

PRECISION32™ CMSIS AND HAL USER'S GUIDE

1. Introduction

CMSIS is the Cortex Microcontroller Software Interface Standard, and the Hardware Access Layer (HAL) is a defined part of this standard.

The HAL provides an access layer for the SiM3xxxx device registers. The functions and macros are non-blocking and simple; they cannot return error codes, so they are designed to never fail. The HAL is designed to replace the individual bit field accesses of the module with a function name that describes the action the bit is controlling.

Note: HAL functions and macros are not designed to be thread-safe. These routines do not disable interrupts during non-monotonic register modifications.

The HAL is one layer above the hardware and is the only code that accesses the registers directly. More complex firmware systems like a Real Time Operating System (RTOS) or code example call the HAL and CMSIS routines.

Figure 1 shows the Precision32™ firmware layer block diagram.

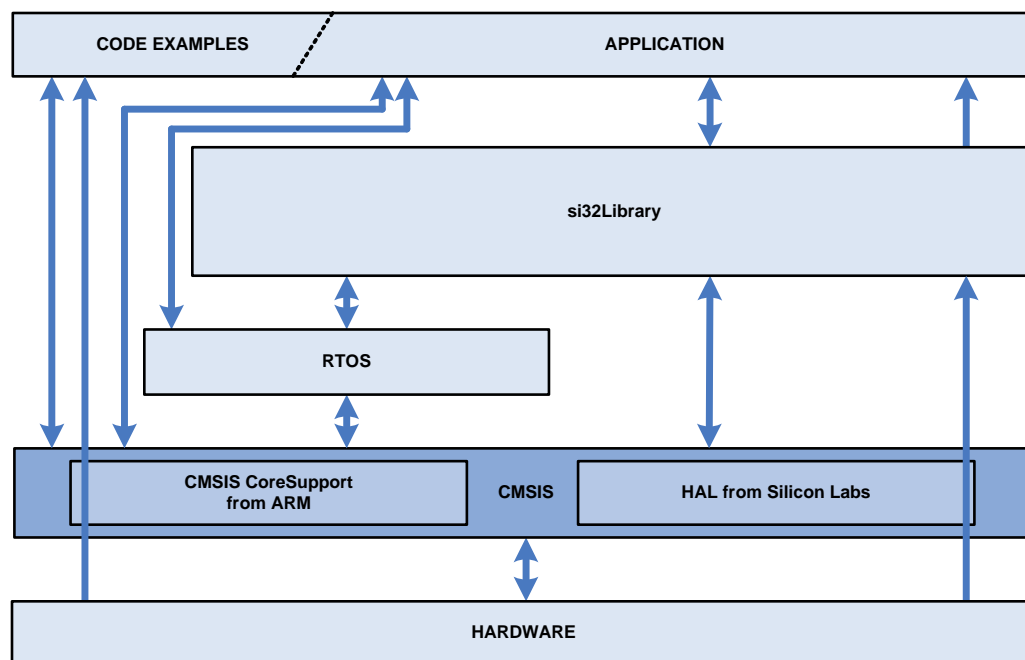


Figure 1. Firmware Layer Block Diagram

2. Relevant Documentation

Precision32 Application Notes are listed on the following website: www.silabs.com/32bit-appnotes.

- AN668: Precision32™ Software Development Kit (SDK) Code Examples Overview
- AN670: Getting Started with the Silicon Labs Precision32™ AppBuilder
- AN672: Precision32™ si32Library Overview
- AN673: Precision32™ Software Development Kit Overview
- AN675: Precision32™ Development Suite Overview

3. Peripheral Memory Organization

Each peripheral exists as a set of registers in memory. Most peripherals start at 0x1000 address blocks in the peripheral memory area starting at address 0x4000_0000. The base pointer of a peripheral points to the starting address of the peripheral, and each register is an offset from the base address. In the case of the USART0 module, the base pointer is SI32_USART_0, and it is assigned an address of 0x4000_0000, since it's the first peripheral in the peripheral memory area.

The registers each take 16 bytes (0x10) of memory: a word each for the register and the SET, CLR, and MSK addresses. These addresses are reserved for registers that do not implement them.

Figure 2 shows the USART0 registers as they appear in memory.

