConfigTable::entries, free(), memset(), CDConfigTable::regime_scores, CDConfigTable::regime_ticks, and CDConfigTable::total_regime_ticks.

Referenced by cd_config_table_init(), and ssm_l8_free_table().

Here is the call graph for this function:



Here is the caller graph for this function:

7.201.2.4 cd_config_table_init()

```
int cd_config_table_init (
            CDConfigTable * table,
            const CDTuning * tuning )
```

Allocate a config table sized for tuning->num_configs / num_regimes.

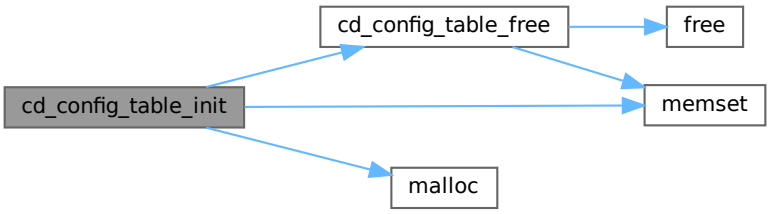
Returns

0 on success, -1 on malloc failure (table left zeroed, unusable)

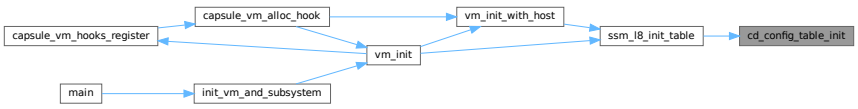
References cd_config_table_free(), CDConfigTable::entries, malloc(), memset(), CDTuning::num_configs, CDConfigTable::num_configs, CDTuning::num_regimes, CDConfigTable::num_regimes, CDConfigTable::regime_scores, CDConfigTable::regime_ticks, and CDConfigTable::total_regime_ticks.

Referenced by ssm_l8_init_table().

Here is the call graph for this function:



Here is the caller graph for this function:



7.201.2.5 cd_config_table_seed()

```
void cd_config_table_seed (
            CDConfigTable * table,
            const CDTuning * tuning,
            const uint32_t * initial_scores,
            uint8_t initial_config )
```

Seed every (regime, config) score with initial_scores[config], and set the starting active config to initial_config.

Parameters

initial_scores	Array of tuning->num_configs initial benefit scores

References CDConfigEntry::_pad, CDConfigEntry::benefit_score, CDConfigEntry::config_bits, CDConfigTable::current_config, CDConfigTable::current_regime, CDConfigTable::entries, CDConfigEntry::has_prev, CDConfigTable::num_configs, CDConfigTable::num_regimes, CDConfigEntry::prev_locality_q16, CDConfigEntry::prev_window, CDConfigTable::regime_scores, CDConfigTable::regime_ticks, CDConfigEntry::tick_count, and CDConfigTable::total_regime_ticks.

Referenced by ssm_l8_seed_from_doe().

Here is the caller graph for this function:

7.201.2.6 cd_config_table_tick()

```
uint8_t cd_config_table_tick (
            CDConfigTable * table,
            const CDTuning * tuning,
            uint8_t regime,
            uint32_t anova_stability_q16,
            int use_joint_convergence,
            uint32_t current_window,
            uint32_t current_locality_q16 )
```

Score the currently-active config from this tick's outcome and UCB1-reselect this tick's config, for the given regime.

Combined reward = joint_weight ∗ window/locality-convergence-stability

- anova_weight ∗ anova_stability_q16 Joint-convergence is skipped (falls back to ANOVA-only) on a config's first tick, or when use_joint_convergence is false (the caller's config bits don't include loops whose convergence this signal is meant to track – word level's L5/L6, see ssm_jacquard.c).

Parameters

table	Config table (must be initialised)
tuning	Tuning knobs matching this table's sizing
regime	Current regime index, < tuning->num_regimes
anova_stability_q16	Caller-supplied stability signal, Q16 [0,65536]
use_joint_convergence	Whether to include the window/locality signal
current_window	Caller's current window-width metric
current_locality_q16	Caller's current locality_q16 from cd_classify_ids

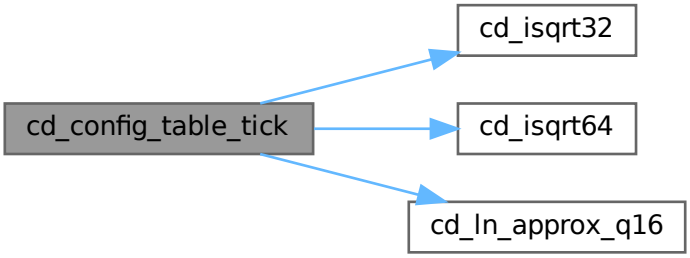
Returns

The newly-selected config's config_bits

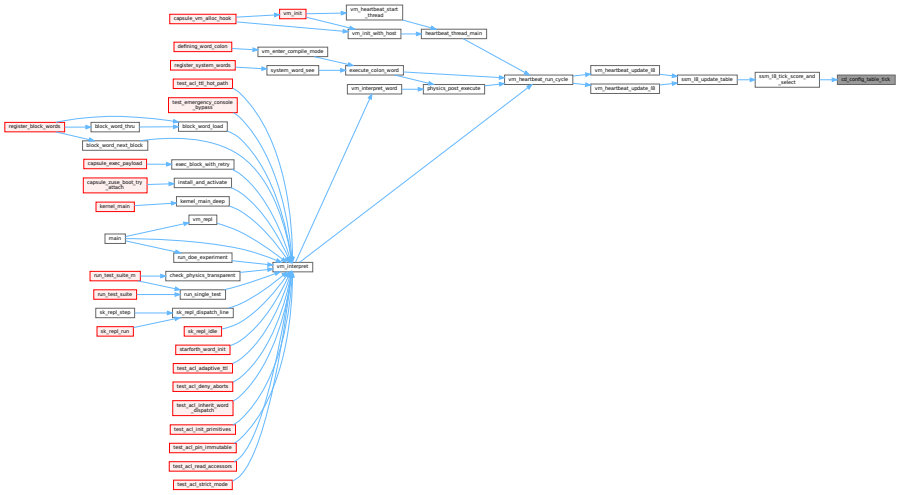
References CDTuning::anova_weight_q16, cd_isqrt32(), cd_isqrt64(), cd_ln_approx_q16(), CDConfigEntry::config_bits, CDConfigTable::current_config, CDConfigTable::current_regime, CDConfigTable::entries, entry, CDTuning::joint_weight_q16, CDConfigTable::num_configs, CDConfigTable::regime_scores, CDConfigTable::regime_ticks, CDTuning::reward_gain, CDTuning::score_decay_factor_q16, CDTuning::score_max, CDTuning::score_min, CDConfigTable::total_regime_ticks, and CDTuning::ucb_k.

Referenced by ssm_l8_tick_score_and_select().

Here is the call graph for this function:



Here is the caller graph for this function:



7.201.2.7 cd_tuning_vm()

```
CDTuning cd_tuning_vm (
            void  )
```

References CDTuning::anova_weight_q16, CDTuning::diversity_high_threshold_q16, CDTuning::id_window_depth, CDTuning::joint_weight_q16, CDTuning::locality_high_threshold_q16, CDTuning::locality_lookback, CDTuning::num_configs, CDTuning::num_regimes, CDTuning::reward_gain, CDTuning::score_decay_factor_q16, CDTuning::score_max, CDTuning::score_min, CDTuning::ucb_k, and CDTuning::volatility_high_threshold_q16.

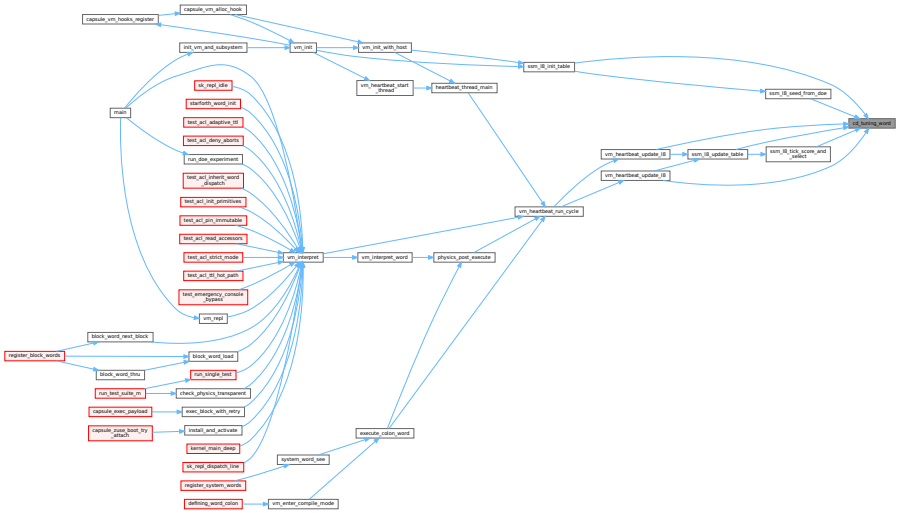
7.201.2.8 cd_tuning_word()

```
CDTuning cd_tuning_word (
            void  )
```

References CDTuning::anova_weight_q16, CDTuning::diversity_high_threshold_q16, CDTuning::id_window_depth, CDTuning::joint_weight_q16, CDTuning::locality_high_threshold_q16, CDTuning::locality_lookback, CDTuning::num_configs, CDTuning::num_regimes, CDTuning::reward_gain, CDTuning::score_decay_factor_q16, CDTuning::score_max, CDTuning::score_min, CDTuning::ucb_k, and CDTuning::volatility_high_threshold_q16.

Referenced by ssm_l8_init_table(), ssm_l8_seed_from_doe(), ssm_l8_tick_score_and_select(), ssm_l8_update_table(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

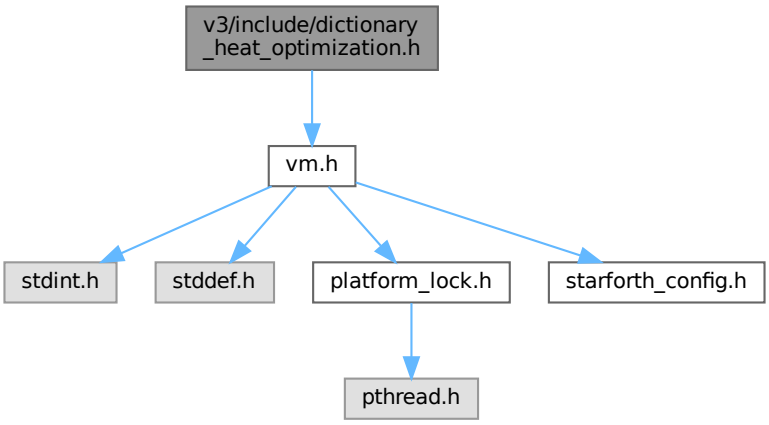
Here is the caller graph for this function:



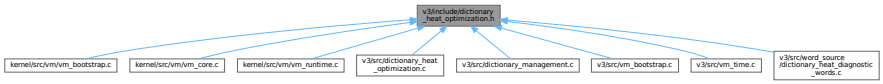
7.202 v3/include/dictionary_heat_optimization.h File Reference

```
#include "vm.h"
```

Include dependency graph for dictionary_heat_optimization.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define SF_FC_BUCKETS 256

Functions

- void dict_update_heat_percentiles (VM *vm)

  Calculate heat percentile thresholds for all words in dictionary.
- void dict_reorganize_buckets_by_heat (VM *vm)

  Reorganize dictionary buckets by inference-driven priorities.
- DictEntry * dict_find_word_heat_aware (VM *vm, const char *name, size_t len)

  Find word with heat-aware search strategy.
- void dict_adaptive_optimization_pass (VM *vm)

  Periodically reoptimize dictionary based on latest heat patterns.

Variables

- DictEntry ** sf_fc_list [256]
- size_t sf_fc_count [256]
- size_t sf_fc_cap [256]

7.202.1 Macro Definition Documentation

7.202.1.1 SF_FC_BUCKETS

```
#define SF_FC_BUCKETS 256
```

7.202.2 Function Documentation

7.202.2.1 dict_adaptive_optimization_pass()

```
void dict_adaptive_optimization_pass (
            VM * vm )
```

Periodically reoptimize dictionary based on latest heat patterns.

Called every ∼1 second or every N executions to adapt lookup strategy to current workload patterns from rolling window.

Periodically reoptimize dictionary based on latest heat patterns.

Called from the interpreter loop (or heartbeat) on every word dispatch; the 1 Hz gate (`now_ns - vm->last_bucket_reorg_ns` < 1,000,000,000) ensures the three expensive sub-steps run at a rate that is imperceptible to FORTH execution while still keeping the dictionary layout fresh:

1. **Update heat percentiles** — calls `dict_update_heat_percentiles()` to re-sample `execution_heat` across all words and compute the 25th / 50th / 75th thresholds used by the stratified lookup.
2. **Reorganize buckets** — calls `dict_reorganize_buckets_by_heat()` to sort each of the 256 first-character hash buckets so that the hottest words sit at the lowest array indices, shortening the average scan depth during the hot-tier pass.
3. **Select lookup strategy** — queries the rolling window for the current pattern-diversity score via `rolling_window_measure_diversity()`:
   - Diversity $>$ 70 (high churn in which words are called) $\rightarrow$ strategy 1 (`heat-aware` lookup, `dict_find_word_heat_aware()`), where the heat stratification most pays off.
   - Diversity $\leq$ 70 (stable repetitive pattern) $\rightarrow$ strategy 0 (naive newest-first bucket scan), which is already nearly O(1) for programs that call the same small word set repeatedly. The chosen strategy is stored in `vm->lookup_strategy` and read by the interpreter's dictionary lookup dispatch.

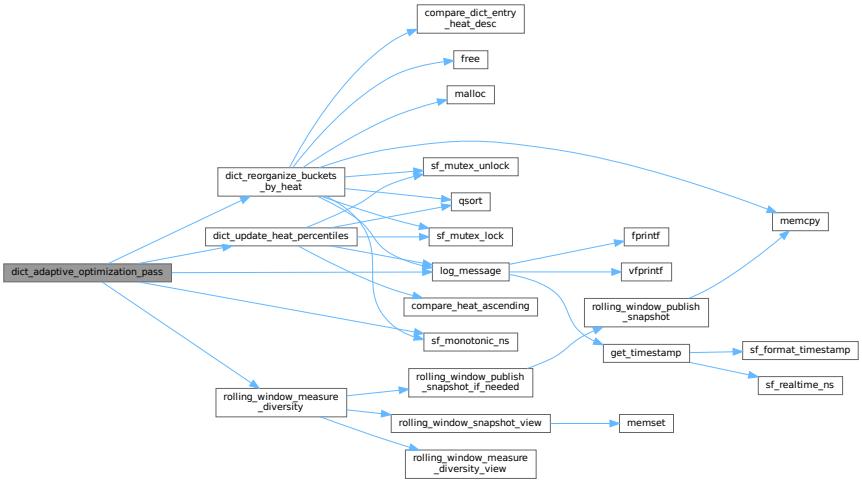
Parameters

vm	The VM to optimise. No-op if NULL or if less than 1 second has elapsed since the last pass (`vm->last_bucket_reorg_ns`).

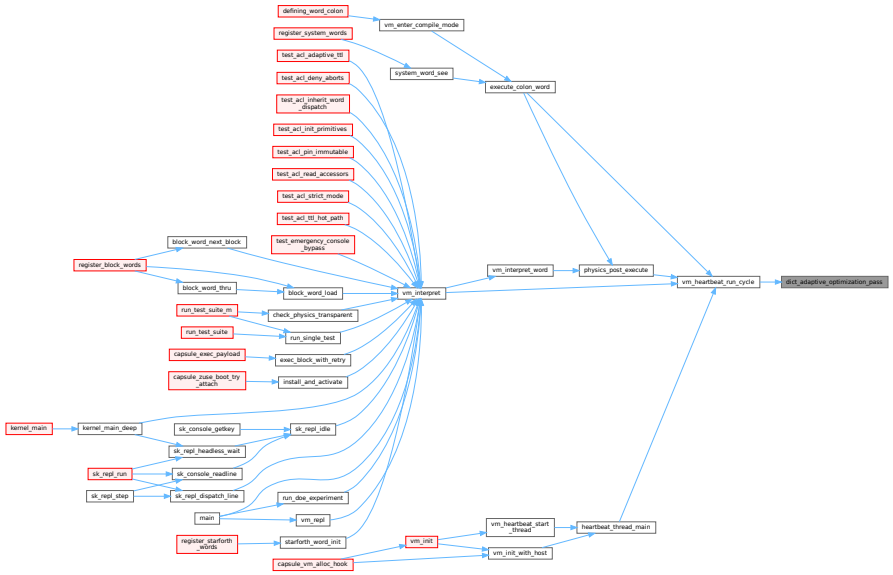
References dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), VM::last_bucket_reorg_ns, LOG_DEBUG, log_message(), VM::lookup_strategy, VM::rolling_window, rolling_window_measure_diversity(), and sf_monotonic_ns().

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.202.2.2 dict_find_word_heat_aware()

```
DictEntry * dict_find_word_heat_aware (
            VM * vm,
            const char * name,
            size_t len )
```

Find word with heat-aware search strategy.

Instead of newest-first, searches buckets in order:

1. Top 25% by heat (likely hits)
2. Middle 50% by heat
3. Bottom 25% (rarely executed)

Find word with heat-aware search strategy.

Searches the first-character bucket `sf_fc_list`[(unsigned char)name[0]] for a word whose `name` and `name_len` match `name` / `len`, scanning in three priority tiers ordered by execution heat:

1. **Hot pass** (heat $\geq$ `heat_threshold_75th`): words in the top 25% by execution frequency. Most FORTH programs spend the vast majority of ticks in a handful of hot primitives; checking this tier first yields a near-constant-time hit on steady-state workloads.
2. **Medium pass** (heat in [threshold_25th, threshold_75th)): the middle 50% of words. These are occasionally-called words that still appear often enough to warrant a dedicated pass before touching the long tail.
3. **Cold pass** (heat $<$ `heat_threshold_25th`): the rarely-executed bottom quartile. Words that have never been called also live here.

Within each pass, matching uses the same cheap-first filter chain as the standard lookup: `name_len` comparison → last-character byte check → full `memcmp`. The last-character pre-filter is skipped for single-character names.

Returns `NULL` only if the word is absent from the bucket; all three passes exhausted without a hit. Also returns `NULL` immediately if `vm`, `name`, or `len` are invalid.

Heat thresholds are updated lazily by `dict_adaptive_optimization_pass()` (≈1 Hz); stale thresholds degrade to a full three-pass scan without affecting correctness.

Parameters

vm	The VM; provides `heat_threshold_*` fields and the bucket table.
name	Word name to search for (not NUL-terminated; length in `len`).
len	Length of `name` in bytes; must be ≥ 1.

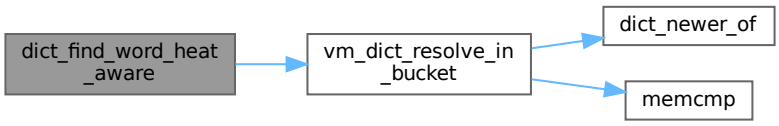
Returns

Pointer to the matching `DictEntry`, or `NULL` if not found.

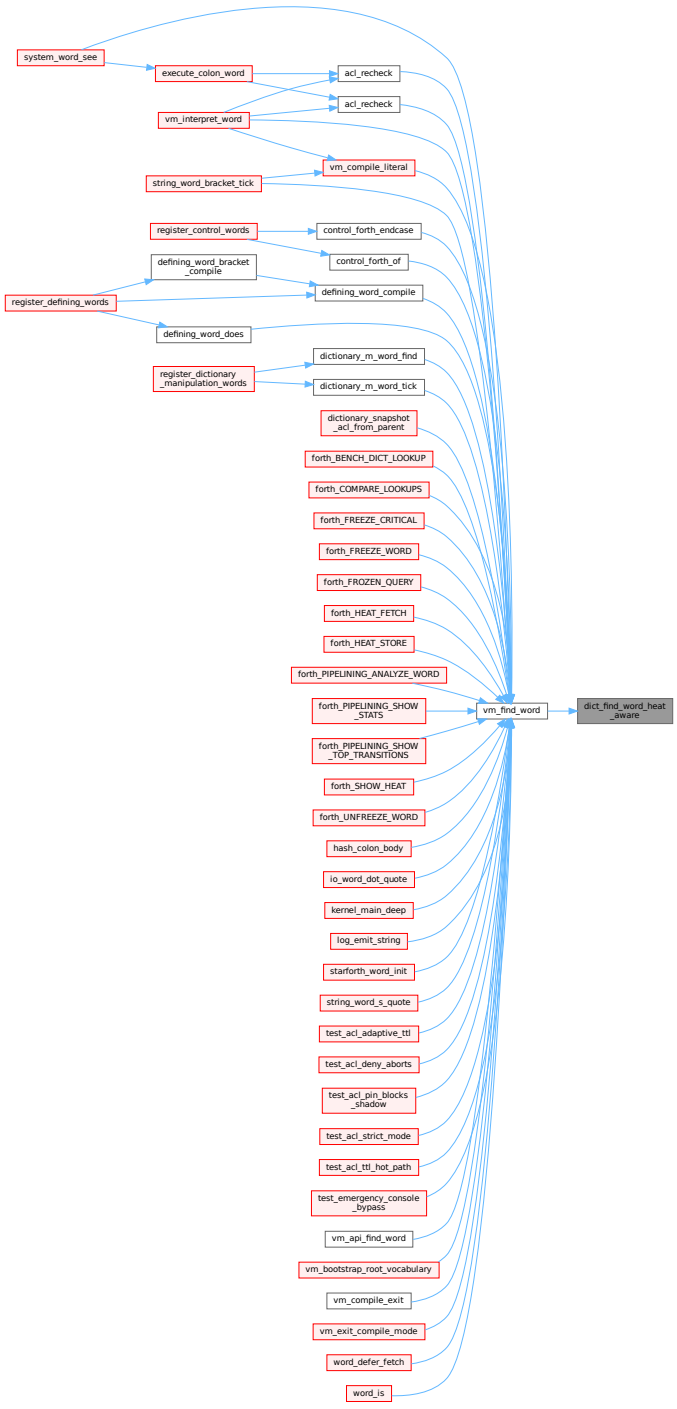
References name, sf_fc_count, sf_fc_list, and vm_dict_resolve_in_bucket().

Referenced by vm_find_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.202.2.3 dict_reorganize_buckets_by_heat()

```
void dict_reorganize_buckets_by_heat (
            VM * vm )
```

Reorganize dictionary buckets by inference-driven priorities.

Uses rolling window co-execution patterns to reorder words within buckets. Hot/frequently co-executing words are placed first for faster lookup.

Reorganize dictionary buckets by inference-driven priorities.

Holds `vm->dict_lock` for the entire operation to prevent concurrent `DictEntry` frees (from word redefinition or GC) from invalidating the pointer array while it is being sorted. For each non-empty bucket in `sf_fc_list`[0..255]:

1. Reads `sf_fc_count`[bucket_id] and `sf_fc_cap`[bucket_id]; skips the bucket if `count > cap` (indicates a TOCTOU race — logs a warning).
2. Allocates a temporary copy of the bucket pointer array.
3. Re-verifies `count` has not changed (TOCTOU double-check); if it has, frees the copy and skips.
4. Sorts the copy with `qsort` + `compare_dict_entry_heat_desc` so that the hottest `DictEntry*` comes first.
5. Copies the sorted array back over the original bucket.
6. Frees the temporary copy.

After returning, `vm->last_bucket_reorg_ns` is updated to the completion timestamp so that `dict_adaptive_optimization_pass()` can enforce its 1 Hz throttle. The elapsed reorganization time is emitted at `LOG_DEBUG`.

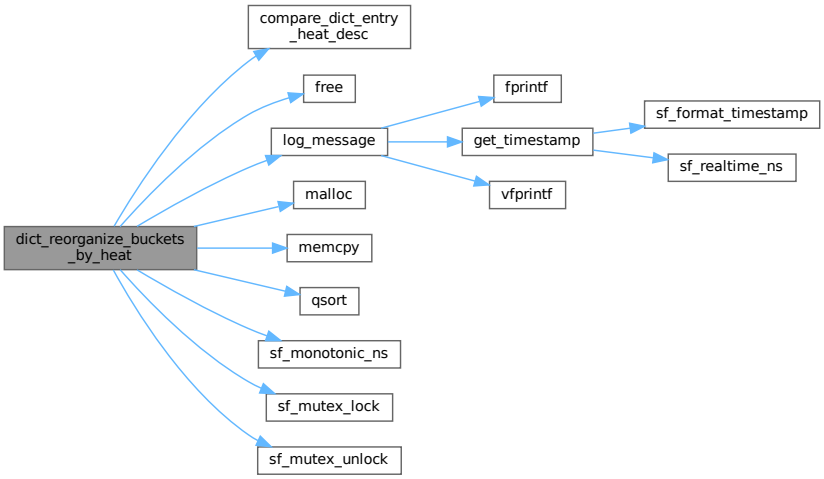
Parameters

vm	The VM whose first-character hash buckets are reorganized. No-op if NULL. `dict_lock` is held during the entire scan.

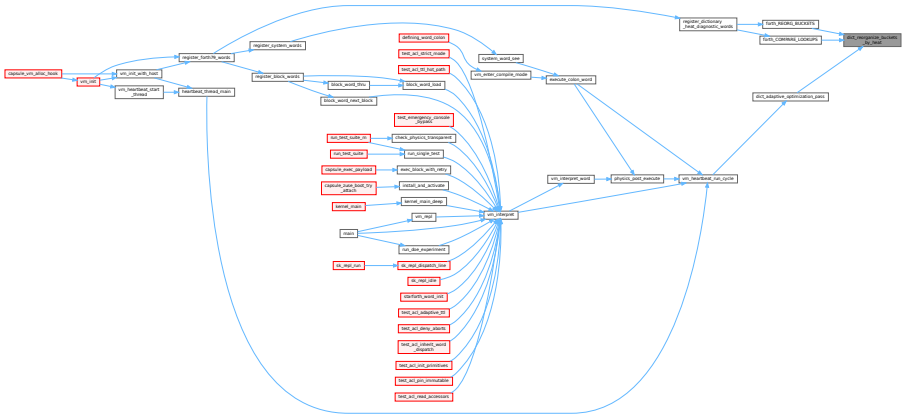
References compare_dict_entry_heat_desc(), count, VM::dict_lock, free(), VM::last_bucket_reorg_ns, LOG_DEBUG, log_message(), LOG_WARN, malloc(), memcpy(), qsort(), sf_fc_cap, sf_fc_count, sf_fc_list, sf_monotonic_ns(), sf_mutex_lock(), and sf_mutex_unlock().

Referenced by dict_adaptive_optimization_pass(), forth_COMPARE_LOOKUPS(), and forth_REORG_BUCKETS().

Here is the call graph for this function:



Here is the caller graph for this function:



7.202.2.4 dict_update_heat_percentiles()

```
void dict_update_heat_percentiles (
            VM * vm )
```

Calculate heat percentile thresholds for all words in dictionary.

Computes 25th, 50th, 75th percentiles of execution_heat across all dictionary entries. Used to partition lookup search order.

Calculate heat percentile thresholds for all words in dictionary.

Traverses the full linked-list dictionary under `vm->dict_lock` to snapshot every word's `execution_heat` into a stack-allocated scratch array (up to `DICTIONARY_SIZE` entries). After releasing the lock it sorts the snapshot with `qsort` + `compare_heat_ascending` and computes percentile indices using integer arithmetic:

```
vm->heat_threshold_25th = heats[(count * 25) / 100];
vm->heat_threshold_50th = heats[(count * 50) / 100];
vm->heat_threshold_75th = heats[(count * 75) / 100];
```

If the dictionary contains no words all three thresholds are set to 0. The lock is held only during traversal; sorting is performed outside the critical section to minimise contention with the concurrent heartbeat decay sweep that also walks the word list.

The resulting thresholds are consumed by `dict_find_word_heat_aware()` (which stratifies its search by heat tier) and by `dict_adaptive_optimization_pass()` (which calls this function as its first step every ∼1 Hz).

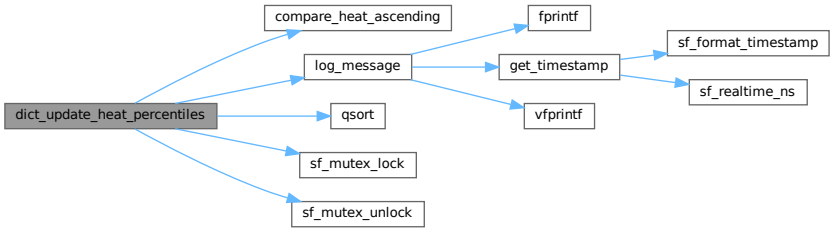
Parameters

vm	The VM whose dictionary is sampled and whose `heat_threshold_25th` / `heat_threshold_50th` / `heat_threshold_75th` fields are updated. No-op if NULL.

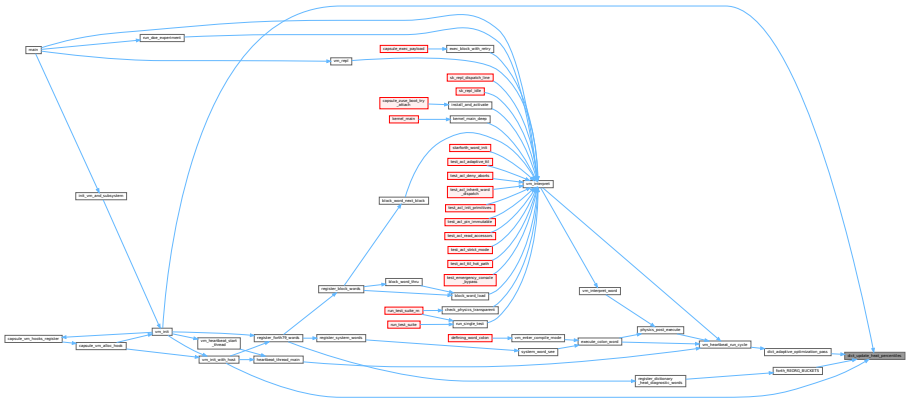
References compare_heat_ascending(), count, VM::dict_lock, DICTIONARY_SIZE, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::latest, LOG_DEBUG, log_message(), qsort(), sf_mutex_lock(), and sf_mutex_unlock().

Referenced by dict_adaptive_optimization_pass(), forth_REORG_BUCKETS(), vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.202.3 Variable Documentation

7.202.3.1 sf_fc_cap

```
size_t sf_fc_cap[256]  [extern]
```

Referenced by dict_reorganize_buckets_by_heat(), sf_fc_clear_all(), and sf_fc_reserve().

7.202.3.2 sf_fc_count

```
size_t sf_fc_count[256]  [extern]
```

Referenced by dict_find_word_heat_aware(), and dict_reorganize_buckets_by_heat().

7.202.3.3 sf_fc_list

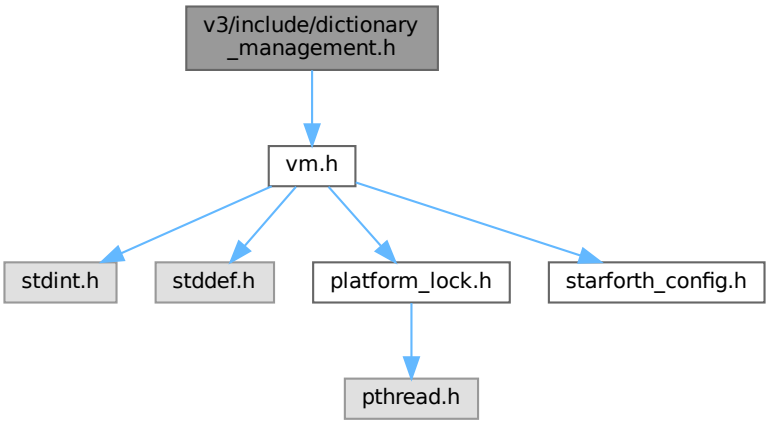
```
DictEntry** sf_fc_list[256]  [extern]
```

Referenced by dict_find_word_heat_aware(), and dict_reorganize_buckets_by_heat().

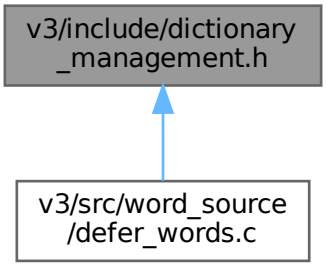
7.203 v3/include/dictionary_management.h File Reference

```
#include "vm.h"
```

Include dependency graph for dictionary_management.h:



This graph shows which files directly or indirectly include this file:



Functions

- void dictionary_init (VM *vm)

  Initialize the Forth dictionary.
- void dictionary_register (VM *vm, const char *name, word_func_t func)

  Register a new word in the dictionary.
- word_func_t dictionary_lookup (VM *vm, const char *name)

  Look up a word in the dictionary by name.
- void dictionary_clear (VM *vm)

  Clear the entire dictionary.

7.203.1 Function Documentation

7.203.1.1 dictionary_clear()

```
void dictionary_clear (
            VM * vm )
```

Clear the entire dictionary.

Parameters

vm	Pointer to the virtual machine instance

Removes all words from the dictionary and frees associated memory. This is an optional operation that may be used during cleanup.

7.203.1.2 dictionary_init()

```
void dictionary_init (
            VM * vm )
```

Initialize the Forth dictionary.

Parameters

vm	Pointer to the virtual machine instance

Initializes all dictionary structures and prepares them for use. Must be called before any other dictionary operations.

7.203.1.3 dictionary_lookup()

```
word_func_t dictionary_lookup (
            VM * vm,
            const char * name )
```

Look up a word in the dictionary by name.

Parameters

vm	Pointer to the virtual machine instance
name	Name of the word to look up

Returns

word_func_t Function pointer to the word's implementation or NULL if not found

7.203.1.4 dictionary_register()

```
void dictionary_register (
            VM * vm,
            const char * name,
            word_func_t func )
```

Register a new word in the dictionary.

Parameters

vm	Pointer to the virtual machine instance
name	Name of the word to register
func	Function pointer to the word's implementation

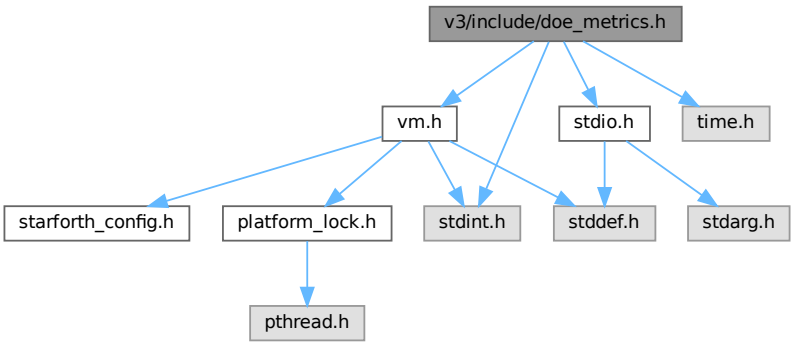
Adds a new word to the dictionary with the specified name and implementation.

7.204 v3/include/doe_metrics.h File Reference

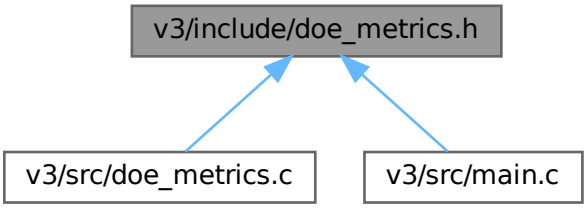
Design of Experiments (DoE) metrics collection API.

```
#include <stdio.h>
#include <stdint.h>
#include <time.h>
#include "vm.h"
```

Include dependency graph for doe_metrics.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct DoeMetrics

  Complete metrics snapshot for a single DoE run.

Functions

- DoeMetrics metrics_from_vm (VM ∗vm, uint64_t workload_duration_ns, int32_t cpu_temp_delta_c, int32_t cpu_freq_delta_mhz)

  Extract complete metrics snapshot from VM.
- void metrics_write_csv_header (FILE ∗out)

  Write CSV header row.
- void metrics_write_csv_row (FILE ∗out, const DoeMetrics ∗metrics)

  Write metrics as CSV row.
- void metrics_write_james_law_csv_row (FILE ∗out, const DoeMetrics ∗metrics, VM ∗vm)

  Write reduced James Law CSV row (20 columns)
- void metrics_print_text (FILE ∗out, const DoeMetrics ∗metrics)

  Print metrics as human-readable text.
- int32_t metrics_get_cpu_temp_c (void)

  Get current CPU temperature (Celsius)
- int32_t metrics_get_cpu_freq_mhz (void)

  Get current CPU frequency (MHz)
- void metrics_get_timestamp (char ∗buf, size_t bufsize)

  Get current timestamp as ISO 8601 string.

7.204.1 Detailed Description

Design of Experiments (DoE) metrics collection API.

Provides C-level programmatic access to VM metrics for physics-based experiments. Enables efficient in-process data collection without string parsing overhead.

Usage: struct DoeMetrics metrics = metrics_from_vm(vm); metrics_write_csv_row(stdout, &metrics, run_number);

7.204.2 Function Documentation

7.204.2.1 metrics_from_vm()

```
DoeMetrics metrics_from_vm (
            VM * vm,
            uint64_t workload_duration_ns,
            int32_t cpu_temp_delta_c,
            int32_t cpu_freq_delta_mhz )
```

Extract complete metrics snapshot from VM.

Collects all metrics from current VM state after a test harness run. Workload duration and CPU deltas must be supplied by caller.

Parameters

vm	Pointer to Forth VM instance
workload_duration_ns	Actual VM workload execution time (nanoseconds)
cpu_temp_delta_c	CPU temperature change during run (°C)
cpu_freq_delta_mhz	CPU frequency change during run (MHz)

Returns

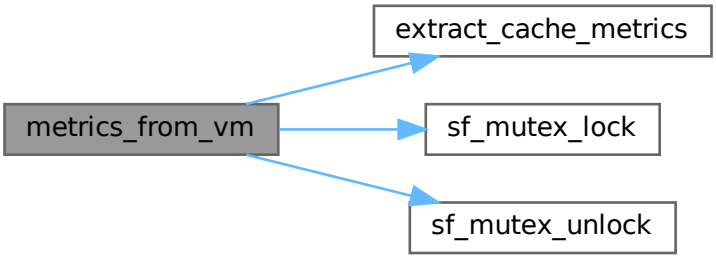
Populated metrics structure (timestamp filled in)

Extract complete metrics snapshot from VM.

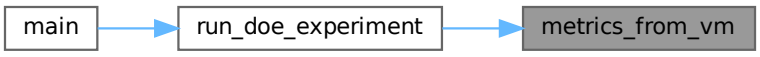
References DoeMetrics::actual_window_size, DoeMetrics::adaptive_shrink_rate, DoeMetrics::avg_word_heat, DoeMetrics::cache_demotions, DoeMetrics::cache_promotions, DoeMetrics::ci_lower_95, DoeMetrics::ci_upper_95, DoeMetrics::context_accuracy_percent, DoeMetrics::context_correct, DoeMetrics::context_predictions_total, DoeMetrics::cpu_freq_delta_mhz_q48, DoeMetrics::cpu_temp_delta_c_q48, DECAY_MIN_INTERVAL, DoeMetrics::decay_min_inter DECAY_RATE_PER_US_Q16, DoeMetrics::decay_rate_q16, DoeMetrics::decay_slope, VM::decay_slope_q48, VM::dict_lock, DoeMetrics::dictionary_lookups, HeartbeatState::dictionary_lookups, DoeMetrics::early_exit_count, HeartbeatState::early_exit_count, RollingWindowOfTruth::effective_window_size, DoeMetrics::enable_hotwords_cache, ENABLE_HOTWORDS_CACHE, DoeMetrics::enable_loop_1_heat_tracking, DoeMetrics::enable_loop_2_rolling_window, DoeMetrics::enable_loop_3_linear_decay, DoeMetrics::enable_loop_4_pipelining, DoeMetrics::enable_loop_5_window_inference, DoeMetrics::enable_loop_6_decay_inference, DoeMetrics::enable_loop_7_adaptive_heartrate, DoeMetrics::enable_pipelining, ENABLE_PIPELINING, HotwordsCache_s::enabled, HotwordsStats::evictions, extract_cache_metrics(), DoeMetrics::final_effective_v VM::heartbeat, DoeMetrics::heat_cache_demotion_threshold, DoeMetrics::hot_word_count, VM::hotwords_cache, HOTWORDS_EXECUTION_HEAT_THRESHOLD, DoeMetrics::inference_run_count, HeartbeatState::inference_run_count, VM::last_inference_outputs, VM::latest, DoeMetrics::memory_allocated_bytes, VM::pipeline_metrics, DoeMetrics::prefetch_accuracy DoeMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_attempts, DoeMetrics::prefetch_hits, PipelineGlobalMetrics::prefetch HotwordsStats::promotions, VM::rolling_window, DoeMetrics::rolling_window_size, ROLLING_WINDOW_SIZE, DoeMetrics::rolling_window_width, sf_mutex_lock(), sf_mutex_unlock(), DoeMetrics::speedup_vs_baseline, DoeMetrics::stale_word_count, DoeMetrics::stale_word_ratio, HotwordsCache_s::stats, DoeMetrics::tick_count, HeartbeatState::tick_count, DoeMetrics::tick_target_ns, HeartbeatState::tick_target_ns, DoeMetrics::total_executions, RollingWindowOfTruth::total_executions, DoeMetrics::total_heat, DoeMetrics::total_lookups, HotwordsStats::total_lookups, DoeMetrics::total_runtime_ms, VM::tuning_lock, DoeMetrics::vm_workload_duration_ns_q48, DoeMetrics::window_diversity_percent DoeMetrics::window_final_size_bytes, DoeMetrics::window_tuning_checks, PipelineGlobalMetrics::window_tuning_checks, DoeMetrics::window_variance_q48, InferenceOutputs::window_variance_q48, word_count, DoeMetrics::words_executed, and HeartbeatState::words_executed.

Referenced by run_doe_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:



7.204.2.2 metrics_get_cpu_freq_mhz()

```
int32_t metrics_get_cpu_freq_mhz (
            void  )
```

Get current CPU frequency (MHz)

Tries multiple sources:

1. /sys/devices/system/cpu/cpu0/cpufreq/scaling_cur_freq
2. /proc/cpuinfo Returns 0 if unavailable.

Returns

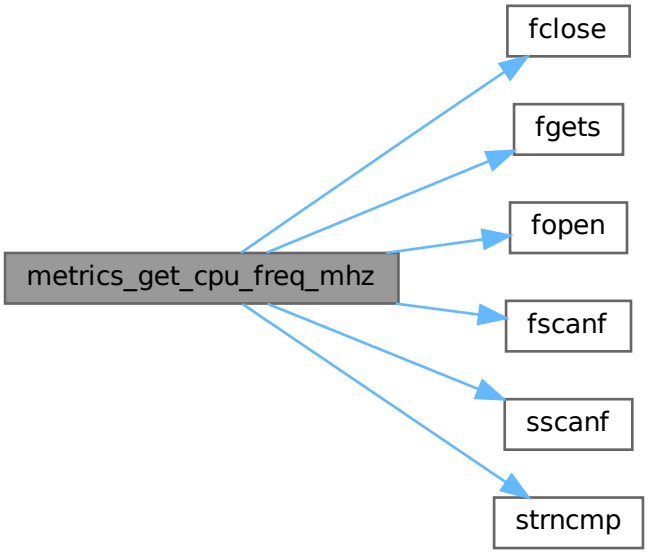
Frequency in MHz, or 0 if unable to read

Get current CPU frequency (MHz)

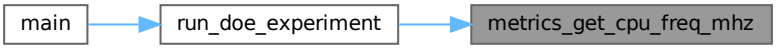
References fclose(), fgets(), fopen(), fscanf(), sscanf(), and strncmp().

Referenced by run_doe_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:



7.204.2.3 metrics_get_cpu_temp_c()

```
int32_t metrics_get_cpu_temp_c (
            void  )
```

Get current CPU temperature (Celsius)

Reads /sys/class/thermal/thermal_zone0/temp on Linux, returns 0 if unavailable.

Returns

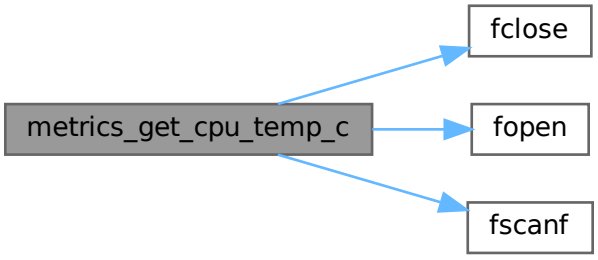
Temperature in °C, or 0 if unable to read

Get current CPU temperature (Celsius)

References fclose(), fopen(), and fscanf().

Referenced by run_doe_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

7.204.2.4 metrics_get_timestamp()

```
void metrics_get_timestamp (
            char * buf,
            size_t bufsize )
```

Get current timestamp as ISO 8601 string.

Format: "YYYY-MM-DDTHH:MM:SS"

Parameters

buf	Buffer to write timestamp (minimum 32 bytes)
bufsize	Size of buffer

7.204.2.5 metrics_print_text()

```
void metrics_print_text (
            FILE * out,
            const DoeMetrics * metrics )
```

Print metrics as human-readable text.

Outputs metrics in formatted text for debugging/verification.

Parameters

out	Output file stream
metrics	Metrics structure to print

References DoeMetrics::bucket_hit_percent, DoeMetrics::bucket_hits, DoeMetrics::bucket_search_latency_ns, DoeMetrics::bucket_search_stddev_ns, DoeMetrics::cache_hit_latency_ns, DoeMetrics::cache_hit_percent, DoeMetrics::cache_hit_stddev_ns, DoeMetrics::cache_hits, DoeMetrics::context_accuracy_percent, DoeMetrics::context_correct, DoeMetrics::context_predictions_total, DoeMetrics::cpu_freq_delta_mhz_q48, DoeMetrics::cpu_temp_delta_c_q48, DoeMetrics::decay_slope, fprintf(), DoeMetrics::rolling_window_width, DoeMetrics::total_lookups, and DoeMetrics::vm_workload_dur

Here is the call graph for this function:

7.204.2.6 metrics_write_csv_header()

```
void metrics_write_csv_header (
            FILE * out )
```

Write CSV header row.

Writes the 35-column CSV header to output stream.

Parameters

out	Output file stream

Write CSV header row.

References fprintf().

Here is the call graph for this function:

7.204.2.7 metrics_write_csv_row()

```
void metrics_write_csv_row (
            FILE * out,
            const DoeMetrics * metrics )
```

Write metrics as CSV row.

Writes a single run's metrics as comma-separated values.

Parameters

out	Output file stream
metrics	Metrics structure to write

Write metrics as CSV row.

References DoeMetrics::actual_window_size, DoeMetrics::adaptive_shrink_rate, DoeMetrics::avg_word_heat, DoeMetrics::bucket_hit_percent, DoeMetrics::bucket_hits, DoeMetrics::bucket_search_latency_ns, DoeMetrics::bucket_search_stdde DoeMetrics::cache_demotions, DoeMetrics::cache_hit_latency_ns, DoeMetrics::cache_hit_percent, DoeMetrics::cache_hit_stddev_n DoeMetrics::cache_hits, DoeMetrics::cache_promotions, DoeMetrics::ci_lower_95, DoeMetrics::ci_upper_95, DoeMetrics::context_accuracy_percent, DoeMetrics::context_correct, DoeMetrics::context_predictions_total, DoeMetrics::cpu_freq_delta_mhz_q48, DoeMetrics::cpu_temp_delta_c_q48, DoeMetrics::decay_min_interval_ns, DoeMetrics::decay_rate_q16, DoeMetrics::decay_slope, DoeMetrics::dictionary_lookups, DoeMetrics::early_exit_count, DoeMetrics::enable_hotwords_cache, DoeMetrics::enable_loop_1_heat_tracking, DoeMetrics::enable_loop_2_rolling_window, DoeMetrics::enable_loop_3_linear_decay, DoeMetrics::enable_loop_4_pipelining, DoeMetrics::enable_loop_5_window_inference, DoeMetrics::enable_loop_6_decay_inference, DoeMetrics::enable_loop_7_adaptive_heartrate, DoeMetrics::enable_pipelining, DoeMetrics::final_effective_window_size, fprintf(), DoeMetrics::heat_cache_demotion_threshold, DoeMetrics::hot_word_count, DoeMetrics::inference_run_count, DoeMetrics::memory_allocated_bytes, DoeMetrics::prefetch_accuracy_percent, DoeMetrics::prefetch_attempts, DoeMetrics::prefetch_hits, DoeMetrics::rolling_window_size, DoeMetrics::rolling_window_width, DoeMetrics::speedup_vs_baseline, DoeMetrics::stale_word_count, DoeMetrics::stale_word_ratio, DoeMetrics::tick_count, DoeMetrics::tick_target_ns, DoeMetrics::total_executions, DoeMetrics::total_heat, DoeMetrics::total_lookups, DoeMetrics::total_runtime_ms, DoeMetrics::vm_workload_duration_ns_q48, DoeMetrics::window_diversity_percent, DoeMetrics::window_final_size_bytes, DoeMetrics::window_tuning_checks, DoeMetrics::window_variance_q48, and DoeMetrics::words_executed.

Here is the call graph for this function:

7.204.2.8 metrics_write_james_law_csv_row()

```
void metrics_write_james_law_csv_row (
            FILE * out,
            const DoeMetrics * metrics,
            VM * vm )
```

Write reduced James Law CSV row (20 columns)

Outputs only the subset of metrics needed for the James Law validation experiment. This matches the header format in run_window_sweep.sh (minus the 5 script-prepended columns).

Parameters

out	Output file stream
metrics	Metrics structure to write
vm	VM instance (for heartbeat bucket aggregates and L8 mode)

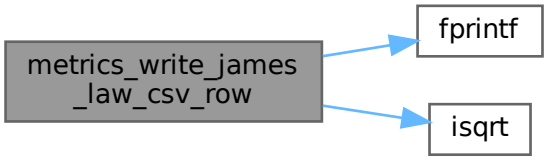
Write reduced James Law CSV row (20 columns)

This outputs only the subset of metrics needed for the James Law validation experiment. Format matches the header in run_window_sweep.sh (minus the 5 script-prepended columns).

Expected columns (20): workload_duration_ns, l8_mode_final, lambda_effective, K_statistic, K_deviation, entropy, cv, temporal_decay, stability_score, ns_per_word, total_runtime_ms, window_final, hot_word_count, avg_heat, bucket_mean_K, bucket_cv_K, bucket_window_var, bucket_heat_var, bucket_mode_transitions, bucket_collapse↩
_flag

References DoeMetrics::avg_word_heat, HeartbeatState::bucket_collapse_flag, HeartbeatState::bucket_mode_transitions, HeartbeatState::bucket_sum_heat_variance, HeartbeatState::bucket_sum_K, HeartbeatState::bucket_sum_K_squared, HeartbeatState::bucket_sum_window_variance, HeartbeatState::bucket_tick_count, DoeMetrics::cache_hit_latency_ns, DoeMetrics::cache_hit_stddev_ns, DoeMetrics::decay_slope, DoeMetrics::final_effective_window_size, fprintf(), VM::heartbeat, HEARTBEAT_TICK_BUFFER_SIZE, DoeMetrics::hot_word_count, isqrt(), HeartbeatTickSnapshot::l8_mode, DoeMetrics::rolling_window_size, DoeMetrics::rolling_window_width, DoeMetrics::stale_word_ratio, HeartbeatState::tick_buffer, HeartbeatState::tick_buffer_write_index, DoeMetrics::total_runtime_ms, DoeMetrics::vm_workload_duration_ns_q48, DoeMetrics::window_diversity_percent, and DoeMetrics::words_executed.

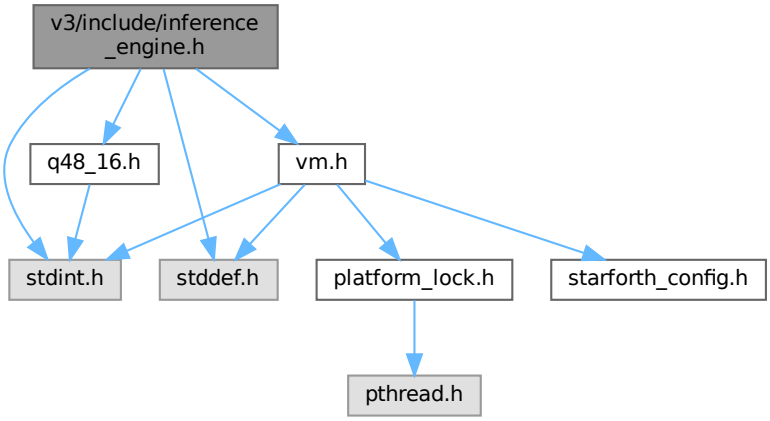
Here is the call graph for this function:



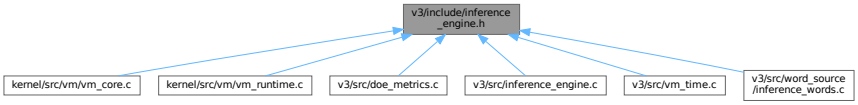
7.205 v3/include/inference_engine.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "vm.h"
#include "q48_16.h"
```

Include dependency graph for inference_engine.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct InferenceInputs
- struct InferenceOutputs

Functions

- void inference_engine_run (InferenceInputs *inputs, InferenceOutputs *outputs)

  Run adaptive inference engine on window data.
- const char * inference_outputs_to_string (const InferenceOutputs *outputs)

  Format inference outputs as a human-readable string.
- int inference_outputs_validate (const InferenceOutputs *outputs)

  Validate inference outputs for sanity.
- q48_16_t compute_variance_q48 (const uint64_t *heat_data, uint64_t length)

  Compute the variance of a heat trajectory in Q48.16 fixed-point.
- uint32_t find_variance_inflection (const uint64_t *heat_data, uint64_t trajectory_length, q48_16_t full_↩ variance)

  Find the minimum window size where heat variance is statistically stable.
- uint64_t infer_decay_slope_q48 (const uint64_t *heat_data, uint64_t length)

  Infer the decay slope from a heat trajectory via log-linear regression.

7.205.1 Function Documentation

7.205.1.1 compute_variance_q48()

```
q48_16_t compute_variance_q48 (
            const uint64_t * heat_data,
            uint64_t length )
```

Compute the variance of a heat trajectory in Q48.16 fixed-point.

Computes the population variance: Σ(heat[i] - mean)^2 / N. All intermediate calculations use Q48.16 arithmetic. Returns 0 for an empty array.

Parameters

heat_data	Array of execution heat values (raw uint64_t counts)
length	Number of elements in `heat_data`

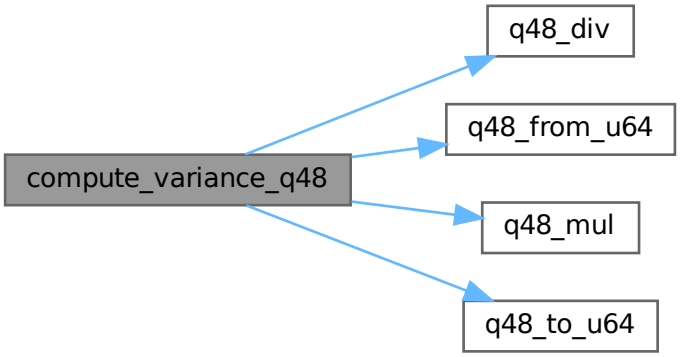
Returns

Population variance in Q48.16 format

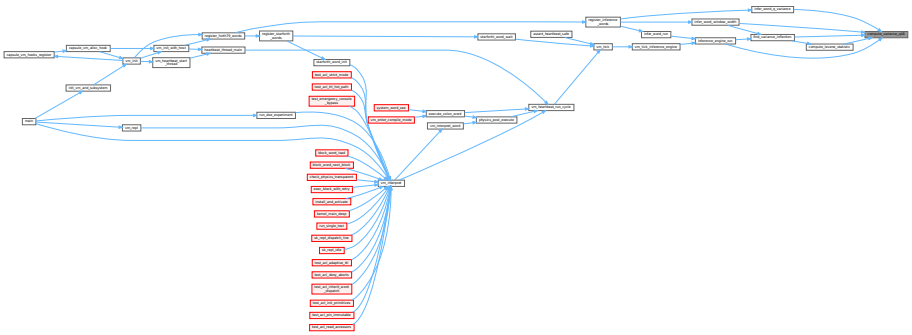
References q48_div(), q48_from_u64(), q48_mul(), and q48_to_u64().

Referenced by compute_levene_statistic(), find_variance_inflection(), infer_word_q_variance(), infer_word_window_width(), and inference_engine_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.205.1.2 find_variance_inflection()

```
uint32_t find_variance_inflection (
            const uint64_t * heat_data,
            uint64_t trajectory_length,
            q48_16_t full_variance )
```

Find the minimum window size where heat variance is statistically stable.

Implements Loop #5 (window width inference). Scans candidate window sizes from ADAPTIVE_MIN_WINDOW↩ _SIZE to the full trajectory in steps of 64, divides the trajectory into disjoint chunks of that size, and applies Levene's test. Returns the first size where W <= 6.5 (α=0.05 critical value). Falls back to the full trajectory length if no size passes. full_variance is unused (retained for API compatibility with callers that pre-compute it).

Parameters

heat_data	Heat trajectory array
trajectory_length	Number of elements in heat_data
full_variance	Unused; retained for API compatibility

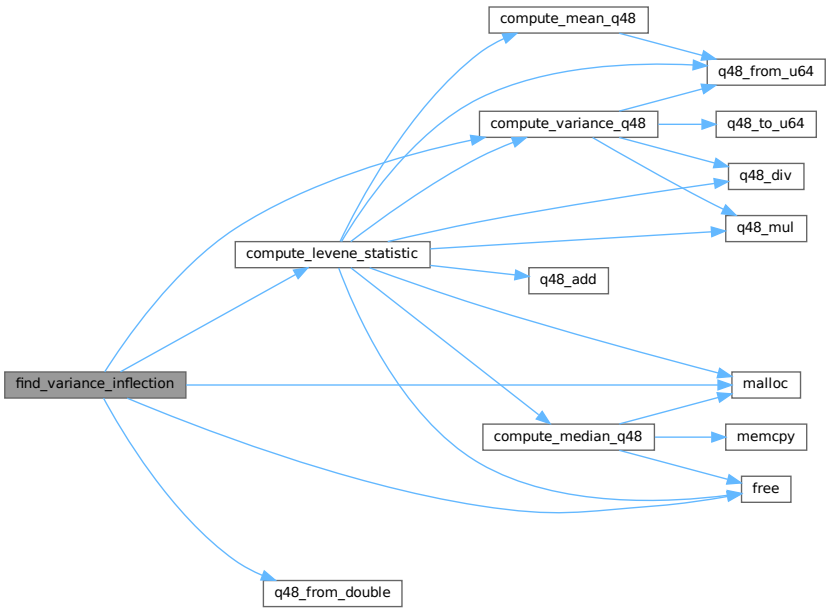
Returns

Minimum sufficient window width in [ADAPTIVE_MIN_WINDOW_SIZE, ROLLING_WINDOW_SIZE]

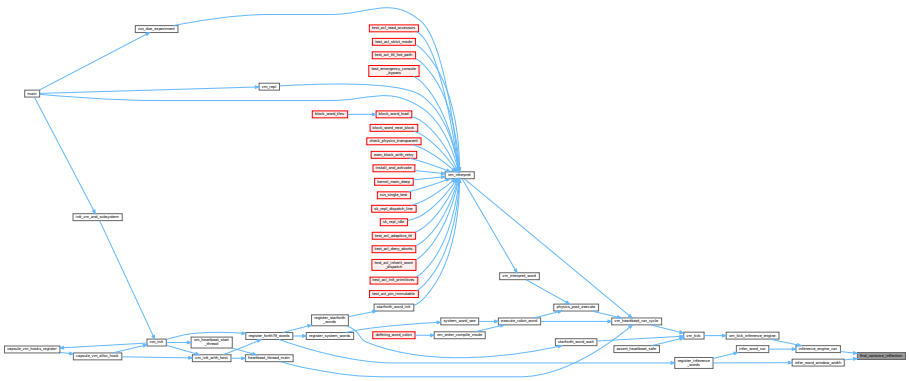
References ADAPTIVE_MIN_WINDOW_SIZE, compute_levene_statistic(), compute_variance_q48(), free(), malloc(), q48_from_double(), and ROLLING_WINDOW_SIZE.

Referenced by infer_word_window_width(), and inference_engine_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.205.1.3 infer_decay_slope_q48()

```
uint64_t infer_decay_slope_q48 (
            const uint64_t * heat_data,
            uint64_t length )
```

Infer the decay slope from a heat trajectory via log-linear regression.

Implements Loop #6 (decay slope inference). Fits the model ln(heat[t]) = ln(h?) - slope∗t using the closed-form OLS solution: slope = (n∗Σ(t·ln(h)) - Σt·Σln(h)) / (n·Σt^2 - $(\Sigma t)^2$). The sign of the numerator is taken as absolute value since decay rate is always positive. Zero heat values are skipped. Returns 0 if fewer than 2 samples are available.

Parameters

heat_data	Array of execution heat values (raw counts)
length	Number of elements in `heat_data`

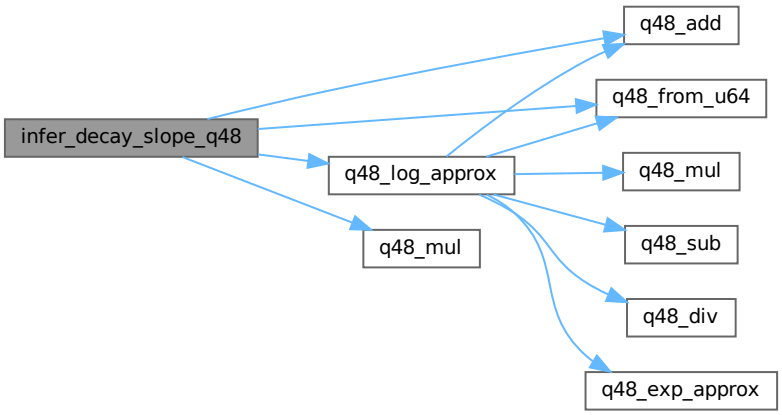
Returns

Inferred decay slope in Q48.16 format (0 = insufficient data)

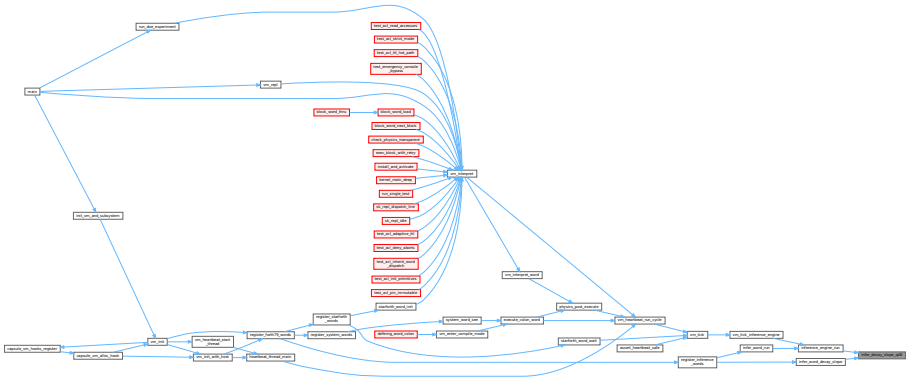
References q48_add(), q48_from_u64(), q48_log_approx(), and q48_mul().

Referenced by infer_word_decay_slope(), and inference_engine_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.205.1.4 inference_engine_run()

```
void inference_engine_run (
            InferenceInputs * inputs,
            InferenceOutputs * outputs )
```

Run adaptive inference engine on window data.

High-level flow:

1. ANOVA Check: Is variance delta $<$ 5%?
   - YES: Return cached outputs immediately (cost: $\sim$100 cycles)
   - NO: Continue to full inference
2. Extract trajectory: Fresh execution_heat snapshot from dictionary
3. Window Width Inference:
   - Compute variance across entire window
   - Detect inflection point (where d(variance)/d(size) $\rightarrow$ 0)
   - Return optimal window size
4. Decay Slope Inference:
   - Transform trajectory to log space (ln(heat[t]))
   - Fit linear regression: ln(heat) = a - slope$*$t
   - Extract slope coefficient in Q48.16
5. Diagnostics:
   - Compute fit quality (R^2 or residual)
   - Store variance metric for next early-exit check

Parameters

inputs	Snapshot of window + metrics (caller-provided)
outputs	Tuning parameters + diagnostics (caller-provided, will be updated)

Returns

void (results_run_01_2025_12_08 in outputs struct)

Preconditions:

- inputs != NULL
- outputs != NULL
- inputs->window != NULL
- inputs->window->is_warm == 1 (window has enough data)
- inputs->trajectory_length > 1

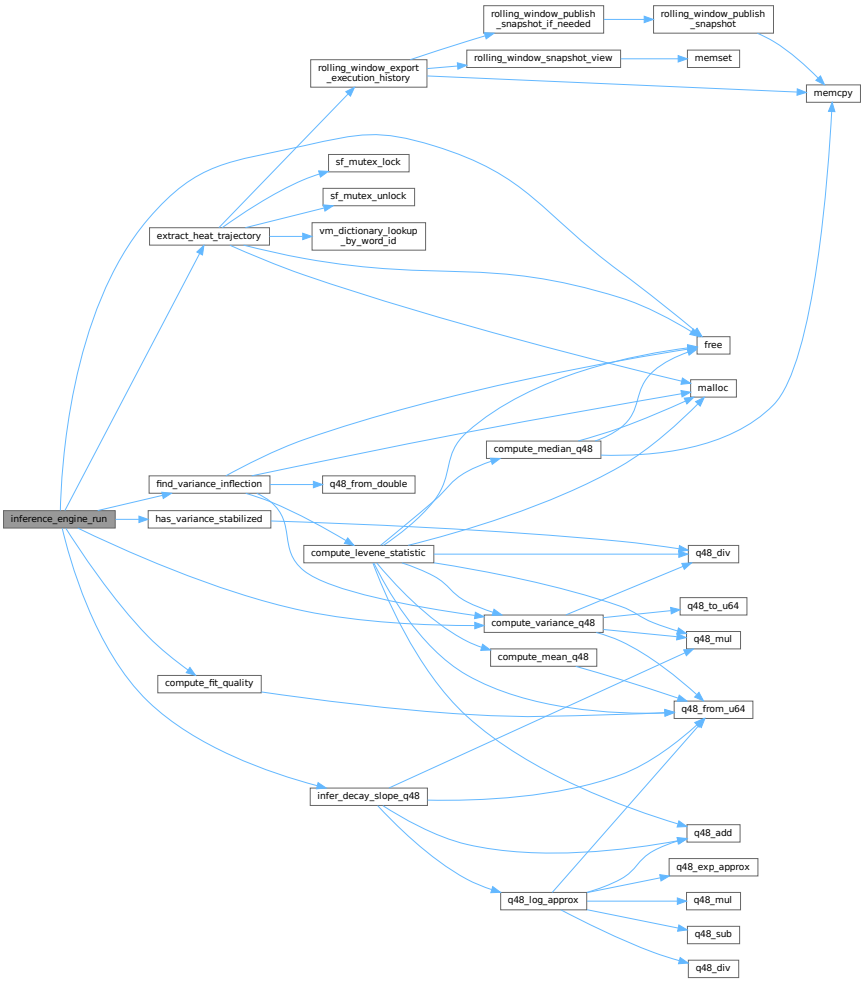
Side Effects:

- Modifies outputs struct (caller must preserve if caching)
- Allocates temporary trajectory buffer (freed on return)

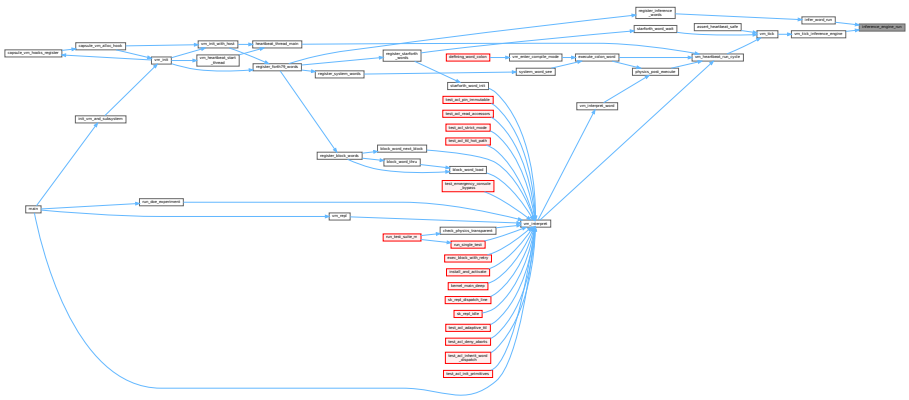
References InferenceOutputs::adaptive_decay_slope, InferenceOutputs::adaptive_window_width, compute_fit_quality(), compute_variance_q48(), InferenceOutputs::early_exited, extract_heat_trajectory(), find_variance_inflection(), free(), has_variance_stabilized(), infer_decay_slope_q48(), ssm_config_t::L5_window_inference, ssm_config_t::L6_decay_inference, InferenceOutputs::slope_fit_quality_q48, VM::ssm_config, InferenceInputs::vm, InferenceInputs::window, and InferenceOutputs::window_variance_q48.

Referenced by infer_word_run(), and vm_tick_inference_engine().

Here is the call graph for this function:



Here is the caller graph for this function:



7.205.1.5 inference_outputs_to_string()

```
const char * inference_outputs_to_string (
```

```
            const InferenceOutputs * outputs )
```

Format inference outputs as a human-readable string.

Writes into a static 256-byte buffer — not thread-safe, for diagnostics only. Format: "window=N var=↩ F slope=F quality=F (cached|full)".

Parameters

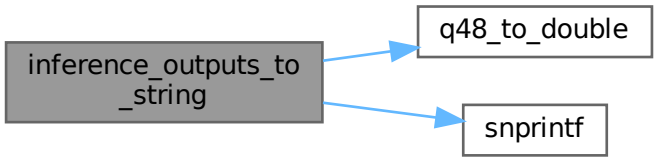
outputs	Inference outputs to format (NULL produces "(null)")

Returns

Pointer to a static string buffer

References InferenceOutputs::adaptive_decay_slope, InferenceOutputs::adaptive_window_width, InferenceOutputs::early_exited, q48_to_double(), InferenceOutputs::slope_fit_quality_q48, snprintf(), and InferenceOutputs::window_variance_q48.

Here is the call graph for this function:



7.205.1.6 inference_outputs_validate()

```
int inference_outputs_validate (
            const InferenceOutputs * outputs )
```

Validate inference outputs for sanity.

Checks that adaptive_window_width is in [ADAPTIVE_MIN_WINDOW_SIZE, ROLLING_WINDOW_↩ SIZE], that adaptive_decay_slope is non-zero and <= 100.0 in Q48.16, and that slope_fit_↩ quality_q48 is in [0.0, 1.0].

Parameters

outputs	Inference outputs to validate (NULL returns 0)

Returns

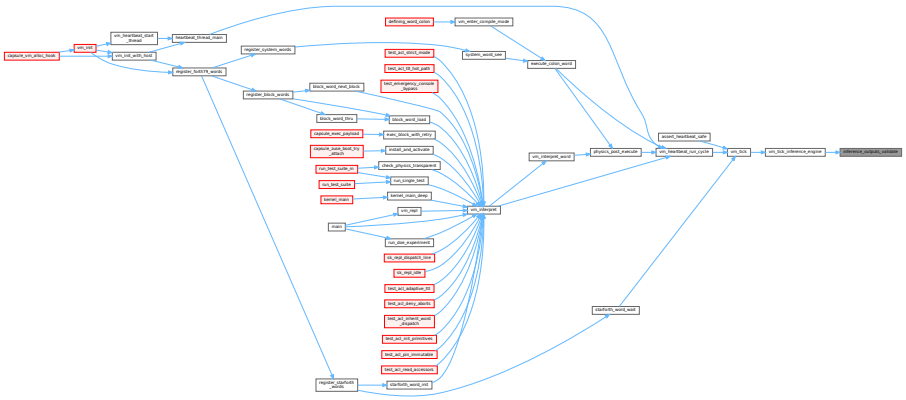
1 if all fields are within acceptable ranges, 0 otherwise

References InferenceOutputs::adaptive_decay_slope, ADAPTIVE_MIN_WINDOW_SIZE, InferenceOutputs::adaptive_window_width, q48_from_u64(), ROLLING_WINDOW_SIZE, and InferenceOutputs::slope_fit_quality_q48.

Referenced by vm_tick_inference_engine().

Here is the call graph for this function:

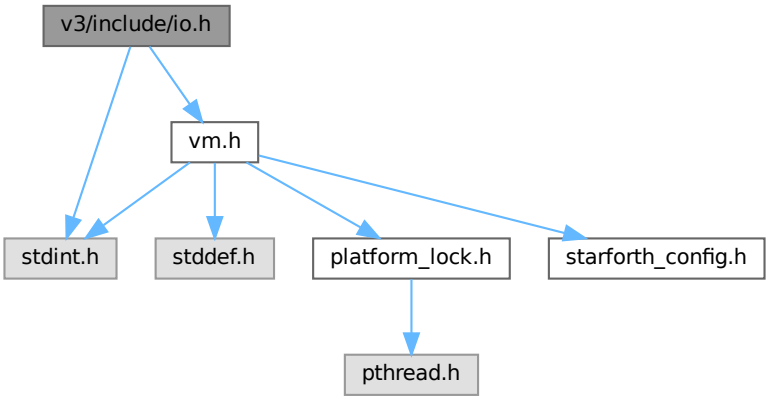
Here is the caller graph for this function:



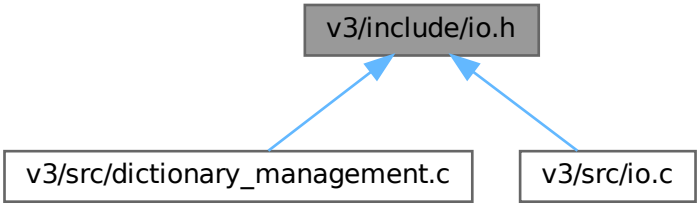
7.206 v3/include/io.h File Reference

```
#include <stdint.h>
#include "vm.h"
```

Include dependency graph for io.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define BLOCK_COUNT 1024

  Total number of blocks available.
- #define MEMORY_SIZE (BLOCK_SIZE ∗ BLOCK_COUNT)

  Total memory size in bytes.

Functions

- void io_init (VM ∗vm)

  Initialize the IO subsystem.
- int io_read_block (VM ∗vm, int block_num, unsigned char ∗buffer)

  Read a block from storage.
- int io_write_block (VM ∗vm, int block_num, const unsigned char ∗buffer)

  Write a block to VM memory.

7.206.1 Macro Definition Documentation

7.206.1.1 BLOCK_COUNT

```
#define BLOCK_COUNT 1024
```

Total number of blocks available.

7.206.1.2 MEMORY_SIZE

```
#define MEMORY_SIZE (BLOCK_SIZE * BLOCK_COUNT)
```

Total memory size in bytes.

7.206.2 Function Documentation

7.206.2.1 io_init()

```
void io_init (
            VM * vm )
```

Initialize the IO subsystem.

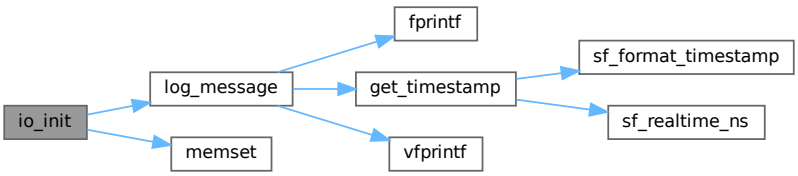
Parameters

vm	Pointer to VM instance

Initializes the block device view over the unified VM memory. Zeros out the entire VM memory space.

References BLOCK_SIZE, LOG_ERROR, LOG_INFO, log_message(), MAX_BLOCKS, VM::memory, memset(), and VM_MEMORY_SIZE.

Here is the call graph for this function:



7.206.2.2 io_read_block()

```
int io_read_block (
            VM * vm,
```

```
            int block_num,
            unsigned char * buffer )
```

Read a block from storage.

Parameters

vm	Pointer to the virtual machine instance
block_num	Block number to read
buffer	Buffer to store the read data

Returns

0 on success, non-zero on failure

7.206.2.3 io_write_block()

```
int io_write_block (
            VM * vm,
            int block_num,
            const unsigned char * buffer )
```

Write a block to VM memory.

Parameters

vm	Pointer to VM instance
block_num	Block number to write (0 to MAX_BLOCKS-1)
buffer	Source buffer containing block data

Returns

0 on success, -1 on error

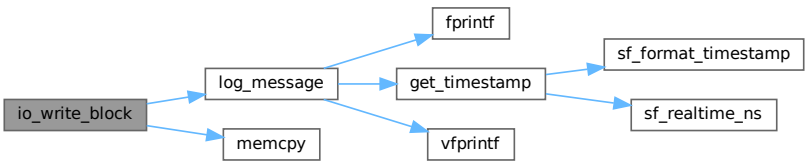
Writes a BLOCK_SIZE chunk of data from the provided buffer into the VM's memory at the specified block number offset. The block number must be within valid range. The entire block is written atomically.

Note

The buffer must contain at least BLOCK_SIZE bytes of valid data

References BLOCK_SIZE, LOG_DEBUG, LOG_ERROR, log_message(), MAX_BLOCKS, memcpy(), and VM::memory.

Here is the call graph for this function:



7.207 kernel/include/starkernel/log.h File Reference

Macros

- #define LOG_MSG_LINE_MAX 256

Enumerations

- enum LogLevel {
  LOG_NONE = -1 , LOG_ERROR = 0 , LOG_WARN , LOG_INFO ,
  LOG_TEST , LOG_DEBUG }

  Log levels — identical to the hosted enumeration so kernel VM code compiled against either header produces compatible call sites.
- enum TestResult { TEST_PASS = 0 , TEST_FAIL , TEST_SKIP , TEST_ERROR }

Functions

- void log_set_level (LogLevel level)

  Set the global logging level.
- LogLevel log_get_level (void)

  Gets the current global logging level.
- void log_message (LogLevel level, const char *fmt,...)

  Log a formatted message at the specified level.
- void log_test_result (const char *word_name, TestResult result)

  Log a test result with colored output.
- void log_set_vm (struct VM *vm)

7.207.1 Macro Definition Documentation

7.207.1.1 LOG_MSG_LINE_MAX

```
#define LOG_MSG_LINE_MAX 256
```

7.207.2 Enumeration Type Documentation

7.207.2.1 LogLevel

```
enum LogLevel
```

Log levels — identical to the hosted enumeration so kernel VM code compiled against either header produces compatible call sites.

Enumerator

LOG_NONE	
LOG_ERROR	
LOG_WARN	
LOG_INFO	
LOG_TEST	
LOG_DEBUG	

7.207.2.2 TestResult

```
enum TestResult
```

Enumerator

TEST_PASS	
TEST_FAIL	
TEST_SKIP	
TEST_ERROR	

7.207.3 Function Documentation

7.207.3.1 log_get_level()

```
LogLevel log_get_level (
            void  )
```

Gets the current global logging level.

Get the current logging level.

Returns

LogLevel Current logging level

7.207.3.2 log_message()

```
void log_message (
            LogLevel level,
            const char * fmt,
             ...  )
```

Log a formatted message at the specified level.

Parameters

level	The logging level for this message
fmt	Printf-style format string
...	Variable arguments for format string

7.207.3.3 log_set_level()

```
void log_set_level (
            LogLevel level )
```

Set the global logging level.

Parameters

level	The new logging level to set

Note

Default level is LOG_INFO

7.207.3.4 log_set_vm()

```
void log_set_vm (
            struct VM * vm )
```

7.207.3.5 log_test_result()

```
void log_test_result (
            const char * word_name,
            TestResult result )
```

Log a test result with colored output.

Parameters

word_name	Name of the word being tested
result	Result of the test execution

7.208 v3/include/log.h File Reference

Macros

- #define LOG_MSG_LINE_MAX 256

Enumerations

- enum LogLevel { LOG_NONE = -1 , LOG_ERROR = 0 , LOG_WARN , LOG_INFO , LOG_TEST , LOG_DEBUG }

  Logging level enumeration.
- enum TestResult { TEST_PASS = 0 , TEST_FAIL , TEST_SKIP , TEST_ERROR }

  Test result type enumeration.

Functions

- void log_set_level (LogLevel level)

  Set the global logging level.
- LogLevel log_get_level (void)

  Get the current logging level.
- void log_message (LogLevel level, const char *fmt,...)

  Log a formatted message at the specified level.
- void log_test_result (const char *word_name, TestResult result)

  Log a test result with colored output.
- void log_set_vm (struct VM *vm)

  Set the VM instance for persistent logging.

7.208.1 Macro Definition Documentation

7.208.1.1 LOG_MSG_LINE_MAX

```
#define LOG_MSG_LINE_MAX 256
```

7.208.2 Enumeration Type Documentation

7.208.2.1 LogLevel

```
enum LogLevel
```

Logging level enumeration.

Defines the available logging levels in order of increasing verbosity.

Enumerator

LOG_NONE	Completely disable all logging.
LOG_ERROR	Error messages only.
LOG_WARN	Warning and error messages.
LOG_INFO	Informational, warning and error messages.
LOG_TEST	Test results_run_01_2025_12_08 and all previous levels.
LOG_DEBUG	Debug messages and all previous levels.

7.208.2.2 TestResult

```
enum TestResult
```

Test result type enumeration.

Defines the possible outcomes of test execution.

Enumerator

TEST_PASS	Test completed successfully.
TEST_FAIL	Test failed.
TEST_SKIP	Test was skipped.
TEST_ERROR	Test encountered an error during execution.

7.208.3 Function Documentation

7.208.3.1 log_get_level()

```
LogLevel log_get_level (
            void  )
```

Get the current logging level.

Returns

The current logging level

Get the current logging level.

Returns

LogLevel Current logging level

References current_level.

Referenced by log_word_get_level().

Here is the caller graph for this function:

7.208.3.2 log_message()

```
void log_message (
            LogLevel level,
            const char * fmt,
             ...  )
```

Log a formatted message at the specified level.

Parameters

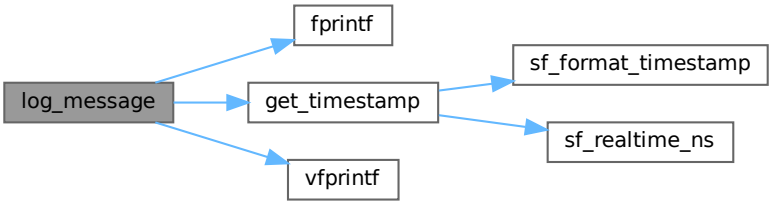
level	The logging level for this message
fmt	Printf-style format string
...	Variable arguments for format string

References color_reset, current_level, fprintf(), get_timestamp(), level, level_colors, level_names, LOG_NONE, stderr, and vfprintf().

Referenced by __attribute__(), acl_recheck(), acl_recheck(), arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), array_ptr(), assert_heartbeat_safe(), assert_stack_depth(), assert_stack_top(), assert_vm_error(), blk_format_or_load_disk(), blk_subsys_add_raw_device(), blk_subsys_attach_device(), blk_subsys_detach_device(), blk_subsys_relocate_block(), capsule_birth_baby(), capsule_birth_mama(), capsule_exec_payload(), capsule_run_experiment(), capsule_vm_kill_all_nonmama(), cf_epoch_sync(), cf_pop_item(), cf_push_item(), check_physics_transparent(), control_forth_0branch(), control_forth_again(), control_forth_begin(), control_forth_branch(), control_forth_case(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_EXIT(), control_forth_I(), control_forth_if(), control_forth_J(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_runtime_do(), control_forth_runtime_leave(), control_forth_runtime_loop(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), control_forth_then(), control_forth_UNLOOP(), control_forth_until(), control_forth_while(), defer_runtime(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_does_rt(), defining_runtime_lit(), defining_runtime_variable(), defining_word_colon(), defining_word_compile(), defining_word_constant(), defining_word_create(), defining_word_does(), defining_word_immediate(), defining_word_left_bracket(), defining_word_literal(), defining_word_right_bracket(), defining_word_variable(), dict_adaptive_optimization_pass(), dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), dictionary_m_word_tick(), dictionary_m_word_to_body(), dictionary_word_fence(), dictionary_word_forget(), dump_and_die(), editor_word_edit(), editor_word_l(), editor_word_s(), editor_word_show(), emit_cell(), enable_benchmark_mode(), execute_colon_word(), fail_and_exit(), fbw_plot(), format_word_hold(), forth_acl_allow_store(), forth_acl_inherit(), forth_acl_mode_store(), forth_acl_ttl_store(), forth_paren(), hosted_lifecycle_birth(), hosted_lifecycle_kill(), hosted_lifecycle_pause(), hosted_lifecycle_resume(), hosted_lifecycle_use(), infer_word_run(), init_blkio(), init_report(), init_vocabulary_system(), io_init(), io_word_type(), io_write_block(), log_do_emit(), log_emit_string(), log_str_emit(), log_word_set_level(), logical_word_and(), logical_word_equals(), logical_word_false(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_true(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), main(), memory_word_cells(), mixed_math_word_mod(), pop_xt(), print_module_summary(), register_arithmetic_words(), register_forth79_words(), register_word(), return_stack_word_r_fetch(), return_stack_word_r_from(), return_stack_word_to_r(), rolling_window_run_adaptive_pass(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), run_acl_words_tests(), run_all_tests(), run_arithmetic_words_tests(), run_benchmark_mode(), run_block_words_tests(), run_break_me_tests(), run_control_words_tests(), run_defining_words_tests(), run_dictionary_manipulation_words_tests(), run_dictionary_words_tests(), run_doe_experiment(), run_double_words_tests(), run_format_words_tests(), run_inference_words_tests(), run_integration_tests(), run_io_words_tests(), run_logical_words_tests(), run_mama_forth_words_tests(), run_memory_words_tests(), run_mixed_arithmetic_words_tests(), run_module_tests(), run_physics_freeze_words_tests(), run_q48_words_tests(), run_return_stack_words_tests(), run_single_test(), run_stack_words_tests(), run_starforth_words_tests(), run_stress_tests(), run_string_words_tests(), run_system_words_tests(), run_test_suite(), run_test_suite_m(), run_vocabulary_words_tests(), run_word_tests(), sk_repl_dispatch_line(), sk_repl_idle(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), stack_word_depth(), stack_word_drop(), stack_word_dup(), stack_word_minus_rot(), stack_word_over(), stack_word_pick(), stack_word_question_dup(), stack_word_roll(), stack_word_rot(), stack_word_swap(), starforth_word_execution_heat_fetch(), starforth_word_execution_heat_store(), starforth_word_init(), starforth_word_paren_dash(), starforth_word_random(), starforth_word_seed(), starforth_word_top_words(), starforth_word_wait(), starforth_word_zuse_pubkey_fetch(), string_word_blank(), string_word_bracket_tick(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_count(), string_word_expect(), string_word_minus_trailing(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), system_word_reboot(), test_acl_adaptive_ttl(), test_acl_strict_mode(), vblk_io(), verify_mint(), vm_align(),

vm_allot(), vm_assert_interpreter_enabled(), vm_bootstrap_root_vocabulary(), vm_bootstrap_scr(), vm_compile_call(), vm_compile_exit(), vm_compile_literal(), vm_compile_word(), vm_create_word(), vm_dictionary_track_entry(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_get_block_addr(), vm_heartbeat_start_thread(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_interpret_word(), vm_load_cell(), vm_load_u8(), vm_make_immediate(), vm_pin_execution_heat(), vm_pop(), vm_push(), vm_repl(), vm_smudge_word(), vm_store_cell(), vm_store_u8(), vm_tick_inference_engine(), vm_tick_slope_validator(), vm_tick_window_tuner(), vm_unpin_execution_heat(), vocabulary_create_vocabulary_direct(), vocabulary_select_runtime(), vocabulary_word_definitions(), vocabulary_word_forth(), vocabulary_word_vocabulary(), vt100_enable_ttf(), vt100_init(), word_defer(), word_defer_fetch(), word_divide(), word_divmod(), word_is(), xhci_bot_read_data_in(), xhci_bot_receive_csw(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_data_out(), xhci_bringup(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), xhci_cmd_configure_hid_endpoint(), xhci_cmd_disable_slot(), xhci_cmd_enable_slot(), xhci_cmd_reset_endpoint(), xhci_cmd_set_tr_dequeue_pointer(), xhci_drain_pending_event(), xhci_ep0_bot_mass_storage_reset(), xhci_ep0_clear_endpoint_ha
xhci_ep0_get_config_descriptor(), xhci_ep0_get_device_descriptor(), xhci_ep0_hid_set_protocol(), xhci_ep0_set_configuration(), xhci_find_and_map(), xhci_handle_bulk_stall(), xhci_handle_port_connected(), xhci_log_hex32(), xhci_poll_one(), xhci_queue_pending_event(), xhci_stall_fail(), and xhci_take_from_bios().

Here is the call graph for this function:



7.208.3.3 log_set_level()

```
void log_set_level (
            LogLevel level )
```

Set the global logging level.

Parameters

level	The new logging level to set

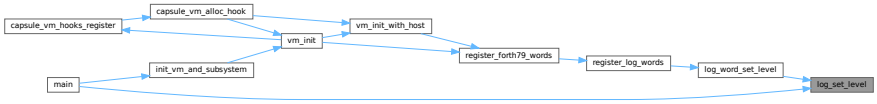
Note

Default level is LOG_INFO

References current_level, and level.

Referenced by log_word_set_level(), and main().

Here is the caller graph for this function:



7.208.3.4 log_set_vm()

```
void log_set_vm (
            struct VM * vm )
```

Set the VM instance for persistent logging.

Parameters

vm	VM instance to use for persistent logging (NULL to disable)

7.208.3.5 log_test_result()

```
void log_test_result (
            const char * word_name,
            TestResult result )
```

Log a test result with colored output.

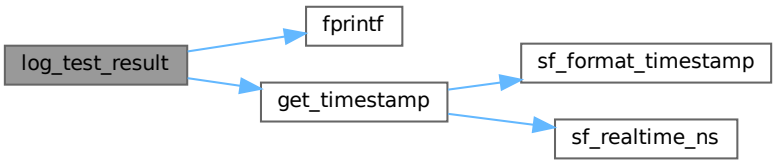
Parameters

word_name	Name of the word being tested
result	Result of the test execution

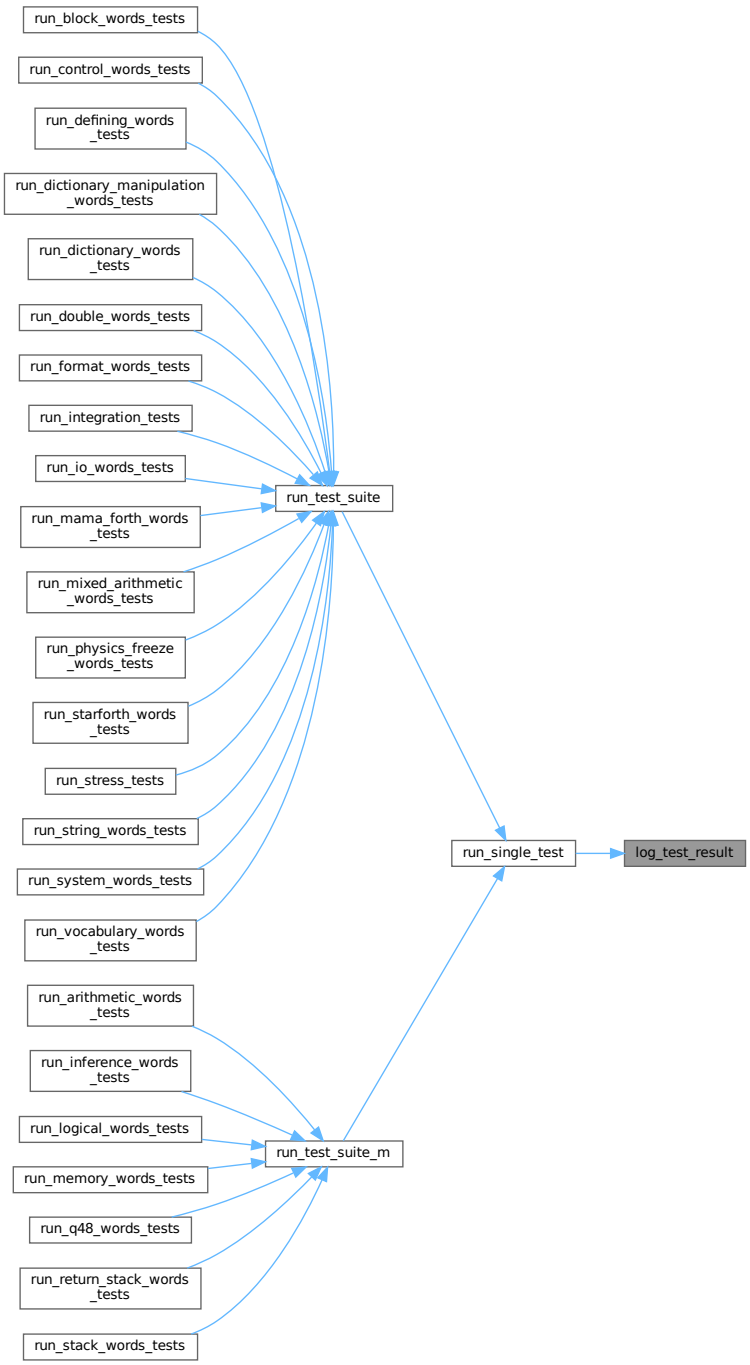
References color_reset, current_level, fprintf(), get_timestamp(), LOG_NONE, LOG_TEST, stderr, TEST_FAIL, test_fail_color, TEST_PASS, test_pass_color, TEST_SKIP, and test_skip_color.

Referenced by run_single_test().

Here is the call graph for this function:



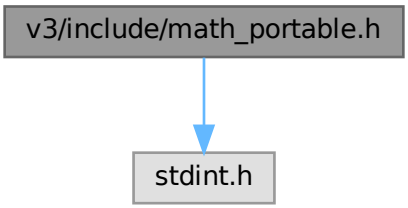
Here is the caller graph for this function:



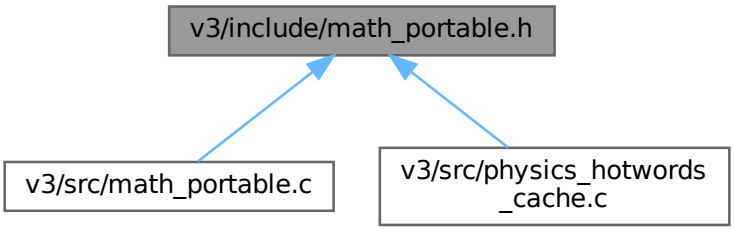
7.209 v3/include/math_portable.h File Reference

```
#include <stdint.h>
```

Include dependency graph for math_portable.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define Q48_SCALE (1LL << 16) /* 65536 */

Functions

- int64_t sqrt_q48 (int64_t x)

  Square root in Q48.16 fixed-point Input: x in Q48.16 format Output: sqrt(x) in Q48.16 format Uses Newton-Raphson: x_{n+1} = (x_n + a/x_n) / 2 Converges in ~10-15 iterations Returns 0 for negative inputs (guard against domain error)
- int64_t erf_q48 (int64_t x)

  Error function in Q48.16 fixed-point Input: x in Q48.16 format (dimensionless Z-score) Output: erf(x) in Q48.16 format (range: -Q48_SCALE to +Q48_SCALE) Uses Abramowitz & Stegun approximation (7.1.26) Maximum error: 1.5e-7 relative to floating-point erf Properties:

7.209.1 Macro Definition Documentation

7.209.1.1 Q48_SCALE

```
#define Q48_SCALE (1LL << 16) /* 65536 */
```

7.209.2 Function Documentation

7.209.2.1 erf_q48()

```
int64_t erf_q48 (
            int64_t x )
```

Error function in Q48.16 fixed-point Input: x in Q48.16 format (dimensionless Z-score) Output: erf(x) in Q48.↩ 16 format (range: -Q48_SCALE to +Q48_SCALE) Uses Abramowitz & Stegun approximation (7.1.26) Maximum error: 1.5e-7 relative to floating-point erf Properties:

- erf(0) = 0
- erf(-x) = -erf(x) (odd function)
- erf(x) approaches ±Q48_SCALE for large |x|

Error function in Q48.16 fixed-point Input: x in Q48.16 format (dimensionless Z-score) Output: erf(x) in Q48.↩ 16 format (range: -Q48_SCALE to +Q48_SCALE) Uses Abramowitz & Stegun approximation (7.1.26) Maximum error: 1.5e-7 relative to floating-point erf Properties:

Implements the rational approximation from Abramowitz & Stegun, formula 7.1.26:
`erf(x) ≈ sign(x) × sqrt(1 ? exp(?x² × (4/π + a·x²) / (1 + a·x²)))`

where a ≈ 0.147 (in Q48.16: 9633). The maximum error of the true mathematical approximation is $|\varepsilon| < 1.5\times10^{-}$?; the fixed-point encoding introduces additional rounding of approximately 1 ULP in Q48.16.

All arithmetic is performed in 64-bit integer Q48.16 format — no floating-point operations. The computation sequence:

1. Extract sign; work with |x|.
2. Compute x^2 with 8-bit prescaling to prevent overflow: x_sq = (x >> 8) * (x >> 8).
3. Evaluate the A&S numerator (4/π + a·x^2) and denominator (1 + a·x^2).
4. Compute ratio = numerator / denominator (shift to preserve Q48.16 scale).
5. Compute exp_arg = ?x^2 × ratio and evaluate exp_q48(exp_arg).
6. Compute base = 1 ? exp_val, clamp to [0, 1].
7. Return sign × sqrt_q48(base).

Q48.16 constants used:

- a_q48 = 9633 (0.147 × 65536)
- four_over_pi_q48 = 83328 (4/π × 65536 ≈ 1.2732 × 65536)

Consumed by hotwords_speedup_estimate() to compute P(speedup > 1.1×) and P(speedup > 2.0×) via the normal CDF identity:
`P(Z ≤ z) = 0.5 × (1 + erf(z / √·2))`

where √·2 in Q48.16 = 92681.

Parameters

x	Input value in Q48.16 format (dimensionless Z-score; 1.0 = 65536). May be negative; sign determines the sign of the result.

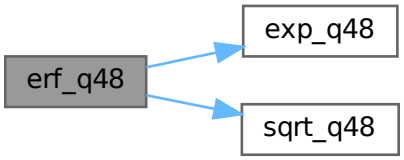
Returns

erf(x) in Q48.16 format, in the range [?65536, +65536] corresponding to (?1.0, +1.0).

References base, exp_q48(), and sqrt_q48().

Referenced by hotwords_speedup_estimate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.209.2.2 sqrt_q48()

```
int64_t sqrt_q48 (
            int64_t x )
```

Square root in Q48.16 fixed-point Input: x in Q48.16 format Output: sqrt(x) in Q48.16 format Uses Newton-↩ Raphson: x_{n+1} = (x_n + a/x_n) / 2 Converges in ∼10-15 iterations Returns 0 for negative inputs (guard against domain error)

Square root in Q48.16 fixed-point Input: x in Q48.16 format Output: sqrt(x) in Q48.16 format Uses Newton-↩ Raphson: x_{n+1} = (x_n + a/x_n) / 2 Converges in ∼10-15 iterations Returns 0 for negative inputs (guard against domain error)

Applies the Newton-Raphson recurrence:
$r_{n+1} = (r_n^2 + x) / (2 \times r_n)$

for up to 20 iterations, with all arithmetic scaled to the Q48.16 representation (1.0 = 65536). Intermediate products use 8-bit right shifts on both operands before squaring to prevent 64-bit overflow:
`guess_squared = (guess » 8) * (guess » 8)`

This sacrifices 16 bits of precision in the squared term, which is acceptable because the division by `2*guess` restores the correct order of magnitude. Convergence is declared when successive iterates differ by at most 1 in Q48.16 units (sub-nanosecond for timing uses).

Special cases handled without iteration:

- x $\leq$ 0 $\rightarrow$ returns 0 (no imaginary results)
- x == 65536 (1.0) $\rightarrow$ returns 65536 exactly

Initial guess: x/2 for x $>$ 1.0, else 1.0. Values above 1.0 converge from above; values in (0, 1.0) converge from the 1.0 initial guess.

Parameters

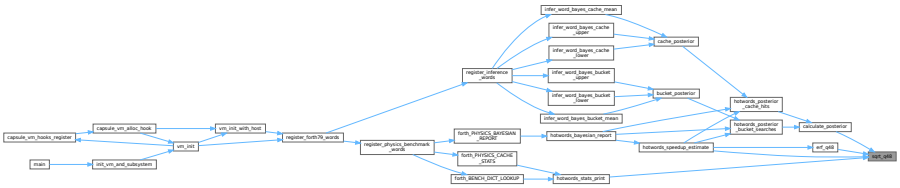
x	Non-negative value in Q48.16 format (1.0 = 65536). Negative values are treated as zero.

Returns

sqrt(x) in Q48.16 format; 0 for x $\leq$ 0.

Referenced by calculate_posterior(), erf_q48(), hotwords_speedup_estimate(), and hotwords_stats_print().

Here is the caller graph for this function:

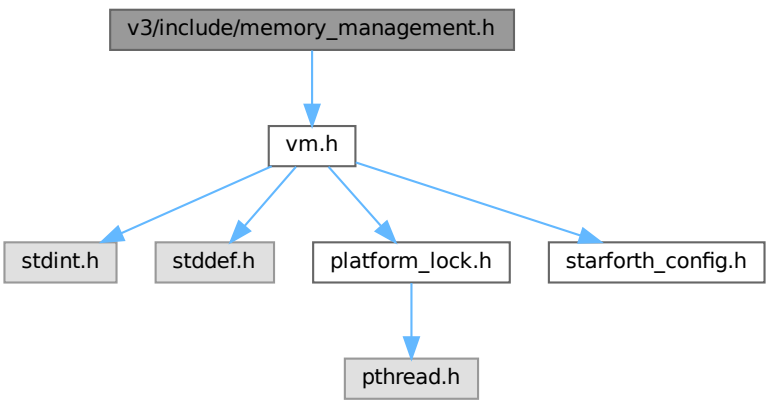


7.210 v3/include/memory_management.h File Reference

Memory management functions for the StarForth virtual machine.

```
#include "vm.h"
```

Include dependency graph for memory_management.h:



Functions

- void * vm_allot (VM *vm, size_t bytes)

  Allocates memory from the VM's dictionary space.
- void vm_align (VM *vm)

  Aligns the VM's dictionary pointer (here) to the cell boundary.

7.210.1 Detailed Description

Memory management functions for the StarForth virtual machine.

This file contains functions for managing memory allocation and alignment in the StarForth virtual machine implementation.

7.210.2 Function Documentation

7.210.2.1 vm_align()

```
void vm_align (
            VM * vm )
```

Aligns the VM's dictionary pointer (here) to the cell boundary.

Parameters

vm	Pointer to the VM instance

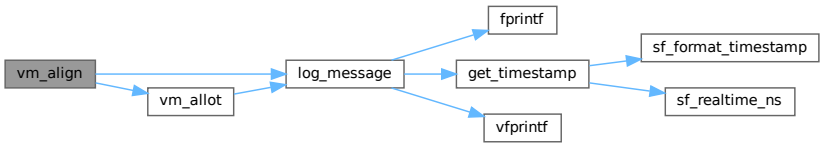
Note

Adds padding bytes if necessary to ensure proper alignment for cell_t type

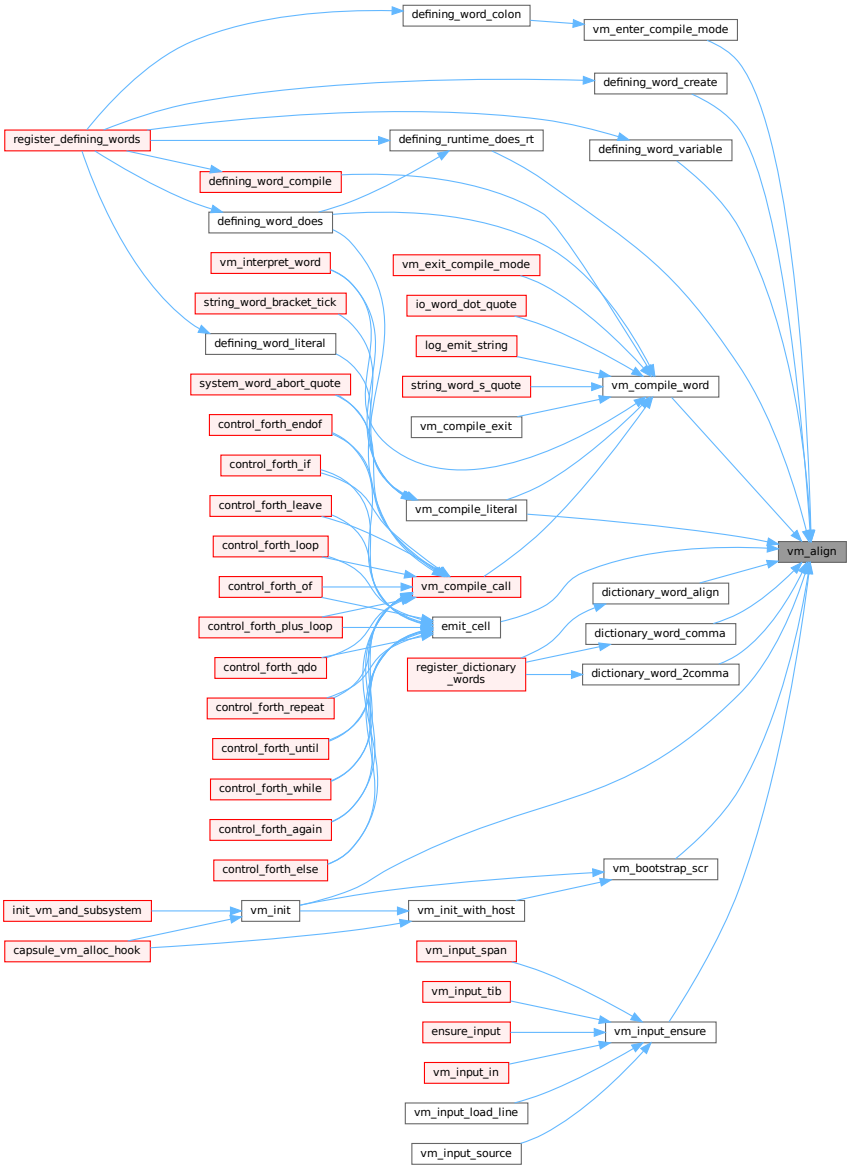
References bytes, VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), and vm_allot().

Referenced by defining_runtime_does_rt(), defining_word_create(), defining_word_variable(), dictionary_word_2comma(), dictionary_word_align(), dictionary_word_comma(), emit_cell(), vm_bootstrap_scr(), vm_compile_literal(), vm_compile_word(), vm_enter_compile_mode(), vm_init(), and vm_input_ensure().

Here is the call graph for this function:



Here is the caller graph for this function:



7.210.2.2 vm_allot()

```
void * vm_allot (
            VM * vm,
            size_t bytes )
```

Allocates memory from the VM's dictionary space.

Parameters

vm	Pointer to the VM instance
bytes	Number of bytes to allocate

Returns

Pointer to the allocated memory or NULL if allocation fails

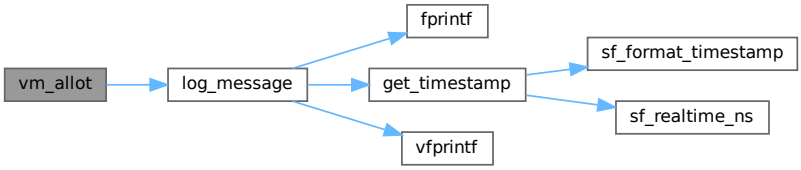
Note

The allocation is done from the VM's dictionary space which is limited to DICTIONARY_MEMORY_SIZE

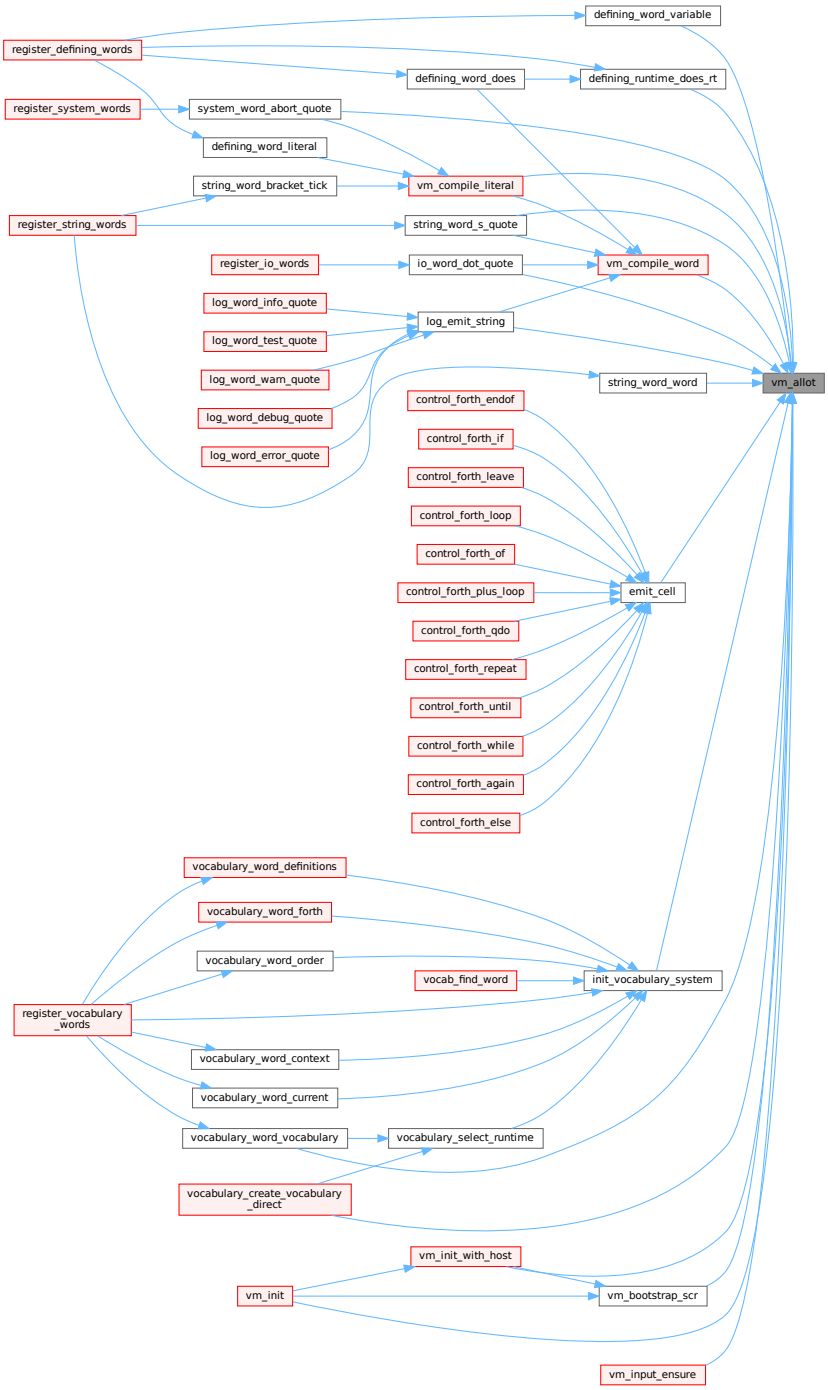
References BLOCK_SIZE, bytes, DICTIONARY_MEMORY_SIZE, VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), and VM::memory.

Referenced by defining_runtime_does_rt(), defining_word_variable(), emit_cell(), init_vocabulary_system(), io_word_dot_quote(), log_emit_string(), string_word_s_quote(), string_word_word(), system_word_abort_quote(), vm_bootstrap_scr(), vm_compile_literal(), vm_compile_word(), vm_init(), vm_init_with_host(), vm_input_ensure(), vocabulary_create_vocabulary_direct(), and vocabulary_word_vocabulary().

Here is the call graph for this function:



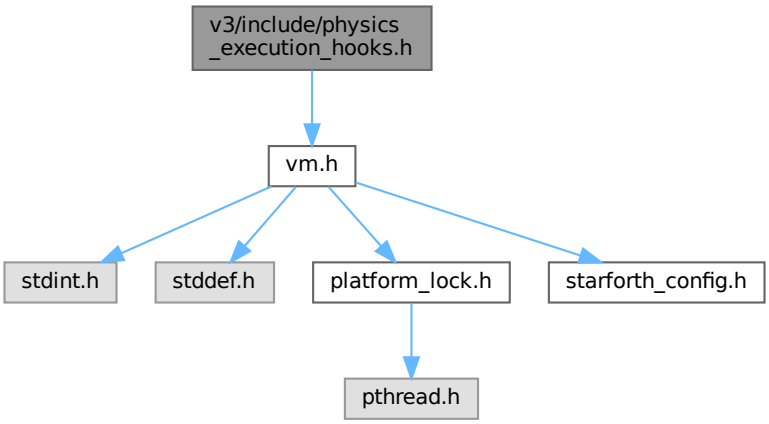
Here is the caller graph for this function:



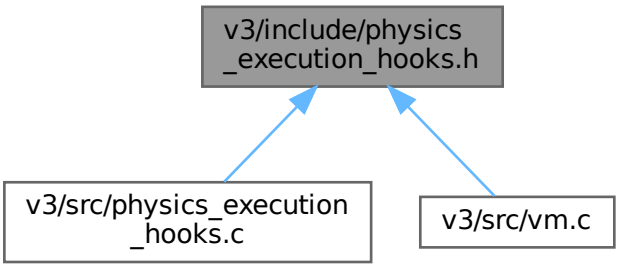
7.211 v3/include/physics_execution_hooks.h File Reference

```
#include "vm.h"
```

Include dependency graph for physics_execution_hooks.h:



This graph shows which files directly or indirectly include this file:



Functions

- void physics_pre_execute (VM *vm, DictEntry *word, DictEntry *prev)

  Pre-execution physics hook — called before every word dispatch.
- void physics_post_execute (VM *vm, DictEntry *word)

  Post-execution physics hook — called after every word dispatch.
- void physics_on_lookup (VM *vm, DictEntry *entry, DictEntry *canon)

  Physics hook for the outer interpreter word-lookup path.

7.211.1 Function Documentation

7.211.1.1 physics_on_lookup()

```
void physics_on_lookup (
            VM * vm,
```

```
        DictEntry * entry,
        DictEntry * canon )
```

Physics hook for the outer interpreter word-lookup path.

Called when the outer interpreter successfully finds a word by name, before executing it. Applies linear decay and increments heat on both the found entry and the canonical entry (if different), and updates `last_active_ns` / `last_decay_ns` on both. Acquires `vm->dict_lock` for the entire operation to ensure thread safety.

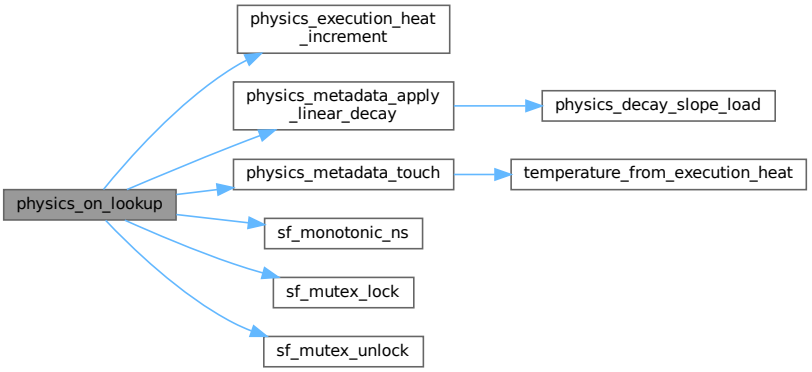
Parameters

vm	Pointer to the VM structure
entry	DictEntry found by name search
canon	Canonical DictEntry (may equal `entry` or be the smudge target)

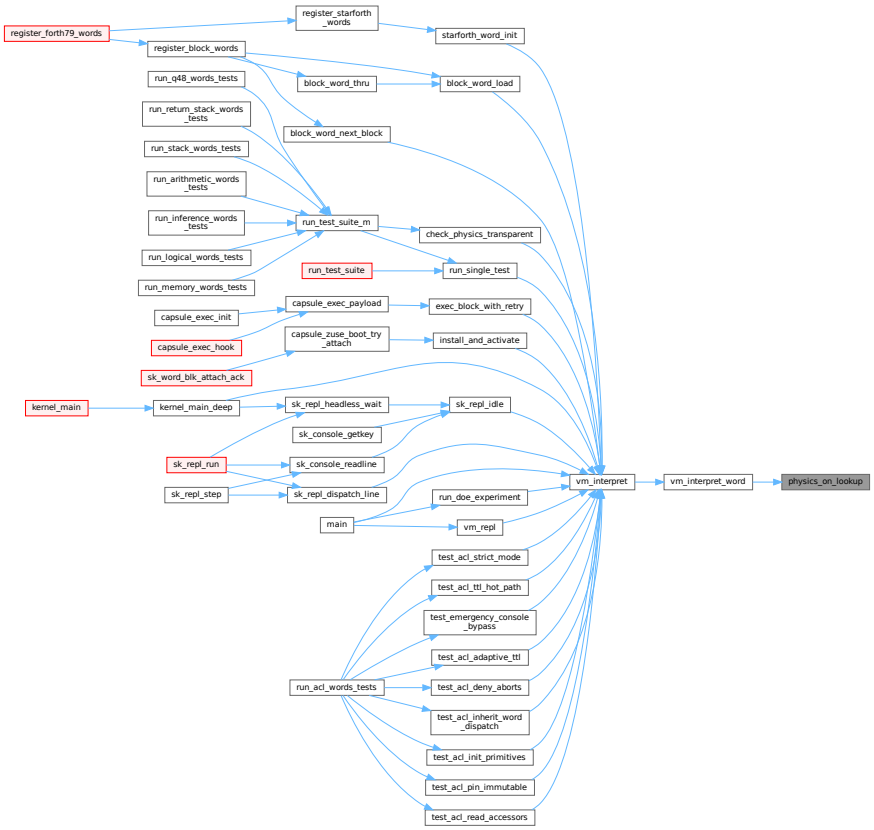
References VM::dict_lock, entry, DictEntry::execution_heat, VM::heartbeat, DictPhysics::last_active_ns, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, DictEntry::physics, physics_execution_heat_increment(), physics_metadata_apply_linear_decay(), physics_metadata_touch(), sf_monotonic_ns(), sf_mutex_lock(), sf_mutex_unlock(), and HeartbeatState::tick_count.

Referenced by vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.211.1.2 physics_post_execute()

```
void physics_post_execute (
            VM * vm,
            DictEntry * word )
```

Post-execution physics hook — called after every word dispatch.

Consolidates all physics work that must happen after a word completes:

- Updates physics metadata (`temperature_q8`, `last_active_ns`) via `physics_metadata_touch()`
- Notifies the profiler (`profiler_word_exit()`)
- Increments `vm->heartbeat.words_executed`
- When running without a background heartbeat thread, checks whether enough words have been executed to trigger a heartbeat cycle (`vm_heartbeat_run_cycle()`)

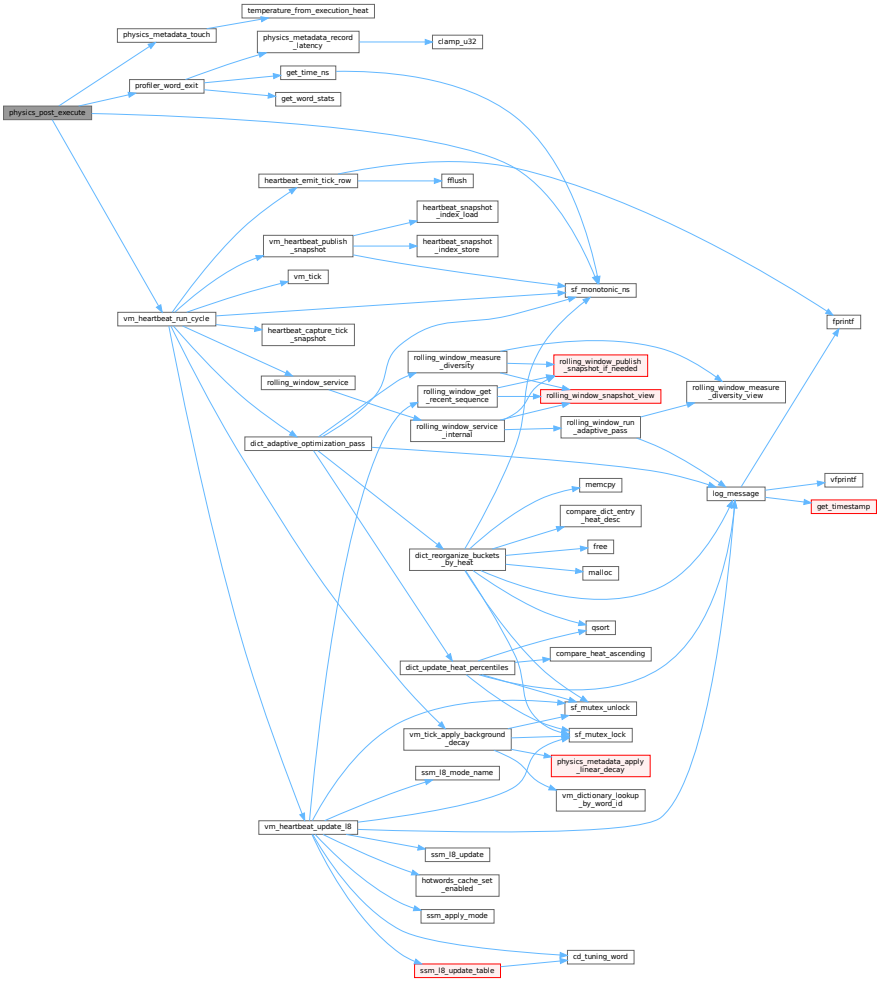
Parameters

vm	Pointer to the VM structure
word	DictEntry that just finished executing

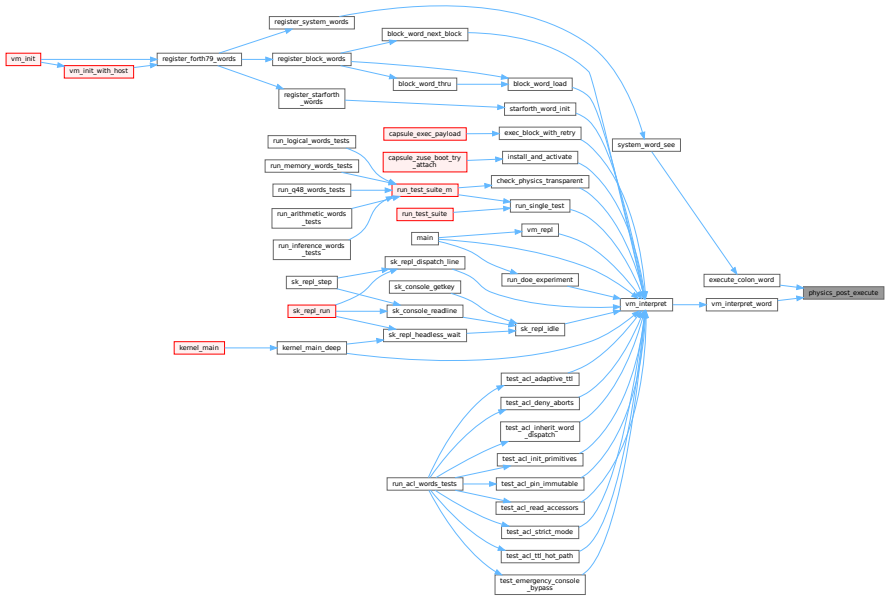
References HeartbeatState::check_counter, DictEntry::execution_heat, VM::heartbeat, HEARTBEAT_CHECK_FREQUENCY, physics_metadata_touch(), profiler_word_exit(), sf_monotonic_ns(), vm_heartbeat_run_cycle(), HeartbeatState::words_executed, and HeartbeatState::worker.

Referenced by execute_colon_word(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.211.1.3 physics_pre_execute()

```
void physics_pre_execute (
            VM * vm,
            DictEntry * word,
            DictEntry * prev )
```

Pre-execution physics hook — called before every word dispatch.

Consolidates all physics work that must happen before a word runs:

- Loop #3: applies linear decay based on elapsed time since last execution
- Loop #1: increments `execution_heat` for the word
- Loop #2: records the word-id into the rolling window of truth
- Loop #4: detects a pipelining prefetch hit (if `prev`'s speculation matched `word`), records the transition from `prev` to `word`, updates the probability cache, and issues a speculative hotwords cache promotion for the most likely next word

Parameters

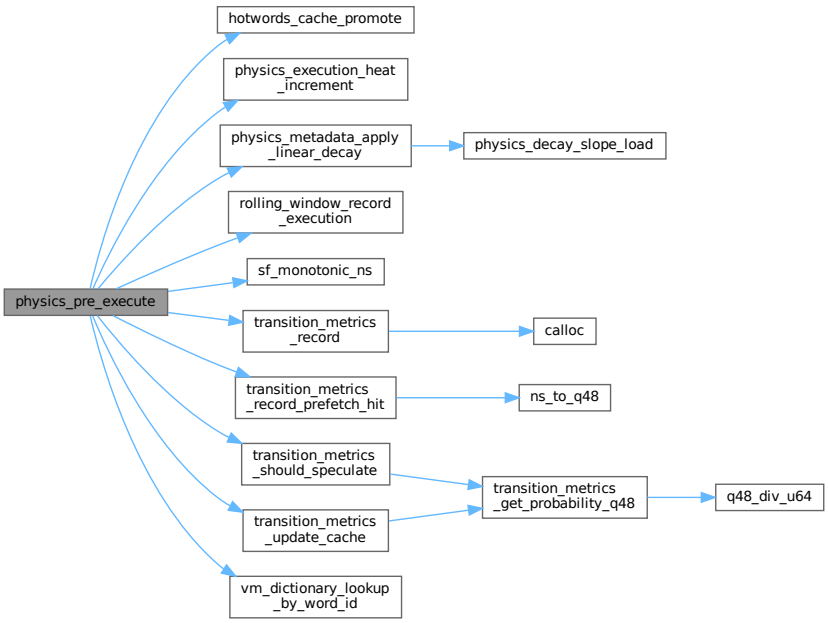
vm	Pointer to the VM structure
word	DictEntry being executed
prev	DictEntry executed immediately before `word` (may be NULL)

References DICTIONARY_SIZE, ENABLE_HOTWORDS_CACHE, ENABLE_PIPELINING, HotwordsCache_s::enabled, DictEntry::execution_heat, VM::heartbeat, VM::hotwords_cache, hotwords_cache_promote(), HOTWORDS_EXECUTION_HEAT_TH

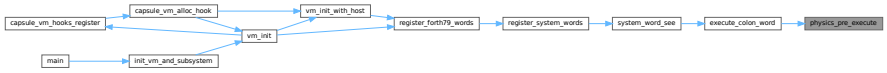
ssm_config_t::L4_pipelining, DictPhysics::last_active_ns, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, WordTransitionMetrics::most_likely_next_word_id, DictEntry::physics, physics_execution_heat_increment(), physics_metadata_apply_linear_decay(), VM::pipeline_metrics, WordTransitionMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::rolling_window, rolling_window_record_executio sf_monotonic_ns(), VM::ssm_config, HeartbeatState::tick_count, DictEntry::transition_metrics, transition_metrics_record(), transition_metrics_record_prefetch_hit(), transition_metrics_should_speculate(), transition_metrics_update_cache(), vm_dictionary_lookup_by_word_id(), word_id, and DictEntry::word_id.

Referenced by execute_colon_word().

Here is the call graph for this function:



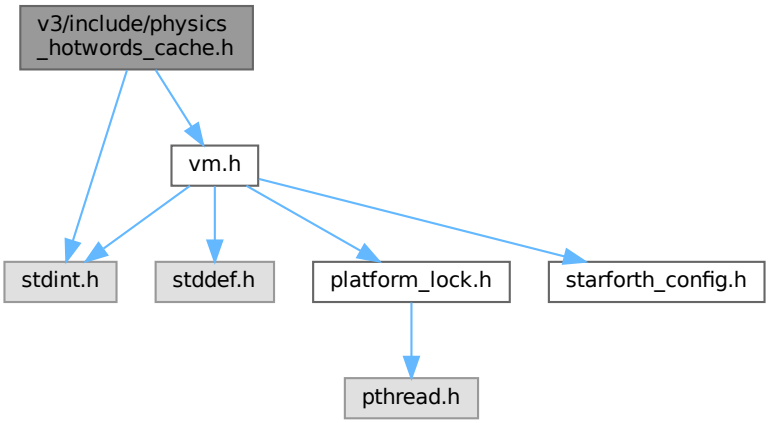
Here is the caller graph for this function:



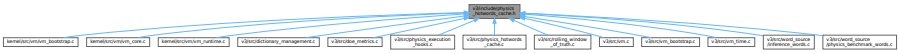
7.212 v3/include/physics_hotwords_cache.h File Reference

```
#include <stdint.h>
#include "vm.h"
```

Include dependency graph for physics_hotwords_cache.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct HotwordsStats
- struct HotwordsCache_s
- struct BayesianLatencyPosterior

  Bayesian statistics structure for inference and credible intervals All values stored in Q48.16 fixed-point (64-bit signed integer) representing nanoseconds with 2^-16 ≈ 0.0000153 ns precision.
- struct SpeedupEstimate

  Calculate speedup estimate with credible interval All values in Q48.16 fixed-point format (64-bit signed integer) Probabilities are in range [0, Q48_SCALE] representing [0%, 100%].

Macros

- #define HOTWORDS_CACHE_SIZE 32

  Maximum number of hot words to cache (typically 16-32)
- #define HOTWORDS_EXECUTION_HEAT_THRESHOLD 50

  Execution heat threshold to consider a word "hot" (execution count)
- #define HOTWORDS_EXECUTION_HEAT_DELTA_THRESHOLD 100

  Reorder bucket when execution heat delta exceeds this (avoid thrashing)

Typedefs

- typedef struct HotwordsCache_s HotwordsCache

Functions

- void hotwords_cache_init (HotwordsCache *cache)

  Initialize hot-words cache Should be called during VM initialization.
- void hotwords_cache_cleanup (HotwordsCache *cache)

  Cleanup hot-words cache.
- DictEntry * hotwords_cache_lookup (VM *vm, HotwordsCache *cache, DictEntry **bucket, size_t bucket_count, const char *name, size_t len)

  Lookup word in cache first, then fall back to bucket search Returns the found word, or NULL if not found.
- void hotwords_cache_promote (HotwordsCache *cache, DictEntry *word)

  Promote a word to the hot-words cache Called when a word's execution heat exceeds threshold.
- void hotwords_cache_evict_entry (HotwordsCache *cache, const DictEntry *word)

  Evict every cache slot holding this exact entry.
- void hotwords_cache_evict_name (HotwordsCache *cache, const char *name, size_t len)

  Evict every cache slot whose entry matches this name.
- void hotwords_bucket_reorder (DictEntry **bucket, size_t count)

  Reorder a bucket by execution heat (move hot words forward) Called when execution heat delta exceeds threshold.
- void hotwords_stats_reset (HotwordsStats *stats)

  Reset statistics (for before/after comparison)
- void hotwords_stats_print (const HotwordsStats *stats)

  Print statistics to stdout.
- void hotwords_cache_set_enabled (HotwordsCache *cache, int enabled)

  Enable/disable cache at runtime (for A/B testing)
- BayesianLatencyPosterior hotwords_posterior_cache_hits (const HotwordsStats *stats)

  Calculate posterior distribution for cache hits Uses accumulated samples to compute credible intervals.
- BayesianLatencyPosterior hotwords_posterior_bucket_searches (const HotwordsStats *stats)

  Calculate posterior distribution for bucket searches Uses accumulated samples to compute credible intervals.
- struct SpeedupEstimate hotwords_speedup_estimate (const HotwordsStats *stats)

  Calculate speedup estimate with uncertainty.
- void hotwords_bayesian_report (const HotwordsStats *stats_with_cache, const HotwordsStats *stats_without_cache)

  Generate detailed Bayesian inference report Compares cache vs bucket performance with confidence measures.

7.212.1 Macro Definition Documentation

7.212.1.1 HOTWORDS_CACHE_SIZE

```
#define HOTWORDS_CACHE_SIZE 32
```

Maximum number of hot words to cache (typically 16-32)

7.212.1.2 HOTWORDS_EXECUTION_HEAT_DELTA_THRESHOLD

```
#define HOTWORDS_EXECUTION_HEAT_DELTA_THRESHOLD 100
```

Reorder bucket when execution heat delta exceeds this (avoid thrashing)

7.212.1.3 HOTWORDS_EXECUTION_HEAT_THRESHOLD

```
#define HOTWORDS_EXECUTION_HEAT_THRESHOLD 50
```

Execution heat threshold to consider a word "hot" (execution count)

7.212.2 Typedef Documentation

7.212.2.1 HotwordsCache

```
typedef struct HotwordsCache_s HotwordsCache
```

7.212.3 Function Documentation

7.212.3.1 hotwords_bayesian_report()

```
void hotwords_bayesian_report (
            const HotwordsStats * stats_with_cache,
            const HotwordsStats * stats_without_cache )
```

Generate detailed Bayesian inference report Compares cache vs bucket performance with confidence measures.

Generate detailed Bayesian inference report Compares cache vs bucket performance with confidence measures.

Emits a structured Unicode report to `stdout` comparing the latency distributions of two measurement sets — one collected with the hot-words cache enabled, the other collected without (baseline). The report is divided into five sections:

1. **WITH CACHE ENABLED** — posterior mean, stddev, and 95%/99% credible intervals for cache-hits and bucket-searches separately, via `hotwords_posterior_cache_hits()` and `hotwords_posterior_bucket_sea`
2. **WITHOUT CACHE (Baseline)** — posterior mean, stddev, and 95% credible interval for all lookups (treated as bucket searches). If no bucket data is available in `stats_without_cache`, the bucket-search mean from the with-cache run is used as an approximation.
3. **SPEEDUP ESTIMATE (Bucket vs Cache)** — `hotwords_speedup_estimate()` point estimate, 95% credible interval, P(>1.1×), and P(>2.0×).
4. **CACHE EFFECTIVENESS** — total lookups, cache-hit rate, bucket-hit rate, and miss rate as percentages of total.
5. **OVERALL PERFORMANCE** — weighted-average latency with cache vs. baseline all-bucket latency, overall speedup, and absolute time saved per lookup. The weighted average is: (N_cache×avg_cache + N_↩ bucket×avg_bucket) / (N_cache + N_bucket).

All latency values are displayed in nanoseconds (floating-point via `q48_to_ns_double()`) for readability; underlying accumulators are Q48.16 integer throughout.

No-op if either `stats_with_cache` or `stats_without_cache` is NULL.

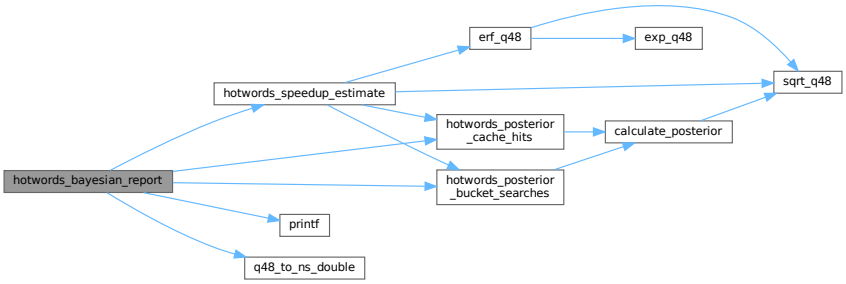
Parameters

stats_with_cache	Statistics from a run with cache enabled.
stats_without_cache	Statistics from a baseline run without cache.

References HotwordsStats::bucket_hits, HotwordsStats::cache_hits, BayesianLatencyPosterior::credible_lower_95, SpeedupEstimate::credible_lower_95_q48, BayesianLatencyPosterior::credible_lower_99, BayesianLatencyPosterior::credible_upper SpeedupEstimate::credible_upper_95_q48, BayesianLatencyPosterior::credible_upper_99, hotwords_posterior_bucket_searches(), hotwords_posterior_cache_hits(), hotwords_speedup_estimate(), BayesianLatencyPosterior::mean_ns_q48, HotwordsStats::misses, printf(), SpeedupEstimate::probability_gt_10pct_q48, SpeedupEstimate::probability_gt_double_q48, q48_to_ns_double(), BayesianLatencyPosterior::sample_count, SpeedupEstimate::speedup_factor_q48, and BayesianLatencyPosterior::stddev_ns_q48.

Referenced by forth_PHYSICS_BAYESIAN_REPORT().

Here is the call graph for this function:



Here is the caller graph for this function:

7.212.3.2 hotwords_bucket_reorder()

```
void hotwords_bucket_reorder (
            DictEntry ** bucket,
            size_t count )
```

Reorder a bucket by execution heat (move hot words forward) Called when execution heat delta exceeds threshold.

Reorder a bucket by execution heat (move hot words forward) Called when execution heat delta exceeds threshold.

Performs a classic in-place bubble sort over the `bucket` array so that words with higher `execution_heat` appear at lower array indices. The hot-words cache and heat-stratified lookup both benefit from having the hottest words at the front of each bucket: the first-character hash buckets are linear arrays, and placing hot words up front reduces the scan depth on Stage 1 cache misses that fall through to Stage 2 bucket search.

Bubble sort is chosen deliberately: buckets are small (typically single digits to low dozens of words per first-character class), already nearly sorted after the previous reorganization pass, and the cost of a O(n^2) inner loop on $n \leq 30$ is negligible compared to the outer `qsort` on all 256 buckets in `dict_reorganize_buckets_by_heat()`. For the individual per-bucket call path (e.g. after a single promotion), bubble sort avoids the `malloc` overhead that `qsort's` temporary storage would require.

No-op for `count` < 2.

Parameters

bucket	Array of `DictEntry*` pointers to sort in-place. NULL-check is the caller's responsibility.
count	Number of valid entries in `bucket`.

References count, and execution_heat.

7.212.3.3 hotwords_cache_cleanup()

```
void hotwords_cache_cleanup (
            HotwordsCache * cache )
```

Cleanup hot-words cache.

Cleanup hot-words cache.

Calls `memset(cache, 0, sizeof(*cache))` to scrub every field including the inline `cache`[] pointer array and all statistics. The cache holds no separately allocated memory (the `DictEntry` pointers inside `cache`[] are owned by the dictionary, not the cache), so no `free()` calls are needed.

Intended for use at VM teardown or when the caller wants to reset the cache to a known-zero state between benchmark runs. After this call the cache is in an unusable state (`enabled` = 0); call `hotwords_cache_init()` to reinitialise it.

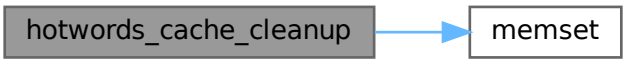
Parameters

cache	Cache to zero; no-op if NULL.

References memset().

Referenced by vm_cleanup().

Here is the call graph for this function:



Here is the caller graph for this function:

7.212.3.4 hotwords_cache_evict_entry()

```
void hotwords_cache_evict_entry (
            HotwordsCache * cache,
            const DictEntry * word )
```

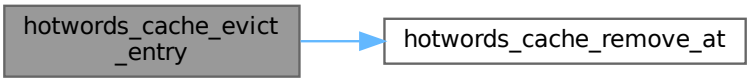
Evict every cache slot holding this exact entry.

Must be called before an entry is freed (FORGET) — a stale pointer in the ring is a use-after-free.

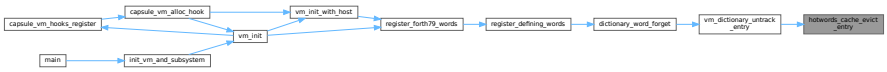
References HotwordsCache_s::cache, HotwordsCache_s::cache_count, and hotwords_cache_remove_at().

Referenced by vm_dictionary_untrack_entry().

Here is the call graph for this function:



Here is the caller graph for this function:



7.212.3.5 hotwords_cache_evict_name()

```
void hotwords_cache_evict_name (
            HotwordsCache * cache,
            const char * name,
            size_t len )
```

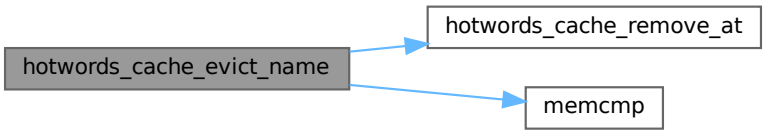
Evict every cache slot whose entry matches this name.

Called whenever name resolution may change: word creation (shadowing), smudge/unsmudge, hide. The next lookup re-resolves through the bucket.

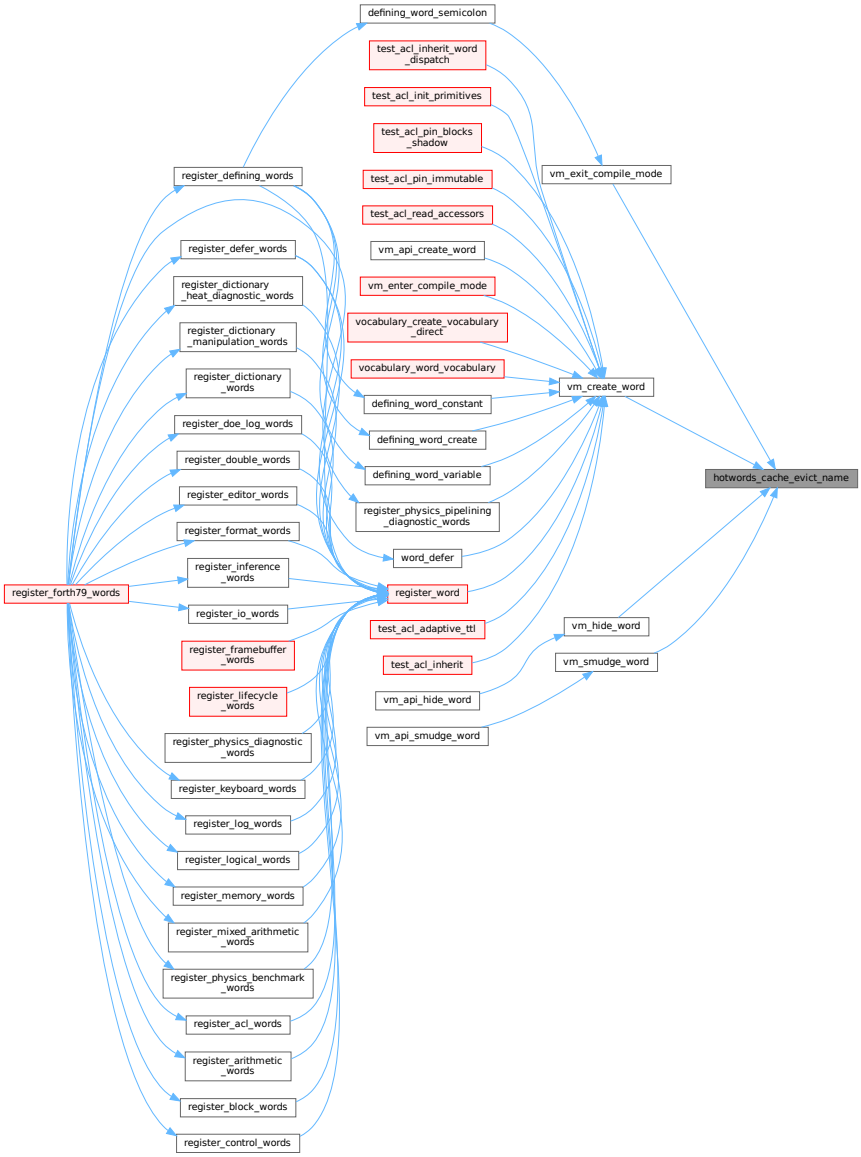
References HotwordsCache_s::cache, HotwordsCache_s::cache_count, hotwords_cache_remove_at(), memcmp(), name, DictEntry::name, and DictEntry::name_len.

Referenced by vm_create_word(), vm_exit_compile_mode(), vm_hide_word(), and vm_smudge_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.212.3.6 hotwords_cache_init()

```
void hotwords_cache_init (
            HotwordsCache * cache )
```

Initialize hot-words cache Should be called during VM initialization.

Initialize hot-words cache Should be called during VM initialization.

Zeroes all fields via `memset` then explicitly sets:

- `cache->enabled` = `ENABLE_HOTWORDS_CACHE` (build-time compile flag; 0 disables the cache globally without a code change).
- `cache->cache_count` = 0, `cache->lru_index` = 0 — empty round-robin eviction ring.
- All counter fields in `cache->stats` to 0.
- `stats.min_cache_hit_ns` = `INT64_MAX`, `stats.max_cache_hit_ns` = `INT64_MIN` (sentinel values; updated to real observations on the first cache hit).
- `stats.min_bucket_search_ns` = `INT64_MAX`, `stats.max_bucket_search_ns` = `INT64_MIN` (same sentinel convention for bucket searches).
- All Q48.16 variance accumulators to 0.

Safe to call multiple times (idempotent via `memset`). Must be called before the first `hotwords_cache_lookup()` invocation; failure to do so leaves the sentinel min/max fields uninitialised, producing nonsense in the Bayesian posterior report.

Parameters

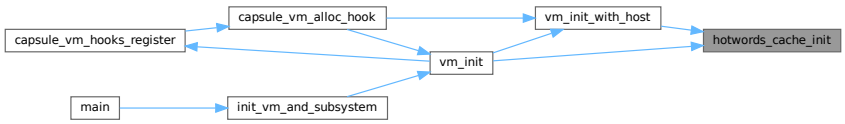
cache	Cache to initialise; no-op if NULL.

References HotwordsStats::bucket_hits, HotwordsStats::bucket_reorders, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsCache_s::cache_count, HotwordsStats::cache_hit_samples, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, HotwordsStats::cache_hits, ENABLE_HOTWORDS_CACHE, HotwordsCache_s::enabled, HotwordsStats::evictions, HotwordsCache_s::lru_index, HotwordsStats::max_bucket_search_ns, HotwordsStats::max_cache_hit_ns, memset(), HotwordsStats::min_bucket_search_ns, HotwordsStats::min_cache_hit_ns, HotwordsStats::misses, HotwordsStats::promotions, HotwordsCache_s::stats, and HotwordsStats::total_lookups.

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:

Here is the caller graph for this function:



7.212.3.7 hotwords_cache_lookup()

```
DictEntry * hotwords_cache_lookup (
            VM * vm,
            HotwordsCache * cache,
            DictEntry ** bucket,
            size_t bucket_count,
            const char * name,
            size_t len )
```

Lookup word in cache first, then fall back to bucket search Returns the found word, or NULL if not found.

This is the main function that replaces vm_find_word() logic. Takes the VM so the bucket fallback can resolve same-named entries by definition age (vm_dict_resolve_in_bucket) — bucket order alone is not authoritative once dict_reorganize_buckets_by_heat() has run.

Lookup word in cache first, then fall back to bucket search Returns the found word, or NULL if not found.

The primary dictionary fast-path. Records a start timestamp via `sf_monotonic_ns()` and then executes a two-stage search:

Stage 1 — Cache check (O(HOTWORDS_CACHE_SIZE)): Scans the `cache->cache[]` ring for an entry whose `name_len` and name match `name/len`, using the cheap-first filter (`name_len` → last-character → `memcmp`). On a hit the elapsed nanoseconds are converted to Q48.16 and accumulated into `stats.cache_hit_total_ns_q48`; the squared value is accumulated into `stats.cache_hit_variance_sum_q48` for Bayesian posterior computation by `calculate_posterior()`. Min/max latency sentinels are also updated.

Stage 2 — Bucket fallback (O(bucket_count)): Scans `bucket[]` in reverse-insertion order (newest definition wins). On a hit the elapsed time is recorded in the `bucket_search_*` accumulators with the same Q48.16 and variance treatment as Stage 1. If the found word's `execution_heat` exceeds `HOTWORDS_EXECUTION_HEAT_THRESHOLD` it is promoted into the cache via `hotwords_cache_promote()`.

Disabled path: If `cache` is NULL or `cache->enabled` is 0, the function skips Stage 1 and performs a bare reverse-linear scan of `bucket[]` returning the result immediately (no statistics are recorded).

A miss increments `stats.misses` and returns NULL.

Parameters

cache	Hot-words cache; may be NULL or disabled (falls back to bucket scan without statistics).
bucket	First-character hash bucket — array of `DictEntry*` pointers, searched in reverse order.
bucket_count	Number of valid pointers in `bucket`.
name	Word name to find (not NUL-terminated).
len	Length of `name` in bytes.

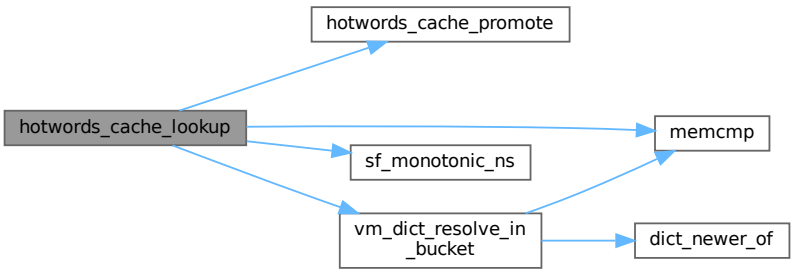
Returns

Matching `DictEntry*`, or NULL if not found.

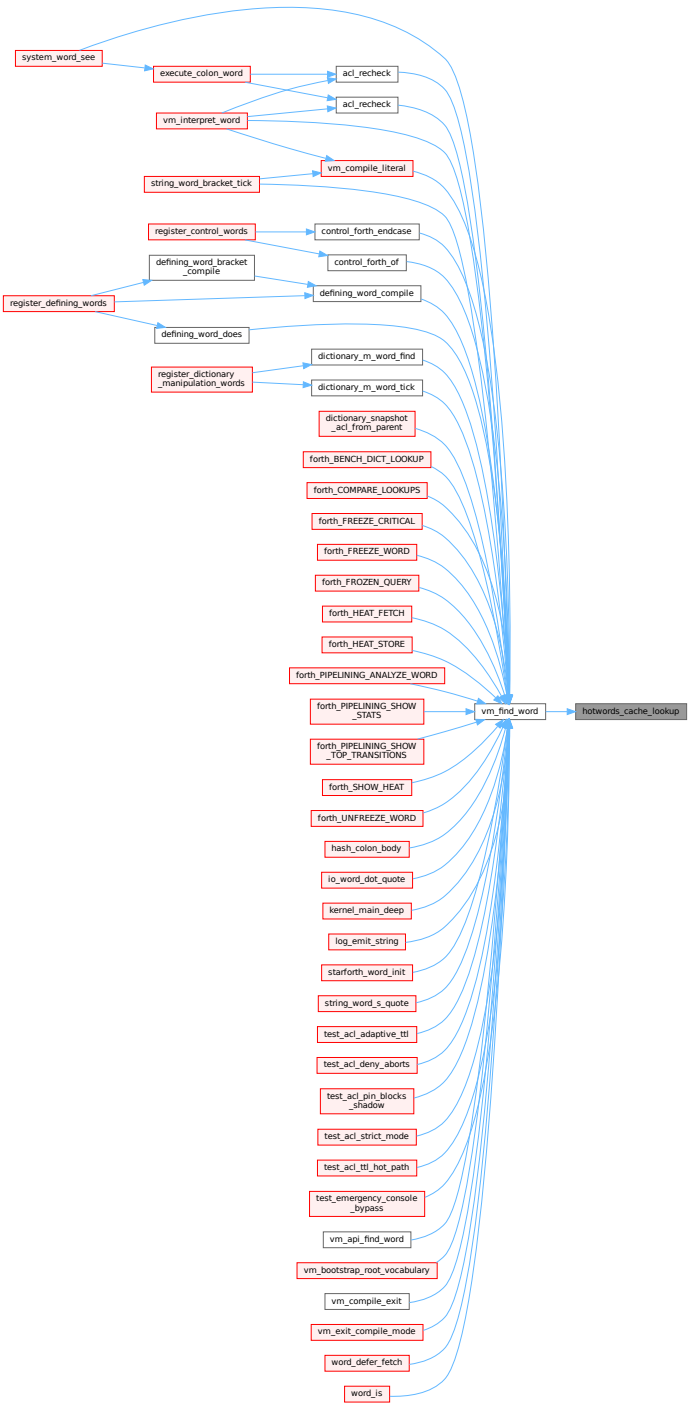
References HotwordsStats::bucket_hits, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsCache_s::cache, HotwordsCache_s::cache_count, HotwordsStats::cache_hit_samples, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, HotwordsStats::cache_hits, HotwordsCache_s::enabled, DictEntry::execution_heat, DictEntry::flags, hotwords_cache_promote(), HOTWORDS_EXECUTION_HEAT_THRESHOLD, HotwordsStats::max_bucket_search_ns, HotwordsStats::max_cache_hit_ns, memcmp(), HotwordsStats::min_bucket_search_ns, HotwordsStats::min_cache_hit_ns, HotwordsStats::misses, name, DictEntry::name, DictEntry::name_len, sf_monotonic_ns(), HotwordsCache_s::stats, HotwordsStats::total_lookups, vm_dict_resolve_in_bucket(), WORD_HIDDEN, and WORD_SMUDGED.

Referenced by vm_find_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.212.3.8 hotwords_cache_promote()

```
void hotwords_cache_promote (
            HotwordsCache * cache,
            DictEntry * word )
```

Promote a word to the hot-words cache Called when a word's execution heat exceeds threshold.

Promote a word to the hot-words cache Called when a word's execution heat exceeds threshold.

Two paths depending on whether the cache has a free slot:

- **Slot available** (`cache->cache_count < HOTWORDS_CACHE_SIZE`): Appends `word` at `cache->cache[cache->cache_count++]` after verifying it is not already present (linear scan). Increments `stats.promotions`.
- **Cache full** (`cache->cache_count >= HOTWORDS_CACHE_SIZE`): Overwrites `cache->cache[cache->lru_index]` with `word` (round-robin least-recently-used eviction) and advances `lru_index` modulo `HOTWORDS_CACHE_SIZE`. Increments `stats.evictions`. The evicted entry is not freed — it remains alive in the dictionary; only its slot in the cache ring is surrendered.

Called from `hotwords_cache_lookup()` whenever a bucket search finds a word hot enough to warrant caching (heat > `HOTWORDS_EXECUTION_HEAT_THRESHOLD`).

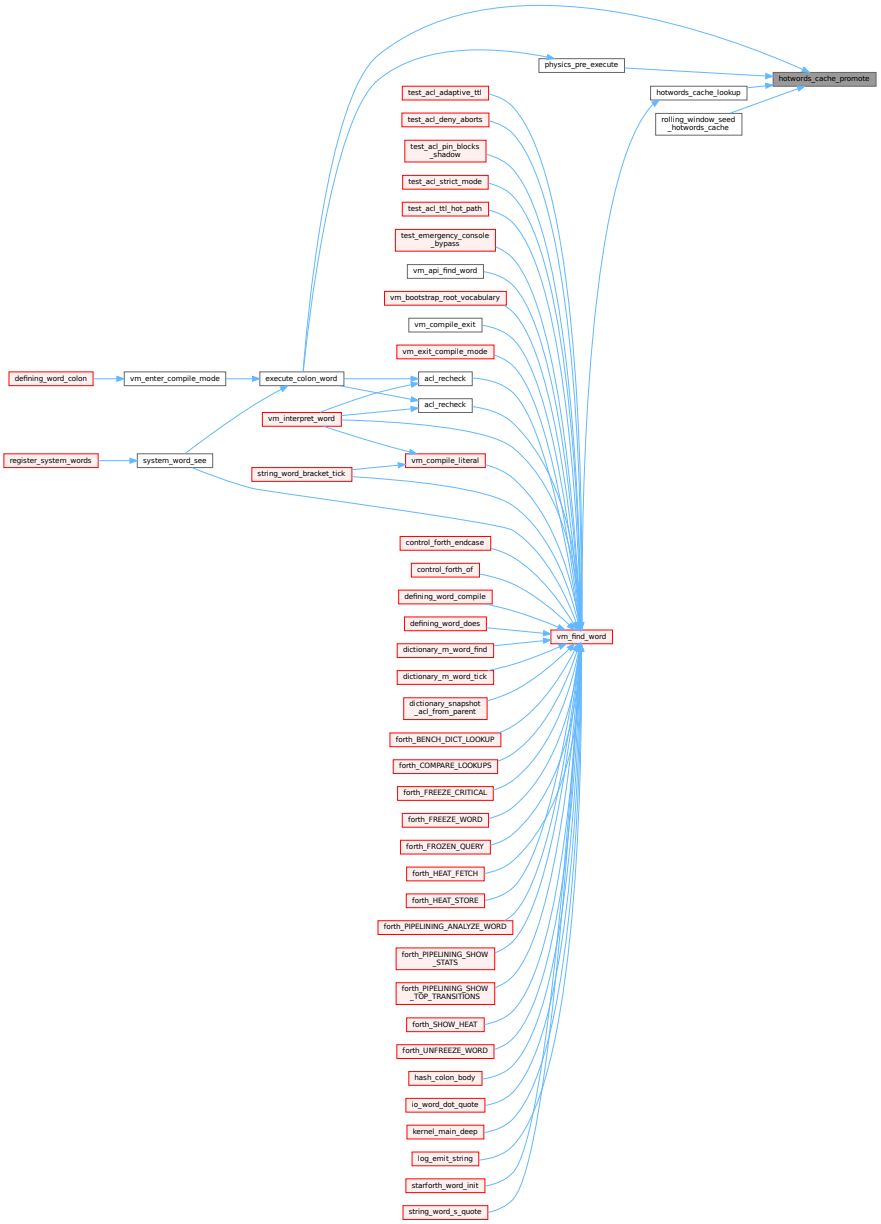
Parameters

cache	The cache to promote into; no-op if NULL.
word	The `DictEntry` to promote; no-op if NULL. Ownership is not transferred — the cache holds a borrowed pointer into the dictionary, which owns the entry.

References HotwordsCache_s::cache, HotwordsCache_s::cache_count, HotwordsStats::evictions, HOTWORDS_CACHE_SIZE, HotwordsCache_s::lru_index, HotwordsStats::promotions, and HotwordsCache_s::stats.

Referenced by execute_colon_word(), hotwords_cache_lookup(), physics_pre_execute(), and rolling_window_seed_hotwords_cache(

Here is the caller graph for this function:



7.212.3.9 hotwords_cache_set_enabled()

```
void hotwords_cache_set_enabled (
            HotwordsCache * cache,
            int enabled )
```

Enable/disable cache at runtime (for A/B testing)

Enable/disable cache at runtime (for A/B testing)

Sets `cache->enabled` to `enabled` (non-zero = active, 0 = bypassed). When disabled, `hotwords_cache_lookup()` skips Stage 1 entirely and falls through directly to a bare bucket scan, recording no statistics. This allows benchmark harnesses to compare cache-on vs. cache-off behaviour without rebuilding the binary.

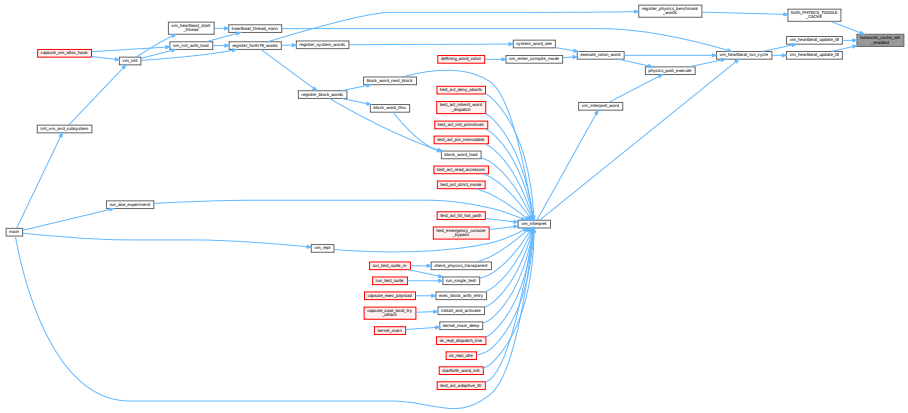
Parameters

cache	Cache to configure; no-op if NULL.
enabled	Non-zero to enable the cache; 0 to disable.

References HotwordsCache_s::enabled, and enabled.

Referenced by forth_PHYSICS_TOGGLE_CACHE(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the caller graph for this function:



7.212.3.10 hotwords_posterior_bucket_searches()

```
BayesianLatencyPosterior hotwords_posterior_bucket_searches (
            const HotwordsStats * stats )
```

Calculate posterior distribution for bucket searches Uses accumulated samples to compute credible intervals.

Calculate posterior distribution for bucket searches Uses accumulated samples to compute credible intervals.

Forwards the bucket-search accumulators from `stats` to `calculate_posterior()`: `bucket_search_↩total_ns_q48`, `bucket_search_variance_sum_q48`, `min_bucket_search_ns`, `max_bucket↩_search_ns`, and `bucket_search_samples`. Returns a zeroed `BayesianLatencyPosterior` if `stats` is NULL or no bucket-search samples have been recorded.

The returned posterior's mean and credible-interval fields feed `hotwords_speedup_estimate()` (as the slower distribution) and the baseline section of `hotwords_bayesian_report()`.

Parameters

stats	`HotwordsStats` containing bucket-search timing accumulators.

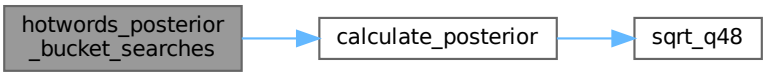
Returns

Posterior in Q48.16; all fields zero if no samples exist.

References HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_v
calculate_posterior(), HotwordsStats::max_bucket_search_ns, and HotwordsStats::min_bucket_search_ns.

Referenced by bucket_posterior(), hotwords_bayesian_report(), and hotwords_speedup_estimate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.212.3.11 hotwords_posterior_cache_hits()

```
BayesianLatencyPosterior hotwords_posterior_cache_hits (
            const HotwordsStats * stats )
```

Calculate posterior distribution for cache hits Uses accumulated samples to compute credible intervals.

Calculate posterior distribution for cache hits Uses accumulated samples to compute credible intervals.

Forwards the cache-hit accumulators from `stats` to `calculate_posterior()`: `cache_hit_total_ns_q48`, `cache_hit_variance_sum_q48`, `min_cache_hit_ns`, `max_cache_hit_ns`, and `cache_hit_samples`. Returns a zeroed `BayesianLatencyPosterior` if `stats` is NULL or no cache-hit samples have been recorded yet.

The returned posterior's `mean_ns_q48`, `stddev_ns_q48`, and 95%/99% credible-interval fields are consumed by `hotwords_speedup_estimate()` and `hotwords_bayesian_report()` to compare cache-hit latency against bucket-search latency.

Parameters

stats	`HotwordsStats` containing cache-hit timing accumulators.

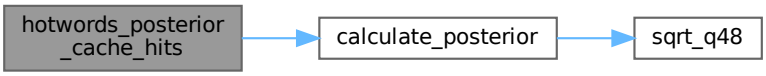
Returns

Posterior in Q48.16; all fields zero if no samples exist.

References HotwordsStats::cache_hit_samples, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q
calculate_posterior(), HotwordsStats::max_cache_hit_ns, and HotwordsStats::min_cache_hit_ns.

Referenced by cache_posterior(), hotwords_bayesian_report(), and hotwords_speedup_estimate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.212.3.12 hotwords_speedup_estimate()

```
struct SpeedupEstimate hotwords_speedup_estimate (
            const HotwordsStats * stats )
```

Calculate speedup estimate with uncertainty.

Calculate speedup estimate with uncertainty.

Derives a dimensionless speedup ratio `S` = bucket_mean / cache_mean in Q48.16 fixed-point and propagates uncertainty via the delta method for ratios:
`SE(S) ≈ S × sqrt( (SE_bucket / bucket_mean)² + (SE_cache / cache_mean)² )`

All arithmetic is Q48.16 integer throughout; the only deviation is the intermediate `sqrt()` call which also runs in Q48.16 via `sqrt_q48()`.

Computed fields in the returned `SpeedupEstimate` (all Q48.16):

- `speedup_factor_q48` — point estimate of `S`.
- `credible_lower_95_q48` / `credible_upper_95_q48` — 95% credible interval: `S` ± 1.96 × SE(S) (Z?? = 128431 in Q48.16). Lower bound clamped at 0.
- `probability_gt_10pct_q48` — P(speedup > 1.1×), computed as `0.5` × (1 + erf(z / √2)) where `z` = (1.1 ? S) / SE(S) is negated to give the right-tail probability and √2 = 92681 in Q48.16.
- `probability_gt_double_q48` — P(speedup > 2.0×), same formula with target = 2.0 × 65536 = 131072.

Returns a default `SpeedupEstimate` with `speedup_factor_q48` = 65536 (1.0×) if either distribution has zero samples or if `stats` is NULL.

Parameters

stats	`HotwordsStats` with both cache-hit and bucket-search samples.

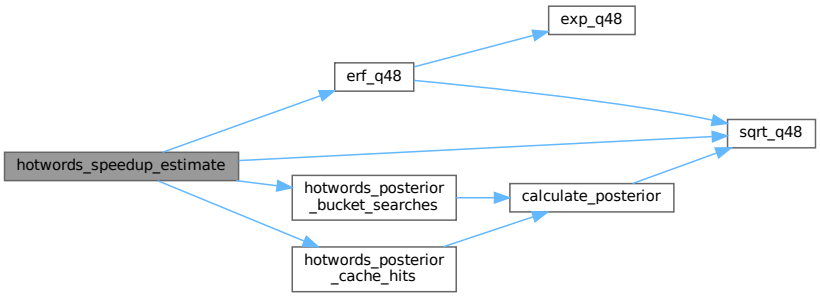
Returns

`SpeedupEstimate` with all fields in Q48.16 fixed-point.

References SpeedupEstimate::credible_lower_95_q48, SpeedupEstimate::credible_upper_95_q48, erf_q48(), hotwords_posterior_bucket_searches(), hotwords_posterior_cache_hits(), BayesianLatencyPosterior::mean_ns_q48, SpeedupEstimate::probability_gt_10pct_q48, SpeedupEstimate::probability_gt_double_q48, SpeedupEstimate::speedup_factor_q48, sqrt_q48(), and BayesianLatencyPosterior::stddev_ns_q48.

Referenced by hotwords_bayesian_report().

Here is the call graph for this function:



Here is the caller graph for this function:

7.212.3.13 hotwords_stats_print()

```
void hotwords_stats_print (
            const HotwordsStats * stats )
```

Print statistics to stdout.

Print statistics to stdout.

Emits a Unicode box-drawing table covering three sections:

LOOKUPS — total, cache hits, bucket hits, misses with percentages.

LATENCY STATISTICS — for each of cache-hits and bucket-searches (when their sample counts are non-zero):

- Min / avg / max in nanoseconds, derived from the Q48.16 accumulators by right-shifting 16 bits: `avg_ns` = `total_ns_q48` / samples >> 16.
- Standard deviation computed from the Welford-style variance accumulator: `var` = E[X^2] ? E[X]^2, then `stddev` = sqrt_q48(var), converted to nanoseconds via `q48_to_ns_double()` for display only.
- Speedup ratio (bucket avg / cache avg) when both sample sets are present.

CACHE MANAGEMENT — promotions, evictions, and bucket reorder counts.

If `stats` is NULL or the total lookup count is zero, prints a brief "No lookups performed." notice instead of the full table. All floating-point usage in this function is display-only (via `q48_to_ns_double()`); the underlying accumulators remain in Q48.16 integer format.

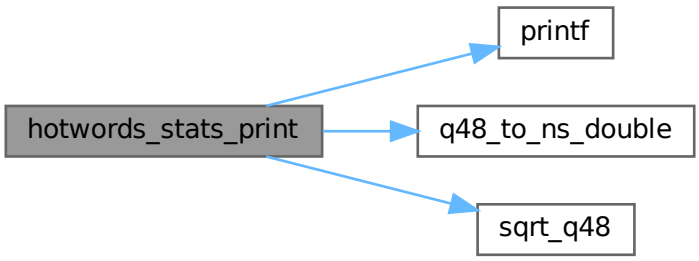
Parameters

stats	Statistics to report; no-op if NULL.

References HotwordsStats::bucket_hits, HotwordsStats::bucket_reorders, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsStats::cache_hit_samples, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, HotwordsStats::cache_hits, HotwordsStats::evictions, HotwordsStats::max_bucket_search_ns, HotwordsStats::max_cache_hit_ns, HotwordsStats::min_bucket_s, HotwordsStats::min_cache_hit_ns, HotwordsStats::misses, printf(), HotwordsStats::promotions, q48_to_ns_double(), and sqrt_q48().

Referenced by forth_BENCH_DICT_LOOKUP(), and forth_PHYSICS_CACHE_STATS().

Here is the call graph for this function:



Here is the caller graph for this function:

7.212.3.14 hotwords_stats_reset()

```
void hotwords_stats_reset (
            HotwordsStats * stats )
```

Reset statistics (for before/after comparison)

Reset statistics (for before/after comparison)

Resets every counter (`total_lookups`, `cache_hits`, `bucket_hits`, `misses`, `evictions`, `promotions`, `bucket_reorders`) to zero, resets all Q48.16 accumulator fields (`cache_hit_total_ns_q48`, `bucket_search_total_ns_q48`, `cache_hit_variance_sum_q48`, `bucket_search_variance_sum_q48`) to zero, resets sample counts to zero, and restores the min/max latency sentinels:

- `min_*_ns` = `INT64_MAX`
- `max_*_ns` = `INT64_MIN`

Intended for DoE benchmark runs that need a clean statistical baseline between treatment cells. The parent `HotwordsCache` also holds the `cache[]` pointer array and LRU state; those are not touched — only the `HotwordsStats` sub-struct is cleared.

Parameters

stats	Statistics structure to reset; no-op if NULL.

References HotwordsStats::bucket_hits, HotwordsStats::bucket_reorders, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsStats::cache_hit_samples HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, HotwordsStats::cache_hits, HotwordsStats::evictions, HotwordsStats::max_bucket_search_ns, HotwordsStats::max_cache_hit_ns, HotwordsStats::min_bucket_s HotwordsStats::min_cache_hit_ns, HotwordsStats::misses, HotwordsStats::promotions, and HotwordsStats::total_lookups.

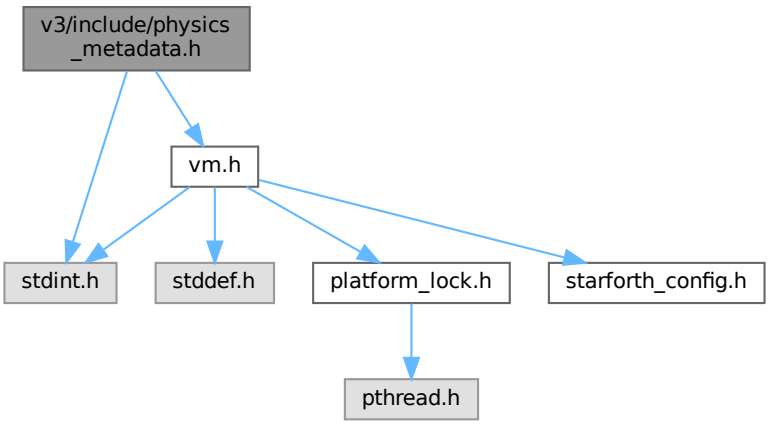
Referenced by forth_BENCH_DICT_LOOKUP(), and forth_PHYSICS_RESET_STATS().

Here is the caller graph for this function:

7.213 v3/include/physics_metadata.h File Reference

```
#include <stdint.h>
#include "vm.h"
```

Include dependency graph for physics_metadata.h:



This graph shows which files directly or indirectly include this file:

Functions

- static void physics_execution_heat_increment (DictEntry *entry)
- static cell_t physics_execution_heat_load (const DictEntry *entry)
- static uint64_t physics_decay_slope_load (const VM *vm)
- void physics_metadata_init (DictEntry *entry, uint32_t header_bytes)

  Initialise physics metadata for a newly registered DictEntry.
- void physics_metadata_set_mass (DictEntry *entry, uint32_t total_bytes)

  Update the mass (byte footprint) of a DictEntry's physics metadata.
- void physics_metadata_touch (DictEntry *entry, cell_t execution_heat, uint64_t now_ns)

  Update physics metadata after a word execution completes.
- void physics_metadata_refresh_state (DictEntry *entry)

  Re-derive and update `state_flags` for a DictEntry.
- void physics_metadata_record_latency (DictEntry *entry, uint64_t sample_ns)

  Record an execution latency sample into the per-word EMA.
- void physics_metadata_apply_seed (DictEntry *entry)

  Apply DoE-derived prior physics values to a named DictEntry.
- void physics_metadata_apply_linear_decay (DictEntry *entry, uint64_t elapsed_ticks, VM *vm)

  Apply Loop #3 linear heat decay to a DictEntry.

7.213.1 Function Documentation

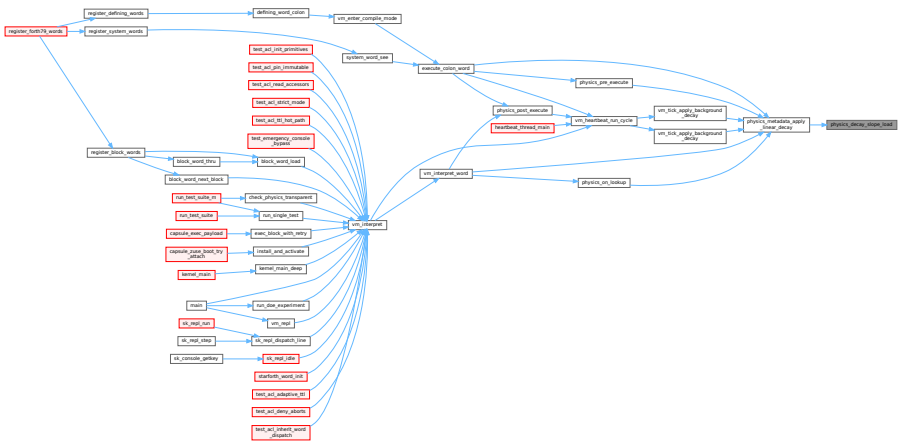
7.213.1.1 physics_decay_slope_load()

```
static uint64_t physics_decay_slope_load (
            const VM * vm )  [inline], [static]
```

References VM::decay_slope_q48.

Referenced by physics_metadata_apply_linear_decay().

Here is the caller graph for this function:



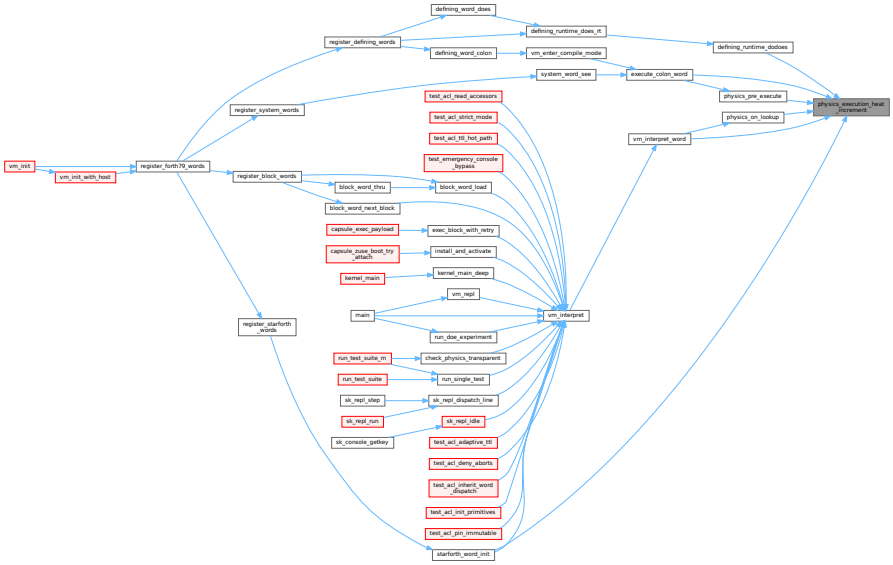
7.213.1.2 physics_execution_heat_increment()

```
static void physics_execution_heat_increment (
            DictEntry * entry )  [inline], [static]
```

References entry.

Referenced by defining_runtime_dodoes(), execute_colon_word(), physics_on_lookup(), physics_pre_execute(), starforth_word_init(), and vm_interpret_word().

Here is the caller graph for this function:



7.213.1.3 physics_execution_heat_load()

```
static cell_t physics_execution_heat_load (
            const DictEntry * entry )  [inline], [static]
```

References entry.

7.213.1.4 physics_metadata_apply_linear_decay()

```
void physics_metadata_apply_linear_decay (
            DictEntry * entry,
            uint64_t elapsed_ticks,
            VM * vm )
```

Apply Loop #3 linear heat decay to a DictEntry.

Implements the thermodynamic dissipation model: H(t) = max(0, H? - d∗t), where t is measured in heartbeat ticks (vm->heartbeat.tick_count), never in wall-clock time. The decay amount is computed as (elapsed_ticks ∗ slope_q48) >> 16 using the Q48.16 adaptive decay slope stored in the VM's heartbeat state. Uses a GCC CAS loop for atomic heat update when __GNUC__ is defined, falling back to a plain subtraction otherwise.

Ticks, not nanoseconds: this entry's `execution_heat` feeds directly into `dict_hash` (see `capsule_dict_hash_hook()`), so any wall-clock dependency here makes dictionary state – and therefore dict_hash – architecture-variable under QEMU/TCG's differing real emulation speed, or whenever real elapsed time between two touches of the same entry varies for reasons unrelated to execution (e.g. a blocking I/O wait between them). `vm->heartbeat.tick_count` only advances from `vm_tick()`, called synchronously from the interpreter's own dispatch path – a purely execution-count-driven clock, immune to how long any intervening real-time work (including blocking I/O) actually took.

No-op when:

- `WORD_FROZEN` flag is set on the entry
- `elapsed_ticks` == 0 (no heartbeat tick has fired since last decay)
- `vm->ssm_config` has L3 disabled by the Jacquard mode selector

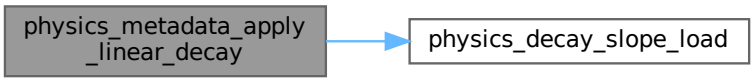
Parameters

entry	DictEntry whose heat is decayed
elapsed_ticks	Heartbeat ticks elapsed since last decay application
vm	VM providing the adaptive decay slope and L3 gate flag

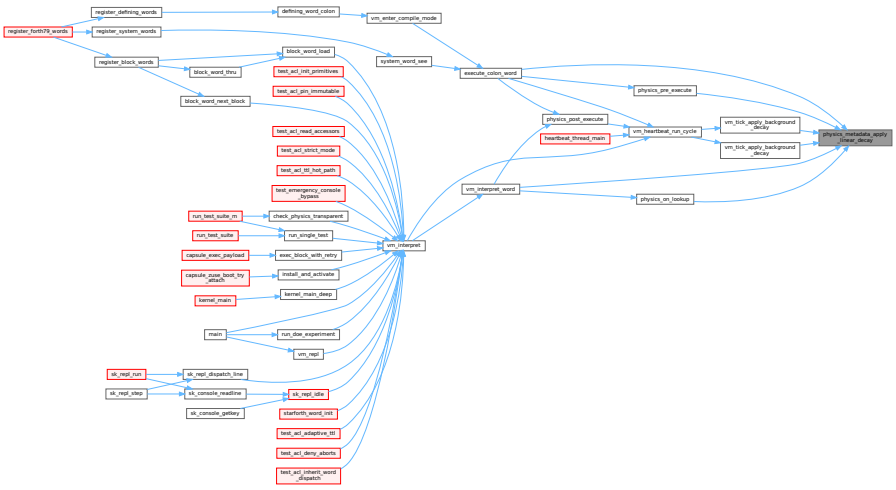
References entry, ssm_config_t::L3_linear_decay, physics_decay_slope_load(), VM::ssm_config, and WORD_FROZEN.

Referenced by execute_colon_word(), physics_on_lookup(), physics_pre_execute(), vm_interpret_word(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

Here is the call graph for this function:



Here is the caller graph for this function:



7.213.1.5 physics_metadata_apply_seed()

```
void physics_metadata_apply_seed (
            DictEntry * entry )
```

Apply DoE-derived prior physics values to a named DictEntry.

Searches the static `physics_seed_table` for an entry matching `entry->name`. If found, seeds `temperature_q8`, `avg_latency_ns`, `acl_hint`, and `pubsub_mask` with values derived from the 2^7 factorial DoE analysis. Only non-zero seed fields overwrite the current value. Called from `register_word()` for built-in primitives.

Parameters

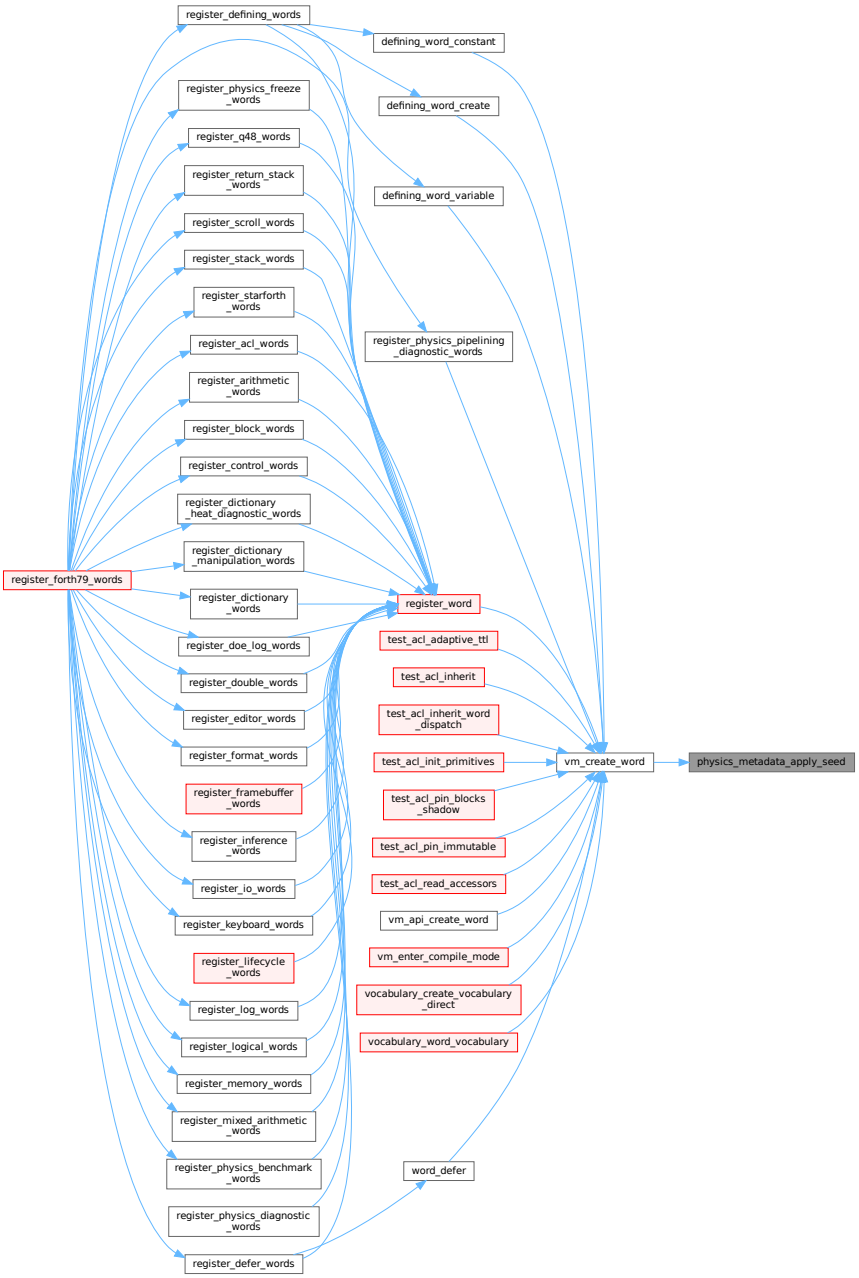
entry	DictEntry to seed (no-op if NULL or no matching table entry)

References entry, physics_seed_definition::name, physics_seed_table, strlen(), strncmp(), and physics_seed_definition::temperature_

Referenced by vm_create_word().

Here is the call graph for this function:

Here is the caller graph for this function:



7.213.1.6 physics_metadata_init()

```
void physics_metadata_init (
            DictEntry * entry,
            uint32_t header_bytes )
```

Initialise physics metadata for a newly registered DictEntry.

Zeroes all `DictPhysics` fields, sets `mass_bytes` to `header_bytes` (the byte size of the entry header), and derives initial `state_flags` from the entry's word flags. Called from `register_word()` immediately after the entry is linked into the dictionary.

Parameters

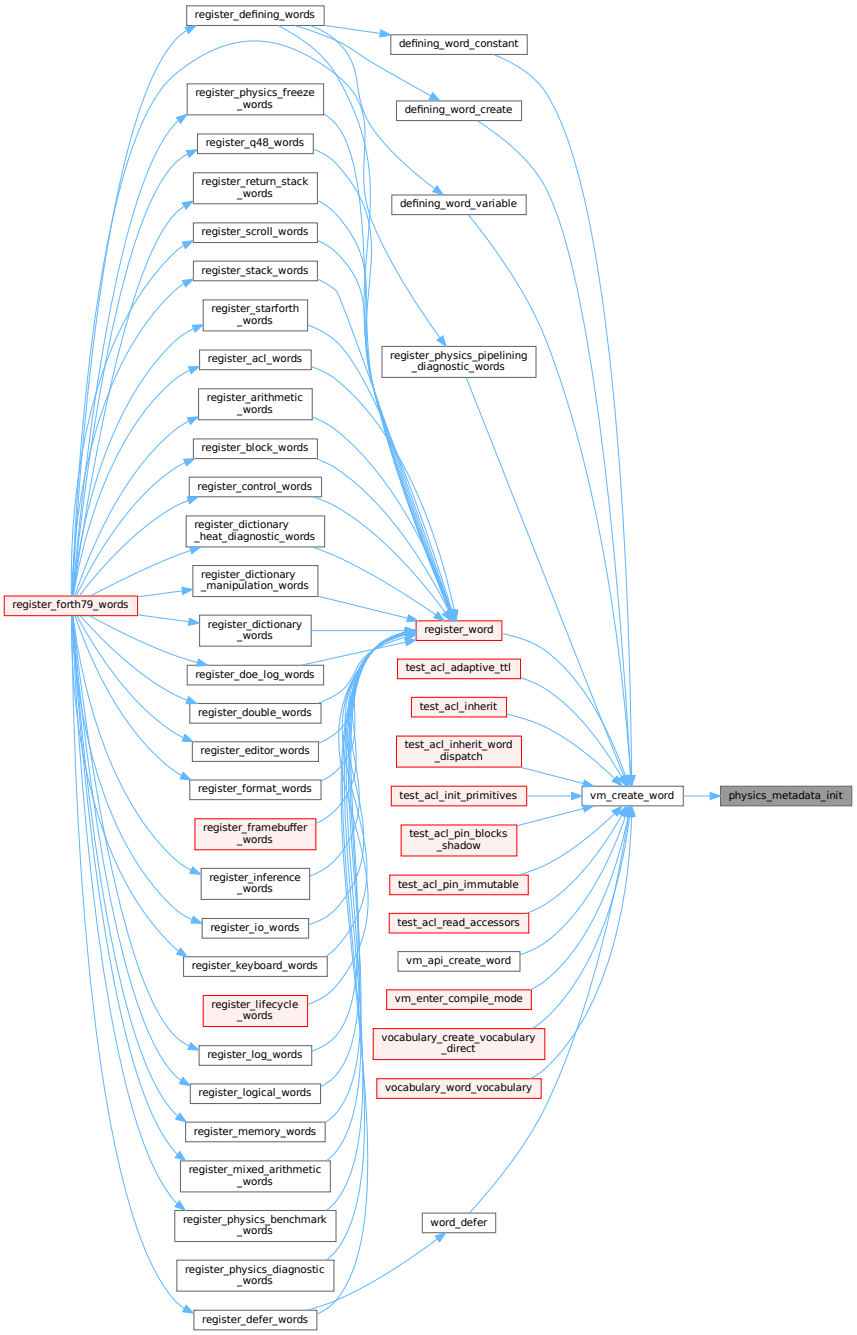
entry	DictEntry to initialise
header_bytes	Byte size of the entry's header region (for mass)

References derive_state_flags(), and entry.

Referenced by vm_create_word().

Here is the call graph for this function:

Here is the caller graph for this function:



7.213.1.7 physics_metadata_record_latency()

```
void physics_metadata_record_latency (
            DictEntry * entry,
            uint64_t sample_ns )
```

Record an execution latency sample into the per-word EMA.

Clamps `sample_ns` to uint32_t, then blends it into `avg_latency_ns` with a 1/4 EMA: new = (3∗prior + sample) / 4. Seeds `avg_latency_ns` directly from the first sample.

Parameters

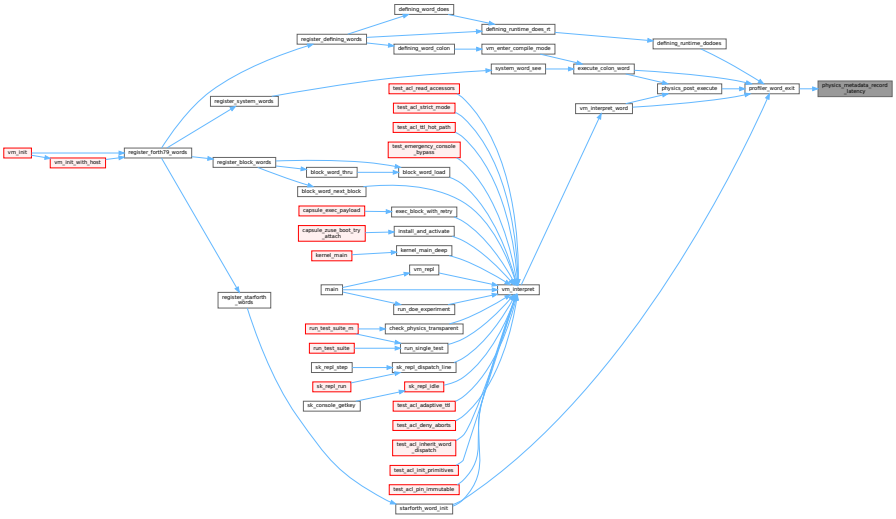
entry	DictEntry whose latency EMA is updated
sample_ns	Measured execution duration in nanoseconds

References clamp_u32(), and entry.

Referenced by profiler_word_exit().

Here is the call graph for this function:

Here is the caller graph for this function:



7.213.1.8 physics_metadata_refresh_state()

```
void physics_metadata_refresh_state (
            DictEntry * entry )
```

Re-derive and update `state_flags` for a DictEntry.

Called after word flags change (e.g. IMMEDIATE is set during compilation) to keep the physics state flags in sync with the word flags.

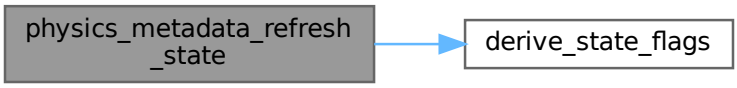
Parameters

entry	DictEntry whose state flags are to be refreshed

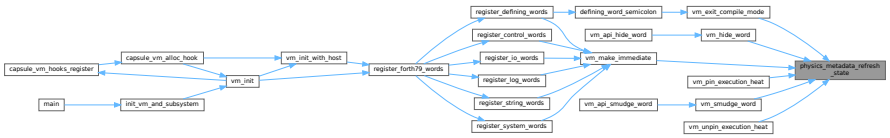
References derive_state_flags(), and entry.

Referenced by vm_exit_compile_mode(), vm_hide_word(), vm_make_immediate(), vm_pin_execution_heat(), vm_smudge_word(), and vm_unpin_execution_heat().

Here is the call graph for this function:



Here is the caller graph for this function:



7.213.1.9 physics_metadata_set_mass()

```
void physics_metadata_set_mass (
            DictEntry * entry,
            uint32_t total_bytes )
```

Update the mass (byte footprint) of a DictEntry's physics metadata.

Called after a colon definition or CREATE body is fully compiled so the mass reflects the total compiled size, not just the header.

Parameters

entry	DictEntry to update
total_bytes	Total compiled byte size (header + body)

References entry.

Referenced by vm_exit_compile_mode().

Here is the caller graph for this function:

7.213.1.10 physics_metadata_touch()

```
void physics_metadata_touch (
            DictEntry * entry,
            cell_t execution_heat,
            uint64_t now_ns )
```

Update physics metadata after a word execution completes.

Derives and stores a new smoothed `temperature_q8` from `execution_heat`, and updates both `last↩_active_ns` and `last_decay_ns` to `now_ns`. Called by `physics_post_execute()` on the post-execution path.

Parameters

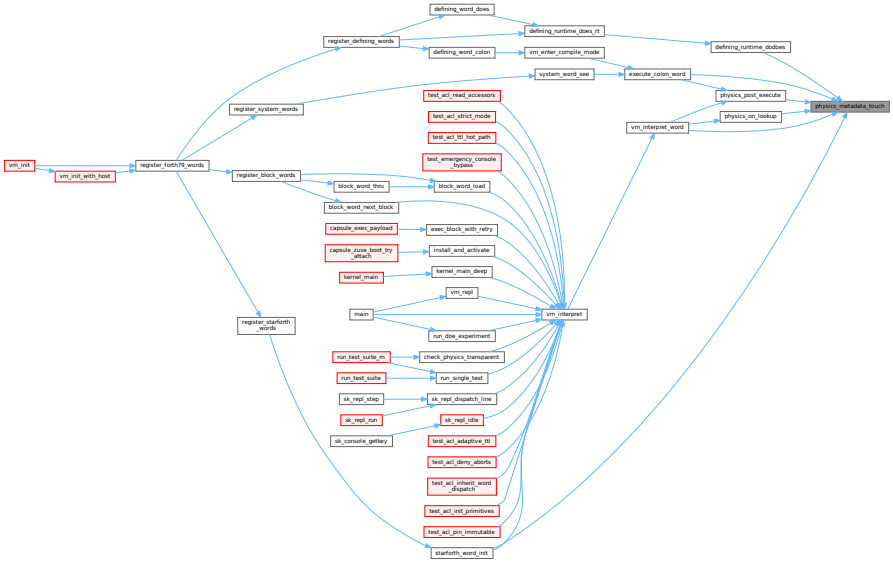
entry	DictEntry that was just executed
execution_heat	Current raw execution heat counter
now_ns	Current monotonic timestamp in nanoseconds

References entry, execution_heat, and temperature_from_execution_heat().

Referenced by defining_runtime_dodoes(), execute_colon_word(), physics_on_lookup(), physics_post_execute(), starforth_word_init(), and vm_interpret_word().

Here is the call graph for this function:

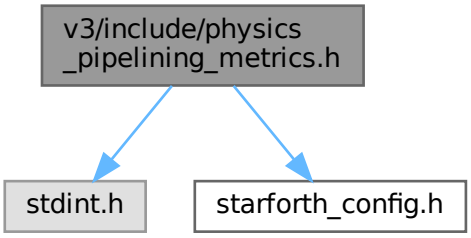
Here is the caller graph for this function:



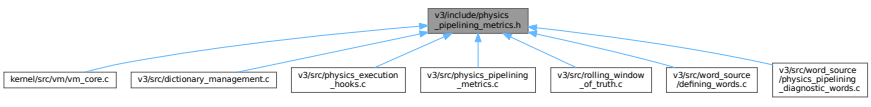
7.214 v3/include/physics_pipelining_metrics.h File Reference

```
#include <stdint.h>
#include "starforth_config.h"
```

Include dependency graph for physics_pipelining_metrics.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct WordTransitionMetrics

  SPECULATION_THRESHOLD_Q48: Minimum probability (Q48.16) to speculate on a word transition.

Typedefs

- typedef struct WordTransitionMetrics WordTransitionMetrics

  SPECULATION_THRESHOLD_Q48: Minimum probability (Q48.16) to speculate on a word transition.

Functions

- int transition_metrics_init (WordTransitionMetrics *metrics)

  Initialise a `WordTransitionMetrics` structure to its empty, ready-to-record state.
- int transition_metrics_record (WordTransitionMetrics *metrics, uint32_t next_word_id, uint32_t dict_size)

  Record one word-to-word transition in the transition heat table.
- int64_t transition_metrics_get_probability_q48 (const WordTransitionMetrics *metrics, uint32_t target_word_id)

  Return the transition probability to `target_word_id` in Q48.16 format.
- void transition_metrics_update_cache (WordTransitionMetrics *metrics, uint32_t dict_size)

  Scan the transition heat table and cache the highest-probability next word.
- void transition_metrics_record_prefetch_hit (WordTransitionMetrics *metrics, int64_t latency_saved_ns)

  Record a successful speculative prefetch and the latency it saved.
- void transition_metrics_record_prefetch_miss (WordTransitionMetrics *metrics, int64_t recovery_cost_ns)

  Record a failed speculative prefetch and its recovery overhead.
- int transition_metrics_should_speculate (const WordTransitionMetrics *metrics, uint32_t target_word_id)

  Decide whether to speculatively prefetch `target_word_id`.
- char * transition_metrics_stats_string (const WordTransitionMetrics *metrics)

  Allocate and return a human-readable transition metrics summary string.
- void transition_metrics_reset (WordTransitionMetrics *metrics)

  Reset a `WordTransitionMetrics` to empty without freeing the context window.
- void transition_metrics_cleanup (WordTransitionMetrics *metrics)

  Release all heap memory held by a `WordTransitionMetrics`.
- int transition_metrics_record_context (WordTransitionMetrics *metrics, const uint32_t *context, uint32_t window_size, uint32_t next_word_id, uint32_t dict_size)

  Record a context-conditioned transition (Phase 1 collection stub).
- int transition_metrics_update_context_window (WordTransitionMetrics *metrics, uint32_t word_id)

  Slide the context window forward by one word, appending `word_id`.
- char * transition_metrics_context_accuracy_string (const WordTransitionMetrics *metrics)

  Allocate and return a context-window status report string (Phase 1 stub).
- uint32_t transition_metrics_binary_chop_suggest_window (const WordTransitionMetrics *metrics, uint32_t current_window, double accuracy_at_current)

  Suggest a new context window size using binary-chop search (Phase 1 stub).

7.214.1 Typedef Documentation

7.214.1.1 WordTransitionMetrics

```
typedef struct WordTransitionMetrics WordTransitionMetrics
```

SPECULATION_THRESHOLD_Q48: Minimum probability (Q48.16) to speculate on a word transition.

Range: 0.10 (very aggressive) to 0.95 (very conservative) Default: see starforth_config.h (STARFORTH↩_CONFIG_SPECULATION_THRESHOLD_Q48_DEFAULT) Q48.16 encoding: 0.50 = 0x8000LL (1LL << 15) SPECULATION_DEPTH: How many words ahead to prefetch speculatively. Range: 1 (next word only) to 4 (very aggressive) Default: see starforth_config.h (STARFORTH_CONFIG_SPECULATION_DEPTH_DEFAULT) MIN_↩SAMPLES_FOR_SPECULATION: Minimum number of transitions observed before making speculation decisions. Range: 1 (immediate) to 100 (very conservative) Default: see starforth_config.h (STARFORTH_CONFIG_MIN↩_SAMPLES_FOR_SPECULATION_DEFAULT) MISPREDICTION_COST_Q48: Estimated cost (in nanoseconds, Q48.16 format) of recovering from wrong speculation. This is calibrated to the actual recovery time on target hardware. Range: 0 to 100 ns Default: see starforth_config.h (STARFORTH_CONFIG_MISPREDICTION_COST↩_Q48_DEFAULT) Q48.16 encoding: 25 ns = 25 << 16 = 0x190000LL MINIMUM_PREFETCH_ROI: Minimum expected Return-On-Investment ratio for speculation to be worthwhile. Speculation succeeds only if: (prefetch↩_latency_saved / total_attempts) > MINIMUM_PREFETCH_ROI Range: 1.0 (always speculate) to 2.0 (very selective) Default: see starforth_config.h (STARFORTH_CONFIG_MINIMUM_PREFETCH_ROI_DEFAULT) Q48.16 encoding: 1.10 = 1.10 ∗ (1 << 16) = 0x1199AL TRANSITION_WINDOW_SIZE: Knob #6 - Execution context depth for prediction

How many previous words to remember when predicting next word. Larger window captures deeper patterns but uses more memory.

Window=1: Only immediate predecessor (A→B predictions) Window=2: Previous 2 words (A,B→C predictions) - good balance Window=4: Previous 4 words (captures multi-level patterns) Window=8: Very deep, expensive – see starforth_config.h for the actual shipped default

Binary Chop Search Space (Phase 2): Iteration 1: Try window=2 (baseline) Iteration 2: Try window=1 and window=4 Iteration 3: Narrow to optimal (1, 2, or 4) Converge: Pick size with highest prediction accuracy

Range: 1 to 8 Default: see starforth_config.h (STARFORTH_CONFIG_TRANSITION_WINDOW_SIZE_DEFAULT) Trade-off: Pattern depth vs. memory usage & complexity

Tuning: make TRANSITION_WINDOW_SIZE=1 (or 2, 4, 8)

7.214.2 Function Documentation

7.214.2.1 transition_metrics_binary_chop_suggest_window()

```
uint32_t transition_metrics_binary_chop_suggest_window (
            const WordTransitionMetrics * metrics,
            uint32_t current_window,
            double accuracy_at_current )
```

Suggest a new context window size using binary-chop search (Phase 1 stub).

In Phase 2 this function will implement a binary-chop search over window sizes to converge on the width that maximises context-prediction accuracy:

- Start at window = 2.

- If accuracy improves when doubling, try 4; if it declines, try 1.
- Continue halving/doubling until the accuracy delta falls below a threshold.

Phase 1 stub behaviour: Doubles the current window each call up to 8, then wraps back to 1:

- `current_window` == 1 → suggests 2
- `current_window` == 2 → suggests 4
- `current_window` == 4 → suggests 8
- `current_window` ≥ 8 → suggests 1 (cycle back)
- Any other value → returns `current_window` unchanged.

The `accuracy_at_current` parameter (prediction accuracy [0.0, 1.0] at the current window size) is accepted for API stability with the Phase 2 caller but is not used in the stub.

Parameters

metrics	The metrics structure (unused in Phase 1 stub; reserved for Phase 2 accuracy history).
current_window	Currently active context window size.
accuracy_at_current	Prediction accuracy at `current_window` (unused in Phase 1 stub; range [0.0, 1.0]).

Returns

Suggested new window size.

7.214.2.2 transition_metrics_cleanup()

```
void transition_metrics_cleanup (
            WordTransitionMetrics * metrics )
```

Release all heap memory held by a `WordTransitionMetrics`.

Frees and NULLs:

- `metrics->transition_heat` — the per-word transition count array.
- `metrics->context_window` — the sliding context-window array.
- `metrics->context_transitions` — the Phase 2 sparse hash table (if allocated).

Does NOT zero the struct fields beyond NULLing the freed pointers. The caller must not use `metrics` after this call without a subsequent `transition_metrics_init()`. Contrast with `transition_metrics_reset()`, which keeps the context window allocated for reuse.

No-op if `metrics` is NULL.

Parameters

metrics	The metrics structure to clean up; no-op if NULL.

References WordTransitionMetrics::context_transitions, WordTransitionMetrics::context_window, free(), and WordTransitionMetrics::transition_heat.

Referenced by dictionary_word_forget().

Here is the call graph for this function:

Here is the caller graph for this function:

7.214.2.3 transition_metrics_context_accuracy_string()

```
char * transition_metrics_context_accuracy_string (
            const WordTransitionMetrics * metrics )
```

Allocate and return a context-window status report string (Phase 1 stub).

Allocates a 1024-byte buffer and fills it with a brief Phase 1 collection status message:

- `actual_window_size` — the active window width (0 if allocation failed).
- `total_context_transitions` — the number of context transitions recorded.
- A "[Phase 1 Collection - Phase 2 Analysis Pending]" status line.

Phase 2 will replace this stub with a real accuracy report showing per-window-size prediction accuracy derived from the sparse context-pattern hash table. The accuracy data will feed `transition_metrics_binary_chop_suggest_windo` to converge on the optimal context window width.

The caller is responsible for calling `free()` on the returned pointer. Returns NULL if `metrics` is NULL or `malloc()` fails.

Parameters

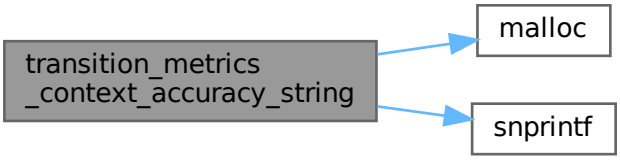
metrics	The metrics structure to report on.

Returns

Heap-allocated NUL-terminated string; caller must `free()`. NULL on allocation failure or NULL `metrics`.

References WordTransitionMetrics::actual_window_size, malloc(), snprintf(), and WordTransitionMetrics::total_context_transitions.

Here is the call graph for this function:



7.214.2.4 transition_metrics_get_probability_q48()

```
int64_t transition_metrics_get_probability_q48 (
            const WordTransitionMetrics * metrics,
            uint32_t target_word_id )
```

Return the transition probability to `target_word_id` in Q48.16 format.

Computes P(next = `target_word_id` | current word) as a Q48.16 fixed-point ratio:
`P = (transition_heat[target_word_id] « 16) / total_transitions`

using `q48_div_u64()` to guard against divide-by-zero.

Returns 0 if:

- `metrics` is NULL.
- `metrics->total_transitions` == 0 (no transitions recorded yet).
- `metrics->transition_heat` is NULL (lazy allocation has not occurred).

The caller is responsible for ensuring `target_word_id` is within the bounds of the allocated `transition_↩ heat` array; this function does not re-check bounds after verifying the NULL guard above (bounds were enforced during `transition_metrics_record()`).

Consumed by `transition_metrics_update_cache()` (scans all words to find the maximum) and `transition_metrics_should_speculate()` (checks whether a specific word's probability exceeds `SPECULATION_THRESHOLD_Q48`).

Parameters

metrics	The metrics structure to query.
target_word↩ _id	Zero-based word ID whose transition probability is requested; must be within the dict_size used at record time.

Returns

P(next = `target_word_id`) in Q48.16; 0 if unavailable.

References count, q48_div_u64(), WordTransitionMetrics::total_transitions, and WordTransitionMetrics::transition_heat.

Referenced by transition_metrics_should_speculate(), and transition_metrics_update_cache().

Here is the call graph for this function:

Here is the caller graph for this function:

7.214.2.5 transition_metrics_init()

```
int transition_metrics_init (
            WordTransitionMetrics * metrics )
```

Initialise a `WordTransitionMetrics` structure to its empty, ready-to-record state.

Sets all counter and accumulator fields to zero and performs the following allocations:

- `metrics->transition_heat` is left NULL — it is lazily allocated by the first call to `transition_metrics_record(` to avoid the `dict_size` parameter being required at construction time.
- If `TRANSITION_WINDOW_SIZE` > 0, allocates `metrics->context_window` as a zero-filled array of `TRANSITION_WINDOW_SIZE` `uint32_t` word IDs and sets `metrics->actual_window_size` accordingly. If the allocation fails, `actual_window_size` is set to 0 and context tracking degrades gracefully (all context functions become no-ops).
- `metrics->context_transitions` is left NULL — it is lazily allocated when Phase 2 context-pattern analysis is implemented.

Returns 0 on success or ?1 if `metrics` is NULL.

Parameters

metrics	The `WordTransitionMetrics` to initialise; must not be NULL.

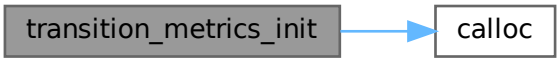
Returns

0 on success; ?1 if `metrics` is NULL.

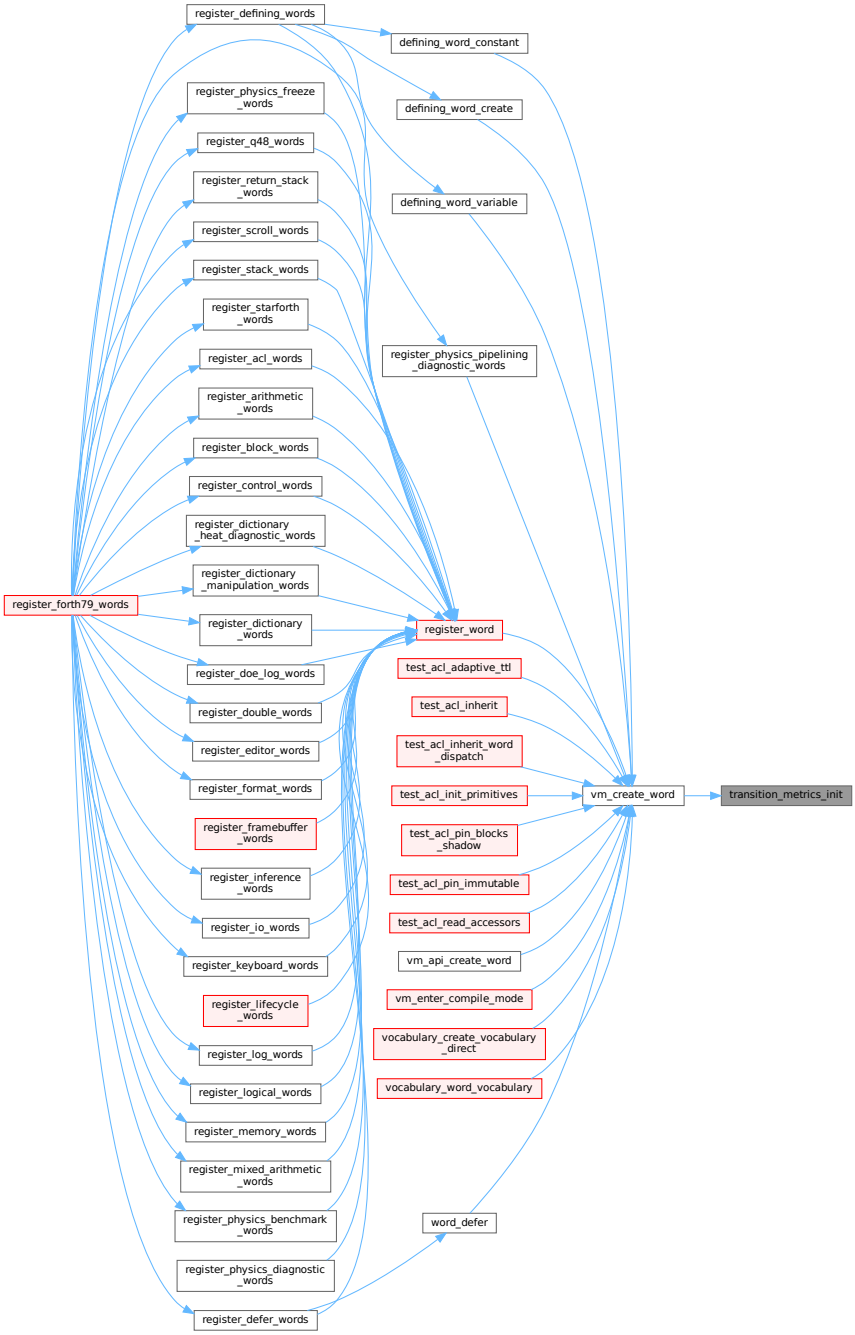
References WordTransitionMetrics::actual_window_size, calloc(), WordTransitionMetrics::context_transitions, WordTransitionMetrics::context_window, WordTransitionMetrics::context_window_pos, WordTransitionMetrics::max_transition_probab WordTransitionMetrics::misprediction_cost_q48, WordTransitionMetrics::most_likely_next_word_id, WordTransitionMetrics::prefetch_a WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_latency_saved_q48, WordTransitionMetrics::prefetch_misses, WordTransitionMetrics::total_context_transitions, WordTransitionMetrics::total_transitions, WordTransitionMetrics::transition_heat, and TRANSITION_WINDOW_SIZE.

Referenced by vm_create_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.214.2.6 transition_metrics_record()

```
int transition_metrics_record (
            WordTransitionMetrics * metrics,
            uint32_t next_word_id,
            uint32_t dict_size )
```

Record one word-to-word transition in the transition heat table.

Called from the interpreter loop each time a word executes and there is a known previous word. Increments `metrics->transition_heat`[next_word_id] by one and `metrics->total_transitions` by one.

Lazy allocation: The `transition_heat` array is not allocated at `transition_metrics_init()` time; on the first call when `metrics->transition_heat` == NULL, it is allocated as a zero-filled array of `dict_size` `uint64_t` counters. If the allocation fails ?1 is returned and the transition is silently dropped.

If `next_word_id` $\geq$ `dict_size` the call is rejected with ?1 to prevent an out-of-bounds write into `transition_heat` (which was allocated with size `dict_size`).

The accumulated `transition_heat`[] table is consumed by `transition_metrics_get_probability_q48()` and `transition_metrics_update_cache()` to determine the most-likely next word for speculative prefetch.

Parameters

metrics	The metrics structure to update.
next_word_id	Zero-based word ID of the word that followed the current word; must be $<$ `dict_size`.
dict_size	Current dictionary size, used both as the bounds check for `next_word_id` and as the allocation size for the lazy-allocated `transition_heat` array.

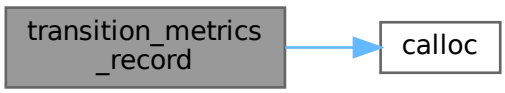
Returns

0 on success; ?1 on NULL `metrics`, out-of-bounds `next_word_id`, or allocation failure.

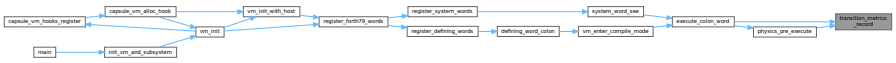
References calloc(), WordTransitionMetrics::total_transitions, and WordTransitionMetrics::transition_heat.

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the call graph for this function:



Here is the caller graph for this function:



7.214.2.7 transition_metrics_record_context()

```
int transition_metrics_record_context (
            WordTransitionMetrics * metrics,
            const uint32_t * context,
            uint32_t window_size,
            uint32_t next_word_id,
            uint32_t dict_size )
```

Record a context-conditioned transition (Phase 1 collection stub).

Accepts a `context` window of `window_size` preceding word IDs and the `next_word_id` that followed. In Phase 1 only the total count is tracked: `metrics->total_context_transitions` is incremented by one, providing a baseline count that Phase 2 analysis can use to size its hash tables.

Phase 2 TODO: Build a sparse hash table keyed on the context pattern (context[0], ..., context[window_size-1]) to record per-context next-word distributions. The Phase 2 analysis will feed `transition_metrics_binary_chop_suggest_w` with accuracy data to tune the optimal window size.

Returns ?1 (no-op) if `metrics` or `context` are NULL, `window_size` is 0, or `next_word_id` $\geq$ `dict_size`.

Parameters

metrics	The metrics structure to update.
context	Array of `window_size` word IDs preceding `next_word_id`.
window_size	Number of entries in `context`; must be > 0.
next_word_id	Word ID that followed the context sequence.
dict_size	Current dictionary size; used for bounds checking `next_word_id`.

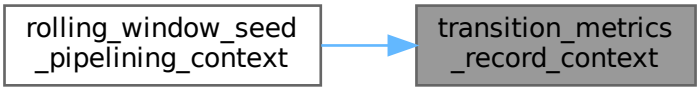
Returns

0 on success; ?1 on invalid arguments.

References WordTransitionMetrics::total_context_transitions.

Referenced by rolling_window_seed_pipelining_context().

Here is the caller graph for this function:



7.214.2.8 transition_metrics_record_prefetch_hit()

```
void transition_metrics_record_prefetch_hit (
            WordTransitionMetrics * metrics,
            int64_t latency_saved_ns )
```

Record a successful speculative prefetch and the latency it saved.

Increments `metrics->prefetch_hits` by one and accumulates `latency_saved_ns` (converted to Q48.16 via `ns_to_q48()`) into `metrics->prefetch_latency_saved_q48`. The accumulated total is reported by `transition_metrics_stats_string()` as the aggregate latency benefit of correct speculation.

Called by the speculative-execution path when a prefetched word matches the word that was actually executed next.

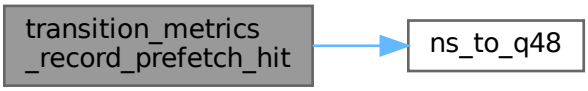
Parameters

metrics	The metrics structure to update; no-op if NULL.
latency_saved_ns	The number of nanoseconds saved by avoiding a full dictionary lookup on this particular hit.

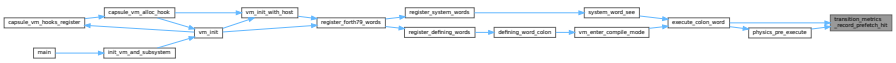
References ns_to_q48(), WordTransitionMetrics::prefetch_hits, and WordTransitionMetrics::prefetch_latency_saved_q48.

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the call graph for this function:



Here is the caller graph for this function:



7.214.2.9 transition_metrics_record_prefetch_miss()

```
void transition_metrics_record_prefetch_miss (
            WordTransitionMetrics * metrics,
            int64_t recovery_cost_ns )
```

Record a failed speculative prefetch and its recovery overhead.

Increments `metrics->prefetch_misses` by one and accumulates `recovery_cost_ns` (converted to Q48.16 via `ns_to_q48()`) into `metrics->misprediction_cost_q48`. The accumulated total is the aggregate penalty paid for incorrect speculation and is reported by `transition_metrics_stats_string()` as "Misprediction Cost".

The net benefit of the pipelining subsystem is:
```
net_ns = prefetch_latency_saved_q48 - misprediction_cost_q48
```

A positive net indicates that speculation is profitable overall.

Called by the speculative-execution path when the prefetched word does not match the word that was actually executed next (branch misprediction analogue).

Parameters

metrics	The metrics structure to update; no-op if NULL.
recovery_cost_ns	The number of nanoseconds spent unwinding the incorrect speculation (cache flush, state restore).

References WordTransitionMetrics::misprediction_cost_q48, ns_to_q48(), and WordTransitionMetrics::prefetch_misses.

Here is the call graph for this function:

7.214.2.10 transition_metrics_reset()

```
void transition_metrics_reset (
            WordTransitionMetrics * metrics )
```

Reset a `WordTransitionMetrics` to empty without freeing the context window.

Frees and NULLs `metrics->transition_heat` (so the next `transition_metrics_record()` will re-allocate it), then zeroes all counter and accumulator fields. Also zeroes the context-window array (if allocated) and resets `context_window_pos` to 0, and frees and NULLs `context_transitions`. `actual_window_size` and the `context_window` pointer itself are preserved — the window stays allocated and ready for reuse.

Intended for DoE benchmark runs that need a clean statistical baseline between treatment cells without the overhead of full teardown and reinitialisation. Cheaper than `transition_metrics_cleanup()` + `transition_metrics_init()` because it avoids reallocating the context window.

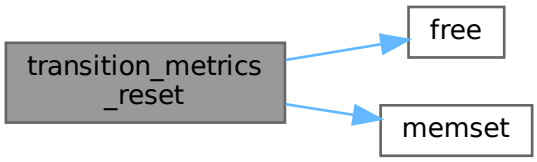
Parameters

metrics	The metrics structure to reset; no-op if NULL.

References WordTransitionMetrics::actual_window_size, WordTransitionMetrics::context_transitions, WordTransitionMetrics::context_
WordTransitionMetrics::context_window_pos, free(), WordTransitionMetrics::max_transition_probability_q48,
memset(), WordTransitionMetrics::misprediction_cost_q48, WordTransitionMetrics::most_likely_next_word_id,
WordTransitionMetrics::prefetch_attempts, WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_latency_saved_q48
WordTransitionMetrics::prefetch_misses, WordTransitionMetrics::total_context_transitions, WordTransitionMetrics::total_transitions,
and WordTransitionMetrics::transition_heat.

Referenced by forth_PIPELINING_RESET_ALL().

Here is the call graph for this function:



Here is the caller graph for this function:

7.214.2.11 transition_metrics_should_speculate()

```
int transition_metrics_should_speculate (
            const WordTransitionMetrics * metrics,
            uint32_t target_word_id )
```

Decide whether to speculatively prefetch `target_word_id`.

Applies a two-gate policy before authorising speculation:

1. **Minimum sample gate:** `metrics->total_transitions` must be $\geq$ `MIN_SAMPLES_FOR_SPECULATION`. Below this threshold the transition probabilities are statistically unreliable — speculation would be indistinguishable from guessing.
2. **Probability threshold gate:** the Q48.16 probability returned by `transition_metrics_get_probability_q48`(metrics, `target_word_id`) must be $\geq$ `SPECULATION_THRESHOLD_Q48`. Words with very low conditional probability of following the current word are not worth prefetching.

Both gates must pass for the function to return 1. A Phase 4 ROI check (comparing expected latency savings against expected misprediction cost) is planned but not yet implemented; a TODO comment marks the extension point.

Returns 0 if `metrics` or `transition_heat` are NULL, or if either gate fails.

Parameters

metrics	The metrics structure to consult.
target_word↩ _id	Zero-based ID of the candidate next word.

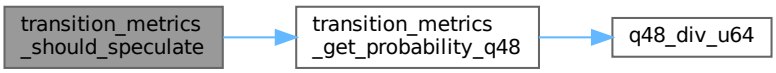
Returns

1 if speculation is recommended; 0 otherwise.

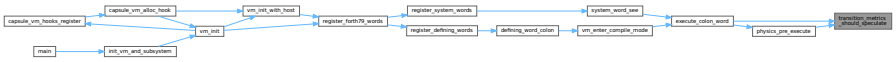
References MIN_SAMPLES_FOR_SPECULATION, SPECULATION_THRESHOLD_Q48, WordTransitionMetrics::total_transitions, WordTransitionMetrics::transition_heat, and transition_metrics_get_probability_q48().

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the call graph for this function:



Here is the caller graph for this function:



7.214.2.12 transition_metrics_stats_string()

```
char * transition_metrics_stats_string (
            const WordTransitionMetrics * metrics )
```

Allocate and return a human-readable transition metrics summary string.

Allocates a 2048-byte buffer and fills it with a multi-line report:

- Total transitions recorded.
- Prefetch attempts, hits (with hit-rate %), and misses.
- Aggregate latency saved by correct speculation (from `prefetch_latency_saved_q48`, converted to integer ns via `q48_to_ns()`).
- Aggregate misprediction cost (from `misprediction_cost_q48`).
- Net benefit (saved ? cost) in nanoseconds.
- The most-likely next word ID and its raw Q48.16 probability.

The caller is responsible for calling `free()` on the returned pointer. Returns NULL if `metrics` is NULL or `malloc()` fails.

Parameters

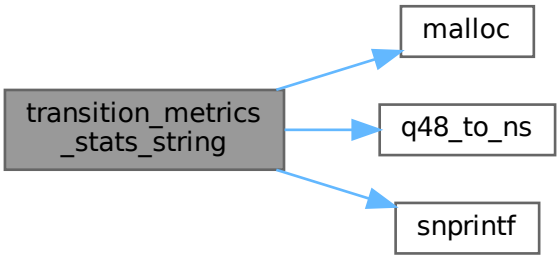
metrics	The metrics structure to summarise.

Returns

Heap-allocated NUL-terminated stats string; caller must `free()`. NULL on allocation failure or NULL `metrics`.

References malloc(), WordTransitionMetrics::max_transition_probability_q48, WordTransitionMetrics::misprediction_cost_q48, WordTransitionMetrics::most_likely_next_word_id, WordTransitionMetrics::prefetch_attempts, WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_latency_saved_q48, WordTransitionMetrics::prefetch_misses, q48_to_ns(), snprintf(), and WordTransitionMetrics::total_transitions.

Here is the call graph for this function:



7.214.2.13 transition_metrics_update_cache()

```
void transition_metrics_update_cache (
            WordTransitionMetrics * metrics,
            uint32_t dict_size )
```

Scan the transition heat table and cache the highest-probability next word.

Iterates over all `dict_size` entries in `metrics->transition_heat[]`, calling `transition_metrics_get_probabil` for each non-zero entry and tracking the maximum. After the scan:

- `metrics->max_transition_probability_q48` holds the peak probability (Q48.16).
- `metrics->most_likely_next_word_id` holds the word ID of that peak.

These two cached fields allow `transition_metrics_should_speculate()` to make a prefetch decision in O(1) without re-scanning the full table on every word dispatch.

If `metrics`, `transition_heat`, or `total_transitions` are not valid, both fields are reset to 0 and the function returns immediately.

Called after each `transition_metrics_record()` in the high-frequency interpreter path, so the implementation must be fast. The full `dict_size` scan runs in O(dict_size) and skips zero-count entries early.

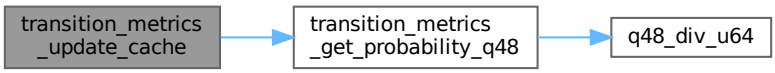
Parameters

metrics	The metrics structure to update.
dict_size	Number of entries in `metrics->transition_heat[]`; must match the size used at allocation time.

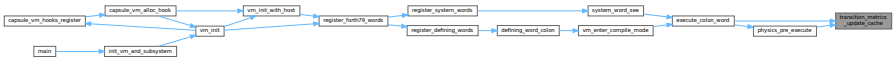
References WordTransitionMetrics::max_transition_probability_q48, WordTransitionMetrics::most_likely_next_word_id, WordTransitionMetrics::total_transitions, WordTransitionMetrics::transition_heat, and transition_metrics_get_probability_q48().

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the call graph for this function:



Here is the caller graph for this function:



7.214.2.14 transition_metrics_update_context_window()

```
int transition_metrics_update_context_window (
            WordTransitionMetrics * metrics,
            uint32_t word_id )
```

Slide the context window forward by one word, appending `word_id`.

Implements a fixed-length sliding window over the recent word-ID history. Each call shifts all existing entries one position to the left (dropping the oldest), then writes `word_id` into the last slot:

```
context_window[0..n-2] = context_window[1..n-1]
context_window[n-1] = word_id
```

This produces a FIFO queue of the last `actual_window_size` word IDs that can be passed to `transition_metrics_record_context()` for context-sensitive transition tracking (Phase 2).

Returns ?1 and is a no-op if:

- `metrics` is NULL.
- `context_window` is NULL (allocation at init failed — degraded mode).
- `actual_window_size` == 0.

Parameters

metrics	The metrics structure whose context window is updated.
word↩ _id	The word ID just executed; appended to the right of the window.

Returns

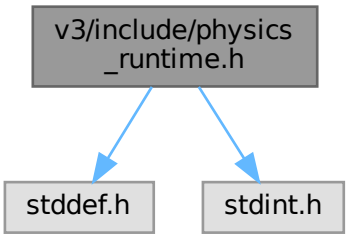
0 on success; ?1 if the context window is unavailable.

References WordTransitionMetrics::actual_window_size, WordTransitionMetrics::context_window, and word_id.

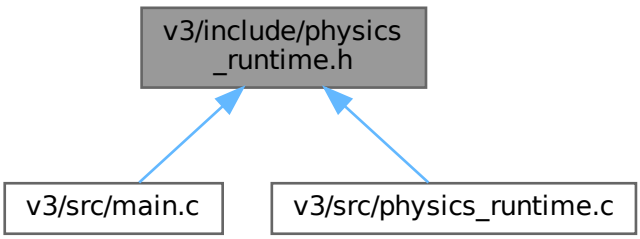
7.215 v3/include/physics_runtime.h File Reference

```
#include <stddef.h>
#include <stdint.h>
```

Include dependency graph for physics_runtime.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct physics_host_snapshot

  Snapshot of scheduler-adjacent host signals.
- struct physics_analytics_event_header

  Event header written into the analytics ring buffer.
- struct physics_analytics_header

  Analytics heap header seen by both producer (VM) and consumer (HOLA).
- struct physics_analytics_heap

  Simple view onto the analytics heap layout.

Macros

- #define PHYSICS_ANALYTICS_DEFAULT_HEAP_BYTES (10u ∗ 1024u ∗ 1024u)

  Default analytics heap size (10 MiB)
- #define HOLA_SHARED_MAGIC 0x484f4c41u

  Magic tag for HOLA analytics heap headers ('HOLA')
- #define HOLA_PROTOCOL_MAJOR 0x0001u

  HOLA protocol version (major.minor)
- #define HOLA_PROTOCOL_MINOR 0x0000u
- #define PHYSICS_ANALYTICS_CHANNEL_HOST_SNAPSHOT 0x00000002u

  Analytics channel ids.
- #define PHYSICS_HOST_FLAG_PSI 0x0001u

  Host snapshot flag bits.
- #define PHYSICS_HOST_FLAG_CGROUP 0x0002u
- #define PHYSICS_HOST_FLAG_CPU_STAT 0x0004u

Typedefs

- typedef enum physics_host_backend physics_host_backend_t

  Host backend identifier.
- typedef struct physics_host_snapshot physics_host_snapshot_t

  Snapshot of scheduler-adjacent host signals.
- typedef struct physics_analytics_event_header physics_analytics_event_header_t

  Event header written into the analytics ring buffer.
- typedef struct physics_analytics_header physics_analytics_header_t

  Analytics heap header seen by both producer (VM) and consumer (HOLA).
- typedef struct physics_analytics_heap physics_analytics_heap_t

  Simple view onto the analytics heap layout.

Enumerations

- enum physics_host_backend { PHYSICS_HOST_BACKEND_POSIX = 0 , PHYSICS_HOST_BACKEND_L4RE = 1 , PHYSICS_HOST_BACKEND_FAKE = 2 }

  Host backend identifier.

Functions

- int physics_runtime_init (size_t analytics_heap_bytes)

  Initialise the physics runtime and analytics heap.
- void physics_runtime_shutdown (void)

  Tear down physics runtime services and release heap storage.
- int physics_host_snapshot (physics_host_snapshot_t *out)

  Capture a host environment snapshot and publish it to the analytics ring.
- int physics_analytics_publish_event (uint32_t channel, const void *payload, uint16_t payload_bytes)

  Publish an analytics event into the ring buffer.
- const physics_analytics_heap_t * physics_analytics_heap_info (void)

  Retrieve the analytics heap descriptor.

7.215.1 Macro Definition Documentation

7.215.1.1 HOLA_PROTOCOL_MAJOR

```
#define HOLA_PROTOCOL_MAJOR 0x0001u
```

HOLA protocol version (major.minor)

7.215.1.2 HOLA_PROTOCOL_MINOR

```
#define HOLA_PROTOCOL_MINOR 0x0000u
```

7.215.1.3 HOLA_SHARED_MAGIC

```
#define HOLA_SHARED_MAGIC 0x484f4c41u
```

Magic tag for HOLA analytics heap headers ('HOLA')

7.215.1.4 PHYSICS_ANALYTICS_CHANNEL_HOST_SNAPSHOT

```
#define PHYSICS_ANALYTICS_CHANNEL_HOST_SNAPSHOT 0x00000002u
```

Analytics channel ids.

7.215.1.5 PHYSICS_ANALYTICS_DEFAULT_HEAP_BYTES

```
#define PHYSICS_ANALYTICS_DEFAULT_HEAP_BYTES (10u * 1024u * 1024u)
```

Default analytics heap size (10 MiB)

7.215.1.6 PHYSICS_HOST_FLAG_CGROUP

```
#define PHYSICS_HOST_FLAG_CGROUP 0x0002u
```

7.215.1.7 PHYSICS_HOST_FLAG_CPU_STAT

```
#define PHYSICS_HOST_FLAG_CPU_STAT 0x0004u
```

7.215.1.8 PHYSICS_HOST_FLAG_PSI

```
#define PHYSICS_HOST_FLAG_PSI 0x0001u
```

Host snapshot flag bits.

7.215.2 Typedef Documentation

7.215.2.1 physics_analytics_event_header_t

```
typedef struct physics_analytics_event_header physics_analytics_event_header_t
```

Event header written into the analytics ring buffer.

7.215.2.2 physics_analytics_header_t

```
typedef struct physics_analytics_header physics_analytics_header_t
```

Analytics heap header seen by both producer (VM) and consumer (HOLA).

7.215.2.3 physics_analytics_heap_t

```
typedef struct physics_analytics_heap physics_analytics_heap_t
```

Simple view onto the analytics heap layout.

7.215.2.4 physics_host_backend_t

```
typedef enum physics_host_backend physics_host_backend_t
```

Host backend identifier.

7.215.2.5 physics_host_snapshot_t

```
typedef struct physics_host_snapshot physics_host_snapshot_t
```

Snapshot of scheduler-adjacent host signals.

Fields are intentionally fixed width to maximise portability and allow the governance repository to consume binary dumps without per-platform quirks.

7.215.3 Enumeration Type Documentation

7.215.3.1 physics_host_backend

```
enum physics_host_backend
```

Host backend identifier.

Enumerator

PHYSICS_HOST_BACKEND_POSIX	
PHYSICS_HOST_BACKEND_L4RE	
PHYSICS_HOST_BACKEND_FAKE	

7.215.4 Function Documentation

7.215.4.1 physics_analytics_heap_info()

```
const physics_analytics_heap_t * physics_analytics_heap_info (
            void  )
```

Retrieve the analytics heap descriptor.

Returns

Pointer to heap descriptor (NULL if runtime not initialised)

Retrieve the analytics heap descriptor.

Returns

Pointer to the heap descriptor, or NULL if not yet initialised

References g_runtime, physics_runtime_state::heap, and physics_runtime_state::heap_ready.

7.215.4.2 physics_analytics_publish_event()

```
int physics_analytics_publish_event (
            uint32_t channel,
            const void * payload,
            uint16_t payload_bytes )
```

Publish an analytics event into the ring buffer.

Writes a `physics_analytics_event_header_t` followed by the payload (8-byte padded) into the ring at the current write offset. If insufficient space is available, increments `dropped_events` and returns -1. The event is timestamped with `sf_monotonic_ns()` at write time.

Parameters

channel	Event channel identifier (e.g. `PHYSICS_ANALYTICS_CHANNEL_HOST_SNAPSHOT`)
payload	Event payload bytes (must not be NULL)
payload_bytes	Length of payload in bytes

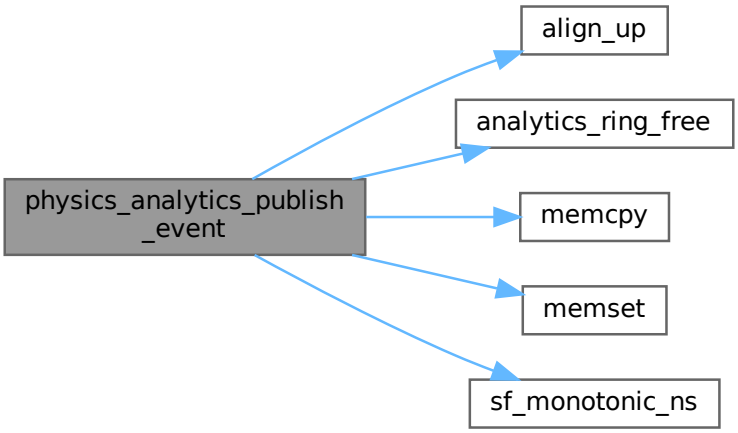
Returns

0 on success, -1 if the heap is not ready, payload is NULL, or ring is full

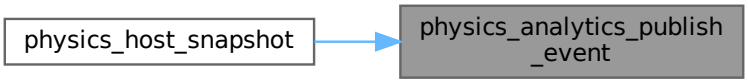
References align_up(), analytics_ring_free(), physics_analytics_event_header::channel, physics_analytics_header::dropped_events, g_runtime, physics_analytics_heap::header, physics_runtime_state::heap, physics_runtime_state::heap_ready, memcpy(), memset(), physics_analytics_event_header::payload_bytes, physics_analytics_header::produce_seq, physics_analytics_event_header::reserved, ring, physics_analytics_heap::ring, physics_analytics_header::ring_bytes, sf_monotonic_ns(), physics_analytics_event_header::timestamp_ns, and physics_analytics_header::write_offset.

Referenced by physics_host_snapshot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.215.4.3 physics_host_snapshot()

```
int physics_host_snapshot (
            physics_host_snapshot_t * out )
```

Capture a host environment snapshot and publish it to the analytics ring.

Uses the POSIX backend. On success also publishes the snapshot as a PHYSICS_ANALYTICS_CHANNEL_↩ HOST_SNAPSHOT event to the analytics ring buffer (if the heap is initialised).

Parameters

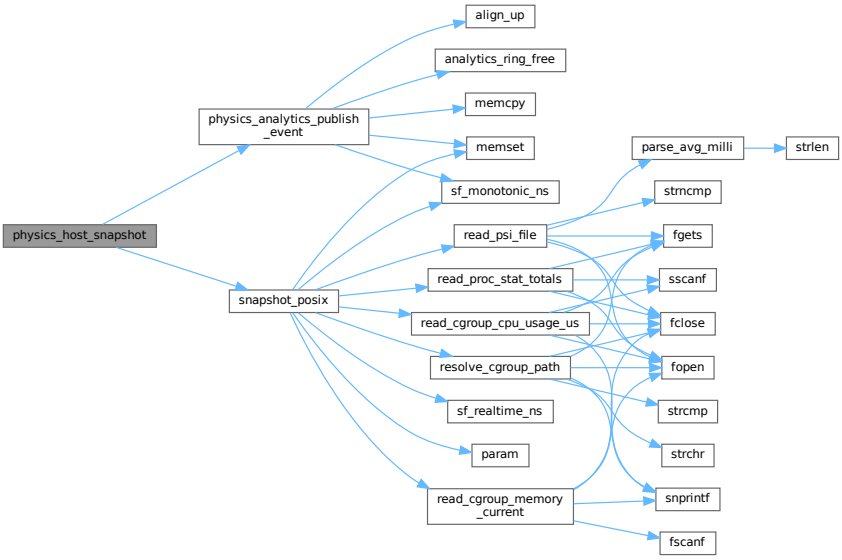
out	Output snapshot struct to populate (must not be NULL)

Returns

0 on success, -1 if `out` is NULL or the backend fails

References g_runtime, physics_runtime_state::heap_ready, PHYSICS_ANALYTICS_CHANNEL_HOST_SNAPSHOT, physics_analytics_publish_event(), and snapshot_posix().

Here is the call graph for this function:



7.215.4.4 physics_runtime_init()

```
int physics_runtime_init (
            size_t analytics_heap_bytes )
```

Initialise the physics runtime and analytics heap.

Must be called before any other physics_runtime_∗ function. Idempotent — safe to call multiple times; subsequent calls return 0 immediately without re-allocating.

Parameters

analytics_heap_bytes	Desired analytics heap size (0 = default)

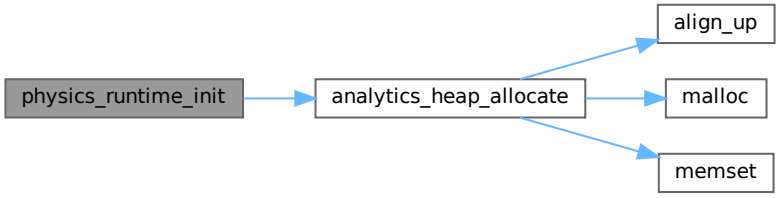
Returns

0 on success, -1 on allocation failure

References analytics_heap_allocate().

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:

7.215.4.5 physics_runtime_shutdown()

```
void physics_runtime_shutdown (
            void  )
```

Tear down physics runtime services and release heap storage.

Tear down physics runtime services and release heap storage.

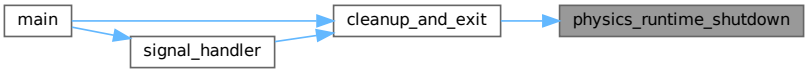
Safe to call when the runtime was never initialised. After this call the analytics heap is gone and no events can be published until `physics_runtime_init()` is called again.

References analytics_heap_release().

Referenced by cleanup_and_exit().

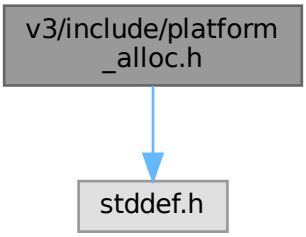
Here is the call graph for this function:

Here is the caller graph for this function:

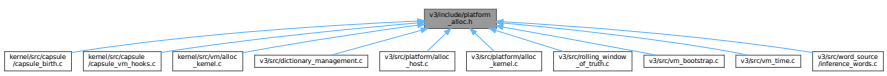


7.216 v3/include/platform_alloc.h File Reference

`#include <stddef.h>`
Include dependency graph for platform_alloc.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct sf_alloc_stats

Typedefs

- typedef struct sf_alloc_stats sf_alloc_stats_t

Functions

- void * sf_malloc (size_t size)

  Allocate `size` bytes from the system heap.
- void * sf_calloc (size_t count, size_t size)

  Allocate a zero-initialised array of `count` elements of `size` bytes each.
- void * sf_realloc (void *ptr, size_t new_size)

  Resize a previously allocated block to `new_size` bytes.
- void sf_free (void *ptr)

  Release a previously allocated block back to the system heap.
- int sf_alloc_init (void)

  Initialise the host allocator statistics.
- void sf_alloc_get_stats (sf_alloc_stats_t *stats)

  Copy the current allocator statistics into `stats`.

7.216.1 Typedef Documentation

7.216.1.1 sf_alloc_stats_t

```
typedef struct sf_alloc_stats sf_alloc_stats_t
```

7.216.2 Function Documentation

7.216.2.1 sf_alloc_get_stats()

```
void sf_alloc_get_stats (
            sf_alloc_stats_t * stats )
```

Copy the current allocator statistics into `stats`.

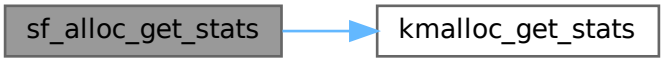
Fills `*stats` with a snapshot of `g_stats`. Note that `used_bytes` overstates the live total when blocks have been freed or reallocated, because freed sizes are not tracked. `free_count` is accurate.

Parameters

stats	Output buffer to populate; no-op if NULL

References sf_alloc_stats::alloc_count, sf_alloc_stats::free_count, g_alloc_count, g_free_count, g_stats, g_stats, kmalloc_get_stats(), kmalloc_stats_t::peak_bytes, sf_alloc_stats::peak_bytes, kmalloc_stats_t::total_bytes, sf_alloc_stats::total_bytes, kmalloc_stats_t::used_bytes, and sf_alloc_stats::used_bytes.

Here is the call graph for this function:



7.216.2.2 sf_alloc_init()

```
int sf_alloc_init (
            void  )
```

Initialise the host allocator statistics.

Resets the `g_stats` struct to zero. Safe to call multiple times; subsequent calls simply reset the counters. No heap memory is allocated by this function — the underlying allocator is the system `malloc`.

Returns

0 always (cannot fail on the hosted path)

Initialise the host allocator statistics.

Resets `g_arena_offset` to zero and clears all `g_stats` fields. Sets `g_initialized` so that `sf_malloc()` skips the lazy-init guard. Safe to call at any point; all prior allocations become invalid after a reset, so this must only be called before any VM allocation takes place.

Returns

0 always (cannot fail)

Initialise the host allocator statistics.

The backing store is now the shared kernel heap (`kmalloc.c`), already initialised at boot (M6) well before any VM allocation can occur – there is nothing left for this function to set up, and "resetting" a heap shared by every other kernel subsystem would be actively wrong. Kept callable (matches its documented "safe to call at any point" contract) so no caller needs to change.

Returns

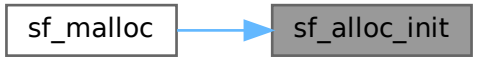
0 always (cannot fail)

References sf_alloc_stats::alloc_count, sf_alloc_stats::free_count, g_arena_offset, g_initialized, g_stats, g_stats, memset(), sf_alloc_stats::peak_bytes, SF_ARENA_SIZE, sf_alloc_stats::total_bytes, and sf_alloc_stats::used_bytes.

Referenced by sf_malloc().

Here is the call graph for this function:

Here is the caller graph for this function:



7.216.2.3 sf_calloc()

```
void * sf_calloc (
            size_t count,
            size_t size )
```

Allocate a zero-initialised array of `count` elements of `size` bytes each.

Delegates to `calloc()`. Updates statistics the same way as `sf_malloc()`: adds `count*size` to `used_bytes`, increments `alloc_count`, and updates `peak_bytes`.

Parameters

count	Number of elements; 0 returns NULL
size	Size of each element in bytes; 0 returns NULL

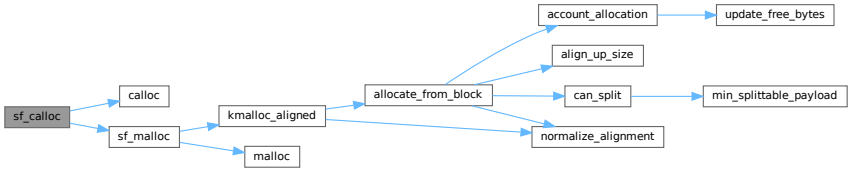
Returns

Pointer to zero-filled memory, or NULL on allocation failure or zero arguments

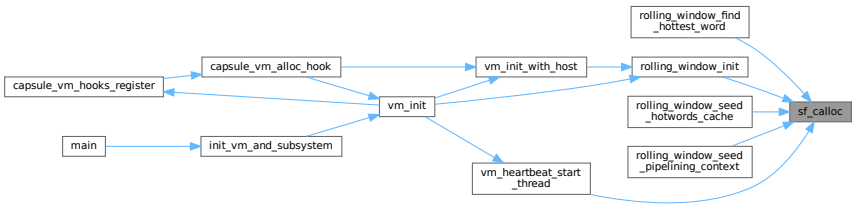
References sf_alloc_stats::alloc_count, calloc(), count, g_stats, sf_alloc_stats::peak_bytes, sf_malloc(), and sf_alloc_stats::used_bytes.

Referenced by rolling_window_find_hottest_word(), rolling_window_init(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), and vm_heartbeat_start_thread().

Here is the call graph for this function:



Here is the caller graph for this function:



7.216.2.4 sf_free()

```
void sf_free (
            void * ptr )
```

Release a previously allocated block back to the system heap.

Delegates to `free()`. Increments `g_stats.free_count` on non-NULL `ptr`. The freed byte count is not subtracted from `used_bytes` because the original size is not tracked — see `sf_realloc()` note.

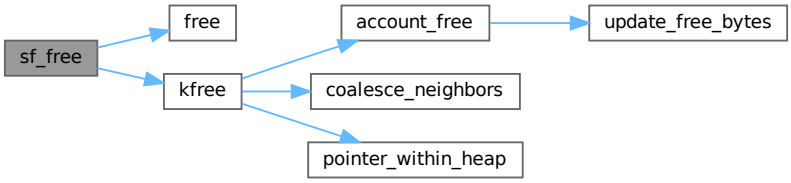
Parameters

ptr	Pointer to free; NULL is a safe no-op

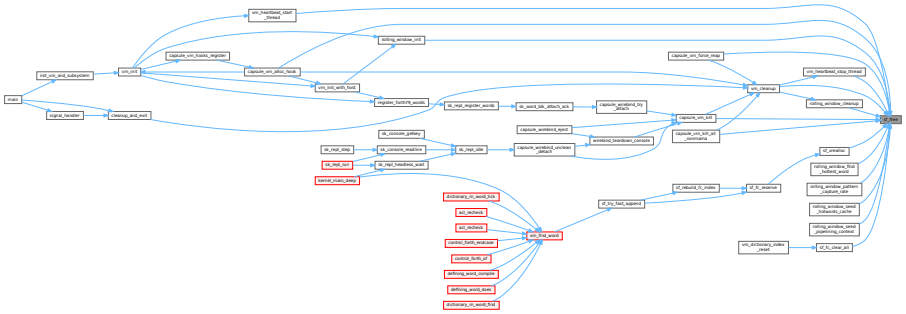
References free(), sf_alloc_stats::free_count, g_free_count, g_stats, g_stats, and kfree().

Referenced by capsule_vm_alloc_hook(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_vm_kill_all_nonmama(), rolling_window_cleanup(), rolling_window_find_hottest_word(), rolling_window_init(), rolling_window_pattern_capture_rate(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), sf_fc_clear_all(), sf_xrealloc(), vm_cleanup(), vm_heartbeat_start_thread(), and vm_heartbeat_stop_thread().

Here is the call graph for this function:



Here is the caller graph for this function:



7.216.2.5 sf_malloc()

```
void * sf_malloc (
            size_t size )
```

Allocate `size` bytes from the system heap.

Delegates to `malloc()`. On success, increments `g_stats.used_bytes` and `g_stats.alloc_count`, and updates `g_stats.peak_bytes` if the new used total exceeds the recorded peak.

Parameters

size	Number of bytes to allocate; 0 returns NULL

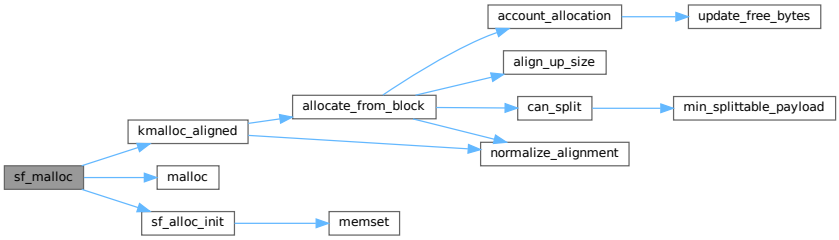
Returns

Pointer to allocated memory, or NULL on allocation failure or zero size

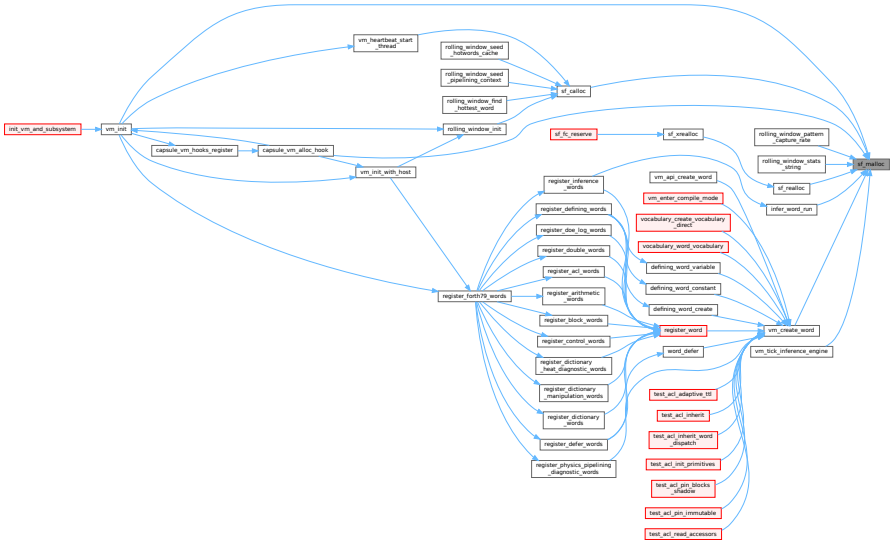
References sf_alloc_stats::alloc_count, g_alloc_count, g_arena_offset, g_initialized, g_stats, g_stats, kmalloc_aligned(), malloc(), sf_alloc_stats::peak_bytes, SF_ALIGN, SF_ALIGN_UP, sf_alloc_init(), SF_ARENA_SIZE, and sf_alloc_stats::used_bytes.

Referenced by capsule_vm_alloc_hook(), infer_word_run(), rolling_window_pattern_capture_rate(), rolling_window_stats_string(), sf_calloc(), sf_realloc(), vm_create_word(), vm_init(), and vm_tick_inference_engine().

Here is the call graph for this function:



Here is the caller graph for this function:



7.216.2.6 sf_realloc()

```
void * sf_realloc (
            void * ptr,
            size_t new_size )
```

Resize a previously allocated block to `new_size` bytes.

Delegates to `realloc()`. On success, increments `g_stats.alloc_count`. The exact byte delta is not tracked because the original allocation size is not stored alongside the pointer — `used_bytes` is therefore approximate after any `sf_realloc()` call. For accurate accounting, wrap allocations with size-tracking headers.

Parameters

ptr	Pointer to an existing allocation, or NULL (behaves like `sf_malloc`)
new_size	Desired new size in bytes; 0 may free the block (platform-defined)

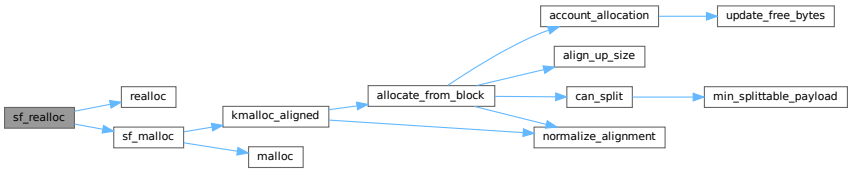
Returns

Pointer to resized memory, or NULL on failure (original block unchanged)

References sf_alloc_stats::alloc_count, g_stats, realloc(), and sf_malloc().

Referenced by sf_xrealloc().

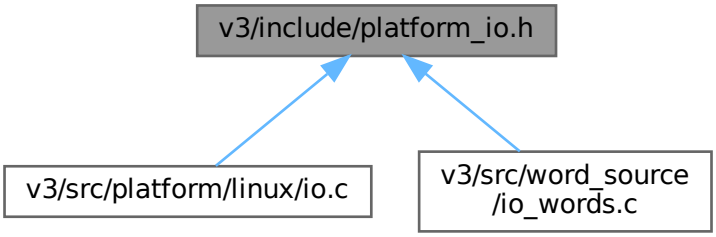
Here is the call graph for this function:



Here is the caller graph for this function:

7.217 v3/include/platform_io.h File Reference

This graph shows which files directly or indirectly include this file:



Functions

- int sf_terminal_ready (void)

  Non-blocking check for whether a key/character is available to read.

7.217.1 Function Documentation

7.217.1.1 sf_terminal_ready()

```
int sf_terminal_ready (
            void  )
```

Non-blocking check for whether a key/character is available to read.

Must not block and must not consume the byte if one is found (a following KEY/getchar() must still return that same byte).

Returns

1 if input is ready, 0 otherwise

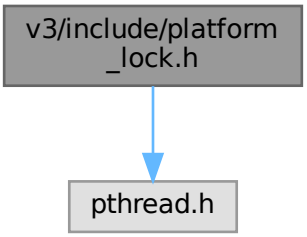
References timeval::tv_sec, and timeval::tv_usec.

Referenced by io_word_question_terminal().

Here is the caller graph for this function:

7.218 v3/include/platform_lock.h File Reference

`#include <pthread.h>`
Include dependency graph for platform_lock.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct sf_mutex

Typedefs

- typedef struct sf_mutex sf_mutex_t

Functions

- int sf_mutex_init (sf_mutex_t *mutex)
  Initialise a POSIX mutex (hosted build).
- void sf_mutex_destroy (sf_mutex_t *mutex)
  Destroy a POSIX mutex (hosted build).
- void sf_mutex_lock (sf_mutex_t *mutex)
  Acquire a POSIX mutex (hosted build).
- void sf_mutex_unlock (sf_mutex_t *mutex)
  Release a POSIX mutex (hosted build).

7.218.1 Typedef Documentation

7.218.1.1 sf_mutex_t

`typedef struct sf_mutex sf_mutex_t`

7.218.2 Function Documentation

7.218.2.1 sf_mutex_destroy()

```
void sf_mutex_destroy (
            sf_mutex_t * mutex )
```

Destroy a POSIX mutex (hosted build).

Delegates to `pthread_mutex_destroy()`. The mutex must not be locked when destroyed. Return value is discarded; callers that need the error code should call `pthread_mutex_destroy()` directly.

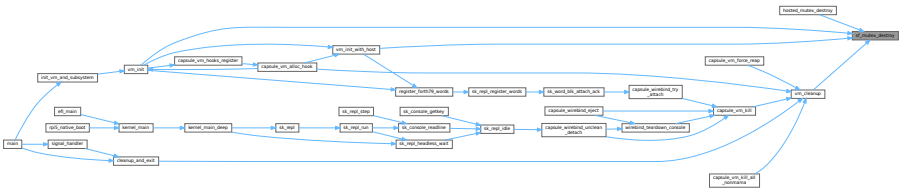
Parameters

mutex	Mutex to destroy; no-op if NULL

References sf_mutex::handle.

Referenced by hosted_mutex_destroy(), vm_cleanup(), vm_init(), and vm_init_with_host().

Here is the caller graph for this function:



7.218.2.2 sf_mutex_init()

```
int sf_mutex_init (
            sf_mutex_t * mutex )
```

Initialise a POSIX mutex (hosted build).

Delegates to `pthread_mutex_init()` with default attributes.

Parameters

mutex	Mutex to initialise; returns -1 if NULL

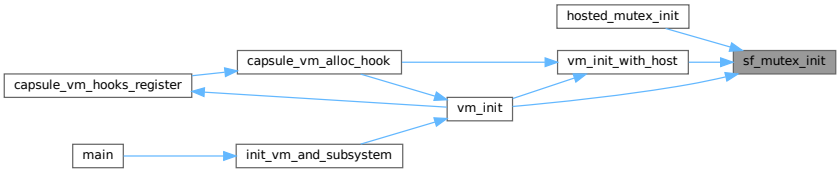
Returns

0 on success, -1 if `mutex` is NULL, or a positive `errno` value propagated from `pthread_mutex_init()`

References sf_mutex::handle.

Referenced by hosted_mutex_init(), vm_init(), and vm_init_with_host().

Here is the caller graph for this function:



7.218.2.3 sf_mutex_lock()

```
void sf_mutex_lock (
            sf_mutex_t * mutex )
```

Acquire a POSIX mutex (hosted build).

Delegates to `pthread_mutex_lock()`. Blocks until the mutex is available. Return value is discarded; a locking error will manifest as a deadlock or data race, not a silent failure.

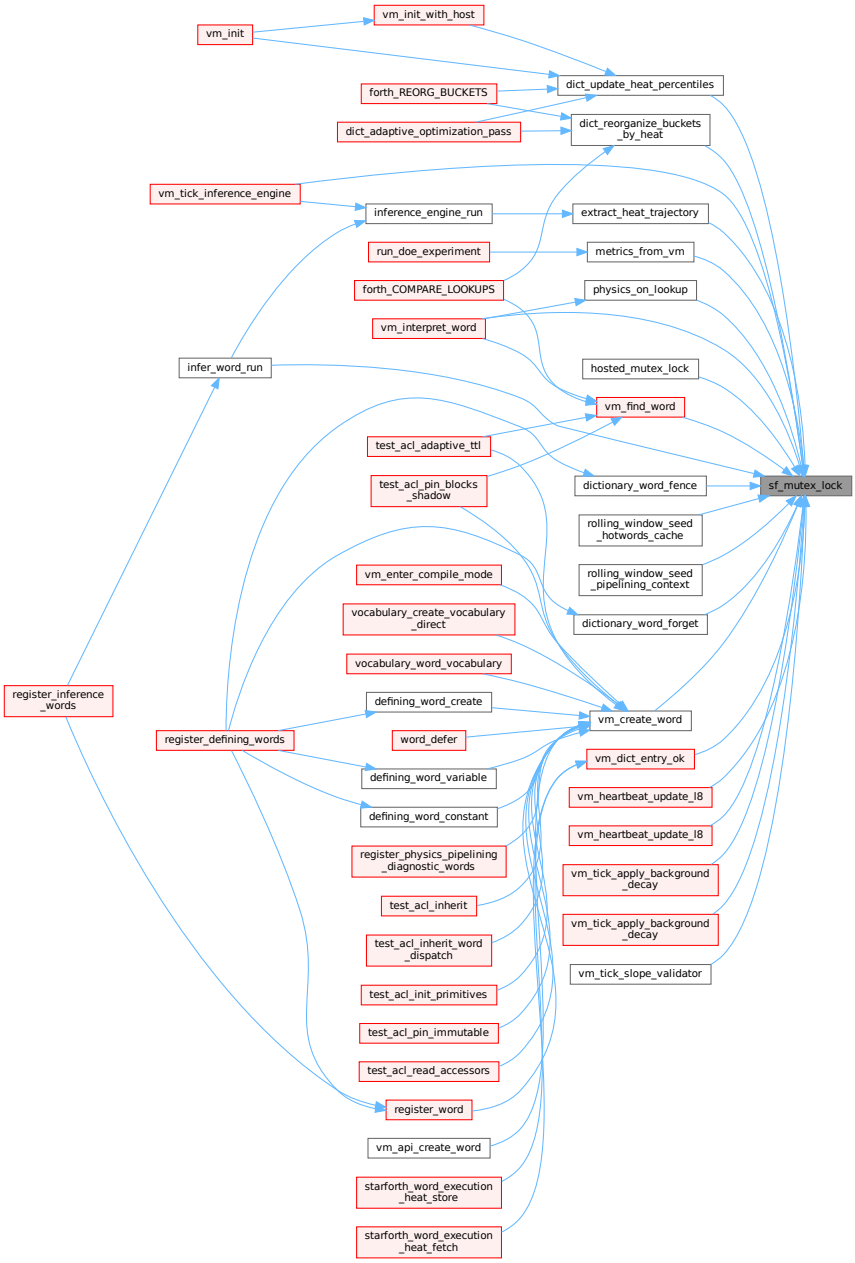
Parameters

mutex	Mutex to lock; no-op if NULL

References sf_mutex::handle.

Referenced by dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), dictionary_word_fence(), dictionary_word_forget(), extract_heat_trajectory(), hosted_mutex_lock(), infer_word_run(), metrics_from_vm(), physics_on_lookup(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), vm_create_word(), vm_dict_entry_ok(), vm_find_word(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_interpret_word(), vm_tick_apply_background_decay(), vm_tick_apply_background_decay(), vm_tick_inference_engine(), and vm_tick_slope_validator().

Here is the caller graph for this function:



7.218.2.4 sf_mutex_unlock()

```
void sf_mutex_unlock (
            sf_mutex_t * mutex )
```

Release a POSIX mutex (hosted build).

Delegates to `pthread_mutex_unlock()`. Must be called by the same thread that acquired the lock. Return value is discarded.

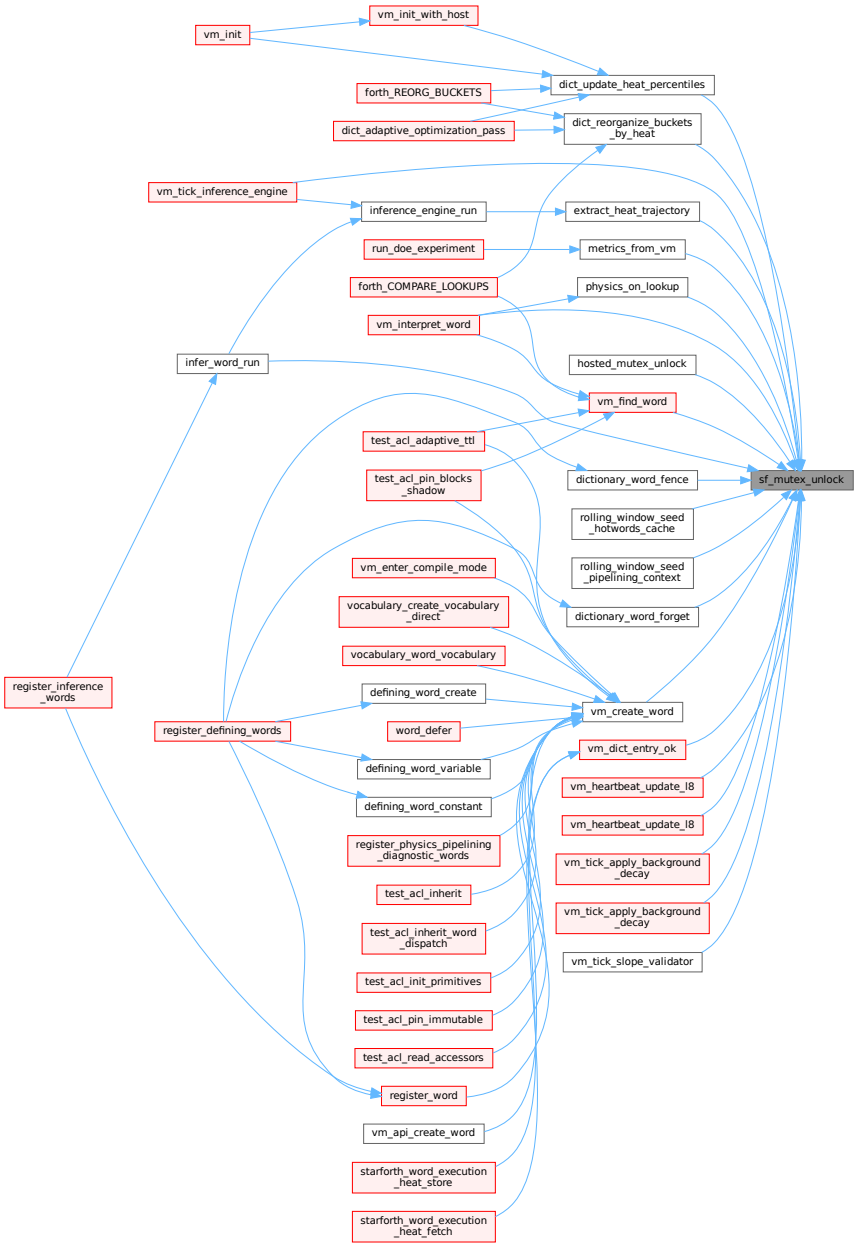
Parameters

mutex	Mutex to unlock; no-op if NULL

References sf_mutex::handle.

Referenced by dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), dictionary_word_fence(), dictionary_word_forget(), extract_heat_trajectory(), hosted_mutex_unlock(), infer_word_run(), metrics_from_vm(), physics_on_lookup(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), vm_create_word(), vm_dict_entry_ok(), vm_find_word(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_interpret_word(), vm_tick_apply_background_decay(), vm_tick_apply_background_decay(), vm_tick_inference_engine(), and vm_tick_slope_validator().

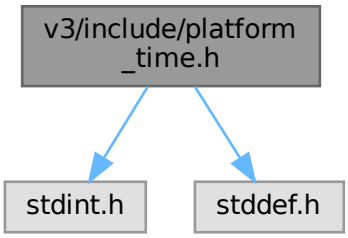
Here is the caller graph for this function:



7.219 v3/include/platform_time.h File Reference

```
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for platform_time.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct sf_time_backend_t

Macros

- #define SF_TIME_STAMP_SIZE 32

Typedefs

- typedef uint64_t sf_time_ns_t

Functions

- static sf_time_ns_t sf_monotonic_ns (void)
- static sf_time_ns_t sf_realtime_ns (void)
- static int sf_set_realtime_ns (sf_time_ns_t ns)
- static int sf_format_timestamp (sf_time_ns_t ns, char ∗buf, int format_24h)
- static int sf_has_rtc (void)
- static sf_time_ns_t sf_seconds_to_ns (uint64_t seconds)
- static uint64_t sf_ns_to_seconds (sf_time_ns_t ns)
- static uint64_t sf_ns_to_ms (sf_time_ns_t ns)
- static uint64_t sf_ns_to_us (sf_time_ns_t ns)
- void sf_time_init (void)

  Initialize platform time subsystem.

Variables

- const sf_time_backend_t * sf_time_backend
- const sf_time_backend_t sf_time_backend_posix
- const sf_time_backend_t sf_time_backend_l4re

7.219.1 Macro Definition Documentation

7.219.1.1 SF_TIME_STAMP_SIZE

```
#define SF_TIME_STAMP_SIZE 32
```

7.219.2 Typedef Documentation

7.219.2.1 sf_time_ns_t

```
typedef uint64_t sf_time_ns_t
```

7.219.3 Function Documentation

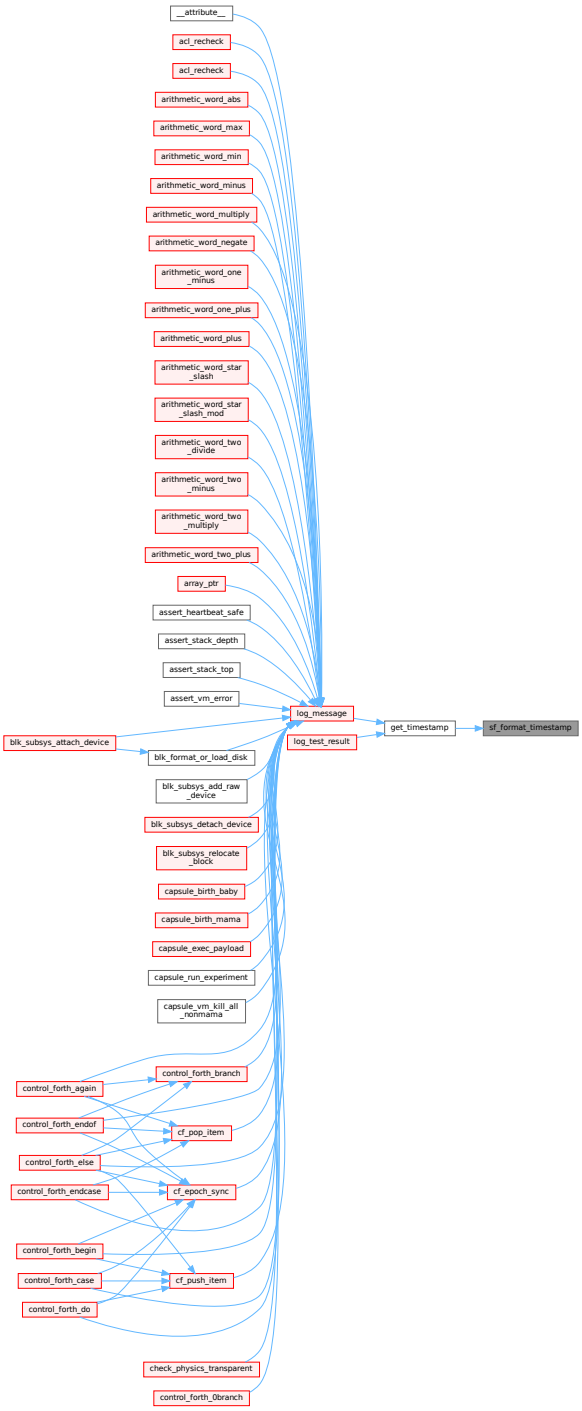
7.219.3.1 sf_format_timestamp()

```
static int sf_format_timestamp (
            sf_time_ns_t ns,
            char * buf,
            int format_24h )  [inline], [static]
```

References sf_time_backend_t::format_timestamp, and sf_time_backend.

Referenced by get_timestamp().

Here is the caller graph for this function:



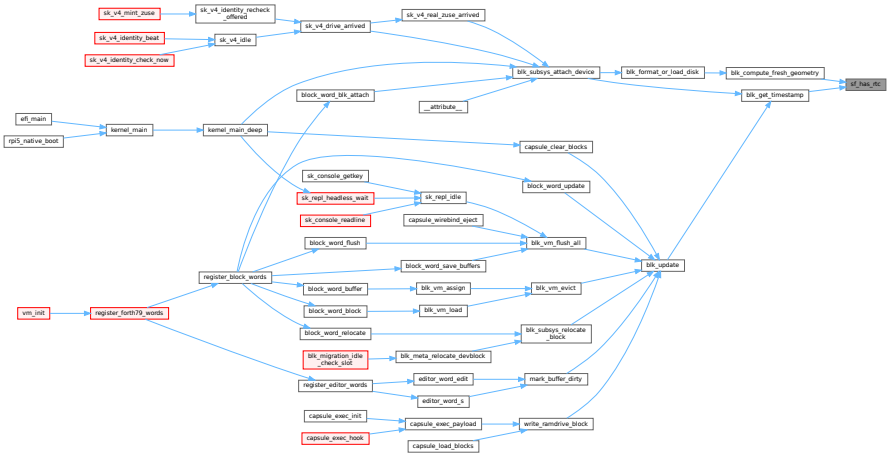
7.219.3.2 sf_has_rtc()

```
static int sf_has_rtc (
            void  )  [inline], [static]
```

References sf_time_backend_t::has_rtc, and sf_time_backend.

Referenced by blk_compute_fresh_geometry(), and blk_get_timestamp().

Here is the caller graph for this function:



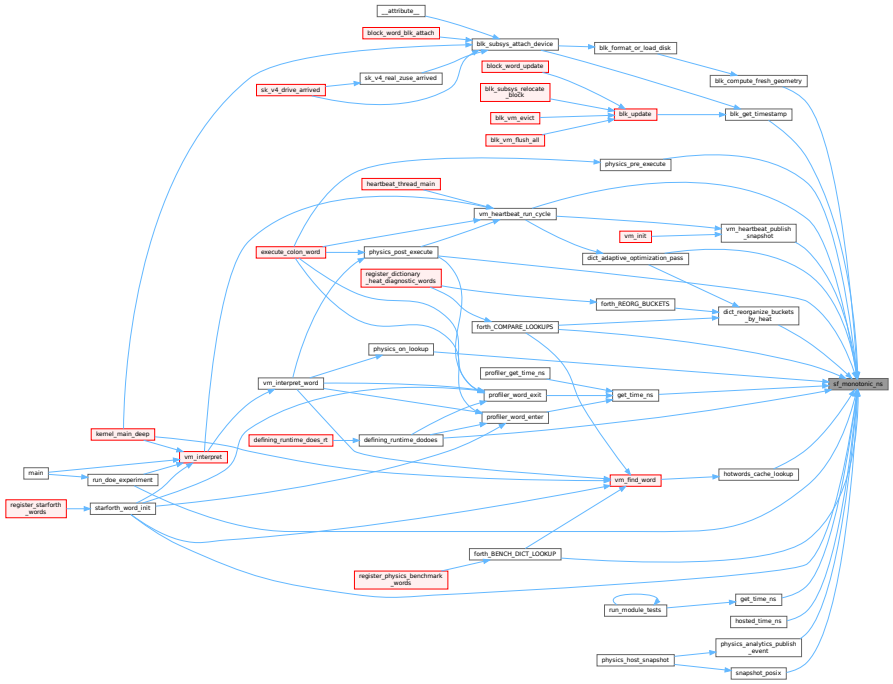
7.219.3.3 sf_monotonic_ns()

```
static sf_time_ns_t sf_monotonic_ns (
            void  )  [inline], [static]
```

References sf_time_backend_t::get_monotonic_ns, and sf_time_backend.

Referenced by blk_compute_fresh_geometry(), blk_get_timestamp(), defining_runtime_dodoes(), dict_adaptive_optimization_pass(), dict_reorganize_buckets_by_heat(), forth_BENCH_DICT_LOOKUP(), forth_COMPARE_LOOKUPS(), get_time_ns(), get_time_ns(), hosted_time_ns(), hotwords_cache_lookup(), physics_analytics_publish_event(), physics_on_lookup(), physics_post_execute(), physics_pre_execute(), run_doe_experiment(), snapshot_posix(), starforth_word_init(), vm_heartbeat_publish_snapshot(), and vm_heartbeat_run_cycle().

Here is the caller graph for this function:



7.219.3.4 sf_ns_to_ms()

```
static uint64_t sf_ns_to_ms (
            sf_time_ns_t ns )  [inline], [static]
```

7.219.3.5 sf_ns_to_seconds()

```
static uint64_t sf_ns_to_seconds (
            sf_time_ns_t ns )  [inline], [static]
```

7.219.3.6 sf_ns_to_us()

```
static uint64_t sf_ns_to_us (
            sf_time_ns_t ns )  [inline], [static]
```

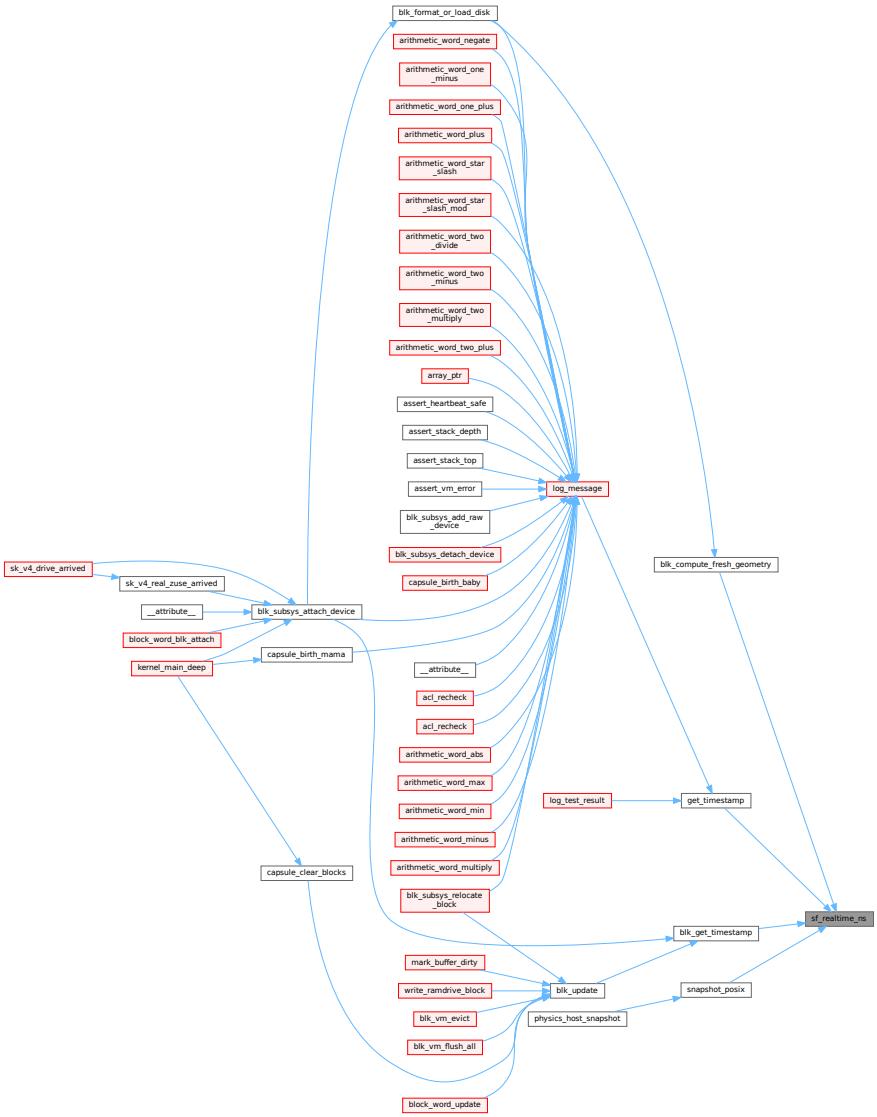
7.219.3.7 sf_realtime_ns()

```
static sf_time_ns_t sf_realtime_ns (
            void  )  [inline], [static]
```

References sf_time_backend_t::get_realtime_ns, and sf_time_backend.

Referenced by blk_compute_fresh_geometry(), blk_get_timestamp(), get_timestamp(), and snapshot_posix().

Here is the caller graph for this function:



7.219.3.8 sf_seconds_to_ns()

```
static sf_time_ns_t sf_seconds_to_ns (
            uint64_t seconds )  [inline], [static]
```

7.219.3.9 sf_set_realtime_ns()

```
static int sf_set_realtime_ns (
            sf_time_ns_t ns )  [inline], [static]
```

References sf_time_backend_t::set_realtime_ns, and sf_time_backend.

7.219.3.10 sf_time_init()

```
void sf_time_init (
            void  )
```

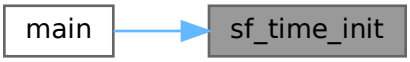
Initialize platform time subsystem.

Selects the POSIX backend (clock_gettime()). Call this once at program startup before using any time functions.

References sf_time_backend, and sf_time_backend_posix.

Referenced by main().

Here is the caller graph for this function:



7.219.4 Variable Documentation

7.219.4.1 sf_time_backend

```
const sf_time_backend_t* sf_time_backend  [extern]
```

Referenced by sf_format_timestamp(), sf_has_rtc(), sf_monotonic_ns(), sf_realtime_ns(), sf_set_realtime_ns(), and sf_time_init().

7.219.4.2 sf_time_backend_l4re

```
const sf_time_backend_t sf_time_backend_l4re  [extern]
```

7.219.4.3 sf_time_backend_posix

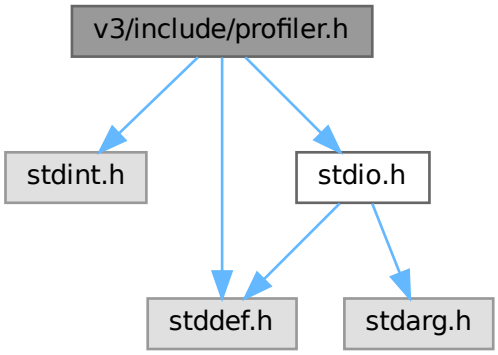
```
const sf_time_backend_t sf_time_backend_posix  [extern]
```

Referenced by sf_time_init().

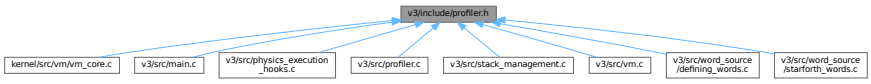
7.220 v3/include/profiler.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include <stdio.h>
```

Include dependency graph for profiler.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct ProfileTimer

  Timer for measuring execution duration.
- struct WordProfile

  Execution statistics for a single word.
- struct MemoryProfile
- struct Profiler
- struct ProfileScope

Macros

- #define PROFILE_ENABLED() (0)
- #define PROFILE_START(category) ((void)0)
- #define PROFILE_END(category) ((void)0)
- #define PROFILE_WORD_ENTER(name) ((void)0)
- #define PROFILE_WORD_EXIT(name) ((void)0)
- #define PROFILE_MEMORY_READ(bytes) ((void)0)
- #define PROFILE_MEMORY_WRITE(bytes) ((void)0)
- #define PROFILE_INC_CYCLES(n) ((void)0)
- #define PROFILE_INC_DICT_LOOKUP() ((void)0)
- #define PROFILE_INC_STACK_OP() ((void)0)

Typedefs

- typedef struct VM VM
- typedef struct DictEntry DictEntry

Enumerations

- enum ProfileLevel {
  PROFILE_DISABLED = 0 , PROFILE_BASIC = 1 , PROFILE_DETAILED = 2 , PROFILE_VERBOSE = 3 ,
  PROFILE_FULL = 4 }

  Profiling detail levels.
- enum ProfileCategory {
  PROF_VM_INIT = 0 , PROF_VM_EXECUTE , PROF_VM_COMPILE , PROF_DICT_LOOKUP ,
  PROF_DICT_ADD , PROF_STACK_OPS , PROF_MEMORY_ACCESS , PROF_WORD_EXEC ,
  PROF_IO_OPS , PROF_CONTROL_FLOW , PROF_CATEGORY_COUNT }

  Profiling measurement categories.

Functions

- int profiler_init (ProfileLevel level)

  Initialize the profiling system.
- void profiler_shutdown (void)

  Shutdown and cleanup the profiling system.
- void profiler_reset (void)

  Reset all profiling statistics.
- void profiler_set_level (ProfileLevel level)

  Change the current profiling detail level.
- uint64_t profiler_get_time_ns (void)
- void profiler_start_timer (ProfileCategory category)
- void profiler_end_timer (ProfileCategory category)
- void profiler_word_enter (const DictEntry *entry)

  Start timing a word execution (PROFILE_DETAILED+)
- void profiler_word_exit (const DictEntry *entry)

  End timing a word execution (PROFILE_DETAILED+)
- void profiler_word_count (const DictEntry *entry)

  Track word execution frequency without timing (PROFILE_BASIC+)
- void profiler_memory_read (size_t bytes)
- void profiler_memory_write (size_t bytes)
- void profiler_memory_alloc (size_t bytes)
- void profiler_inc_vm_cycles (uint64_t cycles)
- void profiler_inc_dict_lookup (void)
- void profiler_inc_stack_op (void)
- void profiler_inc_branch (void)
- void profiler_inc_loop_iter (void)
- void profiler_generate_report (void)

  Generate and print detailed profiling report.
- void profiler_print_summary (void)
- void profiler_print_word_analysis (void)
- void profiler_print_memory_analysis (void)
- void profiler_print_hotspots (void)

  Print hot word analysis with optimization recommendations.
- void profiler_analyze_performance (VM *vm)
- void profiler_suggest_optimizations (void)

Variables

- void * g_profiler

7.220.1 Macro Definition Documentation

7.220.1.1 PROFILE_ENABLED

```
#define PROFILE_ENABLED( ) (0)
```

7.220.1.2 PROFILE_END

```
#define PROFILE_END(
              category ) ((void)0)
```

7.220.1.3 PROFILE_INC_CYCLES

```
#define PROFILE_INC_CYCLES(
              n ) ((void)0)
```

7.220.1.4 PROFILE_INC_DICT_LOOKUP

```
#define PROFILE_INC_DICT_LOOKUP( ) ((void)0)
```

7.220.1.5 PROFILE_INC_STACK_OP

```
#define PROFILE_INC_STACK_OP( ) ((void)0)
```

7.220.1.6 PROFILE_MEMORY_READ

```
#define PROFILE_MEMORY_READ(
              bytes ) ((void)0)
```

7.220.1.7 PROFILE_MEMORY_WRITE

```
#define PROFILE_MEMORY_WRITE(
              bytes ) ((void)0)
```

7.220.1.8 PROFILE_START

```
#define PROFILE_START(
              category ) ((void)0)
```

7.220.1.9 PROFILE_WORD_ENTER

```
#define PROFILE_WORD_ENTER(
              name ) ((void)0)
```

7.220.1.10 PROFILE_WORD_EXIT

```
#define PROFILE_WORD_EXIT(
              name ) ((void)0)
```

7.220.2 Typedef Documentation

7.220.2.1 DictEntry

```
typedef struct DictEntry DictEntry
```

7.220.2.2 VM

```
typedef struct VM VM
```

7.220.3 Enumeration Type Documentation

7.220.3.1 ProfileCategory

```
enum ProfileCategory
```

Profiling measurement categories.

Different aspects of VM operation that can be profiled

Enumerator

PROF_VM_INIT	VM initialization.
PROF_VM_EXECUTE	VM execution loop.
PROF_VM_COMPILE	Word compilation.
PROF_DICT_LOOKUP	Dictionary searches.
PROF_DICT_ADD	Dictionary additions.
PROF_STACK_OPS	Stack operations.
PROF_MEMORY_ACCESS	Memory access operations.
PROF_WORD_EXEC	Word execution.
PROF_IO_OPS	I/O operations.
PROF_CONTROL_FLOW	Control flow operations.
PROF_CATEGORY_COUNT	Total number of categories.

7.220.3.2 ProfileLevel

```
enum ProfileLevel
```

Profiling detail levels.

Controls the amount of profiling information collected during execution. Higher levels include all features from lower levels.

Enumerator

PROFILE_DISABLED	Profiling disabled (zero overhead)
PROFILE_BASIC	Word execution frequency tracking (minimal overhead)
PROFILE_DETAILED	Basic + word execution timing (5-10% overhead)
PROFILE_VERBOSE	Detailed + stack/memory access patterns (15-20% overhead)
PROFILE_FULL	Reserved for future use (full instrumentation)

7.220.4 Function Documentation

7.220.4.1 profiler_analyze_performance()

```
void profiler_analyze_performance (
            VM * vm )
```

7.220.4.2 profiler_end_timer()

```
void profiler_end_timer (
            ProfileCategory category )
```

7.220.4.3 profiler_generate_report()

```
void profiler_generate_report (
            void  )
```

Generate and print detailed profiling report.

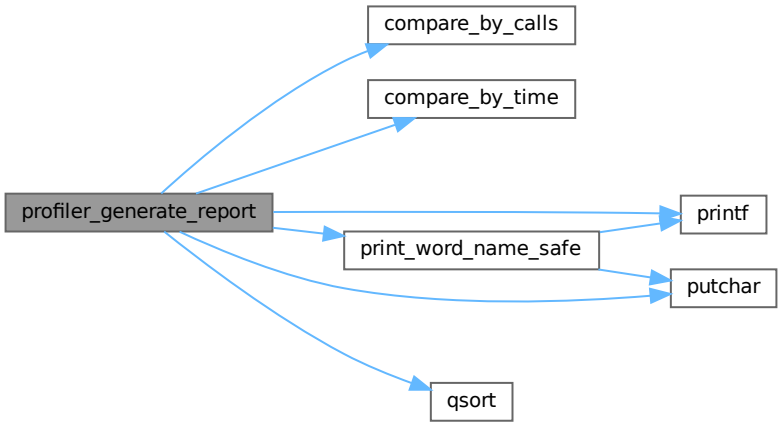
Generates a report including:

- Global statistics (dictionary lookups, stack ops, memory usage)
- Top words by execution time
- Most frequently called words

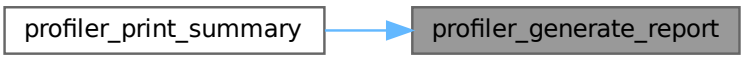
References WordStats::call_count, compare_by_calls(), compare_by_time(), WordStats::entry, limit, WordStats::max_time_ns, name_len, DictEntry::name_len, print_word_name_safe(), printf(), PROFILE_BASIC, PROFILE_DETAILED, PROFILE_VERBOSE, profiler_state, putchar(), qsort(), and WordStats::total_time_ns.

Referenced by profiler_print_summary().

Here is the call graph for this function:



Here is the caller graph for this function:

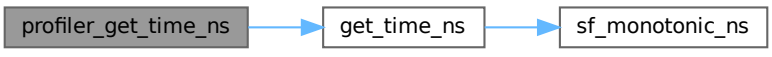


7.220.4.4 profiler_get_time_ns()

```
uint64_t profiler_get_time_ns (
            void  )
```

References get_time_ns().

Here is the call graph for this function:



7.220.4.5 profiler_inc_branch()

```
void profiler_inc_branch (
            void  )
```

7.220.4.6 profiler_inc_dict_lookup()

```
void profiler_inc_dict_lookup (
            void  )
```

References PROFILE_BASIC, and profiler_state.

7.220.4.7 profiler_inc_loop_iter()

```
void profiler_inc_loop_iter (
            void  )
```

7.220.4.8 profiler_inc_stack_op()

```
void profiler_inc_stack_op (
            void  )
```

References PROFILE_VERBOSE, and profiler_state.

7.220.4.9 profiler_inc_vm_cycles()

```
void profiler_inc_vm_cycles (
            uint64_t cycles )
```

7.220.4.10 profiler_init()

```
int profiler_init (
            ProfileLevel level )
```

Initialize the profiling system.

Parameters

level	Initial profiling detail level

Returns

0 on success, non-zero on failure

References calloc(), level, PROFILE_DISABLED, and profiler_state.

Here is the call graph for this function:

7.220.4.11 profiler_memory_alloc()

```
void profiler_memory_alloc (
            size_t bytes )
```

References bytes.

7.220.4.12 profiler_memory_read()

```
void profiler_memory_read (
            size_t bytes )
```

References bytes, PROFILE_VERBOSE, and profiler_state.

7.220.4.13 profiler_memory_write()

```
void profiler_memory_write (
            size_t bytes )
```

References bytes, PROFILE_VERBOSE, and profiler_state.

7.220.4.14 profiler_print_hotspots()

```
void profiler_print_hotspots (
            void  )
```

Print hot word analysis with optimization recommendations.

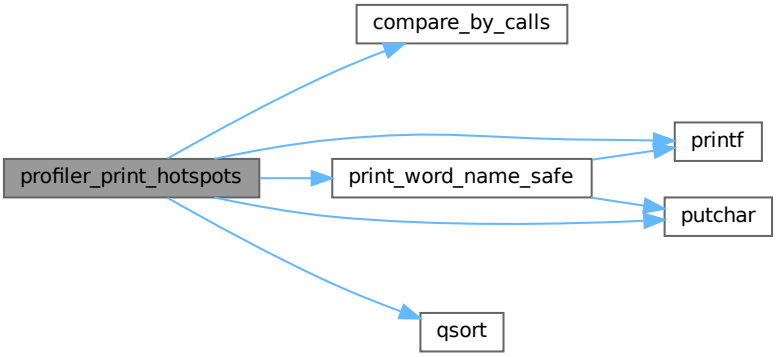
Analyzes word execution frequency and provides actionable recommendations for performance optimization including:

- Assembly optimization candidates
- Inlining opportunities
- Cache-friendly ordering

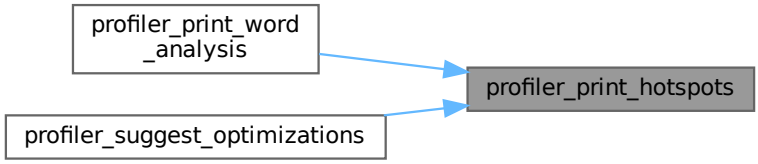
References WordStats::call_count, compare_by_calls(), WordStats::entry, limit, name_len, DictEntry::name_len, print_word_name_safe(), printf(), profiler_state, putchar(), and qsort().

Referenced by profiler_print_word_analysis(), and profiler_suggest_optimizations().

Here is the call graph for this function:



Here is the caller graph for this function:



7.220.4.15 profiler_print_memory_analysis()

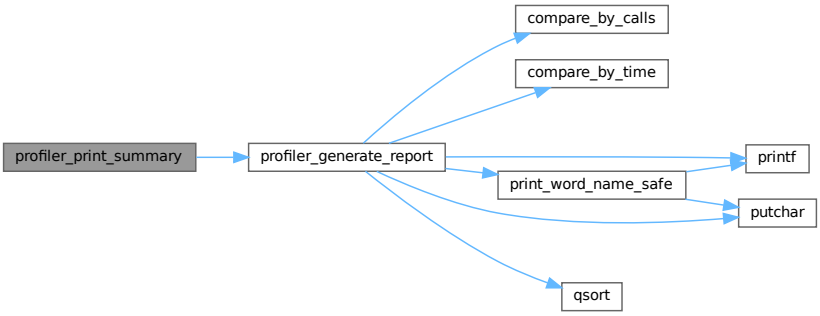
```
void profiler_print_memory_analysis (
            void  )
```

7.220.4.16 profiler_print_summary()

```
void profiler_print_summary (
            void  )
```

References profiler_generate_report().

Here is the call graph for this function:

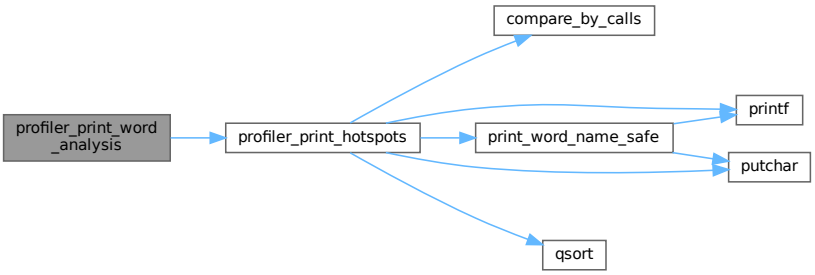


7.220.4.17 profiler_print_word_analysis()

```
void profiler_print_word_analysis (
            void  )
```

References profiler_print_hotspots().

Here is the call graph for this function:



7.220.4.18 profiler_reset()

```
void profiler_reset (
            void  )
```

Reset all profiling statistics.

References profiler_state.

7.220.4.19 profiler_set_level()

```
void profiler_set_level (
            ProfileLevel level )
```

Change the current profiling detail level.

Parameters

level	New profiling level to set

References level, and profiler_state.

7.220.4.20 profiler_shutdown()

```
void profiler_shutdown (
            void  )
```

Shutdown and cleanup the profiling system.

Shutdown and cleanup the profiling system.

References free(), and profiler_state.

Here is the call graph for this function:

7.220.4.21 profiler_start_timer()

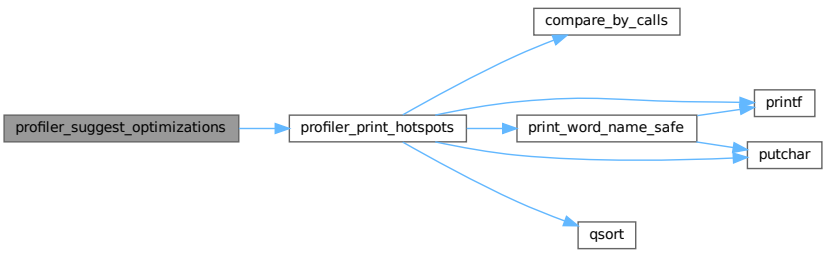
```
void profiler_start_timer (
            ProfileCategory category )
```

7.220.4.22 profiler_suggest_optimizations()

```
void profiler_suggest_optimizations (
            void  )
```

References profiler_print_hotspots().

Here is the call graph for this function:



7.220.4.23 profiler_word_count()

```
void profiler_word_count (
            const DictEntry * entry )
```

Track word execution frequency without timing (PROFILE_BASIC+)

Parameters

entry	Dictionary entry of the word being executed

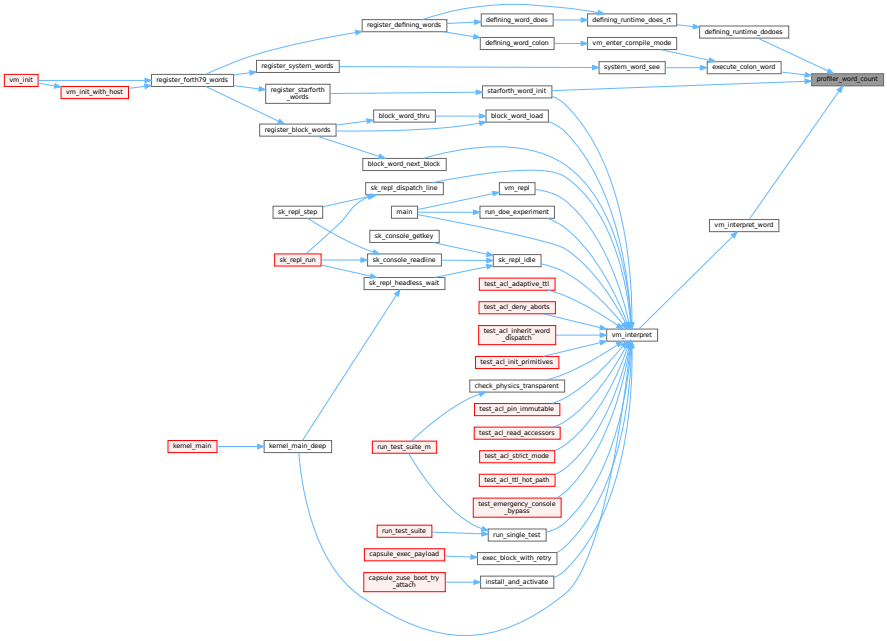
This is a lightweight alternative to profiler_word_enter/exit that only increments call counters without timing overhead. Ideal for identifying hot words (frequently executed) for optimization.

References WordStats::call_count, entry, get_word_stats(), PROFILE_DETAILED, and profiler_state.

Referenced by defining_runtime_dodoes(), execute_colon_word(), starforth_word_init(), and vm_interpret_word().

Here is the call graph for this function:

Here is the caller graph for this function:



7.220.4.24 profiler_word_enter()

```
void profiler_word_enter (
            const DictEntry * entry )
```

Start timing a word execution (PROFILE_DETAILED+)

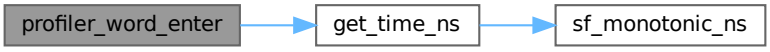
Parameters

entry	Dictionary entry of the word being executed

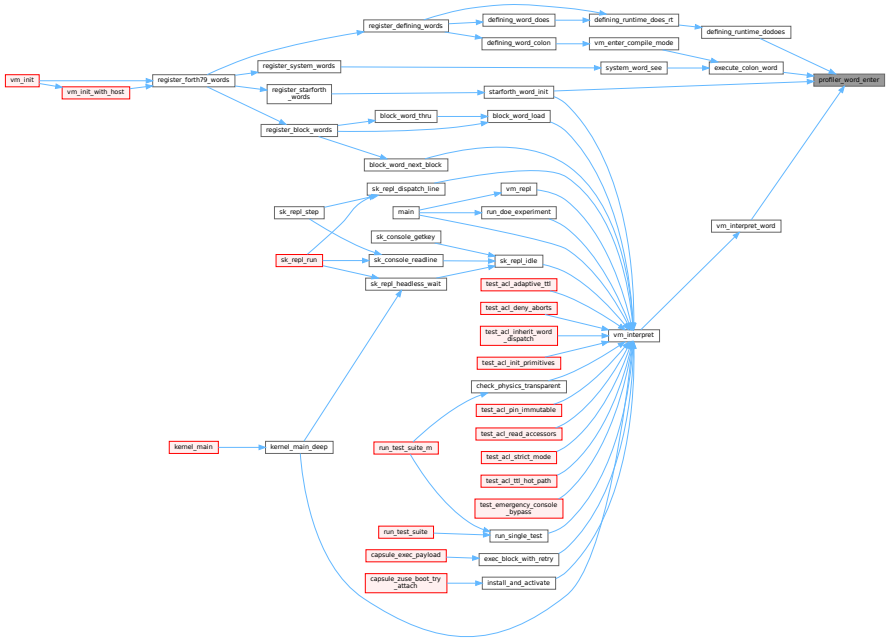
References entry, get_time_ns(), PROFILE_DETAILED, and profiler_state.

Referenced by defining_runtime_dodoes(), execute_colon_word(), starforth_word_init(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.220.4.25 profiler_word_exit()

```
void profiler_word_exit (
            const DictEntry * entry )
```

End timing a word execution (PROFILE_DETAILED+)

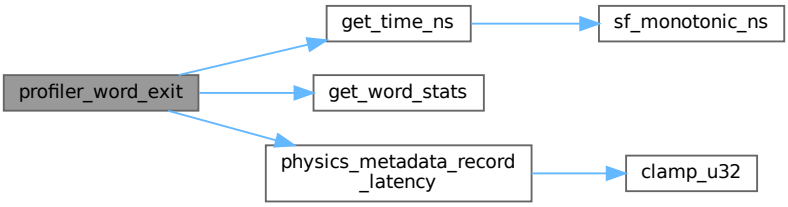
Parameters

entry	Dictionary entry of the word being executed

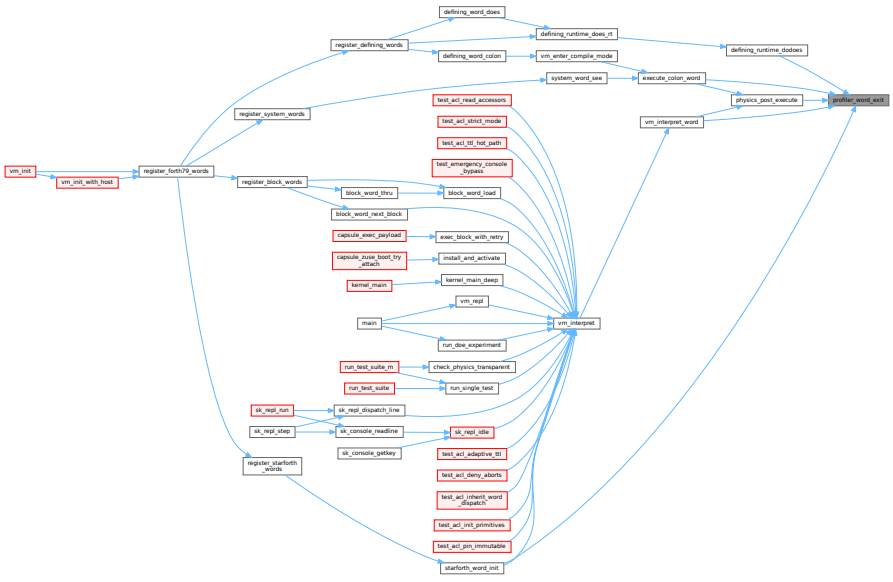
References WordStats::call_count, entry, get_time_ns(), get_word_stats(), WordStats::max_time_ns, WordStats::min_time_ns, physics_metadata_record_latency(), PROFILE_DETAILED, profiler_state, and WordStats::total_time_ns.

Referenced by defining_runtime_dodoes(), execute_colon_word(), physics_post_execute(), starforth_word_init(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.220.5 Variable Documentation

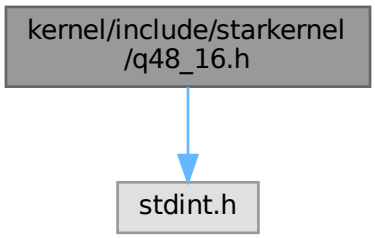
7.220.5.1 g_profiler

```
void* g_profiler  [extern]
```

7.221 kernel/include/starkernel/q48_16.h File Reference

```
#include <stdint.h>
```

Include dependency graph for q48_16.h:



This graph shows which files directly or indirectly include this file:

Macros

- #define Q48_ONE ((q48_16_t)0x10000ULL)

Typedefs

- typedef uint64_t q48_16_t

  q48_16.h - Q48.16 Fixed-Point Arithmetic for StarKernel

Functions

- q48_16_t q48_mul (q48_16_t a, q48_16_t b)

  Multiply two Q48.16 fixed-point values.
- q48_16_t q48_div (q48_16_t a, q48_16_t b)

  Divide two Q48.16 fixed-point values.
- static q48_16_t q48_add (q48_16_t a, q48_16_t b)

  Add two Q48.16 values.
- static q48_16_t q48_sub (q48_16_t a, q48_16_t b)

  Subtract two Q48.16 values.
- static q48_16_t q48_abs (q48_16_t a)

  Absolute value of Q48.16 (treats as unsigned, so just returns a)
- static q48_16_t q48_from_u64 (uint64_t u)

  Convert unsigned 64-bit integer to Q48.16: u << 16.
- static uint64_t q48_to_u64 (q48_16_t q)

Convert Q48.16 to a 64-bit integer (truncate fractional): q >> 16, arithmetic (signed) shift so negative q sign-extends correctly instead of producing garbage from an unsigned logical shift.

- q48_16_t q48_log_approx (q48_16_t x)

  Compute an approximation of `ln(x)` in Q48.16 format (integer-only).
- q48_16_t q48_exp_approx (q48_16_t q)

  Compute an approximation of `e^q` in Q48.16 format (Taylor series).
- q48_16_t q48_sqrt_approx (q48_16_t q)

  Compute an approximation of `sqrt(q)` in Q48.16 format (Newton-Raphson).
- q48_16_t q48_sin_approx (q48_16_t q)

  Compute an approximation of `sin(q)` in Q48.16 format (radians).
- q48_16_t q48_cos_approx (q48_16_t q)

  Compute an approximation of `cos(q)` in Q48.16 format (radians).

7.221.1 Macro Definition Documentation

7.221.1.1 Q48_ONE

```
#define Q48_ONE ((q48_16_t)0x10000ULL)
```

7.221.2 Typedef Documentation

7.221.2.1 q48_16_t

```
typedef uint64_t q48_16_t
```

q48_16.h - Q48.16 Fixed-Point Arithmetic for StarKernel

Format: uint64_t with fixed decimal point after bit 15

- Bits 0-15: Fractional part (1/65536 resolution)
- Bits 16-63: Integer part (up to 2^48-1)

Example: 0x00010000 = 1.0, 0x00018000 = 1.5

All operations are integer-only. NO FLOATING-POINT.

7.221.3 Function Documentation

7.221.3.1 q48_abs()

```
static q48_16_t q48_abs (
            q48_16_t a )  [inline], [static]
```

Absolute value of Q48.16 (treats as unsigned, so just returns a)

7.221.3.2 q48_add()

```
static q48_16_t q48_add (
            q48_16_t a,
            q48_16_t b )  [inline], [static]
```

Add two Q48.16 values.

7.221.3.3 q48_cos_approx()

```
q48_16_t q48_cos_approx (
            q48_16_t q )
```

Compute an approximation of `cos(q)` in Q48.16 format (radians).

Range-reduces into [-pi, pi] via `q48_reduce_angle()`, then sums the Taylor series `1` - x^2/2! + x^4/4! - ... for terms n = 2,4,6,8,10, with an early exit when a term falls below 10. Cosine is even (`cos`(-x) = cos(x)), so no sign correction is needed – `x^2` already absorbs the sign of `x`.

Parameters

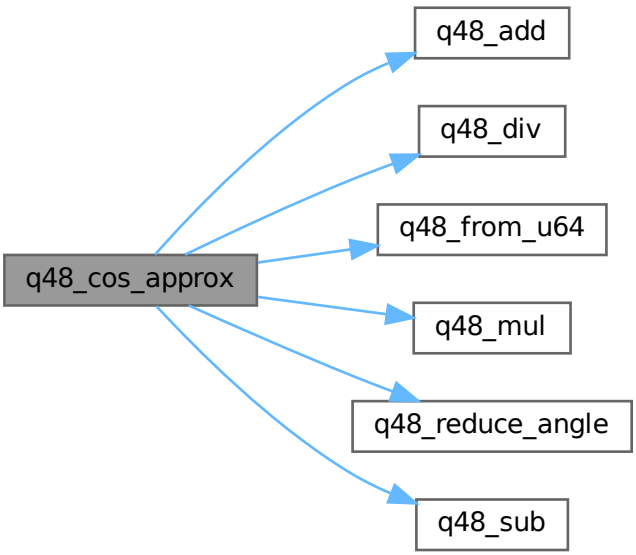
q	Angle in Q48.16 format (radians, any magnitude)

Returns

`cos(q)` in Q48.16 format

References q48_add(), q48_div(), q48_from_u64(), q48_mul(), Q48_ONE, q48_reduce_angle(), and q48_sub().

Here is the call graph for this function:



7.221.3.4 q48_div()

```
q48_16_t q48_div (
            q48_16_t a,
            q48_16_t b )
```

Divide two Q48.16 fixed-point values.

Computes (a << 16) / b. Returns 0 if b == 0 (safe, but callers should guard). Returns UINT64_MAX as a saturation sentinel when a exceeds 2^48, which would overflow the 16-bit left-shift.

Parameters

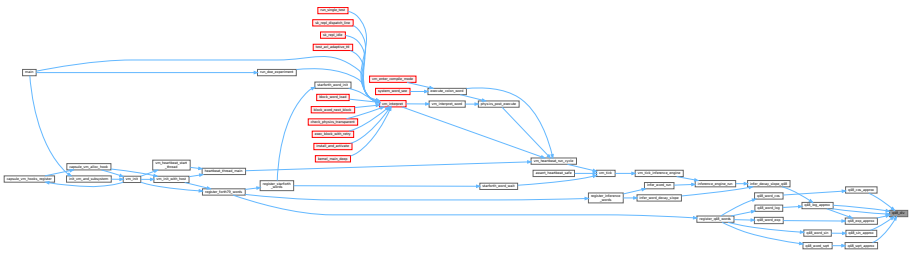
a	Dividend in Q48.16 format
b	Divisor in Q48.16 format; 0 returns 0

Returns

Quotient in Q48.16 format, or UINT64_MAX on saturation

Referenced by q48_cos_approx(), q48_exp_approx(), q48_log_approx(), q48_log_approx(), q48_sin_approx(), and q48_sqrt_approx().

Here is the caller graph for this function:



7.221.3.5 q48_exp_approx()

```
q48_16_t q48_exp_approx (
            q48_16_t q )
```

Compute an approximation of e^q in Q48.16 format (Taylor series).

Supporting function for q48_log_approx() Newton iterations. Uses the Taylor series 1 + x + x^2/2! + ... up to 10 terms, with an early-exit when a term falls below 50 (sub-LSB in Q48.16). Handles negative q by computing e^|q| then returning 1/result. Returns 1.0 (65536) for q == 0, UINT64_MAX for q >= 16.0, and 0 for q <= -16.0.

Parameters

q	Exponent in Q48.16 format (signed interpretation)

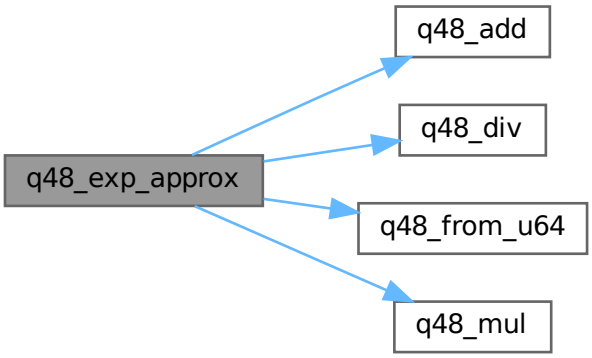
Returns

e^q in Q48.16 format

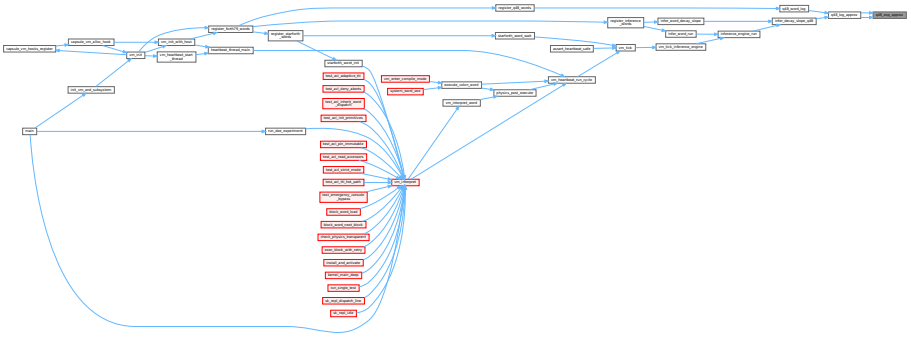
References q48_add(), q48_div(), q48_from_u64(), q48_mul(), and Q48_ONE.

Referenced by q48_log_approx(), and q48_log_approx().

Here is the call graph for this function:



Here is the caller graph for this function:



7.221.3.6 q48_from_u64()

```
static q48_16_t q48_from_u64 (
            uint64_t u )  [inline], [static]
```

Convert unsigned 64-bit integer to Q48.16: u << 16.

7.221.3.7 q48_log_approx()

```
q48_16_t q48_log_approx (
            q48_16_t x )
```

Compute an approximation of `ln(x)` in Q48.16 format (integer-only).

Used by `infer_decay_slope_q48()` (Loop #6) for log-linear OLS regression. Algorithm: range-reduces `x` to the interval [1, 2) by tracking the exponent `k` (so `x` = 2^k * m), applies 6 Newton-Raphson iterations on `e^y` = m starting from the first-order approximation `y_0` = m - 1, then assembles the result as `ln(x)` = k*ln(2) + ln(m). Returns 0 for `x` == 0 (ln undefined) and for `x` == 65536 (ln(1.0) == 0.0 exactly). `LN2_Q48` = 45426 (0.693147... × 65536).

Parameters

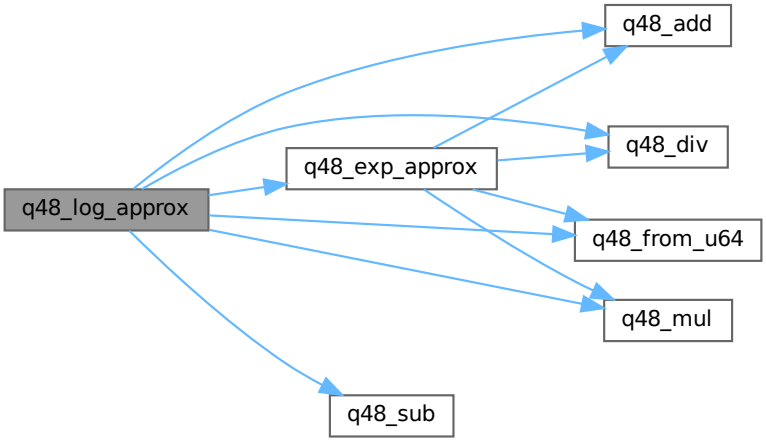
x	Input value in Q48.16 format (uint64_t; value of 65536 = 1.0)

Returns

`ln(x)` in Q48.16 format, or 0 for x==0 or x==65536

References q48_add(), q48_div(), q48_exp_approx(), q48_from_u64(), q48_mul(), Q48_ONE, and q48_sub().

Here is the call graph for this function:



7.221.3.8 q48_mul()

```
q48_16_t q48_mul (
            q48_16_t a,
            q48_16_t b )
```

Multiply two Q48.16 fixed-point values.

Computes (a * b) >> 16 to maintain the Q48.16 scale. Uses `__uint128_t` on GCC/Clang (128-bit intermediate, no precision loss) and falls back to a manual 64-bit four-partial-product path with carry tracking on platforms that lack `__SIZEOF_INT128__`.

Parameters

a	First operand in Q48.16 format
b	Second operand in Q48.16 format

Returns

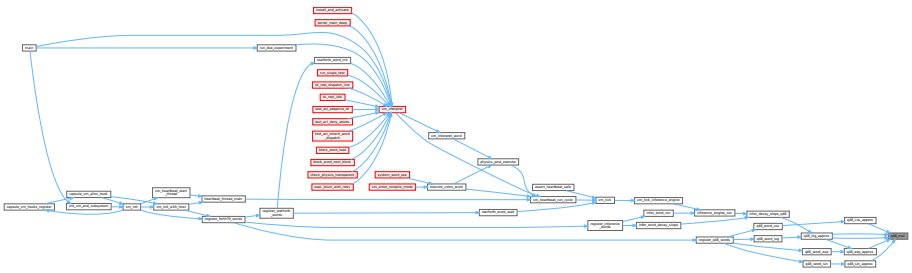
Product in Q48.16 format (truncated, not rounded)

Multiply two Q48.16 fixed-point values.

Freestanding implementation: no libc, no floating-point.

Referenced by q48_cos_approx(), q48_exp_approx(), q48_log_approx(), q48_log_approx(), and q48_sin_approx().

Here is the caller graph for this function:



7.221.3.9 q48_sin_approx()

```
q48_16_t q48_sin_approx (
            q48_16_t q )
```

Compute an approximation of `sin(q)` in Q48.16 format (radians).

Range-reduces into [-pi, pi] via `q48_reduce_angle()`, then sums the Taylor series `x` - x^3/3! + x^5/5! - ... for terms n = 3,5,7,9,11, with an early exit when a term falls below 10 (sub-LSB in Q48.16). Sine is odd (`sin`(-x) = -sin(x)), so the sign is factored out before the series and reapplied to the result.

Parameters

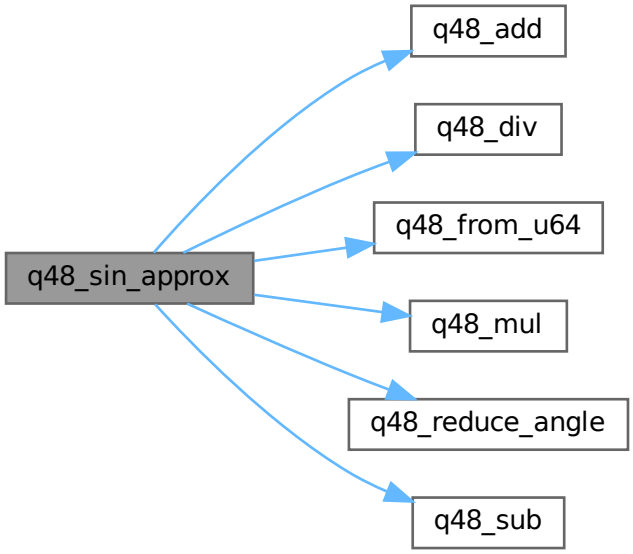
q	Angle in Q48.16 format (radians, any magnitude)

Returns

`sin(q)` in Q48.16 format

References q48_add(), q48_div(), q48_from_u64(), q48_mul(), q48_reduce_angle(), and q48_sub().

Here is the call graph for this function:



7.221.3.10 q48_sqrt_approx()

```
q48_16_t q48_sqrt_approx (
            q48_16_t q )
```

Compute an approximation of `sqrt(q)` in Q48.16 format (Newton-Raphson).

Iterates `x_{n+1}` = (x_n + q/x_n) / 2 starting from (q >> 1) + 16384, for up to 8 iterations. Terminates early when the delta between successive estimates falls below 10 (approximately 0.00015 in Q48.16). Used for R^2 computation in the inference engine. Returns 0 for `q` == 0, and 1.0 (65536) for `q` == 65536.

Parameters

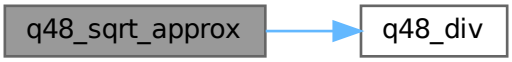
q	Input value in Q48.16 format

Returns

`sqrt(q)` in Q48.16 format

References q48_div(), and Q48_ONE.

Here is the call graph for this function:



7.221.3.11 q48_sub()

```
static q48_16_t q48_sub (
            q48_16_t a,
            q48_16_t b )  [inline], [static]
```

Subtract two Q48.16 values.

7.221.3.12 q48_to_u64()

```
static uint64_t q48_to_u64 (
            q48_16_t q )  [inline], [static]
```

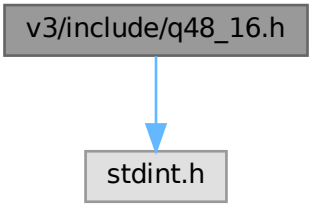
Convert Q48.16 to a 64-bit integer (truncate fractional): q >> 16, arithmetic (signed) shift so negative q sign-extends correctly instead of producing garbage from an unsigned logical shift.

Bit-identical to the old behavior for non-negative q.

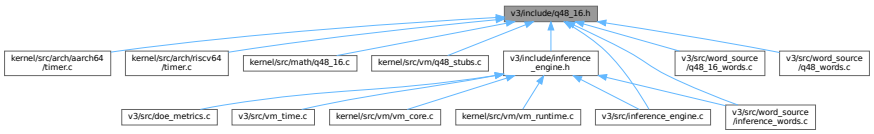
7.222 v3/include/q48_16.h File Reference

```
#include <stdint.h>
```

Include dependency graph for q48_16.h:



This graph shows which files directly or indirectly include this file:



Typedefs

- typedef uint64_t q48_16_t

Functions

- q48_16_t q48_mul (q48_16_t a, q48_16_t b)

  Multiply two Q48.16 fixed-point values.
- q48_16_t q48_div (q48_16_t a, q48_16_t b)

  Divide two Q48.16 fixed-point values.
- static q48_16_t q48_add (q48_16_t a, q48_16_t b)

  Add two Q48.16 values.
- static q48_16_t q48_sub (q48_16_t a, q48_16_t b)

  Subtract two Q48.16 values.
- static q48_16_t q48_abs (q48_16_t a)

  Absolute value of Q48.16.
- static q48_16_t q48_from_u64 (uint64_t u)

  Convert unsigned 64-bit integer to Q48.16.
- static uint64_t q48_to_u64 (q48_16_t q)

  Convert Q48.16 to a 64-bit integer (truncate fractional)
- q48_16_t q48_from_double (double d)

  Convert a `double` to Q48.16 format.
- double q48_to_double (q48_16_t q)

  Convert a Q48.16 value to `double`.
- q48_16_t q48_log_approx (uint64_t x)

  Compute an approximation of `ln(x)` in Q48.16 format (integer-only).
- q48_16_t q48_exp_approx (q48_16_t q)

  Compute an approximation of `e^q` in Q48.16 format (Taylor series).
- q48_16_t q48_sqrt_approx (q48_16_t q)

  Compute an approximation of `sqrt(q)` in Q48.16 format (Newton-Raphson).
- q48_16_t q48_sin_approx (q48_16_t q)

  Compute an approximation of `sin(q)` in Q48.16 format (radians).
- q48_16_t q48_cos_approx (q48_16_t q)

  Compute an approximation of `cos(q)` in Q48.16 format (radians).
- const char * q48_to_string (q48_16_t q)

  Format a Q48.16 value as a decimal string `"INTEGER.FRAC"`.
- int q48_is_valid (q48_16_t q)

  Test whether a Q48.16 value is valid.

7.222.1 Typedef Documentation

7.222.1.1 q48_16_t

```
typedef uint64_t q48_16_t
```

7.222.2 Function Documentation

7.222.2.1 q48_abs()

```
static q48_16_t q48_abs (
            q48_16_t a )  [inline], [static]
```

Absolute value of Q48.16.

Parameters

a	Q48.16 value

Returns

|a| in Q48.16 format

Referenced by q48_word_abs().

Here is the caller graph for this function:

7.222.2.2 q48_add()

```
static q48_16_t q48_add (
            q48_16_t a,
            q48_16_t b )  [inline], [static]
```

Add two Q48.16 values.

Math: (a / 2^16) + (b / 2^16) = (a + b) / 2^16 Returns: a + b (no shift needed, both have same scaling)

Parameters

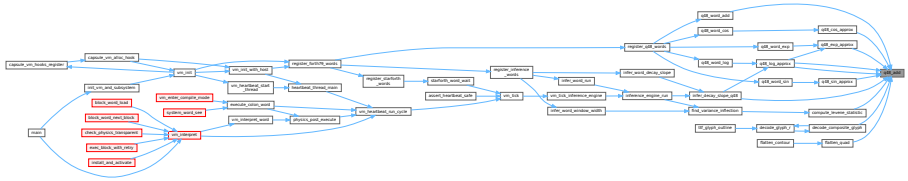
a	First Q48.16 operand
b	Second Q48.16 operand

Returns

a + b in Q48.16 format

Referenced by compute_levene_statistic(), decode_composite_glyph(), flatten_quad(), infer_decay_slope_q48(), q48_cos_approx(), q48_exp_approx(), q48_log_approx(), q48_log_approx(), q48_sin_approx(), and q48_word_add().

Here is the caller graph for this function:



7.222.2.3 q48_cos_approx()

```
q48_16_t q48_cos_approx (
            q48_16_t q )
```

Compute an approximation of `cos(q)` in Q48.16 format (radians).

Range-reduces into [-pi, pi] via `q48_reduce_angle()`, then sums the Taylor series `1 - x^2/2! + x^4/4! - ...` for terms n = 2,4,6,8,10, with an early exit when a term falls below 10. Cosine is even (`cos(-x) = cos(x)`), so no sign correction is needed – `x^2` already absorbs the sign of `x`.

Parameters

q	Angle in Q48.16 format (radians, any magnitude)

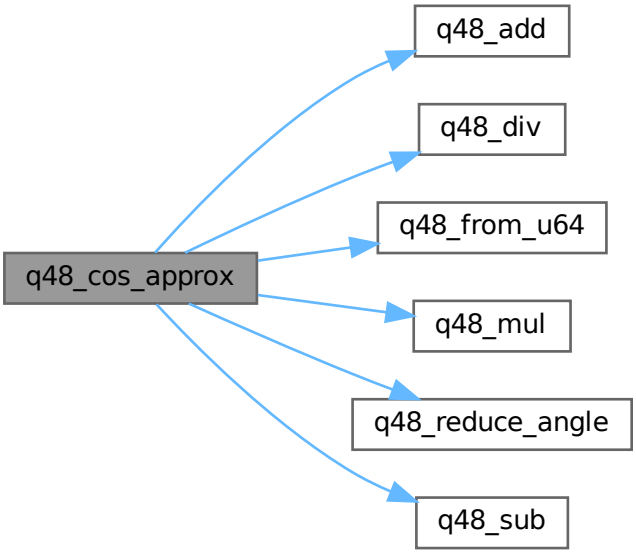
Returns

`cos(q)` in Q48.16 format

References q48_add(), q48_div(), q48_from_u64(), q48_mul(), q48_reduce_angle(), and q48_sub().

Referenced by q48_word_cos().

Here is the call graph for this function:



Here is the caller graph for this function:

7.222.2.4 q48_div()

```
q48_16_t q48_div (
            q48_16_t a,
            q48_16_t b )
```

Divide two Q48.16 fixed-point values.

Computes (a << 16) / b. Returns 0 if b == 0 (safe, but callers should guard). Returns UINT64_MAX as a saturation sentinel when a exceeds 2^48, which would overflow the 16-bit left-shift.

Parameters

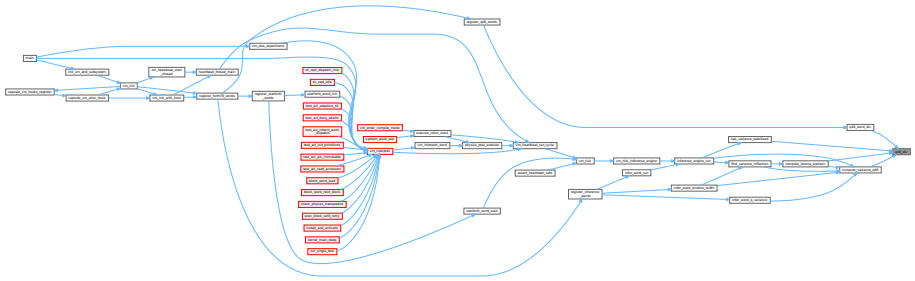
a	Dividend in Q48.16 format
b	Divisor in Q48.16 format; 0 returns 0

Returns

Quotient in Q48.16 format, or UINT64_MAX on saturation

Referenced by compute_levene_statistic(), compute_variance_q48(), has_variance_stabilized(), and q48_word_div().

Here is the caller graph for this function:



7.222.2.5 q48_exp_approx()

```
q48_16_t q48_exp_approx (
            q48_16_t q )
```

Compute an approximation of e^q in Q48.16 format (Taylor series).

Supporting function for `q48_log_approx()` Newton iterations. Uses the Taylor series 1 + x + x^2/2! + ... up to 10 terms, with an early-exit when a term falls below 50 (sub-LSB in Q48.16). Handles negative q by computing e^|q| then returning `1/result`. Returns 1.0 (65536) for q == 0, `UINT64_MAX` for q >= 16.0, and 0 for q <= -16.0.

Parameters

q	Exponent in Q48.16 format (signed interpretation)

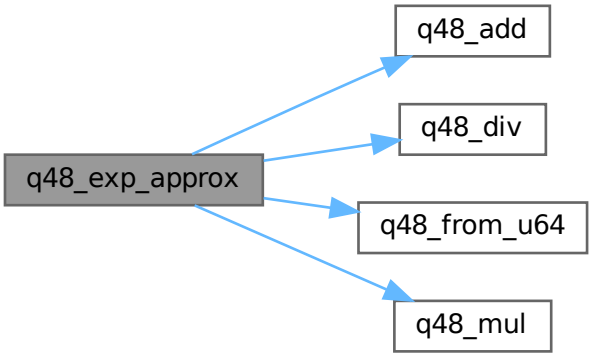
Returns

e^q in Q48.16 format

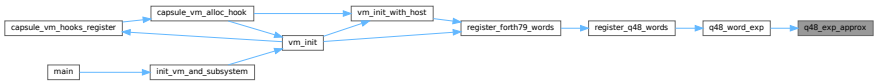
References q48_add(), q48_div(), q48_from_u64(), and q48_mul().

Referenced by q48_word_exp().

Here is the call graph for this function:



Here is the caller graph for this function:



7.222.2.6 q48_from_double()

```
q48_16_t q48_from_double (
            double d )
```

Convert a `double` to Q48.16 format.

Multiplies `d` by 65536.0 and rounds to nearest. Intended for testing and diagnostics only — not called in the inference engine hot path to avoid floating-point dependency.

Parameters

d	Value to convert

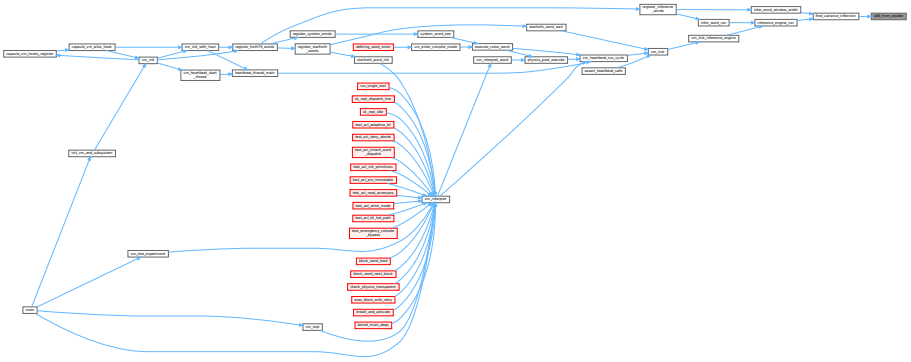
Returns

Nearest Q48.16 representation of `d`

References zero.

Referenced by find_variance_inflection().

Here is the caller graph for this function:



7.222.2.7 q48_from_u64()

```
static q48_16_t q48_from_u64 (
            uint64_t u )  [inline], [static]
```

Convert unsigned 64-bit integer to Q48.16.

Math: u ∗ 2^16 (shift left by 16 bits) Example: q48_from_u64(1) = 0x10000 (1.0 in Q48.16)

Parameters

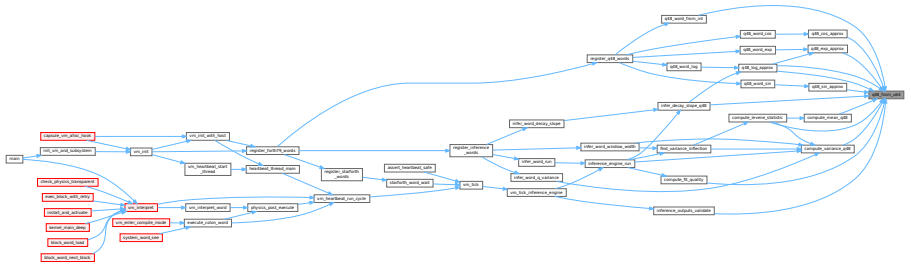
u	Unsigned 64-bit integer (max 2^48-1 to avoid overflow)

Returns

u << 16 in Q48.16 format

Referenced by compute_fit_quality(), compute_levene_statistic(), compute_mean_q48(), compute_variance_q48(), infer_decay_slope_q48(), inference_outputs_validate(), q48_cos_approx(), q48_exp_approx(), q48_log_approx(), q48_log_approx(), q48_sin_approx(), and q48_word_from_int().

Here is the caller graph for this function:



7.222.2.8 q48_is_valid()

```
int q48_is_valid (
            q48_16_t q )
```

Test whether a Q48.16 value is valid.

Currently accepts any `uint64_t` value as valid — all bit patterns are representable in Q48.16. A more sophisticated implementation could check for saturation sentinels or range limits. Returns 1 always.

Parameters

q	Value to validate

Returns

1 always (placeholder for future range validation)

7.222.2.9 q48_log_approx()

```
q48_16_t q48_log_approx (
            uint64_t x )
```

Compute an approximation of `ln(x)` in Q48.16 format (integer-only).

Used by `infer_decay_slope_q48()` (Loop #6) for log-linear OLS regression. Algorithm: range-reduces `x` to the interval [1, 2) by tracking the exponent `k` (so `x` = 2^k ∗ m), applies 6 Newton-Raphson iterations on `e^y` = m starting from the first-order approximation `y_0` = m - 1, then assembles the result as `ln(x)` = k∗ln(2) + ln(m). Returns 0 for `x` == 0 (ln undefined) and for `x` == 65536 (ln(1.0) == 0.0 exactly). `LN2_Q48` = 45426 (0.693147... × 65536).

Parameters

x	Input value in Q48.16 format (uint64_t; value of 65536 = 1.0)

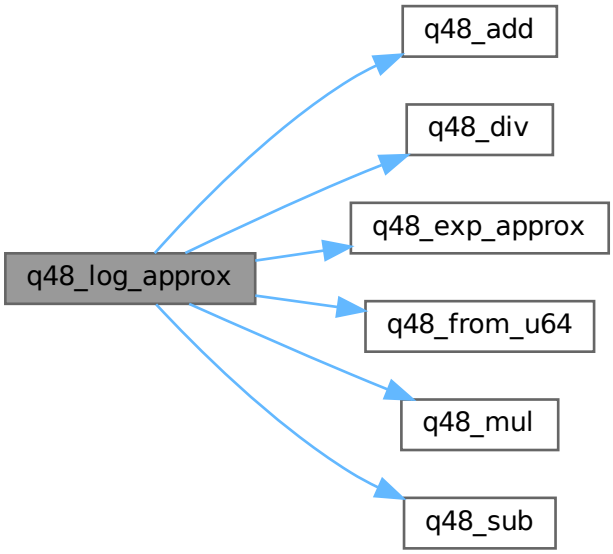
Returns

`ln(x)` in Q48.16 format, or 0 for x==0 or x==65536

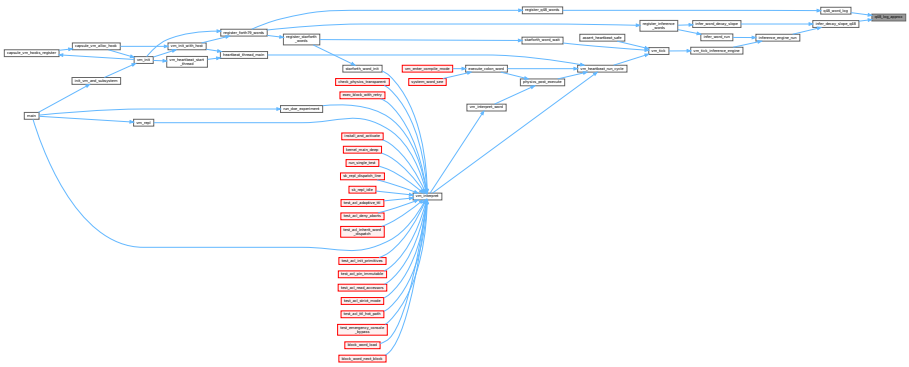
References q48_add(), q48_div(), q48_exp_approx(), q48_from_u64(), q48_mul(), and q48_sub().

Referenced by infer_decay_slope_q48(), and q48_word_log().

Here is the call graph for this function:



Here is the caller graph for this function:



7.222.2.10 q48_mul()

```
q48_16_t q48_mul (
            q48_16_t a,
            q48_16_t b )
```

Multiply two Q48.16 fixed-point values.

Computes (a ∗ b) >> 16 to maintain the Q48.16 scale. Uses __uint128_t on GCC/Clang (128-bit intermediate, no precision loss) and falls back to a manual 64-bit four-partial-product path with carry tracking on platforms that lack __SIZEOF_INT128__.

Parameters

a	First operand in Q48.16 format
b	Second operand in Q48.16 format

Returns

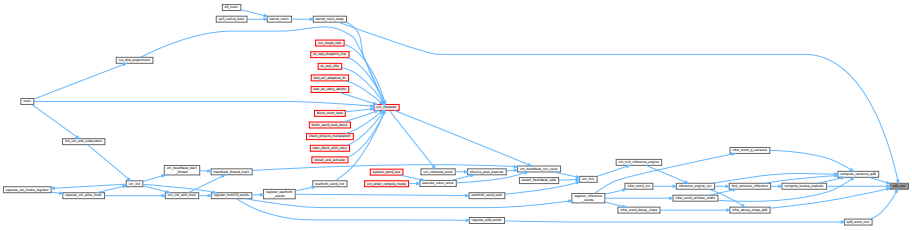
Product in Q48.16 format (truncated, not rounded)

Multiply two Q48.16 fixed-point values.

Freestanding implementation: no libc, no floating-point.

Referenced by compute_levene_statistic(), compute_variance_q48(), infer_decay_slope_q48(), kernel_main_deep(), and q48_word_mul().

Here is the caller graph for this function:



7.222.2.11 q48_sin_approx()

```
q48_16_t q48_sin_approx (
            q48_16_t q )
```

Compute an approximation of `sin(q)` in Q48.16 format (radians).

Range-reduces into [-pi, pi] via `q48_reduce_angle()`, then sums the Taylor series `x` - x^3/3! + x^5/5! - ... for terms n = 3,5,7,9,11, with an early exit when a term falls below 10 (sub-LSB in Q48.16). Sine is odd (`sin`(-x) = -sin(x)), so the sign is factored out before the series and reapplied to the result.

Parameters

q	Angle in Q48.16 format (radians, any magnitude)

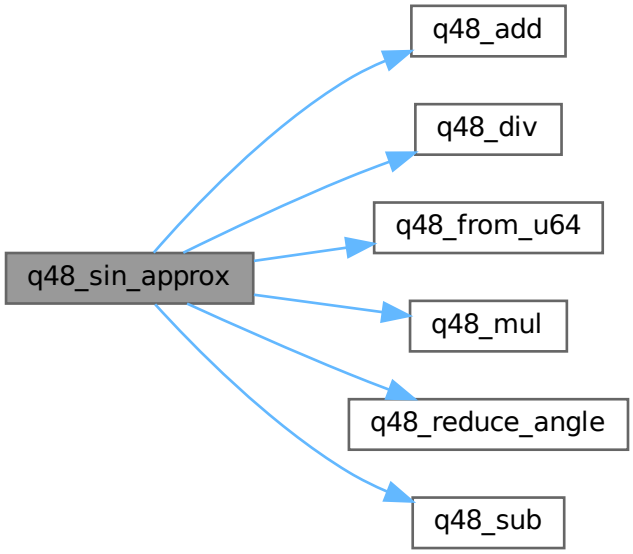
Returns

`sin(q)` in Q48.16 format

References q48_add(), q48_div(), q48_from_u64(), q48_mul(), q48_reduce_angle(), and q48_sub().

Referenced by q48_word_sin().

Here is the call graph for this function:



Here is the caller graph for this function:

7.222.2.12 q48_sqrt_approx()

```
q48_16_t q48_sqrt_approx (
            q48_16_t q )
```

Compute an approximation of `sqrt(q)` in Q48.16 format (Newton-Raphson).

Iterates `x_{n+1}` = (x_n + q/x_n) / 2 starting from (q >> 1) + 16384, for up to 8 iterations. Terminates early when the delta between successive estimates falls below 10 (approximately 0.00015 in Q48.16). Used for R^2 computation in the inference engine. Returns 0 for `q` == 0, and 1.0 (65536) for `q` == 65536.

Parameters

q	Input value in Q48.16 format

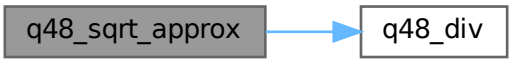
Returns

`sqrt(q)` in Q48.16 format

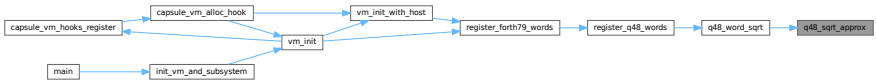
References q48_div().

Referenced by q48_word_sqrt().

Here is the call graph for this function:



Here is the caller graph for this function:



7.222.2.13 q48_sub()

```
static q48_16_t q48_sub (
            q48_16_t a,
            q48_16_t b )  [inline], [static]
```

Subtract two Q48.16 values.

Math: (a / 2^16) - (b / 2^16) = (a - b) / 2^16 Returns: a - b (no shift needed)

Parameters

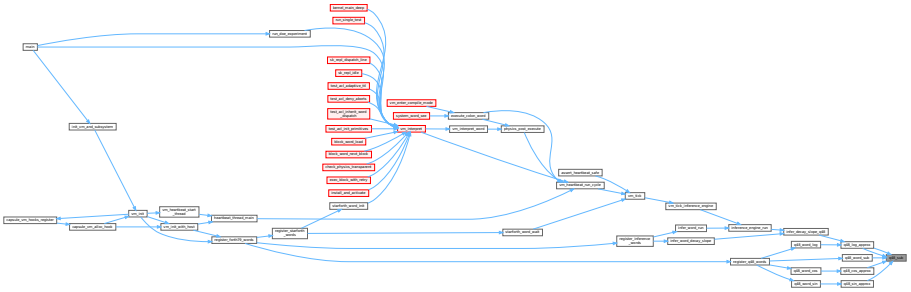
a	Minuend in Q48.16
b	Subtrahend in Q48.16

Returns

a - b in Q48.16 format

Referenced by q48_cos_approx(), q48_log_approx(), q48_log_approx(), q48_sin_approx(), and q48_word_sub().

Here is the caller graph for this function:



7.222.2.14 q48_to_double()

```
double q48_to_double (
            q48_16_t q )
```

Convert a Q48.16 value to `double`.

Divides `q` by 65536.0. Used for logging and RStudio dashboard output; not called in the inference engine hot path.

Parameters

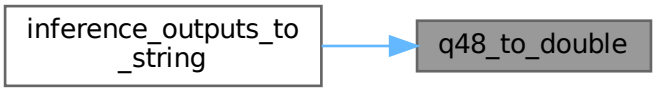
q	Value in Q48.16 format

Returns

Equivalent `double` value

Referenced by inference_outputs_to_string().

Here is the caller graph for this function:



7.222.2.15 q48_to_string()

```
const char * q48_to_string (
            q48_16_t q )
```

Format a Q48.16 value as a decimal string `"INTEGER.FRAC"`.

Writes into a static buffer — not thread-safe and not re-entrant. The fractional part is expressed as 5 decimal digits (`frac_part` * 100000 / 65536). Intended for diagnostic logging.

Parameters

q	Value in Q48.16 format

Returns

Pointer to a static buffer containing the formatted string

References snprintf().

Here is the call graph for this function:

7.222.2.16 q48_to_u64()

```
static uint64_t q48_to_u64 (
            q48_16_t q )  [inline], [static]
```

Convert Q48.16 to a 64-bit integer (truncate fractional)

Math: q / 2^16 (arithmetic shift right by 16 bits) Example: q48_to_u64(0x10000) = 1, q48_to_u64(-0x10000) = -1

q48_16_t values are two's-complement signed under the hood (q48_neg/ q48_abs already treat them that way); a plain unsigned (logical) shift would corrupt negative inputs instead of sign-extending them, so this shifts via a signed intermediate. Bit-identical to the old behavior for non-negative q (the only case this function's other caller, the inference engine's sum-of-squares accumulation, ever produces).

Parameters

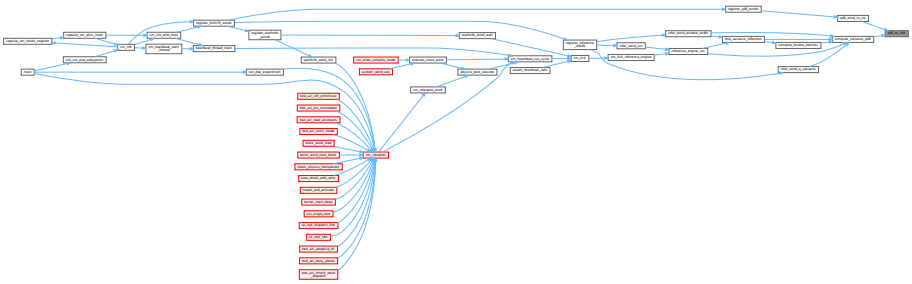
q	Q48.16 value

Returns

q >> 16, sign-extended, reinterpreted as uint64_t

Referenced by compute_variance_q48(), and q48_word_to_int().

Here is the caller graph for this function:



7.223 kernel/include/starkernel/freestanding/README.md File Reference

7.224 kernel/include/starkernel/freestanding/sys/README.md File Reference

7.225 kernel/include/starkernel/hal/README.md File Reference

7.226 kernel/include/starkernel/README.md File Reference

7.227 kernel/include/starkernel/vm/bootstrap/README.md File Reference

7.228 kernel/include/starkernel/vm/README.md File Reference

7.229 kernel/src/arch/aarch64/README.md File Reference

7.230 kernel/src/arch/amd64/README.md File Reference

7.231 kernel/src/arch/riscv64/README.md File Reference

7.232 kernel/src/boot/README.md File Reference

7.233 kernel/src/capsule/README.md File Reference

7.234 kernel/src/hal/README.md File Reference

7.235 kernel/src/hash/README.md File Reference

7.236 kernel/src/math/README.md File Reference

7.237 kernel/src/memory/README.md File Reference

7.238 kernel/src/pci/README.md File Reference

7.239 kernel/src/README.md File Reference

7.240 kernel/src/virtio/README.md File Reference

7.241 kernel/src/vm/bootstrap/README.md File Reference

7.242 kernel/src/vm/host/README.md File Reference

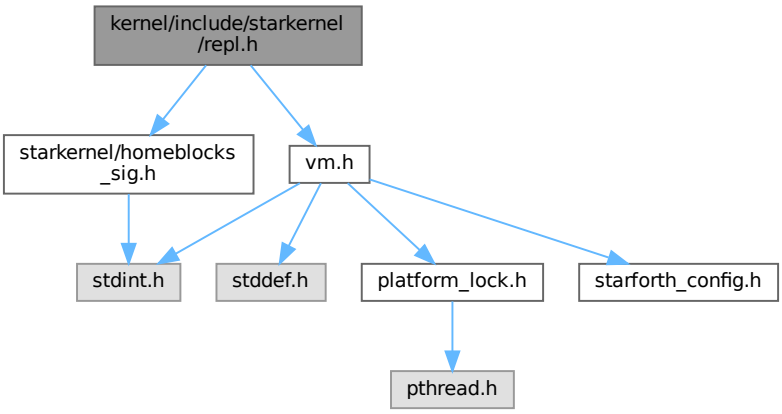
7.243 kernel/src/vm/README.md File Reference

7.244 README.md File Reference

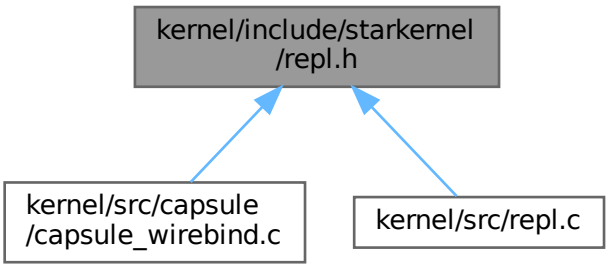
7.245 v3/include/README.md File Reference

```
#include "starkernel/homeblocks_sig.h"
```

Include dependency graph for repl.h:



This graph shows which files directly or indirectly include this file:



Functions

- void sk_repl (VM *vm)

  sk_repl - Run the emergency FORTH REPL on the serial console.
- void sk_repl_run (VM *vm)

  sk_repl_run - Bare REPL loop (no banner).
- int sk_repl_step (VM *vm)

  sk_repl_step - Execute one REPL turn on a VM and return.
- void sk_repl_set_active_vm (VM *vm)

  sk_repl_set_active_vm - Redirect REPL input to a different VM (USE word).
- VM * sk_repl_get_active_vm (void)

  sk_repl_get_active_vm - Return the current USE-redirected VM, or NULL.
- struct blkio_dev * sk_repl_get_homeblocks_dev (void)

sk_repl_get_homeblocks_dev / sk_repl_get_homeblocks_sig - The currently attached home-blocks USB drive, or NULL if none is attached / the attached drive didn't check out as HOMEBLOCKS_SIG_OK (FABRIC-2.md ?F.6/?F.9/?F.18).

- const homeblocks_sig_t * sk_repl_get_homeblocks_sig (void)
- struct blkio_dev * sk_repl_get_attached_blk_dev (void)

  sk_repl_get_attached_blk_dev - The currently attached USB block device, regardless of home-blocks recognition (FABRIC-2.md ?F.8/?F.19) – MINT's own target, since a blank/unminted drive never sets sk_repl_get_homeblocks_dev() above.
- void sk_repl_register_words (VM *vm)

  sk_repl_register_words - Registers repl.c's own FORTH-visible words (currently just BLK-ATTACH-ACK, Artemis's storage-attach reply target – see sk_word_blk_attach_ack()'s doc comment in repl.c).
- int sk_console_getkey (VM *active_vm)

  sk_console_getkey - Real body of the standard dictionary's KEY word (called from shim.c's getchar()).
- int sk_console_key_available (void)

  sk_console_key_available - Real body of the standard dictionary's ?TERMINAL word (called from sf_terminal_ready()).
- int sk_console_readline (char *buf, int size, VM *active_vm, int reanchor_prompt)

  sk_console_readline - Real body of the standard dictionary's QUERY/EXPECT words (called from shim.c's fgets()).
- void sk_repl_headless_wait (VM *mama)

  sk_repl_headless_wait - Idle-service loop with no interactive surface at all: no banner, no prompt, no console_getc()/readline.

7.255.1 Function Documentation

7.255.1.1 sk_console_getkey()

```
int sk_console_getkey (
            VM * active_vm )
```

sk_console_getkey - Real body of the standard dictionary's KEY word (called from shim.c's getchar()).

Blocks until a key is available from either input source (serial console or the PS2/virtio keyboard-event bridge), servicing the heartbeat/idle loop while waiting so a KEY call from inside any word never stalls the heartbeat. No echo – that's the caller's responsibility, same as any standard KEY.

Parameters

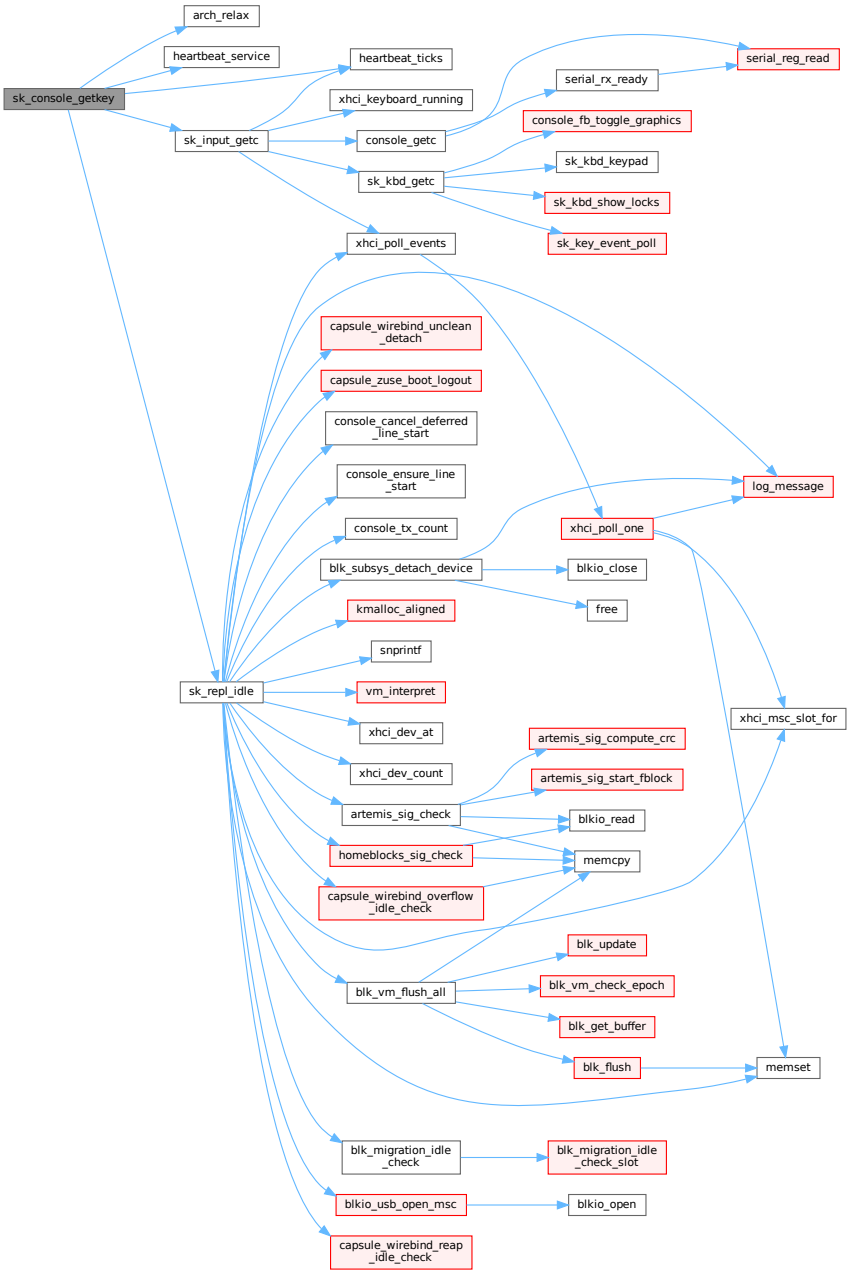
active_vm	VM whose idle dispatch runs while waiting (see sk_repl_idle()'s own doc comment on why this is a parameter rather than read via sk_repl_get_active_vm())

Returns

the key read, as an unsigned byte value

References arch_relax(), g_console_pending_key, g_last_beat_tick, g_repl_active_vm, heartbeat_service(), heartbeat_ticks(), SK_IDLE_BEAT_INTERVAL, sk_input_getc(), and sk_repl_idle().

Here is the call graph for this function:



7.255.1.2 sk_console_key_available()

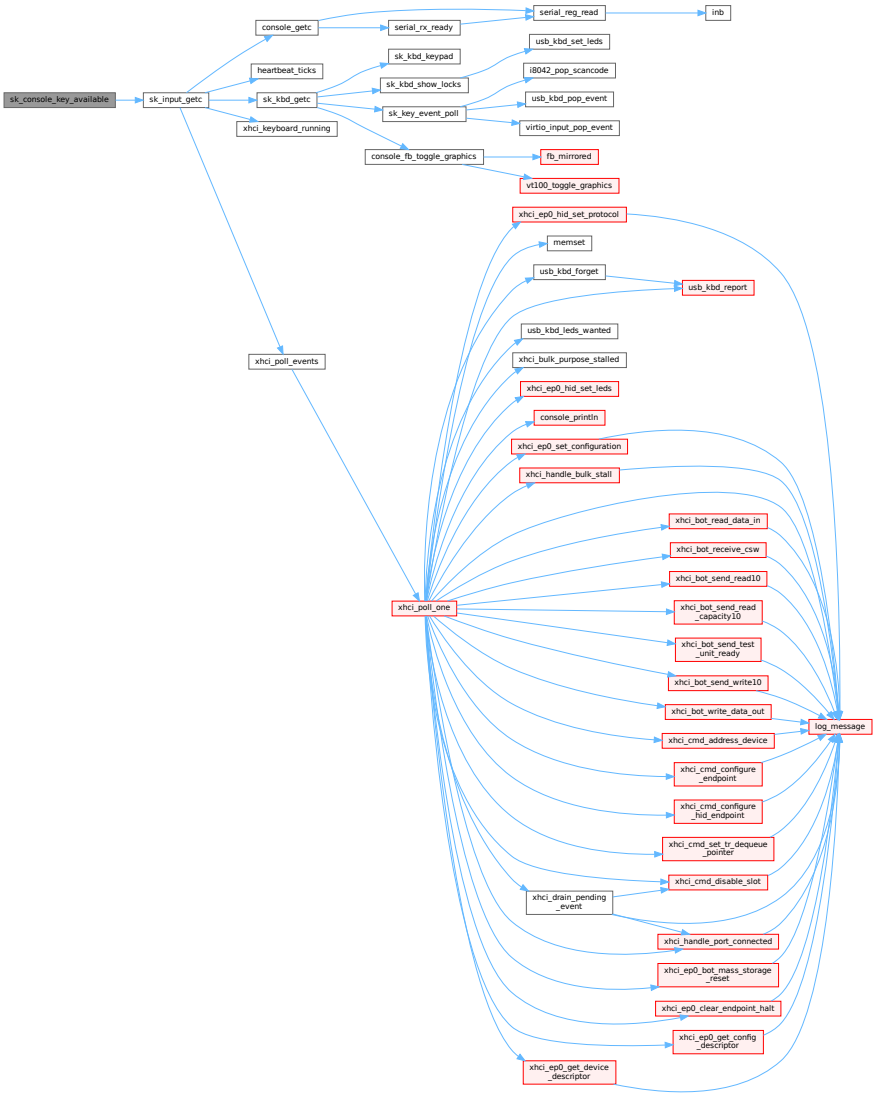
```
int sk_console_key_available (
            void  )
```

sk_console_key_available - Real body of the standard dictionary's ?TERMINAL word (called from sf_terminal_ready()).

Non-blocking peek: returns 1 if a key is ready without consuming it (a following sk_console_getkey() returns that exact key), 0 otherwise.

References g_console_pending_key, and sk_input_getc().

Here is the call graph for this function:



7.255.1.3 sk_console_readline()

```
int sk_console_readline (
            char * buf,
            int size,
            VM * active_vm,
            int reanchor_prompt )
```

sk_console_readline - Real body of the standard dictionary's QUERY/EXPECT words (called from shim.c's fgets()).

Reads one line from the console with echo and backspace support, servicing the heartbeat/ idle loop while waiting – the same line editor the REPL's own prompt uses internally, so a mid-word EXPECT behaves identically to typing at "ok>" itself.

Parameters

buf	Destination buffer
size	Buffer capacity, including the NUL terminator
active_vm	VM whose idle dispatch runs while waiting
reanchor_prompt	Nonzero to re-print the "ok> " prompt whenever an idle bottom half (heartbeat, USB attach/detach) writes to the console while this readline blocks at a bare, untyped prompt – keeps the top-level prompt as the last thing shown once the chatter dies down. Callers whose prompt line is their own (shim.c's fgets(), i.e. QUERY/EXPECT/ACCEPT) pass 0 so "ok> " never gets stamped onto their mid-word input context.

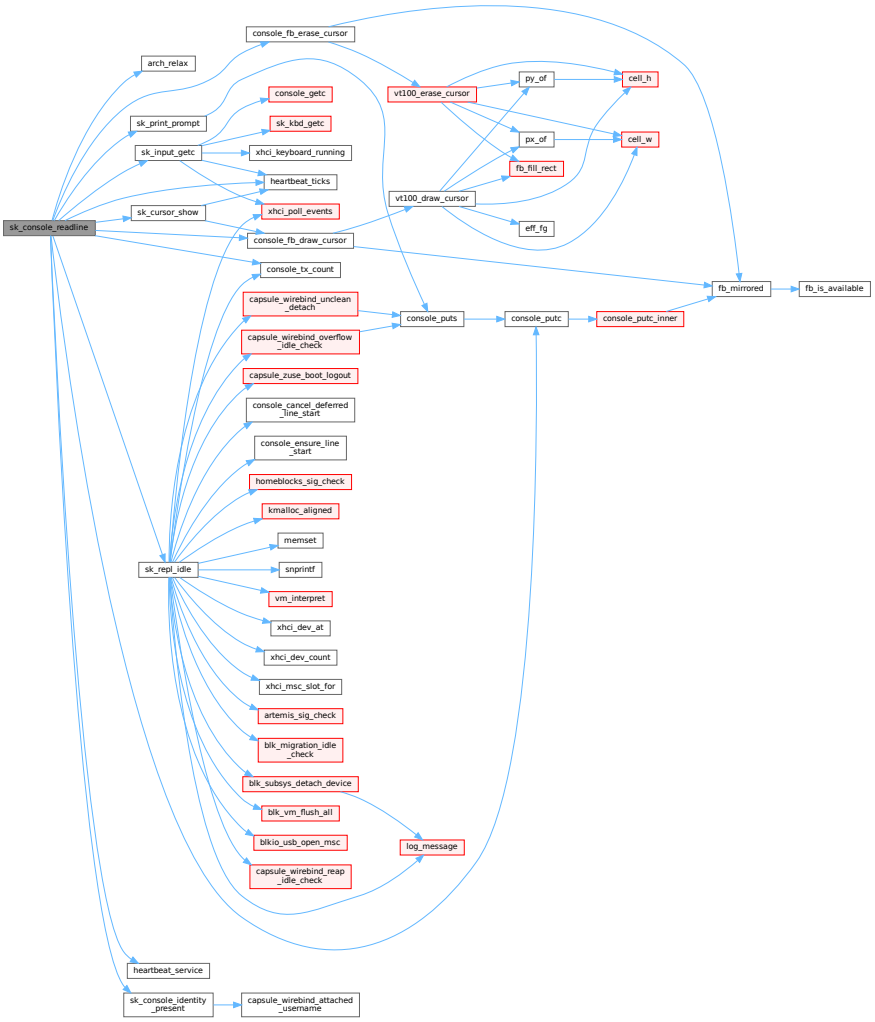
Returns

number of characters placed in buf, not counting the NUL, or -1 (2026-09-06) when reanchor_prompt is nonzero and the attached identity logged out while this call was blocked waiting for input with nothing typed yet – see repl.c's own doc comment on this function for what a caller must do with -1.

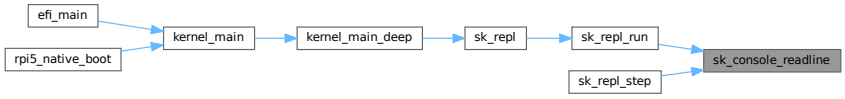
References arch_relax(), console_fb_draw_cursor(), console_fb_erase_cursor(), console_putc(), console_tx_count(), g_console_pending_key, g_cursor_blink_tick, g_cursor_visible, g_last_beat_tick, g_repl_active_vm, heartbeat_service(), heartbeat_ticks(), sk_console_identity_present(), SK_CURSOR_BLINK_INTERVAL, sk_cursor_show(), SK_IDLE_BEAT_INTERVAL, sk_input_getc(), sk_print_prompt(), and sk_repl_idle().

Referenced by sk_repl_run(), and sk_repl_step().

Here is the call graph for this function:



Here is the caller graph for this function:



7.255.1.4 sk_repl()

```
void sk_repl (
            VM * vm )
```

sk_repl - Run the emergency FORTH REPL on the serial console.

Blocks until vm->halted is set (BYE word) or the VM encounters a halt. Runs with interrupts enabled; the APIC heartbeat continues to fire.

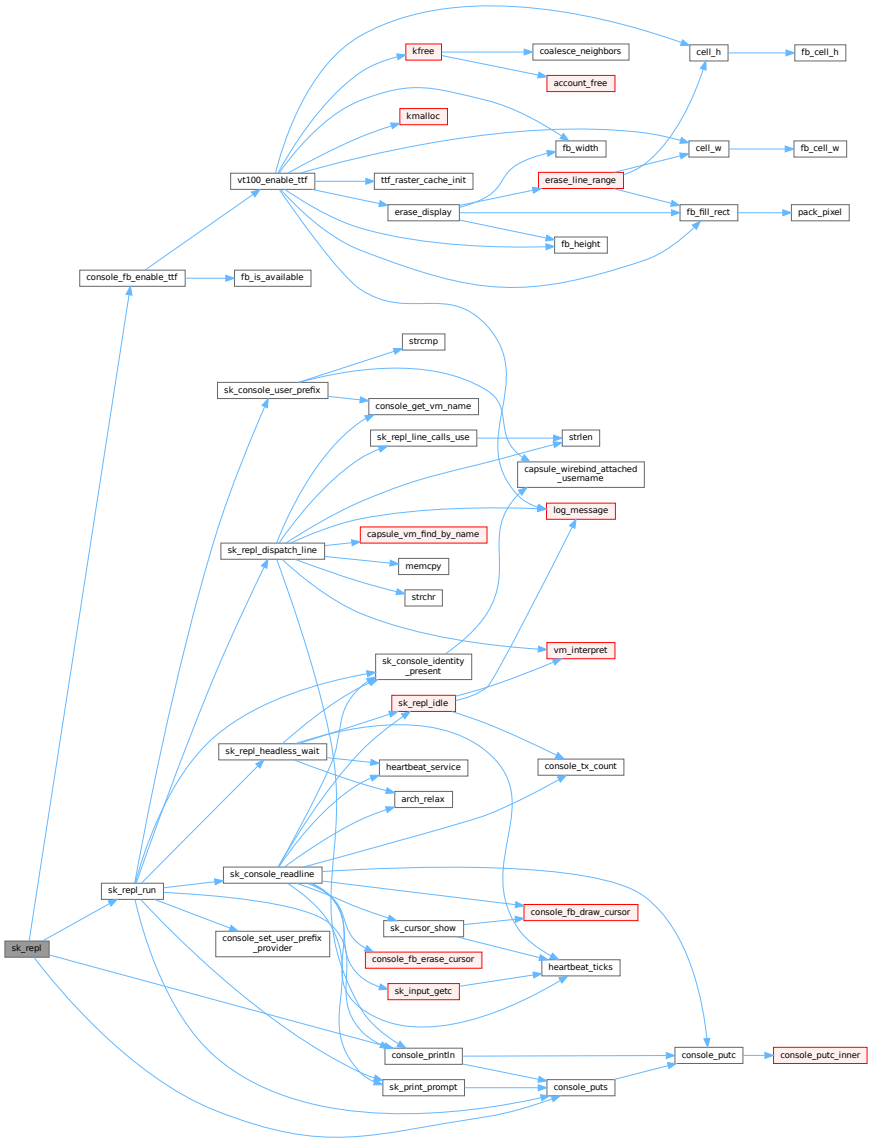
Parameters

vm	Mama VM instance (must be fully initialised)

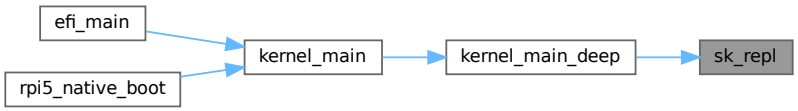
References console_fb_enable_ttf(), console_println(), console_puts(), lithos_version, sk_repl_run(), and STARFORTH_VERSION.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



7.255.1.5 sk_repl_get_active_vm()

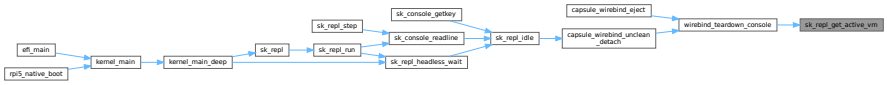
```
VM * sk_repl_get_active_vm (
            void  )
```

sk_repl_get_active_vm - Return the current USE-redirected VM, or NULL.

References g_repl_active_vm.

Referenced by wirebind_teardown_console().

Here is the caller graph for this function:



7.255.1.6 sk_repl_get_attached_blk_dev()

```
struct blkio_dev * sk_repl_get_attached_blk_dev (
            void  )
```

sk_repl_get_attached_blk_dev - The currently attached USB block device, regardless of home-blocks recognition (FABRIC-2.md ?F.8/?F.19) – MINT's own target, since a blank/unminted drive never sets sk_repl_get_homeblocks_dev() above.

NULL if nothing is attached.

References g_attached_blk_dev.

7.255.1.7 sk_repl_get_homeblocks_dev()

```
struct blkio_dev * sk_repl_get_homeblocks_dev (
            void  )
```

sk_repl_get_homeblocks_dev / sk_repl_get_homeblocks_sig - The currently attached home-blocks USB drive, or NULL if none is attached / the attached drive didn't check out as HOMEBLOCKS_SIG_OK (FABRIC-2.md ?F.6/?F.9/?F.18).

Both return NULL together; never one without the other.

References g_homeblocks_dev, and g_homeblocks_sig_valid.

7.255.1.8 sk_repl_get_homeblocks_sig()

```
const homeblocks_sig_t * sk_repl_get_homeblocks_sig (
            void  )
```

References g_homeblocks_sig, and g_homeblocks_sig_valid.

7.255.1.9 sk_repl_headless_wait()

```
void sk_repl_headless_wait (
            VM * mama )
```

sk_repl_headless_wait - Idle-service loop with no interactive surface at all: no banner, no prompt, no console_getc()/readline.

Runs heartbeat_service() and the same SK_IDLE_BEAT_INTERVAL-gated sk_repl_idle(mama) cadence sk_console_readline()'s own idle branch uses – so USB/WIREBIND/Zuse-attach detection, the heartbeat, and all other idle-tick subsystems keep running – until a real identity is currently attached (Zuse's own session, or a WIREBIND user), at which point it returns.

Revised 2026-09-06: originally exited on a one-way sticky "has anyone ever logged in this boot" flag (sk↩ _console_mark_login()/sk_console_ login_occurred(), both retired) – that let a real gap through, found live↩ : once the flag tripped once, it never reset, so a later full logout (nobody attached at all) fell through to a bare, unauthenticated prompt instead of going silent again. This now checks live attach state instead (repl.c's own sk_console_identity_present()), and is called from two places: once from kernel_main.c in place of an immediate sk_repl(mama) call when EMERGENCY_CONSOLE_ENABLED is off (the default, 2026-09-05) – no thumbdrive, no prompt, at boot – and again from inside sk_repl_run()'s own main loop, every time nobody is currently attached, so the same silence re-engages after any later logout mid-boot too. When EMERGENCY_CONSOLE_ENABLED is on (the debug/ recovery escape hatch), neither call site applies – the console shows immediately and stays visible regardless of attach state, exactly as before this change.

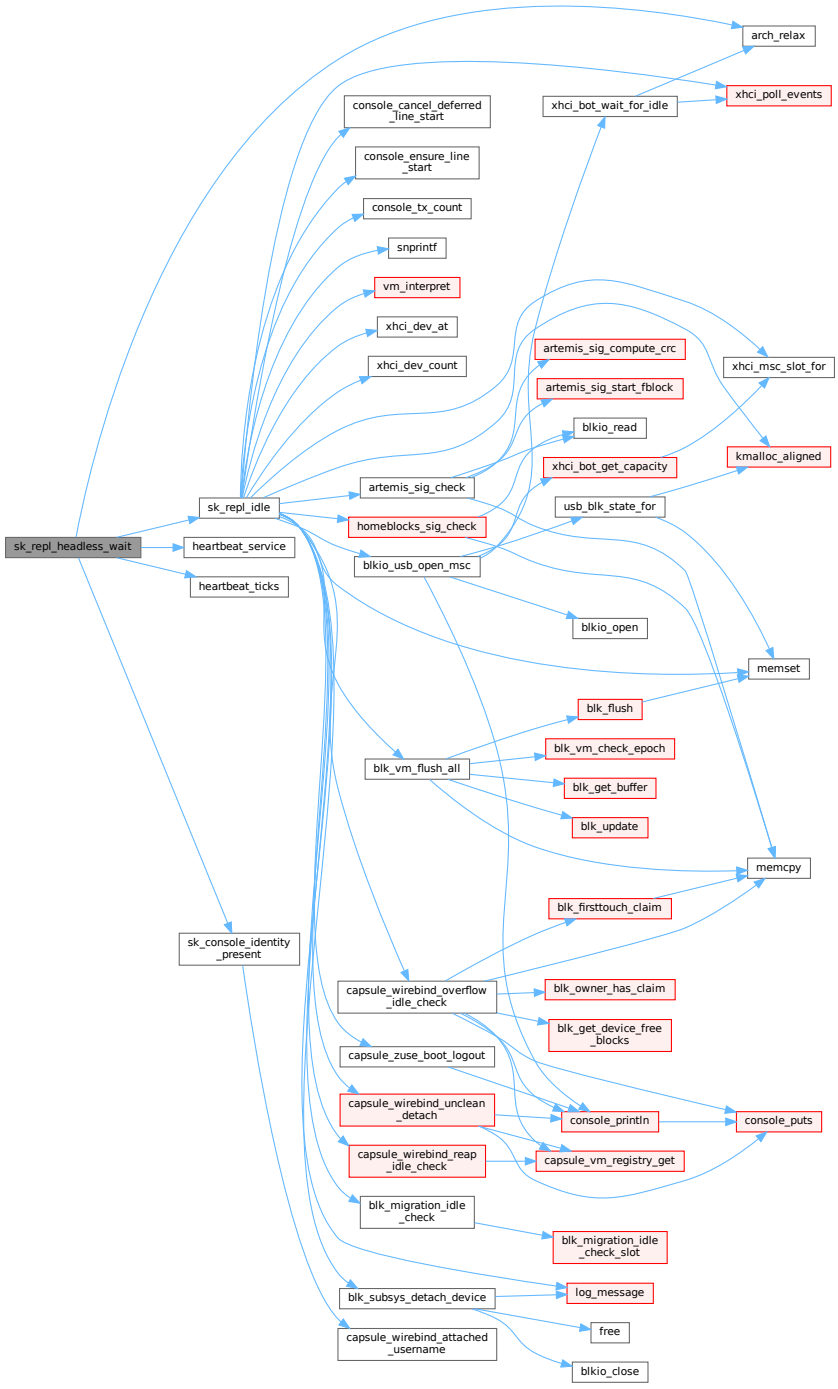
Parameters

mama	Hera's own VM instance – the idle-dispatch target, same as every other sk_repl_idle() caller uses.

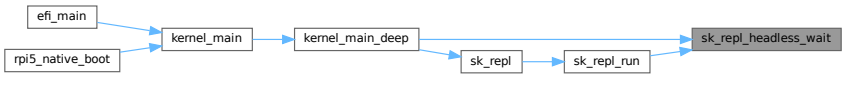
References arch_relax(), g_last_beat_tick, heartbeat_service(), heartbeat_ticks(), sk_console_identity_present(), SK_IDLE_BEAT_INTERVAL, and sk_repl_idle().

Referenced by kernel_main_deep(), and sk_repl_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.255.1.10 sk_repl_register_words()

