ASF4 API Reference Manual

ASF4 API Reference Manual

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1. Advanced Software Framework Version 4 (ASF4) Introduction and Context

This chapter starts with an overview of the features and objectives of ASF4. The context in the larger SW/Tools ecosystem is defined, giving a relation between the ASF4, START, and the IDE. A high-level work-flow overview is presented and documentation resources are described, to give insight into which references to use for what.

1.1 Introduction to ASF4

ASF4 is a collection of software components such as peripheral drivers, middleware, and software applications provided by Microchip. The framework supports the Microchip's SAM family of microcontrollers.

Unlike older versions of the software framework, version 4 is designed to work together with Atmel START. Atmel START is a web-based user interface, which allows the users to configure code according to their needs. The configuration is input to START's code generator, resulting in an optimal code implementing exactly the functionality configured by the user. The generated C-code is exported from START and into the user's development environment of choice for modification and compilation.

The tight integration with Atmel START means that the ASF4 code is more tailored to the users' specification than before. For instance, instead of using C preprocessor conditional expressions to enable/disable code blocks, disabled code blocks can be entirely removed from the project source, which results in cleaner and easier to read code. The integration into Atmel START means that software configuration is done in a much more user-friendly environment and the only configuration information loaded on the device is the raw peripheral register content, which makes the firmware image much more compact. Code generation results in smaller and faster code compared to previous versions of ASF.

ASF4 has many improvements compared to previous ASF versions:

- Common set of software interfaces across different devices
- Smaller code size
- Easier to use

Common set of software interfaces across different devices

ASF4 has a set of fully hardware-abstracted interfaces as a part of the core architecture. These interfaces are use-case driven and supports only a subset of the functionality offered by the hardware. One hardware module is typically supported by multiple interfaces, and START is used to select which interfaces to be included in his project.

Providing common interfaces that are completely abstracted from the hardware makes them easier to use in middleware and software stacks since it is not necessary to add architecture specific code.

Smaller code size

Having START generate the code exactly matching the required configuration reduces the code size according to drivers in previous versions of ASF. Full featured and generic drivers make it hard for the driver developer to make optimal decisions for often mutually exclusive design parameters, such as like high speed, low power, low code size, ease of use, and advanced feature support. Such drivers often miss the target in many applications because some of the parameters are wrongly tuned for the application in mind. However, limiting the scope of the driver to a specific use-case, ASF4 drivers are able to get the balance between these parameters right.

Use-case drivers limit the driver functionality to the functionality required by the user, which usually is a subset of the full functionality provided by the peripheral. The use-cases can also tailor the driver to work in a specific environment such as:

- Barebone synchronous, optimized to be used on the "bare metal" (OS less application)
- RTOS asynchronous, optimized to be used with an RTOS

See 1.5 ASFv4 vs ASFv3 Benchmark for more details on improved code efficiency.

Easier to use
ASF4 is easy to use due to:

- Graphical configuration of the system through Atmel START
- Use-case drivers offering only the functionality required by the user's application, reducing the configuration complexity compared to full-featured generic drivers. ASF4 provides multiple use-case drivers for each peripheral, each with a specific application target.

1.2 ASF4: Atmel START, Software Content and IDEs

This section gives an overview of ASF4 within the larger context of the SAM Tools ecosystem.

Getting Started Topics

Video: AVR and SAM Tools ecosystem overview

1.2.1 Atmel START

Atmel START is a web-based software configuration tool, for various software frameworks, which helps you get started with MCU development. Starting from either a new project or an example project, Atmel START allows you to select and configure software components (from **ASF4** and **AVR Code**), such as drivers and middleware to tailor your embedded application in a usable and optimized manner. Once an optimized software configuration is done, you can download the generated code project and open it in the

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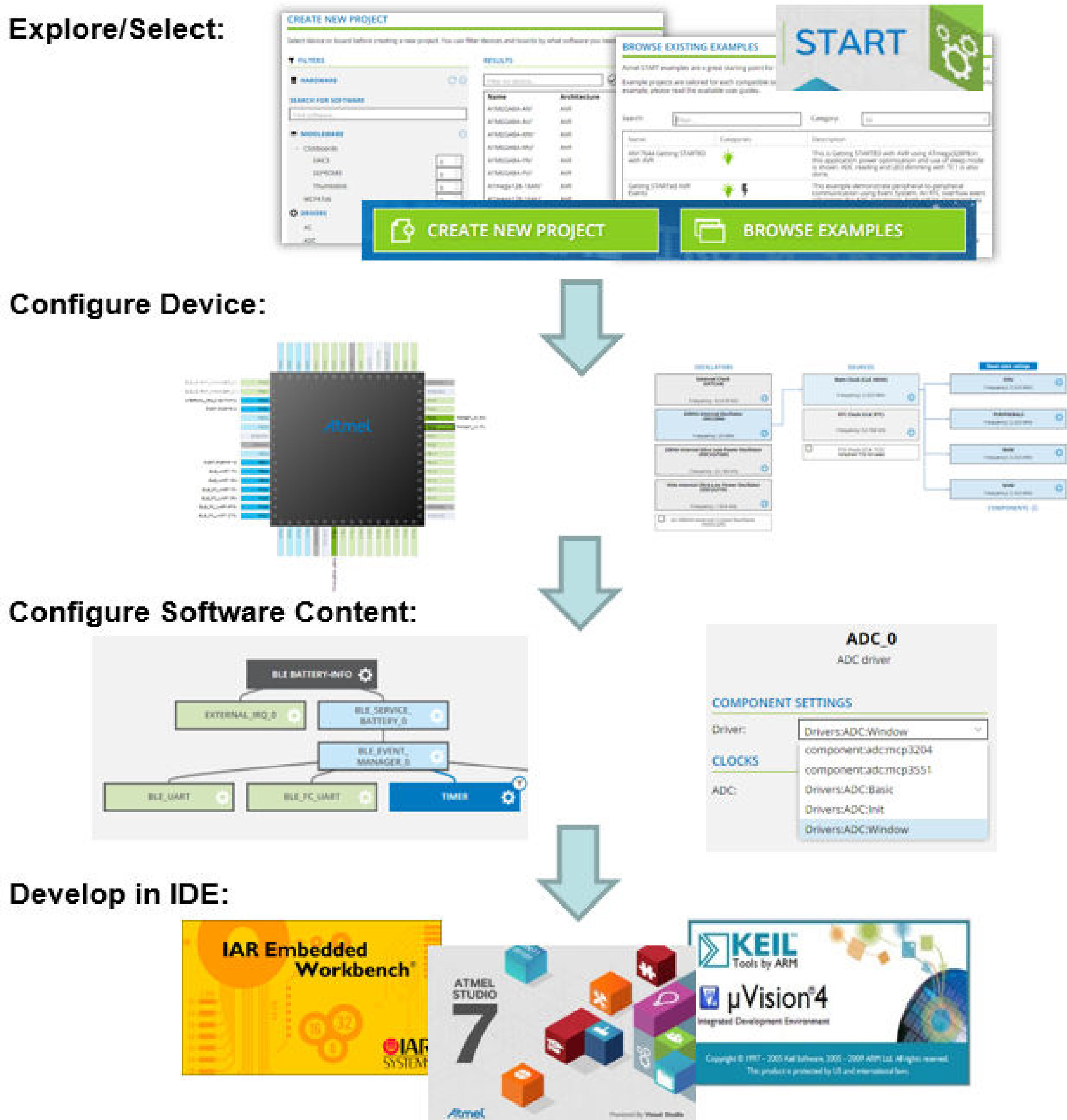
IDE of your choice, including Studio 7, IAR Embedded Workbench®, Keil® µVision®, or simply generate a makefile.

Atmel START enables you to:

- Get help with selecting an MCU, based on both software and hardware requirements
- Find and develop examples for your board
- Configure drivers, middleware, and example projects
- Get help with setting up a valid PINMUX layout
- Configure system clock settings

Figure 1-1. Relation between START, Software Content, and IDEs



1.2.2 Software Content (Drivers and Middlewares)

Advanced Software Framework(ASF)
ASF, the Advanced Software Framework, provides a rich set of proven drivers and code modules developed by experts to reduce customer design-time. It simplifies the usage of microcontrollers by providing an abstraction to the hardware through drivers and high-value middlewares. ASF is a free and open-source code library designed to be used for evaluation, prototyping, design, and production phases.

ASF4, supporting the SAM product line, is the fourth major generation of ASF. **c** represents a complete re-design and -implementation of the whole framework, to improve the memory footprint, code performance, as well as to better integrate with the Atmel START web user interface. ASF4 must be used in conjunction with Atmel START, which replaces the ASF Wizard of ASF2 and 3.

Microchip.com: ASF Product Page

AVR Code
AVR Code, supporting the AVR product line, is a simple firmware framework for AVR 8-bit MCUs, equivalent to Foundation Services, which supports 8- and 16-bit **PIC** MCUs. **AVR Code** is optimized for code-size and -speed, as well as simplicity and readability of code. AVR Code is configured by Atmel START.

1.2.3 Integrated Development Environment (IDE)

An **IDE** (Integrated Development Environment) is used to develop an application (or further develop an example application) based on the software components, such as drivers and middlewares, configured in and exported from Atmel START. Atmel START supports a range of IDEs, including Studio 7, IAR Embedded Workbench®, Keil® µVision®.

Atmel Studio 7 is the integrated development platform (IDP) for developing and debugging all AVR and SAM microcontroller applications. The Atmel Studio 7 IDP gives you a seamless and easy-to-use environment to write, build, and debug your applications written in C/C++ or assembly code. It also connects seamlessly to the debuggers, programmers, and development kits that support AVR and SAM devices. The development experience between Atmel START and Studio 7 has been optimized. Iterative development of START-based projects in Studio 7 is supported through re-configure and merge functionality.

This Getting Started training for Atmel Studio 7 will guide you through all the major features of the IDE. It is designed as a video series with accompanying hands-on. Each section starts with a video, which covers that section.

1.3 Quick Start and Workflow Overview

ASF4 is a software library consisting of peripheral drivers and example applications. The Atmel START web page (http://start.atmel.com) is used to select which software modules are needed in the user's application, and to configure these modules according to the user's needs. When using the **Export Project** screen, the corresponding generated C-code project can be downloaded to the user's computer and imported into an IDE of the user’s choice, such as Atmel Studio 7, IAR™ Embedded Workbench, or Keil µVision. The IDE is used to modify, compile, program, and debug the project.

Installation
ASF4 is configured using the Atmel START web page (http://start.atmel.com), and the configured application is thereafter downloaded to the user’s computer as a zip-file. ASF4 does not need to install

any components locally. The user will normally want to have an IDE or stand-alone toolchain installed on their computer, so the user can compile, program, and debug the downloaded code.

Workflow
The workflow is quite straightforward, starting with either the **Create New Project** screen or the **Browse Existing Examples**.

Starting with the **Browse Existing Examples** screen:

The Atmel START examples were designed to be used as a starting point for development. Efficient filtering mechanisms are therefore available to help developers find the projects closest to their requirements, giving them high quality, production ready code that will work "out of the box". However, these example projects are also easy to modify as the software configuration can be extended by changing the pinout (**PINMUX** screen) or adding additional drivers or middlewares (project **DASHBOARD**). For example, adding support for an extra timer or even adding a BLE interface. See the Configuration Screens section of the Atmel START user manual to understand project configuration options using Atmel START. It is also possible to create or re-configure Atmel START projects, directly from Atmel Studio 7 (**File** > **New** > **Atmel Start project**).

Starting with the **Create New Project** screen:

This screen was designed to help select an MCU for your project, based on both software and hardware requirements.

1. Filter MCUs by requirements before starting a project.
2. Add components to your project, i.e. peripheral drivers and middlewares.
3. Configure each component.
4. Export the project and add it into one of the supported IDEs for further development.

The role of the IDE and Running the Code
Once the user is happy with the software configuration, the project is exported as a zip-file to the developer's IDE of choice. See Using Atmel Start Output in External Tools in the Atmel START user manual for instructions about how to do this, as well as present a list of supported IDEs. ASF4/Atmel START does not need to install any components on your local computer.

An IDE is used to develop the code required to extend the functionality of the example project into the final product, as well as compile, program, and debug the downloaded code. A downloaded application is ready to compile. Refer to your IDE documentation for instructions on compiling the code. The behavior of the downloaded code is application-dependent:

- Configuring a "New project" generates a main()-function initializing all drivers, but no other operations
- Configuring an "Example project" generates a main()-function performing more complex operations

1.4 Documentation Resources

The major sources of documentation are **Getting Started projects**, the **Atmel START User Manual**, as well as **reference manuals** for ASF4 and Foundation Services framework content.

Getting Started projects
How to use the different pieces of the system to get them work together, for example, how to use Atmel START efficiently with an IDE, such as Atmel Studio 7, in order to build your embedded application.

Getting Started projects have training materials like video series and/or hands-on training manuals, linked to the project user guides. The example project itself often represents the goal or end-point of the related hands-on or video training material. Training materials will give you a workflow overview of how the Atmel START and your IDE work together.

- Open Browse Examples, click the "Category" drop-down menu, and select the “Getting started” category
- Links to training materials are found in the example project user-guides, which can be accessed without opening the project
- See the Atmel START User Manual

START User Manual

- What is Atmel START?
- Quick Start and Workflow Overview
  - Using Getting Started projects, finding/reconfiguring relevant example projects
  - Create New Project, selecting an MCU based on both software and hardware project requirements
- How to use the various Atmel START configuration screens:
  - Dashboard
  - PINMUX
  - Event System Configurator
  - QTouch® Configurator
- How to export projects to various IDEs as:
  - Atmel Studio 7
  - IAR Embedded Workbench
  - Keil µVision
  - Makefile
- Content overview, software that Atmel START can configure and generate:
  - ASF4
  - Foundation Services

ASF4 API Reference Manual

- ASF4 Software Architecture
- Driver implementation and Design conventions
- API reference

AVR Code API Reference Manual

- Foundation Services Software Architecture
- Driver implementation and Design conventions
- API reference

1.5 ASFv4 vs ASFv3 Benchmark

ASFv4 vs ASFv3 benchmark comparison.

One of the best ways to show how the changes in ASFv4 have improved the drivers is to show some benchmark numbers. These benchmarks compare applications are written in ASFv4 code with the same application written in ASFv3 code. The behavior of these example applications is exactly the same. In all these examples the default linker script has been used which set aside 8192 bytes of SRAM for a stack. The stack usage has been removed from the SRAM numbers.

Table 1-1. ASFv4 vs. ASFv3 SPI Master Driver Memory Size Benchmark

	FLASH		SRAM	
	Full code	Driver code	Full code	Driver code
ASFv3	4328	2916	184 + STACK	120
ASFv4	2908	1916	208 + STACK	64

Table 1-2. ASFv4 vs. ASFv3 SPI Master Driver Throughput

	Bytes/s
ASFv3	54078
ASFv4	82987

Compiled in Atmel Studio 7 (7.0.582) with GCC 4.9.3, with default settings except for optimization level -O3 and using the C lib specification nano-lib.

Hardware used is a SAMD21J18A. Both the CPU, buses, and SERCOM module are running at 8 MHz.

The example used for this benchmark initializes the device (clock setup, pin multiplexing, interrupts), set up a SERCOM instance for SPI Master mode with 1000,000 baud rate, enables it, and writes "Hello World!" on the SPI bus. "Full code" is the memory usage for the whole application loaded on the device while "driver code" is the memory usage of the SPI driver-specific code components. Because many different drivers support the same hardware in ASFv4, a lookup table is used to figure out which interrupt handler to execute for a given peripheral instance. On Cortex M0+ based devices this table is 112 bytes, and will not grow with the size of the project, this is the reason for ASFv4 slightly higher total (full code) SRAM usage in this small example code.

Table 1-3. ASFv4 vs. ASFv3 USART Driver Memory Size Benchmark

	FLASH		SRAM	
	Full code	Driver code	Full code	Driver code
ASFv3	4940	3376	168 + STACK	80
ASFv4	2684	1756	232 + STACK	88

Compiled in Atmel Studio 7 (7.0.582) with GCC 4.9.3, and with default settings except for optimization level -Os, and using the C lib specification nano-lib.

The code was compiled for SAM D21.

The example used for this benchmark initializes the device (clock setup, pin multiplexing, interrupts), set up a SERCOM instance for USART mode with 9600 baud rate, enables it, and writes "Hello World!" on the USART bus. "Full code" is the memory usage for the whole application loaded on the device while "driver code" is the memory usage of the USART driver-specific code components. It's worth noting that the same 112 bytes interrupt handler lookup table is used in this example, and the USART driver includes a 16 bytes ring buffer for data reception to make it much less likely to lose data.

2. Software Architecture

This chapter documents the architecture and high-level design of ASF4. The ASF4 driver architecture (describes the ASF4 drivers) is built of three layers; HAL, HPL, and HRI. ASF4 has drivers which are designed to support Use-Cases, e.g. Timer and PWM drivers are use-cases of a Timer-Counter (TC) peripheral. Driver Variants are different driver implementation architectures, such the Synchronous-, Asynchronous-, DMA-, and RTOS-Drivers. Driver Types are; Peripheral-, Utility-, and Middleware-drivers.

The ASF4 project folder structure is described, followed by a walk-through of the system initialization sequence, which relies largely on Root Level Files in the project. The following sections describe in more detail elements within the project, namely Examples Folder, Pin Configuration, and a description of START configuration and the Config Folder.

More details are then given about the implementation of the three driver layers, respectively the Hardware Abstraction Layer (HAL), the Hardware Proxy Layer (HPL), and the Hardware Register Interface (HRI). For some of the drivers, there is an I/O system on top of the HAL interface, which disconnects middleware from any driver dependency because the middleware only needs to rely on the interface that the I/O system provides. Mechanisms for RTOS support are described. The implementations of various driver variants, such as Synchronous-, Asynchronous-, DMA-, and RTOS-Drivers, are described in the following chapter in Section Driver Implementation.

2.1 Peripheral Driver - Architecture Overview

Peripheral driver structure
A driver is designed to support a use-case (of a peripheral). For example, instead of one timer-counter driver, the ASF4 has drivers for PWM, timer, and input-capture.

Use-case drivers can sometimes support various peripherals, for example, a timer could run on the TC, TCC, or RTC. These are all peripherals that provide the functionality of the use-case, in this case, a counter and a compare IRQ. For example: On Microchip's M0+ family, the USART, SPI, and I^2C are use-cases of the SERCOM peripheral.

The ASF4 driver architecture is built up of three layers:

- Hardware Abstraction Layer – HAL
- Hardware Proxy Layer – HPL
- Hardware Register Interface – HRI

Users are intended to interact with the HAL layer, which is hardware agnostic and can be used on a wide range of devices and platforms. The three layers are largely transparent to the user, though all are available. Each layer is organized into folders in the project structure, each containing files with API associated with the respective layer.

HAL folder (Hardware Abstraction Layer)
This folder contains hardware independent/agnostic API, for hardware with the same kind of functionality. The interface, which most users will use, is in the HAL layer.
Naming convention: HAL functions start with **usecase_**, for example, **adc_**dma_driver.

In the `hal` folder, there are four sub-folders. The `include` and the `src` folders contain the definition of the HAL interfaces and implementation of the hardware agnostic part of the driver. The `documentation`

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folder contains the documentation of each driver as displayed in the Atmel START help text. The `utils` folder contains API definitions and implementations of the utility function drivers.

HPL folder (Hardware Proxy Layer)
Hardware-aware functionality is needed by the HAL, is implemented in the hardware-aware HPL level, keeping the HAL level hardware agnostic. There will be a peripheral configuration file associated with the HPL layer.
Naming convention: HPL functions start with **_usecase_**, for example: `_usart_async_init()`

The `hpl` folder has multiple subfolders - one folder per hardware module supported by ASF4. These folders contain .h and .c files implementing the HPL layer.

HRI folder (Hardware Register Interface)
HRI level functions are used to configure register bits or bitfields, for example `bit_set()`, `bit_clr()`.

The `hri` folder has multiple .h-files - one file per hardware module supported by ASF4. These files define the register interface of hardware modules.

Layers
The drivers are implemented in layers in order to:

1. Provide software interfaces abstracted from the underlying implementation.
2. Make it easier to document the drivers and architecture making it easier for users and developers to create, use, modify, and debug the code.
3. Multiple layers make it possible to have both stable and unstable APIs. For instance, the top layer HAL API should be as stable as possible, and only modified when necessary, and these modifications must be documented. The HPL layer, however, is not meant to be used as standalone and cannot, in that context, be called a "public" API, which means that the threshold for modifying this interface shall be much lower. For example, support for a new feature in hardware can be performed in the HPL and the HAL is kept untouched.
4. Multiple layers make it easier to separate code making up the hardware support from reusable common code. In ASF4, all hardware support code is in the HPL. The HRI interface describes only the hardware register interface. The HAL usually needs to be written only once and then reused with different HPL layers.

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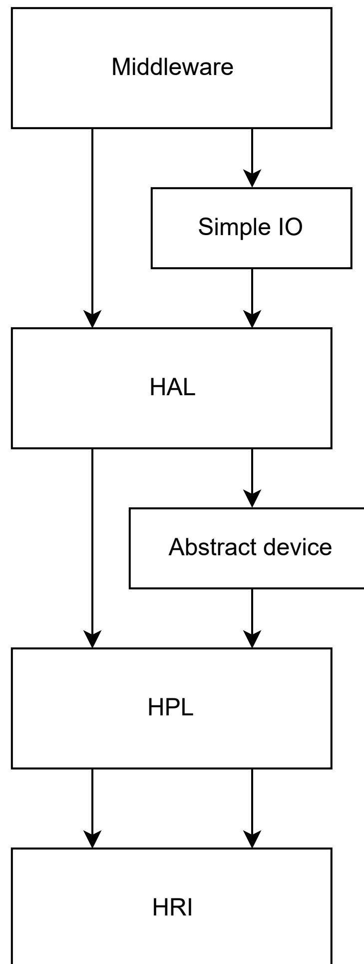
Figure 2-1. The ASF4 Driver Architecture



2.2 Driver Use-cases, Types, and Variants

Driver use-cases The application functionality, which a peripheral can be used for, such as PWM and Timer for a Timer-Counter (TC) peripheral.

Driver variants Different driver implementation architectures, such the Synchronous-, Asynchronous-, DMA-, and RTOS-Drivers.

Driver Types Relates to whether a driver supports a peripheral, utility function, or middleware.

2.2.1 Driver Use-cases

Instead of having one generic driver per peripheral, the ASF4 drivers provide interfaces to ways of using the peripheral. These ways are named "use-cases". A use-case typically implements a subset of the total functionality provided by the peripheral. This is useful as many of the peripherals on SAM devices, such as the SERCOM, provide a very broad functionality. This would cause a generic driver providing access to all the functionality of the module to be very large. Because the use-case limits the scope of functionality provided to the user, the driver is easier to implement and test and is more optimal than a generic driver would be. The figure below shows that a SERCOM hardware module can be used to implement various communication protocols, each protocol (or use-case) being implemented by a specific

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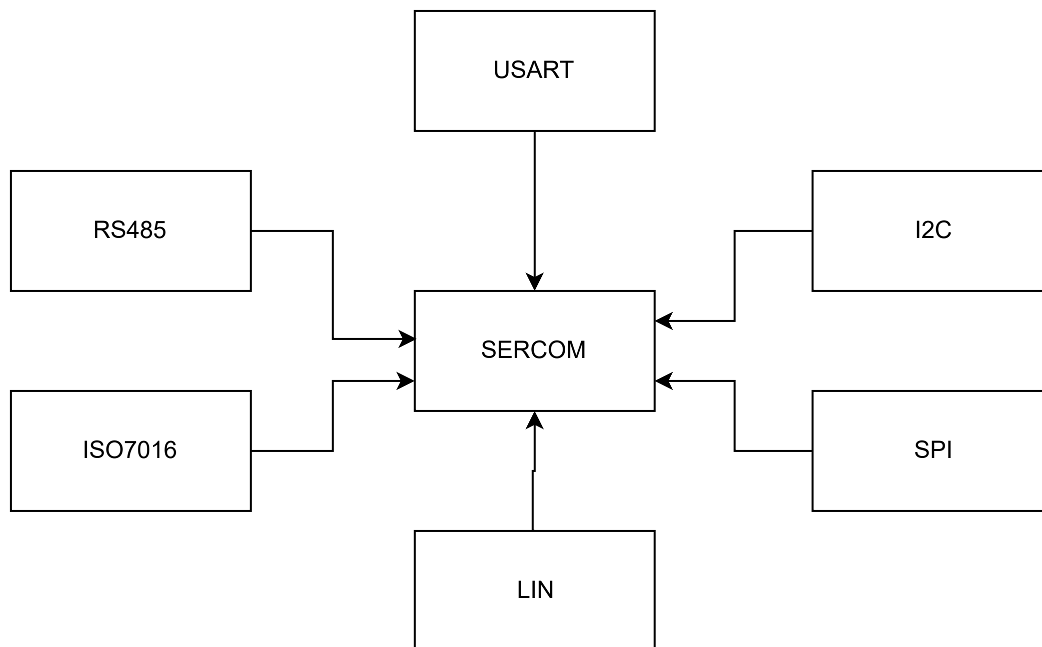
ASF4 driver. There is no generic "SERCOM" driver in the ASF4 HAL layer, but instead a specific "USART" driver, "I^{2}C" driver, "LIN" driver, and so on.

The use-case approach together with the HAL and HPL layers allow the driver to be implemented in different ways, depending on the available hardware. As an example, a driver that issues a periodic interrupt can be implemented using for example:

- TC Timer
- TCC Timer
- RTC
- Systick in CPU

Atmel START is used to select the hardware instance to be used to implement the driver. This is done during ASF4 configuration.

Figure 2-2. Example of Use-cases for a SERCOM Module



ASF4 has different types of drivers; Peripheral-, Utility-, and Middleware-drivers.

2.2.2 Driver Variants

A use-case such as "ADC" can be implemented using drivers with different architectures, such as:

- ADC with blocking receive/transmit functions
- ADC with non-blocking receive/transmit functions
- ADC implemented using DMA transfer of data between peripheral registers to memory
- ADC intended for use with a Real-Time operating system

ADC Synchronous Driver

The driver will block (i.e. not return) until the requested data has been read. Functionality is therefore synchronous to the calling thread, i.e. the thread waits for the result to be ready. The adc_sync_read_channel( ) function will perform a conversion of the voltage on the specified channel and return the result when it is ready.

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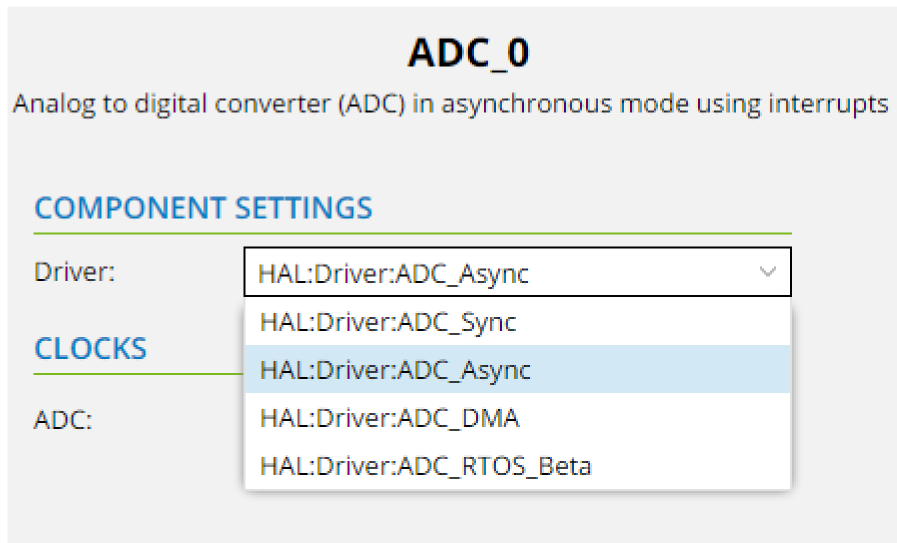
ADC Asynchronous Driver
The driver adc_async_read_channel function will attempt to read the required number of conversion results from a ring buffer. It will return immediately (i.e. not block), even if the requested number of data is not available immediately. If data was not available, or fewer data than requested was available, this will be indicated in the function's return value. The asynchronous driver uses interrupts to communicate that ADC data is available, and the driver's IRQ handler reads data from hardware and into ringbuffers in memory. These ringbuffers decouple the generation of data in the ADC with the timing of the application request for this data. In a way, the producer and consumer events are asynchronous to each other. The user can register a callback function to piggyback on the IRQ handler routine for communicating with the main application.

ADC DMA Driver
Uses DMA system to transfer data from ADC to a memory buffer in RAM. The user must configure the DMAC system driver accordingly. To set the memory buffer and its size the adc_dma_read function is used. This function programs DMA to transfer the results of input signal conversion to the given buffer. A callback is called when all data is transferred if it is registered via the adc_dma_register_callback function.

ADC RTOS Driver
The driver is intended for using ADC functions in a real-time operating system, i.e. a thread-safe system.

For drivers providing multiple variants, the variant to be used is selected during the ASF4 configuration in START.



2.2.3 Driver Types

Driver Types relate to whether a driver supports a peripheral, utility function, or middleware.

Peripheral Driver
A peripheral driver is a driver that is directly related to some functionality in some hardware peripherals. This is usually not the full functionality set available in the hardware peripheral, but a subset to make it portable between hardware platforms with different hardware peripheral implementations. A peripheral driver in the ASF4 consists of the HRI, HPL, and HAL layers. The user will normally interface only with the topmost HAL layer.

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Utility Driver

Utility drivers are hardware agnostic drivers that implement commonly used software concepts. The utility drivers are available for both the ASF4 drivers and the user application. Examples of utility drivers are a generic linked list or a ring buffer. Utility drivers can also be in form of C macro definitions.

Moving commonly used code into utility drivers makes it easier to maintain code and help the compiler to optimize the code because the same code is used by different drivers, but only one copy is needed. The utility drivers are fully abstracted and not bound to any particular hardware platform or type.

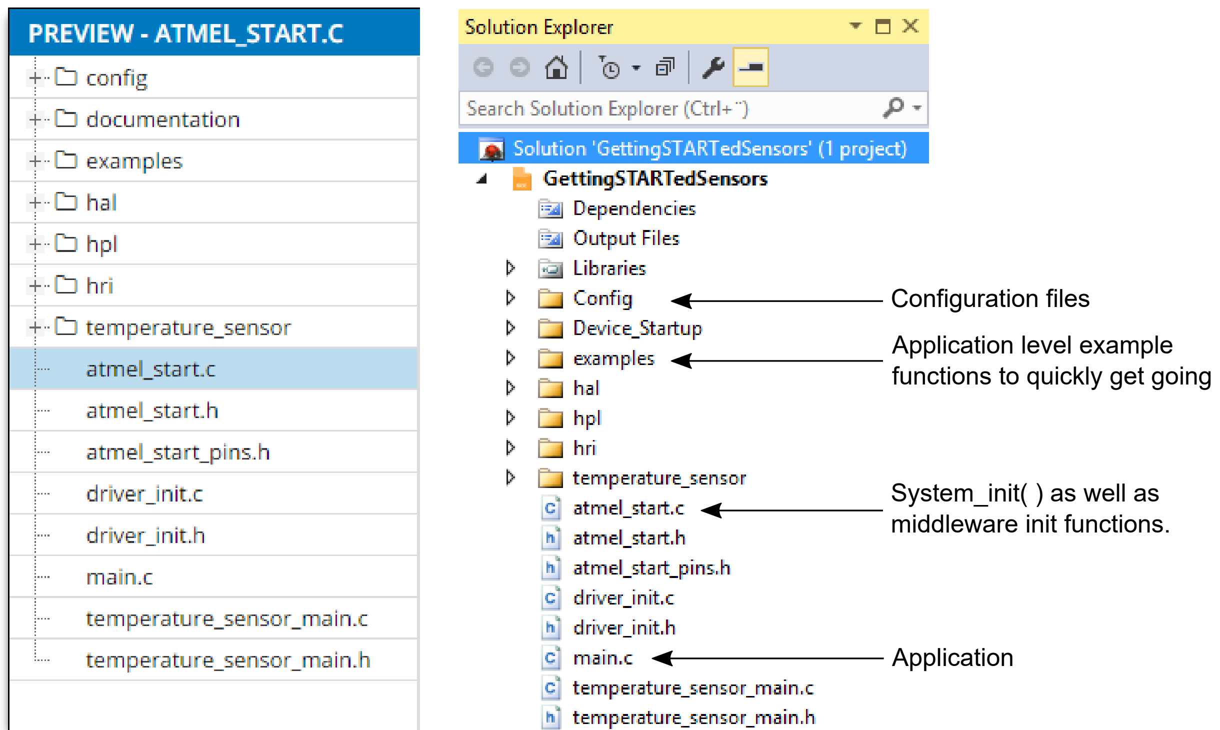
Middleware Driver

Middleware drivers are built on top of peripheral drivers and do not have any direct link to the underlying hardware. A middleware driver can depend on multiple peripheral drivers at the same time or support a range of different peripheral drivers. These drivers usually implement highly abstracted code that implements some kind of software concepts like graphics libraries, USB classes, or file systems.

2.3 ASF4 Project Folder Structure

In this section, the project folder structure and file descriptions of an example Atmel START/ASF4 project are described. By clicking the **VIEW CODE** tab, at the top of the project, the folder structure, as well as the generated code based on the current configuration, can easily be previewed. This will be the same as the one generated in the **Export Project** screen, once the imported into an IDE. For example, the figure below shows the project structure from both the **VIEW CODE** preview, as well as the Atmel Studio 7 solution explorer.

Figure 2-3. Folder Structure of an ASF4 Project Generated from Atmel START



The `config` folder contains one `*_config.h` for each hpl-device configured by Atmel START. The files in the config folder are used by the HPL layer to configure the functionality the user entered in Atmel START. The files use the CMSIS wizard annotation format.

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The `examples` folder contains examples of using the drivers and is useful to see how to use the ASF4 drivers.

The root folder contains the following files:

- `atmel_start.c` – Code for initializing MCU, drivers, and middleware in the project
- `atmel_start.h` – API for initializing MCU, drivers, and middleware in the project
- `atmel_start_pins.h` – Pin MUX mappings as made by the user inside START
- `driver_init.c` – Code for initializing drivers
- `driver_init.h` – API for initializing drivers
- `main.c` – Main application, initializing the selected peripherals

A full expanded project directory for a simple generated project for the SAM D21 with a single USART is available in 2.9 ASF4 Project Folder Structure - Full.

In the following sections, more details are given about Root Level Files, Pin Configuration, Examples Folder, and Config Folder. Then System Initialization walks through the start-up sequence of an ASF4 project.

2.3.1 System Initialization

This section walks you through the startup sequence of an ASF4 project. This system initialization sequence relies mainly on root level files, which are described in more detail in 2.3.2 Root Level Files.

An empty ASF4 project, generated from Atmel START will contain only the `atmel_start_init()` function in `main()`.

```
int main(void)
{
    atmel_start_init();

    /* Replace with your application code */
    while(1) {
    }
}
```

The `atmel_start_init()` function is implemented in `atmel_start.c` and:

- initializes any middleware libraries, which have been added to the project
- calls `system_init()`

```
void system_init(void)
{
    system_init();
    temperature_sensors_init();
}
```

The `system_init()` function is implemented in `driver_init.c` and:

- initializes the MCU (oscillators, clocks, flash wait states, etc.) using the `init_mcu()` function
- initializes the peripherals, which have been selected (in our case the USART), using the `USART_0_init()` function

```
void system_init(void)
{
    init_mcu();
    USART_0_init();
}
```

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The different initialization functions which are called in `system_init()`, use the configuration's parameters that the user has selected during the Atmel START configuration process.

An example initialization of an SPI peripheral is considered in the picture below.

1. In main.c: `main()` calls `atmel_start_init()`.
2. In atmel_start.c: `atmel_start_init()` calls `temperature_sensors_init()`, a middleware initialization function, as well as `system_init()`.
3. In driver_init.c: `system_init()` calls `init_mcu()`, pin configuration functions and driver initialization functions, such as `SPI_0_init()`.
4. `SPI_0_init()` writes START configuration to the SPI (SERCOM) peripheral registers.

SPI

```
#include "atmel_start.h"
#include "atmel_start_pins.h"

int main(void)
{
    uint8_t example_test[] = "Hello World!";
    struct io_descriptor *spi_io;

    atmel_start_init();

    spi_m_sync_enable(&SPI_0);
    spi_m_sync_get_io_descriptor(&SPI_0, &spi_io);

    io_write(spi_io, example_test, 12);

    while(1) {
    }
}
```

atmel_start.c

```
/**
 * Initializes MCU, drivers and middleware in the project
 **/
void atmel_start_init(void)
{
    system_init();
    temperature_sensors_init();
}
```

driver_init.c

```
void system_init(void)
{
    init_mcu();

    // GPIO on PB31

    // Set pin direction to output
    gpio_set_pin_direction(DGI_SS, GPIO_DIRECTION_OUT);

    gpio_set_pin_level(DGI_SS,
            // <y> Initial level
            // <id> pad_initial_level
            // <false"> Low
            // <true"> High
            false);

    gpio_set_pin_function(DGI_SS, GPIO_PIN_FUNCTION_OFF);

    I2C_INSTANCE_init();

    USART_0_init();

    SPI_0_init();

    ADC_0_init();

    delay_driver_init();
}
```

Initializes the MCU (oscillators, clocks, flash wait states…)

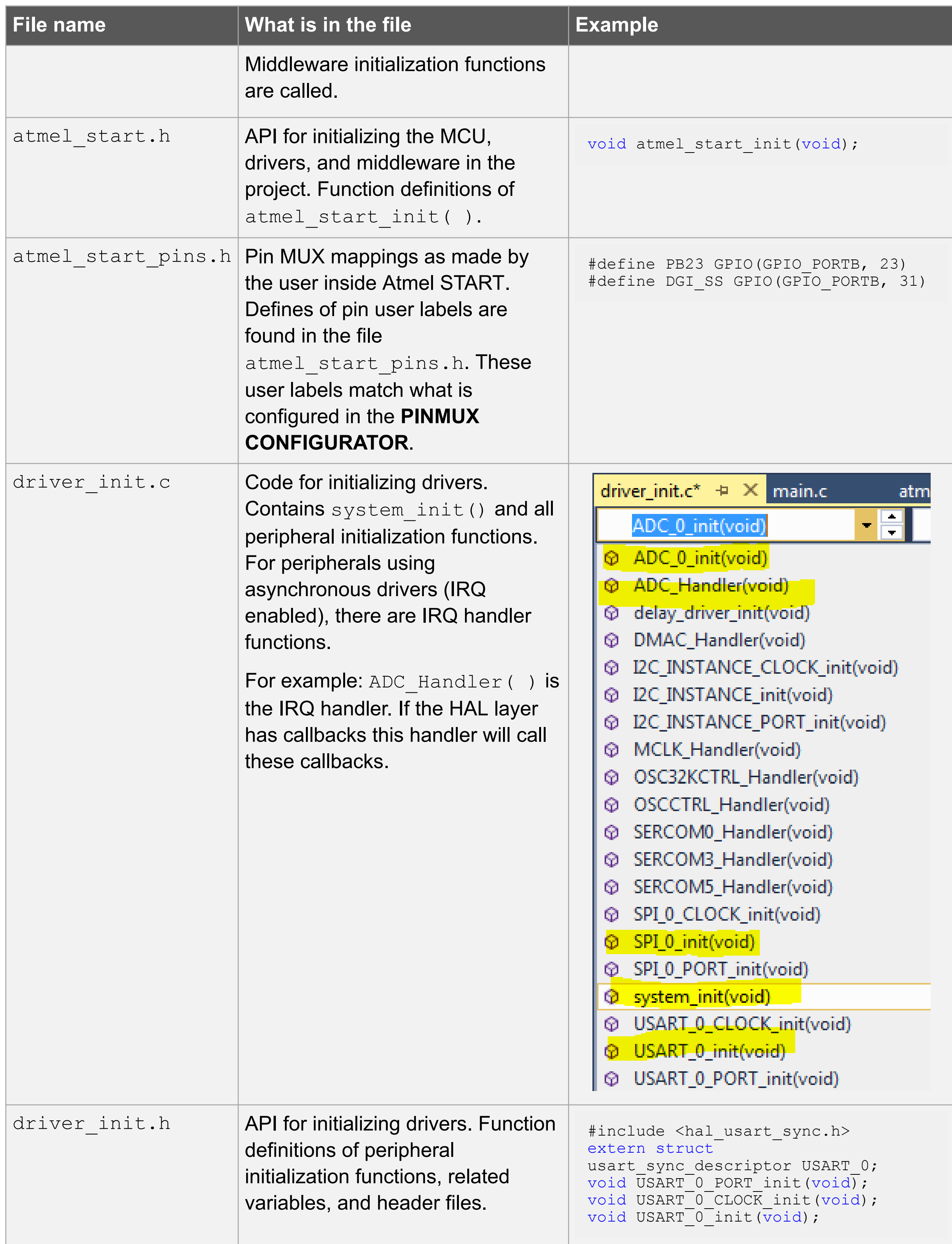
Sets up GPIO, as configured in PINMUX configurator

Writes configuration to peripheral registers

2.3.2 Root Level Files

File name	What is in the file	Example
`main.c`	Main application, initializing the selected peripherals by calling `atmel_start_init( )`.	See project initialization sequence

`atmel_start.c`	Code for initializing the MCU, drivers, and middleware in the project.
	The `system_init( )` function initializes the MCU (oscillators, clocks, flash wait states, etc.) and peripherals, which have been selected.
		`#include <atmel_start.h>`
		`void atmel_start_init(void)`
		`{`
		`  system_init();`
		`  temperature_sensors_init();`
		`}`

File name	What is in the file	Example
	Middleware initialization functions are called.	
`atmel_start.h`	API for initializing the MCU, drivers, and middleware in the project. Function definitions of `atmel_start_init( )`.	`void atmel_start_init(void);`
`atmel_start_pins.h`	Pin MUX mappings as made by the user inside Atmel START. Defines of pin user labels are found in the file `atmel_start_pins.h`. These user labels match what is configured in the **PINMUX CONFIGURATOR**.	`#define PB23 GPIO(GPIO_PORTB, 23)` `#define DGI_SS GPIO(GPIO_PORTB, 31)`
`driver_init.c`	Code for initializing drivers. Contains `system_init()` and all peripheral initialization functions. For peripherals using asynchronous drivers (IRQ enabled), there are IRQ handler functions. For example: `ADC_Handler( )` is the IRQ handler. If the HAL layer has callbacks this handler will call these callbacks.	

`driver_init.h`	API for initializing drivers. Function definitions of peripheral initialization functions, related variables, and header files.	`#include <hal_usart_sync.h>`
		`extern struct`
		`usart_sync_descriptor USART_0;`
		`void USART_0_PORT_init(void);`
		`void USART_0_CLOCK_init(void);`
		`void USART_0_init(void);`

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File name	What is in the file	Example
`middleware_main.c`	Initialization of middleware libraries.	`void temperature_sensors_init(void) { }`
`middleware_main.h`	Function definition of middleware initialization functions, related variables, and header files.	`#include <at30tse75x.h>` `#include <at30tse75x_config.h>` `extern struct temperature_sensor *TEMPERATURE_SENSOR_0;` `void temperature_sensors_init(void);`

2.3.3 Examples Folder

Application level example functions are provided in `examples\driver_examples.c`. When we develop an application in the `main.c` file, these functions may be useful to call and adapt (if required), in order to very quickly build and test peripheral functionality. For example, a function to call “Hello World!” is provided for the USART.

```
/**
 * Example of using USART_0 to write "Hello World" using the IO abstraction.
 */void USART_0_example(void)
{
    struct io_descriptor *io;
    usart_sync_get_io_descriptor(&amp;USART_0, &amp;io);
    usart_sync_enable(&amp;USART_0);

    io_write(io, (uint8_t *)"Hello World!", 12);
}
```

If you have added the USART driver only, you will find USART related functions only as this is the only peripheral that has been added to the project and configured in Atmel START.

Example functions are grouped into separate folders, which can easily be deleted if not needed so that the final project contains the production code only.

2.3.4 Pin Configuration

Defines of pin *user labels* are found in the file `atmel_start_pins.h`. These user labels match what is configured in the **PINMUX CONFIGURATOR**.

PINMUX CONFIGURATOR

#	Pin label: Pad	Pin label: User	Board label: Header	Board label: Pin	Mode	Signal: Label	Signal: Mode
ADC_0							
19	PA10	PA10	EXT2,QT...	ADC+,QT...	Analog	AIN/18	Enabled
I2C_INSTANCE							
17	PA08	PA08	EXT3,EX...	TWI_SDA...	I2C	SDA	
18	PA09	PA09	EXT3,EX...	TWI_SCL...	I2C	SCL	
PORT							
60	PB31	DGI_SS	DGI SPI	DGI_SS	Digital...	PORT/P/...	
SPI_0							
39	PB16	PB16	EXT3,EX...	SPI_MIS...	Digital...	MISO	
49	PB22	PB22	EXT3,EX...	SPI_MOS...	Digital...	MOSI	
50	PB23	PB23	EXT3,EX...	SPI_SCK,...	Digital...	SCK	
USART_0							
43	PA22	PA22	VCP	TXD	Perip...	TX	
44	PA23	PA23	VCP	RXD	Perip...	RX	
No software components							
1	PA00		32kHz X...	XIN32			
2	PA01		32kHz X...	XOUT32			
3	PA02		Buttons,...	SW0,SPI...			
4	PA03		EXT1	ADC(-)			
5	PB04		EXT1	IRQ			
6	PB05		EXT1	ADC(+)			
7	GND...						
8	VDDA...						
9	PB06		EXT1	GPIO0			
10	PB07		EXT1	GPIO1			
11	PB08		EXT1	USART_TX			
12	PB09		EXT1	USART_RX			
13	PA04		EXT1	SPI_MISO			
14	PA05		EXT1	SPI_SS_A			
15	PA06		EXT1	SPI_MOSI			
16	PA07		EXT1	SPI_SCK			
20	PA11		EXT2	ADC-			
21	VDDI...						
22	GNDI...						

Pin 60 (PB31) is used as *PORT/P/60* with *PORT*.

Tip: Use *ctrl* or *shift* to select more than one pin.

User label: DGI_SS

Pin mode: Digital output

Initial level: Low

For example, PB31 is given a user label DGI_SS, which can be seen as the define associated with this pin in the `atmel_start_pins.h` file:

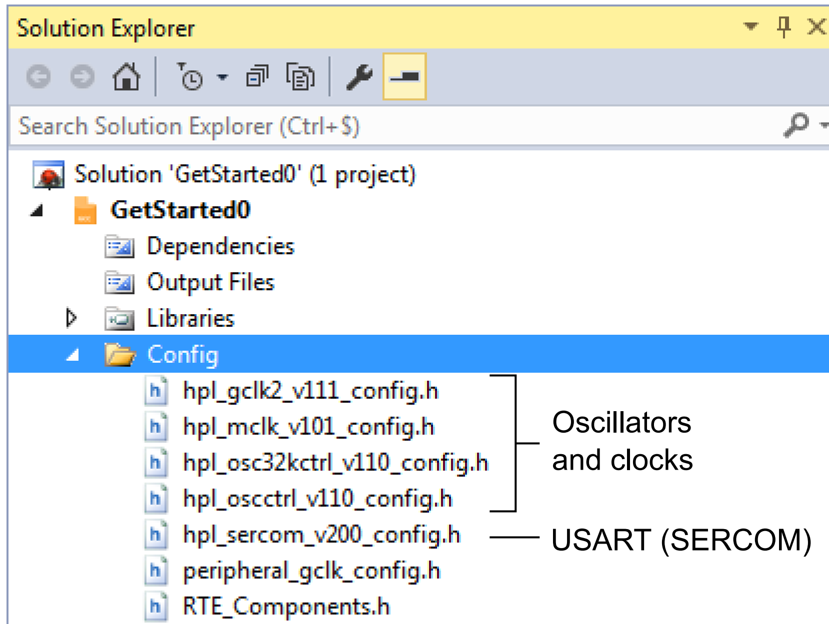
```
#include <hal_gpio.h>

#define PA08  GPIO(GPIO_PORTA, 8)
#define PA09  GPIO(GPIO_PORTA, 9)
#define PA10  GPIO(GPIO_PORTA, 10)
#define PA22  GPIO(GPIO_PORTA, 22)
#define PA23  GPIO(GPIO_PORTA, 23)
#define PB16  GPIO(GPIO_PORTB, 16)
#define PB22  GPIO(GPIO_PORTB, 22)
#define PB23  GPIO(GPIO_PORTB, 23)
#define DGI_SS  GPIO(GPIO_PORTB, 31)
```

2.3.5 Config Folder

The config folder contains header files, which hold the configuration data associated with each driver. These configuration files are associated with the Hardware Proxy Layer (HPL) of the driver. By connecting the configuration file to the HPL it is possible to expose hardware-specific configuration options to the user, that is, the configuration includes settings which are hardware-aware.

The START-based configuration is based on the ARM-CMSIS wizard annotation format.



As an example, if you open the `hpl_oscctrl_vxxx_config.h` file, you can check that the only oscillator enabled is the OSC16M:

```
    // <h> 16MHz Internal Oscillator Control
    // <q> Enable
    // <i> Indicates whether 16MHz Internal Oscillator is enabled or not
    // <id> osc16m_arch_enable
#ifndef CONF_OSC16M_ENABLE
#    define CONF_OSC16M_ENABLE 1
#endif
```

And that the selected frequency for the OSC16M oscillator is 4 MHz:

```
    // <y> Oscillator Frequency Selection(Mhz)
    // <OSCCTRL_OSC16MCTRL_FSEL_4_Val"> 4
    // <OSCCTRL_OSC16MCTRL_FSEL_8_Val"> 8
    // <OSCCTRL_OSC16MCTRL_FSEL_12_Val"> 12
    // <OSCCTRL_OSC16MCTRL_FSEL_16_Val"> 16
    // <i> This defines the oscillator frequency (Mhz)
    // <id> osc16m_freq
#ifndef CONF_OSC16M_FSEL
#    define CONF_OSC16M_FSEL OSCCTRL_OSC16MCTRL_FSEL_4_Val
#endif
```

An extract of the ADC config file (`hpl_adc1_v120_config.h`) is shown below, representing the ADC conversion resolution configuration output.

```
    // <o> Conversion Result Resolution
    // <0x0=>12-bit
    // <0x1=>16-bit (averaging must be enabled)
    // <0x2=>10-bit
    // <0x3=>8-bit
    // <i>  Defines the bit resolution for the ADC sample values (RESSEL)
    // <id> adc_resolution
#ifndef CONF_ADC_0_RESSEL
#    define CONF_ADC_0_RESSEL  0x3
#endif
```

In the #define, the `RESSEL` is the register bit field name. The value of the define represents what will be written to the associated register. The commented out values function as an enumerator of other potential valid values. Enumerators used in ASF3 have been replaced by this syntax.

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Note: To find the register this relates to, open the data sheet register summary for the given peripheral, then search for this bit field value.

Another example is given below, which shows a baud rate calculation of the SERCOM in USART mode, that is the USART use-case of the SERCOM peripheral. Here one can also see the formula in the generated macro in order to calculate the correct value to be programmed into the BAUD register. These calculations will tend to be found near the bottom of the configuration file.

```
// <o> Baud rate <1-3000000>
// <i> USART baud rate setting
// <id> usart_baud_rate
#ifndef CONF_SERCOM_3_USART_BAUD
#   define CONF_SERCOM_3_USART_BAUD  9600
#endif


//                  gclk_freq - (i2c_scl_freq * 10) - (gclk_freq * i2c_scl_freq * Trise)
// BAUD + BAUDLOW = --------------------------------------------------------------------
//                  i2c_scl_freq
// BAUD:    register value low  [7:0]
// BAUDLOW: register value high [15:8], only used for odd BAUD + BAUDLOW
#define CONF_SERCOM_0_I2CM_BAUD_BAUDLOW (((CONF_GCLK_SERCOM0_CORE_FREQUENCY - \
            (CONF_SERCOM_0_I2CM_BAUD * 10) -\
            (CONF_SERCOM_0_I2CM_TRISE * (CONF_SERCOM_0_I2CM_BAUD / 100) * \
                (CONF_GCLK_SERCOM0_CORE_FREQUENCY / 1000) / 10000 )) * 10 + 5) / \
        (CONF_SERCOM_0_I2CM_BAUD * 10))
#ifndef CONF_SERCOM_0_I2CM_BAUD_RATE
```

What configuration files will I see?

The configuration files appearing depends on the configuration selected. For example, consider adding Timer and PWM drivers to a SAM D21 project. Both drivers can run on either the TC or TCC peripherals.

If both the Timer and the PWM are configured to run on the TC, then a single `conf_tc.h` will be placed in the `Config` folder. However, if the Timer driver runs on the TC while the PWM runs on the TCC, then both the `conf_tc.h` and the `conf_tcc.h` will be generated for the Timer and PWM respectively.

Naming convention

What is in the `hpl_adc1_v120_config.h` file name?

hpl	this is the hardware-aware software layer
adc1_v120(a)	adc1 is an ADC project in IC design v120, a silicon version of the ADC integrated peripheral (FYI) (a) variant of the silicon version to support a subset of MCUs.

2.4 Hardware Abstraction Layer (HAL)

The HAL is the topmost driver layer and the only one that most users should interact with. This layer is a common, reusable interface supporting a range of devices and architectures. This layer abstracts away the peculiarities of hardware and provides the same services to the programmer irrespectively of the hardware implementing the HAL. The HAL layer contains functions allowing the user access to the driver's functionality. Therefore, many of the functions are driver specific and may perform things such as:

- Transfer data between the driver and the application
- Start a specific operation provided by the driver, such as start a data transmission

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Driver handle

As part of the abstraction between a specific hardware implementation and the HAL interface, the HAL driver specifies its own handle to store necessary data like hardware register interface pointers, buffer pointers, etc. The handle is used as a parameter to HAL functions in order to identify which resource to address.

The handles have the following definition:

```
struct [namespace]_descriptor
```

```
Example: struct usart_sync_descriptor USART0;
```

2.4.1 Mandatory Driver Functionality

The following functions are found in all drivers and complement the driver-specific functions.

Driver initialization

All HAL interfaces have an initialization function named `init()`. This function is responsible for loading the module configuration, pin MUX setup, and clock source setup found in the configuration file. This function is also responsible for initializing the HAL device handle, with references to the hardware interface and buffers if needed. The parameter list of this function shall start with the HAL device handle, followed by a pointer to the hardware register interface of the module instance to be associated with this HAL device. Any parameters after the first two parameters are interface specific. After this call, the module is enabled and ready for use, if not an error code should be returned to the application.

Name convention

```
[namespace]_init(struct [namespace]_descriptor *desc, adc *hw, ...);
```

Example

```
adc_sync_init(struct adc_sync_descriptor *adc, adc *hw, ...);
```

Driver deinitialization

All high-level HAL interfaces have a deinitialization function named `deinit()`. This function is responsible for releasing the hardware module and any resource allocated by this module. This includes disabling any clock source for the module, resetting any pin MUX setting and resetting the module itself.

Name convention

```
[namespace]_deinit(struct [namespace)_descriptor *desc);
```

Example

```
adc_sync_deinit(struct adc_sync_descriptor *adc);
```

Register interrupt handler callback

APIs supporting interrupts have a function to register different interrupt handlers. When this function returns, the interrupt is enabled in the module and is ready for use. This function does not change the state of the global interrupt flag. Registering a NULL pointer as handler disables the interrupt used by the driver.

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Name convention

```
[namespace]_register_callback(struct [namespace]_descriptor *desc, [namespace]_callback_type
type);
```

Example

```
adc_async_register_callback(struct adc_async_descriptor *adc, adc_async_callback_type type);
```

Get driver version

All HAL drivers are tagged with a version number. The version number has the format 0x00xxyyzz and can be retrieved using the `[namespace]_get_version()` function, e.g. `adc_sync_get_version()`.

- xx: Major version number
  - Additions/changes to the driver and/or driver API
  - Driver does not need to stay backward compatible
- yy: Minor version number
  - Additions to the API
  - Bug-fixes and/or optimization to the implementation
  - The driver shall stay backward compatible
- zz: Revision number
  - Bug-fixes and/or optimizations of the driver
  - The API shall not be changed
  - The driver shall stay backward compatible

Get I/O descriptor

For APIs with I/O system support, there is a function to extract the I/O descriptor from the device descriptor. This function returns a pointer to the generic I/O descriptor type.

Name convention

```
[namespace]_get_io_descriptor(struct [namespace]_descriptor *descriptor, struct io_descriptor
**io);
```

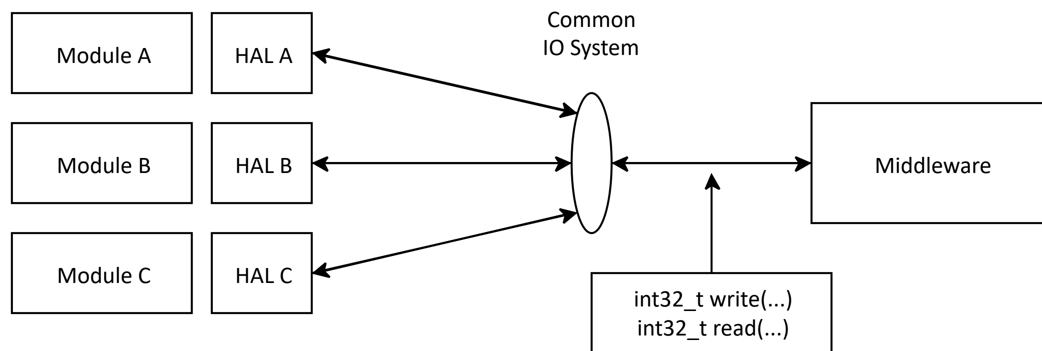
Example

```
usart_sync_get_io_descriptor(struct usart_sync_descriptor *descriptor, struct io_descriptor
**io);
```

2.5 I/O System

For some of the drivers, there is an I/O system on top of the HAL interface. The I/O system disconnects middleware from any driver dependency because the middleware only needs to rely on the interface that the I/O system provides. The I/O system has a write and a read method that are used to move data in/out of the underlying interface. An example is a file system stack that can be used with any of the external interfaces on the device to communicate with an external storage unit. The application will have to set up the interface, and then supply a pointer to the I/O object to the file system stack.

Figure 2-4. Overview of the I/O System



Example of I/O system code

```
/* This is conceptual code, and not copied from ASF4 framwork code */

#define BUF_SIZE  4

uint8_t buf[BUF_SIZE];
int8_t data_received;

io_handle_t   spi_io;
fs_handle_t   fs;
file_handle_t file;

hal_spi_init(&spi_io, hw);

do {
        data_received = io.read(buf, BUF_SIZE);
} while (data_recieved == 0);


if(data_received < 0) {
        /* Something wrong was detected */
        while(1) {
        };
}

/* Write something on the SPI bus */
spi_io.write(buf, data_received);

/* Using a storage device over the SPI interface */
fat_fs_init(fs, spi_io);
fat_fs_write_file(fs, file);
```

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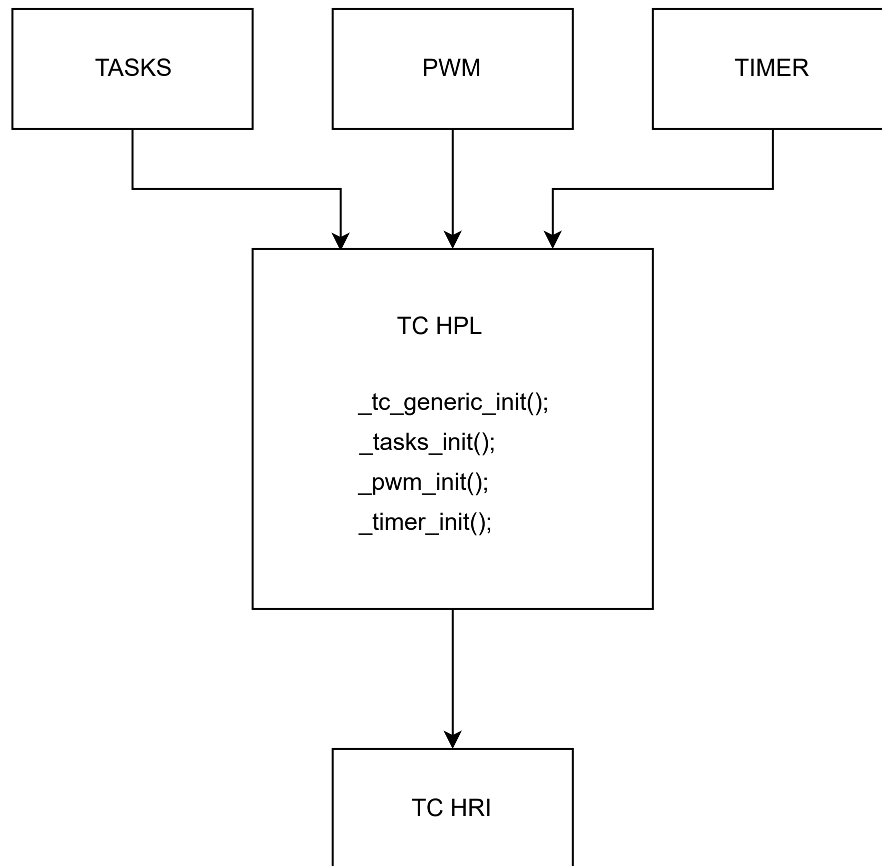
2.6 Hardware Proxy Layer (HPL)

Figure 2-5. Example HPL for TC Supporting Three Different HAL APIs



Most drivers consist of a mix of code that do not require direct hardware peripheral access and code that require hardware access. In ASF4 this code is split into two different layers called the Hardware Abstraction Layer (HAL) and the Hardware Proxy Layer (HPL). The HAL is the layer where all hardware agnostic code is implemented and the interface that the user access, to use the framework, is defined. The HPL is where the hardware-aware code is implemented.