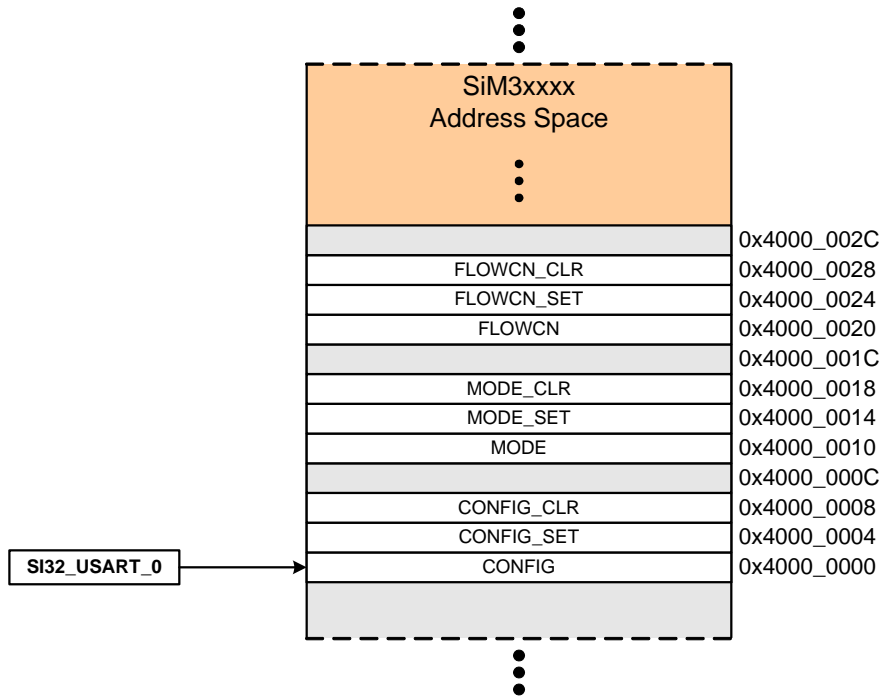


Figure 2. USART0 Registers in Memory

4. HAL Organization

The HAL is organized based on the SiM3xxx peripheral modules. Modules of the same type and revision are exactly the same, so these modules share the same generic description. The individual instances of the modules then instantiate their own copies of the generic description. For example, the HAL implements a USART (module) A (revision) type. This type is then instantiated multiple times for USART0 and USART1, which have their own base pointers.

Each generic module has a *_Registers.h file that contains a module structure comprised of register structures and bit fields properly aligned in memory. The *_Type.h file contains the HAL interface for the module, and the *_Type.c contains the HAL implementation. Some modules will also have a *_Support.h file that contains helpful enumeration definitions. Finally, a device header file named for the device (e.g., sim3u1xx.h) contains base pointer and interrupt vector instantiations for each module on a device.

Figure 3 displays a block diagram showing the relationship of the HAL files.

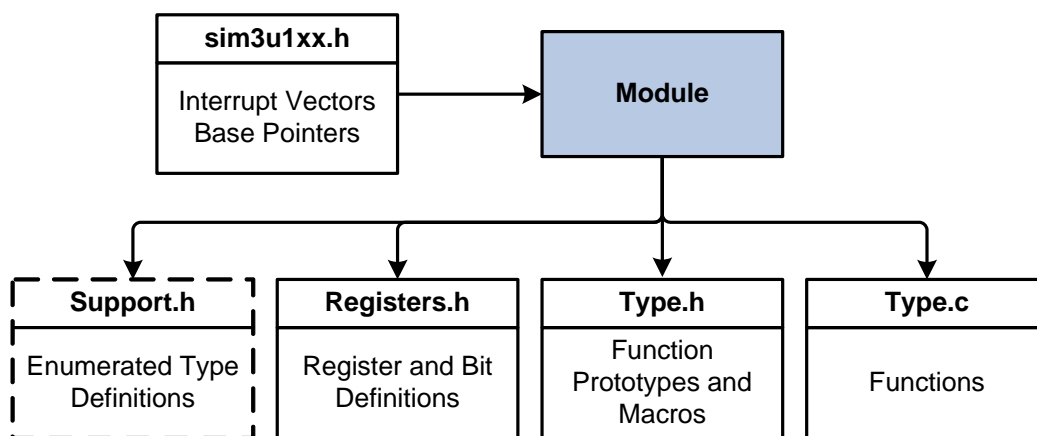


Figure 3. HAL Block Diagram

4.1. USART0 HAL Example

The `sim3u1xx.h` device file contains the USART0 interrupt vector (`USART0_IRQn`) and base pointer information (`SI32_USART_0`). The `SI32_USART_A_Registers.h` file contains the module structure, which includes structures of bit fields for each register. The `SI32_USART_A_Type.h` and `Type.c` files contain routines that access each of these bits.