```
void sk_repl_register_words (
            VM * vm )
```

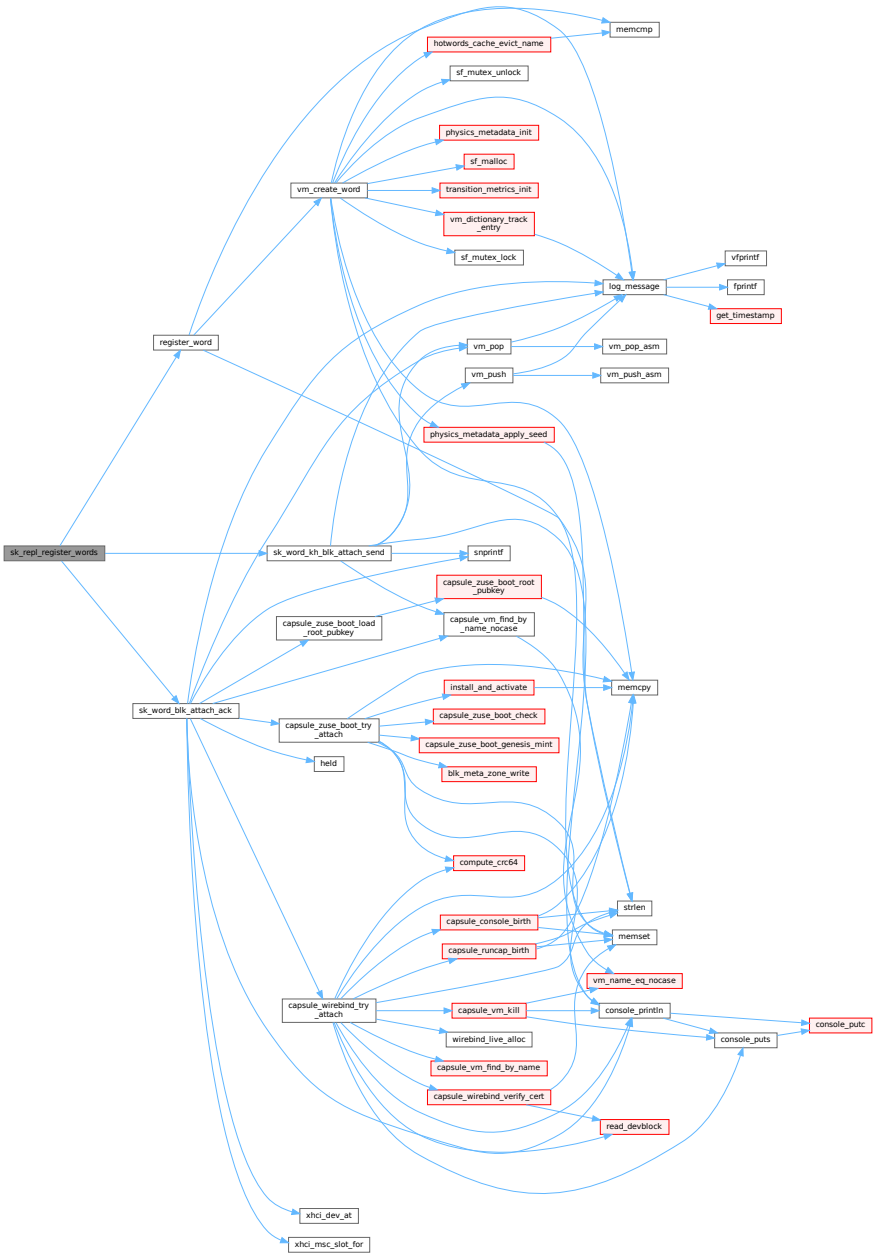
sk_repl_register_words - Registers repl.c's own FORTH-visible words (currently just BLK-ATTACH-ACK, Artemis's storage-attach reply target – see sk_word_blk_attach_ack()'s doc comment in repl.c).

Call once from register_forth79_words() alongside the other **STARKERNEL**-only registration calls.

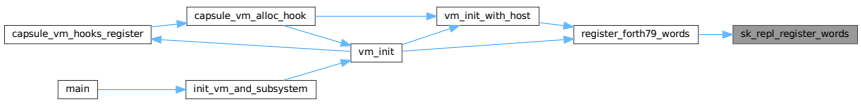
References register_word(), sk_word_blk_attach_ack(), and sk_word_kh_blk_attach_send().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.255.1.11 sk_repl_run()

```
void sk_repl_run (
            VM * vm )
```

sk_repl_run - Bare REPL loop (no banner).

Same as sk_repl but skips the version/welcome banner. Used by START to enter a child VM's interpreter loop without reprinting the header.

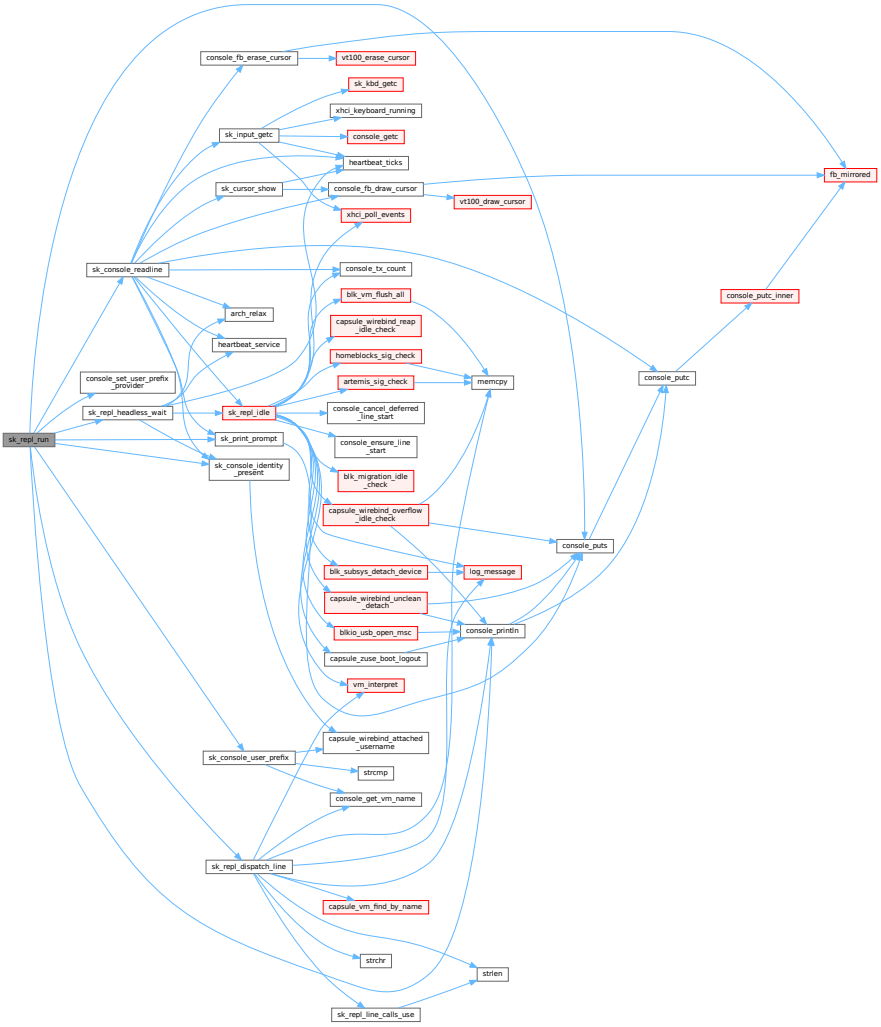
Parameters

vm	Fully initialised VM instance

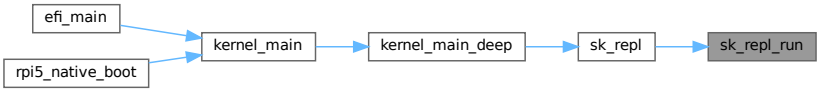
References VM::abort_requested, console_println(), console_puts(), console_set_user_prefix_provider(), VM::error, g_repl_active_vm, VM::halted, INPUT_BUFFER_SIZE, sk_console_identity_present(), sk_console_readline(), sk_console_user_prefix(), sk_print_prompt(), sk_repl_dispatch_line(), and sk_repl_headless_wait().

Referenced by sk_repl().

Here is the call graph for this function:



Here is the caller graph for this function:



7.255.1.12 sk_repl_set_active_vm()

```
void sk_repl_set_active_vm (
            VM * vm )
```

sk_repl_set_active_vm - Redirect REPL input to a different VM (USE word).

Pass NULL to restore default dispatch (Mama's VM). The change takes effect on the next REPL iteration.

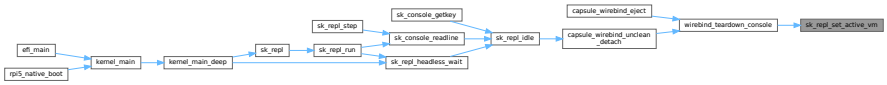
Parameters

vm	Target VM, or NULL for default

References g_repl_active_vm.

Referenced by wirebind_teardown_console().

Here is the caller graph for this function:



7.255.1.13 sk_repl_step()

```
int sk_repl_step (
            VM * vm )
```

sk_repl_step - Execute one REPL turn on a VM and return.

Prints the VM's prompt, reads one line, interprets it, prints ok/ERROR, then returns. Used by the Compudynamics VM-STEP primitive so Hera can give a single REPL quantum to a child VM without surrendering control for the full sk_repl_run() loop.

Parameters

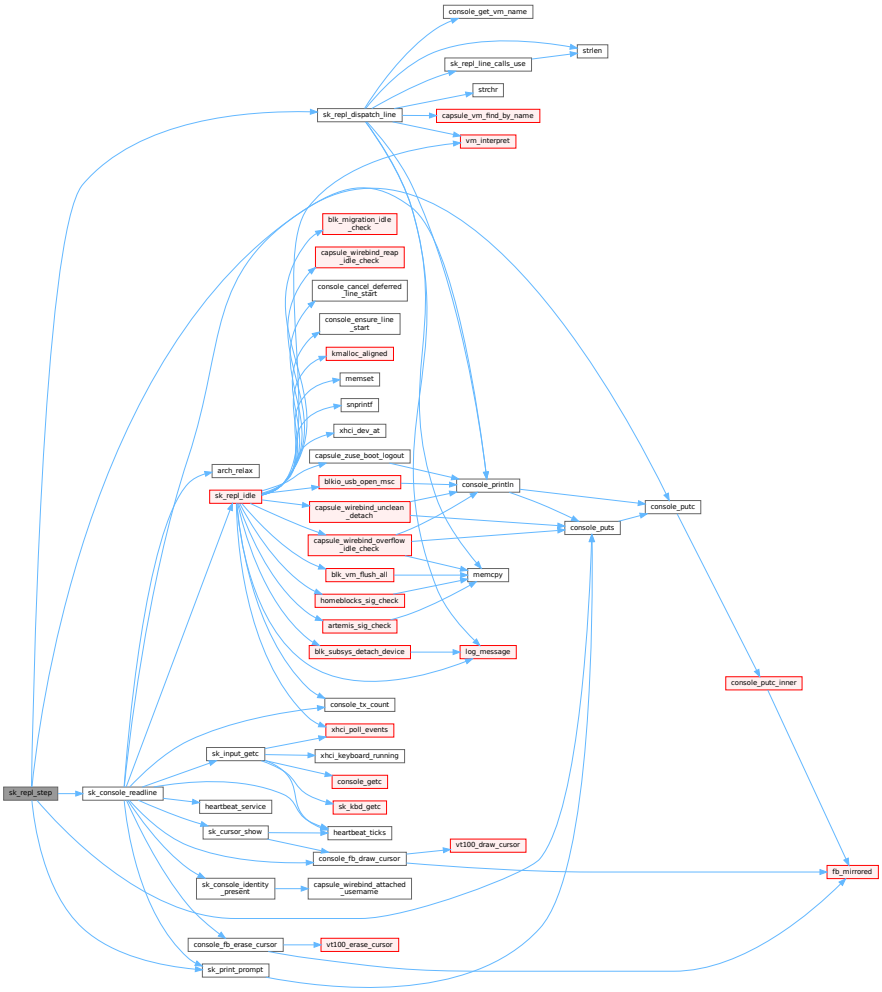
vm	Fully initialised VM instance

Returns

1 if the VM is still running, 0 if it halted during this turn

References VM::abort_requested, console_println(), console_puts(), VM::error, VM::halted, INPUT_BUFFER_SIZE, sk_console_readline(), sk_print_prompt(), and sk_repl_dispatch_line().

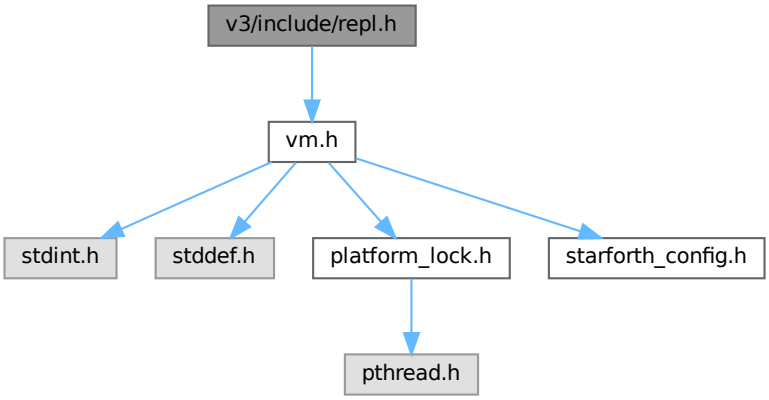
Here is the call graph for this function:



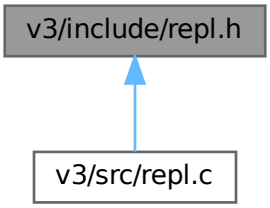
7.256 v3/include/repl.h File Reference

```
#include "vm.h"
```

Include dependency graph for repl.h:



This graph shows which files directly or indirectly include this file:



Functions

- void vm_repl (VM *vm, int script_mode)
  Starts the Forth REPL (Read-Eval-Print Loop)

7.256.1 Function Documentation

7.256.1.1 vm_repl()

```
void vm_repl (
            VM * vm,
            int script_mode )
```

Starts the Forth REPL (Read-Eval-Print Loop)

Parameters

vm	Pointer to the VM structure
script_mode	If 1, suppress prompts and "ok" output (for piped input)

This function implements an interactive REPL for the Forth interpreter. It continuously reads input from the user, interprets it, and prints the result until the VM is halted or an error occurs.

In interactive mode (script_mode=0):

- Prints colored prompt "ok> "
- Acknowledges successful commands with " ok"
- Reports errors with " ERROR"

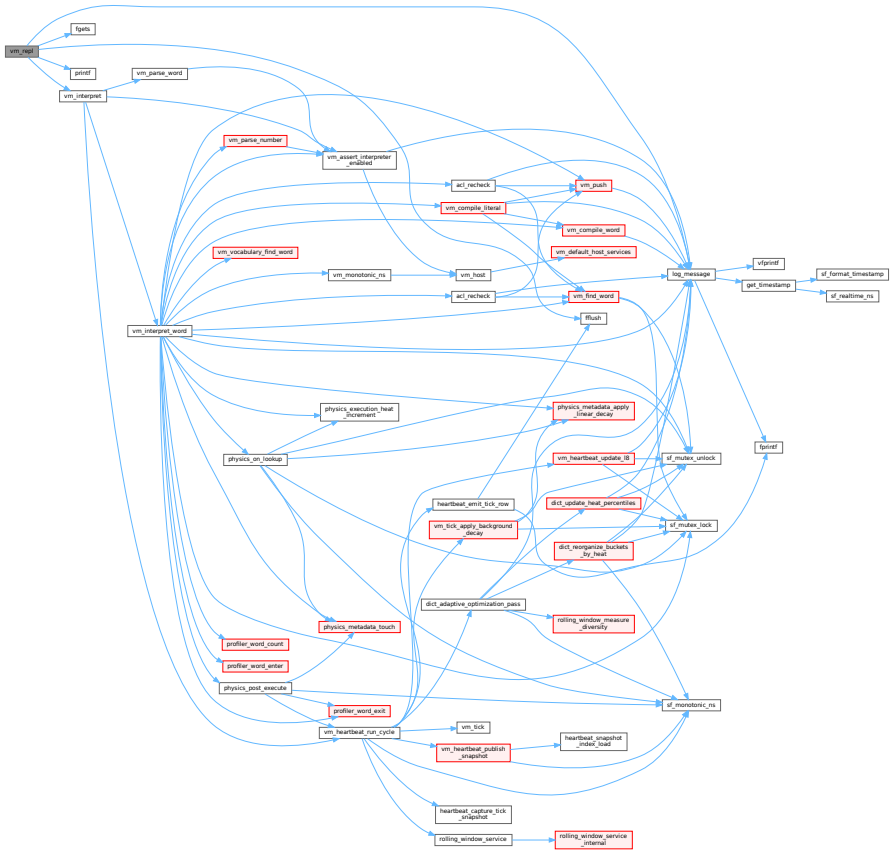
In script mode (script_mode=1):

- Suppresses all prompts and status messages
- Suitable for piped input (heredoc, pipes, redirects)

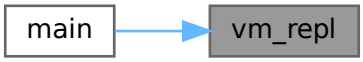
References VM::abort_requested, VM::error, fflush(), fgets(), VM::halted, LOG_INFO, log_message(), printf(), stdin, stdout, vm_interpret(), and VM::zuse_session.

Referenced by main().

Here is the call graph for this function:



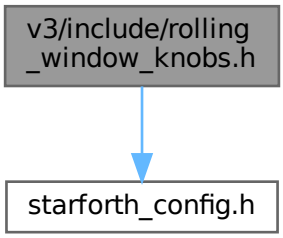
Here is the caller graph for this function:



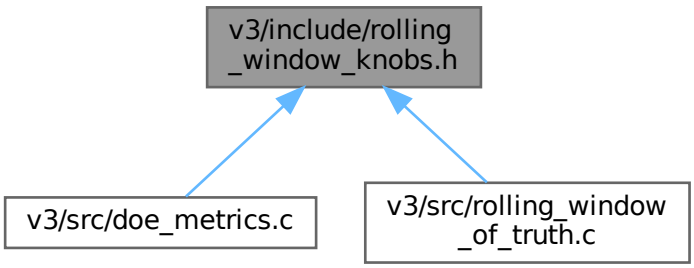
7.257 v3/include/rolling_window_knobs.h File Reference

```
#include "starforth_config.h"
```

Include dependency graph for rolling_window_knobs.h:



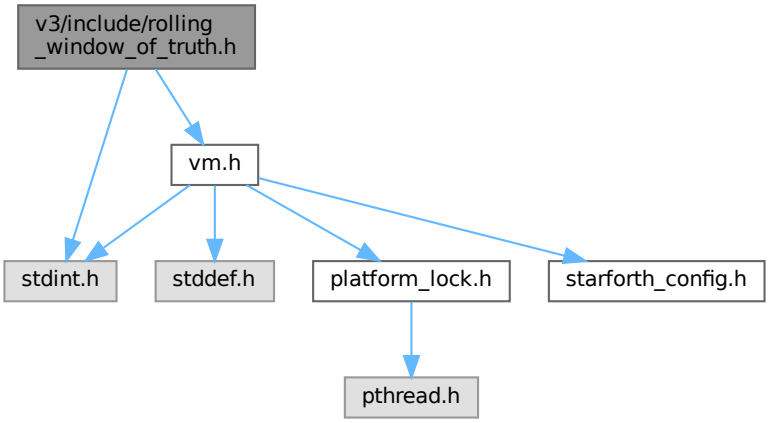
This graph shows which files directly or indirectly include this file:



7.258 v3/include/rolling_window_of_truth.h File Reference

```
#include <stdint.h>
#include "vm.h"
```

Include dependency graph for rolling_window_of_truth.h:



This graph shows which files directly or indirectly include this file:

Functions

- int rolling_window_init (RollingWindowOfTruth *window)

  Initialise a `RollingWindowOfTruth`, allocating its three heap buffers.
- int rolling_window_record_execution (RollingWindowOfTruth *window, uint32_t word_id)

  Record one word execution in the circular history buffer.
- uint32_t rolling_window_get_recent_sequence (const RollingWindowOfTruth *window, uint32_t depth, uint32_t *out_sequence)

  Copy the most recent `depth` word IDs from the rolling window into `out_sequence`.
- uint32_t rolling_window_find_hottest_word (const RollingWindowOfTruth *window, uint32_t dict_size)

  Return the word ID that appears most frequently in the rolling window.
- uint64_t rolling_window_count_transition (const RollingWindowOfTruth *window, uint32_t word_a, uint32_t word_b)

  Count how many times the transition (word_a → word_b) occurs in the history.
- int rolling_window_is_warm (const RollingWindowOfTruth *window)

  Return whether the rolling window has accumulated enough history to be useful.
- char * rolling_window_stats_string (const RollingWindowOfTruth *window)

  Allocate and return a one-page status summary for a `RollingWindowOfTruth`.
- void rolling_window_reset (RollingWindowOfTruth *window)

  Reset the rolling window to an empty cold state without freeing heap memory.

- void rolling_window_cleanup (RollingWindowOfTruth *window)

  Free all heap memory held by a `RollingWindowOfTruth`.
- uint64_t rolling_window_export_execution_history (const RollingWindowOfTruth *window, uint32_t *out_sequence, uint64_t max_count)

  Export up to `max_count` entries from the execution history in chronological order.
- double rolling_window_pattern_capture_rate (const RollingWindowOfTruth *window, uint32_t test_window_size)

  Estimate the fraction of transitions that carry unique contextual information.
- uint64_t rolling_window_measure_diversity (const RollingWindowOfTruth *window)

  Return the current pattern diversity score for the rolling window.
- void rolling_window_check_adaptive_shrink (RollingWindowOfTruth *window)

  Force an immediate adaptive window check, bypassing the accumulator gate.
- void rolling_window_service (RollingWindowOfTruth *window)

  Service the rolling window — publish pending snapshots and run adaptive sizing.

7.258.1 Function Documentation

7.258.1.1 rolling_window_check_adaptive_shrink()

```
void rolling_window_check_adaptive_shrink (
            RollingWindowOfTruth * window )
```

Force an immediate adaptive window check, bypassing the accumulator gate.

Sets `window->adaptive_pending` = 1 unconditionally and then calls `rolling_window_service_internal()` to drain it immediately. This allows external callers (e.g. the heartbeat timer or a FORTH word) to trigger a window-size evaluation outside the normal `ADAPTIVE_CHECK_FREQUENCY` cadence — for example, after a major workload transition or at benchmark checkpoints.

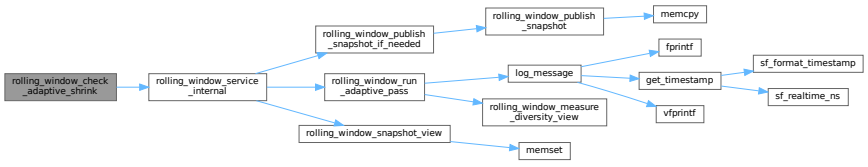
If the window is not warm the adaptive pass is a no-op internally.

Parameters

window	The `RollingWindowOfTruth` to check; no-op if NULL.

References RollingWindowOfTruth::adaptive_pending, and rolling_window_service_internal().

Here is the call graph for this function:



7.258.1.2 rolling_window_cleanup()

```
void rolling_window_cleanup (
            RollingWindowOfTruth * window )
```

Free all heap memory held by a RollingWindowOfTruth.

Calls sf_free() on execution_history and both snapshot_buffers[], setting each to NULL after freeing. Does not zero the scalar fields; the caller must not use window after this call without a subsequent rolling_window_init().

No-op if window is NULL. Each buffer pointer is individually NULL-checked before freeing (defensive against partial-init failures from rolling_window_init()).

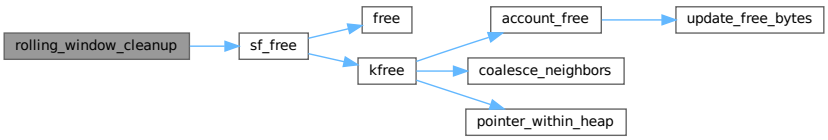
Parameters

window	The RollingWindowOfTruth to clean up; no-op if NULL.

References RollingWindowOfTruth::execution_history, sf_free(), and RollingWindowOfTruth::snapshot_buffers.

Referenced by vm_cleanup().

Here is the call graph for this function:



Here is the caller graph for this function:

7.258.1.3 rolling_window_count_transition()

```
uint64_t rolling_window_count_transition (
            const RollingWindowOfTruth * window,
            uint32_t word_a,
            uint32_t word_b )
```

Count how many times the transition (word_a → word_b) occurs in the history.

Scans all ROLLING_WINDOW_SIZE consecutive adjacent pairs in the current snapshot (wrapping at the buffer end: pair i is (history[i], history[(i+1) % ROLLING_WINDOW_SIZE])) and counts how many pairs match word_a followed by word_b.

Returns 0 if:

- `window` is NULL.
- `window->is_warm` is 0 (the history is too short to be meaningful).
- The snapshot's `is_warm` flag is 0.

Note: because the history is circular and the scan is linear across all slots regardless of `effective_window_size`, the count includes transitions that span the buffer wrap-around boundary. This is intentional: the full `ROLLING_WINDOW_SIZE` is used for transition counting.

Parameters

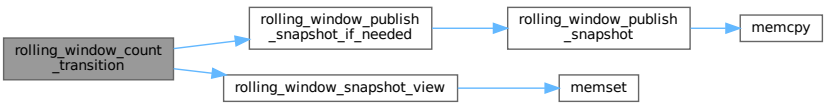
window	The `RollingWindowOfTruth` to query.
word_a	ID of the predecessor word.
word_b	ID of the successor word.

Returns

Count of (word_a → word_b) transitions; 0 if not warm.

References count, rolling_window_view_t::history, RollingWindowOfTruth::is_warm, rolling_window_view_t::is_warm, rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, and rolling_window_snapshot_view().

Here is the call graph for this function:



7.258.1.4 rolling_window_export_execution_history()

```
uint64_t rolling_window_export_execution_history (
            const RollingWindowOfTruth * window,
            uint32_t * out_sequence,
            uint64_t max_count )
```

Export up to `max_count` entries from the execution history in chronological order.

Linearises the internal circular buffer so callers get entries from oldest to newest without knowing the internal `window_pos` cursor. Two cases:

- **Pre-wrap** (`total_executions` < `ROLLING_WINDOW_SIZE`): the buffer has not yet wrapped; entries 0..`total_executions-1` are valid and are copied contiguously from `history`[0].
- **Post-wrap** (`total_executions` ≥ `ROLLING_WINDOW_SIZE`): the oldest entry is at `history`[window_pos]. Two `memcpy` calls stitch the two halves together:
  1. `history`[window_pos .. ROLLING_WINDOW_SIZE-1] (first part)
  2. `history`[0 .. window_pos-1] (second part, if `export_count` > `first_part`)

`export_count` is `min(total_executions, max_count)`. Returns 0 if `window`, `out_sequence` are NULL, `max_count` is 0, the snapshot has no history, or `export_count` is 0.

Parameters

window	The `RollingWindowOfTruth` to export.
out_sequence	Caller-allocated output buffer of at least `max_count` `uint32_t` entries.
max_count	Maximum number of entries to export.

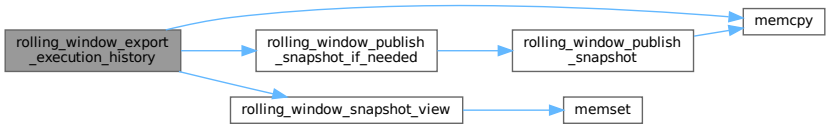
Returns

Actual number of entries written to `out_sequence`.

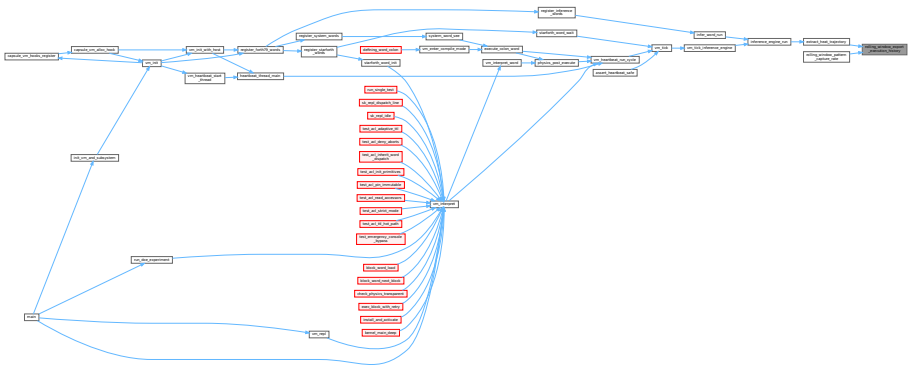
References rolling_window_view_t::history, memcpy(), rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), rolling_window_view_t::total_executions, and rolling_window_view_t::window_pos.

Referenced by extract_heat_trajectory(), and rolling_window_pattern_capture_rate().

Here is the call graph for this function:



Here is the caller graph for this function:



7.258.1.5 rolling_window_find_hottest_word()

```
uint32_t rolling_window_find_hottest_word (
            const RollingWindowOfTruth * window,
            uint32_t dict_size )
```

Return the word ID that appears most frequently in the rolling window.

Obtains the current snapshot, allocates a zero-filled frequency array of `dict_size` `uint32_t` counters via `sf_calloc`, and scans all `ROLLING_WINDOW_SIZE` history slots to tally occurrences. Then performs a linear scan for the maximum and frees the frequency array before returning.

Returns 0 immediately (without allocating) if:

- `window` is NULL.
- `window->is_warm` is 0 (not enough history to be meaningful).
- The snapshot's `is_warm` flag is 0.
- `sf_calloc` fails.

The returned word ID is the zero-based index into the dictionary's word-ID space. Word ID 0 may be returned both as a legitimate hottest word and as the not-warm sentinel; callers should check `rolling_window_is_warm()` before relying on the result.

Parameters

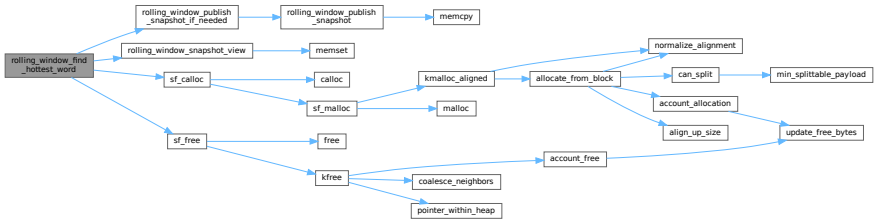
window	The `RollingWindowOfTruth` to analyse.
dict_size	Size of the dictionary's word-ID space; bounds the frequency array and the scan of the history.

Returns

Word ID of the most-frequently-executed word; 0 if the window is not warm or allocation fails.

References rolling_window_view_t::history, RollingWindowOfTruth::is_warm, rolling_window_view_t::is_warm, rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), sf_calloc(), sf_free(), and word_id.

Here is the call graph for this function:



7.258.1.6 rolling_window_get_recent_sequence()

```
uint32_t rolling_window_get_recent_sequence (
            const RollingWindowOfTruth * window,
            uint32_t depth,
            uint32_t * out_sequence )
```

Copy the most recent `depth` word IDs from the rolling window into `out_sequence`.

Calls `rolling_window_publish_snapshot_if_needed()` then reads the current double-buffer snapshot via `rolling_window_snapshot_view()`. Copies at most `min(depth, available)` entries from the most recent portion of the circular buffer into `out_sequence` in chronological order (oldest entry at index 0, most recent at index `actual_depth - 1`).

The available count is capped at `min(total_executions, ROLLING_WINDOW_SIZE)` so callers requesting more history than has been recorded get what is available rather than stale zeros.

Entries are addressed via:
`idx = (window_pos - actual_depth + i + ROLLING_WINDOW_SIZE) % ROLLING_WINDOW_SIZE`

Returns 0 immediately if `window`, `out_sequence` are NULL or `depth` is 0.

Parameters

window	The `RollingWindowOfTruth` to sample.
depth	Maximum number of recent word IDs to copy.
out_sequence	Caller-allocated output buffer of at least `depth` `uint32_t` entries.

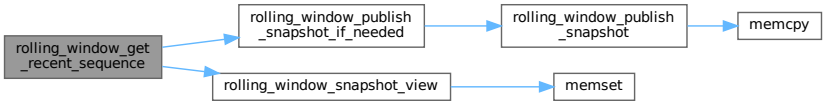
Returns

Actual number of entries written to `out_sequence`; $\leq$ `depth`.

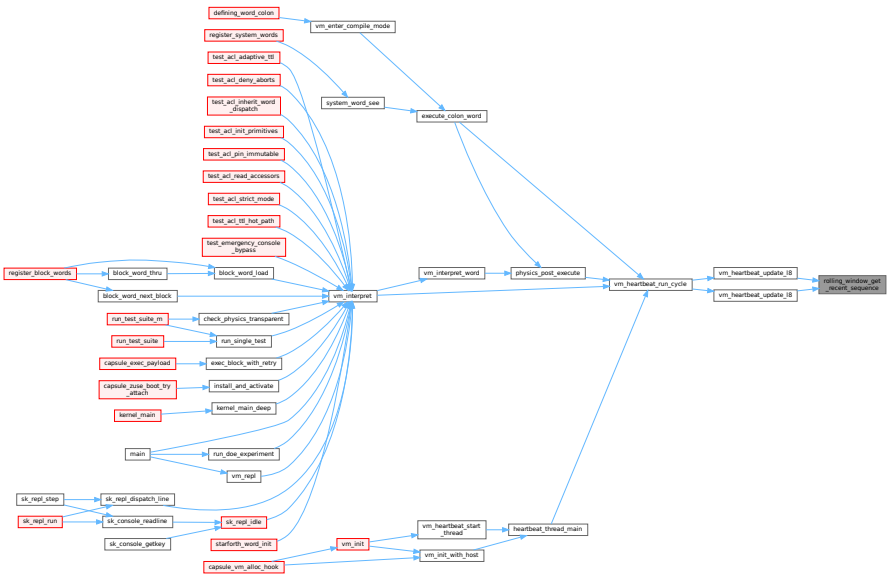
References rolling_window_view_t::history, rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), rolling_window_view_t::total_executions, and rolling_window_view_t::window_pos.

Referenced by vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the call graph for this function:



Here is the caller graph for this function:



7.258.1.7 rolling_window_init()

```
int rolling_window_init (
            RollingWindowOfTruth * window )
```

Initialise a RollingWindowOfTruth, allocating its three heap buffers.

Allocates and zero-initialises three uint32_t arrays, each of ROLLING_WINDOW_SIZE elements, via sf_calloc:

- window->execution_history — the live circular write buffer.
- window->snapshot_buffers[0] — first double-buffer read slot.
- window->snapshot_buffers[1] — second double-buffer read slot.

If any allocation fails, all previously allocated buffers are freed and nulled before returning ?1. Initialises scalar state:

- window_pos = 0, total_executions = 0, is_warm = 0 (cold start).
- effective_window_size = ROLLING_WINDOW_SIZE (start at maximum).
- snapshot_index = 0, snapshot_pending = 1.
- All snapshot_window_pos[] / snapshot_total_executions[] / etc. = 0.
- adaptive_check_accumulator = 0, adaptive_pending = 0.

Immediately calls rolling_window_publish_snapshot() to push the zeroed state into both snapshot slots so that any early read-side call before the first rolling_window_record_execution() gets a coherent (empty) view.

Parameters

window	The RollingWindowOfTruth to initialise; must not be NULL.

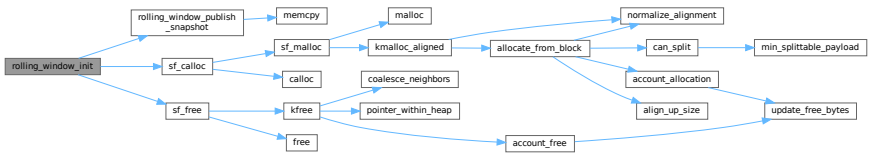
Returns

0 on success; ?1 on NULL window or allocation failure.

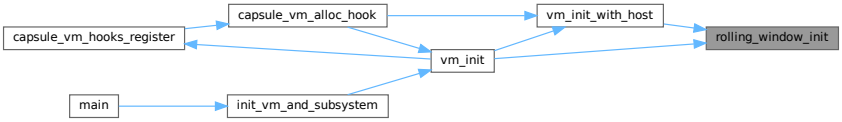
References RollingWindowOfTruth::adaptive_check_accumulator, RollingWindowOfTruth::adaptive_pending, RollingWindowOfTruth::effective_window_size, RollingWindowOfTruth::execution_history, RollingWindowOfTruth::is_warm, RollingWindowOfTruth::last_pattern_diversity, RollingWindowOfTruth::pattern_diversity_check_count, rolling_window_publish_snapsh ROLLING_WINDOW_SIZE, sf_calloc(), sf_free(), RollingWindowOfTruth::snapshot_buffers, RollingWindowOfTruth::snapshot_effectiv RollingWindowOfTruth::snapshot_index, RollingWindowOfTruth::snapshot_is_warm, RollingWindowOfTruth::snapshot_pending, RollingWindowOfTruth::snapshot_total_executions, RollingWindowOfTruth::snapshot_window_pos, RollingWindowOfTruth::total_exec and RollingWindowOfTruth::window_pos.

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.258.1.8 rolling_window_is_warm()

```
int rolling_window_is_warm (
            const RollingWindowOfTruth * window )
```

Return whether the rolling window has accumulated enough history to be useful.

Returns `window->is_warm`, which is set to 1 by `rolling_window_record_execution()` once `total_executions` $\geq$ 1024. Before that threshold the window is considered "cold" — its contents do not yet represent a stable distribution of the program's word usage, and analysis functions (`rolling_window_find_hottest_word()`, `rolling_window_count_transition()`, adaptive sizing) return early with conservative defaults when `is_warm` is 0.

Parameters

window	The `RollingWindowOfTruth` to query; NULL $\rightarrow$ returns 0.

Returns

1 if the window is warm ($\geq$ 1024 executions); 0 otherwise.

References RollingWindowOfTruth::is_warm.

7.258.1.9 rolling_window_measure_diversity()

```
uint64_t rolling_window_measure_diversity (
            const RollingWindowOfTruth * window )
```

Return the current pattern diversity score for the rolling window.

Triggers a lazy snapshot publish via `rolling_window_publish_snapshot_if_needed()`, acquires a read-side view via `rolling_window_snapshot_view()`, and delegates to the internal `rolling_window_measure_diversity_view()` to count the number of unique adjacent-pair transitions in the active window.

Higher diversity means the window is observing a wide variety of word sequences, indicating that the execution pattern is volatile and heat-stratified lookup is more beneficial than stable-pattern nearest-first lookup. Lower diversity means the program is executing a narrow, repetitive sequence — pattern knowledge is concentrated and reliable.

Used by `dict_adaptive_optimization_pass()` to select lookup strategy (threshold = 70 unique transitions) and by `rolling_window_run_adaptive_pass()` to calibrate `effective_window_size`.

Parameters

window	The `RollingWindowOfTruth` to measure.

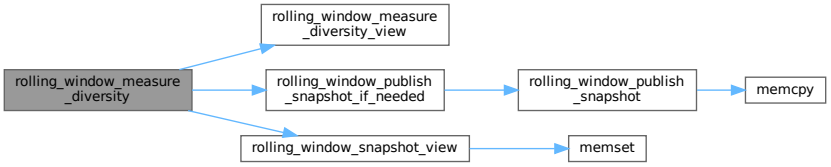
Returns

Count of unique adjacent-pair transitions in the active window; 0 if the window has fewer than 2 executions or `window` is NULL.

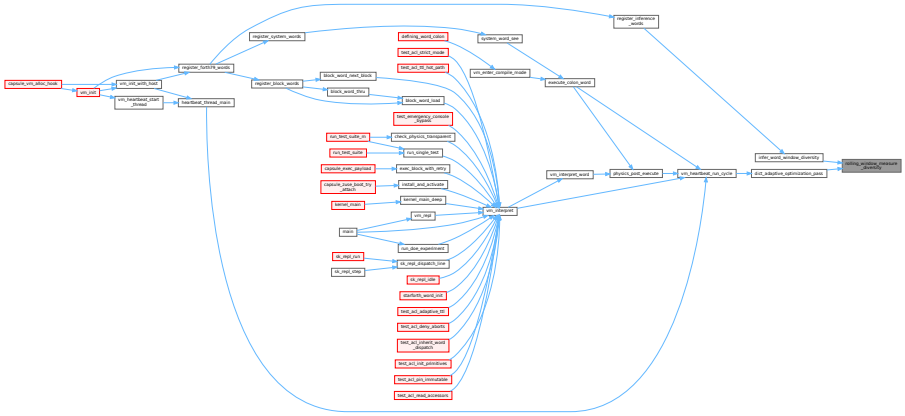
References rolling_window_measure_diversity_view(), rolling_window_publish_snapshot_if_needed(), and rolling_window_snapshot_view().

Referenced by dict_adaptive_optimization_pass(), and infer_word_window_diversity().

Here is the call graph for this function:



Here is the caller graph for this function:



7.258.1.10 rolling_window_pattern_capture_rate()

```
double rolling_window_pattern_capture_rate (
            const RollingWindowOfTruth * window,
            uint32_t test_window_size )
```

Estimate the fraction of transitions that carry unique contextual information.

Measures how many of the recorded adjacent-pair transitions produce a non-zero hash when the preceding `test_window_size` word IDs are incorporated:

```
pattern_hash = (... ((word[i-ws] × 31 + word[i-ws+1]) × 31 + ...) × 31 + word[i+1])
               mod 0x7FFFFFFF
```

A non-zero hash is counted as a "captured" pattern. The capture rate is:

```
rate = patterns_seen / total_transitions × 100  (clamped to [0, 100])
```

In practice, hash collisions with the zero sentinel are extraordinarily rare (probability ~1/2^31), so nearly all transitions contribute to `patterns_seen`. The function thus measures whether `test_window_size` is wide enough to produce a non-trivial hash — a proxy for whether the window introduces meaningful context beyond a single predecessor.

Linearises the circular buffer via `rolling_window_export_execution_history()` before scanning. Returns 0.0 if `window` or `test_window_size` < 1, if the linearised history has fewer than 2 entries, or if `sf_malloc` fails.

Parameters

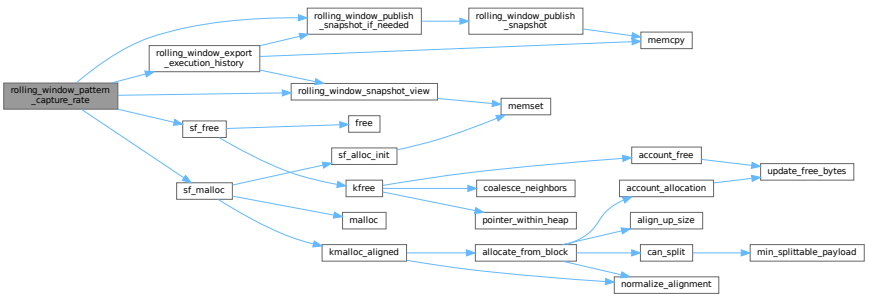
window	The `RollingWindowOfTruth` to analyse.
test_window_size	Number of preceding word IDs to fold into each pattern hash.

Returns

Capture rate as a percentage in [0.0, 100.0].

References rolling_window_view_t::history, rolling_window_export_execution_history(), rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), sf_free(), sf_malloc(), and rolling_window_view_t::total_executions.

Here is the call graph for this function:



7.258.1.11 rolling_window_record_execution()

```
int rolling_window_record_execution (
            RollingWindowOfTruth * window,
            uint32_t word_id )
```

Record one word execution in the circular history buffer.

Writes `word_id` into `window->execution_history`[window_pos], advances `window_pos` modulo `ROLLING_WINDOW_SIZE` (circular wrap), increments `total_executions`, and checks the warm threshold:

- Once `total_executions` $\geq$ 1024 and `is_warm` is still 0, sets `is_warm` = 1. The 1024-execution threshold is calibrated to the POST harness which generates approximately 1450 executions; reaching 1024 guarantees a statistically meaningful execution distribution before diversity or percentile analysis begins.

Sets `snapshot_pending` = 1 to signal that a new snapshot should be published on the next read-side access. When the window is warm and `adaptive_check_accumulator` reaches `ADAPTIVE_CHECK_FREQUENCY`, also sets `adaptive_pending` = 1 to request an `effective_window_size` update.

Called from the interpreter hot path on every word dispatch. All operations are O(1) with no locks and no allocations.

Parameters

window	The `RollingWindowOfTruth` to record into.
word_id	Stable numeric ID of the word just executed.

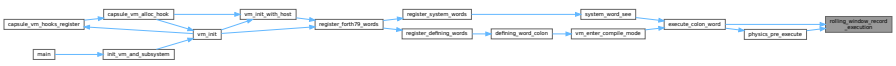
Returns

0 on success; ?1 if `window` or `execution_history` are NULL.

References RollingWindowOfTruth::adaptive_check_accumulator, ADAPTIVE_CHECK_FREQUENCY, RollingWindowOfTruth::adapti RollingWindowOfTruth::execution_history, RollingWindowOfTruth::is_warm, ROLLING_WINDOW_SIZE, RollingWindowOfTruth::snap RollingWindowOfTruth::total_executions, RollingWindowOfTruth::window_pos, and word_id.

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the caller graph for this function:



7.258.1.12 rolling_window_reset()

```
void rolling_window_reset (
            RollingWindowOfTruth * window )
```

Reset the rolling window to an empty cold state without freeing heap memory.

Zeros execution_history via memset and resets the scalar fields: window_pos = 0, total_executions = 0, is_warm = 0. Sets snapshot_pending = 1 so that the next read will publish an empty snapshot.

The three heap buffers (execution_history, snapshot_buffers[0/1]) are preserved; only their contents are zeroed. Intended for benchmark harnesses that need a clean baseline between test runs without the overhead of rolling_window_cleanup() + rolling_window_init().

Parameters

window	The `RollingWindowOfTruth` to reset; no-op if NULL or `execution_history` is NULL.

References RollingWindowOfTruth::execution_history, RollingWindowOfTruth::is_warm, memset(), ROLLING_WINDOW_SIZE, RollingWindowOfTruth::snapshot_pending, RollingWindowOfTruth::total_executions, and RollingWindowOfTruth::window_pos.

Here is the call graph for this function:

7.258.1.13 rolling_window_service()

```
void rolling_window_service (
            RollingWindowOfTruth * window )
```

Service the rolling window — publish pending snapshots and run adaptive sizing.

The public entry point for the rolling window's periodic maintenance. Intended to be called from the heartbeat tick handler or the REPL idle loop at a rate determined by the caller (typically 100 Hz from the APIC timer ISR via `heartbeat_tick()`). Delegates entirely to `rolling_window_service_internal()`:

- Flushes the pending snapshot if `snapshot_pending` is set.
- Runs `rolling_window_run_adaptive_pass()` if `adaptive_pending` is set.

Unlike `rolling_window_check_adaptive_shrink()`, this function does NOT force `adaptive_↩ pending` = 1; it only services flags that the record path has already set. The normal adaptive-pass cadence is therefore governed entirely by `ADAPTIVE_CHECK_FREQUENCY` executions between checks.

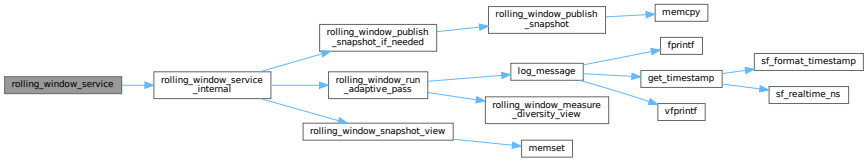
Parameters

window	The `RollingWindowOfTruth` to service; no-op if NULL.

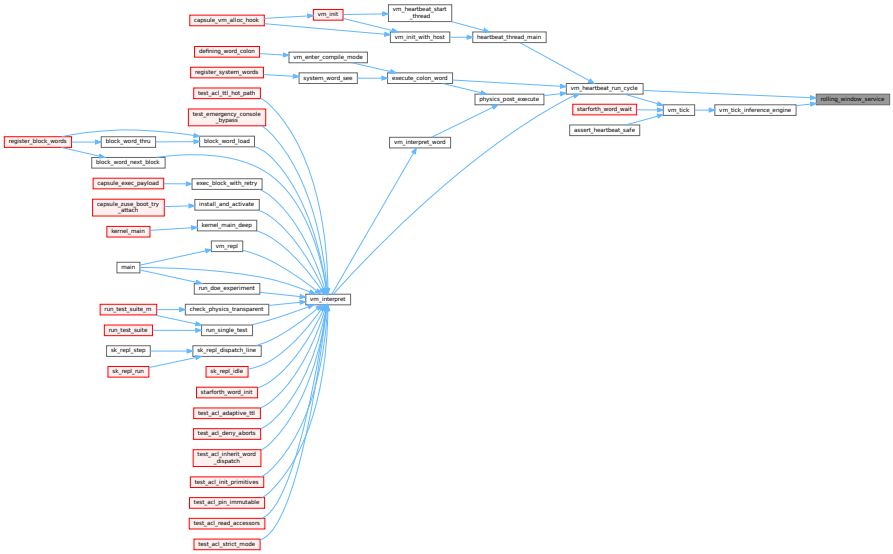
References rolling_window_service_internal().

Referenced by vm_heartbeat_run_cycle(), and vm_tick_inference_engine().

Here is the call graph for this function:



Here is the caller graph for this function:



7.258.1.14 rolling_window_stats_string()

```
char * rolling_window_stats_string (
            const RollingWindowOfTruth * window )
```

Allocate and return a one-page status summary for a `RollingWindowOfTruth`.

Allocates a 1024-byte buffer via `sf_malloc` and fills it with a multi-line report covering:

- `total_executions` — lifetime word-execution count.
- `ROLLING_WINDOW_SIZE` — compile-time capacity constant.
- Warm/cold status: "WARM (representative)" or "COLD (warming up)".
- `window_pos` / `ROLLING_WINDOW_SIZE` — current write-cursor position.

Values are read from the current double-buffer snapshot obtained via `rolling_window_snapshot_view()`; a lazy publish is triggered first by `rolling_window_publish_snapshot_if_needed()`.

The caller is responsible for calling `sf_free()` on the returned pointer. Returns NULL if `window` is NULL or `sf_malloc` fails.

Parameters

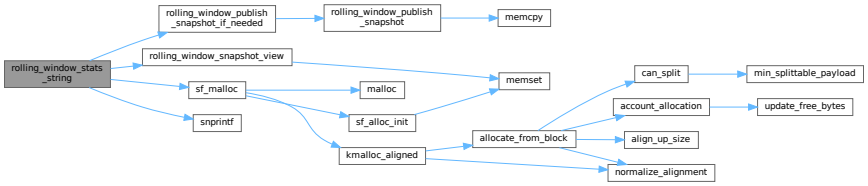
window	The `RollingWindowOfTruth` to describe.

Returns

Heap-allocated NUL-terminated summary string; caller must `sf_free()` it. NULL on failure.

References rolling_window_view_t::is_warm, rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), sf_malloc(), snprintf(), rolling_window_view_t::total_executions, and rolling_window_view_t::window

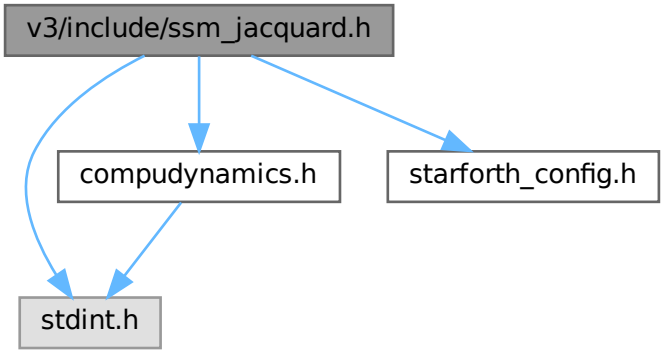
Here is the call graph for this function:



7.259 v3/include/ssm_jacquard.h File Reference

```
#include <stdint.h>
#include "compudynamics.h"
#include "starforth_config.h"
```

Include dependency graph for ssm_jacquard.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct ssm_l8_metrics_t
- struct ssm_config_t
- struct ssm_l8_state_t

Macros

- #define SSM_CFG_L1 0x40u
- #define SSM_CFG_L2 0x20u
- #define SSM_CFG_L3 0x10u
- #define SSM_CFG_L4 0x08u
- #define SSM_CFG_L5 0x04u
- #define SSM_CFG_L6 0x02u
- #define SSM_CFG_L7 0x01u

Enumerations

- enum ssm_l8_mode_t {
  SSM_MODE_C0 = 0x0 , SSM_MODE_C1 = 0x1 , SSM_MODE_C2 = 0x2 , SSM_MODE_C3 = 0x3 ,
  SSM_MODE_C4 = 0x4 , SSM_MODE_C5 = 0x5 , SSM_MODE_C6 = 0x6 , SSM_MODE_C7 = 0x7 ,
  SSM_MODE_C8 = 0x8 , SSM_MODE_C9 = 0x9 , SSM_MODE_C10 = 0xA , SSM_MODE_C11 = 0xB ,
  SSM_MODE_C12 = 0xC , SSM_MODE_C13 = 0xD , SSM_MODE_C14 = 0xE , SSM_MODE_C15 = 0xF }

Functions

- void ssm_l8_init (ssm_l8_state_t *state, ssm_l8_mode_t initial_mode)

  Initialize L8 state (legacy fields only; call ssm_l8_init_table separately)
- void ssm_l8_init_table (ssm_l8_state_t *state)

  Allocate and seed the adaptive config table Sets state->table; must be called after ssm_l8_init().
- void ssm_l8_free_table (ssm_l8_state_t *state)

  Free the adaptive config table.
- void ssm_l8_update_table (ssm_l8_state_t *state, const ssm_l8_metrics_t *metrics, ssm_config_t *config, uint32_t current_window, const uint32_t *recent_word_ids, uint32_t recent_word_ids_count)

  Tick the adaptive UCB table: classify, score, and reselect.
- void ssm_apply_mode_from_table (const ssm_l8_state_t *state, ssm_config_t *config)

  Apply the current table config to ssm_config_t Used on first tick to set the initial DoE-seeded config immediately.
- void ssm_l8_force_config (ssm_l8_state_t *state, ssm_config_t *config, uint8_t config_idx)

  Force the adaptive table onto an externally-chosen config (e.g.
- void ssm_l8_update (const ssm_l8_metrics_t *metrics, ssm_l8_state_t *state)

  Update L8 state based on current metrics (legacy threshold path)
- void ssm_apply_mode (const ssm_l8_state_t *state, ssm_config_t *config)

  Apply L8 mode to SSM configuration (legacy threshold path)
- const char * ssm_l8_mode_name (ssm_l8_mode_t mode)

  Get human-readable mode name.

7.259.1 Macro Definition Documentation

7.259.1.1 SSM_CFG_L1

```
#define SSM_CFG_L1 0x40u
```

7.259.1.2 SSM_CFG_L2

```
#define SSM_CFG_L2 0x20u
```

7.259.1.3 SSM_CFG_L3

```
#define SSM_CFG_L3 0x10u
```

7.259.1.4 SSM_CFG_L4

```
#define SSM_CFG_L4 0x08u
```

7.259.1.5 SSM_CFG_L5

```
#define SSM_CFG_L5 0x04u
```

7.259.1.6 SSM_CFG_L6

```
#define SSM_CFG_L6 0x02u
```

7.259.1.7 SSM_CFG_L7

```
#define SSM_CFG_L7 0x01u
```

7.259.2 Enumeration Type Documentation

7.259.2.1 ssm_l8_mode_t

```
enum ssm_l8_mode_t
```

Enumerator

SSM_MODE_C0	
SSM_MODE_C1	
SSM_MODE_C2	
SSM_MODE_C3	
SSM_MODE_C4	
SSM_MODE_C5	
SSM_MODE_C6	
SSM_MODE_C7	
SSM_MODE_C8	
SSM_MODE_C9	
SSM_MODE_C10	
SSM_MODE_C11	
SSM_MODE_C12	
SSM_MODE_C13	
SSM_MODE_C14	
SSM_MODE_C15	

7.259.3 Function Documentation

7.259.3.1 ssm_apply_mode()

```
void ssm_apply_mode (
            const ssm_l8_state_t * state,
            ssm_config_t * config )
```

Apply L8 mode to SSM configuration (legacy threshold path)

Apply L8 mode to SSM configuration (legacy threshold path)

Extracts the four loop-enable bits (L2/L3/L5/L6) from `state->current_mode` and writes them into `config`. Used by the legacy (non-table) L8 path when the adaptive UCB table is not present.

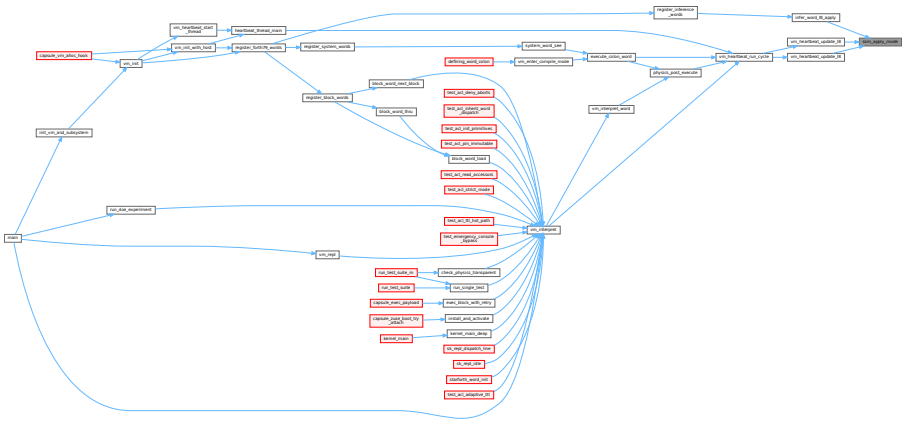
Parameters

state	L8 state containing the committed current mode
config	Runtime configuration to update

References ssm_l8_state_t::current_mode, ssm_config_t::L2_rolling_window, ssm_config_t::L3_linear_decay, ssm_config_t::L5_window_inference, and ssm_config_t::L6_decay_inference.

Referenced by infer_word_l8_apply(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the caller graph for this function:



7.259.3.2 ssm_apply_mode_from_table()

```
void ssm_apply_mode_from_table (
            const ssm_l8_state_t * state,
            ssm_config_t * config )
```

Apply the current table config to ssm_config_t Used on first tick to set the initial DoE-seeded config immediately.

Apply the current table config to ssm_config_t Used on first tick to set the initial DoE-seeded config immediately.

Reads the current winning config entry from the adaptive table and writes all 7 of its bits into `config`. Use this instead of `ssm_apply_mode()` when the adaptive table is present (`state->table` != NULL).

Parameters

state	L8 state with an attached, initialised adaptive table
config	Runtime configuration to update

References CDConfigEntry::config_bits, CDConfigTable::current_config, CDConfigTable::entries, ssm_config_t::L1_heat_tracking, ssm_config_t::L2_rolling_window, ssm_config_t::L3_linear_decay, ssm_config_t::L4_pipelining, ssm_config_t::L5_window_inference, ssm_config_t::L6_decay_inference, ssm_config_t::L7_adaptive_heartrate, SSM_CFG_L1, SSM_CFG_L2, SSM_CFG_L3, SSM_CFG_L4, SSM_CFG_L5, SSM_CFG_L6, SSM_CFG_L7, and ssm_l8_state_t::table.

Referenced by ssm_l8_force_config().

Here is the caller graph for this function:

7.259.3.3 ssm_l8_force_config()

```
void ssm_l8_force_config (
            ssm_l8_state_t * state,
            ssm_config_t * config,
            uint8_t config_idx )
```

Force the adaptive table onto an externally-chosen config (e.g.

a DoE campaign driving a specific tick's config rather than letting the bandit's own UCB selection choose it). See definition for details on why this stays coherent with the bandit's own reward loop.

Force the adaptive table onto an externally-chosen config (e.g.

Sets `current_config` directly (as if the bandit's own UCB selection had picked it) and applies its bits immediately. Since scoring and UCB reselection now run on every heartbeat tick (rev r: one clock, no batching of any kind), this is a one-tick nudge, not a hold: the forced config earns exactly one tick's worth of reward signal into its own regime_score, then the very next tick's ssm_l8_update_table() call scores it and reselects on its own, same as any other tick. Calling this repeatedly (e.g. once per DoE draw, faster than the VM's own tick cadence) keeps a config in effect in practice, not because it's pinned – because it's what's currently forced, most recently.

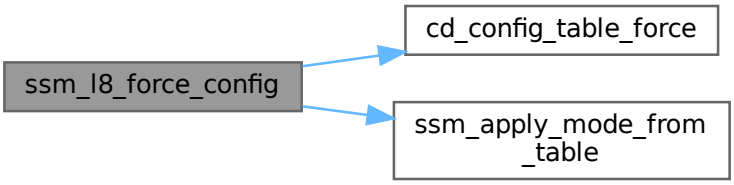
Parameters

state	L8 state with an attached, initialised adaptive table
config	Runtime configuration to update immediately
config_idx	Desired config, masked to the 128-entry (7-bit) space

References cd_config_table_force(), ssm_apply_mode_from_table(), and ssm_l8_state_t::table.

Referenced by infer_word_l8_table_force().

Here is the call graph for this function:



Here is the caller graph for this function:

7.259.3.4 ssm_l8_free_table()

```
void ssm_l8_free_table (
            ssm_l8_state_t * state )
```

Free the adaptive config table.

Free the adaptive config table.

Safe to call with `state->table` == NULL. Sets `state->table` to NULL after freeing so the state falls back to legacy mode.

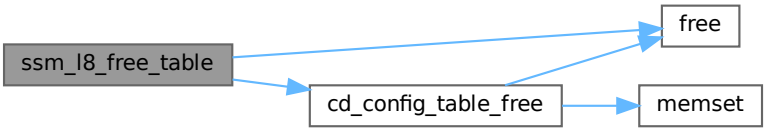
Parameters

state	L8 state whose table is freed

References cd_config_table_free(), free(), and ssm_l8_state_t::table.

Referenced by vm_cleanup().

Here is the call graph for this function:



Here is the caller graph for this function:

7.259.3.5 ssm_l8_init()

```
void ssm_l8_init (
            ssm_l8_state_t * state,
            ssm_l8_mode_t initial_mode )
```

Initialize L8 state (legacy fields only; call ssm_l8_init_table separately)

Initialize L8 state (legacy fields only; call ssm_l8_init_table separately)

Sets `current_mode` and `pending_mode` to `initial_mode`, zeroes `hysteresis_counter`, and sets `table` to NULL. Callers must invoke `ssm_l8_init_table()` separately if the adaptive UCB table is required.

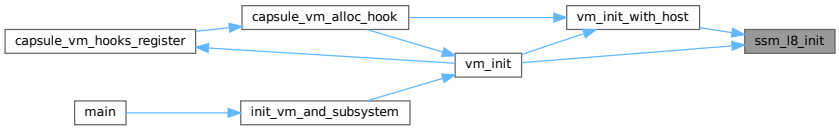
Parameters

state	Pointer to the L8 state to initialise
initial_mode	Starting mode (typically `SSM_MODE_C0`)

References ssm_l8_state_t::current_mode, ssm_l8_state_t::hysteresis_counter, ssm_l8_state_t::pending_mode, and ssm_l8_state_t::table.

Referenced by vm_init(), and vm_init_with_host().

Here is the caller graph for this function:



7.259.3.6 ssm_l8_init_table()

```
void ssm_l8_init_table (
            ssm_l8_state_t * state )
```

Allocate and seed the adaptive config table Sets state->table; must be called after ssm_l8_init().

On allocation failure, state->table remains NULL (legacy mode is used).

Allocate and seed the adaptive config table Sets state->table; must be called after ssm_l8_init().

Mallocs and initialises a `CDConfigTable` sized by `cd_tuning_word()`, seeds it with `ssm_l8_seed_from_doe()`, and attaches it to `state->table`. If either allocation fails, `state->table` is set to NULL and the system falls back to legacy mode (`ssm_apply_mode()`).

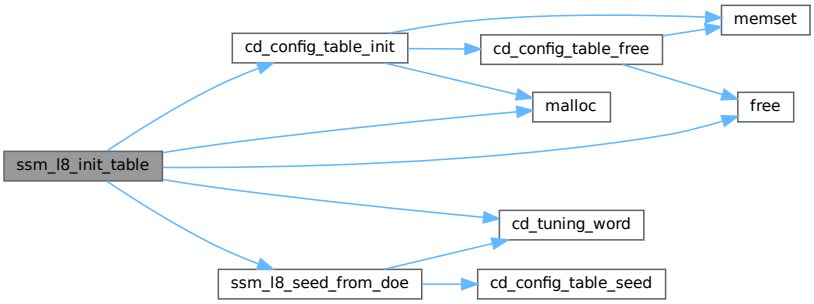
Parameters

state	L8 state that will own the table

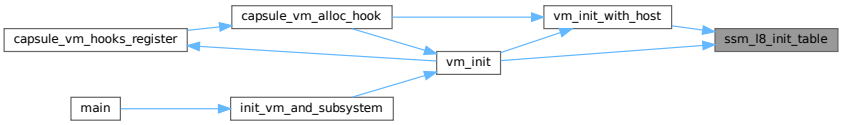
References cd_config_table_init(), cd_tuning_word(), free(), malloc(), ssm_l8_seed_from_doe(), and ssm_l8_state_t::table.

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.259.3.7 ssm_l8_mode_name()

```
const char * ssm_l8_mode_name (
            ssm_l8_mode_t mode )
```

Get human-readable mode name.

Get human-readable mode name.

Returns a static string such as "C4_TEMPORAL" or "C15_FULL_ADAPTIVE". Modes marked ? TOP 5% are the configurations favoured by the DoE study. Returns "UNKNOWN" for out-of-range values.

Parameters

mode	L8 mode enumeration value

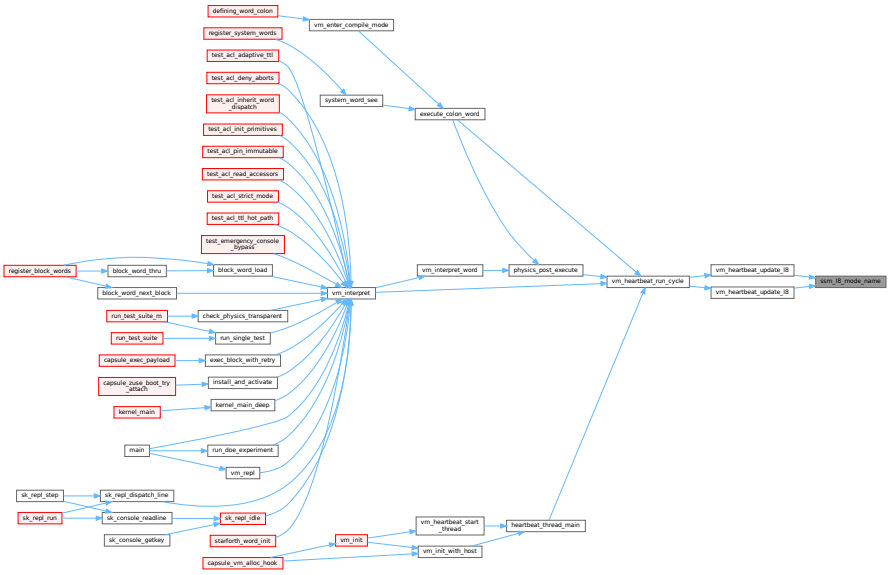
Returns

Pointer to a static null-terminated string (never NULL)

References SSM_MODE_C0, SSM_MODE_C1, SSM_MODE_C10, SSM_MODE_C11, SSM_MODE_C12, SSM_MODE_C13, SSM_MODE_C14, SSM_MODE_C15, SSM_MODE_C2, SSM_MODE_C3, SSM_MODE_C4, SSM_MODE_C5, SSM_MODE_C6, SSM_MODE_C7, SSM_MODE_C8, and SSM_MODE_C9.

Referenced by vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the caller graph for this function:



7.259.3.8 ssm_l8_update()

```
void ssm_l8_update (
            const ssm_l8_metrics_t * metrics,
            ssm_l8_state_t * state )
```

Update L8 state based on current metrics (legacy threshold path)

Update L8 state based on current metrics (legacy threshold path)

Classifies `metrics` into four binary feature bits (L2/L3/L5/L6) derived from DoE top-5% analysis and computes a target mode. Applies hysteresis: the mode only commits after `SSM_HYSTERESIS_TICKS` consecutive ticks with the same target. Called by the heartbeat thread on every tick.

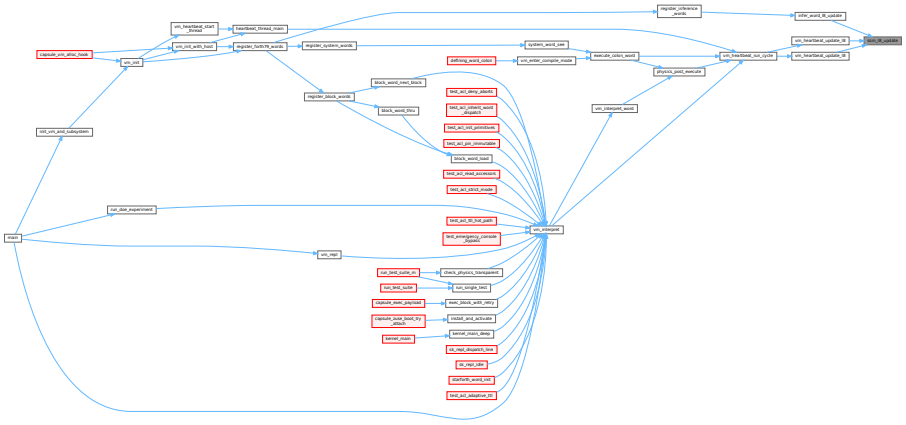
Parameters

metrics	Runtime metrics snapshot (entropy, CV, temporal decay)
state	L8 state to update; `current_mode` is written on commit

References ssm_l8_state_t::current_mode, ssm_l8_metrics_t::cv, ssm_l8_metrics_t::entropy, ssm_l8_state_t::hysteresis_counter, ssm_l8_state_t::pending_mode, SSM_CV_HIGH_THRESHOLD, SSM_ENTROPY_HIGH_THRESHOLD, SSM_HYSTERESIS_TICK SSM_MODE_C0, SSM_TEMPORAL_DECAY_LOW_THRESHOLD, SSM_TEMPORAL_DECAY_THRESHOLD, and ssm_l8_metrics_t::temporal_decay.

Referenced by infer_word_l8_update(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the caller graph for this function:



7.259.3.9 ssm_l8_update_table()

```
void ssm_l8_update_table (
            ssm_l8_state_t * state,
            const ssm_l8_metrics_t * metrics,
            ssm_config_t * config,
            uint32_t current_window,
            const uint32_t * recent_word_ids,
            uint32_t recent_word_ids_count )
```

Tick the adaptive UCB table: classify, score, and reselect.

Classifies the current tick into one of 8 regimes (entropy x CV x locality) and stores it unconditionally, then scores the current config from this tick's outcome and UCB-reselects, every single call – no batching, no derived counter of any kind (VM-FLEET-ATTRACTOR-DESIGN- 20260705.md rev r: one clock, the heartbeat tick, applied uniformly). The locality component of both the regime and the joint-convergence reward comes from cd_classify_ids() over recent_word_ids – purely execution-count-derived, no wall-clock input (rev s; see header comment on this function's declaration for why that matters). Also mirrors the winning L2/L3/L5/L6 bits back into `state->current_mode` for diagnostic display. No-op if `state->table` is NULL.

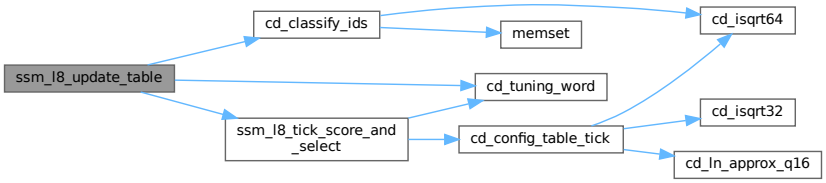
Parameters

state	L8 state with attached adaptive table
metrics	Current runtime metrics snapshot
config	Runtime config updated this tick
current_window	Current rolling window width
recent_word_ids	Recent word-execution-ID history, oldest first
recent_word_ids_count	Number of valid entries in recent_word_ids

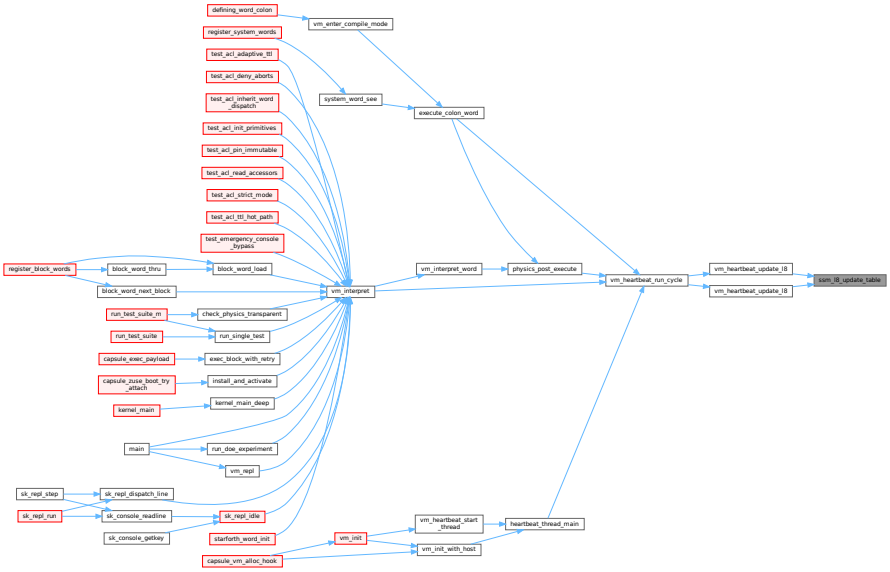
References cd_classify_ids(), cd_tuning_word(), CDConfigEntry::config_bits, CDConfigTable::current_config, ssm_l8_state_t::current_mode, CDConfigTable::current_regime, ssm_l8_metrics_t::cv, CDConfigTable::entries, ssm_l8_metrics_t::entropy, CDTuning::locality_high_threshold_q16, CDTuning::locality_lookback, CDRegimeMetrics::locality_q16, SSM_CFG_L2, SSM_CFG_L3, SSM_CFG_L5, SSM_CFG_L6, SSM_CV_HIGH_THRESHOLD, SSM_ENTROPY_HIGH_THRESHO ssm_l8_tick_score_and_select(), and ssm_l8_state_t::table.

Referenced by vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the call graph for this function:



Here is the caller graph for this function:



7.260 v3/include/starforth_config.h File Reference

This graph shows which files directly or indirectly include this file:

Macros

- #define STARFORTH_CONFIG_STRICT_PTR_DEFAULT 1
- #define STARFORTH_CONFIG_ENABLE_HOTWORDS_CACHE_DEFAULT 0
- #define STARFORTH_CONFIG_ENABLE_PIPELINING_DEFAULT 0
- #define STARFORTH_CONFIG_ROLLING_WINDOW_SIZE_DEFAULT 4096
- #define STARFORTH_CONFIG_TRANSITION_WINDOW_SIZE_DEFAULT 8
- #define STARFORTH_CONFIG_ADAPTIVE_SHRINK_RATE_DEFAULT 50
- #define STARFORTH_CONFIG_ADAPTIVE_MIN_WINDOW_SIZE_DEFAULT 256

- #define STARFORTH_CONFIG_ADAPTIVE_CHECK_FREQUENCY_DEFAULT 512
- #define STARFORTH_CONFIG_ADAPTIVE_GROWTH_THRESHOLD_DEFAULT 5
- #define STARFORTH_CONFIG_INITIAL_DECAY_SLOPE_Q48_DEFAULT 21845
- #define STARFORTH_CONFIG_DECAY_MIN_INTERVAL_DEFAULT 1000ULL
- #define STARFORTH_CONFIG_DECAY_RATE_PER_US_Q16_DEFAULT 1
- #define STARFORTH_CONFIG_HEARTBEAT_THREAD_ENABLED_DEFAULT 1
- #define STARFORTH_CONFIG_HEARTBEAT_TICK_NS_DEFAULT 10000ULL
- #define STARFORTH_CONFIG_HEARTBEAT_INFERENCE_FREQUENCY_DEFAULT 1000
- #define STARFORTH_CONFIG_STADIUM_VM_MEMORY_PERCENT_DEFAULT 50
- #define STARFORTH_CONFIG_STADIUM_CONTAINS_DEPTH_MAX_DEFAULT 5
- #define STARFORTH_CONFIG_STADIUM_CAPACITY_TICK_DEFAULT 4000
- #define STARFORTH_CONFIG_STADIUM_MEMORY_PERCENT_DEFAULT 1
- #define STARFORTH_CONFIG_STADIUM_WORD_HEAT_QUANTUM_DEFAULT 2048
- #define STARFORTH_CONFIG_STADIUM_WORD_COOL_RATE_Q48_DEFAULT 21845
- #define STARFORTH_CONFIG_STADIUM_BLOCK_HEAT_QUANTUM_DEFAULT 2048
- #define STARFORTH_CONFIG_STADIUM_BLOCK_COOL_RATE_Q48_DEFAULT 21845
- #define STARFORTH_CONFIG_STADIUM_BLOCK_TRACK_CAP_MULT_DEFAULT 2
- #define STARFORTH_CONFIG_HEARTBEAT_CHECK_FREQUENCY_DEFAULT 256
- #define STARFORTH_CONFIG_HEARTBEAT_WINDOW_TUNING_FREQUENCY_DEFAULT 1000
- #define STARFORTH_CONFIG_HEARTBEAT_SLOPE_VALIDATION_FREQUENCY_DEFAULT 5000
- #define STARFORTH_CONFIG_SSM_ENTROPY_HIGH_THRESHOLD_DEFAULT 0.75
- #define STARFORTH_CONFIG_SSM_CV_HIGH_THRESHOLD_DEFAULT 0.15
- #define STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_THRESHOLD_DEFAULT 0.5
- #define STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_LOW_THRESHOLD_DEFAULT 0.3
- #define STARFORTH_CONFIG_SSM_HYSTERESIS_TICKS_DEFAULT 5
- #define STARFORTH_CONFIG_SPECULATION_THRESHOLD_Q48_DEFAULT (0x8000LL)
- #define STARFORTH_CONFIG_SPECULATION_DEPTH_DEFAULT 1
- #define STARFORTH_CONFIG_MIN_SAMPLES_FOR_SPECULATION_DEFAULT 10
- #define STARFORTH_CONFIG_MISPREDICTION_COST_Q48_DEFAULT (25LL << 16)
- #define STARFORTH_CONFIG_MINIMUM_PREFETCH_ROI_DEFAULT (0x1199AL)
- #define STRICT_PTR STARFORTH_CONFIG_STRICT_PTR_DEFAULT
- #define VM_STRICT_PTR STRICT_PTR
- #define ENABLE_HOTWORDS_CACHE STARFORTH_CONFIG_ENABLE_HOTWORDS_CACHE_DEFAULT
- #define ENABLE_PIPELINING STARFORTH_CONFIG_ENABLE_PIPELINING_DEFAULT
- #define ROLLING_WINDOW_SIZE STARFORTH_CONFIG_ROLLING_WINDOW_SIZE_DEFAULT
- #define TRANSITION_WINDOW_SIZE STARFORTH_CONFIG_TRANSITION_WINDOW_SIZE_DEFAULT
- #define ADAPTIVE_SHRINK_RATE STARFORTH_CONFIG_ADAPTIVE_SHRINK_RATE_DEFAULT
- #define ADAPTIVE_MIN_WINDOW_SIZE STARFORTH_CONFIG_ADAPTIVE_MIN_WINDOW_SIZE_DEFAULT
- #define ADAPTIVE_CHECK_FREQUENCY STARFORTH_CONFIG_ADAPTIVE_CHECK_FREQUENCY_DEFAULT
- #define ADAPTIVE_GROWTH_THRESHOLD STARFORTH_CONFIG_ADAPTIVE_GROWTH_THRESHOLD_DEFAULT
- #define INITIAL_DECAY_SLOPE_Q48 STARFORTH_CONFIG_INITIAL_DECAY_SLOPE_Q48_DEFAULT
- #define DECAY_MIN_INTERVAL STARFORTH_CONFIG_DECAY_MIN_INTERVAL_DEFAULT
- #define DECAY_RATE_PER_US_Q16 STARFORTH_CONFIG_DECAY_RATE_PER_US_Q16_DEFAULT
- #define HEARTBEAT_THREAD_ENABLED STARFORTH_CONFIG_HEARTBEAT_THREAD_ENABLED_DEFAULT
- #define HEARTBEAT_TICK_NS STARFORTH_CONFIG_HEARTBEAT_TICK_NS_DEFAULT
- #define HEARTBEAT_INFERENCE_FREQUENCY STARFORTH_CONFIG_HEARTBEAT_INFERENCE_FREQUENCY_DEFA
- #define STADIUM_VM_MEMORY_PERCENT STARFORTH_CONFIG_STADIUM_VM_MEMORY_PERCENT_DEFAULT
- #define STADIUM_CONTAINS_DEPTH_MAX STARFORTH_CONFIG_STADIUM_CONTAINS_DEPTH_MAX_DEFAULT
- #define STADIUM_CAPACITY_TICK STARFORTH_CONFIG_STADIUM_CAPACITY_TICK_DEFAULT
- #define STADIUM_MEMORY_PERCENT STARFORTH_CONFIG_STADIUM_MEMORY_PERCENT_DEFAULT
- #define STADIUM_WORD_HEAT_QUANTUM STARFORTH_CONFIG_STADIUM_WORD_HEAT_QUANTUM_DEFAULT
- #define STADIUM_WORD_COOL_RATE_Q48 STARFORTH_CONFIG_STADIUM_WORD_COOL_RATE_Q48_DEFAULT
- #define STADIUM_BLOCK_HEAT_QUANTUM STARFORTH_CONFIG_STADIUM_BLOCK_HEAT_QUANTUM_DEFAULT
- #define STADIUM_BLOCK_COOL_RATE_Q48 STARFORTH_CONFIG_STADIUM_BLOCK_COOL_RATE_Q48_DEFAULT
- #define STADIUM_BLOCK_TRACK_CAP_MULT STARFORTH_CONFIG_STADIUM_BLOCK_TRACK_CAP_MULT_DEFAULT

- #define HEARTBEAT_CHECK_FREQUENCY STARFORTH_CONFIG_HEARTBEAT_CHECK_FREQUENCY_DEFAULT
- #define HEARTBEAT_WINDOW_TUNING_FREQUENCY STARFORTH_CONFIG_HEARTBEAT_WINDOW_TUNING_FREQU
- #define HEARTBEAT_SLOPE_VALIDATION_FREQUENCY STARFORTH_CONFIG_HEARTBEAT_SLOPE_VALIDATION_FRE
- #define SSM_ENTROPY_HIGH_THRESHOLD STARFORTH_CONFIG_SSM_ENTROPY_HIGH_THRESHOLD_DEFAULT
- #define SSM_CV_HIGH_THRESHOLD STARFORTH_CONFIG_SSM_CV_HIGH_THRESHOLD_DEFAULT
- #define SSM_TEMPORAL_DECAY_THRESHOLD STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_THRESHOLD_DEFAU
- #define SSM_TEMPORAL_DECAY_LOW_THRESHOLD STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_LOW_THRESH
- #define SSM_HYSTERESIS_TICKS STARFORTH_CONFIG_SSM_HYSTERESIS_TICKS_DEFAULT
- #define SPECULATION_THRESHOLD_Q48 STARFORTH_CONFIG_SPECULATION_THRESHOLD_Q48_DEFAULT
- #define SPECULATION_DEPTH STARFORTH_CONFIG_SPECULATION_DEPTH_DEFAULT
- #define MIN_SAMPLES_FOR_SPECULATION STARFORTH_CONFIG_MIN_SAMPLES_FOR_SPECULATION_DEFAULT
- #define MISPREDICTION_COST_Q48 STARFORTH_CONFIG_MISPREDICTION_COST_Q48_DEFAULT
- #define MINIMUM_PREFETCH_ROI STARFORTH_CONFIG_MINIMUM_PREFETCH_ROI_DEFAULT

7.260.1 Macro Definition Documentation

7.260.1.1 ADAPTIVE_CHECK_FREQUENCY

```
#define ADAPTIVE_CHECK_FREQUENCY STARFORTH_CONFIG_ADAPTIVE_CHECK_FREQUENCY_DEFAULT
```

7.260.1.2 ADAPTIVE_GROWTH_THRESHOLD

```
#define ADAPTIVE_GROWTH_THRESHOLD STARFORTH_CONFIG_ADAPTIVE_GROWTH_THRESHOLD_DEFAULT
```

7.260.1.3 ADAPTIVE_MIN_WINDOW_SIZE

```
#define ADAPTIVE_MIN_WINDOW_SIZE STARFORTH_CONFIG_ADAPTIVE_MIN_WINDOW_SIZE_DEFAULT
```

7.260.1.4 ADAPTIVE_SHRINK_RATE

```
#define ADAPTIVE_SHRINK_RATE STARFORTH_CONFIG_ADAPTIVE_SHRINK_RATE_DEFAULT
```

7.260.1.5 DECAY_MIN_INTERVAL

```
#define DECAY_MIN_INTERVAL STARFORTH_CONFIG_DECAY_MIN_INTERVAL_DEFAULT
```

7.260.1.6 DECAY_RATE_PER_US_Q16

```
#define DECAY_RATE_PER_US_Q16 STARFORTH_CONFIG_DECAY_RATE_PER_US_Q16_DEFAULT
```

7.260.1.7 ENABLE_HOTWORDS_CACHE

```
#define ENABLE_HOTWORDS_CACHE STARFORTH_CONFIG_ENABLE_HOTWORDS_CACHE_DEFAULT
```

7.260.1.8 ENABLE_PIPELINING

```
#define ENABLE_PIPELINING STARFORTH_CONFIG_ENABLE_PIPELINING_DEFAULT
```

7.260.1.9 HEARTBEAT_CHECK_FREQUENCY

```
#define HEARTBEAT_CHECK_FREQUENCY STARFORTH_CONFIG_HEARTBEAT_CHECK_FREQUENCY_DEFAULT
```

7.260.1.10 HEARTBEAT_INFERENCE_FREQUENCY

```
#define HEARTBEAT_INFERENCE_FREQUENCY STARFORTH_CONFIG_HEARTBEAT_INFERENCE_FREQUENCY_DEFAULT
```

7.260.1.11 HEARTBEAT_SLOPE_VALIDATION_FREQUENCY

```
#define HEARTBEAT_SLOPE_VALIDATION_FREQUENCY STARFORTH_CONFIG_HEARTBEAT_SLOPE_VALIDATION_FREQUENCY_DEFAULT
```

7.260.1.12 HEARTBEAT_THREAD_ENABLED

```
#define HEARTBEAT_THREAD_ENABLED STARFORTH_CONFIG_HEARTBEAT_THREAD_ENABLED_DEFAULT
```

7.260.1.13 HEARTBEAT_TICK_NS

```
#define HEARTBEAT_TICK_NS STARFORTH_CONFIG_HEARTBEAT_TICK_NS_DEFAULT
```

7.260.1.14 HEARTBEAT_WINDOW_TUNING_FREQUENCY

```
#define HEARTBEAT_WINDOW_TUNING_FREQUENCY STARFORTH_CONFIG_HEARTBEAT_WINDOW_TUNING_FREQUENCY_DEFAULT
```

7.260.1.15 INITIAL_DECAY_SLOPE_Q48

```
#define INITIAL_DECAY_SLOPE_Q48 STARFORTH_CONFIG_INITIAL_DECAY_SLOPE_Q48_DEFAULT
```

7.260.1.16 MIN_SAMPLES_FOR_SPECULATION

```
#define MIN_SAMPLES_FOR_SPECULATION STARFORTH_CONFIG_MIN_SAMPLES_FOR_SPECULATION_DEFAULT
```

7.260.1.17 MINIMUM_PREFETCH_ROI

```
#define MINIMUM_PREFETCH_ROI STARFORTH_CONFIG_MINIMUM_PREFETCH_ROI_DEFAULT
```

7.260.1.18 MISPREDICTION_COST_Q48

```
#define MISPREDICTION_COST_Q48 STARFORTH_CONFIG_MISPREDICTION_COST_Q48_DEFAULT
```

7.260.1.19 ROLLING_WINDOW_SIZE

```
#define ROLLING_WINDOW_SIZE STARFORTH_CONFIG_ROLLING_WINDOW_SIZE_DEFAULT
```

7.260.1.20 SPECULATION_DEPTH

```
#define SPECULATION_DEPTH STARFORTH_CONFIG_SPECULATION_DEPTH_DEFAULT
```

7.260.1.21 SPECULATION_THRESHOLD_Q48

```
#define SPECULATION_THRESHOLD_Q48 STARFORTH_CONFIG_SPECULATION_THRESHOLD_Q48_DEFAULT
```

7.260.1.22 SSM_CV_HIGH_THRESHOLD

```
#define SSM_CV_HIGH_THRESHOLD STARFORTH_CONFIG_SSM_CV_HIGH_THRESHOLD_DEFAULT
```

7.260.1.23 SSM_ENTROPY_HIGH_THRESHOLD

```
#define SSM_ENTROPY_HIGH_THRESHOLD STARFORTH_CONFIG_SSM_ENTROPY_HIGH_THRESHOLD_DEFAULT
```

7.260.1.24 SSM_HYSTERESIS_TICKS

```
#define SSM_HYSTERESIS_TICKS STARFORTH_CONFIG_SSM_HYSTERESIS_TICKS_DEFAULT
```

7.260.1.25 SSM_TEMPORAL_DECAY_LOW_THRESHOLD

```
#define SSM_TEMPORAL_DECAY_LOW_THRESHOLD STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_LOW_THRESHOLD_DEFAULT
```

7.260.1.26 SSM_TEMPORAL_DECAY_THRESHOLD

```
#define SSM_TEMPORAL_DECAY_THRESHOLD STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_THRESHOLD_DEFAULT
```

7.260.1.27 STADIUM_BLOCK_COOL_RATE_Q48

```
#define STADIUM_BLOCK_COOL_RATE_Q48 STARFORTH_CONFIG_STADIUM_BLOCK_COOL_RATE_Q48_DEFAULT
```

7.260.1.28 STADIUM_BLOCK_HEAT_QUANTUM

```
#define STADIUM_BLOCK_HEAT_QUANTUM STARFORTH_CONFIG_STADIUM_BLOCK_HEAT_QUANTUM_DEFAULT
```

7.260.1.29 STADIUM_BLOCK_TRACK_CAP_MULT

```
#define STADIUM_BLOCK_TRACK_CAP_MULT STARFORTH_CONFIG_STADIUM_BLOCK_TRACK_CAP_MULT_DEFAULT
```

7.260.1.30 STADIUM_CAPACITY_TICK

```
#define STADIUM_CAPACITY_TICK STARFORTH_CONFIG_STADIUM_CAPACITY_TICK_DEFAULT
```

7.260.1.31 STADIUM_CONTAINS_DEPTH_MAX

```
#define STADIUM_CONTAINS_DEPTH_MAX STARFORTH_CONFIG_STADIUM_CONTAINS_DEPTH_MAX_DEFAULT
```

7.260.1.32 STADIUM_MEMORY_PERCENT

```
#define STADIUM_MEMORY_PERCENT STARFORTH_CONFIG_STADIUM_MEMORY_PERCENT_DEFAULT
```

7.260.1.33 STADIUM_VM_MEMORY_PERCENT

```
#define STADIUM_VM_MEMORY_PERCENT STARFORTH_CONFIG_STADIUM_VM_MEMORY_PERCENT_DEFAULT
```

7.260.1.34 STADIUM_WORD_COOL_RATE_Q48

```
#define STADIUM_WORD_COOL_RATE_Q48 STARFORTH_CONFIG_STADIUM_WORD_COOL_RATE_Q48_DEFAULT
```

7.260.1.35 STADIUM_WORD_HEAT_QUANTUM

```
#define STADIUM_WORD_HEAT_QUANTUM STARFORTH_CONFIG_STADIUM_WORD_HEAT_QUANTUM_DEFAULT
```

7.260.1.36 STARFORTH_CONFIG_ADAPTIVE_CHECK_FREQUENCY_DEFAULT

```
#define STARFORTH_CONFIG_ADAPTIVE_CHECK_FREQUENCY_DEFAULT 512
```

7.260.1.37 STARFORTH_CONFIG_ADAPTIVE_GROWTH_THRESHOLD_DEFAULT

```
#define STARFORTH_CONFIG_ADAPTIVE_GROWTH_THRESHOLD_DEFAULT 5
```

7.260.1.38 STARFORTH_CONFIG_ADAPTIVE_MIN_WINDOW_SIZE_DEFAULT

```
#define STARFORTH_CONFIG_ADAPTIVE_MIN_WINDOW_SIZE_DEFAULT 256
```

7.260.1.39 STARFORTH_CONFIG_ADAPTIVE_SHRINK_RATE_DEFAULT

```
#define STARFORTH_CONFIG_ADAPTIVE_SHRINK_RATE_DEFAULT 50
```

7.260.1.40 STARFORTH_CONFIG_DECAY_MIN_INTERVAL_DEFAULT

```
#define STARFORTH_CONFIG_DECAY_MIN_INTERVAL_DEFAULT 1000ULL
```

7.260.1.41 STARFORTH_CONFIG_DECAY_RATE_PER_US_Q16_DEFAULT

```
#define STARFORTH_CONFIG_DECAY_RATE_PER_US_Q16_DEFAULT 1
```

7.260.1.42 STARFORTH_CONFIG_ENABLE_HOTWORDS_CACHE_DEFAULT

```
#define STARFORTH_CONFIG_ENABLE_HOTWORDS_CACHE_DEFAULT 0
```

7.260.1.43 STARFORTH_CONFIG_ENABLE_PIPELINING_DEFAULT

```
#define STARFORTH_CONFIG_ENABLE_PIPELINING_DEFAULT 0
```

7.260.1.44 STARFORTH_CONFIG_HEARTBEAT_CHECK_FREQUENCY_DEFAULT

```
#define STARFORTH_CONFIG_HEARTBEAT_CHECK_FREQUENCY_DEFAULT 256
```

7.260.1.45 STARFORTH_CONFIG_HEARTBEAT_INFERENCE_FREQUENCY_DEFAULT

```
#define STARFORTH_CONFIG_HEARTBEAT_INFERENCE_FREQUENCY_DEFAULT 1000
```

7.260.1.46 STARFORTH_CONFIG_HEARTBEAT_SLOPE_VALIDATION_FREQUENCY_DEFAULT

```
#define STARFORTH_CONFIG_HEARTBEAT_SLOPE_VALIDATION_FREQUENCY_DEFAULT 5000
```

7.260.1.47 STARFORTH_CONFIG_HEARTBEAT_THREAD_ENABLED_DEFAULT

```
#define STARFORTH_CONFIG_HEARTBEAT_THREAD_ENABLED_DEFAULT 1
```

7.260.1.48 STARFORTH_CONFIG_HEARTBEAT_TICK_NS_DEFAULT

```
#define STARFORTH_CONFIG_HEARTBEAT_TICK_NS_DEFAULT 10000ULL
```

7.260.1.49 STARFORTH_CONFIG_HEARTBEAT_WINDOW_TUNING_FREQUENCY_DEFAULT

```
#define STARFORTH_CONFIG_HEARTBEAT_WINDOW_TUNING_FREQUENCY_DEFAULT 1000
```

7.260.1.50 STARFORTH_CONFIG_INITIAL_DECAY_SLOPE_Q48_DEFAULT

```
#define STARFORTH_CONFIG_INITIAL_DECAY_SLOPE_Q48_DEFAULT 21845
```

7.260.1.51 STARFORTH_CONFIG_MIN_SAMPLES_FOR_SPECULATION_DEFAULT

```
#define STARFORTH_CONFIG_MIN_SAMPLES_FOR_SPECULATION_DEFAULT 10
```

7.260.1.52 STARFORTH_CONFIG_MINIMUM_PREFETCH_ROI_DEFAULT

```
#define STARFORTH_CONFIG_MINIMUM_PREFETCH_ROI_DEFAULT (0x1199AL)
```

7.260.1.53 STARFORTH_CONFIG_MISPREDICTION_COST_Q48_DEFAULT

```
#define STARFORTH_CONFIG_MISPREDICTION_COST_Q48_DEFAULT (25LL << 16)
```

7.260.1.54 STARFORTH_CONFIG_ROLLING_WINDOW_SIZE_DEFAULT

```
#define STARFORTH_CONFIG_ROLLING_WINDOW_SIZE_DEFAULT 4096
```

7.260.1.55 STARFORTH_CONFIG_SPECULATION_DEPTH_DEFAULT

```
#define STARFORTH_CONFIG_SPECULATION_DEPTH_DEFAULT 1
```

7.260.1.56 STARFORTH_CONFIG_SPECULATION_THRESHOLD_Q48_DEFAULT

```
#define STARFORTH_CONFIG_SPECULATION_THRESHOLD_Q48_DEFAULT (0x8000LL)
```

7.260.1.57 STARFORTH_CONFIG_SSM_CV_HIGH_THRESHOLD_DEFAULT

```
#define STARFORTH_CONFIG_SSM_CV_HIGH_THRESHOLD_DEFAULT 0.15
```

7.260.1.58 STARFORTH_CONFIG_SSM_ENTROPY_HIGH_THRESHOLD_DEFAULT

```
#define STARFORTH_CONFIG_SSM_ENTROPY_HIGH_THRESHOLD_DEFAULT 0.75
```

7.260.1.59 STARFORTH_CONFIG_SSM_HYSTERESIS_TICKS_DEFAULT

```
#define STARFORTH_CONFIG_SSM_HYSTERESIS_TICKS_DEFAULT 5
```

7.260.1.60 STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_LOW_THRESHOLD_DEFAULT

```
#define STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_LOW_THRESHOLD_DEFAULT 0.3
```

7.260.1.61 STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_THRESHOLD_DEFAULT

```
#define STARFORTH_CONFIG_SSM_TEMPORAL_DECAY_THRESHOLD_DEFAULT 0.5
```

7.260.1.62 STARFORTH_CONFIG_STADIUM_BLOCK_COOL_RATE_Q48_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_BLOCK_COOL_RATE_Q48_DEFAULT 21845
```

7.260.1.63 STARFORTH_CONFIG_STADIUM_BLOCK_HEAT_QUANTUM_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_BLOCK_HEAT_QUANTUM_DEFAULT 2048
```

7.260.1.64 STARFORTH_CONFIG_STADIUM_BLOCK_TRACK_CAP_MULT_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_BLOCK_TRACK_CAP_MULT_DEFAULT 2
```

7.260.1.65 STARFORTH_CONFIG_STADIUM_CAPACITY_TICK_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_CAPACITY_TICK_DEFAULT 4000
```

7.260.1.66 STARFORTH_CONFIG_STADIUM_CONTAINS_DEPTH_MAX_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_CONTAINS_DEPTH_MAX_DEFAULT 5
```

7.260.1.67 STARFORTH_CONFIG_STADIUM_MEMORY_PERCENT_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_MEMORY_PERCENT_DEFAULT 1
```

7.260.1.68 STARFORTH_CONFIG_STADIUM_VM_MEMORY_PERCENT_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_VM_MEMORY_PERCENT_DEFAULT 50
```

7.260.1.69 STARFORTH_CONFIG_STADIUM_WORD_COOL_RATE_Q48_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_WORD_COOL_RATE_Q48_DEFAULT 21845
```

7.260.1.70 STARFORTH_CONFIG_STADIUM_WORD_HEAT_QUANTUM_DEFAULT

```
#define STARFORTH_CONFIG_STADIUM_WORD_HEAT_QUANTUM_DEFAULT 2048
```

7.260.1.71 STARFORTH_CONFIG_STRICT_PTR_DEFAULT

```
#define STARFORTH_CONFIG_STRICT_PTR_DEFAULT 1
```

7.260.1.72 STARFORTH_CONFIG_TRANSITION_WINDOW_SIZE_DEFAULT

```
#define STARFORTH_CONFIG_TRANSITION_WINDOW_SIZE_DEFAULT 8
```

7.260.1.73 STRICT_PTR

```
#define STRICT_PTR STARFORTH_CONFIG_STRICT_PTR_DEFAULT
```

7.260.1.74 TRANSITION_WINDOW_SIZE

```
#define TRANSITION_WINDOW_SIZE STARFORTH_CONFIG_TRANSITION_WINDOW_SIZE_DEFAULT
```

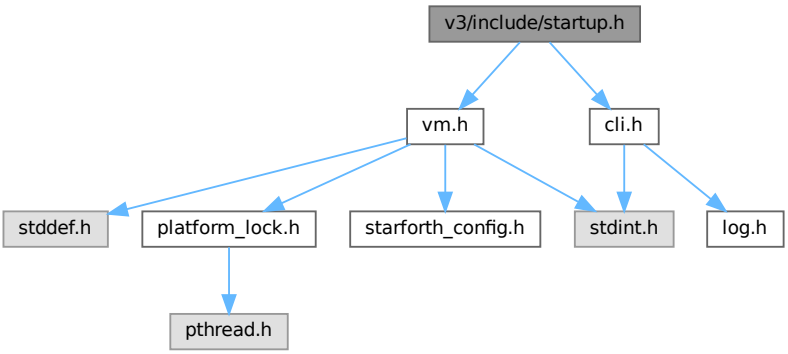
7.260.1.75 VM_STRICT_PTR

```
#define VM_STRICT_PTR STRICT_PTR
```

7.261 v3/include/startup.h File Reference

```
#include "vm.h"
#include "cli.h"
```

Include dependency graph for startup.h:



Functions

- int startup_blkio_init (const CLIConfig *config)
  Initialize block I/O device from CLI configuration.
- void startup_blkio_cleanup (void)
  Clean up block I/O device.
- int startup_vm_init (VM *vm)
  Initialize VM with defaults.
- int startup_block_subsys_init (VM *vm)
  Initialize block subsystem.

7.261.1 Function Documentation

7.261.1.1 startup_blkio_cleanup()

```
void startup_blkio_cleanup (
            void  )
```

Clean up block I/O device.

Flushes and closes block device, frees RAM disk if allocated. Called automatically via atexit().

7.261.1.2 startup_blkio_init()

```
int startup_blkio_init (
            const CLIConfig * config )
```

Initialize block I/O device from CLI configuration.

Opens disk image or allocates RAM disk based on CLIConfig. Must be called before vm_init().

Parameters

config	CLI configuration

Returns

0 on success, 1 on error (logs messages internally)

7.261.1.3 startup_block_subsys_init()

```
int startup_block_subsys_init (
            VM * vm )
```

Initialize block subsystem.

Sets up block buffering and attaches blkio device.

Parameters

vm	Pointer to initialized VM

Returns

0 on success, 1 on error

7.261.1.4 startup_vm_init()

```
int startup_vm_init (
            VM * vm )
```

Initialize VM with defaults.

Initializes the VM state after block device is ready.

Parameters

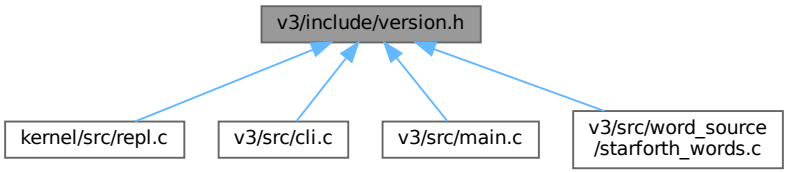
vm	Pointer to VM to initialize

Returns

0 on success, 1 on error

7.262 v3/include/version.h File Reference

This graph shows which files directly or indirectly include this file:



Macros

- #define STARFORTH_VERSION "3.2.0"
- #define STARFORTH_ARCH "amd64"
- #define STARFORTH_TARGET "kernel"
- #define STARFORTH_TIMESTAMP "2026-10-16T22:58:44-04:00"
- #define STARFORTH_VERSION_FULL "StarForth v3.2.0 amd64 kernel 2026-10-16T22:58:44-04:00"
- #define LITHOS_VERSION "2.1.0"
- #define LITHOS_VERSION_STR "LithosAnanke v2.1.0 amd64"

7.262.1 Macro Definition Documentation

7.262.1.1 LITHOS_VERSION

```
#define LITHOS_VERSION "2.1.0"
```

7.262.1.2 LITHOS_VERSION_STR

```
#define LITHOS_VERSION_STR "LithosAnanke v2.1.0 amd64"
```

7.262.1.3 STARFORTH_ARCH

```
#define STARFORTH_ARCH "amd64"
```

7.262.1.4 STARFORTH_TARGET

```
#define STARFORTH_TARGET "kernel"
```

7.262.1.5 STARFORTH_TIMESTAMP

```
#define STARFORTH_TIMESTAMP "2026-10-16T22:58:44-04:00"
```

7.262.1.6 STARFORTH_VERSION

```
#define STARFORTH_VERSION "3.2.0"
```

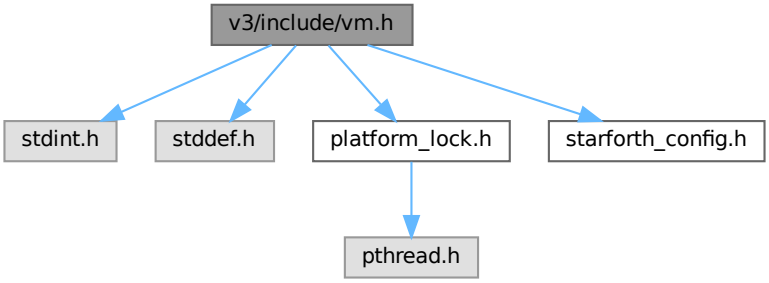
7.262.1.7 STARFORTH_VERSION_FULL

```
#define STARFORTH_VERSION_FULL "StarForth v3.2.0 amd64 kernel 2026-10-16T22:58:44-04:00"
```

7.263 v3/include/vm.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "platform_lock.h"
#include "starforth_config.h"
```

Include dependency graph for vm.h:



Data Structures

- struct RollingWindowOfTruth
- struct HeartbeatSnapshot
- struct HeartbeatTickSnapshot
- struct DictPhysics
- struct HeartbeatState
- struct PipelineGlobalMetrics
- struct DictEntry
- struct VocabularyState
- struct cf_item_t
- struct ControlFlowState
- struct VM

  Main virtual machine state container.

Macros

- #define STACK_SIZE 1024
- #define DICTIONARY_SIZE 1024
- #define WORD_ID_INVALID UINT32_MAX
- #define VM_MEMORY_SIZE (5 * 1024 * 1024) /* 5 MB total VM memory */
- #define INPUT_BUFFER_SIZE 1025
- #define WORD_NAME_MAX 31
- #define COMPILE_BUFFER_SIZE 1024
- #define BLOCK_SIZE 1024 /* 1KB per block */
- #define MAX_BLOCKS (VM_MEMORY_SIZE / BLOCK_SIZE) /* 5120 blocks from 5MB */
- #define BLK_VM_SLOTS 4
- #define BLK_VM_WINDOW_SIZE (BLK_VM_SLOTS * BLOCK_SIZE)
- #define BLK_VM_WINDOW_BASE (VM_MEMORY_SIZE - BLK_VM_WINDOW_SIZE)
- #define DICTIONARY_BLOCKS 2048 /* First 2048 blocks (2MB) for dictionary */
- #define DICTIONARY_MEMORY_SIZE (DICTIONARY_BLOCKS * BLOCK_SIZE)
- #define USER_BLOCKS_START DICTIONARY_BLOCKS /* User blocks start at block 2048 */
- #define LOG_LINE_MAX 64 /* Each log line is 64 bytes */
- #define LOG_LINES_PER_BLOCK (BLOCK_SIZE / LOG_LINE_MAX) /* 16 lines per 1KB block */
- #define LOG_BLOCKS_START 3072 /* Log starts at block 3072 */
- #define LOG_BLOCKS_END 5120 /* Log ends at block 5120 (exclusive) */
- #define LOG_BLOCKS (LOG_BLOCKS_END - LOG_BLOCKS_START) /* 2048 blocks (2MB) for logs */
- #define LOG_LAYER1_MAX_LINES (LOG_BLOCKS * LOG_LINES_PER_BLOCK) /* 32768 max lines */
- #define WORD_IMMEDIATE 0x80 /* Word executes immediately even in compile mode */
- #define WORD_HIDDEN 0x40 /* Word is hidden from dictionary searches */
- #define WORD_SMUDGED 0x20 /* Word is smudged (being defined) - FORTH-79 */
- #define WORD_COMPILED 0x10 /* Word is user-compiled (not built-in) */
- #define WORD_PINNED 0x08 /* Word's execution heat is pinned (cannot decay to zero) */
- #define WORD_FROZEN 0x04 /* Word is frozen: execution heat does not decay (Phase 2) */
- #define ACL_USER_DEFAULT 0x01 /* Default access: users can execute and compile */
- #define ACL_MODE_TTL 0 /* Adaptive TTL countdown; 0 → calls ACL-RECHECK */
- #define ACL_MODE_STRICT 1 /* Re-check every execution (STRICT mode) */
- #define ACL_TTL_OPEN UINT32_MAX /* Permissive TTL before ACL.4th loads */
- #define SPIN_IDLE 0 /* Particle spin state: idle */
- #define CHARGE_NEUTRAL 0 /* Particle charge state: neutral (execution heat acts as charge) */
- #define PHYSICS_STATE_IMMEDIATE 0x01
- #define PHYSICS_STATE_PINNED 0x02
- #define PHYSICS_STATE_HIDDEN 0x04
- #define PHYSICS_STATE_COMPILED 0x08
- #define HEAT_CACHE_DEMOTION_THRESHOLD 10 /* Demotion from hotwords cache threshold */
- #define HEARTBEAT_TICK_BUFFER_SIZE 100000 /* ~100K ticks = ~100 seconds at 1kHz */
- #define VOCAB_FC_BUCKETS 256
- #define CF_STACK_MAX 64
- #define VM_PUSH(vm, val) vm_push_fast(vm, val)
- #define VM_POP(vm) vm_pop_fast(vm)
- #define VM_RPUSH(vm, val) vm_rpush_fast(vm, val)
- #define VM_RPOP(vm) vm_rpop_fast(vm)
- #define LIKELY(x) __builtin_expect(!!(x), 1)
- #define UNLIKELY(x) __builtin_expect(!!(x), 0)

Typedefs

- typedef struct HotwordsCache_s HotwordsCache
- typedef struct WordTransitionMetrics WordTransitionMetrics
- typedef struct VMHostServices VMHostServices
- typedef struct InferenceOutputs InferenceOutputs
- typedef struct HeartbeatWorker HeartbeatWorker
- typedef signed long cell_t
- typedef unsigned long ucell_t
- typedef void(* word_func_t) (struct VM *vm)
- typedef uint64_t vaddr_t
- typedef struct VM VM

Enumerations

- enum vm_mode_t { MODE_INTERPRET = 0 , MODE_COMPILE = 1 }
- enum cf_tag_t {
  CF_BEGIN , CF_IF , CF_ELSE , CF_WHILE ,
  CF_DO , CF_CASE , CF_OF }

Functions

- int vm_addr_ok (struct VM *vm, vaddr_t addr, size_t len)

  Validate that a VM address range lies within `vm->memory`.
- uint8_t * vm_ptr (struct VM *vm, vaddr_t addr)

  Return a host C pointer into VM memory at `addr`.
- uint8_t vm_load_u8 (struct VM *vm, vaddr_t addr)

  Load an unsigned byte from VM memory.
- void vm_store_u8 (struct VM *vm, vaddr_t addr, uint8_t v)

  Store an unsigned byte to VM memory.
- cell_t vm_load_cell (struct VM *vm, vaddr_t addr)

  Load an aligned cell from VM memory.
- void vm_store_cell (struct VM *vm, vaddr_t addr, cell_t v)

  Store an aligned cell to VM memory.
- unsigned vm_get_base (const struct VM *vm)
- void vm_set_base (struct VM *vm, unsigned b)

  Set the VM number base and update both the cell and the host mirror.
- static vaddr_t VM_ADDR (cell_t c)
- static cell_t CELL (vaddr_t a)
- struct DictEntry __attribute__ ((aligned(8))) DictEntry
- void vm_push (VM *vm, cell_t value)

  Push a value onto the data stack.
- cell_t vm_pop (VM *vm)

  Pop a value from the data stack.
- void vm_rpush (VM *vm, cell_t value)

  Push a value onto the return stack.
- cell_t vm_rpop (VM *vm)

  Pop a value from the return stack.
- DictEntry * vm_find_word (VM *vm, const char *name, size_t len)

  Finds a word in the dictionary by name.
- DictEntry * vm_dict_resolve_in_bucket (VM *vm, DictEntry **bucket, size_t n, const char *name, size_t len)

- DictEntry * vm_create_word (VM *vm, const char *name, size_t len, word_func_t func)

  Creates a new word in the dictionary.
- void vm_make_immediate (VM *vm)

  Mark the most recently created word as IMMEDIATE (FORTH-79).
- void vm_bootstrap_root_vocabulary (VM *vm, const char *name)

  Bootstrap a root vocabulary for the VM.
- void vm_hide_word (VM *vm)

  Marks the latest word as hidden.
- void vm_smudge_word (VM *vm)
- void vm_pin_execution_heat (VM *vm)
- void vm_unpin_execution_heat (VM *vm)
- DictEntry * vm_dictionary_find_by_func (VM *vm, word_func_t func)

  Finds a word by its function pointer.
- DictEntry * vm_dictionary_find_latest_by_func (VM *vm, word_func_t func)
- DictEntry * vm_dictionary_lookup_by_word_id (VM *vm, uint32_t word_id)
- int vm_dict_entry_ok (VM *vm, DictEntry *candidate)
- void vm_dictionary_track_entry (VM *vm, DictEntry *entry)
- void vm_dictionary_untrack_entry (VM *vm, DictEntry *entry)
- cell_t * vm_dictionary_get_data_field (DictEntry *entry)

  Gets pointer to a word's data field.
- void vm_compile_word (VM *vm, DictEntry *entry)

  Append a word reference (DictEntry) to the current threaded body.*
- int vm_zuse_cert_install (VM *vm, const uint8_t seed[32], const uint8_t pubkey[32])

  One-time write of the Zuse cert (seed + derived pubkey) – blows the fuse.
- void * vm_allot (VM *vm, size_t bytes)

  Allocates memory from the VM's dictionary space.
- void vm_align (VM *vm)

  Aligns the VM's dictionary pointer (here) to the cell boundary.
- int vm_parse_word (VM *vm, char *word, size_t max_len)

  Parse the next whitespace-delimited token from the input buffer.
- int vm_parse_number (VM *vm, const char *str, cell_t *value)

  Attempt to parse a string as an integer in the current number base.
- void vm_enter_compile_mode (VM *vm, const char *name, size_t len)

  Begin a colon definition and switch the VM to compile mode.
- void vm_exit_compile_mode (VM *vm)

  Finalise a colon definition and return to interpret mode.
- void execute_colon_word (VM *vm)

  Inner interpreter for threaded colon definitions.
- void vm_compile_call (VM *vm, word_func_t func)

  Compile a call to a word identified by its C function pointer.
- void vm_compile_literal (VM *vm, cell_t value)

  Compile a literal value into the current threaded body (or push it).
- void vm_compile_exit (VM *vm)

  Compile an `EXIT` reference into the current threaded body.
- void vm_interpret_word (VM *vm, const char *word_str, size_t len)

  Interpret or compile a single word token.
- void * vm_get_block_addr (VM *vm, int block_num)

  Gets the memory address for a specified block number.
- int vm_addr_to_block (VM *vm, void *addr)

  Converts a memory address to its corresponding block number.
- void vm_run_smoke_tests (VM *vm)

- void vm_cleanup (VM *vm)

  Clean up and free VM resources.
- void vm_tick (VM *vm)

  Central heartbeat dispatcher for time-driven tuning operations.
- void vm_tick_inference_engine (VM *vm)

  Phase 2: Unified Inference Engine - Adaptive Window & Decay Slope Tuning.
- void vm_tick_window_tuner (VM *vm)

  Loop #5: Context-aware window tuning via binary chop search.
- void vm_tick_slope_validator (VM *vm)

  Loop #3: Heat decay slope validation via periodic measurement.
- void vm_snapshot_read (const VM *vm, HeartbeatSnapshot *out_snapshot)
- void heartbeat_capture_tick_snapshot (VM *vm, HeartbeatTickSnapshot *snapshot)

  Capture current VM metrics into a heartbeat tick snapshot.
- void heartbeat_emit_tick_row (VM *vm, HeartbeatTickSnapshot *snapshot)

  Emit a heartbeat tick snapshot as CSV row to stderr.
- void vm_heartbeat_start (VM *vm)
- static void vm_push_fast (VM *vm, cell_t value)
- static cell_t vm_pop_fast (VM *vm)
- static void vm_rpush_fast (VM *vm, cell_t value)
- static cell_t vm_rpop_fast (VM *vm)

Core VM Functions

- void vm_init (VM *vm)

  Initialize a new virtual machine instance.
- void vm_init_with_host (VM *vm, const VMHostServices *host)

  Initialize VM with explicit host services.
- void vm_interpret (VM *vm, const char *input)
- void vm_enable_interpreter (VM *vm)
- void vm_repl (VM *vm, int script_mode)

  Starts the Forth REPL (Read-Eval-Print Loop)

Variables

- typedef __attribute__
- struct DictEntry * link
- word_func_t func
- cell_t flags
- uint8_t name_len
- cell_t execution_heat
- uint8_t acl_default
- uint32_t acl_ttl
- uint8_t acl_allow
- uint8_t acl_mode
- uint8_t acl_pinned
- uint32_t word_id
- DictPhysics physics
- WordTransitionMetrics * transition_metrics
- char name [ ]

7.263.1 Macro Definition Documentation

7.263.1.1 ACL_MODE_STRICT

```
#define ACL_MODE_STRICT 1 /* Re-check every execution (STRICT mode) */
```

7.263.1.2 ACL_MODE_TTL

```
#define ACL_MODE_TTL 0 /* Adaptive TTL countdown; 0 → calls ACL-RECHECK */
```

7.263.1.3 ACL_TTL_OPEN

```
#define ACL_TTL_OPEN UINT32_MAX /* Permissive TTL before ACL.4th loads */
```

7.263.1.4 ACL_USER_DEFAULT

```
#define ACL_USER_DEFAULT 0x01 /* Default access:  users can execute and compile */
```

7.263.1.5 BLK_VM_SLOTS

```
#define BLK_VM_SLOTS 4
```

7.263.1.6 BLK_VM_WINDOW_BASE

```
#define BLK_VM_WINDOW_BASE (VM_MEMORY_SIZE - BLK_VM_WINDOW_SIZE)
```

7.263.1.7 BLK_VM_WINDOW_SIZE

```
#define BLK_VM_WINDOW_SIZE (BLK_VM_SLOTS * BLOCK_SIZE)
```

7.263.1.8 BLOCK_SIZE

```
#define BLOCK_SIZE 1024 /* 1KB per block */
```

7.263.1.9 CF_STACK_MAX

```
#define CF_STACK_MAX 64
```

7.263.1.10 CHARGE_NEUTRAL

```
#define CHARGE_NEUTRAL 0 /* Particle charge state:  neutral (execution heat acts as charge) */
```

7.263.1.11 COMPILE_BUFFER_SIZE

```
#define COMPILE_BUFFER_SIZE 1024
```

7.263.1.12 DICTIONARY_BLOCKS

```
#define DICTIONARY_BLOCKS 2048 /* First 2048 blocks (2MB) for dictionary */
```

7.263.1.13 DICTIONARY_MEMORY_SIZE

```
#define DICTIONARY_MEMORY_SIZE (DICTIONARY_BLOCKS * BLOCK_SIZE)
```

7.263.1.14 DICTIONARY_SIZE

```
#define DICTIONARY_SIZE 1024
```

7.263.1.15 HEARTBEAT_TICK_BUFFER_SIZE

```
#define HEARTBEAT_TICK_BUFFER_SIZE 100000 /* ~100K ticks = ~100 seconds at 1kHz */
```

7.263.1.16 HEAT_CACHE_DEMOTION_THRESHOLD

```
#define HEAT_CACHE_DEMOTION_THRESHOLD 10 /* Demotion from hotwords cache threshold */
```

7.263.1.17 INPUT_BUFFER_SIZE

```
#define INPUT_BUFFER_SIZE 1025
```

7.263.1.18 LIKELY

```
#define LIKELY(
             x ) __builtin_expect(!!(x), 1)
```

7.263.1.19 LOG_BLOCKS

```
#define LOG_BLOCKS (LOG_BLOCKS_END - LOG_BLOCKS_START) /* 2048 blocks (2MB) for logs */
```

7.263.1.20 LOG_BLOCKS_END

```
#define LOG_BLOCKS_END 5120 /* Log ends at block 5120 (exclusive) */
```

7.263.1.21 LOG_BLOCKS_START

```
#define LOG_BLOCKS_START 3072 /* Log starts at block 3072 */
```

7.263.1.22 LOG_LAYER1_MAX_LINES

```
#define LOG_LAYER1_MAX_LINES (LOG_BLOCKS * LOG_LINES_PER_BLOCK) /* 32768 max lines */
```

7.263.1.23 LOG_LINE_MAX

```
#define LOG_LINE_MAX 64 /* Each log line is 64 bytes */
```

7.263.1.24 LOG_LINES_PER_BLOCK

```
#define LOG_LINES_PER_BLOCK (BLOCK_SIZE / LOG_LINE_MAX) /* 16 lines per 1KB block */
```

7.263.1.25 MAX_BLOCKS

```
#define MAX_BLOCKS (VM_MEMORY_SIZE / BLOCK_SIZE) /* 5120 blocks from 5MB */
```

7.263.1.26 PHYSICS_STATE_COMPILED

```
#define PHYSICS_STATE_COMPILED 0x08
```

7.263.1.27 PHYSICS_STATE_HIDDEN

```
#define PHYSICS_STATE_HIDDEN 0x04
```

7.263.1.28 PHYSICS_STATE_IMMEDIATE

```
#define PHYSICS_STATE_IMMEDIATE 0x01
```

7.263.1.29 PHYSICS_STATE_PINNED

```
#define PHYSICS_STATE_PINNED 0x02
```

7.263.1.30 SPIN_IDLE

```
#define SPIN_IDLE 0 /* Particle spin state:  idle */
```

7.263.1.31 STACK_SIZE

```
#define STACK_SIZE 1024
```

7.263.1.32 UNLIKELY

```
#define UNLIKELY(
              x ) __builtin_expect(!!(x), 0)
```

7.263.1.33 USER_BLOCKS_START

```
#define USER_BLOCKS_START DICTIONARY_BLOCKS /* User blocks start at block 2048 */
```

7.263.1.34 VM_MEMORY_SIZE

```
#define VM_MEMORY_SIZE (5 * 1024 * 1024) /* 5 MB total VM memory */
```

7.263.1.35 VM_POP

```
#define VM_POP(
              vm ) vm_pop_fast(vm)
```

7.263.1.36 VM_PUSH

```
#define VM_PUSH(
              vm,
              val ) vm_push_fast(vm, val)
```

7.263.1.37 VM_RPOP

```
#define VM_RPOP(
              vm ) vm_rpop_fast(vm)
```

7.263.1.38 VM_RPUSH

```
#define VM_RPUSH(
              vm,
              val ) vm_rpush_fast(vm, val)
```

7.263.1.39 VOCAB_FC_BUCKETS

```
#define VOCAB_FC_BUCKETS 256
```

7.263.1.40 WORD_COMPILED

```
#define WORD_COMPILED 0x10 /* Word is user-compiled (not built-in) */
```

7.263.1.41 WORD_FROZEN

```
#define WORD_FROZEN 0x04 /* Word is frozen:  execution heat does not decay (Phase 2) */
```

7.263.1.42 WORD_HIDDEN

```
#define WORD_HIDDEN 0x40 /* Word is hidden from dictionary searches */
```

7.263.1.43 WORD_ID_INVALID

```
#define WORD_ID_INVALID UINT32_MAX
```

7.263.1.44 WORD_IMMEDIATE

```
#define WORD_IMMEDIATE 0x80 /* Word executes immediately even in compile mode */
```

7.263.1.45 WORD_NAME_MAX

```
#define WORD_NAME_MAX 31
```

7.263.1.46 WORD_PINNED

```
#define WORD_PINNED 0x08 /* Word's execution heat is pinned (cannot decay to zero) */
```

7.263.1.47 WORD_SMUDGED

```
#define WORD_SMUDGED 0x20 /* Word is smudged (being defined) - FORTH-79 */
```

7.263.2 Typedef Documentation

7.263.2.1 cell_t

```
typedef signed long cell_t
```

7.263.2.2 HeartbeatWorker

```
typedef struct HeartbeatWorker HeartbeatWorker
```

7.263.2.3 HotwordsCache

```
typedef struct HotwordsCache_s HotwordsCache
```

7.263.2.4 InferenceOutputs

```
typedef struct InferenceOutputs InferenceOutputs
```

7.263.2.5 ucell_t

```
typedef unsigned long ucell_t
```

7.263.2.6 vaddr_t

```
typedef uint64_t vaddr_t
```

7.263.2.7 VM

```
typedef struct VM VM
```

7.263.2.8 VMHostServices

```
typedef struct VMHostServices VMHostServices
```

7.263.2.9 word_func_t

```
typedef void(* word_func_t) (struct VM *vm)
```

7.263.2.10 WordTransitionMetrics

```
typedef struct WordTransitionMetrics WordTransitionMetrics
```

7.263.3 Enumeration Type Documentation

7.263.3.1 cf_tag_t

```
enum cf_tag_t
```

Enumerator

CF_BEGIN	
CF_IF	
CF_ELSE	
CF_WHILE	
CF_DO	
CF_CASE	
CF_OF	

7.263.3.2 vm_mode_t

```
enum vm_mode_t
```

Enumerator

MODE_INTERPRET	
MODE_COMPILE	

7.263.4 Function Documentation

7.263.4.1 __attribute__()

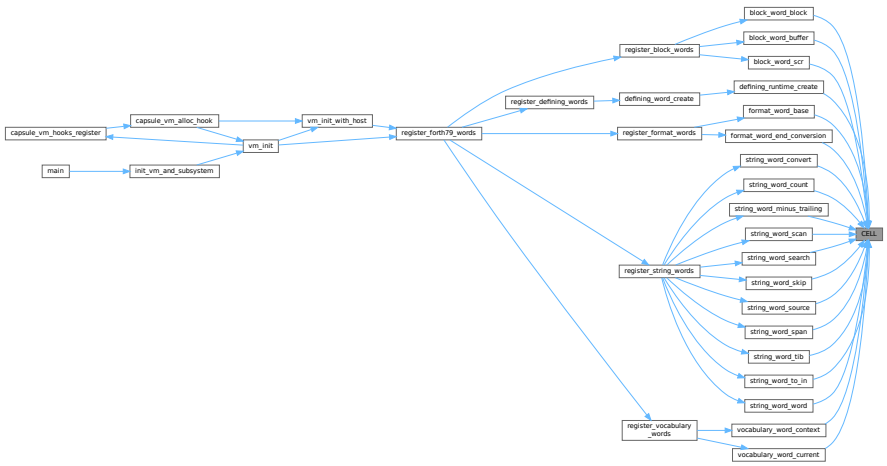
```
struct DictEntry __attribute__ (
            (aligned(8))  )
```

7.263.4.2 CELL()

```
static cell_t CELL (
            vaddr_t a )  [inline], [static]
```

Referenced by block_word_block(), block_word_buffer(), block_word_scr(), defining_runtime_create(), format_word_base(), format_word_end_conversion(), string_word_convert(), string_word_count(), string_word_minus_trailing(), string_word_scan(), string_word_search(), string_word_skip(), string_word_source(), string_word_span(), string_word_tib(), string_word_to_in(), string_word_word(), vocabulary_word_context(), and vocabulary_word_current().

Here is the caller graph for this function:



7.263.4.3 execute_colon_word()

```
void execute_colon_word (
            VM * vm )
```

Inner interpreter for threaded colon definitions.

Runs the body of a colon-defined word whose DictEntry points to a sequence of DictEntry* cells in VM memory (indirect threaded code). The interpreter pointer (IP) is maintained on the return stack so that runtime control-flow words ((BRANCH), (0BRANCH), (DO), etc.) can redirect execution by modifying the top-of-return-stack IP.

Execution loop per iteration:

1. Read DictEntry* w from *ip.
2. Run physics pre-execute hooks (heat, decay, pipelining).
3. ACL hot-path check (decrement TTL; call acl_recheck() on zero).
4. Push ip+1 onto the return stack as the resume point.
5. Call w->func(vm).
6. Run physics post-execute hooks.
7. Check vm->exit_colon (set by EXIT): pop and discard the saved IP, then return to caller.
8. Check vm->abort_requested: unwind and return immediately.
9. Pop the (possibly modified) IP from the return stack and repeat.

vm->ecw_nesting is incremented on entry and decremented on every return path to enable recursive colon calls.

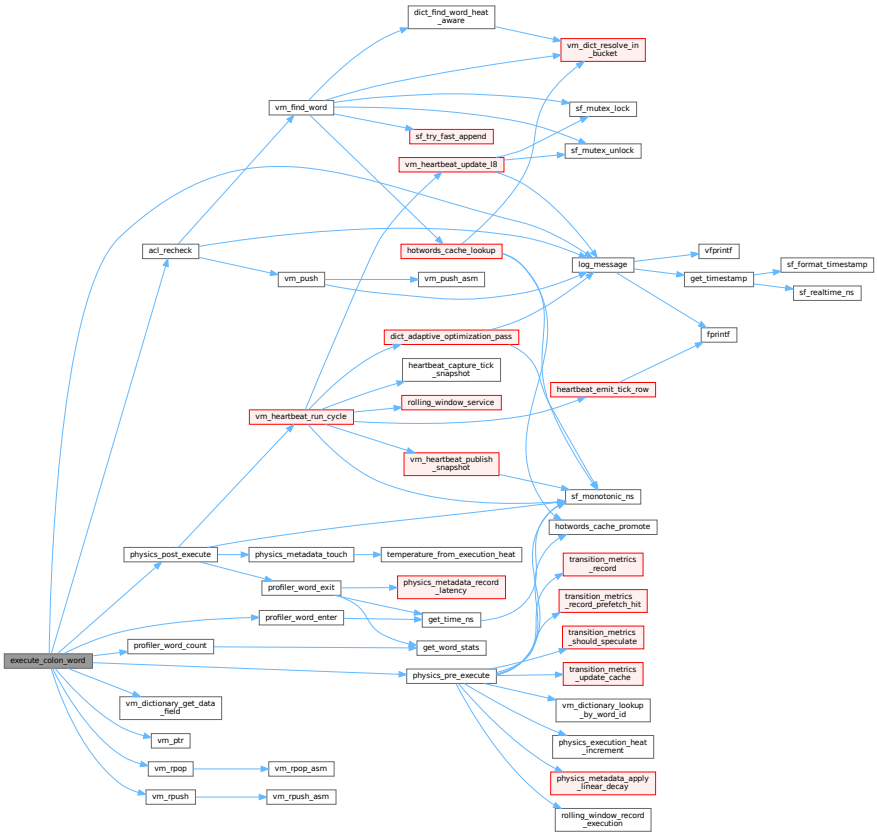
Parameters

vm	VM instance; vm->current_executing_entry must point to the DictEntry being executed.

References VM::abort_requested, DictEntry::acl_allow, acl_recheck(), DictEntry::acl_ttl, VM::current_executing_entry, VM::dsp, VM::ecw_nesting, VM::emergency_console, entry, VM::error, VM::exit_colon, DictEntry::func, LOG_ERROR, log_message(), LOG_WARN, DictEntry::name, DictEntry::name_len, physics_post_execute(), physics_pre_execute(), profiler_word_count(), profiler_word_enter(), VM::rsp, vm_dictionary_get_data_field(), vm_ptr(), vm_rpop(), and vm_rpush().

Referenced by system_word_see().

Here is the call graph for this function:



Here is the caller graph for this function:

7.263.4.4 heartbeat_capture_tick_snapshot()

```
void heartbeat_capture_tick_snapshot (
            VM * vm,
            HeartbeatTickSnapshot * snapshot )
```

Capture current VM metrics into a heartbeat tick snapshot.

Collects 11 metrics per tick for multivariate dynamics analysis. Called every heartbeat tick to record VM state.

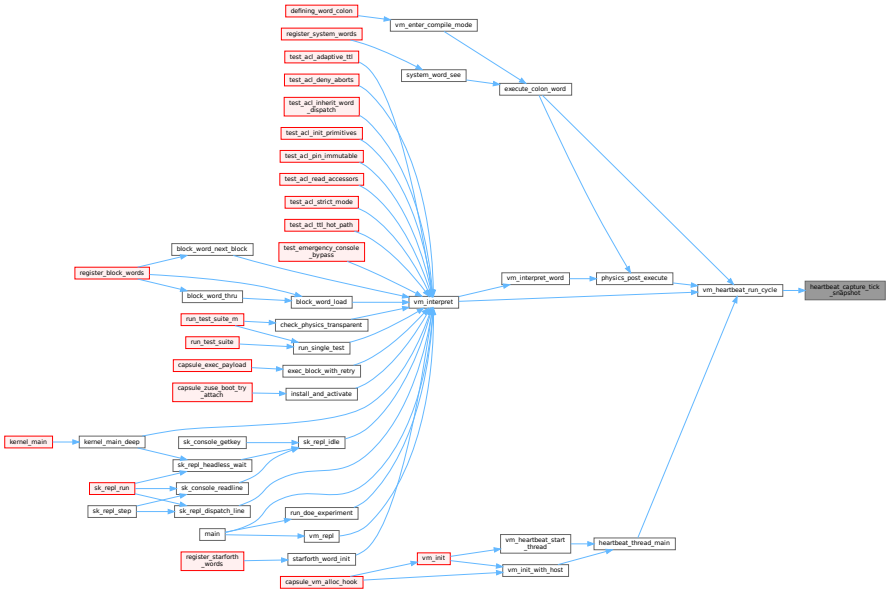
Parameters

vm	Pointer to the VM instance
snapshot	Pointer to snapshot structure to populate

References HeartbeatTickSnapshot::actual_window_size, HeartbeatTickSnapshot::avg_word_heat, HeartbeatTickSnapshot::bucket_
HeartbeatTickSnapshot::cache_hits_delta, HeartbeatState::early_exit_count, RollingWindowOfTruth::effective_window_size,
HeartbeatTickSnapshot::elapsed_ns, entry, HeartbeatTickSnapshot::estimated_jitter_ns, VM::heartbeat, HEARTBEAT_TICK_NS,
HeartbeatTickSnapshot::hot_word_count, VM::latest, HeartbeatTickSnapshot::predicted_label_hits, VM::rolling_window,
HeartbeatState::tick_count, HeartbeatTickSnapshot::tick_interval_ns, HeartbeatTickSnapshot::tick_number,
RollingWindowOfTruth::total_executions, HeartbeatTickSnapshot::window_width, word_count, HeartbeatTickSnapshot::word_executi
and HeartbeatState::words_executed.

Referenced by vm_heartbeat_run_cycle().

Here is the caller graph for this function:



7.263.4.5 heartbeat_emit_tick_row()

```
void heartbeat_emit_tick_row (
            VM * vm,
            HeartbeatTickSnapshot * snapshot )
```

Emit a heartbeat tick snapshot as CSV row to stderr.

Outputs 11 comma-separated values (no header) for real-time streaming. Called every heartbeat tick to emit metrics immediately.

Format: tick_number,elapsed_ns,tick_interval_ns,cache_hits_delta, bucket_hits_delta,word_executions_↩
delta,hot_word_count, avg_word_heat,window_width,actual_window_size,predicted_label_hits,estimated_jitter_ns

Parameters

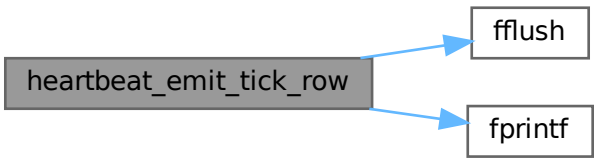
vm	Pointer to the VM instance (unused, for API consistency)
snapshot	Pointer to the snapshot to emit

References HeartbeatTickSnapshot::actual_window_size, HeartbeatTickSnapshot::avg_word_heat, HeartbeatTickSnapshot::bucket_

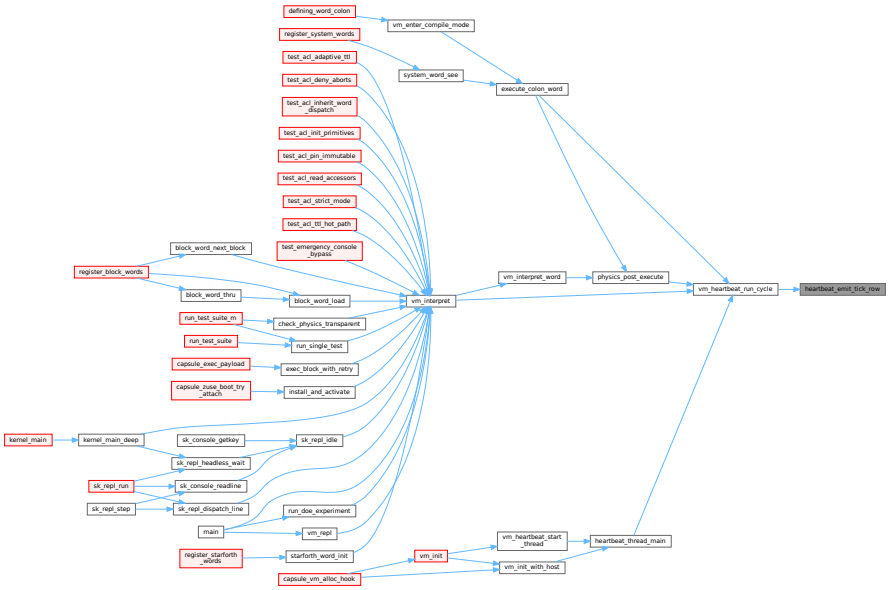
HeartbeatTickSnapshot::cache_hits_delta, HeartbeatTickSnapshot::elapsed_ns, HeartbeatTickSnapshot::estimated_jitter_ns, fflush(), fprintf(), HeartbeatTickSnapshot::hot_word_count, HeartbeatTickSnapshot::predicted_label_hits, stderr, HeartbeatTickSnapshot::tick_interval_ns, HeartbeatTickSnapshot::tick_number, HeartbeatTickSnapshot::window_width, and HeartbeatTickSnapshot::word_executions_delta.

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



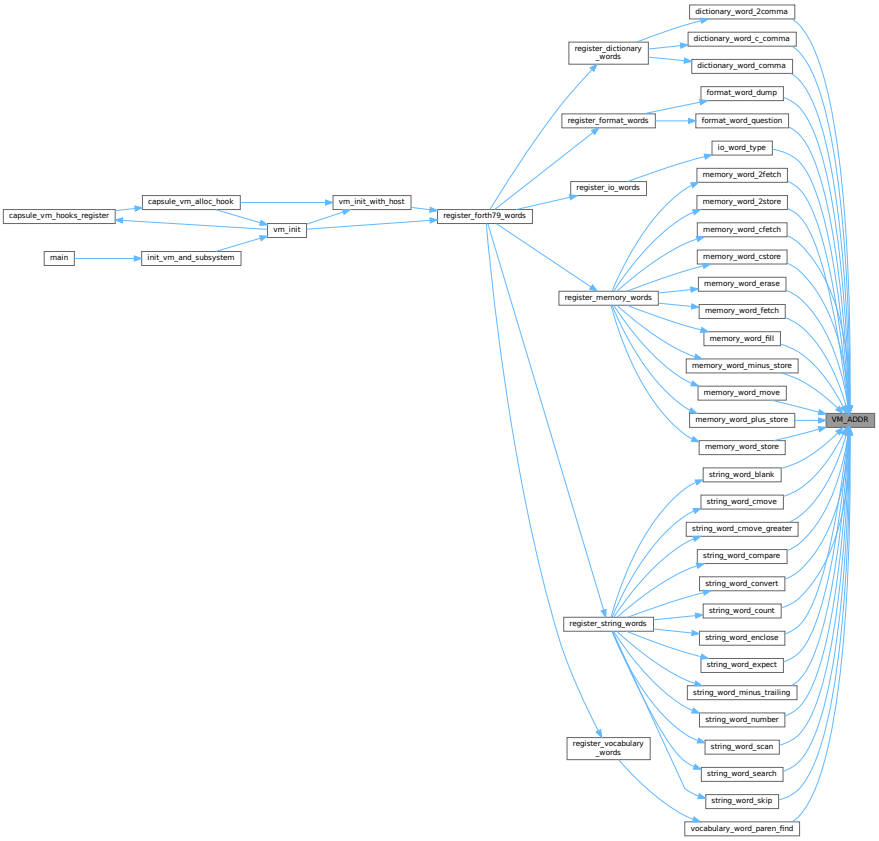
7.263.4.6 VM_ADDR()

```
static vaddr_t VM_ADDR (
            cell_t c )  [inline], [static]
```

Referenced by dictionary_word_2comma(), dictionary_word_c_comma(), dictionary_word_comma(), format_word_dump(), format_word_question(), io_word_type(), memory_word_2fetch(), memory_word_2store(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), string_word_blank(), string_word_cmove(),

string_word_cmove_greater(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_minus_trailing(), string_word_number(), string_word_scan(), string_word_search(), string_word_skip(), and vocabulary_word_paren_find().

Here is the caller graph for this function:



7.263.4.7 vm_addr_ok()

```
int vm_addr_ok (
            struct VM * vm,
            vaddr_t addr,
            size_t len )
```

Validate that a VM address range lies within `vm->memory`.

Checks that [addr, addr+len) is fully contained within the `VM_MEMORY_SIZE`-byte flat address space. The check is done with unsigned arithmetic to avoid UB on overflow: if `len` alone exceeds `VM_MEMORY_SIZE` the range is immediately rejected.

Parameters

vm	VM instance; returns 0 if NULL or memory not allocated.
addr	Start of the range (inclusive).
len	Number of bytes in the range.

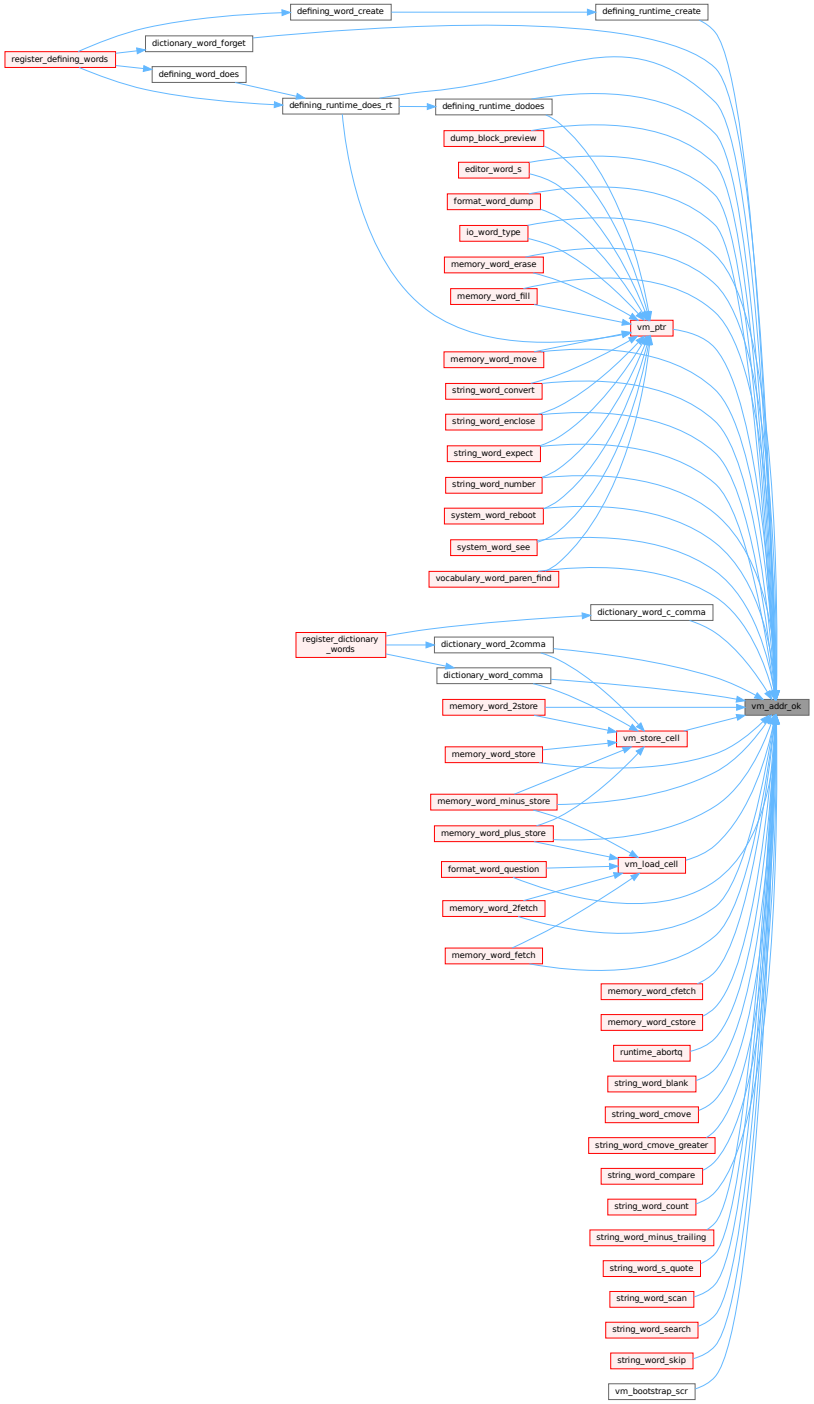
Returns

1 if the full range [addr, addr+len) is in bounds; 0 otherwise.

References VM::memory, and VM_MEMORY_SIZE.

Referenced by defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_does_rt(), dictionary_word_2comma(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_forget(), dump_block_preview(), editor_word_s(), format_word_dump(), format_word_question(), io_word_type(), memory_word_2fetch(), memory_word_2store(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), runtime_abortq(), string_word_blank(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_minus_trailing(), string_word_number(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), system_word_reboot(), system_word_see(), vm_bootstrap_scr(), vm_load_cell(), vm_ptr(), vm_store_cell(), and vocabulary_word_paren_find().

Here is the caller graph for this function:



7.263.4.8 vm_addr_to_block()

```
int vm_addr_to_block (
            VM * vm,
            void * addr )
```

Converts a memory address to its corresponding block number.

Parameters

vm	Pointer to the VM instance
addr	Memory address to convert

Returns

Block number (0 to MAX_BLOCKS-1) or -1 if address is outside VM memory

Note

Used for determining which block a memory address belongs to

References BLOCK_SIZE, VM::memory, and VM_MEMORY_SIZE.

7.263.4.9 vm_align()

```
void vm_align (
            VM * vm )
```

Aligns the VM's dictionary pointer (here) to the cell boundary.

Parameters

vm	Pointer to the VM instance

Note

Adds padding bytes if necessary to ensure proper alignment for cell_t type

7.263.4.10 vm_allot()

```
void * vm_allot (
            VM * vm,
            size_t bytes )
```

Allocates memory from the VM's dictionary space.

Parameters

vm	Pointer to the VM instance
bytes	Number of bytes to allocate

Returns

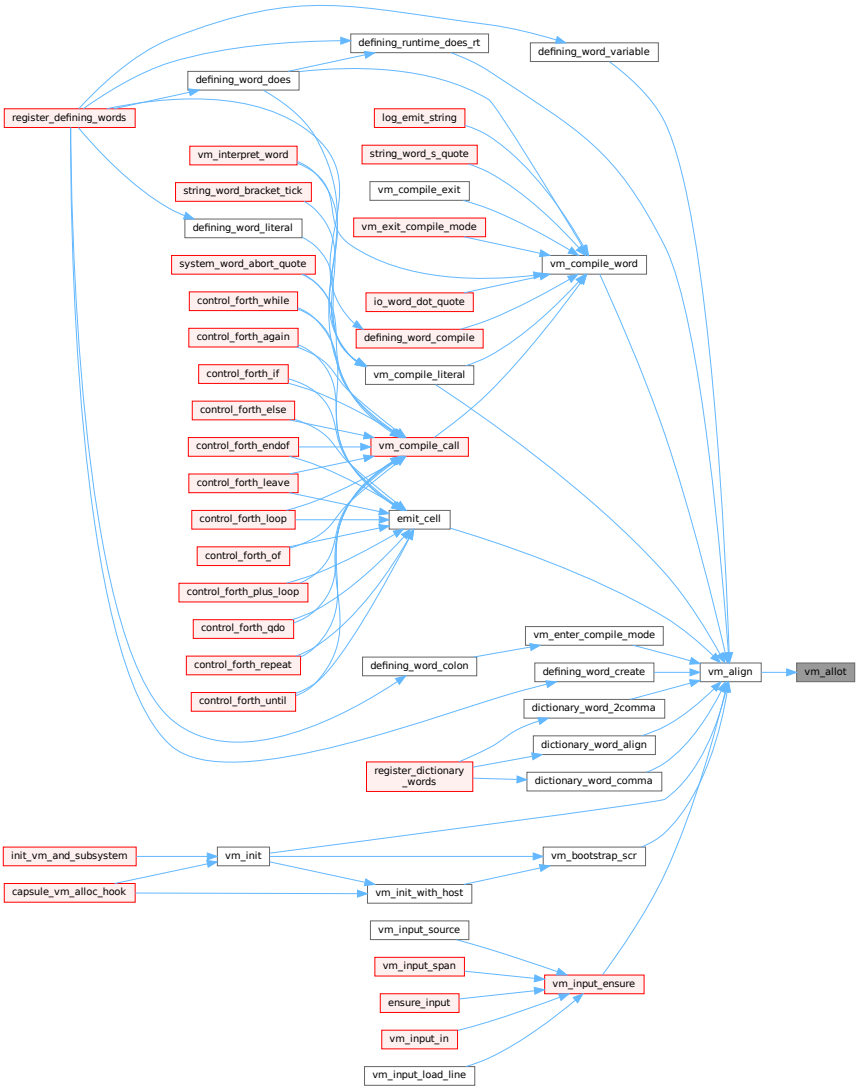
Pointer to the allocated memory or NULL if allocation fails

Note

The allocation is done from the VM's dictionary space which is limited to DICTIONARY_MEMORY_SIZE

Referenced by vm_align().

Here is the caller graph for this function:



7.263.4.11 vm_bootstrap_root_vocabulary()

```
void vm_bootstrap_root_vocabulary (
            VM * vm,
            const char * name )
```

Bootstrap a root vocabulary for the VM.

Creates a vocabulary by name, finds its dictionary entry, executes it to make it current, then calls DEFINITIONS.

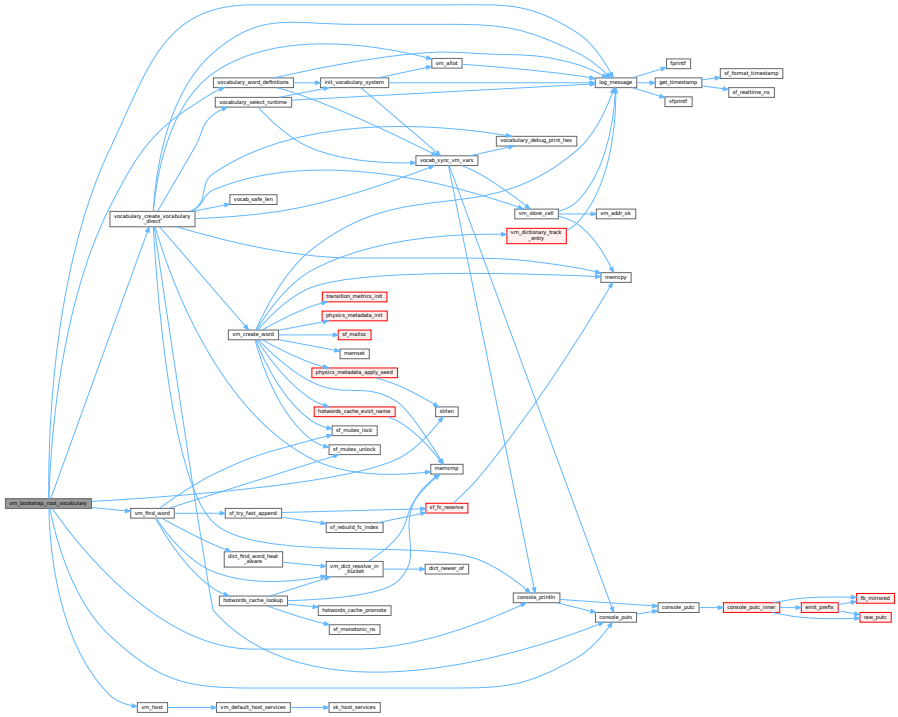
Parameters

vm	Pointer to VM structure
name	Vocabulary name to bootstrap

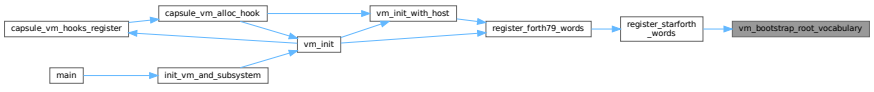
References console_println(), console_puts(), entry, VM::error, VMHostServices::is_executable_ptr, LOG_ERROR, log_message(), name, VMHostServices::panic, strlen(), vm_find_word(), vm_host(), vocabulary_create_vocabulary_direct(), and vocabulary_word_definitions().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.12 vm_cleanup()

```
void vm_cleanup (
            VM * vm )
```

Clean up and free VM resources.

Frees allocated memory and resets VM state.

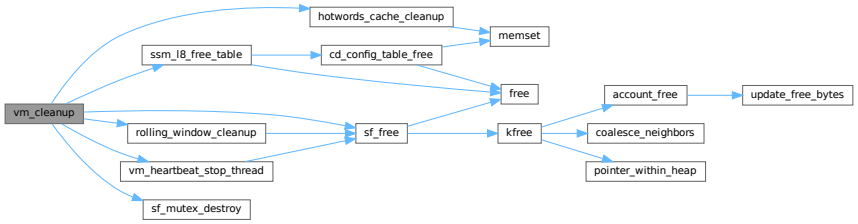
Parameters

vm	Pointer to VM structure to clean up

References VM::dict_lock, VM::here, VM::hotwords_cache, hotwords_cache_cleanup(), VM::latest, DictEntry::link, VM::memory, VM::rolling_window, rolling_window_cleanup(), sf_free(), sf_mutex_destroy(), VM::ssm_config, ssm_l8_free_table(), VM::ssm_l8_state, DictEntry::transition_metrics, VM::tuning_lock, and vm_heartbeat_stop_thread().

Referenced by capsule_vm_alloc_hook(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_vm_kill_all_nonmama(), and cleanup_and_exit().

Here is the call graph for this function:



Here is the caller graph for this function:

7.263.4.13 vm_compile_call()

```
void vm_compile_call (
            VM * vm,
            word_func_t func )
```

Compile a call to a word identified by its C function pointer.

Looks up the `DictEntry` whose `func` field matches `func` via `vm_dictionary_find_by_func()`, then delegates to `vm_compile_word()`. Used by generating words (e.g., `DOES>`) that need to embed a specific runtime routine into a compiled definition without knowing its name.

Sets `vm->error` if not in compile mode or if no matching entry is found.

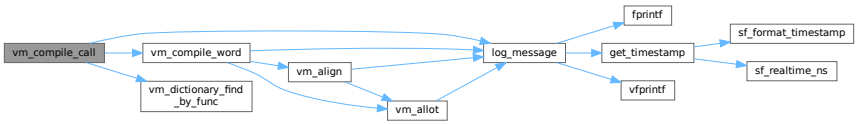
Parameters

vm	VM instance in compile mode.
func	C function pointer identifying the word to compile.

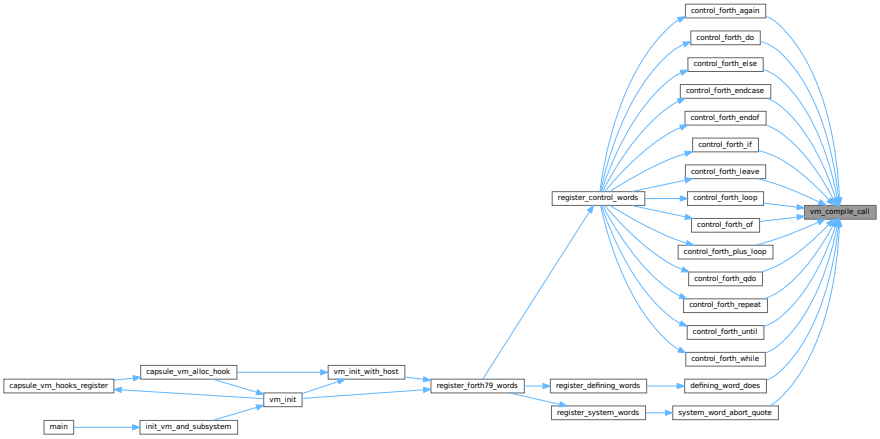
References entry, VM::error, func, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_compile_word(), and vm_dictionary_find_by_func().

Referenced by control_forth_again(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_if(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_until(), control_forth_while(), defining_word_does(), and system_word_abort_quote().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.14 vm_compile_exit()

```
void vm_compile_exit (
            VM * vm )
```

Compile an `EXIT` reference into the current threaded body.

Appends the `EXIT` word entry so that when the threaded body is executed, `execute_colon_word()` sets `vm->exit_colon` and unwinds the inner loop. Used by control-flow generating words (e.g., `IF` optimisation paths) that need an explicit early-return.

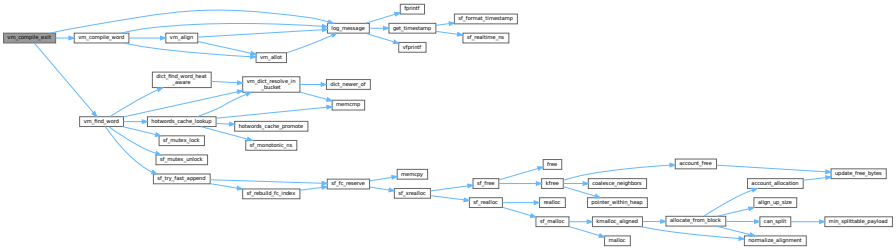
Sets `vm->error` if not in compile mode or if `EXIT` is not found.

Parameters

vm	VM instance in compile mode.

References VM::error, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_compile_word(), and vm_find_word().

Here is the call graph for this function:



7.263.4.15 vm_compile_literal()

```
void vm_compile_literal (
            VM * vm,
            cell_t value )
```

Compile a literal value into the current threaded body (or push it).

In compile mode, appends the `LIT` word reference followed by the literal value so the inner interpreter will push `value` at runtime. In interpret mode, pushes `value` directly onto the data stack.

Sets `vm->error` if `LIT` cannot be found in the dictionary.

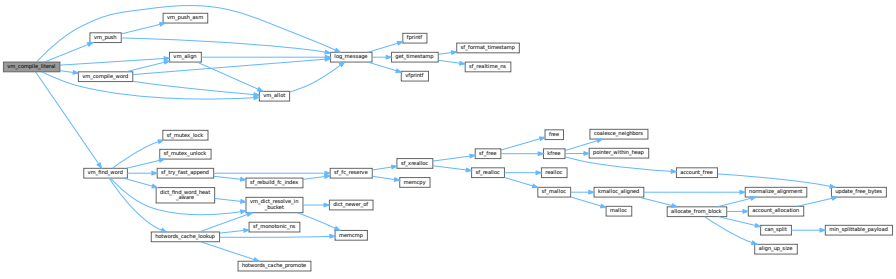
Parameters

vm	VM instance.
value	Cell value to compile or push.

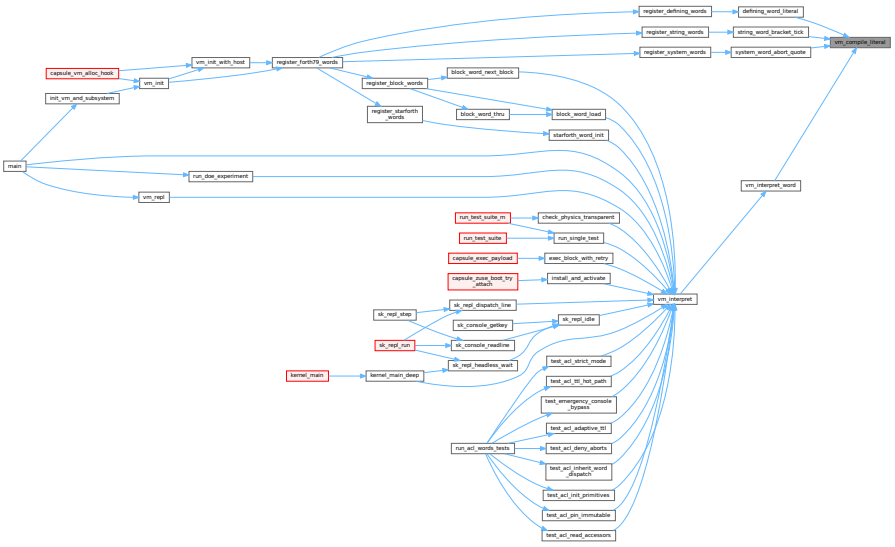
References VM::error, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_align(), vm_allot(), vm_compile_word(), vm_find_word(), and vm_push().

Referenced by defining_word_literal(), string_word_bracket_tick(), system_word_abort_quote(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.16 vm_compile_word()

```
void vm_compile_word (
            VM * vm,
            DictEntry * entry )
```

Append a word reference (DictEntry∗) to the current threaded body.

Aligns `HERE`, then allots one `cell_t` slot and stores the `DictEntry∗` as a cell. This is the fundamental compilation step used by the inner interpreter: each slot in the threaded body is a pointer to the `DictEntry` of the word to call.

Sets `vm->error` if the VM is not in compile mode, `entry` is NULL, or allotment fails.

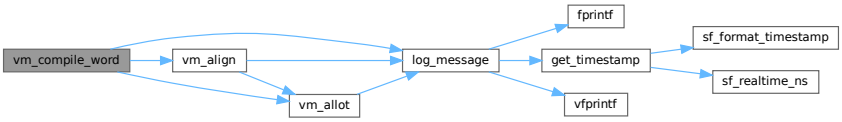
Parameters

vm	VM instance in compile mode.
entry	Dictionary entry of the word to compile; must not be NULL.

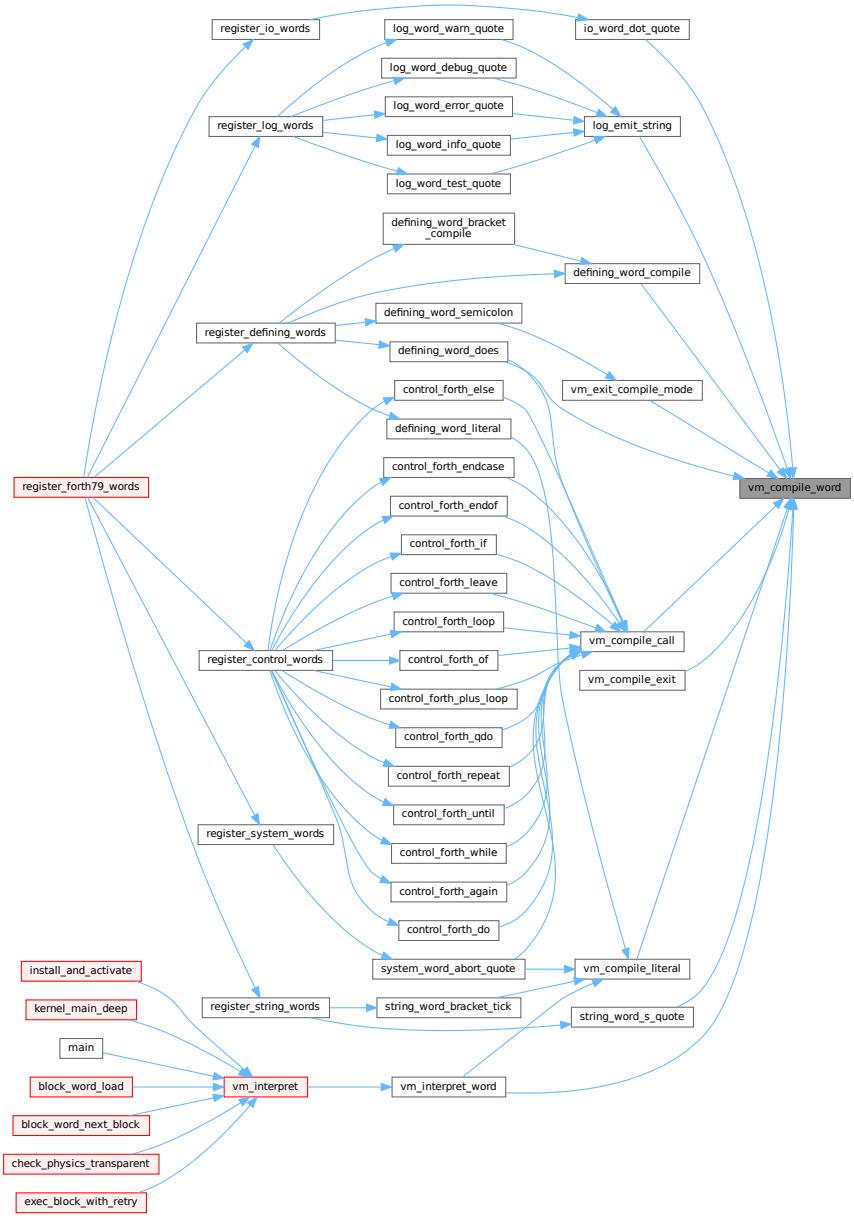
References entry, VM::error, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_align(), and vm_allot().

Referenced by defining_word_compile(), defining_word_does(), io_word_dot_quote(), log_emit_string(), string_word_s_quote(), vm_compile_call(), vm_compile_exit(), vm_compile_literal(), vm_exit_compile_mode(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.17 vm_create_word()

```
DictEntry * vm_create_word (
            VM * vm,
            const char * name,
            size_t len,
            word_func_t func )
```

Creates a new word in the dictionary.

Allocates and initializes a new dictionary entry with the given name and function. The word is added to the dictionary but index update is deferred until next lookup.

Parameters

vm	The virtual machine context
name	Name for the new word
len	Length of the name string
func	Function pointer for the word's behavior

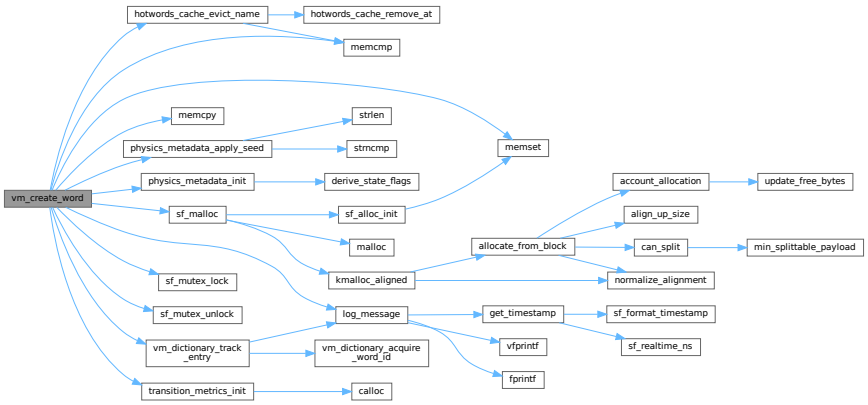
Returns

DictEntry* Pointer to new dictionary entry or NULL on failure

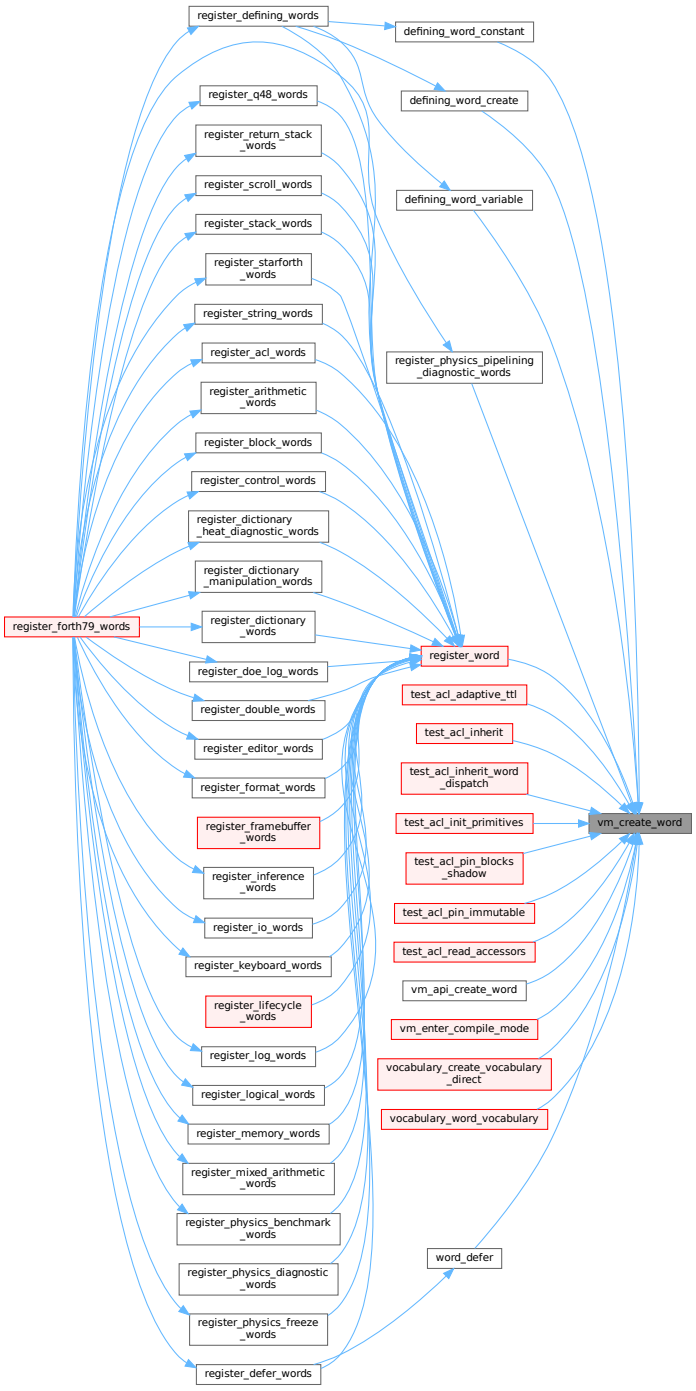
References ACL_MODE_TTL, ACL_USER_DEFAULT, base, VM::dict_lock, entry, VM::error, func, DictEntry::func, VM::hotwords_cache, hotwords_cache_evict_name(), VM::latest, LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, memcmp(), memcpy(), memset(), name, physics_metadata_apply_seed(), physics_metadata_init(), sf_malloc(), sf_mutex_lock(), sf_mutex_unlock(), transition_metrics_init(), vm_dictionary_track_entry(), WORD_ID_INVALID, and WORD_NAME_MAX.

Referenced by defining_word_constant(), defining_word_create(), defining_word_variable(), register_physics_pipelining_diagnostic_w register_word(), test_acl_adaptive_ttl(), test_acl_inherit(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_blocks_shadow(), test_acl_pin_immutable(), test_acl_read_accessors(), vm_api_create_word(), vm_enter_compile_mode(), vocabulary_create_vocabulary_direct(), vocabulary_word_vocabulary(), and word_defer().

Here is the call graph for this function:



Here is the caller graph for this function:



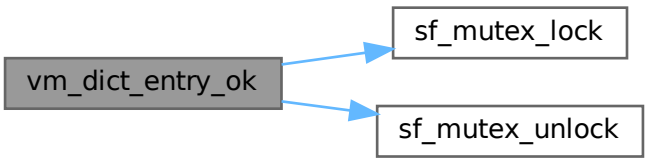
7.263.4.18 vm_dict_entry_ok()

```
int vm_dict_entry_ok (
            VM * vm,
            DictEntry * candidate )
```

References VM::dict_lock, VM::latest, sf_mutex_lock(), and sf_mutex_unlock().

Referenced by starforth_word_execution_heat_fetch(), starforth_word_execution_heat_store(), and system_word_execute().

Here is the call graph for this function:



Here is the caller graph for this function:

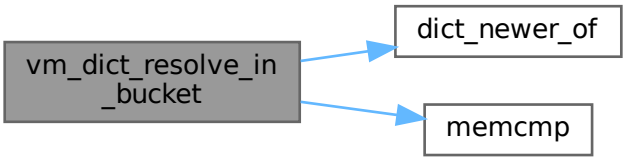
7.263.4.19 vm_dict_resolve_in_bucket()

```
DictEntry * vm_dict_resolve_in_bucket (
            VM * vm,
            DictEntry ** bucket,
            size_t n,
            const char * name,
            size_t len )
```

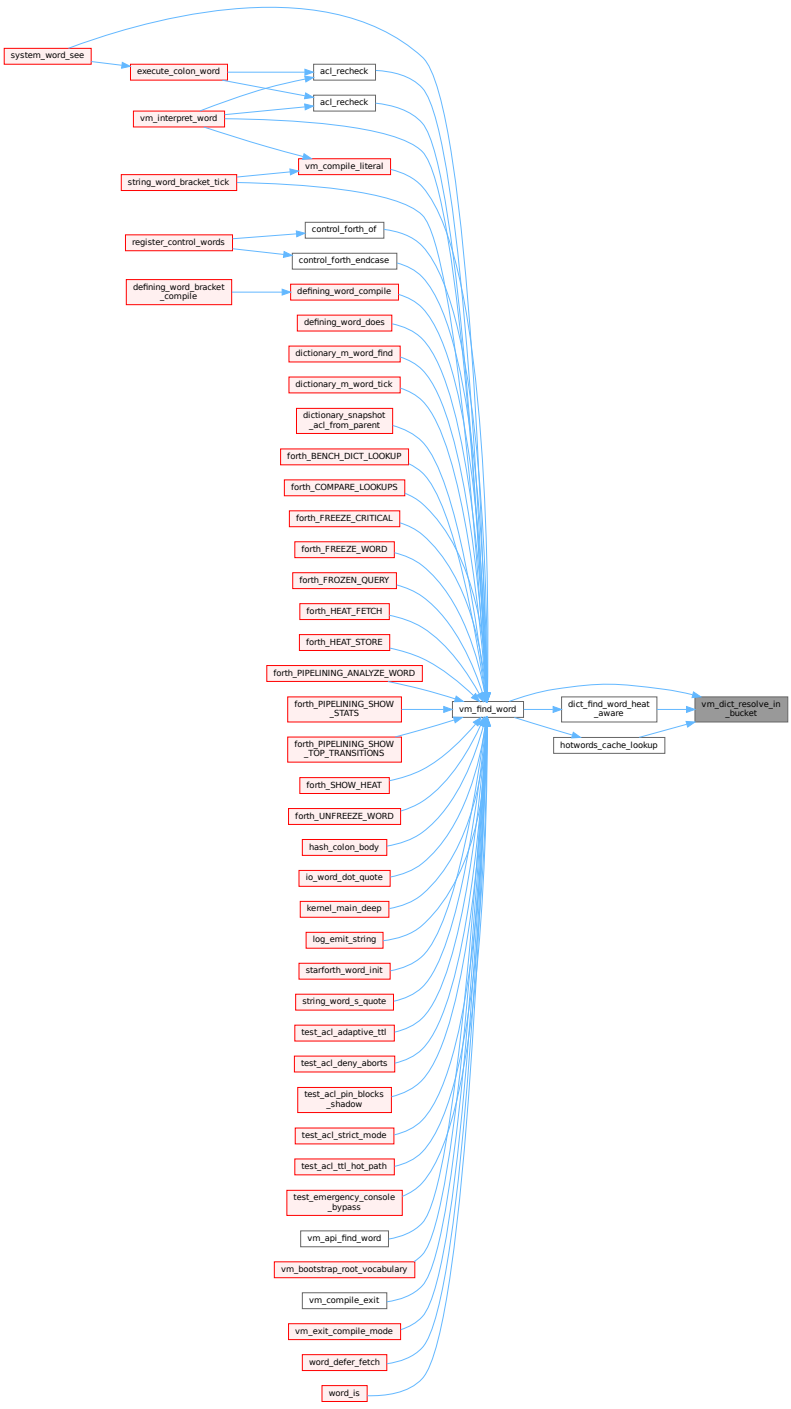
References dict_newer_of(), DictEntry::flags, memcmp(), name, DictEntry::name, DictEntry::name_len, UNLIKELY, WORD_HIDDEN, and WORD_SMUDGED.

Referenced by dict_find_word_heat_aware(), hotwords_cache_lookup(), and vm_find_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.20 vm_dictionary_find_by_func()

```
DictEntry * vm_dictionary_find_by_func (
            VM * vm,
            word_func_t func )
```

Finds a word by its function pointer.

Performs a linear scan of the dictionary to find an entry with matching function.

Parameters

vm	The virtual machine context
func	Function pointer to search for

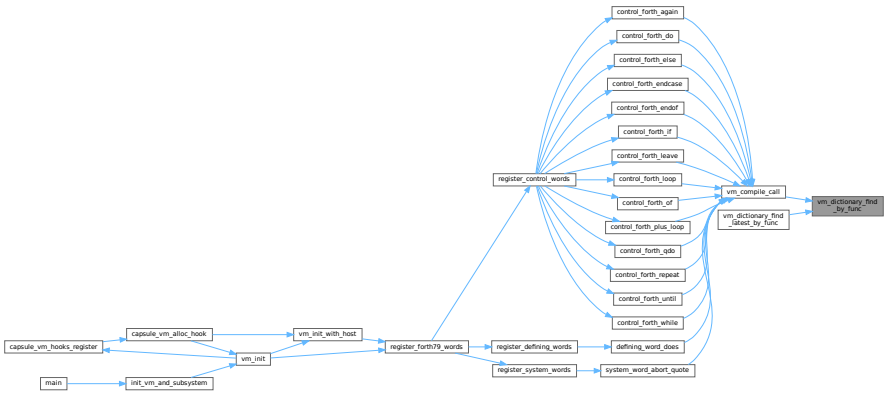
Returns

DictEntry* Pointer to found dictionary entry or NULL if not found

References func, and VM::latest.

Referenced by vm_compile_call(), and vm_dictionary_find_latest_by_func().

Here is the caller graph for this function:

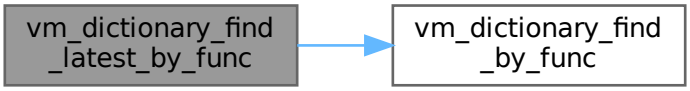


7.263.4.21 vm_dictionary_find_latest_by_func()

```
DictEntry * vm_dictionary_find_latest_by_func (
            VM * vm,
            word_func_t func )
```

References func, and vm_dictionary_find_by_func().

Here is the call graph for this function:



7.263.4.22 vm_dictionary_get_data_field()

```
cell_t * vm_dictionary_get_data_field (
            DictEntry * entry )
```

Gets pointer to a word's data field.

Calculates and returns pointer to the aligned data field following the name field.

Parameters

entry	Dictionary entry to get data field from

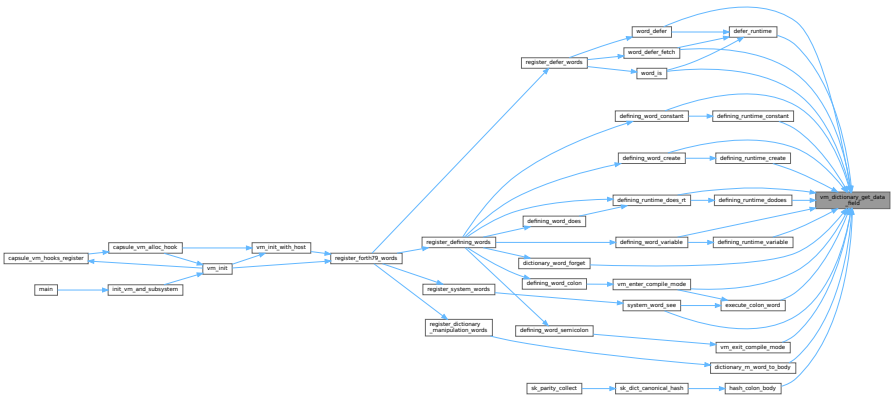
Returns

cell_t* Pointer to data field or NULL if entry is NULL

References base, entry, and name.

Referenced by defer_runtime(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_does_rt(), defining_runtime_variable(), defining_word_constant(), defining_word_create(), defining_word_variable(), dictionary_m_word_to_body(), dictionary_word_forget(), execute_colon_word(), hash_colon_body(), system_word_see(), vm_enter_compile_mode(), vm_exit_compile_mode(), word_defer(), word_defer_fetch(), and word_is().

Here is the caller graph for this function:



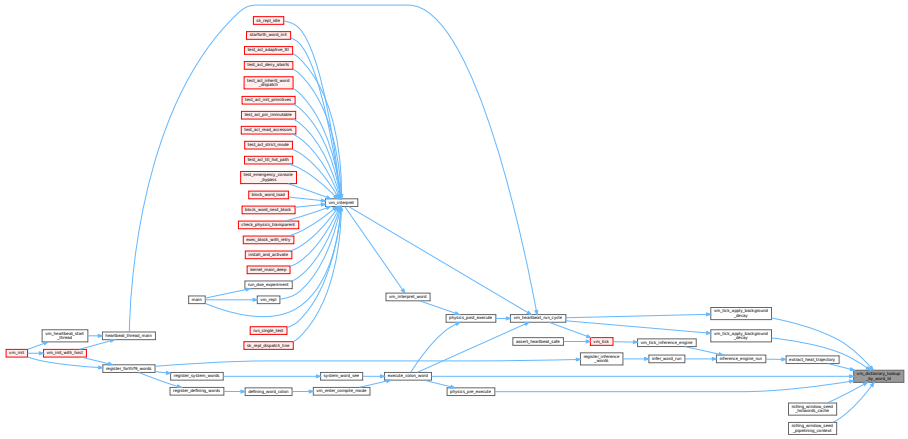
7.263.4.23 vm_dictionary_lookup_by_word_id()

```
DictEntry * vm_dictionary_lookup_by_word_id (
            VM * vm,
            uint32_t word_id )
```

References DICTIONARY_SIZE, word_id, and VM::word_id_map.

Referenced by execute_colon_word(), extract_heat_trajectory(), physics_pre_execute(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

Here is the caller graph for this function:



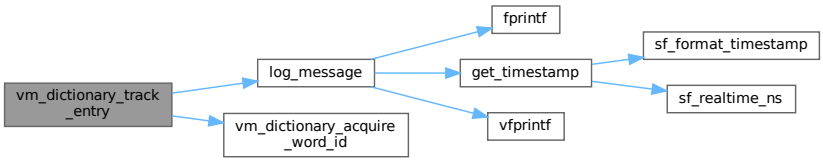
7.263.4.24 vm_dictionary_track_entry()

```
void vm_dictionary_track_entry (
            VM * vm,
            DictEntry * entry )
```

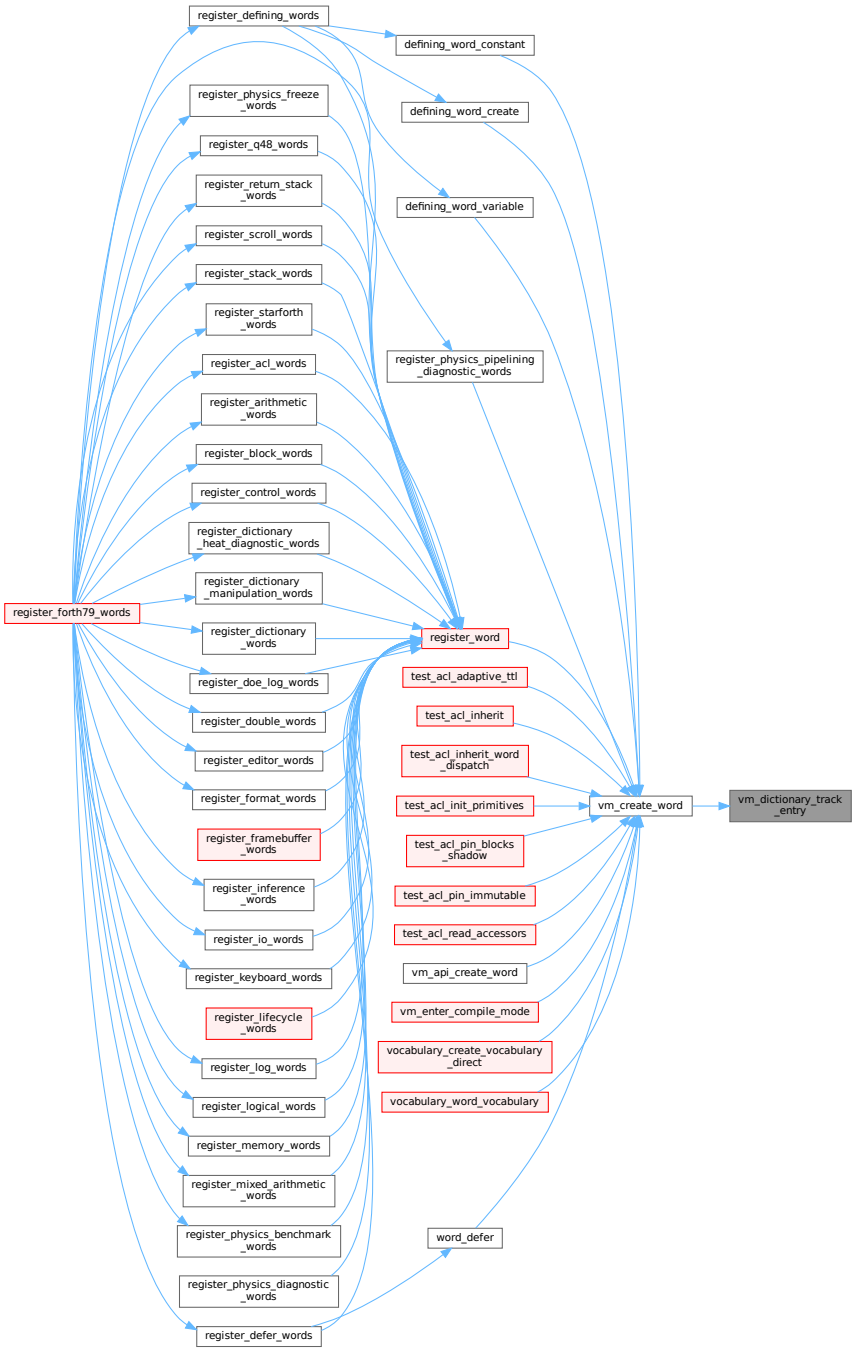
References DICTIONARY_SIZE, entry, log_message(), LOG_WARN, vm_dictionary_acquire_word_id(), word_id, WORD_ID_INVALID, and VM::word_id_map.

Referenced by vm_create_word().

Here is the call graph for this function:



Here is the caller graph for this function:



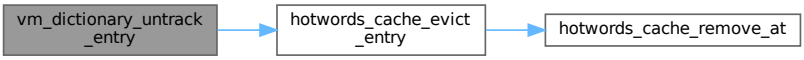
7.263.4.25 vm_dictionary_untrack_entry()

```
void vm_dictionary_untrack_entry (
            VM * vm,
            DictEntry * entry )
```

References DICTIONARY_SIZE, entry, VM::hotwords_cache, hotwords_cache_evict_entry(), VM::recycled_word_id_count, VM::recycled_word_ids, word_id, WORD_ID_INVALID, and VM::word_id_map.

Referenced by dictionary_word_forget().

Here is the call graph for this function:



Here is the caller graph for this function:

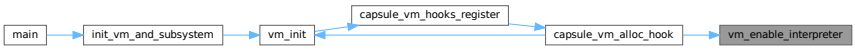
7.263.4.26 vm_enable_interpreter()

```
void vm_enable_interpreter (
            VM * vm )
```

References VM::interpreter_enabled.

Referenced by capsule_vm_alloc_hook().

Here is the caller graph for this function:



7.263.4.27 vm_enter_compile_mode()

```
void vm_enter_compile_mode (
            VM * vm,
            const char * name,
            size_t len )
```

Begin a colon definition and switch the VM to compile mode.

Creates a new dictionary entry for `name` via `vm_create_word()`, marks it `WORD_SMUDGED` so it is invisible to lookups during compilation, sets the VM mode to `MODE_COMPILE`, and writes the current `HERE` address into the entry's data field as the start of the threaded body.

The SMUDGE flag is cleared by `vm_exit_compile_mode()` when the semicolon is encountered.

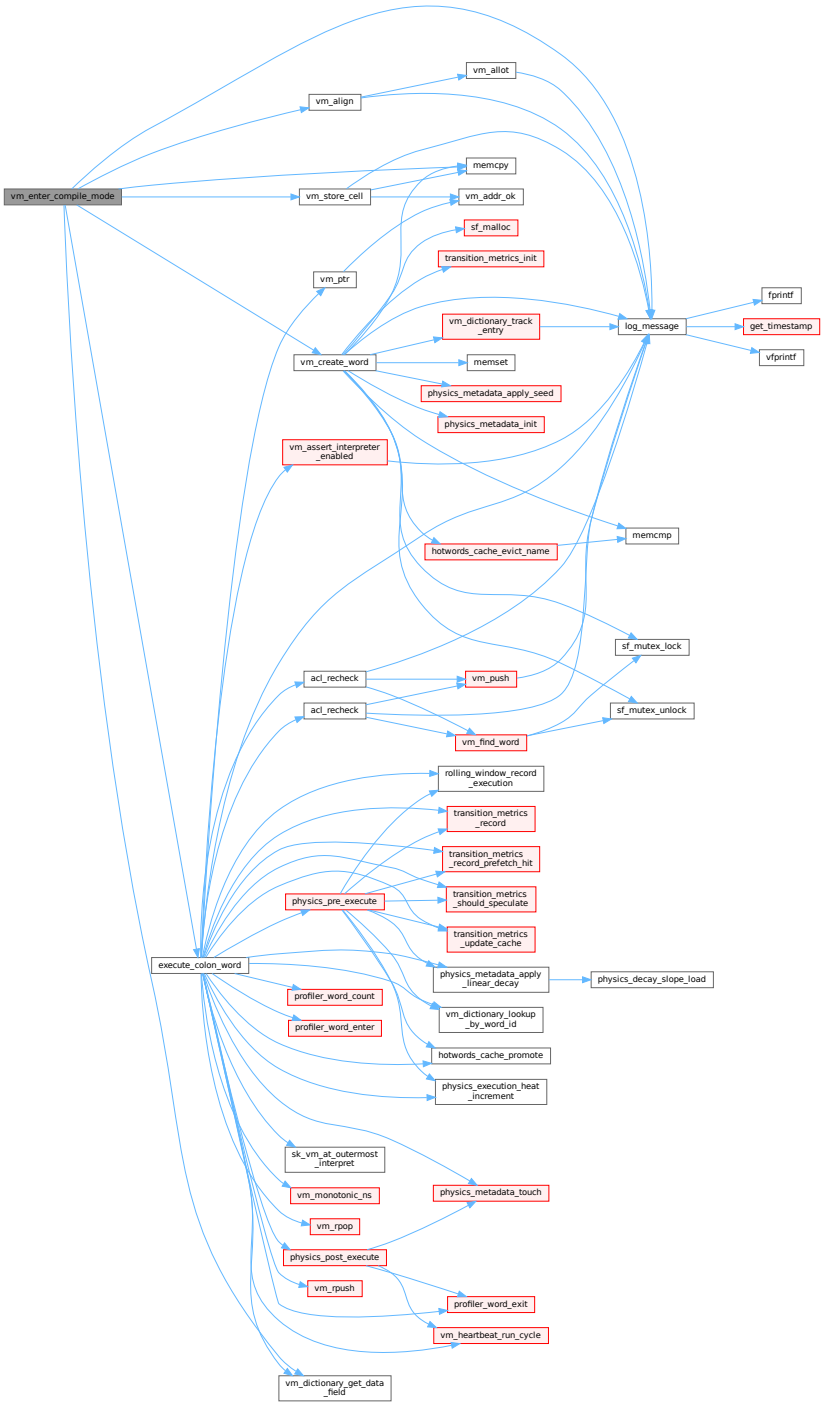
Parameters

vm	VM instance.
name	Word name string (does not need to be NUL-terminated).
len	Length of `name`; clamped to `WORD_NAME_MAX`.

References VM::compiling_word, VM::current_word_name, VM::error, execute_colon_word(), DictEntry::flags, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), memcpy(), VM::mode, MODE_COMPILE, name, VM::state_addr, VM::state_var, vm_align(), vm_create_word(), vm_dictionary_get_data_field(), vm_store_cell(), WORD_NAME_MAX, and WORD_SMUDGED.

Referenced by defining_word_colon().

Here is the call graph for this function:



Here is the caller graph for this function:

7.263.4.28 vm_exit_compile_mode()

```
void vm_exit_compile_mode (
            VM * vm )
```

Finalise a colon definition and return to interpret mode.

Appends a final `EXIT` reference, clears the `WORD_SMUDGED` flag so the new word becomes visible in the dictionary, and sets `WORD_COMPILED`. Also computes the word's mass (header + body bytes) for the physics engine and calls `physics_metadata_refresh_state()`.

Resets `vm->mode` to `MODE_INTERPRET`, clears `vm->state_var`, and NULLs `vm->compiling_word`.

Sets `vm->error` if `vm` has no active `compiling_word` or if `EXIT` cannot be found.

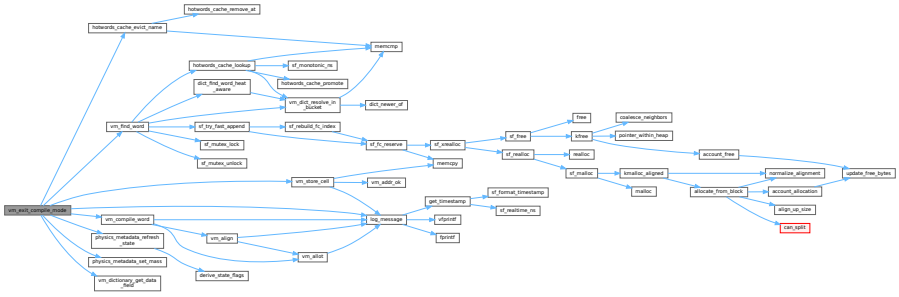
Parameters

vm	VM instance currently in compile mode.

References DictEntry::acl_allow, DictEntry::acl_ttl, ACL_TTL_OPEN, VM::compiling_word, VM::error, DictEntry::flags, VM::here, VM::hotwords_cache, hotwords_cache_evict_name(), LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_INTERPRET, DictEntry::name, DictEntry::name_len, physics_metadata_refresh_state(), physics_metadata_set_mass(), VM::state_addr, VM::state_var, vm_compile_word(), vm_dictionary_get_data_field(), vm_find_word(), vm_store_cell(), WORD_COMPILED, and VM::zuse_session.

Referenced by defining_word_semicolon().

Here is the call graph for this function:



Here is the caller graph for this function:

7.263.4.29 vm_find_word()

```
DictEntry * vm_find_word (
            VM * vm,
```

```
const char * name,
size_t len )
```

Finds a word in the dictionary by name.

Searches for a word in the dictionary using an optimized first-character index. The search is performed newest-first within the matching first-character bucket.

Parameters

vm	The virtual machine context
name	The name to search for
len	Length of the name string

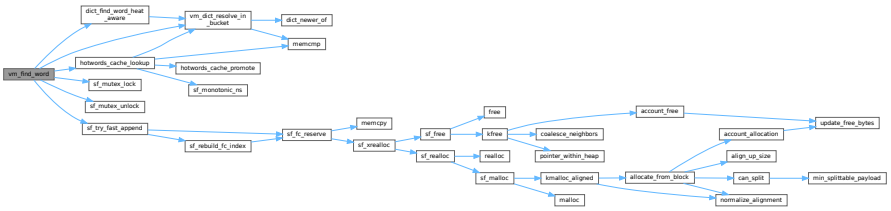
Returns

DictEntry* Pointer to found dictionary entry or NULL if not found

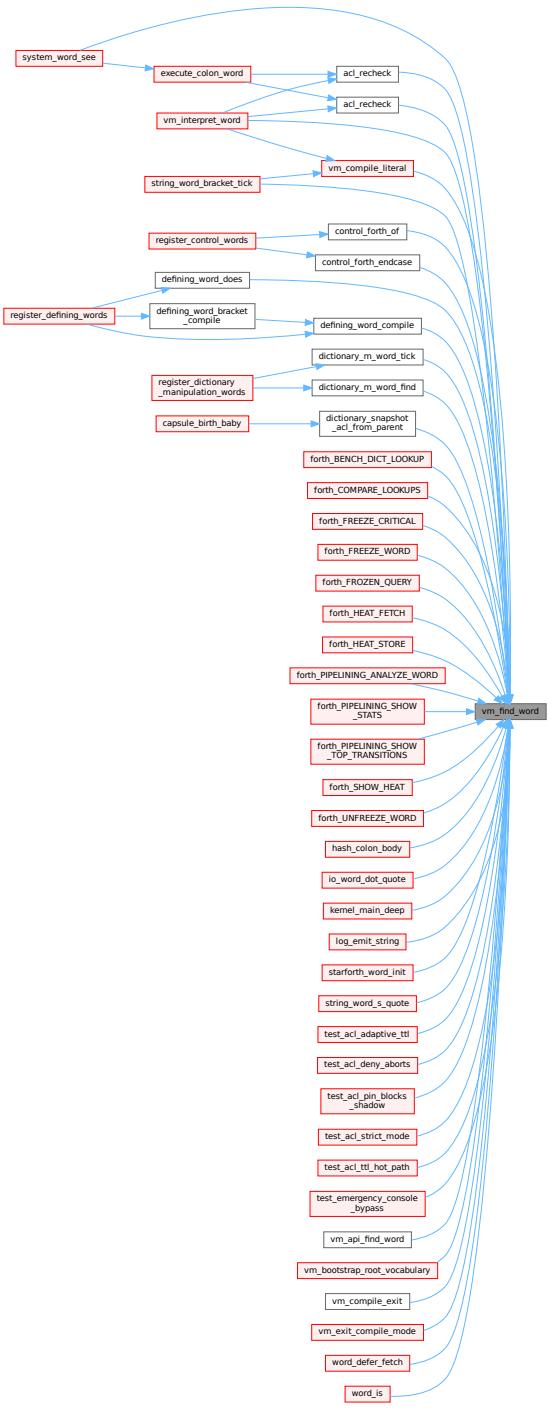
References dict_find_word_heat_aware(), VM::dict_lock, HeartbeatState::dictionary_lookups, VM::heartbeat, VM::hotwords_cache, hotwords_cache_lookup(), VM::latest, VM::lookup_strategy, name, sf_cached_latest, sf_fc_count, sf_fc_list, sf_mutex_lock(), sf_mutex_unlock(), sf_try_fast_append(), UNLIKELY, and vm_dict_resolve_in_bucket().

Referenced by acl_recheck(), acl_recheck(), control_forth_endcase(), control_forth_of(), defining_word_compile(), defining_word_does(), dictionary_m_word_find(), dictionary_m_word_tick(), dictionary_snapshot_acl_from_parent(), forth_BENCH_DICT_LOOKUP(), forth_COMPARE_LOOKUPS(), forth_FREEZE_CRITICAL(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_STORE(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), hash_colon_body(), io_word_dot_quote(), kernel_main_deep(), log_emit_string(), starforth_word_init(), string_word_bracket_tick(), string_word_s_quote(), system_word_see(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_pin_blocks_shadow(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_byp vm_api_find_word(), vm_bootstrap_root_vocabulary(), vm_compile_exit(), vm_compile_literal(), vm_exit_compile_mode(), vm_interpret_word(), word_defer_fetch(), and word_is().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.30 vm_get_base()

```
unsigned vm_get_base (
            const struct VM * vm )
```

7.263.4.31 vm_get_block_addr()

```
void * vm_get_block_addr (
            VM * vm,
            int block_num )
```

Gets the memory address for a specified block number.

Parameters

vm	Pointer to the VM instance
block_num	Block number to get the address for

Returns

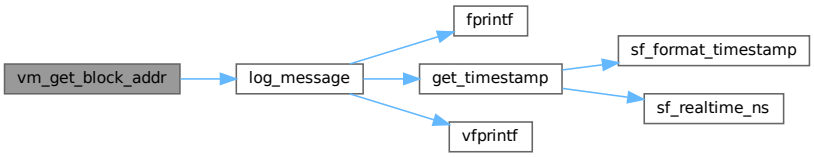
Pointer to the start of the block or NULL if block number is invalid

Note

Blocks are fixed-size memory regions of BLOCK_SIZE bytes

References BLOCK_SIZE, LOG_ERROR, log_message(), MAX_BLOCKS, and VM::memory.

Here is the call graph for this function:



7.263.4.32 vm_heartbeat_start()

```
void vm_heartbeat_start (
            VM * vm )
```

7.263.4.33 vm_hide_word()

```
void vm_hide_word (
            VM * vm )
```

Marks the latest word as hidden.

Sets the WORD_HIDDEN flag on the most recently defined word.

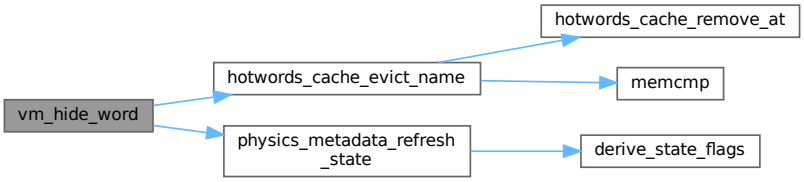
Parameters

vm	The virtual machine context

References DictEntry::flags, VM::hotwords_cache, hotwords_cache_evict_name(), VM::latest, DictEntry::name, DictEntry::name_len, physics_metadata_refresh_state(), and WORD_HIDDEN.

Referenced by vm_api_hide_word().

Here is the call graph for this function:



Here is the caller graph for this function:

7.263.4.34 vm_init()

```
void vm_init (
            VM * vm )
```

Initialize a new virtual machine instance.

Allocates memory and initializes all VM structures including:

- Memory array
- Data and return stacks
- System variables (SCR, STATE, BASE)
- Dictionary
- Forth-79 wordset

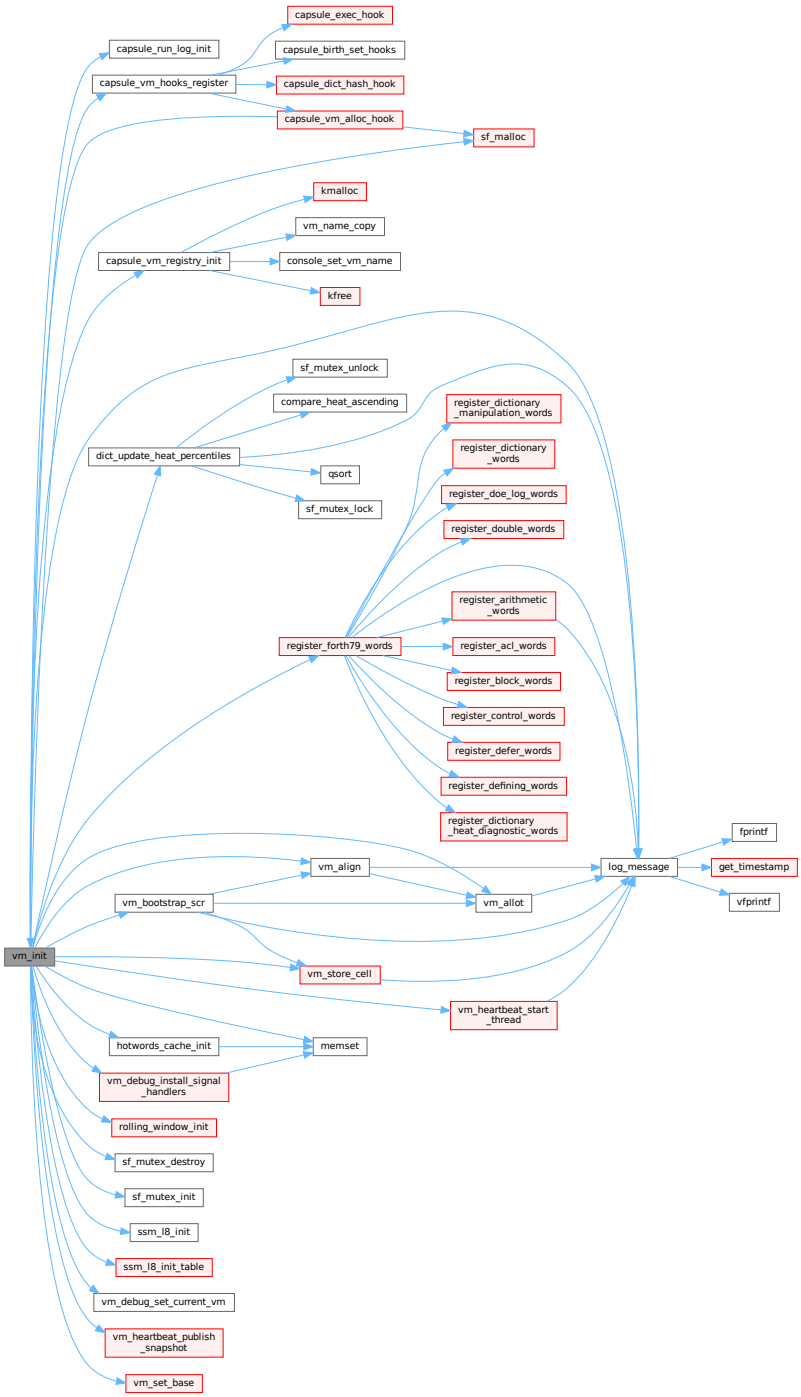
Parameters

vm	Pointer to VM structure to initialize

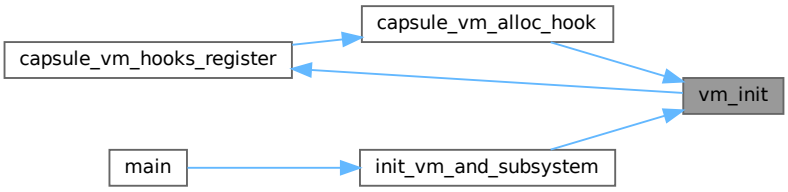
References VM::abort_requested, VM::base_addr, capsule_run_log_init(), capsule_vm_hooks_register(), capsule_vm_registry_init(), VM::cf, ControlFlowState::cf_last_mode, ControlFlowState::cf_sp, HeartbeatState::check_counter, VM::compiling_word, VM::current_executing_entry, VM::decay_slope_direction, VM::decay_slope_q48, VM::dict_fence_here, VM::dict_fence_latest, VM::dict_lock, dict_update_heat_percentiles(), VM::dsp, RollingWindowOfTruth::effective_window_size, ControlFlowState::endof_mark_sp, ControlFlowState::endof_sp, VM::error, VM::exit_colon, VM::halted, VM::heartbeat, VM::heartbeat_decay_cursor_id, HeartbeatState::heartbeat_enabled, HEARTBEAT_TICK_NS, VM::here, VM::hold_addr, VM::hold_pos, VM::hotwords_cache, hotwords_cache_init(), VM::input_length, VM::input_pos, VM::last_bucket_reorg_ns, PipelineGlobalMetrics::last_checked_accuracy, PipelineGlobalMetrics::last_checked_window_size, VM::last_decay_check_ns, HeartbeatState::last_inference_tick, VM::latest, ControlFlowState::leave_mark_sp, ControlFlowState::leave_sp, LOG_ERROR, log_message(), VM::lookup_strategy, VM::memory, memset(), VM::mode, MODE_INTERPRET, VM::next_word_id, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::recycled_word_id_count, register_forth79_words(), VM::rolling_window, rolling_window_init(), VM::rsp, VM::scr_addr, sf_malloc(), sf_mutex_destroy(), sf_mutex_init(), HeartbeatState::snapshot_index, VM::ssm_config, ssm_l8_init(), ssm_l8_init_table(), VM::ssm_l8_state, SSM_MODE_C0, VM::stale_word_count_at_check, VM::state_addr, VM::state_var, PipelineGlobalMetrics::suggested_next_size, HeartbeatState::tick_count, HeartbeatState::tick_target_ns, VM::total_heat_at_last_check, VM::tuning_lock, vm_align(), vm_allot(), vm_bootstrap_scr(), vm_debug_install_signal_handlers(), vm_debug_set_current_vm(), vm_heartbeat_publish_snapshot(), vm_heartbeat_start_thread(), VM_MEMORY_SIZE, vm_set_base(), vm_store_cell(), PipelineGlobalMetrics::window_tuning_checks, WORD_ID_INVALID, and HeartbeatState::worker.

Referenced by capsule_vm_alloc_hook(), and init_vm_and_subsystem().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.35 vm_init_with_host()

```
void vm_init_with_host (
            VM * vm,
            const VMHostServices * host )
```

Initialize VM with explicit host services.

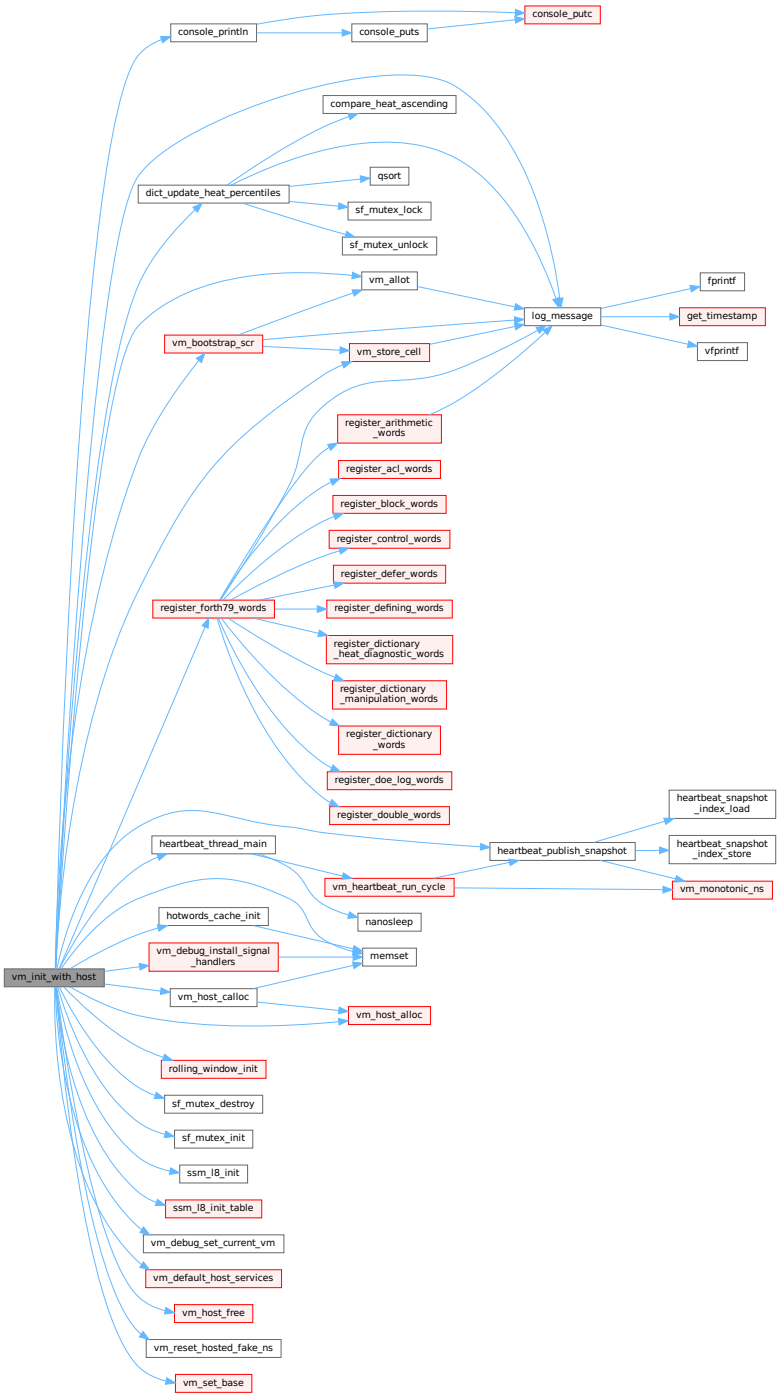
Parameters

vm	Pointer to VM structure to initialize
host	Host services (allocator/time). If NULL, uses build default.

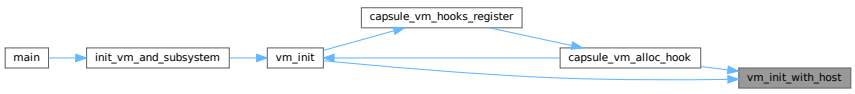
References VM::abort_requested, VM::base_addr, VM::cf, ControlFlowState::cf_last_mode, ControlFlowState::cf_sp, HeartbeatState::check_counter, VM::compiling_word, console_println(), VM::current_executing_entry, VM::decay_slope_direction, VM::decay_slope_q48, VM::dict_fence_here, VM::dict_fence_latest, VM::dict_lock, dict_update_heat_percentiles(), VM::dsp, RollingWindowOfTruth::effective_window_size, ControlFlowState::endof_mark_sp, ControlFlowState::endof_sp, errno, VM::error, VM::exit_colon, VM::halted, VM::heartbeat, VM::heartbeat_decay_cursor_id, HeartbeatState::heartbeat_enabled, heartbeat_publish_snapshot(), heartbeat_thread_main(), HEARTBEAT_TICK_NS, VM::here, VM::hold_addr, VM::hold_pos, VM::host, VM::hotwords_cache, hotwords_cache_init(), VM::input_length, VM::input_pos, VM::interpreter_enabled, VM::last_bucket_reorg_ns, PipelineGlobalMetrics::last_checked_accuracy, PipelineGlobalMetrics::last_chec VM::last_decay_check_ns, HeartbeatState::last_inference_tick, VM::latest, ControlFlowState::leave_mark_sp, ControlFlowState::leave_sp, LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, VM::lookup_strategy, VM::memory, memset(), VM::mode, MODE_INTERPRET, VM::next_word_id, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_ PipelineGlobalMetrics::prefetch_hits, VM::recycled_word_id_count, register_forth79_words(), VM::rolling_window, rolling_window_init(), VM::rsp, sf_mutex_destroy(), sf_mutex_init(), HeartbeatState::snapshot_index, VM::ssm_config, ssm_l8_init(), ssm_l8_init_table(), VM::ssm_l8_state, SSM_MODE_C0, VM::stale_word_count_at_check, VM::state_addr, VM::state_var, PipelineGlobalMetrics::suggested_next_size, HeartbeatState::tick_count, HeartbeatWorker::tick_ns, HeartbeatState::tick_target_ns, VM::total_heat_at_last_check, VM::tuning_lock, vm_allot(), vm_bootstrap_scr(), vm_debug_install_signal_handlers(), vm_debug_set_current_vm(), vm_default_host_services(), vm_host_alloc(), vm_host_calloc(), vm_host_free(), VM_MEMORY_SIZE, vm_reset_hosted_fake_ns(), vm_set_base(), vm_store_cell(), PipelineGlobalMetrics::window_tuning_checks, WORD_ID_INVALID, and HeartbeatState::worker.

Referenced by capsule_vm_alloc_hook(), and vm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



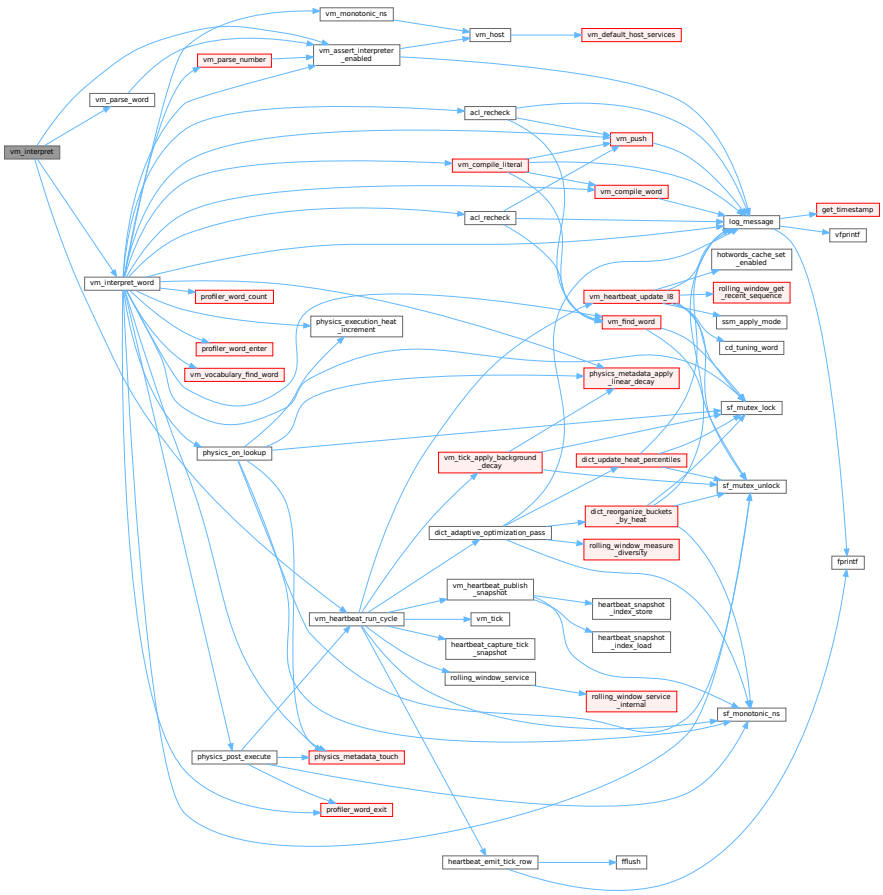
7.263.4.36 vm_interpret()

```
void vm_interpret (
            VM * vm,
            const char * input )
```

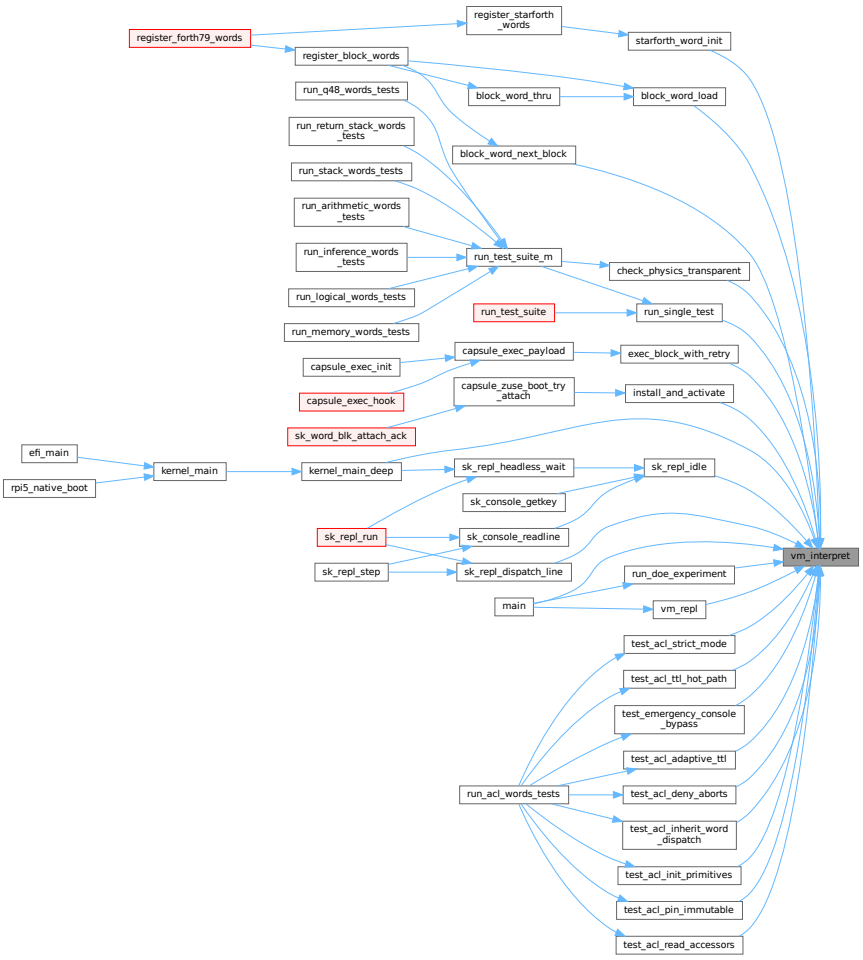
References VM::abort_requested, HeartbeatState::check_counter, VM::error, g_log_attrib_vm, g_vm_interpret_depth, g_vm_interpret_depth, VM::heartbeat, HEARTBEAT_CHECK_FREQUENCY, VM::input_buffer, INPUT_BUFFER_SIZE, VM::input_length, VM::input_pos, vm_assert_interpreter_enabled(), vm_heartbeat_run_cycle(), vm_interpret_word(), vm_parse_word(), and HeartbeatState::worker.

Referenced by block_word_load(), block_word_next_block(), check_physics_transparent(), exec_block_with_retry(), install_and_activate(), kernel_main_deep(), main(), run_doe_experiment(), run_single_test(), sk_repl_dispatch_line(), sk_repl_idle(), starforth_word_init(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_bypass(), and vm_repl().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.37 vm_interpret_word()

```
void vm_interpret_word (
            VM * vm,
            const char * word_str,
            size_t len )
```

Interpret or compile a single word token.

This is the outer interpreter's per-token dispatch:

1. **Dictionary lookup**: vocabulary-aware search, falling back to the canonical flat dictionary. Physics heat is recorded via `physics_on_lookup()`.
2. **Compile mode, non-immediate**: append the entry to the current threaded body via `vm_compile_word()`.
3. **Interpret mode, or immediate in compile mode**: ACL check (hot-path TTL decrement / cold-path `acl_recheck()`), then call `entry->func()`.
4. **Number literal**: if no dictionary match, attempt `vm_parse_number()`. In compile mode, compile as a literal; in interpret mode, push directly.
5. **Error**: unknown token — sets `vm->error`.

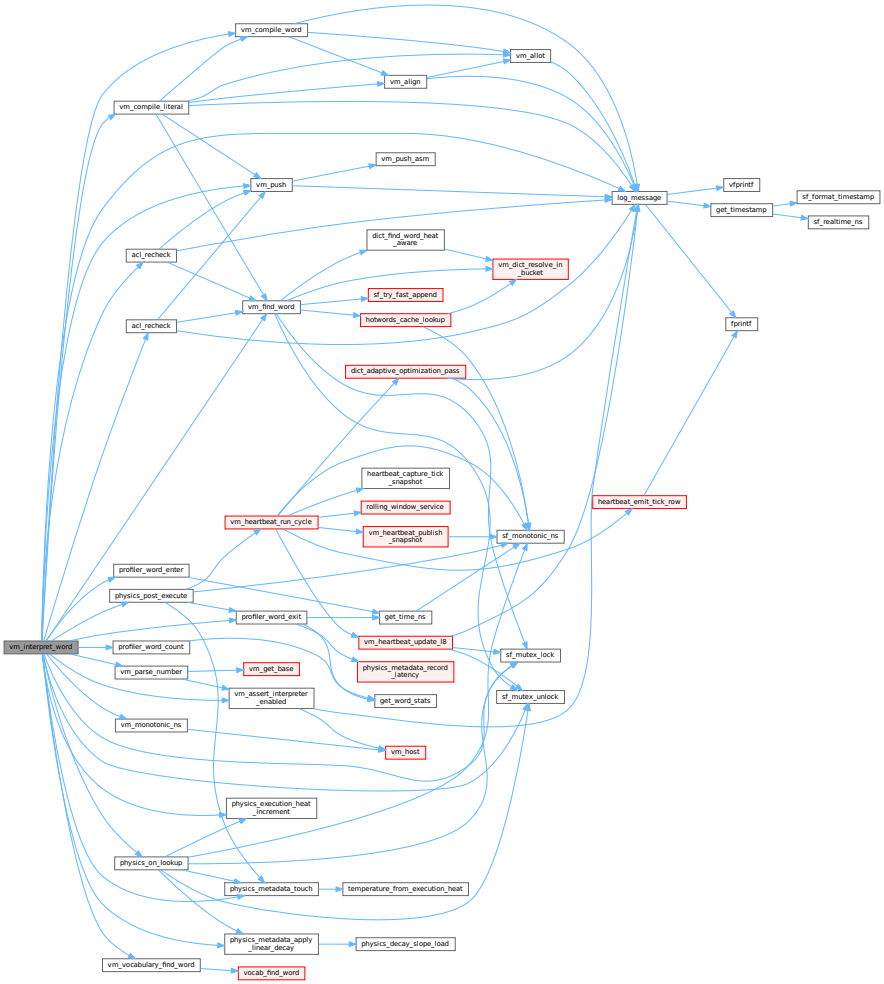
Parameters

vm	VM instance.
word_str	Token string (need not be NUL-terminated).
len	Length of `word_str` in bytes.

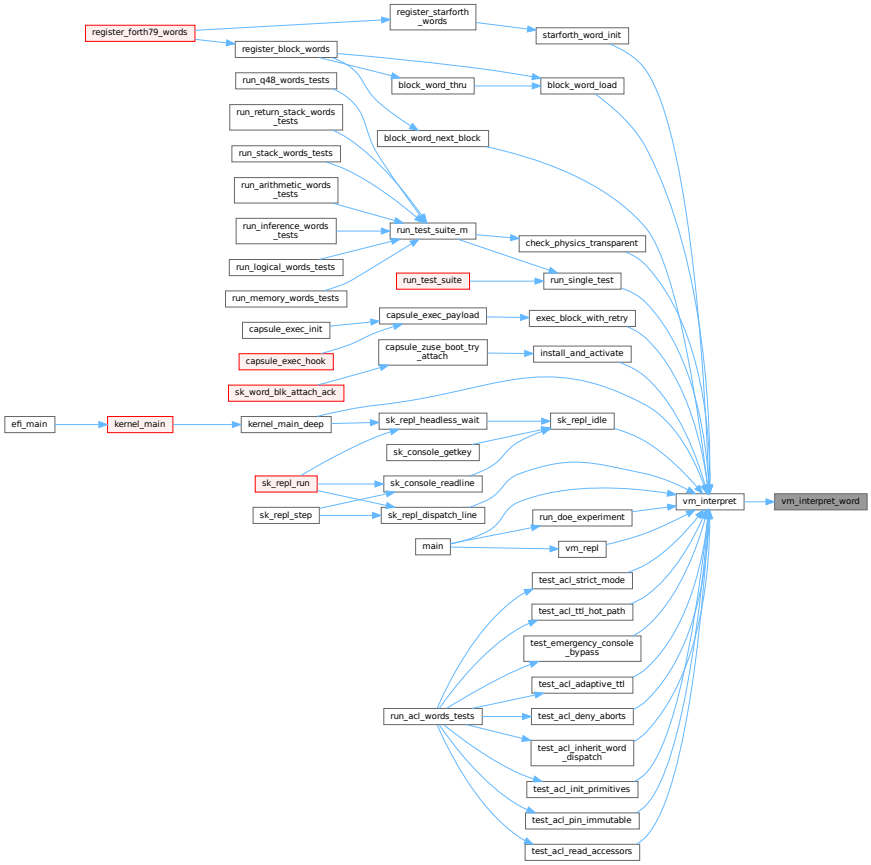
References acl_recheck(), acl_recheck(), VM::current_executing_entry, VM::dict_lock, VM::dsp, VM::emergency_console, entry, VM::error, DictEntry::execution_heat, DictEntry::flags, g_sk_fault_word, VM::heartbeat, DictPhysics::last_active_ns, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, VM::mode, MODE_COMPILE, name, DictEntry::physics, physics_execution_heat_increment(), physics_metadata_apply_linear_decay(), physics_metadata_touch(), physics_on_lookup(), physics_post_execute(), profiler_word_count(), profiler_word_enter(), profiler_word_exit(), VM::rsp, sf_mutex_lock(), sf_mutex_unlock(), HeartbeatState::tick_count, vm_assert_interpreter_enabled(), vm_compile_literal(), vm_compile_word(), vm_find_word(), vm_monotonic_ns(), vm_parse_number(), vm_push(), vm_vocabulary_find_word(), DictEntry::word_id, WORD_IMMEDIATE, and HeartbeatState::words_executed.

Referenced by vm_interpret().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.38 vm_load_cell()

```
cell_t vm_load_cell (
            struct VM * vm,
            vaddr_t addr )
```

Load an aligned cell from VM memory.

Validates that `addr` is within bounds for a full `cell_t` read and that it is naturally aligned (addr % sizeof(cell_t) == 0). Uses `memcpy()` rather than a direct pointer dereference to avoid strict aliasing and alignment UB. Sets `vm->error` and returns 0 on failure.

Parameters

vm	VM instance.
addr	Aligned VM byte offset to read.

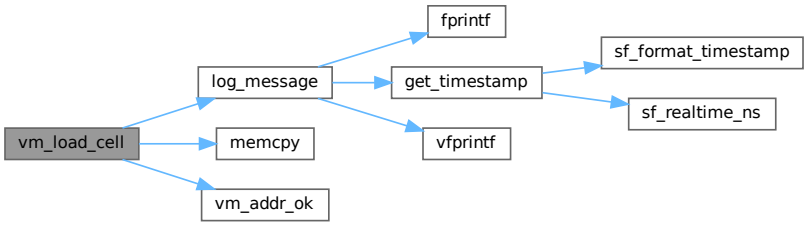
Returns

Cell value at `addr`, or 0 on alignment or bounds error.

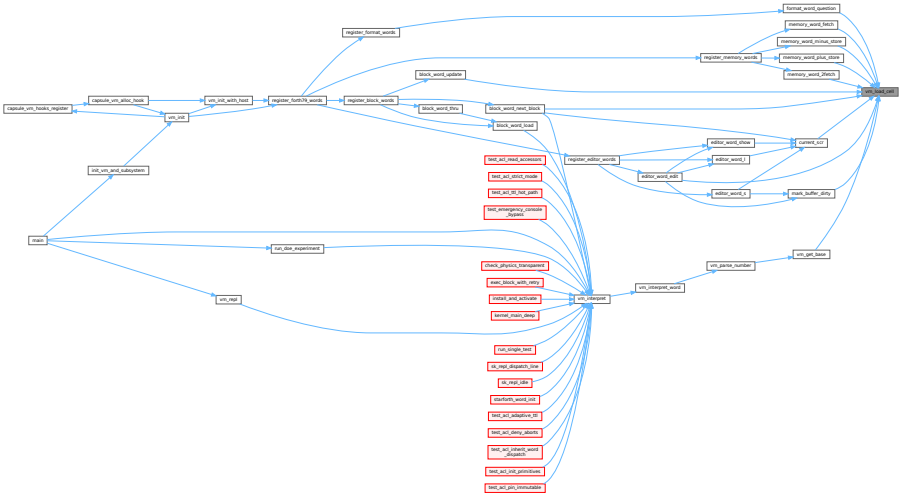
References VM::error, LOG_ERROR, log_message(), memcpy(), VM::memory, and vm_addr_ok().

Referenced by block_word_next_block(), block_word_update(), current_scr(), editor_word_edit(), format_word_question(), mark_buffer_dirty(), memory_word_2fetch(), memory_word_fetch(), memory_word_minus_store(), memory_word_plus_store(), and vm_get_base().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.39 vm_load_u8()

```
uint8_t vm_load_u8 (
            struct VM * vm,
            vaddr_t addr )
```

Load an unsigned byte from VM memory.

Resolves `addr` via `vm_ptr()`. Sets `vm->error` and returns 0 if the address is out of bounds.

Parameters

vm	VM instance.
addr	VM byte offset to read.

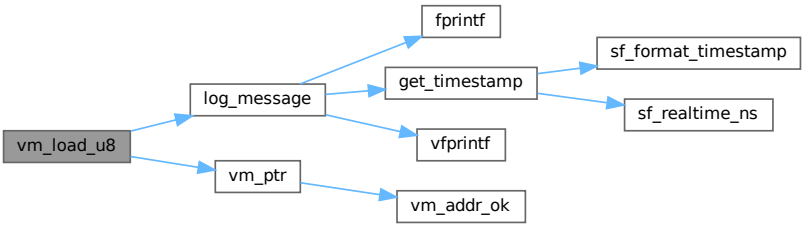
Returns

Byte value at `addr`, or 0 on error.

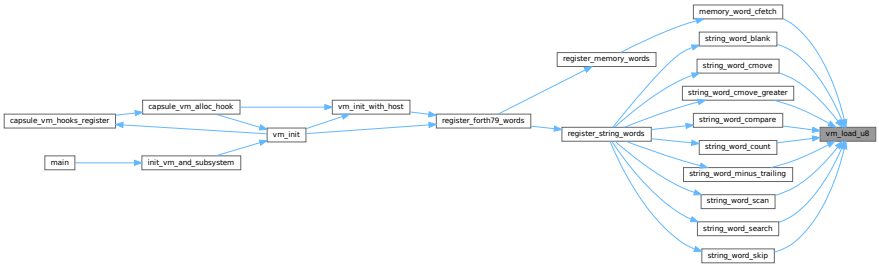
References VM::error, LOG_ERROR, log_message(), and vm_ptr().

Referenced by memory_word_cfetch(), string_word_blank(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_count(), string_word_minus_trailing(), string_word_scan(), string_word_search(), and string_word_skip().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.40 vm_make_immediate()

```
void vm_make_immediate (
            VM * vm )
```

Mark the most recently created word as IMMEDIATE (FORTH-79).

Sets `WORD_IMMEDIATE` on `vm->latest` so the word executes during compilation rather than being compiled into the current definition. Also calls `physics_metadata_refresh_state()` to update the physics engine's record of the entry's flags.

Sets `vm->error` if `vm` has no `latest` entry (i.e., the dictionary is empty or no word has been created yet).

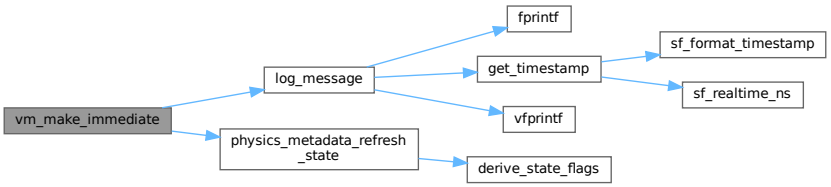
Parameters

vm	VM instance.

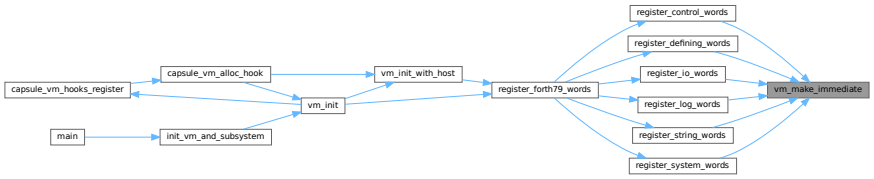
References VM::error, DictEntry::flags, VM::latest, LOG_DEBUG, LOG_ERROR, log_message(), DictEntry::name, DictEntry::name_len, physics_metadata_refresh_state(), and WORD_IMMEDIATE.

Referenced by register_control_words(), register_defining_words(), register_io_words(), register_log_words(), register_string_words(), and register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.41 vm_parse_number()

```
int vm_parse_number (
            VM * vm,
            const char * s,
            cell_t * out )
```

Attempt to parse a string as an integer in the current number base.

Reads the current base from `vm_get_base()`, then converts each character of `s` (case-insensitive, digits 0–9 and letters A–Z/a–z) to a digit value. Returns 0 immediately on any character that is not a valid digit in the current base, or on an empty string after the optional sign.

Handles an optional leading `'+'` or `'-'` sign. The result is a full-width `cell_t` (sign extended for negative values).

Parameters

vm	VM instance (used for base only; may be NULL, in which case base defaults to 10).
s	NUL-terminated string to parse.
out	Pointer to receive the parsed value on success.

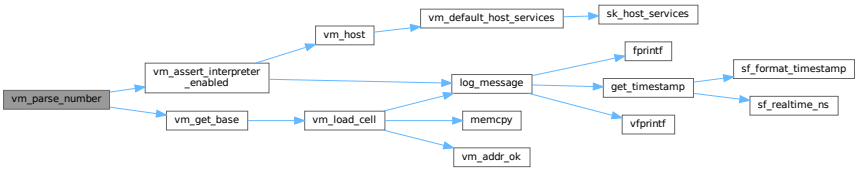
Returns

1 on successful parse, 0 on any parse failure.

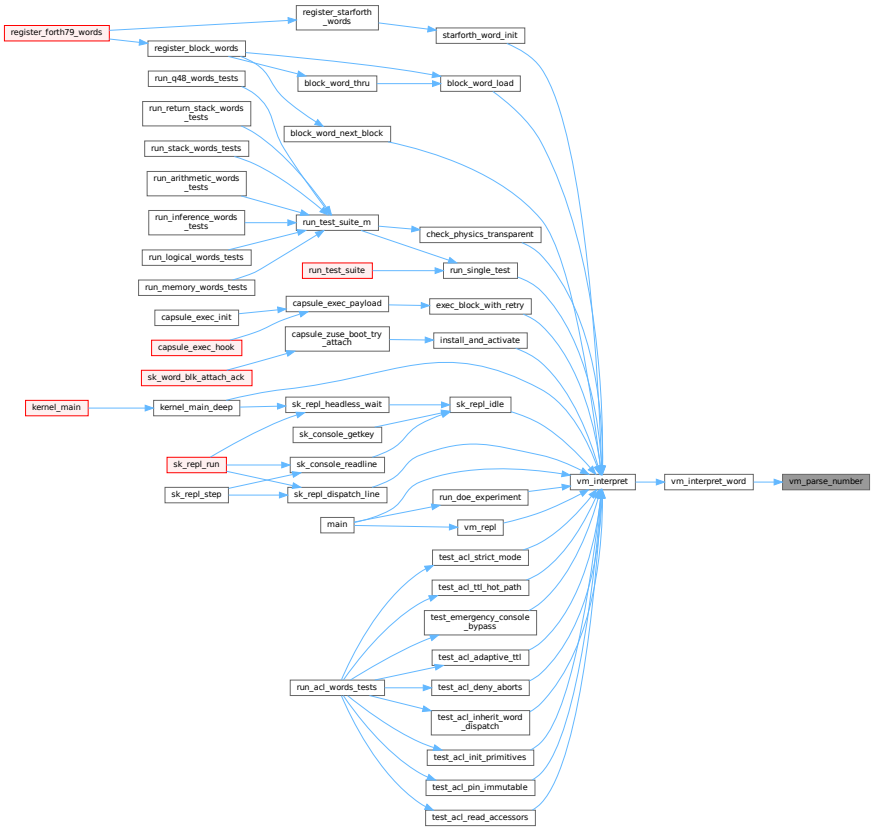
References base, vm_assert_interpreter_enabled(), and vm_get_base().

Referenced by vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.42 vm_parse_word()

```
int vm_parse_word (
            VM * vm,
```

```
char * word,
size_t max_len )
```

Parse the next whitespace-delimited token from the input buffer.

Skips leading whitespace (space, tab, CR, LF), then extracts characters until the next whitespace or end of buffer, storing up to `max_len` ? 1 characters in `word` followed by a NUL terminator. Advances `vm->input_pos` past the consumed token.

Parameters

vm	VM instance; `vm->input_buffer` / `input_pos` / `input_length` must be populated (typically by `vm_interpret()`).
word	Output buffer for the parsed token.
max_len	Size of `word` in bytes (including NUL terminator).

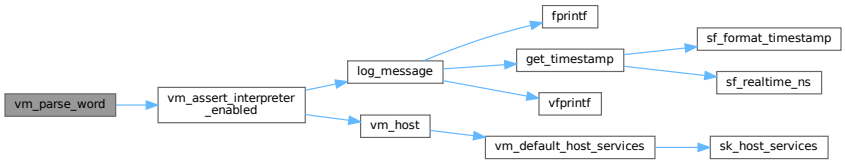
Returns

Number of characters written (excluding NUL), or 0 if the buffer is exhausted or `vm` / `word` is NULL.

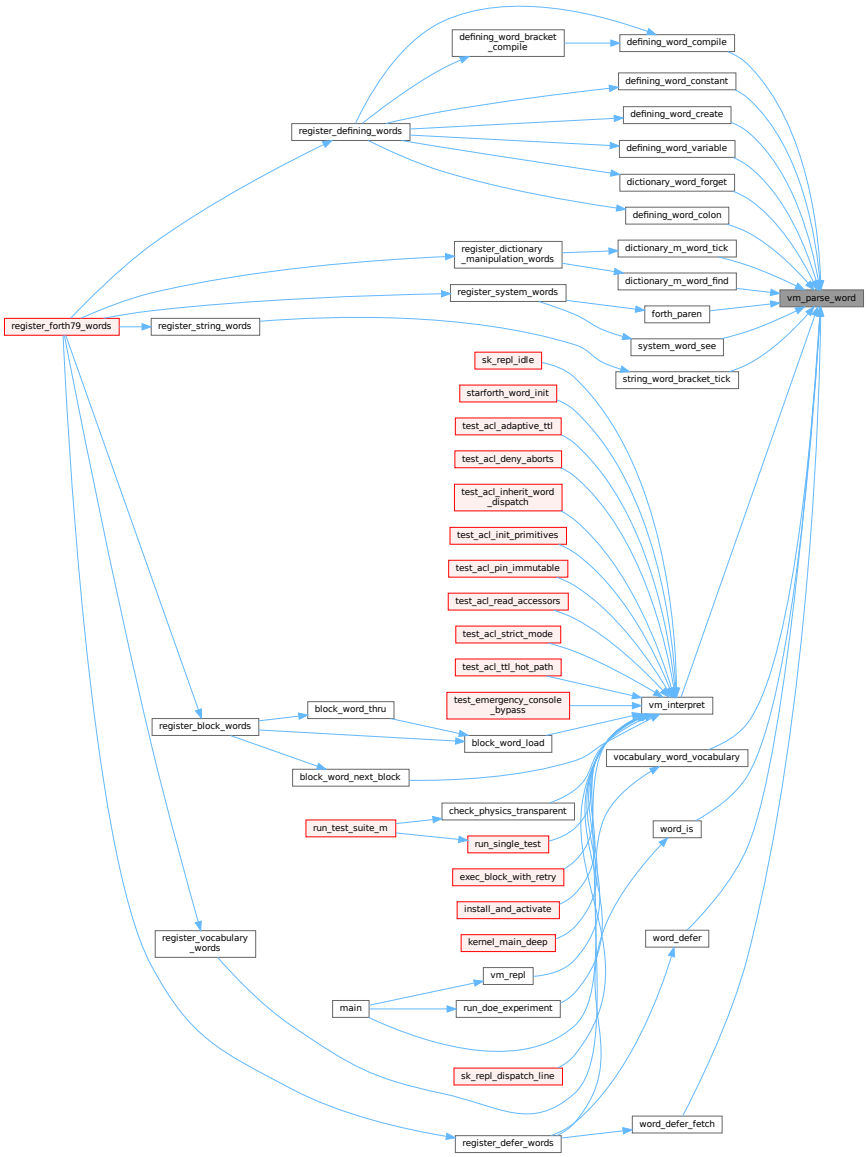
References VM::input_buffer, VM::input_length, VM::input_pos, and vm_assert_interpreter_enabled().

Referenced by defining_word_colon(), defining_word_compile(), defining_word_constant(), defining_word_create(), defining_word_variable(), dictionary_m_word_find(), dictionary_m_word_tick(), dictionary_word_forget(), forth_paren(), string_word_bracket_tick(), system_word_see(), vm_interpret(), vocabulary_word_vocabulary(), word_defer(), word_defer_fetch(), and word_is().

Here is the call graph for this function:



Here is the caller graph for this function:

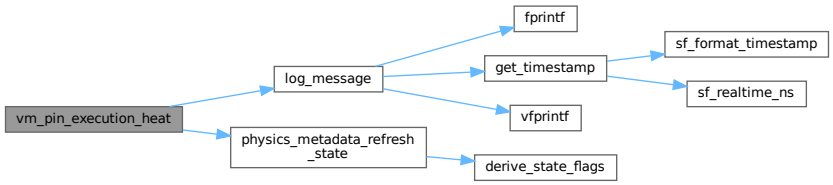


7.263.4.43 vm_pin_execution_heat()

```
void vm_pin_execution_heat (
            VM * vm )
```

References VM::error, DictEntry::flags, VM::latest, LOG_ERROR, log_message(), physics_metadata_refresh_state(), and WORD_PINNED.

Here is the call graph for this function:



7.263.4.44 vm_pop()

```
cell_t vm_pop (
            VM * vm )
```

Pop a value from the data stack.

Parameters

vm	Pointer to the VM structure

Returns

The popped value

Note

Returns 0 and sets error flag if stack underflow occurs

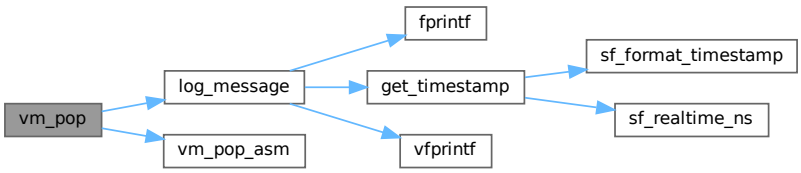
Uses assembly optimization if available for x86_64 or ARM64

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), PROFILE_INC_STACK_OP, and vm_pop_asm().

Referenced by arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), block_word_acl_allow_fetch(), block_word_acl_allow_store(), block_word_acl_ttl_fetch(), block_word_acl_ttl_store(), block_word_blk_attach(), block_word_block(), block_word_buffer(), block_word_confirm_format(), block_word_list(), block_word_load(), block_word_owner_fetch(), block_word_relocate(), block_word_thru(), control_forth_0branch(), control_forth_runtime_do(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), defining_word_constant(), defining_word_literal(), dictionary_m_word_cfa(), dictionary_m_word_link_from(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), dictionary_m_word_traverse(), dictionary_word_2comma(), dictionary_word_allot(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_sp_store(), double_word_2drop(), double_word_2rot(), double_word_2swap(), double_word_2to_r(), double_word_d_equals(), double_word_d_less(), double_word_d_minus(), double_word_d_plus(), double_word_d_two_slash(), double_word_d_two_star(), double_word_d_zero_equals(), double_word_d_zero_less(), double_word_dmax(), double_word_dmin(), double_word_dnegate(), double_word_s_to_d(), editor_word_edit(), editor_word_l(), editor_word_s(), fbw_plot(), format_word_d_dot(), format_word_d_dot_r(), format_word_dot(),

format_word_dot_r(), format_word_dump(), format_word_end_conversion(), format_word_hash(), format_word_hash_s(), format_word_hold(), format_word_question(), format_word_sign(), format_word_u_dot(), format_word_u_dot_r(), forth_acl_allow_store(), forth_acl_mode_store(), forth_acl_ttl_store(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), hosted_lifecycle_birth(), hosted_lifecycle_kill(), hosted_lifecycle_pause(), hosted_lifecycle_resume(), hosted_lifecycle_use(), io_word_type(), log_str_emit(), log_word_set_level(), logical_word_and(), logical_word_equals(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), memory_word_2fetch(), memory_word_2store(), memory_word_cells(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), mixed_math_word_m_minus(), mixed_math_word_m_plus(), mixed_math_word_m_slash_mod(), mixed_math_word_m_star(), mixed_math_word_mod(), mixed_math_word_mod(), mixed_math_word_slash_mod(), mixed_math_word_star_slash(), mixed_math_word_star_slash_mod(), pop_xt(), return_stack_word_to_r(), runtime_abortq(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), stack_word_pick(), starforth_word_execution_heat_fetc starforth_word_execution_heat_store(), starforth_word_random(), starforth_word_seed(), starforth_word_top_words(), starforth_word_wait(), starforth_word_zuse_pubkey_fetch(), string_word_blank(), string_word_cmove(), string_word_cmove_greater() string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_minus_trailing(), string_word_number(), string_word_scan(), string_word_search(), string_word_skip(), string_word_word(), system_word_abort_quote(), system_word_execute(), system_word_reboot(), test_acl_adaptive_ttl(), test_acl_read_accessors(), vm_api_pop(), word_divide(), word_divmod(), and word_is().

Here is the call graph for this function:



7.263.4.45 vm_pop_fast()

```
static cell_t vm_pop_fast (
            VM * vm )  [inline], [static]
```

References VM::data_stack, and VM::dsp.

7.263.4.46 vm_ptr()

```
uint8_t * vm_ptr (
            struct VM * vm,
            vaddr_t addr )
```

Return a host C pointer into VM memory at `addr`.

Validates the address with `vm_addr_ok()` (minimum 1-byte range) and returns `NULL` if the address is out of bounds or `vm` is uninitialised. The returned pointer is valid for at least one byte; callers that need multi-byte access should perform their own range check first.

Parameters

vm	VM instance.
addr	VM byte offset to dereference.

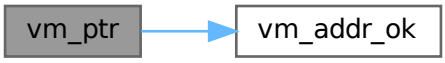
Returns

Host pointer into `vm->memory`, or NULL on bounds failure.

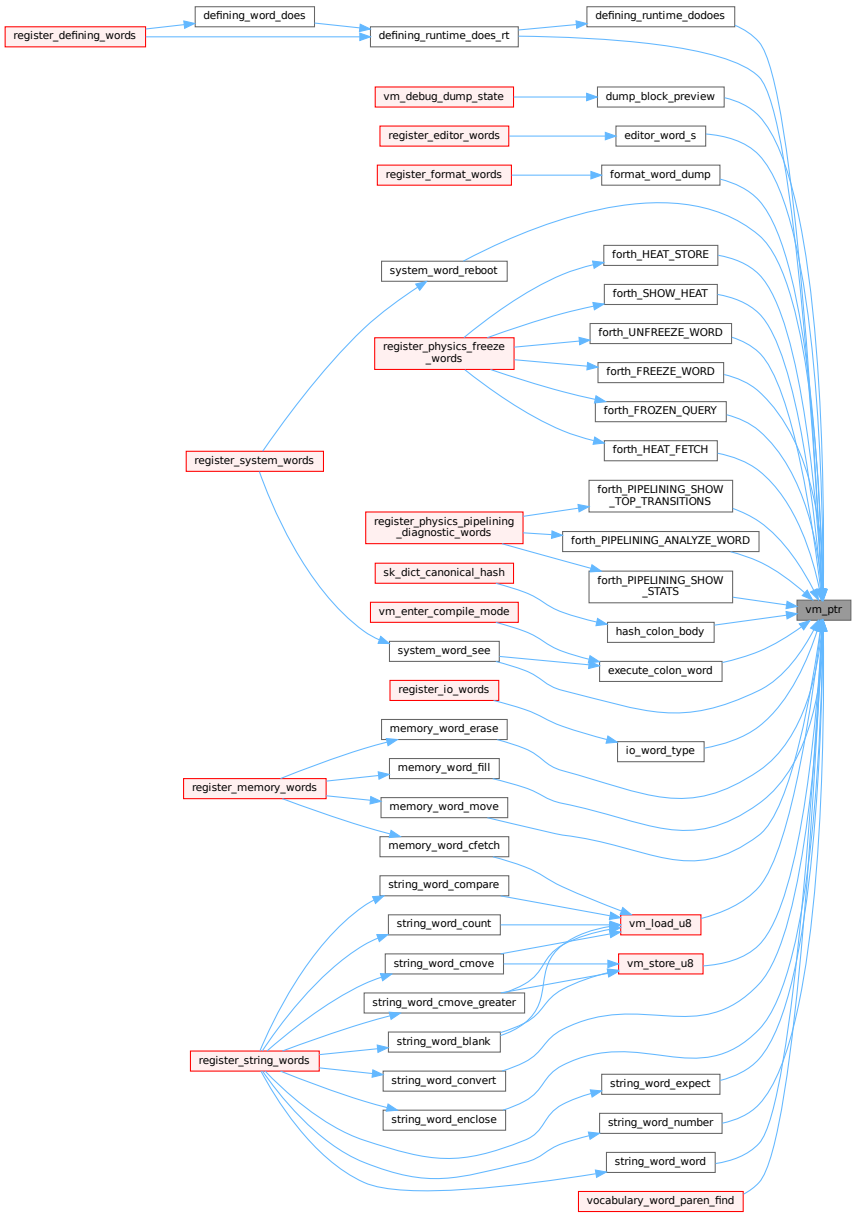
References VM::memory, and vm_addr_ok().

Referenced by defining_runtime_dodoes(), defining_runtime_does_rt(), dump_block_preview(), editor_word_s(), execute_colon_word(), format_word_dump(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_STORE(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TO forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), hash_colon_body(), io_word_type(), memory_word_erase(), memory_word_fill(), memory_word_move(), string_word_convert(), string_word_enclose(), string_word_expect(), string_word_number(), string_word_word(), system_word_reboot(), system_word_see(), vm_load_u8(), vm_store_u8(), and vocabulary_word_paren_find().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.47 vm_push()

```
void vm_push (
            VM * vm,
            cell_t value )
```

Push a value onto the data stack.

Parameters

vm	Pointer to the VM structure
value	Value to push onto the stack

Note

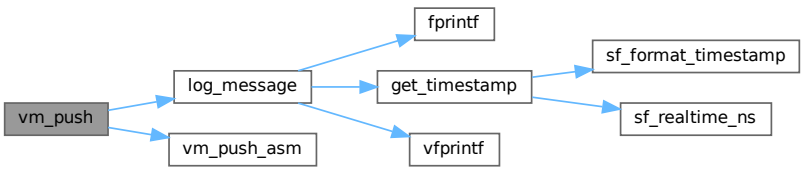
Performs bounds checking to prevent stack overflow

Uses assembly optimization if available for x86_64 or ARM64

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), PROFILE_INC_STACK_OP, STACK_SIZE, and vm_push_asm().

Referenced by acl_recheck(), acl_recheck(), arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), block_word_acl_allow_fetch(), block_word_acl_ttl_fetch(), block_word_blk_attach(), block_word_block(), block_word_buffer(), block_word_owner_fetch(), block_word_scr(), block_word_thru(), control_forth_I(), control_forth_J(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_lit(), defining_runtime_variable(), defining_word_state(), dictionary_m_word_cfa(), dictionary_m_word_find(), dictionary_m_word_link_from(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_tick(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), dictionary_m_word_traverse(), dictionary_word_here(), dictionary_word_latest(), dictionary_word_pad(), dictionary_word_sp_fetch(), double_word_2dup(), double_word_2over(), double_word_2r_fetch(), double_word_2r_from(), double_word_2rot(), double_word_2swap(), double_word_d_equals(), double_word_d_less(), double_word_d_minus(), double_word_d_plus(), double_word_d_two_slash(), double_word_d_two_star(), double_word_d_zero_equals(), double_word_d_zero_less(), double_word_dmax(), double_word_dmin(), double_word_dnegate(), double_word_s_to_d(), editor_word_edit(), emit_cell(), fbw_height(), fbw_width(), format_word_base(), format_word_end_conversion(), format_word_hash(), format_word_hash_s(), format_word_sign(), forth_acl_allow_fetch(), forth_acl_heat_fetch(), forth_acl_mode_fetch(), forth_acl_pinned_query(), forth_acl_ttl_fetch(), forth_acl_word_id(), kbw_debug(), kbw_key_event(), kbw_scan(), kbw_vdebug(), kbw_vevent(), log_word_debug(), log_word_error(), log_word_get_level(), log_word_info(), log_word_test(), log_word_warn(), logical_word_and(), logical_word_equals(), logical_word_false(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_true(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), memory_word_2fetch(), memory_word_cells(), memory_word_cfetch(), memory_word_fetch(), mixed_math_word_m_minus(), mixed_math_word_m_plus(), mixed_math_word_m_slash_mod(), mixed_math_word_m_star(), mixed_math_word_mod(), mixed_math_word_mod(), mixed_math_word_slash_mod(), mixed_math_word_star_slash(), mixed_math_word_star_slash_mod(), return_stack_word_r_fetch(), return_stack_word_r_from(), sk_word_kh_blk_attach_send(), stack_word_pick(), starforth_word_execution_heat_fetch(), starforth_word_heartbeat_ticks(), starforth_word_init(), starforth_word_random(), starforth_word_zuse_cert_installed_query(), starforth_word_zuse_pubkey_fetch(), starforth_word_zuse_session(), string_runtime_s_quote(), string_word_bl(), string_word_bracket_tick(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_minus_trailing(), string_word_number(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), string_word_source(), string_word_span(), string_word_tib(), string_word_to_in(), string_word_word(), system_word_79_standard(), test_acl_adaptive_ttl(), test_acl_inherit_word_dispatch(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), vm_api_push(), vm_compile_literal(), vm_interpret_word(), vocabulary_word_context(), vocabulary_word_current(), vocabulary_word_paren_find(), word_defer_fetch(), word_divide(), and word_divmod().

Here is the call graph for this function:



7.263.4.48 vm_push_fast()

```
static void vm_push_fast (
            VM * vm,
            cell_t value )  [inline], [static]
```

References VM::data_stack, and VM::dsp.

7.263.4.49 vm_repl()

```
void vm_repl (
            VM * vm,
            int script_mode )
```

Starts the Forth REPL (Read-Eval-Print Loop)

Parameters

vm	Pointer to the VM structure
script_mode	If 1, suppress prompts and "ok" output (for piped input)

This function implements an interactive REPL for the Forth interpreter. It continuously reads input from the user, interprets it, and prints the result until the VM is halted or an error occurs.

In interactive mode (script_mode=0):

- Prints colored prompt "ok> "
- Acknowledges successful commands with " ok"
- Reports errors with " ERROR"

In script mode (script_mode=1):

- Suppresses all prompts and status messages
- Suitable for piped input (heredoc, pipes, redirects)

7.263.4.50 vm_rpop()

```
cell_t vm_rpop (
            VM * vm )
```

Pop a value from the return stack.

Parameters

vm	Pointer to the VM structure

Returns

The popped value

Note

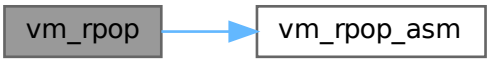
Returns 0 and sets error flag if stack underflow occurs

Uses assembly optimization if available for x86_64 or ARM64

References VM::error, VM::return_stack, VM::rsp, and vm_rpop_asm().

Referenced by execute_colon_word(), return_stack_word_r_from(), and vm_api_rpop().

Here is the call graph for this function:



Here is the caller graph for this function:

7.263.4.51 vm_rpop_fast()

```
static cell_t vm_rpop_fast (
            VM * vm )  [inline], [static]
```

References VM::return_stack, and VM::rsp.

7.263.4.52 vm_rpush()

```
void vm_rpush (
            VM * vm,
            cell_t value )
```

Push a value onto the return stack.

Parameters

vm	Pointer to the VM structure
value	Value to push onto the return stack

Note

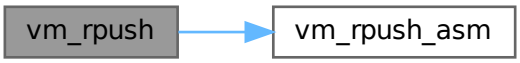
Sets error flag if stack overflow occurs

Uses assembly optimization if available for x86_64 or ARM64

References VM::error, VM::return_stack, VM::rsp, STACK_SIZE, and vm_rpush_asm().

Referenced by execute_colon_word(), return_stack_word_to_r(), and vm_api_rpush().

Here is the call graph for this function:



Here is the caller graph for this function:

7.263.4.53 vm_rpush_fast()

```
static void vm_rpush_fast (
            VM * vm,
            cell_t value )  [inline], [static]
```

References VM::return_stack, and VM::rsp.

7.263.4.54 vm_run_smoke_tests()

```
void vm_run_smoke_tests (
            VM * vm )
```

7.263.4.55 vm_set_base()

```
void vm_set_base (
            VM * vm,
            unsigned b )
```

Set the VM number base and update both the cell and the host mirror.

Clamps `b` to [2, 36] (replacing out-of-range values with 10), then writes to the FORTH `BASE` variable cell at `vm->base_addr` and to the host-mirror field `vm->base` so both sources agree.

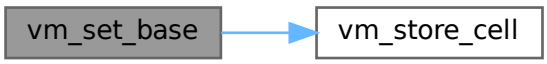
Parameters

vm	VM instance to update.
b	Desired number base; clamped to [2, 36].

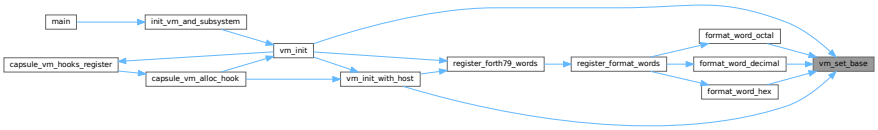
References VM::base, VM::base_addr, and vm_store_cell().

Referenced by format_word_decimal(), format_word_hex(), format_word_octal(), vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



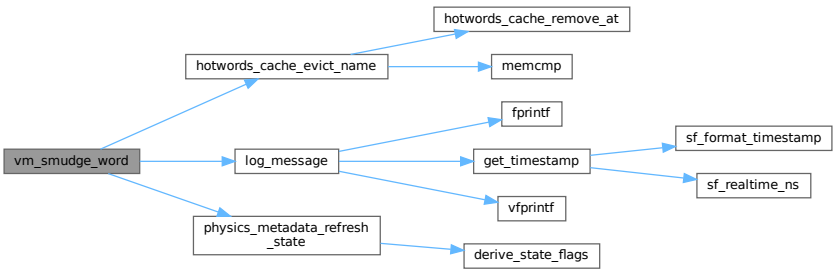
7.263.4.56 vm_smudge_word()

```
void vm_smudge_word (
            VM * vm )
```

References VM::error, DictEntry::flags, VM::hotwords_cache, hotwords_cache_evict_name(), VM::latest, LOG_ERROR, log_message(), DictEntry::name, DictEntry::name_len, physics_metadata_refresh_state(), and WORD_SMUDGED.

Referenced by vm_api_smudge_word().

Here is the call graph for this function:



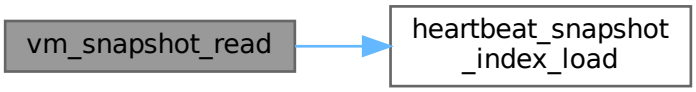
Here is the caller graph for this function:

7.263.4.57 vm_snapshot_read()

```
void vm_snapshot_read (
            const VM * vm,
            HeartbeatSnapshot * out_snapshot )
```

References VM::heartbeat, heartbeat_snapshot_index_load(), HeartbeatState::snapshot_index, and HeartbeatState::snapshots.

Here is the call graph for this function:



7.263.4.58 vm_store_cell()

```
void vm_store_cell (
            struct VM * vm,
            vaddr_t addr,
            cell_t v )
```

Store an aligned cell to VM memory.

Validates alignment and bounds, then copies `v` into VM memory via `memcpy()`. Sets `vm->error` on alignment or bounds failure.

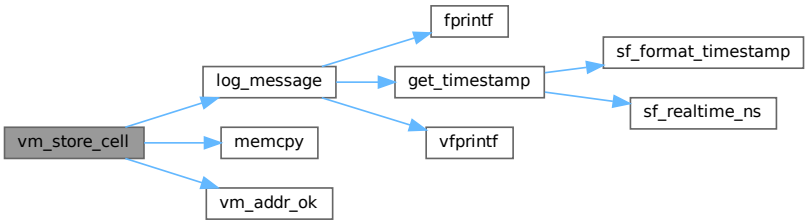
Parameters

vm	VM instance.
addr	Aligned VM byte offset to write.
v	Cell value to store.

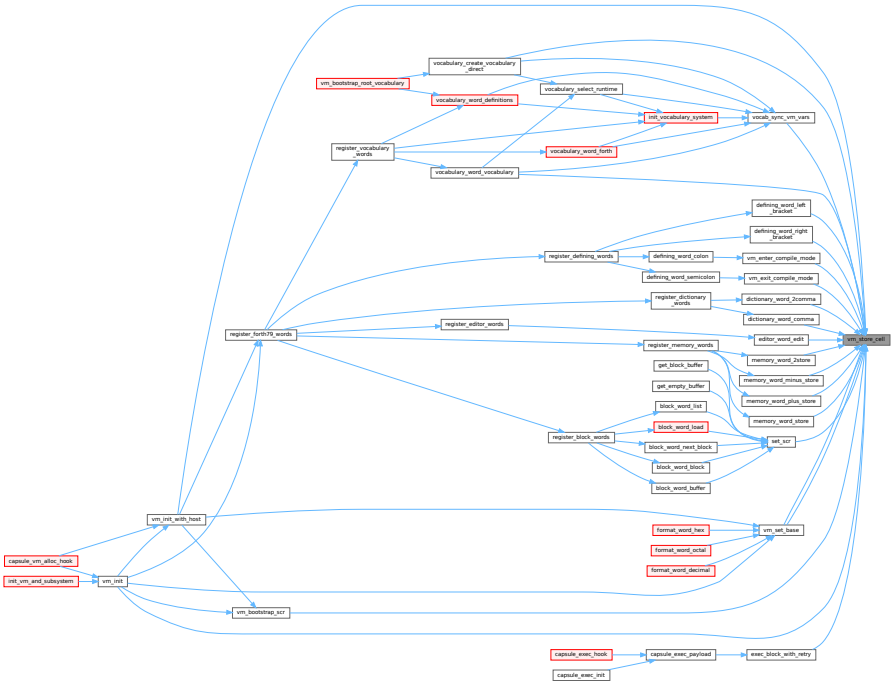
References VM::error, LOG_ERROR, log_message(), memcpy(), VM::memory, and vm_addr_ok().

Referenced by defining_word_left_bracket(), defining_word_right_bracket(), dictionary_word_2comma(), dictionary_word_comma(), editor_word_edit(), exec_block_with_retry(), memory_word_2store(), memory_word_minus_store(), memory_word_plus_store(), memory_word_store(), set_scr(), vm_bootstrap_scr(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_init(), vm_init_with_host(), vm_set_base(), vm_set_base(), vocab_sync_vm_vars(), vocabulary_create_vocabulary_direct(), and vocabulary_word_vocabulary().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.59 vm_store_u8()

```
void vm_store_u8 (
            struct VM * vm,
            vaddr_t addr,
            uint8_t v )
```

Store an unsigned byte to VM memory.

Resolves `addr` via `vm_ptr()`. Sets `vm->error` if the address is out of bounds; otherwise writes `v`.

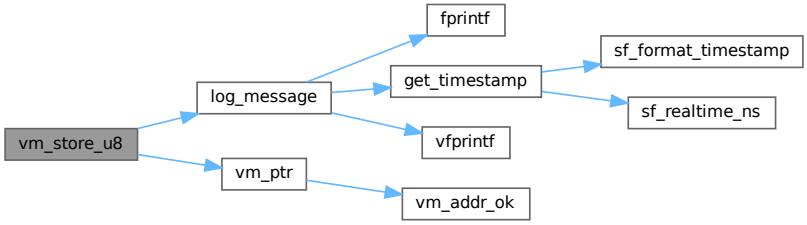
Parameters

vm	VM instance.
addr	VM byte offset to write.
v	Byte value to store.

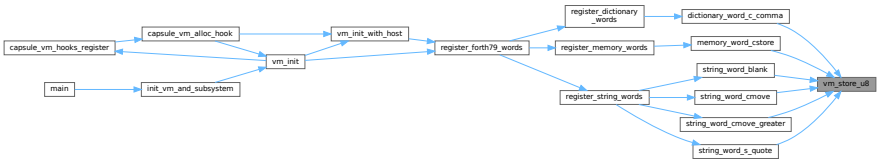
References VM::error, LOG_ERROR, log_message(), and vm_ptr().

Referenced by dictionary_word_c_comma(), memory_word_cstore(), string_word_blank(), string_word_cmove(), string_word_cmove_greater(), and string_word_s_quote().

Here is the call graph for this function:



Here is the caller graph for this function:



7.263.4.60 vm_tick()

```
void vm_tick (
            VM * vm )
```

Central heartbeat dispatcher for time-driven tuning operations.

Aggregates all periodic optimization tasks (Loop #3 and Loop #5) into one place. Designed as plugin architecture - new tuning operations can be added as plugins.

Options for integration:

- Synchronous (now): Called from main execution loop, every N executions
- Background thread (future): Runs in separate thread, decoupled from VM execution

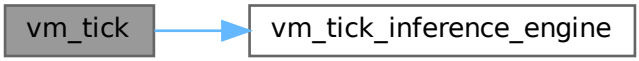
Parameters

vm	Pointer to VM instance

References VM::heartbeat, HeartbeatState::heartbeat_enabled, HEARTBEAT_INFERENCE_FREQUENCY, HeartbeatState::last_inference_tick, HeartbeatState::tick_count, and vm_tick_inference_engine().

Referenced by assert_heartbeat_safe(), and starforth_word_wait().

Here is the call graph for this function:



Here is the caller graph for this function:

7.263.4.61 vm_tick_inference_engine()

```
void vm_tick_inference_engine (
            VM * vm )
```

Phase 2: Unified Inference Engine - Adaptive Window & Decay Slope Tuning.

Coordinates inference on rolling window of truth to determine:

- Optimal adaptive window width (via variance inflection detection)
- Optimal decay slope (via exponential regression on heat trajectory)

Uses ANOVA early-exit to skip full inference when variance is stable (<5% change). All math uses Q48.16 fixed-point (integer-only, no floating-point).

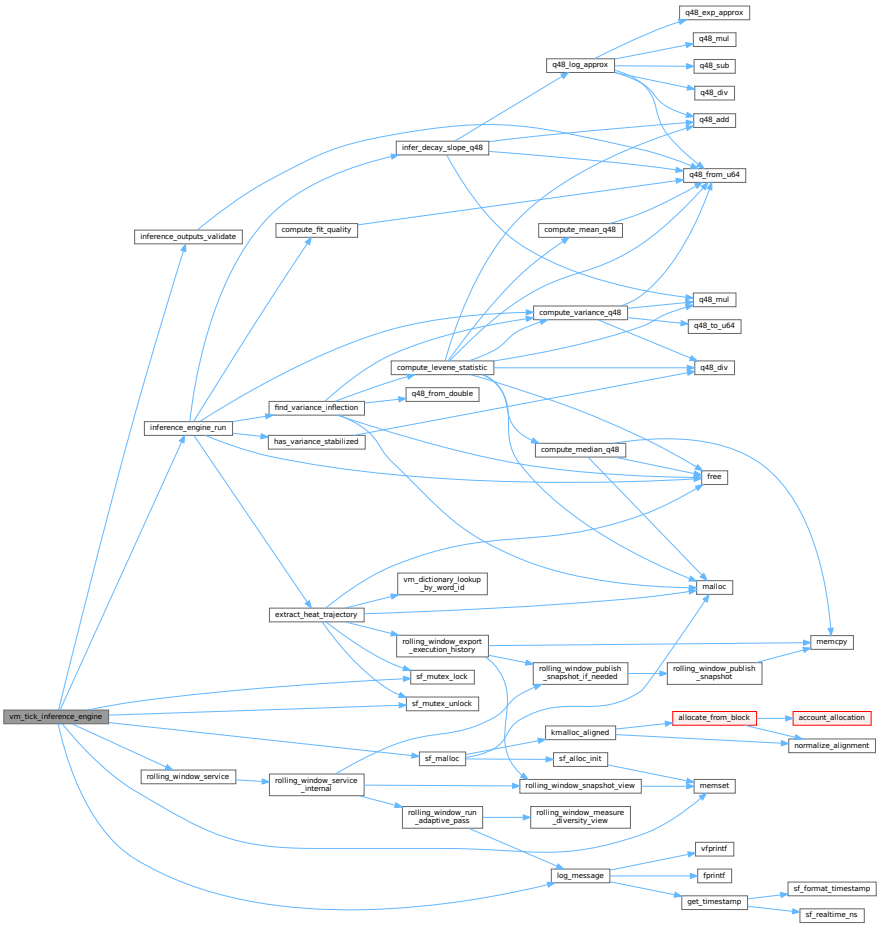
Replaces legacy vm_tick_window_tuner() and vm_tick_slope_validator().

Parameters

vm	Pointer to VM instance

References InferenceOutputs::adaptive_decay_slope, InferenceOutputs::adaptive_window_width, VM::decay_slope_q48, VM::dict_lock, HeartbeatState::early_exit_count, InferenceOutputs::early_exited, RollingWindowOfTruth::effective_window_size, VM::heartbeat, HeartbeatState::heartbeat_enabled, HEARTBEAT_TICK_NS, HOTWORDS_EXECUTION_HEAT_THRESHOLD, inference_engine_run(), inference_outputs_validate(), HeartbeatState::inference_run_count, RollingWindowOfTruth::is_warm, VM::last_inference_outputs, HeartbeatState::last_inference_tick, VM::latest, LOG_DEBUG, LOG_ERROR, LOG_INFO, log_message(), memset(), VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::rolling_window, rolling_window_service(), sf_malloc(), sf_mutex_lock(), sf_mutex_unlock(), InferenceOutputs::slope_fit_quality_q48, VM::stale_word_count_at_check, HeartbeatState::tick_count, HeartbeatWorker::tick_ns, HeartbeatState::tick_target_ns, RollingWindowOfTruth::total_executions, VM::total_heat_at_last_check, VM::tuning_lock, InferenceInputs::window, RollingWindowOfTruth::window_pos, InferenceOutputs::window_variance_q48, word_count, VM::word_count_at_check, and HeartbeatState::worker.

Here is the call graph for this function:



7.263.4.62 vm_tick_slope_validator()

```
void vm_tick_slope_validator (
            VM * vm )
```

Loop #3: Heat decay slope validation via periodic measurement.

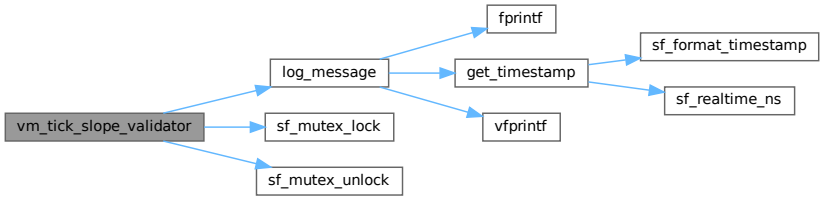
Validates that linear decay is actually helping optimize dictionary caching. Measures stale word ratio, hot word count, and average heat distribution.

Parameters

vm	Pointer to VM instance

References VM::decay_slope_direction, VM::decay_slope_q48, VM::dict_lock, VM::hot_word_count_at_check, HOTWORDS_EXECUTION_HEAT_THRESHOLD, VM::latest, LOG_DEBUG, log_message(), sf_mutex_lock(), sf_mutex_unlock(), VM::stale_word_count_at_check, VM::total_heat_at_last_check, VM::tuning_lock, word_count, and VM::word_count_at_check.

Here is the call graph for this function:



7.263.4.63 vm_tick_window_tuner()

```
void vm_tick_window_tuner (
            VM * vm )
```

Loop #5: Context-aware window tuning via binary chop search.

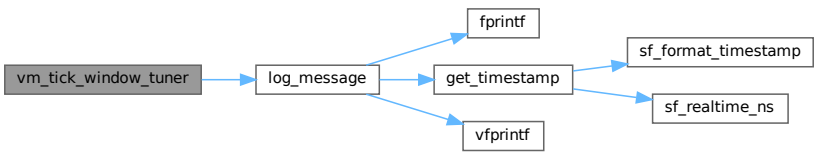
Uses prefetch accuracy to guide window size adaptation. Binary search converges on optimal effective_window_↩ size for current workload.

Parameters

vm	Pointer to VM instance

References ADAPTIVE_MIN_WINDOW_SIZE, RollingWindowOfTruth::effective_window_size, ENABLE_PIPELINING, RollingWindowOfTruth::is_warm, PipelineGlobalMetrics::last_checked_accuracy, PipelineGlobalMetrics::last_checked_window_size, LOG_DEBUG, log_message(), VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::rolling_window, ROLLING_WINDOW_SIZE, and PipelineGlobalMetrics::window_tuning_checks.

Here is the call graph for this function:

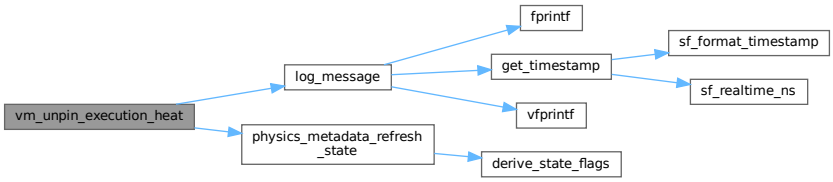


7.263.4.64 vm_unpin_execution_heat()

```
void vm_unpin_execution_heat (
            VM * vm )
```

References VM::error, DictEntry::flags, VM::latest, LOG_ERROR, log_message(), and physics_metadata_refresh_state().

Here is the call graph for this function:



7.263.4.65 vm_zuse_cert_install()

```
int vm_zuse_cert_install (
            VM * vm,
            const uint8_t seed[32],
            const uint8_t pubkey[32] )
```

One-time write of the Zuse cert (seed + derived pubkey) – blows the fuse.

Deliberately not backed by a dictionary CONSTANT: ACL-PIN only blocks redefinition (vm_create_word shadowing), not a >BODY-then-store on the word's data field, so a pinned CONSTANT is not actually immutable against FORTH-level tampering. Keeping the value in a VM struct field with no corresponding FORTH store word closes that path entirely – see FABRIC-2.md's Milestone 4 mint-then-pin writeup for the finding.

Parameters

vm	VM instance.
seed	Ed25519 seed, 32 bytes (the private identity).
pubkey	Ed25519 public key derived from seed, 32 bytes.

Returns

0 on success; -1 if already installed (fuse already blown).

References memcpy(), VM::zuse_cert_installed, VM::zuse_cert_pubkey, and VM::zuse_cert_seed.

Referenced by install_and_activate().

Here is the call graph for this function:

Here is the caller graph for this function:

7.263.5 Variable Documentation

7.263.5.1 __attribute__

```
struct idtr __attribute__
```

7.263.5.2 acl_allow

```
uint8_t acl_allow
```

7.263.5.3 acl_default

```
uint8_t acl_default
```

7.263.5.4 acl_mode

```
uint8_t acl_mode
```

7.263.5.5 acl_pinned

```
uint8_t acl_pinned
```

7.263.5.6 acl_ttl

```
uint32_t acl_ttl
```

7.263.5.7 execution_heat

```
cell_t execution_heat
```

Referenced by forth_ALL_HEATS(), hotwords_bucket_reorder(), physics_metadata_touch(), starforth_word_top_words(), and temperature_from_execution_heat().

7.263.5.8 flags

```
cell_t flags
```

Referenced by blk_flags_set(), capsule_find_mama_init(), contrib_capsule_refused(), decode_composite_glyph(), decode_simple_glyph(), derive_state_flags(), ioapic_init(), ioapic_route_legacy_irq(), make_pte(), vmm_map_page(), and vmm_map_range().

7.263.5.9 func

```
word_func_t func
```

Referenced by register_word(), vm_compile_call(), vm_create_word(), vm_dictionary_find_by_func(), and vm_dictionary_find_latest_by_func().

7.263.5.10 link

```
struct DictEntry* link
```

7.263.5.11 name

```
char name[]
```

Referenced by capsule_birth_baby(), capsule_birth_mama(), capsule_find_by_name(), capsule_parity_log_kill(), capsule_run_experiment(), capsule_vm_find_by_name(), capsule_vm_find_by_name_nocase(), capsule_vm_kill(), capsule_vm_registry_set_name(), cell_prop(), console_set_vm_name(), dict_find_word_heat_aware(), doe_log_heat_by_name(), fdt_find_child(), fdt_find_node_by_name(), fdt_find_prop(), fdt_find_prop_in_node(), fdt_prop_u32(), find_and_cache_pubkey(), forth_FREEZE_CRITICAL(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_STORE(), forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), gpt_write_one(), hosted_lifecycle_birth(), hosted_lifecycle_kill(), hosted_lifecycle_pause(), hosted_lifecycle_resume(), hosted_lifecycle_use(), hotwords_cache_evict_name(), hotwords_cache_lookup(), mb_cell_prop(), node_cells(), register_word(), sig_handler(), vm_bootstrap_root_vocabulary(), vm_create_word(), vm_dict_resolve_in_bucket(), vm_dictionary_get_data_field(), vm_enter_compile_mode(), vm_find_word(), vm_interpret_word(), vm_vocabulary_find_word(), vocab_find_word(), vocabulary_create_vocabulary_direct(), vocabulary_word_paren_find(), vocabulary_word_vocabulary(), word_defer(), word_defer_fetch(), and word_is().

7.263.5.12 name_len

```
uint8_t name_len
```

Referenced by fdt_find_child(), profiler_generate_report(), profiler_print_hotspots(), and traverse_name_field().

7.263.5.13 physics

```
DictPhysics physics
```

7.263.5.14 transition_metrics

```
WordTransitionMetrics* transition_metrics
```

7.263.5.15 word_id

```
uint32_t word_id
```

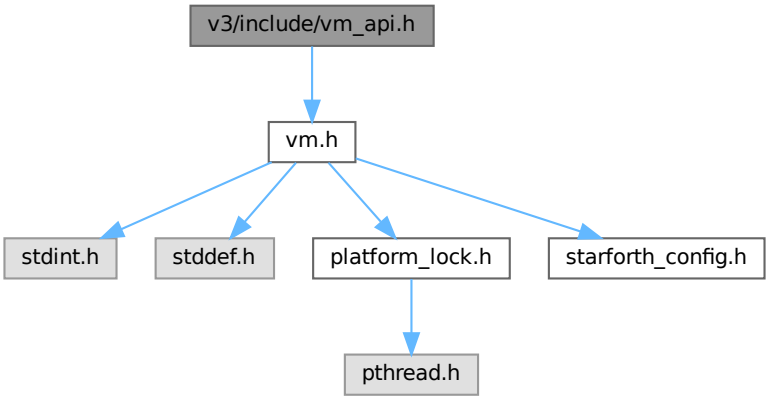
Referenced by execute_colon_word(), extract_heat_trajectory(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), physics_pre_execute(), rolling_window_find_hottest_word(), rolling_window_record_execution(), rolling_window_seed_hotwords_cac transition_metrics_update_context_window(), vm_dictionary_lookup_by_word_id(), vm_dictionary_track_entry(), and vm_dictionary_untrack_entry().

7.264 v3/include/vm_api.h File Reference

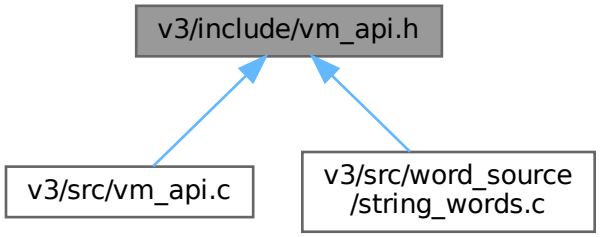
StarForth Virtual Machine Public API.

```
#include "vm.h"
```

Include dependency graph for vm_api.h:



This graph shows which files directly or indirectly include this file:



Functions

- int vm_input_ensure (VM *vm)

  Ensure input buffers are allocated.
- unsigned char * vm_input_tib (VM *vm)

  Get pointer to terminal input buffer (TIB)
- cell_t * vm_input_in (VM *vm)

  Get pointer to input offset variable.
- cell_t * vm_input_span (VM *vm)

  Get pointer to input span variable.
- void vm_input_load_line (VM *vm, const char *src, size_t n)

  Load input line into TIB.
- void vm_input_source (VM *vm, cell_t *out_addr, cell_t *out_len)

  Get current input source buffer info.
- cell_t vm_addr_from_ptr (VM *vm, void *p)

  Convert native pointer to Forth memory address.

7.264.1 Detailed Description

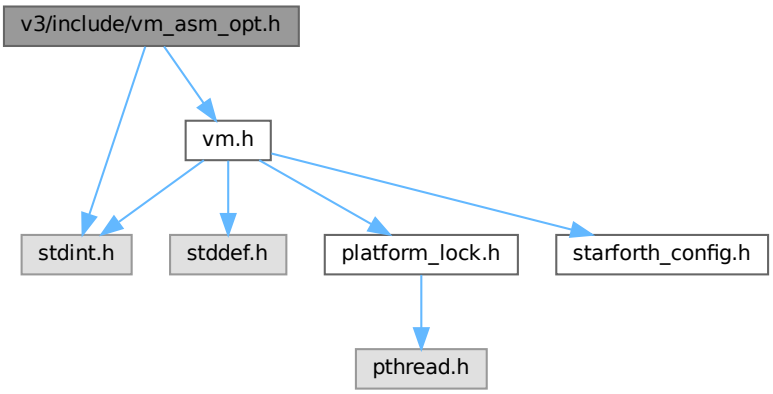
StarForth Virtual Machine Public API.

This header provides the public interface for interacting with the StarForth Virtual Machine, particularly focusing on input handling and memory management.

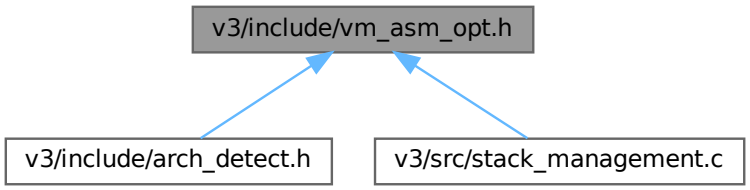
7.265 v3/include/vm_asm_opt.h File Reference

```
#include "vm.h"
#include <stdint.h>
```

Include dependency graph for vm_asm_opt.h:



This graph shows which files directly or indirectly include this file:



Functions

- static void vm_push_asm (VM *vm, cell_t value)

  Optimized data stack push operation.
- static cell_t vm_pop_asm (VM *vm)

  Optimized data stack pop operation.
- static void vm_rpush_asm (VM *vm, cell_t value)

  Optimized return stack push operation.
- static cell_t vm_rpop_asm (VM *vm)

  Optimized return stack pop operation.
- static int vm_add_check_overflow (cell_t a, cell_t b, cell_t *result)

  Performs addition with hardware overflow detection.
- static int vm_sub_check_overflow (cell_t a, cell_t b, cell_t *result)

  Performs subtraction with hardware overflow detection.
- static void vm_mul_double (cell_t a, cell_t b, cell_t *hi, cell_t *lo)

  Performs double-width multiplication.
- static void vm_divmod (cell_t dividend, cell_t divisor, cell_t *quotient, cell_t *remainder)

Performs division with remainder.

- static int vm_strcmp_asm (const char *s1, const char *s2, size_t len)

  Hardware-accelerated string comparison.
- static void vm_memcpy_asm (void *dest, const void *src, size_t len)

  Hardware-accelerated memory copy.
- static void vm_memzero_asm (void *dest, size_t len)

  Hardware-accelerated memory zero.
- static cell_t vm_min_asm (cell_t a, cell_t b)

  Branchless minimum calculation.
- static cell_t vm_max_asm (cell_t a, cell_t b)

  Branchless maximum calculation.
- static void vm_cpuid (uint32_t leaf, uint32_t *eax, uint32_t *ebx, uint32_t *ecx, uint32_t *edx)

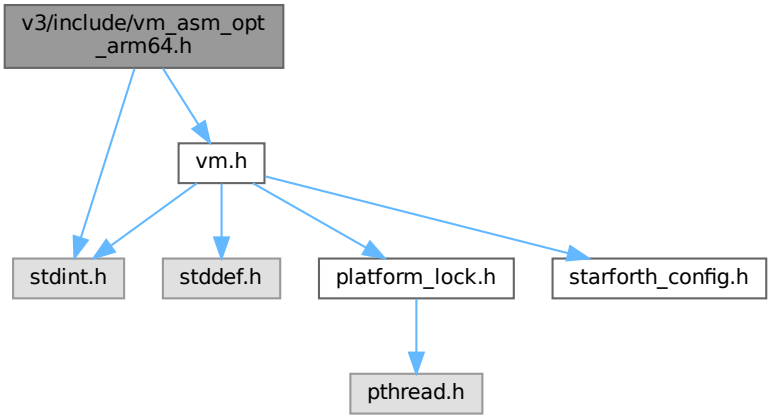
  Wrapper for CPUID instruction.
- static int vm_has_sse42 (void)

  Checks for SSE4.2 support.

7.266 v3/include/vm_asm_opt_arm64.h File Reference

```
#include "vm.h"
#include <stdint.h>
```

Include dependency graph for vm_asm_opt_arm64.h:



Functions

- static void vm_push_asm (VM *vm, cell_t value)

  Optimized assembly implementation of data stack push operation.
- static cell_t vm_pop_asm (VM *vm)

  Optimized assembly implementation of data stack pop operation.
- static void vm_rpush_asm (VM *vm, cell_t value)

  Optimized assembly implementation of return stack push operation.
- static cell_t vm_rpop_asm (VM *vm)

Optimized assembly implementation of return stack pop operation.

- static int vm_add_check_overflow (cell_t a, cell_t b, cell_t *result)

  Fast addition with overflow detection using ARM64 ADDS instruction.
- static int vm_sub_check_overflow (cell_t a, cell_t b, cell_t *result)

  Fast subtraction with overflow detection using ARM64 SUBS instruction.
- static void vm_mul_double (cell_t a, cell_t b, cell_t *hi, cell_t *lo)

  Fast 128-bit multiplication using ARM64 SMULH instruction.
- static void vm_divmod (cell_t dividend, cell_t divisor, cell_t *quotient, cell_t *remainder)

  Fast division with remainder using ARM64 SDIV and MSUB instructions.
- static int vm_strcmp_short_asm (const char *s1, const char *s2, size_t len)

  Optimized string comparison for short strings (<=32 bytes)
- static int vm_strcmp_asm (const char *s1, const char *s2, size_t len)
- static void vm_memcpy_asm (void *dest, const void *src, size_t len)

  Optimized memory copy using ARM64 load/store pair instructions.
- static void vm_memzero_asm (void *dest, size_t len)

  Fast memory zeroing using ARM64 store pair instructions.
- static cell_t vm_min_asm (cell_t a, cell_t b)
- static cell_t vm_max_asm (cell_t a, cell_t b)
- static cell_t vm_abs_asm (cell_t a)
- static int vm_clz (cell_t x)
- static int vm_ctz (cell_t x)
- static int vm_popcnt (cell_t x)
- static uint64_t vm_read_midr (void)
- static int vm_has_neon (void)
- static int vm_is_cortex_a72 (void)
- static void vm_prefetch (const void *addr)
- static void vm_prefetch_stream (const void *addr)
- static void vm_dc_zva (void *addr)

7.266.1 Function Documentation

7.266.1.1 vm_abs_asm()

```
static cell_t vm_abs_asm (
            cell_t a )  [inline], [static]
```

7.266.1.2 vm_add_check_overflow()

```
static int vm_add_check_overflow (
            cell_t a,
            cell_t b,
            cell_t * result )  [inline], [static]
```

Fast addition with overflow detection using ARM64 ADDS instruction.

Parameters

a	First operand
b	Second operand
result	Pointer to store result

Returns

1 if overflow occurred, 0 otherwise

7.266.1.3 vm_clz()

```
static int vm_clz (
            cell_t x )  [inline], [static]
```

7.266.1.4 vm_ctz()

```
static int vm_ctz (
            cell_t x )  [inline], [static]
```

7.266.1.5 vm_dc_zva()

```
static void vm_dc_zva (
            void * addr )  [inline], [static]
```

7.266.1.6 vm_divmod()

```
static void vm_divmod (
            cell_t dividend,
            cell_t divisor,
            cell_t * quotient,
            cell_t * remainder )  [inline], [static]
```

Fast division with remainder using ARM64 SDIV and MSUB instructions.

Parameters

dividend	Dividend value
divisor	Divisor value
quotient	Pointer to store quotient
remainder	Pointer to store remainder

7.266.1.7 vm_has_neon()

```
static int vm_has_neon (
            void  )  [inline], [static]
```

7.266.1.8 vm_is_cortex_a72()

```
static int vm_is_cortex_a72 (
            void  )  [inline], [static]
```

7.266.1.9 vm_max_asm()

```
static cell_t vm_max_asm (
             cell_t a,
             cell_t b )  [inline], [static]
```

7.266.1.10 vm_memcpy_asm()

```
static void vm_memcpy_asm (
             void * dest,
             const void * src,
             size_t len )  [inline], [static]
```

Optimized memory copy using ARM64 load/store pair instructions.

Parameters

dest	Destination buffer
src	Source buffer
len	Number of bytes to copy

7.266.1.11 vm_memzero_asm()

```
static void vm_memzero_asm (
             void * dest,
             size_t len )  [inline], [static]
```

Fast memory zeroing using ARM64 store pair instructions.

Parameters

dest	Buffer to zero
len	Number of bytes to zero

7.266.1.12 vm_min_asm()

```
static cell_t vm_min_asm (
             cell_t a,
             cell_t b )  [inline], [static]
```

7.266.1.13 vm_mul_double()

```
static void vm_mul_double (
             cell_t a,
             cell_t b,
             cell_t * hi,
             cell_t * lo )  [inline], [static]
```

Fast 128-bit multiplication using ARM64 SMULH instruction.

Parameters

a	First operand
b	Second operand
hi	Pointer to store high 64 bits of result
lo	Pointer to store low 64 bits of result

7.266.1.14 vm_pop_asm()

```
static cell_t vm_pop_asm (
            VM * vm )  [inline], [static]
```

Optimized assembly implementation of data stack pop operation.

Parameters

vm	Pointer to VM instance

Returns

Popped value, or 0 on underflow

Note

Sets vm->error on stack underflow

References VM::data_stack, VM::dsp, and VM::error.

7.266.1.15 vm_popcnt()

```
static int vm_popcnt (
            cell_t x )  [inline], [static]
```

7.266.1.16 vm_prefetch()

```
static void vm_prefetch (
            const void * addr )  [inline], [static]
```

7.266.1.17 vm_prefetch_stream()

```
static void vm_prefetch_stream (
            const void * addr )  [inline], [static]
```

7.266.1.18 vm_push_asm()

```
static void vm_push_asm (
            VM * vm,
            cell_t value )  [inline], [static]
```

Optimized assembly implementation of data stack push operation.

Parameters

vm	Pointer to VM instance
value	Value to push onto data stack

Note

Sets vm->error on stack overflow

References VM::data_stack, VM::dsp, and VM::error.

7.266.1.19 vm_read_midr()

```
static uint64_t vm_read_midr (
            void  )  [inline], [static]
```

7.266.1.20 vm_rpop_asm()

```
static cell_t vm_rpop_asm (
            VM * vm )  [inline], [static]
```

Optimized assembly implementation of return stack pop operation.

Parameters

vm	Pointer to VM instance

Returns

Popped value, or 0 on underflow

Note

Sets vm->error on stack underflow

References VM::error, VM::return_stack, and VM::rsp.

7.266.1.21 vm_rpush_asm()

```
static void vm_rpush_asm (
            VM * vm,
            cell_t value )  [inline], [static]
```

Optimized assembly implementation of return stack push operation.

Parameters

vm	Pointer to VM instance
value	Value to push onto return stack

Note

Sets vm->error on stack overflow

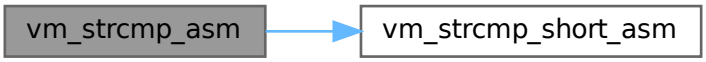
References VM::error, VM::return_stack, and VM::rsp.

7.266.1.22 vm_strcmp_asm()

```
static int vm_strcmp_asm (
            const char * s1,
            const char * s2,
            size_t len )  [inline], [static]
```

References vm_strcmp_short_asm().

Here is the call graph for this function:



7.266.1.23 vm_strcmp_short_asm()

```
static int vm_strcmp_short_asm (
            const char * s1,
            const char * s2,
            size_t len )  [inline], [static]
```

Optimized string comparison for short strings (<=32 bytes)

Parameters

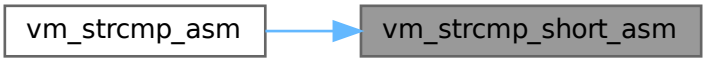
s1	First string
s2	Second string
len	Length to compare

Returns

0 if equal, 1 if different

Referenced by vm_strcmp_asm().

Here is the caller graph for this function:



7.266.1.24 vm_sub_check_overflow()

```
static int vm_sub_check_overflow (
            cell_t a,
            cell_t b,
            cell_t * result )  [inline], [static]
```

Fast subtraction with overflow detection using ARM64 SUBS instruction.

Parameters

a	First operand
b	Second operand
result	Pointer to store result

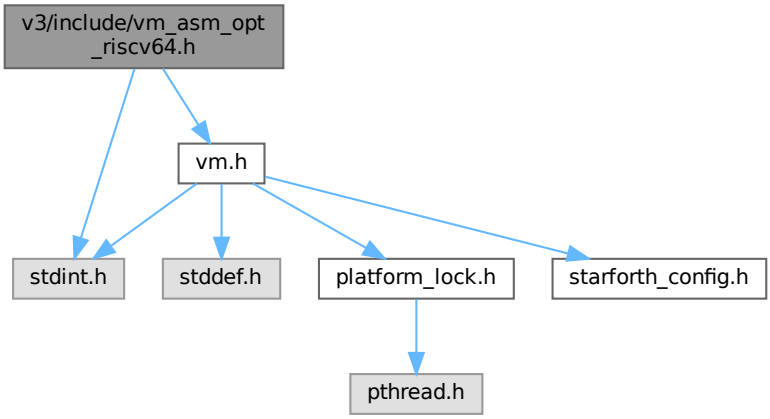
Returns

1 if overflow occurred, 0 otherwise

7.267 v3/include/vm_asm_opt_riscv64.h File Reference

```
#include "vm.h"
#include <stdint.h>
```

Include dependency graph for vm_asm_opt_riscv64.h:



Functions

- static void vm_push_asm (VM *vm, cell_t value)
- static cell_t vm_pop_asm (VM *vm)
- static void vm_rpush_asm (VM *vm, cell_t value)
- static cell_t vm_rpop_asm (VM *vm)
- static int vm_add_check_overflow (cell_t a, cell_t b, cell_t *result)
- static int vm_sub_check_overflow (cell_t a, cell_t b, cell_t *result)
- static void vm_mul_double (cell_t a, cell_t b, cell_t *hi, cell_t *lo)
- static void vm_divmod (cell_t dividend, cell_t divisor, cell_t *quotient, cell_t *remainder)
- static int vm_strcmp_asm (const char *s1, const char *s2, size_t len)
- static void vm_memcpy_asm (void *dest, const void *src, size_t len)
- static void vm_memzero_asm (void *dest, size_t len)
- static cell_t vm_min_asm (cell_t a, cell_t b)
- static cell_t vm_max_asm (cell_t a, cell_t b)
- static cell_t vm_abs_asm (cell_t a)
- static int vm_clz (cell_t x)
- static int vm_ctz (cell_t x)
- static int vm_popcnt (cell_t x)
- static void vm_prefetch (const void *addr)
- static void vm_prefetch_stream (const void *addr)
- static int vm_has_riscv_m_ext (void)
- static int vm_has_riscv_b_ext (void)

7.267.1 Function Documentation

7.267.1.1 vm_abs_asm()

```
static cell_t vm_abs_asm (
            cell_t a )  [inline], [static]
```

7.267.1.2 vm_add_check_overflow()

```
static int vm_add_check_overflow (
            cell_t a,
            cell_t b,
            cell_t * result )  [inline], [static]
```

7.267.1.3 vm_clz()

```
static int vm_clz (
            cell_t x )  [inline], [static]
```

7.267.1.4 vm_ctz()

```
static int vm_ctz (
            cell_t x )  [inline], [static]
```

7.267.1.5 vm_divmod()

```
static void vm_divmod (
            cell_t dividend,
            cell_t divisor,
            cell_t * quotient,
            cell_t * remainder )  [inline], [static]
```

7.267.1.6 vm_has_riscv_b_ext()

```
static int vm_has_riscv_b_ext (
            void  )  [inline], [static]
```

7.267.1.7 vm_has_riscv_m_ext()

```
static int vm_has_riscv_m_ext (
            void  )  [inline], [static]
```

7.267.1.8 vm_max_asm()

```
static cell_t vm_max_asm (
            cell_t a,
            cell_t b )  [inline], [static]
```

7.267.1.9 vm_memcpy_asm()

```
static void vm_memcpy_asm (
            void * dest,
            const void * src,
            size_t len )  [inline], [static]
```

7.267.1.10 vm_memzero_asm()

```
static void vm_memzero_asm (
            void * dest,
            size_t len )  [inline], [static]
```

7.267.1.11 vm_min_asm()

```
static cell_t vm_min_asm (
            cell_t a,
            cell_t b )  [inline], [static]
```

7.267.1.12 vm_mul_double()

```
static void vm_mul_double (
            cell_t a,
            cell_t b,
            cell_t * hi,
            cell_t * lo )  [inline], [static]
```

7.267.1.13 vm_pop_asm()

```
static cell_t vm_pop_asm (
            VM * vm )  [inline], [static]
```

References VM::data_stack, VM::dsp, and VM::error.

7.267.1.14 vm_popcnt()

```
static int vm_popcnt (
            cell_t x )  [inline], [static]
```

7.267.1.15 vm_prefetch()

```
static void vm_prefetch (
            const void * addr )  [inline], [static]
```

7.267.1.16 vm_prefetch_stream()

```
static void vm_prefetch_stream (
            const void * addr )  [inline], [static]
```

7.267.1.17 vm_push_asm()

```
static void vm_push_asm (
            VM * vm,
            cell_t value )  [inline], [static]
```

References VM::data_stack, VM::dsp, and VM::error.

7.267.1.18 vm_rpop_asm()

```
static cell_t vm_rpop_asm (
            VM * vm )  [inline], [static]
```

References VM::error, VM::return_stack, and VM::rsp.

7.267.1.19 vm_rpush_asm()

```
static void vm_rpush_asm (
            VM * vm,
            cell_t value )  [inline], [static]
```

References VM::error, VM::return_stack, and VM::rsp.

7.267.1.20 vm_strcmp_asm()

```
static int vm_strcmp_asm (
            const char * s1,
            const char * s2,
            size_t len )  [inline], [static]
```

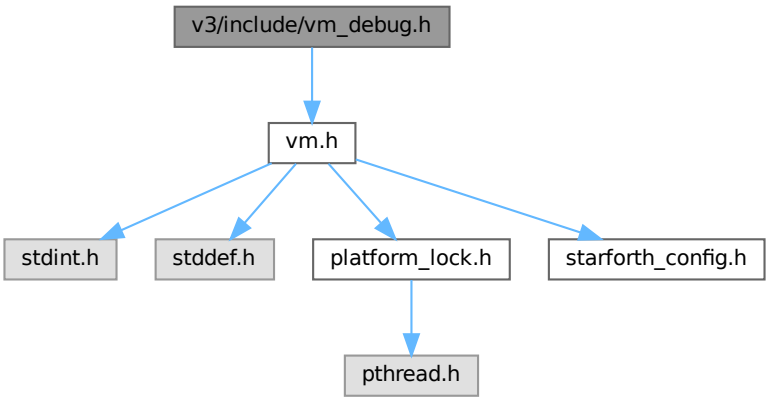
7.267.1.21 vm_sub_check_overflow()

```
static int vm_sub_check_overflow (
            cell_t a,
            cell_t b,
            cell_t * result )  [inline], [static]
```

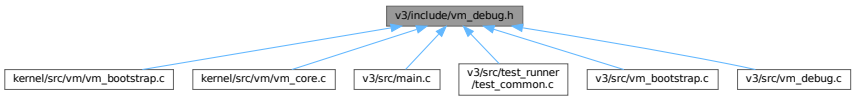
7.268 v3/include/vm_debug.h File Reference

```
#include "vm.h"
```

Include dependency graph for vm_debug.h:



This graph shows which files directly or indirectly include this file:



Functions

- void vm_debug_set_current_vm (VM *vm)

  Sets the VM instance to dump state for when signals occur.
- void vm_debug_install_signal_handlers (void)

  Installs signal handlers for SIGSEGV and SIGABRT.
- void vm_debug_dump_state (const VM *vm, const char *reason)

  Manually dumps the state of a VM instance.

7.268.1 Function Documentation

7.268.1.1 vm_debug_dump_state()

```
void vm_debug_dump_state (
            const VM * vm,
            const char * reason )
```

Manually dumps the state of a VM instance.

Parameters

vm	The VM instance to dump state for
reason	Description of why the dump was triggered

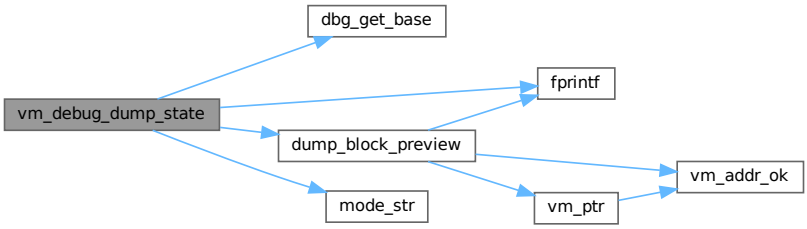
Note

Typically called before exit(1) on test failure

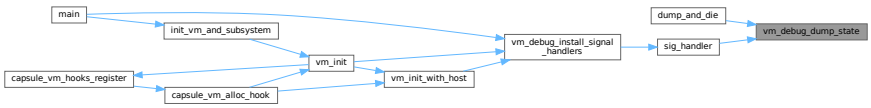
References base, VM::current_executing_entry, dbg_get_base(), VM::dsp, dump_block_preview(), VM::error, fprintf(), VM::here, VM::ip, VM::memory, VM::mode, mode_str(), DictEntry::name, VM::rsp, VM::scr_addr, stderr, and VM_MEMORY_SIZE.

Referenced by dump_and_die(), and sig_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.268.1.2 vm_debug_install_signal_handlers()

```
void vm_debug_install_signal_handlers (
            void  )
```

Installs signal handlers for SIGSEGV and SIGABRT.

The handlers will print VM state before re-raising the signal

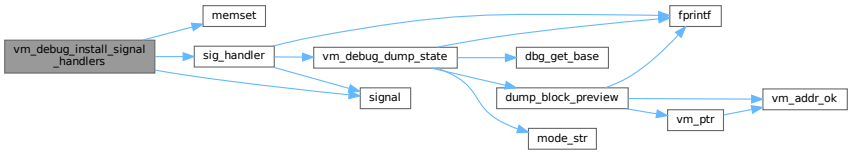
Installs signal handlers for SIGSEGV and SIGABRT.

Sets up handlers for SIGSEGV and SIGABRT to dump VM state on crash

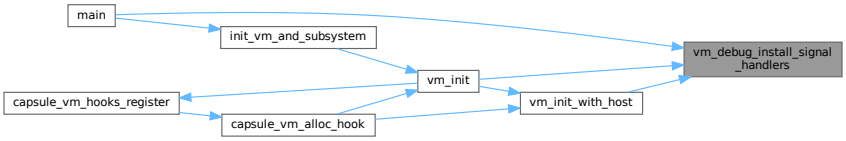
References memset(), sigaction::sa_flags, sigaction::sa_handler, SA_RESETHAND, sig_handler(), SIGABRT, signal(), and SIGSEGV.

Referenced by main(), vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.268.1.3 vm_debug_set_current_vm()

```
void vm_debug_set_current_vm (
            VM * vm )
```

Sets the VM instance to dump state for when signals occur.

Parameters

vm	Pointer to the VM instance to monitor

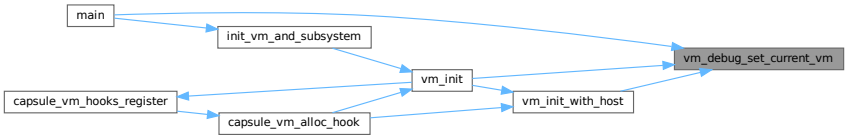
Note

Should be called once after vm_init

References g_vm.

Referenced by main(), vm_init(), and vm_init_with_host().

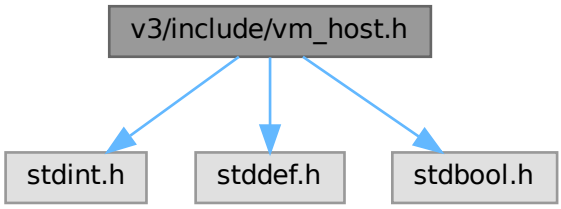
Here is the caller graph for this function:



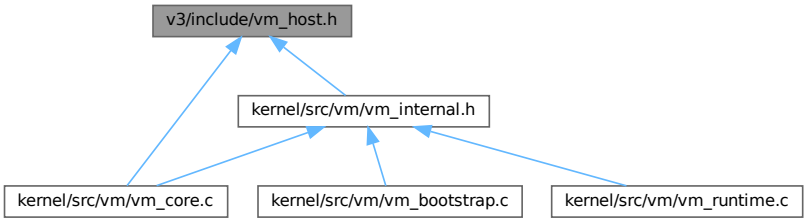
7.269 v3/include/vm_host.h File Reference

```
#include <stdint.h>
#include <stddef.h>
#include <stdbool.h>
```

Include dependency graph for vm_host.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct VMHostServices

  VMHostServices - pluggable host operations.

Macros

- #define SK_ALLOC(size) (sk_host_services()->alloc((size), sizeof(void*)))

  Initialize host services for kernel build.
- #define SK_ALLOC_ALIGNED(s, a) (sk_host_services()->alloc((s), (a)))
- #define SK_FREE(ptr) (sk_host_services()->free(ptr))
- #define SK_TIME_NS() (sk_host_services()->monotonic_ns())
- #define SK_PUTS(str) (sk_host_services()->puts(str))
- #define SK_PUTC(c) (sk_host_services()->putc(c))
- #define SK_MUTEX_INIT(m) (sk_host_services()->mutex_init(m))

  Mutex wrapper macros.
- #define SK_MUTEX_LOCK(m) (sk_host_services()->mutex_lock(m))
- #define SK_MUTEX_UNLOCK(m) (sk_host_services()->mutex_unlock(m))
- #define SK_MUTEX_DESTROY(m) (sk_host_services()->mutex_destroy(m))

Typedefs

- typedef void *(* sk_alloc_fn) (size_t size, size_t align)

  Host allocator function signature Returns NULL on failure.
- typedef void(* sk_free_fn) (void *ptr)

  Host free function signature.
- typedef uint64_t(* sk_time_fn) (void)

  Host monotonic time function signature Returns nanoseconds since arbitrary epoch In PARITY_MODE, returns deterministic fake time.
- typedef int(* sk_mutex_init_fn) (void *mutex)

  Host mutex operations (no-op in kernel single-threaded mode)
- typedef int(* sk_mutex_lock_fn) (void *mutex)
- typedef int(* sk_mutex_unlock_fn) (void *mutex)
- typedef void(* sk_mutex_destroy_fn) (void *mutex)
- typedef int(* sk_puts_fn) (const char *str)

  Host console output (for words that print) Returns number of bytes written, or -1 on error.
- typedef int(* sk_putc_fn) (int c)
- typedef bool(* sk_xt_validate_fn) (const void *ptr)

  Host execution-token validation Returns 1 if pointer is executable, 0 otherwise.
- typedef bool(* sk_xt_entry_owns_fn) (const void *entry, size_t bytes)

  Host dictionary entry ownership check.
- typedef void(* sk_panic_fn) (const char *message)

  Host fatal handler (panic)
- typedef struct VMHostServices VMHostServices

  VMHostServices - pluggable host operations.

Functions

- const VMHostServices * sk_host_services (void)

  Get the current host services instance.

7.269.1 Macro Definition Documentation

7.269.1.1 SK_ALLOC

```
#define SK_ALLOC(
              size ) (sk_host_services()->alloc((size), sizeof(void*)))
```

Initialize host services for kernel build.

Must be called before any VM operations. Convenience macros for common operations Use these instead of direct malloc/free/etc.

7.269.1.2 SK_ALLOC_ALIGNED

```
#define SK_ALLOC_ALIGNED(
              s,
              a ) (sk_host_services()->alloc((s), (a)))
```

7.269.1.3 SK_FREE

```
#define SK_FREE(
              ptr ) (sk_host_services()->free(ptr))
```

7.269.1.4 SK_MUTEX_DESTROY

```
#define SK_MUTEX_DESTROY(
              m ) (sk_host_services()->mutex_destroy(m))
```

7.269.1.5 SK_MUTEX_INIT

```
#define SK_MUTEX_INIT(
              m ) (sk_host_services()->mutex_init(m))
```

Mutex wrapper macros.

7.269.1.6 SK_MUTEX_LOCK

```
#define SK_MUTEX_LOCK(
              m ) (sk_host_services()->mutex_lock(m))
```

7.269.1.7 SK_MUTEX_UNLOCK

```
#define SK_MUTEX_UNLOCK(
              m ) (sk_host_services()->mutex_unlock(m))
```

7.269.1.8 SK_PUTC

```
#define SK_PUTC(
              c ) (sk_host_services()->putc(c))
```

7.269.1.9 SK_PUTS

```
#define SK_PUTS(
              str ) (sk_host_services()->puts(str))
```

7.269.1.10 SK_TIME_NS

```
#define SK_TIME_NS( ) (sk_host_services()->monotonic_ns())
```

7.269.2 Typedef Documentation

7.269.2.1 sk_alloc_fn

```
typedef void *(* sk_alloc_fn) (size_t size, size_t align)
```

Host allocator function signature Returns NULL on failure.

7.269.2.2 sk_free_fn

```
typedef void(* sk_free_fn) (void *ptr)
```

Host free function signature.

7.269.2.3 sk_mutex_destroy_fn

```
typedef void(* sk_mutex_destroy_fn) (void *mutex)
```

7.269.2.4 sk_mutex_init_fn

```
typedef int(* sk_mutex_init_fn) (void *mutex)
```

Host mutex operations (no-op in kernel single-threaded mode)

7.269.2.5 sk_mutex_lock_fn

```
typedef int(* sk_mutex_lock_fn) (void *mutex)
```

7.269.2.6 sk_mutex_unlock_fn

```
typedef int(* sk_mutex_unlock_fn) (void *mutex)
```

7.269.2.7 sk_panic_fn

```
typedef void(* sk_panic_fn) (const char *message)
```

Host fatal handler (panic)

7.269.2.8 sk_putc_fn

```
typedef int(* sk_putc_fn) (int c)
```

7.269.2.9 sk_puts_fn

```
typedef int(* sk_puts_fn) (const char *str)
```

Host console output (for words that print) Returns number of bytes written, or -1 on error.

7.269.2.10 sk_time_fn

```
typedef uint64_t(* sk_time_fn) (void)
```

Host monotonic time function signature Returns nanoseconds since arbitrary epoch In PARITY_MODE, returns deterministic fake time.

7.269.2.11 sk_xt_entry_owns_fn

```
typedef bool(* sk_xt_entry_owns_fn) (const void *entry, size_t bytes)
```

Host dictionary entry ownership check.

7.269.2.12 sk_xt_validate_fn

```
typedef bool(* sk_xt_validate_fn) (const void *ptr)
```

Host execution-token validation Returns 1 if pointer is executable, 0 otherwise.

7.269.2.13 VMHostServices

```
typedef struct VMHostServices VMHostServices
```

VMHostServices - pluggable host operations.

Hosted builds point these at libc functions. Kernel builds point these at kernel implementations.

7.269.3 Function Documentation

7.269.3.1 sk_host_services()

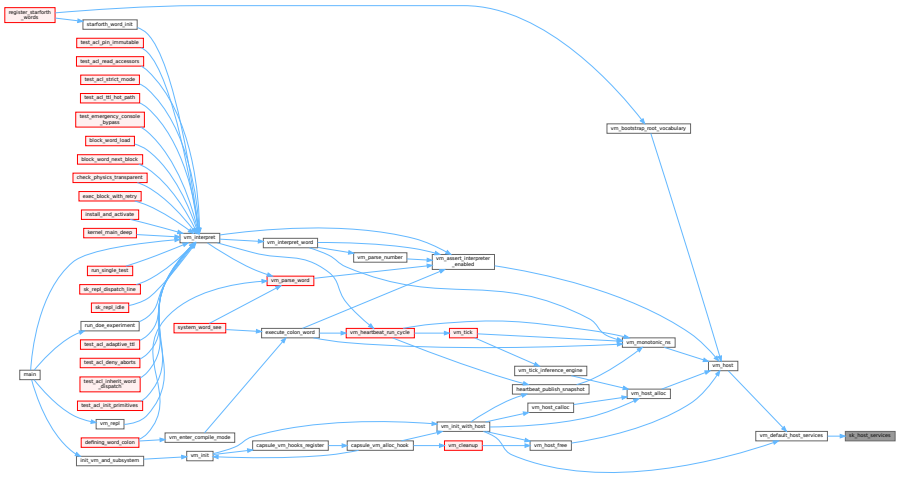
```
const VMHostServices * sk_host_services (
            void  )
```

Get the current host services instance.

Returns hosted or kernel services depending on build.

Referenced by vm_default_host_services().

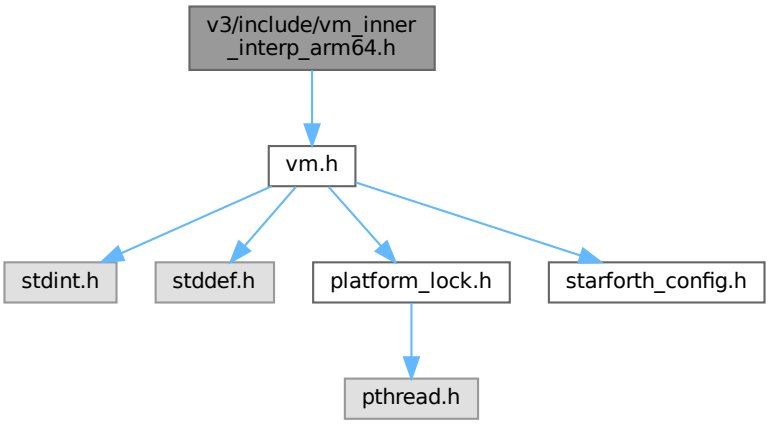
Here is the caller graph for this function:



7.270 v3/include/vm_inner_interp_arm64.h File Reference

```
#include "vm.h"
```

Include dependency graph for vm_inner_interp_arm64.h:



Macros

- #define NEXT_ARM64()
- #define PRIM_DUP_ARM64()

  DUP primitive - duplicates top of stack item.
- #define PRIM_DROP_ARM64()
- #define PRIM_SWAP_ARM64()
- #define PRIM_OVER_ARM64()
- #define PRIM_ROT_ARM64()
- #define PRIM_PLUS_ARM64()
- #define PRIM_MINUS_ARM64()
- #define PRIM_STAR_ARM64()
- #define PRIM_SLASH_ARM64()
- #define PRIM_MOD_ARM64()
- #define PRIM_AND_ARM64()
- #define PRIM_OR_ARM64()
- #define PRIM_XOR_ARM64()
- #define PRIM_INVERT_ARM64()
- #define PRIM_NEGATE_ARM64()
- #define PRIM_FETCH_ARM64()
- #define PRIM_STORE_ARM64()
- #define PRIM_C_FETCH_ARM64()
- #define PRIM_C_STORE_ARM64()
- #define PRIM_TO_R_ARM64()
- #define PRIM_R_FROM_ARM64()
- #define PRIM_R_FETCH_ARM64()
- #define PRIM_2DUP_ARM64()
- #define PRIM_2DROP_ARM64()
- #define PRIM_ZERO_EQUALS_ARM64()
- #define PRIM_ZERO_LESS_ARM64()
- #define PRIM_EQUALS_ARM64()
- #define PRIM_LESS_ARM64()
- #define PRIM_GREATER_ARM64()
- #define PRIM_BRANCH_ARM64()
- #define PRIM_ZBRANCH_ARM64()
- #define PRIM_EXECUTE_ARM64()

Functions

- static void vm_docol_arm64 (VM *vm)
- static void vm_exit_arm64 (void)
- static void vm_setup_registers_arm64 (VM *vm)
- static void vm_save_registers_arm64 (VM *vm)

7.270.1 Macro Definition Documentation

7.270.1.1 NEXT_ARM64

```
#define NEXT_ARM64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ldr     x0, [x20], #8\n\t"       /* Load word ptr from [IP], IP += 8 */ \
        "br      x0\n\t"                  /* Branch to word */ \
        ::: "x0", "memory" \
    )
```

7.270.2 Function Documentation

7.270.2.1 vm_docol_arm64()

```
static void vm_docol_arm64 (
            VM * vm )  [inline], [static]
```

References VM::current_executing_entry, and entry.

7.270.2.2 vm_exit_arm64()

```
static void vm_exit_arm64 (
            void  )  [inline], [static]
```

7.270.2.3 vm_save_registers_arm64()

```
static void vm_save_registers_arm64 (
            VM * vm )  [inline], [static]
```

References VM::data_stack, VM::dsp, VM::ip, VM::return_stack, and VM::rsp.

7.270.2.4 vm_setup_registers_arm64()

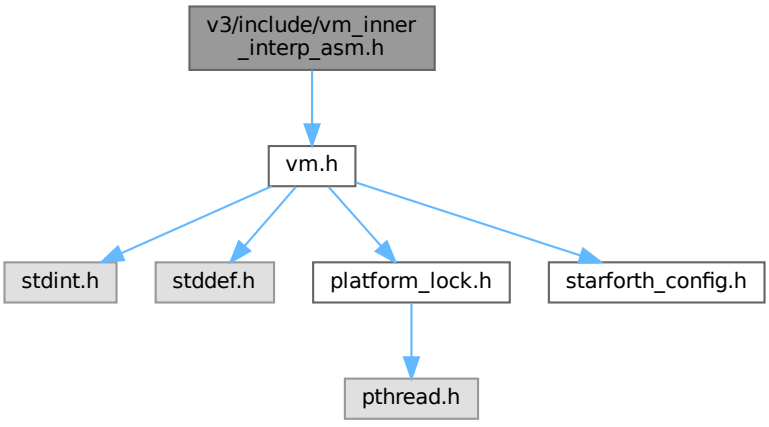
```
static void vm_setup_registers_arm64 (
            VM * vm )  [inline], [static]
```

References VM::data_stack, VM::dsp, VM::ip, VM::return_stack, and VM::rsp.

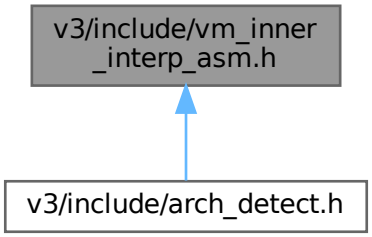
7.271 v3/include/vm_inner_interp_asm.h File Reference

```
#include "vm.h"
```

Include dependency graph for vm_inner_interp_asm.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define NEXT_ASM()

  Register allocation strategy for optimized execution.
- #define PRIM_DUP()
- #define PRIM_DROP()
- #define PRIM_SWAP()
- #define PRIM_PLUS()
- #define PRIM_MINUS()
- #define PRIM_STAR()
- #define PRIM_FETCH()
- #define PRIM_STORE()
- #define PRIM_TO_R()
- #define PRIM_R_FROM()
- #define PRIM_R_FETCH()
- #define PRIM_BRANCH()
- #define PRIM_ZBRANCH()
- #define PRIM_OVER()
- #define PRIM_ROT()
- #define PRIM_SLASH()
- #define PRIM_MOD()
- #define PRIM_AND()
- #define PRIM_OR()
- #define PRIM_XOR()
- #define PRIM_INVERT()
- #define PRIM_NEGATE()
- #define PRIM_C_FETCH()
- #define PRIM_C_STORE()
- #define PRIM_2DUP()
- #define PRIM_2DROP()
- #define PRIM_ZERO_EQUALS()
- #define PRIM_ZERO_LESS()
- #define PRIM_EQUALS()
- #define PRIM_LESS()
- #define PRIM_GREATER()
- #define PRIM_EXECUTE()

Functions

- static void vm_docol_asm (VM *vm)

  Enter a colon definition (DOCOL)
- static void vm_exit_asm (void)

  Return from a colon definition (EXIT)
- static void vm_setup_registers (VM *vm)

  Main interpreter loop implementation.
- static void vm_save_registers (VM *vm)

7.271.1 Macro Definition Documentation

7.271.1.1 NEXT_ASM

```
#define NEXT_ASM( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r13), %%rax\n\t"      /* Load word pointer from [IP] */ \
        "addq    $8, %%r13\n\t"           /* IP++ */ \
        "jmpq    *%%rax\n\t"              /* Jump to word's code */ \
        ::: "rax", "memory" \
    )
```

Register allocation strategy for optimized execution.

Register usage:

- r12 VM pointer (callee-saved, preserved across calls)
- r13 Instruction Pointer (IP) - points to current cell
- r14 Data Stack Pointer (DSP) - points to vm->data_stack[vm->dsp]
- r15 Return Stack Pointer (RSP) - points to vm->return_stack[vm->rsp]

Callee-saved registers are used because:

- They're preserved across function calls
- Allows mixing C and assembly code
- No need to save/restore on each word execution

Core inner interpreter macro - executes next word

Fetches next word pointer from IP, increments IP, and jumps to word

7.271.1.2 PRIM_2DROP

```
#define PRIM_2DROP( )
```

Value:

```
    __asm__ __volatile__ ( \
        "subq    $16, %%r14\n\t"          /* DSP -= 2 */ \
        ::: "r14" \
    )
```

7.271.1.3 PRIM_2DUP

```
#define PRIM_2DUP( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    -8(%%r14), %%rax\n\t"    /* Load NOS (a) */ \
        "movq    (%%r14), %%rcx\n\t"      /* Load TOS (b) */ \
        "movq    %%rax, 8(%%r14)\n\t"     /* Store a above TOS */ \
        "movq    %%rcx, 16(%%r14)\n\t"    /* Store b above that */ \
        "addq    $16, %%r14\n\t"          /* DSP += 2 */ \
        ::: "rax", "rcx", "r14", "memory" \
    )
```

7.271.1.4 PRIM_AND

```
#define PRIM_AND( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "andq    %%rax, -8(%%r14)\n\t"    /* NOS &= TOS */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "r14", "cc", "memory" \
    )
```

7.271.1.5 PRIM_BRANCH

```
#define PRIM_BRANCH( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r13), %%rax\n\t"      /* Load offset from IP */ \
        "addq    %%rax, %%r13\n\t"        /* IP += offset */ \
        ::: "rax", "r13", "memory" \
    )
```

7.271.1.6 PRIM_C_FETCH

```
#define PRIM_C_FETCH( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load address from TOS */ \
        "movq    (%%r12), %%rcx\n\t"      /* Load VM->memory */ \
        "movzbq  (%%rcx, %%rax, 1), %%rax\n\t"  /* Load byte, zero-extend */ \
        "movq    %%rax, (%%r14)\n\t"      /* Store byte value to TOS */ \
        ::: "rax", "rcx", "memory" \
    )
```

7.271.1.7 PRIM_C_STORE

```
#define PRIM_C_STORE( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load address from TOS */ \
        "movq    -8(%%r14), %%rcx\n\t"    /* Load byte value from NOS */ \
        "movq    (%%r12), %%rdx\n\t"      /* Load VM->memory */ \
        "movb    %%cl, (%%rdx, %%rax, 1)\n\t"  /* Store byte */ \
        "subq    $16, %%r14\n\t"          /* DSP -= 2 */ \
        ::: "rax", "rcx", "rdx", "r14", "memory" \
    )
```

7.271.1.8 PRIM_DROP

```
#define PRIM_DROP( )
```

Value:

```
    __asm__ __volatile__ ( \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "r14" \
    )
```

7.271.1.9 PRIM_DUP

```
#define PRIM_DUP( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "addq    $8, %%r14\n\t"           /* DSP++ */ \
        "movq    %%rax, (%%r14)\n\t"      /* Store duplicate */ \
        ::: "rax", "r14", "memory" \
    )
```

7.271.1.10 PRIM_EQUALS

```
#define PRIM_EQUALS( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS (b) */ \
        "cmpq    %%rax, -8(%%r14)\n\t"    /* Compare NOS (a) with TOS (b) */ \
        "sete    %%al\n\t"                 /* AL = 1 if equal */ \
        "movzbq  %%al, %%rax\n\t"         /* Zero-extend */ \
        "negq    %%rax\n\t"               /* -1 if true, 0 if false */ \
        "movq    %%rax, -8(%%r14)\n\t"    /* Store result to NOS slot */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "r14", "cc", "memory" \
    )
```

7.271.1.11 PRIM_EXECUTE

```
#define PRIM_EXECUTE( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load xt from TOS */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        "jmpq    *%%rax\n\t"              /* Jump to execution token */ \
        ::: "rax", "r14", "memory" \
    )
```

7.271.1.12 PRIM_FETCH

```
#define PRIM_FETCH( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load address from TOS */ \
        "movq    (%%r12), %%rcx\n\t"      /* Load VM->memory */ \
        "movq    (%%rcx, %%rax, 1), %%rax\n\t"  /* Load cell from memory */ \
        "movq    %%rax, (%%r14)\n\t"      /* Store to TOS */ \
        ::: "rax", "rcx", "memory" \
    )
```

7.271.1.13 PRIM_GREATER

```
#define PRIM_GREATER( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rcx\n\t"      /* Load TOS (b) */ \
        "movq    -8(%%r14), %%rax\n\t"    /* Load NOS (a) */ \
        "cmpq    %%rcx, %%rax\n\t"        /* rax - rcx: signed compare a vs b */ \
        "setg    %%al\n\t"                 /* AL = 1 if a > b */ \
        "movzbq  %%al, %%rax\n\t"         /* Zero-extend */ \
        "negq    %%rax\n\t"               /* -1 if true, 0 if false */ \
        "movq    %%rax, -8(%%r14)\n\t"    /* Store result to NOS slot */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "rcx", "r14", "cc", "memory" \
    )
```

7.271.1.14 PRIM_INVERT

```
#define PRIM_INVERT( )
```

Value:

```
    __asm__ __volatile__ ( \
        "notq    (%%r14)\n\t"             /* TOS = ~TOS */ \
        ::: "memory" \
    )
```

7.271.1.15 PRIM_LESS

```
#define PRIM_LESS( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rcx\n\t"      /* Load TOS (b) */ \
        "movq    -8(%%r14), %%rax\n\t"    /* Load NOS (a) */ \
        "cmpq    %%rcx, %%rax\n\t"        /* rax - rcx: signed compare a vs b */ \
        "setl    %%al\n\t"                 /* AL = 1 if a < b */ \
        "movzbq  %%al, %%rax\n\t"         /* Zero-extend */ \
        "negq    %%rax\n\t"               /* -1 if true, 0 if false */ \
        "movq    %%rax, -8(%%r14)\n\t"    /* Store result to NOS slot */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "rcx", "r14", "cc", "memory" \
    )
```

7.271.1.16 PRIM_MINUS

```
#define PRIM_MINUS( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "subq    %%rax, -8(%%r14)\n\t"    /* Subtract from NOS */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "r14", "cc", "memory" \
    )
```

7.271.1.17 PRIM_MOD

```
#define PRIM_MOD( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    -8(%%r14), %%rax\n\t"    /* Load dividend (NOS) */ \
        "cqo\n\t"                          /* Sign-extend */ \
        "idivq   (%%r14)\n\t"              /* rdx = remainder */ \
        "movq    %%rdx, -8(%%r14)\n\t"    /* Store remainder to NOS slot */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "rdx", "r14", "cc", "memory" \
    )
```

7.271.1.18 PRIM_NEGATE

```
#define PRIM_NEGATE( )
```

Value:

```
    __asm__ __volatile__ ( \
        "negq    (%%r14)\n\t"            /* TOS = -TOS */ \
        ::: "cc", "memory" \
    )
```

7.271.1.19 PRIM_OR

```
#define PRIM_OR( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "orq     %%rax, -8(%%r14)\n\t"    /* NOS |= TOS */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "r14", "cc", "memory" \
    )
```

7.271.1.20 PRIM_OVER

```
#define PRIM_OVER( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    -8(%%r14), %%rax\n\t"    /* Load NOS */ \
        "addq    $8, %%r14\n\t"           /* DSP++ */ \
        "movq    %%rax, (%%r14)\n\t"      /* Store NOS as new TOS */ \
        ::: "rax", "r14", "memory" \
    )
```

7.271.1.21 PRIM_PLUS

```
#define PRIM_PLUS( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "addq    %%rax, -8(%%r14)\n\t"    /* Add to NOS */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "r14", "cc", "memory" \
    )
```

7.271.1.22 PRIM_R_FETCH

```
#define PRIM_R_FETCH( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    -8(%%r15), %%rax\n\t"    /* Load from top of return stack */ \
        "addq    $8, %%r14\n\t"           /* DSP++ */ \
        "movq    %%rax, (%%r14)\n\t"      /* Store to TOS */ \
        ::: "rax", "r14", "memory" \
    )
```

7.271.1.23 PRIM_R_FROM

```
#define PRIM_R_FROM( )
```

Value:

```
    __asm__ __volatile__ ( \
        "subq    $8, %%r15\n\t"           /* RSP-- */ \
        "movq    (%%r15), %%rax\n\t"      /* Load from return stack */ \
        "addq    $8, %%r14\n\t"           /* DSP++ */ \
        "movq    %%rax, (%%r14)\n\t"      /* Store to TOS */ \
        ::: "rax", "r14", "r15", "memory" \
    )
```

7.271.1.24 PRIM_ROT

```
#define PRIM_ROT( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* c = TOS */ \
        "movq    -8(%%r14), %%rcx\n\t"    /* b = NOS */ \
        "movq    -16(%%r14), %%rdx\n\t"   /* a = third */ \
        "movq    %%rdx, -8(%%r14)\n\t"    /* a -> NOS */ \
        "movq    %%rax, -16(%%r14)\n\t"   /* c -> third */ \
        "movq    %%rcx, (%%r14)\n\t"      /* b -> TOS */ \
        ::: "rax", "rcx", "rdx", "memory" \
    )
```

7.271.1.25 PRIM_SLASH

```
#define PRIM_SLASH( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    -8(%%r14), %%rax\n\t"    /* Load dividend (NOS) */ \
        "cqo\n\t"                          /* Sign-extend rax to rdx:rax */ \
        "idivq   (%%r14)\n\t"              /* Divide by TOS */ \
        "movq    %%rax, -8(%%r14)\n\t"    /* Store quotient to NOS slot */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "rdx", "r14", "cc", "memory" \
    )
```

7.271.1.26 PRIM_STAR

```
#define PRIM_STAR( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "imulq   -8(%%r14), %%rax\n\t"    /* Multiply with NOS */ \
        "movq    %%rax, -8(%%r14)\n\t"    /* Store result */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "rdx", "r14", "cc", "memory" \
    )
```

7.271.1.27 PRIM_STORE

```
#define PRIM_STORE( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load address from TOS */ \
        "movq    -8(%%r14), %%rcx\n\t"    /* Load value from NOS */ \
        "movq    (%%r12), %%rdx\n\t"      /* Load VM->memory */ \
        "movq    %%rcx, (%%rdx, %%rax, 1)\n\t"  /* Store to memory */ \
        "subq    $16, %%r14\n\t"          /* DSP -= 2 */ \
        ::: "rax", "rcx", "rdx", "r14", "memory" \
    )
```

7.271.1.28 PRIM_SWAP

```
#define PRIM_SWAP( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "movq    -8(%%r14), %%rcx\n\t"    /* Load NOS */ \
        "movq    %%rcx, (%%r14)\n\t"      /* Store NOS to TOS */ \
        "movq    %%rax, -8(%%r14)\n\t"    /* Store TOS to NOS */ \
        ::: "rax", "rcx", "memory" \
    )
```

7.271.1.29 PRIM_TO_R

```
#define PRIM_TO_R( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load from TOS */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        "movq    %%rax, (%%r15)\n\t"      /* Store to return stack */ \
        "addq    $8, %%r15\n\t"           /* RSP++ */ \
        ::: "rax", "r14", "r15", "memory" \
    )
```

7.271.1.30 PRIM_XOR

```
#define PRIM_XOR( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "xorq    %%rax, -8(%%r14)\n\t"    /* NOS ^= TOS */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        ::: "rax", "r14", "cc", "memory" \
    )
```

7.271.1.31 PRIM_ZBRANCH

```
#define PRIM_ZBRANCH( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "subq    $8, %%r14\n\t"           /* DSP-- */ \
        "testq   %%rax, %%rax\n\t"        /* Test if zero */ \
        "jnz     1f\n\t"                  /* Skip if non-zero */ \
        "movq    (%%r13), %%rax\n\t"      /* Load offset */ \
        "addq    %%rax, %%r13\n\t"        /* IP += offset */ \
        "jmp     2f\n\t" \
        "1:\n\t" \
        "addq    $8, %%r13\n\t"           /* Skip offset */ \
        "2:\n\t" \
        ::: "rax", "r13", "r14", "cc", "memory" \
    )
```

7.271.1.32 PRIM_ZERO_EQUALS

```
#define PRIM_ZERO_EQUALS( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "testq   %%rax, %%rax\n\t"        /* Test for zero */ \
        "sete    %%al\n\t"                 /* AL = 1 if zero */ \
        "movzbq  %%al, %%rax\n\t"         /* Zero-extend */ \
        "negq    %%rax\n\t"               /* -1 if true, 0 if false */ \
        "movq    %%rax, (%%r14)\n\t"      /* Store result */ \
        ::: "rax", "cc", "memory" \
    )
```

7.271.1.33 PRIM_ZERO_LESS

```
#define PRIM_ZERO_LESS( )
```

Value:

```
    __asm__ __volatile__ ( \
        "movq    (%%r14), %%rax\n\t"      /* Load TOS */ \
        "sarq    $63, %%rax\n\t"          /* Arithmetic shift: -1 if negative, 0 otherwise */ \
        "movq    %%rax, (%%r14)\n\t"      /* Store result */ \
        ::: "rax", "cc", "memory" \
    )
```

7.271.2 Function Documentation

7.271.2.1 vm_docol_asm()

```
static void vm_docol_asm (
            VM * vm )  [inline], [static]
```

Enter a colon definition (DOCOL)

Parameters

vm	Pointer to VM instance

Called when executing a user-defined word

References VM::current_executing_entry, and entry.

7.271.2.2 vm_exit_asm()

```
static void vm_exit_asm (
            void  )  [inline], [static]
```

Return from a colon definition (EXIT)

Pops IP from return stack and continues execution

7.271.2.3 vm_save_registers()

```
static void vm_save_registers (
            VM * vm )  [inline], [static]
```

References VM::data_stack, VM::dsp, VM::ip, VM::return_stack, and VM::rsp.

7.271.2.4 vm_setup_registers()

```
static void vm_setup_registers (
            VM * vm )  [inline], [static]
```

Main interpreter loop implementation.

Replaces execute_colon_word function with optimized assembly

Usage example:

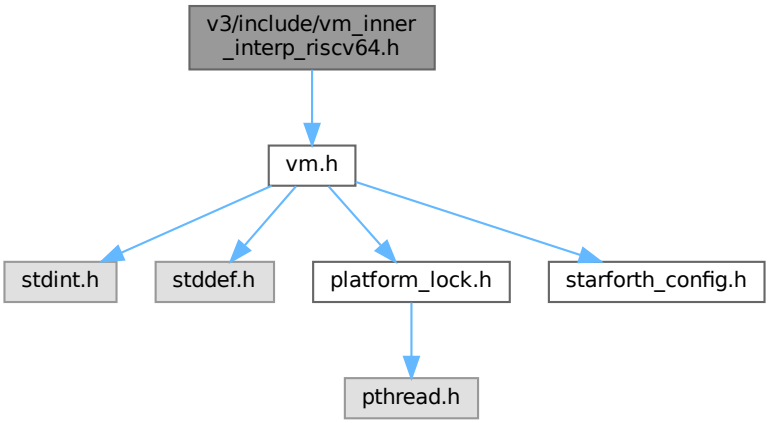
```
vm_setup_registers(vm);
VM_INNER_LOOP();
```

References VM::data_stack, VM::dsp, VM::ip, VM::return_stack, and VM::rsp.

7.272 v3/include/vm_inner_interp_riscv64.h File Reference

```
#include "vm.h"
```

Include dependency graph for vm_inner_interp_riscv64.h:



Macros

- #define NEXT_RV64()
- #define PRIM_DUP_RV64()
- #define PRIM_DROP_RV64()
- #define PRIM_SWAP_RV64()
- #define PRIM_OVER_RV64()
- #define PRIM_ROT_RV64()
- #define PRIM_PLUS_RV64()
- #define PRIM_MINUS_RV64()
- #define PRIM_STAR_RV64()
- #define PRIM_SLASH_RV64()
- #define PRIM_MOD_RV64()
- #define PRIM_AND_RV64()
- #define PRIM_OR_RV64()
- #define PRIM_XOR_RV64()
- #define PRIM_INVERT_RV64()
- #define PRIM_NEGATE_RV64()
- #define PRIM_FETCH_RV64()
- #define PRIM_STORE_RV64()
- #define PRIM_C_FETCH_RV64()
- #define PRIM_C_STORE_RV64()
- #define PRIM_TO_R_RV64()
- #define PRIM_R_FROM_RV64()
- #define PRIM_R_FETCH_RV64()
- #define PRIM_2DUP_RV64()
- #define PRIM_2DROP_RV64()
- #define PRIM_ZERO_EQUALS_RV64()
- #define PRIM_ZERO_LESS_RV64()

- #define PRIM_EQUALS_RV64()
- #define PRIM_LESS_RV64()
- #define PRIM_GREATER_RV64()
- #define PRIM_BRANCH_RV64()
- #define PRIM_ZBRANCH_RV64()
- #define PRIM_EXECUTE_RV64()

Functions

- static void vm_docol_rv64 (VM *vm)
- static void vm_exit_rv64 (void)
- static void vm_setup_registers_rv64 (VM *vm)
- static void vm_save_registers_rv64 (VM *vm)

7.272.1 Macro Definition Documentation

7.272.1.1 NEXT_RV64

```
#define NEXT_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s3)\n\t"    /* a0 = *IP                */ \
        "addi    s3, s3, 8\n\t"    /* IP++                    */ \
        "jr      a0\n\t"           /* jump to code field      */ \
        ::: "a0", "memory" \
    )
```

7.272.1.2 PRIM_2DROP_RV64

```
#define PRIM_2DROP_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      s6, -8(s4)\n\t"   /* new TOS = item3         */ \
        "addi    s4, s4, -16\n\t" \
        ::: "s4", "s6", "memory" \
    )
```

7.272.1.3 PRIM_2DUP_RV64

```
#define PRIM_2DUP_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = NOS                */ \
        "addi    s4, s4, 8\n\t" \
        "sd      a0, 0(s4)\n\t"    /* push NOS                */ \
        "addi    s4, s4, 8\n\t" \
        "sd      s6, 0(s4)\n\t"    /* push TOS copy           */ \
        ::: "a0", "s4", "memory" \
    )
```

7.272.1.4 PRIM_AND_RV64

```
#define PRIM_AND_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        "and     s6, s6, a0\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.5 PRIM_BRANCH_RV64

```
#define PRIM_BRANCH_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s3)\n\t"    /* offset                  */ \
        "add     s3, s3, a0\n\t"   /* IP += offset            */ \
        ::: "a0", "s3", "memory" \
    )
```

7.272.1.6 PRIM_C_FETCH_RV64

```
#define PRIM_C_FETCH_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s2)\n\t" \
        "add     a0, a0, s6\n\t" \
        "lbu     s6, 0(a0)\n\t"    /* zero-extend byte        */ \
        ::: "a0", "s6", "memory" \
    )
```

7.272.1.7 PRIM_C_STORE_RV64

```
#define PRIM_C_STORE_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = addr               */ \
        "addi    s4, s4, -8\n\t" \
        "ld      a1, 0(s2)\n\t" \
        "add     a1, a1, a0\n\t" \
        "sb      s6, 0(a1)\n\t" \
        "ld      s6, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        ::: "a0", "a1", "s4", "s6", "memory" \
    )
```

7.272.1.8 PRIM_DROP_RV64

```
#define PRIM_DROP_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      s6, -8(s4)\n\t"   /* new TOS = NOS           */ \
        "addi    s4, s4, -8\n\t"   /* DSP--                   */ \
        ::: "s4", "s6", "memory" \
    )
```

7.272.1.9 PRIM_DUP_RV64

```
#define PRIM_DUP_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "addi    s4, s4, 8\n\t"    /* DSP++                    */ \
        "sd      s6, 0(s4)\n\t"    /* push TOS copy            */ \
        ::: "s4", "memory" \
    )
```

7.272.1.10 PRIM_EQUALS_RV64

```
#define PRIM_EQUALS_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        "sub     s6, a0, s6\n\t" \
        "seqz    s6, s6\n\t" \
        "neg     s6, s6\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.11 PRIM_EXECUTE_RV64

```
#define PRIM_EXECUTE_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "mv      a0, s6\n\t"       /* a0 = xt                  */ \
        "ld      s6, 0(s4)\n\t"    /* new TOS                  */ \
        "addi    s4, s4, -8\n\t" \
        "jr      a0\n\t"           /* jump to xt               */ \
        ::: "a0", "s4", "s6", "memory" \
    )
```

7.272.1.12 PRIM_FETCH_RV64

```
#define PRIM_FETCH_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s2)\n\t"    /* a0 = vm->memory          */ \
        "add     a0, a0, s6\n\t"   /* a0 = &memory[TOS]        */ \
        "ld      s6, 0(a0)\n\t"    /* TOS = memory[TOS]        */ \
        ::: "a0", "s6", "memory" \
    )
```

7.272.1.13 PRIM_GREATER_RV64

```
#define PRIM_GREATER_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        "slt     s6, s6, a0\n\t"   /* 1 if TOS < NOS, i.e. NOS > TOS */ \
        "neg     s6, s6\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.14 PRIM_INVERT_RV64

```
#define PRIM_INVERT_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "not     s6, s6\n\t" \
        ::: "s6" \
    )
```

7.272.1.15 PRIM_LESS_RV64

```
#define PRIM_LESS_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = NOS                */ \
        "addi    s4, s4, -8\n\t" \
        "slt     s6, a0, s6\n\t"   /* 1 if NOS < TOS          */ \
        "neg     s6, s6\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.16 PRIM_MINUS_RV64

```
#define PRIM_MINUS_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = NOS                */ \
        "addi    s4, s4, -8\n\t" \
        "sub     s6, a0, s6\n\t"   /* TOS = NOS - TOS         */ \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.17 PRIM_MOD_RV64

```
#define PRIM_MOD_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        "rem     s6, a0, s6\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.18 PRIM_NEGATE_RV64

```
#define PRIM_NEGATE_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "neg     s6, s6\n\t" \
        ::: "s6" \
    )
```

7.272.1.19 PRIM_OR_RV64

```
#define PRIM_OR_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        "or      s6, s6, a0\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.20 PRIM_OVER_RV64

```
#define PRIM_OVER_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = NOS               */ \
        "addi    s4, s4, 8\n\t"    /* DSP++                  */ \
        "sd      s6, 0(s4)\n\t"    /* push old TOS           */ \
        "mv      s6, a0\n\t"       /* TOS = NOS              */ \
        ::: "a0", "s4", "s6", "memory" \
    )
```

7.272.1.21 PRIM_PLUS_RV64

```
#define PRIM_PLUS_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        "add     s6, s6, a0\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.22 PRIM_R_FETCH_RV64

```
#define PRIM_R_FETCH_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "addi    s4, s4, 8\n\t" \
        "sd      s6, 0(s4)\n\t" \
        "ld      s6, 0(s5)\n\t"    /* TOS = RS top (no pop)   */ \
        ::: "s4", "s6", "memory" \
    )
```

7.272.1.23 PRIM_R_FROM_RV64

```
#define PRIM_R_FROM_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "addi    s4, s4, 8\n\t" \
        "sd      s6, 0(s4)\n\t"    /* push old TOS           */ \
        "ld      s6, 0(s5)\n\t"    /* TOS = RS top           */ \
        "addi    s5, s5, -8\n\t" \
        ::: "s4", "s5", "s6", "memory" \
    )
```

7.272.1.24 PRIM_ROT_RV64

```
#define PRIM_ROT_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = item2 (NOS)         */ \
        "ld      a1, -8(s4)\n\t"   /* a1 = item3               */ \
        "sd      a1, 0(s4)\n\t"    /* item3 -> NOS position    */ \
        "sd      s6, -8(s4)\n\t"   /* TOS -> item3 position    */ \
        "mv      s6, a0\n\t"       /* item2 -> TOS             */ \
        ::: "a0", "a1", "s6", "memory" \
    )
```

7.272.1.25 PRIM_SLASH_RV64

```
#define PRIM_SLASH_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = NOS (dividend)      */ \
        "addi    s4, s4, -8\n\t" \
        "div     s6, a0, s6\n\t"   /* TOS = NOS / TOS          */ \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.26 PRIM_STAR_RV64

```
#define PRIM_STAR_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        "mul     s6, s6, a0\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.27 PRIM_STORE_RV64

```
#define PRIM_STORE_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = addr (NOS)          */ \
        "addi    s4, s4, -8\n\t" \
        "ld      a1, 0(s2)\n\t"    /* a1 = vm->memory          */ \
        "add     a1, a1, a0\n\t" \
        "sd      s6, 0(a1)\n\t"    /* memory[addr] = TOS       */ \
        "ld      s6, 0(s4)\n\t"    /* load new TOS             */ \
        "addi    s4, s4, -8\n\t" \
        ::: "a0", "a1", "s4", "s6", "memory" \
    )
```

7.272.1.28 PRIM_SWAP_RV64

```
#define PRIM_SWAP_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t"    /* a0 = NOS                 */ \
        "sd      s6, 0(s4)\n\t"    /* NOS = old TOS            */ \
        "mv      s6, a0\n\t"       /* TOS = old NOS            */ \
        ::: "a0", "s6", "memory" \
    )
```

7.272.1.29 PRIM_TO_R_RV64

```
#define PRIM_TO_R_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "addi    s5, s5, 8\n\t" \
        "sd      s6, 0(s5)\n\t"    /* RS[top] = TOS           */ \
        "ld      s6, 0(s4)\n\t"    /* new TOS = NOS           */ \
        "addi    s4, s4, -8\n\t" \
        ::: "s4", "s5", "s6", "memory" \
    )
```

7.272.1.30 PRIM_XOR_RV64

```
#define PRIM_XOR_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s4)\n\t" \
        "addi    s4, s4, -8\n\t" \
        "xor     s6, s6, a0\n\t" \
        ::: "a0", "s4", "s6" \
    )
```

7.272.1.31 PRIM_ZBRANCH_RV64

```
#define PRIM_ZBRANCH_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "ld      a0, 0(s3)\n\t"    /* offset                  */ \
        "ld      s6, 0(s4)\n\t"    /* new TOS                 */ \
        "addi    s4, s4, -8\n\t" \
        /* if old TOS was zero: IP += offset; else IP += 8 */ \
        "bnez    s6, 1f\n\t"       /* skip branch if nonzero  */ \
        "add     s3, s3, a0\n\t" \
        "j       2f\n\t" \
        "1:\n\t" \
        "addi    s3, s3, 8\n\t" \
        "2:\n\t" \
        ::: "a0", "s3", "s4", "s6", "memory" \
    )
```

7.272.1.32 PRIM_ZERO_EQUALS_RV64

```
#define PRIM_ZERO_EQUALS_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "seqz    s6, s6\n\t"       /* 1 if zero, else 0       */ \
        "neg     s6, s6\n\t"       /* convert to -1 (true)    */ \
        ::: "s6" \
    )
```

7.272.1.33 PRIM_ZERO_LESS_RV64

```
#define PRIM_ZERO_LESS_RV64( )
```

Value:

```
    __asm__ __volatile__ ( \
        "srai    s6, s6, 63\n\t"   /* -1 if negative, 0 if >= 0 */ \
        ::: "s6" \
    )
```

7.272.2 Function Documentation

7.272.2.1 vm_docol_rv64()

```
static void vm_docol_rv64 (
            VM * vm )  [inline], [static]
```

References VM::current_executing_entry, and entry.

7.272.2.2 vm_exit_rv64()

```
static void vm_exit_rv64 (
            void  )  [inline], [static]
```

7.272.2.3 vm_save_registers_rv64()

```
static void vm_save_registers_rv64 (
            VM * vm )  [inline], [static]
```

References VM::data_stack, VM::dsp, VM::ip, VM::return_stack, and VM::rsp.

7.272.2.4 vm_setup_registers_rv64()

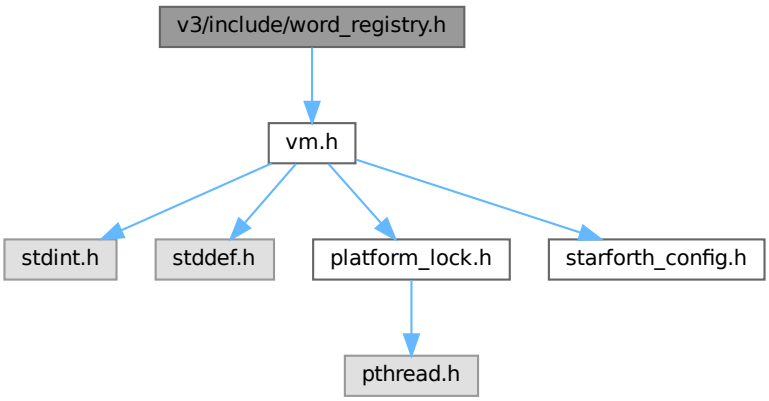
```
static void vm_setup_registers_rv64 (
            VM * vm )  [inline], [static]
```

References VM::data_stack, VM::dsp, VM::ip, VM::return_stack, and VM::rsp.

7.273 v3/include/word_registry.h File Reference

```
#include "vm.h"
```

Include dependency graph for word_registry.h:



This graph shows which files directly or indirectly include this file:

Functions

- void register_word (VM *vm, const char *name, word_func_t func)

  Registers a single FORTH word in the virtual machine.
- void register_forth79_words (VM *vm)

  Registers all standard FORTH-79 words in the virtual machine.

7.273.1 Function Documentation

7.273.1.1 register_forth79_words()

```
void register_forth79_words (
            VM * vm )
```

Registers all standard FORTH-79 words in the virtual machine.

Parameters

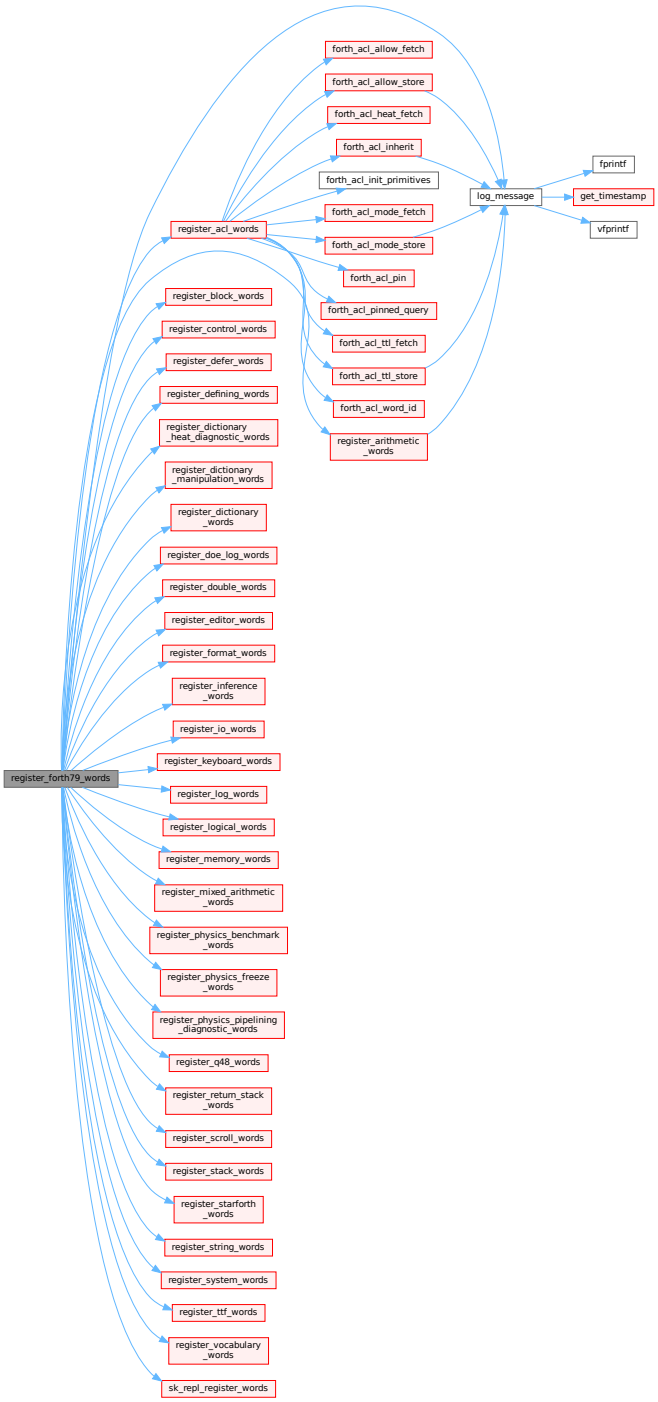
vm	Pointer to the virtual machine instance

Registers all 18 FORTH-79 word modules in dependency order, starting with fundamental stack operations and building up to more complex functionality like control flow and editing.

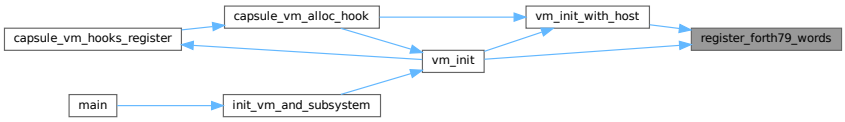
References LOG_INFO, log_message(), register_acl_words(), register_arithmetic_words(), register_block_words(), register_control_words(), register_defer_words(), register_defining_words(), register_dictionary_heat_diagnostic_words(), register_dictionary_manipulation_words(), register_dictionary_words(), register_doe_log_words(), register_double_words(), register_editor_words(), register_format_words(), register_inference_words(), register_io_words(), register_keyboard_words(), register_log_words(), register_logical_words(), register_memory_words(), register_mixed_arithmetic_words(), register_physics_benchmark_words(), register_physics_freeze_words(), register_physics_pipelining_diagnostic_words(), register_q48_words(), register_return_stack_words(), register_scroll_words(), register_stack_words(), register_starforth_words(), register_string_words(), register_system_words(), register_ttf_words(), register_vocabulary_words(), and sk_repl_register_words().

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.273.1.2 register_word()

```
void register_word (
            VM * vm,
            const char * name,
            word_func_t func )
```

Registers a single FORTH word in the virtual machine.

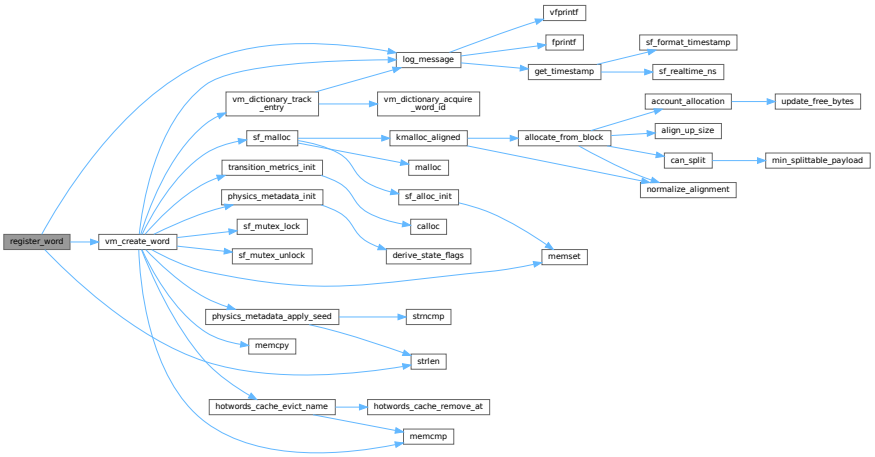
Parameters

vm	Pointer to the virtual machine instance
name	Name of the FORTH word to register
func	Function pointer to the word's implementation

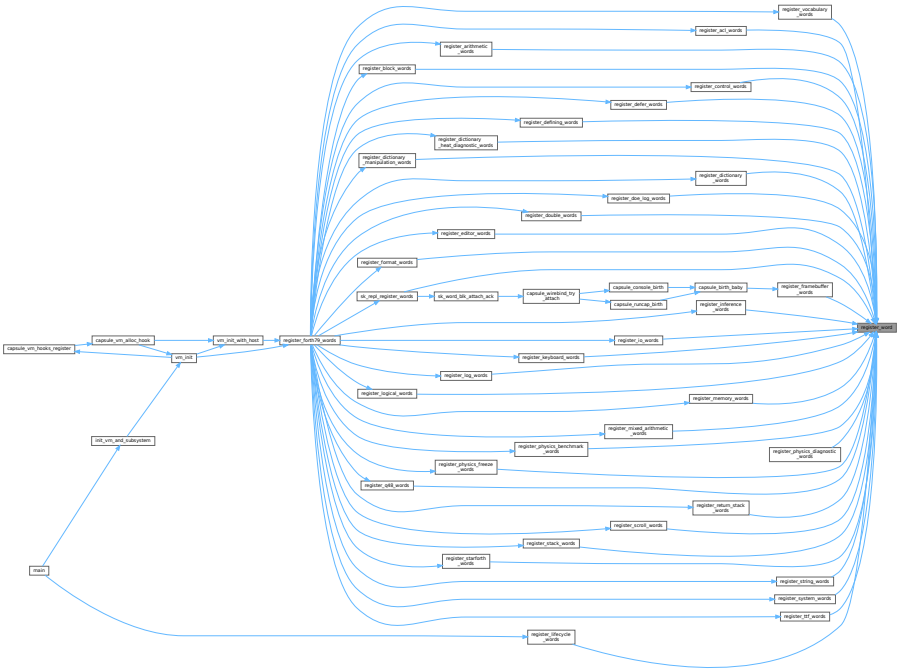
References entry, func, LOG_DEBUG, LOG_ERROR, log_message(), name, strlen(), and vm_create_word().

Referenced by register_acl_words(), register_arithmetic_words(), register_block_words(), register_control_words(), register_defer_words(), register_defining_words(), register_dictionary_heat_diagnostic_words(), register_dictionary_manipulation_wo register_dictionary_words(), register_doe_log_words(), register_double_words(), register_editor_words(), register_format_words(), register_framebuffer_words(), register_inference_words(), register_io_words(), register_keyboard_words(), register_lifecycle_words(), register_log_words(), register_logical_words(), register_memory_words(), register_mixed_arithmetic_word register_physics_benchmark_words(), register_physics_diagnostic_words(), register_physics_freeze_words(), register_q48_words(), register_return_stack_words(), register_scroll_words(), register_stack_words(), register_starforth_words(), register_string_words(), register_system_words(), register_ttf_words(), register_vocabulary_words(), and sk_repl_register_words().

Here is the call graph for this function:



Here is the caller graph for this function:

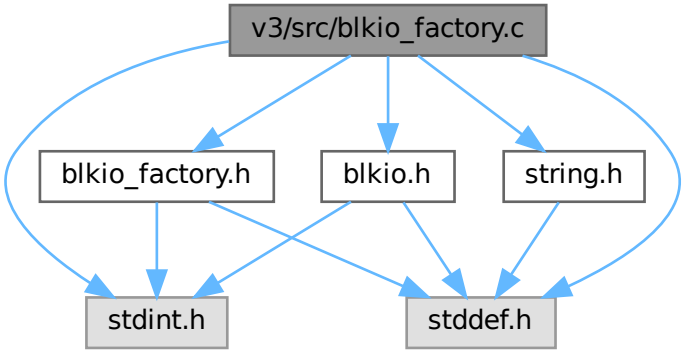


7.274 v3/src/blkio_factory.c File Reference

```
#include <stdint.h>
#include <stddef.h>
#include <string.h>
#include "blkio.h"
```

```
#include "blkio_factory.h"
```

Include dependency graph for blkio_factory.c:



Functions

- size_t blkio_file_state_size (void)

  Return the byte size required for a `blkio_file_state_t`.
- const blkio_vtable_t * blkio_file_vtable (void)

  Return the vtable for the file-backed block I/O backend.
- int blkio_file_init_state (void *state_mem, size_t state_len, const char *path, uint32_t total_blocks, uint32_t fbs, uint8_t read_only, uint8_t create_if_missing, uint8_t truncate_to_size, void **out_opaque)

  Initialise a `blkio_file_state_t` in caller-provided memory.
- size_t blkio_ram_state_size (void)

  Return the byte size required for a `blkio_ram_state_t`.
- const blkio_vtable_t * blkio_ram_vtable (void)

  Return the vtable for the RAM block I/O backend.
- int blkio_ram_init_state (void *state_mem, size_t state_len, uint8_t *base, uint32_t total_blocks, uint32_t fbs, uint8_t read_only, void **out_opaque)

  Initialise a `blkio_ram_state_t` in caller-provided memory.
- static int nonempty (const char *s)

  Return 1 if string `s` is non-NULL and non-empty.
- int blkio_factory_open (blkio_dev_t *dev, const char *disk_img_path, uint8_t read_only, uint32_t total_↩ blocks, uint32_t fbs, void *state_mem, size_t state_len, uint8_t *ram_base, uint32_t ram_blocks, uint8_t *out_used_file)

  Open a block I/O device using the best available backend.

7.274.1 Function Documentation

7.274.1.1 blkio_factory_open()

```
int blkio_factory_open (
            blkio_dev_t * dev,
            const char * disk_img_path,
```

```
    uint8_t read_only,
    uint32_t total_blocks,
    uint32_t fbs,
    void * state_mem,
    size_t state_len,
    uint8_t * ram_base,
    uint32_t ram_blocks,
    uint8_t * out_used_file )
```

Open a block I/O device using the best available backend.

Open a block device using either a file-backed image (if disk_img_path is non-empty) or a RAM-backed buffer (fallback).

Selects the file backend when `disk_img_path` is non-empty, otherwise falls back to the RAM backend using `ram_base` / `ram_blocks`.

File backend behaviour:

- Creates the file if it does not exist (unless `read_only` is set).
- Derives `total_blocks` from the file size when `total_blocks` == 0.
- Sets `*out_used_file` = 1 on success.

RAM backend behaviour:

- `ram_base` must point to at least `ram_blocks * fbs` bytes of caller-owned memory that outlives the device.

Parameters

dev	Output device handle to populate
disk_img_path	Path to disk image file, or NULL/empty for RAM
read_only	1 = open read-only, 0 = read-write
total_blocks	Desired block count (0 = derive from file size)
fbs	FORTH block size in bytes (0 = use `BLKIO_FORTH_BLOCK_SIZE`)
state_mem	Caller-allocated state buffer (must be large enough)
state_len	Size of `state_mem` in bytes
ram_base	Base of RAM block array (used only when no disk path)
ram_blocks	Number of blocks in `ram_base`
out_used_file	Optional output: set to 1 if the file backend was used

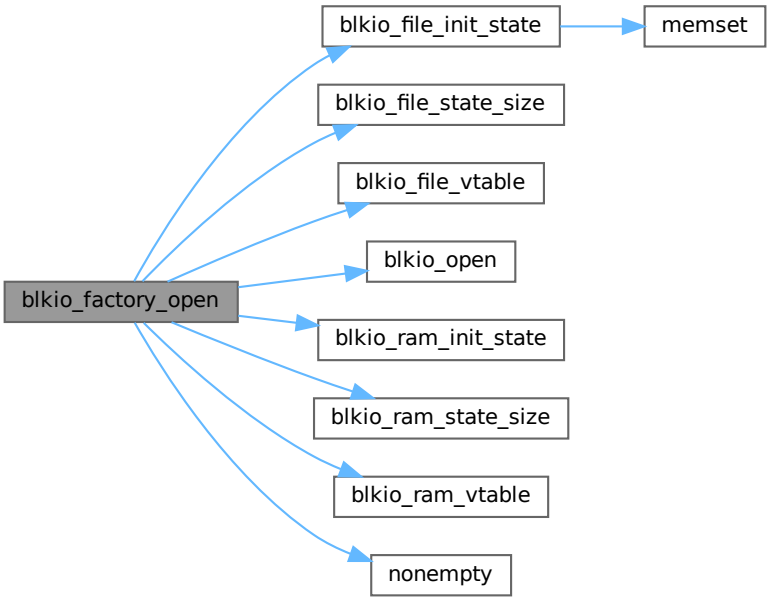
Returns

`BLKIO_OK` on success, or a `BLKIO_E*` error code

References BLKIO_EINVAL, BLKIO_ENOSPACE, blkio_file_init_state(), blkio_file_state_size(), blkio_file_vtable(), BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_open(), blkio_ram_init_state(), blkio_ram_state_size(), blkio_ram_vtable(), blkio_params_t::forth_block_size, nonempty(), and ram_base.

Referenced by init_blkio().

Here is the call graph for this function:



Here is the caller graph for this function:

7.274.1.2 blkio_file_init_state()

```
int blkio_file_init_state (
            void * state_mem,
            size_t state_len,
            const char * path,
            uint32_t total_blocks,
            uint32_t fbs,
            uint8_t read_only,
            uint8_t create_if_missing,
            uint8_t truncate_to_size,
            void ** out_opaque )  [extern]
```

Initialise a `blkio_file_state_t` in caller-provided memory.

Copies the path into state (truncated to PATH_MAX-1), sets `fbs`, `total_blocks`, and `read_only`, and writes the state pointer to `*out_opaque`. The file descriptor is initialised to -1; the actual `open()` call happens in `file_open()` (the vtable open method). `create_if_missing` and `truncate_to_size` are accepted for API compatibility but currently unused (creation is handled in `file_open()`).

Parameters

state_mem	Caller-allocated state buffer
state_len	Size of `state_mem` (must be >= blkio_file_state_size())
path	Path to the disk image file
total_blocks	Total block count (0 = derive from file size at open)
fbs	FORTH block size in bytes
read_only	1 = open read-only, 0 = read-write
create_if_missing	Ignored (reserved for future use)
truncate_to_size	Ignored (reserved for future use)
out_opaque	Output: set to `state_mem` on success

Returns

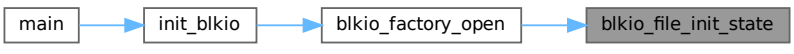
`BLKIO_OK` on success, `BLKIO_EINVAL` on bad arguments

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_file_state_t::fbs, blkio_file_state_t::fd, memset(), blkio_file_state_t::path, PATH_MAX, blkio_file_state_t::read_only, and blkio_file_state_t::total_blocks.

Referenced by blkio_factory_open().

Here is the call graph for this function:

Here is the caller graph for this function:



7.274.1.3 blkio_file_state_size()

```
size_t blkio_file_state_size (
            void  )  [extern]
```

Return the byte size required for a `blkio_file_state_t`.

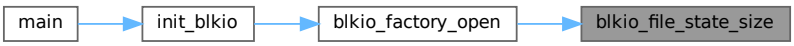
Used by `blkio_factory_open()` to verify the caller's state buffer is large enough before calling `blkio_file_init_state()`.

Returns

sizeof(blkio_file_state_t)

Referenced by blkio_factory_open().

Here is the caller graph for this function:



7.274.1.4 blkio_file_vtable()

```
const blkio_vtable_t * blkio_file_vtable (
            void  )  [extern]
```

Return the vtable for the file-backed block I/O backend.

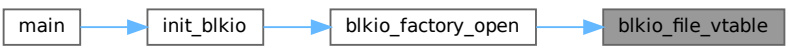
Returns

Pointer to the static `blkio_vtable_t` for file devices

References BLKIO_FILE_VT.

Referenced by blkio_factory_open().

Here is the caller graph for this function:



7.274.1.5 blkio_ram_init_state()

```
int blkio_ram_init_state (
            void * state_mem,
            size_t state_len,
            uint8_t * base,
            uint32_t total_blocks,
            uint32_t fbs,
            uint8_t read_only,
            void ** out_opaque )  [extern]
```

Initialise a `blkio_ram_state_t` in caller-provided memory.

Stores `base`, `total_blocks`, `fbs` (defaulting to `BLKIO_FORTH_BLOCK_SIZE` if zero), and `read_only` into the state struct at `state_mem`. Sets `*out_opaque` to point to the state. The caller owns the `base` memory and must ensure it remains valid for the device lifetime.

Parameters

state_mem	Caller-allocated buffer (must be >= blkio_ram_state_size())
state_len	Size of `state_mem` in bytes
base	Pointer to the RAM block array
total_blocks	Number of FORTH blocks in `base`
fbs	FORTH block size in bytes (0 = use default)
read_only	1 = deny writes, 0 = allow reads and writes
out_opaque	Output: set to `state_mem` on success

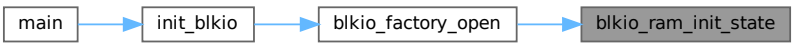
Returns

`BLKIO_OK` on success, `BLKIO_EINVAL` on bad arguments

References base, blkio_ram_state_t::base, BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_ram_state_t::fbs, blkio_ram_state_t::read_only, and blkio_ram_state_t::total_blocks.

Referenced by blkio_factory_open().

Here is the caller graph for this function:



7.274.1.6 blkio_ram_state_size()

```
size_t blkio_ram_state_size (
            void  )  [extern]
```

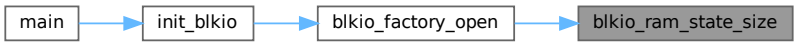
Return the byte size required for a `blkio_ram_state_t`.

Returns

sizeof(blkio_ram_state_t)

Referenced by blkio_factory_open().

Here is the caller graph for this function:



7.274.1.7 blkio_ram_vtable()

```
const blkio_vtable_t * blkio_ram_vtable (
            void  )  [extern]
```

Return the vtable for the RAM block I/O backend.

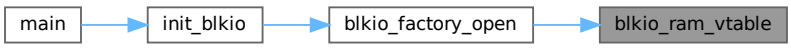
Returns

Pointer to the static `blkio_vtable_t` for RAM devices

References BLKIO_RAM_VT.

Referenced by blkio_factory_open().

Here is the caller graph for this function:



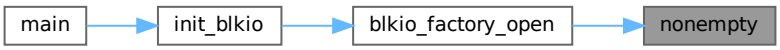
7.274.1.8 nonempty()

```
static int nonempty (
            const char * s )  [static]
```

Return 1 if string `s` is non-NULL and non-empty.

Referenced by blkio_factory_open().

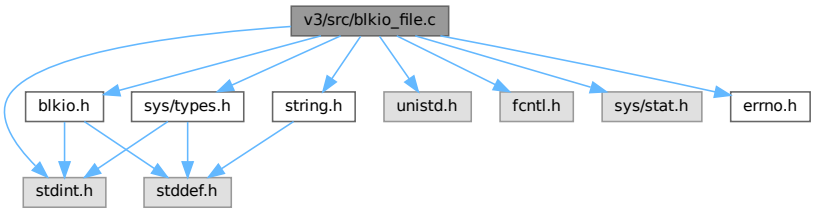
Here is the caller graph for this function:



7.275 v3/src/blkio_file.c File Reference

```
#include "blkio.h"
#include <unistd.h>
#include <fcntl.h>
#include <sys/stat.h>
#include <sys/types.h>
#include <errno.h>
#include <string.h>
#include <stdint.h>
```

Include dependency graph for blkio_file.c:



Data Structures

- struct blkio_file_state_t

Macros

- #define PATH_MAX 4096

Functions

- size_t blkio_file_state_size (void)

  Return the byte size required for a `blkio_file_state_t`.
- int blkio_file_init_state (void *state_mem, size_t state_len, const char *path, uint32_t total_blocks, uint32_t fbs, uint8_t read_only, uint8_t create_if_missing, uint8_t truncate_to_size, void **out_opaque)

  Initialise a `blkio_file_state_t` in caller-provided memory.
- static int full_read_at (int fd, void *buf, size_t len, off_t off_abs)

  Perform a complete read of `len` bytes at absolute offset `off_abs`.
- static int full_write_at (int fd, const void *buf, size_t len, off_t off_abs)

  Perform a complete write of `len` bytes at absolute offset `off_abs`.
- static int file_open (blkio_dev_t *dev, const blkio_params_t *p)

  Open the file and attach it to the device handle.
- static int file_close (blkio_dev_t *dev)

  Close the file descriptor held by the device.
- static int file_read (blkio_dev_t *dev, uint32_t fblock, void *dst)

  Read one FORTH block from the file into `dst`.
- static int file_write (blkio_dev_t *dev, uint32_t fblock, const void *src)

  Write one FORTH block from `src` into the file.

- static int file_flush (blkio_dev_t *dev)

  Flush (fsync) pending writes to the file.
- static int file_info (blkio_dev_t *dev, blkio_info_t *out)

  Return device info (block size, count, physical size, read-only flag).
- const blkio_vtable_t * blkio_file_vtable (void)

  Return the vtable for the file-backed block I/O backend.