A typical example of this split is a function that reads a buffer of some length from a hardware module asynchronously. The application does not know when data will arrive at the peripheral so a ring-buffer is used to store the data until the application is ready to read it. As none of the actual hardware implementations of the module supported through this interface has a hardware-based ring-buffer, a software implementation of the buffer is used. Since the data going into the buffer is hardware independent, the ring-buffer is implemented in the HAL driver. Reading the data from the hardware module will, on the other hand, be hardware dependent as the register location, name, and access sequence might differ. This code will, therefore, be implemented in the HPL driver.

The split between HAL and HPL makes it clear which code has to be updated when adding support for new hardware, and which code can be reused without any modification. The expected interface between the HAL and HPL is defined by an abstract device.

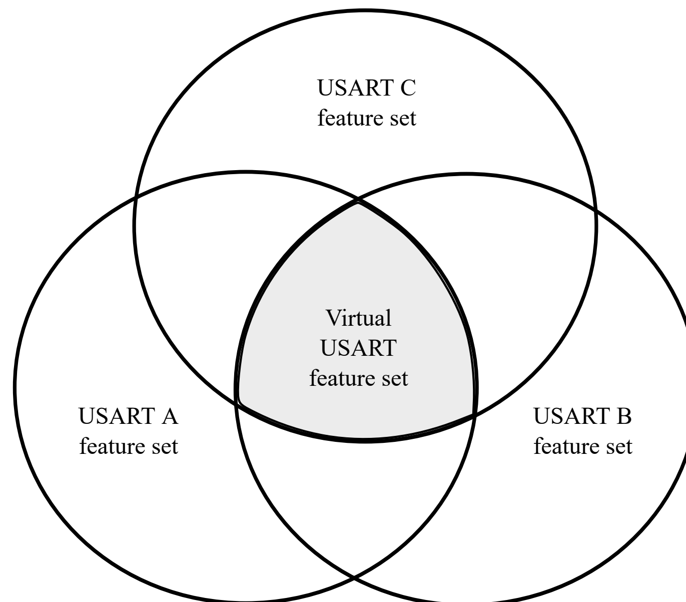
The HPL/HAL driver split allows the different hardware modules with overlapping functionality, to use the same HAL interface. As an example, a device contains different timer/counter module designs: One simple timer/counter design and one more advanced targeted for advanced PWM. Both types can be

used to periodically increment a counter and to trigger an interrupt event when the counter reaches some pre-defined value. The same HAL interface and implementation can be used for both module types but mapped to the two different HPL layers.

The abstracted device and interface

The abstracted device is a definition of a non-physical virtual device with a defined feature set. This feature set can be implemented using compatible features in physical hardware modules. This means that an abstract device has a feature set which is a subset of what the physical hardware modules support.

Figure 2-6. An Abstract USART Device is Defined with a Subset of the Feature Sets in USART A, B, and C



The abstract USART device in the figure above is defined as a subset of what USART A, B, and C can offer. USART implementations often support features like IrDA, SPI-master, Lin, RS485, etc., on top of the USART/UART support, but it is not given which of these features are supported by which implementation. To make sure that the virtual USART device is compatible with the feature set of each physical implementation, the feature scope will be limited to UART/USART. Support for other features can be provided through other abstract device definitions.

The HAL interface gives the user one common interface across multiple hardware implementations. This makes the code easier to port between devices/platforms. Since the HAL implements use cases, the code is more focused, and therefore more optimized for the limited scope than a more general driver would be. Since the HAL driver interfaces hardware through the abstracted device, the HAL driver is completely decoupled from the hardware. The abstract interface is implemented by the hardware's HPL driver.

Example of abstract device

```
struct _usart_device {
        struct _usart_callbacks usart_cb;
        void *hw;
};

_usart_init(void *const hw);
```

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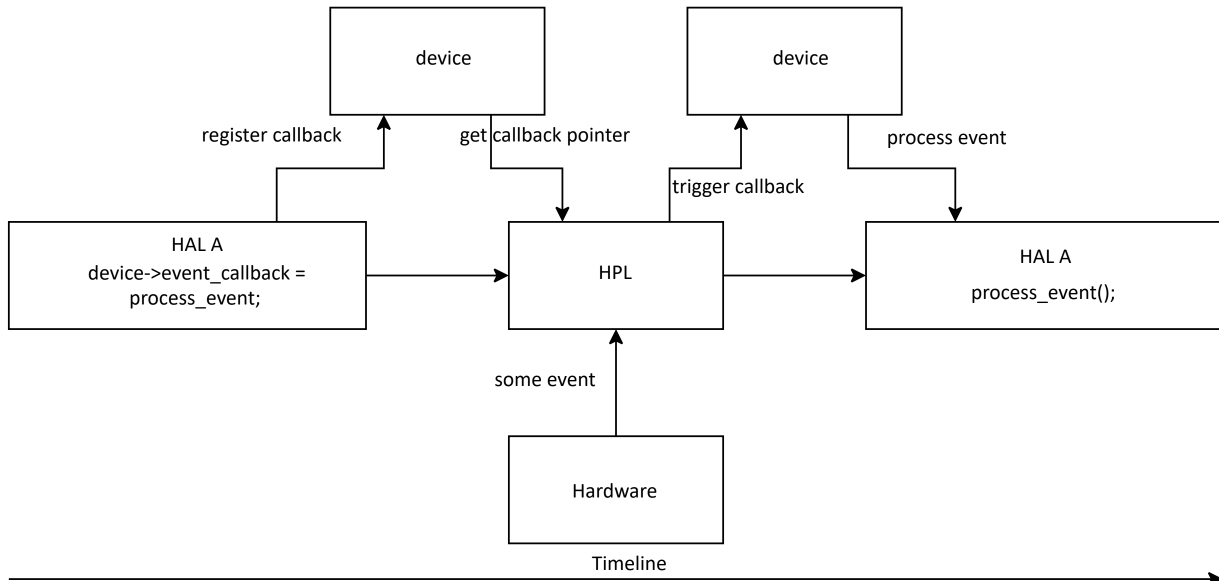
```
_usart_deinit(void *comst hw);
_usart_transmit(void *const hw, uint8_t *const buf, uint32_t length);
```

This is a simple abstract USART device, with a small interface for init, deinit, and transmit data. If we implement this abstract device for SAM D21 an obvious choice would be to use the SERCOM module to implement this abstract device. To accomplish that, a function to set up the SERCOM and put it into USART mode (init), put data into the data register (transmit), and disable the SERCOM (deinit), must be implemented in the HPL driver for the SERCOM.

In ASF4, the abstract device is defined as a data container for any data that is shared between the HAL and the HPL implementation. Examples are pointers to hardware registers, buffers, state information, and callback functions for events (interrupts, error detected, etc.). As an example one can use interrupt events. Parts of an interrupt event are processed in the HPL and parts are processed in the HAL like custom callback functions. As earlier noted, the HAL must stay hardware agnostic, so, to be notified that something happens in the underlying hardware, it must register callback functions in the abstract device. This data is shared with the HPL driver, and the HPL driver can use these callbacks to notify the HAL that something has happened in the hardware. This keeps the HAL and the HPL decoupled and there are no dependencies between those two layers, only to the abstract device.

Figure 2-7. Example of Hardware Event Propagation from the HPL to the HAL



2.7 Hardware Register Interface (HRI)

The layer closest to the hardware is named HRI. This layer is a simple interface with very little logic that do register data content manipulation with a set of defined functions calls. The data manipulation operations can be performed on a bit, bit field, and complete register level.

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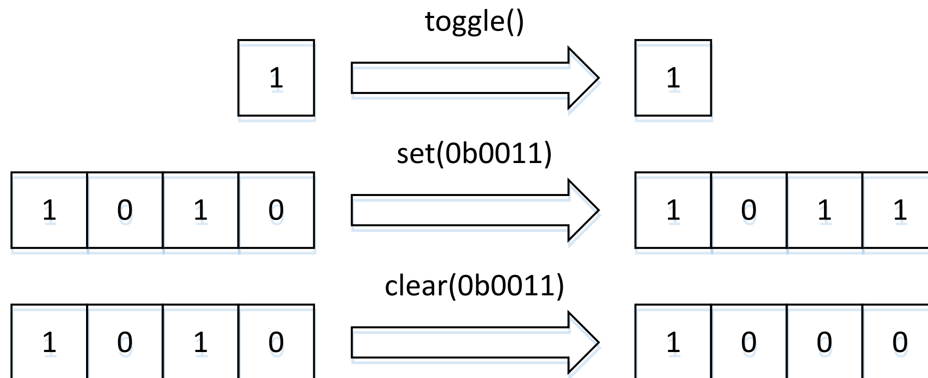
Figure 2-8. HRI Example Data Manipulation of Bit and Bit Field Contents



This layer also abstracts special register access properties like data synchronization between clock domains. It also ensures that data integrity is kept within an interruptible system by inserting critical sections when it is not possible to do data manipulation atomically.

Using the HRI interfaces as access interface to the peripheral registers helps the compiler optimize the code towards targets like low code size or faster code. When targeting fast code, the compiler can choose to inline the function to be able to optimize the code in context and avoid call conventions. For low code size, the compiler can avoid in-lining the function and reuse the same copy of the function multiple times.

All functions in the HRI are defined as static inline. This gives the compiler the possibility to optimize the code within the context of where it is used. Using functions instead of pre-processor macros keeps the possibility to use the compiler for type checking and makes the code a bit safer compared to pre-processor macros.

There are three main categories of access functions; single-bit access functions (accesses one bit at the time), bit field access functions (accesses multiple bits with a common purpose), and register access functions (access the content of a full register).

Different operation types available for the access functions

- get - Returns the value of the bit, bit field, or register (bit fields and registers are anded with a mask)
- set - Sets the value to a high state (bit fields and registers are anded with a mask value)
- clear - Sets the value to a low state (bit fields and registers are anded with a mask value)
- toggle - Value is changed to the opposite (bit fields and registers are anded with a mask value)
- write - Copy all bit states from the input data to the bit field or register
- read - Copy all bit states from the register and return it to the application

Note: If shadow registers are detected for set, toggle, and clear they will be used instead of normal access.

These operations are available for single bit access

- get - read state of bit
- set - set bit state to high
- clear - set bit state to low

- toggle - change bit state to the opposite
- write - change the state of the bit based on input, independent of the previous state

Note: Access to some registers, such as status and INTFLAG registers, only have get and clear access functions.

These operations are available for bit field access

- get (read the state of bits defined by a mask)
- set (set bit states to high for bits defined by a mask)
- clear (set bit states to low for bits defined by a mask)
- toggle (change bit states to opposite for bits defined by a mask)
- write (set states of all bits to the state defined in the input data)
- read (read the state of all bits)

These operations are available for register access

- get (read the state of bits defined by a mask)
- set (set bit states to high for bits defined by a mask)
- clear (set bit states to low for bits defined by a mask)
- toggle (change bit states to opposite for bits defined by a mask)
- read (read the state of all bits in the register)
- write (set the state of all bits in the register based on input data)

These operations are available for write-only register access

- write register

Note: The bit and bitfield operations are not available for write-only register since they are based on the latest value in the register.

These operations are available for read-only register access

- read/get register
- read/get bit field
- get bit

Shadow register access

The shadow registers are grouped registers that share data of named or virtual register value. They offer some atomic way to change this shared data value. As an example, in SAM D20 there is a register group of OUT, OUTCLR, OUTSET, and OUTTGL in PORT peripheral for port outputs. Writing to OUTCLR, OUTSET, and OUTTGL actually modifies the value in OUT register. In SAM V71, there is a similar register group of ODSR, CODR, and SODR in PIO peripheral for I/O outputs, where writing to CODR and SODR causes changes in ODSR and applies to the actual output pin levels.

Shadow registers have all possible operations for register, bit, and bit field access. The operations target the actual named or virtual register: There is register, bit, and bit field operations to access OUT register, but no operation to access OUTCLR, OUTSET, and OUTTGL.

Naming scheme

- module name - The acronym used in the data sheet in lower case letters (e.g. adc) function

- get, set, clear, toggle, write, read bit name - The register position name as written in the data sheet in upper case letters
- bit field name – The register position name (multiple bits) as written in the data sheet in upper case letters register name - The register name as written in the data sheet in upper case letters

Single bit access

```
hri_[module name]_[function]_[REGISTER NAME]_[BIT NAME]
eg. adc_set_CTRLA_ENABLE(hw);
```

Bit field access

```
hri_[module name]_[function]_[REGISTER NAME]__[BIT FIELD NAME]
eg. adc_set_AVGCTRL_SAMPLENUM(hw, mask);
```

Register access

```
hri_[module name]_[function]_[REGISTER NAME]
eg. adc_set_CTRLA(hw, mask);
```

Note: Special naming rule for single bit access to an interrupt flag register. This applies only to interrupt status registers, not interrupt related registers for enabling, disabling, clearing, etc.

```
[module name]_[function]_interrupt_[BIT NAME]
```

2.8 RTOS Support

Some of the drivers in ASF4 have RTOS support. RTOS support is selected as a use case in Atmel START.

Drivers designed for use in RTOSes are designed differently to take advantage of RTOS features. For example, drivers do not need to poll a signal or status, the RTOS provides synchronization mechanisms to notify the driver, releasing CPU resources for other tasks.

Semaphore

Semaphores are used as synchronization mechanism in the drivers since all RTOSes have them. Their behavior and interface are similar, making it easy to support various RTOSes. A typical process of using an RTOS driver looks like this:

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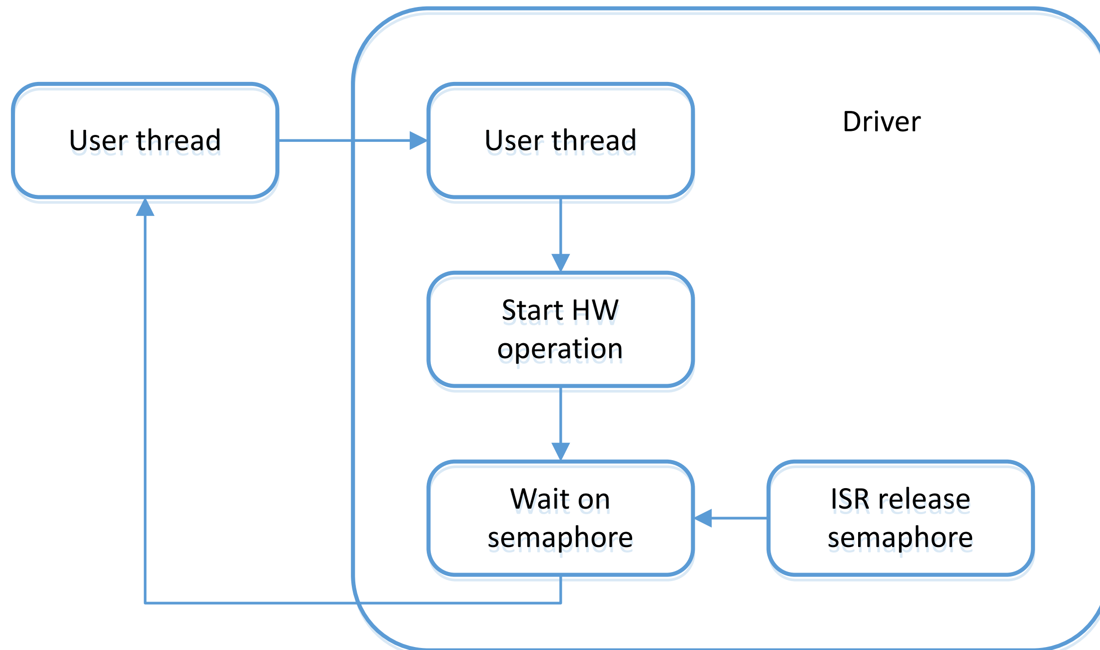
Figure 2-9. RTOS and Semaphores



The driver has an internal semaphore object for synchronizing between the ISR and the thread. The user thread may be suspended in the driver, and be woken up once the ISR finishes.

To be compatible with various RTOSes, an abstraction interface for semaphores is designed:

```
int32_t sem_init(sem_t *sem, uint32_t count);
int32_t sem_up(sem_t *sem);
int32_t sem_down(sem_t *sem, uint32_t timeout);
int32_t sem_deinit(sem_t *sem);
```

To support an RTOS, these functions and the sem_t typedef must be implemented.

OS lock and OS sleep

These two features are useful and are added to the RTOS abstraction. The OS locks/unlocks and disables/enables the OS scheduler and is an easy way to protect shared code and data among threads. OS sleep suspends the current thread for a specified tick period.

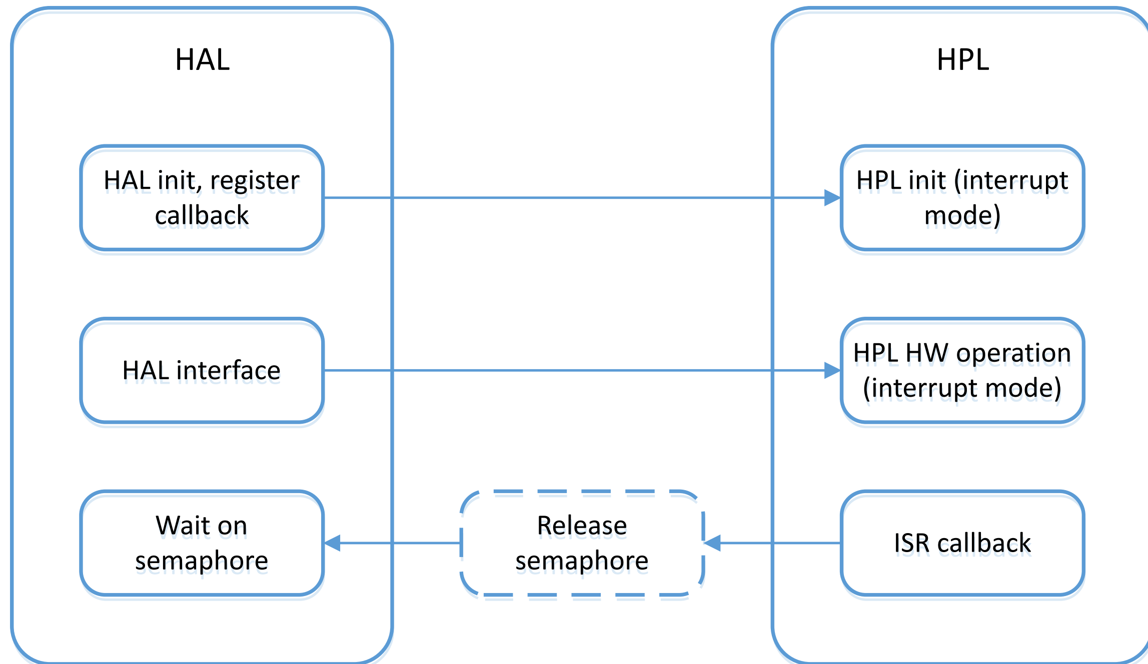
Thread creation

ASF4 does not provide an abstract interface for thread creation. For pre-defined threads in middleware, the thread body function and thread stack usage size are provided to the user, allowing the user to easily create such threads in his application.

HAL and HPL

Since HPL is designed for hardware abstraction, while HAL contains software and algorithms, RTOS support is located in the HAL layer. RTOS-enabled drivers do not change the HPL layer. The figure below shows how these two layers work together in an RTOS.

Figure 2-10. HAL and HPL in RTOS



2.9 ASF4 Project Folder Structure - Full

The following is the folder structure generated for a simple project containing a SAM D21 with a single USART.

The root folder contains the following files:

- `atmel_start.c` – Code for initializing MCU, drivers, and middleware in the project
- `atmel_start.h` – API for initializing MCU, drivers, and middleware in the project
- `atmel_start_pins.h` – Pin MUX mappings as made by the user inside Atmel START
- `driver_init.c` – Code for initializing drivers
- `driver_init.h` – API for initializing drivers
- `main.c` – Main application, initializing the selected peripherals
- `atmel_start_config.atstart` – Atmel START-internal description of the project
- `atmelStart.gpdsc` – Atmel START-internal description of the project

```
.
├── atmel_start.c
├── atmel_start_config.atstart
├── AtmelStart.gpdsc
├── atmel_start.h
├── atmel_start_pins.h
├── config
│   ├── hpl_dmac_v100_config.h
│   ├── hpl_gclk1_v210_config.h
│   ├── hpl_pm1_v201_config.h
│   ├── hpl_sercom_v200_config.h
│   ├── hpl_sysctrl_v201a_config.h
│   └── peripheral_clk_config.h
```

```
├── driver_init.c
├── driver_init.h
├── examples
│   ├── driver_examples.c
│   └── driver_examples.h
├── hal
│   ├── documentation
│   │   └── usart_async.rst
│   ├── include
│   │   ├── hal_atomic.h
│   │   ├── hal_delay.h
│   │   ├── hal_gpio.h
│   │   ├── hal_init.h
│   │   ├── hal_io.h
│   │   ├── hal_sleep.h
│   │   ├── hal_usart_async.h
│   │   ├── hpl_core.h
│   │   ├── hpl_delay.h
│   │   ├── hpl_dma.h
│   │   ├── hpl_gpio.h
│   │   ├── hpl_i2c_m_async.h
│   │   ├── hpl_i2c_m_sync.h
│   │   ├── hpl_i2c_s_async.h
│   │   ├── hpl_i2c_s_sync.h
│   │   ├── hpl_init.h
│   │   ├── hpl_irq.h
│   │   ├── hpl_missing_features.h
│   │   ├── hpl_reset.h
│   │   ├── hpl_sleep.h
│   │   ├── hpl_spi_async.h
│   │   ├── hpl_spi.h
│   │   ├── hpl_spi_m_async.h
│   │   ├── hpl_spi_m_sync.h
│   │   ├── hpl_spi_s_async.h
│   │   ├── hpl_spi_s_sync.h
│   │   ├── hpl_spi_sync.h
│   │   ├── hpl_usart_async.h
│   │   ├── hpl_usart.h
│   │   └── hpl_usart_sync.h
│   ├── src
│   │   ├── hal_atomic.c
│   │   ├── hal_delay.c
│   │   ├── hal_gpio.c
│   │   ├── hal_init.c
│   │   ├── hal_io.c
│   │   ├── hal_sleep.c
│   │   └── hal_usart_async.c
│   └── utils
│       ├── include
│       │   ├── compiler.h
│       │   ├── err_codes.h
│       │   ├── events.h
│       │   ├── parts.h
│       │   ├── utils_assert.h
│       │   ├── utils_event.h
│       │   ├── utils.h
│       │   ├── utils_increment_macro.h
│       │   ├── utils_list.h
│       │   ├── utils_repeat_macro.h
│       │   └── utils_ringbuffer.h
│       └── src
│           ├── utils_assert.c
│           ├── utils_event.c
│           ├── utils_list.c
│           ├── utils_ringbuffer.c
│           └── utils_syscalls.c
├── hpl
│   ├── core
│   │   ├── hpl_core_m0plus_base.c
│   │   ├── hpl_core_port.h
│   │   └── hpl_init.c
│   ├── dmac
│   │   └── hpl_dmac_v100.c
│   ├── gclk
│   │   ├── hpl_gclk1_v210_base.c
│   │   └── hpl_gclk1_v210_base.h
│   │
```

```
│     ├── pm
│     │   ├── hpl_pm1_v201a.c
│     │   └── hpl_pm1_v201_base.h
│     ├── port
│     │   └── hpl_port_v100.c
│     ├── sercom
│     │   └── hpl_sercom_v200.c
│     └── sysctrl
│         └── hpl_sysctrl_v201a.c
├── hri
│   ├── hri_dmac_v100.h
│   ├── hri_gclk1_v210.h
│   ├── hri_nvmctrl_v106.h
│   ├── hri_pm_v201a.h
│   ├── hri_port_v100.h
│   ├── hri_sercom_v200.h
│   └── hri_sysctrl_v201a.h
└── main.c
```

3. Driver Implementation and Design Conventions

3.1 Introduction

This chapter covers driver implementation and design conventions, in the following major sections:

- 3.2 ASF4 and Atmel START Configuration
- 3.3 Driver Implementation
- 3.4 Design Conventions
- 3.5 Toolchain and Device-specific Support
- 3.6 Embedded Software Coding Style

3.2 ASF4 and Atmel START Configuration

The ASF4 framework cannot be used as a stand-alone framework, it must be used together with Atmel START. Atmel START contains a code generator that generates ASF4 C-code based on the user's configuration. Atmel START uses two mechanisms to generate the final C-code:

- Code generation - Atmel START has an internal representation of the C-code. This internal representation is processed by a code generator resulting in C-code.
- Parameter generation - The generated C-code accepts parameters in the form of C #define statements. These statements are generated by Atmel START, based on the user's input. The CMSIS wizard annotation format is used for the parameters.

3.2.1 Hardware Configuration

For microcontroller projects, configuration data is normally available before or at the point of compilation. Calculation of register data and resolving of configuration can therefore be calculated at compile time. This will free up flash space and lower the processing power needed to initialize the module. An added benefit of less code in the initialization function is that time spent to get into the main loop will be shorter. A combination of constants set by Atmel START, pre-processor macros, and static functions are used to avoid doing such calculations in the runtime code.

The configuration for each module and each instance of the module is stored statically in configuration files in the config/ folder as #define macros. All configuration parameters have names in uppercase and belong to the "CONF_" namespace, followed by the name of the hardware module, instance, and then the bit or bit field name as spelled in the data sheet. All parameters that are visible in configuration dialogs in Atmel START are annotated with the CMSIS configuration wizard annotation language.

3.2.2 Output from Atmel START

When exporting a project from Atmel START, the output is a single file with an *.atzip extension. This is basically an ordinary zip-file. Renaming it from *.atzip to *.zip allows it to be unzipped with standard zip-tools. This would result in a file tree as shown in the folder structure section shown elsewhere in this manual.

3.2.3 Reconfiguring Output from Atmel START

There may be a need to reconfigure code generated by ASF4 at a later time, for example changing baudrate of a USART, or moving an I/O pin to a new location. If using Atmel Studio as IDE, the ASF4 code can be imported back into Atmel START again and reconfigured by right-clicking on the project

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name in Project Explorer, and selecting "Re-Configure Atmel Start Project". This will open Atmel START inside a window in Studio, allowing the user to perform the required changes and export the result back into the Studio project. Studio will detect any changed ASF4 files, and attempt to merge them into the original project.

If using other IDEs than Studio, or no IDE at all, an already generated project can be reconfigured by opening the Atmel START webpage, and selecting "Load existing project" from the front page. Use the originally generated *.atzip-file as input file. The project can thereafter be reconfigured and exported anew. Any changes and conflicts between the original and the reconfigured project must be merged manually by the user.

3.2.4 Versioning of ASF4 Code

Atmel START and ASF4 are tightly connected. A specific version of ASF4 code will only run on a compatible version of Atmel START. This may pose problems as an ASF4 code generated with a particular version of Atmel START may not be possible to read back into and reconfigure with newer versions of Atmel START. Since Atmel START is a web-based tool, it may be updated without the user being able to affect the update process.

Future versions of Atmel START will add the concept of versioning, where the web-based Atmel START configurator will support different versions of ASF4.

3.3 Driver Implementation

Drivers consist of two parts; a static part and a dynamic or configurable part. The static part is hardwired code not intended to be changed or reconfigured by the application after being exported from Atmel START. The dynamic part allows the application to configure the behavior of the driver through e.g. callbacks, or provide resources such as ring buffers to drivers.

The dynamic part is normally configured during driver initialization by calling the driver's init-function. This is typically done during the device initialization and startup phase.

The functionality provided by the static and dynamic parts of the driver is unique to each driver, and documented separately for each driver.

3.3.1 Driver Initialization

All drivers configured in Atmel START are automatically initialized. Atmel START generates calls to the init()-functions of all drivers inside driver_init.c. The driver_init.c file is called by the main.c-file generated by Atmel START.

Each driver has an init()- and a deinit()-function. The init() function:

- hooks up IRQ handler and enables the module's IRQs if necessary
- configures the module as desired by writing the module descriptor contents to the correct control registers
- enables the module
- does NOT enable any clocks required by the module, this must be done separately
- does NOT enable any I/O pins required by the module, this must be done separately

The deinit()-function:

- disables and clears the module's interrupts, if enabled
- disbles the module, typically by clearing the module's enable-bit in the module's control register

- does NOT disable any clocks used by the module, this must be done separately
- does NOT disable any I/O pins used by the module, this must be done separately

3.3.2 Descriptors

Descriptors are driver-specific data structures that are used to fine-tune the behavior of the driver. The application populates the descriptors with the desired configuration information, and passes the descriptors into the driver. Typical information contained in descriptors can be:

- pointer to and size of ring buffer to be used by the driver
- desired behavior or configuration of the driver hardware
- description of interrupt routines
- pointers to callback functions

3.3.3 Configuring the Dynamic Part of Drivers

The dynamic part of drivers is normally configured during system initialization. The most commonly configured resources are interrupt routine callback functions and memory buffers. How this is done is best illustrated with an example, using the ADC in synchronous mode as an example. All the following code is found in driver_init.c.

The following code declares and defines various resources that will be made available to the ADC:

```
/* The channel amount for ADC */
#define ADC_0_CH_AMOUNT 1
/* The buffer size for ADC */
#define ADC_0_BUFFER_SIZE 16
/* The maximal channel number of enabled channels */
#define ADC_0_CH_MAX 0
extern struct _irq_descriptor *_irq_table[PERIPH_COUNT_IRQn];
extern void Default_Handler(void);
struct adc_async_descriptor ADC_0;
struct adc_async_channel_descriptor ADC_0_ch[ADC_0_CH_AMOUNT];
static uint8_t ADC_0_buffer[ADC_0_BUFFER_SIZE];
static uint8_t ADC_0_map[ADC_0_CH_MAX+1];
```

The system_init()-function is called by main and initializes the peripheral driver(s), in this case the ADC:

```
void system_init(void)
{
    ADC_0_init();
}
```

The ADC_0_init() function initializes ADC0. The two first lines enable the clock to the ADC.

```
static void ADC_0_init(void)
{    _pm_enable_bus_clock(PM_BUS_APBC, ADC);    _gclk_enable_channel(ADC_GC
LK_ID, CONF_GCLK_ADC_SRC);    adc_async_init(&ADC_0, ADC, ADC_0_map, ADC_0_
CH_MAX, ADC_0_CH_AMOUNT, &ADC_0_ch[0]);    adc_async_register_channel_buffe
r(&ADC_0, 0, ADC_0_buffer, ADC_0_BUFFER_SIZE);}
```

The 5.2.9.1 adc_async_init-function updates the ADC_0 descriptor with information found in the other parameters of the function, and writes this configuration to the ADC hardware. The configured data includes:

- hooking up any callback functions
- configuring the number of channels to use, in this case one channel (channel 0)
- configuring the behavior of each channel used

The 5.2.9.3 adc_async_register_channel_buffer-function hooks the ring buffer ADC_0_buffer with size ADC_0_BUFFER_SIZE up to the ADC descriptor ADC_0, to be used for channel 0.

The ADC_Handler()-function hooks the driver's ISR up to the IRQ vector table. _irq_table[] is a table of interrupt handler descriptors handled by the HPL layer of the IRQ driver.

```
        void ADC_Handler(void)
        {
            if (_irq_table[ ADC_IRQn + 0 ]) {
                _irq_table[ ADC_IRQn + 0 ]-
>handler(_irq_table[ ADC_IRQn + 0 ]->parameter);
            } else {
                Default_Handler();
            }
        }
```

3.3.4 Compile-time Configuration and Parameterization from Atmel START

The user is normally able to configure driver parameters in Atmel START. A typical example is setting of baudrate and parity for a USART. The files in the config-folder are generated by Atmel START in order to transfer the configurations the user made in Atmel START into the HPL layer. The files use the CMSIS wizard annotation format. Example of contents in hpl_sercom_v200_config.h:

```
        // <o> Frame parity
            // <0x0=>No parity
            // <0x1=>Even parity
            // <0x2=>Odd parity
        // <i> Parity bit mode for USART frame
        // <id> usart_parity
        #ifndef CONF_SERCOM_0_USART_PARITY
        #   define CONF_SERCOM_0_USART_PARITY  0x0
        #endif
```

3.3.5 Utility Drivers

The utility drivers support other drivers with commonly used software concepts and macros such as ring buffers, linked lists, state machines, etc. Moving this commonly used code into utility drivers makes it easier to maintain the code and help the compiler to optimize the code because the same code is used by different drivers, but only one copy is needed. The utility drivers are fully abstracted and not bound to any particular hardware platform or type. Utility drivers are located in the hal/utils folder with public declaration files in a include folder and function declaration in a src folder. All filenames starts with the prefix utils_. See the API reference in the file "utils.h" for more information on the utility functions.

3.4 Design Conventions

3.4.1 Memory Buffers

As a rule of thumb, no memory buffer is allocated by the driver. Allocation is done by the application and provided to the driver as pointer variables. This allows the author of the application freedom to choose

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how memory is allocated in the application. In many cases, memory management can be done at compile time by allocating memory statically. Allocation outside the driver also gives the user the possibility of using a memory manager of his choosing.

3.4.2 Parameter List

The parameter list for a given public ASF4 function shall have a hard limit of up to four parameters. If this limit is surpassed the function's purpose shall be redesigned or split into multiple function calls. Another approach would be to use a container for the parameters like a struct.

3.4.3 Naming Convention

3.4.3.1 Reserved Words/Acronyms

Some words/acronyms are given a special meaning in the framework to give the user a better understanding about the purpose of function/symbol/etc. These words are:

3.4.3.1.1 Callback

Short: cb

Typically used for functions or pointers. Refers to functions/code that is triggered by events in hardware or other parts of the software.

```
struct spi_dev_callbacks {
     /* TX callback, see \ref spi_dev_cb_xfer_t. */
     spi_dev_cb_xfer_t tx;
     /* RX callback, see \ref spi_dev_cb_xfer_t. */
     spi_dev_cb_xfer_t rx;
     /* Complete callback, see \ref spi_dev_cb_complete. */
     spi_dev_cb_complete_t complete;
```

3.4.3.1.2 Configuration

Short: conf

Typically used to symbols, macros defining a configuration parameter or a set of configuration parameters.

```
#define CONF_SERCOM_0_USART_DORD              CONF_SERCOM_USART_DATA_ORDER
_LSB

#define CONF_SERCOM_0_USART_CPOL              CONF_SERCOM_USART_CLOCK_POLA
RITY_TX_RISING_EDGE

#define CONF_SERCOM_0_USART_CMODE             CONF_SERCOM_USART_COMMUNICAT
ION_MODE_ASYNCHRONOUS
```

3.4.3.1.3 Deinitialize

Short: deinit

Typically used for a function that resets something to the initial state, for instance deinit of a peripheral should disable it, remove any clock connections and preferably set it back to device power up state.

```
int32_t adc_deinit(struct adc_descriptor *const descr);
```

3.4.3.1.4 Device

Short: dev

Typically used when referring to something that can be described as a "device" like the abstracted device definition.

```
            struct _adc_device {
                   struct _adc_callbacks adc_cb;
                   void *hw;
            };
```

3.4.3.1.5 Initialize

Short: init

Typically used for functions that initializes something, like a peripheral for instance.

```
int32_t usart_sync_init(struct usart_sync_descriptor *const descr, void *co
nst hw);
```

3.4.3.1.6 Interface

Short: iface

Typically used when referring to driver interfaces (APIs) like the abstracted interface used between the HPL and HAL.

```
            struct i2c_interface {
                 int32_t (*init)(struct i2c_device *i2c_dev);
                 int32_t (*deinit)(struct i2c_device *i2c_dev);
                 int32_t (*enable)(struct i2c_device *i2c_dev);
                 int32_t (*disable)(struct i2c_device *i2c_dev);
                 int32_t (*transfer)
(struct i2c_device *i2c_dev, struct i2c_msg *msg);
                 int32_t (*set_baudrate)
(struct i2c_device *i2c_dev, uint32_t clkrate, uint32_t baudrate);
```

3.4.3.1.7 Message

Short: msg

Typically used when data sent over an interface has to be compiled from different data sources before it is sent. For instance, an I2C message has to consist of an address and data.

```
            struct i2c_msg {
             uint16_t addr;
             volatile uint16_t flags;
             int32_t len;
             uint8_t *buffer;
```

3.4.3.1.8 Private

Acronym: prvt

Typically used for private data members or symbols, which contain data that should not be accessed by external code (for instance user code, or it can even be localised to just parts of the owner code).

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Typically used for the hardware pointer member in the device descriptor struct as it should only be accessed by the HPL after it has be assigned.

```
            struct spi_sync_dev {
                    /
* Pointer to the hardware base or private data for special device. */
                    void *prvt;
                    /* CS information,
                     *  Pointer to information list to configure and use I/
O pins as SPI CSes

        *  (master), or CS pin information when \c cs_num is 0 (slave).
                     */
                    union spi_dev_cs cs;
                    /
* Number of Chip Select (CS), set to 0 for SPI slave, 0xFF to ignore CS beh
aviour */
                    int8_t cs_num;
                    /* Data size, number of bytes for each character */
                    uint8_t char_size;
                    /
* Flags for the driver for implementation use (could change in implementati
on) */
                    uint16_t flags;
            };
```

3.4.3.1.9 Status

Short: stat

Typically used when referring to functions/symbols related to returning or storing status information.

3.4.3.1.10 Error

Short: err

Typically used for containers/variables holding information about error state information in hardware or software, can also refer to callbacks or functions referring to error handling code.

```
static void dac_tx_error(struct _dac_device *device, const uint8_t ch);
```

3.4.3.1.11 Transfer

Short: xfer

Typically used when referring to functions/symbols related to moving data in one or both direction.

```
            enum spi_transfer_mode {
                    /
* Leading edge is rising edge, data sample on leading edge. */
                    SPI_MODE_0,
                    /
* Leading edge is rising edge, data sample on trailing edge. */
                    SPI_MODE_1,
                    /
* Leading edge is falling edge, data sample on leading edge. */
                    SPI_MODE_2,
                    /
```

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```
 * Leading edge is falling edge, data sample on trailing edge. */
                    SPI_MODE_3
            };
```

3.5 Toolchain and Device-specific Support

3.5.1 System Startup Sequence

An ASF4 project executes the following startup sequence:

1. The initial value of the stack pointer is read from the linker script, and written to the first 32-bit address in the exception vector. The startup sequencing hardware will write this value to the stack pointer (SP) in the register file, before releasing the CPU from reset.
2. The address of the Reset_Handler() is placed as the second 32-bit word in the exception vector. The ARM hardware will execute the code in this function immediately after releasing the CPU from reset.

The Reset_Handler() function can be found in the /Device_Startup/startup_{device}.c file, where {device} is the name of the device chosen. The reset handler:

1. Initializes various memory segments
2. Configures the bus matrix if applicable
3. Initializes data structures in the C library
4. Jumps to the main() function

3.5.2 Portability of Generated ASF4 Code Between Devices

An ASF4 project generated for one device should in general not be compiled for other devices. There may be differences between devices so that the code may not compile, or may compile but not behave as intended.

3.5.3 CMSIS-CORE Library

The CMSIS-CORE library is provided as part of the Device Family Packages (DFPs) for all Microchip SAM devices. Functions in CMSIS-CORE, for example __set_BASEPRI() can be called from the ASF4 code. ASF4 also provides an HPL library abstracting the CPU core. This core-specific library is part of the *.atzip file exported from Atmel START. The library can be found in the /hpl/core/ directory. The device header file, named {device}.h, present in the device DFP directory, configures the CMSIS-CORE parameters and includes the CMSIS-CORE header file, named core_{core_name}.h. An example of a {device-file, CMSIS-CORE file}-pair is {samd21e15a.h, core_cm0plus.h}.

3.5.4 Interrupt Vectors

The interrupt vector table can be found in the /Device_Startup/startup_{device}.c file, where {device} is the name of the device chosen, e.g. samd21. The vector table is populated with jumps to a Dummy_Handler(), performing an eternal while-loop. The Dummy_Handler() has the GCC attribute "weak", and is intended to be overridden by the appropriate handler provided by ASF4, or defined by the user.

ASF4 does not assign a specific priority to the IRQs, but instead uses the default priority as assigned by the NVIC. Different ARM cores have NVIC interrupt controllers with individual specifications and features. Refer to the device data sheet and NVIC documentation for the ARM core being used in the selected target device for more information on manipulating interrupt priorities and masking interrupts.

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The ARM CMSIS-CORE specification has functions for manipulating the NVIC in order to prioritize IRQs and mask interrupts. Refer to the CMSIS specification and CMSIS-CORE library(doc_driver_hal_intro_toolchain_1s_ds_cmsis) for more information.

3.5.5 C Library

Atmel START generates code to be used together with the GCC tool suite for ARM. This includes system call implementations for the GCC newlib C library, such as _exit() and _close(). The system call implementations can be found in /hal/utils/src/utils_syscalls.c. Other compilers, such as IAR or Keil, may use proprietary C-libraries, and not use these syscall implementations.

3.5.6 Linker Scripts

A set of default linker scripts for the GCC compiler are provided by Atmel START. The scripts are tailored to the device selected in Atmel START. They can be found in the /Device_Startup/*.ld files. Multiple scripts may be provided, e.g. one script for placing code in flash, another for placing code in RAM. Other compilers, such as IAR or Keil, may use proprietary linker scripts and formats, and not use these linker scripts implementations. Atmel START does not generate linker scripts for other compilers than GCC.

3.5.7 Support for Various Toolchains

ASF4 consists of generic C-code and can in be compiled using any ARM C-compiler. However, Atmel START includes support for exporting projects into the following toolchains:

- Atmel Studio/GCC
- IAR Embedded Workbench
- Keil uVision
- Standalone makefile system

3.5.7.1 GCC and Atmel Studio

When generating output for Atmel Studio, an *.atzip file is generated. This file can be opened directly in Studio.

3.5.7.1.1 Compiler options

The various compiler and toolchain options set by default by Atmel START can be examined by right-clicking on the project name in Studio. The default build configuration is Debug, with debug symbol generation enabled (-g) and minimum optimization (-O1).

3.5.7.1.2 Build system

The project in the *.atzip file can be built directly using Studio's build system. Refer to the Studio documentation for more information.

3.5.7.2 IAR Embedded Workbench (EW)

The ASF4 code can be imported into IAR EW. Refer to the Atmel START documentation for more information.

3.5.7.3 Keil uVision

The ASF4 code can be imported into Keil uVision. Refer to the Atmel START documentation for more information.

3.6 Embedded Software Coding Style

3.6.1 MISRA 2004 Compliance

ASF4 follows the MISRA 2004 rules with the CMSIS-CORE exceptions.

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3.6.2 Function and Variable Names

- Functions and variables are named using all lower case letters: [a-z] and [0-9]
- Underscore '_' is used to split function and variable names into more logical groups

3.6.2.1 Example

```
void this_is_a_function_prototype(void);
```

3.6.2.2 Rationale

All-lowercase names are easy on the eyes, and it is a very common style to find in C code.

3.6.3 Constants

- Constants are named using all upper case letters: [A-Z] and [0-9]
- Underscore '_' is used to split constant names into more logical groups
- Enumeration constants shall follow this rule
- Constants made from an expression must have braces around the entire expression; single value constants may skip this
- Constants must always be defined and used instead of "magic numbers" in the code
- Definitions for unsigned integer constants (including hexadecimal values) must use a "u" suffix
- For hexadecimal values, use upper case A-F
- Samme rules apply to enumerations as they are constants too

3.6.3.1 Example

```
#define BUFFER_SIZE              512
#define WTK_FRAME_RESIZE_WIDTH   (WTK_FRAME_RESIZE_RADIUS + 1)
enum buffer_size = {
      BUFFER_SIZE_A = 128,
      BUFFER_SIZE_B = 512,
};
```

3.6.3.2 Rationale

Constants shall stand out from the rest of the code, and all-uppercase names ensure that. Also, all-uppercase constants are very common in specification documents and data sheets, from which many such constants originate. MISRA rule 10.6. MISRA specifies "U", but this is less readable than "u" and both are accepted. The braces around an expression are vital to avoid an unexpected evaluation. For example, a constant consisting of two variables added together, which are later multiplied with a variable in the source code.

```
#define NUM_X_PINS              (24u)
#define XEDGEGRADIENT_MASK      (0x3Fu)
#define NUM_MATRIX_PINS         (NUM_X_PINS + NUM_Y_PINS)
```

Do not include cast operations types in constant definitions:

```
#define THIS_CONSTANT  (uint8_t)(0x0Fu)
```

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3.6.4 Inline Constants

Where a constant value is only to be used once within a particular function, and is not derived from or related to functionality from another module, it should be defined as an appropriately typed const (using variable naming conventions) within that function, e.g.:

```
void this_function(void)
{
      uint8_t const num_x_pins = 24u;  /* max number of X pins */
      ...
```

3.6.4.1 Rationale

Keeps constant definition close to where it is used and in appropriate scope; avoids a large block of often unrelated macro definitions.

3.6.5 Variables

Variables should be defined individually on separate lines. Examples:

```
/* Do like this */
uint8_t x_edge_dist;
uint8_t y_edge_dist;
/* Don't do like this */
uint8_t x_edge_dist, y_edge_dist;
```

Constant or volatile variables should be defined with the qualifier following the type. Examples:

```
/* Do like this */
uint8_t const x_edge_dist;
uint8_t volatile register_status;
/* Don't do like this */
const uint8_t x_edge_dist;
```

Variables must only be defined at the start of a source code block (denoted by {} braces). Examples:

```
void this_function(void)
{    uint8_t x_edge_dist;for (line_idx = LINE_IDX_MIN; line_idx <= LINE_IDX
_MAX; line_idx++){    bool_t this_flag = FALSE;
```

3.6.6 Type Definitions

- stdint.h and stdbool.h types must be used when available
- Type definitions are named using all lower case letters: [a-z] and [0-9]
- Underscore '_' is used to split names into more logical groups
- Every type definition must have a trailing '_t'

3.6.6.1 Example

```
typedef uint8_t buffer_item_t;
```

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3.6.6.2 Rationale

stdint and stdbool ensures that all drivers on all platforms uses the same set of types with clearly defined size. Trailing _t follows the same convention used in stdint and stdbool, which clearly differentiate the type from a variable.

3.6.7 Structures and Unions

- Structures and unions follow the same naming rule as functions and variables
- When the content of the struct shall be kept hidden for the user, typedef shall be used

3.6.7.1 Example

```
struct cmd {
        uint8_t length;
        uint8_t *payload;
    };
union cmd_parser {
        cmd_t cmd_a;
        cmd_t cmd_b;
    };
typedef struct {
        void *hw;
    } device_handle_t;
```

3.6.8 Functions

Lay out functions as follows, explicitly defining function return type and naming any parameters, and where possible writing them all on the same line:

```
return_type_t function_name(param1_t param1, param2_t param2)
{
    statements;
}
```

For a function with a long definition, split it over several lines, with arguments on following lines aligned with the first argument. Example:

```
uint16_t this_function(uint8_t uint8_value,
                       char_t *char_value_ptr,
                       uint16_t *uint16_t_value_ptr);
```

If a function has more than three parameters, consider passing them via a pointer to a structure that contains related values, to save compiled code and/or stack space. Using a structure in this way also avoids having to update a function prototype, and therefore having to update calling software, should additional parameter values be needed. Use "const correctness" to protect parameters passed via pointer from being changed by a function. Example:

```
        void this_function(uint8_t            *value_ptr,        /
* pointer to value */
                           uint8_t      const *const_ptr,        /
* pointer to const value */
                           uint8_t      *const const_value_ptr,  /
```

```
* const pointer to value */
                          uint8_t      const *const_const_ptr); /
* const pointer to const value */
```

3.6.9 Return Statement

Every function should have only one return statement, unless there are specific and commented reasons for multiple return statements e.g. saving compiled code, clarifying functionality.

3.6.9.1 Rationale

MISRA rule 14.7 Easier debugging.

Do not embed conditional compilation inside a return statement. Examples:

```
/* Don't do like this */
return (
#ifdef PRXXX_ADDR
    (uint32_t*)PRXXX _ADDR
#else
    (uint32_t*)NULL_PTR
#endif
);
/* Do like this */
uint32_t* addr_ptr;
...
#ifdef PRXXX_ADDR
addr_ptr = (uint32_t*)PRXXX_ADDR;
#else
addr_ptr = (uint32_t*)NULL_PTR;
#endif
return (addr_ptr);
```

3.6.10 Function like Macro

- Function like macros follow the same naming rules as the functions and variables. This way it is easier to exchange them for inline functions at a later stage.
- Where possible, function like macros shall be blocked into a do {} while (0)
- Function like macros must never access their arguments more than once
- All macro arguments as well as the macro definition itself must be parenthesized
- Function like macros shall be avoided if possible, static inline function shall be used instead.
- Functional macros must not refer to local variables from their "host" calling function, but can make use of global variables or parameters passed into them.

3.6.10.1 Example

```
#define set_io(id) do {          \
       PORTA |= (1 << (id));    \
} while (0)
```

3.6.10.2 Rationale

We want function like macros to behave as close to regular functions as possible. This means that they must be evaluated as a single statement; the do { } while (0) wrapper for "void" macros and surrounding parentheses for macros returning a value ensure this. The macro arguments must be parenthesized to

avoid any surprises related to operator precedence; we want the argument to be fully evaluated before it's being used in an expression inside the macro. Also, evaluation of some macro arguments may have side effects, so the macro must ensure it is only evaluated once (sizeof and typeof expressions don't count).

3.6.11 Indentation

- Indentation is done by using the TAB character. This way one ensures that different editor configurations do not clutter the source code and alignment.
- The TAB characters must be used before expressions/text, for the indentation.
- TAB must not be used after an expression/text, use spaces instead. This will ensure good readability of the source code independent of the TAB size.
- The TAB size shall be fixed to four characters.

3.6.11.1 Example

```
enum scsi_asc_ascq {
[TAB]                                   [spaces]
       SCSI_ASC_NO_ADDITIONAL_SENSE_INFO         = 0x0000,
       SCSI_ASC_LU_NOT_READY_REBUILD_IN_PROGRESS = 0x0405,
       SCSI_ASC_WRITE_ERROR                      = 0x0c00,
       SCSI_ASC_UNRECOVERED_READ_ERROR           = 0x1100,
       SCSI_ASC_INVALID_COMMAND_OPERATION_CODE   = 0x2000,
       SCSI_ASC_INVALID_FIELD_IN_CDB             = 0x2400,
       SCSI_ASC_MEDIUM_NOT_PRESENT               = 0x3a00,
       SCSI_ASC_INTERNAL_TARGET_FAILURE          = 0x4400,
};
```

3.6.11.2 Rationale

The size of the TAB character can be different for each developer. We cannot impose a fixed size. In order to have the best readability, the TAB character can only be used, on a line, before expressions and text. After expressions and text, the TAB character must not be used, use spaces instead. The entire point about indentation is to show clearly where a control block starts and ends. With large indentations, it is much easier to distinguish the various indentation levels from each others than with small indentations (with two-character indentations it is almost impossible to comprehend a non-trivial function). Another advantage of large indentations is that it becomes increasingly difficult to write code with increased levels of nesting, thus providing a good motivation for splitting the function into multiple, more simple units and thus improve the readability further. This obviously requires the 80-character rule to be observed as well. If you're concerned that using TABs will cause the code to not line up properly, see the section about continuation.

3.6.12 Text Formatting

- One line of code, documentation, etc. should not exceed 80 characters, given TAB indentation of four spaces
- Text lines longer than 80 characters should be wrapped and double indented

3.6.12.1 Example

```
          /
* This is a comment which is exactly 80 characters wide for example showing
. */
                 dma_pool_init_coherent(&usbb_desc_pool, addr, size,

               sizeof(struct usbb_sw_dma_desc), USBB_DMA_DESC_ALIGN);
```

```
#define unhandled_case(value)
   \
        do {
   \
            if (ASSERT_ENABLED) {
   \
                dbg_printf_level(DEBUG_ASSERT,
   \
                                  "%s:%d: Unhandled case value %d
\n",                    \
                        __FILE__, __LINE__, (value));
   \
                abort();
   \
            }
   \
                  } while (0)
```

3.6.12.2 Rationale

Keeping line width below 80 characters will help identify excessive levels of nesting or if code should be refactored into separate functions.

3.6.13 Space

- After an expression/text, use spaces instead of the TAB character
- Do not put spaces between parentheses and the expression inside them
- Do not put space between function name and parameters in function calls and function definitions

3.6.13.1 Example

```
          fat_dir_current_sect
                  = ((uint32_t)
(dclusters[fat_dchain_index].cluster + fat_dchain_nb_clust - 1)

                  fat_cluster_size) + fat_ptr_data + (nb_sect % fat_cluster
_size);
```

3.6.14 Continuation

- Continuation is used to break a long expression that does not fit on a single line
- Continuation shall be done by adding an extra TAB to the indentation level

3.6.14.1 Example

```
static void xmega_usb_udc_submit_out_queue(struct xmega_usb_udc *xudc,
                        usb_ep_id_t ep_id, struct xmega_usb_udc_ep *ep)
          {
                 (...)
          }
          #define xmega_usb_read(reg) \
                        mmio_read8((void *)(XMEGA_USB_BASE + XMEGA_USB_
```

```
\sectionreg))
```

3.6.14.2 Rationale

By indenting continuations using an extra TAB, we ensure that the continuation will always be easy to distinguish from code at both the same and the next indentation level. The latter is particularly important in if, while, and for statements. Also, by not requiring anything to be lined up (which will often cause things to end up at the same indentation level as the block, which is being started), things will line up equally well regardless of the TAB size.

3.6.15 Comments

3.6.15.1 Short Comments

Short comments may use the

```
/* Comment */(...)
```

3.6.15.2 Long Comments, Comment Blocks

Long (multiline) comments shall use the

```
/* * Long comment that might wrap multiple lines ... */(...)
```

3.6.15.3 ss_cs_comment_ind Comment Indentation

Indent comments with the corresponding source code. Example:

```
          for (;;) {
              /
* get next token, checking for comments, pausing, and printing */
              process_token(token, token_size);
          }
```

3.6.15.4 Comment Placement

Put comments on lines by themselves, not mixed with the source code. Example:

```
/* get next token */process_token(token, token_size);
```

3.6.15.5 Rationale

Ease of readability, ease of maintenance, makes using file comparison tools easier.

3.6.15.6 Commenting long code

Where a source code block is typically more than 25 lines (so that matching opening/closing braces cannot be seen together onscreen), add a comment to the end brace of the block to clarify which conditional block it belongs to. Example:

```
          if (MAX_LINE_LENGTH <= line_length) {
            /* ...long block of source code... */
          } else { /* MAX_LINE_LENGTH > line_length */
            /* ...long block of source code... */
          } /* end if (MAX_LINE_LENGTH <= line_length) ...else... */
```

3.6.16 Braces

- The opening brace shall be put at the end of the line in all cases, except for function definition. The closing brace is put at the same indent level than the expression

- The code inside the braces is indented
- Single line code blocks should also be wrapped in braces

3.6.16.1 Examples

```
if (byte_cnt == MAX_CNT) {
       do_something();
} else {
       do_something_else();
}
```

3.6.17 Pointer Declaration

When declaring a pointer, link the star (*) to the variable.

3.6.17.1 Example

```
uint8_t *p1;
```

3.6.17.2 Rationale

If multiple variable types are declared on the same line, this rule will make it easier to identify the pointers variables.

3.6.18 Compound Statements

- The opening brace is placed at the end of the line, directly following the parenthesized expression
- The closing brace is placed at the beginning of the line following the body
- Any continuation of the same statement (for example, an 'else' or 'else if' statement, or the 'while' in a do/while statement) is placed on the same line as the closing brace
- The body is indented one level more than the surrounding code
- The 'if', 'else', 'do', 'while', and 'switch' keywords are followed by a space
- Where an else if() clause is used, there must be a closing else clause, even if it is empty. MISRA rule 14.10.

3.6.18.1 Example

```
if (byte_cnt == MAX1_CNT) {
    do_something();
} else if (byte_cnt > MAX1_CNT) {
    do_something_else();
} else {
    now_for_something_completely_different();
}
while (i <= 0xFF) {
    ++i;
}
do {
    ++i;
} while (i <= 0xFF);
for (i = 0; i < 0xFF; ++i) {
    do_something();
}
/* Following example shows how to break a long expression. */
for (uint8_t i = 0, uint8_t ii = 0, uint8_t iii = 0;
        (i < LIMIT_I) && (ii < LIMIT_II) && (iii == LIMIT_III);
```

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```
                ++i, ++ii, ++iii) {
            do_something();
        }
```

3.6.19 Switch-case Statement

- The switch block follows the same rules as other compound statements
- The case labels are on the same indentation level as the switch keyword
- The break keyword is on the same indentation level as the code inside each label
- The code inside each label is indented
- The switch-case shall always end with a default label
- Labels may be shared where the same statements are required for each
- Should primarily be used for flow control; with any complex processing inside each case being moved to (inline if appropriate) functions

3.6.19.1 Example

```
        switch (byte_cnt) {
        case 0:
            ...
            break;
        case 1:
        case 2:
            ...
            break;
        default:
            ...
        }
```

3.6.20 "Fall-through" Switch-cases

Avoid using "fall-through" from one case to a following case where it saves compiled code and/or reduces functional complexity, it may be used but must be clearly commented and explained:

```
        case VALUE_1:
            statements;
            /* no break; - DELIBERATE FALL-
THROUGH TO VALUE_2 CASE TO REDUCE COMPILED CODE SIZE */
        case VALUE_2:
            statements;
            break;
```

3.6.21 Goto Statments

The goto statement must never be used. The only acceptable label is the default: label in a switch() statement.

3.6.22 Operators

Do not add spaces between an unary operator (-, !, ~, &, *, ++, etc.) and its operand. Example:

```
        /* Do like this */
        x = ++y;
```

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```
/* Don't do like this */
x = ++ y;
```

Add a space on either side of a binary operator. Examples:

```
a = b + c;
a *= b;
```

Restrict use of the ternary operator to simple assignments e.g.:

```
range_setting = (5u <= parm_value) ? RANGE_IS_HIGH : RANGE_IS_LOW;
```

Use braces to clarify operator precedence, even if not strictly required. Example:

```
a = b + (c * d);
```

3.6.23 Preprocessor Directives

- The # operator must always at the beginning of the line
- The directives are indented (if needed) after the #

3.6.23.1 Example

```
#if (UART_CONF == UART_SYNC)
#    define INIT_CON       (UART_EN | UART_SYNC | UART_PAUSE)
#elif (UART_CONF == UART_ASYNC)
#    define INIT_CON       (UART_EN | UART_ASYNC)
#elif (UART_CONF==UART_PCM)
#    define INIT_CON       (UART_EN | UART_PCM | UART_NO_HOLE)
#else
#    error Unknown UART configuration
#endif
```

Comment #endif statements to clarify which conditional block they belong to, regardless of how many lines of source code the block comprises of. This is especially important for nested conditional blocks. Example:

```
  statements;
#ifdef DEBUG
  statements;
#endif /* DEBUG */
```

3.6.24 Header Files

3.6.24.1 Include of Header Files

When including header files, one shall use "" for files that are included relative to the current file's path and <> for files that are included relative to an include path. Essentially, this means that "" is for files that

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are included from the ASF module itself, while <> is for files that are included from other ASF modules. For example, in adc.c, one could include accordingly:

```
#include <compiler.h>
#include "adc.h"
```

3.6.24.2 Header File Guard

Include guards are used to avoid the problem of double inclusion. A module header file include guard must be in the form MODULE_H_INCLUDED. For example, in adc.h:

```
#ifndef ADC_H_INCLUDED
#define ADC_H_INCLUDED
#endif /* ADC_H_INCLUDED */
```

3.6.25 Doxygen Comments

Comments that are to appear in Doxygen output shall start with /** characters and end with * / where the comments refer to the following statement. For example:

```
/** node index; */
uint8_t node_idx;
```

End-of-line Doxygen comments shall start with /**< characters and end with * /. The < tells Doxygen that the comment refer to the preceding statement. For example:

```
uint8_t node_idx; /**< node index */
```

3.6.26 End of File

Each file must end with a new line character i.e. have a final blank line.

3.6.26.1 Rationale

ISO C99 requirement.

4. AC Drivers

This Analog Comparator (AC) driver provides an interface for voltage comparison of two input channels.

The following driver variants are available:

- 4.3 AC Synchronous Driver: The driver supports polling for hardware changes, functionality is synchronous to the main clock of the MCU.
- 4.2 AC Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. Functionality is asynchronous to the main clock of the MCU.

4.1 AC Basics and Best Practice

An analog comparator compares two analog voltage levels, and outputs a digital value indicating which is the larger. The comparator has normally two analog inputs, V+ and V-, but internal sources in the MCU can also be used as source for one of the inputs. The digital output value is outputted on Vout.

4.2 AC Asynchronous Driver

In the Analog Comparator (AC) asynchronous driver, a callback function can be registered in the driver by the application and triggered when comparison is done to let the application know the comparison result.

4.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Hookup callback handlers on comparison done
- Enable or disable AC comparator
- Start single-short comparison if signal-shot mode is enabled (no need to start for continuous mode)

4.2.2 Summary of Configuration Options

Below is a list of the main AC parameters that can be configured in START. Many of these parameters are used by the 4.2.9.1 ac_async_init function when initializing the driver and underlying hardware.

- Select positive and negative input for AC comparator
- Select single shot or continuous measurement mode
- Filter length and hysteresis setting, etc.
- Run in Standby or Debug mode
- Various aspects of Event control

4.2.3 Driver Implementation Description

After the AC hardware initialization, the application can register the callback function for comparison done by 4.2.9.5 ac_async_register_callback.

4.2.4 Example of Usage

The following shows a simple example of using the AC. The AC must have been initialized by 4.2.9.1 ac_async_init. This initialization will configure the operation of the AC, such as input pins, single-shot, or continuous measurement mode, etc.

The example registers a callback function for comparison ready and enables comparator 0 of AC, and then finally starts a voltage comparison on this comparator.