Figure 4 displays a block diagram showing the relationship of the HAL files for the USART0 module.

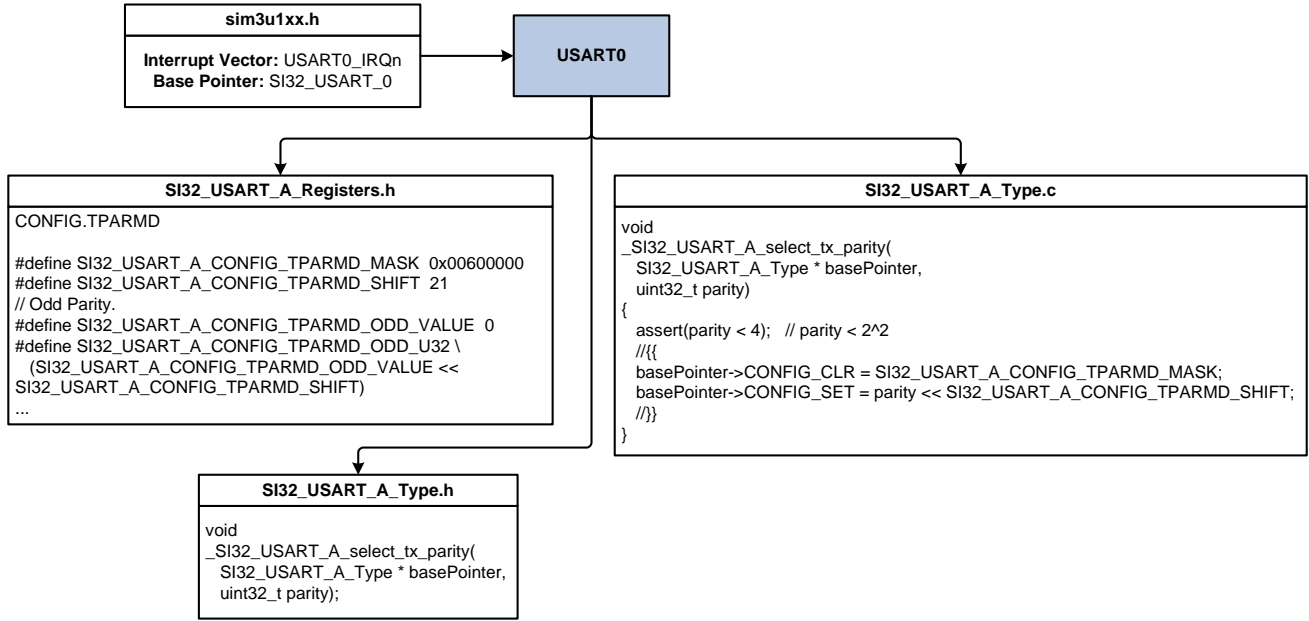


Figure 4. Example USART HAL Block Diagram

Firmware can call the USART0 select tx parity routine using the base pointer defined in `si3mu1xx.h` and the function implemented in `SI32_USART_A_Type.c`:

```
SI32_USART_A_select_tx_parity(SI32_USART_0, parity);
```

Table 1 shows an example set of registers for the USART0 module.

Table 1. Example USART Registers

Register Name	Title	Address (ALL Access)	SET (+0x4)	CLR(+0x8)	MSK (+0xC)
USART0 Registers					
USART0_CONFIG	Module Configuration	0x4000_0000	Y	Y	
USART0_MODE	Module Mode Select	0x4000_0010	Y	Y	
USART0_FLOWCN	Flow Control	0x4000_0020	Y	Y	
USART0_CONTROL	Module Control	0x4000_0030	Y	Y	
USART0_IPDELAY	Inter-Packet Delay	0x4000_0040			
USART0_BAUDRATE	Transmit and Receive Baud Rate	0x4000_0050			
USART0_FIFOCN	FIFO Control	0x4000_0060	Y	Y	
USART0_DATA	FIFO Input/Output Data	0x4000_0070			