Variables

- static const blkio_vtable_t BLKIO_FILE_VT

7.275.1 Macro Definition Documentation

7.275.1.1 PATH_MAX

```
#define PATH_MAX 4096
```

7.275.2 Function Documentation

7.275.2.1 blkio_file_init_state()

```
int blkio_file_init_state (
            void * state_mem,
            size_t state_len,
            const char * path,
            uint32_t total_blocks,
            uint32_t fbs,
            uint8_t read_only,
            uint8_t create_if_missing,
            uint8_t truncate_to_size,
            void ** out_opaque )
```

Initialise a `blkio_file_state_t` in caller-provided memory.

Copies the path into state (truncated to PATH_MAX-1), sets `fbs`, `total_blocks`, and `read_only`, and writes the state pointer to `*out_opaque`. The file descriptor is initialised to -1; the actual `open()` call happens in `file_open()` (the vtable open method). `create_if_missing` and `truncate_to_size` are accepted for API compatibility but currently unused (creation is handled in `file_open()`).

Parameters

state_mem	Caller-allocated state buffer
state_len	Size of `state_mem` (must be >= blkio_file_state_size())
path	Path to the disk image file
total_blocks	Total block count (0 = derive from file size at open)
fbs	FORTH block size in bytes
read_only	1 = open read-only, 0 = read-write
create_if_missing	Ignored (reserved for future use)
truncate_to_size	Ignored (reserved for future use)
out_opaque	Output: set to `state_mem` on success

Returns

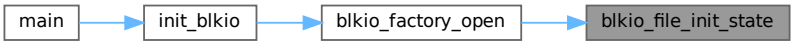
`BLKIO_OK` on success, `BLKIO_EINVAL` on bad arguments

References BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_file_state_t::fbs, blkio_file_state_t::fd, memset(), blkio_file_state_t::path, PATH_MAX, blkio_file_state_t::read_only, and blkio_file_state_t::total_blocks.

Referenced by blkio_factory_open().

Here is the call graph for this function:

Here is the caller graph for this function:



7.275.2.2 blkio_file_state_size()

```
size_t blkio_file_state_size (
            void  )
```

Return the byte size required for a `blkio_file_state_t`.

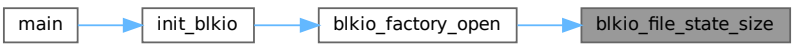
Used by `blkio_factory_open()` to verify the caller's state buffer is large enough before calling `blkio_file_init_state()`.

Returns

sizeof(blkio_file_state_t)

Referenced by blkio_factory_open().

Here is the caller graph for this function:



7.275.2.3 blkio_file_vtable()

```
const blkio_vtable_t * blkio_file_vtable (
            void  )
```

Return the vtable for the file-backed block I/O backend.

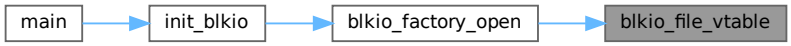
Returns

Pointer to the static `blkio_vtable_t` for file devices

References BLKIO_FILE_VT.

Referenced by blkio_factory_open().

Here is the caller graph for this function:



7.275.2.4 file_close()

```
static int file_close (
            blkio_dev_t * dev )  [static]
```

Close the file descriptor held by the device.

Parameters

dev	Device handle (must have valid state)

Returns

`BLKIO_OK` on success, `BLKIO_EIO` if `close()` fails

References BLKIO_EINVAL, BLKIO_EIO, BLKIO_OK, blkio_file_state_t::fd, and blkio_dev::state.

7.275.2.5 file_flush()

```
static int file_flush (
            blkio_dev_t * dev )  [static]
```

Flush (fsync) pending writes to the file.

Flush pending writes via `fsync()` on Linux/POSIX; no-op elsewhere.

Parameters

dev	Open file device

Returns

`BLKIO_OK` on success, `BLKIO_EIO` if `fsync()` fails

References BLKIO_ECLOSED, BLKIO_EINVAL, BLKIO_EIO, BLKIO_OK, blkio_file_state_t::fd, and blkio_dev::state.

7.275.2.6 file_info()

```
static int file_info (
            blkio_dev_t * dev,
            blkio_info_t * out )  [static]
```

Return device info (block size, count, physical size, read-only flag).

Return device info for the file backend.

Physical sector size is reported as 512 (best-effort guess; no ioctl used). Physical size in bytes comes from `fstat()`.

Parameters

dev	Open file device
out	Output struct to populate

Returns

`BLKIO_OK` on success, `BLKIO_EIO` if `fstat()` fails

References BLKIO_EINVAL, BLKIO_EIO, BLKIO_OK, blkio_file_state_t::fbs, blkio_file_state_t::fd, blkio_info_t::forth_block_size, blkio_info_t::phys_sector_size, blkio_info_t::phys_size_bytes, blkio_info_t::read_only, blkio_file_state_t::read_only, blkio_dev::state, blkio_info_t::total_blocks, and blkio_file_state_t::total_blocks.

Referenced by load_kernel_from_esp().

Here is the caller graph for this function:

7.275.2.7 file_open()

```
static int file_open (
            blkio_dev_t * dev,
            const blkio_params_t * p )  [static]
```

Open the file and attach it to the device handle.

Open the underlying file and populate the device handle.

Opens `st->path` with `O_RDONLY` or `O_RDWR|O_CREAT` depending on `st->read_only`. Derives `total_blocks` from the file size if the state value is 0 — the file size must then be a multiple of `fbs`. Sets `dev->state`, `dev->forth_block_size`, and `dev->total_blocks` on success.

Parameters

dev	Uninitialised device handle
p	Parameters including the pre-initialised opaque state pointer

Returns

`BLKIO_OK` on success, `BLKIO_EIO` or `BLKIO_EINVAL` on failure

References BLKIO_EINVAL, BLKIO_EIO, BLKIO_OK, blkio_file_state_t::fbs, blkio_file_state_t::fd, blkio_dev::forth_block_size, blkio_params_t::opaque, blkio_file_state_t::path, blkio_file_state_t::read_only, blkio_dev::state, blkio_dev::total_blocks, and blkio_file_state_t::total_blocks.

7.275.2.8 file_read()

```
static int file_read (
            blkio_dev_t * dev,
            uint32_t fblock,
            void * dst )  [static]
```

Read one FORTH block from the file into `dst`.

Read one FORTH block from the file backend.

Parameters

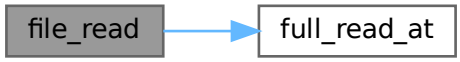
dev	Open file device
fblock	Logical block number (must be < `dev->total_blocks`)
dst	Destination buffer (must be >= `fbs` bytes)

Returns

`BLKIO_OK`, `BLKIO_EINVAL` if `fblock` is out of range, or `BLKIO_EIO`

References BLKIO_ECLOSED, BLKIO_EINVAL, BLKIO_EIO, BLKIO_OK, blkio_file_state_t::fbs, blkio_file_state_t::fd, full_read_at(), blkio_dev::state, and blkio_dev::total_blocks.

Here is the call graph for this function:



7.275.2.9 file_write()

```
static int file_write (
            blkio_dev_t * dev,
            uint32_t fblock,
            const void * src )  [static]
```

Write one FORTH block from `src` into the file.

Write one FORTH block to the file backend.

Parameters

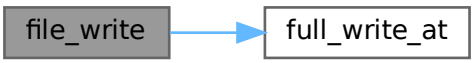
dev	Open file device (must not be read-only)
fblock	Logical block number (must be < `dev->total_blocks`)
src	Source buffer (must be >= `fbs` bytes)

Returns

`BLKIO_OK`, `BLKIO_ENOSUP` if read-only, `BLKIO_EINVAL` if out of range, or `BLKIO_EIO` on write failure

References BLKIO_ECLOSED, BLKIO_EINVAL, BLKIO_EIO, BLKIO_ENOSUP, BLKIO_OK, blkio_file_state_t::fbs, blkio_file_state_t::fd, full_write_at(), blkio_file_state_t::read_only, blkio_dev::state, and blkio_dev::total_blocks.

Here is the call graph for this function:



7.275.2.10 full_read_at()

```
static int full_read_at (
             int fd,
             void * buf,
             size_t len,
             off_t off_abs )  [static]
```

Perform a complete read of `len` bytes at absolute offset `off_abs`.

Uses `lseek()` + `read()` loops to handle short reads and EINTR. Not safe for concurrent readers/writers on the same file descriptor. Returns -1 on any I/O error or unexpected EOF.

Parameters

fd	Open file descriptor
buf	Destination buffer (must be >= `len` bytes)
len	Number of bytes to read
off_abs	Absolute byte offset within the file

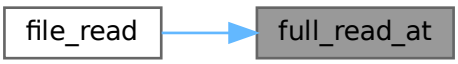
Returns

0 on success, -1 on error (errno set)

References errno, and SEEK_SET.

Referenced by file_read().

Here is the caller graph for this function:



7.275.2.11 full_write_at()

```
static int full_write_at (
             int fd,
             const void * buf,
             size_t len,
             off_t off_abs )  [static]
```

Perform a complete write of `len` bytes at absolute offset `off_abs`.

Uses `lseek()` + `write()` loops to handle short writes and EINTR. Not safe for concurrent readers/writers on the same file descriptor. Returns -1 on any I/O error.

Parameters

fd	Open file descriptor
buf	Source buffer (must be >= `len` bytes)
len	Number of bytes to write
off_abs	Absolute byte offset within the file

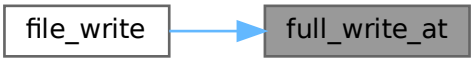
Returns

0 on success, -1 on error (errno set)

References errno, and SEEK_SET.

Referenced by file_write().

Here is the caller graph for this function:



7.275.3 Variable Documentation

7.275.3.1 BLKIO_FILE_VT

```
const blkio_vtable_t BLKIO_FILE_VT  [static]
```

Initial value:

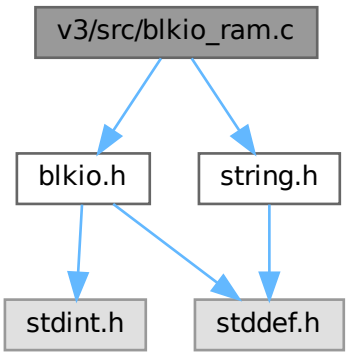
```
= {
    .open = file_open,
    .close = file_close,
    .read = file_read,
    .write = file_write,
    .flush = file_flush,
    .info = file_info
}
```

Referenced by blkio_file_vtable().

7.276 v3/src/blkio_ram.c File Reference

```
#include "blkio.h"
#include <string.h>
```

Include dependency graph for blkio_ram.c:



Data Structures

- struct blkio_ram_state_t

Functions

- size_t blkio_ram_state_size (void)

  Return the byte size required for a `blkio_ram_state_t`.
- int blkio_ram_init_state (void *state_mem, size_t state_len, uint8_t *base, uint32_t total_blocks, uint32_t fbs, uint8_t read_only, void **out_opaque)

  Initialise a `blkio_ram_state_t` in caller-provided memory.
- static int ram_open (blkio_dev_t *dev, const blkio_params_t *p)

  Attach state to the device handle and validate parameters.
- static int ram_close (blkio_dev_t *dev)

  Close the RAM device (no-op; caller owns the memory).
- static int ram_read (blkio_dev_t *dev, uint32_t fblock, void *dst)

  Read one FORTH block from the RAM array into `dst`.
- static int ram_write (blkio_dev_t *dev, uint32_t fblock, const void *src)

  Write one FORTH block from `src` into the RAM array.
- static int ram_flush (blkio_dev_t *dev)

  Flush the RAM device — always a no-op since data is in memory.
- static int ram_info (blkio_dev_t *dev, blkio_info_t *out)

  Return device info (block size, count, physical size, read-only flag).
- const blkio_vtable_t * blkio_ram_vtable (void)

  Return the vtable for the RAM block I/O backend.
- static int in_bounds (const blkio_ram_state_t *st, uint32_t fb)

  Test whether `fb` is a valid block number for the RAM device.

Variables

- static const blkio_vtable_t BLKIO_RAM_VT

7.276.1 Function Documentation

7.276.1.1 blkio_ram_init_state()

```
int blkio_ram_init_state (
            void * state_mem,
            size_t state_len,
            uint8_t * base,
            uint32_t total_blocks,
            uint32_t fbs,
            uint8_t read_only,
            void ** out_opaque )
```

Initialise a `blkio_ram_state_t` in caller-provided memory.

Stores `base`, `total_blocks`, `fbs` (defaulting to `BLKIO_FORTH_BLOCK_SIZE` if zero), and `read_only` into the state struct at `state_mem`. Sets `*out_opaque` to point to the state. The caller owns the `base` memory and must ensure it remains valid for the device lifetime.

Parameters

state_mem	Caller-allocated buffer (must be >= blkio_ram_state_size())
state_len	Size of `state_mem` in bytes
base	Pointer to the RAM block array
total_blocks	Number of FORTH blocks in `base`
fbs	FORTH block size in bytes (0 = use default)
read_only	1 = deny writes, 0 = allow reads and writes
out_opaque	Output: set to `state_mem` on success

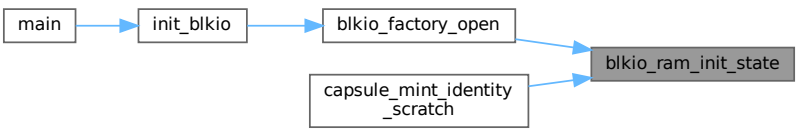
Returns

`BLKIO_OK` on success, `BLKIO_EINVAL` on bad arguments

References base, blkio_ram_state_t::base, BLKIO_EINVAL, BLKIO_FORTH_BLOCK_SIZE, BLKIO_OK, blkio_ram_state_t::fbs, blkio_ram_state_t::read_only, and blkio_ram_state_t::total_blocks.

Referenced by blkio_factory_open(), and capsule_mint_identity_scratch().

Here is the caller graph for this function:



7.276.1.2 blkio_ram_state_size()

```
size_t blkio_ram_state_size (
            void  )
```

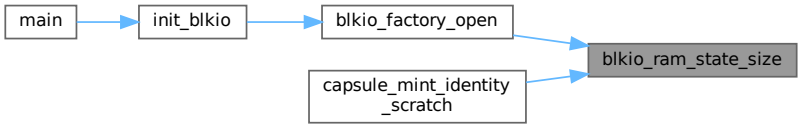
Return the byte size required for a `blkio_ram_state_t`.

Returns

sizeof(blkio_ram_state_t)

Referenced by blkio_factory_open(), and capsule_mint_identity_scratch().

Here is the caller graph for this function:



7.276.1.3 blkio_ram_vtable()

```
const blkio_vtable_t * blkio_ram_vtable (
            void  )
```

Return the vtable for the RAM block I/O backend.

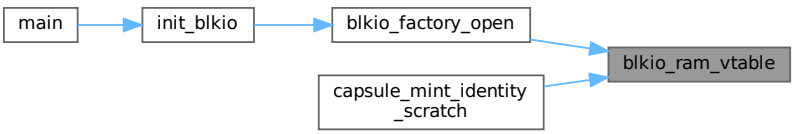
Returns

Pointer to the static `blkio_vtable_t` for RAM devices

References BLKIO_RAM_VT.

Referenced by blkio_factory_open(), and capsule_mint_identity_scratch().

Here is the caller graph for this function:



7.276.1.4 in_bounds()

```
static int in_bounds (
            const blkio_ram_state_t * st,
            uint32_t fb )  [inline], [static]
```

Test whether `fb` is a valid block number for the RAM device.

Parameters

st	RAM state (may be NULL)
fb	Block number to test

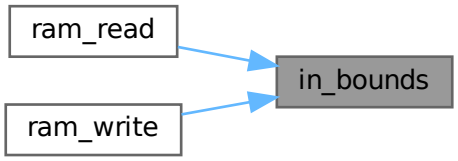
Returns

1 if in bounds, 0 otherwise

References blkio_ram_state_t::total_blocks.

Referenced by ram_read(), and ram_write().

Here is the caller graph for this function:



7.276.1.5 ram_close()

```
static int ram_close (
            blkio_dev_t * dev )  [static]
```

Close the RAM device (no-op; caller owns the memory).

Close the RAM device — caller retains ownership of the RAM buffer.

Parameters

dev	Device handle

Returns

`BLKIO_OK` always (no resources to release)

References BLKIO_EINVAL, BLKIO_OK, and blkio_dev::state.

7.276.1.6 ram_flush()

```
static int ram_flush (
            blkio_dev_t * dev )  [static]
```

Flush the RAM device — always a no-op since data is in memory.

Flush the RAM device — no-op since data is always in memory.

Parameters

dev	Device handle (unused)

Returns

`BLKIO_OK` always

References BLKIO_OK.

7.276.1.7 ram_info()

```
static int ram_info (
            blkio_dev_t * dev,
            blkio_info_t * out )  [static]
```

Return device info (block size, count, physical size, read-only flag).

Return device info for the RAM backend.

Physical sector size equals `fbs` (RAM has no physical sector constraint). Physical size in bytes = `fbs * total_blocks`.

Parameters

dev	Open RAM device
out	Output struct to populate

Returns

`BLKIO_OK` on success, `BLKIO_EINVAL` if `dev` or `out` is NULL

References BLKIO_EINVAL, BLKIO_OK, blkio_ram_state_t::fbs, blkio_info_t::forth_block_size, blkio_info_t::phys_sector_size, blkio_info_t::phys_size_bytes, blkio_info_t::read_only, blkio_ram_state_t::read_only, blkio_dev::state, blkio_info_t::total_blocks, and blkio_ram_state_t::total_blocks.

7.276.1.8 ram_open()

```
static int ram_open (
            blkio_dev_t * dev,
            const blkio_params_t * p )  [static]
```

Attach state to the device handle and validate parameters.

Attach the RAM state to the device handle.

Validates that `base` and `fbs` are non-zero, then sets `dev->state`, `dev->forth_block_size`, and `dev->total_blocks`.

Parameters

dev	Uninitialised device handle
p	Parameters with pre-initialised opaque RAM state pointer

Returns

`BLKIO_OK` on success, `BLKIO_EINVAL` on bad arguments

References blkio_ram_state_t::base, BLKIO_EINVAL, BLKIO_OK, blkio_ram_state_t::fbs, blkio_dev::forth_block_size, blkio_params_t::opaque, blkio_dev::state, blkio_dev::total_blocks, and blkio_ram_state_t::total_blocks.

7.276.1.9 ram_read()

```
static int ram_read (
            blkio_dev_t * dev,
            uint32_t fblock,
            void * dst )  [static]
```

Read one FORTH block from the RAM array into `dst`.

Copy one FORTH block from the RAM array to `dst`.

Parameters

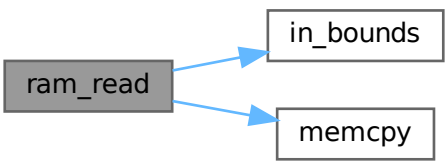
dev	Open RAM device
fblock	Logical block number (must be < `total_blocks`)
dst	Destination buffer (must be >= `fbs` bytes)

Returns

`BLKIO_OK` on success, `BLKIO_EINVAL` if out of range or NULL pointer

References blkio_ram_state_t::base, BLKIO_EINVAL, BLKIO_OK, blkio_ram_state_t::fbs, in_bounds(), memcpy(), and blkio_dev::state.

Here is the call graph for this function:



7.276.1.10 ram_write()

```
static int ram_write (
            blkio_dev_t * dev,
            uint32_t fblock,
            const void * src )  [static]
```

Write one FORTH block from `src` into the RAM array.

Copy one FORTH block from `src` into the RAM array.

Parameters

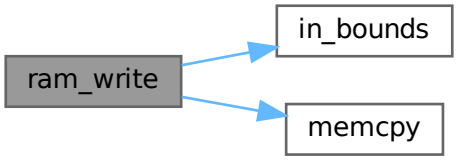
dev	Open RAM device (must not be read-only)
fblock	Logical block number (must be < `total_blocks`)
src	Source buffer (must be >= `fbs` bytes)

Returns

`BLKIO_OK` on success, `BLKIO_ENOSUP` if read-only, `BLKIO_EINVAL` if out of range or NULL pointer

References blkio_ram_state_t::base, BLKIO_EINVAL, BLKIO_ENOSUP, BLKIO_OK, blkio_ram_state_t::fbs, in_bounds(), memcpy(), blkio_ram_state_t::read_only, and blkio_dev::state.

Here is the call graph for this function:



7.276.2 Variable Documentation

7.276.2.1 BLKIO_RAM_VT

```
const blkio_vtable_t BLKIO_RAM_VT  [static]
```

Initial value:

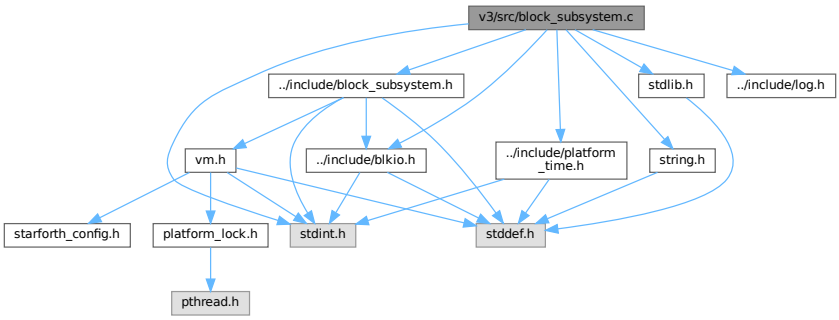
```
= {
    .open = ram_open,
    .close = ram_close,
    .read = ram_read,
    .write = ram_write,
    .flush = ram_flush,
    .info = ram_info
}
```

Referenced by blkio_ram_vtable().

7.277 v3/src/block_subsystem.c File Reference

```
#include "../include/blkio.h"
#include "../include/block_subsystem.h"
#include "../include/log.h"
#include "../include/platform_time.h"
#include <string.h>
#include <stdlib.h>
#include <stdint.h>
```

Include dependency graph for block_subsystem.c:



Data Structures

- struct blk_reloc_entry_t
- struct cache_slot_t
- struct blk_dev_slot

Macros

- #define BLK_FORTH_SYS_RESERVED 32u
- #define BLK_DISK_SYS_RESERVED 32u
- #define META_REGION_OFFSET (BLK_PACK_RATIO ∗ BLK_FORTH_SIZE)
- #define META_REGION_SIZE (BLK_DEVICE_SECTOR - META_REGION_OFFSET)
- #define META_PER_BLOCK (META_REGION_SIZE / BLK_PACK_RATIO)
- #define DISK_CACHE_SLOTS 8
- #define BLK_RELOC_MAX_ENTRIES 500u
- #define BLK_FIRSTTOUCH_MAX_CLAIM 256u
- #define MIGRATION_WEAR_THRESHOLD 10000u
- #define MIGRATION_SCAN_BUDGET 256u

Typedefs

- typedef struct blk_dev_slot blk_dev_slot_t

Functions

- static size_t minzu (size_t a, size_t b)
- static uint32_t udiv_floor (uint32_t a, uint32_t b)
- static void crc64_init (void)
- uint64_t compute_crc64 (const uint8_t *data, size_t len)
- static int pbam_test (const uint8_t *bm, uint32_t i)
- static void pbam_set (uint8_t *bm, uint32_t i)
- static void pbam_clr (uint8_t *bm, uint32_t i)
- static uint32_t resolve_lbn (uint32_t lbn)
- static blk_dev_slot_t * lbn_to_slot (uint32_t lbn)
- static void chain_append (blk_dev_slot_t *slot)
- static uint32_t devblock4k_to_lba1k (blk_dev_slot_t *slot, uint32_t dev4k)
- static uint32_t lbn_to_slot_pbn (blk_dev_slot_t *slot, uint32_t lbn)
- static uint32_t slot_pbn_to_devblock (uint32_t rel_pbn)
- static uint32_t slot_pbn_pack_offset (uint32_t rel_pbn)
- static int read_devblock_4k (blk_dev_slot_t *slot, uint32_t dev4k, uint8_t *buf4k)
- static int write_devblock_4k (blk_dev_slot_t *slot, uint32_t dev4k, const uint8_t *buf4k)
- static void meta_from_slice (blk_meta_t *dst, const uint8_t *slice)
- static void meta_to_slice (const blk_meta_t *src, uint8_t *slice)
- static int cache_writeback (blk_dev_slot_t *slot, cache_slot_t *s)
- static cache_slot_t * cache_get_slot (blk_dev_slot_t *slot, uint32_t dev4k)
- static cache_slot_t * cache_load_devblock (blk_dev_slot_t *slot, uint32_t dev4k)
- static void volmeta_from_buf (blk_volume_meta_t *out, const uint8_t *buf)
- static void volmeta_to_buf (const blk_volume_meta_t *in, uint8_t *buf)
- static int read_header_4k (blk_dev_slot_t *slot, uint8_t *buf4k)
- static int write_header_4k (blk_dev_slot_t *slot, const uint8_t *buf4k)
- static uint32_t choose_B (uint64_t total_devblocks_4k)
- static void compute_totals_from_B (blk_volume_meta_t *m)
- void blk_volume_compute_totals (blk_volume_meta_t *m)
- void blk_subsys_set_format_bam_for (uint64_t total_devblocks)
- static uint32_t bam_pages_used (const blk_dev_slot_t *slot)
- static int bam_sync_from_disk (blk_dev_slot_t *slot)
- static int bam_flush_to_disk (blk_dev_slot_t *slot)
- static int reloc_load_from_disk (blk_dev_slot_t *slot)
- static int reloc_flush_to_disk (blk_dev_slot_t *slot)
- static void blk_compute_fresh_geometry (blk_dev_slot_t *slot)
- static int blk_commit_format (blk_dev_slot_t *slot)
- static int blk_format_or_load_disk (blk_dev_slot_t *slot)
- static uint64_t blk_get_timestamp (void)
- int blk_subsys_init (uint8_t *ram_base, size_t ram_size)
- int blk_subsys_add_raw_device (uint8_t *buf, uint32_t nblocks)
- static blk_dev_slot_t * first_disk_slot (void)
- int blk_subsys_attach_device (struct blkio_dev *dev)
- int blk_subsys_detach_device (struct blkio_dev *dev)
- int blk_subsys_relocate_block (uint32_t home_lbn, uint32_t target_lbn)
- uint64_t blk_subsys_epoch (void)
- int blk_subsys_shutdown (void)
- int blk_subsys_confirm_format (uint32_t lbn)
- uint8_t * blk_get_buffer (uint32_t block_num, int writable)
- uint8_t * blk_get_empty_buffer (uint32_t block_num)
- int blk_update (uint32_t block_num)
- int blk_flush (uint32_t block_num)
- int blk_is_allocated (uint32_t block_num)
- int blk_mark_allocated (uint32_t block_num)

- int blk_mark_free (uint32_t block_num)
- static int devblock_claimed_by_lbn (blk_dev_slot_t *slot, uint32_t lbn)
- int blk_allocate (uint32_t *block_num)
- int blk_get_volume_meta (blk_volume_meta_t *meta)
- int blk_set_volume_meta (const blk_volume_meta_t *meta)
- static blk_dev_slot_t * slot_by_dev (struct blkio_dev *dev)
- int blk_get_device_range (struct blkio_dev *dev, uint32_t *out_start_lbn, uint32_t *out_count)
- const void * blk_lbn_device_handle (uint32_t lbn)
- int blk_get_device_free_blocks (struct blkio_dev *dev, uint64_t *out_free, uint64_t *out_total)
- int blk_get_first_disk_range (uint32_t *out_start_lbn, uint32_t *out_count)
- int blk_meta_zone_read (uint32_t devblock_from_top, uint8_t buf[4096])
- int blk_meta_zone_write (uint32_t devblock_from_top, const uint8_t buf[4096])
- int blk_is_valid (uint32_t block_num)
- uint32_t blk_get_total_blocks (void)
- int blk_get_meta (uint32_t block_num, blk_meta_t *meta)
- int blk_set_meta (uint32_t block_num, const blk_meta_t *meta)
- int blk_owner_fp_get (uint32_t block_num, uint8_t out_fp[8])
- int blk_owner_fp_set (uint32_t block_num, const uint8_t fp[8])
- int blk_acl_allow_get (uint32_t block_num, uint8_t *out_allow)
- int blk_acl_allow_set (uint32_t block_num, uint8_t allow)
- int blk_acl_ttl_get (uint32_t block_num, uint32_t *out_ttl)
- int blk_acl_ttl_set (uint32_t block_num, uint32_t ttl)
- int blk_flags_get (uint32_t block_num, uint64_t *out_flags)
- int blk_flags_set (uint32_t block_num, uint64_t flags)
- static int devblock_is_free (blk_dev_slot_t *slot, uint32_t rep_lbn, const blk_meta_t *m)
- int blk_firsttouch_claim (const uint8_t owner_fp[8], uint32_t count, uint32_t *out_chain_head)
- int blk_owner_has_claim (const uint8_t owner_fp[8])
- int blk_meta_relocate_devblock (uint32_t home_devblock, uint32_t target_devblock)
- static void blk_migration_idle_check_slot (blk_dev_slot_t *slot)
- void blk_migration_idle_check (void)
- __attribute__ ((weak))

Variables

- static uint64_t crc64_table [256]
- static int crc64_inited = 0
- struct {
  uint8_t * ram_base
  size_t ram_size
  uint8_t dirty_ram [BLK_RAM_BLOCKS]
  uint32_t ram_user
  uint64_t total_user_lbn
  blk_dev_slot_t * head
  uint64_t epoch
  blk_reloc_entry_t reloc [500u]
  uint32_t reloc_count
  int initialized
  } g = {0}

- static uint64_t g_format_bam_for

7.277.1 Macro Definition Documentation

7.277.1.1 BLK_DISK_SYS_RESERVED

```
#define BLK_DISK_SYS_RESERVED 32u
```

7.277.1.2 BLK_FIRSTTOUCH_MAX_CLAIM

```
#define BLK_FIRSTTOUCH_MAX_CLAIM 256u
```

7.277.1.3 BLK_FORTH_SYS_RESERVED

```
#define BLK_FORTH_SYS_RESERVED 32u
```

7.277.1.4 BLK_RELOC_MAX_ENTRIES

```
#define BLK_RELOC_MAX_ENTRIES 500u
```

7.277.1.5 DISK_CACHE_SLOTS

```
#define DISK_CACHE_SLOTS 8
```

7.277.1.6 META_PER_BLOCK

```
#define META_PER_BLOCK (META_REGION_SIZE / BLK_PACK_RATIO)
```

7.277.1.7 META_REGION_OFFSET

```
#define META_REGION_OFFSET (BLK_PACK_RATIO * BLK_FORTH_SIZE)
```

7.277.1.8 META_REGION_SIZE

```
#define META_REGION_SIZE (BLK_DEVICE_SECTOR - META_REGION_OFFSET)
```

7.277.1.9 MIGRATION_SCAN_BUDGET

```
#define MIGRATION_SCAN_BUDGET 256u
```

7.277.1.10 MIGRATION_WEAR_THRESHOLD

```
#define MIGRATION_WEAR_THRESHOLD 10000u
```

7.277.2 Typedef Documentation

7.277.2.1 blk_dev_slot_t

```
typedef struct blk_dev_slot blk_dev_slot_t
```

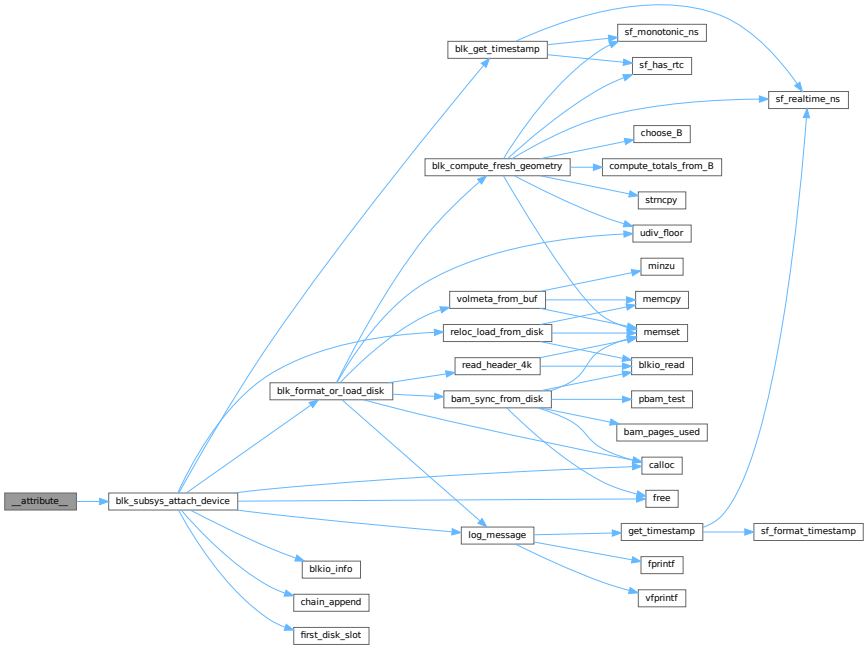
7.277.3 Function Documentation

7.277.3.1 __attribute__()

```
__attribute__ (
            (weak)  )
```

References blk_subsys_attach_device().

Here is the call graph for this function:



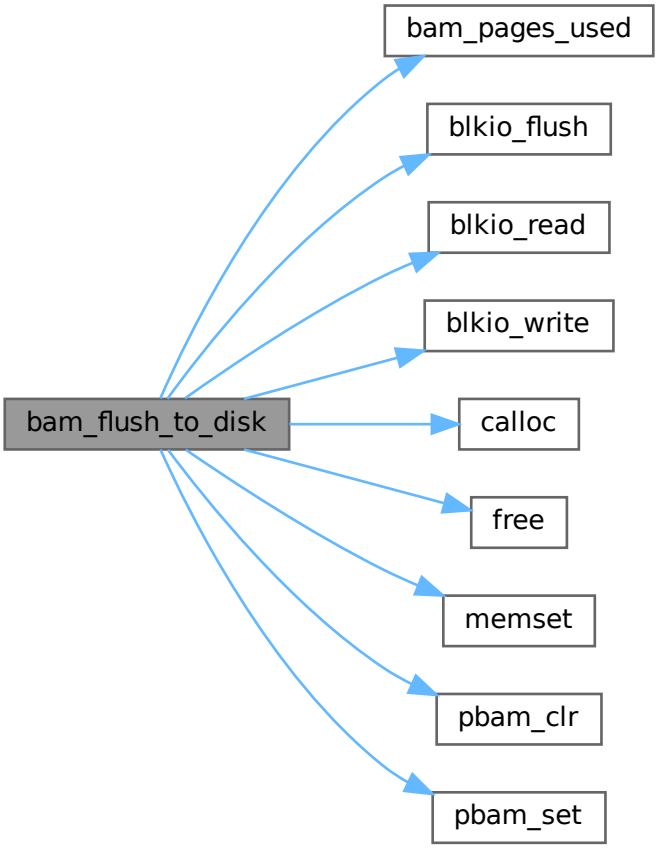
7.277.3.2 bam_flush_to_disk()

```
static int bam_flush_to_disk (
            blk_dev_slot_t * slot )  [static]
```

References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_volume_meta_t::bam_devblocks, blk_dev_slot::bam_dirty, bam_pages_used(), blk_volume_meta_t::bam_start, BLK_DISK_SYS_RESERVED, BLK_EIO, BLK_ENOMEM, BLK_OK, blkio_flush(), BLKIO_OK, blkio_read(), blkio_write(), calloc(), blk_dev_slot::dev, free(), memset(), pbam_clr(), pbam_set(), blk_dev_slot::user_blocks, and blk_dev_slot::vol_meta.

Referenced by blk_commit_format(), and blk_flush().

Here is the call graph for this function:



Here is the caller graph for this function:

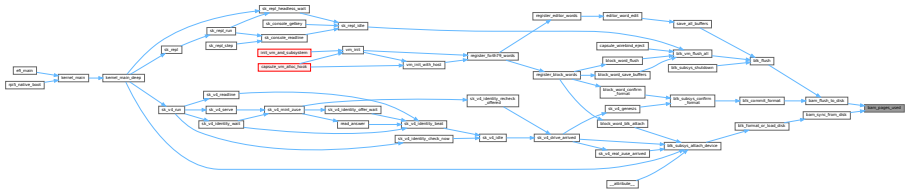
7.277.3.3 bam_pages_used()

```
static uint32_t bam_pages_used (
            const blk_dev_slot_t * slot )  [static]
```

References blk_volume_meta_t::bam_devblocks, BLK_DISK_SYS_RESERVED, blk_dev_slot::user_blocks, and blk_dev_slot::vol_meta.

Referenced by bam_flush_to_disk(), and bam_sync_from_disk().

Here is the caller graph for this function:



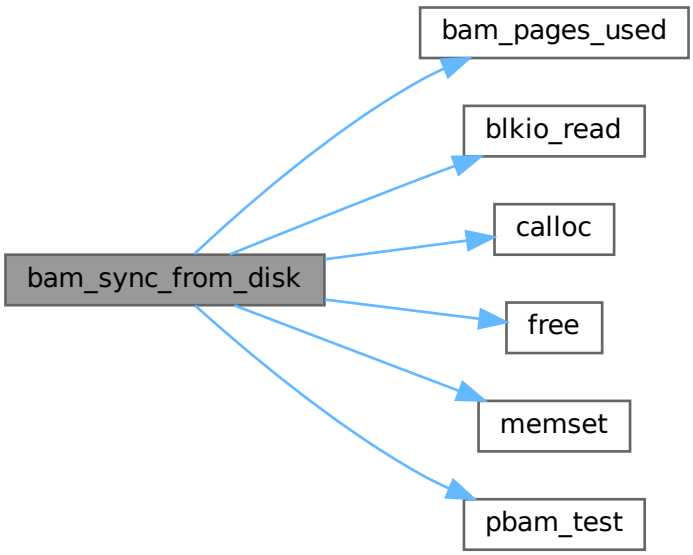
7.277.3.4 bam_sync_from_disk()

```
static int bam_sync_from_disk (
            blk_dev_slot_t * slot )  [static]
```

References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_volume_meta_t::bam_devblocks, blk_dev_slot::bam_dirty, bam_pages_used(), blk_volume_meta_t::bam_start, BLK_DISK_SYS_RESERVED, BLK_EINVAL, BLK_ENOMEM, BLK_OK, BLKIO_OK, blkio_read(), calloc(), blk_dev_slot::dev, free(), memset(), pbam_test(), blk_dev_slot::user_blocks, and blk_dev_slot::vol_meta.

Referenced by blk_format_or_load_disk().

Here is the call graph for this function:



Here is the caller graph for this function:

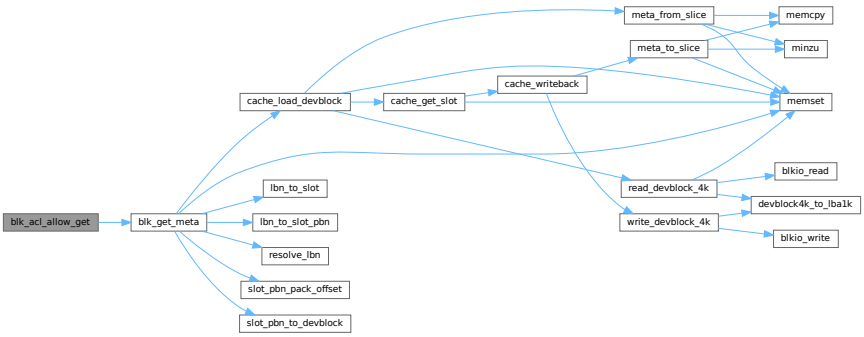
7.277.3.5 blk_acl_allow_get()

```
int blk_acl_allow_get (
            uint32_t block_num,
            uint8_t * out_allow )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, and meta.

Referenced by block_word_acl_allow_fetch().

Here is the call graph for this function:



Here is the caller graph for this function:

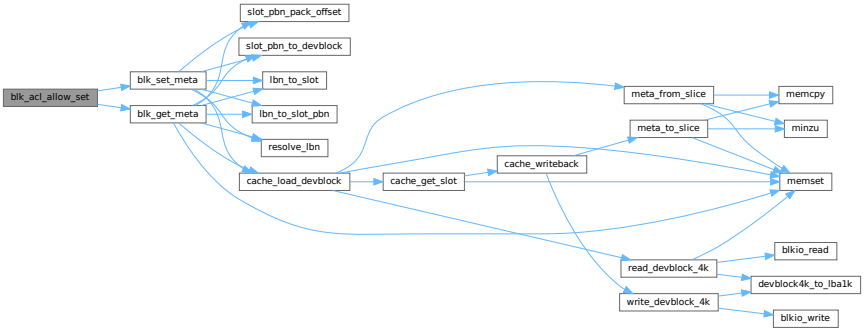
7.277.3.6 blk_acl_allow_set()

```
int blk_acl_allow_set (
            uint32_t block_num,
            uint8_t allow )
```

References blk_get_meta(), BLK_OK, blk_set_meta(), and meta.

Referenced by block_word_acl_allow_store().

Here is the call graph for this function:



Here is the caller graph for this function:

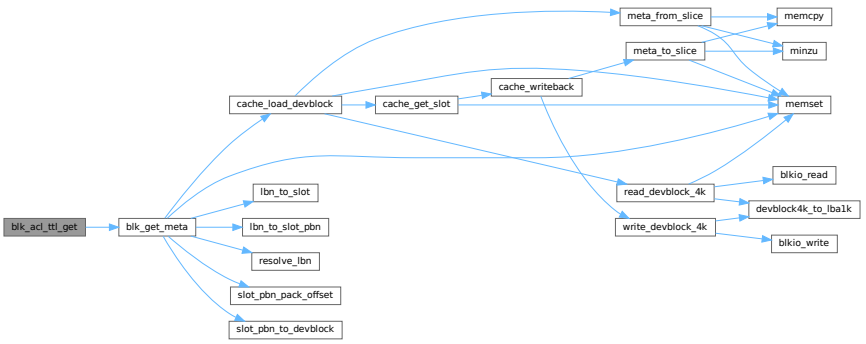
7.277.3.7 blk_acl_ttl_get()

```
int blk_acl_ttl_get (
            uint32_t block_num,
            uint32_t * out_ttl )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, and meta.

Referenced by block_word_acl_ttl_fetch().

Here is the call graph for this function:



Here is the caller graph for this function:

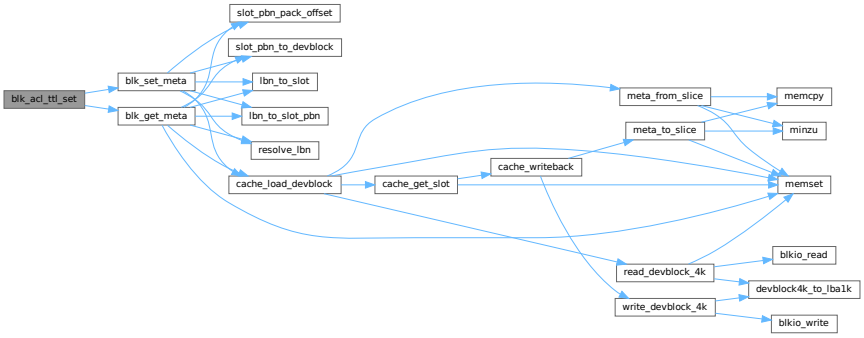
7.277.3.8 blk_acl_ttl_set()

```
int blk_acl_ttl_set (
            uint32_t block_num,
            uint32_t ttl )
```

References blk_get_meta(), BLK_OK, blk_set_meta(), and meta.

Referenced by block_word_acl_ttl_store().

Here is the call graph for this function:



Here is the caller graph for this function:

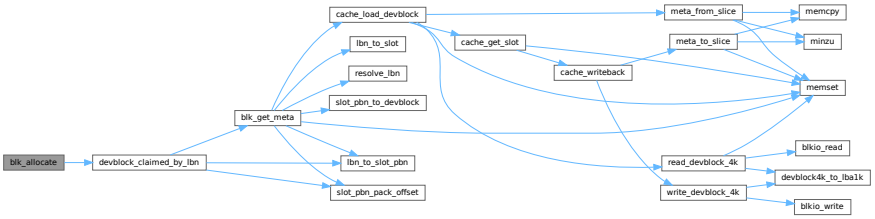
7.277.3.9 blk_allocate()

```
int blk_allocate (
            uint32_t * block_num )
```

References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_dev_slot::bam_dirty, BLK_EINVAL, BLK_ENODEV, BLK_ERANGE, BLK_FMT_PROVISIONAL, BLK_OK, blk_dev_slot::dev, devblock_claimed_by_lbn(), blk_volume_meta_t::first_free, blk_dev_slot::format_state, blk_volume_meta_t::free_blocks, g, blk_volume_meta_t::last_allocated, limit,

blk_dev_slot::next, blk_dev_slot::raw_base, blk_dev_slot::start_lbn, blk_dev_slot::user_blocks, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Here is the call graph for this function:



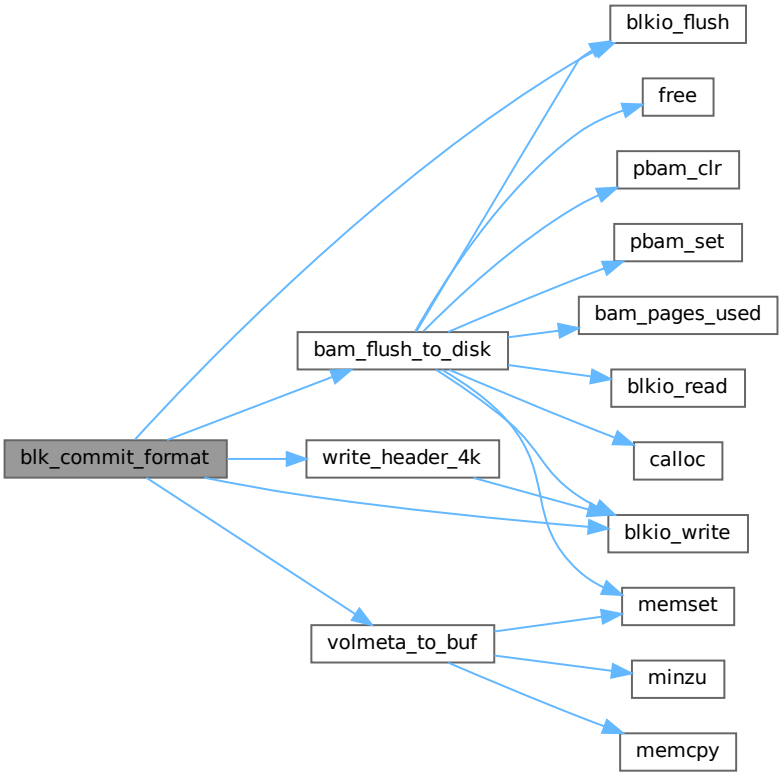
7.277.3.10 blk_commit_format()

```
static int blk_commit_format (
            blk_dev_slot_t * slot )  [static]
```

References blk_volume_meta_t::bam_devblocks, blk_dev_slot::bam_dirty, bam_flush_to_disk(), blk_volume_meta_t::bam_start, BLK_DEVICE_SECTOR, BLK_EINVAL, BLK_FMT_FORMATTED, BLK_OK, blkio_flush(), blkio_write(), blk_dev_slot::dev, blk_dev_slot::format_state, blk_volume_meta_t::reloc_devblocks, blk_volume_meta_t::reloc_start, blk_dev_slot::vol_meta, volmeta_to_buf(), and write_header_4k().

Referenced by blk_subsys_confirm_format().

Here is the call graph for this function:



Here is the caller graph for this function:

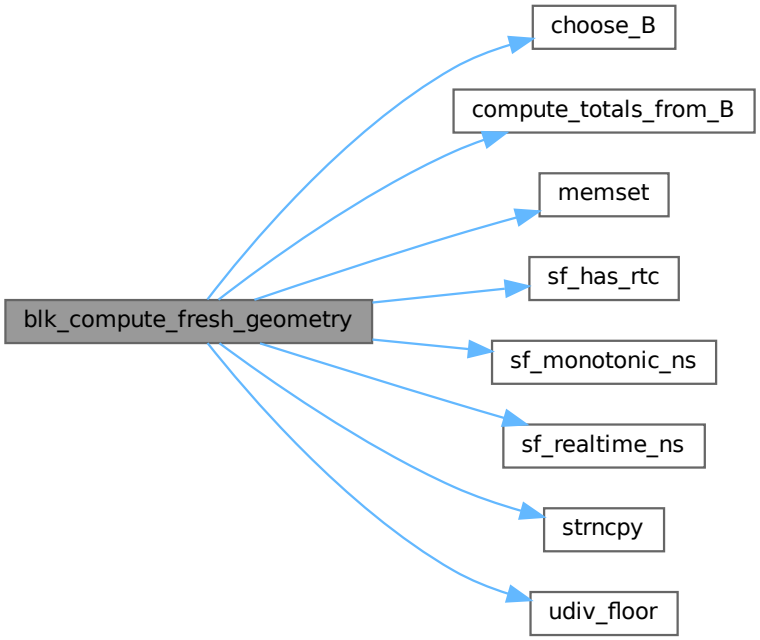
7.277.3.11 blk_compute_fresh_geometry()

```
static void blk_compute_fresh_geometry (
            blk_dev_slot_t * slot )  [static]
```

References blk_volume_meta_t::bam_devblocks, blk_volume_meta_t::bam_start, BLK_DISK_SYS_RESERVED, BLK_FORTH_SYS_RESERVED, BLK_META_FENCE_INIT, choose_B(), compute_totals_from_B(), blk_volume_meta_t::created_tim blk_volume_meta_t::devblock_base, blk_dev_slot::devblock_base_4k, blk_volume_meta_t::first_free, blk_volume_meta_t::free_block g_format_bam_for, blk_volume_meta_t::label, blk_volume_meta_t::last_allocated, blk_volume_meta_t::magic, memset(), blk_volume_meta_t::meta_fence_blocks, blk_volume_meta_t::reloc_devblocks, blk_volume_meta_t::reloc_start, blk_volume_meta_t::reserved_disk_lo, blk_volume_meta_t::reserved_ram_lo, sf_has_rtc(), sf_monotonic_ns(), sf_realtime_ns(), blk_dev_slot::start_lbn, strncpy(), blk_dev_slot::total_blkio_blocks_1k, blk_volume_meta_t::total_blocks, blk_volume_meta_t::total_devblocks, blk_volume_meta_t::total_volumes, udiv_floor(), blk_dev_slot::user_blocks, blk_volume_meta_t::version, and blk_dev_slot::vol_meta.

Referenced by blk_format_or_load_disk().

Here is the call graph for this function:



Here is the caller graph for this function:

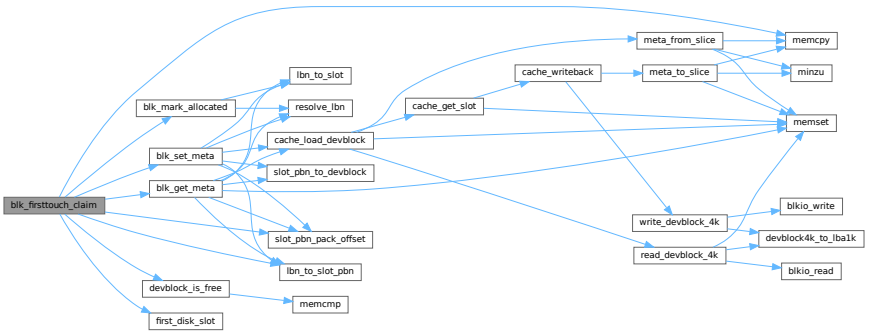
7.277.3.12 blk_firsttouch_claim()

```
int blk_firsttouch_claim (
            const uint8_t owner_fp[8],
            uint32_t count,
            uint32_t * out_chain_head )
```

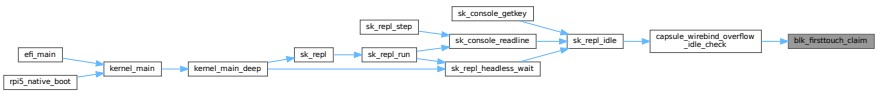
References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ENOSPC, BLK_FIRSTTOUCH_MAX_CLAIM, BLK_FLAG_CLAIMED, blk_get_meta(), blk_mark_allocated(), BLK_OK, BLK_PACK_RATIO, blk_set_meta(), count, devblock_is_free(), first_disk_slot(), blk_volume_meta_t::flags, lbn_to_slot_pbn(), memcpy(), meta, slot_pbn_pack_offset(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by capsule_wirebind_overflow_idle_check().

Here is the call graph for this function:



Here is the caller graph for this function:

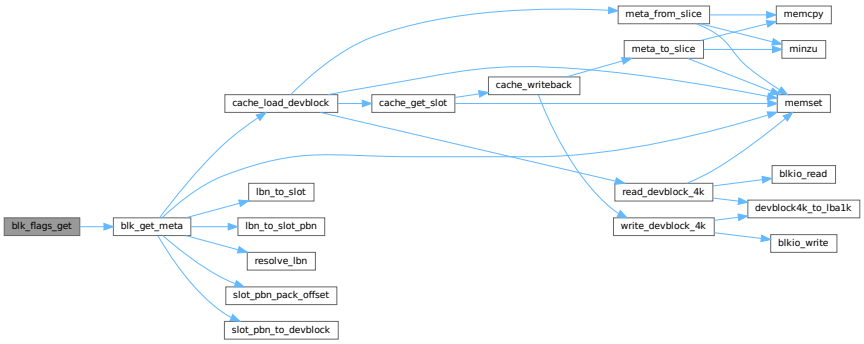


7.277.3.13 blk_flags_get()

```
int blk_flags_get (
            uint32_t block_num,
            uint64_t * out_flags )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, blk_volume_meta_t::flags, and meta.

Here is the call graph for this function:

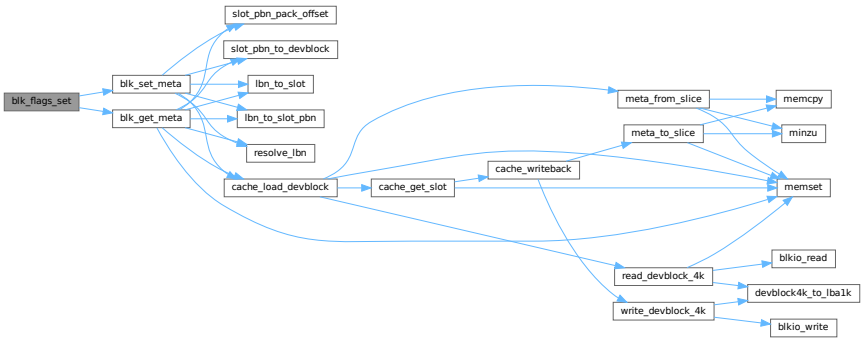


7.277.3.14 blk_flags_set()

```
int blk_flags_set (
            uint32_t block_num,
            uint64_t flags )
```

References blk_get_meta(), BLK_OK, blk_set_meta(), blk_volume_meta_t::flags, flags, and meta.

Here is the call graph for this function:



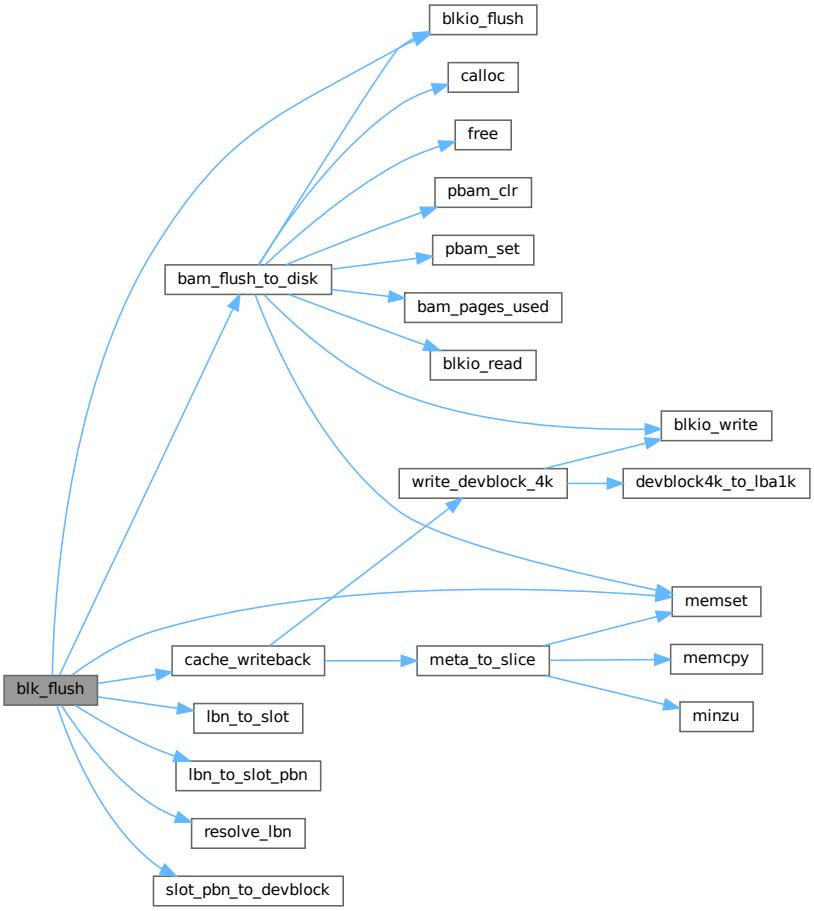
7.277.3.15 blk_flush()

```
int blk_flush (
            uint32_t block_num )
```

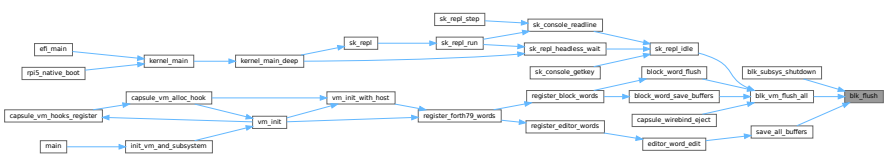
References blk_dev_slot::bam, bam_flush_to_disk(), BLK_ENODEV, BLK_ERANGE, BLK_FORTH_SYS_RESERVED, BLK_OK, BLK_RAM_BLOCKS, blkio_flush(), blk_dev_slot::cache, cache_writeback(), blk_dev_slot::dev, cache_slot_t::devblock, blk_bam_entry_t::dirty, cache_slot_t::dirty, DISK_CACHE_SLOTS, g, lbn_to_slot(), lbn_to_slot_pbn(), memset(), cache_slot_t::meta_dirty, blk_dev_slot::next, blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_to_devblock(), blk_dev_slot::start_lbn, blk_dev_slot::user_blocks, and cache_slot_t::valid.

Referenced by blk_subsys_shutdown(), blk_vm_flush_all(), and save_all_buffers().

Here is the call graph for this function:



Here is the caller graph for this function:



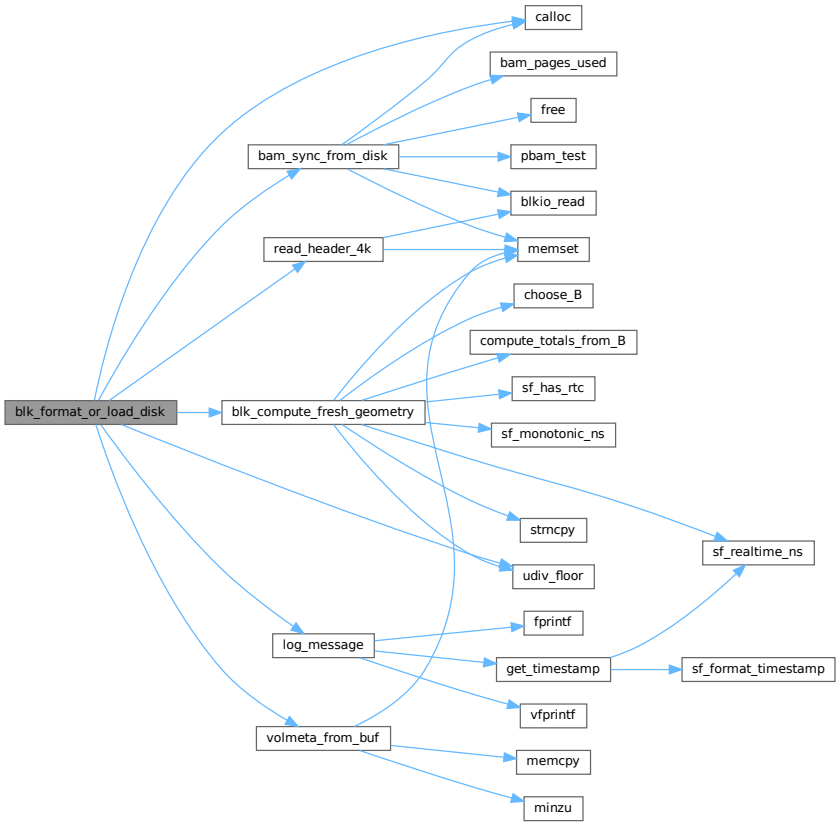
7.277.3.16 blk_format_or_load_disk()

```
static int blk_format_or_load_disk (
            blk_dev_slot_t * slot )  [static]
```

References blk_dev_slot::bam, blk_volume_meta_t::bam_devblocks, bam_sync_from_disk(), blk_compute_fresh_geometry(), BLK_DEVICE_SECTOR, BLK_DISK_SYS_RESERVED, BLK_ENOMEM, BLK_FMT_FORMATTED, BLK_FMT_PROVISIONAL, BLK_OK, calloc(), blk_volume_meta_t::devblock_base, blk_dev_slot::devblock_base_4k, blk_dev_slot::format_state, log_message(), LOG_WARN, blk_volume_meta_t::magic, read_header_4k(), blk_dev_slot::total_blkio_blocks_1k, blk_volume_meta_t::total_blocks, blk_volume_meta_t::total_devblocks, udiv_floor(), blk_dev_slot::user_blocks, blk_volume_meta_t::version, blk_dev_slot::vol_meta, and volmeta_from_buf().

Referenced by blk_subsys_attach_device().

Here is the call graph for this function:



Here is the caller graph for this function:

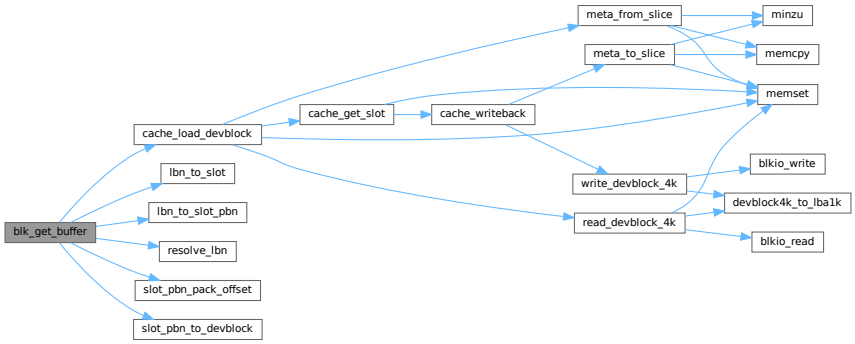
7.277.3.17 blk_get_buffer()

```
uint8_t * blk_get_buffer (
            uint32_t block_num,
            int writable )
```

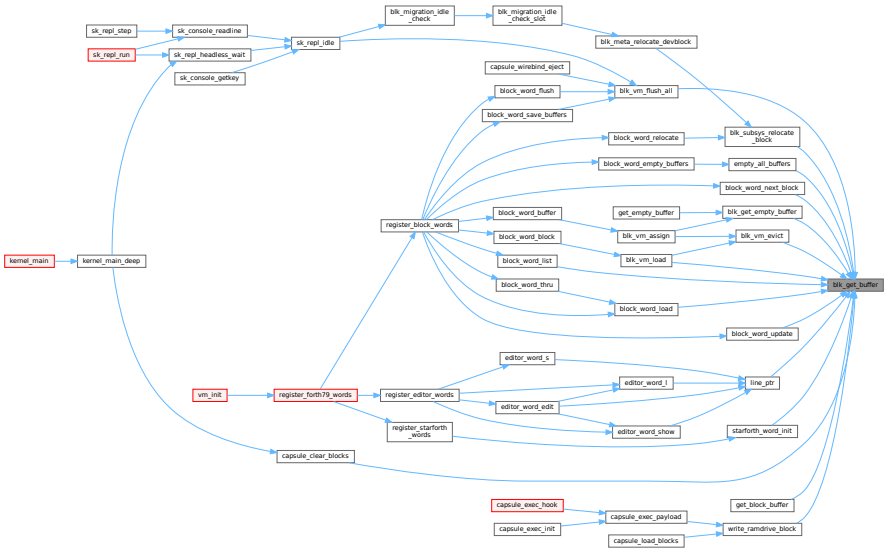
References blk_bam_entry_t::allocated, blk_dev_slot::bam, BLK_FMT_PROVISIONAL, BLK_FORTH_SIZE, BLK_FORTH_SYS_RESERVED, BLK_RAM_BLOCKS, cache_load_devblock(), cache_slot_t::data, blk_bam_entry_t::dirty, cache_slot_t::dirty, blk_dev_slot::format_state, g, lbn_to_slot(), lbn_to_slot_pbn(), blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_pack_offset(), slot_pbn_to_devblock(), and blk_dev_slot::start_lbn.

Referenced by blk_get_empty_buffer(), blk_subsys_relocate_block(), blk_vm_evict(), blk_vm_flush_all(), blk_vm_load(), block_word_list(), block_word_load(), block_word_next_block(), block_word_update(), capsule_clear_blocks(), empty_all_buffers(), get_block_buffer(), line_ptr(), starforth_word_init(), and write_ramdrive_block().

Here is the call graph for this function:



Here is the caller graph for this function:



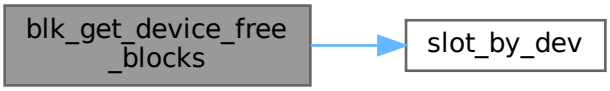
7.277.3.18 blk_get_device_free_blocks()

```
int blk_get_device_free_blocks (
            struct blkio_dev * dev,
            uint64_t * out_free,
            uint64_t * out_total )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, blk_volume_meta_t::free_blocks, blk_dev_slot::raw_base, slot_by_dev(), blk_volume_meta_t::total_blocks, and blk_dev_slot::vol_meta.

Referenced by capsule_wirebind_overflow_idle_check().

Here is the call graph for this function:



Here is the caller graph for this function:

7.277.3.19 blk_get_device_range()

```
int blk_get_device_range (
            struct blkio_dev * dev,
            uint32_t * out_start_lbn,
            uint32_t * out_count )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, slot_by_dev(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by sk_v4_genesis().

Here is the call graph for this function:

Here is the caller graph for this function:

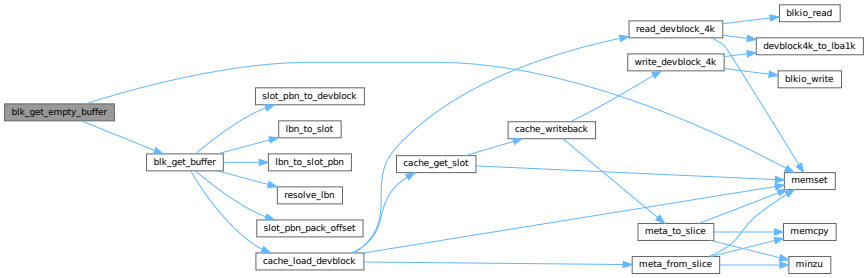
7.277.3.20 blk_get_empty_buffer()

```
uint8_t * blk_get_empty_buffer (
            uint32_t block_num )
```

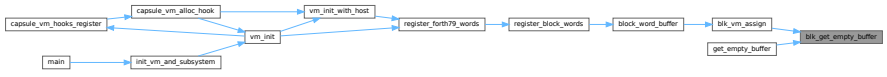
References BLK_FORTH_SIZE, blk_get_buffer(), and memset().

Referenced by blk_vm_assign(), and get_empty_buffer().

Here is the call graph for this function:



Here is the caller graph for this function:

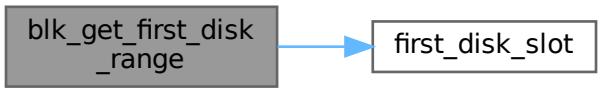


7.277.3.21 blk_get_first_disk_range()

```
int blk_get_first_disk_range (
            uint32_t * out_start_lbn,
            uint32_t * out_count )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, first_disk_slot(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Here is the call graph for this function:



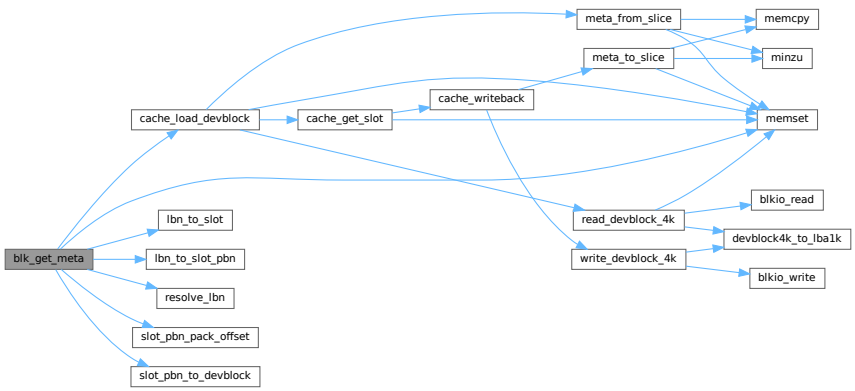
7.277.3.22 blk_get_meta()

```
int blk_get_meta (
            uint32_t block_num,
            blk_meta_t * meta )
```

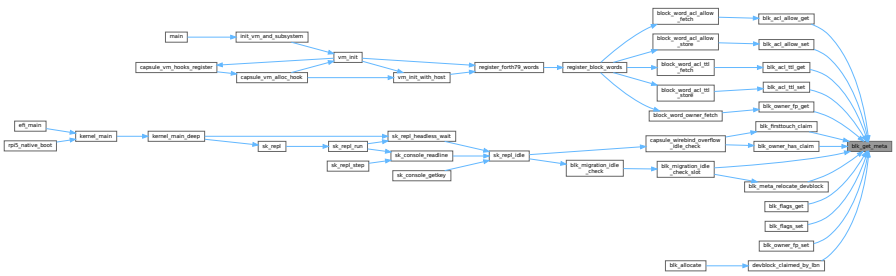
References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ERANGE, BLK_OK, cache_load_devblock(), g, lbn_to_slot(), lbn_to_slot_pbn(), blk_volume_meta_t::magic, memset(), meta, cache_slot_t::meta, blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_pack_offset(), and slot_pbn_to_devblock().

Referenced by blk_acl_allow_get(), blk_acl_allow_set(), blk_acl_ttl_get(), blk_acl_ttl_set(), blk_firsttouch_claim(), blk_flags_get(), blk_flags_set(), blk_meta_relocate_devblock(), blk_migration_idle_check_slot(), blk_owner_fp_get(), blk_owner_fp_set(), blk_owner_has_claim(), and devblock_claimed_by_lbn().

Here is the call graph for this function:



Here is the caller graph for this function:



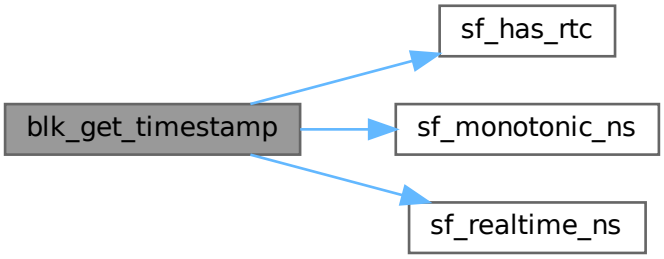
7.277.3.23 blk_get_timestamp()

```
static uint64_t blk_get_timestamp (
            void  )  [inline], [static]
```

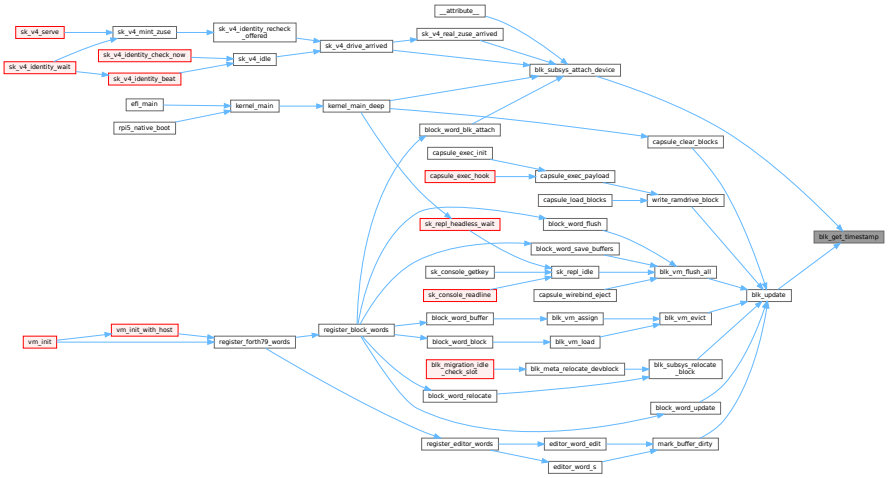
References sf_has_rtc(), sf_monotonic_ns(), and sf_realtime_ns().

Referenced by blk_subsys_attach_device(), and blk_update().

Here is the call graph for this function:



Here is the caller graph for this function:



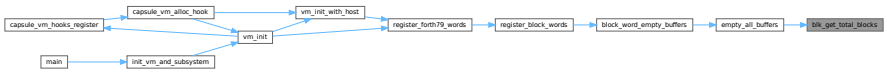
7.277.3.24 blk_get_total_blocks()

```
uint32_t blk_get_total_blocks (
            void  )
```

References g.

Referenced by empty_all_buffers().

Here is the caller graph for this function:

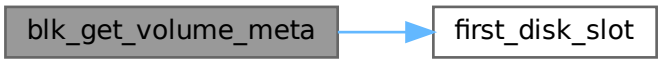


7.277.3.25 blk_get_volume_meta()

```
int blk_get_volume_meta (
            blk_volume_meta_t * meta )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, first_disk_slot(), meta, and blk_dev_slot::vol_meta.

Here is the call graph for this function:

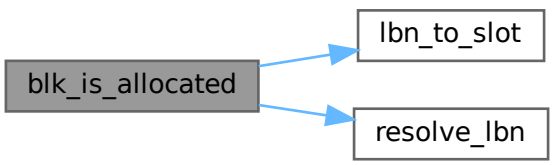


7.277.3.26 blk_is_allocated()

```
int blk_is_allocated (
            uint32_t block_num )
```

References blk_bam_entry_t::allocated, blk_dev_slot::bam, BLK_EINVAL, BLK_ENODEV, g, lbn_to_slot(), resolve_lbn(), and blk_dev_slot::start_lbn.

Here is the call graph for this function:



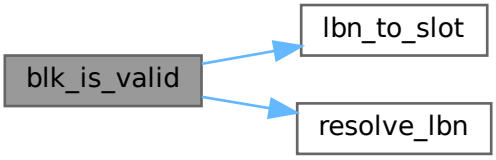
7.277.3.27 blk_is_valid()

```
int blk_is_valid (
            uint32_t block_num )
```

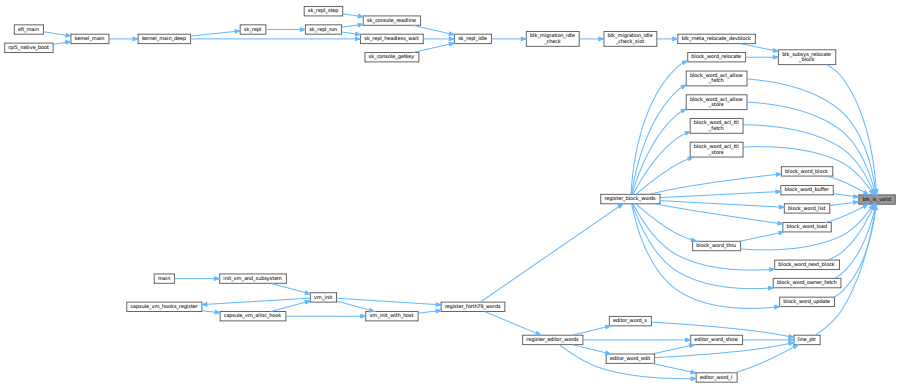
References g, lbn_to_slot(), and resolve_lbn().

Referenced by blk_subsys_relocate_block(), block_word_acl_allow_fetch(), block_word_acl_allow_store(), block_word_acl_ttl_fetch(), block_word_acl_ttl_store(), block_word_block(), block_word_buffer(), block_word_list(), block_word_load(), block_word_next_block(), block_word_owner_fetch(), block_word_thru(), block_word_update(), and line_ptr().

Here is the call graph for this function:



Here is the caller graph for this function:



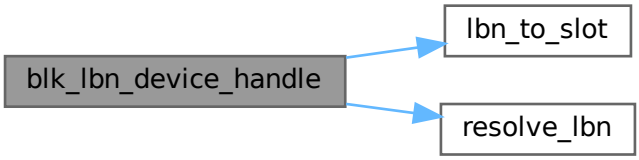
7.277.3.28 blk_lbn_device_handle()

```
const void * blk_lbn_device_handle (
            uint32_t lbn )
```

References lbn_to_slot(), and resolve_lbn().

Referenced by blk_vm_is_cross_device_copy().

Here is the call graph for this function:



Here is the caller graph for this function:

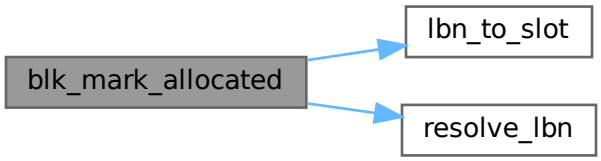
7.277.3.29 blk_mark_allocated()

```
int blk_mark_allocated (
            uint32_t block_num )
```

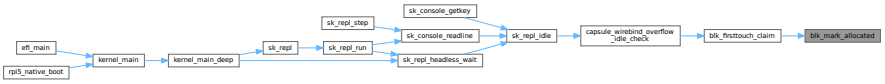
References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_dev_slot::bam_dirty, BLK_EINVAL, BLK_ENODEV, BLK_ERANGE, BLK_ERESERVED, BLK_FMT_PROVISIONAL, BLK_OK, blk_dev_slot::format_state, blk_volume_meta_t::free_blocks, lbn_to_slot(), blk_dev_slot::raw_base, resolve_lbn(), blk_dev_slot::start_lbn, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Referenced by blk_firsttouch_claim().

Here is the call graph for this function:



Here is the caller graph for this function:



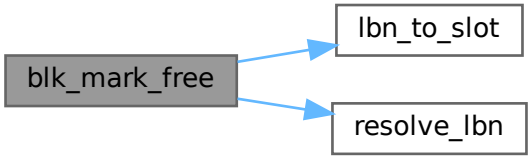
7.277.3.30 blk_mark_free()

```
int blk_mark_free (
            uint32_t block_num )
```

References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_dev_slot::bam_dirty, BLK_EINVAL, BLK_ENODEV, BLK_ERANGE, BLK_ERESERVED, BLK_FMT_PROVISIONAL, BLK_OK, blk_volume_meta_t::first_free, blk_dev_slot::format_state, blk_volume_meta_t::free_blocks, g, lbn_to_slot(), blk_dev_slot::raw_base, resolve_lbn(), blk_dev_slot::start_lbn, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Referenced by blk_subsys_relocate_block().

Here is the call graph for this function:



Here is the caller graph for this function:

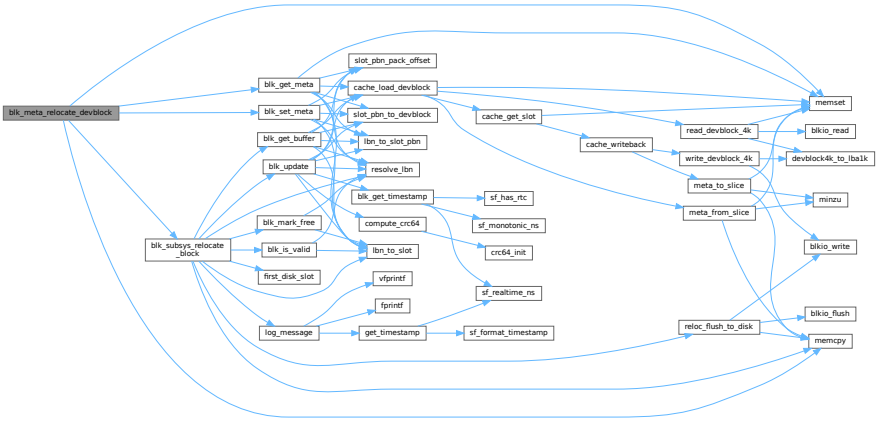
7.277.3.31 blk_meta_relocate_devblock()

```
int blk_meta_relocate_devblock (
            uint32_t home_devblock,
            uint32_t target_devblock )
```

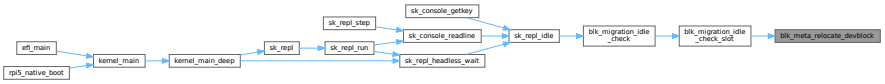
References blk_meta_t::acl_allow, blk_meta_t::acl_ttl, BLK_EINVAL, BLK_EIO, BLK_FLAG_CLAIMED, BLK_FLAG_MIGRATING, blk_get_meta(), BLK_OK, BLK_PACK_RATIO, blk_set_meta(), blk_subsys_relocate_block(), blk_meta_t::flags, memcpy(), memset(), and blk_meta_t::owner_fp.

Referenced by blk_migration_idle_check_slot().

Here is the call graph for this function:



Here is the caller graph for this function:



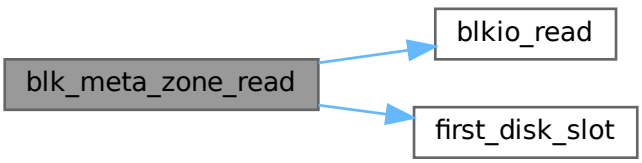
7.277.3.32 blk_meta_zone_read()

```
int blk_meta_zone_read (
            uint32_t devblock_from_top,
            uint8_t buf[4096] )
```

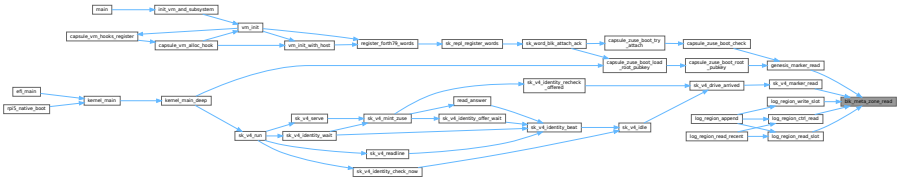
References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_OK, BLKIO_OK, blkio_read(), blk_dev_slot::dev, first_disk_slot(), blk_volume_meta_t::meta_fence_blocks, blk_volume_meta_t::total_devblocks, and blk_dev_slot::vol_meta.

Referenced by genesis_marker_read(), log_region_ctrl_read(), log_region_read_slot(), log_region_write_slot(), and sk_v4_marker_read().

Here is the call graph for this function:



Here is the caller graph for this function:



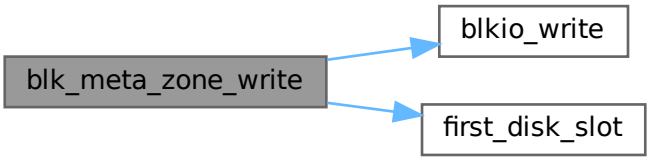
7.277.3.33 blk_meta_zone_write()

```
int blk_meta_zone_write (
            uint32_t devblock_from_top,
            const uint8_t buf[4096] )
```

References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_OK, BLKIO_OK, blkio_write(), blk_dev_slot::dev, first_disk_slot(), blk_volume_meta_t::meta_fence_blocks, blk_volume_meta_t::total_devblocks, and blk_dev_slot::vol_meta.

Referenced by capsule_zuse_boot_try_attach(), log_region_ctrl_write(), log_region_write_slot(), and sk_v4_marker_write().

Here is the call graph for this function:



Here is the caller graph for this function:

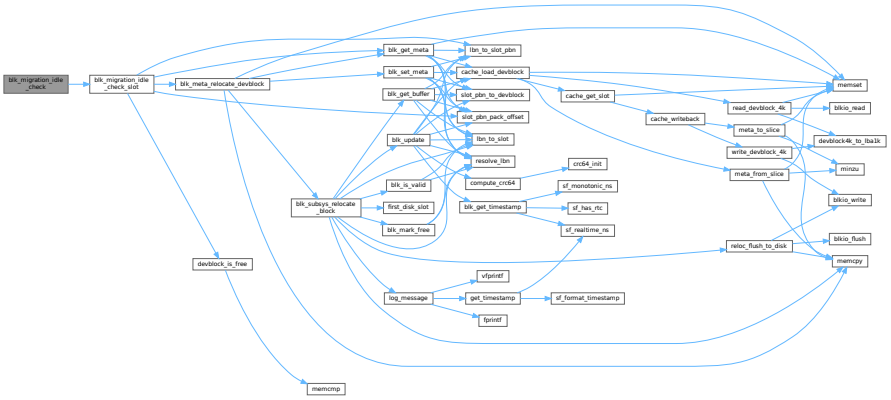
7.277.3.34 blk_migration_idle_check()

```
void blk_migration_idle_check (
            void  )
```

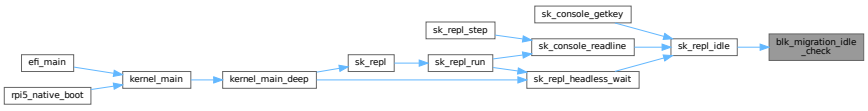
References blk_migration_idle_check_slot(), blk_dev_slot::dev, g, and blk_dev_slot::next.

Referenced by sk_repl_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



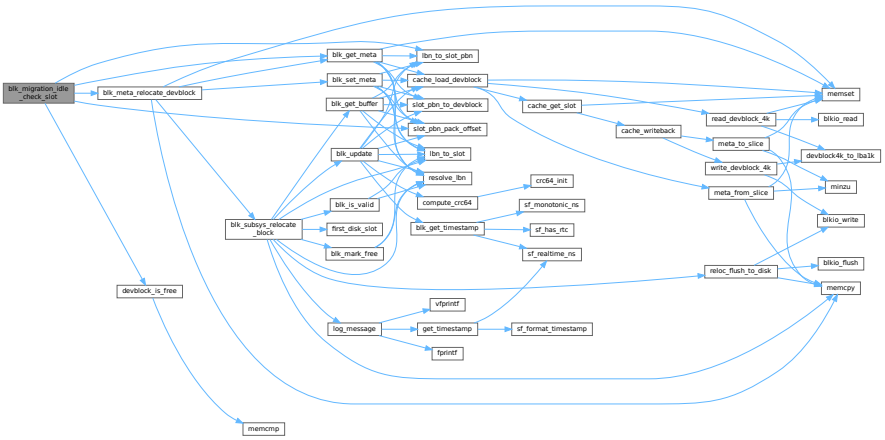
7.277.3.35 blk_migration_idle_check_slot()

```
static void blk_migration_idle_check_slot (
            blk_dev_slot_t * slot )  [static]
```

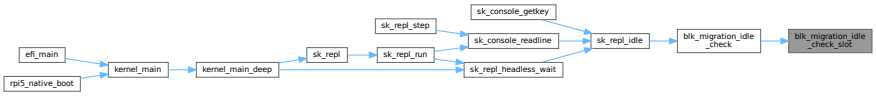
References BLK_FLAG_CLAIMED, BLK_FLAG_MIGRATING, blk_get_meta(), blk_meta_relocate_devblock(), BLK_OK, devblock_is_free(), blk_volume_meta_t::flags, blk_dev_slot::has_ever_claimed, lbn_to_slot_pbn(), meta, MIGRATION_SCAN_BUDGET, blk_dev_slot::migration_scan_lbn, MIGRATION_WEAR_THRESHOLD, slot_pbn_pack_offset(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by blk_migration_idle_check().

Here is the call graph for this function:



Here is the caller graph for this function:



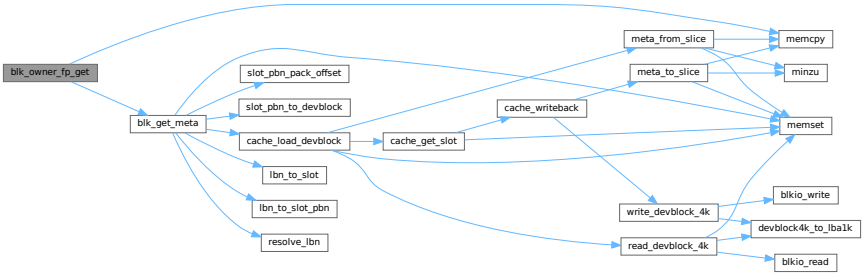
7.277.3.36 blk_owner_fp_get()

```
int blk_owner_fp_get (
            uint32_t block_num,
            uint8_t out_fp[8] )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, memcpy(), and meta.

Referenced by block_word_owner_fetch().

Here is the call graph for this function:



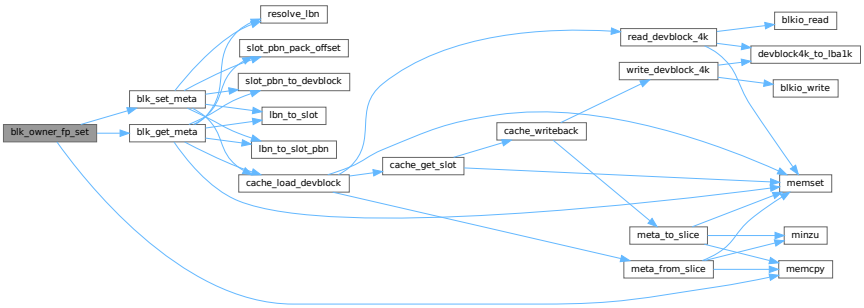
Here is the caller graph for this function:

7.277.3.37 blk_owner_fp_set()

```
int blk_owner_fp_set (
            uint32_t block_num,
            const uint8_t fp[8] )
```

References BLK_EINVAL, blk_get_meta(), BLK_OK, blk_set_meta(), memcpy(), and meta.

Here is the call graph for this function:



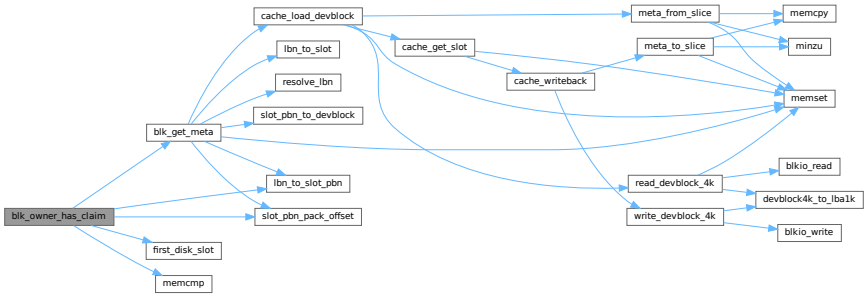
7.277.3.38 blk_owner_has_claim()

```
int blk_owner_has_claim (
            const uint8_t owner_fp[8] )
```

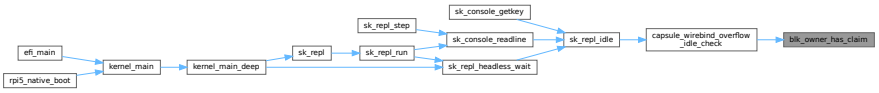
References BLK_FLAG_CLAIMED, blk_get_meta(), BLK_OK, first_disk_slot(), blk_volume_meta_t::flags, lbn_to_slot_pbn(), memcmp(), meta, slot_pbn_pack_offset(), blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by capsule_wirebind_overflow_idle_check().

Here is the call graph for this function:



Here is the caller graph for this function:



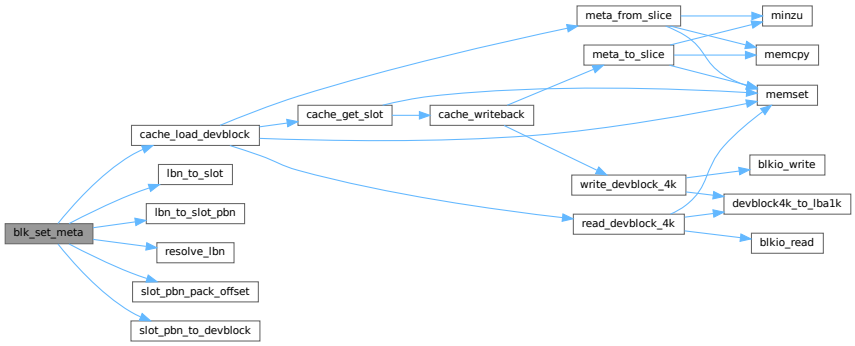
7.277.3.39 blk_set_meta()

```
int blk_set_meta (
            uint32_t block_num,
            const blk_meta_t * meta )
```

References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ERANGE, BLK_FLAG_CLAIMED, BLK_OK, cache_load_devblock(), blk_volume_meta_t::flags, g, blk_dev_slot::has_ever_claimed, lbn_to_slot(), lbn_to_slot_pbn(), meta, cache_slot_t::meta, cache_slot_t::meta_dirty, blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_pack_offset(), and slot_pbn_to_devblock().

Referenced by blk_acl_allow_set(), blk_acl_ttl_set(), blk_firsttouch_claim(), blk_flags_set(), blk_meta_relocate_devblock(), and blk_owner_fp_set().

Here is the call graph for this function:



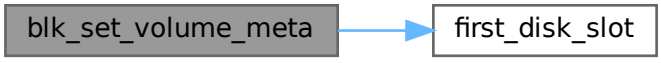
Here is the caller graph for this function:

7.277.3.40 blk_set_volume_meta()

```
int blk_set_volume_meta (
            const blk_volume_meta_t * meta )
```

References BLK_EINVAL, BLK_ENODEV, BLK_OK, first_disk_slot(), meta, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Here is the call graph for this function:

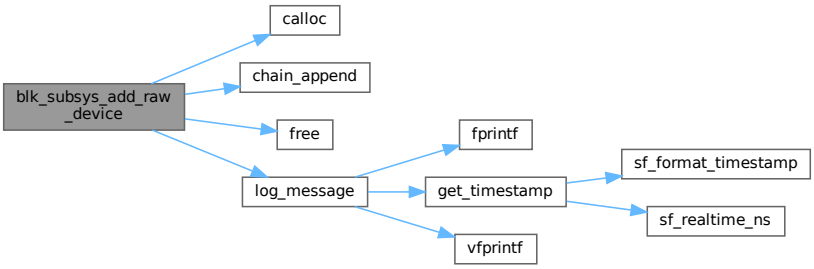


7.277.3.41 blk_subsys_add_raw_device()

```
int blk_subsys_add_raw_device (
            uint8_t * buf,
            uint32_t nblocks )
```

References blk_dev_slot::bam, BLK_EINVAL, BLK_ENODEV, BLK_ENOMEM, BLK_OK, calloc(), chain_append(), free(), g, LOG_INFO, log_message(), blk_dev_slot::raw_base, blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Here is the call graph for this function:



7.277.3.42 blk_subsys_attach_device()

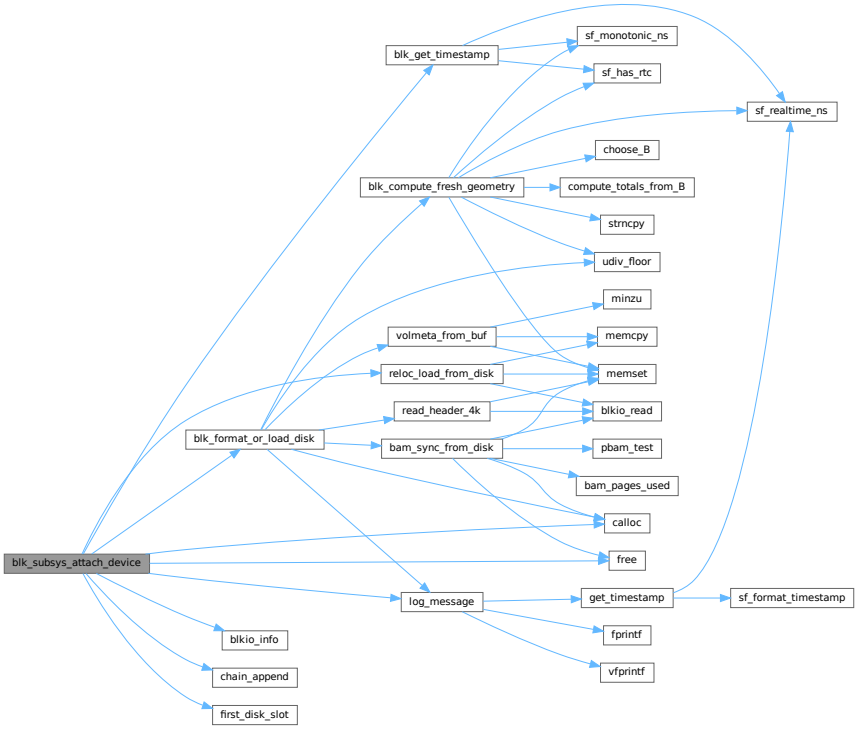
```
int blk_subsys_attach_device (
            struct blkio_dev * dev )
```

References blk_dev_slot::bam, blk_volume_meta_t::bam_devblocks, BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ENOMEM, BLK_FMT_FORMATTED, blk_format_or_load_disk(), blk_get_timestamp(), BLK_OK, blkio_info(),

BLKIO_OK, calloc(), chain_append(), blk_dev_slot::dev, blk_volume_meta_t::devblock_base, first_disk_slot(), blk_dev_slot::format_state, free(), blk_volume_meta_t::free_blocks, g, blk_volume_meta_t::label, LOG_INFO, log_message(), blk_volume_meta_t::meta_fence_blocks, blk_volume_meta_t::mounted_time, reloc_load_from_disk(), blk_dev_slot::start_lbn, blk_dev_slot::total_blkio_blocks_1k, blkio_info_t::total_blocks, blk_volume_meta_t::total_blocks, blk_volume_meta_t::total_devblocks, blk_dev_slot::user_blocks, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Referenced by __attribute__(), block_word_blk_attach(), kernel_main_deep(), sk_v4_drive_arrived(), and sk_v4_real_zuse_arrived().

Here is the call graph for this function:



Here is the caller graph for this function:

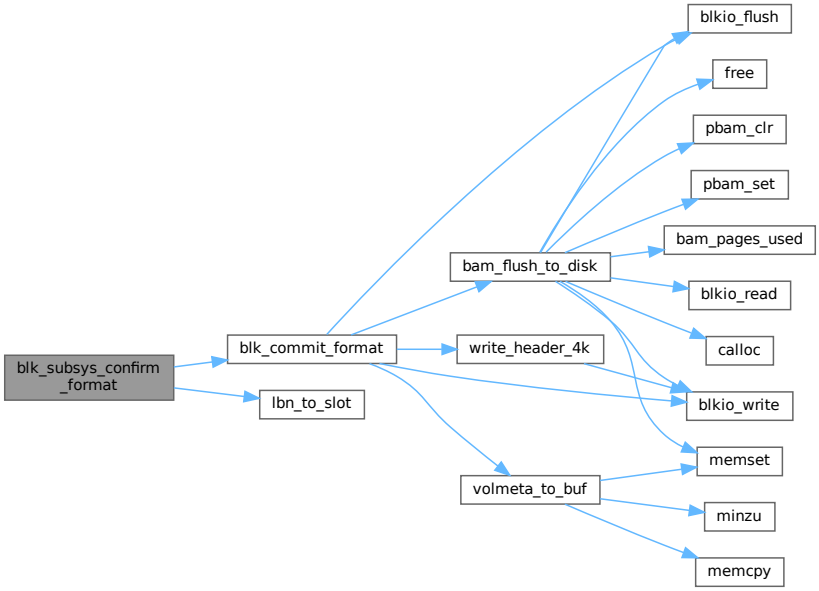
7.277.3.43 blk_subsys_confirm_format()

```
int blk_subsys_confirm_format (
            uint32_t lbn )
```

References blk_commit_format(), BLK_ENODEV, BLK_ERANGE, blk_dev_slot::dev, g, and lbn_to_slot().

Referenced by block_word_confirm_format(), and sk_v4_genesis().

Here is the call graph for this function:



Here is the caller graph for this function:

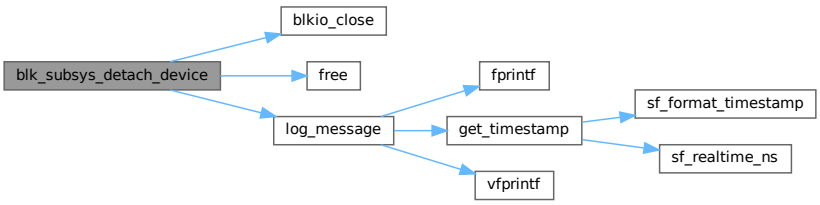
7.277.3.44 blk_subsys_detach_device()

```
int blk_subsys_detach_device (
            struct blkio_dev * dev )
```

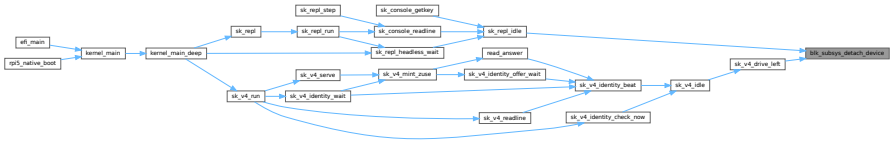
References blk_dev_slot::bam, BLK_EINVAL, BLK_ENODEV, BLK_OK, blkio_close(), blk_dev_slot::dev, free(), g, blk_volume_meta_t::label, LOG_INFO, log_message(), LOG_WARN, blk_dev_slot::next, blk_dev_slot::start_lbn, blk_dev_slot::user_blocks, and blk_dev_slot::vol_meta.

Referenced by sk_repl_idle(), and sk_v4_drive_left().

Here is the call graph for this function:



Here is the caller graph for this function:



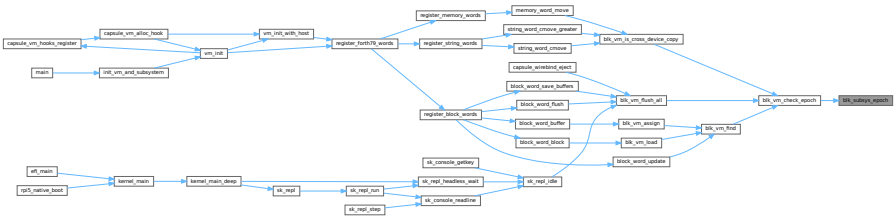
7.277.3.45 blk_subsys_epoch()

```
uint64_t blk_subsys_epoch (
            void  )
```

References g.

Referenced by blk_vm_check_epoch().

Here is the caller graph for this function:



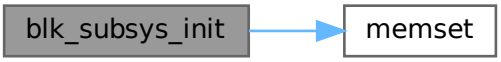
7.277.3.46 blk_subsys_init()

```
int blk_subsys_init (
            uint8_t * ram_base,
            size_t ram_size )
```

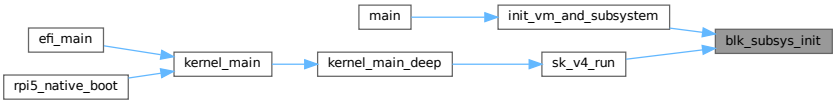
References BLK_EINVAL, BLK_FORTH_SIZE, BLK_FORTH_SYS_RESERVED, BLK_OK, BLK_RAM_BLOCKS, g, memset(), ram_base, and ram_size.

Referenced by init_vm_and_subsystem(), and sk_v4_run().

Here is the call graph for this function:



Here is the caller graph for this function:



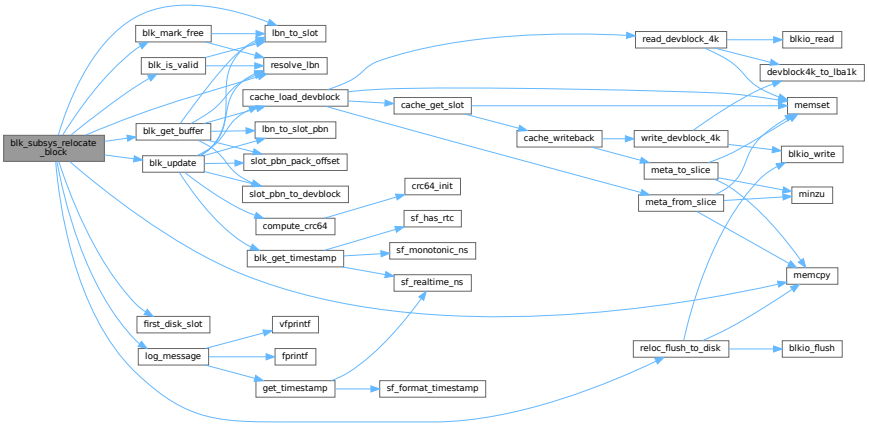
7.277.3.47 blk_subsys_relocate_block()

```
int blk_subsys_relocate_block (
            uint32_t home_lbn,
            uint32_t target_lbn )
```

References BLK_EINVAL, BLK_EIO, BLK_ENODEV, BLK_ENOMEM, BLK_ERANGE, BLK_FORTH_SIZE, blk_get_buffer(), blk_is_valid(), blk_mark_free(), BLK_OK, BLK_RELOC_MAX_ENTRIES, blk_update(), first_disk_slot(), g, lbn_to_slot(), LOG_INFO, log_message(), LOG_WARN, memcpy(), reloc_flush_to_disk(), and resolve_lbn().

Referenced by blk_meta_relocate_devblock(), and block_word_relocate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.277.3.48 blk_subsys_set_format_bam_for()

```
void blk_subsys_set_format_bam_for (
            uint64_t total_devblocks )
```

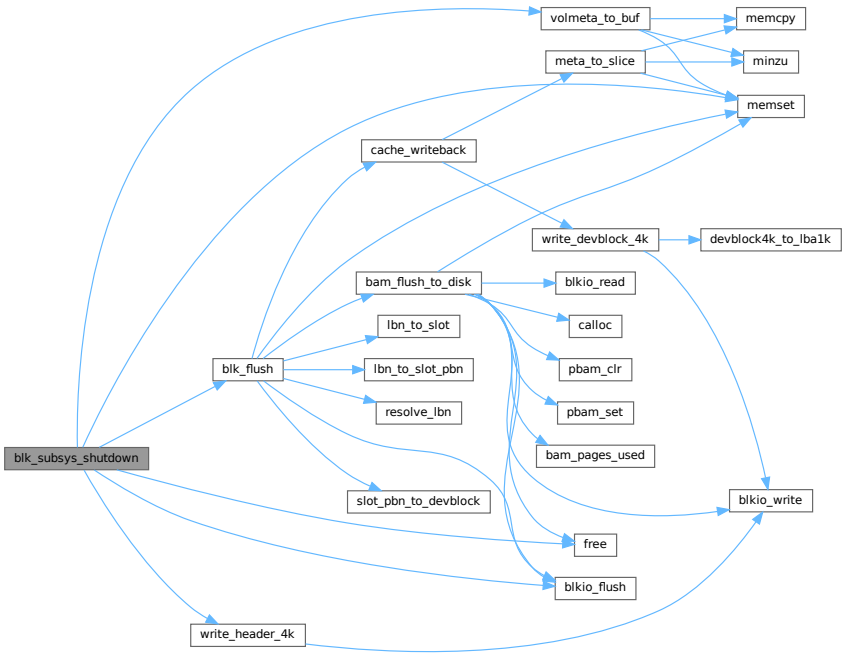
References g_format_bam_for.

7.277.3.49 blk_subsys_shutdown()

```
int blk_subsys_shutdown (
            void  )
```

References blk_dev_slot::bam, BLK_DEVICE_SECTOR, blk_flush(), BLK_FMT_FORMATTED, BLK_OK, blkio_flush(), blk_dev_slot::dev, blk_dev_slot::format_state, free(), g, memset(), blk_dev_slot::next, blk_dev_slot::vol_meta, blk_dev_slot::vol_meta_dirty, volmeta_to_buf(), and write_header_4k().

Here is the call graph for this function:



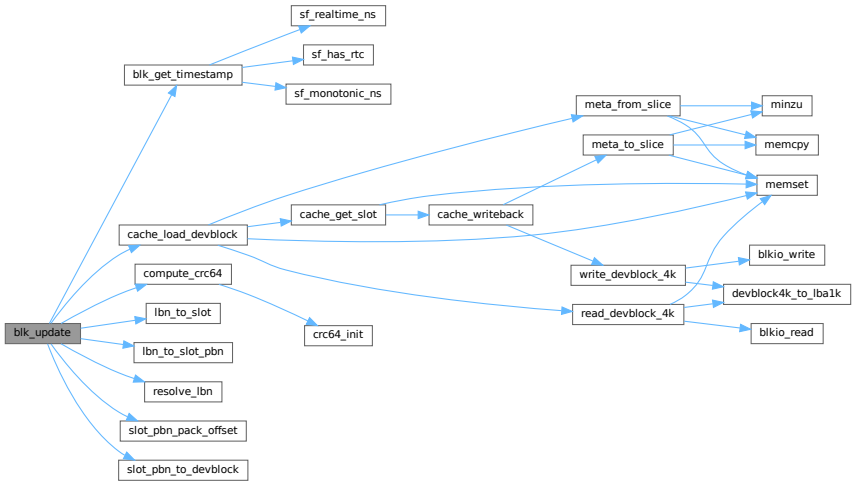
7.277.3.50 blk_update()

```
int blk_update (
            uint32_t block_num )
```

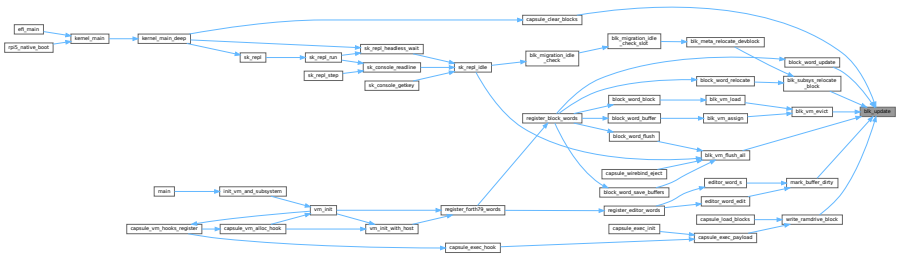
References blk_bam_entry_t::allocated, blk_dev_slot::bam, blk_dev_slot::bam_dirty, BLK_EIO, BLK_ENODEV, BLK_ERANGE, BLK_ERESERVED, BLK_FMT_PROVISIONAL, BLK_FORTH_SIZE, BLK_FORTH_SYS_RESERVED, blk_get_timestamp(), BLK_OK, BLK_RAM_BLOCKS, cache_load_devblock(), blk_meta_t::checksum, compute_crc64(), blk_meta_t::created_time, cache_slot_t::data, blk_bam_entry_t::dirty, cache_slot_t::dirty, blk_dev_slot::format_state, blk_volume_meta_t::free_blocks, g, lbn_to_slot(), lbn_to_slot_pbn(), blk_meta_t::magic, cache_slot_t::meta, cache_slot_t::meta_dirty, blk_meta_t::modified_time, blk_dev_slot::raw_base, resolve_lbn(), slot_pbn_pack_offset(), slot_pbn_to_devblock(), blk_dev_slot::start_lbn, blk_dev_slot::vol_meta, and blk_dev_slot::vol_meta_dirty.

Referenced by blk_subsys_relocate_block(), blk_vm_evict(), blk_vm_flush_all(), block_word_update(), capsule_clear_blocks(), mark_buffer_dirty(), and write_ramdrive_block().

Here is the call graph for this function:



Here is the caller graph for this function:



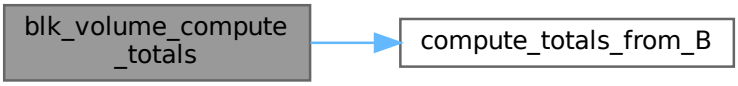
7.277.3.51 blk_volume_compute_totals()

```
void blk_volume_compute_totals (
            blk_volume_meta_t * m )
```

References compute_totals_from_B().

Referenced by sk_v4_grow_artemis().

Here is the call graph for this function:



Here is the caller graph for this function:

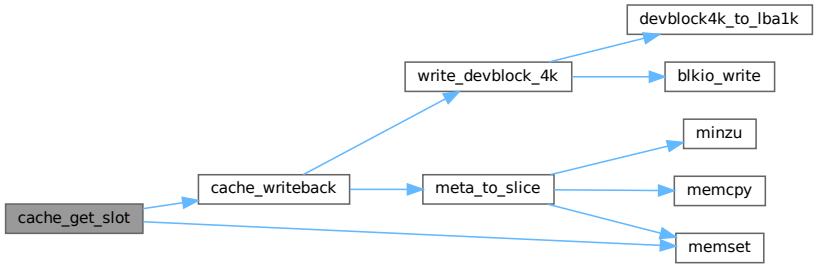
7.277.3.52 cache_get_slot()

```
static cache_slot_t * cache_get_slot (
            blk_dev_slot_t * slot,
            uint32_t dev4k )  [static]
```

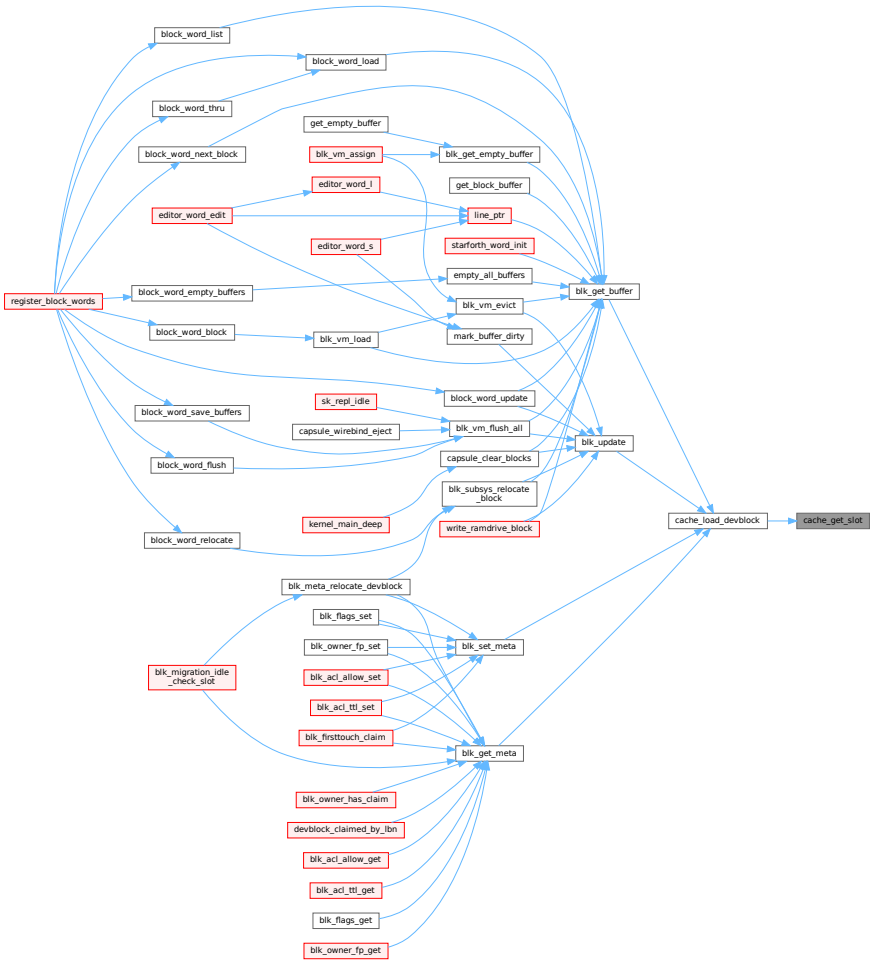
References blk_dev_slot::cache, cache_writeback(), cache_slot_t::devblock, DISK_CACHE_SLOTS, memset(), and cache_slot_t::valid.

Referenced by cache_load_devblock().

Here is the call graph for this function:



Here is the caller graph for this function:



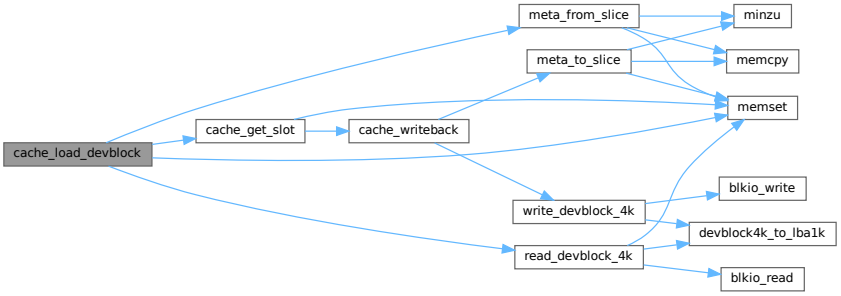
7.277.3.53 cache_load_devblock()

```
static cache_slot_t * cache_load_devblock (
            blk_dev_slot_t * slot,
            uint32_t dev4k )  [static]
```

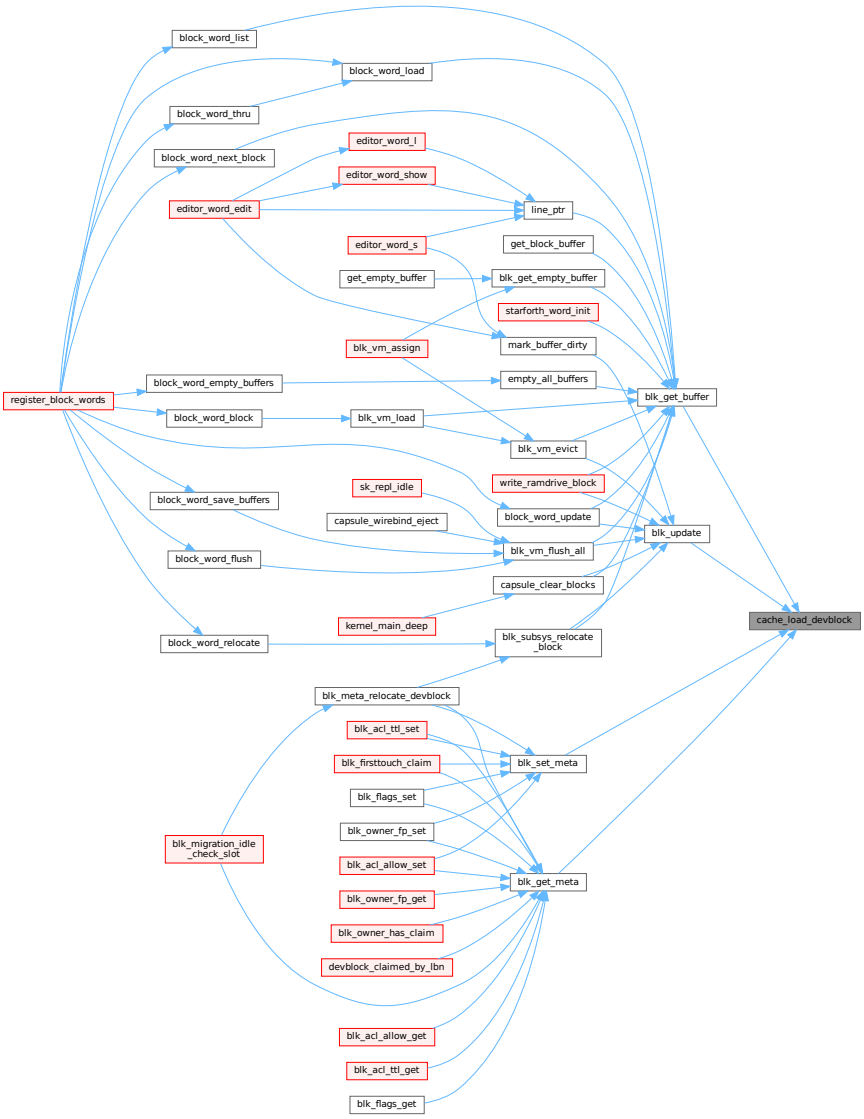
References BLK_PACK_RATIO, cache_get_slot(), cache_slot_t::data, cache_slot_t::loaded, blk_meta_t::magic, memset(), cache_slot_t::meta, meta_from_slice(), META_PER_BLOCK, META_REGION_OFFSET, and read_devblock_4k().

Referenced by blk_get_buffer(), blk_get_meta(), blk_set_meta(), and blk_update().

Here is the call graph for this function:



Here is the caller graph for this function:



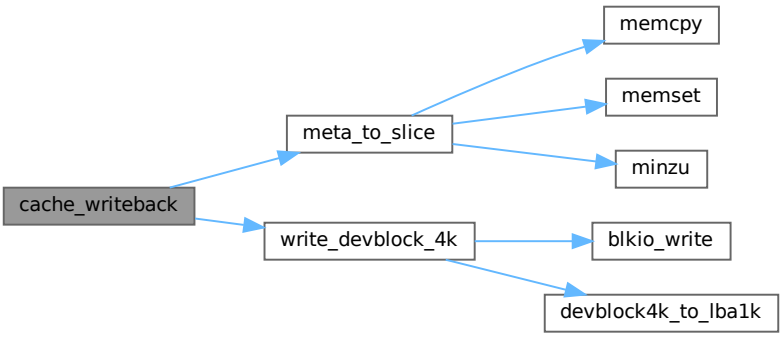
7.277.3.54 cache_writeback()

```
static int cache_writeback (
            blk_dev_slot_t * slot,
            cache_slot_t * s )  [static]
```

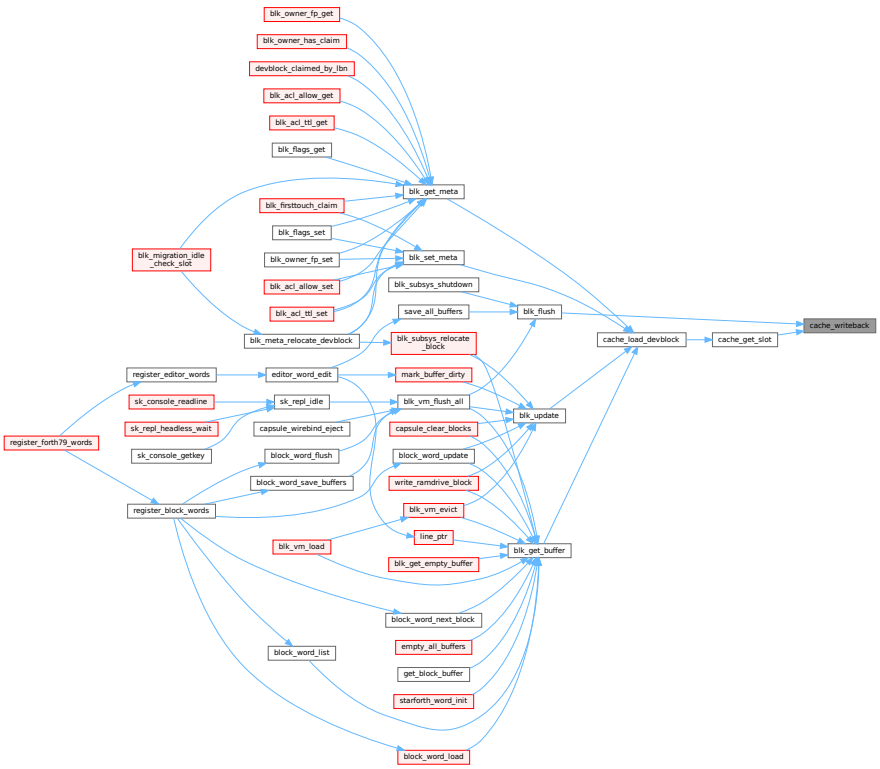
References BLK_OK, BLK_PACK_RATIO, cache_slot_t::data, blk_dev_slot::dev, cache_slot_t::devblock, cache_slot_t::dirty, cache_slot_t::meta, cache_slot_t::meta_dirty, META_PER_BLOCK, META_REGION_OFFSET, meta_to_slice(), and write_devblock_4k().

Referenced by blk_flush(), and cache_get_slot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.277.3.55 chain_append()

```
static void chain_append (
            blk_dev_slot_t * slot )  [static]
```

References g, and blk_dev_slot::next.

Referenced by blk_subsys_add_raw_device(), and blk_subsys_attach_device().

Here is the caller graph for this function:

7.277.3.56 choose_B()

```
static uint32_t choose_B (
            uint64_t total_devblocks_4k )  [static]
```

Referenced by blk_compute_fresh_geometry().

Here is the caller graph for this function:

7.277.3.57 compute_crc64()

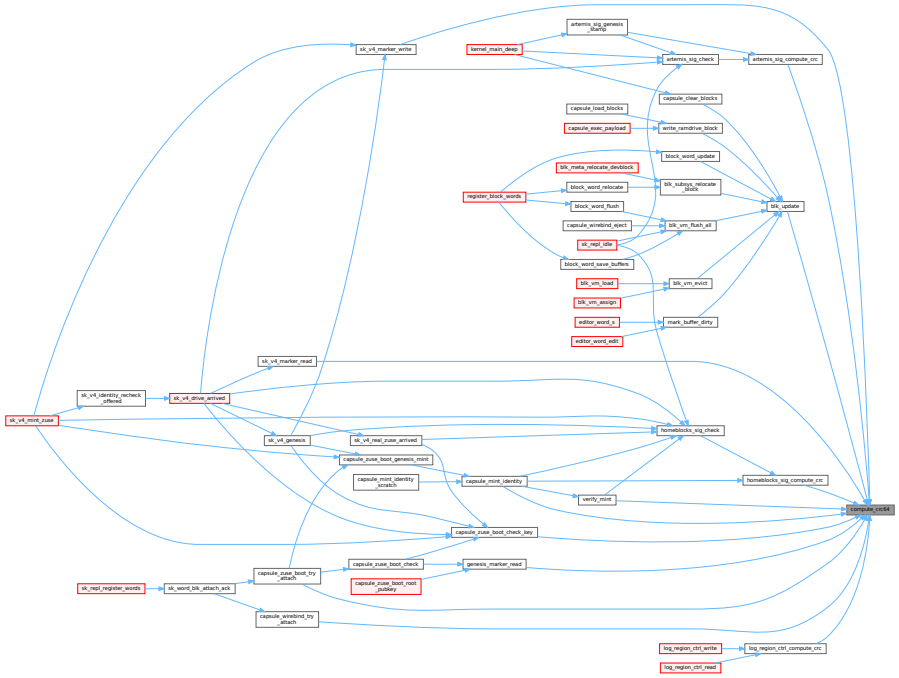
```
uint64_t compute_crc64 (
            const uint8_t * data,
            size_t len )
```

References crc64_init(), crc64_inited, and crc64_table.

Referenced by artemis_sig_compute_crc(), blk_update(), capsule_mint_identity(), capsule_wirebind_try_attach(), capsule_zuse_boot_check_key(), capsule_zuse_boot_try_attach(), genesis_marker_read(), homeblocks_sig_compute_crc(), log_region_ctrl_compute_crc(), sk_v4_marker_read(), sk_v4_marker_write(), and verify_mint().

Here is the call graph for this function:

Here is the caller graph for this function:



7.277.3.58 compute_totals_from_B()

```
static void compute_totals_from_B (
            blk_volume_meta_t * m )  [static]
```

References blk_volume_meta_t::bam_devblocks, blk_volume_meta_t::meta_fence_blocks, blk_volume_meta_t::reloc_devblocks, blk_volume_meta_t::total_blocks, blk_volume_meta_t::total_devblocks, and blk_volume_meta_t::tracked_blocks.

Referenced by blk_compute_fresh_geometry(), and blk_volume_compute_totals().

Here is the caller graph for this function:

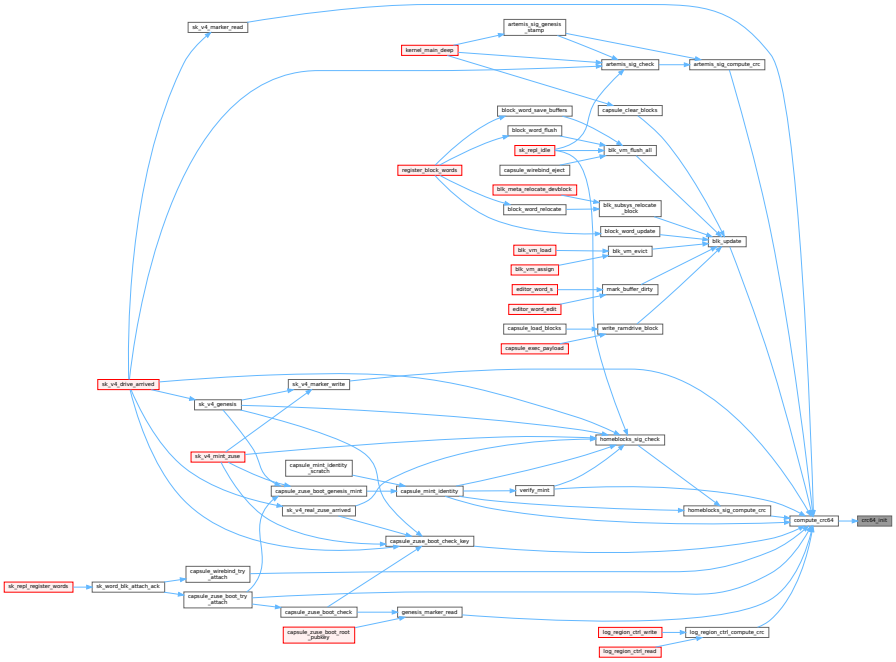
7.277.3.59 crc64_init()

```
static void crc64_init (
            void  )  [static]
```

References crc64_inited, and crc64_table.

Referenced by compute_crc64().

Here is the caller graph for this function:



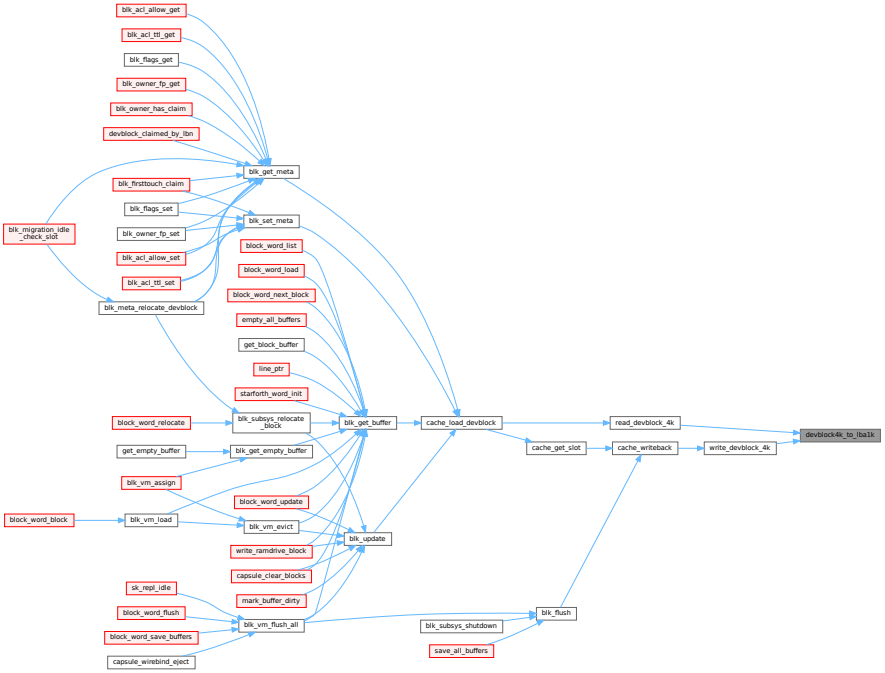
7.277.3.60 devblock4k_to_lba1k()

```
static uint32_t devblock4k_to_lba1k (
            blk_dev_slot_t * slot,
            uint32_t dev4k )  [inline], [static]
```

References blk_dev_slot::devblock_base_4k.

Referenced by read_devblock_4k(), and write_devblock_4k().

Here is the caller graph for this function:



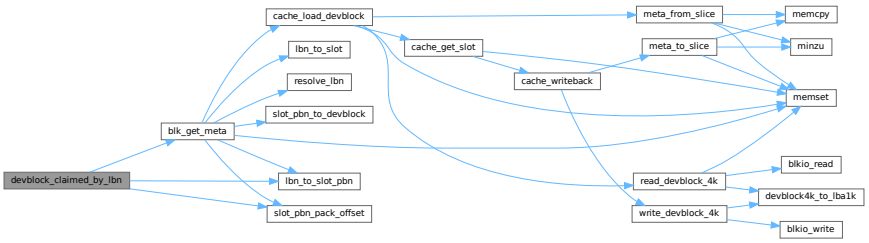
7.277.3.61 devblock_claimed_by_lbn()

```
static int devblock_claimed_by_lbn (
            blk_dev_slot_t * slot,
            uint32_t lbn )  [static]
```

References BLK_FLAG_CLAIMED, blk_get_meta(), BLK_OK, blk_volume_meta_t::flags, lbn_to_slot_pbn(), meta, slot_pbn_pack_offset(), and blk_dev_slot::start_lbn.

Referenced by blk_allocate().

Here is the call graph for this function:



Here is the caller graph for this function:

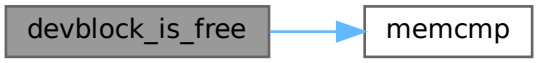
7.277.3.62 devblock_is_free()

```
static int devblock_is_free (
            blk_dev_slot_t * slot,
            uint32_t rep_lbn,
            const blk_meta_t * m )  [static]
```

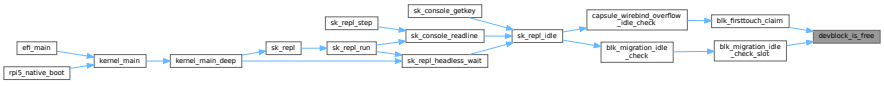
References blk_bam_entry_t::allocated, blk_dev_slot::bam, BLK_FLAG_CLAIMED, BLK_PACK_RATIO, blk_meta_t::flags, memcmp(), blk_meta_t::owner_fp, blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by blk_firsttouch_claim(), and blk_migration_idle_check_slot().

Here is the call graph for this function:



Here is the caller graph for this function:



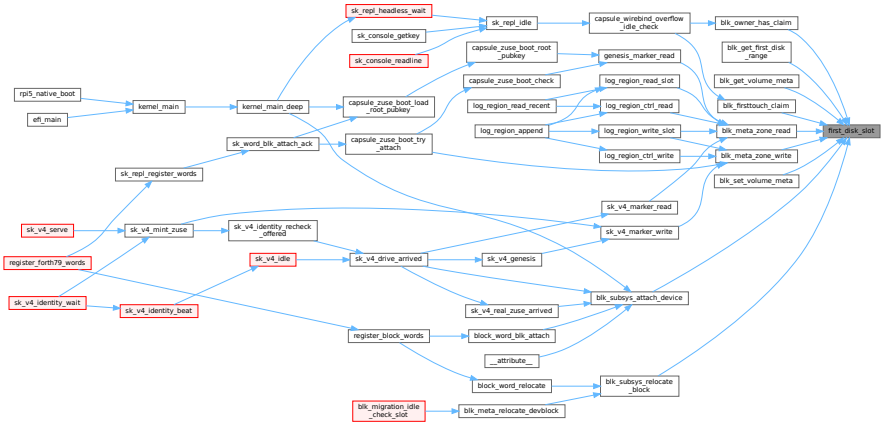
7.277.3.63 first_disk_slot()

```
static blk_dev_slot_t * first_disk_slot (
            void  )  [static]
```

References blk_dev_slot::dev, g, and blk_dev_slot::next.

Referenced by blk_firsttouch_claim(), blk_get_first_disk_range(), blk_get_volume_meta(), blk_meta_zone_read(), blk_meta_zone_write(), blk_owner_has_claim(), blk_set_volume_meta(), blk_subsys_attach_device(), and blk_subsys_relocate_block().

Here is the caller graph for this function:



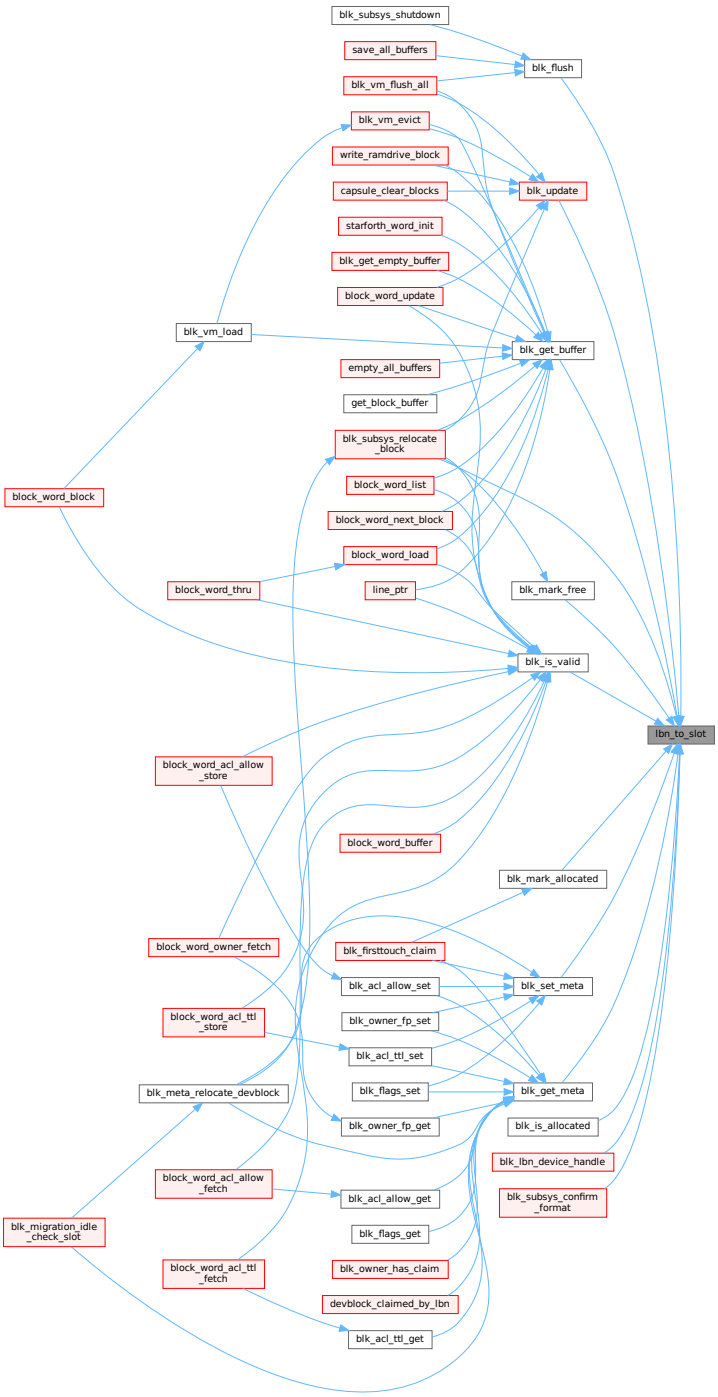
7.277.3.64 lbn_to_slot()

```
static blk_dev_slot_t * lbn_to_slot (
            uint32_t lbn )  [static]
```

References g, blk_dev_slot::next, blk_dev_slot::start_lbn, and blk_dev_slot::user_blocks.

Referenced by blk_flush(), blk_get_buffer(), blk_get_meta(), blk_is_allocated(), blk_is_valid(), blk_lbn_device_handle(), blk_mark_allocated(), blk_mark_free(), blk_set_meta(), blk_subsys_confirm_format(), blk_subsys_relocate_block(), and blk_update().

Here is the caller graph for this function:



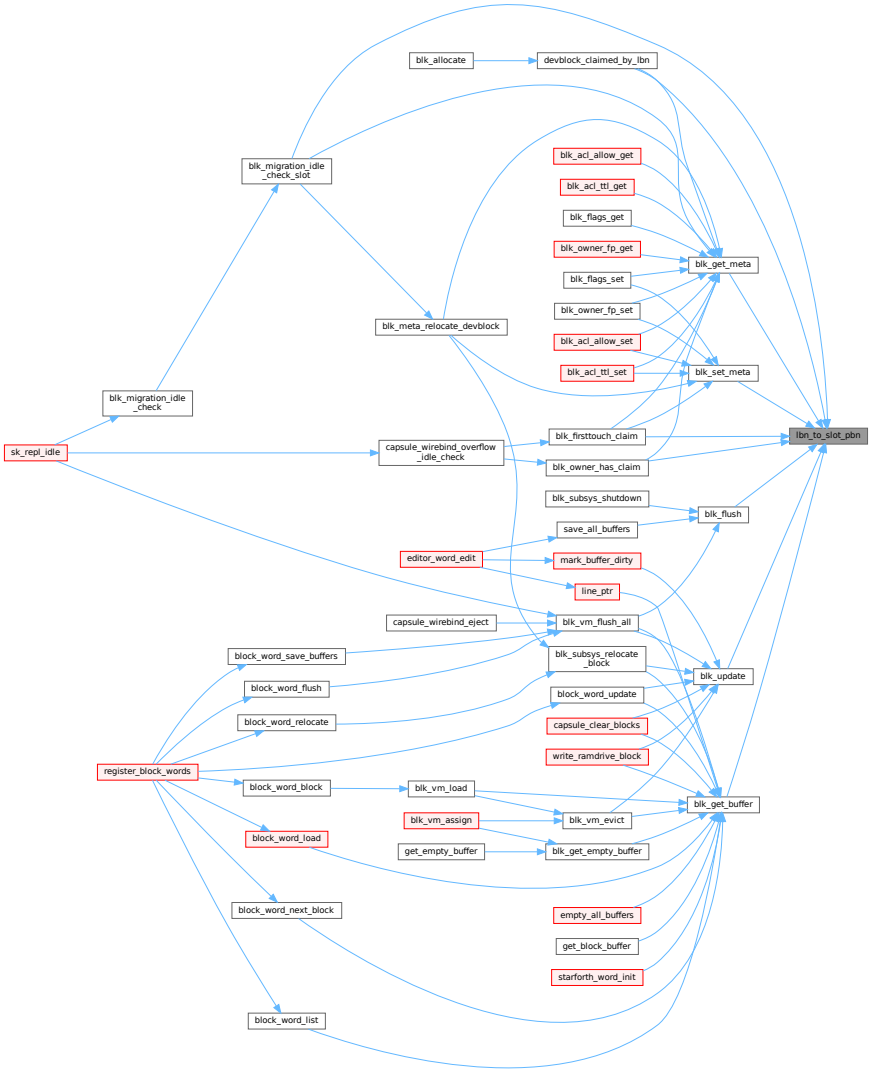
7.277.3.65 lbn_to_slot_pbn()

```
static uint32_t lbn_to_slot_pbn (
            blk_dev_slot_t * slot,
            uint32_t lbn )  [inline], [static]
```

References BLK_DISK_SYS_RESERVED, and blk_dev_slot::start_lbn.

Referenced by blk_firsttouch_claim(), blk_flush(), blk_get_buffer(), blk_get_meta(), blk_migration_idle_check_slot(), blk_owner_has_claim(), blk_set_meta(), blk_update(), and devblock_claimed_by_lbn().

Here is the caller graph for this function:



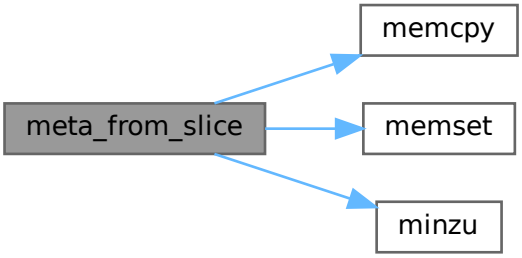
7.277.3.66 meta_from_slice()

```
static void meta_from_slice (
            blk_meta_t * dst,
            const uint8_t * slice )  [static]
```

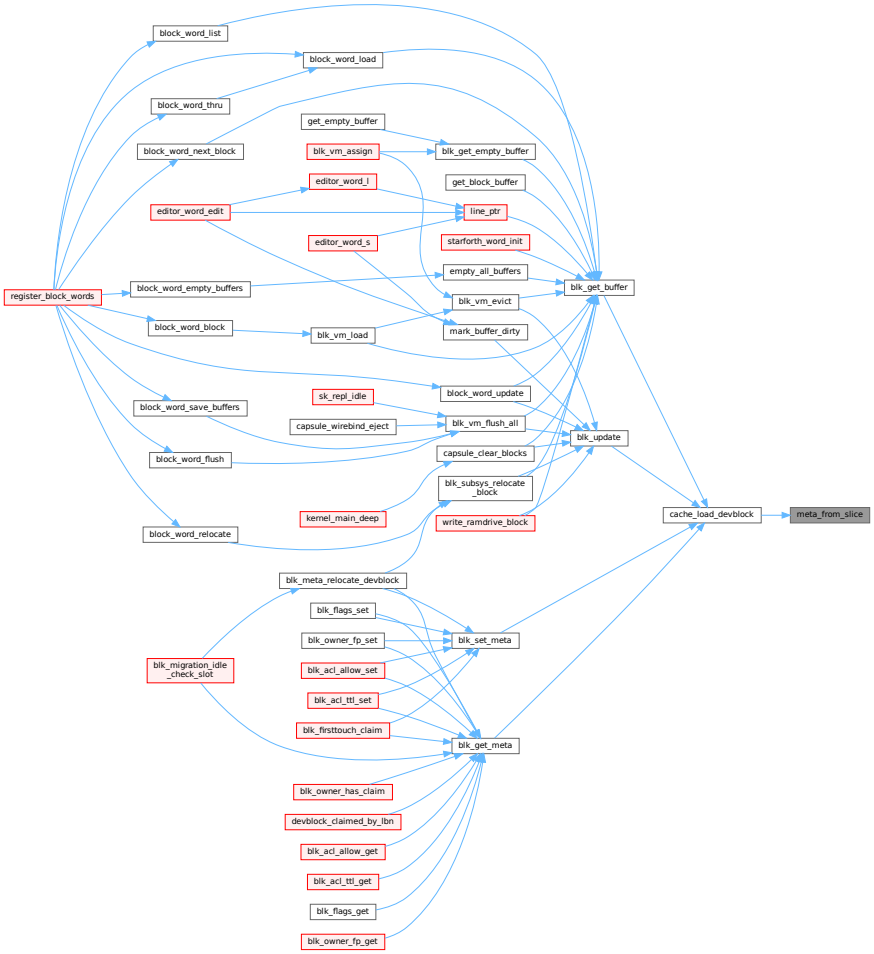
References memcpy(), memset(), META_PER_BLOCK, and minzu().

Referenced by cache_load_devblock().

Here is the call graph for this function:



Here is the caller graph for this function:



7.277.3.67 meta_to_slice()

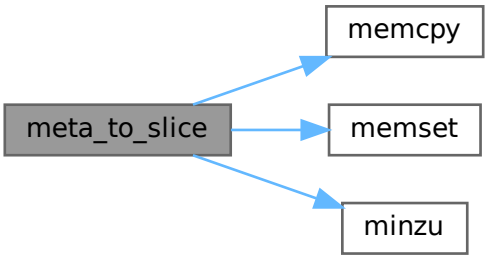
```
static void meta_to_slice (
```

```
const blk_meta_t * src,
uint8_t * slice )  [static]
```

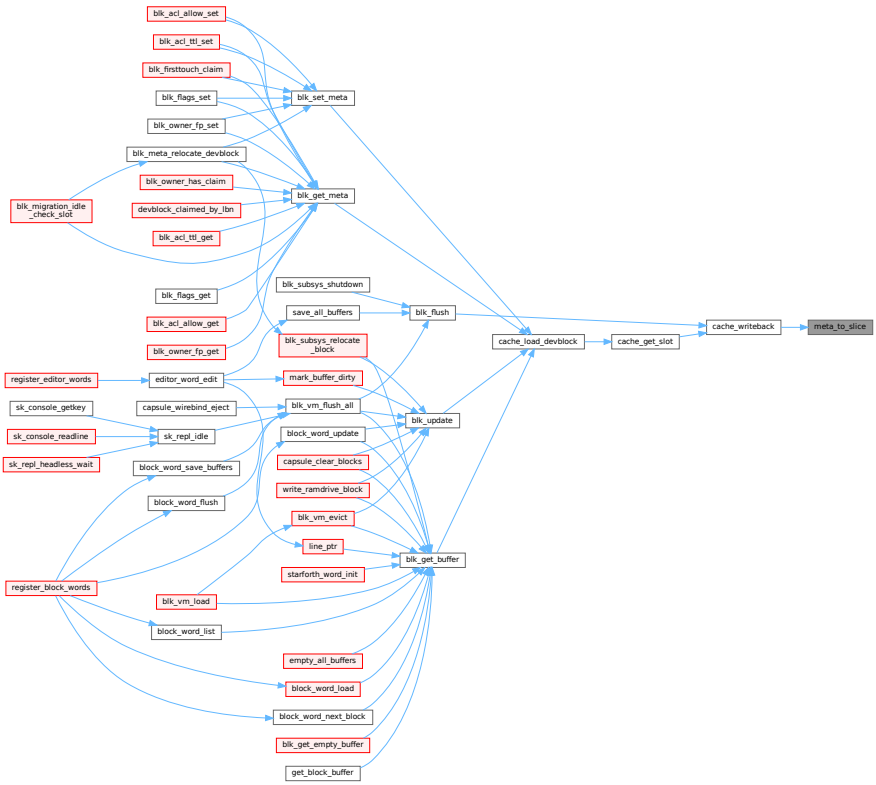
References memcpy(), memset(), META_PER_BLOCK, and minzu().

Referenced by cache_writeback().

Here is the call graph for this function:



Here is the caller graph for this function:

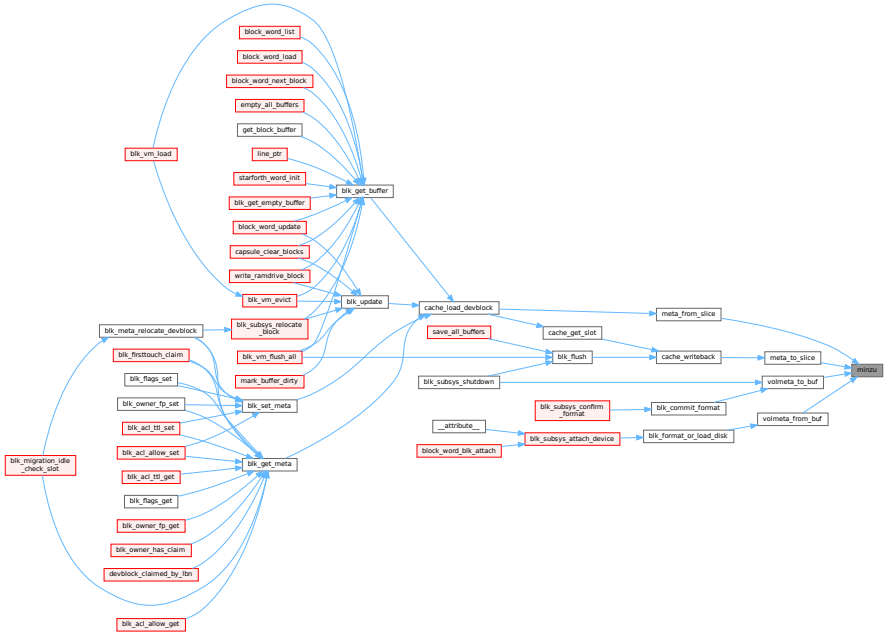


7.277.3.68 minzu()

```
static size_t minzu (
            size_t a,
            size_t b )  [inline], [static]
```

Referenced by meta_from_slice(), meta_to_slice(), volmeta_from_buf(), and volmeta_to_buf().

Here is the caller graph for this function:

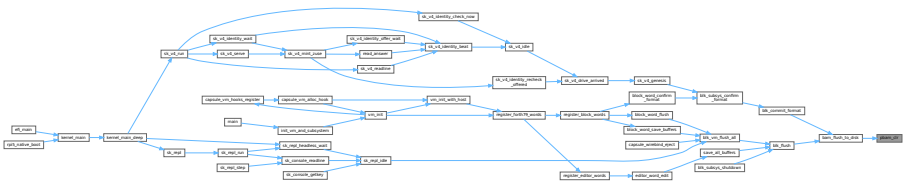


7.277.3.69 pbam_clr()

```
static void pbam_clr (
            uint8_t * bm,
            uint32_t i )  [inline], [static]
```

Referenced by bam_flush_to_disk().

Here is the caller graph for this function:

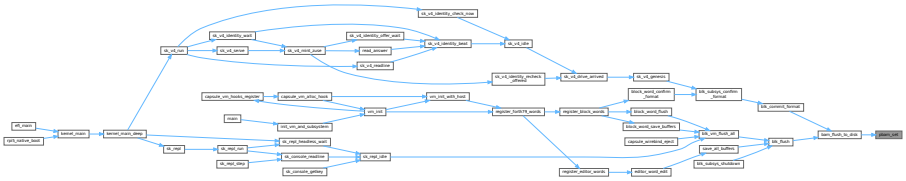


7.277.3.70 pbam_set()

```
static void pbam_set (
            uint8_t * bm,
            uint32_t i )  [inline], [static]
```

Referenced by bam_flush_to_disk().

Here is the caller graph for this function:



7.277.3.71 pbam_test()

```
static int pbam_test (
            const uint8_t * bm,
            uint32_t i )  [inline], [static]
```

Referenced by bam_sync_from_disk().

Here is the caller graph for this function:

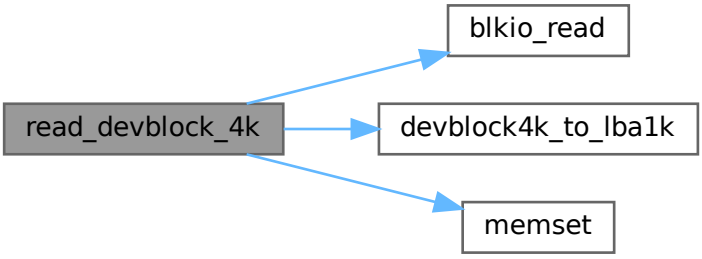
7.277.3.72 read_devblock_4k()

```
static int read_devblock_4k (
            blk_dev_slot_t * slot,
            uint32_t dev4k,
            uint8_t * buf4k )  [static]
```

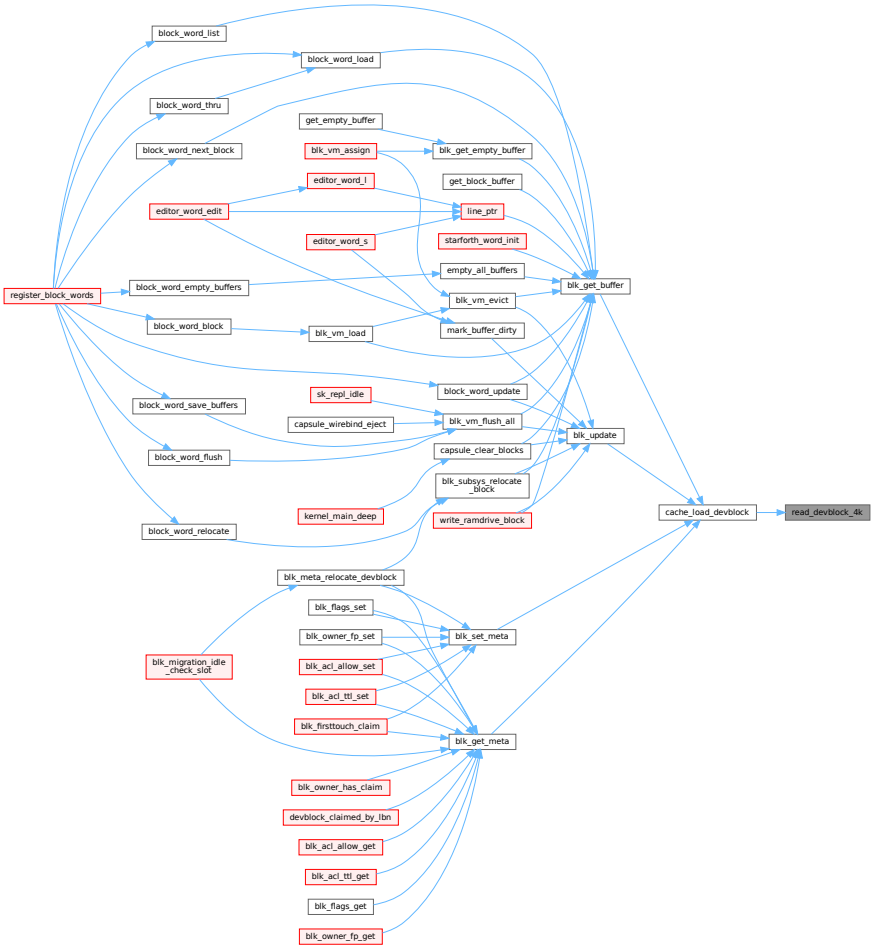
References base, BLK_OK, BLKIO_OK, blkio_read(), blk_dev_slot::dev, devblock4k_to_lba1k(), memset(), and blk_dev_slot::total_blkio_blocks_1k.

Referenced by cache_load_devblock().

Here is the call graph for this function:



Here is the caller graph for this function:



7.277.3.73 read_header_4k()

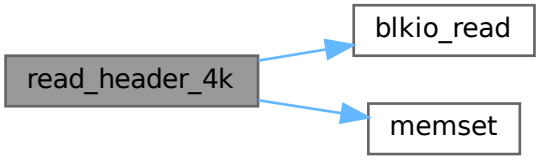
```
static int read_header_4k (
```

```
            blk_dev_slot_t * slot,
            uint8_t * buf4k )  [static]
```

References BLK_OK, BLKIO_OK, blkio_read(), blk_dev_slot::dev, and memset().

Referenced by blk_format_or_load_disk().

Here is the call graph for this function:



Here is the caller graph for this function:

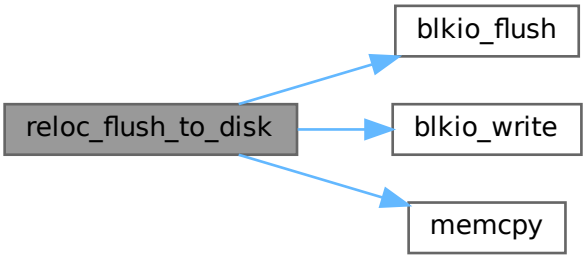
7.277.3.74 reloc_flush_to_disk()

```
static int reloc_flush_to_disk (
            blk_dev_slot_t * slot )  [static]
```

References BLK_EIO, BLK_OK, blkio_flush(), BLKIO_OK, blkio_write(), blk_dev_slot::dev, g, memcpy(), blk_volume_meta_t::reloc_devblocks, blk_volume_meta_t::reloc_start, and blk_dev_slot::vol_meta.

Referenced by blk_subsys_relocate_block().

Here is the call graph for this function:



Here is the caller graph for this function:

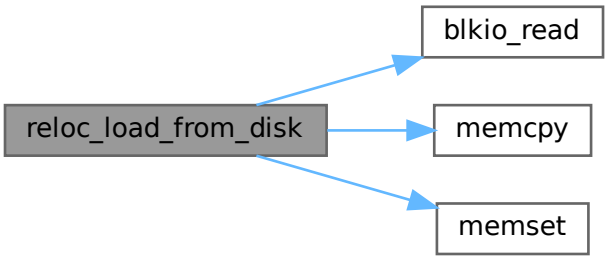
7.277.3.75 reloc_load_from_disk()

```
static int reloc_load_from_disk (
            blk_dev_slot_t * slot )  [static]
```

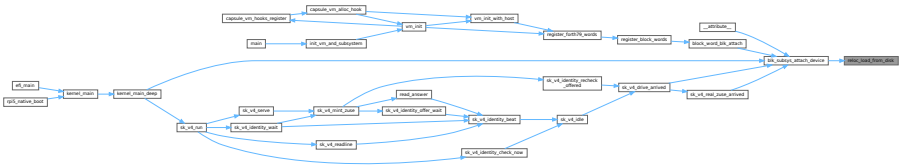
References BLK_EINVAL, BLK_OK, BLK_RELOC_MAX_ENTRIES, BLKIO_OK, blkio_read(), count, blk_dev_slot::dev, g, memcpy(), memset(), blk_volume_meta_t::reloc_devblocks, blk_volume_meta_t::reloc_start, and blk_dev_slot::vol_meta.

Referenced by blk_subsys_attach_device().

Here is the call graph for this function:



Here is the caller graph for this function:



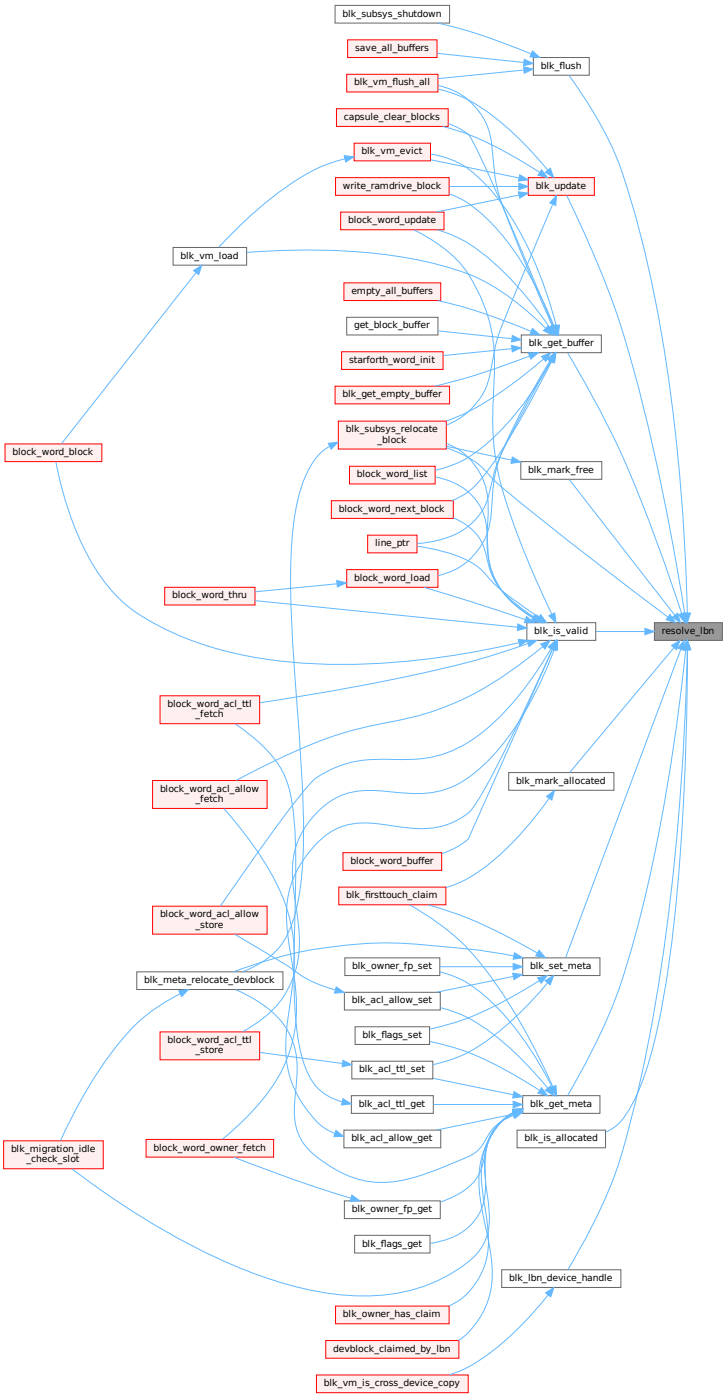
7.277.3.76 resolve_lbn()

```
static uint32_t resolve_lbn (
            uint32_t lbn )  [static]
```

References blk_reloc_entry_t::actual_lbn, and g.

Referenced by blk_flush(), blk_get_buffer(), blk_get_meta(), blk_is_allocated(), blk_is_valid(), blk_lbn_device_handle(), blk_mark_allocated(), blk_mark_free(), blk_set_meta(), blk_subsys_relocate_block(), and blk_update().

Here is the caller graph for this function:



7.277.3.77 slot_by_dev()

```
static blk_dev_slot_t * slot_by_dev (
            struct blkio_dev * dev )  [static]
```

References blk_dev_slot::dev, g, and blk_dev_slot::next.

Referenced by blk_get_device_free_blocks(), and blk_get_device_range().

Here is the caller graph for this function:

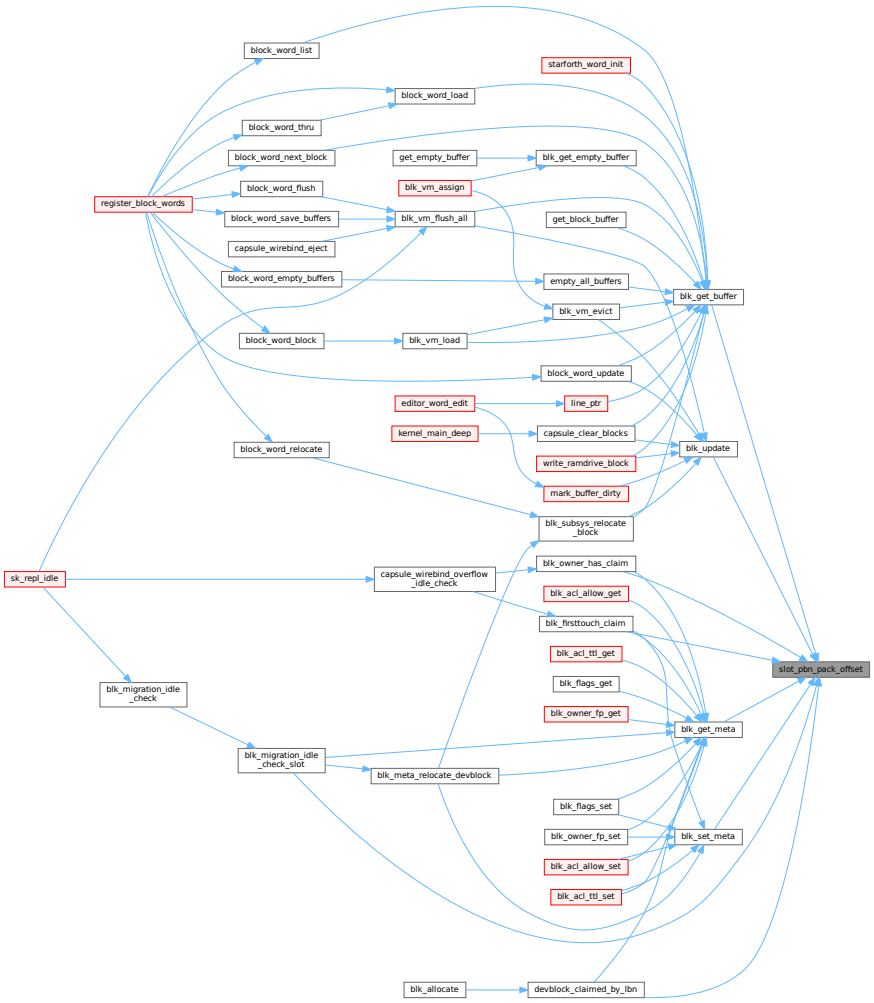
7.277.3.78 slot_pbn_pack_offset()

```
static uint32_t slot_pbn_pack_offset (
            uint32_t rel_pbn )  [inline], [static]
```

References BLK_PACK_RATIO.

Referenced by blk_firsttouch_claim(), blk_get_buffer(), blk_get_meta(), blk_migration_idle_check_slot(), blk_owner_has_claim(), blk_set_meta(), blk_update(), and devblock_claimed_by_lbn().

Here is the caller graph for this function:



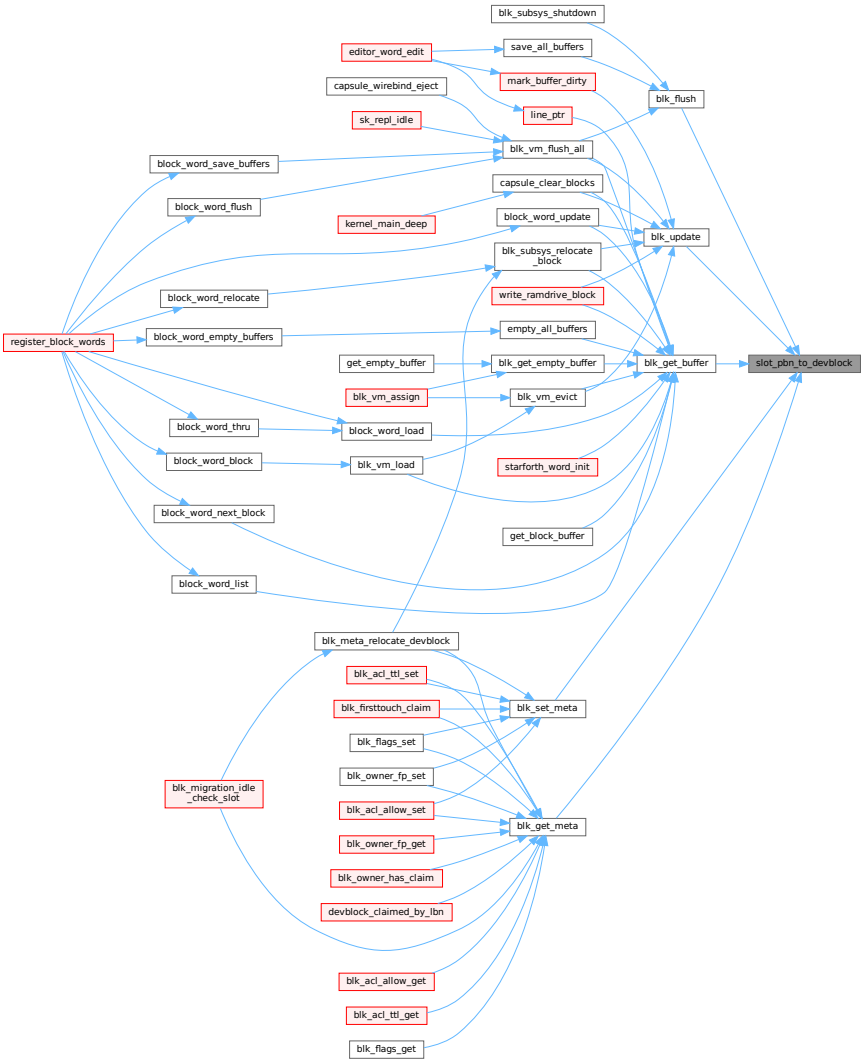
7.277.3.79 slot_pbn_to_devblock()

```
static uint32_t slot_pbn_to_devblock (
            uint32_t rel_pbn )  [inline], [static]
```

References BLK_PACK_RATIO.

Referenced by blk_flush(), blk_get_buffer(), blk_get_meta(), blk_set_meta(), and blk_update().

Here is the caller graph for this function:



7.277.3.80 udiv_floor()

```
static uint32_t udiv_floor (
            uint32_t a,
            uint32_t b )  [inline], [static]
```

Referenced by blk_compute_fresh_geometry(), and blk_format_or_load_disk().

Here is the caller graph for this function:

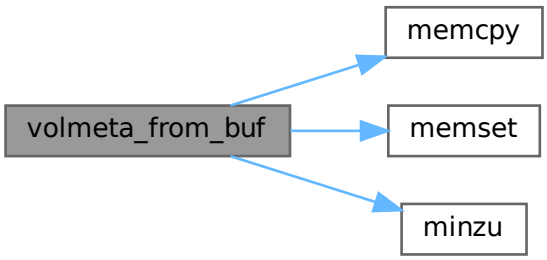
7.277.3.81 volmeta_from_buf()

```
static void volmeta_from_buf (
            blk_volume_meta_t * out,
            const uint8_t * buf )  [inline], [static]
```

References BLK_DEVICE_SECTOR, memcpy(), memset(), and minzu().

Referenced by blk_format_or_load_disk().

Here is the call graph for this function:



Here is the caller graph for this function:

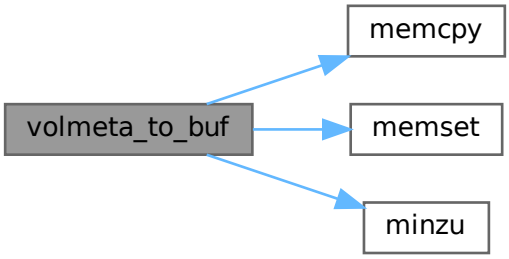
7.277.3.82 volmeta_to_buf()

```
static void volmeta_to_buf (
            const blk_volume_meta_t * in,
            uint8_t * buf )  [inline], [static]
```

References BLK_DEVICE_SECTOR, memcpy(), memset(), and minzu().

Referenced by blk_commit_format(), and blk_subsys_shutdown().

Here is the call graph for this function:



Here is the caller graph for this function:

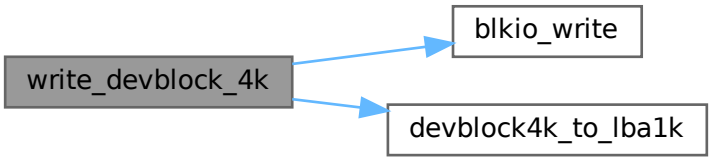
7.277.3.83 write_devblock_4k()

```
static int write_devblock_4k (
            blk_dev_slot_t * slot,
            uint32_t dev4k,
            const uint8_t * buf4k )  [static]
```

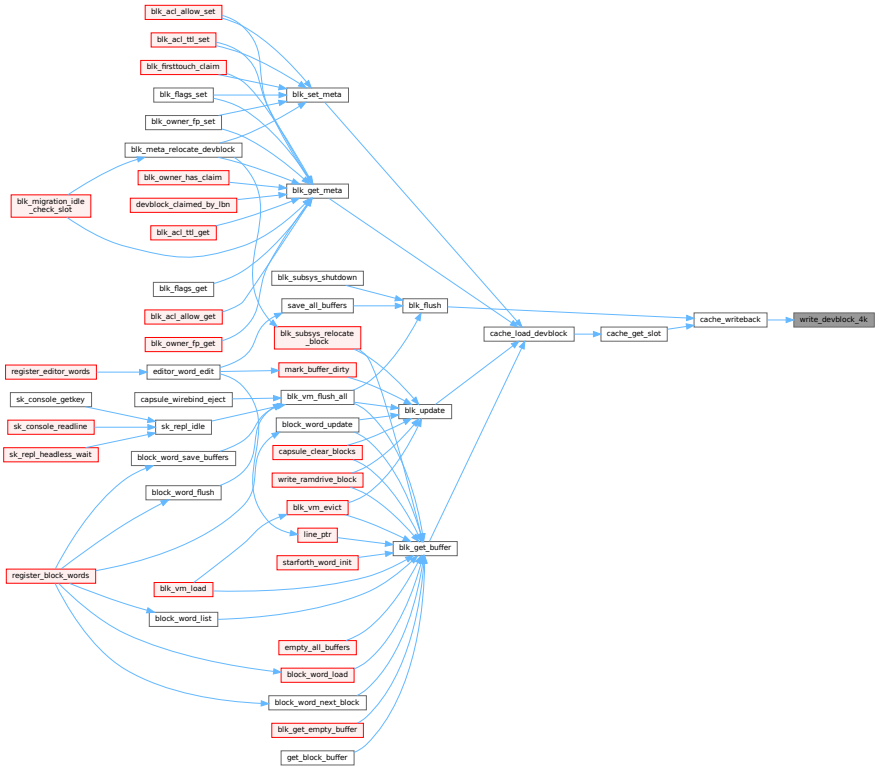
References base, BLK_EIO, BLK_OK, BLKIO_OK, blkio_write(), blk_dev_slot::dev, devblock4k_to_lba1k(), and blk_dev_slot::total_blkio_blocks_1k.

Referenced by cache_writeback().

Here is the call graph for this function:



Here is the caller graph for this function:



7.277.3.84 write_header_4k()

```
static int write_header_4k (
            blk_dev_slot_t * slot,
            const uint8_t * buf4k )  [static]
```

References BLK_EIO, BLK_OK, BLKIO_OK, blkio_write(), and blk_dev_slot::dev.

Referenced by blk_commit_format(), and blk_subsys_shutdown().

Here is the call graph for this function:

Here is the caller graph for this function:

7.277.4 Variable Documentation

7.277.4.1 crc64_inited

```
int crc64_inited = 0  [static]
```

Referenced by compute_crc64(), and crc64_init().

7.277.4.2 crc64_table

```
uint64_t crc64_table[256]  [static]
```

Referenced by compute_crc64(), and crc64_init().

7.277.4.3 dirty_ram

```
uint8_t dirty_ram[BLK_RAM_BLOCKS]
```

7.277.4.4 epoch

```
uint64_t epoch
```

Referenced by blk_vm_check_epoch().

7.277.4.5 [struct]

```
struct { ... } g  [static]
```

Referenced by ansi256_to_rgb(), apply_sgr(), blk_allocate(), blk_flush(), blk_get_buffer(), blk_get_meta(), blk_get_total_blocks(), blk_is_allocated(), blk_is_valid(), blk_mark_allocated(), blk_mark_free(), blk_migration_idle_check(), blk_set_meta(), blk_subsys_add_raw_device(), blk_subsys_attach_device(), blk_subsys_confirm_format(), blk_subsys_detach_device(), blk_subsys_epoch(), blk_subsys_init(), blk_subsys_relocate_block(), blk_subsys_shutdown(), blk_update(), chain_append(), draw_cursor_glyph(), first_disk_slot(), gpt_new_guid(), lbn_to_slot(), pack_pixel(), reloc_flush_to_disk(), reloc_load_from_disk(), resolve_lbn(), sha512_block(), sk_v4_drive_arrived(), and slot_by_dev().

7.277.4.6 g_format_bam_for

```
uint64_t g_format_bam_for  [static]
```

Referenced by blk_compute_fresh_geometry(), and blk_subsys_set_format_bam_for().

7.277.4.7 head

```
blk_dev_slot_t* head
```

Referenced by fc_rebuild().

7.277.4.8 initialized

```
int initialized
```

7.277.4.9 ram_base

```
uint8_t* ram_base
```

Referenced by blk_subsys_init(), blkio_factory_open(), and init_vm_and_subsystem().

7.277.4.10 ram_size

```
size_t ram_size
```

Referenced by blk_subsys_init(), emit_region_with_carveouts(), and init_vm_and_subsystem().

7.277.4.11 ram_user

```
uint32_t ram_user
```

7.277.4.12 reloc

```
blk_reloc_entry_t reloc[500u]
```

7.277.4.13 reloc_count

```
uint32_t reloc_count
```

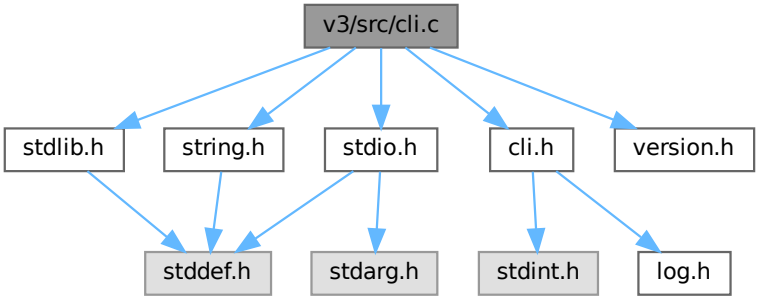
7.277.4.14 total_user_lbn

```
uint64_t total_user_lbn
```

7.278 v3/src/cli.c File Reference

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "cli.h"
#include "version.h"
```

Include dependency graph for cli.c:



Functions

- static int parse_u32 (const char *s, uint32_t *out)
- void cli_print_usage (const char *program_name)

  Print usage/help information.
- CLIConfig cli_parse (int argc, char *argv[])

  Parse command-line arguments into CLIConfig.

7.278.1 Function Documentation

7.278.1.1 cli_parse()

```
CLIConfig cli_parse (
            int argc,
            char * argv[] )
```

Parse command-line arguments into CLIConfig.

Parameters

argc	Argument count
argv	Argument vector

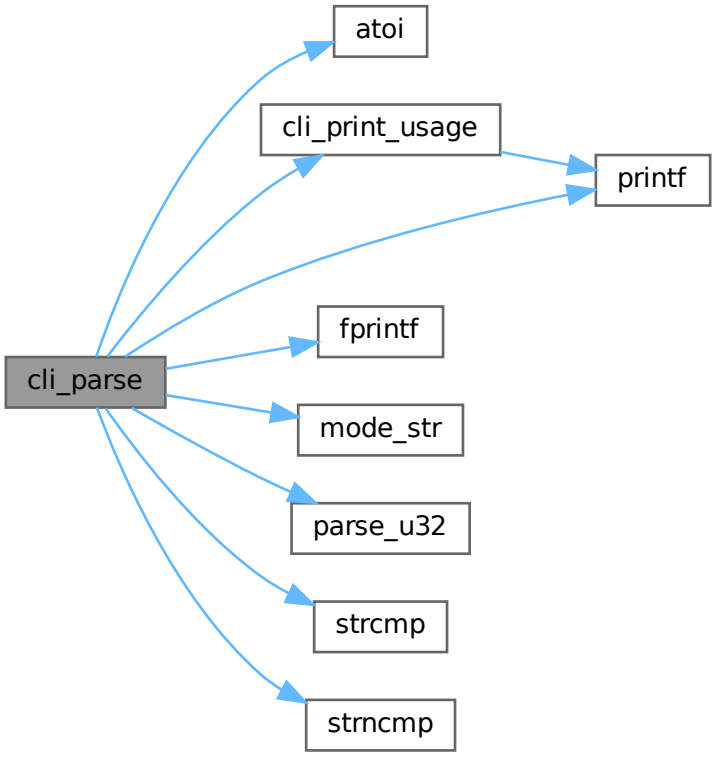
Returns

CLIConfig struct with parsed options, or exits on –version/–help

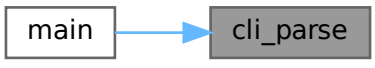
References atoi(), CLIConfig::benchmark, CLIConfig::benchmark_iterations, CLIConfig::break_me, cli_print_usage(), CLIConfig::disk_img_path, CLIConfig::doe_experiment, CLIConfig::fail_fast, fprintf(), HEARTBEAT_LOG_FULL, CLIConfig::heartbeat_log_mode, HEARTBEAT_LOG_OFF, HEARTBEAT_LOG_SUMMARY, LOG_DEBUG, LOG_ERROR, LOG_INFO, CLIConfig::log_level, CLIConfig::log_level_explicitly_set, LOG_NONE, LOG_TEST, LOG_WARN, mode_str(), parse_u32(), printf(), CLIConfig::ram_disk_mb, CLIConfig::run_tests, CLIConfig::run_tests_flag_observed, CLIConfig::script_mode, STARFORTH_VERSION_FULL, stderr, strcmp(), and strncmp().

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.278.1.2 cli_print_usage()

```
void cli_print_usage (
            const char * program_name )
```

Print usage/help information.

Parameters

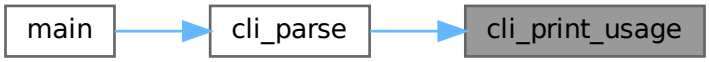
program_name	Name of the executable

References printf().

Referenced by cli_parse().

Here is the call graph for this function:

Here is the caller graph for this function:

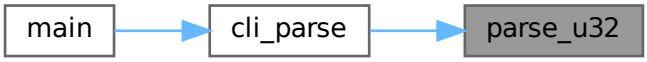


7.278.1.3 parse_u32()

```
static int parse_u32 (
            const char * s,
            uint32_t * out )  [static]
```

Referenced by cli_parse().

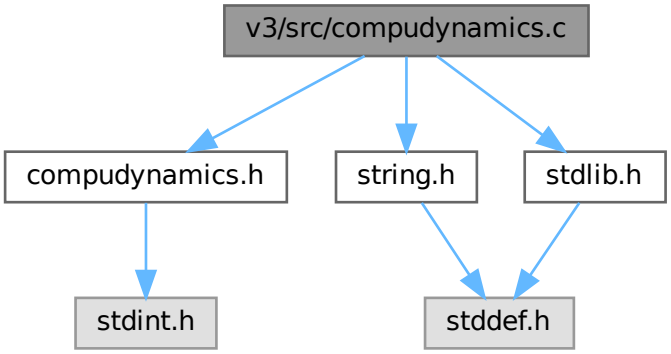
Here is the caller graph for this function:



7.279 v3/src/compudynamics.c File Reference

```
#include "compudynamics.h"
#include <string.h>
#include <stdlib.h>
```

Include dependency graph for compudynamics.c:



Functions

- CDTuning cd_tuning_word (void)
- CDTuning cd_tuning_vm (void)
- static uint32_t cd_isqrt32 (uint32_t n)
- static uint64_t cd_isqrt64 (uint64_t n)
- static uint32_t cd_ln_approx_q16 (uint32_t n)
- CDRegimeMetrics cd_classify_ids (const uint32_t *ids, uint32_t count, uint32_t locality_lookback)

  Classify a recent entity-ID touch sequence into diversity/volatility/ locality, purely from execution counts – no wall-clock input anywhere.
- int cd_config_table_init (CDConfigTable *table, const CDTuning *tuning)

  Allocate a config table sized for tuning->num_configs / num_regimes.
- void cd_config_table_free (CDConfigTable *table)

  Free all memory owned by a config table.
- void cd_config_table_seed (CDConfigTable *table, const CDTuning *tuning, const uint32_t *initial_scores, uint8_t initial_config)

  Seed every (regime, config) score with initial_scores[config], and set the starting active config to initial_config.
- uint8_t cd_config_table_tick (CDConfigTable *table, const CDTuning *tuning, uint8_t regime, uint32_t anova_stability_q16, int use_joint_convergence, uint32_t current_window, uint32_t current_locality_q16)

  Score the currently-active config from this tick's outcome and UCB1-reselect this tick's config, for the given regime.
- void cd_config_table_force (CDConfigTable *table, uint8_t config_idx)

  Force the table onto an externally-chosen config (as if UCB1 had picked it).

7.279.1 Function Documentation

7.279.1.1 cd_classify_ids()

```
CDRegimeMetrics cd_classify_ids (
            const uint32_t * ids,
            uint32_t count,
            uint32_t locality_lookback )
```

Classify a recent entity-ID touch sequence into diversity/volatility/ locality, purely from execution counts – no wall-clock input anywhere.

Parameters

ids	Recent entity IDs, oldest first, chronological order
count	Number of valid entries in ids (clamped internally to CD_MAX_CLASSIFY_DEPTH)
locality_lookback	How many preceding touches count as "recent" for the locality measure (clamped to count)

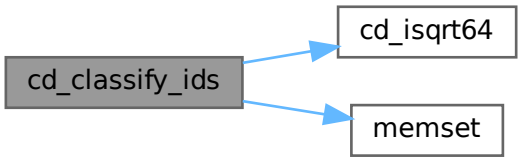
Returns

Classified regime metrics; all-zero if count == 0

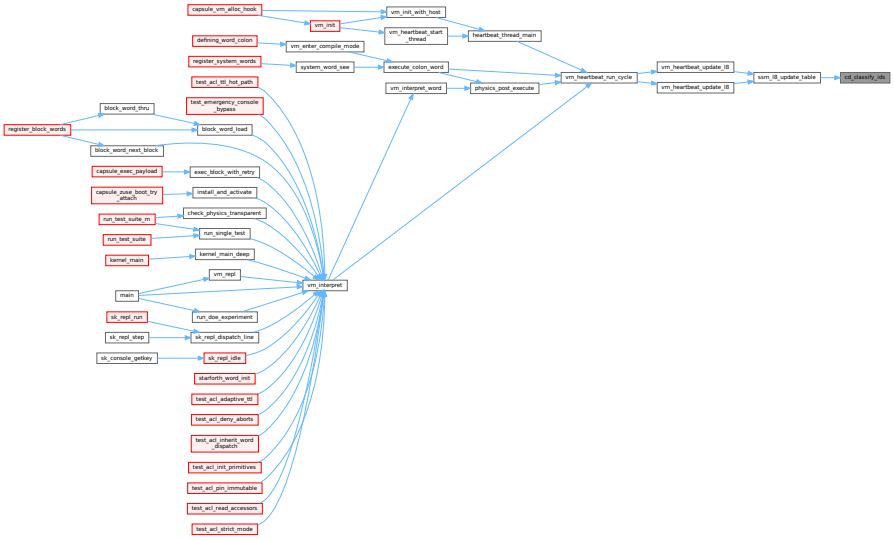
References cd_isqrt64(), CD_MAX_CLASSIFY_DEPTH, count, CDRegimeMetrics::diversity_q16, CDRegimeMetrics::locality_q16, memset(), and CDRegimeMetrics::volatility_q16.

Referenced by ssm_l8_update_table().

Here is the call graph for this function:



Here is the caller graph for this function:



7.279.1.2 cd_config_table_force()

```
void cd_config_table_force (
            CDConfigTable * table,
            uint8_t config_idx )
```

Force the table onto an externally-chosen config (as if UCB1 had picked it).

One-tick nudge, not a hold – see ssm_l8_force_config().

References CDConfigTable::current_config, CDConfigTable::entries, and CDConfigTable::num_configs.

Referenced by ssm_l8_force_config().

Here is the caller graph for this function:

7.279.1.3 cd_config_table_free()

```
void cd_config_table_free (
            CDConfigTable * table )
```

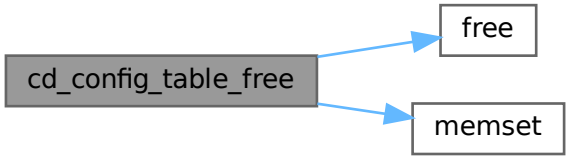
Free all memory owned by a config table.

Safe on a zeroed table.

References CDConfigTable::entries, free(), memset(), CDConfigTable::regime_scores, CDConfigTable::regime_ticks, and CDConfigTable::total_regime_ticks.

Referenced by cd_config_table_init(), and ssm_l8_free_table().

Here is the call graph for this function:



Here is the caller graph for this function:

7.279.1.4 cd_config_table_init()

```
int cd_config_table_init (
            CDConfigTable * table,
            const CDTuning * tuning )
```

Allocate a config table sized for tuning->num_configs / num_regimes.

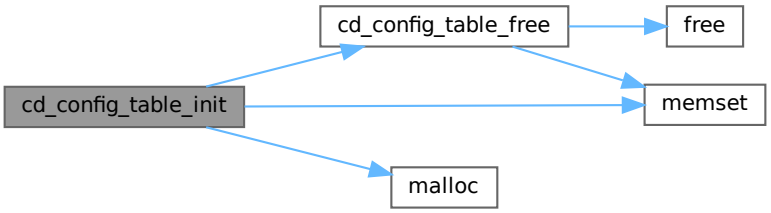
Returns

0 on success, -1 on malloc failure (table left zeroed, unusable)

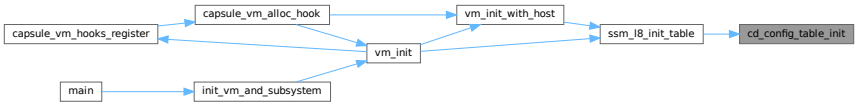
References cd_config_table_free(), CDConfigTable::entries, malloc(), memset(), CDTuning::num_configs, CDConfigTable::num_configs, CDTuning::num_regimes, CDConfigTable::num_regimes, CDConfigTable::regime_scores, CDConfigTable::regime_ticks, and CDConfigTable::total_regime_ticks.

Referenced by ssm_l8_init_table().

Here is the call graph for this function:



Here is the caller graph for this function:



7.279.1.5 cd_config_table_seed()

```
void cd_config_table_seed (
            CDConfigTable * table,
            const CDTuning * tuning,
            const uint32_t * initial_scores,
            uint8_t initial_config )
```

Seed every (regime, config) score with initial_scores[config], and set the starting active config to initial_config.

Parameters

initial_scores	Array of tuning->num_configs initial benefit scores

References CDConfigEntry::_pad, CDConfigEntry::benefit_score, CDConfigEntry::config_bits, CDConfigTable::current_config, CDConfigTable::current_regime, CDConfigTable::entries, CDConfigEntry::has_prev, CDConfigTable::num_configs, CDConfigTable::num_regimes, CDConfigEntry::prev_locality_q16, CDConfigEntry::prev_window, CDConfigTable::regime_scores, CDConfigTable::regime_ticks, CDConfigEntry::tick_count, and CDConfigTable::total_regime_ticks.

Referenced by ssm_l8_seed_from_doe().

Here is the caller graph for this function:

7.279.1.6 cd_config_table_tick()

```
uint8_t cd_config_table_tick (
            CDConfigTable * table,
            const CDTuning * tuning,
            uint8_t regime,
            uint32_t anova_stability_q16,
            int use_joint_convergence,
            uint32_t current_window,
            uint32_t current_locality_q16 )
```

Score the currently-active config from this tick's outcome and UCB1-reselect this tick's config, for the given regime.

Combined reward = joint_weight ∗ window/locality-convergence-stability

- anova_weight ∗ anova_stability_q16 Joint-convergence is skipped (falls back to ANOVA-only) on a config's first tick, or when use_joint_convergence is false (the caller's config bits don't include loops whose convergence this signal is meant to track – word level's L5/L6, see ssm_jacquard.c).

Parameters

table	Config table (must be initialised)
tuning	Tuning knobs matching this table's sizing
regime	Current regime index, < tuning->num_regimes
anova_stability_q16	Caller-supplied stability signal, Q16 [0,65536]
use_joint_convergence	Whether to include the window/locality signal
current_window	Caller's current window-width metric
current_locality_q16	Caller's current locality_q16 from cd_classify_ids

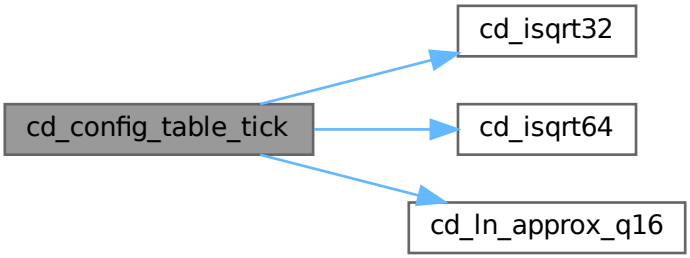
Returns

The newly-selected config's config_bits

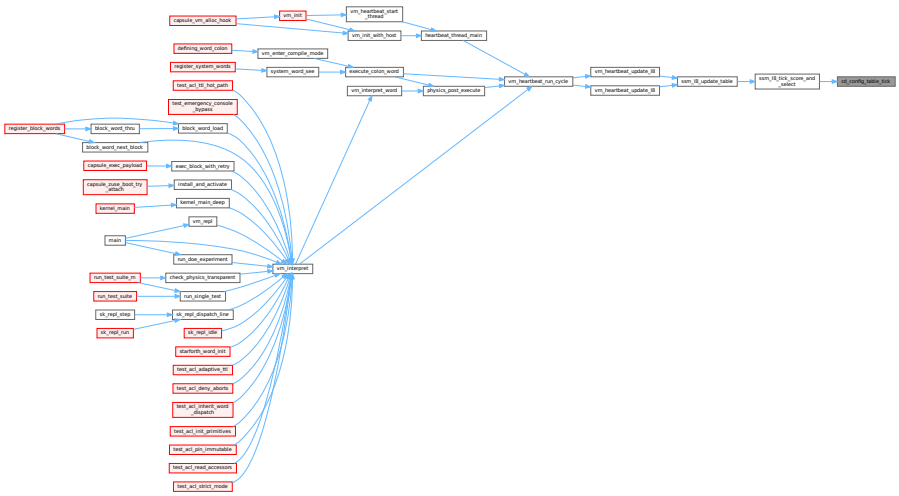
References CDTuning::anova_weight_q16, cd_isqrt32(), cd_isqrt64(), cd_ln_approx_q16(), CDConfigEntry::config_bits, CDConfigTable::current_config, CDConfigTable::current_regime, CDConfigTable::entries, entry, CDTuning::joint_weight_q16, CDConfigTable::num_configs, CDConfigTable::regime_scores, CDConfigTable::regime_ticks, CDTuning::reward_gain, CDTuning::score_decay_factor_q16, CDTuning::score_max, CDTuning::score_min, CDConfigTable::total_regime_ticks, and CDTuning::ucb_k.

Referenced by ssm_l8_tick_score_and_select().

Here is the call graph for this function:



Here is the caller graph for this function:

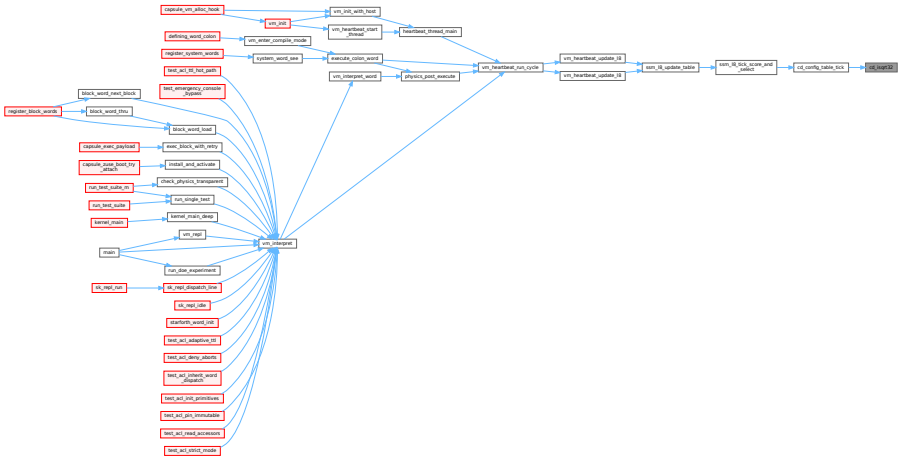


7.279.1.7 cd_isqrt32()

```
static uint32_t cd_isqrt32 (
            uint32_t n )  [static]
```

Referenced by cd_config_table_tick().

Here is the caller graph for this function:

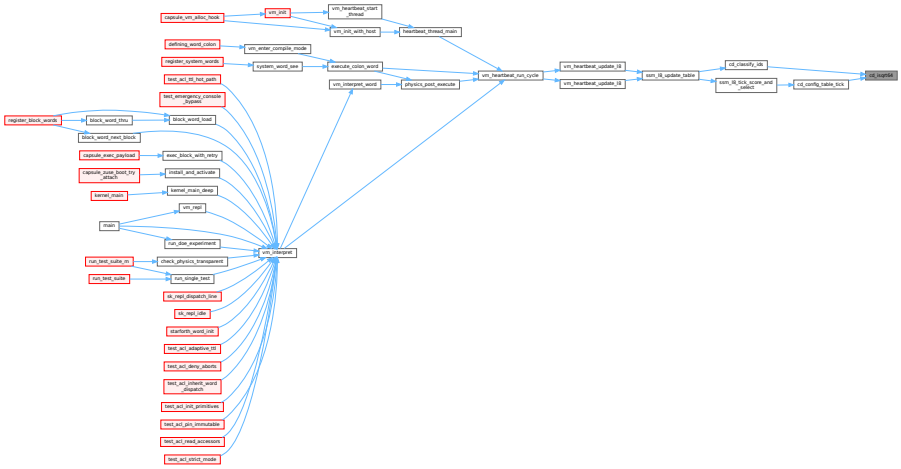


7.279.1.8 cd_isqrt64()

```
static uint64_t cd_isqrt64 (
            uint64_t n )  [static]
```

Referenced by cd_classify_ids(), and cd_config_table_tick().

Here is the caller graph for this function:

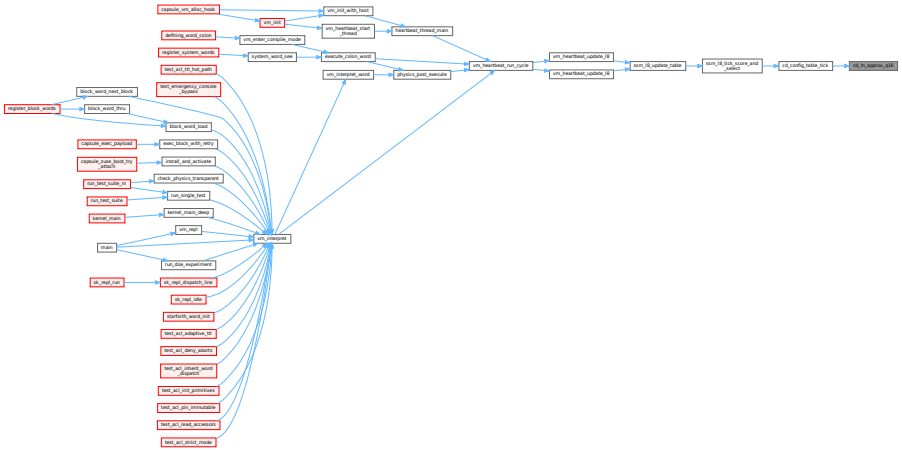


7.279.1.9 cd_ln_approx_q16()

```
static uint32_t cd_ln_approx_q16 (
            uint32_t n )  [static]
```

Referenced by cd_config_table_tick().

Here is the caller graph for this function:



7.279.1.10 cd_tuning_vm()

```
CDTuning cd_tuning_vm (
            void  )
```

References CDTuning::anova_weight_q16, CDTuning::diversity_high_threshold_q16, CDTuning::id_window_depth, CDTuning::joint_weight_q16, CDTuning::locality_high_threshold_q16, CDTuning::locality_lookback, CDTuning::num_configs, CDTuning::num_regimes, CDTuning::reward_gain, CDTuning::score_decay_factor_q16, CDTuning::score_max, CDTuning::score_min, CDTuning::ucb_k, and CDTuning::volatility_high_threshold_q16.

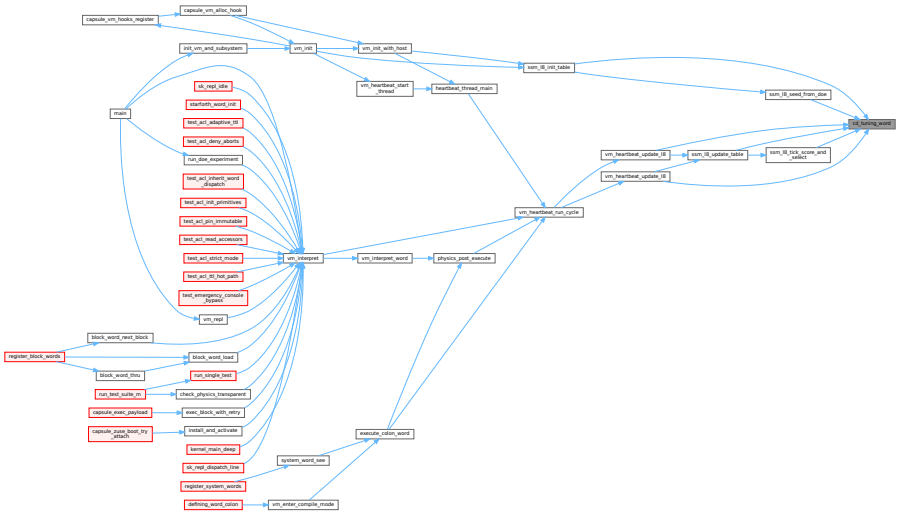
7.279.1.11 cd_tuning_word()

```
CDTuning cd_tuning_word (
            void  )
```

References CDTuning::anova_weight_q16, CDTuning::diversity_high_threshold_q16, CDTuning::id_window_depth, CDTuning::joint_weight_q16, CDTuning::locality_high_threshold_q16, CDTuning::locality_lookback, CDTuning::num_configs, CDTuning::num_regimes, CDTuning::reward_gain, CDTuning::score_decay_factor_q16, CDTuning::score_max, CDTuning::score_min, CDTuning::ucb_k, and CDTuning::volatility_high_threshold_q16.

Referenced by ssm_l8_init_table(), ssm_l8_seed_from_doe(), ssm_l8_tick_score_and_select(), ssm_l8_update_table(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

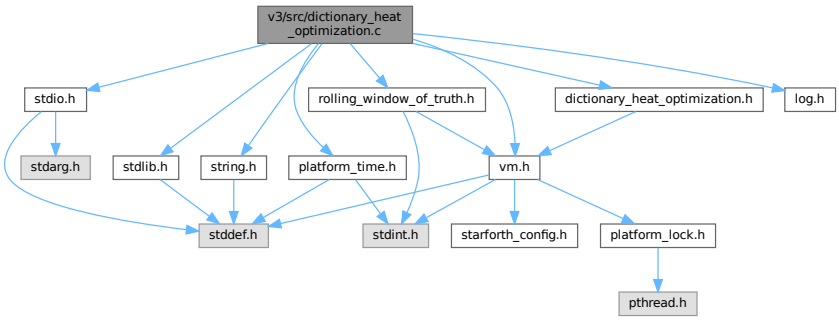
Here is the caller graph for this function:



7.280 v3/src/dictionary_heat_optimization.c File Reference

```
#include <string.h>
#include <stdlib.h>
#include <stdio.h>
#include "vm.h"
#include "rolling_window_of_truth.h"
#include "dictionary_heat_optimization.h"
#include "log.h"
#include "platform_time.h"
```

Include dependency graph for dictionary_heat_optimization.c:



Functions

- static int compare_heat_ascending (const void *a, const void *b)

  qsort comparator for `cell_t` execution-heat values in ascending order.
- void dict_update_heat_percentiles (VM *vm)

  Collect dictionary execution heats and compute the 25th, 50th, and 75th percentiles.

- DictEntry * dict_find_word_heat_aware (VM *vm, const char *name, size_t len)

  Three-pass heat-stratified dictionary lookup, hottest tier first.
- static int compare_dict_entry_heat_desc (const void *a, const void *b)

  qsort comparator for `DictEntry*` pointers in descending execution-heat order.
- void dict_reorganize_buckets_by_heat (VM *vm)

  Sort all 256 first-character hash buckets by descending execution heat.
- void dict_adaptive_optimization_pass (VM *vm)

  Throttled adaptive optimization pass — runs at most once per second.

7.280.1 Function Documentation

7.280.1.1 compare_dict_entry_heat_desc()

```
static int compare_dict_entry_heat_desc (
            const void * a,
            const void * b )  [static]
```

qsort comparator for `DictEntry*` pointers in descending execution-heat order.

Dereferences two `DictEntry**` pointers and compares their `execution_heat` fields, returning ?1 if the first entry is hotter, +1 if the second is hotter, or 0 on a tie. Used exclusively by `dict_reorganize_buckets_by_heat()` to sort each of the 256 first-character hash buckets so that hot words appear at lower array indices, reducing the average scan depth during the medium and cold passes of `dict_find_word_heat_aware()`.

Parameters

a	Pointer to a `DictEntry*` (first element).
b	Pointer to a `DictEntry*` (second element).

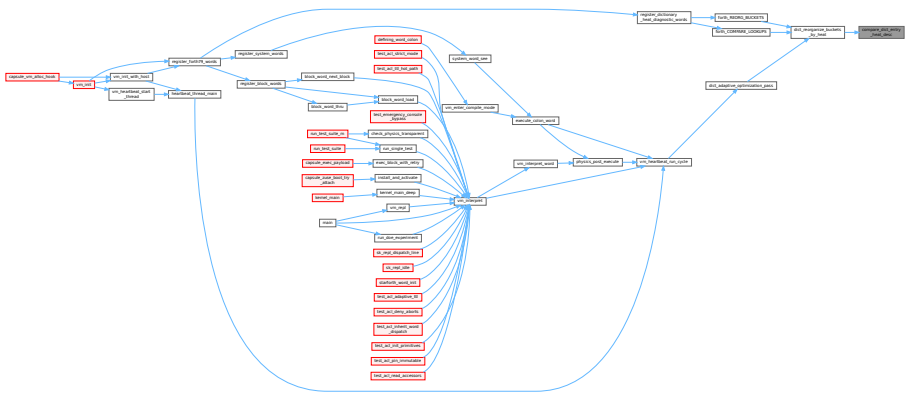
Returns

?1 if `a` is hotter; +1 if `b` is hotter; 0 if equal.

References DictEntry::execution_heat.

Referenced by dict_reorganize_buckets_by_heat().

Here is the caller graph for this function:



7.280.1.2 compare_heat_ascending()

```
static int compare_heat_ascending (
            const void * a,
            const void * b )  [static]
```

qsort comparator for `cell_t` execution-heat values in ascending order.

Compares two `cell_t` values passed as `const void*` pointers (the signature required by `qsort`). Returns ?1, 0, or +1 following C standard three-way comparison convention. Used exclusively by `dict_update_heat_percentiles()` to sort the scratch `heats[]` array before computing the 25th, 50th, and 75th percentile thresholds.

Parameters

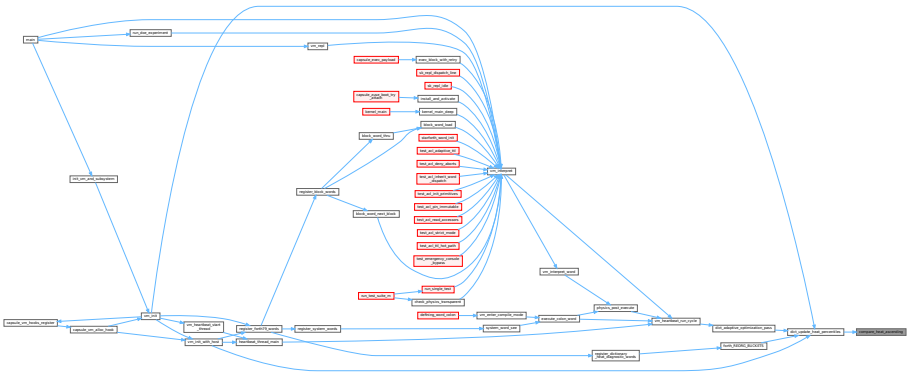
a	Pointer to the first `cell_t` value.
b	Pointer to the second `cell_t` value.

Returns

?1 if $*a < *b$; +1 if $*a > *b$; 0 if equal.

Referenced by dict_update_heat_percentiles().

Here is the caller graph for this function:



7.280.1.3 dict_adaptive_optimization_pass()

```
void dict_adaptive_optimization_pass (
            VM * vm )
```

Throttled adaptive optimization pass — runs at most once per second.

Periodically reoptimize dictionary based on latest heat patterns.

Called from the interpreter loop (or heartbeat) on every word dispatch; the 1 Hz gate (`now_ns - vm->last_↩ bucket_reorg_ns` < 1,000,000,000) ensures the three expensive sub-steps run at a rate that is imperceptible to FORTH execution while still keeping the dictionary layout fresh:

1. **Update heat percentiles** — calls `dict_update_heat_percentiles()` to re-sample `execution_heat` across all words and compute the 25th / 50th / 75th thresholds used by the stratified lookup.
2. **Reorganize buckets** — calls `dict_reorganize_buckets_by_heat()` to sort each of the 256 first-character hash buckets so that the hottest words sit at the lowest array indices, shortening the average scan depth during the hot-tier pass.
3. **Select lookup strategy** — queries the rolling window for the current pattern-diversity score via `rolling_window_measure_diversity()`:
   - Diversity $>$ 70 (high churn in which words are called) $\rightarrow$ strategy 1 (`heat-aware` lookup, `dict_find_word_heat_aware()`), where the heat stratification most pays off.
   - Diversity $\leq$ 70 (stable repetitive pattern) $\rightarrow$ strategy 0 (naive newest-first bucket scan), which is already nearly O(1) for programs that call the same small word set repeatedly. The chosen strategy is stored in `vm->lookup_strategy` and read by the interpreter's dictionary lookup dispatch.

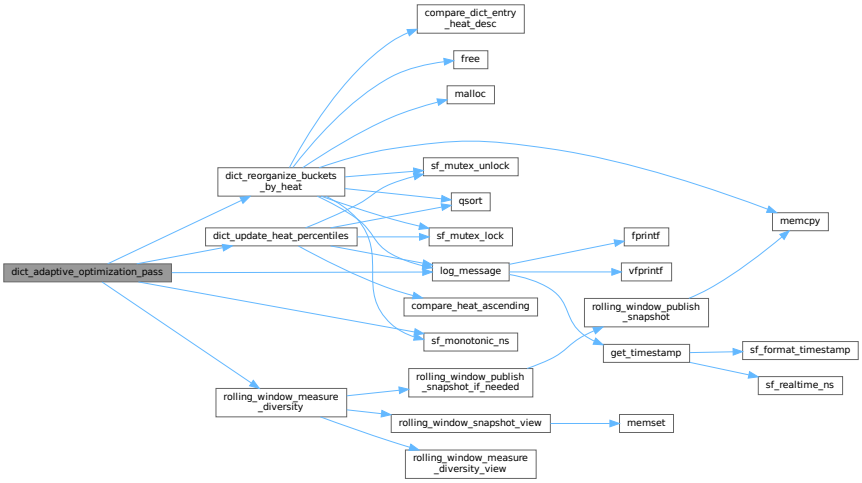
Parameters

vm	The VM to optimise. No-op if NULL or if less than 1 second has elapsed since the last pass (`vm->last_bucket_reorg_ns`).

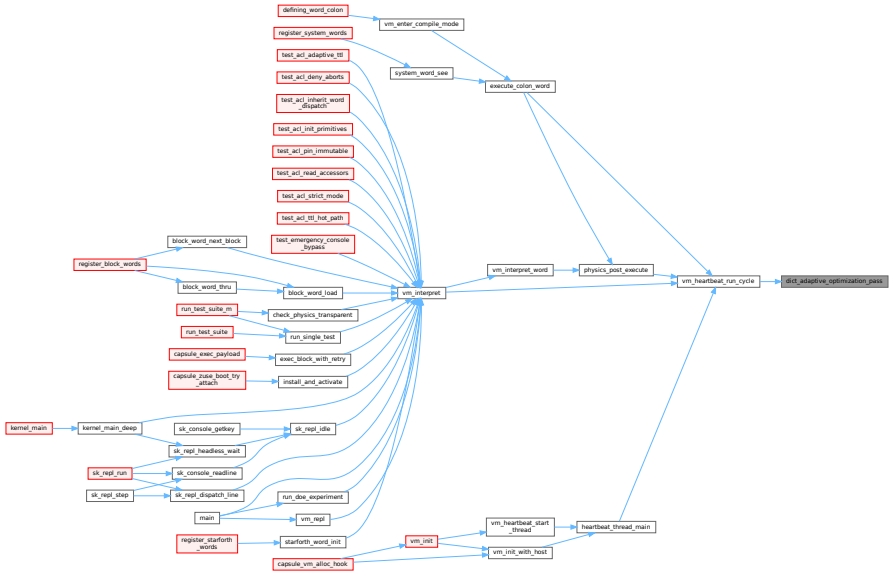
References dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), VM::last_bucket_reorg_ns, LOG_DEBUG, log_message(), VM::lookup_strategy, VM::rolling_window, rolling_window_measure_diversity(), and sf_monotonic_ns().

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.280.1.4 dict_find_word_heat_aware()

```
DictEntry * dict_find_word_heat_aware (
            VM * vm,
            const char * name,
            size_t len )
```

Three-pass heat-stratified dictionary lookup, hottest tier first.

Find word with heat-aware search strategy.

Searches the first-character bucket `sf_fc_list`[(unsigned char)name[0]] for a word whose `name` and `name_len` match `name` / `len`, scanning in three priority tiers ordered by execution heat:

1. **Hot pass** (heat $\geq$ `heat_threshold_75th`): words in the top 25% by execution frequency. Most FORTH programs spend the vast majority of ticks in a handful of hot primitives; checking this tier first yields a near-constant-time hit on steady-state workloads.
2. **Medium pass** (heat in [threshold_25th, threshold_75th)): the middle 50% of words. These are occasionally-called words that still appear often enough to warrant a dedicated pass before touching the long tail.
3. **Cold pass** (heat $<$ `heat_threshold_25th`): the rarely-executed bottom quartile. Words that have never been called also live here.

Within each pass, matching uses the same cheap-first filter chain as the standard lookup: `name_len` comparison $\rightarrow$ last-character byte check $\rightarrow$ full `memcmp`. The last-character pre-filter is skipped for single-character names.

Returns `NULL` only if the word is absent from the bucket; all three passes exhausted without a hit. Also returns `NULL` immediately if `vm`, `name`, or `len` are invalid.

Heat thresholds are updated lazily by `dict_adaptive_optimization_pass()` ($\approx$1 Hz); stale thresholds degrade to a full three-pass scan without affecting correctness.

Parameters

vm	The VM; provides `heat_threshold_*` fields and the bucket table.
name	Word name to search for (not NUL-terminated; length in `len`).
len	Length of `name` in bytes; must be ≥ 1.

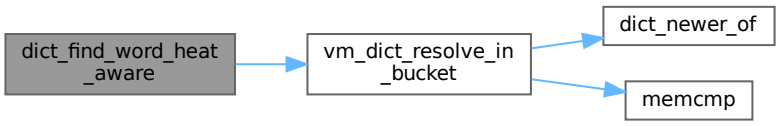
Returns

Pointer to the matching `DictEntry`, or `NULL` if not found.

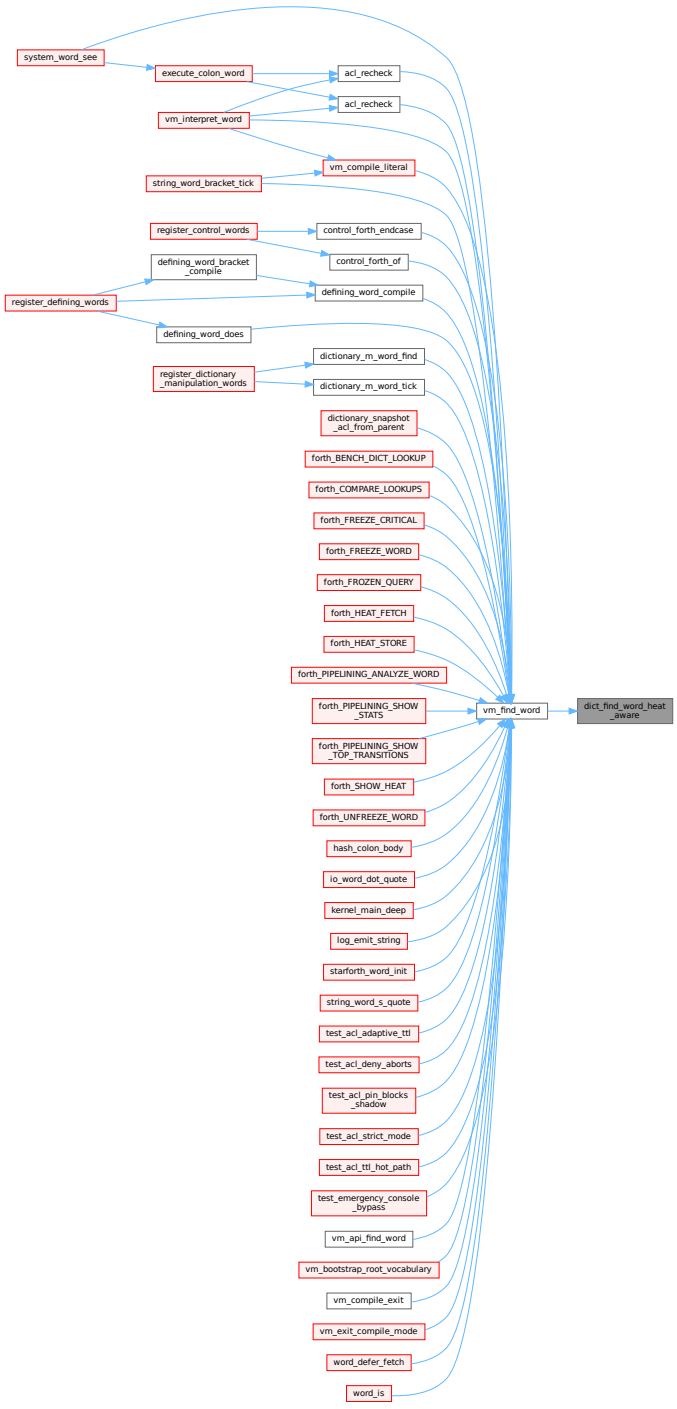
References name, sf_fc_count, sf_fc_list, and vm_dict_resolve_in_bucket().

Referenced by vm_find_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.280.1.5 dict_reorganize_buckets_by_heat()

```
void dict_reorganize_buckets_by_heat (
            VM * vm )
```

Sort all 256 first-character hash buckets by descending execution heat.

Reorganize dictionary buckets by inference-driven priorities.

Holds `vm->dict_lock` for the entire operation to prevent concurrent `DictEntry` frees (from word redefinition or GC) from invalidating the pointer array while it is being sorted. For each non-empty bucket in `sf_fc_list`[0..255]:

1. Reads `sf_fc_count`[bucket_id] and `sf_fc_cap`[bucket_id]; skips the bucket if `count > cap` (indicates a TOCTOU race — logs a warning).
2. Allocates a temporary copy of the bucket pointer array.
3. Re-verifies `count` has not changed (TOCTOU double-check); if it has, frees the copy and skips.
4. Sorts the copy with `qsort` + `compare_dict_entry_heat_desc` so that the hottest `DictEntry*` comes first.
5. Copies the sorted array back over the original bucket.
6. Frees the temporary copy.

After returning, `vm->last_bucket_reorg_ns` is updated to the completion timestamp so that `dict_adaptive_optimization_pass()` can enforce its 1 Hz throttle. The elapsed reorganization time is emitted at `LOG_DEBUG`.

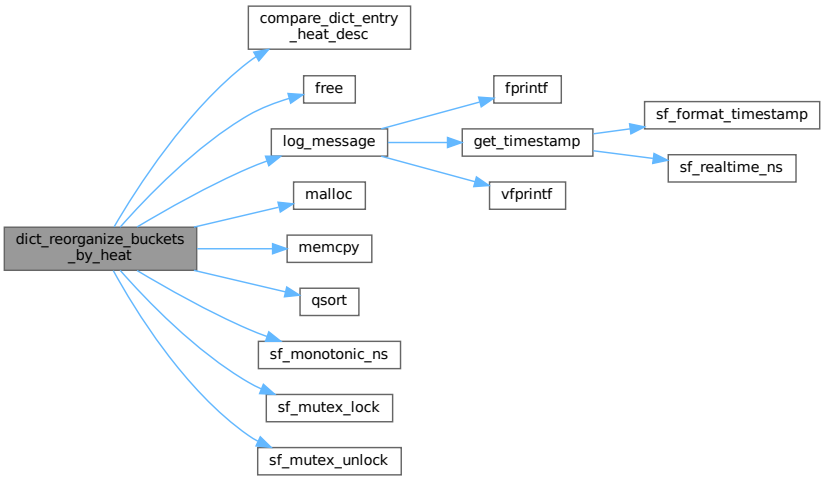
Parameters

vm	The VM whose first-character hash buckets are reorganized. No-op if NULL. `dict_lock` is held during the entire scan.

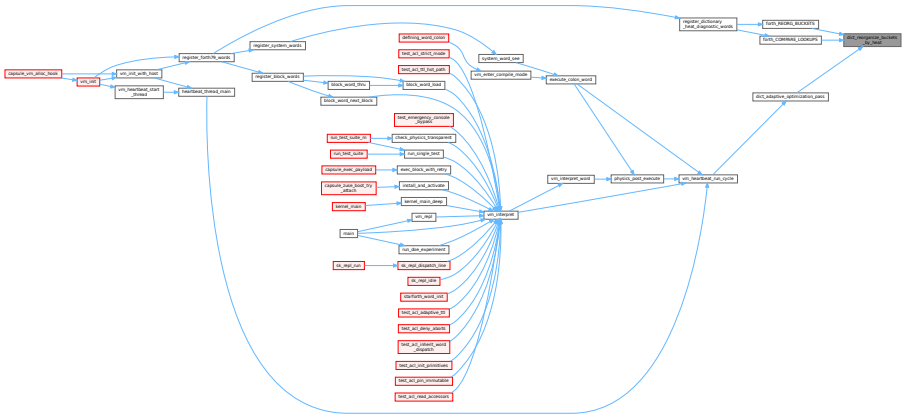
References compare_dict_entry_heat_desc(), count, VM::dict_lock, free(), VM::last_bucket_reorg_ns, LOG_DEBUG, log_message(), LOG_WARN, malloc(), memcpy(), qsort(), sf_fc_cap, sf_fc_count, sf_fc_list, sf_monotonic_ns(), sf_mutex_lock(), and sf_mutex_unlock().

Referenced by dict_adaptive_optimization_pass(), forth_COMPARE_LOOKUPS(), and forth_REORG_BUCKETS().

Here is the call graph for this function:



Here is the caller graph for this function:



7.280.1.6 dict_update_heat_percentiles()

```
void dict_update_heat_percentiles (
                VM * vm )
```

Collect dictionary execution heats and compute the 25th, 50th, and 75th percentiles.

Calculate heat percentile thresholds for all words in dictionary.

Traverses the full linked-list dictionary under `vm->dict_lock` to snapshot every word's `execution_heat` into a stack-allocated scratch array (up to `DICTIONARY_SIZE` entries). After releasing the lock it sorts the snapshot with `qsort` + `compare_heat_ascending` and computes percentile indices using integer arithmetic:

```
vm->heat_threshold_25th = heats[(count * 25) / 100];
vm->heat_threshold_50th = heats[(count * 50) / 100];
vm->heat_threshold_75th = heats[(count * 75) / 100];
```

If the dictionary contains no words all three thresholds are set to 0. The lock is held only during traversal; sorting is performed outside the critical section to minimise contention with the concurrent heartbeat decay sweep that also walks the word list.

The resulting thresholds are consumed by `dict_find_word_heat_aware()` (which stratifies its search by heat tier) and by `dict_adaptive_optimization_pass()` (which calls this function as its first step every ~1 Hz).

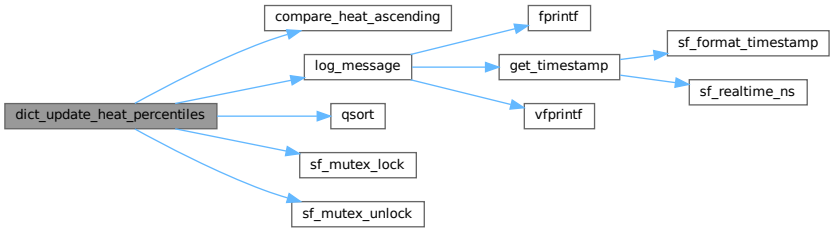
Parameters

vm	The VM whose dictionary is sampled and whose `heat_threshold_25th` / `heat_threshold_50th` / `heat_threshold_75th` fields are updated. No-op if NULL.

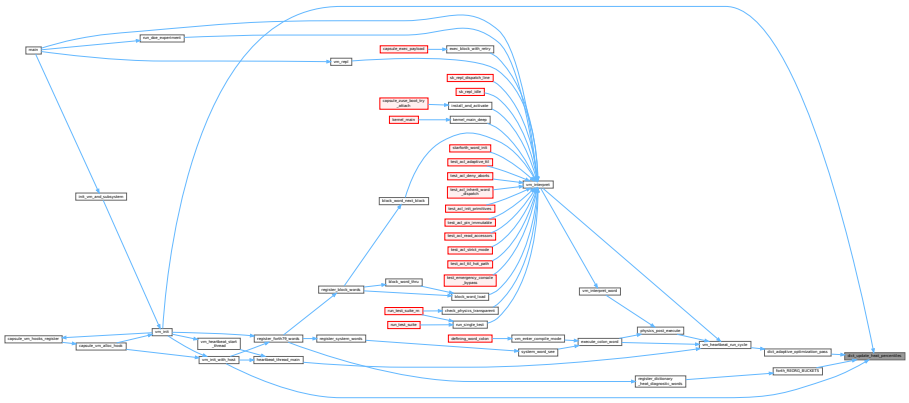
References compare_heat_ascending(), count, VM::dict_lock, DICTIONARY_SIZE, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::latest, LOG_DEBUG, log_message(), qsort(), sf_mutex_lock(), and sf_mutex_unlock().

Referenced by dict_adaptive_optimization_pass(), forth_REORG_BUCKETS(), vm_init(), and vm_init_with_host().

Here is the call graph for this function:



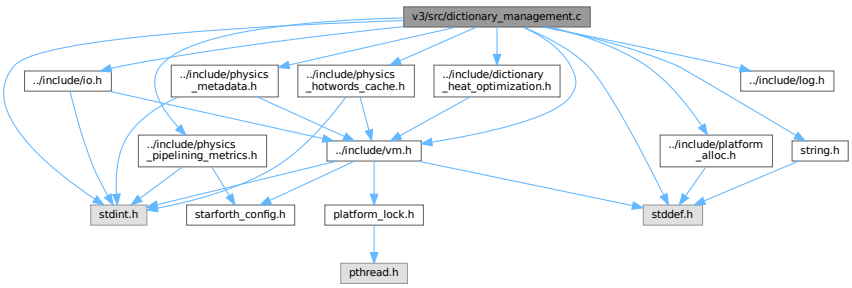
Here is the caller graph for this function:



7.281 v3/src/dictionary_management.c File Reference

```
#include "../include/vm.h"
#include "../include/io.h"
#include "../include/log.h"
#include "../include/physics_metadata.h"
#include "../include/physics_hotwords_cache.h"
#include "../include/physics_pipelining_metrics.h"
#include "../include/dictionary_heat_optimization.h"
#include "../include/platform_alloc.h"
#include <string.h>
#include <stddef.h>
#include <stdint.h>
```

Include dependency graph for dictionary_management.c:



Macros

- #define SF_FC_BUCKETS 256

Functions

- static uint32_t vm_dictionary_acquire_word_id (VM *vm)
- void vm_dictionary_track_entry (VM *vm, DictEntry *entry)
- void vm_dictionary_untrack_entry (VM *vm, DictEntry *entry)
- DictEntry * vm_dictionary_lookup_by_word_id (VM *vm, uint32_t word_id)
- int vm_dict_entry_ok (VM *vm, DictEntry *candidate)
- static void * sf_xrealloc (void *p, size_t nbytes)
- static void sf_fc_clear_all (void)
- static int sf_fc_reserve (size_t i, size_t need)
- static void sf_rebuild_fc_index (VM *vm)
- static void sf_try_fast_append (VM *vm)
- static DictEntry * dict_newer_of (VM *vm, DictEntry *a, DictEntry *b)

  Return whichever of two entries is the more recent definition.
- DictEntry * vm_dict_resolve_in_bucket (VM *vm, DictEntry **bucket, size_t n, const char *name, size_t len)
- DictEntry * vm_find_word (VM *vm, const char *name, size_t len)

  Finds a word in the dictionary by name.
- DictEntry * vm_create_word (VM *vm, const char *name, size_t len, word_func_t func)

  Creates a new word in the dictionary.
- DictEntry * vm_dictionary_find_by_func (VM *vm, word_func_t func)

  Finds a word by its function pointer.
- DictEntry * vm_dictionary_find_latest_by_func (VM *vm, word_func_t func)
- cell_t * vm_dictionary_get_data_field (DictEntry *entry)

  Gets pointer to a word's data field.
- void vm_hide_word (VM *vm)

  Marks the latest word as hidden.
- void vm_smudge_word (VM *vm)
- void vm_pin_execution_heat (VM *vm)
- void vm_unpin_execution_heat (VM *vm)
- void vm_dictionary_index_reset (void)

  Resets the dictionary index.

Variables

- DictEntry ** sf_fc_list [256]
- size_t sf_fc_count [256]
- size_t sf_fc_cap [256]
- static DictEntry * sf_cached_latest = NULL

7.281.1 Macro Definition Documentation

7.281.1.1 SF_FC_BUCKETS

```
#define SF_FC_BUCKETS 256
```

7.281.2 Function Documentation

7.281.2.1 dict_newer_of()

```
static DictEntry * dict_newer_of (
            VM * vm,
            DictEntry * a,
            DictEntry * b )  [static]
```

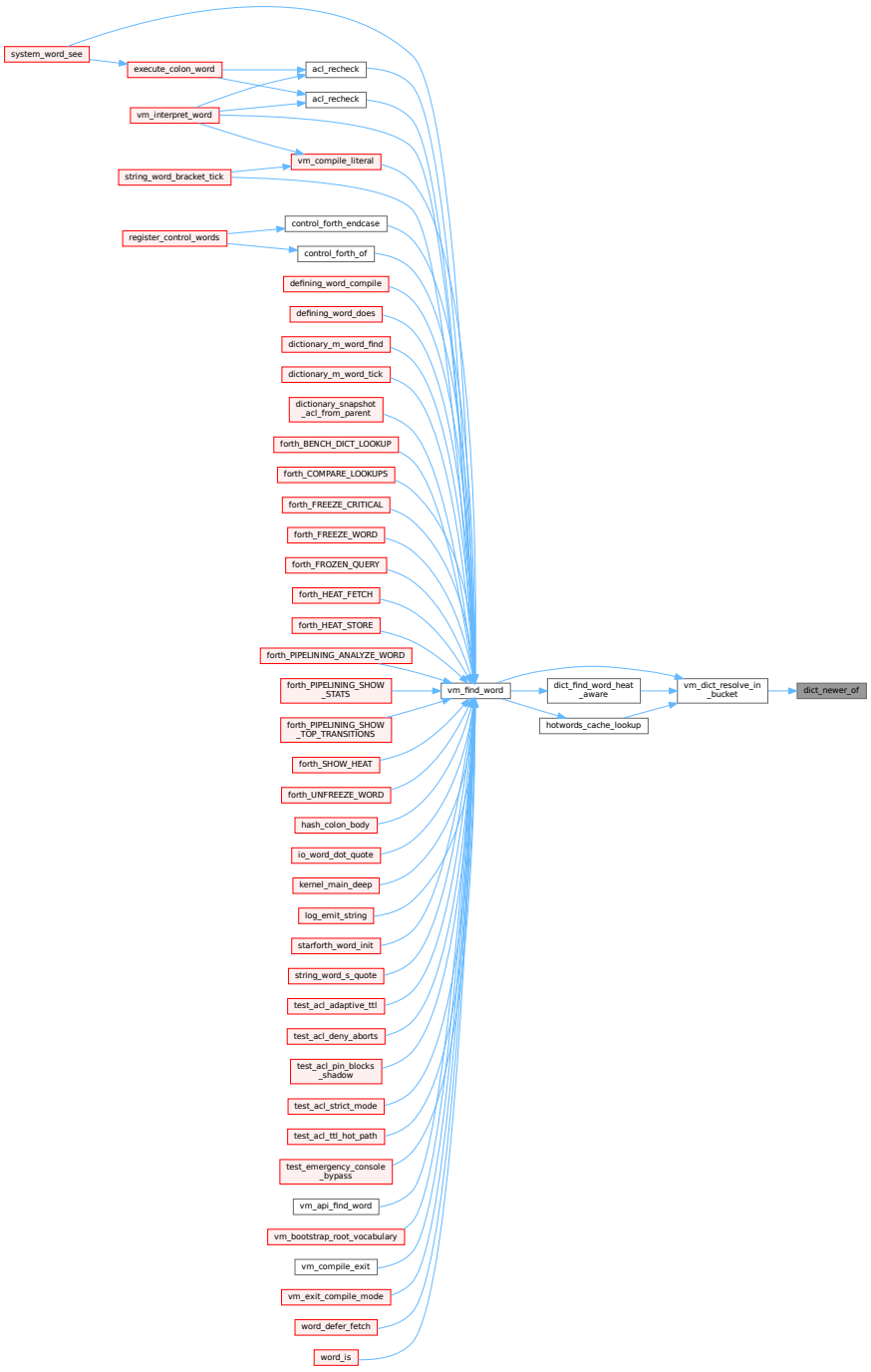
Return whichever of two entries is the more recent definition.

Walks the definition chain from `vm->latest`; the first of (`a`, `b`) encountered is the newer one. The link chain is the only reliable age order — word_id values are recycled and bucket positions are shuffled by `dict_reorganize_buckets_by_heat()`, so neither can arbitrate age. Only invoked when a bucket holds two visible entries with the same name (redefinition/shadowing), so the walk cost is off the common path.

References VM::latest.

Referenced by vm_dict_resolve_in_bucket().

Here is the caller graph for this function:



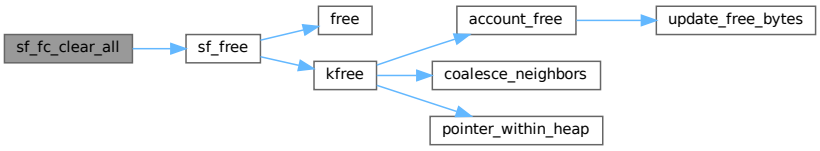
7.281.2.2 sf_fc_clear_all()

```
static void sf_fc_clear_all (
            void  )  [static]
```

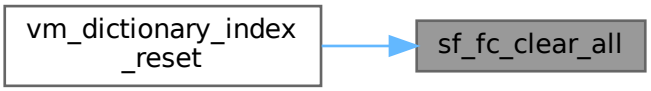
References SF_FC_BUCKETS, sf_fc_cap, sf_fc_count, sf_fc_list, and sf_free().

Referenced by vm_dictionary_index_reset().

Here is the call graph for this function:



Here is the caller graph for this function:



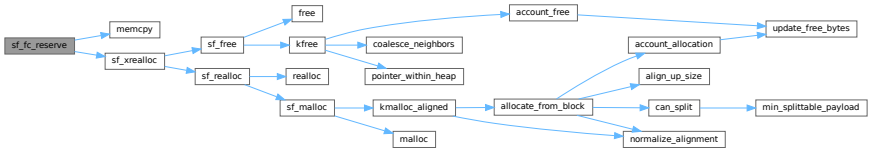
7.281.2.3 sf_fc_reserve()

```
static int sf_fc_reserve (
            size_t i,
            size_t need )  [static]
```

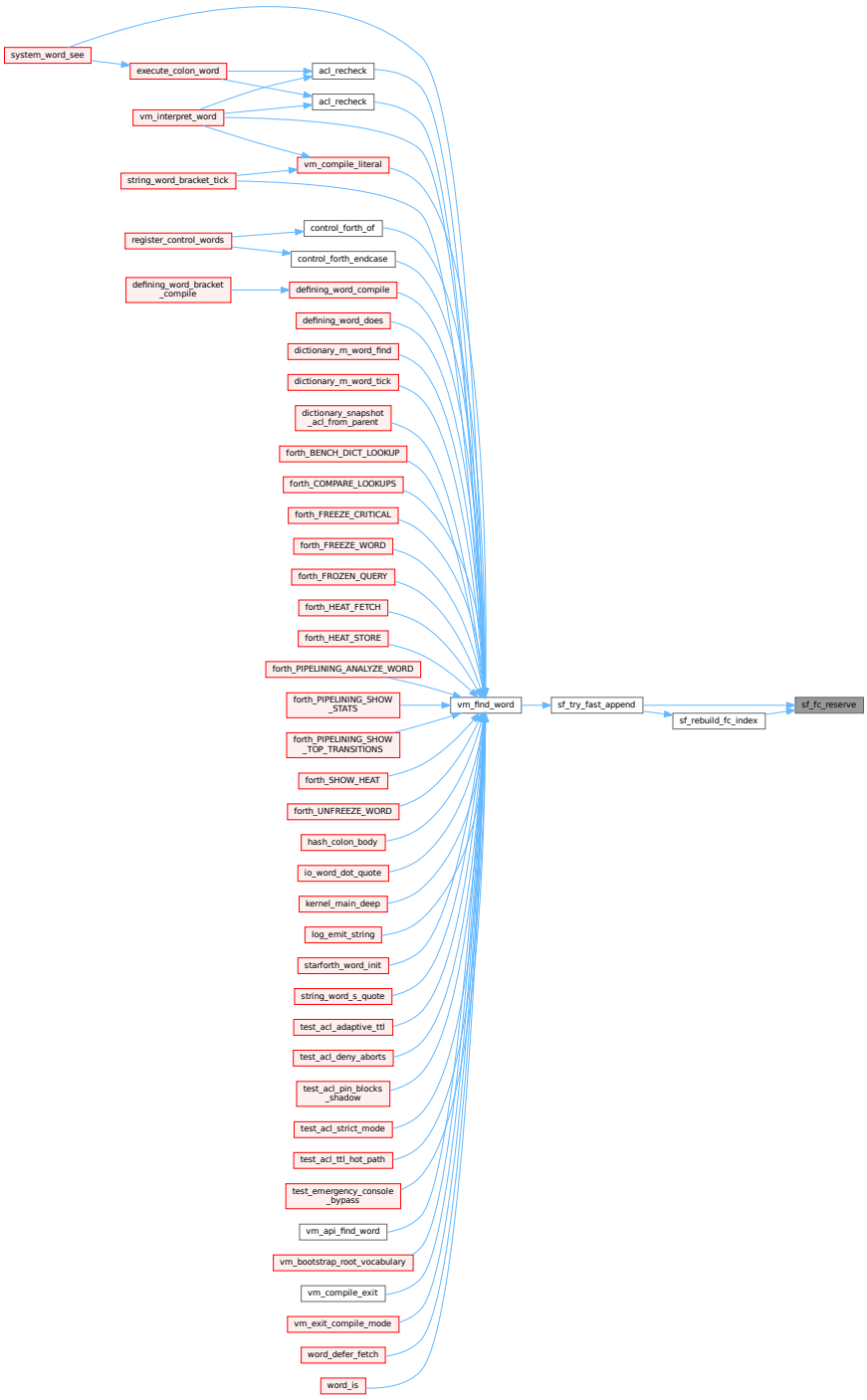
References memcpy(), sf_fc_cap, sf_fc_count, sf_fc_list, and sf_xrealloc().

Referenced by sf_rebuild_fc_index(), and sf_try_fast_append().

Here is the call graph for this function:



Here is the caller graph for this function:



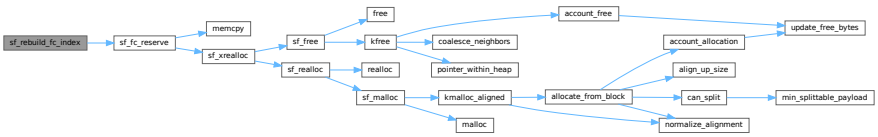
7.281.2.4 sf_rebuild_fc_index()

```
static void sf_rebuild_fc_index (
            VM * vm )  [static]
```

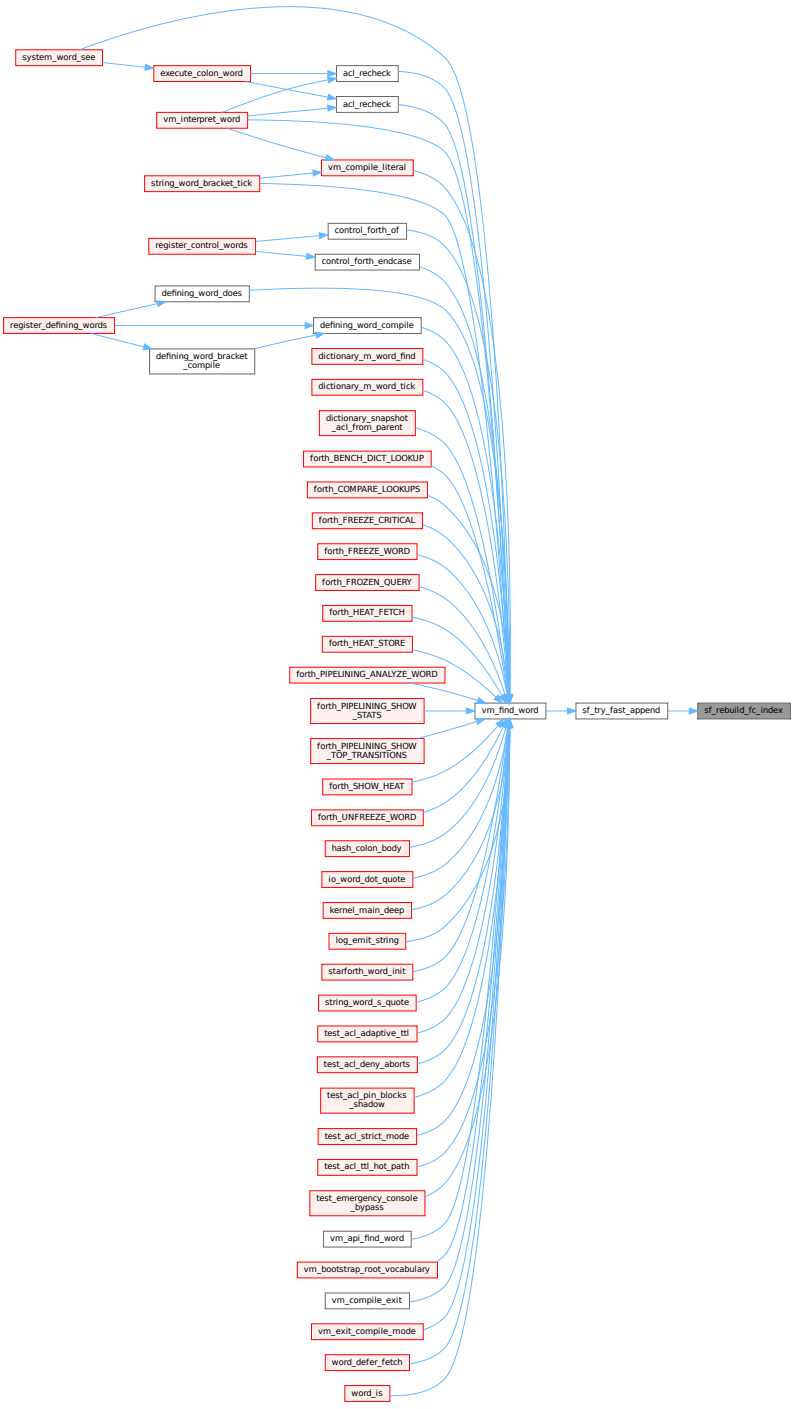
References VM::latest, DictEntry::name, sf_cached_latest, SF_FC_BUCKETS, sf_fc_count, sf_fc_list, and sf_fc_reserve().

Referenced by sf_try_fast_append().

Here is the call graph for this function:



Here is the caller graph for this function:



7.281.2.5 sf_try_fast_append()

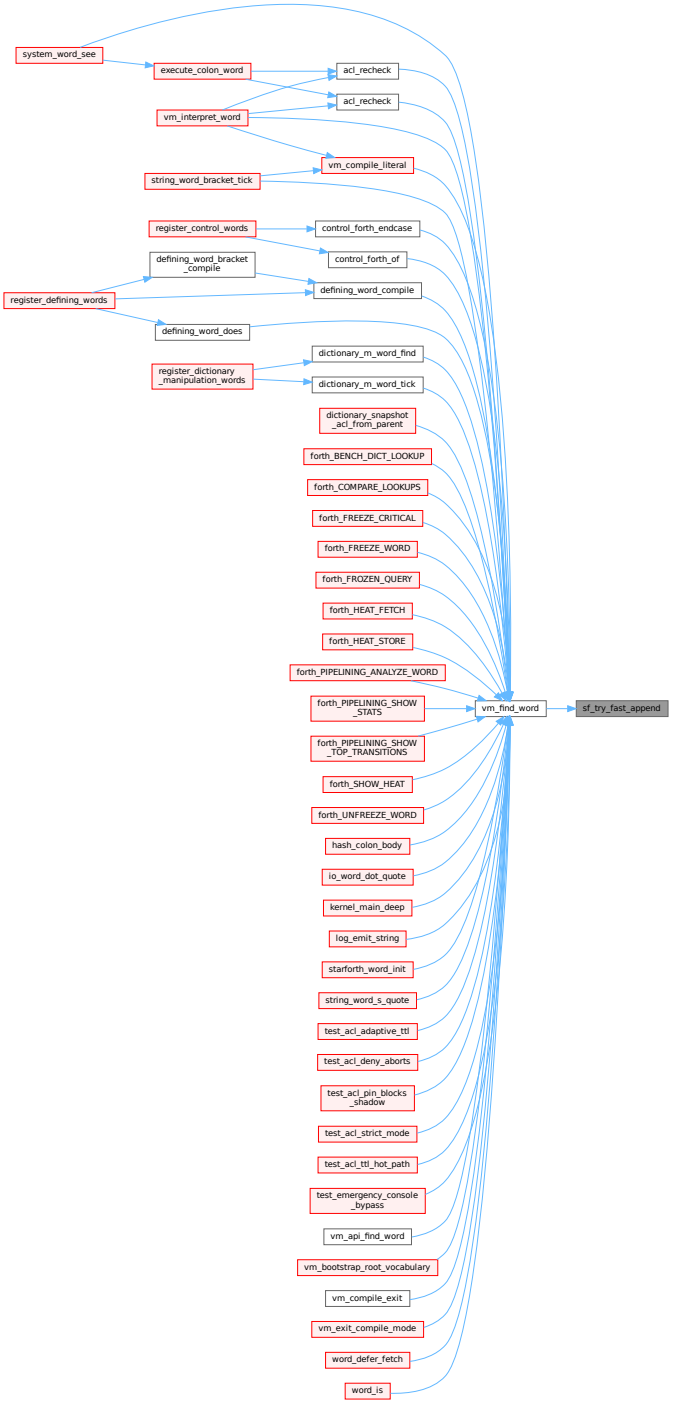
```
static void sf_try_fast_append (
            VM * vm )  [static]
```

References VM::latest, DictEntry::link, DictEntry::name, sf_cached_latest, sf_fc_count, sf_fc_list, sf_fc_reserve(), and sf_rebuild_fc_index().

Referenced by vm_find_word().

Here is the call graph for this function:

Here is the caller graph for this function:



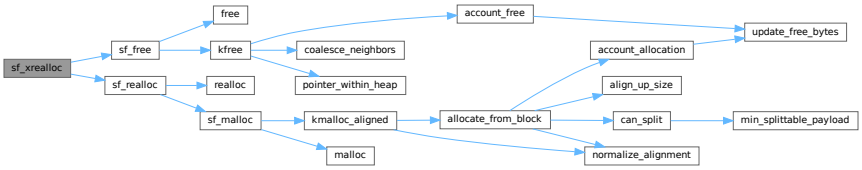
7.281.2.6 sf_xrealloc()

```
static void * sf_xrealloc (
            void * p,
            size_t nbytes )  [inline], [static]
```

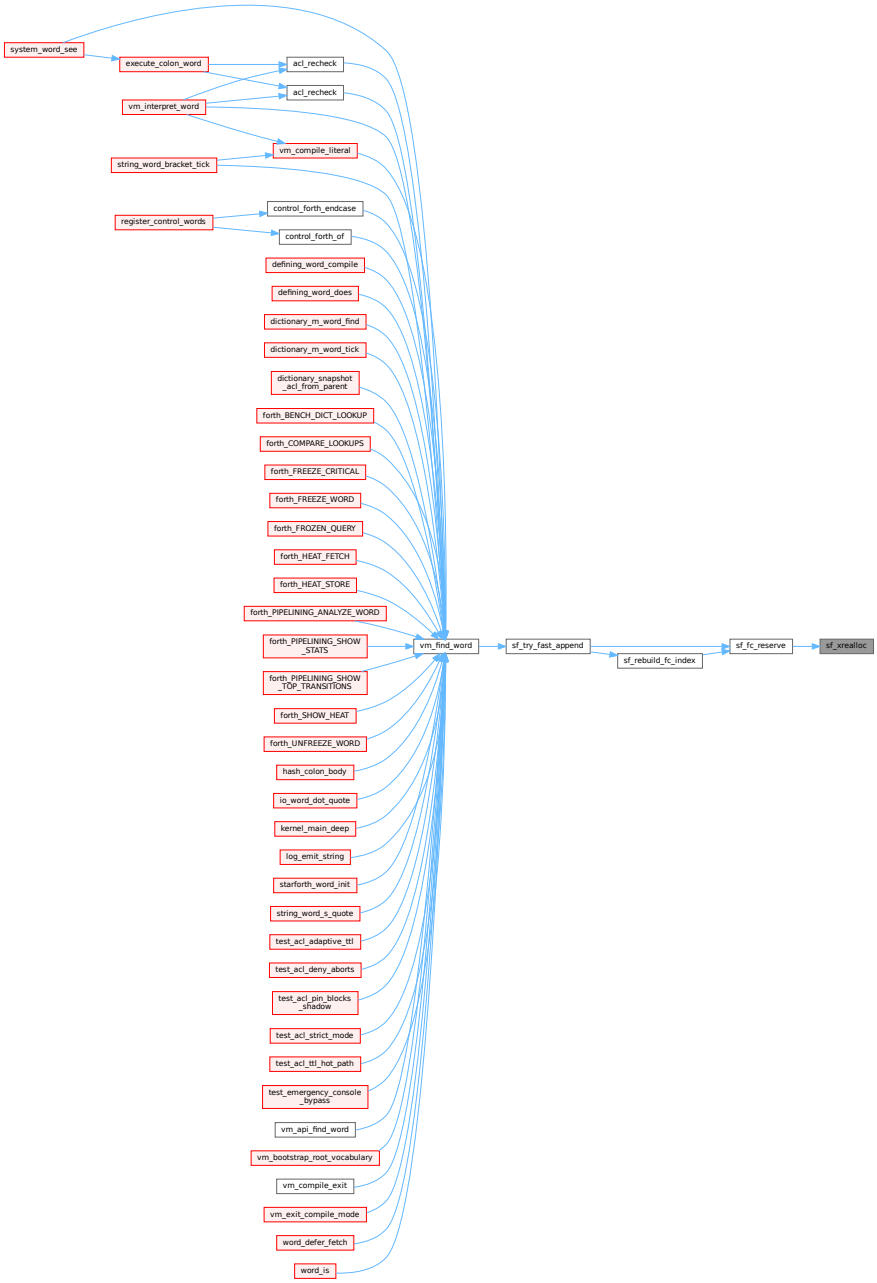
References sf_free(), and sf_realloc().

Referenced by sf_fc_reserve().

Here is the call graph for this function:



Here is the caller graph for this function:



7.281.2.7 vm_create_word()

```
DictEntry * vm_create_word (
            VM * vm,
            const char * name,
            size_t len,
            word_func_t func )
```

Creates a new word in the dictionary.

Allocates and initializes a new dictionary entry with the given name and function. The word is added to the dictionary but index update is deferred until next lookup.

Parameters

vm	The virtual machine context
name	Name for the new word
len	Length of the name string
func	Function pointer for the word's behavior

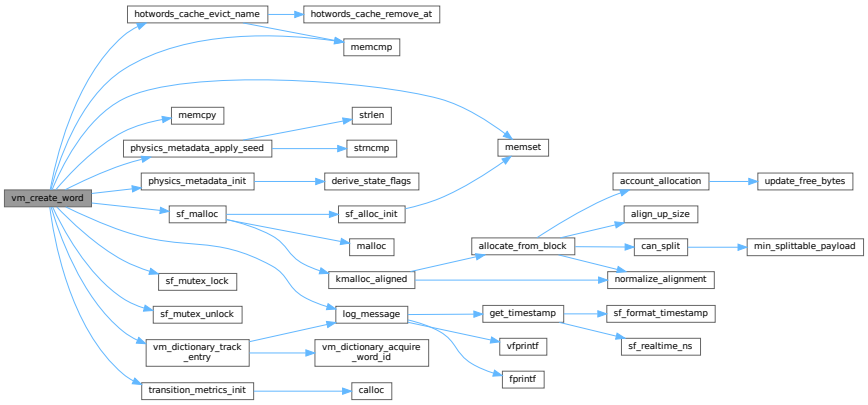
Returns

DictEntry* Pointer to new dictionary entry or NULL on failure

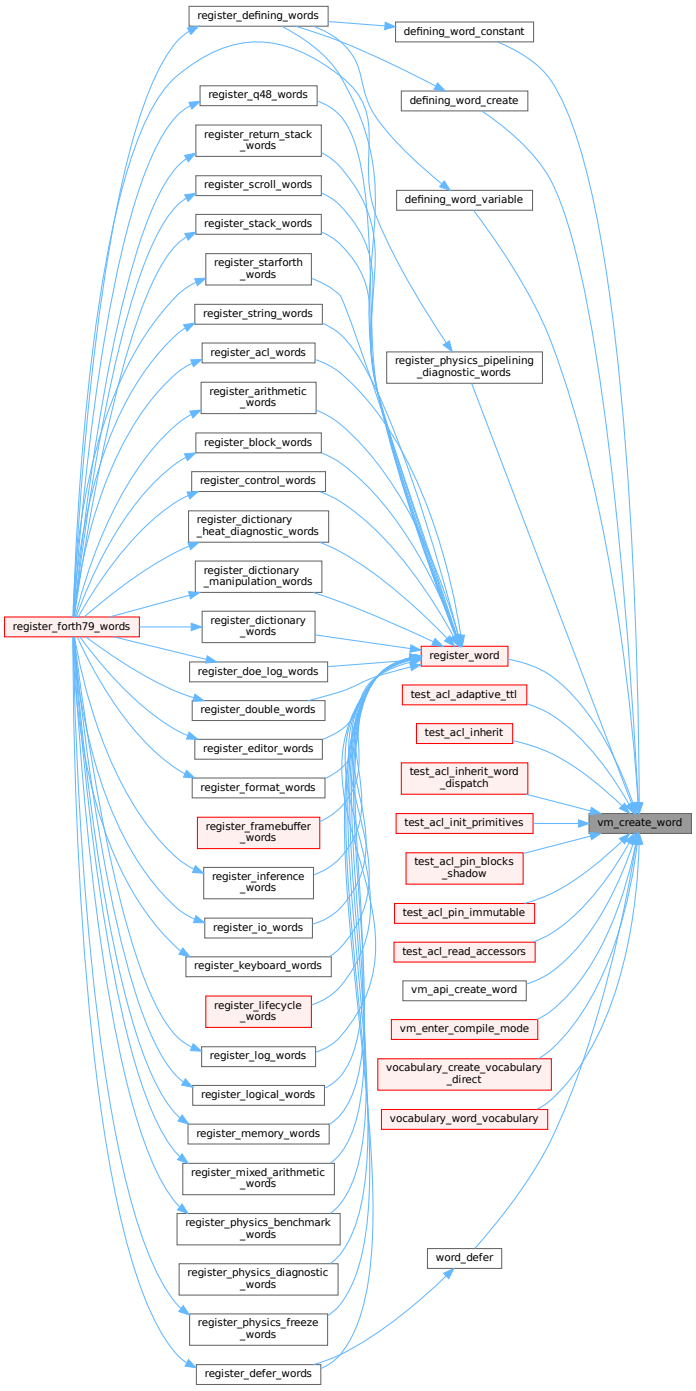
References ACL_MODE_TTL, ACL_USER_DEFAULT, base, VM::dict_lock, entry, VM::error, func, DictEntry::func, VM::hotwords_cache, hotwords_cache_evict_name(), VM::latest, LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, memcmp(), memcpy(), memset(), name, physics_metadata_apply_seed(), physics_metadata_init(), sf_malloc(), sf_mutex_lock(), sf_mutex_unlock(), transition_metrics_init(), vm_dictionary_track_entry(), WORD_ID_INVALID, and WORD_NAME_MAX.

Referenced by defining_word_constant(), defining_word_create(), defining_word_variable(), register_physics_pipelining_diagnostic_w register_word(), test_acl_adaptive_ttl(), test_acl_inherit(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_blocks_shadow(), test_acl_pin_immutable(), test_acl_read_accessors(), vm_api_create_word(), vm_enter_compile_mode(), vocabulary_create_vocabulary_direct(), vocabulary_word_vocabulary(), and word_defer().

Here is the call graph for this function:



Here is the caller graph for this function:



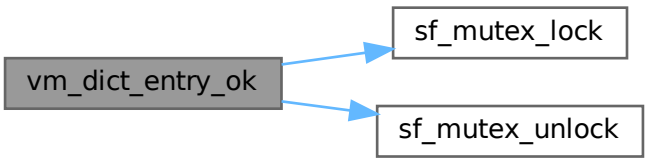
7.281.2.8 vm_dict_entry_ok()

```
int vm_dict_entry_ok (
            VM * vm,
            DictEntry * candidate )
```

References VM::dict_lock, VM::latest, sf_mutex_lock(), and sf_mutex_unlock().

Referenced by starforth_word_execution_heat_fetch(), starforth_word_execution_heat_store(), and system_word_execute().

Here is the call graph for this function:



Here is the caller graph for this function:

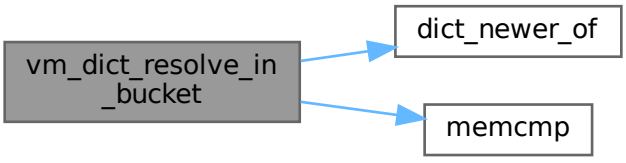
7.281.2.9 vm_dict_resolve_in_bucket()

```
DictEntry * vm_dict_resolve_in_bucket (
            VM * vm,
            DictEntry ** bucket,
            size_t n,
            const char * name,
            size_t len )
```

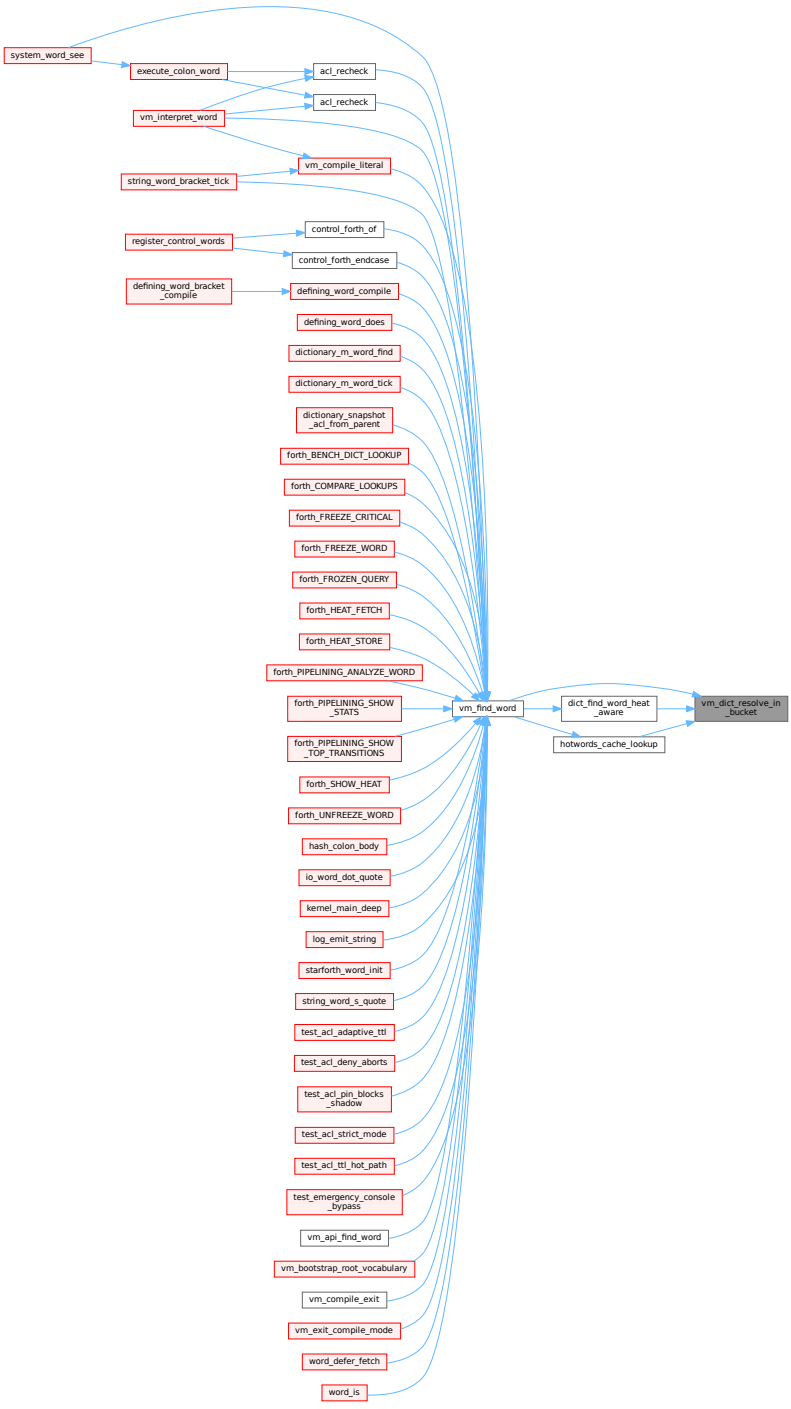
References dict_newer_of(), DictEntry::flags, memcmp(), name, DictEntry::name, DictEntry::name_len, UNLIKELY, WORD_HIDDEN, and WORD_SMUDGED.

Referenced by dict_find_word_heat_aware(), hotwords_cache_lookup(), and vm_find_word().

Here is the call graph for this function:



Here is the caller graph for this function:



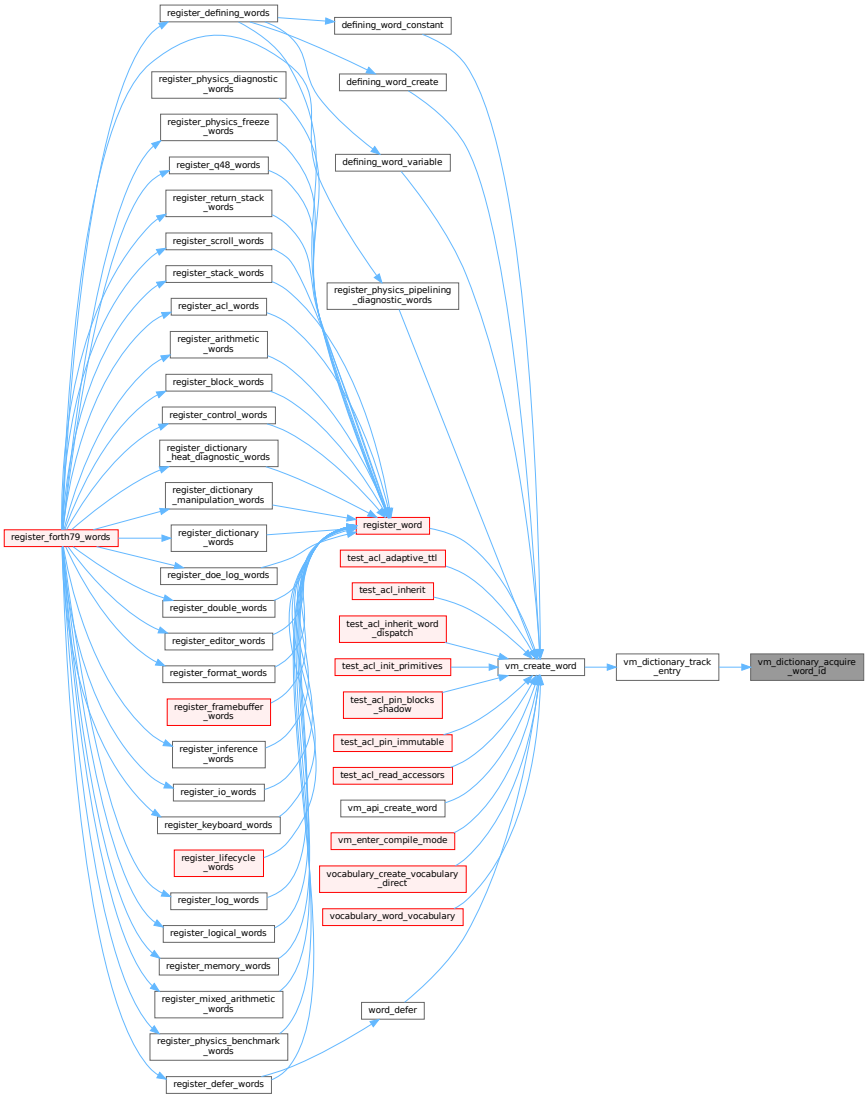
7.281.2.10 vm_dictionary_acquire_word_id()

```
static uint32_t vm_dictionary_acquire_word_id (
            VM * vm )  [static]
```

References DICTIONARY_SIZE, VM::next_word_id, VM::recycled_word_id_count, VM::recycled_word_ids, and WORD_ID_INVALID.

Referenced by vm_dictionary_track_entry().

Here is the caller graph for this function:



7.281.2.11 vm_dictionary_find_by_func()

```
DictEntry * vm_dictionary_find_by_func (
            VM * vm,
            word_func_t func )
```

Finds a word by its function pointer.

Performs a linear scan of the dictionary to find an entry with matching function.

Parameters

vm	The virtual machine context
func	Function pointer to search for

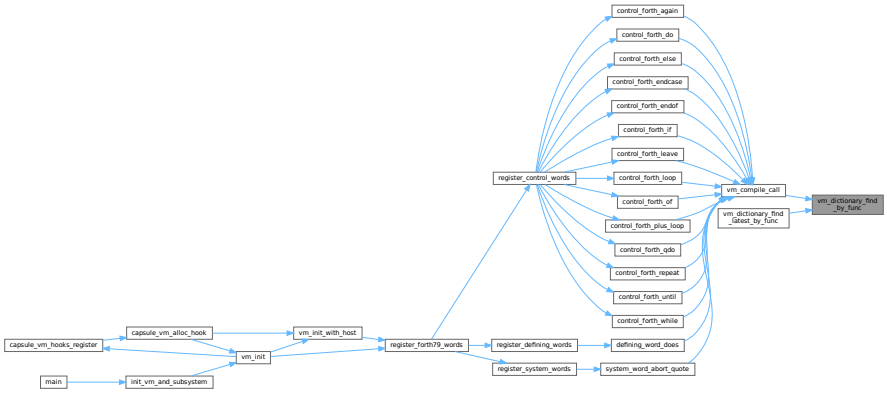
Returns

DictEntry* Pointer to found dictionary entry or NULL if not found

References func, and VM::latest.

Referenced by vm_compile_call(), and vm_dictionary_find_latest_by_func().

Here is the caller graph for this function:



7.281.2.12 vm_dictionary_find_latest_by_func()

```
DictEntry * vm_dictionary_find_latest_by_func (
            VM * vm,
            word_func_t func )
```

References func, and vm_dictionary_find_by_func().

Here is the call graph for this function:

7.281.2.13 vm_dictionary_get_data_field()

```
cell_t * vm_dictionary_get_data_field (
            DictEntry * entry )
```

Gets pointer to a word's data field.

Calculates and returns pointer to the aligned data field following the name field.

Parameters

entry	Dictionary entry to get data field from

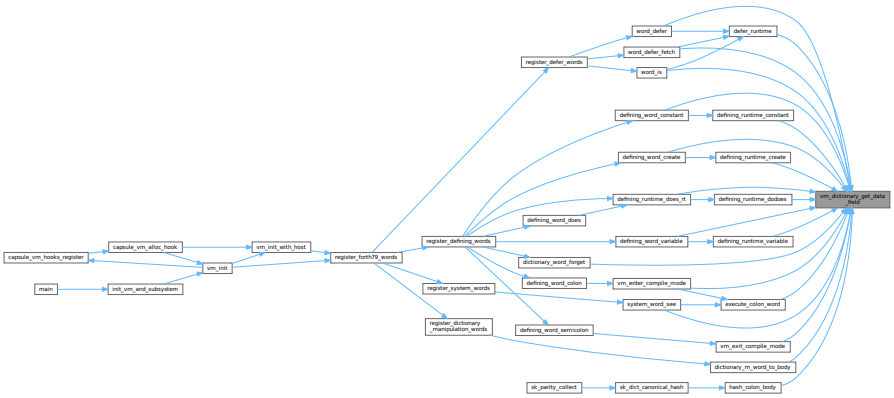
Returns

cell_t* Pointer to data field or NULL if entry is NULL

References base, entry, and name.

Referenced by defer_runtime(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_does_rt(), defining_runtime_variable(), defining_word_constant(), defining_word_create(), defining_word_variable(), dictionary_m_word_to_body(), dictionary_word_forget(), execute_colon_word(), hash_colon_body(), system_word_see(), vm_enter_compile_mode(), vm_exit_compile_mode(), word_defer(), word_defer_fetch(), and word_is().

Here is the caller graph for this function:



7.281.2.14 vm_dictionary_index_reset()

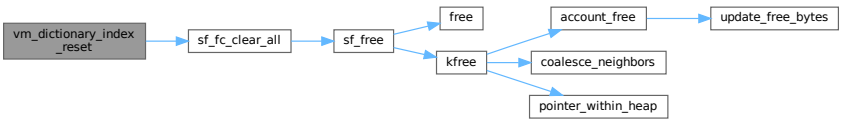
```
void vm_dictionary_index_reset (
            void  )
```

Resets the dictionary index.

Clears all index data and cached state. Used when switching vocabularies.

References sf_cached_latest, and sf_fc_clear_all().

Here is the call graph for this function:



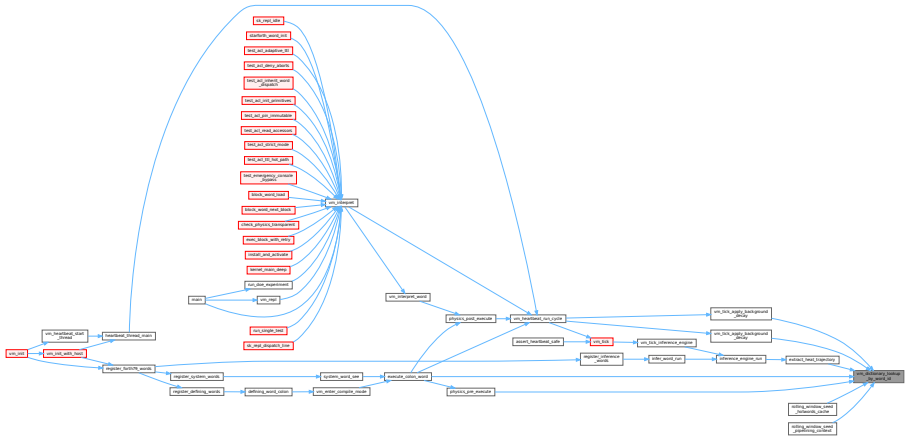
7.281.2.15 vm_dictionary_lookup_by_word_id()

```
DictEntry * vm_dictionary_lookup_by_word_id (
            VM * vm,
            uint32_t word_id )
```

References DICTIONARY_SIZE, word_id, and VM::word_id_map.

Referenced by execute_colon_word(), extract_heat_trajectory(), physics_pre_execute(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

Here is the caller graph for this function:



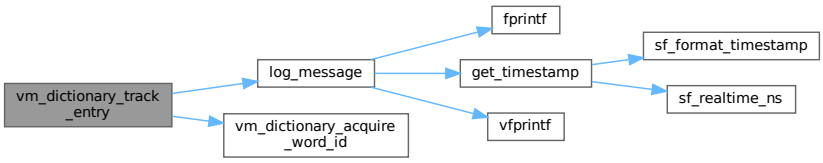
7.281.2.16 vm_dictionary_track_entry()

```
void vm_dictionary_track_entry (
            VM * vm,
            DictEntry * entry )
```

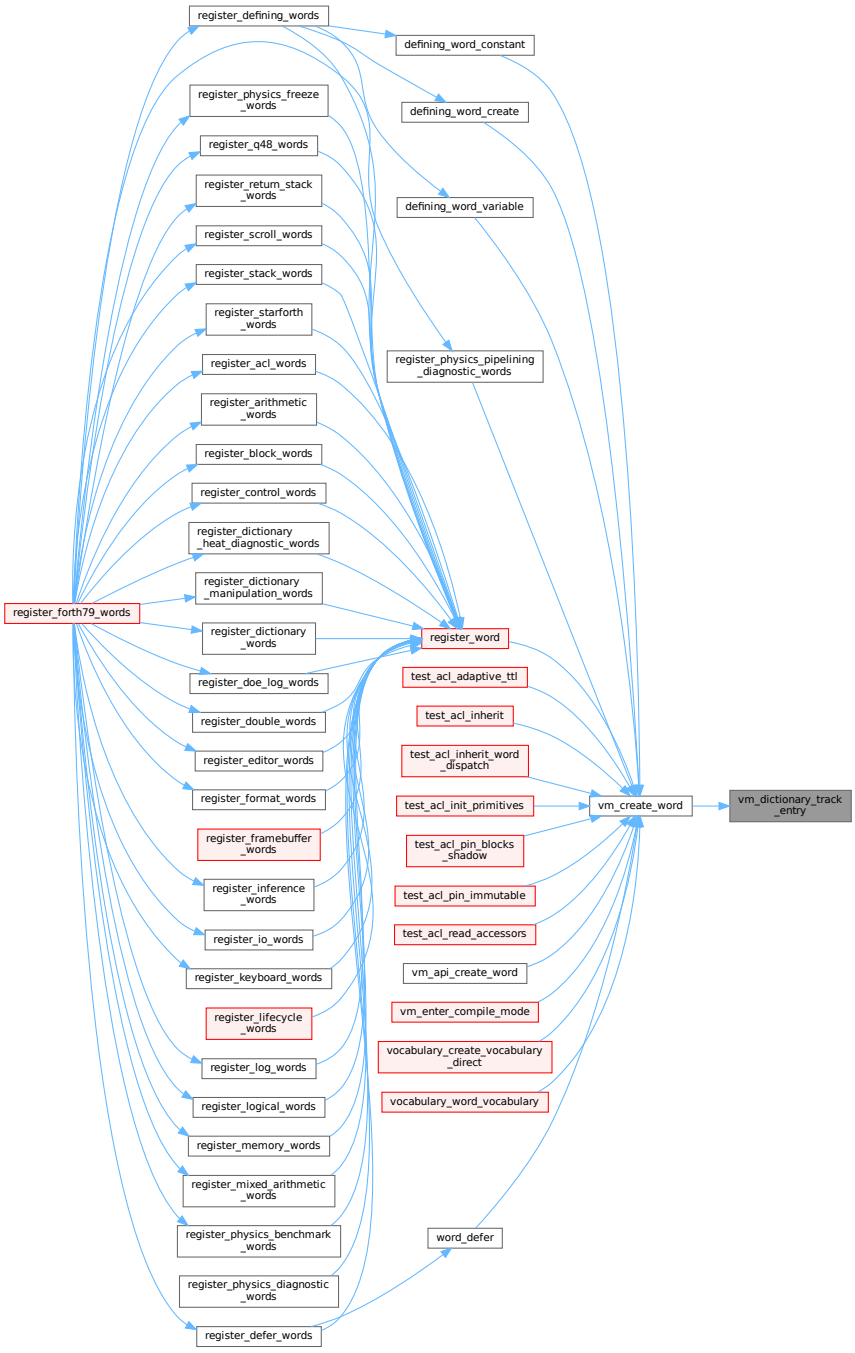
References DICTIONARY_SIZE, entry, log_message(), LOG_WARN, vm_dictionary_acquire_word_id(), word_id, WORD_ID_INVALID, and VM::word_id_map.

Referenced by vm_create_word().

Here is the call graph for this function:



Here is the caller graph for this function:



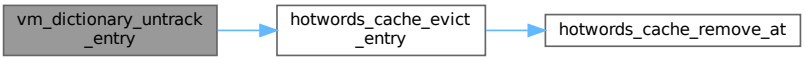
7.281.2.17 vm_dictionary_untrack_entry()

```
void vm_dictionary_untrack_entry (
            VM * vm,
            DictEntry * entry )
```

References DICTIONARY_SIZE, entry, VM::hotwords_cache, hotwords_cache_evict_entry(), VM::recycled_word_id_count, VM::recycled_word_ids, word_id, WORD_ID_INVALID, and VM::word_id_map.

Referenced by dictionary_word_forget().

Here is the call graph for this function:



Here is the caller graph for this function:

7.281.2.18 vm_find_word()

```
DictEntry * vm_find_word (
            VM * vm,
            const char * name,
            size_t len )
```

Finds a word in the dictionary by name.

Searches for a word in the dictionary using an optimized first-character index. The search is performed newest-first within the matching first-character bucket.

Parameters

vm	The virtual machine context
name	The name to search for
len	Length of the name string

Returns

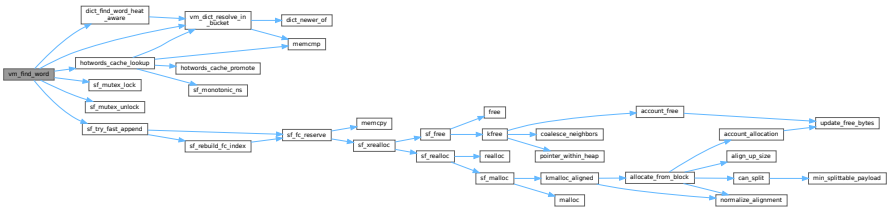
DictEntry* Pointer to found dictionary entry or NULL if not found

References dict_find_word_heat_aware(), VM::dict_lock, HeartbeatState::dictionary_lookups, VM::heartbeat, VM::hotwords_cache, hotwords_cache_lookup(), VM::latest, VM::lookup_strategy, name, sf_cached_latest, sf_fc_count, sf_fc_list, sf_mutex_lock(), sf_mutex_unlock(), sf_try_fast_append(), UNLIKELY, and vm_dict_resolve_in_bucket().

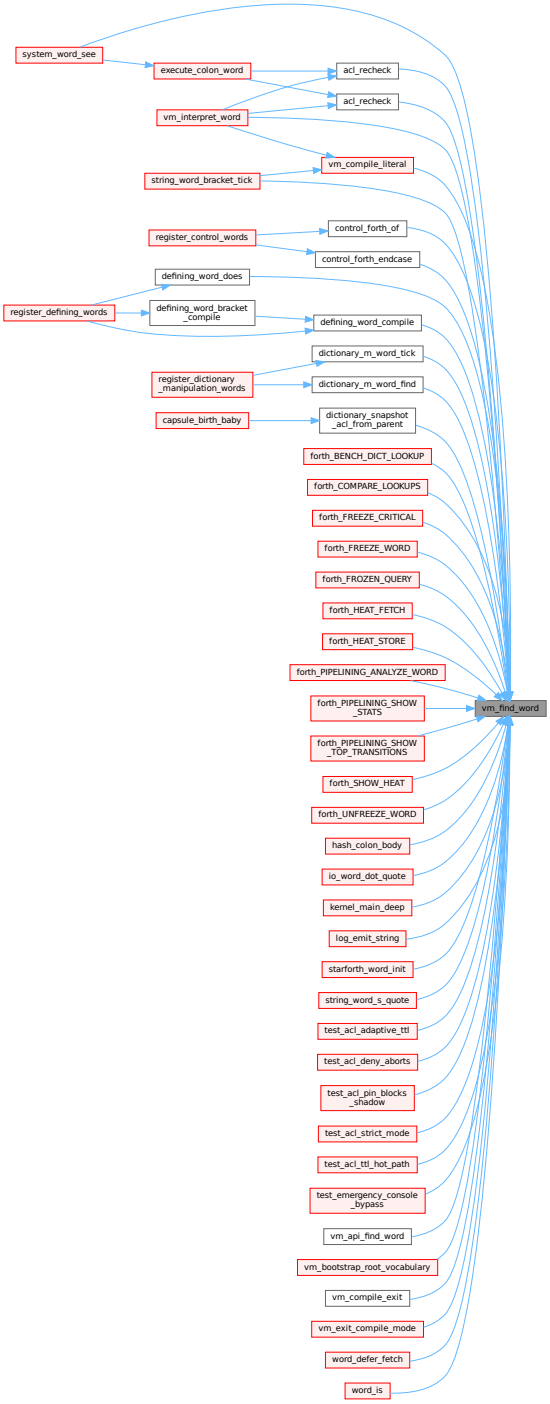
Referenced by acl_recheck(), acl_recheck(), control_forth_endcase(), control_forth_of(), defining_word_compile(), defining_word_does(), dictionary_m_word_find(), dictionary_m_word_tick(), dictionary_snapshot_acl_from_parent(), forth_BENCH_DICT_LOOKUP(), forth_COMPARE_LOOKUPS(), forth_FREEZE_CRITICAL(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_STORE(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), hash_colon_body(), io_word_dot_quote(), kernel_main_deep(), log_emit_string(),

starforth_word_init(), string_word_bracket_tick(), string_word_s_quote(), system_word_see(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_pin_blocks_shadow(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_byp vm_api_find_word(), vm_bootstrap_root_vocabulary(), vm_compile_exit(), vm_compile_literal(), vm_exit_compile_mode(), vm_interpret_word(), word_defer_fetch(), and word_is().

Here is the call graph for this function:



Here is the caller graph for this function:



7.281.2.19 vm_hide_word()

```
void vm_hide_word (
            VM * vm )
```

Marks the latest word as hidden.

Sets the WORD_HIDDEN flag on the most recently defined word.

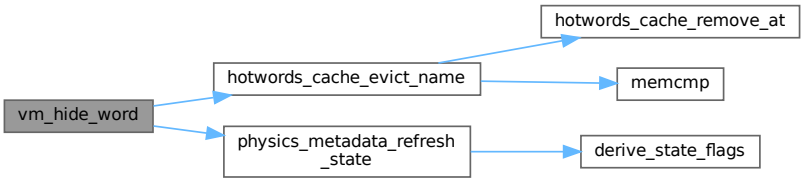
Parameters

vm	The virtual machine context

References DictEntry::flags, VM::hotwords_cache, hotwords_cache_evict_name(), VM::latest, DictEntry::name, DictEntry::name_len, physics_metadata_refresh_state(), and WORD_HIDDEN.

Referenced by vm_api_hide_word().

Here is the call graph for this function:



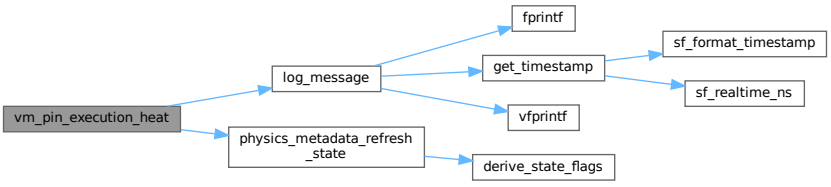
Here is the caller graph for this function:

7.281.2.20 vm_pin_execution_heat()

```
void vm_pin_execution_heat (
            VM * vm )
```

References VM::error, DictEntry::flags, VM::latest, LOG_ERROR, log_message(), physics_metadata_refresh_state(), and WORD_PINNED.

Here is the call graph for this function:



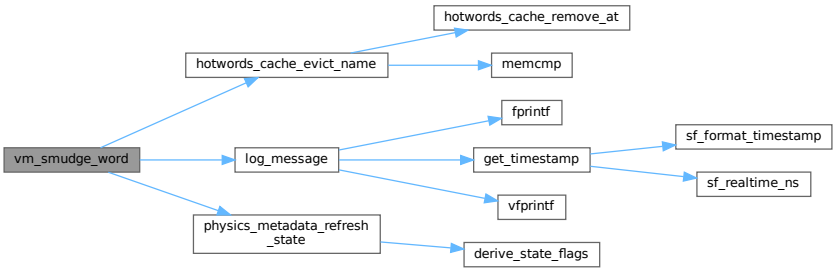
7.281.2.21 vm_smudge_word()

```
void vm_smudge_word (
            VM * vm )
```

References VM::error, DictEntry::flags, VM::hotwords_cache, hotwords_cache_evict_name(), VM::latest, LOG_ERROR, log_message(), DictEntry::name, DictEntry::name_len, physics_metadata_refresh_state(), and WORD_SMUDGED.

Referenced by vm_api_smudge_word().

Here is the call graph for this function:



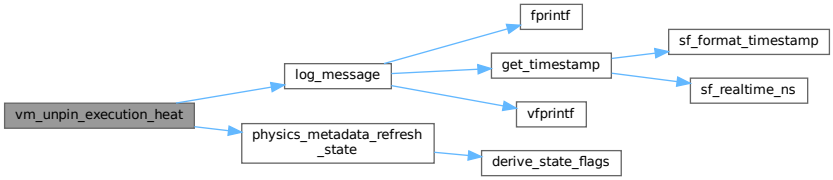
Here is the caller graph for this function:

7.281.2.22 vm_unpin_execution_heat()

```
void vm_unpin_execution_heat (
            VM * vm )
```

References VM::error, DictEntry::flags, VM::latest, LOG_ERROR, log_message(), and physics_metadata_refresh_state().

Here is the call graph for this function:



7.281.3 Variable Documentation

7.281.3.1 sf_cached_latest

```
DictEntry* sf_cached_latest = NULL  [static]
```

Referenced by sf_rebuild_fc_index(), sf_try_fast_append(), vm_dictionary_index_reset(), and vm_find_word().

7.281.3.2 sf_fc_cap

```
size_t sf_fc_cap[256]
```

Referenced by dict_reorganize_buckets_by_heat(), sf_fc_clear_all(), and sf_fc_reserve().

7.281.3.3 sf_fc_count

```
size_t sf_fc_count[256]
```

Referenced by dict_find_word_heat_aware(), dict_reorganize_buckets_by_heat(), sf_fc_clear_all(), sf_fc_reserve(), sf_rebuild_fc_index(), sf_try_fast_append(), and vm_find_word().

7.281.3.4 sf_fc_list

```
DictEntry** sf_fc_list[256]
```

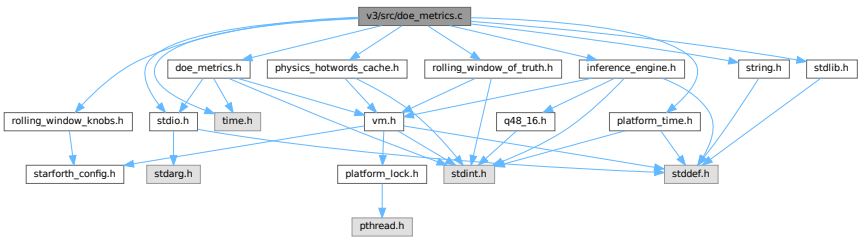
Referenced by dict_find_word_heat_aware(), dict_reorganize_buckets_by_heat(), sf_fc_clear_all(), sf_fc_reserve(), sf_rebuild_fc_index(), sf_try_fast_append(), and vm_find_word().

7.282 v3/src/doe_metrics.c File Reference

Design of Experiments metrics collection implementation.

```
#include "doe_metrics.h"
#include "physics_hotwords_cache.h"
#include "rolling_window_of_truth.h"
#include "rolling_window_knobs.h"
#include "inference_engine.h"
#include "platform_time.h"
#include <time.h>
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
```

Include dependency graph for doe_metrics.c:



Functions

- int32_t metrics_get_cpu_temp_c (void)

  Get current CPU temperature in Celsius.
- int32_t metrics_get_cpu_freq_mhz (void)

  Get current CPU frequency in MHz.
- void metrics_get_timestamp (char *buf, size_t bufsize)

  Get current timestamp as ISO 8601 string.
- static void extract_cache_metrics (const HotwordsCache *cache, DoeMetrics *metrics)

  Extract metrics from VM hotwords cache stats.
- DoeMetrics metrics_from_vm (VM *vm, uint64_t workload_duration_ns, int32_t cpu_temp_delta_c, int32_t cpu_freq_delta_mhz)

  Extract metrics from entire VM.
- void metrics_write_csv_header (FILE *out)

  Write CSV header.
- void metrics_write_csv_row (FILE *out, const DoeMetrics *metrics)

  Write CSV row - MUST match header column order exactly.
- void metrics_print_text (FILE *out, const DoeMetrics *metrics)

  Print metrics as human-readable text.
- static uint64_t isqrt (uint64_t n)

  Integer square root using Newton's method (pure C99, no math.h)
- void metrics_write_james_law_csv_row (FILE *out, const DoeMetrics *metrics, VM *vm)

  Write reduced James Law CSV row (20 columns for window scaling experiment)

Variables

- struct {
    uint64_t total_lookups
    uint64_t cache_hits
    uint64_t bucket_hits
  } physics_global_stats

7.282.1 Detailed Description

Design of Experiments metrics collection implementation.

7.282.2 Function Documentation

7.282.2.1 extract_cache_metrics()

```
static void extract_cache_metrics (
            const HotwordsCache * cache,
            DoeMetrics * metrics )  [static]
```

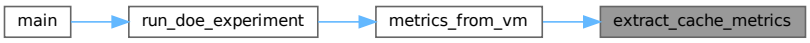
Extract metrics from VM hotwords cache stats.

References DoeMetrics::bucket_hit_percent, DoeMetrics::bucket_hits, HotwordsStats::bucket_hits, DoeMetrics::bucket_search_laten
HotwordsStats::bucket_search_samples, DoeMetrics::bucket_search_stddev_ns, HotwordsStats::bucket_search_total_ns_q48,
HotwordsStats::bucket_search_variance_sum_q48, DoeMetrics::cache_hit_latency_ns, DoeMetrics::cache_hit_percent,

HotwordsStats::cache_hit_samples, DoeMetrics::cache_hit_stddev_ns, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, DoeMetrics::cache_hits, HotwordsStats::cache_hits, HotwordsCache_s::stats, and HotwordsStats::total_lookups.

Referenced by metrics_from_vm().

Here is the caller graph for this function:



7.282.2.2 isqrt()

```
static uint64_t isqrt (
            uint64_t n )  [static]
```

Integer square root using Newton's method (pure C99, no math.h)

Referenced by metrics_write_james_law_csv_row().

Here is the caller graph for this function:

7.282.2.3 metrics_from_vm()

```
DoeMetrics metrics_from_vm (
            VM * vm,
            uint64_t workload_duration_ns,
            int32_t cpu_temp_delta_c,
            int32_t cpu_freq_delta_mhz )
```

Extract metrics from entire VM.

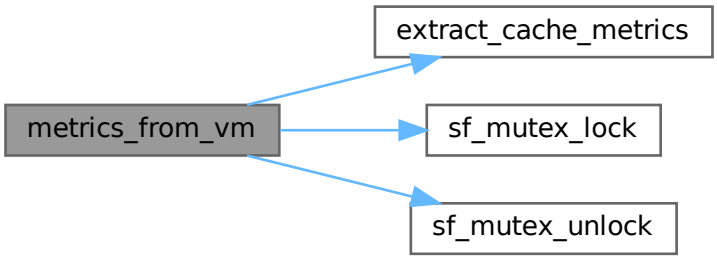
Extract complete metrics snapshot from VM.

References DoeMetrics::actual_window_size, DoeMetrics::adaptive_shrink_rate, DoeMetrics::avg_word_heat, DoeMetrics::cache_demotions, DoeMetrics::cache_promotions, DoeMetrics::ci_lower_95, DoeMetrics::ci_upper_95, DoeMetrics::context_accuracy_percent, DoeMetrics::context_correct, DoeMetrics::context_predictions_total, DoeMetrics::cpu_freq_delta_mhz_q48, DoeMetrics::cpu_temp_delta_c_q48, DECAY_MIN_INTERVAL, DoeMetrics::decay_min_inter

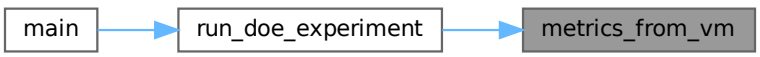
DECAY_RATE_PER_US_Q16, DoeMetrics::decay_rate_q16, DoeMetrics::decay_slope, VM::decay_slope_q48, VM::dict_lock, DoeMetrics::dictionary_lookups, HeartbeatState::dictionary_lookups, DoeMetrics::early_exit_count, HeartbeatState::early_exit_count, RollingWindowOfTruth::effective_window_size, DoeMetrics::enable_hotwords_cache, ENABLE_HOTWORDS_CACHE, DoeMetrics::enable_loop_1_heat_tracking, DoeMetrics::enable_loop_2_rolling_window, DoeMetrics::enable_loop_3_linear_decay, DoeMetrics::enable_loop_4_pipelining, DoeMetrics::enable_loop_5_window_inference, DoeMetrics::enable_loop_6_decay_inference, DoeMetrics::enable_loop_7_adaptive_heartrate, DoeMetrics::enable_pipelining, ENABLE_PIPELINING, HotwordsCache_s::enabled, HotwordsStats::evictions, extract_cache_metrics(), DoeMetrics::final_effective_v VM::heartbeat, DoeMetrics::heat_cache_demotion_threshold, DoeMetrics::hot_word_count, VM::hotwords_cache, HOTWORDS_EXECUTION_HEAT_THRESHOLD, DoeMetrics::inference_run_count, HeartbeatState::inference_run_count, VM::last_inference_outputs, VM::latest, DoeMetrics::memory_allocated_bytes, VM::pipeline_metrics, DoeMetrics::prefetch_accuracy DoeMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_attempts, DoeMetrics::prefetch_hits, PipelineGlobalMetrics::prefetch HotwordsStats::promotions, VM::rolling_window, DoeMetrics::rolling_window_size, ROLLING_WINDOW_SIZE, DoeMetrics::rolling_window_width, sf_mutex_lock(), sf_mutex_unlock(), DoeMetrics::speedup_vs_baseline, DoeMetrics::stale_word_count, DoeMetrics::stale_word_ratio, HotwordsCache_s::stats, DoeMetrics::tick_count, HeartbeatState::tick_count, DoeMetrics::tick_target_ns, HeartbeatState::tick_target_ns, DoeMetrics::total_executions, RollingWindowOfTruth::total_executions, DoeMetrics::total_heat, DoeMetrics::total_lookups, HotwordsStats::total_lookups, DoeMetrics::total_runtime_ms, VM::tuning_lock, DoeMetrics::vm_workload_duration_ns_q48, DoeMetrics::window_diversity_percent DoeMetrics::window_final_size_bytes, DoeMetrics::window_tuning_checks, PipelineGlobalMetrics::window_tuning_checks, DoeMetrics::window_variance_q48, InferenceOutputs::window_variance_q48, word_count, DoeMetrics::words_executed, and HeartbeatState::words_executed.

Referenced by run_doe_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:



7.282.2.4 metrics_get_cpu_freq_mhz()

```
int32_t metrics_get_cpu_freq_mhz (
            void  )
```

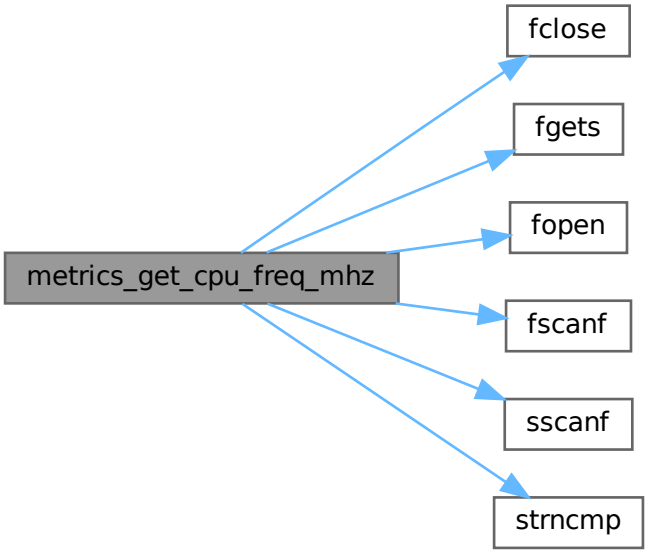
Get current CPU frequency in MHz.

Get current CPU frequency (MHz)

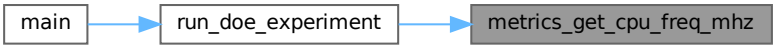
References fclose(), fgets(), fopen(), fscanf(), sscanf(), and strncmp().

Referenced by run_doe_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:



7.282.2.5 metrics_get_cpu_temp_c()

```
int32_t metrics_get_cpu_temp_c (
            void  )
```

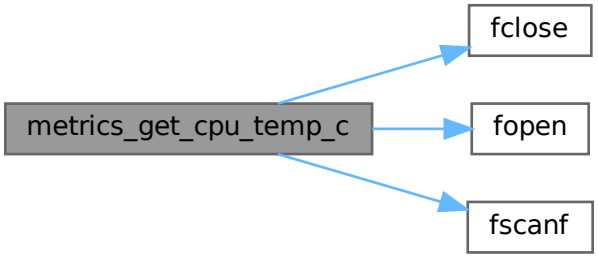
Get current CPU temperature in Celsius.

Get current CPU temperature (Celsius)

References fclose(), fopen(), and fscanf().

Referenced by run_doe_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:

7.282.2.6 metrics_get_timestamp()

```
void metrics_get_timestamp (
            char * buf,
            size_t bufsize )
```

Get current timestamp as ISO 8601 string.

Format: "YYYY-MM-DDTHH:MM:SS"

Parameters

buf	Buffer to write timestamp (minimum 32 bytes)
bufsize	Size of buffer

7.282.2.7 metrics_print_text()

```
void metrics_print_text (
```

```
            FILE * out,
            const DoeMetrics * metrics )
```

Print metrics as human-readable text.

Outputs metrics in formatted text for debugging/verification.

Parameters

out	Output file stream
metrics	Metrics structure to print

References DoeMetrics::bucket_hit_percent, DoeMetrics::bucket_hits, DoeMetrics::bucket_search_latency_ns, DoeMetrics::bucket_search_stddev_ns, DoeMetrics::cache_hit_latency_ns, DoeMetrics::cache_hit_percent, DoeMetrics::cache_hit_stddev_ns, DoeMetrics::cache_hits, DoeMetrics::context_accuracy_percent, DoeMetrics::context_correct, DoeMetrics::context_predictions_total, DoeMetrics::cpu_freq_delta_mhz_q48, DoeMetrics::cpu_temp_delta_c_q48, DoeMetrics::decay_slope, fprintf(), DoeMetrics::rolling_window_width, DoeMetrics::total_lookups, and DoeMetrics::vm_workload_dur

Here is the call graph for this function:

7.282.2.8 metrics_write_csv_header()

```
void metrics_write_csv_header (
            FILE * out )
```

Write CSV header.

Write CSV header row.

References fprintf().

Here is the call graph for this function:

7.282.2.9 metrics_write_csv_row()

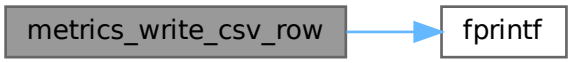
```
void metrics_write_csv_row (
            FILE * out,
            const DoeMetrics * metrics )
```

Write CSV row - MUST match header column order exactly.

Write metrics as CSV row.

References DoeMetrics::actual_window_size, DoeMetrics::adaptive_shrink_rate, DoeMetrics::avg_word_heat, DoeMetrics::bucket_hit_percent, DoeMetrics::bucket_hits, DoeMetrics::bucket_search_latency_ns, DoeMetrics::bucket_search_stdde DoeMetrics::cache_demotions, DoeMetrics::cache_hit_latency_ns, DoeMetrics::cache_hit_percent, DoeMetrics::cache_hit_stddev_n DoeMetrics::cache_hits, DoeMetrics::cache_promotions, DoeMetrics::ci_lower_95, DoeMetrics::ci_upper_95, DoeMetrics::context_accuracy_percent, DoeMetrics::context_correct, DoeMetrics::context_predictions_total, DoeMetrics::cpu_freq_delta_mhz_q48, DoeMetrics::cpu_temp_delta_c_q48, DoeMetrics::decay_min_interval_ns, DoeMetrics::decay_rate_q16, DoeMetrics::decay_slope, DoeMetrics::dictionary_lookups, DoeMetrics::early_exit_count, DoeMetrics::enable_hotwords_cache, DoeMetrics::enable_loop_1_heat_tracking, DoeMetrics::enable_loop_2_rolling_window, DoeMetrics::enable_loop_3_linear_decay, DoeMetrics::enable_loop_4_pipelining, DoeMetrics::enable_loop_5_window_inference, DoeMetrics::enable_loop_6_decay_inference, DoeMetrics::enable_loop_7_adaptive_heartrate, DoeMetrics::enable_pipelining, DoeMetrics::final_effective_window_size, fprintf(), DoeMetrics::heat_cache_demotion_threshold, DoeMetrics::hot_word_count, DoeMetrics::inference_run_count, DoeMetrics::memory_allocated_bytes, DoeMetrics::prefetch_accuracy_percent, DoeMetrics::prefetch_attempts, DoeMetrics::prefetch_hits, DoeMetrics::rolling_window_size, DoeMetrics::rolling_window_width, DoeMetrics::speedup_vs_baseline, DoeMetrics::stale_word_count, DoeMetrics::stale_word_ratio, DoeMetrics::tick_count, DoeMetrics::tick_target_ns, DoeMetrics::total_executions, DoeMetrics::total_heat, DoeMetrics::total_lookups, DoeMetrics::total_runtime_ms, DoeMetrics::vm_workload_duration_ns_q48, DoeMetrics::window_diversity_percent, DoeMetrics::window_final_size_bytes, DoeMetrics::window_tuning_checks, DoeMetrics::window_variance_q48, and DoeMetrics::words_executed.

Here is the call graph for this function:



7.282.2.10 metrics_write_james_law_csv_row()

```
void metrics_write_james_law_csv_row (
            FILE * out,
            const DoeMetrics * metrics,
            VM * vm )
```

Write reduced James Law CSV row (20 columns for window scaling experiment)

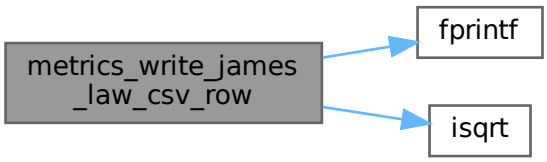
Write reduced James Law CSV row (20 columns)

This outputs only the subset of metrics needed for the James Law validation experiment. Format matches the header in run_window_sweep.sh (minus the 5 script-prepended columns).

Expected columns (20): workload_duration_ns, l8_mode_final, lambda_effective, K_statistic, K_deviation, entropy, cv, temporal_decay, stability_score, ns_per_word, total_runtime_ms, window_final, hot_word_count, avg_heat, bucket_mean_K, bucket_cv_K, bucket_window_var, bucket_heat_var, bucket_mode_transitions, bucket_collapse↩ _flag

References DoeMetrics::avg_word_heat, HeartbeatState::bucket_collapse_flag, HeartbeatState::bucket_mode_transitions, HeartbeatState::bucket_sum_heat_variance, HeartbeatState::bucket_sum_K, HeartbeatState::bucket_sum_K_squared, HeartbeatState::bucket_sum_window_variance, HeartbeatState::bucket_tick_count, DoeMetrics::cache_hit_latency_ns, DoeMetrics::cache_hit_stddev_ns, DoeMetrics::decay_slope, DoeMetrics::final_effective_window_size, fprintf(), VM::heartbeat, HEARTBEAT_TICK_BUFFER_SIZE, DoeMetrics::hot_word_count, isqrt(), HeartbeatTickSnapshot::l8_mode, DoeMetrics::rolling_window_size, DoeMetrics::rolling_window_width, DoeMetrics::stale_word_ratio, HeartbeatState::tick_buffer, HeartbeatState::tick_buffer_write_index, DoeMetrics::total_runtime_ms, DoeMetrics::vm_workload_duration_ns_q48, DoeMetrics::window_diversity_percent, and DoeMetrics::words_executed.

Here is the call graph for this function:



7.282.3 Variable Documentation

7.282.3.1 bucket_hits

```
uint64_t bucket_hits
```

7.282.3.2 cache_hits

```
uint64_t cache_hits
```

7.282.3.3 [struct]

```
struct { ... } physics_global_stats
```

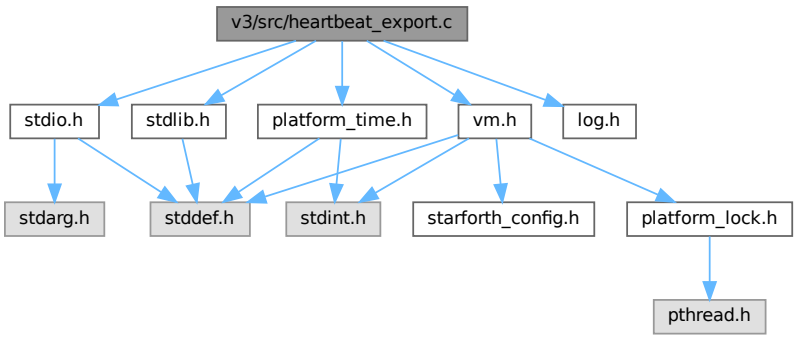
7.282.3.4 total_lookups

```
uint64_t total_lookups
```

7.283 v3/src/heartbeat_export.c File Reference

```
#include "vm.h"
#include "log.h"
#include "platform_time.h"
#include <stdio.h>
#include <stdlib.h>
```

Include dependency graph for heartbeat_export.c:



Functions

- void heartbeat_capture_tick_snapshot (VM *vm, HeartbeatTickSnapshot *snapshot)

  Capture current VM metrics into a heartbeat tick snapshot.
- void heartbeat_emit_tick_row (VM *vm, HeartbeatTickSnapshot *snapshot)

  Emit a heartbeat tick snapshot as CSV row to stderr.

7.283.1 Function Documentation

7.283.1.1 heartbeat_capture_tick_snapshot()

```
void heartbeat_capture_tick_snapshot (
            VM * vm,
            HeartbeatTickSnapshot * snapshot )
```

Capture current VM metrics into a heartbeat tick snapshot.

Collects 11 metrics per tick for multivariate dynamics analysis. Called every heartbeat tick to record VM state.

Parameters

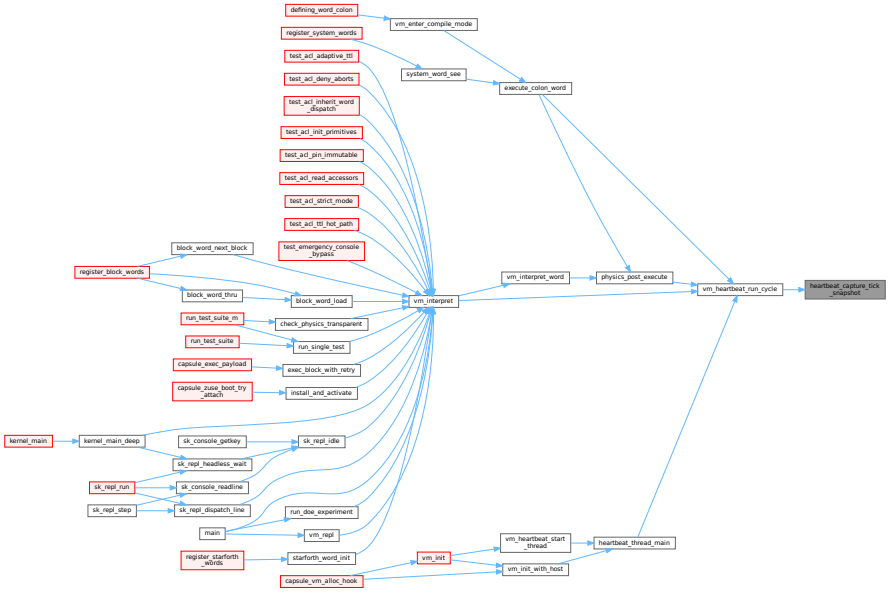
vm	Pointer to the VM instance
snapshot	Pointer to snapshot structure to populate

References HeartbeatTickSnapshot::actual_window_size, HeartbeatTickSnapshot::avg_word_heat, HeartbeatTickSnapshot::bucket_
HeartbeatTickSnapshot::cache_hits_delta, HeartbeatState::early_exit_count, RollingWindowOfTruth::effective_window_size,

HeartbeatTickSnapshot::elapsed_ns, entry, HeartbeatTickSnapshot::estimated_jitter_ns, VM::heartbeat, HEARTBEAT_TICK_NS, HeartbeatTickSnapshot::hot_word_count, VM::latest, HeartbeatTickSnapshot::predicted_label_hits, VM::rolling_window, HeartbeatState::tick_count, HeartbeatTickSnapshot::tick_interval_ns, HeartbeatTickSnapshot::tick_number, RollingWindowOfTruth::total_executions, HeartbeatTickSnapshot::window_width, word_count, HeartbeatTickSnapshot::word_executi and HeartbeatState::words_executed.

Referenced by vm_heartbeat_run_cycle().

Here is the caller graph for this function:



7.283.1.2 heartbeat_emit_tick_row()

```
void heartbeat_emit_tick_row (
            VM * vm,
            HeartbeatTickSnapshot * snapshot )
```

Emit a heartbeat tick snapshot as CSV row to stderr.

Outputs 11 comma-separated values (no header) for real-time streaming. Called every heartbeat tick to emit metrics immediately.

Format: tick_number,elapsed_ns,tick_interval_ns,cache_hits_delta, bucket_hits_delta,word_executions_↩ delta,hot_word_count, avg_word_heat,window_width,actual_window_size,predicted_label_hits,estimated_jitter_ns

Parameters

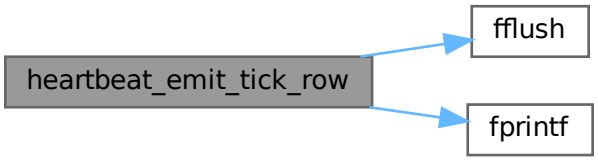
vm	Pointer to the VM instance (unused, for API consistency)
snapshot	Pointer to the snapshot to emit

References HeartbeatTickSnapshot::actual_window_size, HeartbeatTickSnapshot::avg_word_heat, HeartbeatTickSnapshot::bucket_ HeartbeatTickSnapshot::cache_hits_delta, HeartbeatTickSnapshot::elapsed_ns, HeartbeatTickSnapshot::estimated_jitter_ns, fflush(), fprintf(), HeartbeatTickSnapshot::hot_word_count, HeartbeatTickSnapshot::predicted_label_hits, stderr,

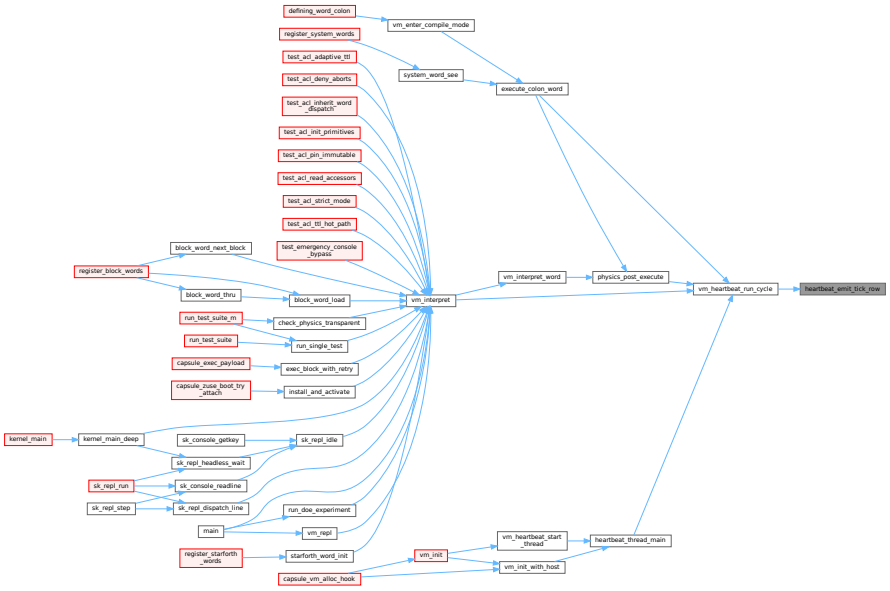
HeartbeatTickSnapshot::tick_interval_ns, HeartbeatTickSnapshot::tick_number, HeartbeatTickSnapshot::window_width, and HeartbeatTickSnapshot::word_executions_delta.

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:

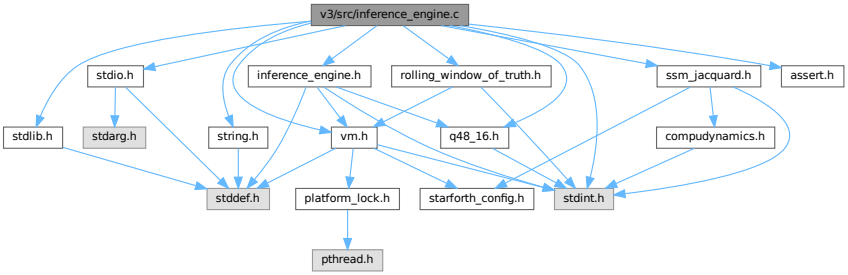


7.284 v3/src/inference_engine.c File Reference

```
#include <stdlib.h>
#include <string.h>
#include <stdio.h>
#include <stdint.h>
#include <assert.h>
#include "inference_engine.h"
#include "q48_16.h"
#include "vm.h"
#include "rolling_window_of_truth.h"
```

```
#include "ssm_jacquard.h"
```

Include dependency graph for inference_engine.c:



Functions

- static int has_variance_stabilized (q48_16_t current_variance, q48_16_t last_variance)

  ANOVA early-exit check: test whether variance has stabilised.
- static uint64_t * extract_heat_trajectory (RollingWindowOfTruth *window, VM *vm, uint64_t *out_length)

  Build a heat trajectory array from the rolling window of truth.
- q48_16_t compute_variance_q48 (const uint64_t *heat_data, uint64_t length)

  Compute the variance of a heat trajectory in Q48.16 fixed-point.
- static q48_16_t compute_median_q48 (const q48_16_t *data, uint32_t length)

  Compute the median of a Q48.16 array.
- static q48_16_t compute_mean_q48 (const q48_16_t *data, uint32_t length)

  Compute the arithmetic mean of a Q48.16 array.
- static q48_16_t compute_levene_statistic (const q48_16_t *chunk_variances, uint32_t num_chunks, uint32_t chunk_size)

  Compute Levene's W statistic for equality of variance.
- uint32_t find_variance_inflection (const uint64_t *heat_data, uint64_t trajectory_length, q48_16_t full_variance)

  Find the minimum window size where heat variance is statistically stable.
- uint64_t infer_decay_slope_q48 (const uint64_t *heat_data, uint64_t length)

  Infer the decay slope from a heat trajectory via log-linear regression.
- static uint64_t compute_fit_quality (const uint64_t *heat_data, uint64_t length, uint64_t slope_q48)

  Compute R^2-style fit quality for the inferred decay slope.
- void inference_engine_run (InferenceInputs *inputs, InferenceOutputs *outputs)

  Run adaptive inference engine on window data.
- const char * inference_outputs_to_string (const InferenceOutputs *outputs)

  Format inference outputs as a human-readable string.
- int inference_outputs_validate (const InferenceOutputs *outputs)

  Validate inference outputs for sanity.

7.284.1 Function Documentation

7.284.1.1 compute_fit_quality()

```
static uint64_t compute_fit_quality (
            const uint64_t * heat_data,
```

```
    uint64_t length,
    uint64_t slope_q48 )  [static]
```

Compute R^2-style fit quality for the inferred decay slope.

Currently returns a fixed placeholder of 0.8 in Q48.16 (52429). A full residual-sum-of-squares implementation is planned but deferred — the placeholder is sufficient for the DoE convergence signal.

Parameters

heat_data	Array of heat values (unused in current implementation)
length	Array length (unused in current implementation)
slope_q48	Inferred slope in Q48.16 (unused in current implementation)

Returns

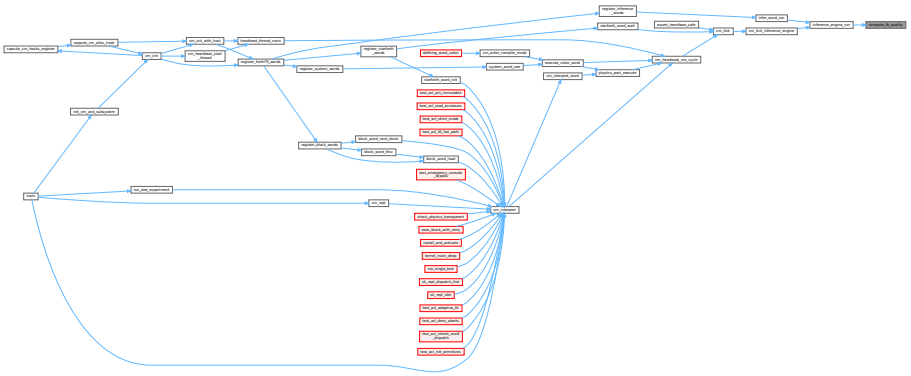
Fit quality in Q48.16; currently always 0.8 (52429)

References q48_from_u64().

Referenced by inference_engine_run().

Here is the call graph for this function:

Here is the caller graph for this function:



7.284.1.2 compute_levene_statistic()

```
static q48_16_t compute_levene_statistic (
            const q48_16_t * chunk_variances,
            uint32_t num_chunks,
            uint32_t chunk_size )  [static]
```

Compute Levene's W statistic for equality of variance.

Tests the null hypothesis H?: all chunk variances are equal. Uses the median-based variant for robustness: z_i = |var_i - median_var|, then W = (K-1)∗N∗Σ(z_i - z_bar)^2 / (K∗N ∗ var(z)). Returns 0 for fewer than 2 chunks. Compare result to LEVENE_CRITICAL_VALUE_Q48 (≈ 6.5 at α=0.05): W $>$ critical means variances differ significantly.

Parameters

chunk_variances	Array of K per-chunk variance values (Q48.16)
num_chunks	Number of chunks K (must be >= 2)
chunk_size	Number of samples N per chunk

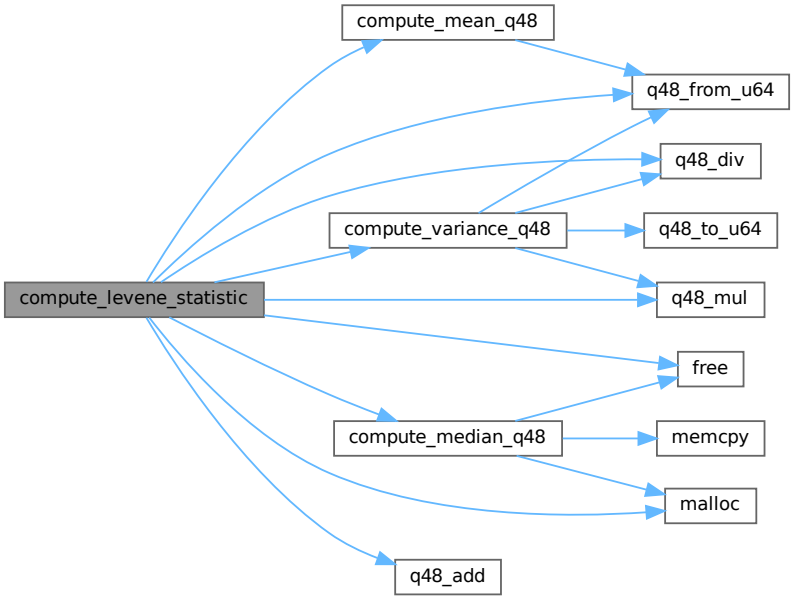
Returns

Levene's W statistic in Q48.16 format

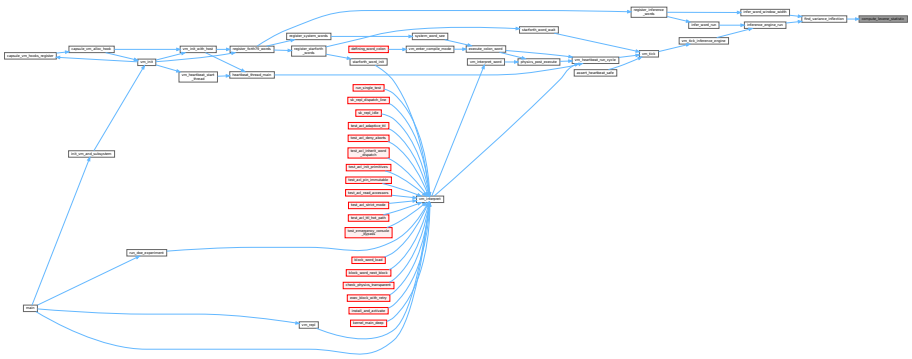
References compute_mean_q48(), compute_median_q48(), compute_variance_q48(), free(), malloc(), q48_add(), q48_div(), q48_from_u64(), and q48_mul().

Referenced by find_variance_inflection().

Here is the call graph for this function:



Here is the caller graph for this function:



7.284.1.3 compute_mean_q48()

```
static q48_16_t compute_mean_q48 (
            const q48_16_t * data,
            uint32_t length )  [static]
```

Compute the arithmetic mean of a Q48.16 array.

Sums the integer parts of each element (>> 16) and returns the result converted back to Q48.16. Returns 0 for an empty array.

Parameters

data	Array of Q48.16 values
length	Number of elements

Returns

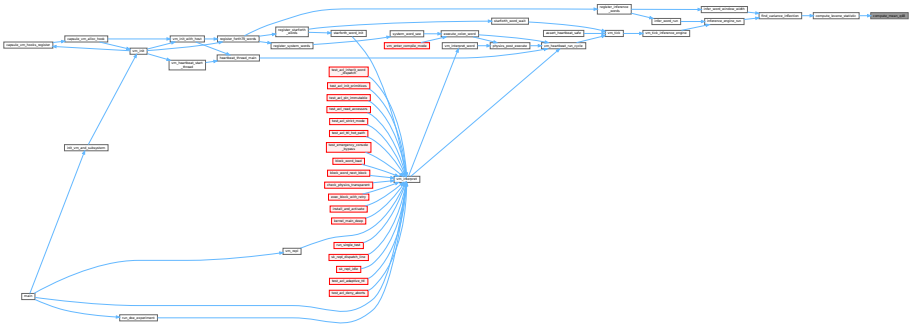
Arithmetic mean in Q48.16 format

References q48_from_u64().

Referenced by compute_levene_statistic().

Here is the call graph for this function:

Here is the caller graph for this function:



7.284.1.4 compute_median_q48()

```
static q48_16_t compute_median_q48 (
            const q48_16_t * data,
            uint32_t length )  [static]
```

Compute the median of a Q48.16 array.

Makes a temporary copy, sorts it with bubble sort (acceptable for the small chunk counts used in Levene's test, typically K <= 16), and returns the middle element. Returns 0 for an empty array.

Parameters

data	Array of Q48.16 values
length	Number of elements

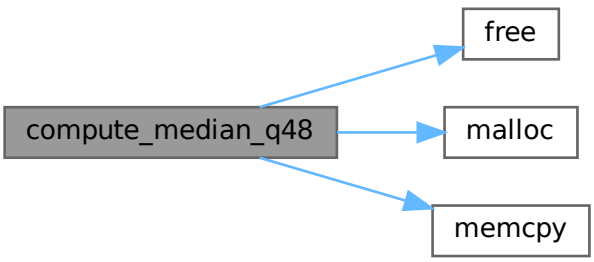
Returns

Median value in Q48.16 format

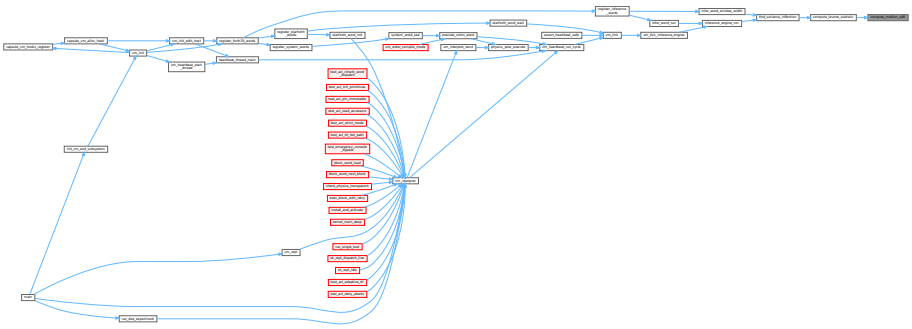
References free(), malloc(), and memcpy().

Referenced by compute_levene_statistic().

Here is the call graph for this function:



Here is the caller graph for this function:



7.284.1.5 compute_variance_q48()

```
q48_16_t compute_variance_q48 (
            const uint64_t * heat_data,
            uint64_t length )
```

Compute the variance of a heat trajectory in Q48.16 fixed-point.

Computes the population variance: Σ(heat[i] - mean)^2 / N. All intermediate calculations use Q48.16 arithmetic. Returns 0 for an empty array.

Parameters

heat_data	Array of execution heat values (raw uint64_t counts)
length	Number of elements in `heat_data`

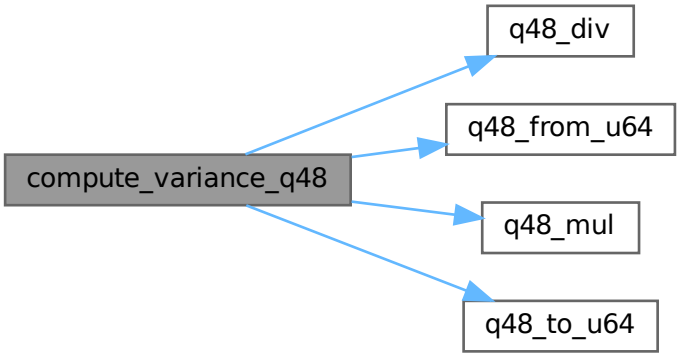
Returns

Population variance in Q48.16 format

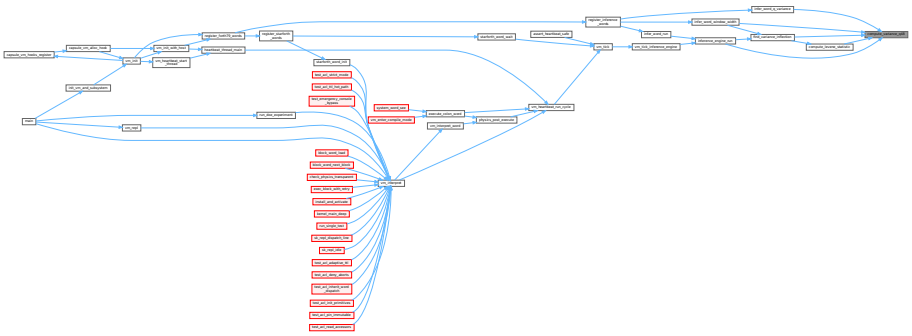
References q48_div(), q48_from_u64(), q48_mul(), and q48_to_u64().

Referenced by compute_levene_statistic(), find_variance_inflection(), infer_word_q_variance(), infer_word_window_width(), and inference_engine_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.284.1.6 extract_heat_trajectory()

```
static uint64_t * extract_heat_trajectory (
            RollingWindowOfTruth * window,
            VM * vm,
            uint64_t * out_length )  [static]
```

Build a heat trajectory array from the rolling window of truth.

Linearises the rolling window via `rolling_window_export_execution_history()`, then translates each word-id slot to its current `execution_heat` by looking up the entry under `vm->dict_lock`. The result is a freshly allocated array of `*out_length` uint64_t values in chronological order. The caller is responsible for freeing the returned pointer. Returns NULL (and sets `*out_length` = 0) on allocation failure or empty window.

Parameters

window	Rolling window to export from
vm	VM whose dictionary is consulted for heat values
out_length	Output: number of elements in the returned array

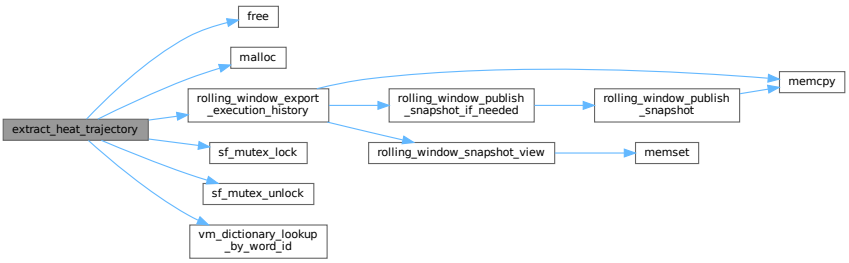
Returns

Heap-allocated trajectory array, or NULL on failure

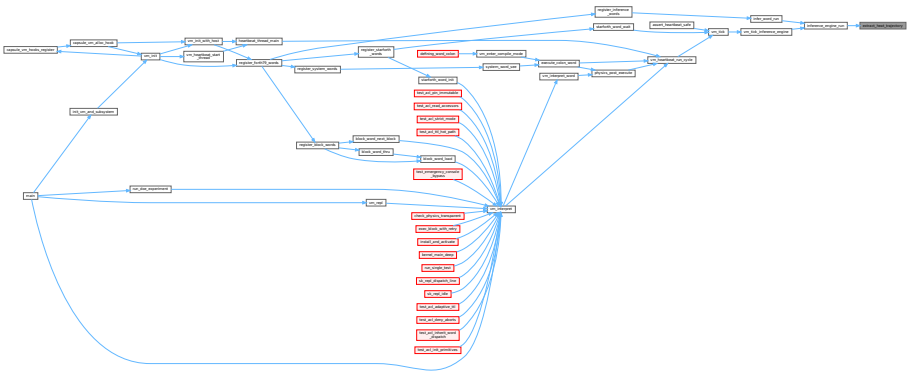
References VM::dict_lock, DICTIONARY_SIZE, RollingWindowOfTruth::effective_window_size, entry, free(), RollingWindowOfTruth::is_warm, malloc(), rolling_window_export_execution_history(), ROLLING_WINDOW_SIZE, sf_mutex_lock(), sf_mutex_unlock(), vm_dictionary_lookup_by_word_id(), and word_id.

Referenced by inference_engine_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.284.1.7 find_variance_inflection()

```
uint32_t find_variance_inflection (
            const uint64_t * heat_data,
            uint64_t trajectory_length,
            q48_16_t full_variance )
```

Find the minimum window size where heat variance is statistically stable.

Implements Loop #5 (window width inference). Scans candidate window sizes from ADAPTIVE_MIN_WINDOW↩ _SIZE to the full trajectory in steps of 64, divides the trajectory into disjoint chunks of that size, and applies Levene's test. Returns the first size where W <= 6.5 (α=0.05 critical value). Falls back to the full trajectory length if no size passes. full_variance is unused (retained for API compatibility with callers that pre-compute it).

Parameters

heat_data	Heat trajectory array
trajectory_length	Number of elements in `heat_data`
full_variance	Unused; retained for API compatibility

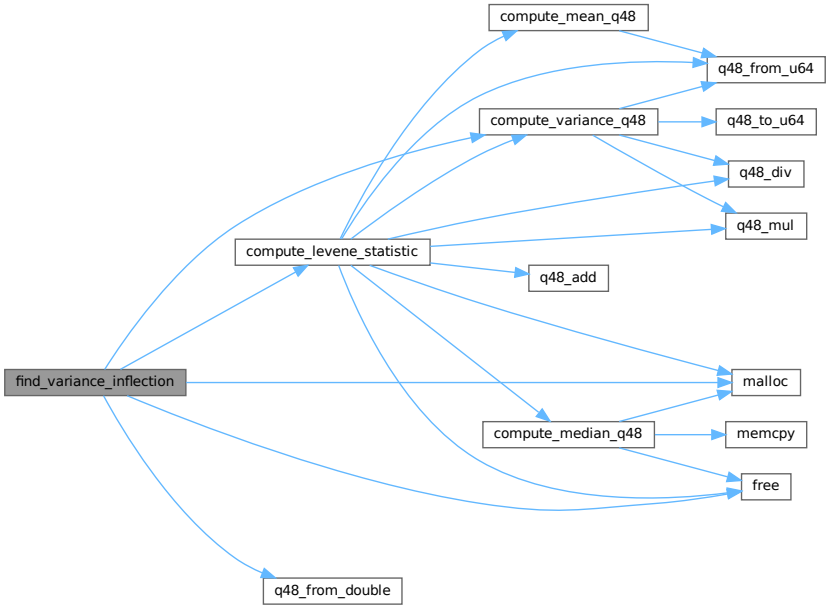
Returns

Minimum sufficient window width in [ADAPTIVE_MIN_WINDOW_SIZE, ROLLING_WINDOW_SIZE]

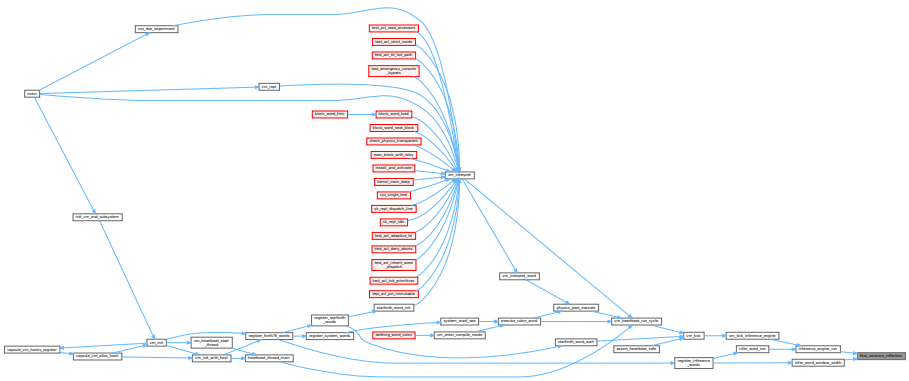
References ADAPTIVE_MIN_WINDOW_SIZE, compute_levene_statistic(), compute_variance_q48(), free(), malloc(), q48_from_double(), and ROLLING_WINDOW_SIZE.

Referenced by infer_word_window_width(), and inference_engine_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.284.1.8 has_variance_stabilized()

```
static int has_variance_stabilized (
            q48_16_t current_variance,
            q48_16_t last_variance )  [static]
```

ANOVA early-exit check: test whether variance has stabilised.

Computes |current - last| / last. If the relative change is <= 5% (threshold = 3276 in Q48.16), the variance is considered stable and full inference can be skipped (~100 cycles vs ~5–10k for a full run). Always returns 0 (unstable) on the first call when `last_variance` == 0.

Parameters

current_variance	Variance from the current snapshot (Q48.16)
last_variance	Variance from the previous inference run (Q48.16)

Returns

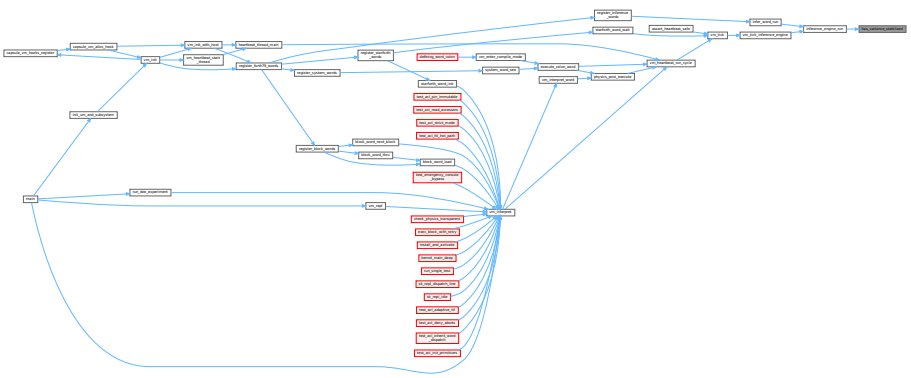
1 if variance is stable (skip inference), 0 if full run needed

References q48_div().

Referenced by inference_engine_run().

Here is the call graph for this function:

Here is the caller graph for this function:



7.284.1.9 infer_decay_slope_q48()

```
uint64_t infer_decay_slope_q48 (
            const uint64_t * heat_data,
            uint64_t length )
```

Infer the decay slope from a heat trajectory via log-linear regression.

Implements Loop #6 (decay slope inference). Fits the model ln(heat[t]) = ln(h?) - slope∗t using the closed-form OLS solution: slope = (n∗Σ(t·ln(h)) - Σt·Σln(h)) / (n·Σt^2 - $(\Sigma t)^2$). The sign of the numerator is taken as absolute value since decay rate is always positive. Zero heat values are skipped. Returns 0 if fewer than 2 samples are available.

Parameters

heat_data	Array of execution heat values (raw counts)
length	Number of elements in `heat_data`

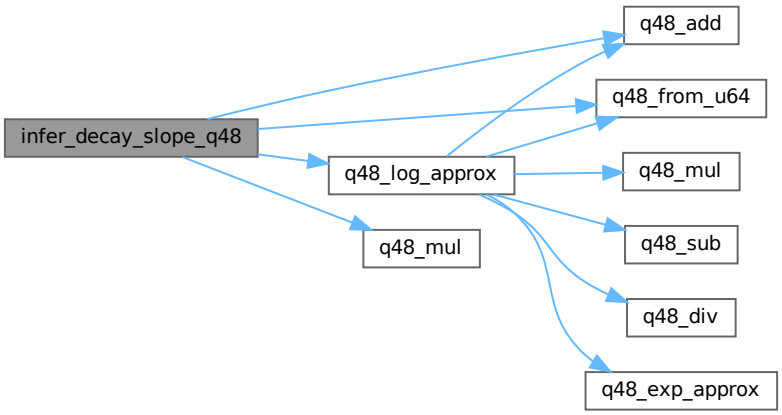
Returns

Inferred decay slope in Q48.16 format (0 = insufficient data)

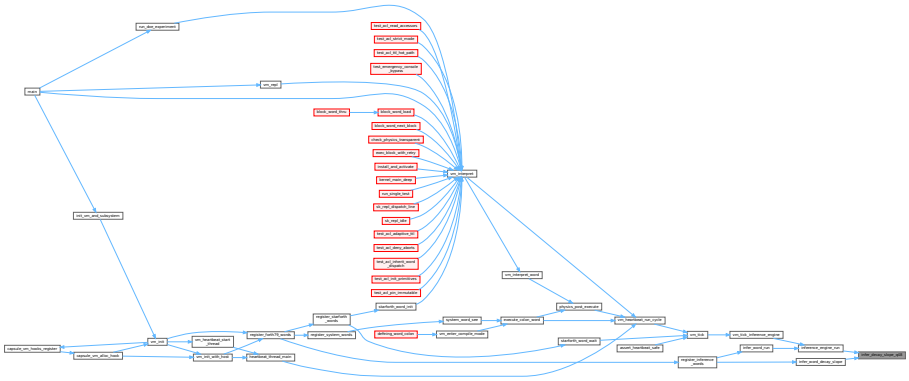
References q48_add(), q48_from_u64(), q48_log_approx(), and q48_mul().

Referenced by infer_word_decay_slope(), and inference_engine_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.284.1.10 inference_engine_run()

```
void inference_engine_run (
            InferenceInputs * inputs,
            InferenceOutputs * outputs )
```

Run adaptive inference engine on window data.

High-level flow:

1. ANOVA Check: Is variance delta $<$ 5%?
   - YES: Return cached outputs immediately (cost: $\sim$100 cycles)
   - NO: Continue to full inference
2. Extract trajectory: Fresh execution_heat snapshot from dictionary
3. Window Width Inference:
   - Compute variance across entire window
   - Detect inflection point (where d(variance)/d(size) $\rightarrow$ 0)
   - Return optimal window size
4. Decay Slope Inference:
   - Transform trajectory to log space (ln(heat[t]))
   - Fit linear regression: ln(heat) = a - slope$*$t
   - Extract slope coefficient in Q48.16
5. Diagnostics:
   - Compute fit quality (R^2 or residual)
   - Store variance metric for next early-exit check

Parameters

inputs	Snapshot of window + metrics (caller-provided)
outputs	Tuning parameters + diagnostics (caller-provided, will be updated)

Returns

void (results_run_01_2025_12_08 in outputs struct)

Preconditions:

- inputs != NULL
- outputs != NULL
- inputs->window != NULL
- inputs->window->is_warm == 1 (window has enough data)
- inputs->trajectory_length > 1

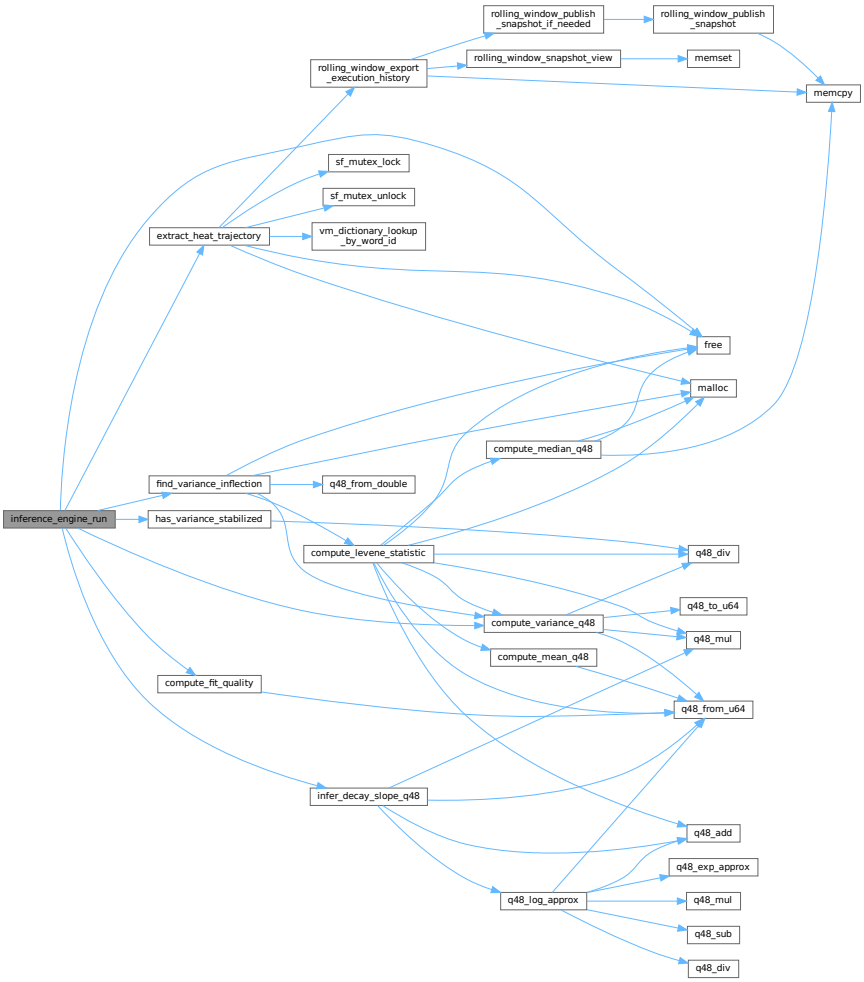
Side Effects:

- Modifies outputs struct (caller must preserve if caching)
- Allocates temporary trajectory buffer (freed on return)

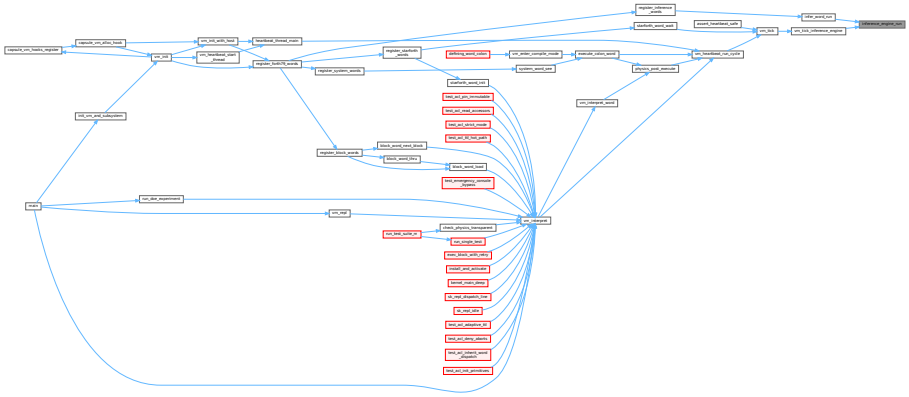
References InferenceOutputs::adaptive_decay_slope, InferenceOutputs::adaptive_window_width, compute_fit_quality(), compute_variance_q48(), InferenceOutputs::early_exited, extract_heat_trajectory(), find_variance_inflection(), free(), has_variance_stabilized(), infer_decay_slope_q48(), ssm_config_t::L5_window_inference, ssm_config_t::L6_decay_inference, InferenceOutputs::slope_fit_quality_q48, VM::ssm_config, InferenceInputs::vm, InferenceInputs::window, and InferenceOutputs::window_variance_q48.

Referenced by infer_word_run(), and vm_tick_inference_engine().

Here is the call graph for this function:



Here is the caller graph for this function:



7.284.1.11 inference_outputs_to_string()

```
const char * inference_outputs_to_string (
```

```
            const InferenceOutputs * outputs )
```

Format inference outputs as a human-readable string.

Writes into a static 256-byte buffer — not thread-safe, for diagnostics only. Format: "window=N var=↩ F slope=F quality=F (cached|full)".

Parameters

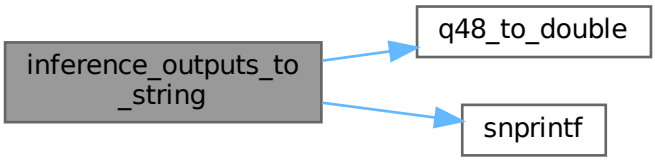
outputs	Inference outputs to format (NULL produces "(null)")

Returns

Pointer to a static string buffer

References InferenceOutputs::adaptive_decay_slope, InferenceOutputs::adaptive_window_width, InferenceOutputs::early_exited, q48_to_double(), InferenceOutputs::slope_fit_quality_q48, snprintf(), and InferenceOutputs::window_variance_q48.

Here is the call graph for this function:



7.284.1.12 inference_outputs_validate()

```
int inference_outputs_validate (
            const InferenceOutputs * outputs )
```

Validate inference outputs for sanity.

Checks that adaptive_window_width is in [ADAPTIVE_MIN_WINDOW_SIZE, ROLLING_WINDOW_↩ SIZE], that adaptive_decay_slope is non-zero and <= 100.0 in Q48.16, and that slope_fit_↩ quality_q48 is in [0.0, 1.0].

Parameters

outputs	Inference outputs to validate (NULL returns 0)

Returns

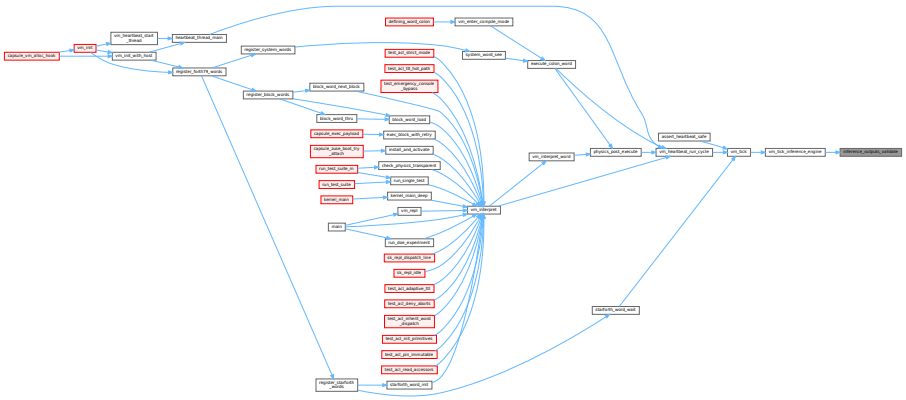
1 if all fields are within acceptable ranges, 0 otherwise

References InferenceOutputs::adaptive_decay_slope, ADAPTIVE_MIN_WINDOW_SIZE, InferenceOutputs::adaptive_window_width, q48_from_u64(), ROLLING_WINDOW_SIZE, and InferenceOutputs::slope_fit_quality_q48.

Referenced by vm_tick_inference_engine().

Here is the call graph for this function:

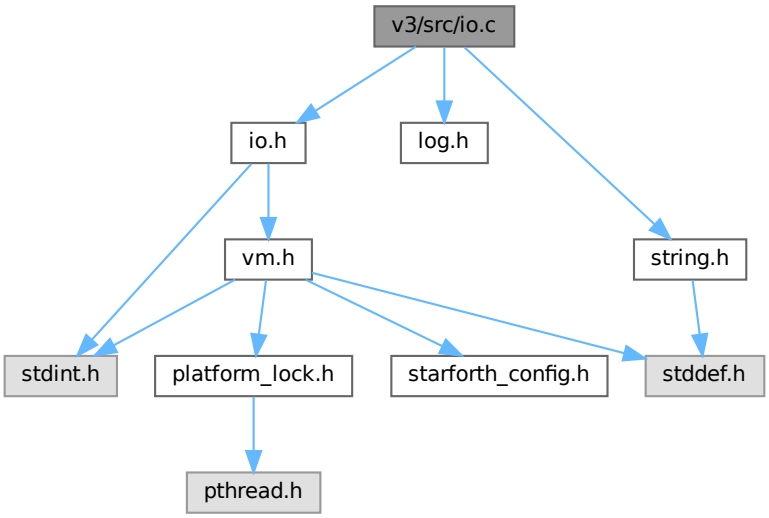
Here is the caller graph for this function:



7.285 v3/src/io.c File Reference

```
#include "io.h"
#include "log.h"
#include <string.h>
```

Include dependency graph for io.c:



Functions

- void io_init (VM *vm)

  Initialize the IO subsystem.
- int io_write_block (VM *vm, int block_num, const unsigned char *buffer)

  Write a block to VM memory.

7.285.1 Function Documentation

7.285.1.1 io_init()

```
void io_init (
            VM * vm )
```

Initialize the IO subsystem.

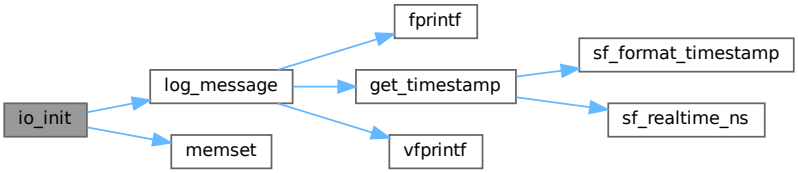
Parameters

vm	Pointer to VM instance

Initializes the block device view over the unified VM memory. Zeros out the entire VM memory space.

References BLOCK_SIZE, LOG_ERROR, LOG_INFO, log_message(), MAX_BLOCKS, VM::memory, memset(), and VM_MEMORY_SIZE.

Here is the call graph for this function:



7.285.1.2 io_write_block()

```
int io_write_block (
            VM * vm,
            int block_num,
            const unsigned char * buffer )
```

Write a block to VM memory.

Parameters

vm	Pointer to VM instance
block_num	Block number to write (0 to MAX_BLOCKS-1)
buffer	Source buffer containing block data

Returns

0 on success, -1 on error

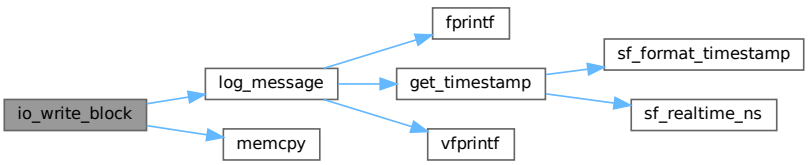
Writes a BLOCK_SIZE chunk of data from the provided buffer into the VM's memory at the specified block number offset. The block number must be within valid range. The entire block is written atomically.

Note

The buffer must contain at least BLOCK_SIZE bytes of valid data

References BLOCK_SIZE, LOG_DEBUG, LOG_ERROR, log_message(), MAX_BLOCKS, memcpy(), and VM::memory.

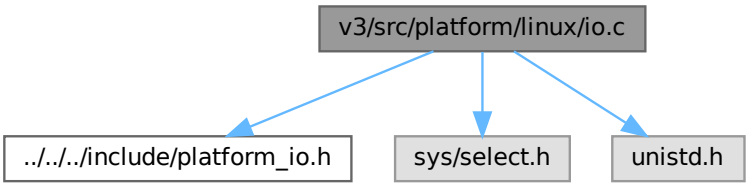
Here is the call graph for this function:



7.286 v3/src/platform/linux/io.c File Reference

```
#include "../../../include/platform_io.h"
#include <sys/select.h>
#include <unistd.h>
```

Include dependency graph for io.c:



Functions

- int sf_terminal_ready (void)

  Non-blocking check for whether a key/character is available to read.

7.286.1 Function Documentation

7.286.1.1 sf_terminal_ready()

```
int sf_terminal_ready (
            void  )
```

Non-blocking check for whether a key/character is available to read.

Must not block and must not consume the byte if one is found (a following KEY/getchar() must still return that same byte).

Returns

1 if input is ready, 0 otherwise

References timeval::tv_sec, and timeval::tv_usec.

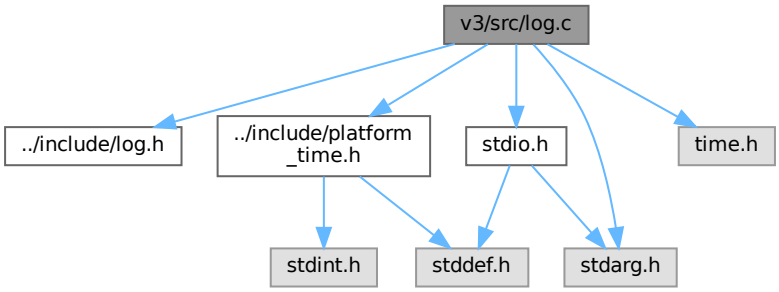
Referenced by io_word_question_terminal().

Here is the caller graph for this function:

7.287 v3/src/log.c File Reference

```
#include "../include/log.h"
#include "../include/platform_time.h"
#include <stdio.h>
#include <stdarg.h>
#include <time.h>
```

Include dependency graph for log.c:



Functions

- void log_set_level (LogLevel level)

  Set the global logging level.
- LogLevel log_get_level (void)

  Gets the current global logging level.
- static void get_timestamp (char ∗buffer, size_t size)

  Helper function to generate timestamp string.
- void log_message (LogLevel level, const char ∗fmt,...)

  Log a formatted message at the specified level.
- void log_test_result (const char ∗word_name, TestResult result)

  Log a test result with colored output.

Variables

- static LogLevel current_level = LOG_INFO
- static const char ∗ level_names [ ]
- static const char ∗ level_colors [ ]
- static const char ∗ test_pass_color = "\x1b[32m"
- static const char ∗ test_fail_color = "\x1b[31m"
- static const char ∗ test_skip_color = "\x1b[33m"
- static const char ∗ color_reset = "\x1b[0m"

7.287.1 Function Documentation

7.287.1.1 get_timestamp()

```
static void get_timestamp (
            char * buffer,
            size_t size )  [static]
```

Helper function to generate timestamp string.

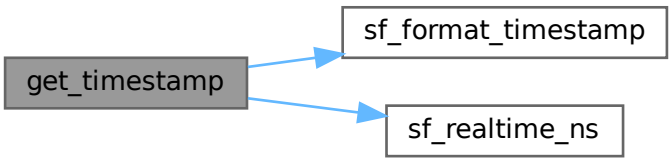
Parameters

buffer	Output buffer for the timestamp string
size	Size of the output buffer

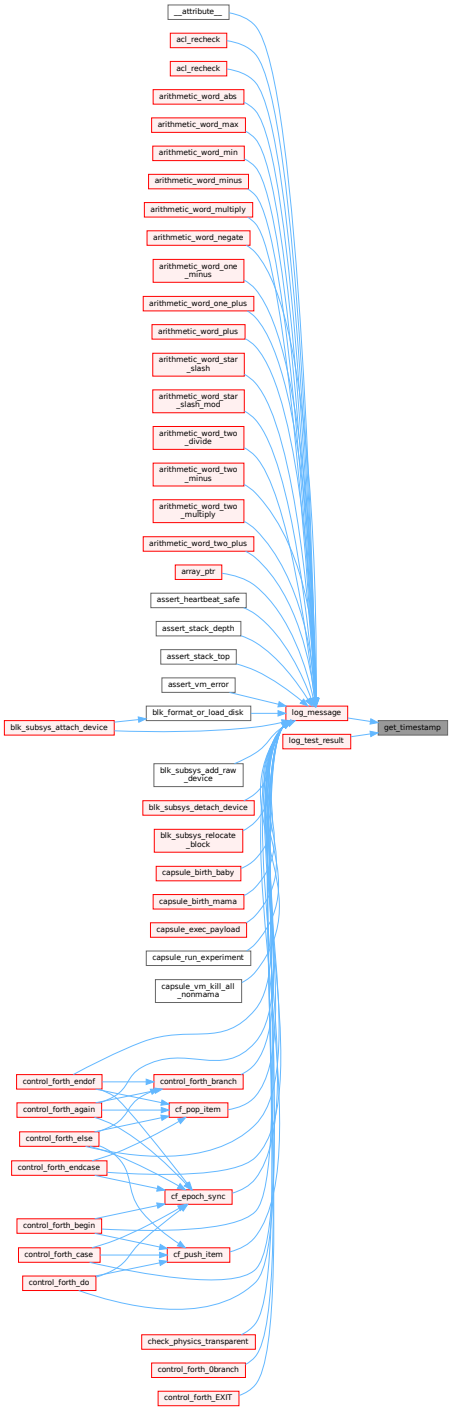
References sf_format_timestamp(), and sf_realtime_ns().

Referenced by log_message(), and log_test_result().

Here is the call graph for this function:



Here is the caller graph for this function:



7.287.1.2 log_get_level()

```
LogLevel log_get_level (
            void  )
```

Gets the current global logging level.

Get the current logging level.

Returns

LogLevel Current logging level

References current_level.

Referenced by log_word_get_level().

Here is the caller graph for this function:

7.287.1.3 log_message()

```
void log_message (
            LogLevel level,
            const char * fmt,
             ...  )
```

Log a formatted message at the specified level.

Parameters

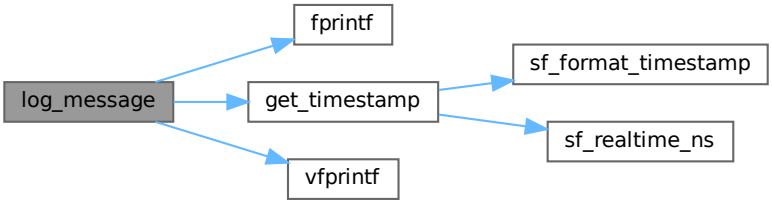
level	The logging level for this message
fmt	Printf-style format string
...	Variable arguments for format string

References color_reset, current_level, fprintf(), get_timestamp(), level, level_colors, level_names, LOG_NONE, stderr, and vfprintf().

Referenced by __attribute__(), acl_recheck(), acl_recheck(), arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), array_ptr(), assert_heartbeat_safe(), assert_stack_depth(), assert_stack_top(), assert_vm_error(), blk_format_or_load_disk(), blk_subsys_add_raw_device(), blk_subsys_attach_device(), blk_subsys_detach_device(), blk_subsys_relocate_block(), capsule_birth_baby(), capsule_birth_mama(), capsule_exec_payload(), capsule_run_experiment(), capsule_vm_kill_all_nonmama(), cf_epoch_sync(), cf_pop_item(), cf_push_item(), check_physics_transparent(), control_forth_0branch(), control_forth_again(), control_forth_begin(), control_forth_branch(), control_forth_case(), control_forth_do(), control_forth_else(), control_forth_endcase(), control_forth_endof(), control_forth_EXIT(), control_forth_I(), control_forth_if(), control_forth_J(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_runtime_do(), control_forth_runtime_leave(), control_forth_runtime_loop(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), control_forth_then(), control_forth_UNLOOP(), control_forth_until(), control_forth_while(), defer_runtime(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_does_rt(), defining_runtime_lit(), defining_runtime_variable(), defining_word_colon(), defining_word_compile(), defining_word_constant(), defining_word_create(), defining_word_does(), defining_word_immediate(), defining_word_left_bracket(), defining_word_literal(), defining_word_right_bracket(), defining_word_variable(), dict_adaptive_optimization_pass(), dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), dictionary_m_word_tick(), dictionary_m_word_to_body(), dictionary_word_fence(), dictionary_word_forget(),

dump_and_die(), editor_word_edit(), editor_word_l(), editor_word_s(), editor_word_show(), emit_cell(), enable_benchmark_mode(), execute_colon_word(), fail_and_exit(), fbw_plot(), format_word_hold(), forth_acl_allow_store(), forth_acl_inherit(), forth_acl_mode_store(), forth_acl_ttl_store(), forth_paren(), hosted_lifecycle_birth(), hosted_lifecycle_kill(), hosted_lifecycle_pause(), hosted_lifecycle_resume(), hosted_lifecycle_use(), infer_word_run(), init_blkio(), init_report(), init_vocabulary_system(), io_init(), io_word_type(), io_write_block(), log_do_emit(), log_emit_string(), log_str_emit(), log_word_set_level(), logical_word_and(), logical_word_equals(), logical_word_false(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_true(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), main(), memory_word_cells(), mixed_math_word_mod(), pop_xt(), print_module_summary(), register_arithmetic_words(), register_forth79_words(), register_word(), return_stack_word_r_fetch(), return_stack_word_r_from(), return_stack_word_to_r(), rolling_window_run_adaptive_pass(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), run_acl_words_tests(), run_all_tests(), run_arithmetic_words_tests(), run_benchmark_mode(), run_block_words_tests(), run_break_me_tests(), run_control_words_tests(), run_defining_words_tests(), run_dictionary_manipulation_words_tests(), run_dictionary_words_tests(), run_doe_experiment(), run_double_words_tests(), run_format_words_tests(), run_inference_words_tests(), run_integration_tests(), run_io_words_tests(), run_logical_words_tests(), run_mama_forth_words_tests(), run_memory_words_tests(), run_mixed_arithmetic_words_tests(), run_module_tests(), run_physics_freeze_words_tests(), run_q48_words_tests(), run_return_stack_words_tests(), run_single_test(), run_stack_words_tests(), run_starforth_words_tests(), run_stress_tests(), run_string_words_tests(), run_system_words_tests(), run_test_suite(), run_test_suite_m(), run_vocabulary_words_tests(), run_word_tests(), sk_repl_dispatch_line(), sk_repl_idle(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), stack_word_depth(), stack_word_drop(), stack_word_dup(), stack_word_minus_rot(), stack_word_over(), stack_word_pick(), stack_word_question_dup(), stack_word_roll(), stack_word_rot(), stack_word_swap(), starforth_word_execution_heat_fetch(), starforth_word_execution_heat_store(), starforth_word_init(), starforth_word_paren_dash(), starforth_word_random(), starforth_word_seed(), starforth_word_top_words(), starforth_word_wait(), starforth_word_zuse_pubkey_fetch(), string_word_blank(), string_word_bracket_tick(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_count(), string_word_expect(), string_word_minus_trailing(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), system_word_reboot(), test_acl_adaptive_ttl(), test_acl_strict_mode(), vblk_io(), verify_mint(), vm_align(), vm_allot(), vm_assert_interpreter_enabled(), vm_bootstrap_root_vocabulary(), vm_bootstrap_scr(), vm_compile_call(), vm_compile_exit(), vm_compile_literal(), vm_compile_word(), vm_create_word(), vm_dictionary_track_entry(), vm_enter_compile_mode(), vm_exit_compile_mode(), vm_get_block_addr(), vm_heartbeat_start_thread(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_init(), vm_init_with_host(), vm_interpret_word(), vm_load_cell(), vm_load_u8(), vm_make_immediate(), vm_pin_execution_heat(), vm_pop(), vm_push(), vm_repl(), vm_smudge_word(), vm_store_cell(), vm_store_u8(), vm_tick_inference_engine(), vm_tick_slope_validator(), vm_tick_window_tuner(), vm_unpin_execution_heat(), vocabulary_create_vocabulary_direct(), vocabulary_select_runtime(), vocabulary_word_definitions(), vocabulary_word_forth(), vocabulary_word_vocabulary(), vt100_enable_ttf(), vt100_init(), word_defer(), word_defer_fetch(), word_divide(), word_divmod(), word_is(), xhci_bot_read_data_in(), xhci_bot_receive_csw(), xhci_bot_send_read10(), xhci_bot_send_read_capacity10(), xhci_bot_send_test_unit_ready(), xhci_bot_send_write10(), xhci_bot_write_data_out(), xhci_bringup(), xhci_cmd_address_device(), xhci_cmd_configure_endpoint(), xhci_cmd_configure_hid_endpoint(), xhci_cmd_disable_slot(), xhci_cmd_enable_slot(), xhci_cmd_reset_endpoint(), xhci_cmd_set_tr_dequeue_pointer(), xhci_drain_pending_event(), xhci_ep0_bot_mass_storage_reset(), xhci_ep0_clear_endpoint_ha
xhci_ep0_get_config_descriptor(), xhci_ep0_get_device_descriptor(), xhci_ep0_hid_set_protocol(), xhci_ep0_set_configuration(), xhci_find_and_map(), xhci_handle_bulk_stall(), xhci_handle_port_connected(), xhci_log_hex32(), xhci_poll_one(), xhci_queue_pending_event(), xhci_stall_fail(), and xhci_take_from_bios().

Here is the call graph for this function:



7.287.1.4 log_set_level()

```
void log_set_level (
            LogLevel level )
```

Set the global logging level.

Parameters

level	The new logging level to set

Note

Default level is LOG_INFO

References current_level, and level.

Referenced by log_word_set_level(), and main().

Here is the caller graph for this function:

7.287.1.5 log_test_result()

```
void log_test_result (
            const char * word_name,
            TestResult result )
```

Log a test result with colored output.

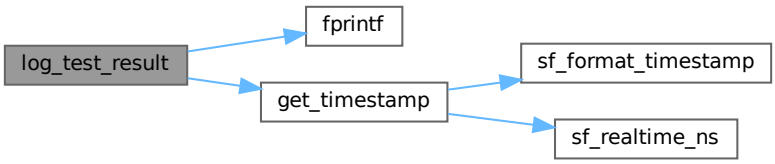
Parameters

word_name	Name of the word being tested
result	Result of the test execution

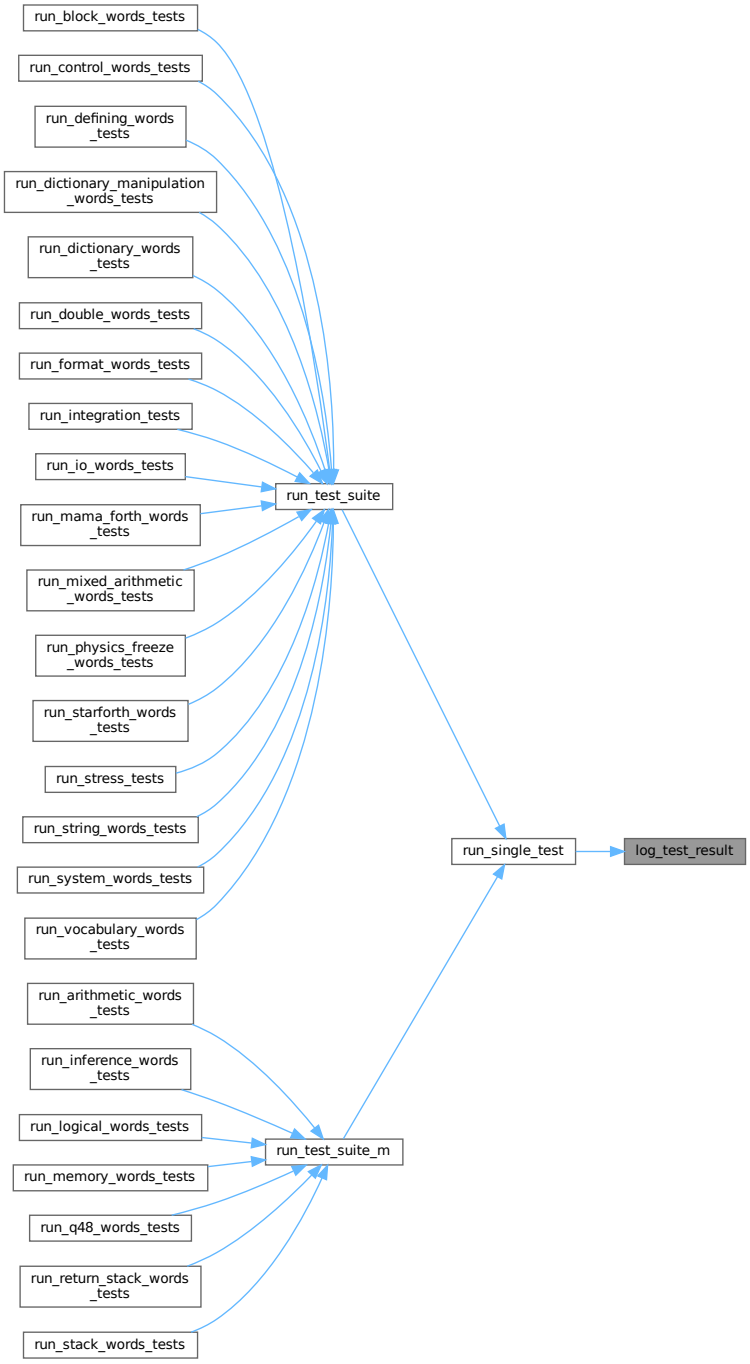
References color_reset, current_level, fprintf(), get_timestamp(), LOG_NONE, LOG_TEST, stderr, TEST_FAIL, test_fail_color, TEST_PASS, test_pass_color, TEST_SKIP, and test_skip_color.

Referenced by run_single_test().

Here is the call graph for this function:



Here is the caller graph for this function:



7.287.2 Variable Documentation

7.287.2.1 color_reset

```
const char* color_reset = "\x1b[0m"  [static]
```

Referenced by log_message(), and log_test_result().

7.287.2.2 current_level

```
LogLevel current_level = LOG_INFO  [static]
```

Referenced by log_get_level(), log_message(), log_set_level(), and log_test_result().

7.287.2.3 level_colors

```
const char* level_colors[]  [static]
```

Initial value:

```
= {
    "\x1b[31m",
    "\x1b[33m",
    "\x1b[32m",
    "\x1b[35m",
    "\x1b[34m"
}
```

Referenced by log_message().

7.287.2.4 level_names

```
const char* level_names[]  [static]
```

Initial value:

```
= {
    "ERROR",
    "WARN",
    "INFO",
    "TEST",
    "DEBUG"
}
```

Referenced by log_message().

7.287.2.5 test_fail_color

```
const char* test_fail_color = "\x1b[31m"  [static]
```

Referenced by log_test_result().

7.287.2.6 test_pass_color

```
const char* test_pass_color = "\x1b[32m"  [static]
```

Referenced by log_test_result().

7.287.2.7 test_skip_color

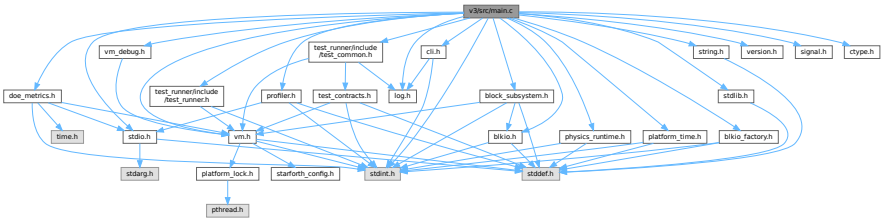
```
const char* test_skip_color = "\x1b[33m"  [static]
```

Referenced by log_test_result().

7.288 v3/src/main.c File Reference

```
#include "vm.h"
#include "vm_debug.h"
#include "log.h"
#include "profiler.h"
#include "physics_runtime.h"
#include "platform_time.h"
#include "version.h"
#include "cli.h"
#include "block_subsystem.h"
#include "test_runner/include/test_runner.h"
#include "test_runner/include/test_common.h"
#include "doe_metrics.h"
#include "blkio.h"
#include "blkio_factory.h"
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <signal.h>
#include <ctype.h>
#include <stdint.h>
```

Include dependency graph for main.c:



Macros

- #define STARFORTH_STATE_BYTES 8192u

Functions

- __attribute__ ((weak))
- static void cleanup_blkio (void)
- void cleanup_and_exit (void)

  Performs cleanup operations before program termination.
- void signal_handler (int sig)
- void print_usage (const char *program_name)

  Prints program usage information.
- static int init_blkio (const CLIConfig *config)

  Initialize block I/O from CLI configuration.
- static int init_vm_and_subsystem (VM *vm)

  Initialize VM core and block subsystem.
- static void run_benchmark_mode (VM *vm, const CLIConfig *config)

  Run benchmark mode and exit.

- static void run_optional_tests (VM *vm, const CLIConfig *config)

  Run optional test modes after system initialization.
- static void run_doe_experiment (VM *vm)

  Run Design of Experiments experiment.
- int main (int argc, char *argv[])

  Main entry point for StarForth.

Variables

- static int g_blkio_opened = 0
- static uint8_t * g_ram_base = NULL
- static size_t g_ram_bytes = 0
- static int g_ram_is_mmap = 0

7.288.1 Macro Definition Documentation

7.288.1.1 STARFORTH_STATE_BYTES

```
#define STARFORTH_STATE_BYTES 8192u
```

7.288.2 Function Documentation

7.288.2.1 __attribute__()

```
__attribute__ (
             (weak)  )
```

7.288.2.2 cleanup_and_exit()

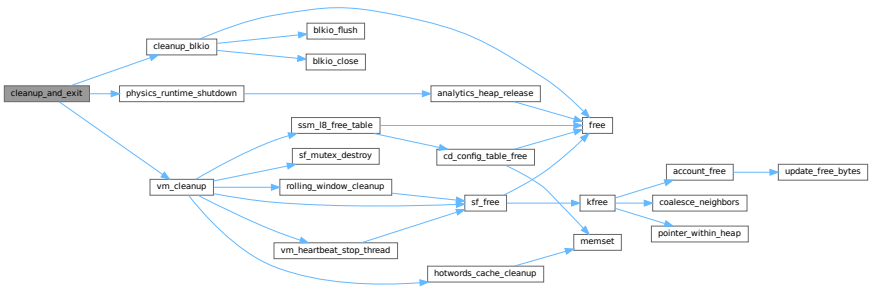
```
void cleanup_and_exit (
             void  )
```

Performs cleanup operations before program termination.

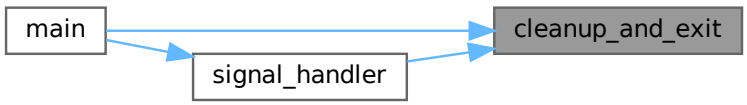
References cleanup_blkio(), physics_runtime_shutdown(), and vm_cleanup().

Referenced by main(), and signal_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



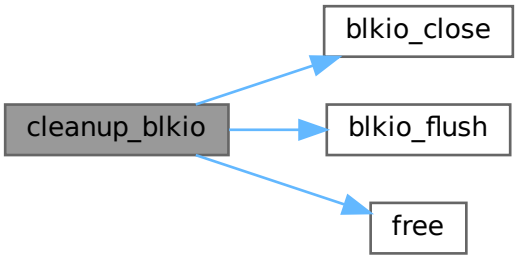
7.288.2.3 cleanup_blkio()

```
static void cleanup_blkio (
            void  )  [static]
```

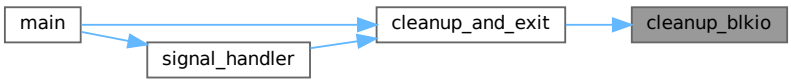
References blkio_close(), blkio_flush(), free(), g_blkio_opened, g_ram_base, g_ram_bytes, and g_ram_is_mmap.

Referenced by cleanup_and_exit().

Here is the call graph for this function:



Here is the caller graph for this function:



7.288.2.4 init_blkio()

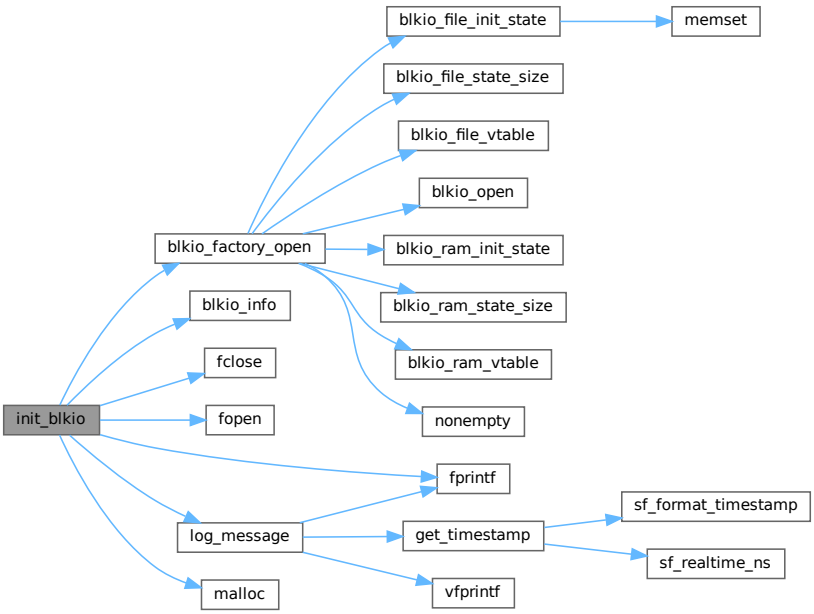
```
static int init_blkio (
            const CLIConfig * config )  [static]
```

Initialize block I/O from CLI configuration.

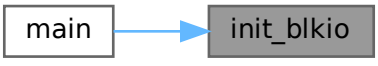
References blkio_factory_open(), BLKIO_FORTH_BLOCK_SIZE, blkio_info(), BLKIO_OK, CLIConfig::disk_img_path, fclose(), fopen(), blkio_info_t::forth_block_size, fprintf(), g_blkio_opened, g_ram_base, g_ram_bytes, g_ram_is_mmap, LOG_INFO, log_message(), LOG_WARN, malloc(), blkio_info_t::phys_size_bytes, CLIConfig::ram_disk_mb, blkio_info_t::read_only, STARFORTH_STATE_BYTES, stderr, and blkio_info_t::total_blocks.

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.288.2.5 init_vm_and_subsystem()

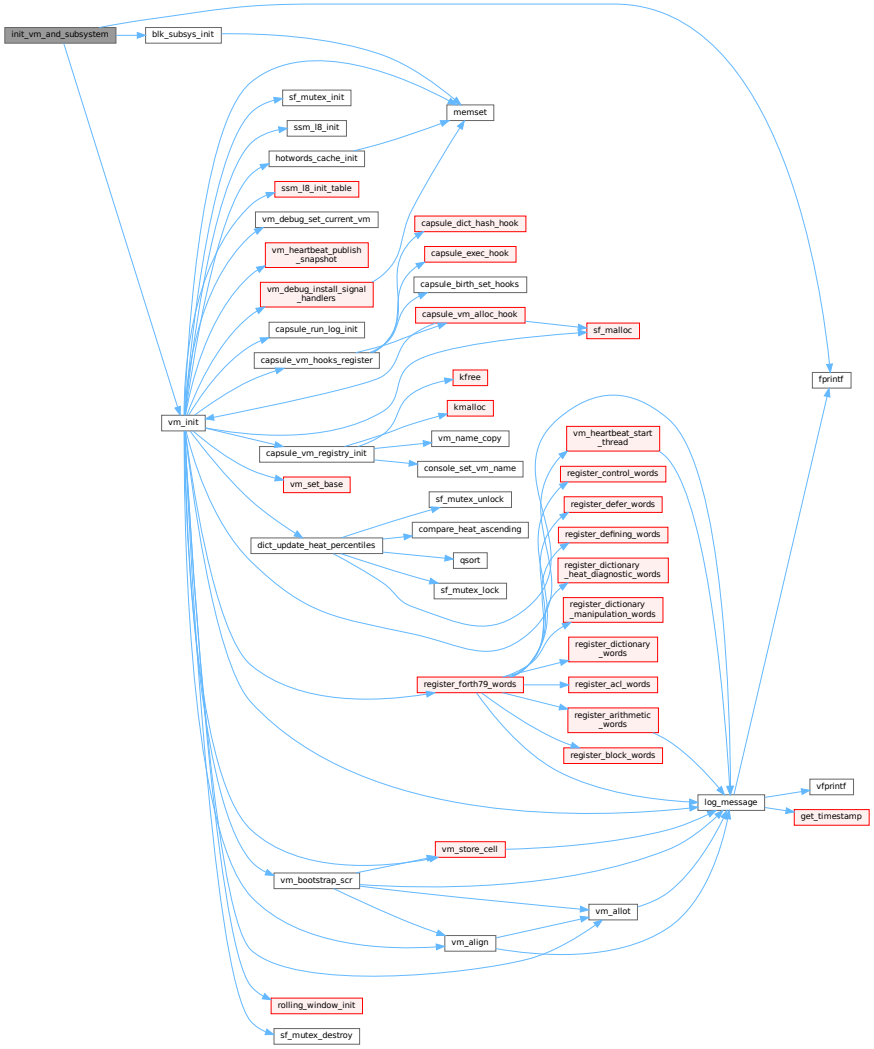
```
static int init_vm_and_subsystem (
            VM * vm )  [static]
```

Initialize VM core and block subsystem.

References BLK_FORTH_SIZE, BLK_RAM_BLOCKS, blk_subsys_init(), VM::error, fprintf(), g_blkio_opened, ram_base, ram_size, stderr, stdout, and vm_init().

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:

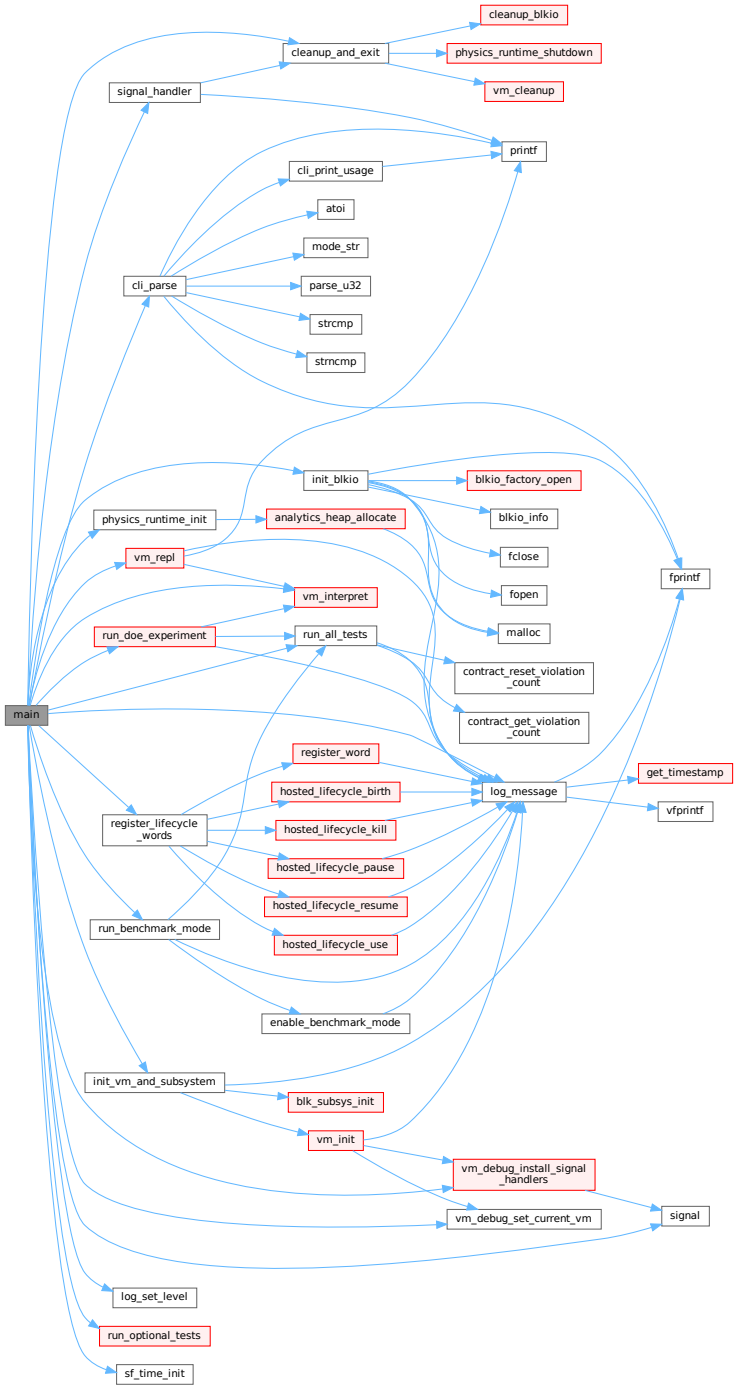
7.288.2.6 main()

```
int main (
            int argc,
            char * argv[] )
```

Main entry point for StarForth.

References CLIConfig::benchmark, CLIConfig::break_me, cleanup_and_exit(), cli_parse(), VM::dict_fence_here, VM::dict_fence_latest, CLIConfig::doe_experiment, VM::error, CLIConfig::fail_fast, fail_fast, VM::here, init_blkio(), init_vm_and_subsystem(), VM::latest, LOG_ERROR, LOG_INFO, CLIConfig::log_level, CLIConfig::log_level_explicitly_set, log_message(), LOG_NONE, log_set_level(), LOG_TEST, LOG_WARN, physics_runtime_init(), register_lifecycle_words(), run_all_tests(), run_benchmark_mode(), run_doe_experiment(), run_optional_tests(), CLIConfig::run_tests_flag_observed, CLIConfig::script_mode, sf_time_init(), SIGINT, signal(), signal_handler(), SIGTERM, vm_debug_install_signal_handlers(), vm_debug_set_current_vm(), vm_interpret(), and vm_repl().

Here is the call graph for this function:



7.288.2.7 print_usage()

```
void print_usage (
            const char * program_name )
```

Prints program usage information.

Parameters

program_name	Name of the executable

References printf().

Here is the call graph for this function:

7.288.2.8 run_benchmark_mode()

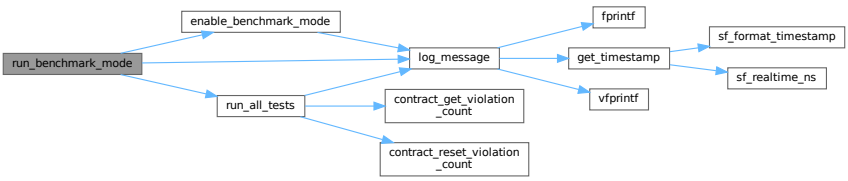
```
static void run_benchmark_mode (
            VM * vm,
            const CLIConfig * config )  [static]
```

Run benchmark mode and exit.

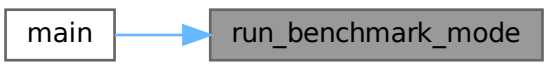
References CLIConfig::benchmark_iterations, enable_benchmark_mode(), LOG_INFO, log_message(), and run_all_tests().

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:



7.288.2.9 run_doe_experiment()

```
static void run_doe_experiment (
            VM * vm )  [static]
```

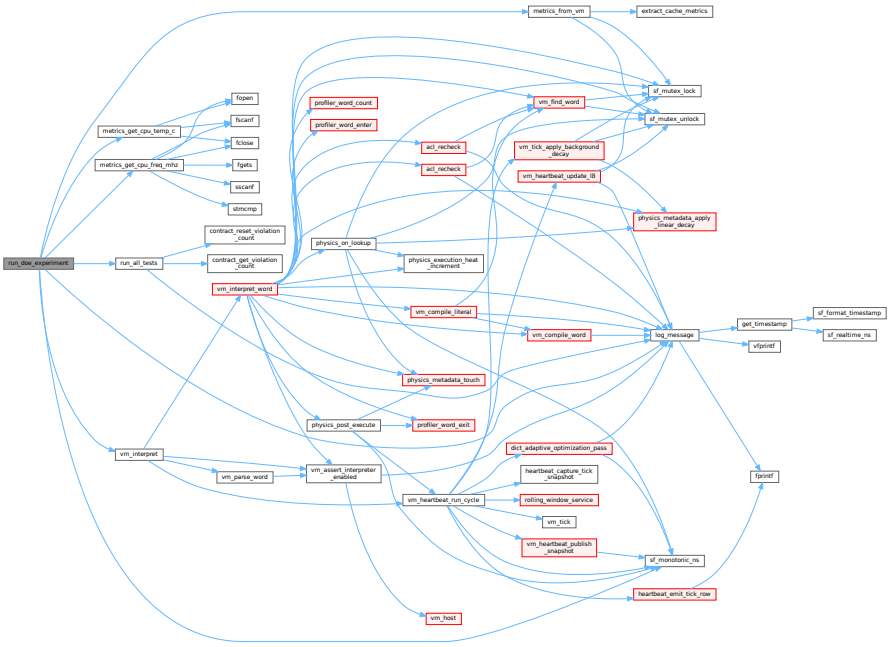
Run Design of Experiments experiment.

Executes the full test harness N times, collecting metrics after each run. Writes results to CSV file for statistical analysis.

References RollingWindowOfTruth::effective_window_size, RollingWindowOfTruth::is_warm, LOG_INFO, log_message(), metrics_from_vm(), metrics_get_cpu_freq_mhz(), metrics_get_cpu_temp_c(), VM::rolling_window, run_all_tests(), sf_monotonic_ns(), RollingWindowOfTruth::total_executions, and vm_interpret().

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:

7.288.2.10 run_optional_tests()

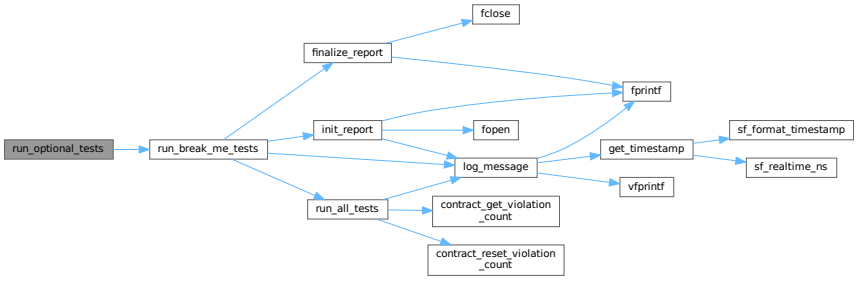
```
static void run_optional_tests (
            VM * vm,
            const CLIConfig * config )  [static]
```

Run optional test modes after system initialization.

References CLIConfig::break_me, and run_break_me_tests().

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:

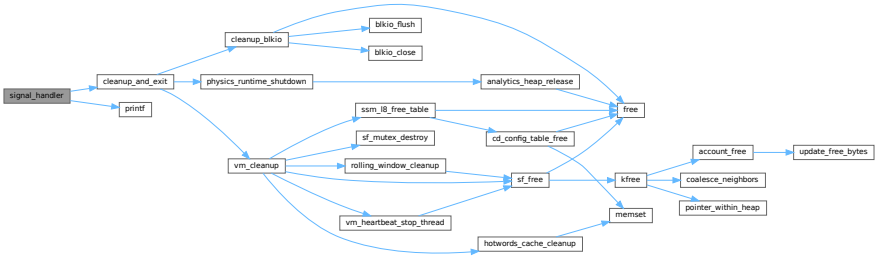
7.288.2.11 signal_handler()

```
void signal_handler (
            int sig )
```

References cleanup_and_exit(), printf(), SIGINT, and SIGTERM.

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:

7.288.3 Variable Documentation

7.288.3.1 g_blkio_opened

```
int g_blkio_opened = 0  [static]
```

Referenced by cleanup_blkio(), init_blkio(), and init_vm_and_subsystem().

7.288.3.2 g_ram_base

```
uint8_t* g_ram_base = NULL  [static]
```

Referenced by cleanup_blkio(), and init_blkio().

7.288.3.3 g_ram_bytes

```
size_t g_ram_bytes = 0  [static]
```

Referenced by cleanup_blkio(), and init_blkio().

7.288.3.4 g_ram_is_mmap

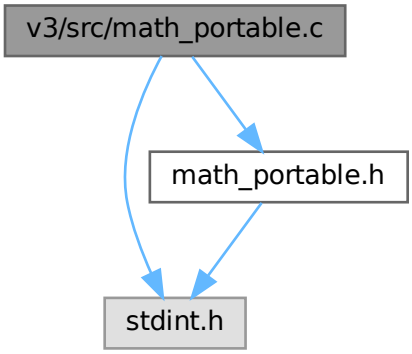
```
int g_ram_is_mmap = 0  [static]
```

Referenced by cleanup_blkio(), and init_blkio().

7.289 v3/src/math_portable.c File Reference

```
#include <stdint.h>
#include "math_portable.h"
```

Include dependency graph for math_portable.c:



Functions

- static int64_t exp_q48 (int64_t x)

  Compute exp(x) via Taylor series in Q48.16 fixed-point.
- int64_t sqrt_q48 (int64_t x)

  Compute sqrt(x) via Newton-Raphson in Q48.16 fixed-point.
- int64_t erf_q48 (int64_t x)

  Compute erf(x) via Abramowitz & Stegun 7.1.26 in Q48.16 fixed-point.

7.289.1 Function Documentation

7.289.1.1 erf_q48()

```
int64_t erf_q48 (
            int64_t x )
```

Compute erf(x) via Abramowitz & Stegun 7.1.26 in Q48.16 fixed-point.

Error function in Q48.16 fixed-point Input: x in Q48.16 format (dimensionless Z-score) Output: erf(x) in Q48.↩ 16 format (range: -Q48_SCALE to +Q48_SCALE) Uses Abramowitz & Stegun approximation (7.1.26) Maximum error: 1.5e-7 relative to floating-point erf Properties:

Implements the rational approximation from Abramowitz & Stegun, formula 7.1.26:
$\mathrm{erf}(x) \approx \mathrm{sign}(x) \times \sqrt{1 - \exp(-x^2 \times (4/\pi + a \cdot x^2) / (1 + a \cdot x^2))}$

where $a \approx 0.147$ (in Q48.16: 9633). The maximum error of the true mathematical approximation is $|\varepsilon| < 1.5 \times 10^{-}$?; the fixed-point encoding introduces additional rounding of approximately 1 ULP in Q48.16.

All arithmetic is performed in 64-bit integer Q48.16 format — no floating-point operations. The computation sequence:

1. Extract sign; work with $|x|$.
2. Compute x^2 with 8-bit prescaling to prevent overflow: `x_sq` = (x >> 8) * (x >> 8).
3. Evaluate the A&S numerator ($4/\pi + a \cdot x^2$) and denominator ($1 + a \cdot x^2$).
4. Compute `ratio` = numerator / denominator (shift to preserve Q48.16 scale).
5. Compute `exp_arg` = ?x^2 × ratio and evaluate `exp_q48(exp_arg)`.
6. Compute `base` = 1 ? exp_val, clamp to [0, 1].
7. Return `sign` × sqrt_q48(base).

Q48.16 constants used:

- `a_q48` = 9633 (0.147 × 65536)
- `four_over_pi_q48` = 83328 ($4/\pi$ × 65536 ≈ 1.2732 × 65536)

Consumed by `hotwords_speedup_estimate()` to compute P(speedup > 1.1×) and P(speedup > 2.0×) via the normal CDF identity:

```
P(Z ≤ z) = 0.5 × (1 + erf(z / √2))
```

where $\sqrt{2}$ in Q48.16 = 92681.

Parameters

x	Input value in Q48.16 format (dimensionless Z-score; 1.0 = 65536). May be negative; sign determines the sign of the result.

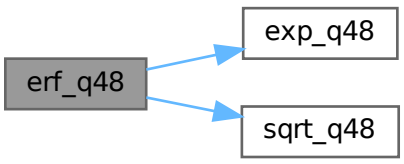
Returns

erf(x) in Q48.16 format, in the range [?65536, +65536] corresponding to (?1.0, +1.0).

References base, exp_q48(), and sqrt_q48().

Referenced by hotwords_speedup_estimate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.289.1.2 exp_q48()

```
static int64_t exp_q48 (
            int64_t x )  [static]
```

Compute exp(x) via Taylor series in Q48.16 fixed-point.

Evaluates the classic Taylor expansion:
exp(x) = 1 + x + $x^2/2!$ + $x^3/3!$ + ... (up to 40 terms)

entirely in 64-bit integer arithmetic using the Q48.16 representation (1.0 = 65536 = 2^16).

The function is intentionally scoped to the range the physics engine actually uses — the argument to `erf_q48()` is $-x^2$ times a ratio near 1, yielding values in roughly the [-20, 0] interval. Outside this range the implementation provides coarse-grained clamping:

- x == 0 → returns `Q48` (1.0 exactly)
- x > 20.0 → saturates at `Q48` << 8 (approx e^20, avoids overflow)
- x < -100.0 → underflows to 0 (result is negligible)

The term loop exits early on the first term smaller than 1 ULP (the series has converged) and guards against intermediate overflow by clamping `result` at `INT64_MAX-1`.

Note

This is a file-local (`static`) helper; callers are `erf_q48()` only.

Parameters

x	Input value in Q48.16 format (1.0 = 65536). Intended range: approximately [-100×65536, +20×65536].

Returns

exp(x) in Q48.16 format; 0 on underflow; saturated at `INT64_MAX-1` on overflow.

Referenced by erf_q48().

Here is the caller graph for this function:

7.289.1.3 sqrt_q48()

```
int64_t sqrt_q48 (
            int64_t x )
```

Compute sqrt(x) via Newton-Raphson in Q48.16 fixed-point.

Square root in Q48.16 fixed-point Input: x in Q48.16 format Output: sqrt(x) in Q48.16 format Uses Newton-↩ Raphson: x_{n+1} = (x_n + a/x_n) / 2 Converges in ∼10-15 iterations Returns 0 for negative inputs (guard against domain error)

Applies the Newton-Raphson recurrence:
`r_{n+1} = (r_n^2 + x) / (2 × r_n)`

for up to 20 iterations, with all arithmetic scaled to the Q48.16 representation (1.0 = 65536). Intermediate products use 8-bit right shifts on both operands before squaring to prevent 64-bit overflow:
`guess_squared = (guess » 8) * (guess » 8)`

This sacrifices 16 bits of precision in the squared term, which is acceptable because the division by `2*guess` restores the correct order of magnitude. Convergence is declared when successive iterates differ by at most 1 in Q48.16 units (sub-nanosecond for timing uses).

Special cases handled without iteration:

- x ≤ 0 → returns 0 (no imaginary results)
- x == 65536 (1.0) → returns 65536 exactly

Initial guess: x/2 for x > 1.0, else 1.0. Values above 1.0 converge from above; values in (0, 1.0) converge from the 1.0 initial guess.

Parameters

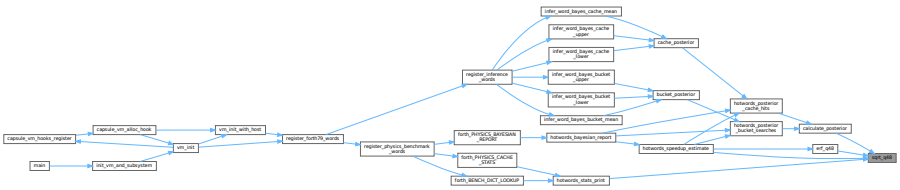
x	Non-negative value in Q48.16 format (1.0 = 65536). Negative values are treated as zero.

Returns

sqrt(x) in Q48.16 format; 0 for x ≤ 0.

Referenced by calculate_posterior(), erf_q48(), hotwords_speedup_estimate(), and hotwords_stats_print().

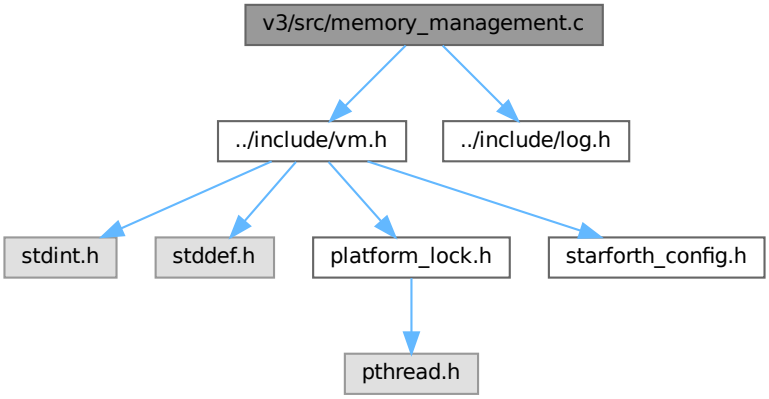
Here is the caller graph for this function:



7.290 v3/src/memory_management.c File Reference

```
#include "../include/vm.h"
#include "../include/log.h"
```

Include dependency graph for memory_management.c:



Functions

- void * vm_allot (VM *vm, size_t bytes)

  Allocates memory from the VM's dictionary space.
- void vm_align (VM *vm)

  Aligns the VM's dictionary pointer (here) to the cell boundary.
- void * vm_get_block_addr (VM *vm, int block_num)

  Gets the memory address for a specified block number.
- int vm_addr_to_block (VM *vm, void *addr)

  Converts a memory address to its corresponding block number.

7.290.1 Function Documentation

7.290.1.1 vm_addr_to_block()

```
int vm_addr_to_block (
            VM * vm,
            void * addr )
```

Converts a memory address to its corresponding block number.

Parameters

vm	Pointer to the VM instance
addr	Memory address to convert

Returns

Block number (0 to MAX_BLOCKS-1) or -1 if address is outside VM memory

Note

Used for determining which block a memory address belongs to

References BLOCK_SIZE, VM::memory, and VM_MEMORY_SIZE.

7.290.1.2 vm_align()

```
void vm_align (
            VM * vm )
```

Aligns the VM's dictionary pointer (here) to the cell boundary.

Parameters

vm	Pointer to the VM instance

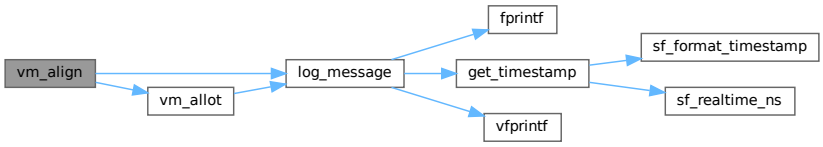
Note

Adds padding bytes if necessary to ensure proper alignment for cell_t type

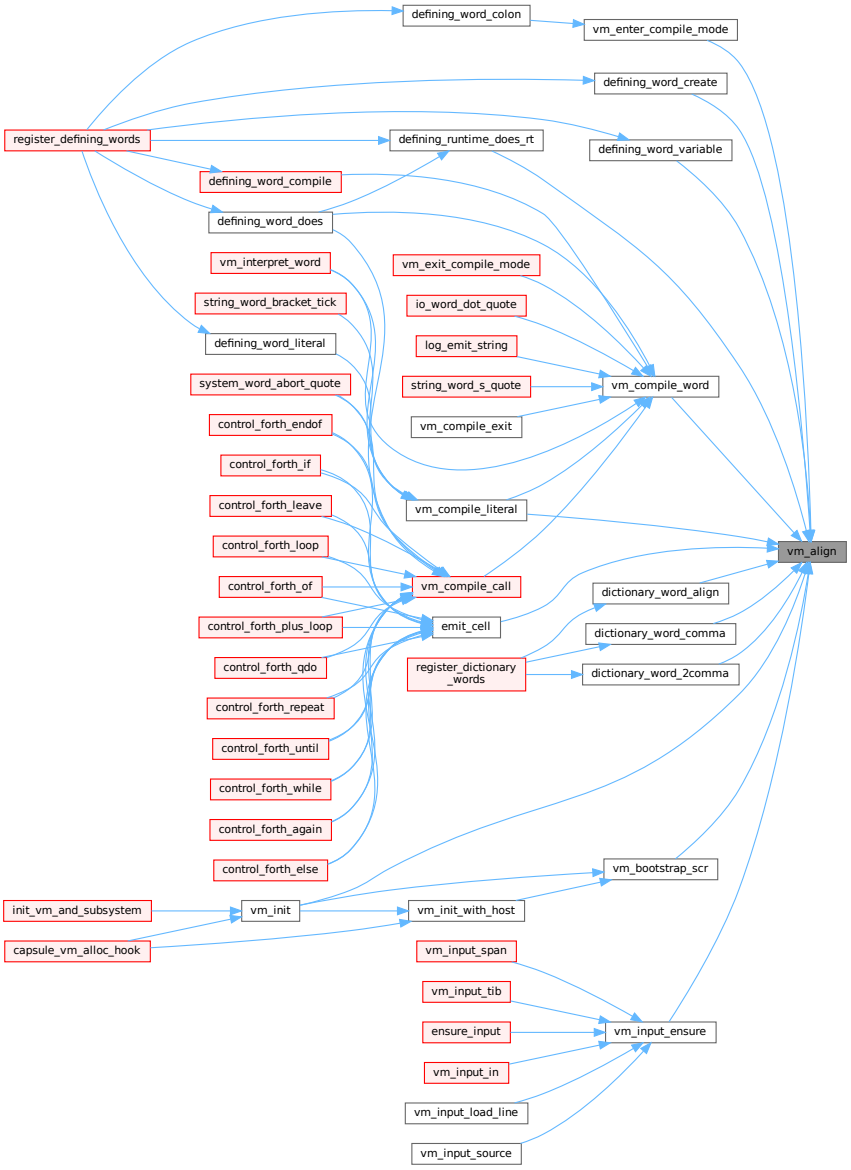
References bytes, VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), and vm_allot().

Referenced by defining_runtime_does_rt(), defining_word_create(), defining_word_variable(), dictionary_word_2comma(), dictionary_word_align(), dictionary_word_comma(), emit_cell(), vm_bootstrap_scr(), vm_compile_literal(), vm_compile_word(), vm_enter_compile_mode(), vm_init(), and vm_input_ensure().

Here is the call graph for this function:



Here is the caller graph for this function:



7.290.1.3 vm_allot()

```
void * vm_allot (
            VM * vm,
            size_t bytes )
```

Allocates memory from the VM's dictionary space.

Parameters

vm	Pointer to the VM instance
bytes	Number of bytes to allocate

Returns

Pointer to the allocated memory or NULL if allocation fails

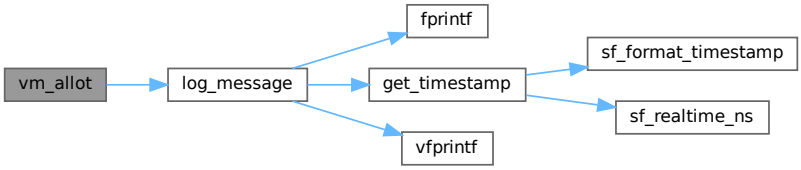
Note

The allocation is done from the VM's dictionary space which is limited to DICTIONARY_MEMORY_SIZE

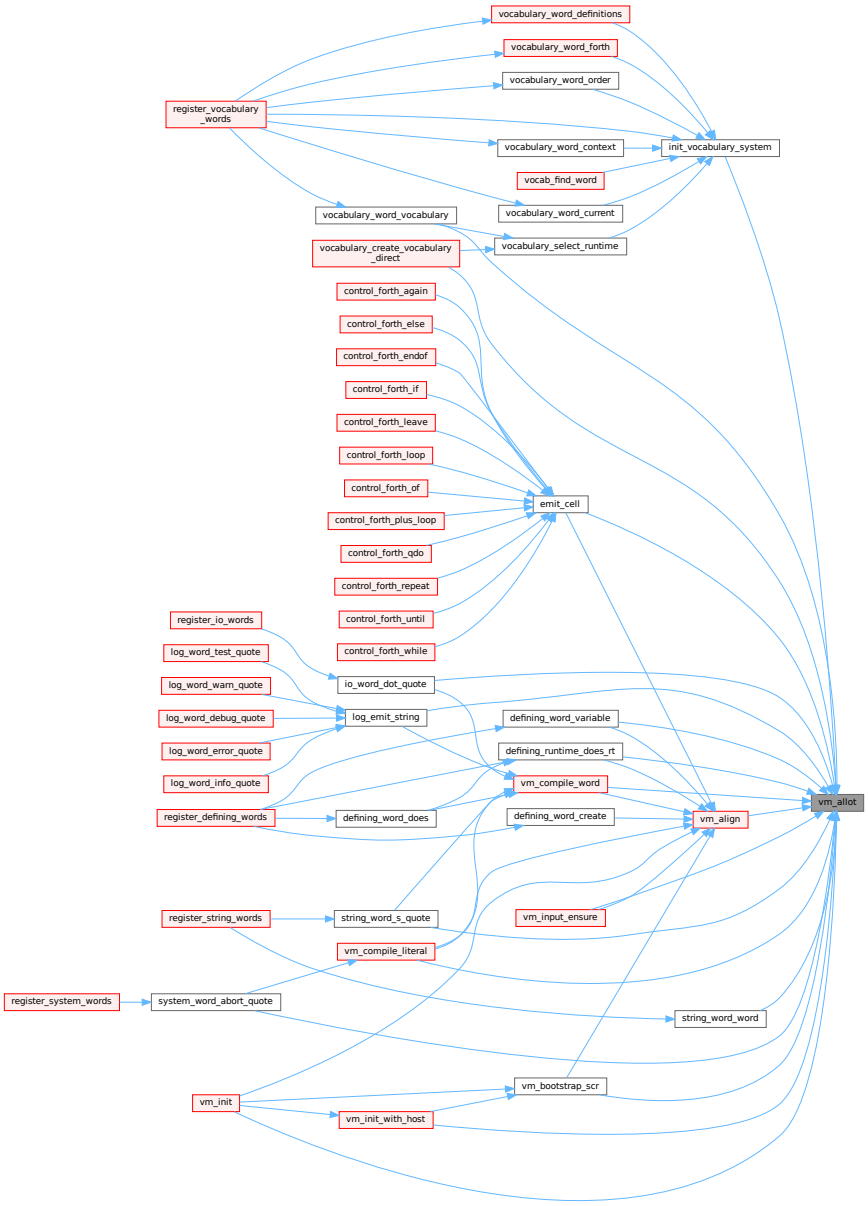
References BLOCK_SIZE, bytes, DICTIONARY_MEMORY_SIZE, VM::error, VM::here, LOG_DEBUG, LOG_ERROR, log_message(), and VM::memory.

Referenced by defining_runtime_does_rt(), defining_word_variable(), emit_cell(), init_vocabulary_system(), io_word_dot_quote(), log_emit_string(), string_word_s_quote(), string_word_word(), system_word_abort_quote(), vm_align(), vm_bootstrap_scr(), vm_compile_literal(), vm_compile_word(), vm_init(), vm_init_with_host(), vm_input_ensure(), vocabulary_create_vocabulary_direct(), and vocabulary_word_vocabulary().

Here is the call graph for this function:



Here is the caller graph for this function:



7.290.1.4 vm_get_block_addr()

```
void * vm_get_block_addr (
            VM * vm,
            int block_num )
```

Gets the memory address for a specified block number.

Parameters

vm	Pointer to the VM instance
block_num	Block number to get the address for

Returns

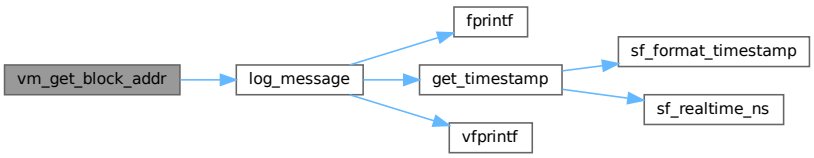
Pointer to the start of the block or NULL if block number is invalid

Note

Blocks are fixed-size memory regions of BLOCK_SIZE bytes

References BLOCK_SIZE, LOG_ERROR, log_message(), MAX_BLOCKS, and VM::memory.

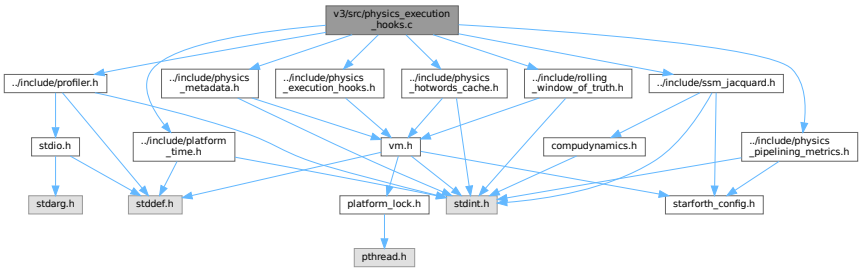
Here is the call graph for this function:



7.291 v3/src/physics_execution_hooks.c File Reference

```
#include "../include/physics_execution_hooks.h"
#include "../include/platform_time.h"
#include "../include/profiler.h"
#include "../include/physics_metadata.h"
#include "../include/physics_hotwords_cache.h"
#include "../include/physics_pipelining_metrics.h"
#include "../include/rolling_window_of_truth.h"
#include "../include/ssm_jacquard.h"
```

Include dependency graph for physics_execution_hooks.c:



Functions

- void physics_pre_execute (VM *vm, DictEntry *word, DictEntry *prev)

  Pre-execution physics hook — called before every word dispatch.
- void physics_post_execute (VM *vm, DictEntry *word)

  Post-execution physics hook — called after every word dispatch.
- void physics_on_lookup (VM *vm, DictEntry *entry, DictEntry *canon)

  Physics hook for the outer interpreter word-lookup path.

7.291.1 Function Documentation

7.291.1.1 physics_on_lookup()

```
void physics_on_lookup (
            VM * vm,
            DictEntry * entry,
            DictEntry * canon )
```

Physics hook for the outer interpreter word-lookup path.

Called when the outer interpreter successfully finds a word by name, before executing it. Applies linear decay and increments heat on both the found entry and the canonical entry (if different), and updates `last_active_ns` / `last_decay_ns` on both. Acquires `vm->dict_lock` for the entire operation to ensure thread safety.

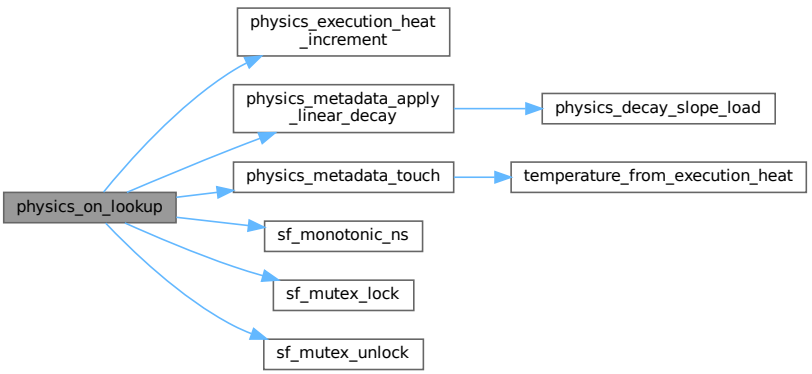
Parameters

vm	Pointer to the VM structure
entry	DictEntry found by name search
canon	Canonical DictEntry (may equal `entry` or be the smudge target)

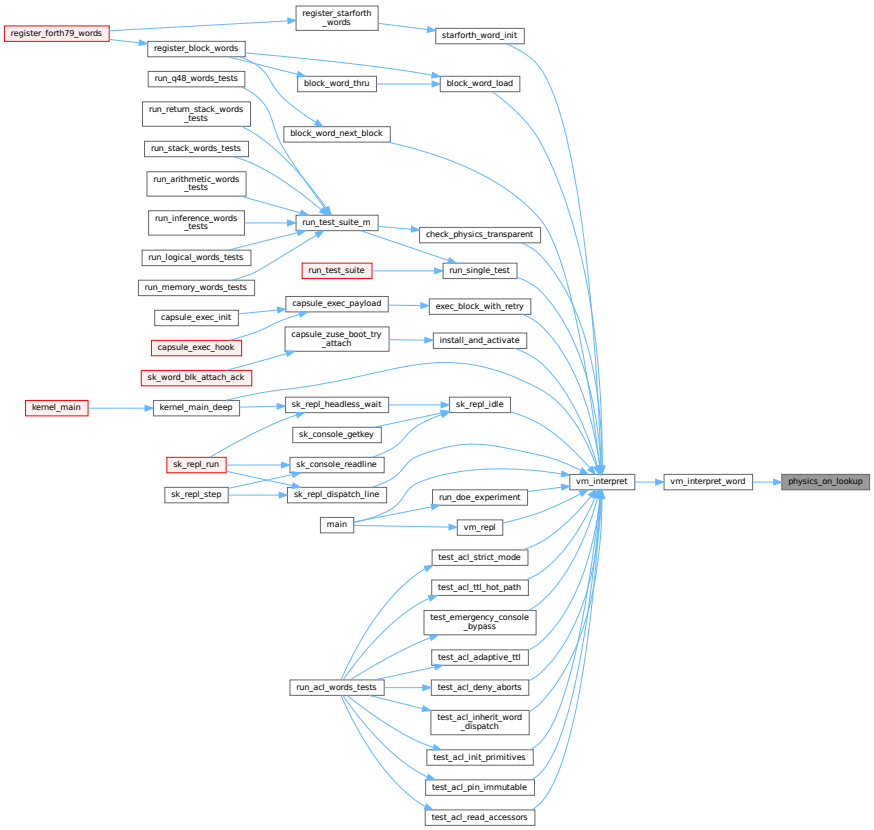
References VM::dict_lock, entry, DictEntry::execution_heat, VM::heartbeat, DictPhysics::last_active_ns, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, DictEntry::physics, physics_execution_heat_increment(), physics_metadata_apply_linear_decay(), physics_metadata_touch(), sf_monotonic_ns(), sf_mutex_lock(), sf_mutex_unlock(), and HeartbeatState::tick_count.

Referenced by vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.291.1.2 physics_post_execute()

```
void physics_post_execute (
            VM * vm,
            DictEntry * word )
```

Post-execution physics hook — called after every word dispatch.

Consolidates all physics work that must happen after a word completes:

- Updates physics metadata (`temperature_q8`, `last_active_ns`) via `physics_metadata_touch()`
- Notifies the profiler (`profiler_word_exit()`)
- Increments `vm->heartbeat.words_executed`
- When running without a background heartbeat thread, checks whether enough words have been executed to trigger a heartbeat cycle (`vm_heartbeat_run_cycle()`)

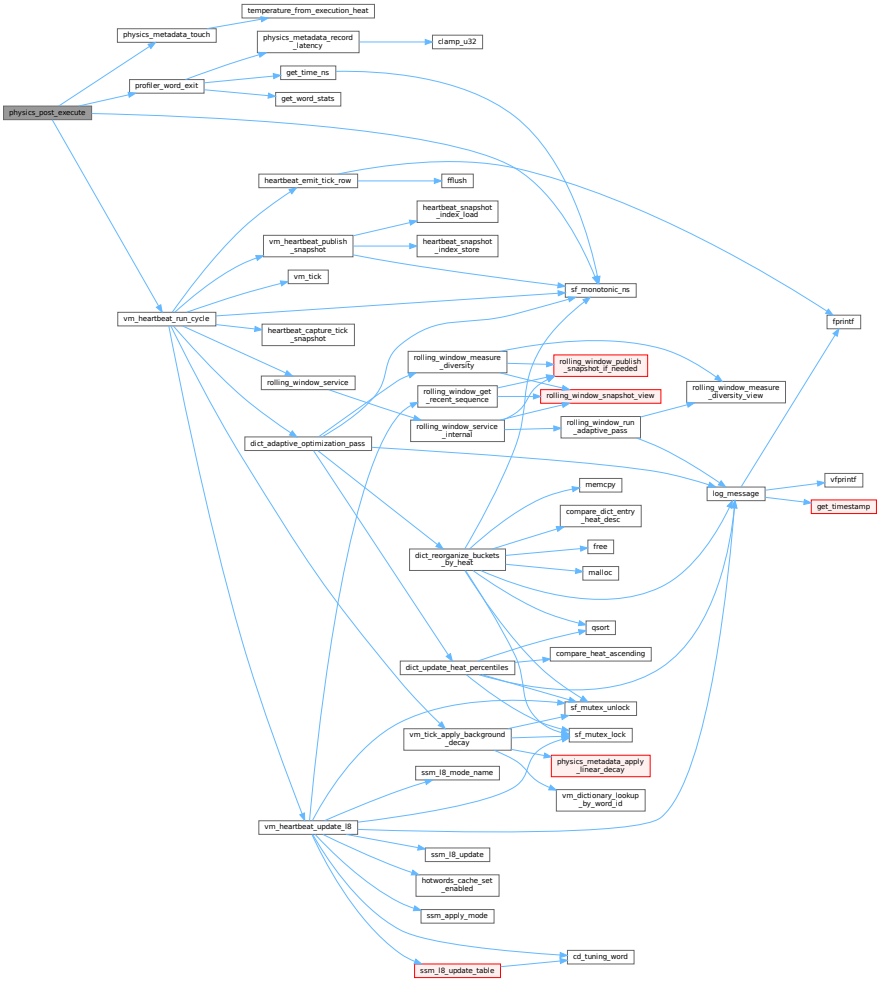
Parameters

vm	Pointer to the VM structure
word	DictEntry that just finished executing

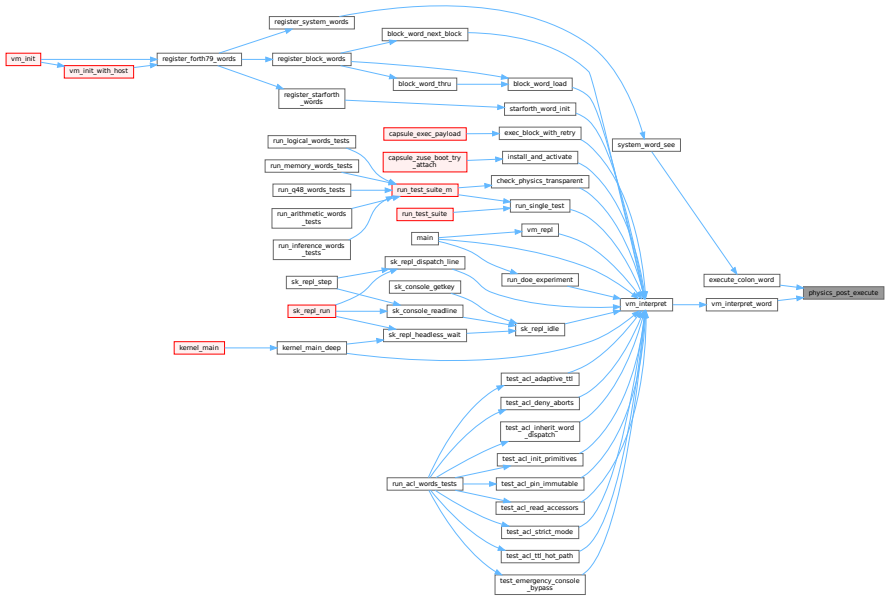
References HeartbeatState::check_counter, DictEntry::execution_heat, VM::heartbeat, HEARTBEAT_CHECK_FREQUENCY, physics_metadata_touch(), profiler_word_exit(), sf_monotonic_ns(), vm_heartbeat_run_cycle(), HeartbeatState::words_executed, and HeartbeatState::worker.

Referenced by execute_colon_word(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.291.1.3 physics_pre_execute()

```
void physics_pre_execute (
            VM * vm,
            DictEntry * word,
            DictEntry * prev )
```

Pre-execution physics hook — called before every word dispatch.

Consolidates all physics work that must happen before a word runs:

- Loop #3: applies linear decay based on elapsed time since last execution
- Loop #1: increments `execution_heat` for the word
- Loop #2: records the word-id into the rolling window of truth
- Loop #4: detects a pipelining prefetch hit (if `prev`'s speculation matched `word`), records the transition from `prev` to `word`, updates the probability cache, and issues a speculative hotwords cache promotion for the most likely next word

Parameters

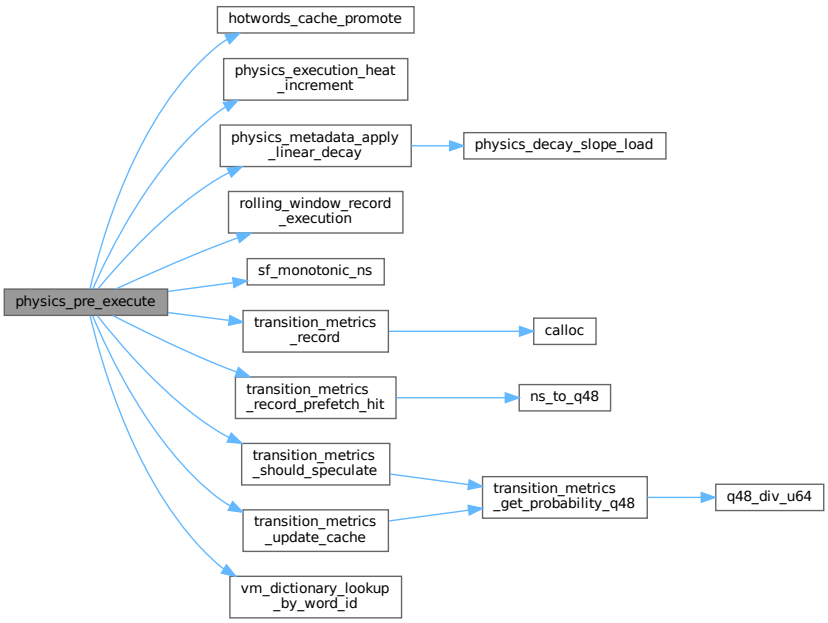
vm	Pointer to the VM structure
word	DictEntry being executed
prev	DictEntry executed immediately before `word` (may be NULL)

References DICTIONARY_SIZE, ENABLE_HOTWORDS_CACHE, ENABLE_PIPELINING, HotwordsCache_s::enabled, DictEntry::execution_heat, VM::heartbeat, VM::hotwords_cache, hotwords_cache_promote(), HOTWORDS_EXECUTION_HEAT_TH

ssm_config_t::L4_pipelining, DictPhysics::last_active_ns, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, WordTransitionMetrics::most_likely_next_word_id, DictEntry::physics, physics_execution_heat_increment(), physics_metadata_apply_linear_decay(), VM::pipeline_metrics, WordTransitionMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::rolling_window, rolling_window_record_executio sf_monotonic_ns(), VM::ssm_config, HeartbeatState::tick_count, DictEntry::transition_metrics, transition_metrics_record(), transition_metrics_record_prefetch_hit(), transition_metrics_should_speculate(), transition_metrics_update_cache(), vm_dictionary_lookup_by_word_id(), word_id, and DictEntry::word_id.

Referenced by execute_colon_word().

Here is the call graph for this function:



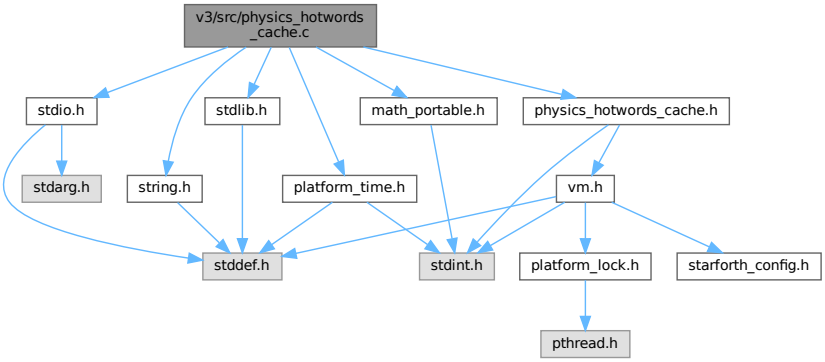
Here is the caller graph for this function:

7.292 v3/src/physics_hotwords_cache.c File Reference

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include "physics_hotwords_cache.h"
#include "platform_time.h"
```

```
#include "math_portable.h"
```

Include dependency graph for physics_hotwords_cache.c:



Functions

- static double q48_to_ns_double (int64_t q48)

  Convert a Q48.16 fixed-point value to a `double` nanosecond count.
- void hotwords_cache_init (HotwordsCache *cache)

  Initialise a `HotwordsCache` to its empty, enabled state.
- void hotwords_cache_cleanup (HotwordsCache *cache)

  Zero all fields in a `HotwordsCache`, releasing no heap memory.
- DictEntry * hotwords_cache_lookup (VM *vm, HotwordsCache *cache, DictEntry **bucket, size_t bucket↩_count, const char *name, size_t len)

  Look up a FORTH word using the hot-words cache, falling back to the bucket.
- static void hotwords_cache_remove_at (HotwordsCache *cache, uint32_t i)
- void hotwords_cache_evict_entry (HotwordsCache *cache, const DictEntry *word)

  Evict every cache slot holding this exact entry.
- void hotwords_cache_evict_name (HotwordsCache *cache, const char *name, size_t len)

  Evict every cache slot whose entry matches this name.
- void hotwords_cache_promote (HotwordsCache *cache, DictEntry *word)

  Promote a `DictEntry` into the hot-words cache, evicting the oldest entry if full.
- void hotwords_bucket_reorder (DictEntry **bucket, size_t count)

  Sort a hash bucket in-place by descending execution heat (bubble sort).
- void hotwords_stats_reset (HotwordsStats *stats)

  Zero all fields in a `HotwordsStats` structure.
- void hotwords_stats_print (const HotwordsStats *stats)

  Print a formatted hot-words cache statistics report to `stdout`.
- void hotwords_cache_set_enabled (HotwordsCache *cache, int enabled)

  Enable or disable the hot-words cache at runtime.
- static BayesianLatencyPosterior calculate_posterior (int64_t total_ns_q48, int64_t variance_sum_q48, int64_t min_ns, int64_t max_ns, uint64_t sample_count)

  Compute a Bayesian latency posterior for one measurement distribution.
- BayesianLatencyPosterior hotwords_posterior_cache_hits (const HotwordsStats *stats)

  Return the Bayesian latency posterior for cache-hit observations.
- BayesianLatencyPosterior hotwords_posterior_bucket_searches (const HotwordsStats *stats)

  Return the Bayesian latency posterior for bucket-search observations.