```
static void ready_cb_AC_0(struct ac_async_descriptor *const descr, const ui
nt8_t comp, const uint8_t result)
        {
            /* Handle date here */
        }
        /**
         * Example of using AC_0 to compare the voltage level.
         */
        void AC_0_example(void)
        {

    ac_async_register_callback(&AC_0, AC_COMPARISON_READY_CB, (ac_cb_t)read
y_cb_AC_0);
            ac_async_enable(&AC_0);
            ac_async_start_comparison(&AC_0, 0);
        }
```

4.2.5 Dependencies

- The AC peripheral and its related I/O lines and clocks
- The NVIC must be configured so that AC interrupt requests are periodically serviced

4.2.6 Structs

4.2.6.1 ac_callbacks Struct

AC callbacks.

Members

comparison_ready

4.2.6.2 ac_async_descriptor Struct

AC descriptor.

Members

device	AC HPL device descriptor
cb	AC Callback handlers

4.2.7 Enums

4.2.7.1 ac_callback_type Enum

AC_COMPARISON_READY_CB	Comparison ready handler

4.2.8 Typedefs

4.2.8.1 ac_cb_t typedef

typedef void(* ac_cb_t) (const struct ac_async_descriptor *const descr, const uint8_t comp, const uint8_t result)

AC callback type.

Parameters

descr	Direction: in An AC descriptor
comp	Direction: in Comparator number
result	Direction: in Comparison result, 0 positive input less than negative input, 1 positive input high than negative input

4.2.9 Functions

4.2.9.1 ac_async_init

Initialize AC.

```
int32_t ac_async_init(
    struct ac_async_descriptor *const descr,
    void *const hw
)
```

This function initializes the given AC descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 4.2.6.2 ac_async_descriptor Struct *const An AC descriptor to initialize
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

4.2.9.2 ac_async_deinit

Deinitialize AC.

```
int32_t ac_async_deinit(
    struct ac_async_descriptor *const descr
)
```

This function deinitializes the given AC descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

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Parameters

descr	Type: struct 4.2.6.2 ac_async_descriptor Struct *const An AC descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

4.2.9.3 ac_async_enable

Enable AC.

```
int32_t ac_async_enable(
    struct ac_async_descriptor *const descr
)
```

This function enables the AC by the given AC descriptor.

Parameters

descr	Type: struct 4.2.6.2 ac_async_descriptor Struct *const An AC descriptor to enable

Returns

Type: int32_t

Enabling status.

4.2.9.4 ac_async_disable

Disable AC.

```
int32_t ac_async_disable(
    struct ac_async_descriptor *const descr
)
```

This function disables the AC by the given AC descriptor.

Parameters

descr	Type: struct 4.2.6.2 ac_async_descriptor Struct *const An AC descriptor to disable

Returns

Type: int32_t

Disabling status.

4.2.9.5 ac_async_register_callback

Register AC callback.

```
int32_t ac_async_register_callback(
    struct ac_async_descriptor *const descr,
    const enum ac_callback_type type,
```

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```
    ac_cb_t cb
)
```

Parameters

descr Type: struct 4.2.6.2 ac_async_descriptor Struct *const

An AC descriptor

type Type: const enum 4.2.7.1 ac_callback_type Enum

Callback type

cb Type: 4.2.8.1 ac_cb_t typedef

A callback function, passing NULL will de-register any registered callback

Returns

Type: int32_t

The status of callback assignment.

-1 Passed parameters were invalid or the AC is not initialized

0 A callback is registered successfully

4.2.9.6 ac_async_start_comparison

Start comparison.

```
int32_t ac_async_start_comparison(
    struct ac_async_descriptor *const descr,
    uint8_t comp
)
```

This function starts the AC comparator comparison.

Parameters

descr Type: struct 4.2.6.2 ac_async_descriptor Struct *const

The pointer to AC descriptor

comp Type: uint8_t

Comparator number

Returns

Type: int32_t

The result of comparator n start operation.

4.2.9.7 ac_async_stop_comparison

Stop comparison.

```
int32_t ac_async_stop_comparison(
    struct ac_async_descriptor *const descr,
    uint8_t comp
)
```

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This function stops the AC comparator comparison.

Parameters

descr	Type: struct 4.2.6.2 ac_async_descriptor Struct *const The pointer to AC descriptor
comp	Type: uint8_t Comparator number

Returns

Type: int32_t

The result of comparator n stop the operation.

4.2.9.8 ac_async_get_version

Retrieve the current driver version.

```
uint32_t ac_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

4.3 AC Synchronous Driver

The functions in the Analog Comparator (AC) synchronous driver will block (i.e. not return) until the operation is done.

The comparison result can be get by 4.3.7.5 ac_sync_get_result, if the return is not ERR_NOT_READY then it's the result of voltage comparison for two input channels.

4.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable the AC comparator
- Start single-short comparison if signal-shot mode is enabled (no need to start for continuous sampling mode)
- Read back the comparison result

4.3.2 Summary of Configuration Options

Below is a list of the main AC parameters that can be configured in START. Many of these parameters are used by the 4.3.7.1 ac_sync_init function when initializing the driver and underlying hardware.

- Select positive and negative input for the AC comparator
- Select single shot or continuous measurement mode
- Filter length and hysteresis setting, etc.

- Run in Standby or Debug mode
- Various aspects of Event control

4.3.3 Driver Implementation Description

After AC hardware initialization, the comparison result can be get by 4.3.7.5 ac_sync_get_result. If the AC hardware is configured to single-shot mode, then 4.3.7.6 ac_sync_start_comparison is needed to start conversion, otherwise the comparator is continuously enabled and performing comparisons.

4.3.4 Example of Usage

The following shows a simple example of using the AC. The AC must have been initialized by 4.3.7.1 ac_sync_init. This initialization will configure the operation of the AC, such as input pins, single-shot, or continuous measurement mode, etc.

The example enables comparator 0 of AC, and finally starts a voltage comparison on this comparator.

```
/**
 * Example of using AC_0 to compare the voltage level.
 */
void AC_0_example(void)
{
    int32_t cmp_result;
    ac_sync_enable(&AC_0);
    ac_sync_start_comparison(&AC_0, 0);
    while (true) {
        cmp_result = ac_sync_get_result(&AC_0, 0);
    }
}
```

4.3.5 Dependencies

- The AC peripheral and its related I/O lines and clocks

4.3.6 Structs

4.3.6.1 ac_sync_descriptor Struct

AC descriptor.

Members

device	AC HPL device descriptor

4.3.7 Functions

4.3.7.1 ac_sync_init

Initialize AC.

```
int32_t ac_sync_init(
    struct ac_sync_descriptor *const descr,
    void *const hw
)
```

This function initializes the given AC descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 4.3.6.1 ac_sync_descriptor Struct *const An AC descriptor to initialize
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

4.3.7.2 ac_sync_deinit

Deinitialize AC.

```
int32_t ac_sync_deinit(
    struct ac_sync_descriptor *const descr
)
```

This function deinitializes the given AC descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr	Type: struct 4.3.6.1 ac_sync_descriptor Struct *const An AC descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

4.3.7.3 ac_sync_enable

Enable AC.

```
int32_t ac_sync_enable(
    struct ac_sync_descriptor *const descr
)
```

This function enables the AC by the given AC descriptor.

Parameters

descr	Type: struct 4.3.6.1 ac_sync_descriptor Struct *const An AC descriptor to enable

Returns

Type: int32_t

Enabling status.

4.3.7.4 ac_sync_disable

Disable AC.

```
int32_t ac_sync_disable(
    struct ac_sync_descriptor *const descr
)
```

This function disables the AC by the given AC descriptor.

Parameters

descr	Type: struct 4.3.6.1 ac_sync_descriptor Struct *const An AC descriptor to disable

Returns

Type: int32_t

Disabling status.

4.3.7.5 ac_sync_get_result

Read Comparison result.

```
int32_t ac_sync_get_result(
    struct ac_sync_descriptor *const descr,
    const uint8_t comp
)
```

Parameters

descr	Type: struct 4.3.6.1 ac_sync_descriptor Struct *const The pointer to AC descriptor
comp	Type: const uint8_t Comparator number

Returns

Type: int32_t

The comparison result.

0	The comparison result is 0
1	The comparison result is 1
ERR_NOT_READY	The comparison result is not ready or input parameters are not correct.

4.3.7.6 ac_sync_start_comparison

Start conversion.

```
int32_t ac_sync_start_comparison(
    struct ac_sync_descriptor *const descr,
    uint8_t comp
)
```

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This function starts single-short comparison if signal-shot mode is enabled.

Parameters

descr Type: struct 4.3.6.1 ac_sync_descriptor Struct *const

The pointer to AC descriptor

comp Type: uint8_t

Comparator number

Returns

Type: int32_t

Start Comparator n start Comparison.

4.3.7.7 ac_sync_stop_comparison

Stop conversion.

```
int32_t ac_sync_stop_comparison(
    struct ac_sync_descriptor *const descr,
    uint8_t comp
)
```

This function stops single-short comparison if signal-shot mode is enabled.

Parameters

descr Type: struct 4.3.6.1 ac_sync_descriptor Struct *const

The pointer to AC descriptor

comp Type: uint8_t

Comparator number

Returns

Type: int32_t

Start Comparator n start Comparison.

4.3.7.8 ac_sync_get_version

Retrieve the current driver version.

```
uint32_t ac_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

5. ADC Drivers

This Analog to Digital Converter (ADC) driver provides an interface for the conversion of analog voltage to digital value.

The following driver variants are available:

- 5.5 ADC Synchronous Driver: The driver will block there (i.e. not return) until the requested data has been read. Functionality is therefore synchronous to the calling thread, i.e. the thread will wait for the result to be ready. The 5.5.7.5 adc_sync_read_channel function will perform a conversion of the voltage on the specified channel and return the result when it is ready.
- 5.2 ADC Asynchronous Driver: The driver 5.2.9.7 adc_async_read_channel function will attempt to read the required number of conversion results from a ring buffer. It will return immediately (i.e. not block), even if the requested number of data is not available. If data was not available, or less data than requested was available, this will be indicated in the function's return value. The asynchronous driver uses interrupts to communicate that ADC data is available, and the driver's IRQ handler reads data from hardware and into ring buffers in memory. These ring buffers decouple the generation of data in the ADC with the timing of the application request for this data. In a way, the producer and consumer events are **asynchronous** to each other. The user can register a callback function to piggyback on the IRQ handler routine for communicating with the main application.
- 5.4 ADC RTOS Driver: The driver is intended to use ADC functions in a Real-Time operating system, i.e. is thread safe.
- 5.3 ADC DMA Driver: The driver uses a DMA system to transfer data from ADC to a memory buffer in RAM.

5.1 ADC Basics and Best Practice

An Analog-to-Digital Converter (ADC) converts analog signals to digital values. A reference signal with a known voltage level is quantified into equally sized chunks, each representing a digital value from 0 to the highest number possible with the bit resolution supported by the ADC. The input voltage measured by the ADC is compared against these chunks and the chunk with the closest voltage level defines the digital value that can be used to represent the analog input voltage level.

Normally an ADC can operate in either differential or single-ended mode. In differential mode two signals (V+ and V-) are compared against each other and the resulting digital value represents the relative voltage level between V+ and V-. This means that if the input voltage level on V+ is lower than on V- the digital value is negative, which also means that in differential mode one bit is lost to the sign. In single-ended mode only V+ is compared against the reference voltage, and the resulting digital value can only be positive, but the full bit-range of the ADC can be used.

Normally multiple resolutions are supported by the ADC. Lower resolution can reduce the conversion time, but lose accuracy.

Some ADCs have a gain stage on the input lines, which can be used to increase the dynamic range. The default gain value is normally x1, which means that the conversion range is from 0V to the reference voltage. Applications can change the gain stage to increase or reduce the conversion range.

The window mode allows the conversion result to be compared to a set of predefined threshold values. Applications can use the callback function to monitor if the conversion result exceeds the predefined threshold value.

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Normally multiple reference voltages are supported by the ADC, both internal and external, with different voltage levels. The reference voltage have an impact on the accuracy, and should be selected to cover the full range of the analog input signal and never less than the expected maximum input voltage.

There are two conversion modes supported by ADC: single shot and free running. In single shot mode the ADC make only one conversion when triggered by the application. In free running mode it continues to make conversion from it is triggered until it is stopped by the application. When window monitoring, the ADC should be set to free running mode.

5.2 ADC Asynchronous Driver

The Analog to Digital Converter (ADC) asynchronous driver 5.2.9.7 adc_async_read_channel function will attempt to read the required number of conversion results from a ring buffer. It will return immediately after call (i.e. not block) if the requested number of data is not available. If data was not available, or less data than requested was available, this will be indicated in the function's return value.

The asynchronous driver uses interrupts to communicate that the ADC data is available, and the IRQ handler reads data from hardware and into ring buffers in memory. These ring buffers decouple the generation of data in the ADC with the timing of the application request for this data. In a way, the producer and consumer events are **asynchronous** to each other. The user can register a callback function to piggyback on the IRQ handler routine for communicating with the main application.

5.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Select single shot or free running conversion modes
- Configure major ADC properties such as resolution and reference source
- Hookup callback handlers on conversion done, error, and monitor events
- Start ADC conversion
- Read back conversion results

5.2.2 Summary of Configuration Options

Below is a list of the main ADC parameters that can be configured in START. Many of these parameters are used by the 5.2.9.1 adc_async_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions, such as 5.2.9.10 adc_async_set_resolution.

- Selecting which ADC input channels to enable for positive and negative input
- Which clock source and prescaler the ADC uses
- Various aspects of Event control
- Single shot or free running conversion modes
- Sampling properties such as resolution, window mode, and reference source
- Run in Standby or Debug mode

5.2.3 Driver Implementation Description

5.2.3.1 Channel Map

The ADC asynchronous driver uses a channel map buffer to map the channel number of each enabled channel and the index of the descriptor for the channel.

The channel map is an array defined as follows:

```
static uint8_t ADC_0_map[ADC_0_CH_MAX+1];
```

The index of the channel map buffer is the channel number, and the value of the channel map buffer is the index of the channel descriptor. For example, when registering (using 5.2.9.3 adc_async_register_channel_buffer) channel_1, channel_5, and channel_9 in sequence, the value of channel_map[1] is 0, the value of channel_map[5] is 1, and the value of channel_map[9] is 2.

5.2.3.2 Ring Buffer

The ADC asynchronous driver uses a ring buffer to store ADC sample data. When the ADC raise the sample complete the interrupt, and a copy of the ADC sample register is stored in the ring buffer at the next free location. This will happen regardless of the ADC being in one shot mode or in free running mode. When the ring buffer is full, the next sample will overwrite the oldest sample in the ring buffer.

The 5.2.9.7 adc_async_read_channel function reads bytes from the ring buffer. For ADC sample size larger than 8-bit the read length has to be a power-of-two number greater than or equal to the sample size.

5.2.4 Example of Usage

The following shows a simple example of using the ADC. The ADC must have been initialized by 5.2.9.1 adc_async_init. This initialization will configure the operation of the ADC, such as single-shot or continuous mode, etc.

The example hooks up a callback handler to be called every time conversion is complete, thereafter enables channel 0 of ADC0, and finally starts a conversion on this channel.

```
        uint32_t number_of_conversions = 0;
        uint8_t  buffer[32];
        /*

 * Example of callback function called by the ADC IRQ handler when conversi
on is complete.
         * The printf-
string is printed every time a conversion is complete.
         */

static void convert_cb_ADC_0(const struct adc_async_descriptor *const descr
, const uint8_t channel)
        {
            number_of_conversions++;
            printf("Number of conversions is now: %d
\n", number_of_conversions);
        }
        /**
         * Example of using ADC_0 to generate waveform.
         */
        void ADC_0_example(void)
        {

    adc_async_register_callback(&ADC_0, 0, ADC_ASYNC_CONVERT_CB, convert_cb
_ADC_0);
            adc_async_enable_channel(&ADC_0, 0);
            adc_async_start_conversion(&ADC_0);
            /* Attempt to read 4 conversion results into buffer */
```

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```
    int32_t conversions_read = adc_async_read_channel(&ADC_0, 0, buffer, 4)
;
        }
```

5.2.5 Dependencies

- The ADC peripheral and its related I/O lines and clocks
- The NVIC must be configured so that ADC interrupt requests are periodically serviced

5.2.6 Structs

5.2.6.1 adc_async_callbacks Struct

ADC callbacks.

Members

monitor	Monitor callback
error	Error callback

5.2.6.2 adc_async_ch_callbacks Struct

ADC channel callbacks.

Members

convert_done	Convert done callback

5.2.6.3 adc_async_channel_descriptor Struct

ADC channel buffer descriptor.

Members

adc_async_ch_cb	ADC channel callbacks type
convert	Convert buffer
bytes_in_buffer	Bytes in buffer

5.2.6.4 adc_async_descriptor Struct

ADC descriptor.

Members

device	ADC device
adc_async_cb	ADC callbacks type
channel_map	Enabled channel map
channel_max	Enabled maximum channel number
channel_amount	Enabled channel amount

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descr_ch	ADC channel descriptor

5.2.7 Enums

5.2.7.1 adc_async_callback_type Enum

ADC_ASYNC_CONVERT_CB	ADC convert done callback
ADC_ASYNC_MONITOR_CB	ADC monitor callback
ADC_ASYNC_ERROR_CB	ADC error callback

5.2.8 Typedefs

5.2.8.1 adc_async_cb_t typedef

typedef void(* adc_async_cb_t) (const struct adc_async_descriptor *const descr, const uint8_t channel)

ADC callback type.

5.2.9 Functions

5.2.9.1 adc_async_init

Initialize ADC.

```
int32_t adc_async_init(
    struct adc_async_descriptor *const descr,
    void *const hw,
    uint8_t * channel_map,
    uint8_t channel_max,
    uint8_t channel_amount,
    struct adc_async_channel_descriptor *const descr_ch,
    void *const func
)
```

This function initializes the given ADC descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const An ADC descriptor to initialize
hw	Type: void *const The pointer to hardware instance
channel_map	Type: uint8_t * The pointer to ADC channel mapping
channel_max	Type: uint8_t ADC enabled maximum channel number
channel_amount	Type: uint8_t ADC enabled channel amount

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descr_ch	Type: struct 5.2.6.3 adc_async_channel_descriptor Struct *const A buffer to keep all channel descriptor
func	Type: void *const The pointer to as set of functions pointers

Returns

Type: int32_t

Initialization status.

-1	Passed parameters were invalid or an ADC is already initialized
0	The initialization is completed successfully

5.2.9.2 adc_async_deinit

Deinitialize ADC.

```
int32_t adc_async_deinit(
    struct adc_async_descriptor *const descr
)
```

This function deinitializes the given ADC descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const An ADC descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

5.2.9.3 adc_async_register_channel_buffer

Register ADC channel buffer.

```
int32_t adc_async_register_channel_buffer(
    struct adc_async_descriptor *const descr,
    const uint8_t channel,
    uint8_t *const convert_buffer,
    const uint16_t convert_buffer_length
)
```

This function initializes the given ADC channel buffer descriptor.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const An ADC descriptor to initialize
channel	Type: const uint8_t

	Channel number
convert_buffer	Type: uint8_t *const A buffer to keep converted values
convert_buffer_length	Type: const uint16_t The length of the buffer above

Returns

Type: int32_t

Initialization status.

-1	Passed parameters were invalid or an ADC is already initialized
0	The initialization is completed successfully

5.2.9.4 adc_async_enable_channel

Enable channel of ADC.

```
int32_t adc_async_enable_channel(
    struct adc_async_descriptor *const descr,
    const uint8_t channel
)
```

Use this function to set the ADC peripheral to enabled state.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const Pointer to the ADC descriptor
channel	Type: const uint8_t Channel number

Returns

Type: int32_t

Operation status.

5.2.9.5 adc_async_disable_channel

Disable channel of ADC.

```
int32_t adc_async_disable_channel(
    struct adc_async_descriptor *const descr,
    const uint8_t channel
)
```

Use this function to set the ADC peripheral to disabled state.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const

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Pointer to the ADC descriptor

channel Type: const uint8_t

Channel number

Returns

Type: int32_t

Operation status.

5.2.9.6 adc_async_register_callback

Register ADC callback.

```
int32_t adc_async_register_callback(
    struct adc_async_descriptor *const descr,
    const uint8_t channel,
    const enum adc_async_callback_type type,
    adc_async_cb_t cb
)
```

Parameters

io_descr	An adc descriptor
channel	Type: const uint8_t Channel number
type	Type: const enum 5.2.7.1 adc_async_callback_type Enum Callback type
cb	Type: 5.2.8.1 adc_async_cb_t typedef A callback function, passing NULL de-registers callback

Returns

Type: int32_t

The status of callback assignment.

-1	Passed parameters were invalid or the ADC is not initialized
0	A callback is registered successfully

5.2.9.7 adc_async_read_channel

Read data from the ADC.

```
int32_t adc_async_read_channel(
    struct adc_async_descriptor *const descr,
    const uint8_t channel,
    uint8_t *const buffer,
    const uint16_t length
)
```

Parameters

descr Type: struct 5.2.6.4 adc_async_descriptor Struct *const

The pointer to the ADC descriptor

channel Type: const uint8_t

Channel number

buf A buffer to read data to

length Type: const uint16_t

The size of a buffer

Returns

Type: int32_t

The number of bytes read.

5.2.9.8 adc_async_start_conversion

Start conversion.

```
int32_t adc_async_start_conversion(
    struct adc_async_descriptor *const descr
)
```

This function starts single conversion if no automatic (free-run) mode is enabled.

Parameters

descr Type: struct 5.2.6.4 adc_async_descriptor Struct *const

The pointer to the ADC descriptor

Returns

Type: int32_t

Start conversion status.

5.2.9.9 adc_async_set_reference

Set ADC reference source.

```
int32_t adc_async_set_reference(
    struct adc_async_descriptor *const descr,
    const adc_reference_t reference
)
```

This function sets ADC reference source.

Parameters

descr Type: struct 5.2.6.4 adc_async_descriptor Struct *const

The pointer to the ADC descriptor

reference Type: const adc_reference_t

A reference source to set

Returns

Type: int32_t

Status of the ADC reference source setting.

5.2.9.10 adc_async_set_resolution

Set ADC resolution.

```
int32_t adc_async_set_resolution(
    struct adc_async_descriptor *const descr,
    const adc_resolution_t resolution
)
```

This function sets ADC resolution.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const The pointer to the ADC descriptor
resolution	Type: const adc_resolution_t A resolution to set

Returns

Type: int32_t

Status of the ADC resolution setting.

5.2.9.11 adc_async_set_inputs

Set ADC input source of a channel.

```
int32_t adc_async_set_inputs(
    struct adc_async_descriptor *const descr,
    const adc_pos_input_t pos_input,
    const adc_neg_input_t neg_input,
    const uint8_t channel
)
```

This function sets the ADC positive and negative input sources.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const The pointer to the ADC descriptor
pos_input	Type: const adc_pos_input_t A positive input source to set
neg_input	Type: const adc_neg_input_t A negative input source to set

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channel Type: const uint8_t

Channel number

Returns

Type: int32_t

Status of the ADC channels setting.

5.2.9.12 adc_async_set_conversion_mode

Set ADC conversion mode.

```
int32_t adc_async_set_conversion_mode(
    struct adc_async_descriptor *const descr,
    const enum adc_conversion_mode mode
)
```

This function sets ADC conversion mode.

Parameters

descr Type: struct 5.2.6.4 adc_async_descriptor Struct *const

The pointer to the ADC descriptor

mode Type: const enum adc_conversion_mode

A conversion mode to set

Returns

Type: int32_t

Status of the ADC conversion mode setting.

5.2.9.13 adc_async_set_channel_differential_mode

Set ADC differential mode.

```
int32_t adc_async_set_channel_differential_mode(
    struct adc_async_descriptor *const descr,
    const uint8_t channel,
    const enum adc_differential_mode mode
)
```

This function sets ADC differential mode.

Parameters

descr Type: struct 5.2.6.4 adc_async_descriptor Struct *const

The pointer to the ADC descriptor

channel Type: const uint8_t

Channel number

mode Type: const enum adc_differential_mode

A differential mode to set

Returns

Type: int32_t

Status of the ADC differential mode setting.

5.2.9.14 adc_async_set_channel_gain

Set ADC channel gain.

```
int32_t adc_async_set_channel_gain(
    struct adc_async_descriptor *const descr,
    const uint8_t channel,
    const adc_gain_t gain
)
```

This function sets ADC channel gain.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const The pointer to the ADC descriptor
channel	Type: const uint8_t Channel number
gain	Type: const adc_gain_t A gain to set

Returns

Type: int32_t

Status of the ADC gain setting.

5.2.9.15 adc_async_set_window_mode

Set ADC window mode.

```
int32_t adc_async_set_window_mode(
    struct adc_async_descriptor *const descr,
    const adc_window_mode_t mode
)
```

This function sets ADC window mode.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const The pointer to the ADC descriptor
mode	Type: const adc_window_mode_t A window mode to set

Returns

Type: int32_t

Status of the ADC window mode setting.

5.2.9.16 adc_async_set_thresholds

Set ADC thresholds.

```
int32_t adc_async_set_thresholds(
    struct adc_async_descriptor *const descr,
    const adc_threshold_t low_threshold,
    const adc_threshold_t up_threshold
)
```

This function sets the ADC positive and negative thresholds.

Parameters

descr	Type: struct 5.2.6.4 adc_async_descriptor Struct *const The pointer to the ADC descriptor
low_threshold	Type: const adc_threshold_t A lower thresholds to set
up_threshold	Type: const adc_threshold_t An upper thresholds to set

Returns

Type: int32_t

Status of the ADC thresholds setting.

5.2.9.17 adc_async_get_threshold_state

Retrieve threshold state.

```
int32_t adc_async_get_threshold_state(
    const struct adc_async_descriptor *const descr,
    adc_threshold_status_t *const state
)
```

This function retrieves ADC threshold state.

Parameters

descr	Type: const struct 5.2.6.4 adc_async_descriptor Struct *const The pointer to the ADC descriptor
state	Type: adc_threshold_status_t *const The threshold state

Returns

Type: int32_t

The state of ADC thresholds state retrieving.

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5.2.9.18 adc_async_is_channel_conversion_complete

Check if conversion is complete.

```
int32_t adc_async_is_channel_conversion_complete(
    const struct adc_async_descriptor *const descr,
    const uint8_t channel
)
```

This function checks if the ADC has finished the conversion.

Parameters

descr Type: const struct 5.2.6.4 adc_async_descriptor Struct *const

The pointer to the ADC descriptor

channel Type: const uint8_t

Channel number

Returns

Type: int32_t

The status of the ADC conversion completion checking.

1 The conversion is complete

0 The conversion is not complete

5.2.9.19 adc_async_flush_rx_buffer

Flush ADC ringbuf.

```
int32_t adc_async_flush_rx_buffer(
    struct adc_async_descriptor *const descr,
    const uint8_t channel
)
```

This function flush ADC RX ringbuf.

Parameters

descr Type: struct 5.2.6.4 adc_async_descriptor Struct *const

The pointer to the ADC descriptor

channel Type: const uint8_t

Channel number

Returns

Type: int32_t

ERR_NONE

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5.2.9.20 adc_async_get_version

Retrieve the current driver version.

```
uint32_t adc_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

5.3 ADC DMA Driver

The Analog to Digital Converter (ADC) DMA driver uses DMA system to transfer data from ADC to a memory buffer in RAM. User must configure DMAC system driver accordingly. To set memory buffer and its size 5.3.9.6 adc_dma_read function is used. This function programs DMA to transfer the results of input signal conversion to the given buffer. A callback is called when all the data is transfered, if it is registered via 5.3.9.5 adc_dma_register_callback function.

5.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Select single shot or free running conversion modes
- Configure major ADC properties such as resolution and reference source
- Notification via callback about errors and transfer completion

5.3.2 Summary of Configuration Options

Below is a list of the main ADC parameters that can be configured in START. Many of these parameters are used by the 5.3.9.1 adc_dma_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions, such as 5.3.9.9 adc_dma_set_resolution.

- Selecting which ADC input channels to enable for positive and negative input
- Which clock source and prescaler the ADC uses
- Various aspects of Event control
- Single shot or free running conversion modes
- Sampling properties such as resolution, window mode, and reference source
- Run in Standby or Debug mode

DMA is a system driver in START and can be enabled and configured there.

5.3.3 Driver Implementation Description

5.3.3.1 Dependencies

- ADC hardware with result ready/conversion done and error interrupts

5.3.4 Example of Usage

The following shows a simple example of using the DMA to transfer ADC results into RAM buffer. User must configure DMAC system driver accordingly in START.

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The ADC must have been initialized by 5.3.9.1 adc_dma_init. This initialization will configure the operation of the ADC, such as resolution and reference source, etc.

```
        /* The buffer size for ADC */
        #define ADC_0_BUFFER_SIZE 16
        static uint8_t ADC_0_buffer[ADC_0_BUFFER_SIZE];

static void convert_cb_ADC_0(const struct adc_dma_descriptor *const descr)
        {
        }
        /**
         * Example of using ADC_0 to generate waveform.
         */
        void ADC_0_example(void)
        {

    adc_dma_register_callback(&ADC_0, ADC_DMA_COMPLETE_CB, convert_cb_ADC_0
);
            adc_dma_enable_channel(&ADC_0, 0);
            adc_dma_read(&ADC_0, ADC_0_buffer, ADC_0_BUFFER_SIZE);
        }
```

5.3.5 Dependencies

- The ADC peripheral and its related I/O lines and clocks
- The NVIC must be configured so that ADC interrupt requests are periodically serviced
- DMA

5.3.6 Structs

5.3.6.1 adc_dma_callbacks Struct

ADC callbacks.

Members

convert_done	DMA convert done callback
error	DMA Error callback

5.3.6.2 adc_dma_descriptor Struct

ADC descriptor.

Members

device	ADC device
adc_dma_cb	ADC callbacks
resource	ADC DMA resource

5.3.7 Enums

5.3.7.1 adc_dma_callback_type Enum

ADC_DMA_COMPLETE_CB	ADC DMA complete callback
ADC_DMA_ERROR_CB	ADC DMA error callback

5.3.8 Typedefs

5.3.8.1 adc_dma_cb_t typedef

typedef void(* adc_dma_cb_t) (const struct adc_dma_descriptor *const descr)

ADC callback type.

5.3.9 Functions

5.3.9.1 adc_dma_init

Initialize ADC.

```
int32_t adc_dma_init(
    struct adc_dma_descriptor *const descr,
    void *const hw
)
```

This function initializes the given ADC descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const An ADC descriptor to initialize
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

-1	Passed parameters were invalid or an ADC is already initialized
0	The initialization is completed successfully

5.3.9.2 adc_dma_deinit

Deinitialize ADC.

```
int32_t adc_dma_deinit(
    struct adc_dma_descriptor *const descr
)
```

This function deinitializes the given ADC descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

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Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const An ADC descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

5.3.9.3 adc_dma_enable_channel

Enable ADC.

```
int32_t adc_dma_enable_channel(
    struct adc_dma_descriptor *const descr,
    const uint8_t channel
)
```

Use this function to set the ADC peripheral to enabled state.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const Pointer to the ADC descriptor
channel	Type: const uint8_t Channel number

Returns

Type: int32_t

Operation status

5.3.9.4 adc_dma_disable_channel

Disable ADC.

```
int32_t adc_dma_disable_channel(
    struct adc_dma_descriptor *const descr,
    const uint8_t channel
)
```

Use this function to set the ADC peripheral to disabled state.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const An ADC descriptor
channel	Type: const uint8_t Channel number

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Returns

Type: int32_t

Operation status

5.3.9.5 adc_dma_register_callback

Register ADC callback.

```
int32_t adc_dma_register_callback(
    struct adc_dma_descriptor *const descr,
    const enum adc_dma_callback_type type,
    adc_dma_cb_t cb
)
```

Parameters

io_descr An ADC descriptor

type Type: const enum 5.3.7.1 adc_dma_callback_type Enum

Callback type

cb Type: 5.3.8.1 adc_dma_cb_t typedef

A callback function, passing NULL de-registers callback

Returns

Type: int32_t

The status of the callback assignment.

-1 Passed parameters were invalid or the ADC is not initialized

0 A callback is registered successfully

5.3.9.6 adc_dma_read

Read data from ADC.

```
int32_t adc_dma_read(
    struct adc_dma_descriptor *const descr,
    uint8_t *const buffer,
    const uint16_t length
)
```

Parameters

descr Type: struct 5.3.6.2 adc_dma_descriptor Struct *const

The pointer to the ADC descriptor

buf A buffer to read data to

length Type: const uint16_t

The size of a buffer

Returns

Type: int32_t

The number of bytes read.

5.3.9.7 adc_dma_start_conversion

Start conversion.

```
int32_t adc_dma_start_conversion(
    struct adc_dma_descriptor *const descr
)
```

This function starts the single conversion if no automatic (free-run) mode is enabled.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const The pointer to the ADC descriptor

Returns

Type: int32_t

Start conversion status.

5.3.9.8 adc_dma_set_reference

Set ADC reference source.

```
int32_t adc_dma_set_reference(
    struct adc_dma_descriptor *const descr,
    const adc_reference_t reference
)
```

This function sets ADC reference source.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const The pointer to the ADC descriptor
reference	Type: const adc_reference_t A reference source to set

Returns

Type: int32_t

Status of the ADC reference source setting.

5.3.9.9 adc_dma_set_resolution

Set ADC resolution.

```
int32_t adc_dma_set_resolution(
    struct adc_dma_descriptor *const descr,
    const adc_resolution_t resolution
)
```

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This function sets ADC resolution.

Parameters

descr Type: struct 5.3.6.2 adc_dma_descriptor Struct *const

The pointer to the ADC descriptor

resolution Type: const adc_resolution_t

A resolution to set

Returns

Type: int32_t

Status of the ADC resolution setting.

5.3.9.10 adc_dma_set_inputs

Set ADC input source of a channel.

```
int32_t adc_dma_set_inputs(
    struct adc_dma_descriptor *const descr,
    const adc_pos_input_t pos_input,
    const adc_neg_input_t neg_input,
    const uint8_t channel
)
```

This function sets ADC positive and negative input sources.

Parameters

descr Type: struct 5.3.6.2 adc_dma_descriptor Struct *const

The pointer to the ADC descriptor

pos_input Type: const adc_pos_input_t

A positive input source to set

neg_input Type: const adc_neg_input_t

A negative input source to set

channel Type: const uint8_t

Channel number

Returns

Type: int32_t

Status of the ADC channels setting.

5.3.9.11 adc_dma_set_conversion_mode

Set ADC conversion mode.

```
int32_t adc_dma_set_conversion_mode(
    struct adc_dma_descriptor *const descr,
    const enum adc_conversion_mode mode
)
```

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This function sets ADC conversion mode.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const The pointer to the ADC descriptor
mode	Type: const enum adc_conversion_mode A conversion mode to set

Returns

Type: int32_t

Status of the ADC conversion mode setting.

5.3.9.12 adc_dma_set_channel_differential_mode

Set ADC differential mode.

```
int32_t adc_dma_set_channel_differential_mode(
    struct adc_dma_descriptor *const descr,
    const uint8_t channel,
    const enum adc_differential_mode mode
)
```

This function sets the ADC differential mode.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const The pointer to the ADC descriptor
channel	Type: const uint8_t Channel number
mode	Type: const enum adc_differential_mode A differential mode to set

Returns

Type: int32_t

Status of the ADC differential mode setting.

5.3.9.13 adc_dma_set_channel_gain

Set ADC channel gain.

```
int32_t adc_dma_set_channel_gain(
    struct adc_dma_descriptor *const descr,
    const uint8_t channel,
    const adc_gain_t gain
)
```

This function sets ADC channel gain.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const The pointer to the ADC descriptor
channel	Type: const uint8_t Channel number
gain	Type: const adc_gain_t A gain to set

Returns

Type: int32_t

Status of the ADC gain setting.

5.3.9.14 adc_dma_set_window_mode

Set ADC window mode.

```
int32_t adc_dma_set_window_mode(
    struct adc_dma_descriptor *const descr,
    const adc_window_mode_t mode
)
```

This function sets ADC window mode.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const The pointer to the ADC descriptor
mode	Type: const adc_window_mode_t A window mode to set

Returns

Type: int32_t

Status of the ADC window mode setting.

5.3.9.15 adc_dma_set_thresholds

Set ADC thresholds.

```
int32_t adc_dma_set_thresholds(
    struct adc_dma_descriptor *const descr,
    const adc_threshold_t low_threshold,
    const adc_threshold_t up_threshold
)
```

This function sets ADC positive and negative thresholds.

Parameters

descr	Type: struct 5.3.6.2 adc_dma_descriptor Struct *const

	The pointer to the ADC descriptor
low_threshold	Type: const adc_threshold_t A lower thresholds to set
up_threshold	Type: const adc_threshold_t An upper thresholds to set

Returns

Type: int32_t

Status of the ADC thresholds setting.

5.3.9.16 adc_dma_get_threshold_state

Retrieve threshold state.

```
int32_t adc_dma_get_threshold_state(
    const struct adc_dma_descriptor *const descr,
    adc_threshold_status_t *const state
)
```

This function retrieves ADC threshold state.

Parameters

descr	Type: const struct 5.3.6.2 adc_dma_descriptor Struct *const The pointer to the ADC descriptor
state	Type: adc_threshold_status_t *const The threshold state

Returns

Type: int32_t

The state of ADC thresholds state retrieving.

5.3.9.17 adc_dma_is_conversion_complete

Check if conversion is complete.

```
int32_t adc_dma_is_conversion_complete(
    const struct adc_dma_descriptor *const descr
)
```

This function checks if ADC has finished the conversion.

Parameters

descr	Type: const struct 5.3.6.2 adc_dma_descriptor Struct *const The pointer to the ADC descriptor

Returns

Type: int32_t

The status of ADC conversion completion checking.

1 The conversion is complete

0 The conversion is not complete

5.3.9.18 adc_dma_get_version

Retrieve the current driver version.

```
uint32_t adc_dma_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

5.4 ADC RTOS Driver

The Analog to Digital Converter (ADC) RTOS driver is intended to use ADC functions in a Real-Time operating system, i.e. is thread safe.

5.4.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Select single shot or free running conversion modes
- Configure major ADC properties such as resolution and reference source
- Start ADC conversion
- Read back conversion results

5.4.2 Summary of Configuration Options

Below is a list of the main ADC parameters that can be configured in START. Many of these parameters are used by the 5.4.7.1 adc_os_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions, such as 5.4.7.9 adc_os_set_resolution.

- Selecting which ADC input channels to enable for positive and negative input
- Which clock source and prescaler the ADC uses
- Various aspects of Event control
- Single shot or free running conversion modes
- Sampling properties such as resolution, window mode, and reference source
- Run in Standby or Debug mode

5.4.3 Driver Implementation Description

The convert functions of the ADC RTOS driver are optimized for RTOS support. That is, the convert functions will not work without RTOS. The convert functions should only be called in an RTOS task or thread.

The ADC OS driver use a ring buffer to store ADC sample data. When the ADC raise the sample complete interrupt, a copy of the ADC sample register is stored in the ring buffer at the next free location.

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This will happen regardless of if the ADC is in one shot mode or in free running mode. When the ring buffer is full, the next sample will overwrite the oldest sample in the ring buffer.

To read the samples from the ring buffer, the function 5.4.7.6 adc_os_read_channel is used. This function reads the number of bytes asked for from the ring buffer, starting from the oldest byte. If the number of bytes asked for are more than currently available in the ring buffer, or more than ringbuf size, the task/thread will be blocked until read done. If the number of bytes asked for is less than the available bytes in the ring buffer, the remaining bytes will be kept until a new call. The 5.4.7.6 adc_os_read_channel function will return the number of bytes that want to read from the buffer back to the caller.

During data conversion, the ADC convert process is not protected, so that a more flexible way can be chosen in the application if multi-task/thread access.

5.4.4 Example of Usage

The following shows a simple example of using the ADC. The ADC must have been initialized by 5.4.7.1 adc_os_init. This initialization will configure the operation of the ADC, such as single-shot or continuous mode, etc.

The example creates two tasks for channel 0 of ADC0: convert task and read task, and finally starts the RTOS task scheduler.

```
        /**
         * Example convert task of using ADC_0.
         */
        void ADC_0_example_convert_task(void *p)
        {
            (void)p;
            adc_os_enable_channel(&ADC_0, 0);
            while (1) {
                adc_os_start_conversion(&ADC_0);
                os_sleep(10);
            }
        }
        /**
         * Example read task of using ADC_0.
         */
        void ADC_0_example_read_task(void *p)
        {
            uint8_t adc_values[8];
            uint8_t num = 0;
            (void)p;
            while (1) {
                num = adc_os_read_channel(&ADC_0, 0, adc_values, 8);
                if (num == 8) {
                    /* read OK, handle data. */;
                } else {
                    /* error. */;
                }
            }
        }
        #define TASK_ADC_CONVERT_STACK_SIZE        ( 256/
sizeof( portSTACK_TYPE ))
        #define TASK_ADC_CONVERT_PRIORITY          ( tskIDLE_PRIORITY + 1 )
        #define TASK_ADC_READ_STACK_SIZE           ( 256/
sizeof( portSTACK_TYPE ))
        #define TASK_ADC_READ_STACK_PRIORITY       ( tskIDLE_PRIORITY + 1 )
        static TaskHandle_t xAdcConvertTask;
```

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```
        static TaskHandle_t xAdcReadTask;
        int main(void)
        {
            /* Initializes MCU, drivers and middleware */
            atmel_start_init();
            /* Create ADC convert task */

    if (xTaskCreate(ADC_0_example_convert_task, "ADC convert", TASK_ADC_CON
VERT_STACK_SIZE,
                            NULL,
                            TASK_ADC_CONVERT_PRIORITY, &xAdcConvertTask) !
= pdPASS) {
                while (1) {
                    ;
                }
            }
            /* Create ADC read task */

    if (xTaskCreate(ADC_0_example_read_task, "ADC read", TASK_ADC_READ_STAC
K_SIZE,
                            NULL,
                            TASK_ADC_READ_STACK_PRIORITY, &xAdcReadTask) !
= pdPASS) {
                while (1) {
                    ;
                }
            }
            /*  Start RTOS scheduler */
            vTaskStartScheduler();
            /* Replace with your application code */
            while (1) {
            }
        }
```

5.4.5 Dependencies

- The ADC peripheral and its related I/O lines and clocks
- The NVIC must be configured so that ADC interrupt requests are periodically serviced
- RTOS

5.4.6 Structs

5.4.6.1 adc_os_channel_descriptor Struct

ADC os channel buffer descriptor.

Members

convert	Storage the ADC convert data
rx_sem	ADC read data semaphore
rxbuf	Pointer to data buffer to RX
size	Size of data characters in RX
num	The user wants to read data number

5.4.6.2 adc_os_descriptor Struct

ADC descriptor.

Members

device	Pointer to ADC device instance
descr_ch	Pointer to ADC os channel instance
monitor_sem	ADC window_threshold_reached semaphore
channel_map	Enabled channel map
channel_max	Enabled maximum channel number
channel_amount	Enabled channel amount

5.4.7 Functions

5.4.7.1 adc_os_init

Initialize ADC.

```
int32_t adc_os_init(
    struct adc_os_descriptor *const descr,
    void *const hw,
    uint8_t * channel_map,
    uint8_t channel_max,
    uint8_t channel_amount,
    struct adc_os_channel_descriptor *const descr_ch
)
```

This function initializes the given ADC descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const An ADC descriptor to initialize
hw	Type: void *const The pointer to hardware instance
channel_map	Type: uint8_t * The pointer to adc channel mapping
channel_max	Type: uint8_t ADC enabled maximum channel number
channel_amount	Type: uint8_t ADC enabled channel amount
descr_ch	Type: struct 5.4.6.1 adc_os_channel_descriptor Struct *const A buffer to keep all channel descriptor

Returns

Type: int32_t

Initialization status.

<0	Passed parameters were invalid or an ADC is already initialized
ERR_NONE	The initialization is completed successfully

5.4.7.2 adc_os_deinit

Deinitialize ADC.

```
int32_t adc_os_deinit(
    struct adc_os_descriptor *const descr
)
```

This function deinitializes the given ADC descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const An ADC descriptor to deinitialize

Returns

Type: int32_t

ERR_NONE

5.4.7.3 adc_os_register_channel_buffer

Register ADC channel buffer.

```
int32_t adc_os_register_channel_buffer(
    struct adc_os_descriptor *const descr,
    const uint8_t channel,
    uint8_t *const convert_buffer,
    const uint16_t convert_buffer_length
)
```

This function initializes the given ADC channel buffer descriptor.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const An ADC descriptor to initialize
channel	Type: const uint8_t Channel number
convert_buffer	Type: uint8_t *const A buffer to keep converted values
convert_buffer_length	Type: const uint16_t

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The length of the buffer above

Returns

Type: int32_t

Initialization status.

-1 Passed parameters were invalid or an ADC is already initialized

0 The initialization is completed successfully

5.4.7.4 adc_os_enable_channel

Enable channel of ADC.

```
int32_t adc_os_enable_channel(
    struct adc_os_descriptor *const descr,
    const uint8_t channel
)
```

Use this function to set the ADC peripheral to enabled state.

Parameters

descr Type: struct 5.4.6.2 adc_os_descriptor Struct *const

Pointer to the ADC descriptor

channel Type: const uint8_t

Channel number

Returns

Type: int32_t

ERR_NONE

5.4.7.5 adc_os_disable_channel

Disable channel of ADC.

```
int32_t adc_os_disable_channel(
    struct adc_os_descriptor *const descr,
    const uint8_t channel
)
```

Use this function to set the ADC peripheral to disabled state.

Parameters

descr Type: struct 5.4.6.2 adc_os_descriptor Struct *const

Pointer to the ADC descriptor

channel Type: const uint8_t

Channel number

Returns

Type: int32_t

ERR_NONE

5.4.7.6 adc_os_read_channel

Read data asked for from the ring buffer.

```
int32_t adc_os_read_channel(
    struct adc_os_descriptor *const descr,
    const uint8_t channel,
    uint8_t *const buffer,
    const uint16_t length
)
```

If the number of data in ring buffer less than want to read, the task/thread will be blocked until read is done.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
channel	Type: const uint8_t Channel number
buf	A buffer to read data
length	Type: const uint16_t The size of the buffer

Returns

Type: int32_t

The number of bytes the user wants to read.

5.4.7.7 adc_os_start_conversion

Start conversion.

```
int32_t adc_os_start_conversion(
    struct adc_os_descriptor *const descr
)
```

This function starts single conversion if no automatic (free-run) mode is enabled.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor

Returns

Type: int32_t

ERR_NONE

5.4.7.8 adc_os_set_reference

Set ADC reference source.

```
int32_t adc_os_set_reference(
    struct adc_os_descriptor *const descr,
    const adc_reference_t reference
)
```

This function sets ADC reference source.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
reference	Type: const adc_reference_t A reference source to set

Returns

Type: int32_t

ERR_NONE

5.4.7.9 adc_os_set_resolution

Set ADC resolution.

```
int32_t adc_os_set_resolution(
    struct adc_os_descriptor *const descr,
    const adc_resolution_t resolution
)
```

This function sets ADC resolution.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
resolution	Type: const adc_resolution_t A resolution to set

Returns

Type: int32_t

ERR_NONE

5.4.7.10 adc_os_set_inputs

Set ADC input source of a channel.

```
int32_t adc_os_set_inputs(
    struct adc_os_descriptor *const descr,
    const adc_pos_input_t pos_input,
    const adc_neg_input_t neg_input,
    const uint8_t channel
)
```

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This function sets ADC positive and negative input sources.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
pos_input	Type: const adc_pos_input_t A positive input source to set
neg_input	Type: const adc_neg_input_t A negative input source to set
channel	Type: const uint8_t Channel number

Returns

Type: int32_t

ERR_NONE

5.4.7.11 adc_os_set_conversion_mode

Set ADC conversion mode.

```
int32_t adc_os_set_conversion_mode(
    struct adc_os_descriptor *const descr,
    const enum adc_conversion_mode mode
)
```

This function sets ADC conversion mode.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
mode	Type: const enum adc_conversion_mode A conversion mode to set

Returns

Type: int32_t

ERR_NONE

5.4.7.12 adc_os_set_channel_differential_mode

Set ADC differential mode.

```
int32_t adc_os_set_channel_differential_mode(
    struct adc_os_descriptor *const descr,
    const uint8_t channel,
    const enum adc_differential_mode mode
)
```

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This function sets ADC differential mode.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
channel	Type: const uint8_t Channel number
mode	Type: const enum adc_differential_mode A differential mode to set

Returns

Type: int32_t

ERR_NONE

5.4.7.13 adc_os_set_channel_gain

Set ADC gain.

```
int32_t adc_os_set_channel_gain(
    struct adc_os_descriptor *const descr,
    const uint8_t channel,
    const adc_gain_t gain
)
```

This function sets ADC gain.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
channel	Type: const uint8_t Channel number
gain	Type: const adc_gain_t A gain to set

Returns

Type: int32_t

ERR_NONE

5.4.7.14 adc_os_set_window_mode

Set ADC window mode.

```
int32_t adc_os_set_window_mode(
    struct adc_os_descriptor *const descr,
    const adc_window_mode_t mode
)
```

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This function sets ADC window mode.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
mode	Type: const adc_window_mode_t A window mode to set

Returns

Type: int32_t

ERR_NONE

5.4.7.15 adc_os_set_thresholds

Set ADC thresholds.

```
int32_t adc_os_set_thresholds(
    struct adc_os_descriptor *const descr,
    const adc_threshold_t low_threshold,
    const adc_threshold_t up_threshold
)
```

This function sets ADC positive and negative thresholds.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
low_threshold	Type: const adc_threshold_t A lower threshold to set
up_threshold	Type: const adc_threshold_t An upper threshold to set

Returns

Type: int32_t

ERR_NONE

5.4.7.16 adc_os_get_threshold_state

Retrieve threshold state.

```
int32_t adc_os_get_threshold_state(
    const struct adc_os_descriptor *const descr,
    adc_threshold_status_t *const state
)
```

This function retrieves ADC threshold state.

Parameters

descr	Type: const struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
state	Type: adc_threshold_status_t *const The threshold state

Returns

Type: int32_t

ERR_NONE

5.4.7.17 adc_os_wait_channel_threshhold_reach

Wait reach the ADC window threshhold.

```
int32_t adc_os_wait_channel_threshhold_reach(
    struct adc_os_descriptor *const descr,
    const uint8_t channel
)
```

This function waits for the reach of ADC window threshhold. The task/thread will block until reach window threshhold.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const The pointer to ADC descriptor
channel	Type: const uint8_t Channel number

Returns

Type: int32_t

ERR_TIMEOUT	The semaphore down timeout
ERR_NONE	The window threshhold has reached

5.4.7.18 adc_os_flush_rx_buffer

Flush ADC ringbuf.

```
int32_t adc_os_flush_rx_buffer(
    struct adc_os_descriptor *const descr,
    const uint8_t channel
)
```

This function flushes ADC RX ringbuf.

Parameters

descr	Type: struct 5.4.6.2 adc_os_descriptor Struct *const

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	The pointer to ADC descriptor
channel	Type: const uint8_t Channel number

Returns

Type: int32_t

ERR_NONE

5.4.7.19 adc_os_get_version

Retrieve the current ADC RTOS driver version.

```
uint32_t adc_os_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

5.5 ADC Synchronous Driver

The Analog to Digital Converter (ADC) synchronous driver will block (i.e. not return) there until the requested data has been read. Functionality is therefore synchronous to the calling thread, i.e. the thread will wait for the result to be ready. The 5.5.7.5 adc_sync_read_channel function will perform a conversion of the voltage on the specified channel and return the result when it is ready.

5.5.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Select single shot or free running conversion modes
- Configure major ADC properties such as resolution and reference source
- Read back conversion results

5.5.2 Summary of Configuration Options

Below is a list of the main ADC parameters that can be configured in START. Many of these parameters are used by the 5.5.7.1 adc_sync_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions, such as 5.5.7.7 adc_sync_set_resolution.

- Selecting which ADC input channels to enable for positive and negative input
- Which clock source and prescaler the ADC uses
- Various aspects of Event control
- Single shot or free running conversion modes
- Sampling properties such as resolution, window mode, and reference source
- Run in Standby or Debug mode

5.5.3 Driver Implementation Description

The functions in the ADC synchronous driver will block (i.e. not return) until the operation is done.

5.5.4 Example of Usage

The following shows a simple example of using the ADC. The ADC must have been initialized by 5.5.7.1 adc_sync_init. This initialization will configure the operation of the ADC, such as single-shot or continuous mode, etc.

The example enables channel 0 of ADC0, and finally starts a conversion on this channel.

```
/**
 * Example of using ADC_0 to generate waveform.
 */
void ADC_0_example(void)
{
    uint8_t buffer[2];
    adc_sync_enable_channel(&ADC_0, 0);
    while (1) {
        adc_sync_read_channel(&ADC_0, 0, buffer, 2);
    }
}
```

5.5.5 Dependencies

- ADC peripheral and its related I/O lines and clocks

5.5.6 Structs

5.5.6.1 adc_sync_descriptor Struct

ADC descriptor.

Members

device	ADC device

5.5.7 Functions

5.5.7.1 adc_sync_init

Initialize ADC.

```
int32_t adc_sync_init(
    struct adc_sync_descriptor *const descr,
    void *const hw,
    void *const func
)
```

This function initializes the given ADC descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr Type: struct 5.5.6.1 adc_sync_descriptor Struct *const

An ADC descriptor to initialize

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hw Type: void *const

The pointer to hardware instance

func Type: void *const

The pointer to a set of functions pointers

Returns

Type: int32_t

Initialization status.

5.5.7.2 adc_sync_deinit

Deinitialize ADC.

```
int32_t adc_sync_deinit(
    struct adc_sync_descriptor *const descr
)
```

This function deinitializes the given ADC descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr Type: struct 5.5.6.1 adc_sync_descriptor Struct *const

An ADC descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

5.5.7.3 adc_sync_enable_channel

Enable ADC.

```
int32_t adc_sync_enable_channel(
    struct adc_sync_descriptor *const descr,
    const uint8_t channel
)
```

Use this function to set the ADC peripheral to enabled state.

Parameters

descr Type: struct 5.5.6.1 adc_sync_descriptor Struct *const

Pointer to the ADC descriptor

channel Type: const uint8_t

Channel number

Returns

Type: int32_t

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Operation status

5.5.7.4 adc_sync_disable_channel

Disable ADC.

```
int32_t adc_sync_disable_channel(
    struct adc_sync_descriptor *const descr,
    const uint8_t channel
)
```

Use this function to set the ADC peripheral to disabled state.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const Pointer to the ADC descriptor
channel	Type: const uint8_t Channel number

Returns

Type: int32_t

Operation status

5.5.7.5 adc_sync_read_channel

Read data from ADC.

```
int32_t adc_sync_read_channel(
    struct adc_sync_descriptor *const descr,
    const uint8_t channel,
    uint8_t *const buffer,
    const uint16_t length
)
```

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
channel	Type: const uint8_t Channel number
buf	A buffer to read data to
length	Type: const uint16_t The size of a buffer

Returns

Type: int32_t

The number of bytes read.

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5.5.7.6 adc_sync_set_reference

Set ADC reference source.

```
int32_t adc_sync_set_reference(
    struct adc_sync_descriptor *const descr,
    const adc_reference_t reference
)
```

This function sets ADC reference source.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
reference	Type: const adc_reference_t A reference source to set

Returns

Type: int32_t

Status of the ADC reference source setting.

5.5.7.7 adc_sync_set_resolution

Set ADC resolution.

```
int32_t adc_sync_set_resolution(
    struct adc_sync_descriptor *const descr,
    const adc_resolution_t resolution
)
```

This function sets ADC resolution.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
resolution	Type: const adc_resolution_t A resolution to set

Returns

Type: int32_t

Status of the ADC resolution setting.

5.5.7.8 adc_sync_set_inputs

Set ADC input source of a channel.

```
int32_t adc_sync_set_inputs(
    struct adc_sync_descriptor *const descr,
    const adc_pos_input_t pos_input,
    const adc_neg_input_t neg_input,
    const uint8_t channel
)
```

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This function sets ADC positive and negative input sources.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
pos_input	Type: const adc_pos_input_t A positive input source to set
neg_input	Type: const adc_neg_input_t A negative input source to set
channel	Type: const uint8_t Channel number

Returns

Type: int32_t

Status of the ADC channels setting.

5.5.7.9 adc_sync_set_conversion_mode

Set ADC conversion mode.

```
int32_t adc_sync_set_conversion_mode(
    struct adc_sync_descriptor *const descr,
    const enum adc_conversion_mode mode
)
```

This function sets ADC conversion mode.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
mode	Type: const enum adc_conversion_mode A conversion mode to set

Returns

Type: int32_t

Status of the ADC conversion mode setting.

5.5.7.10 adc_sync_set_channel_differential_mode

Set ADC differential mode.

```
int32_t adc_sync_set_channel_differential_mode(
    struct adc_sync_descriptor *const descr,
    const uint8_t channel,
    const enum adc_differential_mode mode
)
```

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This function sets ADC differential mode.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
channel	Type: const uint8_t Channel number
mode	Type: const enum adc_differential_mode A differential mode to set

Returns

Type: int32_t

Status of the ADC differential mode setting.

5.5.7.11 adc_sync_set_channel_gain

Set ADC channel gain.

```
int32_t adc_sync_set_channel_gain(
    struct adc_sync_descriptor *const descr,
    const uint8_t channel,
    const adc_gain_t gain
)
```

This function sets ADC channel gain.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
channel	Type: const uint8_t Channel number
gain	Type: const adc_gain_t A gain to set

Returns

Type: int32_t

Status of the ADC gain setting.

5.5.7.12 adc_sync_set_window_mode

Set ADC window mode.

```
int32_t adc_sync_set_window_mode(
    struct adc_sync_descriptor *const descr,
    const adc_window_mode_t mode
)
```

This function sets ADC window mode.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
mode	Type: const adc_window_mode_t A window mode to set

Returns
Type: int32_t

Status of the ADC window mode setting.

5.5.7.13 adc_sync_set_thresholds

Set ADC thresholds.

```
int32_t adc_sync_set_thresholds(
    struct adc_sync_descriptor *const descr,
    const adc_threshold_t low_threshold,
    const adc_threshold_t up_threshold
)
```

This function sets ADC positive and negative thresholds.

Parameters

descr	Type: struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
low_threshold	Type: const adc_threshold_t A lower thresholds to set
up_threshold	Type: const adc_threshold_t An upper thresholds to set

Returns
Type: int32_t

Status of the ADC thresholds setting.

5.5.7.14 adc_sync_get_threshold_state

Retrieve threshold state.

```
int32_t adc_sync_get_threshold_state(
    const struct adc_sync_descriptor *const descr,
    adc_threshold_status_t *const state
)
```

This function retrieves ADC threshold state.

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Parameters

descr	Type: const struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
state	Type: adc_threshold_status_t *const The threshold state

Returns
Type: int32_t

The state of ADC thresholds state retrieving.

5.5.7.15 adc_sync_is_channel_conversion_complete

Check if conversion is complete.

```
int32_t adc_sync_is_channel_conversion_complete(
    const struct adc_sync_descriptor *const descr,
    const uint8_t channel
)
```

This function checks if the ADC has finished the conversion.

Parameters

descr	Type: const struct 5.5.6.1 adc_sync_descriptor Struct *const The pointer to the ADC descriptor
channel	Type: const uint8_t Channel number

Returns
Type: int32_t

The status of ADC conversion completion checking.

1	The conversion is complete
0	The conversion is not complete

5.5.7.16 adc_sync_get_version

Retrieve the current driver version.

```
uint32_t adc_sync_get_version(
    void
)
```

Returns
Type: uint32_t

Current driver version.

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6. Analog Glue Function

This custom analog driver offers a way to initialize on-chip programmable analog units, such as Operational Amplifiers (OPAMP), so that a specific analog circuit is built. Then this analog "circuit" can be connected to internal or external analog circuit to perform analog signal processing.

6.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enabling and disabling

6.2 Summary of Configuration Options

Most custom analog driver parameters are configured in START. Many of these parameters are used by the 6.6.1 custom_analog_init function when initializing the driver and underlying hardware (for example, OPAMP).

6.3 Driver Implementation Description

The implementation is simple in this driver and most custom analog parameters are static configuration.

6.4 Example of Usage

The following shows a simple example of using the custom analog driver. The custom analog driver must have been initialized by 6.6.1 custom_analog_init. This initialization will configure the operation of the hardware programmable analog instance.

```
        /**
         * Example of using ANALOG_GLUE_FUNCTION_0 to generate waveform.
         */
        void ANALOG_GLUE_FUNCTION_0_example(void)
        {
            custom_analog_enable();
            /
* Now custom analog (operational amplifiers) works as configured */
        }
```

6.5 Dependencies

- On-chip programmable analog units, such as Operational Amplifiers (OPAMP)

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6.6 Functions

6.6.1 custom_analog_init

Initialize the custom logic hardware.

```
static int32_t custom_analog_init(
    void
)
```

Returns

Type: int32_t

Initialization operation status

6.6.2 custom_analog_deinit

Disable and reset the custom logic hardware.

```
static void custom_analog_deinit(
    void
)
```

Returns

Type: void

6.6.3 custom_analog_enable

Enable the custom logic hardware.

```
static int32_t custom_analog_enable(
    void
)
```

Returns

Type: int32_t

Initialization operation status

6.6.4 custom_analog_disable

Disable the custom logic hardware.