Figure 5 illustrates the resulting USART module structure in Registers.h.

```

typedef struct SI32_USART_A_Struct
{
    struct SI32_USART_A_CONFIG_Struct          CONFIG           ; // Base Address + 0x0
    volatile uint32_t                          CONFIG_SET;
    volatile uint32_t                          CONFIG_CLR;
    uint32_t                                    reserved0;
    struct SI32_USART_A_MODE_Struct            MODE           ; // Base Address + 0x10
    volatile uint32_t                          MODE_SET;
    volatile uint32_t                          MODE_CLR;
    uint32_t                                    reserved1;
    struct SI32_USART_A_FLOWCN_Struct          FLOWCN         ; // Base Address + 0x20
    volatile uint32_t                          FLOWCN_SET;
    volatile uint32_t                          FLOWCN_CLR;
    uint32_t                                    reserved2;
    struct SI32_USART_A_CONTROL_Struct         CONTROL        ; // Base Address + 0x30
    volatile uint32_t                          CONTROL_SET;
    volatile uint32_t                          CONTROL_CLR;
    uint32_t                                    reserved3;
    struct SI32_USART_A_IPDELAY_Struct         IPDELAY        ; // Base Address + 0x40
    uint32_t                                    reserved4;
    uint32_t                                    reserved5;
    uint32_t                                    reserved6;
    struct SI32_USART_A_BAUDRATE_Struct        BAUDRATE       ; // Base Address + 0x50
    uint32_t                                    reserved7;
    uint32_t                                    reserved8;
    uint32_t                                    reserved9;
    struct SI32_USART_A_FIFOCN_Struct          FIFOCN         ; // Base Address + 0x60
    volatile uint32_t                          FIFOCN_SET;
    volatile uint32_t                          FIFOCN_CLR;
    uint32_t                                    reserved10;
    struct SI32_USART_A_DATA_Struct           DATA          ; // Base Address + 0x70
    uint32_t                                    reserved11;
    uint32_t                                    reserved12;
    uint32_t                                    reserved13;
} SI32_USART_A_Type;

```

Figure 5. Example USART Module Structure

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Each of the registers has a corresponding structure that defines the bit fields within that register. In addition, registers that implement the clear and set addresses have 32-bit variables defined at the appropriate addresses. Figure 6 shows the CONFIG register structure, which is declared as a part of the USART module structure.

```
struct SI32_USART_A_CONFIG_Struct
{
    union
    {
        struct
        {
            // Receiver Start Enable
            volatile uint32_t RSTRTEN: 1;
            // Receiver Parity Enable
            volatile uint32_t RPAREN: 1;

            ●
            ●
            ●

            // Transmitter Stop Mode
            volatile uint32_t TSTPMD: 2;
            // Transmitter Parity Mode
            volatile uint32_t TPARMD: 2;
            uint32_t reserved2: 1;
            // Transmitter Data Length
            volatile uint32_t TDATLN: 3;
            uint32_t reserved3: 1;

            ●
            ●
            ●

            // Transmitter Synchronous Mode Enable
            volatile uint32_t TSYNCEN: 1;
        };
        volatile uint32_t U32;
    };
};
```

Figure 6. Example USART CONFIG Register Structure

This CONFIG register structure has the TPARMD 2-bit field that controls the transmit parity. The U32 value declared at the bottom of the structure is a union with the bit fields and is an entity that firmware can use to access the entire register at one time.

The HAL Type.c functions and macros can access the entire USART0 CONFIG register:

```
SI32_USART_0->CONFIG.U32 = config;
```

The HAL can also read or write the TPARMD field in the USART0 CONFIG register:

```
parity = SI32_USART_0->CONFIG.TPARMD;
SI32_USART_0->CONFIG_SET = parity << SI32_USART_A_CONFIG_TPARMD_SHIFT;
```

Finally, the HAL can clear the TPARMD field:

```
SI32_USART_0->CONFIG_CLR = SI32_USART_A_CONFIG_TPARMD_MASK;
```

2. Detailed HAL Overview

The HAL for each module consists of *_Registers.h, *_Type.h, and *_Type.c file. Some modules will have an additional *_Support.h file. This section discusses the role of each of these files in detail.

Note: All definitions, functions, and macros in the Silicon Labs HAL start with a **SI32_** shield to prevent any potential conflicts with other code in the system.

2.1. Registers Header File (Registers.h)

The *_Registers.h file creates a memory map of the module's registers and bits. In addition, this file declares detailed definitions to manipulate each bit or field.