- struct SpeedupEstimate hotwords_speedup_estimate (const HotwordsStats *stats)

  Compute a speedup estimate with credible intervals using the delta method.
- void hotwords_bayesian_report (const HotwordsStats *stats_with_cache, const HotwordsStats *stats_without_cache)

  Print a full Bayesian cache performance report comparing two experimental conditions.

Variables

- HotwordsCache g_hotwords_cache = {0}

7.292.1 Function Documentation

7.292.1.1 calculate_posterior()

```
static BayesianLatencyPosterior calculate_posterior (
            int64_t total_ns_q48,
            int64_t variance_sum_q48,
            int64_t min_ns,
            int64_t max_ns,
            uint64_t sample_count )  [static]
```

Compute a Bayesian latency posterior for one measurement distribution.

Given the accumulated Q48.16 statistics for a set of `sample_count` timing observations (either cache-hit or bucket-search latencies), computes the following posterior quantities entirely in Q48.16 integer arithmetic:

- **Mean** (`mean_ns_q48`): `total_ns_q48` / sample_count.
- **Variance** (`stddev_ns_q48`): $E[X^2]$? $E[X]^2$ where $E[X^2]$ is the per-sample average of `variance_sum_q48` and $E[X]^2$ = $mean^2$ scaled to Q48.16 via $>>$ 16. Variance is clamped to 0 to guard numerical rounding.
- **Standard deviation** (`stddev_ns_q48`): `sqrt_q48(variance)`.
- **Median** (`median_ns_q48`): (min_ns + max_ns) / 2 — a quick midpoint estimate rather than a true median, consistent across all call sites.
- **Standard error** (`se_q48`): `stddev` / $\sqrt{\cdot}$N, computed by converting `sample_count` to Q48.16 (`sample_count` $<<$ 16) and calling `sqrt_q48()`, then dividing `stddev` $<<$ 16 by the result.
- **95% credible interval**: `mean` $\pm$ Z?? $\times$ SE where `Z??` = 128431 (1.96 $\times$ 65536).
- **99% credible interval**: `mean` $\pm$ Z?? $\times$ SE where `Z??` = 168888 (2.576 $\times$ 65536). Lower credible bounds are clamped at 0 (latency is non-negative).

Returns a zeroed `BayesianLatencyPosterior` if `sample_count` is 0.

Parameters

total_ns_q48	Sum of all latency observations in Q48.16.
variance_sum_q48	Sum of squared latency observations in Q48.16 (i.e., Σ(x?^{2} $<<$ 16)).
min_ns	Minimum observed latency in integer nanoseconds.
max_ns	Maximum observed latency in integer nanoseconds.
sample_count	Number of observations; 0 $\rightarrow$ returns zeroed struct.

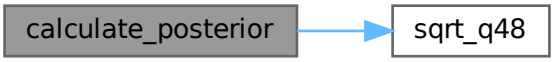
Returns

`BayesianLatencyPosterior` with all fields in Q48.16.

References BayesianLatencyPosterior::credible_lower_95, BayesianLatencyPosterior::credible_lower_99, BayesianLatencyPosterior:
BayesianLatencyPosterior::credible_upper_99, BayesianLatencyPosterior::mean_ns_q48, BayesianLatencyPosterior::median_ns_q4
BayesianLatencyPosterior::sample_count, sqrt_q48(), and BayesianLatencyPosterior::stddev_ns_q48.

Referenced by hotwords_posterior_bucket_searches(), and hotwords_posterior_cache_hits().

Here is the call graph for this function:



Here is the caller graph for this function:

7.292.1.2 hotwords_bayesian_report()

```
void hotwords_bayesian_report (
            const HotwordsStats * stats_with_cache,
            const HotwordsStats * stats_without_cache )
```

Print a full Bayesian cache performance report comparing two experimental conditions.

Generate detailed Bayesian inference report Compares cache vs bucket performance with confidence measures.

Emits a structured Unicode report to `stdout` comparing the latency distributions of two measurement sets — one collected with the hot-words cache enabled, the other collected without (baseline). The report is divided into five sections:

1. **WITH CACHE ENABLED** — posterior mean, stddev, and 95%/99% credible intervals for cache-hits and bucket-searches separately, via `hotwords_posterior_cache_hits()` and `hotwords_posterior_bucket_sea`
2. **WITHOUT CACHE (Baseline)** — posterior mean, stddev, and 95% credible interval for all lookups (treated as bucket searches). If no bucket data is available in `stats_without_cache`, the bucket-search mean from the with-cache run is used as an approximation.
3. **SPEEDUP ESTIMATE (Bucket vs Cache)** — `hotwords_speedup_estimate()` point estimate, 95% credible interval, P($>1.1\times$), and P($>2.0\times$).

4. **CACHE EFFECTIVENESS** — total lookups, cache-hit rate, bucket-hit rate, and miss rate as percentages of total.
5. **OVERALL PERFORMANCE** — weighted-average latency with cache vs. baseline all-bucket latency, overall speedup, and absolute time saved per lookup. The weighted average is: (N_cache×avg_cache + N_↩ bucket×avg_bucket) / (N_cache + N_bucket).

All latency values are displayed in nanoseconds (floating-point via `q48_to_ns_double()`) for readability; underlying accumulators are Q48.16 integer throughout.

No-op if either `stats_with_cache` or `stats_without_cache` is NULL.

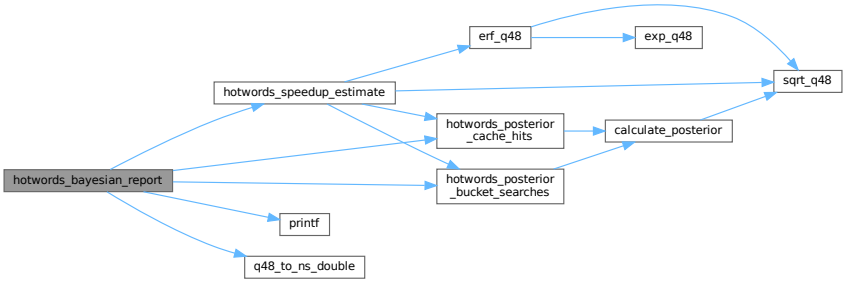
Parameters

stats_with_cache	Statistics from a run with cache enabled.
stats_without_cache	Statistics from a baseline run without cache.

References HotwordsStats::bucket_hits, HotwordsStats::cache_hits, BayesianLatencyPosterior::credible_lower_95, SpeedupEstimate::credible_lower_95_q48, BayesianLatencyPosterior::credible_lower_99, BayesianLatencyPosterior::credible_upper SpeedupEstimate::credible_upper_95_q48, BayesianLatencyPosterior::credible_upper_99, hotwords_posterior_bucket_searches(), hotwords_posterior_cache_hits(), hotwords_speedup_estimate(), BayesianLatencyPosterior::mean_ns_q48, HotwordsStats::misses, printf(), SpeedupEstimate::probability_gt_10pct_q48, SpeedupEstimate::probability_gt_double_q48, q48_to_ns_double(), BayesianLatencyPosterior::sample_count, SpeedupEstimate::speedup_factor_q48, and BayesianLatencyPosterior::stddev_ns_q48.

Referenced by forth_PHYSICS_BAYESIAN_REPORT().

Here is the call graph for this function:



Here is the caller graph for this function:

7.292.1.3 hotwords_bucket_reorder()

```
void hotwords_bucket_reorder (
            DictEntry ** bucket,
            size_t count )
```

Sort a hash bucket in-place by descending execution heat (bubble sort).

Reorder a bucket by execution heat (move hot words forward) Called when execution heat delta exceeds threshold.

Performs a classic in-place bubble sort over the `bucket` array so that words with higher `execution_heat` appear at lower array indices. The hot-words cache and heat-stratified lookup both benefit from having the hottest words at the front of each bucket: the first-character hash buckets are linear arrays, and placing hot words up front reduces the scan depth on Stage 1 cache misses that fall through to Stage 2 bucket search.

Bubble sort is chosen deliberately: buckets are small (typically single digits to low dozens of words per first-character class), already nearly sorted after the previous reorganization pass, and the cost of a $O(n^2)$ inner loop on $n \leq 30$ is negligible compared to the outer `qsort` on all 256 buckets in `dict_reorganize_buckets_by_heat()`. For the individual per-bucket call path (e.g. after a single promotion), bubble sort avoids the `malloc` overhead that `qsort's` temporary storage would require.

No-op for `count` < 2.

Parameters

bucket	Array of `DictEntry*` pointers to sort in-place. NULL-check is the caller's responsibility.
count	Number of valid entries in `bucket`.

References count, and execution_heat.

7.292.1.4 hotwords_cache_cleanup()

```
void hotwords_cache_cleanup (
            HotwordsCache * cache )
```

Zero all fields in a `HotwordsCache`, releasing no heap memory.

Cleanup hot-words cache.

Calls `memset(cache, 0, sizeof(*cache))` to scrub every field including the inline `cache[]` pointer array and all statistics. The cache holds no separately allocated memory (the `DictEntry` pointers inside `cache[]` are owned by the dictionary, not the cache), so no `free()` calls are needed.

Intended for use at VM teardown or when the caller wants to reset the cache to a known-zero state between benchmark runs. After this call the cache is in an unusable state (`enabled` = 0); call `hotwords_cache_init()` to reinitialise it.

Parameters

cache	Cache to zero; no-op if NULL.

References memset().

Referenced by vm_cleanup().

Here is the call graph for this function:

Here is the caller graph for this function:

7.292.1.5 hotwords_cache_evict_entry()

```
void hotwords_cache_evict_entry (
            HotwordsCache * cache,
            const DictEntry * word )
```

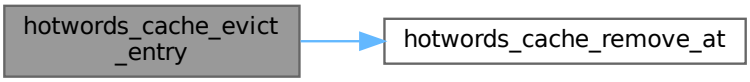
Evict every cache slot holding this exact entry.

Must be called before an entry is freed (FORGET) — a stale pointer in the ring is a use-after-free.

References HotwordsCache_s::cache, HotwordsCache_s::cache_count, and hotwords_cache_remove_at().

Referenced by vm_dictionary_untrack_entry().

Here is the call graph for this function:



Here is the caller graph for this function:

7.292.1.6 hotwords_cache_evict_name()

```
void hotwords_cache_evict_name (
            HotwordsCache * cache,
            const char * name,
            size_t len )
```

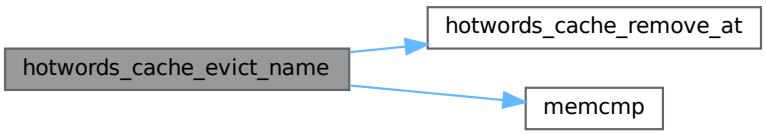
Evict every cache slot whose entry matches this name.

Called whenever name resolution may change: word creation (shadowing), smudge/unsmudge, hide. The next lookup re-resolves through the bucket.

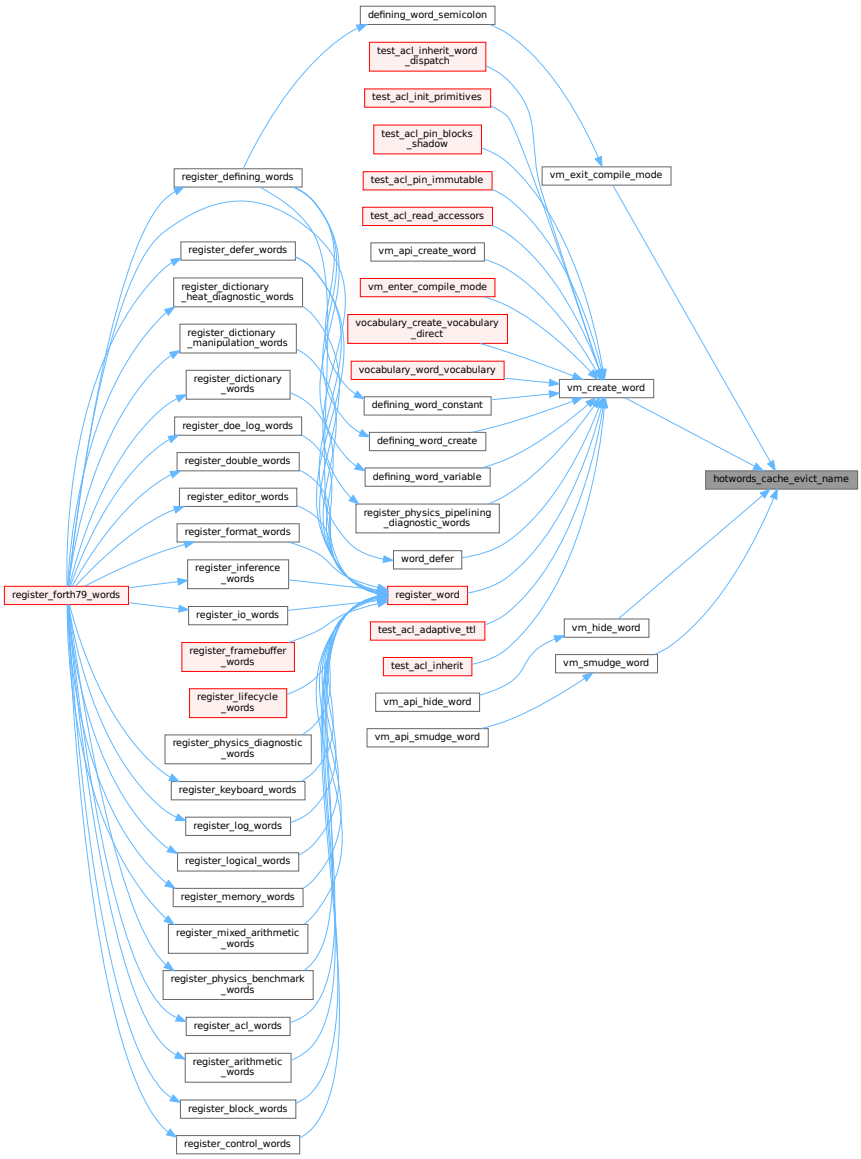
References HotwordsCache_s::cache, HotwordsCache_s::cache_count, hotwords_cache_remove_at(), memcmp(), name, DictEntry::name, and DictEntry::name_len.

Referenced by vm_create_word(), vm_exit_compile_mode(), vm_hide_word(), and vm_smudge_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.292.1.7 hotwords_cache_init()

```
void hotwords_cache_init (
            HotwordsCache * cache )
```

Initialise a `HotwordsCache` to its empty, enabled state.

Initialize hot-words cache Should be called during VM initialization.

Zeroes all fields via `memset` then explicitly sets:

- `cache->enabled` = `ENABLE_HOTWORDS_CACHE` (build-time compile flag; 0 disables the cache globally without a code change).

- `cache->cache_count` = 0, `cache->lru_index` = 0 — empty round-robin eviction ring.
- All counter fields in `cache->stats` to 0.
- `stats.min_cache_hit_ns` = `INT64_MAX`, `stats.max_cache_hit_ns` = `INT64_MIN` (sentinel values; updated to real observations on the first cache hit).
- `stats.min_bucket_search_ns` = `INT64_MAX`, `stats.max_bucket_search_ns` = `INT64_MIN` (same sentinel convention for bucket searches).
- All Q48.16 variance accumulators to 0.

Safe to call multiple times (idempotent via `memset`). Must be called before the first `hotwords_cache_lookup()` invocation; failure to do so leaves the sentinel min/max fields uninitialised, producing nonsense in the Bayesian posterior report.

Parameters

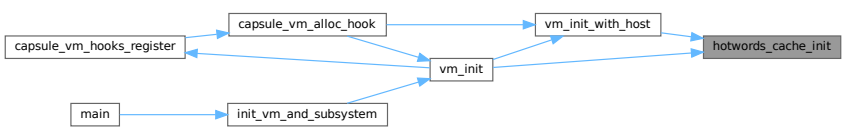
cache	Cache to initialise; no-op if NULL.

References HotwordsStats::bucket_hits, HotwordsStats::bucket_reorders, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsCache_s::cache_count, HotwordsStats::cache_hit_samples, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, HotwordsStats::cache_hits, ENABLE_HOTWORDS_CACHE, HotwordsCache_s::enabled, HotwordsStats::evictions, HotwordsCache_s::lru_index, HotwordsStats::max_bucket_search_ns, HotwordsStats::max_cache_hit_ns, memset(), HotwordsStats::min_bucket_search_ns, HotwordsStats::min_cache_hit_ns, HotwordsStats::misses, HotwordsStats::promotions, HotwordsCache_s::stats, and HotwordsStats::total_lookups.

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:

Here is the caller graph for this function:



7.292.1.8 hotwords_cache_lookup()

```
DictEntry * hotwords_cache_lookup (
            VM * vm,
            HotwordsCache * cache,
            DictEntry ** bucket,
            size_t bucket_count,
            const char * name,
            size_t len )
```

Look up a FORTH word using the hot-words cache, falling back to the bucket.

Lookup word in cache first, then fall back to bucket search Returns the found word, or NULL if not found.

The primary dictionary fast-path. Records a start timestamp via `sf_monotonic_ns()` and then executes a two-stage search:

Stage 1 — Cache check (O(HOTWORDS_CACHE_SIZE)): Scans the `cache->cache[]` ring for an entry whose `name_len` and name match `name/len`, using the cheap-first filter (`name_len` → last-character → `memcmp`). On a hit the elapsed nanoseconds are converted to Q48.16 and accumulated into `stats.cache_hit_total_ns_q48`; the squared value is accumulated into `stats.cache_hit_variance_sum_q48` for Bayesian posterior computation by `calculate_posterior()`. Min/max latency sentinels are also updated.

Stage 2 — Bucket fallback (O(bucket_count)): Scans `bucket[]` in reverse-insertion order (newest definition wins). On a hit the elapsed time is recorded in the `bucket_search_*` accumulators with the same Q48.16 and variance treatment as Stage 1. If the found word's `execution_heat` exceeds `HOTWORDS_EXECUTION_HEAT_THRESHOLD` it is promoted into the cache via `hotwords_cache_promote()`.

Disabled path: If `cache` is NULL or `cache->enabled` is 0, the function skips Stage 1 and performs a bare reverse-linear scan of `bucket[]` returning the result immediately (no statistics are recorded).

A miss increments `stats.misses` and returns NULL.

Parameters

cache	Hot-words cache; may be NULL or disabled (falls back to bucket scan without statistics).
bucket	First-character hash bucket — array of `DictEntry*` pointers, searched in reverse order.
bucket_count	Number of valid pointers in `bucket`.
name	Word name to find (not NUL-terminated).
len	Length of `name` in bytes.

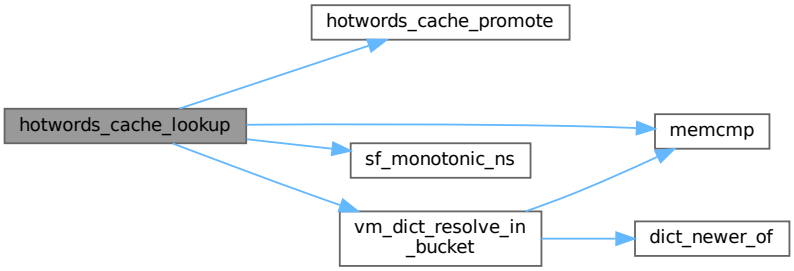
Returns

Matching `DictEntry*`, or NULL if not found.

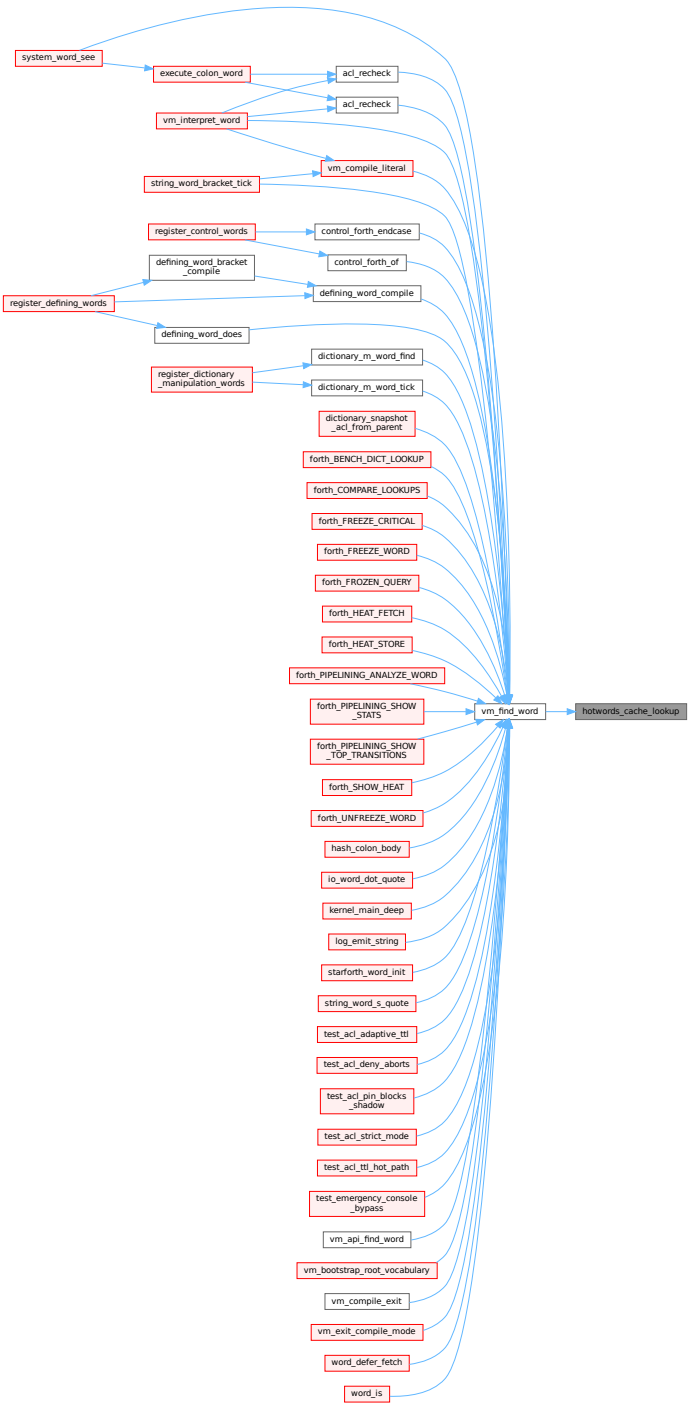
References HotwordsStats::bucket_hits, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsCache_s::cache, HotwordsCache_s::cache_count, HotwordsStats::cache_hit_samples, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, HotwordsStats::cache_hits, HotwordsCache_s::enabled, DictEntry::execution_heat, DictEntry::flags, hotwords_cache_promote(), HOTWORDS_EXECUTION_HEAT_THRESHOLD, HotwordsStats::max_bucket_search_ns, HotwordsStats::max_cache_hit_ns, memcmp(), HotwordsStats::min_bucket_search_ns, HotwordsStats::min_cache_hit_ns, HotwordsStats::misses, name, DictEntry::name, DictEntry::name_len, sf_monotonic_ns(), HotwordsCache_s::stats, HotwordsStats::total_lookups, vm_dict_resolve_in_bucket(), WORD_HIDDEN, and WORD_SMUDGED.

Referenced by vm_find_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.292.1.9 hotwords_cache_promote()

```
void hotwords_cache_promote (
            HotwordsCache * cache,
            DictEntry * word )
```

Promote a DictEntry into the hot-words cache, evicting the oldest entry if full.

Promote a word to the hot-words cache Called when a word's execution heat exceeds threshold.

Two paths depending on whether the cache has a free slot:

- **Slot available** (cache->cache_count < HOTWORDS_CACHE_SIZE): Appends word at cache->cache[cache↩ _count++] after verifying it is not already present (linear scan). Increments stats.promotions.
- **Cache full** (cache->cache_count >= HOTWORDS_CACHE_SIZE): Overwrites cache->cache[cache->lru_index] with word (round-robin least-recently-used eviction) and advances lru_index modulo HOTWORDS_CACHE_SIZE. Increments stats.evictions. The evicted entry is not freed — it remains alive in the dictionary; only its slot in the cache ring is surrendered.

Called from hotwords_cache_lookup() whenever a bucket search finds a word hot enough to warrant caching (heat > HOTWORDS_EXECUTION_HEAT_THRESHOLD).

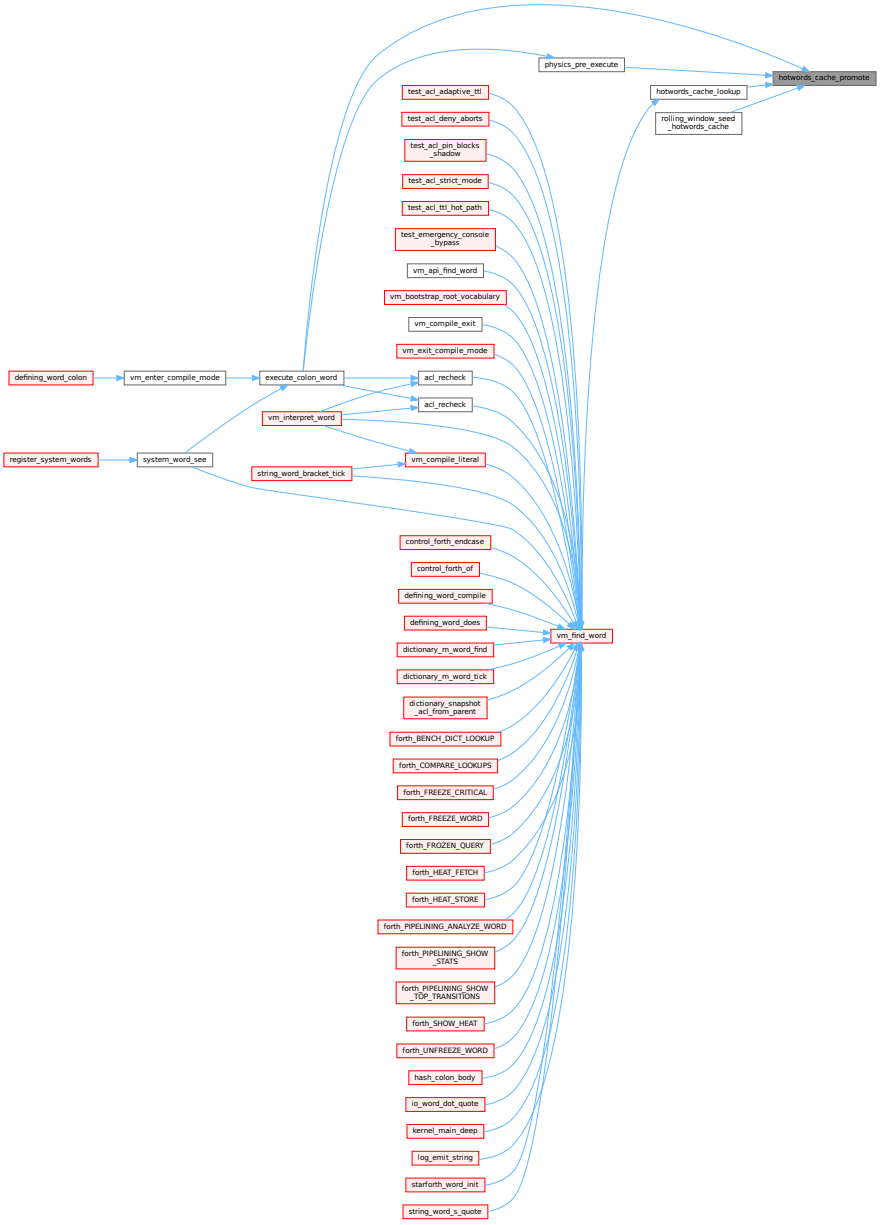
Parameters

cache	The cache to promote into; no-op if NULL.
word	The DictEntry to promote; no-op if NULL. Ownership is not transferred — the cache holds a borrowed pointer into the dictionary, which owns the entry.

References HotwordsCache_s::cache, HotwordsCache_s::cache_count, HotwordsStats::evictions, HOTWORDS_CACHE_SIZE, HotwordsCache_s::lru_index, HotwordsStats::promotions, and HotwordsCache_s::stats.

Referenced by execute_colon_word(), hotwords_cache_lookup(), physics_pre_execute(), and rolling_window_seed_hotwords_cache(

Here is the caller graph for this function:



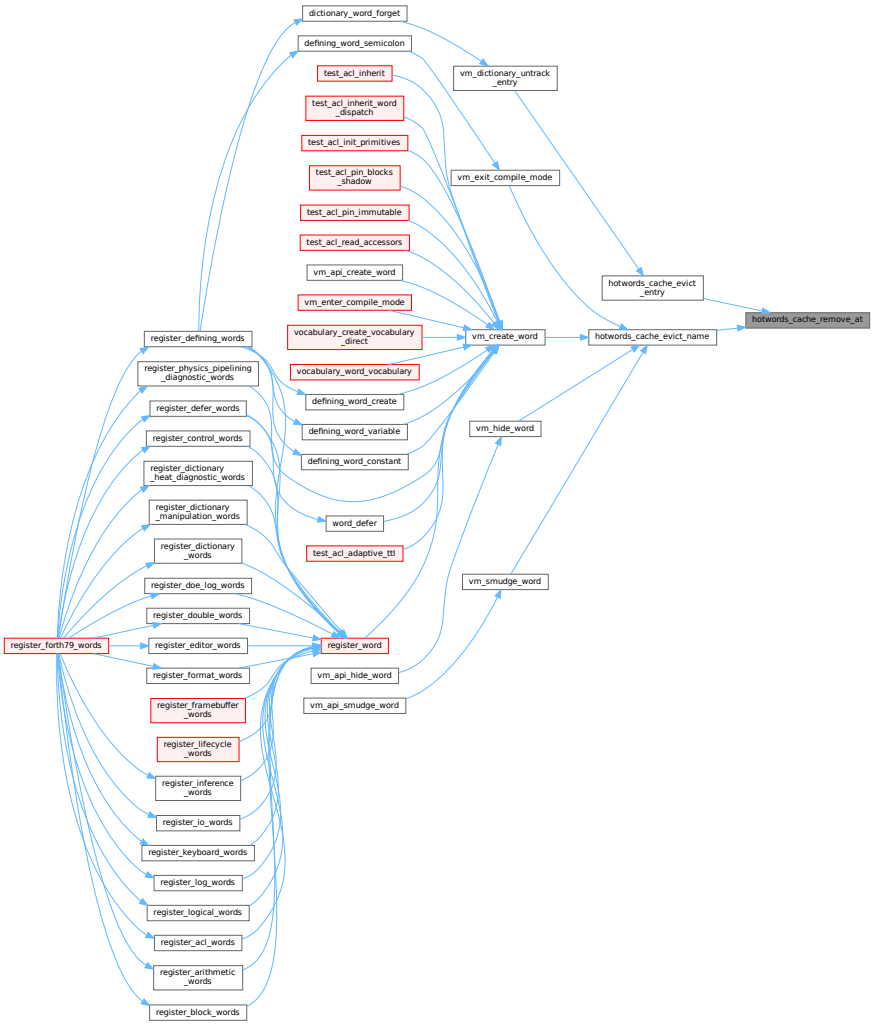
7.292.1.10 hotwords_cache_remove_at()

```
static void hotwords_cache_remove_at (
            HotwordsCache * cache,
            uint32_t i )  [static]
```

References HotwordsCache_s::cache, HotwordsCache_s::cache_count, and HotwordsCache_s::lru_index.

Referenced by hotwords_cache_evict_entry(), and hotwords_cache_evict_name().

Here is the caller graph for this function:



7.292.1.11 hotwords_cache_set_enabled()

```
void hotwords_cache_set_enabled (
            HotwordsCache * cache,
            int enabled )
```

Enable or disable the hot-words cache at runtime.

Enable/disable cache at runtime (for A/B testing)

Sets `cache->enabled` to `enabled` (non-zero = active, 0 = bypassed). When disabled, `hotwords_cache_lookup()` skips Stage 1 entirely and falls through directly to a bare bucket scan, recording no statistics. This allows benchmark harnesses to compare cache-on vs. cache-off behaviour without rebuilding the binary.

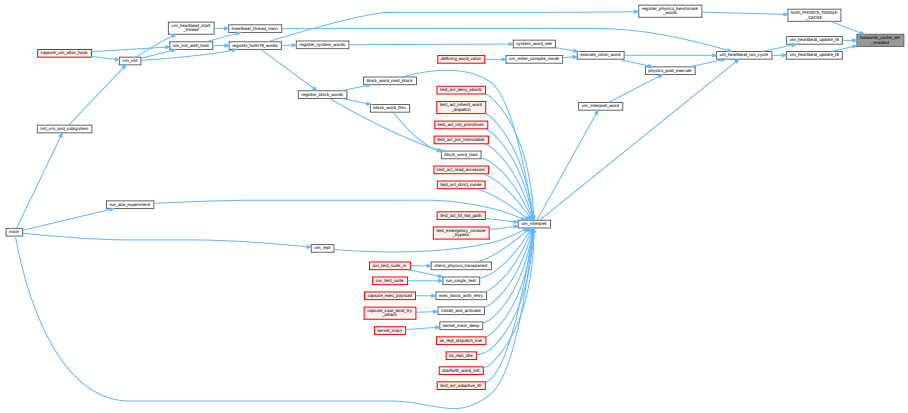
Parameters

cache	Cache to configure; no-op if NULL.
enabled	Non-zero to enable the cache; 0 to disable.

References HotwordsCache_s::enabled, and enabled.

Referenced by forth_PHYSICS_TOGGLE_CACHE(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the caller graph for this function:



7.292.1.12 hotwords_posterior_bucket_searches()

```
BayesianLatencyPosterior hotwords_posterior_bucket_searches (
            const HotwordsStats * stats )
```

Return the Bayesian latency posterior for bucket-search observations.

Calculate posterior distribution for bucket searches Uses accumulated samples to compute credible intervals.

Forwards the bucket-search accumulators from `stats` to `calculate_posterior()`: `bucket_search_total_ns_q48`, `bucket_search_variance_sum_q48`, `min_bucket_search_ns`, `max_bucket_search_ns`, and `bucket_search_samples`. Returns a zeroed `BayesianLatencyPosterior` if `stats` is NULL or no bucket-search samples have been recorded.

The returned posterior's mean and credible-interval fields feed `hotwords_speedup_estimate()` (as the slower distribution) and the baseline section of `hotwords_bayesian_report()`.

Parameters

stats	`HotwordsStats` containing bucket-search timing accumulators.

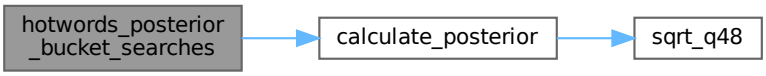
Returns

Posterior in Q48.16; all fields zero if no samples exist.

References HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_v
calculate_posterior(), HotwordsStats::max_bucket_search_ns, and HotwordsStats::min_bucket_search_ns.

Referenced by bucket_posterior(), hotwords_bayesian_report(), and hotwords_speedup_estimate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.292.1.13 hotwords_posterior_cache_hits()

```
BayesianLatencyPosterior hotwords_posterior_cache_hits (
            const HotwordsStats * stats )
```

Return the Bayesian latency posterior for cache-hit observations.

Calculate posterior distribution for cache hits Uses accumulated samples to compute credible intervals.

Forwards the cache-hit accumulators from `stats` to `calculate_posterior()`: `cache_hit_total_ns_q48`, `cache_hit_variance_sum_q48`, `min_cache_hit_ns`, `max_cache_hit_ns`, and `cache_hit_samples`. Returns a zeroed `BayesianLatencyPosterior` if `stats` is NULL or no cache-hit samples have been recorded yet.

The returned posterior's `mean_ns_q48`, `stddev_ns_q48`, and 95%/99% credible-interval fields are consumed by `hotwords_speedup_estimate()` and `hotwords_bayesian_report()` to compare cache-hit latency against bucket-search latency.

Parameters

stats	`HotwordsStats` containing cache-hit timing accumulators.

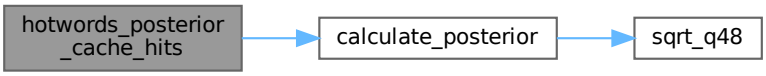
Returns

Posterior in Q48.16; all fields zero if no samples exist.

References HotwordsStats::cache_hit_samples, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, calculate_posterior(), HotwordsStats::max_cache_hit_ns, and HotwordsStats::min_cache_hit_ns.

Referenced by cache_posterior(), hotwords_bayesian_report(), and hotwords_speedup_estimate().

Here is the call graph for this function:



Here is the caller graph for this function:

7.292.1.14 hotwords_speedup_estimate()

```
struct SpeedupEstimate hotwords_speedup_estimate (
            const HotwordsStats * stats )
```

Compute a speedup estimate with credible intervals using the delta method.

Calculate speedup estimate with uncertainty.

Derives a dimensionless speedup ratio S = bucket_mean / cache_mean in Q48.16 fixed-point and propagates uncertainty via the delta method for ratios:
SE(S) ≈ S × sqrt((SE_bucket / bucket_mean)^2 + (SE_cache / cache_mean)^2)

All arithmetic is Q48.16 integer throughout; the only deviation is the intermediate `sqrt()` call which also runs in Q48.16 via `sqrt_q48()`.

Computed fields in the returned `SpeedupEstimate` (all Q48.16):

- `speedup_factor_q48` — point estimate of S.
- `credible_lower_95_q48` / `credible_upper_95_q48` — 95% credible interval: S ± 1.96 × SE(S) (Z?? = 128431 in Q48.16). Lower bound clamped at 0.
- `probability_gt_10pct_q48` — P(speedup > 1.1×), computed as `0.5` × (1 + erf(z / √2)) where z = (1.1 ? S) / SE(S) is negated to give the right-tail probability and √2 = 92681 in Q48.16.
- `probability_gt_double_q48` — P(speedup > 2.0×), same formula with target = 2.0 × 65536 = 131072.

Returns a default `SpeedupEstimate` with `speedup_factor_q48` = 65536 (1.0×) if either distribution has zero samples or if `stats` is NULL.

Parameters

stats	`HotwordsStats` with both cache-hit and bucket-search samples.

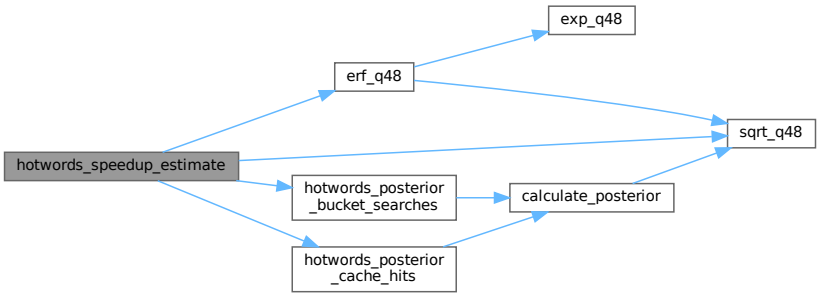
Returns

`SpeedupEstimate` with all fields in Q48.16 fixed-point.

References SpeedupEstimate::credible_lower_95_q48, SpeedupEstimate::credible_upper_95_q48, erf_q48(), hotwords_posterior_bucket_searches(), hotwords_posterior_cache_hits(), BayesianLatencyPosterior::mean_ns_q48, SpeedupEstimate::probability_gt_10pct_q48, SpeedupEstimate::probability_gt_double_q48, SpeedupEstimate::speedup_factor_q48, sqrt_q48(), and BayesianLatencyPosterior::stddev_ns_q48.

Referenced by hotwords_bayesian_report().

Here is the call graph for this function:



Here is the caller graph for this function:

7.292.1.15 hotwords_stats_print()

```
void hotwords_stats_print (
            const HotwordsStats * stats )
```

Print a formatted hot-words cache statistics report to `stdout`.

Print statistics to stdout.

Emits a Unicode box-drawing table covering three sections:

LOOKUPS — total, cache hits, bucket hits, misses with percentages.

LATENCY STATISTICS — for each of cache-hits and bucket-searches (when their sample counts are non-zero):

- Min / avg / max in nanoseconds, derived from the Q48.16 accumulators by right-shifting 16 bits: `avg_ns` = `total_ns_q48` / samples >> 16.
- Standard deviation computed from the Welford-style variance accumulator: `var` = $E[X^2]$? $E[X]^2$, then `stddev` = sqrt_q48(var), converted to nanoseconds via `q48_to_ns_double()` for display only.
- Speedup ratio (bucket avg / cache avg) when both sample sets are present.

CACHE MANAGEMENT — promotions, evictions, and bucket reorder counts.

If `stats` is NULL or the total lookup count is zero, prints a brief "No lookups performed." notice instead of the full table. All floating-point usage in this function is display-only (via `q48_to_ns_double()`); the underlying accumulators remain in Q48.16 integer format.

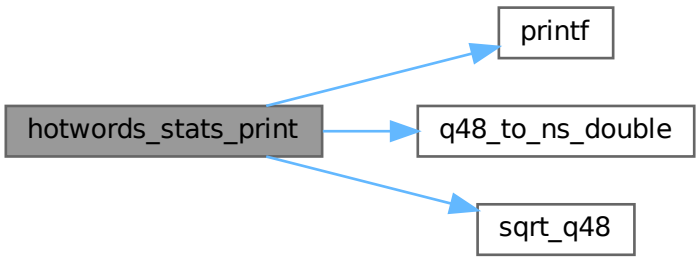
Parameters

stats	Statistics to report; no-op if NULL.

References HotwordsStats::bucket_hits, HotwordsStats::bucket_reorders, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsStats::cache_hit_samples, HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, HotwordsStats::cache_hits, HotwordsStats::evictions, HotwordsStats::max_bucket_search_ns, HotwordsStats::max_cache_hit_ns, HotwordsStats::min_bucket_s, HotwordsStats::min_cache_hit_ns, HotwordsStats::misses, printf(), HotwordsStats::promotions, q48_to_ns_double(), and sqrt_q48().

Referenced by forth_BENCH_DICT_LOOKUP(), and forth_PHYSICS_CACHE_STATS().

Here is the call graph for this function:



Here is the caller graph for this function:

7.292.1.16 hotwords_stats_reset()

```
void hotwords_stats_reset (
            HotwordsStats * stats )
```

Zero all fields in a `HotwordsStats` structure.

Reset statistics (for before/after comparison)

Resets every counter (`total_lookups`, `cache_hits`, `bucket_hits`, `misses`, `evictions`, `promotions`, `bucket_reorders`) to zero, resets all Q48.16 accumulator fields (`cache_hit_total_ns_q48`, `bucket_search_total_ns_q48`, `cache_hit_variance_sum_q48`, `bucket_search_variance_sum_q48`) to zero, resets sample counts to zero, and restores the min/max latency sentinels:

- `min_*_ns` = `INT64_MAX`
- `max_*_ns` = `INT64_MIN`

Intended for DoE benchmark runs that need a clean statistical baseline between treatment cells. The parent `HotwordsCache` also holds the `cache`[] pointer array and LRU state; those are not touched — only the `HotwordsStats` sub-struct is cleared.

Parameters

stats	Statistics structure to reset; no-op if NULL.

References HotwordsStats::bucket_hits, HotwordsStats::bucket_reorders, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsStats::cache_hit_samples HotwordsStats::cache_hit_total_ns_q48, HotwordsStats::cache_hit_variance_sum_q48, HotwordsStats::cache_hits, HotwordsStats::evictions, HotwordsStats::max_bucket_search_ns, HotwordsStats::max_cache_hit_ns, HotwordsStats::min_bucket_s HotwordsStats::min_cache_hit_ns, HotwordsStats::misses, HotwordsStats::promotions, and HotwordsStats::total_lookups.

Referenced by forth_BENCH_DICT_LOOKUP(), and forth_PHYSICS_RESET_STATS().

Here is the caller graph for this function:

7.292.1.17 q48_to_ns_double()

```
static double q48_to_ns_double (
            int64_t q48 )  [inline], [static]
```

Convert a Q48.16 fixed-point value to a `double` nanosecond count.

Divides `q48` by 65536.0 to recover the real-valued nanosecond count. This is the only floating-point operation in the module and is intentionally confined to display paths — `hotwords_stats_print()` and `hotwords_bayesian_report()` — so that all internal accumulation and statistical computation remains in Q48.16 integer arithmetic.

Parameters

q48	Value in Q48.16 format (1.0 ns = 65536).

Returns

The same quantity as a `double` in nanoseconds.

Referenced by hotwords_bayesian_report(), and hotwords_stats_print().

Here is the caller graph for this function:

7.292.2 Variable Documentation

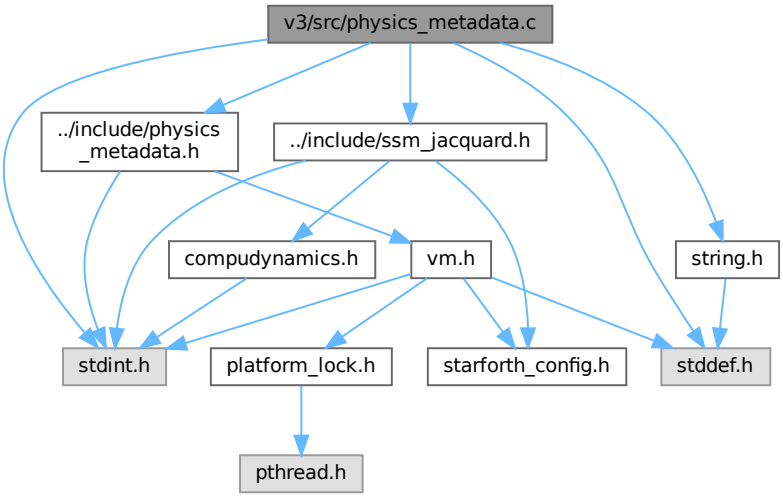
7.292.2.1 g_hotwords_cache

```
HotwordsCache g_hotwords_cache = {0}
```

7.293 v3/src/physics_metadata.c File Reference

```
#include "../include/physics_metadata.h"
#include "../include/ssm_jacquard.h"
#include <stddef.h>
#include <stdint.h>
#include <string.h>
```

Include dependency graph for physics_metadata.c:



Data Structures

- struct physics_seed_definition

Typedefs

- typedef struct physics_seed_definition physics_seed_definition_t

Functions

- static uint32_t clamp_u32 (uint64_t value)

  Clamp a uint64_t value to the uint32_t range.
- static uint16_t temperature_from_execution_heat (cell_t execution_heat, uint16_t prior_q8)

  Derive a smoothed Q8 temperature from raw execution heat.
- static uint8_t derive_state_flags (const DictEntry *entry)

  Derive the physics state flags bitmask from a DictEntry's word flags.
- void physics_metadata_init (DictEntry *entry, uint32_t header_bytes)

  Initialise physics metadata for a newly registered DictEntry.
- void physics_metadata_set_mass (DictEntry *entry, uint32_t total_bytes)

  Update the mass (byte footprint) of a DictEntry's physics metadata.
- void physics_metadata_touch (DictEntry *entry, cell_t execution_heat, uint64_t now_ns)

  Update physics metadata after a word execution completes.
- void physics_metadata_refresh_state (DictEntry *entry)

  Re-derive and update `state_flags` for a DictEntry.
- void physics_metadata_record_latency (DictEntry *entry, uint64_t sample_ns)

  Record an execution latency sample into the per-word EMA.
- void physics_metadata_apply_seed (DictEntry *entry)

  Apply DoE-derived prior physics values to a named DictEntry.
- void physics_metadata_apply_linear_decay (DictEntry *entry, uint64_t elapsed_ticks, VM *vm)

  Apply Loop #3 linear heat decay to a DictEntry.

Variables

- static const physics_seed_definition_t physics_seed_table [ ]

7.293.1 Typedef Documentation

7.293.1.1 physics_seed_definition_t

```
typedef struct physics_seed_definition physics_seed_definition_t
```

7.293.2 Function Documentation

7.293.2.1 clamp_u32()

```
static uint32_t clamp_u32 (
            uint64_t value )  [static]
```

Clamp a uint64_t value to the uint32_t range.

Parameters

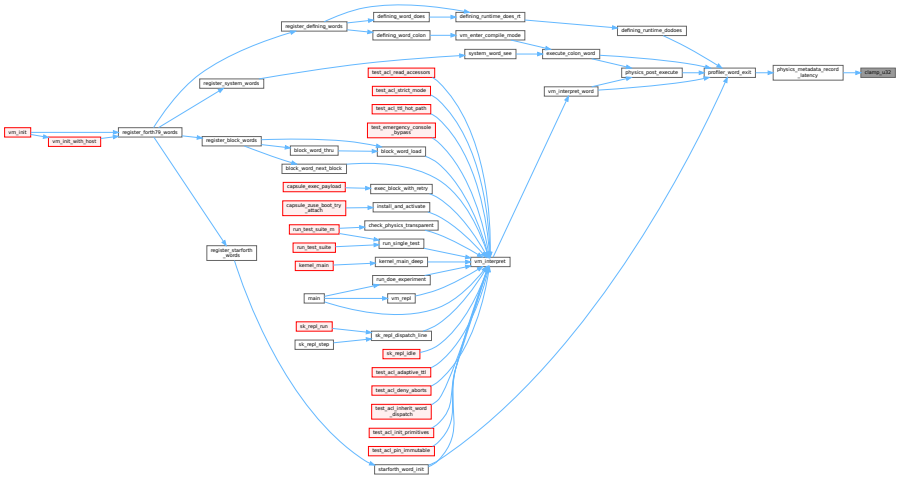
value	Input value to clamp

Returns

UINT32_MAX if value > UINT32_MAX, else (uint32_t)value

Referenced by physics_metadata_record_latency().

Here is the caller graph for this function:



7.293.2.2 derive_state_flags()

```
static uint8_t derive_state_flags (
            const DictEntry * entry )  [static]
```

Derive the physics state flags bitmask from a DictEntry's word flags.

Maps WORD_IMMEDIATE → PHYSICS_STATE_IMMEDIATE, WORD_PINNED → PHYSICS_STATE_PINNED, WORD_HIDDEN → PHYSICS_STATE_HIDDEN, and WORD_COMPILED → PHYSICS_STATE_COMPILED.

Parameters

entry	DictEntry to inspect (NULL returns 0)

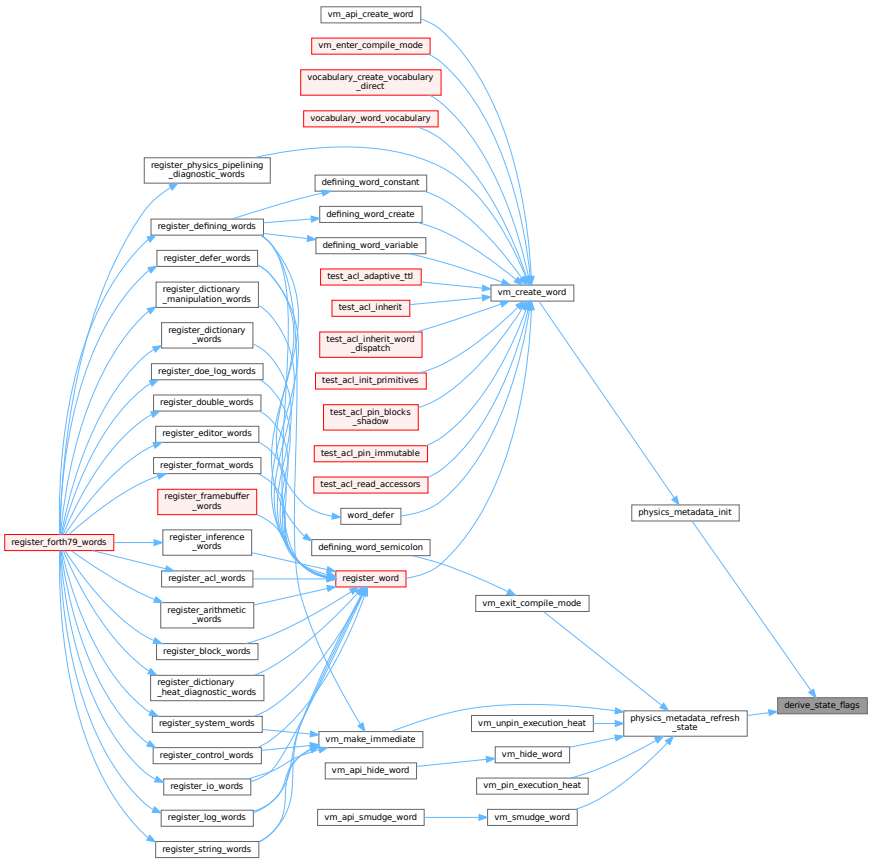
Returns

Bitmask of PHYSICS_STATE_* flags

References entry, flags, PHYSICS_STATE_COMPILED, PHYSICS_STATE_HIDDEN, PHYSICS_STATE_IMMEDIATE, PHYSICS_STATE_PINNED, WORD_COMPILED, WORD_HIDDEN, WORD_IMMEDIATE, and WORD_PINNED.

Referenced by physics_metadata_init(), and physics_metadata_refresh_state().

Here is the caller graph for this function:



7.293.2.3 physics_metadata_apply_linear_decay()

```
void physics_metadata_apply_linear_decay (
            DictEntry * entry,
            uint64_t elapsed_ticks,
            VM * vm )
```

Apply Loop #3 linear heat decay to a DictEntry.

Implements the thermodynamic dissipation model: H(t) = max(0, H? - d∗t), where t is measured in heartbeat ticks (`vm->heartbeat.tick_count`), never in wall-clock time. The decay amount is computed as (elapsed_ticks ∗ slope_q48) >> 16 using the Q48.16 adaptive decay slope stored in the VM's heartbeat state. Uses a GCC CAS loop for atomic heat update when __GNUC__ is defined, falling back to a plain subtraction otherwise.

Ticks, not nanoseconds: this entry's `execution_heat` feeds directly into `dict_hash` (see `capsule_dict_hash_hook()`), so any wall-clock dependency here makes dictionary state – and therefore dict_hash – architecture-variable under QEMU/TCG's differing real emulation speed, or whenever real elapsed time between two touches of the same entry varies for reasons unrelated to execution (e.g. a blocking I/O wait between them). `vm->heartbeat.tick_count` only advances from `vm_tick()`, called synchronously from the interpreter's own dispatch path – a purely execution-count-driven clock, immune to how long any intervening real-time work (including blocking I/O) actually took.

No-op when:

- `WORD_FROZEN` flag is set on the entry
- `elapsed_ticks` == 0 (no heartbeat tick has fired since last decay)
- `vm->ssm_config` has L3 disabled by the Jacquard mode selector

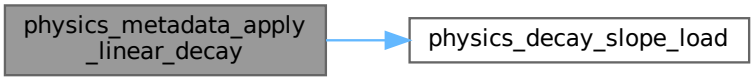
Parameters

entry	DictEntry whose heat is decayed
elapsed_ticks	Heartbeat ticks elapsed since last decay application
vm	VM providing the adaptive decay slope and L3 gate flag

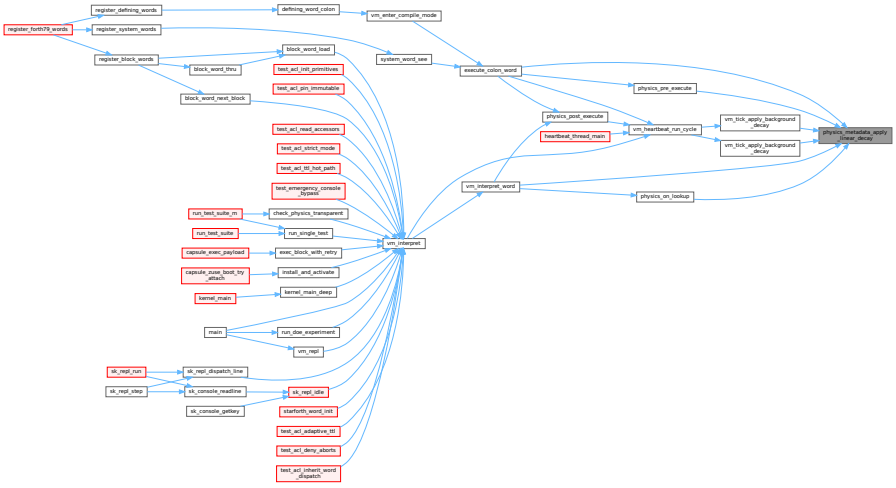
References entry, ssm_config_t::L3_linear_decay, physics_decay_slope_load(), VM::ssm_config, and WORD_FROZEN.

Referenced by execute_colon_word(), physics_on_lookup(), physics_pre_execute(), vm_interpret_word(), vm_tick_apply_background_decay(), and vm_tick_apply_background_decay().

Here is the call graph for this function:



Here is the caller graph for this function:



7.293.2.4 physics_metadata_apply_seed()

```
void physics_metadata_apply_seed (
            DictEntry * entry )
```

Apply DoE-derived prior physics values to a named DictEntry.

Searches the static `physics_seed_table` for an entry matching `entry->name`. If found, seeds `temperature_q8`, `avg_latency_ns`, `acl_hint`, and `pubsub_mask` with values derived from the 2^7 factorial DoE analysis. Only non-zero seed fields overwrite the current value. Called from `register_word()` for built-in primitives.

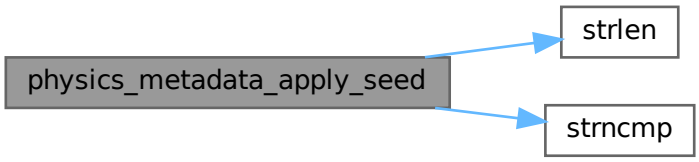
Parameters

entry	DictEntry to seed (no-op if NULL or no matching table entry)

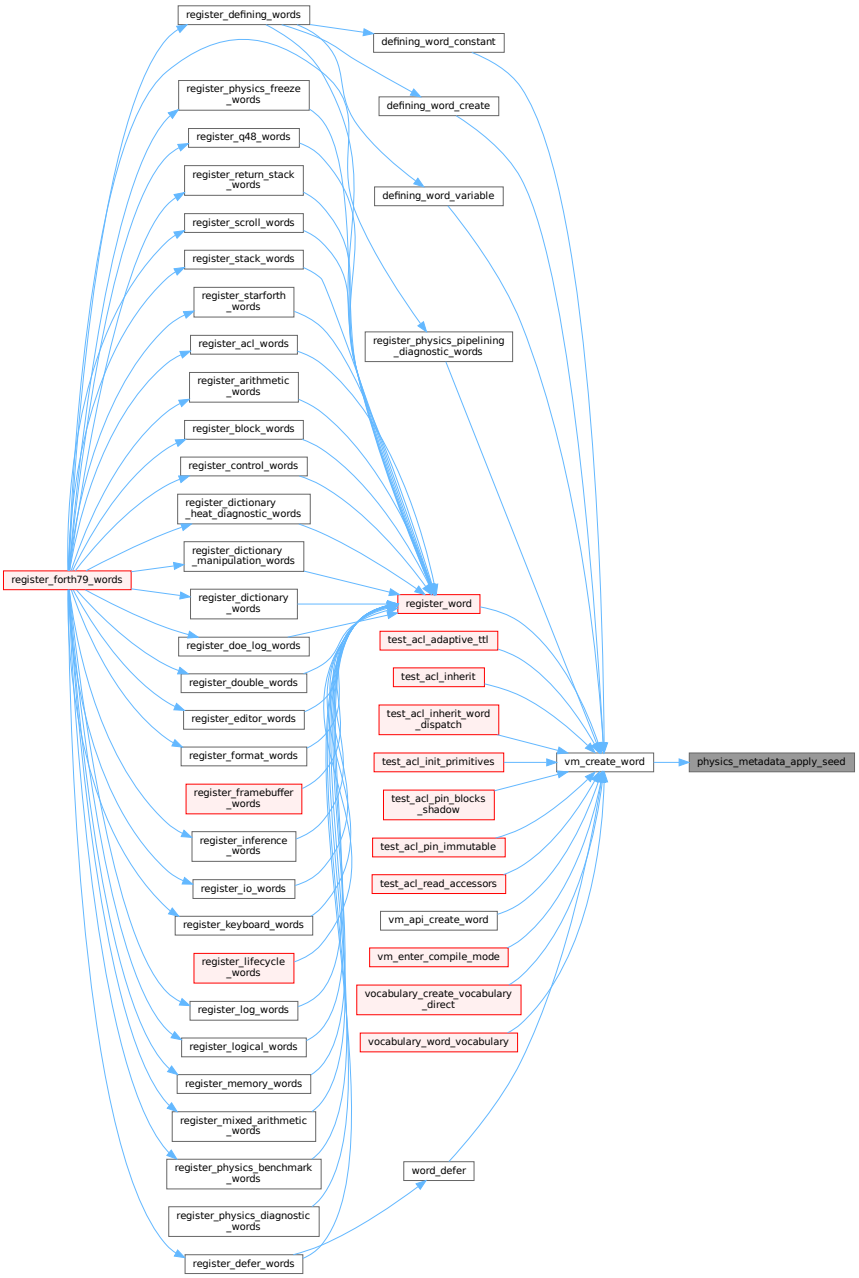
References entry, physics_seed_definition::name, physics_seed_table, strlen(), strncmp(), and physics_seed_definition::temperature_

Referenced by vm_create_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.293.2.5 physics_metadata_init()

```
void physics_metadata_init (
            DictEntry * entry,
            uint32_t header_bytes )
```

Initialise physics metadata for a newly registered DictEntry.

Zeroes all `DictPhysics` fields, sets `mass_bytes` to `header_bytes` (the byte size of the entry header), and derives initial `state_flags` from the entry's word flags. Called from `register_word()` immediately after the entry is linked into the dictionary.

Parameters

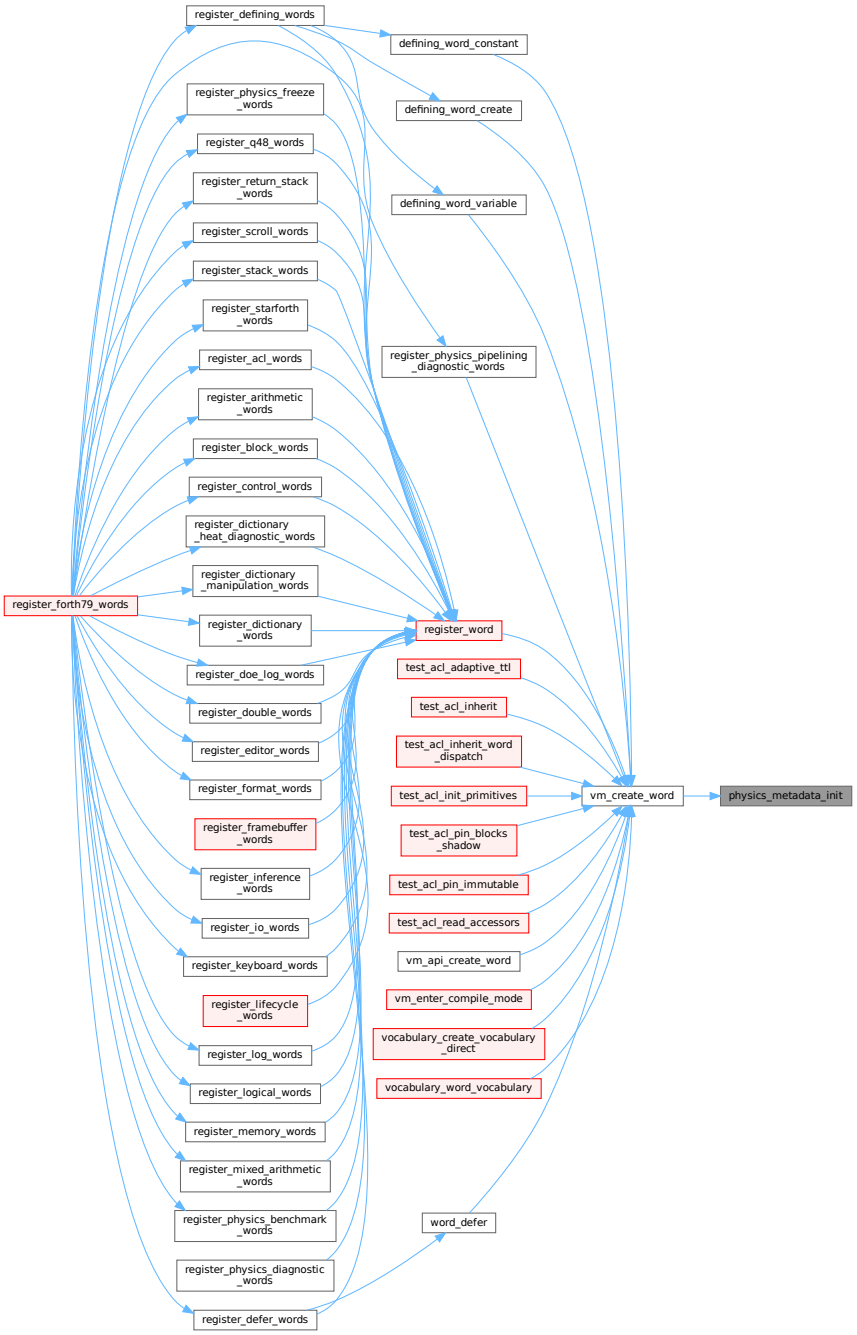
entry	DictEntry to initialise
header_bytes	Byte size of the entry's header region (for mass)

References derive_state_flags(), and entry.

Referenced by vm_create_word().

Here is the call graph for this function:

Here is the caller graph for this function:



7.293.2.6 physics_metadata_record_latency()

```
void physics_metadata_record_latency (
            DictEntry * entry,
            uint64_t sample_ns )
```

Record an execution latency sample into the per-word EMA.

Clamps `sample_ns` to uint32_t, then blends it into `avg_latency_ns` with a 1/4 EMA: new = (3∗prior + sample) / 4. Seeds `avg_latency_ns` directly from the first sample.

Parameters

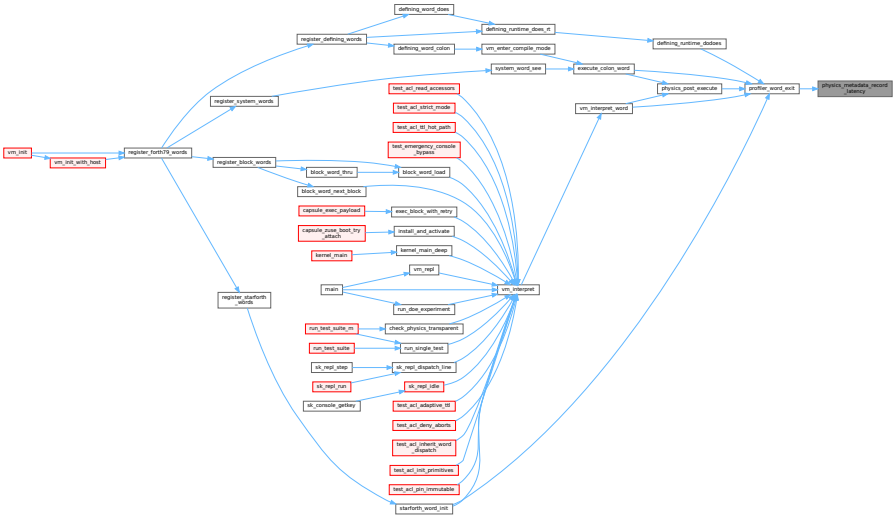
entry	DictEntry whose latency EMA is updated
sample_ns	Measured execution duration in nanoseconds

References clamp_u32(), and entry.

Referenced by profiler_word_exit().

Here is the call graph for this function:

Here is the caller graph for this function:



7.293.2.7 physics_metadata_refresh_state()

```
void physics_metadata_refresh_state (
            DictEntry * entry )
```

Re-derive and update `state_flags` for a DictEntry.

Called after word flags change (e.g. IMMEDIATE is set during compilation) to keep the physics state flags in sync with the word flags.

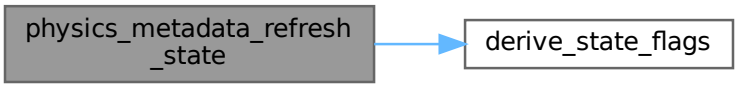
Parameters

entry	DictEntry whose state flags are to be refreshed

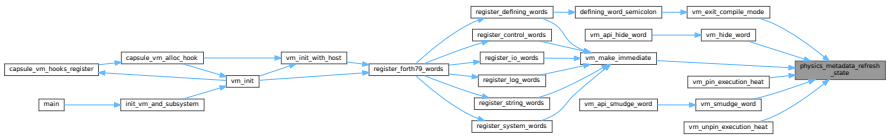
References derive_state_flags(), and entry.

Referenced by vm_exit_compile_mode(), vm_hide_word(), vm_make_immediate(), vm_pin_execution_heat(), vm_smudge_word(), and vm_unpin_execution_heat().

Here is the call graph for this function:



Here is the caller graph for this function:



7.293.2.8 physics_metadata_set_mass()

```
void physics_metadata_set_mass (
            DictEntry * entry,
            uint32_t total_bytes )
```

Update the mass (byte footprint) of a DictEntry's physics metadata.

Called after a colon definition or CREATE body is fully compiled so the mass reflects the total compiled size, not just the header.

Parameters

entry	DictEntry to update
total_bytes	Total compiled byte size (header + body)

References entry.

Referenced by vm_exit_compile_mode().

Here is the caller graph for this function:

7.293.2.9 physics_metadata_touch()

```
void physics_metadata_touch (
            DictEntry * entry,
            cell_t execution_heat,
            uint64_t now_ns )
```

Update physics metadata after a word execution completes.

Derives and stores a new smoothed `temperature_q8` from `execution_heat`, and updates both `last_active_ns` and `last_decay_ns` to `now_ns`. Called by `physics_post_execute()` on the post-execution path.

Parameters

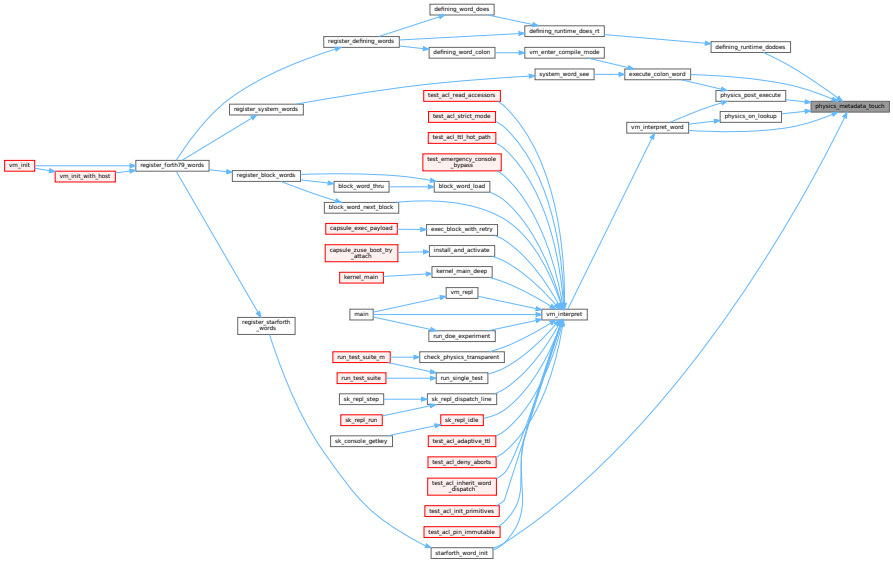
entry	DictEntry that was just executed
execution_heat	Current raw execution heat counter
now_ns	Current monotonic timestamp in nanoseconds

References entry, execution_heat, and temperature_from_execution_heat().

Referenced by defining_runtime_dodoes(), execute_colon_word(), physics_on_lookup(), physics_post_execute(), starforth_word_init(), and vm_interpret_word().

Here is the call graph for this function:

Here is the caller graph for this function:



7.293.2.10 temperature_from_execution_heat()

```
static uint16_t temperature_from_execution_heat (
            cell_t execution_heat,
            uint16_t prior_q8 )  [static]
```

Derive a smoothed Q8 temperature from raw execution heat.

Converts `execution_heat` to Q8 by left-shifting 8 bits, clamps to UINT16_MAX, then applies a 1/4 EMA blend with `prior_q8` to suppress jitter: result = (3∗prior + target) / 4. Returns 0 for non-positive heat.

Parameters

execution_heat	Raw execution heat counter for the word
prior_q8	Previous smoothed temperature in Q8 format

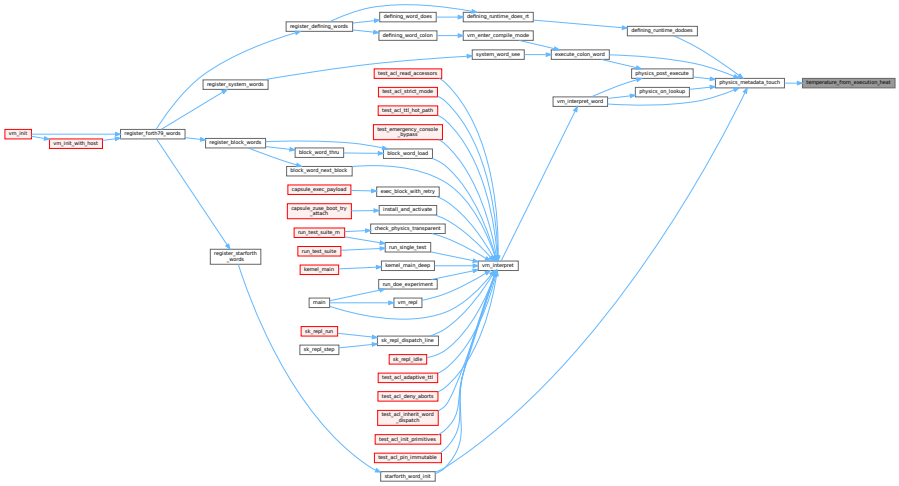
Returns

Updated smoothed temperature in Q8 format

References execution_heat.

Referenced by physics_metadata_touch().

Here is the caller graph for this function:



7.293.3 Variable Documentation

7.293.3.1 physics_seed_table

```
const physics_seed_definition_t physics_seed_table[]  [static]
```

Initial value:

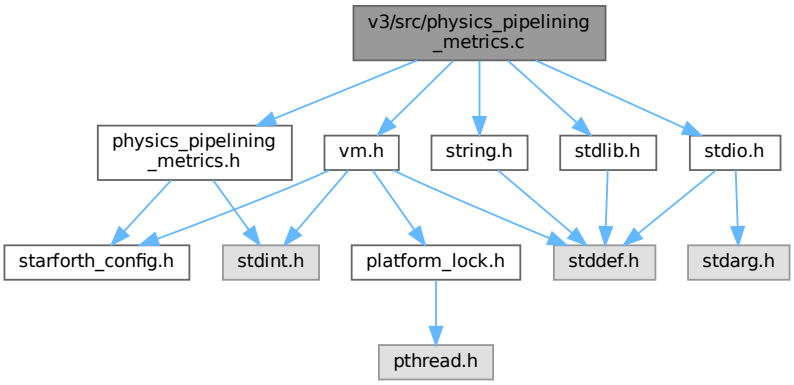
```
= {
    {"IF", 0x0100u, 400u, 0, 0},
    {"ELSE", 0x0100u, 400u, 0, 0},
    {"THEN", 0x0100u, 350u, 0, 0},
    {"BEGIN", 0x0120u, 450u, 0, 0},
    {"WHILE", 0x0120u, 450u, 0, 0},
    {"REPEAT", 0x0120u, 450u, 0, 0},
    {"DO", 0x0180u, 500u, 0, 0},
    {"LOOP", 0x0180u, 500u, 0, 0},
    {"+LOOP", 0x0200u, 520u, 0, 0},
    {"LEAVE", 0x0200u, 520u, 0, 0},
    {".", 0x0080u, 300u, 0, 0},
    {"EMIT", 0x0180u, 800u, 0, 0x02u},
    {"TYPE", 0x0180u, 900u, 0, 0x02u},
    {"BLOCK", 0x0200u, 950u, 0, 0x04u},
    {"BUFFER", 0x01C0u, 900u, 0, 0x04u},
    {"SAVE-BUFFERS", 0x0260u, 1400u, 0, 0x04u},
    {"FLUSH", 0x0240u, 1200u, 0, 0x04u},
    {"LOAD", 0x0220u, 1100u, 0, 0x04u},
    {"LIST", 0x0200u, 1000u, 0, 0x04u},
    {"SAVE-SYSTEM", 0x0280u, 2000u, 0x80u, 0x08u},
    {NULL, 0, 0, 0, 0}
}
```

Referenced by physics_metadata_apply_seed().

7.294 v3/src/physics_pipelining_metrics.c File Reference

```
#include "physics_pipelining_metrics.h"
#include "vm.h"
#include <stdlib.h>
#include <string.h>
```

`#include <stdio.h>`
Include dependency graph for physics_pipelining_metrics.c:



Functions

- static int64_t ns_to_q48 (int64_t ns)

  Convert a nanosecond count to Q48.16 fixed-point.
- static int64_t q48_to_ns (int64_t q48)

  Convert a Q48.16 fixed-point value to integer nanoseconds (truncated).
- static int64_t q48_div_u64 (int64_t a_q48, uint64_t b)

  Divide a Q48.16 value by a `uint64_t`, returning Q48.16.
- int transition_metrics_init (WordTransitionMetrics *metrics)

  Initialise a `WordTransitionMetrics` structure to its empty, ready-to-record state.
- int transition_metrics_record (WordTransitionMetrics *metrics, uint32_t next_word_id, uint32_t dict_size)

  Record one word-to-word transition in the transition heat table.
- int64_t transition_metrics_get_probability_q48 (const WordTransitionMetrics *metrics, uint32_t target_word_id)

  Return the transition probability to `target_word_id` in Q48.16 format.
- void transition_metrics_update_cache (WordTransitionMetrics *metrics, uint32_t dict_size)

  Scan the transition heat table and cache the highest-probability next word.
- void transition_metrics_record_prefetch_hit (WordTransitionMetrics *metrics, int64_t latency_saved_ns)

  Record a successful speculative prefetch and the latency it saved.
- void transition_metrics_record_prefetch_miss (WordTransitionMetrics *metrics, int64_t recovery_cost_ns)

  Record a failed speculative prefetch and its recovery overhead.
- int transition_metrics_should_speculate (const WordTransitionMetrics *metrics, uint32_t target_word_id)

  Decide whether to speculatively prefetch `target_word_id`.
- char * transition_metrics_stats_string (const WordTransitionMetrics *metrics)

  Allocate and return a human-readable transition metrics summary string.
- void transition_metrics_reset (WordTransitionMetrics *metrics)

  Reset a `WordTransitionMetrics` to empty without freeing the context window.
- void transition_metrics_cleanup (WordTransitionMetrics *metrics)

  Release all heap memory held by a `WordTransitionMetrics`.
- int transition_metrics_update_context_window (WordTransitionMetrics *metrics, uint32_t word_id)

  Slide the context window forward by one word, appending `word_id`.

- int transition_metrics_record_context (WordTransitionMetrics *metrics, const uint32_t *context, uint32_t window_size, uint32_t next_word_id, uint32_t dict_size)

  Record a context-conditioned transition (Phase 1 collection stub).
- char * transition_metrics_context_accuracy_string (const WordTransitionMetrics *metrics)

  Allocate and return a context-window status report string (Phase 1 stub).
- uint32_t transition_metrics_binary_chop_suggest_window (const WordTransitionMetrics *metrics, uint32_t current_window, double accuracy_at_current)

  Suggest a new context window size using binary-chop search (Phase 1 stub).

7.294.1 Function Documentation

7.294.1.1 ns_to_q48()

```
static int64_t ns_to_q48 (
            int64_t ns )  [inline], [static]
```

Convert a nanosecond count to Q48.16 fixed-point.

Shifts `ns` left by 16 bits to produce a Q48.16 value where the integer part represents nanoseconds (1.0 ns = 65536 in Q48.16). Used to convert raw platform nanosecond timestamps into the common Q48.16 format before accumulating into `prefetch_latency_saved_q48` and `misprediction_cost_q48`.

Parameters

ns	Integer nanosecond value to convert.

Returns

`ns` in Q48.16 format (`ns` × 65536).

Referenced by transition_metrics_record_prefetch_hit(), and transition_metrics_record_prefetch_miss().

Here is the caller graph for this function:

7.294.1.2 q48_div_u64()

```
static int64_t q48_div_u64 (
            int64_t a_q48,
            uint64_t b )  [inline], [static]
```

Divide a Q48.16 value by a `uint64_t`, returning Q48.16.

Computes `a_q48` / `b` using integer division. The result preserves the Q48.16 scaling of `a_q48` because `b` is dimensionless. Guards against divide-by-zero by returning 0 when `b` == 0. Used by `transition_metrics_get_probability_q48()` to compute the per-word transition probability:

```
P(next = w) = (count_q48 « 16) / total_transitions
```

where `count_q48` = (uint64_t)count << 16 and `total_transitions` is the denominator `b`.

Parameters

a_q48	Numerator in Q48.16 format.
b	Denominator as a plain `uint64_t` (dimensionless count).

Returns

`a_q48` / `b` in Q48.16; 0 if `b` == 0.

Referenced by transition_metrics_get_probability_q48().

Here is the caller graph for this function:

7.294.1.3 q48_to_ns()

```
static int64_t q48_to_ns (
            int64_t q48 )  [inline], [static]
```

Convert a Q48.16 fixed-point value to integer nanoseconds (truncated).

Shifts `q48` right by 16 bits, discarding the fractional part. The result is the integer nanosecond count represented by the Q48.16 value. Used in `transition_metrics_stats_string()` to convert the accumulated `prefetch_latency_saved_q48` and `misprediction_cost_q48` back to human-readable nanosecond integers for the stats report string.

Parameters

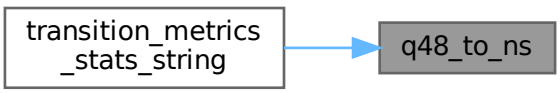
q48	Value in Q48.16 format.

Returns

Integer nanosecond equivalent (truncated, not rounded).

Referenced by transition_metrics_stats_string().

Here is the caller graph for this function:



7.294.1.4 transition_metrics_binary_chop_suggest_window()

```
uint32_t transition_metrics_binary_chop_suggest_window (
            const WordTransitionMetrics * metrics,
            uint32_t current_window,
            double accuracy_at_current )
```

Suggest a new context window size using binary-chop search (Phase 1 stub).

In Phase 2 this function will implement a binary-chop search over window sizes to converge on the width that maximises context-prediction accuracy:

- Start at window = 2.
- If accuracy improves when doubling, try 4; if it declines, try 1.
- Continue halving/doubling until the accuracy delta falls below a threshold.

Phase 1 stub behaviour: Doubles the current window each call up to 8, then wraps back to 1:

- `current_window` == 1 → suggests 2
- `current_window` == 2 → suggests 4
- `current_window` == 4 → suggests 8
- `current_window` ≥ 8 → suggests 1 (cycle back)
- Any other value → returns `current_window` unchanged.

The `accuracy_at_current` parameter (prediction accuracy [0.0, 1.0] at the current window size) is accepted for API stability with the Phase 2 caller but is not used in the stub.

Parameters

metrics	The metrics structure (unused in Phase 1 stub; reserved for Phase 2 accuracy history).
current_window	Currently active context window size.
accuracy_at_current	Prediction accuracy at `current_window` (unused in Phase 1 stub; range [0.0, 1.0]).

Returns

Suggested new window size.

7.294.1.5 transition_metrics_cleanup()

```
void transition_metrics_cleanup (
            WordTransitionMetrics * metrics )
```

Release all heap memory held by a `WordTransitionMetrics`.

Frees and NULLs:

- `metrics->transition_heat` — the per-word transition count array.
- `metrics->context_window` — the sliding context-window array.
- `metrics->context_transitions` — the Phase 2 sparse hash table (if allocated).

Does NOT zero the struct fields beyond NULLing the freed pointers. The caller must not use `metrics` after this call without a subsequent `transition_metrics_init()`. Contrast with `transition_metrics_reset()`, which keeps the context window allocated for reuse.

No-op if `metrics` is NULL.

Parameters

metrics	The metrics structure to clean up; no-op if NULL.

References WordTransitionMetrics::context_transitions, WordTransitionMetrics::context_window, free(), and WordTransitionMetrics::transition_heat.

Referenced by dictionary_word_forget().

Here is the call graph for this function:

Here is the caller graph for this function:

7.294.1.6 transition_metrics_context_accuracy_string()

```
char * transition_metrics_context_accuracy_string (
            const WordTransitionMetrics * metrics )
```

Allocate and return a context-window status report string (Phase 1 stub).

Allocates a 1024-byte buffer and fills it with a brief Phase 1 collection status message:

- `actual_window_size` — the active window width (0 if allocation failed).

- `total_context_transitions` — the number of context transitions recorded.
- A "[Phase 1 Collection - Phase 2 Analysis Pending]" status line.

Phase 2 will replace this stub with a real accuracy report showing per-window-size prediction accuracy derived from the sparse context-pattern hash table. The accuracy data will feed `transition_metrics_binary_chop_suggest_windo` to converge on the optimal context window width.

The caller is responsible for calling `free()` on the returned pointer. Returns NULL if `metrics` is NULL or `malloc()` fails.

Parameters

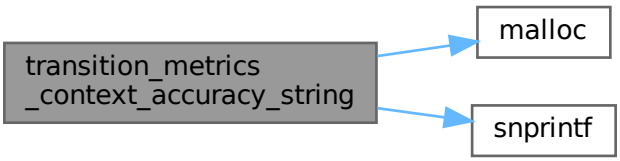
metrics	The metrics structure to report on.

Returns

Heap-allocated NUL-terminated string; caller must `free()`. NULL on allocation failure or NULL `metrics`.

References WordTransitionMetrics::actual_window_size, malloc(), snprintf(), and WordTransitionMetrics::total_context_transitions.

Here is the call graph for this function:



7.294.1.7 transition_metrics_get_probability_q48()

```
int64_t transition_metrics_get_probability_q48 (
            const WordTransitionMetrics * metrics,
            uint32_t target_word_id )
```

Return the transition probability to `target_word_id` in Q48.16 format.

Computes P(next = `target_word_id` | current word) as a Q48.16 fixed-point ratio:
`P = (transition_heat[target_word_id] « 16) / total_transitions`

using `q48_div_u64()` to guard against divide-by-zero.

Returns 0 if:

- `metrics` is NULL.

- `metrics->total_transitions` == 0 (no transitions recorded yet).
- `metrics->transition_heat` is NULL (lazy allocation has not occurred).

The caller is responsible for ensuring `target_word_id` is within the bounds of the allocated `transition_↩ heat` array; this function does not re-check bounds after verifying the NULL guard above (bounds were enforced during `transition_metrics_record()`).

Consumed by `transition_metrics_update_cache()` (scans all words to find the maximum) and `transition_metrics_should_speculate()` (checks whether a specific word's probability exceeds `SPECULATION_THRESHOLD_Q48`).

Parameters

metrics	The metrics structure to query.
target_word↩ _id	Zero-based word ID whose transition probability is requested; must be within the dict_size used at record time.

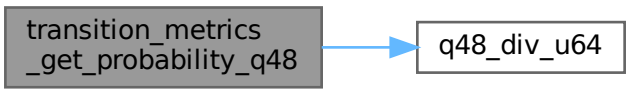
Returns

P(next = `target_word_id`) in Q48.16; 0 if unavailable.

References count, q48_div_u64(), WordTransitionMetrics::total_transitions, and WordTransitionMetrics::transition_heat.

Referenced by transition_metrics_should_speculate(), and transition_metrics_update_cache().

Here is the call graph for this function:



Here is the caller graph for this function:

7.294.1.8 transition_metrics_init()

```
int transition_metrics_init (
            WordTransitionMetrics * metrics )
```

Initialise a `WordTransitionMetrics` structure to its empty, ready-to-record state.

Sets all counter and accumulator fields to zero and performs the following allocations:

- `metrics->transition_heat` is left NULL — it is lazily allocated by the first call to `transition_metrics_record(` to avoid the `dict_size` parameter being required at construction time.
- If `TRANSITION_WINDOW_SIZE` > 0, allocates `metrics->context_window` as a zero-filled array of `TRANSITION_WINDOW_SIZE` `uint32_t` word IDs and sets `metrics->actual_window_size` accordingly. If the allocation fails, `actual_window_size` is set to 0 and context tracking degrades gracefully (all context functions become no-ops).
- `metrics->context_transitions` is left NULL — it is lazily allocated when Phase 2 context-pattern analysis is implemented.

Returns 0 on success or ?1 if `metrics` is NULL.

Parameters

metrics	The `WordTransitionMetrics` to initialise; must not be NULL.

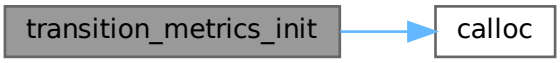
Returns

0 on success; ?1 if `metrics` is NULL.

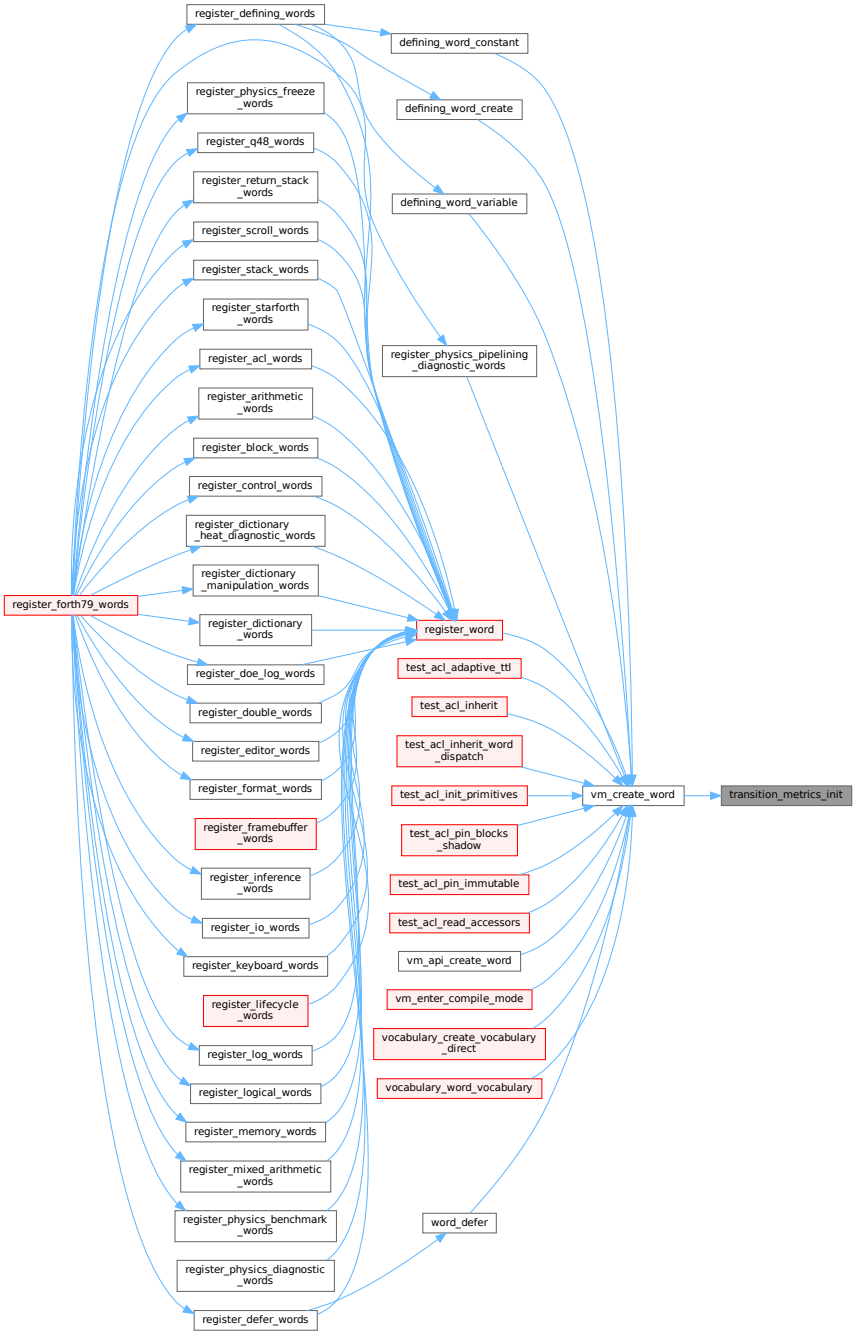
References WordTransitionMetrics::actual_window_size, calloc(), WordTransitionMetrics::context_transitions, WordTransitionMetrics::context_window, WordTransitionMetrics::context_window_pos, WordTransitionMetrics::max_transition_probab WordTransitionMetrics::misprediction_cost_q48, WordTransitionMetrics::most_likely_next_word_id, WordTransitionMetrics::prefetch_a WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_latency_saved_q48, WordTransitionMetrics::prefetch_misses, WordTransitionMetrics::total_context_transitions, WordTransitionMetrics::total_transitions, WordTransitionMetrics::transition_heat, and TRANSITION_WINDOW_SIZE.

Referenced by vm_create_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.294.1.9 transition_metrics_record()

```
int transition_metrics_record (
            WordTransitionMetrics * metrics,
            uint32_t next_word_id,
            uint32_t dict_size )
```

Record one word-to-word transition in the transition heat table.

Called from the interpreter loop each time a word executes and there is a known previous word. Increments `metrics->transition_heat`[next_word_id] by one and `metrics->total_transitions` by one.

Lazy allocation: The `transition_heat` array is not allocated at `transition_metrics_init()` time; on the first call when `metrics->transition_heat` == NULL, it is allocated as a zero-filled array of `dict_size` `uint64_t` counters. If the allocation fails ?1 is returned and the transition is silently dropped.

If `next_word_id` $\geq$ `dict_size` the call is rejected with ?1 to prevent an out-of-bounds write into `transition_heat` (which was allocated with size `dict_size`).

The accumulated `transition_heat`[] table is consumed by `transition_metrics_get_probability_q48()` and `transition_metrics_update_cache()` to determine the most-likely next word for speculative prefetch.

Parameters

metrics	The metrics structure to update.
next_word_id	Zero-based word ID of the word that followed the current word; must be $<$ `dict_size`.
dict_size	Current dictionary size, used both as the bounds check for `next_word_id` and as the allocation size for the lazy-allocated `transition_heat` array.

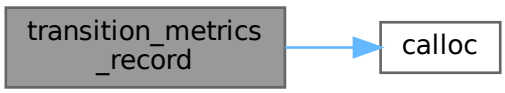
Returns

0 on success; ?1 on NULL `metrics`, out-of-bounds `next_word_id`, or allocation failure.

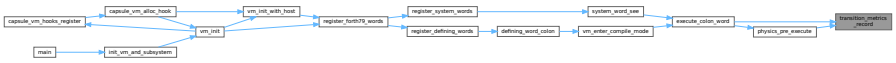
References calloc(), WordTransitionMetrics::total_transitions, and WordTransitionMetrics::transition_heat.

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the call graph for this function:



Here is the caller graph for this function:



7.294.1.10 transition_metrics_record_context()

```
int transition_metrics_record_context (
            WordTransitionMetrics * metrics,
            const uint32_t * context,
            uint32_t window_size,
            uint32_t next_word_id,
            uint32_t dict_size )
```

Record a context-conditioned transition (Phase 1 collection stub).

Accepts a `context` window of `window_size` preceding word IDs and the `next_word_id` that followed. In Phase 1 only the total count is tracked: `metrics->total_context_transitions` is incremented by one, providing a baseline count that Phase 2 analysis can use to size its hash tables.

Phase 2 TODO: Build a sparse hash table keyed on the context pattern (context[0], ..., context[window_size-1]) to record per-context next-word distributions. The Phase 2 analysis will feed `transition_metrics_binary_chop_suggest_w` with accuracy data to tune the optimal window size.

Returns ?1 (no-op) if `metrics` or `context` are NULL, `window_size` is 0, or `next_word_id` ≥ `dict_size`.

Parameters

metrics	The metrics structure to update.
context	Array of `window_size` word IDs preceding `next_word_id`.
window_size	Number of entries in `context`; must be > 0.
next_word_id	Word ID that followed the context sequence.
dict_size	Current dictionary size; used for bounds checking `next_word_id`.

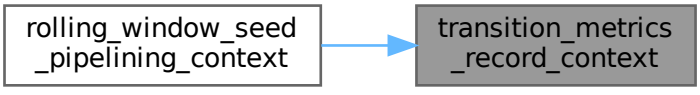
Returns

0 on success; ?1 on invalid arguments.

References WordTransitionMetrics::total_context_transitions.

Referenced by rolling_window_seed_pipelining_context().

Here is the caller graph for this function:



7.294.1.11 transition_metrics_record_prefetch_hit()

```
void transition_metrics_record_prefetch_hit (
            WordTransitionMetrics * metrics,
            int64_t latency_saved_ns )
```

Record a successful speculative prefetch and the latency it saved.

Increments `metrics->prefetch_hits` by one and accumulates `latency_saved_ns` (converted to Q48.16 via `ns_to_q48()`) into `metrics->prefetch_latency_saved_q48`. The accumulated total is reported by `transition_metrics_stats_string()` as the aggregate latency benefit of correct speculation.

Called by the speculative-execution path when a prefetched word matches the word that was actually executed next.

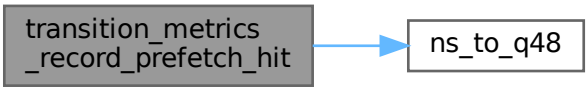
Parameters

metrics	The metrics structure to update; no-op if NULL.
latency_saved_ns	The number of nanoseconds saved by avoiding a full dictionary lookup on this particular hit.

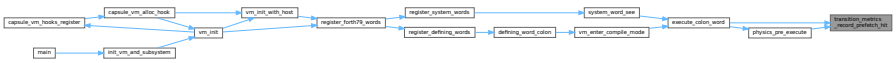
References ns_to_q48(), WordTransitionMetrics::prefetch_hits, and WordTransitionMetrics::prefetch_latency_saved_q48.

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the call graph for this function:



Here is the caller graph for this function:



7.294.1.12 transition_metrics_record_prefetch_miss()

```
void transition_metrics_record_prefetch_miss (
            WordTransitionMetrics * metrics,
            int64_t recovery_cost_ns )
```

Record a failed speculative prefetch and its recovery overhead.

Increments `metrics->prefetch_misses` by one and accumulates `recovery_cost_ns` (converted to Q48.16 via `ns_to_q48()`) into `metrics->misprediction_cost_q48`. The accumulated total is the aggregate penalty paid for incorrect speculation and is reported by `transition_metrics_stats_string()` as "Misprediction Cost".

The net benefit of the pipelining subsystem is:
```
net_ns = prefetch_latency_saved_q48 - misprediction_cost_q48
```

A positive net indicates that speculation is profitable overall.

Called by the speculative-execution path when the prefetched word does not match the word that was actually executed next (branch misprediction analogue).

Parameters

metrics	The metrics structure to update; no-op if NULL.
recovery_cost_ns	The number of nanoseconds spent unwinding the incorrect speculation (cache flush, state restore).

References WordTransitionMetrics::misprediction_cost_q48, ns_to_q48(), and WordTransitionMetrics::prefetch_misses.

Here is the call graph for this function:

7.294.1.13 transition_metrics_reset()

```
void transition_metrics_reset (
            WordTransitionMetrics * metrics )
```

Reset a `WordTransitionMetrics` to empty without freeing the context window.

Frees and NULLs `metrics->transition_heat` (so the next `transition_metrics_record()` will re-allocate it), then zeroes all counter and accumulator fields. Also zeroes the context-window array (if allocated) and resets `context_window_pos` to 0, and frees and NULLs `context_transitions`. `actual_window_size` and the `context_window` pointer itself are preserved — the window stays allocated and ready for reuse.

Intended for DoE benchmark runs that need a clean statistical baseline between treatment cells without the overhead of full teardown and reinitialisation. Cheaper than `transition_metrics_cleanup()` + `transition_metrics_init()` because it avoids reallocating the context window.

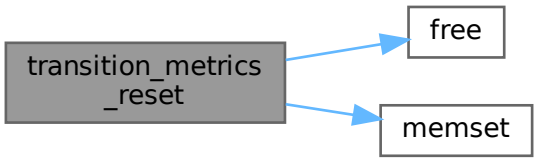
Parameters

metrics	The metrics structure to reset; no-op if NULL.

References WordTransitionMetrics::actual_window_size, WordTransitionMetrics::context_transitions, WordTransitionMetrics::context_
WordTransitionMetrics::context_window_pos, free(), WordTransitionMetrics::max_transition_probability_q48,
memset(), WordTransitionMetrics::misprediction_cost_q48, WordTransitionMetrics::most_likely_next_word_id,
WordTransitionMetrics::prefetch_attempts, WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_latency_saved_q48
WordTransitionMetrics::prefetch_misses, WordTransitionMetrics::total_context_transitions, WordTransitionMetrics::total_transitions,
and WordTransitionMetrics::transition_heat.

Referenced by forth_PIPELINING_RESET_ALL().

Here is the call graph for this function:



Here is the caller graph for this function:

7.294.1.14 transition_metrics_should_speculate()

```
int transition_metrics_should_speculate (
            const WordTransitionMetrics * metrics,
            uint32_t target_word_id )
```

Decide whether to speculatively prefetch `target_word_id`.

Applies a two-gate policy before authorising speculation:

1. **Minimum sample gate:** `metrics->total_transitions` must be $\geq$ `MIN_SAMPLES_FOR_SPECULATION`. Below this threshold the transition probabilities are statistically unreliable — speculation would be indistinguishable from guessing.
2. **Probability threshold gate:** the Q48.16 probability returned by `transition_metrics_get_probability_q48`(metrics, `target_word_id`) must be $\geq$ `SPECULATION_THRESHOLD_Q48`. Words with very low conditional probability of following the current word are not worth prefetching.

Both gates must pass for the function to return 1. A Phase 4 ROI check (comparing expected latency savings against expected misprediction cost) is planned but not yet implemented; a TODO comment marks the extension point.

Returns 0 if `metrics` or `transition_heat` are NULL, or if either gate fails.

Parameters

metrics	The metrics structure to consult.
target_word↩ _id	Zero-based ID of the candidate next word.

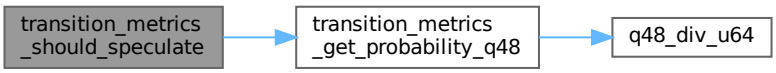
Returns

1 if speculation is recommended; 0 otherwise.

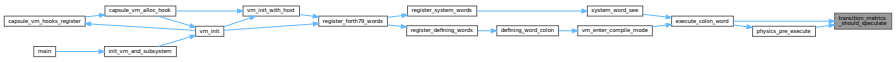
References MIN_SAMPLES_FOR_SPECULATION, SPECULATION_THRESHOLD_Q48, WordTransitionMetrics::total_transitions, WordTransitionMetrics::transition_heat, and transition_metrics_get_probability_q48().

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the call graph for this function:



Here is the caller graph for this function:



7.294.1.15 transition_metrics_stats_string()

```
char * transition_metrics_stats_string (
            const WordTransitionMetrics * metrics )
```

Allocate and return a human-readable transition metrics summary string.

Allocates a 2048-byte buffer and fills it with a multi-line report:

- Total transitions recorded.
- Prefetch attempts, hits (with hit-rate %), and misses.
- Aggregate latency saved by correct speculation (from `prefetch_latency_saved_q48`, converted to integer ns via `q48_to_ns()`).
- Aggregate misprediction cost (from `misprediction_cost_q48`).
- Net benefit (saved ? cost) in nanoseconds.
- The most-likely next word ID and its raw Q48.16 probability.

The caller is responsible for calling `free()` on the returned pointer. Returns NULL if `metrics` is NULL or `malloc()` fails.

Parameters

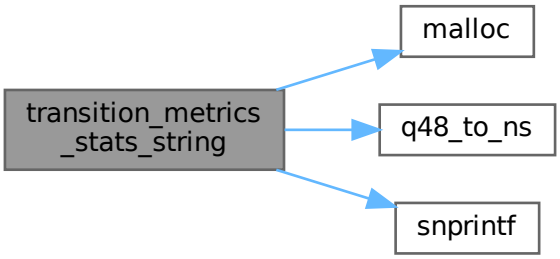
metrics	The metrics structure to summarise.

Returns

Heap-allocated NUL-terminated stats string; caller must `free()`. NULL on allocation failure or NULL `metrics`.

References malloc(), WordTransitionMetrics::max_transition_probability_q48, WordTransitionMetrics::misprediction_cost_q48, WordTransitionMetrics::most_likely_next_word_id, WordTransitionMetrics::prefetch_attempts, WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_latency_saved_q48, WordTransitionMetrics::prefetch_misses, q48_to_ns(), snprintf(), and WordTransitionMetrics::total_transitions.

Here is the call graph for this function:



7.294.1.16 transition_metrics_update_cache()

```
void transition_metrics_update_cache (
            WordTransitionMetrics * metrics,
            uint32_t dict_size )
```

Scan the transition heat table and cache the highest-probability next word.

Iterates over all `dict_size` entries in `metrics->transition_heat`[], calling `transition_metrics_get_probabil` for each non-zero entry and tracking the maximum. After the scan:

- `metrics->max_transition_probability_q48` holds the peak probability (Q48.16).
- `metrics->most_likely_next_word_id` holds the word ID of that peak.

These two cached fields allow `transition_metrics_should_speculate()` to make a prefetch decision in O(1) without re-scanning the full table on every word dispatch.

If `metrics`, `transition_heat`, or `total_transitions` are not valid, both fields are reset to 0 and the function returns immediately.

Called after each `transition_metrics_record()` in the high-frequency interpreter path, so the implementation must be fast. The full `dict_size` scan runs in O(dict_size) and skips zero-count entries early.

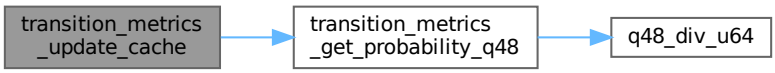
Parameters

metrics	The metrics structure to update.
dict_size	Number of entries in `metrics->transition_heat[]`; must match the size used at allocation time.

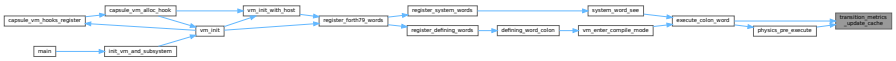
References WordTransitionMetrics::max_transition_probability_q48, WordTransitionMetrics::most_likely_next_word_id, WordTransitionMetrics::total_transitions, WordTransitionMetrics::transition_heat, and transition_metrics_get_probability_q48().

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the call graph for this function:



Here is the caller graph for this function:



7.294.1.17 transition_metrics_update_context_window()

```
int transition_metrics_update_context_window (
            WordTransitionMetrics * metrics,
            uint32_t word_id )
```

Slide the context window forward by one word, appending `word_id`.

Implements a fixed-length sliding window over the recent word-ID history. Each call shifts all existing entries one position to the left (dropping the oldest), then writes `word_id` into the last slot:

```
context_window[0..n-2] = context_window[1..n-1]
context_window[n-1] = word_id
```

This produces a FIFO queue of the last `actual_window_size` word IDs that can be passed to `transition_metrics_record_context()` for context-sensitive transition tracking (Phase 2).

Returns ?1 and is a no-op if:

- `metrics` is NULL.
- `context_window` is NULL (allocation at init failed — degraded mode).
- `actual_window_size` == 0.

Parameters

metrics	The metrics structure whose context window is updated.
word↩ _id	The word ID just executed; appended to the right of the window.

Returns

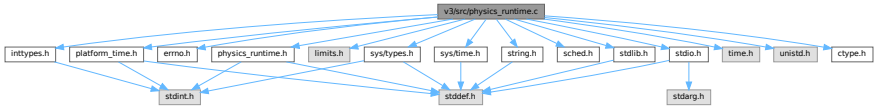
0 on success; ?1 if the context window is unavailable.

References WordTransitionMetrics::actual_window_size, WordTransitionMetrics::context_window, and word_id.

7.295 v3/src/physics_runtime.c File Reference

```
#include "physics_runtime.h"
#include "platform_time.h"
#include <errno.h>
#include <inttypes.h>
#include <limits.h>
#include <stdlib.h>
#include <string.h>
#include <stdio.h>
#include <sched.h>
#include <sys/time.h>
#include <sys/types.h>
#include <time.h>
#include <unistd.h>
#include <ctype.h>
```

Include dependency graph for physics_runtime.c:



Data Structures

- struct physics_runtime_state

Macros

- #define PATH_MAX 4096

Typedefs

- typedef struct physics_runtime_state physics_runtime_state_t

Functions

- static size_t align_up (size_t value, size_t alignment)

  Round `value` up to the next multiple of `alignment`.
- static uint32_t parse_avg_milli (const char *line, const char *tag)

  Parse a floating-point average field from a Linux PSI file line.
- static int read_psi_file (const char *path, uint32_t *some10, uint32_t *some60, uint32_t *some300, uint32_t *full10, uint32_t *full60, uint32_t *full300)

  Read a Linux Pressure Stall Information (PSI) file.
- static int read_proc_stat_totals (uint64_t *total, uint64_t *idle)

  Read aggregate CPU jiffy totals from `/proc/stat`.
- static int resolve_cgroup_path (char *out, size_t out_sz)

  Resolve the cgroup v2 filesystem path for the current process.
- static uint64_t read_cgroup_cpu_usage_us (const char *cgpath)

  Read the cumulative CPU usage in microseconds from a cgroup's `cpu.stat`.
- static uint64_t read_cgroup_memory_current (const char *cgpath)

  Read current memory usage in bytes from a cgroup's `memory.current`.
- static int analytics_heap_allocate (size_t requested_bytes)

  Allocate and initialise the HOLA analytics heap.
- static void analytics_heap_release (void)

  Free the analytics heap and reset all global heap state.
- static size_t analytics_ring_free (const physics_analytics_header_t *hdr)

  Compute free bytes available in the analytics ring buffer.
- int physics_runtime_init (size_t analytics_heap_bytes)

  Initialise the physics runtime and analytics heap.
- void physics_runtime_shutdown (void)

  Shut down the physics runtime and release the analytics heap.
- const physics_analytics_heap_t * physics_analytics_heap_info (void)

  Return a pointer to the live analytics heap descriptor.
- int physics_analytics_publish_event (uint32_t channel, const void *payload, uint16_t payload_bytes)

  Publish an analytics event into the ring buffer.
- static int snapshot_posix (physics_host_snapshot_t *out)

  Collect a host system snapshot using POSIX / Linux interfaces.
- int physics_host_snapshot (physics_host_snapshot_t *out)

  Capture a host environment snapshot and publish it to the analytics ring.

Variables

- static physics_runtime_state_t g_runtime = {0}

7.295.1 Macro Definition Documentation

7.295.1.1 PATH_MAX

```
#define PATH_MAX 4096
```

7.295.2 Typedef Documentation

7.295.2.1 physics_runtime_state_t

```
typedef struct physics_runtime_state physics_runtime_state_t
```

7.295.3 Function Documentation

7.295.3.1 align_up()

```
static size_t align_up (
            size_t value,
            size_t alignment )  [static]
```

Round `value` up to the next multiple of `alignment`.

`alignment` must be a power of two. Used internally to satisfy cache-line and struct alignment requirements in the analytics heap.

Parameters

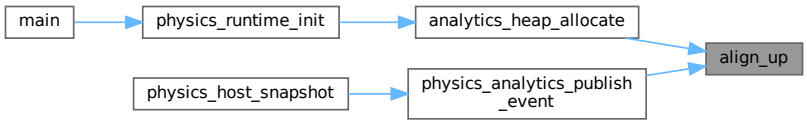
value	Value to align
alignment	Alignment boundary (must be power of two)

Returns

Smallest multiple of `alignment` that is >= `value`

Referenced by analytics_heap_allocate(), and physics_analytics_publish_event().

Here is the caller graph for this function:



7.295.3.2 analytics_heap_allocate()

```
static int analytics_heap_allocate (
            size_t requested_bytes )  [static]
```

Allocate and initialise the HOLA analytics heap.

Allocates a contiguous block of at least `requested_bytes` (or `PHYSICS_ANALYTICS_DEFAULT_HEAP↩_BYTES` if 0), enforcing a minimum that accommodates the header plus 512 KB ring buffer. Partitions the block into header (cache-line aligned), ring (60%), summary (30%), and scratch regions, then populates the `physics↩_analytics_header_t` with magic, version, and offsets. Safe to call repeatedly — returns 0 immediately if already ready.

Parameters

requested_bytes	Desired heap size in bytes (0 = use default)

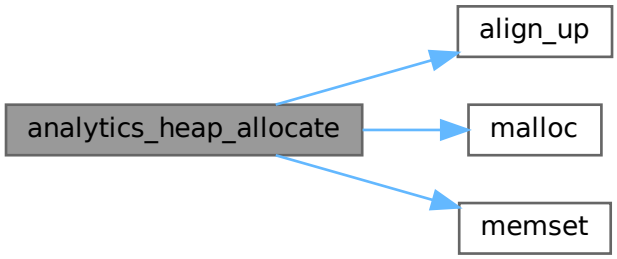
Returns

0 on success, -1 if allocation failed

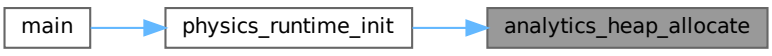
References align_up(), physics_runtime_state::backend_seq, base, physics_analytics_heap::base, bytes, physics_analytics_heap::bytes, physics_analytics_header::consume_seq, physics_analytics_header::dropped_events, physics_analytics_header::flags, g_runtime, physics_analytics_heap::header, physics_runtime_state::heap, physics_analytics_header::heap_bytes, physics_runtime_state::heap_ready, HOLA_PROTOCOL_MAJOR, HOLA_PROTOCOL_MINOR, HOLA_SHARED_MAGIC, physics_analytics_header::magic, malloc(), memset(), PHYSICS_ANALYTICS_DEFAULT_HEAP_BYTES, physics_analytics_header::produce_seq, physics_analytics_header::read_offset, physics_analytics_heap::ring, physics_analytics_header::ring_bytes, physics_analytics_heap::ring_bytes, physics_analytics_header::, physics_analytics_heap::scratch, physics_analytics_header::scratch_bytes, physics_analytics_heap::scratch_bytes, physics_analytics_header::scratch_offset, physics_analytics_heap::summary, physics_analytics_header::summary_bytes, physics_analytics_heap::summary_bytes, physics_analytics_header::summary_offset, physics_analytics_header::version_major, physics_analytics_header::version_minor, and physics_analytics_header::write_offset.

Referenced by physics_runtime_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.295.3.3 analytics_heap_release()

```
static void analytics_heap_release (
            void  )  [static]
```

Free the analytics heap and reset all global heap state.

Safe to call when the heap is not ready. After this call, `g_runtime.heap_ready` is 0 and the heap pointer is NULL.

References physics_runtime_state::backend_seq, physics_analytics_heap::base, free(), g_runtime, physics_runtime_state::heap, and physics_runtime_state::heap_ready.

Referenced by physics_runtime_shutdown().

Here is the call graph for this function:

Here is the caller graph for this function:

7.295.3.4 analytics_ring_free()

```
static size_t analytics_ring_free (
            const physics_analytics_header_t * hdr )  [static]
```

Compute free bytes available in the analytics ring buffer.

Assumes single-producer, single-consumer access with no concurrent writers. Clamps out-of-range `write_offset` and `read_offset` before computing.

Parameters

hdr	Pointer to the analytics heap header

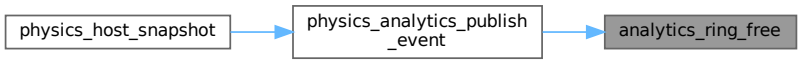
Returns

Number of free bytes available for a new event write

References physics_analytics_header::read_offset, physics_analytics_header::ring_bytes, and physics_analytics_header::write_offse

Referenced by physics_analytics_publish_event().

Here is the caller graph for this function:



7.295.3.5 parse_avg_milli()

```
static uint32_t parse_avg_milli (
            const char * line,
            const char * tag )  [static]
```

Parse a floating-point average field from a Linux PSI file line.

Searches `line` for `tag` (e.g. `"avg10="`), reads the following floating-point value, and returns it scaled to millipercentage (×1000). Returns 0 on parse failure or negative value.

Parameters

line	Raw text line from a `/proc/pressure/` PSI file (cpu, memory, or io)
tag	Field prefix to locate (e.g. `"avg10="`)

Returns

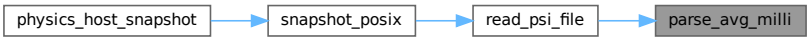
Scaled value in milli-units, or 0 on failure

References errno, and strlen().

Referenced by read_psi_file().

Here is the call graph for this function:

Here is the caller graph for this function:



7.295.3.6 physics_analytics_heap_info()

```
const physics_analytics_heap_t * physics_analytics_heap_info (
            void  )
```

Return a pointer to the live analytics heap descriptor.

Retrieve the analytics heap descriptor.

Returns

Pointer to the heap descriptor, or NULL if not yet initialised

References g_runtime, physics_runtime_state::heap, and physics_runtime_state::heap_ready.

7.295.3.7 physics_analytics_publish_event()

```
int physics_analytics_publish_event (
            uint32_t channel,
            const void * payload,
            uint16_t payload_bytes )
```

Publish an analytics event into the ring buffer.

Writes a `physics_analytics_event_header_t` followed by the payload (8-byte padded) into the ring at the current write offset. If insufficient space is available, increments `dropped_events` and returns -1. The event is timestamped with `sf_monotonic_ns()` at write time.

Parameters

channel	Event channel identifier (e.g. `PHYSICS_ANALYTICS_CHANNEL_HOST_SNAPSHOT`)
payload	Event payload bytes (must not be NULL)
payload_bytes	Length of payload in bytes

Returns

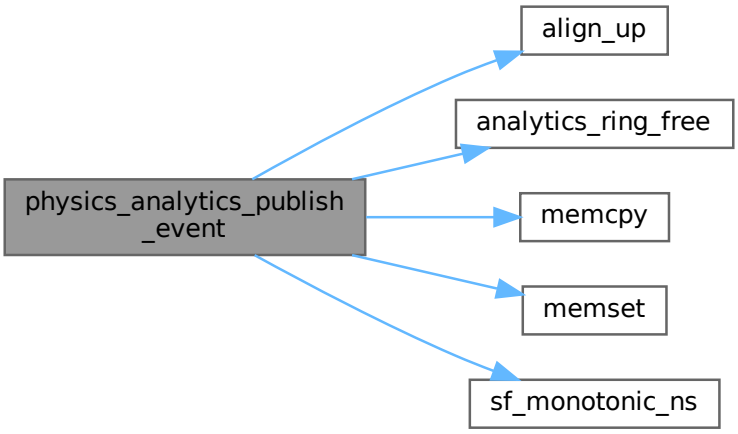
0 on success, -1 if the heap is not ready, payload is NULL, or ring is full

References align_up(), analytics_ring_free(), physics_analytics_event_header::channel, physics_analytics_header::dropped_events, g_runtime, physics_analytics_heap::header, physics_runtime_state::heap, physics_runtime_state::heap_ready, memcpy(), memset(), physics_analytics_event_header::payload_bytes, physics_analytics_header::produce_seq,

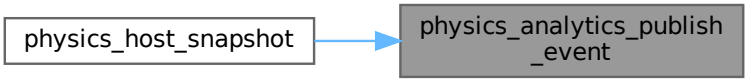
physics_analytics_event_header::reserved, ring, physics_analytics_heap::ring, physics_analytics_header::ring_bytes, sf_monotonic_ns(), physics_analytics_event_header::timestamp_ns, and physics_analytics_header::write_offset.

Referenced by physics_host_snapshot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.295.3.8 physics_host_snapshot()

```
int physics_host_snapshot (
            physics_host_snapshot_t * out )
```

Capture a host environment snapshot and publish it to the analytics ring.

Uses the POSIX backend. On success also publishes the snapshot as a PHYSICS_ANALYTICS_CHANNEL_↩ HOST_SNAPSHOT event to the analytics ring buffer (if the heap is initialised).

Parameters

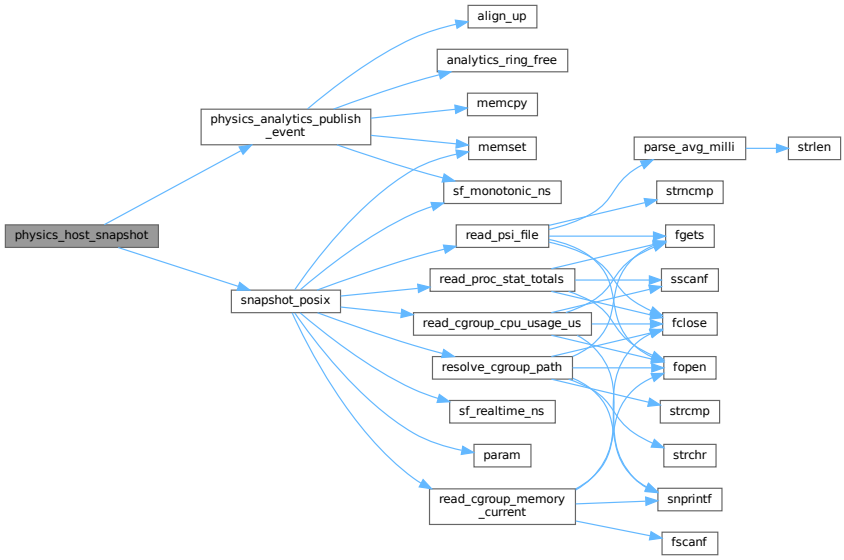
out	Output snapshot struct to populate (must not be NULL)

Returns

0 on success, -1 if `out` is NULL or the backend fails

References g_runtime, physics_runtime_state::heap_ready, PHYSICS_ANALYTICS_CHANNEL_HOST_SNAPSHOT, physics_analytics_publish_event(), and snapshot_posix().

Here is the call graph for this function:



7.295.3.9 physics_runtime_init()

```
int physics_runtime_init (
            size_t analytics_heap_bytes )
```

Initialise the physics runtime and analytics heap.

Must be called before any other physics_runtime_∗ function. Idempotent — safe to call multiple times; subsequent calls return 0 immediately without re-allocating.

Parameters

analytics_heap_bytes	Desired analytics heap size (0 = default)

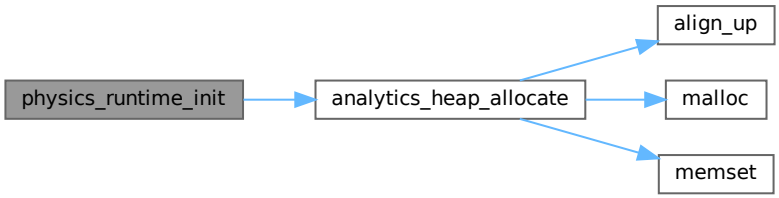
Returns

0 on success, -1 on allocation failure

References analytics_heap_allocate().

Referenced by main().

Here is the call graph for this function:



Here is the caller graph for this function:

7.295.3.10 physics_runtime_shutdown()

```
void physics_runtime_shutdown (
            void  )
```

Shut down the physics runtime and release the analytics heap.

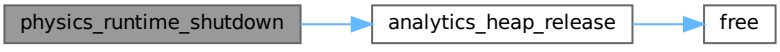
Tear down physics runtime services and release heap storage.

Safe to call when the runtime was never initialised. After this call the analytics heap is gone and no events can be published until `physics_runtime_init()` is called again.

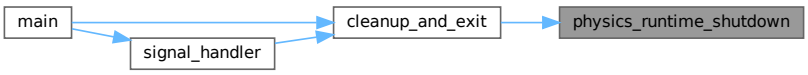
References analytics_heap_release().

Referenced by cleanup_and_exit().

Here is the call graph for this function:



Here is the caller graph for this function:



7.295.3.11 read_cgroup_cpu_usage_us()

```
static uint64_t read_cgroup_cpu_usage_us (
            const char * cgpath )  [static]
```

Read the cumulative CPU usage in microseconds from a cgroup's `cpu.stat`.

Opens <cgpath>/cpu.stat and extracts the `usage_usec` field. Returns 0 if the file cannot be opened or the field is absent.

Parameters

cgpath	Absolute path to the cgroup directory

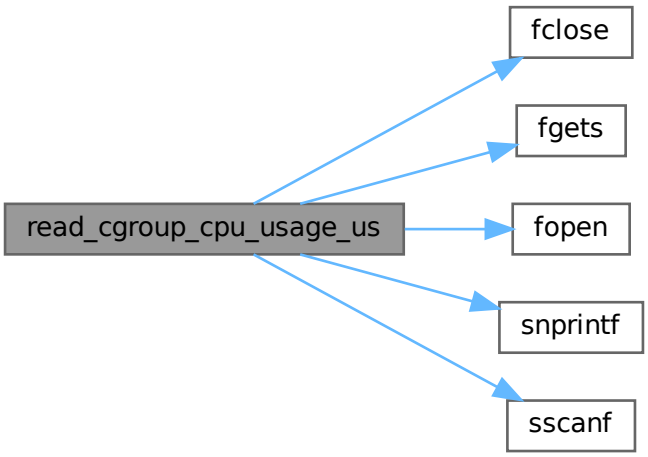
Returns

Cumulative CPU usage in microseconds, or 0 on failure

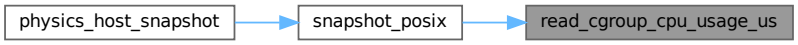
References fclose(), fgets(), fopen(), PATH_MAX, snprintf(), and sscanf().

Referenced by snapshot_posix().

Here is the call graph for this function:



Here is the caller graph for this function:



7.295.3.12 read_cgroup_memory_current()

```
static uint64_t read_cgroup_memory_current (
            const char * cgpath )  [static]
```

Read current memory usage in bytes from a cgroup's `memory.current`.

Opens <cgpath>/memory.current and reads the single integer value. Returns 0 if the file cannot be opened or parsed.

Parameters

cgpath	Absolute path to the cgroup directory

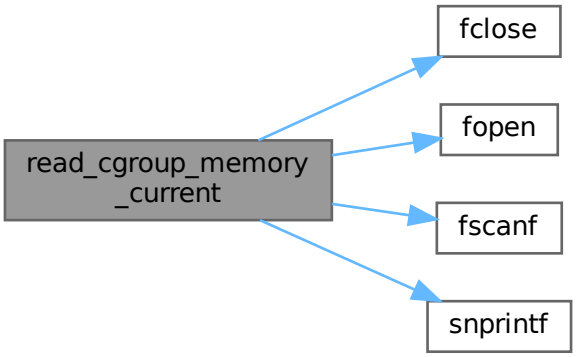
Returns

Current memory usage in bytes, or 0 on failure

References fclose(), fopen(), fscanf(), PATH_MAX, and snprintf().

Referenced by snapshot_posix().

Here is the call graph for this function:



Here is the caller graph for this function:

7.295.3.13 read_proc_stat_totals()

```
static int read_proc_stat_totals (
            uint64_t * total,
            uint64_t * idle )  [static]
```

Read aggregate CPU jiffy totals from `/proc/stat`.

Parses the first `cpu` line from `/proc/stat` and sums user, nice, system, idle, iowait, irq, softirq, and steal columns into `*total`. The idle estimate is `idle_j` + `iowait`. Either output pointer may be NULL.

Parameters

total	Output: total jiffy count across all categories
idle	Output: idle + iowait jiffies (effective idle)

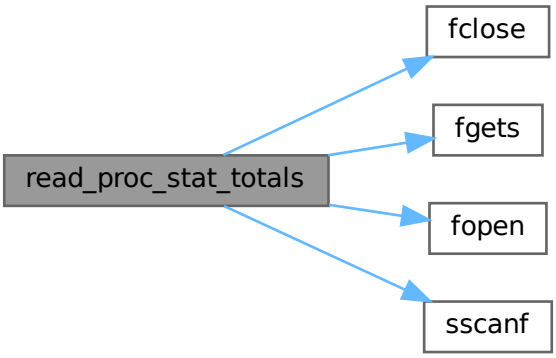
Returns

0 on success, -1 on file open or parse failure

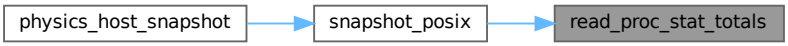
References fclose(), fgets(), fopen(), and sscanf().

Referenced by snapshot_posix().

Here is the call graph for this function:



Here is the caller graph for this function:



7.295.3.14 read_psi_file()

```
static int read_psi_file (
            const char * path,
            uint32_t * some10,
            uint32_t * some60,
            uint32_t * some300,
            uint32_t * full10,
            uint32_t * full60,
            uint32_t * full300 )  [static]
```

Read a Linux Pressure Stall Information (PSI) file.

Parses `/proc/pressure/{cpu,io,memory}` and populates the six output pointers with avg10/avg60/avg300 milli-values for both the `some` and `full` stall categories. Any output pointer may be NULL to skip that field. Returns a bitmask: bit 0 set if `some` line was found, bit 1 if `full`.

Parameters

path	Path to PSI file (e.g. `"/proc/pressure/cpu"`)
some10	avg10 for the `some` stall category (milli-units), or NULL
some60	avg60 for the `some` stall category, or NULL
some300	avg300 for the `some` stall category, or NULL
full10	avg10 for the `full` stall category, or NULL
full60	avg60 for the `full` stall category, or NULL
full300	avg300 for the `full` stall category, or NULL

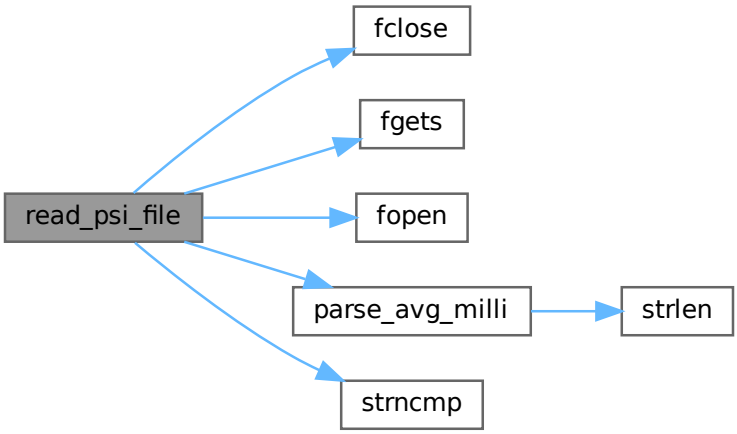
Returns

Bitmask of parsed sections (0 = none, 1 = some, 2 = full, 3 = both)

References fclose(), fgets(), fopen(), parse_avg_milli(), and strncmp().

Referenced by snapshot_posix().

Here is the call graph for this function:



Here is the caller graph for this function:

7.295.3.15 resolve_cgroup_path()

```
static int resolve_cgroup_path (
            char * out,
            size_t out_sz )  [static]
```

Resolve the cgroup v2 filesystem path for the current process.

Reads `/proc/self/cgroup`, finds the cgroup2 hierarchy entry (the line with `"::"` separator), and constructs the full sysfs path under `/sys/fs/cgroup`. The root cgroup ("/") maps to `/sys/fs/cgroup` itself.

Parameters

out	Output buffer for the resolved path
out_sz	Size of `out` in bytes

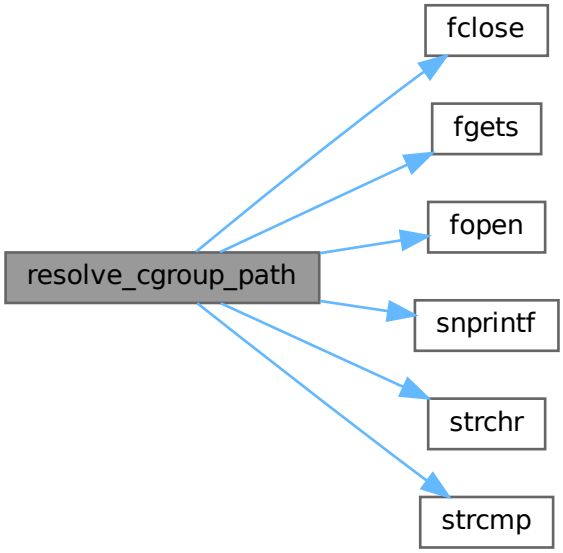
Returns

0 on success, -1 if the path could not be resolved

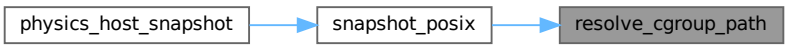
References fclose(), fgets(), fopen(), snprintf(), strchr(), and strcmp().

Referenced by snapshot_posix().

Here is the call graph for this function:



Here is the caller graph for this function:



7.295.3.16 snapshot_posix()

```
static int snapshot_posix (
            physics_host_snapshot_t * out )  [static]
```

Collect a host system snapshot using POSIX / Linux interfaces.

Populates `out` with monotonic and realtime timestamps, CPU count, scheduler policy and priority, load average (scaled × 1000), runnable thread estimate, PSI pressure readings, `/proc/stat` CPU jiffy totals, and cgroup v2 CPU usage and memory current values. Sets flags in `out->flags` to indicate which fields were successfully populated.

Parameters

out	Output snapshot struct; zeroed and populated by this function

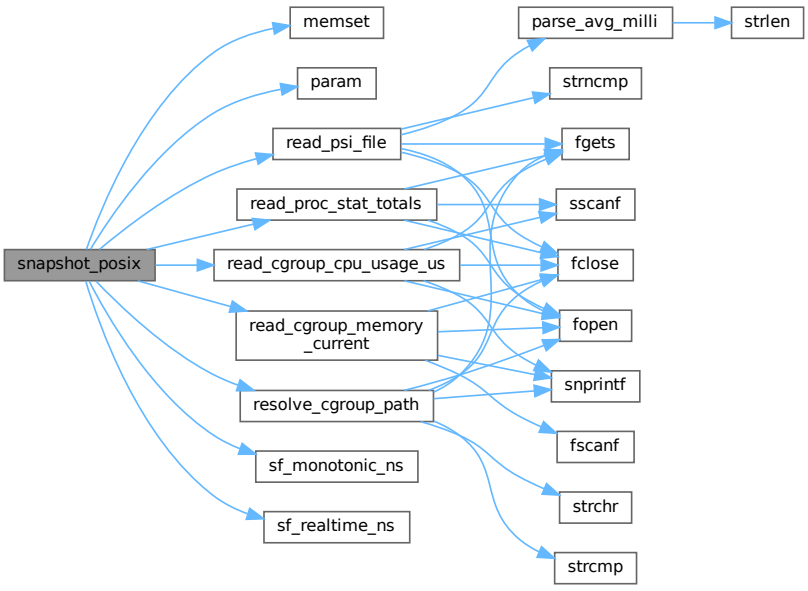
Returns

0 on success

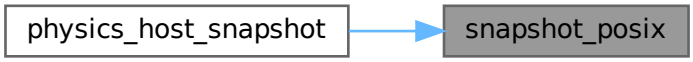
References physics_host_snapshot::backend, physics_host_snapshot::backend_seq, physics_runtime_state::backend_seq, physics_host_snapshot::cgroup_cpu_usage_us, physics_host_snapshot::cgroup_memory_current_bytes, physics_host_snapshot::cp physics_host_snapshot::cpu_idle_jiffies, physics_host_snapshot::cpu_total_jiffies, physics_host_snapshot::flags, g_runtime, physics_host_snapshot::load_avg_milli, memset(), physics_host_snapshot::monotonic_time_ns, param(), PATH_MAX, PHYSICS_HOST_BACKEND_POSIX, PHYSICS_HOST_FLAG_CGROUP, PHYSICS_HOST_FLAG_CPU_ST PHYSICS_HOST_FLAG_PSI, physics_host_snapshot::psi_cpu_full_avg10_milli, physics_host_snapshot::psi_cpu_full_avg300_milli, physics_host_snapshot::psi_cpu_full_avg60_milli, physics_host_snapshot::psi_cpu_some_avg10_milli, physics_host_snapshot::psi_ physics_host_snapshot::psi_cpu_some_avg60_milli, physics_host_snapshot::psi_io_full_avg10_milli, physics_host_snapshot::psi_io physics_host_snapshot::psi_io_full_avg60_milli, physics_host_snapshot::psi_io_some_avg10_milli, physics_host_snapshot::psi_io_s physics_host_snapshot::psi_io_some_avg60_milli, physics_host_snapshot::psi_mem_some_avg10_milli, physics_host_snapshot::ps physics_host_snapshot::psi_mem_some_avg60_milli, read_cgroup_cpu_usage_us(), read_cgroup_memory_current(), read_proc_stat_totals(), read_psi_file(), physics_host_snapshot::realtime_ns, resolve_cgroup_path(), physics_host_snapshot::runnab physics_host_snapshot::scheduler_policy, physics_host_snapshot::scheduler_priority, physics_host_snapshot::scheduler_quantum_ sf_monotonic_ns(), sf_realtime_ns(), timespec::tv_nsec, and timespec::tv_sec.

Referenced by physics_host_snapshot().

Here is the call graph for this function:



Here is the caller graph for this function:



7.295.4 Variable Documentation

7.295.4.1 g_runtime

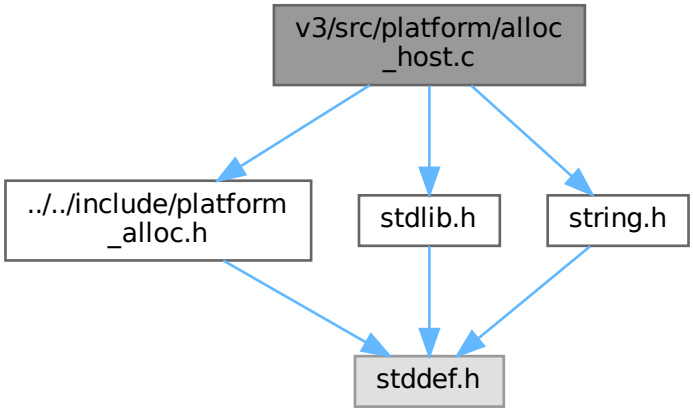
```
physics_runtime_state_t g_runtime = {0}  [static]
```

Referenced by analytics_heap_allocate(), analytics_heap_release(), physics_analytics_heap_info(), physics_analytics_publish_event(), physics_host_snapshot(), and snapshot_posix().

7.296 v3/src/platform/alloc_host.c File Reference

```
#include "../../include/platform_alloc.h"
#include <stdlib.h>
#include <string.h>
```

Include dependency graph for alloc_host.c:



Functions

- int sf_alloc_init (void)

  Initialise the host allocator statistics.
- void * sf_malloc (size_t size)

  Allocate `size` bytes from the system heap.
- void * sf_calloc (size_t count, size_t size)

  Allocate a zero-initialised array of `count` elements of `size` bytes each.
- void * sf_realloc (void *ptr, size_t new_size)

  Resize a previously allocated block to `new_size` bytes.
- void sf_free (void *ptr)

  Release a previously allocated block back to the system heap.
- void sf_alloc_get_stats (sf_alloc_stats_t *stats)

  Copy the current allocator statistics into `stats`.

Variables

- static sf_alloc_stats_t g_stats = {0}

7.296.1 Function Documentation

7.296.1.1 sf_alloc_get_stats()

```
void sf_alloc_get_stats (
            sf_alloc_stats_t * stats )
```

Copy the current allocator statistics into `stats`.

Fills `*stats` with a snapshot of `g_stats`. Note that `used_bytes` overstates the live total when blocks have been freed or reallocated, because freed sizes are not tracked. `free_count` is accurate.

Parameters

stats	Output buffer to populate; no-op if NULL

7.296.1.2 sf_alloc_init()

```
int sf_alloc_init (
            void  )
```

Initialise the host allocator statistics.

Resets the `g_stats` struct to zero. Safe to call multiple times; subsequent calls simply reset the counters. No heap memory is allocated by this function — the underlying allocator is the system `malloc`.

Returns

0 always (cannot fail on the hosted path)

7.296.1.3 sf_calloc()

```
void * sf_calloc (
            size_t count,
            size_t size )
```

Allocate a zero-initialised array of `count` elements of `size` bytes each.

Delegates to `calloc()`. Updates statistics the same way as `sf_malloc()`: adds `count*size` to `used_bytes`, increments `alloc_count`, and updates `peak_bytes`.

Parameters

count	Number of elements; 0 returns NULL
size	Size of each element in bytes; 0 returns NULL

Returns

Pointer to zero-filled memory, or NULL on allocation failure or zero arguments

7.296.1.4 sf_free()

```
void sf_free (
            void * ptr )
```

Release a previously allocated block back to the system heap.

Delegates to `free()`. Increments `g_stats.free_count` on non-NULL `ptr`. The freed byte count is not subtracted from `used_bytes` because the original size is not tracked — see `sf_realloc()` note.

Parameters

ptr	Pointer to free; NULL is a safe no-op

7.296.1.5 sf_malloc()

```
void * sf_malloc (
            size_t size )
```

Allocate `size` bytes from the system heap.

Delegates to `malloc()`. On success, increments `g_stats.used_bytes` and `g_stats.alloc_count`, and updates `g_stats.peak_bytes` if the new used total exceeds the recorded peak.

Parameters

size	Number of bytes to allocate; 0 returns NULL

Returns

Pointer to allocated memory, or NULL on allocation failure or zero size

7.296.1.6 sf_realloc()

```
void * sf_realloc (
            void * ptr,
            size_t new_size )
```

Resize a previously allocated block to `new_size` bytes.

Delegates to `realloc()`. On success, increments `g_stats.alloc_count`. The exact byte delta is not tracked because the original allocation size is not stored alongside the pointer — `used_bytes` is therefore approximate after any `sf_realloc()` call. For accurate accounting, wrap allocations with size-tracking headers.

Parameters

ptr	Pointer to an existing allocation, or NULL (behaves like `sf_malloc`)
new_size	Desired new size in bytes; 0 may free the block (platform-defined)

Returns

Pointer to resized memory, or NULL on failure (original block unchanged)

7.296.2 Variable Documentation

7.296.2.1 g_stats

```
sf_alloc_stats_t g_stats = {0}  [static]
```

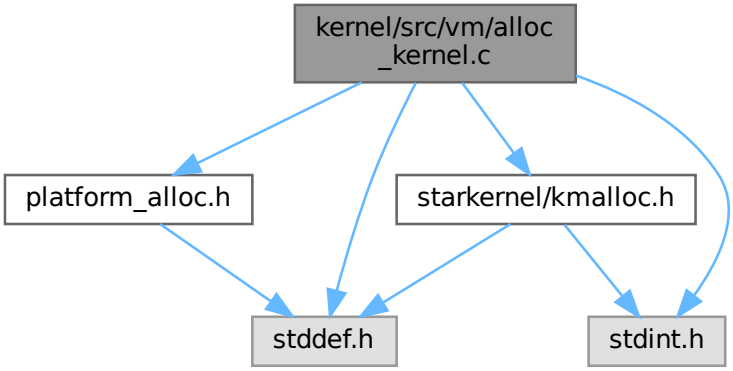
Referenced by sf_alloc_get_stats(), sf_alloc_init(), sf_calloc(), sf_free(), sf_malloc(), and sf_realloc().

7.297 kernel/src/vm/alloc_kernel.c File Reference

```
#include "platform_alloc.h"
#include "starkernel/kmalloc.h"
#include <stdint.h>
```

```
#include <stddef.h>
```

Include dependency graph for alloc_kernel.c:



Macros

- #define SF_ALIGN 8

Functions

- int sf_alloc_init (void)

  No-op: kept only for API compatibility with `platform_alloc.h`.
- void * sf_malloc (size_t size)

  Allocate `size` bytes from the system heap.
- void * sf_calloc (size_t count, size_t size)

  Allocate a zero-initialised array of `count` elements of `size` bytes each.
- void * sf_realloc (void *ptr, size_t new_size)

  Resize a previously allocated block to `new_size` bytes.
- void sf_free (void *ptr)

  Release a previously allocated block back to the system heap.
- void sf_alloc_get_stats (sf_alloc_stats_t *stats)

  Copy the current allocator statistics into `stats`.

Variables

- static size_t g_alloc_count = 0
- static size_t g_free_count = 0

7.297.1 Macro Definition Documentation

7.297.1.1 SF_ALIGN

```
#define SF_ALIGN 8
```

7.297.2 Function Documentation

7.297.2.1 sf_alloc_get_stats()

```
void sf_alloc_get_stats (
            sf_alloc_stats_t * stats )
```

Copy the current allocator statistics into `stats`.

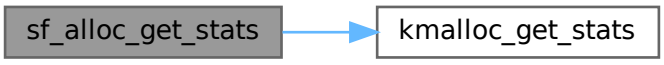
Fills `*stats` with a snapshot of `g_stats`. Note that `used_bytes` overstates the live total when blocks have been freed or reallocated, because freed sizes are not tracked. `free_count` is accurate.

Parameters

stats	Output buffer to populate; no-op if NULL

References sf_alloc_stats::alloc_count, sf_alloc_stats::free_count, g_alloc_count, g_free_count, g_stats, kmalloc_get_stats(), kmalloc_stats_t::peak_bytes, sf_alloc_stats::peak_bytes, kmalloc_stats_t::total_bytes, sf_alloc_stats::total_bytes, kmalloc_stats_t::used_bytes, and sf_alloc_stats::used_bytes.

Here is the call graph for this function:



7.297.2.2 sf_alloc_init()

```
int sf_alloc_init (
            void  )
```

No-op: kept only for API compatibility with `platform_alloc.h`.

Initialise the host allocator statistics.

The backing store is now the shared kernel heap (`kmalloc.c`), already initialised at boot (M6) well before any VM allocation can occur – there is nothing left for this function to set up, and "resetting" a heap shared by every other kernel subsystem would be actively wrong. Kept callable (matches its documented "safe to call at any point" contract) so no caller needs to change.

Returns

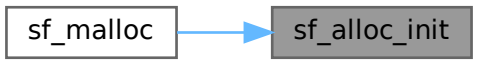
0 always (cannot fail)

References g_stats, and memset().

Referenced by sf_malloc().

Here is the call graph for this function:

Here is the caller graph for this function:



7.297.2.3 sf_calloc()

```
void * sf_calloc (
            size_t count,
            size_t size )
```

Allocate a zero-initialised array of `count` elements of `size` bytes each.

Delegates to `calloc()`. Updates statistics the same way as `sf_malloc()`: adds `count*size` to `used_bytes`, increments `alloc_count`, and updates `peak_bytes`.

Parameters

count	Number of elements; 0 returns NULL
size	Size of each element in bytes; 0 returns NULL

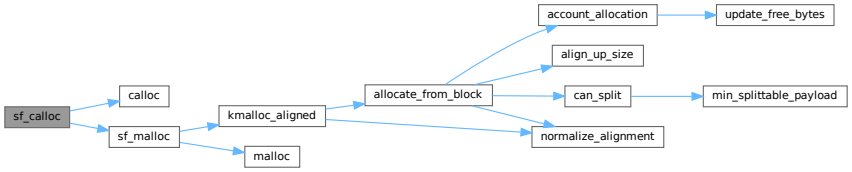
Returns

Pointer to zero-filled memory, or NULL on allocation failure or zero arguments

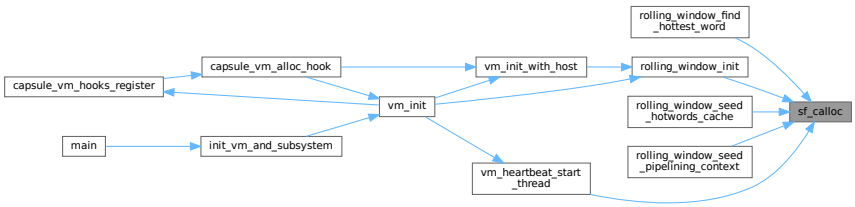
References sf_alloc_stats::alloc_count, calloc(), count, g_stats, sf_alloc_stats::peak_bytes, sf_malloc(), and sf_alloc_stats::used_bytes.

Referenced by rolling_window_find_hottest_word(), rolling_window_init(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), and vm_heartbeat_start_thread().

Here is the call graph for this function:



Here is the caller graph for this function:



7.297.2.4 sf_free()

```
void sf_free (
            void * ptr )
```

Release a previously allocated block back to the system heap.

Delegates to `free()`. Increments `g_stats.free_count` on non-NULL `ptr`. The freed byte count is not subtracted from `used_bytes` because the original size is not tracked — see `sf_realloc()` note.

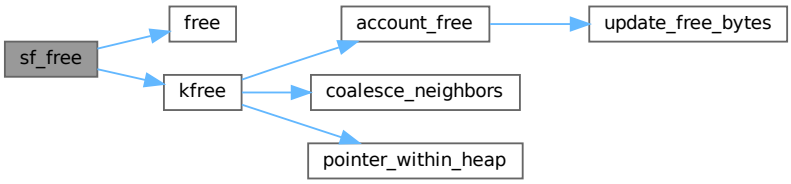
Parameters

ptr	Pointer to free; NULL is a safe no-op

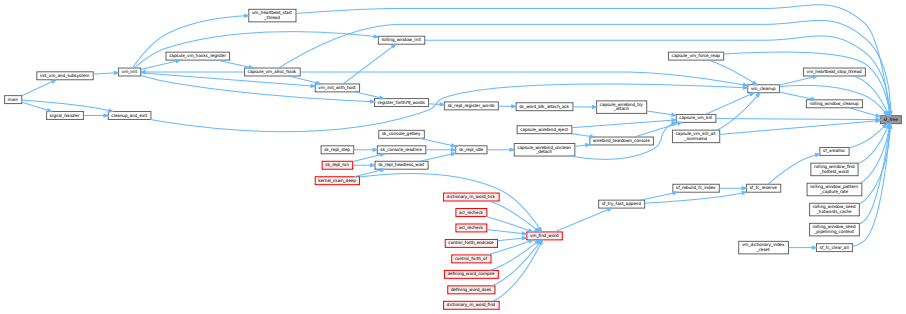
References free(), sf_alloc_stats::free_count, g_free_count, g_stats, and kfree().

Referenced by capsule_vm_alloc_hook(), capsule_vm_force_reap(), capsule_vm_kill(), capsule_vm_kill_all_nonmama(), rolling_window_cleanup(), rolling_window_find_hottest_word(), rolling_window_init(), rolling_window_pattern_capture_rate(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), sf_fc_clear_all(), sf_xrealloc(), vm_cleanup(), vm_heartbeat_start_thread(), and vm_heartbeat_stop_thread().

Here is the call graph for this function:



Here is the caller graph for this function:



7.297.2.5 sf_malloc()

```
void * sf_malloc (
            size_t size )
```

Allocate `size` bytes from the system heap.

Delegates to `malloc()`. On success, increments `g_stats.used_bytes` and `g_stats.alloc_count`, and updates `g_stats.peak_bytes` if the new used total exceeds the recorded peak.

Parameters

size	Number of bytes to allocate; 0 returns NULL

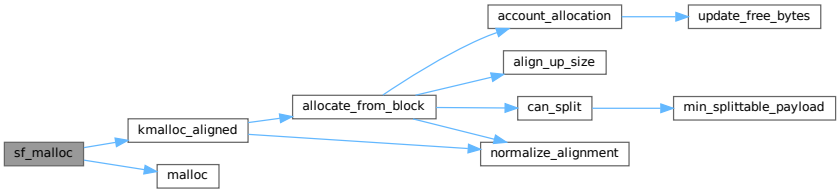
Returns

Pointer to allocated memory, or NULL on allocation failure or zero size

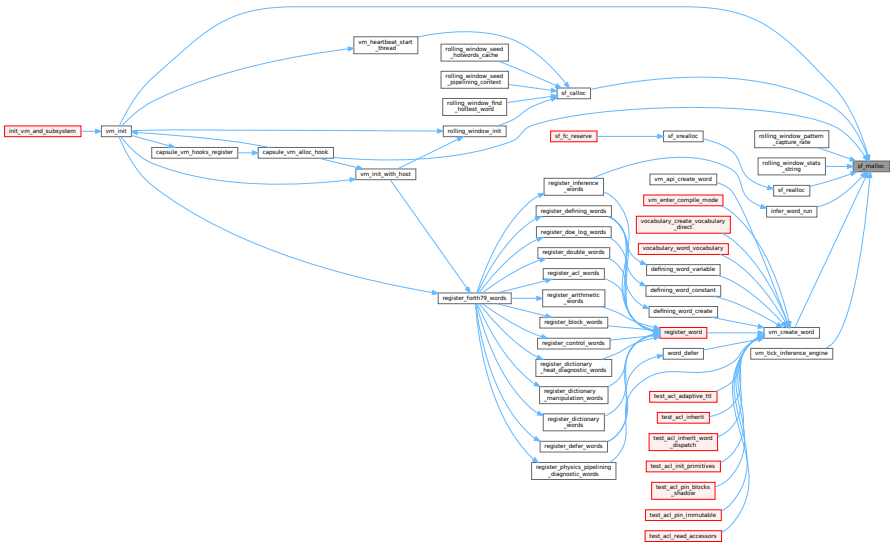
References sf_alloc_stats::alloc_count, g_alloc_count, g_stats, kmalloc_aligned(), malloc(), sf_alloc_stats::peak_bytes, SF_ALIGN, and sf_alloc_stats::used_bytes.

Referenced by capsule_vm_alloc_hook(), infer_word_run(), rolling_window_pattern_capture_rate(), rolling_window_stats_string(), sf_calloc(), sf_realloc(), vm_create_word(), vm_init(), and vm_tick_inference_engine().

Here is the call graph for this function:



Here is the caller graph for this function:



7.297.2.6 sf_realloc()

```
void * sf_realloc (
            void * ptr,
            size_t new_size )
```

Resize a previously allocated block to `new_size` bytes.

Delegates to `realloc()`. On success, increments `g_stats.alloc_count`. The exact byte delta is not tracked because the original allocation size is not stored alongside the pointer — `used_bytes` is therefore approximate after any `sf_realloc()` call. For accurate accounting, wrap allocations with size-tracking headers.

Parameters

ptr	Pointer to an existing allocation, or NULL (behaves like `sf_malloc`)
new_size	Desired new size in bytes; 0 may free the block (platform-defined)

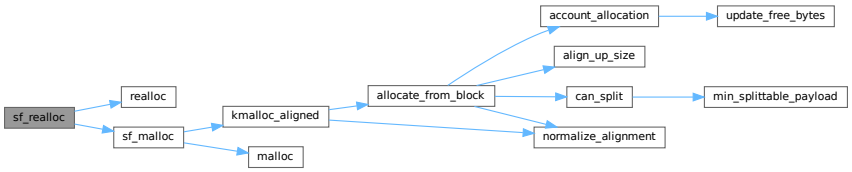
Returns

Pointer to resized memory, or NULL on failure (original block unchanged)

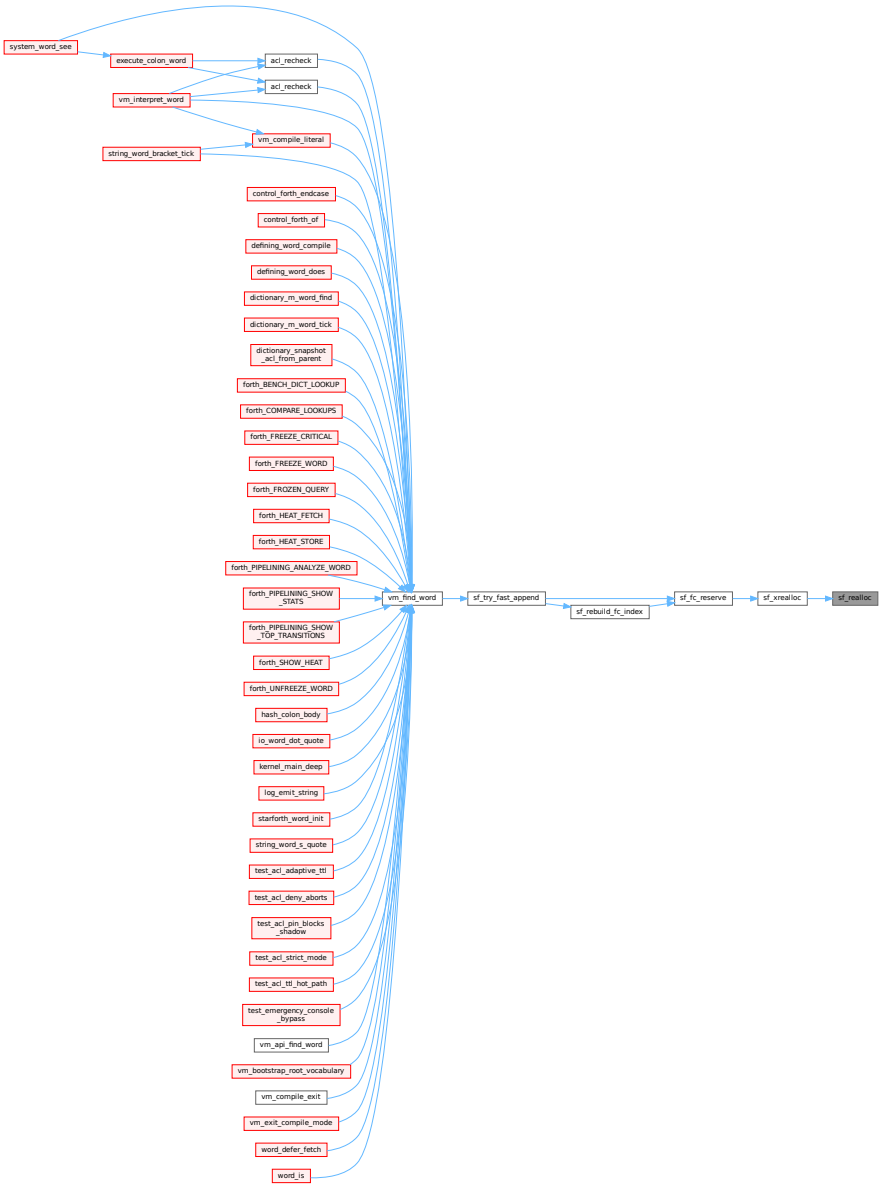
References sf_alloc_stats::alloc_count, g_stats, realloc(), and sf_malloc().

Referenced by sf_xrealloc().

Here is the call graph for this function:



Here is the caller graph for this function:



7.297.3 Variable Documentation

7.297.3.1 g_alloc_count

```
size_t g_alloc_count = 0  [static]
```

Referenced by sf_alloc_get_stats(), and sf_malloc().

7.297.3.2 g_free_count

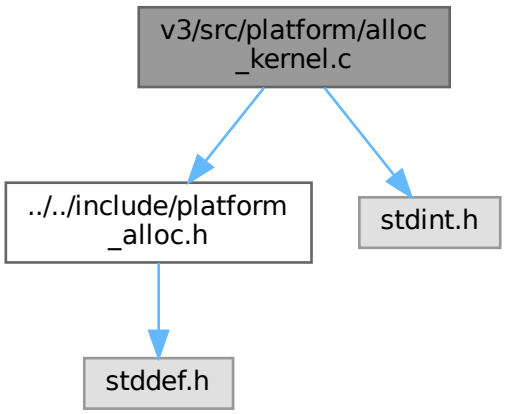
```
size_t g_free_count = 0  [static]
```

Referenced by sf_alloc_get_stats(), and sf_free().

7.298 v3/src/platform/alloc_kernel.c File Reference

```
#include "../../include/platform_alloc.h"
#include <stdint.h>
```

Include dependency graph for alloc_kernel.c:



Macros

- #define SF_ARENA_SIZE (4 ∗ 1024 ∗ 1024) /∗ 4MB default ∗/
- #define SF_ALIGN 8
- #define SF_ALIGN_UP(x) (((x) + (SF_ALIGN - 1)) & ∼(SF_ALIGN - 1))

Functions

- int sf_alloc_init (void)

  Initialise the kernel bump allocator.
- void ∗ sf_malloc (size_t size)

  Allocate `size` bytes from the system heap.
- void ∗ sf_calloc (size_t count, size_t size)

  Allocate a zero-initialised array of `count` elements of `size` bytes each.
- void ∗ sf_realloc (void ∗ptr, size_t new_size)

  Resize a previously allocated block to `new_size` bytes.
- void sf_free (void ∗ptr)

  Release a previously allocated block back to the system heap.
- void sf_alloc_get_stats (sf_alloc_stats_t ∗stats)

  Copy the current allocator statistics into `stats`.

Variables

- static uint8_t g_arena[(4 ∗1024 ∗1024) __attribute__)((aligned(8)))
- static size_t g_arena_offset = 0
- static int g_initialized = 0
- static sf_alloc_stats_t g_stats = {0}

7.298.1 Macro Definition Documentation

7.298.1.1 SF_ALIGN

```
#define SF_ALIGN 8
```

7.298.1.2 SF_ALIGN_UP

```
#define SF_ALIGN_UP(
              x ) (((x) + (SF_ALIGN - 1)) & ~(SF_ALIGN - 1))
```

7.298.1.3 SF_ARENA_SIZE

```
#define SF_ARENA_SIZE (4 * 1024 * 1024) /* 4MB default */
```

7.298.2 Function Documentation

7.298.2.1 sf_alloc_get_stats()

```
void sf_alloc_get_stats (
             sf_alloc_stats_t * stats )
```

Copy the current allocator statistics into `stats`.

Fills `*stats` with a snapshot of `g_stats`. Note that `used_bytes` overstates the live total when blocks have been freed or reallocated, because freed sizes are not tracked. `free_count` is accurate.

Parameters

stats	Output buffer to populate; no-op if NULL

References g_stats.

7.298.2.2 sf_alloc_init()

```
int sf_alloc_init (
             void  )
```

Initialise the kernel bump allocator.

Initialise the host allocator statistics.

Resets `g_arena_offset` to zero and clears all `g_stats` fields. Sets `g_initialized` so that `sf_malloc()` skips the lazy-init guard. Safe to call at any point; all prior allocations become invalid after a reset, so this must only be called before any VM allocation takes place.

Returns

0 always (cannot fail)

References sf_alloc_stats::alloc_count, sf_alloc_stats::free_count, g_arena_offset, g_initialized, g_stats, sf_alloc_stats::peak_bytes, SF_ARENA_SIZE, sf_alloc_stats::total_bytes, and sf_alloc_stats::used_bytes.

7.298.2.3 sf_calloc()

```
void * sf_calloc (
            size_t count,
            size_t size )
```

Allocate a zero-initialised array of `count` elements of `size` bytes each.

Delegates to `calloc()`. Updates statistics the same way as `sf_malloc()`: adds `count*size` to `used_bytes`, increments `alloc_count`, and updates `peak_bytes`.

Parameters

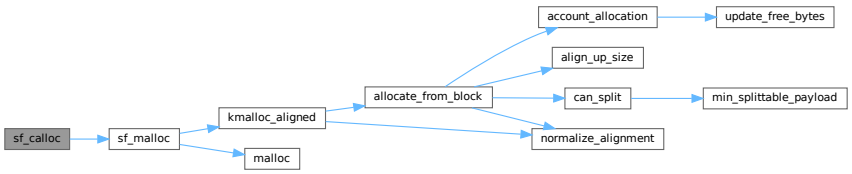
count	Number of elements; 0 returns NULL
size	Size of each element in bytes; 0 returns NULL

Returns

Pointer to zero-filled memory, or NULL on allocation failure or zero arguments

References count, and sf_malloc().

Here is the call graph for this function:



7.298.2.4 sf_free()

```
void sf_free (
            void * ptr )
```

Release a previously allocated block back to the system heap.

Delegates to `free()`. Increments `g_stats.free_count` on non-NULL `ptr`. The freed byte count is not subtracted from `used_bytes` because the original size is not tracked — see `sf_realloc()` note.

Parameters

ptr	Pointer to free; NULL is a safe no-op

References sf_alloc_stats::free_count, and g_stats.

7.298.2.5 sf_malloc()

```
void * sf_malloc (
            size_t size )
```

Allocate `size` bytes from the system heap.

Delegates to `malloc()`. On success, increments `g_stats.used_bytes` and `g_stats.alloc_count`, and updates `g_stats.peak_bytes` if the new used total exceeds the recorded peak.

Parameters

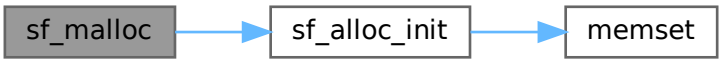
size	Number of bytes to allocate; 0 returns NULL

Returns

Pointer to allocated memory, or NULL on allocation failure or zero size

References sf_alloc_stats::alloc_count, g_arena_offset, g_initialized, g_stats, sf_alloc_stats::peak_bytes, SF_ALIGN_UP, sf_alloc_init(), SF_ARENA_SIZE, and sf_alloc_stats::used_bytes.

Here is the call graph for this function:



7.298.2.6 sf_realloc()

```
void * sf_realloc (
            void * ptr,
            size_t new_size )
```

Resize a previously allocated block to `new_size` bytes.

Delegates to `realloc()`. On success, increments `g_stats.alloc_count`. The exact byte delta is not tracked because the original allocation size is not stored alongside the pointer — `used_bytes` is therefore approximate after any `sf_realloc()` call. For accurate accounting, wrap allocations with size-tracking headers.

Parameters

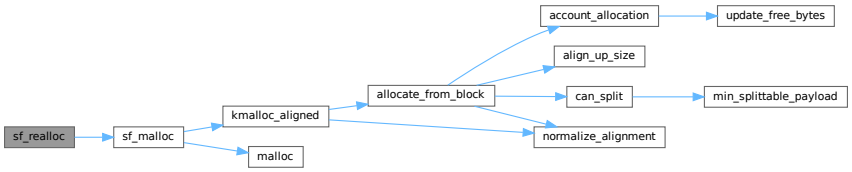
ptr	Pointer to an existing allocation, or NULL (behaves like `sf_malloc`)
new_size	Desired new size in bytes; 0 may free the block (platform-defined)

Returns

Pointer to resized memory, or NULL on failure (original block unchanged)

References sf_malloc().

Here is the call graph for this function:



7.298.3 Variable Documentation

7.298.3.1 __attribute__

```
uint8_t g_arena[(4 *1024 *1024) __attribute__) ((aligned(8))) (
            (aligned(8))  )  [static]
```

7.298.3.2 g_arena_offset

```
size_t g_arena_offset = 0  [static]
```

Referenced by sf_alloc_init(), and sf_malloc().

7.298.3.3 g_initialized

```
int g_initialized = 0  [static]
```

Referenced by sf_alloc_init(), and sf_malloc().

7.298.3.4 g_stats

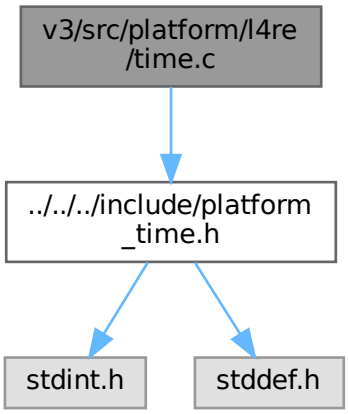
```
sf_alloc_stats_t g_stats = {0}  [static]
```

Referenced by sf_alloc_get_stats(), sf_alloc_init(), sf_free(), and sf_malloc().

7.299 v3/src/platform/l4re/time.c File Reference

```
#include "../../../include/platform_time.h"
```

Include dependency graph for time.c:



Functions

- void sf_time_init_l4re (void)

Variables

- const sf_time_backend_t sf_time_backend_l4re = {0}

7.299.1 Function Documentation

7.299.1.1 sf_time_init_l4re()

```
void sf_time_init_l4re (
            void  )
```

7.299.2 Variable Documentation

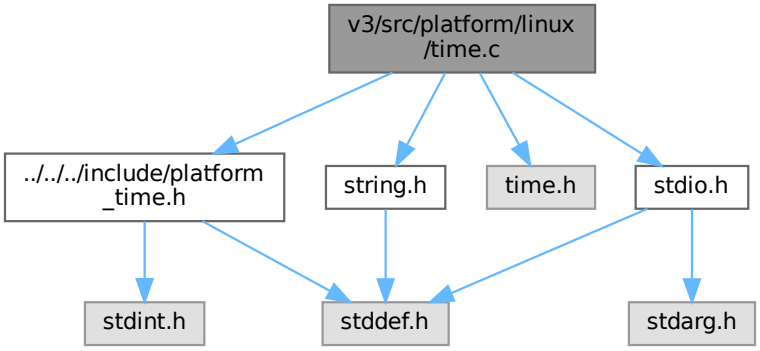
7.299.2.1 sf_time_backend_l4re

```
const sf_time_backend_t sf_time_backend_l4re = {0}
```

7.300 v3/src/platform/linux/time.c File Reference

```
#include "../../../include/platform_time.h"
#include <stdio.h>
#include <time.h>
#include <string.h>
```

Include dependency graph for time.c:



Macros

- #define _POSIX_C_SOURCE 199309L

Functions

- static sf_time_ns_t posix_get_monotonic_ns (void)

  Return the current monotonic time in nanoseconds.
- static sf_time_ns_t posix_get_realtime_ns (void)

  Return the current wall-clock time in nanoseconds since the Unix epoch.
- static int posix_set_realtime_ns (sf_time_ns_t ns_since_epoch)

  Set the system real-time clock to `ns_since_epoch`.
- static int posix_format_timestamp (sf_time_ns_t ns_since_epoch, char ∗buf, int format_24h)

  Format a nanosecond-precision wall-clock time as a human-readable string.
- static int posix_has_rtc (void)

  Probe whether a real-time clock is available.

Variables

- const sf_time_backend_t sf_time_backend_posix

7.300.1 Macro Definition Documentation

7.300.1.1 _POSIX_C_SOURCE

```
#define _POSIX_C_SOURCE 199309L
```

7.300.2 Function Documentation

7.300.2.1 posix_format_timestamp()

```
static int posix_format_timestamp (
            sf_time_ns_t ns_since_epoch,
            char * buf,
            int format_24h )  [static]
```

Format a nanosecond-precision wall-clock time as a human-readable string.

Converts `ns_since_epoch` to local time, formats hours/minutes/seconds via `strftime()`, then appends a three-digit millisecond suffix. The result is written into `buf` (must be at least `SF_TIME_STAMP_SIZE` bytes). On `localtime()` or `strftime()` failure, writes `"??:??:??.???"` into `buf` and returns -1.

Parameters

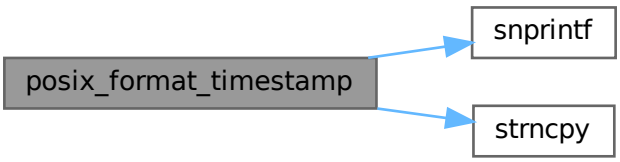
ns_since_epoch	Wall-clock time in nanoseconds since Unix epoch
buf	Output buffer (at least `SF_TIME_STAMP_SIZE` bytes); must not be NULL
format_24h	Non-zero for 24-hour format (`H`:M:S), zero for 12-hour (`I`:M:S p)

Returns

0 on success, -1 if `buf` is NULL or time formatting fails

References SF_TIME_STAMP_SIZE, snprintf(), and strncpy().

Here is the call graph for this function:



7.300.2.2 posix_get_monotonic_ns()

```
static sf_time_ns_t posix_get_monotonic_ns (
            void  )  [static]
```

Return the current monotonic time in nanoseconds.

Reads `CLOCK_MONOTONIC` via `clock_gettime()`. The clock advances continuously and is unaffected by wall-clock adjustments — suitable for measuring elapsed durations such as execution latency and decay intervals. Returns 0 on `clock_gettime()` failure (should not occur on any modern POSIX kernel).

Returns

Nanoseconds since an arbitrary but fixed epoch, or 0 on error

References timespec::tv_nsec, and timespec::tv_sec.

7.300.2.3 posix_get_realtime_ns()

```
static sf_time_ns_t posix_get_realtime_ns (
            void  )  [static]
```

Return the current wall-clock time in nanoseconds since the Unix epoch.

Reads CLOCK_REALTIME via clock_gettime(). Subject to NTP or settimeofday() adjustments — use posix_get_monotonic_ns() for interval timing. Returns 0 on clock_gettime() failure.

Returns

Nanoseconds since 1970-01-01 00:00:00 UTC, or 0 on error

References timespec::tv_nsec, and timespec::tv_sec.

7.300.2.4 posix_has_rtc()

```
static int posix_has_rtc (
            void  )  [static]
```

Probe whether a real-time clock is available.

Attempts a clock_gettime(CLOCK_REALTIME) probe. POSIX systems invariably support CLOCK_↩ REALTIME so this will return 1 in practice; the check mirrors the bare-metal backend's interface where RTC presence is genuinely uncertain.

Returns

1 if CLOCK_REALTIME is readable, 0 otherwise

7.300.2.5 posix_set_realtime_ns()

```
static int posix_set_realtime_ns (
            sf_time_ns_t ns_since_epoch )  [static]
```

Set the system real-time clock to ns_since_epoch.

Converts ns_since_epoch to a struct timespec and calls clock_settime(CLOCK_REALTIME). Requires CAP_SYS_TIME or equivalent privilege; fails with EPERM if the caller lacks permission.

Parameters

ns_since_epoch	Desired new wall-clock time in nanoseconds since Unix epoch

Returns

0 on success, non-zero errno-encoded error on failure

References timespec::tv_nsec, and timespec::tv_sec.

7.300.3 Variable Documentation

7.300.3.1 sf_time_backend_posix

```
const sf_time_backend_t sf_time_backend_posix
```

Initial value:

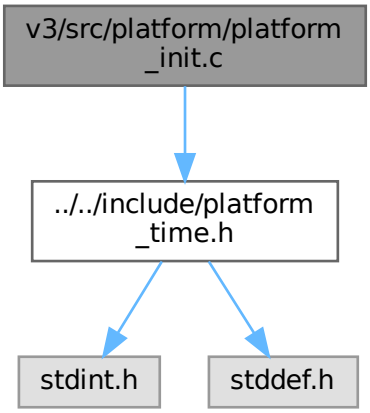
```
= {
    .get_monotonic_ns = posix_get_monotonic_ns,
    .get_realtime_ns = posix_get_realtime_ns,
    .set_realtime_ns = posix_set_realtime_ns,
    .format_timestamp = posix_format_timestamp,
    .has_rtc = posix_has_rtc,
}
```

Referenced by sf_time_init().

7.301 v3/src/platform/platform_init.c File Reference

```
#include "../../include/platform_time.h"
```

Include dependency graph for platform_init.c:



Functions

- void sf_time_init (void)

  Initialize platform time subsystem.

Variables

- const sf_time_backend_t * sf_time_backend = NULL

7.301.1 Function Documentation

7.301.1.1 sf_time_init()

```
void sf_time_init (
            void  )
```

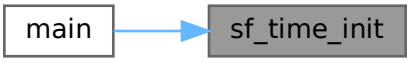
Initialize platform time subsystem.

Selects the POSIX backend (clock_gettime()). Call this once at program startup before using any time functions.

References sf_time_backend, and sf_time_backend_posix.

Referenced by main().

Here is the caller graph for this function:



7.301.2 Variable Documentation

7.301.2.1 sf_time_backend

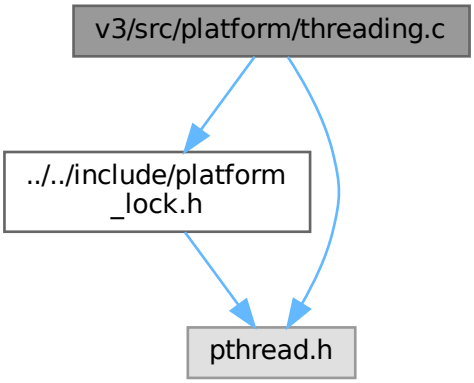
```
const sf_time_backend_t* sf_time_backend = NULL
```

Referenced by sf_format_timestamp(), sf_has_rtc(), sf_monotonic_ns(), sf_realtime_ns(), sf_set_realtime_ns(), and sf_time_init().

7.302 v3/src/platform/threading.c File Reference

```
#include "../../include/platform_lock.h"
#include <pthread.h>
```

Include dependency graph for threading.c:



Functions

- int sf_mutex_init (sf_mutex_t *mutex)

  Initialise a POSIX mutex (hosted build).
- void sf_mutex_destroy (sf_mutex_t *mutex)

  Destroy a POSIX mutex (hosted build).
- void sf_mutex_lock (sf_mutex_t *mutex)

  Acquire a POSIX mutex (hosted build).
- void sf_mutex_unlock (sf_mutex_t *mutex)

  Release a POSIX mutex (hosted build).

7.302.1 Function Documentation

7.302.1.1 sf_mutex_destroy()

```
void sf_mutex_destroy (
            sf_mutex_t * mutex )
```

Destroy a POSIX mutex (hosted build).

Delegates to `pthread_mutex_destroy()`. The mutex must not be locked when destroyed. Return value is discarded; callers that need the error code should call `pthread_mutex_destroy()` directly.

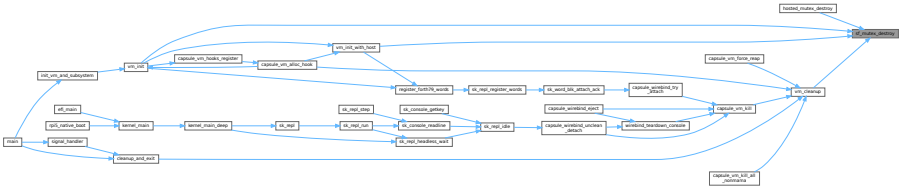
Parameters

mutex	Mutex to destroy; no-op if NULL

References sf_mutex::handle.

Referenced by hosted_mutex_destroy(), vm_cleanup(), vm_init(), and vm_init_with_host().

Here is the caller graph for this function:



7.302.1.2 sf_mutex_init()

```
int sf_mutex_init (
            sf_mutex_t * mutex )
```

Initialise a POSIX mutex (hosted build).

Delegates to `pthread_mutex_init()` with default attributes.

Parameters

mutex	Mutex to initialise; returns -1 if NULL

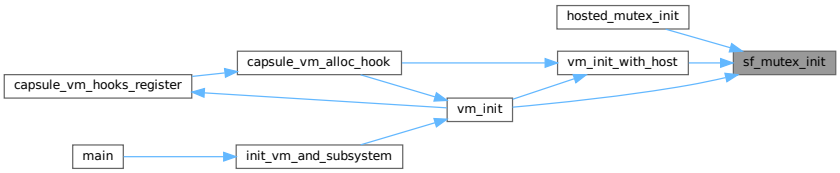
Returns

0 on success, -1 if `mutex` is NULL, or a positive `errno` value propagated from `pthread_mutex_init()`

References sf_mutex::handle.

Referenced by hosted_mutex_init(), vm_init(), and vm_init_with_host().

Here is the caller graph for this function:



7.302.1.3 sf_mutex_lock()

```
void sf_mutex_lock (
            sf_mutex_t * mutex )
```

Acquire a POSIX mutex (hosted build).

Delegates to `pthread_mutex_lock()`. Blocks until the mutex is available. Return value is discarded; a locking error will manifest as a deadlock or data race, not a silent failure.

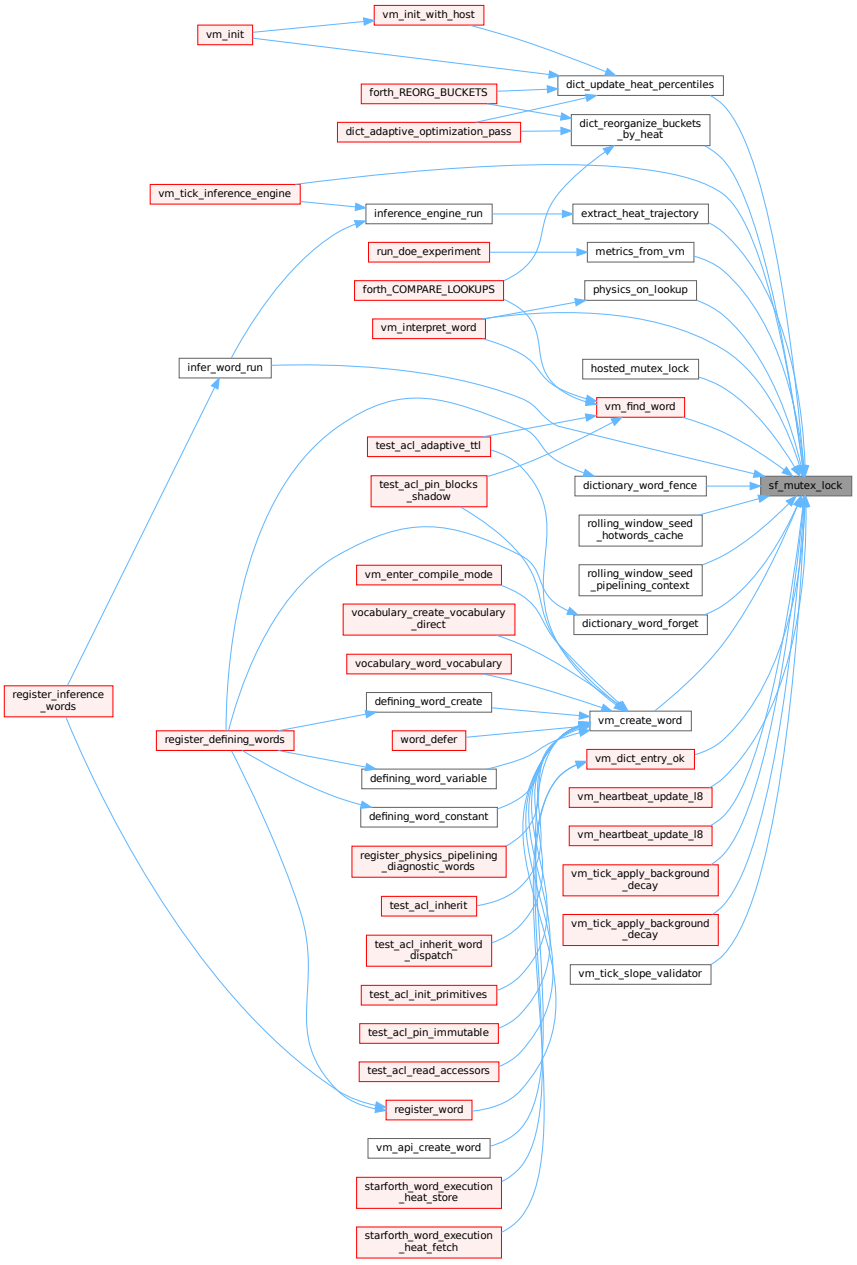
Parameters

mutex	Mutex to lock; no-op if NULL

References sf_mutex::handle.

Referenced by dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), dictionary_word_fence(), dictionary_word_forget(), extract_heat_trajectory(), hosted_mutex_lock(), infer_word_run(), metrics_from_vm(), physics_on_lookup(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), vm_create_word(), vm_dict_entry_ok(), vm_find_word(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_interpret_word(), vm_tick_apply_background_decay(), vm_tick_apply_background_decay(), vm_tick_inference_engine(), and vm_tick_slope_validator().

Here is the caller graph for this function:



7.302.1.4 sf_mutex_unlock()

```
void sf_mutex_unlock (
            sf_mutex_t * mutex )
```

Release a POSIX mutex (hosted build).

Delegates to `pthread_mutex_unlock()`. Must be called by the same thread that acquired the lock. Return value is discarded.

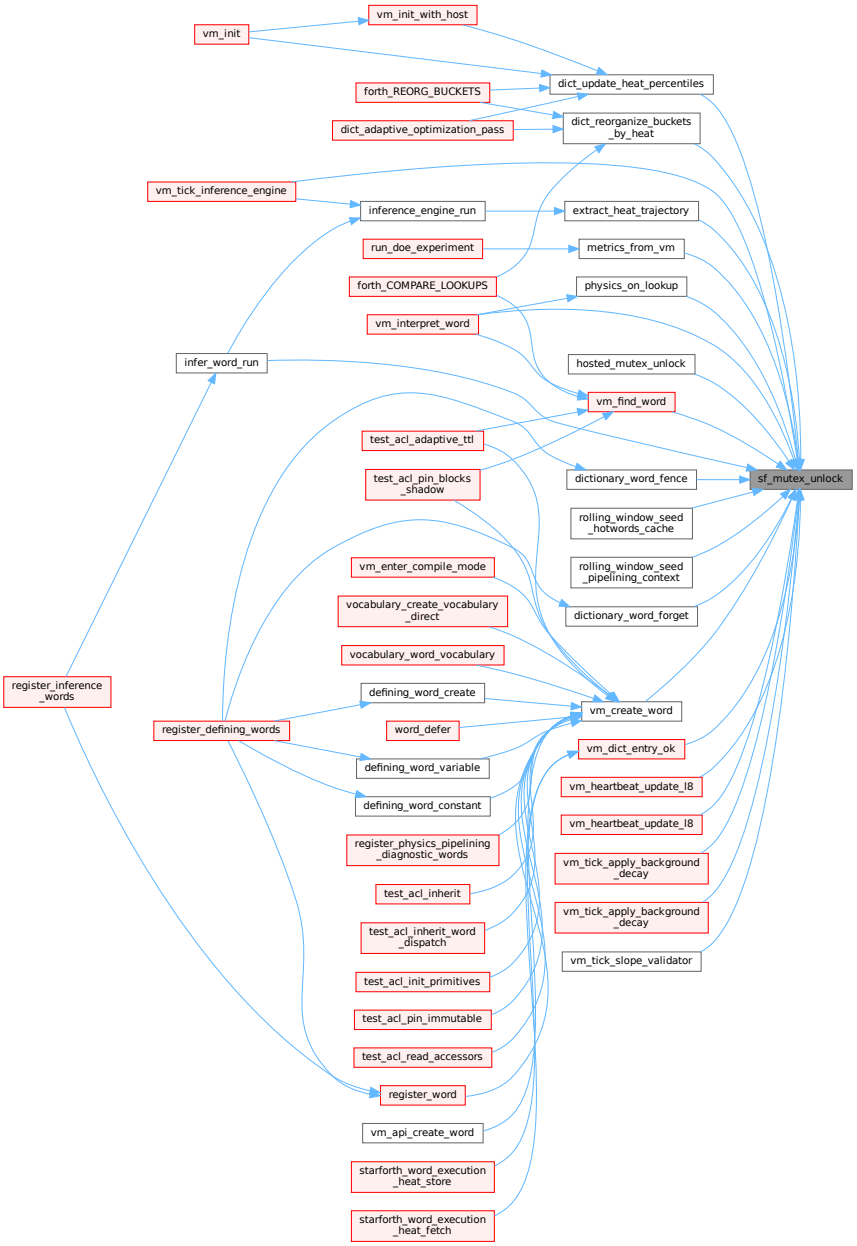
Parameters

mutex	Mutex to unlock; no-op if NULL

References sf_mutex::handle.

Referenced by dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), dictionary_word_fence(), dictionary_word_forget(), extract_heat_trajectory(), hosted_mutex_unlock(), infer_word_run(), metrics_from_vm(), physics_on_lookup(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), vm_create_word(), vm_dict_entry_ok(), vm_find_word(), vm_heartbeat_update_l8(), vm_heartbeat_update_l8(), vm_interpret_word(), vm_tick_apply_background_decay(), vm_tick_apply_background_decay(), vm_tick_inference_engine(), and vm_tick_slope_validator().

Here is the caller graph for this function:



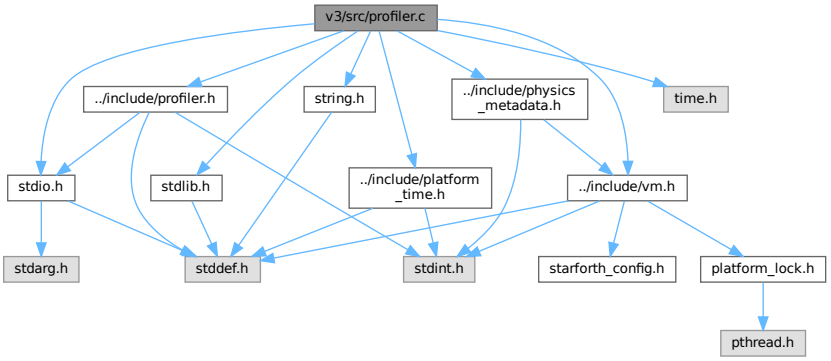
7.303 v3/src/profiler.c File Reference

Performance profiling implementation for StarForth.

```
#include "../include/profiler.h"
#include "../include/platform_time.h"
#include "../include/vm.h"
#include "../include/physics_metadata.h"
#include <stdio.h>
#include <stdlib.h>
```

```
#include <string.h>
#include <time.h>
```

Include dependency graph for profiler.c:



Data Structures

- struct WordStats

  Statistics for individual word execution.

Macros

- #define _POSIX_C_SOURCE 199309L

Typedefs

- typedef struct DictEntry DictEntry

Functions

- static uint64_t get_time_ns (void)

  Get current time in nanoseconds.
- static void print_word_name_safe (const DictEntry *entry)

  Safely print a word name, handling non-null-terminated names.
- int profiler_init (ProfileLevel level)

  Initialize the profiling system.
- void profiler_shutdown (void)

  Shutdown the profiler and free resources.
- static WordStats * get_word_stats (const DictEntry *entry)

  Find or create statistics entry for a word.
- void profiler_word_enter (const DictEntry *entry)

  Start timing a word execution (PROFILE_DETAILED+)
- void profiler_word_exit (const DictEntry *entry)

  End timing a word execution (PROFILE_DETAILED+)
- void profiler_word_count (const DictEntry *entry)

  Track word execution frequency without timing (PROFILE_BASIC+)

- void profiler_inc_dict_lookup (void)
- void profiler_inc_stack_op (void)
- void profiler_memory_read (size_t bytes)
- void profiler_memory_write (size_t bytes)
- static int compare_by_time (const void *a, const void *b)

  Compare two WordStats entries by total execution time.
- static int compare_by_calls (const void *a, const void *b)

  Compare two WordStats entries by call count.
- void profiler_generate_report (void)

  Generate and print detailed profiling report.
- void profiler_reset (void)

  Reset all profiling statistics.
- void profiler_set_level (ProfileLevel level)

  Change the current profiling detail level.
- uint64_t profiler_get_time_ns (void)
- void profiler_start_timer (ProfileCategory category)
- void profiler_end_timer (ProfileCategory category)
- void profiler_memory_alloc (size_t bytes)
- void profiler_inc_vm_cycles (uint64_t cycles)
- void profiler_inc_branch (void)
- void profiler_inc_loop_iter (void)
- void profiler_print_summary (void)
- void profiler_print_hotspots (void)

  Print hot word analysis with optimization recommendations.
- void profiler_print_word_analysis (void)
- void profiler_print_memory_analysis (void)
- void profiler_analyze_performance (VM *vm)
- void profiler_suggest_optimizations (void)

Variables

- struct {
    ProfileLevel level
    int enabled
    WordStats * word_stats
    size_t word_count
    size_t word_capacity
    const char * current_word
    uint64_t current_start_time
    uint64_t total_dict_lookups
    uint64_t total_stack_ops
    uint64_t total_memory_reads
    uint64_t total_memory_writes
  } profiler_state = {0}

- void * g_profiler = &profiler_state

7.303.1 Detailed Description

Performance profiling implementation for StarForth.

This module implements performance profiling functionality for the StarForth virtual machine. It tracks execution statistics including:

- Word execution counts and timing
- Dictionary lookup frequency
- Stack operations
- Memory usage patterns

The profiler supports multiple detail levels from basic to verbose profiling.

7.303.2 Macro Definition Documentation

7.303.2.1 _POSIX_C_SOURCE

```
#define _POSIX_C_SOURCE 199309L
```

7.303.3 Typedef Documentation

7.303.3.1 DictEntry

```
typedef struct DictEntry DictEntry
```

7.303.4 Function Documentation

7.303.4.1 compare_by_calls()

```
static int compare_by_calls (
            const void * a,
            const void * b )  [static]
```

Compare two WordStats entries by call count.

Parameters

a	First WordStats entry to compare
b	Second WordStats entry to compare

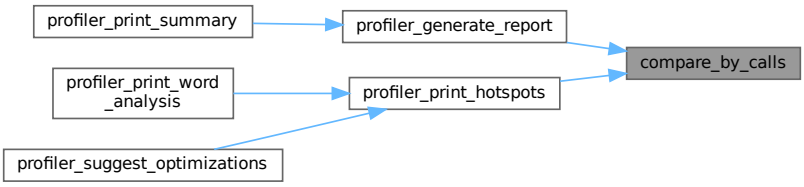
Returns

-1, 0, or 1 for qsort ordering

References WordStats::call_count.

Referenced by profiler_generate_report(), and profiler_print_hotspots().

Here is the caller graph for this function:



7.303.4.2 compare_by_time()

```
static int compare_by_time (
            const void * a,
            const void * b )  [static]
```

Compare two WordStats entries by total execution time.

Parameters

a	First WordStats entry to compare
b	Second WordStats entry to compare

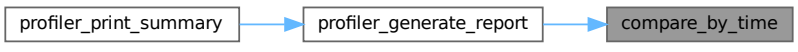
Returns

-1, 0, or 1 for qsort ordering

References WordStats::total_time_ns.

Referenced by profiler_generate_report().

Here is the caller graph for this function:



7.303.4.3 get_time_ns()

```
static uint64_t get_time_ns (
            void  )  [static]
```

Get current time in nanoseconds.

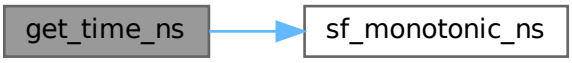
Returns

Current time in nanoseconds from monotonic clock

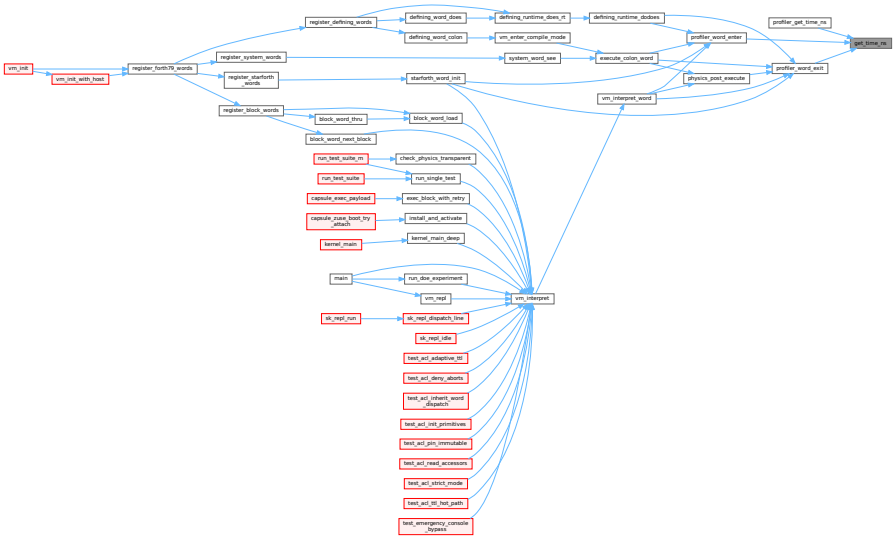
References sf_monotonic_ns().

Referenced by profiler_get_time_ns(), profiler_word_enter(), and profiler_word_exit().

Here is the call graph for this function:



Here is the caller graph for this function:



7.303.4.4 get_word_stats()

```
static WordStats * get_word_stats (
            const DictEntry * entry )  [static]
```

Find or create statistics entry for a word.

Parameters

entry	Dictionary entry to find/create stats for

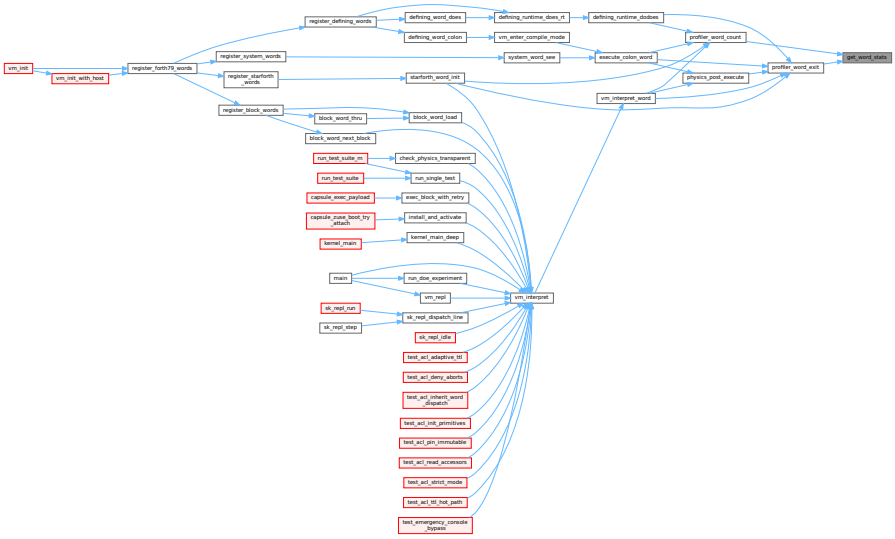
Returns

Pointer to word stats or NULL if not found/created

References WordStats::call_count, entry, WordStats::entry, WordStats::max_time_ns, WordStats::min_time_ns, profiler_state, and WordStats::total_time_ns.

Referenced by profiler_word_count(), and profiler_word_exit().

Here is the caller graph for this function:



7.303.4.5 print_word_name_safe()

```
static void print_word_name_safe (
            const DictEntry * entry )  [static]
```

Safely print a word name, handling non-null-terminated names.

Parameters

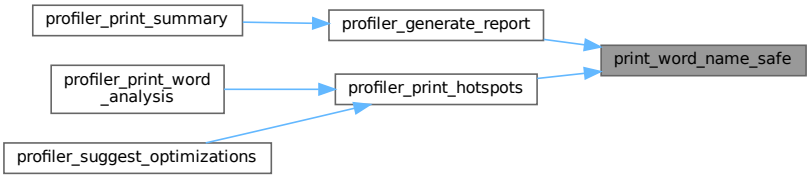
entry	Dictionary entry whose name to print

References entry, printf(), and putchar().

Referenced by profiler_generate_report(), and profiler_print_hotspots().

Here is the call graph for this function:

Here is the caller graph for this function:



7.303.4.6 profiler_analyze_performance()

```
void profiler_analyze_performance (
            VM * vm )
```

7.303.4.7 profiler_end_timer()

```
void profiler_end_timer (
            ProfileCategory category )
```

7.303.4.8 profiler_generate_report()

```
void profiler_generate_report (
            void  )
```

Generate and print detailed profiling report.

Generates a report including:

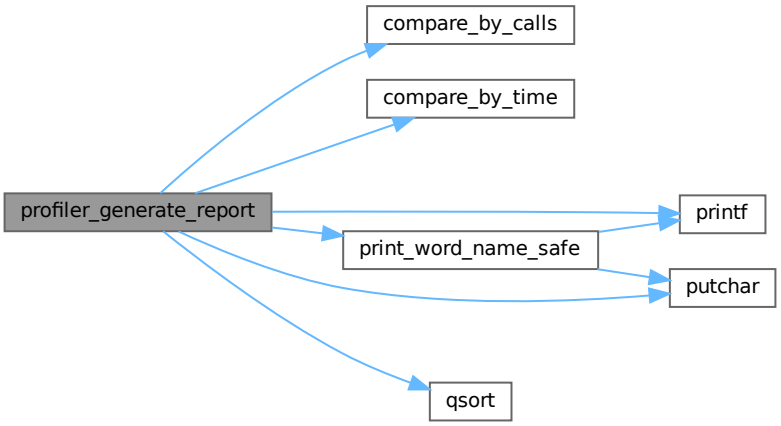
- Global statistics (dictionary lookups, stack ops, memory usage)
- Top words by execution time

- Most frequently called words

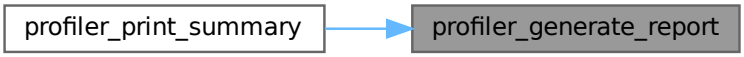
References WordStats::call_count, compare_by_calls(), compare_by_time(), WordStats::entry, limit, WordStats::max_time_ns, name_len, DictEntry::name_len, print_word_name_safe(), printf(), PROFILE_BASIC, PROFILE_DETAILED, PROFILE_VERBOSE, profiler_state, putchar(), qsort(), and WordStats::total_time_ns.

Referenced by profiler_print_summary().

Here is the call graph for this function:



Here is the caller graph for this function:

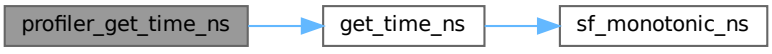


7.303.4.9 profiler_get_time_ns()

```
uint64_t profiler_get_time_ns (
            void  )
```

References get_time_ns().

Here is the call graph for this function:



7.303.4.10 profiler_inc_branch()

```
void profiler_inc_branch (
            void  )
```

7.303.4.11 profiler_inc_dict_lookup()

```
void profiler_inc_dict_lookup (
            void  )
```

References PROFILE_BASIC, and profiler_state.

7.303.4.12 profiler_inc_loop_iter()

```
void profiler_inc_loop_iter (
            void  )
```

7.303.4.13 profiler_inc_stack_op()

```
void profiler_inc_stack_op (
            void  )
```

References PROFILE_VERBOSE, and profiler_state.

7.303.4.14 profiler_inc_vm_cycles()

```
void profiler_inc_vm_cycles (
            uint64_t cycles )
```

7.303.4.15 profiler_init()

```
int profiler_init (
            ProfileLevel level )
```

Initialize the profiling system.

Parameters

level	Initial profiling detail level

Returns

0 on success, non-zero on failure

References calloc(), level, PROFILE_DISABLED, and profiler_state.

Here is the call graph for this function:

7.303.4.16 profiler_memory_alloc()

```
void profiler_memory_alloc (
            size_t bytes )
```

References bytes.

7.303.4.17 profiler_memory_read()

```
void profiler_memory_read (
            size_t bytes )
```

References bytes, PROFILE_VERBOSE, and profiler_state.

7.303.4.18 profiler_memory_write()

```
void profiler_memory_write (
            size_t bytes )
```

References bytes, PROFILE_VERBOSE, and profiler_state.

7.303.4.19 profiler_print_hotspots()

```
void profiler_print_hotspots (
            void  )
```

Print hot word analysis with optimization recommendations.

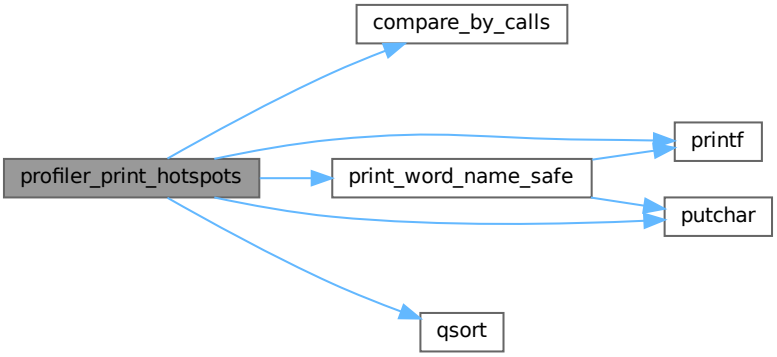
Analyzes word execution frequency and provides actionable recommendations for performance optimization including:

- Assembly optimization candidates
- Inlining opportunities
- Cache-friendly ordering

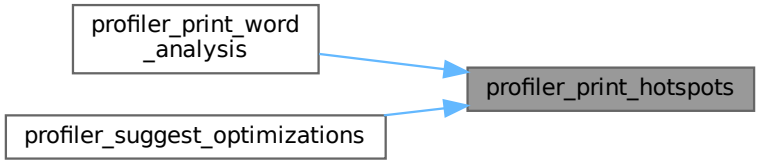
References WordStats::call_count, compare_by_calls(), WordStats::entry, limit, name_len, DictEntry::name_len, print_word_name_safe(), printf(), profiler_state, putchar(), and qsort().

Referenced by profiler_print_word_analysis(), and profiler_suggest_optimizations().

Here is the call graph for this function:



Here is the caller graph for this function:



7.303.4.20 profiler_print_memory_analysis()

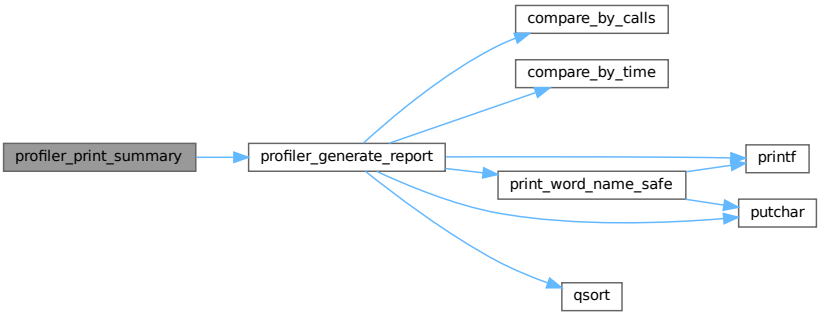
```
void profiler_print_memory_analysis (
            void  )
```

7.303.4.21 profiler_print_summary()

```
void profiler_print_summary (
            void  )
```

References profiler_generate_report().

Here is the call graph for this function:

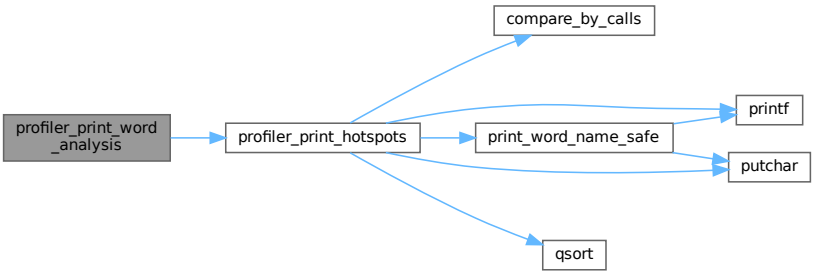


7.303.4.22 profiler_print_word_analysis()

```
void profiler_print_word_analysis (
            void  )
```

References profiler_print_hotspots().

Here is the call graph for this function:



7.303.4.23 profiler_reset()

```
void profiler_reset (
            void  )
```

Reset all profiling statistics.

References profiler_state.

7.303.4.24 profiler_set_level()

```
void profiler_set_level (
            ProfileLevel level )
```

Change the current profiling detail level.

Parameters

level	New profiling level to set

References level, and profiler_state.

7.303.4.25 profiler_shutdown()

```
void profiler_shutdown (
            void  )
```

Shutdown the profiler and free resources.

Shutdown and cleanup the profiling system.

References free(), and profiler_state.

Here is the call graph for this function:

7.303.4.26 profiler_start_timer()

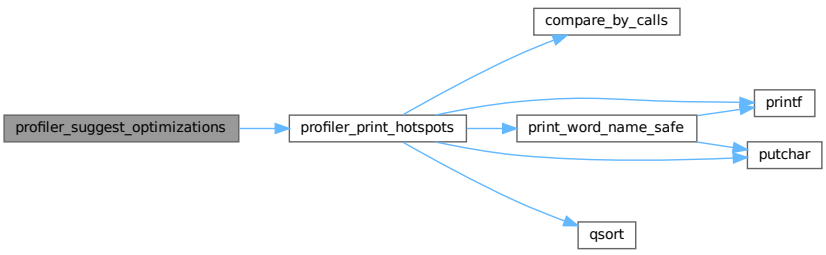
```
void profiler_start_timer (
            ProfileCategory category )
```

7.303.4.27 profiler_suggest_optimizations()

```
void profiler_suggest_optimizations (
            void  )
```

References profiler_print_hotspots().

Here is the call graph for this function:



7.303.4.28 profiler_word_count()

```
void profiler_word_count (
            const DictEntry * entry )
```

Track word execution frequency without timing (PROFILE_BASIC+)

Parameters

entry	Dictionary entry of the word being executed

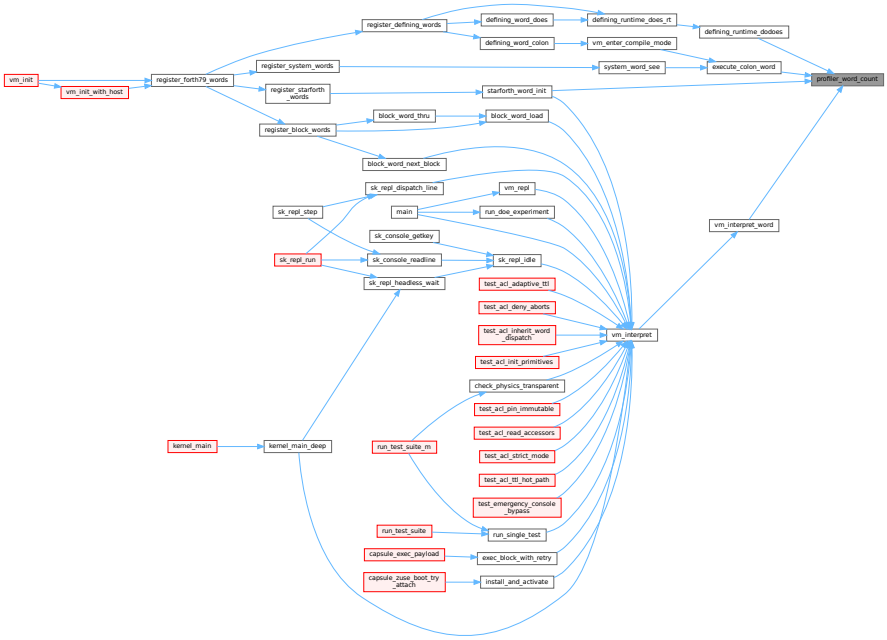
This is a lightweight alternative to profiler_word_enter/exit that only increments call counters without timing overhead. Ideal for identifying hot words (frequently executed) for optimization.

References WordStats::call_count, entry, get_word_stats(), PROFILE_DETAILED, and profiler_state.

Referenced by defining_runtime_dodoes(), execute_colon_word(), starforth_word_init(), and vm_interpret_word().

Here is the call graph for this function:

Here is the caller graph for this function:



7.303.4.29 profiler_word_enter()

```
void profiler_word_enter (
            const DictEntry * entry )
```

Start timing a word execution (PROFILE_DETAILED+)

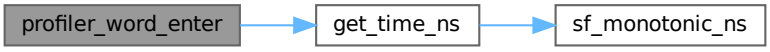
Parameters

entry	Dictionary entry of the word being executed

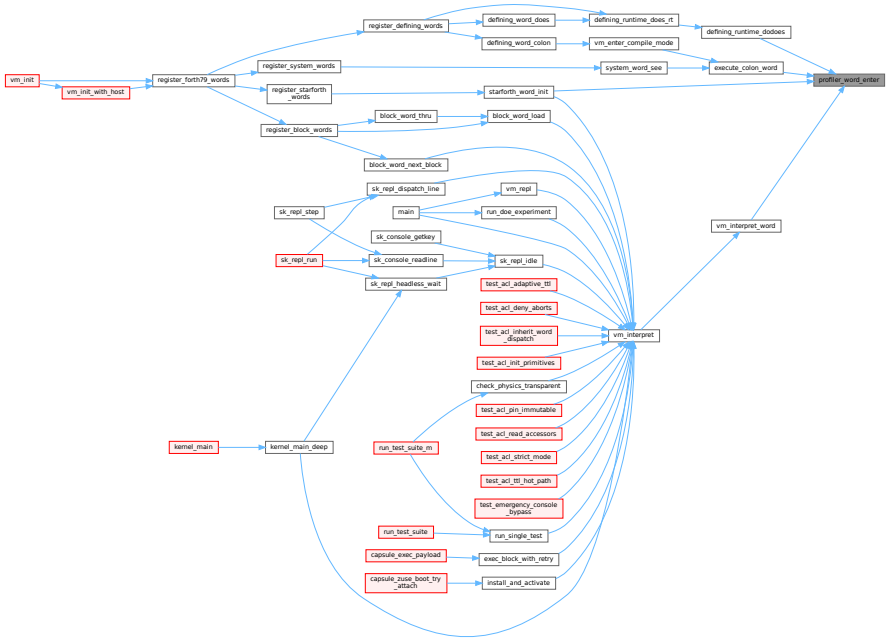
References entry, get_time_ns(), PROFILE_DETAILED, and profiler_state.

Referenced by defining_runtime_dodoes(), execute_colon_word(), starforth_word_init(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.303.4.30 profiler_word_exit()

```
void profiler_word_exit (
            const DictEntry * entry )
```

End timing a word execution (PROFILE_DETAILED+)

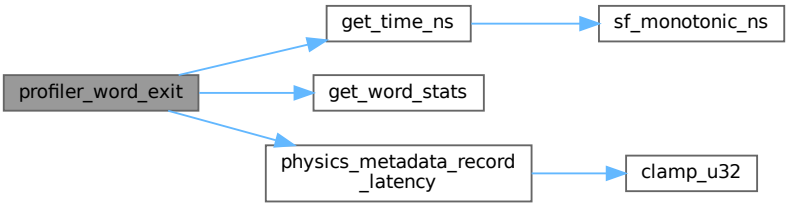
Parameters

entry	Dictionary entry of the word being executed

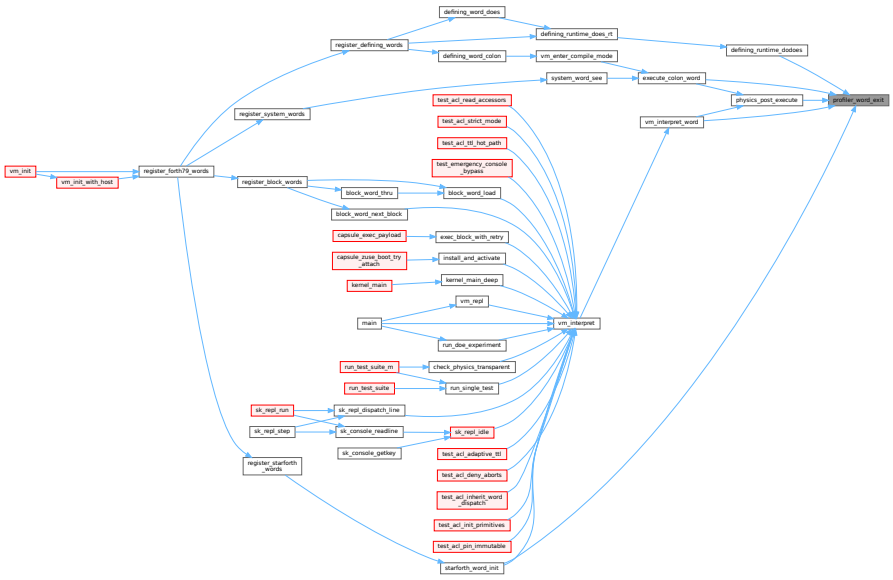
References WordStats::call_count, entry, get_time_ns(), get_word_stats(), WordStats::max_time_ns, WordStats::min_time_ns, physics_metadata_record_latency(), PROFILE_DETAILED, profiler_state, and WordStats::total_time_ns.

Referenced by defining_runtime_dodoes(), execute_colon_word(), physics_post_execute(), starforth_word_init(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.303.5 Variable Documentation

7.303.5.1 current_start_time

```
uint64_t current_start_time
```

7.303.5.2 current_word

```
const char* current_word
```

7.303.5.3 enabled

```
int enabled
```

Referenced by hotwords_cache_set_enabled(), and set_forth_79_compliance().

7.303.5.4 g_profiler

```
void* g_profiler = &profiler_state
```

7.303.5.5 level

```
ProfileLevel level
```

Referenced by log_do_emit(), log_emit_string(), log_message(), log_region_append(), log_set_level(), log_str_emit(), profiler_init(), and profiler_set_level().

7.303.5.6 [struct]

```
struct { ... } profiler_state [static]
```

Referenced by get_word_stats(), profiler_generate_report(), profiler_inc_dict_lookup(), profiler_inc_stack_op(), profiler_init(), profiler_memory_read(), profiler_memory_write(), profiler_print_hotspots(), profiler_reset(), profiler_set_level(), profiler_shutdown(), profiler_word_count(), profiler_word_enter(), and profiler_word_exit().

7.303.5.7 total_dict_lookups

```
uint64_t total_dict_lookups
```

7.303.5.8 total_memory_reads

```
uint64_t total_memory_reads
```

7.303.5.9 total_memory_writes

```
uint64_t total_memory_writes
```

7.303.5.10 total_stack_ops

```
uint64_t total_stack_ops
```

7.303.5.11 word_capacity

```
size_t word_capacity
```

7.303.5.12 word_count

```
size_t word_count
```

Referenced by forth_PIPELINING_STATS(), heartbeat_capture_tick_snapshot(), infer_word_run(), metrics_from_vm(), starforth_word_top_words(), starforth_word_word_execution_heat(), system_word_see(), vm_tick_inference_engine(), and vm_tick_slope_validator().

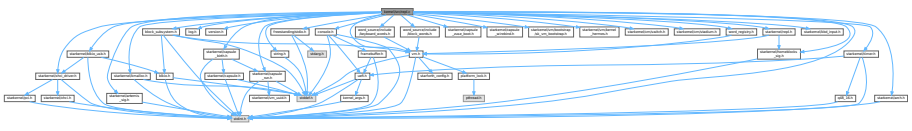
7.303.5.13 word_stats

```
WordStats* word_stats
```

7.304 kernel/src/repl.c File Reference

```
#include "starkernel/repl.h"
#include "console.h"
#include "log.h"
#include "vm.h"
#include "version.h"
#include "starkernel/timer.h"
#include "starkernel/arch.h"
#include "starkernel/xhci_driver.h"
#include "starkernel/blkio_usb.h"
#include "starkernel/kmalloc.h"
#include "starkernel/homeblocks_sig.h"
#include "starkernel/artemis_sig.h"
#include "starkernel/capsule_birth.h"
#include "starkernel/capsule_zuse_boot.h"
#include "starkernel/capsule_wirebind.h"
#include "starkernel/capsule_run.h"
#include "starkernel/vm/bootstrap/sk_vm_bootstrap.h"
#include "starkernel/vm/kernel_hermes.h"
#include "starkernel/vm/switch.h"
#include "starkernel/vm/stadium.h"
#include "block_subsystem.h"
#include "word_source/include/keyboard_words.h"
#include "starkernel/kbd_input.h"
#include "word_source/include/block_words.h"
#include "word_registry.h"
#include "freestanding/stdio.h"
#include <stdint.h>
#include <string.h>
```

Include dependency graph for repl.c:



Data Structures

- struct sk_blk_attach_pending_t
- struct sk_usb_ctrl_t

Macros

- #define SK_PROMPT_TEXT "\x1b[38;2;85;255;255mok> \x1b[39m"

  repl.c - Emergency FORTH REPL for LithosAnanke kernel
- #define SK_KH_BLK_ATTACH_BUF_SIZE 80
- #define SK_IDLE_BEAT_INTERVAL 100u /* ticks between idle service calls (1 s at 100 Hz) */
- #define SK_CURSOR_BLINK_INTERVAL 50u /* ticks between blink toggles (500 ms at 100 Hz) */

Functions

- static void sk_print_prompt (void)
- static const char * sk_console_user_prefix (void)
- void sk_repl_set_active_vm (VM *vm)

  sk_repl_set_active_vm - Redirect REPL input to a different VM (USE word).
- VM * sk_repl_get_active_vm (void)

  sk_repl_get_active_vm - Return the current USE-redirected VM, or NULL.
- static int sk_console_identity_present (void)
- blkio_dev_t * sk_repl_get_homeblocks_dev (void)

  sk_repl_get_homeblocks_dev / sk_repl_get_homeblocks_sig - The currently attached home-blocks USB drive, or NULL if none is attached / the attached drive didn't check out as HOMEBLOCKS_SIG_OK (FABRIC-2.md ?F.6/?F.9/?F.18).
- const homeblocks_sig_t * sk_repl_get_homeblocks_sig (void)
- blkio_dev_t * sk_repl_get_attached_blk_dev (void)

  sk_repl_get_attached_blk_dev - The currently attached USB block device, regardless of home-blocks recognition (FABRIC-2.md ?F.8/?F.19) – MINT's own target, since a blank/unminted drive never sets sk_repl_get_homeblocks_dev() above.
- blkio_dev_t * sk_repl_get_artemis_usb_dev (void)
- static void sk_word_blk_attach_ack (VM *vm)
- static void sk_word_kh_blk_attach_send (VM *vm)
- void sk_repl_register_words (VM *vm)

  sk_repl_register_words - Registers repl.c's own FORTH-visible words (currently just BLK-ATTACH-ACK, Artemis's storage-attach reply target – see sk_word_blk_attach_ack()'s doc comment in repl.c).
- static void sk_cursor_show (void)
- static void sk_repl_idle (VM *active_vm)
- int sk_console_getkey (VM *active_vm)

  sk_console_getkey - Real body of the standard dictionary's KEY word (called from shim.c's getchar()).
- void sk_repl_headless_wait (VM *mama)

  sk_repl_headless_wait - Idle-service loop with no interactive surface at all: no banner, no prompt, no console_getc()/readline.
- int sk_console_key_available (void)

  sk_console_key_available - Real body of the standard dictionary's ?TERMINAL word (called from sf_terminal_ready()).
- int sk_console_readline (char *buf, int size, VM *active_vm, int reanchor_prompt)

  sk_console_readline - Real body of the standard dictionary's QUERY/EXPECT words (called from shim.c's fgets()).
- static int sk_repl_line_calls_use (const char *input)
- static void sk_repl_dispatch_line (VM *vm, const char *input)
- int sk_repl_step (VM *vm)

  sk_repl_step - Execute one REPL turn on a VM and return.
- void sk_repl_run (VM *vm)

  sk_repl_run - Bare REPL loop (no banner).
- void sk_repl (VM *vm)

  sk_repl - Run the emergency FORTH REPL on the serial console.

Variables

- const char lithos_version [64] = "LithosAnanke v2.1.0 amd64"
- static VM * g_repl_active_vm = (void *)0
- static blkio_dev_t * g_homeblocks_dev = (void *)0
- static homeblocks_sig_t g_homeblocks_sig
- static int g_homeblocks_sig_valid = 0
- static blkio_dev_t * g_attached_blk_dev = (void *)0
- static blkio_dev_t * g_artemis_usb_dev = (void *)0
- static sk_usb_ctrl_t g_usb_ctrl [8u]
- static char g_kh_blk_attach_buf [80]
- static uint64_t g_last_beat_tick
- static uint64_t g_cursor_blink_tick
- static int g_cursor_visible = 1
- static int g_mama_interpreting
- static int g_idle_pump_active
- static int g_console_pending_key = -1
- static char g_kh_console_cmd_buf [SK_HERMES_CHUNK_MAX_PAYLOAD]

7.304.1 Macro Definition Documentation

7.304.1.1 SK_CURSOR_BLINK_INTERVAL

```
#define SK_CURSOR_BLINK_INTERVAL 50u /* ticks between blink toggles (500 ms at 100 Hz) */
```

7.304.1.2 SK_IDLE_BEAT_INTERVAL

```
#define SK_IDLE_BEAT_INTERVAL 100u /* ticks between idle service calls (1 s at 100 Hz) */
```

7.304.1.3 SK_KH_BLK_ATTACH_BUF_SIZE

```
#define SK_KH_BLK_ATTACH_BUF_SIZE 80
```

7.304.1.4 SK_PROMPT_TEXT

```
#define SK_PROMPT_TEXT "\x1b[38;2;85;255;255mok> \x1b[39m"
```

repl.c - Emergency FORTH REPL for LithosAnanke kernel

Direct adaptation of src/repl.c for the freestanding kernel context. Replaces libc stdio (fgets/printf/fflush) with HAL serial I/O:

- Input: console_getc() non-blocking poll with local echo and backspace
- Output: console_puts() / console_putc()

Idle spin: polls console_getc() and services the adaptive heartbeat. The timer ISR's top half (heartbeat_tick()) latches one sample per interrupt; the idle spin drains it every iteration via heartbeat_service() (item 0.8, FABRIC-0.md ?26) and calls sk_repl_idle() once per SK_IDLE_BEAT_INTERVAL ticks for coarser subsystem dispatch. On QEMU TCG the ISR must fire for ticks to advance — check "Heartbeat: N ticks" in the serial log to confirm.

Runs with interrupts enabled so the APIC heartbeat fires normally. Designed as the last thing kernel_main does before the idle loop.

7.304.2 Function Documentation

7.304.2.1 sk_console_getkey()

```
int sk_console_getkey (
            VM * active_vm )
```

sk_console_getkey - Real body of the standard dictionary's KEY word (called from shim.c's getchar()).

Blocks until a key is available from either input source (serial console or the PS2/virtio keyboard-event bridge), servicing the heartbeat/idle loop while waiting so a KEY call from inside any word never stalls the heartbeat. No echo – that's the caller's responsibility, same as any standard KEY.

Parameters

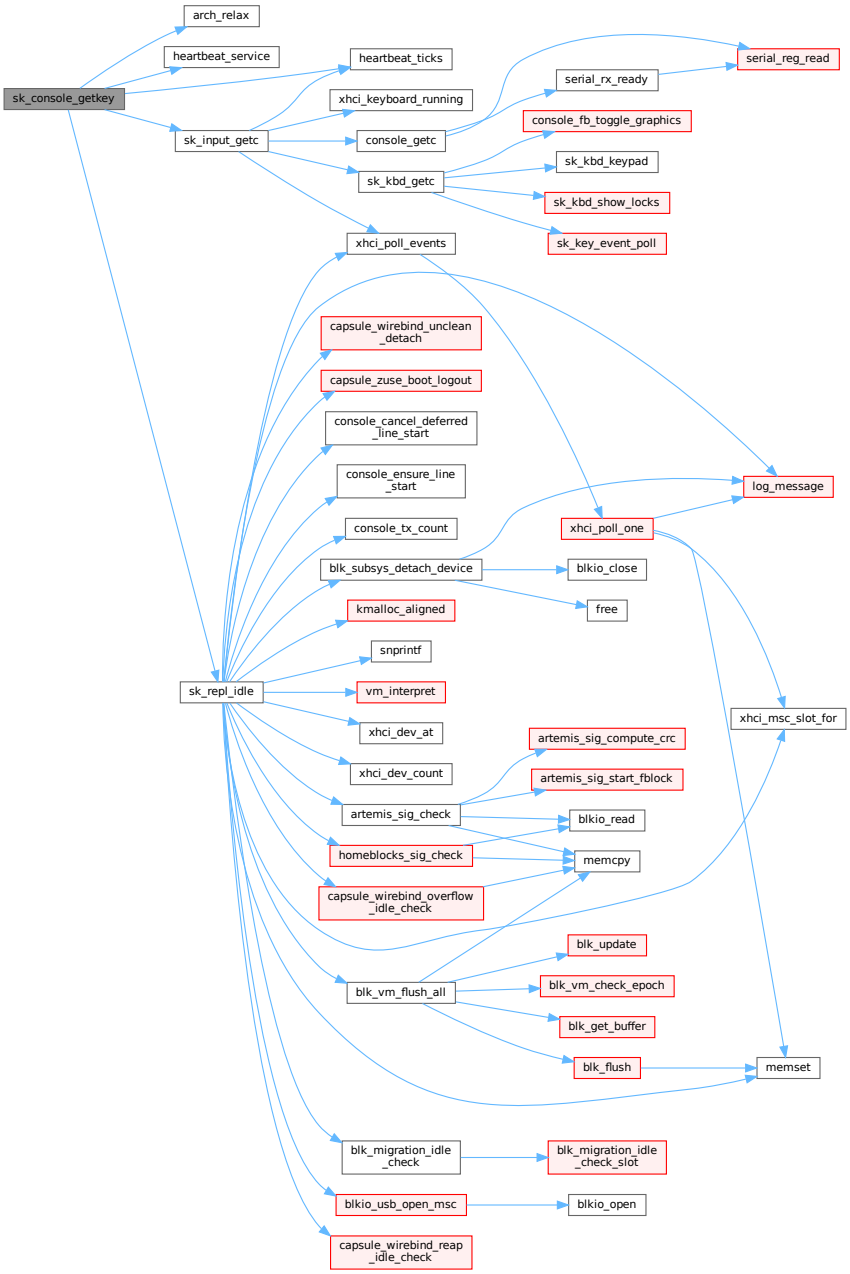
active_vm	VM whose idle dispatch runs while waiting (see sk_repl_idle()'s own doc comment on why this is a parameter rather than read via sk_repl_get_active_vm())

Returns

the key read, as an unsigned byte value

References arch_relax(), g_console_pending_key, g_last_beat_tick, g_repl_active_vm, heartbeat_service(), heartbeat_ticks(), SK_IDLE_BEAT_INTERVAL, sk_input_getc(), and sk_repl_idle().

Here is the call graph for this function:



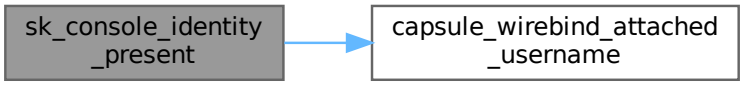
7.304.2.2 sk_console_identity_present()

```
static int sk_console_identity_present (
            void  )  [static]
```

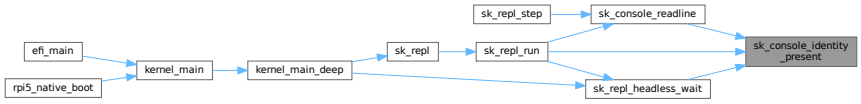
References capsule_wirebind_attached_username(), and VM::zuse_session.

Referenced by sk_console_readline(), sk_repl_headless_wait(), and sk_repl_run().

Here is the call graph for this function:



Here is the caller graph for this function:



7.304.2.3 sk_console_key_available()

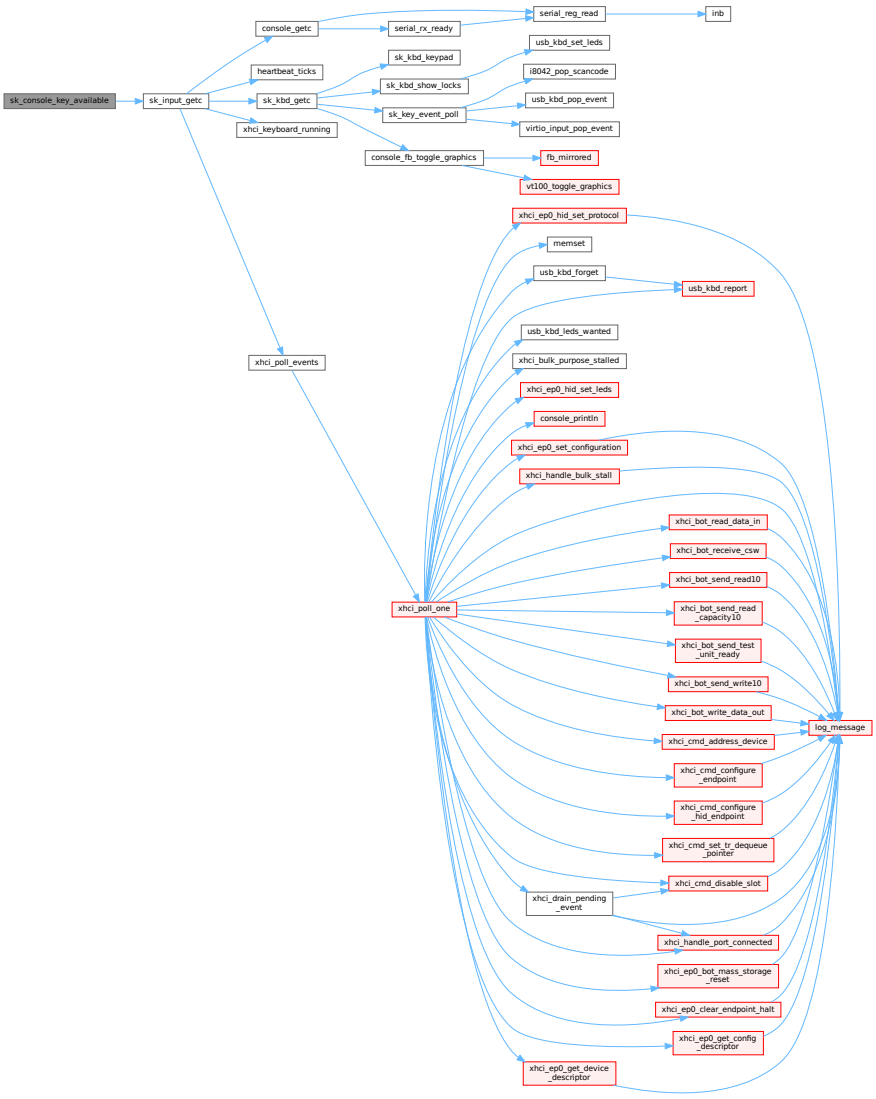
```
int sk_console_key_available (
            void  )
```

sk_console_key_available - Real body of the standard dictionary's ?TERMINAL word (called from sf_terminal_ready()).

Non-blocking peek: returns 1 if a key is ready without consuming it (a following sk_console_getkey() returns that exact key), 0 otherwise.

References g_console_pending_key, and sk_input_getc().

Here is the call graph for this function:



7.304.2.4 sk_console_readline()

```
int sk_console_readline (
            char * buf,
            int size,
            VM * active_vm,
            int reanchor_prompt )
```

sk_console_readline - Real body of the standard dictionary's QUERY/EXPECT words (called from shim.c's fgets()).

Reads one line from the console with echo and backspace support, servicing the heartbeat/ idle loop while waiting – the same line editor the REPL's own prompt uses internally, so a mid-word EXPECT behaves identically to typing at "ok>" itself.

Parameters

buf	Destination buffer
size	Buffer capacity, including the NUL terminator
active_vm	VM whose idle dispatch runs while waiting
reanchor_prompt	Nonzero to re-print the "ok> " prompt whenever an idle bottom half (heartbeat, USB attach/detach) writes to the console while this readline blocks at a bare, untyped prompt – keeps the top-level prompt as the last thing shown once the chatter dies down. Callers whose prompt line is their own (shim.c's fgets(), i.e. QUERY/EXPECT/ACCEPT) pass 0 so "ok> " never gets stamped onto their mid-word input context.

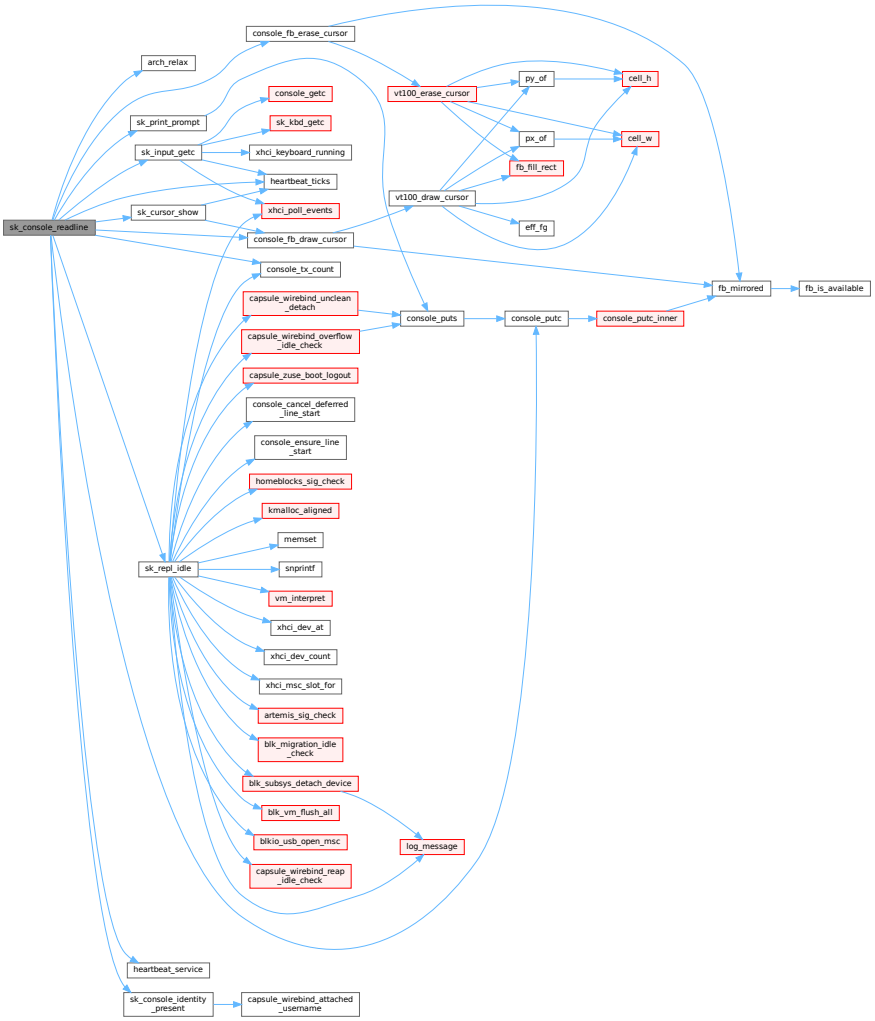
Returns

number of characters placed in buf, not counting the NUL, or -1 (2026-09-06) when reanchor_prompt is nonzero and the attached identity logged out while this call was blocked waiting for input with nothing typed yet – see repl.c's own doc comment on this function for what a caller must do with -1.

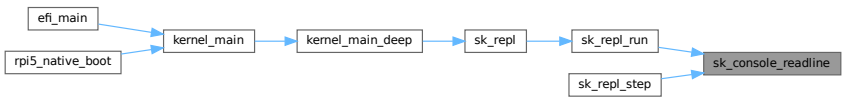
References arch_relax(), console_fb_draw_cursor(), console_fb_erase_cursor(), console_putc(), console_tx_count(), g_console_pending_key, g_cursor_blink_tick, g_cursor_visible, g_last_beat_tick, g_repl_active_vm, heartbeat_service(), heartbeat_ticks(), sk_console_identity_present(), SK_CURSOR_BLINK_INTERVAL, sk_cursor_show(), SK_IDLE_BEAT_INTERVAL, sk_input_getc(), sk_print_prompt(), and sk_repl_idle().

Referenced by sk_repl_run(), and sk_repl_step().

Here is the call graph for this function:



Here is the caller graph for this function:



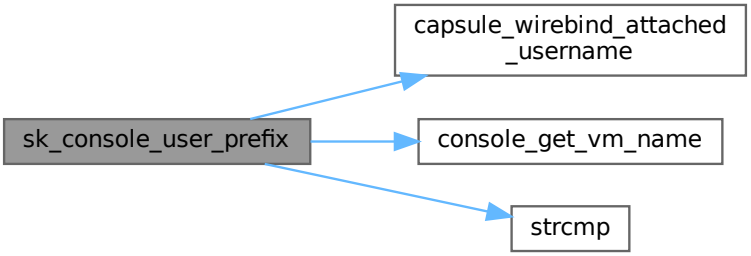
7.304.2.5 sk_console_user_prefix()

```
static const char * sk_console_user_prefix (
            void  )  [static]
```

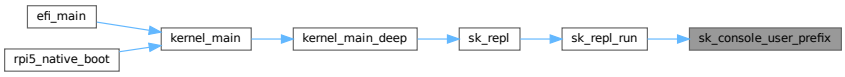
References capsule_wirebind_attached_username(), console_get_vm_name(), strcmp(), and VM::zuse_session.

Referenced by sk_repl_run().

Here is the call graph for this function:



Here is the caller graph for this function:



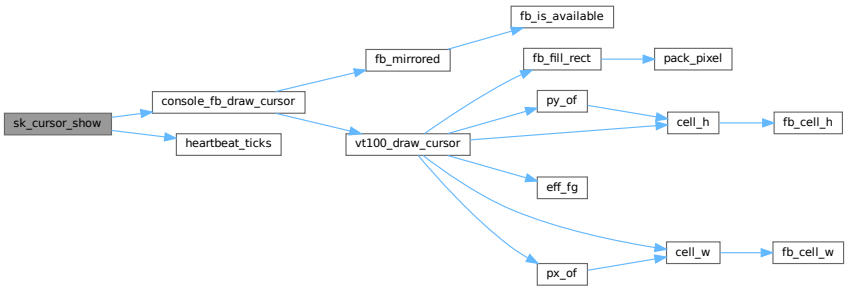
7.304.2.6 sk_cursor_show()

```
static void sk_cursor_show (
            void  )  [static]
```

References console_fb_draw_cursor(), g_cursor_blink_tick, g_cursor_visible, and heartbeat_ticks().

Referenced by sk_console_readline().

Here is the call graph for this function:



Here is the caller graph for this function:

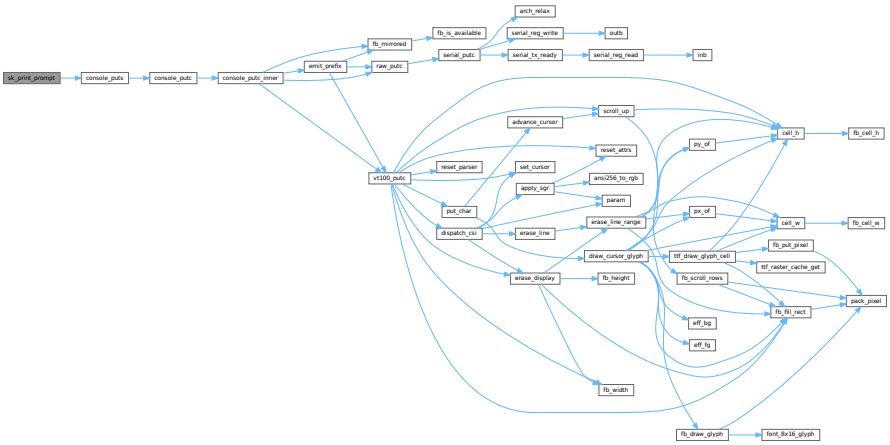
7.304.2.7 sk_print_prompt()

```
static void sk_print_prompt (
            void  )  [static]
```

References console_puts(), and SK_PROMPT_TEXT.

Referenced by sk_console_readline(), sk_repl_run(), and sk_repl_step().

Here is the call graph for this function:



Here is the caller graph for this function:

7.304.2.8 sk_repl()

```
void sk_repl (
            VM * vm )
```

sk_repl - Run the emergency FORTH REPL on the serial console.

Blocks until vm->halted is set (BYE word) or the VM encounters a halt. Runs with interrupts enabled; the APIC heartbeat continues to fire.

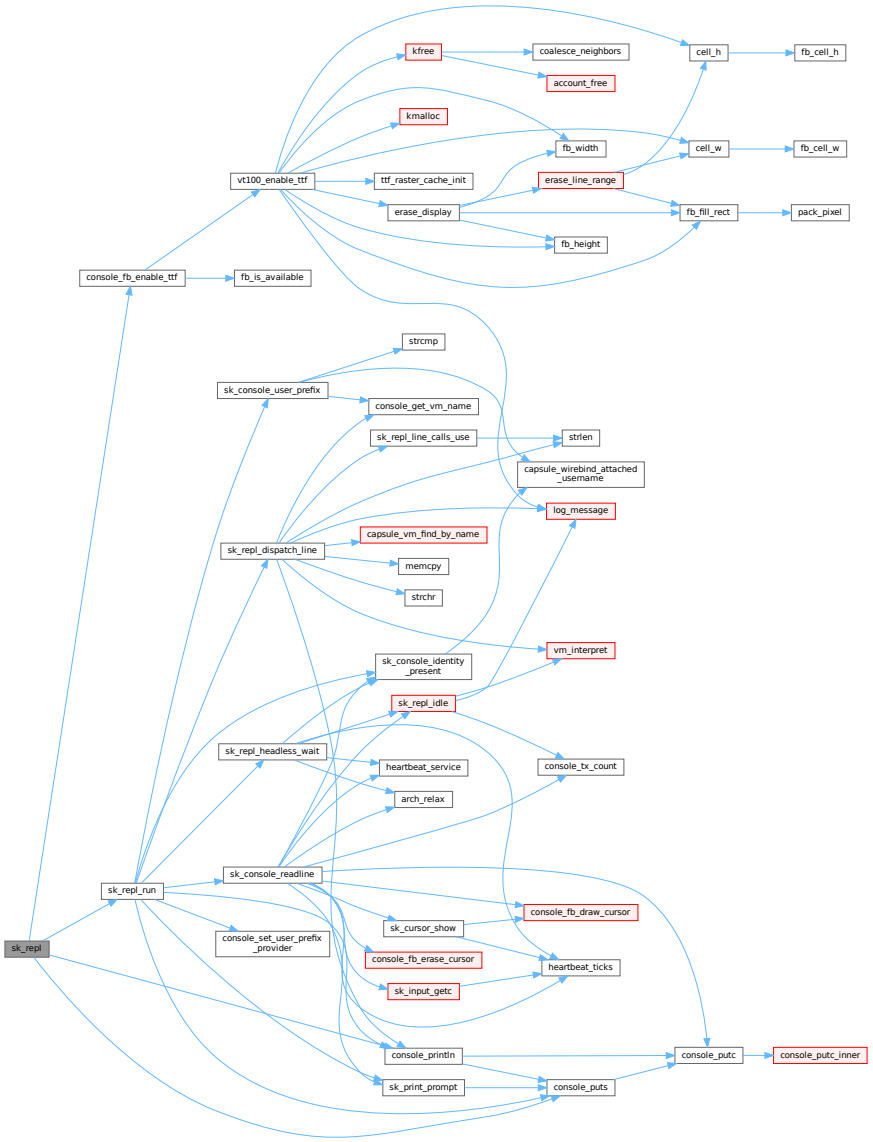
Parameters

vm	Mama VM instance (must be fully initialised)

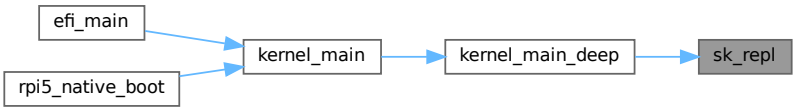
References console_fb_enable_ttf(), console_println(), console_puts(), lithos_version, sk_repl_run(), and STARFORTH_VERSION.

Referenced by kernel_main_deep().

Here is the call graph for this function:



Here is the caller graph for this function:



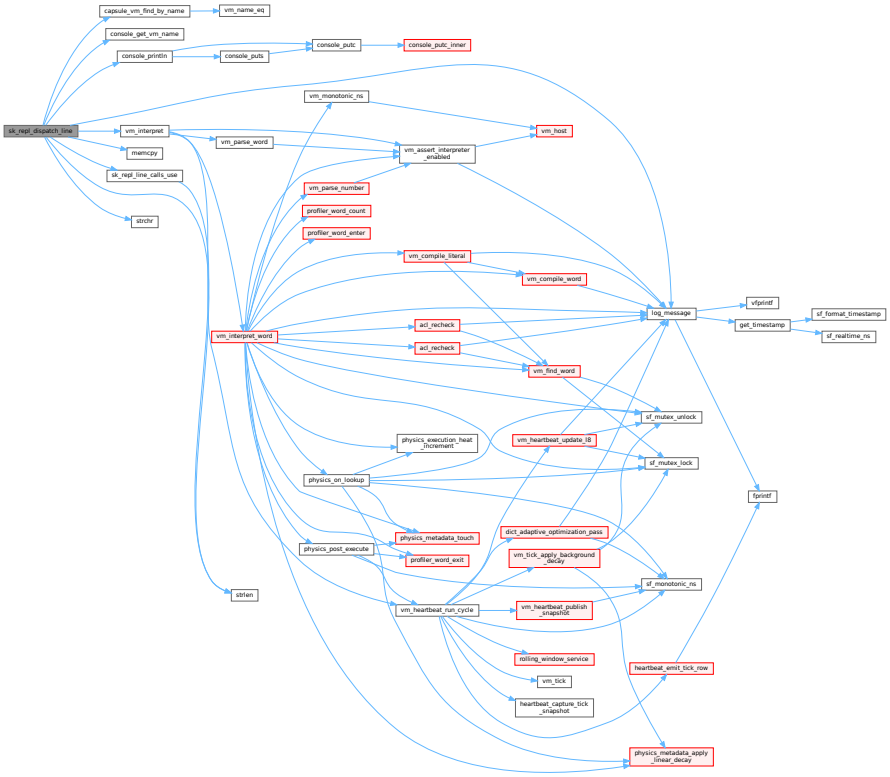
7.304.2.9 sk_repl_dispatch_line()

```
static void sk_repl_dispatch_line (
            VM * vm,
            const char * input )  [static]
```

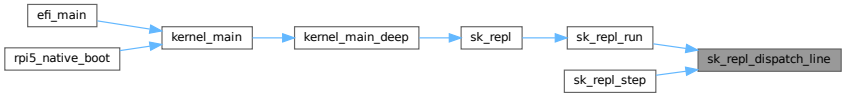
References capsule_vm_find_by_name(), console_get_vm_name(), console_println(), g_kh_console_cmd_buf, g_mama_interpreting, LOG_ERROR, log_message(), memcpy(), sk_repl_line_calls_use(), VMRegistryEntry::state, strchr(), strlen(), VMRegistryEntry::vm_id, vm_interpret(), VM_NAME_MAX, and VM_STATE_LIVE.

Referenced by sk_repl_run(), and sk_repl_step().

Here is the call graph for this function:



Here is the caller graph for this function:



7.304.2.10 sk_repl_get_active_vm()

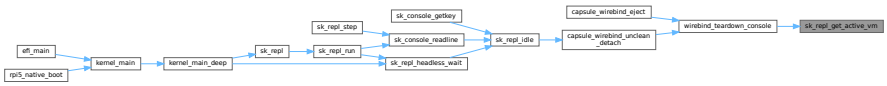
```
VM * sk_repl_get_active_vm (
            void  )
```

sk_repl_get_active_vm - Return the current USE-redirected VM, or NULL.

References g_repl_active_vm.

Referenced by wirebind_teardown_console().

Here is the caller graph for this function:



7.304.2.11 sk_repl_get_artemis_usb_dev()

```
blkio_dev_t * sk_repl_get_artemis_usb_dev (
            void  )
```

References g_artemis_usb_dev.

7.304.2.12 sk_repl_get_attached_blk_dev()

```
blkio_dev_t * sk_repl_get_attached_blk_dev (
            void  )
```

sk_repl_get_attached_blk_dev - The currently attached USB block device, regardless of home-blocks recognition (FABRIC-2.md ?F.8/?F.19) – MINT's own target, since a blank/unminted drive never sets sk_repl_get_homeblocks_dev() above.

NULL if nothing is attached.

References g_attached_blk_dev.

7.304.2.13 sk_repl_get_homeblocks_dev()

```
blkio_dev_t * sk_repl_get_homeblocks_dev (
            void  )
```

sk_repl_get_homeblocks_dev / sk_repl_get_homeblocks_sig - The currently attached home-blocks USB drive, or NULL if none is attached / the attached drive didn't check out as HOMEBLOCKS_SIG_OK (FABRIC-2.md ?F.6/?F.9/?F.18).

Both return NULL together; never one without the other.

References g_homeblocks_dev, and g_homeblocks_sig_valid.

7.304.2.14 sk_repl_get_homeblocks_sig()

```
const homeblocks_sig_t * sk_repl_get_homeblocks_sig (
            void  )
```

References g_homeblocks_sig, and g_homeblocks_sig_valid.

7.304.2.15 sk_repl_headless_wait()

```
void sk_repl_headless_wait (
            VM * mama )
```

sk_repl_headless_wait - Idle-service loop with no interactive surface at all: no banner, no prompt, no console_getc()/readline.

Runs heartbeat_service() and the same SK_IDLE_BEAT_INTERVAL-gated sk_repl_idle(mama) cadence sk_console_readline()'s own idle branch uses – so USB/WIREBIND/Zuse-attach detection, the heartbeat, and all other idle-tick subsystems keep running – until a real identity is currently attached (Zuse's own session, or a WIREBIND user), at which point it returns.

Revised 2026-09-06: originally exited on a one-way sticky "has anyone ever logged in this boot" flag (sk↩ _console_mark_login()/sk_console_ login_occurred(), both retired) – that let a real gap through, found live↩ : once the flag tripped once, it never reset, so a later full logout (nobody attached at all) fell through to a bare, unauthenticated prompt instead of going silent again. This now checks live attach state instead (repl.c's own sk_console_identity_present()), and is called from two places: once from kernel_main.c in place of an immediate sk_repl(mama) call when EMERGENCY_CONSOLE_ENABLED is off (the default, 2026-09-05) – no thumbdrive, no prompt, at boot – and again from inside sk_repl_run()'s own main loop, every time nobody is currently attached, so the same silence re-engages after any later logout mid-boot too. When EMERGENCY_CONSOLE_ENABLED is on (the debug/ recovery escape hatch), neither call site applies – the console shows immediately and stays visible regardless of attach state, exactly as before this change.

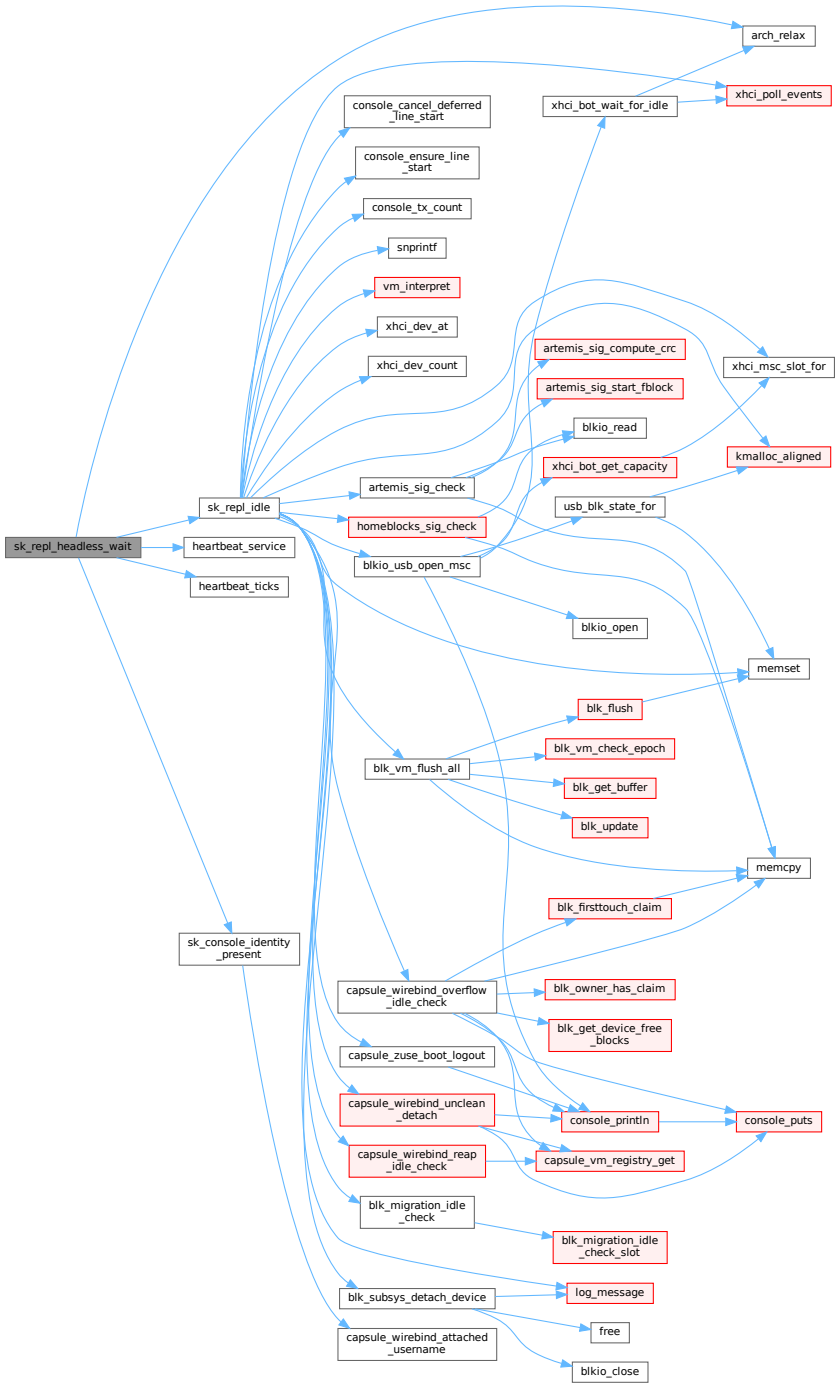
Parameters

mama	Hera's own VM instance – the idle-dispatch target, same as every other sk_repl_idle() caller uses.

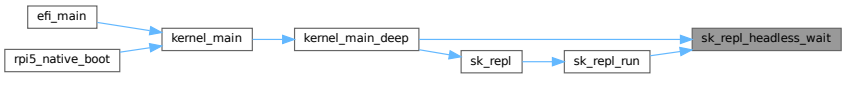
References arch_relax(), g_last_beat_tick, heartbeat_service(), heartbeat_ticks(), sk_console_identity_present(), SK_IDLE_BEAT_INTERVAL, and sk_repl_idle().

Referenced by kernel_main_deep(), and sk_repl_run().

Here is the call graph for this function:



Here is the caller graph for this function:



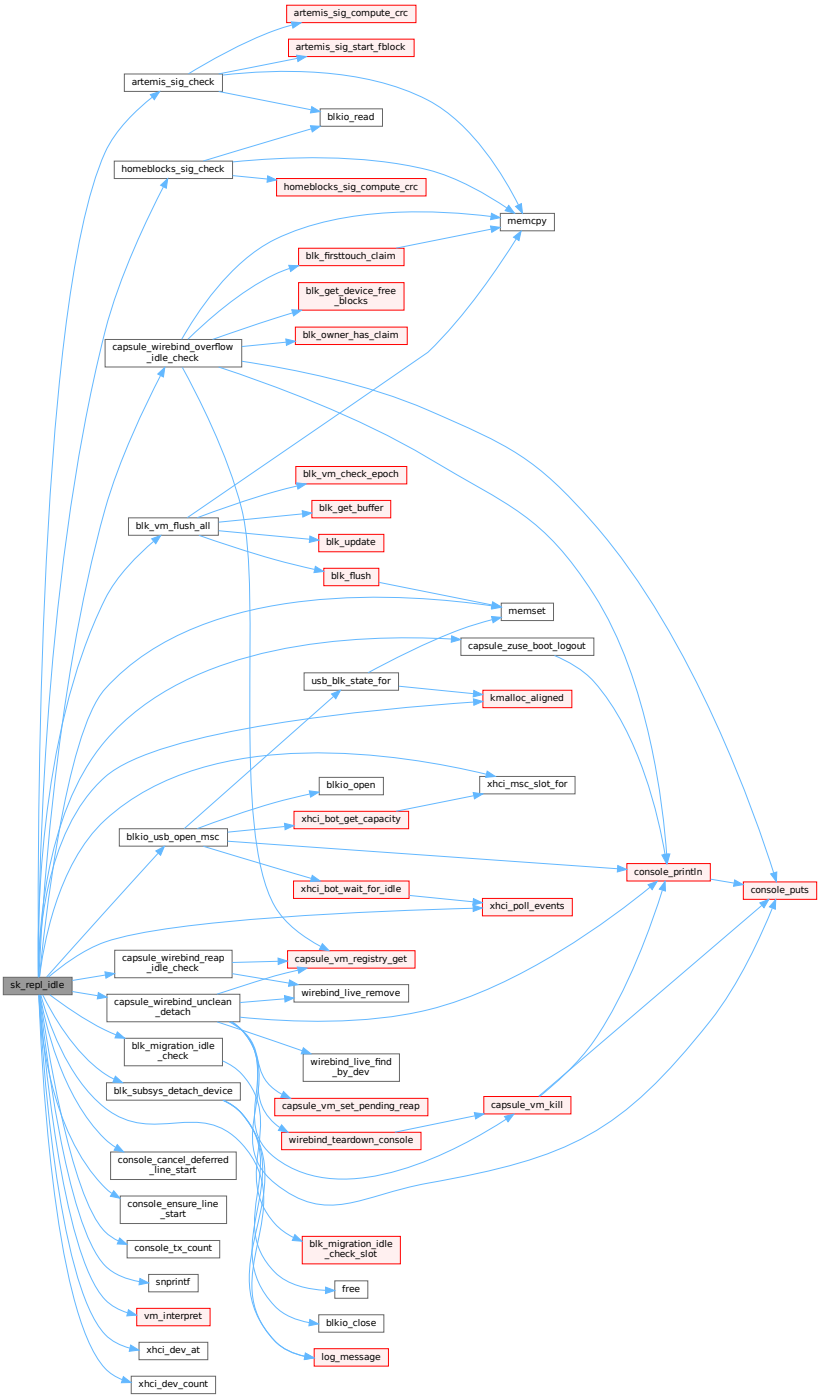
7.304.2.16 sk_repl_idle()

```
static void sk_repl_idle (
            VM * active_vm )  [static]
```

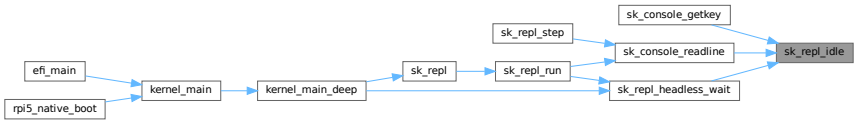
References artemis_sig_check(), ARTEMIS_SIG_OK, blk_migration_idle_check(), blk_subsys_detach_device(), blk_vm_flush_all(), blkio_usb_open_msc(), xhci_msc_slot_t::bot_msc_attach_pending, xhci_msc_slot_t::bot_msc_detach_pending, bytes, capsule_wirebind_overflow_idle_check(), capsule_wirebind_reap_idle_check(), capsule_wirebind_unclean_detach(), capsule_zuse_boot_logout(), console_cancel_deferred_line_start(), console_ensure_line_start(), console_tx_count(), sk_usb_ctrl_t::count, g_attached_blk_dev, g_homeblocks_dev, g_homeblocks_sig, g_homeblocks_sig_valid, g_idle_pump_active, g_mama_interpreting, g_usb_ctrl, HOMEBLOCKS_SIG_BAD_CRC, HOMEBLOCKS_SIG_BAD_VERSION, HOMEBLOCKS_SIG_BLANK, homeblocks_sig_check(), HOMEBLOCKS_SIG_OK, HOMEBLOCKS_SIG_READ_ERROR, HOMEBLOCKS_SIG_START_FBLOCK, sk_blk_attach_pending_t::is_artemis, kmalloc_aligned(), LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, xhci_dev_t::max_slots, memset(), sk_blk_attach_pending_t::pending, sk_usb_ctrl_t::pending, sk_blk_attach_pending_t::sig, sk_blk_attach_pending_t::sig_rc, sk_usb_ctrl_t::slots, snprintf(), vm_interpret(), xdev, xhci_dev_at(), xhci_dev_count(), XHCI_MAX_CONTROLLERS, xhci_msc_slot_for(), and xhci_poll_events().

Referenced by sk_console_getkey(), sk_console_readline(), and sk_repl_headless_wait().

Here is the call graph for this function:



Here is the caller graph for this function:



7.304.2.17 sk_repl_line_calls_use()

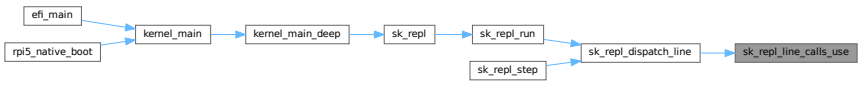
```
static int sk_repl_line_calls_use (
            const char * input )  [static]
```

References strlen().

Referenced by sk_repl_dispatch_line().

Here is the call graph for this function:

Here is the caller graph for this function:



7.304.2.18 sk_repl_register_words()

```
void sk_repl_register_words (
            VM * vm )
```

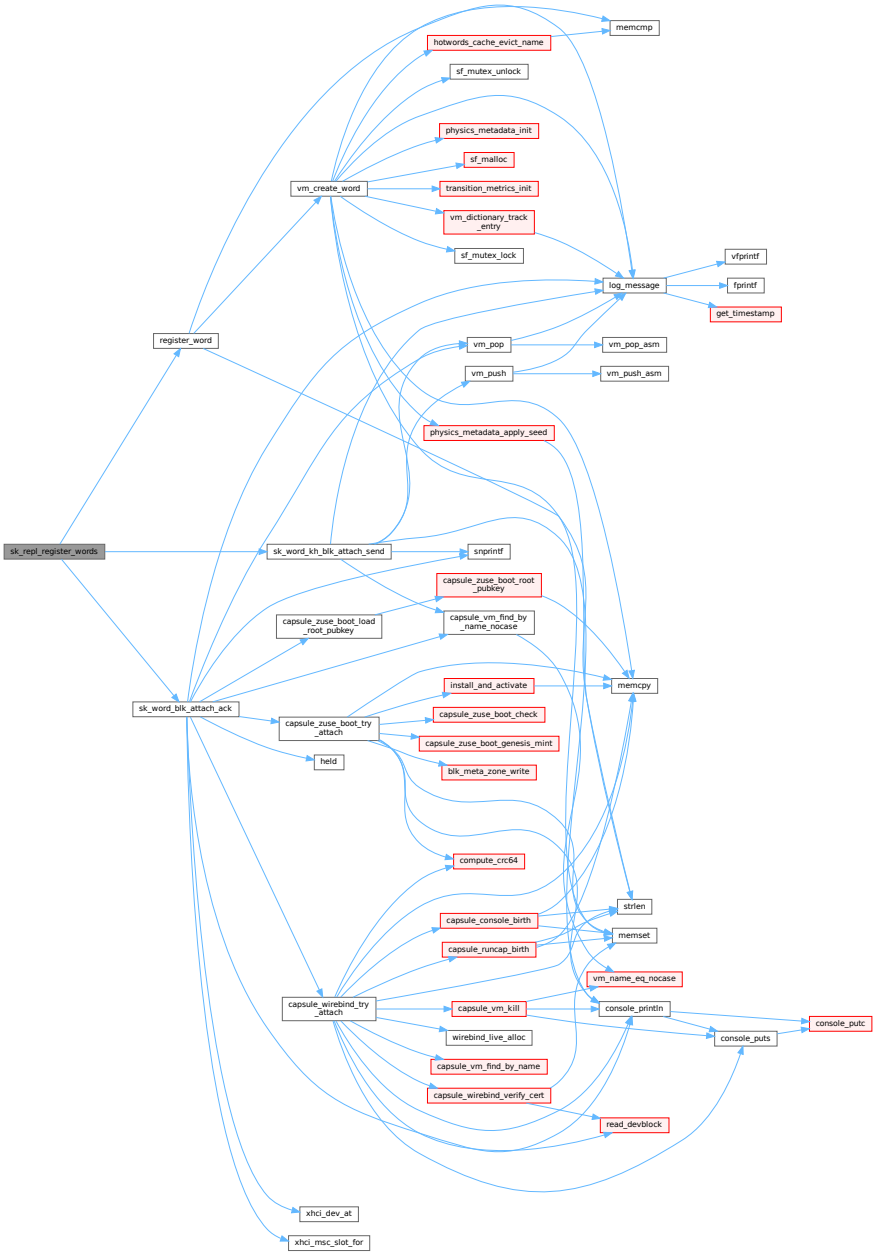
sk_repl_register_words - Registers repl.c's own FORTH-visible words (currently just BLK-ATTACH-ACK, Artemis's storage-attach reply target – see sk_word_blk_attach_ack()'s doc comment in repl.c).

Call once from register_forth79_words() alongside the other **STARKERNEL**-only registration calls.

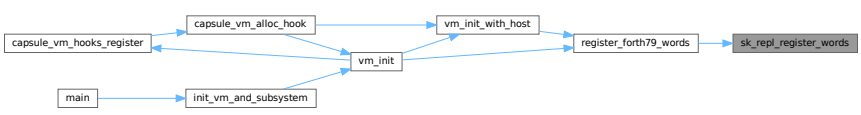
References register_word(), sk_word_blk_attach_ack(), and sk_word_kh_blk_attach_send().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.304.2.19 sk_repl_run()

```
void sk_repl_run (
            VM * vm )
```

sk_repl_run - Bare REPL loop (no banner).

Same as sk_repl but skips the version/welcome banner. Used by START to enter a child VM's interpreter loop without reprinting the header.

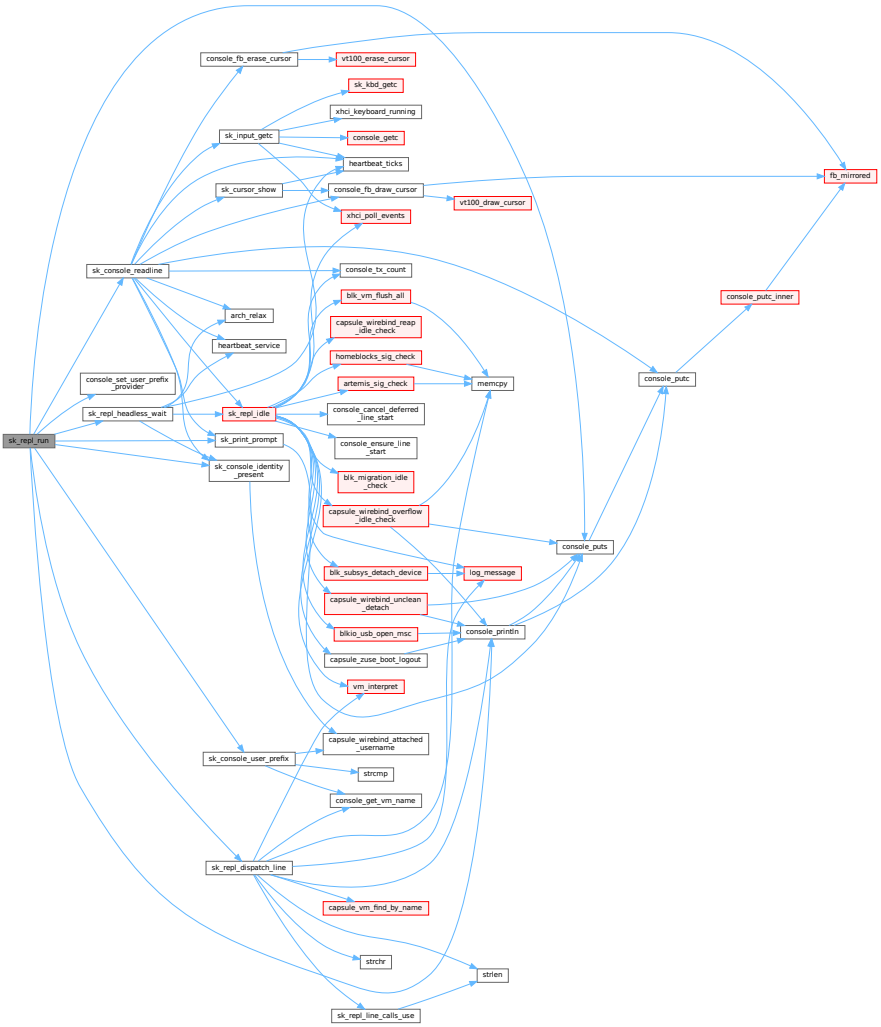
Parameters

vm	Fully initialised VM instance

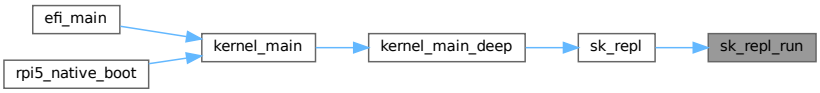
References VM::abort_requested, console_println(), console_puts(), console_set_user_prefix_provider(), VM::error, g_repl_active_vm, VM::halted, INPUT_BUFFER_SIZE, sk_console_identity_present(), sk_console_readline(), sk_console_user_prefix(), sk_print_prompt(), sk_repl_dispatch_line(), and sk_repl_headless_wait().

Referenced by sk_repl().

Here is the call graph for this function:



Here is the caller graph for this function:



7.304.2.20 sk_repl_set_active_vm()

```
void sk_repl_set_active_vm (
            VM * vm )
```

sk_repl_set_active_vm - Redirect REPL input to a different VM (USE word).

Pass NULL to restore default dispatch (Mama's VM). The change takes effect on the next REPL iteration.

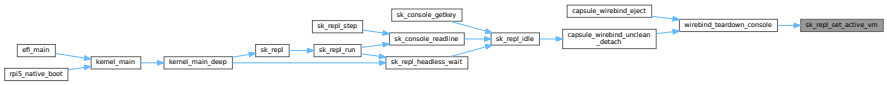
Parameters

vm	Target VM, or NULL for default

References g_repl_active_vm.

Referenced by wirebind_teardown_console().

Here is the caller graph for this function:



7.304.2.21 sk_repl_step()

```
int sk_repl_step (
            VM * vm )
```

sk_repl_step - Execute one REPL turn on a VM and return.

Prints the VM's prompt, reads one line, interprets it, prints ok/ERROR, then returns. Used by the Compudynamics VM-STEP primitive so Hera can give a single REPL quantum to a child VM without surrendering control for the full sk_repl_run() loop.

Parameters

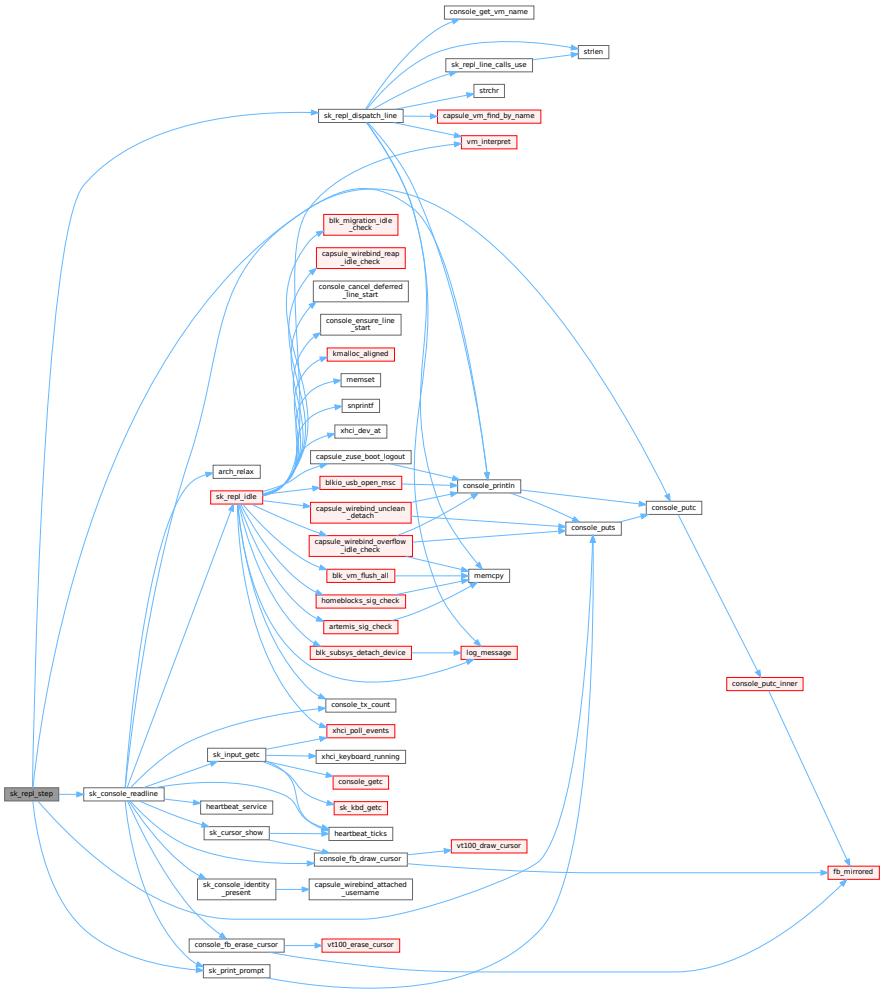
vm	Fully initialised VM instance

Returns

1 if the VM is still running, 0 if it halted during this turn

References VM::abort_requested, console_println(), console_puts(), VM::error, VM::halted, INPUT_BUFFER_SIZE, sk_console_readline(), sk_print_prompt(), and sk_repl_dispatch_line().

Here is the call graph for this function:



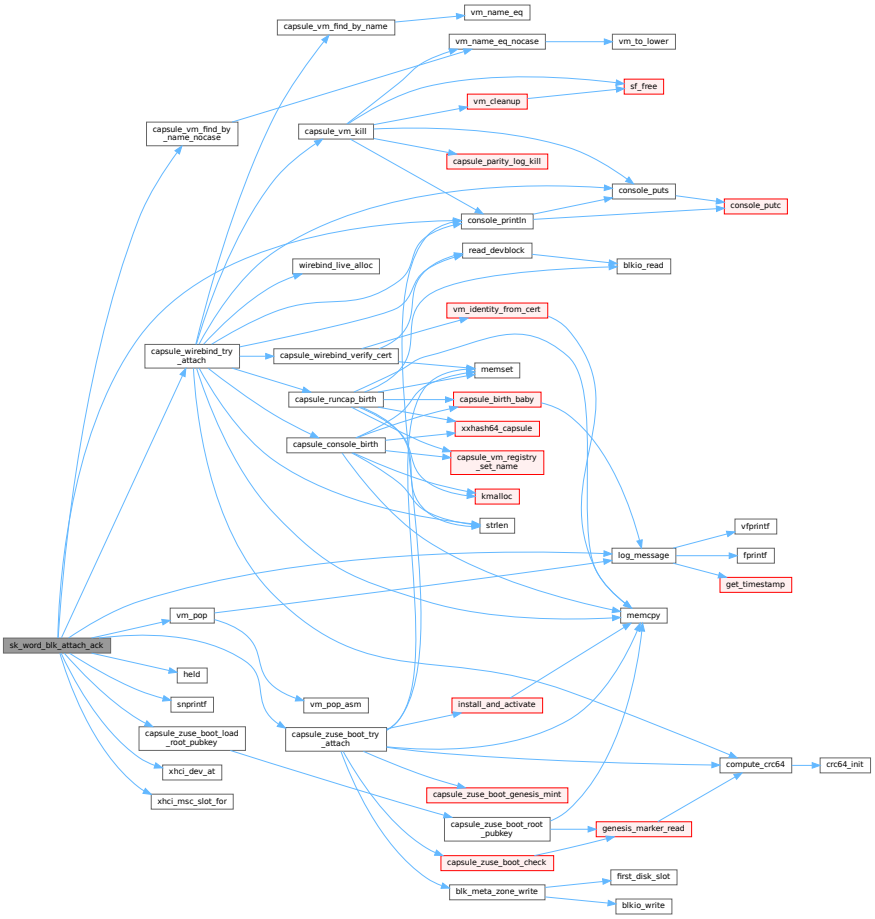
7.304.2.22 sk_word_blk_attach_ack()

```
static void sk_word_blk_attach_ack (
            VM * vm )  [static]
```

References xhci_msc_slot_t::bot_msc_attached, capsule_vm_find_by_name_nocase(), capsule_wirebind_try_attach(), capsule_zuse_boot_load_root_pubkey(), capsule_zuse_boot_try_attach(), console_println(), sk_usb_ctrl_t::count, VM::dsp, VM::error, g_artemis_usb_dev, g_attached_blk_dev, g_usb_ctrl, held(), HOMEBLOCKS_SIG_OK, sk_blk_attach_pending_t::is_artemis, LOG_ERROR, LOG_INFO, log_message(), sk_blk_attach_pending_t::pending, sk_usb_ctrl_t::pending, sk_blk_attach_pending_t::sig, sk_blk_attach_pending_t::sig_rc, slots, snprintf(), VMRegistryEntry::vm_id, vm_pop(), VMRegistryEntry::vm_ptr, xdev, xhci_dev_at(), XHCI_MAX_CONTROLLERS, and xhci_msc_slot_for().

Referenced by sk_repl_register_words().

Here is the call graph for this function:



Here is the caller graph for this function:

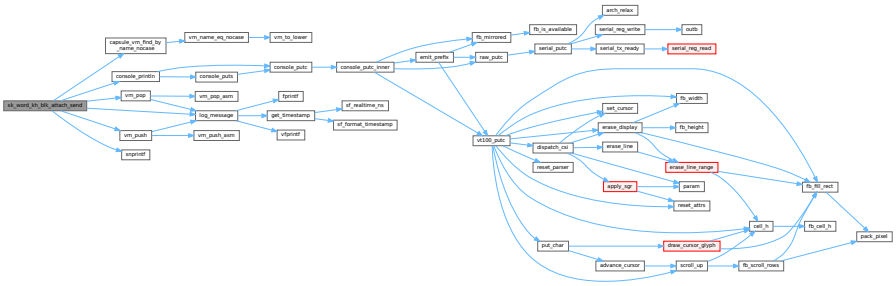
7.304.2.23 sk_word_kh_blk_attach_send()

```
static void sk_word_kh_blk_attach_send (
            VM * vm )  [static]
```

References capsule_vm_find_by_name_nocase(), console_println(), VM::dsp, VM::error, g_kh_blk_attach_buf, LOG_ERROR, log_message(), snprintf(), vm_pop(), VMRegistryEntry::vm_ptr, and vm_push().

Referenced by sk_repl_register_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.304.3 Variable Documentation

7.304.3.1 g_artemis_usb_dev

```
blkio_dev_t* g_artemis_usb_dev = (void *)0  [static]
```

Referenced by sk_repl_get_artemis_usb_dev(), and sk_word_blk_attach_ack().

7.304.3.2 g_attached_blk_dev

```
blkio_dev_t* g_attached_blk_dev = (void *)0  [static]
```

Referenced by sk_repl_get_attached_blk_dev(), sk_repl_idle(), and sk_word_blk_attach_ack().

7.304.3.3 g_console_pending_key

```
int g_console_pending_key = -1  [static]
```

Referenced by sk_console_getkey(), sk_console_key_available(), and sk_console_readline().

7.304.3.4 g_cursor_blink_tick

```
uint64_t g_cursor_blink_tick  [static]
```

Referenced by sk_console_readline(), and sk_cursor_show().

7.304.3.5 g_cursor_visible

```
int g_cursor_visible = 1  [static]
```

Referenced by sk_console_readline(), and sk_cursor_show().

7.304.3.6 g_homeblocks_dev

```
blkio_dev_t* g_homeblocks_dev = (void *)0  [static]
```

Referenced by sk_repl_get_homeblocks_dev(), and sk_repl_idle().

7.304.3.7 g_homeblocks_sig

```
homeblocks_sig_t g_homeblocks_sig  [static]
```

Referenced by sk_repl_get_homeblocks_sig(), and sk_repl_idle().

7.304.3.8 g_homeblocks_sig_valid

```
int g_homeblocks_sig_valid = 0  [static]
```

Referenced by sk_repl_get_homeblocks_dev(), sk_repl_get_homeblocks_sig(), and sk_repl_idle().

7.304.3.9 g_idle_pump_active

```
int g_idle_pump_active  [static]
```

Referenced by sk_repl_idle().

7.304.3.10 g_kh_blk_attach_buf

```
char g_kh_blk_attach_buf[80]  [static]
```

Referenced by sk_word_kh_blk_attach_send().

7.304.3.11 g_kh_console_cmd_buf

```
char g_kh_console_cmd_buf[SK_HERMES_CHUNK_MAX_PAYLOAD]  [static]
```

Referenced by sk_repl_dispatch_line().

7.304.3.12 g_last_beat_tick

```
uint64_t g_last_beat_tick  [static]
```

Referenced by sk_console_getkey(), sk_console_readline(), and sk_repl_headless_wait().

7.304.3.13 g_mama_interpreting

```
int g_mama_interpreting  [static]
```

Referenced by sk_repl_dispatch_line(), and sk_repl_idle().

7.304.3.14 g_repl_active_vm

```
VM* g_repl_active_vm = (void *)0  [static]
```

Referenced by sk_console_getkey(), sk_console_readline(), sk_repl_get_active_vm(), sk_repl_run(), and sk_repl_set_active_vm().

7.304.3.15 g_usb_ctrl

```
sk_usb_ctrl_t g_usb_ctrl[8u]  [static]
```

Referenced by sk_repl_idle(), and sk_word_blk_attach_ack().

7.304.3.16 lithos_version

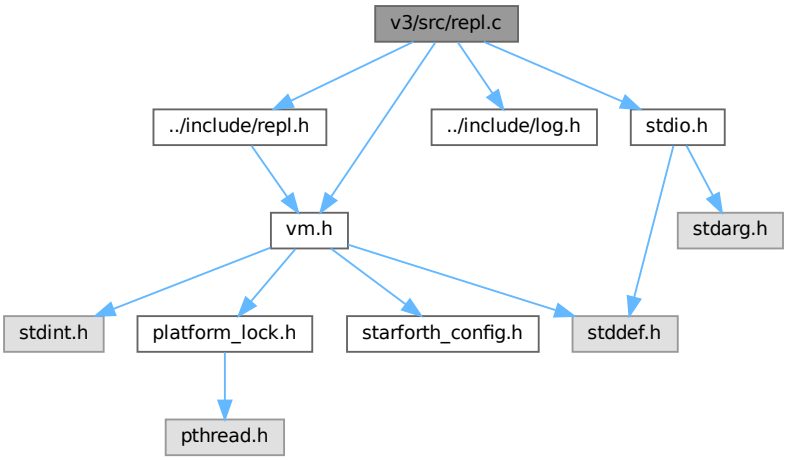
```
const char lithos_version[64] = "LithosAnanke v2.1.0 amd64"
```

Referenced by sk_repl().

7.305 v3/src/repl.c File Reference

```
#include "../include/repl.h"
#include "../include/log.h"
#include "../include/vm.h"
#include <stdio.h>
```

Include dependency graph for repl.c:



Functions

- __attribute__ ((weak))

  Extension point for non-recoverable VM errors (weak symbol).
- void vm_repl (VM *vm, int script_mode)

  Starts the Forth REPL (Read-Eval-Print Loop)

7.305.1 Function Documentation

7.305.1.1 __attribute__()

```
__attribute__ (
             (weak)  )
```

Extension point for non-recoverable VM errors (weak symbol).

Called by the REPL when `EMERGENCY_CONSOLE_ENABLED` = 0 and an error occurs. The default implementation logs the fault at `LOG_ERROR` level and sets `vm->halted` = 1, causing the REPL loop to exit cleanly.

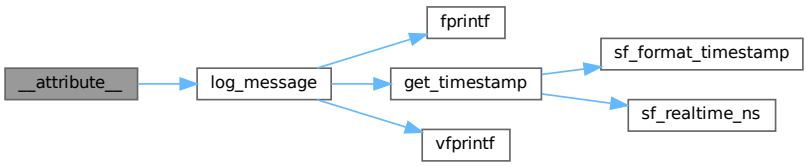
Platforms that need hardware reset, watchdog kick, or JTAG debug-probe integration should provide a strong definition in a platform-specific file (e.g., `starkernel/hal/fault.c`) to override this weak default.

Parameters

vm	Active VM whose `vm->error` triggered the fault path

References VM::halted, LOG_ERROR, and log_message().

Here is the call graph for this function:



7.305.1.2 vm_repl()

```
void vm_repl (
             VM * vm,
             int script_mode )
```

Starts the Forth REPL (Read-Eval-Print Loop)

Parameters

vm	Pointer to the VM structure
script_mode	If 1, suppress prompts and "ok" output (for piped input)

This function implements an interactive REPL for the Forth interpreter. It continuously reads input from the user, interprets it, and prints the result until the VM is halted or an error occurs.

In interactive mode (script_mode=0):

- Prints colored prompt "ok> "
- Acknowledges successful commands with " ok"
- Reports errors with " ERROR"

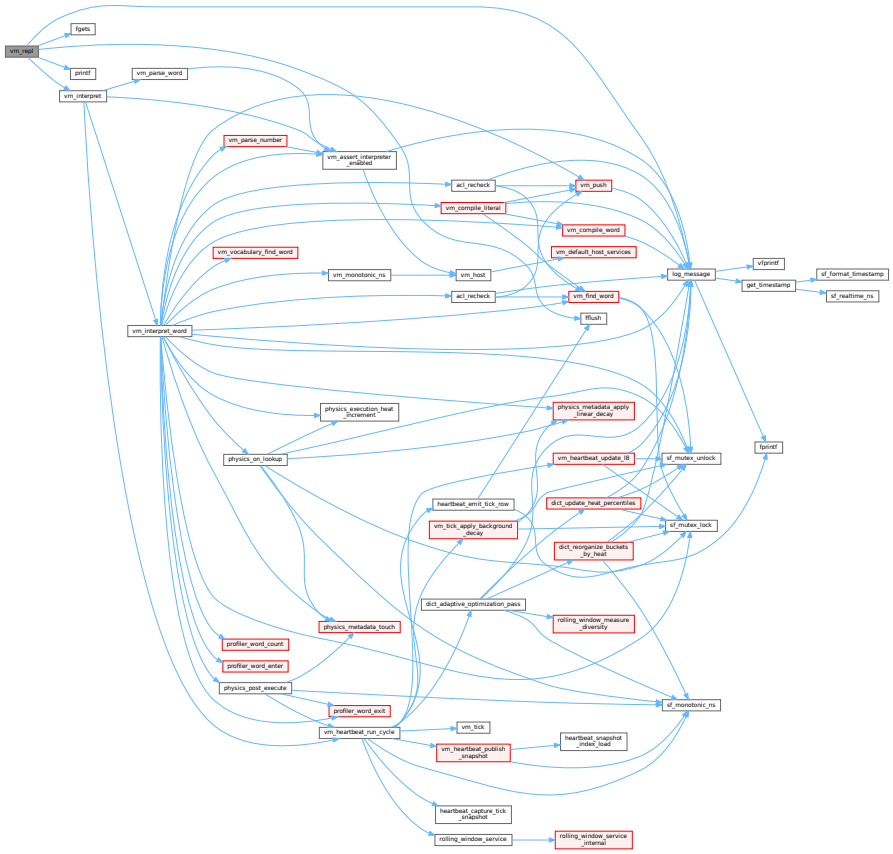
In script mode (script_mode=1):

- Suppresses all prompts and status messages
- Suitable for piped input (heredoc, pipes, redirects)

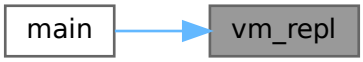
References VM::abort_requested, VM::error, fflush(), fgets(), VM::halted, LOG_INFO, log_message(), printf(), stdin, stdout, vm_interpret(), and VM::zuse_session.

Referenced by main().