```
static void custom_analog_disable(
    void
)
```

Returns

Type: void

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7. Audio Driver

An audio peripheral can be interfaced to most available codec devices to provide microcontroller-based audio solution. The audio driver is designed to provide raw data read and write function through different audio peripherals.

The following driver variants are available:

- 7.2 Audio DMA Driver: The driver uses a DMA system to transfer data from audio peripheral to memory buffer in RAM.

7.1 Audio Basics and Best Practice

Audio peripheral is a serial bus standard for connecting to most available codec devices to provide microcontroller-based audio solution. The driver only focus on raw data transfer, so it supports most audio protocols like I2S, TDM, PCM, even though a PDM microphone.

In most use case, the audio driver should work with some of decoder libraries. Like AAC/FLAC/MP3/Opus/Speex/WMA Decoder Library. And a thirdpart codec driver maybe included if the audio peripheral connected to a configable codec device, Like AK4662 codec have a I2C Control Interface.

7.2 Audio DMA Driver

The Audio DMA driver provides a set of data buffer based transfer functions, both of writing or reads data to/from the audio peripheral. Each buffer should be assigned with a handler. In the Audio DMA driver, a callback function can be registered in the driver by the application and triggered when buffer transfer is done to let the application know the transfer result. The callback function has a handler parameter to let the application know which buffer was processed. The driver has an internal buffer queue mechanism, the queue size can be configurable in drivers configurations. The driver also needs to know the DMA channel number for each write and read.

7.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Hookup callback handlers on data buffer transfer done
- Enable or disable Audio hardware
- Add buffer to write/read data from hardware
- Flush(discard) data buffer for write/read which not transferred yet
- Return the number of bytes has been processed in the buffer queue

7.2.2 Summary of Configuration Options

Below is a list of the main audio parameters that can be configured in START. Many of these parameters are used by the 7.2.9.1 audio_dma_init function when initializing the driver and underlying hardware.

- Select Clock for audio hardware to generate peripheral clock and audio clock.
- Select Pin for audio hardware.
- Configure Audio peripherals, such like data format, baud rate, etc.
- Select DMA channel for data to write/read operation.

- Select queue size for internal buffer queue mechanism.

7.2.3 Driver Implementation Description

After the Audio hardware initialization, the application can register the callback function for transfer done by 7.2.9.5 audio_dma_register_callback, and invoke 7.2.9.6 audio_dma_add_buffer to write/read data from audio hardware.

7.2.4 Example of Usage

The following shows a simple example of using the Audio DMA driver. The Audio must have been initialized by 7.2.9.1 audio_dma_init. This initialization will configure the operation of the Audio Peripheral, such as the clock, input pins, baud rate, format, etc.

The example registers a callback function for data transfer done and enables Audio hardware, and then finally starts a buffer transfer to the hardware.

```
        audio_buffer_handler_t tx_buffer_handler = 0;
        uint8_t data[1024];
        uint8_t tx_result = 0;

void audio_buffer_event_handler(enum audio_buffer_event event, audio_buffer
_handler_t handler)
        {
            if (tx_buffer_handler == 0) {
                if (event == AUDIO_BUFFER_EVENT_COMPLETE) {
                    tx_result = 1;
                } else {
                    tx_result = 2;
                }
            }

        }
        /**
         * Example of using AUDIO_0 to write data
         */
        void audio_example(void)
        {
            uint32_t len;

    audio_dma_register_callback(&AUDIO_0, audio_buffer_event_handler);
            audio_dma_enable(&AUDIO_0);
            audio_dma_add_buffer(&AUDIO_0, AUDIO_WRITE, data, 1024);
            /* Wait for buffer send out */
            while (tx_result == 0) {
            }
            /**
              * Error handling here.

      * We can find out how many bytes were processed in this buffer
              * before the error occurred.
              */
            if (tx_result == 2) {
                len = audio_dma_get_buffer_size(&AUDIO_0, AUDIO_WRITE);
            }
        }
```

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7.2.5 Dependencies

- The AUDIO peripheral and it's related I/O lines and clocks
- The DMA peripheral and its configuration must be aligned with AUDIO peripheral

7.2.6 Structs

7.2.6.1 audio_dma_descriptor Struct

Audio Driver descriptor.

Members

dev	Audio HPL device descriptor
cb	Audio Buffer Callback function
txq	Internal TX Queue
rxq	Internal RX Queue

7.2.7 Enums

7.2.7.1 audio_dir Enum

AUDIO_READ	Read data from codec or microphone
AUDIO_WRITE	Write data to codec or speaker

7.2.7.2 audio_buffer_event Enum

AUDIO_BUFFER_EVENT_COMPLETE	Data was transferred successfully
AUDIO_BUFFER_EVENT_ERROR	Data while processing the request
AUDIO_BUFFER_EVENT_ABORT	Data transfer aborted

7.2.8 Typedefs

7.2.8.1 audio_buffer_handler_t typedef

typedef uint32_t audio_buffer_handler_t

7.2.8.2 audio_buffer_cb typedef

typedef void(* audio_buffer_cb) (enum audio_buffer_event event, audio_buffer_handler_t handler)

Audio Buffer Event Handler Function.

Parameters

event	Direction: in Identifies the type of event
handler	Direction: in Handle identifying the buffer which the event relates

context Direction: in

Value identifying the context of the application that registered the event handling function

7.2.9 Functions

7.2.9.1 audio_dma_init

Initialize Audio Device Driver.

```
int32_t audio_dma_init(
    struct audio_dma_descriptor *const desc,
    void *const hw
)
```

This function initializes the Audio Driver Descriptor for the given hardware instance. Making it ready for application enable and use it.

Parameters

desc Type: struct 7.2.6.1 audio_dma_descriptor Struct *const

Pointer to the driver descriptor

hw Type: void *const

Pointer to the hardware instance

Returns

Type: int32_t

Initialization status.

7.2.9.2 audio_dma_deinit

Deinitialize Audio Device Driver.

```
int32_t audio_dma_deinit(
    struct audio_dma_descriptor *const desc
)
```

This function deinitializes the given Audio Driver descriptor. Disabling its operation (and any hardware). Invalidates all the internal data.

Parameters

desc Type: struct 7.2.6.1 audio_dma_descriptor Struct *const

Pointer to the audio driver descriptor

Returns

Type: int32_t

De-initialization status.

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7.2.9.3 audio_dma_enable

Enable Audio Device.

```
int32_t audio_dma_enable(
    struct audio_dma_descriptor *const desc
)
```

This function enables the Audio Driver by the given Audio Driver descriptor.

Parameters

desc Type: struct 7.2.6.1 audio_dma_descriptor Struct *const

Pointer to the audio driver descriptor

Returns

Type: int32_t

Enabling status.

7.2.9.4 audio_dma_disable

Disable Audio Device.

```
int32_t audio_dma_disable(
    struct audio_dma_descriptor *const desc
)
```

This function disables the Audio Driver by the given Driver descriptor.

Parameters

desc Type: struct 7.2.6.1 audio_dma_descriptor Struct *const

Pointer to the Audio Driver descriptor

Returns

Type: int32_t

Disabling status.

7.2.9.5 audio_dma_register_callback

Register Audio callback function.

```
int32_t audio_dma_register_callback(
    struct audio_dma_descriptor *const desc,
    audio_buffer_cb cb
)
```

This function allows the application to register a function for the driver to call back when queued buffer transfer has finished, or error happens.

Parameters

desc Type: struct 7.2.6.1 audio_dma_descriptor Struct *const

Pointer to the audio driver descriptor

cb	Type: 7.2.8.2 audio_buffer_cb typedef Callback function, passing NULL will de-register any registered callback function

Returns

Type: int32_t

The status of callback assignment.

7.2.9.6 audio_dma_add_buffer

Schedule a non-blocking read or write operation.

```
int32_t audio_dma_add_buffer(
    struct audio_dma_descriptor *const desc,
    enum audio_dir dir,
    audio_buffer_handler_t handler,
    void * buf,
    uint32_t size
)
```

This function schedules a non-blocking read or write operation. The function adds the requests to the hardware instance queue and returns immediately.

Parameters

desc	Type: struct 7.2.6.1 audio_dma_descriptor Struct *const Pointer to the audio driver descriptor
dir	Type: enum 7.2.7.1 audio_dir Enum Identifies add the buffer to read or write queue
handler	Type: 7.2.8.1 audio_buffer_handler_t typedef Pointer the return buffer handle
buf	Type: void * Buffer where the read or write data will be stored
size	Type: uint32_t Buffer size in bytes

Returns

Type: int32_t

The state of the buffer operation.

ERR_NONE	Schedule buffer operation success
ERR_NO_RESOURCE	Buffer queue was full

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7.2.9.7 audio_dma_flush_buffer

Flush off the buffers.

```
int32_t audio_dma_flush_buffer(
    struct audio_dma_descriptor *const desc,
    enum audio_dir dir
)
```

This function flushes off the write or read buffers and disable the DMA channel.

Parameters

desc Type: struct 7.2.6.1 audio_dma_descriptor Struct *const

Pointer to audio driver descriptor

dir Type: enum 7.2.7.1 audio_dir Enum

Identifies flush the read or write queue

Returns

Type: int32_t

The result of comparator n stop the operation.

7.2.9.8 audio_dma_get_buffer_size

Get the number of bytes has been processed for the queued buffer.

```
int32_t audio_dma_get_buffer_size(
    struct audio_dma_descriptor *const desc,
    enum audio_dir dir
)
```

This function returns the number of bytes has been processed in the buffer queue of the driver instance. The application can use this function to know how many bytes has been processed.

Parameters

desc Type: struct 7.2.6.1 audio_dma_descriptor Struct *const

Pointer to audio driver descriptor

dir Type: enum 7.2.7.1 audio_dir Enum

Identifies flush the read or write queue

Returns

Type: int32_t

The number of bytes that have been processed for this buffer

7.2.9.9 audio_dma_get_version

Retrieve the current driver version.

```
uint32_t audio_dma_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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8. CAN Driver

This Control Area Network (CAN) driver provides an interface for CAN message transfer.

The following driver variant is available:

- 8.2 CAN Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. Functionality is asynchronous to the main clock of the MCU.

8.1 CAN Basics and Best Practice

CAN is a multi-master serial bus standard for connecting Electronic Control Units (ECUs) also known as nodes. Two or more nodes are required on the CAN network to communicate. The complexity of the node can range from a simple I/O device up to an embedded computer with a CAN interface and sophisticated software.

CAN bus is a message based protocol designed specifically for automotive applications, but is also used in areas such as aerospace, maritime, railway vehicles, industrial automation, and medical equipment. The CAN message ID not only provides identification for the type of message being sent or received, it also determines the priority of the message. Message IDs must be unique on a single CAN bus, otherwise two nodes would continue transmission beyond the end of the arbitration field (ID) causing an error.

8.2 CAN Asynchronous Driver

In Control Area Network (CAN) asynchronous driver, a callback function can be registered in the driver by the application and triggered when CAN message transfer done or error happen.

8.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable CAN instance
- CAN message transfer: transmission, reception
- Callback on message transmitted, recepted, error
- Callback on error warning, error active, error passive, bus off, data overrun
- Set CAN mode: normal, monitoring

8.2.2 Summary of Configuration Options

Below is a list of the main CAN parameters that can be configured in START. Many of these parameters are used by the 8.2.8.1 can_async_init function when initializing the driver and underlying hardware.

- CAN TX and RX signal pin
- Data bit timing and prescaler configuration
- Normal bit timing and prescaler configuration
- TX FIFO configuration
- RX FIFO configuration
- Filter configuration

8.2.3 Driver Implementation Description

The driver is focus on the MAC layer and try to offer the APIs which can be used by upper application layer.

8.2.4 Example of Usage

The following shows a simple example of using the CAN. The CAN must have been initialized by 8.2.8.1 can_async_init. This initialization will configure the operation of the CAN, such as input pins, single-shot, or continuous measurement mode, etc.

The example registers callback functions for CAN message send and receive.

```
        void CAN_0_tx_callback(struct can_async_descriptor *const descr)
        {
            (void)descr;
        }
        void CAN_0_rx_callback(struct can_async_descriptor *const descr)
        {
            struct can_message msg;
            uint8_t            data[64];
            msg.data = data;
            can_async_read(descr, &msg);
            return;
        }
        /**
         * Example of using CAN_0 to Encrypt/Decrypt data.
         */
        void CAN_0_example(void)
        {
            struct can_message msg;
            struct can_filter  filter;
            uint8_t            send_data[4];
            send_data[0] = 0x00;
            send_data[1] = 0x01;
            send_data[2] = 0x02;
            send_data[3] = 0x03;
            msg.id   = 0x45A;
            msg.type = CAN_TYPE_DATA;
            msg.data = send_data;
            msg.len  = 4;
            msg.fmt  = CAN_FMT_STDID;

    can_async_register_callback(&CAN_0, CAN_ASYNC_TX_CB, (FUNC_PTR)CAN_0_tx
_callback);
            can_async_enable(&CAN_0);
            /**
              * CAN_0_tx_callback callback should be invoked after call

      * can_async_write, and remote device should receive message with ID=0
x45A
              */
            can_async_write(&CAN_0, &msg);
            msg.id  = 0x100000A5;
            msg.fmt = CAN_FMT_EXTID;
            /**
             * remote device should receive message with ID=0x100000A5
              */
            can_async_write(&CAN_0, &msg);
            /**
              * CAN_0_rx_callback callback should be invoked after call
```

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```
      * can_async_set_filter and remote device send CAN Message with the sa
me
              * content as the filter.
              */

    can_async_register_callback(&CAN_0, CAN_ASYNC_RX_CB, (FUNC_PTR)CAN_0_rx
_callback);
            filter.id   = 0x469;
            filter.mask = 0;
            can_async_set_filter(&CAN_0, 0, CAN_FMT_STDID, &filter);
            filter.id   = 0x10000096;
            filter.mask = 0;
            can_async_set_filter(&CAN_0, 1, CAN_FMT_EXTID, &filter);
        }
```

8.2.5 Dependencies

- The CAN peripheral and its related I/O lines and clocks
- The NVIC must be configured so that CAN interrupt requests are periodically serviced

8.2.6 Structs

8.2.6.1 can_callbacks Struct

CAN callbacks.

Members

tx_done

rx_done

irq_handler

8.2.6.2 can_async_descriptor Struct

CAN descriptor.

Members

dev	CAN HPL device descriptor
cb	CAN Interrupt Callbacks handler

8.2.7 Typedefs

8.2.7.1 can_cb_t typedef

typedef void(* can_cb_t) (struct can_async_descriptor *const descr)

8.2.8 Functions

8.2.8.1 can_async_init

Initialize CAN.

```
int32_t can_async_init(
    struct can_async_descriptor *const descr,
    void *const hw
)
```

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This function initializes the given CAN descriptor.

Parameters

descr Type: struct 8.2.6.2 can_async_descriptor Struct *const

A CAN descriptor to initialize.

hw Type: void *const

The pointer to hardware instance.

Returns

Type: int32_t

Initialization status.

8.2.8.2 can_async_deinit

Deinitialize CAN.

```
int32_t can_async_deinit(
    struct can_async_descriptor *const descr
)
```

This function deinitializes the given CAN descriptor.

Parameters

descr Type: struct 8.2.6.2 can_async_descriptor Struct *const

The CAN descriptor to deinitialize.

Returns

Type: int32_t

De-initialization status.

8.2.8.3 can_async_enable

Enable CAN.

```
int32_t can_async_enable(
    struct can_async_descriptor *const descr
)
```

This function enables CAN by the given can descriptor.

Parameters

descr Type: struct 8.2.6.2 can_async_descriptor Struct *const

The CAN descriptor to enable.

Returns

Type: int32_t

Enabling status.

8.2.8.4 can_async_disable

Disable CAN.

```
int32_t can_async_disable(
    struct can_async_descriptor *const descr
)
```

This function disables CAN by the given can descriptor.

Parameters

descr	Type: struct 8.2.6.2 can_async_descriptor Struct *const The CAN descriptor to disable.

Returns

Type: int32_t

Disabling status.

8.2.8.5 can_async_read

Read a CAN message.

```
int32_t can_async_read(
    struct can_async_descriptor *const descr,
    struct can_message * msg
)
```

Parameters

descr	Type: struct 8.2.6.2 can_async_descriptor Struct *const The CAN descriptor to read message.
msg	Type: struct can_message * The CAN message to read to.

Returns

Type: int32_t

The status of read message.

8.2.8.6 can_async_write

Write a CAN message.

```
int32_t can_async_write(
    struct can_async_descriptor *const descr,
    struct can_message * msg
)
```

Parameters

descr	Type: struct 8.2.6.2 can_async_descriptor Struct *const The CAN descriptor to write message.

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msg Type: struct can_message *

The CAN message to write.

Returns

Type: int32_t

The status of write message.

8.2.8.7 can_async_register_callback

Register CAN callback function to interrupt.

```
int32_t can_async_register_callback(
    struct can_async_descriptor *const descr,
    enum can_async_callback_type type,
    FUNC_PTR cb
)
```

Parameters

descr Type: struct 8.2.6.2 can_async_descriptor Struct *const

The CAN descriptor

type Type: enum can_async_callback_type

Callback type

cb Type: 40.3.2.1 FUNC_PTR typedef

A callback function, passing NULL will de-register any registered callback

Returns

Type: int32_t

The status of callback assignment.

8.2.8.8 can_async_get_rxerr

Return number of read errors.

```
uint8_t can_async_get_rxerr(
    struct can_async_descriptor *const descr
)
```

This function returns the number of read errors.

Parameters

descr Type: struct 8.2.6.2 can_async_descriptor Struct *const

The CAN descriptor pointer

Returns

Type: uint8_t

The number of read errors.

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8.2.8.9 can_async_get_txerr

Return number of write errors.

```
uint8_t can_async_get_txerr(
    struct can_async_descriptor *const descr
)
```

This function returns the number of write errors.

Parameters

descr Type: struct 8.2.6.2 can_async_descriptor Struct *const

The CAN descriptor pointer

Returns

Type: uint8_t

The number of write errors.

8.2.8.10 can_async_set_mode

Set CAN to the specified mode.

```
int32_t can_async_set_mode(
    struct can_async_descriptor *const descr,
    enum can_mode mode
)
```

This function sets CAN to a specified mode.

Parameters

descr Type: struct 8.2.6.2 can_async_descriptor Struct *const

The CAN descriptor pointer

mode Type: enum can_mode

The CAN operation mode

Returns

Type: int32_t

Status of the operation.

8.2.8.11 can_async_set_filter

Set CAN Filter.

```
int32_t can_async_set_filter(
    struct can_async_descriptor *const descr,
    uint8_t index,
    enum can_format fmt,
    struct can_filter * filter
)
```

This function sets CAN to a specified mode.

Parameters

descr	Type: struct 8.2.6.2 can_async_descriptor Struct *const The CAN descriptor pointer
index	Type: uint8_t Index of Filter list
fmt	Type: enum can_format CAN Indentify Type
filter	Type: struct can_filter * CAN Filter struct, NULL for clear filter

Returns

Type: int32_t

Status of the operation.

8.2.8.12 can_async_get_version

Retrieve the current driver version.

```
uint32_t can_async_get_version(
    void
)
```

Returns

Type: uint32_t

The current driver version.

9. CRC Driver

This Cyclic Redundancy Check (CRC) driver provides an interface for the CRC calculation of given length data.

The following driver variant is available:

- 9.2 CRC Synchronous Driver: The driver supports polling for hardware changes, functionality is synchronous to the main clock of the MCU.

9.1 CRC Basics and Best Practice

A Cyclic Redundancy Check (CRC) is an error-detecting code for detecting errors of raw data. It takes a data block of any length, and gives out a fixed length check value. The CRC cannot make corrections when errors are detected.

In the CRC method, a fixed length check value (often called Checksum) is appended to the transmit data block. The receiver can use the same CRC function to check whether the checksum matches the received data. If the received checksum does not match the computation checksum, it means something is wrong when the transfered data. The receiver can request the data to be send.

Below is an application example for how to use this driver:

- Calculate a checksum for a data block to be sent and append it to the data. When the data block with checksum has been received by the receiver, the receive checksum can be compared with the new and calculated checksum from the data block.

9.2 CRC Synchronous Driver

The functions in the Cyclic Redundancy Check (CRC) synchronous driver will block (i.e. not return) until the operation is done.

9.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialization and de-initialization
- Enabling and Disabling
- CRC32 (IEEE-802.3)
- CRC16 (CCITT)

9.2.2 Summary of Configuration Options

Normally there is no parameter to be configured in START.

9.2.3 Driver Implementation Description

The driver supports IEEE CRC32 polynomial and CCITT CRC16 polynomial. The initial value used for the CRC calculation must be assigned. This value is normally 0xFFFFFFFF(CRC32) or 0xFFFF(CRC16), but can be, for example, the result of a previously computed CRC separate memory blocks.

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9.2.4 Example of Usage

The following shows a simple example of using the CRC32 functions.

```
        /* CRC Data in flash */
        COMPILER_ALIGNED(4)
        static const uint32_t crc_datas[] = {0x00000000,
                                             0x11111111,
                                             0x22222222,
                                             0x33333333,
                                             0x44444444,
                                             0x55555555,
                                             0x66666666,
                                             0x77777777,
                                             0x88888888,
                                             0x99999999};
        /**
         * Example of using CRC_0 to Calculate CRC32 for a buffer.
         */
        void CRC_0_example(void)
        {
            /
* The initial value used for the CRC32 calculation usually be 0xFFFFFFFF,

      * but can be, for example, the result of a previous CRC32 calculation
 if
              * generating a common CRC32 of separate memory blocks.
              */
            uint32_t crc = 0xFFFFFFFF;
            uint32_t crc2;
            uint32_t ind;
            crc_sync_enable(&CRC_0);
            crc_sync_crc32(&CRC_0, (uint32_t *)crc_datas, 10, &crc);
            /* The read value must be complemented to match standard CRC32
              * implementations or kept non-
inverted if used as starting point for
              * subsequent CRC32 calculations.
              */
            crc ^= 0xFFFFFFFF;
            /
* Calculate the same data with subsequent CRC32 calculations, the result
              * should be same as previous way.
              */
            crc2 = 0xFFFFFFFF;
            for (ind = 0; ind < 10; ind++) {

        crc_sync_crc32(&CRC_0, (uint32_t *)&crc_datas[ind], 1, &crc2);
            }
            crc2 ^= 0xFFFFFFFF;
            /* The calculate result should be same. */
            while (crc != crc2)
                ;
        }
```

9.2.5 Dependencies

- CRC capable hardware. For Cortex-M0+ based SAM devices, the CRC uses hardware DSU engine which only supports CRC32 (IEEE-802.3) reversed polynomial representation.

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9.2.6 Structs

9.2.6.1 crc_sync_descriptor Struct

CRC descriptor.

Members

dev	CRC HPL device descriptor

9.2.7 Functions

9.2.7.1 crc_sync_init

Initialize CRC.

```
int32_t crc_sync_init(
    struct crc_sync_descriptor *const descr,
    void *const hw
)
```

This function initializes the given CRC descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 9.2.6.1 crc_sync_descriptor Struct *const A CRC descriptor to initialize
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

9.2.7.2 crc_sync_deinit

Deinitialize CRC.

```
int32_t crc_sync_deinit(
    struct crc_sync_descriptor *const descr
)
```

This function deinitializes the given CRC descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr	Type: struct 9.2.6.1 crc_sync_descriptor Struct *const A CRC descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

9.2.7.3 crc_sync_enable

Enable CRC.

```
int32_t crc_sync_enable(
    struct crc_sync_descriptor *const descr
)
```

This function enables CRC by the given CRC descriptor.

Parameters

descr	Type: struct 9.2.6.1 crc_sync_descriptor Struct *const A CRC descriptor to enable

Returns

Type: int32_t

Enabling status.

9.2.7.4 crc_sync_disable

Disable CRC.

```
int32_t crc_sync_disable(
    struct crc_sync_descriptor *const descr
)
```

This function disables CRC by the given CRC descriptor.

Parameters

descr	Type: struct 9.2.6.1 crc_sync_descriptor Struct *const A CRC descriptor to disable

Returns

Type: int32_t

Disabling status.

9.2.7.5 crc_sync_crc32

Calculate CRC32 value of the buffer.

```
int32_t crc_sync_crc32(
    struct crc_sync_descriptor *const descr,
    uint32_t *const data,
    const uint32_t len,
    uint32_t * pcrc
)
```

This function calculates the standard CRC-32 (IEEE 802.3).

Parameters

data	Type: uint32_t *const

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	Pointer to the input data buffer
len	Type: const uint32_t
	Length of the input data buffer
pcrc	Type: uint32_t *
	Pointer to the CRC value

Returns

Type: int32_t

Calculated result.

9.2.7.6 crc_sync_crc16

Calculate the CRC16 value of the buffer.

```
int32_t crc_sync_crc16(
    struct crc_sync_descriptor *const descr,
    uint16_t *const data,
    const uint32_t len,
    uint16_t * pcrc
)
```

This function calculates CRC-16 (CCITT).

Parameters

data	Type: uint16_t *const
	Pointer to the input data buffer
len	Type: const uint32_t
	Length of the input data buffer
pcrc	Type: uint16_t *
	Pointer to the CRC value

Returns

Type: int32_t

Calculated result.

9.2.7.7 crc_sync_get_version

Retrieve the current driver version.

```
uint32_t crc_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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10. Calendar Drivers

This Calendar driver provides an interface to set and get the current date and time, and also the alarm functionality.

The following driver variants are available:

- 10.2 Calendar Bare-bone Driver: The driver supports setting and getting the current date and time, and alarm functionality with callback handler.
- 10.3 Calendar RTOS Driver: The driver is intended for using calendar functions in a Real-Time operating system, i.e. is thread safe.

10.1 Calendar Basics and Best Practice

The Calendar driver provides functions to set and get the current date and time. After enabling, an instance of the driver starts counting time from the base date with a resolution of one second. The default base date is 00:00:00 1st of January 1970.

The current date and time is kept internally in a relative form as the difference between the current date and the time, and the base date and time. This means that changing the base year changes current date.

The base date and time defines time "zero" or the earliest possible point in time that the calender driver can describe, this means that current time and alarms cannot be set to anything earlier than this time.

The Calendar driver provides an alarm functionality. An alarm is a software trigger, which fires on a given date and time with given periodicity. Upon firing, the given callback function is called.

An alarm can be in single-shot mode, firing only once at matching time; or in repeating mode, meaning that it will reschedule a new alarm automatically based on the repeating mode configuration. In single-shot mode an alarm is removed from the alarm queue before its callback is called. It allows an application to reuse the memory of an expired alarm in the callback.

An alarm can be triggered on the following events: match on second, minute, hour, day, month, or year. Matching on second means that the alarm is triggered when the value of seconds of the current time is equal to the alarm's value of seconds. This means repeating alarm with match on seconds is triggered with the period of a minute. Matching on minute means that the calendar's minute and seconds values have to match the alarms, the rest of the date-time values are ignored. In repeating mode this means a new alarm every hour. The same logic is applied to match on hour, day, month, and year.

Each instance of the Calendar driver supports an infinite amount of software alarms, only limited by the amount of RAM available.

Below are some application examples for how to use this driver:

- A source of current date and time for an embedded system
- Periodical functionality in low-power applications since the driver is designed to use 1Hz clock
- Periodical function calls in case if it is more convenient to operate with absolute time

10.2 Calendar Bare-bone Driver

This Calendar bare-bone driver provides an interface to set and get current date and time, and also alarm functionality.

Refer 10. Calendar Drivers for more detailed calendar basics.

10.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable and disable calendar instance
- Set time, date, and base year
- Get current date and time
- Set the software alarm timer with callback handler on the alarm event happen

10.2.2 Summary of Configuration Options

Below is the main Calendar parameters that can be configured in START. These parameters are used by the 10.2.8.1 calendar_init function when initializing the driver and underlying hardware.

- The clock source and the prescaler of counter hardware used by the calendar

10.2.3 Driver Implementation Description

The calendar driver implementation is based on a hardware counter which is configured to increase with one every second. The hardware may be RTC (Real-Time Counter) or RTT (Real-time Timer) depend on the device.

10.2.3.1 Concurrency

The Calendar driver is an interrupt driven driver. This means that the interrupt that triggers an alarm may occur during the process of adding or removing an alarm via the driver's API. In such case the interrupt processing is postponed until the alarm adding or removing is complete.

The alarm queue is not protected from the access by interrupts not used by the driver. Due to this it is not recommended to add or remove an alarm from such interrupts: in case if a higher priority interrupt supersedes the driver's interrupt. Adding or removing an alarm may cause unpredictable behavior of the driver.

10.2.3.2 Limitations

- Only years divisible by 4 are leap year. This gives a correct result between the years 1901 to 2099
- The driver is designed to work outside of an operating system environment. The software alarm queue is therefore processed in interrupt context, which may delay execution of other interrupts
- If there are a lot of frequently called interrupts with a priority higher than the driver's one, it may cause a delay in the alarm's triggering
- Changing the base year or setting current date or time does not shift the alarms' date and time accordingly or expires alarms

10.2.4 Example of Usage

The following shows a simple example of using the Calendar. The calendar must have been initialized by 10.2.8.1 calendar_init. This initialization will configure the operation of the underlying hardware counter.

The example first sets the given date and time, then sets a repeat alarm timer on specific second match with a callback function.

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Tip:
Take for example SAM D21. The RTC peripheral is used in counter mode and to be increased by one every second. Correct RTC clock settings can be configured in START:

- Clock
  - Select OSCULP32K source as generic clock generator 1 input
  - Enable generic clock generator 1 with division 32 to get 1kHz output
- Calendar driver (RTC)
  - Select generic clock generator 1 as RTC clock input
  - Set prescaler to 1024, then RTC get a 1Hz clock input

```
static void alarm_cb(struct calendar_descriptor *const descr)
{
  /* alarm expired */
}
void CALENDAR_0_example(void)
{
  struct calendar_date date;
  struct calendar_time time;
  calendar_enable(&CALENDAR_0);
  date.year  = 2000;
  date.month = 12;
  date.day   = 31;
  time.hour = 12;
  time.min  = 59;
  time.sec  = 59;
  calendar_set_date(&CALENDAR_0, &date);
  calendar_set_time(&CALENDAR_0, &time);
  alarm.cal_alarm.datetime.time.sec = 4;
  alarm.cal_alarm.option            = CALENDAR_ALARM_MATCH_SEC;
  alarm.cal_alarm.mode              = REPEAT;
  calendar_set_alarm(&CALENDAR_0, &alarm, alarm_cb);
}
```

10.2.5 Dependencies

- This driver expects a counter to be increased by one every second to count date and time correctly
- Each instance of the driver requires separate hardware timer

10.2.6 Structs

10.2.6.1 calendar_alarm Struct

Struct for alarm time.

Members

elem

cal_alarm

callback

10.2.7 Typedefs

10.2.7.1 calendar_cb_alarm_t typedef

typedef void(* calendar_cb_alarm_t) (struct calendar_descriptor *const calendar)

Prototype of callback on alarm match.

Parameters

calendar	Direction: Pointer to the HAL Calendar instance.

10.2.8 Functions

10.2.8.1 calendar_init

Initialize the Calendar HAL instance and hardware.

```
int32_t calendar_init(
    struct calendar_descriptor *const calendar,
    const void * hw
)
```

Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.
hw	Type: const void * Pointer to the hardware instance.

Returns

Type: int32_t

Operation status of init

0	Completed successfully.

10.2.8.2 calendar_deinit

Reset the Calendar HAL instance and hardware.

```
int32_t calendar_deinit(
    struct calendar_descriptor *const calendar
)
```

Reset Calendar instance to hardware defaults.

Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.

Returns

Type: int32_t

Operation status of reset.

0	Completed successfully.

10.2.8.3 calendar_enable

Enable the Calendar HAL instance and hardware.

```
int32_t calendar_enable(
    struct calendar_descriptor *const calendar
)
```

Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.

Returns

Type: int32_t

Operation status of init

0	Completed successfully.

10.2.8.4 calendar_disable

Disable the Calendar HAL instance and hardware.

```
int32_t calendar_disable(
    struct calendar_descriptor *const calendar
)
```

Disable Calendar instance to hardware defaults.

Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.

Returns

Type: int32_t

Operation status of reset.

0	Completed successfully.

10.2.8.5 calendar_set_baseyear

Configure the base year for calendar HAL instance and hardware.

```
int32_t calendar_set_baseyear(
    struct calendar_descriptor *const calendar,
    const uint32_t p_base_year
)
```

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Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.
p_base_year	Type: const uint32_t The desired base year.

Returns

Type: int32_t

0	Completed successfully.

10.2.8.6 calendar_set_time

Configure the time for calendar HAL instance and hardware.

```
int32_t calendar_set_time(
    struct calendar_descriptor *const calendar,
    struct calendar_time *const p_calendar_time
)
```

Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.
p_calendar_time	Type: struct calendar_time *const Pointer to the time configuration.

Returns

Type: int32_t

0	Completed successfully.

10.2.8.7 calendar_set_date

Configure the date for calendar HAL instance and hardware.

```
int32_t calendar_set_date(
    struct calendar_descriptor *const calendar,
    struct calendar_date *const p_calendar_date
)
```

Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.
p_calendar_date	Type: struct calendar_date *const Pointer to the date configuration.

Returns

Type: int32_t

Operation status of time set.

0	Completed successfully.

10.2.8.8 calendar_get_date_time

Get the time for calendar HAL instance and hardware.

```
int32_t calendar_get_date_time(
    struct calendar_descriptor *const calendar,
    struct calendar_date_time *const date_time
)
```

Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.
date_time	Type: struct calendar_date_time *const Pointer to the value that will be filled with the current time.

Returns

Type: int32_t

Operation status of time retrieve.

0	Completed successfully.

10.2.8.9 calendar_set_alarm

Config the alarm time for calendar HAL instance and hardware.

```
int32_t calendar_set_alarm(
    struct calendar_descriptor *const calendar,
    struct calendar_alarm *const alarm,
    calendar_cb_alarm_t callback
)
```

Set the alarm time to calendar instance. If the callback is NULL, remove the alarm if the alarm is already added, otherwise, ignore the alarm.

Parameters

calendar	Type: struct calendar_descriptor *const Pointer to the HAL Calendar instance.
alarm	Type: struct 10.2.6.1 calendar_alarm Struct *const Pointer to the configuration.
callback	Type: 10.2.7.1 calendar_cb_alarm_t typedef Pointer to the callback function.

Returns

Type: int32_t

Operation status of alarm time set.

0	Completed successfully.

10.2.8.10 calendar_get_version

Retrieve the current driver version.

```
uint32_t calendar_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

10.3 Calendar RTOS Driver

This Calendar RTOS driver provides an interface to set and get current date and time, and also alarm functionality used in a Real-Time operating system.

Refer 10. Calendar Drivers for more detailed calendar basics.

10.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Set time, date and base year
- Get current date, and time
- Set the software alarm timer with callback handler on the alarm event happen

10.3.2 Summary of Configuration Options

Below is the main Calendar parameters that can be configured in START. These parameters are used by the 10.3.9.1 calendar_os_init function when initializing the driver and underlying hardware.

- The clock source and the prescaler of counter hardware used by the calendar

10.3.3 Driver Implementation Description

The calendar driver implementation is based on a hardware counter which is configured to increase with one every second. The hardware may be RTC (Real-Time Counter) or RTT (Real-time Timer) depend on the device.

To use the software alarm, the alarm task API (calendar_os_task) should be called as an RTOS task or in the user while-loop thread.

The alarm task functions use semaphore to block the current task or thread until an alarm occurs. So the alarm task functions do not work without RTOS, and must be called in an RTOS task or thread.

10.3.3.1 Limitations

- Only years divisible by 4 are leap year. This gives a correct result between the years 1901 to 2099
- The task API (calendar_os_task) should be called in a user while-loop thread

10.3.4 Example of Usage

The following shows a simple example of using the Calendar. The calendar must have been initialized by 10.3.9.1 calendar_os_init. This initialization will configure the operation of the underlying hardware counter.

The example creates the calendar example task. In the task, it first sets the given date and time, then it sets two alarm timers on specific second match with a callback function. Finally, the 10.3.9.6 calendar_os_task is called in the while-loop thread.

Tip:
Take for example SAM D21. The RTC peripheral is used in counter mode and is to be increased by one every second. Correct RTC clock settings can be configured in START:

- Clock
  - Select OSCULP32K source as generic clock generator 1 input
  - Enable generic clock generator 1 with division 32 to get 1kHz output
- Calendar driver (RTC)
  - Select generic clock generator 1 as RTC clock input
  - Set prescaler to 1024, then RTC get a 1Hz clock input

```
        static struct calendar_os_alarm alarm1, alarm2;
        /**
         * Example of using CALENDAR_0.
         */
        static void alarm_cb(struct calendar_os_descriptor *const descr)
        {
            /* Handle alarm event */
        }
        /**
         * The alarm task function(calendar_os_task) should be called
         * in user while-
loop thread, so that the soft alarm could be processed and
         * the alarm_cb function could be called.
         */
        void CALENDAR_0_example_task(void)
        {
            struct calendar_date_time dt;
            dt.date.year  = 2000;
            dt.date.month = 12;
            dt.date.day   = 31;
            dt.time.hour = 12;
            dt.time.min  = 59;
            dt.time.sec  = 59;
            calendar_os_set_date_time(&CALENDAR_0, &dt);
            alarm1.cal_alarm.datetime.time.sec = 20;
            alarm1.cal_alarm.option            = CALENDAR_ALARM_MATCH_SEC;
            alarm1.cal_alarm.mode              = ONESHOT;
            calendar_os_set_alarm(&CALENDAR_0, &alarm1, alarm_cb);
            alarm2.cal_alarm.datetime.time.sec = 40;
            alarm2.cal_alarm.option            = CALENDAR_ALARM_MATCH_SEC;
            alarm2.cal_alarm.mode              = REPEAT;
            calendar_os_set_alarm(&CALENDAR_0, &alarm2, alarm_cb);
            while(1) {
                calendar_os_task(&CALENDAR_0);
```

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```
            }
        }
        #define TASK_EXAMPLE_STACK_SIZE (256 / sizeof(portSTACK_TYPE))
        #define TASK_EXAMPLE_STACK_PRIORITY (tskIDLE_PRIORITY + 1)
        static TaskHandle_t      xCreatedExampleTask;
        int main(void)
        {
            /* Initializes MCU, drivers and middleware */
            atmel_start_init();
            if (xTaskCreate(

            CALENDAR_0_example_task, "Example", TASK_EXAMPLE_STACK_SIZE, NU
LL,
                    TASK_EXAMPLE_STACK_PRIORITY, xCreatedExampleTask) !
= pdPASS) {
                while (1) {
                    ;
                }
            }
            vTaskStartScheduler();
            /* Replace with your application code */
            while (1) {
            }
        }
```

10.3.5 Dependencies

- This driver expects a counter to be increased by one every second to count date and time correctly
- Each instance of the driver requires a separate hardware timer
- RTOS

10.3.6 Structs

10.3.6.1 calendar_os_descriptor Struct

Calendar HAL driver struct.

Members

device

alarms

alarm_sem

10.3.6.2 calendar_os_alarm Struct

Struct for alarm time.

Members

elem

cal_alarm

callback

10.3.7 Defines

10.3.7.1 DEFAULT_BASE_YEAR

#define DEFAULT_BASE_YEAR( ) 1970

Default base year.

10.3.8 Typedefs

10.3.8.1 calendar_os_cb_alarm_t typedef

typedef void(* calendar_os_cb_alarm_t) (struct calendar_os_descriptor *const calendar)

Prototype of callback on alarm match.

Parameters

calendar	Direction: Pointer to the HAL Calendar instance.

10.3.9 Functions

10.3.9.1 calendar_os_init

Initialize the Calendar HAL instance and hardware.

```
int32_t calendar_os_init(
    struct calendar_os_descriptor *const calendar,
    const void * hw
)
```

Parameters

calendar	Type: struct 10.3.6.1 calendar_os_descriptor Struct *const Pointer to the HAL Calendar instance.
hw	Type: const void * Pointer to the hardware instance.

Returns

Type: int32_t

Operation status of init

0	Completed successfully.

10.3.9.2 calendar_os_deinit

Reset the Calendar HAL instance and hardware.

```
int32_t calendar_os_deinit(
    struct calendar_os_descriptor *const calendar
)
```

Reset Calendar instance to hardware defaults.

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Parameters

calendar	Type: struct 10.3.6.1 calendar_os_descriptor Struct *const Pointer to the HAL Calendar instance.

Returns

Type: int32_t

Operation status of reset.

0	Completed successfully.

10.3.9.3 calendar_os_set_date_time

Configure the time for calendar HAL instance and hardware.

```
int32_t calendar_os_set_date_time(
    struct calendar_os_descriptor *const calendar,
    struct calendar_date_time *const time
)
```

Parameters

calendar	Type: struct 10.3.6.1 calendar_os_descriptor Struct *const Pointer to the HAL Calendar instance.
time	Type: struct calendar_date_time *const Pointer to the time configuration.

Returns

Type: int32_t

0	Completed successfully.

10.3.9.4 calendar_os_get_date_time

Get the time for calendar HAL instance and hardware.

```
int32_t calendar_os_get_date_time(
    struct calendar_os_descriptor *const calendar,
    struct calendar_date_time *const time
)
```

Retrieve the time from calendar instance.

Parameters

calendar	Type: struct 10.3.6.1 calendar_os_descriptor Struct *const Pointer to the HAL Calendar instance.
time	Type: struct calendar_date_time *const Pointer to the value that will be filled with the current time.

Returns

Type: int32_t

Operation status of time retrieve.

0	Completed successfully.

10.3.9.5 calendar_os_set_alarm

Config the alarm time for calendar HAL instance and hardware.

```
int32_t calendar_os_set_alarm(
    struct calendar_os_descriptor *const calendar,
    struct calendar_os_alarm *const alarm,
    calendar_os_cb_alarm_t callback
)
```

Set the alarm time to the calendar instance. If callback is NULL, remove the alarm if the alarm is already added, otherwise, ignore the alarm.

Parameters

calendar	Type: struct 10.3.6.1 calendar_os_descriptor Struct *const Pointer to the HAL Calendar instance.
alarm	Type: struct 10.3.6.2 calendar_os_alarm Struct *const Pointer to the configuration.
callback	Type: 10.3.8.1 calendar_os_cb_alarm_t typedef Pointer to the callback function.

Returns

Type: int32_t

Operation status of alarm time set.

0	Completed successfully.

10.3.9.6 calendar_os_task

Alarm process task.

```
int32_t calendar_os_task(
    struct calendar_os_descriptor *const calendar
)
```

It should be called in the user thread or while loop.

Parameters

calendar	Type: struct 10.3.6.1 calendar_os_descriptor Struct *const Pointer to the HAL calendar instance.

Returns

Type: int32_t

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Operation status of alarm task.

0	Completed successfully.

10.3.9.7 calendar_os_get_version

Retrieve the current driver version.

```
uint32_t calendar_os_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

11. Camera Driver

This Camera driver provides an interface for a CMOS digital image sensor.

The following driver variant is available:

- 11.2 Camera Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.

11.1 Camera Basics and Best Practice

A Camera can be used to interface a CMOS digital image sensor to the processor and provide image capture.

The Camera interface driver supports the CMOS sensor data format configuration and data stream capture.

11.2 Camera Asynchronous Driver

In the Camera asynchronous driver, a callback function can be registered in the driver by the application and triggered when the capture is done.

The Camera interface driver supports the CMOS sensor data format configuration and data stream capture. The "Image Sensor" middleware is used to select which image sensor is to be used.

11.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enabling and disabling
- Hookup callback handlers on capture done
- Data stream capture

11.2.2 Summary of Configuration Options

Below is a list of the main Camera parameters that can be configured in START. Many of these parameters are used by the 11.2.9.1 camera_async_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Select input data stream format
- Select input data stream path
- Set vertical and horizontal size of the image sensor
- Set vertical and horizontal size of the preview path
- Which clock source is used

11.2.3 Driver Implementation Description

After the Camera hardware initialization, the application can register a callback function for capture done by 11.2.9.5 camera_async_register_callback.

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11.2.4 Example of Usage

The following shows a simple example of using the Camera. The Camera must have been initialized by 11.2.9.1 camera_async_init. This initialization will configure the operation of the Camera, such as input pins, Camera configuration, and interrupt configuration, etc.

The example registers a callback function for capture done and enables the Camera to start recording.

```
        /**
         * Example of using CAMERA_0.
         */
static void capture_cb(struct camera_async_descriptor *const descr, uint32_
t ch)
        {
            if (ch == 0) {
                // Application can process data in frame_buf.
                camera_async_capture_start(&CAMERA_0, 0, frame_buf);
            }
        }
        /**
         * Application example.
         */
        void CAMERA_0_example(void)
        {
            camera_async_register_callback(&CAMERA_0, capture_cb);
            camera_async_enable(&CAMERA_0);
            camera_async_capture_start(&CAMERA_0, 0, frame_buf);
        }
```

11.2.5 Dependencies

- The Camera peripheral and its related I/O lines and clocks
- The NVIC must be configured so that Camera interrupt requests are periodically serviced

11.2.6 Structs

11.2.6.1 camera_async_descriptor Struct

Camera sensor descriptor.

Members

device	Camera sensor HPL device descriptor
capture_done	Capture done callback handlers on camera channels

11.2.7 Defines

11.2.7.1 CAMERA_ASYNC_DRIVER_VERSION

#define CAMERA_ASYNC_DRIVER_VERSION( ) 0x00000001u

Camera driver version.

11.2.8 Typedefs

11.2.8.1 camera_async_cb_t typedef

typedef void(* camera_async_cb_t) (struct camera_async_descriptor *const descr, uint32_t ch)

Camera sensor callback type.

Parameters

descr	Direction: in Camera sensor descriptor
ch	Direction: in Camera channel number

11.2.9 Functions

11.2.9.1 camera_async_init

Initialize Camera sensor.

```
int32_t camera_async_init(
    struct camera_async_descriptor *const descr,
    void *const hw
)
```

This function initializes the given Camera sensor descriptor. It checks if the given hardware is initialized or not and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 11.2.6.1 camera_async_descriptor Struct *const The camera sensor descriptor to initialize
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

11.2.9.2 camera_async_deinit

Deinitialize camera sensor.

```
static int32_t camera_async_deinit(
    struct camera_async_descriptor *const descr
)
```

This function deinitializes the given camera sensor descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr	Type: struct 11.2.6.1 camera_async_descriptor Struct *const Camera sensor descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

11.2.9.3 camera_async_enable

Enable camera sensor.

```
static int32_t camera_async_enable(
    struct camera_async_descriptor *const descr
)
```

This function enables the camera sensor by the given camera sensor descriptor.

Parameters

descr	Type: struct 11.2.6.1 camera_async_descriptor Struct *const Camera sensor descriptor to enable

Returns

Type: int32_t

Enabling status.

11.2.9.4 camera_async_disable

Disable camera sensor.

```
static int32_t camera_async_disable(
    struct camera_async_descriptor *const descr
)
```

This function disables the camera sensor by the given camera sensor descriptor.

Parameters

descr	Type: struct 11.2.6.1 camera_async_descriptor Struct *const The camera sensor descriptor to disable

Returns

Type: int32_t

Disabling status.

11.2.9.5 camera_async_register_callback

Register camera sensor callback.

```
static int32_t camera_async_register_callback(
    struct camera_async_descriptor *const descr,
    camera_async_cb_t cb
)
```

Parameters

descr	Type: struct 11.2.6.1 camera_async_descriptor Struct *const

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Pointer to the HAL descriptor

cb Type: 11.2.8.1 camera_async_cb_t typedef

A callback function, passing NULL de-registers callback

Returns

Type: int32_t

The status of callback assignment.

ERR_NONE	A callback is registered successfully
-1	Passed parameters were invalid

11.2.9.6 camera_async_capture_start

Start camera data capture.

```
static int32_t camera_async_capture_start(
    struct camera_async_descriptor *const descr,
    uint32_t ch,
    uint32_t * buf
)
```

This function starts capturing camera data.

Parameters

descr Type: struct 11.2.6.1 camera_async_descriptor Struct *const

Camera sensor descriptor

ch Type: uint32_t

Capture channel

buf Type: uint32_t *

Pointer to frame buffer

Returns

Type: int32_t

Capture start status.

11.2.9.7 camera_async_get_version

Retrieve the current driver version.

```
static uint32_t camera_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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12. Cryptography (AES) Driver

This Cryptography driver provides an interface for encryption or decryption.

The following driver variant is available:

- 12.2 AES Synchronous Driver: The driver will block (i.e. not return) until the requested data has been read. Functionality is therefore synchronous to the calling thread, i.e. the thread wait for the result to be ready.

12.1 AES Basics and Best Practice

The Advanced Encryption Standard (AES) is a specification for the encryption of electronic data established by the U.S. National Institute of Standards and Technology (NIST) in 2001. AES operates on a 128-bit block of input data. The key size used for an AES cipher specifies the number of repetitions of transformation rounds that converts the input, called the plaintext, into the final output, called the ciphertext. The AES works on a symmetric-key algorithm, meaning the same key is used for both encrypting and decrypting the data.

The driver supports ECB/CBC/CFB/OFB/CTR mode for data encryption, and GCM/CCM for authenticated encryption. Before using any encrypted mode of AES, the key must be first be set. For privacy situation, after encrypting/decrypting data, the key should be cleared by the application. Common practice is to set the key to zero.

12.2 AES Synchronous Driver

The Advanced Encryption Standard (AES) driver provides an interface for encryption or decryption.

The driver will block (i.e. not return) until the requested data has been read. Functionality is therefore synchronous to the calling thread, i.e. the thread waits for the result to be ready.

Refer 12. Cryptography (AES) Driver for more detailed calendar basics.

12.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable the driver
- Configure 128/192/256 bit cryptographic keys
- Support of the Modes of Operation Specified in the NIST Special Publication 800-38A and NIST Special Publication 800-38D:
  - ECB: Electronic Code Book
  - CBC: Cipher Block Chaining
  - CFB: Cipher Feedback in 8,16,32,64,128 bits size
  - OFB: Output Feedback
  - CTR: Counter
  - CCM: Counter with CBC-MAC mode for authenticated encryption
  - GCM: Galois Counter mode encryption and authentication

12.2.2 Summary of Configuration Options

The user selects which clock source the AES uses in START. No more parameters are configured when initializing the driver and underlying hardware.

12.2.3 Driver Implementation Description

The functions in the AES synchronous driver will block (i.e. not return) until operation is done.

12.2.3.1 Limitations

- The GCM supports data processes with known lengths only. This mean the 12.2.7.19 aes_sync_gcm_update cannot be invoked multiple times. The application should assembly all data into a data buffer and then call the 12.2.7.19 aes_sync_gcm_update to encrypt/decrypt data.

12.2.4 Example of Usage

The following shows a simple example of using the AES. The AES must have been initialized by 12.2.7.1 aes_sync_init.

The example enables AES driver and sets ac encrypt key, and then invokes the function for Electronic Code Book (ECB) mode. Finally, we can get the ciphered data. If the ciphered data isn't similar to the plain data, the project will go into an infinite loop.

```
        static uint8_t aes_plain_text[16]

    = {0x6b, 0xc1, 0xbe, 0xe2, 0x2e, 0x40, 0x9f, 0x96, 0xe9, 0x3d, 0x7e, 0x
11, 0x73, 0x93, 0x17, 0x2a};
        static uint8_t aes_key[16]

    = {0x2b, 0x7e, 0x15, 0x16, 0x28, 0xae, 0xd2, 0xa6, 0xab, 0xf7, 0x15, 0x
88, 0x09, 0xcf, 0x4f, 0x3c};
        static uint8_t aes_cipher_text[16]

    = {0x3a, 0xd7, 0x7b, 0xb4, 0x0d, 0x7a, 0x36, 0x60, 0xa8, 0x9e, 0xca, 0x
f3, 0x24, 0x66, 0xef, 0x97};
        uint8_t aes_output[16] = {0x00};
        /**
         * Example of using CRYPTOGRAPHY_0 to Encrypt/Decrypt datas.
         */
        void CRYPTOGRAPHY_0_example(void)
        {
            int32_t i;
            aes_sync_enable(&CRYPTOGRAPHY_0);

    aes_sync_set_encrypt_key(&CRYPTOGRAPHY_0, aes_key, AES_KEY_128);

    aes_sync_ecb_crypt(&CRYPTOGRAPHY_0, AES_ENCRYPT, aes_plain_text, aes_ou
tput);
            for (i = 0; i < 16; i++) {
                while (aes_output[i] != aes_cipher_text[i])
                    ;
            }
        }
```

12.2.5 Dependencies

- AES peripheral and its related clocks

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12.2.6 Structs

12.2.6.1 aes_sync_descriptor Struct

Members

dev	AES HPL device descriptor

12.2.7 Functions

12.2.7.1 aes_sync_init

Initialize AES Descriptor.

```
int32_t aes_sync_init(
    struct aes_sync_descriptor * descr,
    void *const hw
)
```

Parameters

desc	The AES descriptor to be initialized
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

12.2.7.2 aes_sync_deinit

Deinitialize AES Descriptor.

```
int32_t aes_sync_deinit(
    struct aes_sync_descriptor * desc
)
```

Parameters

desc	Type: struct 12.2.6.1 aes_sync_descriptor Struct * The AES descriptor to be deinitialized

Returns

Type: int32_t

12.2.7.3 aes_sync_enable

Enable AES.

```
int32_t aes_sync_enable(
    struct aes_sync_descriptor * desc
)
```

Parameters

desc	Type: struct 12.2.6.1 aes_sync_descriptor Struct * The AES descriptor

Returns

Type: int32_t

12.2.7.4 aes_sync_disable

Disable AES.

```
int32_t aes_sync_disable(
    struct aes_sync_descriptor * desc
)
```

Parameters

desc	Type: struct 12.2.6.1 aes_sync_descriptor Struct * The AES descriptor

Returns

Type: int32_t

12.2.7.5 aes_sync_set_encrypt_key

Set AES Key (encryption).

```
int32_t aes_sync_set_encrypt_key(
    struct aes_sync_descriptor * descr,
    const uint8_t * key,
    const enum aes_keysize size
)
```

Parameters

desc	The AES descriptor
key	Type: const uint8_t * Encryption key
size	Type: const enum aes_keysize Bit length of key

Returns

Type: int32_t

12.2.7.6 aes_sync_set_decrypt_key

Set AES Key (decryption).

```
int32_t aes_sync_set_decrypt_key(
    struct aes_sync_descriptor * descr,
    const uint8_t * key,
```

```
    const enum aes_keysize size
)
```

Parameters

desc	The AES descriptor
key	Type: const uint8_t * Decryption key
size	Type: const enum aes_keysize Bit length of key

Returns

Type: int32_t

12.2.7.7 aes_sync_ecb_crypt

AES-ECB block encryption/decryption.

```
int32_t aes_sync_ecb_crypt(
    struct aes_sync_descriptor * descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct * The AES descriptor
enc	Type: const enum aes_action AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t * 16-byte input data
output	Type: uint8_t * 16-byte output data

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.8 aes_sync_cbc_crypt

The AES-CBC block encryption/decryption length should be a multiple of 16 bytes.

```
int32_t aes_sync_cbc_crypt(
    struct aes_sync_descriptor * descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output,
```

```
    uint32_t length,
    uint8_t iv
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *
	The AES descriptor
enc	Type: const enum aes_action
	AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t *
	16-byte input data
output	Type: uint8_t *
	16-byte output data
length	Type: uint32_t
	Byte length of the input data
iv	Type: uint8_t
	Initialization vector (updated after use)

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.9 aes_sync_cfb128_crypt

AES-CFB128 block encryption/decryption.

```
int32_t aes_sync_cfb128_crypt(
    struct aes_sync_descriptor * descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    uint8_t * iv,
    uint32_t * iv_ofst
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *
	The AES descriptor
enc	Type: const enum aes_action
	AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t *

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	Buffer holding the input data
output	Type: uint8_t *
	Buffer holding the output data
length	Type: uint32_t
	Byte length of the input data
iv	Type: uint8_t *
	Initialization Vector (updated after use)
iv_ofst	Type: uint32_t *
	Offset in IV (updated after use)

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.10 aes_sync_cfb64_crypt

AES-CFB64 block encryption/decryption.

```
int32_t aes_sync_cfb64_crypt(
    struct aes_sync_descriptor * descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    uint8_t * iv,
    uint32_t * iv_ofst
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *
	The AES descriptor
enc	Type: const enum aes_action
	AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t *
	Buffer holding the input data
output	Type: uint8_t *
	Buffer holding the output data
length	Type: uint32_t
	Byte length of the input data
iv	Type: uint8_t *

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	Initialization Vector (updated after use)
iv_ofst	Type: uint32_t * Offset in IV (updated after use)

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.11 aes_sync_cfb32_crypt

AES-CFB32 block encryption/decryption.

```
int32_t aes_sync_cfb32_crypt(
    struct aes_sync_descriptor * descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    uint8_t * iv,
    uint32_t * iv_ofst
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct * The AES descriptor
enc	Type: const enum aes_action AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
length	Type: uint32_t Byte length of the input data
iv	Type: uint8_t * Initialization Vector (updated after use)
iv_ofst	Type: uint32_t * Offset in IV (updated after use)

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.12 aes_sync_cfb16_crypt

AES-CFB16 block encryption/decryption.

```
int32_t aes_sync_cfb16_crypt(
    struct aes_sync_descriptor * descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    uint8_t * iv,
    uint32_t * iv_ofst
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct * The AES descriptor
enc	Type: const enum aes_action AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
length	Type: uint32_t Byte length of the input data
iv	Type: uint8_t * Initialization Vector (updated after use)
iv_ofst	Type: uint32_t * Offset in IV (updated after use)

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.13 aes_sync_cfb8_crypt

AES-CFB8 block encryption/decryption.

```
int32_t aes_sync_cfb8_crypt(
    struct aes_sync_descriptor * descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    uint8_t * iv
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct * The AES descriptor
enc	Type: const enum aes_action AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
iv	Type: uint8_t * Initialization Vector (updated after use)

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.14 aes_sync_ofb_crypt

AES-OFB block encryption/decryption.

```
int32_t aes_sync_ofb_crypt(
    struct aes_sync_descriptor * descr,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    uint8_t * iv,
    uint32_t * iv_ofst
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct * The AES descriptor
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
length	Type: uint32_t Byte length of the input data
iv	Type: uint8_t * Initialization Vector (updated after use)

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iv_ofst Type: uint32_t *

Offset in IV (updated after use)

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.15 aes_sync_ctr_crypt

AES-CTR block encryption/decryption.

```
int32_t aes_sync_ctr_crypt(
    struct aes_sync_descriptor * descr,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    uint8_t buffer,
    uint8_t nc,
    uint32_t * nc_ofst
)
```

Parameters

descr Type: struct 12.2.6.1 aes_sync_descriptor Struct *

The AES descriptor

input Type: const uint8_t *

Buffer holding the input data

output Type: uint8_t *

Buffer holding the output data

length Type: uint32_t

Byte length of the input data

buffer Type: uint8_t

Stream block for resuming

nc Type: uint8_t

The 128-bit nonce and counter

nc_ofst Type: uint32_t *

The offset in the current stream_block (for resuming within current cipher stream). The offset pointer should be 0 at the start of a stream.

Returns

Type: int32_t

ERR_NONE if successful

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12.2.7.16 aes_sync_gcm_crypt_and_tag

AES-GCM block encryption/decryption.

```
int32_t aes_sync_gcm_crypt_and_tag(
    struct aes_sync_descriptor *const descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    const uint8_t * iv,
    uint32_t iv_len,
    const uint8_t * aad,
    uint32_t aad_len,
    uint8_t * tag,
    uint32_t tag_len
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *const The AES descriptor
enc	Type: const enum aes_action AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
length	Type: uint32_t Byte length of the input data
iv	Type: const uint8_t * Initialization Vector
iv_len	Type: uint32_t Length of IV
aad	Type: const uint8_t * Additional data
aad_len	Type: uint32_t Length of additional data
tag	Type: uint8_t * Buffer holding the input data
tag_len	Type: uint32_t Length of tag

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Returns

Type: int32_t

ERR_NONE if successful

12.2.7.17 aes_sync_gcm_auth_decrypt

AES-GCM block encryption.

```
int32_t aes_sync_gcm_auth_decrypt(
    struct aes_sync_descriptor *const descr,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    const uint8_t * iv,
    uint32_t iv_len,
    const uint8_t * aad,
    uint32_t aad_len,
    const uint8_t * tag,
    uint32_t tag_len
)
```

Parameters

desc	The AES descriptor
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
length	Type: uint32_t Byte length of the input data
iv	Type: const uint8_t * Initialization Vector
iv_len	Type: uint32_t Length of IV
aad	Type: const uint8_t * Additional data
aad_len	Type: uint32_t Length of additional data
tag	Type: const uint8_t * Buffer holding the input data
tag_len	Type: uint32_t Length of tag

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Returns

Type: int32_t

ERR_NONE if successful

12.2.7.18 aes_sync_gcm_start

AES-GCM block start.

```
int32_t aes_sync_gcm_start(
    struct aes_sync_descriptor *const descr,
    const enum aes_action enc,
    const uint8_t * iv,
    uint32_t iv_len,
    const uint8_t * aad,
    uint32_t aad_len
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *const The AES descriptor
enc	Type: const enum aes_action AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
iv	Type: const uint8_t * Initialization Vector
iv_len	Type: uint32_t Length of the IV
aad	Type: const uint8_t * Additional data
aad_len	Type: uint32_t Length of additional data

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.19 aes_sync_gcm_update

AES-GCM block update.

```
int32_t aes_sync_gcm_update(
    struct aes_sync_descriptor *const descr,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *const The AES descriptor
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
length	Type: uint32_t Byte length of the input data

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.20 aes_sync_gcm_finish

AES-GCM block finish.