2.1.1. Registers

Each of the module's registers are defined as:

```
struct SI32_Peripheral_R_Register_Struct
{
    union
    {
        struct
        {
            volatile uint32_t bitfield0: 4;
            volatile uint32_t bitfield1: 12;
            volatile uint8_t bitfield2;
            volatile uint32_t bitfield3: 4;
            uint32_t reserved0: 4;
        };
        volatile uint32_t U32;
    };
};
```

In this definition, **Peripheral** is the generic name of the peripheral (USART, for example), **R** is the revision (A, B, etc.), and **Register** is the name of the register. The size of the bitfields in a register structure must add up to 32 bits. Any 8- or 16-bit bitfields aligned on 8-bit boundaries are not defined as bitfields but as **uint8_t** or **uint16_t**. Unused bitfield regions are defined as **reserved#**.

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FIFO registers are not defined using any bitfields. If byte accesses are not allowed, the register structure does not include a `uint8_t` definition. The same applies to half-word accesses and the `uint16_t` definition. All FIFOs are accessed from the least significant byte, so there is no explicit access provided for the upper three bytes or the upper half-word.

```
struct SI32_Peripheral_R_Register_Struct
{
    union
    {
        volatile uint8_t U8;
        volatile uint16_t U16;
        volatile uint32_t U32;
    };
};
```

2.1.2. Bitfields

Each of the bitfields of a module has several defines in the `*_Registers.h` file. These defines all have the form **SI32_Module_Revision_Register_Bitfield_DefineType**. The DefineType is:

- **MASK**: a bit mask for the position of the bit or field in the register.
- **SHIFT**: a left-shift value for the position of the bit or field in the register.
- **Enumeration_VALUE or Enumeration_U32**: These enumerations define every valid value of the bit or field. The enumerations also include a U32 version that the HAL routines can write to entire register using the defined **SHIFT** value.

For example, with the IPRDY bit in the EPCONTROL register (bit 0) of the USBEP module:

```
#define SI32_USBEP_A_EPCONTROL_IPRDYI_MASK 0x00000001
#define SI32_USBEP_A_EPCONTROL_IPRDYI_SHIFT 0
// The packet has been sent or there is an open FIFO slot.
#define SI32_USBEP_A_EPCONTROL_IPRDYI_NOT_SET_VALUE 0
#define SI32_USBEP_A_EPCONTROL_IPRDYI_NOT_SET_U32 \
    (SI32_USBEP_A_EPCONTROL_IPRDYI_NOT_SET_VALUE <<
     SI32_USBEP_A_EPCONTROL_IPRDYI_SHIFT)
// A packet is loaded in the FIFO.
#define SI32_USBEP_A_EPCONTROL_IPRDYI_SET_VALUE 1
#define SI32_USBEP_A_EPCONTROL_IPRDYI_SET_U32 \
    (SI32_USBEP_A_EPCONTROL_IPRDYI_SET_VALUE <<
     SI32_USBEP_A_EPCONTROL_IPRDYI_SHIFT)
```

The **NOT_SET** and **SET** definitions are the enumerations for this bit. The **VALUE** definitions set the value of each valid bit value, and the **U32** definitions are the appropriate write value for the bit when writing to entire register.

2.1.2.1. Using the MASK Definition

The HAL uses **MASK** definitions to clear or set bitfields in registers that support clear and set addresses. In these cases, the address can be set equal to the mask directly to manipulate the bitfield. For example:

```
void
_SI32_USART_A_disable_rx_start_bit(SI32_USART_A_Type * basePointer)
{
    //{{
    basePointer->CONFIG_CLR = SI32_USART_A_CONFIG_RSTRTEN_MASK;
    //}}
}
```

2.1.2.2. Using the SHIFT Definition

The HAL uses the **SHIFT** definition when a field value is passed to a routine. This allows the calling code to pass in a raw value, and the HAL can handle the actual placement of the bitfield in the register. For example:

```
void
_SI32_USART_A_select_rx_stop_bits(SI32_USART_A_Type * basePointer,
    SI32_USART_A_STOP_BITS_Enum_Type bits)
{
    assert(bits < 4);    // bits < 2^2
    //{{
    basePointer->CONFIG_CLR = SI32_USART_A_CONFIG_RSTPMD_MASK;
    basePointer->CONFIG_SET = bits << SI32_USART_A_CONFIG_RSTPMD_SHIFT;
    //}}
}
```