Here is the call graph for this function:



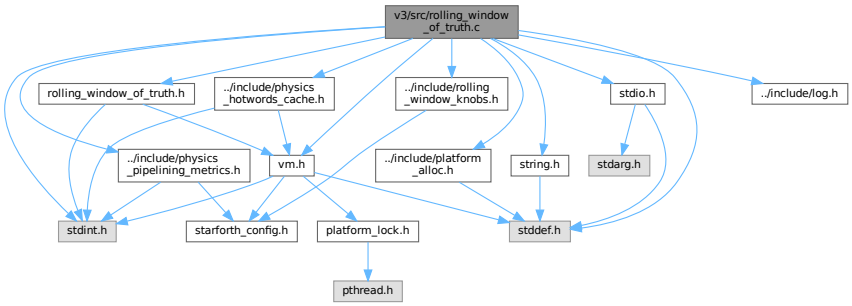
Here is the caller graph for this function:



7.306 v3/src/rolling_window_of_truth.c File Reference

```
#include "rolling_window_of_truth.h"
#include "../include/vm.h"
#include "../include/rolling_window_knobs.h"
#include "../include/physics_hotwords_cache.h"
#include "../include/physics_pipelining_metrics.h"
#include "../include/log.h"
#include "../include/platform_alloc.h"
#include <string.h>
#include <stdio.h>
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for rolling_window_of_truth.c:



Data Structures

- struct rolling_window_view_t

  Immutable snapshot view of a `RollingWindowOfTruth`.

Functions

- static uint64_t rolling_window_measure_diversity_view (const rolling_window_view_t *view)

  Count unique consecutive-pair transitions in a snapshot view.
- static void rolling_window_snapshot_view (const RollingWindowOfTruth *window, rolling_window_view_t *view)

Populate a `rolling_window_view_t` from the current double-buffer snapshot.

- static void rolling_window_publish_snapshot (RollingWindowOfTruth *window)

  Publish the live execution history into the inactive double-buffer slot.
- static void rolling_window_publish_snapshot_if_needed (RollingWindowOfTruth *window)

  Publish a new snapshot only if the `snapshot_pending` flag is set.
- int rolling_window_init (RollingWindowOfTruth *window)

  Initialise a `RollingWindowOfTruth`, allocating its three heap buffers.
- int rolling_window_record_execution (RollingWindowOfTruth *window, uint32_t word_id)

  Record one word execution in the circular history buffer.
- uint32_t rolling_window_get_recent_sequence (const RollingWindowOfTruth *window, uint32_t depth, uint32_t *out_sequence)

  Copy the most recent `depth` word IDs from the rolling window into `out_sequence`.
- uint32_t rolling_window_find_hottest_word (const RollingWindowOfTruth *window, uint32_t dict_size)

  Return the word ID that appears most frequently in the rolling window.
- uint64_t rolling_window_count_transition (const RollingWindowOfTruth *window, uint32_t word_a, uint32_t word_b)

  Count how many times the transition (word_a → word_b) occurs in the history.
- int rolling_window_is_warm (const RollingWindowOfTruth *window)

  Return whether the rolling window has accumulated enough history to be useful.
- char * rolling_window_stats_string (const RollingWindowOfTruth *window)

  Allocate and return a one-page status summary for a `RollingWindowOfTruth`.
- void rolling_window_reset (RollingWindowOfTruth *window)

  Reset the rolling window to an empty cold state without freeing heap memory.
- void rolling_window_cleanup (RollingWindowOfTruth *window)

  Free all heap memory held by a `RollingWindowOfTruth`.
- void rolling_window_seed_hotwords_cache (const RollingWindowOfTruth *window, struct VM *vm)

  Warm-start the hot-words cache from POST execution history.
- void rolling_window_seed_pipelining_context (const RollingWindowOfTruth *window, struct VM *vm)

  Warm-start pipelining context windows from POST execution history.
- uint64_t rolling_window_export_execution_history (const RollingWindowOfTruth *window, uint32_t *out_↩ sequence, uint64_t max_count)

  Export up to `max_count` entries from the execution history in chronological order.
- double rolling_window_pattern_capture_rate (const RollingWindowOfTruth *window, uint32_t test_window↩ _size)

  Estimate the fraction of transitions that carry unique contextual information.
- uint64_t rolling_window_measure_diversity (const RollingWindowOfTruth *window)

  Return the current pattern diversity score for the rolling window.
- static void rolling_window_run_adaptive_pass (RollingWindowOfTruth *window, const rolling_window_view_t *view)

  Adjust `effective_window_size` based on pattern diversity growth rate.
- static void rolling_window_service_internal (RollingWindowOfTruth *window)

  Drain both pending flags — snapshot and adaptive — in one call.
- void rolling_window_check_adaptive_shrink (RollingWindowOfTruth *window)

  Force an immediate adaptive window check, bypassing the accumulator gate.
- void rolling_window_service (RollingWindowOfTruth *window)

  Service the rolling window — publish pending snapshots and run adaptive sizing.

7.306.1 Function Documentation

7.306.1.1 rolling_window_check_adaptive_shrink()

```
void rolling_window_check_adaptive_shrink (
            RollingWindowOfTruth * window )
```

Force an immediate adaptive window check, bypassing the accumulator gate.

Sets `window->adaptive_pending` = 1 unconditionally and then calls `rolling_window_service_internal()` to drain it immediately. This allows external callers (e.g. the heartbeat timer or a FORTH word) to trigger a window-size evaluation outside the normal `ADAPTIVE_CHECK_FREQUENCY` cadence — for example, after a major workload transition or at benchmark checkpoints.

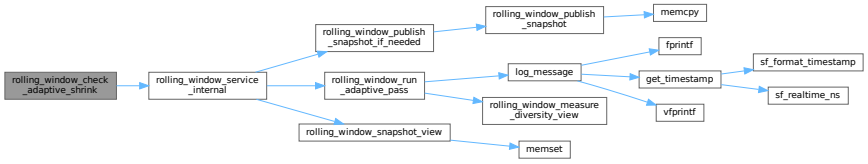
If the window is not warm the adaptive pass is a no-op internally.

Parameters

window	The `RollingWindowOfTruth` to check; no-op if NULL.

References RollingWindowOfTruth::adaptive_pending, and rolling_window_service_internal().

Here is the call graph for this function:



7.306.1.2 rolling_window_cleanup()

```
void rolling_window_cleanup (
            RollingWindowOfTruth * window )
```

Free all heap memory held by a `RollingWindowOfTruth`.

Calls `sf_free()` on `execution_history` and both `snapshot_buffers`[], setting each to NULL after freeing. Does not zero the scalar fields; the caller must not use `window` after this call without a subsequent `rolling_window_init()`.

No-op if `window` is NULL. Each buffer pointer is individually NULL-checked before freeing (defensive against partial-init failures from `rolling_window_init()`).

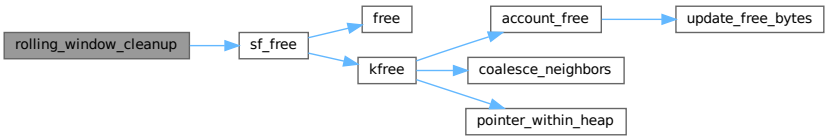
Parameters

window	The `RollingWindowOfTruth` to clean up; no-op if NULL.

References RollingWindowOfTruth::execution_history, sf_free(), and RollingWindowOfTruth::snapshot_buffers.

Referenced by vm_cleanup().

Here is the call graph for this function:



Here is the caller graph for this function:

7.306.1.3 rolling_window_count_transition()

```
uint64_t rolling_window_count_transition (
            const RollingWindowOfTruth * window,
            uint32_t word_a,
            uint32_t word_b )
```

Count how many times the transition (word_a → word_b) occurs in the history.

Scans all `ROLLING_WINDOW_SIZE` consecutive adjacent pairs in the current snapshot (wrapping at the buffer end: pair `i` is (history[i], history[(i+1) % ROLLING_WINDOW_SIZE])) and counts how many pairs match `word_a` followed by `word_b`.

Returns 0 if:

- `window` is NULL.
- `window->is_warm` is 0 (the history is too short to be meaningful).
- The snapshot's `is_warm` flag is 0.

Note: because the history is circular and the scan is linear across all slots regardless of `effective_window_size`, the count includes transitions that span the buffer wrap-around boundary. This is intentional: the full `ROLLING_WINDOW_SIZE` is used for transition counting.

Parameters

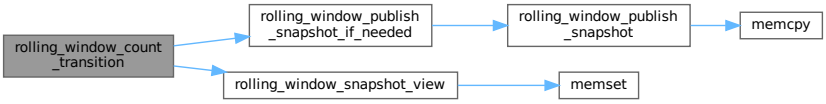
window	The `RollingWindowOfTruth` to query.
word_a	ID of the predecessor word.
word_b	ID of the successor word.

Returns

Count of (word_a → word_b) transitions; 0 if not warm.

References count, rolling_window_view_t::history, RollingWindowOfTruth::is_warm, rolling_window_view_t::is_warm, rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, and rolling_window_snapshot_view().

Here is the call graph for this function:



7.306.1.4 rolling_window_export_execution_history()

```
uint64_t rolling_window_export_execution_history (
            const RollingWindowOfTruth * window,
            uint32_t * out_sequence,
            uint64_t max_count )
```

Export up to `max_count` entries from the execution history in chronological order.

Linearises the internal circular buffer so callers get entries from oldest to newest without knowing the internal `window_pos` cursor. Two cases:

- **Pre-wrap** (`total_executions` < `ROLLING_WINDOW_SIZE`): the buffer has not yet wrapped; entries 0..`total_executions-1` are valid and are copied contiguously from `history`[0].
- **Post-wrap** (`total_executions` ≥ `ROLLING_WINDOW_SIZE`): the oldest entry is at `history`[window↩_pos]. Two `memcpy` calls stitch the two halves together:
  1. `history`[window_pos .. ROLLING_WINDOW_SIZE-1] (first part)
  2. `history`[0 .. window_pos-1] (second part, if `export_count` > `first_part`)

`export_count` is `min`(`total_executions`, `max_count`). Returns 0 if `window`, `out_sequence` are NULL, `max_count` is 0, the snapshot has no history, or `export_count` is 0.

Parameters

window	The `RollingWindowOfTruth` to export.
out_sequence	Caller-allocated output buffer of at least `max_count` `uint32_t` entries.
max_count	Maximum number of entries to export.

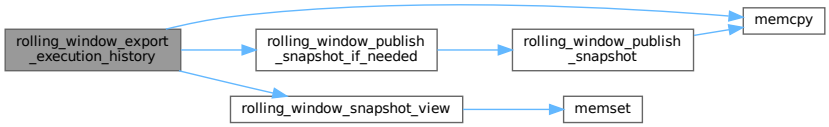
Returns

Actual number of entries written to `out_sequence`.

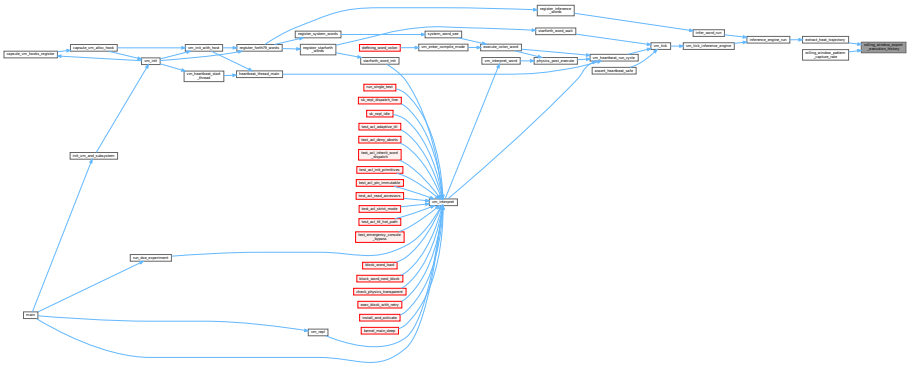
References rolling_window_view_t::history, memcpy(), rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), rolling_window_view_t::total_executions, and rolling_window_view_t::window_pos.

Referenced by extract_heat_trajectory(), and rolling_window_pattern_capture_rate().

Here is the call graph for this function:



Here is the caller graph for this function:



7.306.1.5 rolling_window_find_hottest_word()

```
uint32_t rolling_window_find_hottest_word (
            const RollingWindowOfTruth * window,
            uint32_t dict_size )
```

Return the word ID that appears most frequently in the rolling window.

Obtains the current snapshot, allocates a zero-filled frequency array of `dict_size` `uint32_t` counters via `sf_calloc`, and scans all `ROLLING_WINDOW_SIZE` history slots to tally occurrences. Then performs a linear scan for the maximum and frees the frequency array before returning.

Returns 0 immediately (without allocating) if:

- `window` is NULL.
- `window->is_warm` is 0 (not enough history to be meaningful).
- The snapshot's `is_warm` flag is 0.
- `sf_calloc` fails.

The returned word ID is the zero-based index into the dictionary's word-ID space. Word ID 0 may be returned both as a legitimate hottest word and as the not-warm sentinel; callers should check `rolling_window_is_warm()` before relying on the result.

Parameters

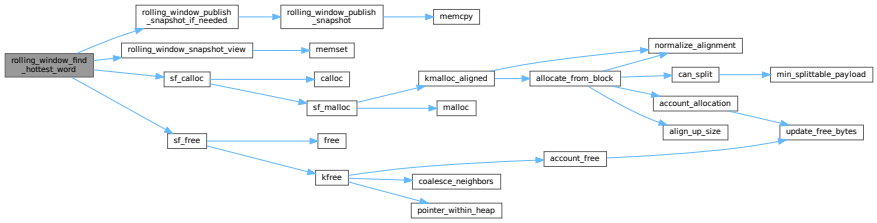
window	The `RollingWindowOfTruth` to analyse.
dict_size	Size of the dictionary's word-ID space; bounds the frequency array and the scan of the history.

Returns

Word ID of the most-frequently-executed word; 0 if the window is not warm or allocation fails.

References rolling_window_view_t::history, RollingWindowOfTruth::is_warm, rolling_window_view_t::is_warm, rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), sf_calloc(), sf_free(), and word_id.

Here is the call graph for this function:



7.306.1.6 rolling_window_get_recent_sequence()

```
uint32_t rolling_window_get_recent_sequence (
            const RollingWindowOfTruth * window,
            uint32_t depth,
            uint32_t * out_sequence )
```

Copy the most recent `depth` word IDs from the rolling window into `out_sequence`.

Calls `rolling_window_publish_snapshot_if_needed()` then reads the current double-buffer snapshot via `rolling_window_snapshot_view()`. Copies at most `min(depth`, available) entries from the most recent portion of the circular buffer into `out_sequence` in chronological order (oldest entry at index 0, most recent at index `actual_depth` - 1).

The available count is capped at `min(total_executions`, `ROLLING_WINDOW_SIZE)` so callers requesting more history than has been recorded get what is available rather than stale zeros.

Entries are addressed via:
`idx = (window_pos - actual_depth + i + ROLLING_WINDOW_SIZE) % ROLLING_WINDOW_SIZE`

Returns 0 immediately if `window`, `out_sequence` are NULL or `depth` is 0.

Parameters

window	The `RollingWindowOfTruth` to sample.
depth	Maximum number of recent word IDs to copy.
out_sequence	Caller-allocated output buffer of at least `depth` `uint32_t` entries.

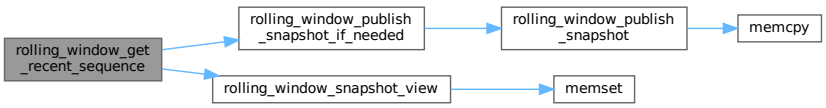
Returns

Actual number of entries written to `out_sequence`; ≤ `depth`.

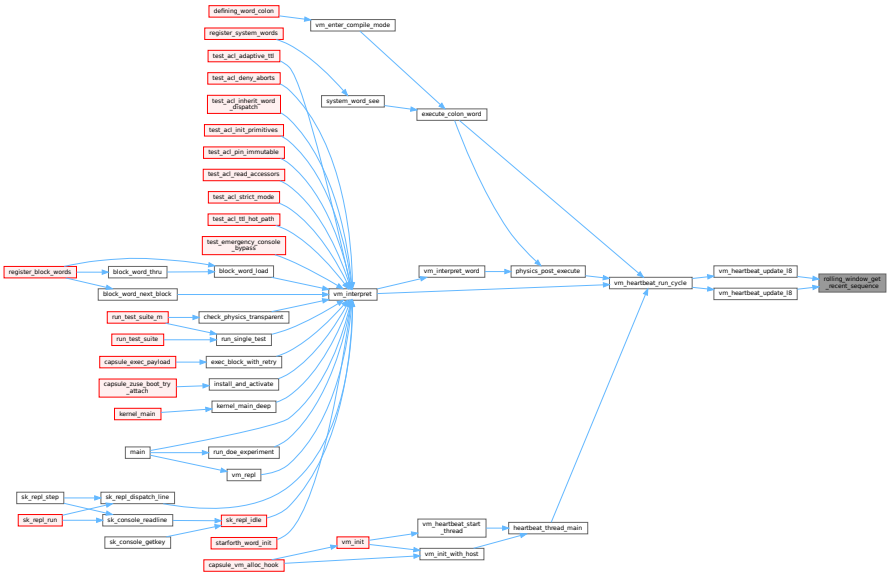
References rolling_window_view_t::history, rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), rolling_window_view_t::total_executions, and rolling_window_view_t::window_pos.

Referenced by vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the call graph for this function:



Here is the caller graph for this function:



7.306.1.7 rolling_window_init()

```
int rolling_window_init (
            RollingWindowOfTruth * window )
```

Initialise a `RollingWindowOfTruth`, allocating its three heap buffers.

Allocates and zero-initialises three `uint32_t` arrays, each of `ROLLING_WINDOW_SIZE` elements, via `sf_↩ calloc`:

- `window->execution_history` — the live circular write buffer.

- `window->snapshot_buffers[0]` — first double-buffer read slot.
- `window->snapshot_buffers[1]` — second double-buffer read slot.

If any allocation fails, all previously allocated buffers are freed and nulled before returning ?1. Initialises scalar state:

- `window_pos` = 0, `total_executions` = 0, `is_warm` = 0 (cold start).
- `effective_window_size` = `ROLLING_WINDOW_SIZE` (start at maximum).
- `snapshot_index` = 0, `snapshot_pending` = 1.
- All `snapshot_window_pos[]` / `snapshot_total_executions[]` / etc. = 0.
- `adaptive_check_accumulator` = 0, `adaptive_pending` = 0.

Immediately calls `rolling_window_publish_snapshot()` to push the zeroed state into both snapshot slots so that any early read-side call before the first `rolling_window_record_execution()` gets a coherent (empty) view.

Parameters

window	The `RollingWindowOfTruth` to initialise; must not be NULL.

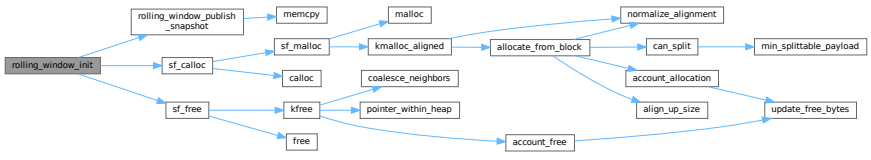
Returns

0 on success; ?1 on NULL `window` or allocation failure.

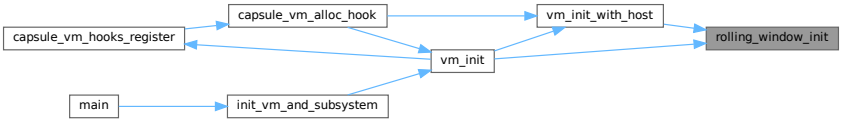
References RollingWindowOfTruth::adaptive_check_accumulator, RollingWindowOfTruth::adaptive_pending, RollingWindowOfTruth::effective_window_size, RollingWindowOfTruth::execution_history, RollingWindowOfTruth::is_warm, RollingWindowOfTruth::last_pattern_diversity, RollingWindowOfTruth::pattern_diversity_check_count, rolling_window_publish_snapsh ROLLING_WINDOW_SIZE, sf_calloc(), sf_free(), RollingWindowOfTruth::snapshot_buffers, RollingWindowOfTruth::snapshot_effectiv RollingWindowOfTruth::snapshot_index, RollingWindowOfTruth::snapshot_is_warm, RollingWindowOfTruth::snapshot_pending, RollingWindowOfTruth::snapshot_total_executions, RollingWindowOfTruth::snapshot_window_pos, RollingWindowOfTruth::total_exec and RollingWindowOfTruth::window_pos.

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.306.1.8 rolling_window_is_warm()

```
int rolling_window_is_warm (
            const RollingWindowOfTruth * window )
```

Return whether the rolling window has accumulated enough history to be useful.

Returns `window->is_warm`, which is set to 1 by `rolling_window_record_execution()` once `total_executions` $\geq$ 1024. Before that threshold the window is considered "cold" — its contents do not yet represent a stable distribution of the program's word usage, and analysis functions (`rolling_window_find_hottest_word()`, `rolling_window_count_transition()`, adaptive sizing) return early with conservative defaults when `is_warm` is 0.

Parameters

window	The `RollingWindowOfTruth` to query; NULL → returns 0.

Returns

1 if the window is warm ($\geq$ 1024 executions); 0 otherwise.

References RollingWindowOfTruth::is_warm.

7.306.1.9 rolling_window_measure_diversity()

```
uint64_t rolling_window_measure_diversity (
            const RollingWindowOfTruth * window )
```

Return the current pattern diversity score for the rolling window.

Triggers a lazy snapshot publish via `rolling_window_publish_snapshot_if_needed()`, acquires a read-side view via `rolling_window_snapshot_view()`, and delegates to the internal `rolling_window_measure_diversity_view()` to count the number of unique adjacent-pair transitions in the active window.

Higher diversity means the window is observing a wide variety of word sequences, indicating that the execution pattern is volatile and heat-stratified lookup is more beneficial than stable-pattern nearest-first lookup. Lower diversity means the program is executing a narrow, repetitive sequence — pattern knowledge is concentrated and reliable.

Used by `dict_adaptive_optimization_pass()` to select lookup strategy (threshold = 70 unique transitions) and by `rolling_window_run_adaptive_pass()` to calibrate `effective_window_size`.

Parameters

window	The `RollingWindowOfTruth` to measure.

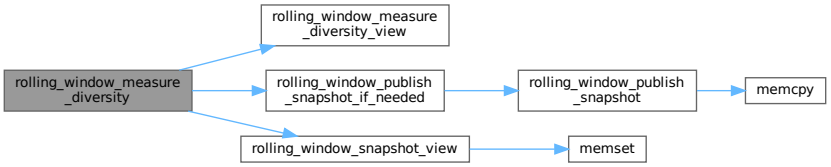
Returns

Count of unique adjacent-pair transitions in the active window; 0 if the window has fewer than 2 executions or `window` is NULL.

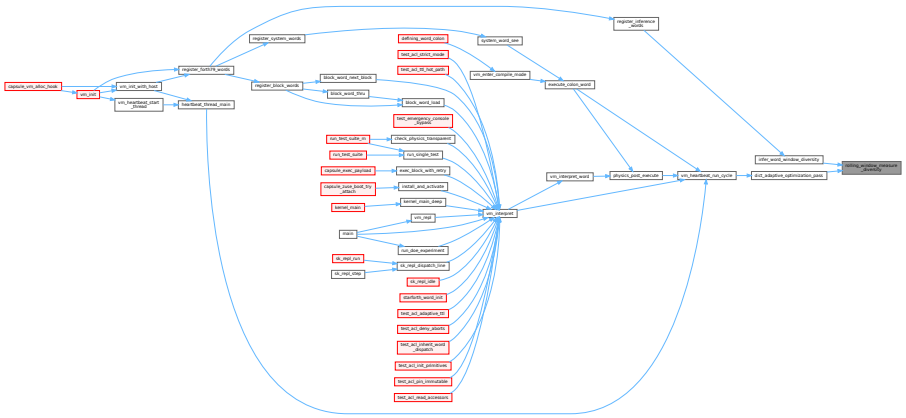
References rolling_window_measure_diversity_view(), rolling_window_publish_snapshot_if_needed(), and rolling_window_snapshot_view().

Referenced by dict_adaptive_optimization_pass(), and infer_word_window_diversity().

Here is the call graph for this function:



Here is the caller graph for this function:



7.306.1.10 rolling_window_measure_diversity_view()

```
static uint64_t rolling_window_measure_diversity_view (
            const rolling_window_view_t * view )  [static]
```

Count unique consecutive-pair transitions in a snapshot view.

Scans the `view`'s history buffer over the most recent `effective_window_size` entries (when warm) or all `ROLLING_WINDOW_SIZE` entries (when cold) and counts the number of adjacent pairs (history[i], history[i+1]) where `history`[i+1] $\neq$ `history`[i].

This is the primary pattern-diversity metric used by:

- `dict_adaptive_optimization_pass()` — to choose between heat-aware and naive lookup strategies (diversity $>$ 70 $\rightarrow$ heat-aware).
- `rolling_window_run_adaptive_pass()` — to decide whether to shrink or grow `effective_window_size`.

Returns 0 if `view` is NULL, has no history, or has fewer than 2 total executions.

Parameters

view	Immutable snapshot view; must have `history` != NULL.

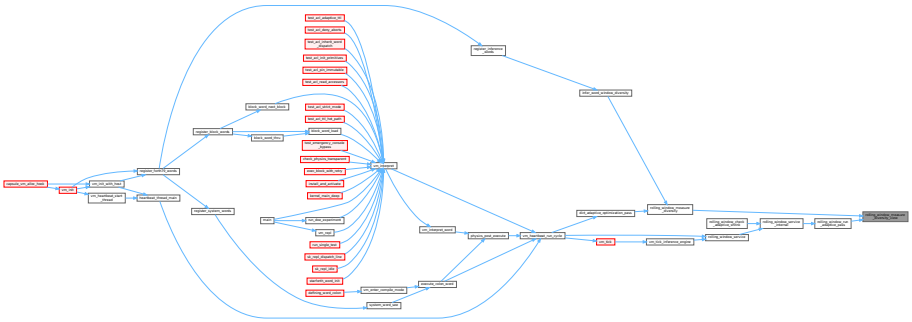
Returns

Count of unique adjacent-pair transitions in the active window.

References rolling_window_view_t::effective_window_size, rolling_window_view_t::history, rolling_window_view_t::is_warm, ROLLING_WINDOW_SIZE, rolling_window_view_t::total_executions, and rolling_window_view_t::window_pos.

Referenced by rolling_window_measure_diversity(), and rolling_window_run_adaptive_pass().

Here is the caller graph for this function:



7.306.1.11 rolling_window_pattern_capture_rate()

```
double rolling_window_pattern_capture_rate (
            const RollingWindowOfTruth * window,
            uint32_t test_window_size )
```

Estimate the fraction of transitions that carry unique contextual information.

Measures how many of the recorded adjacent-pair transitions produce a non-zero hash when the preceding `test_window_size` word IDs are incorporated:

```
pattern_hash = (... ((word[i-ws] × 31 + word[i-ws+1]) × 31 + ...) × 31 + word[i+1])
            mod 0x7FFFFFFF
```

A non-zero hash is counted as a "captured" pattern. The capture rate is:

```
rate = patterns_seen / total_transitions × 100  (clamped to [0, 100])
```

In practice, hash collisions with the zero sentinel are extraordinarily rare (probability ~1/2^31), so nearly all transitions contribute to `patterns_seen`. The function thus measures whether `test_window_size` is wide enough to produce a non-trivial hash — a proxy for whether the window introduces meaningful context beyond a single predecessor.

Linearises the circular buffer via `rolling_window_export_execution_history()` before scanning. Returns 0.0 if `window` or `test_window_size` < 1, if the linearised history has fewer than 2 entries, or if `sf_malloc` fails.

Parameters

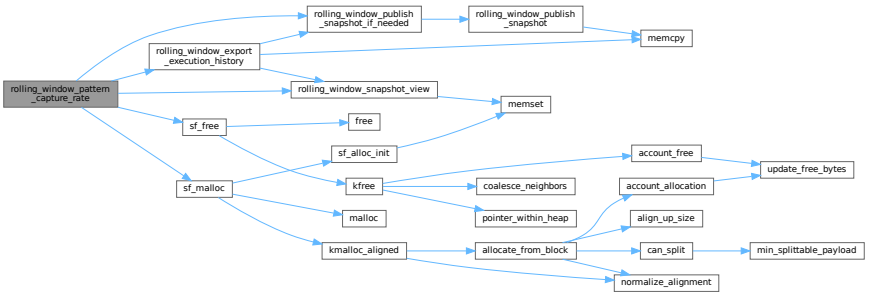
window	The RollingWindowOfTruth to analyse.
test_window_size	Number of preceding word IDs to fold into each pattern hash.

Returns

Capture rate as a percentage in [0.0, 100.0].

References rolling_window_view_t::history, rolling_window_export_execution_history(), rolling_window_publish_snapshot_if_needed, ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), sf_free(), sf_malloc(), and rolling_window_view_t::total_executions.

Here is the call graph for this function:



7.306.1.12 rolling_window_publish_snapshot()

```
static void rolling_window_publish_snapshot (
            RollingWindowOfTruth * window )  [static]
```

Publish the live execution history into the inactive double-buffer slot.

Implements the write side of the lock-free double buffer:

1. Identifies the inactive slot as `write_idx` = `snapshot_index` XOR 1.
2. Copies `window->execution_history` (the live circular buffer) into `snapshot_buffers`[write_idx] via `memcpy`.
3. Copies the current `window_pos`, `total_executions`, `effective_window_size`, and `is_warm` into the corresponding `snapshot_*` parallel arrays.
4. Flips `snapshot_index` to `write_idx` with `__ATOMIC_RELEASE`, making the new snapshot visible to readers.
5. Clears `snapshot_pending` with `__ATOMIC_RELEASE`.

Must only be called from the writer (main VM thread). No-op if `window`, `window->execution_history`, or `snapshot_buffers`[0] are NULL.

Parameters

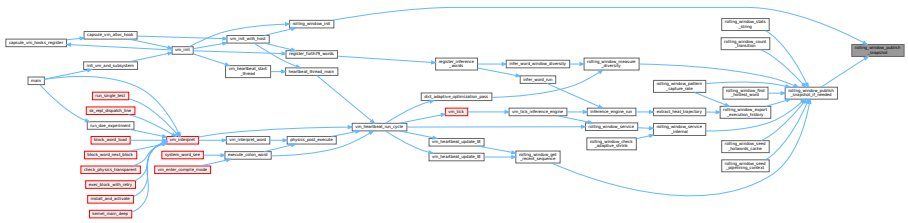
window	The `RollingWindowOfTruth` to snapshot.

References RollingWindowOfTruth::effective_window_size, RollingWindowOfTruth::execution_history, RollingWindowOfTruth::is_warm, memcpy(), ROLLING_WINDOW_SIZE, RollingWindowOfTruth::snapshot_buffers, RollingWindowOfTruth::snapshot_effective_window, RollingWindowOfTruth::snapshot_index, RollingWindowOfTruth::snapshot_is_warm, RollingWindowOfTruth::snapshot_pending, RollingWindowOfTruth::snapshot_total_executions, RollingWindowOfTruth::snapshot_window_pos, RollingWindowOfTruth::total_exec, and RollingWindowOfTruth::window_pos.

Referenced by rolling_window_init(), and rolling_window_publish_snapshot_if_needed().

Here is the call graph for this function:

Here is the caller graph for this function:



7.306.1.13 rolling_window_publish_snapshot_if_needed()

```
static void rolling_window_publish_snapshot_if_needed (
            RollingWindowOfTruth * window )  [static]
```

Publish a new snapshot only if the `snapshot_pending` flag is set.

Atomically exchanges `window->snapshot_pending` with 0 using `__ATOMIC_ACQ_REL`. If the exchanged value was non-zero (meaning `rolling_window_record_execution()` has written new data since the last publish), calls `rolling_window_publish_snapshot()` to make the current state visible to readers. Otherwise returns without copying.

This is the lazy-publish counterpart to `rolling_window_record_execution()`'s eager flag set. By batching publish work to read-side call sites (`rolling_window_get_recent_sequence()`, `rolling_window_find_hottest_word()`, etc.), unnecessary `memcpy` of the full `ROLLING_WINDOW_SIZE` buffer is avoided when no new data has arrived.

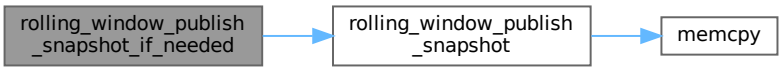
Parameters

window	The `RollingWindowOfTruth` to conditionally snapshot. No-op if NULL.

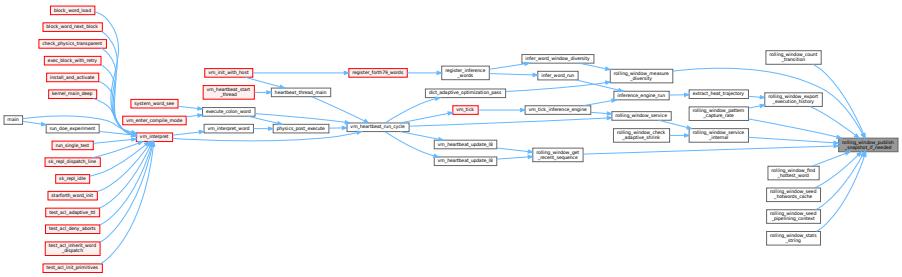
References rolling_window_publish_snapshot(), and RollingWindowOfTruth::snapshot_pending.

Referenced by rolling_window_count_transition(), rolling_window_export_execution_history(), rolling_window_find_hottest_word(), rolling_window_get_recent_sequence(), rolling_window_measure_diversity(), rolling_window_pattern_capture_rate(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), rolling_window_service_internal(), and rolling_window_stats_string().

Here is the call graph for this function:



Here is the caller graph for this function:



7.306.1.14 rolling_window_record_execution()

```
int rolling_window_record_execution (
            RollingWindowOfTruth * window,
            uint32_t word_id )
```

Record one word execution in the circular history buffer.

Writes `word_id` into `window->execution_history`[window_pos], advances `window_pos` modulo `ROLLING_WINDOW_SIZE` (circular wrap), increments `total_executions`, and checks the warm threshold:

- Once `total_executions` $\geq$ 1024 and `is_warm` is still 0, sets `is_warm` = 1. The 1024-execution threshold is calibrated to the POST harness which generates approximately 1450 executions; reaching 1024 guarantees a statistically meaningful execution distribution before diversity or percentile analysis begins.

Sets `snapshot_pending` = 1 to signal that a new snapshot should be published on the next read-side access. When the window is warm and `adaptive_check_accumulator` reaches `ADAPTIVE_CHECK_↩ FREQUENCY`, also sets `adaptive_pending` = 1 to request an `effective_window_size` update.

Called from the interpreter hot path on every word dispatch. All operations are O(1) with no locks and no allocations.

Parameters

window	The `RollingWindowOfTruth` to record into.
word_id	Stable numeric ID of the word just executed.

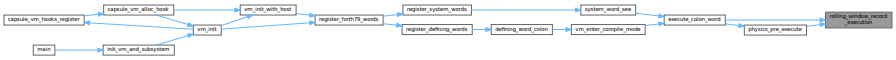
Returns

0 on success; ?1 if `window` or `execution_history` are NULL.

References RollingWindowOfTruth::adaptive_check_accumulator, ADAPTIVE_CHECK_FREQUENCY, RollingWindowOfTruth::adapti RollingWindowOfTruth::execution_history, RollingWindowOfTruth::is_warm, ROLLING_WINDOW_SIZE, RollingWindowOfTruth::snap RollingWindowOfTruth::total_executions, RollingWindowOfTruth::window_pos, and word_id.

Referenced by execute_colon_word(), and physics_pre_execute().

Here is the caller graph for this function:



7.306.1.15 rolling_window_reset()

```
void rolling_window_reset (
            RollingWindowOfTruth * window )
```

Reset the rolling window to an empty cold state without freeing heap memory.

Zeros `execution_history` via `memset` and resets the scalar fields: `window_pos` = 0, `total_executions` = 0, `is_warm` = 0. Sets `snapshot_pending` = 1 so that the next read will publish an empty snapshot.

The three heap buffers (`execution_history`, `snapshot_buffers`[0/1]) are preserved; only their contents are zeroed. Intended for benchmark harnesses that need a clean baseline between test runs without the overhead of `rolling_window_cleanup()` + `rolling_window_init()`.

Parameters

window	The `RollingWindowOfTruth` to reset; no-op if NULL or `execution_history` is NULL.

References RollingWindowOfTruth::execution_history, RollingWindowOfTruth::is_warm, memset(), ROLLING_WINDOW_SIZE, RollingWindowOfTruth::snapshot_pending, RollingWindowOfTruth::total_executions, and RollingWindowOfTruth::window_pos.

Here is the call graph for this function:

7.306.1.16 rolling_window_run_adaptive_pass()

```
static void rolling_window_run_adaptive_pass (
            RollingWindowOfTruth * window,
            const rolling_window_view_t * view )  [static]
```

Adjust `effective_window_size` based on pattern diversity growth rate.

Runs the core adaptive window logic using the snapshot `view`. Measures the current diversity via `rolling_window_measure_diversity_view()`, computes the fractional growth rate relative to `window->last_pattern_diversity` in Q16.16 fixed-point:

```
growth_rate_q48 = (diversity_delta « 16) / last_pattern_diversity
```

and compares it against a threshold:

```
threshold_q48 = (ADAPTIVE_GROWTH_THRESHOLD « 16) / 100
```

Shrink path (`growth_rate_q48 < threshold_q48`): diversity is plateauing; reducing the window saves scan work. The new size is:

```
new_size = max(effective_window_size × ADAPTIVE_SHRINK_RATE / 100,
               ADAPTIVE_MIN_WINDOW_SIZE)
```

Already at `ADAPTIVE_MIN_WINDOW_SIZE` → no change (logs "Floor Reached").

Grow path (`growth_rate_q48 ≥ threshold_q48`): diversity is still increasing; the larger window is capturing new patterns. The new size is:

```
new_size = min(effective_window_size × 100 / ADAPTIVE_SHRINK_RATE,
               ROLLING_WINDOW_SIZE)
```

Already at `ROLLING_WINDOW_SIZE` → no change (logs "Ceiling Reached").

On the very first call after init, `last_pattern_diversity` == 0; only the baseline is recorded and the function returns without resizing. All decisions are logged at `LOG_DEBUG` for offline analysis.

No-op if `window` or `view` are NULL or the view is not warm.

Parameters

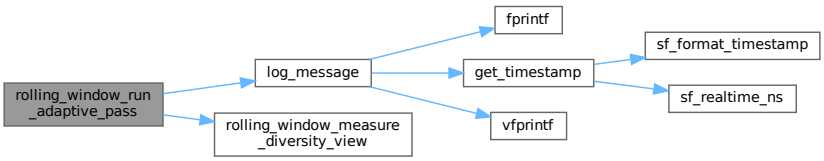
window	The `RollingWindowOfTruth` whose `effective_window_size` and `last_pattern_diversity` are updated.
view	Current immutable snapshot; must be warm.

References ADAPTIVE_GROWTH_THRESHOLD, ADAPTIVE_MIN_WINDOW_SIZE, ADAPTIVE_SHRINK_RATE, RollingWindowOfTruth::effective_window_size, rolling_window_view_t::history, rolling_window_view_t::is_warm,

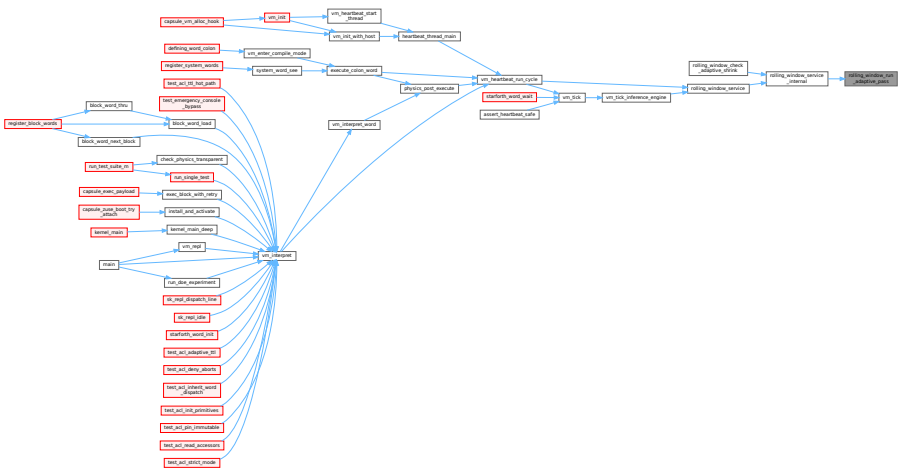
RollingWindowOfTruth::last_pattern_diversity, LOG_DEBUG, log_message(), RollingWindowOfTruth::pattern_diversity_check_count, rolling_window_measure_diversity_view(), ROLLING_WINDOW_SIZE, and rolling_window_view_t::total_executions.

Referenced by rolling_window_service_internal().

Here is the call graph for this function:



Here is the caller graph for this function:



7.306.1.17 rolling_window_seed_hotwords_cache()

```
void rolling_window_seed_hotwords_cache (
            const RollingWindowOfTruth * window,
            struct VM * vm )
```

Warm-start the hot-words cache from POST execution history.

Called exactly once after POST completes and before the REPL begins, so that the first interactive command benefits from cache entries derived from real POST execution data rather than starting cold. The algorithm:

1. Allocates a zero-filled frequency array of `DICTIONARY_SIZE` `uint32_t` counters via `sf_calloc`.
2. Obtains the current snapshot and tallies occurrences of each word ID over all `ROLLING_WINDOW_SIZE` history slots.
3. Computes a promotion threshold: words appearing more than the average frequency across all non-zero-frequency words are considered "hot".

4. Iterates over the frequency array; for each word above the threshold, looks up the live `DictEntry` via `vm_dictionary_lookup_by_word_id()` (under `vm->dict_lock`), updates `entry->execution_heat` to the observed frequency count, and calls `hotwords_cache_promote()` to insert it into the cache.

5. Logs the count of promoted words at `LOG_INFO`.

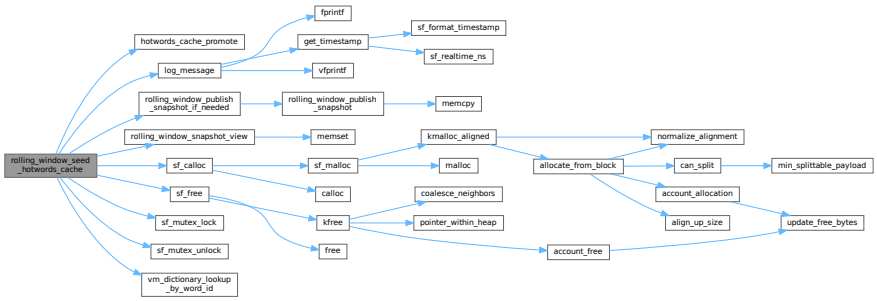
No-op if `window` is NULL, not warm, `vm` is NULL, or `vm->hotwords_cache` is NULL. Also no-op if the snapshot's `is_warm` flag is 0.

Parameters

window	Warm `RollingWindowOfTruth` containing POST execution data.
vm	The VM whose `hotwords_cache` is seeded and whose `dict_lock` is held during `DictEntry` updates.

References VM::dict_lock, DICTIONARY_SIZE, entry, rolling_window_view_t::history, VM::hotwords_cache, hotwords_cache_promote(), RollingWindowOfTruth::is_warm, rolling_window_view_t::is_warm, LOG_INFO, log_message(), rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), sf_calloc(), sf_free(), sf_mutex_lock(), sf_mutex_unlock(), vm_dictionary_lookup_by_word_id(), and word_id.

Here is the call graph for this function:



7.306.1.18 rolling_window_seed_pipelining_context()

```
void rolling_window_seed_pipelining_context (
            const RollingWindowOfTruth * window,
            struct VM * vm )
```

Warm-start pipelining context windows from POST execution history.

Called exactly once after POST completes and before the REPL begins, to populate each word's `transition_metrics` context window with real predecessor data so that speculative prefetch can begin making informed decisions on the first interactive command. The algorithm:

1. Allocates a sliding `context[]` buffer of `context_window_size` `uint32_t` entries (max(`TRANSITION_WINDOW_SIZE`, 2)) and initialises it with the first `context_window_size` entries from the history.

2. Scans all `ROLLING_WINDOW_SIZE` consecutive adjacent pairs in the snapshot:

- Looks up `current_entry = vm_dictionary_lookup_by_word_id(current_id)` (under `vm->dict_lock`, released immediately).
- If `current_entry->transition_metrics` is set, calls `transition_metrics_record_context()` with the current `context[]` and `next_id` to populate the Phase 1 context-transition counter.
- Shifts the `context[]` buffer left by one, appending `next_id` at the right end (sliding window advance).

3. Logs seeded-words and seeded-transitions counts at `LOG_INFO`.

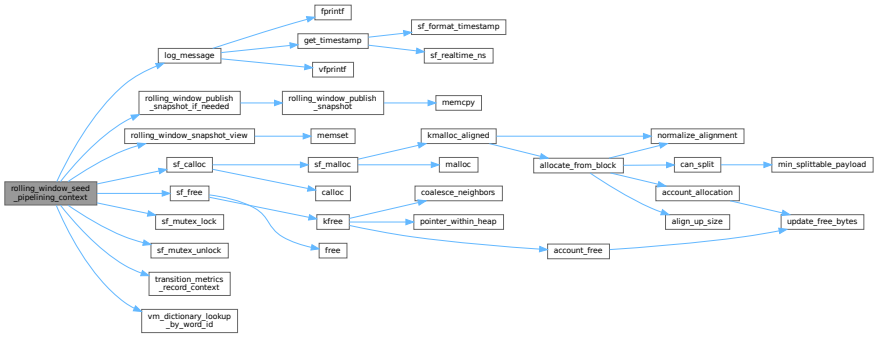
No-op if `window` is NULL, not warm, `vm` is NULL, `ENABLE_PIPELINING` is 0, or the context buffer allocation fails.

Parameters

window	Warm `RollingWindowOfTruth` containing POST execution data.
vm	The VM whose per-word `transition_metrics` structures are seeded; `dict_lock` is briefly held per lookup.

References VM::dict_lock, DICTIONARY_SIZE, ENABLE_PIPELINING, rolling_window_view_t::history, RollingWindowOfTruth::is_wa
rolling_window_view_t::is_warm, LOG_INFO, log_message(), rolling_window_publish_snapshot_if_needed(),
ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), sf_calloc(), sf_free(), sf_mutex_lock(), sf_mutex_unlock(),
DictEntry::transition_metrics, transition_metrics_record_context(), TRANSITION_WINDOW_SIZE, and vm_dictionary_lookup_by_wo

Here is the call graph for this function:



7.306.1.19 rolling_window_service()

```
void rolling_window_service (
            RollingWindowOfTruth * window )
```

Service the rolling window — publish pending snapshots and run adaptive sizing.

The public entry point for the rolling window's periodic maintenance. Intended to be called from the heartbeat tick handler or the REPL idle loop at a rate determined by the caller (typically 100 Hz from the APIC timer ISR via `heartbeat_tick()`). Delegates entirely to `rolling_window_service_internal()`:

- Flushes the pending snapshot if `snapshot_pending` is set.
- Runs `rolling_window_run_adaptive_pass()` if `adaptive_pending` is set.

Unlike `rolling_window_check_adaptive_shrink()`, this function does NOT force `adaptive_pending = 1`; it only services flags that the record path has already set. The normal adaptive-pass cadence is therefore governed entirely by `ADAPTIVE_CHECK_FREQUENCY` executions between checks.

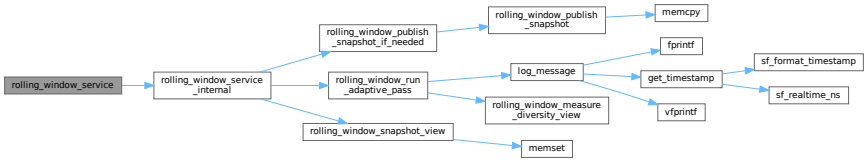
Parameters

window	The `RollingWindowOfTruth` to service; no-op if NULL.

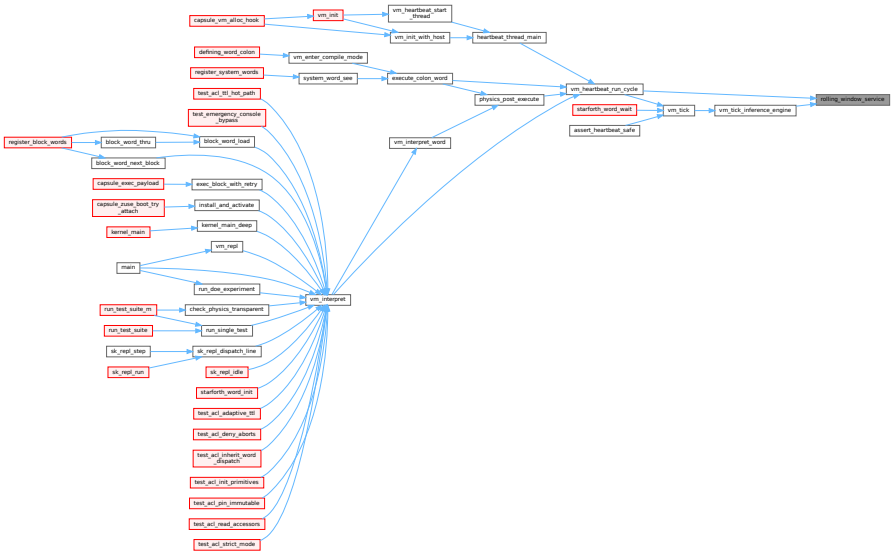
References rolling_window_service_internal().

Referenced by vm_heartbeat_run_cycle(), and vm_tick_inference_engine().

Here is the call graph for this function:



Here is the caller graph for this function:



7.306.1.20 rolling_window_service_internal()

```
static void rolling_window_service_internal (
            RollingWindowOfTruth * window )  [static]
```

Drain both pending flags — snapshot and adaptive — in one call.

Called from both `rolling_window_check_adaptive_shrink()` and `rolling_window_service()` as the single internal dispatch point:

1. Calls `rolling_window_publish_snapshot_if_needed()` to flush any pending execution history into the double-buffer snapshot.
2. Checks `window->adaptive_pending`; if set, acquires a view, runs `rolling_window_run_adaptive_pass()`, then clears `adaptive_pending`.

No-op if `window` is NULL.

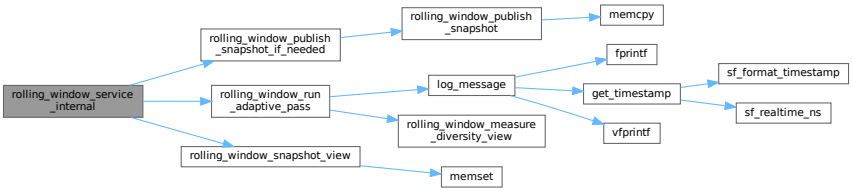
Parameters

window	The `RollingWindowOfTruth` to service.

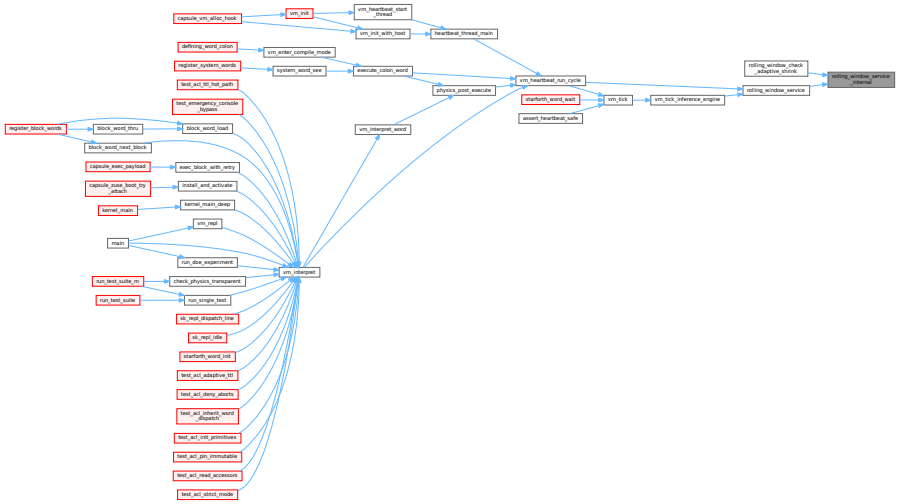
References RollingWindowOfTruth::adaptive_pending, rolling_window_publish_snapshot_if_needed(), rolling_window_run_adaptive_ and rolling_window_snapshot_view().

Referenced by rolling_window_check_adaptive_shrink(), and rolling_window_service().

Here is the call graph for this function:



Here is the caller graph for this function:



7.306.1.21 rolling_window_snapshot_view()

```
static void rolling_window_snapshot_view (
            const RollingWindowOfTruth * window,
            rolling_window_view_t * view )  [static]
```

Populate a `rolling_window_view_t` from the current double-buffer snapshot.

Reads `window->snapshot_index` with `__ATOMIC_ACQUIRE` to determine which of the two snapshot buffers (`snapshot_buffers`[0] or [1]) is the most recently published. Fills `view` with the corresponding history pointer and metadata fields (`window_pos`, `total_executions`, `effective_window_size`, `is_warm`). If `window` or `view` is NULL, `view` is zeroed and the function returns early.

Callers hold no lock — the acquire barrier on `snapshot_index` ensures they see a coherent snapshot that was fully written before `rolling_window_publish_snapshot()` released it via `__ATOMIC_RELEASE`.

Parameters

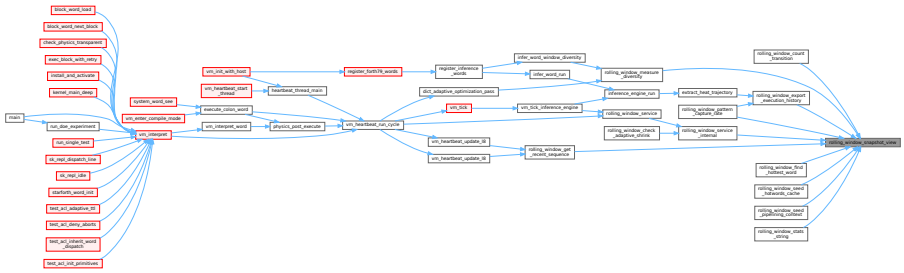
window	The `RollingWindowOfTruth` to sample.
view	Output `rolling_window_view_t`; zeroed on NULL `window`.

References rolling_window_view_t::effective_window_size, rolling_window_view_t::history, rolling_window_view_t::is_warm, memset(), RollingWindowOfTruth::snapshot_buffers, RollingWindowOfTruth::snapshot_effective_window_size, RollingWindowOfTruth::snapshot_index, RollingWindowOfTruth::snapshot_is_warm, RollingWindowOfTruth::snapshot_total_executio RollingWindowOfTruth::snapshot_window_pos, rolling_window_view_t::total_executions, and rolling_window_view_t::window_pos.

Referenced by rolling_window_count_transition(), rolling_window_export_execution_history(), rolling_window_find_hottest_word(), rolling_window_get_recent_sequence(), rolling_window_measure_diversity(), rolling_window_pattern_capture_rate(), rolling_window_seed_hotwords_cache(), rolling_window_seed_pipelining_context(), rolling_window_service_internal(), and rolling_window_stats_string().

Here is the call graph for this function:

Here is the caller graph for this function:



7.306.1.22 rolling_window_stats_string()

```
char * rolling_window_stats_string (
            const RollingWindowOfTruth * window )
```

Allocate and return a one-page status summary for a `RollingWindowOfTruth`.

Allocates a 1024-byte buffer via `sf_malloc` and fills it with a multi-line report covering:

- `total_executions` — lifetime word-execution count.
- `ROLLING_WINDOW_SIZE` — compile-time capacity constant.

- Warm/cold status: "WARM (representative)" or "COLD (warming up)".
- `window_pos` / `ROLLING_WINDOW_SIZE` — current write-cursor position.

Values are read from the current double-buffer snapshot obtained via `rolling_window_snapshot_view()`; a lazy publish is triggered first by `rolling_window_publish_snapshot_if_needed()`.

The caller is responsible for calling `sf_free()` on the returned pointer. Returns NULL if `window` is NULL or `sf_malloc` fails.

Parameters

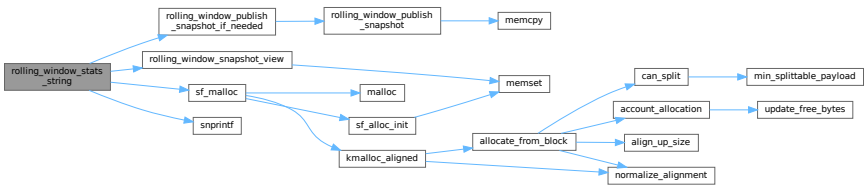
window	The `RollingWindowOfTruth` to describe.

Returns

Heap-allocated NUL-terminated summary string; caller must `sf_free()` it. NULL on failure.

References rolling_window_view_t::is_warm, rolling_window_publish_snapshot_if_needed(), ROLLING_WINDOW_SIZE, rolling_window_snapshot_view(), sf_malloc(), snprintf(), rolling_window_view_t::total_executions, and rolling_window_view_t::window

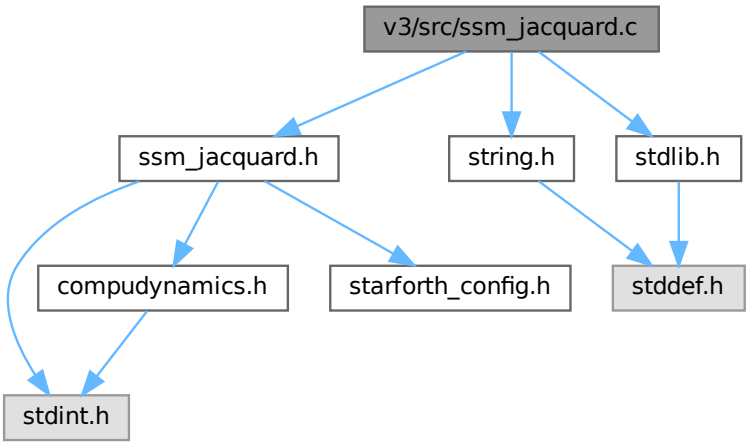
Here is the call graph for this function:



7.307 v3/src/ssm_jacquard.c File Reference

```
#include "ssm_jacquard.h"
#include <string.h>
#include <stdlib.h>
```

Include dependency graph for ssm_jacquard.c:



Functions

- void ssm_l8_init (ssm_l8_state_t *state, ssm_l8_mode_t initial_mode)

  Initialise the L8 Jacquard steady-state machine.
- void ssm_l8_update (const ssm_l8_metrics_t *metrics, ssm_l8_state_t *state)

  Update the L8 mode selector using current runtime metrics.
- void ssm_apply_mode (const ssm_l8_state_t *state, ssm_config_t *config)

  Apply the current L8 mode to a runtime configuration struct.
- const char * ssm_l8_mode_name (ssm_l8_mode_t mode)

  Return a human-readable name string for the given L8 mode.
- static void ssm_l8_seed_from_doe (CDConfigTable *table)

  Seed the adaptive UCB config table with DoE prior scores.
- static void ssm_l8_tick_score_and_select (CDConfigTable *table, ssm_config_t *config, const ssm_l8_metrics_t *metrics, uint32_t current_window, uint32_t locality_q16)

  Score the current config from this tick's outcome and UCB-select this tick's config.
- void ssm_l8_init_table (ssm_l8_state_t *state)

  Allocate and initialise the adaptive UCB config table.
- void ssm_l8_free_table (ssm_l8_state_t *state)

  Free the adaptive UCB config table owned by `state`.
- void ssm_l8_update_table (ssm_l8_state_t *state, const ssm_l8_metrics_t *metrics, ssm_config_t *config, uint32_t current_window, const uint32_t *recent_word_ids, uint32_t recent_word_ids_count)

  Tick the adaptive UCB table: classify, score, and reselect.
- void ssm_apply_mode_from_table (const ssm_l8_state_t *state, ssm_config_t *config)

  Apply the UCB-selected config bits to a runtime configuration struct.
- void ssm_l8_force_config (ssm_l8_state_t *state, ssm_config_t *config, uint8_t config_idx)

  Force the adaptive table onto an externally-chosen config.

7.307.1 Function Documentation

7.307.1.1 ssm_apply_mode()

```
void ssm_apply_mode (
            const ssm_l8_state_t * state,
            ssm_config_t * config )
```

Apply the current L8 mode to a runtime configuration struct.

Apply L8 mode to SSM configuration (legacy threshold path)

Extracts the four loop-enable bits (L2/L3/L5/L6) from `state->current_mode` and writes them into `config`. Used by the legacy (non-table) L8 path when the adaptive UCB table is not present.

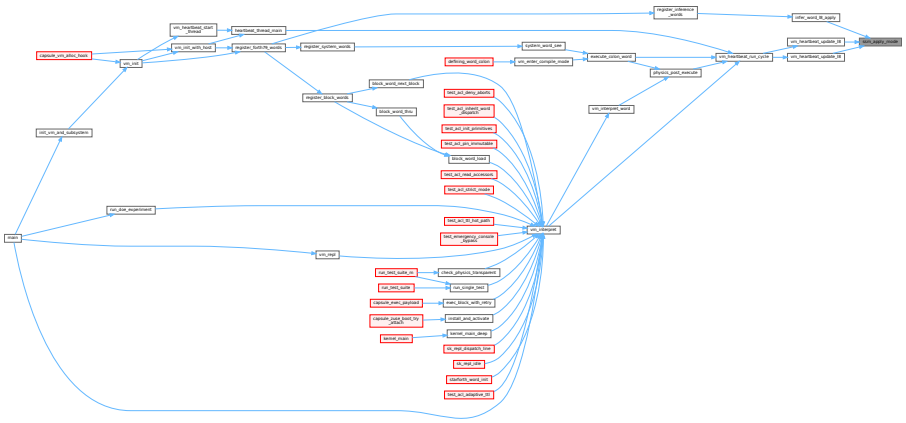
Parameters

state	L8 state containing the committed current mode
config	Runtime configuration to update

References ssm_l8_state_t::current_mode, ssm_config_t::L2_rolling_window, ssm_config_t::L3_linear_decay, ssm_config_t::L5_window_inference, and ssm_config_t::L6_decay_inference.

Referenced by infer_word_l8_apply(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the caller graph for this function:



7.307.1.2 ssm_apply_mode_from_table()

```
void ssm_apply_mode_from_table (
            const ssm_l8_state_t * state,
            ssm_config_t * config )
```

Apply the UCB-selected config bits to a runtime configuration struct.

Apply the current table config to ssm_config_t Used on first tick to set the initial DoE-seeded config immediately.

Reads the current winning config entry from the adaptive table and writes all 7 of its bits into `config`. Use this instead of `ssm_apply_mode()` when the adaptive table is present (`state->table` != NULL).

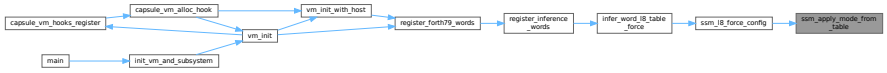
Parameters

state	L8 state with an attached, initialised adaptive table
config	Runtime configuration to update

References CDConfigEntry::config_bits, CDConfigTable::current_config, CDConfigTable::entries, ssm_config_t::L1_heat_tracking, ssm_config_t::L2_rolling_window, ssm_config_t::L3_linear_decay, ssm_config_t::L4_pipelining, ssm_config_t::L5_window_inference, ssm_config_t::L6_decay_inference, ssm_config_t::L7_adaptive_heartrate, SSM_CFG_L1, SSM_CFG_L2, SSM_CFG_L3, SSM_CFG_L4, SSM_CFG_L5, SSM_CFG_L6, SSM_CFG_L7, and ssm_l8_state_t::table.

Referenced by ssm_l8_force_config().

Here is the caller graph for this function:



7.307.1.3 ssm_l8_force_config()

```
void ssm_l8_force_config (
            ssm_l8_state_t * state,
            ssm_config_t * config,
            uint8_t config_idx )
```

Force the adaptive table onto an externally-chosen config.

Force the adaptive table onto an externally-chosen config (e.g.

Sets `current_config` directly (as if the bandit's own UCB selection had picked it) and applies its bits immediately. Since scoring and UCB reselection now run on every heartbeat tick (rev r: one clock, no batching of any kind), this is a one-tick nudge, not a hold: the forced config earns exactly one tick's worth of reward signal into its own regime_score, then the very next tick's ssm_l8_update_table() call scores it and reselects on its own, same as any other tick. Calling this repeatedly (e.g. once per DoE draw, faster than the VM's own tick cadence) keeps a config in effect in practice, not because it's pinned – because it's what's currently forced, most recently.

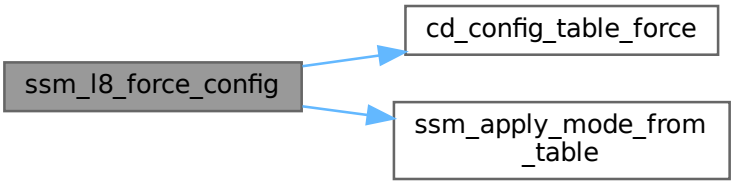
Parameters

state	L8 state with an attached, initialised adaptive table
config	Runtime configuration to update immediately
config_idx	Desired config, masked to the 128-entry (7-bit) space

References cd_config_table_force(), ssm_apply_mode_from_table(), and ssm_l8_state_t::table.

Referenced by infer_word_l8_table_force().

Here is the call graph for this function:



Here is the caller graph for this function:

7.307.1.4 ssm_l8_free_table()

```
void ssm_l8_free_table (
            ssm_l8_state_t * state )
```

Free the adaptive UCB config table owned by `state`.

Free the adaptive config table.

Safe to call with `state->table` == NULL. Sets `state->table` to NULL after freeing so the state falls back to legacy mode.

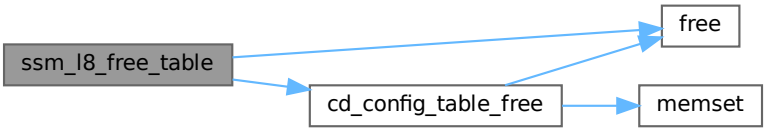
Parameters

state	L8 state whose table is freed

References cd_config_table_free(), free(), and ssm_l8_state_t::table.

Referenced by vm_cleanup().

Here is the call graph for this function:



Here is the caller graph for this function:

7.307.1.5 ssm_l8_init()

```
void ssm_l8_init (
            ssm_l8_state_t * state,
            ssm_l8_mode_t initial_mode )
```

Initialise the L8 Jacquard steady-state machine.

Initialize L8 state (legacy fields only; call ssm_l8_init_table separately)

Sets `current_mode` and `pending_mode` to `initial_mode`, zeroes `hysteresis_counter`, and sets `table` to NULL. Callers must invoke `ssm_l8_init_table()` separately if the adaptive UCB table is required.

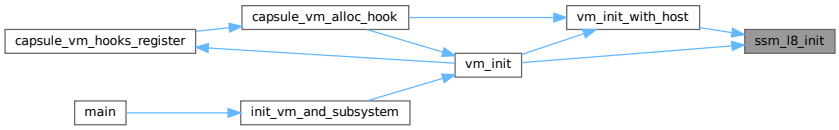
Parameters

state	Pointer to the L8 state to initialise
initial_mode	Starting mode (typically `SSM_MODE_C0`)

References ssm_l8_state_t::current_mode, ssm_l8_state_t::hysteresis_counter, ssm_l8_state_t::pending_mode, and ssm_l8_state_t::table.

Referenced by vm_init(), and vm_init_with_host().

Here is the caller graph for this function:



7.307.1.6 ssm_l8_init_table()

```
void ssm_l8_init_table (
            ssm_l8_state_t * state )
```

Allocate and initialise the adaptive UCB config table.

Allocate and seed the adaptive config table Sets state->table; must be called after ssm_l8_init().

Mallocs and initialises a `CDConfigTable` sized by `cd_tuning_word()`, seeds it with `ssm_l8_seed_from_doe()`, and attaches it to `state->table`. If either allocation fails, `state->table` is set to NULL and the system falls back to legacy mode (`ssm_apply_mode()`).

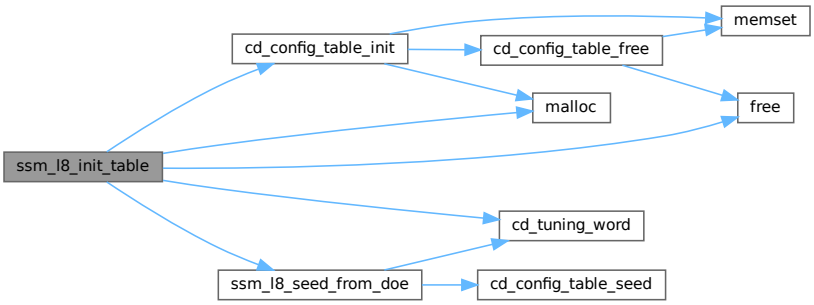
Parameters

state	L8 state that will own the table

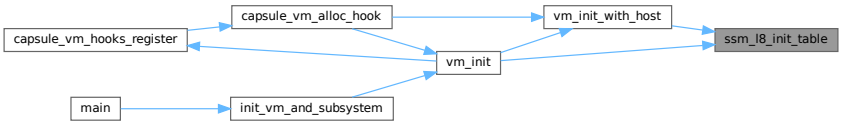
References cd_config_table_init(), cd_tuning_word(), free(), malloc(), ssm_l8_seed_from_doe(), and ssm_l8_state_t::table.

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.307.1.7 ssm_l8_mode_name()

```
const char * ssm_l8_mode_name (
            ssm_l8_mode_t mode )
```

Return a human-readable name string for the given L8 mode.

Get human-readable mode name.

Returns a static string such as "C4_TEMPORAL" or "C15_FULL_ADAPTIVE". Modes marked ? TOP 5% are the configurations favoured by the DoE study. Returns "UNKNOWN" for out-of-range values.

Parameters

mode	L8 mode enumeration value

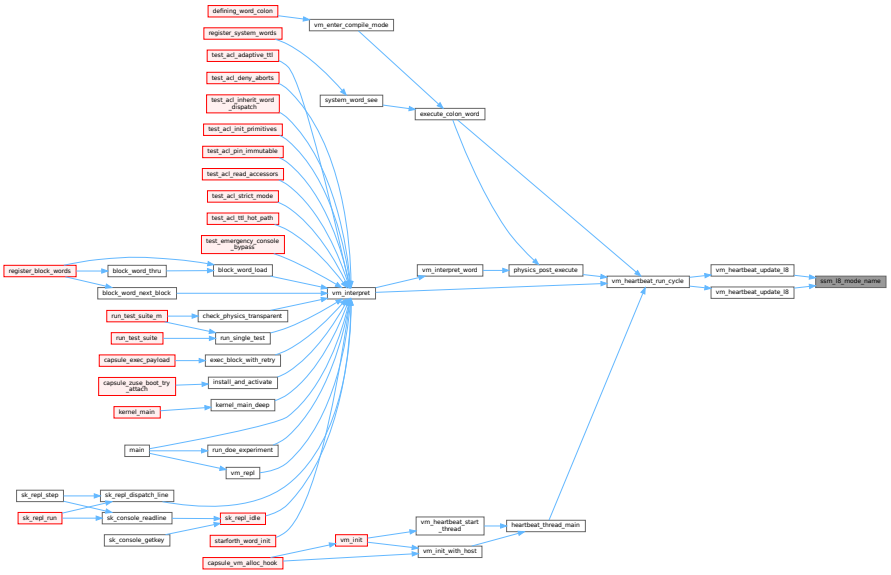
Returns

Pointer to a static null-terminated string (never NULL)

References SSM_MODE_C0, SSM_MODE_C1, SSM_MODE_C10, SSM_MODE_C11, SSM_MODE_C12, SSM_MODE_C13, SSM_MODE_C14, SSM_MODE_C15, SSM_MODE_C2, SSM_MODE_C3, SSM_MODE_C4, SSM_MODE_C5, SSM_MODE_C6, SSM_MODE_C7, SSM_MODE_C8, and SSM_MODE_C9.

Referenced by vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the caller graph for this function:



7.307.1.8 ssm_l8_seed_from_doe()

```
static void ssm_l8_seed_from_doe (
            CDConfigTable * table )  [static]
```

Seed the adaptive UCB config table with DoE prior scores.

Computes benefit scores derived from the DoE top-5% analysis for all `cd_tuning_word()`.num_configs (128) configs and hands them to `cd_config_table_seed()`. The five top-5% configs (C4/C7/C9/C11/C12 in 4-bit space → indices 17/23/35/39/49 in 7-bit space) receive 80% of `cd_tuning_word()`.score_max; configs involving L1 or L4 (known expensive loops) receive 5–10%; all others receive 40%. Sets the starting config to index 17 (C4-equivalent: L3+L7 only).

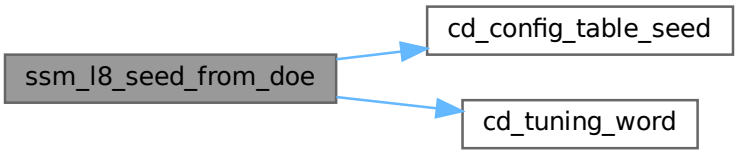
Parameters

table	Pointer to the CDConfigTable to seed (already initialised via cd_config_table_init())

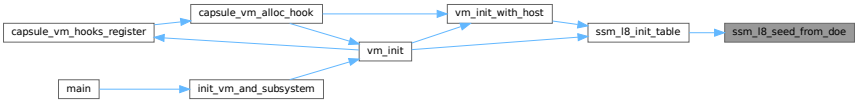
References cd_config_table_seed(), cd_tuning_word(), CDTuning::num_configs, CDTuning::score_max, SSM_CFG_L1, and SSM_CFG_L4.

Referenced by ssm_l8_init_table().

Here is the call graph for this function:



Here is the caller graph for this function:



7.307.1.9 ssm_l8_tick_score_and_select()

```
static void ssm_l8_tick_score_and_select (
            CDConfigTable * table,
            ssm_config_t * config,
            const ssm_l8_metrics_t * metrics,
            uint32_t current_window,
            uint32_t locality_q16 )  [static]
```

Score the current config from this tick's outcome and UCB-select this tick's config.

Computes a joint convergence signal from this tick's ANOVA outcome and the relative delta between this tick's and the previous tick's (window, locality) pair. Updates the regime-specific benefit score for the current config using exponential decay plus a signed delta – the decay is what provides smoothing over time; there's no separate multi-tick batching on top of it (VM-FLEET-ATTRACTOR-DESIGN-20260705.md rev r: one clock, the heartbeat tick – a tick is a tick). Then runs UCB1 over all 128 configs for the current regime, selecting the one with the highest upper confidence bound as this tick's config.

Parameters

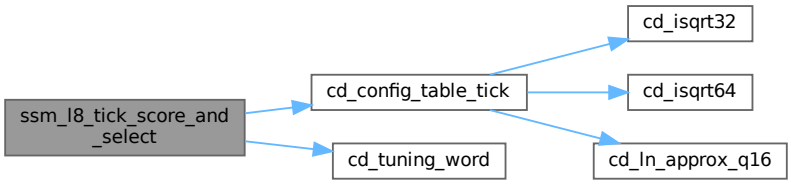
table	Adaptive config table
config	Runtime config to update with the newly selected bits
metrics	This tick's metrics snapshot (for the ANOVA signal)
current_window	Current rolling window width, this tick
locality_q16	Current locality signal from cd_classify_ids(), this tick

References cd_config_table_tick(), cd_tuning_word(), CDConfigEntry::config_bits, CDConfigTable::current_config, CDConfigTable::current_regime, CDConfigTable::entries, ssm_l8_metrics_t::inference_early_exited, ssm_l8_metrics_t::inference_ran

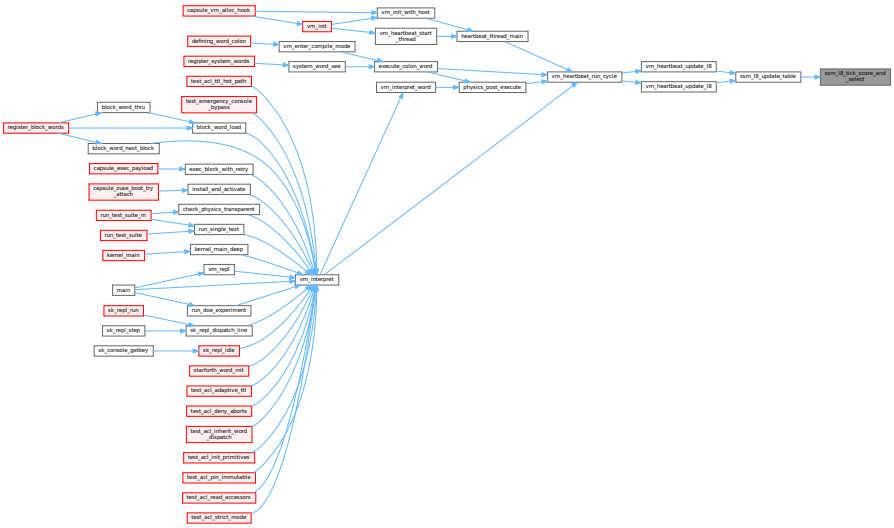
ssm_config_t::L1_heat_tracking, ssm_config_t::L2_rolling_window, ssm_config_t::L3_linear_decay, ssm_config_t::L4_pipelining, ssm_config_t::L5_window_inference, ssm_config_t::L6_decay_inference, ssm_config_t::L7_adaptive_heartrate, SSM_CFG_L1, SSM_CFG_L2, SSM_CFG_L3, SSM_CFG_L4, SSM_CFG_L5, SSM_CFG_L6, and SSM_CFG_L7.

Referenced by ssm_l8_update_table().

Here is the call graph for this function:



Here is the caller graph for this function:



7.307.1.10 ssm_l8_update()

```
void ssm_l8_update (
            const ssm_l8_metrics_t * metrics,
            ssm_l8_state_t * state )
```

Update the L8 mode selector using current runtime metrics.

Update L8 state based on current metrics (legacy threshold path)

Classifies `metrics` into four binary feature bits (L2/L3/L5/L6) derived from DoE top-5% analysis and computes a target mode. Applies hysteresis: the mode only commits after `SSM_HYSTERESIS_TICKS` consecutive ticks with the same target. Called by the heartbeat thread on every tick.

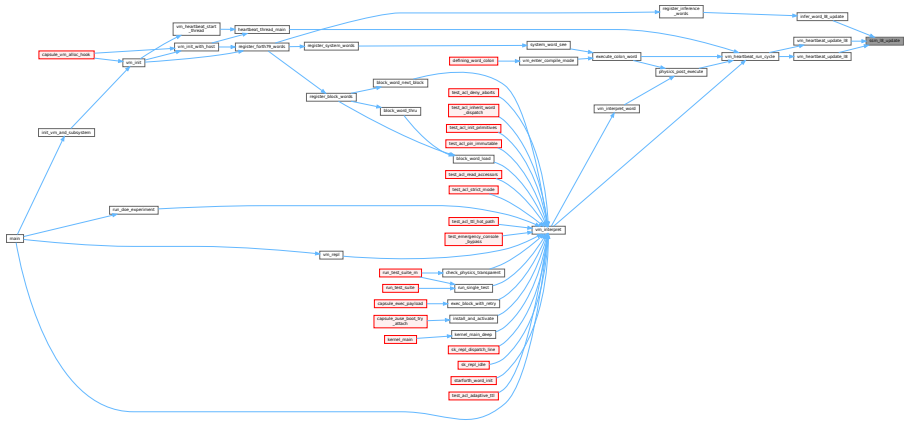
Parameters

metrics	Runtime metrics snapshot (entropy, CV, temporal decay)
state	L8 state to update; `current_mode` is written on commit

References ssm_l8_state_t::current_mode, ssm_l8_metrics_t::cv, ssm_l8_metrics_t::entropy, ssm_l8_state_t::hysteresis_counter, ssm_l8_state_t::pending_mode, SSM_CV_HIGH_THRESHOLD, SSM_ENTROPY_HIGH_THRESHOLD, SSM_HYSTERESIS_TICK SSM_MODE_C0, SSM_TEMPORAL_DECAY_LOW_THRESHOLD, SSM_TEMPORAL_DECAY_THRESHOLD, and ssm_l8_metrics_t::temporal_decay.

Referenced by infer_word_l8_update(), vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the caller graph for this function:



7.307.1.11 ssm_l8_update_table()

```
void ssm_l8_update_table (
            ssm_l8_state_t * state,
            const ssm_l8_metrics_t * metrics,
            ssm_config_t * config,
            uint32_t current_window,
            const uint32_t * recent_word_ids,
            uint32_t recent_word_ids_count )
```

Tick the adaptive UCB table: classify, score, and reselect.

Classifies the current tick into one of 8 regimes (entropy x CV x locality) and stores it unconditionally, then scores the current config from this tick's outcome and UCB-reselects, every single call – no batching, no derived counter of any kind (VM-FLEET-ATTRACTOR-DESIGN- 20260705.md rev r: one clock, the heartbeat tick, applied uniformly). The locality component of both the regime and the joint-convergence reward comes from cd_classify_ids() over recent_word_ids – purely execution-count-derived, no wall-clock input (rev s; see header comment on this function's declaration for why that matters). Also mirrors the winning L2/L3/L5/L6 bits back into `state->current_mode` for diagnostic display. No-op if `state->table` is NULL.

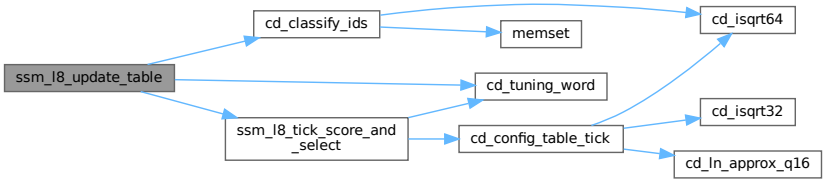
Parameters

state	L8 state with attached adaptive table
metrics	Current runtime metrics snapshot
config	Runtime config updated this tick
current_window	Current rolling window width
recent_word_ids	Recent word-execution-ID history, oldest first
recent_word_ids_count	Number of valid entries in recent_word_ids

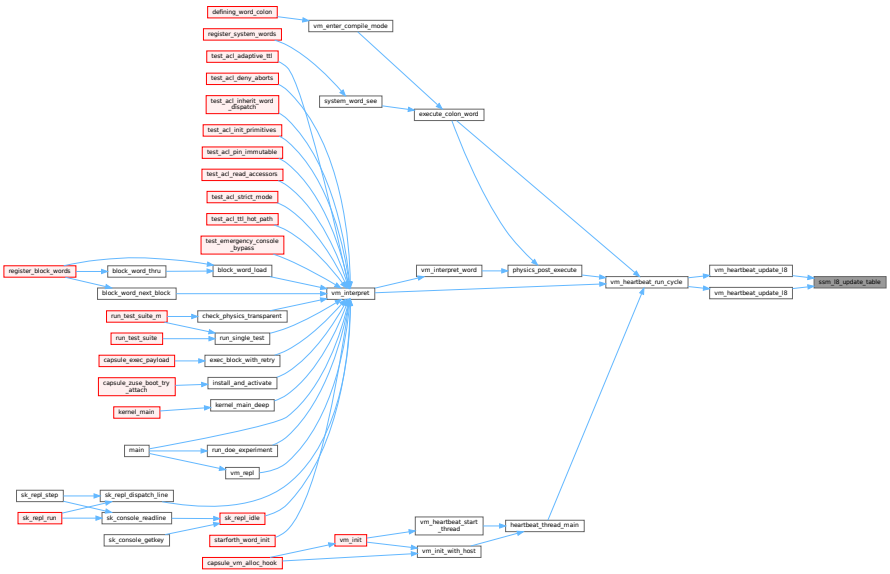
References cd_classify_ids(), cd_tuning_word(), CDConfigEntry::config_bits, CDConfigTable::current_config, ssm_l8_state_t::current_mode, CDConfigTable::current_regime, ssm_l8_metrics_t::cv, CDConfigTable::entries, ssm_l8_metrics_t::entropy, CDTuning::locality_high_threshold_q16, CDTuning::locality_lookback, CDRegimeMetrics::locality_q16, SSM_CFG_L2, SSM_CFG_L3, SSM_CFG_L5, SSM_CFG_L6, SSM_CV_HIGH_THRESHOLD, SSM_ENTROPY_HIGH_THRESHO ssm_l8_tick_score_and_select(), and ssm_l8_state_t::table.

Referenced by vm_heartbeat_update_l8(), and vm_heartbeat_update_l8().

Here is the call graph for this function:



Here is the caller graph for this function:



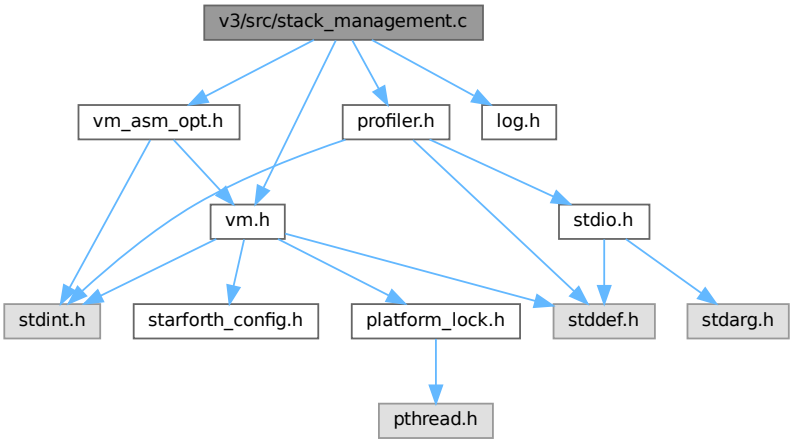
7.308 v3/src/stack_management.c File Reference

Implementation of stack operations for the Forth virtual machine.

```
#include "vm.h"
#include "log.h"
#include "profiler.h"
```

```
#include "vm_asm_opt.h"
```

Include dependency graph for stack_management.c:



Functions

- void vm_push (VM *vm, cell_t value)

  Push a value onto the data stack.
- cell_t vm_pop (VM *vm)

  Pop a value from the data stack.
- void vm_rpush (VM *vm, cell_t value)

  Push a value onto the return stack.
- cell_t vm_rpop (VM *vm)

  Pop a value from the return stack.

7.308.1 Detailed Description

Implementation of stack operations for the Forth virtual machine.

This module provides the core stack manipulation functions for both the data stack and return stack of the Forth virtual machine. It includes optimized assembly implementations for x86_64 and ARM64 architectures when available.

7.308.2 Function Documentation

7.308.2.1 vm_pop()

```
cell_t vm_pop (
            VM * vm )
```

Pop a value from the data stack.

Parameters

vm	Pointer to the VM structure

Returns

The popped value

Note

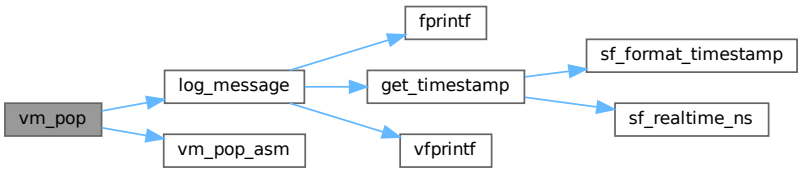
Returns 0 and sets error flag if stack underflow occurs

Uses assembly optimization if available for x86_64 or ARM64

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), PROFILE_INC_STACK_OP, and vm_pop_asm().

Referenced by arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), block_word_acl_allow_fetch(), block_word_acl_allow_store(), block_word_acl_ttl_fetch(), block_word_acl_ttl_store(), block_word_blk_attach(), block_word_block(), block_word_buffer(), block_word_confirm_format(), block_word_list(), block_word_load(), block_word_owner_fetch(), block_word_relocate(), block_word_thru(), control_forth_0branch(), control_forth_runtime_do(), control_forth_runtime_plus_loop(), control_forth_runtime_qdo(), defining_word_constant(), defining_word_literal(), dictionary_m_word_cfa(), dictionary_m_word_link_from(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), dictionary_m_word_traverse(), dictionary_word_2comma(), dictionary_word_allot(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_sp_store(), double_word_2drop(), double_word_2rot(), double_word_2swap(), double_word_2to_r(), double_word_d_equals(), double_word_d_less(), double_word_d_minus(), double_word_d_plus(), double_word_d_two_slash(), double_word_d_two_star(), double_word_d_zero_equals(), double_word_d_zero_less(), double_word_dmax(), double_word_dmin(), double_word_dnegate(), double_word_s_to_d(), editor_word_edit(), editor_word_l(), editor_word_s(), fbw_plot(), format_word_d_dot(), format_word_d_dot_r(), format_word_dot(), format_word_dot_r(), format_word_dump(), format_word_end_conversion(), format_word_hash(), format_word_hash_s(), format_word_hold(), format_word_question(), format_word_sign(), format_word_u_dot(), format_word_u_dot_r(), forth_acl_allow_store(), forth_acl_mode_store(), forth_acl_ttl_store(), forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), hosted_lifecycle_birth(), hosted_lifecycle_kill(), hosted_lifecycle_pause(), hosted_lifecycle_resume(), hosted_lifecycle_use(), io_word_type(), log_str_emit(), log_word_set_level(), logical_word_and(), logical_word_equals(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), memory_word_2fetch(), memory_word_2store(), memory_word_cells(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), mixed_math_word_m_minus(), mixed_math_word_m_plus(), mixed_math_word_m_slash_mod(), mixed_math_word_m_star(), mixed_math_word_mod(), mixed_math_word_mod(), mixed_math_word_slash_mod(), mixed_math_word_star_slash(), mixed_math_word_star_slash_mod(), pop_xt(), return_stack_word_to_r(), runtime_abortq(), sk_word_blk_attach_ack(), sk_word_kh_blk_attach_send(), stack_word_pick(), starforth_word_execution_heat_fetc starforth_word_execution_heat_store(), starforth_word_random(), starforth_word_seed(), starforth_word_top_words(), starforth_word_wait(), starforth_word_zuse_pubkey_fetch(), string_word_blank(), string_word_cmove(), string_word_cmove_greater() string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_minus_trailing(), string_word_number(), string_word_scan(), string_word_search(), string_word_skip(), string_word_word(), system_word_abort_quote(), system_word_execute(), system_word_reboot(), test_acl_adaptive_ttl(), test_acl_read_accessors(), vm_api_pop(), word_divide(), word_divmod(), and word_is().

Here is the call graph for this function:



7.308.2.2 vm_push()

```
void vm_push (
            VM * vm,
            cell_t value )
```

Push a value onto the data stack.

Parameters

vm	Pointer to the VM structure
value	Value to push onto the stack

Note

Performs bounds checking to prevent stack overflow

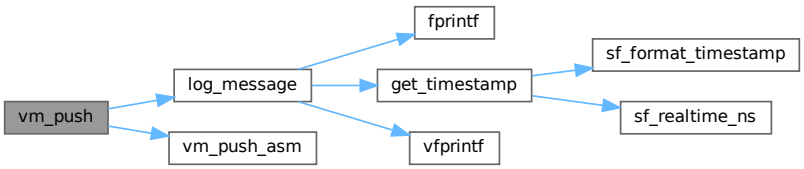
Uses assembly optimization if available for x86_64 or ARM64

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), PROFILE_INC_STACK_OP, STACK_SIZE, and vm_push_asm().

Referenced by acl_recheck(), acl_recheck(), arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), block_word_acl_allow_fetch(), block_word_acl_ttl_fetch(), block_word_blk_attach(), block_word_block(), block_word_buffer(), block_word_owner_fetch(), block_word_scr(), block_word_thru(), control_forth_I(), control_forth_J(), defining_runtime_constant(), defining_runtime_create(), defining_runtime_dodoes(), defining_runtime_lit(), defining_runtime_variable(), defining_word_state(), dictionary_m_word_cfa(), dictionary_m_word_find(), dictionary_m_word_link_from(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_tick(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), dictionary_m_word_traverse(), dictionary_word_here(), dictionary_word_latest(), dictionary_word_pad(), dictionary_word_sp_fetch(), double_word_2dup(), double_word_2over(), double_word_2r_fetch(), double_word_2r_from(), double_word_2rot(), double_word_2swap(), double_word_d_equals(), double_word_d_less(), double_word_d_minus(), double_word_d_plus(), double_word_d_two_slash(), double_word_d_two_star(), double_word_d_zero_equals(), double_word_d_zero_less(), double_word_dmax(), double_word_dmin(), double_word_dnegate(), double_word_s_to_d(), editor_word_edit(), emit_cell(), fbw_height(), fbw_width(), format_word_base(), format_word_end_conversion(), format_word_hash(), format_word_hash_s(), format_word_sign(), forth_acl_allow_fetch(), forth_acl_heat_fetch(), forth_acl_mode_fetch(), forth_acl_pinned_query(), forth_acl_ttl_fetch(), forth_acl_word_id(), kbw_debug(), kbw_key_event(), kbw_scan(), kbw_vdebug(), kbw_vevent(), log_word_debug(), log_word_error(), log_word_get_level(), log_word_info(), log_word_test(), log_word_warn(),

logical_word_and(), logical_word_equals(), logical_word_false(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_true(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), memory_word_2fetch(), memory_word_cells(), memory_word_cfetch(), memory_word_fetch(), mixed_math_word_m_minus(), mixed_math_word_m_plus(), mixed_math_word_m_slash_mod(), mixed_math_word_m_star(), mixed_math_word_mod(), mixed_math_word_mod(), mixed_math_word_slash_mod(), mixed_math_word_star_slash(), mixed_math_word_star_slash_mod(), return_stack_word_r_fetch(), return_stack_word_r_from(), sk_word_kh_blk_attach_send(), stack_word_pick(), starforth_word_execution_heat_fetch(), starforth_word_heartbeat_ticks(), starforth_word_init(), starforth_word_random(), starforth_word_zuse_cert_installed_query(), starforth_word_zuse_pubkey_fetch(), starforth_word_zuse_session(), string_runtime_s_quote(), string_word_bl(), string_word_bracket_tick(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_minus_trailing(), string_word_number(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), string_word_source(), string_word_span(), string_word_tib(), string_word_to_in(), string_word_word(), system_word_79_standard(), test_acl_adaptive_ttl(), test_acl_inherit_word_dispatch(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), vm_api_push(), vm_compile_literal(), vm_interpret_word(), vocabulary_word_context(), vocabulary_word_current(), vocabulary_word_paren_find(), word_defer_fetch(), word_divide(), and word_divmod().

Here is the call graph for this function:



7.308.2.3 vm_rpop()

```
cell_t vm_rpop (
            VM * vm )
```

Pop a value from the return stack.

Parameters

vm	Pointer to the VM structure

Returns

The popped value

Note

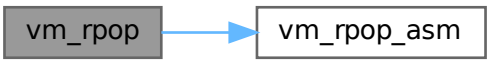
Returns 0 and sets error flag if stack underflow occurs

Uses assembly optimization if available for x86_64 or ARM64

References VM::error, VM::return_stack, VM::rsp, and vm_rpop_asm().

Referenced by execute_colon_word(), return_stack_word_r_from(), and vm_api_rpop().

Here is the call graph for this function:



Here is the caller graph for this function:

7.308.2.4 vm_rpush()

```
void vm_rpush (
            VM * vm,
            cell_t value )
```

Push a value onto the return stack.

Parameters

vm	Pointer to the VM structure
value	Value to push onto the return stack

Note

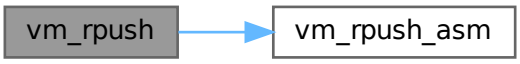
Sets error flag if stack overflow occurs

Uses assembly optimization if available for x86_64 or ARM64

References VM::error, VM::return_stack, VM::rsp, STACK_SIZE, and vm_rpush_asm().

Referenced by execute_colon_word(), return_stack_word_to_r(), and vm_api_rpush().

Here is the call graph for this function:



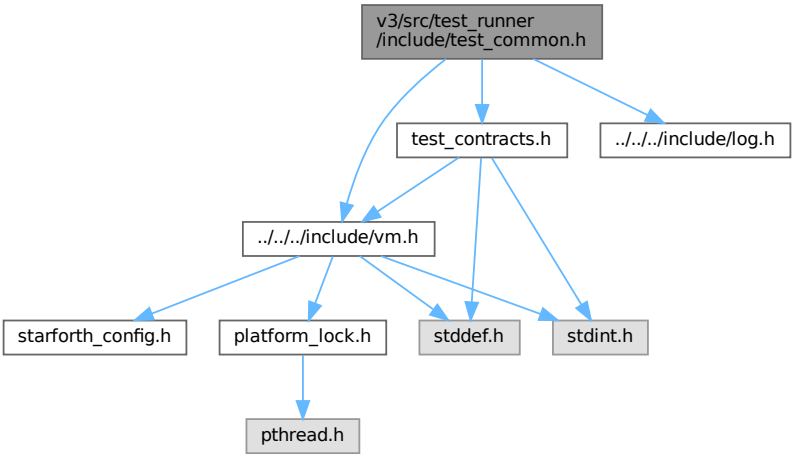
Here is the caller graph for this function:

7.309 v3/src/test_runner/include/test_common.h File Reference

Common test utilities and structures for StarForth test runner.

```
#include "../../../include/vm.h"
#include "../../../include/log.h"
#include "test_contracts.h"
```

Include dependency graph for test_common.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct TestCase

  Structure representing a single test case.
- struct WordTestSuite

  Collection of test cases for a single Forth word.

Macros

Test Configuration

- #define MAX_TEST_OUTPUT 1024

  Maximum length of test output buffer.
- #define MAX_TEST_INPUT 256

  Maximum length of test input buffer.
- #define MAX_TESTS_PER_WORD 20

  Maximum number of test cases per word.

Enumerations

- enum TestType { TEST_NORMAL = 0 , TEST_EDGE_CASE = 1 , TEST_ERROR_CASE = 2 }

  Types of test cases.

Functions

Core Test Execution Functions

- TestResult run_single_test (VM *vm, const char *word_name, const TestCase *test)

  Executes a single test case.
- void run_test_suite (VM *vm, const WordTestSuite *suite)

  Executes a complete test suite for a Forth word.
- void run_test_suite_m (VM *vm, const WordTestSuite *suite, WordContract module_contract)

  Runs all tests in a suite with an inherited module-level contract.
- void print_module_summary (const char *module_name, int pass, int fail, int skip, int error)

  Prints test module execution summary.

Test Assertion Functions

- int assert_stack_depth (VM *vm, int expected_depth)

  Verifies VM stack depth matches expected value.
- int assert_stack_top (VM *vm, int expected_value)

  Verifies top value on VM stack matches expected value.
- int assert_vm_error (VM *vm, int should_have_error)

  Verifies VM error state matches expectation.

VM State Management Functions

- void save_vm_state (VM *vm, int *dsp, int *rsp, int *error, vm_mode_t *mode)

  Saves current VM state.
- void restore_vm_state (VM *vm, int dsp, int rsp, int error, vm_mode_t mode)

  Restores previously saved VM state.
- void save_dict_state (VM *vm, DictEntry **latest, size_t *here)

  Saves current dictionary state before test execution.
- void restore_dict_state (VM *vm, DictEntry *latest, size_t here)

  Restores dictionary state after test execution.

Variables

- int fail_fast

  Global flag to control test execution behavior.

7.309.1 Detailed Description

Common test utilities and structures for StarForth test runner.

This file contains test configuration, structures, and utility functions used throughout the StarForth test framework.

7.309.2 Macro Definition Documentation

7.309.2.1 MAX_TEST_INPUT

```
#define MAX_TEST_INPUT 256
```

Maximum length of test input buffer.

7.309.2.2 MAX_TEST_OUTPUT

```
#define MAX_TEST_OUTPUT 1024
```

Maximum length of test output buffer.

7.309.2.3 MAX_TESTS_PER_WORD

```
#define MAX_TESTS_PER_WORD 20
```

Maximum number of test cases per word.

7.309.3 Enumeration Type Documentation

7.309.3.1 TestType

```
enum TestType
```

Types of test cases.

Enumerator

TEST_NORMAL	Standard test case.
TEST_EDGE_CASE	Edge case test.
TEST_ERROR_CASE	Error condition test.

7.309.4 Function Documentation

7.309.4.1 assert_stack_depth()

```
int assert_stack_depth (
            VM * vm,
            int expected_depth )
```

Verifies VM stack depth matches expected value.

Parameters

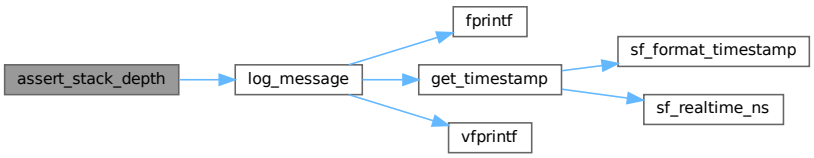
vm	Pointer to VM instance
expected_depth	Expected stack depth

Returns

1 if assertion passes, 0 if it fails

References VM::dsp, LOG_ERROR, and log_message().

Here is the call graph for this function:



7.309.4.2 assert_stack_top()

```
int assert_stack_top (
            VM * vm,
            int expected_value )
```

Verifies top value on VM stack matches expected value.

Parameters

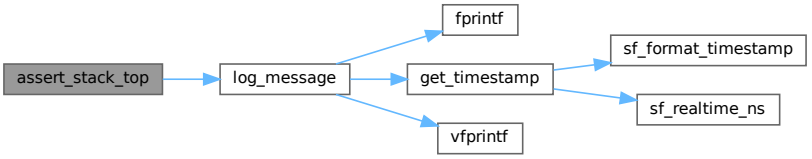
vm	Pointer to VM instance
expected_value	Expected value on top of stack

Returns

1 if assertion passes, 0 if it fails

References VM::data_stack, VM::dsp, LOG_ERROR, and log_message().

Here is the call graph for this function:



7.309.4.3 assert_vm_error()

```
int assert_vm_error (
            VM * vm,
            int should_have_error )
```

Verifies VM error state matches expectation.

Parameters

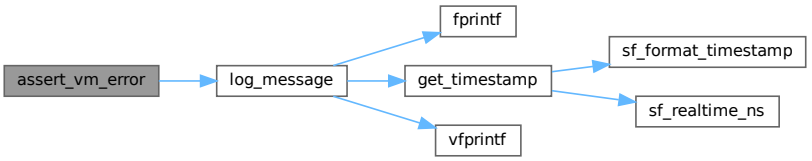
vm	Pointer to VM instance
should_have_error	Expected error state (1 for error, 0 for no error)

Returns

1 if assertion passes, 0 if it fails

References VM::error, LOG_ERROR, and log_message().

Here is the call graph for this function:



7.309.4.4 print_module_summary()

```
void print_module_summary (
            const char * module_name,
```

```
int pass,
int fail,
int skip,
int error )
```

Prints test module execution summary.

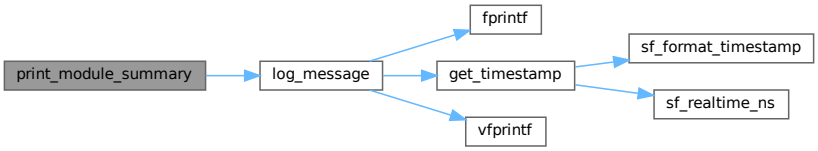
Parameters

module_name	Name of the test module
pass	Number of passed tests
fail	Number of failed tests
skip	Number of skipped tests
error	Number of tests with errors

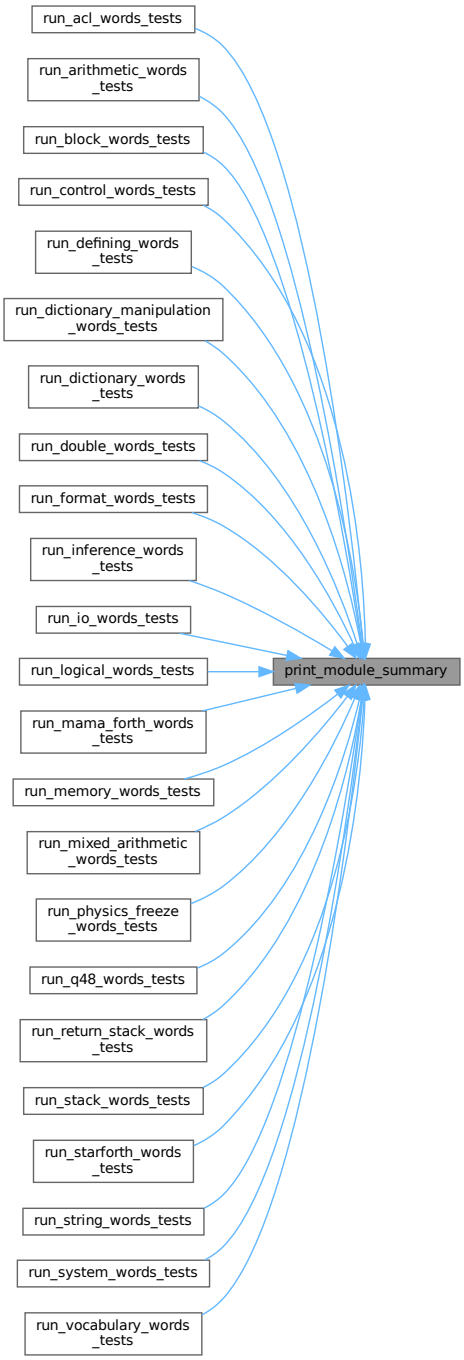
References log_message(), and LOG_TEST.

Referenced by run_acl_words_tests(), run_arithmetic_words_tests(), run_block_words_tests(), run_control_words_tests(), run_defining_words_tests(), run_dictionary_manipulation_words_tests(), run_dictionary_words_tests(), run_double_words_tests(), run_format_words_tests(), run_inference_words_tests(), run_io_words_tests(), run_logical_words_tests(), run_mama_forth_words_tests(), run_memory_words_tests(), run_mixed_arithmetic_words_tests(), run_physics_freeze_words_tests(run_q48_words_tests(), run_return_stack_words_tests(), run_stack_words_tests(), run_starforth_words_tests(), run_string_words_tests(), run_system_words_tests(), and run_vocabulary_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.309.4.5 restore_dict_state()

```
void restore_dict_state (
            VM * vm,
            DictEntry * latest,
            size_t here )
```

Restores dictionary state after test execution.

Parameters

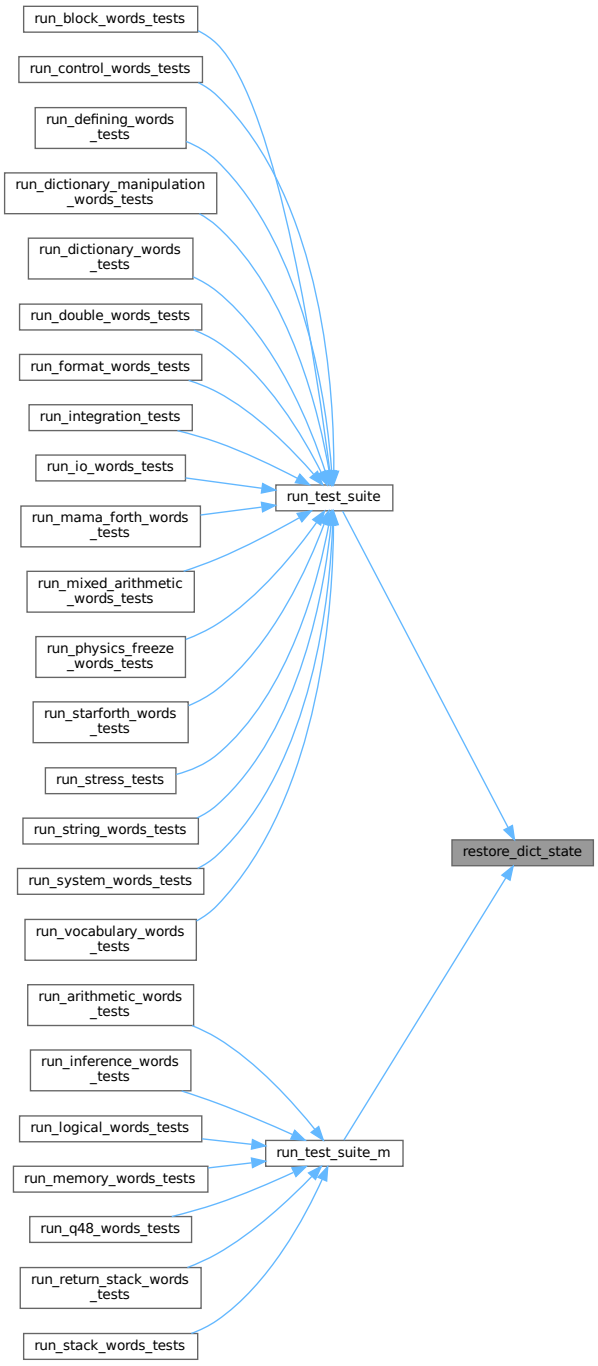
vm	Pointer to VM instance
latest	Latest dictionary entry to restore
here	HERE pointer to restore

Removes all words added during test by restoring dictionary pointers. This prevents test pollution of the dictionary and ensures each test starts with a clean slate.

References VM::here, and VM::latest.

Referenced by run_test_suite(), and run_test_suite_m().

Here is the caller graph for this function:



7.309.4.6 restore_vm_state()

```
void restore_vm_state (
            VM * vm,
            int dsp,
            int rsp,
```

```
    int error,
    vm_mode_t mode )
```

Restores previously saved VM state.

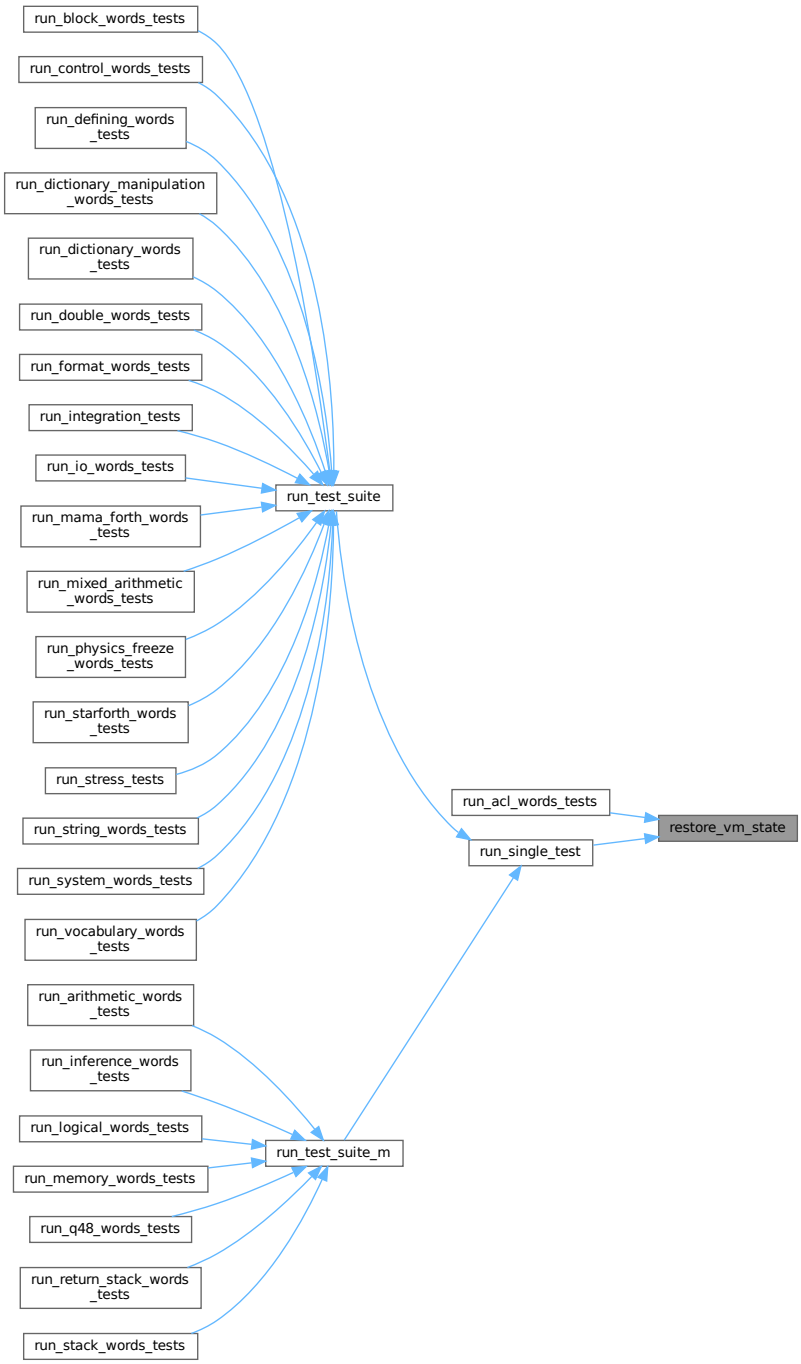
Parameters

vm	Pointer to VM instance
dsp	Data stack pointer to restore
rsp	Return stack pointer to restore
error	Error state to restore
mode	VM mode to restore

References VM::abort_requested, VM::compiling_word, VM::current_executing_entry, VM::dsp, VM::error, VM::exit_colon, VM::mode, and VM::rsp.

Referenced by run_acl_words_tests(), and run_single_test().

Here is the caller graph for this function:



7.309.4.7 run_single_test()

```
TestResult run_single_test (
            VM * vm,
            const char * word_name,
            const TestCase * test )
```

Executes a single test case.

Parameters

vm	Pointer to VM instance
word_name	Name of the word being tested
test	Pointer to test case definition

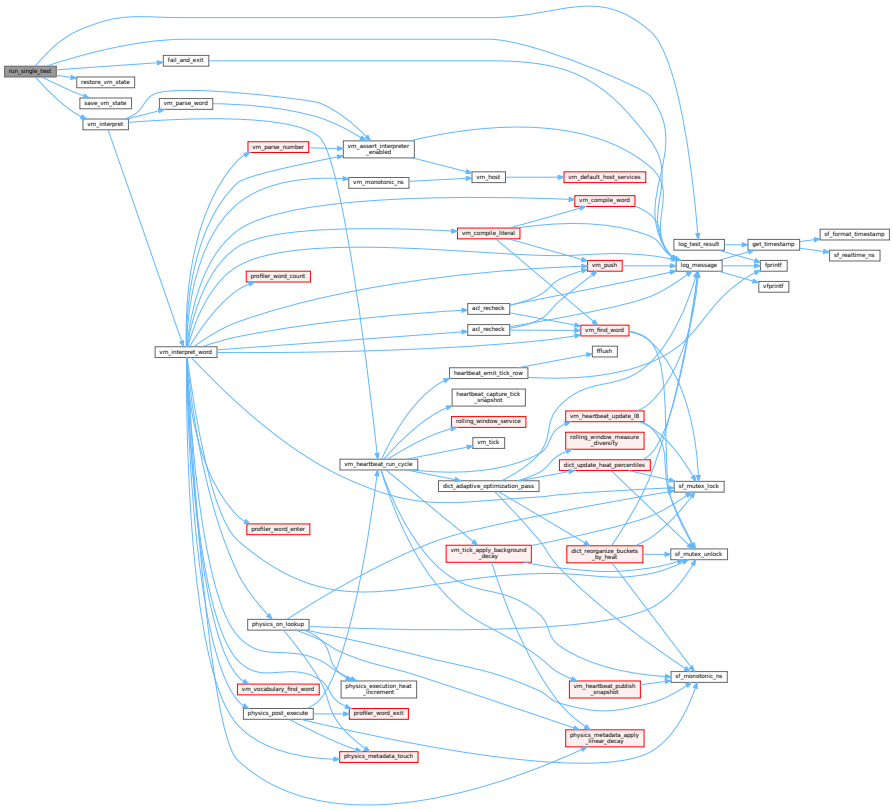
Returns

Test result (PASS, FAIL, SKIP, or ERROR)

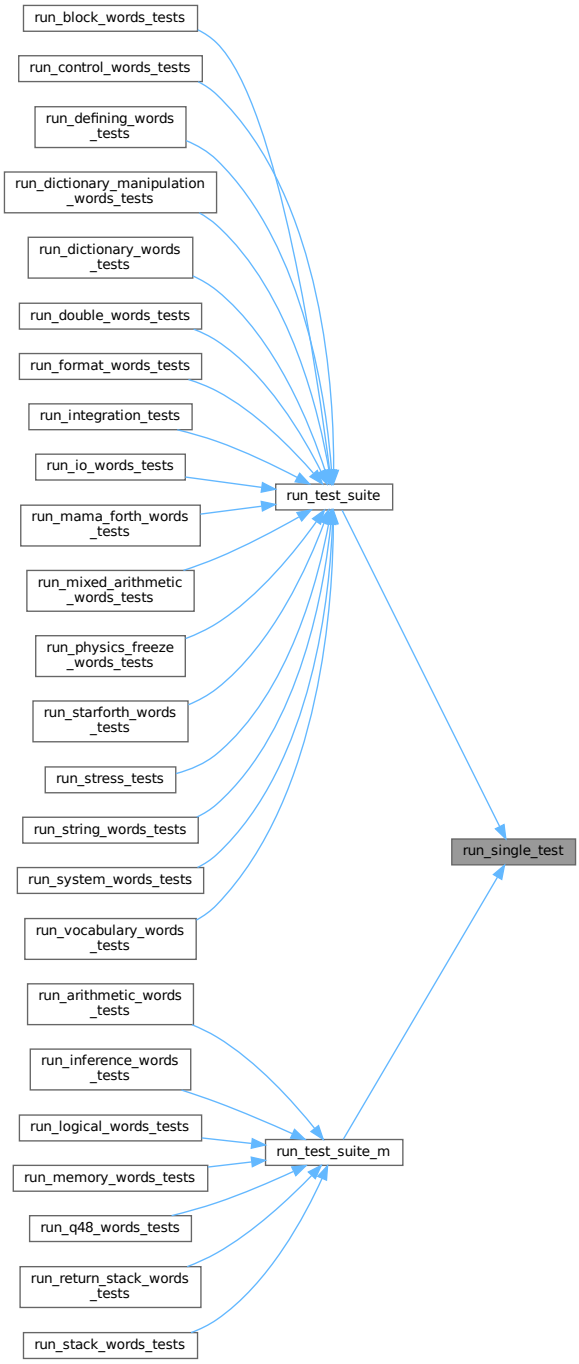
References VM::error, TestCase::expected, fail_and_exit(), fail_fast, TestCase::implemented, TestCase::input, LOG_ERROR, log_message(), LOG_TEST, log_test_result(), TestCase::name, restore_vm_state(), save_vm_state(), TestCase::should_error, TEST_FAIL, TEST_PASS, TEST_SKIP, and vm_interpret().

Referenced by run_test_suite(), and run_test_suite_m().

Here is the call graph for this function:



Here is the caller graph for this function:



7.309.4.8 run_test_suite()

```
void run_test_suite (
            VM * vm,
            const WordTestSuite * suite )
```

Executes a complete test suite for a Forth word.

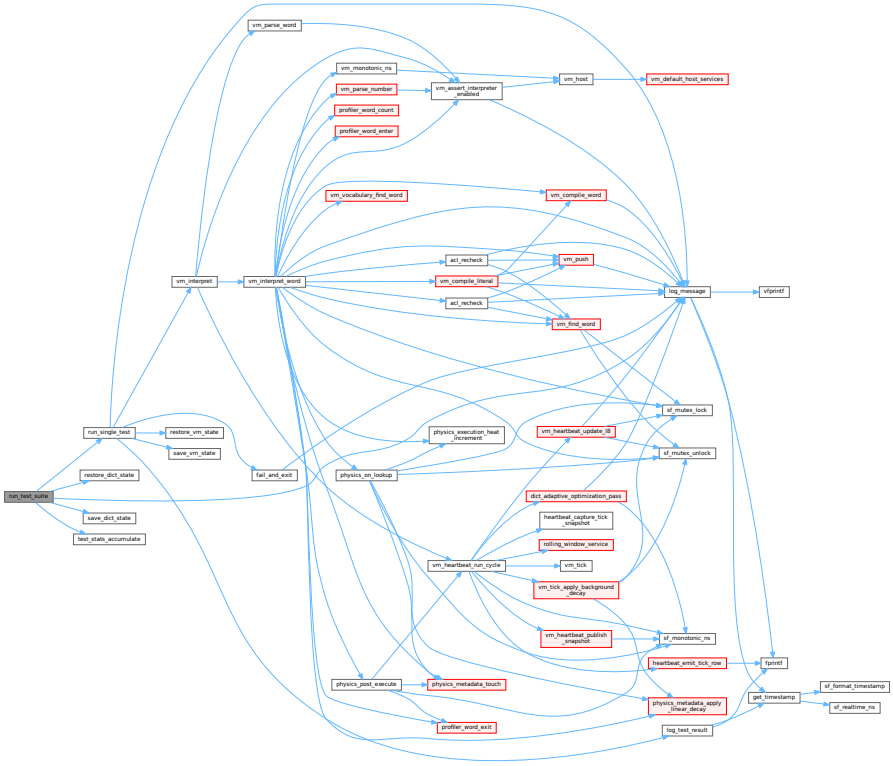
Parameters

vm	Pointer to VM instance
suite	Pointer to test suite definition

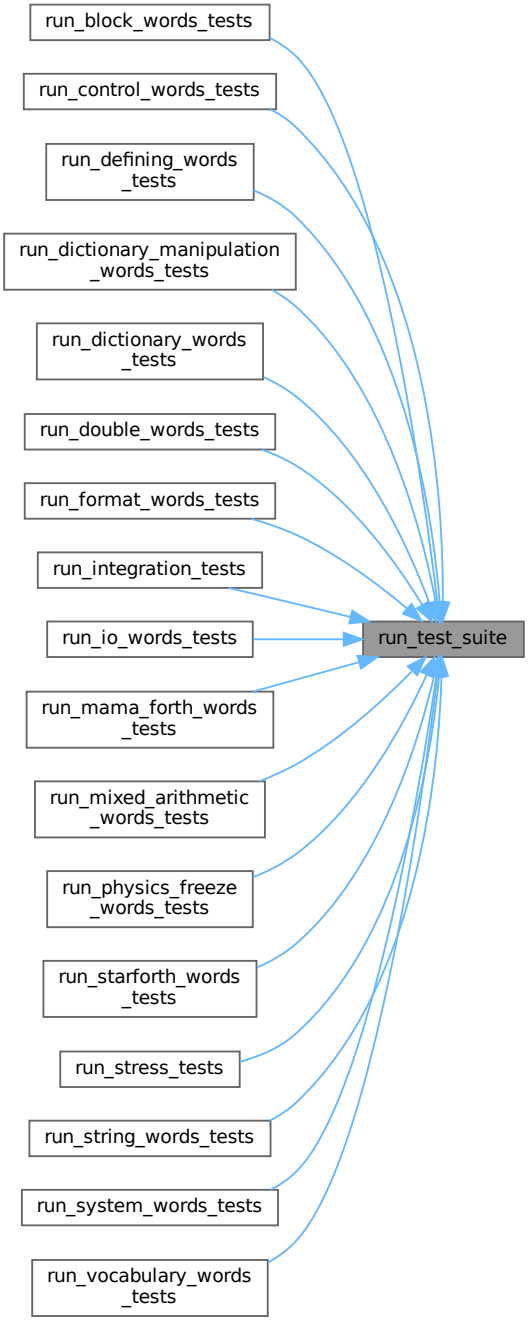
References TestCase::implemented, log_message(), LOG_TEST, TestCase::name, restore_dict_state(), run_single_test(), save_dict_state(), WordTestSuite::test_count, TEST_ERROR, TEST_FAIL, TEST_PASS, TEST_SKIP, test_stats_accumulate(), WordTestSuite::tests, and WordTestSuite::word_name.

Referenced by run_block_words_tests(), run_control_words_tests(), run_defining_words_tests(), run_dictionary_manipulation_words_ run_dictionary_words_tests(), run_double_words_tests(), run_format_words_tests(), run_integration_tests(), run_io_words_tests(), run_mama_forth_words_tests(), run_mixed_arithmetic_words_tests(), run_physics_freeze_words_tests(), run_starforth_words_tests(), run_stress_tests(), run_string_words_tests(), run_system_words_tests(), and run_vocabulary_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.309.4.9 run_test_suite_m()

```
void run_test_suite_m (
            VM * vm,
            const WordTestSuite * suite,
            WordContract module_contract )
```

Runs all tests in a suite with an inherited module-level contract.

Contract resolution order (first non-NONE wins): test->contract > suite->suite_contract > module_contract

When CONTRACTS_ENABLED=1, each passing TEST_NORMAL test is re-run under physics perturbation to witness A4' (word_physics_transparent).

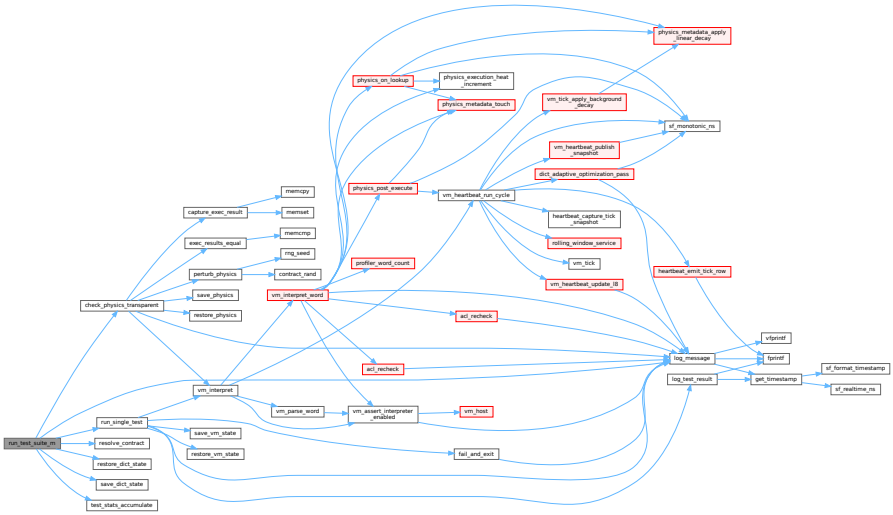
Parameters

vm	Pointer to the VM instance
suite	Test suite to execute
module_contract	Default contract for tests that don't specify one

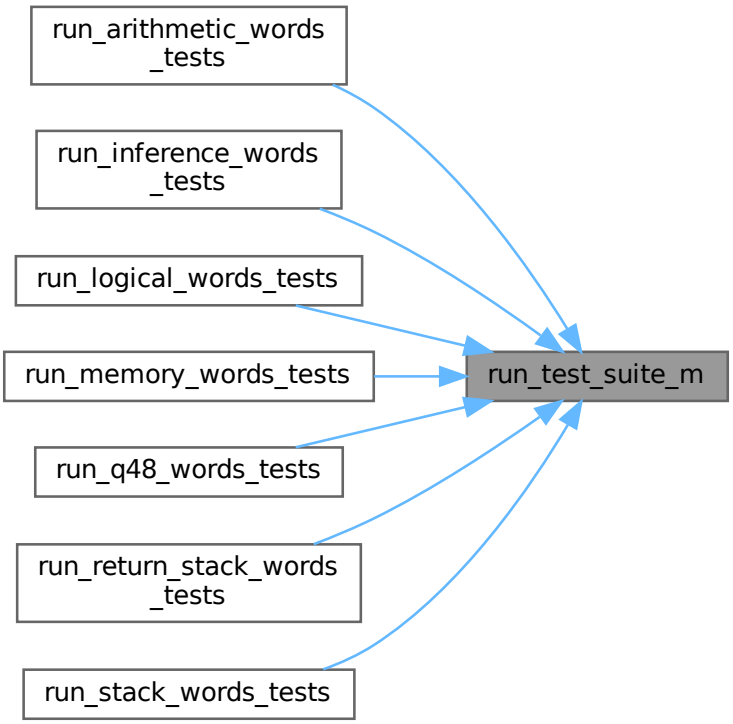
References check_physics_transparent(), TestCase::contract, CONTRACT_PHYSICS_TRANSPARENT, WordContract::flags, WordContract::fuzz_rounds, TestCase::implemented, TestCase::input, log_message(), LOG_TEST, TestCase::name, resolve_contract(), restore_dict_state(), run_single_test(), save_dict_state(), TestCase::should_error, WordTestSuite::suite_contract, WordTestSuite::test_count, TEST_ERROR, TEST_ERROR_CASE, TEST_FAIL, TEST_PASS, TEST_SKIP, test_stats_accumulate(), WordTestSuite::tests, TestCase::type, and WordTestSuite::word_name.

Referenced by run_arithmetic_words_tests(), run_inference_words_tests(), run_logical_words_tests(), run_memory_words_tests(), run_q48_words_tests(), run_return_stack_words_tests(), and run_stack_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.309.4.10 save_dict_state()

```
void save_dict_state (
            VM * vm,
            DictEntry ** latest,
            size_t * here )
```

Saves current dictionary state before test execution.

Parameters

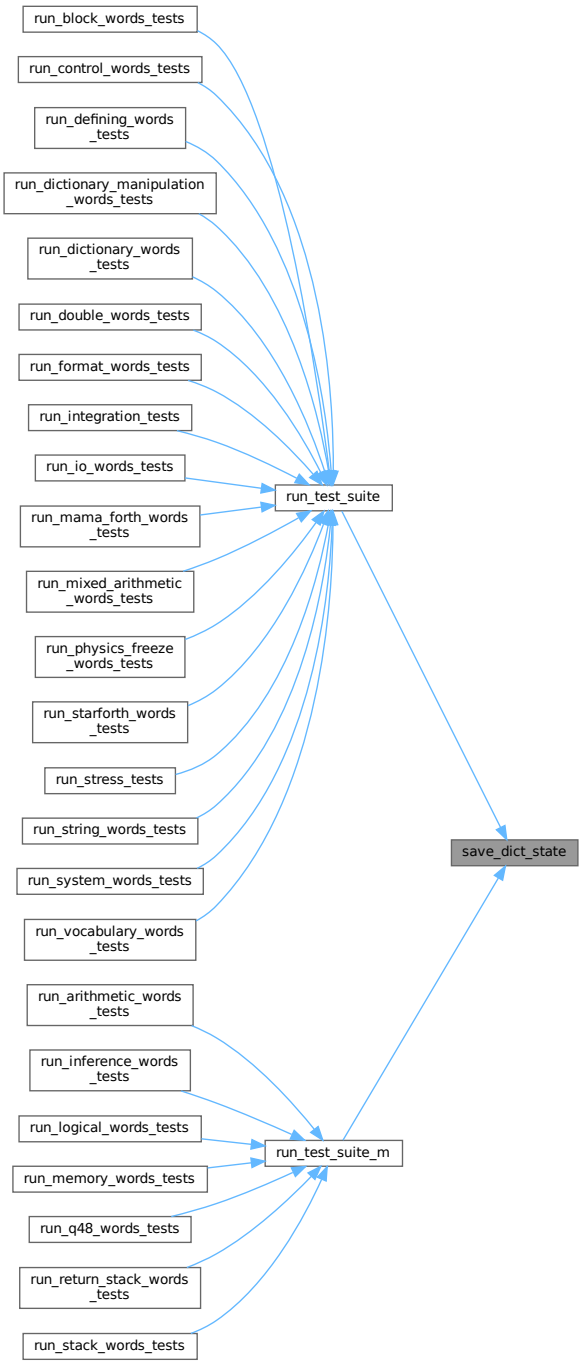
vm	Pointer to VM instance
latest	Pointer to store latest dictionary entry
here	Pointer to store HERE pointer

Captures dictionary state so tests can be cleaned up after execution

References VM::here, and VM::latest.

Referenced by run_test_suite(), and run_test_suite_m().

Here is the caller graph for this function:



7.309.4.11 save_vm_state()

```
void save_vm_state (
            VM * vm,
            int * dsp,
            int * rsp,
```

```
    int * error,
    vm_mode_t * mode )
```

Saves current VM state.

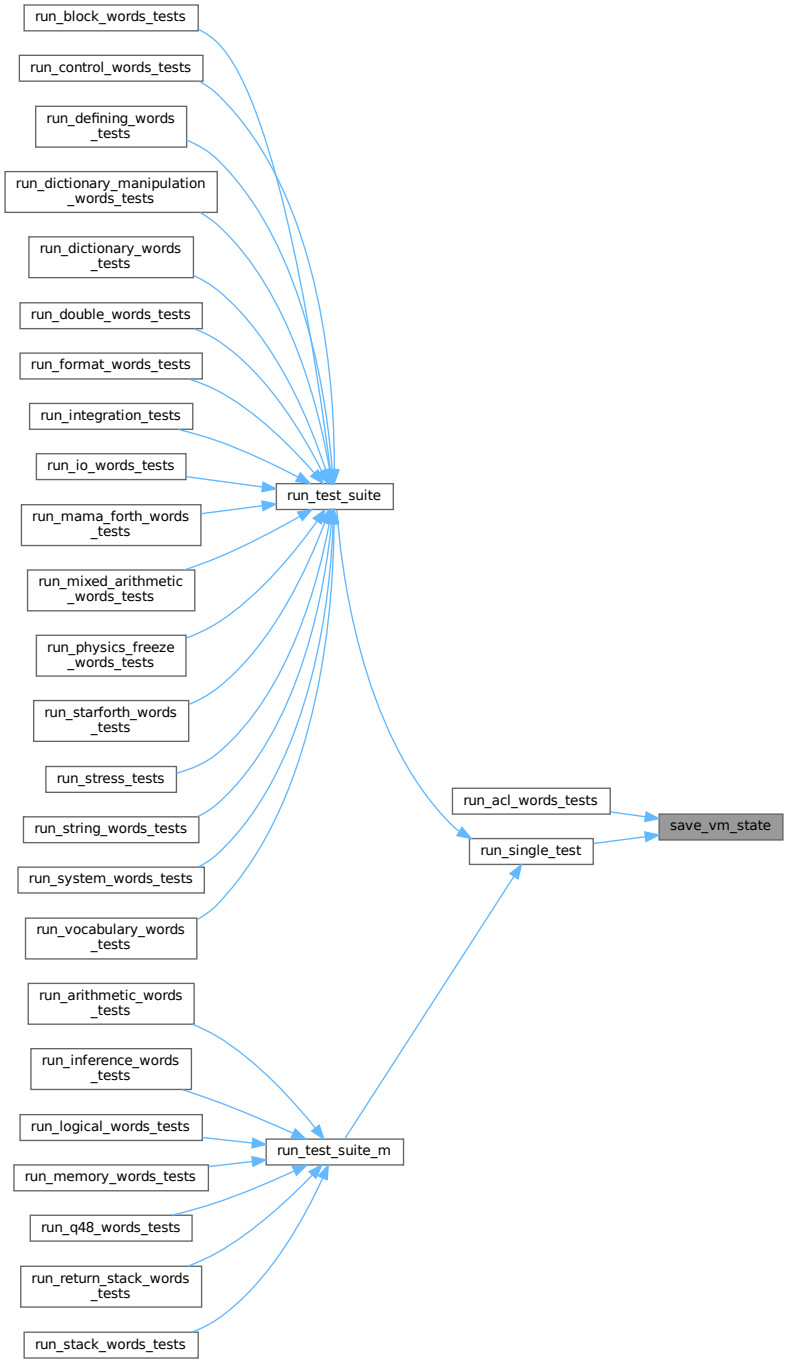
Parameters

vm	Pointer to VM instance
dsp	Pointer to store data stack pointer
rsp	Pointer to store return stack pointer
error	Pointer to store error state
mode	Pointer to store VM mode

References VM::dsp, VM::error, VM::mode, and VM::rsp.

Referenced by run_acl_words_tests(), and run_single_test().

Here is the caller graph for this function:



7.309.5 Variable Documentation

7.309.5.1 fail_fast

```
int fail_fast  [extern]
```

Global flag to control test execution behavior.

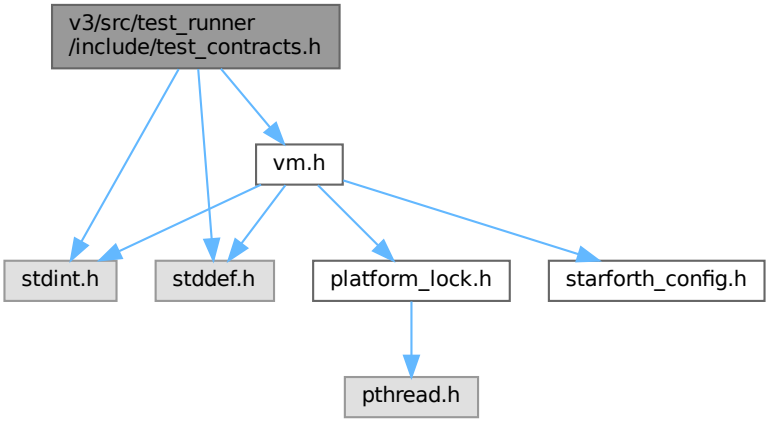
When set to non-zero, causes test runner to exit immediately on first failure

Referenced by main(), and run_single_test().

7.310 v3/src/test_runner/include/test_contracts.h File Reference

```
#include "vm.h"
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for test_contracts.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct WordContract
- struct ExecResult
- struct PhysicsSnapshot

Macros

- #define CONTRACT_NONE 0u
- #define CONTRACT_PHYSICS_TRANSPARENT (1u << 0)
- #define CONTRACT_HEARTBEAT_SAFE (1u << 1)
- #define CONTRACT_DEFAULT_FUZZ_ROUNDS 4

Typedefs

- typedef uint32_t contract_flags_t

Functions

- int contract_get_violation_count (void)

  Return the current count of accumulated contract violations.
- void contract_reset_violation_count (void)

  Reset the contract violation counter to zero.
- void capture_exec_result (VM *vm, ExecResult *r)

  Snapshot the execution-domain fields of a VM into an `ExecResult`.
- int exec_results_equal (const ExecResult *a, const ExecResult *b)

  Compare two `ExecResult` snapshots for execution-domain equality.
- void save_physics (VM *vm, PhysicsSnapshot *s)

  Save the key physics scalars touched by the seven feedback loops.
- void restore_physics (VM *vm, const PhysicsSnapshot *s)

  Restore the physics scalars from a previously saved snapshot.
- void perturb_physics (VM *vm, int round)

  Randomly perturb key physics scalars to expose A4' violations.
- int check_physics_transparent (VM *vm, const char *word_name, const char *input, int should_error, int implemented, int fuzz_rounds)

  A4' contract check — verify a word is transparent to physics state.
- int assert_heartbeat_safe (VM *vm)

  A1 contract check — verify `vm_tick()` does not modify the execution domain.

Variables

- int global_contract_violations

7.310.1 Macro Definition Documentation

7.310.1.1 CONTRACT_DEFAULT_FUZZ_ROUNDS

```
#define CONTRACT_DEFAULT_FUZZ_ROUNDS 4
```

7.310.1.2 CONTRACT_HEARTBEAT_SAFE

```
#define CONTRACT_HEARTBEAT_SAFE (1u << 1)
```

7.310.1.3 CONTRACT_NONE

```
#define CONTRACT_NONE 0u
```

7.310.1.4 CONTRACT_PHYSICS_TRANSPARENT

```
#define CONTRACT_PHYSICS_TRANSPARENT (1u << 0)
```

7.310.2 Typedef Documentation

7.310.2.1 contract_flags_t

```
typedef uint32_t contract_flags_t
```

7.310.3 Function Documentation

7.310.3.1 assert_heartbeat_safe()

```
int assert_heartbeat_safe (
            VM * vm )
```

A1 contract check — verify `vm_tick()` does not modify the execution domain.

Axiom A1 (heartbeat isolation): the background heartbeat tick must never alter stacks, error state, or any other execution-domain field observable by FORTH words. This function captures an `ExecResult` before and after one `vm_tick()` call and compares them with `exec_results_equal()`.

On violation, logs [A1 CONTRACT] VIOLATION with before/after dsp and rsp values, and increments `global_contract_violations`.

Parameters

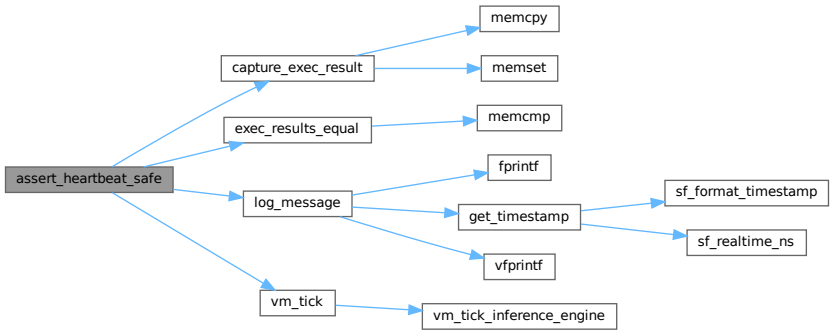
vm	VM instance; stacks and error state must already be in a known reference state before calling.

Returns

1 if the heartbeat left the execution domain unchanged, 0 on violation.

References capture_exec_result(), ExecResult::dsp, exec_results_equal(), global_contract_violations, LOG_ERROR, log_message(), ExecResult::rsp, and vm_tick().

Here is the call graph for this function:



7.310.3.2 capture_exec_result()

```
void capture_exec_result (
            VM * vm,
            ExecResult * r )
```

Snapshot the execution-domain fields of a VM into an `ExecResult`.

Captures `dsp`, `rsp`, `error`, and the live portion of the data stack (indices 0 ... dsp?1). The remainder of `r->stack` is zeroed for deterministic `memcmp()` comparisons in `exec_results_equal()`.

Only execution-domain fields are captured — physics scalars, heartbeat state, and rolling-window counters are deliberately excluded.

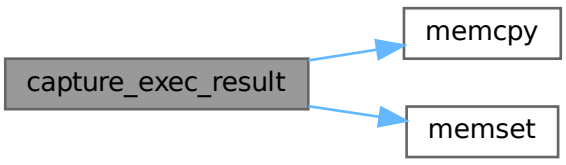
Parameters

vm	VM instance to snapshot.
r	Output `ExecResult` struct to populate.

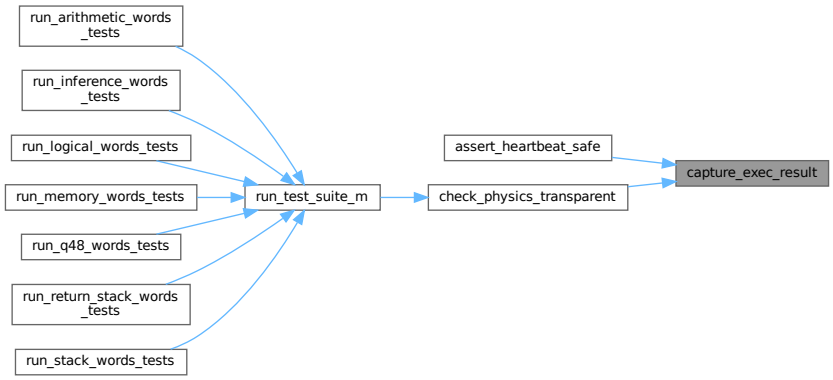
References VM::data_stack, VM::dsp, ExecResult::dsp, VM::error, ExecResult::error, memcpy(), memset(), VM::rsp, ExecResult::rsp, ExecResult::stack, and STACK_SIZE.

Referenced by assert_heartbeat_safe(), and check_physics_transparent().

Here is the call graph for this function:



Here is the caller graph for this function:



7.310.3.3 check_physics_transparent()

```
int check_physics_transparent (
            VM * vm,
            const char * word_name,
            const char * input,
            int should_error,
            int implemented,
            int fuzz_rounds )
```

A4' contract check — verify a word is transparent to physics state.

Axiom A4' (physics transparency): a FORTH word's execution-domain result (`ExecResult`) must be identical regardless of the values of the seven physics feedback-loop scalars.

Protocol:

1. Run `input` with current (unperturbed) physics; capture baseline.
2. For each of `fuzz_rounds` rounds: seed RNG, perturb physics, re-run `input`, capture result, compare to baseline.
3. On divergence, log the violation and increment `global_contract_violations`.
4. Always restore original physics state before returning.

Error-expected tests (`should_error`) and unimplemented words (`implemented` == 0) are skipped: exec-equivalent divergence is legitimate for error paths.

Parameters

vm	VM instance.
word_name	Human-readable word name for diagnostic messages.
input	FORTH source string to execute (same each round).
should_error	Non-zero if the test is expected to raise an error.
implemented	Non-zero if the word is implemented and should be checked.
fuzz_rounds	Number of perturbation rounds; 0 → CONTRACT_DEFAULT_FUZZ_ROUNDS.

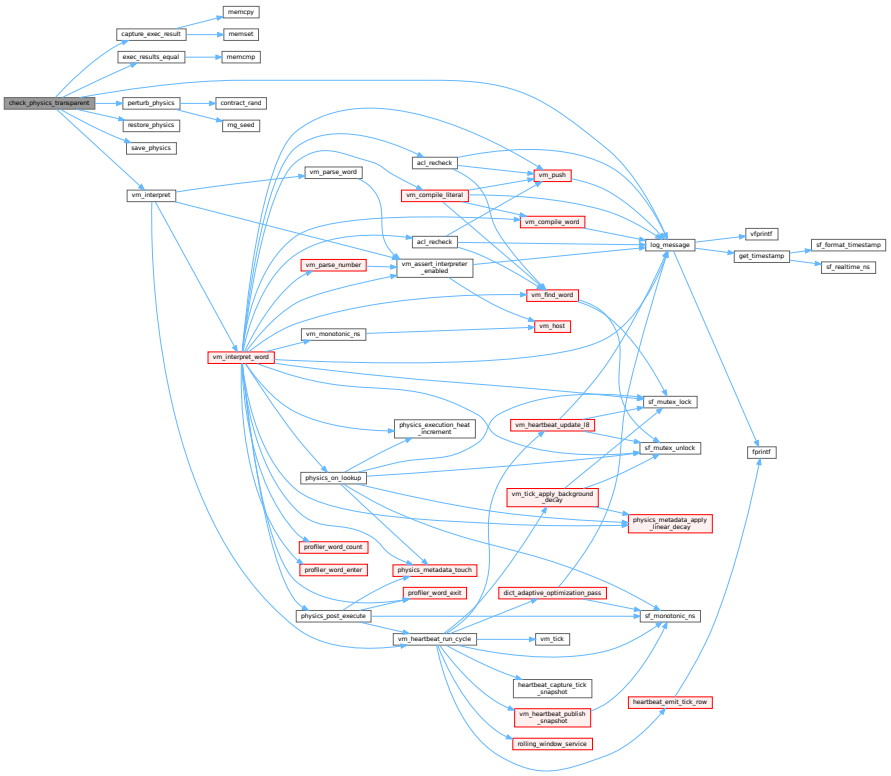
Returns

1 if all rounds passed (or test skipped), 0 on any violation.

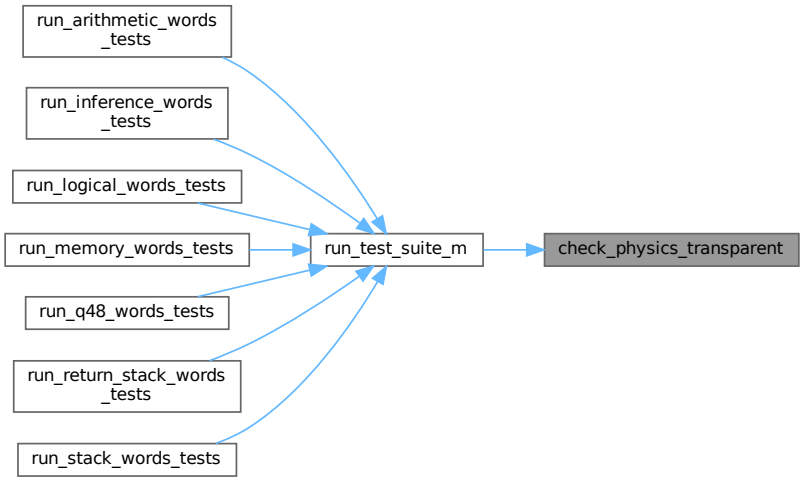
References VM::abort_requested, capture_exec_result(), CONTRACT_DEFAULT_FUZZ_ROUNDS, VM::dsp, ExecResult::dsp, VM::error, exec_results_equal(), VM::exit_colon, global_contract_violations, LOG_ERROR, log_message(), perturb_physics(), restore_physics(), VM::rsp, save_physics(), and vm_interpret().

Referenced by run_test_suite_m().

Here is the call graph for this function:



Here is the caller graph for this function:



7.310.3.4 contract_get_violation_count()

```
int contract_get_violation_count (
            void  )
```

Return the current count of accumulated contract violations.

Reads `global_contract_violations` directly; same-TU access avoids GOT double-dereference in `-fPIC` PE32+ builds where `R_X86_64_REX_GOTPCRELX` is not relaxed to a LEA instruction.

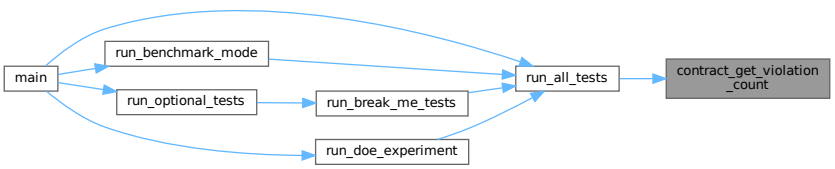
Returns

Number of contract violations recorded since last reset.

References global_contract_violations.

Referenced by run_all_tests().

Here is the caller graph for this function:



7.310.3.5 contract_reset_violation_count()

```
void contract_reset_violation_count (
            void  )
```

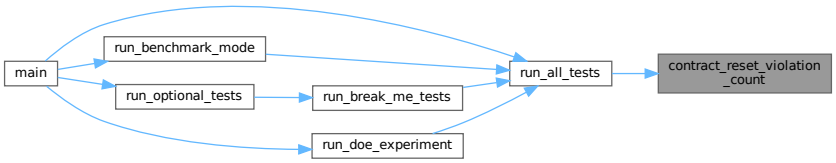
Reset the contract violation counter to zero.

Call before a fresh round of contract checks so that counts from earlier test phases do not accumulate across module boundaries.

References global_contract_violations.

Referenced by run_all_tests().

Here is the caller graph for this function:



7.310.3.6 exec_results_equal()

```
int exec_results_equal (
            const ExecResult * a,
            const ExecResult * b )
```

Compare two `ExecResult` snapshots for execution-domain equality.

Returns 1 only if `dsp`, `rsp`, `error`, and the live stack contents are all identical. Stack comparison uses `memcmp()` over the live portion (0 ... dsp?1 cells); the zeroed tail guarantees no false positives from uninitialised padding.

Parameters

a	First snapshot.
b	Second snapshot.

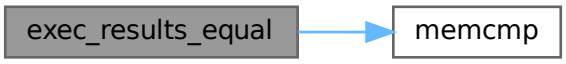
Returns

1 if execution-domain is identical, 0 if any field differs.

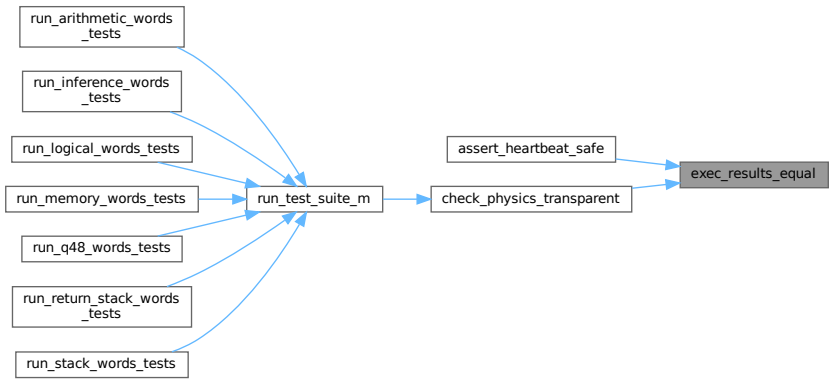
References ExecResult::dsp, ExecResult::error, memcmp(), ExecResult::rsp, and ExecResult::stack.

Referenced by assert_heartbeat_safe(), and check_physics_transparent().

Here is the call graph for this function:



Here is the caller graph for this function:



7.310.3.7 perturb_physics()

```
void perturb_physics (
            VM * vm,
            int round )
```

Randomly perturb key physics scalars to expose A4' violations.

Seeds the RNG via `rng_seed(round)` for deterministic but distinct perturbations per round, then overwrites the eight tracked physics fields with random values that still satisfy their well-formedness invariants:

- `decay_slope_q48`: LSB forced to 1 (must be $>$ 0 per `slope_wf`)
- `effective_window_size`: [1, ROLLING_WINDOW_SIZE] (never 0)
- `tick_target_ns`: LSB forced to 1 (must be $>$ 0 per `hb_state_wf`)
- Heat thresholds: arbitrary positive values (no strict invariant)
- `prefetch_attempts` / `total_executions`: arbitrary counts

After perturbation, running the same FORTH input must produce an identical `ExecResult`; divergence is an A4' violation.

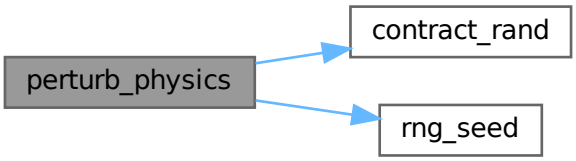
Parameters

vm	VM instance to perturb.
round	Fuzz round index (used to seed the RNG).

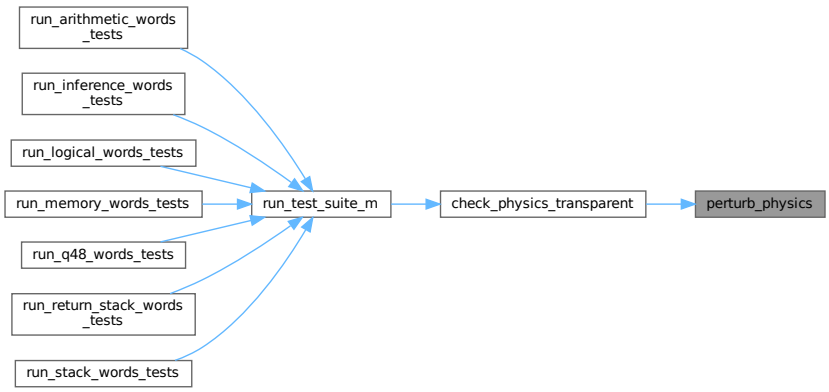
References contract_rand(), VM::decay_slope_q48, RollingWindowOfTruth::effective_window_size, VM::heartbeat, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch rng_seed(), VM::rolling_window, ROLLING_WINDOW_SIZE, HeartbeatState::tick_target_ns, and RollingWindowOfTruth::total_execu

Referenced by check_physics_transparent().

Here is the call graph for this function:



Here is the caller graph for this function:



7.310.3.8 restore_physics()

```
void restore_physics (
            VM * vm,
            const PhysicsSnapshot * s )
```

Restore the physics scalars from a previously saved snapshot.

Writes back the eight fields saved by save_physics(), undoing any perturbations made by perturb_physics(). Called at the end of each fuzz round and after the full check_physics_transparent() loop so the VM state is clean for the next contract check.

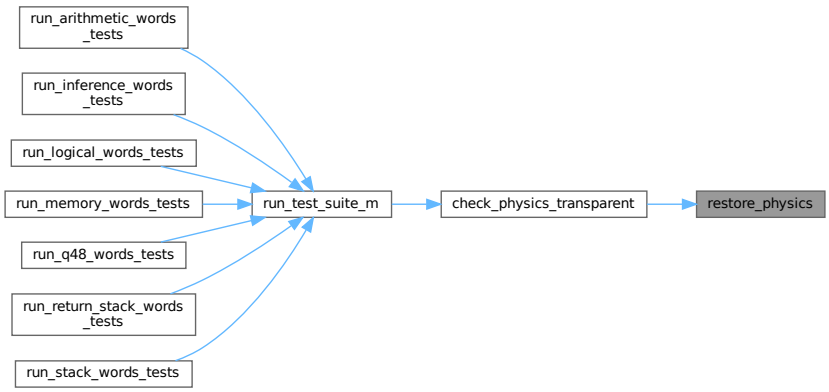
Parameters

vm	VM instance to restore.
s	Source `PhysicsSnapshot` to restore from.

References VM::decay_slope_q48, PhysicsSnapshot::decay_slope_q48, PhysicsSnapshot::eff_window_size, RollingWindowOfTruth::effective_window_size, VM::heartbeat, PhysicsSnapshot::heat_25th, PhysicsSnapshot::heat_50th, PhysicsSnapshot::heat_75th, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PhysicsSnapshot::prefetch_attempts, VM::rolling_window, HeartbeatState::tick_target_ns, PhysicsSnapshot::tick_target_ns, RollingWindowOfTruth::total_executions, and PhysicsSnapshot::total_executions.

Referenced by check_physics_transparent().

Here is the caller graph for this function:



7.310.3.9 save_physics()

```
void save_physics (
            VM * vm,
            PhysicsSnapshot * s )
```

Save the key physics scalars touched by the seven feedback loops.

Captures the eight fields that `perturb_physics()` will randomise: `decay_slope_q48`, `effective_window_size`, `tick_target_ns`, the three heat percentile thresholds, `prefetch_attempts`, and `total_executions`. Used as a bracket pair with `restore_physics()` around each fuzz round so the VM returns to a known state.

Parameters

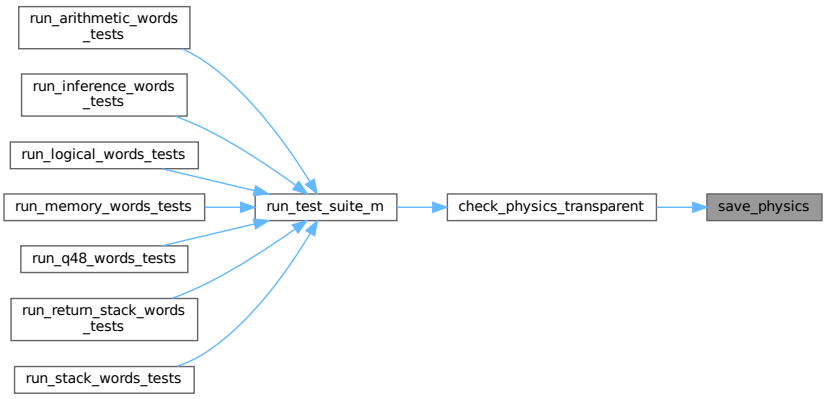
vm	VM instance to snapshot.
s	Output `PhysicsSnapshot` to populate.

References VM::decay_slope_q48, PhysicsSnapshot::decay_slope_q48, PhysicsSnapshot::eff_window_size,

RollingWindowOfTruth::effective_window_size, VM::heartbeat, PhysicsSnapshot::heat_25th, PhysicsSnapshot::heat_50th, PhysicsSnapshot::heat_75th, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PhysicsSnapshot::prefetch_attempts, VM::rolling_window, HeartbeatState::tick_target_ns, PhysicsSnapshot::tick_target_ns, RollingWindowOfTruth::total_executions, and PhysicsSnapshot::total_executions.

Referenced by check_physics_transparent().

Here is the caller graph for this function:



7.310.4 Variable Documentation

7.310.4.1 global_contract_violations

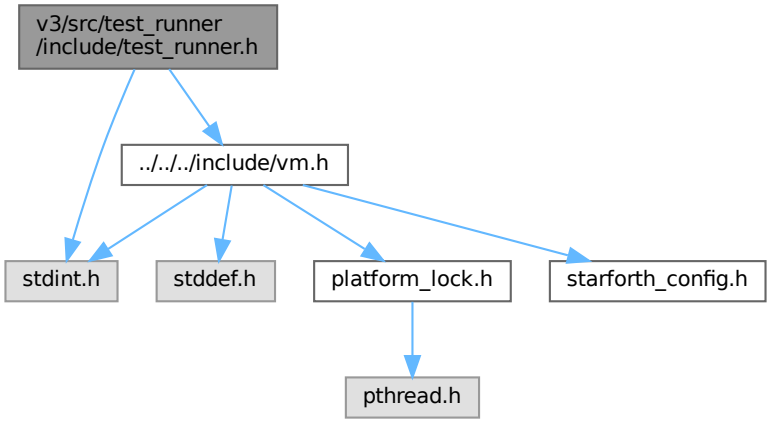
```
int global_contract_violations  [extern]
```

Referenced by assert_heartbeat_safe(), check_physics_transparent(), contract_get_violation_count(), and contract_reset_violation_count().

7.311 v3/src/test_runner/include/test_runner.h File Reference

```
#include "../../../include/vm.h"
#include <stdint.h>
```

Include dependency graph for test_runner.h:



This graph shows which files directly or indirectly include this file:

Data Structures

- struct TestStats

  Structure holding test execution statistics.
- struct TestModule

  Structure representing a test module.

Functions

- void test_stats_accumulate (int tests, int pass, int fail, int skip, int error)
- void run_stack_words_tests (VM *vm)

  Executes all test suites for stack manipulation words.
- void run_return_stack_words_tests (VM *vm)

  Executes all test suites for return stack manipulation words.
- void run_memory_words_tests (VM *vm)

  Executes the test suite for memory manipulation words.
- void run_arithmetic_words_tests (VM *vm)

  Executes all arithmetic word test suites.
- void run_logical_words_tests (VM *vm)

  Executes all logical words test suites.
- void run_mixed_arithmetic_words_tests (VM *vm)

  Module 7 entry point — run all mixed-arithmetic word POST tests.
- void run_double_words_tests (VM *vm)

  Executes all test suites for double number words.
- void run_dictionary_words_tests (VM *vm)

Executes all dictionary word test suites.

- void run_io_words_tests (VM *vm)

  Executes all I/O words test suites.
- void run_format_words_tests (VM *vm)

  Executes all format words test suites.
- void run_string_words_tests (VM *vm)

  Executes all string manipulation word tests.
- void run_dictionary_manipulation_words_tests (VM *vm)

  Executes all dictionary manipulation words test suites.
- void run_vocabulary_words_tests (VM *vm)

  Executes all vocabulary word test suites.
- void run_block_words_tests (VM *vm)

  Executes all block words test suites.
- void run_system_words_tests (VM *vm)

  Executes all system word tests.
- void run_defining_words_tests (VM *vm)

  Executes all test suites for Forth defining words.
- void run_control_words_tests (VM *vm)

  Executes all control words test suites.
- void run_starforth_words_tests (VM *vm)

  Executes all StarForth words test suites.
- void run_acl_words_tests (VM *vm)

  Module 24 entry point — run all word-level ACL POST tests.
- void run_q48_words_tests (VM *vm)

  Executes all Q48.16 fixed-point word test suites.
- void run_inference_words_tests (VM *vm)

  Executes the proof-covered subset of inference-engine word test suites.
- void run_physics_freeze_words_tests (VM *vm)

  Executes the proof-covered subset of physics-freeze word test suites.
- void run_mama_forth_words_tests (VM *vm)

  Executes all Mama FORTH vocabulary test suites.
- void enable_benchmark_mode (int iterations)

  Enable benchmark mode for test execution.
- void run_stress_tests (VM *vm)

  Execute comprehensive stress test suites.
- void run_integration_tests (VM *vm)

  Executes all integration test suites for StarForth.
- void run_all_tests (VM *vm)

  Run all test modules with optional benchmarking.
- void run_module_tests (VM *vm, const char *module_name)

  Run tests for a specific module.
- void run_word_tests (VM *vm, const char *word_name)

  Run tests for a specific Forth word.
- void run_break_me_tests (VM *vm)

  Run ultra-comprehensive break-me diagnostic suite.

Variables

- TestStats global_test_stats

  Global statistics for test execution.

7.311.1 Function Documentation

7.311.1.1 enable_benchmark_mode()

```
void enable_benchmark_mode (
            int iterations )
```

Enable benchmark mode for test execution.

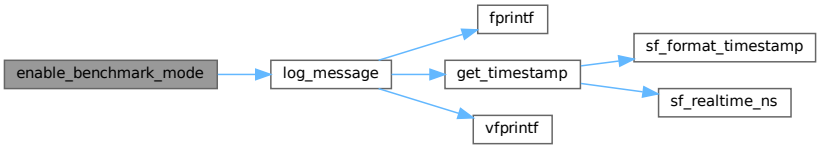
Parameters

iterations	Number of times each test should be repeated

References benchmark_iterations, benchmark_mode, LOG_INFO, and log_message().

Referenced by run_benchmark_mode().

Here is the call graph for this function:



Here is the caller graph for this function:

7.311.1.2 run_acl_words_tests()

```
void run_acl_words_tests (
            VM * vm )
```

Module 24 entry point — run all word-level ACL POST tests.

Saves the current VM state (dsp, rsp, error, mode, emergency_console) before each sub-test and restores it between tests so failures do not cascade. Runs eleven tests covering:

1. ACL-PIN one-way ratchet (4 assertions)

2. ACL-INHERIT semantics (4 assertions)
3. emergency_console bypass (1 assertion)
4. ACL denial aborts word execution (2 assertions)
5. TTL hot-path decrement (1 assertion)
6. STRICT mode — TTL stays 0 (1 assertion or conditional skip)
7. Adaptive TTL via ACL-TTL-COMPUTE (1 assertion or conditional skip)
8. Pin blocks shadowing (3 assertions)
9. Read accessors — ACL-MODE@/PINNED?/TTL@/ALLOW@/HEAT@/WORD-ID (6 assertions)
10. ACL-INHERIT as an interpreted word, not just its C twin (2 assertions)
11. ACL-INIT-PRIMITIVES resets unpinned, skips pinned (4 assertions)

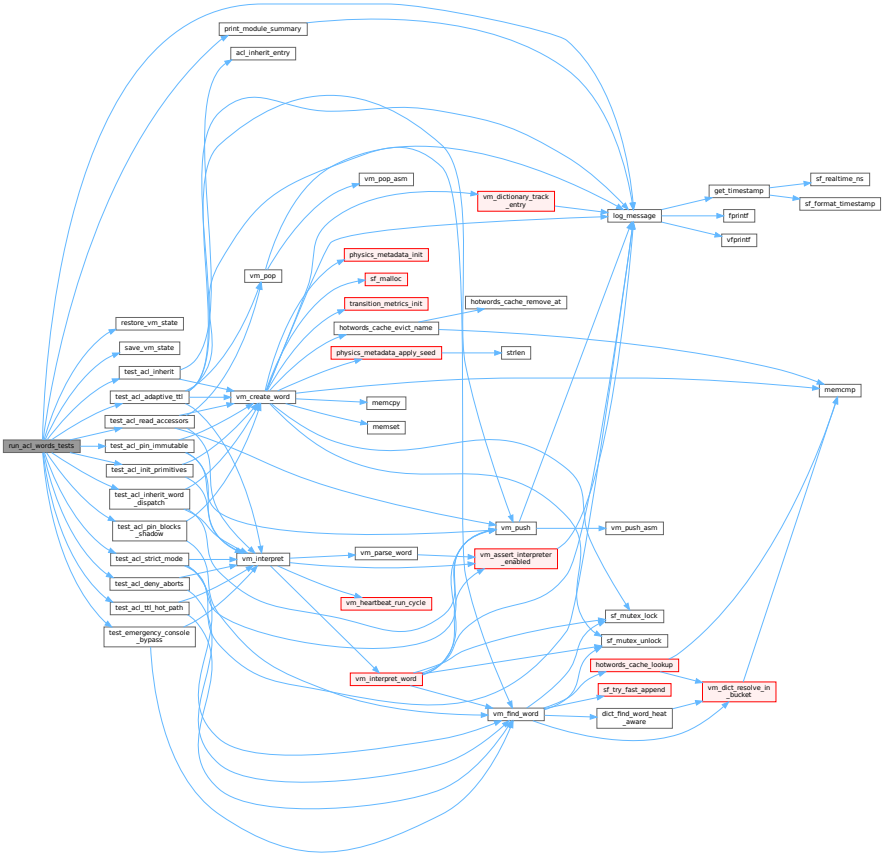
Tests that depend on `ACL.4th` being loaded are conditionally skipped during bare POST (before `ACL.4th` runs) and counted as passes so the POST score is not penalised by load-order.

Parameters

vm	VM instance; must be initialised and have the standard word vocabulary available.

References VM::emergency_console, LOG_INFO, log_message(), print_module_summary(), restore_vm_state(), save_vm_state(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_inherit(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_blocks_shadow(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_bypass(), tests_failed, and tests_passed.

Here is the call graph for this function:



7.311.1.3 run_all_tests()

```
void run_all_tests (
            VM * vm )
```

Run all test modules with optional benchmarking.

Executes all registered test modules sequentially, collecting statistics and/or benchmark data depending on the current mode.

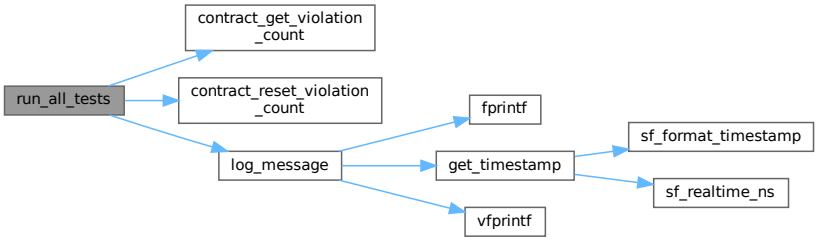
Parameters

vm	Pointer to the Forth virtual machine instance

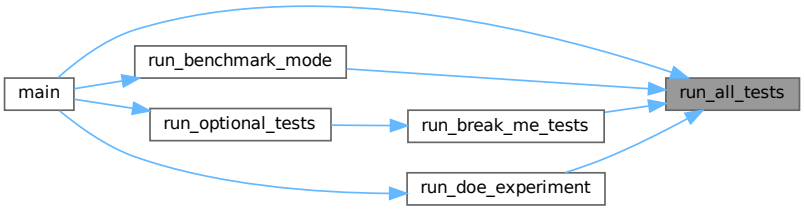
References contract_get_violation_count(), contract_reset_violation_count(), global_test_stats, LOG_ERROR, LOG_INFO, log_message(), LOG_WARN, TestModule::module_name, test_modules, TestStats::total_error, TestStats::total_fail, TestStats::total_pass, TestStats::total_skip, and TestStats::total_tests.

Referenced by main(), run_benchmark_mode(), run_break_me_tests(), and run_doe_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:



7.311.1.4 run_arithmetic_words_tests()

```
void run_arithmetic_words_tests (
            VM * vm )
```

Executes all arithmetic word test suites.

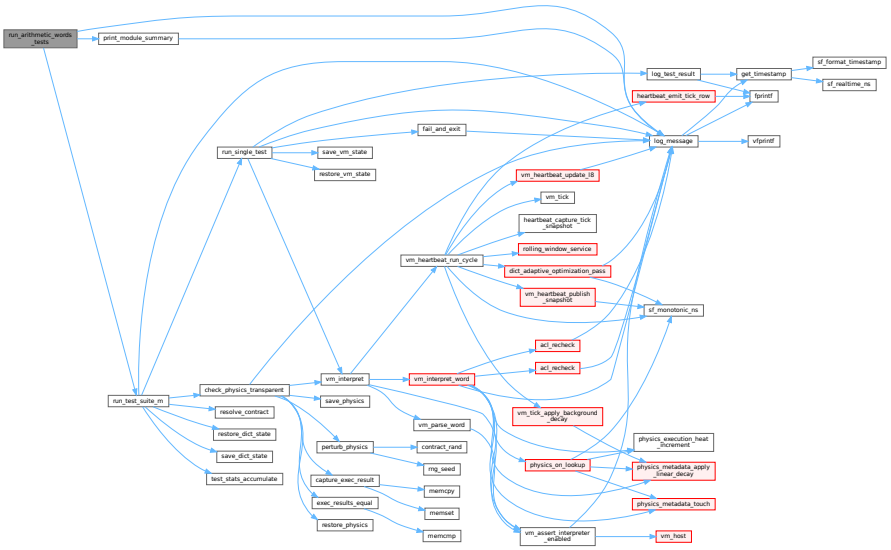
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all test cases for arithmetic operations including basic operations (+, -, ∗, /), modulo operations (MOD, /MOD), and numeric functions (ABS, NEGATE, MIN, MAX)

References arithmetic_word_suites, CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.5 run_block_words_tests()

```
void run_block_words_tests (
            VM * vm )
```

Executes all block words test suites.

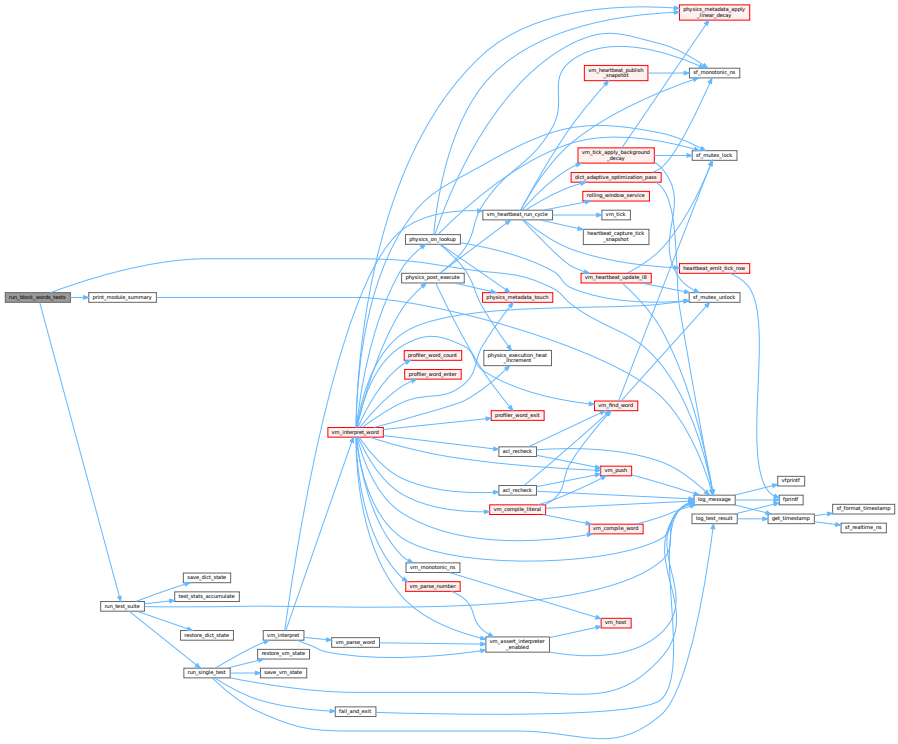
Parameters

vm	Pointer to the FORTH virtual machine instance

Runs through all test cases for block manipulation words, including block access, buffer management, and block I/O operations. Results are logged and summarized after completion.

References block_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.6 run_break_me_tests()

```
void run_break_me_tests (
            VM * vm )
```

Run ultra-comprehensive break-me diagnostic suite.

Parameters

vm	Pointer to the VM instance

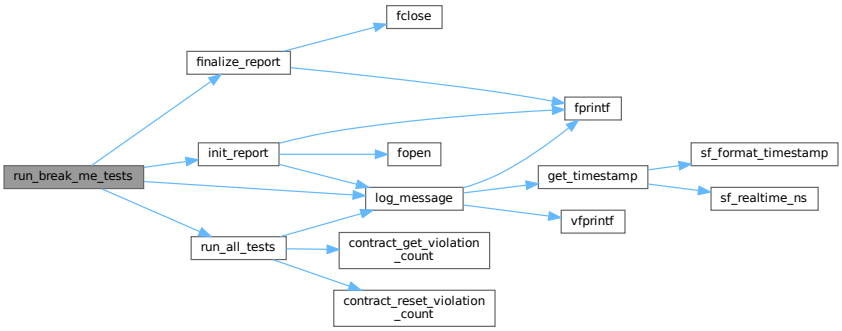
Executes the most exhaustive test battery ever designed for StarForth, generates a detailed markdown report in docs/BREAK_ME_REPORT.md, and includes a surprise easter egg at the end.

Run ultra-comprehensive break-me diagnostic suite.

References finalize_report(), global_test_stats, init_report(), LOG_ERROR, LOG_INFO, log_message(), run_all_tests(), TestStats::total_tests, and total_tests_run.

Referenced by run_optional_tests().

Here is the call graph for this function:



Here is the caller graph for this function:

7.311.1.7 run_control_words_tests()

```
void run_control_words_tests (
            VM * vm )
```

Executes all control words test suites.

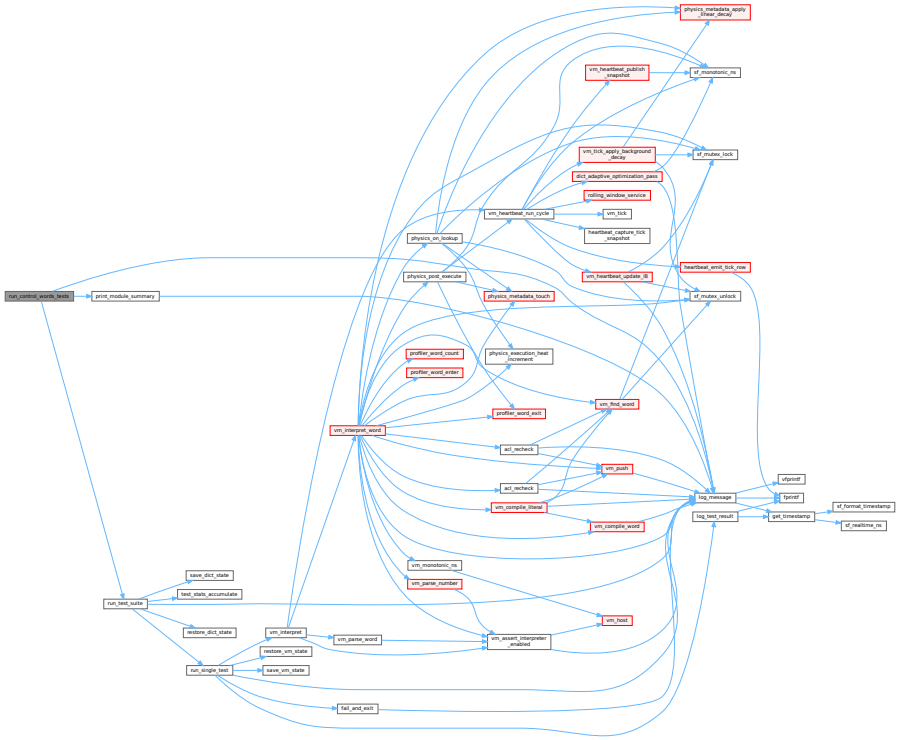
Parameters

vm	Pointer to the FORTH virtual machine instance

Runs through all defined test cases for control words, testing conditional branches and loop constructs

References control_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.8 run_defining_words_tests()

```
void run_defining_words_tests (
            VM * vm )
```

Executes all test suites for Forth defining words.

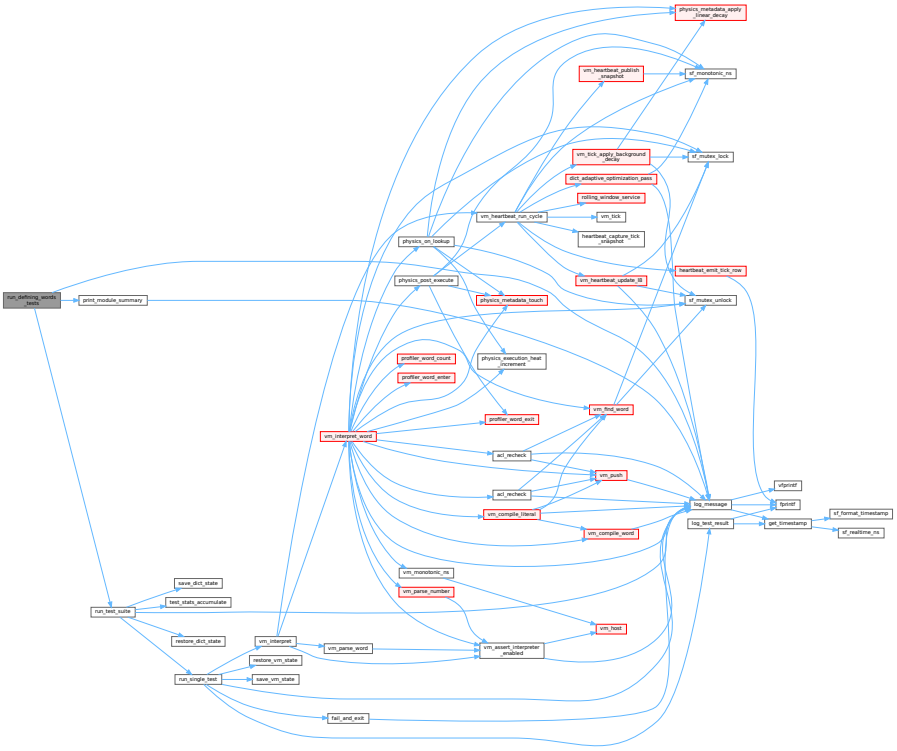
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through each test suite in defining_word_suites array, executing individual test cases and logging results_↩ run_01_2025_12_08

References defining_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.9 run_dictionary_manipulation_words_tests()

```
void run_dictionary_manipulation_words_tests (
            VM * vm )
```

Executes all dictionary manipulation words test suites.

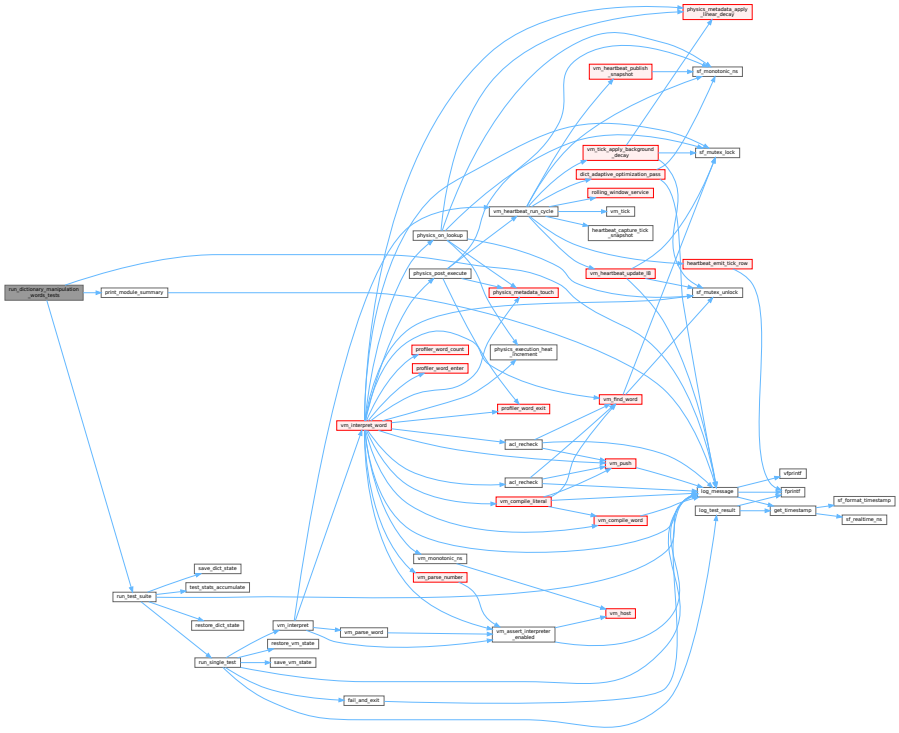
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all test cases for CREATE, FORGET, IMMEDIATE, FIND, DEFINITIONS, SMUDGE, LATEST, >BODY, and HIDDEN words

References dict_manip_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.10 run_dictionary_words_tests()

```
void run_dictionary_words_tests (
            VM * vm )
```

Executes all dictionary word test suites.

Parameters

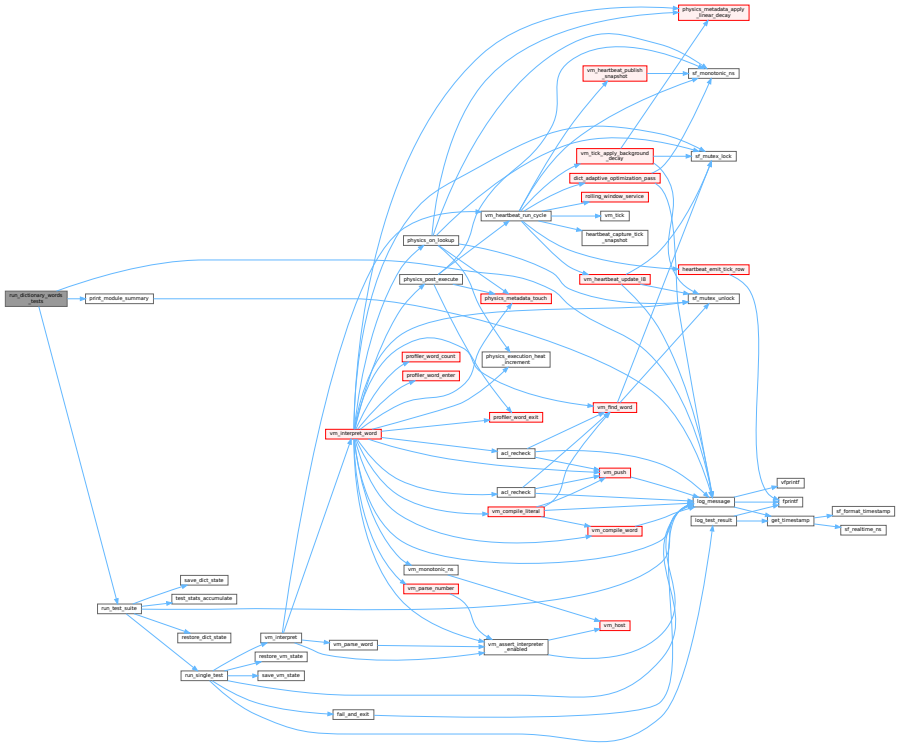
vm	Pointer to the FORTH virtual machine instance

This function runs through all dictionary word test suites, including tests for:

- HERE (dictionary pointer)
- ALLOT (memory allocation)
- Comma operations (, C, 2,)
- PAD (scratch pad area)
- Stack pointer operations (SP@ SP!)
- LATEST (most recent dictionary entry)
- Compilation sequences
- Stack management operations

References dictionary_word_suites, LOG_INFO, log_message(), print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.11 run_double_words_tests()

```
void run_double_words_tests (
            VM * vm )
```

Executes all test suites for double number words.

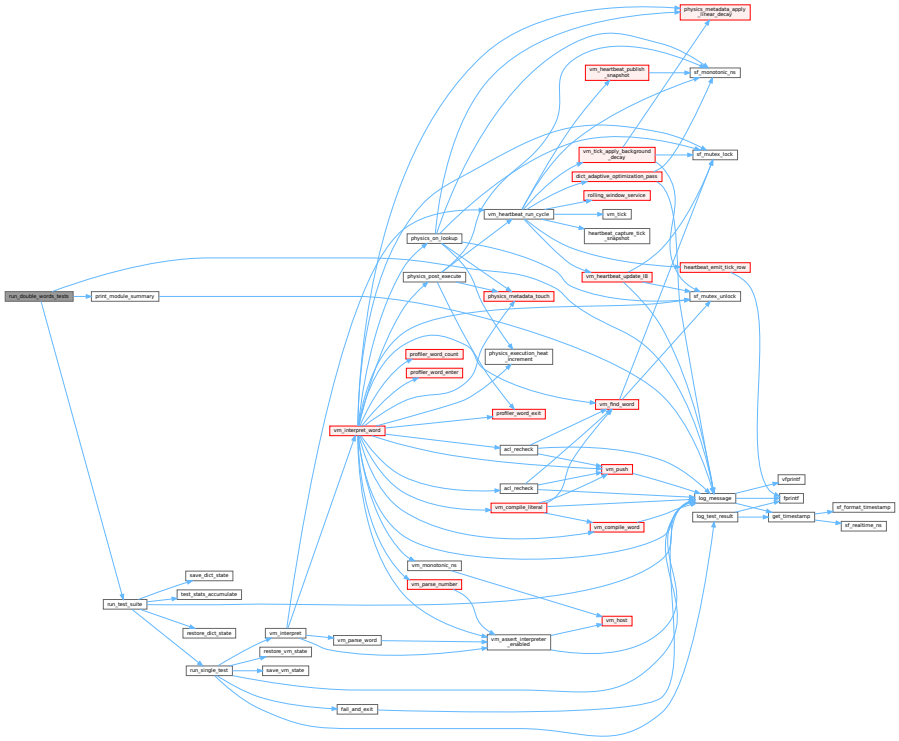
This function runs comprehensive tests for all double number word operations, including stack manipulation (2DROP, 2DUP, etc.), arithmetic operations (D+, D-, etc.), and comparison operations (D=, D<, etc.).

Parameters

vm	Pointer to the virtual machine instance where tests will be executed

References double_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.12 run_format_words_tests()

```
void run_format_words_tests (
            VM * vm )
```

Executes all format words test suites.

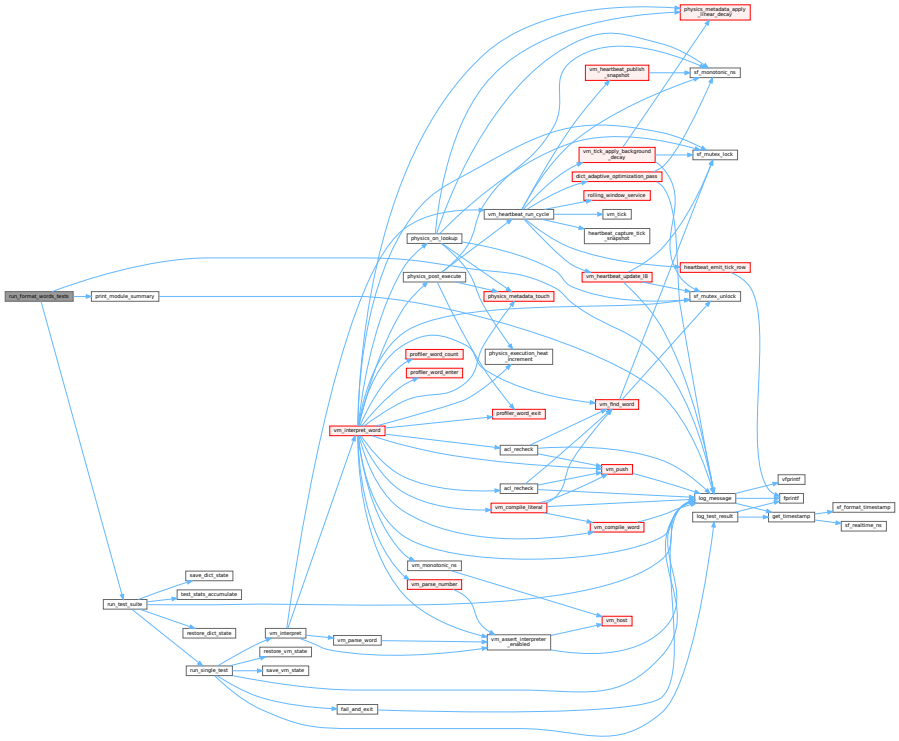
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all test cases for number base manipulation and formatting words

References format_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.13 run_inference_words_tests()

```
void run_inference_words_tests (
            VM * vm )
```

Executes the proof-covered subset of inference-engine word test suites.

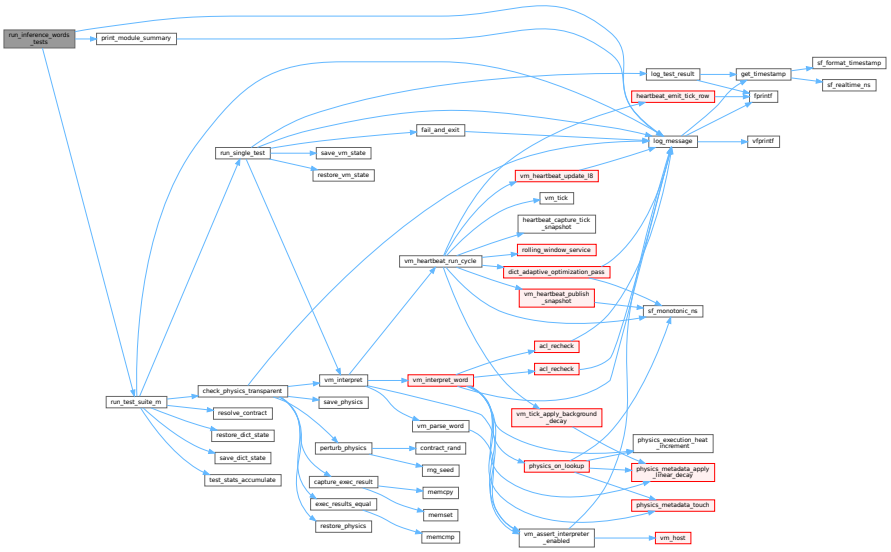
Parameters

vm	Pointer to the Forth virtual machine instance

Covers the 8 words proof/COVERAGE.md marks as proof-covered in inference_words.c: the three array-based primitives (Q.VARIANCE, INFER-DECAY-SLOPE, INFER-WINDOW-WIDTH), INFER-RUN, and the four ∗-@ output accessors (INFER-WINDOW@/DECAY@/VARIANCE@/FIT@) plus INFER-EARLY-EXIT. Does not cover the L8 Jacquard or Bayesian posterior words in the same file — not claimed as proof-covered.

References CONTRACT_NONE, inference_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.14 run_integration_tests()

```
void run_integration_tests (
            VM * vm )
```

Executes all integration test suites for StarForth.

Parameters

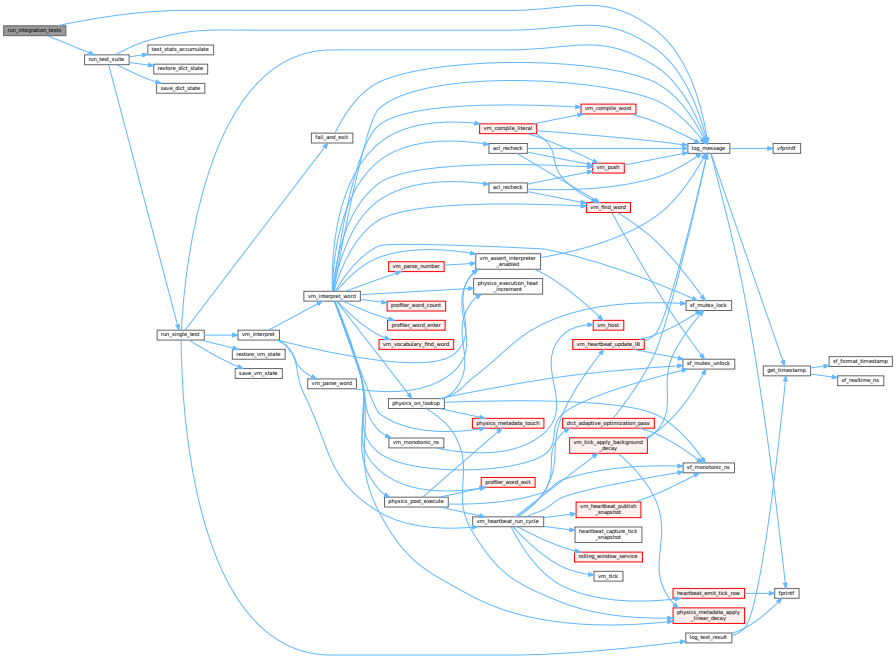
vm	Pointer to the Forth virtual machine instance

This function runs through all defined integration test suites, including:

- Complete Programs suite (prime checker, array operations, etc)
- Data Structures suite (linked list, min/max tracker)
- Algorithms suite (sorting, GCD)

References integration_suites, LOG_INFO, log_message(), and run_test_suite().

Here is the call graph for this function:



7.311.1.15 run_io_words_tests()

```
void run_io_words_tests (
            VM * vm )
```

Executes all I/O words test suites.

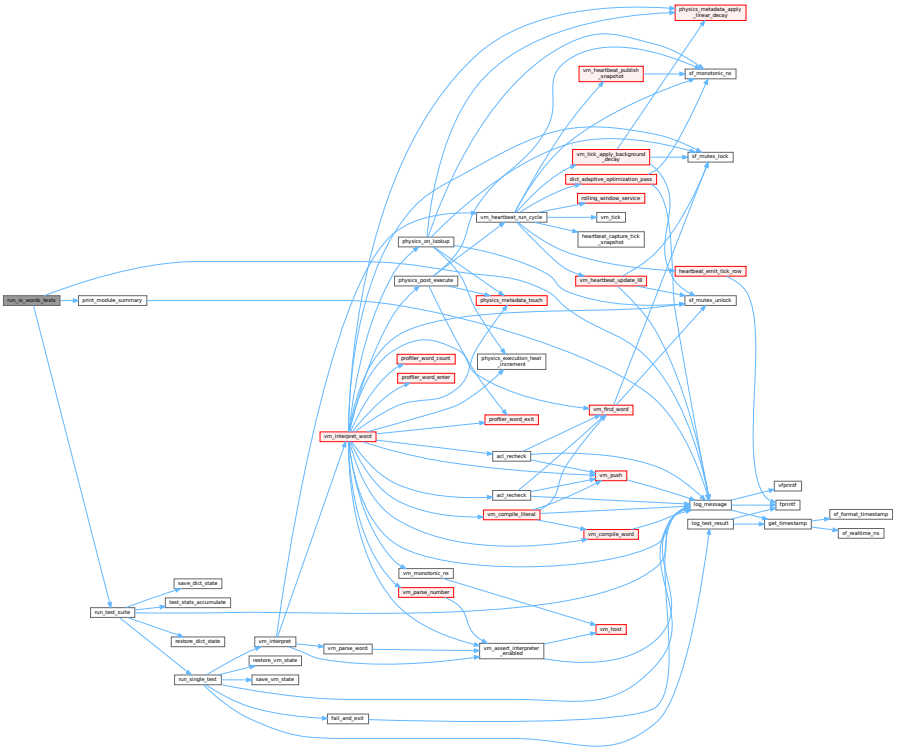
Parameters

vm	Pointer to the FORTH virtual machine instance

Runs through all defined test suites for I/O words, logging results_run_01_2025_12_08 and providing a summary of the test execution

References io_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.16 run_logical_words_tests()

```
void run_logical_words_tests (
            VM * vm )
```

Executes all logical words test suites.

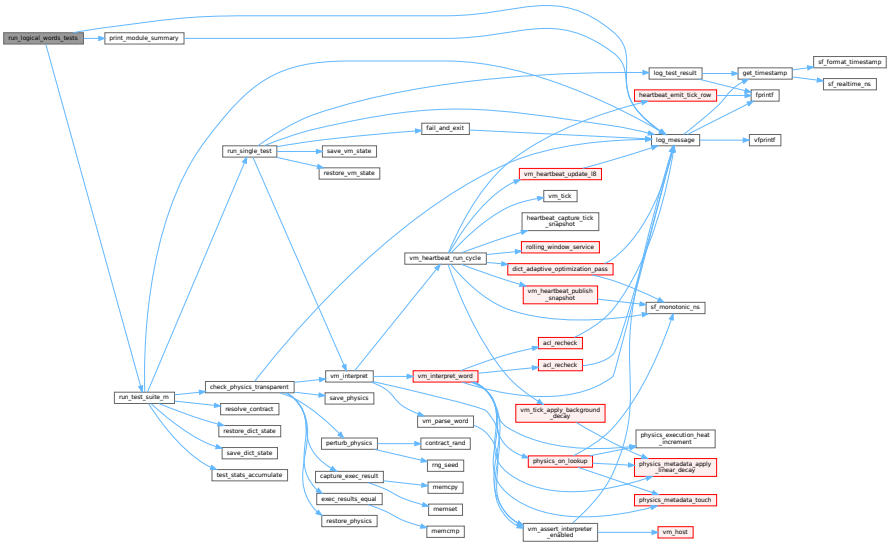
This function runs comprehensive tests for all FORTH logical and comparison operators, including stack underflow checks and edge cases.

Parameters

vm	Pointer to the FORTH virtual machine instance

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, logical_word_suites, print_module_summary(), run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.17 run_mama_forth_words_tests()

```
void run_mama_forth_words_tests (
            VM * vm )
```

Executes all Mama FORTH vocabulary test suites.

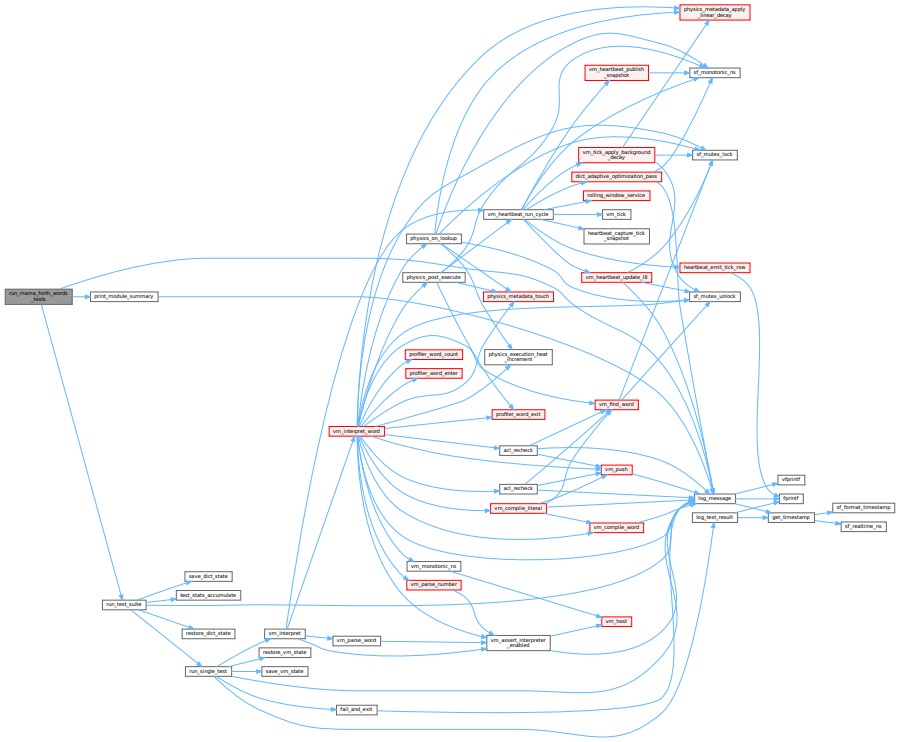
In hosted builds, all tests will be skipped since MAMA_IMPLEMENTED=0. In kernel builds, tests will execute against the capsule system.

Parameters

vm	Pointer to the Forth virtual machine instance

References LOG_INFO, log_message(), mama_word_suites, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.18 run_memory_words_tests()

```
void run_memory_words_tests (
            VM * vm )
```

Executes the test suite for memory manipulation words.

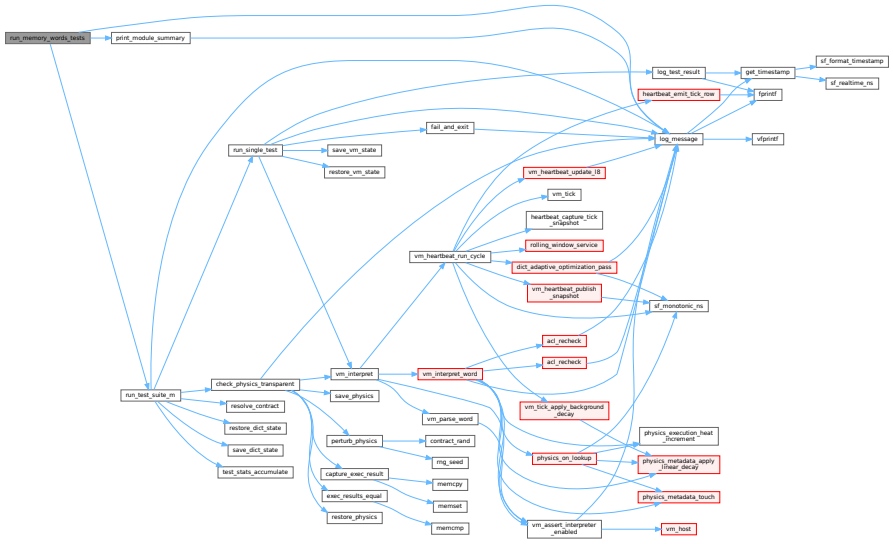
Runs through a series of test cases for Forth memory operations including store, fetch, allot, and other memory-related words

Parameters

vm	Pointer to the Forth virtual machine instance

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, memory_word_suites, print_module_summary(), run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.19 run_mixed_arithmetic_words_tests()

```
void run_mixed_arithmetic_words_tests (
            VM * vm )
```

Module 7 entry point — run all mixed-arithmetic word POST tests.

Iterates `mixed_arithmetic_word_suites` and delegates each to `run_test_suite()`. Covers five word families:

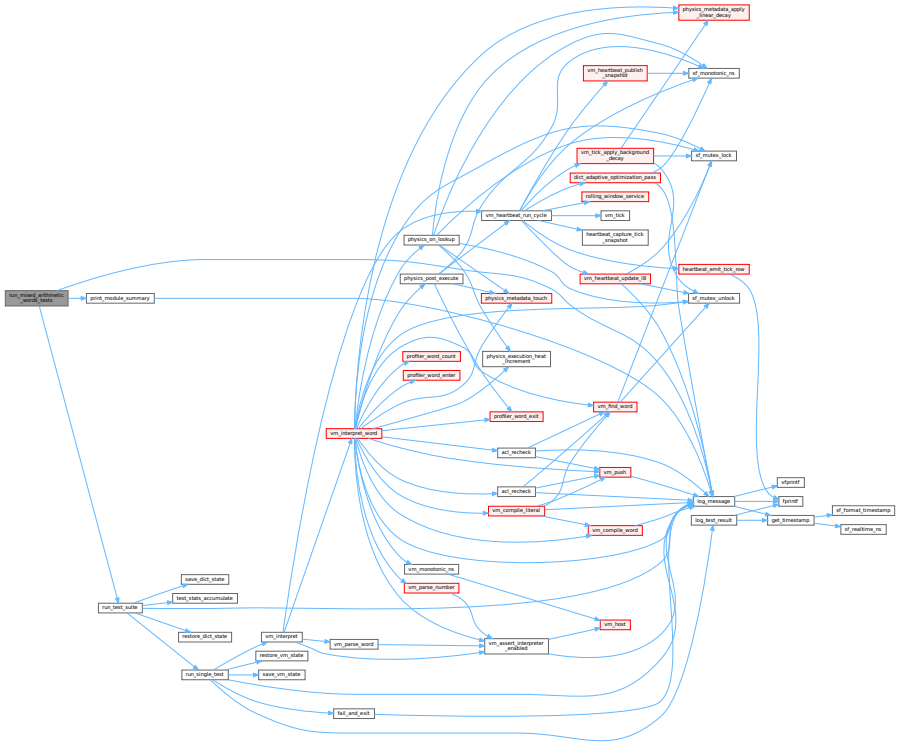
- `*-/` (n1 n2 n3 – n4) — scale: n1*n2/n3 in 64-bit intermediate
- `*-/MOD` (n1 n2 n3 – rem quot) — scale with remainder
- `M+` (d n – d') — add single to double
- `M*` (n1 n2 – d) — signed multiply to double
- `M/MOD` (d n – rem quot) — double divided by single

Parameters

vm	VM instance; must be initialised with the standard vocabulary.

References LOG_INFO, log_message(), LOG_TEST, mixed_arithmetic_word_suites, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.20 run_module_tests()

```
void run_module_tests (
            VM * vm,
            const char * module_name )
```

Run tests for a specific module.

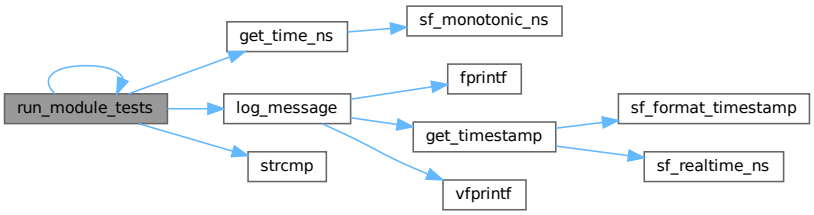
Parameters

vm	Pointer to the Forth virtual machine instance
module_name	Name of the module to test

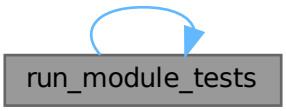
References benchmark_iterations, benchmark_mode, get_time_ns(), LOG_ERROR, LOG_INFO, log_message(), LOG_WARN, TestModule::module_name, run_module_tests(), TestModule::run_module_tests, strcmp(), and test_modules.

Referenced by run_module_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.311.1.21 run_physics_freeze_words_tests()

```
void run_physics_freeze_words_tests (
            VM * vm )
```

Executes the proof-covered subset of physics-freeze word test suites.

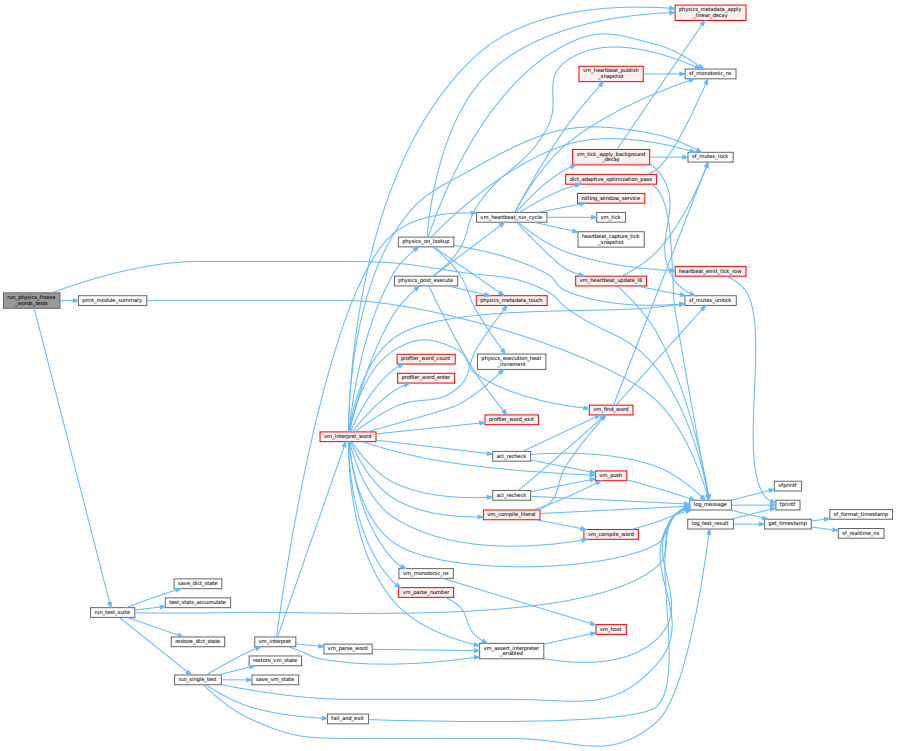
Parameters

vm	Pointer to the Forth virtual machine instance

Covers the 6 words proof/StarForth_Physics_Freeze_Words.thy gives real lemmas for: FREEZE-WORD, UNFREEZE-WORD, FROZEN?, HEAT!, HEAT@, DECAY-RATE. Does not cover FREEZE-CRITICAL, SHOW-HEAT, or ALL-HEATS — those carry only trivial/not-modelled lemmas in the same theory file.

References LOG_INFO, log_message(), LOG_TEST, physics_freeze_word_suites, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.22 run_q48_words_tests()

```
void run_q48_words_tests (
            VM * vm )
```

Executes all Q48.16 fixed-point word test suites.

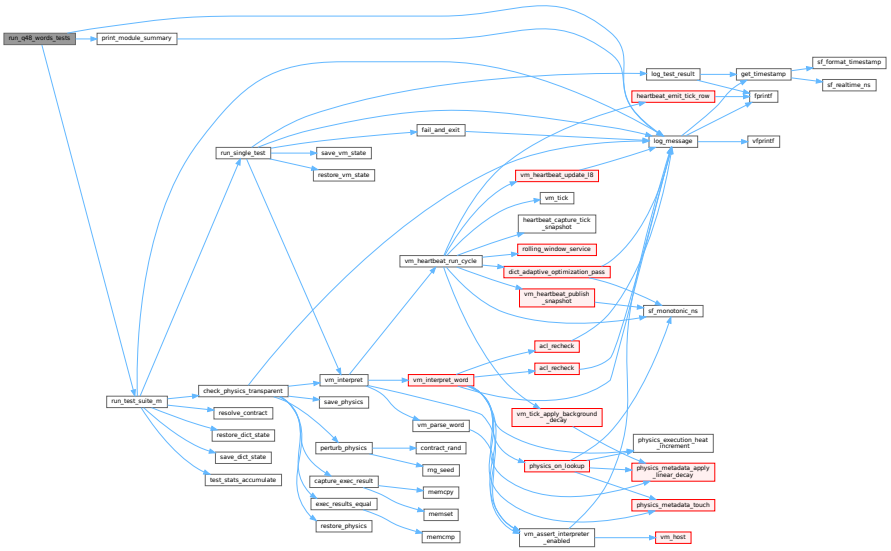
Parameters

vm	Pointer to the Forth virtual machine instance

Covers all 23 words registered by register_q48_words() (q48_words.c): arithmetic (+, -, ∗, /), sign (ABS, NEG), transcendental approximations (LOG, EXP, SQRT, SIN, COS), conversions (FROM-INT, TO-INT), constants (1, 0, SCALE), comparisons (=, <, >, 0=, MAX, MIN), and PRINT.

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), q48_word_suites, run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.23 run_return_stack_words_tests()

```
void run_return_stack_words_tests (
            VM * vm )
```

Executes all test suites for return stack manipulation words.

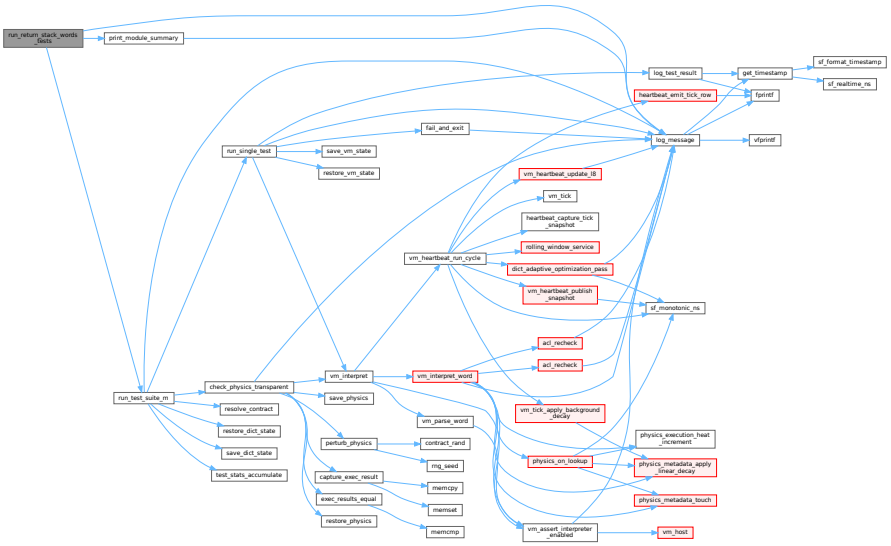
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all defined test cases for >R, R>, and R@ words and reports results_run_01_2025_12_08 through the logging system

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), return_stack_word_suites, run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.24 run_stack_words_tests()

```
void run_stack_words_tests (
            VM * vm )
```

Executes all test suites for stack manipulation words.

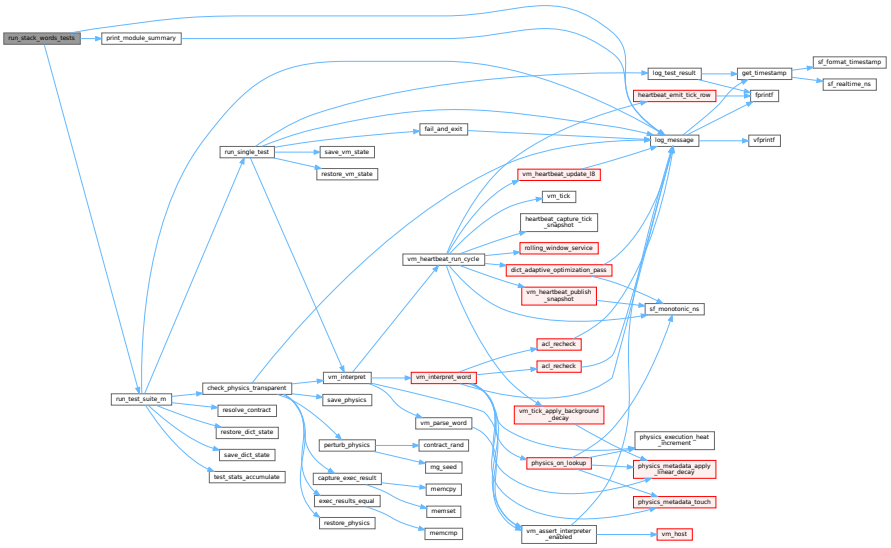
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all defined test cases for stack manipulation words and reports results_run_01_2025_12_08 through the logging system

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite_m(), stack_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.25 run_starforth_words_tests()

```
void run_starforth_words_tests (
            VM * vm )
```

Executes all StarForth words test suites.

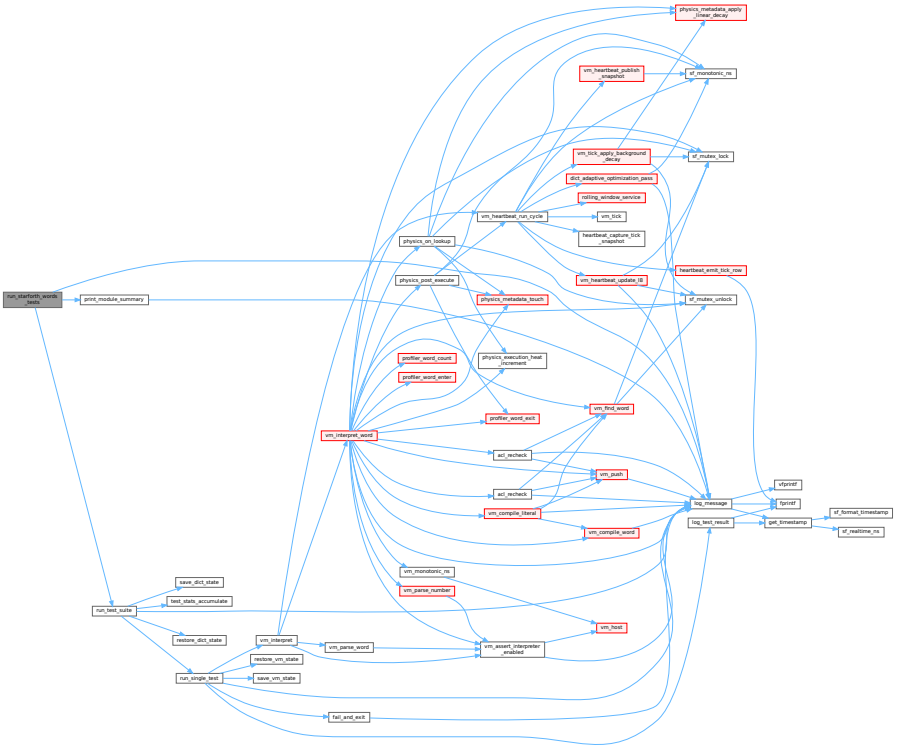
Parameters

vm	Pointer to the FORTH virtual machine instance

Runs through all test cases for StarForth-specific implementation words, including entropy tracking, comments, and initialization.

References LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), starforth_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.26 run_stress_tests()

```
void run_stress_tests (
            VM * vm )
```

Execute comprehensive stress test suites.

Runs an extensive set of stress tests to verify the VM's behavior under extreme conditions. Tests include:

- Stack operations and boundaries
- Deep nesting and control flow
- Numeric boundaries and overflow
- Dictionary pressure
- Memory allocation patterns
- Error recovery
- Mixed complexity scenarios

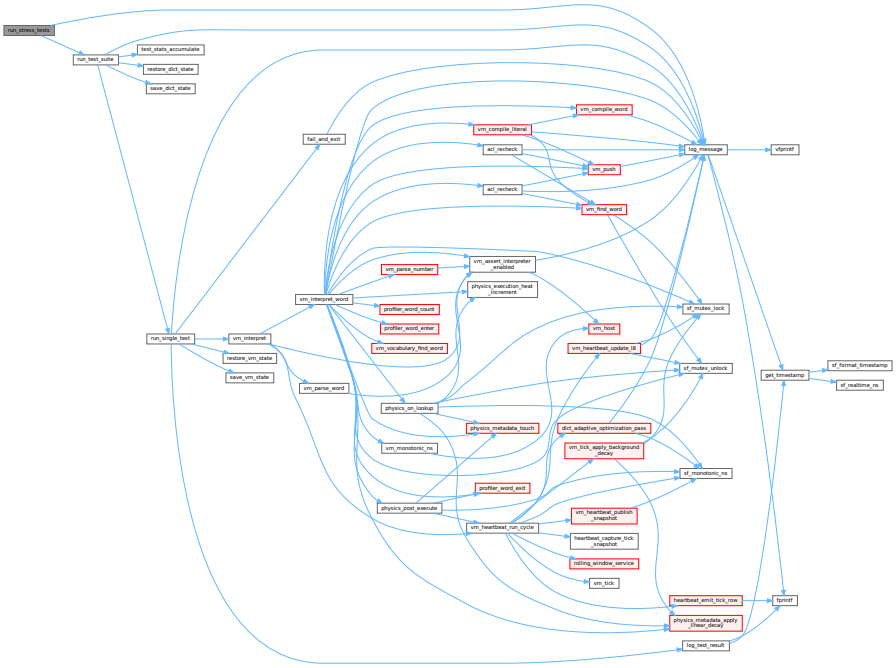
All tests are FORTH-79 compliant.

Parameters

vm	Pointer to the Forth virtual machine instance

References global_test_stats, LOG_INFO, log_message(), LOG_TEST, run_test_suite(), stress_suites, TestStats::total_error, TestStats::total_fail, TestStats::total_pass, TestStats::total_skip, and TestStats::total_tests.

Here is the call graph for this function:



7.311.1.27 run_string_words_tests()

```
void run_string_words_tests (
            VM * vm )
```

Executes all string manipulation word tests.

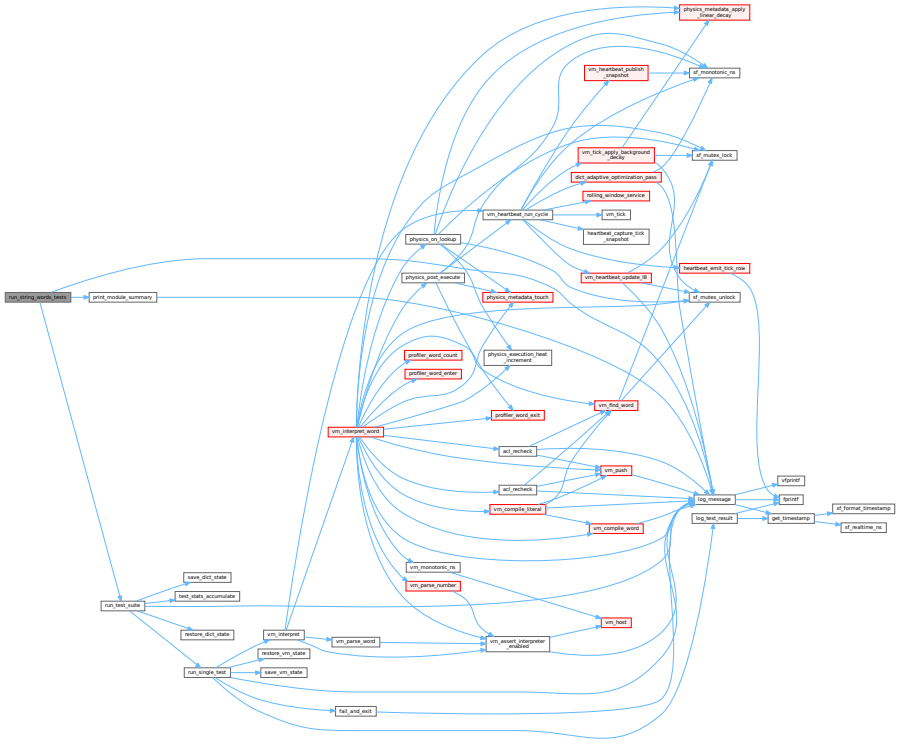
Runs test suites for FORTH string operations including COUNT, -TRAILING, CMOVE, CMOVE>, COMPARE, SEARCH, SCAN, SKIP, and BLANK

Parameters

vm	Pointer to the Forth virtual machine instance

References LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), string_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.28 run_system_words_tests()

```
void run_system_words_tests (
            VM * vm )
```

Executes all system word tests.

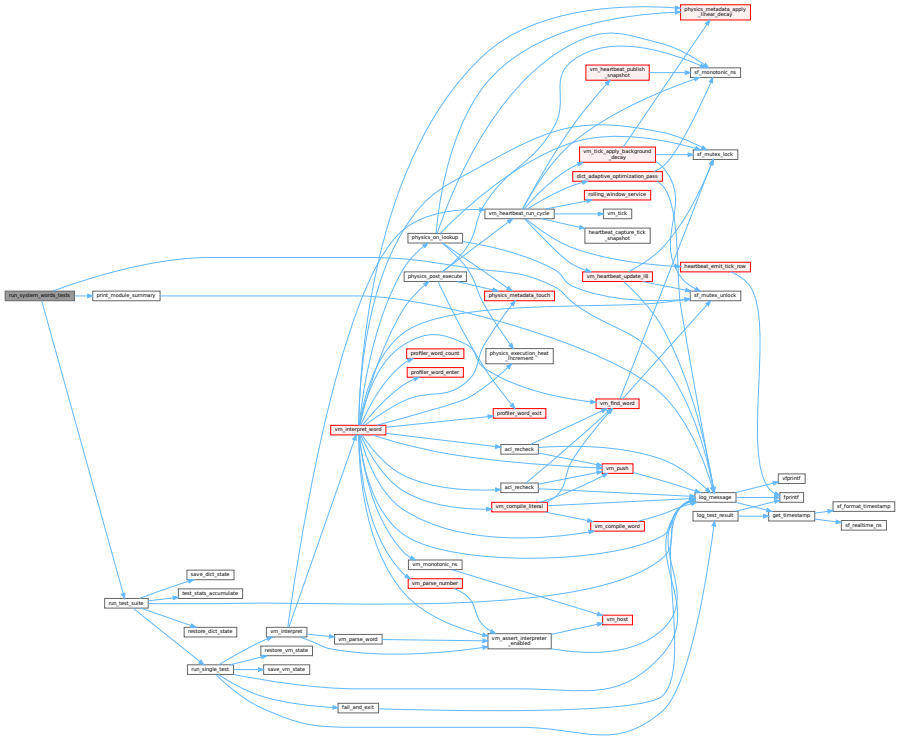
Runs test suites for FORTH system control operations including QUIT, ABORT, ABORT", BYE, COLD, and WARM. Some tests are marked as unimplemented due to their system-level effects

Parameters

vm	Pointer to the Forth virtual machine instance

References LOG_INFO, log_message(), LOG_TEST, LOG_WARN, print_module_summary(), run_test_suite(), system_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.29 run_vocabulary_words_tests()

```
void run_vocabulary_words_tests (
            VM * vm )
```

Executes all vocabulary word test suites.

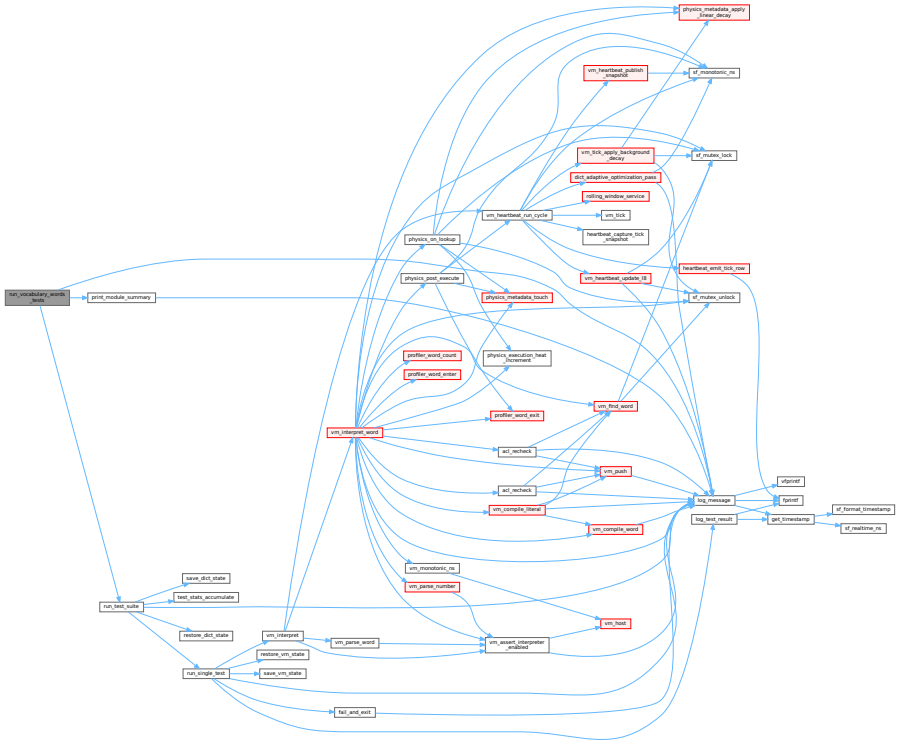
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all vocabulary-related test suites, executing each test case and logging the results_run_01_2025_↩ 12_08. Tests vocabulary creation, selection, and manipulation.

References LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), vocabulary_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.311.1.30 run_word_tests()

```
void run_word_tests (
            VM * vm,
            const char * word_name )
```

Run tests for a specific Forth word.

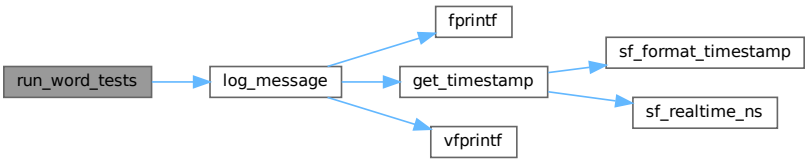
Searches all modules for tests related to the specified word and executes them.

Parameters

vm	Pointer to the Forth virtual machine instance
word_name	Name of the Forth word to test

References LOG_INFO, log_message(), LOG_WARN, TestModule::module_name, and test_modules.

Here is the call graph for this function:



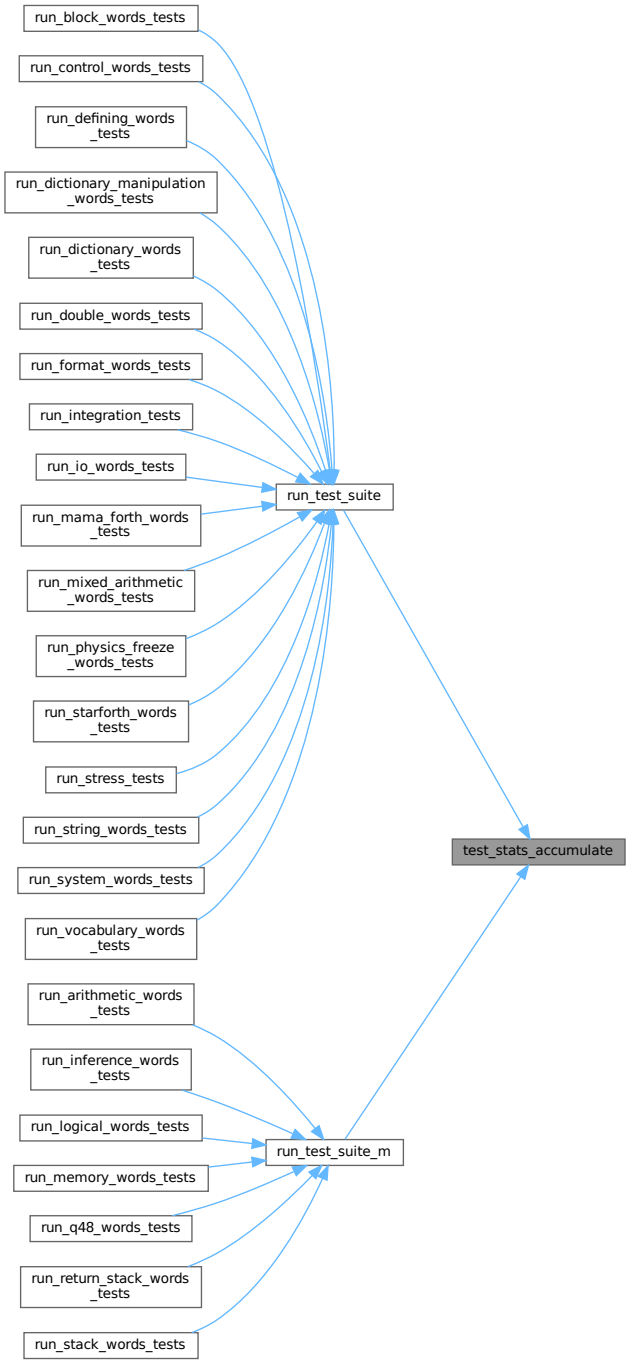
7.311.1.31 test_stats_accumulate()

```
void test_stats_accumulate (
            int tests,
            int pass,
            int fail,
            int skip,
            int error )
```

References global_test_stats, TestStats::total_error, TestStats::total_fail, TestStats::total_pass, TestStats::total_skip, and TestStats::total_tests.

Referenced by run_test_suite(), and run_test_suite_m().

Here is the caller graph for this function:



7.311.2 Variable Documentation

7.311.2.1 global_test_stats

```
TestStats global_test_stats  [extern]
```

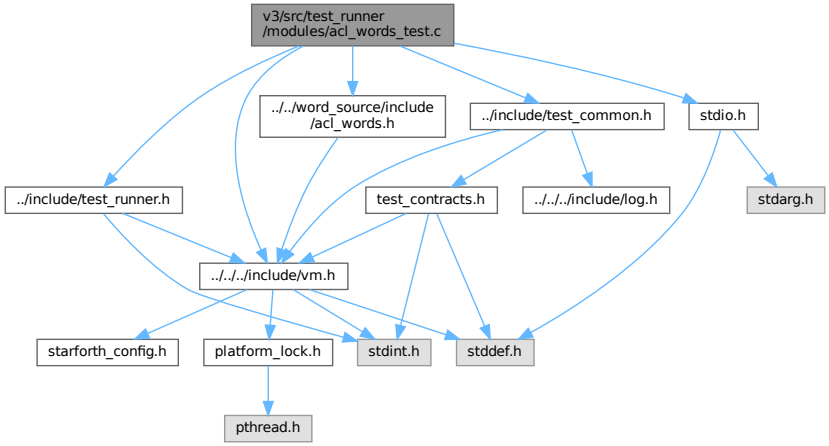
Global statistics for test execution.

Referenced by run_all_tests(), run_break_me_tests(), run_stress_tests(), sk_parity_collect(), and test_stats_accumulate().

7.312 v3/src/test_runner/modules/acl_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
#include "../../../include/vm.h"
#include "../../word_source/include/acl_words.h"
#include <stdio.h>
```

Include dependency graph for acl_words_test.c:



Macros

- #define ACL_ASSERT(cond, msg)

Functions

- static void test_acl_pin_immutable (VM *vm)

  Test 1 — ACL-PIN is a one-way ratchet.
- static void test_acl_inherit (VM *vm)

  Test 2 — ACL-INHERIT copies mode, clears pin, and resets TTL/allow.
- static void test_emergency_console_bypass (VM *vm)

  Test 3 — emergency_console flag bypasses a denied word.
- static void test_acl_deny_aborts (VM *vm)

  Test 4 — ACL denial aborts execution without running the word body.
- static void test_acl_ttl_hot_path (VM *vm)

  Test 5 — ACL TTL hot-path decrements without invoking recheck.
- static void test_acl_strict_mode (VM *vm)

  Test 6 — STRICT mode keeps TTL at 0 after every recheck.
- static void test_acl_adaptive_ttl (VM *vm)

  Test 7 — Adaptive TTL scales with execution heat via ACL-TTL-COMPUTE.
- static void test_acl_pin_blocks_shadow (VM *vm)

  Test 8 — A pinned word cannot be shadowed by redefinition.
- static void test_acl_read_accessors (VM *vm)

Test 9 — ACL-MODE@/ACL-PINNED?/ACL-TTL@/ACL-ALLOW@/ACL-HEAT@/ ACL-WORD-ID read a word's ACL fields via the interpreter.

- static void test_acl_inherit_word_dispatch (VM *vm)

  Test 10 — ACL-INHERIT, as an interpreted FORTH word (src dst –).

- static void test_acl_init_primitives (VM *vm)

  Test 11 — ACL-INIT-PRIMITIVES resets unpinned words, skips pinned ones.

- void run_acl_words_tests (VM *vm)

  Module 24 entry point — run all word-level ACL POST tests.

Variables

- static int tests_passed = 0
- static int tests_failed = 0

7.312.1 Macro Definition Documentation

7.312.1.1 ACL_ASSERT

```
#define ACL_ASSERT(
                cond,
                msg )
```

Value:

```
    do { \
        if (cond) { \
            tests_passed++; \
            log_message(LOG_DEBUG, "  PASS: %s", msg); \
        } else { \
            tests_failed++; \
            log_message(LOG_ERROR, "  FAIL: %s", msg); \
        } \
    } while (0)
```

7.312.2 Function Documentation

7.312.2.1 run_acl_words_tests()

```
void run_acl_words_tests (
              VM * vm )
```

Module 24 entry point — run all word-level ACL POST tests.

Saves the current VM state (dsp, rsp, error, mode, emergency_console) before each sub-test and restores it between tests so failures do not cascade. Runs eleven tests covering:

1. ACL-PIN one-way ratchet (4 assertions)
2. ACL-INHERIT semantics (4 assertions)
3. emergency_console bypass (1 assertion)
4. ACL denial aborts word execution (2 assertions)
5. TTL hot-path decrement (1 assertion)

6. STRICT mode — TTL stays 0 (1 assertion or conditional skip)
7. Adaptive TTL via ACL-TTL-COMPUTE (1 assertion or conditional skip)
8. Pin blocks shadowing (3 assertions)
9. Read accessors — ACL-MODE@/PINNED?/TTL@/ALLOW@/HEAT@/WORD-ID (6 assertions)
10. ACL-INHERIT as an interpreted word, not just its C twin (2 assertions)
11. ACL-INIT-PRIMITIVES resets unpinned, skips pinned (4 assertions)

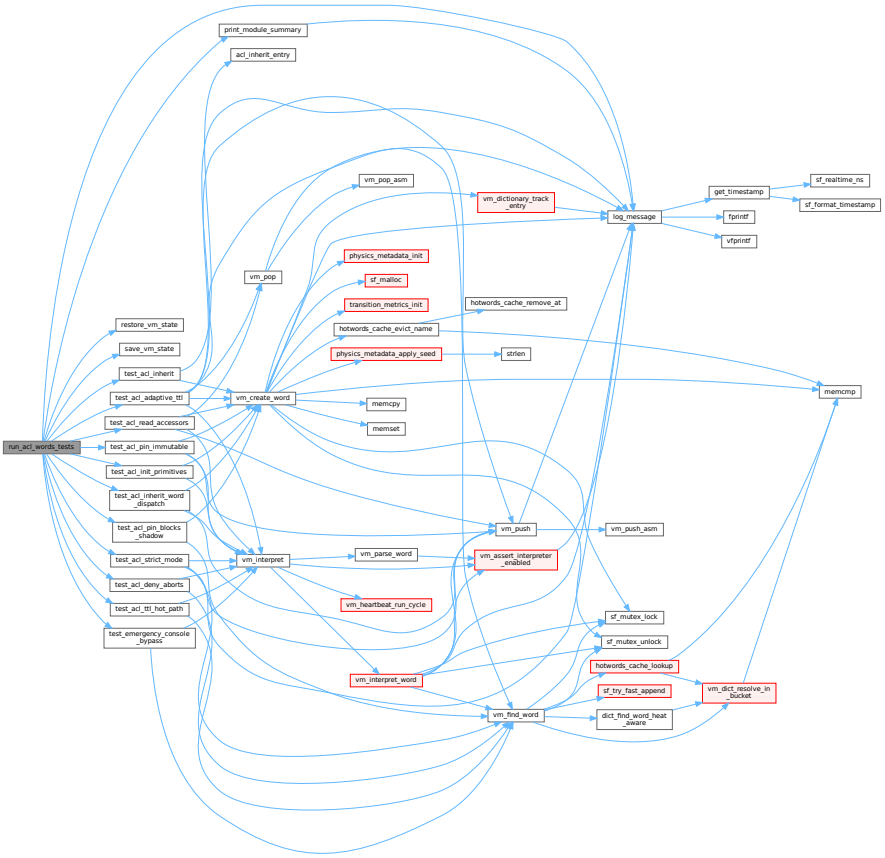
Tests that depend on `ACL.4th` being loaded are conditionally skipped during bare POST (before `ACL.4th` runs) and counted as passes so the POST score is not penalised by load-order.

Parameters

vm	VM instance; must be initialised and have the standard word vocabulary available.

References VM::emergency_console, LOG_INFO, log_message(), print_module_summary(), restore_vm_state(), save_vm_state(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_inherit(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_blocks_shadow(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), test_emergency_console_bypass(), tests_failed, and tests_passed.

Here is the call graph for this function:



7.312.2.2 test_acl_adaptive_ttl()

```
static void test_acl_adaptive_ttl (
            VM * vm )  [static]
```

Test 7 — Adaptive TTL scales with execution heat via ACL-TTL-COMPUTE.

Sets `execution_heat=2560` on a temporary entry and invokes `ACL-TTL-COMPUTE` if the word is present (i.e., `ACL.4th` is loaded). The expected formula is `ttl` = heat/4 + 256 = 640 + 256 = 896.

If `ACL-TTL-COMPUTE` is not present (ACL.4th not yet loaded), the test is conditionally skipped and counted as a pass.

Expected assertions (1, or skip):

- `ACL-TTL-COMPUTE` returns 896 for heat=2560.

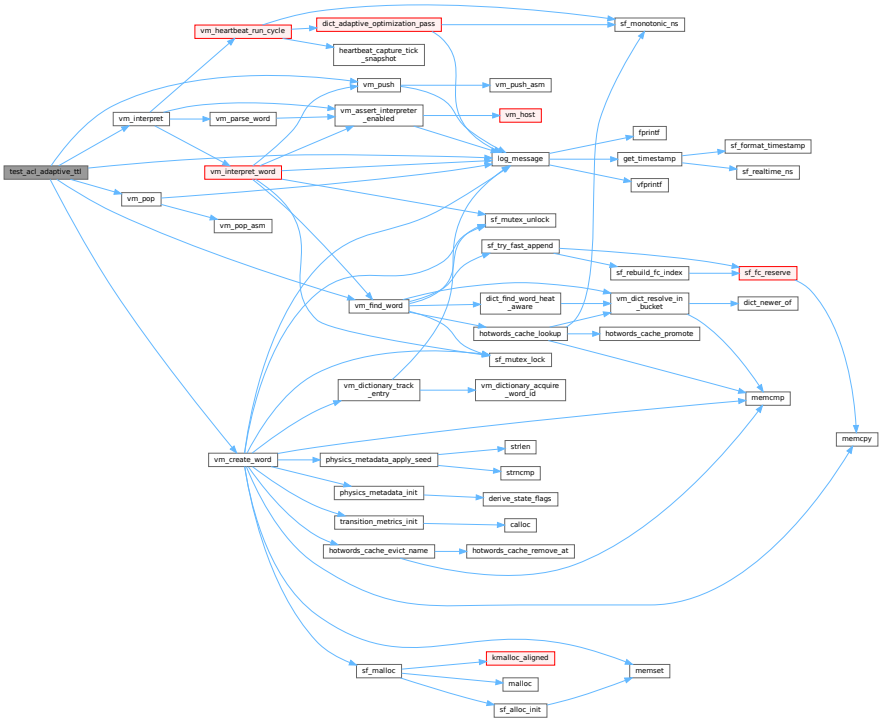
Parameters

vm	VM instance.

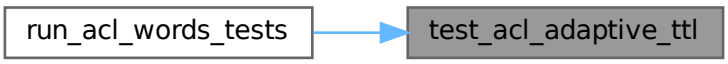
References DictEntry::acl_allow, ACL_ASSERT, DictEntry::acl_pinned, VM::dsp, VM::error, DictEntry::execution_heat, LOG_ERROR, LOG_INFO, log_message(), tests_failed, tests_passed, vm_create_word(), vm_find_word(), vm_interpret(), vm_pop(), and vm_push().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.3 test_acl_deny_aborts()

```
static void test_acl_deny_aborts (
            VM * vm )  [static]
```

Test 4 — ACL denial aborts execution without running the word body.

Defines a word that pushes a sentinel (99), then denies it with `acl_allow=0` and `acl_ttl=1` (hot-path decrement triggers the deny check without invoking `acl_recheck()`). Verifies that executing the word sets either `vm->abort_requested`, `vm->error`, or leaves the stack depth unchanged — and that the sentinel was never pushed.

`acl_ttl=1` is used rather than 0 to stay on the hot path (TTL decrements to 0 → check; avoids the fail-open cold-path recheck).

Expected assertions (2):

- Execution was aborted (abort_requested || error || stack unchanged)
- Stack depth is unchanged (sentinel was not pushed)

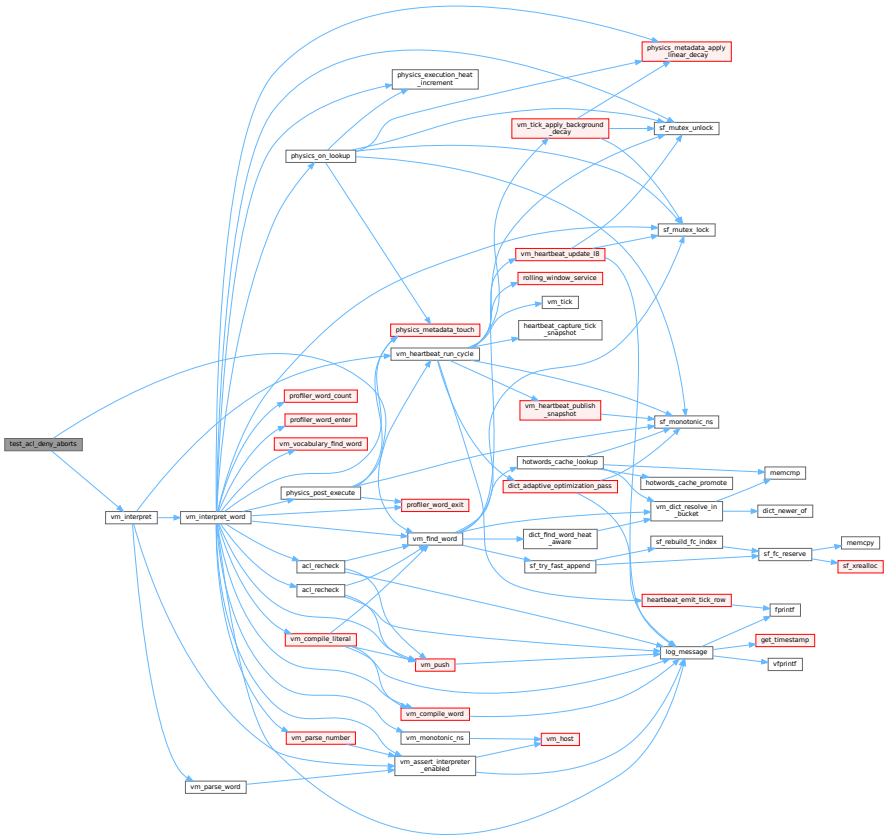
Parameters

vm	VM instance.

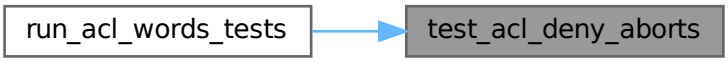
References VM::abort_requested, DictEntry::acl_allow, ACL_ASSERT, DictEntry::acl_pinned, DictEntry::acl_ttl, VM::dsp, VM::emergency_console, VM::error, tests_failed, vm_find_word(), and vm_interpret().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.4 test_acl_inherit()

```
static void test_acl_inherit (
            VM * vm )  [static]
```

Test 2 — ACL-INHERIT copies mode, clears pin, and resets TTL/allow.

Constructs a source entry with STRICT mode, pinned, TTL=5000, allow=0, and a destination entry with a different mode and also pinned. Calls `acl_inherit_entry()` directly and checks the resulting destination state. Verifies the Isabelle/HOL lemma `ACL_Inherit_Clears_Pin`.

Expected assertions (4):

- `dst->acl_mode` == ACL_MODE_STRICT (mode copied from src)
- `dst->acl_pinned` == 0 (pin cleared regardless of dst's original pin)
- `dst->acl_ttl` == 0 (TTL reset to 0)
- `dst->acl_allow` == 1 (allow reset to 1)

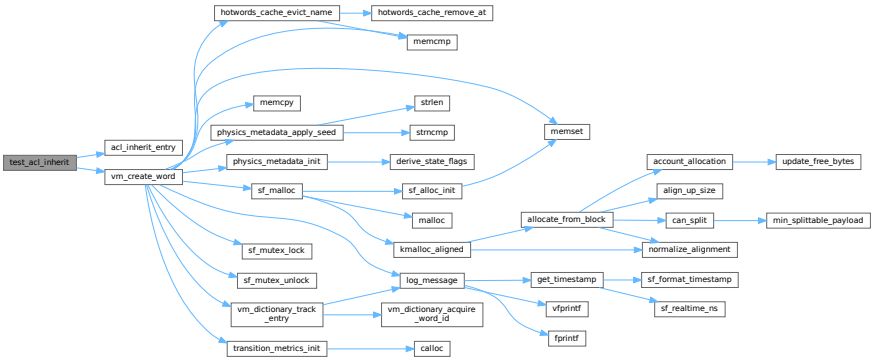
Parameters

vm	VM instance (used for word creation; not modified beyond that).

References DictEntry::acl_allow, ACL_ASSERT, acl_inherit_entry(), DictEntry::acl_mode, ACL_MODE_STRICT, ACL_MODE_TTL, DictEntry::acl_pinned, DictEntry::acl_ttl, tests_failed, and vm_create_word().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:

7.312.2.5 test_acl_inherit_word_dispatch()

```
static void test_acl_inherit_word_dispatch (
            VM * vm )  [static]
```

Test 10 — ACL-INHERIT, as an interpreted FORTH word (src dst –).

`test_acl_inherit` above already proves the underlying `acl_inherit_entry()` C function is correct (Isabelle lemma `ACL_Inherit_Clears_Pin`) by calling it directly. This test instead exercises the FORTH-level dispatch path itself — pushing two xts and interpreting "ACL-INHERIT" — which nothing in this file previously did, so the word's own stack-popping/argument-order code was untested.

Expected assertions (2):

- `dst->acl_mode` == ACL_MODE_STRICT after interpreting ACL-INHERIT
- `dst->acl_pinned` == 0 after interpreting ACL-INHERIT

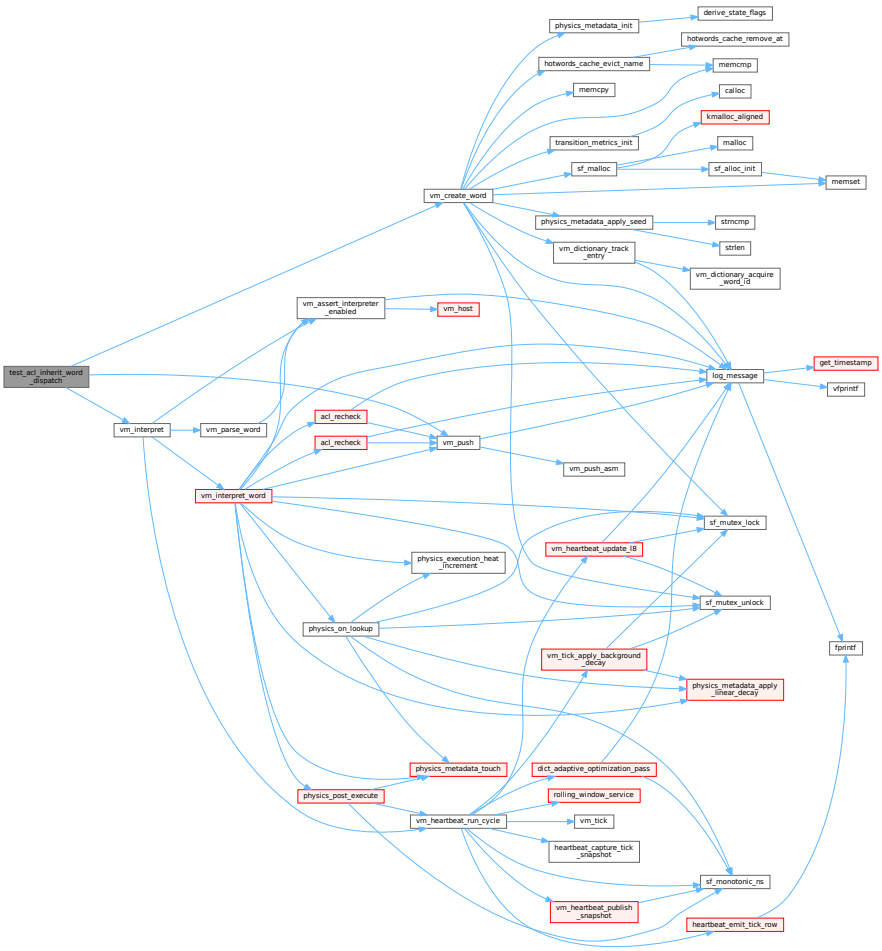
Parameters

vm	VM instance.

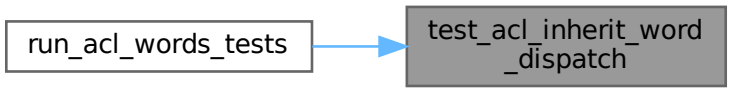
References ACL_ASSERT, DictEntry::acl_mode, ACL_MODE_STRICT, ACL_MODE_TTL, DictEntry::acl_pinned, VM::error, tests_failed, vm_create_word(), vm_interpret(), and vm_push().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.6 test_acl_init_primitives()

```
static void test_acl_init_primitives (
            VM * vm )  [static]
```

Test 11 — ACL-INIT-PRIMITIVES resets unpinned words, skips pinned ones.

Creates two fresh words with non-default ACL state: one left unpinned, one pinned. Interprets "ACL-INIT-↩ PRIMITIVES" (which walks the entire dictionary) and verifies the unpinned word was reset to the permissive defaults (`acl_ttl=0`, `acl_allow=1`, `acl_mode=ACL_MODE_TTL`) while the pinned word's deliberately-different state was left untouched.

Expected assertions (4):

- unpinned word's `acl_ttl` reset to 0
- unpinned word's `acl_allow` reset to 1
- unpinned word's `acl_mode` reset to ACL_MODE_TTL
- pinned word's `acl_ttl` is NOT reset (still its original value)

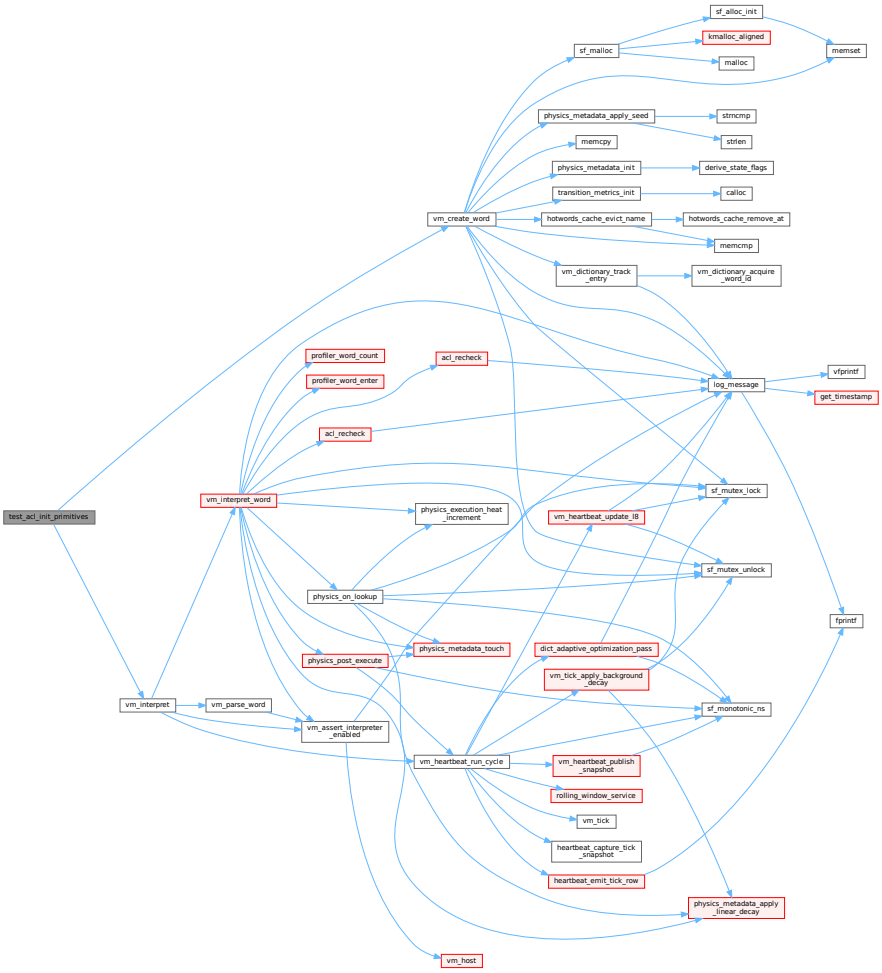
Parameters

vm	VM instance.

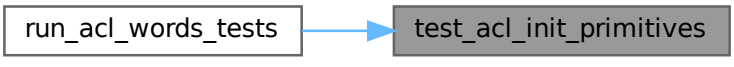
References DictEntry::acl_allow, ACL_ASSERT, DictEntry::acl_mode, ACL_MODE_STRICT, ACL_MODE_TTL, DictEntry::acl_pinned, DictEntry::acl_ttl, VM::error, tests_failed, vm_create_word(), and vm_interpret().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.7 test_acl_pin_blocks_shadow()

```
static void test_acl_pin_blocks_shadow (
            VM * vm )  [static]
```

Test 8 — A pinned word cannot be shadowed by redefinition.

Creates a word, pins it, then attempts to create another word with the same name via `vm_create_word()`. Verifies that the second create returns NULL and sets `vm->error`, and that the original pinned entry is still the one returned by `vm_find_word()`.

This enforces the Isabelle/HOL lemma `ACL_Pin_Monotone:` pin is permanent and cannot be overridden even by a new definition.

Expected assertions (3):

- `vm_create_word()` returns NULL for the shadowed name
- `vm->error` is non-zero after the blocked create
- `vm_find_word()` still returns the original pinned entry

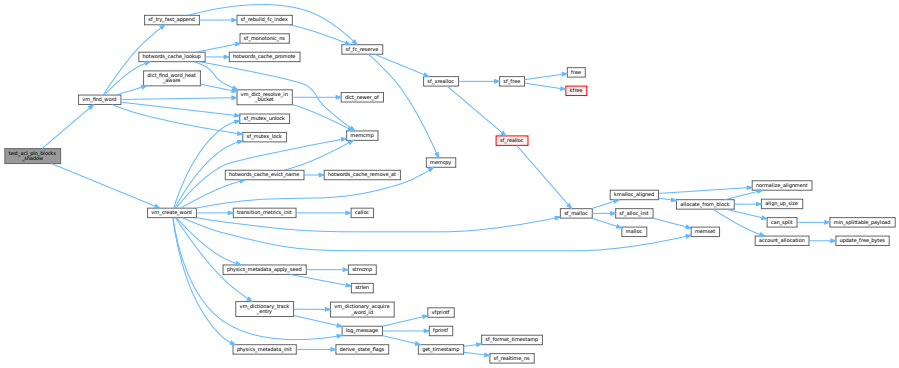
Parameters

vm	VM instance.

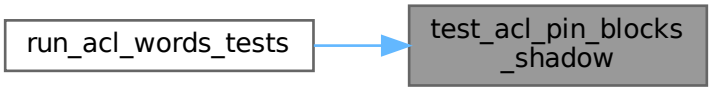
References ACL_ASSERT, DictEntry::acl_pinned, VM::error, tests_failed, vm_create_word(), and vm_find_word().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.8 test_acl_pin_immutable()

```
static void test_acl_pin_immutable (
            VM * vm )  [static]
```

Test 1 — ACL-PIN is a one-way ratchet.

Creates a temporary word and pins it via `ACL-PIN`. Verifies that subsequent calls to `ACL-MODE!`, `ACL-TTL!`, and `ACL-ALLOW!` are all no-ops while the word is pinned. The pin flag itself must remain 1.

Expected assertions (4):

- `acl_pinned` == 1 after ACL-PIN
- `acl_mode` unchanged after ACL-MODE! on pinned entry
- `acl_ttl` unchanged after ACL-TTL! on pinned entry
- `acl_allow` unchanged after ACL-ALLOW! on pinned entry

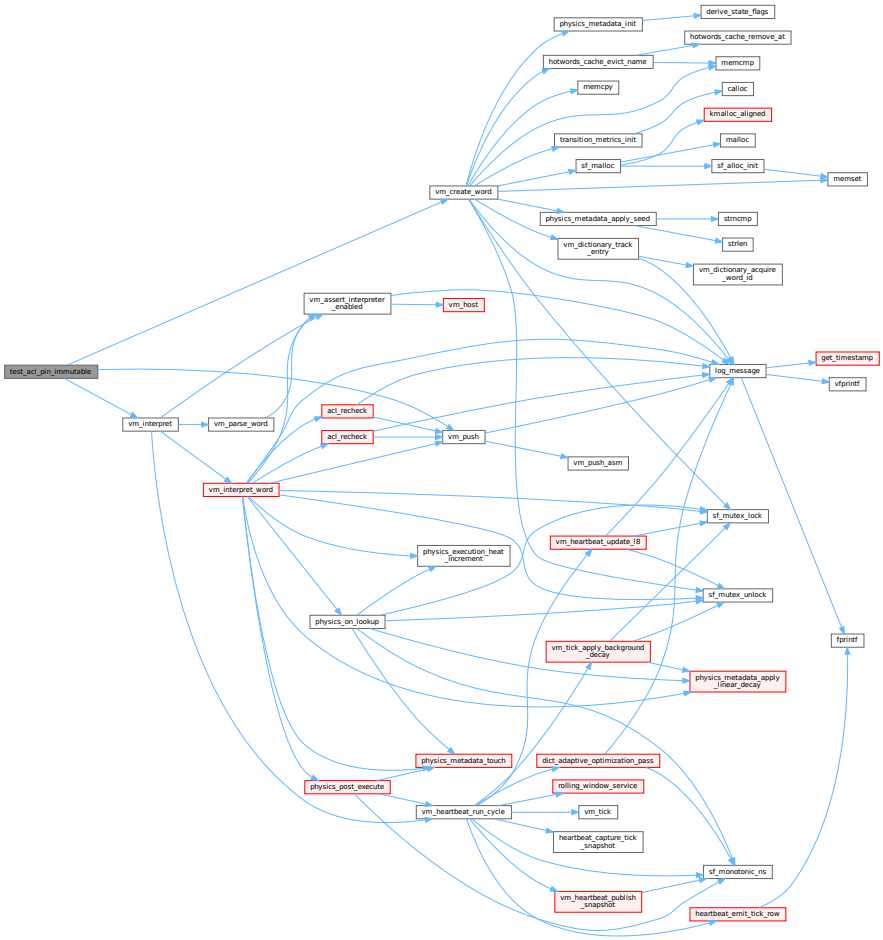
Parameters

vm	VM instance (shared state; caller restores after this function).

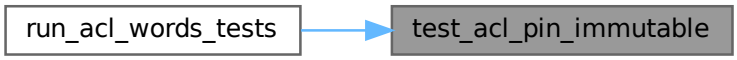
References DictEntry::acl_allow, ACL_ASSERT, DictEntry::acl_mode, ACL_MODE_STRICT, ACL_MODE_TTL, DictEntry::acl_pinned, DictEntry::acl_ttl, VM::error, tests_failed, vm_create_word(), vm_interpret(), and vm_push().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.9 test_acl_read_accessors()

```
static void test_acl_read_accessors (
            VM * vm )  [static]
```

Test 9 — ACL-MODE@/ACL-PINNED?/ACL-TTL@/ACL-ALLOW@/ACL-HEAT@/ ACL-WORD-ID read a word's ACL fields via the interpreter.

Proof-covered field accessors (`proof/StarForth_ACL_*.thy`) that had no interpreter-level POST coverage before this test — every other ACL test in this file exercises the write accessors (`ACL-MODE!`/`ACL-TTL!`/`ACL-ALLOW!`) or calls the underlying C functions directly, but never pushed an xt and interpreted these six read words.

Sets each field to a distinctive non-default value directly on a fresh test word, then pushes its xt and interprets each accessor in turn, checking the value returned on the stack.

Expected assertions (6):

- ACL-MODE@ returns `ACL_MODE_STRICT`
- ACL-PINNED? returns -1 (true) for a pinned entry
- ACL-TTL@ returns 4242
- ACL-ALLOW@ returns 0 (false)
- ACL-HEAT@ returns the entry's `execution_heat`
- ACL-WORD-ID returns the entry's `word_id`

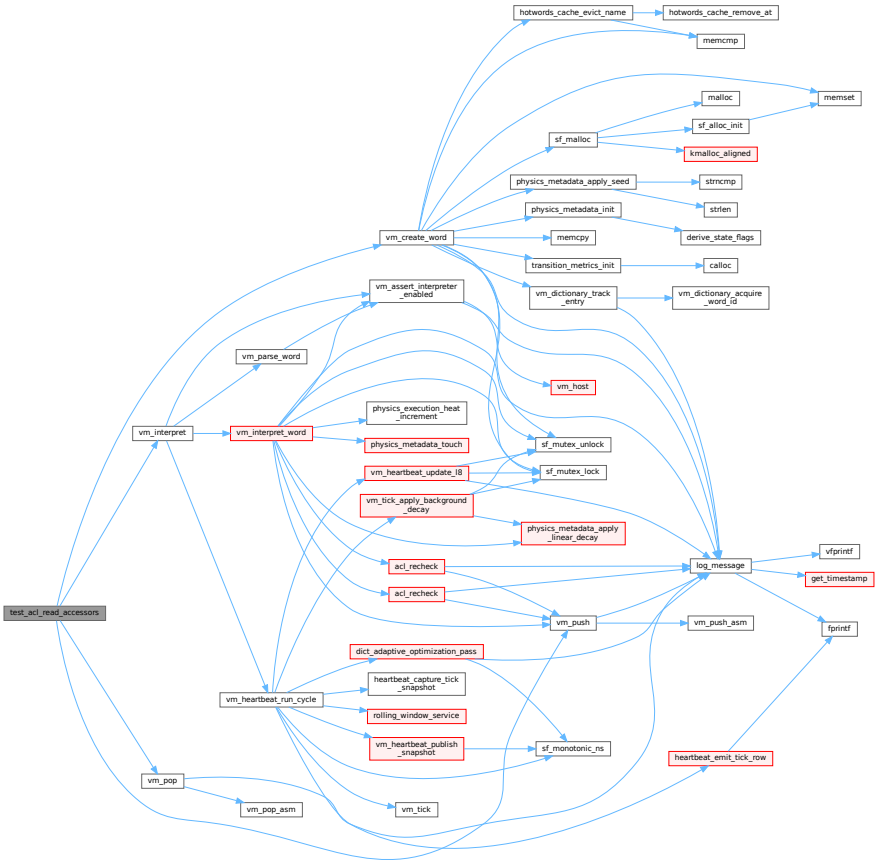
Parameters

vm	VM instance.

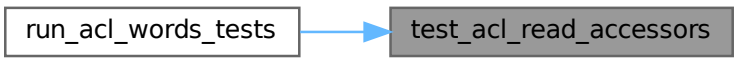
References DictEntry::acl_allow, ACL_ASSERT, DictEntry::acl_mode, ACL_MODE_STRICT, DictEntry::acl_pinned, DictEntry::acl_ttl, VM::error, DictEntry::execution_heat, tests_failed, vm_create_word(), vm_interpret(), vm_pop(), vm_push(), and DictEntry::word_id.

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.10 test_acl_strict_mode()

```
static void test_acl_strict_mode (
            VM * vm )  [static]
```

Test 6 — STRICT mode keeps TTL at 0 after every recheck.

In `ACL_MODE_STRICT`, `ACL-RECHECK` must reset `acl_ttl` to 0 after each allow decision so the recheck fires on every subsequent execution.

If `ACL.4th` is not loaded, `ACL-RECHECK` is absent and `acl_recheck()` fails open (`acl_ttl` = `ACL_TTL_OPEN`). In that case the test is conditionally skipped (counted as a pass) since the ACL system is not yet active.

Expected assertions (1, or skip counted as 1 pass):

- `e->acl_ttl` == 0 after one execution in STRICT mode with ACL loaded.

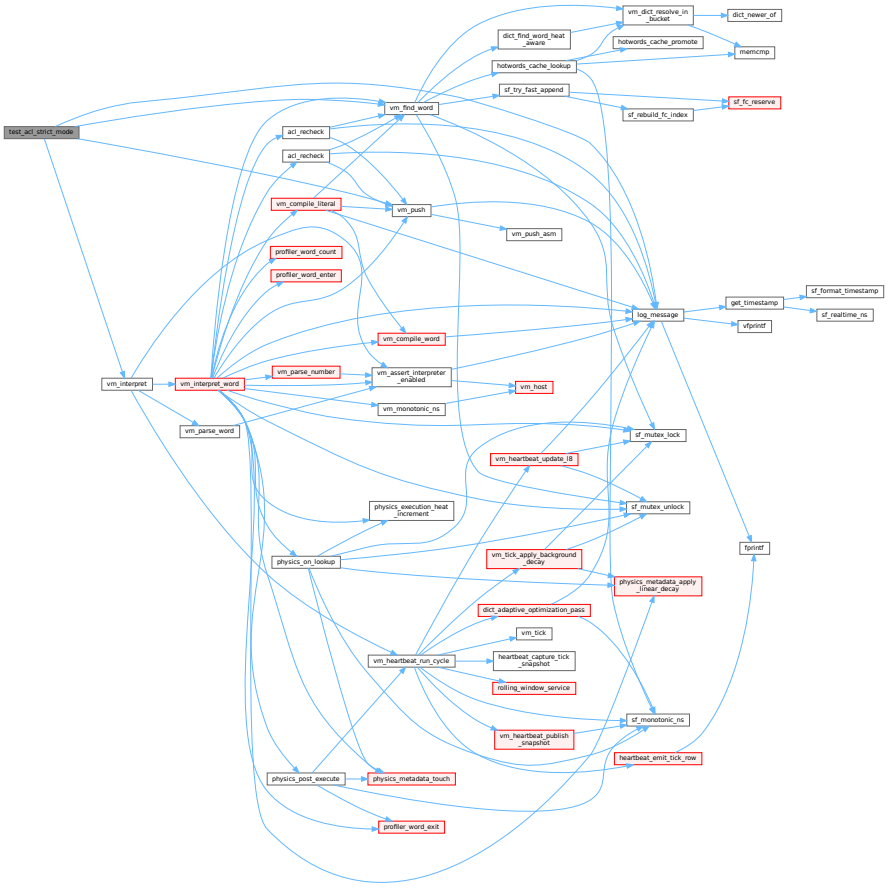
Parameters

vm	VM instance.

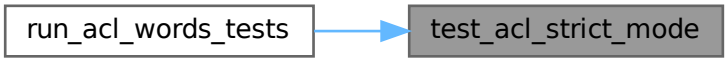
References DictEntry::acl_allow, ACL_ASSERT, DictEntry::acl_mode, ACL_MODE_STRICT, DictEntry::acl_pinned, DictEntry::acl_ttl, VM::dsp, VM::error, LOG_INFO, log_message(), tests_failed, tests_passed, vm_find_word(), vm_interpret(), and vm_push().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.11 test_acl_ttl_hot_path()

```
static void test_acl_ttl_hot_path (
            VM * vm )  [static]
```

Test 5 — ACL TTL hot-path decrements without invoking recheck.

Defines a word with `acl_ttl=10` and `acl_allow=1`, then executes it three times via the outer interpreter. Each outer-interpreter execution decrements `acl_ttl` by 1, so the expected final value is 7.

This confirms the hot-path optimisation: the interpreter only calls `acl_recheck()` when `acl_ttl` reaches 0, not on every invocation.

Expected assertions (1):

- `e->acl_ttl` == 7 after three executions (10 → 9 → 8 → 7)

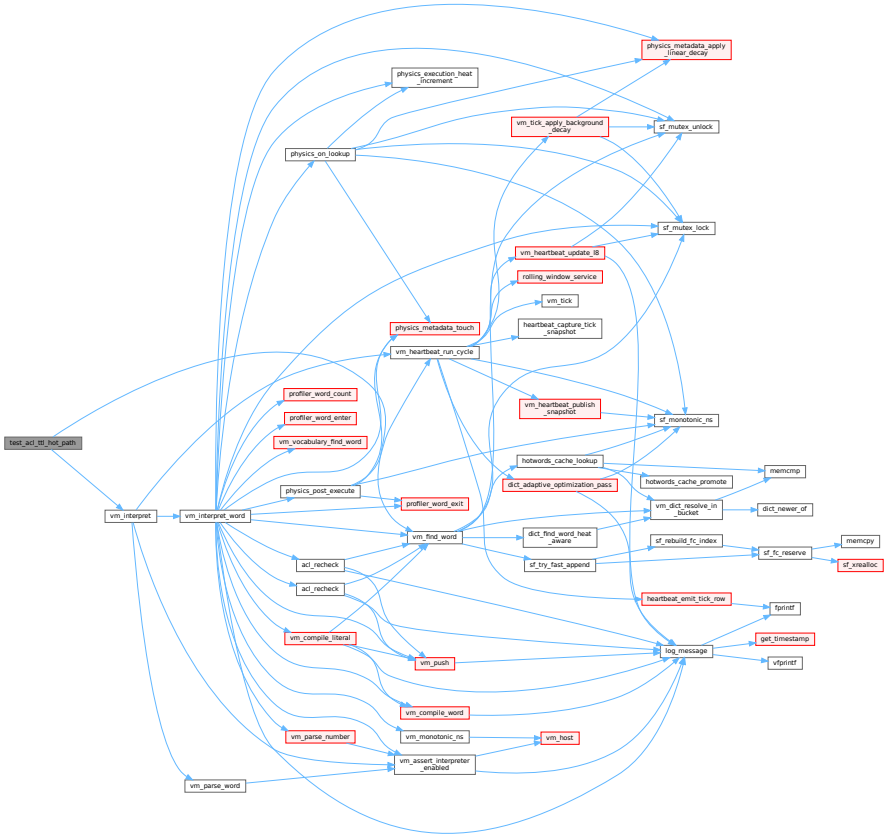
Parameters

vm	VM instance.

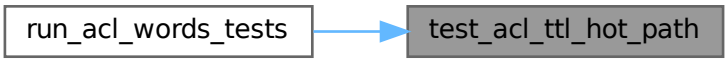
References DictEntry::acl_allow, ACL_ASSERT, DictEntry::acl_mode, ACL_MODE_TTL, DictEntry::acl_pinned, DictEntry::acl_ttl, VM::emergency_console, VM::error, tests_failed, vm_find_word(), and vm_interpret().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.2.12 test_emergency_console_bypass()

```
static void test_emergency_console_bypass (
            VM * vm )  [static]
```

Test 3 — emergency_console flag bypasses a denied word.

Defines a FORTH word that pushes 42, then sets its `acl_allow` to 0 to simulate a policy denial. Executes the word with `emergency_console=1` and verifies that the word body ran (stack depth increased by 1).

The `emergency_console` bypass is required by the bare-metal fault handler so that critical recovery words can always execute.

Expected assertions (1):

- `vm->dsp` == saved_dsp + 1 (word ran despite deny)

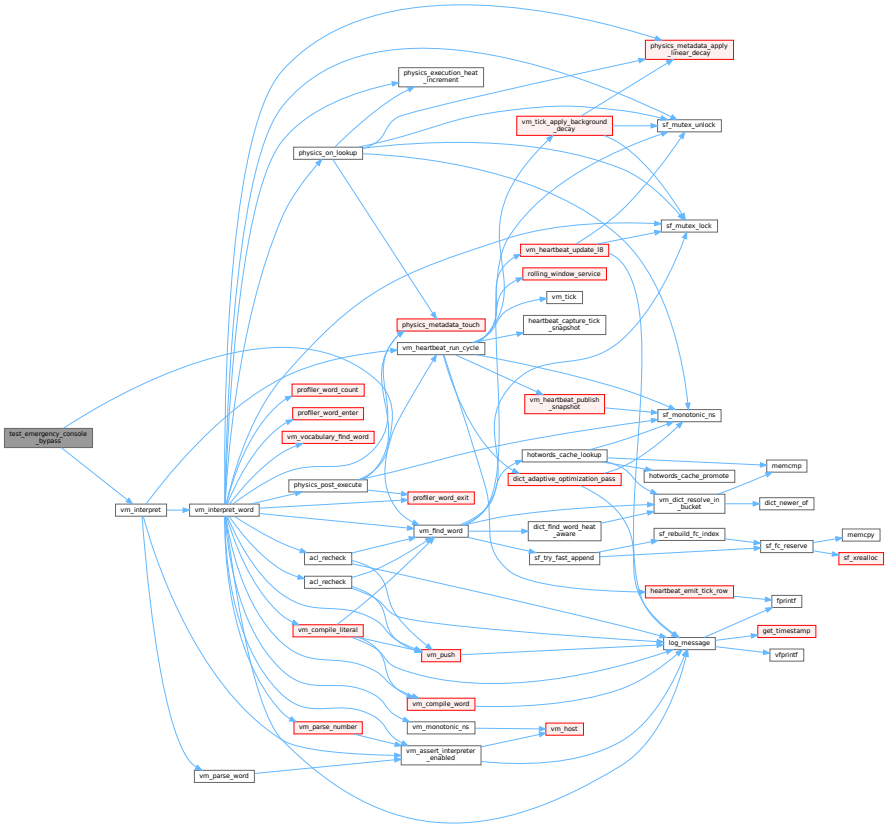
Parameters

vm	VM instance.

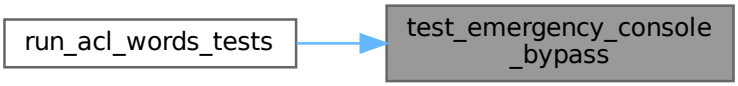
References DictEntry::acl_allow, ACL_ASSERT, DictEntry::acl_pinned, DictEntry::acl_ttl, VM::dsp, VM::emergency_console, VM::error, tests_failed, vm_find_word(), and vm_interpret().

Referenced by run_acl_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.312.3 Variable Documentation

7.312.3.1 tests_failed

```
int tests_failed = 0  [static]
```

Referenced by run_acl_words_tests(), test_acl_adaptive_ttl(), test_acl_deny_aborts(), test_acl_inherit(), test_acl_inherit_word_dispatch(), test_acl_init_primitives(), test_acl_pin_blocks_shadow(), test_acl_pin_immutable(), test_acl_read_accessors(), test_acl_strict_mode(), test_acl_ttl_hot_path(), and test_emergency_console_bypass().

7.312.3.2 tests_passed

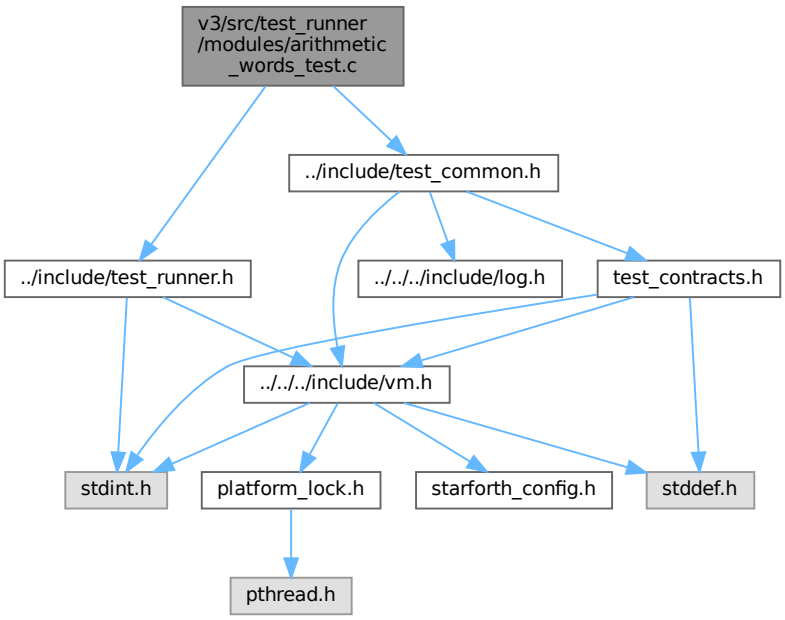
```
int tests_passed = 0  [static]
```

Referenced by run_acl_words_tests(), test_acl_adaptive_ttl(), and test_acl_strict_mode().

7.313 v3/src/test_runner/modules/arithmetic_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for arithmetic_words_test.c:



Functions

- void run_arithmetic_words_tests (VM *vm)

  Executes all arithmetic word test suites.

Variables

- static WordTestSuite arithmetic_word_suites [ ]

7.313.1 Function Documentation

7.313.1.1 run_arithmetic_words_tests()

```
void run_arithmetic_words_tests (
            VM * vm )
```

Executes all arithmetic word test suites.

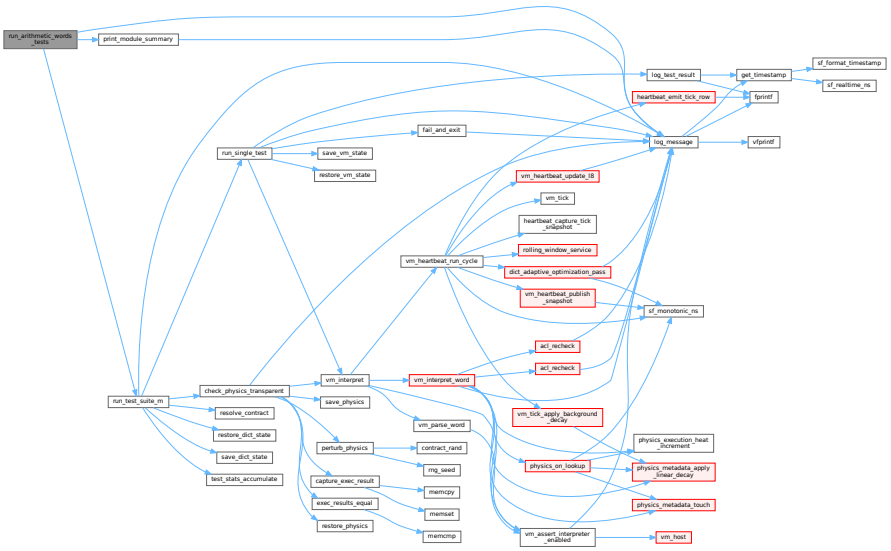
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all test cases for arithmetic operations including basic operations (+, -, ∗, /), modulo operations (MOD, /MOD), and numeric functions (ABS, NEGATE, MIN, MAX)

References arithmetic_word_suites, CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.313.2 Variable Documentation

7.313.2.1 arithmetic_word_suites

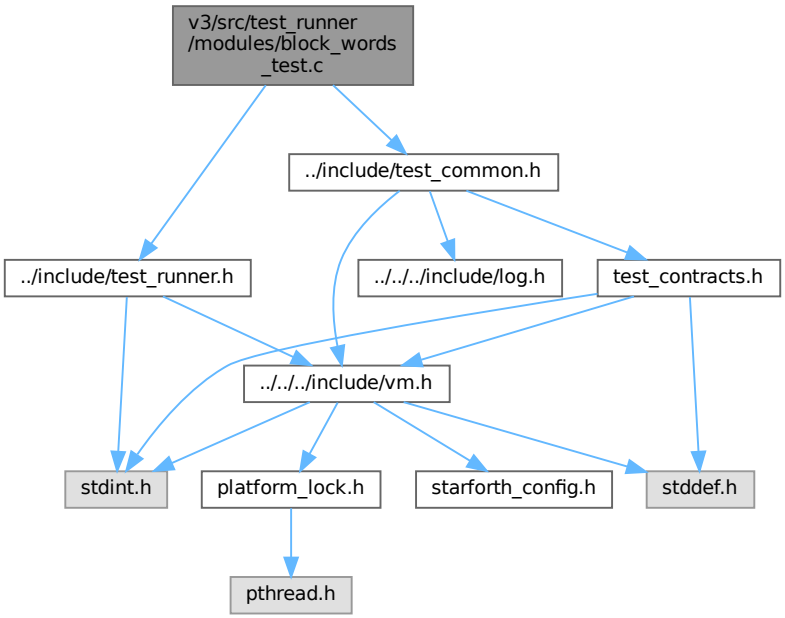
```
WordTestSuite arithmetic_word_suites[ ]  [static]
```

Referenced by run_arithmetic_words_tests().

7.314 v3/src/test_runner/modules/block_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for block_words_test.c:



Functions

- void run_block_words_tests (VM *vm)

  Executes all block words test suites.

Variables

- static WordTestSuite block_word_suites [ ]

  Test suites for FORTH block words (Module 16)

7.314.1 Function Documentation

7.314.1.1 run_block_words_tests()

```
void run_block_words_tests (
            VM * vm )
```

Executes all block words test suites.

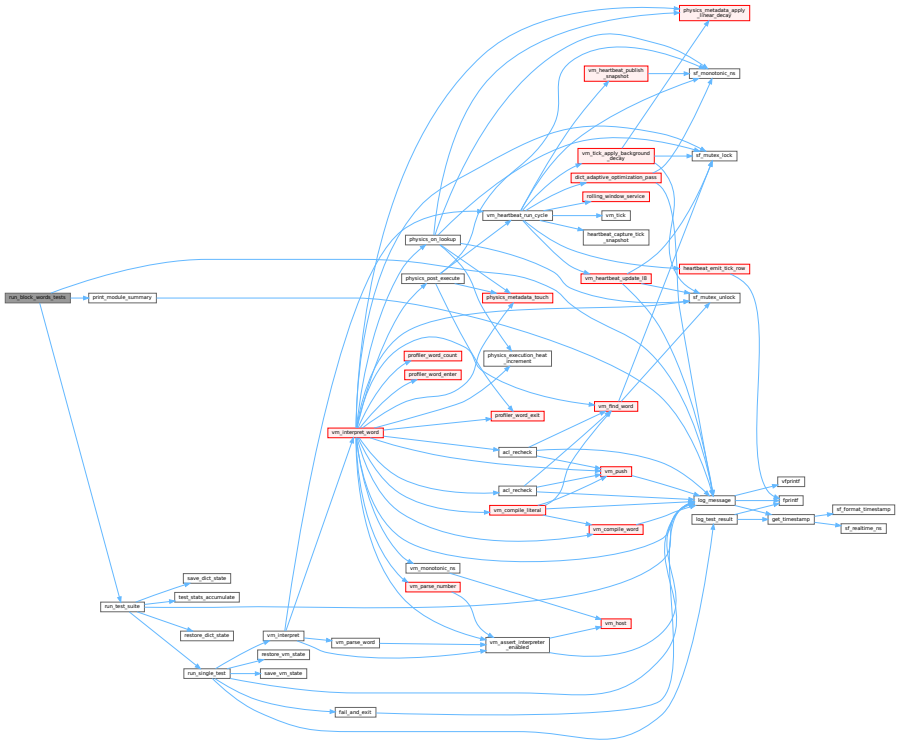
Parameters

vm	Pointer to the FORTH virtual machine instance

Runs through all test cases for block manipulation words, including block access, buffer management, and block I/O operations. Results are logged and summarized after completion.

References block_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.314.2 Variable Documentation

7.314.2.1 block_word_suites

```
WordTestSuite block_word_suites[]  [static]
```

Test suites for FORTH block words (Module 16)

Contains test cases for the following FORTH words:

- BLOCK: Block access
- BUFFER: Buffer management
- UPDATE: Block modification marking
- SAVE-BUFFERS: Buffer flushing

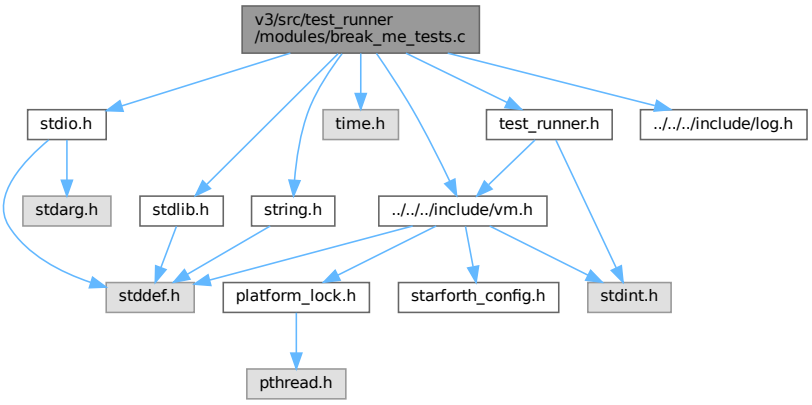
- EMPTY-BUFFERS: Buffer invalidation
- FLUSH: Buffer saving and invalidation
- LOAD: Block interpretation
- LIST: Block display
- SCR: Current block number
- THRU: Load block range
- -->: Continue to next block

Referenced by run_block_words_tests().

7.315 v3/src/test_runner/modules/break_me_tests.c File Reference

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>
#include "test_runner.h"
#include "../../../include/log.h"
#include "../../../include/vm.h"
```

Include dependency graph for break_me_tests.c:



Functions

- static int init_report (void)

  Initialize markdown report file.
- static void finalize_report (VM *vm)

  Finalize report with system info and easter egg.
- void run_break_me_tests (VM *vm)

  Main entry point for –break-me mode.

Variables

- static FILE * report_file = NULL
- static time_t test_start_time
- static time_t test_end_time
- static int total_tests_run = 0

7.315.1 Function Documentation

7.315.1.1 finalize_report()

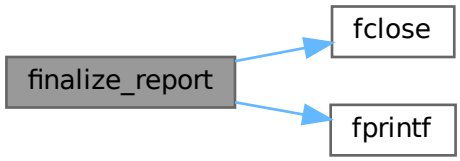
```
static void finalize_report (
            VM * vm )  [static]
```

Finalize report with system info and easter egg.

References fclose(), fprintf(), report_file, STACK_SIZE, test_end_time, test_start_time, total_tests_run, and VM_MEMORY_SIZE.

Referenced by run_break_me_tests().

Here is the call graph for this function:



Here is the caller graph for this function:

7.315.1.2 init_report()

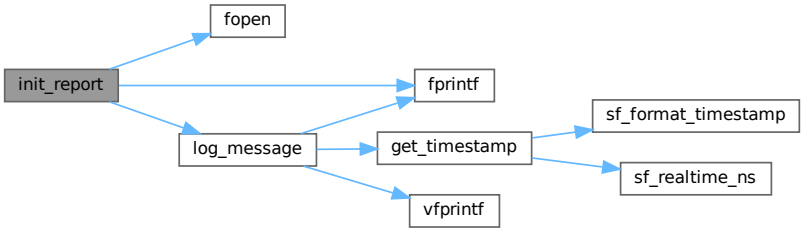
```
static int init_report (
            void  )  [static]
```

Initialize markdown report file.

References fopen(), fprintf(), LOG_ERROR, log_message(), report_file, and test_start_time.

Referenced by run_break_me_tests().

Here is the call graph for this function:



Here is the caller graph for this function:

7.315.1.3 run_break_me_tests()

```
void run_break_me_tests (
            VM * vm )
```

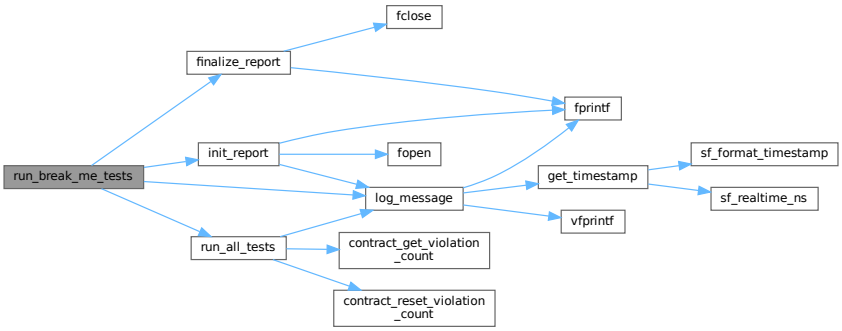
Main entry point for –break-me mode.

Run ultra-comprehensive break-me diagnostic suite.

References finalize_report(), global_test_stats, init_report(), LOG_ERROR, LOG_INFO, log_message(), run_all_tests(), TestStats::total_tests, and total_tests_run.

Referenced by run_optional_tests().

Here is the call graph for this function:



Here is the caller graph for this function:

7.315.2 Variable Documentation

7.315.2.1 report_file

```
FILE* report_file = NULL  [static]
```

Referenced by finalize_report(), and init_report().

7.315.2.2 test_end_time

```
time_t test_end_time  [static]
```

Referenced by finalize_report().

7.315.2.3 test_start_time

```
time_t test_start_time  [static]
```

Referenced by finalize_report(), and init_report().

7.315.2.4 total_tests_run

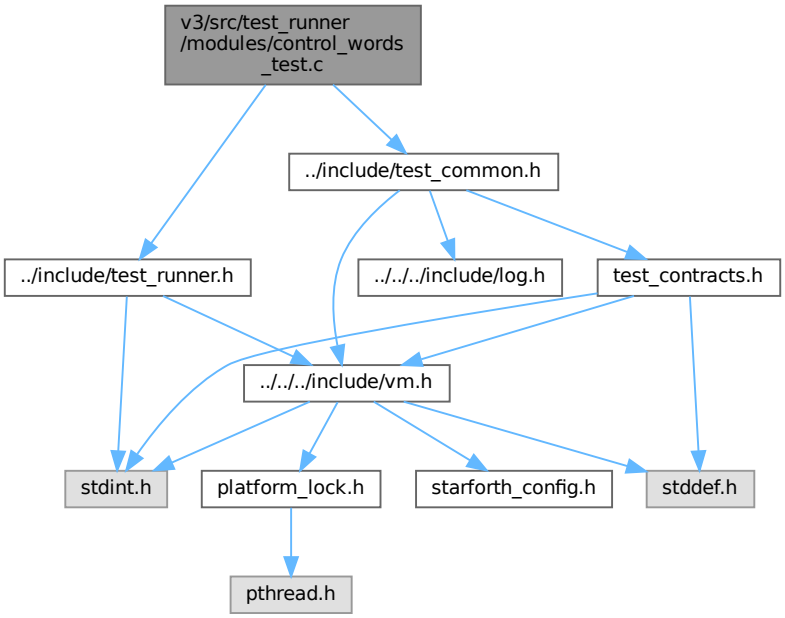
```
int total_tests_run = 0  [static]
```

Referenced by finalize_report(), and run_break_me_tests().

7.316 v3/src/test_runner/modules/control_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for control_words_test.c:



Functions

- void run_control_words_tests (VM *vm)

  Executes all control words test suites.

Variables

- static WordTestSuite control_word_suites [ ]

  Test suites for FORTH control words.

7.316.1 Function Documentation

7.316.1.1 run_control_words_tests()

```
void run_control_words_tests (
            VM * vm )
```

Executes all control words test suites.

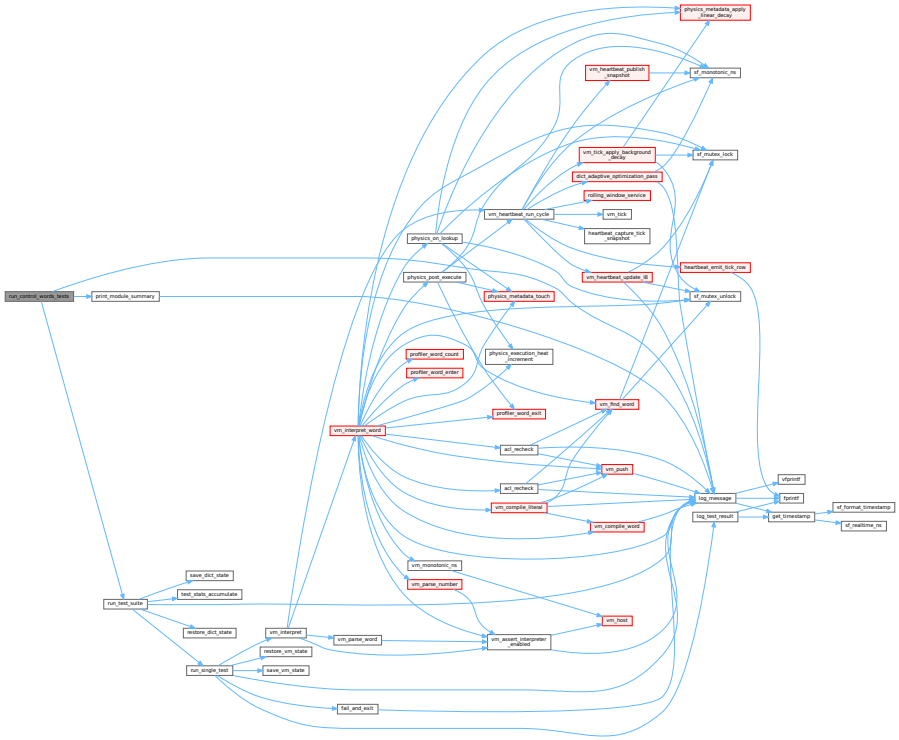
Parameters

vm	Pointer to the FORTH virtual machine instance

Runs through all defined test cases for control words, testing conditional branches and loop constructs

References control_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.316.2 Variable Documentation

7.316.2.1 control_word_suites

```
WordTestSuite control_word_suites[]  [static]
```

Test suites for FORTH control words.

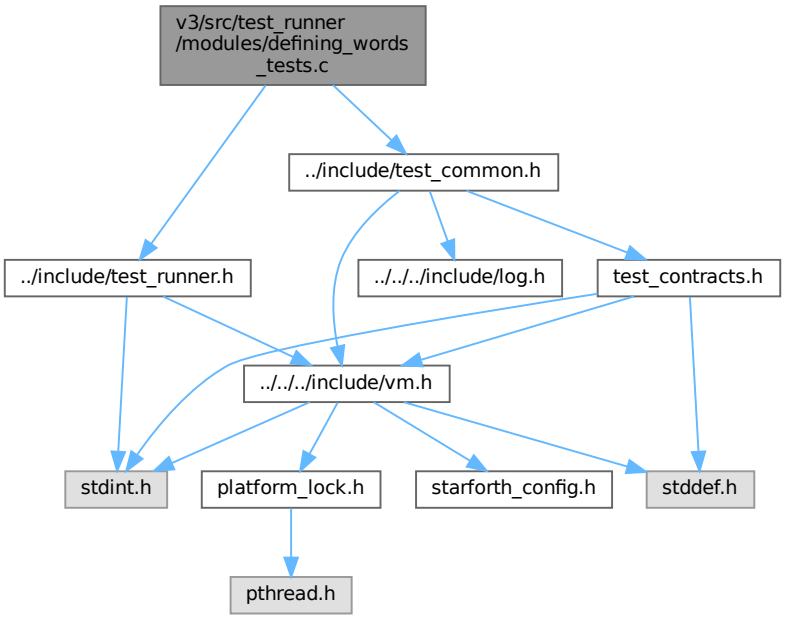
Contains test cases for all control flow words in Module 12, including conditional branches and loop structures

Referenced by run_control_words_tests().

7.317 v3/src/test_runner/modules/defining_words_tests.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for defining_words_tests.c:



Functions

- void run_defining_words_tests (VM *vm)

  Executes all test suites for Forth defining words.

Variables

- static WordTestSuite defining_word_suites [ ]

  Test suites for Forth defining words (Module 13)

7.317.1 Function Documentation

7.317.1.1 run_defining_words_tests()

```
void run_defining_words_tests (
            VM * vm )
```

Executes all test suites for Forth defining words.

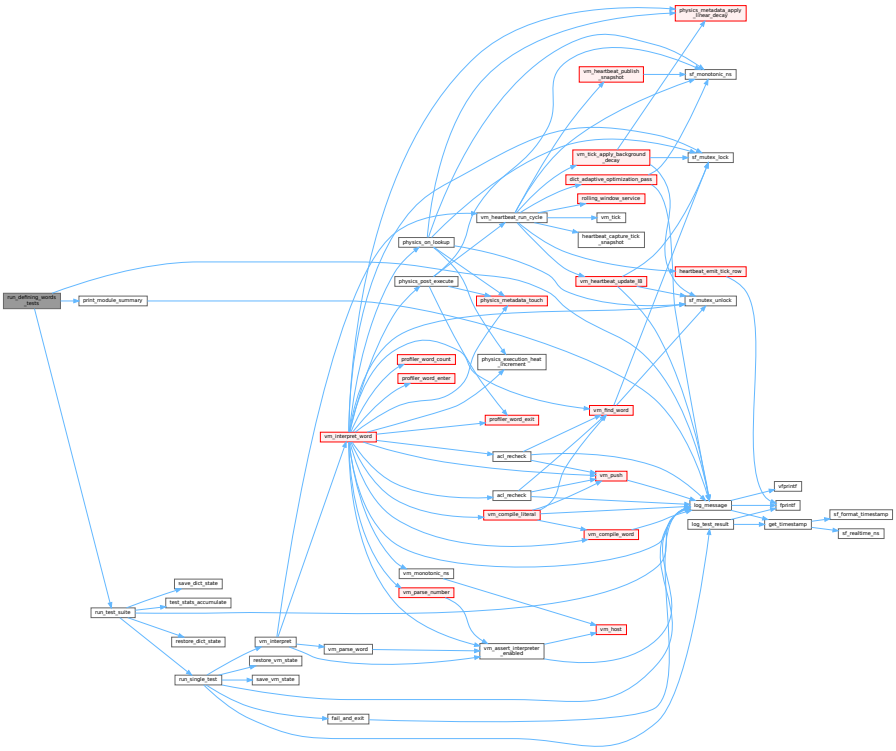
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through each test suite in defining_word_suites array, executing individual test cases and logging results_↩ run_01_2025_12_08

References defining_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.317.2 Variable Documentation

7.317.2.1 defining_word_suites

```
WordTestSuite defining_word_suites[]  [static]
```

Test suites for Forth defining words (Module 13)

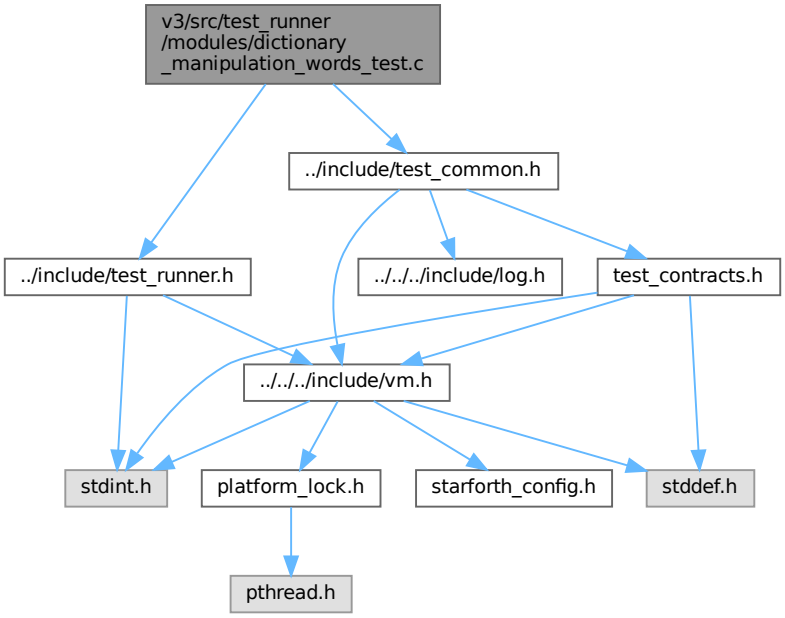
Contains test cases for core defining words including: :, ;, CONSTANT, VARIABLE, CREATE, DOES>, [, and]

Referenced by run_defining_words_tests().

7.318 v3/src/test_runner/modules/dictionary_manipulation_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for dictionary_manipulation_words_test.c:



Functions

- void run_dictionary_manipulation_words_tests (VM *vm)

  Executes all dictionary manipulation words test suites.

Variables

- static WordTestSuite dict_manip_word_suites [ ]

7.318.1 Function Documentation

7.318.1.1 run_dictionary_manipulation_words_tests()

```
void run_dictionary_manipulation_words_tests (
            VM * vm )
```

Executes all dictionary manipulation words test suites.

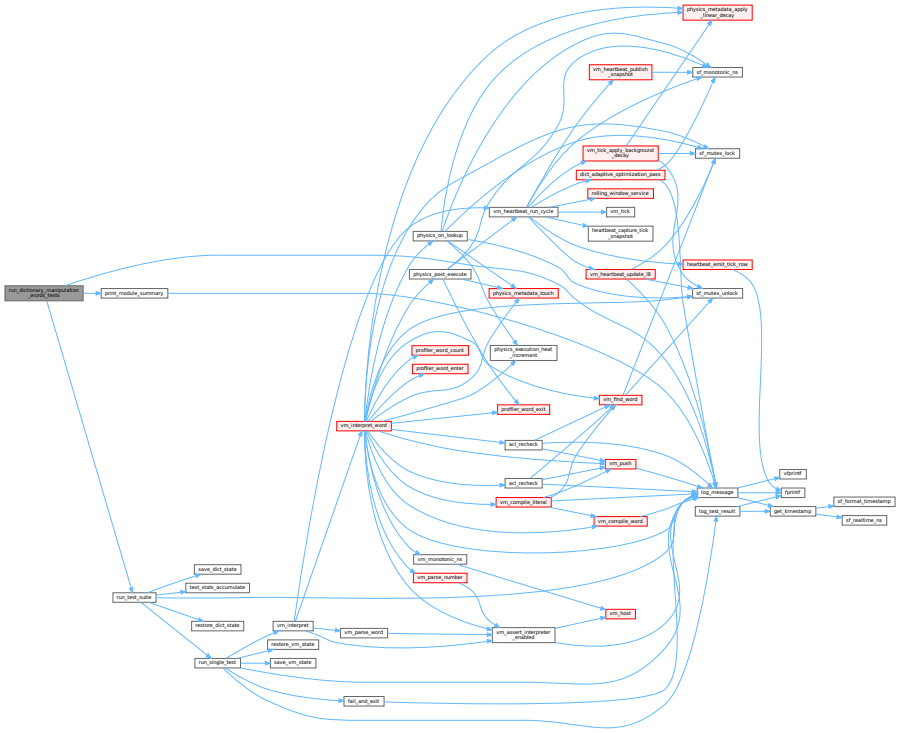
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all test cases for CREATE, FORGET, IMMEDIATE, FIND, DEFINITIONS, SMUDGE, LATEST, >BODY, and HIDDEN words

References dict_manip_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.318.2 Variable Documentation

7.318.2.1 dict_manip_word_suites

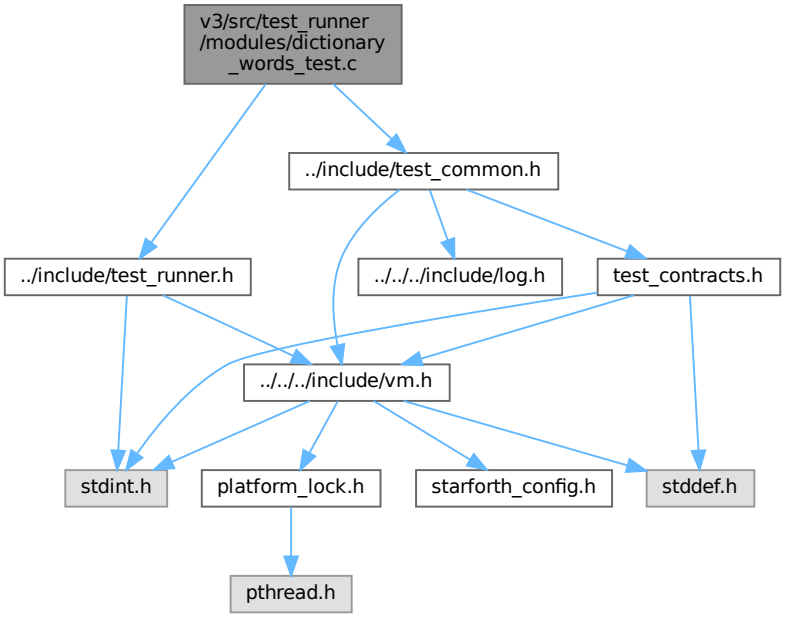
```
WordTestSuite dict_manip_word_suites[]  [static]
```

Referenced by run_dictionary_manipulation_words_tests().

7.319 v3/src/test_runner/modules/dictionary_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for dictionary_words_test.c:



Functions

- void run_dictionary_words_tests (VM *vm)

  Executes all dictionary word test suites.

Variables

- static WordTestSuite dictionary_word_suites [ ]

7.319.1 Function Documentation

7.319.1.1 run_dictionary_words_tests()

```
void run_dictionary_words_tests (
            VM * vm )
```

Executes all dictionary word test suites.

Parameters

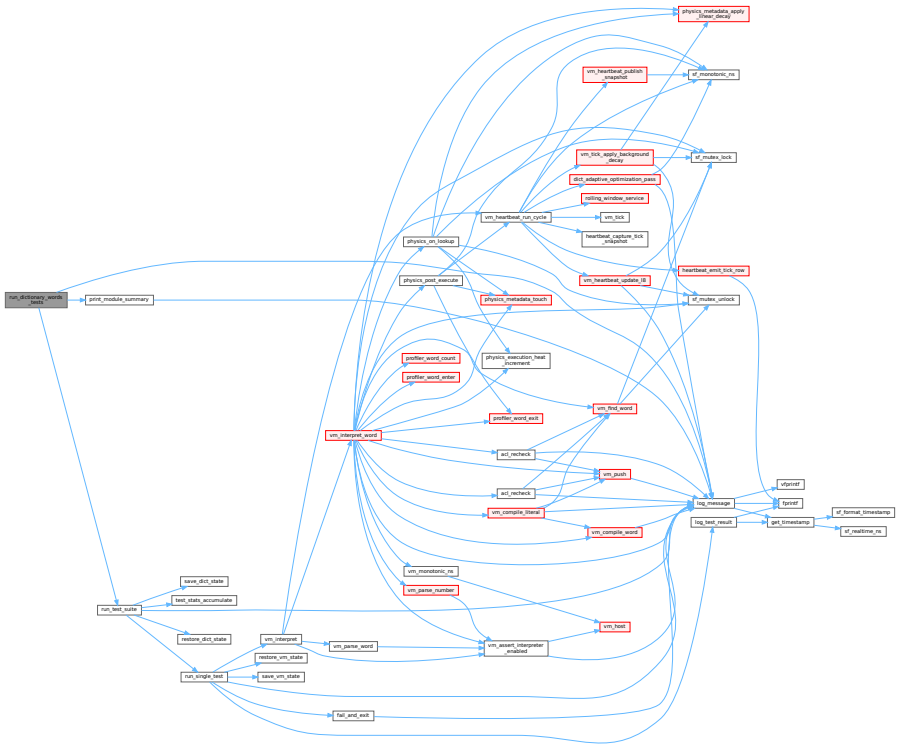
vm	Pointer to the FORTH virtual machine instance

This function runs through all dictionary word test suites, including tests for:

- HERE (dictionary pointer)
- ALLOT (memory allocation)
- Comma operations (, C, 2,)
- PAD (scratch pad area)
- Stack pointer operations (SP@ SP!)
- LATEST (most recent dictionary entry)
- Compilation sequences
- Stack management operations

References dictionary_word_suites, LOG_INFO, log_message(), print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.319.2 Variable Documentation

7.319.2.1 dictionary_word_suites

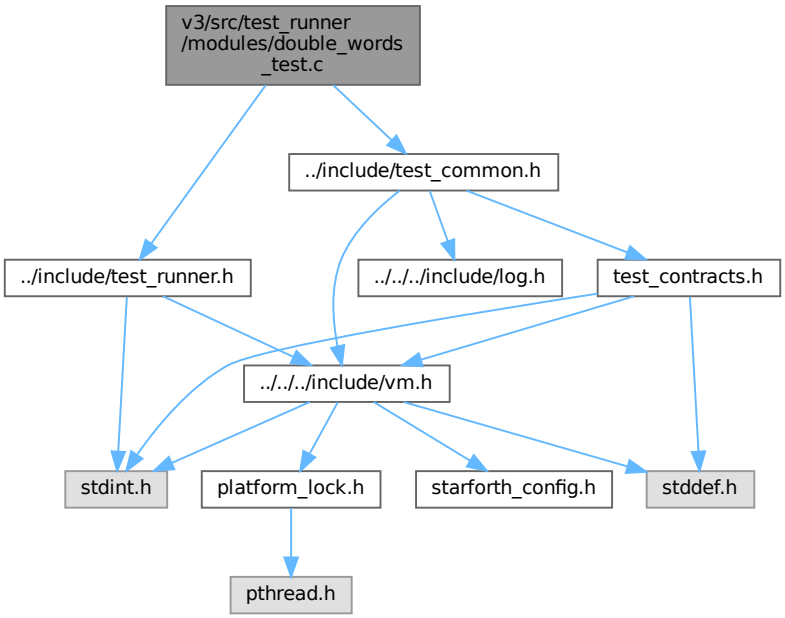
```
WordTestSuite dictionary_word_suites[]  [static]
```

Referenced by run_dictionary_words_tests().

7.320 v3/src/test_runner/modules/double_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for double_words_test.c:



Functions

- void run_double_words_tests (VM *vm)

  Executes all test suites for double number words.

Variables

- static WordTestSuite double_word_suites [ ]

7.320.1 Function Documentation

7.320.1.1 run_double_words_tests()

```
void run_double_words_tests (
            VM * vm )
```

Executes all test suites for double number words.

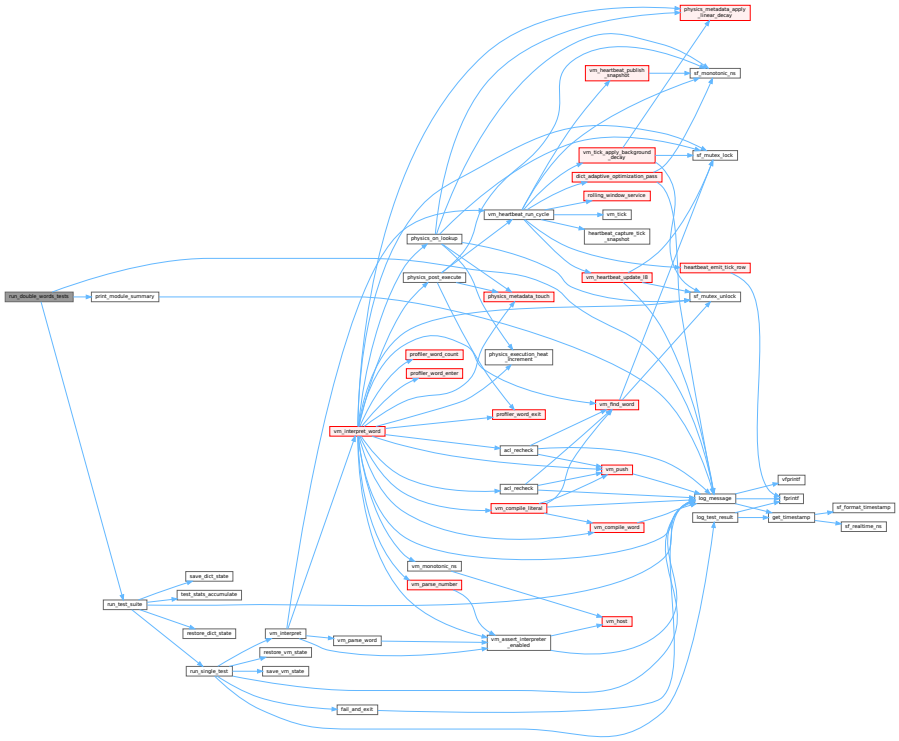
This function runs comprehensive tests for all double number word operations, including stack manipulation (2DROP, 2DUP, etc.), arithmetic operations (D+, D-, etc.), and comparison operations (D=, D<, etc.).

Parameters

vm	Pointer to the virtual machine instance where tests will be executed

References double_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.320.2 Variable Documentation

7.320.2.1 double_word_suites

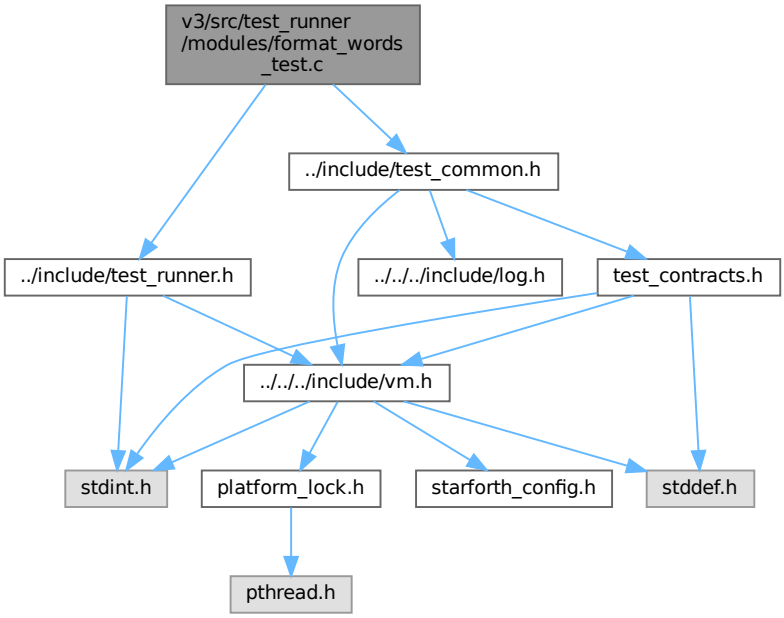
```
WordTestSuite double_word_suites[]  [static]
```

Referenced by run_double_words_tests().

7.321 v3/src/test_runner/modules/format_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for format_words_test.c:



Functions

- void run_format_words_tests (VM *vm)

  Executes all format words test suites.

Variables

- static WordTestSuite format_word_suites [ ]

  Test suites for format words (Module 10) Contains test cases for number base conversion and formatting operations.

7.321.1 Function Documentation

7.321.1.1 run_format_words_tests()

```
void run_format_words_tests (
            VM * vm )
```

Executes all format words test suites.

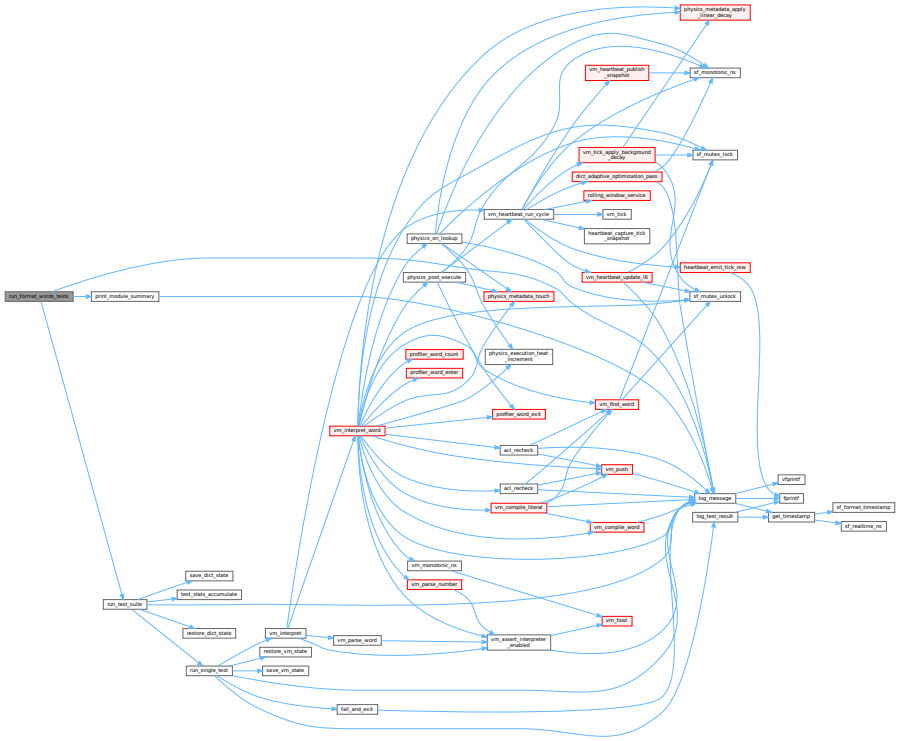
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all test cases for number base manipulation and formatting words

References format_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.321.2 Variable Documentation

7.321.2.1 format_word_suites

```
WordTestSuite format_word_suites[]  [static]
```

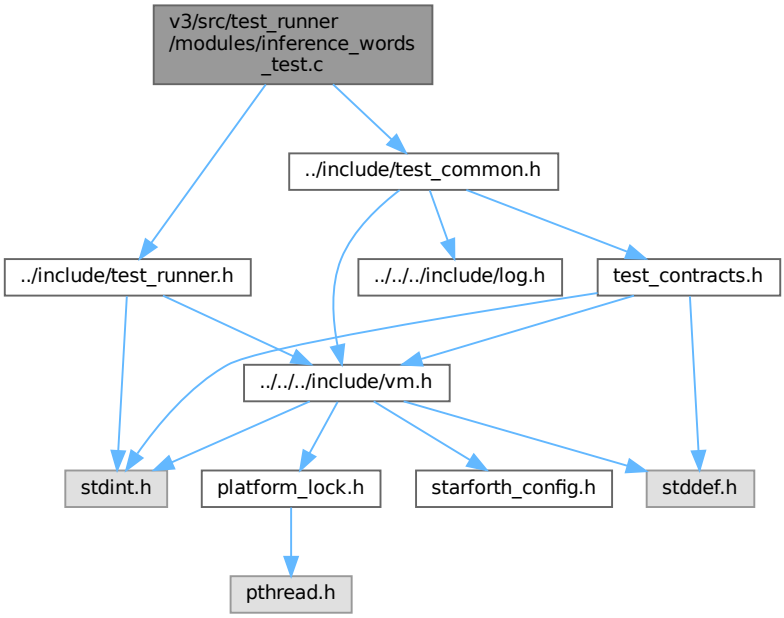
Test suites for format words (Module 10) Contains test cases for number base conversion and formatting operations.

Referenced by run_format_words_tests().

7.322 v3/src/test_runner/modules/inference_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for inference_words_test.c:



Functions

- void run_inference_words_tests (VM *vm)

  Executes the proof-covered subset of inference-engine word test suites.

Variables

- static WordTestSuite inference_word_suites [ ]

7.322.1 Function Documentation

7.322.1.1 run_inference_words_tests()

```
void run_inference_words_tests (
            VM * vm )
```

Executes the proof-covered subset of inference-engine word test suites.

Parameters

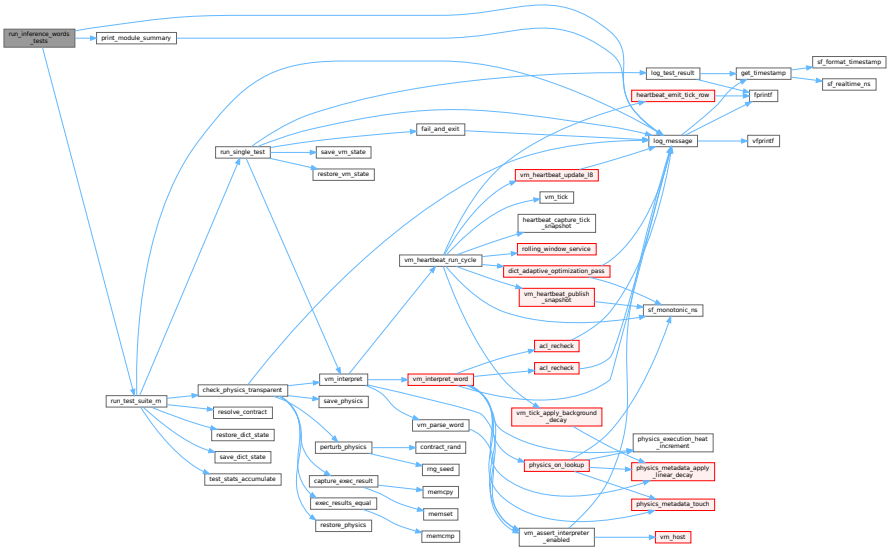
vm	Pointer to the Forth virtual machine instance

Covers the 8 words proof/COVERAGE.md marks as proof-covered in inference_words.c: the three array-based primitives (Q.VARIANCE, INFER-DECAY-SLOPE, INFER-WINDOW-WIDTH), INFER-RUN, and the four *-@ output

accessors (INFER-WINDOW@/DECAY@/VARIANCE@/FIT@) plus INFER-EARLY-EXIT. Does not cover the L8 Jacquard or Bayesian posterior words in the same file — not claimed as proof-covered.

References CONTRACT_NONE, inference_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.322.2 Variable Documentation

7.322.2.1 inference_word_suites

```
WordTestSuite inference_word_suites[]  [static]
```

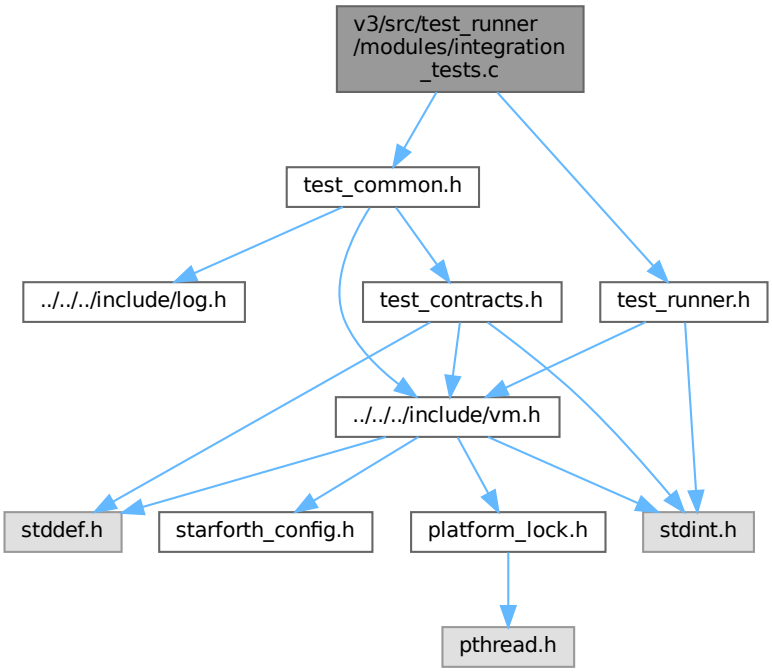
Referenced by run_inference_words_tests().

7.323 v3/src/test_runner/modules/integration_tests.c File Reference

Full program integration tests for StarForth.

```
#include "test_common.h"
#include "test_runner.h"
```

Include dependency graph for integration_tests.c:



Functions

- void run_integration_tests (VM *vm)

  Executes all integration test suites for StarForth.

Variables

- static WordTestSuite integration_suites [ ]

7.323.1 Detailed Description

Full program integration tests for StarForth.

This file contains integration tests that verify complete Forth programs as regression tests. It includes test suites for complete programs, data structures, and algorithms implementations.

7.323.2 Function Documentation

7.323.2.1 run_integration_tests()

```
void run_integration_tests (
            VM * vm )
```

Executes all integration test suites for StarForth.

Parameters

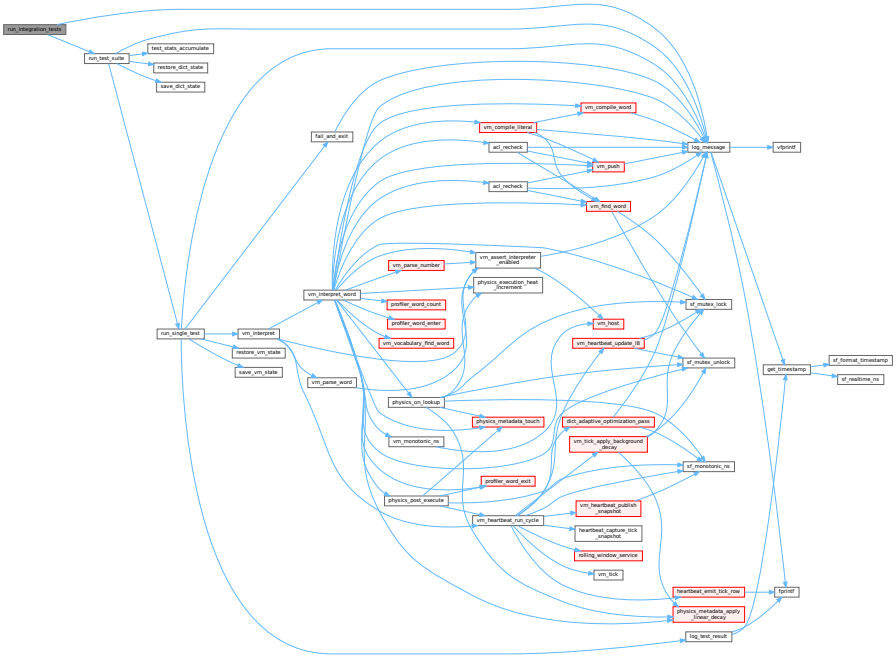
vm	Pointer to the Forth virtual machine instance

This function runs through all defined integration test suites, including:

- Complete Programs suite (prime checker, array operations, etc)
- Data Structures suite (linked list, min/max tracker)
- Algorithms suite (sorting, GCD)

References integration_suites, LOG_INFO, log_message(), and run_test_suite().

Here is the call graph for this function:



7.323.3 Variable Documentation

7.323.3.1 integration_suites

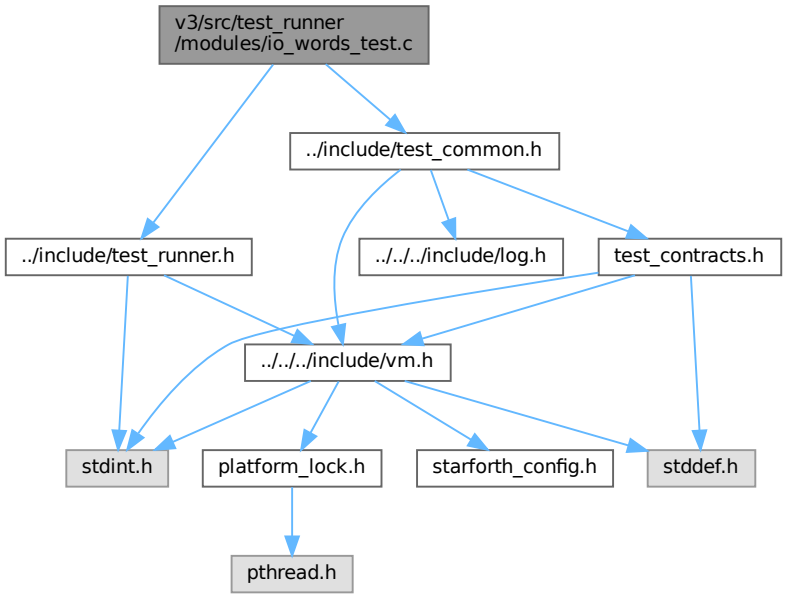
```
WordTestSuite integration_suites[]  [static]
```

Referenced by run_integration_tests().

7.324 v3/src/test_runner/modules/io_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for io_words_test.c:



Functions

- void run_io_words_tests (VM *vm)

  Executes all I/O words test suites.

Variables

- static WordTestSuite io_word_suites [ ]

  Test suites for I/O words (Module 9)

7.324.1 Function Documentation

7.324.1.1 run_io_words_tests()

```
void run_io_words_tests (
            VM * vm )
```

Executes all I/O words test suites.

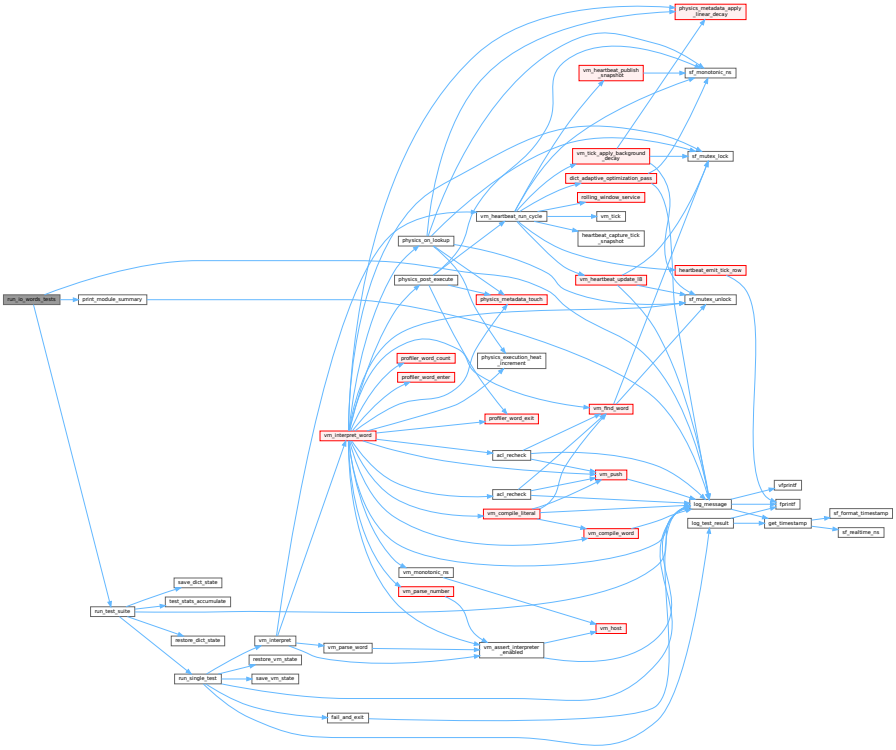
Parameters

vm	Pointer to the FORTH virtual machine instance

Runs through all defined test suites for I/O words, logging results_run_01_2025_12_08 and providing a summary of the test execution

References io_word_suites, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.324.2 Variable Documentation

7.324.2.1 io_word_suites

```
WordTestSuite io_word_suites[]  [static]
```

Test suites for I/O words (Module 9)

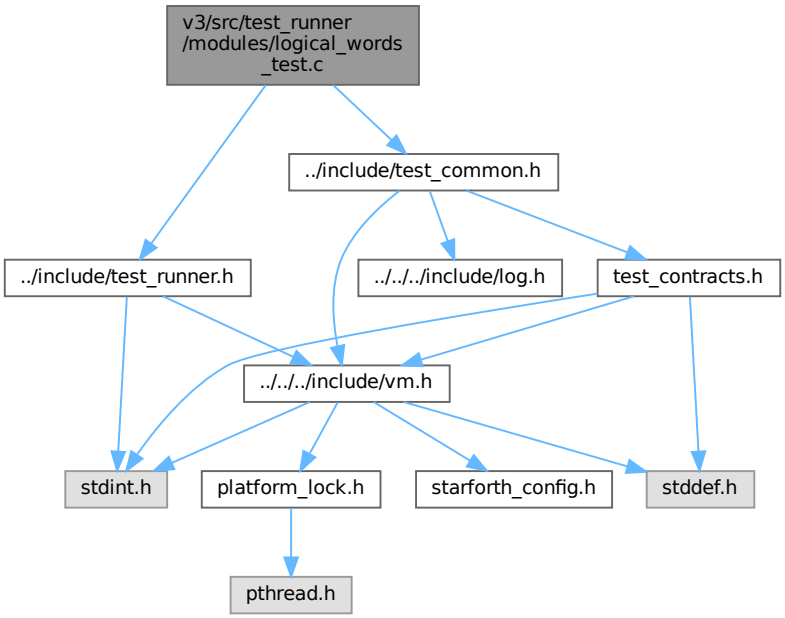
Contains comprehensive test cases for all I/O related FORTH words including output formatting, character I/O, and base conversion operations

Referenced by run_io_words_tests().

7.325 v3/src/test_runner/modules/logical_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for logical_words_test.c:



Functions

- void run_logical_words_tests (VM *vm)

  Executes all logical words test suites.

Variables

- static WordTestSuite logical_word_suites [ ]

7.325.1 Function Documentation

7.325.1.1 run_logical_words_tests()

```
void run_logical_words_tests (
            VM * vm )
```

Executes all logical words test suites.

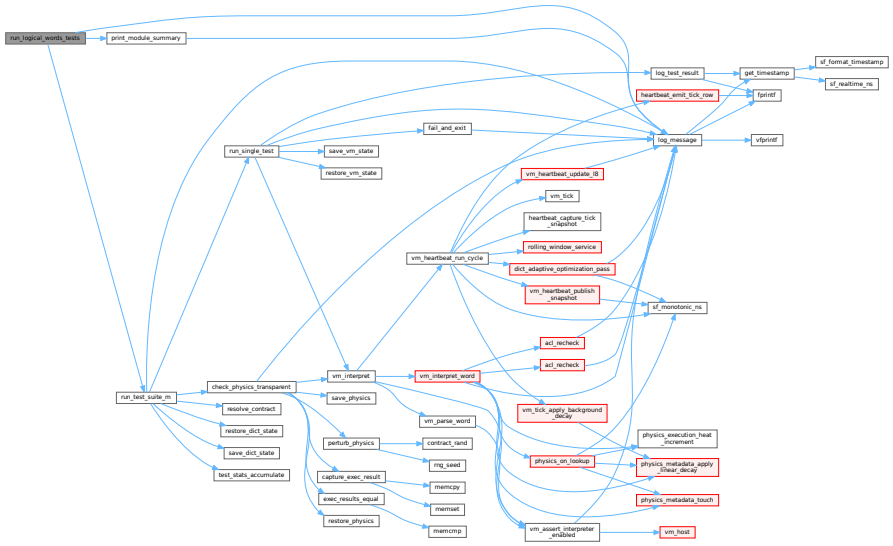
This function runs comprehensive tests for all FORTH logical and comparison operators, including stack underflow checks and edge cases.

Parameters

vm	Pointer to the FORTH virtual machine instance

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, logical_word_suites, print_module_summary(), run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.325.2 Variable Documentation

7.325.2.1 logical_word_suites

```
WordTestSuite logical_word_suites[]  [static]
```

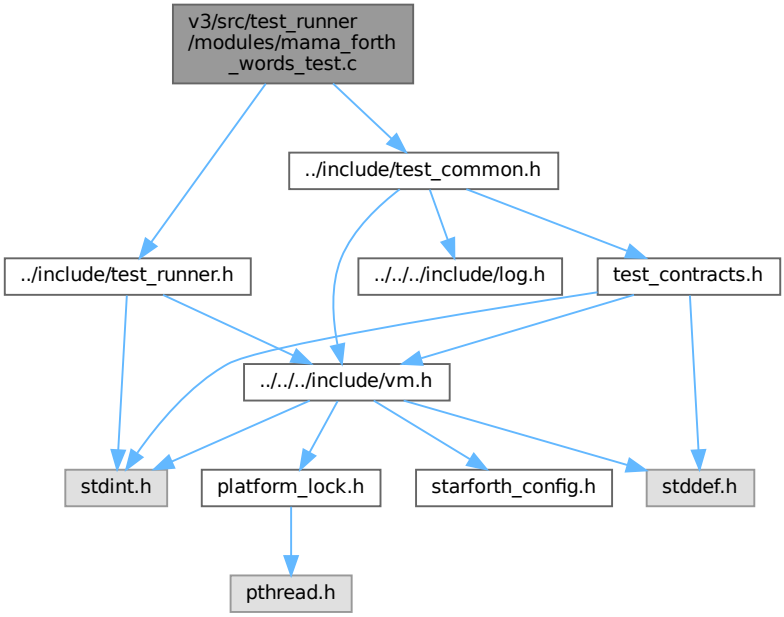
Referenced by run_logical_words_tests().

7.326 v3/src/test_runner/modules/mama_forth_words_test.c File Reference

Test module for Mama FORTH vocabulary (M7.1 Capsule System)

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for mama_forth_words_test.c:



Macros

- #define MAMA_IMPLEMENTED 0

Functions

- void run_mama_forth_words_tests (VM *vm)

  Executes all Mama FORTH vocabulary test suites.

Variables

- static WordTestSuite mama_word_suites [ ]

7.326.1 Detailed Description

Test module for Mama FORTH vocabulary (M7.1 Capsule System)

Tests for the MAMA vocabulary words. These words are kernel-only (**STARKERNEL**), so in hosted builds all tests are marked as not implemented and will be skipped.

In kernel builds, these tests validate:

- Capsule directory enumeration
- Descriptor field access
- VM birth protocol
- Experiment execution

7.326.2 Macro Definition Documentation

7.326.2.1 MAMA_IMPLEMENTED

```
#define MAMA_IMPLEMENTED 0
```

7.326.3 Function Documentation

7.326.3.1 run_mama_forth_words_tests()

```
void run_mama_forth_words_tests (
            VM * vm )
```

Executes all Mama FORTH vocabulary test suites.

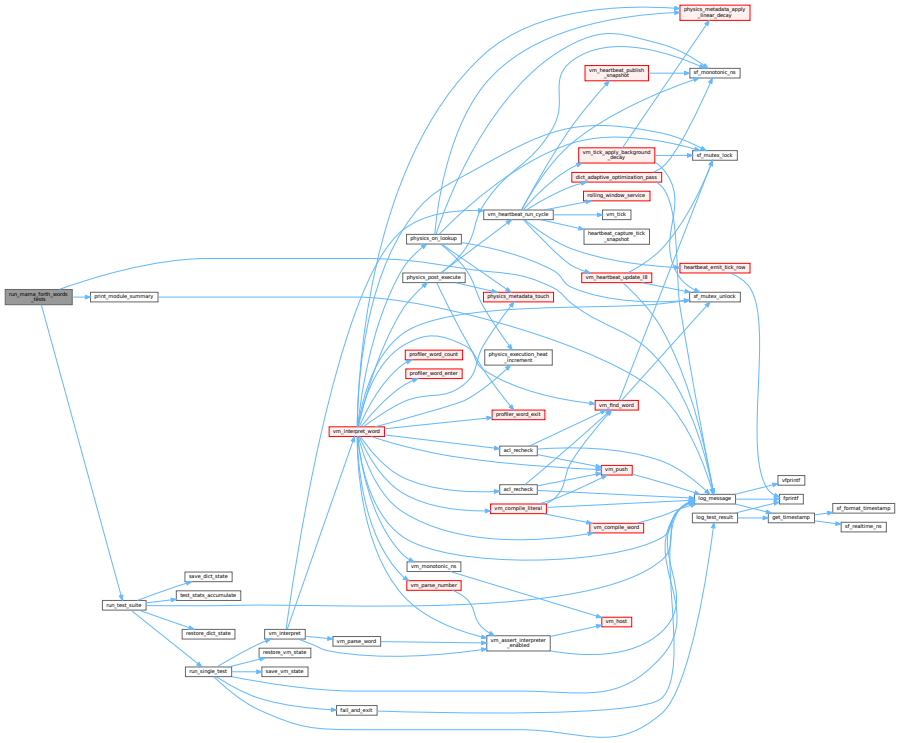
In hosted builds, all tests will be skipped since MAMA_IMPLEMENTED=0. In kernel builds, tests will execute against the capsule system.

Parameters

vm	Pointer to the Forth virtual machine instance

References LOG_INFO, log_message(), mama_word_suites, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.326.4 Variable Documentation

7.326.4.1 mama_word_suites

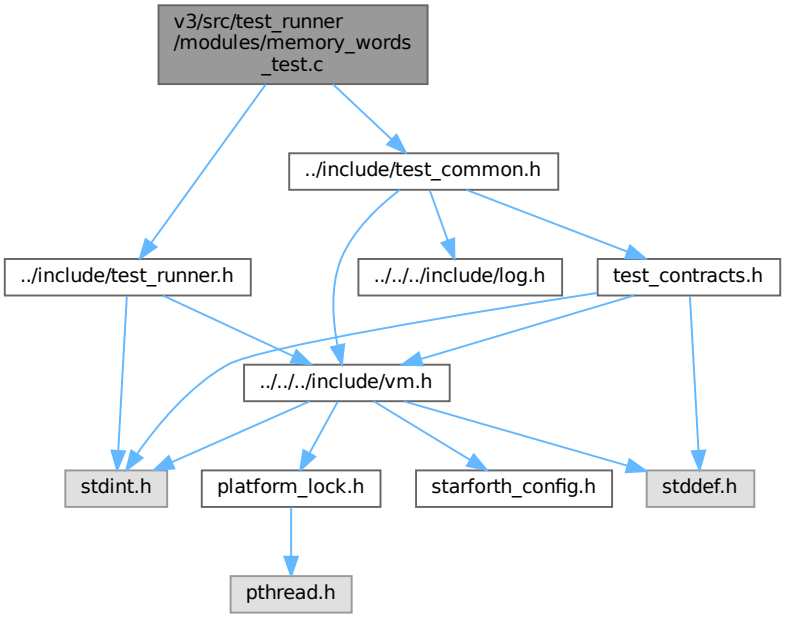
```
WordTestSuite mama_word_suites[]  [static]
```

Referenced by run_mama_forth_words_tests().

7.327 v3/src/test_runner/modules/memory_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for memory_words_test.c:



Functions

- void run_memory_words_tests (VM *vm)

  Executes the test suite for memory manipulation words.

Variables

- static WordTestSuite memory_word_suites [ ]

7.327.1 Function Documentation

7.327.1.1 run_memory_words_tests()

```
void run_memory_words_tests (
            VM * vm )
```

Executes the test suite for memory manipulation words.

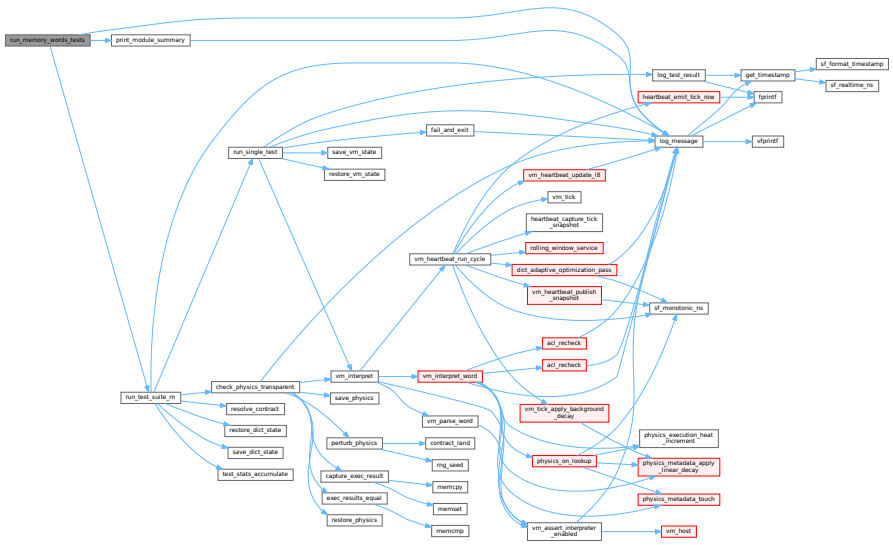
Runs through a series of test cases for Forth memory operations including store, fetch, allot, and other memory-related words

Parameters

vm	Pointer to the Forth virtual machine instance

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, memory_word_suites, print_module_summary(), run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.327.2 Variable Documentation

7.327.2.1 memory_word_suites

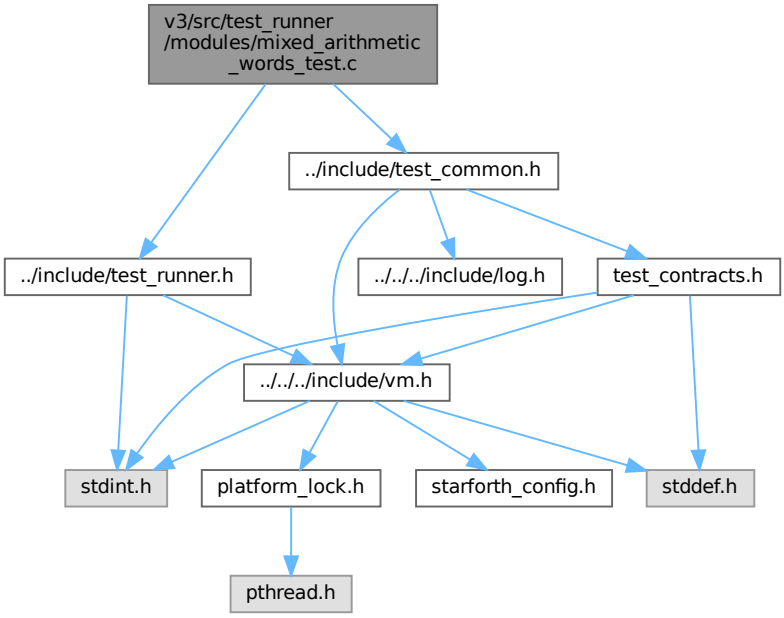
```
WordTestSuite memory_word_suites[]  [static]
```

Referenced by run_memory_words_tests().

7.328 v3/src/test_runner/modules/mixed_arithmetic_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for mixed_arithmetic_words_test.c:



Functions

- void run_mixed_arithmetic_words_tests (VM *vm)

  Module 7 entry point — run all mixed-arithmetic word POST tests.

Variables

- static WordTestSuite mixed_arithmetic_word_suites [ ]

  Module 7 test-suite table for mixed-arithmetic FORTH-79 words.

7.328.1 Function Documentation

7.328.1.1 run_mixed_arithmetic_words_tests()

```
void run_mixed_arithmetic_words_tests (
            VM * vm )
```

Module 7 entry point — run all mixed-arithmetic word POST tests.

Iterates `mixed_arithmetic_word_suites` and delegates each to `run_test_suite()`. Covers five word families:

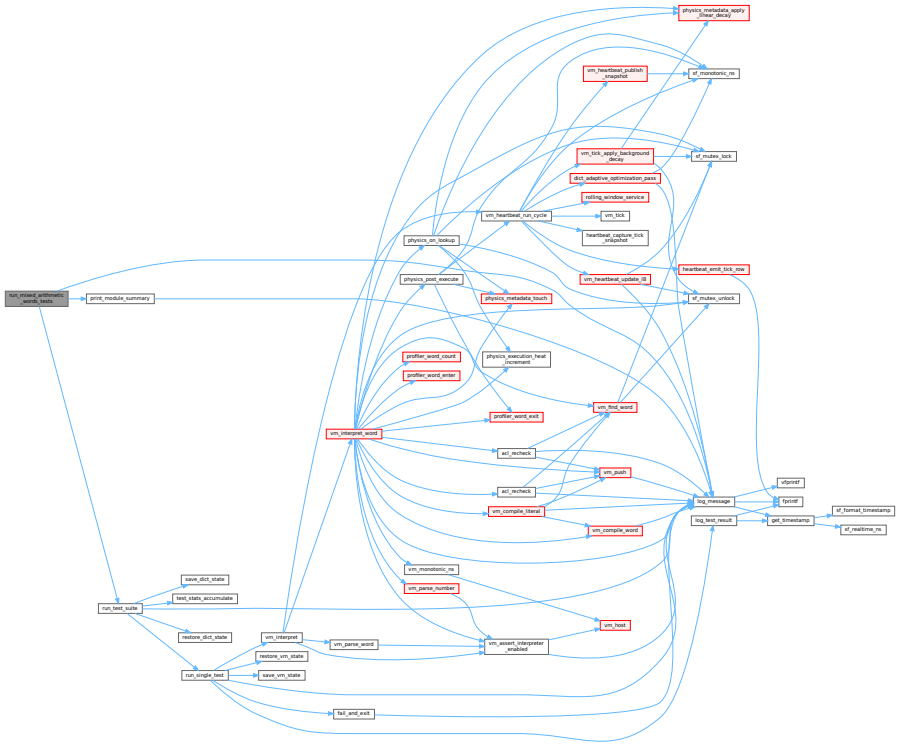
- `*-/` (n1 n2 n3 – n4) — scale: n1*n2/n3 in 64-bit intermediate
- `*-/MOD` (n1 n2 n3 – rem quot) — scale with remainder
- `M+` (d n – d') — add single to double
- `M*` (n1 n2 – d) — signed multiply to double
- `M/MOD` (d n – rem quot) — double divided by single

Parameters

vm	VM instance; must be initialised with the standard vocabulary.

References LOG_INFO, log_message(), LOG_TEST, mixed_arithmetic_word_suites, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.328.2 Variable Documentation

7.328.2.1 mixed_arithmetic_word_suites

```
WordTestSuite mixed_arithmetic_word_suites[]  [static]
```

Module 7 test-suite table for mixed-arithmetic FORTH-79 words.

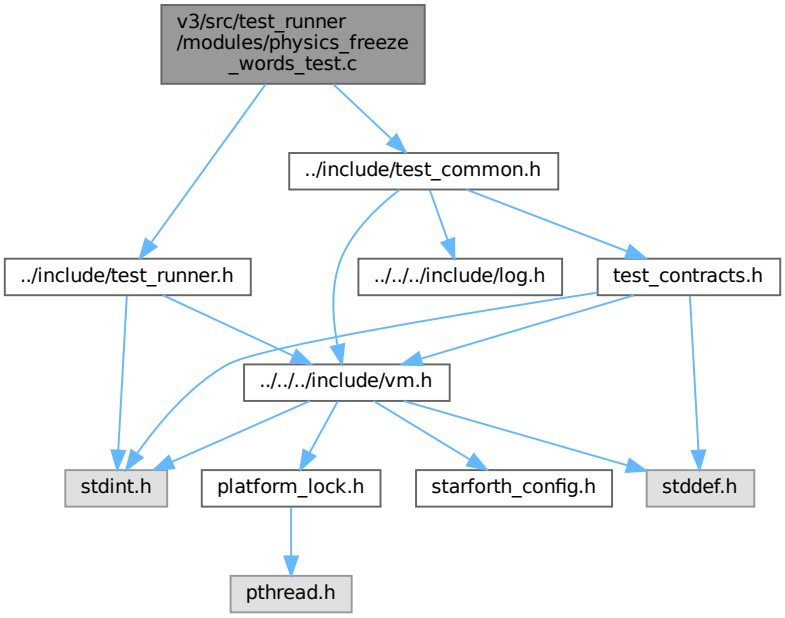
Covers the five combined multiply-divide words: `*-/` , `*-/MOD` , `M+` , `M*` , and `M/MOD` . Each suite exercises normal cases, edge cases (overflow, large products), and error cases (division by zero, stack underflow). The table is terminated with a NULL sentinel.

Referenced by run_mixed_arithmetic_words_tests().

7.329 v3/src/test_runner/modules/physics_freeze_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for physics_freeze_words_test.c:



Functions

- void run_physics_freeze_words_tests (VM *vm)

  Executes the proof-covered subset of physics-freeze word test suites.

Variables

- static WordTestSuite physics_freeze_word_suites [ ]

7.329.1 Function Documentation

7.329.1.1 run_physics_freeze_words_tests()

```
void run_physics_freeze_words_tests (
            VM * vm )
```

Executes the proof-covered subset of physics-freeze word test suites.

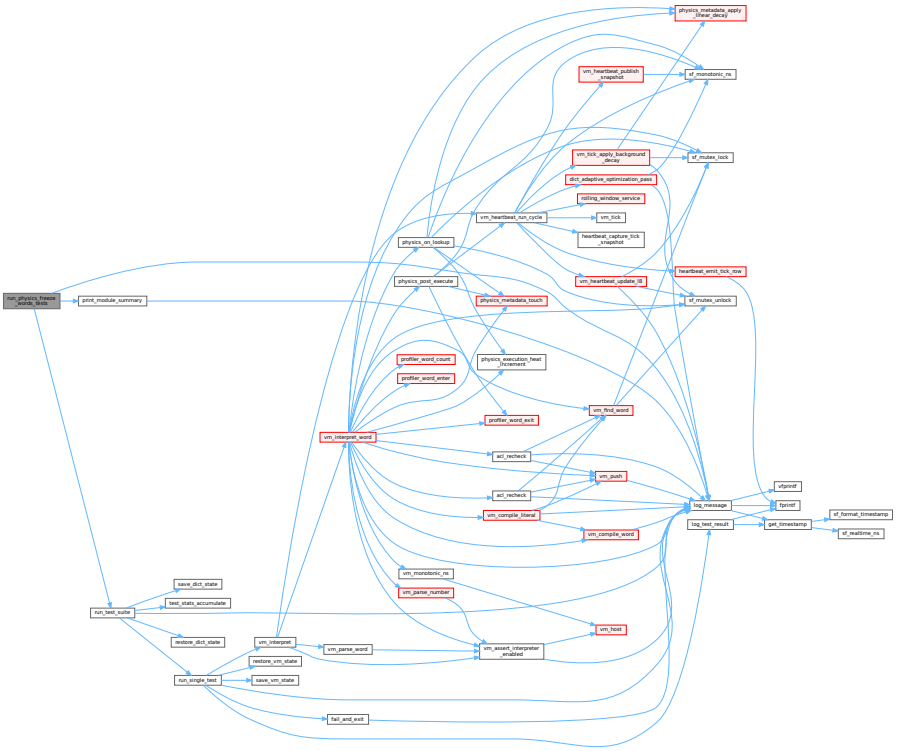
Parameters

vm	Pointer to the Forth virtual machine instance

Covers the 6 words proof/StarForth_Physics_Freeze_Words.thy gives real lemmas for: FREEZE-WORD, UNFREEZE-WORD, FROZEN?, HEAT!, HEAT@, DECAY-RATE. Does not cover FREEZE-CRITICAL, SHOW-HEAT, or ALL-HEATS — those carry only trivial/not-modelled lemmas in the same theory file.

References LOG_INFO, log_message(), LOG_TEST, physics_freeze_word_suites, print_module_summary(), run_test_suite(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.329.2 Variable Documentation

7.329.2.1 physics_freeze_word_suites

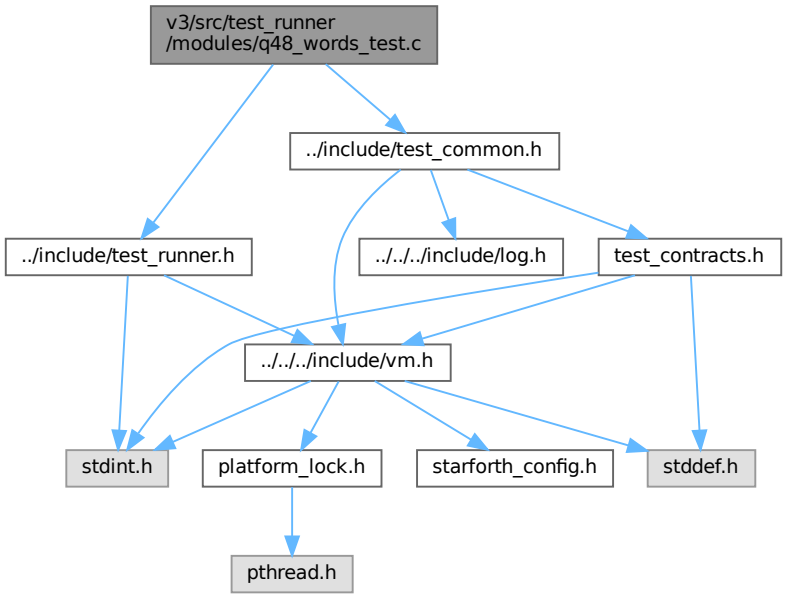
```
WordTestSuite physics_freeze_word_suites[]  [static]
```

Referenced by run_physics_freeze_words_tests().

7.330 v3/src/test_runner/modules/q48_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for q48_words_test.c:



Functions

- void run_q48_words_tests (VM *vm)

  Executes all Q48.16 fixed-point word test suites.

Variables

- static WordTestSuite q48_word_suites [ ]

7.330.1 Function Documentation

7.330.1.1 run_q48_words_tests()

```
void run_q48_words_tests (
            VM * vm )
```

Executes all Q48.16 fixed-point word test suites.

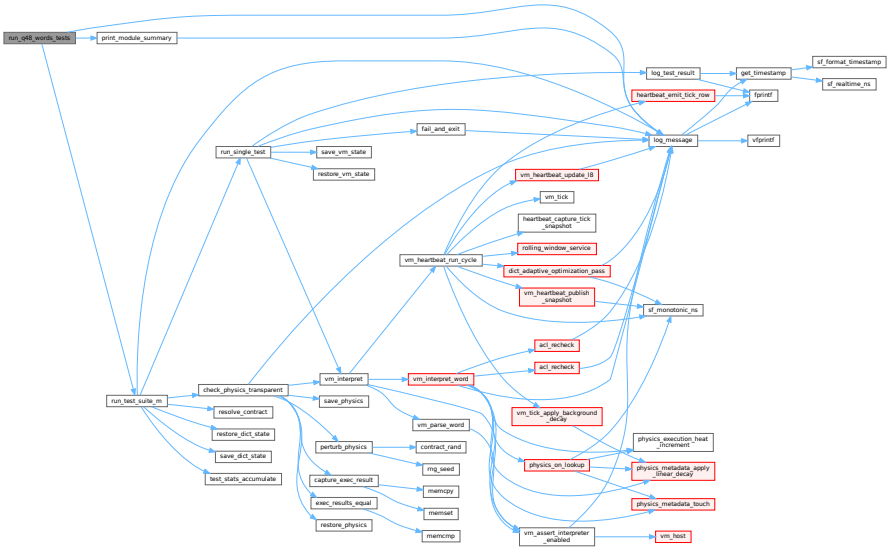
Parameters

vm	Pointer to the Forth virtual machine instance

Covers all 23 words registered by register_q48_words() (q48_words.c): arithmetic (+, -, ∗, /), sign (ABS, NEG), transcendental approximations (LOG, EXP, SQRT, SIN, COS), conversions (FROM-INT, TO-INT), constants (1, 0, SCALE), comparisons (=, <, >, 0=, MAX, MIN), and PRINT.

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), q48_word_suites, run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.330.2 Variable Documentation

7.330.2.1 q48_word_suites

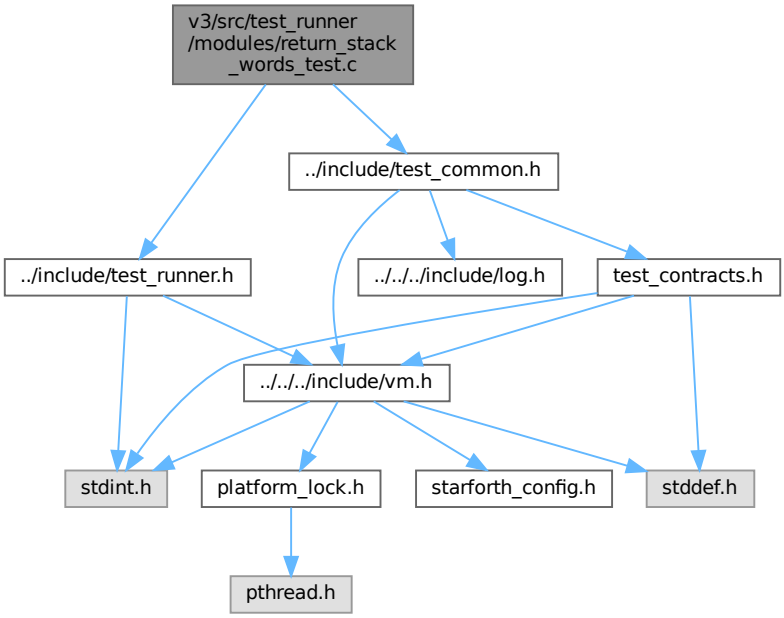
```
WordTestSuite q48_word_suites[]  [static]
```

Referenced by run_q48_words_tests().

7.331 v3/src/test_runner/modules/return_stack_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for return_stack_words_test.c:



Functions

- void run_return_stack_words_tests (VM *vm)

  Executes all test suites for return stack manipulation words.

Variables

- static WordTestSuite return_stack_word_suites [ ]

  Test suites for return stack manipulation words.

7.331.1 Function Documentation

7.331.1.1 run_return_stack_words_tests()

```
void run_return_stack_words_tests (
            VM * vm )
```

Executes all test suites for return stack manipulation words.

Parameters

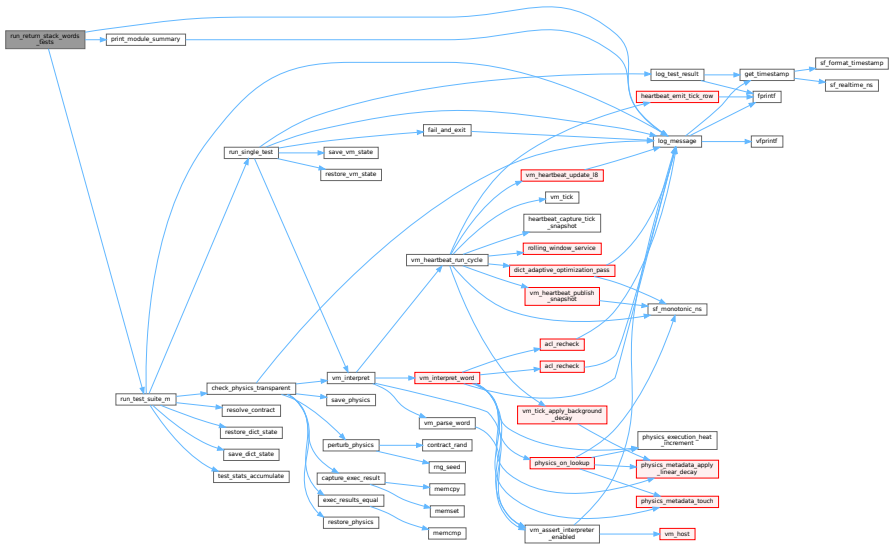
vm	Pointer to the Forth virtual machine instance

Runs through all defined test cases for >R, R>, and R@ words and reports results_run_01_2025_12_08 through

the logging system

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), return_stack_word_suites, run_test_suite_m(), and WordTestSuite::word_name.

Here is the call graph for this function:



7.331.2 Variable Documentation

7.331.2.1 return_stack_word_suites

```
WordTestSuite return_stack_word_suites[]  [static]
```

Test suites for return stack manipulation words.

Contains test cases for >R (push to return stack), R> (pop from return stack), and R@ (copy top of return stack)

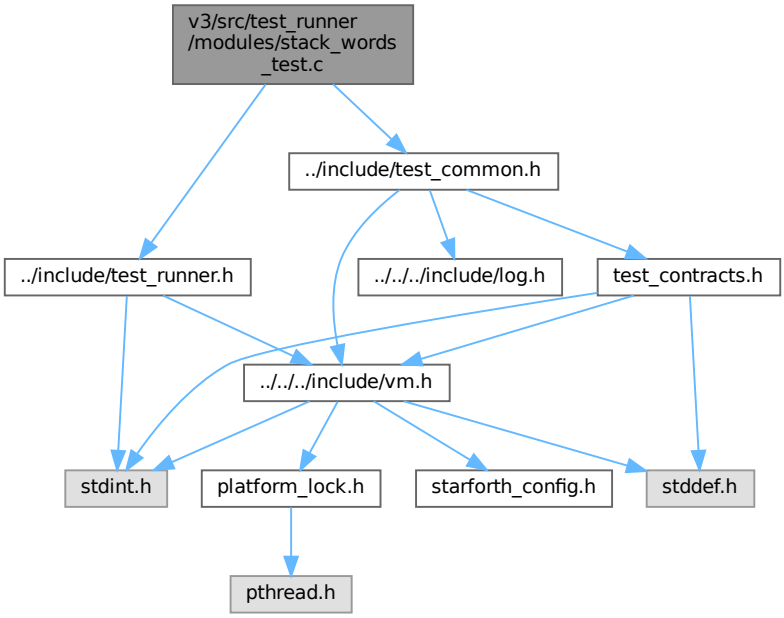
Referenced by run_return_stack_words_tests().

7.332 v3/src/test_runner/modules/stack_words_test.c File Reference

Test module for Forth stack manipulation words.

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for stack_words_test.c:



Functions

- void run_stack_words_tests (VM *vm)

  Executes all test suites for stack manipulation words.

Variables

- static WordTestSuite stack_word_suites [ ]

  Test suites for stack manipulation words.

7.332.1 Detailed Description

Test module for Forth stack manipulation words.

Contains test suites for basic stack operations including DUP, DROP, SWAP, OVER, ROT, DEPTH, PICK, and ROLL

7.332.2 Function Documentation

7.332.2.1 run_stack_words_tests()

```
void run_stack_words_tests (
            VM * vm )
```

Executes all test suites for stack manipulation words.

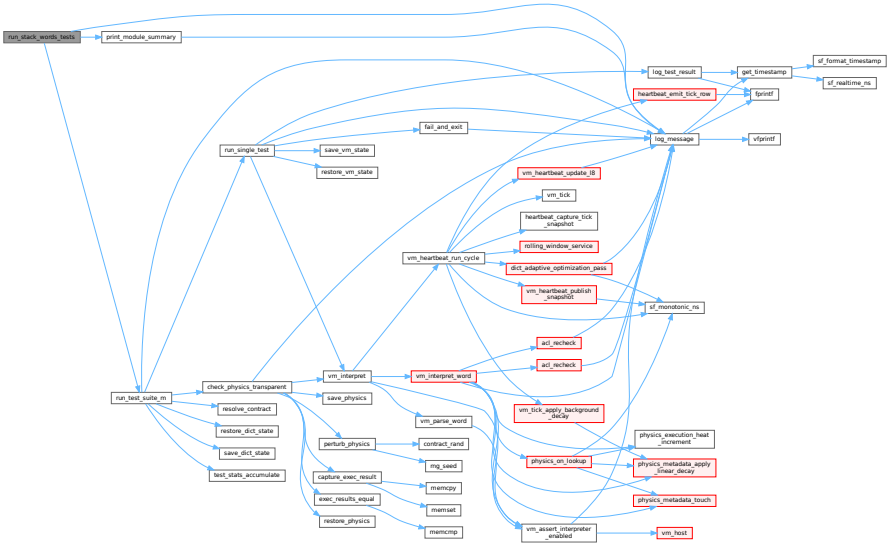
Parameters

vm	Pointer to the Forth virtual machine instance

Runs through all defined test cases for stack manipulation words and reports results_run_01_2025_12_08 through the logging system

References CONTRACT_PHYSICS_TRANSPARENT, LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite_m(), stack_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.332.3 Variable Documentation

7.332.3.1 stack_word_suites

```
WordTestSuite stack_word_suites[]  [static]
```

Test suites for stack manipulation words.

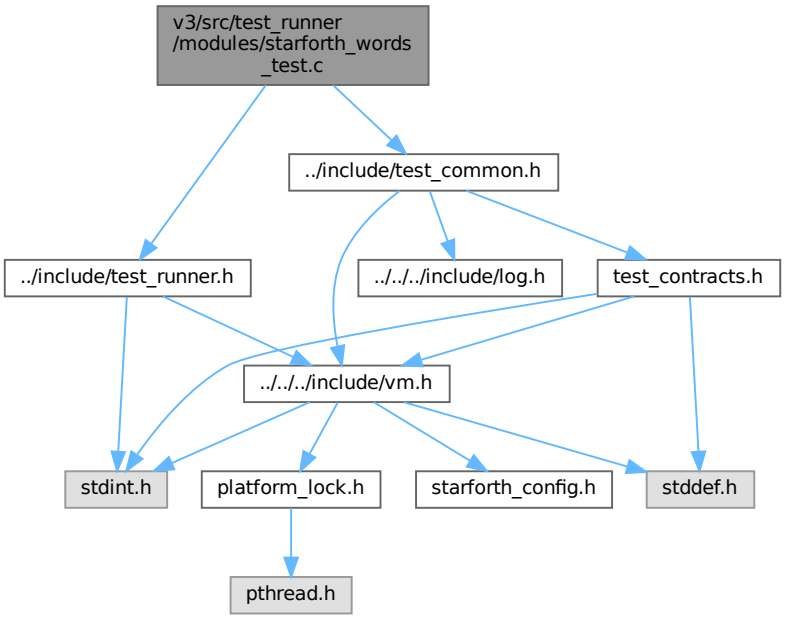
Contains comprehensive test cases for all standard stack operations, including normal cases, edge cases, and error conditions

Referenced by run_stack_words_tests().

7.333 v3/src/test_runner/modules/starforth_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for starforth_words_test.c:



Functions

- void run_starforth_words_tests (VM *vm)

  Executes all StarForth words test suites.

Variables

- static WordTestSuite starforth_word_suites [ ]

  Test suites for StarForth-specific words.

7.333.1 Function Documentation

7.333.1.1 run_starforth_words_tests()

```
void run_starforth_words_tests (
            VM * vm )
```

Executes all StarForth words test suites.

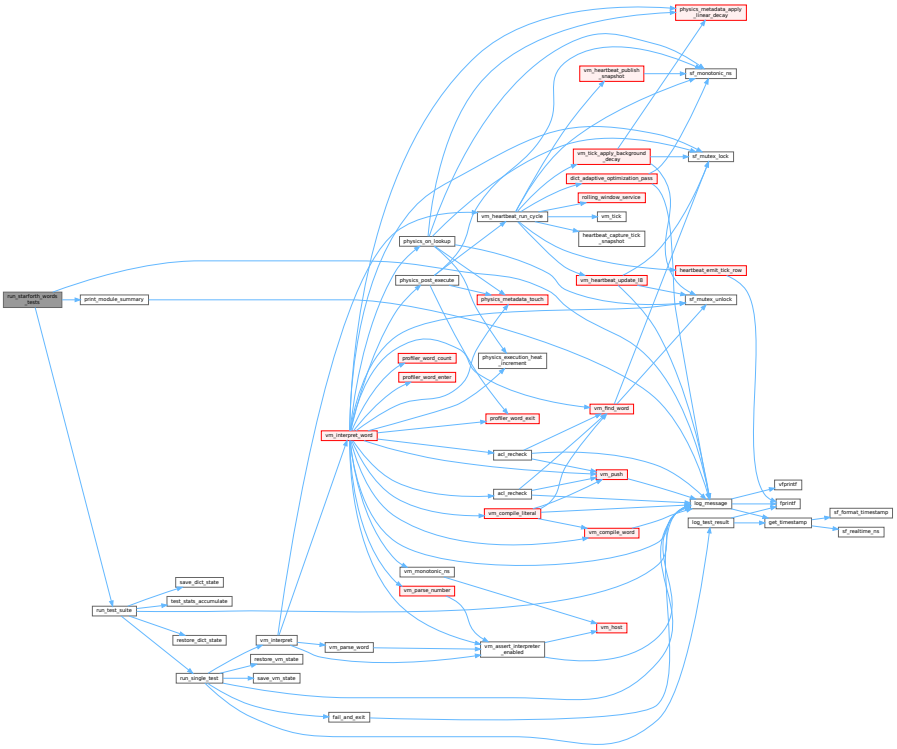
Parameters

vm	Pointer to the FORTH virtual machine instance

Runs through all test cases for StarForth-specific implementation words, including entropy tracking, comments, and initialization.

References LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), starforth_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.333.2 Variable Documentation

7.333.2.1 starforth_word_suites

```
WordTestSuite starforth_word_suites[]  [static]
```

Test suites for StarForth-specific words.

Contains test cases for the following StarForth implementation words:

- ENTROPY@: Fetch word execution count
- ENTROPY!: Store word execution count
- WORD-ENTROPY: Get execution count for a word by name
- RESET-ENTROPY: Reset all word execution counts
- TOP-WORDS: Display most frequently executed words
- (-: Comment to end of line
- INIT: System initialization

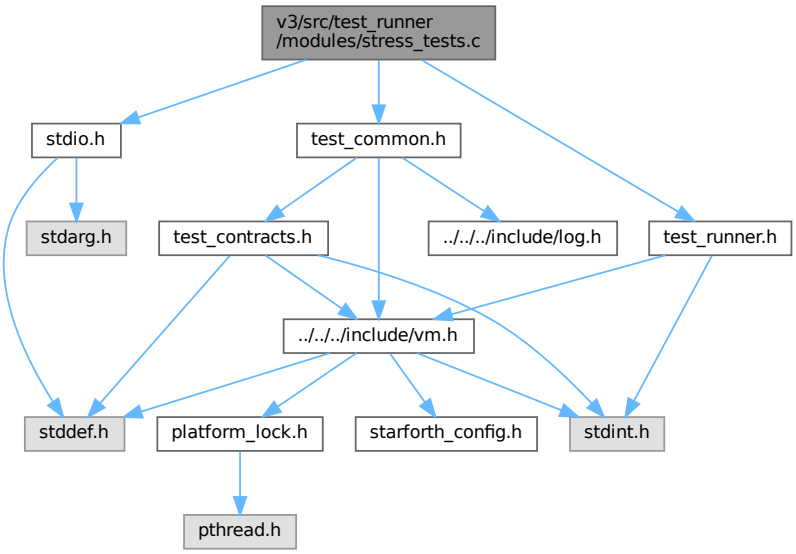
Referenced by run_starforth_words_tests().

7.334 v3/src/test_runner/modules/stress_tests.c File Reference

FORTH-79 Standard Comprehensive Stress Testing Module.

```
#include <stdio.h>
#include "test_common.h"
#include "test_runner.h"
```

Include dependency graph for stress_tests.c:



Functions

- void run_stress_tests (VM *vm)

  Execute comprehensive stress test suites.

Variables

- static WordTestSuite stress_suites [ ]

7.334.1 Detailed Description

FORTH-79 Standard Comprehensive Stress Testing Module.

This module contains extensive stress tests that verify the interpreter's behavior under extreme conditions while remaining within FORTH-79 standard compliance.

Test categories (expanded):

- Deep nesting of control structures (up to 5 levels)

- Stack exhaustion and boundary tests (near-limit operations)
- Numeric boundary conditions (cell_t min/max, overflow)
- Dictionary pressure (many definitions, long names)
- Word execution chains (deep call stacks)
- Control flow edge cases (empty loops, large counts, EXIT)
- Memory allocation patterns (fragmentation, large blocks)
- Error recovery (ABORT, stack underflow recovery)
- Large definitions and word chains

IMPORTANT: These tests only use FORTH-79 standard words. Features from later standards (ANS Forth 1994, Forth 2012) are NOT tested here:

- RECURSE (ANS Forth) - not in FORTH-79
- Self-referential definitions - not supported in FORTH-79
- Extended VARIABLE usage - only standard semantics tested

For testing extended/non-standard features, see integration_tests.c

7.334.2 Function Documentation

7.334.2.1 run_stress_tests()

```
void run_stress_tests (
            VM * vm )
```

Execute comprehensive stress test suites.

Runs an extensive set of stress tests to verify the VM's behavior under extreme conditions. Tests include:

- Stack operations and boundaries
- Deep nesting and control flow
- Numeric boundaries and overflow
- Dictionary pressure
- Memory allocation patterns
- Error recovery
- Mixed complexity scenarios

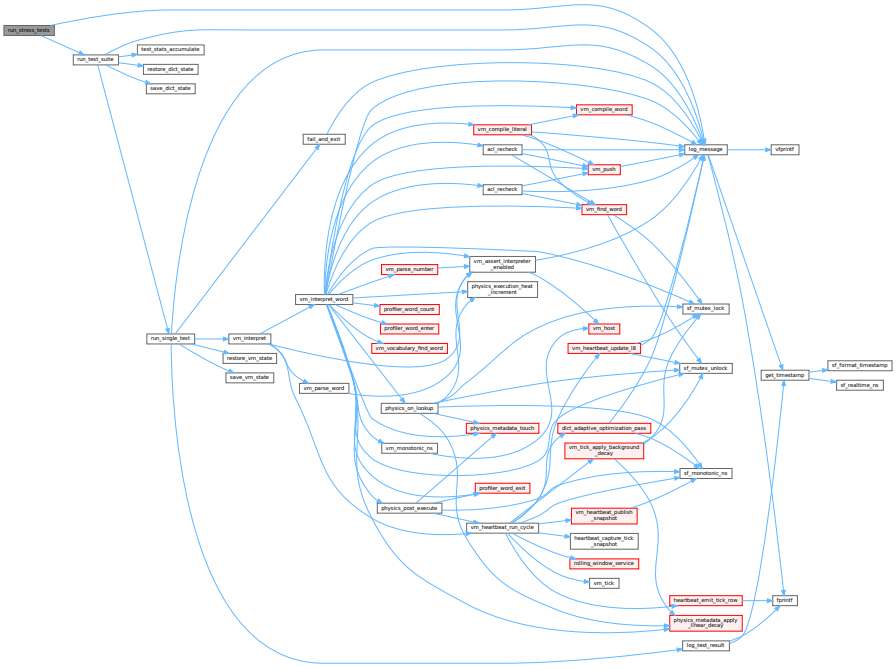
All tests are FORTH-79 compliant.

Parameters

vm	Pointer to the Forth virtual machine instance

References global_test_stats, LOG_INFO, log_message(), LOG_TEST, run_test_suite(), stress_suites, TestStats::total_error, TestStats::total_fail, TestStats::total_pass, TestStats::total_skip, and TestStats::total_tests.

Here is the call graph for this function:



7.334.3 Variable Documentation

7.334.3.1 stress_suites

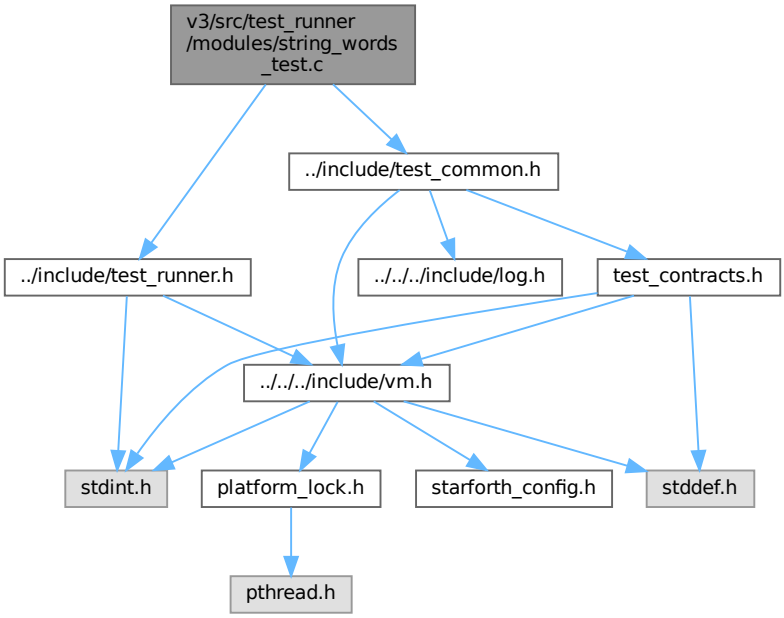
```
WordTestSuite stress_suites[]  [static]
```

Referenced by run_stress_tests().

7.335 v3/src/test_runner/modules/string_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for string_words_test.c:



Functions

- void run_string_words_tests (VM *vm)

  Executes all string manipulation word tests.

Variables

- static WordTestSuite string_word_suites [ ]

7.335.1 Function Documentation

7.335.1.1 run_string_words_tests()

```
void run_string_words_tests (
            VM * vm )
```

Executes all string manipulation word tests.

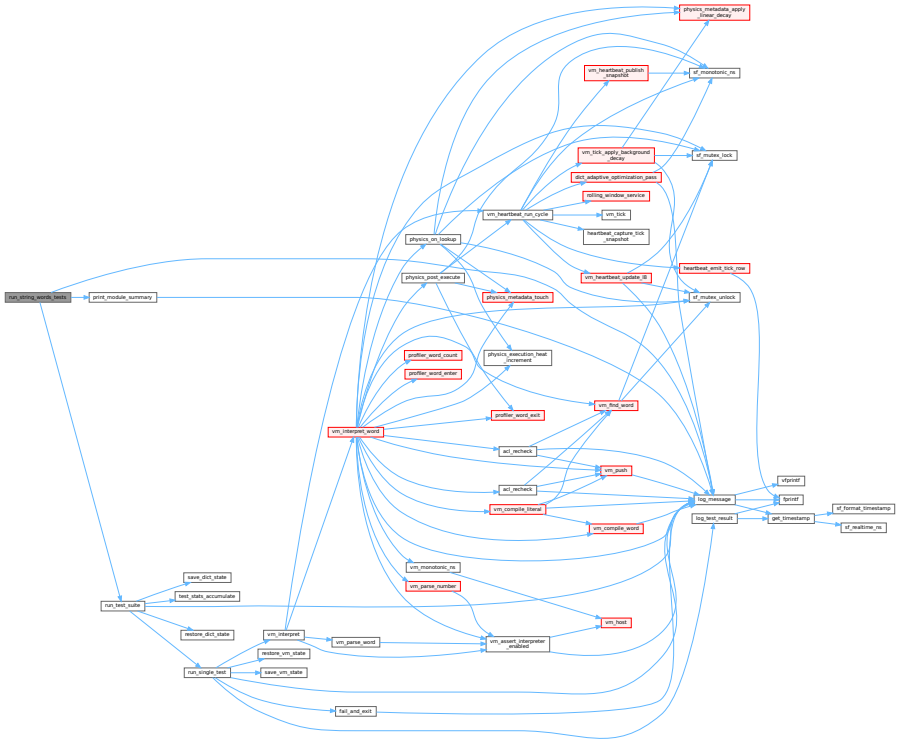
Runs test suites for FORTH string operations including COUNT, -TRAILING, CMOVE, CMOVE>, COMPARE, SEARCH, SCAN, SKIP, and BLANK

Parameters

vm	Pointer to the Forth virtual machine instance

References LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), string_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.335.2 Variable Documentation

7.335.2.1 string_word_suites

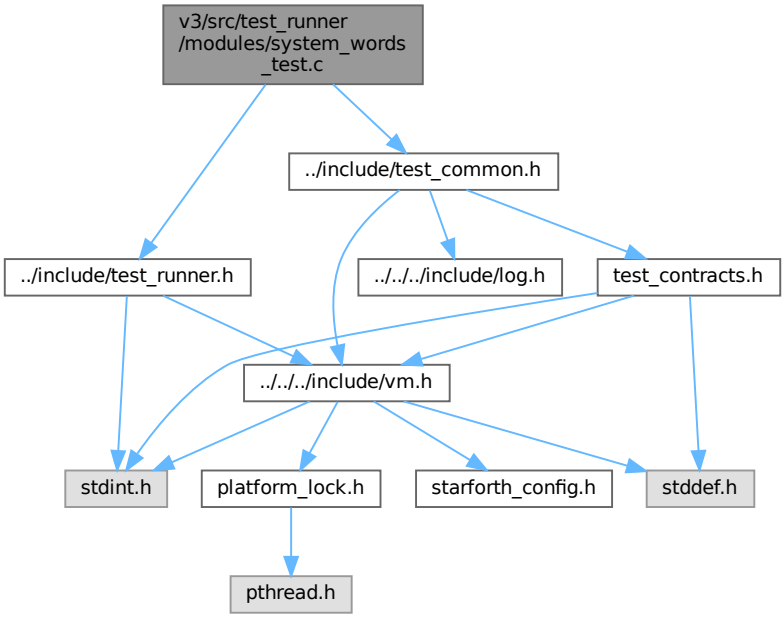
```
WordTestSuite string_word_suites[]  [static]
```

Referenced by run_string_words_tests().

7.336 v3/src/test_runner/modules/system_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for system_words_test.c:



Functions

- void run_system_words_tests (VM *vm)

  Executes all system word tests.

Variables

- static WordTestSuite system_word_suites [ ]

  Test suite definitions for system control words.

7.336.1 Function Documentation

7.336.1.1 run_system_words_tests()

```
void run_system_words_tests (
            VM * vm )
```

Executes all system word tests.

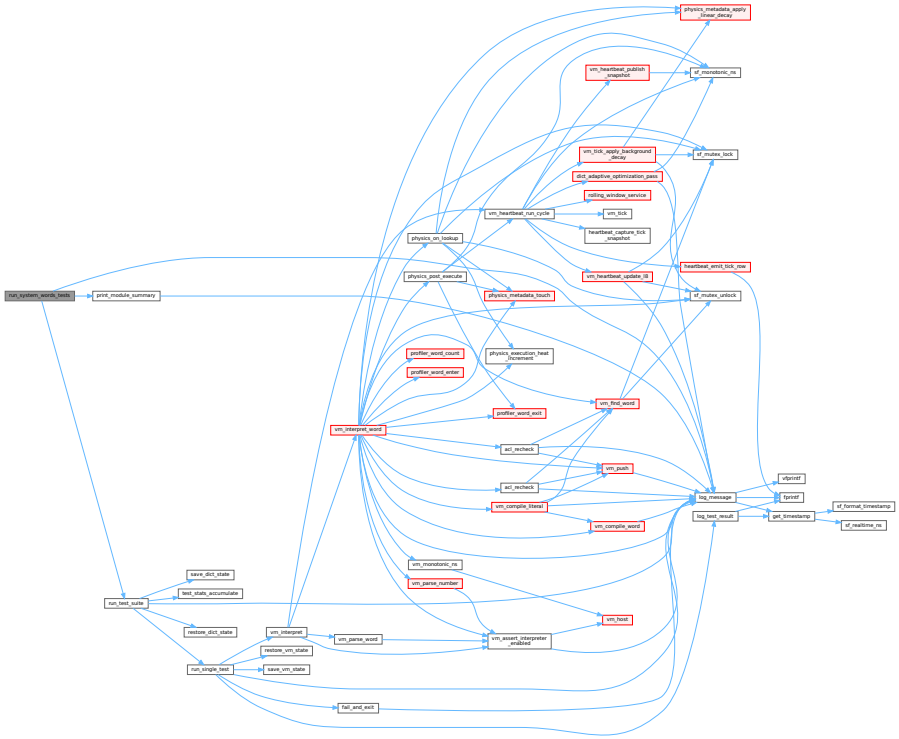
Runs test suites for FORTH system control operations including QUIT, ABORT, ABORT", BYE, COLD, and WARM. Some tests are marked as unimplemented due to their system-level effects

Parameters

vm	Pointer to the Forth virtual machine instance

References LOG_INFO, log_message(), LOG_TEST, LOG_WARN, print_module_summary(), run_test_suite(), system_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.336.2 Variable Documentation

7.336.2.1 system_word_suites

```
WordTestSuite system_word_suites[]  [static]
```

Test suite definitions for system control words.

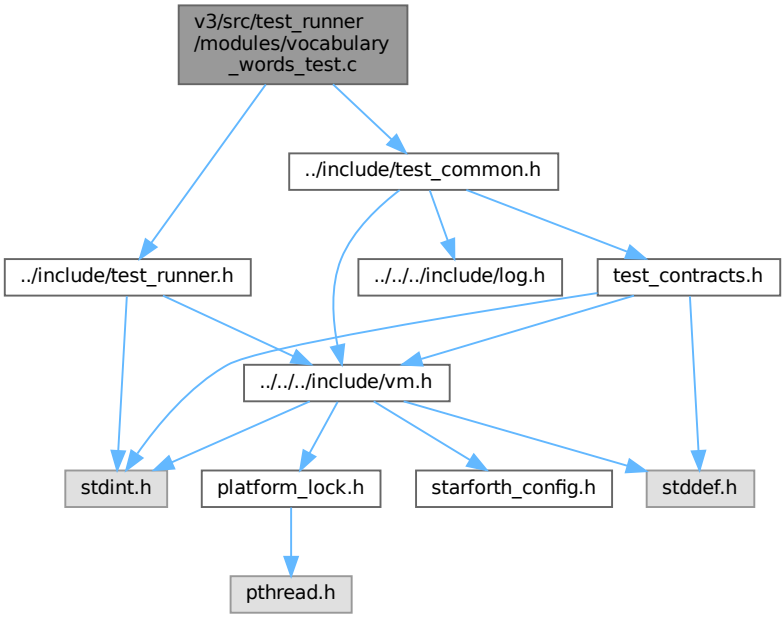
Contains test cases for each system word including normal operations and error conditions

Referenced by run_system_words_tests().

7.337 v3/src/test_runner/modules/vocabulary_words_test.c File Reference

```
#include "../include/test_runner.h"
#include "../include/test_common.h"
```

Include dependency graph for vocabulary_words_test.c:



Functions

- void run_vocabulary_words_tests (VM *vm)

  Executes all vocabulary word test suites.

Variables

- static WordTestSuite vocabulary_word_suites [ ]

  Test suites for vocabulary-related FORTH words (Module 15)

7.337.1 Function Documentation

7.337.1.1 run_vocabulary_words_tests()

```
void run_vocabulary_words_tests (
            VM * vm )
```

Executes all vocabulary word test suites.

Parameters

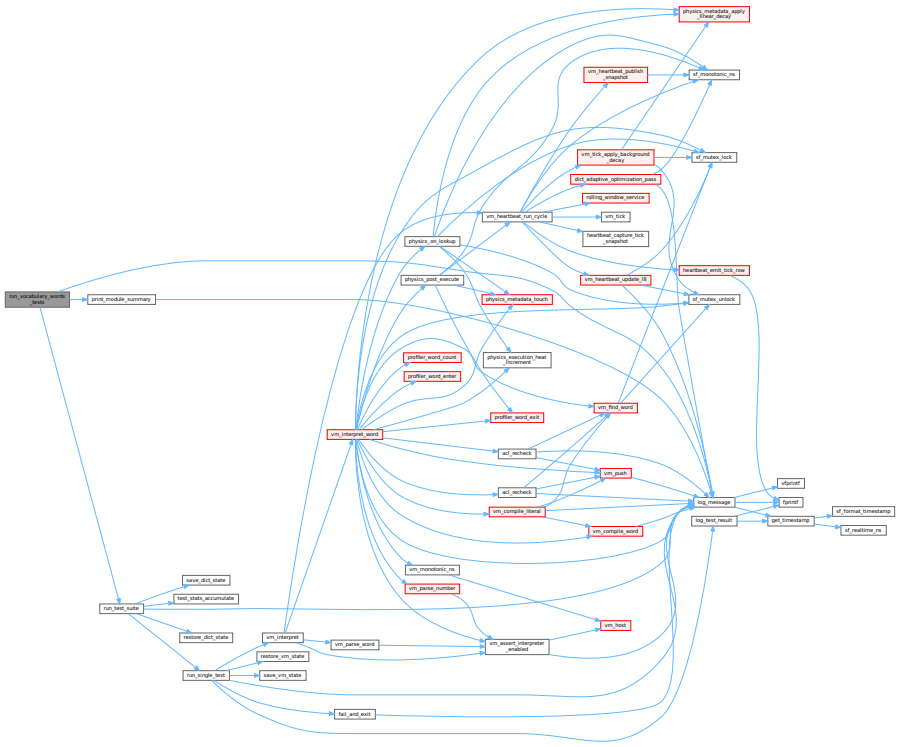
vm	Pointer to the Forth virtual machine instance

Runs through all vocabulary-related test suites, executing each test case and logging the results_run_01_2025_↩

12_08. Tests vocabulary creation, selection, and manipulation.

References LOG_INFO, log_message(), LOG_TEST, print_module_summary(), run_test_suite(), vocabulary_word_suites, and WordTestSuite::word_name.

Here is the call graph for this function:



7.337.2 Variable Documentation

7.337.2.1 vocabulary_word_suites

```
WordTestSuite vocabulary_word_suites[]  [static]
```

Test suites for vocabulary-related FORTH words (Module 15)

Contains test cases for each vocabulary word, including normal operations and error cases. Each suite tests specific functionality of the vocabulary system.

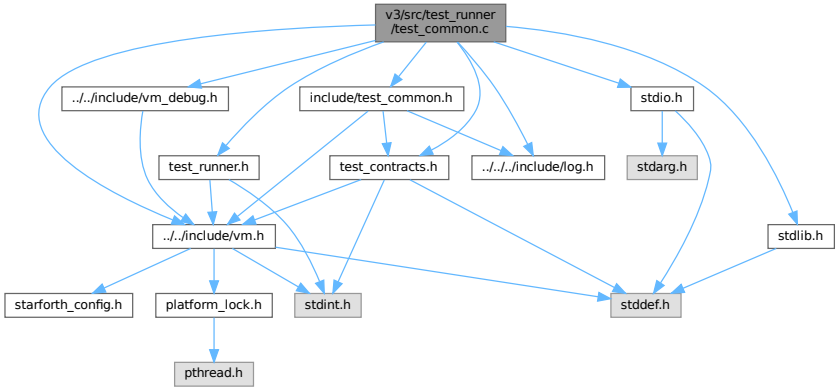
Referenced by run_vocabulary_words_tests().

7.338 v3/src/test_runner/test_common.c File Reference

```
#include "../../include/vm.h"
#include "../../include/vm_debug.h"
#include "include/test_common.h"
#include "include/test_contracts.h"
#include "../../include/log.h"
```

```
#include "test_runner.h"
#include <stdio.h>
#include <stdlib.h>
```

Include dependency graph for test_common.c:



Macros

- #define test_fatal_exit() exit(1)
- #define DIE(vm, why) dump_and_die((vm), (why), __FILE__, __LINE__)

Functions

- static void dump_and_die (VM *vm, const char *reason, const char *file, int line)

  Dumps VM state and terminates execution.
- static void fail_and_exit (VM *vm, const char *module, const char *case_name, const char *input, const char *reason)

  Handles test failure and exits.
- void save_vm_state (VM *vm, int *dsp, int *rsp, int *error, vm_mode_t *mode)

  Saves current VM state.
- void restore_vm_state (VM *vm, int dsp, int rsp, int error, vm_mode_t mode)

  Restores previously saved VM state.
- int assert_stack_depth (VM *vm, int expected_depth)

  Verifies VM stack depth matches expected value.
- int assert_stack_top (VM *vm, int expected_value)

  Verifies top value on VM stack matches expected value.
- int assert_vm_error (VM *vm, int should_have_error)

  Verifies VM error state matches expectation.
- TestResult run_single_test (VM *vm, const char *word_name, const TestCase *test)

  Executes a single test case.
- void run_test_suite (VM *vm, const WordTestSuite *suite)

  Executes a complete test suite for a Forth word.
- static WordContract resolve_contract (WordContract test_c, WordContract suite_c, WordContract module_c)

  Resolves the effective contract for a test case.
- void run_test_suite_m (VM *vm, const WordTestSuite *suite, WordContract module_contract)

  Runs all tests in a suite with an inherited module-level contract.

- void print_module_summary (const char *module_name, int pass, int fail, int skip, int error)

  Prints test module execution summary.
- void save_dict_state (VM *vm, DictEntry **latest, size_t *here)

  Saves current dictionary state before test execution.
- void restore_dict_state (VM *vm, DictEntry *latest, size_t here)

  Restores dictionary state after test execution.

Variables

- int fail_fast = 0

  Global flag to control test execution behavior.

7.338.1 Macro Definition Documentation

7.338.1.1 DIE

```
#define DIE(
              vm,
              why ) dump_and_die((vm), (why), __FILE__, __LINE__)
```

7.338.1.2 test_fatal_exit

```
#define test_fatal_exit( ) exit(1)
```

7.338.2 Function Documentation

7.338.2.1 assert_stack_depth()

```
int assert_stack_depth (
            VM * vm,
            int expected_depth )
```

Verifies VM stack depth matches expected value.

Parameters

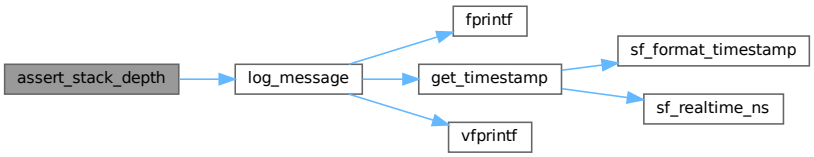
vm	Pointer to VM instance
expected_depth	Expected stack depth

Returns

1 if assertion passes, 0 if it fails

References VM::dsp, LOG_ERROR, and log_message().

Here is the call graph for this function:



7.338.2.2 assert_stack_top()

```
int assert_stack_top (
            VM * vm,
            int expected_value )
```

Verifies top value on VM stack matches expected value.

Parameters

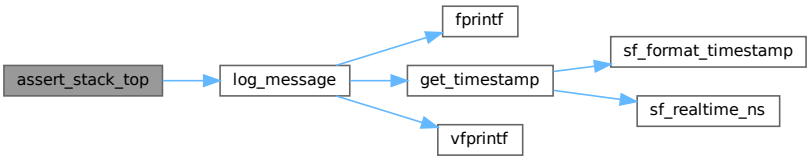
vm	Pointer to VM instance
expected_value	Expected value on top of stack

Returns

1 if assertion passes, 0 if it fails

References VM::data_stack, VM::dsp, LOG_ERROR, and log_message().

Here is the call graph for this function:



7.338.2.3 assert_vm_error()

```
int assert_vm_error (
            VM * vm,
            int should_have_error )
```

Verifies VM error state matches expectation.

Parameters

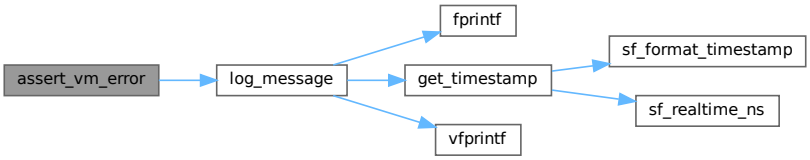
vm	Pointer to VM instance
should_have_error	Expected error state (1 for error, 0 for no error)

Returns

1 if assertion passes, 0 if it fails

References VM::error, LOG_ERROR, and log_message().

Here is the call graph for this function:



7.338.2.4 dump_and_die()

```
static void dump_and_die (
            VM * vm,
            const char * reason,
            const char * file,
            int line )  [static]
```

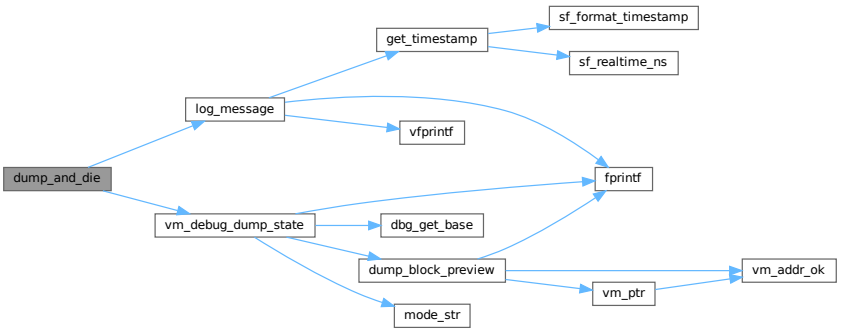
Dumps VM state and terminates execution.

Parameters

vm	Pointer to VM instance
reason	String describing the failure reason
file	Source file where failure occurred
line	Line number where failure occurred

References LOG_ERROR, log_message(), test_fatal_exit, and vm_debug_dump_state().

Here is the call graph for this function:



7.338.2.5 fail_and_exit()

```
static void fail_and_exit (
            VM * vm,
            const char * module,
            const char * case_name,
            const char * input,
            const char * reason )  [static]
```

Handles test failure and exits.

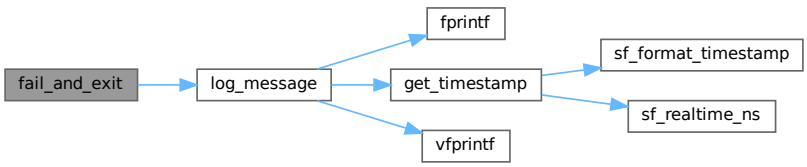
Parameters

vm	Pointer to VM instance
module	Name of the test module
case_name	Name of the test case
input	Test input that caused the failure
reason	Description of failure reason

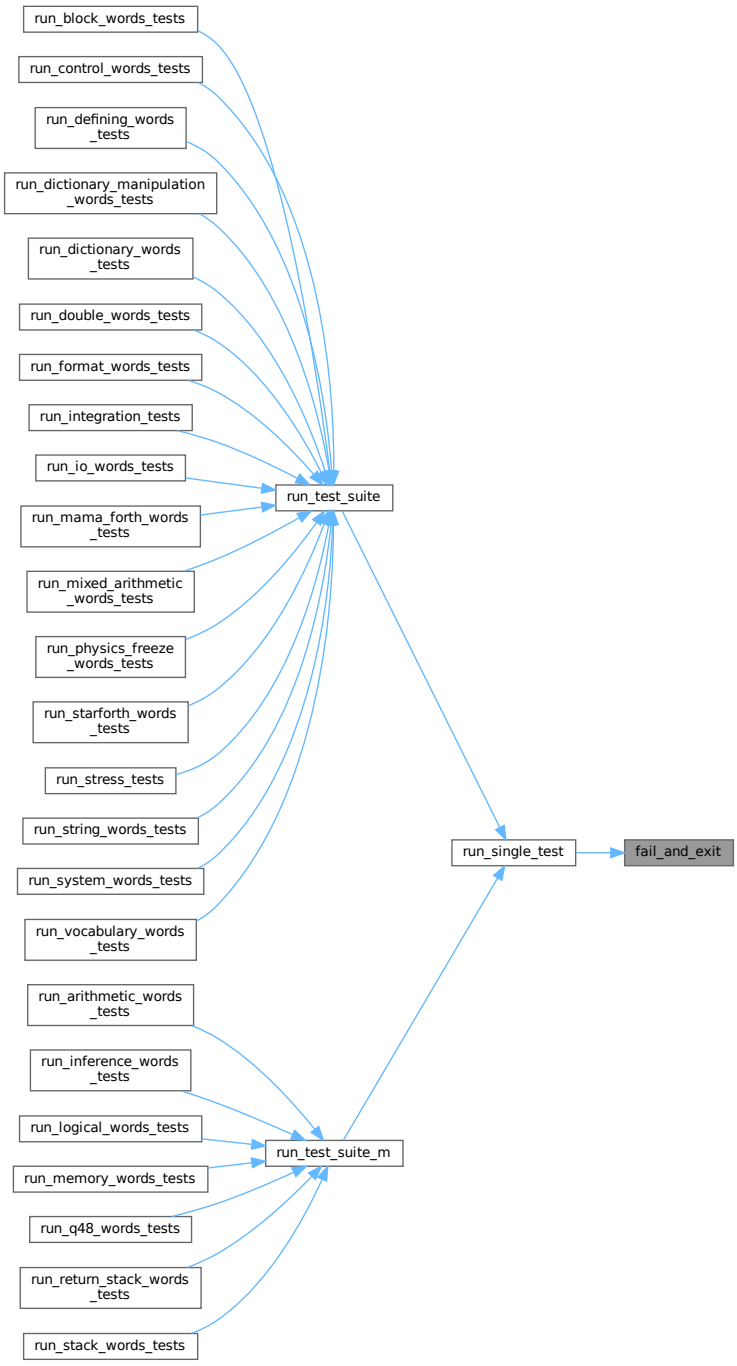
References DIE, LOG_ERROR, and log_message().

Referenced by run_single_test().

Here is the call graph for this function:



Here is the caller graph for this function:



7.338.2.6 print_module_summary()

```
void print_module_summary (
            const char * module_name,
            int pass,
            int fail,
```

```
int skip,
int error )
```

Prints test module execution summary.