```
int32_t aes_sync_gcm_finish(
    struct aes_sync_descriptor *const descr,
    uint8_t * tag,
    uint32_t tag_len
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *const The AES descriptor
tag	Type: uint8_t * Buffer holding the input data
tag_len	Type: uint32_t Length of tag

Returns

Type: int32_t

ERR_NONE if successful

12.2.7.21 aes_sync_ccm_crypt_and_tag

AES-CCM block encryption/decryption.

```
int32_t aes_sync_ccm_crypt_and_tag(
    struct aes_sync_descriptor *const descr,
    const enum aes_action enc,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
```

```
    const uint8_t * iv,
    uint32_t iv_len,
    const uint8_t * aad,
    uint32_t aad_len,
    uint8_t * tag,
    uint32_t tag_len
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *const The AES descriptor
enc	Type: const enum aes_action AES_SYNC_ENCRYPT or AES_SYNC_DECRYPT
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
length	Type: uint32_t Byte length of the input data
iv	Type: const uint8_t * Initialization Vector
iv_len	Type: uint32_t Length of IV
aad	Type: const uint8_t * Additional data
aad_len	Type: uint32_t Length of additional data
tag	Type: uint8_t * Buffer holding the input data
tag_len	Type: uint32_t Length of tag

Returns

Type: int32_t

ERR_NONE if successful

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12.2.7.22 aes_sync_ccm_auth_decrypt

AES-CCM block authenticated decryption.

```
int32_t aes_sync_ccm_auth_decrypt(
    struct aes_sync_descriptor *const descr,
    const uint8_t * input,
    uint8_t * output,
    uint32_t length,
    const uint8_t * iv,
    uint32_t iv_len,
    const uint8_t * aad,
    uint32_t aad_len,
    const uint8_t * tag,
    uint32_t tag_len
)
```

Parameters

descr	Type: struct 12.2.6.1 aes_sync_descriptor Struct *const The AES descriptor
input	Type: const uint8_t * Buffer holding the input data
output	Type: uint8_t * Buffer holding the output data
length	Type: uint32_t Byte length of the input data
iv	Type: const uint8_t * Initialization Vector
iv_len	Type: uint32_t Length of IV
aad	Type: const uint8_t * Additional data
aad_len	Type: uint32_t Length of additional data
tag	Type: const uint8_t * Buffer holding the input data
tag_len	Type: uint32_t Length of tag

Returns

Type: int32_t

ERR_NONE if successful

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12.2.7.23 aes_sync_get_version

Retrieve the current driver version.

```
uint32_t aes_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

13. DAC Drivers

This Digital-to-Analog Converter (DAC) driver provides an interface for the conversion of digital values to analog voltage.

The following driver variants are available:

- 13.4 DAC Synchronous Driver: The driver supports polling for hardware changes. The functionality is synchronous to the main clock of the MCU.
- 13.2 DAC Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.
- 13.3 DAC RTOS Driver: The driver is intended for using functions in a Real-Time operating system, i.e. is thread safe.

13.1 DAC Basics and Best Practice

A Digital-to-Analog Converter (DAC) converts a digital value to an analog voltage. The digital from 0 to the highest value represents the output voltage value. The highest digital value is possible with the bit resolution supported by the DAC. For example, for a 10-bit resolution DAC hardware, the highest value is 1024. The highest output voltage is possible with the reference voltage.

A common use of DAC is to generate audio signals by connecting the DAC output to a speaker, or to generate a reference voltage; either for an external circuit or an internal peripheral, such as the Analog Comparator.

13.2 DAC Asynchronous Driver

In the Digital-to-Analog Converter (DAC) asynchronous driver, the callback functions can be registered in the driver by the application and triggered when the DAC convention is done or an error happens.

13.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Hookup callback handlers on DAC conversion done or error
- Enable and disable DAC channel
- Write buffers with multiple digital data to DAC

13.2.2 Summary of Configuration Options

Below is a list of the main DAC parameters that can be configured in START. Many of these parameters are used by the 13.2.9.1 dac_async_init function when initializing the driver and underlying hardware.

- Select which DAC output signals are to be enabled
- Which clock source and prescaler the DAC uses
- Reference voltage selection
- Various aspects of Event control, such as "Start Conversion on Event Input"
- Run in Standby or Debug mode

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13.2.3 Driver Implementation Description

The driver can convert a serial digital value. The pre-defined data should be put in a data array. Application can invoke 13.2.9.6 dac_async_write to start the conversion, and get a notice by the registered callback function.

Implementation of 13.2.9.6 dac_async_write is based on the underlying DAC peripheral. Normally, there is a FIFO buffer for writing conversion data. Take SAM D21 for example, the Data Buffer register (DATABUF) and the Data register (DATA) are linked together to form a two-stage FIFO. The DAC uses the Start Conversion event to load data from DATABUF into DATA and start a new conversion. In the SAM D21 case, 13.2.9.6 dac_async_write will write data to the DATABUF register, so the Start Conversion event should be configured properly to use this asynchronous driver.

13.2.4 Example of Usage

The following shows a simple example of using the DAC. The DAC must have been initialized by 13.2.9.1 dac_async_init. This initialization will configure the operation of the DAC, such as reference voltage and Start Conversion Event Input, etc.

The example registers a callback function for conversion done and enables channel 0 of DAC0, and finally starts a D/A conversion to output a waveform.

Tip:
Normally it is also necessary to configure the Event system to trigger the DAC conversion. Take SAM D21 for example, the RTC period 0 event can be used to trigger loading data from DATABUF into DATA and start a new conversion in the DAC peripheral. These drivers are needed for this example, with some configurations in START:

- Calendar driver (RTC)
  - Select 32.768kHz as RTC clock input
  - Enable "Periodic Interval 0 Event Output"
- Event driver
  - Enable one event channel for DAC and configure it
  - Select "RTC period 0" as Event generator and choose Event channel for DAC
  - Select Event path "Asynchronous path"
- DAC
  - Enable "Start Conversion on Event Input"

```
        static uint16_t example_DAC_0[10] = {
            0, 100, 200, 300, 400,
            500, 600, 700, 800, 900
        };
static void tx_cb_DAC_0(struct dac_async_descriptor *const descr, const uin
t8_t ch)
        {
            dac_async_write(descr, 0, example_DAC_0, 10);
        }
        /**
         * Example of using DAC_0 to generate waveform.
         */
        void DAC_0_example(void)
        {
```

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```
            dac_async_enable_channel(&DAC_0, 0);

    dac_async_register_callback(&DAC_0, DAC_ASYNC_CONVERSION_DONE_CB, tx_cb
_DAC_0);
            dac_async_write(&DAC_0, 0, example_DAC_0, 10);
        }
```

13.2.5 Dependencies

- The DAC peripheral and its related I/O lines and clocks
- The NVIC must be configured so that DAC interrupt requests are periodically serviced
- The Event Driver
- The driver (e.g RTC) of Event generator, which is used to trigger DAC convention

13.2.6 Structs

13.2.6.1 dac_async_callbacks Struct

DAC callback handlers.

Members

conversion_done	Conversion done event handler
error	Error event handler

13.2.6.2 dac_async_channel Struct

DAC asynchronous channel descriptor.

Members

buffer	Pointer to buffer what to be converted
length	The length of the buffer

13.2.6.3 dac_async_descriptor Struct

DAC asynchronous descriptor.

Members

dac_cb	DAC callback handlers
device	DAC device
sel_ch	DAC channel handlers

13.2.7 Enums

13.2.7.1 dac_async_callback_type Enum

DAC_ASYNC_CONVERSION_DONE_CB	DAC conversion done
DAC_ASYNC_ERROR_CB	DAC conversion error

13.2.8 Typedefs

13.2.8.1 dac_async_cb_t typedef

typedef void(* dac_async_cb_t) (struct dac_async_descriptor *const descr, const uint8_t ch)

DAC callback type

Parameters

descr	Direction: in A DAC descriptor
ch	Direction: in DAC channel number

13.2.9 Functions

13.2.9.1 dac_async_init

Initialize the DAC HAL instance and hardware.

```
int32_t dac_async_init(
    struct dac_async_descriptor *const descr,
    void *const hw
)
```

Parameters

descr	Type: struct 13.2.6.3 dac_async_descriptor Struct *const A DAC descriptor to initialize
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Operation status.

13.2.9.2 dac_async_deinit

Deinitialize the DAC HAL instance and hardware.

```
int32_t dac_async_deinit(
    struct dac_async_descriptor *const descr
)
```

Parameters

descr	Type: struct 13.2.6.3 dac_async_descriptor Struct *const Pointer to the HAL DAC descriptor

Returns

Type: int32_t

Operation status.

13.2.9.3 dac_async_enable_channel

Enable DAC channel.

```
int32_t dac_async_enable_channel(
    struct dac_async_descriptor *const descr,
    const uint8_t ch
)
```

Parameters

descr Type: struct 13.2.6.3 dac_async_descriptor Struct *const

Pointer to the HAL DAC descriptor

ch Type: const uint8_t

channel number

Returns

Type: int32_t

Operation status.

13.2.9.4 dac_async_disable_channel

Disable DAC channel.

```
int32_t dac_async_disable_channel(
    struct dac_async_descriptor *const descr,
    const uint8_t ch
)
```

Parameters

descr Type: struct 13.2.6.3 dac_async_descriptor Struct *const

Pointer to the HAL DAC descriptor

ch Type: const uint8_t

Channel number

Returns

Type: int32_t

Operation status.

13.2.9.5 dac_async_register_callback

Register DAC callback.

```
int32_t dac_async_register_callback(
    struct dac_async_descriptor *const descr,
    const enum dac_async_callback_type type,
```

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```
    dac_async_cb_t cb
)
```

Parameters

descr	Type: struct 13.2.6.3 dac_async_descriptor Struct *const Pointer to the HAL DAC descriptor
type	Type: const enum 13.2.7.1 dac_async_callback_type Enum Interrupt source type
cb	Type: 13.2.8.1 dac_async_cb_t typedef A callback function, passing NULL de-registers callback

Returns

Type: int32_t

Operation status

0	Success
-1	Error

13.2.9.6 dac_async_write

DAC converts digital data to analog output.

```
int32_t dac_async_write(
    struct dac_async_descriptor *const descr,
    const uint8_t ch,
    uint16_t * buffer,
    uint32_t length
)
```

Parameters

descr	Type: struct 13.2.6.3 dac_async_descriptor Struct *const Pointer to the HAL DAC descriptor
ch	Type: const uint8_t The channel selected to output
buffer	Type: uint16_t * Pointer to digital data or buffer
length	Type: uint32_t The number of elements in buffer

Returns

Type: int32_t

Operation status.

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13.2.9.7 dac_async_get_version

Get DAC driver version.

```
uint32_t dac_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

13.3 DAC RTOS Driver

The convert functions of the Digital-to-Analog Converter (DAC) RTOS driver are optimized for RTOS support. That is, the convert functions will not work without RTOS, the convert functions should only be called in an RTOS task or thread.

13.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable and disable the DAC channel
- Write buffers with multiple digital data to DAC

13.3.2 Summary of Configuration Options

Below is a list of the main DAC parameters that can be configured in START. Many of these parameters are used by the 13.3.7.1 dac_os_init function when initializing the driver and underlying hardware.

- Select which DAC output signals to be enabled
- Which clock source and prescaler the DAC uses
- Reference voltage selection
- Various aspects of Event control, such as "Start conversion on Event Input"
- Run in Standby or Debug mode

13.3.3 Driver Implementation Description

The driver can convert a serial digital value. The pre-defined data should be put in a data array. The Application can invoke 13.3.7.5 dac_os_write to start the conversion (asyn mode). The task/thread will be blocked until the conversion is done.

During data conversion, the DAC convert process is not protected, so that a more flexible way can be chosen in the application.

13.3.4 Example of Usage

The following shows a simple example of using the DAC. The DAC must have been initialized by the 13.3.7.1 dac_os_init. This initialization will configure the operation of the DAC, such as reference voltage and Start Conversion Event Input, etc.

The example creates one convert task for channel 0 of DAC0 and finally starts the RTOS task scheduler.

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Tip:
Normally it is also necessary to configure the Event system to trigger the DAC conversion. See the example in 13.2 DAC Asynchronous Driver for reference.

```
        static uint16_t example_DAC_0[10] = {
            0, 100, 200, 300, 400,
            500, 600, 700, 800, 900
        };
        /**
         * Example task of using DAC_0 to generate waveform.
         */
        void DAC_0_example_task(void *p)
        {
            (void)p;
            dac_os_enable_channel(&DAC_0, 0);
            for(;;) {
                if (dac_os_write(&DAC_0, 0, example_DAC_0, 10) == 10) {
                    /* convert OK */;
                } else {
                    /* error. */;
                }
            }
        }
        #define TASK_DAC_CONVERT_STACK_SIZE        ( 256/
sizeof( portSTACK_TYPE ))
        #define TASK_DAC_CONVERT_PRIORITY          ( tskIDLE_PRIORITY + 1 )
        static TaskHandle_t xDacConvertTask;
        int main(void)
        {
            /* Initializes MCU, drivers and middleware */
            atmel_start_init();
            /* Create DAC convert task */

    if (xTaskCreate(DAC_0_example_task, "DAC convert", TASK_DAC_CONVERT_STA
CK_SIZE,
                            NULL,
                            TASK_DAC_CONVERT_PRIORITY, &xDacConvertTask) !
= pdPASS) {
                while (1) {
                    ;
                }
            }
            /*  Start RTOS scheduler */
            vTaskStartScheduler();
            /* Replace with your application code */
            while (1) {
            }
        }
```

13.3.5 Dependencies

- The DAC peripheral and its related I/O lines and clocks
- The NVIC must be configured so that DAC interrupt requests are periodically serviced
- RTOS

13.3.6 Structs

13.3.6.1 dac_os_channel Struct

DAC RTOS channel descriptor.

Members

buffer	
length	Pointer to buffer what to be converted

13.3.6.2 dac_os_descriptor Struct

DAC RTOS descriptor.

Members

device	
sel_ch	DAC device
tx_sem	DAC channel handlers
error	DAC channel write data semaphore

13.3.7 Functions

13.3.7.1 dac_os_init

Initialize the DAC HAL instance and hardware.

```
int32_t dac_os_init(
    struct dac_os_descriptor *const descr,
    void *const hw
)
```

Parameters

descr	Type: struct 13.3.6.2 dac_os_descriptor Struct *const A DAC descriptor to initialize
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Operation status.

<0	The passed parameters were invalid or a DAC is already initialized
ERR_NONE	The initialization has completed successfully

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13.3.7.2 dac_os_deinit

Deinitialize the DAC HAL instance and hardware.

```
int32_t dac_os_deinit(
    struct dac_os_descriptor *const descr
)
```

Parameters

descr Type: struct 13.3.6.2 dac_os_descriptor Struct *const

Pointer to the HAL DAC descriptor

Returns

Type: int32_t

ERR_NONE

13.3.7.3 dac_os_enable_channel

Enable DAC channel.

```
int32_t dac_os_enable_channel(
    struct dac_os_descriptor *const descr,
    const uint8_t ch
)
```

Parameters

descr Type: struct 13.3.6.2 dac_os_descriptor Struct *const

Pointer to the HAL DAC descriptor

ch Type: const uint8_t

Channel number

Returns

Type: int32_t

ERR_NONE

13.3.7.4 dac_os_disable_channel

Disable DAC channel.

```
int32_t dac_os_disable_channel(
    struct dac_os_descriptor *const descr,
    const uint8_t ch
)
```

Parameters

descr Type: struct 13.3.6.2 dac_os_descriptor Struct *const

Pointer to the HAL DAC descriptor

ch Type: const uint8_t

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Channel number

Returns
Type: int32_t

ERR_NONE

13.3.7.5 dac_os_write

The DAC convert digital data to analog output.

```
int32_t dac_os_write(
    struct dac_os_descriptor *const descr,
    const uint8_t ch,
    uint16_t * buffer,
    uint32_t length
)
```

It blocks the task/thread until the conversation is done. The buffer sample should be 16-bit wide. 8-bit data will not be supported. You must convert to 16-bit if there are 8-bit samples.

Parameters

descr	Type: struct 13.3.6.2 dac_os_descriptor Struct *const Pointer to the HAL DAC descriptor
ch	Type: const uint8_t The channel selected to output
buffer	Type: uint16_t * Pointer to digital data or buffer
length	Type: uint32_t The number of elements in buffer

Returns
Type: int32_t

Operation status.

<0	Error code
length	Convert success

13.3.7.6 dac_os_get_version

Get DAC driver version.

```
uint32_t dac_os_get_version(
    void
)
```

Returns
Type: uint32_t

Current driver version.

13.4 DAC Synchronous Driver

The functions in Digital-to-Analog Converter (DAC) synchronous driver will block (i.e. not return) until the operation is done.

The 13.4.7.5 dac_sync_write function will perform a conversion of digital value to analog voltage and return the result when it is ready.

13.4.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable and disable the DAC channel
- Write buffers with multiple digital data to DAC

13.4.2 Summary of Configuration Options

Below is a list of the main DAC parameters that can be configured in START. Many of these parameters are used by the 13.4.7.1 dac_sync_init function when initializing the driver and underlying hardware.

- Select which DAC output signals to be enabled
- Which clock source and prescaler the DAC uses
- Reference voltage selection
- Run in Standby or Debug mode

13.4.3 Driver Implementation Description

In DAC synchronous driver, new digital values will be written directly to the DAC hardware and returned when all digital data has been converted.

13.4.4 Example of Usage

The following shows a simple example of using the DAC. The DAC must have been initialized by 13.4.7.1 dac_sync_init. This initialization will configure the operation of the DAC, such as reference voltage, etc.

The example enables channel 0 of DAC0, and finally starts a D/A conversion to output a waveform.

```
/**
 * Example of using DAC_0 to generate waveform.
 */
void DAC_0_example(void)
{
    uint16_t i = 0;
    dac_sync_enable_channel(&DAC_0, 0);
    for(;;) {
        dac_sync_write(&DAC_0, 0, &i, 1);
        i = (i+1) % 1024;
    }
}
```

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13.4.5 Dependencies

- The DAC peripheral and its related I/O lines and clocks

13.4.6 Structs

13.4.6.1 dac_sync_channel Struct

DAC synchronous channel descriptor.

Members

buffer	Pointer to buffer what to be converted
length	The length of buffer

13.4.6.2 dac_sync_descriptor Struct

DAC synchronous descriptor.

Members

device	DAC device
sel_ch	DAC selected channel

13.4.7 Functions

13.4.7.1 dac_sync_init

Initialize the DAC HAL instance and hardware.

```
int32_t dac_sync_init(
    struct dac_sync_descriptor *const descr,
    void *const hw
)
```

Parameters

descr	Type: struct 13.4.6.2 dac_sync_descriptor Struct *const A DAC descriptor to initialize
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Operation status.

13.4.7.2 dac_sync_deinit

Deinitialize the DAC HAL instance and hardware.

```
int32_t dac_sync_deinit(
    struct dac_sync_descriptor *const descr
)
```

Parameters

descr	Type: struct 13.4.6.2 dac_sync_descriptor Struct *const Pointer to the HAL DAC descriptor

Returns

Type: int32_t

Operation status.

13.4.7.3 dac_sync_enable_channel

Enable DAC channel.

```
int32_t dac_sync_enable_channel(
    struct dac_sync_descriptor *const descr,
    const uint8_t ch
)
```

Parameters

descr	Type: struct 13.4.6.2 dac_sync_descriptor Struct *const Pointer to the HAL DAC descriptor
ch	Type: const uint8_t Channel number

Returns

Type: int32_t

Operation status.

13.4.7.4 dac_sync_disable_channel

Disable DAC channel.

```
int32_t dac_sync_disable_channel(
    struct dac_sync_descriptor *const descr,
    const uint8_t ch
)
```

Parameters

descr	Type: struct 13.4.6.2 dac_sync_descriptor Struct *const Pointer to the HAL DAC descriptor
ch	Type: const uint8_t Channel number

Returns

Type: int32_t

Operation status.

13.4.7.5 dac_sync_write

DAC converts digital data to analog output.

```
int32_t dac_sync_write(
    struct dac_sync_descriptor *const descr,
    const uint8_t ch,
    uint16_t * buffer,
    uint32_t length
)
```

Parameters

descr	Type: struct 13.4.6.2 dac_sync_descriptor Struct *const Pointer to the HAL DAC descriptor
ch	Type: const uint8_t the Channel selected to output
buffer	Type: uint16_t * Pointer to digital data or buffer
length	Type: uint32_t The number of elements in the buffer

Returns

Type: int32_t

Operation status.

13.4.7.6 dac_sync_get_version

Get DAC driver version.

```
uint32_t dac_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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14. Delay Driver

This Delay driver provides an interface for basic delay functions for applications requiring a brief wait during execution.

14.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize the Delay driver and associated hardware
- Delay for the given amount of microseconds
- Delay for the given amount of milliseconds

14.2 Summary of Configuration Options

No configuration is needed in START.

14.3 Driver Implementation Description

The driver will first calculate the amount of cycles to delay for the given time according to the system clock, then use Systick to delay these cycles.

14.4 Example of Usage

The following shows a simple example of using the delay function. The delay driver must have been initialized by 14.6.1 delay_init. This initialization will configure the operation of the SysTick.

```
void delay_example(void)
{
    delay_ms(5000);
}
```

14.5 Dependencies

- SysTick

14.6 Functions

14.6.1 delay_init

Initialize Delay driver.

```
void delay_init(
    void *const hw
)
```

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Parameters

hw	Type: void *const The pointer to hardware instance

Returns
Type: void

14.6.2 delay_us

Perform delay in us.

```
void delay_us(
    const uint16_t us
)
```

This function performs delay for the given amount of microseconds.

Parameters

us	Type: const uint16_t The amount delay in us

Returns
Type: void

14.6.3 delay_ms

Perform delay in ms.

```
void delay_ms(
    const uint16_t ms
)
```

This function performs delay for the given amount of milliseconds.

Parameters

ms	Type: const uint16_t The amount delay in ms

Returns
Type: void

14.6.4 delay_get_version

Retrieve the current driver version.

```
uint32_t delay_get_version(
    void
)
```

Returns
Type: uint32_t

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Current driver version.

15. Digital Glue Logic

This custom logic driver offers a way to initialize on-chip programmable logic units, so that a specific logic box is built. Then this "box" can be connected to an internal or external circuit to perform the logic operations.

15.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enabling and disabling digital glue logic

15.2 Summary of Configuration Options

Most custom logic parameters are configured in START. Many of these parameters are used by the 15.6.1 custom_logic_init function when initializing the driver and underlying hardware (for example, CCL).

15.3 Driver Implementation Description

The implementation is simple in this driver and most custom logic parameters are static configuration.

15.4 Example of Usage

The following shows a simple example of using the custom logic driver. The custom logic driver must have been initialized by 15.6.1 custom_logic_init. This initialization will configure the operation of the hardware programmable logic instance.

```
/**
 * Example of using DIGITAL_GLUE_LOGIC_0.
 */
void DIGITAL_GLUE_LOGIC_0_example(void)
{
    custom_logic_enable();
    /* Customer logic now works. */
}
```

15.5 Dependencies

- Programmable logic control units, such as Configurable Custom Logic (CCL)

15.6 Functions

15.6.1 custom_logic_init

Initialize the custom logic hardware.

```
static int32_t custom_logic_init(
    void
)
```

Returns

Type: int32_t

Initialization operation status

15.6.2 custom_logic_deinit

Disable and reset the custom logic hardware.

```
static void custom_logic_deinit(
    void
)
```

Returns

Type: void

15.6.3 custom_logic_enable

Enable the custom logic hardware.

```
static int32_t custom_logic_enable(
    void
)
```

Returns

Type: int32_t

Initialization operation status

15.6.4 custom_logic_disable

Disable the custom logic hardware.

```
static void custom_logic_disable(
    void
)
```

Returns

Type: void

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16. Ethernet MAC Driver

The Ethernet MAC driver implements a 10/100 Mbps Ethernet MAC compatible with the IEEE 802.3 standard.

16.1 Ethernet Asynchronous Driver

The Ethernet MAC driver implements a 10/100 Mbps Ethernet MAC compatible with the IEEE 802.3 standard. It co-works with the thirdparty TCP/IP stacks. E.g., Lwip, Cyclone IP stack.

16.1.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enabling/disabling
- Data transfer: transmission, reception
- Enabling/disabling Interrupt
- Notifications about transfer completion and frame received via callbacks
- Address Filter for Specific 48-bit Addresses and Type ID
- Address Filter for unicast and multicast Addresses
- Reading/writing PHY registers

16.1.2 Dependencies

- MAC capable hardware compatible with the IEEE 802.3 standard

16.1.3 Structs

16.1.3.1 mac_async_callbacks Struct

MAC callbacks.

Members

receive

transmit

16.1.3.2 mac_async_descriptor Struct

MAC descriptor.

Members

dev	MAC HPL device descriptor
cb	MAC Callback handlers

16.1.4 Typedefs

16.1.4.1 mac_async_cb_t typedef

typedef void(* mac_async_cb_t) (struct mac_async_descriptor *const descr)

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MAC callback type.

Parameters

descr	Direction: in A MAC descriptor

16.1.4.2 mac_cb typedef

typedef void(* mac_cb) (struct mac_async_descriptor *const descr)

16.1.5 Functions

16.1.5.1 mac_async_init

Initialize the MAC driver.

```
int32_t mac_async_init(
    struct mac_async_descriptor *const descr,
    void *const dev
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const A MAC descriptor to init.
hw	Hardware instance pointer.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.2 mac_async_deinit

Deinitialize the MAC driver.

```
int32_t mac_async_deinit(
    struct mac_async_descriptor *const descr
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const A MAC descriptor to deinitialize.

Returns

Type: int32_t

Operation status.

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ERR_NONE	Success.

16.1.5.3 mac_async_enable

Enable the MAC.

```
int32_t mac_async_enable(
    struct mac_async_descriptor *const descr
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.4 mac_async_disable

Disable the MAC.

```
int32_t mac_async_disable(
    struct mac_async_descriptor *const descr
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.5 mac_async_write

Write raw data to MAC.

```
int32_t mac_async_write(
    struct mac_async_descriptor *const descr,
    uint8_t * buf,
    uint32_t len
)
```

Write the raw data to the MAC that will be transmitted

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Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor.
buf	Type: uint8_t * Pointer to the data buffer.
len	Type: uint32_t Length of the data buffer.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.6 mac_async_read

Read raw data from MAC.

```
uint32_t mac_async_read(
    struct mac_async_descriptor *const descr,
    uint8_t * buf,
    uint32_t len
)
```

Read received raw data from MAC

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor.
buffer	Pointer to the data buffer. If the pointer is NULL, then the frame will be discarded.
length	The max. length of the data buffer to be read. If the length is zero, then the frame will be discard

Returns

Type: uint32_t

Number of bytes that received

16.1.5.7 mac_async_read_len

Get next valid package length.

```
uint32_t mac_async_read_len(
    struct mac_async_descriptor *const descr
)
```

Get next valid package length from the MAC. The application can use this function to fetch the length of the next package, malloc a buffer with this length, and then invoke mac_async_read to read out the package data.

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor.

Returns

Type: uint32_t

The number of bytes in the next package that can be read.

16.1.5.8 mac_async_enable_irq

Enable the MAC IRQ.

```
void mac_async_enable_irq(
    struct mac_async_descriptor *const descr
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor

Returns

Type: void

16.1.5.9 mac_async_disable_irq

Disable the MAC IRQ.

```
void mac_async_disable_irq(
    struct mac_async_descriptor *const descr
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor

Returns

Type: void

16.1.5.10 mac_async_register_callback

Register the MAC callback function.

```
int32_t mac_async_register_callback(
    struct mac_async_descriptor *const descr,
    const enum mac_async_cb_type type,
    const FUNC_PTR func
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const

Pointer to the HAL MAC descriptor.

type Type: const enum mac_async_cb_type

Callback function type.

func Type: const 40.3.2.1 FUNC_PTR typedef

A callback function. Passing NULL will de-register any registered callback.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.11 mac_async_set_filter

Set MAC filter.

```
int32_t mac_async_set_filter(
    struct mac_async_descriptor *const descr,
    uint8_t index,
    struct mac_async_filter * filter
)
```

Set MAC filter. Ethernet frames matching the filter, will be received.

Parameters

descr Type: struct 16.1.3.2 mac_async_descriptor Struct *const

Pointer to the HAL MAC descriptor.

index Type: uint8_t

MAC filter index. Start from 0. The maximum value depends on the hardware specifications.

filter Type: struct mac_async_filter *

Pointer to the filter descriptor.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.12 mac_async_set_filter_ex

Set MAC filter (expanded).

```
int32_t mac_async_set_filter_ex(
    struct mac_async_descriptor *const descr,
    uint8_t mac
)
```

Set MAC filter. The Ethernet frames matching the filter, will be received.

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Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor
mac	Type: uint8_t MAC address

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.13 mac_async_write_phy_reg

Write PHY register.

```
int32_t mac_async_write_phy_reg(
    struct mac_async_descriptor *const descr,
    uint16_t addr,
    uint16_t reg,
    uint16_t val
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor.
addr	Type: uint16_t PHY address.
reg	Type: uint16_t Register address.
val	Type: uint16_t Register value.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.14 mac_async_read_phy_reg

Read PHY register.

```
int32_t mac_async_read_phy_reg(
    struct mac_async_descriptor *const descr,
    uint16_t addr,
```

```
    uint16_t reg,
    uint16_t * val
)
```

Parameters

descr	Type: struct 16.1.3.2 mac_async_descriptor Struct *const Pointer to the HAL MAC descriptor.
addr	Type: uint16_t PHY address.
reg	Type: uint16_t Register address.
val	Type: uint16_t * Register value.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.

16.1.5.15 mac_async_get_version

Get the MAC driver version.

```
uint32_t mac_async_get_version(
    void
)
```

Returns

Type: uint32_t

17. Event System Driver

The Event system driver allows to configure the event system of an MCU.

17.1 Event System Basics and Best Practice

The Event system allows autonomous, low-latency, and configurable communication between peripherals.

Communication is made without CPU intervention and without consuming system resources such as bus or RAM bandwidth. This reduces the load on the CPU and system resources, compared to a traditional interrupt-based system.

The Event system consists of several channels, which route the internal events from generators to users. Each event generator can be selected as source for multiple channels, but a channel cannot be set to use multiple event generators at the same time.

Several peripherals can be configured to generate and/or respond to signals known as events. The exact condition to generate an event, or the action taken upon receiving an event, is specific to each peripheral. Peripherals that respond to events are event users, peripherals that generate events are called event generators. A peripheral can have one or more event generators and can have one or more event users.

17.1.1 Event Channels

The Event module in each device consists of several channels, which can be freely linked to an event generator (i.e. a peripheral within the device that is capable of generating events). Each channel can be individually configured to select the generator peripheral, signal path, and edge detection applied to the input event signal, before being passed to any event user(s).

Event channels can support multiple users within the device in a standardized manner. When an Event User is linked to an Event Channel, the channel will automatically handshake with all attached users to ensure that all modules correctly receive and acknowledge the event.

17.1.2 Event Users

Event Users are able to subscribe to an Event Channel, once it has been configured. Each Event User consists of a fixed connection to one of the peripherals within the device (for example, an ADC module, or Timer module) and is capable of being connected to a single Event Channel.

17.2 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable and disable the generator and user for a given channel

17.3 Summary of Configuration Options

Below is a list of the main Event parameters that can be configured in START. All of these are used by the 17.7.1 event_system_init function when initializing the driver and underlying hardware.

- Select clock source for each Event channel
- Select Event parameters for each channel

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  - Edge detection
  - Path selection
  - Event generator
  - Interrupt setting for Event, etc.
- Event channel selection for peripheral users

17.4 Driver Implementation Description

All Event configuration is static and configured in START. Event API functions can be used to enable or disable a specific generator or user for a given channel.

17.5 Example of Usage

Refer example in 13.2 DAC Asynchronous Driver of using the RTC period 0 event to trigger DAC convention.

17.6 Dependencies

- Event peripheral and its related clocks
- Related peripheral generator and user, such as RTC, ADC, DAC, etc.

17.7 Functions

17.7.1 event_system_init

Initialize event system.

```
int32_t event_system_init(
    void
)
```

Returns

Type: int32_t

Initialization status.

17.7.2 event_system_deinit

Deinitialize event system.

```
int32_t event_system_deinit(
    void
)
```

Returns

Type: int32_t

De-initialization status.

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17.7.3 event_system_enable_user

Enable event reception by the given user from the given channel.

```
int32_t event_system_enable_user(
    const uint16_t user,
    const uint16_t channel
)
```

Parameters

user	Type: const uint16_t A user to enable
channel	Type: const uint16_t A channel the user is assigned to

Returns

Type: int32_t

Status of operation.

17.7.4 event_system_disable_user

Disable event reception by the given user from the given channel.

```
int32_t event_system_disable_user(
    const uint16_t user,
    const uint16_t channel
)
```

Parameters

user	Type: const uint16_t A user to disable
channel	Type: const uint16_t A channel the user is assigned to

Returns

Type: int32_t

Status of operation.

17.7.5 event_system_enable_generator

Enable event generation by the given generator for the given channel.

```
int32_t event_system_enable_generator(
    const uint16_t generator,
    const uint16_t channel
)
```

Parameters

generator	Type: const uint16_t A generator to disable
channel	Type: const uint16_t A channel the generator is assigned to

Returns

Type: int32_t

Status of operation.

17.7.6 event_system_disable_generator

Disable event generation by the given generator for the given channel.

```
int32_t event_system_disable_generator(
    const uint16_t generator,
    const uint16_t channel
)
```

Parameters

generator	Type: const uint16_t A generator to disable
channel	Type: const uint16_t A channel the generator is assigned to

Returns

Type: int32_t

Status of operation.

17.7.7 event_system_get_version

Retrieve the current driver version.

```
uint32_t event_system_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

18. External Bus Driver

The External Bus Interface (EBI) connects external memory and peripheral devices such as static memory and SDRAM, so that they can be accessed via reading or writing to their address spaces.

18.1 Summary of the API's Functional Features

No special API is provided for this driver, just accessing the external memory via their address space.

The configured EBI parameters in Atmel START are automatically initialized via atmel_start_init() in main.c.

18.2 Summary of Configuration Options

Depend on device, all EBI parameters can be configured in START, such as pin signals, chip select, and bus timing etc.

18.3 Example of Usage

The following shows a simple example of access external memory. The EBI parameters must be configured correctly according to hardware in START. The EBI driver must have been initialized by atmel_start_init(). This initialization will configure the operation of the hardware EBI instance.

```
/** Memory base address for EBI access example */
#warning no external memory enabled, please check!
static uint32_t MEM_BASE[1];
/*
 * Example of accessing external bus memory
 */
void EXTERNAL_BUS_0_example(void)
{
    volatile uint32_t *pu32 = (uint32_t *)MEM_BASE;
    volatile uint16_t *pu16 = (uint16_t *)MEM_BASE;
    volatile uint8_t * pu8  = (uint8_t *)MEM_BASE;
    /* Backup one WORD */
    uint32_t bak = _ext_bus_read_u32((void *)pu32);
    /* Write and verify BYTE */
     *pu8 = 0xAA;
    if (*pu8 != 0xAA) {
        /* Error ! */
        while (1)
            ;
    }
     *pu8 = 0x55;
    if (*pu8 != 0x55) {
        /* Error ! */
        while (1)
            ;
    }
    /* Write and verify HALF WORD */
     *pu16 = 0xAAAA;
    if (*pu16 != 0xAAAA) {
        /* Error ! */
        while (1)
```

```
                ;
        }
         *pu16 = 0x5555;
        if (*pu16 != 0x5555) {
            /* Error ! */
            while (1)
                ;
        }
        /* Write and verify WORD */
         *pu32 = 0xAAAA5555;
        if (*pu32 != 0xAAAA5555) {
            /* Error ! */
            while (1)
                ;
        }
         *pu32 = 0x5A5A55AA;
        if (*pu32 != 0x5A5A55AA) {
            /* Error ! */
            while (1)
                ;
        }
        /* Restore one WORD */
        _ext_bus_write_u32((void *)pu32, bak);
    }
```

18.4 Dependencies

- External bus interface

19. External IRQ Driver

The External Interrupt driver allows external pins to be configured as interrupt lines. Each interrupt line can be individually masked and generate an interrupt on rising, falling, or both edges, or on high or low levels. Some of the external pins can also be configured to wake up the device from sleep modes where all clocks have been disabled.

19.1 External IRQ Basics and Best Practice

The driver can be used for such application:

- Generate an interrupt on rising, falling or both edges, or on high or low levels

19.2 Summary of the API's Functional Features

- Initialize and deinitialize the driver and associated hardware
- Hookup callback handler on external pin interrupt
- Enable or disable interrupt on external pin

19.3 Summary of Configuration Options

Below is a list of the main External Interrupt parameters that can be configured in START. Many of these parameters are used by the 19.7.1 ext_irq_init function when initializing the driver and underlying hardware.

- Select external pin signal for each interrupt line
- Select interrupt detection type for a pin (rising, falling, or both edges etc.)
- Select if pin interrupt will wake up the device

19.4 Example of Usage

The following shows a simple example of registering a callback on an external pin interrupt.

The External Interrupt driver must have been initialized by 19.7.1 ext_irq_init. This initialization will configure the operation of the hardware External Interrupt instance.

```
static void button_on_PA16_pressed(void)
{
}
/**
 * Example of using EXTERNAL_IRQ_0
 */
void EXTERNAL_IRQ_0_example(void)
{
    ext_irq_register(PIN_PA16, button_on_PA16_pressed);
}
```

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19.5 Dependencies

- External Interrupt Controller and its related I/O lines and clocks

19.6 Typedefs

19.6.1 ext_irq_cb_t typedef

typedef void(* ext_irq_cb_t) (void)

External IRQ callback type.

19.7 Functions

19.7.1 ext_irq_init

Initialize external IRQ component, if any.

```
int32_t ext_irq_init(
    void
)
```

Returns

Type: int32_t

Initialization status.

-1 External IRQ module is already initialized

0 The initialization is completed successfully

19.7.2 ext_irq_deinit

Deinitialize external IRQ, if any.

```
int32_t ext_irq_deinit(
    void
)
```

Returns

Type: int32_t

De-initialization status.

-1 External IRQ module is already deinitialized

0 The de-initialization is completed successfully

19.7.3 ext_irq_register

Register callback for the given external interrupt.

```
int32_t ext_irq_register(
    const uint32_t pin,
    ext_irq_cb_t cb
)
```

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Parameters

pin	Type: const uint32_t Pin to enable external IRQ on
cb	Type: 19.6.1 ext_irq_cb_t typedef Callback function

Returns

Type: int32_t

Registration status.

-1	Passed parameters were invalid
0	The callback registration is completed successfully

19.7.4 ext_irq_enable

Enable external IRQ.

```
int32_t ext_irq_enable(
    const uint32_t pin
)
```

Parameters

pin	Type: const uint32_t Pin to enable external IRQ on

Returns

Type: int32_t

Enabling status.

-1	Passed parameters were invalid
0	The enabling is completed successfully

19.7.5 ext_irq_disable

Disable external IRQ.

```
int32_t ext_irq_disable(
    const uint32_t pin
)
```

Parameters

pin	Type: const uint32_t Pin to enable external IRQ on

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Returns

Type: int32_t

Disabling status.

-1	Passed parameters were invalid
0	The disabling is completed successfully

19.7.6 ext_irq_get_version

Retrieve the current driver version.

```
uint32_t ext_irq_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

20. Flash Driver

Flash is a re-programmable memory that retains program and data storage even with the power off.

The user can write or read several bytes from any valid address in a flash.

20.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Writing/Reading bytes
- Locking/Unlocking/Erasing pages
- Get page size and total pages information
- Notifications about errors or being ready for a new command

20.2 Summary of Configuration Options

Depend on device, few flash parameters can be configured in START.

20.3 Driver Implementation Description

As to the erase/lock/unlock command, the input parameter of an address should be a byte address aligned with the page start, otherwise, the command will fail to be executed. At the meantime, the number of pages that can be locked or unlocked at once depends on the region size of the flash. The user can get the real number from the function return value, which can be different for the different devices.

20.4 Example of Usage

The following shows a simple example of using the Flash. The Flash driver must have been initialized by 20.9.1 flash_init. This initialization will configure the operation of the hardware Flash instance.

The example writes one page size of data into flash and read it back.

```
static uint8_t src_data[128];
static uint8_t chk_data[128];
/**
 * Example of using FLASH_0 to read and write buffer.
 */
void FLASH_0_example(void)
{
    uint32_t page_size;
    uint16_t i;
    /* Init source data */
    page_size = flash_get_page_size(&FLASH_0);
    for (i = 0; i < page_size; i++) {
        src_data[i] = i;
    }
    /* Write data to flash */
    flash_write(&FLASH_0, 0x3200, src_data, page_size);
    /* Read data from flash */
    flash_read(&FLASH_0, 0x3200, chk_data, page_size);
```

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```
        }
```

20.5 Dependencies

- Non-Volatile Memory (NVM) peripheral and clocks

20.6 Structs

20.6.1 flash_callbacks Struct

FLASH HAL callbacks.

Members

cb_ready	Callback invoked when ready to accept a new command
cb_error	Callback invoked when error occurs

20.6.2 flash_descriptor Struct

FLASH HAL driver struct for asynchronous access.

Members

dev	Pointer to FLASH device instance
callbacks	Callbacks for asynchronous transfer

20.7 Enums

20.7.1 flash_cb_type Enum

FLASH_CB_READY	Callback type for ready to accept a new command
FLASH_CB_ERROR	Callback type for error
FLASH_CB_N	

20.8 Typedefs

20.8.1 flash_cb_t typedef

typedef void(* flash_cb_t) (struct flash_descriptor *const descr)

Prototype of callback on FLASH.

20.9 Functions

20.9.1 flash_init

Initialize the FLASH HAL instance and hardware for callback mode.

```
int32_t flash_init(
    struct flash_descriptor * flash,
    void *const hw
)
```

Initialize FLASH HAL with interrupt mode (uses callbacks).

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance.
hw	Type: void *const Pointer to the hardware base.

Returns

Type: int32_t

Initialize status.

20.9.2 flash_deinit

Deinitialize the FLASH HAL instance.

```
int32_t flash_deinit(
    struct flash_descriptor * flash
)
```

Abort transfer, disable and reset FLASH, and deinitialize software.

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance.

Returns

Type: int32_t

Deinitialze status.

20.9.3 flash_write

Writes a number of bytes to a page in the internal Flash.

```
int32_t flash_write(
    struct flash_descriptor * flash,
    uint32_t dst_addr,
    uint8_t * buffer,
    uint32_t length
)
```

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Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance.
dst_addr	Type: uint32_t Destination bytes address to write into flash
buffer	Type: uint8_t * Pointer to a buffer where the content will be written to the flash
length	Type: uint32_t Number of bytes to write

Returns

Type: int32_t

Write status.

20.9.4 flash_append

Appends a number of bytes to a page in the internal Flash.

```
int32_t flash_append(
    struct flash_descriptor * flash,
    uint32_t dst_addr,
    uint8_t * buffer,
    uint32_t length
)
```

This functions never erases the flash before writing.

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance.
dst_addr	Type: uint32_t Destination bytes address to write to flash
buffer	Type: uint8_t * Pointer to a buffer with data to write to flash
length	Type: uint32_t Number of bytes to append

Returns

Type: int32_t

Append status.

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20.9.5 flash_read

Reads a number of bytes to a page in the internal Flash.

```
int32_t flash_read(
    struct flash_descriptor * flash,
    uint32_t src_addr,
    uint8_t * buffer,
    uint32_t length
)
```

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct *
	Pointer to the HAL FLASH instance.
src_addr	Type: uint32_t
	Source bytes address to read from flash
buffer	Type: uint8_t *
	Pointer to a buffer where the content of the read pages will be stored
length	Type: uint32_t
	Number of bytes to read

Returns

Type: int32_t

Read status.

20.9.6 flash_register_callback

Register a function as FLASH transfer completion callback.

```
int32_t flash_register_callback(
    struct flash_descriptor * flash,
    const enum flash_cb_type type,
    flash_cb_t func
)
```

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct *
	Pointer to the HAL FLASH instance.
type	Type: const enum 20.7.1 flash_cb_type Enum
	Callback type (20.7.1 flash_cb_type Enum).
func	Type: 20.8.1 flash_cb_t typedef
	Pointer to callback function.

Returns

Type: int32_t

0	Success
-1	Error

20.9.7 flash_lock

Execute lock in the internal flash.

```
int32_t flash_lock(
    struct flash_descriptor * flash,
    const uint32_t dst_addr,
    const uint32_t page_nums
)
```

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance.
dst_addr	Type: const uint32_t Destination bytes address aligned with page start to be locked
page_nums	Type: const uint32_t Number of pages to be locked

Returns

Type: int32_t

Real locked numbers of pages.

20.9.8 flash_unlock

Execute unlock in the internal flash.

```
int32_t flash_unlock(
    struct flash_descriptor * flash,
    const uint32_t dst_addr,
    const uint32_t page_nums
)
```

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance.
dst_addr	Type: const uint32_t Destination bytes address aligned with page start to be unlocked
page_nums	Type: const uint32_t Number of pages to be unlocked

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Returns

Type: int32_t

Real unlocked numbers of pages.

20.9.9 flash_erase

Execute erase in the internal flash.

```
int32_t flash_erase(
    struct flash_descriptor * flash,
    const uint32_t dst_addr,
    const uint32_t page_nums
)
```

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance.
dst_addr	Type: const uint32_t Destination bytes address aligned with page start to be erased
page_nums	Type: const uint32_t Number of pages to be erased

Returns

Type: int32_t

0	Success
-1	Error

20.9.10 flash_get_page_size

Get the flash page size.

```
uint32_t flash_get_page_size(
    struct flash_descriptor * flash
)
```

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance

Returns

Type: uint32_t

The flash page size

20.9.11 flash_get_total_pages

Get the number of flash page.

```
uint32_t flash_get_total_pages(
    struct flash_descriptor * flash
)
```

Parameters

flash	Type: struct 20.6.2 flash_descriptor Struct * Pointer to the HAL FLASH instance.

Returns

Type: uint32_t

The flash total page numbers

20.9.12 flash_get_version

Retrieve the current driver version.

```
uint32_t flash_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

21. Frequency Meter Drivers

This Frequency Meter (FREQM) driver provides an interface for measure the frequency of a clock by comparing it to a known reference clock.

The following driver variants are available:

- 21.3 Frequency Meter Synchronous Driver: The driver supports polling for hardware changes, functionality is synchronous to the main clock of the MCU.
- 21.2 Frequency Meter Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. Functionality is asynchronous to the main clock of the MCU.

21.1 Frequency Meter Basics and Best Practice

The Frequency Meter driver provides means to measure the frequency or the period of the input clock signal.

The driver uses a direct method of frequency measurement, that means it counts the amount of low-to-high transitions in the input signal during a period of time. The lower the measured frequency, the longer the measurement period should be for higher accuracy.

21.2 Frequency Meter Asynchronous Driver

In Frequency Meter (FREQM) asynchronous driver, a callback function can be registered in the driver by the application and triggered when measurement is done to let the application know the result.

21.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable Frequency Meter
- Set measurement parameter (measure period, frequency or period measurement)
- Hookup callback handlers on frequency measurement done
- Start frequency measurement

21.2.2 Summary of Configuration Options

Below is a list of the main FREQM parameters that can be configured in START. Many of these parameters are used by the 21.2.9.1 freqmeter_async_init function when initializing the driver and underlying hardware.

- Clock to be measured
- Reference clock
- Number of reference clock cycles (measure period)

21.2.3 Driver Implementation Description

The driver uses a ring buffer to store the results of measurements. When the done interrupt is raised, the result is stored in the ring buffer at the next free location. When the ring buffer is full, the next sample will overwrite the oldest sample in the ring buffer.

To read the results from the ring buffer, the function 21.2.9.9 freqmeter_async_read is used. This function reads the number of measurement results asked for from the ring buffer, starting from the oldest byte. If

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the number of bytes asked for are more than currently available in the ring buffer, the number of available bytes is read. The 21.2.9.9 freqmeter_async_read function returns the actual number of bytes read from the buffer back to the caller. If the number of bytes asked for is less than the available bytes in the ring buffer, the remaining bytes will be kept until a new call to 21.2.9.9 freqmeter_async_read or it's overwritten because the ring buffer is full.

21.2.4 Example of Usage

The following shows a simple example of using the FREQM. The FREQM must have been initialized by 4.2.9.1 ac_async_init. This initialization will configure the operation of the FREQM, such as clock to be measured, reference clock, etc.

The example registers a callback function for measurement ready and enables FREQM, finally starts a frequency measurement.

```
static void freqmeter_cb(const struct freqmeter_async_descriptor *const des
cr)
        {
            uint32_t value;
            freqmeter_async_read(&FREQUENCY_METER_0, &value, 1);
            freqmeter_async_start(&FREQUENCY_METER_0);
        }
        void FREQUENCY_METER_0_example(void)
        {

    freqmeter_async_register_callback(&FREQUENCY_METER_0, FREQMETER_ASYNC_M
EASUREMENT_DONE, freqmeter_cb);
            freqmeter_async_enable(&FREQUENCY_METER_0);
            freqmeter_async_start(&FREQUENCY_METER_0);
        }
```

21.2.5 Dependencies

- FREQM peripheral and its related I/O lines and clocks
- NVIC must be configured so that FREQM interrupt requests are periodically serviced.

21.2.6 Structs

21.2.6.1 freqmeter_async_callbacks Struct

Frequency meter callbacks.

Members

done

21.2.6.2 freqmeter_async_descriptor Struct

Asynchronous frequency meter descriptor.

Members

period

param

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device

cbs

measures

21.2.7 Enums

21.2.7.1 freqmeter_async_callback_type Enum

FREQMETER_ASYNC_MEASUREMENT_DONE

21.2.8 Typedefs

21.2.8.1 freqmeter_cb_t typedef

typedef void(* freqmeter_cb_t) (const struct freqmeter_async_descriptor *const descr)

Frequency meter callback type.

21.2.9 Functions

21.2.9.1 freqmeter_async_init

Initialize frequency meter.

```
int32_t freqmeter_async_init(
    struct freqmeter_async_descriptor *const descr,
    void *const hw,
    uint8_t *const buffer,
    const uint16_t buffer_length
)
```

Parameters

descr

Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const

The pointer to the frequency meter descriptor

hw

Type: void *const

The pointer to the hardware instance

buffer

Type: uint8_t *const

A buffer to keep the measured values

buffer_length

Type: const uint16_t

The length of the buffer above

Returns

Type: int32_t

Initialization status.

21.2.9.2 freqmeter_async_deinit

Deinitialize frequency meter.

```
int32_t freqmeter_async_deinit(
    struct freqmeter_async_descriptor *const descr
)
```

Parameters

descr Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const

The pointer to the frequency meter descriptor

Returns

Type: int32_t

De-initialization status.

21.2.9.3 freqmeter_async_enable

Enable frequency meter.

```
int32_t freqmeter_async_enable(
    struct freqmeter_async_descriptor *const descr
)
```

Parameters

descr Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const

The pointer to the frequency meter descriptor

Returns

Type: int32_t

Enabling status.

21.2.9.4 freqmeter_async_disable

Disable frequency meter.

```
int32_t freqmeter_async_disable(
    struct freqmeter_async_descriptor *const descr
)
```

Parameters

descr Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const

The pointer to the frequency meter descriptor

Returns

Type: int32_t

Disabling status.

21.2.9.5 freqmeter_async_start

Start frequency meter.

```
int32_t freqmeter_async_start(
    struct freqmeter_async_descriptor *const descr
)
```

Parameters

descr	Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const The pointer to the frequency meter descriptor

Returns

Type: int32_t

Starting status.

21.2.9.6 freqmeter_async_register_callback

Register frequency meter callback.

```
int32_t freqmeter_async_register_callback(
    struct freqmeter_async_descriptor *const descr,
    const enum freqmeter_async_callback_type type,
    freqmeter_cb_t cb
)
```

Parameters

descr	Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const A frequency meter descriptor
type	Type: const enum 21.2.7.1 freqmeter_async_callback_type Enum Callback type
cb	Type: 21.2.8.1 freqmeter_cb_t typedef A callback function

Returns

Type: int32_t

The status of callback assignment.

-1	Passed parameters were invalid or the interface is not initialized
0	A callback is registered successfully

21.2.9.7 freqmeter_async_set_measurement_period

Set period of measurement.

```
int32_t freqmeter_async_set_measurement_period(
    struct freqmeter_async_descriptor *const descr,
    const uint32_t period
)
```

Parameters

descr	Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const The pointer to the frequency meter descriptor
period	Type: const uint32_t Period in microseconds

Returns
Type: int32_t

Status for the period setting

21.2.9.8 freqmeter_async_set_measurement_parameter

Set the parameter to measure.

```
int32_t freqmeter_async_set_measurement_parameter(
    struct freqmeter_async_descriptor *const descr,
    const enum freqmeter_parameter parameter
)
```

Parameters

descr	Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const The pointer to the frequency meter descriptor
parameter	Type: const enum freqmeter_parameter The signal parameter to measure

Returns
Type: int32_t

Status for parameter setting

21.2.9.9 freqmeter_async_read

Read values from the frequency meter.

```
int32_t freqmeter_async_read(
    struct freqmeter_async_descriptor *const descr,
    uint32_t *const data,
    const uint16_t length
)
```

Parameters

descr	Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const The pointer to the frequency meter descriptor
data	Type: uint32_t *const The point to the data buffer to write data to
length	Type: const uint16_t

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The amount of measurements to read

Returns
Type: int32_t

Amount of bytes read

21.2.9.10 freqmeter_async_flush_rx_buffer

Flush frequency meter ring buffer.

```
int32_t freqmeter_async_flush_rx_buffer(
    struct freqmeter_async_descriptor *const descr
)
```

Parameters

descr	Type: struct 21.2.6.2 freqmeter_async_descriptor Struct *const The pointer to the frequency meter descriptor

Returns
Type: int32_t

ERR_NONE

21.2.9.11 freqmeter_async_get_version

Retrieve the current driver version.

```
uint32_t freqmeter_async_get_version(
    void
)
```

Returns
Type: uint32_t

Current driver version.

21.3 Frequency Meter Synchronous Driver

The functions in Frequency Meter (FREQM) synchronous driver will block (i.e. not return) until the operation is done.

21.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable Frequency Meter
- Set measurement parameter (measure period, frequency or period measurement)
- Read measurement results

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21.3.2 Summary of Configuration Options

Below is a list of the main FREQM parameters that can be configured in START. Many of these parameters are used by the 21.3.7.1 freqmeter_sync_init function when initializing the driver and underlying hardware.

- Clock to be measured
- Reference clock
- Number of reference clock cycles (measure period)

21.3.3 Driver Implementation Description

After FREQM hardware initialization, the measure result can get by 21.3.7.7 freqmeter_sync_read.

21.3.4 Example of Usage

The following shows a simple example of using the FREQM. The FREQM must have been initialized by 21.3.7.1 freqmeter_sync_init. This initialization will configure the operation of the FREQM, such as clock to be measured, reference clock, etc.

The example enables FREQM, and finally starts to read measurement results.

```
void FREQUENCY_METER_0_example(void)
{
    uint32_t value;
    freqmeter_sync_enable(&FREQUENCY_METER_0);
    freqmeter_sync_read(&FREQUENCY_METER_0, &value, 1);
}
```

21.3.5 Dependencies

- FREQM peripheral and its related I/O lines and clocks

21.3.6 Structs

21.3.6.1 freqmeter_sync_descriptor Struct

Synchronous frequency meter descriptor.

Members

period

param

device

21.3.7 Functions

21.3.7.1 freqmeter_sync_init

Initialize the frequency meter.

```
int32_t freqmeter_sync_init(
    struct freqmeter_sync_descriptor *const descr,
    void *const hw
)
```

Parameters

descr	Type: struct 21.3.6.1 freqmeter_sync_descriptor Struct *const The pointer to the frequency meter descriptor
hw	Type: void *const The pointer to the hardware instance

Returns

Type: int32_t

Initialization status.

21.3.7.2 freqmeter_sync_deinit

Deinitialize the frequency meter.

```
int32_t freqmeter_sync_deinit(
    struct freqmeter_sync_descriptor *const descr
)
```

Parameters

descr	Type: struct 21.3.6.1 freqmeter_sync_descriptor Struct *const The pointer to the frequency meter descriptor

Returns

Type: int32_t

De-initialization status.

21.3.7.3 freqmeter_sync_enable

Enable the frequency meter.

```
int32_t freqmeter_sync_enable(
    struct freqmeter_sync_descriptor *const descr
)
```

Parameters

descr	Type: struct 21.3.6.1 freqmeter_sync_descriptor Struct *const The pointer to the frequency meter descriptor

Returns

Type: int32_t

Enabling status.

21.3.7.4 freqmeter_sync_disable

Disable the frequency meter.

```
int32_t freqmeter_sync_disable(
    struct freqmeter_sync_descriptor *const descr
)
```

Parameters

descr Type: struct 21.3.6.1 freqmeter_sync_descriptor Struct *const

The pointer to the frequency meter descriptor

Returns

Type: int32_t

Disabling status.

21.3.7.5 freqmeter_sync_set_measurement_period

Set period of measurement.

```
int32_t freqmeter_sync_set_measurement_period(
    struct freqmeter_sync_descriptor *const descr,
    const uint32_t period
)
```

Parameters

descr Type: struct 21.3.6.1 freqmeter_sync_descriptor Struct *const

The pointer to the frequency meter descriptor

period Type: const uint32_t

Period in microseconds

Returns

Type: int32_t

Status for period setting

21.3.7.6 freqmeter_sync_set_measurement_parameter

Set the parameter to measure.

```
int32_t freqmeter_sync_set_measurement_parameter(
    struct freqmeter_sync_descriptor *const descr,
    const enum freqmeter_parameter parameter
)
```

Parameters

descr Type: struct 21.3.6.1 freqmeter_sync_descriptor Struct *const

The pointer to the frequency meter descriptor

parameter Type: const enum freqmeter_parameter

Signal parameter to measure

Returns

Type: int32_t

Status for the parameter setting

21.3.7.7 freqmeter_sync_read

Read values from the frequency meter.

```
int32_t freqmeter_sync_read(
    struct freqmeter_sync_descriptor *const descr,
    uint32_t *const data,
    const uint16_t length
)
```

Parameters

descr	Type: struct 21.3.6.1 freqmeter_sync_descriptor Struct *const The pointer to the frequency meter descriptor
data	Type: uint32_t *const The point to the data buffer to write data to
length	Type: const uint16_t The amount of measurements to read

Returns

Type: int32_t

Amount of bytes to read

21.3.7.8 freqmeter_sync_get_version

Retrieve the current driver version.

```
uint32_t freqmeter_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

22. Graphic LCD Driver

A LCD Controller typically consists of logic for transferring LCD image data from an external display buffer to an LCD module. The Graphic LCD driver is designed to provide basic interface for LCD Controller, like initialization and de-initialization, enabling and disabling. And some common interface used to work with thirdpart graphic library like SEGGER emWin and Microchip Graphic library. So for most use cases, the Graphic LCD driver should works with a graphic library.

22.1 Summary of the API's Functional Features

The API provides functions to:

- Initializing and deinitializing the driver and associated hardware
- Enabling and Disabling
- Interface for thirdpart graphic library.

22.2 Summary of Configuration Options

Depend on device, LCD controller parameters can be configured in START.

22.3 Driver Implementation Description

The driver supply some API for working with thirdpart graphic library. And the range of layer parameter for the API depends on device. The driver supports to operate display layer by given layer index.

22.4 Example of Usage

The following shows a simple example of using the Graphic LCD. The Graphic driver must have been initialized fristly. This initialization configures the hardware LCD controller instance.

The example sets the base layer to visible on LCD Display. The framebuffer(fb) was allocated by application, normally in SDRAM memory area. And the size of the framebuffer is depend on LCD size and bpp size (Bits per pixel) which defined in LCD's configurations. For example if LCD size is 480 * 320, and bpp is 32bits. Then the framebuffer size is 480 * 320 * 4bytes.

```
/**
 * Example of using Graphic LCD to set backgroup layer visible.

 * \param[in] fb Pointer to framebuffer
 */
void LCD_0_example(void *fb)
{
    /* Enable LCD Controller */
    lcd_enable();
    /* Set Layer 0(backgroup layer) framebuffer */
    lcd_show(0, fb);
    /* Set layer 0(backgroup layer) to visible */
    lcd_set_visible(0, 1);
}
```

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22.5 Dependencies

- LCD Controller peripheral, clock and singals.

22.6 Defines

22.6.1 HAL_LCD_DRIVER_VERSION

#define HAL_LCD_DRIVER_VERSION( ) 0x00000001u

Driver version.

22.7 Functions

22.7.1 lcd_init

Initialize LCD.

```
static int32_t lcd_init(
    void
)
```

This function initializes the LCD.

Returns

Type: int32_t

Initialization status.

22.7.2 lcd_deinit

De-initialize LCD.

```
static int32_t lcd_deinit(
    void
)
```

This function de-initializes the LCD.

Returns

Type: int32_t

De-initialization status.

22.7.3 lcd_enable

Enable LCD.

```
static int32_t lcd_enable(
    void
)
```

This function enable LCD.

Returns

Type: int32_t

Enabling status.

22.7.4 lcd_disable

Disable LCD.

```
static int32_t lcd_disable(
    void
)
```

This function disable LCD.

Returns

Type: int32_t

Disabling status.

22.7.5 lcd_set_lut_entry

Setup color lookup table entry.