2.1.2.3. Using the Enumeration Definitions

The HAL uses the U32 enumeration definitions for the clear and set addresses or when accessing the entire register. The HAL does not use the value definitions themselves whenever possible, since accessing a single bitfield in a register is inefficient. For example:

```
void
_SI32_USART_A_enable_rx_error_interrupts(SI32_USART_A_Type *
    basePointer)
{
    //{{
    basePointer->CONTROL_SET = SI32_USART_A_CONTROL_RERIEN_ENABLED_U32;
    //}}
}
```

2.1.3. Modules

A module structure at the end of each *_Registers.h file aggregates all of the peripherals's registers and spaces them from the peripheral base pointer address:

```
typedef struct SI32_Peripheral_R_Struct
{
    struct SI32_PERIPHERAL_R_REGNAME1_Struct    Register1;
    uint32                                     Register1_SET;
    uint32                                     Register1_CLR;
    uint32_t                                  reserved0;
    struct SI32_Peripheral_R_Register2_Struct  Register2;
    uint32_t                                  reserved1;
    uint32_t                                  reserved2;
    uint32_t                                  reserved3;
} SI32_Peripheral_R_Type;
```

The struct is assumed to start at offset 0x0 from the peripheral's base pointer. In this example, **Register1** is at address 0x0 and supports clear and set addresses, so **Register1_SET** is located at 0x04 and **Register1_CLR** is located at 0x08. There is no mask address defined for this register, so the corresponding address 0x0C is simply marked as **reserved#**. **Register2** has no set, clear, or mask addresses, so these offsets are also defined as **reserved#**.

This struct is never allocated as a variable; it is simply used as offsets from a base pointer.

2.2. Type Header (Type.h) and Code (Type.c) Files

The *_Type.h file creates the interface definition of the module. This file includes function prototypes and macro definitions for each of the HAL routines. Including this file in a source file means that file now has access to all of the HAL routines for a module.

The *_Type.c file is the implementation of the module HAL functions. This file includes all of the function declarations for the prototypes in the *_Type.h file.

Each of the routines starts with the **SI32_** shield and the module name. The descriptive name of the function then follows. For example, the routine to set the IPRDYI bit in the USBEP module is:

```
void _SI32_USBEP_A_set_in_packet_ready(SI32_USBEP_A_Type * basePointer);
```

2.2.1. Function Naming

The function names for the HAL follow a set of guidelines to make them consistent and predictable across modules:

- Names are in lower case, including acronyms: **read_nss_pin**.
- Do not use abbreviations, with one exception being **tx** for transmit and **rx** for receive.
- Separate words using underscores.
- Use **enable_module** and **disable_module** for bits that control the whole module.
- Use **reset_module** for bits that reset the whole module.
- Use **select** for functions that are selecting an item that is mutually exclusive from other options. This is common with settings that involve multiple bitfields.
- Use **enter_mode_description_mode** and **exit_mode_description_mode** for non-mutually exclusive items, and all **enter_mode** functions must have an **exit_mode** counterpart. For example, to enter the IrDA mode in the USART module: **enter_rx_irda_mode**.
- Use **set**, **get**, and **clear** for bits and registers. For example: **set_parity_even**, **get_status**, **clear_carry_flag**.
- Use numerical value for numbers. For example: **set_fifo_threshold_1**, **set_fifo_threshold_2**.
- Use **read** and **write** when manipulating data or pins. For example: **read_fifo**, **write_fifo**, **read_nss_pin**.
- Use **start** and **stop** for things that run, like oscillators and timers.
- Use **enable**, **disable**, “**is enabled**”, “**is pending**”, and **clear** for interrupts. For example: **enable_overrun_interrupt**, **disable_overrun_interrupt**, **is_overrun_interrupt_pending**, and **clear_overrun_interrupt**.
- Use **has** for events that have flags but do not cause interrupts. For example: **has_buffer_overflow_occurred**.
- For debug bits, use the **enable_stall_in_debug_mode** and **disable_stall_in_debug_mode** routine names.
- Functions referring to the peripheral should always use the **module** keyword.

2.2.2. Required Functions

Each module must have the following functions:

- **initialize**
- **enable_module** whenever a corresponding bit exists
- **disable_module** whenever a corresponding bit exists
- **reset_module** whenever a corresponding bit exists
- A **write_<register>** function for each register
- A **read_<register>** function for each register
- **enable_<interrupt>_interrupt** for each interrupt
- **disable_<interrupt>_interrupt** for each interrupt
- **is_<interrupt>_interrupt_enabled** for each interrupt
- **is_<interrupt>_interrupt_pending** for each interrupt
- **clear_<interrupt>_interrupt** for each interrupt

The initialize function takes all writable registers as parameters and copies them into the registers. This function is knowledgeable about order, whenever order matters.