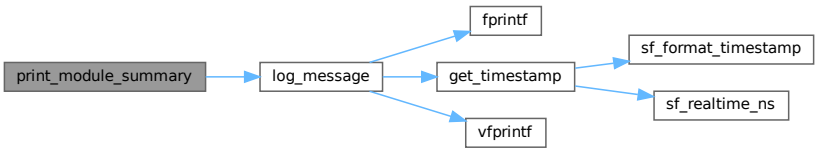
Parameters

module_name	Name of the test module
pass	Number of passed tests
fail	Number of failed tests
skip	Number of skipped tests
error	Number of tests with errors

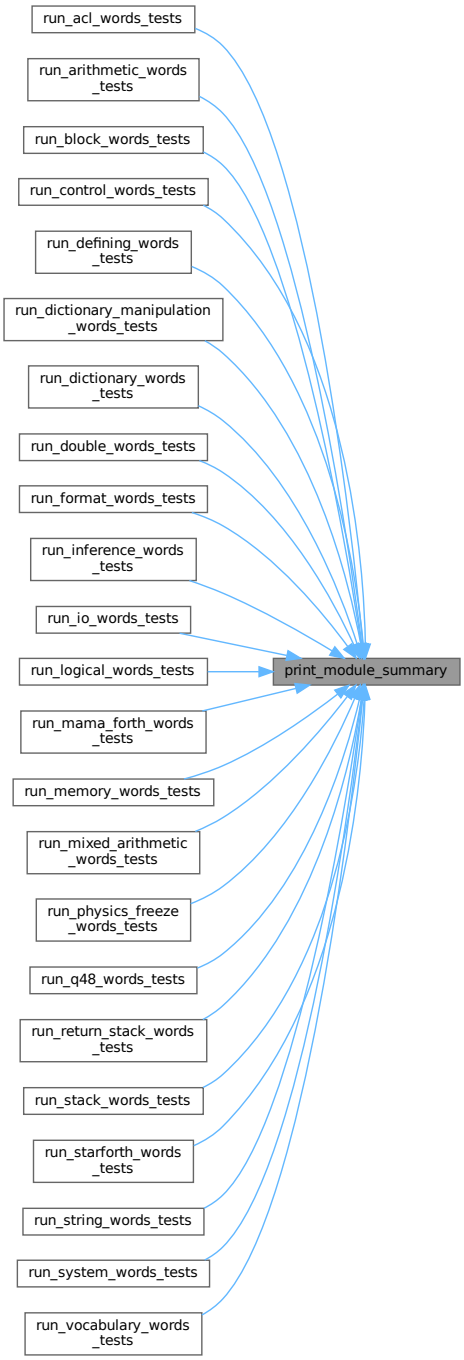
References log_message(), and LOG_TEST.

Referenced by run_acl_words_tests(), run_arithmetic_words_tests(), run_block_words_tests(), run_control_words_tests(), run_defining_words_tests(), run_dictionary_manipulation_words_tests(), run_dictionary_words_tests(), run_double_words_tests(), run_format_words_tests(), run_inference_words_tests(), run_io_words_tests(), run_logical_words_tests(), run_mama_forth_words_tests(), run_memory_words_tests(), run_mixed_arithmetic_words_tests(), run_physics_freeze_words_tests(), run_q48_words_tests(), run_return_stack_words_tests(), run_stack_words_tests(), run_starforth_words_tests(), run_string_words_tests(), run_system_words_tests(), and run_vocabulary_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.338.2.7 resolve_contract()

```
static WordContract resolve_contract (
            WordContract test_c,
            WordContract suite_c,
            WordContract module_c )  [static]
```

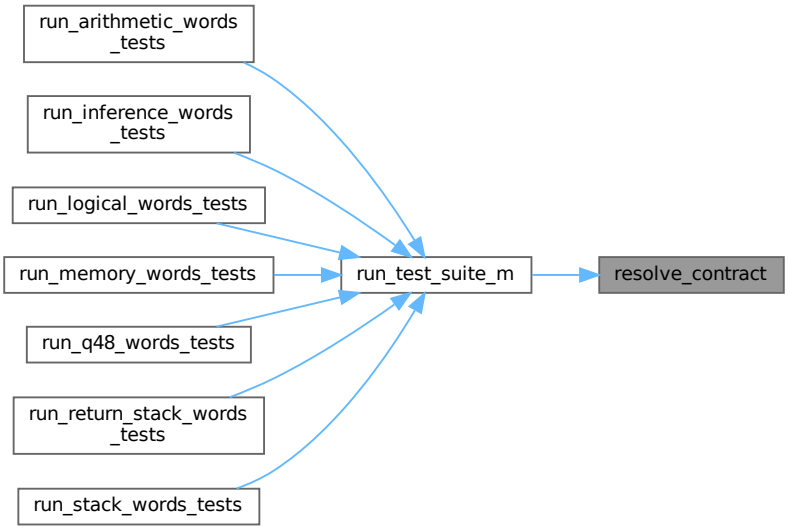
Resolves the effective contract for a test case.

First non-NONE source wins: per-test > per-suite > module.

References WordContract::flags.

Referenced by run_test_suite_m().

Here is the caller graph for this function:



7.338.2.8 restore_dict_state()

```
void restore_dict_state (
            VM * vm,
            DictEntry * latest,
            size_t here )
```

Restores dictionary state after test execution.

Parameters

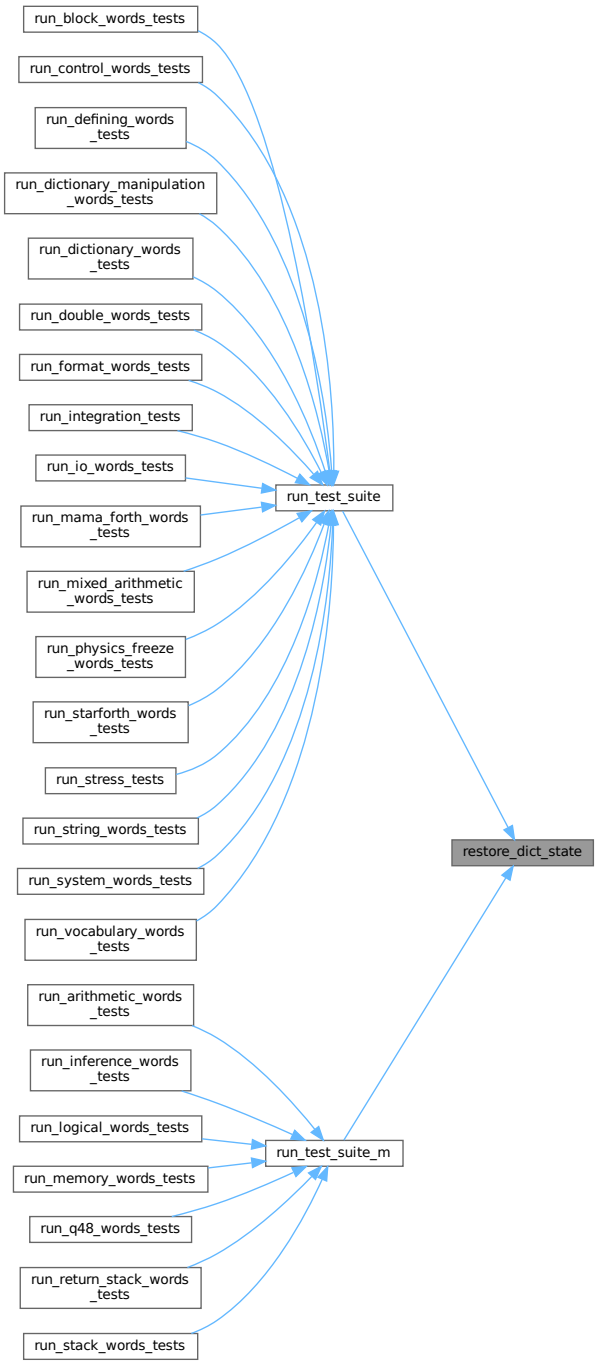
vm	Pointer to VM instance
latest	Latest dictionary entry to restore
here	HERE pointer to restore

Removes all words added during test by restoring dictionary pointers. This prevents test pollution of the dictionary and ensures each test starts with a clean slate.

References VM::here, and VM::latest.

Referenced by run_test_suite(), and run_test_suite_m().

Here is the caller graph for this function:



7.338.2.9 restore_vm_state()

```
void restore_vm_state (
            VM * vm,
            int dsp,
            int rsp,
```

```
    int error,
    vm_mode_t mode )
```

Restores previously saved VM state.

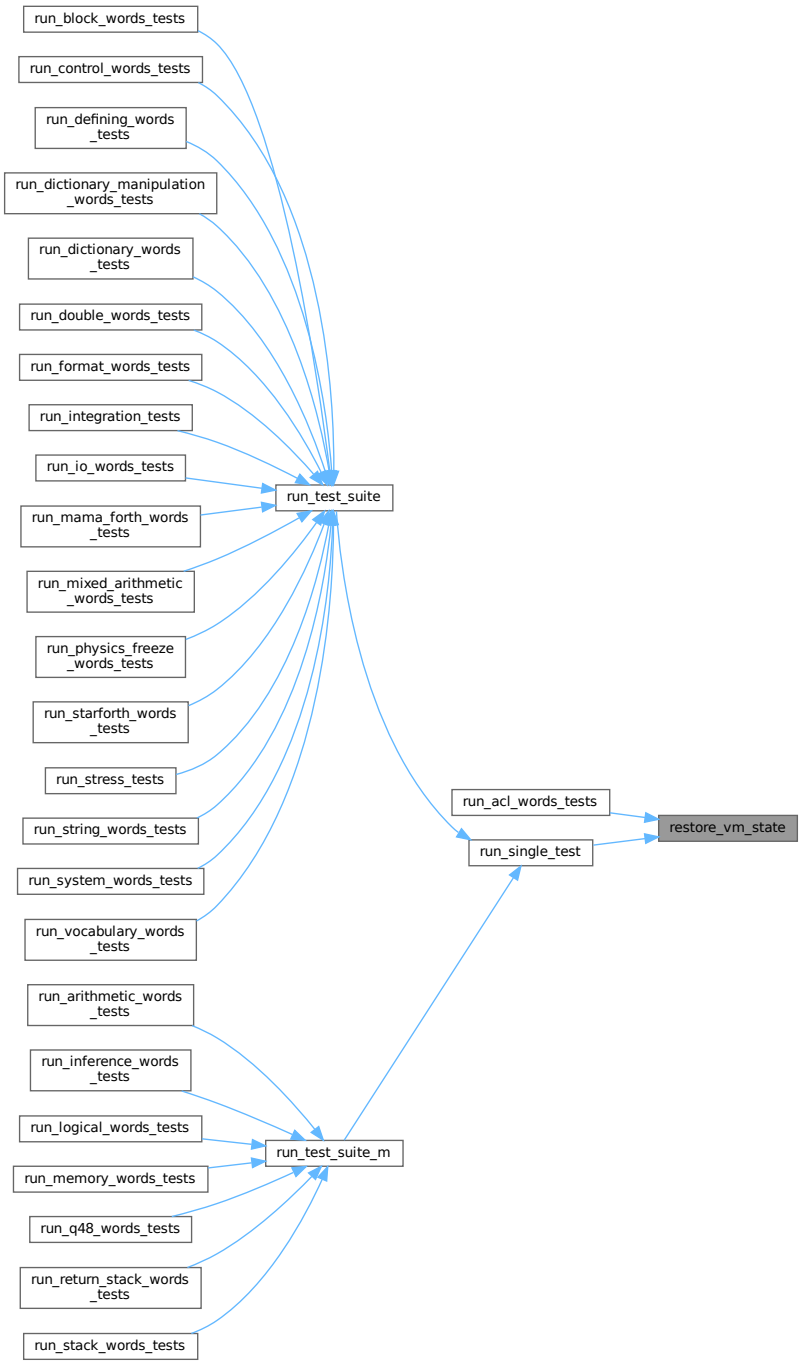
Parameters

vm	Pointer to VM instance
dsp	Data stack pointer to restore
rsp	Return stack pointer to restore
error	Error state to restore
mode	VM mode to restore

References VM::abort_requested, VM::compiling_word, VM::current_executing_entry, VM::dsp, VM::error, VM::exit_colon, VM::mode, and VM::rsp.

Referenced by run_acl_words_tests(), and run_single_test().

Here is the caller graph for this function:



7.338.2.10 run_single_test()

```
TestResult run_single_test (
            VM * vm,
            const char * word_name,
            const TestCase * test )
```

Executes a single test case.

Parameters

vm	Pointer to VM instance
word_name	Name of the word being tested
test	Pointer to test case definition

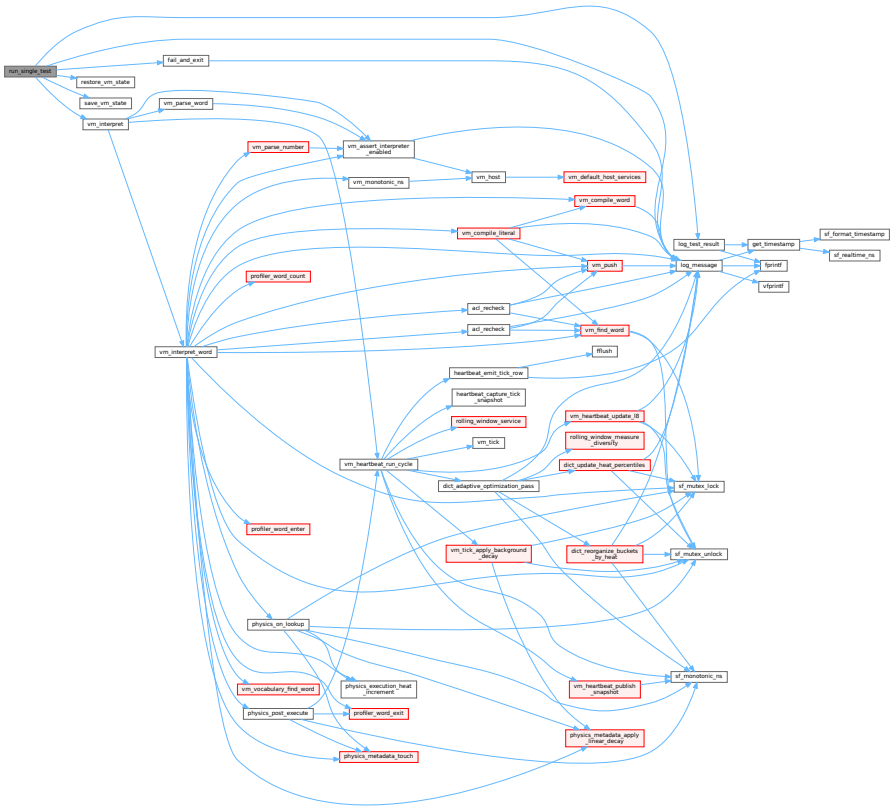
Returns

Test result (PASS, FAIL, SKIP, or ERROR)

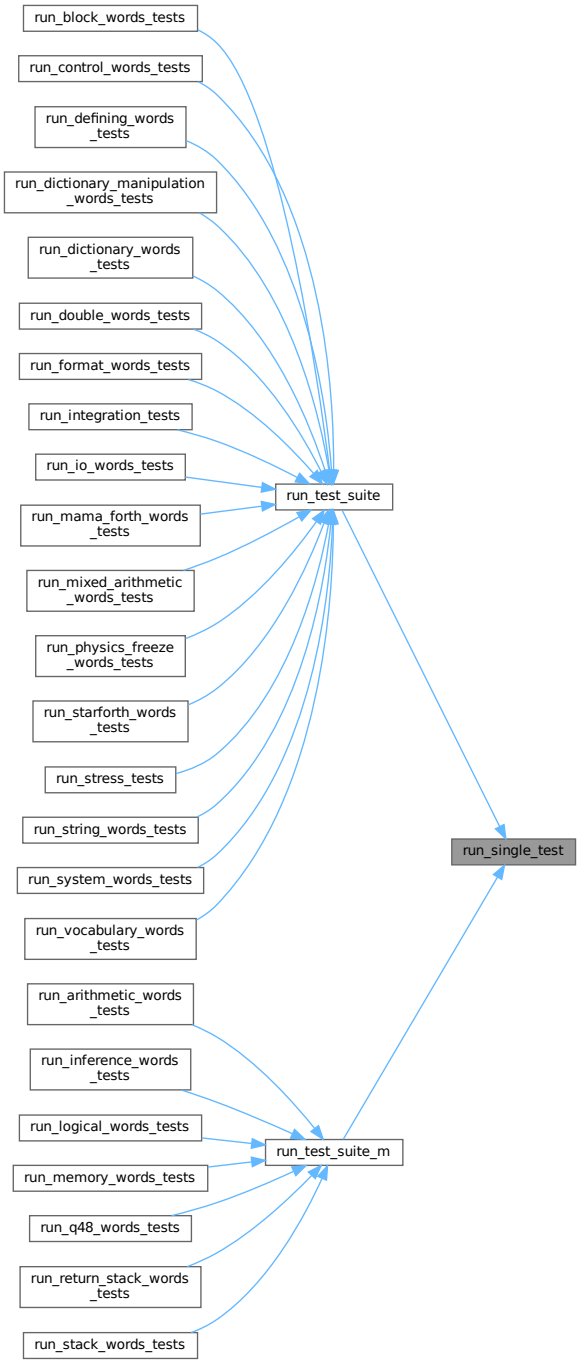
References VM::error, TestCase::expected, fail_and_exit(), fail_fast, TestCase::implemented, TestCase::input, LOG_ERROR, log_message(), LOG_TEST, log_test_result(), TestCase::name, restore_vm_state(), save_vm_state(), TestCase::should_error, TEST_FAIL, TEST_PASS, TEST_SKIP, and vm_interpret().

Referenced by run_test_suite(), and run_test_suite_m().

Here is the call graph for this function:



Here is the caller graph for this function:



7.338.2.11 run_test_suite()

```
void run_test_suite (
            VM * vm,
            const WordTestSuite * suite )
```

Executes a complete test suite for a Forth word.

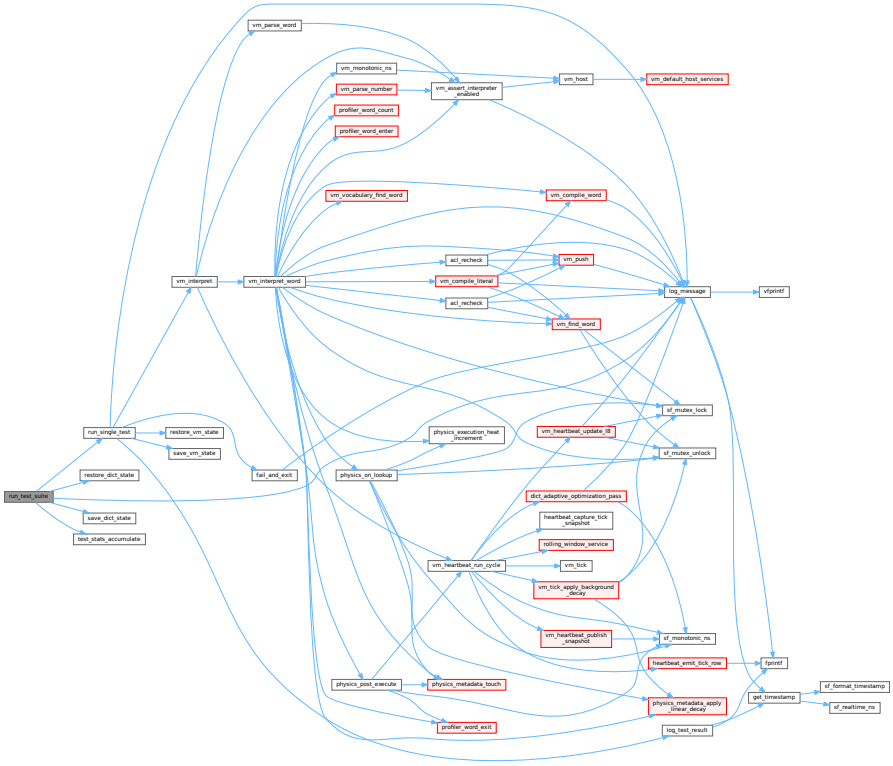
Parameters

vm	Pointer to VM instance
suite	Pointer to test suite definition

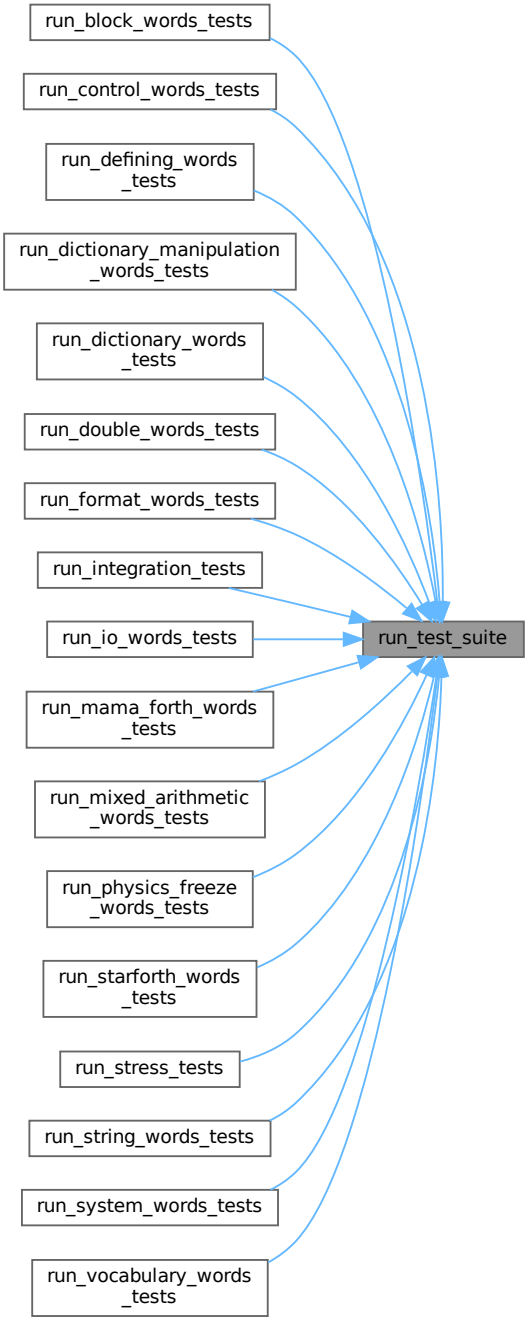
References TestCase::implemented, log_message(), LOG_TEST, TestCase::name, restore_dict_state(), run_single_test(), save_dict_state(), WordTestSuite::test_count, TEST_ERROR, TEST_FAIL, TEST_PASS, TEST_SKIP, test_stats_accumulate(), WordTestSuite::tests, and WordTestSuite::word_name.

Referenced by run_block_words_tests(), run_control_words_tests(), run_defining_words_tests(), run_dictionary_manipulation_words_ run_dictionary_words_tests(), run_double_words_tests(), run_format_words_tests(), run_integration_tests(), run_io_words_tests(), run_mama_forth_words_tests(), run_mixed_arithmetic_words_tests(), run_physics_freeze_words_tests(), run_starforth_words_tests(), run_stress_tests(), run_string_words_tests(), run_system_words_tests(), and run_vocabulary_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.338.2.12 run_test_suite_m()

```
void run_test_suite_m (
            VM * vm,
            const WordTestSuite * suite,
            WordContract module_contract )
```

Runs all tests in a suite with an inherited module-level contract.

Contract resolution order (first non-NONE wins): test->contract > suite->suite_contract > module_contract

When CONTRACTS_ENABLED=1, each passing TEST_NORMAL test is re-run under physics perturbation to witness A4' (word_physics_transparent).

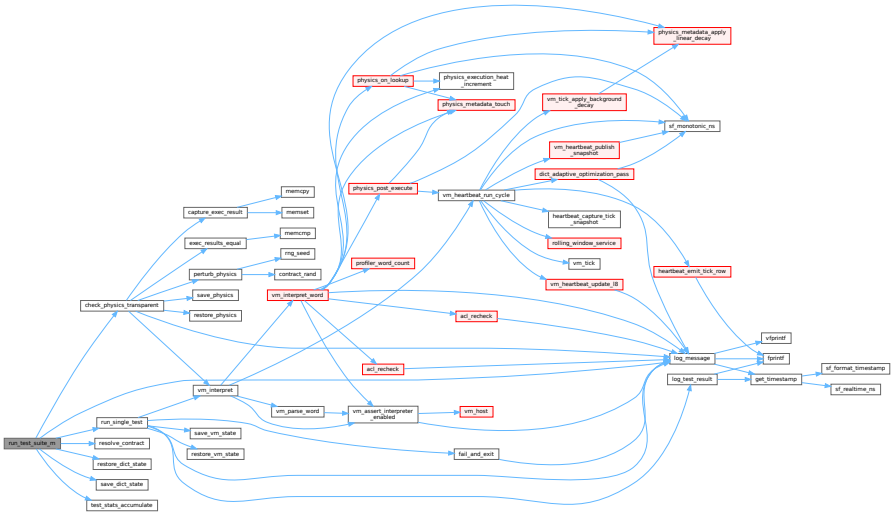
Parameters

vm	Pointer to the VM instance
suite	Test suite to execute
module_contract	Default contract for tests that don't specify one

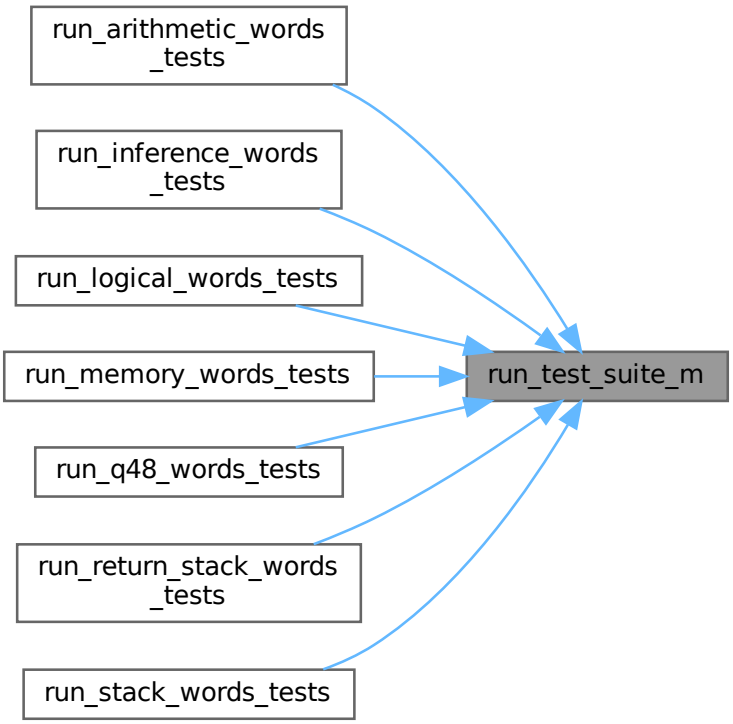
References check_physics_transparent(), TestCase::contract, CONTRACT_PHYSICS_TRANSPARENT, WordContract::flags, WordContract::fuzz_rounds, TestCase::implemented, TestCase::input, log_message(), LOG_TEST, TestCase::name, resolve_contract(), restore_dict_state(), run_single_test(), save_dict_state(), TestCase::should_error, WordTestSuite::suite_contract, WordTestSuite::test_count, TEST_ERROR, TEST_ERROR_CASE, TEST_FAIL, TEST_PASS, TEST_SKIP, test_stats_accumulate(), WordTestSuite::tests, TestCase::type, and WordTestSuite::word_name.

Referenced by run_arithmetic_words_tests(), run_inference_words_tests(), run_logical_words_tests(), run_memory_words_tests(), run_q48_words_tests(), run_return_stack_words_tests(), and run_stack_words_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.338.2.13 save_dict_state()

```
void save_dict_state (
            VM * vm,
            DictEntry ** latest,
            size_t * here )
```

Saves current dictionary state before test execution.

Parameters

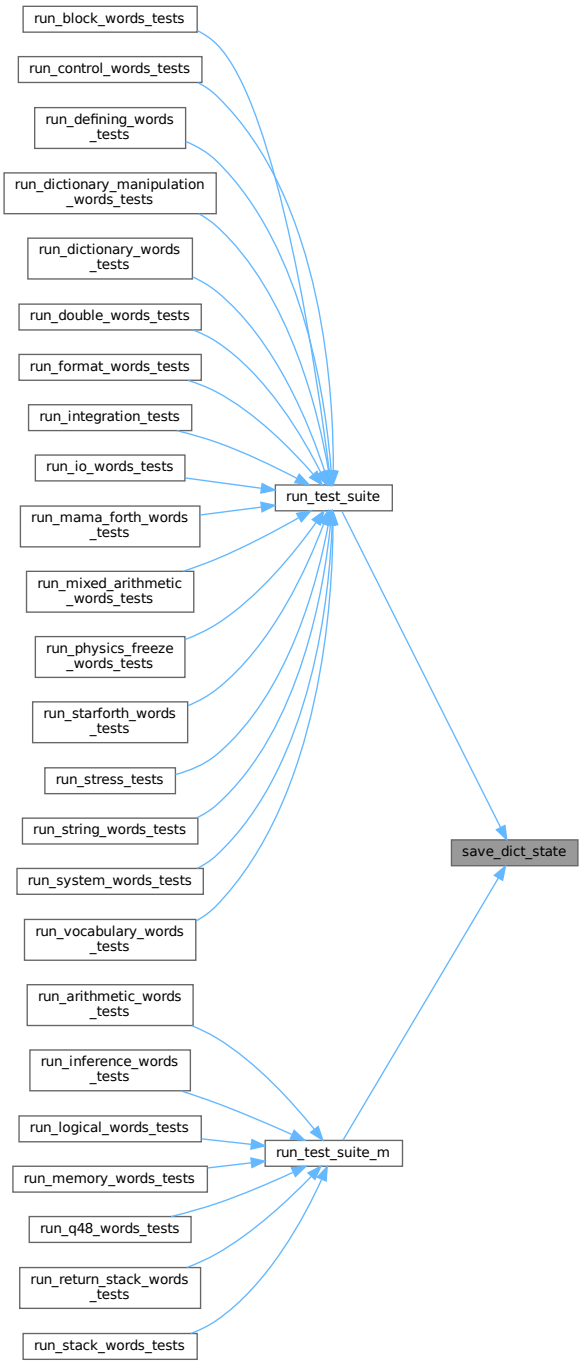
vm	Pointer to VM instance
latest	Pointer to store latest dictionary entry
here	Pointer to store HERE pointer

Captures dictionary state so tests can be cleaned up after execution

References VM::here, and VM::latest.

Referenced by run_test_suite(), and run_test_suite_m().

Here is the caller graph for this function:



7.338.2.14 save_vm_state()

```
void save_vm_state (
            VM * vm,
            int * dsp,
            int * rsp,
```

```
    int * error,
    vm_mode_t * mode )
```

Saves current VM state.

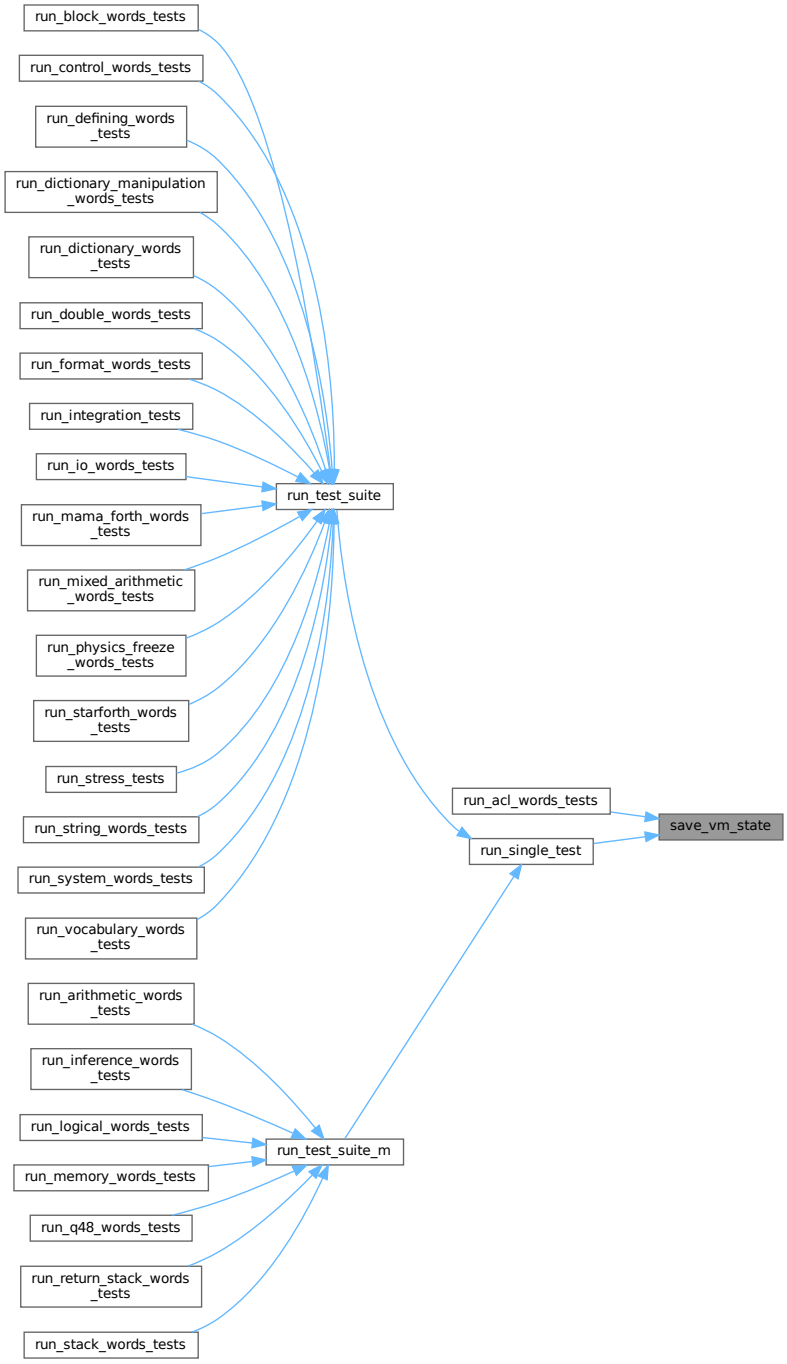
Parameters

vm	Pointer to VM instance
dsp	Pointer to store data stack pointer
rsp	Pointer to store return stack pointer
error	Pointer to store error state
mode	Pointer to store VM mode

References VM::dsp, VM::error, VM::mode, and VM::rsp.

Referenced by run_acl_words_tests(), and run_single_test().

Here is the caller graph for this function:



7.338.3 Variable Documentation

7.338.3.1 fail_fast

```
int fail_fast = 0
```

Global flag to control test execution behavior.

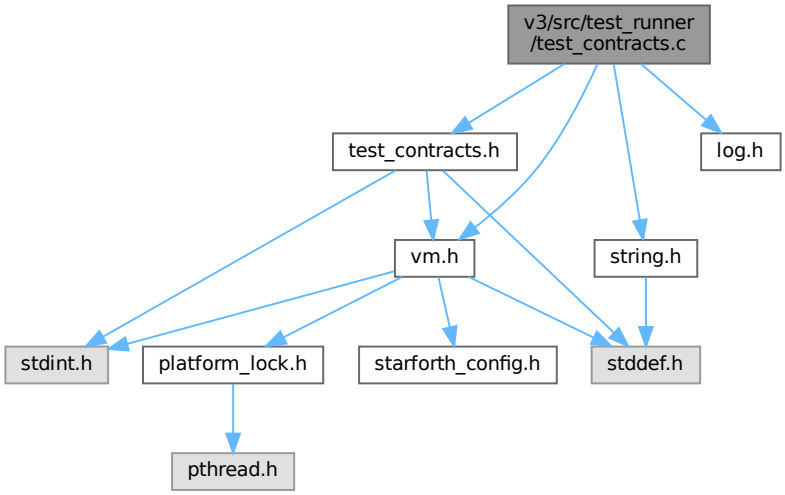
When set to non-zero, causes test runner to exit immediately on first failure

Referenced by main(), and run_single_test().

7.339 v3/src/test_runner/test_contracts.c File Reference

```
#include "test_contracts.h"
#include "log.h"
#include "vm.h"
#include <string.h>
```

Include dependency graph for test_contracts.c:



Functions

- int contract_get_violation_count (void)

  Return the current count of accumulated contract violations.
- void contract_reset_violation_count (void)

  Reset the contract violation counter to zero.
- static uint64_t contract_rand (void)

  Generate the next pseudo-random 64-bit value via xorshift64.
- static void rng_seed (int round)

  Seed the RNG for a given fuzz round.
- void capture_exec_result (VM *vm, ExecResult *r)

  Snapshot the execution-domain fields of a VM into an `ExecResult`.
- int exec_results_equal (const ExecResult *a, const ExecResult *b)

  Compare two `ExecResult` snapshots for execution-domain equality.
- void save_physics (VM *vm, PhysicsSnapshot *s)

  Save the key physics scalars touched by the seven feedback loops.
- void restore_physics (VM *vm, const PhysicsSnapshot *s)

  Restore the physics scalars from a previously saved snapshot.

- void perturb_physics (VM *vm, int round)

  Randomly perturb key physics scalars to expose A4' violations.
- int check_physics_transparent (VM *vm, const char *word_name, const char *input, int should_error, int implemented, int fuzz_rounds)

  A4' contract check — verify a word is transparent to physics state.
- int assert_heartbeat_safe (VM *vm)

  A1 contract check — verify `vm_tick()` does not modify the execution domain.

Variables

- int global_contract_violations = 0
- static uint64_t rng_state = 0xDEADBEEFCAFEBABEULL

7.339.1 Function Documentation

7.339.1.1 assert_heartbeat_safe()

```
int assert_heartbeat_safe (
            VM * vm )
```

A1 contract check — verify `vm_tick()` does not modify the execution domain.

Axiom A1 (heartbeat isolation): the background heartbeat tick must never alter stacks, error state, or any other execution-domain field observable by FORTH words. This function captures an `ExecResult` before and after one `vm_tick()` call and compares them with `exec_results_equal()`.

On violation, logs [A1 CONTRACT] VIOLATION with before/after dsp and rsp values, and increments `global_↩ contract_violations`.

Parameters

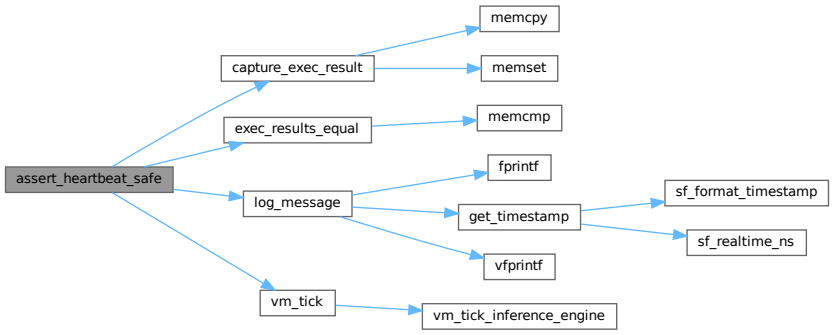
vm	VM instance; stacks and error state must already be in a known reference state before calling.

Returns

1 if the heartbeat left the execution domain unchanged, 0 on violation.

References capture_exec_result(), ExecResult::dsp, exec_results_equal(), global_contract_violations, LOG_ERROR, log_message(), ExecResult::rsp, and vm_tick().

Here is the call graph for this function:



7.339.1.2 capture_exec_result()

```
void capture_exec_result (
            VM * vm,
            ExecResult * r )
```

Snapshot the execution-domain fields of a VM into an `ExecResult`.

Captures `dsp`, `rsp`, `error`, and the live portion of the data stack (indices 0 ... dsp?1). The remainder of `r->stack` is zeroed for deterministic `memcmp()` comparisons in `exec_results_equal()`.

Only execution-domain fields are captured — physics scalars, heartbeat state, and rolling-window counters are deliberately excluded.

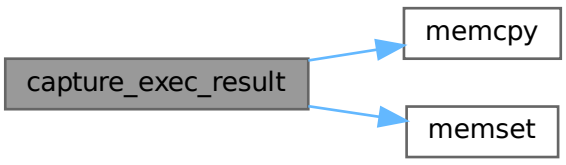
Parameters

vm	VM instance to snapshot.
r	Output `ExecResult` struct to populate.

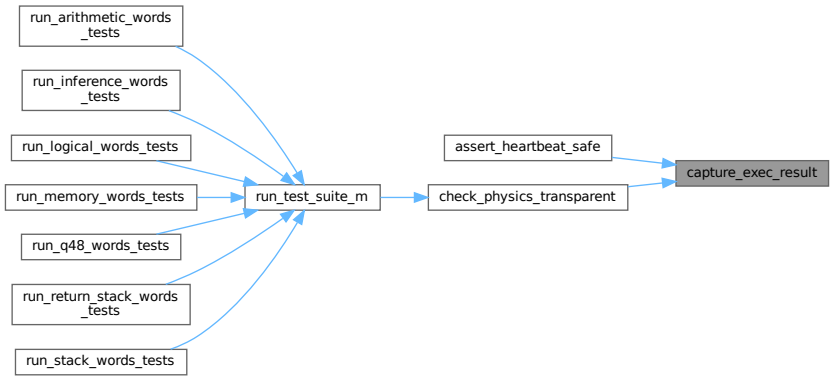
References VM::data_stack, VM::dsp, ExecResult::dsp, VM::error, ExecResult::error, memcpy(), memset(), VM::rsp, ExecResult::rsp, ExecResult::stack, and STACK_SIZE.

Referenced by assert_heartbeat_safe(), and check_physics_transparent().

Here is the call graph for this function:



Here is the caller graph for this function:



7.339.1.3 check_physics_transparent()

```
int check_physics_transparent (
            VM * vm,
            const char * word_name,
            const char * input,
            int should_error,
            int implemented,
            int fuzz_rounds )
```

A4' contract check — verify a word is transparent to physics state.

Axiom A4' (physics transparency): a FORTH word's execution-domain result (`ExecResult`) must be identical regardless of the values of the seven physics feedback-loop scalars.

Protocol:

1. Run `input` with current (unperturbed) physics; capture baseline.
2. For each of `fuzz_rounds` rounds: seed RNG, perturb physics, re-run `input`, capture result, compare to baseline.
3. On divergence, log the violation and increment `global_contract_violations`.
4. Always restore original physics state before returning.

Error-expected tests (`should_error`) and unimplemented words (`implemented` == 0) are skipped: exec-equivalent divergence is legitimate for error paths.

Parameters

vm	VM instance.
word_name	Human-readable word name for diagnostic messages.
input	FORTH source string to execute (same each round).
should_error	Non-zero if the test is expected to raise an error.
implemented	Non-zero if the word is implemented and should be checked.
fuzz_rounds	Number of perturbation rounds; 0 → CONTRACT_DEFAULT_FUZZ_ROUNDS.

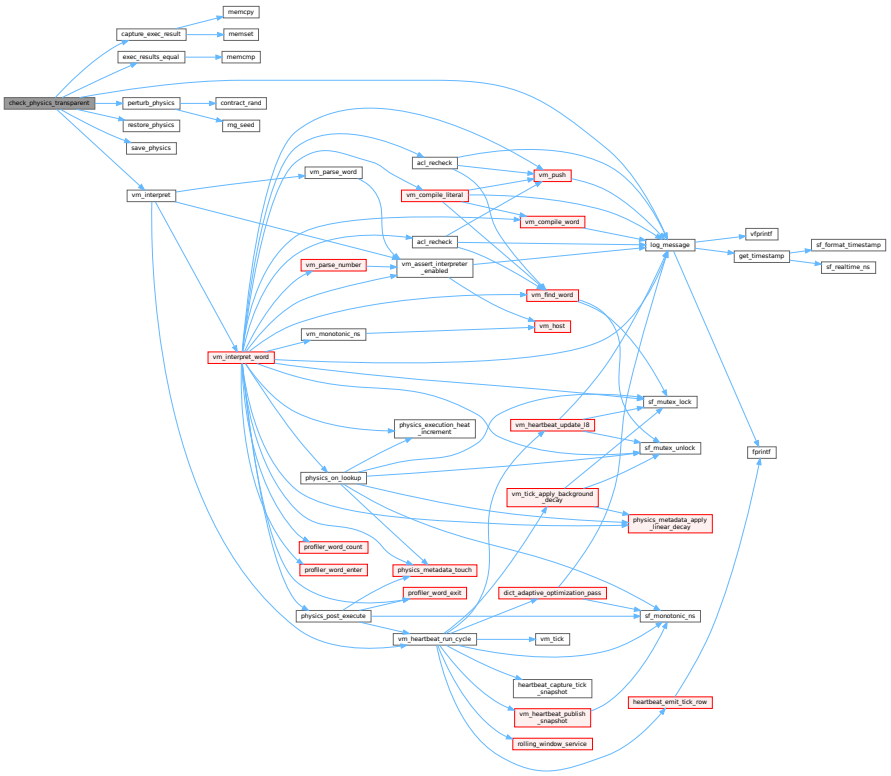
Returns

1 if all rounds passed (or test skipped), 0 on any violation.

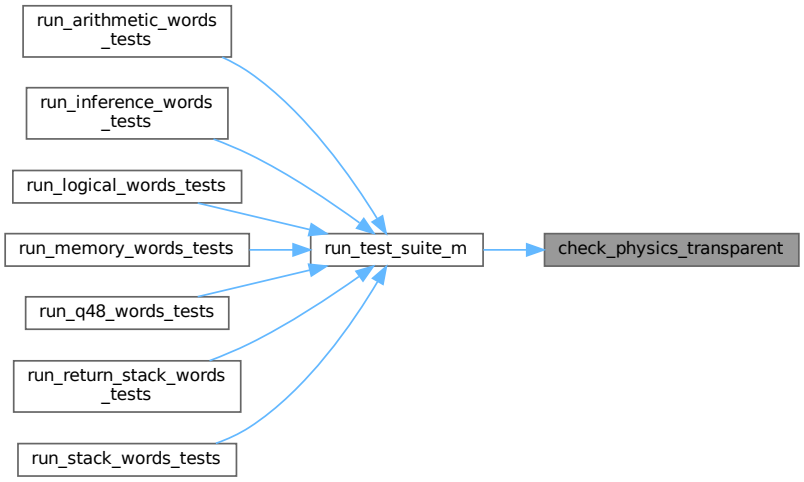
References VM::abort_requested, capture_exec_result(), CONTRACT_DEFAULT_FUZZ_ROUNDS, VM::dsp, ExecResult::dsp, VM::error, exec_results_equal(), VM::exit_colon, global_contract_violations, LOG_ERROR, log_message(), perturb_physics(), restore_physics(), VM::rsp, save_physics(), and vm_interpret().

Referenced by run_test_suite_m().

Here is the call graph for this function:



Here is the caller graph for this function:



7.339.1.4 contract_get_violation_count()

```
int contract_get_violation_count (
            void  )
```

Return the current count of accumulated contract violations.

Reads `global_contract_violations` directly; same-TU access avoids GOT double-dereference in `-fPIC` PE32+ builds where `R_X86_64_REX_GOTPCRELX` is not relaxed to a LEA instruction.

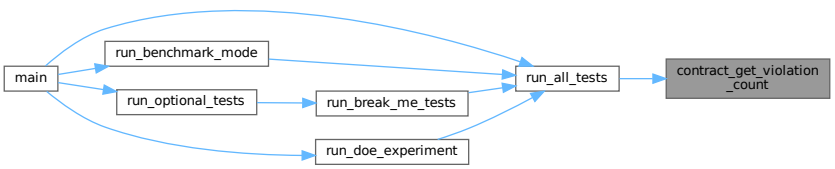
Returns

Number of contract violations recorded since last reset.

References global_contract_violations.

Referenced by run_all_tests().

Here is the caller graph for this function:



7.339.1.5 contract_rand()

```
static uint64_t contract_rand (
            void  )  [static]
```

Generate the next pseudo-random 64-bit value via xorshift64.

Uses the global `rng_state`. The xorshift64 parameters (13, 7, 17) produce a full-period sequence over all non-zero 64-bit states. Caller must seed via `rng_seed()` before starting a new fuzz round to ensure different perturbation sequences across rounds.

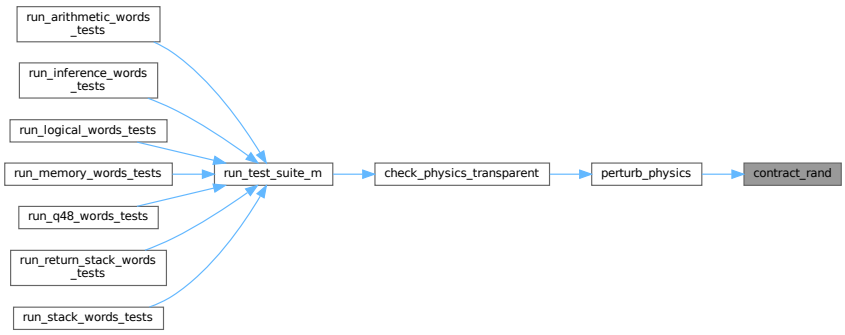
Returns

Next pseudo-random 64-bit integer.

References rng_state.

Referenced by perturb_physics().

Here is the caller graph for this function:



7.339.1.6 contract_reset_violation_count()

```
void contract_reset_violation_count (
            void  )
```

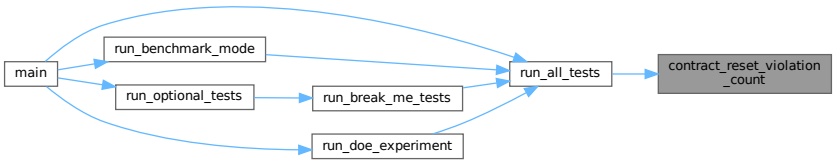
Reset the contract violation counter to zero.

Call before a fresh round of contract checks so that counts from earlier test phases do not accumulate across module boundaries.

References global_contract_violations.

Referenced by run_all_tests().

Here is the caller graph for this function:



7.339.1.7 exec_results_equal()

```
int exec_results_equal (
            const ExecResult * a,
            const ExecResult * b )
```

Compare two `ExecResult` snapshots for execution-domain equality.

Returns 1 only if `dsp`, `rsp`, `error`, and the live stack contents are all identical. Stack comparison uses `memcmp()` over the live portion (0 . . . dsp?1 cells); the zeroed tail guarantees no false positives from uninitialised padding.

Parameters

a	First snapshot.
b	Second snapshot.

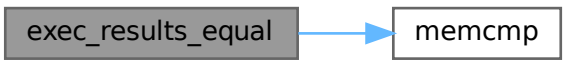
Returns

1 if execution-domain is identical, 0 if any field differs.

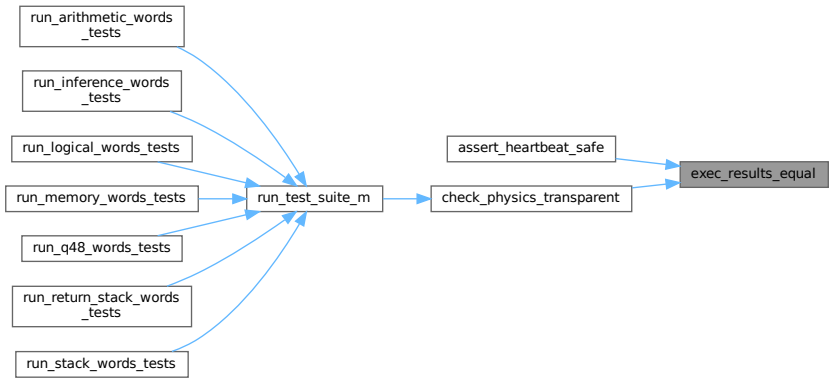
References ExecResult::dsp, ExecResult::error, memcmp(), ExecResult::rsp, and ExecResult::stack.

Referenced by assert_heartbeat_safe(), and check_physics_transparent().

Here is the call graph for this function:



Here is the caller graph for this function:



7.339.1.8 perturb_physics()

```
void perturb_physics (
            VM * vm,
            int round )
```

Randomly perturb key physics scalars to expose A4' violations.

Seeds the RNG via `rng_seed(round)` for deterministic but distinct perturbations per round, then overwrites the eight tracked physics fields with random values that still satisfy their well-formedness invariants:

- `decay_slope_q48`: LSB forced to 1 (must be $>$ 0 per `slope_wf`)
- `effective_window_size`: [1, ROLLING_WINDOW_SIZE] (never 0)
- `tick_target_ns`: LSB forced to 1 (must be $>$ 0 per `hb_state_wf`)
- Heat thresholds: arbitrary positive values (no strict invariant)
- `prefetch_attempts` / `total_executions`: arbitrary counts

After perturbation, running the same FORTH input must produce an identical `ExecResult`; divergence is an A4' violation.

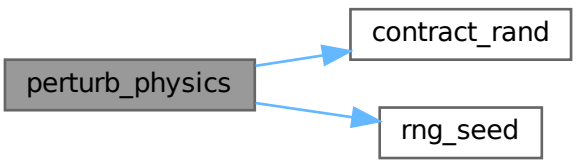
Parameters

vm	VM instance to perturb.
round	Fuzz round index (used to seed the RNG).

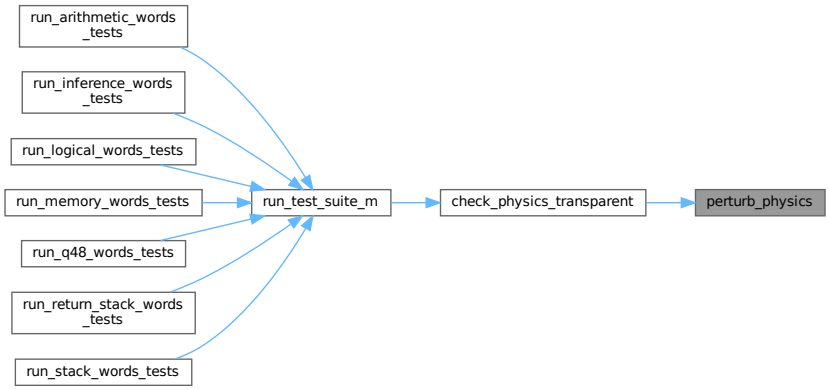
References contract_rand(), VM::decay_slope_q48, RollingWindowOfTruth::effective_window_size, VM::heartbeat, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch rng_seed(), VM::rolling_window, ROLLING_WINDOW_SIZE, HeartbeatState::tick_target_ns, and RollingWindowOfTruth::total_execu

Referenced by check_physics_transparent().

Here is the call graph for this function:



Here is the caller graph for this function:



7.339.1.9 restore_physics()

```
void restore_physics (
            VM * vm,
            const PhysicsSnapshot * s )
```

Restore the physics scalars from a previously saved snapshot.

Writes back the eight fields saved by `save_physics()`, undoing any perturbations made by `perturb_physics()`. Called at the end of each fuzz round and after the full `check_physics_transparent()` loop so the VM state is clean for the next contract check.

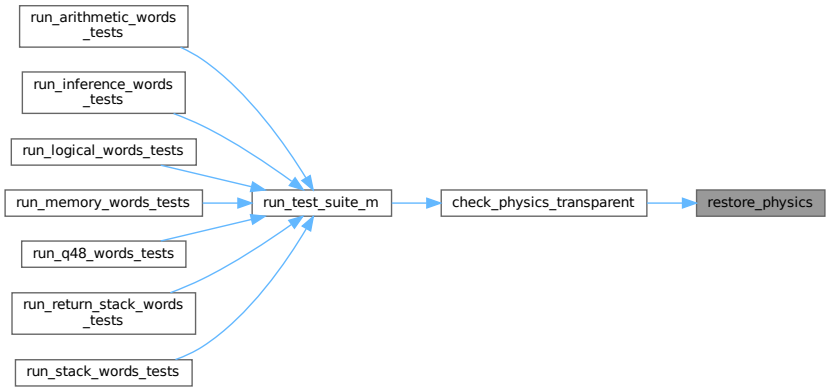
Parameters

vm	VM instance to restore.
s	Source `PhysicsSnapshot` to restore from.

References VM::decay_slope_q48, PhysicsSnapshot::decay_slope_q48, PhysicsSnapshot::eff_window_size, RollingWindowOfTruth::effective_window_size, VM::heartbeat, PhysicsSnapshot::heat_25th, PhysicsSnapshot::heat_50th, PhysicsSnapshot::heat_75th, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PhysicsSnapshot::prefetch_attempts, VM::rolling_window, HeartbeatState::tick_target_ns, PhysicsSnapshot::tick_target_ns, RollingWindowOfTruth::total_executions, and PhysicsSnapshot::total_executions.

Referenced by check_physics_transparent().

Here is the caller graph for this function:



7.339.1.10 rng_seed()

```
static void rng_seed (
            int round )  [static]
```

Seed the RNG for a given fuzz round.

Derives a deterministic seed from the round index mixed with a Fibonacci multiplier (`0x9E3779B97F4A7C15`) so each round produces a distinct, reproducible perturbation sequence regardless of how many rounds have previously run.

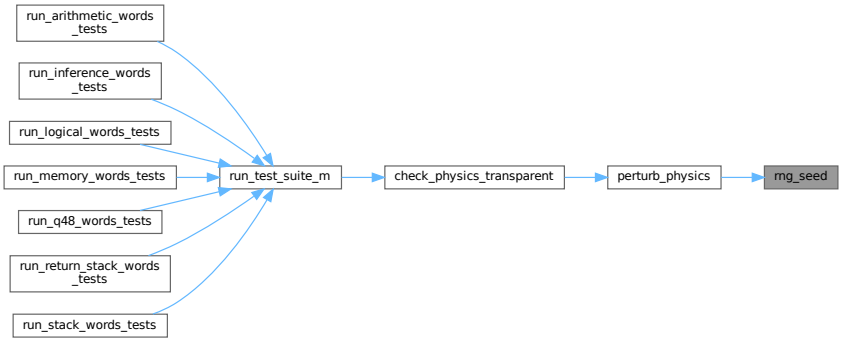
Parameters

round	Zero-based fuzz round index.

References rng_state.

Referenced by perturb_physics().

Here is the caller graph for this function:



7.339.1.11 save_physics()

```
void save_physics (
            VM * vm,
            PhysicsSnapshot * s )
```

Save the key physics scalars touched by the seven feedback loops.

Captures the eight fields that perturb_physics() will randomise: decay_slope_q48, effective_window_size, tick_target_ns, the three heat percentile thresholds, prefetch_attempts, and total_executions. Used as a bracket pair with restore_physics() around each fuzz round so the VM returns to a known state.

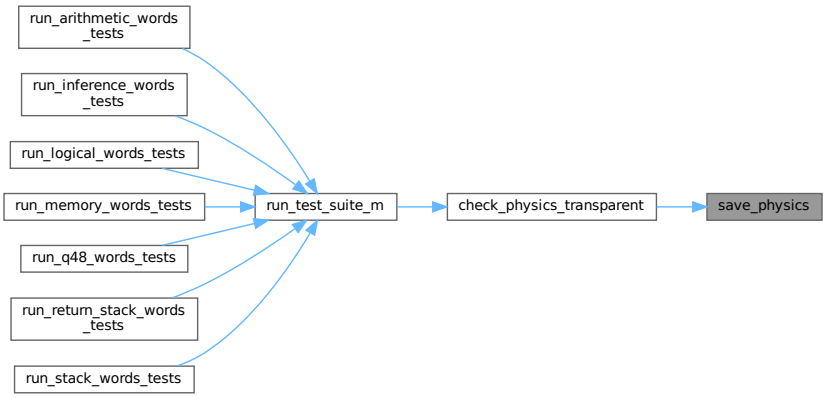
Parameters

vm	VM instance to snapshot.
s	Output PhysicsSnapshot to populate.

References VM::decay_slope_q48, PhysicsSnapshot::decay_slope_q48, PhysicsSnapshot::eff_window_size, RollingWindowOfTruth::effective_window_size, VM::heartbeat, PhysicsSnapshot::heat_25th, PhysicsSnapshot::heat_50th, PhysicsSnapshot::heat_75th, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PhysicsSnapshot::prefetch_attempts, VM::rolling_window, HeartbeatState::tick_target_ns, PhysicsSnapshot::tick_target_ns, RollingWindowOfTruth::total_executions, and PhysicsSnapshot::total_executions.

Referenced by check_physics_transparent().

Here is the caller graph for this function:



7.339.2 Variable Documentation

7.339.2.1 global_contract_violations

```
int global_contract_violations = 0
```

Referenced by assert_heartbeat_safe(), check_physics_transparent(), contract_get_violation_count(), and contract_reset_violation_count().

7.339.2.2 rng_state

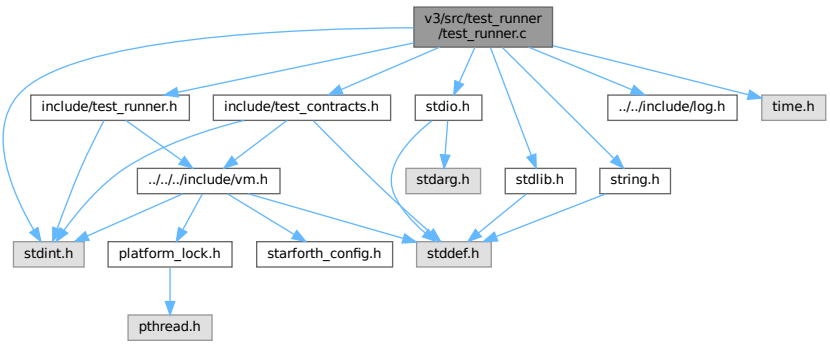
```
uint64_t rng_state = 0xDEADBEEFCAFEBABEULL  [static]
```

Referenced by contract_rand(), and rng_seed().

7.340 v3/src/test_runner/test_runner.c File Reference

```
#include "include/test_runner.h"
#include "include/test_contracts.h"
#include "../../include/log.h"
#include <stdint.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>
```

Include dependency graph for test_runner.c:



Functions

- void test_stats_accumulate (int tests, int pass, int fail, int skip, int error)
- static uint64_t get_time_ns (void)

  Get current time in nanoseconds.
- void enable_benchmark_mode (int iterations)

  Enable benchmark mode for test execution.
- void run_all_tests (VM *vm)

  Run all test modules with optional benchmarking.
- void run_module_tests (VM *vm, const char *module_name)

  Run tests for a specific module.
- void run_word_tests (VM *vm, const char *word_name)

  Run tests for a specific Forth word.

Variables

- TestStats global_test_stats = {0, 0, 0, 0, 0}

  Global statistics for test execution.
- static int benchmark_mode = 0

  Flag indicating if benchmark mode is enabled.
- static int benchmark_iterations = 1000

  Number of iterations for benchmark tests.
- static TestModule test_modules [ ]

7.340.1 Function Documentation

7.340.1.1 enable_benchmark_mode()

```
void enable_benchmark_mode (
            int iterations )
```

Enable benchmark mode for test execution.

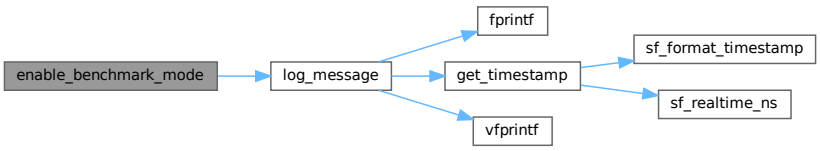
Parameters

iterations	Number of times each test should be repeated

References benchmark_iterations, benchmark_mode, LOG_INFO, and log_message().

Referenced by run_benchmark_mode().

Here is the call graph for this function:



Here is the caller graph for this function:

7.340.1.2 get_time_ns()

```
static uint64_t get_time_ns (
            void  )  [static]
```

Get current time in nanoseconds.

Uses platform-specific timing: sf_monotonic_ns() on kernel, clock() on hosted.

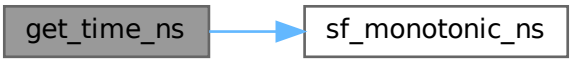
Returns

Current time in nanoseconds, or 0 on error

References sf_monotonic_ns().

Referenced by run_module_tests().

Here is the call graph for this function:



Here is the caller graph for this function:

7.340.1.3 run_all_tests()

```
void run_all_tests (
            VM * vm )
```

Run all test modules with optional benchmarking.

Executes all registered test modules sequentially, collecting statistics and/or benchmark data depending on the current mode.

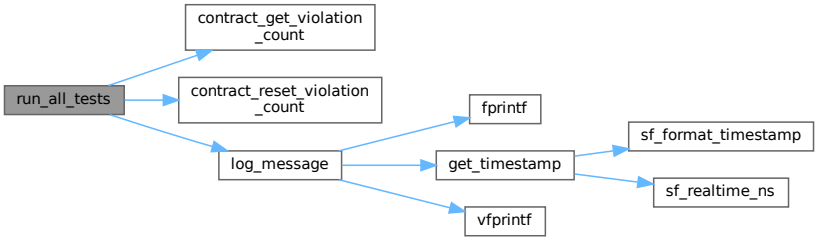
Parameters

vm	Pointer to the Forth virtual machine instance

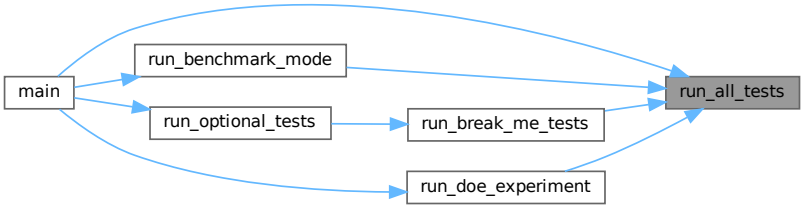
References contract_get_violation_count(), contract_reset_violation_count(), global_test_stats, LOG_ERROR, LOG_INFO, log_message(), LOG_WARN, TestModule::module_name, test_modules, TestStats::total_error, TestStats::total_fail, TestStats::total_pass, TestStats::total_skip, and TestStats::total_tests.

Referenced by main(), run_benchmark_mode(), run_break_me_tests(), and run_doe_experiment().

Here is the call graph for this function:



Here is the caller graph for this function:



7.340.1.4 run_module_tests()

```
void run_module_tests (
            VM * vm,
            const char * module_name )
```

Run tests for a specific module.

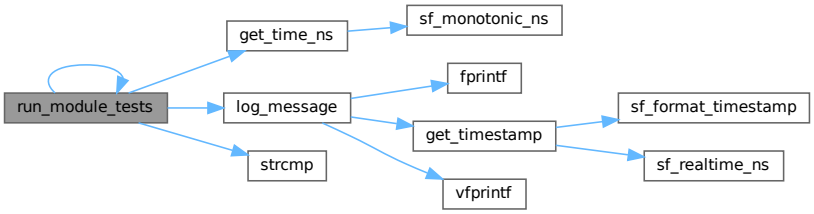
Parameters

vm	Pointer to the Forth virtual machine instance
module_name	Name of the module to test

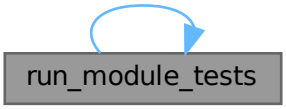
References benchmark_iterations, benchmark_mode, get_time_ns(), LOG_ERROR, LOG_INFO, log_message(), LOG_WARN, TestModule::module_name, run_module_tests(), TestModule::run_module_tests, strcmp(), and test_modules.

Referenced by run_module_tests().

Here is the call graph for this function:



Here is the caller graph for this function:



7.340.1.5 run_word_tests()

```
void run_word_tests (
            VM * vm,
            const char * word_name )
```

Run tests for a specific Forth word.

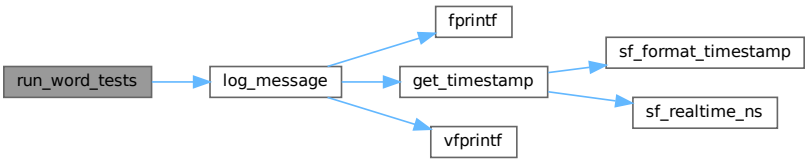
Searches all modules for tests related to the specified word and executes them.

Parameters

vm	Pointer to the Forth virtual machine instance
word_name	Name of the Forth word to test

References LOG_INFO, log_message(), LOG_WARN, TestModule::module_name, and test_modules.

Here is the call graph for this function:



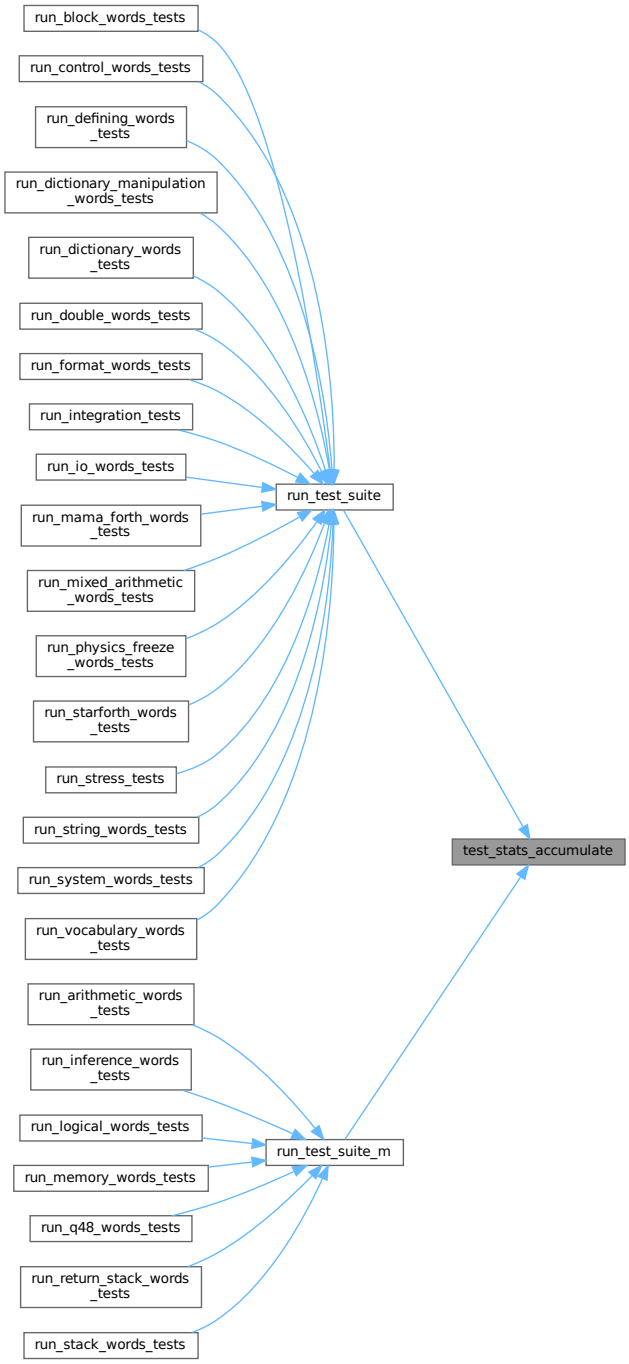
7.340.1.6 test_stats_accumulate()

```
void test_stats_accumulate (
            int tests,
            int pass,
            int fail,
            int skip,
            int error )
```

References global_test_stats, TestStats::total_error, TestStats::total_fail, TestStats::total_pass, TestStats::total_skip, and TestStats::total_tests.

Referenced by run_test_suite(), and run_test_suite_m().

Here is the caller graph for this function:



7.340.2 Variable Documentation

7.340.2.1 benchmark_iterations

```
int benchmark_iterations = 1000  [static]
```

Number of iterations for benchmark tests.

Referenced by enable_benchmark_mode(), and run_module_tests().

7.340.2.2 benchmark_mode

```
int benchmark_mode = 0  [static]
```

Flag indicating if benchmark mode is enabled.

Referenced by enable_benchmark_mode(), and run_module_tests().

7.340.2.3 global_test_stats

```
TestStats global_test_stats = {0, 0, 0, 0, 0}
```

Global statistics for test execution.

Referenced by run_all_tests(), run_break_me_tests(), run_stress_tests(), sk_parity_collect(), and test_stats_accumulate().

7.340.2.4 test_modules

```
TestModule test_modules[]  [static]
```

Initial value:

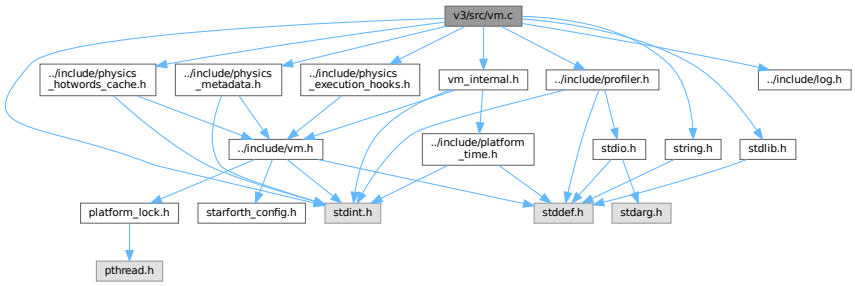
```
= {

    {"Stack Words", NULL, 0, run_stack_words_tests},
    {"Return Stack Words", NULL, 0, run_return_stack_words_tests},
    {"Memory Words", NULL, 0, run_memory_words_tests},
    {"Arithmetic Words", NULL, 0, run_arithmetic_words_tests},
    {"Logical Words", NULL, 0, run_logical_words_tests},
    {"Mixed Arithmetic Words", NULL, 0, run_mixed_arithmetic_words_tests},
    {"Double Words", NULL, 0, run_double_words_tests},
    {"Format Words", NULL, 0, run_format_words_tests},
    {"String Words", NULL, 0, run_string_words_tests},
    {"I/O Words", NULL, 0, run_io_words_tests},
    {"Block Words", NULL, 0, run_block_words_tests},
    {"Dictionary Words", NULL, 0, run_dictionary_words_tests},
    {"Dictionary Manipulation Words", NULL, 0, run_dictionary_manipulation_words_tests},
    {"Vocabulary Words", NULL, 0, run_vocabulary_words_tests},
    {"System Words", NULL, 0, run_system_words_tests},
    {"Defining Words", NULL, 0, run_defining_words_tests},
    {"Control Words", NULL, 0, run_control_words_tests},
    {"StarForth Words", NULL, 0, run_starforth_words_tests},
    {"ACL Words", NULL, 0, run_acl_words_tests},
    {"Mama FORTH Words", NULL, 0, run_mama_forth_words_tests},
    {"Q48.16 Words", NULL, 0, run_q48_words_tests},
    {"Inference Engine Words", NULL, 0, run_inference_words_tests},
    {"Physics Freeze Words", NULL, 0, run_physics_freeze_words_tests},
    {NULL, NULL, 0, NULL}
}
```

Referenced by run_all_tests(), run_module_tests(), and run_word_tests().

7.341 v3/src/vm.c File Reference

```
#include "vm_internal.h"
#include "../include/log.h"
#include "../include/profiler.h"
#include "../include/physics_metadata.h"
#include "../include/physics_execution_hooks.h"
#include "../include/physics_hotwords_cache.h"
#include <stdlib.h>
#include <string.h>
#include <stdint.h>
```

Include dependency graph for vm.c:



Functions

- unsigned vm_get_base (const VM *vm)

  Read the current number base from the VM.
- void vm_set_base (VM *vm, unsigned b)

  Set the VM number base and update both the cell and the host mirror.
- int vm_zuse_cert_install (VM *vm, const uint8_t seed[32], const uint8_t pubkey[32])

  One-time write of the Zuse cert (seed + derived pubkey) – blows the fuse.
- int vm_parse_word (VM *vm, char *word, size_t max_len)

  Parse the next whitespace-delimited token from the input buffer.
- int vm_parse_number (VM *vm, const char *s, cell_t *out)

  Attempt to parse a string as an integer in the current number base.
- void vm_enter_compile_mode (VM *vm, const char *name, size_t len)

  Begin a colon definition and switch the VM to compile mode.
- void vm_compile_word (VM *vm, DictEntry *entry)

  Append a word reference (DictEntry) to the current threaded body.*
- void vm_compile_literal (VM *vm, cell_t value)

  Compile a literal value into the current threaded body (or push it).
- void vm_compile_call (VM *vm, word_func_t func)

  Compile a call to a word identified by its C function pointer.
- void vm_compile_exit (VM *vm)

  Compile an `EXIT` reference into the current threaded body.
- void vm_exit_compile_mode (VM *vm)

  Finalise a colon definition and return to interpret mode.
- static void acl_recheck (VM *vm, DictEntry *entry)

  Cold-path ACL enforcement called when a word's TTL counter hits zero.

- void execute_colon_word (VM *vm)

  Inner interpreter for threaded colon definitions.
- void vm_interpret_word (VM *vm, const char *word_str, size_t len)

  Interpret or compile a single word token.
- void vm_interpret (VM *vm, const char *input)
- int vm_addr_ok (struct VM *vm, vaddr_t addr, size_t len)

  Validate that a VM address range lies within `vm->memory`.
- uint8_t * vm_ptr (struct VM *vm, vaddr_t addr)

  Return a host C pointer into VM memory at `addr`.
- uint8_t vm_load_u8 (struct VM *vm, vaddr_t addr)

  Load an unsigned byte from VM memory.
- void vm_store_u8 (struct VM *vm, vaddr_t addr, uint8_t v)

  Store an unsigned byte to VM memory.
- cell_t vm_load_cell (struct VM *vm, vaddr_t addr)

  Load an aligned cell from VM memory.
- void vm_store_cell (struct VM *vm, vaddr_t addr, cell_t v)

  Store an aligned cell to VM memory.
- void vm_make_immediate (VM *vm)

  Mark the most recently created word as IMMEDIATE (FORTH-79).

Variables

- static int g_vm_interpret_depth

  Interpret a NUL-terminated string of FORTH source code.

7.341.1 Function Documentation

7.341.1.1 acl_recheck()

```
static void acl_recheck (
            VM * vm,
            DictEntry * entry )  [static]
```

Cold-path ACL enforcement called when a word's TTL counter hits zero.

Looks up the FORTH word `ACL-RECHECK` in the dictionary. If found, calls it with `emergency_console` temporarily set to 1 so the recheck itself cannot be denied by the ACL system. The FORTH word is expected to update `entry->acl_allow` and `entry->acl_ttl` before returning.

If `ACL-RECHECK` is not yet loaded (early boot before `ACL.4th` runs), the function **fails open**: sets `acl_allow=1` and `acl_ttl=ACL_TTL_OPEN` so execution continues unimpeded. The same fail-open behaviour applies if `ACL-RECHECK` itself raises an error (error flag is cleared).

This function is the cold path; the hot path in `execute_colon_word()` and `vm_interpret_word()` simply decrements `acl_ttl`.

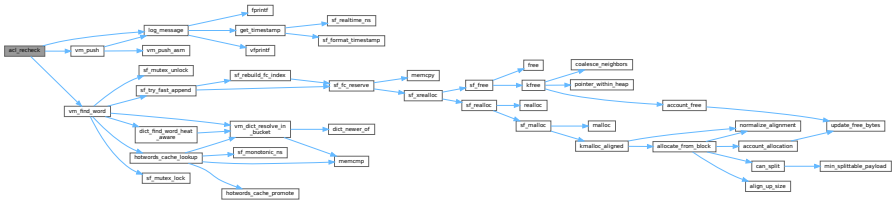
Parameters

vm	VM instance.
entry	Dictionary entry whose TTL has expired and needs rechecking.

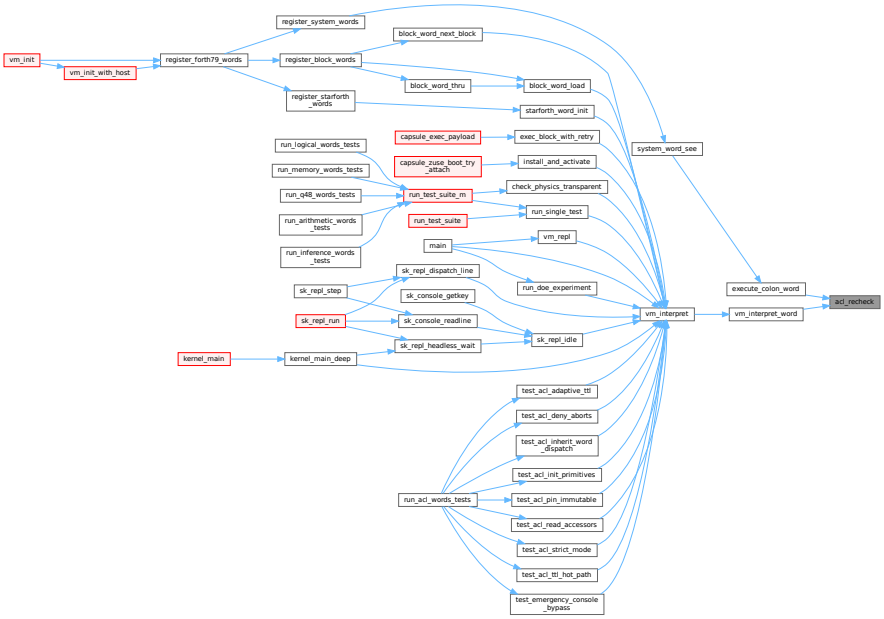
References ACL_TTL_OPEN, VM::current_executing_entry, VM::emergency_console, entry, VM::error, DictEntry::func, log_message(), LOG_WARN, vm_find_word(), and vm_push().

Referenced by execute_colon_word(), and vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.341.1.2 execute_colon_word()

```
void execute_colon_word (
            VM * vm )
```

Inner interpreter for threaded colon definitions.

Runs the body of a colon-defined word whose `DictEntry` points to a sequence of `DictEntry*` cells in VM memory (indirect threaded code). The interpreter pointer (IP) is maintained on the return stack so that runtime control-flow words ((BRANCH), (0BRANCH), (DO), etc.) can redirect execution by modifying the top-of-return-stack IP.

Execution loop per iteration:

1. Read `DictEntry* w` from `*ip`.
2. Run physics pre-execute hooks (heat, decay, pipelining).
3. ACL hot-path check (decrement TTL; call `acl_recheck()` on zero).
4. Push `ip+1` onto the return stack as the resume point.
5. Call `w->func(vm)`.
6. Run physics post-execute hooks.
7. Check `vm->exit_colon` (set by `EXIT`): pop and discard the saved IP, then return to caller.
8. Check `vm->abort_requested`: unwind and return immediately.
9. Pop the (possibly modified) IP from the return stack and repeat.

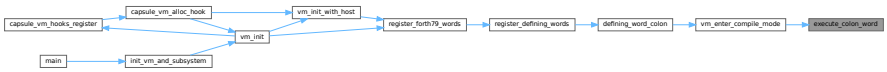
`vm->ecw_nesting` is incremented on entry and decremented on every return path to enable recursive colon calls.

Parameters

vm	VM instance; `vm->current_executing_entry` must point to the `DictEntry` being executed.

Referenced by vm_enter_compile_mode().

Here is the caller graph for this function:



7.341.1.3 vm_addr_ok()

```
int vm_addr_ok (
            struct VM * vm,
            vaddr_t addr,
            size_t len )
```

Validate that a VM address range lies within `vm->memory`.

Checks that [addr, addr+len) is fully contained within the `VM_MEMORY_SIZE`-byte flat address space. The check is done with unsigned arithmetic to avoid UB on overflow: if `len` alone exceeds `VM_MEMORY_SIZE` the range is immediately rejected.

Parameters

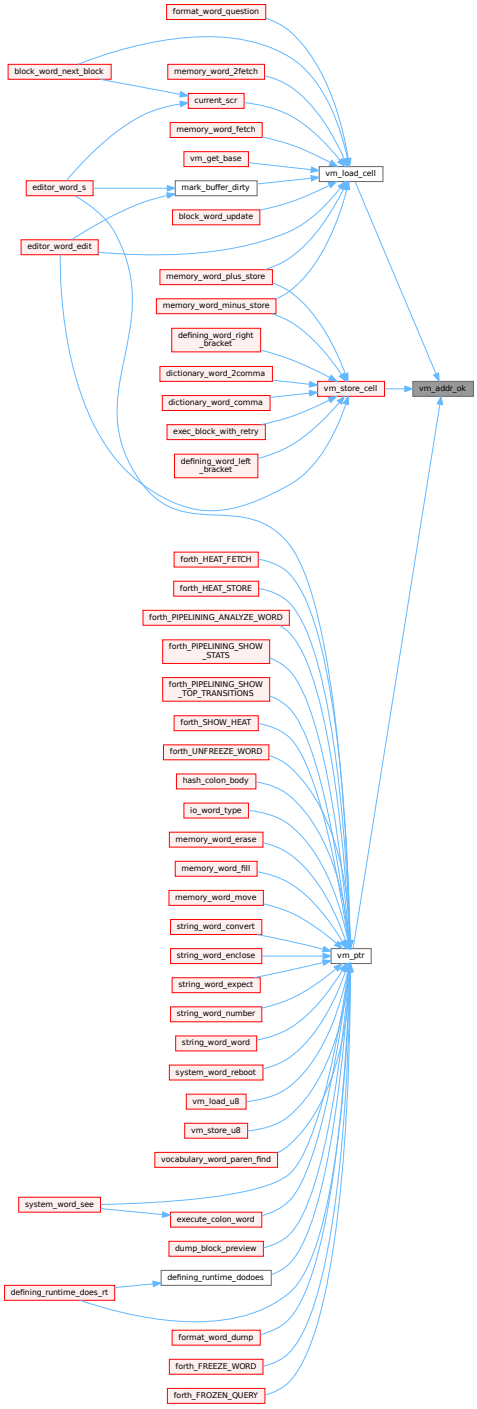
vm	VM instance; returns 0 if NULL or memory not allocated.
addr	Start of the range (inclusive).
len	Number of bytes in the range.

Returns

1 if the full range [addr, addr+len) is in bounds; 0 otherwise.

Referenced by vm_load_cell(), vm_ptr(), and vm_store_cell().

Here is the caller graph for this function:



7.341.1.4 vm_compile_call()

```
void vm_compile_call (
            VM * vm,
            word_func_t func )
```

Compile a call to a word identified by its C function pointer.

Looks up the DictEntry whose func field matches func via vm_dictionary_find_by_func(), then delegates to vm_compile_word(). Used by generating words (e.g., DOES>) that need to embed a specific runtime routine into a compiled definition without knowing its name.

Sets vm->error if not in compile mode or if no matching entry is found.

Parameters

vm	VM instance in compile mode.
func	C function pointer identifying the word to compile.

7.341.1.5 vm_compile_exit()

```
void vm_compile_exit (
            VM * vm )
```

Compile an EXIT reference into the current threaded body.

Appends the EXIT word entry so that when the threaded body is executed, execute_colon_word() sets vm->exit_colon and unwinds the inner loop. Used by control-flow generating words (e.g., IF optimisation paths) that need an explicit early-return.

Sets vm->error if not in compile mode or if EXIT is not found.

Parameters

vm	VM instance in compile mode.

7.341.1.6 vm_compile_literal()

```
void vm_compile_literal (
            VM * vm,
            cell_t value )
```

Compile a literal value into the current threaded body (or push it).

In compile mode, appends the LIT word reference followed by the literal value so the inner interpreter will push value at runtime. In interpret mode, pushes value directly onto the data stack.

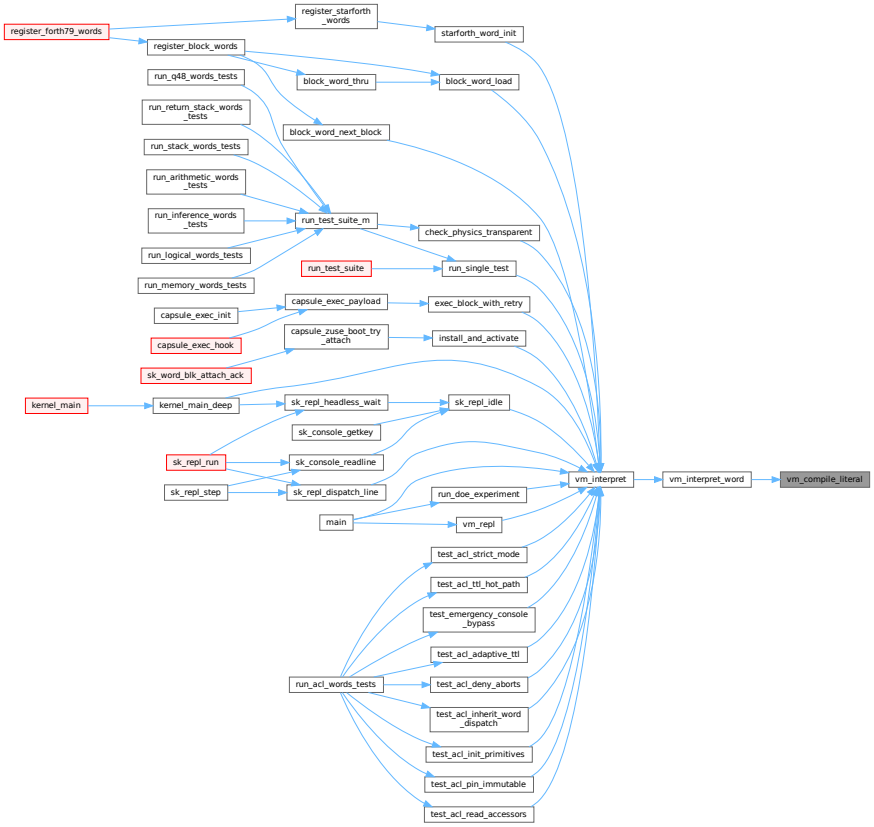
Sets vm->error if LIT cannot be found in the dictionary.

Parameters

vm	VM instance.
value	Cell value to compile or push.

Referenced by vm_interpret_word().

Here is the caller graph for this function:



7.341.1.7 vm_compile_word()

```
void vm_compile_word (
            VM * vm,
            DictEntry * entry )
```

Append a word reference (DictEntry*) to the current threaded body.

Aligns `HERE`, then allots one `cell_t` slot and stores the `DictEntry*` as a cell. This is the fundamental compilation step used by the inner interpreter: each slot in the threaded body is a pointer to the `DictEntry` of the word to call.

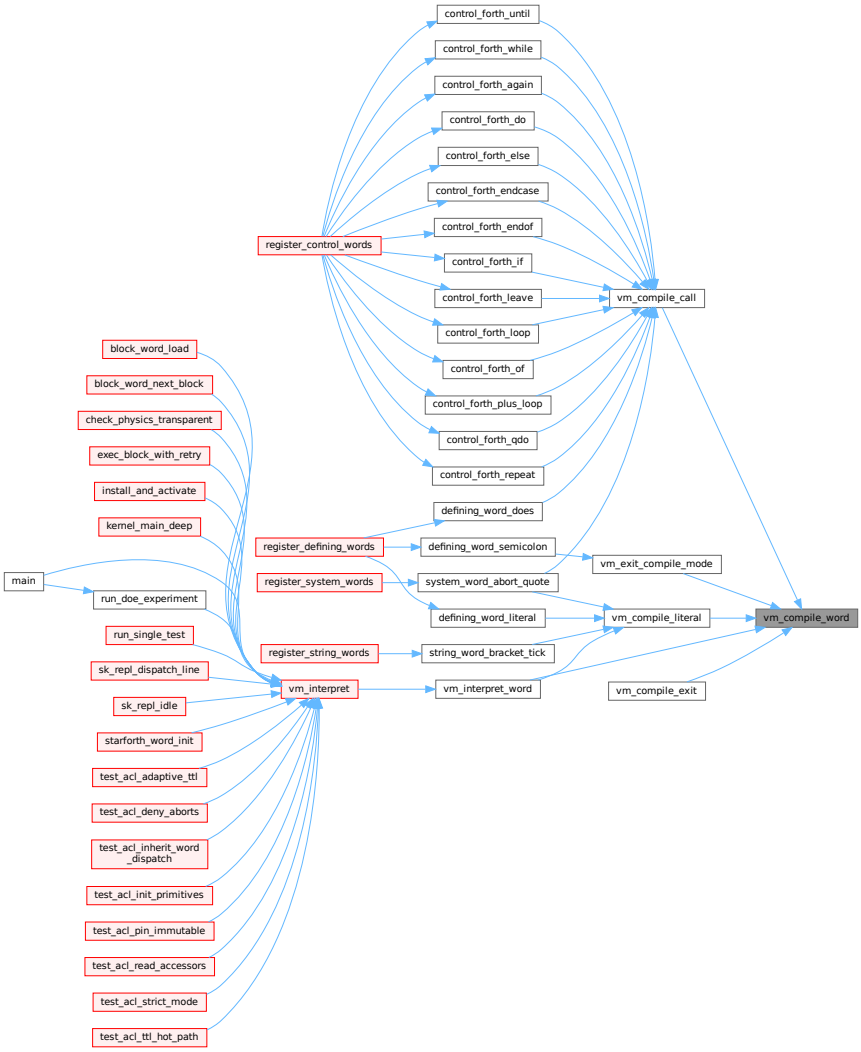
Sets `vm->error` if the VM is not in compile mode, `entry` is NULL, or allotment fails.

Parameters

vm	VM instance in compile mode.
entry	Dictionary entry of the word to compile; must not be NULL.

Referenced by vm_compile_call(), vm_compile_exit(), vm_compile_literal(), vm_exit_compile_mode(), and vm_interpret_word().

Here is the caller graph for this function:



7.341.1.8 vm_enter_compile_mode()

```
void vm_enter_compile_mode (
            VM * vm,
            const char * name,
            size_t len )
```

Begin a colon definition and switch the VM to compile mode.

Creates a new dictionary entry for `name` via `vm_create_word()`, marks it `WORD_SMUDGED` so it is invisible to lookups during compilation, sets the VM mode to `MODE_COMPILE`, and writes the current `HERE` address into the entry's data field as the start of the threaded body.

The SMUDGE flag is cleared by `vm_exit_compile_mode()` when the semicolon is encountered.

Parameters

vm	VM instance.
name	Word name string (does not need to be NUL-terminated).
len	Length of `name`; clamped to `WORD_NAME_MAX`.

7.341.1.9 vm_exit_compile_mode()

```
void vm_exit_compile_mode (
            VM * vm )
```

Finalise a colon definition and return to interpret mode.

Appends a final `EXIT` reference, clears the `WORD_SMUDGED` flag so the new word becomes visible in the dictionary, and sets `WORD_COMPILED`. Also computes the word's mass (header + body bytes) for the physics engine and calls `physics_metadata_refresh_state()`.

Resets `vm->mode` to `MODE_INTERPRET`, clears `vm->state_var`, and NULLs `vm->compiling_word`.

Sets `vm->error` if `vm` has no active `compiling_word` or if `EXIT` cannot be found.

Parameters

vm	VM instance currently in compile mode.

7.341.1.10 vm_get_base()

```
unsigned vm_get_base (
            const VM * vm )
```

Read the current number base from the VM.

Prefers the cell stored at `vm->base_addr` (the canonical FORTH `BASE` variable) if it is aligned and in the valid range [2, 36]. Falls back to the host-mirror `vm->base` if the cell is out of range, and finally returns 10 if both are invalid or `vm` is NULL.

The double-read (cell + mirror) keeps the VM consistent when C code modifies `vm->base` directly without going through `vm_set_base()`.

Parameters

vm	VM instance to query (may be NULL; returns 10 in that case).

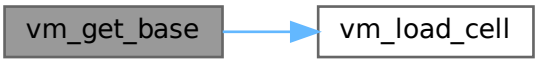
Returns

Current number base in range [2, 36].

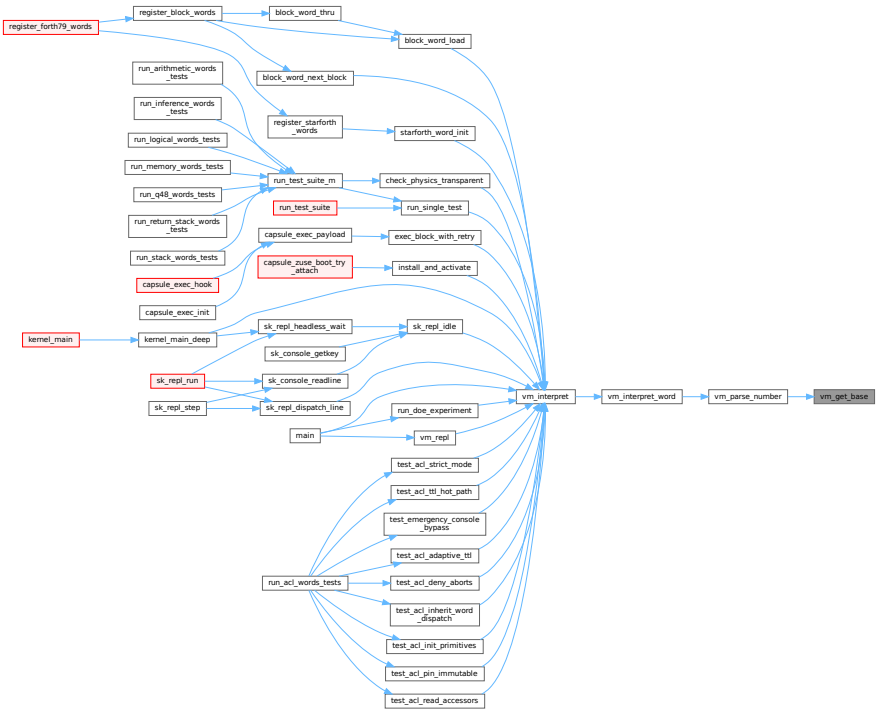
References VM::base, VM::base_addr, vm_load_cell(), and VM_MEMORY_SIZE.

Referenced by vm_parse_number().

Here is the call graph for this function:



Here is the caller graph for this function:



7.341.1.11 vm_interpret()

```
void vm_interpret (
            VM * vm,
            const char * input )
```

7.341.1.12 vm_interpret_word()

```
void vm_interpret_word (
            VM * vm,
            const char * word_str,
            size_t len )
```

Interpret or compile a single word token.

This is the outer interpreter's per-token dispatch:

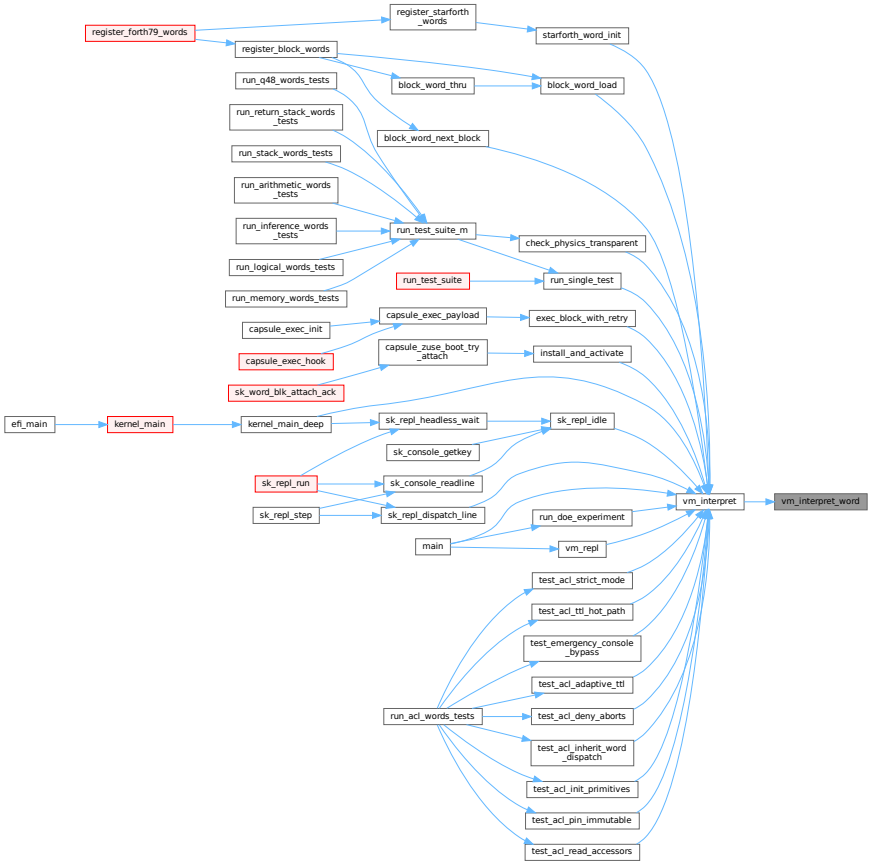
1. **Dictionary lookup**: vocabulary-aware search, falling back to the canonical flat dictionary. Physics heat is recorded via `physics_on_lookup()`.
2. **Compile mode, non-immediate**: append the entry to the current threaded body via `vm_compile_word()`.
3. **Interpret mode, or immediate in compile mode**: ACL check (hot-path TTL decrement / cold-path `acl_recheck()`), then call `entry->func()`.
4. **Number literal**: if no dictionary match, attempt `vm_parse_number()`. In compile mode, compile as a literal; in interpret mode, push directly.
5. **Error**: unknown token — sets `vm->error`.

Parameters

vm	VM instance.
word_str	Token string (need not be NUL-terminated).
len	Length of `word_str` in bytes.

Referenced by vm_interpret().

Here is the caller graph for this function:



7.341.1.13 vm_load_cell()

```
cell_t vm_load_cell (
            struct VM * vm,
            vaddr_t addr )
```

Load an aligned cell from VM memory.

Validates that `addr` is within bounds for a full `cell_t` read and that it is naturally aligned (addr % sizeof(cell_t) == 0). Uses `memcpy()` rather than a direct pointer dereference to avoid strict aliasing and alignment UB. Sets `vm->error` and returns 0 on failure.

Parameters

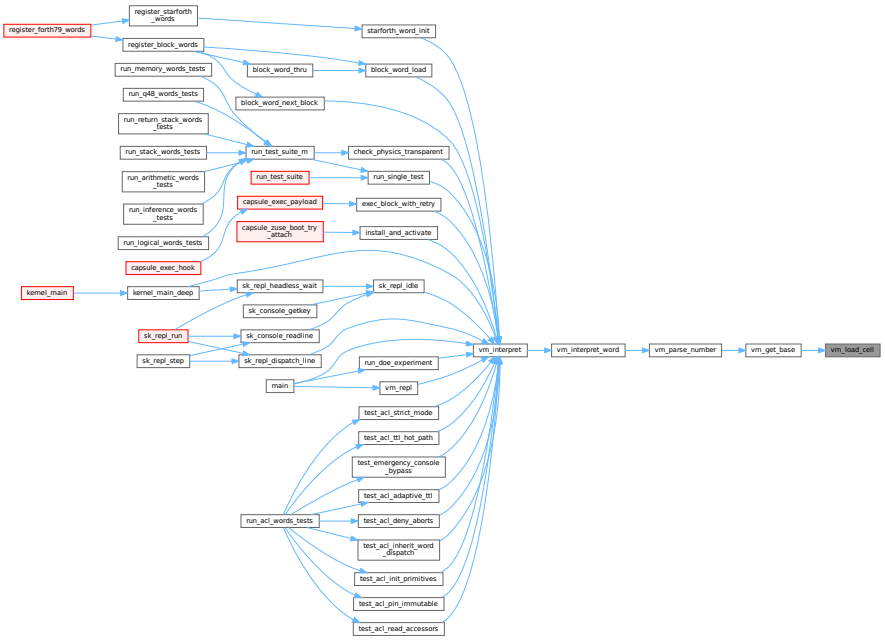
vm	VM instance.
addr	Aligned VM byte offset to read.

Returns

Cell value at `addr`, or 0 on alignment or bounds error.

Referenced by vm_get_base().

Here is the caller graph for this function:



7.341.1.14 vm_load_u8()

```
uint8_t vm_load_u8 (
            struct VM * vm,
            vaddr_t addr )
```

Load an unsigned byte from VM memory.

Resolves `addr` via `vm_ptr()`. Sets `vm->error` and returns 0 if the address is out of bounds.

Parameters

vm	VM instance.
addr	VM byte offset to read.

Returns

Byte value at `addr`, or 0 on error.

7.341.1.15 vm_make_immediate()

```
void vm_make_immediate (
            VM * vm )
```

Mark the most recently created word as IMMEDIATE (FORTH-79).

Sets `WORD_IMMEDIATE` on `vm->latest` so the word executes during compilation rather than being compiled into the current definition. Also calls `physics_metadata_refresh_state()` to update the physics engine's record of the entry's flags.

Sets `vm->error` if `vm` has no `latest` entry (i.e., the dictionary is empty or no word has been created yet).

Parameters

vm	VM instance.

7.341.1.16 vm_parse_number()

```
int vm_parse_number (
            VM * vm,
            const char * s,
            cell_t * out )
```

Attempt to parse a string as an integer in the current number base.

Reads the current base from `vm_get_base()`, then converts each character of `s` (case-insensitive, digits 0–9 and letters A–Z/a–z) to a digit value. Returns 0 immediately on any character that is not a valid digit in the current base, or on an empty string after the optional sign.

Handles an optional leading `'+'` or `'-'` sign. The result is a full-width `cell_t` (sign extended for negative values).

Parameters

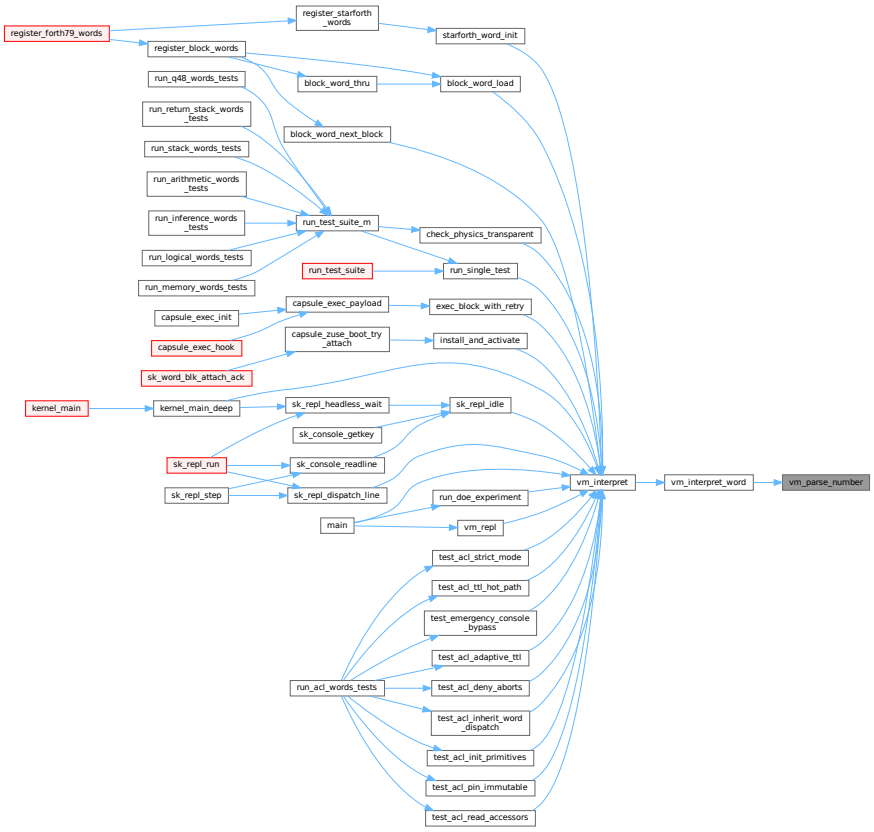
vm	VM instance (used for base only; may be NULL, in which case base defaults to 10).
s	NUL-terminated string to parse.
out	Pointer to receive the parsed value on success.

Returns

1 on successful parse, 0 on any parse failure.

Referenced by vm_interpret_word().

Here is the caller graph for this function:



7.341.1.17 vm_parse_word()

```
int vm_parse_word (
            VM * vm,
            char * word,
            size_t max_len )
```

Parse the next whitespace-delimited token from the input buffer.

Skips leading whitespace (space, tab, CR, LF), then extracts characters until the next whitespace or end of buffer, storing up to `max_len` ? 1 characters in `word` followed by a NUL terminator. Advances `vm->input_pos` past the consumed token.

Parameters

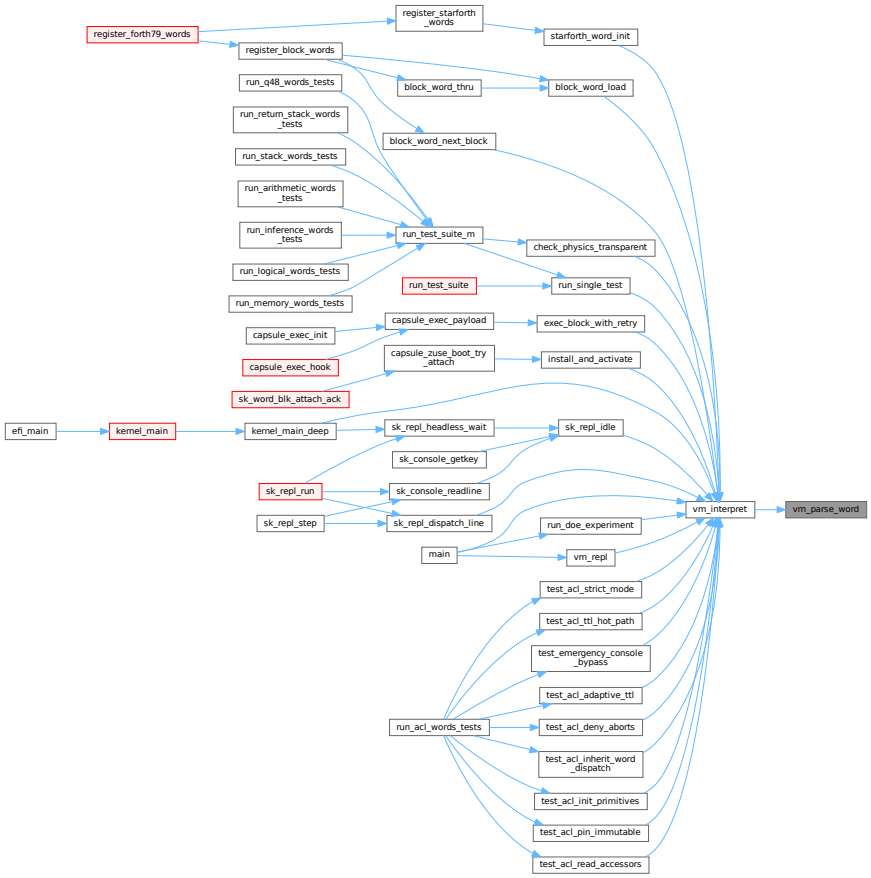
vm	VM instance; `vm->input_buffer` / `input_pos` / `input_length` must be populated (typically by `vm_interpret()`).
word	Output buffer for the parsed token.
max_len	Size of `word` in bytes (including NUL terminator).

Returns

Number of characters written (excluding NUL), or 0 if the buffer is exhausted or `vm` / `word` is NULL.

Referenced by vm_interpret().

Here is the caller graph for this function:



7.341.1.18 vm_ptr()

```
uint8_t * vm_ptr (
            struct VM * vm,
            vaddr_t addr )
```

Return a host C pointer into VM memory at `addr`.

Validates the address with `vm_addr_ok()` (minimum 1-byte range) and returns `NULL` if the address is out of bounds or `vm` is uninitialised. The returned pointer is valid for at least one byte; callers that need multi-byte access should perform their own range check first.

Parameters

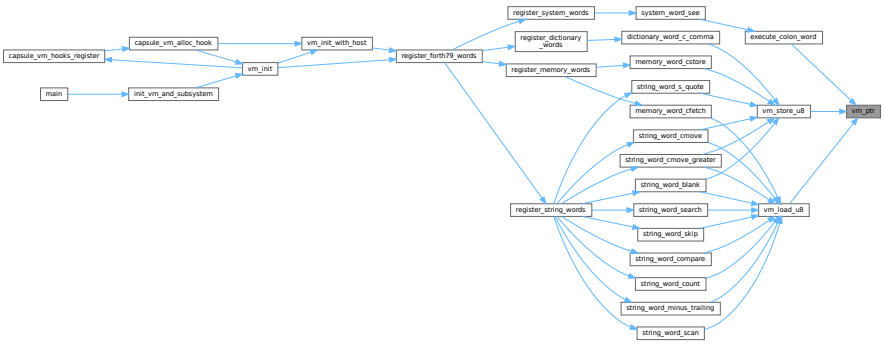
vm	VM instance.
addr	VM byte offset to dereference.

Returns

Host pointer into `vm->memory`, or NULL on bounds failure.

Referenced by execute_colon_word(), vm_load_u8(), and vm_store_u8().

Here is the caller graph for this function:



7.341.1.19 vm_set_base()

```
void vm_set_base (
            VM * vm,
            unsigned b )
```

Set the VM number base and update both the cell and the host mirror.

Clamps `b` to [2, 36] (replacing out-of-range values with 10), then writes to the FORTH `BASE` variable cell at `vm->base_addr` and to the host-mirror field `vm->base` so both sources agree.

Parameters

vm	VM instance to update.
b	Desired number base; clamped to [2, 36].

7.341.1.20 vm_store_cell()

```
void vm_store_cell (
            struct VM * vm,
            vaddr_t addr,
            cell_t v )
```

Store an aligned cell to VM memory.

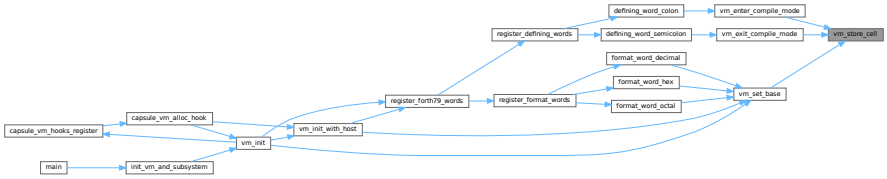
Validates alignment and bounds, then copies `v` into VM memory via `memcpy()`. Sets `vm->error` on alignment or bounds failure.

Parameters

vm	VM instance.
addr	Aligned VM byte offset to write.
v	Cell value to store.

Referenced by vm_enter_compile_mode(), vm_exit_compile_mode(), and vm_set_base().

Here is the caller graph for this function:



7.341.1.21 vm_store_u8()

```
void vm_store_u8 (
            struct VM * vm,
            vaddr_t addr,
            uint8_t v )
```

Store an unsigned byte to VM memory.

Resolves `addr` via `vm_ptr()`. Sets `vm->error` if the address is out of bounds; otherwise writes `v`.

Parameters

vm	VM instance.
addr	VM byte offset to write.
v	Byte value to store.

7.341.1.22 vm_zuse_cert_install()

```
int vm_zuse_cert_install (
            VM * vm,
            const uint8_t seed[32],
            const uint8_t pubkey[32] )
```

One-time write of the Zuse cert (seed + derived pubkey) – blows the fuse.

Deliberately not backed by a dictionary CONSTANT: ACL-PIN only blocks redefinition (vm_create_word shadowing), not a >BODY-then-store on the word's data field, so a pinned CONSTANT is not actually immutable against FORTH-level tampering. Keeping the value in a VM struct field with no corresponding FORTH store word closes that path entirely – see FABRIC-2.md's Milestone 4 mint-then-pin writeup for the finding.

Parameters

vm	VM instance.
seed	Ed25519 seed, 32 bytes (the private identity).
pubkey	Ed25519 public key derived from seed, 32 bytes.

Returns

0 on success; -1 if already installed (fuse already blown).

7.341.2 Variable Documentation

7.341.2.1 g_vm_interpret_depth

```
int g_vm_interpret_depth  [static]
```

Interpret a NUL-terminated string of FORTH source code.

Copies `input` into `vm->input_buffer` (capped at `INPUT_BUFFER_SIZE` ? 1 bytes, NUL-terminated), then drives the word-parse / token-dispatch loop until the buffer is exhausted or `vm->error` is set. Each token is dispatched to `vm_interpret_word()`.

This is the top-level entry point used by the REPL, `INCLUDE`, and inline `-c` execution. It does not reset `vm->error` before running — the caller is responsible for clearing error state if desired.

Parameters

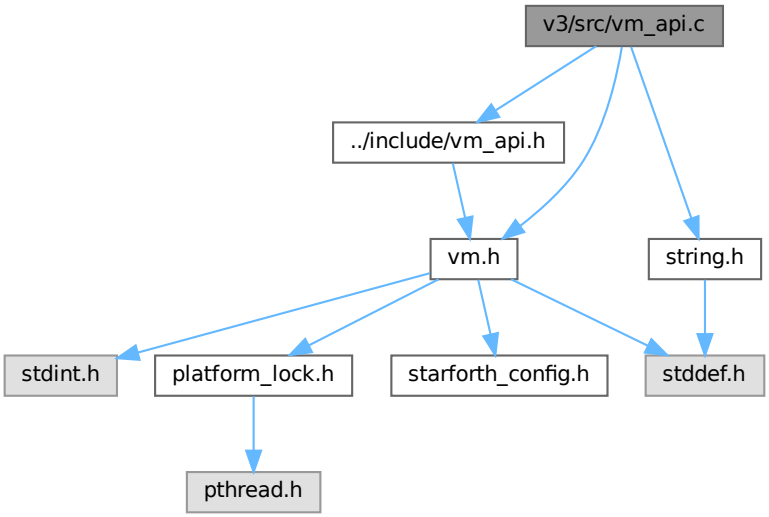
vm	VM instance.
input	NUL-terminated FORTH source string to interpret.

Referenced by vm_interpret().

7.342 v3/src/vm_api.c File Reference

```
#include "../include/vm_api.h"
#include "../include/vm.h"
#include <string.h>
```

Include dependency graph for vm_api.c:



Functions

- int vm_input_ensure (VM *vm)

  Ensure input buffers are allocated.
- unsigned char * vm_input_tib (VM *vm)

  Get pointer to terminal input buffer (TIB)
- cell_t * vm_input_in (VM *vm)

  Get pointer to input offset variable.
- cell_t * vm_input_span (VM *vm)

  Get pointer to input span variable.
- void vm_input_load_line (VM *vm, const char *src, size_t n)

  Load input line into TIB.
- void vm_input_source (VM *vm, cell_t *out_addr, cell_t *out_len)

  Get current input source buffer info.

Stack Operations

- void vm_api_push (VM *vm, intptr_t v)

  Push value onto data stack.
- intptr_t vm_api_pop (VM *vm)

  Pop value from data stack.
- void vm_api_rpush (VM *vm, intptr_t v)

  Push value onto return stack.
- intptr_t vm_api_rpop (VM *vm)

  Pop value from return stack.

Dictionary Operations

- void * vm_api_create_word (VM *vm, const char *n, size_t len, word_func_t fn)

Create new word in dictionary.

- void * vm_api_find_word (VM *vm, const char *n, size_t len)
  Find word in dictionary.
- void vm_api_hide_word (VM *vm)
  Hide last defined word.
- void vm_api_smudge_word (VM *vm)
  Toggle smudge bit of last word.

Memory Operations

- cell_t vm_addr_from_ptr (VM *vm, void *p)
  Convert native pointer to Forth memory address.

7.342.1 Function Documentation

7.342.1.1 vm_api_create_word()

```
void * vm_api_create_word (
            VM * vm,
            const char * n,
            size_t len,
            word_func_t fn )
```

Create new word in dictionary.

Parameters

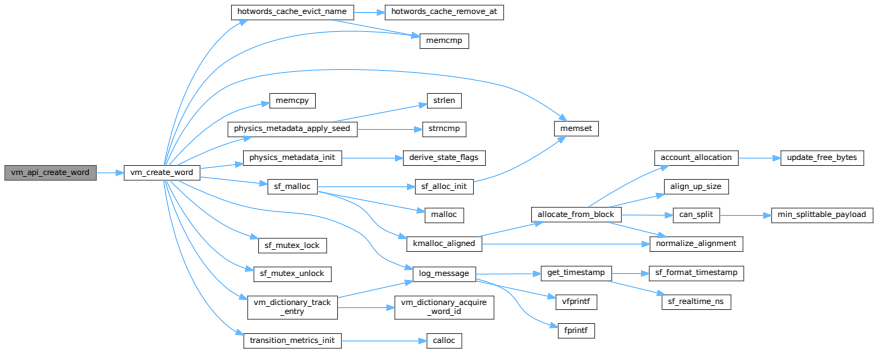
vm	VM instance
n	Word name
len	Name length
fn	Word implementation function

Returns

Pointer to created dictionary entry

References vm_create_word().

Here is the call graph for this function:



7.342.1.2 vm_api_find_word()

```
void * vm_api_find_word (
            VM * vm,
            const char * n,
            size_t len )
```

Find word in dictionary.

Parameters

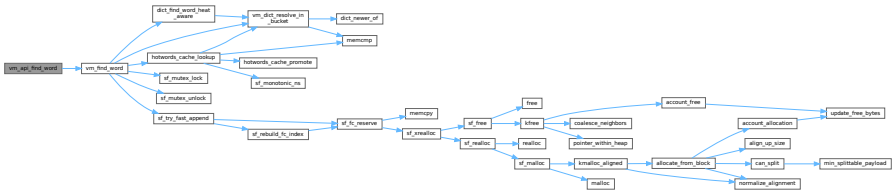
vm	VM instance
n	Word name to find
len	Name length

Returns

Pointer to found dictionary entry or NULL

References vm_find_word().

Here is the call graph for this function:



7.342.1.3 vm_api_hide_word()

```
void vm_api_hide_word (
            VM * vm )
```

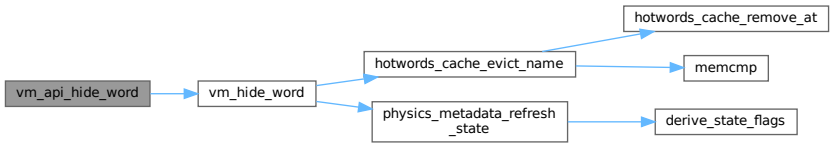
Hide last defined word.

Parameters

vm	VM instance

References vm_hide_word().

Here is the call graph for this function:



7.342.1.4 vm_api_pop()

```
intptr_t vm_api_pop (
            VM * vm )
```

Pop value from data stack.

Parameters

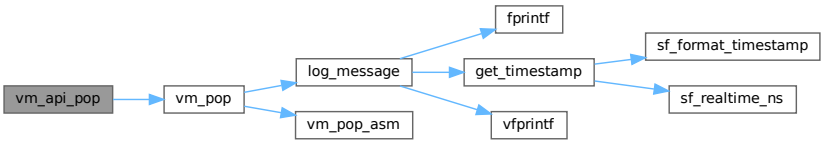
vm	VM instance

Returns

Popped value

References vm_pop().

Here is the call graph for this function:



7.342.1.5 vm_api_push()

```
void vm_api_push (
            VM * vm,
            intptr_t v )
```

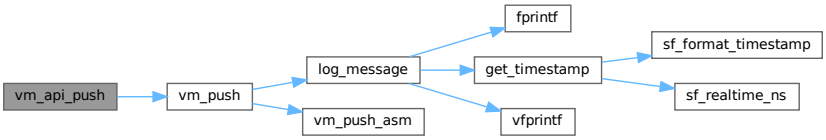
Push value onto data stack.

Parameters

vm	VM instance
v	Value to push

References vm_push().

Here is the call graph for this function:



7.342.1.6 vm_api_rpop()

```
intptr_t vm_api_rpop (
            VM * vm )
```

Pop value from return stack.

Parameters

vm	VM instance

Returns

Popped value

References vm_rpop().

Here is the call graph for this function:

7.342.1.7 vm_api_rpush()

```
void vm_api_rpush (
            VM * vm,
            intptr_t v )
```

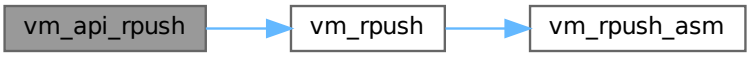
Push value onto return stack.

Parameters

vm	VM instance
v	Value to push

References vm_rpush().

Here is the call graph for this function:



7.342.1.8 vm_api_smudge_word()

```
void vm_api_smudge_word (
            VM * vm )
```

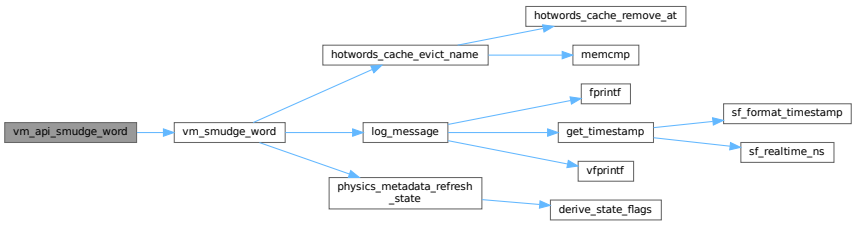
Toggle smudge bit of last word.

Parameters

vm	VM instance

References vm_smudge_word().

Here is the call graph for this function:

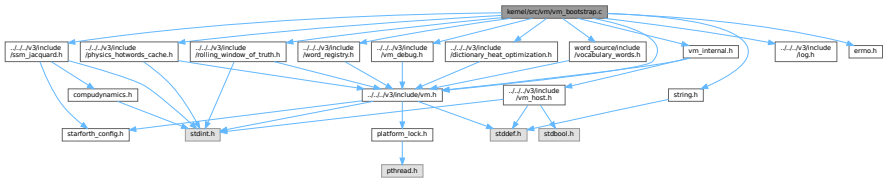


7.343 kernel/src/vm/vm_bootstrap.c File Reference

```
#include "../../../v3/include/vm.h"
#include "../../../v3/include/log.h"
#include "../../../v3/include/word_registry.h"
```

```
#include "../../../v3/include/vm_debug.h"
#include "../../../v3/include/physics_hotwords_cache.h"
#include "../../../v3/include/rolling_window_of_truth.h"
#include "../../../v3/include/dictionary_heat_optimization.h"
#include "../../../v3/include/ssm_jacquard.h"
#include "word_source/include/vocabulary_words.h"
#include "vm_internal.h"
#include <string.h>
#include <errno.h>
```

Include dependency graph for vm_bootstrap.c:



Functions

- static void vm_bootstrap_scr (VM *vm)
- void vm_bootstrap_root_vocabulary (VM *vm, const char *name)

  Bootstrap a root vocabulary for the VM.
- void vm_init (VM *vm)

  Initialize a new virtual machine instance.
- void vm_init_with_host (VM *vm, const VMHostServices *host)

  Initialize VM with explicit host services.

7.343.1 Function Documentation

7.343.1.1 vm_bootstrap_root_vocabulary()

```
void vm_bootstrap_root_vocabulary (
            VM * vm,
            const char * name )
```

Bootstrap a root vocabulary for the VM.

Creates a vocabulary by name, finds its dictionary entry, executes it to make it current, then calls DEFINITIONS.

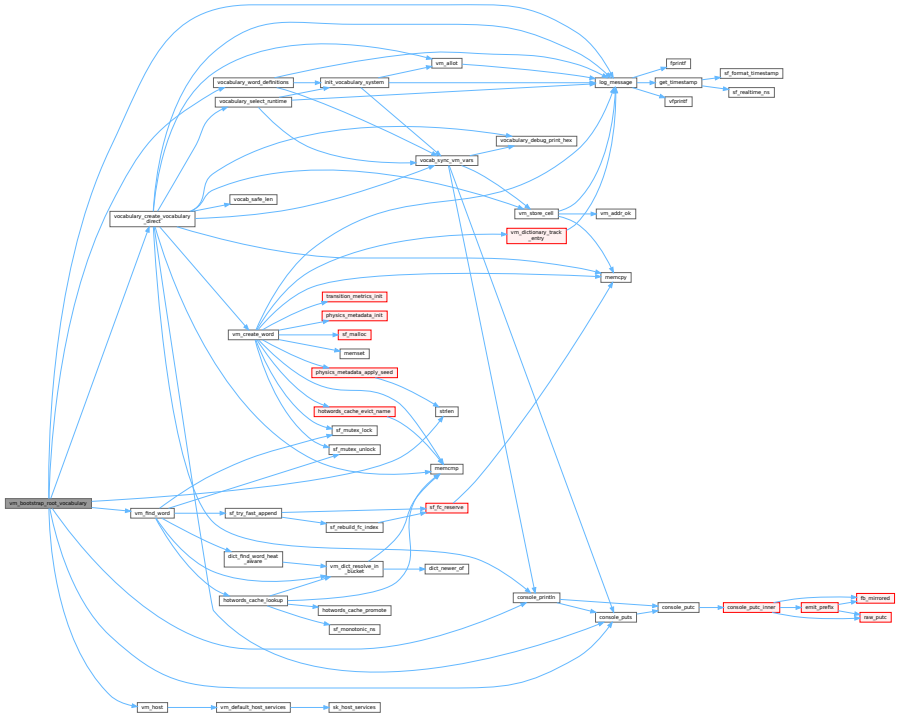
Parameters

vm	Pointer to VM structure
name	Vocabulary name to bootstrap

References console_println(), console_puts(), entry, VM::error, VMHostServices::is_executable_ptr, LOG_ERROR, log_message(), name, VMHostServices::panic, strlen(), vm_find_word(), vm_host(), vocabulary_create_vocabulary_direct(), and vocabulary_word_definitions().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

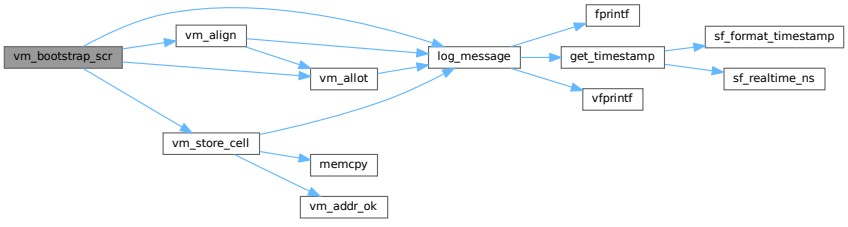
7.343.1.2 vm_bootstrap_scr()

```
static void vm_bootstrap_scr (
            VM * vm )  [static]
```

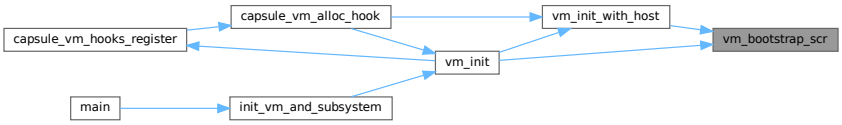
References VM::error, LOG_ERROR, log_message(), VM::memory, VM::scr_addr, vm_align(), vm_allot(), and vm_store_cell().

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.343.1.3 vm_init()

```
void vm_init (
            VM * vm )
```

Initialize a new virtual machine instance.

Allocates memory and initializes all VM structures including:

- Memory array
- Data and return stacks
- System variables (SCR, STATE, BASE)
- Dictionary
- Forth-79 wordset

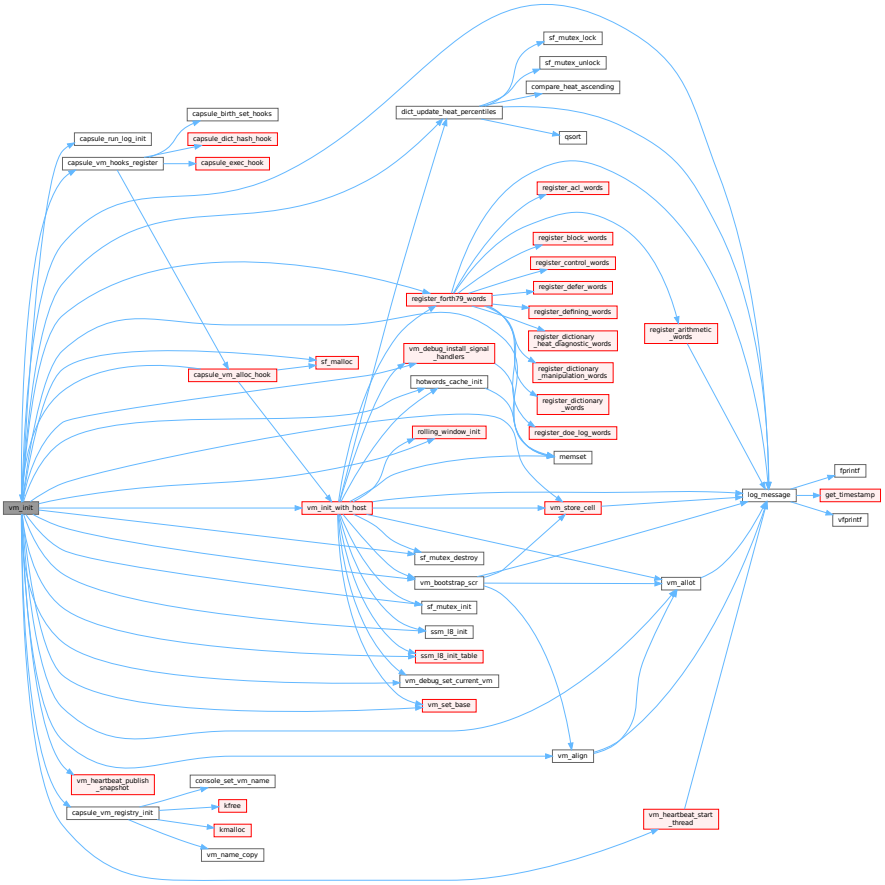
Parameters

vm	Pointer to VM structure to initialize

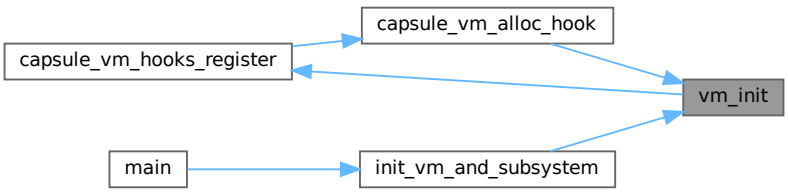
References VM::abort_requested, VM::base_addr, capsule_run_log_init(), capsule_vm_hooks_register(), capsule_vm_registry_init(), VM::cf, ControlFlowState::cf_last_mode, ControlFlowState::cf_sp, HeartbeatState::check_counter, VM::compiling_word, VM::current_executing_entry, VM::decay_slope_direction, VM::decay_slope_q48, VM::dict_fence_here, VM::dict_fence_latest, VM::dict_lock, dict_update_heat_percentiles(), VM::dsp, RollingWindowOfTruth::effective_window_size, ControlFlowState::endof_mark_sp, ControlFlowState::endof_sp, VM::error, VM::exit_colon, VM::halted, VM::heartbeat, VM::heartbeat_decay_cursor_id, HeartbeatState::heartbeat_enabled, HEARTBEAT_TICK_NS, VM::here, VM::hold_addr, VM::hold_pos, VM::hotwords_cache, hotwords_cache_init(), VM::input_length, VM::input_pos, VM::last_bucket_reorg_ns, PipelineGlobalMetrics::last_checked_accuracy, PipelineGlobalMetrics::last_checked_window_size, VM::last_decay_check_ns, HeartbeatState::last_inference_tick, VM::latest, ControlFlowState::leave_mark_sp, ControlFlowState::leave_sp, LOG_ERROR, log_message(), VM::lookup_strategy, VM::memory, memset(), VM::mode, MODE_INTERPRET, VM::next_word_id, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::recycled_word_id_count, register_forth79_words(), VM::rolling_window, rolling_window_init(), VM::rsp, VM::scr_addr, sf_malloc(), sf_mutex_destroy(), sf_mutex_init(), HeartbeatState::snapshot_index, VM::ssm_config, ssm_l8_init(), ssm_l8_init_table(), VM::ssm_l8_state, SSM_MODE_C0, VM::stale_word_count_at_check, VM::state_addr, VM::state_var, PipelineGlobalMetrics::suggested_next_size, HeartbeatState::tick_count, HeartbeatState::tick_target_ns, VM::total_heat_at_last_check, VM::tuning_lock, vm_align(), vm_allot(), vm_bootstrap_scr(), vm_debug_install_signal_handlers(), vm_debug_set_current_vm(), vm_heartbeat_publish_snapshot(), vm_heartbeat_start_thread(), vm_init_with_host(), VM_MEMORY_SIZE, vm_set_base(), vm_store_cell(), PipelineGlobalMetrics::window_tuning_checks, WORD_ID_INVALID, and HeartbeatState::worker.

Referenced by capsule_vm_alloc_hook(), and init_vm_and_subsystem().

Here is the call graph for this function:



Here is the caller graph for this function:



7.343.1.4 vm_init_with_host()

```
void vm_init_with_host (
            VM * vm,
            const VMHostServices * host )
```

Initialize VM with explicit host services.

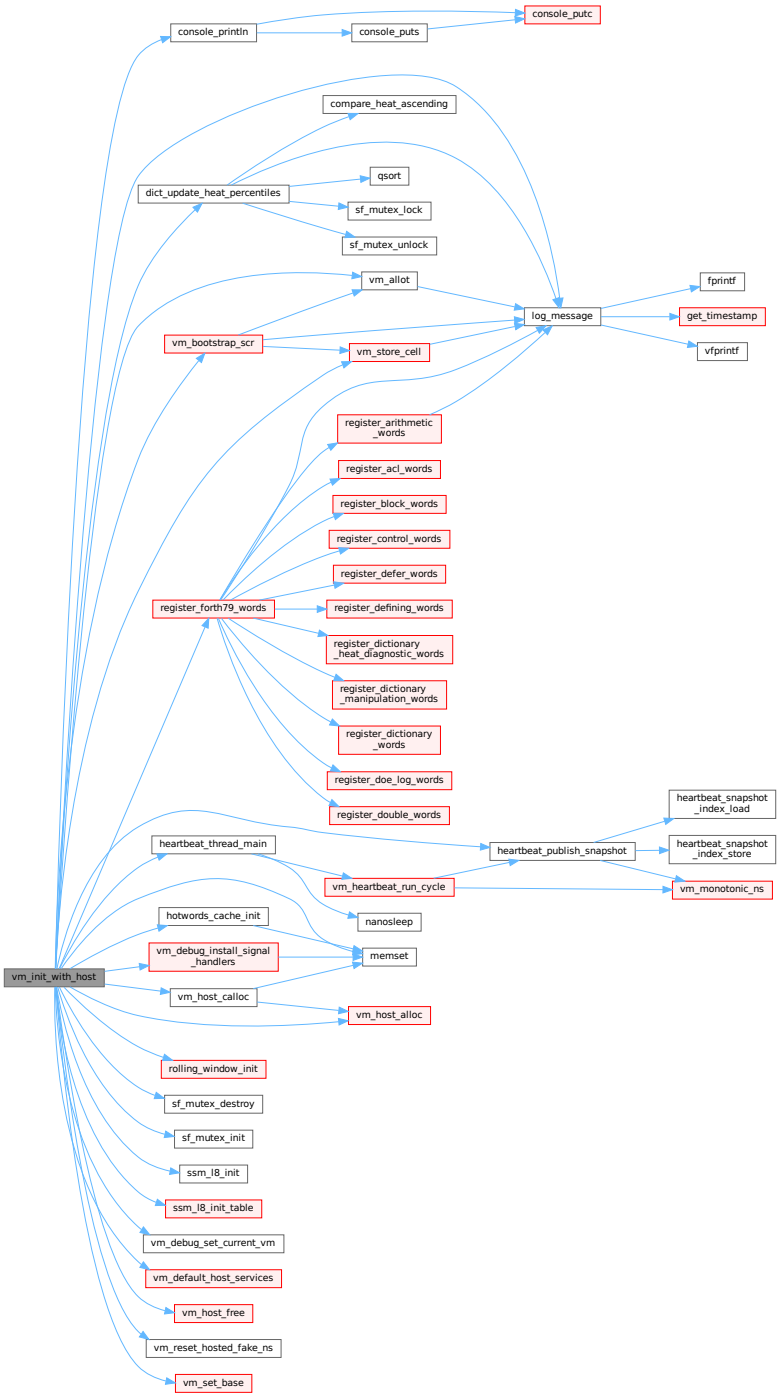
Parameters

vm	Pointer to VM structure to initialize
host	Host services (allocator/time). If NULL, uses build default.

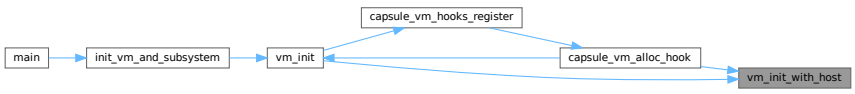
References VM::abort_requested, VM::base_addr, VM::cf, ControlFlowState::cf_last_mode, ControlFlowState::cf_sp, HeartbeatState::check_counter, VM::compiling_word, console_println(), VM::current_executing_entry, VM::decay_slope_direction, VM::decay_slope_q48, VM::dict_fence_here, VM::dict_fence_latest, VM::dict_lock, dict_update_heat_percentiles(), VM::dsp, RollingWindowOfTruth::effective_window_size, ControlFlowState::endof_mark_sp, ControlFlowState::endof_sp, errno, VM::error, VM::exit_colon, VM::halted, VM::heartbeat, VM::heartbeat_decay_cursor_id, HeartbeatState::heartbeat_enabled, heartbeat_publish_snapshot(), heartbeat_thread_main(), HEARTBEAT_TICK_NS, VM::here, VM::hold_addr, VM::hold_pos, VM::host, VM::hotwords_cache, hotwords_cache_init(), VM::input_length, VM::input_pos, VM::interpreter_enabled, VM::last_bucket_reorg_ns, PipelineGlobalMetrics::last_checked_accuracy, PipelineGlobalMetrics::last_chec VM::last_decay_check_ns, HeartbeatState::last_inference_tick, VM::latest, ControlFlowState::leave_mark_sp, ControlFlowState::leave_sp, LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, VM::lookup_strategy, VM::memory, memset(), VM::mode, MODE_INTERPRET, VM::next_word_id, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_ PipelineGlobalMetrics::prefetch_hits, VM::recycled_word_id_count, register_forth79_words(), VM::rolling_window, rolling_window_init(), VM::rsp, sf_mutex_destroy(), sf_mutex_init(), HeartbeatState::snapshot_index, VM::ssm_config, ssm_l8_init(), ssm_l8_init_table(), VM::ssm_l8_state, SSM_MODE_C0, VM::stale_word_count_at_check, VM::state_addr, VM::state_var, PipelineGlobalMetrics::suggested_next_size, HeartbeatState::tick_count, HeartbeatWorker::tick_ns, HeartbeatState::tick_target_ns, VM::total_heat_at_last_check, VM::tuning_lock, vm_allot(), vm_bootstrap_scr(), vm_debug_install_signal_handlers(), vm_debug_set_current_vm(), vm_default_host_services(), vm_host_alloc(), vm_host_calloc(), vm_host_free(), VM_MEMORY_SIZE, vm_reset_hosted_fake_ns(), vm_set_base(), vm_store_cell(), PipelineGlobalMetrics::window_tuning_checks, WORD_ID_INVALID, and HeartbeatState::worker.

Referenced by capsule_vm_alloc_hook(), and vm_init().

Here is the call graph for this function:



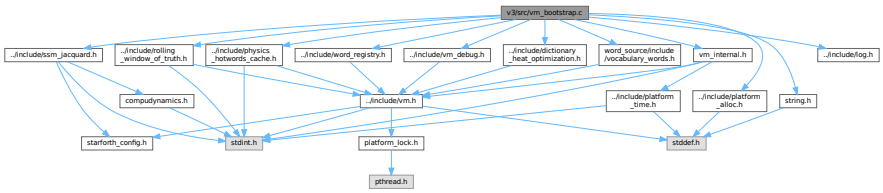
Here is the caller graph for this function:



7.344 v3/src/vm_bootstrap.c File Reference

```
#include "vm_internal.h"
#include "../include/log.h"
#include "../include/word_registry.h"
#include "../include/vm_debug.h"
#include "../include/physics_hotwords_cache.h"
#include "../include/rolling_window_of_truth.h"
#include "../include/dictionary_heat_optimization.h"
#include "../include/ssm_jacquard.h"
#include "../include/platform_alloc.h"
#include "word_source/include/vocabulary_words.h"
#include <string.h>
```

Include dependency graph for vm_bootstrap.c:



Functions

- static void vm_bootstrap_scr (VM *vm)

  Ensure the SCR (Screen) system variable cell is allocated and zeroed.
- void vm_bootstrap_root_vocabulary (VM *vm, const char *name)

  Bootstrap a root vocabulary for the VM.
- void vm_init (VM *vm)

  Initialize a new virtual machine instance.
- void vm_cleanup (VM *vm)

  Clean up and free VM resources.

7.344.1 Function Documentation

7.344.1.1 vm_bootstrap_root_vocabulary()

```
void vm_bootstrap_root_vocabulary (
            VM * vm,
            const char * name )
```

Bootstrap a root vocabulary for the VM.

Creates a vocabulary by name, finds its dictionary entry, executes it to make it current, then calls DEFINITIONS.

Parameters

vm	Pointer to VM structure
name	Vocabulary name to bootstrap

7.344.1.2 vm_bootstrap_scr()

```
static void vm_bootstrap_scr (
            VM * vm )  [static]
```

Ensure the SCR (Screen) system variable cell is allocated and zeroed.

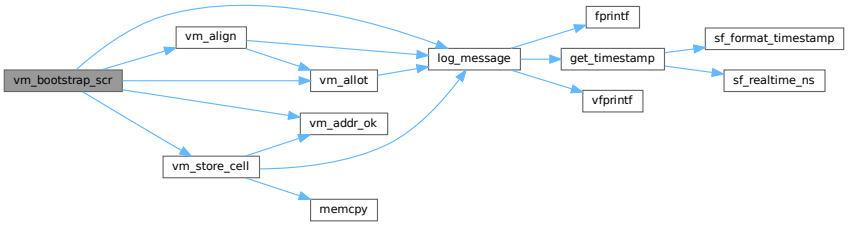
If `vm->scr_addr` does not point to a valid, aligned cell inside the VM memory array, aligns the allocation pointer and allots a new cell. Always writes 0 to the SCR cell on exit. Called at the end of `vm_init()` to guarantee a clean SCR state regardless of how the initial allot sequence progressed.

Parameters

vm	Active VM; sets `vm->error` = 1 and logs if allot fails

References VM::error, LOG_ERROR, log_message(), VM::memory, VM::scr_addr, vm_addr_ok(), vm_align(), vm_allot(), and vm_store_cell().

Here is the call graph for this function:



7.344.1.3 vm_cleanup()

```
void vm_cleanup (
            VM * vm )
```

Clean up and free VM resources.

Frees allocated memory and resets VM state.

Parameters

vm	Pointer to VM structure to clean up

7.344.1.4 vm_init()

```
void vm_init (
            VM * vm )
```

Initialize a new virtual machine instance.

Allocates memory and initializes all VM structures including:

- Memory array
- Data and return stacks
- System variables (SCR, STATE, BASE)
- Dictionary
- Forth-79 wordset

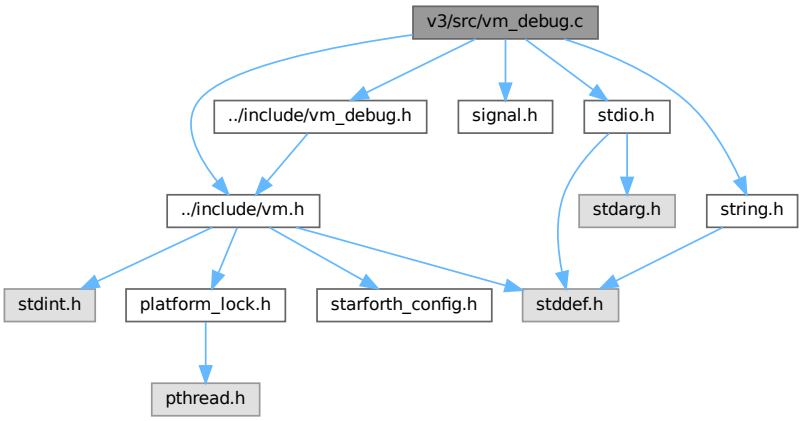
Parameters

vm	Pointer to VM structure to initialize

7.345 v3/src/vm_debug.c File Reference

```
#include "../include/vm.h"
#include "../include/vm_debug.h"
#include <signal.h>
#include <stdio.h>
#include <string.h>
```

Include dependency graph for vm_debug.c:



Functions

- void vm_debug_set_current_vm (VM *vm)

  Sets the VM instance to dump state for when signals occur.
- static unsigned dbg_get_base (const VM *vm)

  Safely retrieves the current number base from VM.
- static const char * mode_str (int m)

  Converts VM mode to string representation.

- static void dump_block_preview (const VM *vm, cell_t scr)

  Dumps preview of a block's contents.
- void vm_debug_dump_state (const VM *vm, const char *reason)

  Manually dumps the state of a VM instance.
- static void sig_handler (int sig)

  Signal handler for crash debugging.
- void vm_debug_install_signal_handlers (void)

  Installs signal handlers for crash debugging.

Variables

- static VM * g_vm = NULL

7.345.1 Function Documentation

7.345.1.1 dbg_get_base()

```
static unsigned dbg_get_base (
            const VM * vm )  [static]
```

Safely retrieves the current number base from VM.

Parameters

vm	Pointer to the VM instance

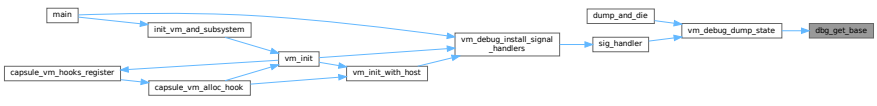
Returns

Current number base (2-36) or 10 if invalid

References VM::base, VM::base_addr, VM::memory, and VM_MEMORY_SIZE.

Referenced by vm_debug_dump_state().

Here is the caller graph for this function:



7.345.1.2 dump_block_preview()

```
static void dump_block_preview (
            const VM * vm,
            cell_t scr )  [static]
```

Dumps preview of a block's contents.

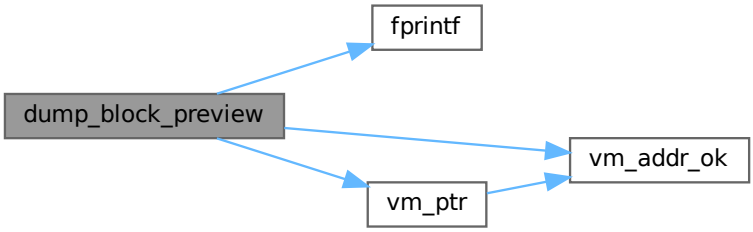
Parameters

vm	Pointer to the VM instance
scr	Block number to preview

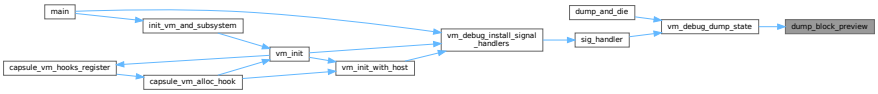
References BLOCK_SIZE, fprintf(), MAX_BLOCKS, stderr, vm_addr_ok(), and vm_ptr().

Referenced by vm_debug_dump_state().

Here is the call graph for this function:



Here is the caller graph for this function:



7.345.1.3 mode_str()

```
static const char * mode_str (
            int m )  [static]
```

Converts VM mode to string representation.

Parameters

m	The VM mode value

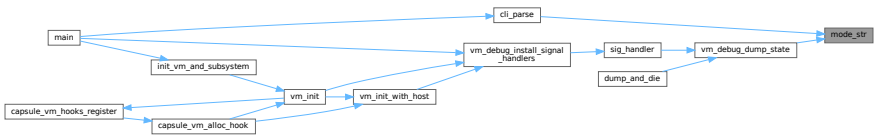
Returns

String representing the mode

References MODE_COMPILE, and MODE_INTERPRET.

Referenced by cli_parse(), and vm_debug_dump_state().

Here is the caller graph for this function:



7.345.1.4 sig_handler()

```
static void sig_handler (
            int sig )  [static]
```

Signal handler for crash debugging.

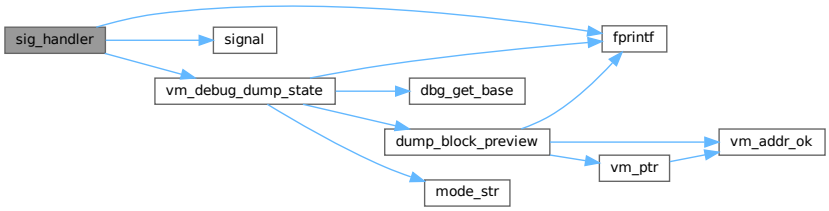
Parameters

sig	Signal number that was caught

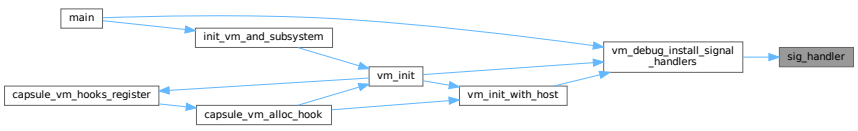
References fprintf(), g_vm, name, SIG_DFL, SIGABRT, signal(), SIGSEGV, stderr, and vm_debug_dump_state().

Referenced by vm_debug_install_signal_handlers().

Here is the call graph for this function:



Here is the caller graph for this function:



7.345.1.5 vm_debug_dump_state()

```
void vm_debug_dump_state (
            const VM * vm,
            const char * reason )
```

Manually dumps the state of a VM instance.

Parameters

vm	The VM instance to dump state for
reason	Description of why the dump was triggered

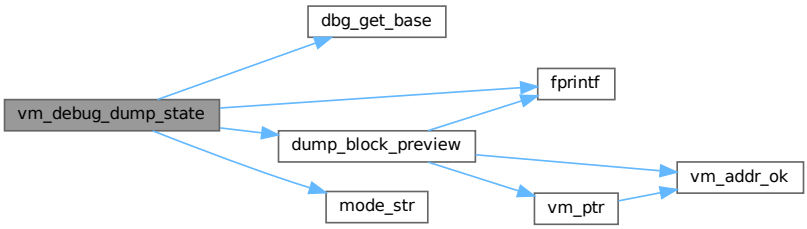
Note

Typically called before exit(1) on test failure

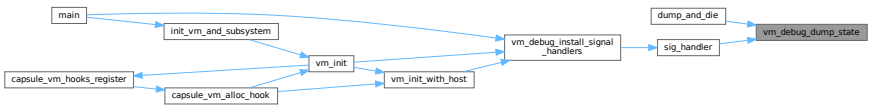
References base, VM::current_executing_entry, dbg_get_base(), VM::dsp, dump_block_preview(), VM::error, fprintf(), VM::here, VM::ip, VM::memory, VM::mode, mode_str(), DictEntry::name, VM::rsp, VM::scr_addr, stderr, and VM_MEMORY_SIZE.

Referenced by dump_and_die(), and sig_handler().

Here is the call graph for this function:



Here is the caller graph for this function:



7.345.1.6 vm_debug_install_signal_handlers()

```
void vm_debug_install_signal_handlers (
            void  )
```

Installs signal handlers for crash debugging.

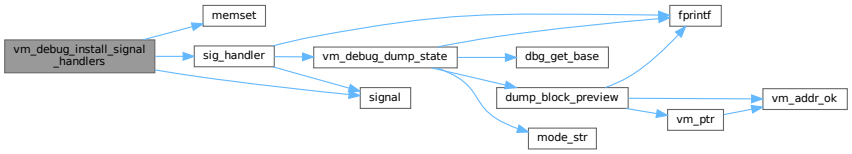
Installs signal handlers for SIGSEGV and SIGABRT.

Sets up handlers for SIGSEGV and SIGABRT to dump VM state on crash

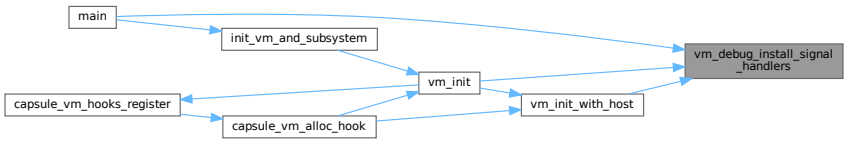
References memset(), sigaction::sa_flags, sigaction::sa_handler, SA_RESETHAND, sig_handler(), SIGABRT, signal(), and SIGSEGV.

Referenced by main(), vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.345.1.7 vm_debug_set_current_vm()

```
void vm_debug_set_current_vm (
            VM * vm )
```

Sets the VM instance to dump state for when signals occur.

Parameters

vm	Pointer to the VM instance to monitor

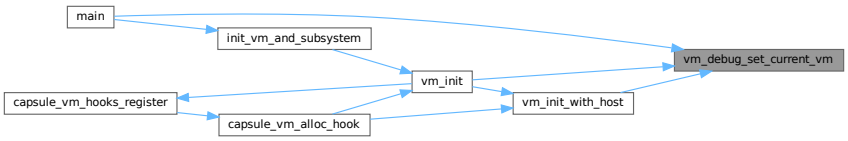
Note

Should be called once after vm_init

References g_vm.

Referenced by main(), vm_init(), and vm_init_with_host().

Here is the caller graph for this function:



7.345.2 Variable Documentation

7.345.2.1 g_vm

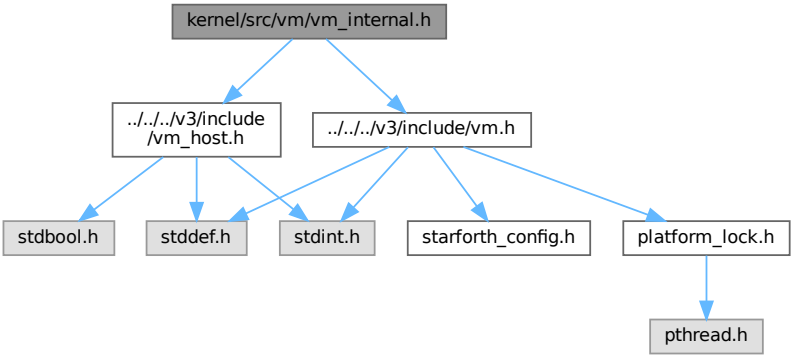
```
VM* g_vm = NULL  [static]
```

Referenced by sig_handler(), and vm_debug_set_current_vm().

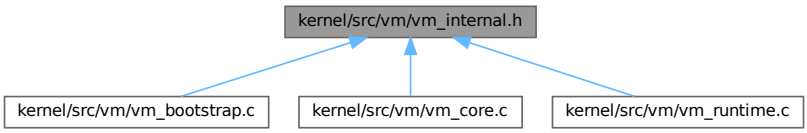
7.346 kernel/src/vm/vm_internal.h File Reference

```
#include "../../../v3/include/vm.h"
#include "../../../v3/include/vm_host.h"
```

Include dependency graph for vm_internal.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct HeartbeatWorker

Macros

- #define PARITY_MODE 0
- #define SK_PARITY_DEBUG 0
- #define HEARTBEAT_HAS_THREADS 0
- #define HEARTBEAT_DECAY_BATCH 64u

Typedefs

- typedef struct HeartbeatWorker HeartbeatWorker

Functions

- const VMHostServices * vm_default_host_services (void)
- const VMHostServices * vm_host (const VM *vm)
- void * vm_host_alloc (VM *vm, size_t size, size_t align)
- void * vm_host_calloc (VM *vm, size_t n, size_t size)
- void vm_host_free (VM *vm, void *ptr)
- void vm_reset_hosted_fake_ns (VM *vm)
- uint64_t vm_monotonic_ns (VM *vm)
- unsigned vm_get_base (const VM *vm)

  Read the current number base from the VM.
- void vm_set_base (VM *vm, unsigned b)

  Set the VM number base and update both the cell and the host mirror.
- uint32_t heartbeat_snapshot_index_load (const volatile uint32_t *ptr)
- void heartbeat_snapshot_index_store (volatile uint32_t *ptr, uint32_t value)
- void heartbeat_publish_snapshot (VM *vm)
- void vm_heartbeat_run_cycle (VM *vm)

7.346.1 Macro Definition Documentation

7.346.1.1 HEARTBEAT_DECAY_BATCH

```
#define HEARTBEAT_DECAY_BATCH 64u
```

7.346.1.2 HEARTBEAT_HAS_THREADS

```
#define HEARTBEAT_HAS_THREADS 0
```

7.346.1.3 PARITY_MODE

```
#define PARITY_MODE 0
```

7.346.1.4 SK_PARITY_DEBUG

```
#define SK_PARITY_DEBUG 0
```

7.346.2 Typedef Documentation

7.346.2.1 HeartbeatWorker

```
typedef struct HeartbeatWorker HeartbeatWorker
```

7.346.3 Function Documentation

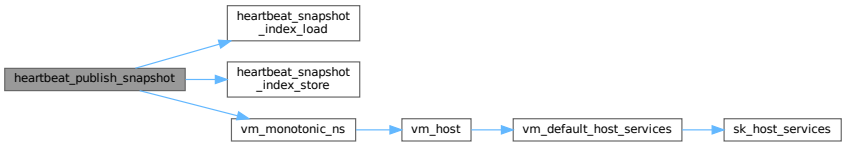
7.346.3.1 heartbeat_publish_snapshot()

```
void heartbeat_publish_snapshot (
            VM * vm )
```

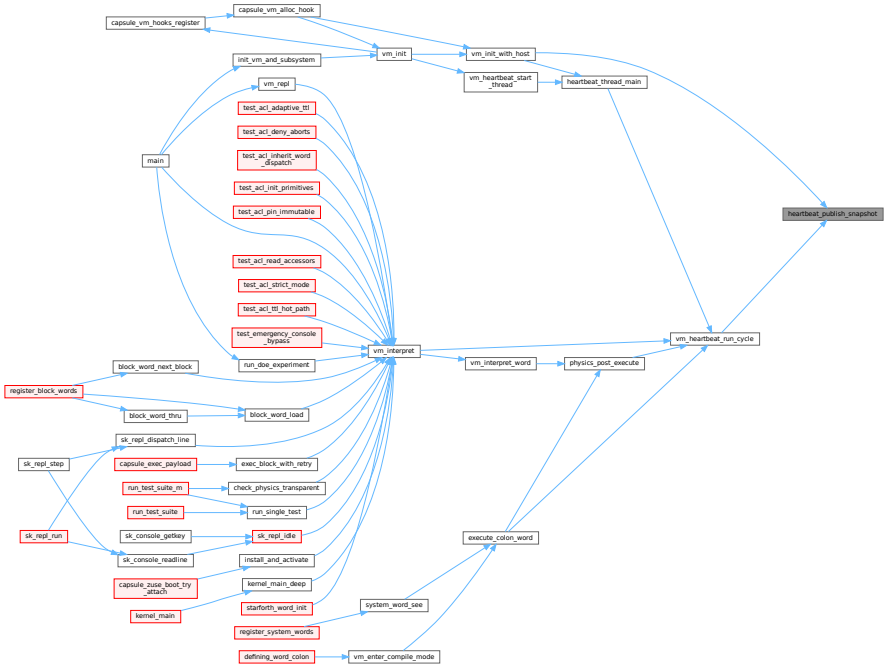
References HeartbeatSnapshot::decay_slope_q48, VM::decay_slope_q48, RollingWindowOfTruth::effective_window_size, VM::heartbeat, heartbeat_snapshot_index_load(), heartbeat_snapshot_index_store(), HeartbeatSnapshot::hot_word_count, VM::hot_word_count_at_check, HeartbeatSnapshot::published_ns, HeartbeatSnapshot::published_tick, VM::rolling_window, HeartbeatState::snapshot_index, HeartbeatState::snapshots, HeartbeatSnapshot::stale_word_count, VM::stale_word_count_at_chec HeartbeatState::tick_count, HeartbeatSnapshot::total_heat, VM::total_heat_at_last_check, vm_monotonic_ns(), and HeartbeatSnapshot::window_width.

Referenced by vm_heartbeat_run_cycle(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:

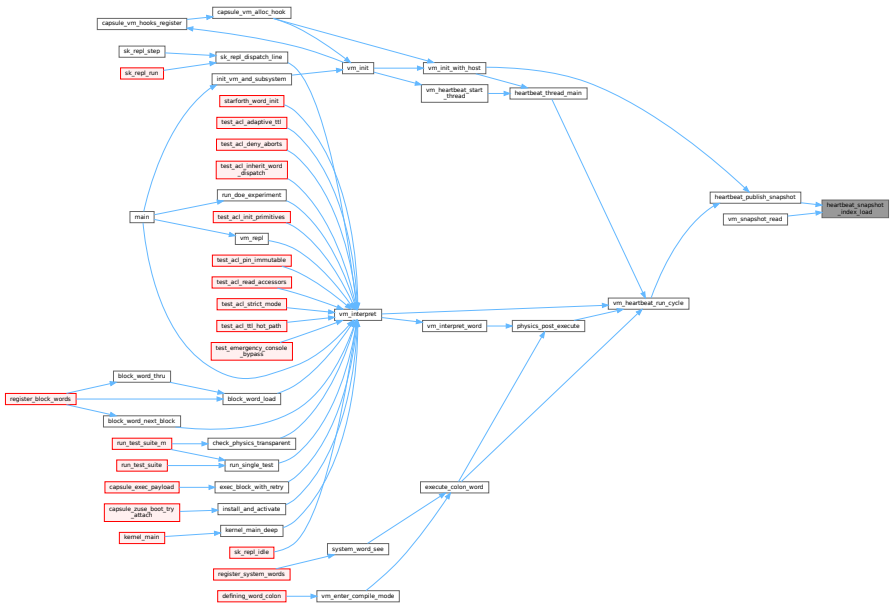


7.346.3.2 heartbeat_snapshot_index_load()

```
uint32_t heartbeat_snapshot_index_load (
            const volatile uint32_t * ptr )
```

Referenced by heartbeat_publish_snapshot(), and vm_snapshot_read().

Here is the caller graph for this function:

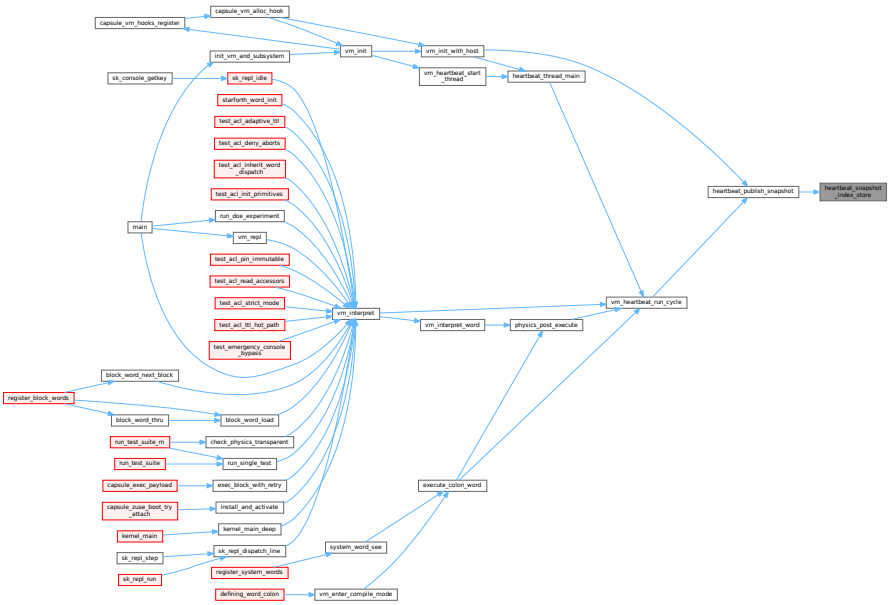


7.346.3.3 heartbeat_snapshot_index_store()

```
void heartbeat_snapshot_index_store (
            volatile uint32_t * ptr,
            uint32_t value )
```

Referenced by heartbeat_publish_snapshot().

Here is the caller graph for this function:



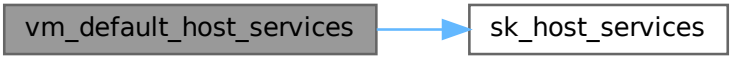
7.346.3.4 vm_default_host_services()

```
const VMHostServices * vm_default_host_services (
            void  )
```

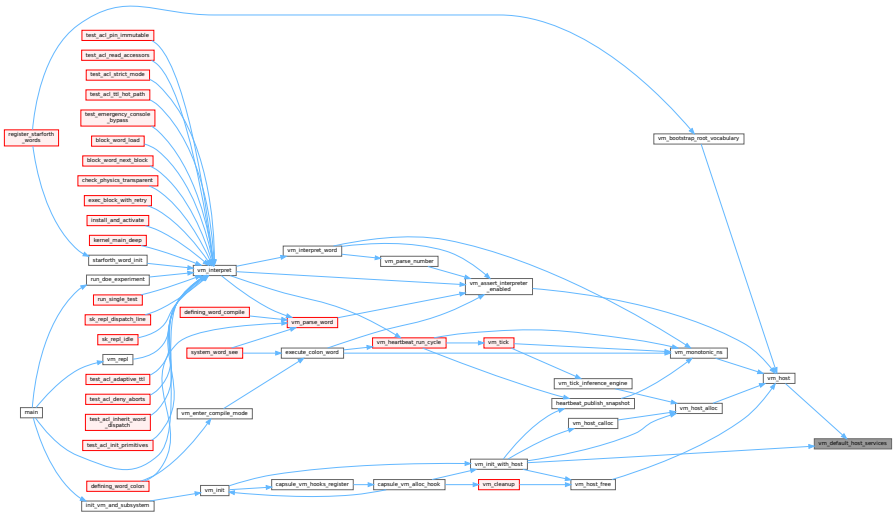
References hosted_services, and sk_host_services().

Referenced by vm_host(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.346.3.5 vm_get_base()

```
unsigned vm_get_base (
            const VM * vm )
```

Read the current number base from the VM.

Prefers the cell stored at `vm->base_addr` (the canonical FORTH `BASE` variable) if it is aligned and in the valid range [2, 36]. Falls back to the host-mirror `vm->base` if the cell is out of range, and finally returns 10 if both are invalid or `vm` is NULL.

The double-read (cell + mirror) keeps the VM consistent when C code modifies `vm->base` directly without going through `vm_set_base()`.

Parameters

vm	VM instance to query (may be NULL; returns 10 in that case).

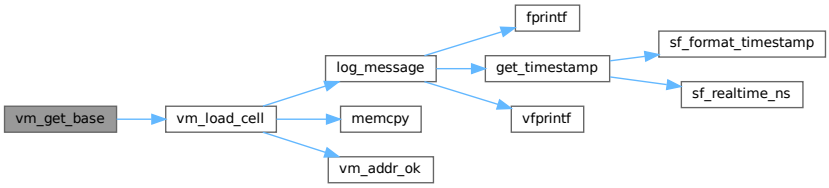
Returns

Current number base in range [2, 36].

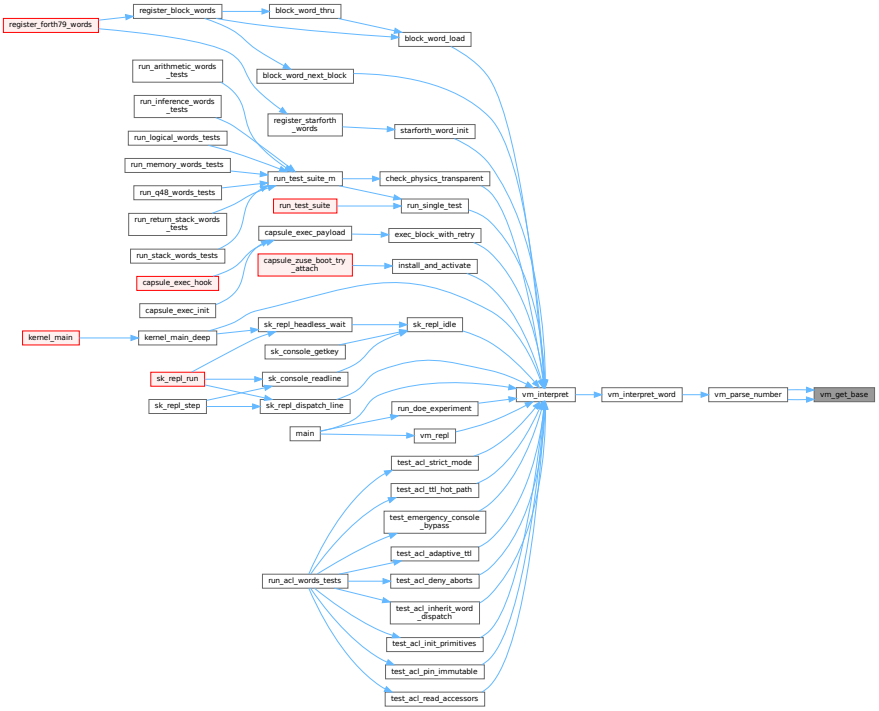
References VM::base, VM::base_addr, vm_load_cell(), and VM_MEMORY_SIZE.

Referenced by vm_parse_number(), and vm_parse_number().

Here is the call graph for this function:



Here is the caller graph for this function:



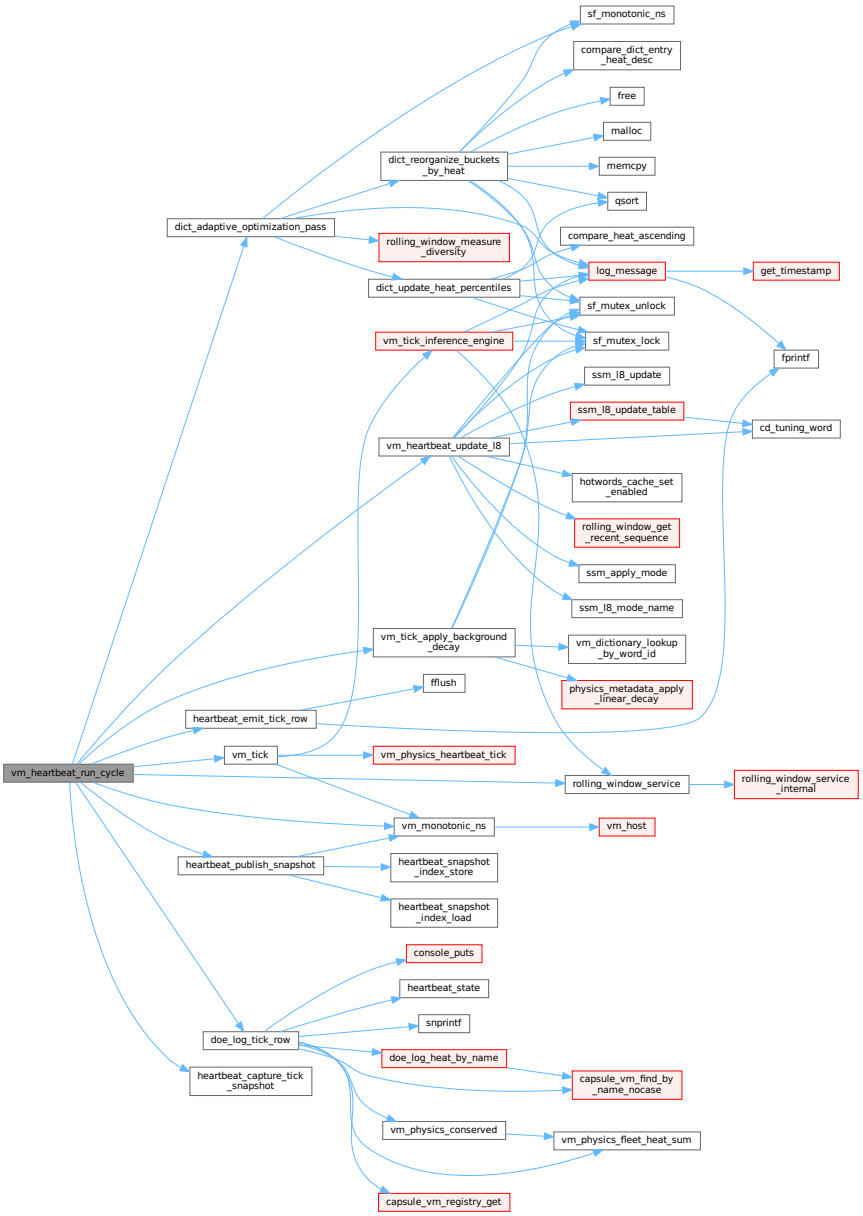
7.346.3.6 vm_heartbeat_run_cycle()

```
void vm_heartbeat_run_cycle (
            VM * vm )
```

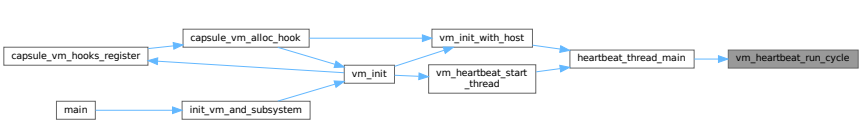
References dict_adaptive_optimization_pass(), doe_log_tick_row(), VM::heartbeat, heartbeat_capture_tick_snapshot(), heartbeat_emit_tick_row(), HeartbeatState::heartbeat_enabled, heartbeat_publish_snapshot(), VM::rolling_window, rolling_window_service(), vm_heartbeat_update_l8(), vm_monotonic_ns(), vm_tick(), and vm_tick_apply_background_decay().

Referenced by heartbeat_thread_main().

Here is the call graph for this function:



Here is the caller graph for this function:



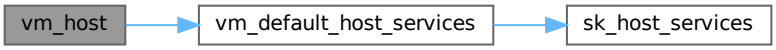
7.346.3.7 vm_host()

```
const VMHostServices * vm_host (
            const VM * vm )
```

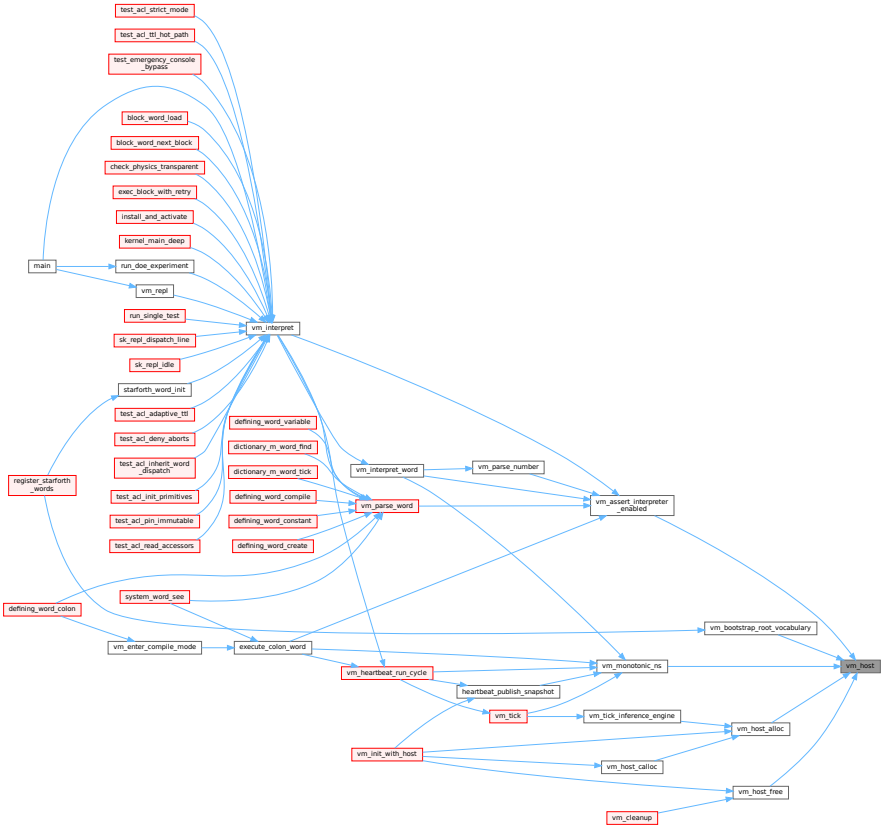
References VM::host, and vm_default_host_services().

Referenced by vm_assert_interpreter_enabled(), vm_bootstrap_root_vocabulary(), vm_host_alloc(), vm_host_free(), and vm_monotonic_ns().

Here is the call graph for this function:



Here is the caller graph for this function:



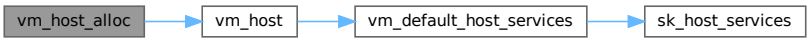
7.346.3.8 vm_host_alloc()

```
void * vm_host_alloc (
            VM * vm,
            size_t size,
            size_t align )
```

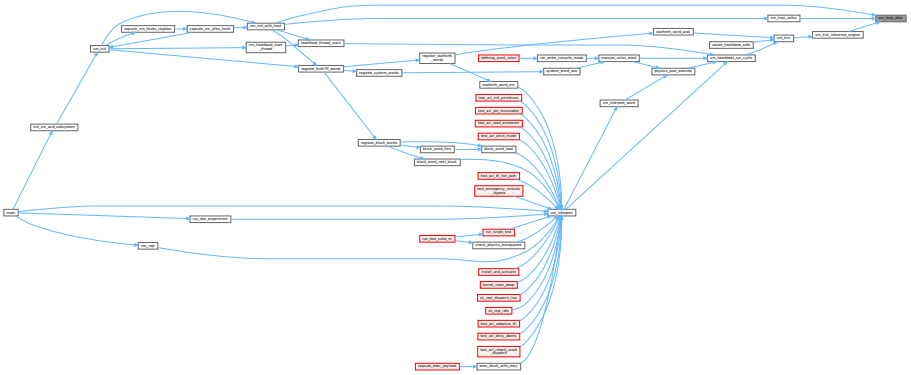
References VMHostServices::alloc, and vm_host().

Referenced by vm_host_calloc(), vm_init_with_host(), and vm_tick_inference_engine().

Here is the call graph for this function:



Here is the caller graph for this function:



7.346.3.9 vm_host_calloc()

```
void * vm_host_calloc (
            VM * vm,
            size_t n,
            size_t size )
```

References memset(), and vm_host_alloc().

Referenced by vm_init_with_host().

Here is the call graph for this function:

Here is the caller graph for this function:

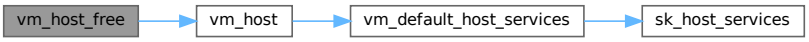
7.346.3.10 vm_host_free()

```
void vm_host_free (
            VM * vm,
            void * ptr )
```

References VMHostServices::free, and vm_host().

Referenced by vm_cleanup(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:

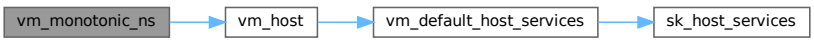
7.346.3.11 vm_monotonic_ns()

```
uint64_t vm_monotonic_ns (
            VM * vm )
```

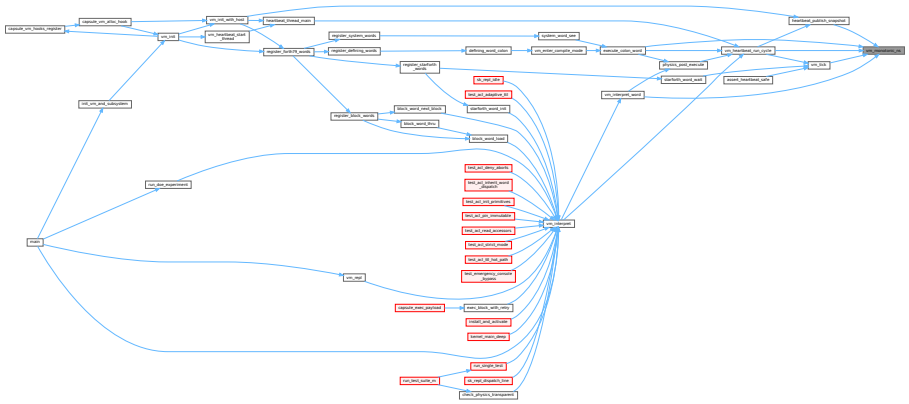
References VMHostServices::monotonic_ns, and vm_host().

Referenced by execute_colon_word(), heartbeat_publish_snapshot(), vm_heartbeat_run_cycle(), vm_interpret_word(), and vm_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.346.3.12 vm_reset_hosted_fake_ns()

```
void vm_reset_hosted_fake_ns (
            VM * vm )
```

References VM::host, hosted_fake_ns, hosted_services, and PARITY_MODE.

Referenced by vm_init_with_host().

Here is the caller graph for this function:

7.346.3.13 vm_set_base()

```
void vm_set_base (
            VM * vm,
            unsigned b )
```

Set the VM number base and update both the cell and the host mirror.

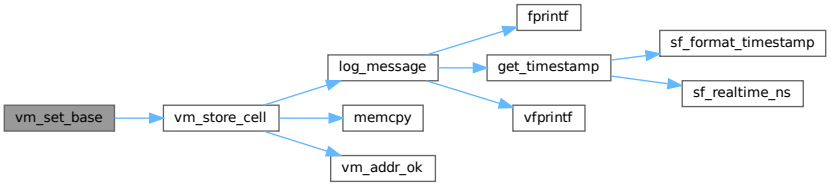
Clamps `b` to [2, 36] (replacing out-of-range values with 10), then writes to the FORTH `BASE` variable cell at `vm->base_addr` and to the host-mirror field `vm->base` so both sources agree.

Parameters

vm	VM instance to update.
b	Desired number base; clamped to [2, 36].

References VM::base, VM::base_addr, and vm_store_cell().

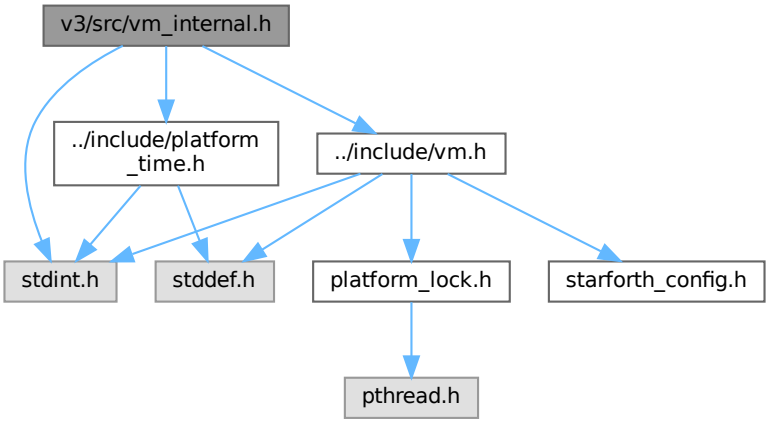
Here is the call graph for this function:



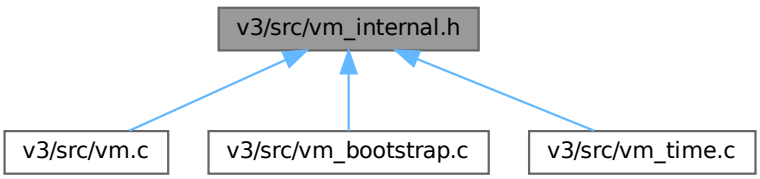
7.347 v3/src/vm_internal.h File Reference

```
#include "../include/vm.h"
#include "../include/platform_time.h"
#include <stdint.h>
```

Include dependency graph for vm_internal.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct HeartbeatWorker

Macros

- #define HEARTBEAT_HAS_THREADS 0
- #define HEARTBEAT_DECAY_BATCH 64u

Typedefs

- typedef struct HeartbeatWorker HeartbeatWorker

Functions

- static uint32_t heartbeat_snapshot_index_load (const volatile uint32_t *ptr)
- static void heartbeat_snapshot_index_store (volatile uint32_t *ptr, uint32_t value)
- void execute_colon_word (VM *vm)

  Inner interpreter for threaded colon definitions.
- void vm_tick (VM *vm)

  Central heartbeat dispatcher for time-driven tuning operations.
- void vm_tick_window_tuner (VM *vm)

  Loop #5: Context-aware window tuning via binary chop search.
- void vm_tick_slope_validator (VM *vm)

  Loop #3: Heat decay slope validation via periodic measurement.
- void vm_tick_inference_engine (VM *vm)

  Phase 2: Unified Inference Engine - Adaptive Window & Decay Slope Tuning.
- void vm_heartbeat_run_cycle (VM *vm)
- void vm_snapshot_read (const VM *vm, HeartbeatSnapshot *out_snapshot)
- void vm_heartbeat_start_thread (VM *vm)
- void vm_heartbeat_stop_thread (VM *vm)
- void vm_heartbeat_publish_snapshot (VM *vm)
- void vm_init (VM *vm)

  Initialize a new virtual machine instance.
- void vm_cleanup (VM *vm)

  Clean up and free VM resources.
- unsigned vm_get_base (const VM *vm)

  Read the current number base from the VM.
- void vm_set_base (VM *vm, unsigned b)

  Set the VM number base and update both the cell and the host mirror.

7.347.1 Macro Definition Documentation

7.347.1.1 HEARTBEAT_DECAY_BATCH

```
#define HEARTBEAT_DECAY_BATCH 64u
```

7.347.1.2 HEARTBEAT_HAS_THREADS

```
#define HEARTBEAT_HAS_THREADS 0
```

7.347.2 Typedef Documentation

7.347.2.1 HeartbeatWorker

```
typedef struct HeartbeatWorker HeartbeatWorker
```

7.347.3 Function Documentation

7.347.3.1 execute_colon_word()

```
void execute_colon_word (
            VM * vm )
```

Inner interpreter for threaded colon definitions.

Runs the body of a colon-defined word whose `DictEntry` points to a sequence of `DictEntry*` cells in VM memory (indirect threaded code). The interpreter pointer (IP) is maintained on the return stack so that runtime control-flow words ((BRANCH), (0BRANCH), (DO), etc.) can redirect execution by modifying the top-of-return-stack IP.

Execution loop per iteration:

1. Read `DictEntry* w` from `*ip`.
2. Run physics pre-execute hooks (heat, decay, pipelining).
3. ACL hot-path check (decrement TTL; call `acl_recheck()` on zero).
4. Push `ip+1` onto the return stack as the resume point.
5. Call `w->func(vm)`.
6. Run physics post-execute hooks.
7. Check `vm->exit_colon` (set by `EXIT`): pop and discard the saved IP, then return to caller.
8. Check `vm->abort_requested`: unwind and return immediately.
9. Pop the (possibly modified) IP from the return stack and repeat.

`vm->ecw_nesting` is incremented on entry and decremented on every return path to enable recursive colon calls.

Parameters

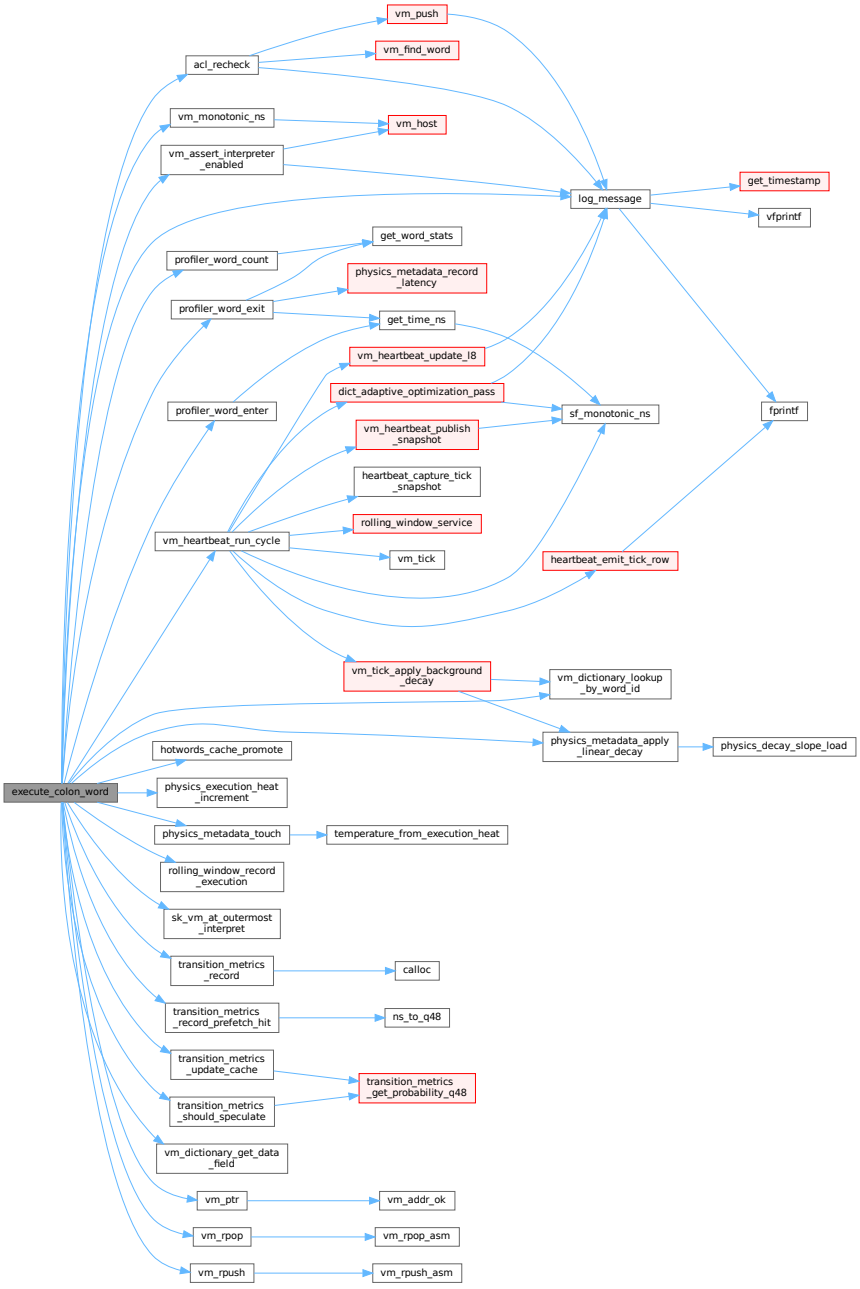
vm	VM instance; `vm->current_executing_entry` must point to the `DictEntry` being executed.

References VM::abort_requested, DictEntry::acl_allow, acl_recheck(), DictEntry::acl_ttl, HeartbeatState::check_counter, VM::current_executing_entry, DICTIONARY_SIZE, VM::dsp, VM::ecw_nesting, VM::emergency_console,

ENABLE_HOTWORDS_CACHE, ENABLE_PIPELINING, entry, VM::error, DictEntry::execution_heat, VM::exit_colon, DictEntry::func, g_sk_fault_word, VM::heartbeat, HEARTBEAT_CHECK_FREQUENCY, VM::hotwords_cache, hotwords_cache_promote(), HOTWORDS_EXECUTION_HEAT_THRESHOLD, DictPhysics::last_active_ns, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, LOG_DEBUG, LOG_ERROR, log_message(), LOG_WARN, WordTransitionMetrics::most_likely_next_word_id, DictEntry::name, DictEntry::name_len, DictEntry::physics, physics_execution_heat_increment(), physics_metadata_apply_linear_decay(), physics_metadata_touch(), VM::pipeline_metrics, WordTransitionMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, profiler_word_count(), profiler_word_enter(), profiler_word_exit(), VM::rolling_window, rolling_window_record_execution(), VM::rsp, sk_vm_at_outermost_interpret(), HeartbeatState::tick_count, DictEntry::transition_metrics, transition_metrics_record(), transition_metrics_record_prefetch_hit(), transition_metrics_should_specula transition_metrics_update_cache(), vm_assert_interpreter_enabled(), vm_dictionary_get_data_field(), vm_dictionary_lookup_by_wor vm_heartbeat_run_cycle(), vm_monotonic_ns(), vm_ptr(), vm_rpop(), vm_rpush(), word_id, DictEntry::word_id, HeartbeatState::words_executed, and HeartbeatState::worker.

Referenced by vm_enter_compile_mode().

Here is the call graph for this function:



Here is the caller graph for this function:

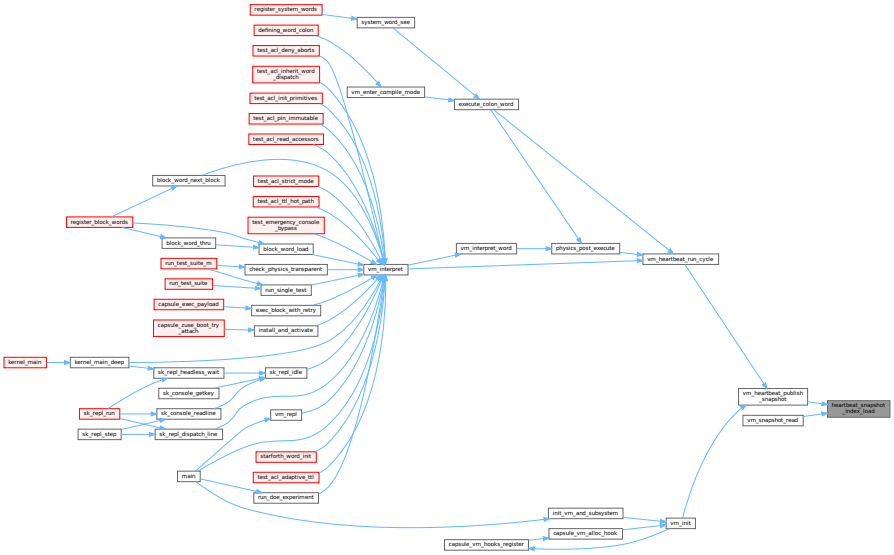
7.347.3.2 heartbeat_snapshot_index_load()

```
static uint32_t heartbeat_snapshot_index_load (
```

```
            const volatile uint32_t * ptr )  [inline], [static]
```

Referenced by vm_heartbeat_publish_snapshot(), and vm_snapshot_read().

Here is the caller graph for this function:

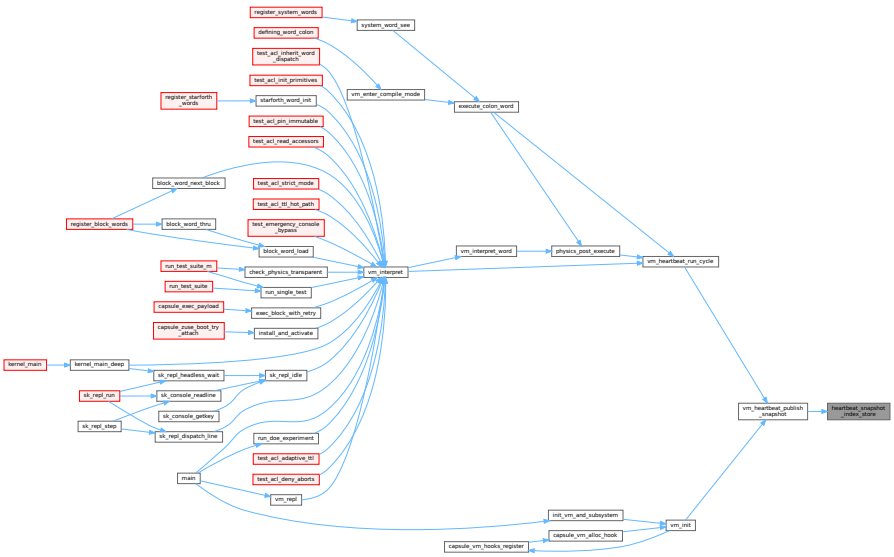


7.347.3.3 heartbeat_snapshot_index_store()

```
static void heartbeat_snapshot_index_store (
            volatile uint32_t * ptr,
            uint32_t value )  [inline], [static]
```

Referenced by vm_heartbeat_publish_snapshot().

Here is the caller graph for this function:



7.347.3.4 vm_cleanup()

```
void vm_cleanup (
            VM * vm )
```

Clean up and free VM resources.

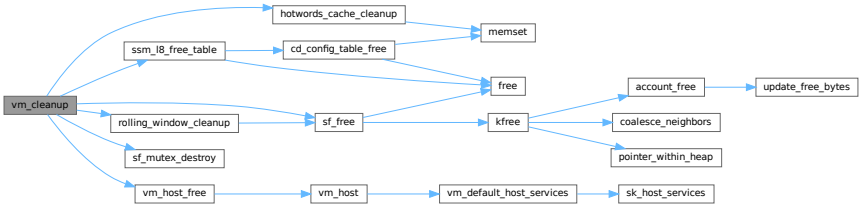
Frees allocated memory and resets VM state.

Parameters

vm	Pointer to VM structure to clean up

References VM::dict_lock, VM::heartbeat, VM::here, VM::hotwords_cache, hotwords_cache_cleanup(), VM::latest, DictEntry::link, VM::memory, VM::rolling_window, rolling_window_cleanup(), sf_free(), sf_mutex_destroy(), VM::ssm_config, ssm_l8_free_table(), VM::ssm_l8_state, HeartbeatWorker::stop_requested, DictEntry::transition_metrics, VM::tuning_lock, vm_host_free(), and HeartbeatState::worker.

Here is the call graph for this function:



7.347.3.5 vm_get_base()

```
unsigned vm_get_base (
            const VM * vm )
```

Read the current number base from the VM.

Prefers the cell stored at `vm->base_addr` (the canonical FORTH `BASE` variable) if it is aligned and in the valid range [2, 36]. Falls back to the host-mirror `vm->base` if the cell is out of range, and finally returns 10 if both are invalid or `vm` is NULL.

The double-read (cell + mirror) keeps the VM consistent when C code modifies `vm->base` directly without going through `vm_set_base()`.

Parameters

vm	VM instance to query (may be NULL; returns 10 in that case).

Returns

Current number base in range [2, 36].

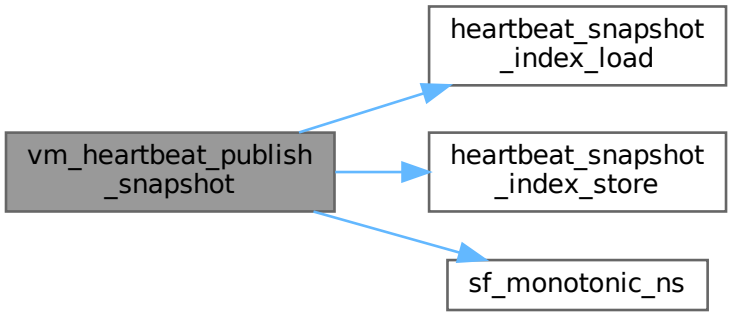
7.347.3.6 vm_heartbeat_publish_snapshot()

```
void vm_heartbeat_publish_snapshot (
            VM * vm )
```

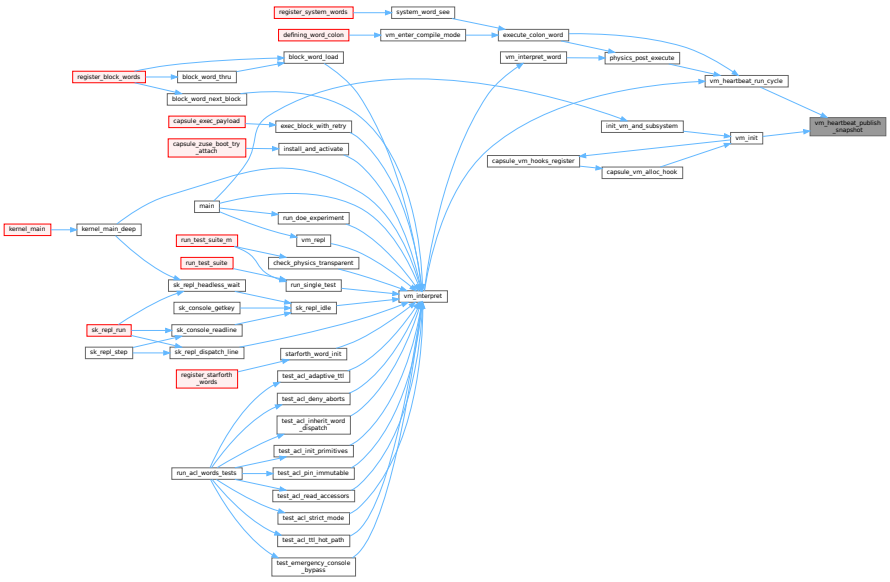
References HeartbeatSnapshot::actual_window_size, HeartbeatSnapshot::decay_slope_q48, VM::decay_slope_q48, RollingWindowOfTruth::effective_window_size, VM::heartbeat, heartbeat_snapshot_index_load(), heartbeat_snapshot_index_store(), HeartbeatSnapshot::hot_word_count, VM::hot_word_count_at_check, HeartbeatSnapshot::published_ns, HeartbeatSnapshot::publis VM::rolling_window, ROLLING_WINDOW_SIZE, sf_monotonic_ns(), HeartbeatState::snapshot_index, HeartbeatState::snapshots, HeartbeatSnapshot::stale_word_count, VM::stale_word_count_at_check, HeartbeatState::tick_count, RollingWindowOfTruth::total_ex HeartbeatSnapshot::total_heat, VM::total_heat_at_last_check, and HeartbeatSnapshot::window_width.

Referenced by vm_heartbeat_run_cycle(), and vm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



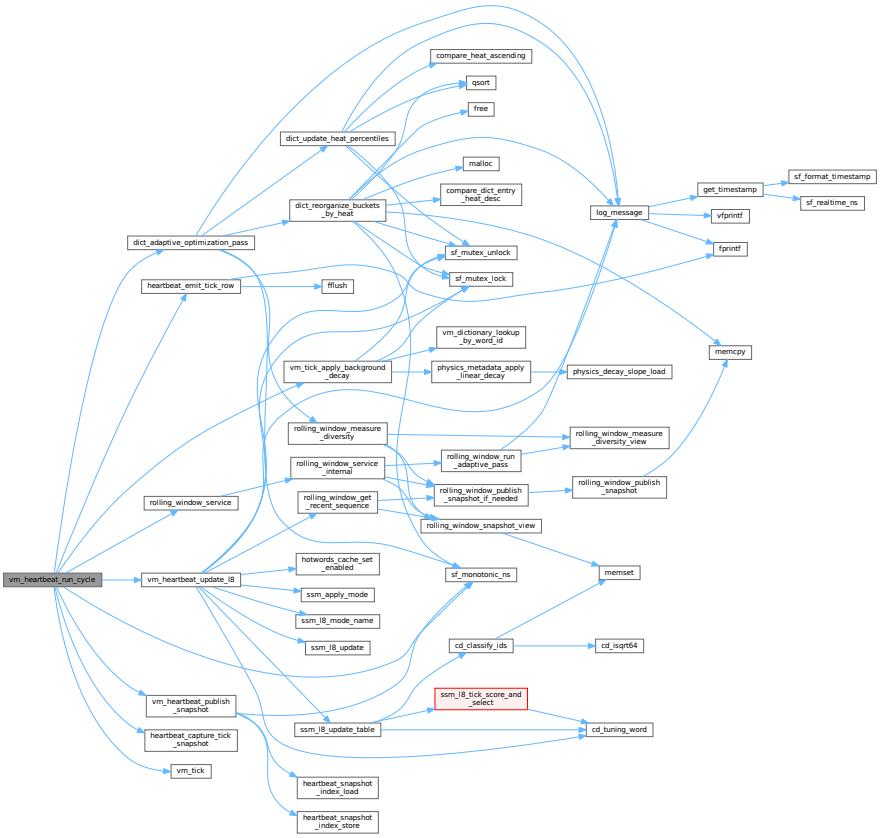
7.347.3.7 vm_heartbeat_run_cycle()

```
void vm_heartbeat_run_cycle (
            VM * vm )
```

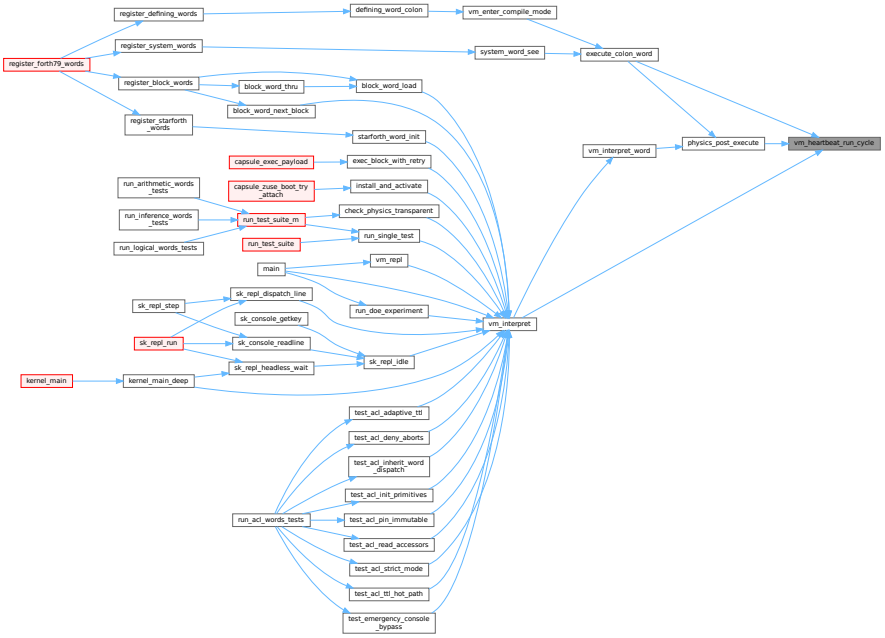
References dict_adaptive_optimization_pass(), VM::heartbeat, heartbeat_capture_tick_snapshot(), heartbeat_emit_tick_row(), HeartbeatState::heartbeat_enabled, VM::rolling_window, rolling_window_service(), sf_monotonic_ns(), vm_heartbeat_publish_snaps vm_heartbeat_update_l8(), vm_tick(), and vm_tick_apply_background_decay().

Referenced by execute_colon_word(), physics_post_execute(), and vm_interpret().

Here is the call graph for this function:



Here is the caller graph for this function:



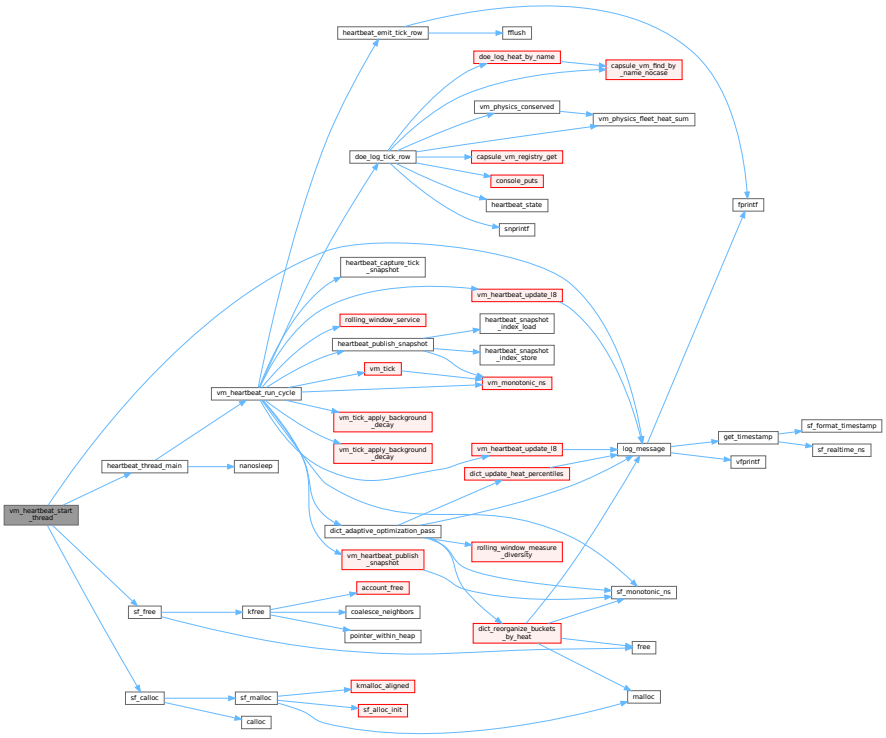
7.347.3.8 vm_heartbeat_start_thread()

```
void vm_heartbeat_start_thread (
            VM * vm )
```

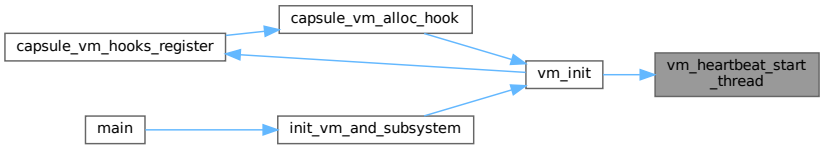
References errno, VM::heartbeat, heartbeat_thread_main(), HEARTBEAT_TICK_NS, log_message(), LOG_WARN, sf_calloc(), sf_free(), HeartbeatWorker::tick_ns, and HeartbeatState::worker.

Referenced by vm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



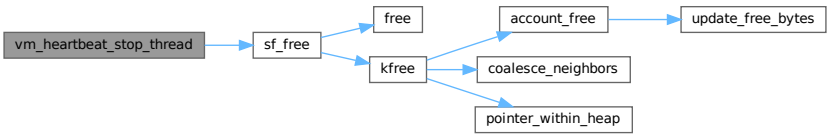
7.347.3.9 vm_heartbeat_stop_thread()

```
void vm_heartbeat_stop_thread (
            VM * vm )
```

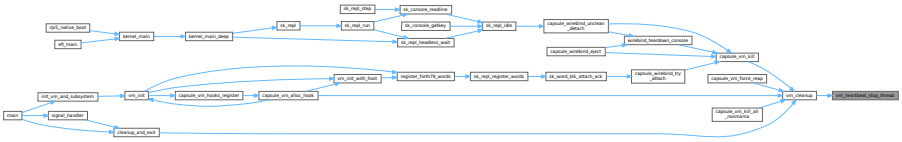
References VM::heartbeat, sf_free(), HeartbeatWorker::stop_requested, and HeartbeatState::worker.

Referenced by vm_cleanup().

Here is the call graph for this function:



Here is the caller graph for this function:



7.347.3.10 vm_init()

```
void vm_init (
            VM * vm )
```

Initialize a new virtual machine instance.

Allocates memory and initializes all VM structures including:

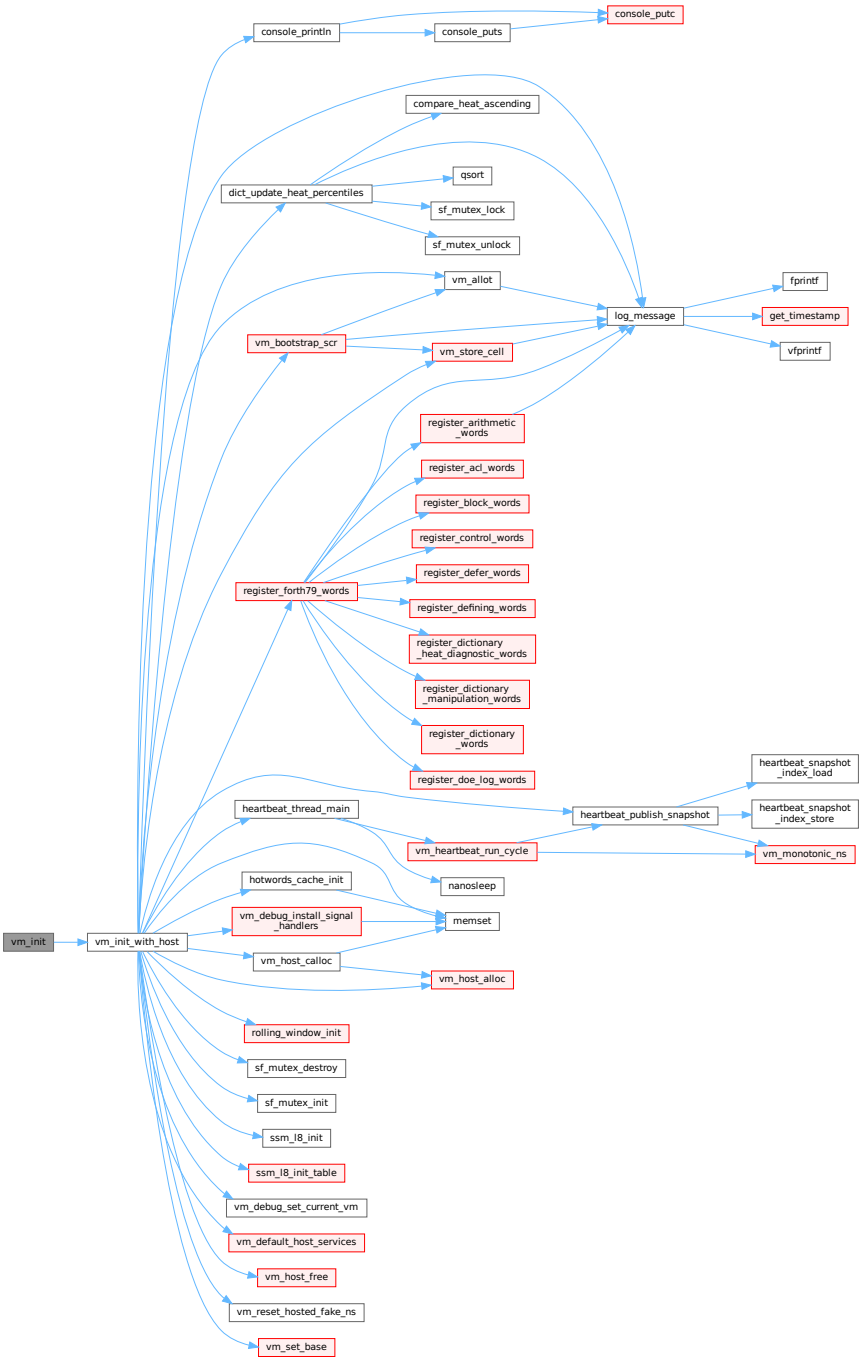
- Memory array
- Data and return stacks
- System variables (SCR, STATE, BASE)
- Dictionary
- Forth-79 wordset

Parameters

vm	Pointer to VM structure to initialize

References vm_init_with_host().

Here is the call graph for this function:



7.347.3.11 vm_set_base()

```
void vm_set_base (
            VM * vm,
            unsigned b )
```

Set the VM number base and update both the cell and the host mirror.

Clamps `b` to [2, 36] (replacing out-of-range values with 10), then writes to the FORTH `BASE` variable cell at `vm->base_addr` and to the host-mirror field `vm->base` so both sources agree.

Parameters

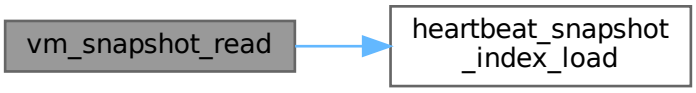
vm	VM instance to update.
b	Desired number base; clamped to [2, 36].

7.347.3.12 vm_snapshot_read()

```
void vm_snapshot_read (
            const VM * vm,
            HeartbeatSnapshot * out_snapshot )
```

References VM::heartbeat, heartbeat_snapshot_index_load(), HeartbeatState::snapshot_index, and HeartbeatState::snapshots.

Here is the call graph for this function:



7.347.3.13 vm_tick()

```
void vm_tick (
            VM * vm )
```

Central heartbeat dispatcher for time-driven tuning operations.

Aggregates all periodic optimization tasks (Loop #3 and Loop #5) into one place. Designed as plugin architecture - new tuning operations can be added as plugins.

Options for integration:

- Synchronous (now): Called from main execution loop, every N executions
- Background thread (future): Runs in separate thread, decoupled from VM execution

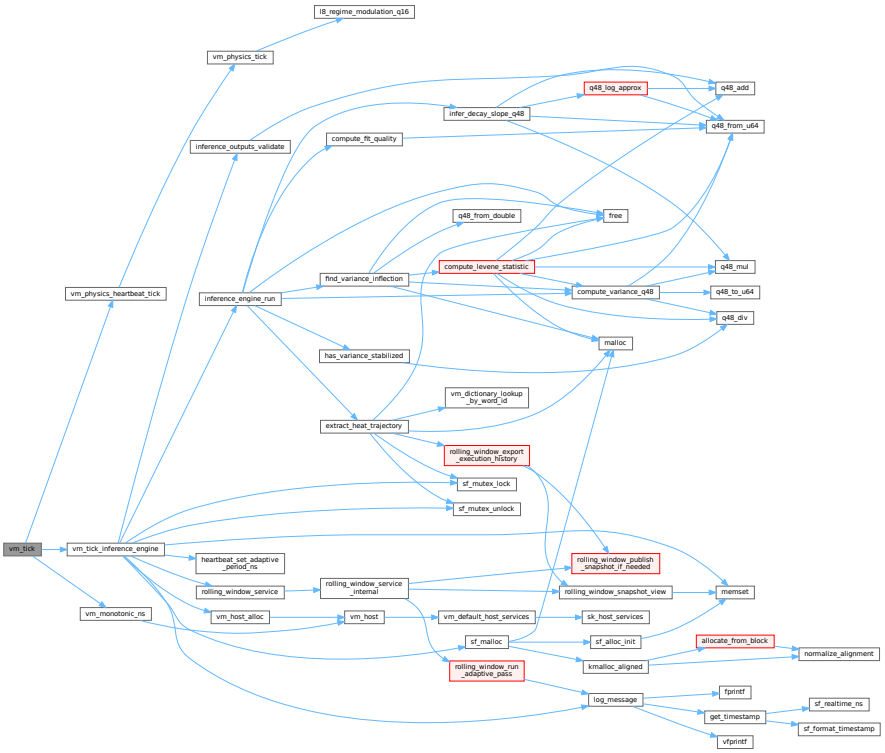
Parameters

vm	Pointer to VM instance

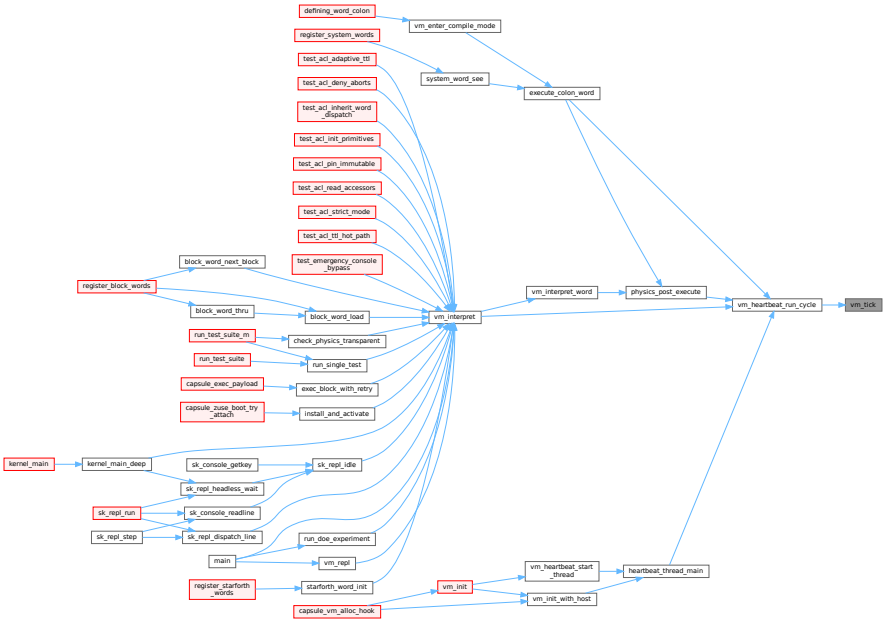
References VM::heartbeat, HeartbeatState::heartbeat_enabled, HEARTBEAT_INFERENCE_FREQUENCY, HeartbeatState::last_inference_tick, HeartbeatState::tick_count, vm_monotonic_ns(), vm_physics_heartbeat_tick(), and vm_tick_inference_engine().

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.347.3.14 vm_tick_inference_engine()

```
void vm_tick_inference_engine (
            VM * vm )
```

Phase 2: Unified Inference Engine - Adaptive Window & Decay Slope Tuning.

Coordinates inference on rolling window of truth to determine:

- Optimal adaptive window width (via variance inflection detection)
- Optimal decay slope (via exponential regression on heat trajectory)

Uses ANOVA early-exit to skip full inference when variance is stable (<5% change). All math uses Q48.16 fixed-point (integer-only, no floating-point).

Replaces legacy vm_tick_window_tuner() and vm_tick_slope_validator().

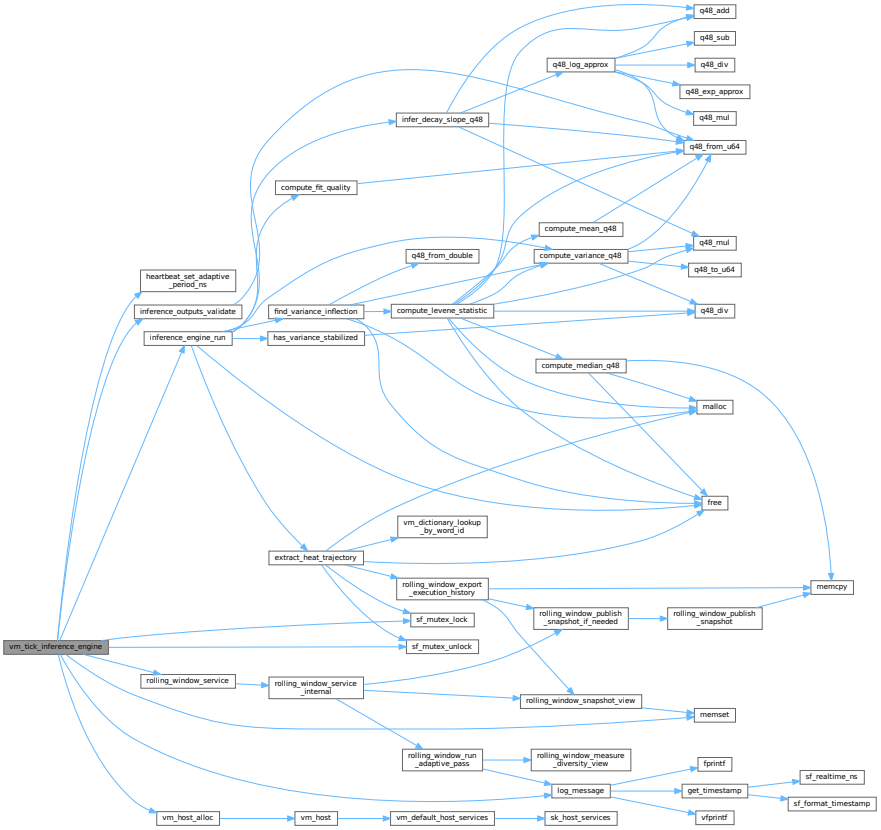
Parameters

vm	Pointer to VM instance

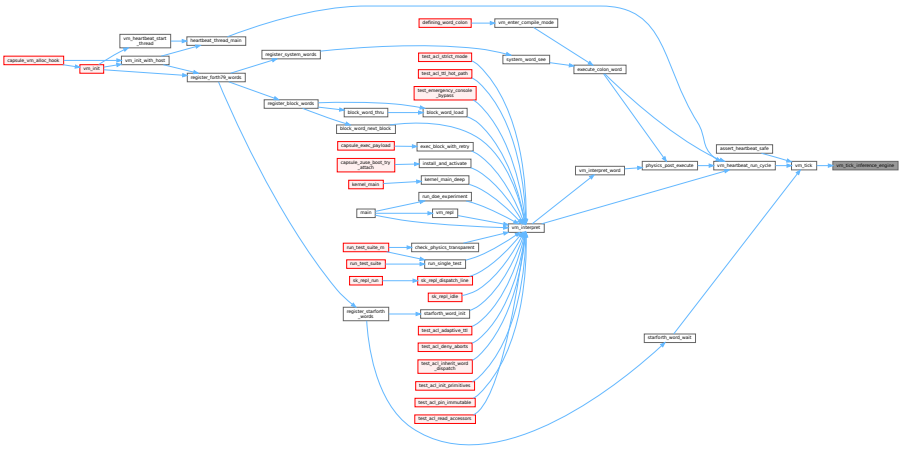
References InferenceOutputs::adaptive_decay_slope, InferenceOutputs::adaptive_window_width, VM::decay_slope_q48, VM::dict_lock, HeartbeatState::early_exit_count, InferenceOutputs::early_exited, RollingWindowOfTruth::effective_window_size, VM::heartbeat, HeartbeatState::heartbeat_enabled, heartbeat_set_adaptive_period_ns(), HEARTBEAT_TICK_NS, HOTWORDS_EXECUTION_HEAT_THRESHOLD, inference_engine_run(), inference_outputs_validate(), HeartbeatState::inference_, RollingWindowOfTruth::is_warm, VM::last_inference_outputs, HeartbeatState::last_inference_tick, VM::latest, LOG_DEBUG, LOG_ERROR, LOG_INFO, log_message(), memset(), VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::rolling_window, rolling_window_service(), sf_mutex_lock(), sf_mutex_unlock(), InferenceOutputs::slope_fit_quality_q48, VM::stale_word_count_at_check, HeartbeatState::tick_count, HeartbeatWorker::tick_ns, HeartbeatState::tick_target_ns, RollingWindowOfTruth::total_executions, VM::total_heat_at_last_check, VM::tuning_lock, vm_host_alloc(), InferenceInputs::window, RollingWindowOfTruth::window_pos, InferenceOutputs::window_variance_q48, word_count, VM::word_count_at_check, and HeartbeatState::worker.

Referenced by vm_tick().

Here is the call graph for this function:



Here is the caller graph for this function:



7.347.3.15 vm_tick_slope_validator()

```
void vm_tick_slope_validator (
            VM * vm )
```

Loop #3: Heat decay slope validation via periodic measurement.

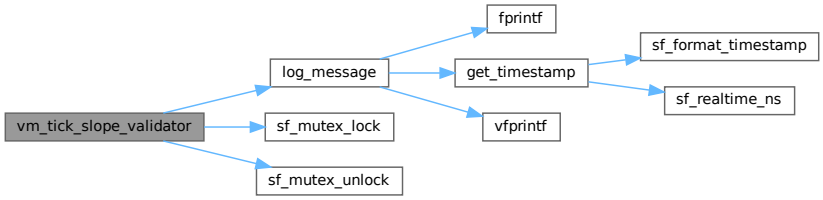
Validates that linear decay is actually helping optimize dictionary caching. Measures stale word ratio, hot word count, and average heat distribution.

Parameters

vm	Pointer to VM instance

References VM::decay_slope_direction, VM::decay_slope_q48, VM::dict_lock, VM::hot_word_count_at_check, HOTWORDS_EXECUTION_HEAT_THRESHOLD, VM::latest, LOG_INFO, log_message(), sf_mutex_lock(), sf_mutex_unlock(), VM::stale_word_count_at_check, VM::total_heat_at_last_check, VM::tuning_lock, word_count, and VM::word_count_at_check.

Here is the call graph for this function:



7.347.3.16 vm_tick_window_tuner()

```
void vm_tick_window_tuner (
            VM * vm )
```

Loop #5: Context-aware window tuning via binary chop search.

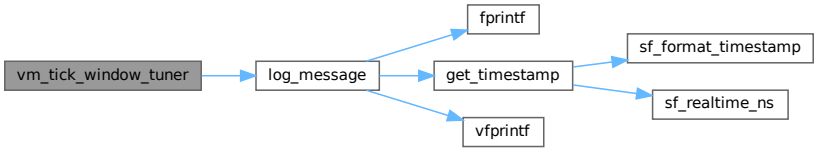
Uses prefetch accuracy to guide window size adaptation. Binary search converges on optimal effective_window_↩ size for current workload.

Parameters

vm	Pointer to VM instance

References ADAPTIVE_MIN_WINDOW_SIZE, RollingWindowOfTruth::effective_window_size, ENABLE_PIPELINING, RollingWindowOfTruth::is_warm, PipelineGlobalMetrics::last_checked_accuracy, PipelineGlobalMetrics::last_checked_window_size, LOG_INFO, log_message(), VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, VM::rolling_window, ROLLING_WINDOW_SIZE, and PipelineGlobalMetrics::window_tuning_checks.

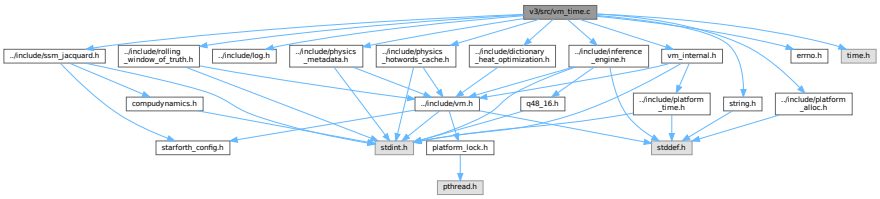
Here is the call graph for this function:



7.348 v3/src/vm_time.c File Reference

```
#include "vm_internal.h"
#include "../include/inference_engine.h"
#include "../include/log.h"
#include "../include/physics_metadata.h"
#include "../include/physics_hotwords_cache.h"
#include "../include/rolling_window_of_truth.h"
#include "../include/dictionary_heat_optimization.h"
#include "../include/ssm_jacquard.h"
#include "../include/platform_alloc.h"
#include <string.h>
#include <errno.h>
#include <time.h>
```

Include dependency graph for vm_time.c:



Functions

- static void vm_tick_apply_background_decay (VM *vm, uint64_t now_ns)
- static void vm_heartbeat_update_l8 (VM *vm)

  L8 FINAL INTEGRATION: Jacquard mode selector heartbeat update.
- void vm_heartbeat_publish_snapshot (VM *vm)
- void vm_tick (VM *vm)

  Central heartbeat dispatcher for time-driven tuning operations.
- void vm_tick_window_tuner (VM *vm)

  Loop #5: Context-aware window tuning via binary chop search.
- void vm_tick_slope_validator (VM *vm)

  Loop #3: Heat decay slope validation via periodic measurement.
- void vm_heartbeat_run_cycle (VM *vm)
- void vm_snapshot_read (const VM *vm, HeartbeatSnapshot *out_snapshot)
- void vm_tick_inference_engine (VM *vm)

  Phase 2: Unified Inference Engine - Adaptive Window & Decay Slope Tuning.
- void vm_heartbeat_start_thread (VM *vm)
- void vm_heartbeat_stop_thread (VM *vm)

7.348.1 Function Documentation

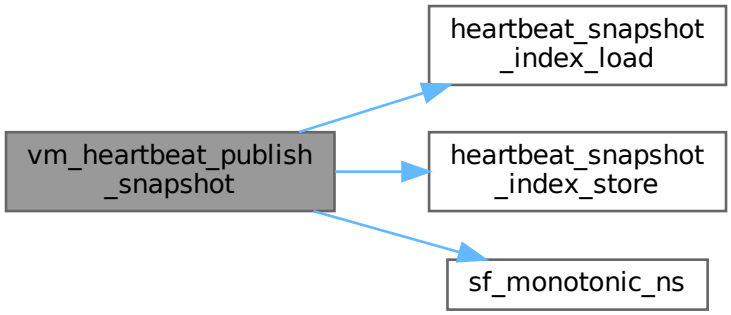
7.348.1.1 vm_heartbeat_publish_snapshot()

```
void vm_heartbeat_publish_snapshot (
            VM * vm )
```

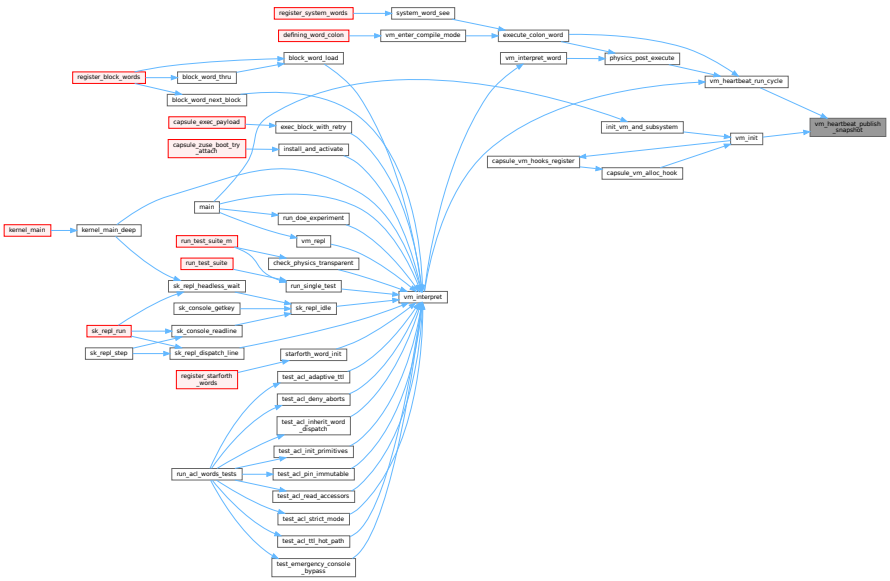
References HeartbeatSnapshot::actual_window_size, HeartbeatSnapshot::decay_slope_q48, VM::decay_slope_q48, RollingWindowOfTruth::effective_window_size, VM::heartbeat, heartbeat_snapshot_index_load(), heartbeat_snapshot_index_store(), HeartbeatSnapshot::hot_word_count, VM::hot_word_count_at_check, HeartbeatSnapshot::published_ns, HeartbeatSnapshot::publish VM::rolling_window, ROLLING_WINDOW_SIZE, sf_monotonic_ns(), HeartbeatState::snapshot_index, HeartbeatState::snapshots, HeartbeatSnapshot::stale_word_count, VM::stale_word_count_at_check, HeartbeatState::tick_count, RollingWindowOfTruth::total_ex HeartbeatSnapshot::total_heat, VM::total_heat_at_last_check, and HeartbeatSnapshot::window_width.

Referenced by vm_heartbeat_run_cycle(), and vm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



7.348.1.2 vm_heartbeat_run_cycle()

```
void vm_heartbeat_run_cycle (
            VM * vm )
```

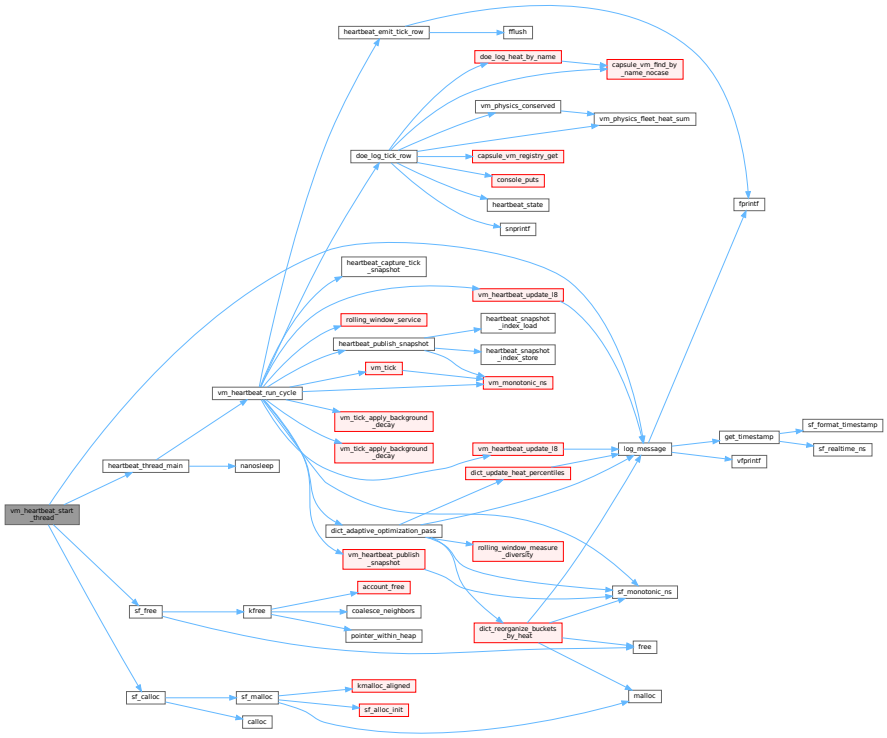
7.348.1.3 vm_heartbeat_start_thread()

```
void vm_heartbeat_start_thread (
            VM * vm )
```

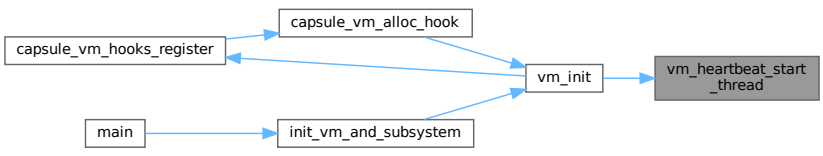
References errno, VM::heartbeat, heartbeat_thread_main(), HEARTBEAT_TICK_NS, log_message(), LOG_WARN, sf_calloc(), sf_free(), HeartbeatWorker::tick_ns, and HeartbeatState::worker.

Referenced by vm_init().

Here is the call graph for this function:



Here is the caller graph for this function:



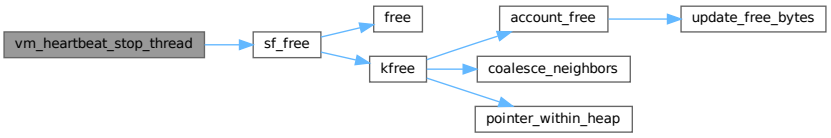
7.348.1.4 vm_heartbeat_stop_thread()

```
void vm_heartbeat_stop_thread (
            VM * vm )
```

References VM::heartbeat, sf_free(), HeartbeatWorker::stop_requested, and HeartbeatState::worker.

Referenced by vm_cleanup().

Here is the call graph for this function:



Here is the caller graph for this function:

7.348.1.5 vm_heartbeat_update_l8()

```
static void vm_heartbeat_update_l8 (
            VM * vm )  [static]
```

L8 FINAL INTEGRATION: Jacquard mode selector heartbeat update.

Collects metrics from L1-L7 physics layers and feeds them to the L8 Jacquard mode selector. L8 then chooses the optimal configuration mode based on workload characteristics and applies it to the runtime.

This is the SOLE policy engine - all adaptive decisions flow through L8.

Parameters

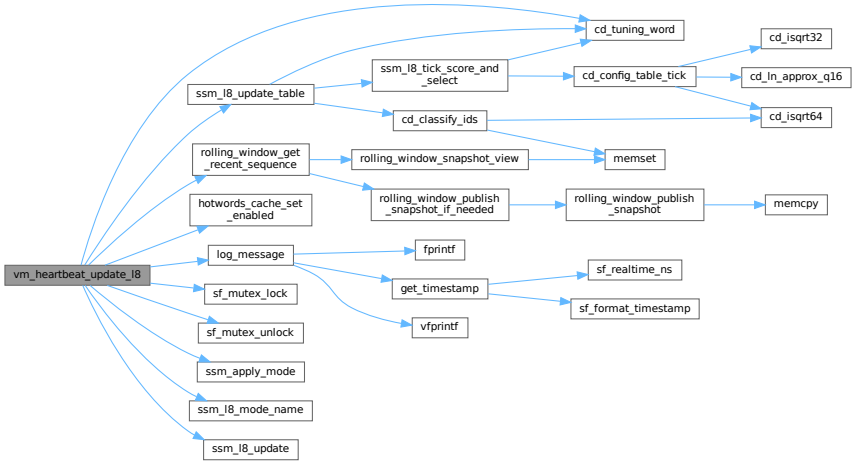
vm	Pointer to VM instance

References CD_MAX_CLASSIFY_DEPTH, cd_tuning_word(), CDConfigEntry::config_bits, CDConfigTable::current_config, ssm_l8_state_t::current_mode, CDConfigTable::current_regime, ssm_l8_metrics_t::cv, VM::decay_slope_q48, InferenceOutputs::early_exited, RollingWindowOfTruth::effective_window_size, CDConfigTable::entries, ssm_l8_metrics_t::entropy, VM::heartbeat, VM::hotwords_cache, hotwords_cache_set_enabled(), CDTuning::id_window_depth, ssm_l8_metrics_t::inference_ea ssm_l8_metrics_t::inference_ran_this_tick, ssm_config_t::L1_heat_tracking, ssm_config_t::L2_rolling_window, ssm_config_t::L3_linear_decay, ssm_config_t::L4_pipelining, ssm_config_t::L5_window_inference, ssm_config_t::L6_decay_inferenc

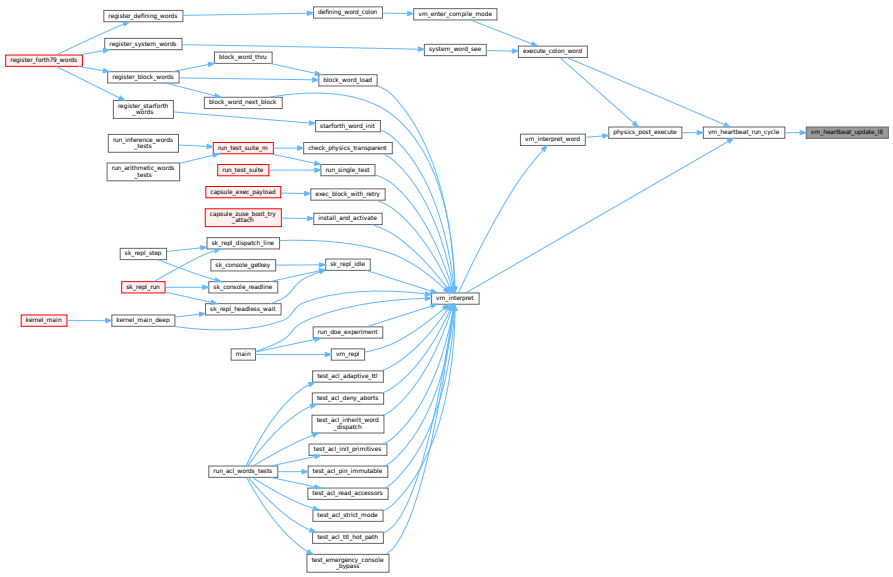
ssm_config_t::L7_adaptive_heartrate, VM::last_inference_outputs, HeartbeatState::last_inference_tick, LOG_DEBUG, log_message(), CDConfigTable::num_configs, VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, CDConfigTable::regime_scores, VM::rolling_window, rolling_window_get_recent_sequence(), ROLLING_WINDOW_SIZE, sf_mutex_lock(), sf_mutex_unlock(), ssm_apply_mode(), VM::ssm_config, ssm_l8_mode_name(), VM::ssm_l8_state, ssm_l8_update(), ssm_l8_update_table(), ssm_l8_metrics_t::stability_score, ssm_l8_state_t::table, ssm_l8_metrics_t::temporal_decay, HeartbeatState::tick_count, RollingWindowOfTruth::total_executions, and VM::tuning_lock.

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.348.1.6 vm_snapshot_read()

```
void vm_snapshot_read (
            const VM * vm,
            HeartbeatSnapshot * out_snapshot )
```

7.348.1.7 vm_tick()

```
void vm_tick (
            VM * vm )
```

Central heartbeat dispatcher for time-driven tuning operations.

Aggregates all periodic optimization tasks (Loop #3 and Loop #5) into one place. Designed as plugin architecture - new tuning operations can be added as plugins.

Options for integration:

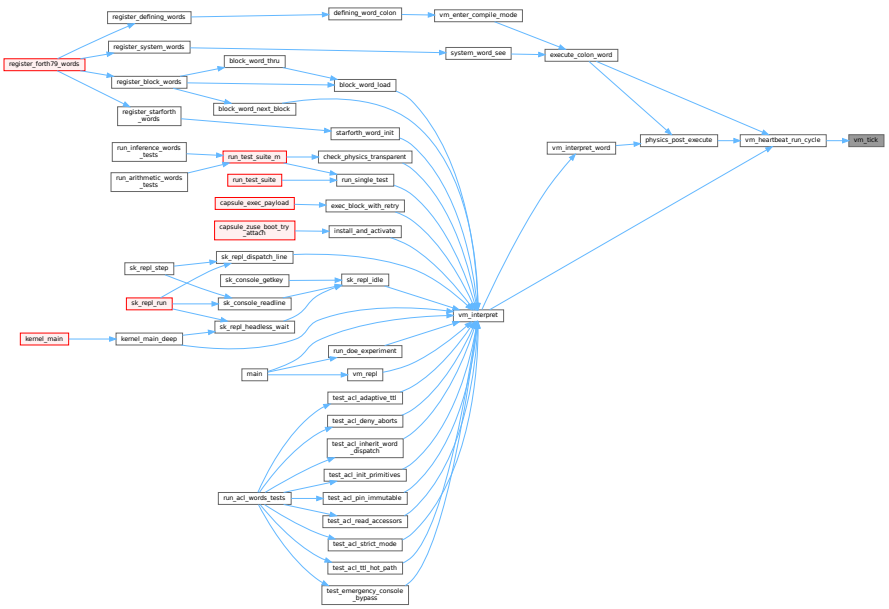
- Synchronous (now): Called from main execution loop, every N executions
- Background thread (future): Runs in separate thread, decoupled from VM execution

Parameters

vm	Pointer to VM instance

Referenced by vm_heartbeat_run_cycle().

Here is the caller graph for this function:



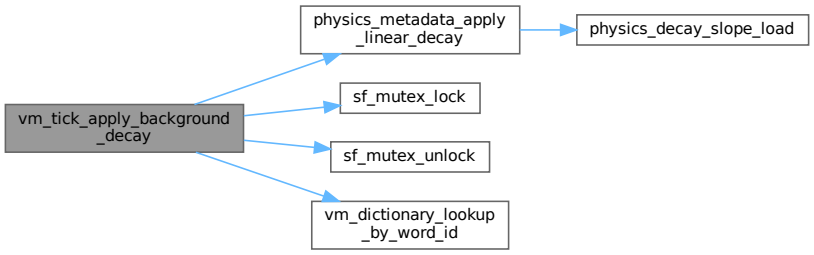
7.348.1.8 vm_tick_apply_background_decay()

```
static void vm_tick_apply_background_decay (
            VM * vm,
            uint64_t now_ns )  [static]
```

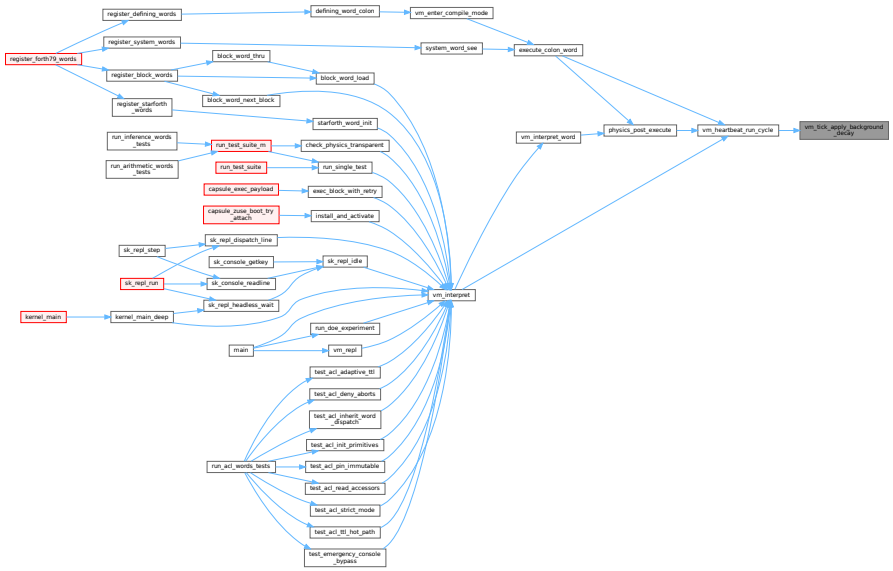
References VM::dict_lock, VM::heartbeat, HEARTBEAT_DECAY_BATCH, VM::heartbeat_decay_cursor_id, DictPhysics::last_decay_ns, DictPhysics::last_decay_tick, VM::latest, DictEntry::link, DictEntry::physics, physics_metadata_apply_line sf_mutex_lock(), sf_mutex_unlock(), HeartbeatState::tick_count, vm_dictionary_lookup_by_word_id(), DictEntry::word_id, and WORD_ID_INVALID.

Referenced by vm_heartbeat_run_cycle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.348.1.9 vm_tick_inference_engine()

```
void vm_tick_inference_engine (
            VM * vm )
```

Phase 2: Unified Inference Engine - Adaptive Window & Decay Slope Tuning.

Coordinates inference on rolling window of truth to determine:

- Optimal adaptive window width (via variance inflection detection)
- Optimal decay slope (via exponential regression on heat trajectory)

Uses ANOVA early-exit to skip full inference when variance is stable (<5% change). All math uses Q48.16 fixed-point (integer-only, no floating-point).

Replaces legacy vm_tick_window_tuner() and vm_tick_slope_validator().

Parameters

vm	Pointer to VM instance

Referenced by vm_tick().

Here is the caller graph for this function:

7.348.1.10 vm_tick_slope_validator()

```
void vm_tick_slope_validator (
            VM * vm )
```

Loop #3: Heat decay slope validation via periodic measurement.

Validates that linear decay is actually helping optimize dictionary caching. Measures stale word ratio, hot word count, and average heat distribution.

Parameters

vm	Pointer to VM instance

7.348.1.11 vm_tick_window_tuner()

```
void vm_tick_window_tuner (
            VM * vm )
```

Loop #5: Context-aware window tuning via binary chop search.

Uses prefetch accuracy to guide window size adaptation. Binary search converges on optimal effective_window_↩ size for current workload.

Parameters

vm	Pointer to VM instance

7.349 v3/src/word_registry.c File Reference

```
#include "../include/word_registry.h"
#include "../include/log.h"
#include <string.h>
#include "word_source/include/acl_words.h"
#include "word_source/include/stack_words.h"
#include "word_source/include/return_stack_words.h"
#include "word_source/include/memory_words.h"
#include "word_source/include/dictionary_words.h"
#include "word_source/include/arithmetic_words.h"
#include "word_source/include/double_words.h"
#include "word_source/include/mixed_arithmetic_words.h"
#include "word_source/include/logical_words.h"
#include "word_source/include/io_words.h"
#include "word_source/include/format_words.h"
#include "word_source/include/string_words.h"
#include "word_source/include/control_words.h"
#include "word_source/include/defining_words.h"
#include "word_source/include/dictionary_manipulation_words.h"
#include "word_source/include/vocabulary_words.h"
#include "word_source/include/block_words.h"
#include "word_source/include/editor_words.h"
#include "word_source/include/system_words.h"
#include "word_source/include/starforth_words.h"
#include "word_source/include/physics_benchmark_words.h"
#include "word_source/include/physics_pipelining_diagnostic_words.h"
#include "word_source/include/physics_freeze_words.h"
#include "word_source/include/dictionary_heat_diagnostic_words.h"
#include "word_source/include/log_words.h"
#include "word_source/include/q48_words.h"
#include "word_source/include/inference_words.h"
#include "word_source/include/defer_words.h"
#include "word_source/include/framebuffer_words.h"
#include "word_source/include/keyboard_words.h"
#include "word_source/include/ttf_words.h"
#include "word_source/include/scroll_words.h"
```

Include dependency graph for word_registry.c:

Functions

- void register_word (VM ∗vm, const char ∗name, word_func_t func)

Registers a single FORTH word in the virtual machine.

- void register_forth79_words (VM *vm)

  Registers all standard FORTH-79 words in the virtual machine.

7.349.1 Function Documentation

7.349.1.1 register_forth79_words()

```
void register_forth79_words (
            VM * vm )
```

Registers all standard FORTH-79 words in the virtual machine.

Parameters

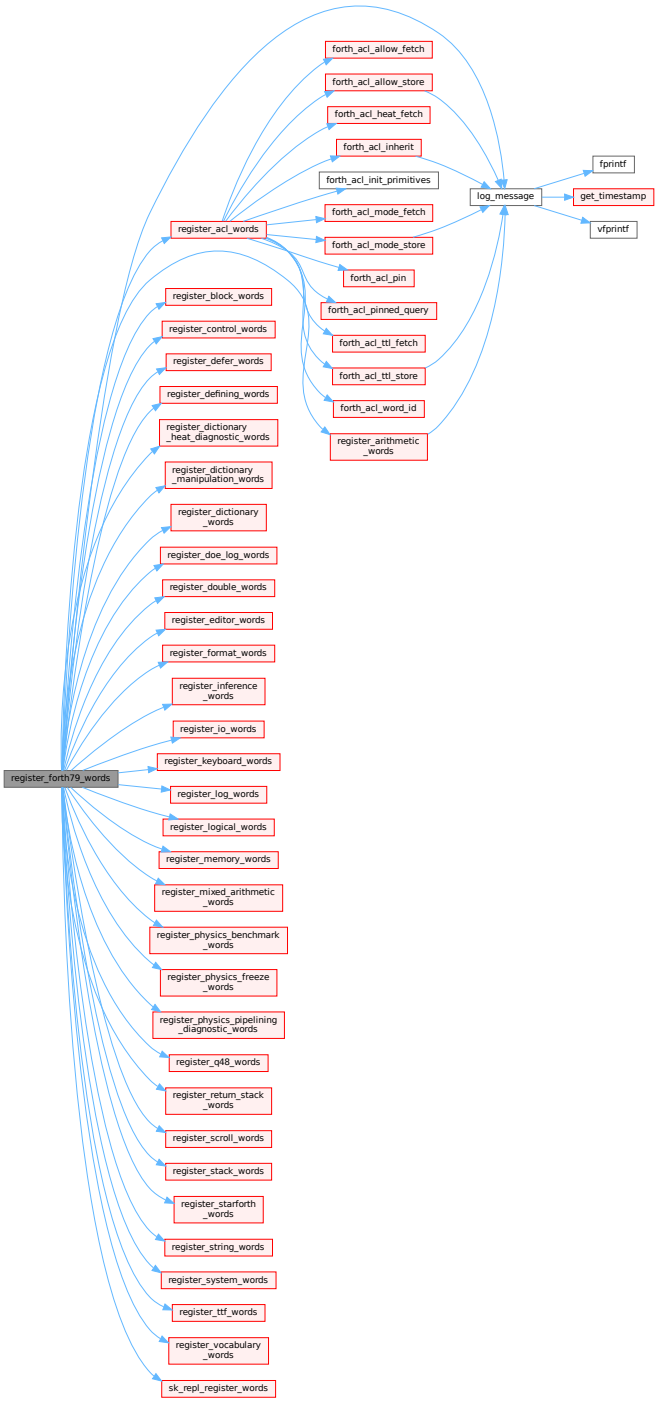
vm	Pointer to the virtual machine instance

Registers all 18 FORTH-79 word modules in dependency order, starting with fundamental stack operations and building up to more complex functionality like control flow and editing.

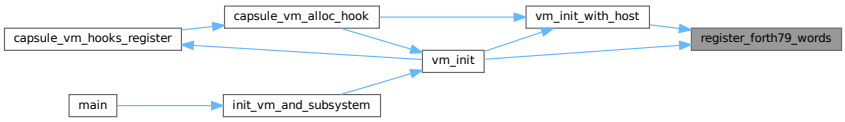
References LOG_INFO, log_message(), register_acl_words(), register_arithmetic_words(), register_block_words(), register_control_words(), register_defer_words(), register_defining_words(), register_dictionary_heat_diagnostic_words(), register_dictionary_manipulation_words(), register_dictionary_words(), register_doe_log_words(), register_double_words(), register_editor_words(), register_format_words(), register_inference_words(), register_io_words(), register_keyboard_words(), register_log_words(), register_logical_words(), register_memory_words(), register_mixed_arithmetic_words(), register_physics_benchmark_words(), register_physics_freeze_words(), register_physics_pipelining_diagnostic_words(), register_q48_words(), register_return_stack_words(), register_scroll_words(), register_stack_words(), register_starforth_words(), register_string_words(), register_system_words(), register_ttf_words(), register_vocabulary_words(), and sk_repl_register_words().

Referenced by vm_init(), and vm_init_with_host().

Here is the call graph for this function:



Here is the caller graph for this function:



7.349.1.2 register_word()

```
void register_word (
            VM * vm,
            const char * name,
            word_func_t func )
```

Registers a single FORTH word in the virtual machine.

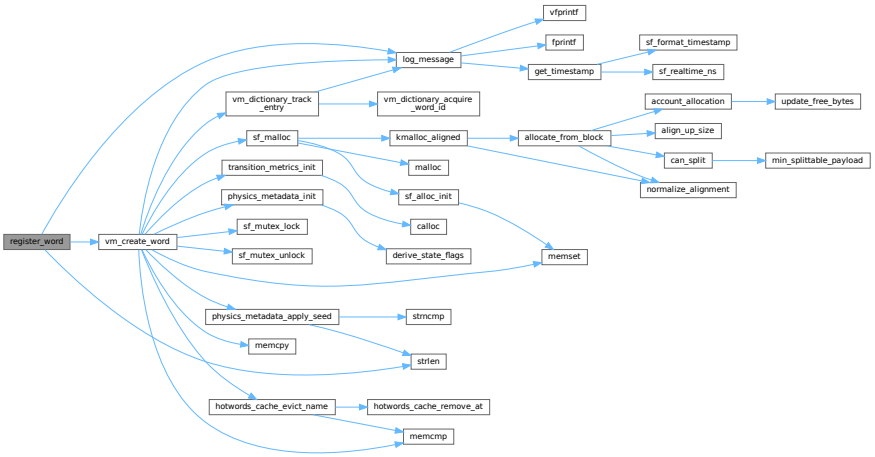
Parameters

vm	Pointer to the virtual machine instance
name	Name of the FORTH word to register
func	Function pointer to the word's implementation

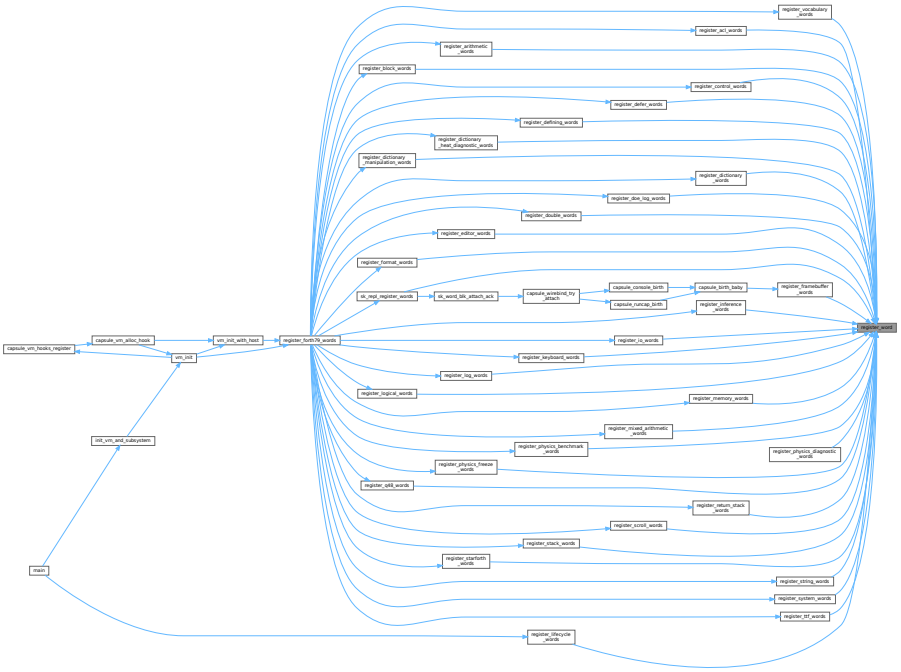
References entry, func, LOG_DEBUG, LOG_ERROR, log_message(), name, strlen(), and vm_create_word().

Referenced by register_acl_words(), register_arithmetic_words(), register_block_words(), register_control_words(), register_defer_words(), register_defining_words(), register_dictionary_heat_diagnostic_words(), register_dictionary_manipulation_wo register_dictionary_words(), register_doe_log_words(), register_double_words(), register_editor_words(), register_format_words(), register_framebuffer_words(), register_inference_words(), register_io_words(), register_keyboard_words(), register_lifecycle_words(), register_log_words(), register_logical_words(), register_memory_words(), register_mixed_arithmetic_word register_physics_benchmark_words(), register_physics_diagnostic_words(), register_physics_freeze_words(), register_q48_words(), register_return_stack_words(), register_scroll_words(), register_stack_words(), register_starforth_words(), register_string_words(), register_system_words(), register_ttf_words(), register_vocabulary_words(), and sk_repl_register_words().

Here is the call graph for this function:



Here is the caller graph for this function:

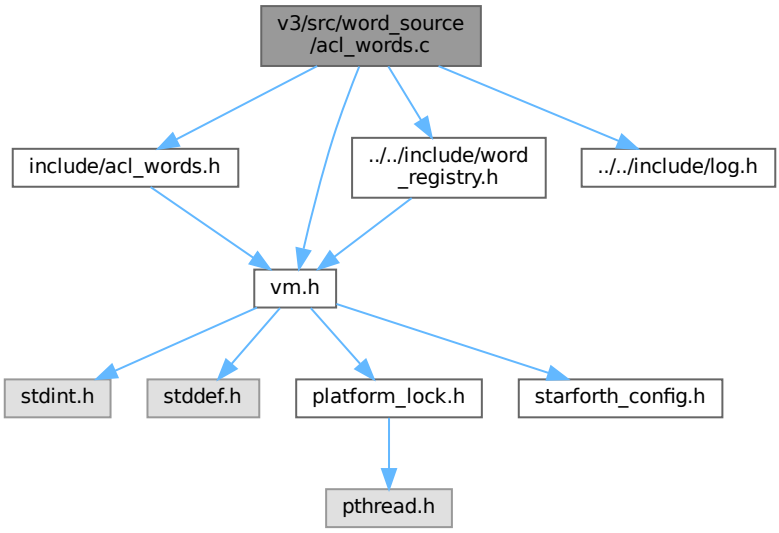


7.350 v3/src/word_source/acl_words.c File Reference

```
#include "include/acl_words.h"
#include "../../include/vm.h"
#include "../../include/word_registry.h"
```

```
#include "../../include/log.h"
```

Include dependency graph for acl_words.c:



Functions

- static DictEntry * pop_xt (VM *vm)

  Pop an execution token (XT) from the data stack and return the corresponding DictEntry pointer.
- static void forth_acl_mode_fetch (VM *vm)

  Implements FORTH word `ACL-MODE@` — fetch ACL enforcement mode.
- static void forth_acl_mode_store (VM *vm)

  Implements FORTH word `ACL-MODE!` — store ACL enforcement mode.
- static void forth_acl_pinned_query (VM *vm)

  Implements FORTH word `ACL-PINNED?` — query pin status.
- static void forth_acl_pin (VM *vm)

  Implements FORTH word `ACL-PIN` — pin a word's ACL entry.
- static void forth_acl_ttl_fetch (VM *vm)

  Implements FORTH word `ACL-TTL@` — fetch TTL countdown value.
- static void forth_acl_ttl_store (VM *vm)

  Implements FORTH word `ACL-TTL!` — store TTL countdown value.
- static void forth_acl_allow_fetch (VM *vm)

  Implements FORTH word `ACL-ALLOW@` — fetch cached allow/deny flag.
- static void forth_acl_allow_store (VM *vm)

  Implements FORTH word `ACL-ALLOW!` — store cached allow/deny flag.
- static void forth_acl_heat_fetch (VM *vm)

  Implements FORTH word `ACL-HEAT@` — fetch execution heat.
- static void forth_acl_word_id (VM *vm)

  Implements FORTH word `ACL-WORD-ID` — fetch stable word identifier.
- static void forth_acl_inherit (VM *vm)

  Implements FORTH word `ACL-INHERIT` — inherit ACL policy from parent.
- static void forth_acl_init_primitives (VM *vm)

Implements FORTH word `ACL-INIT-PRIMITIVES` — reset ACL fields on all unpinned dictionary entries.

- void acl_inherit_entry (DictEntry *src, DictEntry *dst)

  Direct C entry point for ACL policy inheritance on the capsule birth path.

- void register_acl_words (VM *vm)

  Register all ACL C-primitive words with the VM dictionary.

7.350.1 Function Documentation

7.350.1.1 acl_inherit_entry()

```
void acl_inherit_entry (
            DictEntry * src,
            DictEntry * dst )
```

Direct C entry point for ACL policy inheritance on the capsule birth path.

Copies `acl_mode` from `src` to `dst`, clears `acl_pinned`, resets `acl_ttl` to 0, and sets `acl_allow` to 1. Called from capsule birth code (not from FORTH) — no stack manipulation is performed.

Parameters

src	Source DictEntry whose `acl_mode` is inherited
dst	Destination DictEntry whose ACL fields are updated

References DictEntry::acl_allow, DictEntry::acl_mode, DictEntry::acl_pinned, and DictEntry::acl_ttl.

Referenced by forth_acl_inherit(), and test_acl_inherit().

Here is the caller graph for this function:

7.350.1.2 forth_acl_allow_fetch()

```
static void forth_acl_allow_fetch (
            VM * vm )  [static]
```

Implements FORTH word `ACL-ALLOW@` — fetch cached allow/deny flag.

Stack effect: (xt – flag) Pushes the cached ACL decision for the word: -1 = allowed, 0 = denied. This cached value is checked on every execution in TTL mode; the cache is refreshed by `acl_recheck()` when TTL expires.

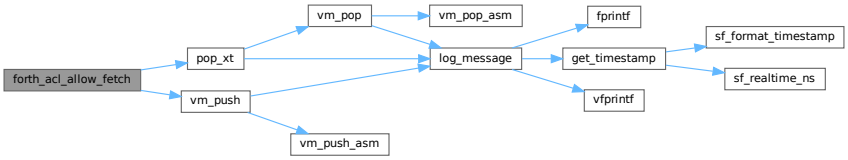
Parameters

vm	Pointer to the VM structure

References DictEntry::acl_allow, pop_xt(), and vm_push().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.3 forth_acl_allow_store()

```
static void forth_acl_allow_store (
            VM * vm )  [static]
```

Implements FORTH word `ACL-ALLOW!` — store cached allow/deny flag.

Stack effect: (flag xt –) Sets the cached ACL decision: any non-zero `flag` = allowed, 0 = denied. No-op if the word is pinned.

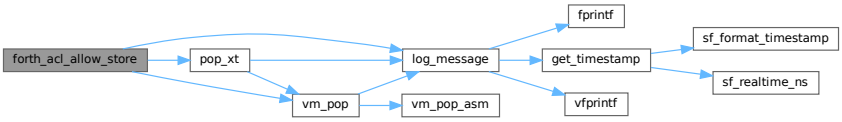
Parameters

vm	Pointer to the VM structure

References DictEntry::acl_allow, DictEntry::acl_pinned, VM::dsp, VM::error, LOG_ERROR, log_message(), pop_xt(), and vm_pop().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.4 forth_acl_heat_fetch()

```
static void forth_acl_heat_fetch (
            VM * vm )  [static]
```

Implements FORTH word `ACL-HEAT@` — fetch execution heat.

Stack effect: (xt – heat) Pushes the `execution_heat` counter for the word identified by `xt`. Used by `ACL-TTL-COMPUTE` in `ACL.4th` to calibrate the TTL value based on how frequently the word is executed.

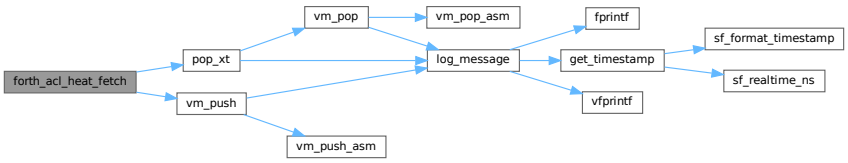
Parameters

vm	Pointer to the VM structure

References DictEntry::execution_heat, pop_xt(), and vm_push().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.5 forth_acl_inherit()

```
static void forth_acl_inherit (
            VM * vm )  [static]
```

Implements FORTH word ACL-INHERIT — inherit ACL policy from parent.

Stack effect: (src dst –) Copies acl_mode from src to dst, then clears dst->acl_pinned, resets acl_ttl to 0, and sets acl_allow to 1 (optimistic default). This is a C primitive because FORTH code cannot clear acl_pinned — pin is a one-way ratchet that only C can reset during inheritance.

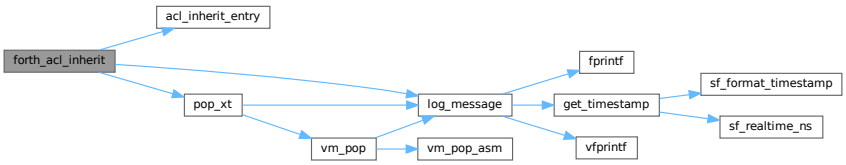
Parameters

vm	Pointer to the VM structure

References acl_inherit_entry(), VM::dsp, VM::error, LOG_ERROR, log_message(), and pop_xt().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.6 forth_acl_init_primitives()

```
static void forth_acl_init_primitives (
            VM * vm )  [static]
```

Implements FORTH word ACL-INIT-PRIMITIVES — reset ACL fields on all unpinned dictionary entries.

Stack effect: (–) Walks the entire dictionary and resets ACL fields on every entry that is not pinned: sets acl_ttl = 0 (force recheck on first execution), acl_allow = 1 (optimistic default), acl_mode = ACL_MODE_TTL. Called by ACL-BOOT in ACL.4th immediately after the ACL capsule finishes loading.

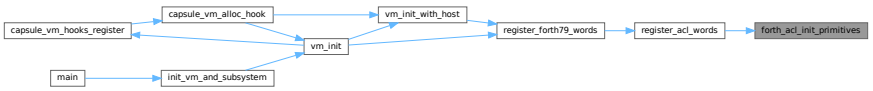
Parameters

vm	Pointer to the VM structure

References ACL_MODE_TTL, and VM::latest.

Referenced by register_acl_words().

Here is the caller graph for this function:



7.350.1.7 forth_acl_mode_fetch()

```
static void forth_acl_mode_fetch (
            VM * vm )  [static]
```

Implements FORTH word `ACL-MODE@` — fetch ACL enforcement mode.

Stack effect: (xt – mode) Pushes the enforcement mode of the word identified by `xt`: 0 = STRICT (allow/deny is permanent), 1 = TTL (expires after countdown).

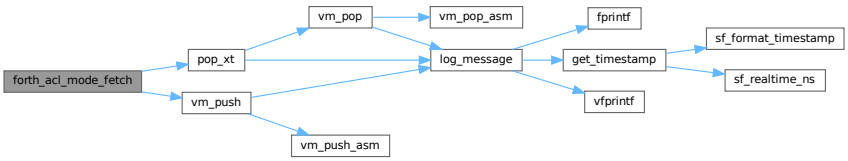
Parameters

vm	Pointer to the VM structure

References DictEntry::acl_mode, pop_xt(), and vm_push().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.8 forth_acl_mode_store()

```
static void forth_acl_mode_store (
            VM * vm )  [static]
```

Implements FORTH word `ACL-MODE!` — store ACL enforcement mode.

Stack effect: (mode xt –) Sets the enforcement mode of the word identified by `xt`. No-op if the word is pinned — pinned entries are immutable.

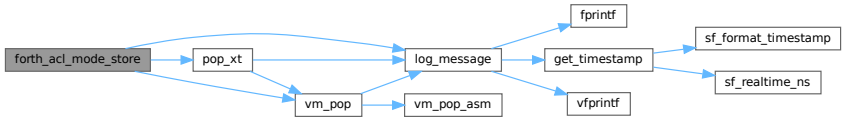
Parameters

vm	Pointer to the VM structure

References DictEntry::acl_mode, DictEntry::acl_pinned, VM::dsp, VM::error, LOG_ERROR, log_message(), pop_xt(), and vm_pop().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.9 forth_acl_pin()

```
static void forth_acl_pin (
            VM * vm )  [static]
```

Implements FORTH word `ACL-PIN` — pin a word's ACL entry.

Stack effect: (xt –) Sets `acl_pinned` = 1 on the word identified by `xt`. This is a one-way ratchet: once set it can never be cleared, even by ACL-INHERIT. Use with ' WORD ACL-PIN in FORTH, never from C policy code.

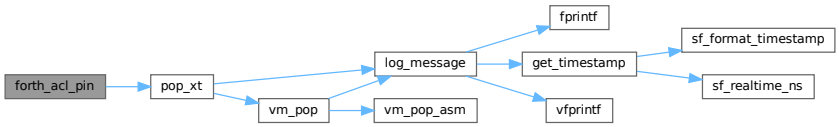
Parameters

vm	Pointer to the VM structure

References DictEntry::acl_pinned, and pop_xt().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.10 forth_acl_pinned_query()

```
static void forth_acl_pinned_query (
            VM * vm )  [static]
```

Implements FORTH word `ACL-PINNED?` — query pin status.

Stack effect: (xt – flag) Pushes -1 (true) if the word is pinned, 0 (false) otherwise. A pinned word's ACL fields cannot be modified by any FORTH operation.

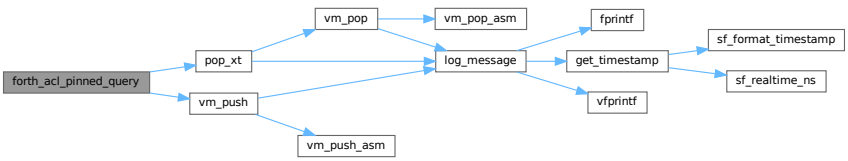
Parameters

vm	Pointer to the VM structure

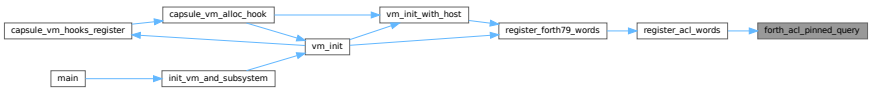
References DictEntry::acl_pinned, pop_xt(), and vm_push().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.350.1.11 forth_acl_ttl_fetch()

```
static void forth_acl_ttl_fetch (
            VM * vm )  [static]
```

Implements FORTH word `ACL-TTL@` — fetch TTL countdown value.

Stack effect: (xt – n) Pushes the current TTL (time-to-live) countdown of the word's ACL entry. When TTL reaches zero in TTL mode the interpreter calls `acl_recheck()`.

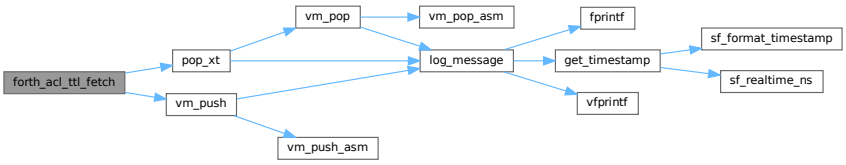
Parameters

vm	Pointer to the VM structure

References DictEntry::acl_ttl, pop_xt(), and vm_push().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.12 forth_acl_ttl_store()

```
static void forth_acl_ttl_store (
            VM * vm )  [static]
```

Implements FORTH word `ACL-TTL!` — store TTL countdown value.

Stack effect: (n xt –) Sets the TTL countdown on the word's ACL entry. Negative values are clamped to 0; values above UINT32_MAX are clamped to UINT32_MAX. No-op if the word is pinned.

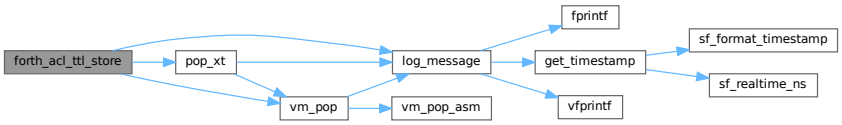
Parameters

vm	Pointer to the VM structure

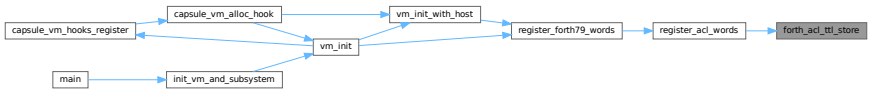
References DictEntry::acl_pinned, DictEntry::acl_ttl, VM::dsp, VM::error, LOG_ERROR, log_message(), pop_xt(), and vm_pop().

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.350.1.13 forth_acl_word_id()

```
static void forth_acl_word_id (
            VM * vm )  [static]
```

Implements FORTH word `ACL-WORD-ID` — fetch stable word identifier.

Stack effect: (xt – n) Pushes the stable `word_id` for the entry identified by `xt`. Unlike dictionary positions, `word_id` is assigned at registration and never changes, making it safe to use as a persistent table index in `ACL.4th`.

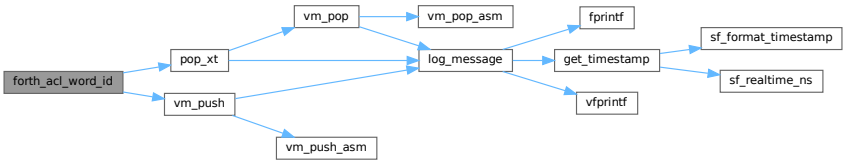
Parameters

vm	Pointer to the VM structure

References pop_xt(), vm_push(), and DictEntry::word_id.

Referenced by register_acl_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.350.1.14 pop_xt()

```
static DictEntry * pop_xt (
            VM * vm )  [static]
```

Pop an execution token (XT) from the data stack and return the corresponding DictEntry pointer.

Sets `vm->error` and returns NULL on stack underflow or if the XT is zero. All ACL word implementations call this before accessing DictEntry fields.

Parameters

vm	Pointer to the VM structure

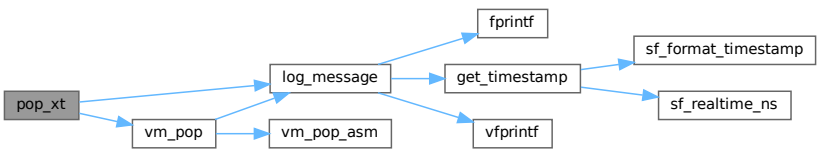
Returns

Pointer to the DictEntry, or NULL on error

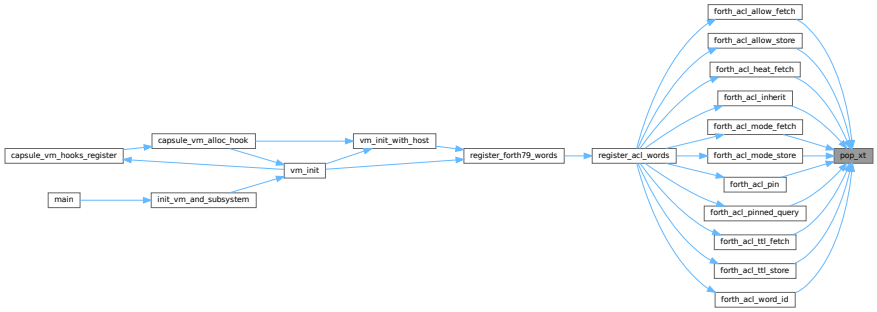
References VM::dsp, entry, VM::error, LOG_ERROR, log_message(), and vm_pop().

Referenced by forth_acl_allow_fetch(), forth_acl_allow_store(), forth_acl_heat_fetch(), forth_acl_inherit(), forth_acl_mode_fetch(), forth_acl_mode_store(), forth_acl_pin(), forth_acl_pinned_query(), forth_acl_ttl_fetch(), forth_acl_ttl_store(), and forth_acl_word_id().

Here is the call graph for this function:



Here is the caller graph for this function:



7.350.1.15 register_acl_words()

```
void register_acl_words (
            VM * vm )
```

Register all ACL C-primitive words with the VM dictionary.

Registers: field accessors (ACL-MODE@ / ACL-MODE! / ACL-PINNED? / ACL-TTL@ / ACL-TTL! / ACL-↩ ALLOW@ / ACL-ALLOW! / ACL-HEAT@ / ACL-WORD-ID), and mutation words (ACL-PIN / ACL-INHERIT / ACL-INIT-PRIMITIVES). Called from vm_bootstrap.c during VM initialisation.

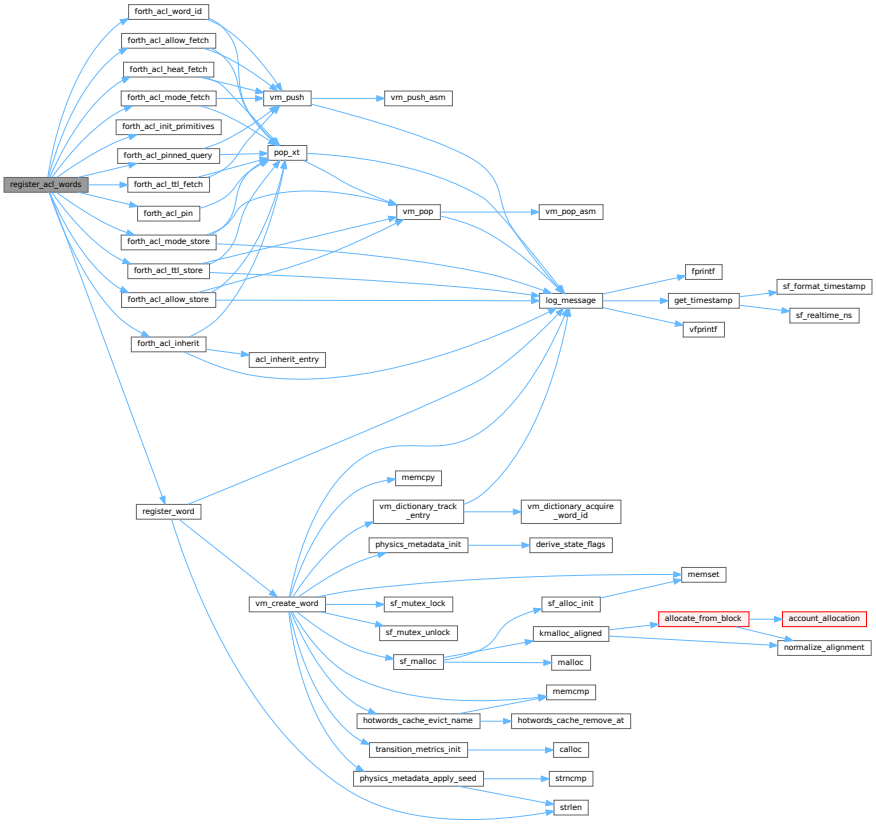
Parameters

vm	Pointer to the VM structure

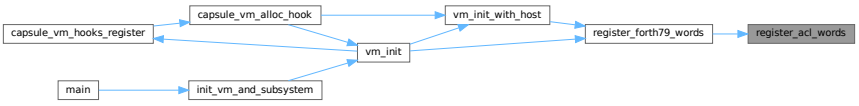
References forth_acl_allow_fetch(), forth_acl_allow_store(), forth_acl_heat_fetch(), forth_acl_inherit(), forth_acl_init_primitives(), forth_acl_mode_fetch(), forth_acl_mode_store(), forth_acl_pin(), forth_acl_pinned_query(), forth_acl_ttl_fetch(), forth_acl_ttl_store(), forth_acl_word_id(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



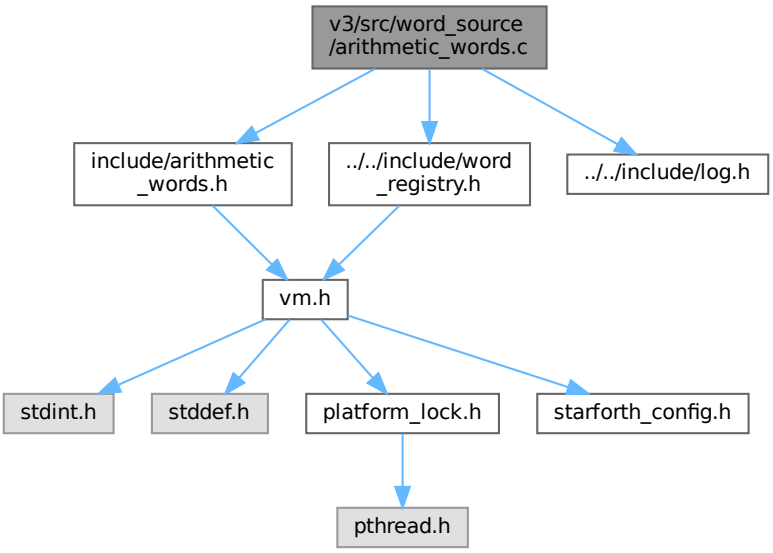
Here is the caller graph for this function:



7.351 v3/src/word_source/arithmetic_words.c File Reference

```
#include "include/arithmetic_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
```

Include dependency graph for arithmetic_words.c:



Functions

- static void arithmetic_word_star_slash (VM *vm)
- static void arithmetic_word_star_slash_mod (VM *vm)
- void arithmetic_word_plus (VM *vm)

  Implements FORTH word "+" that adds two numbers.
- static void arithmetic_word_minus (VM *vm)

  Implements FORTH word "-" that subtracts two numbers.
- static void arithmetic_word_multiply (VM *vm)

  Implements FORTH word "" that multiplies two numbers.*
- static void word_divide (VM *vm)
- static void mixed_math_word_mod (VM *vm)
- static void word_divmod (VM *vm)
- static void arithmetic_word_one_plus (VM *vm)
- static void arithmetic_word_one_minus (VM *vm)
- static void arithmetic_word_two_plus (VM *vm)
- static void arithmetic_word_two_minus (VM *vm)
- static void arithmetic_word_two_multiply (VM *vm)
- static void arithmetic_word_two_divide (VM *vm)
- static void arithmetic_word_abs (VM *vm)
- static void arithmetic_word_negate (VM *vm)
- static void arithmetic_word_min (VM *vm)
- static void arithmetic_word_max (VM *vm)
- void register_arithmetic_words (VM *vm)

  Registers all FORTH-79 arithmetic words with the virtual machine.

7.351.1 Function Documentation

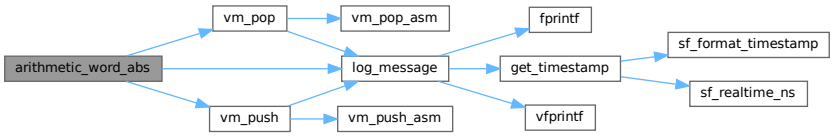
7.351.1.1 arithmetic_word_abs()

```
static void arithmetic_word_abs (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

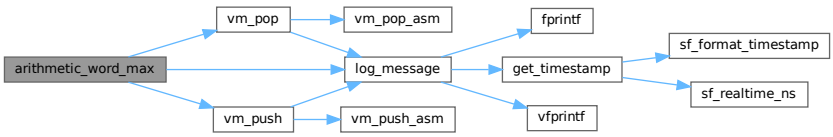
7.351.1.2 arithmetic_word_max()

```
static void arithmetic_word_max (
            VM * vm )  [static]
```

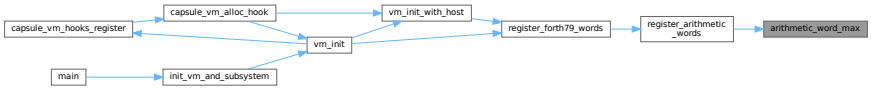
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:



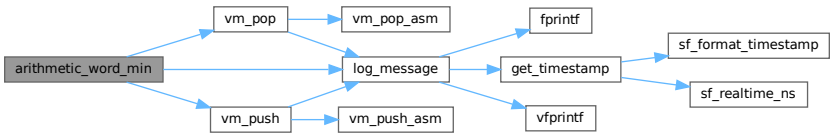
7.351.1.3 arithmetic_word_min()

```
static void arithmetic_word_min (
            VM * vm )  [static]
```

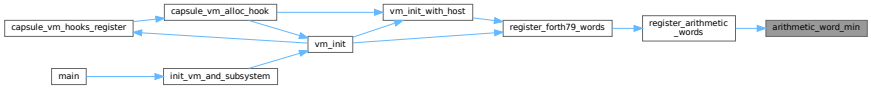
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.351.1.4 arithmetic_word_minus()

```
static void arithmetic_word_minus (
            VM * vm )  [static]
```

Implements FORTH word "-" that subtracts two numbers.

Stack effect: (n1 n2 – n3) Subtracts n2 from n1, pushing their difference n3 onto the stack.

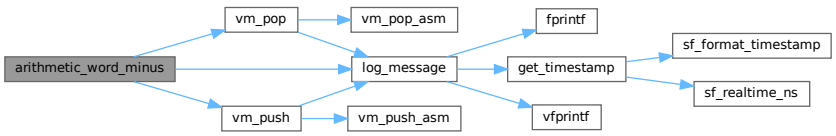
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.351.1.5 arithmetic_word_multiply()

```
static void arithmetic_word_multiply (
            VM * vm )  [static]
```

Implements FORTH word "∗" that multiplies two numbers.

Stack effect: (n1 n2 – n3) Multiplies n1 by n2, pushing their product n3 onto the stack.

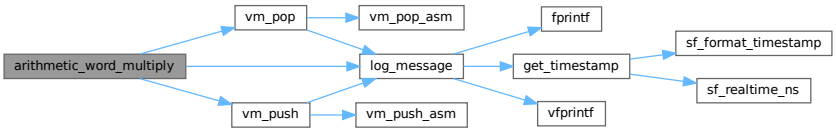
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

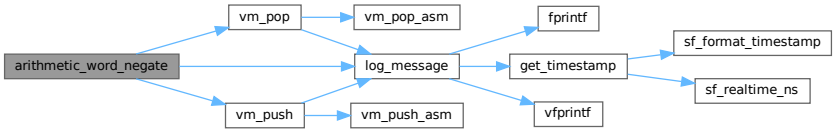
7.351.1.6 arithmetic_word_negate()

```
static void arithmetic_word_negate (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

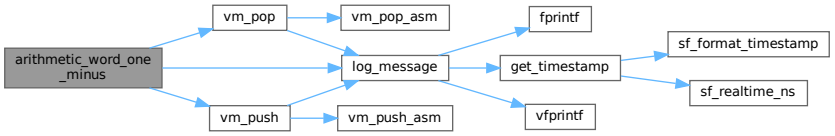
7.351.1.7 arithmetic_word_one_minus()

```
static void arithmetic_word_one_minus (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

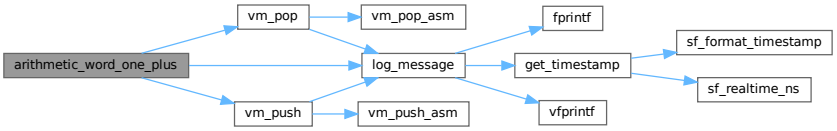
7.351.1.8 arithmetic_word_one_plus()

```
static void arithmetic_word_one_plus (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.351.1.9 arithmetic_word_plus()

```
void arithmetic_word_plus (
            VM * vm )
```

Implements FORTH word "+" that adds two numbers.

Stack effect: (n1 n2 – n3) Adds n1 and n2, pushing their sum n3 onto the stack.

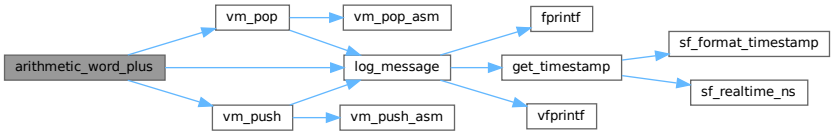
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

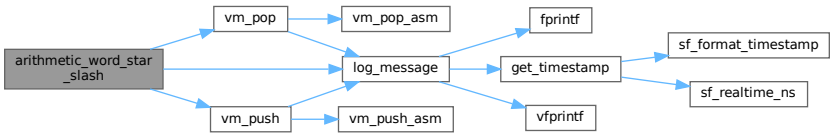
7.351.1.10 arithmetic_word_star_slash()

```
static void arithmetic_word_star_slash (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

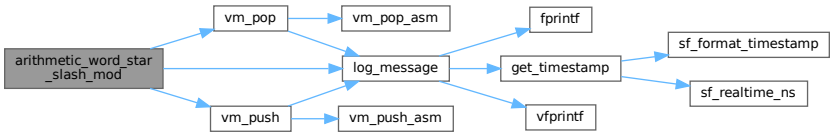
7.351.1.11 arithmetic_word_star_slash_mod()

```
static void arithmetic_word_star_slash_mod (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

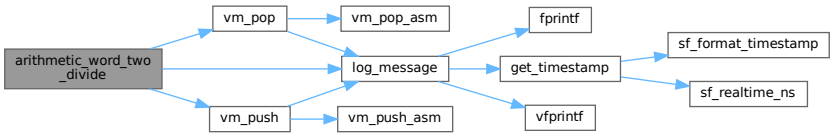
7.351.1.12 arithmetic_word_two_divide()

```
static void arithmetic_word_two_divide (
            VM * vm )  [static]
```

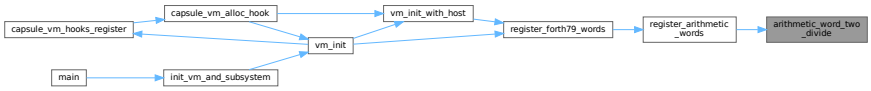
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:



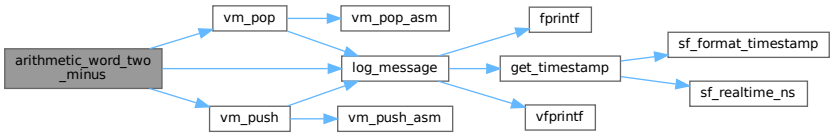
7.351.1.13 arithmetic_word_two_minus()

```
static void arithmetic_word_two_minus (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

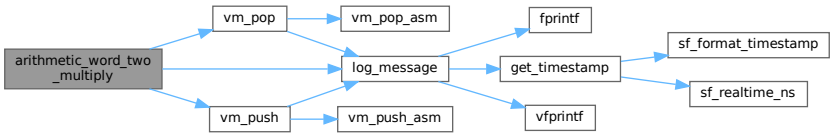
7.351.1.14 arithmetic_word_two_multiply()

```
static void arithmetic_word_two_multiply (
            VM * vm )  [static]
```

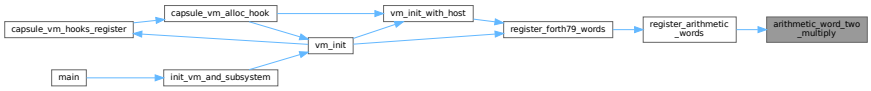
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:



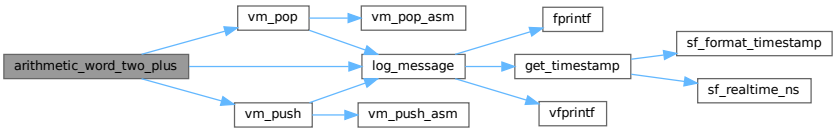
7.351.1.15 arithmetic_word_two_plus()

```
static void arithmetic_word_two_plus (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

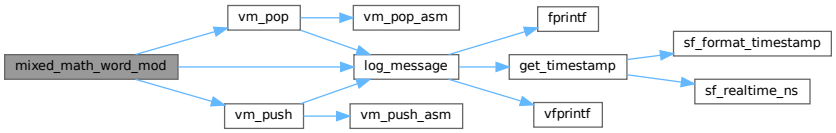
7.351.1.16 mixed_math_word_mod()

```
static void mixed_math_word_mod (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.351.1.17 register_arithmetic_words()

```
void register_arithmetic_words (
            VM * vm )
```

Registers all FORTH-79 arithmetic words with the virtual machine.

Registers the following words:

- + (add)
- - (subtract)
- * (multiply)
- / (divide)
- MOD (modulo)
- /MOD (divide with remainder)
- NEGATE
- ABS (absolute)
- MIN
- MAX
- 1+ (increment)
- 1- (decrement)
- 2* (multiply by 2)
- 2/ (divide by 2)
- STAR-SLASH (multiply then divide)

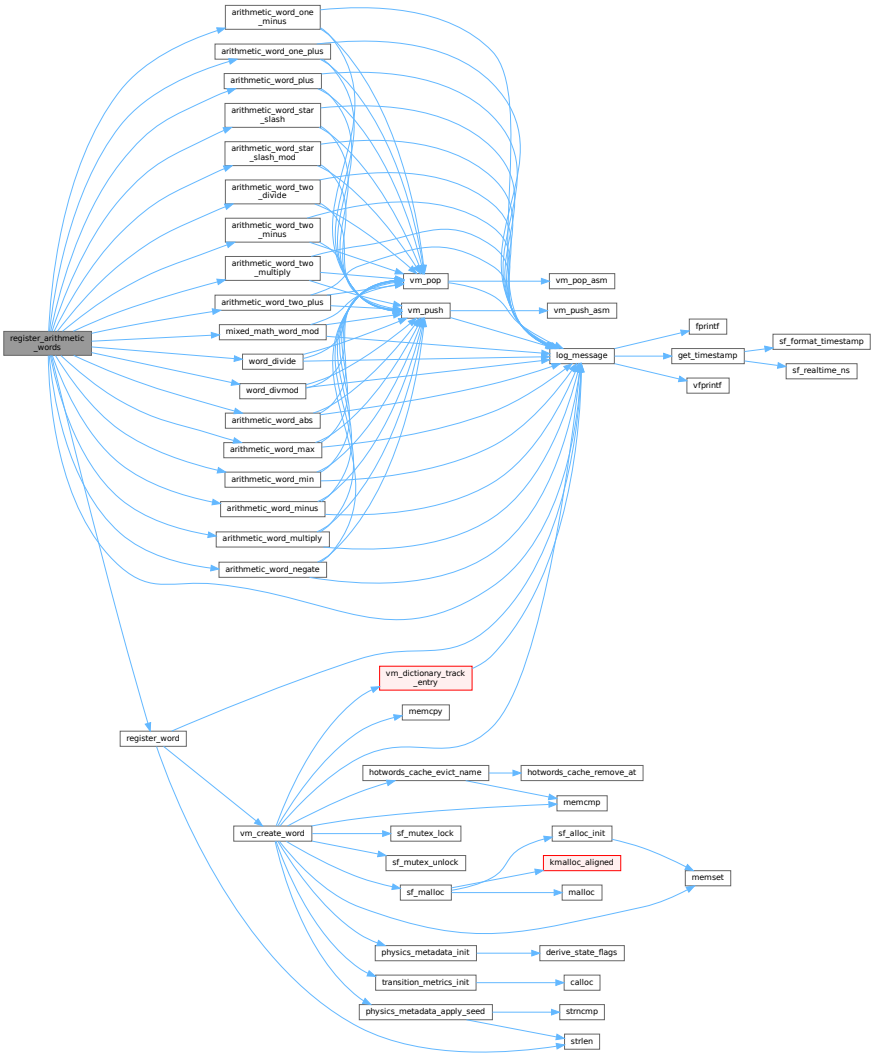
Parameters

vm	Pointer to the Forth virtual machine instance

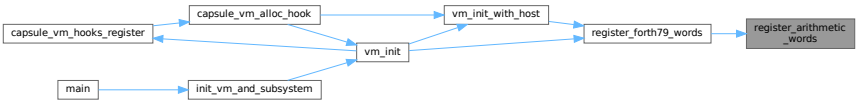
References arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), LOG_INFO, log_message(), mixed_math_word_mod(), register_word(), word_divide(), and word_divmod().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



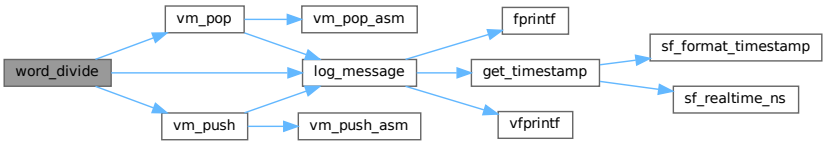
7.351.1.18 word_divide()

```
static void word_divide (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

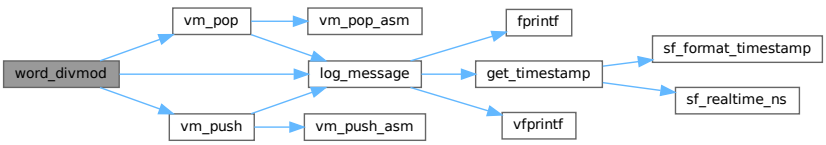
7.351.1.19 word_divmod()

```
static void word_divmod (
            VM * vm )  [static]
```

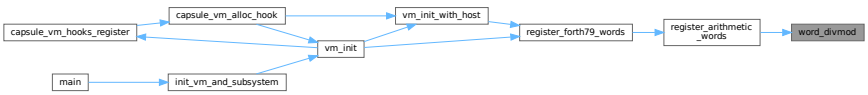
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_arithmetic_words().

Here is the call graph for this function:



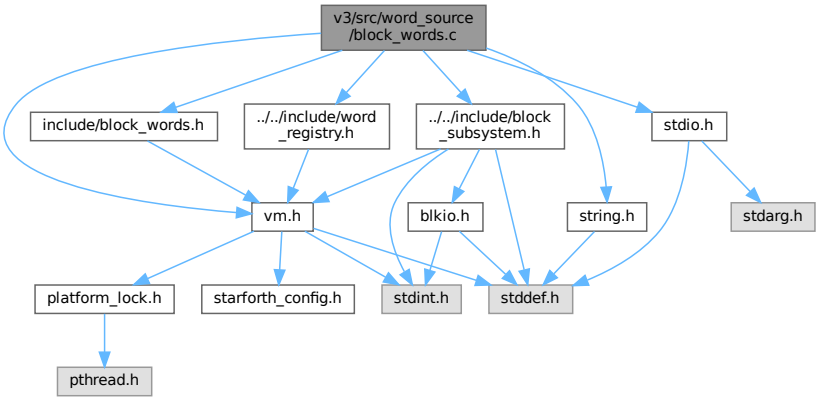
Here is the caller graph for this function:



7.352 v3/src/word_source/block_words.c File Reference

```
#include "include/block_words.h"
#include "../../include/word_registry.h"
#include "../../include/vm.h"
#include "../../include/block_subsystem.h"
#include <string.h>
#include <stdio.h>
```

Include dependency graph for block_words.c:



Functions

- static void set_scr (VM *vm, cell_t blk)
- void init_block_system (VM *vm)

  Initializes the block system.
- unsigned char * get_block_buffer (VM *vm, int block_num)

  Gets a buffer for the specified block.
- unsigned char * get_empty_buffer (VM *vm, int block_num)

  Gets an empty buffer for the specified block.
- void mark_buffer_dirty (VM *vm)

  Marks the current buffer as modified.
- void save_all_buffers (VM *vm)
- void empty_all_buffers (VM *vm)

  Empties all user block buffers.
- void blk_vm_check_epoch (VM *vm)

  Discards vm->blk_vm_lbn[]/cbuf[]/dirty[] if the device chain has changed since last validated (see this function's own doc comment in block_words.c for why).
- int blk_vm_slot_for_addr (vaddr_t addr)

  Does `addr` fall inside the block I/O window? Pure address arithmetic against the window's fixed compile-time base/size – no VM state needed.
- int blk_vm_is_cross_device_copy (VM *vm, vaddr_t addr1, vaddr_t addr2)

  True if addr1/addr2 are both block-window addresses currently loaded from two different physical devices (Phase 8 v3, 2026-09-23) – the check MOVE/CMOVE/CMOVE> call before copying to refuse a same-VM, cross-device raw block copy.
- static int blk_vm_find (VM *vm, uint32_t lbn)
- static int blk_vm_evict (VM *vm)

- static vaddr_t blk_vm_load (VM *vm, uint32_t lbn, int writable)
- static vaddr_t blk_vm_assign (VM *vm, uint32_t lbn)
- void blk_vm_flush_all (VM *vm)

  Sync every dirty VM block-window slot to the C-layer block cache, then flush the whole block subsystem to physical media – the complete SAVE-BUFFERS implementation (unlike save_all_buffers() above, which only calls blk_flush() and so misses any BUFFER-modified-but-not-yet-UPDATE'd content still sitting only in vm->memory's window).
- void block_word_block (VM *vm)
- void block_word_buffer (VM *vm)
- void block_word_update (VM *vm)
- void block_word_confirm_format (VM *vm)
- void block_word_relocate (VM *vm)
- void block_word_save_buffers (VM *vm)
- void block_word_empty_buffers (VM *vm)
- void block_word_flush (VM *vm)
- void block_word_load (VM *vm)
- void block_word_list (VM *vm)
- void block_word_thru (VM *vm)
- void block_word_scr (VM *vm)
- void block_word_next_block (VM *vm)
- static void block_word_acl_allow_fetch (VM *vm)
- static void block_word_acl_allow_store (VM *vm)
- static void block_word_acl_ttl_fetch (VM *vm)
- static void block_word_acl_ttl_store (VM *vm)
- static void block_word_owner_fetch (VM *vm)
- static void block_word_blk_attach (VM *vm)
- void register_block_words (VM *vm)

  Registers all block and buffer words with the virtual machine.

7.352.1 Function Documentation

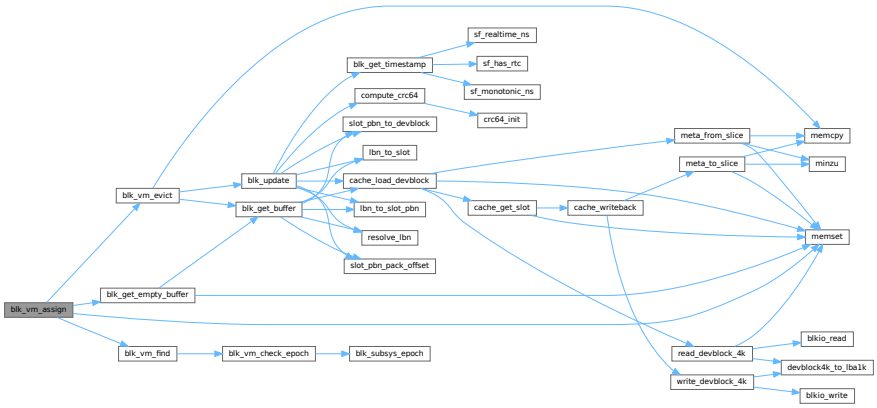
7.352.1.1 blk_vm_assign()

```
static vaddr_t blk_vm_assign (
            VM * vm,
            uint32_t lbn )  [static]
```

References base, blk_get_empty_buffer(), VM::blk_vm_cbuf, VM::blk_vm_dirty, blk_vm_evict(), blk_vm_find(), VM::blk_vm_lbn, BLK_VM_SLOTS, BLK_VM_WINDOW_BASE, BLOCK_SIZE, VM::memory, and memset().

Referenced by block_word_buffer().

Here is the call graph for this function:



Here is the caller graph for this function:

7.352.1.2 blk_vm_check_epoch()

```
void blk_vm_check_epoch (
            VM * vm )
```

Discards vm->blk_vm_lbn[]/cbuf[]/dirty[] if the device chain has changed since last validated (see this function's own doc comment in block_words.c for why).

Exposed (Phase 8 v3, 2026-09-23) so callers outside this file that read vm->blk_vm_lbn[] directly (MOVE/↩ CMOVE's cross-device block-copy check, memory_words.c/string_words.c) go through the same invalidation contract blk_vm_find() already uses internally, rather than a second, divergent copy of this logic.

Parameters

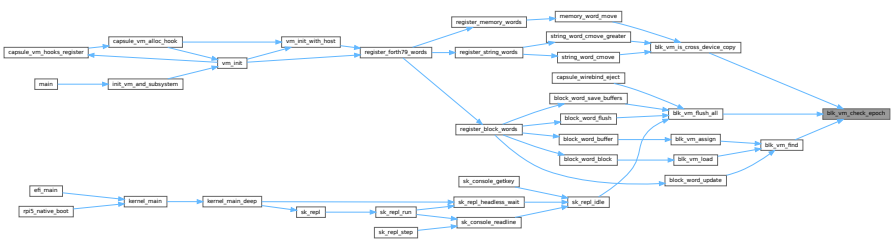
vm	Pointer to the Forth virtual machine instance

References blk_subsys_epoch(), VM::blk_vm_cbuf, VM::blk_vm_dirty, VM::blk_vm_epoch, VM::blk_vm_lbn, BLK_VM_SLOTS, and epoch.

Referenced by blk_vm_find(), blk_vm_flush_all(), and blk_vm_is_cross_device_copy().

Here is the call graph for this function:

Here is the caller graph for this function:



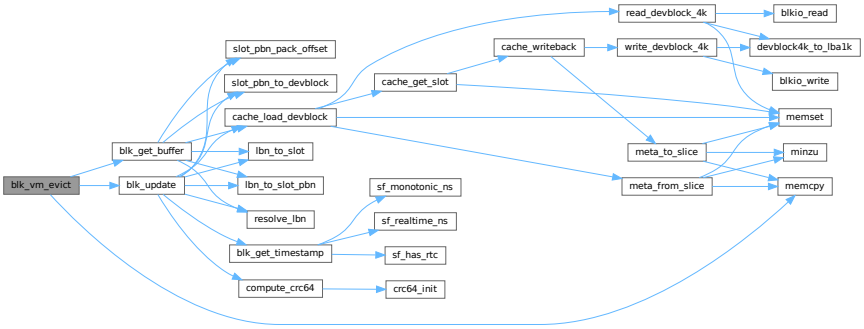
7.352.1.3 blk_vm_evict()

```
static int blk_vm_evict (
            VM * vm )  [static]
```

References base, blk_get_buffer(), blk_update(), VM::blk_vm_cbuf, VM::blk_vm_dirty, VM::blk_vm_lbn, VM::blk_vm_next, BLK_VM_SLOTS, BLK_VM_WINDOW_BASE, BLOCK_SIZE, memcpy(), and VM::memory.

Referenced by blk_vm_assign(), and blk_vm_load().

Here is the call graph for this function:



Here is the caller graph for this function:

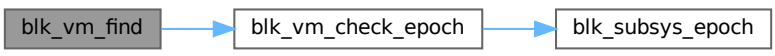
7.352.1.4 blk_vm_find()

```
static int blk_vm_find (
            VM * vm,
            uint32_t lbn )  [static]
```

References VM::blk_vm_cbuf, blk_vm_check_epoch(), VM::blk_vm_lbn, and BLK_VM_SLOTS.

Referenced by blk_vm_assign(), blk_vm_load(), and block_word_update().

Here is the call graph for this function:



Here is the caller graph for this function:

7.352.1.5 blk_vm_flush_all()

```
void blk_vm_flush_all (
            VM * vm )
```

Sync every dirty VM block-window slot to the C-layer block cache, then flush the whole block subsystem to physical media – the complete SAVE-BUFFERS implementation (unlike save_all_buffers() above, which only calls blk_flush() and so misses any BUFFER-modified-but-not-yet-UPDATE'd content still sitting only in vm->memory's window).

Cheap to call when nothing is dirty – every check inside is a small fixed-size scan, no I/O happens unless something actually needs writing. Safe to call from outside word dispatch (e.g. a periodic idle-tick auto-flush); vm must be non-NULL.

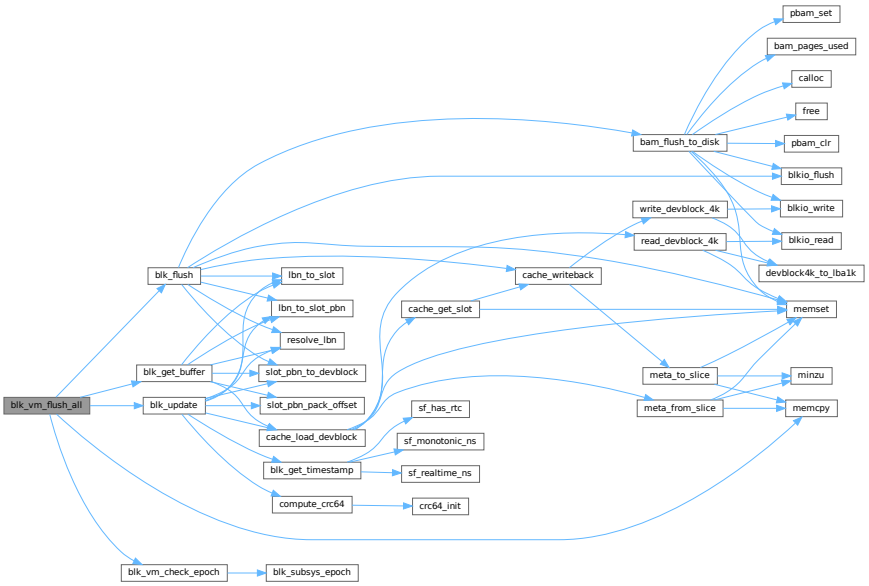
Parameters

vm	Pointer to the Forth virtual machine instance

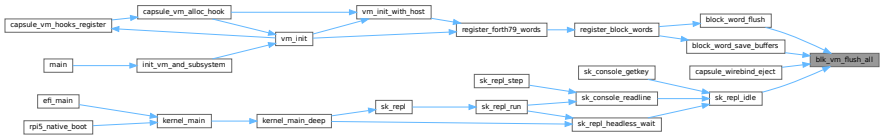
References base, blk_flush(), blk_get_buffer(), blk_update(), VM::blk_vm_cbuf, blk_vm_check_epoch(), VM::blk_vm_dirty, VM::blk_vm_lbn, BLK_VM_SLOTS, BLK_VM_WINDOW_BASE, BLOCK_SIZE, memcpy(), and VM::memory.

Referenced by block_word_flush(), block_word_save_buffers(), capsule_wirebind_eject(), and sk_repl_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.352.1.6 blk_vm_is_cross_device_copy()

```
int blk_vm_is_cross_device_copy (
            VM * vm,
            vaddr_t addr1,
            vaddr_t addr2 )
```

True if addr1/addr2 are both block-window addresses currently loaded from two different physical devices (Phase 8 v3, 2026-09-23) – the check MOVE/CMOVE/CMOVE> call before copying to refuse a same-VM, cross-device raw block copy.

See this function's own doc comment in block_words.c for exactly what is and isn't flagged.

Parameters

vm	VM performing the copy
addr1	first VM offset (source or destination, order doesn't matter)
addr2	second VM offset

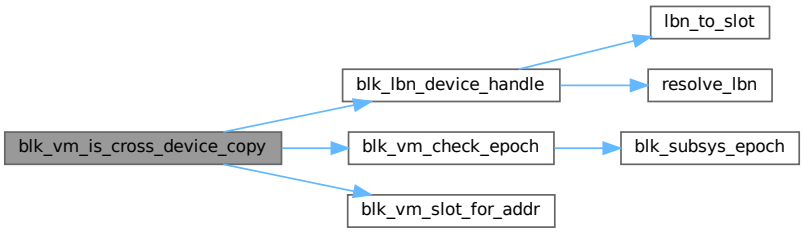
Returns

1 if this copy should be refused, 0 otherwise

References blk_lbn_device_handle(), blk_vm_check_epoch(), VM::blk_vm_lbn, and blk_vm_slot_for_addr().

Referenced by memory_word_move(), string_word_cmove(), and string_word_cmove_greater().

Here is the call graph for this function:



Here is the caller graph for this function:

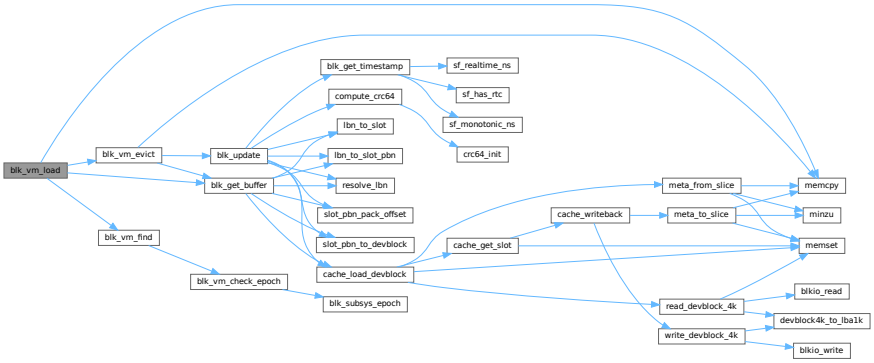
7.352.1.7 blk_vm_load()

```
static vaddr_t blk_vm_load (
            VM * vm,
            uint32_t lbn,
            int writable )  [static]
```

References base, blk_get_buffer(), VM::blk_vm_cbuf, VM::blk_vm_dirty, blk_vm_evict(), blk_vm_find(), VM::blk_vm_lbn, BLK_VM_SLOTS, BLK_VM_WINDOW_BASE, BLOCK_SIZE, memcpy(), and VM::memory.

Referenced by block_word_block().

Here is the call graph for this function:



Here is the caller graph for this function:

7.352.1.8 blk_vm_slot_for_addr()

```
int blk_vm_slot_for_addr (
            vaddr_t addr )
```

Does `addr` fall inside the block I/O window? Pure address arithmetic against the window's fixed compile-time base/size – no VM state needed.

Exposed (Phase 8 v3, 2026-09-23) for MOVE/CMOVE/CMOVE>'s cross-device block-copy check.

Parameters

addr	VM offset to test

Returns

slot index (0..BLK_VM_SLOTS-1) if inside the window, -1 otherwise

References BLK_VM_WINDOW_BASE, BLK_VM_WINDOW_SIZE, and BLOCK_SIZE.

Referenced by blk_vm_is_cross_device_copy().

Here is the caller graph for this function:

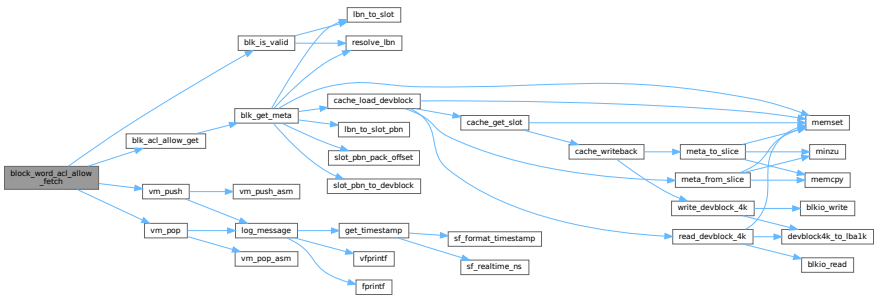
7.352.1.9 block_word_acl_allow_fetch()

```
static void block_word_acl_allow_fetch (
            VM * vm )  [static]
```

References blk_acl_allow_get(), blk_is_valid(), BLK_OK, VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

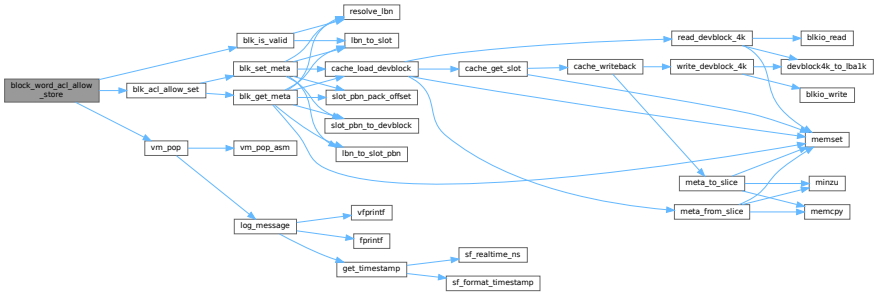
7.352.1.10 block_word_acl_allow_store()

```
static void block_word_acl_allow_store (
            VM * vm )  [static]
```

References blk_acl_allow_set(), blk_is_valid(), BLK_OK, VM::dsp, VM::error, and vm_pop().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

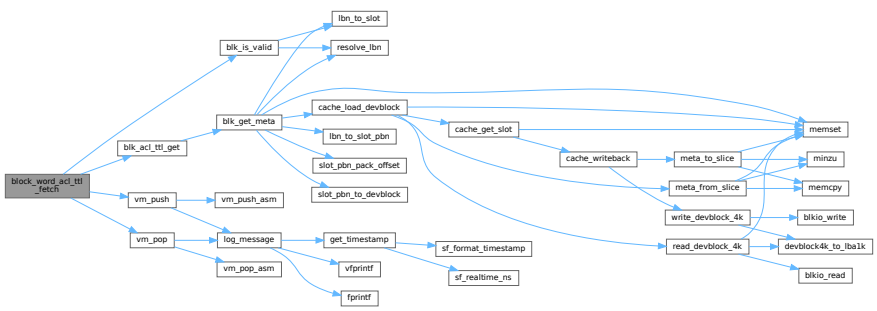
7.352.1.11 block_word_acl_ttl_fetch()

```
static void block_word_acl_ttl_fetch (
            VM * vm )  [static]
```

References blk_acl_ttl_get(), blk_is_valid(), BLK_OK, VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

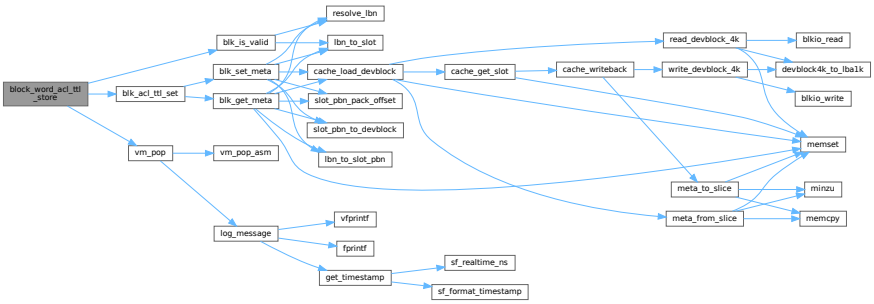
7.352.1.12 block_word_acl_ttl_store()

```
static void block_word_acl_ttl_store (
            VM * vm )  [static]
```

References blk_acl_ttl_set(), blk_is_valid(), BLK_OK, VM::dsp, VM::error, and vm_pop().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

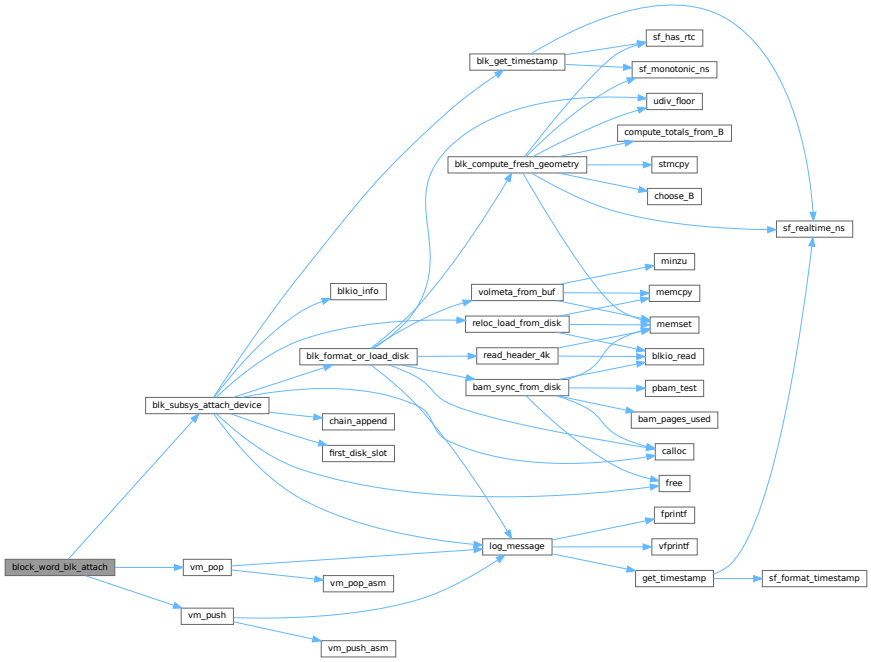
7.352.1.13 block_word_blk_attach()

```
static void block_word_blk_attach (
            VM * vm )  [static]
```

References BLK_OK, blk_subsys_attach_device(), VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

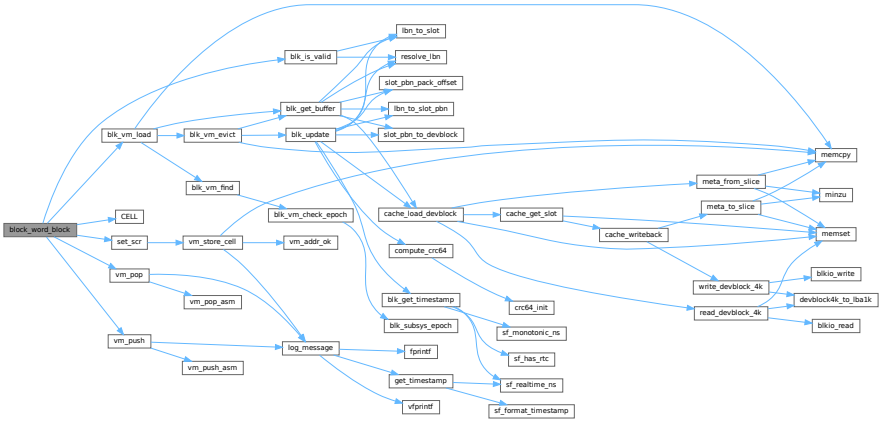
7.352.1.14 block_word_block()

```
void block_word_block (
            VM * vm )
```

References blk_is_valid(), blk_vm_load(), CELL(), VM::dsp, VM::error, VM::heartbeat, set_scr(), HeartbeatState::tick_count, vm_pop(), and vm_push().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

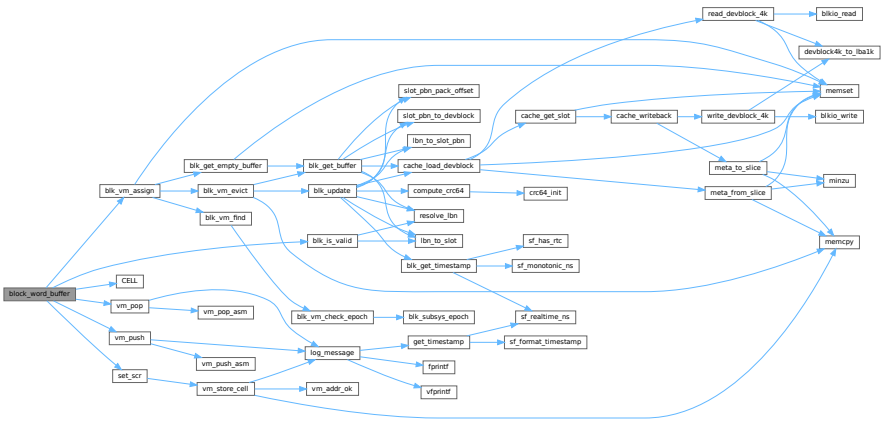
7.352.1.15 block_word_buffer()

```
void block_word_buffer (
            VM * vm )
```

References blk_is_valid(), blk_vm_assign(), CELL(), VM::dsp, VM::error, VM::heartbeat, set_scr(), HeartbeatState::tick_count, vm_pop(), and vm_push().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

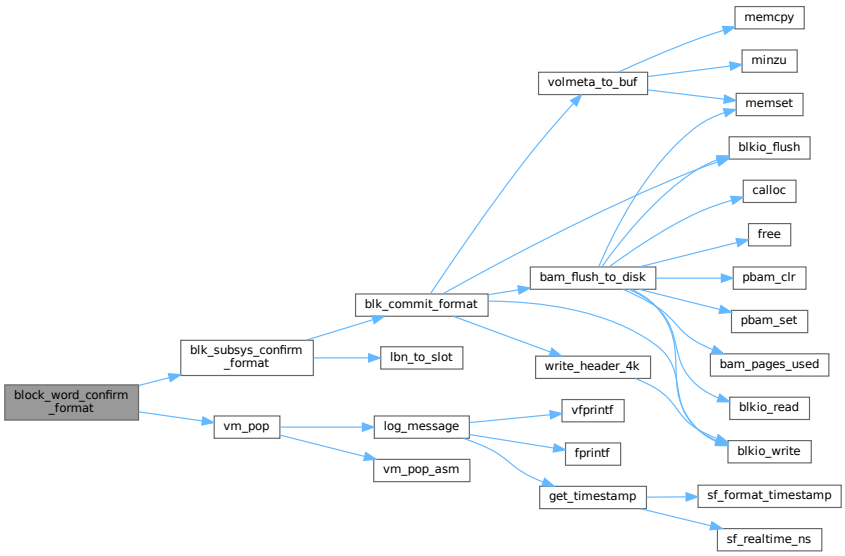
7.352.1.16 block_word_confirm_format()

```
void block_word_confirm_format (
            VM * vm )
```

References BLK_OK, blk_subsys_confirm_format(), VM::dsp, VM::error, and vm_pop().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

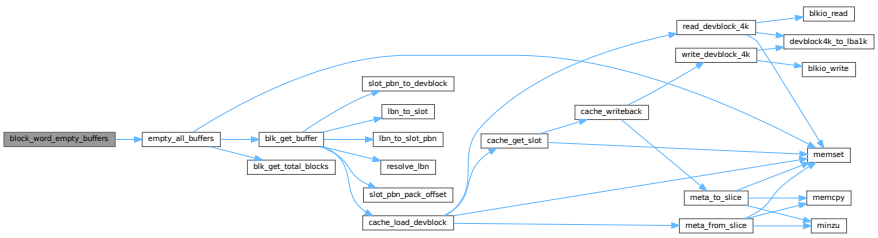
7.352.1.17 block_word_empty_buffers()

```
void block_word_empty_buffers (
            VM * vm )
```

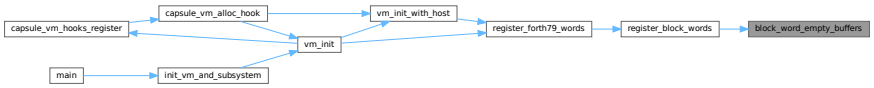
References VM::blk_vm_cbuf, VM::blk_vm_dirty, VM::blk_vm_lbn, BLK_VM_SLOTS, and empty_all_buffers().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:



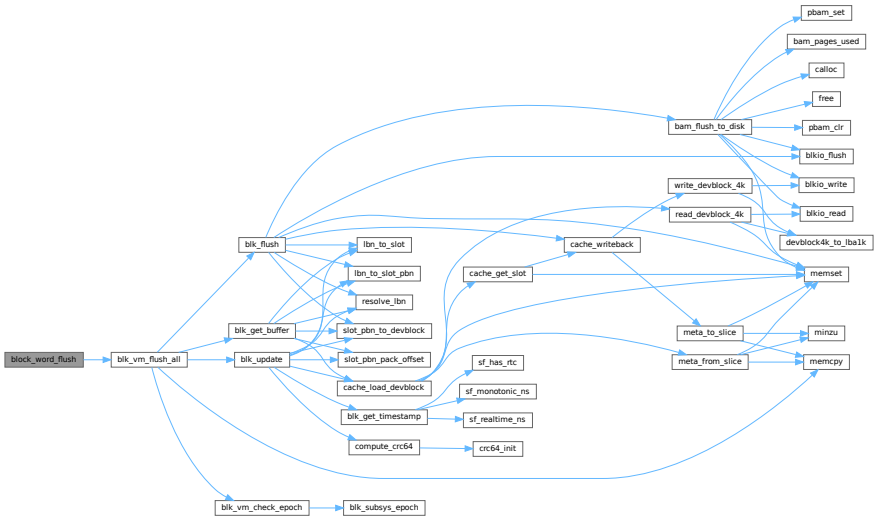
7.352.1.18 block_word_flush()

```
void block_word_flush (
            VM * vm )
```

References blk_vm_flush_all().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

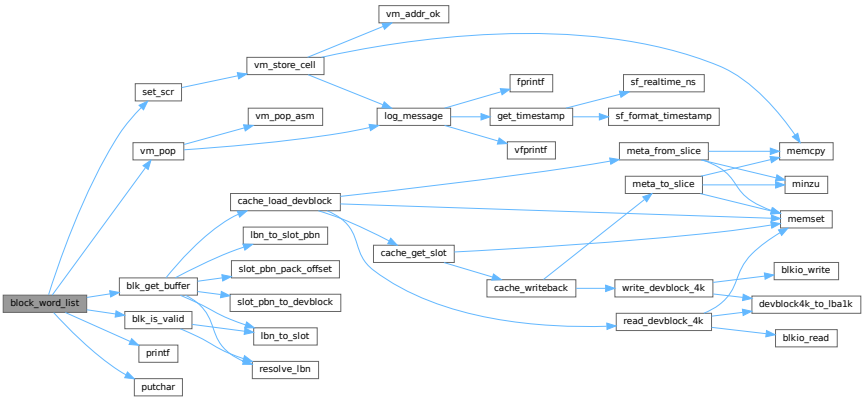
7.352.1.19 block_word_list()

```
void block_word_list (
            VM * vm )
```

References blk_get_buffer(), blk_is_valid(), VM::dsp, VM::error, printf(), putchar(), set_scr(), and vm_pop().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

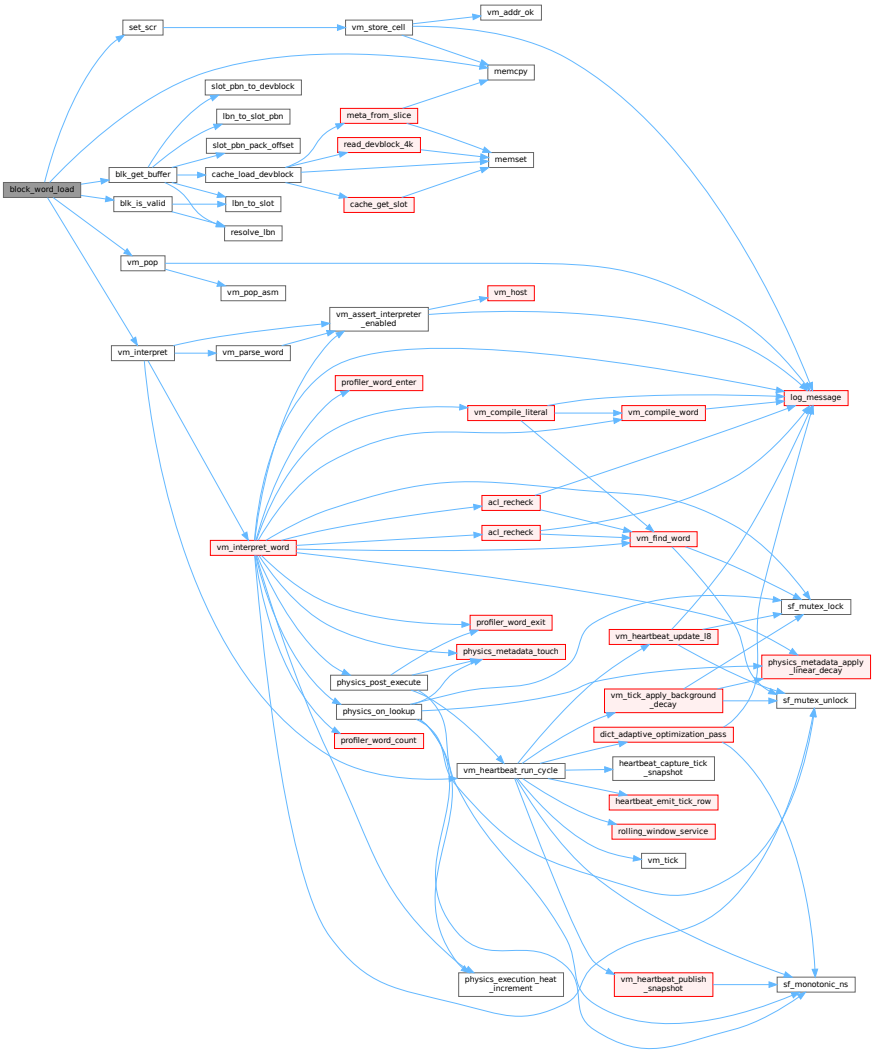
7.352.1.20 block_word_load()

```
void block_word_load (
            VM * vm )
```

References blk_get_buffer(), blk_is_valid(), VM::dsp, VM::error, memcpy(), set_scr(), vm_interpret(), and vm_pop().

Referenced by block_word_thru(), and register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

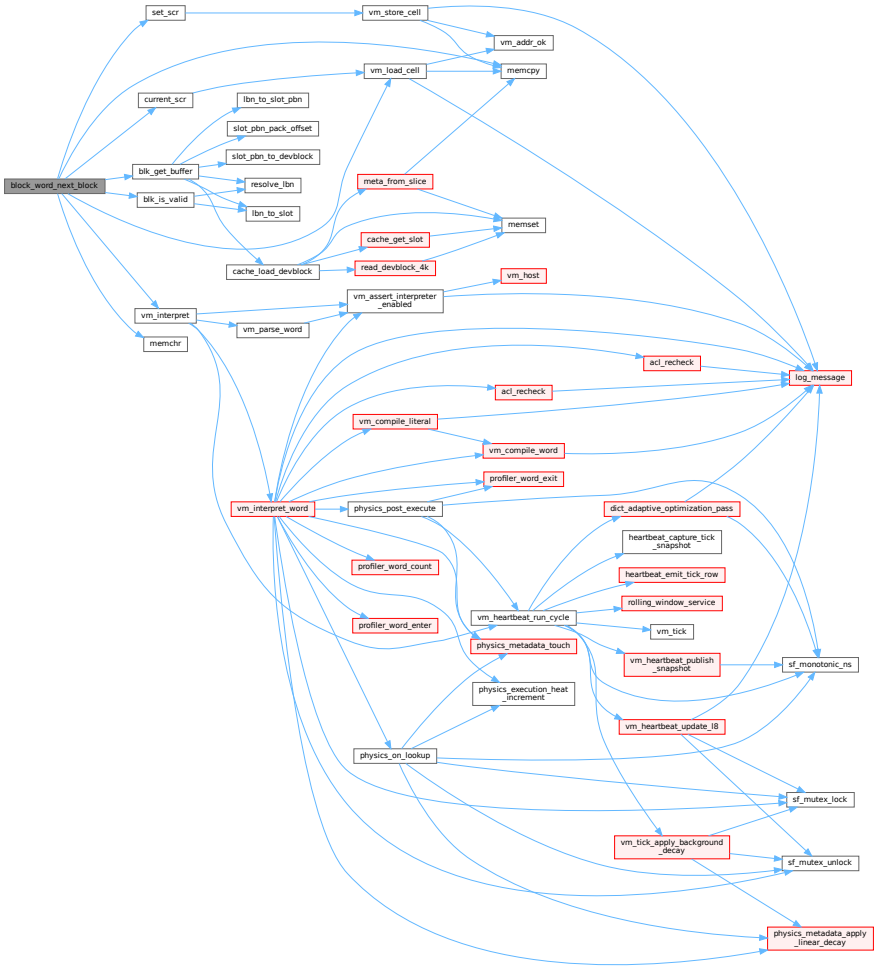
7.352.1.21 block_word_next_block()

```
void block_word_next_block (
            VM * vm )
```

References VM::abort_requested, blk_get_buffer(), blk_is_valid(), current_scr(), VM::error, memchr(), memcpy(), VM::scr_addr, set_scr(), vm_interpret(), and vm_load_cell().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

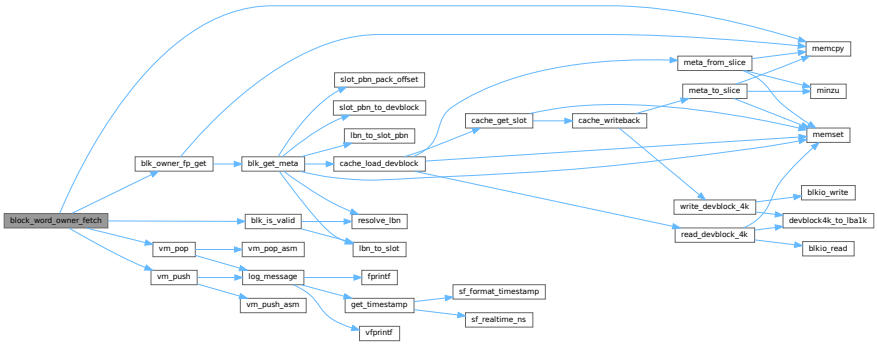
7.352.1.22 block_word_owner_fetch()

```
static void block_word_owner_fetch (
            VM * vm )  [static]
```

References blk_is_valid(), BLK_OK, blk_owner_fp_get(), VM::dsp, VM::error, memcpy(), vm_pop(), and vm_push().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

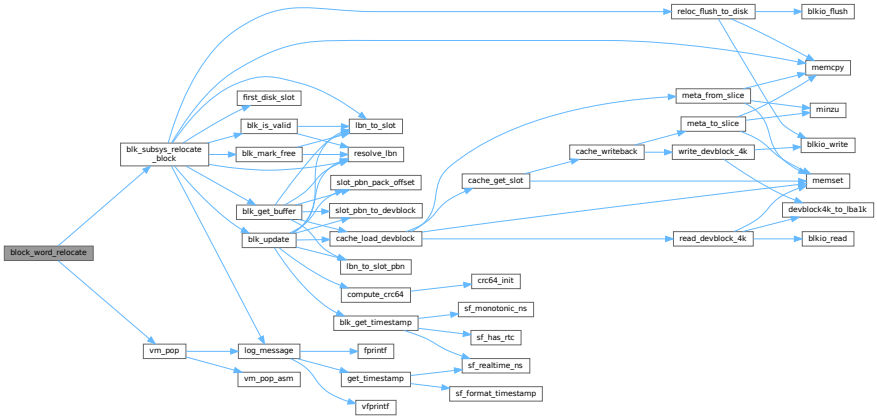
7.352.1.23 block_word_relocate()

```
void block_word_relocate (
            VM * vm )
```

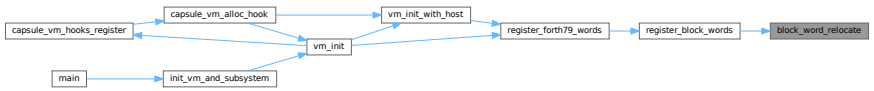
References BLK_OK, blk_subsys_relocate_block(), VM::dsp, VM::error, and vm_pop().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:



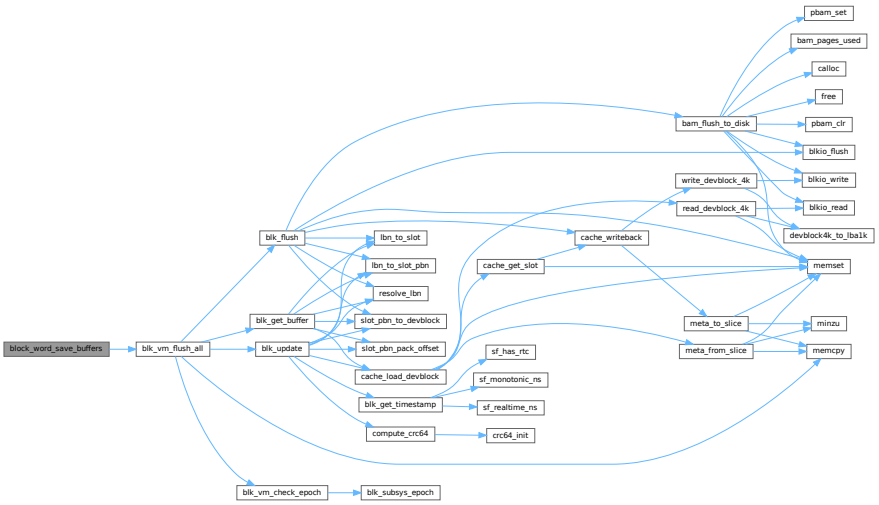
7.352.1.24 block_word_save_buffers()

```
void block_word_save_buffers (
            VM * vm )
```

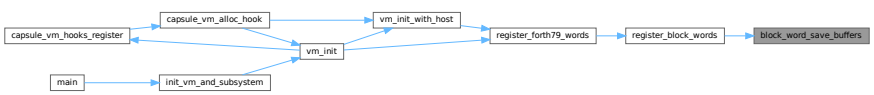
References blk_vm_flush_all().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:



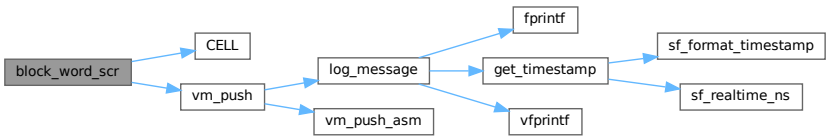
7.352.1.25 block_word_scr()

```
void block_word_scr (
            VM * vm )
```

References CELL(), VM::scr_addr, and vm_push().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

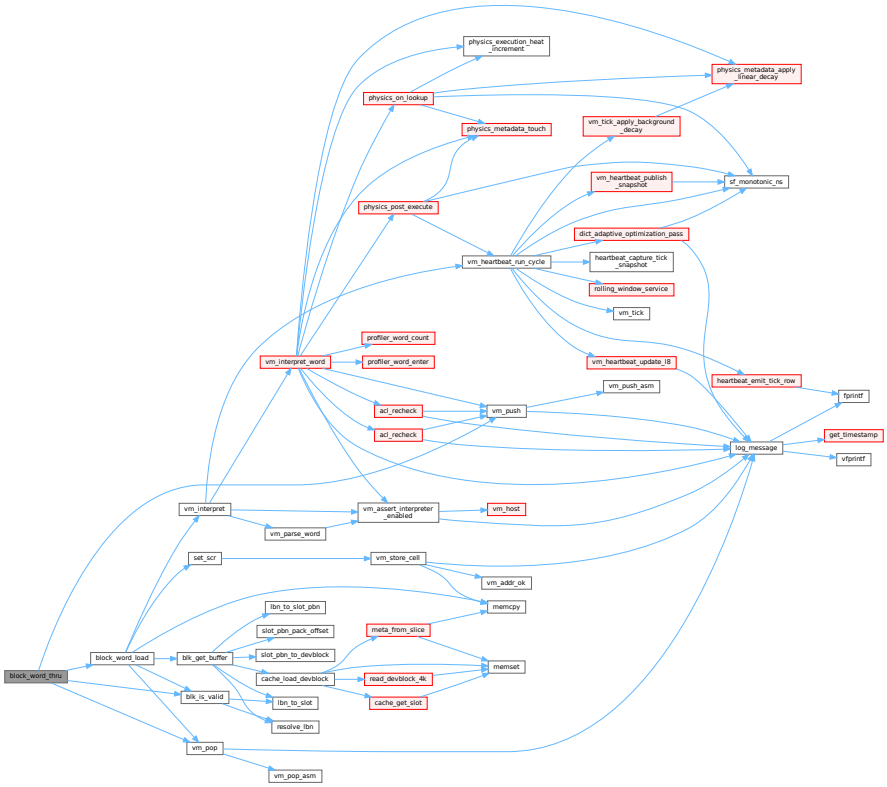
7.352.1.26 block_word_thru()

```
void block_word_thru (
            VM * vm )
```

References VM::abort_requested, blk_is_valid(), block_word_load(), VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

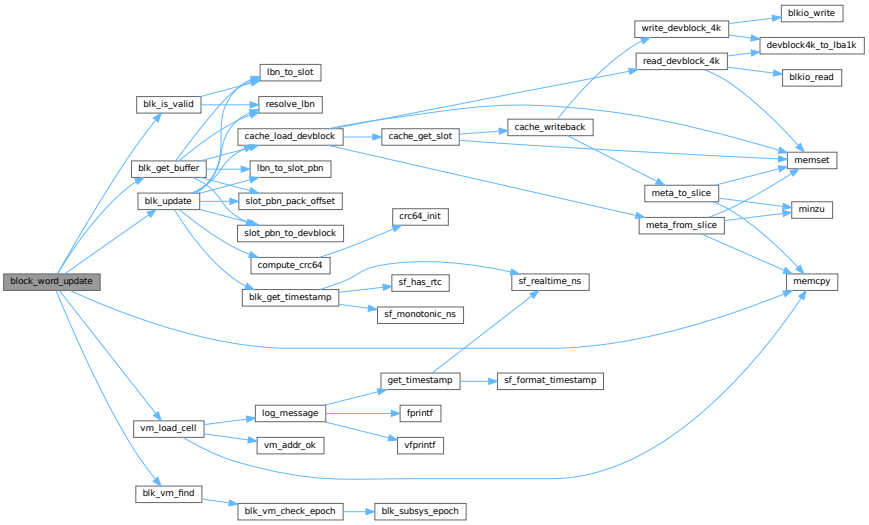
7.352.1.27 block_word_update()

```
void block_word_update (
            VM * vm )
```

References base, blk_get_buffer(), blk_is_valid(), blk_update(), VM::blk_vm_cbuf, VM::blk_vm_dirty, blk_vm_find(), BLK_VM_WINDOW_BASE, BLOCK_SIZE, VM::error, VM::heartbeat, memcpy(), VM::memory, VM::scr_addr, HeartbeatState::tick_count, and vm_load_cell().

Referenced by register_block_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.352.1.28 empty_all_buffers()

```
void empty_all_buffers (
            VM * vm )
```

Empties all user block buffers.

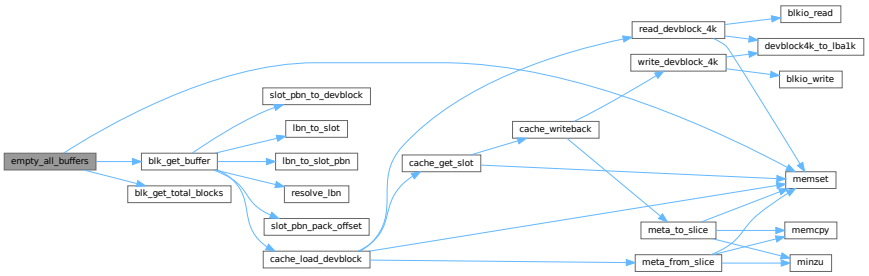
Parameters

vm	Pointer to the VM instance

References blk_get_buffer(), blk_get_total_blocks(), BLOCK_SIZE, memset(), and USER_BLOCKS_START.

Referenced by block_word_empty_buffers().

Here is the call graph for this function:



Here is the caller graph for this function:

7.352.1.29 get_block_buffer()

```
unsigned char * get_block_buffer (
            VM * vm,
            int block_num )
```

Gets a buffer for the specified block.

Parameters

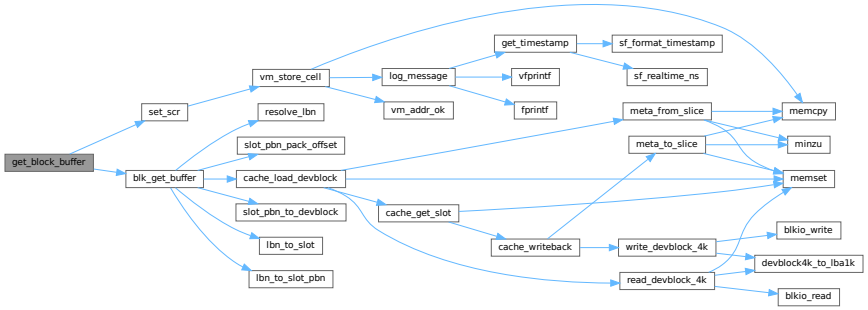
vm	Pointer to the VM instance
block_num	Block number to retrieve

Returns

Pointer to block buffer or NULL if invalid

References blk_get_buffer(), and set_scr().

Here is the call graph for this function:



7.352.1.30 get_empty_buffer()

```
unsigned char * get_empty_buffer (
            VM * vm,
            int block_num )
```

Gets an empty buffer for the specified block.

Parameters

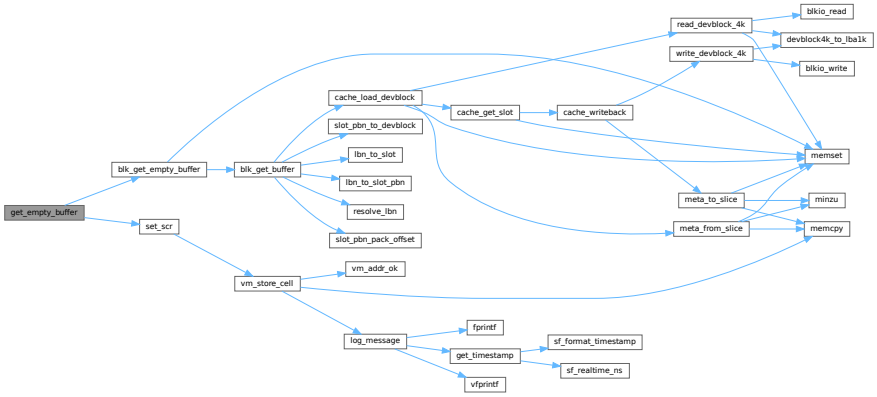
vm	Pointer to the VM instance
block_num	Block number to create

Returns

Pointer to empty block buffer or NULL if invalid

References blk_get_empty_buffer(), and set_scr().

Here is the call graph for this function:



7.352.1.31 init_block_system()

```
void init_block_system (
            VM * vm )
```

Initializes the block system.

Parameters

vm	Pointer to the Forth virtual machine instance

7.352.1.32 mark_buffer_dirty()

```
void mark_buffer_dirty (
            VM * vm )
```

Marks the current buffer as modified.

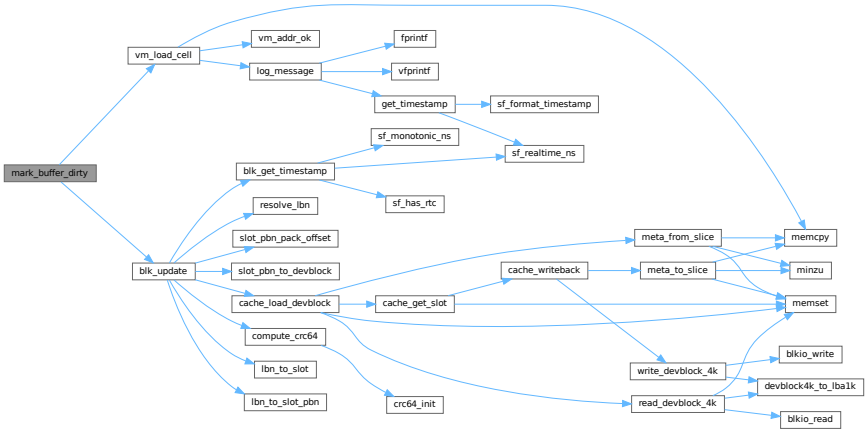
Parameters

vm	Pointer to the Forth virtual machine instance

References blk_update(), VM::scr_addr, and vm_load_cell().

Referenced by editor_word_edit(), and editor_word_s().

Here is the call graph for this function:



Here is the caller graph for this function:

7.352.1.33 register_block_words()

```
void register_block_words (
            VM * vm )
```

Registers all block and buffer words with the virtual machine.

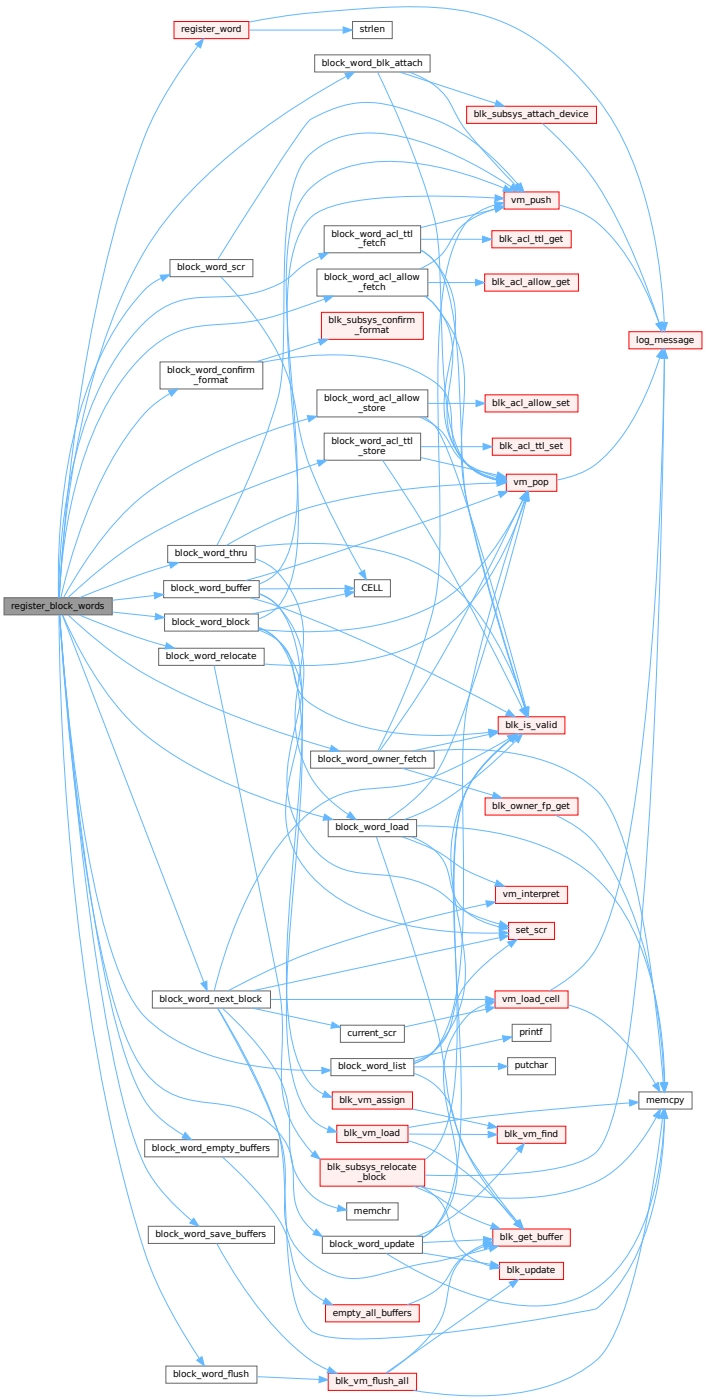
Parameters

vm	Pointer to the Forth virtual machine instance

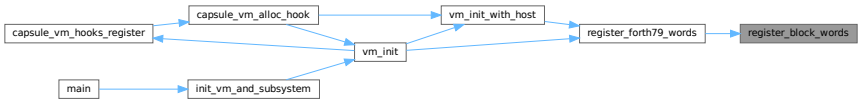
References block_word_acl_allow_fetch(), block_word_acl_allow_store(), block_word_acl_ttl_fetch(), block_word_acl_ttl_store(), block_word_blk_attach(), block_word_block(), block_word_buffer(), block_word_confirm_format(), block_word_empty_buffers(), block_word_flush(), block_word_list(), block_word_load(), block_word_next_block(), block_word_owner_fetch(), block_word_relocate(), block_word_save_buffers(), block_word_scr(), block_word_thru(), block_word_update(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



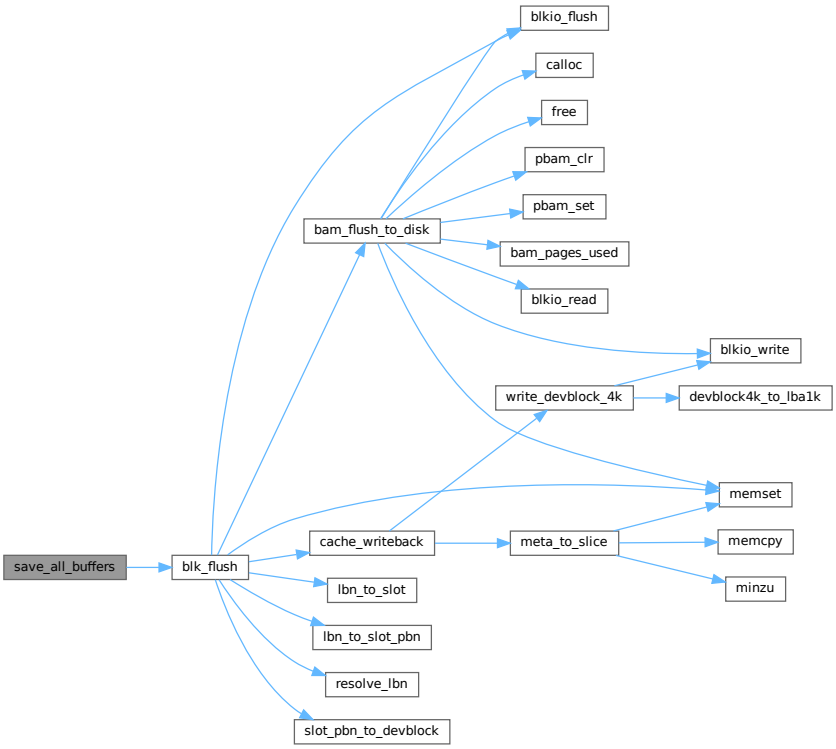
7.352.1.34 save_all_buffers()

```
void save_all_buffers (
            VM * vm )
```

References blk_flush().

Referenced by editor_word_edit().

Here is the call graph for this function:



Here is the caller graph for this function:

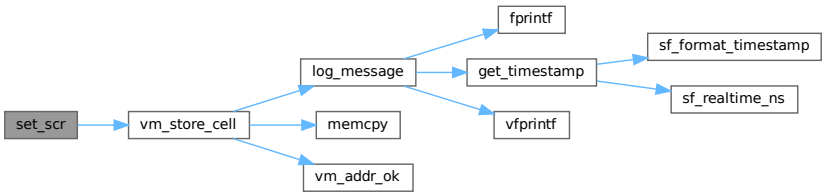
7.352.1.35 set_scr()

```
static void set_scr (
            VM * vm,
            cell_t blk )  [static]
```

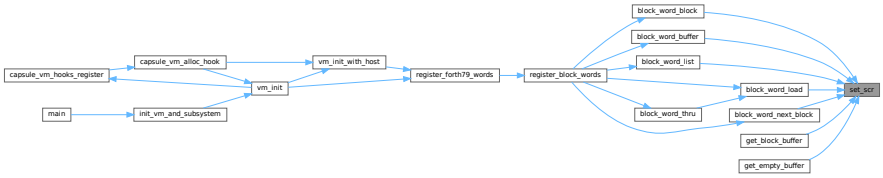
References VM::scr_addr, and vm_store_cell().

Referenced by block_word_block(), block_word_buffer(), block_word_list(), block_word_load(), block_word_next_block(), get_block_buffer(), and get_empty_buffer().

Here is the call graph for this function:



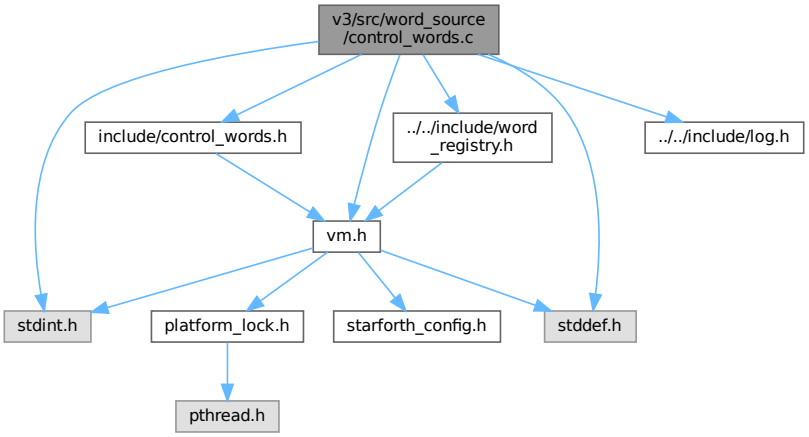
Here is the caller graph for this function:



7.353 v3/src/word_source/control_words.c File Reference

```
#include "include/control_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include "../../include/vm.h"
#include <stddef.h>
#include <stdint.h>
```

Include dependency graph for control_words.c:



Functions

- static void cf_epoch_sync (VM *vm)
- static int cf_push_item (VM *vm, cf_tag_t tag, size_t mark)
- static int cf_pop_item (VM *vm, cf_item_t *out)
- static int cf_peek_item (VM *vm, cf_item_t *out)
- static size_t emit_cell (VM *vm, cell_t value)
- static void control_forth_UNLOOP (VM *vm)
- static void control_forth_if (VM *vm)
- static void control_forth_else (VM *vm)
- static void control_forth_then (VM *vm)
- static void control_forth_begin (VM *vm)
- static void control_forth_until (VM *vm)
- static void control_forth_again (VM *vm)
- static void control_forth_while (VM *vm)
- static void control_forth_repeat (VM *vm)
- static void control_forth_qdo (VM *vm)
- static void control_forth_do (VM *vm)
- static void control_forth_leave (VM *vm)
- static void control_forth_loop (VM *vm)
- static void control_forth_plus_loop (VM *vm)
- static void control_forth_case (VM *vm)
- static void control_forth_of (VM *vm)
- static void control_forth_endof (VM *vm)
- static void control_forth_endcase (VM *vm)
- void register_control_words (VM *vm)

  Registers all control flow words with the Forth virtual machine.

Internal Runtime Functions

Forward declarations for internal runtime helpers and control flow primitives

- static void control_forth_branch (VM *vm)

  Execute unconditional branch.
- static void control_forth_0branch (VM *vm)

  Execute conditional branch based on top of stack.
- static void control_forth_runtime_qdo (VM *vm)

  Runtime handler for ?DO loops.
- static void control_forth_runtime_do (VM *vm)

  Runtime handler for DO loops.
- static void control_forth_runtime_loop (VM *vm)

  Runtime handler for LOOP.
- static void control_forth_runtime_plus_loop (VM *vm)

  Runtime handler for +LOOP.
- static void control_forth_runtime_leave (VM *vm)

  Runtime handler for LEAVE.
- static void control_forth_I (VM *vm)

  Get current loop index.
- static void control_forth_J (VM *vm)

  Get outer loop index.
- static void control_forth_EXIT (VM *vm)

  Exit from current definition.

7.353.1 Function Documentation

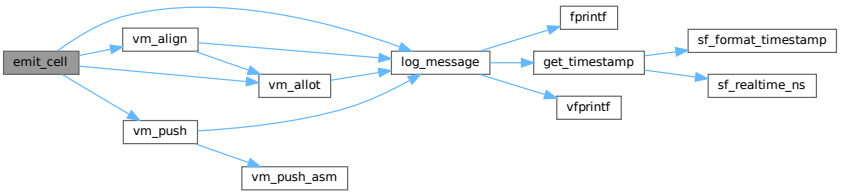
7.353.1.1 emit_cell()

```
static size_t emit_cell (
            VM * vm,
            cell_t value )  [inline], [static]
```

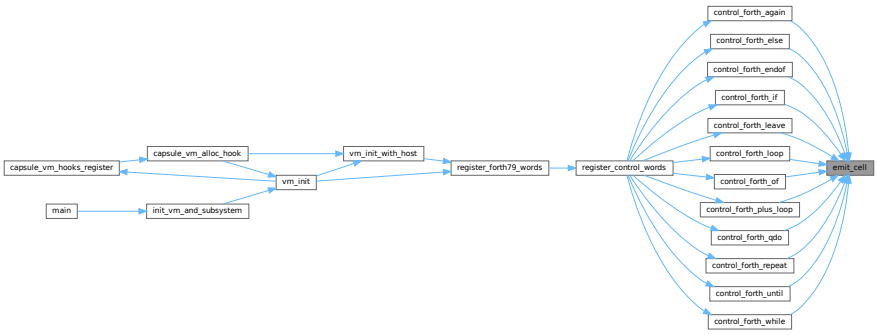
References VM::error, LOG_ERROR, log_message(), VM::memory, VM::mode, MODE_COMPILE, vm_align(), vm_allot(), and vm_push().

Referenced by control_forth_again(), control_forth_else(), control_forth_endof(), control_forth_if(), control_forth_leave(), control_forth_loop(), control_forth_of(), control_forth_plus_loop(), control_forth_qdo(), control_forth_repeat(), control_forth_until(), and control_forth_while().

Here is the call graph for this function:



Here is the caller graph for this function:

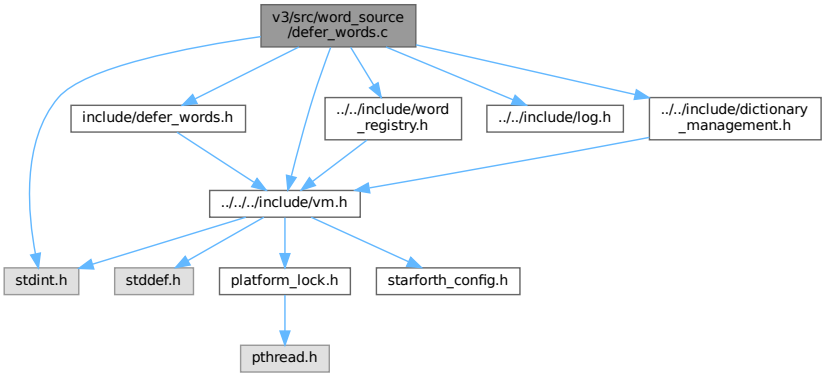


7.354 v3/src/word_source/defer_words.c File Reference

```
#include "include/defer_words.h"
#include "../../include/vm.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include "../../include/dictionary_management.h"
```

```
#include <stdint.h>
```

Include dependency graph for defer_words.c:



Functions

- static void defer_runtime (VM *vm)
- static void word_defer (VM *vm)
- static void word_is (VM *vm)
- static void word_defer_fetch (VM *vm)
- void register_defer_words (VM *vm)

7.354.1 Function Documentation

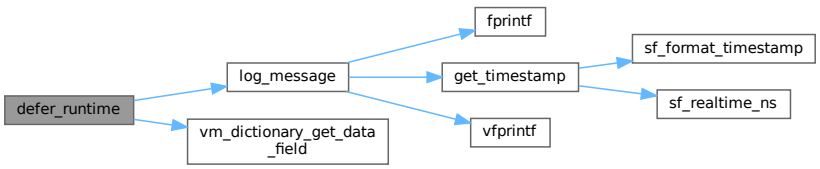
7.354.1.1 defer_runtime()

```
static void defer_runtime (
            VM * vm )  [static]
```

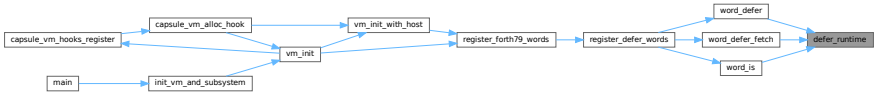
References VM::current_executing_entry, VM::error, DictEntry::func, LOG_ERROR, log_message(), DictEntry::name, DictEntry::name_len, and vm_dictionary_get_data_field().

Referenced by word_defer(), word_defer_fetch(), and word_is().

Here is the call graph for this function:



Here is the caller graph for this function:



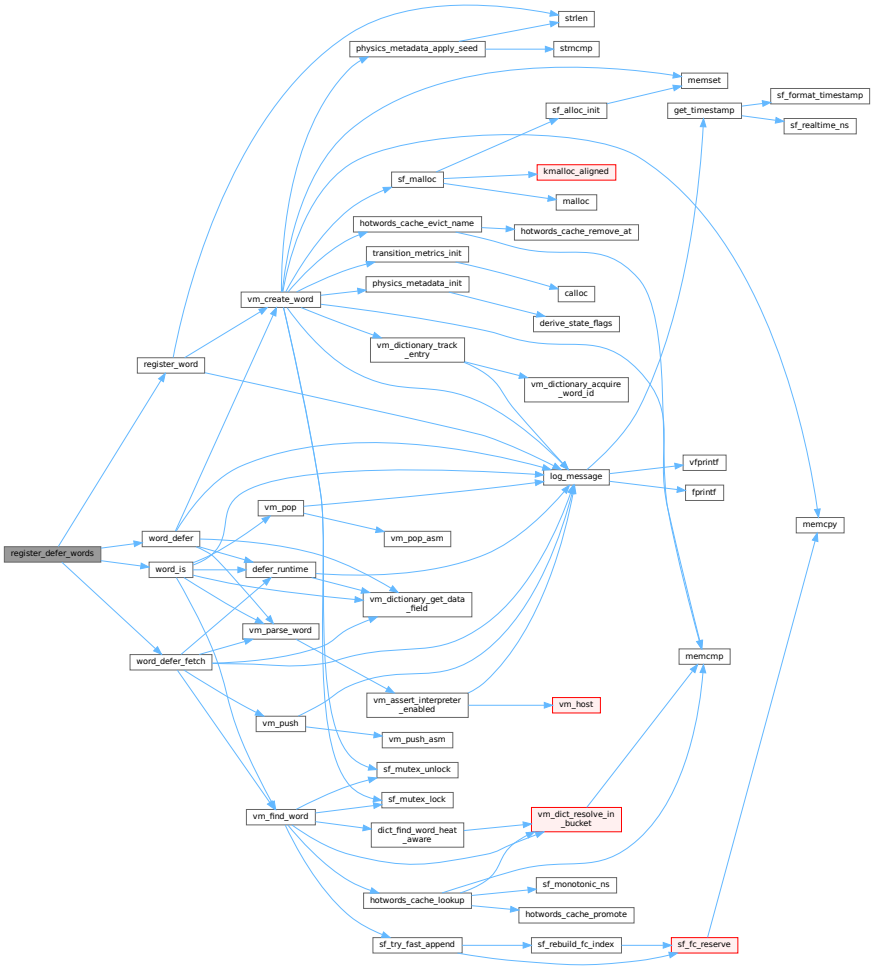
7.354.1.2 register_defer_words()

```
void register_defer_words (
            VM * vm )
```

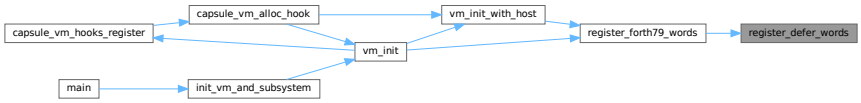
References register_word(), word_defer(), word_defer_fetch(), and word_is().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



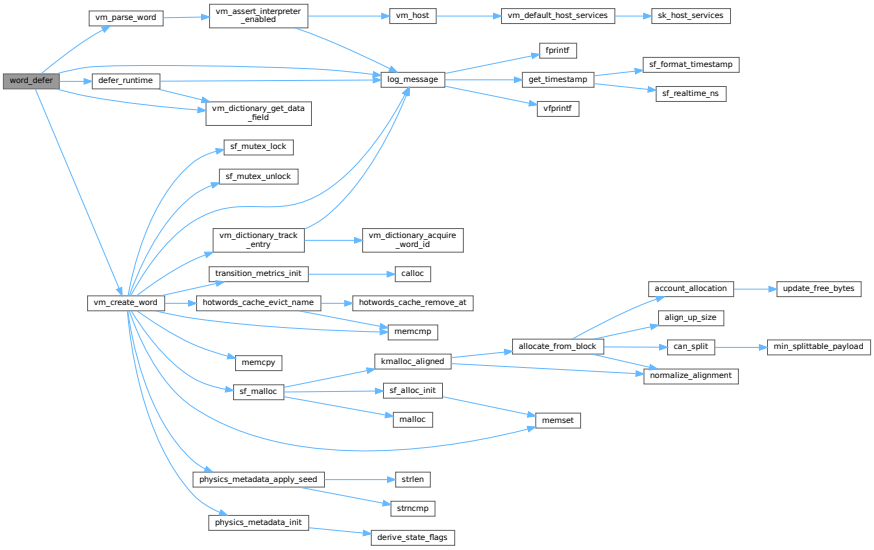
7.354.1.3 word_defer()

```
static void word_defer (
            VM * vm )  [static]
```

References defer_runtime(), VM::error, LOG_DEBUG, LOG_ERROR, log_message(), name, vm_create_word(), vm_dictionary_get_data_field(), vm_parse_word(), and WORD_NAME_MAX.