```
static int32_t lcd_set_lut_entry(
    uint8_t layer,
    uint8_t index,
    uint32_t val
)
```

This function set color lookup table entry by given layer.

Parameters

layer	Type: uint8_t Index of layer, 0 for base layer.
index	Type: uint8_t Lookup table index.
val	Type: uint32_t 7:0 Blue, 15:8 Green, 23:16 Red, 31:24 Alpha.

Returns

Type: int32_t

Set status.

22.7.6 lcd_set_alpha

Set the required layer alpha value.

```
static int32_t lcd_set_alpha(
    uint8_t layer,
    uint8_t val
)
```

This function set the required layer alpha value.

Parameters

layer Type: uint8_t

Index of layer, 0 for base layer.

val Type: uint8_t

Alpha value to be used. 255 for transparent and 0 for opaque.

Returns

Type: int32_t

Set status.

22.7.7 lcd_set_position

Set the required layer position.

```
static int32_t lcd_set_position(
    uint8_t layer,
    int32_t x,
    int32_t y
)
```

This function set the required layer position.

Parameters

layer Type: uint8_t

Index of layer, 0 for base layer.

x Type: int32_t

Physical X-position to be used to set up the layer position.

y Type: int32_t

Physical Y-position to be used to set up the layer position.

Returns

Type: int32_t

Set status.

22.7.8 lcd_set_size

Set the required layer size.

```
static int32_t lcd_set_size(
    uint8_t layer,
    int32_t x,
    int32_t y
)
```

This function set the required layer size.

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Parameters

layer	Type: uint8_t Index of layer, 0 for base layer.
x	Type: int32_t Physical X-position to be used to set up the layer size.
y	Type: int32_t Physical Y-position to be used to set up the layer size.

Returns

Type: int32_t

Set status.

22.7.9 lcd_set_visible

Set the required layer visible or invisible.

```
static int32_t lcd_set_visible(
    uint8_t layer,
    int8_t on
)
```

This function set the required layer visible or invisible.

Parameters

layer	Type: uint8_t Index of layer, 0 for base layer.
on	Type: int8_t 1 if layer should be visible, 0 for invisible.

Returns

Type: int32_t

Set status.

22.7.10 lcd_show

Set framebuffer for the required layer.

```
static int32_t lcd_show(
    uint8_t layer,
    void * fb
)
```

This function set the framebuffer pointer for the required layer.

Parameters

layer	Type: uint8_t

	Index of layer.
fb	Type: void *
	Pointer to framebuffer.

Returns

Type: int32_t

Set status.

22.7.11 lcd_show_streams

Set YUV framebuffer for the required layer.

```
static int32_t lcd_show_streams(
    uint8_t layer,
    void * fb1,
    void * fb2,
    void * fb3
)
```

This function set the YUV framebuffer pointer for the required layer.

Parameters

layer	Type: uint8_t
	Index of layer.
fb1	Type: void *
	Pointer to framebuffer of Y.
fb2	Type: void *
	Pointer to framebuffer of U or UV, NULL if no used.
fb3	Type: void *
	Pointer to framebuffer of V, NULL if no used.

Returns

Type: int32_t

Set status.

22.7.12 lcd_get_version

Retrieve the current driver version.

```
static uint32_t lcd_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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23. Graphics Processing Unit Driver(2D)

Graphics Processing Unit(GPU) manipulates and alters the contents of the frame buffer in system RAM or DRAM memory to accelerate the generation of images for eventual pixel display. Hardware acceleration is brought to numerous 2-D applications, such as graphic user interfaces (menus, objects, etc.), touch screen user interfaces, Flash animation and gaming among others.

23.1 Summary of the API's Functional Features

The API provides functions to:

- Initializing and de-initializing the driver and associated hardware
- Enabling and Disabling
- Register Interrupt Callback function
- Invoke GPU instruction(FILL, COPY, BLEND) to manipulate and alters the contents of the frame buffer.

23.2 Summary of Configuration Options

Depend on the device, GPU parameters can be configured in START.

23.3 Driver Implementation Description

The driver support FILL, COPY, BLEND GPU instruction to manipulates and alters the contents of the frame buffer. Those functions are asynchronous, an application can call the gpu_register_callback function to register a callback function. The callback function will be invoked when one GPU operation finished or an error occurs.

23.4 Example of Usage

The following shows an example of using the Graphic Processing Unit. The GPU driver must have been initialized firstly. This initialization configures the hardware Graphic Processing Unit instance.

This example will invoke a FILL instruction to fill an area (10x10 pixel) with BLUE color(ARGB format 0x000000FF).

```
# include <utils.h>
/* Frame buffer for 10x10 pixel, ARGB 32bit format */
COMPILER_ALIGNED(4) uint32_t framebuffer[100];
/* Indicate end of execute instruction */
volatile uint8_t gpu_end = 0;
void gpu_cb(uint8_t state)
{
    gpu_end = state;
}
/**
 * Example of using GPU to fill a frame buffer with color.
 */
void GPU_example(void)
{
    struct gpu_buffer     dst;
```

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```
        struct gpu_rectangle  rect;
        uint32_t i;
        gpu_enable(ringbuffer, 0x40);
        gpu_register_callback(gpu_callback);
        dst.width = 10;
        dst.height = 10;
        dst.fmt = GPU_ARGB8888;
        dst.addr = framebuffer;
        rect.x = 0;
        rect.y = 0;
        rect.width = 10;
        rect.height = 10;
        gpu_fill(&dst, &rect, GPU_COLOR(0,0,0,0xFF));
        /* Wait for instruction process finished */
        while (gpu_end == 0) {
        };
        /* Check if all data in framebuffer was set to 0x000000FF */
        for (i = 0; i < 100; i ++) {
            if (((uint32_t *)framebuffer)[i] != 0x000000FF) {
                /* Error happened */
                while (1) {};
            }
        }
        /* Success */
        return;
    }
```

23.5 Dependencies

- 2D Graphic Engine peripheral.

23.6 Defines

23.6.1 HAL_GPU_ASYNC_DRIVER_VERSION

#define HAL_GPU_ASYNC_DRIVER_VERSION( ) 0x00000001u

Driver version.

23.7 Functions

23.7.1 gpu_async_init

Initialize GPU.

```
static int32_t gpu_async_init(
    void
)
```

This function initializes the GPU.

Returns

Type: int32_t

Initialization status.

23.7.2 gpu_async_deinit

De-initialize GPU.

```
static int32_t gpu_async_deinit(
    void
)
```

This function de-initializes the gpu.

Returns

Type: int32_t

De-initialization status.

23.7.3 gpu_async_enable

Enable GPU.

```
static int32_t gpu_async_enable(
    void
)
```

This function enable GPU.

Returns

Type: int32_t

Enabling status.

23.7.4 gpu_async_disable

Disable GPU.

```
static int32_t gpu_async_disable(
    void
)
```

This function disable GPU.

Returns

Type: int32_t

Disabling status.

23.7.5 gpu_async_fill

FILL a frame-buffer with color.

```
static int32_t gpu_async_fill(
    struct gpu_buffer * dst,
    struct gpu_rectangle * rect,
    gpu_color_t color
)
```

This function FILL a destination-filled area with color. This function is asynchronous, application can call 23.7.8 gpu_async_register_callback function to register a callback function. The callback function will be invoked when GPU operation finished.

Parameters

dst	Type: struct gpu_buffer * Pointer to the destination-filled area buffer.
rect	Type: struct gpu_rectangle * Pointer to the destination-filled area rectangle.
color	Type: gpu_color_t A 32-bit ARGB color resized to the area pixel format.

Returns
Type: int32_t

Operation status.

ERR_BUSY	A GPU Operation still in processing.

23.7.6 gpu_async_copy

COPY from a frame-buffer to another.

```
static int32_t gpu_async_copy(
    struct gpu_buffer * dst,
    struct gpu_rectangle * dst_rect,
    struct gpu_buffer * src,
    struct gpu_rectangle * src_rect
)
```

This function COPY a frame-buffer to a destination frame-buffer. This function is asynchronous, application can call 23.7.8 gpu_async_register_callback function to register a callback function. The callback function will be invoked when GPU operation finished.

Parameters

dst	Type: struct gpu_buffer * Pointer to the destination area buffer.
dst_rect	Type: struct gpu_rectangle * Pointer to the destination area rectangle.
src	Type: struct gpu_buffer * Pointer to the source area buffer.
src_rect	Type: struct gpu_rectangle * Pointer to the source area rectangle.

Returns
Type: int32_t

Operation status.

ERR_BUSY	A GPU Operation still in processing.

23.7.7 gpu_async_blend

Blend foreground and background to a destination frame-buffer.

```
static int32_t gpu_async_blend(
    struct gpu_buffer * dst,
    struct gpu_rectangle * dst_rect,
    struct gpu_buffer * fg,
    struct gpu_rectangle * fg_rect,
    struct gpu_buffer * bg,
    struct gpu_rectangle * bg_rect,
    enum gpu_blend blend
)
```

This function BLEND a foreground frame-buffer and a background frame-buffer to a destination frame-buffer. This function is asynchronous, application can call 23.7.8 gpu_async_register_callback function to register a callback function. The callback function will be invoked when GPU operation finished.

Parameters

dst	Type: struct gpu_buffer * Pointer to the destination area buffer.
dst_rect	Type: struct gpu_rectangle * Pointer to the destination area rectangle.
fg	Type: struct gpu_buffer * Pointer to the foreground area buffer.
fg_rect	Type: struct gpu_rectangle * Pointer to the foreground area rectangle.
bg	Type: struct gpu_buffer * Pointer to the background area buffer.
bg_rect	Type: struct gpu_rectangle * Pointer to the background area rectangle.
blend	Type: enum gpu_blend Blend function.

Returns

Type: int32_t

Operation status.

ERR_BUSY	A GPU Operation still in processing.

23.7.8 gpu_async_register_callback

Register GPU callback.

```
static int32_t gpu_async_register_callback(
    gpu_cb_t cb
)
```

Parameters

cb Type: gpu_cb_t

A callback function, passing NULL will de-register.

Returns

Type: int32_t

The status of callback assignment.

23.7.9 gpu_async_get_version

Retrieve the current driver version.

```
static uint32_t gpu_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

24. Hash Algorithm Driver

The Secure Hash Algorithm (SHA) is a family of cryptographic hash functions published by the National Institute of Standards and Technology (NIST) as a U.S. Federal Information Processing Standard (FIPS). SHA is useful in the generation and verification of digital signatures and message authentication codes, and in the generation of random numbers (bits).

The driver supports the SHA-1/224/256 mode for data hash.

24.1 SHA Synchronous Driver

The driver supports the SHA-1/224/256 mode for data hash.

24.1.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enabling and Disabling
- Compute SHA-1/224/256 message digest

24.1.2 Driver Implementation Description

24.1.2.1 Limitations

The sha_context struct must align for some devices, it depends if the array that holding message digest required to align, for example, SAMV71 must align 128 bytes.

24.1.3 Dependencies

- The SHA capable hardware

24.1.4 Structs

24.1.4.1 sha_sync_descriptor Struct

Members

dev	SHA HPL device descriptor

24.1.5 Functions

24.1.5.1 sha_sync_init

Initialize the SHA Descriptor.

```
int32_t sha_sync_init(
    struct sha_sync_descriptor * descr,
    void *const hw
)
```

Parameters

desc	The SHA descriptor to be initialized

hw Type: void *const

The pointer to hardware instance

Returns
Type: int32_t

Initialization status.

24.1.5.2 sha_sync_deinit

Deinitialize SHA Descriptor.

```
int32_t sha_sync_deinit(
    struct sha_sync_descriptor * desc
)
```

Parameters

desc Type: struct 24.1.4.1 sha_sync_descriptor Struct *

The SHA descriptor to be deinitialized

Returns
Type: int32_t

De-initialization status.

24.1.5.3 sha_sync_enable

Enable SHA.

```
int32_t sha_sync_enable(
    struct sha_sync_descriptor * desc
)
```

Parameters

desc Type: struct 24.1.4.1 sha_sync_descriptor Struct *

SHA descriptor

Returns
Type: int32_t

Enabling status.

24.1.5.4 sha_sync_disable

Disable SHA.

```
int32_t sha_sync_disable(
    struct sha_sync_descriptor * desc
)
```

Parameters

desc	Type: struct 24.1.4.1 sha_sync_descriptor Struct *
	SHA descriptor

Returns

Type: int32_t

Disabling status.

24.1.5.5 sha_sync_sha1_start

SHA-1 start.

```
int32_t sha_sync_sha1_start(
    struct sha_sync_descriptor * descr,
    struct sha_context * ctx
)
```

Parameters

descr	Type: struct 24.1.4.1 sha_sync_descriptor Struct *
	SHA descriptor
ctx	Type: struct sha_context *
	SHA context structure

Returns

Type: int32_t

Start status.

24.1.5.6 sha_sync_sha256_start

SHA-256/224 start.

```
int32_t sha_sync_sha256_start(
    struct sha_sync_descriptor * descr,
    struct sha_context * ctx,
    bool is224
)
```

Parameters

descr	Type: struct 24.1.4.1 sha_sync_descriptor Struct *
	SHA descriptor
ctx	Type: struct sha_context *
	SHA context structure
is224	Type: bool
	If true, use SHA-224

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Returns

Type: int32_t

Start status.

24.1.5.7 sha_sync_sha1_update

SHA-1 input update.

```
int32_t sha_sync_sha1_update(
    struct sha_sync_descriptor * descr,
    const uint8_t * input,
    uint32_t length
)
```

Parameters

descr	Type: struct 24.1.4.1 sha_sync_descriptor Struct * SHA descriptor
input	Type: const uint8_t * Buffer holding the input data
length	Type: uint32_t Byte length of the input data

Returns

Type: int32_t

Update status.

24.1.5.8 sha_sync_sha256_update

SHA-256/224 input update.

```
int32_t sha_sync_sha256_update(
    struct sha_sync_descriptor * descr,
    const uint8_t * input,
    uint32_t length
)
```

Parameters

descr	Type: struct 24.1.4.1 sha_sync_descriptor Struct * SHA descriptor
input	Type: const uint8_t * Buffer holding the input data
length	Type: uint32_t Byte length of the input data

Returns

Type: int32_t

Update status.

24.1.5.9 sha_sync_sha1_finish

SHA-1 finish.

```
int32_t sha_sync_sha1_finish(
    struct sha_sync_descriptor * descr,
    uint8_t output
)
```

Parameters

descr	Type: struct 24.1.4.1 sha_sync_descriptor Struct * SHA descriptor
output	Type: uint8_t SHA digest data

Returns

Type: int32_t

Finish status.

24.1.5.10 sha_sync_sha256_finish

SHA-256/224 finish.

```
int32_t sha_sync_sha256_finish(
    struct sha_sync_descriptor * descr,
    uint8_t output
)
```

Parameters

descr	Type: struct 24.1.4.1 sha_sync_descriptor Struct * SHA descriptor
output	Type: uint8_t SHA digest data

Returns

Type: int32_t

Finish status.

24.1.5.11 sha_sync_sha1_compute

SHA-1 compute digest.

```
int32_t sha_sync_sha1_compute(
    struct sha_sync_descriptor * descr,
    struct sha_context * ctx,
    const uint8_t * input,
    uint32_t length,
    uint8_t output
)
```

Parameters

descr	Type: struct 24.1.4.1 sha_sync_descriptor Struct * SHA descriptor
ctx	Type: struct sha_context * SHA context structure
input	Type: const uint8_t * Buffer holding the input data
length	Type: uint32_t Byte length of the input data
output	Type: uint8_t SHA digest data

Returns

Type: int32_t

Compute status.

24.1.5.12 sha_sync_sha256_compute

SHA-256/224 compute digest.

```
int32_t sha_sync_sha256_compute(
    struct sha_sync_descriptor * descr,
    struct sha_context * ctx,
    bool is224,
    const uint8_t * input,
    uint32_t length,
    uint8_t output
)
```

Parameters

descr	Type: struct 24.1.4.1 sha_sync_descriptor Struct * SHA descriptor
ctx	Type: struct sha_context * SHA context structure
is224	Type: bool If true, use SHA-224
input	Type: const uint8_t * Buffer holding the input data
length	Type: uint32_t Byte length of the input data

output	Type: uint8_t SHA digest data

Returns

Type: int32_t

Compute status.

24.1.5.13 sha_sync_get_version

Retrieve the current driver version.

```
uint32_t sha_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

25. Helper Drivers

The following helper functions are available:

- 25.1 Atomic Driver
- 25.3 Init Driver
- 25.2 I/O Driver
- 25.4 Reset Driver
- 25.5 Sleep Driver

25.1 Atomic Driver

25.1.1 Defines

25.1.1.1 CRITICAL_SECTION_ENTER

#define CRITICAL_SECTION_ENTER( ) {volatile hal_atomic_t __atomic;
atomic_enter_critical(&__atomic);

Helper macro for entering critical sections.

This macro is recommended to be used instead of a direct call hal_enterCritical() function to enter critical sections. No semicolon is required after the macro.

25.1.1.2 CRITICAL_SECTION_LEAVE

#define CRITICAL_SECTION_LEAVE( ) atomic_leave_critical(&__atomic);}

Helper macro for leaving critical sections.

This macro is recommended to be used instead of a direct call hal_leaveCritical() function to leave critical sections. No semicolon is required after the macro.

25.1.2 Typedefs

25.1.2.1 hal_atomic_t typedef

typedef uint32_t hal_atomic_t

Type for the register holding global interrupt enable flag.

25.1.3 Functions

25.1.3.1 atomic_enter_critical

Disable interrupts, enter critical section.

```
void atomic_enter_critical(
    hal_atomic_t volatile * atomic
)
```

Disables global interrupts. Supports nested critical sections, so that global interrupts are only re-enabled upon leaving the outermost nested critical section.

Parameters

atomic	Type: 25.1.2.1 hal_atomic_t typedef volatile *

The pointer to a variable to store the value of global interrupt enable flag

Returns

Type: void

25.1.3.2 atomic_leave_critical

Exit atomic section.

```
void atomic_leave_critical(
    hal_atomic_t volatile * atomic
)
```

Enables global interrupts. Supports nested critical sections, so that global interrupts are only re-enabled upon leaving the outermost nested critical section.

Parameters

atomic	Type: 25.1.2.1 hal_atomic_t typedef volatile * The pointer to a variable, which stores the latest stored value of the global interrupt enable flag

Returns

Type: void

25.1.3.3 atomic_get_version

Retrieve the current driver version.

```
uint32_t atomic_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

25.2 I/O Driver

25.2.1 Structs

25.2.1.1 io_descriptor Struct

I/O descriptor.

Members

write	
read	The write function pointer.

25.2.2 Typedefs

25.2.2.1 io_write_t typedef

typedef int32_t(* io_write_t) (struct io_descriptor *const io_descr, const uint8_t *const buf, const uint16_t length)

I/O write function pointer type.

25.2.2.2 io_read_t typedef

typedef int32_t(* io_read_t) (struct io_descriptor *const io_descr, uint8_t *const buf, const uint16_t length)

I/O read function pointer type.

25.2.3 Functions

25.2.3.1 io_write

I/O write interface.

```
int32_t io_write(
    struct io_descriptor *const io_descr,
    const uint8_t *const buf,
    const uint16_t length
)
```

This function writes up to `length` of bytes to a given I/O descriptor. It returns the number of bytes actually write.

Parameters

descr	An I/O descriptor to write
buf	Type: const uint8_t *const The buffer pointer to story the write data
length	Type: const uint16_t The number of bytes to write

Returns

Type: int32_t

The number of bytes written

25.2.3.2 io_read

I/O read interface.

```
int32_t io_read(
    struct io_descriptor *const io_descr,
    uint8_t *const buf,
    const uint16_t length
)
```

This function reads up to `length` bytes from a given I/O descriptor, and stores it in the buffer pointed to by `buf`. It returns the number of bytes actually read.

Parameters

descr	An I/O descriptor to read
buf	Type: uint8_t *const The buffer pointer to story the read data
length	Type: const uint16_t The number of bytes to read

Returns

Type: int32_t

The number of bytes actually read. This number can be less than the requested length. E.g., in a driver that uses ring buffer for reception, it may depend on the availability of data in the ring buffer.

25.3 Init Driver

25.3.1 Functions

25.3.1.1 init_mcu

Initialize the hardware abstraction layer.

```
static void init_mcu(
    void
)
```

This function calls the various initialization functions. Currently the following initialization functions are supported:

- System clock initialization

Returns

Type: void

25.3.1.2 init_get_version

Retrieve the current driver version.

```
uint32_t init_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

25.4 Reset Driver

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25.4.1 Functions

25.4.1.1 reset_mcu

Reset the MCU.

```
void reset_mcu(
    void
)
```

Returns

Type: void

25.4.1.2 get_reset_reason

Retrieve the reset reason.

```
enum reset_reason get_reset_reason(
    void
)
```

Retrieves the reset reason of the last MCU reset.

Returns

Type: enum reset_reason

An enum value indicating the reason of the last reset.

25.4.1.3 reset_get_version

Retrieve the current driver version.

```
uint32_t reset_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

25.5 Sleep Driver

25.5.1 Functions

25.5.1.1 sleep

Set the sleep mode of the device and put the MCU to sleep.

```
int sleep(
    const uint8_t mode
)
```

For an overview of which systems are disabled in sleep for the different sleep modes, see the data sheet.

Parameters

mode	Type: const uint8_t

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Sleep mode to use

Returns

Type: int

The status of a sleep request

-1	The requested sleep mode was invalid or not available
0	The operation completed successfully, returned after leaving the sleep

25.5.1.2 sleep_get_version

Retrieve the current driver version.

```
uint32_t sleep_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

26. I2C Drivers

Three driver variants are available for the I2C Master: Synchronous, Asynchronous, and RTOS.

- 26.4 I2C Master Synchronous Driver: The driver supports polling for hardware changes. The functionality is synchronous to the main clock of the MCU.
- 26.2 I2C Master Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.
- 26.3 I2C Master RTOS Driver: The driver supports a Real-Time operating system, i.e. is thread safe.

Two driver variants are available for the I2C Slave: Synchronous and Asynchronous.

- 26.6 I2C Slave Synchronous Driver: The driver supports polling for hardware changes. The functionality is synchronous to the main clock of the MCU.
- 26.5 I2C Slave Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.

26.1 I2C Basics and Best Practice

I2C (Inter-Integrated Circuit) is a two-wire serial interface normally used for on-board low-speed bidirectional communication between controllers and peripherals. The master device is responsible for initiating and controlling all transfers on the I2C bus. Only one master device can be active on the I2C bus at the time, but the master role can be transferred between devices on the same I2C bus. I2C uses only two bidirectional open-drain lines, normally designated SDA (Serial Data Line) and SCL (Serial Clock Line), with pull up resistors.

26.2 I2C Master Asynchronous Driver

In Inter-Integrated Circuit (I2C) master asynchronous driver, a callback function can be registered in the driver by the application and triggered when the transfer done. It provides an interface to read/write the data from/to the slave device.

The stop condition is automatically controlled by the driver if the I/O write and read functions are used, but can be manually controlled by using the 26.2.10.10 i2c_m_async_transfer function.

Often a master accesses different information in the slave by accessing different registers in the slave. This is done by first sending a message to the target slave containing the register address, followed by a repeated start condition (no stop condition in between) ending with transferring register data. This scheme is supported by the 26.2.10.8 i2c_m_async_cmd_write and 26.2.10.9 i2c_m_async_cmd_read function, but limited to 8-bit register addresses.

Transfer callbacks are executed at the end of a full transfer, that is, when a complete message with address is either sent or read from the slave. When the 26.2.10.10 i2c_m_async_transfer function is used the TX and RX callbacks are triggered regardless if a stop condition is generated at the end of the message.

The TX and RX callbacks are reused for the cmd functions and are triggered at the end of a full register write or read, that is, after the register address has been written to the slave and data has been transferred to or from the master.

The error callback is executed as soon as an error is detected, the error situation can both be detected while processing an interrupt or detected by the hardware which may trigger a special error interrupt. In situations where errors are detected by the software, there will be a slight delay from the error occurs until the error callback is triggered due to software processing.

I2C Modes (standard mode/fastmode+/highspeed mode) can only be selected in START. If the SCL frequency (baudrate) has changed run-time, make sure to stick within the SCL clock frequency range supported by the selected mode. The requested SCL clock frequency is not validated by the 26.2.10.5 i2c_m_async_set_baudrate function against the selected I2C mode.

26.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable I2C master
- Hookup callback handlers on TX complete, RX complete, or error events
- Set the address of slave device
- Read/Write message to/from the slave

26.2.2 Summary of Configuration Options

Below is a list of the main I2C master parameters that can be configured in START. Many of these parameters are used by the 26.2.10.1 i2c_m_async_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions, such as 26.2.10.5 i2c_m_async_set_baudrate.

- Set I2C bus clock speed
- Which clock source is used

26.2.3 Driver Implementation Description

After I2C hardware initialization, the 26.2.10.13 i2c_m_async_get_io_descriptor function is needed to register an I/O descriptor. Then enable the I2C hardware, and use the 26.2.10.4 i2c_m_async_register_callback to register callback function for RX/TX complete. After that, the application needs to set the slave address by the 26.2.10.3 i2c_m_async_set_slaveaddr function. At the end, start the read/write operation.

26.2.3.1 Limitations

- System Management Bus (SMBus) not supported
- Power Management Bus (PMBus) not supported
- The register value for the requested I2C speed is calculated and placed in the correct register, but not validated if it works correctly with the clock/prescaler settings used for the module. To validate the I2C speed setting use the formula found in the configuration file for the module. Selectable speed is automatically limited within the speed range defined by the I2C mode selected

26.2.4 Example of Usage

The following shows a simple example of using the I2C master. The I2C master must have been initialized by 26.2.10.1 i2c_m_async_init. This initialization will configure the operation of the I2C master.

The example registers an I/O descriptor and enables the hardware. Then it registers a callback for TX complete, sets the slave address, finally starts a writing operation.

```
static uint8_t I2C_0_example_str[12] = "Hello World!";
```

```
        void I2C_0_tx_complete(struct i2c_m_async_desc *const i2c)
        {
        }
        void I2C_0_example(void)
        {
            struct io_descriptor *I2C_0_io;
            i2c_m_async_get_io_descriptor(&I2C_0, &I2C_0_io);
            i2c_m_async_enable(&I2C_0);

    i2c_m_async_register_callback(&I2C_0, I2C_M_ASYNC_TX_COMPLETE, (FUNC_PT
R)I2C_0_tx_complete);
            i2c_m_async_set_slaveaddr(&I2C_0, 0x12, I2C_M_SEVEN);
            io_write(I2C_0_io, I2C_0_example_str, 12);
        }
```

26.2.5 Dependencies

- The I2C master peripheral and its related I/O lines and clocks
- The NVIC must be configured so that I2C interrupt requests are periodically serviced

26.2.6 Structs

26.2.6.1 i2c_m_async_status Struct

I2C status.

Members

flags	Status flags
left	The number of characters left in the message buffer

26.2.6.2 i2c_m_async_callback Struct

I2C master callback pointers structure.

Members

error

tx_complete

rx_complete

26.2.6.3 i2c_m_async_desc Struct

I2C descriptor structure, embed i2c_device & i2c_interface.

Members

device

io

i2c_cb

slave_addr

26.2.7 Defines

26.2.7.1 I2C_M_MAX_RETRY

#define I2C_M_MAX_RETRY( ) 1

26.2.8 Enums

26.2.8.1 i2c_m_async_callback_type Enum

I2C_M_ASYNC_ERROR

I2C_M_ASYNC_TX_COMPLETE

I2C_M_ASYNC_RX_COMPLETE

26.2.9 Typedefs

26.2.9.1 i2c_complete_cb_t typedef

typedef void(* i2c_complete_cb_t) (struct i2c_m_async_desc *const i2c)

The I2C master callback function type for completion of RX or TX.

26.2.9.2 i2c_error_cb_t typedef

typedef void(* i2c_error_cb_t) (struct i2c_m_async_desc *const i2c, int32_t error)

The I2C master callback function type for error.

26.2.10 Functions

26.2.10.1 i2c_m_async_init

Initialize the asynchronous I2C master interface.

```
int32_t i2c_m_async_init(
    struct i2c_m_async_desc *const i2c,
    void *const hw
)
```

This function initializes the given I2C descriptor to be used as asynchronous I2C master interface descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

hw Type: void *const

The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

26.2.10.2 i2c_m_async_deinit

Deinitialize asynchronous I2C master interface.

```
int32_t i2c_m_async_deinit(
    struct i2c_m_async_desc *const i2c
)
```

This function deinitializes the given asynchronous I2C master descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

Returns

Type: int32_t

De-initialization status.

-1 The passed parameters were invalid or the interface is already deinitialized

0 The de-initialization is completed successfully

26.2.10.3 i2c_m_async_set_slaveaddr

Set the slave device address.

```
int32_t i2c_m_async_set_slaveaddr(
    struct i2c_m_async_desc *const i2c,
    int16_t addr,
    int32_t addr_len
)
```

This function sets the next transfer target slave I2C device address. It takes no effect to an already started access.

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

addr Type: int16_t

The slave address to access

addr_len Type: int32_t

The slave address length, can be I2C_M_TEN or I2C_M_SEVEN

Returns

Type: int32_t

Masked slave address. The mask is maximum a 10-bit address, and the 10th bit set if 10-bit address is used

26.2.10.4 i2c_m_async_register_callback

Register callback function.

```
int32_t i2c_m_async_register_callback(
    struct i2c_m_async_desc *const i2c,
    enum i2c_m_async_callback_type type,
    FUNC_PTR func
)
```

This function registers one callback function to the I2C master device specified by the given descriptor

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

type Type: enum 26.2.8.1 i2c_m_async_callback_type Enum

Type of a callback to set

func Type: 40.3.2.1 FUNC_PTR typedef

Callback function pointer

Returns

Type: int32_t

Callback setting status

-1 The passed parameters were invalid

0 The callback set is completed successfully

26.2.10.5 i2c_m_async_set_baudrate

Set baudrate.

```
int32_t i2c_m_async_set_baudrate(
    struct i2c_m_async_desc *const i2c,
    uint32_t clkrate,
    uint32_t baudrate
)
```

This function sets the I2C master device to a specified baudrate. It only takes effect when the hardware is disabled.

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

clkrate Type: uint32_t

Unused parameter, should always be 0

baudrate Type: uint32_t

The baudrate value set to master

Returns

Type: int32_t

The status whether successfully set the baudrate

-1 The passed parameters were invalid or the device is already enabled

0 The baudrate set is completed successfully

26.2.10.6 i2c_m_async_enable

Async version of enable hardware.

```
int32_t i2c_m_async_enable(
    struct i2c_m_async_desc *const i2c
)
```

This function enables the I2C master device and then waits for this enabling operation to be done.

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

Returns

Type: int32_t

The status whether successfully enabled

-1 The passed parameters were invalid or the device enable failed

0 The hardware enabling is completed successfully

26.2.10.7 i2c_m_async_disable

Async version of disable hardware.

```
int32_t i2c_m_async_disable(
    struct i2c_m_async_desc *const i2c
)
```

This function disables the I2C master device and then waits for this disabling operation to be done.

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

Returns

Type: int32_t

The status whether successfully disabled

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-1 The passed parameters were invalid or the device disable failed

0 The hardware disabling is completed successfully

26.2.10.8 i2c_m_async_cmd_write

Async version of the write command to I2C slave.

```
int32_t i2c_m_async_cmd_write(
    struct i2c_m_async_desc *const i2c,
    uint8_t reg,
    uint8_t value
)
```

This function will write the value to a specified register in the I2C slave device, and then return before the last sub-operation is done.

The sequence of this routine is sta->address(write)->ack->reg address->ack->resta->address(write)->ack->reg value->nack->stt

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

reg Type: uint8_t

The internal address/register of the I2C slave device

value Type: uint8_t

The value write to the I2C slave device

Returns

Type: int32_t

The status whether successfully write to the device

<0 The passed parameters were invalid or write fail

0 Writing to register is completed successfully

26.2.10.9 i2c_m_async_cmd_read

Async version of read register value from the I2C slave.

```
int32_t i2c_m_async_cmd_read(
    struct i2c_m_async_desc *const i2c,
    uint8_t reg,
    uint8_t * value
)
```

This function will read a byte value from a specified reg in the I2C slave device and then return before the last sub-operation is done.

The sequence of this routine is sta->address(write)->ack->reg address->ack->resta->address(read)->ack->reg value->nack->stt

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

reg Type: uint8_t

The internal address/register of the I2C slave device

value Type: uint8_t *

The value read from the I2C slave device

Returns

Type: int32_t

The status whether successfully read from the device

<0 The passed parameters were invalid or read fail

0 Reading from register is completed successfully

26.2.10.10 i2c_m_async_transfer

Async version of transfer message to/from I2C slave.

```
int32_t i2c_m_async_transfer(
    struct i2c_m_async_desc *const i2c,
    struct _i2c_m_msg * msg
)
```

This function will transfer a message between the I2C slave and the master. This function will not wait for the transfer to complete.

Parameters

i2c Type: struct 26.2.6.3 i2c_m_async_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

msg Type: struct _i2c_m_msg *

An i2c_m_msg struct

Returns

Type: int32_t

The status of the operation

0 Operation completed successfully

<0 Operation failed

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26.2.10.11 i2c_m_async_send_stop

Generate stop condition on the I2C bus.

```
int32_t i2c_m_async_send_stop(
    struct i2c_m_async_desc *const i2c
)
```

This function will generate a stop condition on the I2C bus

Parameters

i2c	Type: struct 26.2.6.3 i2c_m_async_desc Struct *const An I2C master descriptor, which is used to communicate through I2C

Returns

Type: int32_t

Operation status

0	Operation executed successfully
<0	Operation failed

26.2.10.12 i2c_m_async_get_status

Returns the status during the transfer.

```
int32_t i2c_m_async_get_status(
    struct i2c_m_async_desc *const i2c,
    struct i2c_m_async_status * stat
)
```

Parameters

i2c	Type: struct 26.2.6.3 i2c_m_async_desc Struct *const An i2c descriptor which is used to communicate through I2C
stat	Type: struct 26.2.6.1 i2c_m_async_status Struct * Pointer to the detailed status descriptor, set to NULL

Returns

Type: int32_t

Status of transfer

0	No error detected
<0	Error code

26.2.10.13 i2c_m_async_get_io_descriptor

Return I/O descriptor for this I2C instance.

```
int32_t i2c_m_async_get_io_descriptor(
    struct i2c_m_async_desc *const i2c,
```

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```
    struct io_descriptor ** io
)
```

This function will return an I/O instance for this I2C driver instance

Parameters

i2c	Type: struct 26.2.6.3 i2c_m_async_desc Struct *const An I2C master descriptor, which is used to communicate through I2C
io	Type: struct 25.2.1.1 io_descriptor Struct ** A pointer to an I/O descriptor pointer type

Returns
Type: int32_t

Error code

0	No error detected
<0	Error code

26.2.10.14 i2c_m_get_version

Retrieve the current driver version.

```
uint32_t i2c_m_get_version(
    void
)
```

Returns
Type: uint32_t

Current driver version.

26.3 I2C Master RTOS Driver

The driver is intended to use I2C master functions in a Real-Time operating system, i.e. is thread safe.

The stop condition is automatically controlled by the driver if the I/O write and read functions are used, but can be manually controlled by using the 26.3.7.7 i2c_m_os_transfer function.

The transfer functions of the I2C Master RTOS driver are optimized for RTOS support. When data transfer is in progress, the transfer functions use semaphore to block the current task or thread until the transfer end. So the transfer functions do not work without RTOS, the transfer functions must be called in an RTOS task or thread.

During data transfer, the I2C transfer process is not protected, so that a more flexible way can be chosen in the application.

I2C Modes (standard mode/fastmode+/highspeed mode) can only be selected in START. If the SCL frequency (baudrate) has changed run-time, make sure to stick within the SCL clock frequency range supported by the selected mode. The requested SCL clock frequency is not validated by the 26.3.7.4 i2c_m_os_set_baudrate function against the selected I2C mode.

26.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable I2C master
- Hookup callback handlers on TX complete, RX complete, and error events
- Set the address of the slave device
- Read/Write message to/from the slave

26.3.2 Summary of Configuration Options

Below is a list of the main I2C master parameters that can be configured in START. Many of these parameters are used by the 26.3.7.1 i2c_m_os_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions, such as 26.3.7.4 i2c_m_os_set_baudrate.

- Set I2C bus clock speed
- Which clock source is used

26.3.3 Driver Implementation Description

After I2C hardware initialization, the 26.3.7.9 i2c_m_os_get_io function is needed to register an I/O descriptor. Then the application needs to set the slave address by the 26.3.7.3 i2c_m_os_set_slaveaddr function. At the end, start the read/write operation.

26.3.3.1 Limitations

- System Management Bus (SMBus) is not supported
- Power Management Bus (PMBus) is not supported
- The register value for the requested I2C speed is calculated and placed in the correct register, but not validated if it works correctly with the clock/prescaler settings used for the module. To validate the I2C speed setting use the formula found in the configuration file for the module. Selectable speed is automatically limited within the speed range defined by the I2C mode selected

26.3.4 Example of Usage

The following shows a simple example of using the I2C master. The I2C master must have been initialized by 26.3.7.1 i2c_m_os_init. This initialization will configure the operation of the I2C master.

The example registers an I/O descriptor and sets the slave address, and finally starts a writing operation.

The example creates an I2C master example task. In the task, it registers an I/O descriptor for an I2C instance, then sets the slave address. Here we assume that the I2C device is a 0AT30TSE temperature sensor on an I/O1 Xplained Pro connected to an Xplained board. Write the data to the slave device, and the RTOS task scheduler starts to read the data from the slave device.

```
        /**
         * Example task of using I2C_0 to echo using the I/O abstraction.
 * Assume the I2C device is AT30TSE temp sensor on IO1 Xplained Pro connect
ed to
         * XPlained board.
         */
        void I2C_example_task(void *p)
        {
            struct io_descriptor *io;
```

```
            uint16_t              data;
            uint8_t               buf[2];
            (void)p;
            i2c_m_os_get_io(&I2C_0, &io);
            /* Address of the temp sensor. */
            i2c_m_os_set_slaveaddr(&I2C_0, 0x4f, 0);
            /* Set configuration to use 12-bit temperature */
            buf[0] = 1;
            buf[1] = 3 << 5;
            io_write(&I2C_0.io, buf, 2);
            /* Set to temperature register. */
            buf[0] = 0;
            io_write(&I2C_0.io, buf, 1);
            for (;;) {
                if (io->read(io, (uint8_t *)&data, 2) == 2) {
                    /* read OK, handle data. */;
                } else {
                    /* error. */;
                }
            }
        }
        #define TASK_TRANSFER_STACK_SIZE            ( 256/
sizeof( portSTACK_TYPE ))

#define TASK_TRANSFER_STACK_PRIORITY        ( tskIDLE_PRIORITY + 0 )
        static TaskHandle_t xCreatedTransferTask;
        static void task_transfer_create(void)
        {
            /* Create the task that handles the CLI. */

    if (xTaskCreate(I2C_example_task, "transfer", TASK_TRANSFER_STACK_SIZE,
 NULL,
            TASK_TRANSFER_STACK_PRIORITY, &xCreatedTransferTask) !
= pdPASS) {
                while(1) {;
                }
            }
        }
        static void tasks_run(void)
        {
            vTaskStartScheduler();
        }
        int main(void)
        {
            /* Initializes MCU, drivers and middleware */
            atmel_start_init();
            task_transfer_create();
            tasks_run();
            /* Replace with your application code */
            while (1) {
            }
        }
```

26.3.5 Dependencies

- The I2C master peripheral and its related I/O lines and clocks
- The NVIC must be configured so that I2C interrupt requests are periodically serviced
- RTOS

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26.3.6 Structs

26.3.6.1 i2c_m_os_desc Struct

I2C descriptor structure, embed i2c_device & i2c_interface.

Members

device

io

xfer_sem

slave_addr

error

26.3.7 Functions

26.3.7.1 i2c_m_os_init

Initialize I2C master interface.

```
int32_t i2c_m_os_init(
    struct i2c_m_os_desc *const i2c,
    void *const hw
)
```

This function initializes the given I2C descriptor to be used as an RTOS I2C master interface descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate

hw Type: void *const

The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

-1 The passed parameters were invalid or already initialized

0 The initialization is completed successfully

26.3.7.2 i2c_m_os_deinit

Deinitialize I2C master interface.

```
int32_t i2c_m_os_deinit(
    struct i2c_m_os_desc *const i2c
)
```

This function deinitializes the given RTOS I2C master descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

Returns

Type: int32_t

De-initialization status.

-1 The passed parameters were invalid or the interface is already deinitialized

0 The de-initialization is completed successfully

26.3.7.3 i2c_m_os_set_slaveaddr

Set the slave device address.

```
int32_t i2c_m_os_set_slaveaddr(
    struct i2c_m_os_desc *const i2c,
    int16_t addr,
    int32_t addr_len
)
```

This function sets the next transfer target slave I2C device address. It takes no effect to any already started access.

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

addr Type: int16_t

The slave address to access

addr_len Type: int32_t

The slave address length, can be I2C_M_TEN or I2C_M_SEVEN

Returns

Type: int32_t

Masked slave address, the mask is a maximum 10-bit address, and the 10th bit is set if a 10-bit address is used

26.3.7.4 i2c_m_os_set_baudrate

Set baudrate.

```
int32_t i2c_m_os_set_baudrate(
    struct i2c_m_os_desc *const i2c,
    uint32_t clkrate,
    uint32_t baudrate
)
```

This function sets the I2C master device to a specified baudrate, and it only takes effect when the hardware is disabled

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

clkrate Type: uint32_t

Unused parameter, should always be 0

baudrate Type: uint32_t

The baudrate value set to master

Returns

Type: int32_t

The status whether successfully set the baudrate

-1 The passed parameters were invalid or the device is already enabled

0 The baudrate set is completed successfully

26.3.7.5 i2c_m_os_enable

Enable hardware.

```
int32_t i2c_m_os_enable(
    struct i2c_m_os_desc *const i2c
)
```

This function enables the I2C master device and then waits for this enabling operation to be done

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

Returns

Type: int32_t

The status whether successfully enable the device

-1 The passed parameters were invalid or the device enable failed

0 The hardware enabling is completed successfully

26.3.7.6 i2c_m_os_disable

Disable hardware.

```
int32_t i2c_m_os_disable(
    struct i2c_m_os_desc *const i2c
)
```

This function disables the I2C master device and then waits for this disabling operation to be done

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

Returns

Type: int32_t

The status whether successfully disable the device

-1 The passed parameters were invalid or the device disable failed

0 The hardware disabling is completed successfully

26.3.7.7 i2c_m_os_transfer

Async version of transfer message to/from I2C slave.

```
int32_t i2c_m_os_transfer(
    struct i2c_m_os_desc *const i2c,
    struct _i2c_m_msg * msg,
    int n
)
```

This function will transfer messages between the I2C slave and the master. The function will wait for the transfer to complete.

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

msg Type: struct _i2c_m_msg *

An _i2c_m_msg struct array

n Type: int

The number of msgs in the array

Returns

Type: int32_t

The status of the operation

0 Operation completed successfully

<0 Operation failed

26.3.7.8 i2c_m_os_send_stop

Generate stop condition on the I2C bus.

```
int32_t i2c_m_os_send_stop(
    struct i2c_m_os_desc *const i2c
)
```

This function will generate a stop condition on the I2C bus

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

Returns

Type: int32_t

Operation status

0	Operation executed successfully
<0	Operation failed

26.3.7.9 i2c_m_os_get_io

Return I/O descriptor for this I2C instance.

```
static int32_t i2c_m_os_get_io(
    struct i2c_m_os_desc *const i2c,
    struct io_descriptor ** io
)
```

This function will return a I/O instance for this I2C driver instance

Parameters

i2c Type: struct 26.3.6.1 i2c_m_os_desc Struct *const

An I2C master descriptor, which is used to communicate through I2C

io Type: struct 25.2.1.1 io_descriptor Struct **

A pointer to an I/O descriptor pointer type

Returns

Type: int32_t

Error code

0	No error detected
<0	Error code

26.3.7.10 i2c_m_get_version

Retrieve the current driver version.

```
uint32_t i2c_m_get_version(
    void
)
```

Returns

Type: uint32_t

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Current driver version.

26.4 I2C Master Synchronous Driver

The functions in the Inter-Integrated Circuit (I2C) Master synchronous driver provide an interface to read/ write the data from/to the slave device.

The stop condition is automatically controlled by the driver if the I/O write and read functions are used, but can be manually controlled by using the 26.4.8.9 i2c_m_sync_transfer function.

Often a master accesses different information in the slave by accessing different registers in the slave. This is done by first sending a message to the target slave containing the register address, followed by a repeated start condition (no stop condition in between) ending with transferring the register data. This scheme is supported by the 26.4.8.7 i2c_m_sync_cmd_write and 26.4.8.8 i2c_m_sync_cmd_read function, but limited to 8-bit register addresses.

I2C Modes (standard mode/fastmode+/highspeed mode) can only be selected in START. If the SCL frequency (baudrate) has changed run-time, make sure to stick within the SCL clock frequency range supported by the selected mode. The requested SCL clock frequency is not validated by the 26.4.8.4 i2c_m_sync_set_baudrate function against the selected I2C mode.

26.4.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable the I2C master
- Set the address of the slave device
- Read/Write message to/from the slave

26.4.2 Summary of Configuration Options

Below is a list of the main I2C master parameters that can be configured in START. Many of these parameters are used by the 26.4.8.1 i2c_m_sync_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions, such as 26.4.8.4 i2c_m_sync_set_baudrate.

- Set I2C bus clock speed
- Which clock source is used

26.4.3 Driver Implementation Description

After the I2C hardware initialization, the 26.4.8.11 i2c_m_sync_get_io_descriptor function is needed to register an I/O descriptor. Then enable the I2C hardware, and use the 26.4.8.3 i2c_m_sync_set_slaveaddr function to set the slave address. At the end, start the read/write operation.

26.4.4 Example of Usage

The following shows a simple example of using the I2C master. The I2C master must have been initialized by 26.4.8.1 i2c_m_sync_init. This initialization will configure the operation of the I2C master.

26.4.4.1 Limitations

- System Management Bus (SMBus) is not supported
- Power Management Bus (PMBus) is not supported

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- The register value for the requested I2C speed is calculated and placed in the correct register, but not validated if it works correctly with the clock/prescaler settings used for the module. To validate the I2C speed setting use the formula found in the configuration file for the module. Selectable speed is automatically limited within the speed range defined by the I2C mode selected

The example enables the I2C master, and finally starts a writing operation to the slave.

```
void I2C_0_example(void)
{    struct io_descriptor *I2C_0_io;     i2c_m_sync_get_io_descriptor(&I2C_0
, &I2C_0_io);    i2c_m_sync_enable(&I2C_0);    i2c_m_sync_set_slaveaddr(&I2
C_0, 0x12, I2C_M_SEVEN);    io_write(I2C_0_io, (uint8_t *)"Hello World!", 1
2);}
```

26.4.5 Dependencies

- The I2C master peripheral and its related I/O lines and clocks

26.4.6 Structs

26.4.6.1 i2c_m_sync_desc Struct

I2C descriptor structure, embed i2c_device & i2c_interface.

Members

device

io

slave_addr

26.4.7 Defines

26.4.7.1 I2C_M_MAX_RETRY

#define I2C_M_MAX_RETRY( ) 1

26.4.8 Functions

26.4.8.1 i2c_m_sync_init

Initialize synchronous I2C interface.

```
int32_t i2c_m_sync_init(
    struct i2c_m_sync_desc * i2c,
    void * hw
)
```

This function initializes the given I/O descriptor to be used as a synchronous I2C interface descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

i2c Type: struct 26.4.6.1 i2c_m_sync_desc Struct *

An I2C descriptor, which is used to communicate through I2C

hw Type: void *

The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

-1 The passed parameters were invalid or the interface is already initialized

0 The initialization is completed successfully

26.4.8.2 i2c_m_sync_deinit

Deinitialize I2C interface.

```
int32_t i2c_m_sync_deinit(
    struct i2c_m_sync_desc * i2c
)
```

This function deinitializes the given I/O descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

i2c Type: struct 26.4.6.1 i2c_m_sync_desc Struct *

An I2C descriptor, which is used to communicate through I2C

Returns

Type: int32_t

Uninitialization status.

-1 The passed parameters were invalid or the interface is already deinitialized

0 The de-initialization is completed successfully

26.4.8.3 i2c_m_sync_set_slaveaddr

Set the slave device address.

```
int32_t i2c_m_sync_set_slaveaddr(
    struct i2c_m_sync_desc * i2c,
    int16_t addr,
    int32_t addr_len
)
```

This function sets the next transfer target slave I2C device address. It takes no effect to any already started access.

Parameters

i2c Type: struct 26.4.6.1 i2c_m_sync_desc Struct *

An I2C descriptor, which is used to communicate through I2C

addr Type: int16_t

The slave address to access

addr_len Type: int32_t

The slave address length, can be I2C_M_TEN or I2C_M_SEVEN

Returns

Type: int32_t

Masked slave address. The mask is a maximum 10-bit address, and 10th bit is set if a 10-bit address is used

26.4.8.4 i2c_m_sync_set_baudrate

Set baudrate.

```
int32_t i2c_m_sync_set_baudrate(
    struct i2c_m_sync_desc * i2c,
    uint32_t clkrate,
    uint32_t baudrate
)
```

This function sets the I2C device to the specified baudrate. It only takes effect when the hardware is disabled.

Parameters

i2c	Type: struct 26.4.6.1 i2c_m_sync_desc Struct * An I2C descriptor, which is used to communicate through I2C
clkrate	Type: uint32_t Unused parameter. Should always be 0
baudrate	Type: uint32_t The baudrate value set to master

Returns

Type: int32_t

Whether successfully set the baudrate

-1	The passed parameters were invalid or the device is already enabled
0	The baudrate set is completed successfully

26.4.8.5 i2c_m_sync_enable

Sync version of enable hardware.

```
int32_t i2c_m_sync_enable(
    struct i2c_m_sync_desc * i2c
)
```

This function enables the I2C device, and then waits for this enabling operation to be done

Parameters

i2c	Type: struct 26.4.6.1 i2c_m_sync_desc Struct *

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An I2C descriptor, which is used to communicate through I2C

Returns

Type: int32_t

Whether successfully enable the device

-1 The passed parameters were invalid or the device enable failed

0 The hardware enabling is completed successfully

26.4.8.6 i2c_m_sync_disable

Sync version of disable hardware.

```
int32_t i2c_m_sync_disable(
    struct i2c_m_sync_desc * i2c
)
```

This function disables the I2C device and then waits for this disabling operation to be done

Parameters

i2c Type: struct 26.4.6.1 i2c_m_sync_desc Struct *

An I2C descriptor, which is used to communicate through I2C

Returns

Type: int32_t

Whether successfully disable the device

-1 The passed parameters were invalid or the device disable failed

0 The hardware disabling is completed successfully

26.4.8.7 i2c_m_sync_cmd_write

Sync version of write command to I2C slave.

```
int32_t i2c_m_sync_cmd_write(
    struct i2c_m_sync_desc * i2c,
    uint8_t reg,
    uint8_t * buffer,
    uint8_t length
)
```

This function will write the value to a specified register in the I2C slave device and then wait for this operation to be done.

The sequence of this routine is sta->address(write)->ack->reg address->ack->resta->address(write)->ack->reg value->nack->stt

Parameters

i2c Type: struct 26.4.6.1 i2c_m_sync_desc Struct *

An I2C descriptor, which is used to communicate through I2C

reg Type: uint8_t

The internal address/register of the I2C slave device

buffer Type: uint8_t *

The buffer holding data to write to the I2C slave device

length Type: uint8_t

The length (in bytes) to write to the I2C slave device

Returns

Type: int32_t

Whether successfully write to the device

<0 The passed parameters were invalid or write fail

0 Writing to register is completed successfully

26.4.8.8 i2c_m_sync_cmd_read

Sync version of read register value from I2C slave.

```
int32_t i2c_m_sync_cmd_read(
    struct i2c_m_sync_desc * i2c,
    uint8_t reg,
    uint8_t * buffer,
    uint8_t length
)
```

This function will read a byte value from a specified register in the I2C slave device and then wait for this operation to be done.

The sequence of this routine is sta->address(write)->ack->reg address->ack->resta->address(read)->ack->reg value->nack->stt

Parameters

i2c Type: struct 26.4.6.1 i2c_m_sync_desc Struct *

An I2C descriptor, which is used to communicate through I2C

reg Type: uint8_t

The internal address/register of the I2C slave device

buffer Type: uint8_t *

The buffer to hold the read data from the I2C slave device

length Type: uint8_t

The length (in bytes) to read from the I2C slave device

Returns
Type: int32_t

Whether successfully read from the device

<0	The passed parameters were invalid or read fail
0	Reading from register is completed successfully

26.4.8.9 i2c_m_sync_transfer

Sync version of transfer message to/from the I2C slave.

```
int32_t i2c_m_sync_transfer(
    struct i2c_m_sync_desc *const i2c,
    struct _i2c_m_msg * msg
)
```

This function will transfer a message between the I2C slave and the master. This function will wait for the operation to be done.

Parameters

i2c	Type: struct 26.4.6.1 i2c_m_sync_desc Struct *const An I2C descriptor, which is used to communicate through I2C
msg	Type: struct _i2c_m_msg * An i2c_m_msg struct

Returns
Type: int32_t

The status of the operation

0	Operation completed successfully
<0	Operation failed

26.4.8.10 i2c_m_sync_send_stop

Sync version of send stop condition on the i2c bus.

```
int32_t i2c_m_sync_send_stop(
    struct i2c_m_sync_desc *const i2c
)
```

This function will create a stop condition on the i2c bus to release the bus

Parameters

i2c	Type: struct 26.4.6.1 i2c_m_sync_desc Struct *const An I2C descriptor, which is used to communicate through I2C

Returns
Type: int32_t

The status of the operation

0	Operation completed successfully
<0	Operation failed

26.4.8.11 i2c_m_sync_get_io_descriptor

Return I/O descriptor for this I2C instance.

```
int32_t i2c_m_sync_get_io_descriptor(
    struct i2c_m_sync_desc *const i2c,
    struct io_descriptor ** io
)
```

This function will return a I/O instance for this I2C driver instance

Parameters

i2c_m_sync_desc	An I2C descriptor, which is used to communicate through I2C
io_descriptor	A pointer to an I/O descriptor pointer type

Returns

Type: int32_t

Error code

0	No error detected
<0	Error code

26.4.8.12 i2c_m_sync_get_version

Retrieve the current driver version.

```
uint32_t i2c_m_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

26.5 I2C Slave Asynchronous Driver

In Inter-Integrated Circuit (I2C) slave asynchronous driver, a callback function can be registered in the driver by the application and triggered when the transfer is done. The driver 25.2.3.2 io_read/io_write() function will attempt to read/write the data from/to the master device.

I2C Modes (standard mode/fastmode+/highspeed mode) can only be selected in START. Make sure that the selected speed mode is within the expected SCL clock frequency range of the i2c bus.

The error callback is executed as soon as an error is detected by the hardware.

The RX callback is invoked each time a byte is received by an I2C slave device, the byte is put into the ring buffer prior to the callback calling. Received data can be read out in the callback via the I/O read function.

The TX pending callback is invoked when a master device requests data from a slave device via sending slave device address with R/W bit set to one. A slave device can send data to a master device via the I/O write function.

The TX callback is invoked at the end of buffer transfer caused by a call to the I/O write function.

26.5.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register the I/O descriptor
- Enable or disable the I2C slave
- Hookup callback handlers on TX complete, RX complete, or error events
- Set the address of the slave device
- Read/Write message to/from the master

26.5.2 Summary of Configuration Options

Below is a list of the main I2C slave parameters that can be configured in START. Many of these parameters are used by the 26.5.9.1 i2c_s_async_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden.

- Set I2C slave device address
- Which clock source is used

26.5.3 Driver Implementation Description

After the I2C hardware initialization, the 26.5.9.7 i2c_s_async_get_io_descriptor function is needed to register an I/O descriptor. Then use 26.5.9.4 i2c_s_async_register_callback to register the callback function for RX/TX complete, and enable the I2C hardware. At the end, start the read/write operation.

26.5.3.1 Limitations

- System Management Bus (SMBus) is not supported
- Power Management Bus (PMBus) is not supported
- During the write operation the buffer content should not be changed before the transfer is complete

26.5.4 Example of Usage

The following shows a simple example of using the I2C slave. The I2C slave must have been initialized by 26.5.9.1 i2c_s_async_init. This initialization will configure the operation of the I2C slave.

The example registers an I/O descriptor and enables the hardware. Then it registers a callback for RX complete, and finally starts a reading operation.

```
        static struct io_descriptor *io;

static void I2C_0_rx_complete(const struct i2c_s_async_descriptor *const de
scr)
        {
            uint8_t c;
            io_read(io, &c, 1);
        }
```

```
        void I2C_0_example(void)
        {
            i2c_s_async_get_io_descriptor(&I2C_0, &io);

    i2c_s_async_register_callback(&I2C_0, I2C_S_RX_COMPLETE, I2C_0_rx_compl
ete);
            i2c_s_async_enable(&I2C_0);
        }
```

26.5.5 Dependencies

- The I2C slave peripheral and its related I/O lines and clocks
- The NVIC must be configured so that I2C interrupt requests are periodically serviced

26.5.6 Structs

26.5.6.1 i2c_s_async_callbacks Struct

i2c callback pointers structure

Members

error

tx_pending

tx

rx

26.5.6.2 i2c_s_async_descriptor Struct

I2C slave descriptor structure.

Members

device

io

cbs

rx

tx_buffer

tx_buffer_length

tx_por

26.5.7 Enums

26.5.7.1 i2c_s_async_callback_type Enum

I2C_S_ERROR

I2C_S_TX_PENDING

I2C_S_TX_COMPLETE

I2C_S_RX_COMPLETE

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26.5.8 Typedefs

26.5.8.1 i2c_s_async_cb_t typedef

typedef void(* i2c_s_async_cb_t) (const struct i2c_s_async_descriptor *const descr)

I2C slave callback function type.

26.5.9 Functions

26.5.9.1 i2c_s_async_init

Initialize asynchronous I2C slave interface.

```
int32_t i2c_s_async_init(
    struct i2c_s_async_descriptor *const descr,
    void *const hw,
    uint8_t *const rx_buffer,
    const uint16_t rx_buffer_length
)
```

This function initializes the given I2C descriptor to be used as asynchronous I2C slave interface descriptor. It checks if the given hardware is not initialized and if it is permitted to be initialized.

Parameters

descr	Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const An I2C slave descriptor which is used to communicate through I2C
hw	Type: void *const The pointer to hardware instance
rx_buffer	Type: uint8_t *const An RX buffer
rx_buffer_length	Type: const uint16_t The length of the buffer above

Returns

Type: int32_t

Initialization status.

26.5.9.2 i2c_s_async_deinit

Deinitialize asynchronous I2C slave interface.

```
int32_t i2c_s_async_deinit(
    struct i2c_s_async_descriptor *const descr
)
```

This function deinitializes the given asynchronous I2C slave descriptor. It checks if the given hardware is initialized and if it is permitted to be deinitialized.

Parameters

descr	Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const

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An I2C slave descriptor which is used to communicate through I2C

Returns

Type: int32_t

De-initialization status.

26.5.9.3 i2c_s_async_set_addr

Set the device address.

```
int32_t i2c_s_async_set_addr(
    struct i2c_s_async_descriptor *const descr,
    const uint16_t addr
)
```

This function sets the I2C slave device address.

Parameters

descr Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through I2C

address An address

Returns

Type: int32_t

Status of address setting.

26.5.9.4 i2c_s_async_register_callback

Register callback function.

```
int32_t i2c_s_async_register_callback(
    struct i2c_s_async_descriptor *const descr,
    const enum i2c_s_async_callback_type type,
    i2c_s_async_cb_t func
)
```

This function registers callback functions to the I2C slave device specified by the given descriptor

Parameters

descr Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through I2C

type Type: const enum 26.5.7.1 i2c_s_async_callback_type Enum

Type of a callback to set

func Type: 26.5.8.1 i2c_s_async_cb_t typedef

Callback function pointer

Returns

Type: int32_t

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Callback setting status.

-1 Passed parameters were invalid

0 The callback set is completed successfully

26.5.9.5 i2c_s_async_enable

Enable I2C slave communication.

```
int32_t i2c_s_async_enable(
    struct i2c_s_async_descriptor *const descr
)
```

This function enables the I2C slave device

Parameters

descr Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through I2C

Returns

Type: int32_t

Enabling status.

26.5.9.6 i2c_s_async_disable

Disable I2C slave communication.

```
int32_t i2c_s_async_disable(
    struct i2c_s_async_descriptor *const descr
)
```

This function disables the I2C slave device

Parameters

descr Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through I2C

Returns

Type: int32_t

Disabling status

26.5.9.7 i2c_s_async_get_io_descriptor

Retrieve I/O descriptor.

```
int32_t i2c_s_async_get_io_descriptor(
    struct i2c_s_async_descriptor *const descr,
    struct io_descriptor ** io
)
```

This function returns a I/O instance for the given I2C slave driver instance

Parameters

descr Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through I2C

io Type: struct 25.2.1.1 io_descriptor Struct **

A pointer to an I/O descriptor pointer type

Returns

Type: int32_t

I/O retrieving status.

26.5.9.8 i2c_s_async_get_bytes_received

Retrieve the number of received bytes in the buffer.

```
int32_t i2c_s_async_get_bytes_received(
    const struct i2c_s_async_descriptor *const descr
)
```

This function retrieves the number of received bytes which were not read out

Parameters

descr Type: const struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through

Returns

Type: int32_t

The amount of bytes received

26.5.9.9 i2c_s_async_get_bytes_sent

Retrieve the number of bytes sent.

```
int32_t i2c_s_async_get_bytes_sent(
    const struct i2c_s_async_descriptor *const descr
)
```

This function retrieves the number of sent bytes for the last write operation

Parameters

descr Type: const struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through

Returns

Type: int32_t

The amount of bytes sent

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26.5.9.10 i2c_s_async_flush_rx_buffer

Flush received data.