The write register functions take the register value as a parameter and copies it into the register. The read register functions return the value of the register.

2.2.3. Return and Parameter Types

Return types must be one of the following:

- void
- bool
- uint32_t
- uint16_t
- uint8_t
- Enumeration Type defined for the module in *_Support.h

When returning a bool value, the functions explicitly typecast the return value as a bool.

Parameters must be one of the following:

- uint32_t
- uint16_t
- uint8_t
- bool
- Enumeration Type defined for the module in *_Support.h

The functions use these types for all parameters used to carry values that are smaller than 32 bits but are passed wide for efficiency:

- **wide8_t**: value can be converted to signed 8-bit number without loss of precision
- **uwide8_t**: value can be converted to unsigned 8-bit number without loss of precision
- **wide16_t**: value can be converted to signed 16-bit number without loss of precision
- **uwide_16_t**: value can be converted to unsigned 16-bit number without loss of precision

These types indicate to the calling code that, while the parameter is passed wide, the actual value will be stored narrow in the indicated storage format.

2.2.4. Function Implementation Guidelines

Functions do not block or return error codes. This serves several purposes:

1. This eliminates the need for the HAL to validate parameters, beyond debug bounds assertions.
2. This eliminates the need for the calling code to validate the return codes.

If a function could not be safely implemented without polling, such as enabling an external oscillator, then it is not a HAL function. This functionality is left to a higher level of firmware, like the si32Library or AppBuilder.

Functions are not allowed to allocate memory locally or use global variables. As a result, the functions will not be able to maintain state separate from what is maintained in the registers themselves.

Functions are as efficient as possible. For set or clear operations, functions use the set or clear addresses, where applicable. Read-modify-write operations are used only when absolutely necessary when clearing a field before setting it to a new value causes an issue, like undesired pin transitions.

All functions have four or fewer parameters whenever possible, including the base pointer to the module.

2.3. Optional Support Files (Support.h)

The *_Support.h files are optional for a module and share the same basic template as *_Type.h files. These files contain helpful enumerations for modules and any other support code necessary. The format for these enumerations is:

```
typedef enum SI32_Peripheral_Struct
{
    SI32_Peripheral_EnumName1 = 0,
    SI32_Peripheral_EnumName2 = 1,
    ...
} SI32_Peripheral_Enum_Type;
```

The enumerations provide set values for a function parameter to eliminate the chance of using an invalid value and to make code more readable. For example:

```
typedef enum SI32_RSTSRC_Struct
{
    SI32_RSTSRC_PIN_RESET = 0,
    SI32_RSTSRC_POWER_ON_RESET = 1,
    SI32_RSTSRC_VDD_MONITOR = 2,
    ...
} SI32_RSTSRC_Enum_Type;
```

The **get_last_reset_source** routine can then return a value of this enumeration type:

```
SI32_RSTSRC_Enum_Type _SI32_RSTSRC_A_get_last_reset_source(
    SI32_RSTSRC_A_Type * basePointer);
```

Firmware can then decode the return value of this routine using the enumeration values defined in SI32_RSTSRC_A_Support.h to create readable and less error-prone code.

2.4. HAL Startup Code

The si32Hal startup implementation differs from the CMSIS recommendation in order to support multiple tool chains. Each individual application has explicit control over all of its memory model, including the stack, heap, RAM, retention RAM, and EMIF. The symbols used to define the base and size of these memory areas is available for use by the application without duplication.

The HAL uses tool chain-specific linker control files in the **si32-x.y\si32Hal\device** directory to specify these ranges. These files are:

- **GCC/Precision32:** linker_DeviceFamily_p32.ld
- **ARM:** linker_DeviceFamily_arm.sct
- **IAR:** linker_DeviceFamily_iar.icf

The code examples also provide basic linker control files that are sufficient for many applications. For cases where these linker files are not sufficient, the application developer should use application-specific linker files.

3. Performance

The HAL implements both macros and functions for most routines. This allows firmware layers that call the HAL to choose between the faster performance of macros or the smaller footprint of functions. For the routines that do not have an implemented macro, a macro still exists, but it just calls the function.