Referenced by register_defer_words().

Here is the call graph for this function:



Here is the caller graph for this function:

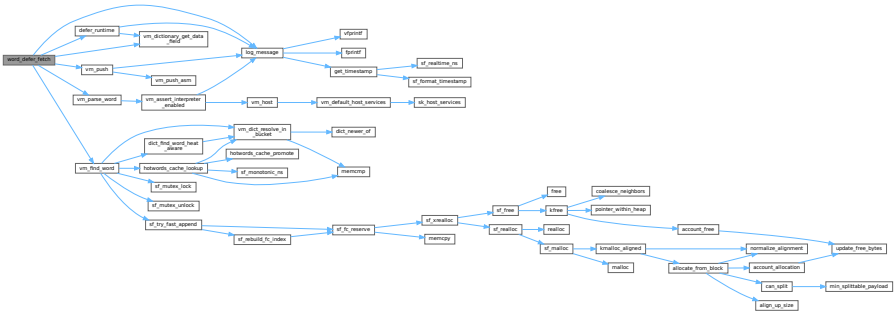
7.354.1.4 word_defer_fetch()

```
static void word_defer_fetch (
            VM * vm )  [static]
```

References defer_runtime(), VM::error, DictEntry::func, LOG_DEBUG, LOG_ERROR, log_message(), name, vm_dictionary_get_data_field(), vm_find_word(), vm_parse_word(), vm_push(), and WORD_NAME_MAX.

Referenced by register_defer_words().

Here is the call graph for this function:



Here is the caller graph for this function:

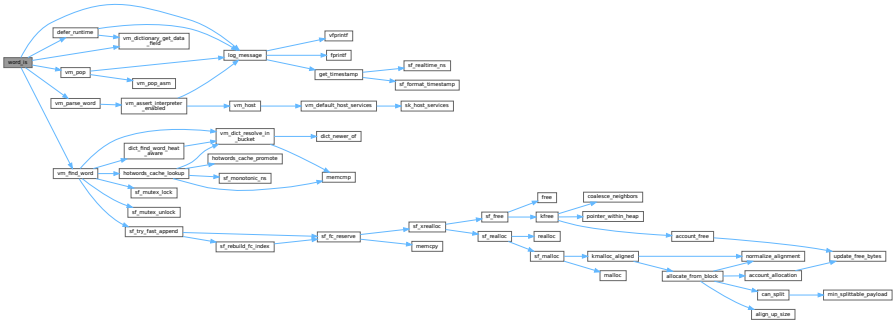
7.354.1.5 word_is()

```
static void word_is (
            VM * vm )  [static]
```

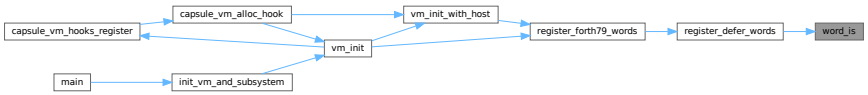
References defer_runtime(), VM::dsp, VM::error, DictEntry::func, LOG_DEBUG, LOG_ERROR, log_message(), name, vm_dictionary_get_data_field(), vm_find_word(), vm_parse_word(), vm_pop(), and WORD_NAME_MAX.

Referenced by register_defer_words().

Here is the call graph for this function:



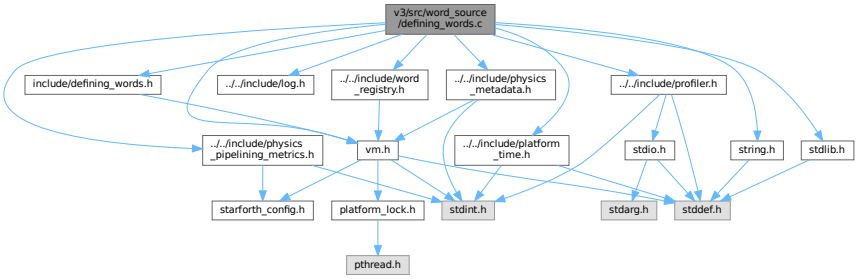
Here is the caller graph for this function:



7.355 v3/src/word_source/defining_words.c File Reference

```
#include "include/defining_words.h"
#include "../../include/vm.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include "../../include/profiler.h"
#include "../../include/physics_metadata.h"
#include "../../include/platform_time.h"
#include "../../include/physics_pipelining_metrics.h"
#include <string.h>
#include <stdlib.h>
```

Include dependency graph for defining_words.c:



Functions

- static void defining_runtime_create (VM *vm)

  Runtime behavior for words defined by CREATE.
- static void defining_runtime_constant (VM *vm)

  Runtime behavior for CONSTANT words.
- static void defining_runtime_variable (VM *vm)

  Runtime behavior for VARIABLE words.
- static void defining_runtime_lit (VM *vm)

  Runtime behavior for literal values in threaded code.
- static void defining_runtime_dodoes (VM *vm)

  Runtime behavior for words defined with DOES>
- static void defining_runtime_does_rt (VM *vm)

  Helper routine executed at DOES> time.
- static void defining_word_colon (VM *vm)
- static void defining_word_semicolon (VM *vm)

- static void defining_word_create (VM *vm)
- static void defining_word_constant (VM *vm)
- static void defining_word_variable (VM *vm)
- static void defining_word_left_bracket (VM *vm)
- static void defining_word_right_bracket (VM *vm)
- static void defining_word_state (VM *vm)
- static void defining_word_compile (VM *vm)
- static void defining_word_bracket_compile (VM *vm)
- static void defining_word_literal (VM *vm)
- static void defining_word_does (VM *vm)
- static void defining_word_immediate (VM *vm)
- static void dictionary_word_forget (VM *vm)
- static void dictionary_word_fence (VM *vm)
- void register_defining_words (VM *vm)

  Register all defining words in the dictionary.

7.355.1 Function Documentation

7.355.1.1 defining_runtime_constant()

```
static void defining_runtime_constant (
            VM * vm )  [static]
```

Runtime behavior for CONSTANT words.

Pushes the constant value stored in the word's data field onto the stack. Stack effect: (– n)

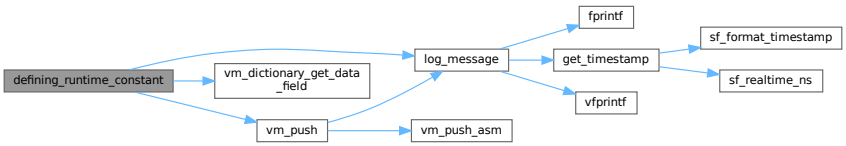
Parameters

vm	Pointer to the VM context

References VM::current_executing_entry, entry, VM::error, LOG_DEBUG, log_message(), vm_dictionary_get_data_field(), and vm_push().

Referenced by defining_word_constant().

Here is the call graph for this function:



Here is the caller graph for this function:

7.355.1.2 defining_runtime_create()

```
static void defining_runtime_create (
            VM * vm )  [static]
```

Runtime behavior for words defined by CREATE.

Pushes the word's data field address (DFA) captured at CREATE time. Stack effect: (– addr)

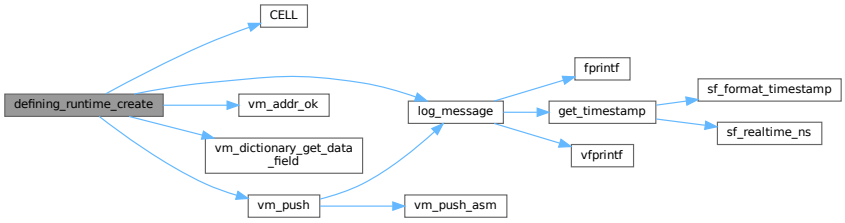
Parameters

vm	Pointer to the VM context

References CELL(), VM::current_executing_entry, entry, VM::error, LOG_DEBUG, log_message(), vm_addr_ok(), vm_dictionary_get_data_field(), and vm_push().

Referenced by defining_word_create().

Here is the call graph for this function:



Here is the caller graph for this function:

7.355.1.3 defining_runtime_dodoes()

```
static void defining_runtime_dodoes (
            VM * vm )  [static]
```

Runtime behavior for words defined with DOES>

Pushes the address of user data area then executes the DOES> body code. PFA layout: [body_vaddr][user_data...]

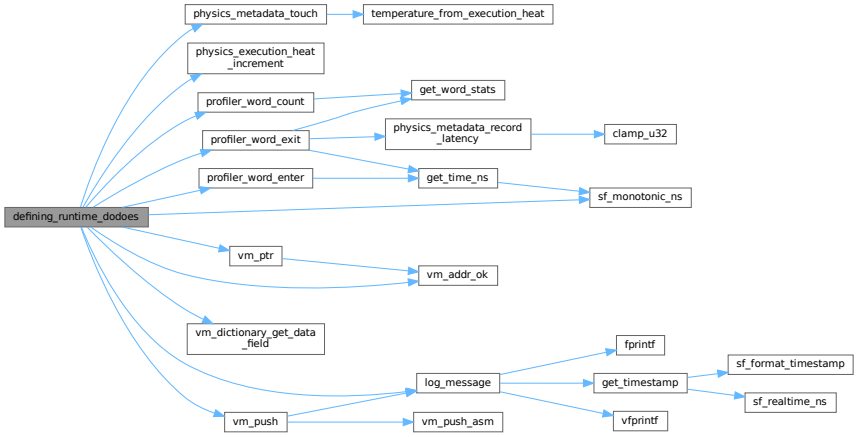
Parameters

vm	Pointer to the VM context

References VM::abort_requested, VM::current_executing_entry, entry, VM::error, VM::exit_colon, LOG_DEBUG, LOG_ERROR, log_message(), physics_execution_heat_increment(), physics_metadata_touch(), profiler_word_count(), profiler_word_enter(), profiler_word_exit(), VM::return_stack, VM::rsp, sf_monotonic_ns(), STACK_SIZE, vm_addr_ok(), vm_dictionary_get_data_field(), vm_ptr(), and vm_push().

Referenced by defining_runtime_does_rt().

Here is the call graph for this function:



Here is the caller graph for this function:

7.355.1.4 defining_runtime_does_rt()

```
static void defining_runtime_does_rt (
            VM * vm )  [static]
```

Helper routine executed at DOES> time.

Converts the just-created child word to use DODOES runtime behavior and records the DOES> body address in the child's PFA.

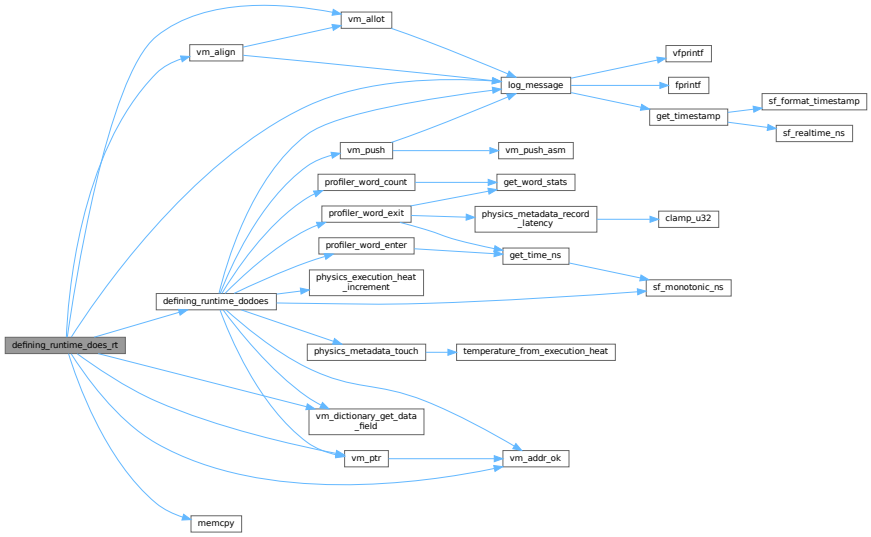
Parameters

vm	Pointer to the VM context

References defining_runtime_dodoes(), VM::error, DictEntry::func, VM::here, VM::latest, LOG_ERROR, log_message(), memcpy(), VM::memory, VM::return_stack, VM::rsp, vm_addr_ok(), vm_align(), vm_allot(), vm_dictionary_get_data_field(), and vm_ptr().

Referenced by defining_word_does(), and register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.355.1.5 defining_runtime_lit()

```
static void defining_runtime_lit (
            VM * vm )  [static]
```

Runtime behavior for literal values in threaded code.

Fetches the next cell from threaded code via IP and pushes it. Stack effect: (– n)

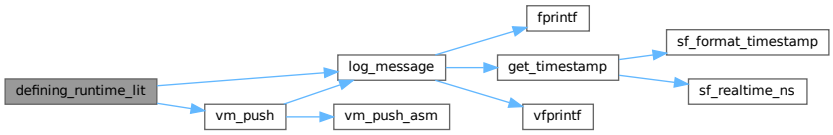
Parameters

vm	Pointer to the VM context

References VM::error, LOG_DEBUG, log_message(), VM::return_stack, VM::rsp, and vm_push().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.355.1.6 defining_runtime_variable()

```
static void defining_runtime_variable (
            VM * vm )  [static]
```

Runtime behavior for VARIABLE words.

Pushes the variable's address (VM offset) stored in the word's data field. Stack effect: (– addr)

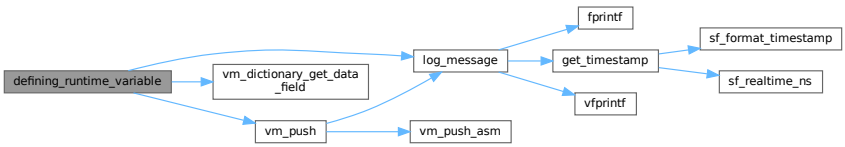
Parameters

vm	Pointer to the VM context

References VM::current_executing_entry, entry, VM::error, LOG_DEBUG, log_message(), vm_dictionary_get_data_field(), and vm_push().

Referenced by defining_word_variable().

Here is the call graph for this function:



Here is the caller graph for this function:

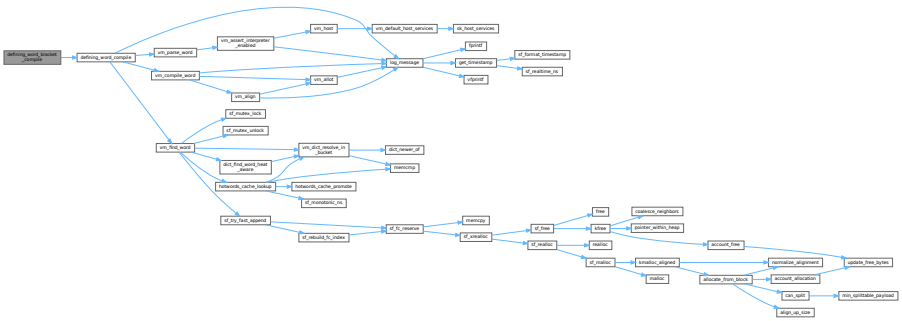
7.355.1.7 defining_word_bracket_compile()

```
static void defining_word_bracket_compile (
            VM * vm )  [static]
```

References defining_word_compile().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

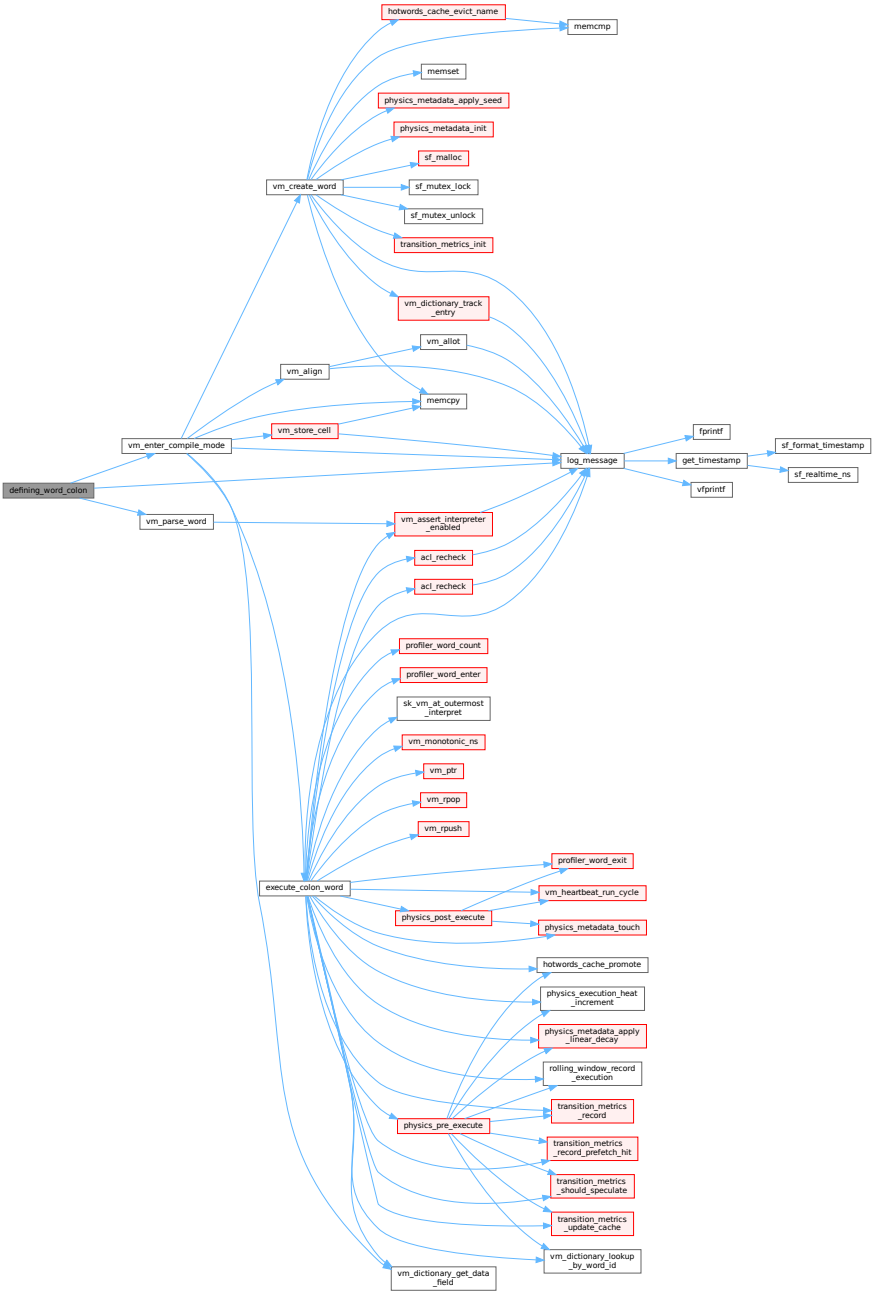
7.355.1.8 defining_word_colon()

```
static void defining_word_colon (
            VM * vm )  [static]
```

References VM::error, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_enter_compile_mode(), vm_parse_word(), and WORD_NAME_MAX.

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

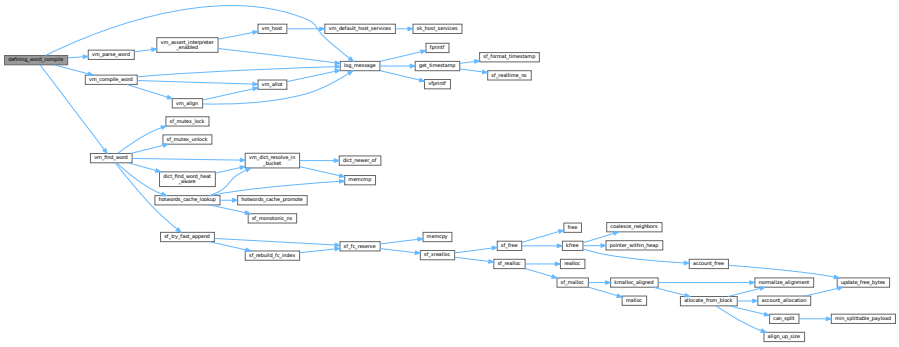
7.355.1.9 defining_word_compile()

```
static void defining_word_compile (
            VM * vm )  [static]
```

References entry, VM::error, LOG_DEBUG, log_message(), vm_compile_word(), vm_find_word(), vm_parse_word(), and WORD_NAME_MAX.

Referenced by defining_word_bracket_compile(), and register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

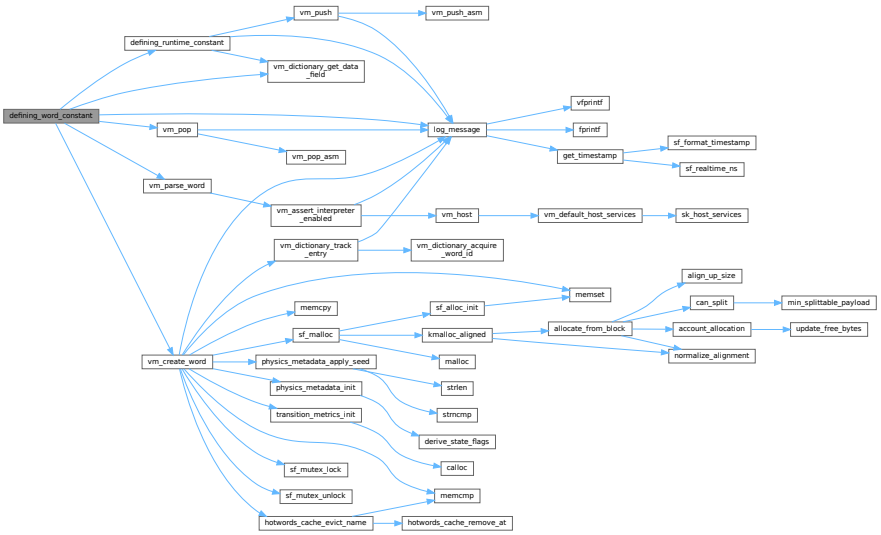
7.355.1.10 defining_word_constant()

```
static void defining_word_constant (
            VM * vm )  [static]
```

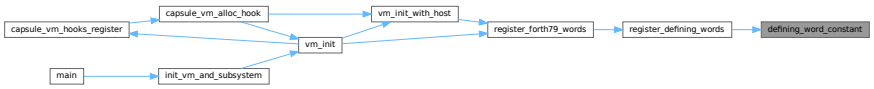
References defining_runtime_constant(), VM::dsp, entry, VM::error, LOG_DEBUG, log_message(), vm_create_word(), vm_dictionary_get_data_field(), vm_parse_word(), vm_pop(), and WORD_NAME_MAX.

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:



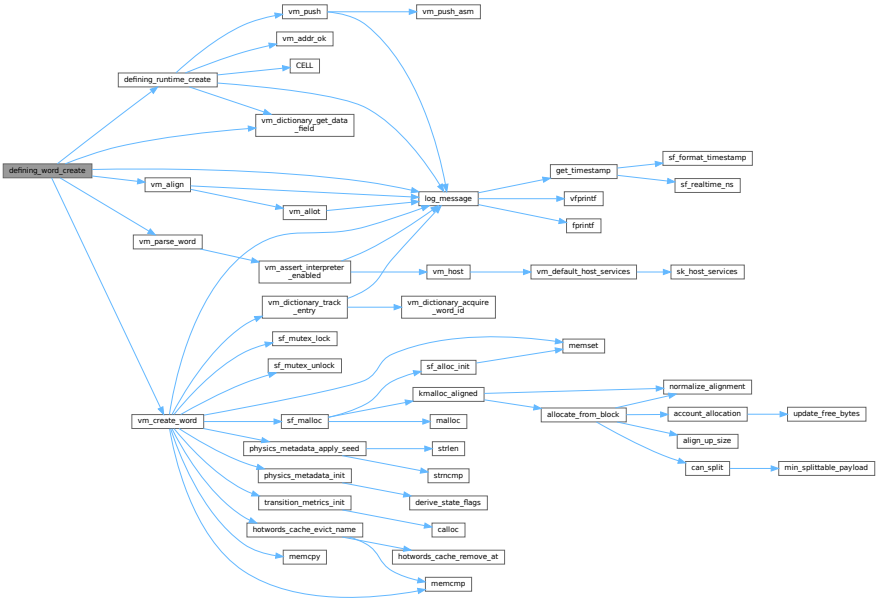
7.355.1.11 defining_word_create()

```
static void defining_word_create (
            VM * vm )  [static]
```

References defining_runtime_create(), entry, VM::error, VM::here, LOG_DEBUG, log_message(), vm_align(), vm_create_word(), vm_dictionary_get_data_field(), vm_parse_word(), and WORD_NAME_MAX.

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

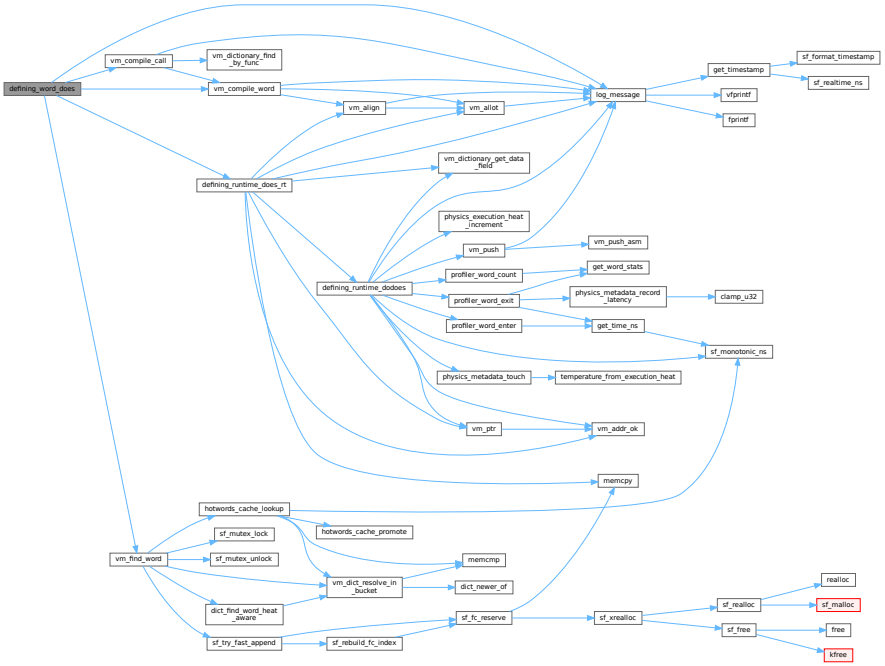
7.355.1.12 defining_word_does()

```
static void defining_word_does (
            VM * vm )  [static]
```

References defining_runtime_does_rt(), VM::error, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_compile_call(), vm_compile_word(), and vm_find_word().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

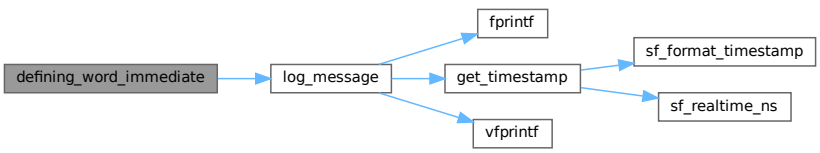
7.355.1.13 defining_word_immediate()

```
static void defining_word_immediate (
            VM * vm )  [static]
```

References VM::error, DictEntry::flags, VM::latest, LOG_DEBUG, log_message(), DictEntry::name, DictEntry::name_len, and WORD_IMMEDIATE.

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

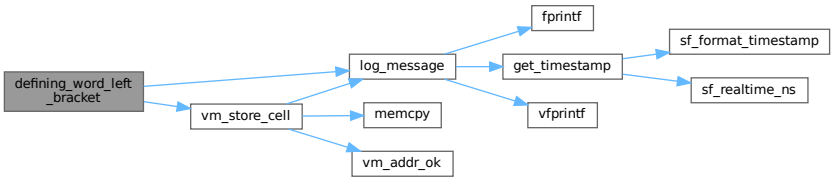
7.355.1.14 defining_word_left_bracket()

```
static void defining_word_left_bracket (
            VM * vm )  [static]
```

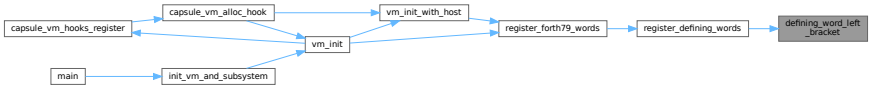
References LOG_DEBUG, log_message(), VM::mode, MODE_INTERPRET, VM::state_addr, and vm_store_cell().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:



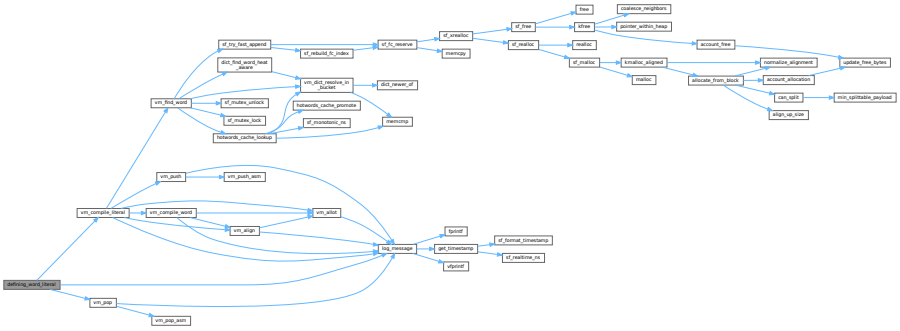
7.355.1.15 defining_word_literal()

```
static void defining_word_literal (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, log_message(), vm_compile_literal(), and vm_pop().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

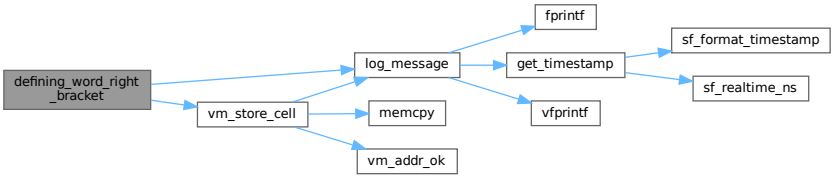
7.355.1.16 defining_word_right_bracket()

```
static void defining_word_right_bracket (
            VM * vm )  [static]
```

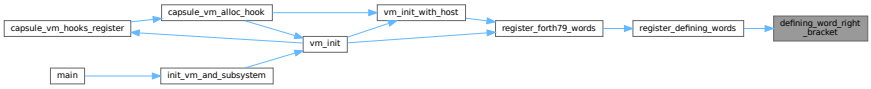
References LOG_DEBUG, log_message(), VM::mode, MODE_COMPILE, VM::state_addr, and vm_store_cell().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:



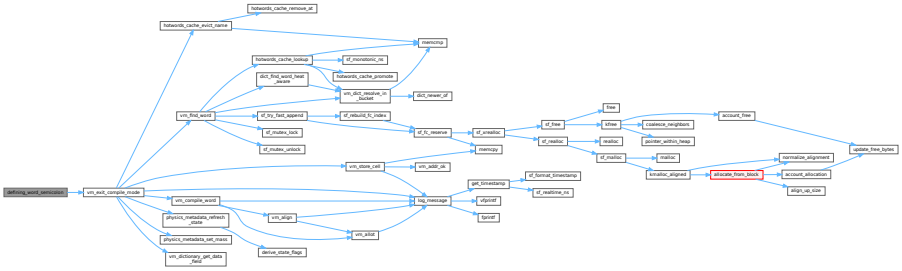
7.355.1.17 defining_word_semicolon()

```
static void defining_word_semicolon (
            VM * vm )  [static]
```

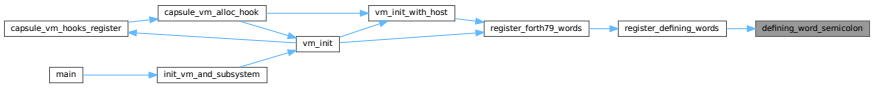
References VM::error, VM::mode, MODE_COMPILE, and vm_exit_compile_mode().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:



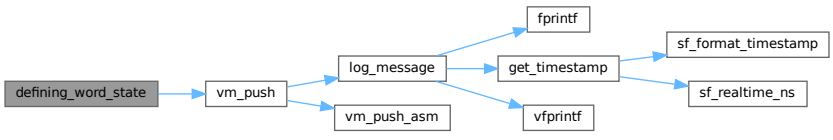
7.355.1.18 defining_word_state()

```
static void defining_word_state (
            VM * vm )  [static]
```

References VM::state_addr, and vm_push().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

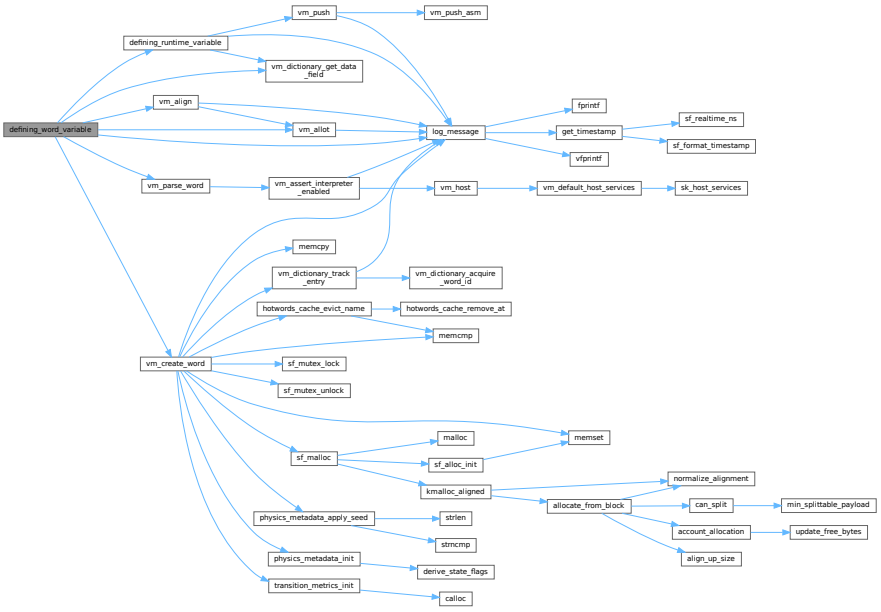
7.355.1.19 defining_word_variable()

```
static void defining_word_variable (
            VM * vm )  [static]
```

References defining_runtime_variable(), entry, VM::error, VM::here, LOG_DEBUG, log_message(), vm_align(), vm_allot(), vm_create_word(), vm_dictionary_get_data_field(), vm_parse_word(), and WORD_NAME_MAX.

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

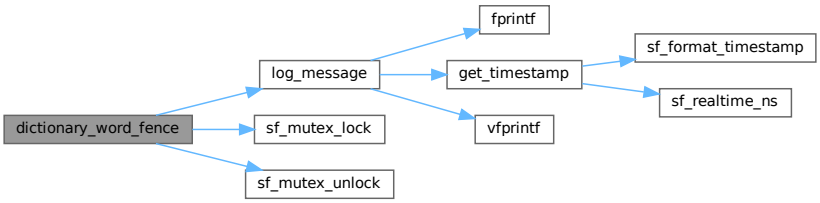
7.355.1.20 dictionary_word_fence()

```
static void dictionary_word_fence (
            VM * vm )  [static]
```

References VM::dict_fence_here, VM::dict_fence_latest, VM::dict_lock, VM::here, VM::latest, LOG_DEBUG, log_message(), sf_mutex_lock(), and sf_mutex_unlock().

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:

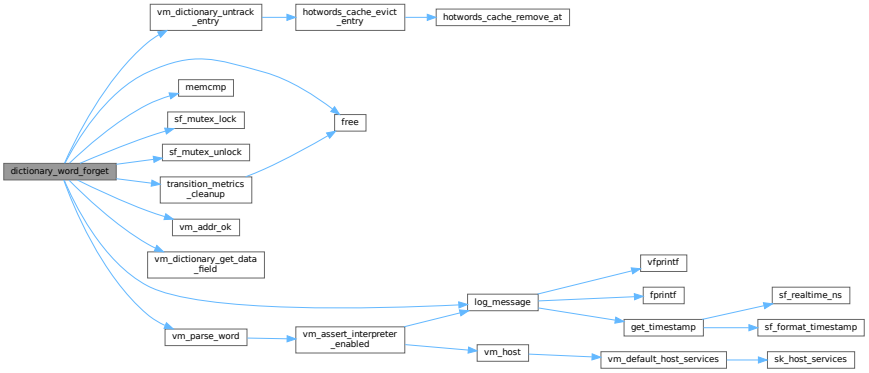
7.355.1.21 dictionary_word_forget()

```
static void dictionary_word_forget (
            VM * vm )  [static]
```

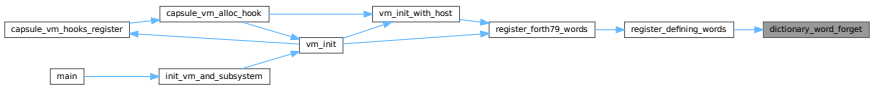
References VM::dict_fence_here, VM::dict_fence_latest, VM::dict_lock, VM::error, DictEntry::flags, free(), VM::here, VM::latest, DictEntry::link, LOG_DEBUG, log_message(), memcmp(), DictEntry::name, DictEntry::name_len, sf_mutex_lock(), sf_mutex_unlock(), DictEntry::transition_metrics, transition_metrics_cleanup(), vm_addr_ok(), vm_dictionary_get_data_field(), vm_dictionary_untrack_entry(), vm_parse_word(), WORD_HIDDEN, and WORD_NAME_MAX.

Referenced by register_defining_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.355.1.22 register_defining_words()

```
void register_defining_words (
            VM * vm )
```

Register all defining words in the dictionary.

Registers core defining words like :, ;, CREATE, CONSTANT, VARIABLE, and their support words like IMMEDIATE, STATE, etc.

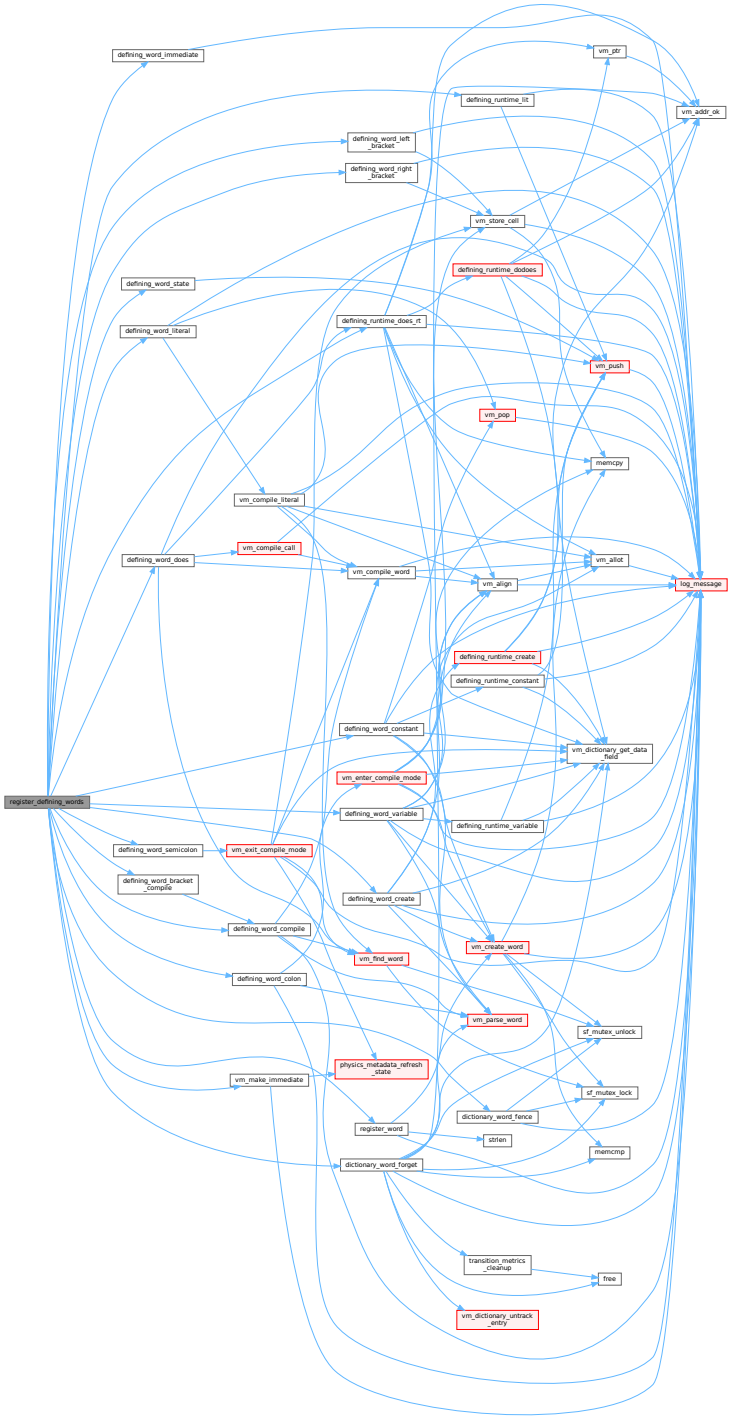
Parameters

vm	Pointer to the VM context

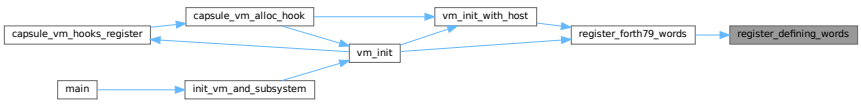
References defining_runtime_does_rt(), defining_runtime_lit(), defining_word_bracket_compile(), defining_word_colon(), defining_word_compile(), defining_word_constant(), defining_word_create(), defining_word_does(), defining_word_immediate(), defining_word_left_bracket(), defining_word_literal(), defining_word_right_bracket(), defining_word_semicolon(), defining_word_state(), defining_word_variable(), dictionary_word_fence(), dictionary_word_forget(), register_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



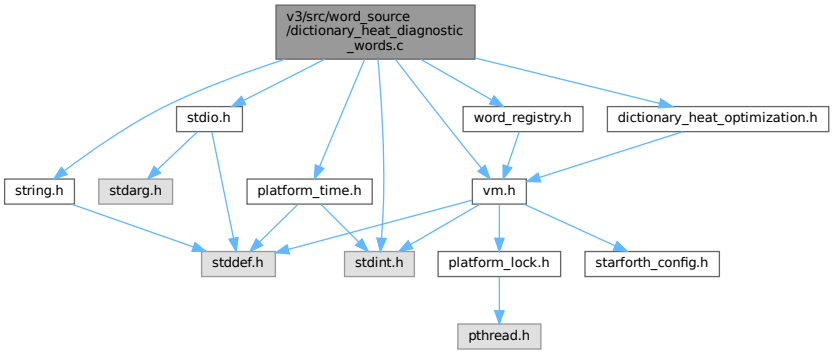
Here is the caller graph for this function:



7.356 v3/src/word_source/dictionary_heat_diagnostic_words.c File Reference

```
#include <stdio.h>
#include <stdint.h>
#include <string.h>
#include "vm.h"
#include "word_registry.h"
#include "platform_time.h"
#include "dictionary_heat_optimization.h"
```

Include dependency graph for dictionary_heat_diagnostic_words.c:



Functions

- void forth_HEAT_PERCENTILES (VM *vm)

  HEAT-PERCENTILES (– 25th 50th 75th)
- void forth_LOOKUP_STRATEGY_FETCH (VM *vm)

  LOOKUP-STRATEGY@ (– strategy)
- void forth_LOOKUP_STRATEGY_STORE (VM *vm)

  LOOKUP-STRATEGY! (strategy –)
- void forth_REORG_BUCKETS (VM *vm)

  REORG-BUCKETS (–)
- void forth_SHOW_HEAT_OPTIMIZATION (VM *vm)

  SHOW-HEAT-OPTIMIZATION (–)
- void forth_COMPARE_LOOKUPS (VM *vm)

  COMPARE-LOOKUPS (iterations –)
- void register_dictionary_heat_diagnostic_words (VM *vm)

  Register all dictionary heat diagnostic words with the VM dictionary.

7.356.1 Function Documentation

7.356.1.1 forth_COMPARE_LOOKUPS()

```
void forth_COMPARE_LOOKUPS (
            VM * vm )
```

COMPARE-LOOKUPS (iterations –)

Micro-benchmark that measures naive vs heat-aware dictionary lookup performance over `iterations` passes through six common test words (DUP, DROP, SWAP, @, !, EMIT). Prints elapsed time in milliseconds and the percentage speedup (or slowdown) for heat-aware vs naive. Restores the original `vm->lookup_strategy` on completion. Intended for interactive diagnostics; not used in DoE mode.

Stack effect: (iterations –)

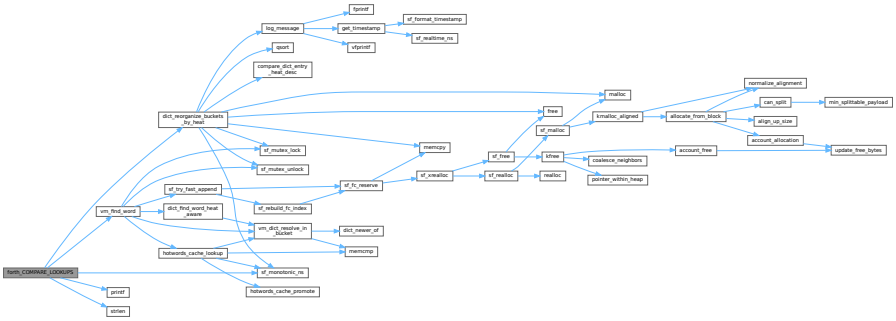
Parameters

vm	Active VM; sets `vm->error` = 1 on underflow or non-positive `iterations`

References VM::data_stack, dict_reorganize_buckets_by_heat(), VM::dsp, VM::error, VM::lookup_strategy, printf(), sf_monotonic_ns(), strlen(), and vm_find_word().

Referenced by register_dictionary_heat_diagnostic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.356.1.2 forth_HEAT_PERCENTILES()

```
void forth_HEAT_PERCENTILES (
            VM * vm )
```

HEAT-PERCENTILES (– 25th 50th 75th)

Pushes the three heat percentile thresholds currently used by the heat-aware dictionary lookup strategy: `heat_threshold_25th`, `heat_threshold_50th`, and `heat_threshold_75th`. These are updated by `dict_update_heat_percentiles()` during bucket reorganisation.

Stack effect: (– 25th 50th 75th) TOS = 75th

Parameters

vm	Active VM; sets `vm->error` = 1 on stack overflow

References VM::data_stack, VM::dsp, VM::error, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, and STACK_SIZE.

Referenced by register_dictionary_heat_diagnostic_words().

Here is the caller graph for this function:

7.356.1.3 forth_LOOKUP_STRATEGY_FETCH()

```
void forth_LOOKUP_STRATEGY_FETCH (
            VM * vm )
```

LOOKUP-STRATEGY@ (– strategy)

Pushes the current dictionary lookup strategy: 0 = naive (newest-first linear scan), 1 = heat-aware (hot-bucket-first).

Stack effect: (– strategy)

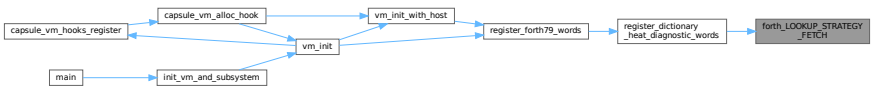
Parameters

vm	Active VM; sets `vm->error` = 1 on stack overflow

References VM::data_stack, VM::dsp, VM::error, VM::lookup_strategy, and STACK_SIZE.

Referenced by register_dictionary_heat_diagnostic_words().

Here is the caller graph for this function:



7.356.1.4 forth_LOOKUP_STRATEGY_STORE()

```
void forth_LOOKUP_STRATEGY_STORE (
            VM * vm )
```

LOOKUP-STRATEGY! (strategy –)

Sets `vm->lookup_strategy` to `strategy`. Only values 0 (naive) and 1 (heat-aware) are accepted; out-of-range values are silently discarded.

Stack effect: (strategy –)

Parameters

vm	Active VM; sets `vm->error` = 1 on stack underflow

References VM::data_stack, VM::dsp, VM::error, and VM::lookup_strategy.

Referenced by register_dictionary_heat_diagnostic_words().

Here is the caller graph for this function:

7.356.1.5 forth_REORG_BUCKETS()

```
void forth_REORG_BUCKETS (
            VM * vm )
```

REORG-BUCKETS (–)

Immediately triggers `dict_reorganize_buckets_by_heat()` followed by `dict_update_heat_percentiles()` to re-sort the dictionary's lookup buckets by current execution heat and refresh the percentile thresholds. Normally this happens automatically on a heartbeat cycle; this word forces it on-demand for testing or after a large batch of `HEAT!` assignments.

Stack effect: (–)

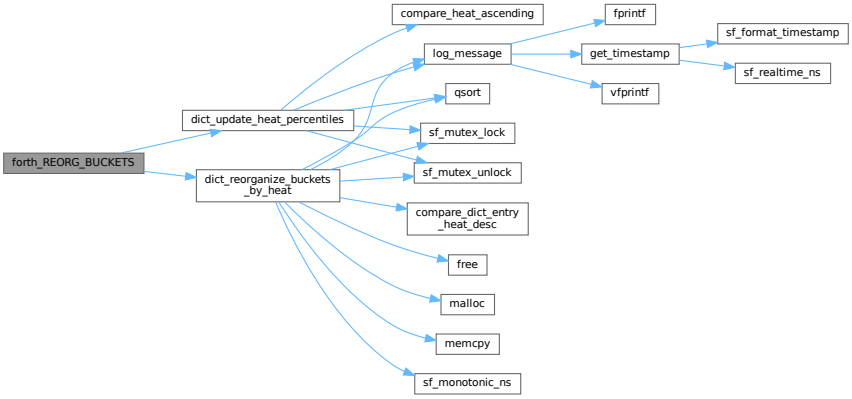
Parameters

vm	Active VM; no-op if `vm->error` is set

References dict_reorganize_buckets_by_heat(), dict_update_heat_percentiles(), and VM::error.

Referenced by register_dictionary_heat_diagnostic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.356.1.6 forth_SHOW_HEAT_OPTIMIZATION()

```
void forth_SHOW_HEAT_OPTIMIZATION (
            VM * vm )
```

SHOW-HEAT-OPTIMIZATION (–)

Prints a summary of the current dictionary heat optimization state to `stdout`: the active lookup strategy (naive or heat-aware), the three percentile threshold values, and the resulting hot/warm/cool heat zones. Intended for interactive diagnostics.

Stack effect: (–)

Parameters

vm	Active VM; no-op if `vm->error` is set

References VM::error, VM::heat_threshold_25th, VM::heat_threshold_50th, VM::heat_threshold_75th, VM::lookup_strategy, and printf().

Referenced by register_dictionary_heat_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:

7.356.1.7 register_dictionary_heat_diagnostic_words()

```
void register_dictionary_heat_diagnostic_words (
            VM * vm )
```

Register all dictionary heat diagnostic words with the VM dictionary.

Register all dictionary heat diagnostic words with the VM.

Registers: `HEAT-PERCENTILES`, `LOOKUP-STRATEGY@`, `LOOKUP-STRATEGY!`, `REORG-BUCKETS`, `SHOW-HEAT-OPTIMIZATION`, `COMPARE-LOOKUPS`. Called during VM bootstrap.

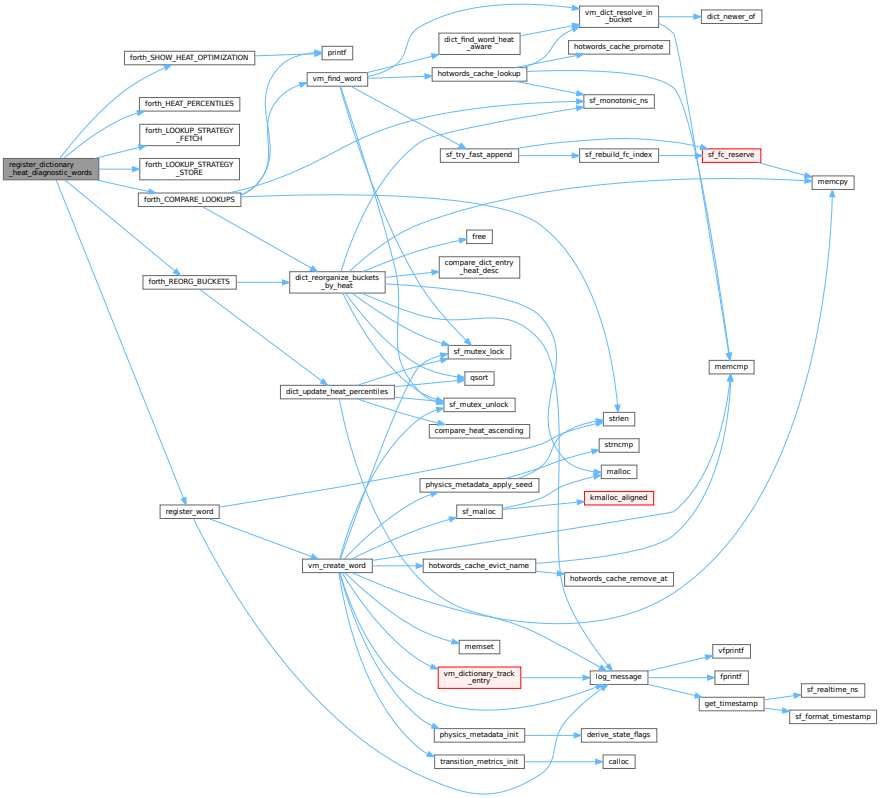
Parameters

vm	Active VM to register words into

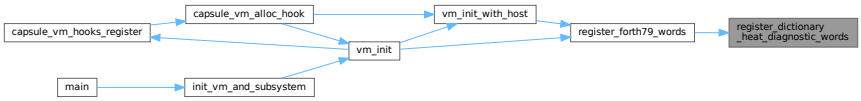
References forth_COMPARE_LOOKUPS(), forth_HEAT_PERCENTILES(), forth_LOOKUP_STRATEGY_FETCH(), forth_LOOKUP_STRATEGY_STORE(), forth_REORG_BUCKETS(), forth_SHOW_HEAT_OPTIMIZATION(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



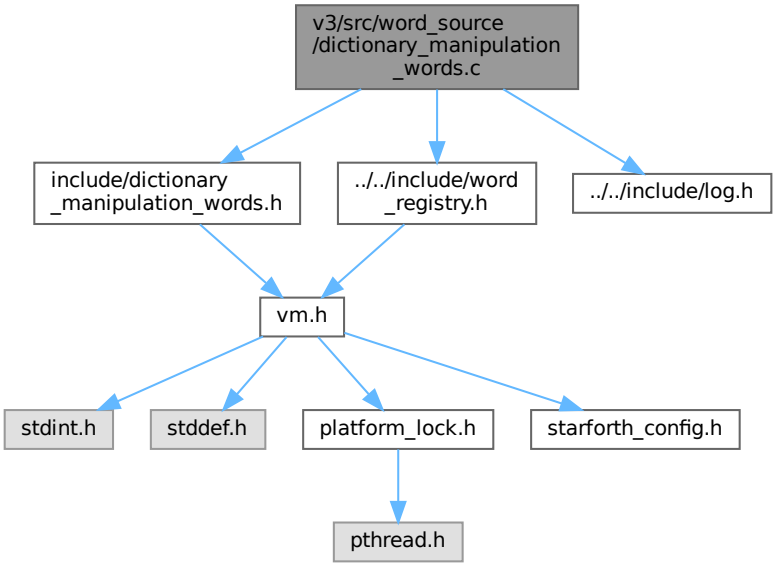
Here is the caller graph for this function:



7.357 v3/src/word_source/dictionary_manipulation_words.c File Reference

```
#include "include/dictionary_manipulation_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
```

Include dependency graph for dictionary_manipulation_words.c:



Functions

- static uintptr_t align_address (uintptr_t addr)
- static char * get_name_field (DictEntry *entry)
- static void * get_body_address (DictEntry *entry)
- static DictEntry * find_entry_from_name (VM *vm, char *name_field)
- static char * traverse_name_field (char *name_addr, int direction)
- static void dictionary_m_word_smudge (VM *vm)

  FORTH word SMUDGE - Toggle smudge bit of latest word.
- void dictionary_m_word_to_body (VM *vm)
- void dictionary_m_word_to_name (VM *vm)
- void dictionary_m_word_name_to (VM *vm)
- void dictionary_m_word_to_link (VM *vm)
- void dictionary_m_word_link_from (VM *vm)
- void dictionary_m_word_cfa (VM *vm)
- void dictionary_m_word_lfa (VM *vm)
- void dictionary_m_word_nfa (VM *vm)
- void dictionary_m_word_pfa (VM *vm)
- void dictionary_m_word_traverse (VM *vm)
- void dictionary_m_word_interpret (VM *vm)
- static void dictionary_m_word_find (VM *vm)
- static void dictionary_m_word_tick (VM *vm)
- static void dictionary_m_word_hidden (VM *vm)
- void register_dictionary_manipulation_words (VM *vm)

  Register all dictionary manipulation words with the virtual machine.

Variables

- static cell_t state_variable = 0

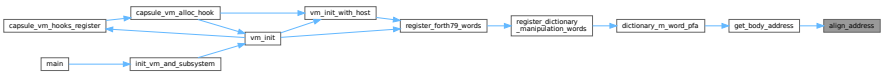
7.357.1 Function Documentation

7.357.1.1 align_address()

```
static uintptr_t align_address (
            uintptr_t addr )  [static]
```

Referenced by get_body_address().

Here is the caller graph for this function:



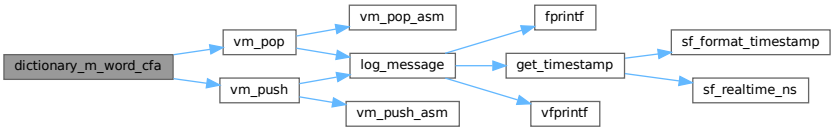
7.357.1.2 dictionary_m_word_cfa()

```
void dictionary_m_word_cfa (
            VM * vm )
```

References VM::dsp, entry, VM::error, vm_pop(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

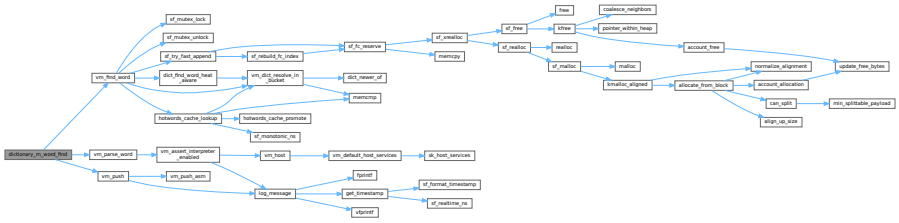
7.357.1.3 dictionary_m_word_find()

```
static void dictionary_m_word_find (
            VM * vm )  [static]
```

References VM::error, vm_find_word(), vm_parse_word(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

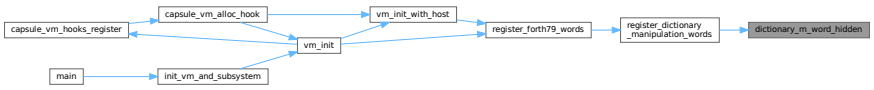
7.357.1.4 dictionary_m_word_hidden()

```
static void dictionary_m_word_hidden (
            VM * vm )  [static]
```

References VM::error, DictEntry::flags, VM::latest, VM::mode, MODE_COMPILE, WORD_HIDDEN, and WORD_SMUDGED.

Referenced by register_dictionary_manipulation_words().

Here is the caller graph for this function:



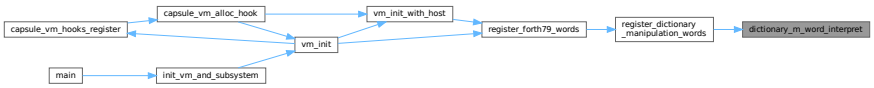
7.357.1.5 dictionary_m_word_interpret()

```
void dictionary_m_word_interpret (
            VM * vm )
```

References VM::mode, MODE_INTERPRET, and state_variable.

Referenced by register_dictionary_manipulation_words().

Here is the caller graph for this function:



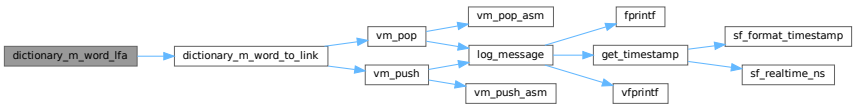
7.357.1.6 dictionary_m_word_lfa()

```
void dictionary_m_word_lfa (
            VM * vm )
```

References dictionary_m_word_to_link().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

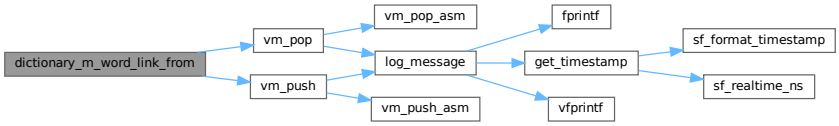
7.357.1.7 dictionary_m_word_link_from()

```
void dictionary_m_word_link_from (
            VM * vm )
```

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

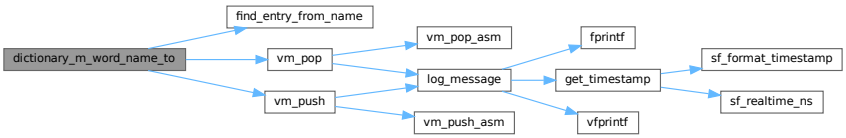
7.357.1.8 dictionary_m_word_name_to()

```
void dictionary_m_word_name_to (
            VM * vm )
```

References VM::dsp, entry, VM::error, find_entry_from_name(), vm_pop(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

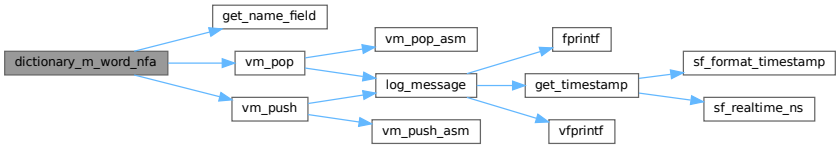
7.357.1.9 dictionary_m_word_nfa()

```
void dictionary_m_word_nfa (
            VM * vm )
```

References VM::dsp, entry, VM::error, get_name_field(), vm_pop(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

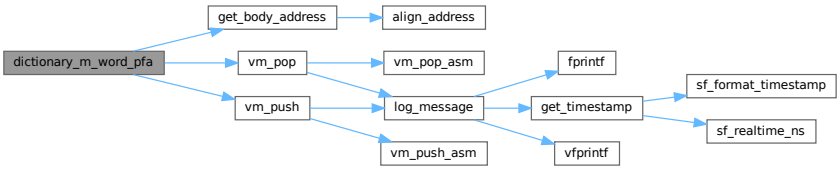
7.357.1.10 dictionary_m_word_pfa()

```
void dictionary_m_word_pfa (
            VM * vm )
```

References VM::dsp, entry, VM::error, get_body_address(), vm_pop(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.357.1.11 dictionary_m_word_smudge()

```
static void dictionary_m_word_smudge (
            VM * vm )  [static]
```

FORTH word SMUDGE - Toggle smudge bit of latest word.

Parameters

vm	Pointer to VM instance @stack (–)

Note

Compile-only word

References VM::error, VM::mode, and MODE_COMPILE.

Referenced by register_dictionary_manipulation_words().

Here is the caller graph for this function:

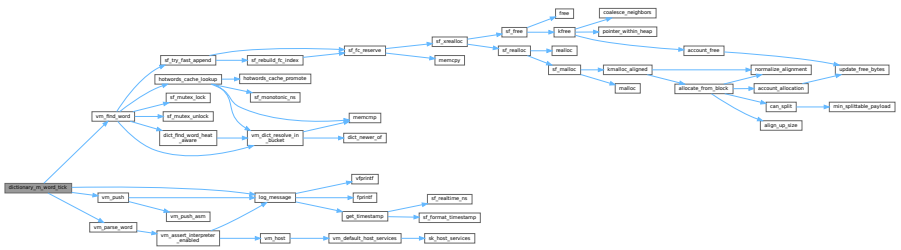
7.357.1.12 dictionary_m_word_tick()

```
static void dictionary_m_word_tick (
            VM * vm )  [static]
```

References VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_find_word(), vm_parse_word(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

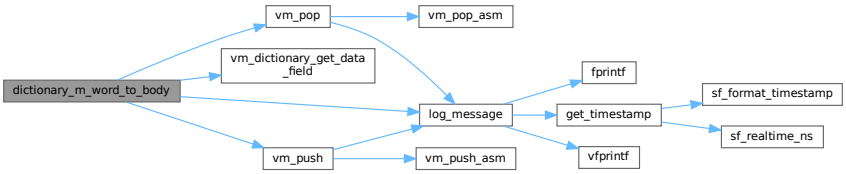
7.357.1.13 dictionary_m_word_to_body()

```
void dictionary_m_word_to_body (
            VM * vm )
```

References VM::dsp, entry, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_dictionary_get_data_field(), vm_pop(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

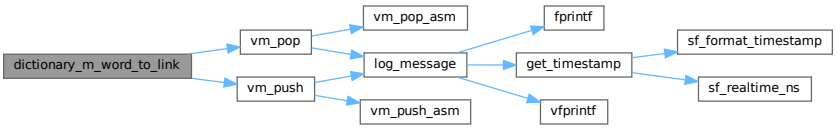
7.357.1.14 dictionary_m_word_to_link()

```
void dictionary_m_word_to_link (
            VM * vm )
```

References VM::dsp, entry, VM::error, vm_pop(), and vm_push().

Referenced by dictionary_m_word_lfa(), and register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

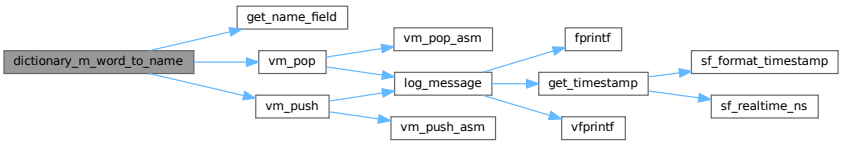
7.357.1.15 dictionary_m_word_to_name()

```
void dictionary_m_word_to_name (
            VM * vm )
```

References VM::dsp, entry, VM::error, get_name_field(), vm_pop(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

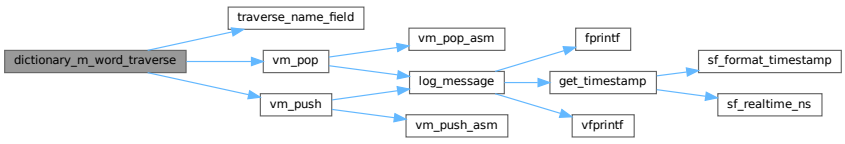
7.357.1.16 dictionary_m_word_traverse()

```
void dictionary_m_word_traverse (
            VM * vm )
```

References VM::dsp, VM::error, traverse_name_field(), vm_pop(), and vm_push().

Referenced by register_dictionary_manipulation_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.357.1.17 find_entry_from_name()

```
static DictEntry * find_entry_from_name (
            VM * vm,
            char * name_field )  [static]
```

References entry, VM::latest, and DictEntry::link.

Referenced by dictionary_m_word_name_to().

Here is the caller graph for this function:

7.357.1.18 get_body_address()

```
static void * get_body_address (
            DictEntry * entry )  [static]
```

References align_address(), and entry.

Referenced by dictionary_m_word_pfa().

Here is the call graph for this function:

Here is the caller graph for this function:

7.357.1.19 get_name_field()

```
static char * get_name_field (
            DictEntry * entry )  [static]
```

References entry.

Referenced by dictionary_m_word_nfa(), and dictionary_m_word_to_name().

Here is the caller graph for this function:

7.357.1.20 register_dictionary_manipulation_words()

```
void register_dictionary_manipulation_words (
            VM * vm )
```

Register all dictionary manipulation words with the virtual machine.

Parameters

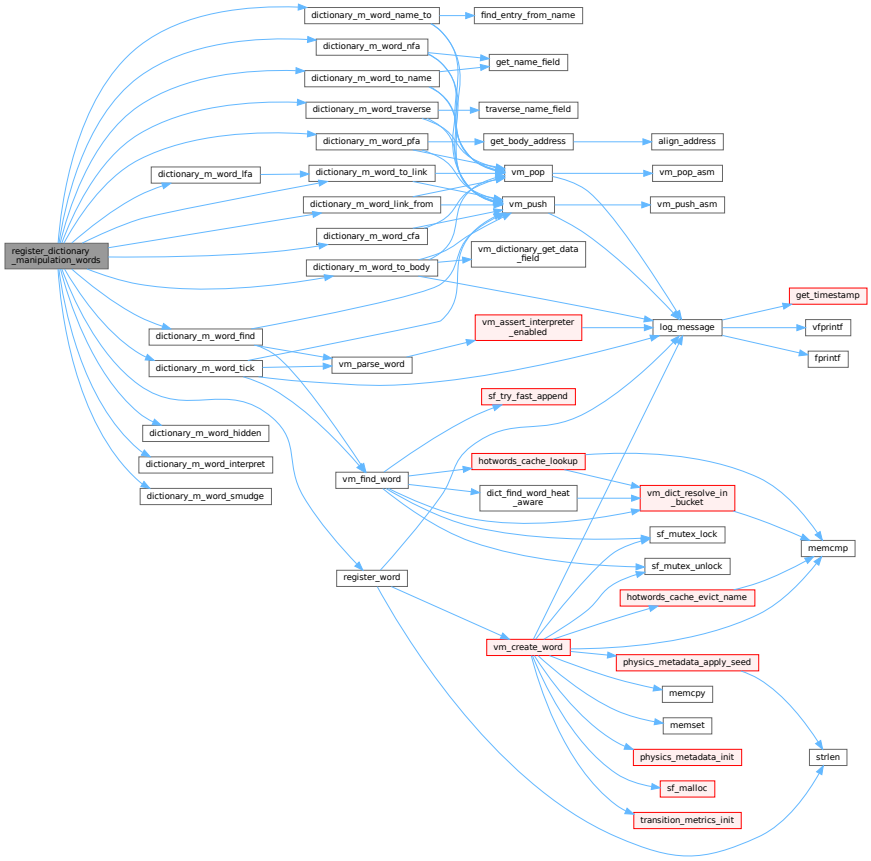
vm	Pointer to the virtual machine instance

This function registers all FORTH-79 standard dictionary manipulation words with the provided virtual machine instance. These words are essential for dictionary management and word definition functionality.

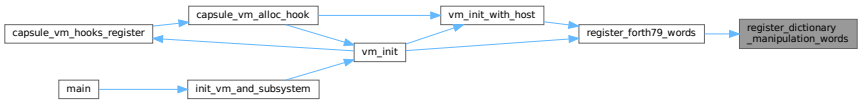
References dictionary_m_word_cfa(), dictionary_m_word_find(), dictionary_m_word_hidden(), dictionary_m_word_interpret(), dictionary_m_word_lfa(), dictionary_m_word_link_from(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_smudge(), dictionary_m_word_tick(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), dictionary_m_word_traverse(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.357.1.21 traverse_name_field()

```
static char * traverse_name_field (
            char * name_addr,
            int direction )  [static]
```

References name_len.

Referenced by dictionary_m_word_traverse().

Here is the caller graph for this function:

7.357.2 Variable Documentation

7.357.2.1 state_variable

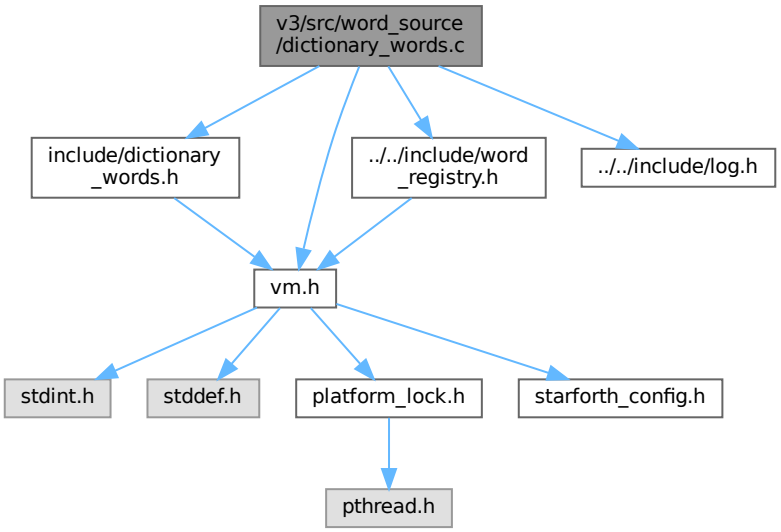
```
cell_t state_variable = 0  [static]
```

Referenced by dictionary_m_word_interpret().

7.358 v3/src/word_source/dictionary_words.c File Reference

```
#include "include/dictionary_words.h"
#include "../../include/word_registry.h"
#include "vm.h"
#include "../../include/log.h"
```

Include dependency graph for dictionary_words.c:



Functions

- void dictionary_word_here (VM *vm)

  HERE (– addr) Returns the dictionary pointer.
- static void dictionary_word_align (VM *vm)
- void dictionary_word_allot (VM *vm)

  ALLOT (n –) Allocate n bytes in dictionary.
- void dictionary_word_comma (VM *vm)

  , (n –) Compile cell into dictionary
- void dictionary_word_c_comma (VM *vm)

  C, (c –) Compile byte into dictionary.
- void dictionary_word_2comma (VM *vm)

2, (d –) Compile double-cell into dictionary

- void dictionary_word_pad (VM *vm)

  PAD (– addr) Get scratch pad buffer address.

- void dictionary_word_sp_fetch (VM *vm)

  SP@ (– sp) Get current stack pointer.

- void dictionary_word_sp_store (VM *vm)

  SP! (sp –) Set stack pointer.

- void dictionary_word_latest (VM *vm)

  LATEST (– addr) Get latest definition address.

- void register_dictionary_words (VM *vm)

  Registers all dictionary and compilation words with the Forth VM.

7.358.1 Function Documentation

7.358.1.1 dictionary_word_2comma()

```
void dictionary_word_2comma (
            VM * vm )
```

2, (d –) Compile double-cell into dictionary

Parameters

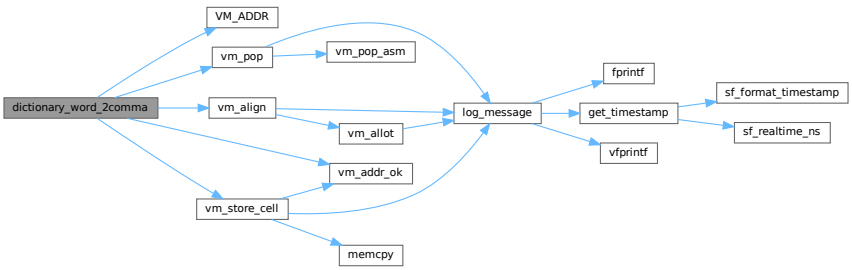
vm	Pointer to the VM structure

Compiles a double cell value into the dictionary at HERE, low cell first

References DICTIONARY_MEMORY_SIZE, VM::dsp, VM::error, VM::here, VM_ADDR(), vm_addr_ok(), vm_align(), vm_pop(), and vm_store_cell().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

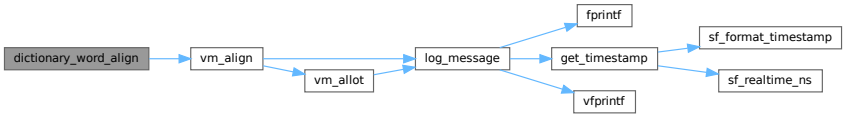
7.358.1.2 dictionary_word_align()

```
static void dictionary_word_align (
            VM * vm )  [static]
```

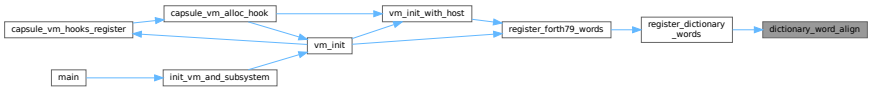
References vm_align().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.358.1.3 dictionary_word_allot()

```
void dictionary_word_allot (
            VM * vm )
```

ALLOT (n –) Allocate n bytes in dictionary.

Parameters

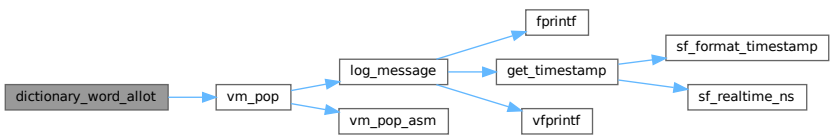
vm	Pointer to the VM structure

Allocates n bytes in the dictionary. n can be negative to deallocate space

References DICTIONARY_MEMORY_SIZE, VM::dsp, VM::error, VM::here, and vm_pop().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.358.1.4 dictionary_word_c_comma()

```
void dictionary_word_c_comma (
            VM * vm )
```

C, (c –) Compile byte into dictionary.

Parameters

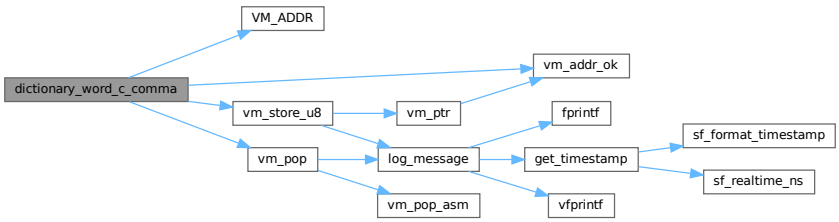
vm	Pointer to the VM structure

Compiles a single byte value into the dictionary at HERE

References DICTIONARY_MEMORY_SIZE, VM::dsp, VM::error, VM::here, VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_store_u8().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.358.1.5 dictionary_word_comma()

```
void dictionary_word_comma (
            VM * vm )
```

, (n –) Compile cell into dictionary

Parameters

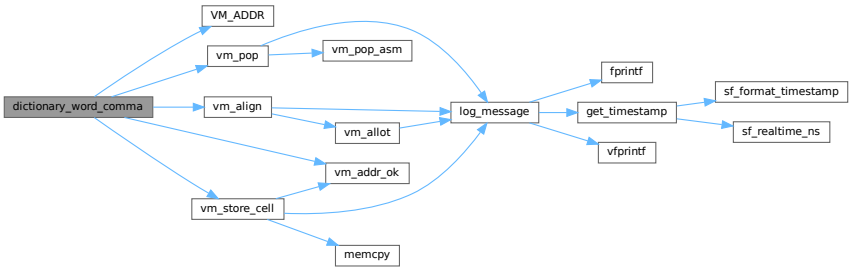
vm	Pointer to the VM structure

Compiles a single cell value into the dictionary at HERE

References DICTIONARY_MEMORY_SIZE, VM::dsp, VM::error, VM::here, VM_ADDR(), vm_addr_ok(), vm_align(), vm_pop(), and vm_store_cell().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.358.1.6 dictionary_word_here()

```
void dictionary_word_here (
            VM * vm )
```

HERE (– addr) Returns the dictionary pointer.

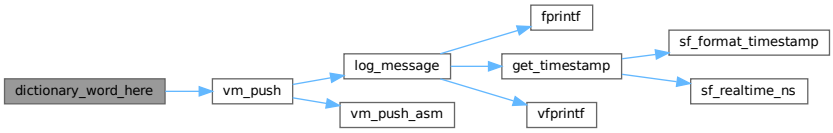
Parameters

vm	Pointer to the VM structure

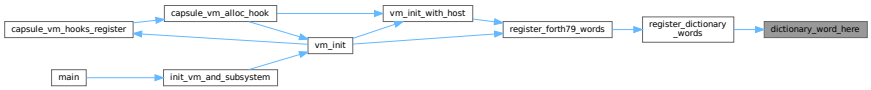
References VM::here, and vm_push().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.358.1.7 dictionary_word_latest()

```
void dictionary_word_latest (
            VM * vm )
```

LATEST (– addr) Get latest definition address.

Parameters

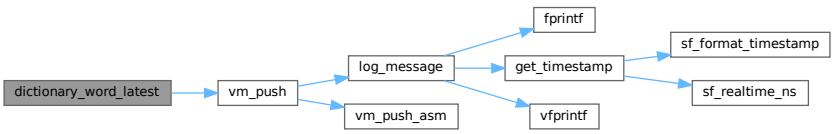
vm	Pointer to the VM structure

Returns VM address near most recent compiled definition (end of dictionary)

References VM::here, and vm_push().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.358.1.8 dictionary_word_pad()

```
void dictionary_word_pad (
            VM * vm )
```

PAD (– addr) Get scratch pad buffer address.

Parameters

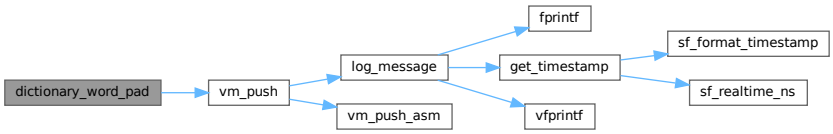
vm	Pointer to the VM structure

Returns VM address of 512-byte temporary text buffer at top of memory

References VM_MEMORY_SIZE, and vm_push().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.358.1.9 dictionary_word_sp_fetch()

```
void dictionary_word_sp_fetch (
            VM * vm )
```

SP@ (– sp) Get current stack pointer.

Parameters

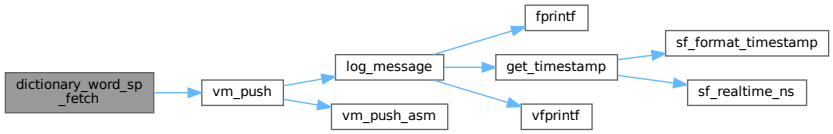
vm	Pointer to the VM structure

Returns the current stack-pointer index (top is 0)

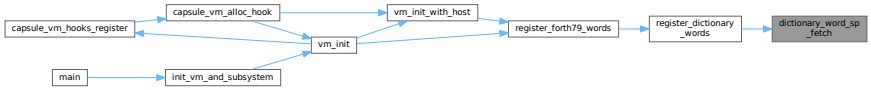
References VM::dsp, and vm_push().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.358.1.10 dictionary_word_sp_store()

```
void dictionary_word_sp_store (
            VM * vm )
```

SP! (sp –) Set stack pointer.

Parameters

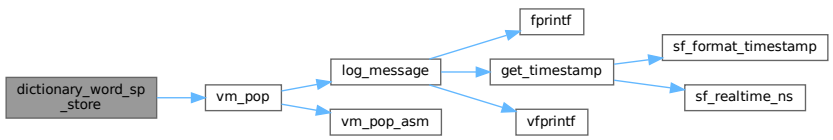
vm	Pointer to the VM structure

Restores the stack-pointer, but never allows growing the stack

References VM::dsp, VM::error, and vm_pop().

Referenced by register_dictionary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.358.1.11 register_dictionary_words()

```
void register_dictionary_words (
            VM * vm )
```

Registers all dictionary and compilation words with the Forth VM.

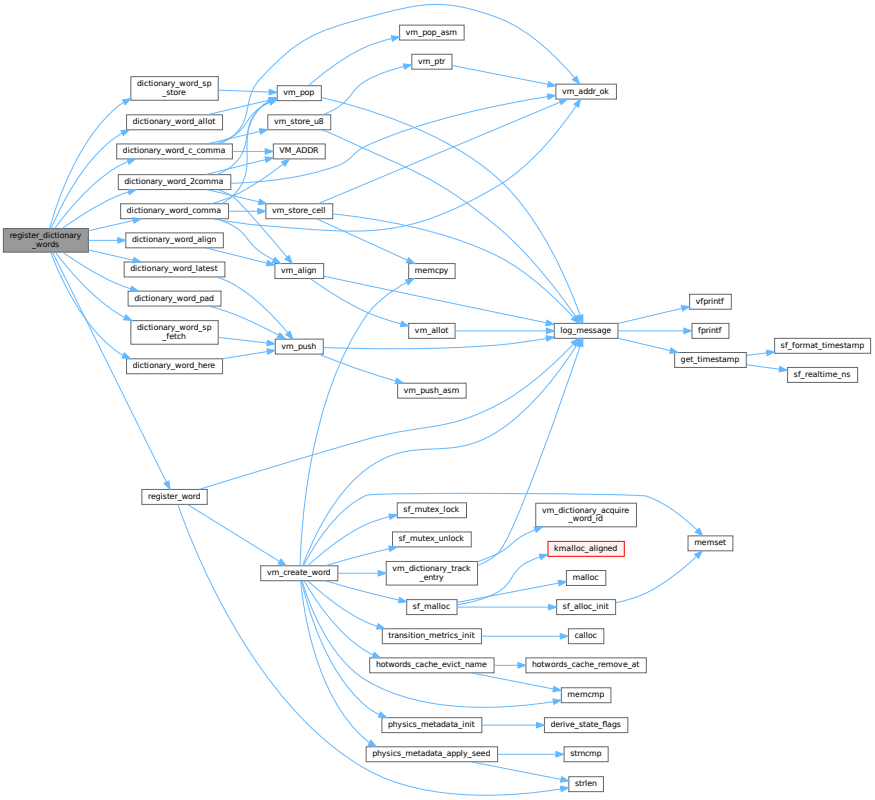
Parameters

vm	Pointer to the Forth virtual machine instance

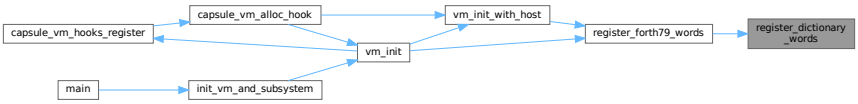
References dictionary_word_2comma(), dictionary_word_align(), dictionary_word_allot(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_here(), dictionary_word_latest(), dictionary_word_pad(), dictionary_word_sp_fetch(), dictionary_word_sp_store(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



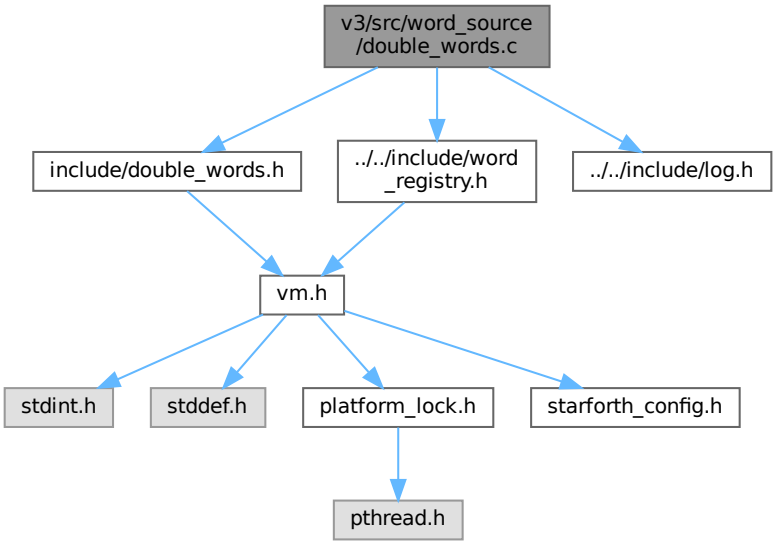
Here is the caller graph for this function:



7.359 v3/src/word_source/double_words.c File Reference

```
#include "include/double_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
```

Include dependency graph for double_words.c:



Functions

- void double_word_s_to_d (VM *vm)

  Convert single number to double (n – d)
- void double_word_d_plus (VM *vm)
- void double_word_d_minus (VM *vm)
- void double_word_dnegate (VM *vm)
- void double_word_dabs (VM *vm)
- static int d_compare (cell_t d1h, cell_t d1l, cell_t d2h, cell_t d2l)

  Compare two double numbers.
- void double_word_dmax (VM *vm)
- void double_word_dmin (VM *vm)
- void double_word_d_less (VM *vm)

- void double_word_d_equals (VM *vm)
- void double_word_2drop (VM *vm)
- void double_word_2dup (VM *vm)
- void double_word_2swap (VM *vm)
- void double_word_2over (VM *vm)
- void double_word_2rot (VM *vm)
- void double_word_2to_r (VM *vm)
- void double_word_2r_from (VM *vm)
- void double_word_2r_fetch (VM *vm)
- void double_word_d_zero_equals (VM *vm)
- void double_word_d_zero_less (VM *vm)
- void double_word_d_two_star (VM *vm)
- void double_word_d_two_slash (VM *vm)
- void register_double_words (VM *vm)

  Register all double number words.

7.359.1 Function Documentation

7.359.1.1 d_compare()

```
static int d_compare (
            cell_t d1h,
            cell_t d1l,
            cell_t d2h,
            cell_t d2l )  [static]
```

Compare two double numbers.

Parameters

d1h	High cell of first double number
d1l	Low cell of first double number
d2h	High cell of second double number
d2l	Low cell of second double number

Returns

int -1 if d1<d2, 0 if d1=d2, 1 if d1>d2

Referenced by double_word_d_equals(), double_word_d_less(), double_word_dmax(), and double_word_dmin().

Here is the caller graph for this function:

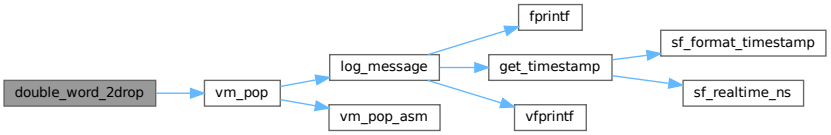
7.359.1.2 double_word_2drop()

```
void double_word_2drop (
            VM * vm )
```

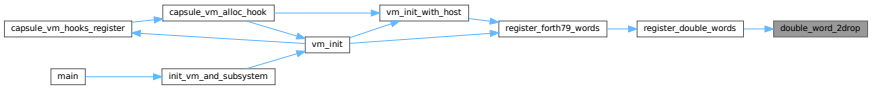
References VM::dsp, VM::error, and vm_pop().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



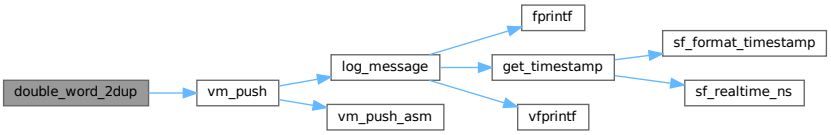
7.359.1.3 double_word_2dup()

```
void double_word_2dup (
            VM * vm )
```

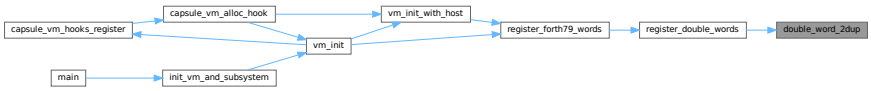
References VM::data_stack, VM::dsp, VM::error, and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



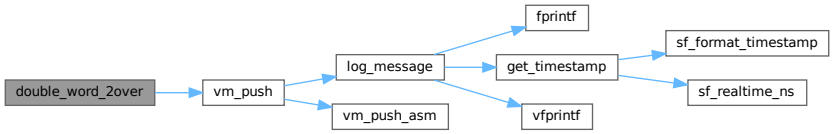
7.359.1.4 double_word_2over()

```
void double_word_2over (
            VM * vm )
```

References VM::data_stack, VM::dsp, VM::error, and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

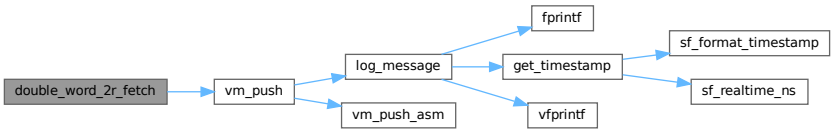
7.359.1.5 double_word_2r_fetch()

```
void double_word_2r_fetch (
            VM * vm )
```

References VM::ecw_nesting, VM::error, VM::return_stack, VM::rsp, and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

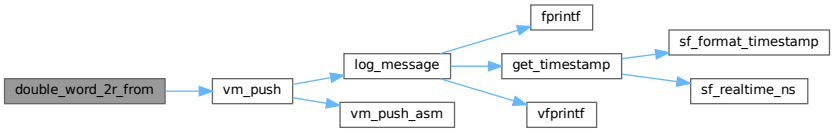
7.359.1.6 double_word_2r_from()

```
void double_word_2r_from (
            VM * vm )
```

References VM::ecw_nesting, VM::error, VM::return_stack, VM::rsp, and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

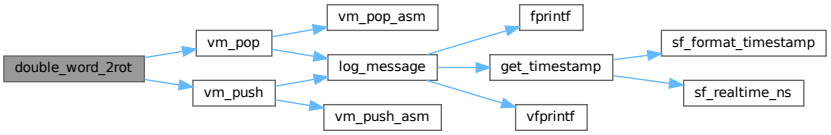
7.359.1.7 double_word_2rot()

```
void double_word_2rot (
            VM * vm )
```

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

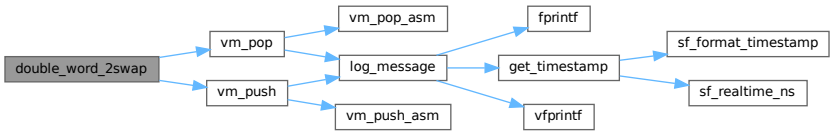
7.359.1.8 double_word_2swap()

```
void double_word_2swap (
            VM * vm )
```

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

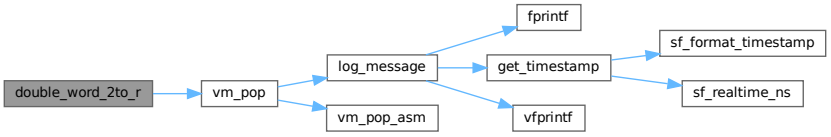
7.359.1.9 double_word_2to_r()

```
void double_word_2to_r (
            VM * vm )
```

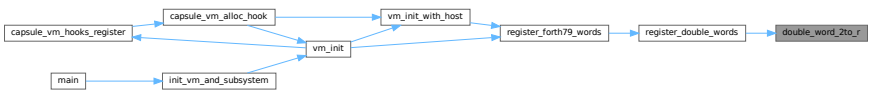
References VM::dsp, VM::ecw_nesting, VM::error, VM::return_stack, VM::rsp, STACK_SIZE, and vm_pop().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



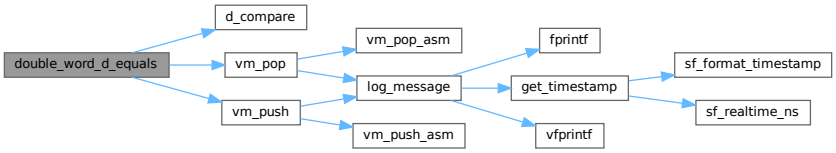
7.359.1.10 double_word_d_equals()

```
void double_word_d_equals (
            VM * vm )
```

References d_compare(), VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

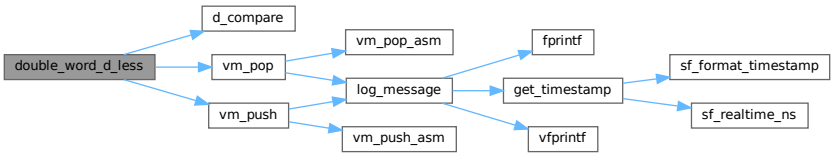
7.359.1.11 double_word_d_less()

```
void double_word_d_less (
            VM * vm )
```

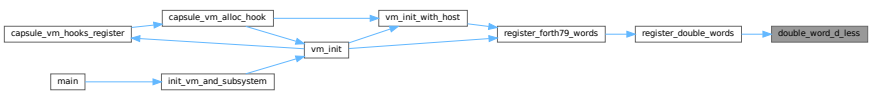
References d_compare(), VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



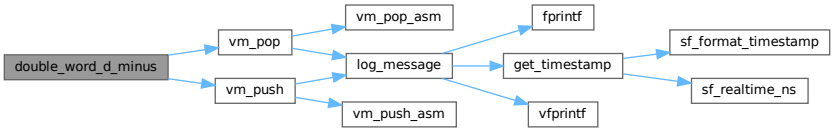
7.359.1.12 double_word_d_minus()

```
void double_word_d_minus (
            VM * vm )
```

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

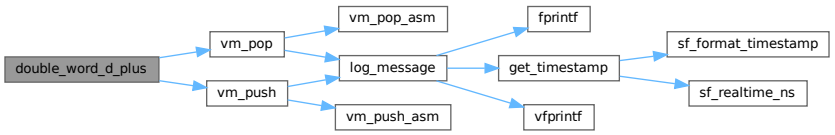
7.359.1.13 double_word_d_plus()

```
void double_word_d_plus (
            VM * vm )
```

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

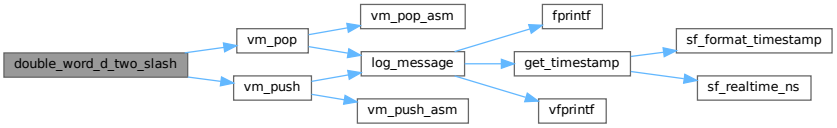
7.359.1.14 double_word_d_two_slash()

```
void double_word_d_two_slash (
            VM * vm )
```

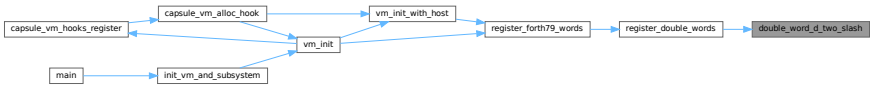
References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



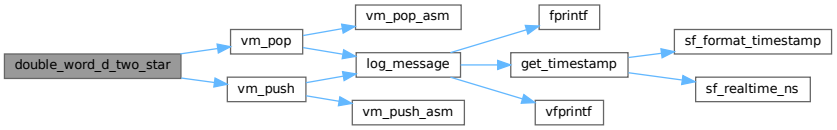
7.359.1.15 double_word_d_two_star()

```
void double_word_d_two_star (
            VM * vm )
```

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

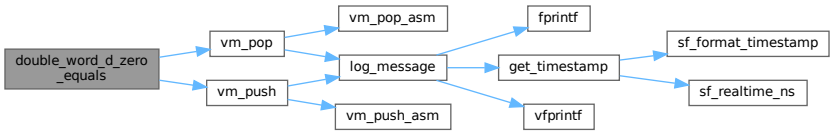
7.359.1.16 double_word_d_zero_equals()

```
void double_word_d_zero_equals (
            VM * vm )
```

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

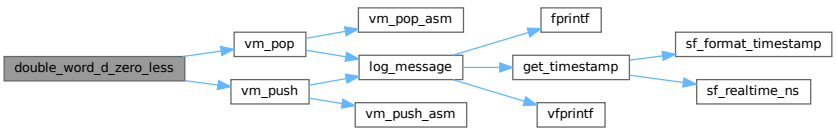
7.359.1.17 double_word_d_zero_less()

```
void double_word_d_zero_less (
            VM * vm )
```

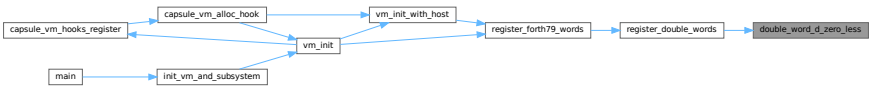
References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



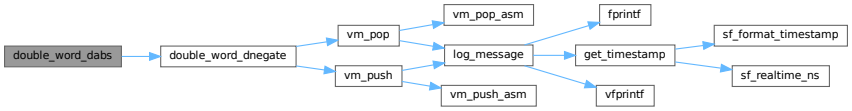
7.359.1.18 double_word_dabs()

```
void double_word_dabs (
            VM * vm )
```

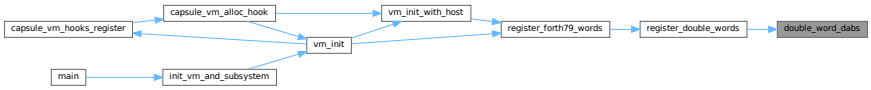
References VM::data_stack, double_word_dnegate(), VM::dsp, and VM::error.

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



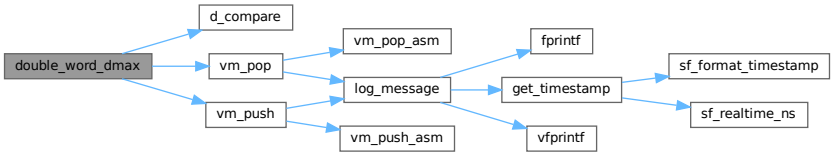
7.359.1.19 double_word_dmax()

```
void double_word_dmax (
            VM * vm )
```

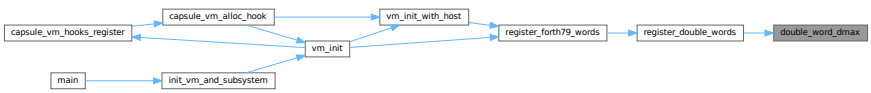
References d_compare(), VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



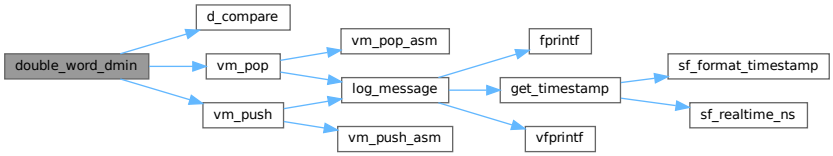
7.359.1.20 double_word_dmin()

```
void double_word_dmin (
            VM * vm )
```

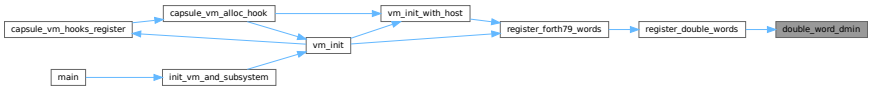
References d_compare(), VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:



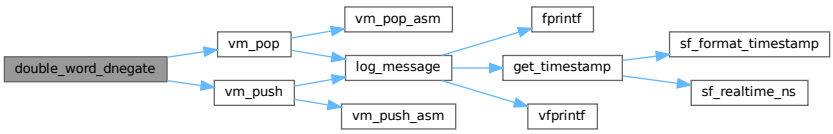
7.359.1.21 double_word_dnegate()

```
void double_word_dnegate (
            VM * vm )
```

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by double_word_dabs(), and register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.359.1.22 double_word_s_to_d()

```
void double_word_s_to_d (
            VM * vm )
```

Convert single number to double (n – d)

Converts a single-precision number to double-precision format. Result is pushed as (dlow dhigh) with high cell on top.

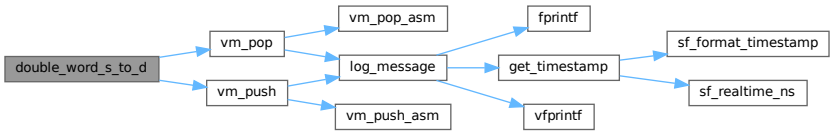
Parameters

vm	Pointer to the virtual machine state

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_double_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.359.1.23 register_double_words()

```
void register_double_words (
            VM * vm )
```

Register all double number words.

Registers all double-precision number operations with the virtual machine.

Parameters

vm	Pointer to the virtual machine state

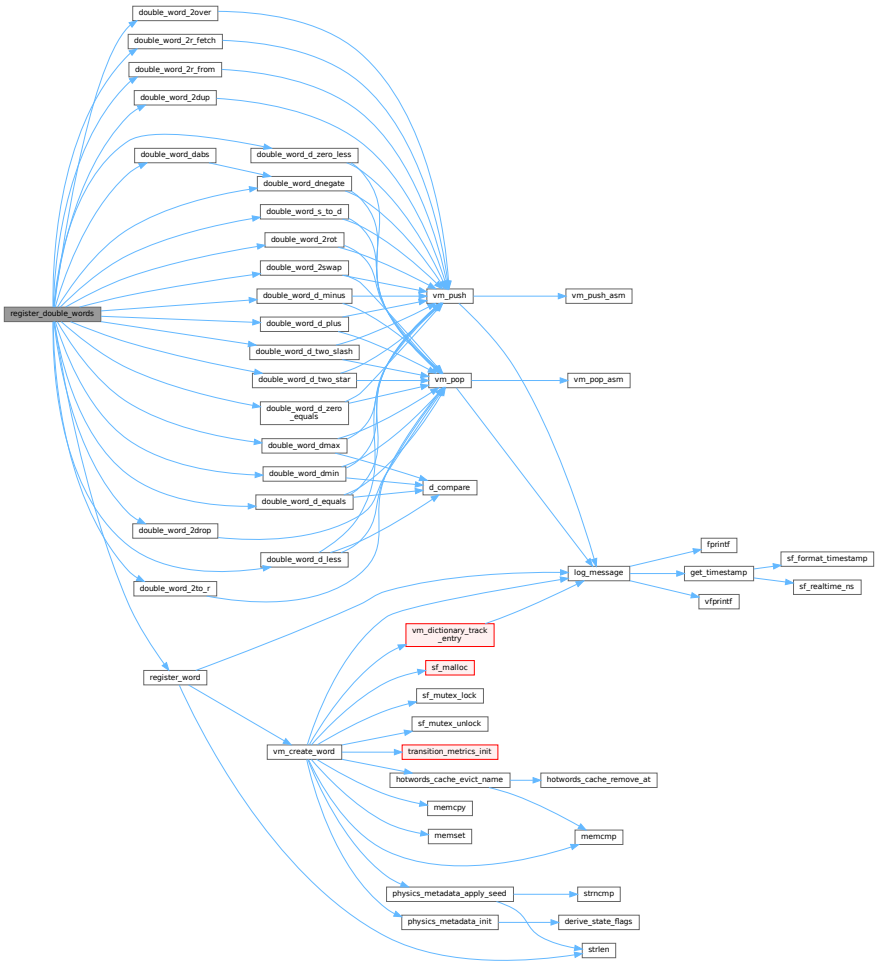
Note

This function must be called during VM initialization.

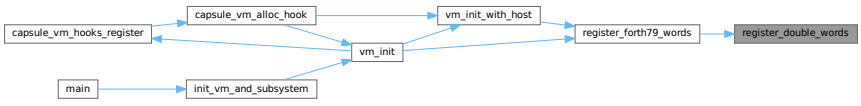
References double_word_2drop(), double_word_2dup(), double_word_2over(), double_word_2r_fetch(), double_word_2r_from(), double_word_2rot(), double_word_2swap(), double_word_2to_r(), double_word_d_equals(), double_word_d_less(), double_word_d_minus(), double_word_d_plus(), double_word_d_two_slash(), double_word_d_two_star(), double_word_d_zero_equals(), double_word_d_zero_less(), double_word_dabs(), double_word_dmax(), double_word_dmin(), double_word_dnegate(), double_word_s_to_d(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



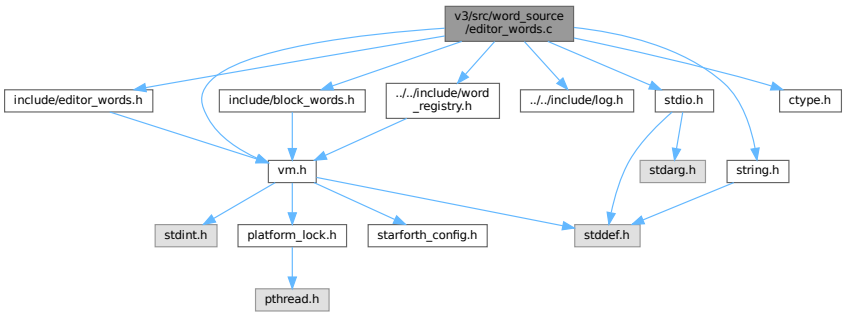
Here is the caller graph for this function:



7.360 v3/src/word_source/editor_words.c File Reference

```
#include "include/editor_words.h"
#include "include/block_words.h"
#include "../../include/vm.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include <stdio.h>
#include <string.h>
#include <ctype.h>
```

Include dependency graph for editor_words.c:



Functions

- static cell_t current_scr (VM *vm)

  Get current screen number from VM.
- static int line_ptr (VM *vm, cell_t scr, cell_t line, unsigned char **out)

  Get pointer to specific line in a screen.
- static void print_line_64 (const unsigned char *p)

  Print 64-character line with character filtering.
- static void editor_word_l (VM *vm)
- static void editor_word_s (VM *vm)
- static void editor_word_show (VM *vm)
- static void editor_word_edit (VM *vm)
- void register_editor_words (VM *vm)

  Register all editor words with the Forth virtual machine.

7.360.1 Function Documentation

7.360.1.1 current_scr()

```
static cell_t current_scr (
            VM * vm )  [inline], [static]
```

Get current screen number from VM.

Parameters

vm	Pointer to VM instance

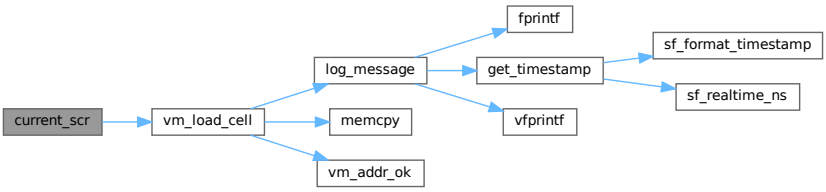
Returns

Current screen number

References VM::scr_addr, and vm_load_cell().

Referenced by block_word_next_block(), editor_word_l(), editor_word_s(), and editor_word_show().

Here is the call graph for this function:



Here is the caller graph for this function:

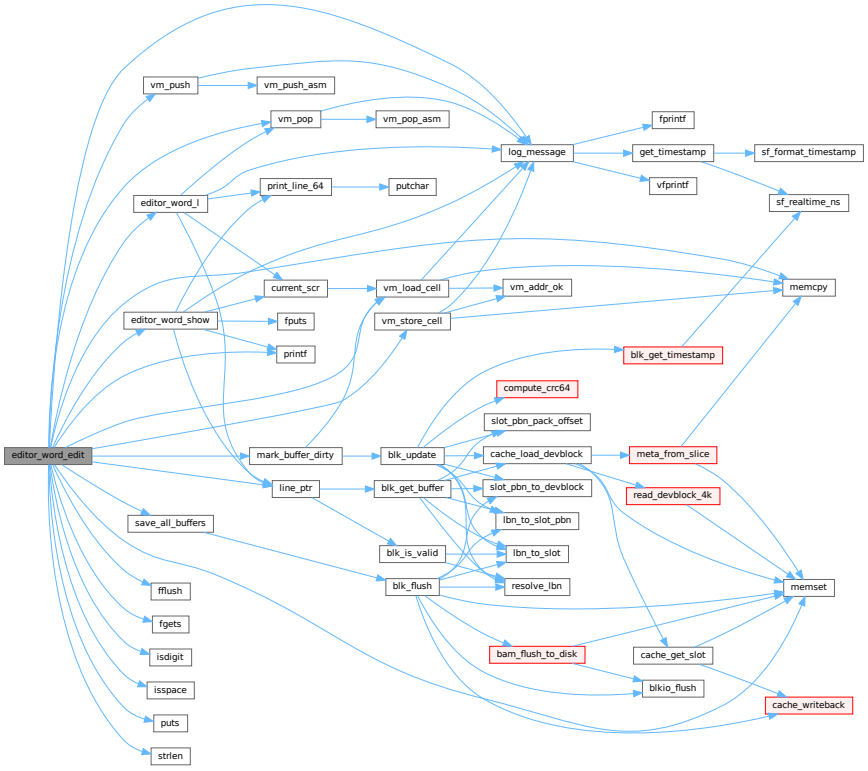
7.360.1.2 editor_word_edit()

```
static void editor_word_edit (
            VM * vm )  [static]
```

References VM::dsp, editor_word_l(), editor_word_show(), VM::error, fflush(), fgets(), isdigit(), isspace(), line_ptr(), LOG_ERROR, log_message(), mark_buffer_dirty(), MAX_BLOCKS, memcpy(), memset(), printf(), puts(), save_all_buffers(), VM::scr_addr, stdin, stdout, strlen(), vm_load_cell(), vm_pop(), vm_push(), and vm_store_cell().

Referenced by register_editor_words().

Here is the call graph for this function:



Here is the caller graph for this function:

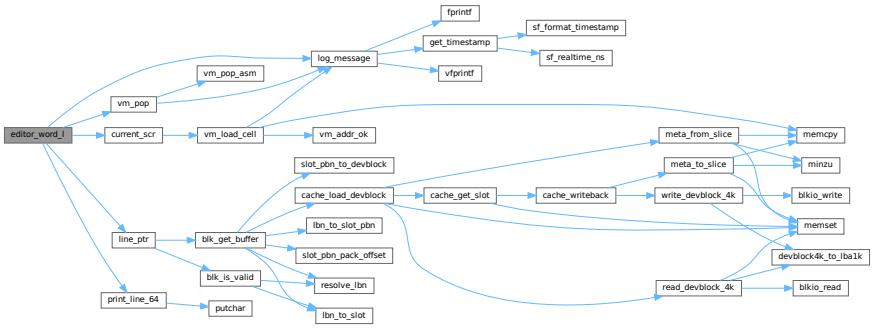
7.360.1.3 editor_word_l()

```
static void editor_word_l (
            VM * vm )  [static]
```

References current_scr(), VM::dsp, VM::error, line_ptr(), LOG_ERROR, log_message(), MAX_BLOCKS, print_line_64(), and vm_pop().

Referenced by editor_word_edit(), and register_editor_words().

Here is the call graph for this function:



Here is the caller graph for this function:

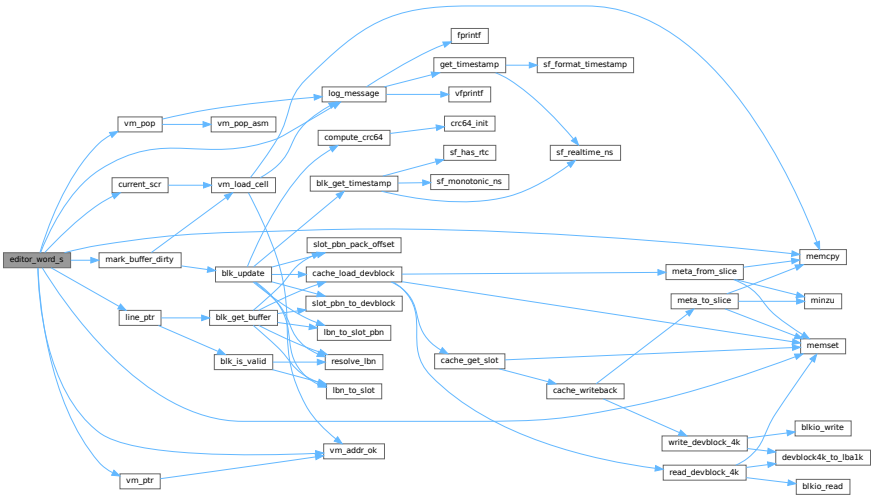
7.360.1.4 editor_word_s()

```
static void editor_word_s (
            VM * vm )  [static]
```

References current_scr(), VM::dsp, VM::error, line_ptr(), LOG_ERROR, log_message(), mark_buffer_dirty(), MAX_BLOCKS, memcpy(), memset(), vm_addr_ok(), vm_pop(), and vm_ptr().

Referenced by register_editor_words().

Here is the call graph for this function:



Here is the caller graph for this function:

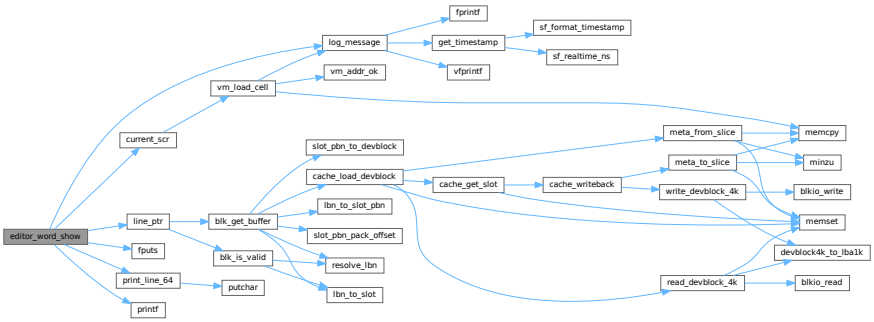
7.360.1.5 editor_word_show()

```
static void editor_word_show (
            VM * vm )  [static]
```

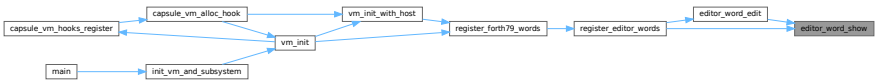
References current_scr(), VM::error, fputs(), line_ptr(), LOG_ERROR, log_message(), MAX_BLOCKS, print_line_64(), printf(), and stdout.

Referenced by editor_word_edit(), and register_editor_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.360.1.6 line_ptr()

```
static int line_ptr (
            VM * vm,
            cell_t scr,
            cell_t line,
            unsigned char ** out )  [static]
```

Get pointer to specific line in a screen.

Parameters

vm	Pointer to VM instance
scr	Screen number (1-based)
line	Line number (0-15)
out	Output parameter for line pointer

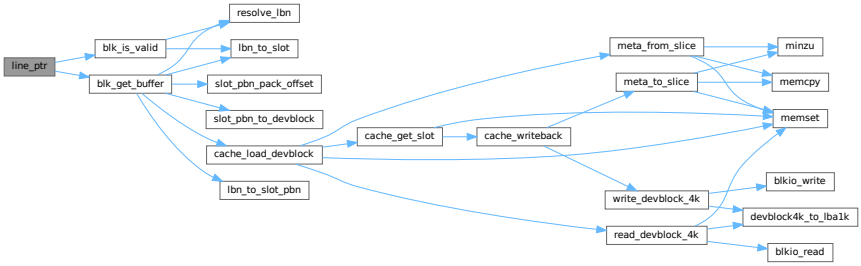
Returns

1 if successful, 0 if parameters invalid

References blk_get_buffer(), blk_is_valid(), and MAX_BLOCKS.

Referenced by editor_word_edit(), editor_word_l(), editor_word_s(), and editor_word_show().

Here is the call graph for this function:



Here is the caller graph for this function:

7.360.1.7 print_line_64()

```
static void print_line_64 (
            const unsigned char * p )  [static]
```

Print 64-character line with character filtering.

Parameters

p	Pointer to 64-byte line buffer

References putchar().

Referenced by editor_word_l(), and editor_word_show().

Here is the call graph for this function:

Here is the caller graph for this function:

7.360.1.8 register_editor_words()

```
void register_editor_words (
            VM * vm )
```

Register all editor words with the Forth virtual machine.

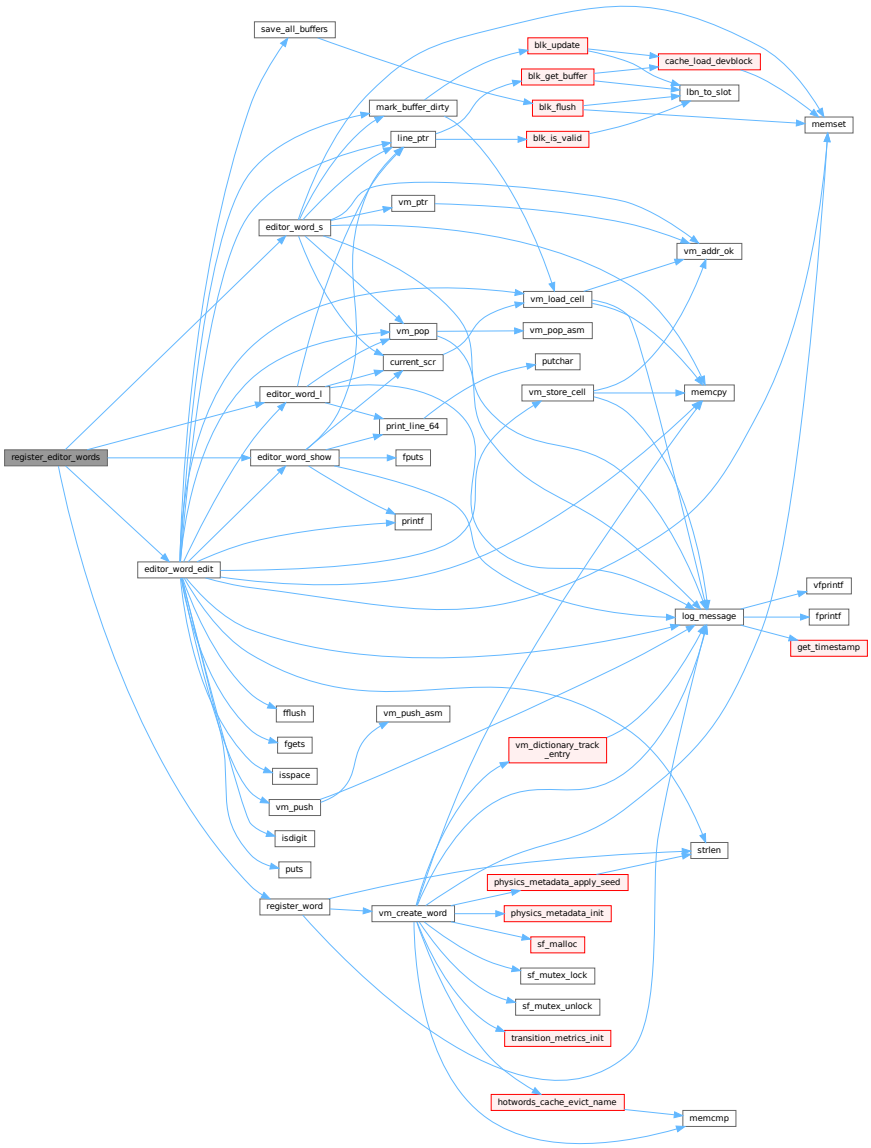
Parameters

vm	Pointer to the Forth virtual machine instance

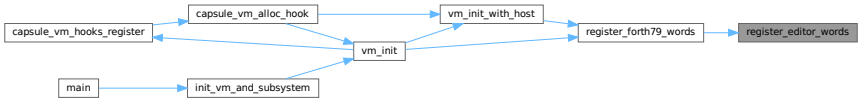
References editor_word_edit(), editor_word_l(), editor_word_s(), editor_word_show(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

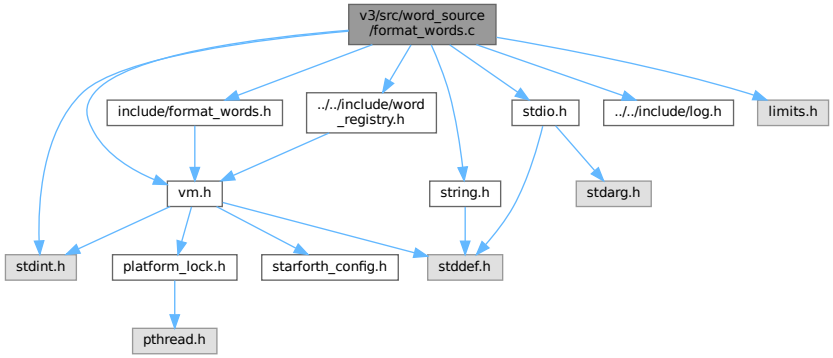


7.361 v3/src/word_source/format_words.c File Reference

```
#include "include/format_words.h"
#include "../../include/word_registry.h"
```

```
#include "../../include/log.h"
#include "../../include/vm.h"
#include <stdint.h>
#include <limits.h>
#include <string.h>
#include <stdio.h>
```

Include dependency graph for format_words.c:



Macros

- #define PN_CAP 64
- #define PN_BUF(vm) ((unsigned char ∗)((vm)->memory + (vm)->hold_addr))
- #define CELL_BITS ((int)(sizeof(cell_t) ∗ CHAR_BIT))
- #define CHUNK_BITS 16
- #define CHUNK_MASK ((uint64_t)(UINT64_C(1) << CHUNK_BITS) - 1)

Functions

- static unsigned current_base (VM ∗vm)

  Returns current numeric conversion base, defaulting to 10 if invalid.
- static char digit_for (unsigned v)

  Converts value 0-35 to character '0'-'9' or 'A'-'Z'.
- static void div_ud_by_base (cell_t dhigh_in, cell_t dlow_in, unsigned base, cell_t ∗qhigh_out, cell_t ∗qlow↩ _out, unsigned ∗rem_out)

  Divides unsigned double-cell number by base using portable C99 code.
- static void print_number_formatted (VM ∗vm, cell_t n, int width, int is_unsigned)

  Prints number with optional width field and sign handling.
- void format_word_base (VM ∗vm)
- void format_word_decimal (VM ∗vm)
- void format_word_hex (VM ∗vm)
- void format_word_octal (VM ∗vm)
- void format_word_begin_conversion (VM ∗vm)
- void format_word_hold (VM ∗vm)
- void format_word_sign (VM ∗vm)
- void format_word_hash (VM ∗vm)
- void format_word_hash_s (VM ∗vm)
- void format_word_end_conversion (VM ∗vm)

- void format_word_dot (VM *vm)
- void format_word_dot_r (VM *vm)
- void format_word_u_dot (VM *vm)
- void format_word_u_dot_r (VM *vm)
- void format_word_d_dot (VM *vm)
- void format_word_d_dot_r (VM *vm)
- void format_word_dot_s (VM *vm)
- void format_word_question (VM *vm)
- void format_word_dump (VM *vm)
- void register_format_words (VM *vm)

  Registers all formatting and numeric conversion words with the VM.

7.361.1 Macro Definition Documentation

7.361.1.1 CELL_BITS

```
#define CELL_BITS ((int)(sizeof(cell_t) * CHAR_BIT))
```

7.361.1.2 CHUNK_BITS

```
#define CHUNK_BITS 16
```

7.361.1.3 CHUNK_MASK

```
#define CHUNK_MASK ((uint64_t)(UINT64_C(1) << CHUNK_BITS) - 1)
```

7.361.1.4 PN_BUF

```
#define PN_BUF(
              vm ) ((unsigned char *)((vm)->memory + (vm)->hold_addr))
```

7.361.1.5 PN_CAP

```
#define PN_CAP 64
```

7.361.2 Function Documentation

7.361.2.1 current_base()

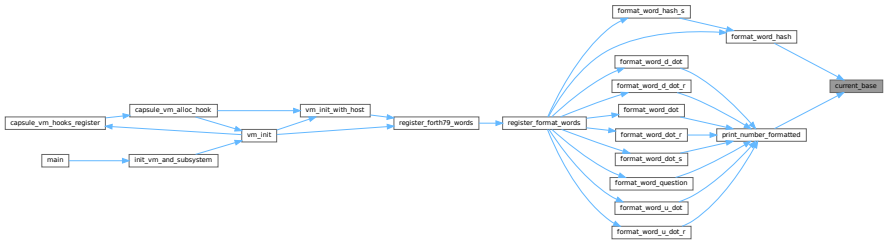
```
static unsigned current_base (
            VM * vm )  [static]
```

Returns current numeric conversion base, defaulting to 10 if invalid.

References VM::base.

Referenced by format_word_hash(), and print_number_formatted().

Here is the caller graph for this function:



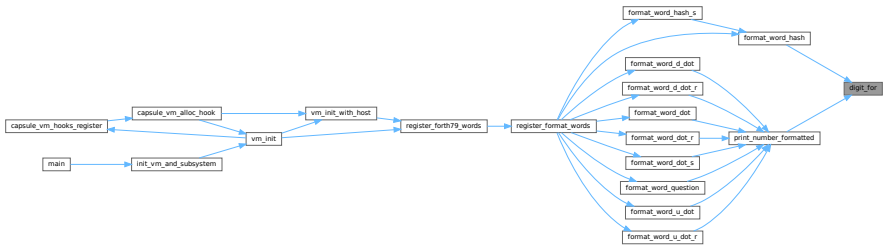
7.361.2.2 digit_for()

```
static char digit_for (
            unsigned v )  [static]
```

Converts value 0-35 to character '0'-'9' or 'A'-'Z'.

Referenced by format_word_hash(), and print_number_formatted().

Here is the caller graph for this function:



7.361.2.3 div_ud_by_base()

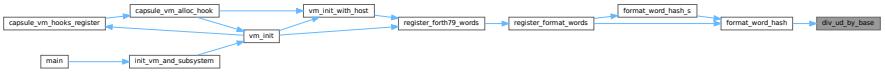
```
static void div_ud_by_base (
            cell_t dhigh_in,
            cell_t dlow_in,
            unsigned base,
            cell_t * qhigh_out,
            cell_t * qlow_out,
            unsigned * rem_out )  [static]
```

Divides unsigned double-cell number by base using portable C99 code.

References base, CELL_BITS, CHUNK_BITS, and CHUNK_MASK.

Referenced by format_word_hash().

Here is the caller graph for this function:



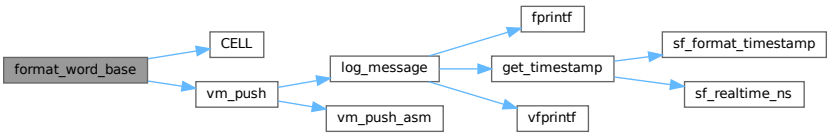
7.361.2.4 format_word_base()

```
void format_word_base (
            VM * vm )
```

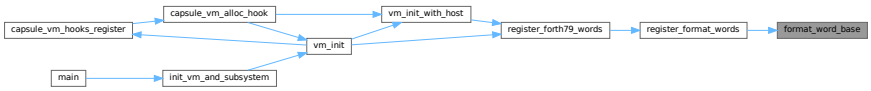
References VM::base_addr, CELL(), and vm_push().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.361.2.5 format_word_begin_conversion()

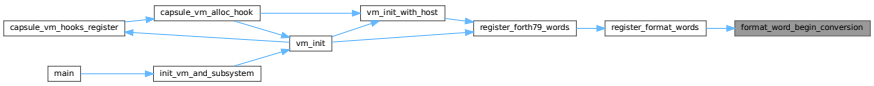
```
void format_word_begin_conversion (
            VM * vm )
```

References VM::hold_pos, memset(), PN_BUF, and PN_CAP.

Referenced by register_format_words().

Here is the call graph for this function:

Here is the caller graph for this function:



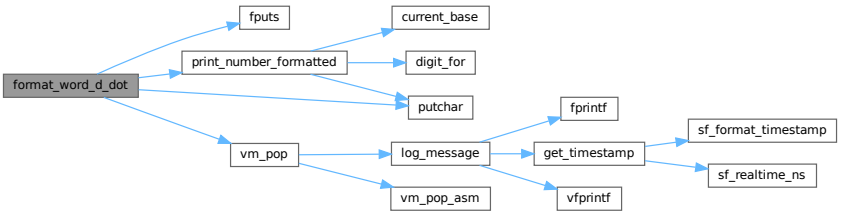
7.361.2.6 format_word_d_dot()

```
void format_word_d_dot (
            VM * vm )
```

References VM::dsp, VM::error, fputs(), print_number_formatted(), putchar(), stdout, and vm_pop().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

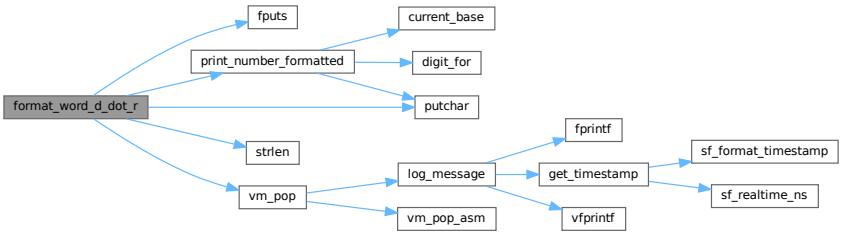
7.361.2.7 format_word_d_dot_r()

```
void format_word_d_dot_r (
            VM * vm )
```

References VM::dsp, VM::error, fputs(), print_number_formatted(), putchar(), stdout, strlen(), and vm_pop().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

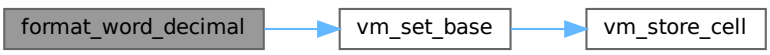
7.361.2.8 format_word_decimal()

```
void format_word_decimal (
            VM * vm )
```

References vm_set_base().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

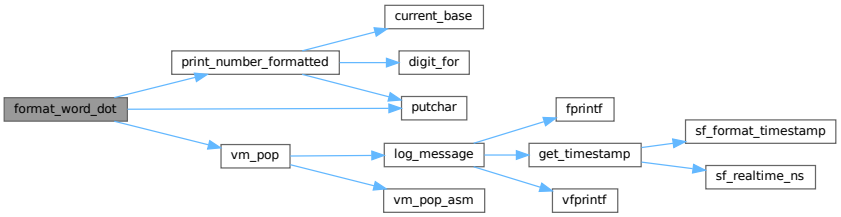
7.361.2.9 format_word_dot()

```
void format_word_dot (
            VM * vm )
```

References VM::dsp, VM::error, print_number_formatted(), putchar(), and vm_pop().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

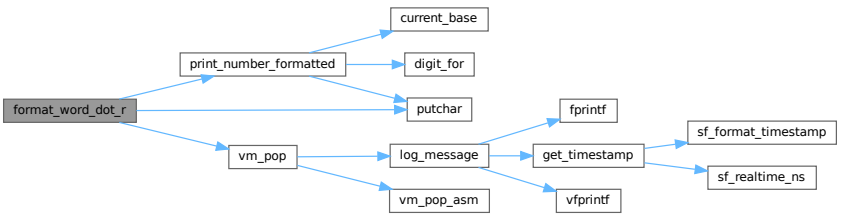
7.361.2.10 format_word_dot_r()

```
void format_word_dot_r (
            VM * vm )
```

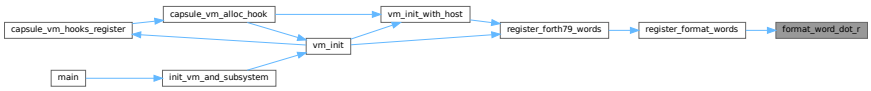
References VM::dsp, VM::error, print_number_formatted(), putchar(), and vm_pop().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:



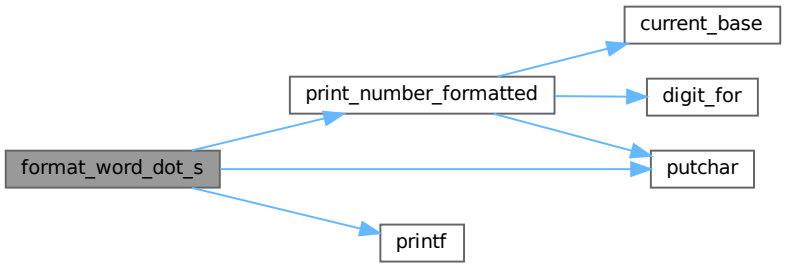
7.361.2.11 format_word_dot_s()

```
void format_word_dot_s (
            VM * vm )
```

References VM::data_stack, VM::dsp, print_number_formatted(), printf(), and putchar().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

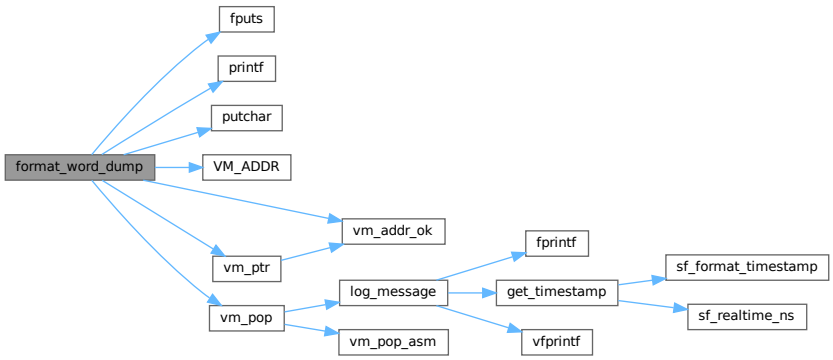
7.361.2.12 format_word_dump()

```
void format_word_dump (
            VM * vm )
```

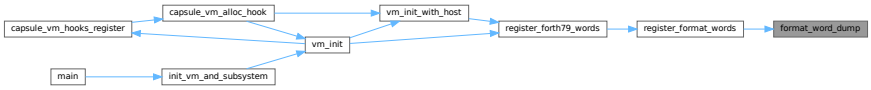
References VM::dsp, VM::error, fputs(), printf(), putchar(), stdout, VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_ptr().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:



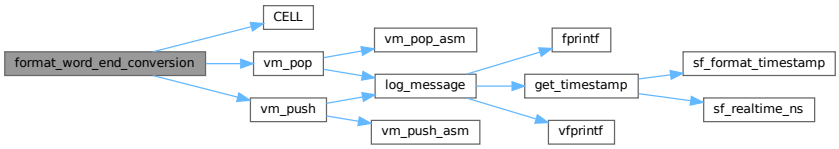
7.361.2.13 format_word_end_conversion()

```
void format_word_end_conversion (
            VM * vm )
```

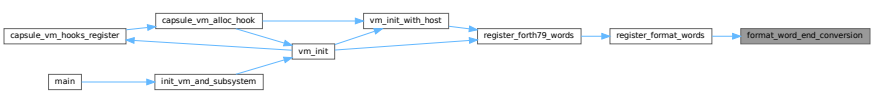
References CELL(), VM::dsp, VM::hold_addr, VM::hold_pos, vm_pop(), and vm_push().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:



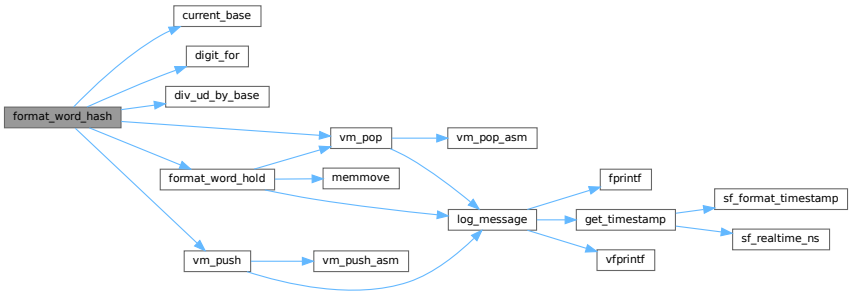
7.361.2.14 format_word_hash()

```
void format_word_hash (
            VM * vm )
```

References base, current_base(), digit_for(), div_ud_by_base(), VM::dsp, VM::error, format_word_hold(), vm_pop(), and vm_push().

Referenced by format_word_hash_s(), and register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

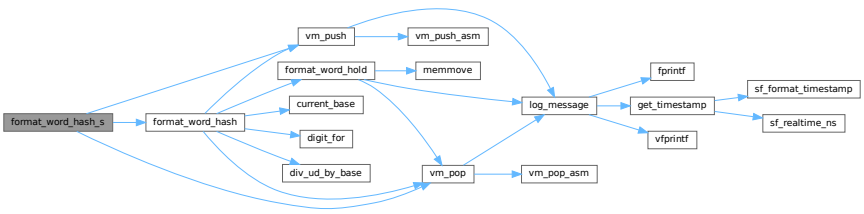
7.361.2.15 format_word_hash_s()

```
void format_word_hash_s (
            VM * vm )
```

References VM::data_stack, VM::dsp, VM::error, format_word_hash(), vm_pop(), and vm_push().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

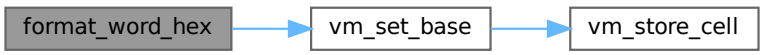
7.361.2.16 format_word_hex()

```
void format_word_hex (
            VM * vm )
```

References vm_set_base().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

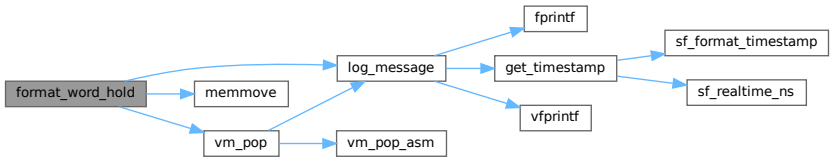
7.361.2.17 format_word_hold()

```
void format_word_hold (
            VM * vm )
```

References VM::dsp, VM::error, VM::hold_pos, LOG_ERROR, log_message(), memmove(), PN_BUF, PN_CAP, and vm_pop().

Referenced by format_word_hash(), format_word_sign(), and register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

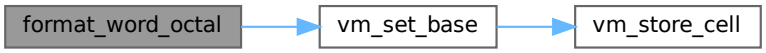
7.361.2.18 format_word_octal()

```
void format_word_octal (
            VM * vm )
```

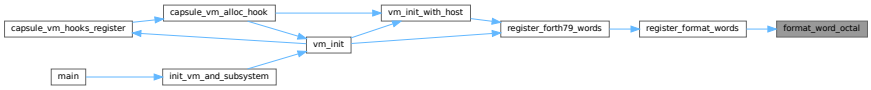
References vm_set_base().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:



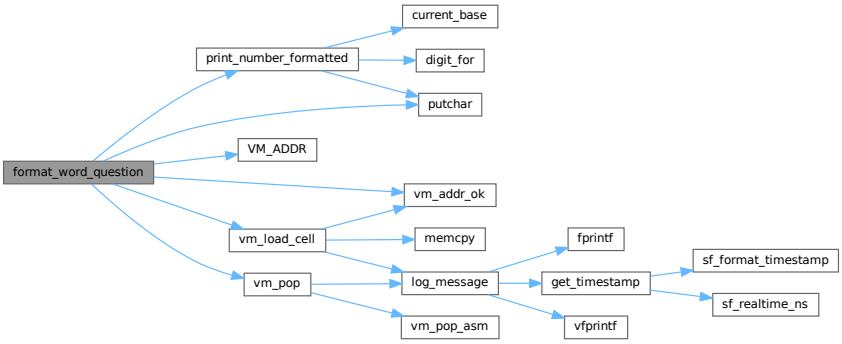
7.361.2.19 format_word_question()

```
void format_word_question (
            VM * vm )
```

References VM::dsp, VM::error, print_number_formatted(), putchar(), VM_ADDR(), vm_addr_ok(), vm_load_cell(), and vm_pop().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

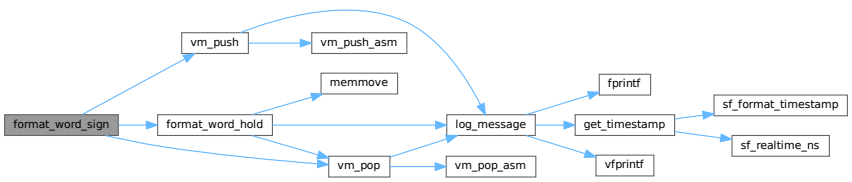
7.361.2.20 format_word_sign()

```
void format_word_sign (
            VM * vm )
```

References VM::dsp, VM::error, format_word_hold(), vm_pop(), and vm_push().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

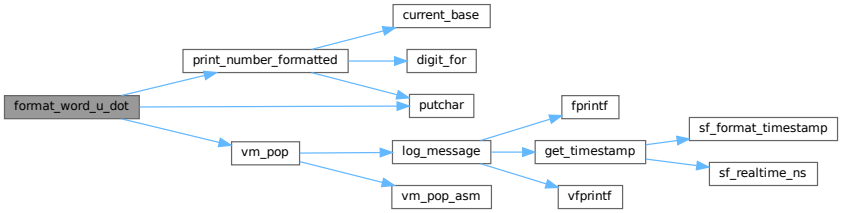
7.361.2.21 format_word_u_dot()

```
void format_word_u_dot (
            VM * vm )
```

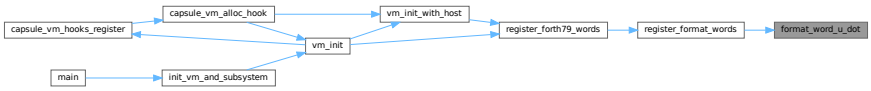
References VM::dsp, VM::error, print_number_formatted(), putchar(), and vm_pop().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:



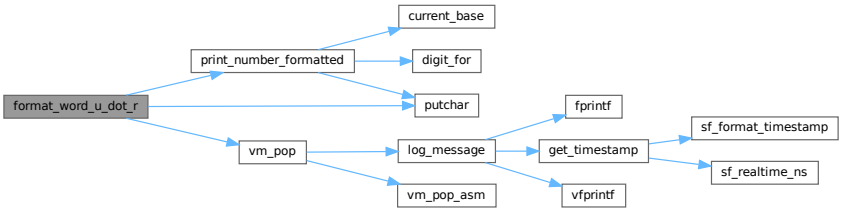
7.361.2.22 format_word_u_dot_r()

```
void format_word_u_dot_r (
            VM * vm )
```

References VM::dsp, VM::error, print_number_formatted(), putchar(), and vm_pop().

Referenced by register_format_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.361.2.23 print_number_formatted()

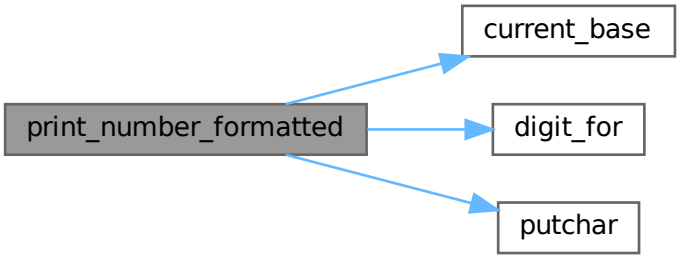
```
static void print_number_formatted (
            VM * vm,
            cell_t n,
            int width,
            int is_unsigned )  [static]
```

Prints number with optional width field and sign handling.

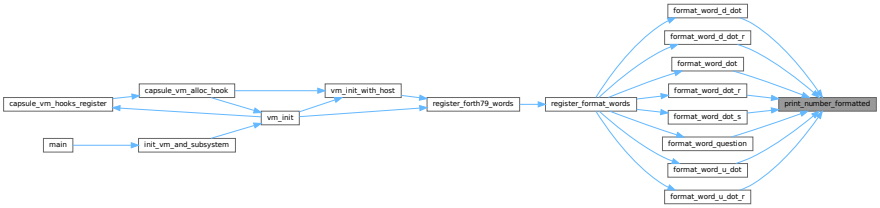
References base, current_base(), digit_for(), and putchar().

Referenced by format_word_d_dot(), format_word_d_dot_r(), format_word_dot(), format_word_dot_r(), format_word_dot_s(), format_word_question(), format_word_u_dot(), and format_word_u_dot_r().

Here is the call graph for this function:



Here is the caller graph for this function:



7.361.2.24 register_format_words()

```
void register_format_words (
            VM * vm )
```

Registers all formatting and numeric conversion words with the VM.

This function registers the standard FORTH formatting words including:

- Number output words (., .R, U., U.R, D., D.R, .S, ?)
- Picture number formatting (<#, #, #S, #>, HOLD, SIGN)
- Base conversion (BASE, DECIMAL, HEX, OCTAL)
- Memory dump (DUMP)

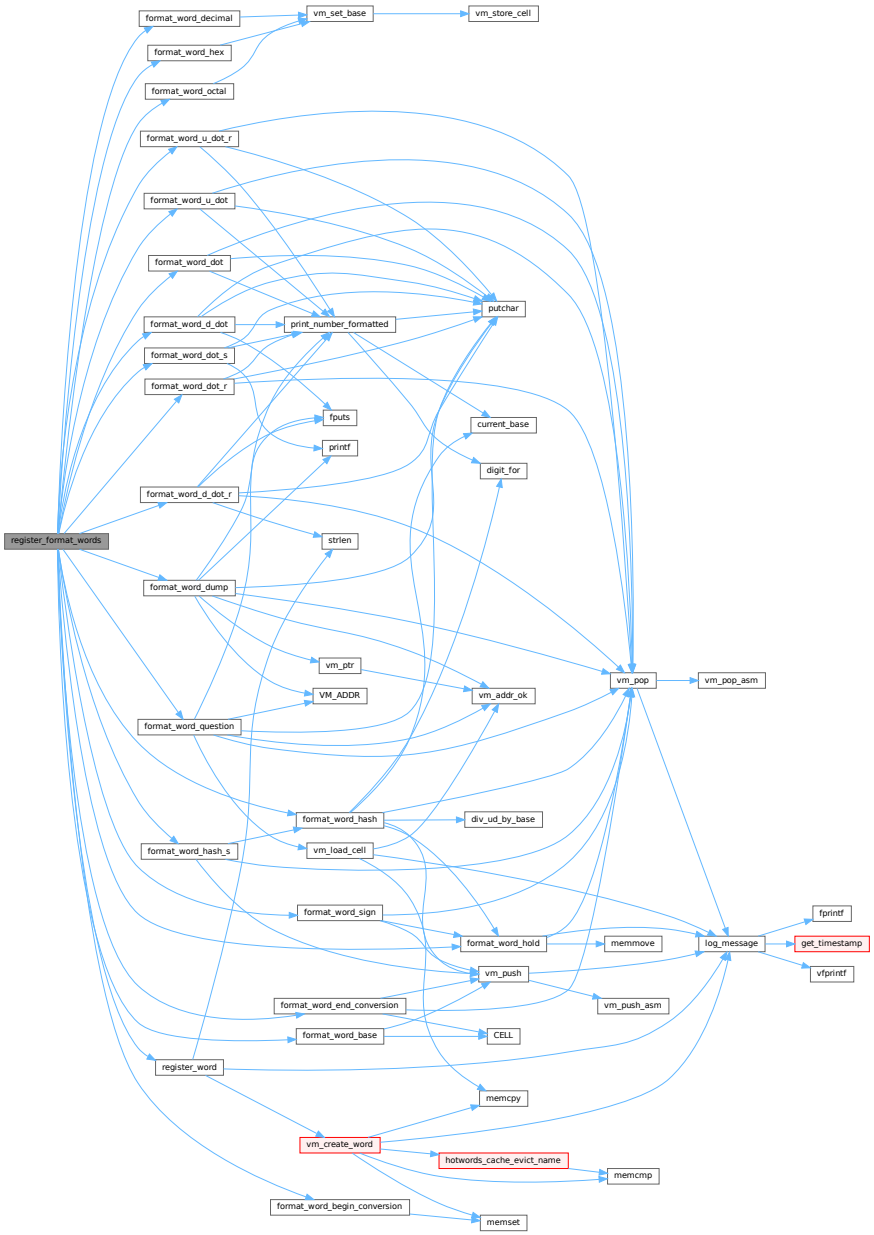
Parameters

vm	Pointer to the virtual machine instance

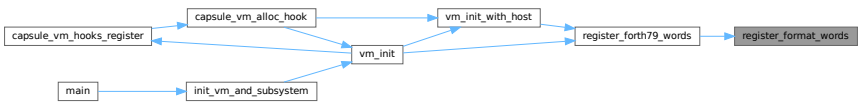
References format_word_base(), format_word_begin_conversion(), format_word_d_dot(), format_word_d_dot_r(), format_word_decimal(), format_word_dot(), format_word_dot_r(), format_word_dot_s(), format_word_dump(), format_word_end_conversion(), format_word_hash(), format_word_hash_s(), format_word_hex(), format_word_hold(), format_word_octal(), format_word_question(), format_word_sign(), format_word_u_dot(), format_word_u_dot_r(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

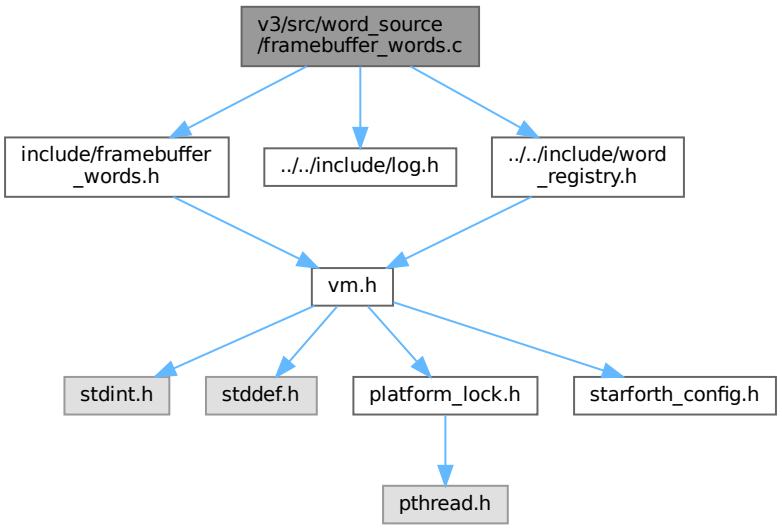


7.362 v3/src/word_source/framebuffer_words.c File Reference

```
#include "include/framebuffer_words.h"
```

```
#include "../../include/log.h"
#include "../../include/word_registry.h"
```

Include dependency graph for framebuffer_words.c:



Functions

- static void fbw_plot (VM *vm)
- static void fbw_width (VM *vm)
- static void fbw_height (VM *vm)
- void register_framebuffer_words (VM *vm)

7.362.1 Function Documentation

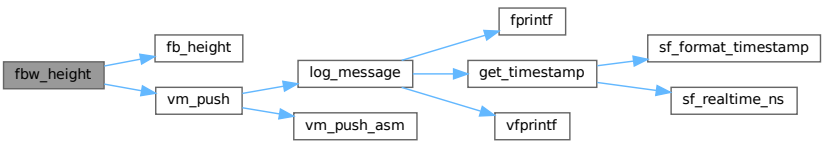
7.362.1.1 fbw_height()

```
static void fbw_height (
            VM * vm )  [static]
```

References fb_height(), and vm_push().

Referenced by register_framebuffer_words().

Here is the call graph for this function:



Here is the caller graph for this function:

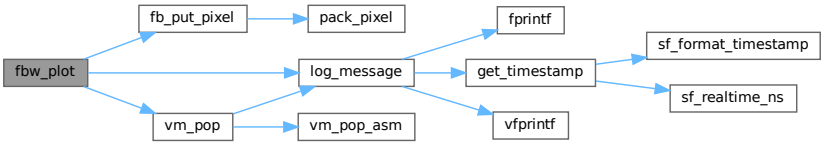
7.362.1.2 fbw_plot()

```
static void fbw_plot (
            VM * vm )  [static]
```

References VM::dsp, VM::error, fb_put_pixel(), LOG_ERROR, log_message(), and vm_pop().

Referenced by register_framebuffer_words().

Here is the call graph for this function:



Here is the caller graph for this function:

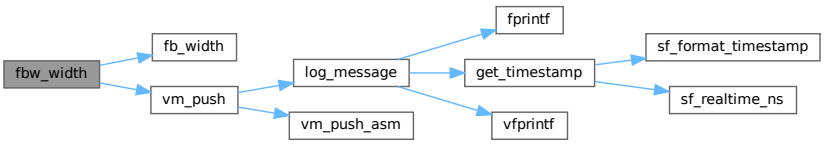
7.362.1.3 fbw_width()

```
static void fbw_width (
            VM * vm )  [static]
```

References fb_width(), and vm_push().

Referenced by register_framebuffer_words().

Here is the call graph for this function:



Here is the caller graph for this function:

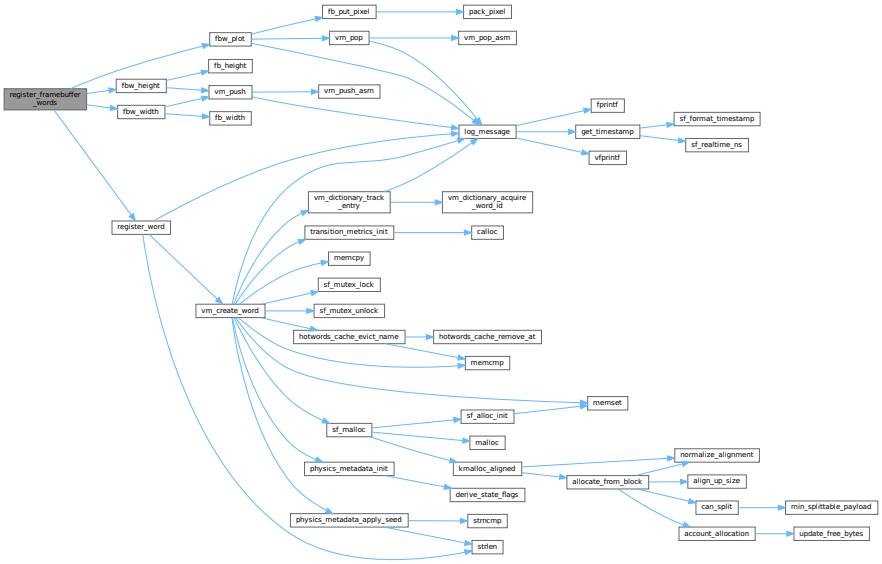
7.362.1.4 register_framebuffer_words()

```
void register_framebuffer_words (
            VM * vm )
```

References fbw_height(), fbw_plot(), fbw_width(), and register_word().

Referenced by capsule_birth_baby().

Here is the call graph for this function:

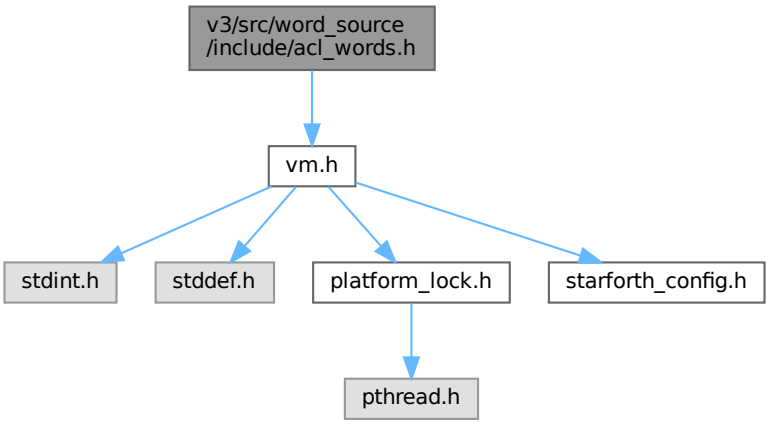


Here is the caller graph for this function:

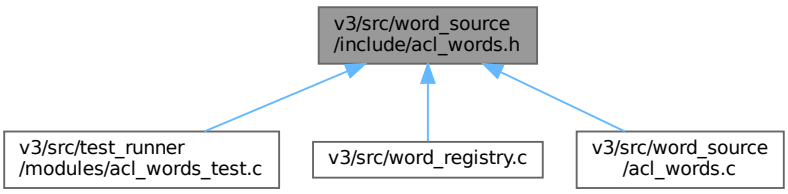
7.363 v3/src/word_source/include/acl_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for acl_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_acl_words (VM *vm)

  Register all ACL C-primitive words with the VM dictionary.
- void acl_inherit_entry (DictEntry *src, DictEntry *dst)

  Direct C entry point for ACL policy inheritance on the capsule birth path.

7.363.1 Function Documentation

7.363.1.1 acl_inherit_entry()

```
void acl_inherit_entry (
            DictEntry * src,
            DictEntry * dst )
```

Direct C entry point for ACL policy inheritance on the capsule birth path.

Copies `acl_mode` from `src` to `dst`, clears `acl_pinned`, resets `acl_ttl` to 0, and sets `acl_allow` to 1. Called from capsule birth code (not from FORTH) — no stack manipulation is performed.

Parameters

src	Source DictEntry whose `acl_mode` is inherited
dst	Destination DictEntry whose ACL fields are updated

References DictEntry::acl_allow, DictEntry::acl_mode, DictEntry::acl_pinned, and DictEntry::acl_ttl.

Referenced by forth_acl_inherit(), and test_acl_inherit().

Here is the caller graph for this function:

7.363.1.2 register_acl_words()

```
void register_acl_words (
              VM * vm )
```

Register all ACL C-primitive words with the VM dictionary.

Registers: field accessors (`ACL-MODE@` / `ACL-MODE!` / `ACL-PINNED?` / `ACL-TTL@` / `ACL-TTL!` / `ACL-ALLOW@` / `ACL-ALLOW!` / `ACL-HEAT@` / `ACL-WORD-ID`), and mutation words (`ACL-PIN` / `ACL-INHERIT` / `ACL-INIT-PRIMITIVES`). Called from `vm_bootstrap.c` during VM initialisation.

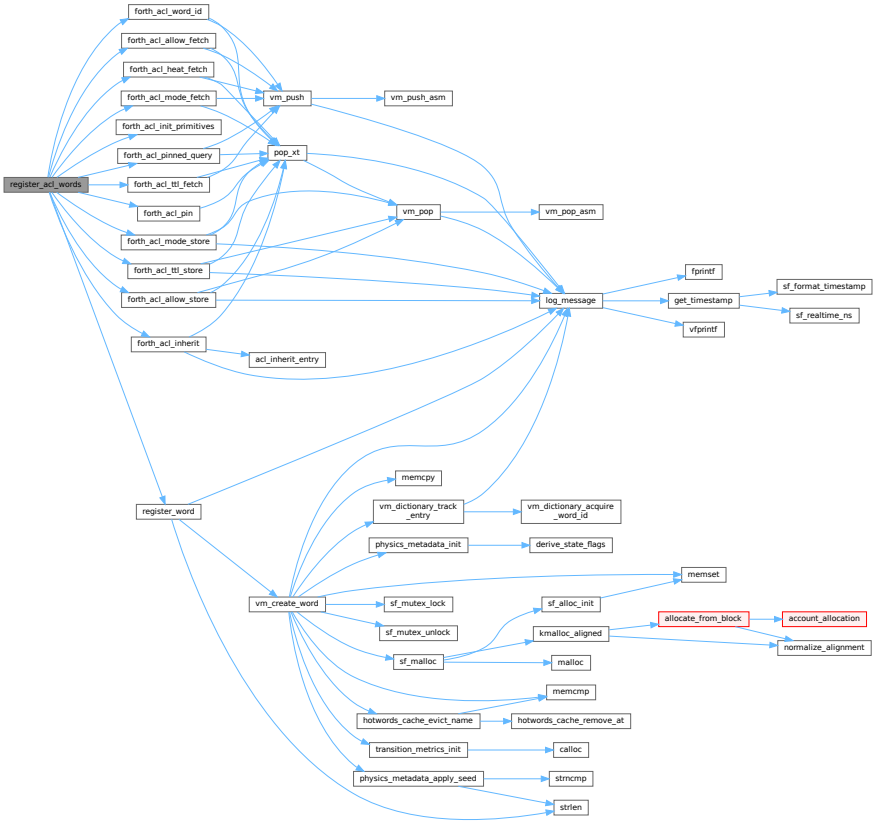
Parameters

vm	Pointer to the VM structure

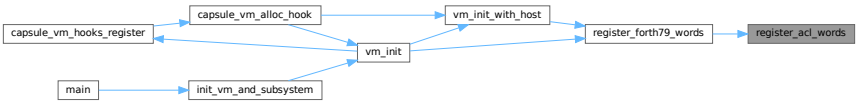
References forth_acl_allow_fetch(), forth_acl_allow_store(), forth_acl_heat_fetch(), forth_acl_inherit(), forth_acl_init_primitives(), forth_acl_mode_fetch(), forth_acl_mode_store(), forth_acl_pin(), forth_acl_pinned_query(), forth_acl_ttl_fetch(), forth_acl_ttl_store(), forth_acl_word_id(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



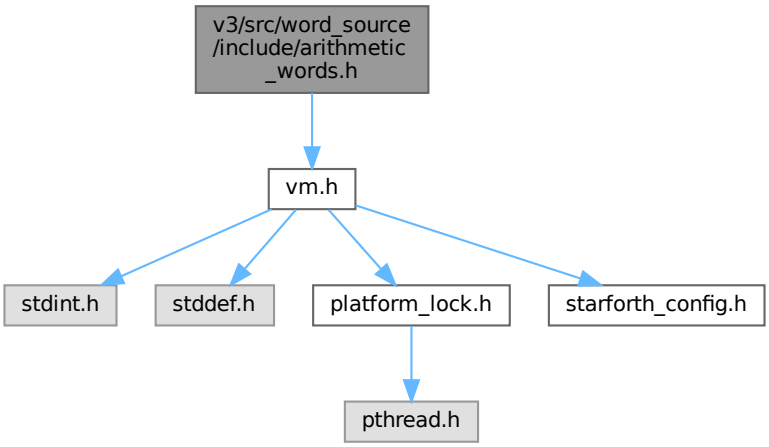
Here is the caller graph for this function:



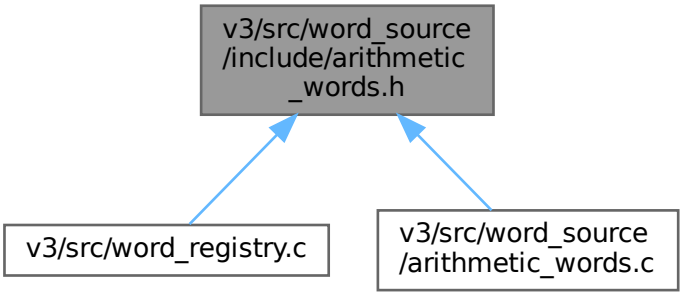
7.364 v3/src/word_source/include/arithmetic_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for arithmetic_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_arithmetic_words (VM *vm)

  Registers all FORTH-79 arithmetic words with the virtual machine.

7.364.1 Function Documentation

7.364.1.1 register_arithmetic_words()

```
void register_arithmetic_words (
            VM * vm )
```

Registers all FORTH-79 arithmetic words with the virtual machine.

Registers the following words:

- + (add)
- - (subtract)
- ∗ (multiply)
- / (divide)
- MOD (modulo)
- /MOD (divide with remainder)
- NEGATE
- ABS (absolute)
- MIN
- MAX
- 1+ (increment)
- 1- (decrement)
- 2∗ (multiply by 2)
- 2/ (divide by 2)
- STAR-SLASH (multiply then divide)

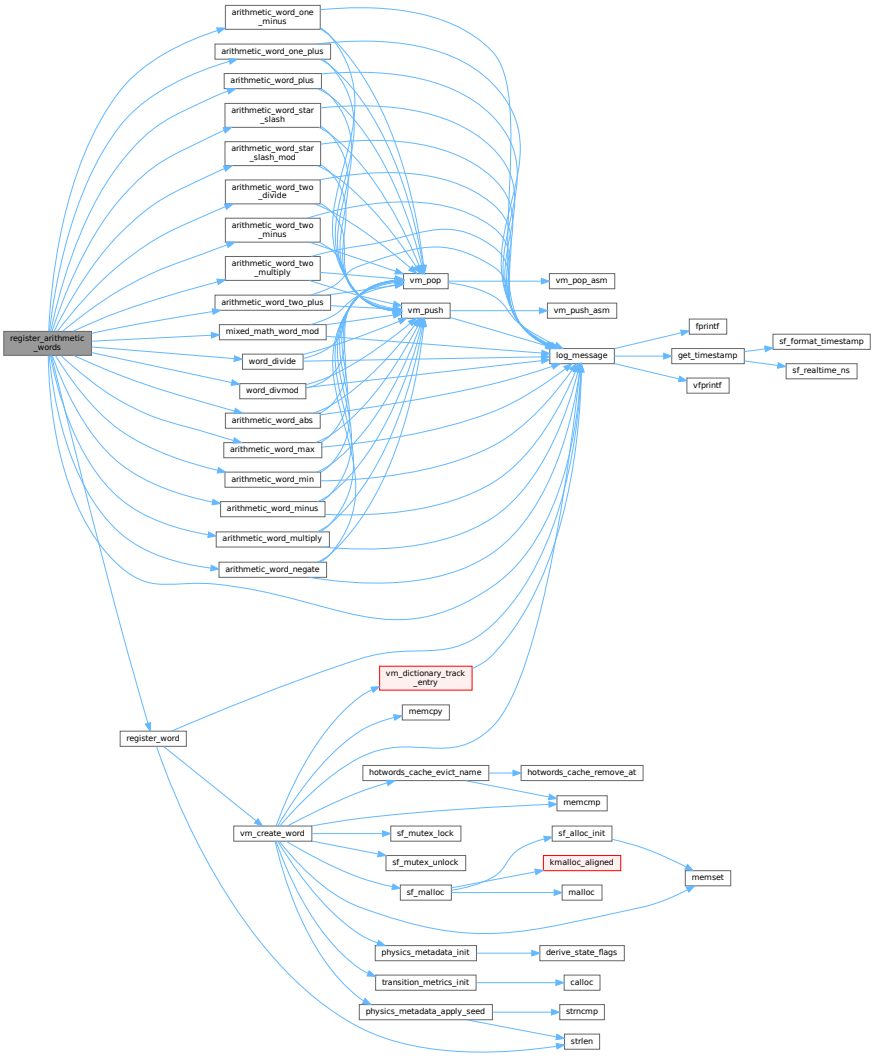
Parameters

vm	Pointer to the Forth virtual machine instance

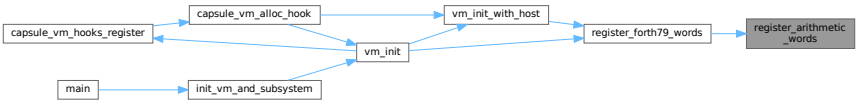
References arithmetic_word_abs(), arithmetic_word_max(), arithmetic_word_min(), arithmetic_word_minus(), arithmetic_word_multiply(), arithmetic_word_negate(), arithmetic_word_one_minus(), arithmetic_word_one_plus(), arithmetic_word_plus(), arithmetic_word_star_slash(), arithmetic_word_star_slash_mod(), arithmetic_word_two_divide(), arithmetic_word_two_minus(), arithmetic_word_two_multiply(), arithmetic_word_two_plus(), LOG_INFO, log_message(), mixed_math_word_mod(), register_word(), word_divide(), and word_divmod().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

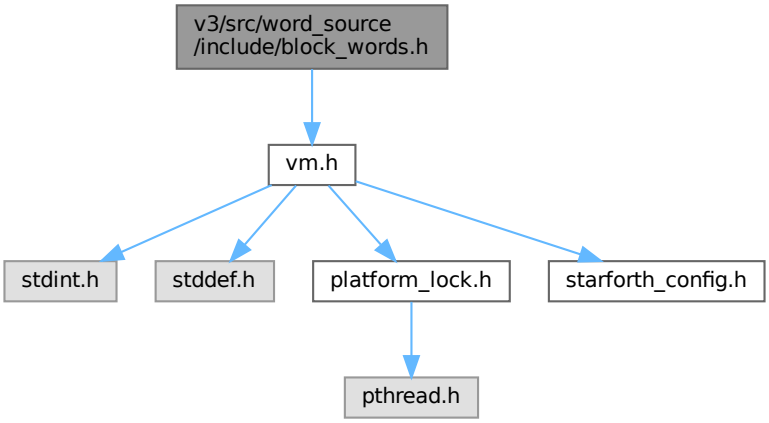


7.365 v3/src/word_source/include/block_words.h File Reference

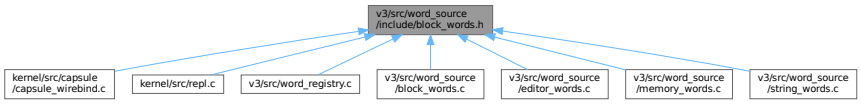
FORTH-79 Block and Buffer System Implementation.

```
#include "vm.h"
```

Include dependency graph for block_words.h:



This graph shows which files directly or indirectly include this file:



Data Structures

- struct BlockBuffer

  Block buffer structure maintaining buffer state.

Macros

Block System Configuration

- #define BLOCK_SIZE 1024

  Size of each block in bytes (1KB)
- #define MAX_BLOCKS (VM_MEMORY_SIZE / BLOCK_SIZE)

  Maximum number of blocks (1024 blocks from 1MB memory)
- #define BUFFER_COUNT 4

  Number of block buffers in memory.

Enumerations

- enum buffer_type_t { BUFFER_TYPE_MEMORY , BUFFER_TYPE_HARDWARE , BUFFER_TYPE_STORAGE , BUFFER_TYPE_NETWORK }

  Block buffer types for different storage mechanisms.

Functions

- void register_block_words (VM *vm)

  Registers all block and buffer words with the virtual machine.
- void init_block_system (VM *vm)

  Initializes the block system.
- unsigned char * get_block_buffer (VM *vm, int block_num)

  Gets a buffer for the specified block.
- unsigned char * get_empty_buffer (VM *vm, int block_num)

  Gets an empty buffer for the specified block.
- void mark_buffer_dirty (VM *vm)

  Marks the current buffer as modified.
- void save_all_buffers (VM *vm)
- void blk_vm_flush_all (VM *vm)

  Sync every dirty VM block-window slot to the C-layer block cache, then flush the whole block subsystem to physical media – the complete SAVE-BUFFERS implementation (unlike save_all_buffers() above, which only calls blk_flush() and so misses any BUFFER-modified-but-not-yet-UPDATE'd content still sitting only in vm->memory's window).
- void empty_all_buffers (VM *vm)

  Empties all user block buffers.
- void blk_vm_check_epoch (VM *vm)

  Discards vm->blk_vm_lbn[]/cbuf[]/dirty[] if the device chain has changed since last validated (see this function's own doc comment in block_words.c for why).
- int blk_vm_slot_for_addr (vaddr_t addr)

  Does `addr` fall inside the block I/O window? Pure address arithmetic against the window's fixed compile-time base/size – no VM state needed.
- int blk_vm_is_cross_device_copy (VM *vm, vaddr_t addr1, vaddr_t addr2)

  True if addr1/addr2 are both block-window addresses currently loaded from two different physical devices (Phase 8 v3, 2026-09-23) – the check MOVE/CMOVE/CMOVE> call before copying to refuse a same-VM, cross-device raw block copy.

7.365.1 Detailed Description

FORTH-79 Block and Buffer System Implementation.

This file implements the standard FORTH-79 block and buffer words:

- BLOCK (u – addr) Get block buffer address
- BUFFER (u – addr) Get empty buffer for block
- UPDATE (–) Mark current block as modified
- SAVE-BUFFERS (–) Save all modified blocks
- EMPTY-BUFFERS (–) Mark all buffers as empty
- FLUSH (–) Save buffers and empty them
- LIST (u –) List block contents
- LOAD (u –) Load and interpret block
- SCR (– addr) Variable: screen/block being listed
- THRU (u1 u2 –) Load blocks from u1 to u2
- --> or → (–) Continue to next block

7.365.2 Macro Definition Documentation

7.365.2.1 BLOCK_SIZE

```
#define BLOCK_SIZE 1024
```

Size of each block in bytes (1KB)

7.365.2.2 BUFFER_COUNT

```
#define BUFFER_COUNT 4
```

Number of block buffers in memory.

7.365.2.3 MAX_BLOCKS

```
#define MAX_BLOCKS (VM_MEMORY_SIZE / BLOCK_SIZE)
```

Maximum number of blocks (1024 blocks from 1MB memory)

7.365.3 Enumeration Type Documentation

7.365.3.1 buffer_type_t

```
enum buffer_type_t
```

Block buffer types for different storage mechanisms.

Enumerator

BUFFER_TYPE_MEMORY	Direct memory access (current implementation)
BUFFER_TYPE_HARDWARE	Future: Hardware register blocks.
BUFFER_TYPE_STORAGE	Future: Persistent storage blocks.
BUFFER_TYPE_NETWORK	Future: Network packet buffers.

7.365.4 Function Documentation

7.365.4.1 blk_vm_check_epoch()

```
void blk_vm_check_epoch (
            VM * vm )
```

Discards vm->blk_vm_lbn[]/cbuf[]/dirty[] if the device chain has changed since last validated (see this function's own doc comment in block_words.c for why).

Exposed (Phase 8 v3, 2026-09-23) so callers outside this file that read vm->blk_vm_lbn[] directly (MOVE/↩ CMOVE's cross-device block-copy check, memory_words.c/string_words.c) go through the same invalidation contract blk_vm_find() already uses internally, rather than a second, divergent copy of this logic.

Parameters

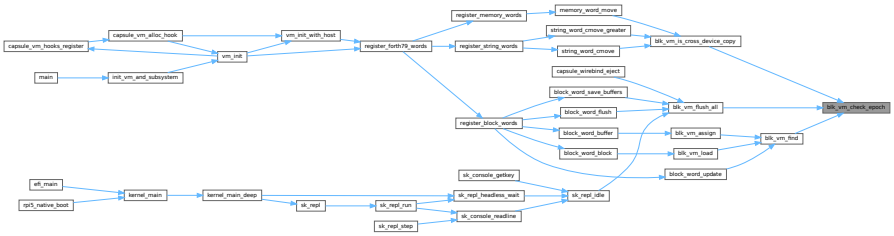
vm	Pointer to the Forth virtual machine instance

References blk_subsys_epoch(), VM::blk_vm_cbuf, VM::blk_vm_dirty, VM::blk_vm_epoch, VM::blk_vm_lbn, BLK_VM_SLOTS, and epoch.

Referenced by blk_vm_find(), blk_vm_flush_all(), and blk_vm_is_cross_device_copy().

Here is the call graph for this function:

Here is the caller graph for this function:



7.365.4.2 blk_vm_flush_all()

```
void blk_vm_flush_all (
            VM * vm )
```

Sync every dirty VM block-window slot to the C-layer block cache, then flush the whole block subsystem to physical media – the complete SAVE-BUFFERS implementation (unlike save_all_buffers() above, which only calls blk_flush() and so misses any BUFFER-modified-but-not-yet-UPDATE'd content still sitting only in vm->memory's window).

Cheap to call when nothing is dirty – every check inside is a small fixed-size scan, no I/O happens unless something actually needs writing. Safe to call from outside word dispatch (e.g. a periodic idle-tick auto-flush); vm must be non-NULL.

Parameters

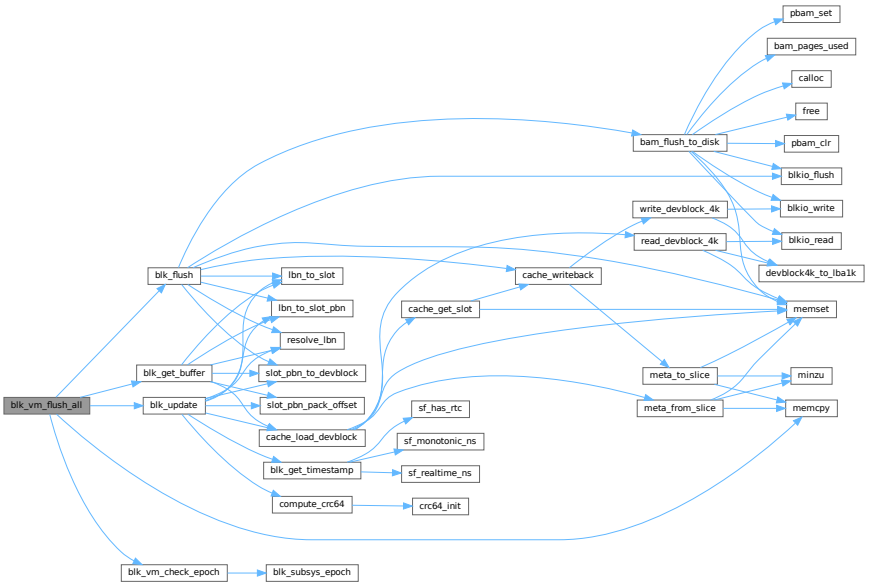
vm	Pointer to the Forth virtual machine instance

References base, blk_flush(), blk_get_buffer(), blk_update(), VM::blk_vm_cbuf, blk_vm_check_epoch(),

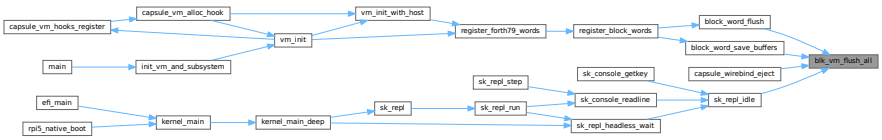
VM::blk_vm_dirty, VM::blk_vm_lbn, BLK_VM_SLOTS, BLK_VM_WINDOW_BASE, BLOCK_SIZE, memcpy(), and VM::memory.

Referenced by block_word_flush(), block_word_save_buffers(), capsule_wirebind_eject(), and sk_repl_idle().

Here is the call graph for this function:



Here is the caller graph for this function:



7.365.4.3 blk_vm_is_cross_device_copy()

```
int blk_vm_is_cross_device_copy (
            VM * vm,
            vaddr_t addr1,
            vaddr_t addr2 )
```

True if addr1/addr2 are both block-window addresses currently loaded from two different physical devices (Phase 8 v3, 2026-09-23) – the check MOVE/CMOVE/CMOVE> call before copying to refuse a same-VM, cross-device raw block copy.

See this function's own doc comment in block_words.c for exactly what is and isn't flagged.

Parameters

vm	VM performing the copy
addr1	first VM offset (source or destination, order doesn't matter)
addr2	second VM offset

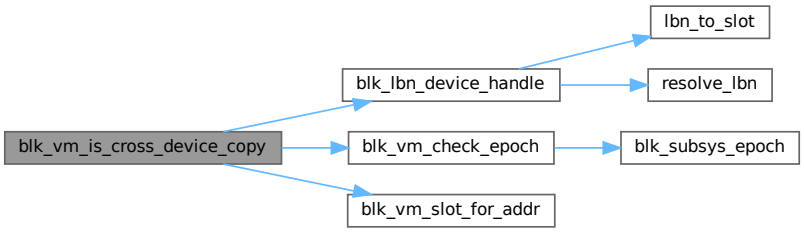
Returns

1 if this copy should be refused, 0 otherwise

References blk_lbn_device_handle(), blk_vm_check_epoch(), VM::blk_vm_lbn, and blk_vm_slot_for_addr().

Referenced by memory_word_move(), string_word_cmove(), and string_word_cmove_greater().

Here is the call graph for this function:



Here is the caller graph for this function:

7.365.4.4 blk_vm_slot_for_addr()

```
int blk_vm_slot_for_addr (
            vaddr_t addr )
```

Does `addr` fall inside the block I/O window? Pure address arithmetic against the window's fixed compile-time base/size – no VM state needed.

Exposed (Phase 8 v3, 2026-09-23) for MOVE/CMOVE/CMOVE>'s cross-device block-copy check.

Parameters

addr	VM offset to test

Returns

slot index (0..BLK_VM_SLOTS-1) if inside the window, -1 otherwise

References BLK_VM_WINDOW_BASE, BLK_VM_WINDOW_SIZE, and BLOCK_SIZE.

Referenced by blk_vm_is_cross_device_copy().

Here is the caller graph for this function:

7.365.4.5 empty_all_buffers()

```
void empty_all_buffers (
            VM * vm )
```

Empties all user block buffers.

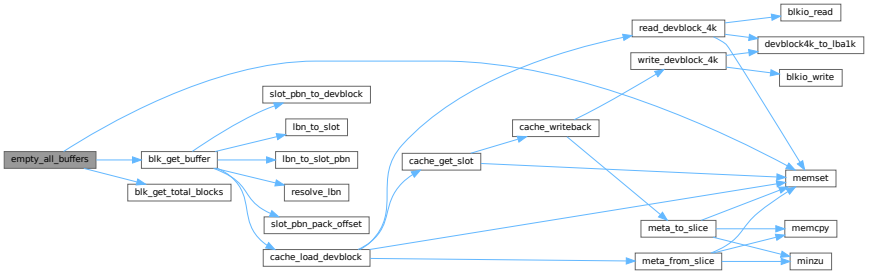
Parameters

vm	Pointer to the VM instance

References blk_get_buffer(), blk_get_total_blocks(), BLOCK_SIZE, memset(), and USER_BLOCKS_START.

Referenced by block_word_empty_buffers().

Here is the call graph for this function:



Here is the caller graph for this function:

7.365.4.6 get_block_buffer()

```
unsigned char * get_block_buffer (
            VM * vm,
            int block_num )
```

Gets a buffer for the specified block.

Parameters

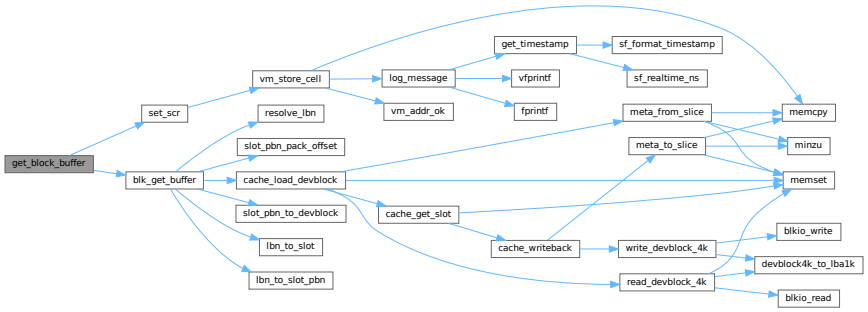
vm	Pointer to the VM instance
block_num	Block number to retrieve

Returns

Pointer to block buffer or NULL if invalid

References blk_get_buffer(), and set_scr().

Here is the call graph for this function:



7.365.4.7 get_empty_buffer()

```
unsigned char * get_empty_buffer (
            VM * vm,
            int block_num )
```

Gets an empty buffer for the specified block.

Parameters

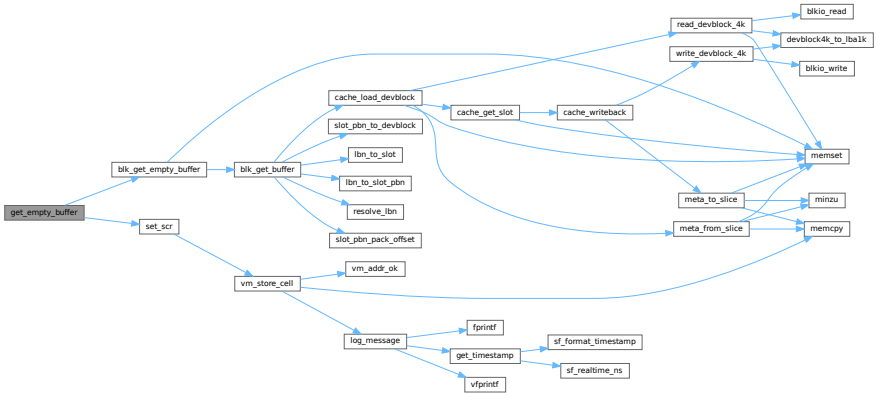
vm	Pointer to the VM instance
block_num	Block number to create

Returns

Pointer to empty block buffer or NULL if invalid

References blk_get_empty_buffer(), and set_scr().

Here is the call graph for this function:



7.365.4.8 init_block_system()

```
void init_block_system (
            VM * vm )
```

Initializes the block system.

Parameters

vm	Pointer to the Forth virtual machine instance

7.365.4.9 mark_buffer_dirty()

```
void mark_buffer_dirty (
            VM * vm )
```

Marks the current buffer as modified.

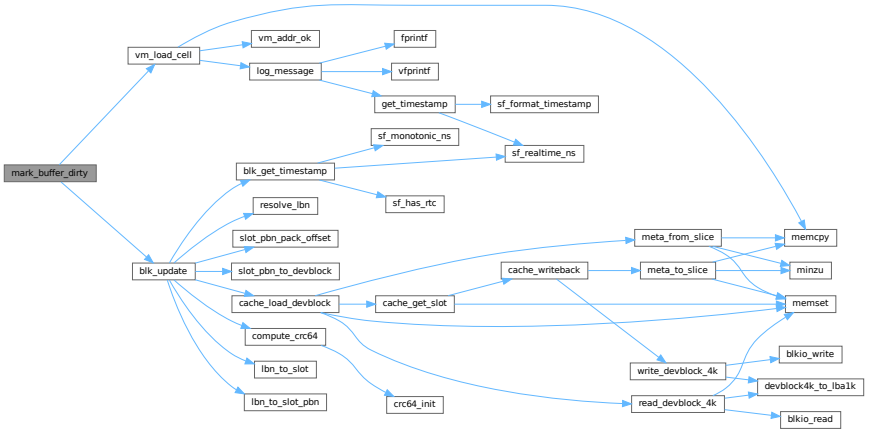
Parameters

vm	Pointer to the Forth virtual machine instance

References blk_update(), VM::scr_addr, and vm_load_cell().

Referenced by editor_word_edit(), and editor_word_s().

Here is the call graph for this function:



Here is the caller graph for this function:

7.365.4.10 register_block_words()

```
void register_block_words (
            VM * vm )
```

Registers all block and buffer words with the virtual machine.

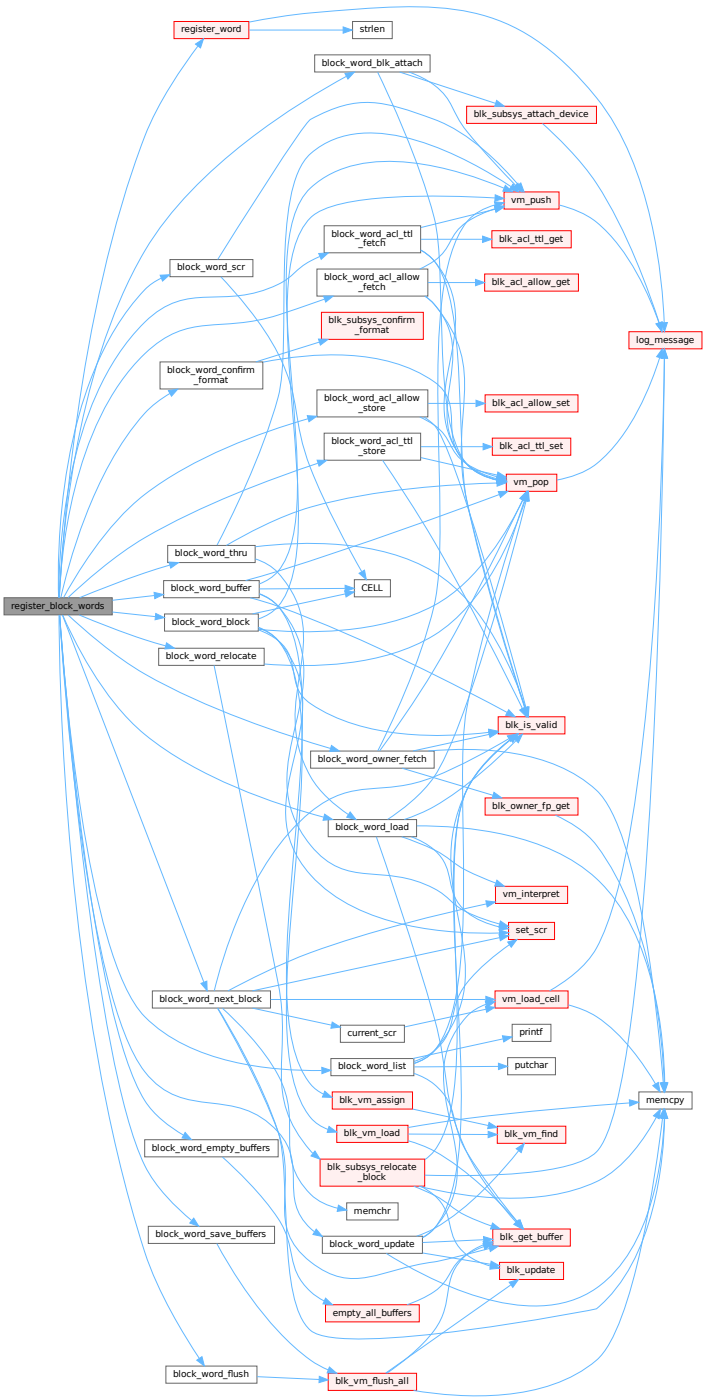
Parameters

vm	Pointer to the Forth virtual machine instance

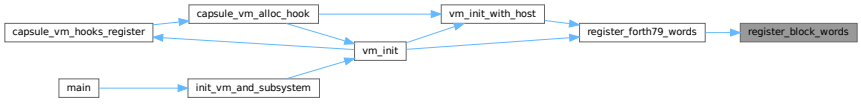
References block_word_acl_allow_fetch(), block_word_acl_allow_store(), block_word_acl_ttl_fetch(), block_word_acl_ttl_store(), block_word_blk_attach(), block_word_block(), block_word_buffer(), block_word_confirm_format(), block_word_empty_buffers(), block_word_flush(), block_word_list(), block_word_load(), block_word_next_block(), block_word_owner_fetch(), block_word_relocate(), block_word_save_buffers(), block_word_scr(), block_word_thru(), block_word_update(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



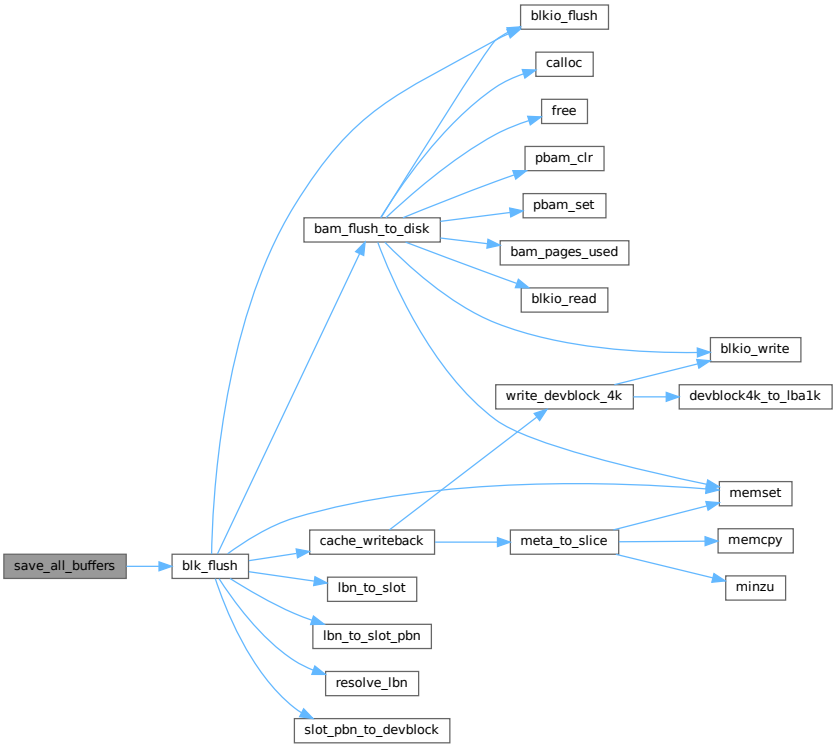
7.365.4.11 save_all_buffers()

```
void save_all_buffers (
            VM * vm )
```

References blk_flush().

Referenced by editor_word_edit().

Here is the call graph for this function:

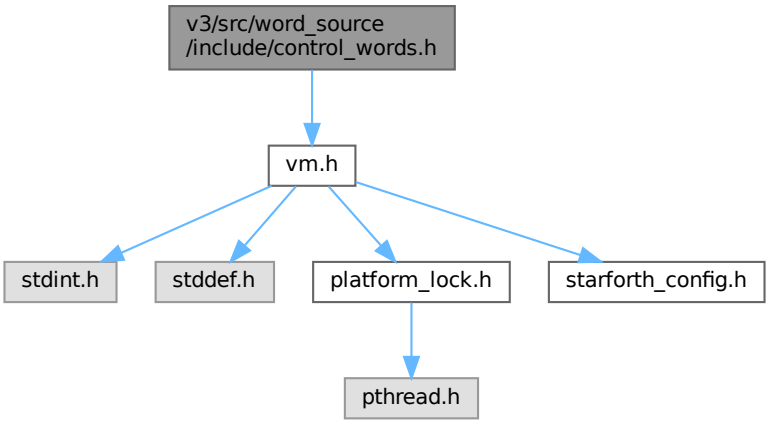


Here is the caller graph for this function:

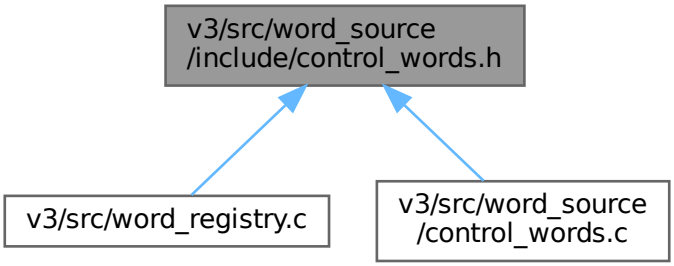
7.366 v3/src/word_source/include/control_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for control_words.h:



This graph shows which files directly or indirectly include this file:



Functions

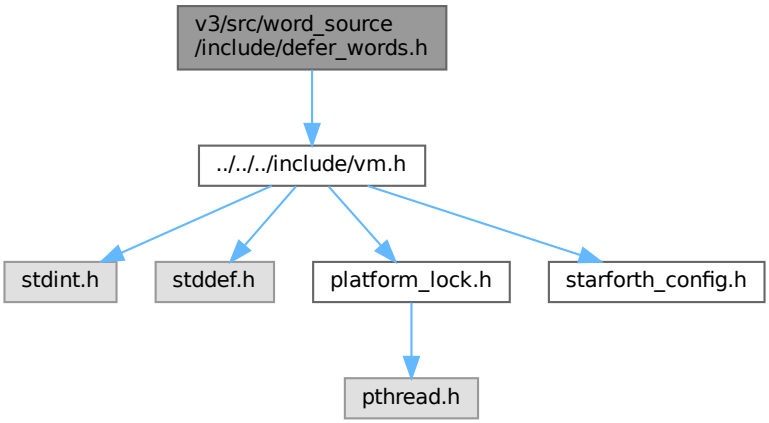
- void register_control_words (VM *vm)

  Registers all control flow words with the Forth virtual machine.

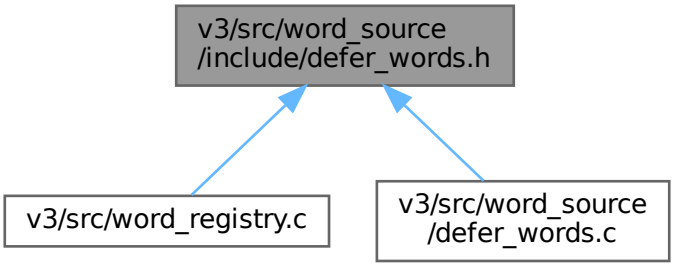
7.367 v3/src/word_source/include/defer_words.h File Reference

```
#include "../../../include/vm.h"
```

Include dependency graph for defer_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_defer_words (VM *vm)

7.367.1 Function Documentation

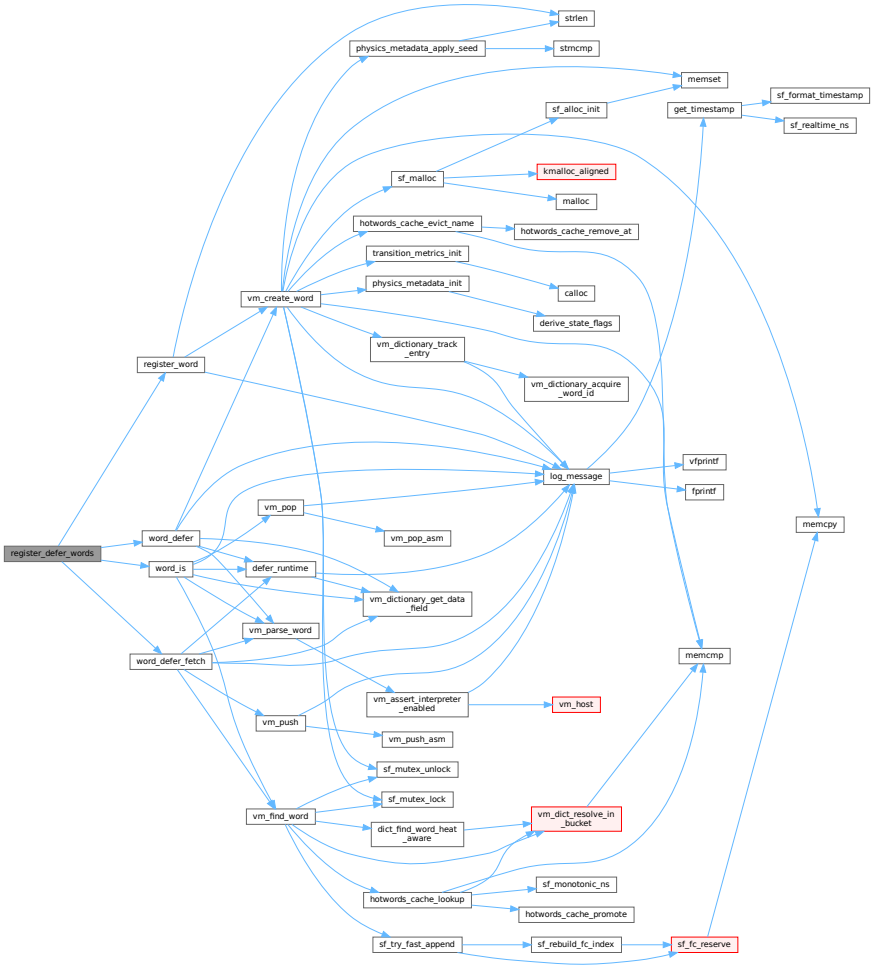
7.367.1.1 register_defer_words()

```
void register_defer_words (
            VM * vm )
```

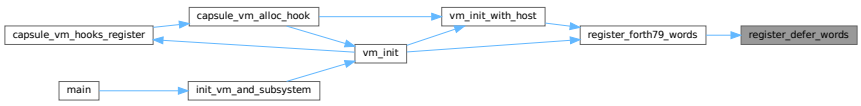
References register_word(), word_defer(), word_defer_fetch(), and word_is().

Referenced by register_forth79_words().

Here is the call graph for this function:



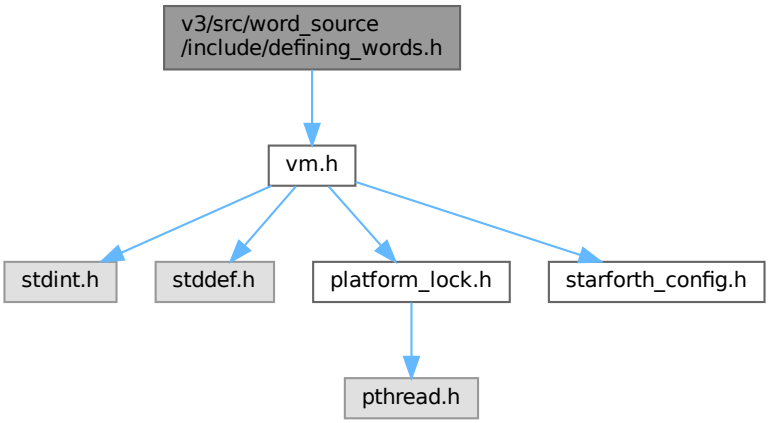
Here is the caller graph for this function:



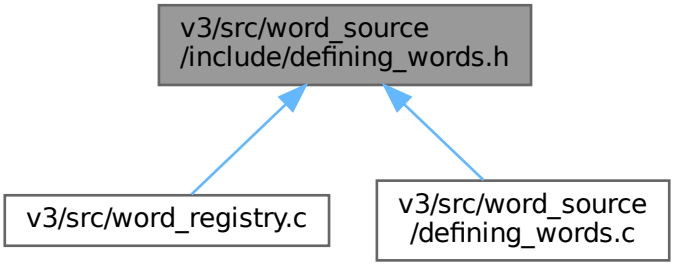
7.368 v3/src/word_source/include/defining_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for defining_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_defining_words (VM *vm)
  Register all defining words in the dictionary.

7.368.1 Function Documentation

7.368.1.1 register_defining_words()

```
void register_defining_words (
            VM * vm )
```

Register all defining words in the dictionary.

Registers core defining words like :, ;, CREATE, CONSTANT, VARIABLE, and their support words like IMMEDIATE, STATE, etc.

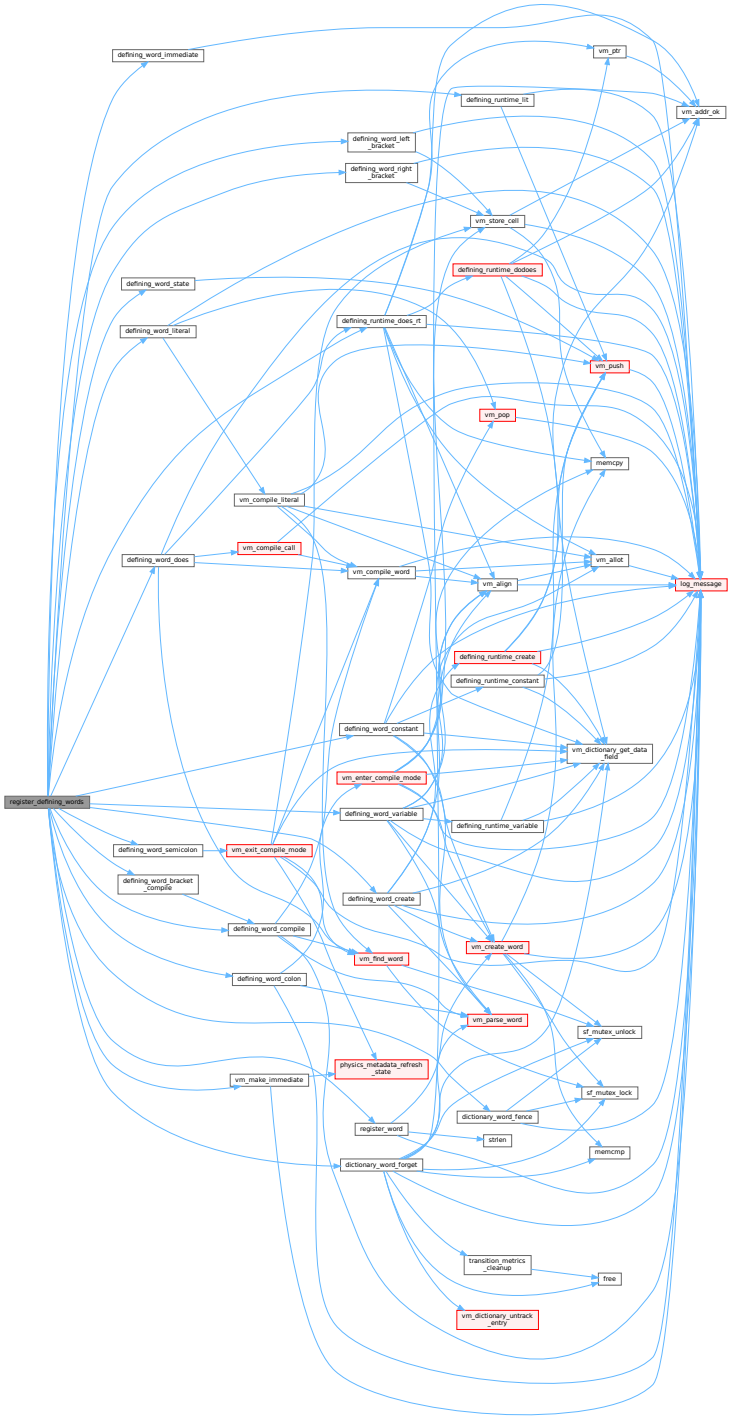
Parameters

vm	Pointer to the VM context

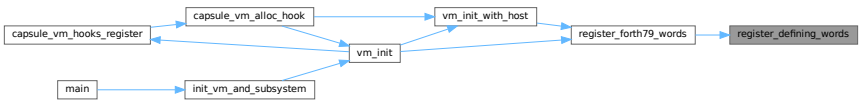
References defining_runtime_does_rt(), defining_runtime_lit(), defining_word_bracket_compile(), defining_word_colon(), defining_word_compile(), defining_word_constant(), defining_word_create(), defining_word_does(), defining_word_immediate(), defining_word_left_bracket(), defining_word_literal(), defining_word_right_bracket(), defining_word_semicolon(), defining_word_state(), defining_word_variable(), dictionary_word_fence(), dictionary_word_forget(), register_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



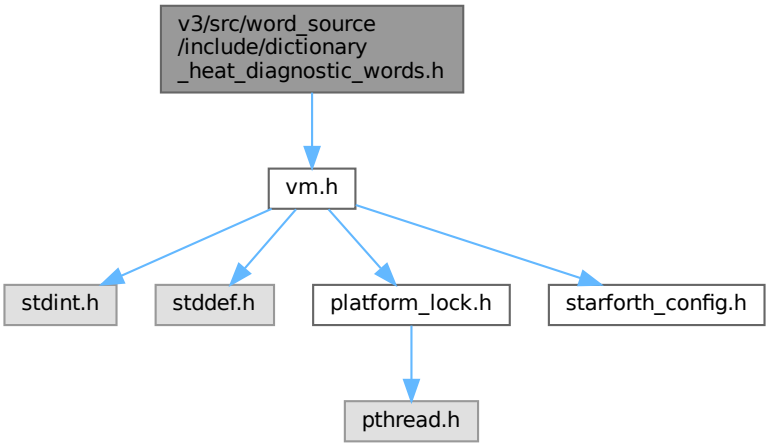
Here is the caller graph for this function:



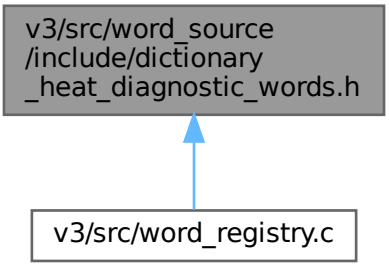
7.369 v3/src/word_source/include/dictionary_heat_diagnostic_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for dictionary_heat_diagnostic_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_dictionary_heat_diagnostic_words (VM *vm)

  Register all dictionary heat diagnostic words with the VM.

7.369.1 Function Documentation

7.369.1.1 register_dictionary_heat_diagnostic_words()

```
void register_dictionary_heat_diagnostic_words (
            VM * vm )
```

Register all dictionary heat diagnostic words with the VM.

Register all dictionary heat diagnostic words with the VM.

Registers: `HEAT-PERCENTILES`, `LOOKUP-STRATEGY@`, `LOOKUP-STRATEGY!`, `REORG-BUCKETS`, `SHOW-HEAT-OPTIMIZATION`, `COMPARE-LOOKUPS`. Called during VM bootstrap.

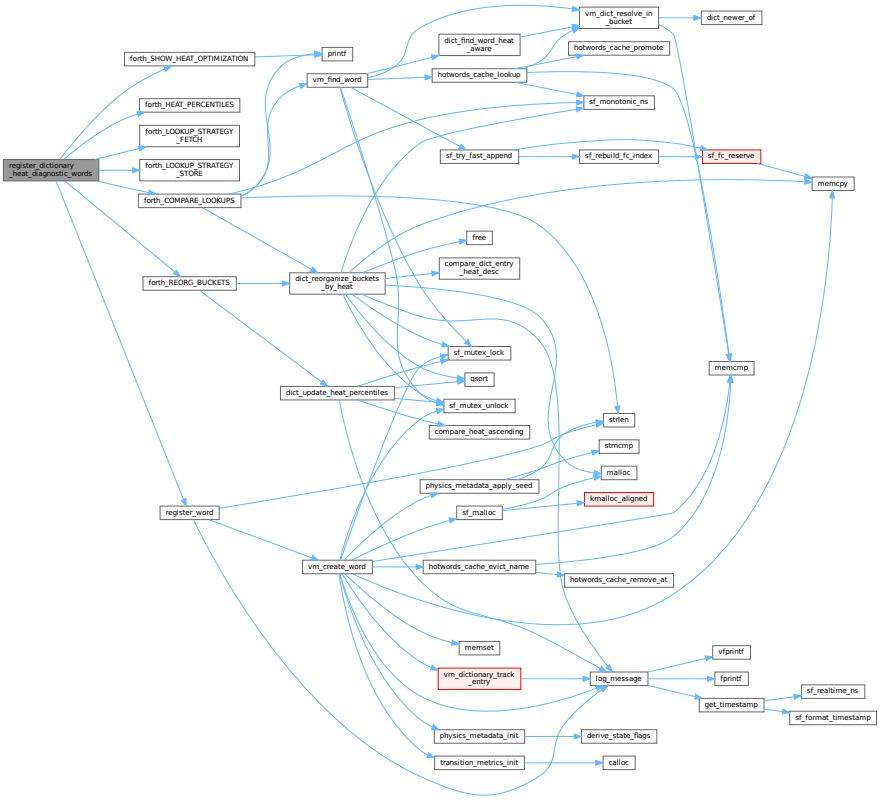
Parameters

vm	Active VM to register words into

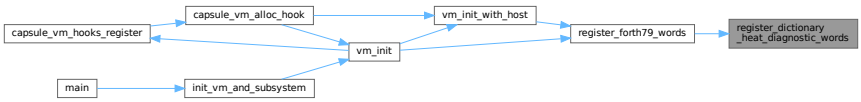
References forth_COMPARE_LOOKUPS(), forth_HEAT_PERCENTILES(), forth_LOOKUP_STRATEGY_FETCH(), forth_LOOKUP_STRATEGY_STORE(), forth_REORG_BUCKETS(), forth_SHOW_HEAT_OPTIMIZATION(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:

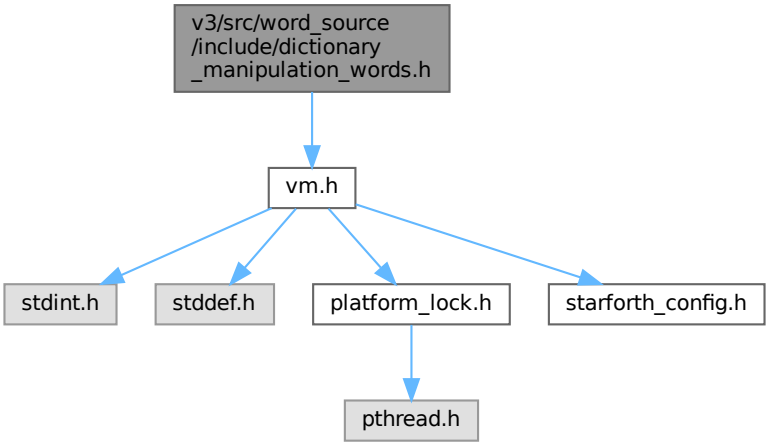


Here is the caller graph for this function:

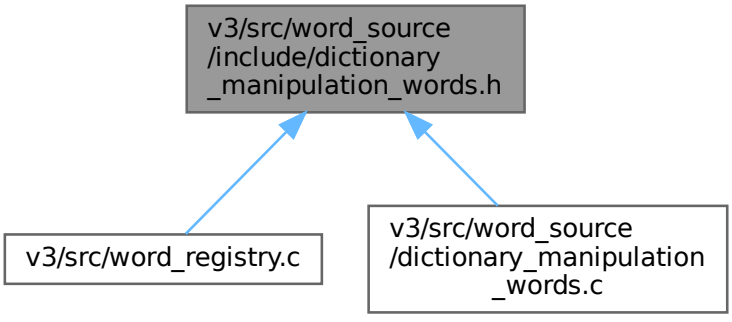


7.370 v3/src/word_source/include/dictionary_manipulation_words.h File Reference

`#include "vm.h"`
Include dependency graph for dictionary_manipulation_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_dictionary_manipulation_words (VM *vm)

  Register all dictionary manipulation words with the virtual machine.

7.370.1 Function Documentation

7.370.1.1 register_dictionary_manipulation_words()

```
void register_dictionary_manipulation_words (
            VM * vm )
```

Register all dictionary manipulation words with the virtual machine.

Parameters

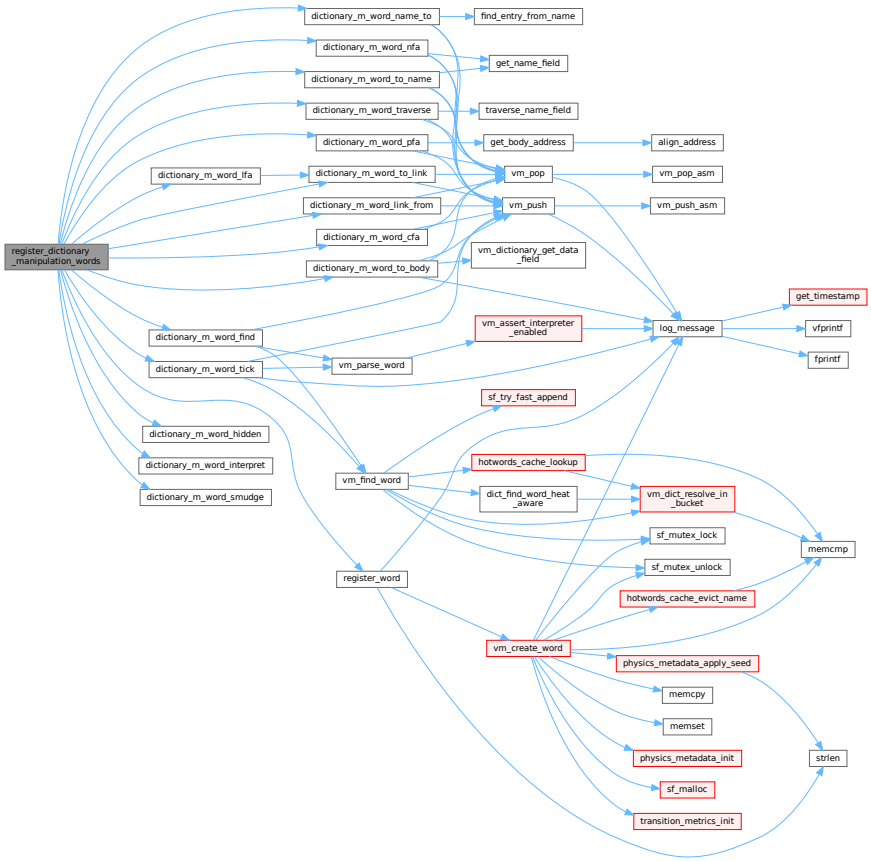
vm	Pointer to the virtual machine instance

This function registers all FORTH-79 standard dictionary manipulation words with the provided virtual machine instance. These words are essential for dictionary management and word definition functionality.

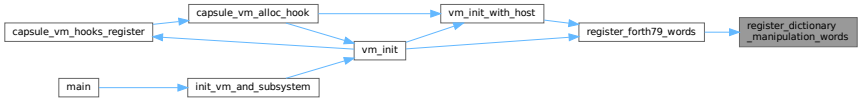
References dictionary_m_word_cfa(), dictionary_m_word_find(), dictionary_m_word_hidden(), dictionary_m_word_interpret(), dictionary_m_word_lfa(), dictionary_m_word_link_from(), dictionary_m_word_name_to(), dictionary_m_word_nfa(), dictionary_m_word_pfa(), dictionary_m_word_smudge(), dictionary_m_word_tick(), dictionary_m_word_to_body(), dictionary_m_word_to_link(), dictionary_m_word_to_name(), dictionary_m_word_traverse(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



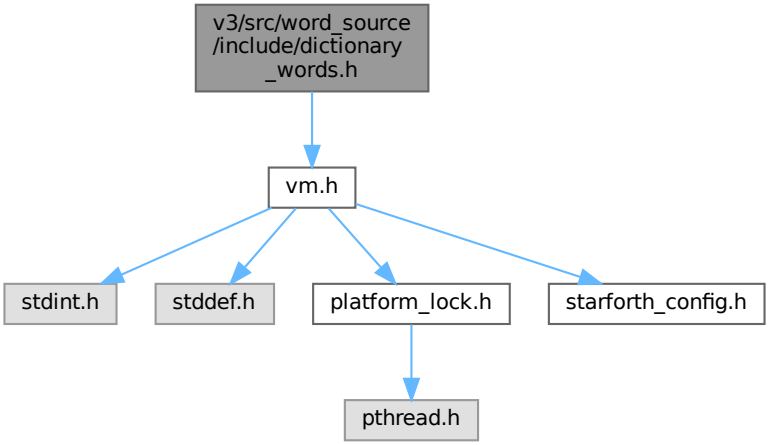
Here is the caller graph for this function:



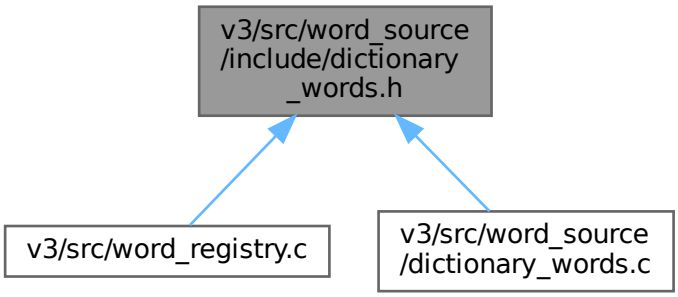
7.371 v3/src/word_source/include/dictionary_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for dictionary_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_dictionary_words (VM *vm)

  Registers all dictionary and compilation words with the Forth VM.

7.371.1 Function Documentation

7.371.1.1 register_dictionary_words()

```
void register_dictionary_words (
            VM * vm )
```

Registers all dictionary and compilation words with the Forth VM.

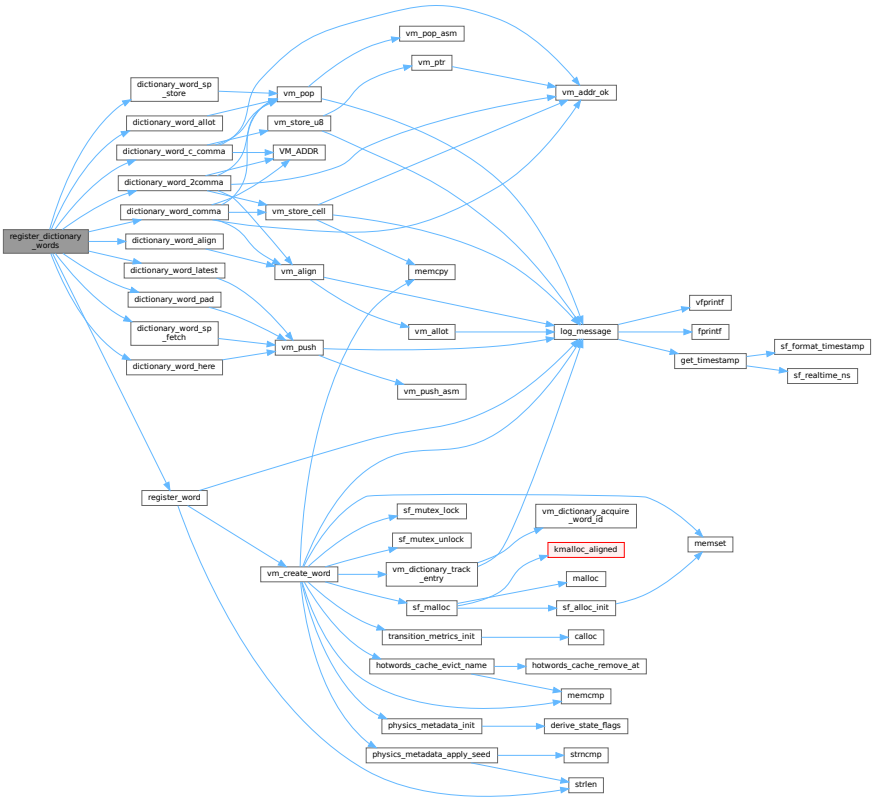
Parameters

vm	Pointer to the Forth virtual machine instance

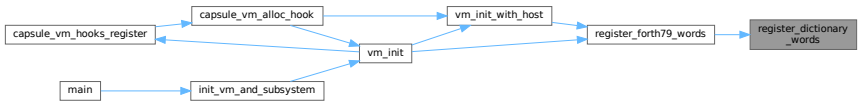
References dictionary_word_2comma(), dictionary_word_align(), dictionary_word_allot(), dictionary_word_c_comma(), dictionary_word_comma(), dictionary_word_here(), dictionary_word_latest(), dictionary_word_pad(), dictionary_word_sp_fetch(), dictionary_word_sp_store(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



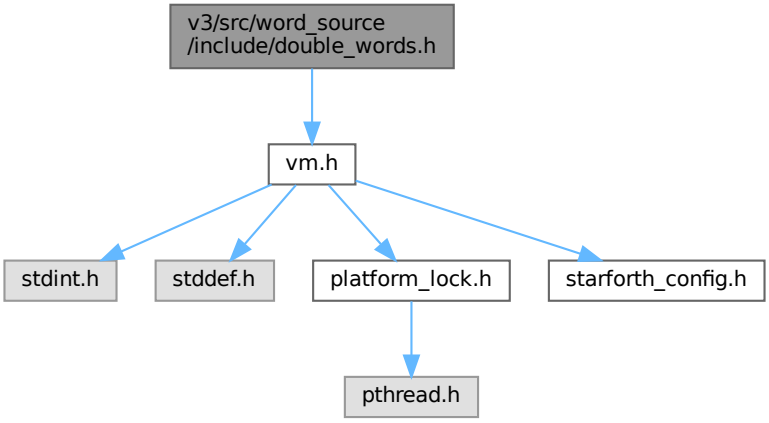
Here is the caller graph for this function:



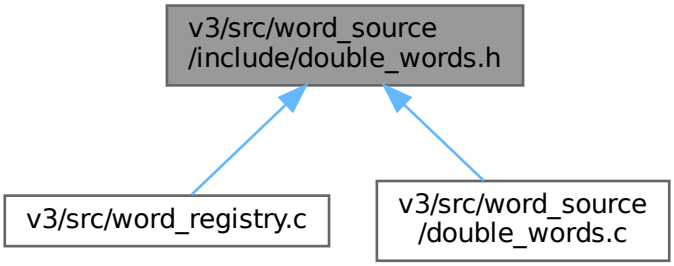
7.372 v3/src/word_source/include/double_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for double_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_double_words (VM *vm)

  Register all double number words.

7.372.1 Function Documentation

7.372.1.1 register_double_words()

```
void register_double_words (
            VM * vm )
```

Register all double number words.

Registers all double-precision number operations with the virtual machine.

Parameters

vm	Pointer to the virtual machine state

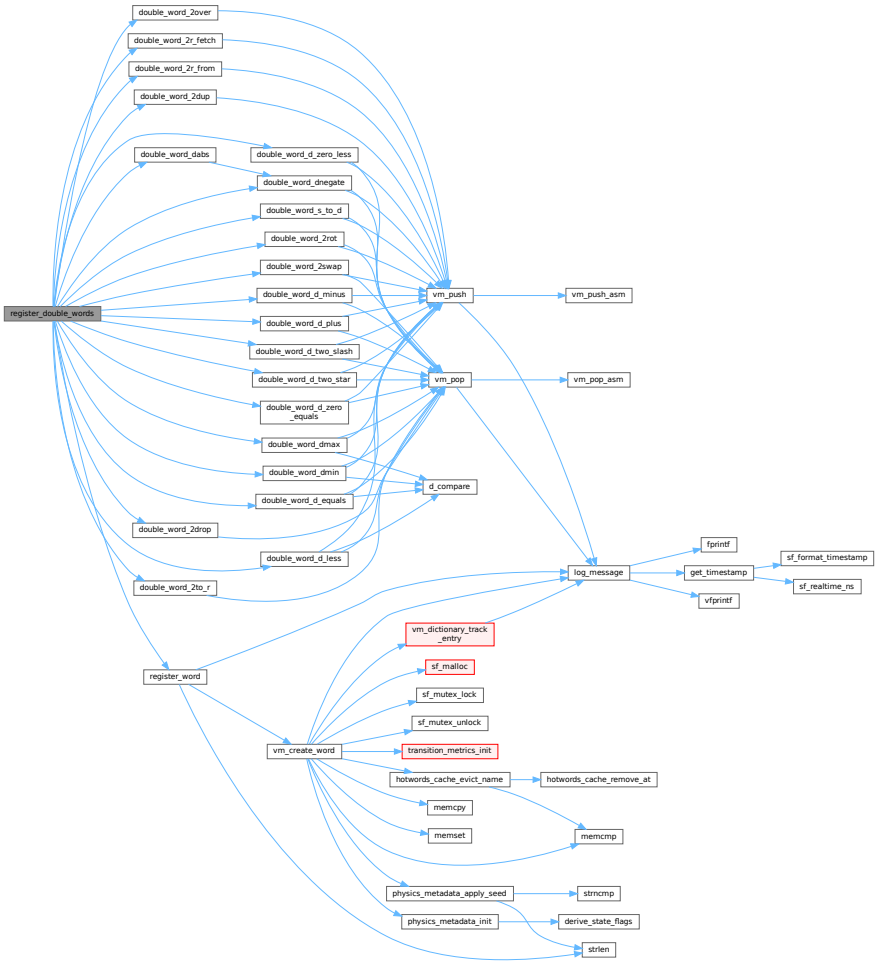
Note

This function must be called during VM initialization.

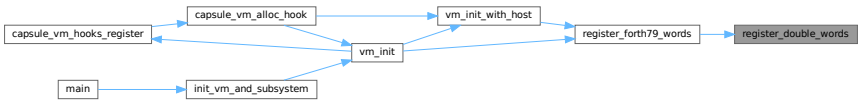
References double_word_2drop(), double_word_2dup(), double_word_2over(), double_word_2r_fetch(), double_word_2r_from(), double_word_2rot(), double_word_2swap(), double_word_2to_r(), double_word_d_equals(), double_word_d_less(), double_word_d_minus(), double_word_d_plus(), double_word_d_two_slash(), double_word_d_two_star(), double_word_d_zero_equals(), double_word_d_zero_less(), double_word_dabs(), double_word_dmax(), double_word_dmin(), double_word_dnegate(), double_word_s_to_d(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



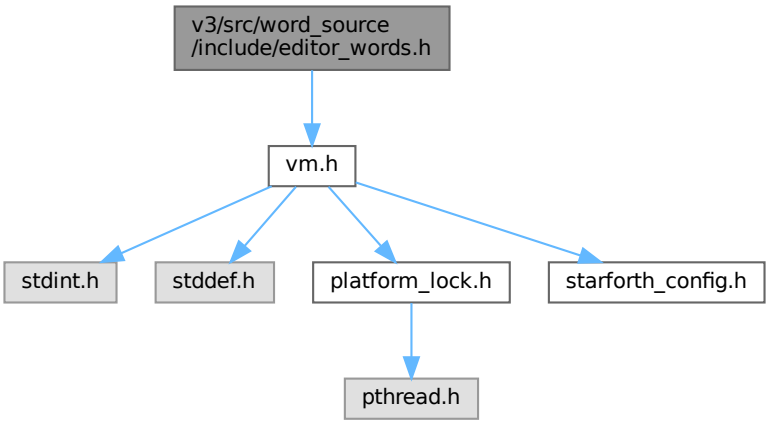
Here is the caller graph for this function:



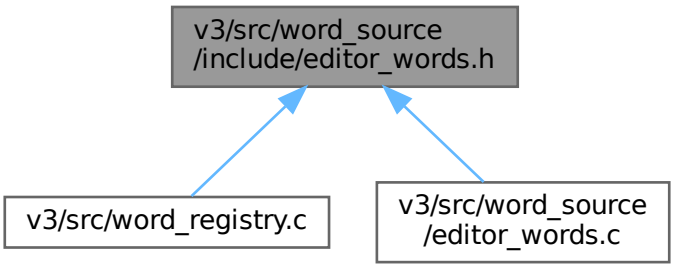
7.373 v3/src/word_source/include/editor_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for editor_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_editor_words (VM *vm)

  Register all editor words with the Forth virtual machine.

7.373.1 Function Documentation

7.373.1.1 register_editor_words()

```
void register_editor_words (
            VM * vm )
```

Register all editor words with the Forth virtual machine.

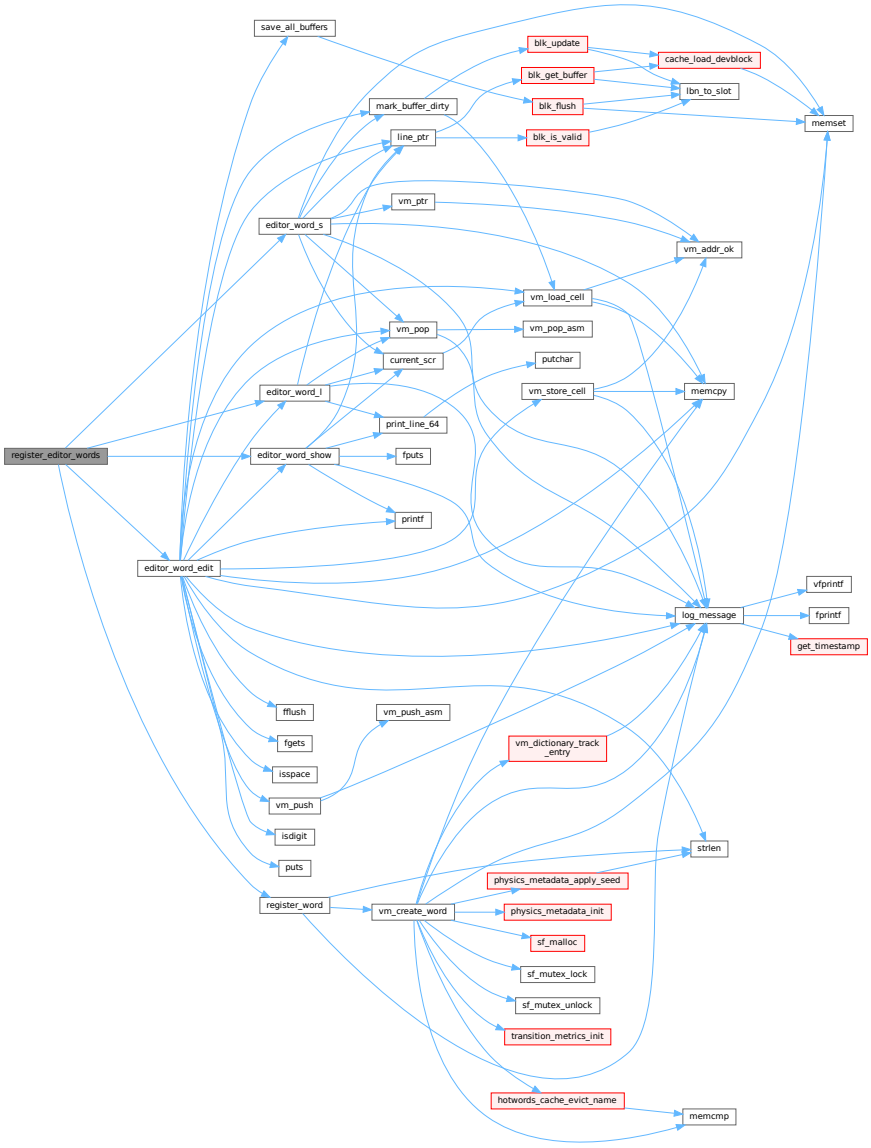
Parameters

vm	Pointer to the Forth virtual machine instance

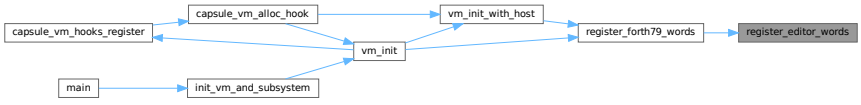
References editor_word_edit(), editor_word_l(), editor_word_s(), editor_word_show(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



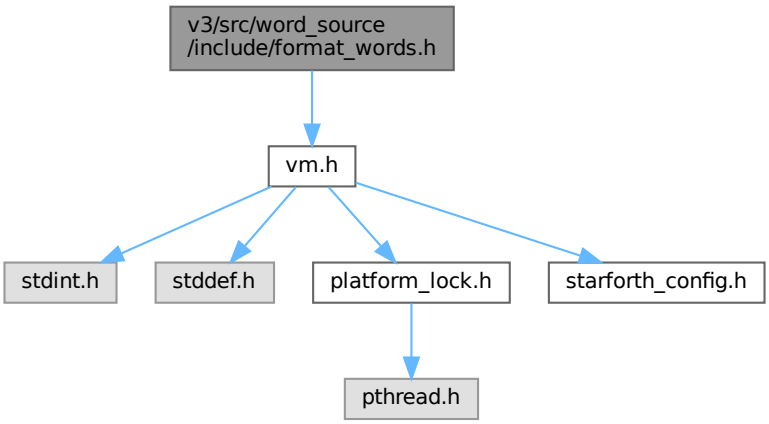
Here is the caller graph for this function:



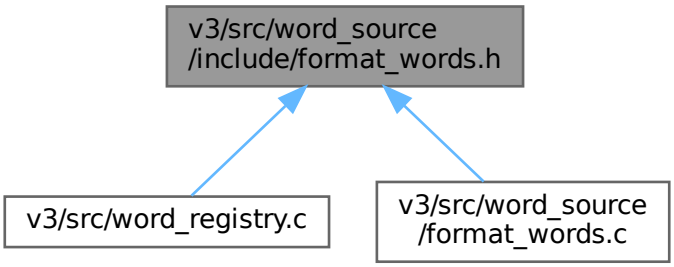
7.374 v3/src/word_source/include/format_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for format_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_format_words (VM *vm)

  Registers all formatting and numeric conversion words with the VM.

7.374.1 Function Documentation

7.374.1.1 register_format_words()

```
void register_format_words (
            VM * vm )
```

Registers all formatting and numeric conversion words with the VM.

This function registers the standard FORTH formatting words including:

- Number output words (., .R, U., U.R, D., D.R, .S, ?)
- Picture number formatting (<#, #, #S, #>, HOLD, SIGN)
- Base conversion (BASE, DECIMAL, HEX, OCTAL)
- Memory dump (DUMP)

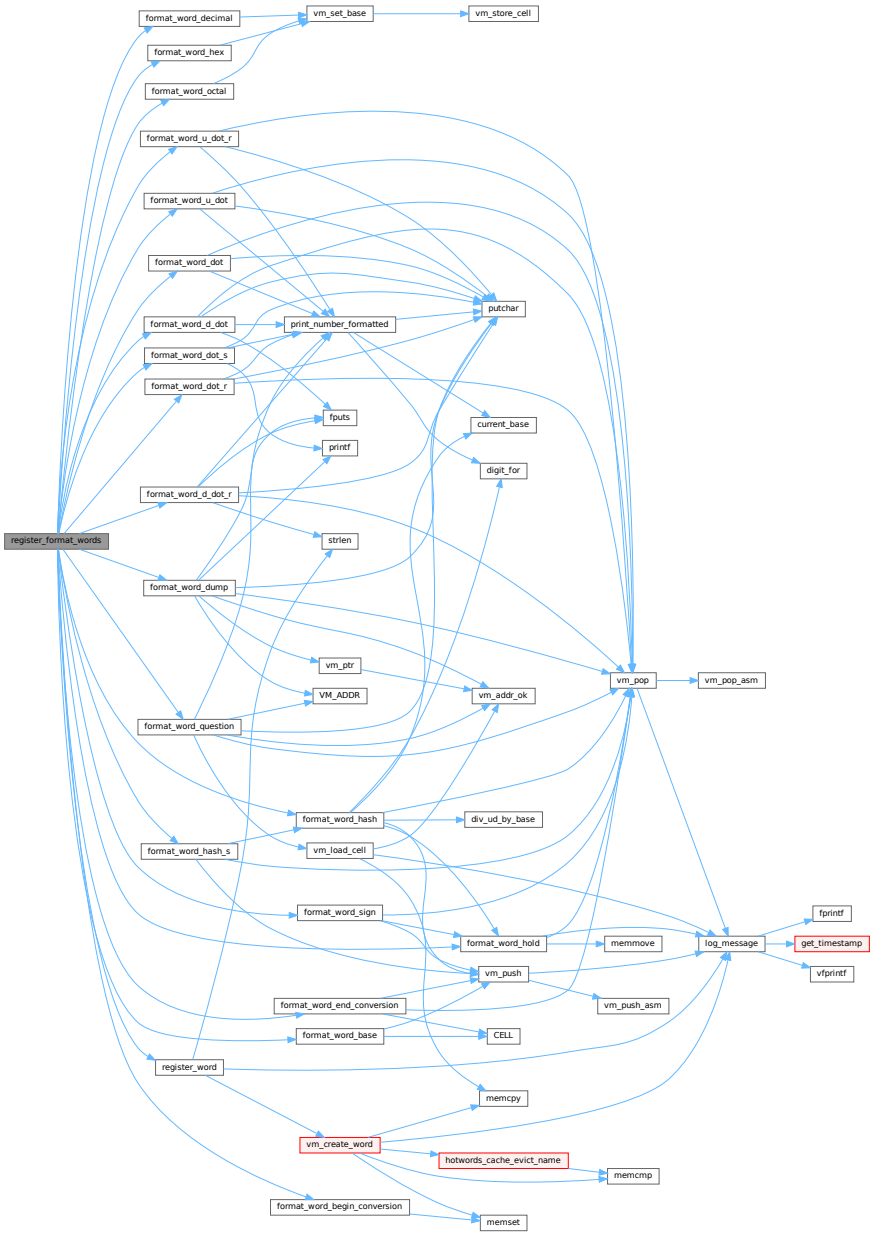
Parameters

vm	Pointer to the virtual machine instance

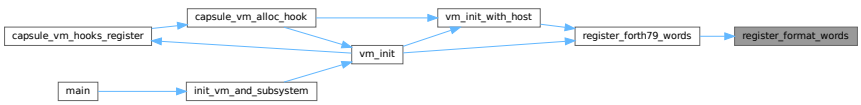
References format_word_base(), format_word_begin_conversion(), format_word_d_dot(), format_word_d_dot_r(), format_word_decimal(), format_word_dot(), format_word_dot_r(), format_word_dot_s(), format_word_dump(), format_word_end_conversion(), format_word_hash(), format_word_hash_s(), format_word_hex(), format_word_hold(), format_word_octal(), format_word_question(), format_word_sign(), format_word_u_dot(), format_word_u_dot_r(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



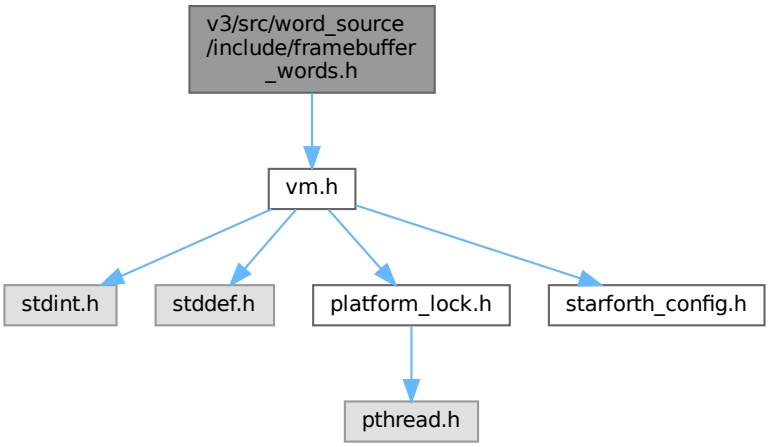
Here is the caller graph for this function:



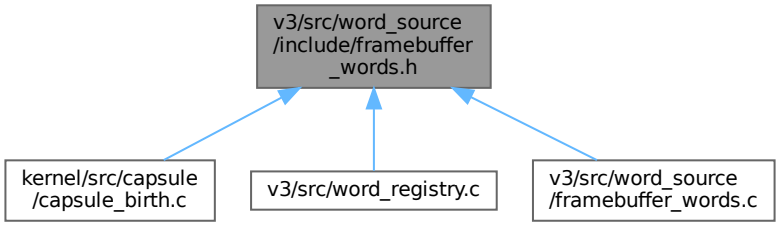
7.375 v3/src/word_source/include/framebuffer_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for framebuffer_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_framebuffer_words (VM *vm)

7.375.1 Function Documentation

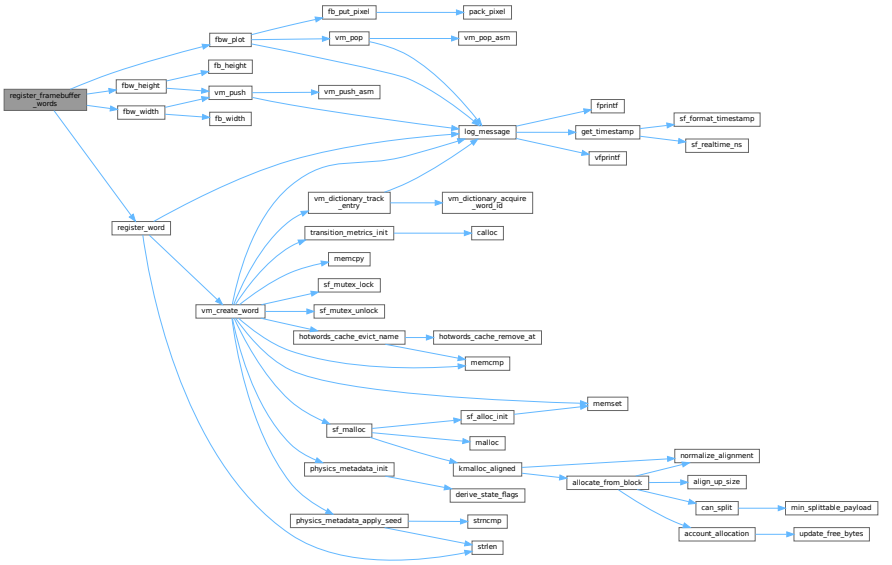
7.375.1.1 register_framebuffer_words()

```
void register_framebuffer_words (
            VM * vm )
```

References fbw_height(), fbw_plot(), fbw_width(), and register_word().

Referenced by capsule_birth_baby().

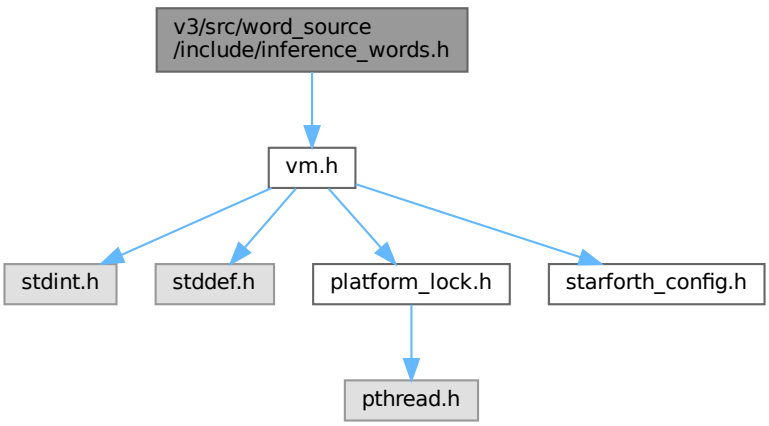
Here is the call graph for this function:



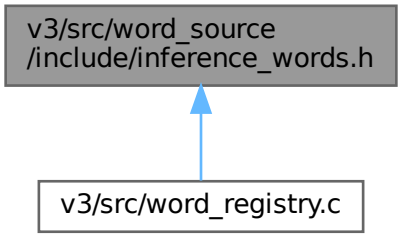
Here is the caller graph for this function:

7.376 v3/src/word_source/include/inference_words.h File Reference

`#include "vm.h"`
Include dependency graph for inference_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_inference_words (VM ∗vm)

  inference_words.h — Module 26: SSM inference engine + Jacquard FORTH words

7.376.1 Function Documentation

7.376.1.1 register_inference_words()

```
void register_inference_words (
            VM * vm )
```

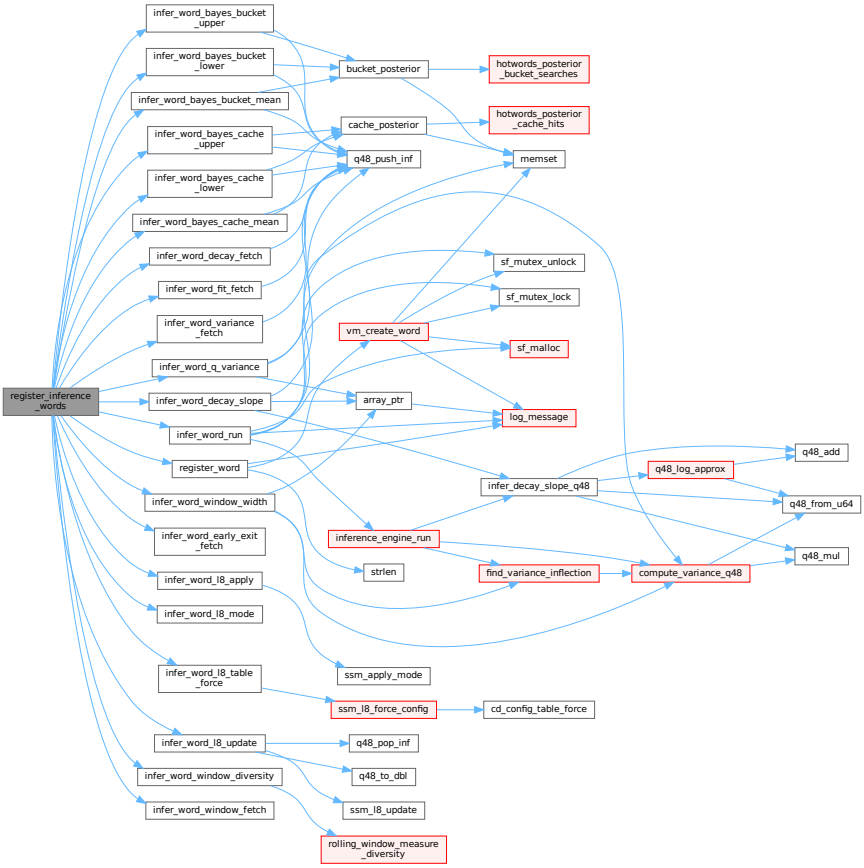
inference_words.h — Module 26: SSM inference engine + Jacquard FORTH words

Register all inference engine / Jacquard FORTH words with the VM. Module 26 in register_forth79_words().

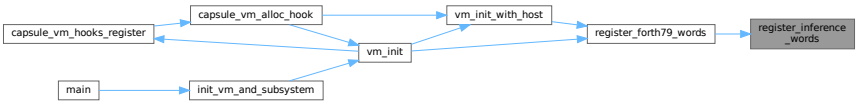
References infer_word_bayes_bucket_lower(), infer_word_bayes_bucket_mean(), infer_word_bayes_bucket_upper(), infer_word_bayes_cache_lower(), infer_word_bayes_cache_mean(), infer_word_bayes_cache_upper(), infer_word_decay_fetch(), infer_word_decay_slope(), infer_word_early_exit_fetch(), infer_word_fit_fetch(), infer_word_l8_apply(), infer_word_l8_mode(), infer_word_l8_table_force(), infer_word_l8_update(), infer_word_q_variance(), infer_word_run(), infer_word_variance_fetch(), infer_word_window_diversity(), infer_word_window_fetch(), infer_word_window_width(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



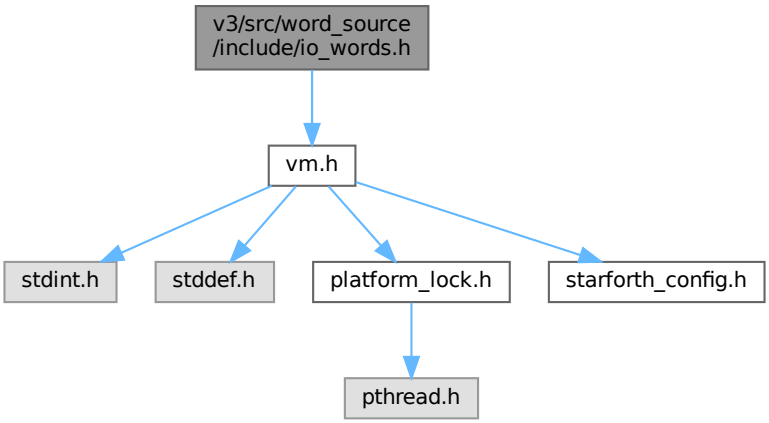
Here is the caller graph for this function:



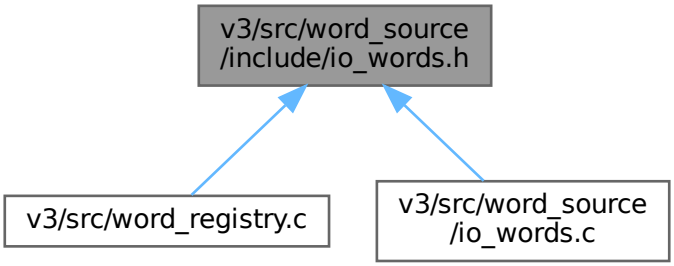
7.377 v3/src/word_source/include/io_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for io_words.h:



This graph shows which files directly or indirectly include this file:



Macros

- #define IO_WORDS_H
  < *Include guard*

Functions

- void register_io_words (VM *vm)
  Registers all I/O related FORTH words with the virtual machine.

7.377.1 Macro Definition Documentation

7.377.1.1 IO_WORDS_H

```
#define IO_WORDS_H
```

< Include guard

Include guard

7.377.2 Function Documentation

7.377.2.1 register_io_words()

```
void register_io_words (
            VM * vm )
```

Registers all I/O related FORTH words with the virtual machine.

Parameters

vm	Pointer to the virtual machine instance

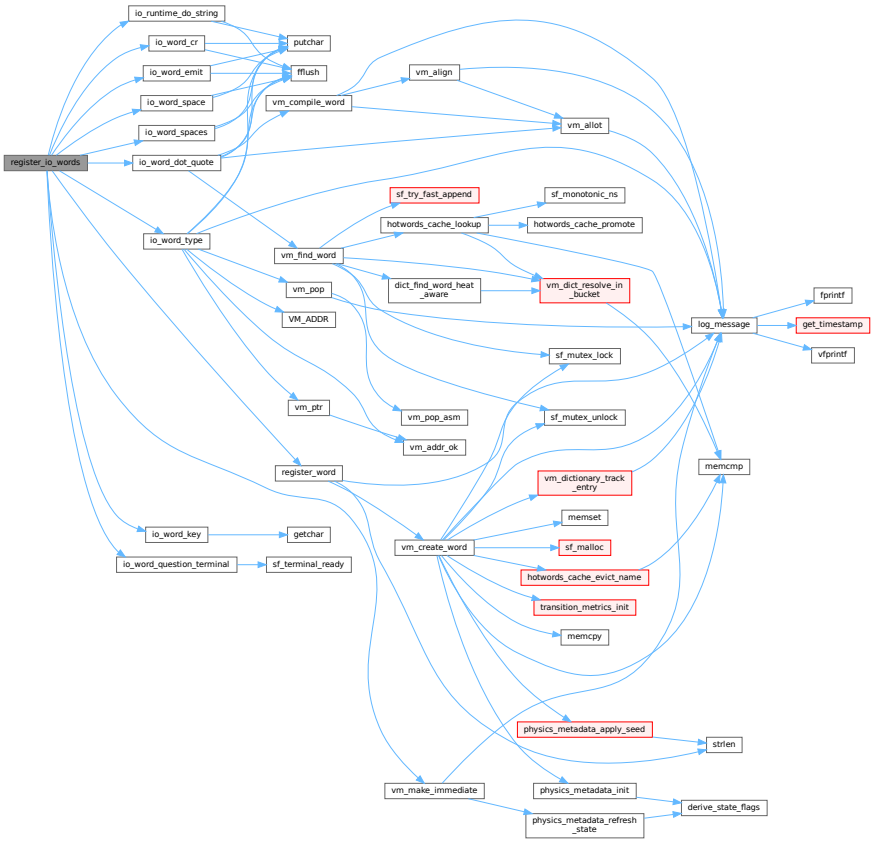
Registers the following FORTH-79 I/O & Terminal Words:

- EMIT (c –) Output character c
- CR (–) Output carriage return
- KEY (– c) Input character from keyboard
- ?TERMINAL (– flag) True if key pressed
- TYPE (addr u –) Output u characters from addr
- SPACE (–) Output one space
- SPACES (n –) Output n spaces

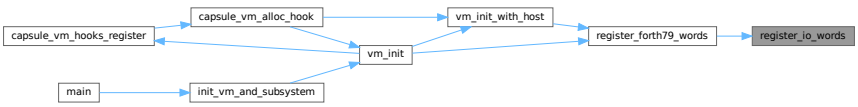
References io_runtime_do_string(), io_word_cr(), io_word_dot_quote(), io_word_emit(), io_word_key(), io_word_question_terminal(), io_word_space(), io_word_spaces(), io_word_type(), register_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



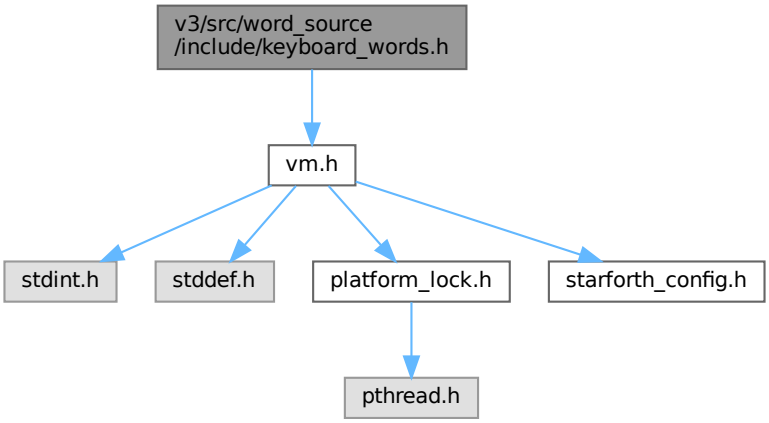
Here is the caller graph for this function:



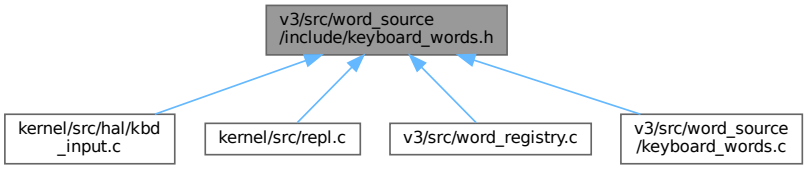
7.378 v3/src/word_source/include/keyboard_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for keyboard_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_keyboard_words (VM *vm)
- int sk_key_event_poll (uint16_t *keycode, int *pressed)

  FABRIC-0.md item 4.4v: shared C-level poll, one converged event stream (Linux input keycode namespace, all three architectures) – see KEY-EVENT's doc comment above for the full per-arch translation rationale.

7.378.1 Function Documentation

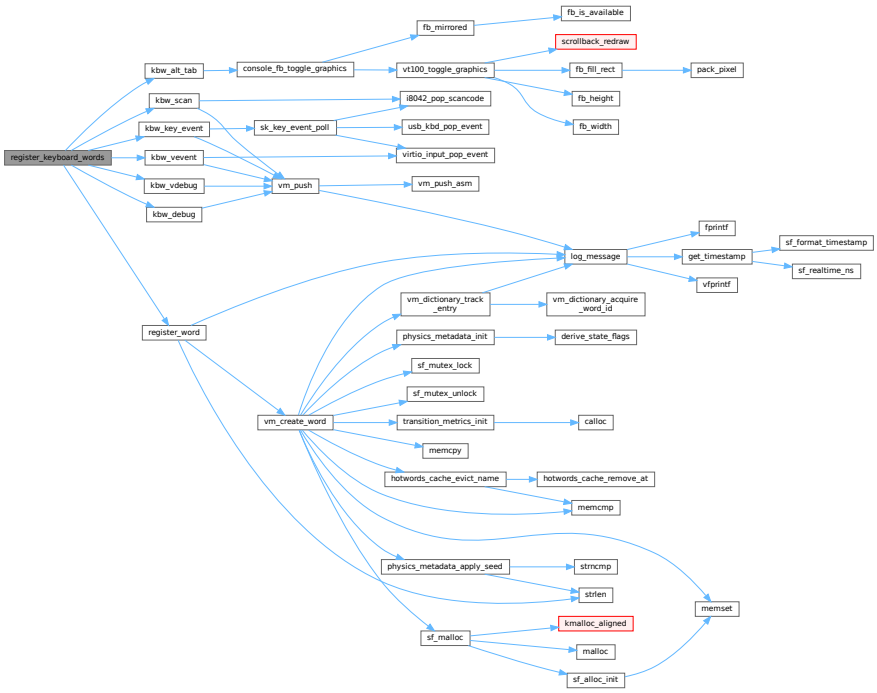
7.378.1.1 register_keyboard_words()

```
void register_keyboard_words (
            VM * vm )
```

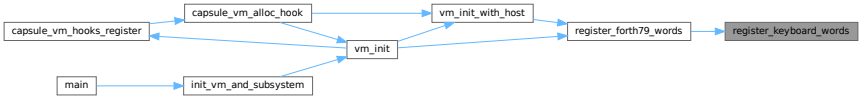
References kbw_alt_tab(), kbw_debug(), kbw_key_event(), kbw_scan(), kbw_vdebug(), kbw_vevent(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.378.1.2 sk_key_event_poll()

```
int sk_key_event_poll (
            uint16_t * keycode,
            int * pressed )
```

FABRIC-0.md item 4.4v: shared C-level poll, one converged event stream (Linux input keycode namespace, all three architectures) – see KEY-EVENT's doc comment above for the full per-arch translation rationale.

Used by both kbw_key_event() (the FORTH word) and the REPL keyboard bridge (repl.c), so there is exactly one implementation.

Parameters

keycode	Written with the Linux input keycode on success.
pressed	Written with 1 (press/repeat) or 0 (release) on success.

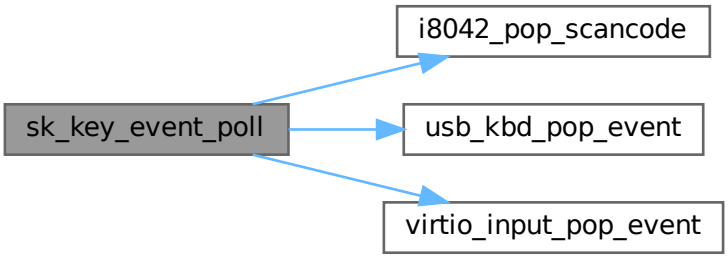
Returns

1 if an event was available, 0 otherwise.

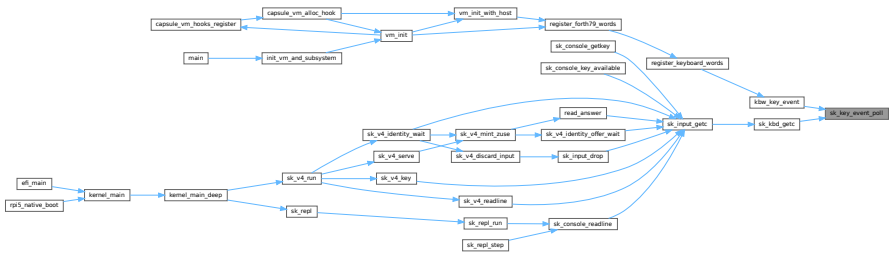
References i8042_pop_scancode(), keycode, pressed, usb_kbd_pop_event(), and virtio_input_pop_event().

Referenced by kbw_key_event(), and sk_kbd_getc().

Here is the call graph for this function:



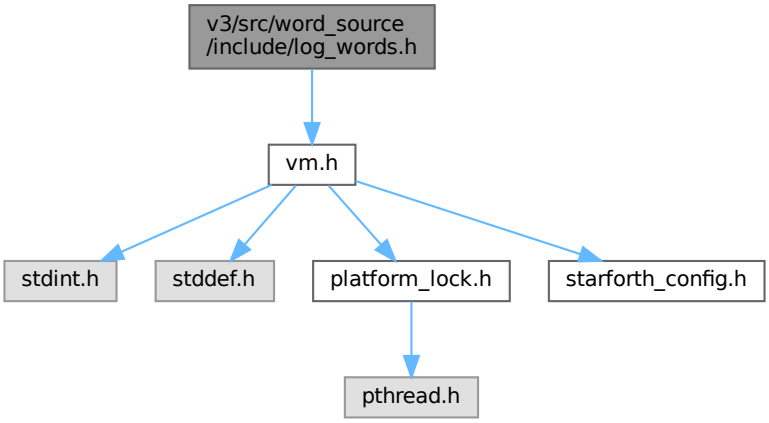
Here is the caller graph for this function:



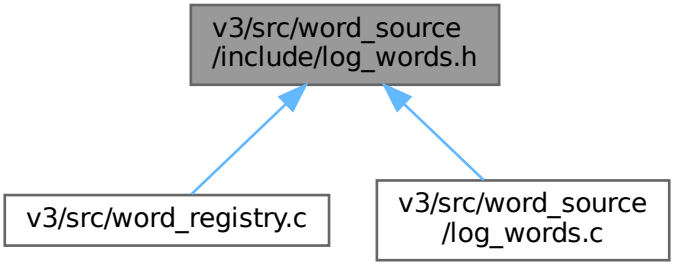
7.379 v3/src/word_source/include/log_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for log_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_log_words (VM *vm)

  Register all log words with the VM dictionary.

7.379.1 Function Documentation

7.379.1.1 register_log_words()

```
void register_log_words (
            VM * vm )
```

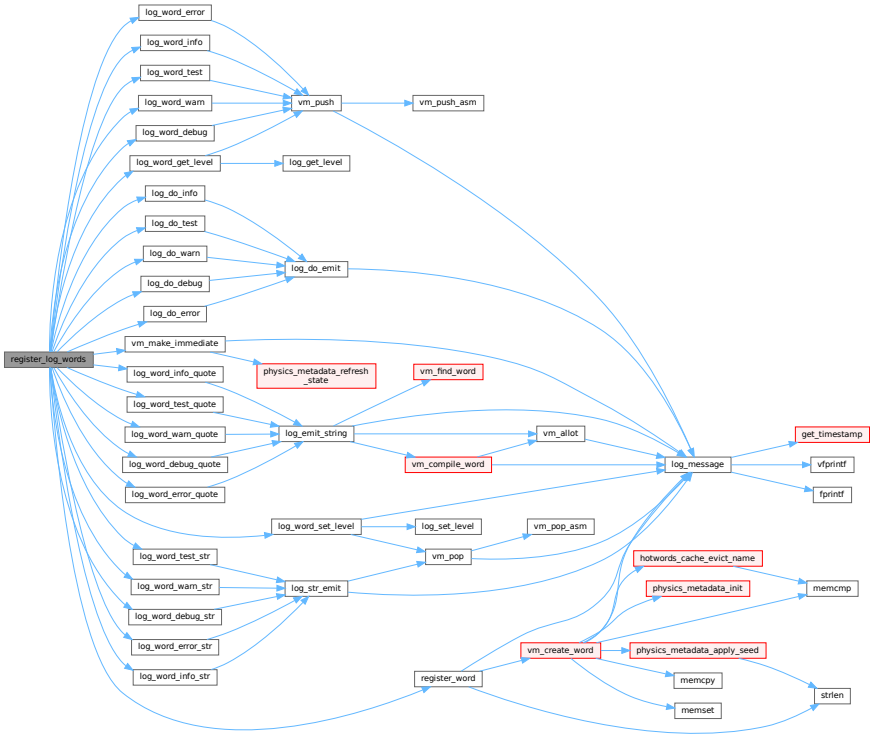
Register all log words with the VM dictionary.

Level constants: LOG-ERROR LOG-WARN LOG-INFO LOG-TEST LOG-DEBUG Level control: LOG-LEVEL! LOG-LEVEL@ Runtime (hidden): (do-log-error) (do-log-warn) (do-log-info) (do-log-test) (do-log-debug) String literals: LOG-ERROR" LOG-WARN" LOG-INFO" LOG-TEST" LOG-DEBUG" Stack string: LOG-ERROR-STR LOG-WARN-STR LOG-INFO-STR LOG-TEST-STR LOG-DEBUG-STR Kernel only: (LOG-APPEND-RAW) LOG-FLUSH

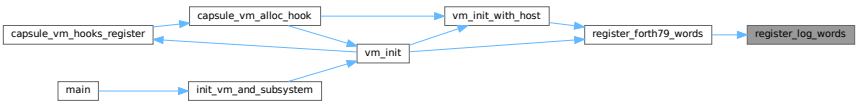
References log_do_debug(), log_do_error(), log_do_info(), log_do_test(), log_do_warn(), log_word_debug(), log_word_debug_quote(), log_word_debug_str(), log_word_error(), log_word_error_quote(), log_word_error_str(), log_word_get_level(), log_word_info(), log_word_info_quote(), log_word_info_str(), log_word_set_level(), log_word_test(), log_word_test_quote(), log_word_test_str(), log_word_warn(), log_word_warn_quote(), log_word_warn_str(), register_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



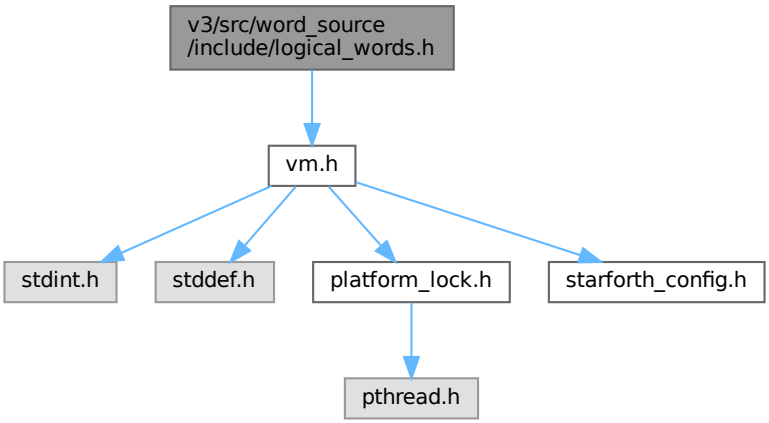
Here is the caller graph for this function:



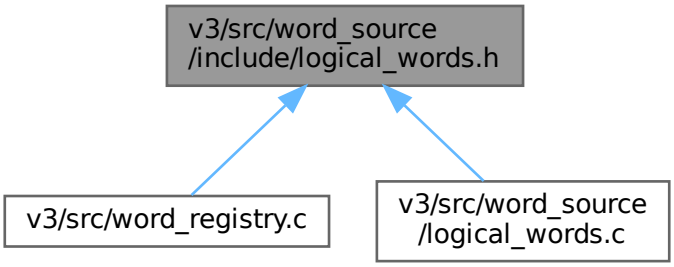
7.380 v3/src/word_source/include/logical_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for logical_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_logical_words (VM *vm)

  Registers all FORTH-79 logical and comparison words with the VM.

7.380.1 Function Documentation

7.380.1.1 register_logical_words()

```
void register_logical_words (
            VM * vm )
```

Registers all FORTH-79 logical and comparison words with the VM.

Parameters

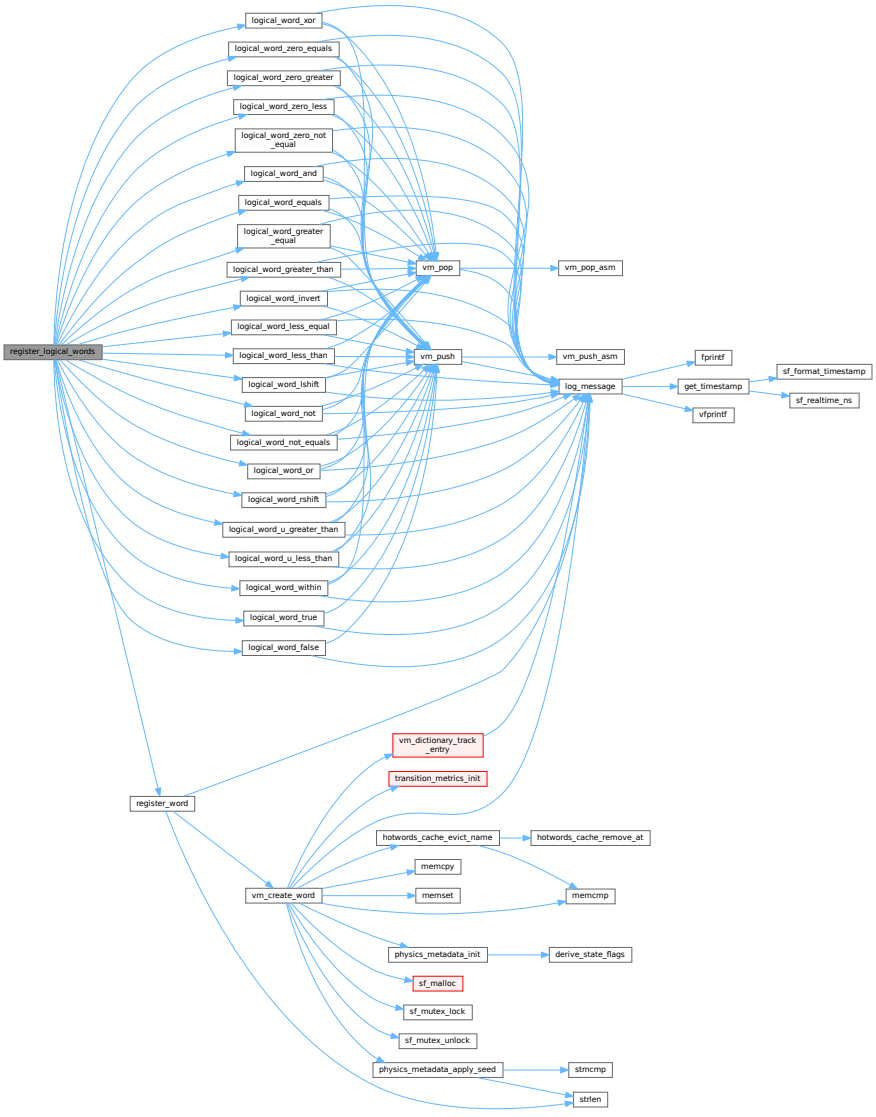
vm	Pointer to the virtual machine instance

Registers logical operations (AND, OR, XOR, NOT), comparison operations (=, <>, <, >, etc.), and constant words (TRUE, FALSE) with the virtual machine.

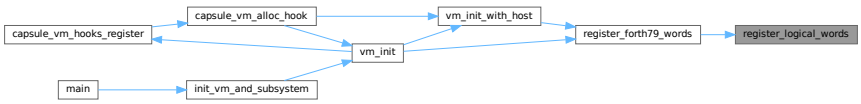
References logical_word_and(), logical_word_equals(), logical_word_false(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_true(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

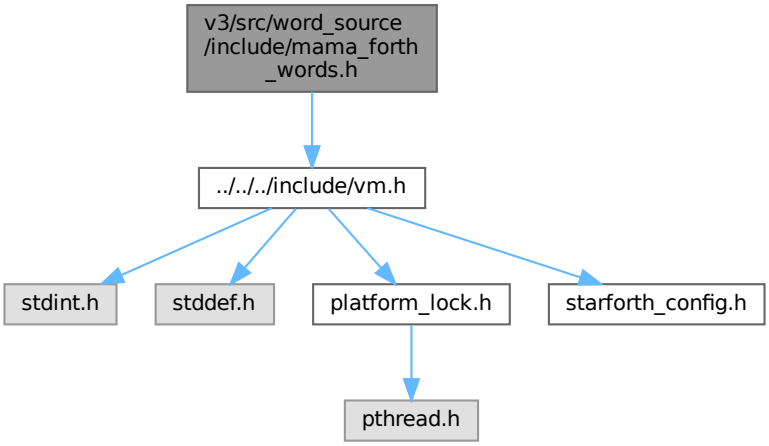


7.381 v3/src/word_source/include/mama_forth_words.h File Reference

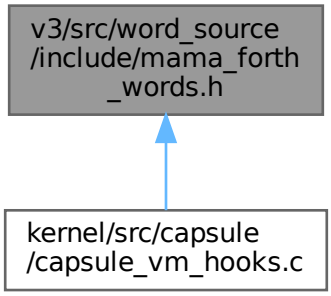
Mama FORTH vocabulary words for kernel capsule system (M7.1)

```
#include "../../../include/vm.h"
```

Include dependency graph for mama_forth_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- static void register_mama_forth_words (VM *vm)

  Stub for hosted builds - does nothing.

7.381.1 Detailed Description

Mama FORTH vocabulary words for kernel capsule system (M7.1)

This header defines the Mama FORTH vocabulary - kernel-only words for the LithosAnanke capsule birth protocol.

These words are ONLY available in **STARKERNEL** builds. Hosted StarForth builds do not include capsule functionality.

Mama FORTH Vocabulary: CAPSULE-COUNT (– n) Number of capsules in directory CAPSULE@ (idx – desc) Get descriptor address by index CAPSULE-HASH@ (desc – hash) Get capsule content hash CAPSULE-FLAGS@ (desc – flags) Get capsule flags CAPSULE-LEN@ (desc – len) Get payload length CAPSULE-BIRTH (hash – vm-id) Birth baby VM from (p) capsule CAPSULE-RUN (hash –) Run (e) capsule on Mama MAMA-VM-ID (– 0) Mama's VM ID (always 0) VM-COUNT (– n) Number of live VMs

7.381.2 Function Documentation

7.381.2.1 register_mama_forth_words()

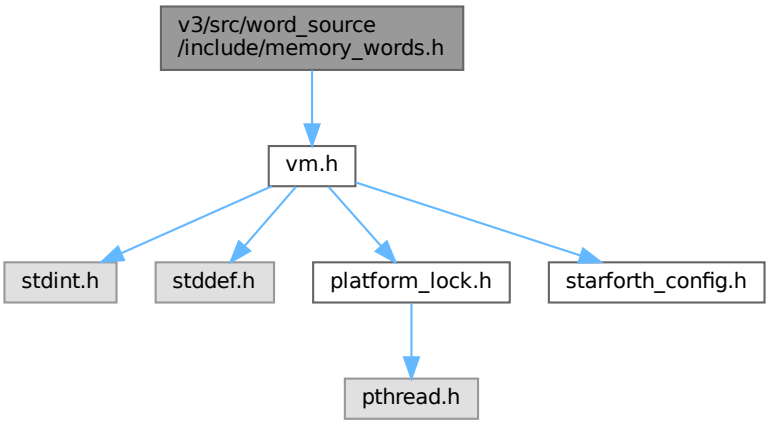
```
static void register_mama_forth_words (
            VM * vm )  [inline], [static]
```

Stub for hosted builds - does nothing.

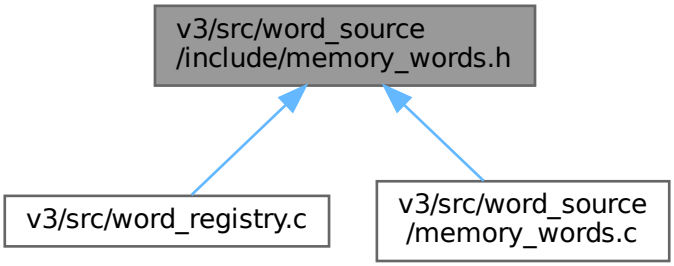
7.382 v3/src/word_source/include/memory_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for memory_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_memory_words (VM *vm)

  Register all memory manipulation words with the VM.

7.382.1 Function Documentation

7.382.1.1 register_memory_words()

```
void register_memory_words (
            VM * vm )
```

Register all memory manipulation words with the VM.

Registers all standard memory words (@, !, C@, C!, etc.) with the VM's word dictionary.

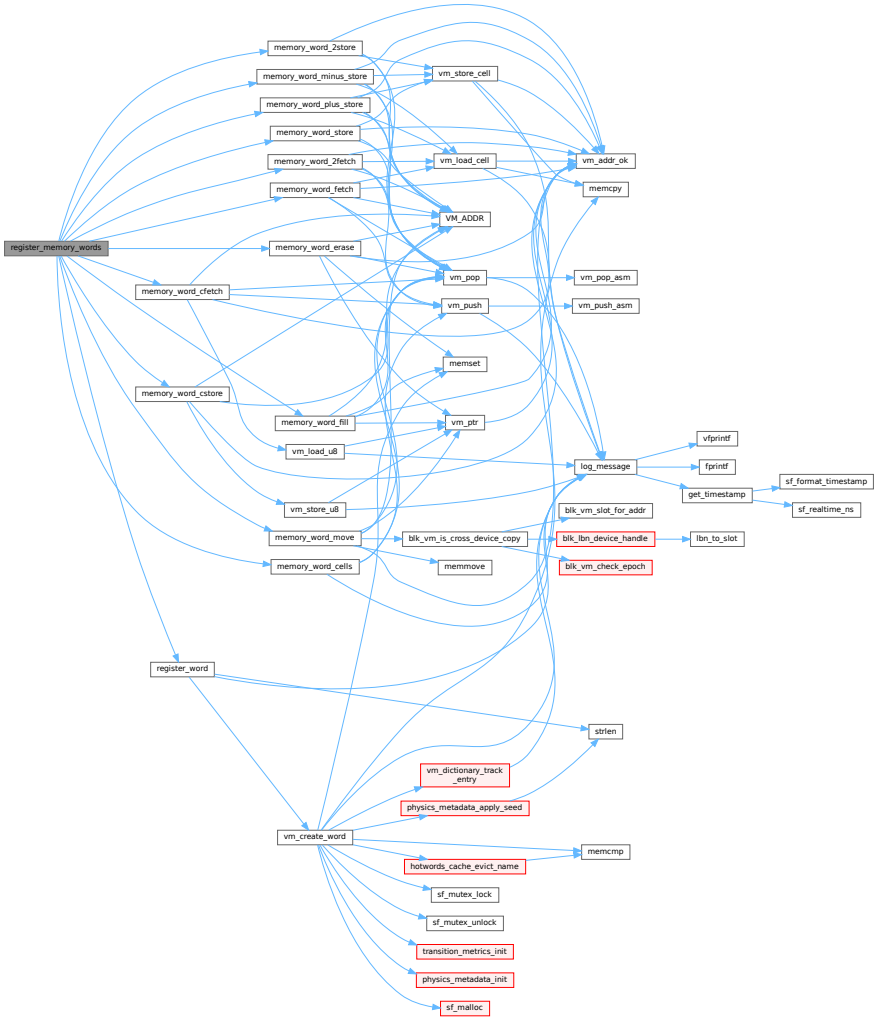
Parameters

vm	Pointer to the VM structure

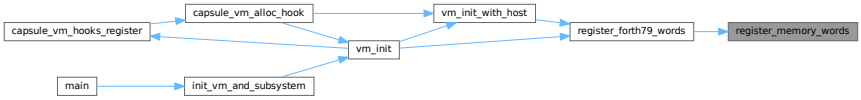
References memory_word_2fetch(), memory_word_2store(), memory_word_cells(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



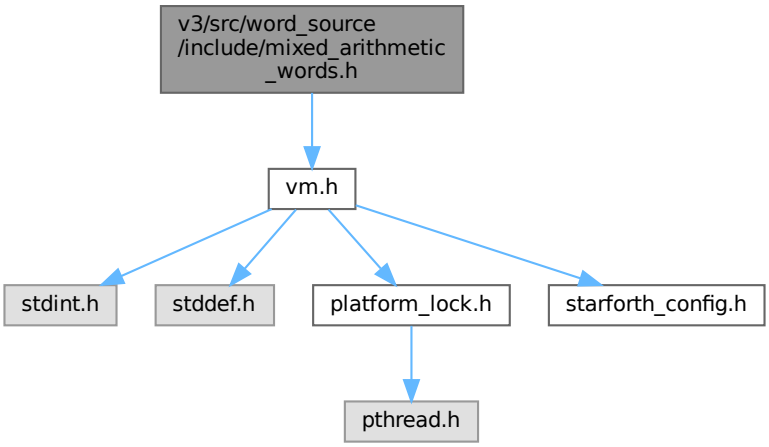
Here is the caller graph for this function:



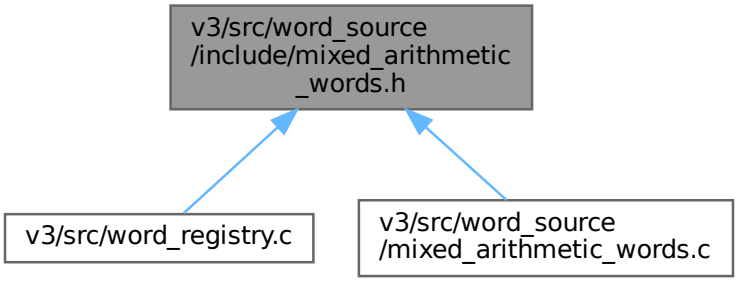
7.383 v3/src/word_source/include/mixed_arithmetic_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for mixed_arithmetic_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_mixed_arithmetic_words (VM *vm)

  Register all FORTH-79 mixed arithmetic words with the VM dictionary.

7.383.1 Function Documentation

7.383.1.1 register_mixed_arithmetic_words()

```
void register_mixed_arithmetic_words (
            VM * vm )
```

Register all FORTH-79 mixed arithmetic words with the VM dictionary.

Registers: `M+`, `M-`, `M*`, `M/MOD`, `MOD`, `/MOD`, `*\/`, `*\/MOD`. Called during VM bootstrap.

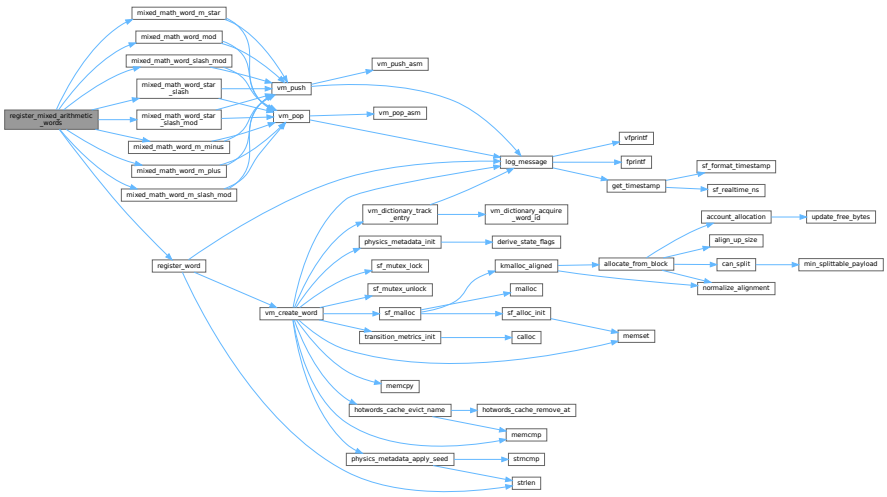
Parameters

vm	Active VM to register words into

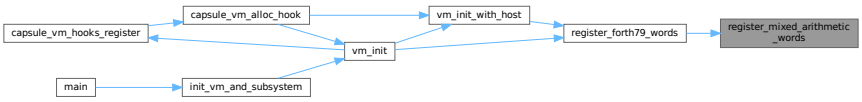
References mixed_math_word_m_minus(), mixed_math_word_m_plus(), mixed_math_word_m_slash_mod(), mixed_math_word_m_star(), mixed_math_word_mod(), mixed_math_word_slash_mod(), mixed_math_word_star_slash(), mixed_math_word_star_slash_mod(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



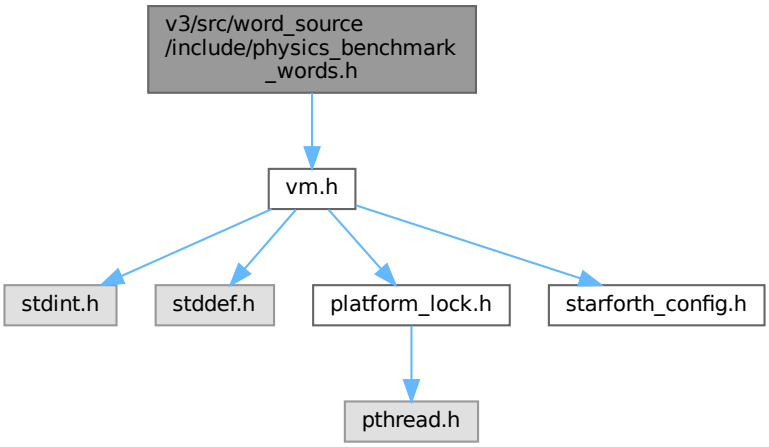
Here is the caller graph for this function:



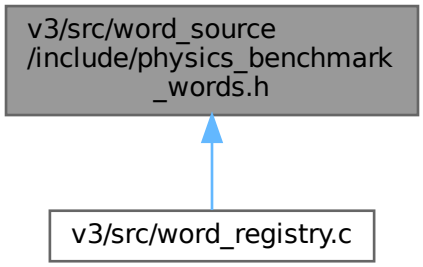
7.384 v3/src/word_source/include/physics_benchmark_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for physics_benchmark_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_physics_benchmark_words (VM *vm)

  Register all physics benchmark words with the VM.

7.384.1 Function Documentation

7.384.1.1 register_physics_benchmark_words()

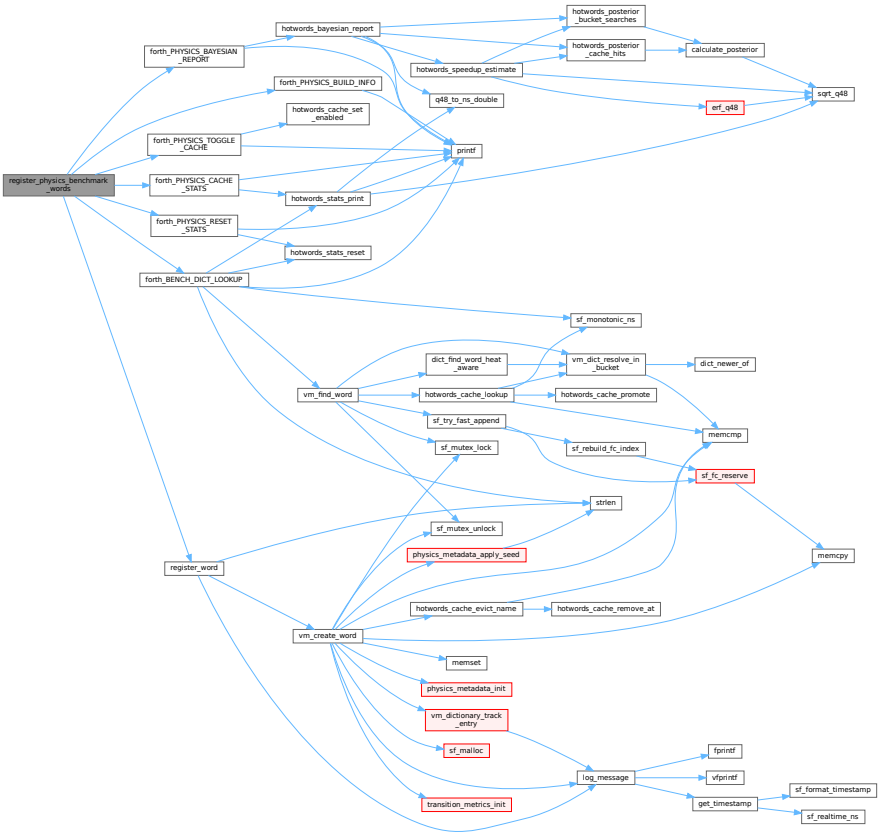
```
void register_physics_benchmark_words (
            VM * vm )
```

Register all physics benchmark words with the VM.

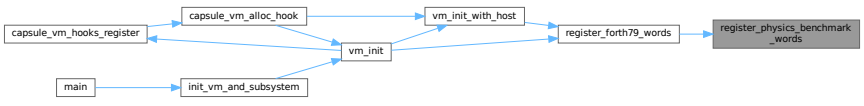
References forth_BENCH_DICT_LOOKUP(), forth_PHYSICS_BAYESIAN_REPORT(), forth_PHYSICS_BUILD_INFO(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_RESET_STATS(), forth_PHYSICS_TOGGLE_CACHE(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



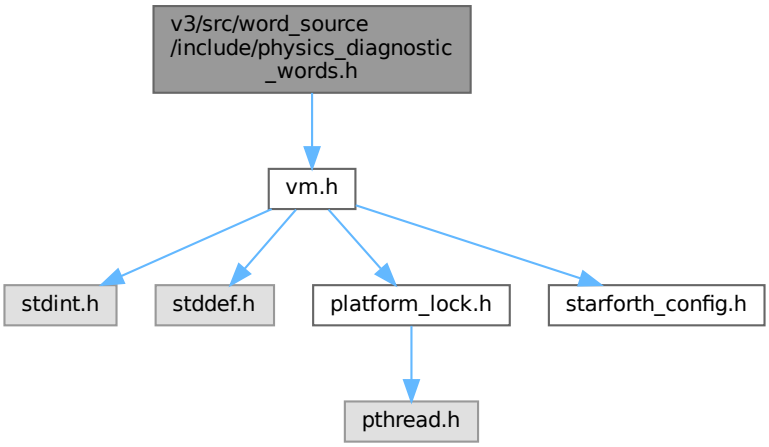
Here is the caller graph for this function:



7.385 v3/src/word_source/include/physics_diagnostic_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for physics_diagnostic_words.h:



Functions

- void forth_PHYSICS_WORD_METRICS (VM *vm)

  Display detailed physics metrics for the most recently executed word.
- void forth_PHYSICS_CALC_KNOBS (VM *vm)

  Calculate and show knob adjustments based on current thermal metrics.
- void forth_PHYSICS_BURN (VM *vm)

  Execute a word repeatedly (burn) and show thermal feedback.
- void forth_PHYSICS_SHOW_FEEDBACK (VM *vm)

  Display the complete feedback loop: inputs → math → knobs → effect.
- void register_physics_diagnostic_words (VM *vm)

  Register all physics diagnostic words with the VM.

7.385.1 Function Documentation

7.385.1.1 forth_PHYSICS_BURN()

```
void forth_PHYSICS_BURN (
            VM * vm )
```

Execute a word repeatedly (burn) and show thermal feedback.

Execute a word repeatedly (burn) and show thermal feedback.

Execute the top-of-stack word n times and show thermal feedback.

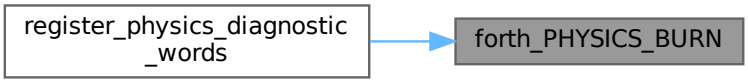
Usage: : HOTTEST 100 0 DO 1 2 + 3 * LOOP ; HOTTEST 10 PHYSICS-BURN (execute 10 times) PHYSICS-↩ SHOW-FEEDBACK

References VM::data_stack, VM::dsp, VM::error, DictEntry::execution_heat, DictEntry::func, DictPhysics::last_active_ns, VM::latest, DictEntry::name, DictEntry::physics, printf(), and DictPhysics::temperature_q8.

Referenced by register_physics_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



7.385.1.2 forth_PHYSICS_CALC_KNOBS()

```
void forth_PHYSICS_CALC_KNOBS (
            VM * vm )
```

Calculate and show knob adjustments based on current thermal metrics.

Calculate and show knob adjustments based on current thermal metrics.

Calculate what knobs should be adjusted based on current word metrics. Shows:

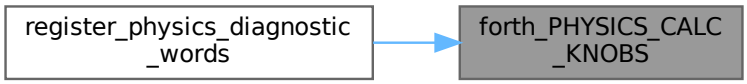
- Thermal pressure (0.0 to 1.0)
- Recommended priority adjustment
- Recommended sampling rate
- Stack depth limit
- Core affinity preference

References VM::error, DictPhysics::last_active_ns, VM::latest, DictEntry::name, DictEntry::physics, printf(), and DictPhysics::temperature_q8.

Referenced by register_physics_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



7.385.1.3 forth_PHYSICS_SHOW_FEEDBACK()

```
void forth_PHYSICS_SHOW_FEEDBACK (
            VM * vm )
```

Display the complete feedback loop: inputs → math → knobs → effect.

Display the complete feedback loop: inputs → math → knobs → effect.

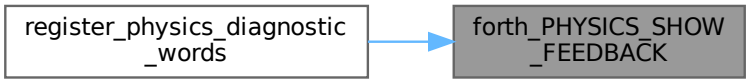
Display the complete feedback loop for the most recent word. Shows: Metrics → Calculations → Knobs → Effect

References DictPhysics::avg_latency_ns, VM::error, DictEntry::execution_heat, DictPhysics::last_active_ns, VM::latest, DictPhysics::mass_bytes, DictEntry::name, DictEntry::physics, printf(), and DictPhysics::temperature_q8.

Referenced by register_physics_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



7.385.1.4 forth_PHYSICS_WORD_METRICS()

```
void forth_PHYSICS_WORD_METRICS (
            VM * vm )
```

Display detailed physics metrics for the most recently executed word.

Display detailed physics metrics for the most recently executed word.

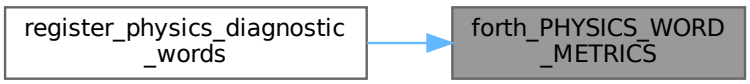
Display detailed physics metrics for a word. Looks up the most recently executed word and shows its state.

References DictPhysics::avg_latency_ns, VM::error, DictEntry::execution_heat, DictPhysics::last_active_ns, VM::latest, DictPhysics::mass_bytes, DictEntry::name, DictEntry::physics, printf(), and DictPhysics::temperature_q8.

Referenced by register_physics_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



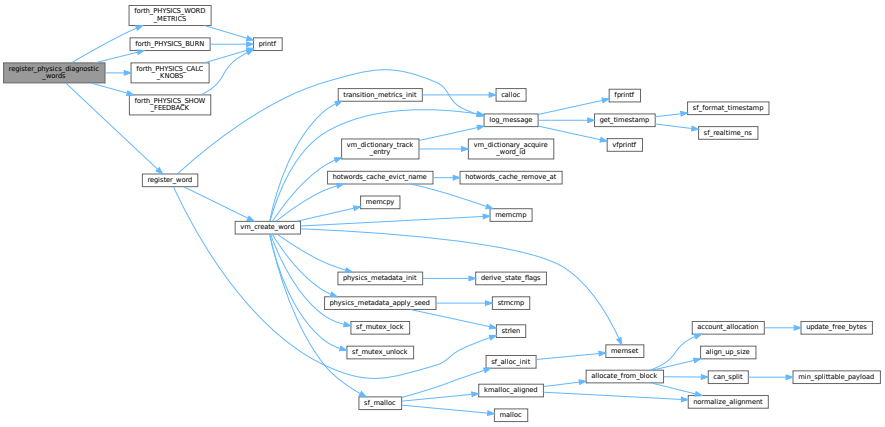
7.385.1.5 register_physics_diagnostic_words()

```
void register_physics_diagnostic_words (
            VM * vm )
```

Register all physics diagnostic words with the VM.

References forth_PHYSICS_BURN(), forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_SHOW_FEEDBACK(), forth_PHYSICS_WORD_METRICS(), and register_word().

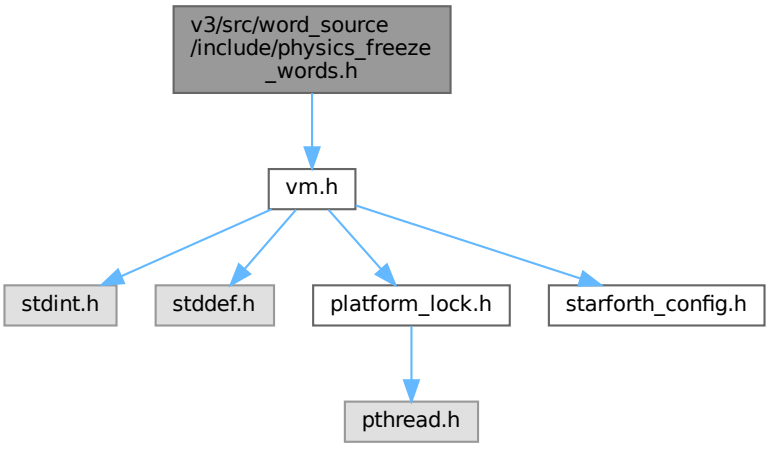
Here is the call graph for this function:



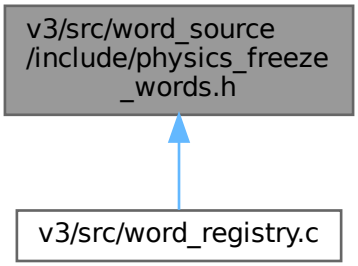
7.386 v3/src/word_source/include/physics_freeze_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for physics_freeze_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_physics_freeze_words (VM *vm)

  Register all Phase 2 freeze/decay control words with the VM.

7.386.1 Function Documentation

7.386.1.1 register_physics_freeze_words()

```
void register_physics_freeze_words (
            VM * vm )
```

Register all Phase 2 freeze/decay control words with the VM.

Register all Phase 2 freeze/decay control words with the VM.

Registers: FREEZE-WORD, UNFREEZE-WORD, FROZEN?, HEAT!, HEAT@, SHOW-HEAT, ALL-HEATS, DECAY-RATE@, FREEZE-CRITICAL. Called during VM bootstrap by the word registration subsystem.

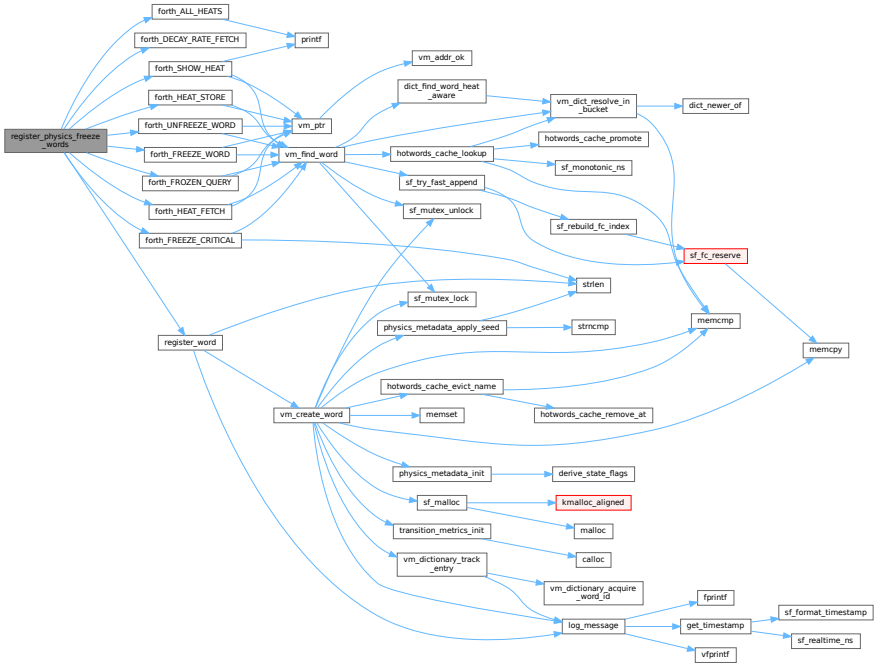
Parameters

vm	Active VM to register words into

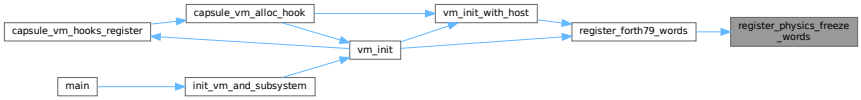
References forth_ALL_HEATS(), forth_DECAY_RATE_FETCH(), forth_FREEZE_CRITICAL(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_STORE(), forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



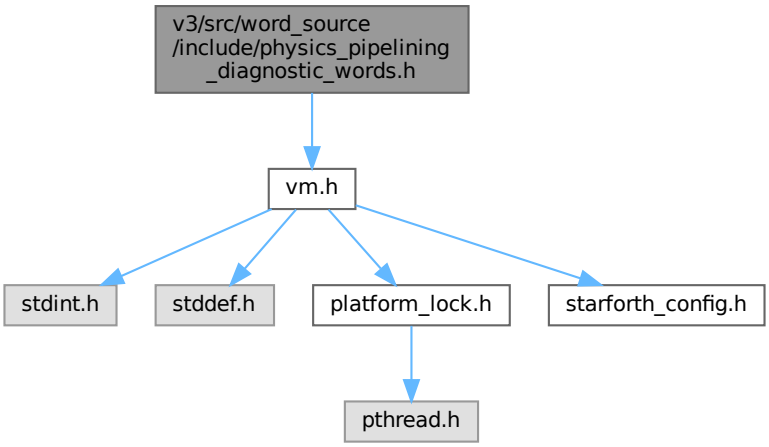
Here is the caller graph for this function:



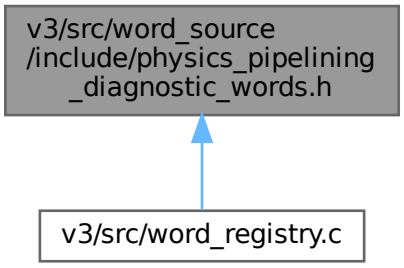
7.387 v3/src/word_source/include/physics_pipelining_diagnostic_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for physics_pipelining_diagnostic_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_physics_pipelining_diagnostic_words (VM *vm)

  Register all pipelining diagnostic words Called during VM initialization.

7.387.1 Function Documentation

7.387.1.1 register_physics_pipelining_diagnostic_words()

```
void register_physics_pipelining_diagnostic_words (
            VM * vm )
```

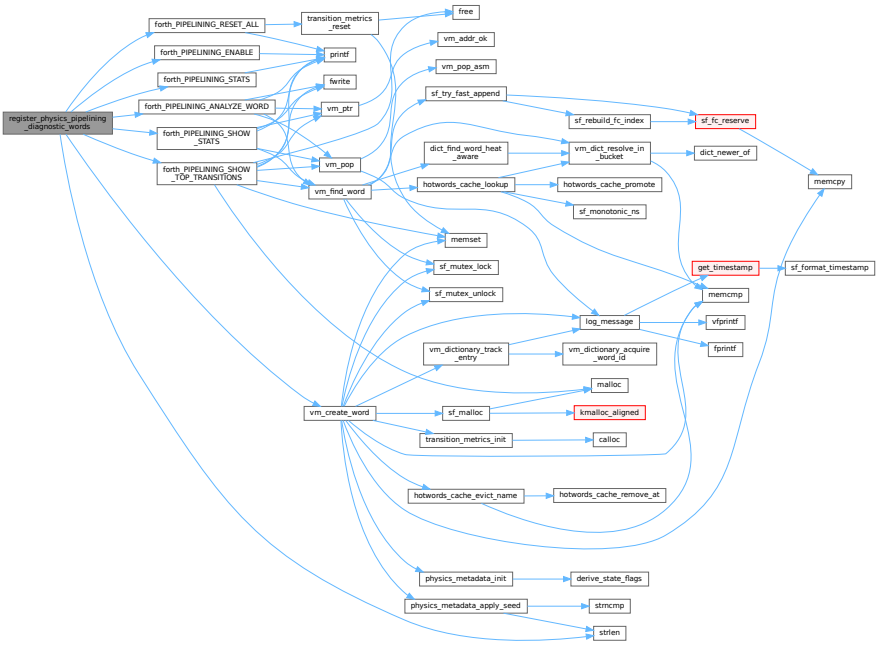
Register all pipelining diagnostic words Called during VM initialization.

Register all pipelining diagnostic words Called during VM initialization.

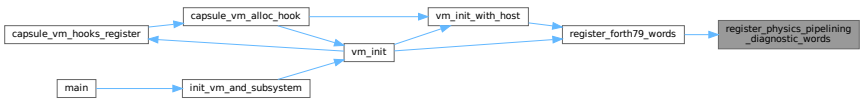
References forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_ENABLE(), forth_PIPELINING_RESET_ALL(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), forth_PIPELINING_STATS(), strlen(), and vm_create_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



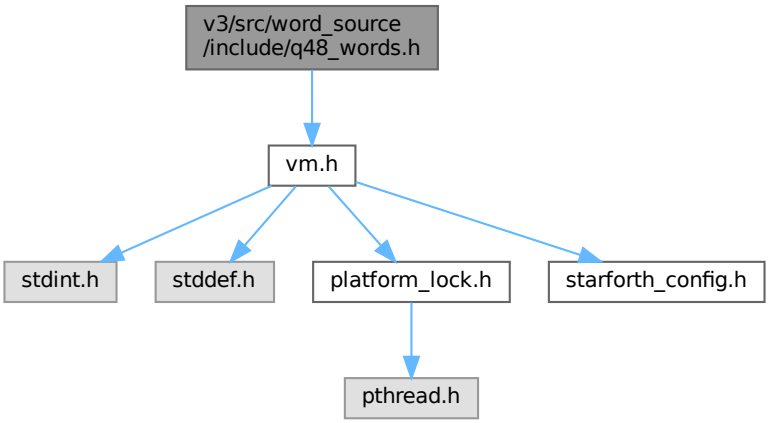
Here is the caller graph for this function:



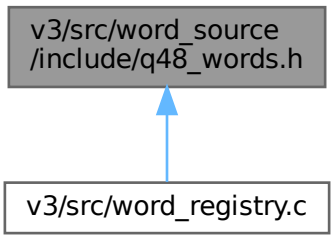
7.388 v3/src/word_source/include/q48_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for q48_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_q48_words (VM *vm)

  q48_words.h — Module 25: Q48.16 fixed-point FORTH words

7.388.1 Function Documentation

7.388.1.1 register_q48_words()

```
void register_q48_words (
            VM * vm )
```

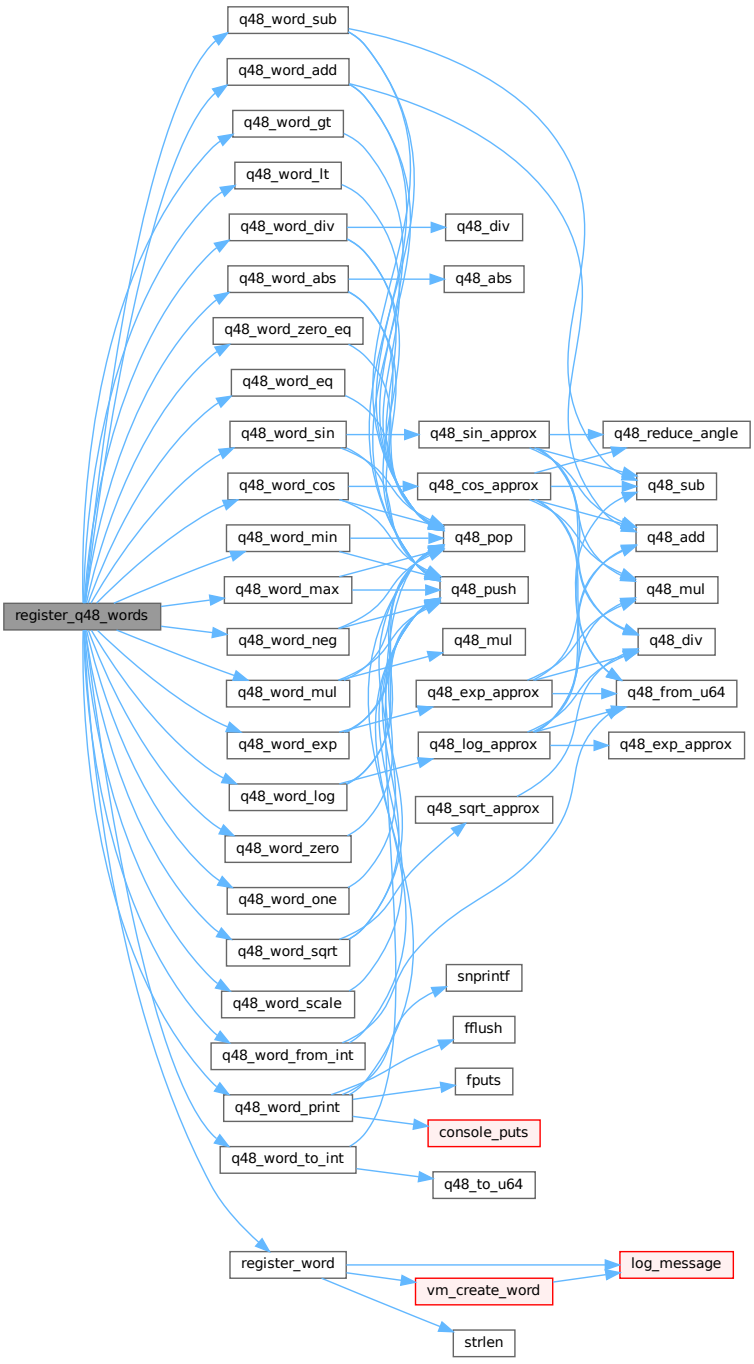
q48_words.h — Module 25: Q48.16 fixed-point FORTH words

Register all Q48.16 FORTH words with the VM. Module 25 in register_forth79_words().

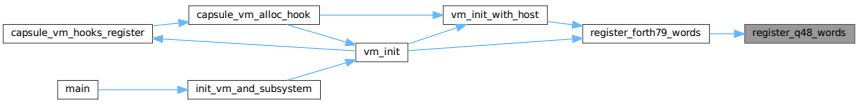
References q48_word_abs(), q48_word_add(), q48_word_cos(), q48_word_div(), q48_word_eq(), q48_word_exp(), q48_word_from_int(), q48_word_gt(), q48_word_log(), q48_word_lt(), q48_word_max(), q48_word_min(), q48_word_mul(), q48_word_neg(), q48_word_one(), q48_word_print(), q48_word_scale(), q48_word_sin(), q48_word_sqrt(), q48_word_sub(), q48_word_to_int(), q48_word_zero(), q48_word_zero_eq(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:

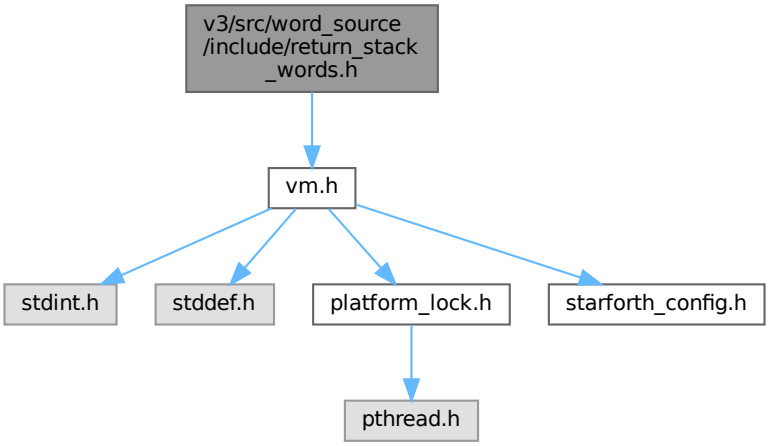


Here is the caller graph for this function:

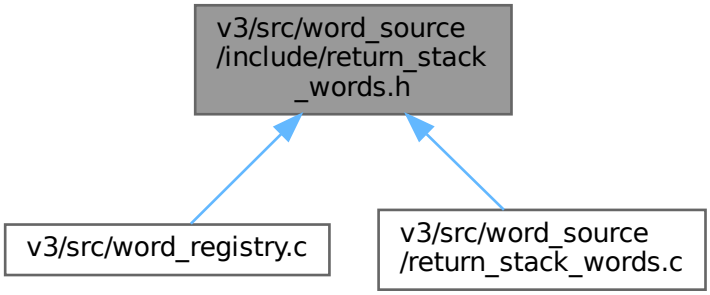


7.389 v3/src/word_source/include/return_stack_words.h File Reference

`#include "vm.h"`
Include dependency graph for return_stack_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_return_stack_words (VM *vm)

  Register all FORTH-79 return stack manipulation words.

7.389.1 Function Documentation

7.389.1.1 register_return_stack_words()

```
void register_return_stack_words (
            VM * vm )
```

Register all FORTH-79 return stack manipulation words.

Parameters

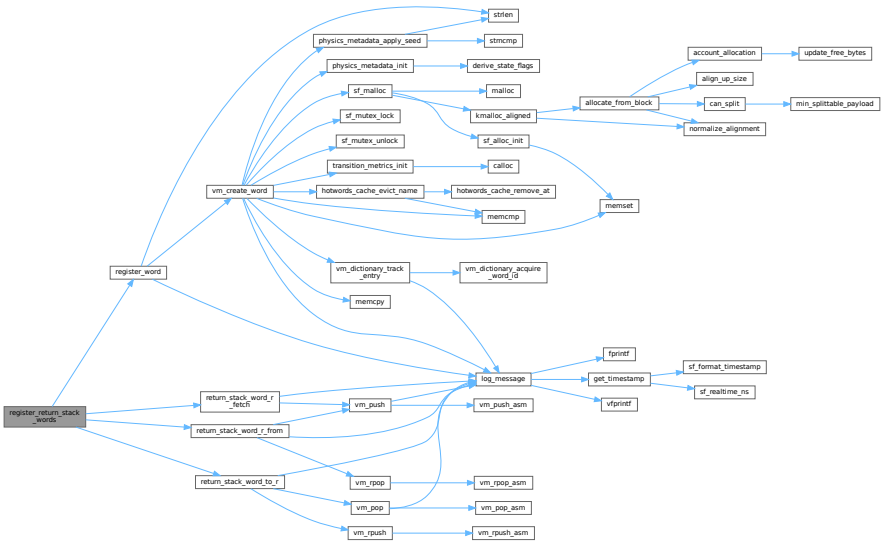
vm	Pointer to VM instance

Registers >R, R>, and R@ words. Direct stack addressing words (RP!, RP@) are deliberately omitted for FORTH-79 compliance.

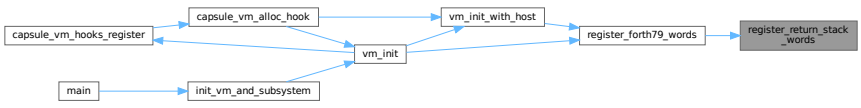
References register_word(), return_stack_word_r_fetch(), return_stack_word_r_from(), and return_stack_word_to_r().

Referenced by register_forth79_words().

Here is the call graph for this function:



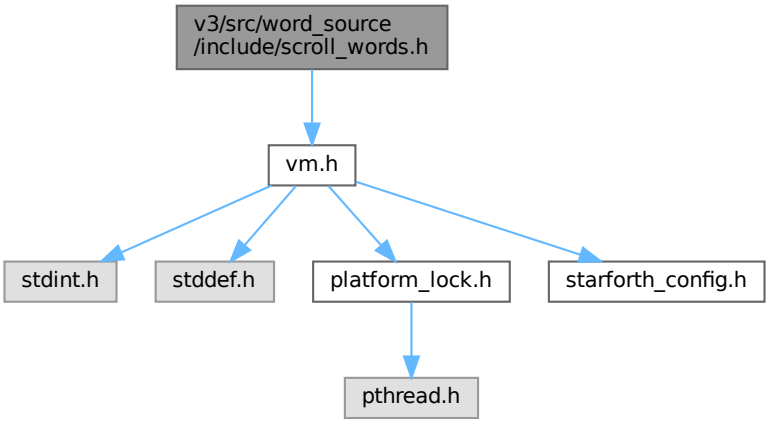
Here is the caller graph for this function:



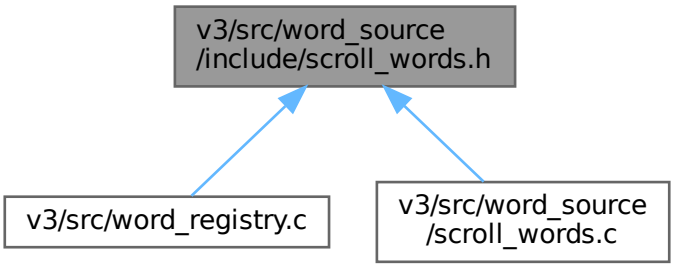
7.390 v3/src/word_source/include/scroll_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for scroll_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_scroll_words (VM *vm)

7.390.1 Function Documentation

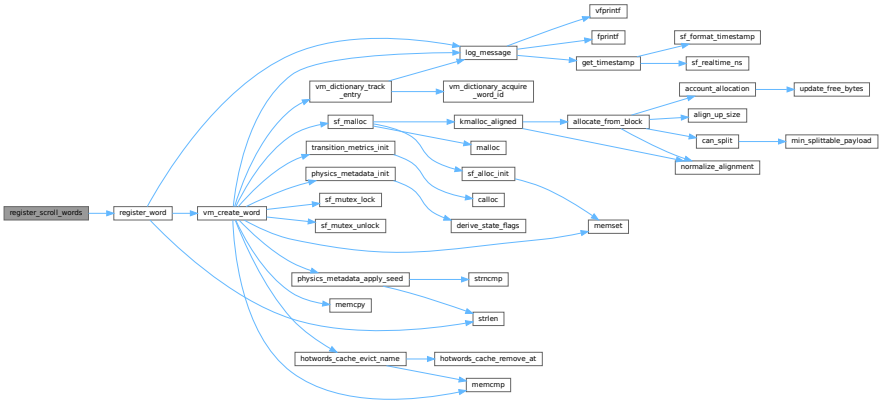
7.390.1.1 register_scroll_words()

```
void register_scroll_words (
            VM * vm )
```

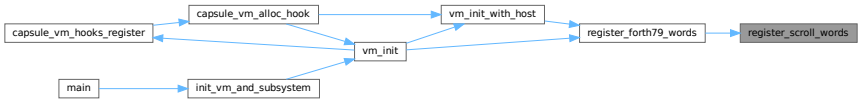
References register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



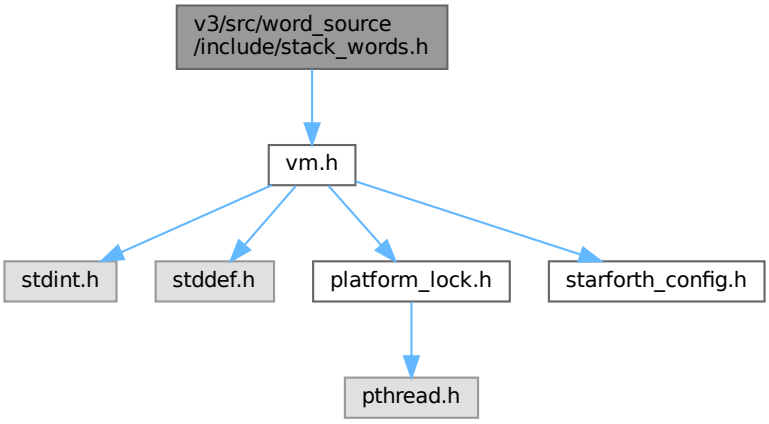
Here is the caller graph for this function:



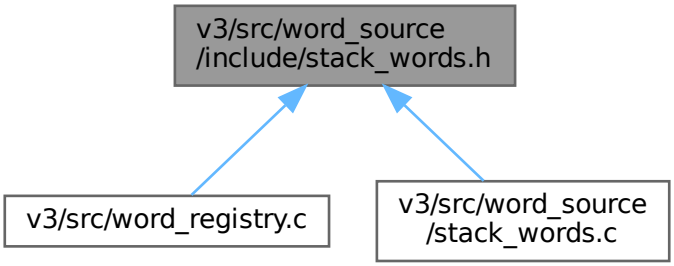
7.391 v3/src/word_source/include/stack_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for stack_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_stack_words (VM *vm)

  Registers all stack operation words with the virtual machine.

7.391.1 Function Documentation

7.391.1.1 register_stack_words()

```
void register_stack_words (
            VM * vm )
```

Registers all stack operation words with the virtual machine.

Parameters

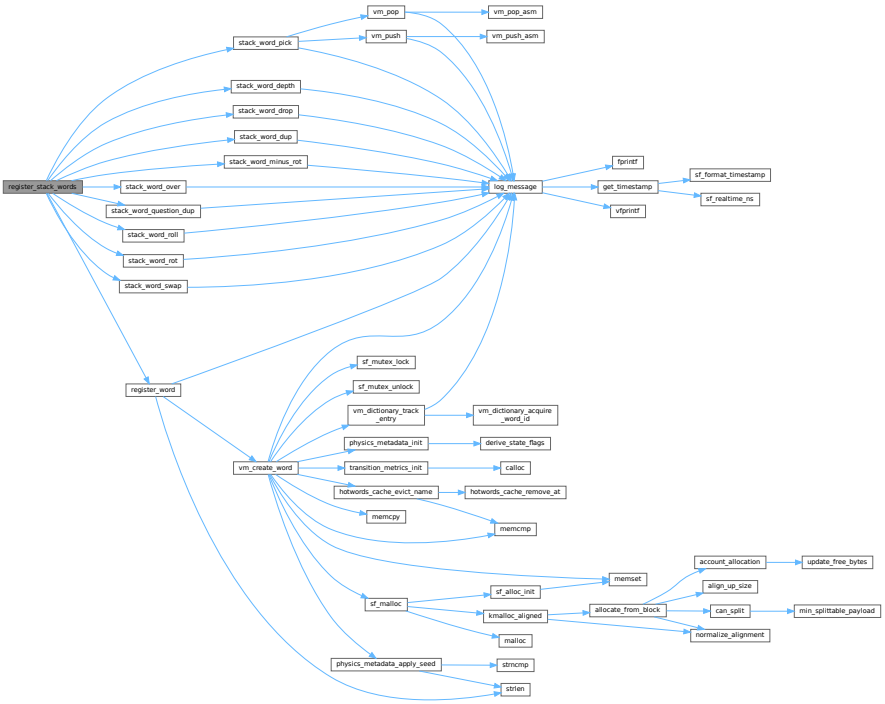
vm	Pointer to the virtual machine state

Registers all FORTH-79 standard stack operation words with the word registry.

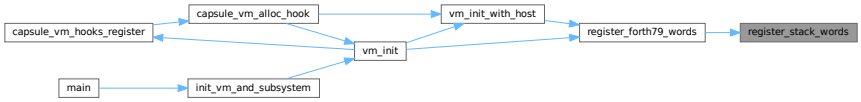
References register_word(), stack_word_depth(), stack_word_drop(), stack_word_dup(), stack_word_minus_rot(), stack_word_over(), stack_word_pick(), stack_word_question_dup(), stack_word_roll(), stack_word_rot(), and stack_word_swap().

Referenced by register_forth79_words().

Here is the call graph for this function:



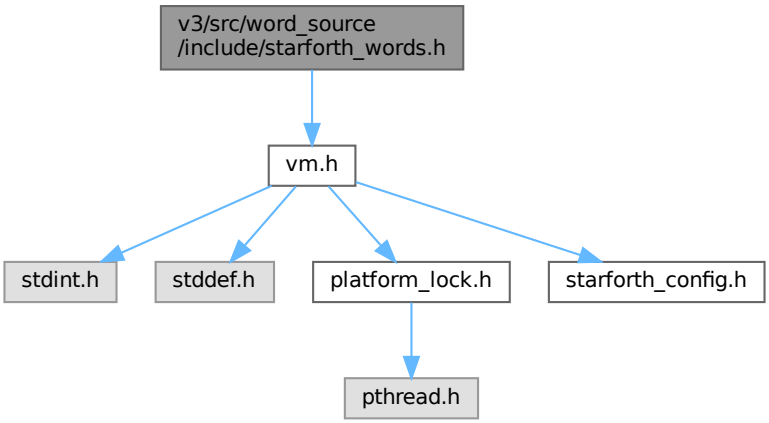
Here is the caller graph for this function:



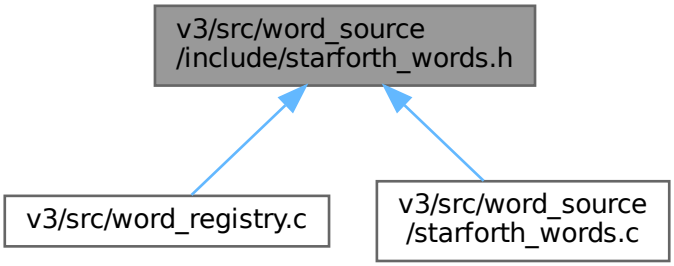
7.392 v3/src/word_source/include/starforth_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for starforth_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_starforth_words (VM *vm)

  Register StarForth vocabulary words with the VM.

StarForth Implementation Vocabulary Words

- void starforth_word_entropy_fetch (VM *vm)

  Fetch entropy value from address.
- void starforth_word_entropy_store (VM *vm)

  Store entropy value to address.
- void starforth_word_word_entropy (VM *vm)

  Calculate word entropy.
- void starforth_word_reset_entropy (VM *vm)

Reset entropy values.

- void starforth_word_top_words (VM *vm)
  Display the N most frequently used words.
- void starforth_word_paren_dash (VM *vm)
  Shebang-style comment word for init.4th metadata.
- void starforth_word_init (VM *vm)
  Initialize system from init.4th configuration file.
- void starforth_word_seed (VM *vm)
  Set the PRNG seed.
- void starforth_word_random (VM *vm)
  Generate bounded random number.
- void starforth_word_wait (VM *vm)
  Wait for specified number of heartbeat ticks.

7.392.1 Function Documentation

7.392.1.1 register_starforth_words()

```
void register_starforth_words (
            VM * vm )
```

Register StarForth vocabulary words with the VM.

Registers all StarForth-specific words and creates the STARFORTH vocabulary

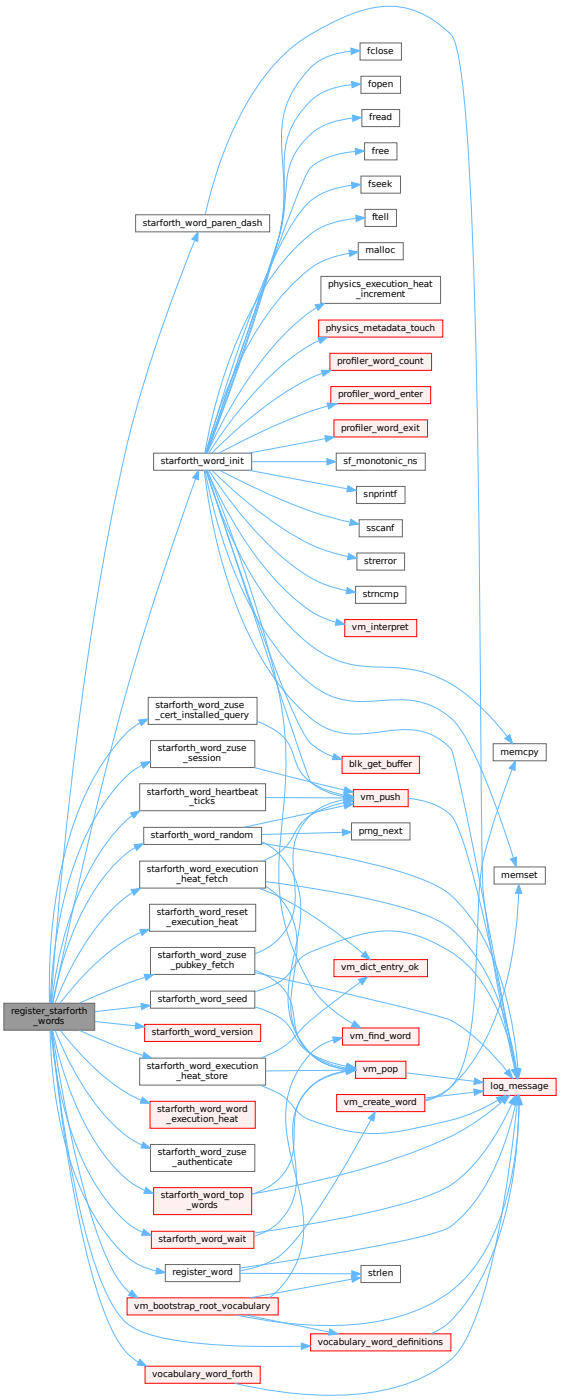
Parameters

vm	Pointer to the VM instance

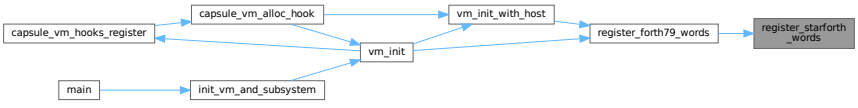
References register_word(), STARFORTH_CHECK_ARENA, starforth_word_execution_heat_fetch(), starforth_word_execution_heat_
starforth_word_heartbeat_ticks(), starforth_word_init(), starforth_word_paren_dash(), starforth_word_random(),
starforth_word_reset_execution_heat(), starforth_word_seed(), starforth_word_top_words(), starforth_word_version(),
starforth_word_wait(), starforth_word_word_execution_heat(), starforth_word_zuse_authenticate(), starforth_word_zuse_cert_installe
starforth_word_zuse_pubkey_fetch(), starforth_word_zuse_session(), vm_bootstrap_root_vocabulary(), vocabulary_word_definitions(
and vocabulary_word_forth().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.392.1.2 starforth_word_entropy_fetch()

```
void starforth_word_entropy_fetch (
            VM * vm )
```

Fetch entropy value from address.

Parameters

vm	Pointer to VM instance @stack (addr – n)

7.392.1.3 starforth_word_entropy_store()

```
void starforth_word_entropy_store (
            VM * vm )
```

Store entropy value to address.

Parameters

vm	Pointer to VM instance @stack (n addr –)

7.392.1.4 starforth_word_init()

```
void starforth_word_init (
            VM * vm )
```

Initialize system from init.4th configuration file.

Reads ./capsules/core/init.4th, parses Block headers, copies blocks sequentially starting at block 1, then executes them. Stack effect: (–)

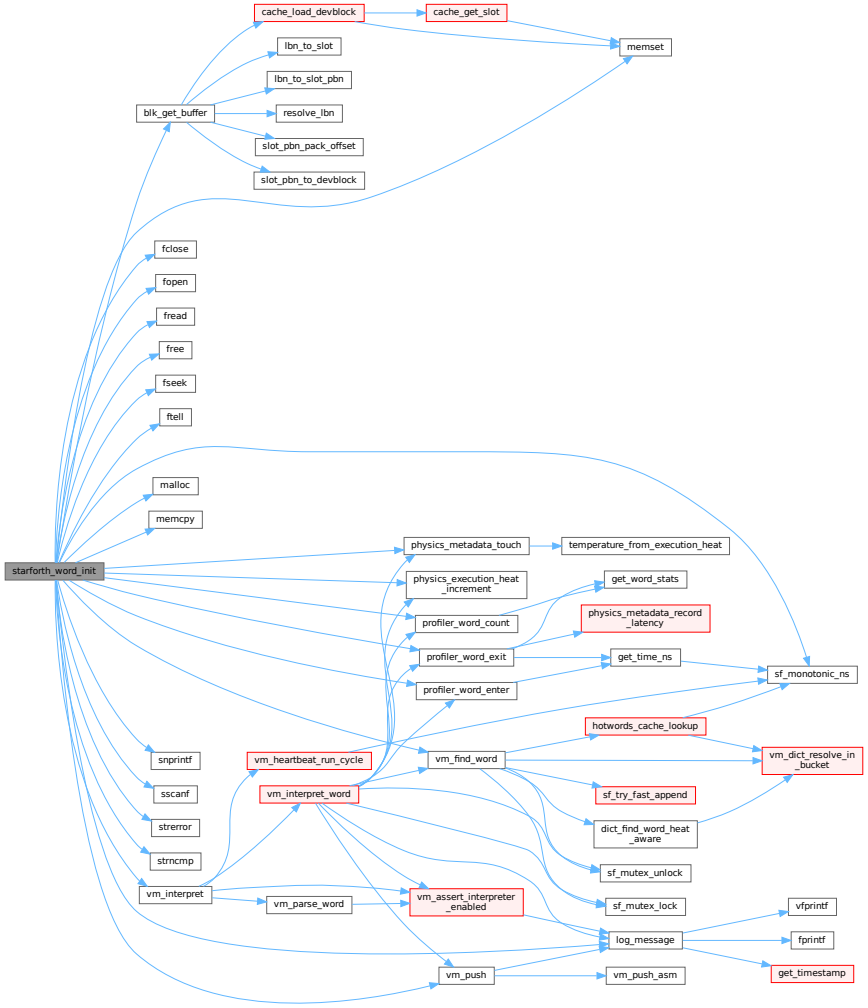
Parameters

vm	Pointer to the VM instance

References blk_get_buffer(), VM::current_executing_entry, ENOENT, errno, VM::error, DictEntry::execution_heat, fclose(), fopen(), fread(), free(), fseek(), ftell(), DictEntry::func, VM::halted, LOG_DEBUG, LOG_ERROR, LOG_INFO, log_message(), LOG_WARN, malloc(), memcpy(), memset(), physics_execution_heat_increment(), physics_metadata_touch(), profiler_word_count(), profiler_word_enter(), profiler_word_exit(), SEEK_END, SEEK_SET, sf_monotonic_ns(), snprintf(), sscanf(), strerror(), strncmp(), vm_find_word(), vm_interpret(), and vm_push().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.392.1.5 starforth_word_paren_dash()

```
void starforth_word_paren_dash (
            VM * vm )
```

Shebang-style comment word for init.4th metadata.

Starts with "(- " and consumes input until closing ")" Used for marking blocks that should be extracted to init.4th Stack effect: (–)

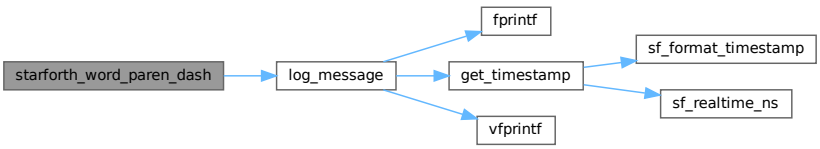
Parameters

vm	Pointer to the VM instance

References VM::input_buffer, VM::input_length, VM::input_pos, LOG_DEBUG, log_message(), and LOG_WARN.

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.392.1.6 starforth_word_random()

```
void starforth_word_random (
            VM * vm )
```

Generate bounded random number.

Parameters

vm	Pointer to VM instance @stack (lo hi – n)

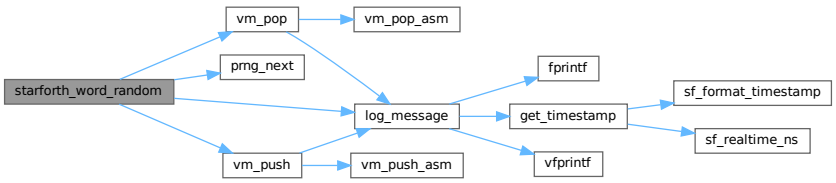
Note

Returns random value in inclusive range [lo, hi]

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), prng_next(), vm_pop(), and vm_push().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.392.1.7 starforth_word_reset_entropy()

```
void starforth_word_reset_entropy (
            VM * vm )
```

Reset entropy values.

Parameters

vm	Pointer to VM instance @stack (–)

7.392.1.8 starforth_word_seed()

```
void starforth_word_seed (
            VM * vm )
```

Set the PRNG seed.

Stack effect: (n –) Sets the internal PRNG state for reproducible random sequences.

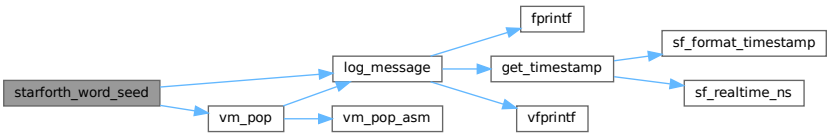
Parameters

vm	Pointer to the VM instance

References VM::dsp, VM::error, g_prng_state, LOG_DEBUG, LOG_ERROR, log_message(), and vm_pop().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.392.1.9 starforth_word_top_words()

```
void starforth_word_top_words (
            VM * vm )
```

Display the N most frequently used words.

Stack effect: (n –)

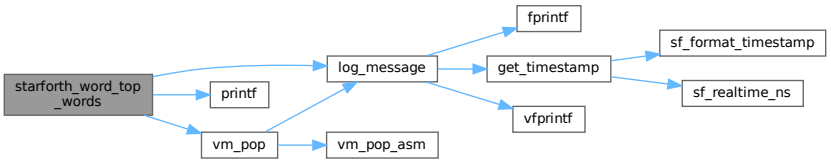
Parameters

vm	Pointer to the VM instance

References VM::dsp, entry, VM::error, execution_heat, VM::latest, LOG_ERROR, log_message(), printf(), vm_pop(), and word_count.

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.392.1.10 starforth_word_wait()

```
void starforth_word_wait (
            VM * vm )
```

Wait for specified number of heartbeat ticks.

Stack effect: (n –) Counts n heartbeat ticks by calling vm_tick() n times. Time is relative — we count heartbeats, not wall-clock milliseconds. This is architecture-independent: works on amd64, aarch64, riscv64 without depending on any platform timer.

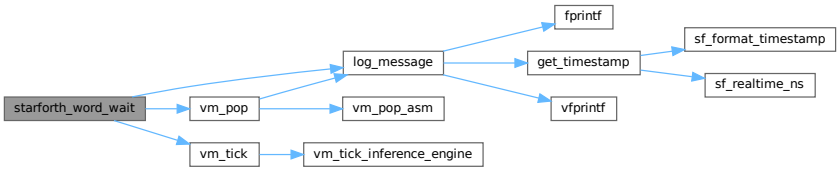
Parameters

vm	Pointer to the VM instance

References VM::dsp, VM::error, LOG_ERROR, log_message(), vm_pop(), and vm_tick().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.392.1.11 starforth_word_word_entropy()

```
void starforth_word_word_entropy (
            VM * vm )
```

Calculate word entropy.

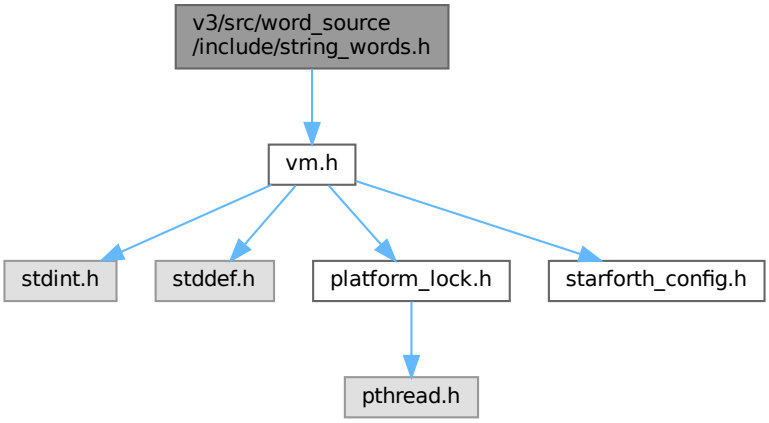
Parameters

vm	Pointer to VM instance @stack (–)

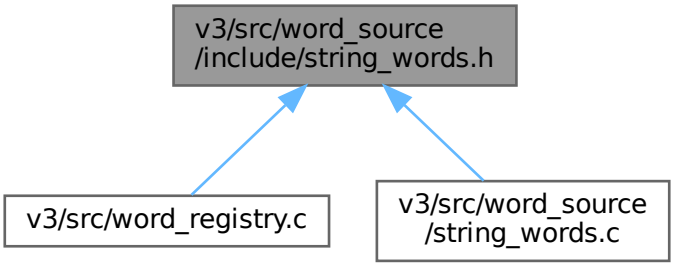
7.393 v3/src/word_source/include/string_words.h File Reference

FORTH-79 Standard string and text processing words implementation.

`#include "vm.h"`
Include dependency graph for string_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_string_words (VM *vm)

  COUNT (addr1 – addr2 u) Get string length and address Returns the character count and address of a counted string.

7.393.1 Detailed Description

FORTH-79 Standard string and text processing words implementation.

This file contains the implementation of FORTH-79 standard string and text processing words. These words provide functionality for string manipulation, input handling, and parsing.

7.393.2 Function Documentation

7.393.2.1 register_string_words()

```
void register_string_words (
            VM * vm )
```

COUNT (addr1 – addr2 u) Get string length and address Returns the character count and address of a counted string.

EXPECT (addr u –) Accept input line Accepts up to u characters of input and stores them at addr

SPAN (– addr) Variable: number of characters input Contains the count of characters actually received by EXPECT

QUERY (–) Accept input into TIB Accepts a line of input into the Terminal Input Buffer

TIB (– addr) Terminal input buffer address Returns the address of the Terminal Input Buffer

WORD (c – addr) Parse next word, delimited by c Parses the next word from input stream using c as delimiter

>IN (– addr) Input stream pointer Contains the offset into the input buffer

SOURCE (– addr u) Input source specification Returns current input buffer address and length

BL (– c) ASCII space character (32) Pushes ASCII space character value onto stack

FIND (addr – addr flag) Find word in dictionary Searches dictionary for word, returns status flag

' (– xt) Get execution token of next word Returns execution token of next word in input stream

['] (– xt) Compile execution token Compiles execution token as literal

LITERAL (n –) Compile literal number Compiles top stack value as literal

[LITERAL] (n –) Compile literal at compile time Compiles literal during compilation

CONVERT (d1 addr1 – d2 addr2) Convert string to number Converts string starting at addr1 to number

NUMBER (addr – n flag) Convert string to single number Converts string to single precision number

ENCLOSE (addr c – addr1 n1 n2 n3) Parse for delimiter Parses string for delimiter character

Register all string processing words with VM

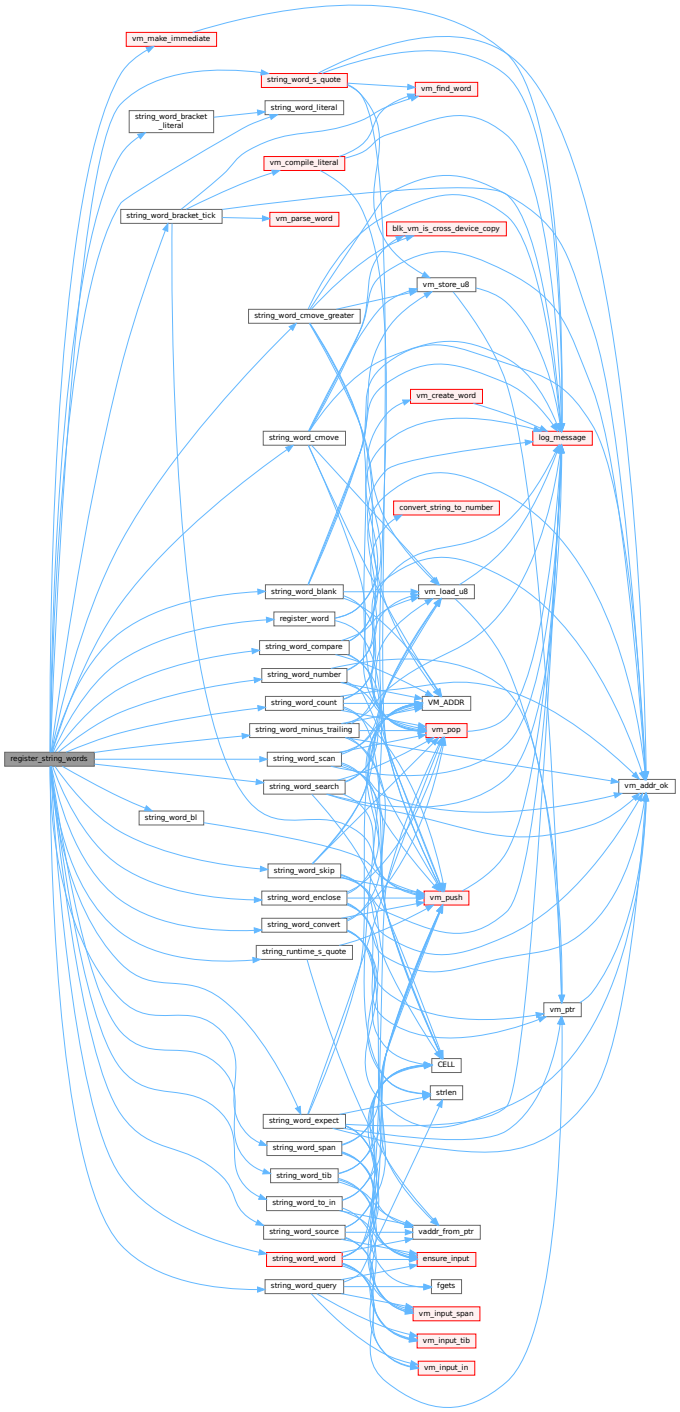
Parameters

vm	Pointer to VM instance where words will be registered

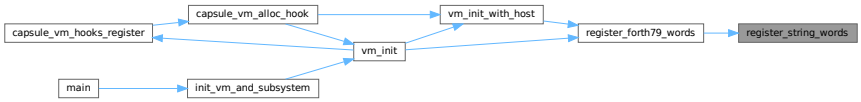
References register_word(), string_runtime_s_quote(), string_word_bl(), string_word_blank(), string_word_bracket_literal(), string_word_bracket_tick(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_literal(), string_word_minus_trailing(), string_word_number(), string_word_query(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), string_word_source(), string_word_span(), string_word_tib(), string_word_to_in(), string_word_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:

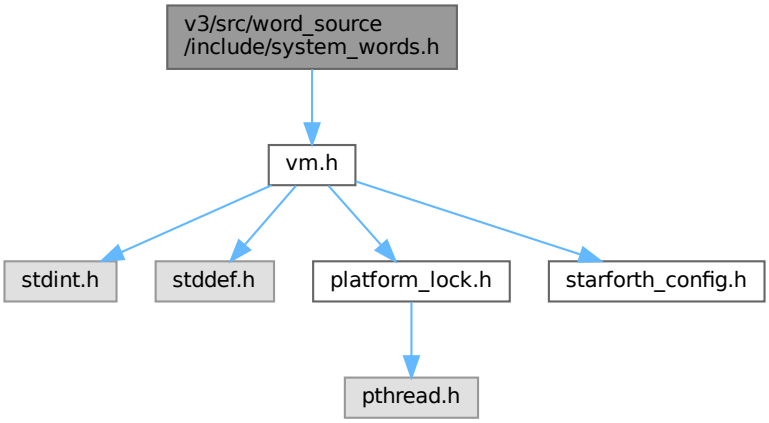


Here is the caller graph for this function:

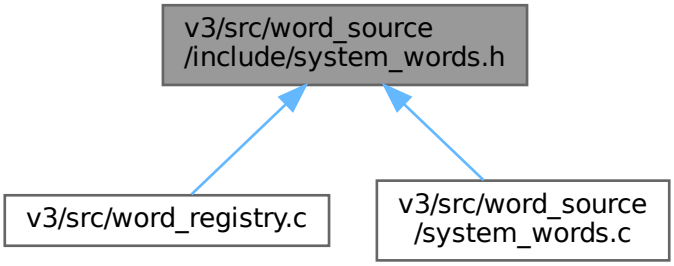


7.394 v3/src/word_source/include/system_words.h File Reference

`#include "vm.h"`
Include dependency graph for system_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_system_words (VM *vm)

  Registers all system words with the virtual machine.

7.394.1 Function Documentation

7.394.1.1 register_system_words()

```
void register_system_words (
            VM * vm )
```

Registers all system words with the virtual machine.

Parameters

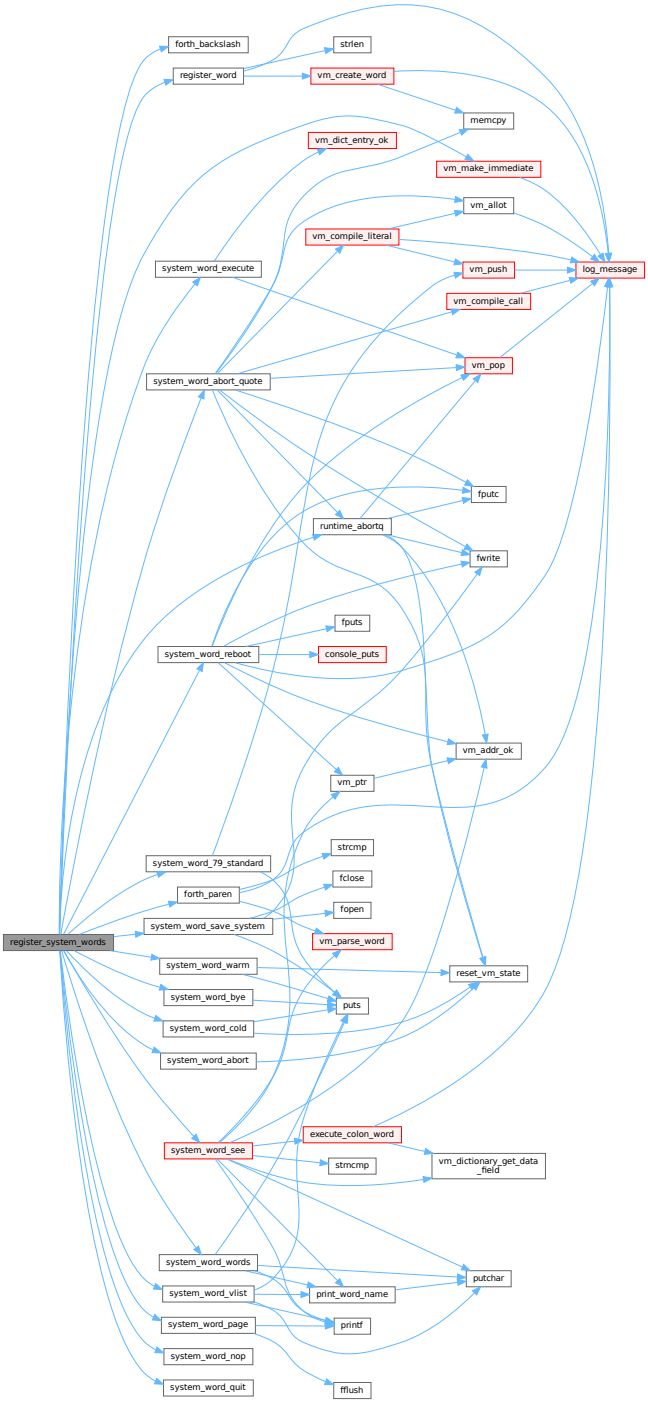
vm	Pointer to the virtual machine instance

This function registers all FORTH-79 system and environment words with the specified virtual machine instance, making them available for use in the FORTH environment.

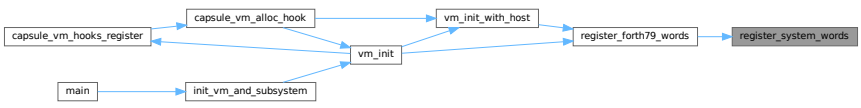
References forth_backslash(), forth_paren(), register_word(), runtime_abortq(), system_word_79_standard(), system_word_abort(), system_word_abort_quote(), system_word_bye(), system_word_cold(), system_word_execute(), system_word_nop(), system_word_page(), system_word_quit(), system_word_reboot(), system_word_save_system(), system_word_see(), system_word_vlist(), system_word_warm(), system_word_words(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



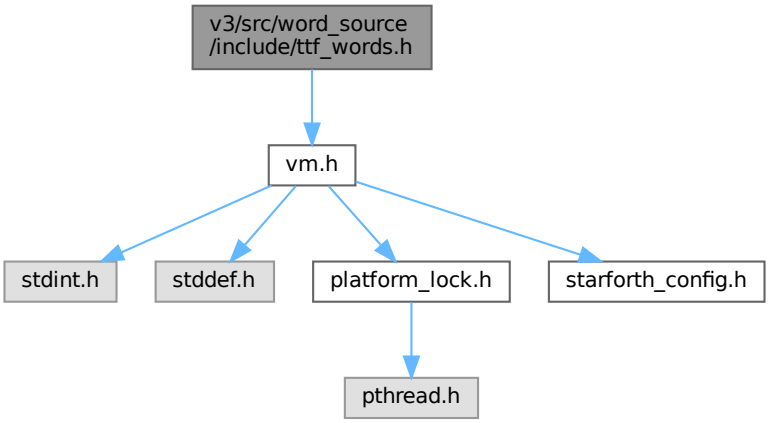
Here is the caller graph for this function:



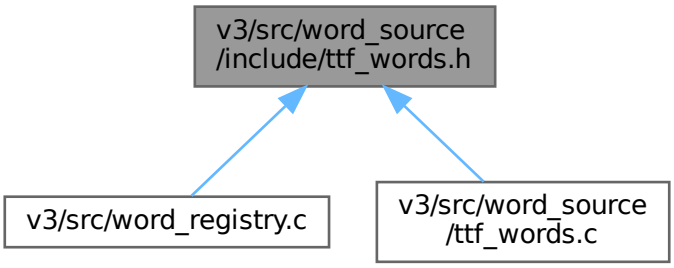
7.395 v3/src/word_source/include/ttf_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for ttf_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_ttf_words (VM *vm)

7.395.1 Function Documentation

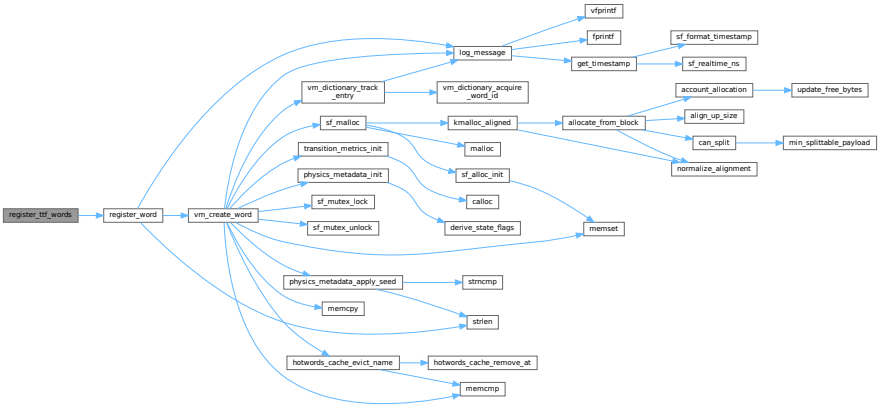
7.395.1.1 register_ttf_words()

```
void register_ttf_words (
            VM * vm )
```

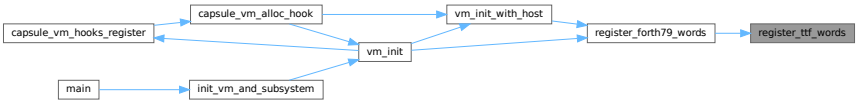
References register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



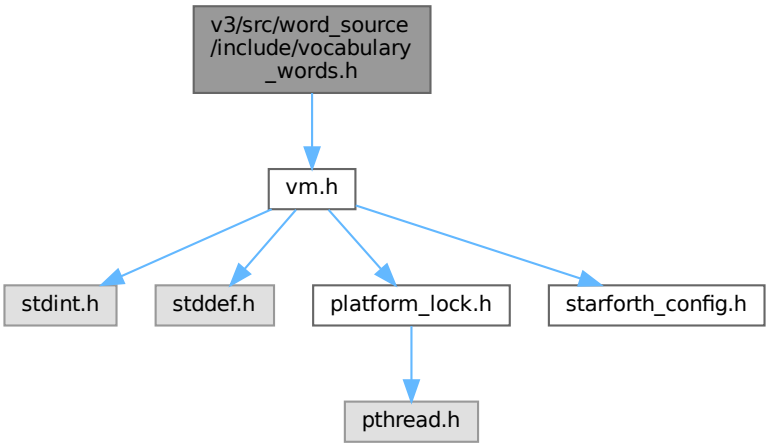
Here is the caller graph for this function:



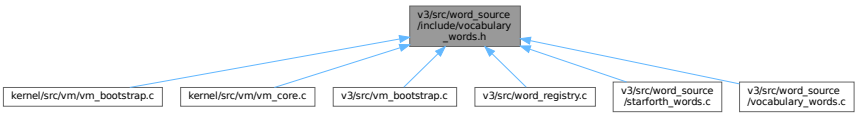
7.396 v3/src/word_source/include/vocabulary_words.h File Reference

```
#include "vm.h"
```

Include dependency graph for vocabulary_words.h:



This graph shows which files directly or indirectly include this file:



Functions

- void register_vocabulary_words (VM *vm)

  Register all FORTH-79 vocabulary words.
- void vocabulary_create_vocabulary_direct (VM *vm, const char *name)

  Direct vocabulary creation (kernel bootstrap)
- void vocabulary_word_definitions (VM *vm)

  DEFINITIONS (–) Set CURRENT to CONTEXT.
- void vocabulary_word_forth (VM *vm)

  FORTH (–) Select FORTH vocabulary.

7.396.1 Function Documentation

7.396.1.1 register_vocabulary_words()

```
void register_vocabulary_words (
            VM * vm )
```

Register all FORTH-79 vocabulary words.

Registers VOCABULARY, DEFINITIONS, CONTEXT, CURRENT, FORTH, ORDER, and (FIND)

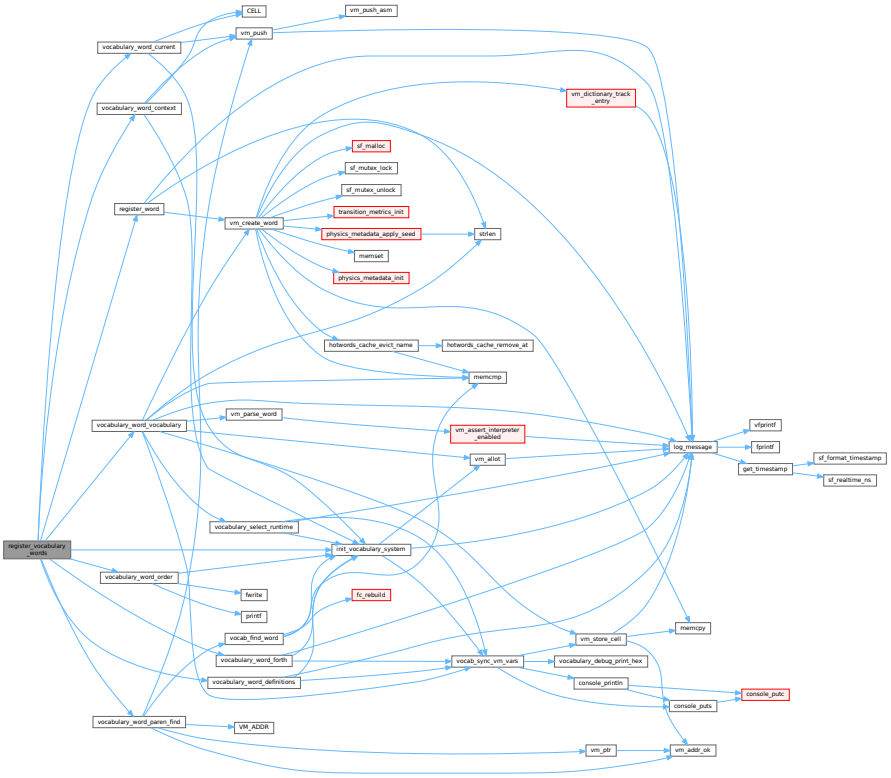
Parameters

vm	Pointer to VM instance

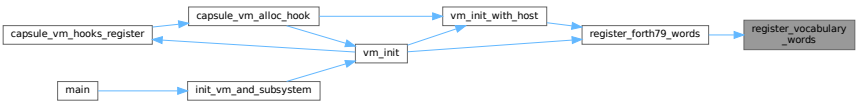
References init_vocabulary_system(), register_word(), vocabulary_word_context(), vocabulary_word_current(), vocabulary_word_definitions(), vocabulary_word_forth(), vocabulary_word_order(), vocabulary_word_paren_find(), and vocabulary_word_vocabulary().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.396.1.2 vocabulary_create_vocabulary_direct()

```
void vocabulary_create_vocabulary_direct (
            VM * vm,
            const char * name )
```

Direct vocabulary creation (kernel bootstrap)

Parameters

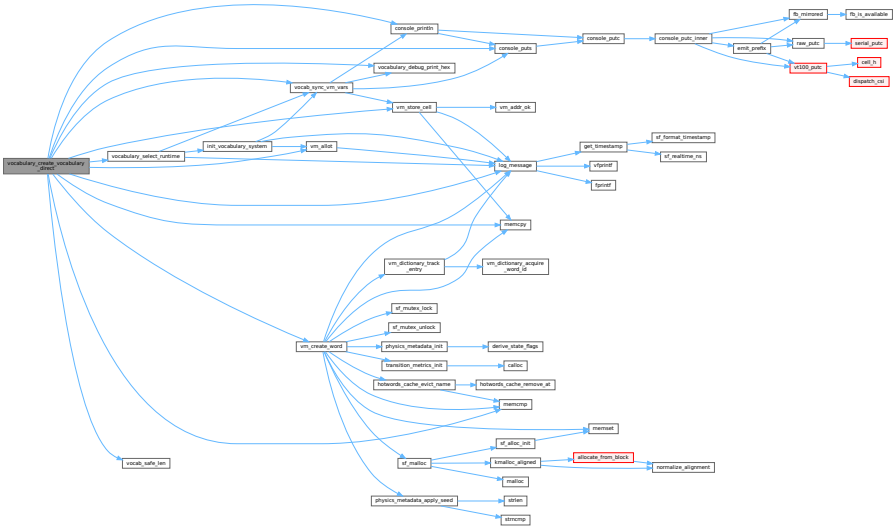
vm	Pointer to the virtual machine instance
name	Vocabulary name

References console_println(), console_puts(), entry, VM::error, VM::here, VM::latest, LOG_DEBUG, LOG_ERROR,

log_message(), memcmp(), memcpy(), VM::memory, name, vm_allot(), vm_create_word(), vm_store_cell(), vocab_safe_len(), vocab_sync_vm_vars(), vocabulary_debug_print_hex(), and vocabulary_select_runtime().

Referenced by vm_bootstrap_root_vocabulary().

Here is the call graph for this function:



Here is the caller graph for this function:

7.396.1.3 vocabulary_word_definitions()

```
void vocabulary_word_definitions (
            VM * vm )
```

DEFINITIONS (–) Set CURRENT to CONTEXT.

Makes new words be defined in the CONTEXT vocabulary

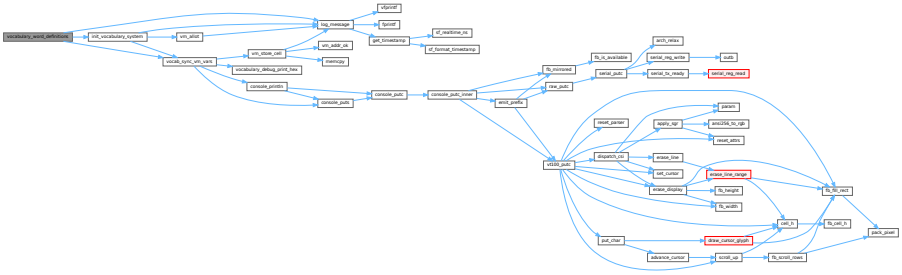
Parameters

vm	Pointer to VM instance

References VocabularyState::context_vocab, VocabularyState::current_vocab, init_vocabulary_system(), LOG_DEBUG, log_message(), VM::vocab, and vocab_sync_vm_vars().

Referenced by register_starforth_words(), register_vocabulary_words(), and vm_bootstrap_root_vocabulary().

Here is the call graph for this function:



Here is the caller graph for this function:

7.396.1.4 vocabulary_word_forth()

```
void vocabulary_word_forth (
            VM * vm )
```

FORTH (–) Select FORTH vocabulary.

Makes FORTH the CONTEXT vocabulary

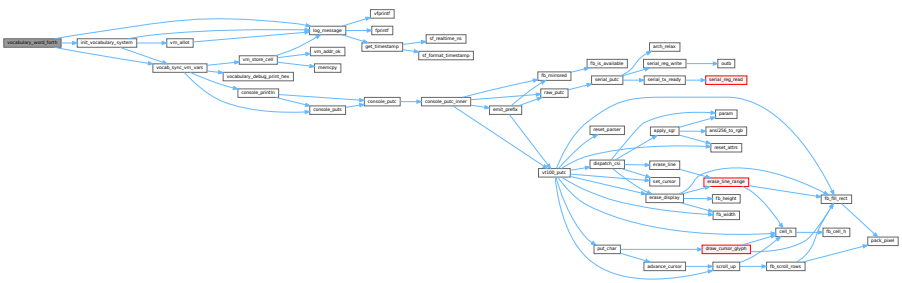
Parameters

vm	Pointer to VM instance

References VocabularyState::context_vocab, VocabularyState::forth_vocab, init_vocabulary_system(), LOG_DEBUG, log_message(), VM::vocab, and vocab_sync_vm_vars().

Referenced by register_starforth_words(), and register_vocabulary_words().

Here is the call graph for this function:

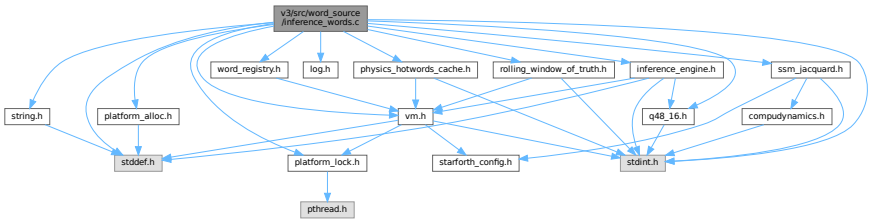


Here is the caller graph for this function:

7.397 v3/src/word_source/inference_words.c File Reference

```
#include <stdint.h>
#include <stddef.h>
#include <string.h>
#include "vm.h"
#include "word_registry.h"
#include "log.h"
#include "q48_16.h"
#include "inference_engine.h"
#include "ssm_jacquard.h"
#include "rolling_window_of_truth.h"
#include "physics_hotwords_cache.h"
#include "platform_alloc.h"
#include "platform_lock.h"
```

Include dependency graph for inference_words.c:



Functions

- static q48_16_t q48_pop_inf (VM *vm)

  inference_words.c — Module 26: SSM inference engine + Jacquard FORTH words
- static void q48_push_inf (VM *vm, q48_16_t q)
- static double q48_to_dbl (q48_16_t q)
- static const uint64_t * array_ptr (VM *vm, vaddr_t addr, cell_t u)
- static void infer_word_q_variance (VM *vm)
- static void infer_word_decay_slope (VM *vm)
- static void infer_word_window_width (VM *vm)
- static void infer_word_window_diversity (VM *vm)
- static void infer_word_run (VM *vm)
- static void infer_word_window_fetch (VM *vm)
- static void infer_word_decay_fetch (VM *vm)
- static void infer_word_variance_fetch (VM *vm)
- static void infer_word_fit_fetch (VM *vm)
- static void infer_word_early_exit_fetch (VM *vm)

- static void infer_word_l8_mode (VM *vm)
- static void infer_word_l8_update (VM *vm)
- static void infer_word_l8_apply (VM *vm)
- static void infer_word_l8_table_force (VM *vm)
- static BayesianLatencyPosterior cache_posterior (VM *vm)
- static BayesianLatencyPosterior bucket_posterior (VM *vm)
- static void infer_word_bayes_cache_mean (VM *vm)
- static void infer_word_bayes_cache_lower (VM *vm)
- static void infer_word_bayes_cache_upper (VM *vm)
- static void infer_word_bayes_bucket_mean (VM *vm)
- static void infer_word_bayes_bucket_lower (VM *vm)
- static void infer_word_bayes_bucket_upper (VM *vm)
- void register_inference_words (VM *vm)

inference_words.h — Module 26: SSM inference engine + Jacquard FORTH words

7.397.1 Function Documentation

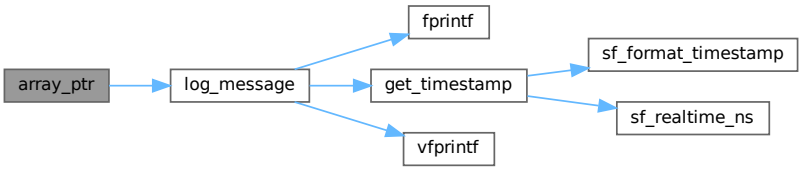
7.397.1.1 array_ptr()

```
static const uint64_t * array_ptr (
            VM * vm,
            vaddr_t addr,
            cell_t u )  [static]
```

References bytes, VM::error, LOG_ERROR, log_message(), VM::memory, and VM_MEMORY_SIZE.

Referenced by infer_word_decay_slope(), infer_word_q_variance(), and infer_word_window_width().

Here is the call graph for this function:



Here is the caller graph for this function:

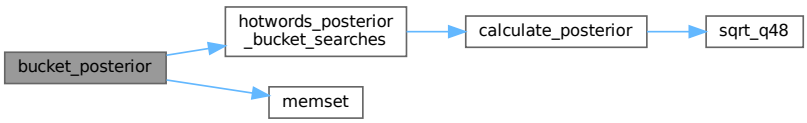
7.397.1.2 bucket_posterior()

```
static BayesianLatencyPosterior bucket_posterior (
            VM * vm )  [static]
```

References VM::hotwords_cache, hotwords_posterior_bucket_searches(), memset(), HotwordsCache_s::stats, and zero.

Referenced by infer_word_bayes_bucket_lower(), infer_word_bayes_bucket_mean(), and infer_word_bayes_bucket_upper().

Here is the call graph for this function:



Here is the caller graph for this function:

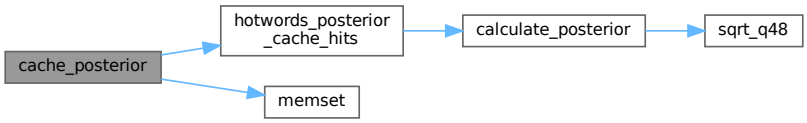
7.397.1.3 cache_posterior()

```
static BayesianLatencyPosterior cache_posterior (
            VM * vm )  [static]
```

References VM::hotwords_cache, hotwords_posterior_cache_hits(), memset(), HotwordsCache_s::stats, and zero.

Referenced by infer_word_bayes_cache_lower(), infer_word_bayes_cache_mean(), and infer_word_bayes_cache_upper().

Here is the call graph for this function:



Here is the caller graph for this function:

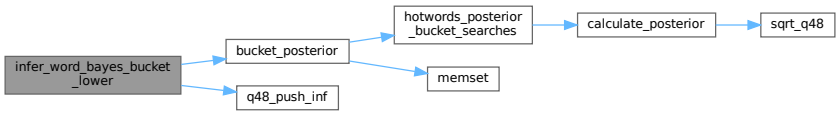
7.397.1.4 infer_word_bayes_bucket_lower()

```
static void infer_word_bayes_bucket_lower (
            VM * vm )  [static]
```

References bucket_posterior(), and q48_push_inf().

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

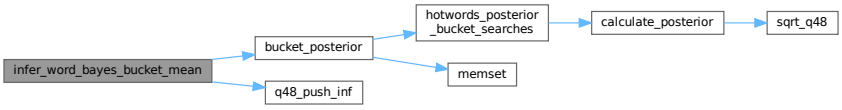
7.397.1.5 infer_word_bayes_bucket_mean()

```
static void infer_word_bayes_bucket_mean (
            VM * vm )  [static]
```

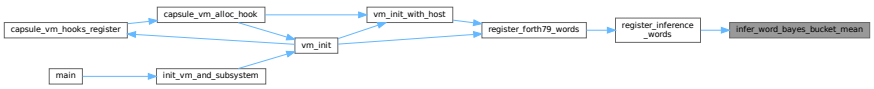
References bucket_posterior(), and q48_push_inf().

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:



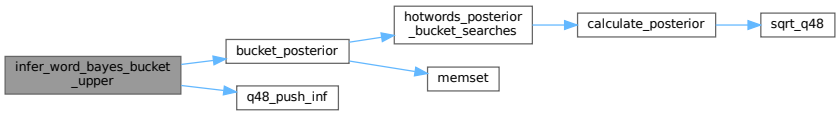
7.397.1.6 infer_word_bayes_bucket_upper()

```
static void infer_word_bayes_bucket_upper (
            VM * vm )  [static]
```

References bucket_posterior(), and q48_push_inf().

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

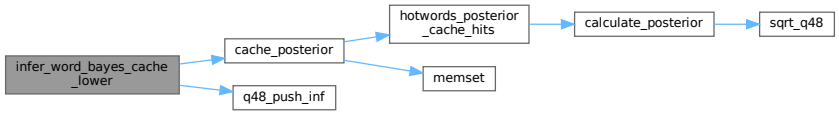
7.397.1.7 infer_word_bayes_cache_lower()

```
static void infer_word_bayes_cache_lower (
            VM * vm )  [static]
```

References cache_posterior(), and q48_push_inf().

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

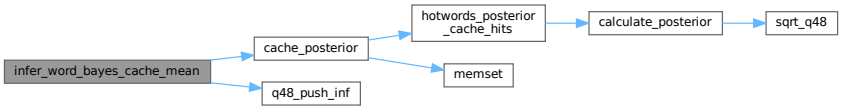
7.397.1.8 infer_word_bayes_cache_mean()

```
static void infer_word_bayes_cache_mean (
            VM * vm )  [static]
```

References cache_posterior(), and q48_push_inf().

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

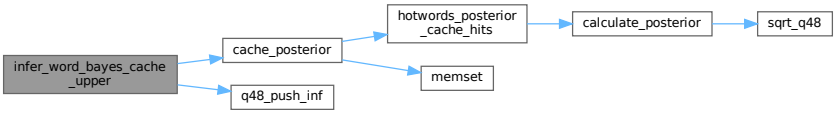
7.397.1.9 infer_word_bayes_cache_upper()

```
static void infer_word_bayes_cache_upper (
            VM * vm )  [static]
```

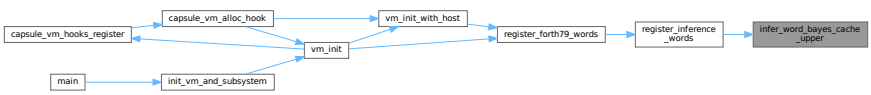
References cache_posterior(), and q48_push_inf().

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.397.1.10 infer_word_decay_fetch()

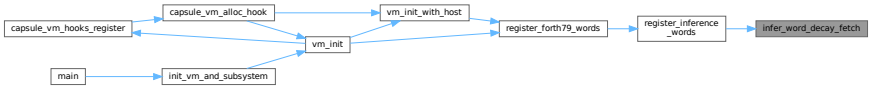
```
static void infer_word_decay_fetch (
            VM * vm )  [static]
```

References InferenceOutputs::adaptive_decay_slope, VM::last_inference_outputs, and q48_push_inf().

Referenced by register_inference_words().

Here is the call graph for this function:

Here is the caller graph for this function:



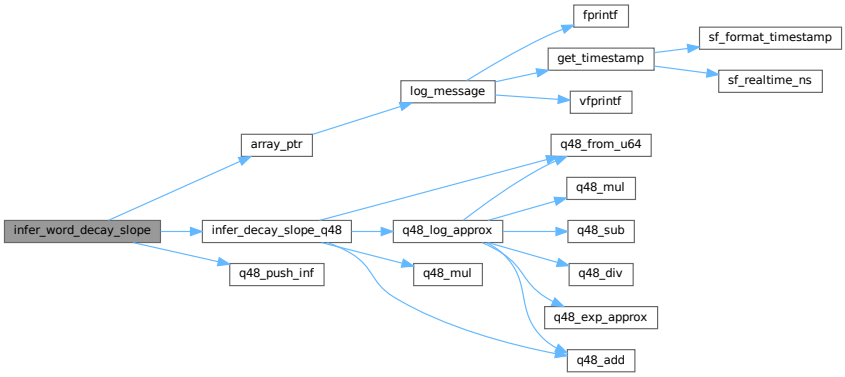
7.397.1.11 infer_word_decay_slope()