```
int32_t i2c_s_async_flush_rx_buffer(
    struct i2c_s_async_descriptor *const descr
)
```

This function flushes all received data

Parameters

descr Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through

Returns

Type: int32_t

The status of data flushing

26.5.9.11 i2c_s_async_abort_tx

Abort sending.

```
int32_t i2c_s_async_abort_tx(
    struct i2c_s_async_descriptor *const descr
)
```

This function aborts data sending

Parameters

descr Type: struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C slave descriptor which is used to communicate through

Returns

Type: int32_t

The amount of bytes received

26.5.9.12 i2c_s_async_get_status

Retrieve the current interface status.

```
int32_t i2c_s_async_get_status(
    const struct i2c_s_async_descriptor *const descr,
    i2c_s_status_t *const status
)
```

Parameters

descr Type: const struct 26.5.6.2 i2c_s_async_descriptor Struct *const

An I2C descriptor which is used to communicate via USART

status Type: i2c_s_status_t *const

The state of I2C slave

Returns

Type: int32_t

The status of the I2C status retrieving.

26.5.9.13 i2c_s_async_get_version

Retrieve the current driver version.

```
uint32_t i2c_s_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

26.6 I2C Slave Synchronous Driver

The functions in the Inter-Integrated Circuit (I2C) Slave synchronous driver provides an interface to read/write the data from/to the master device. The functions will be blocked until the operation is done.

I2C Modes (standard mode/fastmode+/highspeed mode) can only be selected in START.

26.6.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register the I/O descriptor
- Set the address of the slave device
- Enable or disable the I2C slave
- Read/Write message to/from the master

26.6.2 Summary of Configuration Options

Below is a list of the main I2C slave parameters that can be configured in START. Many of these parameters are used by the 26.6.7.1 i2c_s_sync_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden.

- Set the I2C slave device address
- Which clock source is used

26.6.3 Driver Implementation Description

After the I2C hardware initialization, the 26.6.7.6 i2c_s_sync_get_io_descriptor function is needed to register an I/O descriptor. Then use the 26.6.7.3 i2c_s_sync_set_addr function to set the slave address and enable the I2C hardware. At the end, start the read/write operation.

26.6.3.1 Limitations

- System Management Bus (SMBus) is not supported
- Power Management Bus (PMBus) is not supported

26.6.4 Example of Usage

The following shows a simple example of using the I2C slave. The I2C slave must have been initialized by 26.6.7.1 i2c_s_sync_init. This initialization will configure the operation of the I2C slave.

The example enables the I2C slave, and finally starts a reading operation to the master.

```
void I2C_0_example(void)
{    struct io_descriptor *io;    uint8_t                   c;    i2c_s_sync_ge
t_io_descriptor(&I2C_0, &io);    i2c_s_sync_set_addr(&I2C_0, 1);    i2c_s_s
ync_enable(&I2C_0);    io_read(io, &c, 1);}
```

26.6.5 Dependencies

- The I2C slave peripheral and its related I/O lines and clocks

26.6.6 Structs

26.6.6.1 i2c_s_sync_descriptor Struct

I2C slave descriptor structure.

Members

device

io

26.6.7 Functions

26.6.7.1 i2c_s_sync_init

Initialize synchronous I2C slave interface.

```
int32_t i2c_s_sync_init(
    struct i2c_s_sync_descriptor *const descr,
    void * hw
)
```

This function initializes the given I2C descriptor to be used as synchronous I2C slave interface descriptor. It checks if the given hardware is not initialized and if it is permitted to be initialized.

Parameters

descr Type: struct 26.6.6.1 i2c_s_sync_descriptor Struct *const

An I2C slave descriptor which is used to communicate through I2C

hw Type: void *

The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

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26.6.7.2 i2c_s_sync_deinit

Deinitialize synchronous I2C slave interface.

```
int32_t i2c_s_sync_deinit(
    struct i2c_s_sync_descriptor *const descr
)
```

This function deinitializes the given synchronous I2C slave descriptor. It checks if the given hardware is initialized and if it is permitted to be deinitialized.

Parameters

descr Type: struct 26.6.6.1 i2c_s_sync_descriptor Struct *const

An I2C slave descriptor which is used to communicate through I2C

Returns

Type: int32_t

De-initialization status.

26.6.7.3 i2c_s_sync_set_addr

Set the device address.

```
int32_t i2c_s_sync_set_addr(
    struct i2c_s_sync_descriptor *const descr,
    const uint16_t address
)
```

This function sets the I2C slave device address.

Parameters

descr Type: struct 26.6.6.1 i2c_s_sync_descriptor Struct *const

An I2C slave descriptor which is used to communicate through I2C

address Type: const uint16_t

An address

Returns

Type: int32_t

Status of the address setting.

26.6.7.4 i2c_s_sync_enable

Enable I2C slave communication.

```
int32_t i2c_s_sync_enable(
    struct i2c_s_sync_descriptor *const descr
)
```

This function enables the I2C slave device

Parameters

descr	Type: struct 26.6.6.1 i2c_s_sync_descriptor Struct *const An I2C slave descriptor which is used to communicate through I2C

Returns

Type: int32_t

Enabling status.

26.6.7.5 i2c_s_sync_disable

Disable I2C slave communication.

```
int32_t i2c_s_sync_disable(
    struct i2c_s_sync_descriptor *const descr
)
```

This function disables the I2C slave device

Parameters

descr	Type: struct 26.6.6.1 i2c_s_sync_descriptor Struct *const An I2C slave descriptor which is used to communicate through I2C

Returns

Type: int32_t

Disabling status.

26.6.7.6 i2c_s_sync_get_io_descriptor

Retrieve I/O descriptor.

```
int32_t i2c_s_sync_get_io_descriptor(
    struct i2c_s_sync_descriptor *const descr,
    struct io_descriptor ** io
)
```

This function returns a I/O instance for the given I2C slave driver instance

Parameters

descr	Type: struct 26.6.6.1 i2c_s_sync_descriptor Struct *const An I2C slave descriptor which is used to communicate through I2C
io	Type: struct 25.2.1.1 io_descriptor Struct ** A pointer to an I/O descriptor pointer type

Returns

Type: int32_t

I/O retrieving status.

26.6.7.7 i2c_s_sync_get_status

Retrieve the current interface status.

```
int32_t i2c_s_sync_get_status(
    const struct i2c_s_sync_descriptor *const descr,
    i2c_s_status_t *const status
)
```

Parameters

descr
Type: const struct 26.6.6.1 i2c_s_sync_descriptor Struct *const

An i2c descriptor which is used to communicate via USART

status
Type: i2c_s_status_t *const

The state of I2C slave

Returns

Type: int32_t

The status of I2C status retrieving.

26.6.7.8 i2c_s_sync_get_version

Retrieve the current driver version.

```
uint32_t i2c_s_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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27. I2S Controller Driver

The following driver variant is available:

- 27.1 I2S Controller Synchronous Driver: The driver supports polling for hardware changes, functionality is synchronous to the main clock of the MCU.

27.1 I2S Controller Synchronous Driver

The Inter-IC Sound (I2S) module provides a bidirectional, synchronous, and digital audio link for transferring the PCM audio data. The I2S bus has separate clock signals for lower jitter than typical serial buses. When the I2S module is in controller mode it will only provide control signals (MCK, SCK, and FS) on the I2S bus, the data transfer will happen between the separate I2S Transmitter and I2S Receiver slave modules on the same bus.

It's used to generate continuous I2S compatible clock and control signals for I2S slaves such like audio codecs to use.

27.1.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable the I2S controller hardware
- Change clock and control signals settings, including:
  - Serial Clock (SCK) generation
  - Word Select (WS)/Frame Select (FS) generation

27.1.2 Dependencies

- The I2S master/controller capable hardware

27.1.3 Structs

27.1.3.1 i2s_c_sync_desc Struct

Members

dev	HPL device instance for I2S Controller.

27.1.4 Enums

27.1.4.1 i2s_c_iface Enum

I2S_C_IFACE_0	I2S controller interface 0.
I2S_C_IFACE_1	I2S controller interface 1.

27.1.5 Functions

27.1.5.1 i2s_c_sync_init

Initialize the I2S Controller.

```
int32_t i2s_c_sync_init(
    struct i2s_c_sync_desc * i2s,
    const void * hw,
    const enum i2s_c_iface iface
)
```

Parameters

i2s	Type: struct 27.1.3.1 i2s_c_sync_desc Struct * Pointer to the I2S Controller instance.
hw	Type: const void * Pointer to the hardware base.
iface	Type: const enum 27.1.4.1 i2s_c_iface Enum The I2S interface used.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error.

27.1.5.2 i2s_c_sync_deinit

Deinitialize the I2S Controller.

```
void i2s_c_sync_deinit(
    struct i2s_c_sync_desc * i2s
)
```

Parameters

i2s	Type: struct 27.1.3.1 i2s_c_sync_desc Struct * Pointer to the I2S Controller instance.

Returns

Type: void

27.1.5.3 i2s_c_sync_enable

Enable the I2S Controller.

```
int32_t i2s_c_sync_enable(
    struct i2s_c_sync_desc * i2s
)
```

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Parameters

i2s	Type: struct 27.1.3.1 i2s_c_sync_desc Struct * Pointer to the I2S Controller instance.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error.

27.1.5.4 i2s_c_sync_disable

Disable the I2S Controller.

```
void i2s_c_sync_disable(
    struct i2s_c_sync_desc * i2s
)
```

Parameters

i2s	Type: struct 27.1.3.1 i2s_c_sync_desc Struct * Pointer to the I2S Controller instance.

Returns

Type: void

27.1.5.5 i2s_c_sync_set_ws_length

Set the Word Select pulse Length of the I2S Controller.

```
int32_t i2s_c_sync_set_ws_length(
    struct i2s_c_sync_desc * i2s,
    const uint16_t n_sck
)
```

Note that it works only when the I2S Controller is disabled.

Parameters

i2s	Type: struct 27.1.3.1 i2s_c_sync_desc Struct * Pointer to the I2S Controller instance.
n_sck	Type: const uint16_t Describes how many SCK bits generates a Word Select pulse.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error.

27.1.5.6 i2s_c_sync_set_sck_div

Set the SCK division from MCK.

```
int32_t i2s_c_sync_set_sck_div(
    struct i2s_c_sync_desc * i2s,
    const uint32_t n_mck
)
```

Note that it works only when the I2S Controller is disabled.

Parameters

i2s	Type: struct 27.1.3.1 i2s_c_sync_desc Struct * Pointer to the I2S Controller instance.
n_mck	Type: const uint32_t Describes how many MCK bits generates a SCK clock.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error.

27.1.5.7 i2s_c_sync_get_version

Retrieve the current driver version.

```
uint32_t i2s_c_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

28. MCI Drivers

The MCI (Multimedia Card / Memory Card Interface) driver are commonly used in an application for reading and writing SD/MMC/SDIO type card.

The following driver variants are available:

- 28.2 MCI Synchronous Driver: The driver supports polling for hardware changes, functionality is synchronous to the main clock of the MCU.
- 28.1 MCI RTOS Driver: The driver supports a Real-Time operating system, i.e. is thread safe.

28.1 MCI RTOS Driver

The MCI (Multimedia Card / Memory Card Interface) RTOS driver is used for a high level stack implementation, which supports the MultiMedia Card (MMC) Specification V4.3, the SD Memory Card Specification V2.0, and the SDIO V2.0 specification.

The read/write functions of MCI RTOS driver are optimized for RTOS support. When data transfer is in progress, the read/write functions use semaphore to block the current task or thread until transfer end. That is, the read/write functions will not work without RTOS support, the read/write functions should only be called in a RTOS task or thread.

During data read/write, the MCI read/write process is not protected, so that a more flexible way can be chosen in application.

28.1.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Device selection/de-selection
- Send command on the selected slot
- Data transfer: reading, writing

28.1.2 Dependencies

- Multimedia Card / Memory Card Interface capable hardware
- RTOS

28.1.3 Structs

28.1.3.1 mci_os_desc Struct

mci descriptor structure

Members

dev	
xfer_sem	MCI transfer semphore
error	MCI transfer status, 0:no error

28.1.4 Functions

28.1.4.1 mci_os_init

Initialize MCI low level driver.

```
int32_t mci_os_init(
    struct mci_os_desc *const desc,
    void *const hw
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
hw	Type: void *const Mci hardware instance

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

28.1.4.2 mci_os_deinit

Deinitialize MCI low level driver.

```
int32_t mci_os_deinit(
    struct mci_os_desc *const desc
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

28.1.4.3 mci_os_select_device

Select a device and initialize it.

```
int32_t mci_os_select_device(
    struct mci_os_desc *const desc,
```

```
    uint8_t slot,
    uint32_t clock,
    uint8_t bus_width,
    bool high_speed
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
slot	Type: uint8_t Selected slot
clock	Type: uint32_t Maximum clock to use (Hz)
bus_width	Type: uint8_t Bus width to use (1, 4 or 8)
high_speed	Type: bool true, to enable high speed mode

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

28.1.4.4 mci_os_deselect_device

Deselect a device by an assigned slot.

```
int32_t mci_os_deselect_device(
    struct mci_os_desc *const desc,
    uint8_t slot
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
slot	Type: uint8_t Selected slot

Returns

Type: int32_t

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Operation status.

0	Success.
<0	Error code.

28.1.4.5 mci_os_get_bus_width

Get the maximum bus width of a device by a selected slot.

```
uint8_t mci_os_get_bus_width(
    struct mci_os_desc *const desc,
    uint8_t slot
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
slot	Type: uint8_t Selected slot

Returns

Type: uint8_t

bus width.

28.1.4.6 mci_os_is_high_speed_capable

Get the high speed capability of the device.

```
bool mci_os_is_high_speed_capable(
    struct mci_os_desc *const desc
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor

Returns

Type: bool

true, if the high speed is supported.

28.1.4.7 mci_os_send_init_sequence

Send 74 clock cycles on the line.

```
void mci_os_send_init_sequence(
    struct mci_os_desc *const desc
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor

Returns
Type: void

28.1.4.8 mci_os_send_cmd

Send a command on the selected slot.

```
bool mci_os_send_cmd(
    struct mci_os_desc *const desc,
    uint32_t cmd,
    uint32_t arg
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
cmd	Type: uint32_t Command definition
arg	Type: uint32_t Argument of the command

Returns
Type: bool

true if success, otherwise false

28.1.4.9 mci_os_get_response

Get 32 bits response of the last command.

```
uint32_t mci_os_get_response(
    struct mci_os_desc *const desc
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor

Returns
Type: uint32_t

32 bits response.

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28.1.4.10 mci_os_get_response_128

Get 128 bits response of the last command.

```
void mci_os_get_response_128(
    struct mci_os_desc *const desc,
    uint8_t * response
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
response	Type: uint8_t * Pointer on the array to fill with the 128 bits response.

Returns

Type: void

28.1.4.11 mci_os_adtc_start

Send an ADTC command on the selected slot An ADTC (Addressed Data Transfer Commands) command is used for read/write access..

```
bool mci_os_adtc_start(
    struct mci_os_desc *const desc,
    uint32_t cmd,
    uint32_t arg,
    uint16_t block_size,
    uint16_t nb_block,
    bool access_block
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
cmd	Type: uint32_t Command definition.
arg	Type: uint32_t Argument of the command.
block_size	Type: uint16_t Block size used for the transfer.
nb_block	Type: uint16_t Total number of block for this transfer
access_block	Type: bool

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if true, the x_read_blocks() and x_write_blocks() functions must be used after this function. If false, the mci_read_word() and mci_write_word() functions must be used after this function.

Returns

Type: bool

true if success, otherwise false

28.1.4.12 mci_os_adtc_stop

Send a command to stop an ADTC command on the selected slot.

```
bool mci_os_adtc_stop(
    struct mci_os_desc *const desc,
    uint32_t cmd,
    uint32_t arg
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
cmd	Type: uint32_t Command definition
arg	Type: uint32_t Argument of the command

Returns

Type: bool

true if success, otherwise false

28.1.4.13 mci_os_read_bytes

Read a word on the line.

```
bool mci_os_read_bytes(
    struct mci_os_desc *const desc,
    uint32_t * value
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
value	Type: uint32_t * Pointer on a word to fill.

Returns

Type: bool

true if success, otherwise false

28.1.4.14 mci_os_write_bytes

Write a word on the line.

```
bool mci_os_write_bytes(
    struct mci_os_desc *const desc,
    uint32_t value
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
value	Type: uint32_t Word to send

Returns

Type: bool

true if success, otherwise false

28.1.4.15 mci_os_start_read_blocks

Start a read blocks transfer on the line Note: The driver will use the DMA available to speed up the transfer.

```
bool mci_os_start_read_blocks(
    struct mci_os_desc *const desc,
    void * dst,
    uint16_t nb_block
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
dst	Type: void * Pointer on the buffer to fill
nb_block	Type: uint16_t Number of block to transfer

Returns

Type: bool

true if started, otherwise false

28.1.4.16 mci_os_start_write_blocks

Start a write blocks transfer on the line Note: The driver will use the DMA available to speed up the transfer.

```
bool mci_os_start_write_blocks(
    struct mci_os_desc *const desc,
    const void * src,
    uint16_t nb_block
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor
src	Type: const void * Pointer on the buffer to send
nb_block	Type: uint16_t Number of block to transfer

Returns

Type: bool

true if started, otherwise false

28.1.4.17 mci_os_wait_end_of_read_blocks

Wait the end of transfer initiated by mci_start_read_blocks()

```
bool mci_os_wait_end_of_read_blocks(
    struct mci_os_desc *const desc
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor

Returns

Type: bool

true if success, otherwise false

28.1.4.18 mci_os_wait_end_of_write_blocks

Wait the end of transfer initiated by mci_start_write_blocks()

```
bool mci_os_wait_end_of_write_blocks(
    struct mci_os_desc *const desc
)
```

Parameters

desc	Type: struct 28.1.3.1 mci_os_desc Struct *const Mci os descriptor

Returns

Type: bool

true if success, otherwise false

28.1.4.19 mci_os_get_version

Retrieve the current driver version.

```
uint32_t mci_os_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

28.2 MCI Synchronous Driver

The MCI (Multimedia Card / Memory Card Interface) synchronous driver is used for a high level stack implementation, which supports the MultiMedia Card (MMC) Specification V4.3, the SD Memory Card Specification V2.0, and the SDIO V2.0 specification.

28.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Device selection/de-selection
- Send command on the selected slot
- Data transfer: reading, writing

28.2.2 Dependencies

- Multimedia Card / Memory Card Interface capable hardware

28.2.3 Structs

28.2.3.1 mci_sync_desc Struct

MCI descriptor structure.

Members

device

28.2.4 Functions

28.2.4.1 mci_sync_init

Initialize MCI low level driver.

```
int32_t mci_sync_init(
    struct mci_sync_desc * mci,
    void * hw
)
```

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

28.2.4.2 mci_sync_deinit

Deinitialize MCI low level driver.

```
int32_t mci_sync_deinit(
    struct mci_sync_desc * mci
)
```

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

28.2.4.3 mci_sync_select_device

Select a device and initialize it.

```
int32_t mci_sync_select_device(
    struct mci_sync_desc * mci,
    uint8_t slot,
    uint32_t clock,
    uint8_t bus_width,
    bool high_speed
)
```

Parameters

slot	Type: uint8_t Selected slot
clock	Type: uint32_t Maximum clock to use (Hz)
bus_width	Type: uint8_t

	Bus width to use (1, 4, or 8)
high_speed	Type: bool True, to enable high speed mode

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

28.2.4.4 mci_sync_deselect_device

Deselect a device by an assigned slot.

```
int32_t mci_sync_deselect_device(
    struct mci_sync_desc * mci,
    uint8_t slot
)
```

Parameters

slot	Type: uint8_t Selected slot

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

28.2.4.5 mci_sync_get_bus_width

Get the maximum bus width of a device by a selected slot.

```
uint8_t mci_sync_get_bus_width(
    struct mci_sync_desc * mci,
    uint8_t slot
)
```

Parameters

slot	Type: uint8_t Selected slot

Returns

Type: uint8_t

Bus width.

28.2.4.6 mci_sync_is_high_speed_capable

Get the high-speed capability of the device.

```
bool mci_sync_is_high_speed_capable(
    struct mci_sync_desc * mci
)
```

Returns

Type: bool

True, if the high-speed is supported.

28.2.4.7 mci_sync_send_clock

Send 74 clock cycles on the line. Note: It is required after card plug and before card install.

```
void mci_sync_send_clock(
    struct mci_sync_desc * mci
)
```

Returns

Type: void

28.2.4.8 mci_sync_send_cmd

Send a command on the selected slot.

```
bool mci_sync_send_cmd(
    struct mci_sync_desc * mci,
    uint32_t cmd,
    uint32_t arg
)
```

Parameters

cmd	Type: uint32_t Command definition
arg	Type: uint32_t Argument of the command

Returns

Type: bool

True if success, otherwise false

28.2.4.9 mci_sync_get_response

Get 32-bits response of the last command.

```
uint32_t mci_sync_get_response(
    struct mci_sync_desc * mci
)
```

Returns

Type: uint32_t

32-bits response.

28.2.4.10 mci_sync_get_response_128

Get 128-bits response of the last command.

```
void mci_sync_get_response_128(
    struct mci_sync_desc * mci,
    uint8_t * response
)
```

Parameters

response	Type: uint8_t * Pointer on the array to fill with the 128-bits response.

Returns

Type: void

28.2.4.11 mci_sync_adtc_start

Send an ADTC command on the selected slot. An ADTC (Addressed Data Transfer Commands) command is used for read/write access.

```
bool mci_sync_adtc_start(
    struct mci_sync_desc * mci,
    uint32_t cmd,
    uint32_t arg,
    uint16_t block_size,
    uint16_t nb_block,
    bool access_block
)
```

Parameters

cmd	Type: uint32_t Command definition.
arg	Type: uint32_t Argument of the command.
block_size	Type: uint16_t Block size used for the transfer.
nb_block	Type: uint16_t Total number of blocks for this transfer
access_block	Type: bool If true, the x_read_blocks() and x_write_blocks() functions must be used after this function. If false, the mci_read_word() and mci_write_word() functions must be used after this function.

Returns

Type: bool

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True if success, otherwise false

28.2.4.12 mci_sync_adtc_stop

Send a command to stop an ADTC command on the selected slot.

```
bool mci_sync_adtc_stop(
    struct mci_sync_desc * mci,
    uint32_t cmd,
    uint32_t arg
)
```

Parameters

cmd	Type: uint32_t Command definition
arg	Type: uint32_t Argument of the command

Returns

Type: bool

True if success, otherwise false

28.2.4.13 mci_sync_read_word

Read a word on the line.

```
bool mci_sync_read_word(
    struct mci_sync_desc * mci,
    uint32_t * value
)
```

Parameters

value	Type: uint32_t * Pointer on a word to fill.

Returns

Type: bool

True if success, otherwise false

28.2.4.14 mci_sync_write_word

Write a word on the line.

```
bool mci_sync_write_word(
    struct mci_sync_desc * mci,
    uint32_t value
)
```

Parameters

value	Type: uint32_t

Word to send

Returns

Type: bool

True if success, otherwise false

28.2.4.15 mci_sync_start_read_blocks

Start a read blocks transfer on the line.

```
bool mci_sync_start_read_blocks(
    struct mci_sync_desc * mci,
    void * dst,
    uint16_t nb_block
)
```

Note: The driver will use the DMA available to speed up the transfer.

Parameters

dst	Type: void * Pointer on the buffer to fill
nb_block	Type: uint16_t Number of block to transfer

Returns

Type: bool

True if started, otherwise false

28.2.4.16 mci_sync_start_write_blocks

Start a write blocks transfer on the line.

```
bool mci_sync_start_write_blocks(
    struct mci_sync_desc * mci,
    const void * src,
    uint16_t nb_block
)
```

Note: The driver will use the DMA available to speed up the transfer.

Parameters

src	Type: const void * Pointer on the buffer to send
nb_block	Type: uint16_t Number of block to transfer

Returns

Type: bool

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True if started, otherwise false

28.2.4.17 mci_sync_wait_end_of_read_blocks

Wait for the end of transfer to be initiated by the mci_start_read_blocks()

```
bool mci_sync_wait_end_of_read_blocks(
    struct mci_sync_desc * mci
)
```

Returns

Type: bool

True if success, otherwise false

28.2.4.18 mci_sync_wait_end_of_write_blocks

Wait for the end of transfer to be initiated by the mci_start_write_blocks()

```
bool mci_sync_wait_end_of_write_blocks(
    struct mci_sync_desc * mci
)
```

Returns

Type: bool

True if success, otherwise false

28.2.4.19 mci_sync_get_version

Retrieve the current driver version.

```
uint32_t mci_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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29. PAC Driver

The Peripheral Access Controller (PAC) provides write protection for registers of the peripherals.

The user can use periph_lock to enable a selected peripheral's write-protection, and periph_unlock to disable the selected peripheral's write-protection.

If a peripheral is write-protected, and if a write access is performed, data will not be written.

29.1 Summary of the API's Functional Features

The API provides functions to:

- Lock(enable write-protection)
- Unlock(disable write-protection)
- Get the write-protection state

29.2 Summary of Configuration Options

No PAC parameter needed to be configured in START.

29.3 Driver Implementation Description

29.3.1 Limitations

- Double write-protection or double unprotection may lead to an access error

29.4 Example of Usage

The following shows a simple example of using the PAC to lock GCLK peripheral.

```
/**
 * Lock GCLK.
 */
void pac_example(void)
{
    bool stat;
    periph_get_lock_state(GCLK, &stat);
    if (!stat) {
        periph_lock(GCLK);
    }
}
```

29.5 Dependencies

- PAC peripheral and clocks

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29.6 Functions

29.6.1 periph_lock

Enable write protect for the given hardware module.

```
static int32_t periph_lock(
    void *const module
)
```

Parameters

module	Type: void *const Pointer to the hardware module

Returns

Type: int32_t

29.6.2 periph_unlock

Disable write protect for the given hardware module.

```
static int32_t periph_unlock(
    void *const module
)
```

Parameters

module	Type: void *const Pointer to the hardware module

Returns

Type: int32_t

29.6.3 periph_get_lock_state

Get write protect state for the given hardware module.

```
static int32_t periph_get_lock_state(
    void *const module,
    bool *const state
)
```

Parameters

module	Type: void *const Pointer to the hardware module
state	Type: bool *const Pointer to write protect state for specified module

Returns

Type: int32_t

29.6.4 pac_get_version

Get PAC driver version.

```
uint32_t pac_get_version(
    void
)
```

Returns

Type: uint32_t

30. PWM Driver

This Pulse Width Modulation (PWM) driver provides an interface for generating PWM waveforms.

The following driver variant is available:

- 30.2 PWM Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. Functionality is asynchronous to the main clock of the MCU.

30.1 PWM Basics and Best Practice

The Pulse-width modulation (PWM) is used to create an analog behavior digitally by controlling the amount of power transferred to the connected peripheral. This is achieved by controlling the high period (duty-cycle) of a periodic signal.

The PWM can be used in motor control, ballast, LED, H-bridge, power converters, and other types of power control applications.

30.2 PWM Asynchronous Driver

In the Pulse Width Modulation (PWM) asynchronous driver, a callback function can be registered in the driver by the application and triggered when errors and one PWM period is done.

The user can change the period or duty cycle whenever PWM is running. The function 30.2.9.6 pwm_set_parameters is used to configure these two parameters. Note that these are raw register values and the parameter duty_cycle means the period of first half during one cycle, which should be not beyond the total period value.

In addition, the user can also get multiple PWM channels output from different peripherals at the same time, which is implemented more flexible by the function pointers.

30.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Hookup callback handlers on errors and one PWM period
- Enable or disable the PWM related hardware
- Run-time control of PWM duty-cycle and period

30.2.2 Summary of Configuration Options

Below is a list of the main PWM parameters that can be configured in START. Many of these parameters are used by the 30.2.9.1 pwm_init function when initializing the driver and underlying hardware.

- The PWM waveform duty value
- The PWM waveform period value

30.2.3 Driver Implementation Description

30.2.3.1 Limitations

The current driver doesn't support the features like recoverable, non-recoverable faults, dithering, and dead-time insertion.

30.2.4 Example of Usage

The following shows a simple example of using the PWM. The PWM must have been initialized by 30.2.9.1 pwm_init. This initialization will configure the operation of the related PWM hardware, such as input pins, period, and duty cycle.

```
/**
 * Example of using PWM_0.
 */
void PWM_0_example(void)
{
    pwm_set_parameters(&PWM_0, 10000, 5000);
    pwm_enable(&PWM_0);
}
```

30.2.5 Dependencies

- The peripheral which can perform waveform generation like frequency generation and pulse-width modulation, such as Timer/Counter.
- The NVIC must be configured so that the peripheral interrupt requests are periodically serviced

30.2.6 Structs

30.2.6.1 pwm_callbacks Struct

PWM callbacks.

Members

period

error

30.2.6.2 pwm_descriptor Struct

PWM descriptor.

Members

device	PWM device
pwm_cb	PWM callback structure

30.2.7 Enums

30.2.7.1 pwm_callback_type Enum

PWM_PERIOD_CB

PWM_ERROR_CB

30.2.8 Typedefs

30.2.8.1 pwm_cb_t typedef

typedef void(* pwm_cb_t) (const struct pwm_descriptor *const descr)

PWM callback type.

30.2.9 Functions

30.2.9.1 pwm_init

Initialize the PWM HAL instance and hardware.

```
int32_t pwm_init(
    struct pwm_descriptor *const descr,
    void *const hw,
    struct _pwm_hpl_interface *const func
)
```

Parameters

descr	Type: struct 30.2.6.2 pwm_descriptor Struct *const Pointer to the HAL PWM descriptor
hw	Type: void *const The pointer to hardware instance
func	Type: struct _pwm_hpl_interface *const The pointer to a set of functions pointers

Returns

Type: int32_t

Operation status.

30.2.9.2 pwm_deinit

Deinitialize the PWM HAL instance and hardware.

```
int32_t pwm_deinit(
    struct pwm_descriptor *const descr
)
```

Parameters

descr	Type: struct 30.2.6.2 pwm_descriptor Struct *const Pointer to the HAL PWM descriptor

Returns

Type: int32_t

Operation status.

30.2.9.3 pwm_enable

PWM output start.

```
int32_t pwm_enable(
    struct pwm_descriptor *const descr
)
```

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Parameters

descr	Type: struct 30.2.6.2 pwm_descriptor Struct *const Pointer to the HAL PWM descriptor

Returns

Type: int32_t

Operation status.

30.2.9.4 pwm_disable

PWM output stop.

```
int32_t pwm_disable(
    struct pwm_descriptor *const descr
)
```

Parameters

descr	Type: struct 30.2.6.2 pwm_descriptor Struct *const Pointer to the HAL PWM descriptor

Returns

Type: int32_t

Operation status.

30.2.9.5 pwm_register_callback

Register PWM callback.

```
int32_t pwm_register_callback(
    struct pwm_descriptor *const descr,
    enum pwm_callback_type type,
    pwm_cb_t cb
)
```

Parameters

descr	Type: struct 30.2.6.2 pwm_descriptor Struct *const Pointer to the HAL PWM descriptor
type	Type: enum 30.2.7.1 pwm_callback_type Enum Callback type
cb	Type: 30.2.8.1 pwm_cb_t typedef A callback function, passing NULL de-registers callback

Returns

Type: int32_t

Operation status.

0	Success
-1	Error

30.2.9.6 pwm_set_parameters

Change PWM parameter.

```
int32_t pwm_set_parameters(
    struct pwm_descriptor *const descr,
    const pwm_period_t period,
    const pwm_period_t duty_cycle
)
```

Parameters

descr	Type: struct 30.2.6.2 pwm_descriptor Struct *const Pointer to the HAL PWM descriptor
period	Type: const pwm_period_t Total period of one PWM cycle
duty_cycle	Type: const pwm_period_t Period of PWM first half during one cycle

Returns

Type: int32_t

Operation status.

30.2.9.7 pwm_get_version

Get PWM driver version.

```
uint32_t pwm_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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31. Position Decoder Driver

The Position Decoder (PDEC) driver provides an interface for detection the movement of a motor axis.

The following driver variant is available:

- 31.2 PDEC Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. Functionality is asynchronous to the main clock of the MCU.

31.1 PDEC Basics and Best Practice

Position decoder can be used for a wide range of applications. The driver supports both motor axis position and window monitor position. The window monitor can be used to monitor the axis position and compare it to a predefined threshold. The callback function can be registered as overflow interrupt, direction interrupt, position changed interrupt, and error interrupt. Once the condition happens, the callback function is invoked to notify the application.

Normally a PDEC operates in QDEC mode. This mode can be used to measure the position, rotation, and speed of motor, to detect the missing pulse and auto-correction. There are three signal inputs in this mode. Signal 0 and Signal 1 control logic inputs refer to Phase A and Phase B in the quadrature decoder direction mode, and to count/direction in the decoder direction mode. The Signal 3 control logic input refers to the Index, in both quadrature decoder direction and decoder direction mode of the operation.

31.2 PDEC Asynchronous Driver

In the Position Decoder (PDEC) asynchronous driver, a callback function can be registered in the driver by the application, and the callback function will be triggered when axis position changed.

The driver 31.2.8.6 pdec_async_read_position function will attempt to read the required position results of the axis.

31.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Hookup callback handlers on position changed done and IRQ events
- Enable or disable PDEC module
- Read back axis position result

31.2.2 Summary of Configuration Options

Below is a list of the main PDEC parameters that can be configured in START. Many of these parameters are used by the 5.2.9.1 adc_async_init function when initializing the driver and underlying hardware.

- Select whether phase A, B, or index invert is to be used
- Select whether phase A or B should be swapped
- Which clock source and prescaler the PDEC uses
- Which configuration the PDEC uses
- Which events the PDEC interrupt uses
- Run in Standby or Debug mode

31.2.3 Driver Implementation Description

After PDEC hardware initialization, thee application can register the callback function for axis position changed and IRQ events by 31.2.8.9 pdec_async_register_callback.

31.2.4 Example of Usage

The following shows a simple example of using the PDEC. The PDEC must have been initialized by 31.2.8.1 pdec_async_init. This initialization will configure the operation of the PDEC, such as input pins, prescaler value, PDEC configuration, and interrupt configuration, etc.

The example registers a callback function for comparison ready and enables the PDEC, and read back the result of the axis position changed.

```
static void position_cb_POSITION_DECODER_0(struct pdec_async_descriptor *co
nst descr, uint8_t ch)
        {
            uint16_t count;
            count = pdec_async_read_position(descr, ch);
        }

static void irq_handler_cb_POSITION_DECODER_0(struct pdec_async_descriptor
*const descr,

                                              enum pdec_async_callback_type
 type, uint8_t ch)
        {
        }
        /**
         * Example of using POSITION_DECODER_0.
         */
        void POSITION_DECODER_0_example(void)
        {
            pdec_async_register_callback(

        &POSITION_DECODER_0, PDEC_ASYNC_POS_CHANGED_CB, (FUNC_PTR)position_
cb_POSITION_DECODER_0);

    pdec_async_register_callback(&POSITION_DECODER_0, PDEC_ASYNC_IRQ_CB, (F
UNC_PTR)irq_handler_cb_POSITION_DECODER_0);
            pdec_async_enable(&POSITION_DECODER_0);
        }
```

31.2.5 Dependencies

- The PDEC peripheral and its related I/O lines and clocks
- The NVIC must be configured so that PDEC interrupt requests are periodically serviced

31.2.6 Structs

31.2.6.1 pdec_async_callbacks Struct

Position Decoder callbacks.

Members

pos_changed

irq_handler

31.2.6.2 pdec_async_descriptor Struct

Position Decoder descriptor.

Members

device

pdec_async_cb

31.2.7 Typedefs

31.2.7.1 pdec_async_position_cb_t typedef

typedef void(* pdec_async_position_cb_t) (const struct pdec_async_descriptor *const descr, uint8_t ch)

31.2.7.2 pdec_async_irq_cb_t typedef

typedef void(* pdec_async_irq_cb_t) (const struct pdec_async_descriptor *const descr, enum pdec_async_interrupt_type type, uint8_t ch)

31.2.8 Functions

31.2.8.1 pdec_async_init

Initialize Position Decoder.

```
int32_t pdec_async_init(
    struct pdec_async_descriptor *const descr,
    void *const hw
)
```

This function initializes the given Position Decoder descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 31.2.6.2 pdec_async_descriptor Struct *const A Position Decoder descriptor to be initialized
hw	Type: void *const The pointer to hardware instance

Returns

Type: int32_t

Initialization status.

-1	Passed parameters were invalid
0	The initialization is completed successfully

31.2.8.2 pdec_async_deinit

Deinitialize Position Decoder.

```
int32_t pdec_async_deinit(
    struct pdec_async_descriptor *const descr
)
```

This function deinitializes the given Position Decoder descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr Type: struct 31.2.6.2 pdec_async_descriptor Struct *const

A Position Decoder descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

31.2.8.3 pdec_async_enable

Eanble Position Decoder.

```
int32_t pdec_async_enable(
    struct pdec_async_descriptor *const descr
)
```

This function starts the Position Decoder

Parameters

descr Type: struct 31.2.6.2 pdec_async_descriptor Struct *const

The pointer to the Position Decoder descriptor

Returns

Type: int32_t

Enabling status.

31.2.8.4 pdec_async_disable

Disable Position Decoder.

```
int32_t pdec_async_disable(
    struct pdec_async_descriptor *const descr
)
```

This function stops of Position Decoder

Parameters

descr Type: struct 31.2.6.2 pdec_async_descriptor Struct *const

The pointer to the Position Decoder descriptor

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Returns

Type: int32_t

Disabling status.

31.2.8.5 pdec_async_write_position

Write motor axis position.

```
int32_t pdec_async_write_position(
    struct pdec_async_descriptor *const descr,
    uint32_t value,
    uint8_t axis
)
```

Parameters

descr Type: struct 31.2.6.2 pdec_async_descriptor Struct *const

The pointer to the Position Decoder descriptor

value Type: uint32_t

The position count to write

axis Type: uint8_t

The axis number to read

Returns

Type: int32_t

Write operation status

31.2.8.6 pdec_async_read_position

Read motor axis position.

```
uint32_t pdec_async_read_position(
    struct pdec_async_descriptor *const descr,
    uint8_t axis
)
```

This function reads the position count of the motor axis. With this count, the user will know if the motor axis movement is clockwise (increase) or re-clockwise (decrease), and the position of the movement.

Parameters

descr Type: struct 31.2.6.2 pdec_async_descriptor Struct *const

The pointer to the Position Decoder descriptor

axis Type: uint8_t

The axis number to read

Returns

Type: uint32_t

The position count of the motor axis.

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31.2.8.7 pdec_async_set_up_threshold

Set Position Decoder upper threshold.

```
int32_t pdec_async_set_up_threshold(
    struct pdec_async_descriptor *const descr,
    const uint32_t up_threshold,
    uint8_t axis
)
```

This function sets Position Decoder upper threshold.

Parameters

descr	Type: struct 31.2.6.2 pdec_async_descriptor Struct *const The pointer to the Position Decoder descriptor
up_threshold	Type: const uint32_t An upper threshold to set

Returns

Type: int32_t

Status of the Position Decoder upper threshold setting.

31.2.8.8 pdec_async_set_low_threshold

Set Position Decoder lower threshold.

```
int32_t pdec_async_set_low_threshold(
    struct pdec_async_descriptor *const descr,
    const uint32_t low_threshold,
    uint8_t axis
)
```

This function sets Position Decoder lower threshold.

Parameters

descr	Type: struct 31.2.6.2 pdec_async_descriptor Struct *const The pointer to the Position Decoder descriptor
low_threshold	Type: const uint32_t A lower threshold to set
axis	Type: uint8_t The axis number to set

Returns

Type: int32_t

Status of the Position Decoder lower threshold setting.

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31.2.8.9 pdec_async_register_callback

Register Position Decoder callback.

```
int32_t pdec_async_register_callback(
    struct pdec_async_descriptor *const descr,
    const enum pdec_async_callback_type type,
    FUNC_PTR cb
)
```

Parameters

io_descr A Position Decoder descriptor

type Type: const enum pdec_async_callback_type

Callback type

cb Type: 40.3.2.1 FUNC_PTR typedef

A callback function, passing NULL de-registers callback

Returns

Type: int32_t

The status of callback assignment.

-1 Passed parameters were invalid

0 A callback is registered successfully

31.2.8.10 pdec_async_get_version

Retrieve the current driver version.

```
uint32_t pdec_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

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32. Quad SPI Drivers

This Quad SPI Interface (QSPI) driver provides a synchronous serial communication interface to operate a serial flash memory.

The following driver variants are available:

- Quad SPI Synchronous Driver: The driver supports polling for hardware changes, functionality is synchronous to the main clock of the MCU.
- Quad SPI DMA Driver: The driver uses a DMA system to transfer and receive data between the QSPI and a memory buffer. It supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.

32.1 Quad SPI Basics and Best Practice

The QSPI is a synchronous serial data link that provides communication with external devices in master mode. The QSPI is a high-speed synchronous data transfer interface and operates as a master. It initiates and controls all data transactions.

The QSPI is commonly used in an application for using serial flash memory operating in single-bit SPI, Dual SPI and Quad SPI.

32.2 Quad SPI DMA Driver

The Quad SPI Interface (QSPI) DMA driver provides a communication interface to operate a serial flash memory with DMA support.

User must configure DMAC system driver accordingly. The callback function is called when all the data is transferred or transfer error occurred, if it is registered via 32.2.7.6 qspi_dma_register_callback function.

32.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable QSPI master
- Hookup callback handlers on the data is transferred or transfer error occurred
- Execute command in Serial Memory Mode

32.2.2 Summary of Configuration Options

Below is a list of the main QSPI parameters that can be configured in START. Many of these parameters are used by the 32.2.7.1 qspi_dma_init function when initializing the driver and underlying hardware.

- Select QSPI pins signals
- Set QSPI baudrate
- Select QSPI clock polarity and phase
- Select QSPI DMA TX channel
- Select QSPI DMA RX channel

32.2.3 Driver Implementation Description

The driver can be used for SPI serial memory middleware which support flash earse, program and read.

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32.2.4 Example of Usage

The following shows a simple example of using the QSPI to send command to a serial memory flash. The callback function is called when the data is transferred.

The QSPI driver must have been initialized by 32.2.7.1 qspi_dma_init. This initialization will configure the operation of the QSPI master.

```
        static uint8_t buf[16] = {0x0};

static void xfer_complete_cb_QUAD_SPI_0(struct _dma_resource *resource)
        {
            /* Transfer completed */
        }
        /**
         * Example of using QUAD_SPI_0 to get N25Q256A status value,

 * and check bit 0 which indicate embedded operation is busy or not.
         */
        void QUAD_SPI_0_example(void)
        {
            struct _qspi_command cmd = {
                .inst_frame.bits.inst_en = 1,
                .inst_frame.bits.data_en = 1,
                .inst_frame.bits.addr_en = 1,
                .inst_frame.bits.dummy_cycles = 8,
                .inst_frame.bits.tfr_type = QSPI_READMEM_ACCESS,
                .instruction = 0x0B,
                .address = 0,
                .buf_len = 14,
                .rx_buf = buf,
            };
            qspi_dma_register_callback(&QUAD_SPI_0, QSPI_DMA_CB_XFER_DONE,
                    xfer_complete_cb_QUAD_SPI_0);
            qspi_dma_enable(&QUAD_SPI_0);
            qspi_dma_serial_run_command(&QUAD_SPI_0, &cmd);
        }
```

32.2.5 Dependencies

- QSPI peripheral and its related I/O lines and clocks
- The NVIC must be configured so that QSPI interrupt requests are periodically serviced
- DMA

32.2.6 Structs

32.2.6.1 qspi_dma_descriptor Struct

QSPI descriptor structure.

Members

dev	Pointer to QSPI device instance

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32.2.7 Functions

32.2.7.1 qspi_dma_init

Initialize QSPI low level driver.

```
int32_t qspi_dma_init(
    struct qspi_dma_descriptor * qspi,
    void * hw
)
```

Parameters

qspi	Type: struct 32.2.6.1 qspi_dma_descriptor Struct * Pointer to the QSPI device instance
hw	Type: void * Pointer to the hardware base

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.2.7.2 qspi_dma_deinit

Deinitialize QSPI low level driver.

```
int32_t qspi_dma_deinit(
    struct qspi_dma_descriptor * qspi
)
```

Parameters

qspi	Type: struct 32.2.6.1 qspi_dma_descriptor Struct * Pointer to the QSPI device instance

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.2.7.3 qspi_dma_enable

Enable QSPI for access without interrupts.

```
int32_t qspi_dma_enable(
    struct qspi_dma_descriptor * qspi
)
```

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Parameters

qspi	Type: struct 32.2.6.1 qspi_dma_descriptor Struct *
	Pointer to the QSPI device instance.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.2.7.4 qspi_dma_disable

Disable QSPI for access without interrupts.

```
int32_t qspi_dma_disable(
    struct qspi_dma_descriptor * qspi
)
```

Disable QSPI. Deactivate all CS pins if it works as master.

Parameters

qspi	Type: struct 32.2.6.1 qspi_dma_descriptor Struct *
	Pointer to the QSPI device instance.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.2.7.5 qspi_dma_serial_run_command

Execute command in Serial Memory Mode.

```
int32_t qspi_dma_serial_run_command(
    struct qspi_dma_descriptor * qspi,
    const struct _qspi_command * cmd
)
```

Parameters

qspi	Type: struct 32.2.6.1 qspi_dma_descriptor Struct *
	Pointer to the HAL QSPI instance
cmd	Type: const struct _qspi_command *
	Pointer to the command structure

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.2.7.6 qspi_dma_register_callback

Register a function as QSPI transfer completion callback.

```
void qspi_dma_register_callback(
    struct qspi_dma_descriptor * qspi,
    const enum _qspi_dma_cb_type type,
    _qspi_dma_cb_t cb
)
```

Register callback function specified by its `type`.

- QSPI_DMA_CB_XFER_DONE: set the function that will be called on QSPI transfer completion including deactivate the CS.
- QSPI_DMA_CB_ERROR: set the function that will be called on QSPI transfer error. Register NULL function to not use the callback.

Parameters

qspi	Type: struct 32.2.6.1 qspi_dma_descriptor Struct * Pointer to the HAL QSPI instance
type	Type: const enum _qspi_dma_cb_type Callback type (_qspi_dma_cb_type)
cb	Type: _qspi_dma_cb_t Pointer to callback function

Returns

Type: void

32.2.7.7 qspi_dma_get_version

Retrieve the current driver version.

```
uint32_t qspi_dma_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

32.3 Quad SPI Synchronous Driver

The Quad SPI Interface (QSPI) synchronous driver provides a communication interface to operate a serial flash memory.

The function 32.3.7.5 qspi_sync_serial_run_command can be used to send command (ex: READ, PROGRAM, ERASE, LOCK, etc.) to a serial flash memory.

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32.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable QSPI master
- Execute command in Serial Memory Mode

32.3.2 Summary of Configuration Options

Below is a list of the main QSPI parameters that can be configured in START. Many of these parameters are used by the 32.3.7.1 qspi_sync_init function when initializing the driver and underlying hardware.

- Select QSPI pins signals
- Set QSPI baudrate
- Select QSPI clock polarity and phase

32.3.3 Driver Implementation Description

The driver can be used for SPI serial memory middleware which support flash earse, program and read.

32.3.4 Example of Usage

The following shows a simple example of using the QSPI to send command to a serial memory flash.

The QSPI driver must have been initialized by 32.3.7.1 qspi_sync_init. This initialization will configure the operation of the QSPI master.

```
        /**
         * Example of using QUAD_SPI_0 to get N25Q256A status value,

  * and check bit 0 which indicate embedded operation is busy or not.
         */
        void QUAD_SPI_0_example(void)
        {
            uint8_t status = 0xFF;
            struct _qspi_command cmd = {
                .inst_frame.bits.inst_en = 1,
                .inst_frame.bits.data_en = 1,
                .inst_frame.bits.tfr_type = QSPI_READ_ACCESS,
                .instruction = 0x05,
                .buf_len = 1,
                .rx_buf = &status,
            };
            qspi_sync_enable(&QUAD_SPI_0);
            while(status & (1 << 0)) {
                qspi_sync_serial_run_command(&QUAD_SPI_0, &cmd);
            }
            qspi_sync_deinit(&QUAD_SPI_0);
        }
```

32.3.5 Dependencies

- QSPI peripheral and its related I/O lines and clocks

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32.3.6 Structs

32.3.6.1 qspi_sync_descriptor Struct

QSPI descriptor structure.

Members

dev

32.3.7 Functions

32.3.7.1 qspi_sync_init

Initialize QSPI low level driver.

```
int32_t qspi_sync_init(
    struct qspi_sync_descriptor * qspi,
    void * hw
)
```

Parameters

qspi Type: struct 32.3.6.1 qspi_sync_descriptor Struct *

Pointer to the QSPI device instance

hw Type: void *

Pointer to the hardware base

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.3.7.2 qspi_sync_deinit

Deinitialize QSPI low level driver.

```
int32_t qspi_sync_deinit(
    struct qspi_sync_descriptor * qspi
)
```

Parameters

qspi Type: struct 32.3.6.1 qspi_sync_descriptor Struct *

Pointer to the QSPI device instance

Returns

Type: int32_t

Operation status.

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ERR_NONE	Success

32.3.7.3 qspi_sync_enable

Enable QSPI for access without interrupts.

```
int32_t qspi_sync_enable(
    struct qspi_sync_descriptor * qspi
)
```

Parameters

qspi	Type: struct 32.3.6.1 qspi_sync_descriptor Struct * Pointer to the QSPI device instance

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.3.7.4 qspi_sync_disable

Disable QSPI for access without interrupts.

```
int32_t qspi_sync_disable(
    struct qspi_sync_descriptor * qspi
)
```

Disable QSPI. Deactivate all CS pins if it works as master.

Parameters

qspi	Type: struct 32.3.6.1 qspi_sync_descriptor Struct * Pointer to the QSPI device instance

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.3.7.5 qspi_sync_serial_run_command

Execute command in Serial Memory Mode.

```
int32_t qspi_sync_serial_run_command(
    struct qspi_sync_descriptor * qspi,
    const struct _qspi_command * cmd
)
```

Parameters

qspi	Type: struct 32.3.6.1 qspi_sync_descriptor Struct * Pointer to the HAL QSPI instance
cmd	Type: const struct _qspi_command * Pointer to the command structure

Returns

Type: int32_t

Operation status.

ERR_NONE	Success

32.3.7.6 qspi_sync_get_version

Retrieve the current driver version.

```
uint32_t qspi_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

33. RAND Driver

The Random Number Generator (RAND) generates a sequence of numbers that can not be reasonably predicted better than by a random chance.

33.1 RAND Synchronous Driver

The Random Number Generator (RAND) generates a sequence of numbers that can not be reasonably predicted better than by a random chance.

In some implementation cases, seed is required for the Random Number Generator to generate random numbers. The 33.1.4.5 rand_sync_set_seed function is used to update the seed. If it's actually not required by the generator implementation, the function returns ERR_UNSUPPORTED_OP.

33.1.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enabling and Disabling
- Setting seed
- 8-bit and 32-bit random data/data array generation

33.1.2 Dependencies

- The Random number generation hardware/software

33.1.3 Structs

33.1.3.1 rand_sync_desc Struct

Members

dev

33.1.4 Functions

33.1.4.1 rand_sync_init

Initialize the Random Number Generator Driver.

```
int32_t rand_sync_init(
    struct rand_sync_desc *const desc,
    void *const hw
)
```

Parameters

desc Type: struct 33.1.3.1 rand_sync_desc Struct *const

Pointer to the device descriptor instance struct

hw Type: void *const

Pointer to the hardware for device instance

Returns

Type: int32_t

Initialization operation result status, ERR_NONE (0) for OK.

33.1.4.2 rand_sync_deinit

Deinitialize the Random Number Generator Driver.

```
void rand_sync_deinit(
    struct rand_sync_desc *const desc
)
```

Parameters

desc	Type: struct 33.1.3.1 rand_sync_desc Struct *const Pointer to the device descriptor instance struct

Returns

Type: void

33.1.4.3 rand_sync_enable

Enable the Random Number Generator Driver.

```
int32_t rand_sync_enable(
    struct rand_sync_desc *const desc
)
```

Parameters

desc	Type: struct 33.1.3.1 rand_sync_desc Struct *const Pointer to the device descriptor instance struct

Returns

Type: int32_t

Enable operation result status, ERR_NONE (0) for OK.

33.1.4.4 rand_sync_disable

Disable the Random Number Generator Driver.

```
void rand_sync_disable(
    struct rand_sync_desc *const desc
)
```

Parameters

desc	Type: struct 33.1.3.1 rand_sync_desc Struct *const Pointer to the device descriptor instance struct

Returns

Type: void

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33.1.4.5 rand_sync_set_seed

Set seed for the Random Number Generator Driver.

```
int32_t rand_sync_set_seed(
    struct rand_sync_desc *const desc,
    const uint32_t seed
)
```

Parameters

desc	Type: struct 33.1.3.1 rand_sync_desc Struct *const Pointer to the device descriptor instance struct

Returns

Type: int32_t

33.1.4.6 rand_sync_read8

Read the 8-bit Random Number.

```
uint8_t rand_sync_read8(
    const struct rand_sync_desc *const desc
)
```

Parameters

desc	Type: const struct 33.1.3.1 rand_sync_desc Struct *const Pointer to the device descriptor instance struct

Returns

Type: uint8_t

The random number generated

33.1.4.7 rand_sync_read32

Read the 32-bit Random Number.

```
uint32_t rand_sync_read32(
    const struct rand_sync_desc *const desc
)
```

Parameters

desc	Type: const struct 33.1.3.1 rand_sync_desc Struct *const Pointer to the device descriptor instance struct

Returns

Type: uint32_t

The random number generated

33.1.4.8 rand_sync_read_buf8

Read the 8-bit Random Number Sequence into a buffer.

```
void rand_sync_read_buf8(
    const struct rand_sync_desc *const desc,
    uint8_t * buf,
    uint32_t len
)
```

Parameters

desc Type: const struct 33.1.3.1 rand_sync_desc Struct *const

Pointer to the device descriptor instance struct

buf Type: uint8_t *

Pointer to the buffer to fill an array of generated numbers

len Type: uint32_t

Number of random numbers to read

Returns

Type: void

33.1.4.9 rand_sync_read_buf32

Read the 32-bit Random Number Sequence into a buffer.

```
void rand_sync_read_buf32(
    const struct rand_sync_desc *const desc,
    uint32_t * buf,
    uint32_t len
)
```

Parameters

desc Type: const struct 33.1.3.1 rand_sync_desc Struct *const

Pointer to the device descriptor instance struct

buf Type: uint32_t *

Pointer to the buffer to fill an array of generated numbers

len Type: uint32_t

Number of random numbers to read

Returns

Type: void

33.1.4.10 rand_sync_get_version

Retrieve the current driver version.

```
uint32_t rand_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

34. SPI Drivers

Four driver variants are available for the SPI Master: Synchronous, Asynchronous, RTOS, and DMA.

- 34.5 SPI Master Synchronous Driver: The driver supports polling for hardware changes. The functionality is synchronous to the main clock of the MCU.
- 34.2 SPI Master Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.
- 34.4 SPI Master RTOS Driver: The driver supports a Real-Time operating system, i.e. is thread safe.
- 34.3 SPI Master DMA Driver: The driver uses a DMA system to transfer and receive data between the SPI and a memory buffer. It supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.

Two driver variants are available for the SPI Slave: Synchronous and Asynchronous.

- 34.7 SPI Slave Synchronous Driver: The driver supports polling for hardware changes. The functionality is synchronous to the main clock of the MCU.
- 34.6 SPI Slave Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.

34.1 SPI Basics and Best Practice

The Serial Peripheral Interface (SPI) is a synchronous serial communication interface.

SPI devices communicate in full duplex mode using a master-slave architecture with a single master. The master device originates the frame for reading and writing. Multiple slave devices are supported through selection by individual slave select (SS) lines.

34.2 SPI Master Asynchronous Driver

In the serial peripheral interface (SPI) driver, a callback function can be registered in the driver by the application and triggered when the transfer done. It provides an interface to read/write the data from/to the slave device.

Refer 34. SPI Drivers for more detailed SPI basics.

34.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable SPI master
- Hookup callback handlers on read/write/transfer complete, or error events
- Read/Write message to/from the slave

34.2.2 Summary of Configuration Options

Below is a list of the main SPI master parameters that can be configured in START. Many of these parameters are used by the 34.2.10.1 spi_m_async_init function when initializing the driver and

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underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Select character size
- Set SPI baudrate
- Which clock source is used

34.2.3 Driver Implementation Description

After the SPI hardware initialization, the 34.2.10.12 spi_m_async_get_io_descriptor function is needed to register an I/O descriptor. Then use 34.2.10.11 spi_m_async_register_callback to register a callback function for the RX/TX/transfer, and enable the SPI hardware. After that, control the slave select (SS) pin and start the read/write operation.

34.2.3.1 Limitations

The slave select (SS) is not automatically inserted during read/write/transfer, user must use I/O to control the devices' SS.

While read/write/transfer is in progress, the data buffer used must be kept unchanged.

34.2.4 Example of Usage

The following shows a simple example of using the SPI master. The SPI master must have been initialized by 34.2.10.1 spi_m_async_init. This initialization will configure the operation of the SPI master.

The example registers an I/O descriptor and enables the hardware. Then it registers a callback, and finally starts a writing operation.

```
        /**
         * Example of using SPI_0 to write "Hello World" using the I/
O abstraction.

 * Since the driver is asynchronous we need to use statically allocated mem
ory for string

 * because driver initiates transfer and then returns before the transmissi
on is completed.

 * Once transfer has been completed the tx_cb function will be called.
         */
        static uint8_t example_SPI_0[12] = "Hello World!";
        static uint8_t flag = false;

static void complete_cb_SPI_0(const struct spi_m_async_descriptor *const io
_descr)
        {
            /* Transfer completed */
            flag = true;
        }
        void SPI_0_example(void)
        {
            struct io_descriptor *io;
            spi_m_async_get_io_descriptor(&SPI_0, &io);

    spi_m_async_register_callback(&SPI_0, SPI_M_ASYNC_CB_XFER, (FUNC_PTR)co
mplete_cb_SPI_0);
            spi_m_async_enable(&SPI_0);
            /* Control the slave select (SS) pin */
```

```
            //gpio_set_pin_level(SPI_0_SS, false);
            io_write(io, example_SPI_0, 12);
            while (!flag) {
            }
            flag = false;
            /* Control the slave select (SS) pin */
            //gpio_set_pin_level(SPI_0_SS, true);
        }
```

34.2.5 Dependencies

- The SPI master peripheral and its related I/O lines and clocks
- The NVIC must be configured so that SPI interrupt requests are periodically serviced

34.2.6 Structs

34.2.6.1 spi_m_async_status Struct

SPI status.

Members

flags	Status flags
xfercnt	Number of characters transmitted

34.2.6.2 spi_m_callbacks Struct

SPI HAL callbacks.

Members

cb_xfer	Callback invoked when the buffer read/write/transfer done.
cb_error	Callback invoked when the CS deactivates, goes wrong, or aborts.

34.2.6.3 spi_m_async_descriptor Struct

SPI HAL driver struct for asynchronous access.

Members

dev	Pointer to the SPI device instance
io	I/O read/write
stat	SPI transfer status
callbacks	Callbacks for asynchronous transfer
xfer	Transfer information copy, for R/W/Transfer
xfercnt	Character count in current transfer

34.2.7 Defines

34.2.7.1 SPI_M_ASYNC_STATUS_BUSY

#define SPI_M_ASYNC_STATUS_BUSY( ) 0x0010

SPI is busy (read/write/transfer, with CS activated)

34.2.7.2 SPI_M_ASYNC_STATUS_TX_DONE

#define SPI_M_ASYNC_STATUS_TX_DONE( ) 0x0020

SPI finished transmit buffer

34.2.7.3 SPI_M_ASYNC_STATUS_RX_DONE

#define SPI_M_ASYNC_STATUS_RX_DONE( ) 0x0040

SPI finished receive buffer

34.2.7.4 SPI_M_ASYNC_STATUS_COMPLETE

#define SPI_M_ASYNC_STATUS_COMPLETE( ) 0x0080

SPI finished everything including CS deactivate

34.2.7.5 SPI_M_ASYNC_STATUS_ERR_MASK

#define SPI_M_ASYNC_STATUS_ERR_MASK( ) 0x000F

34.2.7.6 SPI_M_ASYNC_STATUS_ERR_POS

#define SPI_M_ASYNC_STATUS_ERR_POS( ) 0

34.2.7.7 SPI_M_ASYNC_STATUS_ERR_OVRF

#define SPI_M_ASYNC_STATUS_ERR_OVRF( ) ((-ERR_OVERFLOW) << SPI_M_ASYNC_STATUS_ERR_POS)

34.2.7.8 SPI_M_ASYNC_STATUS_ERR_ABORT

#define SPI_M_ASYNC_STATUS_ERR_ABORT( ) ((-ERR_ABORTED) << SPI_M_ASYNC_STATUS_ERR_POS)

34.2.7.9 SPI_M_ASYNC_STATUS_ERR_EXTRACT

#define SPI_M_ASYNC_STATUS_ERR_EXTRACT( ) (((st) >> SPI_M_ASYNC_STATUS_ERR_POS) & SPI_M_ASYNC_STATUS_ERR_MASK)

34.2.8 Enums

34.2.8.1 spi_m_async_cb_type Enum

SPI_M_ASYNC_CB_XFER	Callback type for read/write/transfer buffer done, see 34.2.9.2 spi_m_async_cb_xfer_t typedef.
SPI_M_ASYNC_CB_ERROR	Callback type for CS deactivate, error, or abort, see 34.2.9.1 spi_m_async_cb_error_t typedef.
SPI_M_ASYNC_CB_N	

34.2.9 Typedefs

34.2.9.1 spi_m_async_cb_error_t typedef

typedef void(* spi_m_async_cb_error_t) (struct spi_m_async_descriptor *, const int32_t status)

Prototype of callback on SPI transfer errors.