The functions and macros have the same parameters and names, but functions have an underscore prefix. For example, the function for setting the USART transmit parity is:

```
_SI32_USART_A_select_tx_parity(SI32_USART_0, parity);
```

The macro for the same routine is:

```
SI32_USART_A_select_tx_parity(SI32_USART_0, parity);
```

4. Revisions

Each version of the HAL sits in a separate folder. The path of these is **C:\SiLabs\32bit\si32\si32-x.y**, where **x** is the primary HAL version and **y** is the secondary HAL version. Each time a new version of the HAL is installed, it will leave all previous versions to eliminate the chance of a new install breaking a working firmware project.

In addition, any deprecated functions will remain a part of the HAL. These functions will either remain unchanged or call the new version to prevent the need to modify firmware when migrating to a newer version of the HAL.

5. Code Examples

Each version of the HAL includes stand-alone code examples for the device modules that use the macro routines by default. These examples can be found in **C:\SiLabs\32bit\si32-x.y\Examples** after installing the Precision32 IDE.

6. The HAL and AppBuilder

The Silicon Labs AppBuilder program uses HAL macros when configuring peripherals. The AppBuilder project options can select between different versions of the HAL.

7. Detailed Documentation

The detailed Silicon Labs CMSIS documentation can be found in the si32Hal Windows help file (si32Hal.chm). The documentation includes the Cortex-M3 Core Register Definitions, Core Function Interface, and Core Instruction Interface, as well as the SiM3xxxx HAL.

The si32Hal file shown in Figure 7 is installed in **C:\SiLabs\32bit\si32-x.y\Documentation** after installing the Precision32 software package from www.silabs.com/32bit-software.

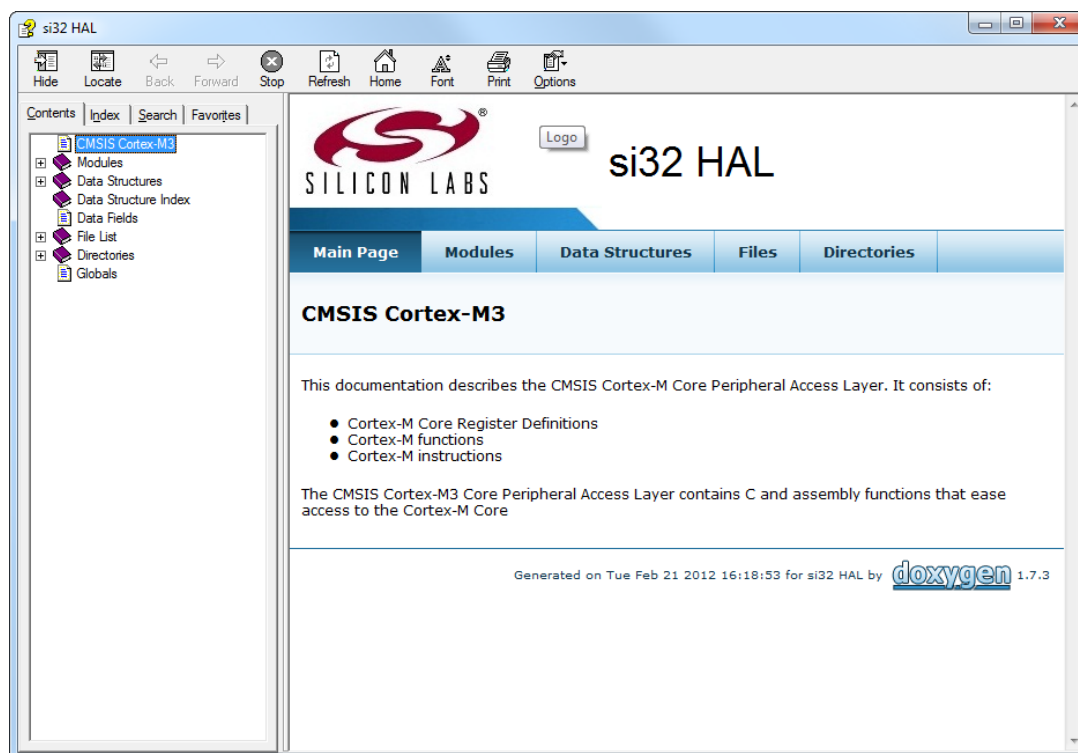


Figure 7. Silicon Labs HAL and CMSIS Documentation

DOCUMENT CHANGE LIST

Revision 0.1 to Revision 0.2

- Updated Figure 1.
- Updated the name of the HAL help file to si32Hal.chm.
- Added Section 2.

NOTES:

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