```
static void infer_word_decay_slope (
            VM * vm )  [static]
```

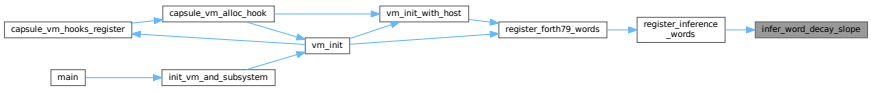
References array_ptr(), infer_decay_slope_q48(), q48_push_inf(), and VM_POP.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.397.1.12 infer_word_early_exit_fetch()

```
static void infer_word_early_exit_fetch (
            VM * vm )  [static]
```

References InferenceOutputs::early_exited, VM::last_inference_outputs, and VM_PUSH.

Referenced by register_inference_words().

Here is the caller graph for this function:

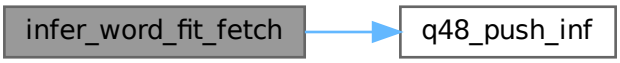
7.397.1.13 infer_word_fit_fetch()

```
static void infer_word_fit_fetch (
            VM * vm )  [static]
```

References VM::last_inference_outputs, q48_push_inf(), and InferenceOutputs::slope_fit_quality_q48.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.397.1.14 infer_word_l8_apply()

```
static void infer_word_l8_apply (
            VM * vm )  [static]
```

References ssm_apply_mode(), VM::ssm_config, and VM::ssm_l8_state.

Referenced by register_inference_words().

Here is the call graph for this function:

Here is the caller graph for this function:

7.397.1.15 infer_word_l8_mode()

```
static void infer_word_l8_mode (
            VM * vm )  [static]
```

References ssm_l8_state_t::current_mode, VM::ssm_l8_state, and VM_PUSH.

Referenced by register_inference_words().

Here is the caller graph for this function:

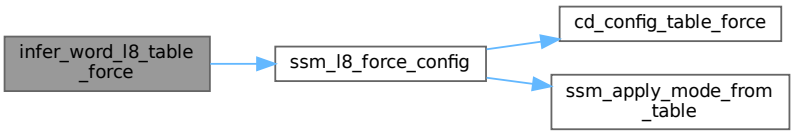
7.397.1.16 infer_word_l8_table_force()

```
static void infer_word_l8_table_force (
            VM * vm )  [static]
```

References VM::ssm_config, ssm_l8_force_config(), VM::ssm_l8_state, and VM_POP.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

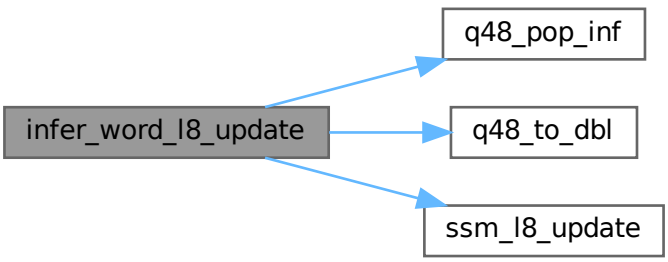
7.397.1.17 infer_word_l8_update()

```
static void infer_word_l8_update (
            VM * vm )  [static]
```

References ssm_l8_metrics_t::cv, ssm_l8_metrics_t::entropy, q48_pop_inf(), q48_to_dbl(), VM::ssm_l8_state, ssm_l8_update(), ssm_l8_metrics_t::stability_score, ssm_l8_metrics_t::temporal_decay, and VM_POP.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

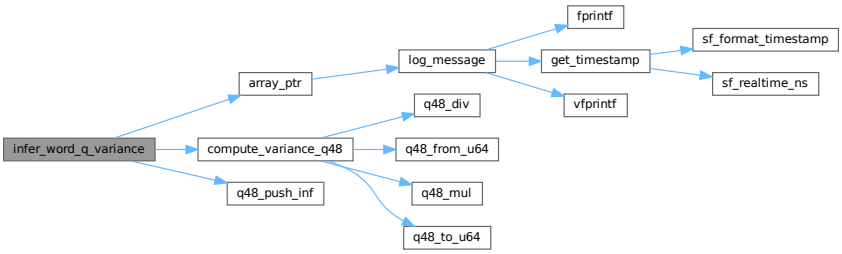
7.397.1.18 infer_word_q_variance()

```
static void infer_word_q_variance (
            VM * vm )  [static]
```

References array_ptr(), compute_variance_q48(), q48_push_inf(), and VM_POP.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.397.1.19 infer_word_run()

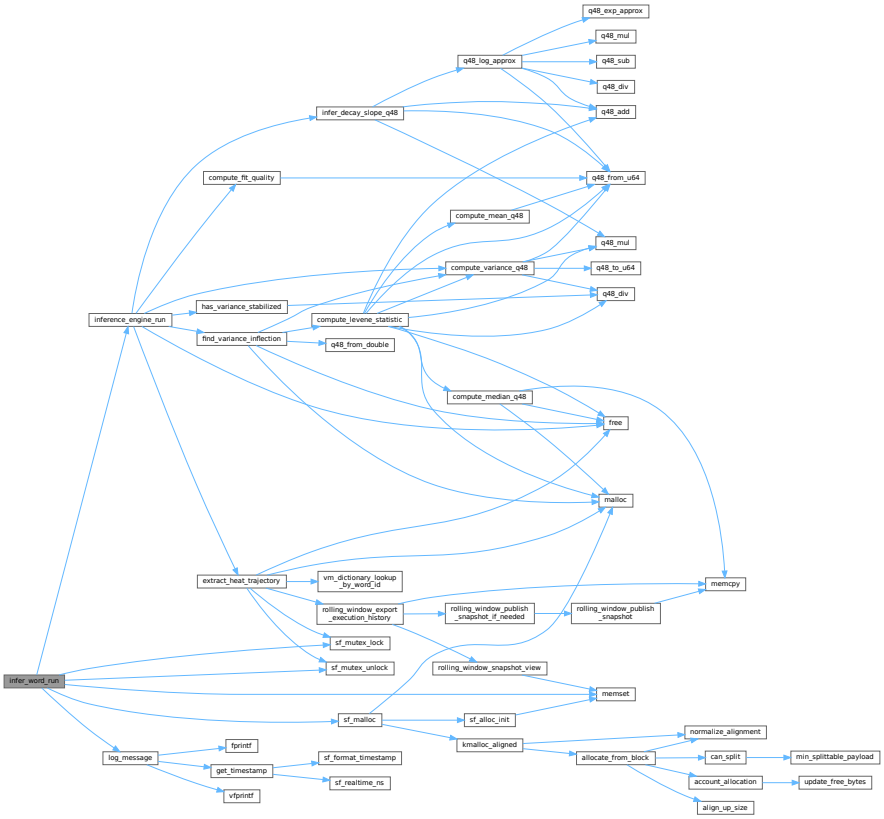
```
static void infer_word_run (
            VM * vm )  [static]
```

References VM::dict_lock, VM::error, DictEntry::execution_heat, InferenceInputs::hot_word_count, HOTWORDS_EXECUTION_HEAT
inference_engine_run(), VM::last_inference_outputs, InferenceInputs::last_stale_count, InferenceInputs::last_total_heat,
VM::latest, DictEntry::link, LOG_ERROR, log_message(), memset(), VM::pipeline_metrics, InferenceInputs::prefetch_attempts,
PipelineGlobalMetrics::prefetch_attempts, InferenceInputs::prefetch_hits, PipelineGlobalMetrics::prefetch_hits,
VM::rolling_window, sf_malloc(), sf_mutex_lock(), sf_mutex_unlock(), InferenceInputs::stale_word_count,
VM::stale_word_count_at_check, RollingWindowOfTruth::total_executions, InferenceInputs::total_heat, VM::total_heat_at_last_check

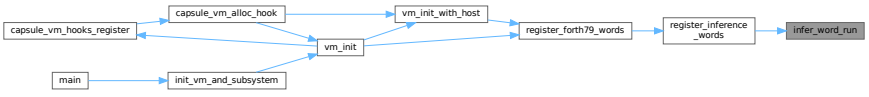
InferenceInputs::trajectory_length, InferenceInputs::vm, InferenceInputs::window, RollingWindowOfTruth::window_pos, InferenceInputs::word_count, and word_count.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:



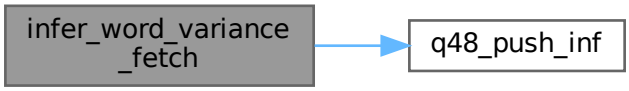
7.397.1.20 infer_word_variance_fetch()

```
static void infer_word_variance_fetch (
            VM * vm )  [static]
```

References VM::last_inference_outputs, q48_push_inf(), and InferenceOutputs::window_variance_q48.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

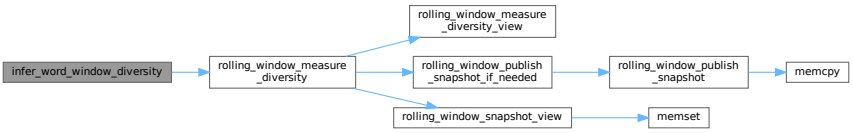
7.397.1.21 infer_word_window_diversity()

```
static void infer_word_window_diversity (
            VM * vm )  [static]
```

References VM::rolling_window, rolling_window_measure_diversity(), and VM_PUSH.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.397.1.22 infer_word_window_fetch()

```
static void infer_word_window_fetch (
            VM * vm )  [static]
```

References InferenceOutputs::adaptive_window_width, VM::last_inference_outputs, and VM_PUSH.

Referenced by register_inference_words().

Here is the caller graph for this function:

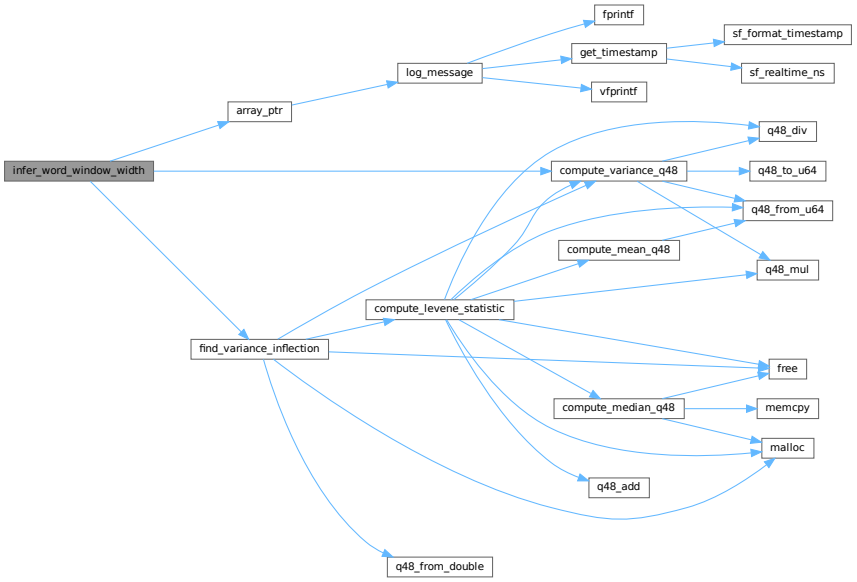
7.397.1.23 infer_word_window_width()

```
static void infer_word_window_width (
            VM * vm )  [static]
```

References array_ptr(), compute_variance_q48(), find_variance_inflection(), VM_POP, and VM_PUSH.

Referenced by register_inference_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.397.1.24 q48_pop_inf()

```
static q48_16_t q48_pop_inf (
            VM * vm )  [inline], [static]
```

inference_words.c — Module 26: SSM inference engine + Jacquard FORTH words

Exposes the SSM physics engine to FORTH:

- Variance / decay-slope / window-width inference on arbitrary arrays
- Full inference engine run on this VM's rolling window
- L8 Jacquard mode selector: update, query, apply
- Bayesian latency posteriors for cache-hit and bucket-search latencies
- Rolling window diversity (entropy metric)
- Readable inference output fields from vm->last_inference_outputs

All Q48.16 values pushed as cell_t (int64_t), reinterpreted as uint64_t.

Words registered: Q.VARIANCE (addr u – q) variance of u cells at addr (Q48.16) INFER-DECAY-SLOPE (addr u – q) exponential decay slope (Q48.16) INFER-WINDOW-WIDTH (addr u – n) optimal window width from inflection WINDOW-DIVERSITY (– u) rolling window diversity (entropy) INFER-RUN (–) run full inference, update vm->last_inference_outputs INFER-WINDOW@ (– u) last adaptive_window_width INFER-DECAY@ (– q) last adaptive_decay_slope (Q48.16) INFER-VARIANCE@ (– q) last window_variance_q48 INFER-FIT@ (– q) last slope_fit_quality_q48 INFER-EARLY-EXIT@ (– flag) 1 if last INFER-RUN used ANOVA early-exit L8-MODE (– n) current Jacquard mode (0-15) L8-UPDATE (entropy_q cv_q temporal_q stability_q –) L8-APPLY (–) apply current mode to vm->ssm_config (legacy 16-mode) L8-TABLE-FORCE (config_idx –) force the adaptive table onto config_idx (0-127) BAYES-CACHE-MEAN (– q) Bayesian mean latency for cache hits (Q48.16) BAYES-CACHE-LOWER (– q) 95% credible lower bound, cache hits BAYES-CACHE-UPPER (– q) 95% credible upper bound, cache hits BAYES-BUCKET-MEAN (– q) Bayesian mean latency for bucket searches BAYES-BUCKET-LOWER (– q) 95% credible lower bound, bucket searches BAYES-BUCKET-UPPER (– q) 95% credible upper bound, bucket searches

References VM_POP.

Referenced by infer_word_l8_update().

Here is the caller graph for this function:

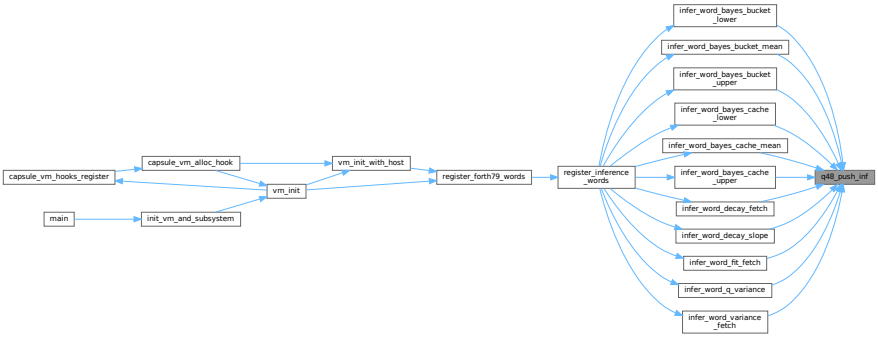
7.397.1.25 q48_push_inf()

```
static void q48_push_inf (
            VM * vm,
            q48_16_t q )  [inline], [static]
```

References VM_PUSH.

Referenced by infer_word_bayes_bucket_lower(), infer_word_bayes_bucket_mean(), infer_word_bayes_bucket_upper(), infer_word_bayes_cache_lower(), infer_word_bayes_cache_mean(), infer_word_bayes_cache_upper(), infer_word_decay_fetch(), infer_word_decay_slope(), infer_word_fit_fetch(), infer_word_q_variance(), and infer_word_variance_fetch().

Here is the caller graph for this function:

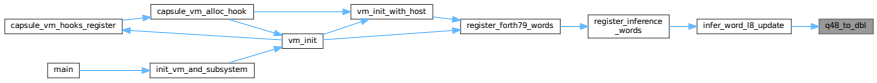


7.397.1.26 q48_to_dbl()

```
static double q48_to_dbl (
            q48_16_t q )  [inline], [static]
```

Referenced by infer_word_l8_update().

Here is the caller graph for this function:



7.397.1.27 register_inference_words()

```
void register_inference_words (
            VM * vm )
```

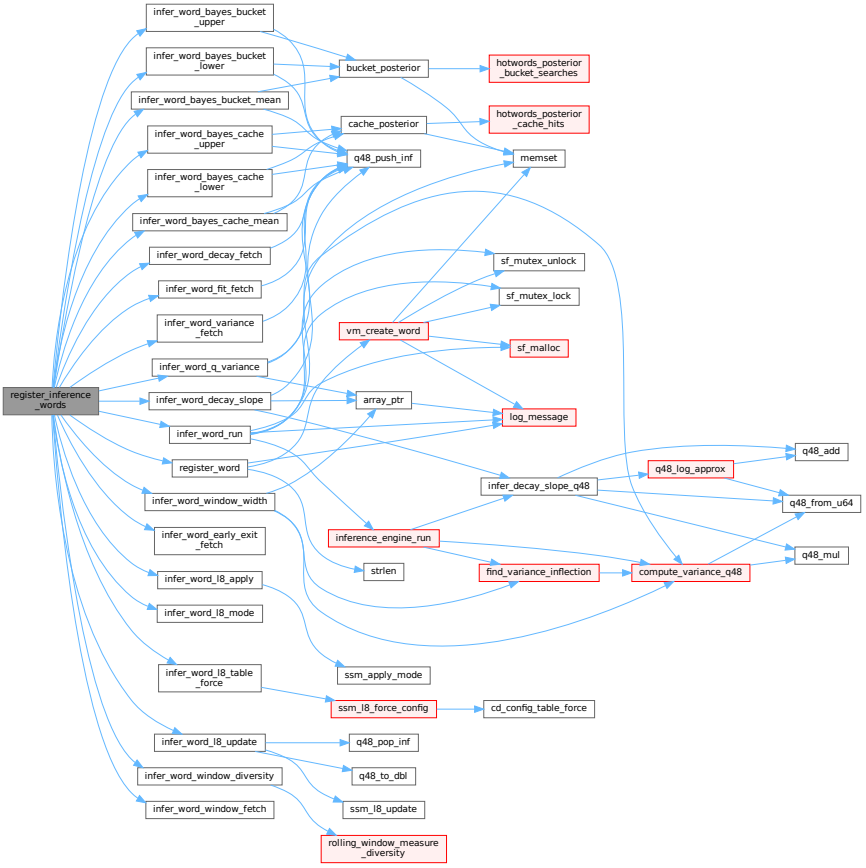
inference_words.h — Module 26: SSM inference engine + Jacquard FORTH words

Register all inference engine / Jacquard FORTH words with the VM. Module 26 in register_forth79_words().

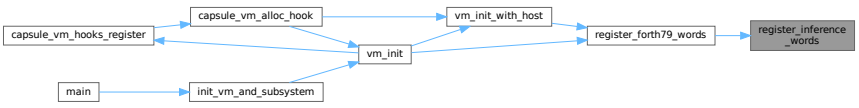
References infer_word_bayes_bucket_lower(), infer_word_bayes_bucket_mean(), infer_word_bayes_bucket_upper(), infer_word_bayes_cache_lower(), infer_word_bayes_cache_mean(), infer_word_bayes_cache_upper(), infer_word_decay_fetch(), infer_word_decay_slope(), infer_word_early_exit_fetch(), infer_word_fit_fetch(), infer_word_l8_apply(), infer_word_l8_mode(), infer_word_l8_table_force(), infer_word_l8_update(), infer_word_q_variance(), infer_word_run(), infer_word_variance_fetch(), infer_word_window_diversity(), infer_word_window_fetch(), infer_word_window_width(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

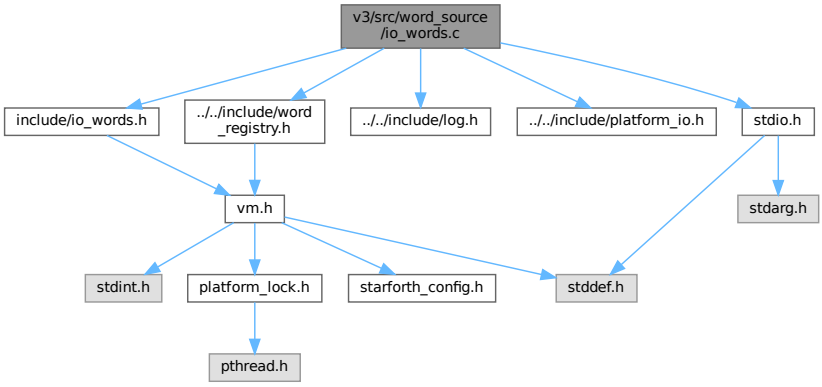


7.398 v3/src/word_source/io_words.c File Reference

```
#include "include/io_words.h"
#include "../../include/word_registry.h"
```

```
#include "../../include/log.h"
#include "../../include/platform_io.h"
#include <stdio.h>
```

Include dependency graph for io_words.c:



Functions

- static void io_word_emit (VM *vm)

  FORTH word EMIT - Output character to terminal.
- static void io_word_cr (VM *vm)

  FORTH word CR - Output carriage return.
- static void io_word_key (VM *vm)

  FORTH word KEY - Input character from terminal.
- static void io_word_question_terminal (VM *vm)

  FORTH word ?TERMINAL - Check if input is available.
- static void io_word_type (VM *vm)

  FORTH word TYPE - Output string of characters.
- static void io_word_space (VM *vm)

  FORTH word SPACE - Output one space character.
- static void io_word_spaces (VM *vm)

  FORTH word SPACES - Output multiple spaces.
- static void io_runtime_do_string (VM *vm)
- static void io_word_dot_quote (VM *vm)
- void register_io_words (VM *vm)

  Registers all I/O related FORTH words with the virtual machine.

7.398.1 Function Documentation

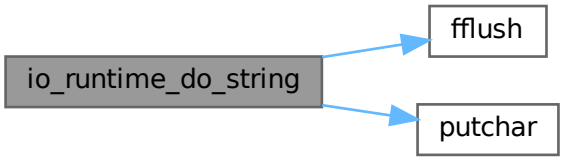
7.398.1.1 io_runtime_do_string()

```
static void io_runtime_do_string (
            VM * vm )  [static]
```

References VM::error, fflush(), putchar(), VM::return_stack, VM::rsp, and stdout.

Referenced by register_io_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.398.1.2 io_word_cr()

```
static void io_word_cr (
            VM * vm )  [static]
```

FORTH word CR - Output carriage return.

Parameters

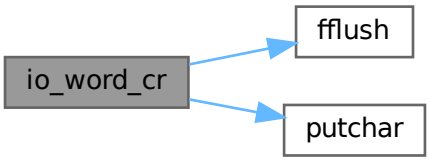
vm	Pointer to the VM structure

Stack effect: (–) Outputs a newline character to the terminal

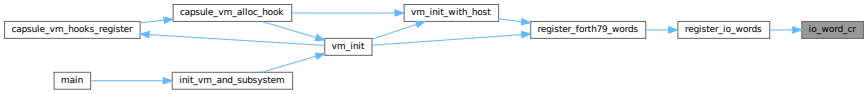
References fflush(), putchar(), and stdout.

Referenced by register_io_words().

Here is the call graph for this function:



Here is the caller graph for this function:



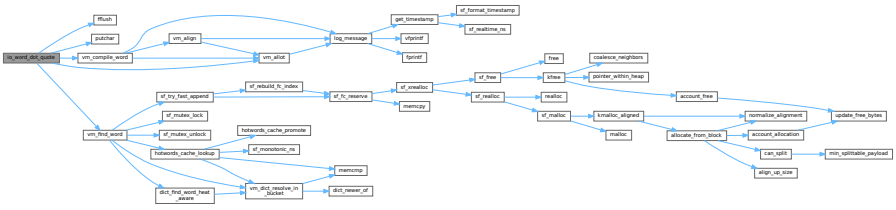
7.398.1.3 io_word_dot_quote()

```
static void io_word_dot_quote (
            VM * vm )  [static]
```

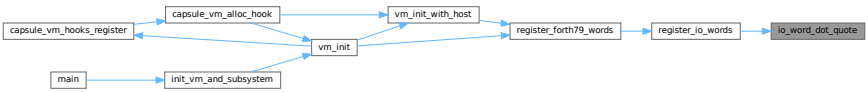
References VM::error, fflush(), VM::input_buffer, VM::input_length, VM::input_pos, VM::mode, MODE_INTERPRET, putchar(), stdout, vm_allot(), vm_compile_word(), and vm_find_word().

Referenced by register_io_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.398.1.4 io_word_emit()

```
static void io_word_emit (
            VM * vm )  [static]
```

FORTH word EMIT - Output character to terminal.

Parameters

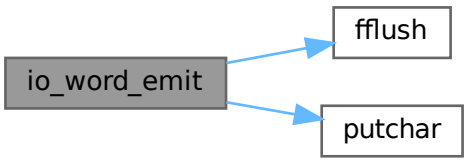
vm	Pointer to the VM structure

Stack effect: (c –) Outputs the character from top of stack to the terminal

References VM::data_stack, VM::dsp, VM::error, fflush(), putchar(), and stdout.

Referenced by register_io_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.398.1.5 io_word_key()

```
static void io_word_key (
            VM * vm )  [static]
```

FORTH word KEY - Input character from terminal.

Parameters

vm	Pointer to the VM structure

Stack effect: (– c) Reads one character from terminal and pushes it to stack

References VM::data_stack, VM::dsp, VM::error, getchar(), and STACK_SIZE.

Referenced by register_io_words().

Here is the call graph for this function:

Here is the caller graph for this function:

7.398.1.6 io_word_question_terminal()

```
static void io_word_question_terminal (
            VM * vm )  [static]
```

FORTH word ?TERMINAL - Check if input is available.

Parameters

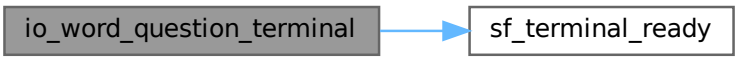
vm	Pointer to the VM structure

Stack effect: (– flag) Pushes true if input is available, false otherwise

References VM::data_stack, VM::dsp, VM::error, sf_terminal_ready(), and STACK_SIZE.

Referenced by register_io_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.398.1.7 io_word_space()

```
static void io_word_space (
            VM * vm )  [static]
```

FORTH word SPACE - Output one space character.

Parameters

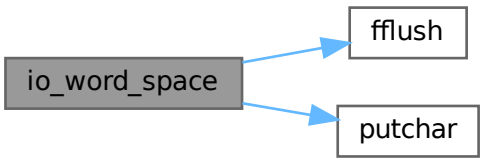
vm	Pointer to the VM structure

Stack effect: (–) Outputs a single space character to terminal

References fflush(), putchar(), and stdout.

Referenced by register_io_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.398.1.8 io_word_spaces()

```
static void io_word_spaces (
            VM * vm )  [static]
```

FORTH word SPACES - Output multiple spaces.

Parameters

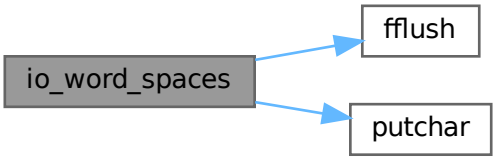
vm	Pointer to the VM structure

Stack effect: (n –) Outputs n space characters to terminal

References count, VM::data_stack, VM::dsp, VM::error, fflush(), putchar(), and stdout.

Referenced by register_io_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.398.1.9 io_word_type()

```
static void io_word_type (
            VM * vm )  [static]
```

FORTH word TYPE - Output string of characters.

Parameters

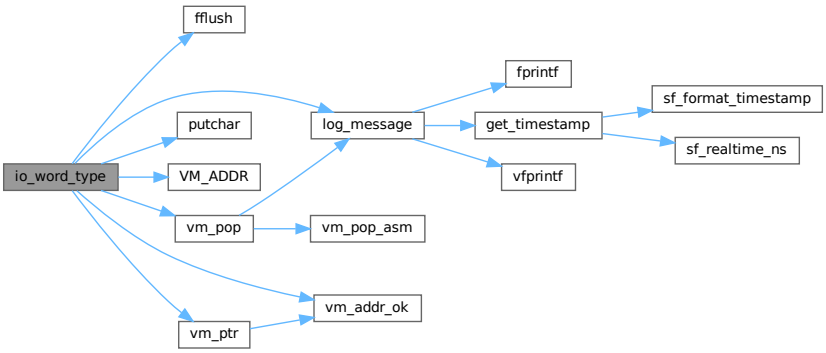
vm	Pointer to the VM structure

Stack effect: (addr u –) Outputs u characters from memory starting at addr

References count, VM::dsp, VM::error, fflush(), LOG_DEBUG, LOG_ERROR, log_message(), putchar(), stdout, VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_ptr().

Referenced by register_io_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.398.1.10 register_io_words()

```
void register_io_words (
            VM * vm )
```

Registers all I/O related FORTH words with the virtual machine.

Parameters

vm	Pointer to the virtual machine instance

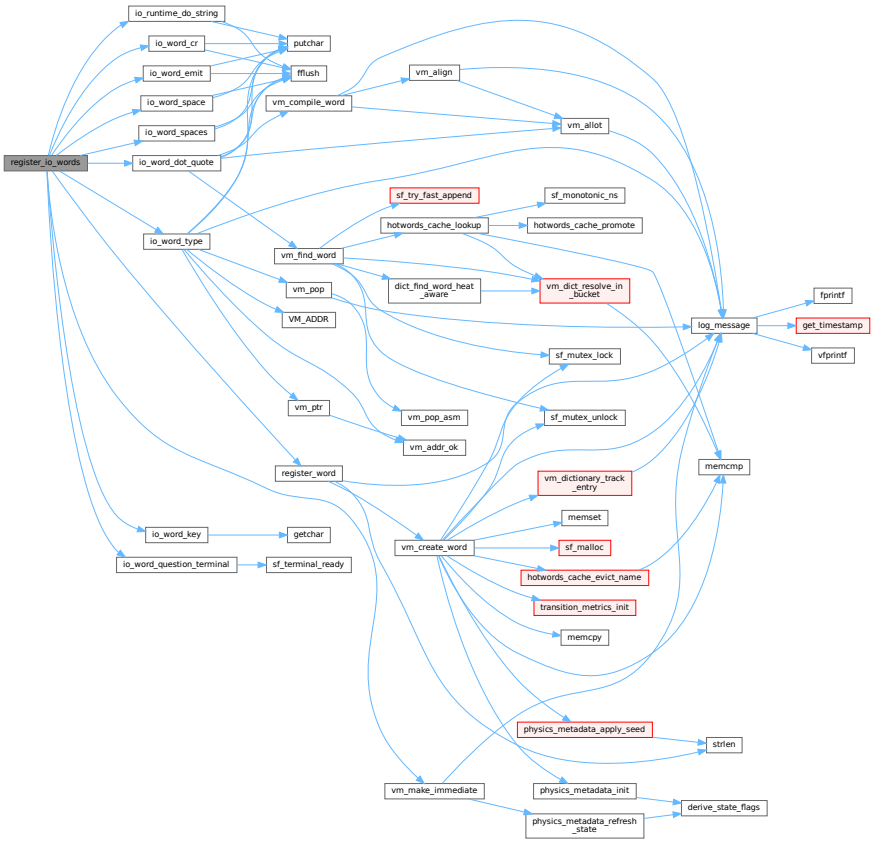
Registers the following FORTH-79 I/O & Terminal Words:

- EMIT (c –) Output character c
- CR (–) Output carriage return
- KEY (– c) Input character from keyboard
- ?TERMINAL (– flag) True if key pressed
- TYPE (addr u –) Output u characters from addr
- SPACE (–) Output one space
- SPACES (n –) Output n spaces

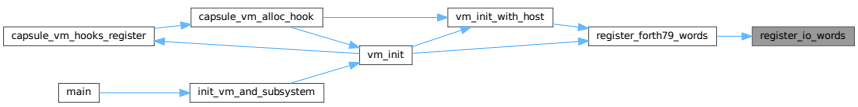
References io_runtime_do_string(), io_word_cr(), io_word_dot_quote(), io_word_emit(), io_word_key(), io_word_question_terminal(), io_word_space(), io_word_spaces(), io_word_type(), register_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



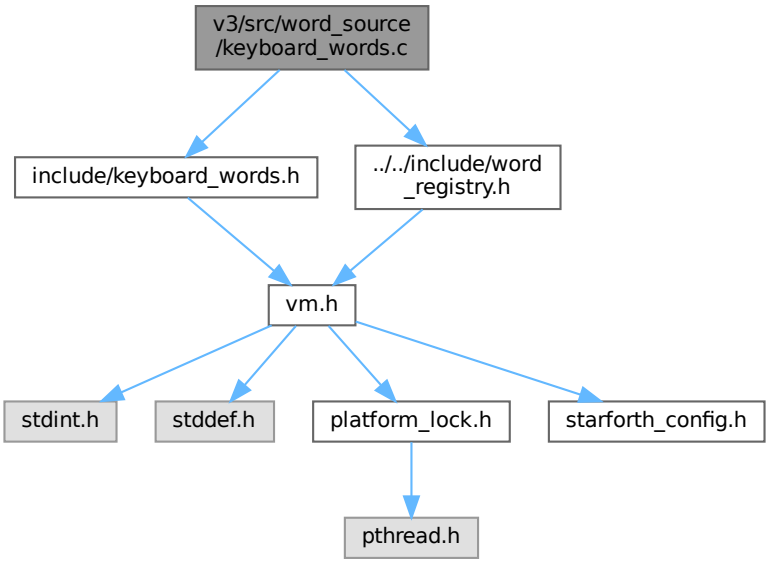
Here is the caller graph for this function:



7.399 v3/src/word_source/keyboard_words.c File Reference

```
#include "include/keyboard_words.h"
#include "../../include/word_registry.h"
```

Include dependency graph for keyboard_words.c:



Functions

- static void kbw_scan (VM *vm)
- static void kbw_debug (VM *vm)
- static void kbw_vevent (VM *vm)
- static void kbw_vdebug (VM *vm)
- int sk_key_event_poll (uint16_t *keycode, int *pressed)

  FABRIC-0.md item 4.4v: shared C-level poll, one converged event stream (Linux input keycode namespace, all three architectures) – see KEY-EVENT's doc comment above for the full per-arch translation rationale.
- static void kbw_key_event (VM *vm)
- static void kbw_alt_tab (VM *vm)
- void register_keyboard_words (VM *vm)

Variables

- volatile uint32_t g_i8042_isr_count
- volatile uint32_t g_spurious_count
- volatile uint32_t g_virtio_input_isr_count

7.399.1 Function Documentation

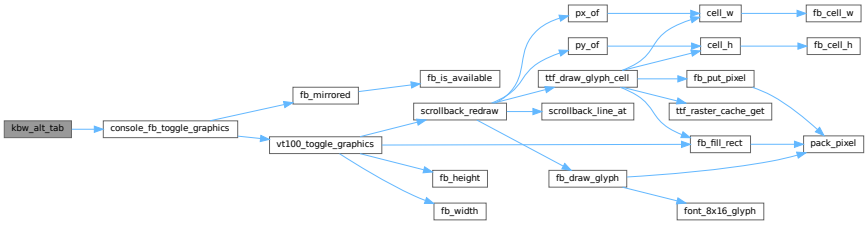
7.399.1.1 kbw_alt_tab()

```
static void kbw_alt_tab (
            VM * vm )  [static]
```

References console_fb_toggle_graphics().

Referenced by register_keyboard_words().

Here is the call graph for this function:



Here is the caller graph for this function:

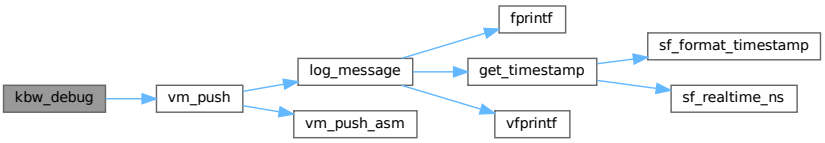
7.399.1.2 kbw_debug()

```
static void kbw_debug (
            VM * vm )  [static]
```

References g_i8042_isr_count, g_spurious_count, and vm_push().

Referenced by register_keyboard_words().

Here is the call graph for this function:



Here is the caller graph for this function:

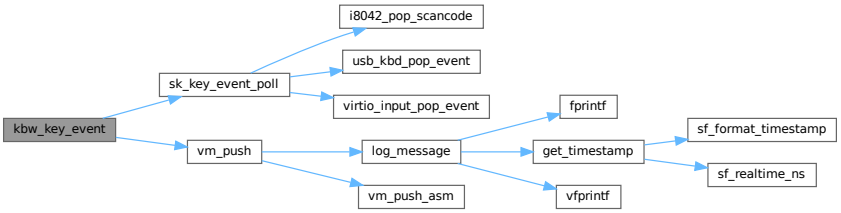
7.399.1.3 kbw_key_event()

```
static void kbw_key_event (
            VM * vm )  [static]
```

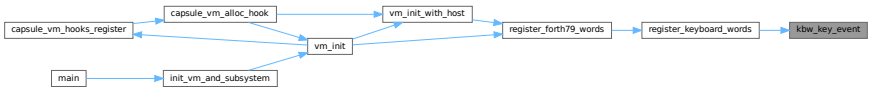
References keycode, pressed, sk_key_event_poll(), and vm_push().

Referenced by register_keyboard_words().

Here is the call graph for this function:



Here is the caller graph for this function:



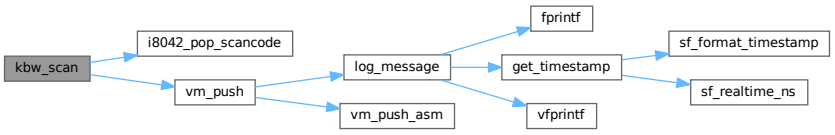
7.399.1.4 kbw_scan()

```
static void kbw_scan (
            VM * vm )  [static]
```

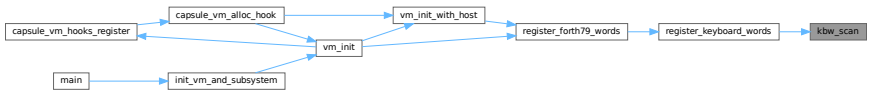
References i8042_pop_scancode(), and vm_push().

Referenced by register_keyboard_words().

Here is the call graph for this function:



Here is the caller graph for this function:



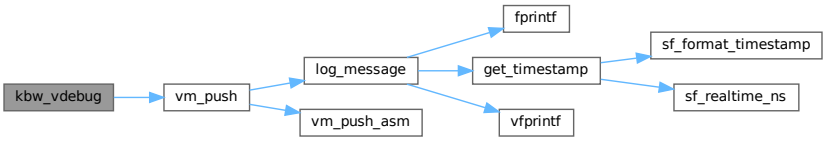
7.399.1.5 kbw_vdebug()

```
static void kbw_vdebug (
            VM * vm )  [static]
```

References g_virtio_input_isr_count, and vm_push().

Referenced by register_keyboard_words().

Here is the call graph for this function:



Here is the caller graph for this function:

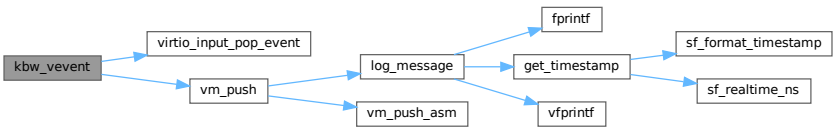
7.399.1.6 kbw_vevent()

```
static void kbw_vevent (
            VM * vm )  [static]
```

References virtio_input_pop_event(), and vm_push().

Referenced by register_keyboard_words().

Here is the call graph for this function:



Here is the caller graph for this function:

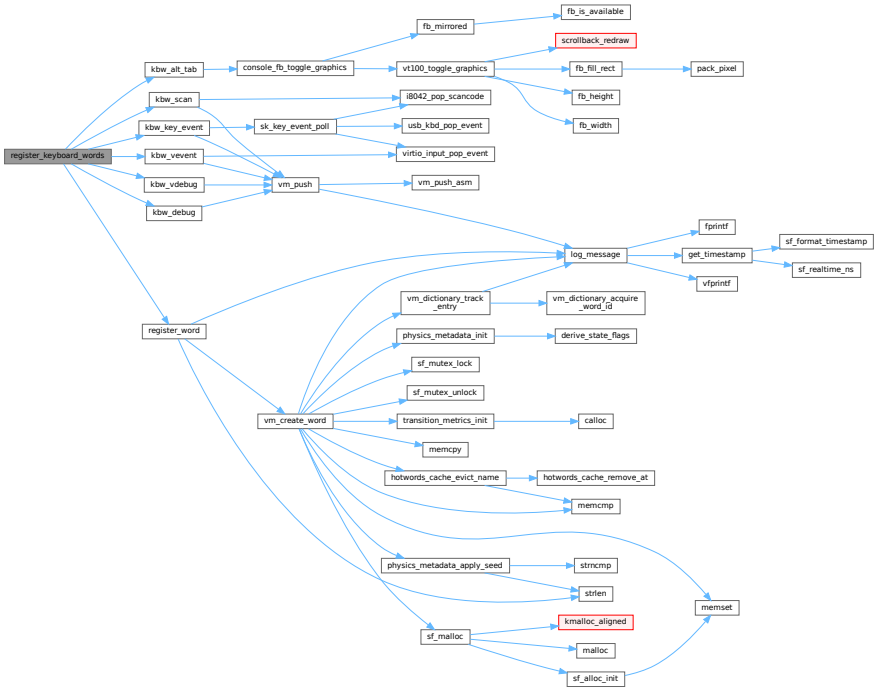
7.399.1.7 register_keyboard_words()

```
void register_keyboard_words (
            VM * vm )
```

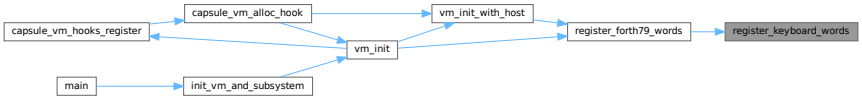
References kbw_alt_tab(), kbw_debug(), kbw_key_event(), kbw_scan(), kbw_vdebug(), kbw_vevent(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.399.1.8 sk_key_event_poll()

```
int sk_key_event_poll (
            uint16_t * keycode,
            int * pressed )
```

FABRIC-0.md item 4.4v: shared C-level poll, one converged event stream (Linux input keycode namespace, all three architectures) – see KEY-EVENT's doc comment above for the full per-arch translation rationale.

Used by both kbw_key_event() (the FORTH word) and the REPL keyboard bridge (repl.c), so there is exactly one implementation.

Parameters

keycode	Written with the Linux input keycode on success.
pressed	Written with 1 (press/repeat) or 0 (release) on success.

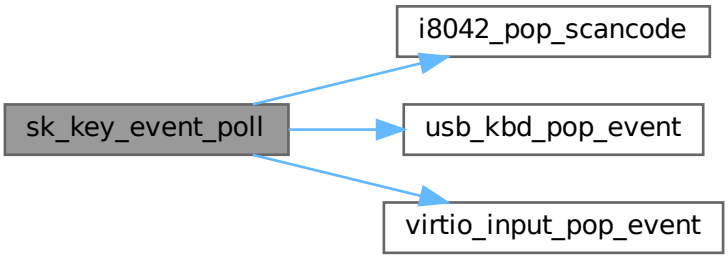
Returns

1 if an event was available, 0 otherwise.

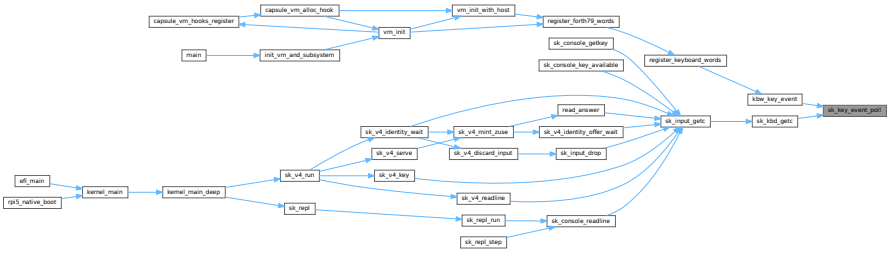
References i8042_pop_scancode(), keycode, pressed, usb_kbd_pop_event(), and virtio_input_pop_event().

Referenced by kbw_key_event(), and sk_kbd_getc().

Here is the call graph for this function:



Here is the caller graph for this function:



7.399.2 Variable Documentation

7.399.2.1 g_i8042_isr_count

```
volatile uint32_t g_i8042_isr_count  [extern]
```

Referenced by kbw_debug().

7.399.2.2 g_spurious_count

```
volatile uint32_t g_spurious_count  [extern]
```

Referenced by isr_common_handler(), and kbw_debug().

7.399.2.3 g_virtio_input_isr_count

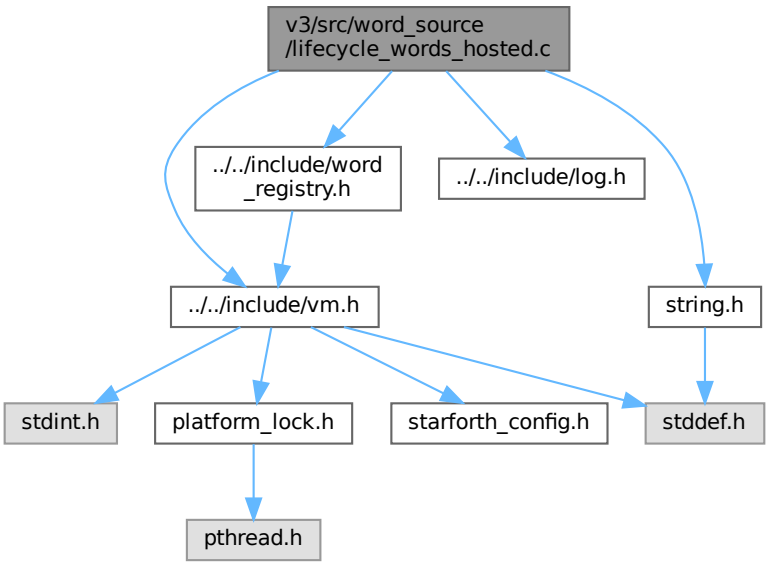
```
volatile uint32_t g_virtio_input_isr_count  [extern]
```

Referenced by kbw_vdebug(), and virtio_input_isr().

7.400 v3/src/word_source/lifecycle_words_hosted.c File Reference

```
#include "../../include/vm.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include <string.h>
```

Include dependency graph for lifecycle_words_hosted.c:



Macros

- #define NAME_MAX_LEN 64

  lifecycle_words_hosted.c - BIRTH KILL PAUSE RESUME USE for hosted Linux build

Functions

- static void extract_name (VM ∗vm, cell_t caddr, cell_t u, char ∗out, int max)
- static void hosted_lifecycle_birth (VM ∗vm)
- static void hosted_lifecycle_kill (VM ∗vm)
- static void hosted_lifecycle_pause (VM ∗vm)
- static void hosted_lifecycle_resume (VM ∗vm)
- static void hosted_lifecycle_use (VM ∗vm)
- void register_lifecycle_words (VM ∗vm)

7.400.1 Macro Definition Documentation

7.400.1.1 NAME_MAX_LEN

```
#define NAME_MAX_LEN 64
```

lifecycle_words_hosted.c - BIRTH KILL PAUSE RESUME USE for hosted Linux build

Hosted-build counterpart to src/starkernel/capsule/lifecycle_words.c. All five words are (c-addr u –), stack-clean, errors logged not pushed.

In the hosted build there is no capsule blob or kernel VM registry, so these implementations consume their arguments and log intent. The kernel build (compiled with -D__STARKERNEL__) skips this file entirely because the Makefile glob does not include src/word_source/ for that target.

7.400.2 Function Documentation

7.400.2.1 extract_name()

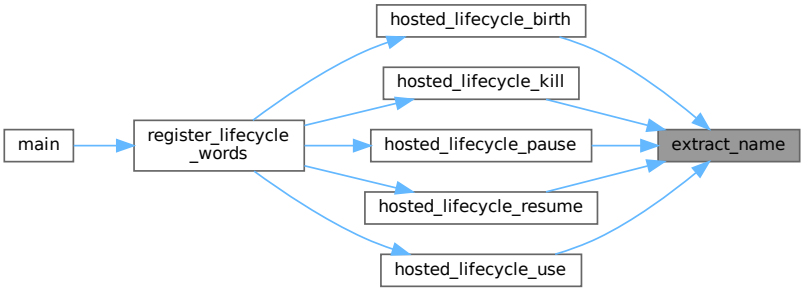
```
static void extract_name (
            VM * vm,
            cell_t caddr,
            cell_t u,
            char * out,
            int max )  [static]
```

References memcpy(), VM::memory, and VM_MEMORY_SIZE.

Referenced by hosted_lifecycle_birth(), hosted_lifecycle_kill(), hosted_lifecycle_pause(), hosted_lifecycle_resume(), and hosted_lifecycle_use().

Here is the call graph for this function:

Here is the caller graph for this function:



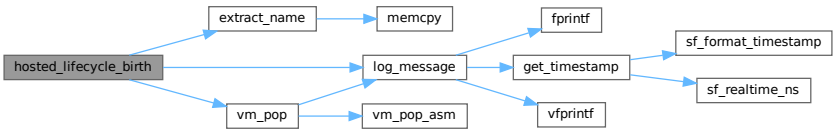
7.400.2.2 hosted_lifecycle_birth()

```
static void hosted_lifecycle_birth (
            VM * vm )  [static]
```

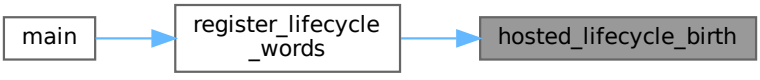
References extract_name(), LOG_INFO, log_message(), name, NAME_MAX_LEN, and vm_pop().

Referenced by register_lifecycle_words().

Here is the call graph for this function:



Here is the caller graph for this function:



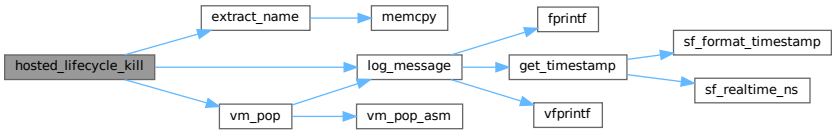
7.400.2.3 hosted_lifecycle_kill()

```
static void hosted_lifecycle_kill (
            VM * vm )  [static]
```

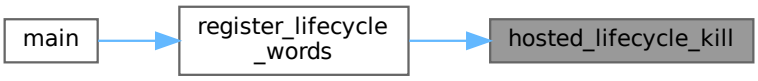
References extract_name(), LOG_INFO, log_message(), name, NAME_MAX_LEN, and vm_pop().

Referenced by register_lifecycle_words().

Here is the call graph for this function:



Here is the caller graph for this function:



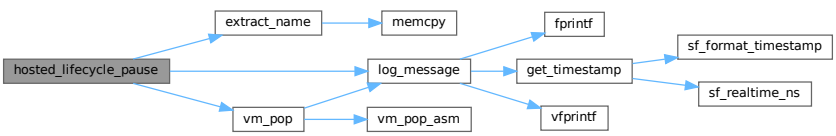
7.400.2.4 hosted_lifecycle_pause()

```
static void hosted_lifecycle_pause (
            VM * vm )  [static]
```

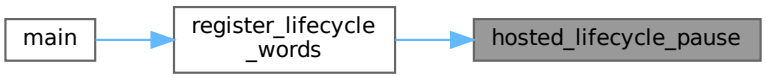
References extract_name(), LOG_INFO, log_message(), name, NAME_MAX_LEN, and vm_pop().

Referenced by register_lifecycle_words().

Here is the call graph for this function:



Here is the caller graph for this function:



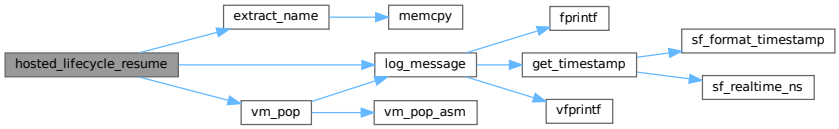
7.400.2.5 hosted_lifecycle_resume()

```
static void hosted_lifecycle_resume (
            VM * vm )  [static]
```

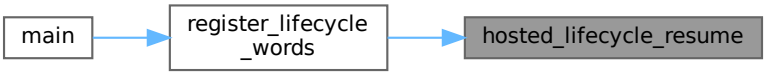
References extract_name(), LOG_INFO, log_message(), name, NAME_MAX_LEN, and vm_pop().

Referenced by register_lifecycle_words().

Here is the call graph for this function:



Here is the caller graph for this function:



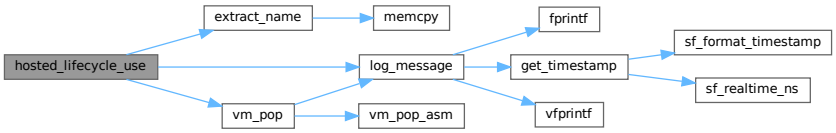
7.400.2.6 hosted_lifecycle_use()

```
static void hosted_lifecycle_use (
            VM * vm )  [static]
```

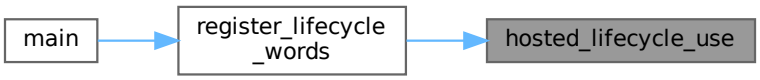
References extract_name(), LOG_INFO, log_message(), name, NAME_MAX_LEN, and vm_pop().

Referenced by register_lifecycle_words().

Here is the call graph for this function:



Here is the caller graph for this function:



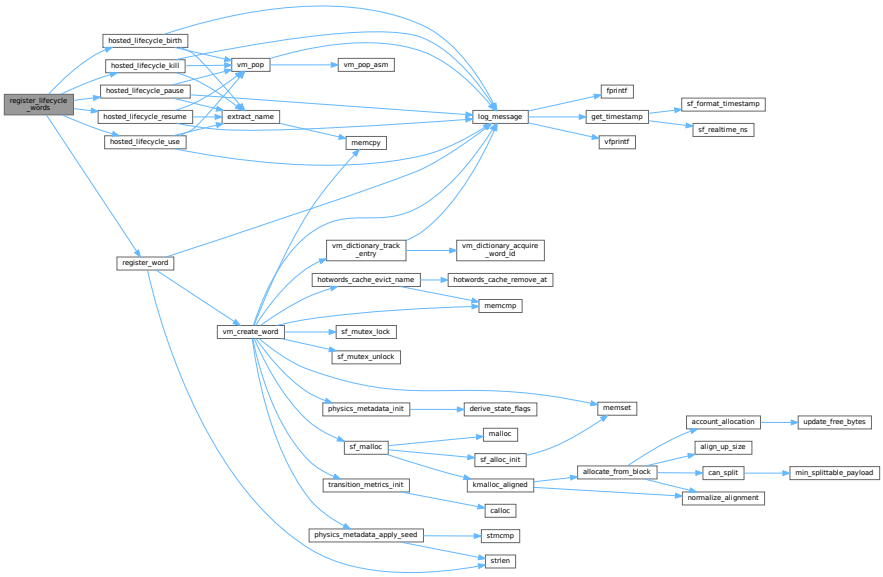
7.400.2.7 register_lifecycle_words()

```
void register_lifecycle_words (
            VM * vm )
```

References hosted_lifecycle_birth(), hosted_lifecycle_kill(), hosted_lifecycle_pause(), hosted_lifecycle_resume(), hosted_lifecycle_use(), and register_word().

Referenced by main().

Here is the call graph for this function:

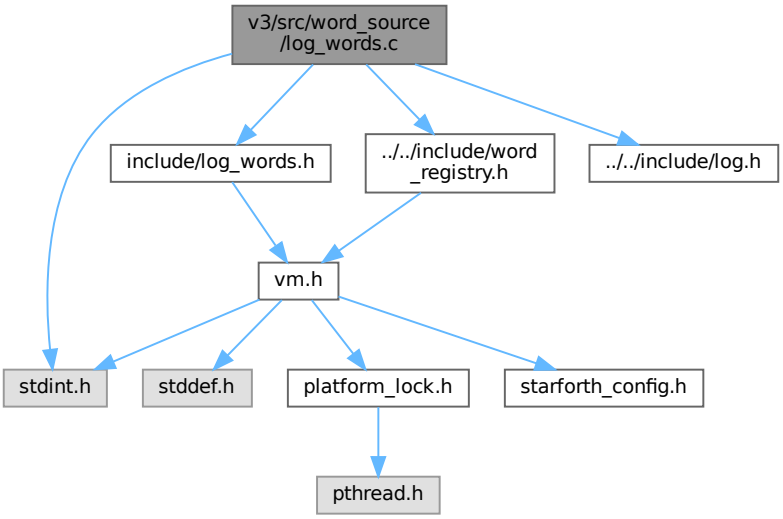


Here is the caller graph for this function:

7.401 v3/src/word_source/log_words.c File Reference

```
#include "include/log_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include <stdint.h>
```

Include dependency graph for log_words.c:



Functions

- static void log_word_error (VM *vm)

  LOG-ERROR (– n) Push the `LOG_ERROR` level constant.
- static void log_word_warn (VM *vm)

  LOG-WARN (– n) Push the `LOG_WARN` level constant.
- static void log_word_info (VM *vm)

  LOG-INFO (– n) Push the `LOG_INFO` level constant.
- static void log_word_test (VM *vm)

LOG-TEST (– n) Push the `LOG_TEST` level constant.

- static void log_word_debug (VM *vm)

  LOG-DEBUG (– n) Push the `LOG_DEBUG` level constant.
- static void log_word_set_level (VM *vm)

  LOG-LEVEL! (n –)
- static void log_word_get_level (VM *vm)

  LOG-LEVEL@ (– n)
- static void log_do_emit (VM *vm, LogLevel level)
- static void log_do_error (VM *vm)
- static void log_do_warn (VM *vm)
- static void log_do_info (VM *vm)
- static void log_do_test (VM *vm)
- static void log_do_debug (VM *vm)
- static void log_emit_string (VM *vm, LogLevel level, const char *rt_name, int rt_nlen)
- static void log_word_error_quote (VM *vm)

  LOG-ERROR" ("ccc<quote>" –) Log string at ERROR level.
- static void log_word_warn_quote (VM *vm)

  LOG-WARN" ("ccc<quote>" –) Log string at WARN level.
- static void log_word_info_quote (VM *vm)

  LOG-INFO" ("ccc<quote>" –) Log string at INFO level.
- static void log_word_test_quote (VM *vm)

  LOG-TEST" ("ccc<quote>" –) Log string at TEST level.
- static void log_word_debug_quote (VM *vm)

  LOG-DEBUG" ("ccc<quote>" –) Log string at DEBUG level.
- static void log_str_emit (VM *vm, LogLevel level)
- static void log_word_error_str (VM *vm)

  LOG-ERROR-STR (c-addr u –) Log string from stack at ERROR level.
- static void log_word_warn_str (VM *vm)

  LOG-WARN-STR (c-addr u –) Log string from stack at WARN level.
- static void log_word_info_str (VM *vm)

  LOG-INFO-STR (c-addr u –) Log string from stack at INFO level.
- static void log_word_test_str (VM *vm)

  LOG-TEST-STR (c-addr u –) Log string from stack at TEST level.
- static void log_word_debug_str (VM *vm)

  LOG-DEBUG-STR (c-addr u –) Log string from stack at DEBUG level.
- void register_log_words (VM *vm)

  Register all log words with the VM dictionary.

7.401.1 Function Documentation

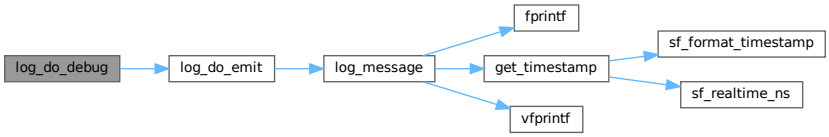
7.401.1.1 log_do_debug()

```
static void log_do_debug (
            VM * vm )  [static]
```

References LOG_DEBUG, and log_do_emit().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

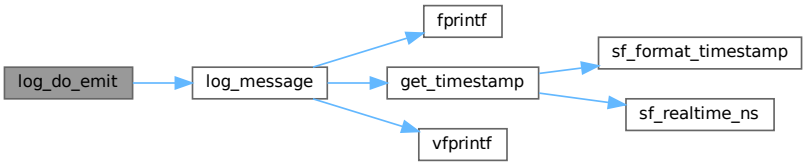
7.401.1.2 log_do_emit()

```
static void log_do_emit (
            VM * vm,
            LogLevel level )  [static]
```

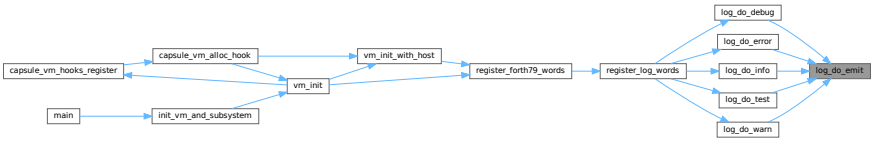
References VM::error, level, LOG_ERROR, log_message(), VM::return_stack, and VM::rsp.

Referenced by log_do_debug(), log_do_error(), log_do_info(), log_do_test(), and log_do_warn().

Here is the call graph for this function:



Here is the caller graph for this function:



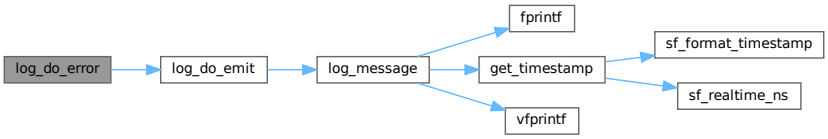
7.401.1.3 log_do_error()

```
static void log_do_error (
            VM * vm )  [static]
```

References log_do_emit(), and LOG_ERROR.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

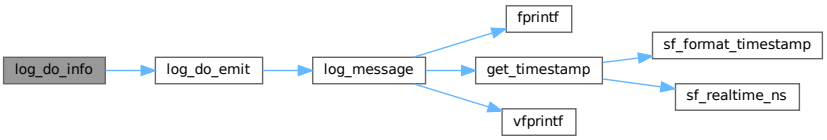
7.401.1.4 log_do_info()

```
static void log_do_info (
            VM * vm )  [static]
```

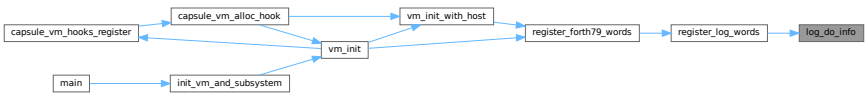
References log_do_emit(), and LOG_INFO.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:



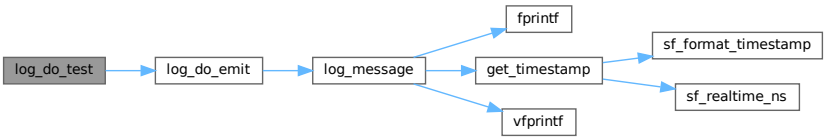
7.401.1.5 log_do_test()

```
static void log_do_test (
            VM * vm )  [static]
```

References log_do_emit(), and LOG_TEST.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

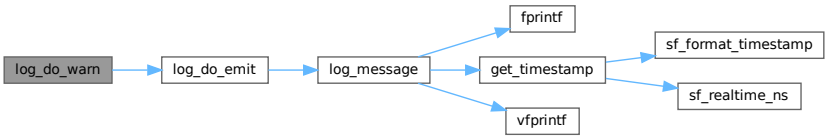
7.401.1.6 log_do_warn()

```
static void log_do_warn (
            VM * vm )  [static]
```

References log_do_emit(), and LOG_WARN.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

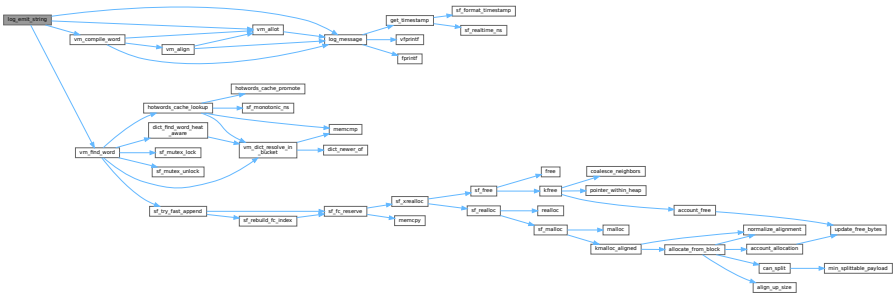
7.401.1.7 log_emit_string()

```
static void log_emit_string (
            VM * vm,
            LogLevel level,
            const char * rt_name,
            int rt_nlen )  [static]
```

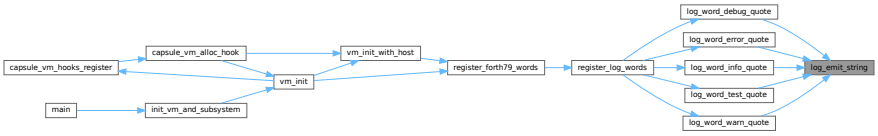
References VM::error, VM::input_buffer, VM::input_length, VM::input_pos, level, LOG_ERROR, log_message(), VM::mode, MODE_INTERPRET, vm_allot(), vm_compile_word(), and vm_find_word().

Referenced by log_word_debug_quote(), log_word_error_quote(), log_word_info_quote(), log_word_test_quote(), and log_word_warn_quote().

Here is the call graph for this function:



Here is the caller graph for this function:



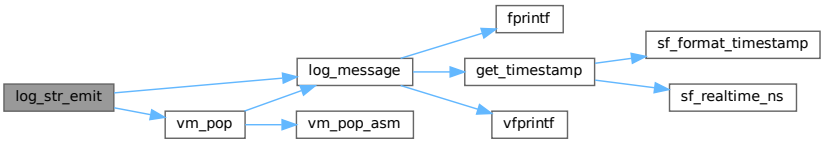
7.401.1.8 log_str_emit()

```
static void log_str_emit (
            VM * vm,
            LogLevel level )  [static]
```

References VM::dsp, VM::error, level, LOG_ERROR, LOG_LINE_MAX, log_message(), VM::memory, VM_MEMORY_SIZE, and vm_pop().

Referenced by log_word_debug_str(), log_word_error_str(), log_word_info_str(), log_word_test_str(), and log_word_warn_str().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.9 log_word_debug()

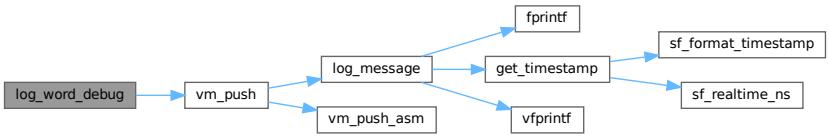
```
static void log_word_debug (
            VM * vm )  [static]
```

LOG-DEBUG (– n) Push the `LOG_DEBUG` level constant.

References LOG_DEBUG, and vm_push().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.10 log_word_debug_quote()

```
static void log_word_debug_quote (
            VM * vm )  [static]
```

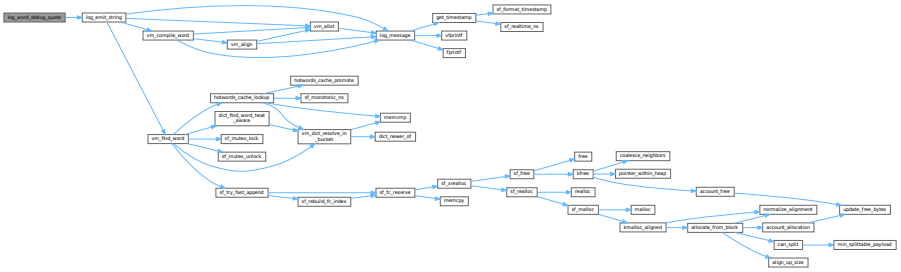
LOG-DEBUG" ("ccc<quote>" –) Log string at DEBUG level.

IMMEDIATE.

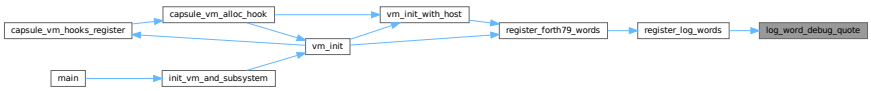
References LOG_DEBUG, and log_emit_string().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.401.1.11 log_word_debug_str()

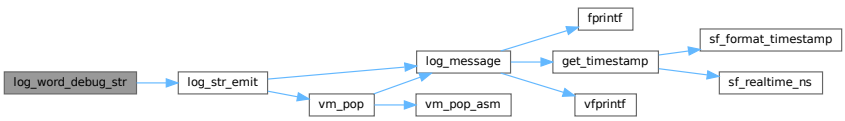
```
static void log_word_debug_str (
            VM * vm )  [static]
```

LOG-DEBUG-STR (c-addr u –) Log string from stack at DEBUG level.

References LOG_DEBUG, and log_str_emit().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.12 log_word_error()

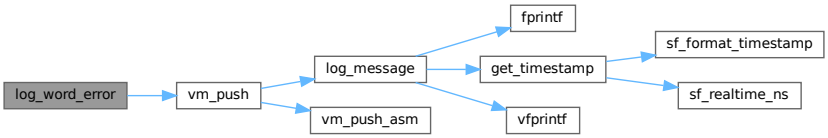
```
static void log_word_error (
            VM * vm )  [static]
```

LOG-ERROR (– n) Push the LOG_ERROR level constant.

References LOG_ERROR, and vm_push().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.13 log_word_error_quote()

```
static void log_word_error_quote (
            VM * vm )  [static]
```

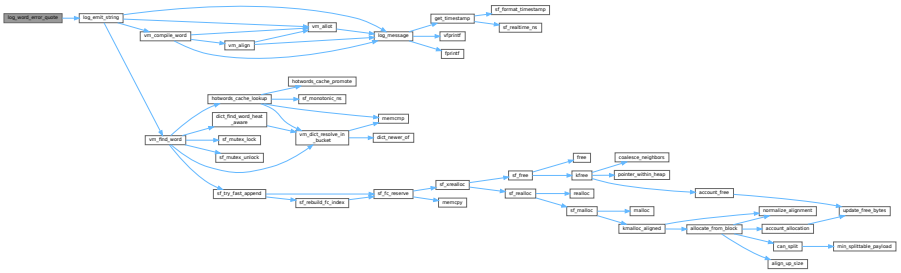
LOG-ERROR" ("ccc<quote>" –) Log string at ERROR level.

IMMEDIATE.

References log_emit_string(), and LOG_ERROR.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.14 log_word_error_str()

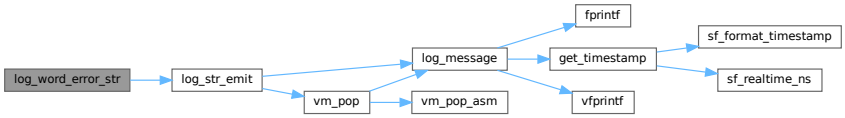
```
static void log_word_error_str (
            VM * vm )  [static]
```

LOG-ERROR-STR (c-addr u –) Log string from stack at ERROR level.

References LOG_ERROR, and log_str_emit().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.15 log_word_get_level()

```
static void log_word_get_level (
            VM * vm )  [static]
```

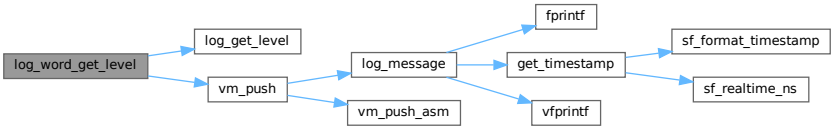
LOG-LEVEL@ (– n)

Pushes the current log level onto the stack.

References log_get_level(), and vm_push().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.16 log_word_info()

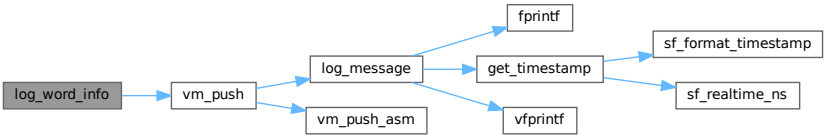
```
static void log_word_info (
            VM * vm )  [static]
```

LOG-INFO (– n) Push the `LOG_INFO` level constant.

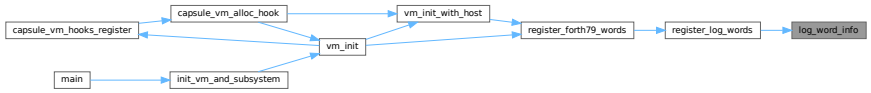
References LOG_INFO, and vm_push().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.401.1.17 log_word_info_quote()

```
static void log_word_info_quote (
            VM * vm )  [static]
```

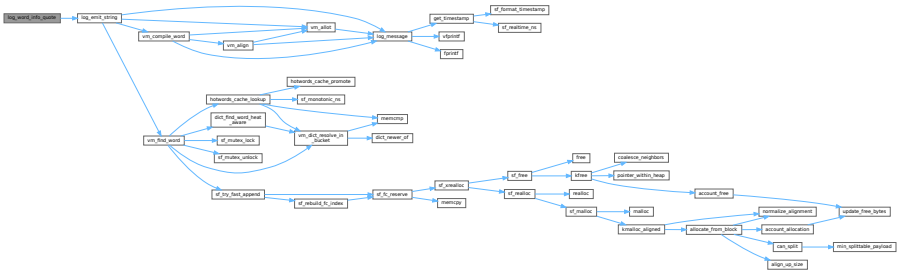
LOG-INFO" ("ccc<quote>" –) Log string at INFO level.

IMMEDIATE.

References log_emit_string(), and LOG_INFO.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.18 log_word_info_str()

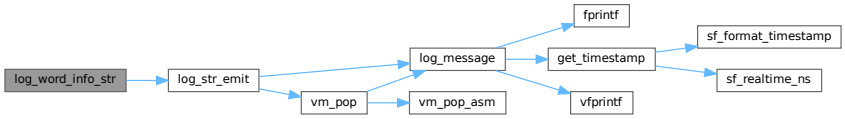
```
static void log_word_info_str (
            VM * vm )  [static]
```

LOG-INFO-STR (c-addr u –) Log string from stack at INFO level.

References LOG_INFO, and log_str_emit().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.19 log_word_set_level()

```
static void log_word_set_level (
            VM * vm )  [static]
```

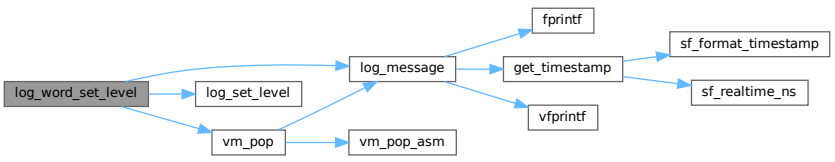
LOG-LEVEL! (n –)

Pops `n` from the stack and calls `log_set_level()` to update the active log filter. Values below `LOG_ERROR` are clamped to `LOG_ERROR`; values above `LOG_DEBUG` are clamped to `LOG_DEBUG`.

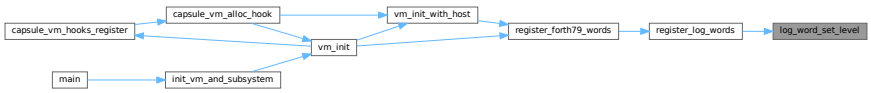
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), log_set_level(), and vm_pop().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.401.1.20 log_word_test()

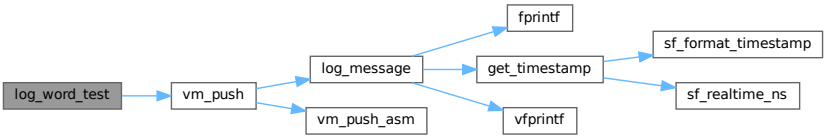
```
static void log_word_test (
            VM * vm )  [static]
```

LOG-TEST (– n) Push the LOG_TEST level constant.

References LOG_TEST, and vm_push().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.21 log_word_test_quote()

```
static void log_word_test_quote (
            VM * vm )  [static]
```

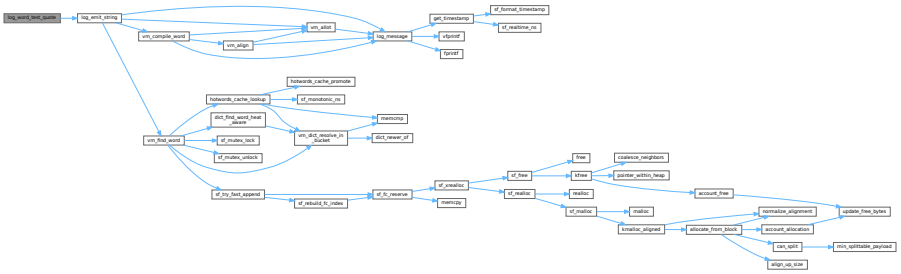
LOG-TEST" ("ccc<quote>" –) Log string at TEST level.

IMMEDIATE.

References log_emit_string(), and LOG_TEST.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.22 log_word_test_str()

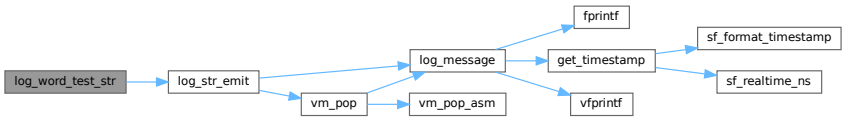
```
static void log_word_test_str (
            VM * vm )  [static]
```

LOG-TEST-STR (c-addr u –) Log string from stack at TEST level.

References log_str_emit(), and LOG_TEST.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.23 log_word_warn()

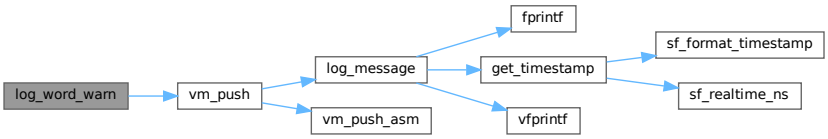
```
static void log_word_warn (
            VM * vm )  [static]
```

LOG-WARN (– n) Push the LOG_WARN level constant.

References LOG_WARN, and vm_push().

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.24 log_word_warn_quote()

```
static void log_word_warn_quote (
            VM * vm )  [static]
```

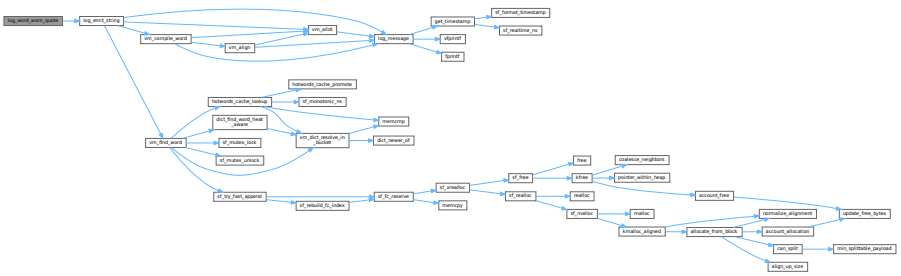
LOG-WARN" ("ccc<quote>" –) Log string at WARN level.

IMMEDIATE.

References log_emit_string(), and LOG_WARN.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.25 log_word_warn_str()

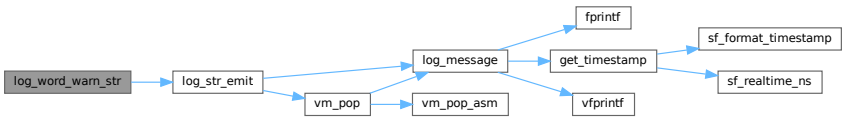
```
static void log_word_warn_str (
            VM * vm )  [static]
```

LOG-WARN-STR (c-addr u –) Log string from stack at WARN level.

References log_str_emit(), and LOG_WARN.

Referenced by register_log_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.401.1.26 register_log_words()

```
void register_log_words (
            VM * vm )
```

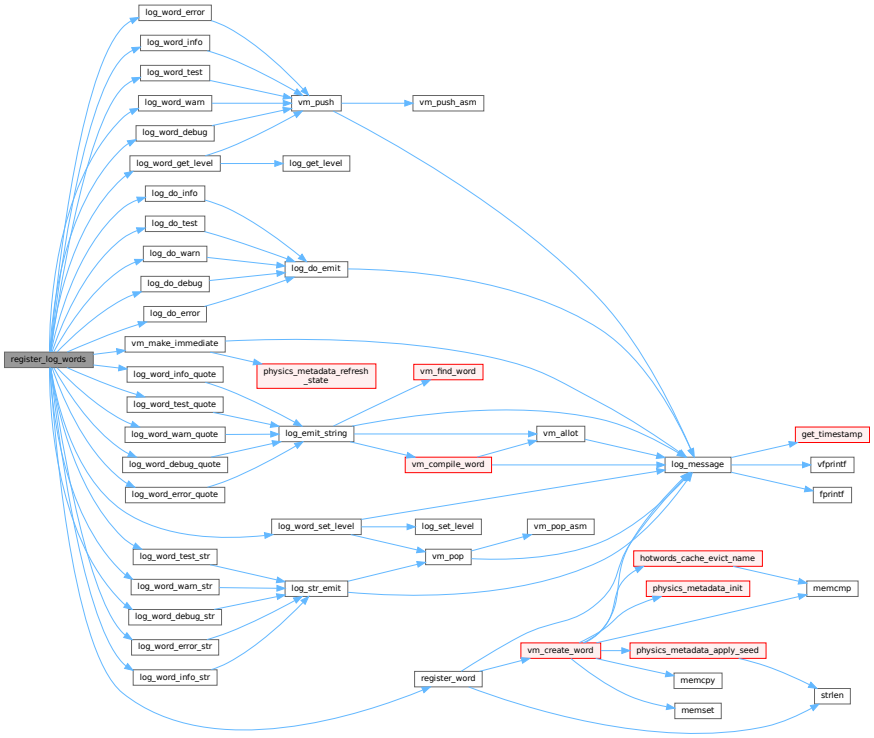
Register all log words with the VM dictionary.

Level constants: LOG-ERROR LOG-WARN LOG-INFO LOG-TEST LOG-DEBUG Level control: LOG-LEVEL! LOG-LEVEL@ Runtime (hidden): (do-log-error) (do-log-warn) (do-log-info) (do-log-test) (do-log-debug) String literals: LOG-ERROR" LOG-WARN" LOG-INFO" LOG-TEST" LOG-DEBUG" Stack string: LOG-ERROR-STR LOG-WARN-STR LOG-INFO-STR LOG-TEST-STR LOG-DEBUG-STR Kernel only: (LOG-APPEND-RAW) LOG-FLUSH

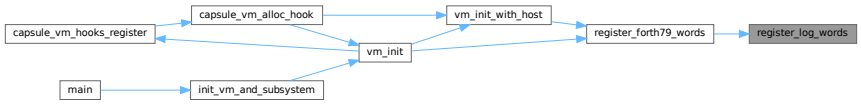
References log_do_debug(), log_do_error(), log_do_info(), log_do_test(), log_do_warn(), log_word_debug(), log_word_debug_quote(), log_word_debug_str(), log_word_error(), log_word_error_quote(), log_word_error_str(), log_word_get_level(), log_word_info(), log_word_info_quote(), log_word_info_str(), log_word_set_level(), log_word_test(), log_word_test_quote(), log_word_test_str(), log_word_warn(), log_word_warn_quote(), log_word_warn_str(), register_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

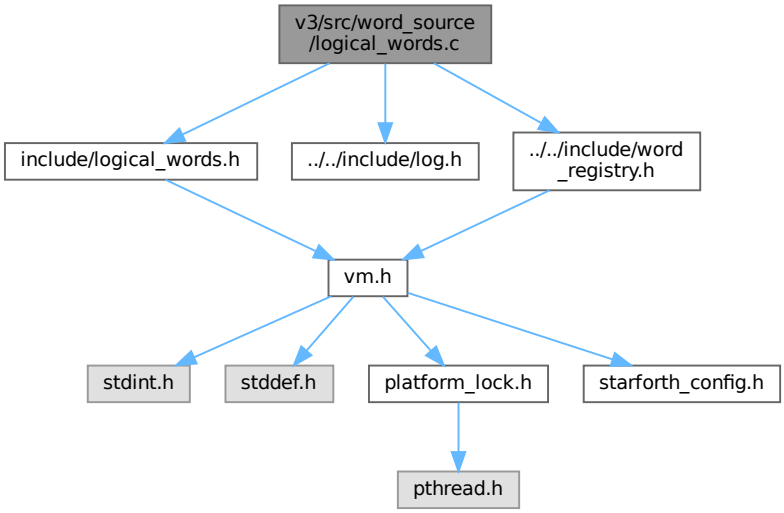


7.402 v3/src/word_source/logical_words.c File Reference

```
#include "include/logical_words.h"
#include "../../include/log.h"
```

```
#include "../../include/word_registry.h"
```

Include dependency graph for logical_words.c:



Macros

- #define FORTH_TRUE ((cell_t)-1)

  FORTH-79 TRUE value (-1, all bits set)
- #define FORTH_FALSE ((cell_t)0)

  FORTH-79 FALSE value (0)

Functions

- static void logical_word_and (VM *vm)

  FORTH word: AND (n1 n2 – n3)
- static void logical_word_or (VM *vm)
- static void logical_word_xor (VM *vm)
- static void logical_word_not (VM *vm)
- static void logical_word_invert (VM *vm)
- static void logical_word_lshift (VM *vm)
- static void logical_word_rshift (VM *vm)
- static void logical_word_zero_equals (VM *vm)
- static void logical_word_zero_less (VM *vm)
- static void logical_word_zero_greater (VM *vm)
- static void logical_word_equals (VM *vm)
- static void logical_word_not_equals (VM *vm)
- static void logical_word_less_than (VM *vm)
- static void logical_word_greater_than (VM *vm)
- static void logical_word_greater_equal (VM *vm)
- static void logical_word_less_equal (VM *vm)
- static void logical_word_u_less_than (VM *vm)
- static void logical_word_u_greater_than (VM *vm)

- static void logical_word_within (VM *vm)
- static void logical_word_true (VM *vm)
- static void logical_word_false (VM *vm)
- void logical_word_zero_not_equal (VM *vm)
- void register_logical_words (VM *vm)

  Registers all FORTH-79 logical and comparison words with the VM.

7.402.1 Macro Definition Documentation

7.402.1.1 FORTH_FALSE

```
#define FORTH_FALSE ((cell_t)0)
```

FORTH-79 FALSE value (0)

7.402.1.2 FORTH_TRUE

```
#define FORTH_TRUE ((cell_t)-1)
```

FORTH-79 TRUE value (-1, all bits set)

7.402.2 Function Documentation

7.402.2.1 logical_word_and()

```
static void logical_word_and (
            VM * vm )  [static]
```

FORTH word: AND (n1 n2 – n3)

Parameters

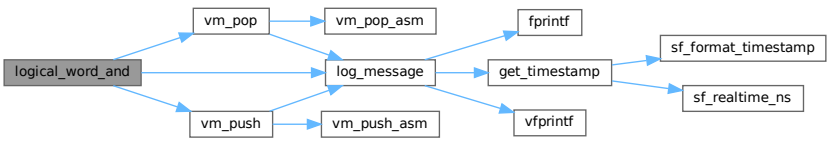
vm	Pointer to the virtual machine instance

Performs bitwise AND operation on top two stack values. Stack effect: (n1 n2 – n3) where n3 = n1 AND n2

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

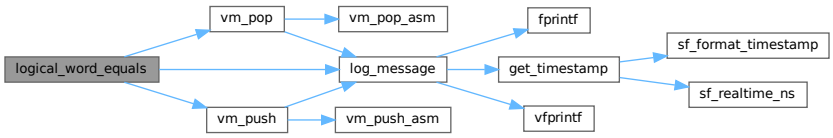
7.402.2.2 logical_word_equals()

```
static void logical_word_equals (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

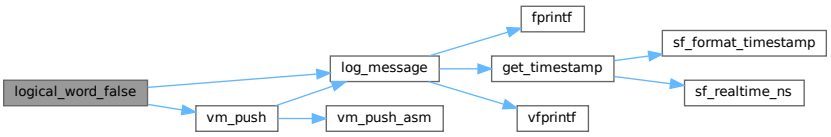
7.402.2.3 logical_word_false()

```
static void logical_word_false (
            VM * vm )  [static]
```

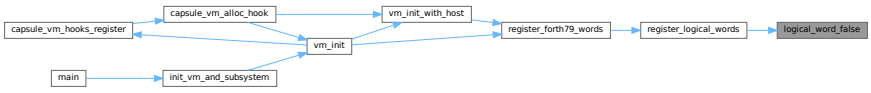
References FORTH_FALSE, LOG_DEBUG, log_message(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:



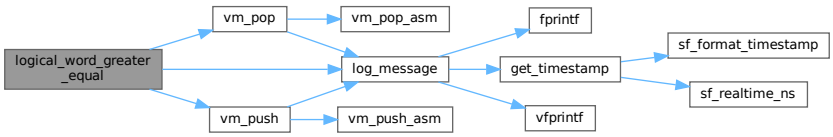
7.402.2.4 logical_word_greater_equal()

```
static void logical_word_greater_equal (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

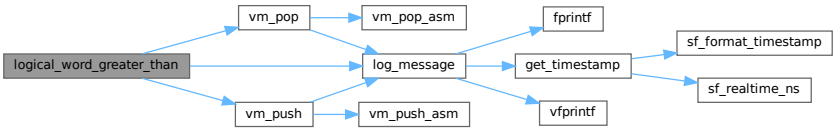
7.402.2.5 logical_word_greater_than()

```
static void logical_word_greater_than (
            VM * vm )  [static]
```

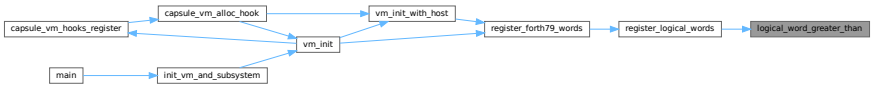
References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:



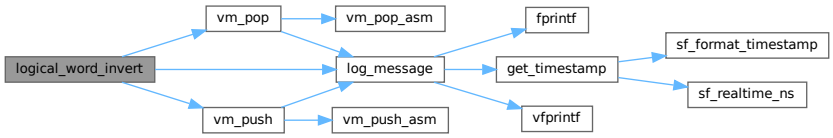
7.402.2.6 logical_word_invert()

```
static void logical_word_invert (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

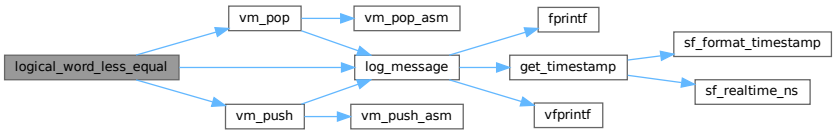
7.402.2.7 logical_word_less_equal()

```
static void logical_word_less_equal (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

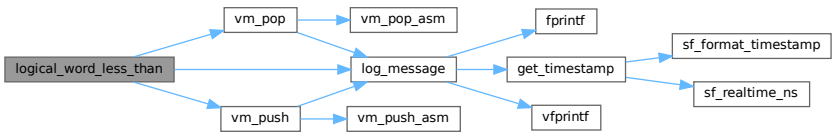
7.402.2.8 logical_word_less_than()

```
static void logical_word_less_than (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

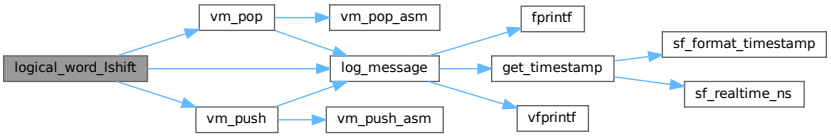
7.402.2.9 logical_word_lshift()

```
static void logical_word_lshift (
            VM * vm )  [static]
```

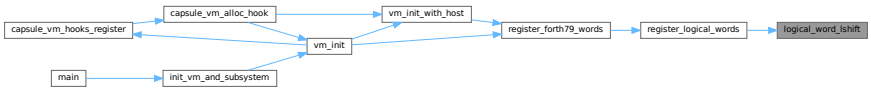
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:



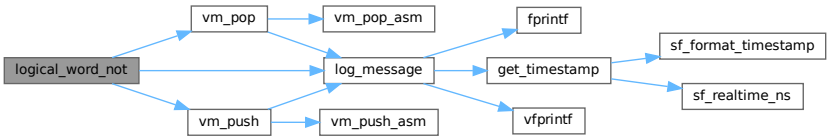
7.402.2.10 logical_word_not()

```
static void logical_word_not (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

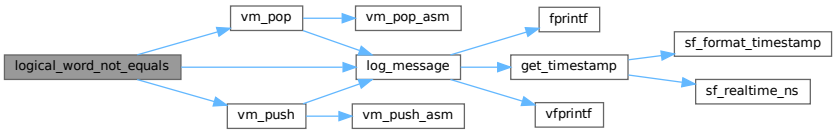
7.402.2.11 logical_word_not_equals()

```
static void logical_word_not_equals (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

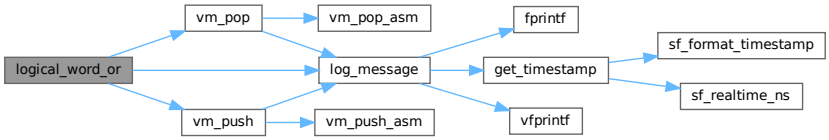
7.402.2.12 logical_word_or()

```
static void logical_word_or (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

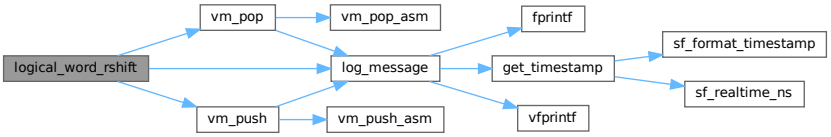
7.402.2.13 logical_word_rshift()

```
static void logical_word_rshift (
            VM * vm )  [static]
```

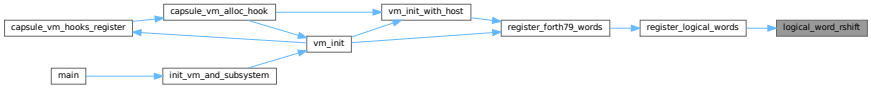
References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:



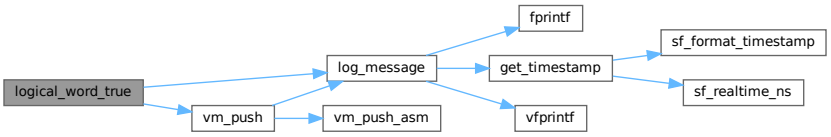
7.402.2.14 logical_word_true()

```
static void logical_word_true (
            VM * vm )  [static]
```

References FORTH_TRUE, LOG_DEBUG, log_message(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

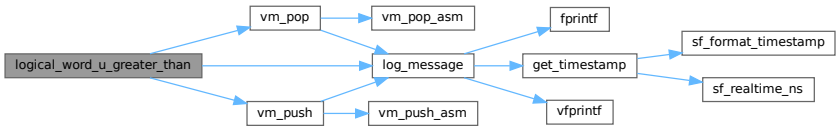
7.402.2.15 logical_word_u_greater_than()

```
static void logical_word_u_greater_than (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

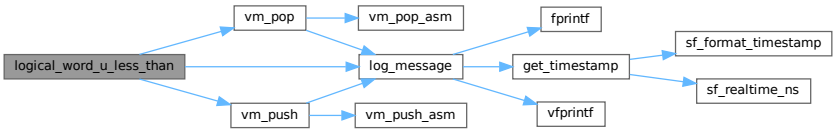
7.402.2.16 logical_word_u_less_than()

```
static void logical_word_u_less_than (
            VM * vm )  [static]
```

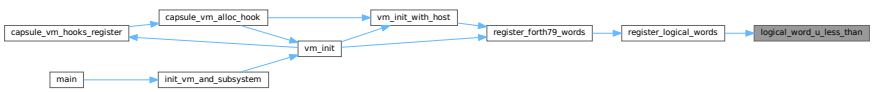
References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:



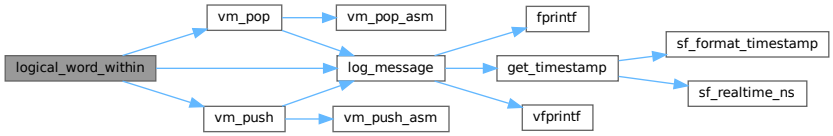
7.402.2.17 logical_word_within()

```
static void logical_word_within (
            VM * vm )  [static]
```

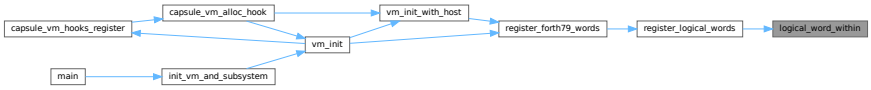
References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:



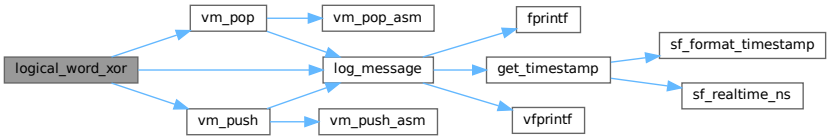
7.402.2.18 logical_word_xor()

```
static void logical_word_xor (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

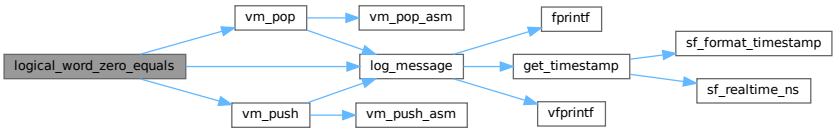
7.402.2.19 logical_word_zero_equals()

```
static void logical_word_zero_equals (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

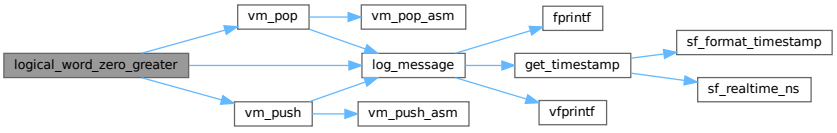
7.402.2.20 logical_word_zero_greater()

```
static void logical_word_zero_greater (
            VM * vm )  [static]
```

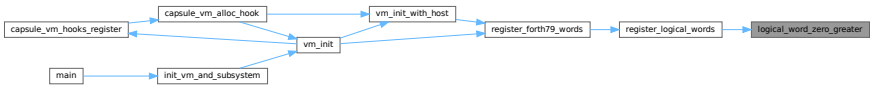
References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:



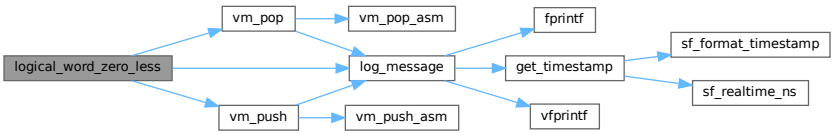
7.402.2.21 logical_word_zero_less()

```
static void logical_word_zero_less (
            VM * vm )  [static]
```

References VM::dsp, VM::error, FORTH_FALSE, FORTH_TRUE, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

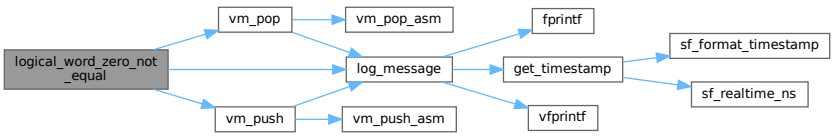
7.402.2.22 logical_word_zero_not_equal()

```
void logical_word_zero_not_equal (
            VM * vm )
```

References VM::dsp, VM::error, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_logical_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.402.2.23 register_logical_words()

```
void register_logical_words (
            VM * vm )
```

Registers all FORTH-79 logical and comparison words with the VM.

Parameters

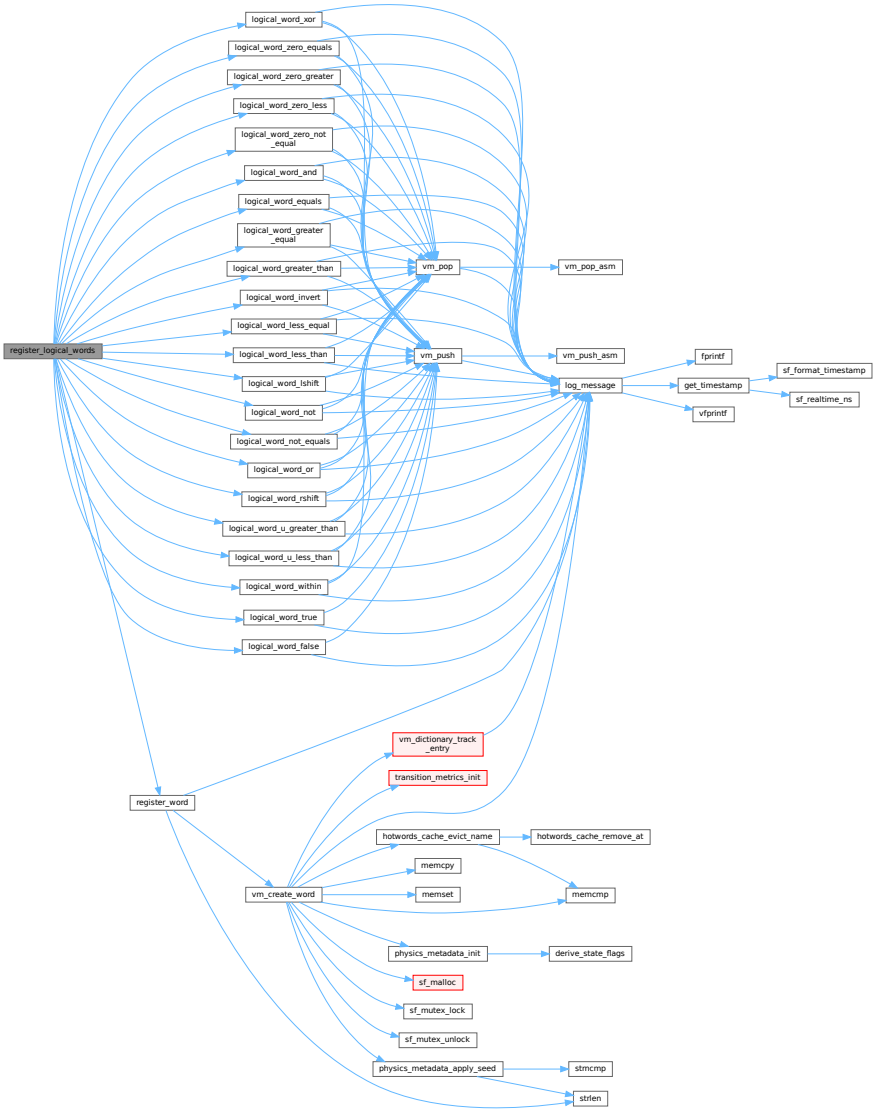
vm	Pointer to the virtual machine instance

Registers logical operations (AND, OR, XOR, NOT), comparison operations (=, <>, <, >, etc.), and constant words (TRUE, FALSE) with the virtual machine.

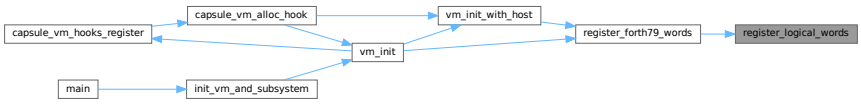
References logical_word_and(), logical_word_equals(), logical_word_false(), logical_word_greater_equal(), logical_word_greater_than(), logical_word_invert(), logical_word_less_equal(), logical_word_less_than(), logical_word_lshift(), logical_word_not(), logical_word_not_equals(), logical_word_or(), logical_word_rshift(), logical_word_true(), logical_word_u_greater_than(), logical_word_u_less_than(), logical_word_within(), logical_word_xor(), logical_word_zero_equals(), logical_word_zero_greater(), logical_word_zero_less(), logical_word_zero_not_equal(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

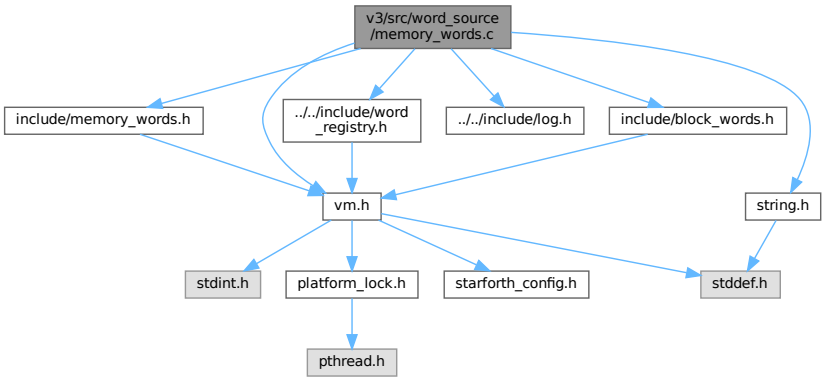


7.403 v3/src/word_source/memory_words.c File Reference

```
#include "include/memory_words.h"
#include "../../include/word_registry.h"
#include "vm.h"
```

```
#include "../../include/log.h"
#include "include/block_words.h"
#include <string.h>
```

Include dependency graph for memory_words.c:



Functions

- void memory_word_fetch (VM *vm)

  Implements FORTH word '@' - Fetch cell from VM memory.
- void memory_word_store (VM *vm)

  Implements FORTH word '!' - Store cell into VM memory.
- void memory_word_cfetch (VM *vm)

  Implements FORTH word 'C@' - Fetch byte from VM memory.
- void memory_word_cstore (VM *vm)

  Implements FORTH word 'C!' - Store byte into VM memory.
- void memory_word_plus_store (VM *vm)

  Implements FORTH word '+!' - Add to contents of cell.
- void memory_word_minus_store (VM *vm)

  Implements FORTH word '-!' - Subtract from contents of cell.
- void memory_word_fill (VM *vm)

  Implements FORTH word 'FILL' - Fill memory with byte value.
- void memory_word_move (VM *vm)

  Implements FORTH word 'MOVE' - Copy memory region.
- void memory_word_erase (VM *vm)

  Implements FORTH word 'ERASE' - Zero memory region.
- void memory_word_2fetch (VM *vm)

  Implements FORTH word '2@' - Fetch double cell.
- void memory_word_2store (VM *vm)

  Implements FORTH word '2!' - Store double cell.
- static void memory_word_cells (VM *vm)

  Implements FORTH word 'CELLS' - Scale by cell size.
- void register_memory_words (VM *vm)

  Register all memory manipulation words with the VM.

7.403.1 Function Documentation

7.403.1.1 memory_word_2fetch()

```
void memory_word_2fetch (
            VM * vm )
```

Implements FORTH word '2@' - Fetch double cell.

Stack effect: (addr – x_low x_high) Fetches two consecutive cells from memory, pushing low cell then high cell.

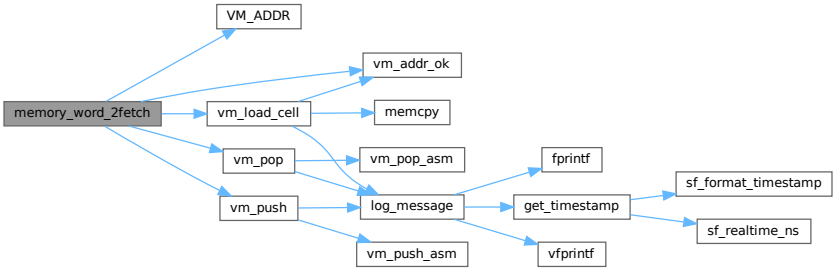
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_load_cell(), vm_pop(), and vm_push().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.2 memory_word_2store()

```
void memory_word_2store (
            VM * vm )
```

Implements FORTH word '2!' - Store double cell.

Stack effect: (x_low x_high addr –) Stores two consecutive cells to memory, low cell at addr, high cell at addr+cell.

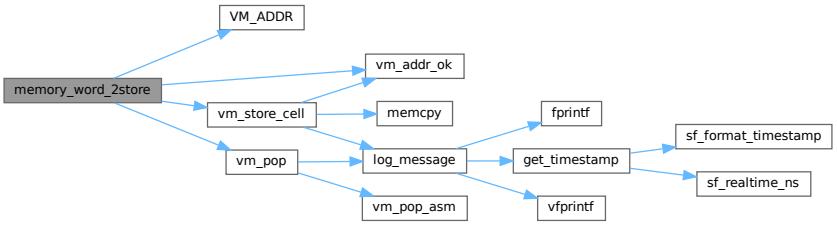
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_store_cell().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.3 memory_word_cells()

```
static void memory_word_cells (
            VM * vm )  [static]
```

Implements FORTH word 'CELLS' - Scale by cell size.

Stack effect: (n – n') Multiplies top of stack by cell size in bytes.

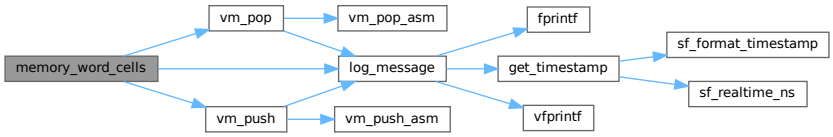
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.4 memory_word_cfetch()

```
void memory_word_cfetch (
            VM * vm )
```

Implements FORTH word 'C@' - Fetch byte from VM memory.

Stack effect: (addr – c) Fetches a byte value from the given memory address in VM memory.

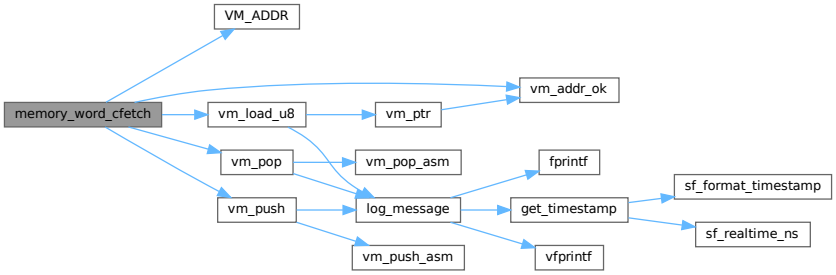
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_push().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.5 memory_word_cstore()

```
void memory_word_cstore (
            VM * vm )
```

Implements FORTH word 'C!' - Store byte into VM memory.

Stack effect: (c addr –) Stores a byte value at the given memory address in VM memory.

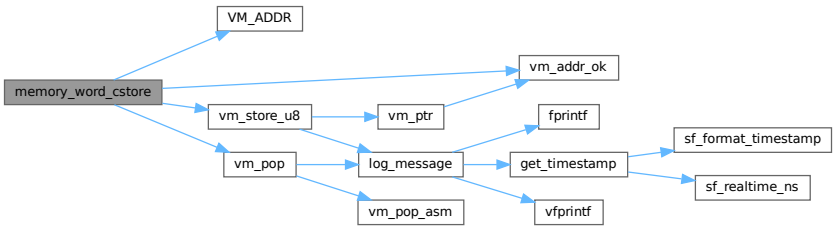
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_store_u8().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.6 memory_word_erase()

```
void memory_word_erase (
            VM * vm )
```

Implements FORTH word 'ERASE' - Zero memory region.

Stack effect: (addr len –) Sets len bytes to zero starting at addr.

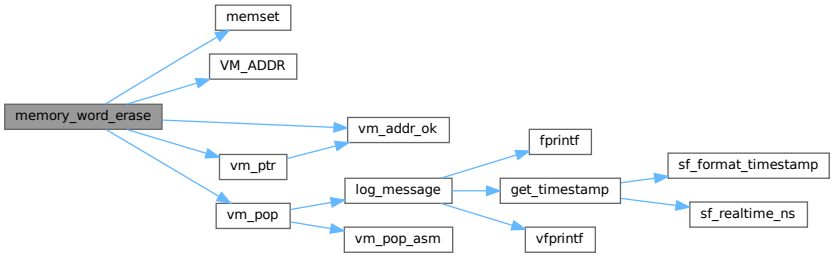
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, memset(), VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_ptr().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.7 memory_word_fetch()

```
void memory_word_fetch (
            VM * vm )
```

Implements FORTH word '@' - Fetch cell from VM memory.

Stack effect: (addr – n) Fetches a cell value from the given memory address in VM memory.

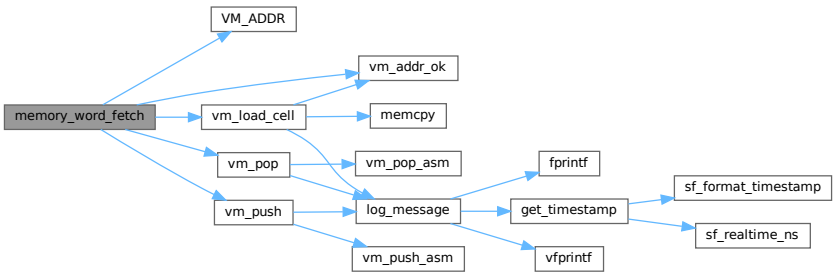
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_load_cell(), vm_pop(), and vm_push().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.8 memory_word_fill()

```
void memory_word_fill (
            VM * vm )
```

Implements FORTH word 'FILL' - Fill memory with byte value.

Stack effect: (addr len c –) Fills len bytes of memory starting at addr with the value c.

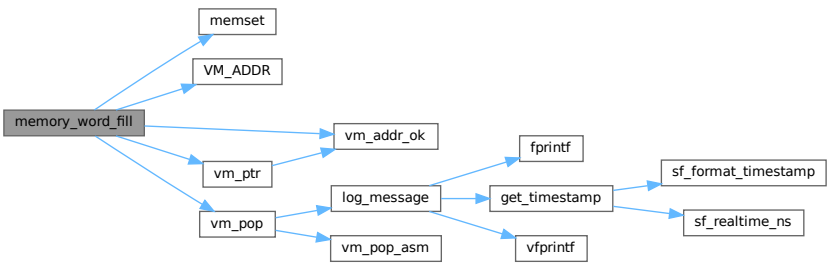
Parameters

vm	Pointer to the VM structure

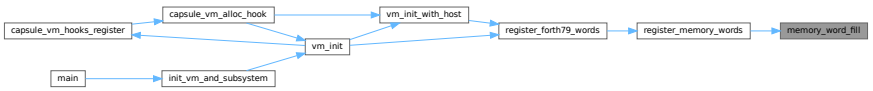
References VM::dsp, VM::error, memset(), VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_ptr().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.403.1.9 memory_word_minus_store()

```
void memory_word_minus_store (
            VM * vm )
```

Implements FORTH word '-!' - Subtract from contents of cell.

Stack effect: (n addr –) Subtracts n from the contents of the cell at the given address.

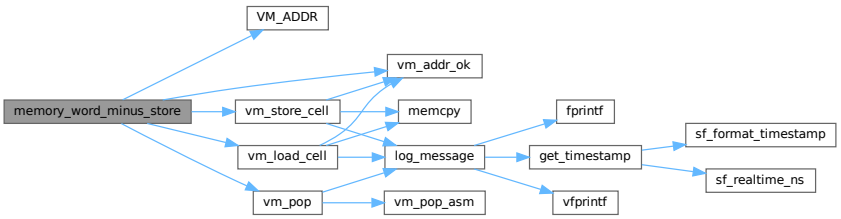
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_load_cell(), vm_pop(), and vm_store_cell().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.10 memory_word_move()

```
void memory_word_move (
            VM * vm )
```

Implements FORTH word 'MOVE' - Copy memory region.

Stack effect: (addr1 addr2 len –) Copies len bytes from addr1 to addr2, handling overlapping regions correctly.

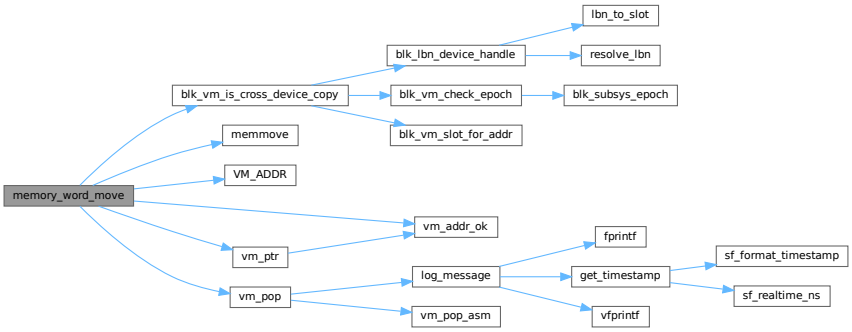
Parameters

vm	Pointer to the VM structure

References blk_vm_is_cross_device_copy(), VM::dsp, VM::error, memmove(), VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_ptr().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.11 memory_word_plus_store()

```
void memory_word_plus_store (
            VM * vm )
```

Implements FORTH word '+!' - Add to contents of cell.

Stack effect: (n addr –) Adds n to the contents of the cell at the given address.

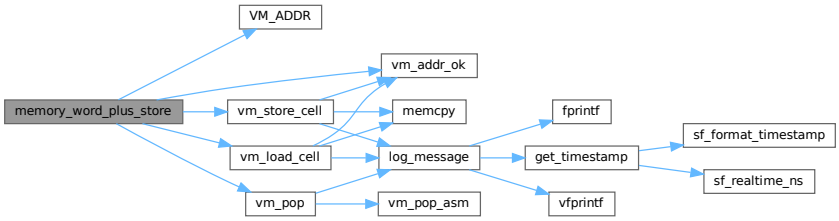
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_load_cell(), vm_pop(), and vm_store_cell().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.12 memory_word_store()

```
void memory_word_store (
            VM * vm )
```

Implements FORTH word '!' - Store cell into VM memory.

Stack effect: (n addr –) Stores a cell value at the given memory address in VM memory.

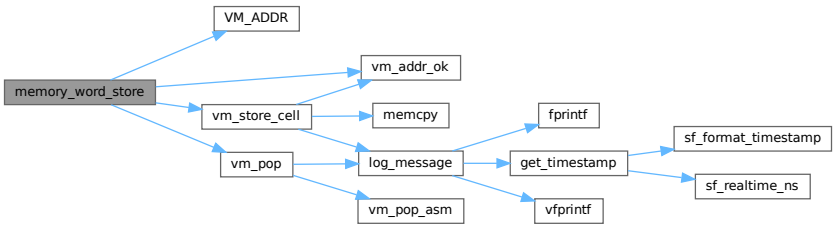
Parameters

vm	Pointer to the VM structure

References VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_pop(), and vm_store_cell().

Referenced by register_memory_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.403.1.13 register_memory_words()

```
void register_memory_words (
            VM * vm )
```

Register all memory manipulation words with the VM.

Registers all standard memory words (@, !, C@, C!, etc.) with the VM's word dictionary.

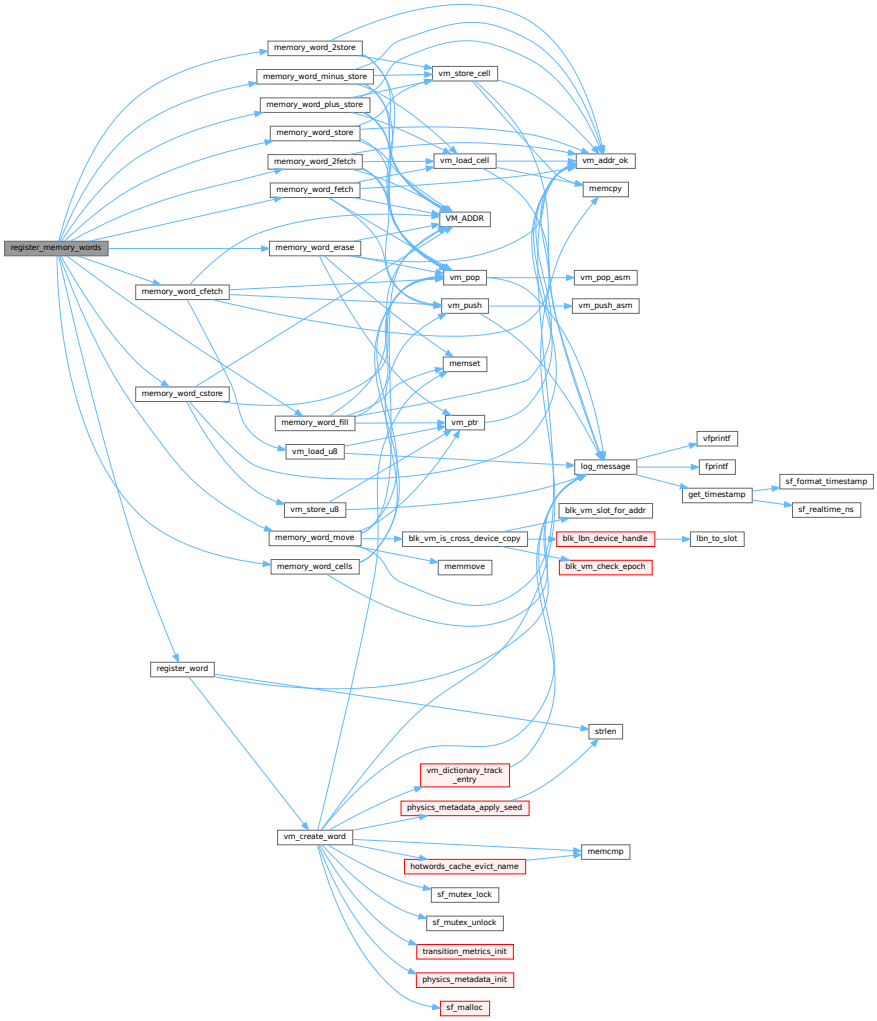
Parameters

vm	Pointer to the VM structure

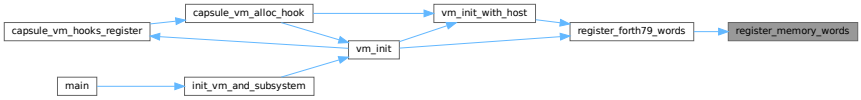
References memory_word_2fetch(), memory_word_2store(), memory_word_cells(), memory_word_cfetch(), memory_word_cstore(), memory_word_erase(), memory_word_fetch(), memory_word_fill(), memory_word_minus_store(), memory_word_move(), memory_word_plus_store(), memory_word_store(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

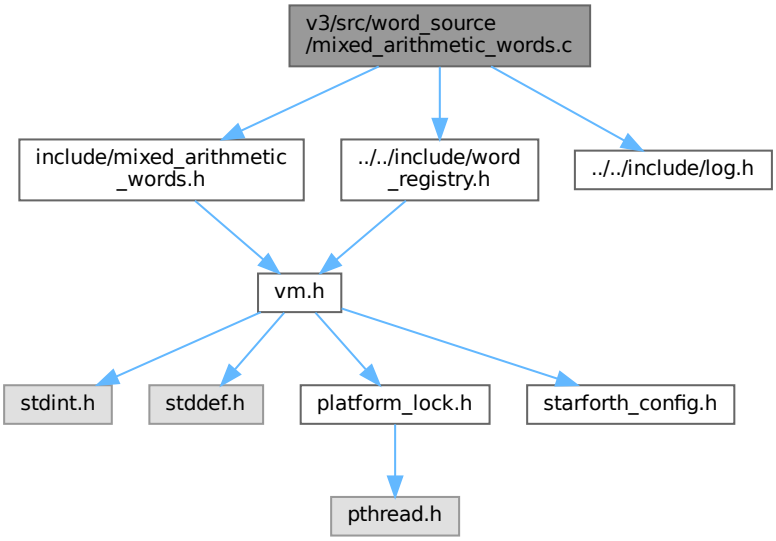


7.404 v3/src/word_source/mixed_arithmetic_words.c File Reference

```
#include "include/mixed_arithmetic_words.h"
#include "../../include/word_registry.h"
```

```
#include "../../include/log.h"
```

Include dependency graph for mixed_arithmetic_words.c:



Functions

- void mixed_math_word_m_plus (VM *vm)

  M+ (d n – d)
- void mixed_math_word_m_minus (VM *vm)

  M- (d n – d)
- void mixed_math_word_m_star (VM *vm)

  M (n1 n2 – d)*
- void mixed_math_word_m_slash_mod (VM *vm)

  M/MOD (d n – rem quot)
- void mixed_math_word_mod (VM *vm)

  MOD (n1 n2 – r)
- void mixed_math_word_slash_mod (VM *vm)

  /MOD (n1 n2 – rem quot)
- void mixed_math_word_star_slash (VM *vm)

  *STAR-SLASH (FORTH word: */) — multiply then divide.*
- void mixed_math_word_star_slash_mod (VM *vm)

  *STAR-SLASH-MOD (FORTH word: */MOD) — multiply then divide, leaving remainder.*
- void register_mixed_arithmetic_words (VM *vm)

  Register all FORTH-79 mixed arithmetic words with the VM dictionary.

7.404.1 Function Documentation

7.404.1.1 mixed_math_word_m_minus()

```
void mixed_math_word_m_minus (
            VM * vm )
```

M- (d n – d)

Subtracts the single-cell signed integer `n` from the double-cell value `d`, producing a new double-cell result. Mirrors `M+` carry logic: a positive `n` that causes the low cell to wrap below zero decrements the high cell, and vice versa.

Stack effect: (d_high d_low n – d_high' d_low')

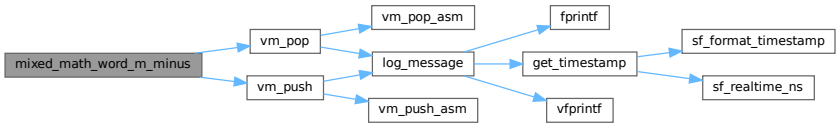
Parameters

vm	Active VM; sets `vm->error` = 1 on stack underflow

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_mixed_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.404.1.2 mixed_math_word_m_plus()

```
void mixed_math_word_m_plus (
            VM * vm )
```

M+ (d n – d)

Adds the single-cell signed integer `n` to the double-cell value `d`, producing a new double-cell result. Handles carry propagation: if the low cell addition overflows a positive `n`, the high cell is incremented; if it underflows a negative `n`, the high cell is decremented.

Stack effect: (d_high d_low n – d_high' d_low')

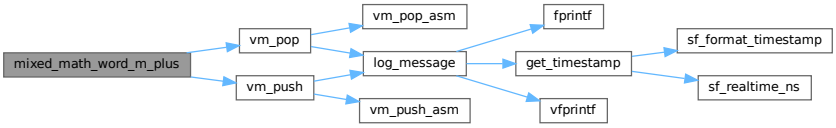
Parameters

vm	Active VM; sets `vm->error` = 1 on stack underflow

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_mixed_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.404.1.3 mixed_math_word_m_slash_mod()

```
void mixed_math_word_m_slash_mod (
            VM * vm )
```

M/MOD (d n – rem quot)

Divides the double-cell dividend `d` by the single-cell divisor `n`, pushing the remainder deeper and the quotient on TOS. A "double" here is two full `cell_t-width` cells (128 bits total on a 64-bit build) – same convention as M∗ (see that word's own doc comment for the full story). The previous implementation reconstructed the dividend as a plain 64-bit `long` long from `(dhigh << 32) | (dlow & 0xFFFFFFFF)`, the same wrong "32-bit halves of a 64-bit value" assumption M∗ had – silently discarding the upper 32 bits of `dlow` and losing `dhigh` entirely once it wasn't just 0 or -1. Latent for any dividend whose true magnitude fit in 32 bits (never exercised otherwise until M∗'s own fix started producing genuine wide doubles to feed it – FABRIC-3.md ?XII.4).

Fixed via a hand-rolled unsigned 128-bit-by-64-bit bit-serial (restoring) long division, not `__int128's` own `//%` operators: those need libgcc's `__udivti3/__umodti3`, unavailable in this freestanding, `-nostdlib` build (confirmed in `src/starkernel/arch/amd64/timer.c`'s own doc comment – `__int128` multiply/shift-by-constant/compare/subtract all compile cleanly with zero undefined symbols on all three toolchains, only division doesn't). Shift-by-1, compare, and subtract on `unsigned __int128` are all in that safe set, so the classic 128-iteration shift-and-subtract algorithm works without any libgcc dependency. Operates on magnitudes (converted via unsigned negation from 0, which is well-defined even for the extreme negative edge, unlike signed negation); signs are reapplied afterward matching C99 truncating-toward-zero division (quotient sign = XOR of operand signs, remainder sign = the dividend's own sign) – the same convention the previous, narrower implementation already used via plain C `//%`, unchanged here.

On 32-bit builds, only handles the case where the high cell is zero; sets `vm->error` = 1 otherwise.

Stack effect: (d_high d_low n – remainder quotient) TOS = quotient

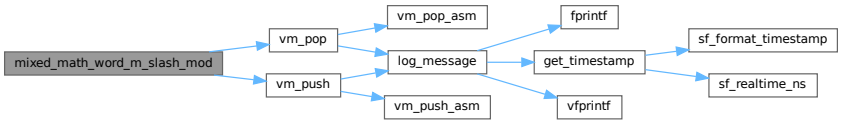
Parameters

vm	Active VM; sets `vm->error` = 1 on underflow or division by zero

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_mixed_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.404.1.4 mixed_math_word_m_star()

```
void mixed_math_word_m_star (
            VM * vm )
```

M∗ (n1 n2 – d)

Multiplies two single-cell signed integers, producing a double-cell result. A "double" here is two full `cell_t-width` cells (128 bits total on a 64-bit build), matching what D+/D-/D./etc. all expect – NOT the low/high 32-bit halves of a single 64-bit product. The previous implementation confused the two: it computed an ordinary 64-bit `long` long product (already truncated/overflowed for any operand pair whose true product doesn't fit in 64 bits) and then split THAT into 32-bit low/high halves, as if `cell_t` were 32-bit. For a small negative product like `-123 456 M∗` (-56088, which fits entirely in one 64-bit cell with sign extension), that produced a positive, zero-extended `dlow` paired with a correctly-looking `dhigh=-1` – a malformed double that D.'s overflow check (correctly) rejected as DOUBLE-OVERFLOW on every architecture, every time a negative product was printed (FABRIC-3.md ?XII.4 bug 1).

Fixed via `__int128` (a genuine 64x64->128-bit multiply, no truncation) – an established, safe pattern in this codebase for exactly this operation: see src/starkernel/crypto/fe25519.c and scalar25519.c, and src/starkernel/arch/amd64/timer.c's own doc comment confirming __int128 multiply/shift-by-constant compile cleanly with zero undefined symbols on all three target toolchains (only *division* needs libgcc support unavailable in this freestanding build – not used here).

Stack effect: (n1 n2 – d_low d_high) TOS = high

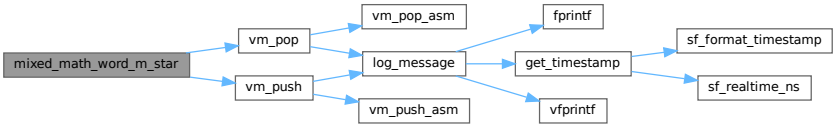
Parameters

vm	Active VM; sets `vm->error` = 1 on stack underflow

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_mixed_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.404.1.5 mixed_math_word_mod()

```
void mixed_math_word_mod (
            VM * vm )
```

MOD (n1 n2 – r)

Computes `n1` % `n2`, leaving the remainder on the stack. Sets `vm->error` = 1 if `n2` is zero (division by zero guard).

Stack effect: (n1 n2 – remainder)

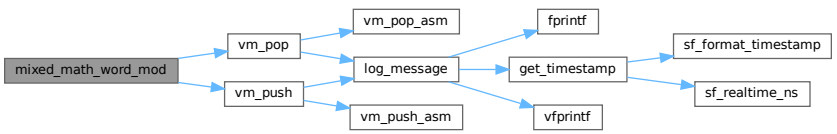
Parameters

vm	Active VM; sets `vm->error` = 1 on underflow or zero divisor

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_mixed_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.404.1.6 mixed_math_word_slash_mod()

```
void mixed_math_word_slash_mod (
            VM * vm )
```

/MOD (n1 n2 – rem quot)

Divides `n1` by `n2`, pushing the remainder deeper and the quotient on TOS. Sets `vm->error` = 1 if `n2` is zero.

Stack effect: (n1 n2 – remainder quotient) TOS = quotient

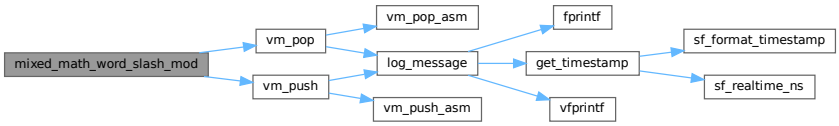
Parameters

vm	Active VM; sets `vm->error` = 1 on underflow or zero divisor

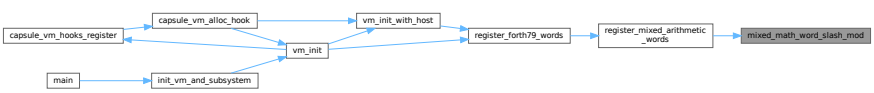
References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_mixed_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.404.1.7 mixed_math_word_star_slash()

```
void mixed_math_word_star_slash (
            VM * vm )
```

STAR-SLASH (FORTH word: `*-/`) — multiply then divide.

(n1 n2 n3 – n4)

Computes (n1 * n2) / n3 using a `long` long intermediate on 64-bit builds to avoid intermediate overflow. On 32-bit builds falls back to `long` double. Sets `vm->error` = 1 if `n3` is zero.

Stack effect: (n1 n2 n3 – quotient)

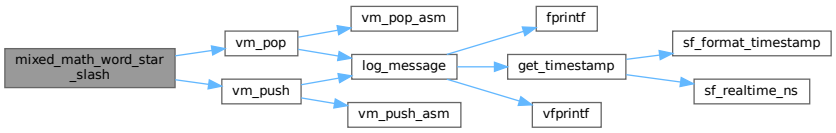
Parameters

vm	Active VM; sets `vm->error` = 1 on underflow or zero divisor

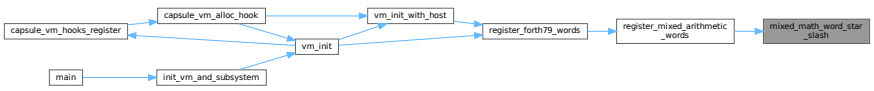
References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_mixed_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.404.1.8 mixed_math_word_star_slash_mod()

```
void mixed_math_word_star_slash_mod (
            VM * vm )
```

STAR-SLASH-MOD (FORTH word: `*-/MOD`) — multiply then divide, leaving remainder.

(n1 n2 n3 – rem quot)

Computes (n1 * n2) / n3 and leaves both the remainder (deeper) and quotient (TOS). Uses `long` long on 64-bit builds; falls back to `long` double with integer remainder reconstruction on 32-bit builds. Sets `vm->error` = 1 if `n3` is zero.

Stack effect: (n1 n2 n3 – remainder quotient) TOS = quotient

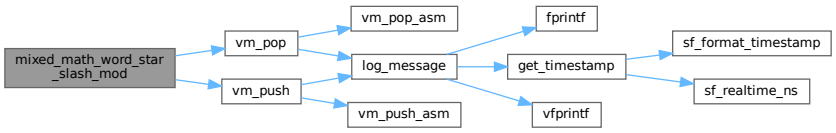
Parameters

vm	Active VM; sets `vm->error` = 1 on underflow or zero divisor

References VM::dsp, VM::error, vm_pop(), and vm_push().

Referenced by register_mixed_arithmetic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.404.1.9 register_mixed_arithmetic_words()

```
void register_mixed_arithmetic_words (
            VM * vm )
```

Register all FORTH-79 mixed arithmetic words with the VM dictionary.

Registers: `M+`, `M-`, `M*`, `M/MOD`, `MOD`, `/MOD`, `*\/`, `*\/MOD`. Called during VM bootstrap.

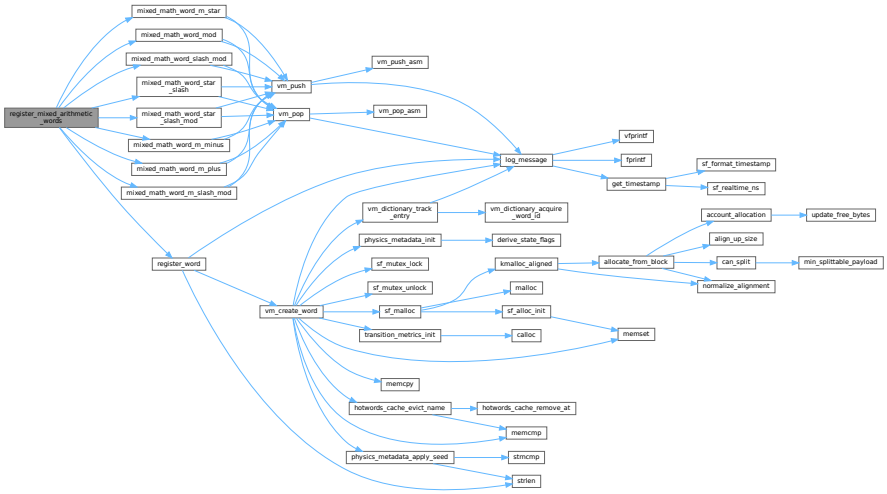
Parameters

vm	Active VM to register words into

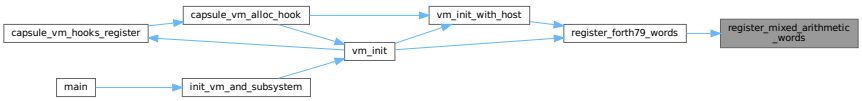
References mixed_math_word_m_minus(), mixed_math_word_m_plus(), mixed_math_word_m_slash_mod(), mixed_math_word_m_star(), mixed_math_word_mod(), mixed_math_word_slash_mod(), mixed_math_word_star_slash(), mixed_math_word_star_slash_mod(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



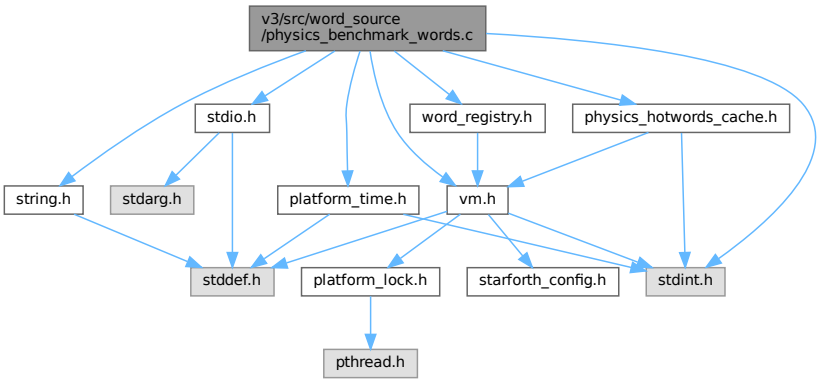
Here is the caller graph for this function:



7.405 v3/src/word_source/physics_benchmark_words.c File Reference

```
#include <stdio.h>
#include <stdint.h>
#include <string.h>
#include "vm.h"
#include "physics_hotwords_cache.h"
#include "platform_time.h"
#include "word_registry.h"
```

Include dependency graph for physics_benchmark_words.c:



Functions

- void forth_BENCH_DICT_LOOKUP (VM *vm)

  BENCH-DICT-LOOKUP (iterations –)
- void forth_PHYSICS_CACHE_STATS (VM *vm)

  PHYSICS-CACHE-STATS (–)
- void forth_PHYSICS_TOGGLE_CACHE (VM *vm)

  PHYSICS-TOGGLE-CACHE (–)
- void forth_PHYSICS_RESET_STATS (VM *vm)

  PHYSICS-RESET-STATS (–)
- void forth_PHYSICS_BUILD_INFO (VM *vm)

  PHYSICS-BUILD-INFO (–)
- void forth_PHYSICS_BAYESIAN_REPORT (VM *vm)

  PHYSICS-BAYESIAN-REPORT (addr_baseline –)
- void register_physics_benchmark_words (VM *vm)

  Register all physics benchmark words with the VM.

Variables

- DictEntry ** sf_fc_list [256]
- size_t sf_fc_count [256]

7.405.1 Function Documentation

7.405.1.1 forth_BENCH_DICT_LOOKUP()

```
void forth_BENCH_DICT_LOOKUP (
            VM * vm )
```

BENCH-DICT-LOOKUP (iterations –)

Benchmark dictionary lookup performance with statistically valid sample sizes.

STATISTICAL VALIDITY:

- Minimum recommended: 10,000 iterations (95% confidence interval)
- Standard test: 100,000 iterations (tight confidence intervals)
- Stress test: 1,000,000 iterations (ultra-precise measurements)

FOR BAYESIAN INFERENCE:

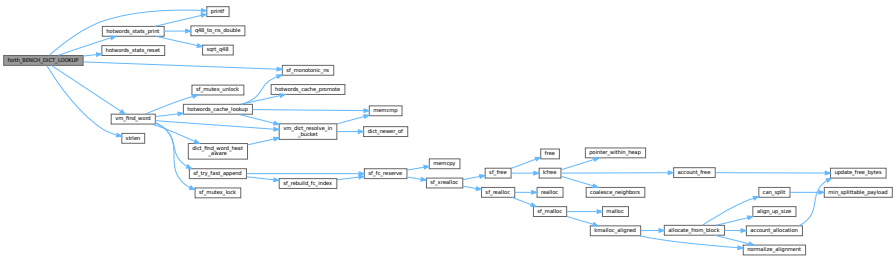
- All latencies recorded in 64-bit Q48.16 fixed-point format
- Variance accumulators enable prior/posterior calculations
- Sample sizes affect confidence in ML decisions

USAGE: 100000 BENCH-DICT-LOOKUP (statistically valid baseline) 1000000 BENCH-DICT-LOOKUP (stress test, ∼30sec on modern CPUs)

References VM::data_stack, VM::dsp, ENABLE_HOTWORDS_CACHE, VM::error, VM::hotwords_cache, hotwords_stats_print(), hotwords_stats_reset(), printf(), sf_monotonic_ns(), HotwordsCache_s::stats, strlen(), and vm_find_word().

Referenced by register_physics_benchmark_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.405.1.2 forth_PHYSICS_BAYESIAN_REPORT()

```
void forth_PHYSICS_BAYESIAN_REPORT (
            VM * vm )
```

PHYSICS-BAYESIAN-REPORT (addr_baseline –)

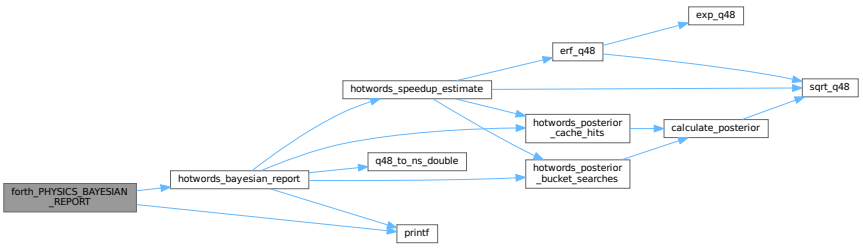
Generate Bayesian inference report comparing current cache stats against baseline stats stored at given address

Usage: PHYSICS-RESET-STATS [run baseline benchmark without cache] [save stats somewhere] PHYSICS-↩ RESET-STATS [run benchmark with cache] PHYSICS-BAYESIAN-REPORT

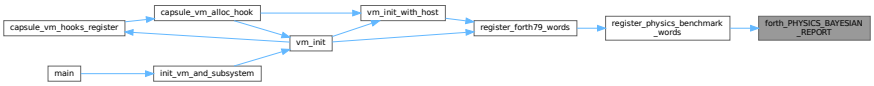
References HotwordsStats::bucket_hits, HotwordsStats::bucket_search_samples, HotwordsStats::bucket_search_total_ns_q48, HotwordsStats::bucket_search_variance_sum_q48, HotwordsStats::cache_hits, VM::error, hotwords_bayesian_report(), VM::hotwords_cache, HotwordsStats::max_bucket_search_ns, HotwordsStats::min_bucket_search_ns, printf(), and HotwordsCache_s::stats.

Referenced by register_physics_benchmark_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.405.1.3 forth_PHYSICS_BUILD_INFO()

```
void forth_PHYSICS_BUILD_INFO (
            VM * vm )
```

PHYSICS-BUILD-INFO (–)

Show current build configuration for this variant

References HotwordsCache_s::cache_count, ENABLE_HOTWORDS_CACHE, HotwordsCache_s::enabled, VM::error, VM::hotwords_cache, HOTWORDS_CACHE_SIZE, HOTWORDS_EXECUTION_HEAT_DELTA_THRESHOLD, HOTWORDS_EXECUTION_HEAT_THRESHOLD, and printf().

Referenced by register_physics_benchmark_words().

Here is the call graph for this function:

Here is the caller graph for this function:

7.405.1.4 forth_PHYSICS_CACHE_STATS()

```
void forth_PHYSICS_CACHE_STATS (
            VM * vm )
```

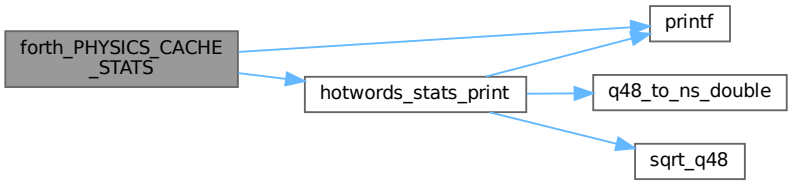
PHYSICS-CACHE-STATS (–)

Display detailed hot-words cache statistics

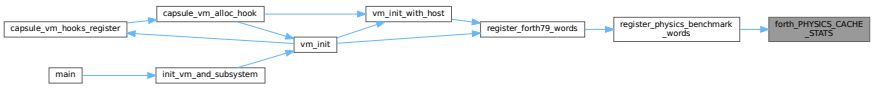
References HotwordsCache_s::cache, HotwordsCache_s::cache_count, ENABLE_HOTWORDS_CACHE, VM::error, DictEntry::execution_heat, VM::hotwords_cache, hotwords_stats_print(), DictEntry::name, DictEntry::physics, printf(), HotwordsCache_s::stats, and DictPhysics::temperature_q8.

Referenced by register_physics_benchmark_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.405.1.5 forth_PHYSICS_RESET_STATS()

```
void forth_PHYSICS_RESET_STATS (
            VM * vm )
```

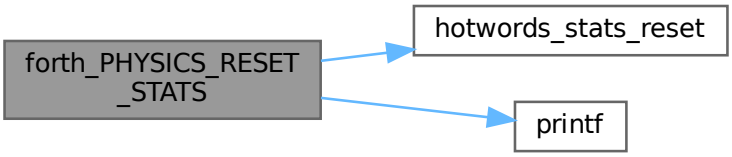
PHYSICS-RESET-STATS (–)

Reset cache statistics for clean before/after comparison

References VM::error, VM::hotwords_cache, hotwords_stats_reset(), VM::pipeline_metrics, PipelineGlobalMetrics::prefetch_attempts, PipelineGlobalMetrics::prefetch_hits, printf(), HotwordsCache_s::stats, and PipelineGlobalMetrics::window_tuning_checks.

Referenced by register_physics_benchmark_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.405.1.6 forth_PHYSICS_TOGGLE_CACHE()

```
void forth_PHYSICS_TOGGLE_CACHE (
            VM * vm )
```

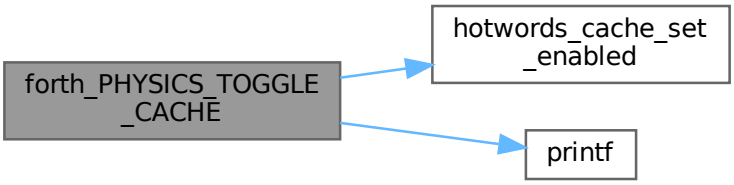
PHYSICS-TOGGLE-CACHE (–)

Enable/disable hot-words cache at runtime (for A/B testing)

References ENABLE_HOTWORDS_CACHE, HotwordsCache_s::enabled, VM::error, VM::hotwords_cache, hotwords_cache_set_enabled(), and printf().

Referenced by register_physics_benchmark_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.405.1.7 register_physics_benchmark_words()

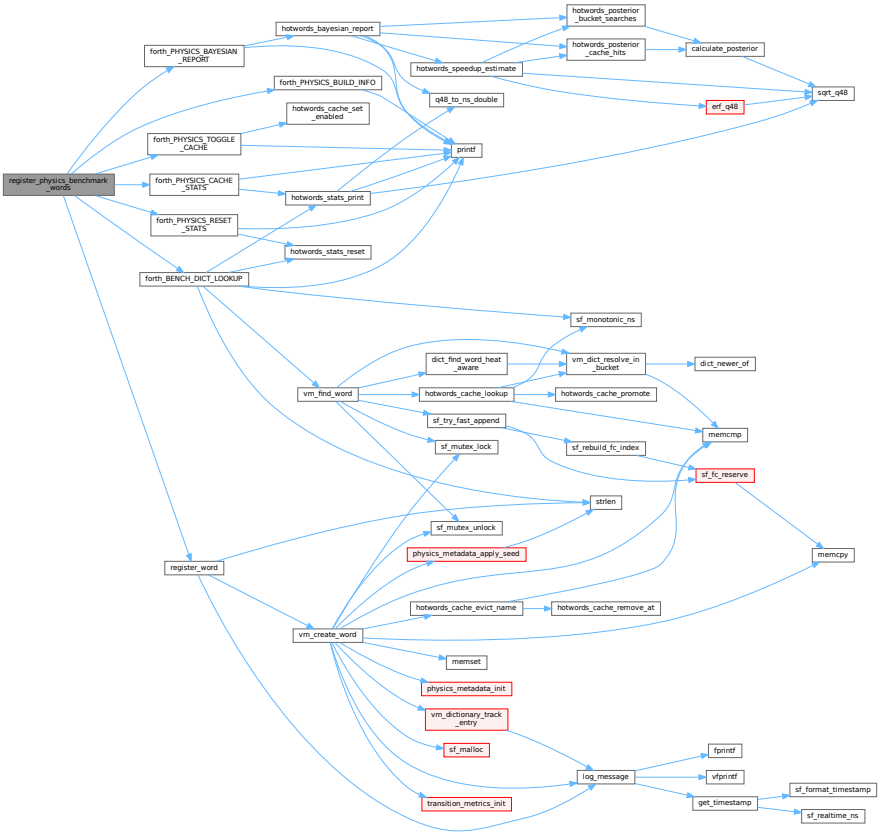
```
void register_physics_benchmark_words (
            VM * vm )
```

Register all physics benchmark words with the VM.

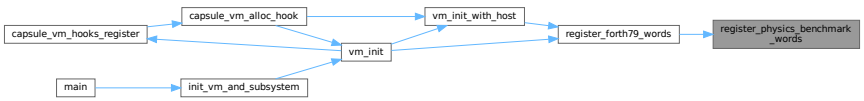
References forth_BENCH_DICT_LOOKUP(), forth_PHYSICS_BAYESIAN_REPORT(), forth_PHYSICS_BUILD_INFO(), forth_PHYSICS_CACHE_STATS(), forth_PHYSICS_RESET_STATS(), forth_PHYSICS_TOGGLE_CACHE(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.405.2 Variable Documentation

7.405.2.1 sf_fc_count

```
size_t sf_fc_count[256]  [extern]
```

Referenced by sf_fc_clear_all(), sf_fc_reserve(), sf_rebuild_fc_index(), sf_try_fast_append(), and vm_find_word().

7.405.2.2 sf_fc_list

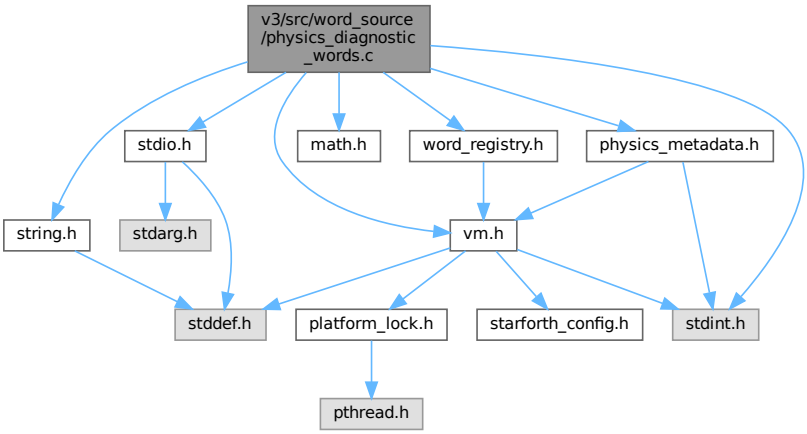
```
DictEntry** sf_fc_list[256]  [extern]
```

Referenced by sf_fc_clear_all(), sf_fc_reserve(), sf_rebuild_fc_index(), sf_try_fast_append(), and vm_find_word().

7.406 v3/src/word_source/physics_diagnostic_words.c File Reference

```
#include <stdio.h>
#include <stdint.h>
#include <string.h>
#include <math.h>
#include "vm.h"
#include "physics_metadata.h"
#include "word_registry.h"
```

Include dependency graph for physics_diagnostic_words.c:



Functions

- void forth_PHYSICS_WORD_METRICS (VM *vm)

  PHYSICS-WORD-METRICS (–)
- void forth_PHYSICS_CALC_KNOBS (VM *vm)

  PHYSICS-CALC-KNOBS (–)
- void forth_PHYSICS_BURN (VM *vm)

  PHYSICS-BURN (n –)
- void forth_PHYSICS_SHOW_FEEDBACK (VM *vm)

  PHYSICS-SHOW-FEEDBACK (–)
- void register_physics_diagnostic_words (VM *vm)

  Register all physics diagnostic words with the VM.

7.406.1 Function Documentation

7.406.1.1 forth_PHYSICS_BURN()

```
void forth_PHYSICS_BURN (
            VM * vm )
```

PHYSICS-BURN (n –)

Execute a word repeatedly (burn) and show thermal feedback.

Execute the top-of-stack word n times and show thermal feedback.

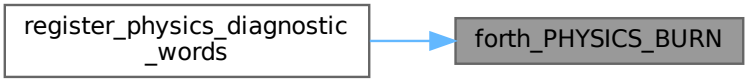
Usage: : HOTTEST 100 0 DO 1 2 + 3 * LOOP ; HOTTEST 10 PHYSICS-BURN (execute 10 times) PHYSICS-↩ SHOW-FEEDBACK

References VM::data_stack, VM::dsp, VM::error, DictEntry::execution_heat, DictEntry::func, DictPhysics::last_active_ns, VM::latest, DictEntry::name, DictEntry::physics, printf(), and DictPhysics::temperature_q8.

Referenced by register_physics_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



7.406.1.2 forth_PHYSICS_CALC_KNOBS()

```
void forth_PHYSICS_CALC_KNOBS (
            VM * vm )
```

PHYSICS-CALC-KNOBS (–)

Calculate and show knob adjustments based on current thermal metrics.

Calculate what knobs should be adjusted based on current word metrics. Shows:

- Thermal pressure (0.0 to 1.0)
- Recommended priority adjustment
- Recommended sampling rate
- Stack depth limit

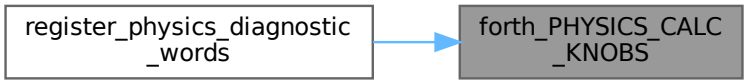
- Core affinity preference

References VM::error, DictPhysics::last_active_ns, VM::latest, DictEntry::name, DictEntry::physics, printf(), and DictPhysics::temperature_q8.

Referenced by register_physics_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



7.406.1.3 forth_PHYSICS_SHOW_FEEDBACK()

```
void forth_PHYSICS_SHOW_FEEDBACK (
            VM * vm )
```

PHYSICS-SHOW-FEEDBACK (–)

Display the complete feedback loop: inputs → math → knobs → effect.

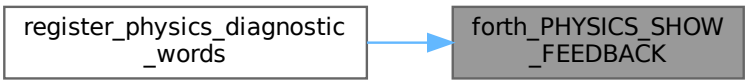
Display the complete feedback loop for the most recent word. Shows: Metrics → Calculations → Knobs → Effect

References DictPhysics::avg_latency_ns, VM::error, DictEntry::execution_heat, DictPhysics::last_active_ns, VM::latest, DictPhysics::mass_bytes, DictEntry::name, DictEntry::physics, printf(), and DictPhysics::temperature_q8.

Referenced by register_physics_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



7.406.1.4 forth_PHYSICS_WORD_METRICS()

```
void forth_PHYSICS_WORD_METRICS (
            VM * vm )
```

PHYSICS-WORD-METRICS (–)

Display detailed physics metrics for the most recently executed word.

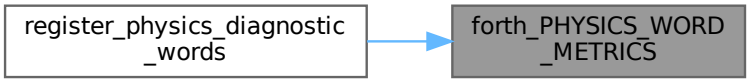
Display detailed physics metrics for a word. Looks up the most recently executed word and shows its state.

References DictPhysics::avg_latency_ns, VM::error, DictEntry::execution_heat, DictPhysics::last_active_ns, VM::latest, DictPhysics::mass_bytes, DictEntry::name, DictEntry::physics, printf(), and DictPhysics::temperature_q8.

Referenced by register_physics_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



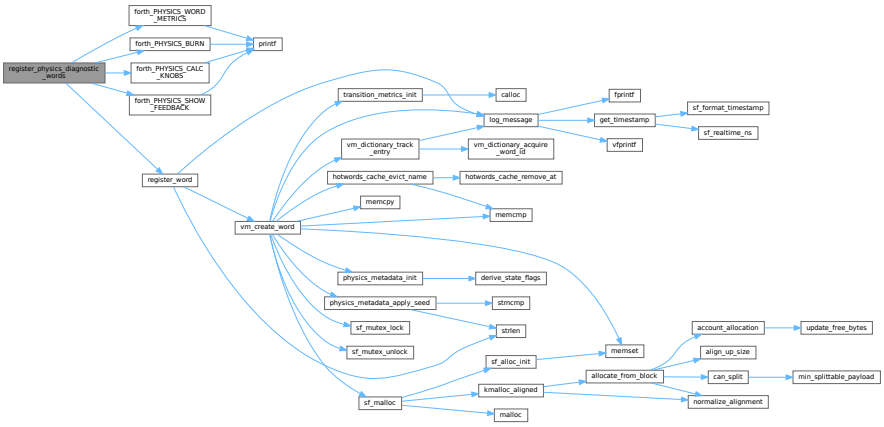
7.406.1.5 register_physics_diagnostic_words()

```
void register_physics_diagnostic_words (
            VM * vm )
```

Register all physics diagnostic words with the VM.

References forth_PHYSICS_BURN(), forth_PHYSICS_CALC_KNOBS(), forth_PHYSICS_SHOW_FEEDBACK(), forth_PHYSICS_WORD_METRICS(), and register_word().

Here is the call graph for this function:

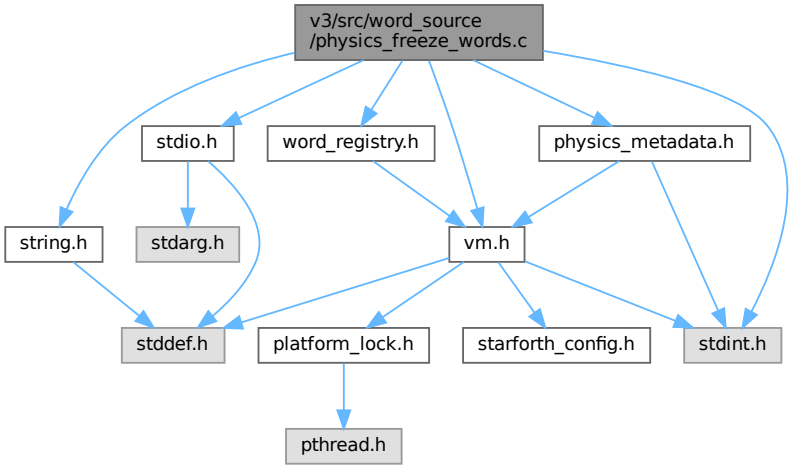


7.407 v3/src/word_source/physics_freeze_words.c File Reference

```
#include <stdio.h>
#include <stdint.h>
#include <string.h>
#include "vm.h"
#include "physics_metadata.h"
```

```
#include "word_registry.h"
```

Include dependency graph for physics_freeze_words.c:



Functions

- void forth_FREEZE_WORD (VM *vm)

  FREEZE-WORD (caddr u –)
- void forth_UNFREEZE_WORD (VM *vm)

  UNFREEZE-WORD (caddr u –)
- void forth_FROZEN_QUERY (VM *vm)

  FROZEN? (caddr u – flag)
- void forth_HEAT_STORE (VM *vm)

  HEAT! (heat caddr u –)
- void forth_HEAT_FETCH (VM *vm)

  HEAT@ (caddr u – heat)
- void forth_SHOW_HEAT (VM *vm)

  SHOW-HEAT (caddr u –)
- void forth_ALL_HEATS (VM *vm)

  ALL-HEATS (–)
- void forth_DECAY_RATE_FETCH (VM *vm)

  DECAY-RATE@ (– rate)
- void forth_FREEZE_CRITICAL (VM *vm)

  FREEZE-CRITICAL (–)
- void register_physics_freeze_words (VM *vm)

  Register all Phase 2 freeze/decay control words with the VM dictionary.

7.407.1 Function Documentation

7.407.1.1 forth_ALL_HEATS()

```
void forth_ALL_HEATS (
            VM * vm )
```

ALL-HEATS (–)

Iterates the entire dictionary, collects up to 1024 entries, sorts them by descending `execution_heat` using an $O(n^2)$ bubble sort, then prints a formatted table to `stdout` with columns for word name, heat value, and status (frozen/pinned). Intended for interactive diagnostics; the $O(n^2)$ sort is acceptable for dictionary sizes below 1000 words.

Stack effect: (–)

Parameters

vm	Active VM; no-op if `vm->error` is set

References count, VM::error, execution_heat, DictEntry::execution_heat, DictEntry::flags, VM::latest, DictEntry::name, DictEntry::name_len, printf(), WORD_FROZEN, and WORD_PINNED.

Referenced by register_physics_freeze_words().

Here is the call graph for this function:

Here is the caller graph for this function:

7.407.1.2 forth_DECAY_RATE_FETCH()

```
void forth_DECAY_RATE_FETCH (
            VM * vm )
```

DECAY-RATE@ (– rate)

Pushes the compile-time constant `DECAY_RATE_PER_US_Q16` as a Q48.16 fixed-point value. This is the base heat decay rate per microsecond used by Loop #3 before adaptive tuning by Loop #6. Intended for introspection and diagnostics.

Stack effect: (– rate)

Parameters

vm	Active VM; sets `vm->error` = 1 on stack overflow

References VM::data_stack, DECAY_RATE_PER_US_Q16, VM::dsp, VM::error, and STACK_SIZE.

Referenced by register_physics_freeze_words().

Here is the caller graph for this function:

7.407.1.3 forth_FREEZE_CRITICAL()

```
void forth_FREEZE_CRITICAL (
            VM * vm )
```

FREEZE-CRITICAL (–)

Sets `WORD_FROZEN` on a hard-coded list of 21 system-critical words (DUP, DROP, SWAP, OVER, ROT, @, !, C@, C!, EXECUTE, IF, THEN, ELSE, DO, LOOP, BEGIN, UNTIL, REPEAT, ., EMIT, CR). Silently skips any word not found in the current dictionary. Intended to be called once at startup to prevent essential words from decaying out of the hot-words cache.

Stack effect: (–)

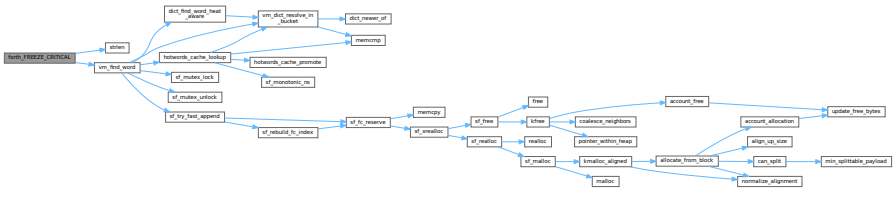
Parameters

vm	Active VM; no-op if `vm->error` is set

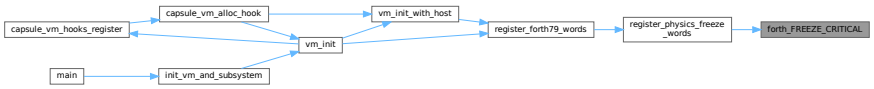
References entry, VM::error, name, strlen(), vm_find_word(), and WORD_FROZEN.

Referenced by register_physics_freeze_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.407.1.4 forth_FREEZE_WORD()

```
void forth_FREEZE_WORD (
            VM * vm )
```

FREEZE-WORD (caddr u –)

Set the `WORD_FROZEN` flag on the named word, preventing `physics_metadata_apply_linear_decay()` from reducing its `execution_heat`. Frozen words stay hot across OS context switches indefinitely. Silently succeeds if the word is not found (lenient policy).

Stack effect: (caddr u –)

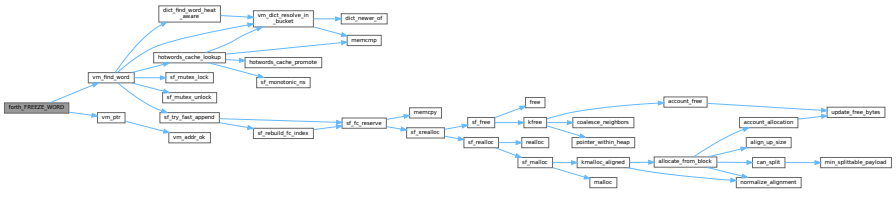
Parameters

vm	Active VM; `vm->error` is set and returns early on underflow

References VM::data_stack, VM::dsp, entry, VM::error, name, vm_find_word(), vm_ptr(), WORD_FROZEN, and WORD_NAME_MAX.

Referenced by register_physics_freeze_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.407.1.5 forth_FROZEN_QUERY()

```
void forth_FROZEN_QUERY (
            VM * vm )
```

FROZEN? (caddr u – flag)

Tests whether the WORD_FROZEN flag is set on the named word. Pushes -1 (FORTH true) if frozen, 0 otherwise. Also pushes 0 when the word is not found or u is out of range, so callers need not distinguish "not frozen" from "not found".

Stack effect: (caddr u – flag)

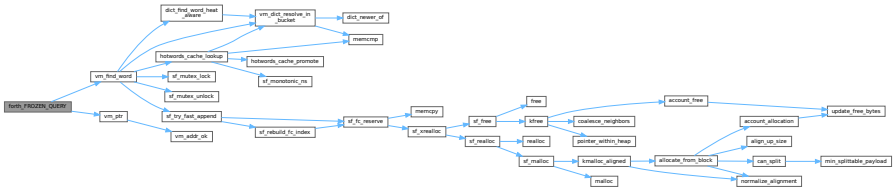
Parameters

vm	Active VM; vm->error is set and returns early on underflow

References VM::data_stack, VM::dsp, entry, VM::error, name, vm_find_word(), vm_ptr(), WORD_FROZEN, and WORD_NAME_MAX.

Referenced by register_physics_freeze_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.407.1.6 forth_HEAT_FETCH()

```
void forth_HEAT_FETCH (
            VM * vm )
```

HEAT@ (caddr u – heat)

Pushes the current execution_heat of the named word. Pushes 0 when the word is not found, u is out of range, or the word genuinely has zero heat.

Stack effect: (caddr u – heat)

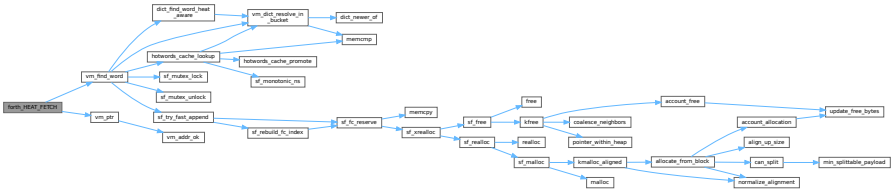
Parameters

vm	Active VM; `vm->error` is set and returns early on underflow

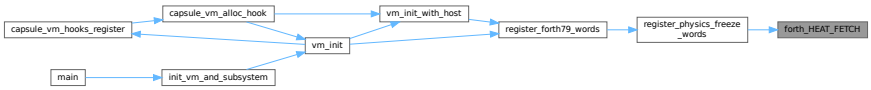
References VM::data_stack, VM::dsp, entry, VM::error, name, vm_find_word(), vm_ptr(), and WORD_NAME_MAX.

Referenced by register_physics_freeze_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.407.1.7 forth_HEAT_STORE()

```
void forth_HEAT_STORE (
            VM * vm )
```

HEAT! (heat caddr u –)

Directly writes `heat` into `entry->execution_heat` for the named word. Intended for diagnostics and testing; bypasses Loop #1 accumulation and Loop #3 decay. Silently succeeds if the word is not found or `u` is out of range.

Stack effect: (heat caddr u –)

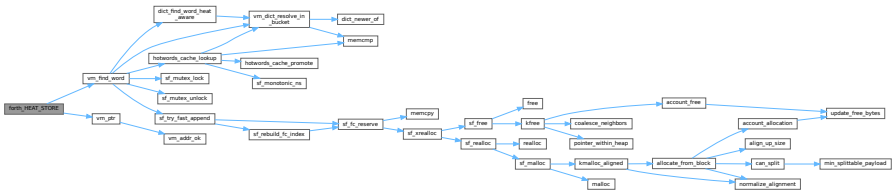
Parameters

vm	Active VM; `vm->error` is set and returns early on underflow

References VM::data_stack, VM::dsp, entry, VM::error, name, vm_find_word(), vm_ptr(), and WORD_NAME_MAX.

Referenced by register_physics_freeze_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.407.1.8 forth_SHOW_HEAT()

```
void forth_SHOW_HEAT (
                VM * vm )
```

SHOW-HEAT (caddr u –)

Prints the `execution_heat` of the named word to `stdout` along with its freeze and pinned status flags. Output format: `"NAME: HEAT (frozen) (pinned)"`. Prints `"Word not found: NAME"` when the dictionary lookup fails. Intended for interactive diagnostics.

Stack effect: (caddr u –)

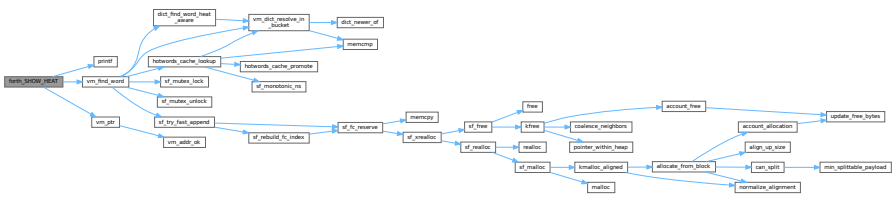
Parameters

vm	Active VM; `vm->error` is set and returns early on underflow

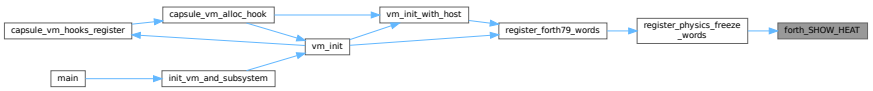
References VM::data_stack, VM::dsp, entry, VM::error, name, printf(), vm_find_word(), vm_ptr(), WORD_FROZEN, WORD_NAME_MAX, and WORD_PINNED.

Referenced by register_physics_freeze_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.407.1.9 forth_UNFREEZE_WORD()

```
void forth_UNFREEZE_WORD (
            VM * vm )
```

UNFREEZE-WORD (caddr u –)

Clears the `WORD_FROZEN` flag on the named word, allowing its `execution_heat` to decay normally via Loop #3. Does not alter `WORD_PINNED`. Silently succeeds if the word is not found or `u` is out of range.

Stack effect: (caddr u –)

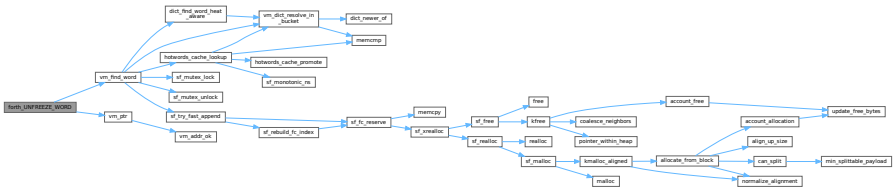
Parameters

vm	Active VM; `vm->error` is set and returns early on underflow

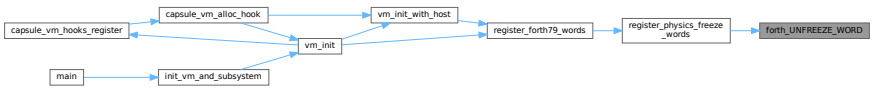
References VM::data_stack, VM::dsp, entry, VM::error, name, vm_find_word(), vm_ptr(), and WORD_NAME_MAX.

Referenced by register_physics_freeze_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.407.1.10 register_physics_freeze_words()

```
void register_physics_freeze_words (
            VM * vm )
```

Register all Phase 2 freeze/decay control words with the VM dictionary.

Register all Phase 2 freeze/decay control words with the VM.

Registers: `FREEZE-WORD`, `UNFREEZE-WORD`, `FROZEN?`, `HEAT!`, `HEAT@`, `SHOW-HEAT`, `ALL-HEATS`, `DECAY-RATE@`, `FREEZE-CRITICAL`. Called during VM bootstrap by the word registration subsystem.

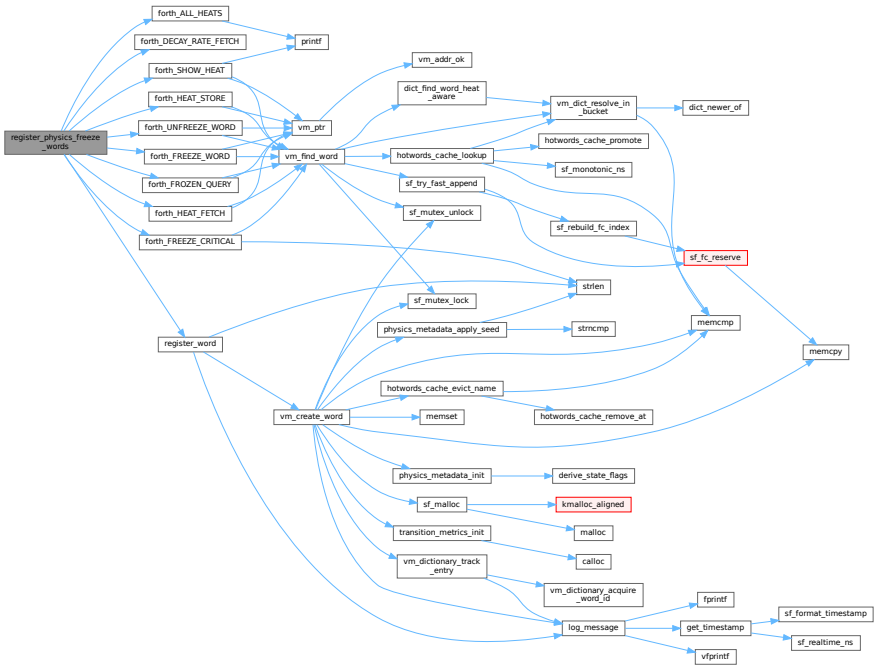
Parameters

vm	Active VM to register words into

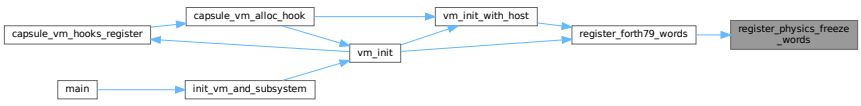
References forth_ALL_HEATS(), forth_DECAY_RATE_FETCH(), forth_FREEZE_CRITICAL(), forth_FREEZE_WORD(), forth_FROZEN_QUERY(), forth_HEAT_FETCH(), forth_HEAT_STORE(), forth_SHOW_HEAT(), forth_UNFREEZE_WORD(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



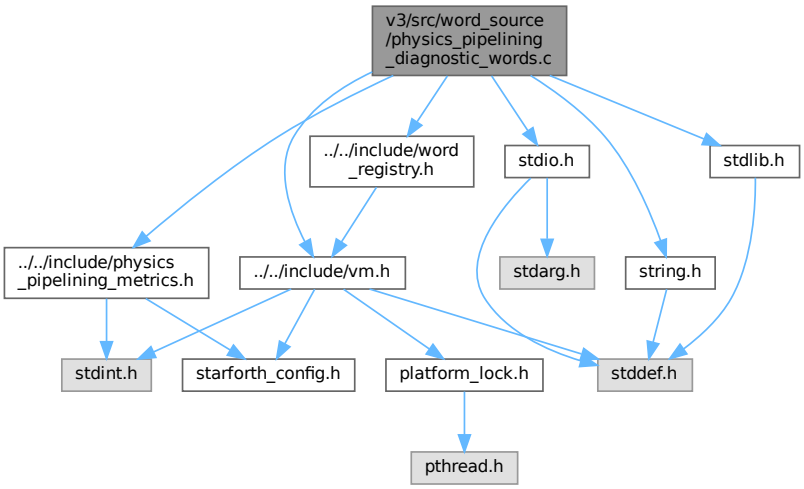
Here is the caller graph for this function:



7.408 v3/src/word_source/physics_pipelining_diagnostic_words.c File Reference

```
#include "../../include/vm.h"
#include "../../include/physics_pipelining_metrics.h"
#include "../../include/word_registry.h"
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
```

Include dependency graph for physics_pipelining_diagnostic_words.c:



Functions

- static void forth_PIPELINING_SHOW_STATS (VM *vm)

  PIPELINING-SHOW-STATS (<wordname> –)
- static void forth_PIPELINING_SHOW_TOP_TRANSITIONS (VM *vm)

  PIPELINING-SHOW-TOP-TRANSITIONS (<wordname> N –)
- static void forth_PIPELINING_RESET_ALL (VM *vm)

  PIPELINING-RESET-ALL (–)
- static void forth_PIPELINING_ENABLE (VM *vm)

  PIPELINING-ENABLE (–)
- static void forth_PIPELINING_STATS (VM *vm)

  PIPELINING-STATS (–)
- static void forth_PIPELINING_ANALYZE_WORD (VM *vm)

  PIPELINING-ANALYZE-WORD (<wordname> –)
- void register_physics_pipelining_diagnostic_words (VM *vm)

  Register all pipelining diagnostic words.

7.408.1 Function Documentation

7.408.1.1 forth_PIPELINING_ANALYZE_WORD()

```
static void forth_PIPELINING_ANALYZE_WORD (
            VM * vm )  [static]
```

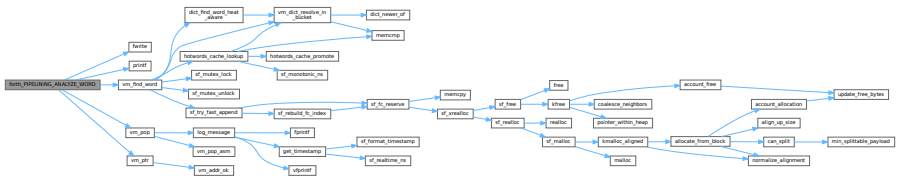
PIPELINING-ANALYZE-WORD (<wordname> –)

Comprehensive analysis of a single word's transition pattern. Shows raw data and interpretation hints.

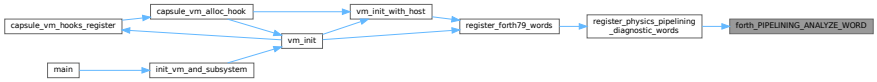
References DICTIONARY_SIZE, VM::dsp, entry, VM::error, fwrite(), WordTransitionMetrics::max_transition_probability_q48, WordTransitionMetrics::misprediction_cost_q48, WordTransitionMetrics::most_likely_next_word_id, WordTransitionMetrics::prefetch_a WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_latency_saved_q48, printf(), stdout, WordTransitionMetrics::total_transitions, WordTransitionMetrics::transition_heat, vm_find_word(), vm_pop(), and vm_ptr().

Referenced by register_physics_pipelining_diagnostic_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.408.1.2 forth_PIPELINING_ENABLE()

```
static void forth_PIPELINING_ENABLE (
            VM * vm )  [static]
```

PIPELINING-ENABLE (–)

Enable pipelining metrics collection (sets ENABLE_PIPELINING flag). Note: This is compile-time on/off for now; this word is a placeholder.

References printf().

Referenced by register_physics_pipelining_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:

7.408.1.3 forth_PIPELINING_RESET_ALL()

```
static void forth_PIPELINING_RESET_ALL (
            VM * vm )  [static]
```

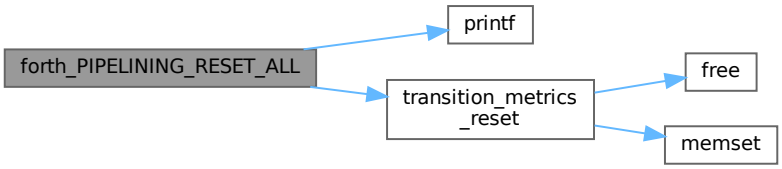
PIPELINING-RESET-ALL (–)

Clear all transition metrics from the dictionary. Useful for starting fresh measurements.

References count, entry, VM::latest, printf(), and transition_metrics_reset().

Referenced by register_physics_pipelining_diagnostic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.408.1.4 forth_PIPELINING_SHOW_STATS()

```
static void forth_PIPELINING_SHOW_STATS (
            VM * vm )  [static]
```

PIPELINING-SHOW-STATS (<wordname> –)

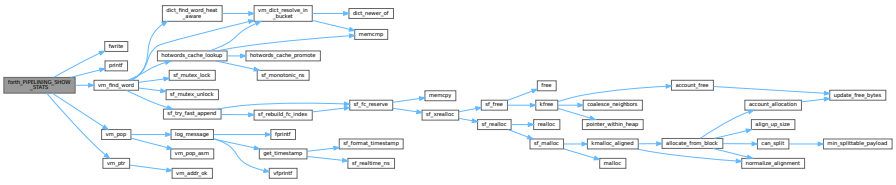
Display transition metrics for a given word. Typical usage: PIPELINING-SHOW-STATS EXIT (show where EXIT typically goes) PIPELINING-SHOW-STATS BENCH-DICT (show where BENCH-DICT transitions)

Requires: word must exist in dictionary Effect: Prints transition statistics to stdout

References VM::dsp, entry, VM::error, fwrite(), WordTransitionMetrics::max_transition_probability_q48, WordTransitionMetrics::mispre WordTransitionMetrics::most_likely_next_word_id, WordTransitionMetrics::prefetch_attempts, WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_latency_saved_q48, WordTransitionMetrics::prefetch_misses, printf(), stdout, WordTransitionMetrics::total_transitions, vm_find_word(), vm_pop(), and vm_ptr().

Referenced by register_physics_pipelining_diagnostic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.408.1.5 forth_PIPELINING_SHOW_TOP_TRANSITIONS()

```
static void forth_PIPELINING_SHOW_TOP_TRANSITIONS (
            VM * vm )  [static]
```

PIPELINING-SHOW-TOP-TRANSITIONS (<wordname> N –)

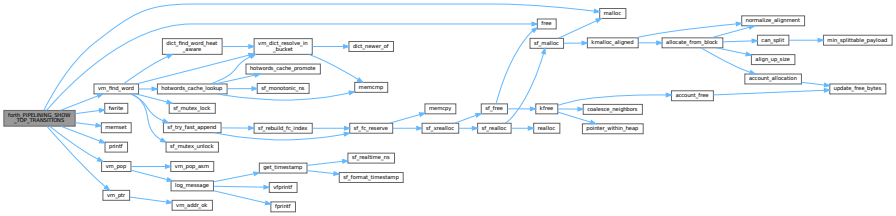
Display the top N words that typically follow a given word. Useful for understanding hot execution paths.

Stack: <wordname> N – Example: " EXIT" 5 PIPELINING-SHOW-TOP-TRANSITIONS (Show top 5 words that usually follow EXIT)

References count, DICTIONARY_SIZE, VM::dsp, entry, VM::error, free(), fwrite(), malloc(), memset(), printf(), stdout, WordTransitionMetrics::total_transitions, WordTransitionMetrics::transition_heat, vm_find_word(), vm_pop(), vm_ptr(), and word_id.

Referenced by register_physics_pipelining_diagnostic_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.408.1.6 forth_PIPELINING_STATS()

```
static void forth_PIPELINING_STATS (
            VM * vm ) [static]
```

PIPELINING-STATS (–)

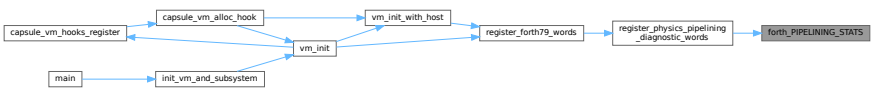
Display aggregate pipelining statistics across entire dictionary.

References entry, VM::latest, WordTransitionMetrics::prefetch_attempts, WordTransitionMetrics::prefetch_hits, WordTransitionMetrics::prefetch_misses, printf(), WordTransitionMetrics::total_transitions, and word_count.

Referenced by register_physics_pipelining_diagnostic_words().

Here is the call graph for this function:

Here is the caller graph for this function:



7.408.1.7 register_physics_pipelining_diagnostic_words()

```
void register_physics_pipelining_diagnostic_words (
            VM * vm )
```

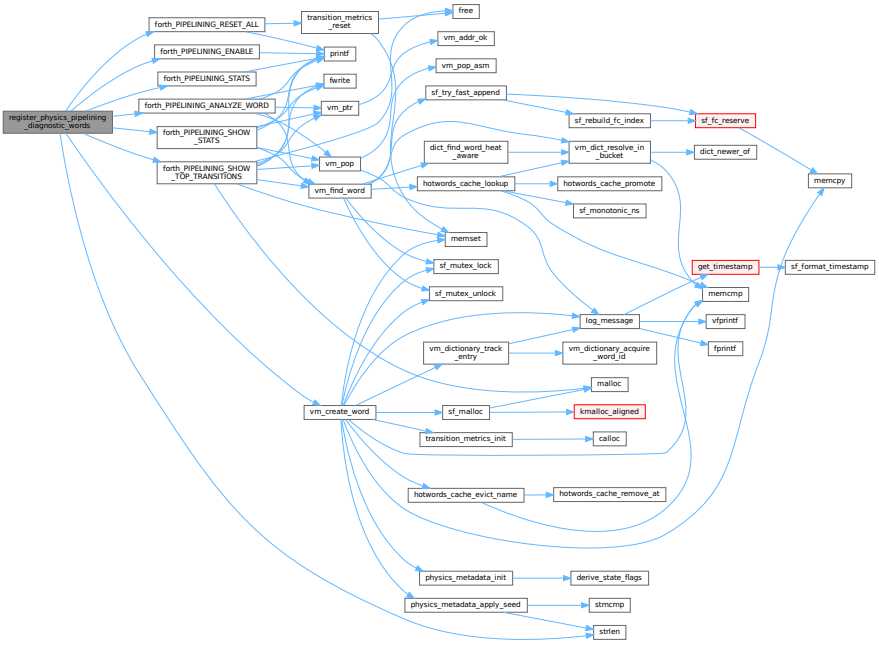
Register all pipelining diagnostic words.

Register all pipelining diagnostic words Called during VM initialization.

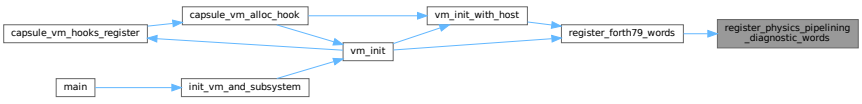
References forth_PIPELINING_ANALYZE_WORD(), forth_PIPELINING_ENABLE(), forth_PIPELINING_RESET_ALL(), forth_PIPELINING_SHOW_STATS(), forth_PIPELINING_SHOW_TOP_TRANSITIONS(), forth_PIPELINING_STATS(), strlen(), and vm_create_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



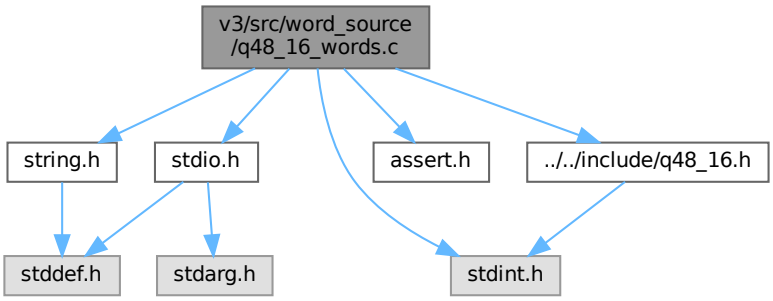
Here is the caller graph for this function:



7.409 v3/src/word_source/q48_16_words.c File Reference

```
#include <stdint.h>
#include <string.h>
#include <stdio.h>
#include <assert.h>
#include "../../include/q48_16.h"
```

Include dependency graph for q48_16_words.c:



Functions

- q48_16_t q48_mul (q48_16_t a, q48_16_t b)

  Multiply two Q48.16 fixed-point values.
- q48_16_t q48_div (q48_16_t a, q48_16_t b)

  Divide two Q48.16 fixed-point values.
- q48_16_t q48_from_double (double d)

  Convert a `double` to Q48.16 format.
- double q48_to_double (q48_16_t q)

  Convert a Q48.16 value to `double`.
- q48_16_t q48_log_approx (uint64_t x)

  Compute an approximation of `ln(x)` in Q48.16 format (integer-only).
- q48_16_t q48_exp_approx (q48_16_t q)

  Compute an approximation of `e^q` in Q48.16 format (Taylor series).
- q48_16_t q48_sqrt_approx (q48_16_t q)

  Compute an approximation of `sqrt(q)` in Q48.16 format (Newton-Raphson).
- static int64_t q48_reduce_angle (int64_t x)

  Reduce a signed Q48.16 angle into [-PI_Q48, PI_Q48].
- q48_16_t q48_sin_approx (q48_16_t q)

  Compute an approximation of `sin(q)` in Q48.16 format (radians).
- q48_16_t q48_cos_approx (q48_16_t q)

  Compute an approximation of `cos(q)` in Q48.16 format (radians).
- const char * q48_to_string (q48_16_t q)

  Format a Q48.16 value as a decimal string `"INTEGER.FRAC"`.
- int q48_is_valid (q48_16_t q)

  Test whether a Q48.16 value is valid.

7.409.1 Function Documentation

7.409.1.1 q48_cos_approx()

```
q48_16_t q48_cos_approx (
            q48_16_t q )
```

Compute an approximation of `cos(q)` in Q48.16 format (radians).

Range-reduces into [-pi, pi] via `q48_reduce_angle()`, then sums the Taylor series `1` - x^2/2! + x^4/4! - ... for terms n = 2,4,6,8,10, with an early exit when a term falls below 10. Cosine is even (`cos`(-x) = cos(x)), so no sign correction is needed – `x^2` already absorbs the sign of `x`.

Parameters

q	Angle in Q48.16 format (radians, any magnitude)

Returns

`cos(q)` in Q48.16 format

7.409.1.2 q48_div()

```
q48_16_t q48_div (
            q48_16_t a,
            q48_16_t b )
```

Divide two Q48.16 fixed-point values.

Computes (a << 16) / b. Returns 0 if `b` == 0 (safe, but callers should guard). Returns `UINT64_MAX` as a saturation sentinel when `a` exceeds 2^48, which would overflow the 16-bit left-shift.

Parameters

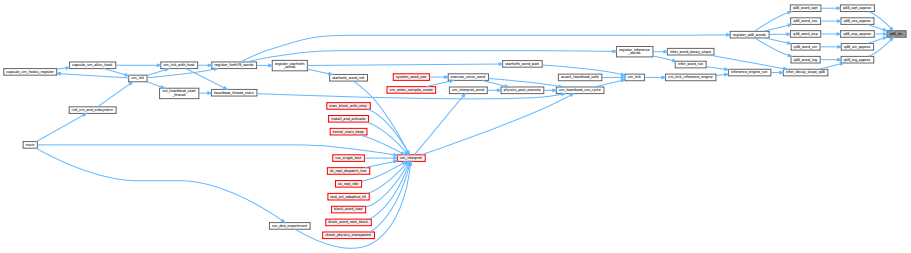
a	Dividend in Q48.16 format
b	Divisor in Q48.16 format; 0 returns 0

Returns

Quotient in Q48.16 format, or UINT64_MAX on saturation

Referenced by q48_cos_approx(), q48_exp_approx(), q48_log_approx(), q48_sin_approx(), and q48_sqrt_approx().

Here is the caller graph for this function:



7.409.1.3 q48_exp_approx()

```
q48_16_t q48_exp_approx (
            q48_16_t q )
```

Compute an approximation of e^q in Q48.16 format (Taylor series).

Supporting function for q48_log_approx() Newton iterations. Uses the Taylor series 1 + x + x^2/2! + ... up to 10 terms, with an early-exit when a term falls below 50 (sub-LSB in Q48.16). Handles negative q by computing e^|q| then returning 1/result. Returns 1.0 (65536) for q == 0, UINT64_MAX for q >= 16.0, and 0 for q <= -16.0.

Parameters

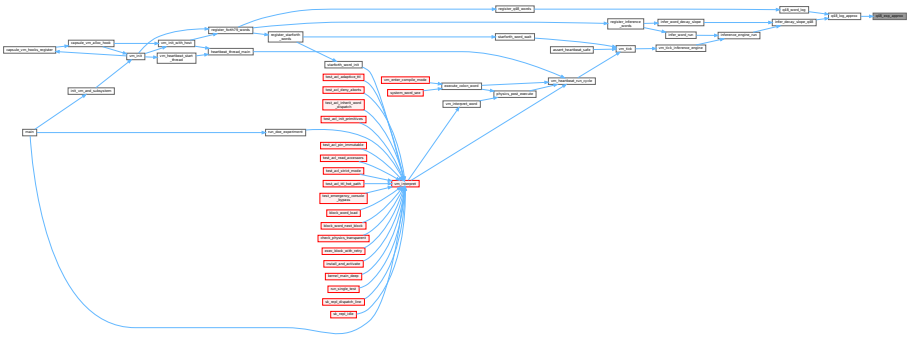
q	Exponent in Q48.16 format (signed interpretation)

Returns

e^q in Q48.16 format

Referenced by q48_log_approx().

Here is the caller graph for this function:



7.409.1.4 q48_from_double()

```
q48_16_t q48_from_double (
            double d )
```

Convert a `double` to Q48.16 format.

Multiplies `d` by 65536.0 and rounds to nearest. Intended for testing and diagnostics only — not called in the inference engine hot path to avoid floating-point dependency.

Parameters

d	Value to convert

Returns

Nearest Q48.16 representation of `d`

7.409.1.5 q48_is_valid()

```
int q48_is_valid (
            q48_16_t q )
```

Test whether a Q48.16 value is valid.

Currently accepts any `uint64_t` value as valid — all bit patterns are representable in Q48.16. A more sophisticated implementation could check for saturation sentinels or range limits. Returns 1 always.

Parameters

q	Value to validate

Returns

1 always (placeholder for future range validation)

7.409.1.6 q48_log_approx()

```
q48_16_t q48_log_approx (
            uint64_t x )
```

Compute an approximation of `ln(x)` in Q48.16 format (integer-only).

Used by `infer_decay_slope_q48()` (Loop #6) for log-linear OLS regression. Algorithm: range-reduces `x` to the interval [1, 2) by tracking the exponent `k` (so `x` = 2^k * m), applies 6 Newton-Raphson iterations on `e^y` = m starting from the first-order approximation `y_0` = m - 1, then assembles the result as `ln(x)` = k*ln(2) + ln(m). Returns 0 for `x` == 0 (ln undefined) and for `x` == 65536 (ln(1.0) == 0.0 exactly). `LN2_Q48` = 45426 (0.693147... × 65536).

Parameters

x	Input value in Q48.16 format (uint64_t; value of 65536 = 1.0)

Returns

`ln(x)` in Q48.16 format, or 0 for x==0 or x==65536

7.409.1.7 q48_mul()

```
q48_16_t q48_mul (
            q48_16_t a,
            q48_16_t b )
```

Multiply two Q48.16 fixed-point values.

Computes (a * b) >> 16 to maintain the Q48.16 scale. Uses `__uint128_t` on GCC/Clang (128-bit intermediate, no precision loss) and falls back to a manual 64-bit four-partial-product path with carry tracking on platforms that lack `__SIZEOF_INT128__`.

Parameters

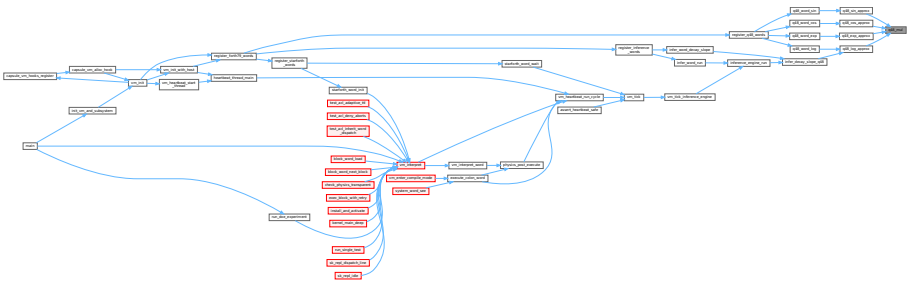
a	First operand in Q48.16 format
b	Second operand in Q48.16 format

Returns

Product in Q48.16 format (truncated, not rounded)

Referenced by q48_cos_approx(), q48_exp_approx(), q48_log_approx(), and q48_sin_approx().

Here is the caller graph for this function:



7.409.1.8 q48_reduce_angle()

```
static int64_t q48_reduce_angle (
            int64_t x )  [static]
```

Reduce a signed Q48.16 angle into [-PI_Q48, PI_Q48].

A single integer division on the raw Q48.16 representations gives the correct (scale-independent) quotient of how many full 2∗pi turns to remove, then a bounded fix-up loop (at most one or two iterations) handles the remainder landing just outside the target interval.

Parameters

x	Signed angle in Q48.16 format (any magnitude)

Returns

Equivalent angle in Q48.16 format, within [-PI_Q48, PI_Q48]

Referenced by q48_cos_approx(), and q48_sin_approx().

Here is the caller graph for this function:

7.409.1.9 q48_sin_approx()

```
q48_16_t q48_sin_approx (
            q48_16_t q )
```

Compute an approximation of `sin(q)` in Q48.16 format (radians).

Range-reduces into [-pi, pi] via `q48_reduce_angle()`, then sums the Taylor series `x` - x^3/3! + x^5/5! - ... for terms n = 3,5,7,9,11, with an early exit when a term falls below 10 (sub-LSB in Q48.16). Sine is odd (`sin`(-x) = -sin(x)), so the sign is factored out before the series and reapplied to the result.

Parameters

q	Angle in Q48.16 format (radians, any magnitude)

Returns

`sin(q)` in Q48.16 format

7.409.1.10 q48_sqrt_approx()

```
q48_16_t q48_sqrt_approx (
            q48_16_t q )
```

Compute an approximation of `sqrt(q)` in Q48.16 format (Newton-Raphson).

Iterates `x_{n+1}` = (x_n + q/x_n) / 2 starting from (q >> 1) + 16384, for up to 8 iterations. Terminates early when the delta between successive estimates falls below 10 (approximately 0.00015 in Q48.16). Used for R^2 computation in the inference engine. Returns 0 for `q` == 0, and 1.0 (65536) for `q` == 65536.

Parameters

q	Input value in Q48.16 format

Returns

`sqrt(q)` in Q48.16 format

7.409.1.11 q48_to_double()

```
double q48_to_double (
            q48_16_t q )
```

Convert a Q48.16 value to `double`.

Divides `q` by 65536.0. Used for logging and RStudio dashboard output; not called in the inference engine hot path.

Parameters

q	Value in Q48.16 format

Returns

Equivalent `double` value

7.409.1.12 q48_to_string()

```
const char * q48_to_string (
            q48_16_t q )
```

Format a Q48.16 value as a decimal string `"INTEGER.FRAC"`.

Writes into a static buffer — not thread-safe and not re-entrant. The fractional part is expressed as 5 decimal digits (`frac_part` * 100000 / 65536). Intended for diagnostic logging.

Parameters

q	Value in Q48.16 format

Returns

Pointer to a static buffer containing the formatted string

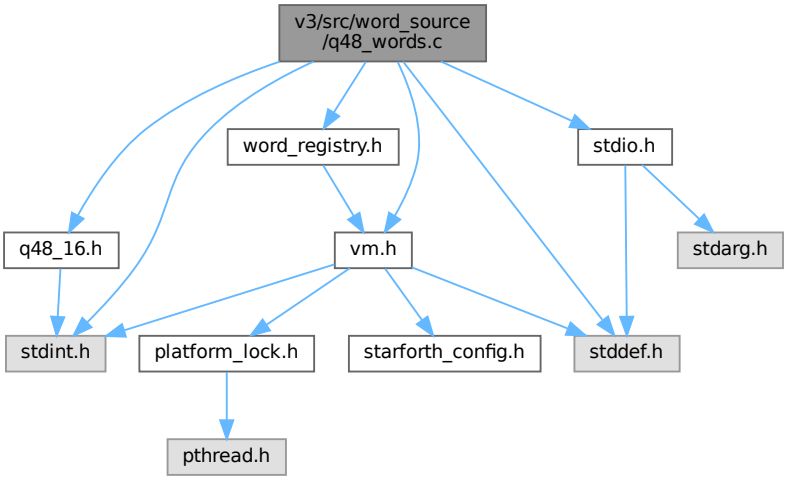
References snprintf().

Here is the call graph for this function:

7.410 v3/src/word_source/q48_words.c File Reference

```
#include <stdint.h>
#include <stddef.h>
#include "q48_16.h"
#include "vm.h"
#include "word_registry.h"
#include <stdio.h>
```

Include dependency graph for q48_words.c:



Functions

- static q48_16_t q48_pop (VM *vm)

  q48_words.c — Module 25: Q48.16 fixed-point FORTH words
- static void q48_push (VM *vm, q48_16_t q)
- static void q48_word_add (VM *vm)
- static void q48_word_sub (VM *vm)
- static void q48_word_mul (VM *vm)
- static void q48_word_div (VM *vm)
- static void q48_word_abs (VM *vm)

- static void q48_word_neg (VM *vm)
- static void q48_word_log (VM *vm)
- static void q48_word_exp (VM *vm)
- static void q48_word_sqrt (VM *vm)
- static void q48_word_sin (VM *vm)
- static void q48_word_cos (VM *vm)
- static void q48_word_from_int (VM *vm)
- static void q48_word_to_int (VM *vm)
- static void q48_word_one (VM *vm)
- static void q48_word_zero (VM *vm)
- static void q48_word_scale (VM *vm)
- static void q48_word_eq (VM *vm)
- static void q48_word_lt (VM *vm)
- static void q48_word_gt (VM *vm)
- static void q48_word_zero_eq (VM *vm)
- static void q48_word_max (VM *vm)
- static void q48_word_min (VM *vm)
- static void q48_word_print (VM *vm)
- void register_q48_words (VM *vm)

q48_words.h — Module 25: Q48.16 fixed-point FORTH words

7.410.1 Function Documentation

7.410.1.1 q48_pop()

```
static q48_16_t q48_pop (
            VM * vm )  [inline], [static]
```

q48_words.c — Module 25: Q48.16 fixed-point FORTH words

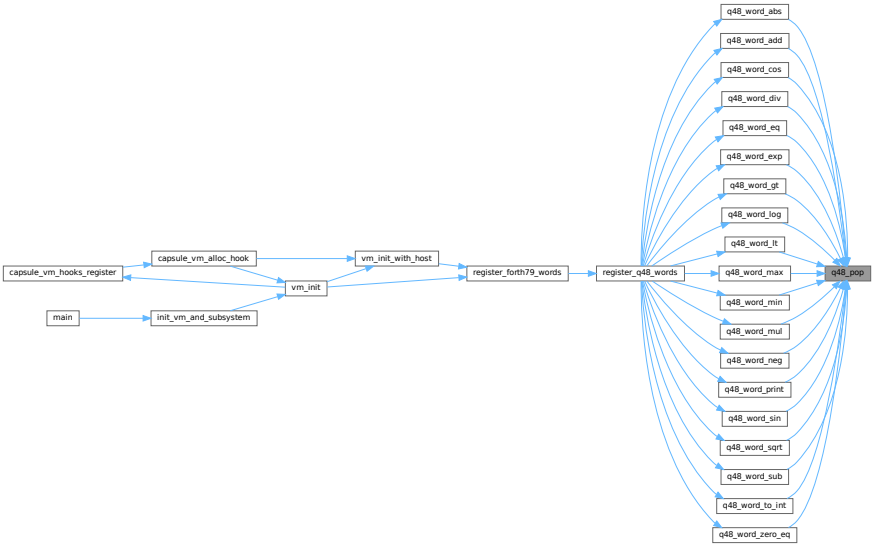
FORTH word set for Q48.16 fixed-point arithmetic. All stack values are cell_t (int64_t) reinterpreted as uint64_t Q48.16. 1.0 = 0x10000 = 65536. Fractional resolution = 1/65536 ≈ 0.0000153.

Words registered: Q.+ (q1 q2 – q_sum) Q.- (q1 q2 – q_diff) Q.* (q1 q2 – q_prod) Q./ (q1 q2 – q_quot) division by zero → q=0 Q.ABS (q – |q|) Q.NEG (q – -q) Q.LOG (q – ln_q) natural log, Newton-Raphson Q.EXP (q – e^q) Taylor series Q.SQRT (q – sqrt_q) Newton-Raphson Q.SIN (q – sin_q) Taylor series, radians, any magnitude Q.COS (q – cos_q) Taylor series, radians, any magnitude Q.FROM-INT (n – q) integer → Q48.16 (n << 16) Q.TO-INT (q – n) Q48.16 → integer (q >> 16, truncate) Q.1 (– 65536) 1.0 in Q48.16 Q.0 (– 0) 0.0 in Q48.16 Q.SCALE (– 65536) scale factor (alias of Q.1) Q.= (q1 q2 – flag) -1 if equal, 0 otherwise Q.< (q1 q2 – flag) -1 if q1 < q2 Q.> (q1 q2 – flag) -1 if q1 > q2 Q.0= (q – flag) -1 if q = 0 Q.MAX (q1 q2 – q_max) Q.MIN (q1 q2 – q_min) Q.PRINT (q –) print as "integer.frac" to console

References VM_POP.

Referenced by q48_word_abs(), q48_word_add(), q48_word_cos(), q48_word_div(), q48_word_eq(), q48_word_exp(), q48_word_gt(), q48_word_log(), q48_word_lt(), q48_word_max(), q48_word_min(), q48_word_mul(), q48_word_neg(), q48_word_print(), q48_word_sin(), q48_word_sqrt(), q48_word_sub(), q48_word_to_int(), and q48_word_zero_eq().

Here is the caller graph for this function:



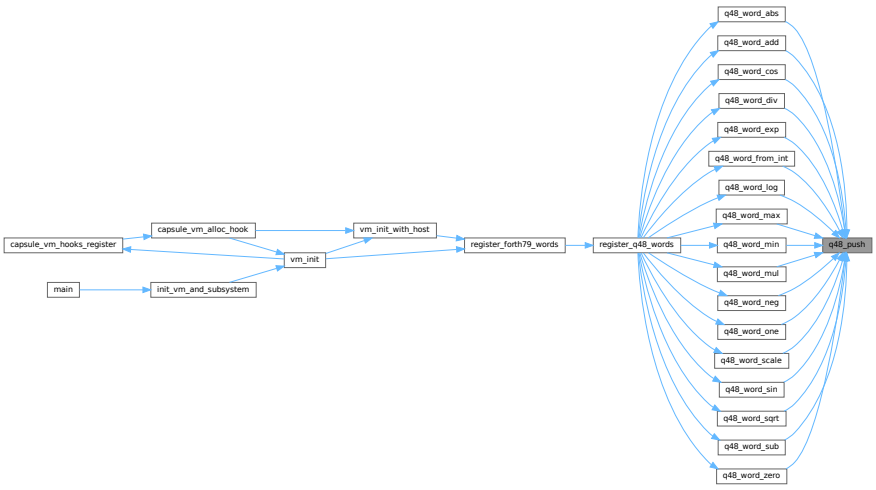
7.410.1.2 q48_push()

```
static void q48_push (
            VM * vm,
            q48_16_t q )  [inline], [static]
```

References VM_PUSH.

Referenced by q48_word_abs(), q48_word_add(), q48_word_cos(), q48_word_div(), q48_word_exp(), q48_word_from_int(), q48_word_log(), q48_word_max(), q48_word_min(), q48_word_mul(), q48_word_neg(), q48_word_one(), q48_word_scale(), q48_word_sin(), q48_word_sqrt(), q48_word_sub(), and q48_word_zero().

Here is the caller graph for this function:



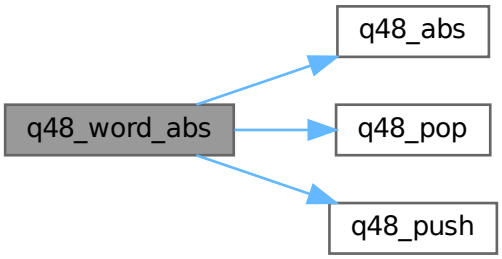
7.410.1.3 q48_word_abs()

```
static void q48_word_abs (
            VM * vm )  [static]
```

References q48_abs(), q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

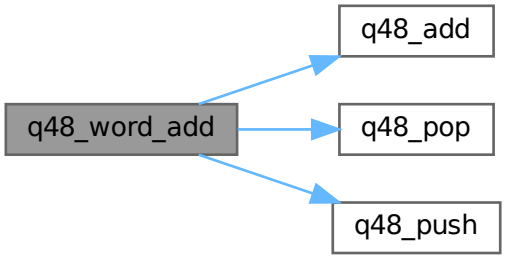
7.410.1.4 q48_word_add()

```
static void q48_word_add (
            VM * vm )  [static]
```

References q48_add(), q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

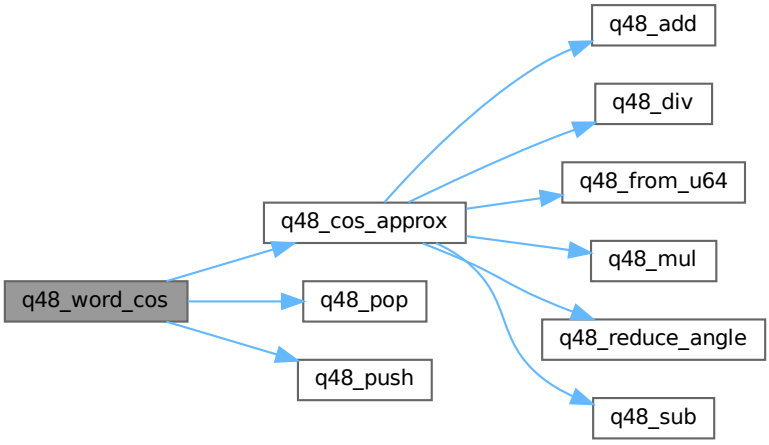
7.410.1.5 q48_word_cos()

```
static void q48_word_cos (
            VM * vm )  [static]
```

References q48_cos_approx(), q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

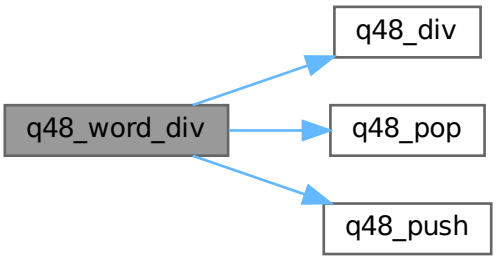
7.410.1.6 q48_word_div()

```
static void q48_word_div (
            VM * vm )  [static]
```

References q48_div(), q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.410.1.7 q48_word_eq()

```
static void q48_word_eq (
            VM * vm )  [static]
```

References q48_pop(), and VM_PUSH.

Referenced by register_q48_words().

Here is the call graph for this function:

Here is the caller graph for this function:

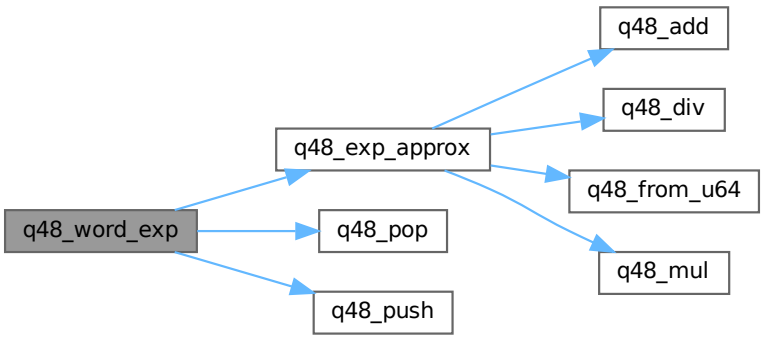
7.410.1.8 q48_word_exp()

```
static void q48_word_exp (
            VM * vm )  [static]
```

References q48_exp_approx(), q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

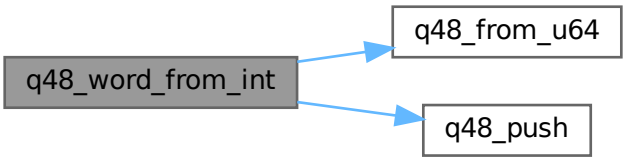
7.410.1.9 q48_word_from_int()

```
static void q48_word_from_int (
            VM * vm )  [static]
```

References q48_from_u64(), q48_push(), and VM_POP.

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.410.1.10 q48_word_gt()

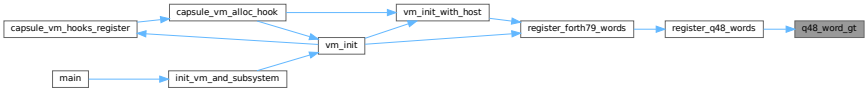
```
static void q48_word_gt (
            VM * vm )  [static]
```

References q48_pop(), and VM_PUSH.

Referenced by register_q48_words().

Here is the call graph for this function:

Here is the caller graph for this function:



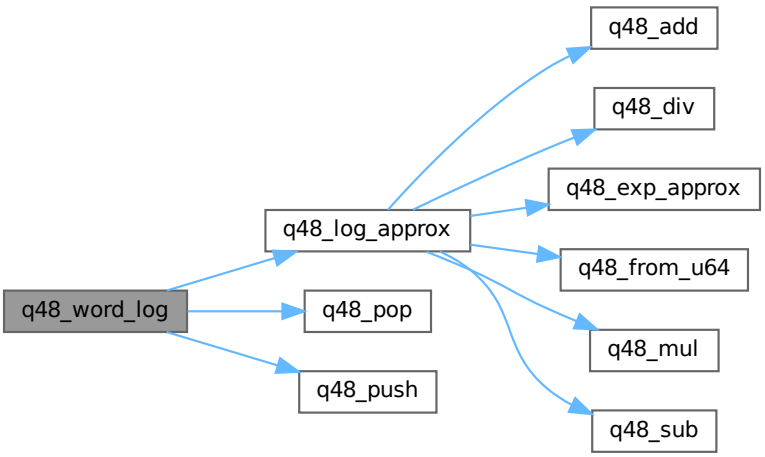
7.410.1.11 q48_word_log()

```
static void q48_word_log (
            VM * vm )  [static]
```

References q48_log_approx(), q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.410.1.12 q48_word_lt()

```
static void q48_word_lt (
            VM * vm )  [static]
```

References q48_pop(), and VM_PUSH.

Referenced by register_q48_words().

Here is the call graph for this function:

Here is the caller graph for this function:

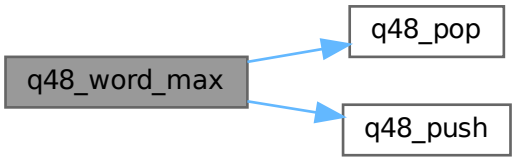
7.410.1.13 q48_word_max()

```
static void q48_word_max (
            VM * vm )  [static]
```

References q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

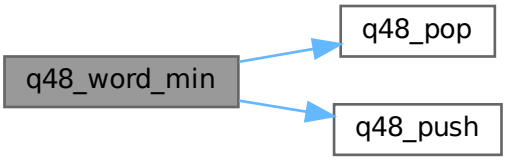
7.410.1.14 q48_word_min()

```
static void q48_word_min (
            VM * vm )  [static]
```

References q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

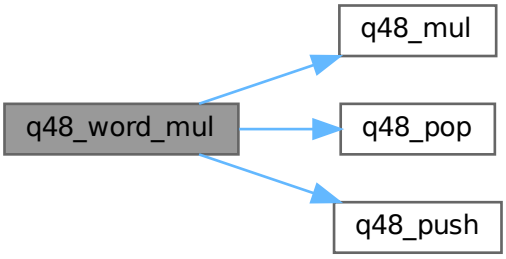
7.410.1.15 q48_word_mul()

```
static void q48_word_mul (
            VM * vm )  [static]
```

References q48_mul(), q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

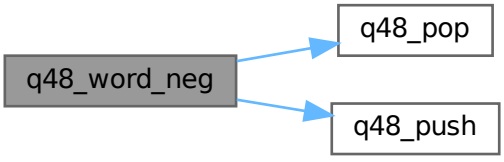
7.410.1.16 q48_word_neg()

```
static void q48_word_neg (
            VM * vm )  [static]
```

References q48_pop(), and q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.410.1.17 q48_word_one()

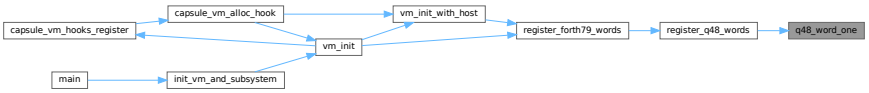
```
static void q48_word_one (
            VM * vm )  [static]
```

References q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:

Here is the caller graph for this function:



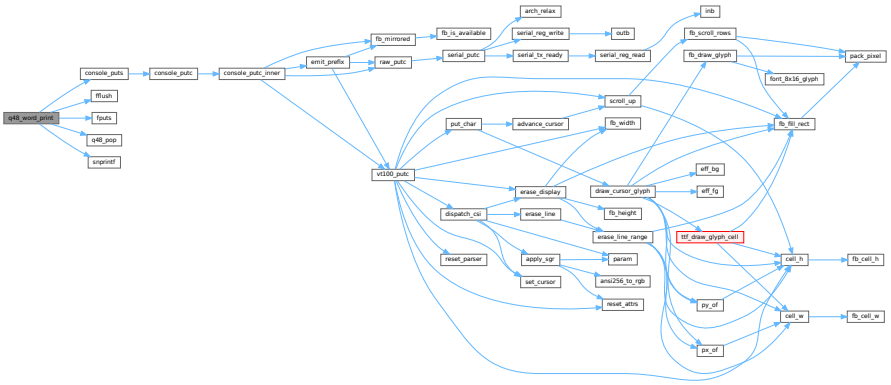
7.410.1.18 q48_word_print()

```
static void q48_word_print (
            VM * vm )  [static]
```

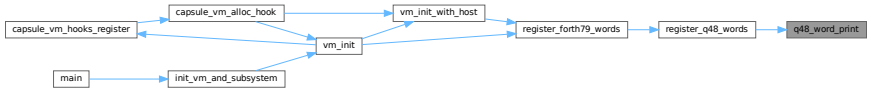
References console_puts(), fflush(), fputs(), q48_pop(), snprintf(), and stdout.

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.410.1.19 q48_word_scale()

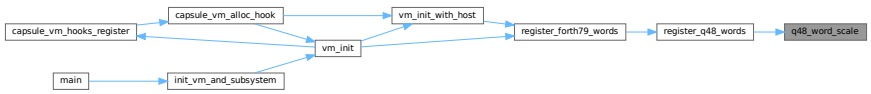
```
static void q48_word_scale (
            VM * vm )  [static]
```

References q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:

Here is the caller graph for this function:



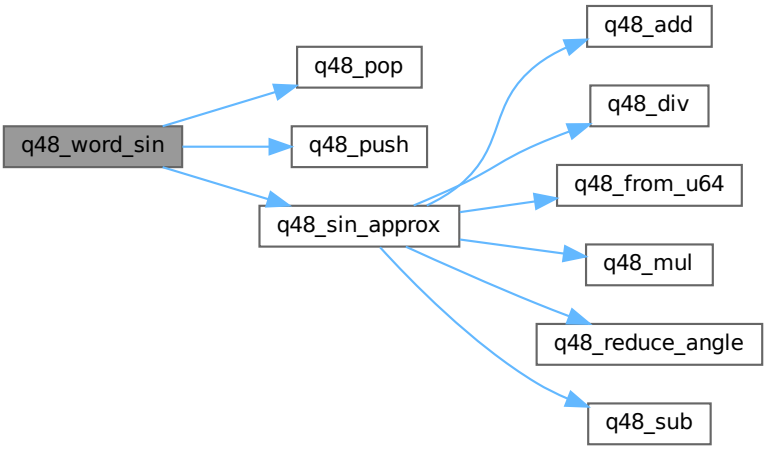
7.410.1.20 q48_word_sin()

```
static void q48_word_sin (
            VM * vm )  [static]
```

References q48_pop(), q48_push(), and q48_sin_approx().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

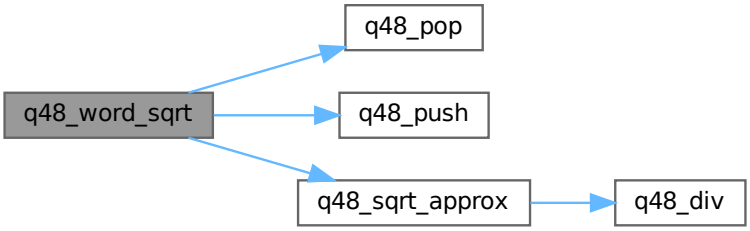
7.410.1.21 q48_word_sqrt()

```
static void q48_word_sqrt (
            VM * vm )  [static]
```

References q48_pop(), q48_push(), and q48_sqrt_approx().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

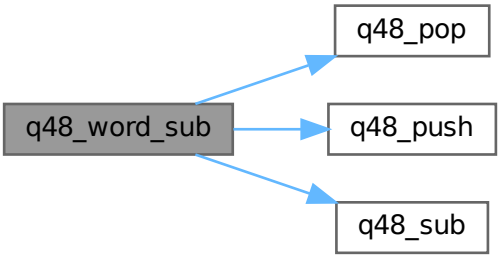
7.410.1.22 q48_word_sub()

```
static void q48_word_sub (
            VM * vm )  [static]
```

References q48_pop(), q48_push(), and q48_sub().

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

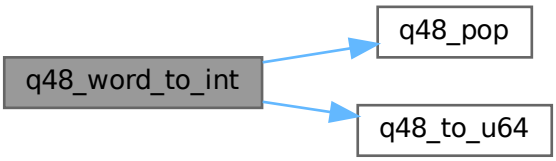
7.410.1.23 q48_word_to_int()

```
static void q48_word_to_int (
            VM * vm )  [static]
```

References q48_pop(), q48_to_u64(), and VM_PUSH.

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.410.1.24 q48_word_zero()

```
static void q48_word_zero (
            VM * vm )  [static]
```

References q48_push().

Referenced by register_q48_words().

Here is the call graph for this function:

Here is the caller graph for this function:

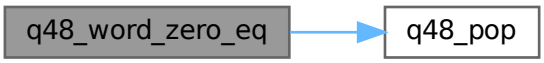
7.410.1.25 q48_word_zero_eq()

```
static void q48_word_zero_eq (
            VM * vm )  [static]
```

References q48_pop(), and VM_PUSH.

Referenced by register_q48_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.410.1.26 register_q48_words()

```
void register_q48_words (
            VM * vm )
```

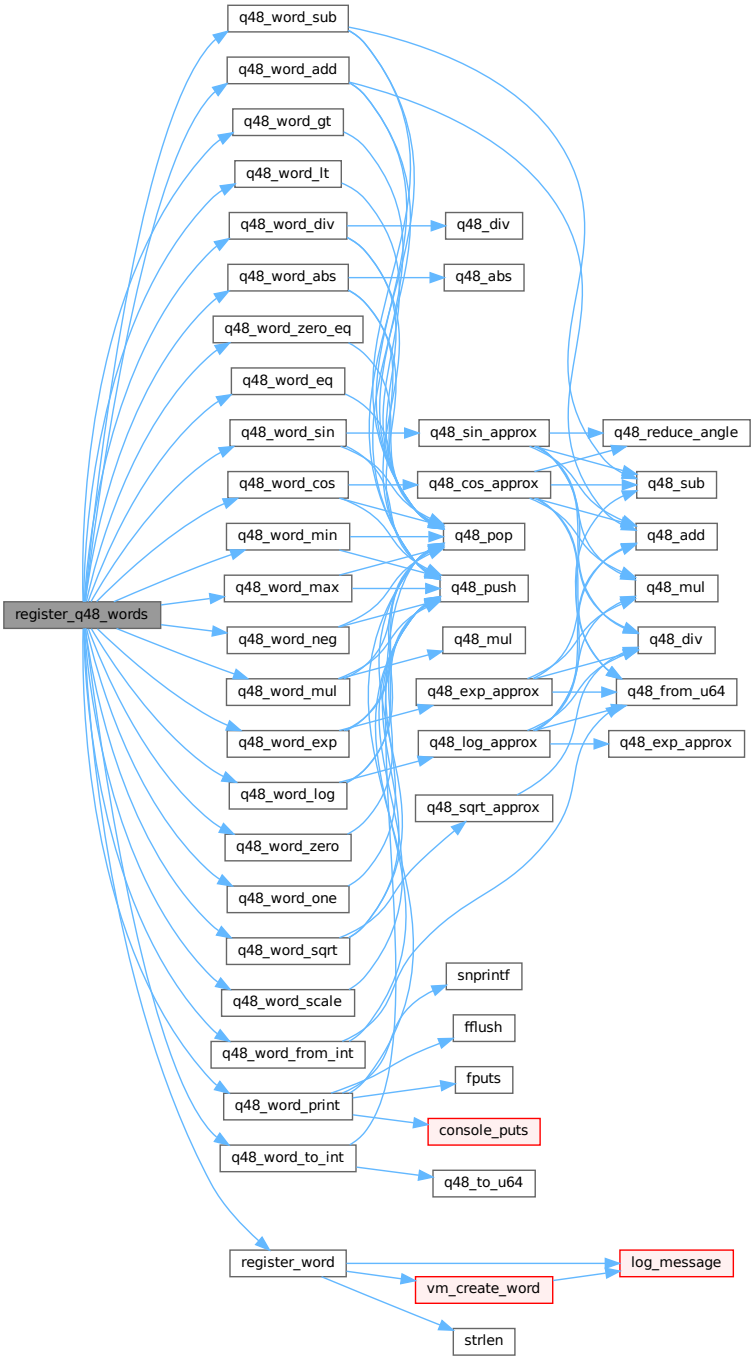
q48_words.h — Module 25: Q48.16 fixed-point FORTH words

Register all Q48.16 FORTH words with the VM. Module 25 in register_forth79_words().

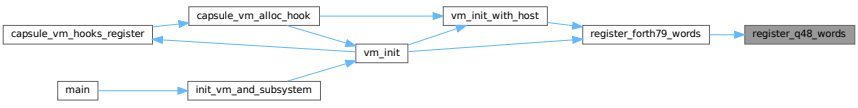
References q48_word_abs(), q48_word_add(), q48_word_cos(), q48_word_div(), q48_word_eq(), q48_word_exp(), q48_word_from_int(), q48_word_gt(), q48_word_log(), q48_word_lt(), q48_word_max(), q48_word_min(), q48_word_mul(), q48_word_neg(), q48_word_one(), q48_word_print(), q48_word_scale(), q48_word_sin(), q48_word_sqrt(), q48_word_sub(), q48_word_to_int(), q48_word_zero(), q48_word_zero_eq(), and register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:

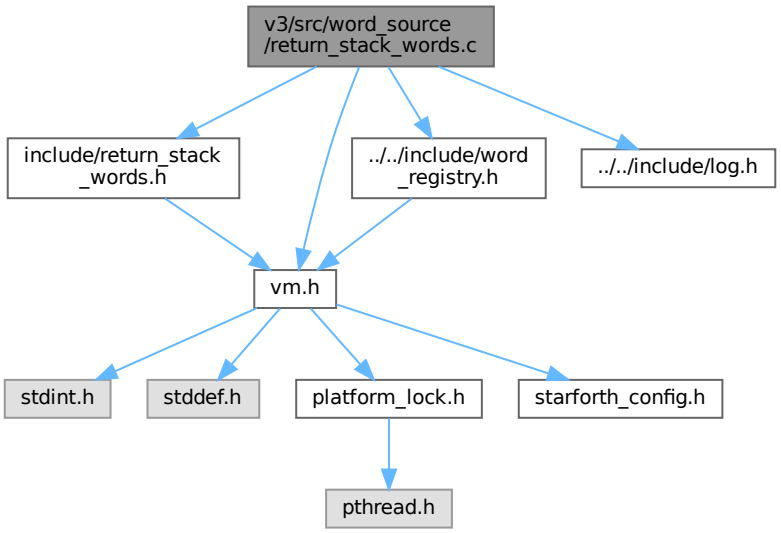


7.411 v3/src/word_source/return_stack_words.c File Reference

Implementation of FORTH-79 standard return stack words.

```
#include "include/return_stack_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include "../../include/vm.h"
```

Include dependency graph for return_stack_words.c:



Functions

- static void return_stack_word_to_r (VM *vm)

  Move TOS from data stack to return stack (>R word)
- static void return_stack_word_r_from (VM *vm)

  Move TOS from return stack back to data stack (R> word)
- static void return_stack_word_r_fetch (VM *vm)

  Copy TOS of return stack to data stack (R@ word)
- void register_return_stack_words (VM *vm)

  Register all FORTH-79 return stack manipulation words.

7.411.1 Detailed Description

Implementation of FORTH-79 standard return stack words.

StarForth - FORTH-79 Standard and ANSI C99 ONLY Last modified - 2025-09-10 See LICENSE file — No warranty.

FORTH-79 compliance:

- Provide only >R, R>, R@ for return stack transfer.
- No direct stack addressing (no RP!, RP@) — forbidden by FORTH-79.

7.411.2 Function Documentation

7.411.2.1 register_return_stack_words()

```
void register_return_stack_words (
            VM * vm )
```

Register all FORTH-79 return stack manipulation words.

Parameters

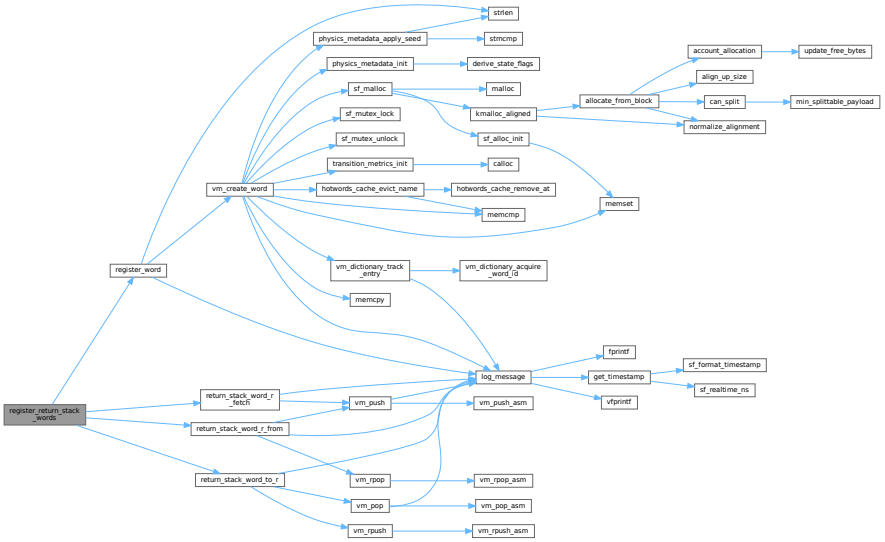
vm	Pointer to VM instance

Registers >R, R>, and R@ words. Direct stack addressing words (RP!, RP@) are deliberately omitted for FORTH-79 compliance.

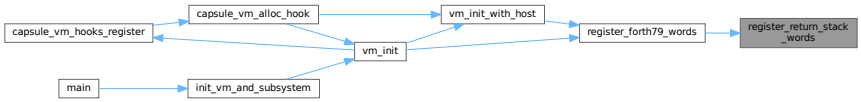
References register_word(), return_stack_word_r_fetch(), return_stack_word_r_from(), and return_stack_word_to_r().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.411.2.2 return_stack_word_r_fetch()

```
static void return_stack_word_r_fetch (
            VM * vm )  [static]
```

Copy TOS of return stack to data stack (R@ word)

Parameters

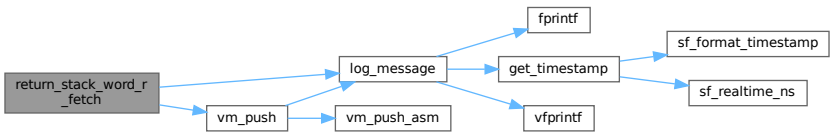
vm	Pointer to VM instance

Stack effect: (– x)

References VM::dsp, VM::ecw_nesting, VM::error, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, STACK_SIZE, and vm_push().

Referenced by register_return_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.411.2.3 return_stack_word_r_from()

```
static void return_stack_word_r_from (
            VM * vm )  [static]
```

Move TOS from return stack back to data stack (R> word)

Parameters

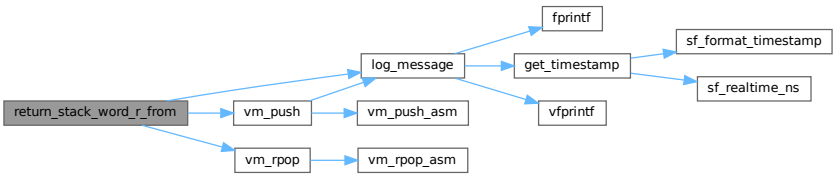
vm	Pointer to VM instance

Stack effect: (– x)

References VM::dsp, VM::ecw_nesting, VM::error, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, STACK_SIZE, vm_push(), and vm_rpop().

Referenced by register_return_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.411.2.4 return_stack_word_to_r()

```
static void return_stack_word_to_r (
            VM * vm )  [static]
```

Move TOS from data stack to return stack (>R word)

Parameters

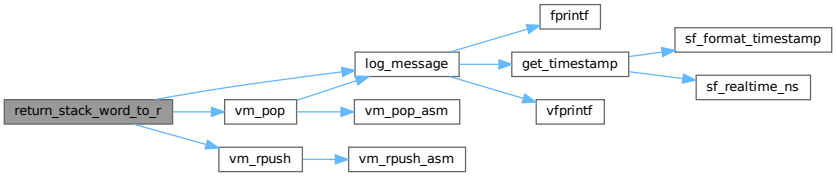
vm	Pointer to VM instance

Stack effect: (x –)

References VM::dsp, VM::ecw_nesting, VM::error, LOG_ERROR, log_message(), VM::return_stack, VM::rsp, STACK_SIZE, vm_pop(), and vm_rpush().

Referenced by register_return_stack_words().

Here is the call graph for this function:

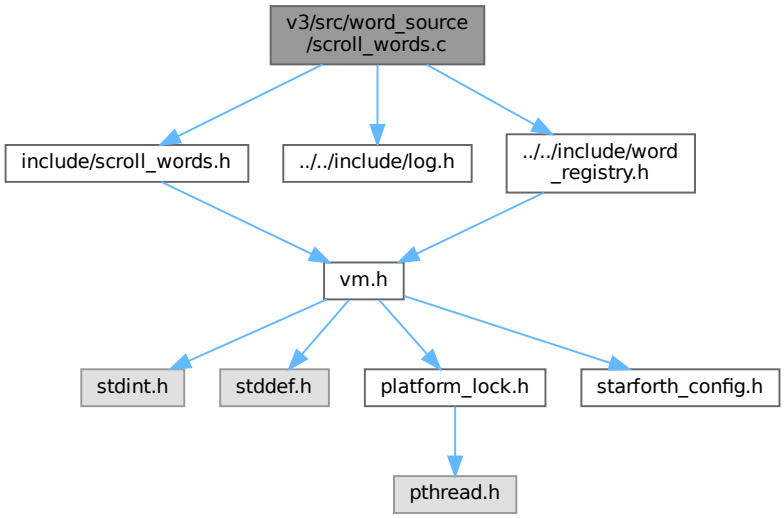


Here is the caller graph for this function:

7.412 v3/src/word_source/scroll_words.c File Reference

```
#include "include/scroll_words.h"
#include "../../include/log.h"
#include "../../include/word_registry.h"
```

Include dependency graph for scroll_words.c:



Functions

- void register_scroll_words (VM *vm)

7.412.1 Function Documentation

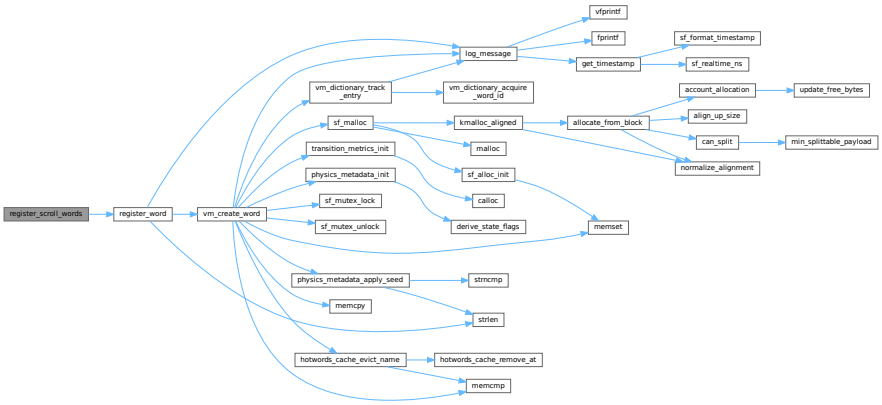
7.412.1.1 register_scroll_words()

```
void register_scroll_words (
            VM * vm )
```

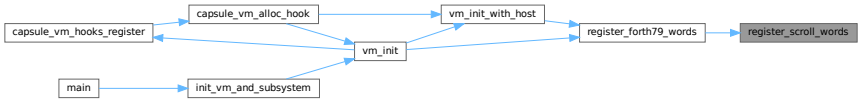
References register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



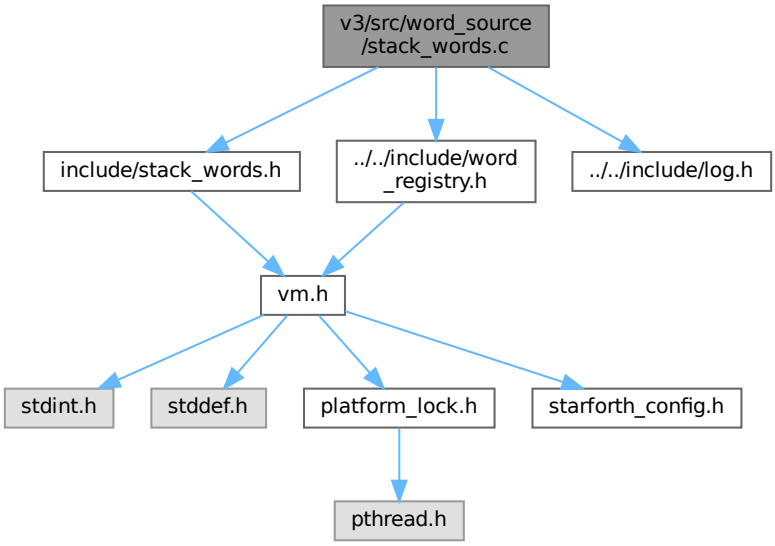
Here is the caller graph for this function:



7.413 v3/src/word_source/stack_words.c File Reference

```
#include "include/stack_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
```

Include dependency graph for stack_words.c:



Functions

- static void stack_word_drop (VM *vm)

  Implements DROP (n –) - Removes top stack item.
- static void stack_word_dup (VM *vm)

  Implements DUP (n – n n) - Duplicates top stack item.
- static void stack_word_question_dup (VM *vm)

  Implements ?DUP (n – n n | n – 0) - Conditionally duplicates top stack item.
- static void stack_word_swap (VM *vm)

  Implements SWAP (n1 n2 – n2 n1) - Exchanges top two stack items.
- static void stack_word_over (VM *vm)

  Implements OVER (n1 n2 – n1 n2 n1) - Copies second stack item to top.
- static void stack_word_rot (VM *vm)

  Implements ROT (n1 n2 n3 – n2 n3 n1) - Rotates top three stack items.
- static void stack_word_minus_rot (VM *vm)

  Implements -ROT (n1 n2 n3 – n3 n1 n2) - Reverse rotates top three items.
- static void stack_word_depth (VM *vm)

  Implements DEPTH (– n) - Returns number of stack items.
- static void stack_word_pick (VM *vm)

  Implements PICK (n – stack[n]) - Copies nth stack item to top.
- static void stack_word_roll (VM *vm)

  Implements ROLL (n –) - Moves nth stack item to top.
- void register_stack_words (VM *vm)

  Registers all stack operation words with the virtual machine.

7.413.1 Function Documentation

7.413.1.1 register_stack_words()

```
void register_stack_words (
            VM * vm )
```

Registers all stack operation words with the virtual machine.

Parameters

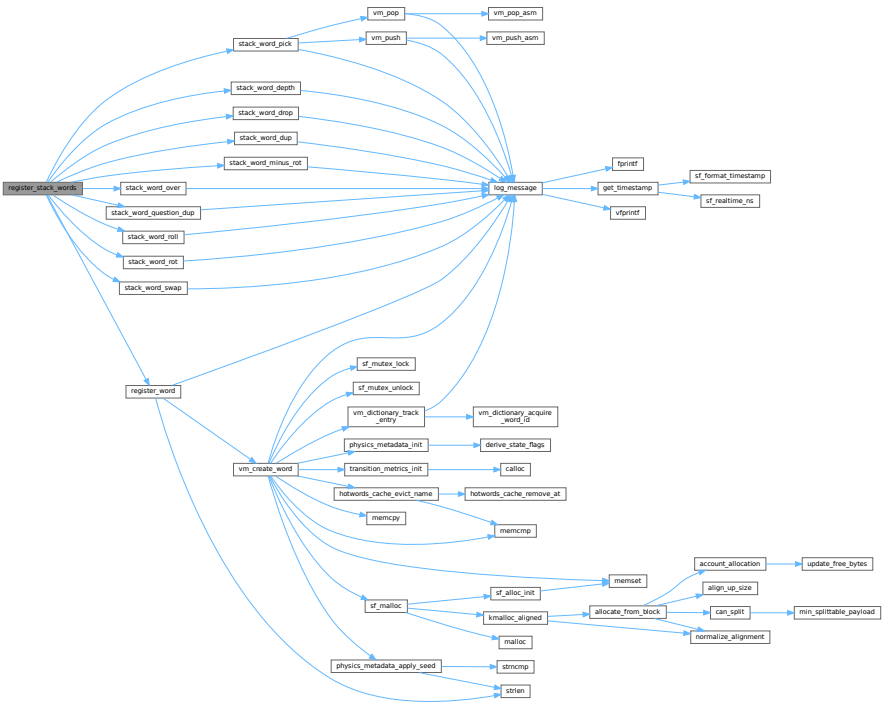
vm	Pointer to the virtual machine state

Registers all FORTH-79 standard stack operation words with the word registry.

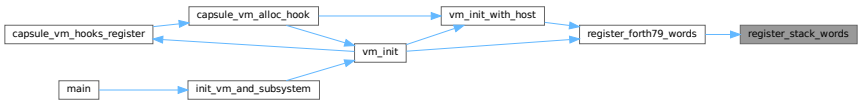
References register_word(), stack_word_depth(), stack_word_drop(), stack_word_dup(), stack_word_minus_rot(), stack_word_over(), stack_word_pick(), stack_word_question_dup(), stack_word_roll(), stack_word_rot(), and stack_word_swap().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.413.1.2 stack_word_depth()

```
static void stack_word_depth (
            VM * vm )  [static]
```

Implements DEPTH (– n) - Returns number of stack items.

Parameters

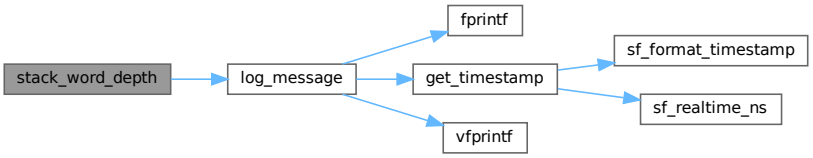
vm	Pointer to the virtual machine state

Pushes the current number of items on the data stack onto the stack.

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), and STACK_SIZE.

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.413.1.3 stack_word_drop()

```
static void stack_word_drop (
            VM * vm )  [static]
```

Implements DROP (n –) - Removes top stack item.

Parameters

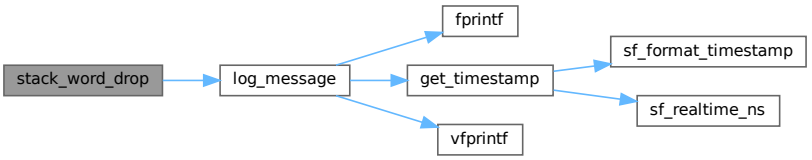
vm	Pointer to the virtual machine state

Removes the top item from the data stack. Generates an error on stack underflow.

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, and log_message().

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.413.1.4 stack_word_dup()

```
static void stack_word_dup (
            VM * vm )  [static]
```

Implements DUP (n – n n) - Duplicates top stack item.

Parameters

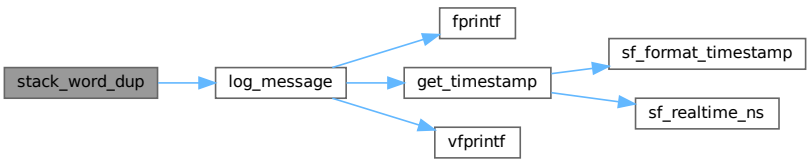
vm	Pointer to the virtual machine state

Duplicates the top item on the data stack. Generates an error on stack underflow/overflow.

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), STACK_SIZE, and UNLIKELY.

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.413.1.5 stack_word_minus_rot()

```
static void stack_word_minus_rot (
            VM * vm )  [static]
```

Implements -ROT (n1 n2 n3 – n3 n1 n2) - Reverse rotates top three items.

Parameters

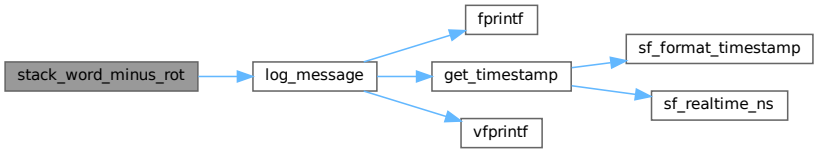
vm	Pointer to the virtual machine state

Performs the reverse rotation of the top three stack items.

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, and log_message().

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.413.1.6 stack_word_over()

```
static void stack_word_over (
            VM * vm )  [static]
```

Implements OVER (n1 n2 – n1 n2 n1) - Copies second stack item to top.

Parameters

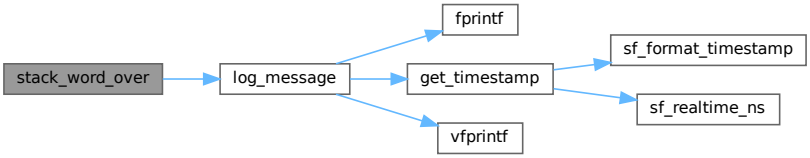
vm	Pointer to the virtual machine state

Copies the second item from the top of the stack to the top.

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), and STACK_SIZE.

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.413.1.7 stack_word_pick()

```
static void stack_word_pick (
            VM * vm )  [static]
```

Implements PICK (n – stack[n]) - Copies nth stack item to top.

Parameters

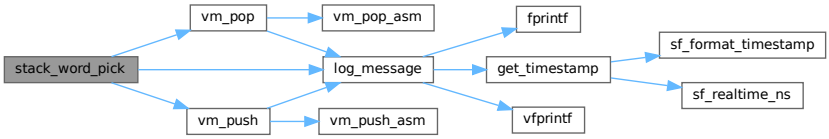
vm	Pointer to the virtual machine state

Copies the nth item from the stack to the top, where n is popped from the stack.

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_pop(), and vm_push().

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.413.1.8 stack_word_question_dup()

```
static void stack_word_question_dup (
            VM * vm )  [static]
```

Implements ?DUP (n – n n | n – 0) - Conditionally duplicates top stack item.

Parameters

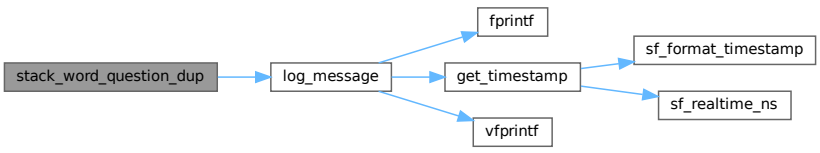
vm	Pointer to the virtual machine state

Duplicates top stack item if it's non-zero, otherwise leaves it unchanged.

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), and STACK_SIZE.

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.413.1.9 stack_word_roll()

```
static void stack_word_roll (
            VM * vm )  [static]
```

Implements ROLL (n –) - Moves nth stack item to top.

Parameters

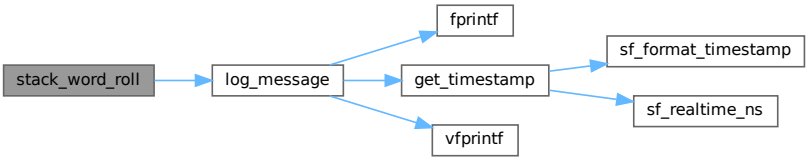
vm	Pointer to the virtual machine state

Moves the nth item from the stack to the top, shifting intermediate items down.

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, and log_message().

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.413.1.10 stack_word_rot()

```
static void stack_word_rot (
            VM * vm )  [static]
```

Implements ROT (n1 n2 n3 – n2 n3 n1) - Rotates top three stack items.

Parameters

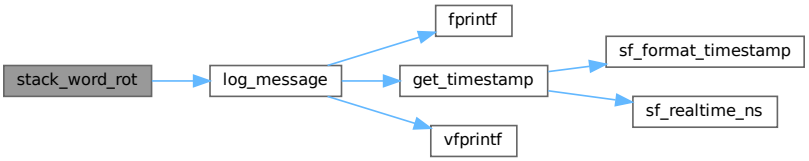
vm	Pointer to the virtual machine state

Rotates the top three items on the stack, moving the third item to the top.

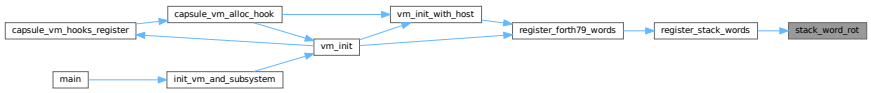
References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, and log_message().

Referenced by register_stack_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.413.1.11 stack_word_swap()

```
static void stack_word_swap (
            VM * vm )  [static]
```

Implements SWAP (n1 n2 – n2 n1) - Exchanges top two stack items.

Parameters

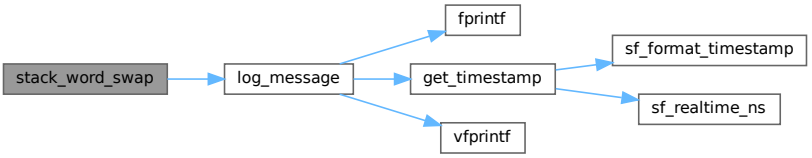
vm	Pointer to the virtual machine state

Exchanges the positions of the top two items on the data stack.

References VM::data_stack, VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), and UNLIKELY.

Referenced by register_stack_words().

Here is the call graph for this function:

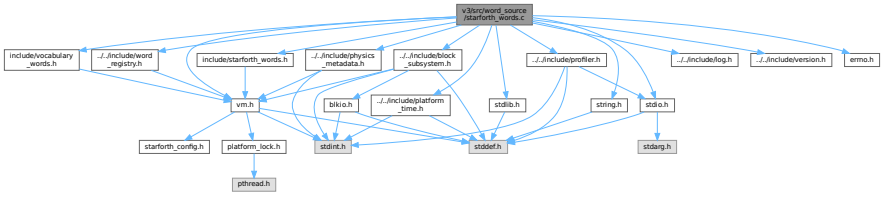


Here is the caller graph for this function:

7.414 v3/src/word_source/starforth_words.c File Reference

```
#include "include/starforth_words.h"
#include "include/vocabulary_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include "../../include/vm.h"
#include "../../include/version.h"
#include "../../include/physics_metadata.h"
#include "../../include/platform_time.h"
#include "../../include/profiler.h"
#include "../../include/block_subsystem.h"
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <errno.h>
```

Include dependency graph for starforth_words.c:



Macros

- #define STARFORTH_CHECK_ARENA(tag) ((void)0)

Functions

- void starforth_word_execution_heat_fetch (VM *vm)
- void starforth_word_execution_heat_store (VM *vm)

  Set execution heat count for word at dictionary address.
- void starforth_word_word_execution_heat (VM *vm)

  Display execution heat statistics for all words in dictionary.
- void starforth_word_reset_execution_heat (VM *vm)

  Reset all execution heat counters to zero.
- void starforth_word_top_words (VM *vm)

  Display the N most frequently used words.
- void starforth_word_paren_dash (VM *vm)

  Shebang-style comment word for init.4th metadata.
- void starforth_word_init (VM *vm)

  Initialize system from init.4th configuration file.
- static uint64_t prng_next (void)

  Internal PRNG step using Linear Congruential Generator.
- void starforth_word_seed (VM *vm)

  Set the PRNG seed.
- void starforth_word_random (VM *vm)

  Generate bounded random number.
- void starforth_word_wait (VM *vm)

  Wait for specified number of heartbeat ticks.
- void starforth_word_version (VM *vm)

  Print StarForth version information (compliance)
- static void starforth_word_zuse_authenticate (VM *vm)
- static void starforth_word_zuse_session (VM *vm)
- static void starforth_word_zuse_pubkey_fetch (VM *vm)
- static void starforth_word_zuse_cert_installed_query (VM *vm)
- static void starforth_word_heartbeat_ticks (VM *vm)

  Read-only accessor for the canonical heartbeat tick counter.
- void register_starforth_words (VM *vm)

  Register StarForth vocabulary words with the VM.

Variables

- static uint64_t g_prng_state = 1

7.414.1 Macro Definition Documentation

7.414.1.1 STARFORTH_CHECK_ARENA

```
#define STARFORTH_CHECK_ARENA(
              tag ) ((void)0)
```

7.414.2 Function Documentation

7.414.2.1 prng_next()

```
static uint64_t prng_next (
            void  )  [static]
```

Internal PRNG step using Linear Congruential Generator.

Uses Numerical Recipes LCG constants for good statistical properties.

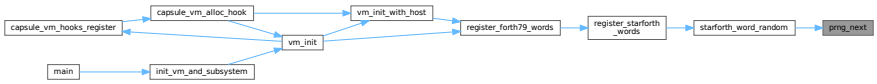
Returns

Next pseudo-random 64-bit value

References g_prng_state.

Referenced by starforth_word_random().

Here is the caller graph for this function:



7.414.2.2 register_starforth_words()

```
void register_starforth_words (
            VM * vm )
```

Register StarForth vocabulary words with the VM.

Registers all StarForth-specific words and creates the STARFORTH vocabulary

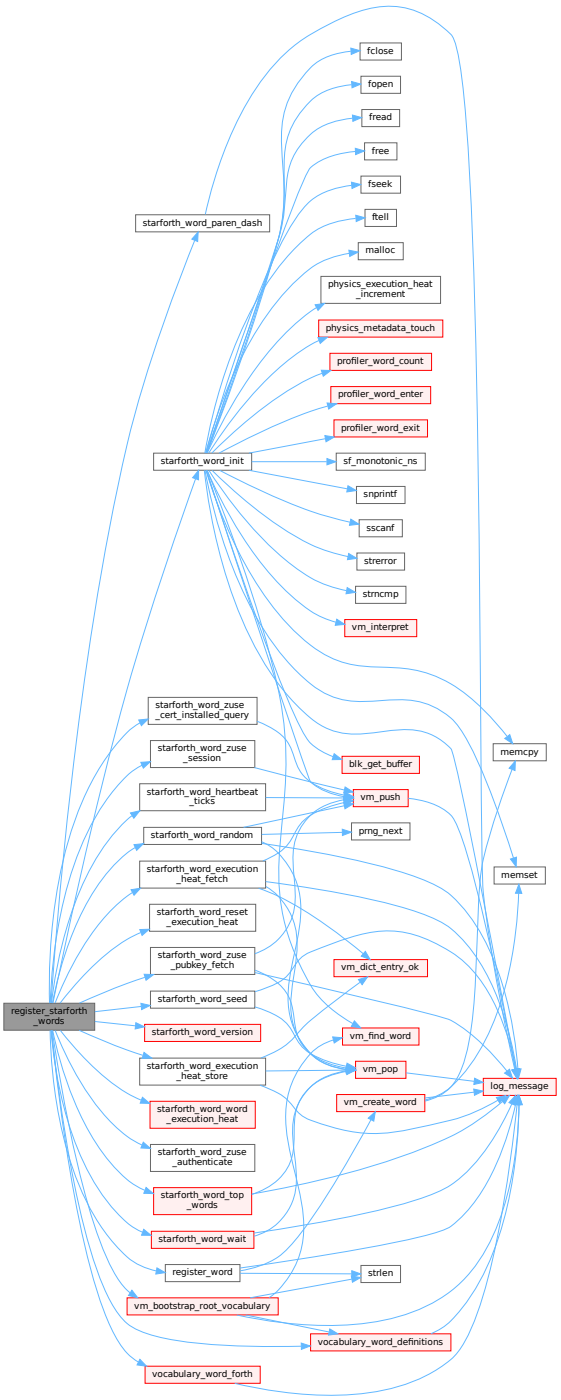
Parameters

vm	Pointer to the VM instance

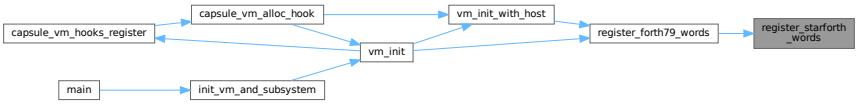
References register_word(), STARFORTH_CHECK_ARENA, starforth_word_execution_heat_fetch(), starforth_word_execution_heat_
starforth_word_heartbeat_ticks(), starforth_word_init(), starforth_word_paren_dash(), starforth_word_random(),
starforth_word_reset_execution_heat(), starforth_word_seed(), starforth_word_top_words(), starforth_word_version(),
starforth_word_wait(), starforth_word_word_execution_heat(), starforth_word_zuse_authenticate(), starforth_word_zuse_cert_installe
starforth_word_zuse_pubkey_fetch(), starforth_word_zuse_session(), vm_bootstrap_root_vocabulary(), vocabulary_word_definitions(
and vocabulary_word_forth().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



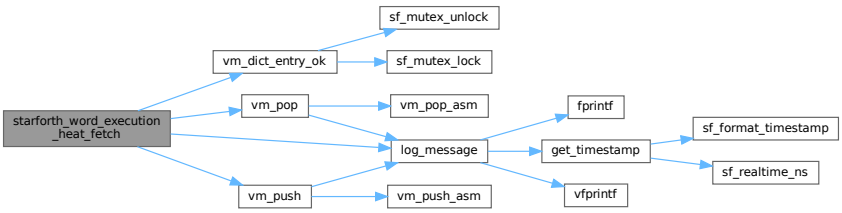
7.414.2.3 starforth_word_execution_heat_fetch()

```
void starforth_word_execution_heat_fetch (
            VM * vm )
```

References VM::dsp, entry, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_dict_entry_ok(), vm_pop(), and vm_push().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.414.2.4 starforth_word_execution_heat_store()

```
void starforth_word_execution_heat_store (
            VM * vm )
```

Set execution heat count for word at dictionary address.

Stack effect: (n addr –) Note: Exposed as ENTROPY! for FORTH compatibility, but sets execution heat.

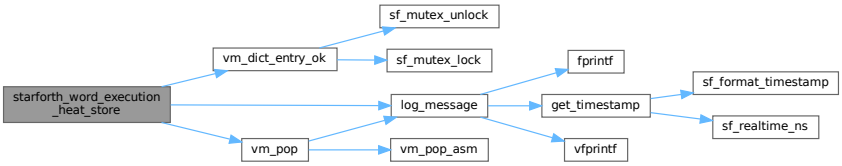
Parameters

vm	Pointer to the VM instance

References VM::dsp, entry, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), vm_dict_entry_ok(), and vm_pop().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.414.2.5 starforth_word_heartbeat_ticks()

```
static void starforth_word_heartbeat_ticks (
            VM * vm )  [static]
```

Read-only accessor for the canonical heartbeat tick counter.

Stack effect: (– n) Pushes vm->heartbeat.tick_count – Loop #7 "Adaptive Heartrate", the one clock this project's timing measurements are supposed to read, not host wall-clock. Read-only: no corresponding store word exists or should exist.

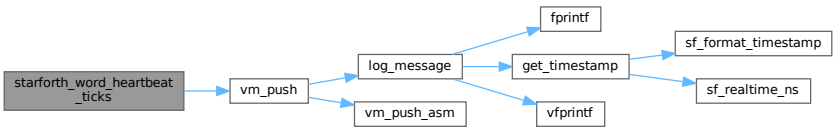
Parameters

vm	Pointer to the VM instance

References VM::heartbeat, HeartbeatState::tick_count, and vm_push().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.414.2.6 starforth_word_init()

```
void starforth_word_init (
            VM * vm )
```

Initialize system from init.4th configuration file.

Reads ./capsules/core/init.4th, parses Block headers, copies blocks sequentially starting at block 1, then executes them. Stack effect: (–)

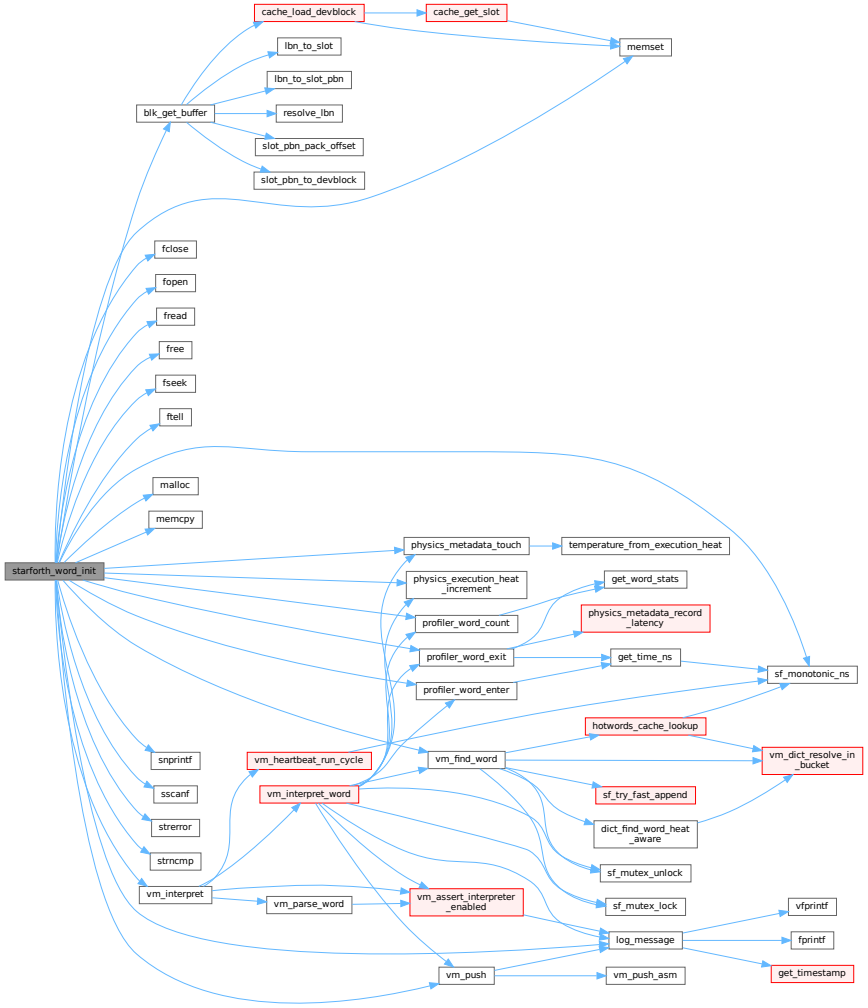
Parameters

vm	Pointer to the VM instance

References blk_get_buffer(), VM::current_executing_entry, ENOENT, errno, VM::error, DictEntry::execution_heat, fclose(), fopen(), fread(), free(), fseek(), ftell(), DictEntry::func, VM::halted, LOG_DEBUG, LOG_ERROR, LOG_INFO, log_message(), LOG_WARN, malloc(), memcpy(), memset(), physics_execution_heat_increment(), physics_metadata_touch(), profiler_word_count(), profiler_word_enter(), profiler_word_exit(), SEEK_END, SEEK_SET, sf_monotonic_ns(), snprintf(), sscanf(), strerror(), strncmp(), vm_find_word(), vm_interpret(), and vm_push().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.414.2.7 starforth_word_paren_dash()

```
void starforth_word_paren_dash (
            VM * vm )
```

Shebang-style comment word for init.4th metadata.

Starts with "(- " and consumes input until closing ")" Used for marking blocks that should be extracted to init.4th Stack effect: (–)

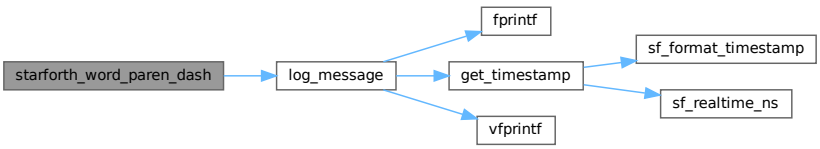
Parameters

vm	Pointer to the VM instance

References VM::input_buffer, VM::input_length, VM::input_pos, LOG_DEBUG, log_message(), and LOG_WARN.

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.414.2.8 starforth_word_random()

```
void starforth_word_random (
            VM * vm )
```

Generate bounded random number.

Parameters

vm	Pointer to VM instance @stack (lo hi – n)

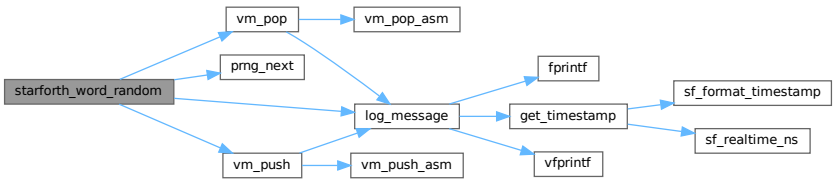
Note

Returns random value in inclusive range [lo, hi]

References VM::dsp, VM::error, LOG_DEBUG, LOG_ERROR, log_message(), prng_next(), vm_pop(), and vm_push().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.414.2.9 starforth_word_reset_execution_heat()

```
void starforth_word_reset_execution_heat (
            VM * vm )
```

Reset all execution heat counters to zero.

Stack effect: (–)

Parameters

vm	Pointer to the VM instance

References entry, and VM::latest.

Referenced by register_starforth_words().

Here is the caller graph for this function:

7.414.2.10 starforth_word_seed()

```
void starforth_word_seed (
            VM * vm )
```

Set the PRNG seed.

Stack effect: (n –) Sets the internal PRNG state for reproducible random sequences.

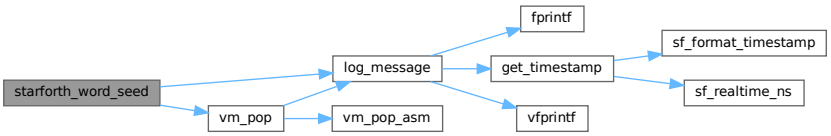
Parameters

vm	Pointer to the VM instance

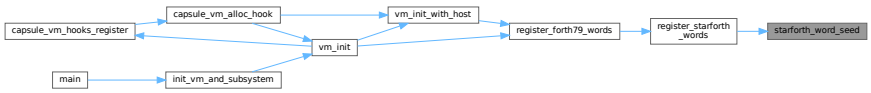
References VM::dsp, VM::error, g_prng_state, LOG_DEBUG, LOG_ERROR, log_message(), and vm_pop().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.414.2.11 starforth_word_top_words()

```
void starforth_word_top_words (
            VM * vm )
```

Display the N most frequently used words.

Stack effect: (n –)

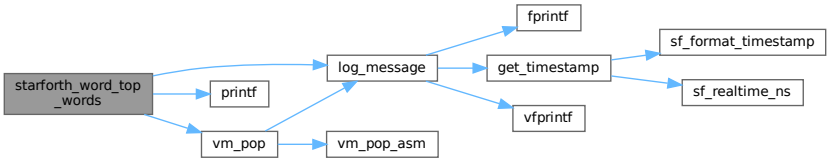
Parameters

vm	Pointer to the VM instance

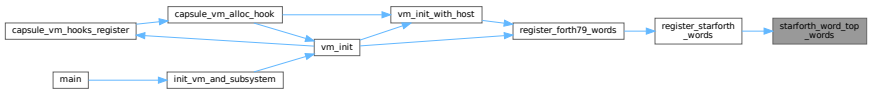
References VM::dsp, entry, VM::error, execution_heat, VM::latest, LOG_ERROR, log_message(), printf(), vm_pop(), and word_count.

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.414.2.12 starforth_word_version()

```
void starforth_word_version (
            VM * vm )
```

Print StarForth version information (compliance)

Prints: StarForth v<version> <architecture> <variant> <timestamp> Stack effect: (–)

Parameters

vm	Pointer to the VM instance

References printf(), and STARFORTH_VERSION_FULL.

Referenced by register_starforth_words().

Here is the call graph for this function:

Here is the caller graph for this function:

7.414.2.13 starforth_word_wait()

```
void starforth_word_wait (
            VM * vm )
```

Wait for specified number of heartbeat ticks.

Stack effect: (n –) Counts n heartbeat ticks by calling vm_tick() n times. Time is relative — we count heartbeats, not wall-clock milliseconds. This is architecture-independent: works on amd64, aarch64, riscv64 without depending on any platform timer.

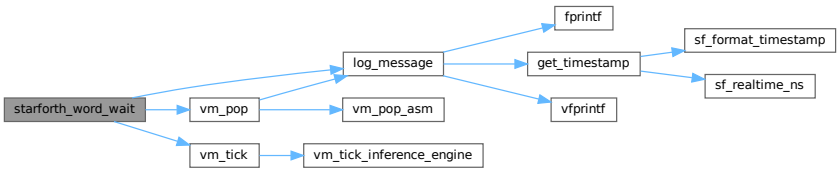
Parameters

vm	Pointer to the VM instance

References VM::dsp, VM::error, LOG_ERROR, log_message(), vm_pop(), and vm_tick().

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.414.2.14 starforth_word_word_execution_heat()

```
void starforth_word_word_execution_heat (
            VM * vm )
```

Display execution heat statistics for all words in dictionary.

Stack effect: (–) Shows execution frequency (execution_heat) for each word.

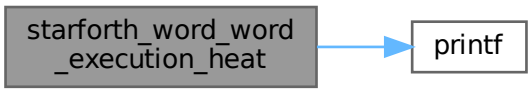
Parameters

vm	Pointer to the VM instance

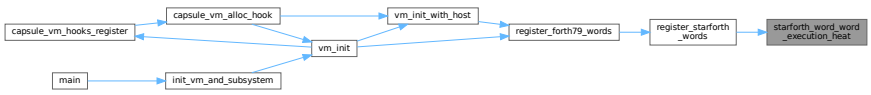
References entry, VM::latest, printf(), and word_count.

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.414.2.15 starforth_word_zuse_authenticate()

```
static void starforth_word_zuse_authenticate (
            VM * vm )  [static]
```

References VM::zuse_session.

Referenced by register_starforth_words().

Here is the caller graph for this function:

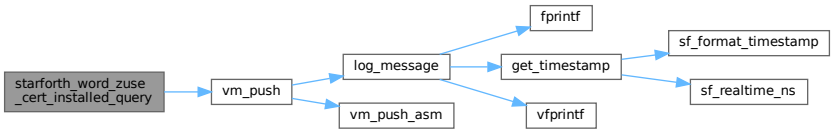
7.414.2.16 starforth_word_zuse_cert_installed_query()

```
static void starforth_word_zuse_cert_installed_query (
            VM * vm )  [static]
```

References vm_push(), and VM::zuse_cert_installed.

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

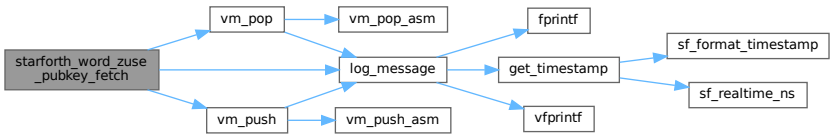
7.414.2.17 starforth_word_zuse_pubkey_fetch()

```
static void starforth_word_zuse_pubkey_fetch (
            VM * vm )  [static]
```

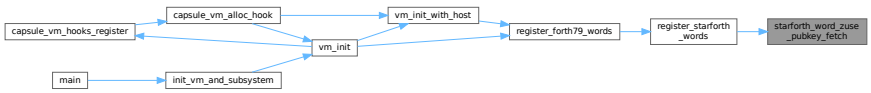
References VM::dsp, VM::error, LOG_ERROR, log_message(), vm_pop(), vm_push(), and VM::zuse_cert_pubkey.

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:



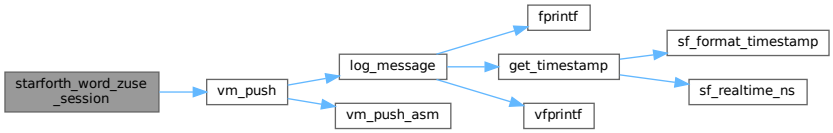
7.414.2.18 starforth_word_zuse_session()

```
static void starforth_word_zuse_session (
            VM * vm )  [static]
```

References vm_push(), and VM::zuse_session.

Referenced by register_starforth_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.414.3 Variable Documentation

7.414.3.1 g_prng_state

```
uint64_t g_prng_state = 1  [static]
```

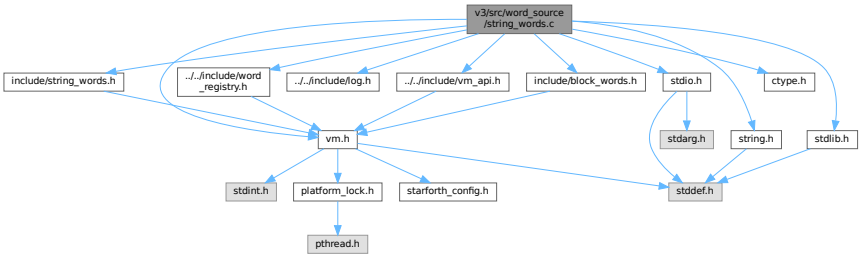
Referenced by prng_next(), and starforth_word_seed().

7.415 v3/src/word_source/string_words.c File Reference

```
#include "include/string_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include "../../include/vm.h"
#include "../../include/vm_api.h"
#include "include/block_words.h"
#include <stdio.h>
#include <string.h>
#include <ctype.h>
```

```
#include <stdlib.h>
```

Include dependency graph for string_words.c:



Macros

- #define WORD_SCRATCH_CAP 64

Functions

- static vaddr_t vaddr_from_ptr (VM *vm, const void *p)

  Convert a C pointer that points into vm->memory into a VM address (offset)
- static int ensure_input (VM *vm)

  Ensure input buffers and variables are available.
- static int convert_string_to_number (const char *str, size_t len, cell_t *result)
- void string_word_count (VM *vm)

  COUNT (addr1 – addr2 u)
- void string_word_expect (VM *vm)
- void string_word_span (VM *vm)
- void string_word_query (VM *vm)
- void string_word_tib (VM *vm)
- void string_word_word (VM *vm)
- void string_word_to_in (VM *vm)
- void string_word_source (VM *vm)
- void string_word_bl (VM *vm)
- void string_word_bracket_tick (VM *vm)
- void string_word_literal (VM *vm)
- void string_word_bracket_literal (VM *vm)
- void string_word_convert (VM *vm)
- void string_word_number (VM *vm)
- void string_word_enclose (VM *vm)
- static void string_runtime_s_quote (VM *vm)
- static void string_word_s_quote (VM *vm)
- static void string_word_minus_trailing (VM *vm)
- static void string_word_cmove (VM *vm)
- static void string_word_cmove_greater (VM *vm)
- static void string_word_compare (VM *vm)
- static void string_word_search (VM *vm)
- static void string_word_scan (VM *vm)
- static void string_word_skip (VM *vm)
- static void string_word_blank (VM *vm)
- void register_string_words (VM *vm)

  COUNT (addr1 – addr2 u) Get string length and address Returns the character count and address of a counted string.

Variables

- static vaddr_t word_scratch_addr = 0

7.415.1 Macro Definition Documentation

7.415.1.1 WORD_SCRATCH_CAP

```
#define WORD_SCRATCH_CAP 64
```

7.415.2 Function Documentation

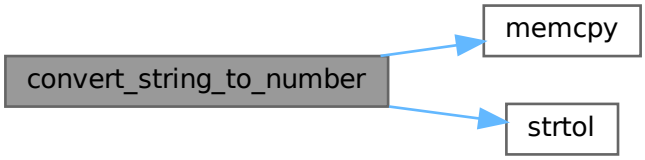
7.415.2.1 convert_string_to_number()

```
static int convert_string_to_number (
            const char * str,
            size_t len,
            cell_t * result )  [static]
```

References memcpy(), and strtol().

Referenced by string_word_number().

Here is the call graph for this function:



Here is the caller graph for this function:

7.415.2.2 ensure_input()

```
static int ensure_input (
            VM * vm )  [inline], [static]
```

Ensure input buffers and variables are available.

Parameters

vm	Pointer to VM instance

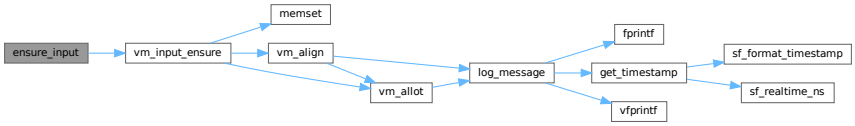
Returns

0 on success, non-zero on error

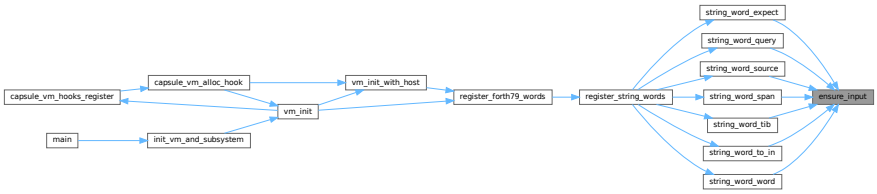
References VM::error, and vm_input_ensure().

Referenced by string_word_expect(), string_word_query(), string_word_source(), string_word_span(), string_word_tib(), string_word_to_in(), and string_word_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.415.2.3 register_string_words()

```
void register_string_words (
            VM * vm )
```

COUNT (addr1 – addr2 u) Get string length and address Returns the character count and address of a counted string.

EXPECT (addr u –) Accept input line Accepts up to u characters of input and stores them at addr

SPAN (– addr) Variable: number of characters input Contains the count of characters actually received by EXPECT

QUERY (–) Accept input into TIB Accepts a line of input into the Terminal Input Buffer

TIB (– addr) Terminal input buffer address Returns the address of the Terminal Input Buffer

WORD (c – addr) Parse next word, delimited by c Parses the next word from input stream using c as delimiter

>IN (– addr) Input stream pointer Contains the offset into the input buffer

SOURCE (– addr u) Input source specification Returns current input buffer address and length

BL (– c) ASCII space character (32) Pushes ASCII space character value onto stack

FIND (addr – addr flag) Find word in dictionary Searches dictionary for word, returns status flag

' (– xt) Get execution token of next word Returns execution token of next word in input stream

['] (– xt) Compile execution token Compiles execution token as literal

LITERAL (n –) Compile literal number Compiles top stack value as literal

[LITERAL] (n –) Compile literal at compile time Compiles literal during compilation

CONVERT (d1 addr1 – d2 addr2) Convert string to number Converts string starting at addr1 to number

NUMBER (addr – n flag) Convert string to single number Converts string to single precision number

ENCLOSE (addr c – addr1 n1 n2 n3) Parse for delimiter Parses string for delimiter character

Register all string processing words with VM

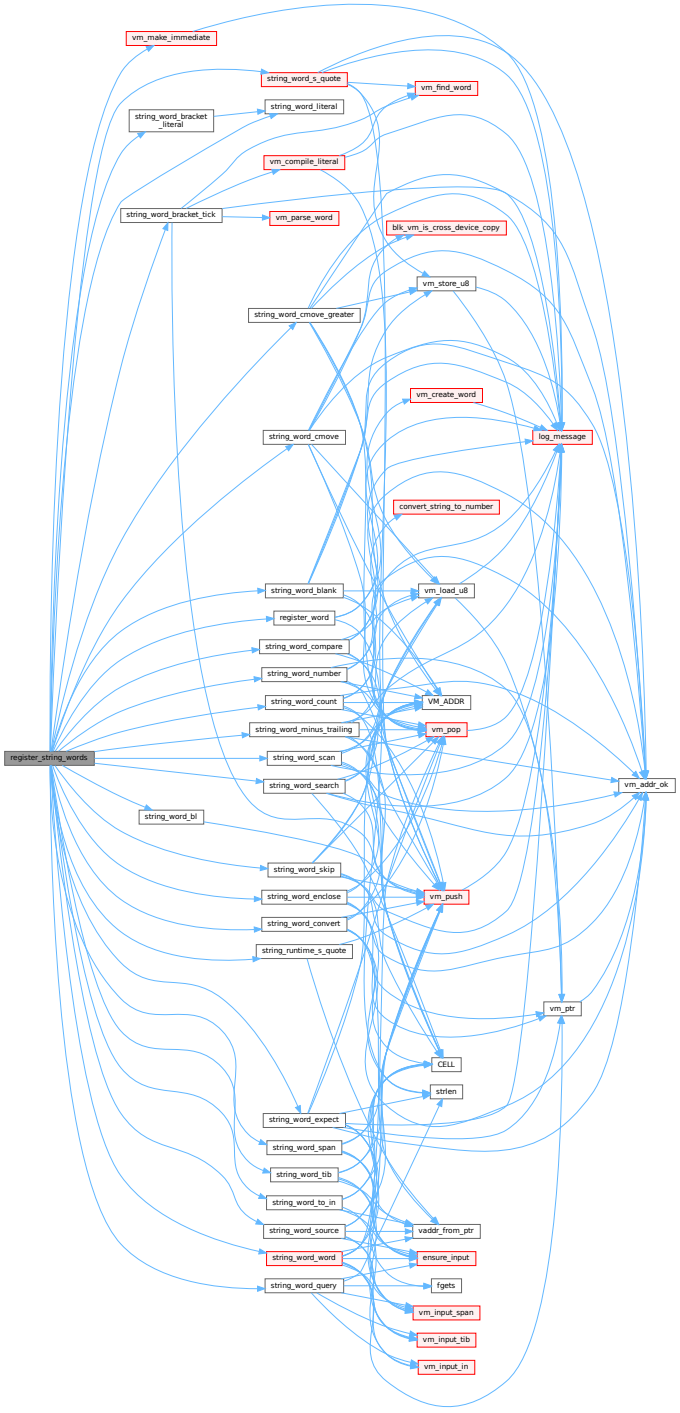
Parameters

vm	Pointer to VM instance where words will be registered

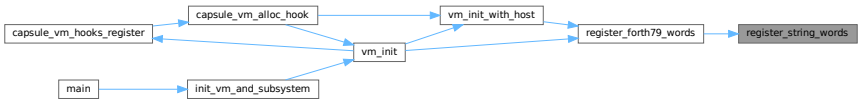
References register_word(), string_runtime_s_quote(), string_word_bl(), string_word_blank(), string_word_bracket_literal(), string_word_bracket_tick(), string_word_cmove(), string_word_cmove_greater(), string_word_compare(), string_word_convert(), string_word_count(), string_word_enclose(), string_word_expect(), string_word_literal(), string_word_minus_trailing(), string_word_number(), string_word_query(), string_word_s_quote(), string_word_scan(), string_word_search(), string_word_skip(), string_word_source(), string_word_span(), string_word_tib(), string_word_to_in(), string_word_word(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



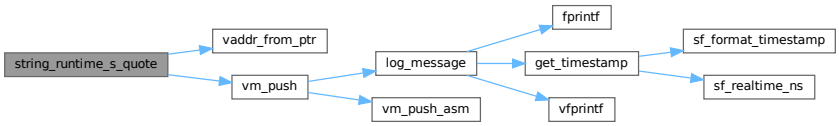
7.415.2.4 string_runtime_s_quote()

```
static void string_runtime_s_quote (
            VM * vm )  [static]
```

References VM::error, VM::return_stack, VM::rsp, vaddr_from_ptr(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

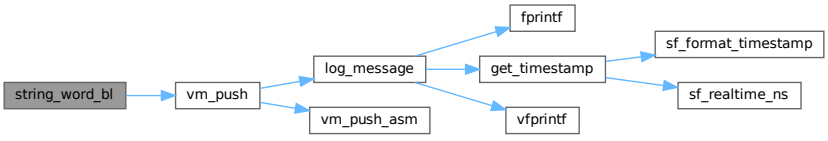
7.415.2.5 string_word_bl()

```
void string_word_bl (
            VM * vm )
```

References vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

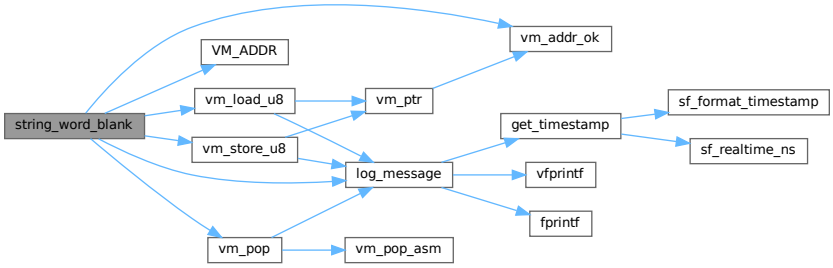
7.415.2.6 string_word_blank()

```
static void string_word_blank (
            VM * vm )  [static]
```

References VM::dsp, VM::error, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_store_u8().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

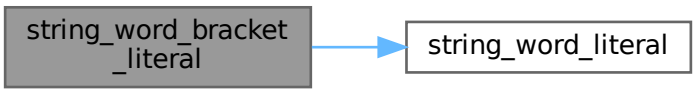
7.415.2.7 string_word_bracket_literal()

```
void string_word_bracket_literal (
            VM * vm )
```

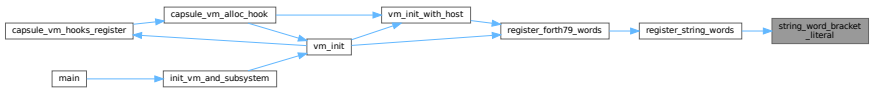
References string_word_literal().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:



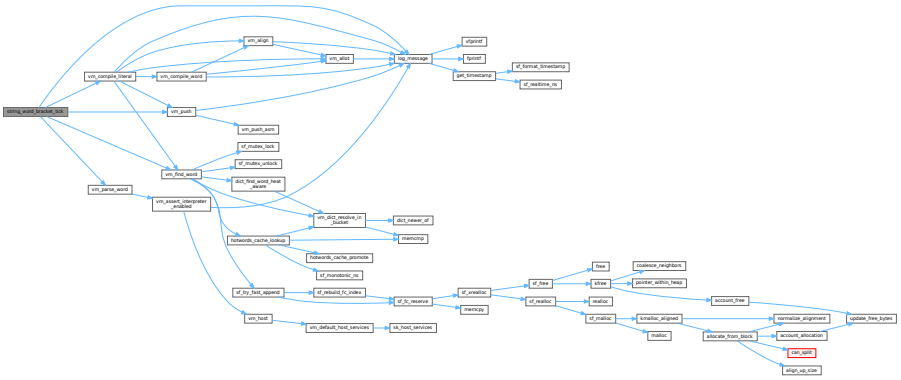
7.415.2.8 string_word_bracket_tick()

```
void string_word_bracket_tick (
            VM * vm )
```

References VM::error, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_compile_literal(), vm_find_word(), vm_parse_word(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

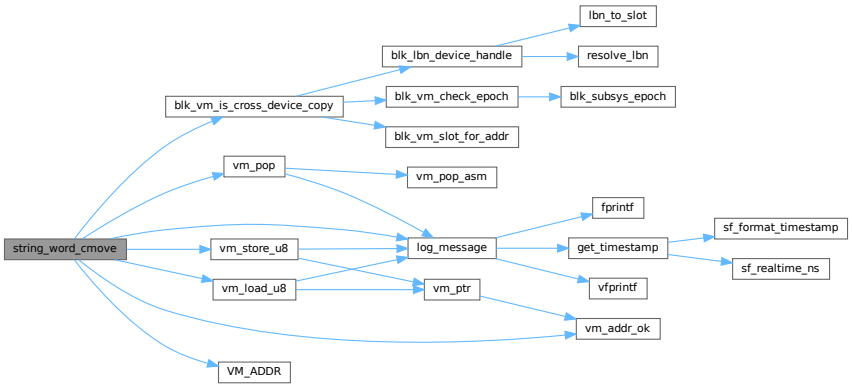
7.415.2.9 string_word_cmove()

```
static void string_word_cmove (
            VM * vm )  [static]
```

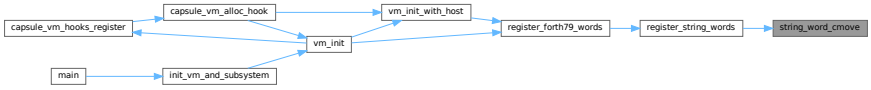
References blk_vm_is_cross_device_copy(), VM::dsp, VM::error, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_store_u8().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:



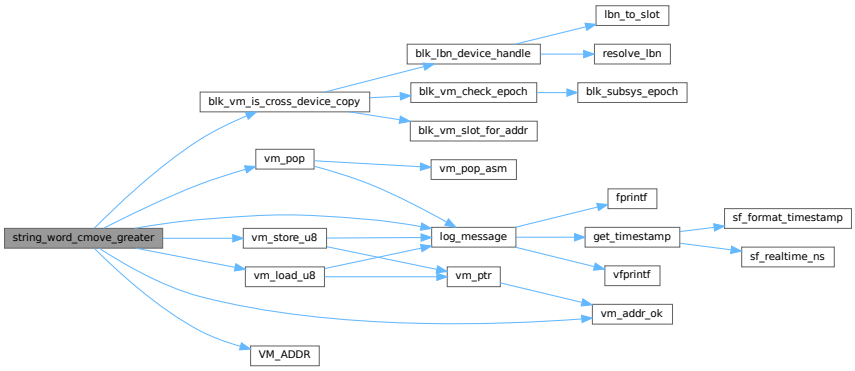
7.415.2.10 string_word_cmove_greater()

```
static void string_word_cmove_greater (
            VM * vm )  [static]
```

References blk_vm_is_cross_device_copy(), VM::dsp, VM::error, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_store_u8().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

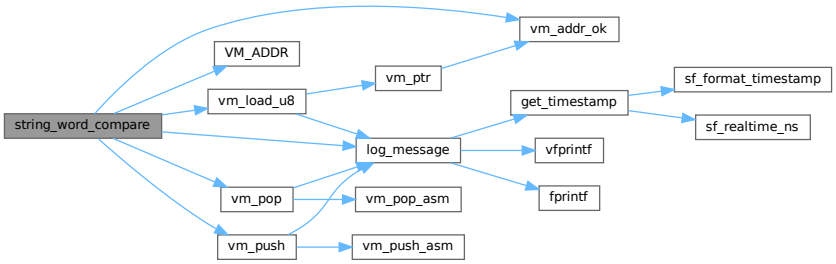
7.415.2.11 string_word_compare()

```
static void string_word_compare (
            VM * vm )  [static]
```

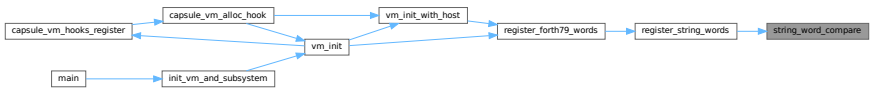
References VM::dsp, VM::error, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:



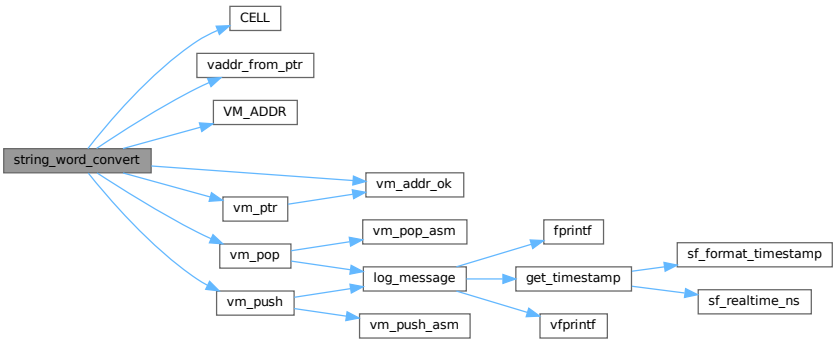
7.415.2.12 string_word_convert()

```
void string_word_convert (
            VM * vm )
```

References CELL(), VM::dsp, VM::error, vaddr_from_ptr(), VM_ADDR(), vm_addr_ok(), vm_pop(), vm_ptr(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.415.2.13 string_word_count()

```
void string_word_count (
            VM * vm )
```

COUNT (addr1 – addr2 u)

Get string length and address. Converts a counted string at addr1 into an address (addr2) and length (u) pair.

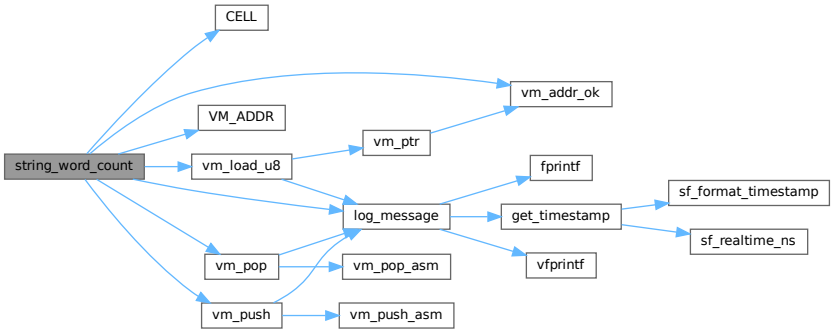
Parameters

vm	Pointer to VM instance

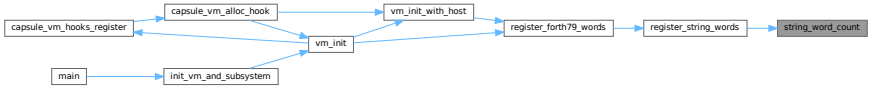
References CELL(), count, VM::dsp, VM::error, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:



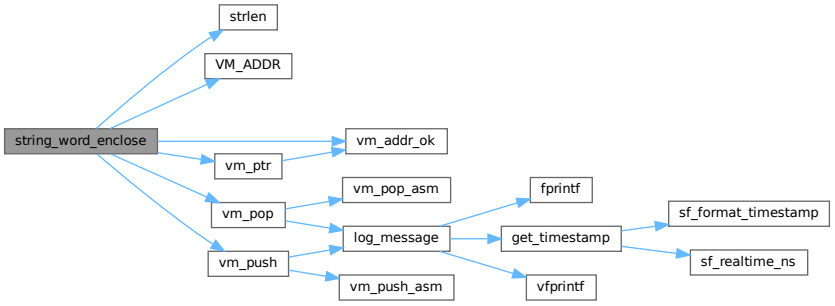
7.415.2.14 string_word_enclose()

```
void string_word_enclose (
            VM * vm )
```

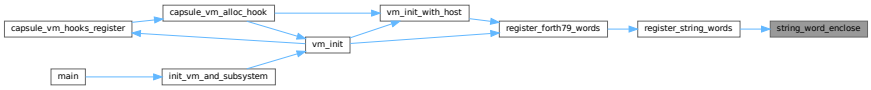
References VM::dsp, VM::error, strlen(), VM_ADDR(), vm_addr_ok(), vm_pop(), vm_ptr(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:



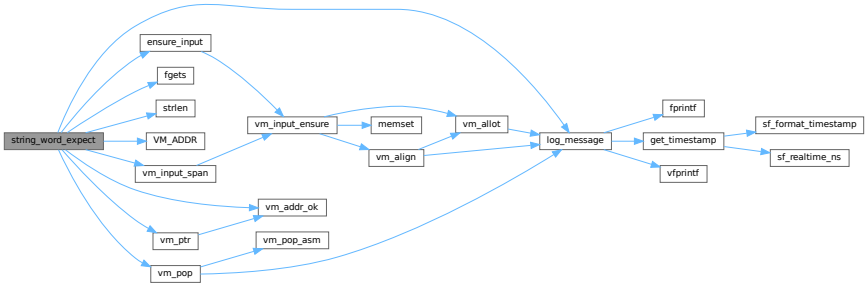
7.415.2.15 string_word_expect()

```
void string_word_expect (
            VM * vm )
```

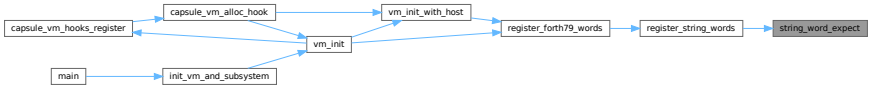
References VM::dsp, ensure_input(), VM::error, fgets(), LOG_ERROR, log_message(), stdin, strlen(), VM_ADDR(), vm_addr_ok(), vm_input_span(), vm_pop(), and vm_ptr().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.415.2.16 string_word_literal()

```
void string_word_literal (
            VM * vm )
```

Referenced by register_string_words(), and string_word_bracket_literal().

Here is the caller graph for this function:

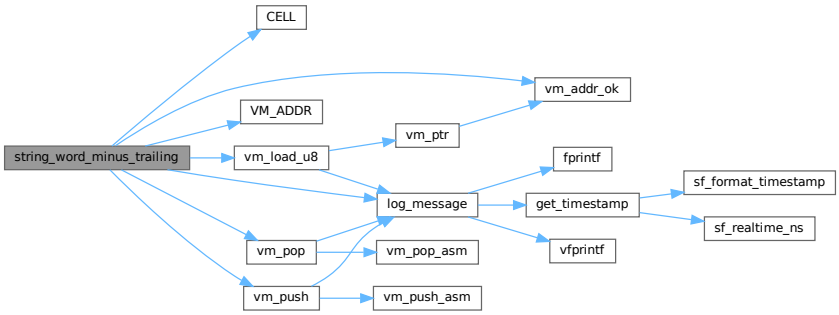
7.415.2.17 string_word_minus_trailing()

```
static void string_word_minus_trailing (
            VM * vm )  [static]
```

References CELL(), VM::dsp, VM::error, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

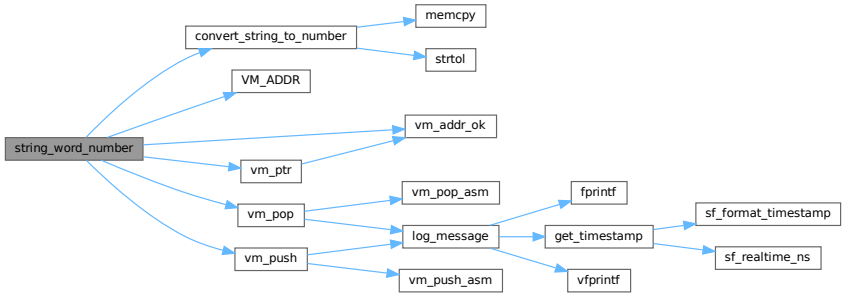
7.415.2.18 string_word_number()

```
void string_word_number (
            VM * vm )
```

References convert_string_to_number(), VM::dsp, VM::error, VM_ADDR(), vm_addr_ok(), vm_pop(), vm_ptr(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

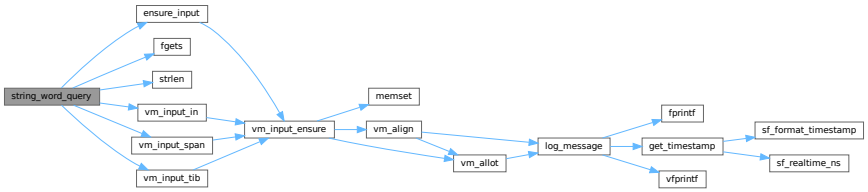
7.415.2.19 string_word_query()

```
void string_word_query (
            VM * vm )
```

References ensure_input(), VM::error, fgets(), INPUT_BUFFER_SIZE, stdin, strlen(), vm_input_in(), vm_input_span(), and vm_input_tib().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

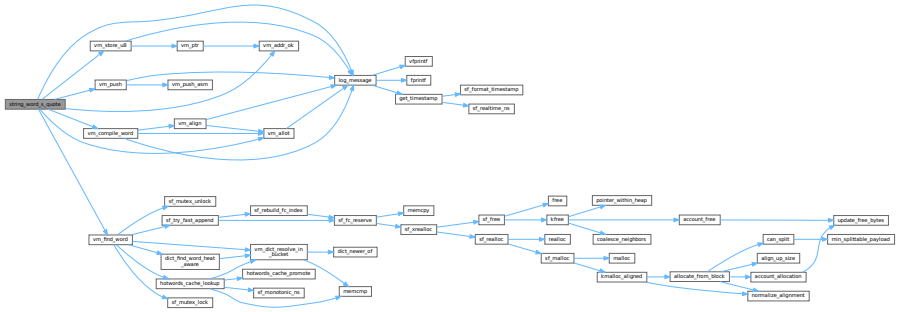
7.415.2.20 string_word_s_quote()

```
static void string_word_s_quote (
            VM * vm )  [static]
```

References VM::error, VM::here, VM::input_buffer, VM::input_length, VM::input_pos, LOG_DEBUG, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, vm_addr_ok(), vm_allot(), vm_compile_word(), vm_find_word(), vm_push(), and vm_store_u8().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

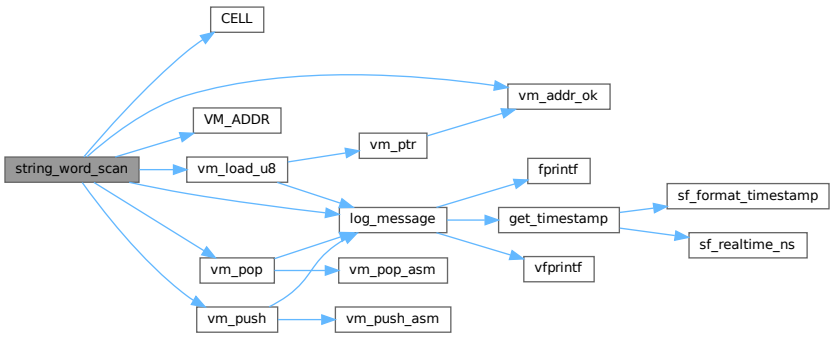
7.415.2.21 string_word_scan()

```
static void string_word_scan (
            VM * vm )  [static]
```

References CELL(), VM::dsp, VM::error, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

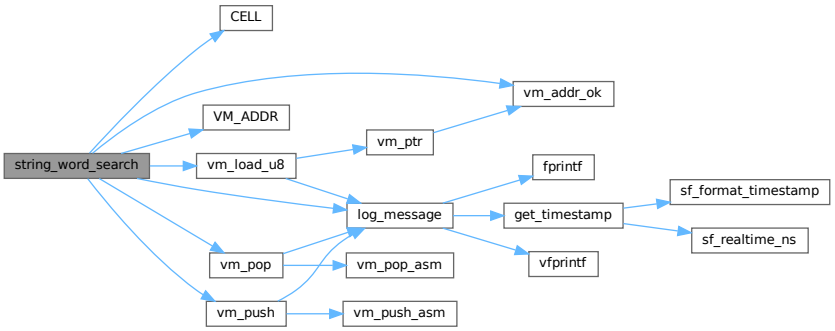
7.415.2.22 string_word_search()

```
static void string_word_search (
            VM * vm )  [static]
```

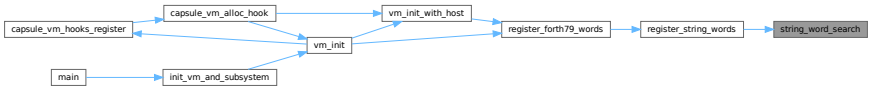
References CELL(), VM::dsp, VM::error, limit, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:



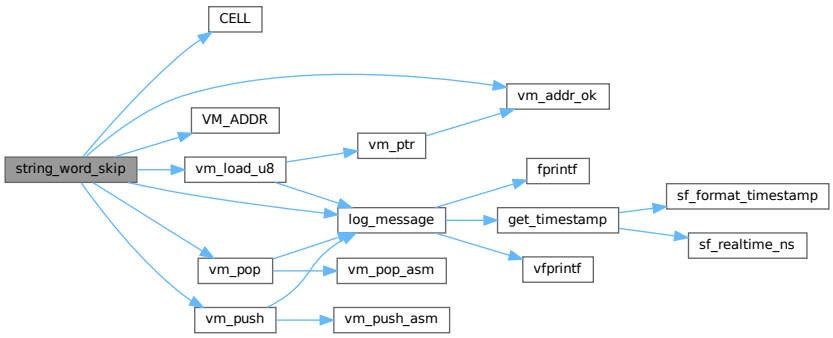
7.415.2.23 string_word_skip()

```
static void string_word_skip (
            VM * vm )  [static]
```

References CELL(), VM::dsp, VM::error, LOG_ERROR, log_message(), VM_ADDR(), vm_addr_ok(), vm_load_u8(), vm_pop(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

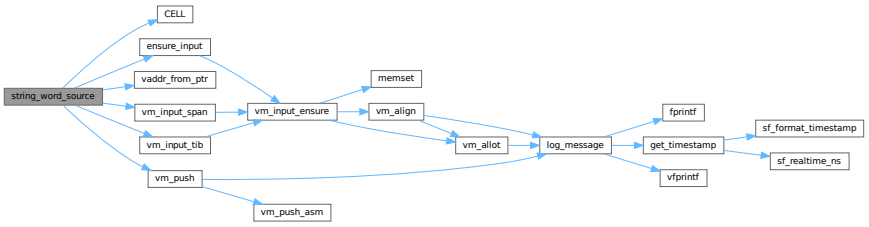
7.415.2.24 string_word_source()

```
void string_word_source (
            VM * vm )
```

References CELL(), ensure_input(), VM::error, vaddr_from_ptr(), vm_input_span(), vm_input_tib(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

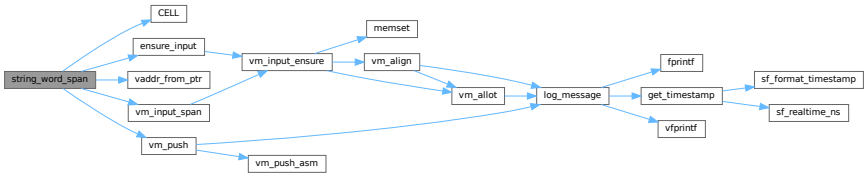
7.415.2.25 string_word_span()

```
void string_word_span (
            VM * vm )
```

References CELL(), ensure_input(), VM::error, vaddr_from_ptr(), vm_input_span(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

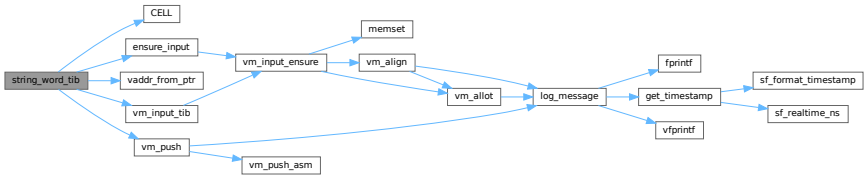
7.415.2.26 string_word_tib()

```
void string_word_tib (
            VM * vm )
```

References CELL(), ensure_input(), VM::error, vaddr_from_ptr(), vm_input_tib(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

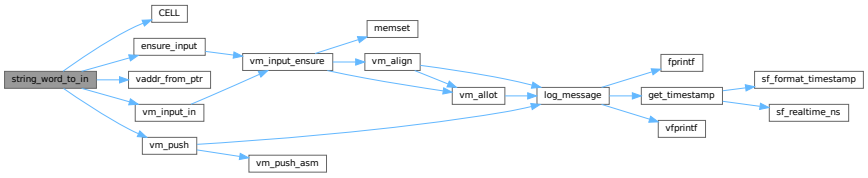
7.415.2.27 string_word_to_in()

```
void string_word_to_in (
            VM * vm )
```

References CELL(), ensure_input(), VM::error, vaddr_from_ptr(), vm_input_in(), and vm_push().

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

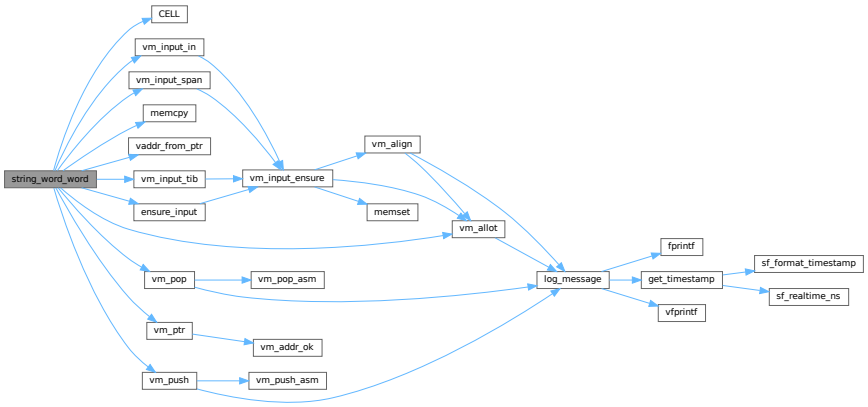
7.415.2.28 string_word_word()

```
void string_word_word (
            VM * vm )
```

References CELL(), VM::dsp, ensure_input(), VM::error, memcpy(), vaddr_from_ptr(), vm_allot(), vm_input_in(), vm_input_span(), vm_input_tib(), vm_pop(), vm_ptr(), vm_push(), word_scratch_addr, and WORD_SCRATCH_CAP.

Referenced by register_string_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.415.2.29 vaddr_from_ptr()

```
static vaddr_t vaddr_from_ptr (
            VM * vm,
            const void * p )  [inline], [static]
```

Convert a C pointer that points into vm->memory into a VM address (offset)

Parameters

vm	Pointer to VM instance
p	Pointer into VM memory space

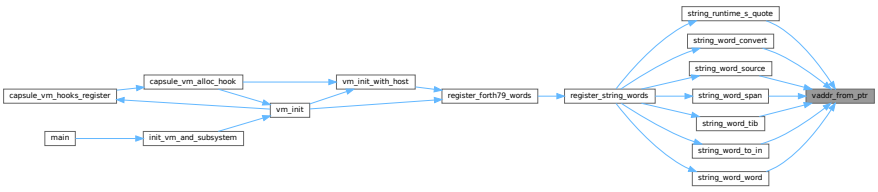
Returns

Virtual address (offset) corresponding to the pointer

References VM::memory.

Referenced by string_runtime_s_quote(), string_word_convert(), string_word_source(), string_word_span(), string_word_tib(), string_word_to_in(), and string_word_word().

Here is the caller graph for this function:



7.415.3 Variable Documentation

7.415.3.1 word_scratch_addr

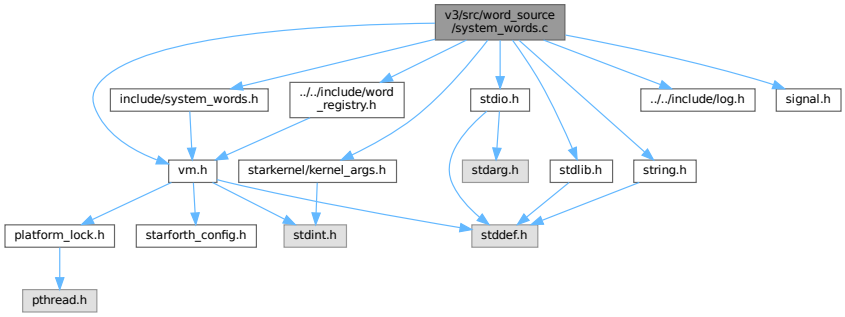
```
vaddr_t word_scratch_addr = 0  [static]
```

Referenced by string_word_word().

7.416 v3/src/word_source/system_words.c File Reference

```
#include "include/system_words.h"
#include "../../include/vm.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <signal.h>
#include "starkernel/kernel_args.h"
```

Include dependency graph for system_words.c:



Functions

- static void print_word_name (const DictEntry *entry)
- static void reset_vm_state (VM *vm, int cold_start)
- static void forth_paren (VM *vm)
- static void forth_backslash (VM *vm)
- void system_word_cold (VM *vm)
- void system_word_warm (VM *vm)
- void system_word_bye (VM *vm)
- void system_word_save_system (VM *vm)
- void system_word_words (VM *vm)
- void system_word_vlist (VM *vm)
- void system_word_page (VM *vm)
- void system_word_nop (VM *vm)
- void system_word_79_standard (VM *vm)
- static void system_word_quit (VM *vm)
- static void system_word_abort (VM *vm)
- static void runtime_abortq (VM *vm)
- static void system_word_abort_quote (VM *vm)
- static void system_word_see (VM *vm)
- static void system_word_reboot (VM *vm)
- static void system_word_execute (VM *vm)
- int system_is_running (void)
- void set_forth_79_compliance (int enabled)
- void register_system_words (VM *vm)

  Registers all system words with the virtual machine.

Variables

- static int system_running = 1

  Flag indicating if the Forth system is currently running.
- static int forth_79_standard = 1

  Flag controlling FORTH-79 standard compliance mode.

7.416.1 Function Documentation

7.416.1.1 forth_backslash()

```
static void forth_backslash (
            VM * vm )  [static]
```

References VM::input_buffer, VM::input_length, and VM::input_pos.

Referenced by register_system_words().

Here is the caller graph for this function:

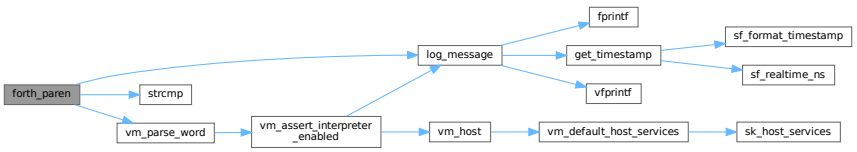
7.416.1.2 forth_paren()

```
static void forth_paren (
            VM * vm )  [static]
```

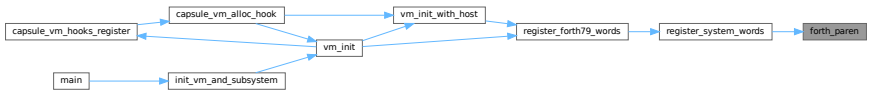
References log_message(), LOG_WARN, strcmp(), and vm_parse_word().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:



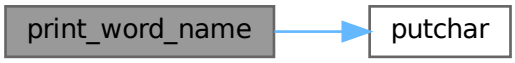
7.416.1.3 print_word_name()

```
static void print_word_name (
            const DictEntry * entry )  [static]
```

References entry, and putchar().

Referenced by system_word_see(), system_word_vlist(), and system_word_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.416.1.4 register_system_words()

```
void register_system_words (
            VM * vm )
```

Registers all system words with the virtual machine.

Parameters

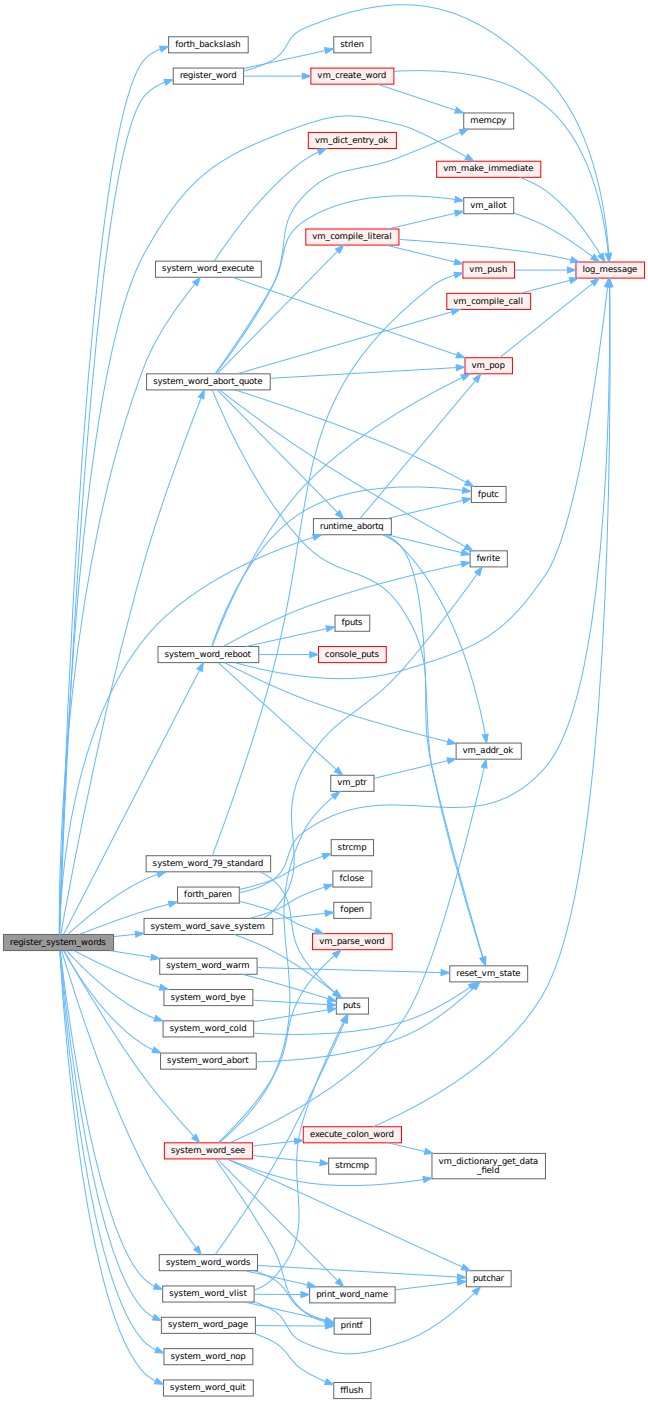
vm	Pointer to the virtual machine instance

This function registers all FORTH-79 system and environment words with the specified virtual machine instance, making them available for use in the FORTH environment.

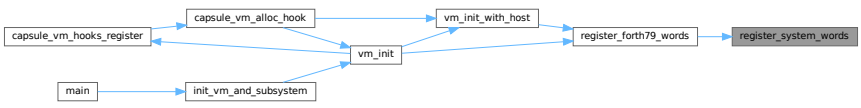
References forth_backslash(), forth_paren(), register_word(), runtime_abortq(), system_word_79_standard(), system_word_abort(), system_word_abort_quote(), system_word_bye(), system_word_cold(), system_word_execute(), system_word_nop(), system_word_page(), system_word_quit(), system_word_reboot(), system_word_save_system(), system_word_see(), system_word_vlist(), system_word_warm(), system_word_words(), and vm_make_immediate().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.416.1.5 reset_vm_state()

```
static void reset_vm_state (
            VM * vm,
            int cold_start )  [static]
```

References VM::dsp, VM::error, VM::here, VM::mode, MODE_INTERPRET, VM::rsp, and system_running.

Referenced by runtime_abortq(), system_word_abort(), system_word_abort_quote(), system_word_cold(), and system_word_warm().

Here is the caller graph for this function:

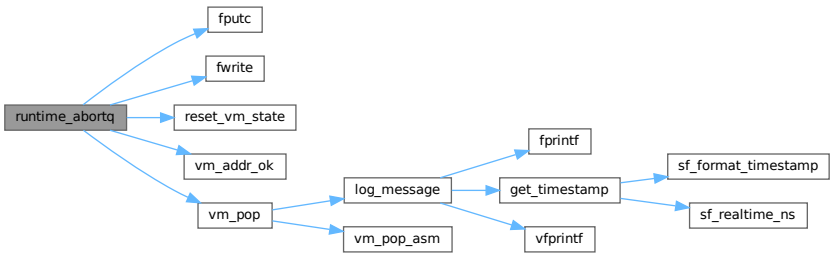
7.416.1.6 runtime_abortq()

```
static void runtime_abortq (
            VM * vm )  [static]
```

References VM::dsp, VM::error, fputc(), fwrite(), VM::memory, reset_vm_state(), stdout, vm_addr_ok(), and vm_pop().

Referenced by register_system_words(), and system_word_abort_quote().

Here is the call graph for this function:



Here is the caller graph for this function:

7.416.1.7 set_forth_79_compliance()

```
void set_forth_79_compliance (
            int enabled )
```

References enabled, and forth_79_standard.

7.416.1.8 system_is_running()

```
int system_is_running (
            void  )
```

References system_running.

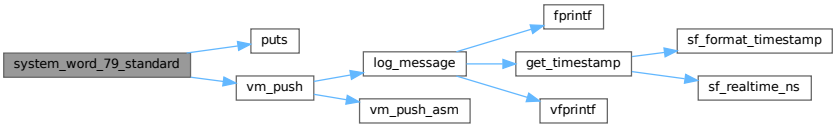
7.416.1.9 system_word_79_standard()

```
void system_word_79_standard (
            VM * vm )
```

References forth_79_standard, puts(), and vm_push().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.416.1.10 system_word_abort()

```
static void system_word_abort (
            VM * vm )  [static]
```

References VM::abort_requested, VM::error, and reset_vm_state().

Referenced by register_system_words().

Here is the call graph for this function:

Here is the caller graph for this function:

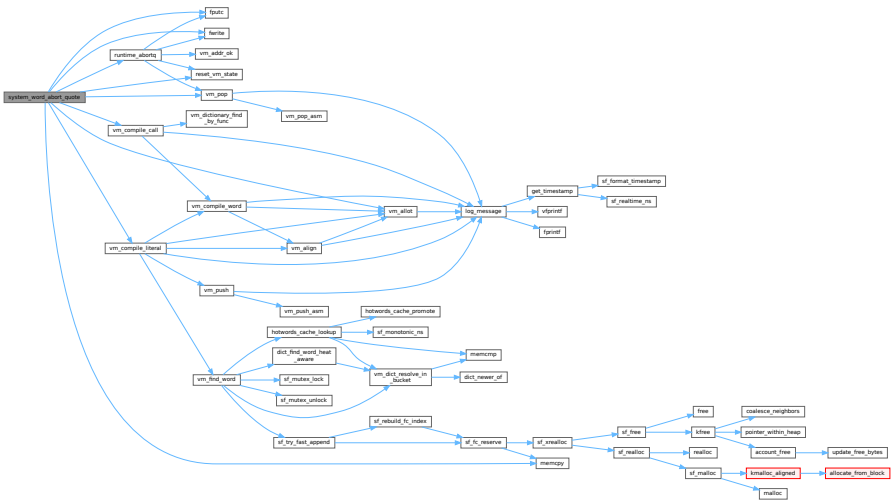
7.416.1.11 system_word_abort_quote()

```
static void system_word_abort_quote (
            VM * vm )  [static]
```

References VM::dsp, VM::error, fputc(), fwrite(), VM::input_buffer, VM::input_length, VM::input_pos, memcpy(), VM::memory, VM::mode, MODE_INTERPRET, reset_vm_state(), runtime_abortq(), stdout, vm_allot(), vm_compile_call(), vm_compile_literal(), and vm_pop().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.416.1.12 system_word_bye()

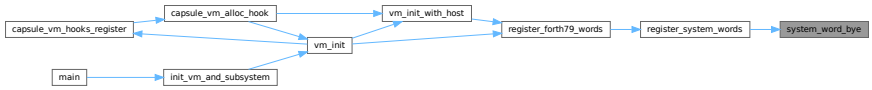
```
void system_word_bye (
            VM * vm )
```

References VM::halted, and puts().

Referenced by register_system_words().

Here is the call graph for this function:

Here is the caller graph for this function:



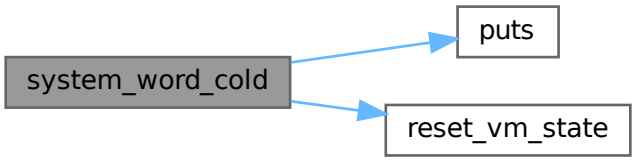
7.416.1.13 system_word_cold()

```
void system_word_cold (
            VM * vm )
```

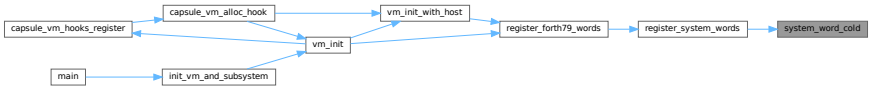
References puts(), and reset_vm_state().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:



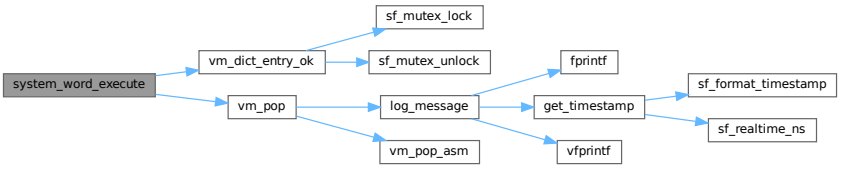
7.416.1.14 system_word_execute()

```
static void system_word_execute (
            VM * vm )  [static]
```

References VM::current_executing_entry, VM::dsp, entry, VM::error, DictEntry::func, vm_dict_entry_ok(), and vm_pop().

Referenced by register_system_words().

Here is the call graph for this function:



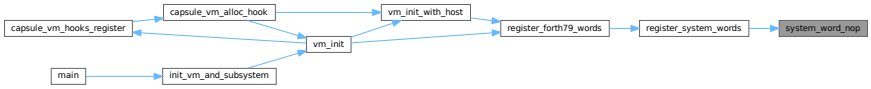
Here is the caller graph for this function:

7.416.1.15 system_word_nop()

```
void system_word_nop (
            VM * vm )
```

Referenced by register_system_words().

Here is the caller graph for this function:



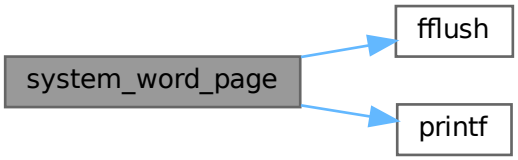
7.416.1.16 system_word_page()

```
void system_word_page (
            VM * vm )
```

References fflush(), printf(), and stdout.

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:

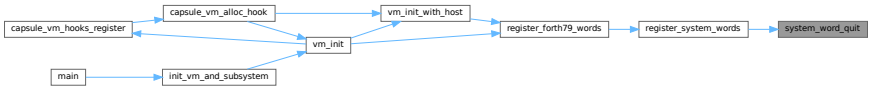
7.416.1.17 system_word_quit()

```
static void system_word_quit (
            VM * vm )  [static]
```

References VM::error, VM::mode, MODE_COMPILE, MODE_INTERPRET, and VM::rsp.

Referenced by register_system_words().

Here is the caller graph for this function:



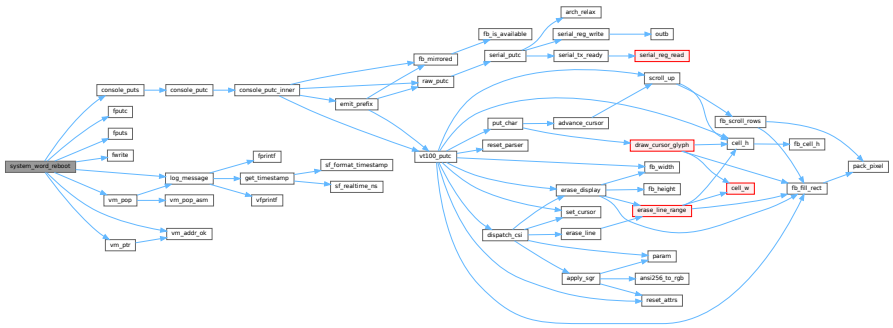
7.416.1.18 system_word_reboot()

```
static void system_word_reboot (
            VM * vm )  [static]
```

References console_puts(), VM::dsp, EFI_SUCCESS, EFI_VARIABLE_BOOTSERVICE_ACCESS, EFI_VARIABLE_NON_VOLATILE EFI_VARIABLE_RUNTIME_ACCESS, EfiResetCold, VM::error, fputc(), fputs(), fwrite(), g_sk_runtime_services, _EFI_RUNTIME_SERVICES::GetVariable, VM::halted, KERNEL_ARGS_CMDLINE_MAX, LOG_ERROR, log_message(), VM::mode, MODE_COMPILE, REBOOT_MAX_TRIES, _EFI_RUNTIME_SERVICES::ResetSystem, _EFI_RUNTIME_SERVICES::SetVariable, SF_VAR_BOOT_ARGS, SF_VAR_REBOOT_TRIES, STARFORTH_VENDOR_GUID, stdout, vm_addr_ok(), vm_pop(), and vm_ptr().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:

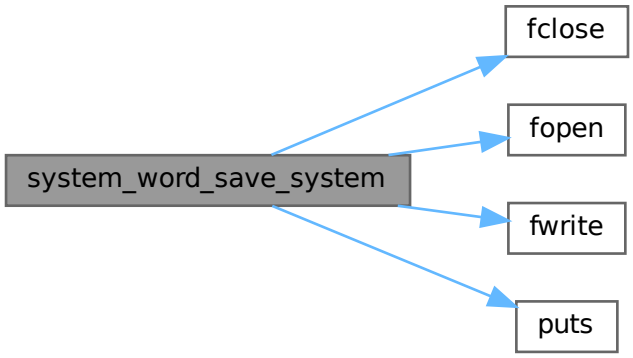
7.416.1.19 system_word_save_system()

```
void system_word_save_system (
            VM * vm )
```

References VM::error, fclose(), fopen(), fwrite(), VM::here, VM::memory, and puts().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:

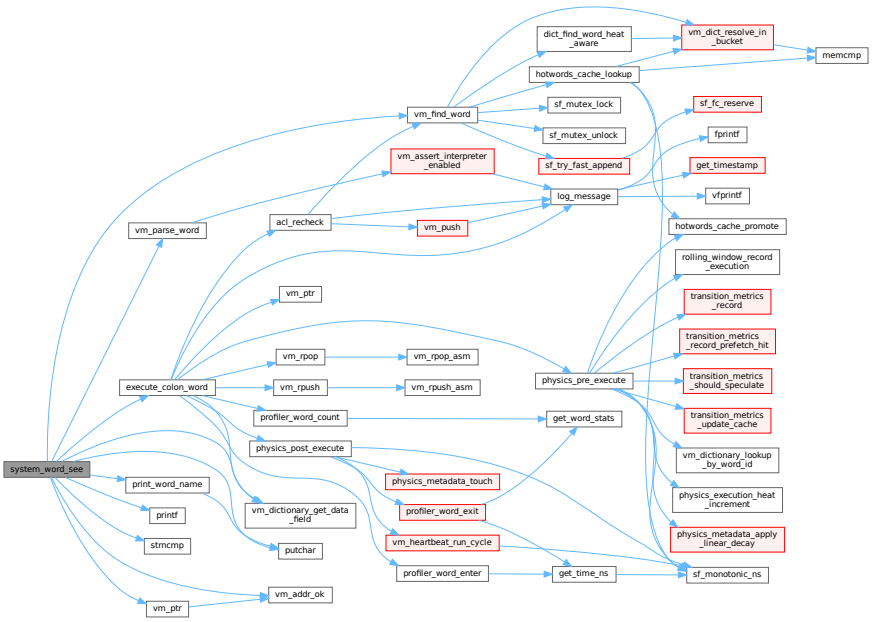
7.416.1.20 system_word_see()

```
static void system_word_see (
            VM * vm )  [static]
```

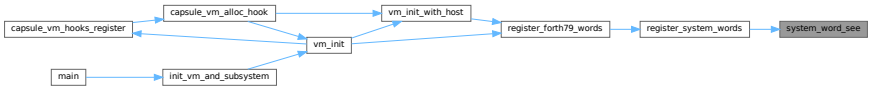
References entry, VM::error, execute_colon_word(), VM::memory, DictEntry::name, DictEntry::name_len, print_word_name(), printf(), putchar(), strncmp(), vm_addr_ok(), vm_dictionary_get_data_field(), vm_find_word(), vm_parse_word(), vm_ptr(), word_count, and WORD_NAME_MAX.

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:



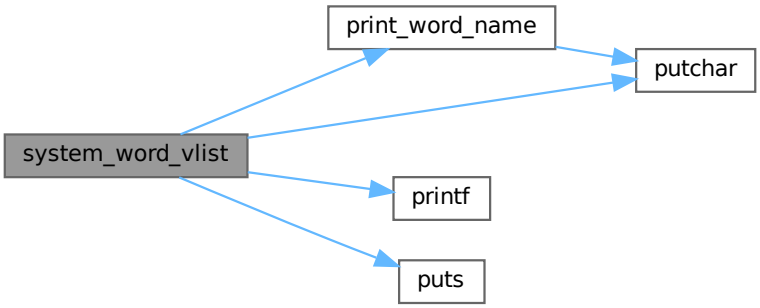
7.416.1.21 system_word_vlist()

```
void system_word_vlist (
            VM * vm )
```

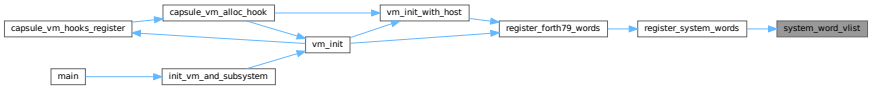
References count, DictEntry::flags, VM::latest, DictEntry::name_len, print_word_name(), printf(), putchar(), and puts().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:



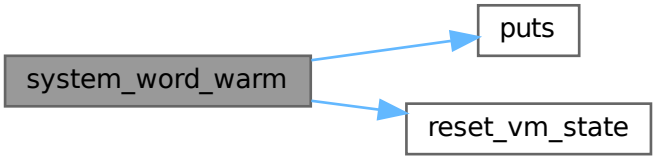
7.416.1.22 system_word_warm()

```
void system_word_warm (
            VM * vm )
```

References puts(), and reset_vm_state().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:

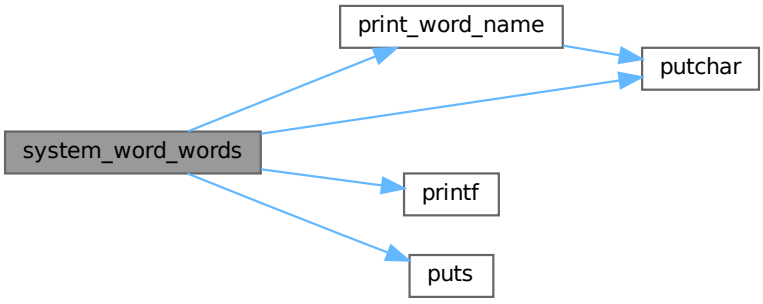
7.416.1.23 system_word_words()

```
void system_word_words (
            VM * vm )
```

References count, VM::latest, DictEntry::link, print_word_name(), printf(), putchar(), and puts().

Referenced by register_system_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.416.2 Variable Documentation

7.416.2.1 forth_79_standard

```
int forth_79_standard = 1  [static]
```

Flag controlling FORTH-79 standard compliance mode.

Referenced by set_forth_79_compliance(), and system_word_79_standard().

7.416.2.2 system_running

```
int system_running = 1  [static]
```

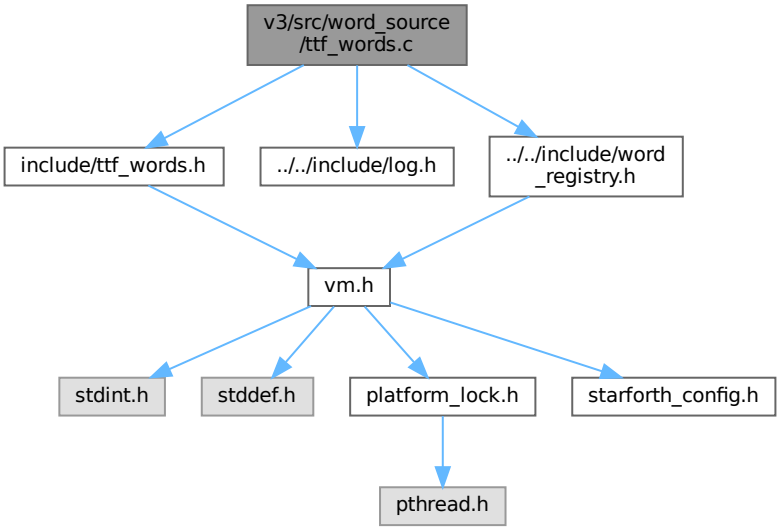
Flag indicating if the Forth system is currently running.

Referenced by reset_vm_state(), and system_is_running().

7.417 v3/src/word_source/ttf_words.c File Reference

```
#include "include/ttf_words.h"
#include "../../include/log.h"
#include "../../include/word_registry.h"
```

Include dependency graph for ttf_words.c:



Functions

- void register_ttf_words (VM *vm)

7.417.1 Function Documentation

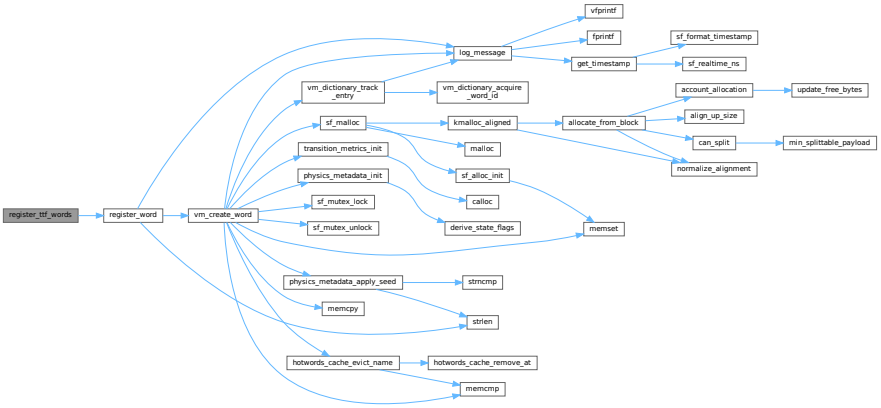
7.417.1.1 register_ttf_words()

```
void register_ttf_words (
            VM * vm )
```

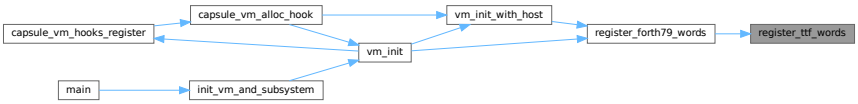
References register_word().

Referenced by register_forth79_words().

Here is the call graph for this function:



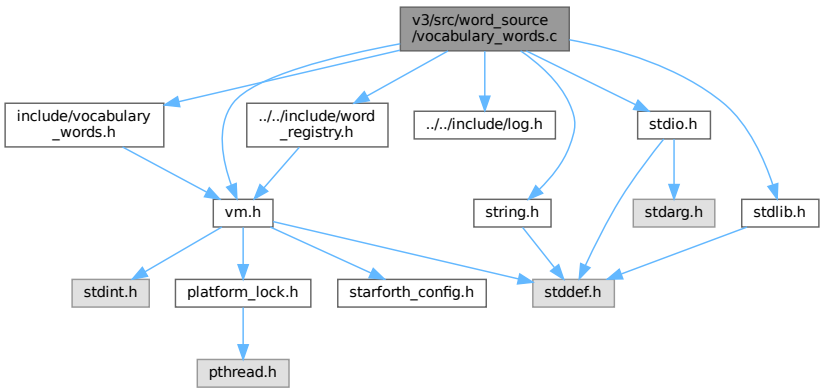
Here is the caller graph for this function:



7.418 v3/src/word_source/vocabulary_words.c File Reference

```
#include "include/vocabulary_words.h"
#include "../../include/word_registry.h"
#include "../../include/log.h"
#include "../../include/vm.h"
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
```

Include dependency graph for vocabulary_words.c:



Functions

- static void vocabulary_debug_print_hex (uint64_t value) __attribute__((unused))
- static size_t vocab_safe_len (const char *text, size_t max_len)
- static void fc_free (DictEntry ***lists, size_t *counts)
- static void fc_rebuild (DictEntry *head, DictEntry ***lists, size_t *counts, DictEntry **cached_head)
- static void vocab_sync_vm_vars (VM *vm)
- static void init_vocabulary_system (VM *vm)

  Initialize the FORTH vocabulary system.
- static DictEntry * vocab_find_word (VM *vm, const char *name, size_t len)
- static void vocabulary_select_runtime (VM *vm)
- void vocabulary_word_vocabulary (VM *vm)

  VOCABULARY (–) Create a new vocabulary.
- void vocabulary_create_vocabulary_direct (VM *vm, const char *name)

  Direct vocabulary creation (kernel bootstrap)
- void vocabulary_word_definitions (VM *vm)

  DEFINITIONS (–) Set CURRENT to CONTEXT.
- void vocabulary_word_context (VM *vm)

  CONTEXT (– addr) Get CONTEXT variable address.
- void vocabulary_word_current (VM *vm)

  CURRENT (– addr) Get CURRENT variable address.
- void vocabulary_word_forth (VM *vm)

  FORTH (–) Select FORTH vocabulary.
- void vocabulary_word_paren_find (VM *vm)

  (FIND) (addr – addr flag) Find word in dictionary
- void vocabulary_word_order (VM *vm)

  ORDER (–) Display search order.
- DictEntry * vm_vocabulary_find_word (VM *vm, const char *name, size_t len)

  Find word in vocabulary-aware dictionary.
- void register_vocabulary_words (VM *vm)

  Register all FORTH-79 vocabulary words.

7.418.1 Function Documentation

7.418.1.1 fc_free()

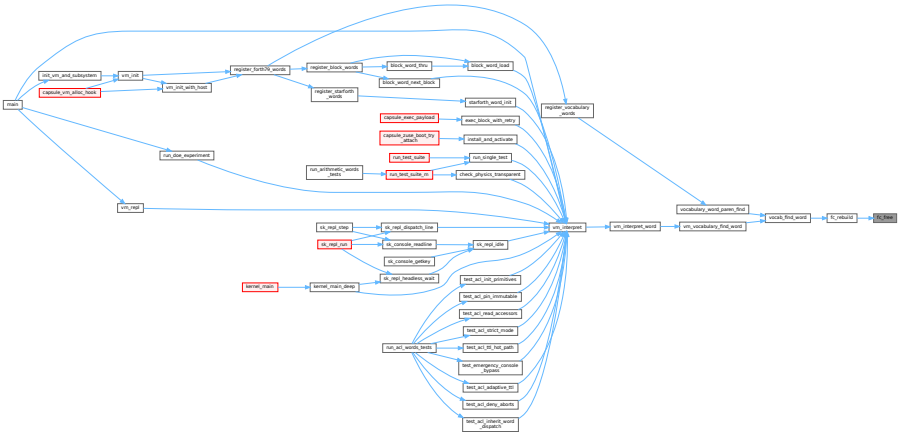
```
static void fc_free (
            DictEntry *** lists,
            size_t * counts )  [static]
```

References free(), and VOCAB_FC_BUCKETS.

Referenced by fc_rebuild().

Here is the call graph for this function:

Here is the caller graph for this function:



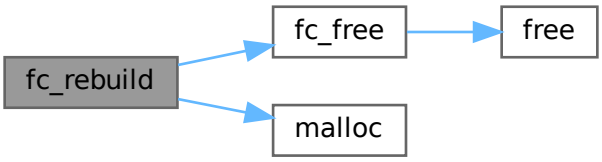
7.418.1.2 fc_rebuild()

```
static void fc_rebuild (
            DictEntry * head,
            DictEntry *** lists,
            size_t * counts,
            DictEntry ** cached_head )  [static]
```

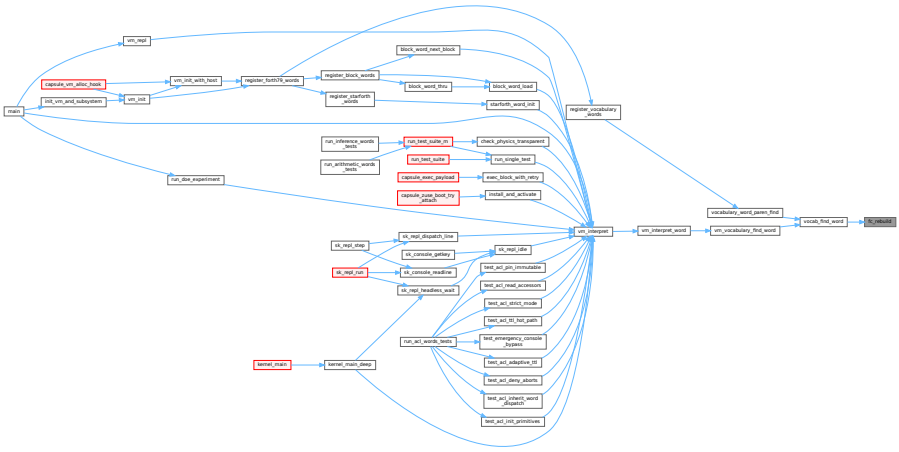
References fc_free(), head, malloc(), DictEntry::name, and VOCAB_FC_BUCKETS.

Referenced by vocab_find_word().

Here is the call graph for this function:



Here is the caller graph for this function:



7.418.1.3 init_vocabulary_system()

```
static void init_vocabulary_system (
            VM * vm )  [static]
```

Initialize the FORTH vocabulary system.

Sets up FORTH as root vocabulary and allocates VM cells for CONTEXT/CURRENT. Per-VM (vm->vocab.↩ initialized): each VM in the fleet seeds its own vocabulary roots from its own dictionary, rather than every VM after the first silently sharing whichever VM ran this first.

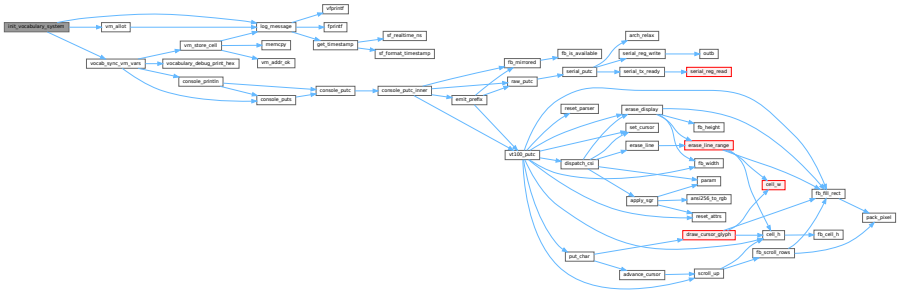
Parameters

vm	Pointer to VM instance

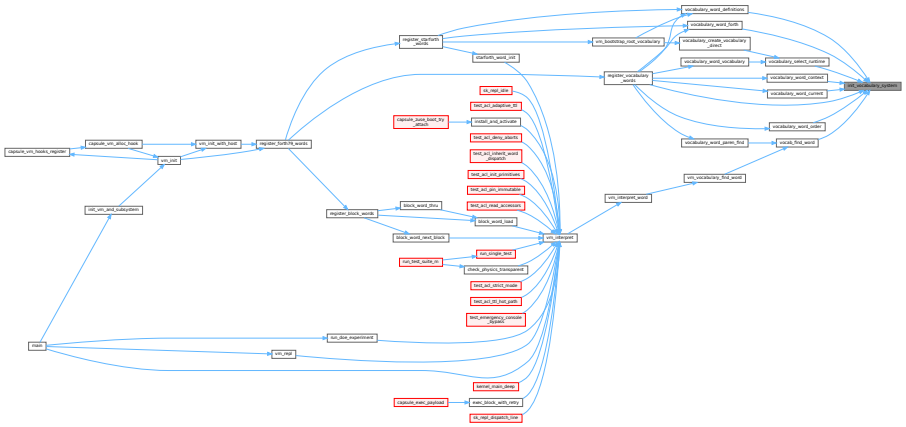
References VocabularyState::context_var_addr, VocabularyState::context_vocab, VocabularyState::current_var_addr, VocabularyState::current_vocab, VM::error, VocabularyState::forth_vocab, VocabularyState::initialized, VM::latest, LOG_ERROR, log_message(), VM::memory, vm_allot(), VM::vocab, and vocab_sync_vm_vars().

Referenced by register_vocabulary_words(), vocab_find_word(), vocabulary_select_runtime(), vocabulary_word_context(), vocabulary_word_current(), vocabulary_word_definitions(), vocabulary_word_forth(), and vocabulary_word_order().

Here is the call graph for this function:



Here is the caller graph for this function:



7.418.1.4 register_vocabulary_words()

```
void register_vocabulary_words (
            VM * vm )
```

Register all FORTH-79 vocabulary words.

Registers VOCABULARY, DEFINITIONS, CONTEXT, CURRENT, FORTH, ORDER, and (FIND)

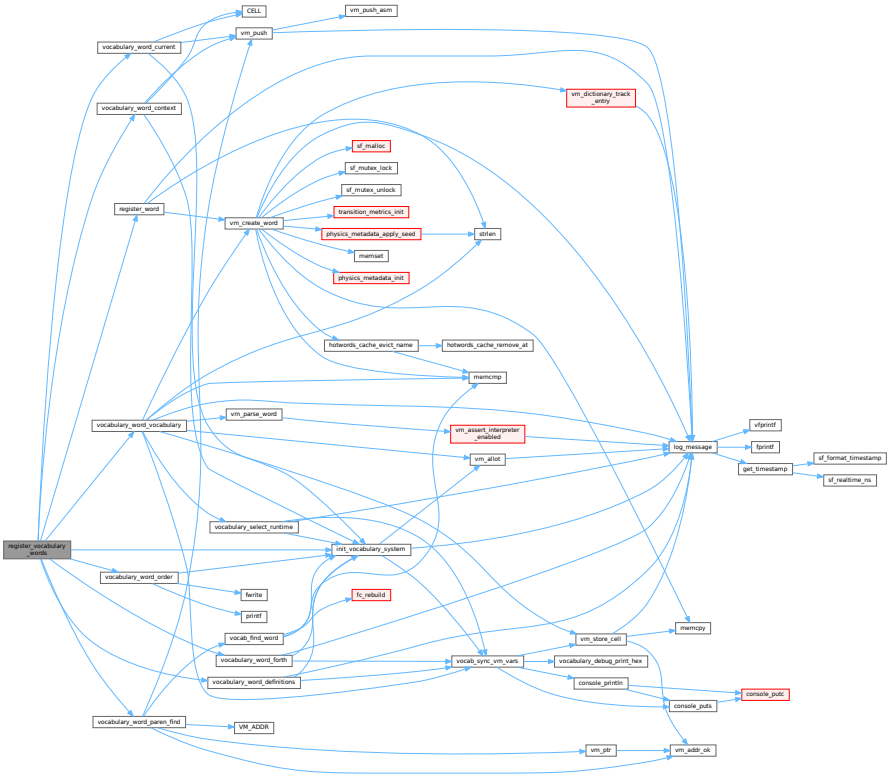
Parameters

vm	Pointer to VM instance

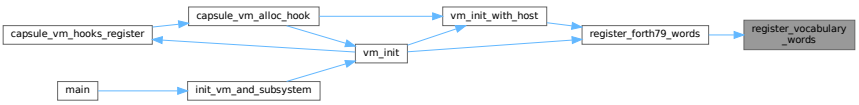
References init_vocabulary_system(), register_word(), vocabulary_word_context(), vocabulary_word_current(), vocabulary_word_definitions(), vocabulary_word_forth(), vocabulary_word_order(), vocabulary_word_paren_find(), and vocabulary_word_vocabulary().

Referenced by register_forth79_words().

Here is the call graph for this function:



Here is the caller graph for this function:



7.418.1.5 vm_vocabulary_find_word()

```
DictEntry * vm_vocabulary_find_word (
            VM * vm,
            const char * name,
            size_t len )
```

Find word in vocabulary-aware dictionary.

Searches CONTEXT then FORTH vocabularies

Parameters

vm	Pointer to VM instance
name	Word name to find
len	Length of word name

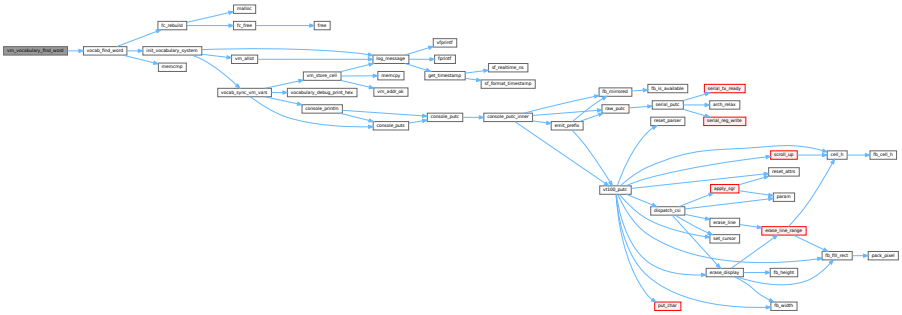
Returns

Pointer to dictionary entry if found, NULL if not found

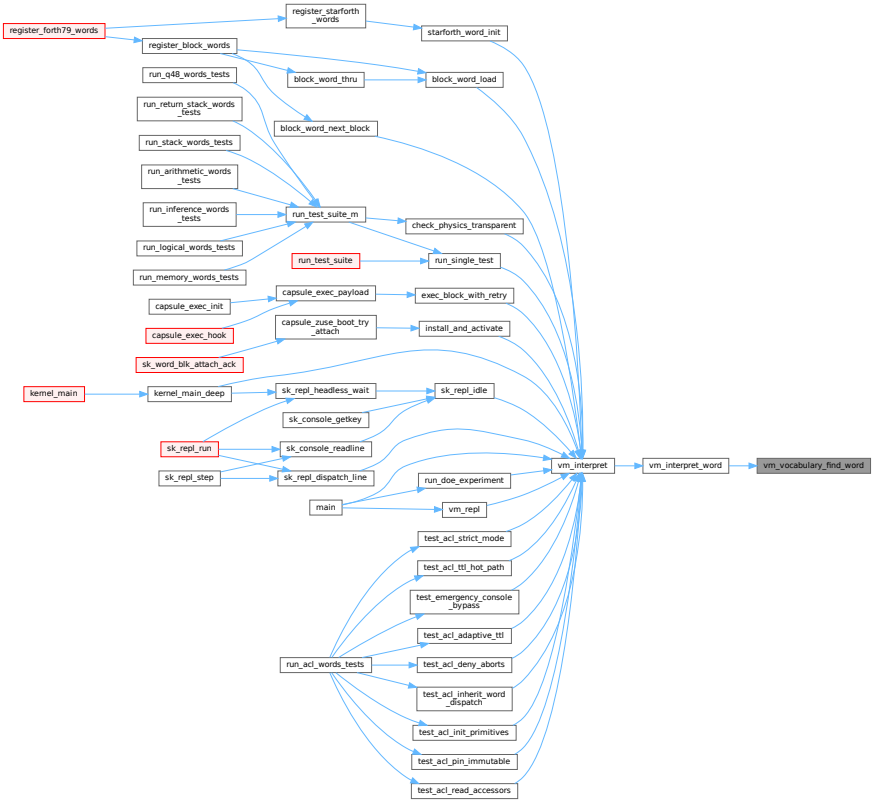
References name, and vocab_find_word().

Referenced by vm_interpret_word().

Here is the call graph for this function:



Here is the caller graph for this function:



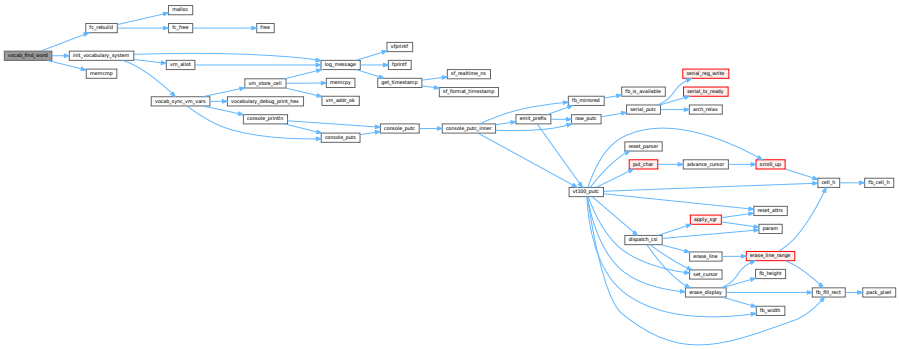
7.418.1.6 vocab_find_word()

```
static DictEntry * vocab_find_word (
            VM * vm,
            const char * name,
            size_t len )  [static]
```

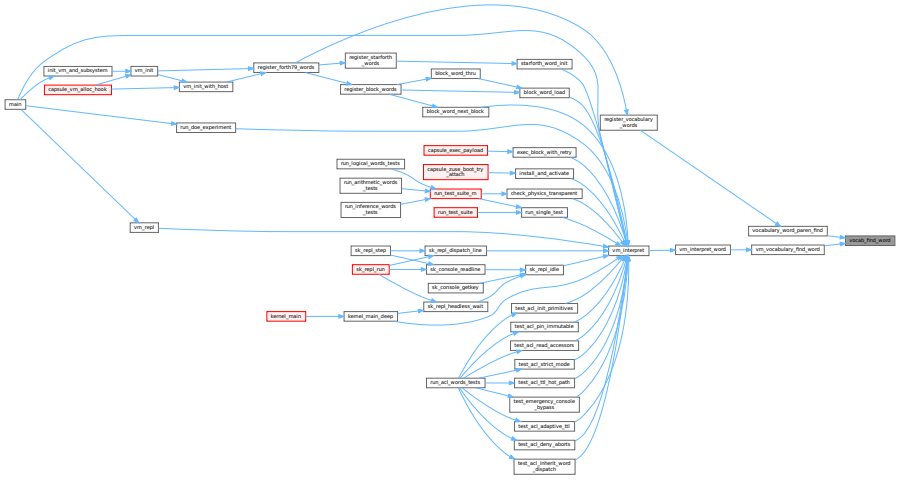
References VocabularyState::context_vocab, VocabularyState::ctx_cached_head, VocabularyState::ctx_fc, VocabularyState::ctx_n, fc_rebuild(), DictEntry::flags, VocabularyState::forth_cached_head, VocabularyState::forth_fc, VocabularyState::forth_n, VocabularyState::forth_vocab, init_vocabulary_system(), memcmp(), name, DictEntry::name, DictEntry::name_len, UNLIKELY, VM::vocab, WORD_HIDDEN, and WORD_SMUDGED.

Referenced by vm_vocabulary_find_word(), and vocabulary_word_paren_find().

Here is the call graph for this function:



Here is the caller graph for this function:

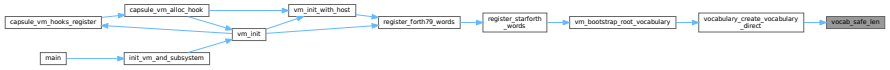


7.418.1.7 vocab_safe_len()

```
static size_t vocab_safe_len (
            const char * text,
            size_t max_len )  [static]
```

Referenced by vocabulary_create_vocabulary_direct().

Here is the caller graph for this function:



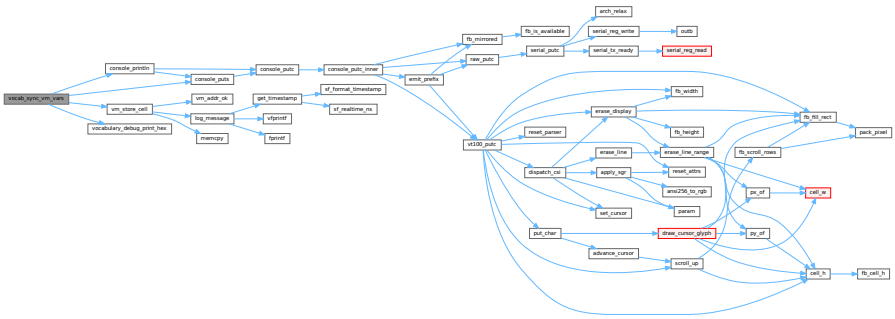
7.418.1.8 vocab_sync_vm_vars()

```
static void vocab_sync_vm_vars (
            VM * vm )  [inline], [static]
```

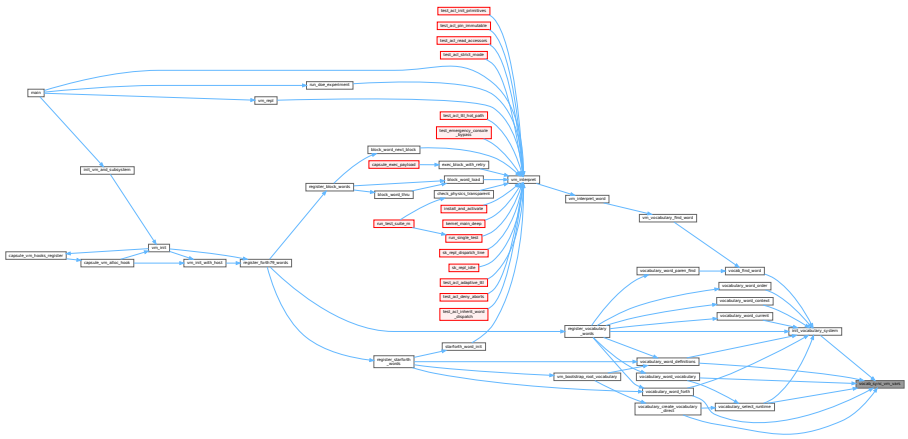
References base, console_println(), console_puts(), VocabularyState::context_var_addr, VocabularyState::context_vocab, VocabularyState::current_var_addr, VocabularyState::current_vocab, VM::memory, vm_store_cell(), VM::vocab, and vocabulary_debug_print_hex().

Referenced by init_vocabulary_system(), vocabulary_create_vocabulary_direct(), vocabulary_select_runtime(), vocabulary_word_definitions(), vocabulary_word_forth(), and vocabulary_word_vocabulary().

Here is the call graph for this function:



Here is the caller graph for this function:



7.418.1.9 vocabulary_create_vocabulary_direct()

```
void vocabulary_create_vocabulary_direct (
            VM * vm,
            const char * name )
```

Direct vocabulary creation (kernel bootstrap)

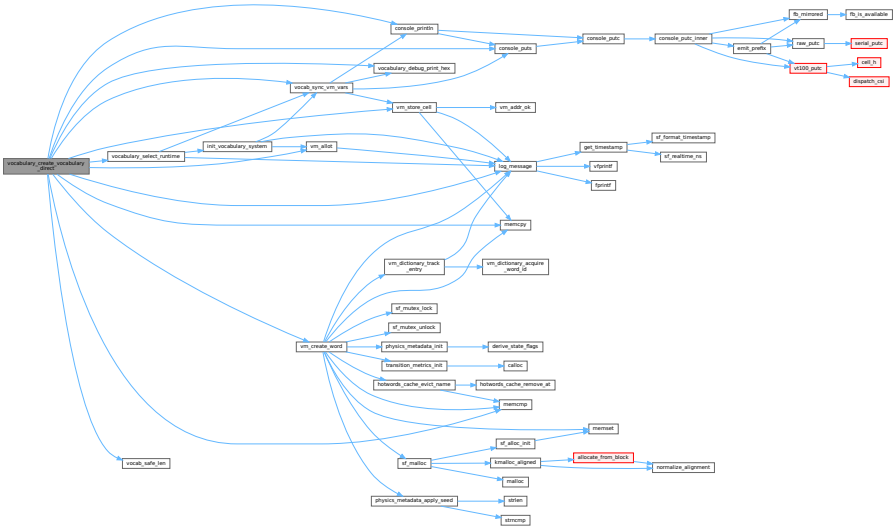
Parameters

vm	Pointer to the virtual machine instance
name	Vocabulary name

References console_println(), console_puts(), entry, VM::error, VM::here, VM::latest, LOG_DEBUG, LOG_ERROR, log_message(), memcmp(), memcpy(), VM::memory, name, vm_allot(), vm_create_word(), vm_store_cell(), vocab_safe_len(), vocab_sync_vm_vars(), vocabulary_debug_print_hex(), and vocabulary_select_runtime().

Referenced by vm_bootstrap_root_vocabulary().

Here is the call graph for this function:



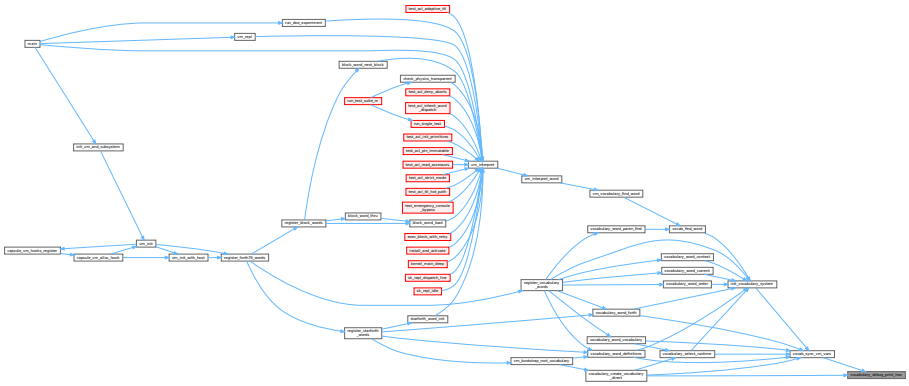
Here is the caller graph for this function:

7.418.1.10 vocabulary_debug_print_hex()

```
static void vocabulary_debug_print_hex (
            uint64_t value ) [static]
```

Referenced by vocab_sync_vm_vars(), and vocabulary_create_vocabulary_direct().

Here is the caller graph for this function:



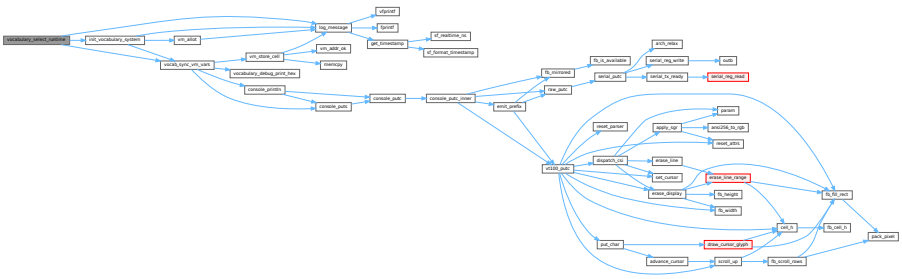
7.418.1.11 vocabulary_select_runtime()

```
static void vocabulary_select_runtime (
            VM * vm )  [static]
```

References VocabularyState::context_vocab, VM::current_executing_entry, init_vocabulary_system(), VM::latest, LOG_DEBUG, log_message(), VM::vocab, and vocab_sync_vm_vars().

Referenced by vocabulary_create_vocabulary_direct(), and vocabulary_word_vocabulary().

Here is the call graph for this function:



Here is the caller graph for this function:

7.418.1.12 vocabulary_word_context()

```
void vocabulary_word_context (
            VM * vm )
```

CONTEXT (– addr) Get CONTEXT variable address.

Returns VM address of cell containing CONTEXT vocabulary pointer

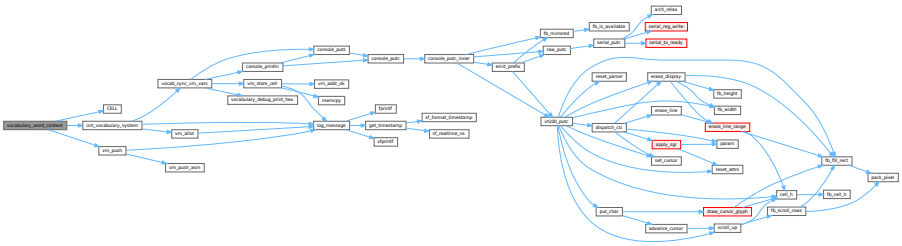
Parameters

vm	Pointer to VM instance

References CELL(), VocabularyState::context_var_addr, init_vocabulary_system(), vm_push(), and VM::vocab.

Referenced by register_vocabulary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.418.1.13 vocabulary_word_current()

```
void vocabulary_word_current (
            VM * vm )
```

CURRENT (– addr) Get CURRENT variable address.

Returns VM address of cell containing CURRENT vocabulary pointer

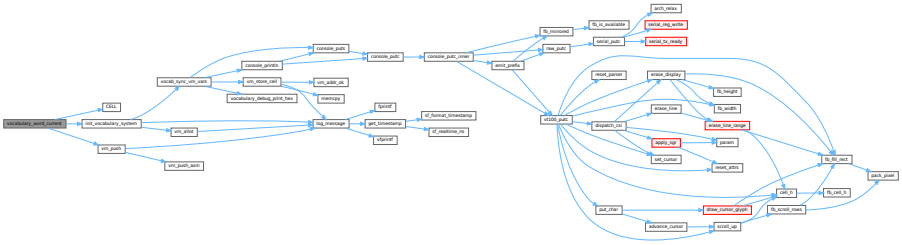
Parameters

vm	Pointer to VM instance

References CELL(), VocabularyState::current_var_addr, init_vocabulary_system(), vm_push(), and VM::vocab.

Referenced by register_vocabulary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.418.1.14 vocabulary_word_definitions()

```
void vocabulary_word_definitions (
            VM * vm )
```

DEFINITIONS (–) Set CURRENT to CONTEXT.

Makes new words be defined in the CONTEXT vocabulary

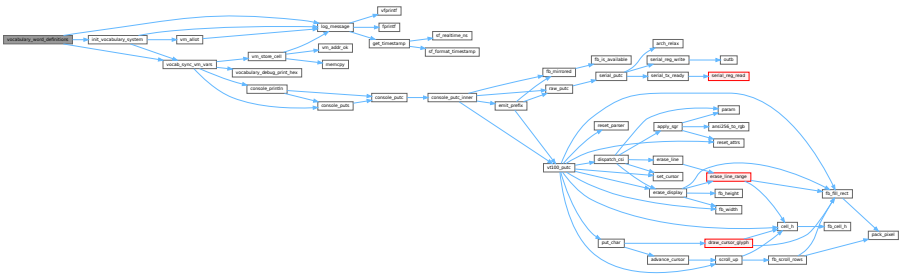
Parameters

vm	Pointer to VM instance

References VocabularyState::context_vocab, VocabularyState::current_vocab, init_vocabulary_system(), LOG_DEBUG, log_message(), VM::vocab, and vocab_sync_vm_vars().

Referenced by register_starforth_words(), register_vocabulary_words(), and vm_bootstrap_root_vocabulary().

Here is the call graph for this function:



Here is the caller graph for this function:

7.418.1.15 vocabulary_word_forth()

```
void vocabulary_word_forth (
            VM * vm )
```

FORTH (–) Select FORTH vocabulary.

Makes FORTH the CONTEXT vocabulary

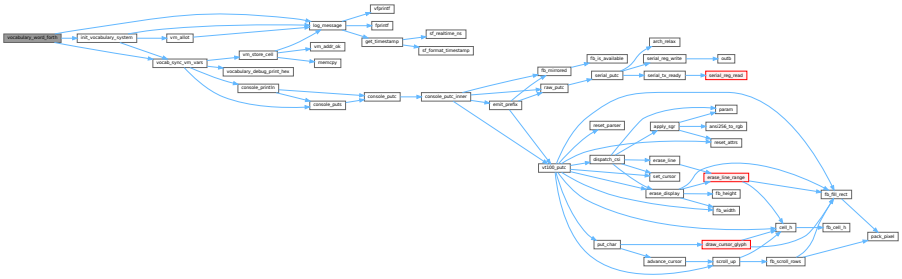
Parameters

vm	Pointer to VM instance

References VocabularyState::context_vocab, VocabularyState::forth_vocab, init_vocabulary_system(), LOG_DEBUG, log_message(), VM::vocab, and vocab_sync_vm_vars().

Referenced by register_starforth_words(), and register_vocabulary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.418.1.16 vocabulary_word_order()

```
void vocabulary_word_order (
            VM * vm )
```

ORDER (–) Display search order.

Shows CONTEXT and FORTH vocabularies plus CURRENT

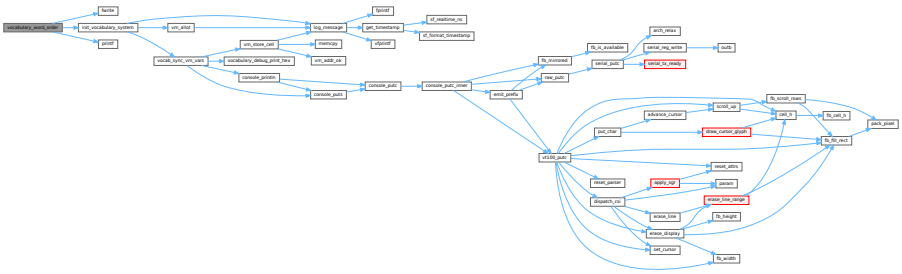
Parameters

vm	Pointer to VM instance

References VocabularyState::context_vocab, VocabularyState::current_vocab, VocabularyState::forth_vocab, fwrite(), init_vocabulary_system(), DictEntry::name, DictEntry::name_len, printf(), stdout, and VM::vocab.

Referenced by register_vocabulary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.418.1.17 vocabulary_word_paren_find()

```
void vocabulary_word_paren_find (
            VM * vm )
```

(FIND) (addr – addr flag) Find word in dictionary

Searches for counted string at addr in CONTEXT then FORTH vocabularies

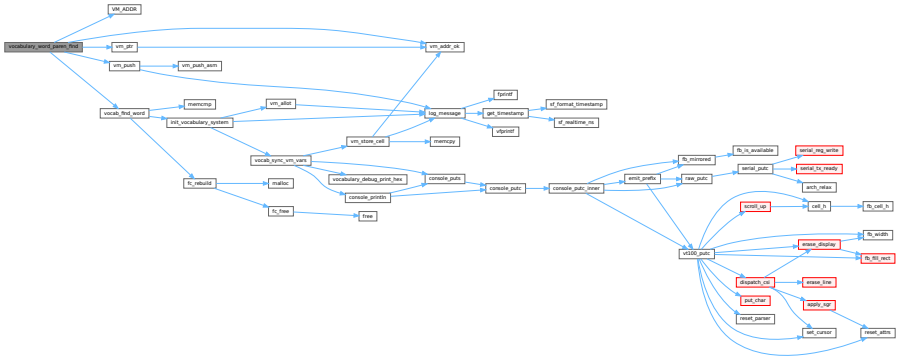
Parameters

vm	Pointer to VM instance

References VM::data_stack, VM::dsp, VM::error, DictEntry::flags, name, VM_ADDR(), vm_addr_ok(), vm_ptr(), vm_push(), vocab_find_word(), and WORD_IMMEDIATE.

Referenced by register_vocabulary_words().

Here is the call graph for this function:



Here is the caller graph for this function:

7.418.1.18 vocabulary_word_vocabulary()

```
void vocabulary_word_vocabulary (
            VM * vm )
```

VOCABULARY (–) Create a new vocabulary.

Creates a vocabulary that when executed makes itself the CONTEXT

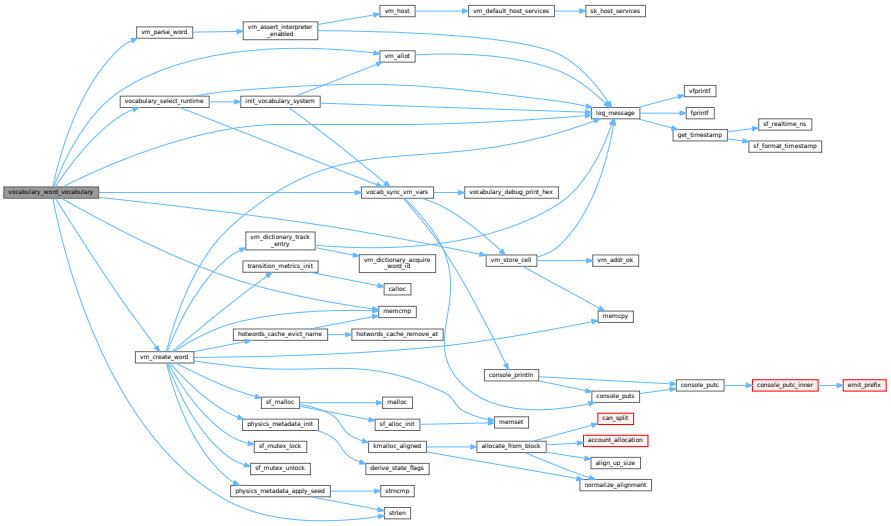
Parameters

vm	Pointer to VM instance

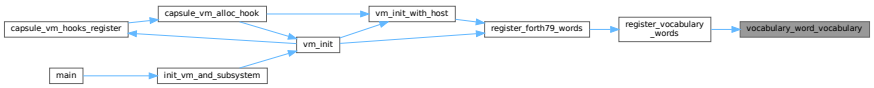
References entry, VM::error, VM::latest, LOG_DEBUG, LOG_ERROR, log_message(), memcmp(), VM::memory, name, strlen(), vm_allot(), vm_create_word(), vm_parse_word(), vm_store_cell(), vocab_sync_vm_vars(), and vocabulary_select_runtime().

Referenced by register_vocabulary_words().

Here is the call graph for this function:



Here is the caller graph for this function:



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