34.2.9.2 spi_m_async_cb_xfer_t typedef

typedef void(* spi_m_async_cb_xfer_t) (struct spi_m_async_descriptor *)

Prototype of callback on SPI read/write/transfer buffer completion.

34.2.10 Functions

34.2.10.1 spi_m_async_init

Initialize the SPI HAL instance and hardware for callback mode.

```
int32_t spi_m_async_init(
    struct spi_m_async_descriptor * spi,
    void *const hw
)
```

Initialize SPI HAL with interrupt mode (uses callbacks).

Parameters

spi	Type: struct 34.2.6.3 spi_m_async_descriptor Struct * Pointer to the HAL SPI instance.
hw	Type: void *const Pointer to the hardware base.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_INVALID_DATA	Error, initialized.

34.2.10.2 spi_m_async_deinit

Deinitialize the SPI HAL instance.

```
void spi_m_async_deinit(
    struct spi_m_async_descriptor * spi
)
```

Abort transfer, disable and reset SPI, de-init software.

Parameters

spi	Type: struct 34.2.6.3 spi_m_async_descriptor Struct * Pointer to the HAL SPI instance.

Returns

Type: void

Operation status.

ERR_NONE	Success.
<0	Error code.

34.2.10.3 spi_m_async_enable

Enable SPI.

```
void spi_m_async_enable(
    struct spi_m_async_descriptor * spi
)
```

Parameters

spi Type: struct 34.2.6.3 spi_m_async_descriptor Struct *

Pointer to the HAL SPI instance.

Returns

Type: void

Operation status.

ERR_NONE	Success.
<0	Error code.

34.2.10.4 spi_m_async_disable

Disable the SPI and abort any pending transfer in progress.

```
void spi_m_async_disable(
    struct spi_m_async_descriptor * spi
)
```

If there is any pending transfer, the complete callback is invoked with the `ERR_ABORTED` status.

Parameters

spi Type: struct 34.2.6.3 spi_m_async_descriptor Struct *

Pointer to the HAL SPI instance.

Returns

Type: void

Operation status.

ERR_NONE	Success.
<0	Error code.

34.2.10.5 spi_m_async_set_baudrate

Set SPI baudrate.

```
int32_t spi_m_async_set_baudrate(
    struct spi_m_async_descriptor * spi,
    const uint32_t baud_val
)
```

Works if the SPI is initialized as master. In the function a sanity check is used to confirm it's called in the correct mode.

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Parameters

spi	Type: struct 34.2.6.3 spi_m_async_descriptor Struct * Pointer to the HAL SPI instance.
baud_val	Type: const uint32_t The target baudrate value (see "baudrate calculation" for calculating the value).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy.

34.2.10.6 spi_m_async_set_mode

Set SPI mode.

```
int32_t spi_m_async_set_mode(
    struct spi_m_async_descriptor * spi,
    const enum spi_transfer_mode mode
)
```

Set the SPI transfer mode (spi_transfer_mode), which controls the clock polarity and clock phase:

- Mode 0: leading edge is rising edge, data sample on leading edge.
- Mode 1: leading edge is rising edge, data sample on trailing edge.
- Mode 2: leading edge is falling edge, data sample on leading edge.
- Mode 3: leading edge is falling edge, data sample on trailing edge.

Parameters

spi	Type: struct 34.2.6.3 spi_m_async_descriptor Struct * Pointer to the HAL SPI instance.
mode	Type: const enum spi_transfer_mode The mode (spi_transfer_mode).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.

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34.2.10.7 spi_m_async_set_char_size

Set SPI transfer character size in number of bits.

```
int32_t spi_m_async_set_char_size(
    struct spi_m_async_descriptor * spi,
    const enum spi_char_size char_size
)
```

The character size (spi_char_size) influence the way the data is sent/received. For char size <= 8-bit, data is stored byte by byte. For char size between 9-bit ~ 16-bit, data is stored in 2-byte length. Note that the default and recommended char size is 8-bit since it's supported by all system.

Parameters

spi	Type: struct 34.2.6.3 spi_m_async_descriptor Struct * Pointer to the HAL SPI instance.
char_size	Type: const enum spi_char_size The char size (spi_char_size).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.
ERR_INVALID_ARG	The char size is not supported.

34.2.10.8 spi_m_async_set_data_order

Set SPI transfer data order.

```
int32_t spi_m_async_set_data_order(
    struct spi_m_async_descriptor * spi,
    const enum spi_data_order dord
)
```

Parameters

spi	Type: struct 34.2.6.3 spi_m_async_descriptor Struct * Pointer to the HAL SPI instance.
dord	Type: const enum spi_data_order The data order: send LSB/MSB first.

Returns

Type: int32_t

Operation status.

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ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.
ERR_INVALID	The data order is not supported.

34.2.10.9 spi_m_async_transfer

Perform the SPI data transfer (TX and RX) asynchronously.

```
int32_t spi_m_async_transfer(
    struct spi_m_async_descriptor * spi,
    uint8_t const * txbuf,
    uint8_t *const rxbuf,
    const uint16_t length
)
```

Log the TX and RX buffers and transfer them in the background. It never blocks.

Parameters

spi	Type: struct 34.2.6.3 spi_m_async_descriptor Struct * Pointer to the HAL SPI instance.
txbuf	Type: uint8_t const * Pointer to the transfer information (spi_transfer).
rxbuf	Type: uint8_t *const Pointer to the receiver information (spi_receive).
length	Type: const uint16_t SPI transfer data length.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy.

34.2.10.10 spi_m_async_get_status

Get the SPI transfer status.

```
int32_t spi_m_async_get_status(
    struct spi_m_async_descriptor * spi,
    struct spi_m_async_status * stat
)
```

Get transfer status, transfer counts in a structured way.

Parameters

spi	Type: struct 34.2.6.3 spi_m_async_descriptor Struct *

Pointer to the HAL SPI instance.

stat Type: struct 34.2.6.1 spi_m_async_status Struct *

Pointer to the detailed status descriptor, set to NULL to not return details.

Returns

Type: int32_t

Status.

ERR_NONE	Not busy.
ERR_BUSY	Busy.

34.2.10.11 spi_m_async_register_callback

Register a function as SPI transfer completion callback.

```
void spi_m_async_register_callback(
    struct spi_m_async_descriptor * spi,
    const enum spi_m_async_cb_type type,
    FUNC_PTR func
)
```

Register callback function specified by its `type`.

- SPI_CB_COMPLETE: set the function that will be called on the SPI transfer completion including deactivating the CS.
- SPI_CB_XFER: set the function that will be called on the SPI buffer transfer completion. Register NULL function to not use the callback.

Parameters

spi Type: struct 34.2.6.3 spi_m_async_descriptor Struct *

Pointer to the HAL SPI instance.

type Type: const enum 34.2.8.1 spi_m_async_cb_type Enum

Callback type (34.2.8.1 spi_m_async_cb_type Enum).

func Type: 40.3.2.1 FUNC_PTR typedef

Pointer to callback function.

Returns

Type: void

34.2.10.12 spi_m_async_get_io_descriptor

Return I/O descriptor for this SPI instance.

```
int32_t spi_m_async_get_io_descriptor(
    struct spi_m_async_descriptor *const spi,
    struct io_descriptor ** io
)
```

This function will return an I/O instance for this SPI driver instance

Parameters

spi Type: struct 34.2.6.3 spi_m_async_descriptor Struct *const

An SPI master descriptor, which is used to communicate through SPI

io Type: struct 25.2.1.1 io_descriptor Struct **

A pointer to an I/O descriptor pointer type

Returns
Type: int32_t

ERR_NONE

34.2.10.13 spi_m_async_get_version

Retrieve the current driver version.

```
uint32_t spi_m_async_get_version(
    void
)
```

Returns
Type: uint32_t

Current driver version.

34.3 SPI Master DMA Driver

The serial peripheral interface (SPI) is a DMA serial communication interface.

The SPI Master DMA driver uses the DMA system to transfer data from a memory buffer to the SPI (Memory to Peripheral), and receive data from the SPI to a memory buffer (Peripheral to Memory). User must configure the DMA system driver accordingly. A callback is called when all the data is transfered or received, if it is registered via the 34.3.9.10 spi_m_dma_register_callback function.

Refer 34. SPI Drivers for more detailed SPI basics.

34.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable SPI master
- Hookup callback handlers on read/write/transfer complete, or error events
- Read/Write message to/from the slave

34.3.2 Summary of Configuration Options

Below is a list of the main SPI master DMA parameters that can be configured in START. Many of these parameters are used by the 34.3.9.1 spi_m_dma_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Select SPI DMA TX channel
- Select SPI DMA RX channel
- Select character size
- Set SPI baudrate
- Which clock source is used

34.3.3 Driver Implementation Description

After the SPI hardware initialization, the 34.3.9.11 spi_m_dma_get_io_descriptor function is needed to register an I/O descriptor. Then use 34.3.9.10 spi_m_dma_register_callback to register a callback function for the RX/TX/transfer, and enable SPI hardware complete. Then, control the slave select (SS) pin and start the read/write operation.

34.3.3.1 Limitations

The slave select (SS) is not automatically inserted during read/write/transfer. The user must use an I/O to control the devices'SS.

When the DMA channel is only used for receiving data, the transfer channel must be enabled to send dummy data to the slave.

While read/write/transfer is in progress, the data buffer used must be kept unchanged.

34.3.4 Example of Usage

The following shows a simple example of using the SPI master DMA. The SPI master must have been initialized by 34.3.9.1 spi_m_dma_init. This initialization will configure the operation of the SPI master.

The example registers an I/O descriptor and enables the hardware. Then it registers a callback, and finally starts a writing operation.

```
         /**
          * Example of using SPI_0 to write "Hello World" using the I/
O abstraction.

 * Since the driver is asynchronous we need to use statically allocated mem
ory for string

 * because driver initiates transfer and then returns before the transmissi
on is completed.

 * Once transfer has been completed the tx_cb function will be called.
          */
         static uint8_t example_SPI_0[12] = "Hello World!";
         static void tx_complete_cb_SPI_0(struct _dma_resource *resource)
         {
             /* Transfer completed */
         }
         void SPI_0_example(void)
         {
             struct io_descriptor *io;
             spi_m_dma_get_io_descriptor(&SPI_0, &io);

    spi_m_dma_register_callback(&SPI_0, SPI_M_DMA_CB_TX_DONE, (FUNC_PTR)tx_
complete_cb_SPI_0);
             spi_m_dma_enable(&SPI_0);
             /* Control the slave select (SS) pin */
             //gpio_set_pin_level(SPI_0_SS, false);
```

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```
            io_write(io, example_SPI_0, 12);
        }
```

34.3.5 Dependencies

- The SPI master peripheral and its related I/O lines and clocks
- The NVIC must be configured so that SPI interrupt requests are periodically serviced
- DMA

34.3.6 Structs

34.3.6.1 spi_m_dma_descriptor Struct

SPI HAL driver struct for DMA access.

Members

dev	Pointer to SPI device instance
io	I/O read/write
resource	DMA resource

34.3.7 Enums

34.3.7.1 spi_m_dma_cb_type Enum

SPI_M_DMA_CB_TX_DONE	Callback type for DMA transfer buffer done
SPI_M_DMA_CB_RX_DONE	Callback type for DMA receive buffer done
SPI_M_DMA_CB_ERROR	Callback type for DMA errors
SPI_M_DMA_CB_N	

34.3.8 Typedefs

34.3.8.1 spi_m_dma_cb_t typedef

typedef void(* spi_m_dma_cb_t) (struct _dma_resource *resource)

SPI Master DMA callback type.

34.3.9 Functions

34.3.9.1 spi_m_dma_init

Initialize the SPI HAL instance and hardware for DMA mode.

```
int32_t spi_m_dma_init(
    struct spi_m_dma_descriptor * spi,
    void *const hw
)
```

Initialize SPI HAL with dma mode.

Parameters

spi	Type: struct 34.3.6.1 spi_m_dma_descriptor Struct * Pointer to the HAL SPI instance.
hw	Type: void *const Pointer to the hardware base.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_INVALID_DATA	Error, initialized.

34.3.9.2 spi_m_dma_deinit

Deinitialize the SPI HAL instance.

```
void spi_m_dma_deinit(
    struct spi_m_dma_descriptor * spi
)
```

Abort transfer, disable and reset SPI, de-init software.

Parameters

spi	Type: struct 34.3.6.1 spi_m_dma_descriptor Struct * Pointer to the HAL SPI instance.

Returns

Type: void

Operation status.

ERR_NONE	Success.
<0	Error code.

34.3.9.3 spi_m_dma_enable

Enable SPI.

```
void spi_m_dma_enable(
    struct spi_m_dma_descriptor * spi
)
```

Parameters

spi	Type: struct 34.3.6.1 spi_m_dma_descriptor Struct * Pointer to the HAL SPI instance.

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Returns
Type: void

Operation status.

ERR_NONE	Success.
<0	Error code.

34.3.9.4 spi_m_dma_disable

Disable SPI.

```
void spi_m_dma_disable(
    struct spi_m_dma_descriptor * spi
)
```

Parameters

spi Type: struct 34.3.6.1 spi_m_dma_descriptor Struct *

Pointer to the HAL SPI instance.

Returns
Type: void

Operation status.

ERR_NONE	Success.
<0	Error code.

34.3.9.5 spi_m_dma_set_baudrate

Set SPI baudrate.

```
int32_t spi_m_dma_set_baudrate(
    struct spi_m_dma_descriptor * spi,
    const uint32_t baud_val
)
```

Works if SPI is initialized as master. In the function a sanity check is used to confirm it's called in the correct mode.

Parameters

spi Type: struct 34.3.6.1 spi_m_dma_descriptor Struct *

Pointer to the HAL SPI instance.

baud_val Type: const uint32_t

The target baudrate value (See "baudrate calculation" for calculating the value).

Returns
Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy.

34.3.9.6 spi_m_dma_set_mode

Set SPI mode.

```
int32_t spi_m_dma_set_mode(
    struct spi_m_dma_descriptor * spi,
    const enum spi_transfer_mode mode
)
```

Set SPI transfer mode (spi_transfer_mode), which controls clock polarity and clock phase:

- Mode 0: leading edge is rising edge, data sample on leading edge.
- Mode 1: leading edge is rising edge, data sample on trailing edge.
- Mode 2: leading edge is falling edge, data sample on leading edge.
- Mode 3: leading edge is falling edge, data sample on trailing edge.

Parameters

spi	Type: struct 34.3.6.1 spi_m_dma_descriptor Struct * Pointer to the HAL SPI instance.
mode	Type: const enum spi_transfer_mode The mode (spi_transfer_mode).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.

34.3.9.7 spi_m_dma_set_char_size

Set the SPI transfer character size in number of bits.

```
int32_t spi_m_dma_set_char_size(
    struct spi_m_dma_descriptor * spi,
    const enum spi_char_size char_size
)
```

The character size (spi_char_size) influence the way the data is sent/received. For char size <= 8-bit, data is stored byte by byte. For char size between 9-bit ~ 16-bit, data is stored in 2-byte length. Note that the default and recommended char size is 8-bit since it's supported by all system.

Parameters

spi	Type: struct 34.3.6.1 spi_m_dma_descriptor Struct * Pointer to the HAL SPI instance.

char_size	Type: const enum spi_char_size The char size (spi_char_size).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.
ERR_INVALID_ARG	The char size is not supported.

34.3.9.8 spi_m_dma_set_data_order

Set SPI transfer data order.

```
int32_t spi_m_dma_set_data_order(
    struct spi_m_dma_descriptor * spi,
    const enum spi_data_order dord
)
```

Parameters

spi	Type: struct 34.3.6.1 spi_m_dma_descriptor Struct * Pointer to the HAL SPI instance.
dord	Type: const enum spi_data_order The data order: send LSB/MSB first.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.
ERR_INVALID	The data order is not supported.

34.3.9.9 spi_m_dma_transfer

Perform the SPI data transfer (TX and RX) with the DMA.

```
int32_t spi_m_dma_transfer(
    struct spi_m_dma_descriptor * spi,
    uint8_t const * txbuf,
    uint8_t *const rxbuf,
    const uint16_t length
)
```

Parameters

spi	Type: struct 34.3.6.1 spi_m_dma_descriptor Struct * Pointer to the HAL SPI instance.
txbuf	Type: uint8_t const * Pointer to the transfer information.
rxbuf	Type: uint8_t *const Pointer to the receiver information.
length	Type: const uint16_t SPI transfer data length.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy.

34.3.9.10 spi_m_dma_register_callback

Register a function as an SPI transfer completion callback.

```
void spi_m_dma_register_callback(
    struct spi_m_dma_descriptor * spi,
    const enum spi_m_dma_cb_type type,
    spi_m_dma_cb_t func
)
```

Register a callback function specified by its `type`.

- SPI_CB_COMPLETE: set the function that will be called on the SPI transfer completion including deactivating the CS.
- SPI_CB_XFER: set the function that will be called on the SPI buffer transfer completion. Register a NULL function to not use the callback.

Parameters

spi	Type: struct 34.3.6.1 spi_m_dma_descriptor Struct * Pointer to the HAL SPI instance.
type	Type: const enum 34.3.7.1 spi_m_dma_cb_type Enum Callback type (34.3.7.1 spi_m_dma_cb_type Enum).
func	Type: 34.3.8.1 spi_m_dma_cb_t typedef Pointer to callback function.

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Returns

Type: void

34.3.9.11 spi_m_dma_get_io_descriptor

Return I/O descriptor for this SPI instance.

```
int32_t spi_m_dma_get_io_descriptor(
    struct spi_m_dma_descriptor *const spi,
    struct io_descriptor ** io
)
```

This function will return an I/O instance for this SPI driver instance

Parameters

spi Type: struct 34.3.6.1 spi_m_dma_descriptor Struct *const

An SPI master descriptor, which is used to communicate through SPI

io Type: struct 25.2.1.1 io_descriptor Struct **

A pointer to an I/O descriptor pointer type

Returns

Type: int32_t

ERR_NONE

34.3.9.12 spi_m_dma_get_version

Retrieve the current driver version.

```
uint32_t spi_m_dma_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

34.4 SPI Master RTOS Driver

The driver is intended for using the SPI master functions in a Real-Time operating system, i.e. is thread safe.

The transfer functions of the SPI Master RTOS driver are optimized for RTOS support. When data transfer is in progress, the transfer functions use semaphore to block the current task or thread until the transfer ends. So the transfer functions do not work without RTOS as the transfer functions must be called in an RTOS task or thread.

During data transfer, the SPI transfer process is not protected, so that a more flexible way can be chosen in application.

34.4.1 Summary of the API's Functional Features

The API provides functions to:

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- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable SPI master
- Hookup callback handlers on read/write/transfer complete, or error events
- Read/Write message to/from the slave

34.4.2 Summary of Configuration Options

Below is a list of the main SPI master parameters that can be configured in START. Many of these parameters are used by the 34.4.7.1 spi_m_os_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Select character size
- Set SPI baudrate
- Which clock source is used

34.4.3 Driver Implementation Description

After the SPI hardware initialization, the 34.4.7.10 spi_m_os_get_io_descriptor function is needed to register an I/O descriptor. Then control the slave select (SS) pin, and start the read/write operation.

34.4.3.1 Limitations

The slave select (SS) is not automatically inserted during read/write/transfer, user must use I/O to control the devices' SS.

While read/write/transfer is in progress, the data buffer used must be kept unchanged.

34.4.4 Example of Usage

The following shows a simple example of using the SPI master. The SPI master must have been initialized by 34.4.7.1 spi_m_os_init. This initialization will configure the operation of the SPI master.

The example registers an I/O descriptor and then starts a reading operation.

```
/** * Example task of using SPI_0 to echo using the I/O abstraction. */
void SPI_0_example_task(void *p)
{    struct io_descriptor *io;    uint16_t              data;    (void)p;
  spi_m_os_get_io_descriptor(&SPI_0, &io);    /
* Control the slave select (SS) pin */    //
gpio_set_pin_level(SPI_0_SS, false);    for (;;) {        if (io_read(io, (
uint8_t *)&data, 2) == 2) {            /
* read OK, handle data. */;        } else {            /
* error. */;        }    }}#define TASK_TRANSFER_STACK_SIZE            ( 25
6/
sizeof( portSTACK_TYPE ))#define TASK_TRANSFER_STACK_PRIORITY        ( tskI
DLE_PRIORITY + 0 )static TaskHandle_t xCreatedTransferTask;static void task
_transfer_create(void){    /
* Create the task that handles the CLI. */    if (xTaskCreate(SPI_0_example
_task, "transfer", TASK_TRANSFER_STACK_SIZE, NULL,    TASK_TRANSFER_STACK_P
RIORITY, &xCreatedTransferTask) !
= pdPASS) {        while(1) {;        }    }}static void tasks_run(void)
{    vTaskStartScheduler();}int main(void){    /
* Initializes MCU, drivers and middleware */    atmel_start_init();    task
_transfer_create();    tasks_run();    /
* Replace with your application code */    while (1) {    }}
```

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34.4.5 Dependencies

- The SPI master peripheral and its related I/O lines and clocks
- The NVIC must be configured so that SPI interrupt requests are periodically serviced
- RTOS

34.4.6 Structs

34.4.6.1 spi_m_os_descriptor Struct

SPI HAL driver struct for asynchronous access.

Members

dev	
io	Pointer to SPI device instance
xfer_sem	I/O read/write
xfer	SPI semphore
xfercnt	Transfer information copy, for R/W/Transfer
error	Character count in current transfer

34.4.7 Functions

34.4.7.1 spi_m_os_init

Initialize the SPI HAL instance and hardware for RTOS mode.

```
int32_t spi_m_os_init(
    struct spi_m_os_descriptor *const spi,
    void *const hw
)
```

Initialize SPI HAL with interrupt mode (uses RTOS).

Parameters

spi Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const

Pointer to the HAL SPI instance.

hw Type: void *const

Pointer to the hardware base.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_INVALID_DATA	Error, initialized.

34.4.7.2 spi_m_os_deinit

Deinitialize the SPI HAL instance.

```
int32_t spi_m_os_deinit(
    struct spi_m_os_descriptor *const spi
)
```

Abort transfer, disable and reset SPI, de-init software.

Parameters

spi Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const

Pointer to the HAL SPI instance.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
<0	Error code.

34.4.7.3 spi_m_os_enable

Enable SPI.

```
int32_t spi_m_os_enable(
    struct spi_m_os_descriptor *const spi
)
```

Parameters

spi Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const

Pointer to the HAL SPI instance.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
<0	Error code.

34.4.7.4 spi_m_os_disable

Disable the SPI and abort any pending transfer in progress.

```
int32_t spi_m_os_disable(
    struct spi_m_os_descriptor *const spi
)
```

If there is any pending transfer, the complete callback is invoked with the `ERR_ABORTED` status.

Parameters

spi	Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const Pointer to the HAL SPI instance.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
<0	Error code.

34.4.7.5 spi_m_os_set_baudrate

Set SPI baudrate.

```
int32_t spi_m_os_set_baudrate(
    struct spi_m_os_descriptor *const spi,
    const uint32_t baud_val
)
```

Works if the SPI is initialized as master. In the function a sanity check is used to confirm it's called in the correct mode.

Parameters

spi	Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const Pointer to the HAL SPI instance.
baud_val	Type: const uint32_t The target baudrate value (see "baudrate calculation" for calculating the value).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy.

34.4.7.6 spi_m_os_set_mode

Set SPI mode.

```
int32_t spi_m_os_set_mode(
    struct spi_m_os_descriptor *const spi,
    const enum spi_transfer_mode mode
)
```

Set the SPI transfer mode (spi_transfer_mode), which controls the clock polarity and clock phase:

- Mode 0: leading edge is rising edge, data sample on leading edge.
- Mode 1: leading edge is rising edge, data sample on trailing edge.

- Mode 2: leading edge is falling edge, data sample on leading edge.
- Mode 3: leading edge is falling edge, data sample on trailing edge.

Parameters

spi	Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const Pointer to the HAL SPI instance.
mode	Type: const enum spi_transfer_mode The mode (spi_transfer_mode).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.

34.4.7.7 spi_m_os_set_char_size

Set SPI transfer character size in number of bits.

```
int32_t spi_m_os_set_char_size(
    struct spi_m_os_descriptor *const spi,
    const enum spi_char_size char_size
)
```

The character size (spi_char_size) influence the way the data is sent/received. For char size <= 8-bit, data is stored byte by byte. For char size between 9-bit ~ 16-bit, data is stored in 2-byte length. Note that the default and recommended char size is 8-bit since it's supported by all system.

Parameters

spi	Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const Pointer to the HAL SPI instance.
char_size	Type: const enum spi_char_size The char size (spi_char_size).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.
ERR_INVALID_ARG	The char size is not supported.

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34.4.7.8 spi_m_os_set_data_order

Set SPI transfer data order.

```
int32_t spi_m_os_set_data_order(
    struct spi_m_os_descriptor *const spi,
    const enum spi_data_order order
)
```

Parameters

spi	Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const Pointer to the HAL SPI instance.
order	Type: const enum spi_data_order The data order: send LSB/MSB first.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy, CS activated.
ERR_INVALID	The data order is not supported.

34.4.7.9 spi_m_os_transfer

Perform the SPI data transfer (TX and RX) using RTOS.

```
int32_t spi_m_os_transfer(
    struct spi_m_os_descriptor *const spi,
    uint8_t const * txbuf,
    uint8_t *const rxbuf,
    const uint16_t length
)
```

Log the TX and RX buffers and transfer them in background. It blocks task/thread until the transfer done.

Parameters

spi	Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const Pointer to the HAL SPI instance.
txbuf	Type: uint8_t const * Pointer to the transfer information (spi_transfer).
rxbuf	Type: uint8_t *const Pointer to the receiver information (spi_receive).
length	Type: const uint16_t SPI transfer data length.

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Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy.

34.4.7.10 spi_m_os_get_io_descriptor

Return the I/O descriptor for this SPI instance.

```
static int32_t spi_m_os_get_io_descriptor(
    struct spi_m_os_descriptor *const spi,
    struct io_descriptor ** io
)
```

This function will return an I/O instance for this SPI driver instance.

Parameters

spi Type: struct 34.4.6.1 spi_m_os_descriptor Struct *const

An SPI master descriptor, which is used to communicate through SPI

io Type: struct 25.2.1.1 io_descriptor Struct **

A pointer to an I/O descriptor pointer type

Returns

Type: int32_t

ERR_NONE

34.4.7.11 spi_m_os_get_version

Retrieve the current driver version.

```
uint32_t spi_m_os_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

34.5 SPI Master Synchronous Driver

The Serial Peripheral Interface (SPI) Master synchronous driver provides a communication interface to read/write the data from/to the slave device.

Refer 34. SPI Drivers for more detailed calendar basics.

34.5.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable SPI master
- Data transfer: transmission, reception, and full-duplex

34.5.2 Summary of Configuration Options

Below is a list of the main SPI master parameters that can be configured in START. Many of these parameters are used by the 34.5.7.1 spi_m_sync_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Select character size
- Set SPI baudrate
- Which clock source is used

34.5.3 Driver Implementation Description

After SPI hardware initialization, the 34.5.7.10 spi_m_sync_get_io_descriptor function is needed to register an I/O descriptor. Then enable the SPI hardware. At the end, control the slave select (SS) pin, and start the read/write operation.

34.5.3.1 Limitations

The slave select (SS) is not automatically inserted during read/write/transfer, user must use I/O to control the devices' SS.

34.5.4 Example of Usage

The following shows a simple example of using the SPI master. The SPI master must have been initialized by 34.5.7.1 spi_m_sync_init. This initialization will configure the operation of the SPI master.

The example enables the SPI master, and finally starts a writing operation to the slave.

```
/** * Example of using SPI_0 to write "Hello World" using the I/
O abstraction. */
static uint8_t example_SPI_0[12] = "Hello World!";void SPI_0_example(void)
{    struct io_descriptor *io;    spi_m_sync_get_io_descriptor(&SPI_0, &io)
;    spi_m_sync_enable(&SPI_0);    /
* Control the slave select (SS) pin */    //
gpio_set_pin_level(SPI_0_SS, false);    io_write(io, example_SPI_0, 12);
 /* Control the slave select (SS) pin */    //
gpio_set_pin_level(SPI_0_SS, true);}
```

34.5.5 Dependencies

- SPI master peripheral and its related I/O lines and clocks

34.5.6 Structs

34.5.6.1 spi_m_sync_descriptor Struct

SPI HAL driver struct for polling mode.

Members

dev	SPI device instance
io	I/O read/write

flags	Flags for HAL driver

34.5.7 Functions

34.5.7.1 spi_m_sync_init

Initialize SPI HAL instance and hardware for polling mode.

```
int32_t spi_m_sync_init(
    struct spi_m_sync_descriptor * spi,
    void *const hw
)
```

Initialize SPI HAL with polling mode.

Parameters

spi	Type: struct 34.5.6.1 spi_m_sync_descriptor Struct * Pointer to the HAL SPI instance.
hw	Type: void *const Pointer to the hardware base.

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_INVALID_DATA	Error, initialized.

34.5.7.2 spi_m_sync_deinit

Deinitialize the SPI HAL instance and hardware.

```
void spi_m_sync_deinit(
    struct spi_m_sync_descriptor * spi
)
```

Abort transfer, disable and reset SPI, deinit software.

Parameters

spi	Type: struct 34.5.6.1 spi_m_sync_descriptor Struct * Pointer to the HAL SPI instance.

Returns

Type: void

Operation status.

ERR_NONE	Success.

<0	Error code.

34.5.7.3 spi_m_sync_enable

Enable SPI.

```
void spi_m_sync_enable(
    struct spi_m_sync_descriptor * spi
)
```

Parameters

spi	Type: struct 34.5.6.1 spi_m_sync_descriptor Struct *
	Pointer to the HAL SPI instance.

Returns

Type: void

Operation status.

ERR_NONE	Success.
<0	Error code.

34.5.7.4 spi_m_sync_disable

Disable SPI.

```
void spi_m_sync_disable(
    struct spi_m_sync_descriptor * spi
)
```

Parameters

spi	Type: struct 34.5.6.1 spi_m_sync_descriptor Struct *
	Pointer to the HAL SPI instance.

Returns

Type: void

Operation status.

ERR_NONE	Success.
<0	Error code.

34.5.7.5 spi_m_sync_set_baudrate

Set SPI baudrate.

```
int32_t spi_m_sync_set_baudrate(
    struct spi_m_sync_descriptor * spi,
    const uint32_t baud_val
)
```

Works if SPI is initialized as master, it sets the baudrate.

Parameters

spi	Type: struct 34.5.6.1 spi_m_sync_descriptor Struct * Pointer to the HAL SPI instance.
baud_val	Type: const uint32_t The target baudrate value (see "baudrate calculation" for calculating the value).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy
ERR_INVALID_ARG	The baudrate is not supported.

34.5.7.6 spi_m_sync_set_mode

Set SPI mode.

```
int32_t spi_m_sync_set_mode(
    struct spi_m_sync_descriptor * spi,
    const enum spi_transfer_mode mode
)
```

Set the SPI transfer mode (spi_transfer_mode), which controls the clock polarity and clock phase:

- Mode 0: leading edge is rising edge, data sample on leading edge.
- Mode 1: leading edge is rising edge, data sample on trailing edge.
- Mode 2: leading edge is falling edge, data sample on leading edge.
- Mode 3: leading edge is falling edge, data sample on trailing edge.

Parameters

spi	Type: struct 34.5.6.1 spi_m_sync_descriptor Struct * Pointer to the HAL SPI instance.
mode	Type: const enum spi_transfer_mode The mode (0~3).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy
ERR_INVALID_ARG	The mode is not supported.

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34.5.7.7 spi_m_sync_set_char_size

Set SPI transfer character size in number of bits.

```
int32_t spi_m_sync_set_char_size(
    struct spi_m_sync_descriptor * spi,
    const enum spi_char_size char_size
)
```

The character size (spi_char_size) influence the way the data is sent/received. For char size <= 8-bit, data is stored byte by byte. For char size between 9-bit ~ 16-bit, data is stored in 2-byte length. Note that the default and recommended char size is 8-bit since it's supported by all system.

Parameters

spi	Type: struct 34.5.6.1 spi_m_sync_descriptor Struct * Pointer to the HAL SPI instance.
char_size	Type: const enum spi_char_size The char size (~16, recommended 8).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_BUSY	Busy
ERR_INVALID_ARG	The char size is not supported.

34.5.7.8 spi_m_sync_set_data_order

Set SPI transfer data order.

```
int32_t spi_m_sync_set_data_order(
    struct spi_m_sync_descriptor * spi,
    const enum spi_data_order dord
)
```

Parameters

spi	Type: struct 34.5.6.1 spi_m_sync_descriptor Struct * Pointer to the HAL SPI instance.
dord	Type: const enum spi_data_order The data order: send LSB/MSB first.

Returns

Type: int32_t

Operation status.

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ERR_NONE	Success.
ERR_BUSY	Busy
ERR_INVALID_ARG	The data order is not supported.

34.5.7.9 spi_m_sync_transfer

Perform the SPI data transfer (TX and RX) in polling way.

```
int32_t spi_m_sync_transfer(
    struct spi_m_sync_descriptor * spi,
    const struct spi_xfer * xfer
)
```

Activate CS, do TX and RX and deactivate CS. It blocks.

Parameters

spi Type: struct 34.5.6.1 spi_m_sync_descriptor Struct *

Pointer to the HAL SPI instance.

xfer Type: const struct spi_xfer *

Pointer to the transfer information (spi_xfer).

Returns

Type: int32_t

size	Success.
>=0	Timeout, with number of characters transferred.
ERR_BUSY	SPI is busy

34.5.7.10 spi_m_sync_get_io_descriptor

Return the I/O descriptor for this SPI instance.

```
int32_t spi_m_sync_get_io_descriptor(
    struct spi_m_sync_descriptor *const spi,
    struct io_descriptor ** io
)
```

This function will return an I/O instance for this SPI driver instance.

Parameters

spi Type: struct 34.5.6.1 spi_m_sync_descriptor Struct *const

An SPI master descriptor, which is used to communicate through SPI

io Type: struct 25.2.1.1 io_descriptor Struct **

A pointer to an I/O descriptor pointer type

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Returns

Type: int32_t

ERR_NONE

34.5.7.11 spi_m_sync_get_version

Retrieve the current driver version.

```
uint32_t spi_m_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

34.6 SPI Slave Asynchronous Driver

In the serial peripheral interface (SPI) slave asynchronous driver, a callback function can be registered in the driver by the application and triggered when the transfer is done. The driver 25.2.3.2 io_read/io_write() function will attempt to read/write the data from/to the master device.

When data is written through the I/O writing function, the data buffer pointer and its size is logged internally by the driver. The data is sent character by character in background interrupts. When all data in the buffer is sent, a callback is invoked to notify that it's done.

When the driver is enabled, the characters shifted in will be filled to a receiving ring buffer, then the available data can be read out through the I/O reading function. On each character's reception a callback is invoked.

In some cases, the SS deactivation is considered. It's notified through a completion callback with status code zero. When status code is lower than zero, an error is indicated.

Refer 34. SPI Drivers for more detailed SPI basics.

34.6.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable SPI slave
- Hookup callback handlers on TX complete, RX complete, or error events
- Read/Write message to/from the master

34.6.2 Summary of Configuration Options

Below is a list of the main SPI slave parameters that can be configured in START. Many of these parameters are used by the 34.6.9.1 spi_s_async_init function when initializing the driver and underlying hardware. Most of the initialized values can be overridden.

- Select character size
- Which clock source is used

34.6.3 Driver Implementation Description

After the SPI hardware initialization, the 34.6.9.12 spi_s_async_get_io_descriptor function is needed to register an I/O descriptor. Then use 34.6.9.9 spi_s_async_register_callback to register a callback function for the RX/TX complete, and enable the SPI hardware. At the end, start the read/write operation.

34.6.3.1 Limitations

When received data is not read promptly, the ring buffer is used. In this case the oldest characters will be overwritten by the newest ones.

34.6.3.2 Known Issues and Workarounds

When writing data through the SPI slave, the time that the data appears on the data line depends on the SPI hardware, and previous writing state, since there can be data in output fifo filled by previous broken transmitting. The number of such dummy/broken characters is limited by the hardware. Whether these dummy/broken characters can be flushed is also limited by the hardware.

34.6.4 Example of Usage

The following shows a simple example of using the SPI slave. The SPI slave must have been initialized by 34.6.9.1 spi_s_async_init. This initialization will configure the operation of the SPI slave.

The example registers an I/O descriptor and enables the hardware. Then it registers a callback for RX complete and finally starts a reading operation.

```
        /**
         * Example of using SPI_0 to write "Hello World" using the I/
O abstraction.

 * Since the driver is asynchronous we need to use statically allocated mem
ory for string

 * because driver initiates transfer and then returns before the transmissi
on is completed.

 * Once transfer has been completed the tx_cb function will be called.
         */
        static uint8_t example_SPI_0[12] = "Hello World!";

static void complete_cb_SPI_0(const struct spi_s_async_descriptor *const de
sc)
        {
            /* Transfer completed */
        }
        void SPI_0_example(void)
        {
            struct io_descriptor *io;
            spi_s_async_get_io_descriptor(&SPI_0, &io);

    spi_s_async_register_callback(&SPI_0, SPI_S_CB_TX, (FUNC_PTR)complete_c
b_SPI_0);
            spi_s_async_enable(&SPI_0);
            io_write(io, example_SPI_0, 12);
        }
```

34.6.5 Dependencies

- The SPI slave peripheral and its related I/O lines and clocks

- The NVIC must be configured so that SPI interrupt requests are periodically serviced

34.6.6 Structs

34.6.6.1 spi_s_async_status Struct

SPI slave status.

Members

txcnt	Number of characters to send
rxrdy_cnt	Number of characters ready in buffer
error	Last error code.
tx_busy	TX busy.

34.6.6.2 spi_s_async_callbacks Struct

SPI Slave HAL callbacks.

Members

complete	Callback invoked when the CS deactivates, goes wrong, or aborts.
tx	Callback invoked when transmitting has been down.
rx	Callback invoked when each character received.

34.6.6.3 spi_s_async_descriptor Struct

SPI Slave HAL driver struct for asynchronous access with ring buffer.

Members

dev	SPI device instance
io	I/O read/write
callbacks	Callbacks for asynchronous transfer
txbuf	Transmit buffer.
txsize	Transmit size in number of characters.
txcnt	Transmit count in number of characters.
rx_rb	ring buffer for RX.
error	Last error code.
busy	TX busy.
enabled	Enabled.

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34.6.7 Enums

34.6.7.1 spi_s_async_cb_type Enum

SPI_S_CB_TX	Callback type for TX finish, see spi_s_cb_xfer_t.
SPI_S_CB_RX	Callback type for RX notification, see spi_s_cb_xfer_t.
SPI_S_CB_COMPLETE	Callback type for CS deactivate, error or abort, see spi_s_cb_complete_t.

34.6.8 Typedefs

34.6.8.1 spi_s_async_cb_complete_t typedef

typedef void(* spi_s_async_cb_complete_t) (struct spi_s_async_descriptor *, const int32_t status)

Prototype of callback on SPI transfer completion.

34.6.8.2 spi_s_async_cb_xfer_t typedef

typedef void(* spi_s_async_cb_xfer_t) (struct spi_s_async_descriptor *)

Prototype of callback on SPI transfer notification.

34.6.9 Functions

34.6.9.1 spi_s_async_init

Initialize the SPI Slave HAL instance and hardware for callback mode.

```
int32_t spi_s_async_init(
    struct spi_s_async_descriptor * spi,
    void *const hw,
    uint8_t *const rxbuf,
    int16_t bufsize
)
```

Initialize SPI Slave HAL with interrupt mode (uses callbacks).

Parameters

spi	Type: struct 34.6.6.3 spi_s_async_descriptor Struct * Pointer to the SPI Slave HAL instance.
hw	Type: void *const Pointer to the hardware base.
rxbuf	Type: uint8_t *const Pointer to the buffer for receiving ring buffer.
bufsize	Type: int16_t The receiving ring buffer size.

Returns

Type: int32_t

Operation status.

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0	Success.
-1	Error.

34.6.9.2 spi_s_async_deinit

Deinitialize the SPI HAL instance.

```
void spi_s_async_deinit(
    struct spi_s_async_descriptor * spi
)
```

Abort transfer, flush buffers, disable and reset SPI, de-init software.

Parameters

spi	Type: struct 34.6.6.3 spi_s_async_descriptor Struct * Pointer to the SPI Slave HAL instance.

Returns

Type: void

34.6.9.3 spi_s_async_enable

Enable SPI and start background RX.

```
void spi_s_async_enable(
    struct spi_s_async_descriptor * spi
)
```

Enable the hardware and start RX with buffer in background.

Parameters

spi	Type: struct 34.6.6.3 spi_s_async_descriptor Struct * Pointer to the SPI Slave HAL instance.

Returns

Type: void

34.6.9.4 spi_s_async_disable

Disable SPI and abort any pending transfer in progress and flush buffers.

```
void spi_s_async_disable(
    struct spi_s_async_descriptor * spi
)
```

Disable SPI and flush buffers. If there is pending transfer, the complete callback is invoked with `SPI_ERR_ABORT` status.

Parameters

spi	Type: struct 34.6.6.3 spi_s_async_descriptor Struct * Pointer to the SPI Slave HAL instance.

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Returns

Type: void

34.6.9.5 spi_s_async_set_mode

Set SPI mode.

```
int32_t spi_s_async_set_mode(
    struct spi_s_async_descriptor * spi,
    const enum spi_transfer_mode mode
)
```

Set the SPI transfer mode (spi_transfer_mode_t), which controls the clock polarity and clock phase:

- Mode 0: leading edge is rising edge, data sample on leading edge.
- Mode 1: leading edge is rising edge, data sample on trailing edge.
- Mode 2: leading edge is falling edge, data sample on leading edge.
- Mode 3: leading edge is falling edge, data sample on trailing edge. Note that SPI must be disabled to change mode.

Parameters

spi	Type: struct 34.6.6.3 spi_s_async_descriptor Struct * Pointer to the HAL SPI instance.
mode	Type: const enum spi_transfer_mode The mode (spi_transfer_mode_t).

Returns

Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_DENIED	Not Ready
ERR_BUSY	Busy, CS activated.

34.6.9.6 spi_s_async_set_char_size

Set SPI transfer character size in number of bits.

```
int32_t spi_s_async_set_char_size(
    struct spi_s_async_descriptor * spi,
    const enum spi_char_size char_size
)
```

The character size (spi_char_size_t) influence the way the data is sent/received. For char size <= 8-bit, data is stored byte by byte. For char size between 9-bit ~ 16-bit, data is stored in 2-byte length. Note that the default and recommended char size is 8-bit since it's supported by all system. Note that the SPI must be disabled to change character size. Also it affects buffer accessing, the ring buffer should be flushed before changing it to avoid conflicts.

Parameters

spi	Type: struct 34.6.6.3 spi_s_async_descriptor Struct * Pointer to the HAL SPI instance.
char_size	Type: const enum spi_char_size The char size (~32, recommended 8).

Returns
Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_DENIED	Not Ready
ERR_BUSY	Busy, CS activated.

34.6.9.7 spi_s_async_set_data_order

Set SPI transfer data order.

```
int32_t spi_s_async_set_data_order(
    struct spi_s_async_descriptor * spi,
    const enum spi_data_order dord
)
```

Note that the SPI must be disabled to change data order.

Parameters

spi	Type: struct 34.6.6.3 spi_s_async_descriptor Struct * Pointer to the HAL SPI instance.
dord	Type: const enum spi_data_order The data order: send LSB/MSB first.

Returns
Type: int32_t

Operation status.

ERR_NONE	Success.
ERR_DENIED	Not Ready
ERR_BUSY	Busy, CS activated.

34.6.9.8 spi_s_async_get_status

Get SPI transfer status.

```
int32_t spi_s_async_get_status(
    struct spi_s_async_descriptor * spi,
```

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```
    struct spi_s_async_status * stat
)
```

Get transfer status, buffers statuses in a structured way.

Parameters

spi Type: struct 34.6.6.3 spi_s_async_descriptor Struct *

Pointer to the HAL SPI instance.

stat Type: struct 34.6.6.1 spi_s_async_status Struct *

Pointer to the detailed status descriptor, set to NULL to not return details.

Returns

Type: int32_t

Status.

0	Not busy.
ERR_BUSY	Busy.
-1	Error.

34.6.9.9 spi_s_async_register_callback

Register a function as SPI transfer completion callback.

```
void spi_s_async_register_callback(
    struct spi_s_async_descriptor * spi,
    const enum spi_s_async_cb_type type,
    const FUNC_PTR func
)
```

Register callback function specified by its `type`.

- SPI_S_CB_COMPLETE: set the function that will be called on SPI transfer completion including deactivating the CS.
- SPI_S_CB_TX: set the function that will be called on the TX threshold notification.
- SPI_S_CB_RX: set the function that will be called on the RX threshold notification. Register a NULL function to not use the callback.

Parameters

spi Type: struct 34.6.6.3 spi_s_async_descriptor Struct *

Pointer to the HAL SPI instance.

type Type: const enum 34.6.7.1 spi_s_async_cb_type Enum

Callback type (spi_s_cb_type).

func Type: const 40.3.2.1 FUNC_PTR typedef

Pointer to callback function.

Returns

Type: void

34.6.9.10 spi_s_async_flush_rx_buffer

Flush the RX ring buffer.

```
void spi_s_async_flush_rx_buffer(
    struct spi_s_async_descriptor * spi
)
```

Parameters

spi Type: struct 34.6.6.3 spi_s_async_descriptor Struct *

Pointer to the HAL SPI instance.

Returns

Type: void

34.6.9.11 spi_s_async_abort_tx

Abort pending transmission.

```
void spi_s_async_abort_tx(
    struct spi_s_async_descriptor * spi
)
```

Parameters

spi Type: struct 34.6.6.3 spi_s_async_descriptor Struct *

Pointer to the HAL SPI instance.

Returns

Type: void

34.6.9.12 spi_s_async_get_io_descriptor

Return I/O descriptor for this SPI instance.

```
int32_t spi_s_async_get_io_descriptor(
    struct spi_s_async_descriptor * spi,
    struct io_descriptor ** io
)
```

This function will return an I/O instance for this SPI driver instance

Parameters

spi Type: struct 34.6.6.3 spi_s_async_descriptor Struct *

An spi slave descriptor which is used to communicate through SPI

io Type: struct 25.2.1.1 io_descriptor Struct **

A pointer to an I/O descriptor pointer type

Returns

Type: int32_t

Error code

0	No error detected
<0	Error code

34.6.9.13 spi_s_async_get_version

Retrieve the current driver version.

```
uint32_t spi_s_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

34.7 SPI Slave Synchronous Driver

The functions in the serial peripheral interface (SPI) Slave synchronous driver provides an interface to read/write the data from/to the master device.

When data is read or written through the I/O writing function, the driver keeps polling until the correct amount of data is achieved. Also, it's possible to perform a full-duplex read and write through transfer function, which process both read and write at the same time.

When SS detection is considered, a "break on SS detection" option can be enabled to make it possible to terminate the read/write/transfer on SS desertion.

Refer 34. SPI Drivers for more detailed SPI basics.

34.7.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable SPI slave
- Read/Write message to/from the master
- Data transfer: transmission, reception, and full-duplex

34.7.2 Summary of Configuration Options

Below is a list of the main SPI slave parameters that can be configured in START. Many of these parameters are used by the 34.7.7.1 spi_s_sync_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden.

- Select character size
- Which clock source is used

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34.7.3 Driver Implementation Description

After the SPI hardware initialization, the 34.7.7.10 spi_s_sync_get_io_descriptor function is needed to register an I/O descriptor. Then enable SPI hardware and start the read/write operation.

34.7.3.1 Known Issues and Workarounds

When writing data through SPI slave, the time that the data appears on the data line depends on the SPI hardware and previous writing state, since there can be data in output FIFO filled by previous broken transmitting. The number of such dummy/broken characters is limited by the hardware. Whether these dummy/broken characters can be flushed is also limited by the hardware.

34.7.4 Example of Usage

The following shows a simple example of using the SPI slave. The SPI slave must have been initialized by 34.7.7.1 spi_s_sync_init. This initialization will configure the operation of the SPI slave.

The example enables SPI slave, and finally starts a reading operation to the master.

```
/** * Example of using SPI_0 to write "Hello World" using the I/
O abstraction. */
static uint8_t example_SPI_0[12] = "Hello World!";void SPI_0_example(void)
{    struct io_descriptor *io;    spi_s_sync_get_io_descriptor(&SPI_0, &io)
;    spi_s_sync_enable(&SPI_0);    io_write(io, example_SPI_0, 12);}
```

34.7.5 Dependencies

- SPI slave peripheral and its related I/O lines and clocks

34.7.6 Structs

34.7.6.1 spi_s_sync_descriptor Struct

SPI Slave HAL driver struct for synchronous access.

Members

dev	SPI device instance
io	I/O read/write
break_on_ss_det	Break on SS desert detection.

34.7.7 Functions

34.7.7.1 spi_s_sync_init

Initialize the SPI Slave HAL instance and hardware.

```
int32_t spi_s_sync_init(
    struct spi_s_sync_descriptor * spi,
    void *const hw
)
```

Initialize SPI Slave HAL with polling mode.

Parameters

spi Type: struct 34.7.6.1 spi_s_sync_descriptor Struct *

Pointer to the SPI Slave HAL instance.

hw Type: void *const

Pointer to the hardware base.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error.

34.7.7.2 spi_s_sync_deinit

Deinitialize the SPI HAL instance.

```
void spi_s_sync_deinit(
    struct spi_s_sync_descriptor * spi
)
```

Disable and reset SPI, de-init software.

Parameters

spi Type: struct 34.7.6.1 spi_s_sync_descriptor Struct *

Pointer to the SPI Slave HAL instance.

Returns

Type: void

34.7.7.3 spi_s_sync_enable

Enable SPI.

```
void spi_s_sync_enable(
    struct spi_s_sync_descriptor * spi
)
```

Parameters

spi Type: struct 34.7.6.1 spi_s_sync_descriptor Struct *

Pointer to the SPI Slave HAL instance.

Returns

Type: void

34.7.7.4 spi_s_sync_disable

Disable SPI.

```
void spi_s_sync_disable(
    struct spi_s_sync_descriptor * spi
)
```

Parameters

spi	Type: struct 34.7.6.1 spi_s_sync_descriptor Struct * Pointer to the SPI Slave HAL instance.

Returns

Type: void

34.7.7.5 spi_s_sync_set_mode

Set SPI mode.

```
int32_t spi_s_sync_set_mode(
    struct spi_s_sync_descriptor * spi,
    const enum spi_transfer_mode mode
)
```

Set the SPI transfer mode (spi_transfer_mode_t), which controls the clock polarity and clock phase:

- Mode 0: leading edge is rising edge, data sample on leading edge.
- Mode 1: leading edge is rising edge, data sample on trailing edge.
- Mode 2: leading edge is falling edge, data sample on leading edge.
- Mode 3: leading edge is falling edge, data sample on trailing edge. Note that SPI must be disabled to change mode.

Parameters

spi	Type: struct 34.7.6.1 spi_s_sync_descriptor Struct * Pointer to the HAL SPI instance.
mode	Type: const enum spi_transfer_mode The mode (spi_transfer_mode_t).

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error.

34.7.7.6 spi_s_sync_set_char_size

Set SPI transfer character size in number of bits.

```
int32_t spi_s_sync_set_char_size(
    struct spi_s_sync_descriptor * spi,
    const enum spi_char_size char_size
)
```

The character size (spi_char_size_t) influence the way the data is sent/received. For char size <= 8-bit, data is stored byte by byte. For char size between 9-bit ~ 16-bit, data is stored in 2-byte length. Note that the default and recommended char size is 8-bit since it's supported by all system. Note that the SPI must

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be disabled to change character size. Also it affects buffer accessing, the ring buffer should be flushed before changing it to avoid conflicts.

Parameters

spi	Type: struct 34.7.6.1 spi_s_sync_descriptor Struct * Pointer to the HAL SPI instance.
char_size	Type: const enum spi_char_size The char size (~32, recommended 8).

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error.

34.7.7.7 spi_s_sync_set_data_order

Set SPI transfer data order.

```
int32_t spi_s_sync_set_data_order(
    struct spi_s_sync_descriptor * spi,
    const enum spi_data_order dord
)
```

Note that the SPI must be disabled to change data order.

Parameters

spi	Type: struct 34.7.6.1 spi_s_sync_descriptor Struct * Pointer to the HAL SPI instance.
dord	Type: const enum spi_data_order The data order: send LSB/MSB first.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error.

34.7.7.8 spi_s_sync_break_on_ss_detect

Enable/disable break on SS desert detection.

```
void spi_s_sync_break_on_ss_detect(
    struct spi_s_sync_descriptor * spi,
```

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```
    const bool enable
)
```

Parameters

spi	Type: struct 34.7.6.1 spi_s_sync_descriptor Struct * Pointer to the HAL SPI instance.
enable	Type: const bool Set to `true` to break R/W loop on SS desert.

Returns

Type: void

34.7.7.9 spi_s_sync_transfer

Write/read at the same time.

```
int32_t spi_s_sync_transfer(
    struct spi_s_sync_descriptor * spi,
    const struct spi_xfer * xfer
)
```

Parameters

spi	Type: struct 34.7.6.1 spi_s_sync_descriptor Struct * Pointer to the HAL SPI instance.
xfer	Type: const struct spi_xfer * Pointer to the transfer information (spi_xfer).

Returns

Type: int32_t

Operation result.

<0	Error.
>=0	Number of characters transferred.

34.7.7.10 spi_s_sync_get_io_descriptor

Return I/O descriptor for this SPI instance.

```
int32_t spi_s_sync_get_io_descriptor(
    struct spi_s_sync_descriptor * spi,
    struct io_descriptor ** io
)
```

This function will return an I/O instance for this SPI driver instance

Parameters

spi	Type: struct 34.7.6.1 spi_s_sync_descriptor Struct *

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An SPI slave descriptor, which is used to communicate through SPI

io Type: struct 25.2.1.1 io_descriptor Struct **

A pointer to an I/O descriptor pointer type

Returns

Type: int32_t

Error code.

0	No error detected
<0	Error code

34.7.7.11 spi_s_sync_get_version

Retrieve the current driver version.

```
uint32_t spi_s_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

35. Segment LCD Drivers

This Segment LCD driver provides an interface for segment on/off/blink, animation, and character display.

The following driver variants are available:

- 35.1 Segment LCD Synchronous Driver: The driver supports polling for hardware changes, functionality is synchronous to the main clock of the MCU.

35.1 Segment LCD Synchronous Driver

An LCD display is made of several segments (pixels or complete symbols) which can block the light or let it through. In each segment one electrode is connected to the common terminal (COM pin) and one is connected to the segment terminal (SEG pin). When a voltage above a certain threshold level is applied across the liquid crystal, the crystal orientation will change and either let the light through or block it.

The driver supports segment on/off/blink, animation, and character display.

Each segment has a unique int32 segment ID which is used by the driver. The ID is combined by a common number(COM) and a segment number(SEG). The COM and SEG start from 0. The unique segment ID is calculated by this formula: (COM << 16) | SEG. For example an 8(coms)*8(segments)SLCD, the unique segment ID for a segment should be:

```
+-----+-----+---------+
| COM | SEG |    ID   |
+-----+-----+---------+
|  0  |  0  | 0x00000 |
+-----+-----+---------+
|  1  |  0  | 0x10000 |
+-----+-----+---------+
|  7  |  7  | 0x70007 |
+-----+-----+---------+
```

The segment ID can be calculated using the pre-defined macro SLCD_SEGID(com, seg).

For character display, the "segment character mapping table" and "character mapping table" should be set up during the configuration. The driver has no API to set up/change those mapping settings.

There are two pre-defined "segment character mapping tables" in this driver, the 7-segments and the 14-segments. The 7-segments character mapping can display 0-9 and a-f, the 14-segments character mapping can display 0-9, A-Z and some special ASCII. For more details refer to hpl_slcd_cm_7_seg_mapping.h and hpl_slcd_cm_14_seg_mapping.h. The application can also adjust this mapping table in the configuration header file to add more character mappings or remove some unused characters.

The "character mapping" is used to set up each character in SLCD display screen. The driver supports multiple character mapping, the max. number varies according to which MCU/MPU is used. For example, if an LCD display screen has five 7-segments character and eight 14-segments character, and the MCU supports max. 44 characters setting, then the 13 characters should have been set up during the configuration. Application can select any position from those 44 characters setting to save those 13 characters. The index of the character setting will be used in the driver API. For example, five 7-segments character settings to 0 to 4 and eight 14-segments character settings to 10 to 17. Then the application can use the index from 0 to 4 to display the 7-segments character and use the index from 10 to 14 to display the 14-segments character.

The driver can be used in following applications:

- SLCD display control, segment on/off/blink
- Play battery animation, running wheel, WIFI signal, etc.
- Display Time Clock by 7 segments character mapping
- Display ASCII character by 14 segments character mapping

35.1.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable the SLCD hardware
- Switch segment on/off
- Set segment blink
- Autonomous animation
- Character display

35.1.2 Dependencies

- The SLCD capable hardware

35.1.3 Structs

35.1.3.1 slcd_sync_descriptor Struct

Members

dev	SLCD HPL device descriptor

35.1.4 Functions

35.1.4.1 slcd_sync_init

Initialize SLCD Descriptor.

```
int32_t slcd_sync_init(
    struct slcd_sync_descriptor *const descr,
    void *const hw
)
```

Parameters

descr Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const

SLCD descriptor to be initialized

hw Type: void *const

The pointer to hardware instance

Returns

Type: int32_t

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35.1.4.2 slcd_sync_deinit

Deinitialize SLCD Descriptor.

```
int32_t slcd_sync_deinit(
    struct slcd_sync_descriptor *const descr
)
```

Parameters

descr	Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const SLCD descriptor to be deinitialized

Returns

Type: int32_t

35.1.4.3 slcd_sync_enable

Enable SLCD driver.

```
int32_t slcd_sync_enable(
    struct slcd_sync_descriptor *const descr
)
```

Parameters

descr	Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const SLCD descriptor to be initialized

Returns

Type: int32_t

35.1.4.4 slcd_sync_disable

Disable SLCD driver.

```
int32_t slcd_sync_disable(
    struct slcd_sync_descriptor *const descr
)
```

Parameters

descr	Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const SLCD descriptor to be disabled

Returns

Type: int32_t

35.1.4.5 slcd_sync_seg_on

Turn on a Segment.

```
int32_t slcd_sync_seg_on(
    struct slcd_sync_descriptor *const descr,
    uint32_t seg
)
```

Parameters

descr Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const

SLCD descriptor to be enabled

seg Type: uint32_t

Segment index. The segment index is by the combination of common and segment terminal index. The SLCD_SEGID(com, seg) macro can generate the index.

Returns

Type: int32_t

35.1.4.6 slcd_sync_seg_off

Turn off a Segment.

```
int32_t slcd_sync_seg_off(
    struct slcd_sync_descriptor *const descr,
    uint32_t seg
)
```

Parameters

descr Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const

SLCD descriptor

seg Type: uint32_t

Segment index value is "(common terminals << 16 | segment terminal)"

Returns

Type: int32_t

35.1.4.7 slcd_sync_seg_blink

Blink a Segment.

```
int32_t slcd_sync_seg_blink(
    struct slcd_sync_descriptor *const descr,
    uint32_t seg,
    const uint32_t period
)
```

Parameters

descr Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const

SLCD descriptor

seg Type: uint32_t

Segment index value is "(common terminals << 16 | segment terminal)"

period Type: const uint32_t

Blink period, unit is millisecond

Returns

Type: int32_t

35.1.4.8 slcd_sync_write_char

Displays a character.

```
int32_t slcd_sync_write_char(
    struct slcd_sync_descriptor *const descr,
    const uint8_t character,
    uint32_t index
)
```

Parameters

descr	Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const SLCD descriptor
character	Type: const uint8_t Character to be displayed
index	Type: uint32_t Index of the character Mapping Group

Returns

Type: int32_t

35.1.4.9 slcd_sync_write_string

Displays character string string.

```
int32_t slcd_sync_write_string(
    struct slcd_sync_descriptor *const descr,
    uint8_t *const str,
    uint32_t len,
    uint32_t index
)
```

Parameters

descr	Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const SLCD descriptor
str	Type: uint8_t *const String to be displayed, 0 will turn off the corresponding char to display
len	Type: uint32_t Length of the string array
index	Type: uint32_t Index of the character Mapping Group

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Returns

Type: int32_t

35.1.4.10 slcd_sync_start_animation

Start animation play by a segment array.

```
int32_t slcd_sync_start_animation(
    struct slcd_sync_descriptor *const descr,
    const uint32_t segs,
    uint32_t len,
    const uint32_t period
)
```

Parameters

descr Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const

SLCD descriptor

segs Type: const uint32_t

Segment array

len Type: uint32_t

Length of the segment array

period Type: const uint32_t

Period (milliseconds) of each segment to animation

Returns

Type: int32_t

35.1.4.11 slcd_sync_stop_animation

Stop animation play by a segment array.

```
int32_t slcd_sync_stop_animation(
    struct slcd_sync_descriptor *const descr,
    const uint32_t segs,
    uint32_t len
)
```

Parameters

descr Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const

SLCD descriptor

segs Type: const uint32_t

Segment array

len Type: uint32_t

Length of the segment array

Returns

Type: int32_t

35.1.4.12 slcd_sync_set_animation_period

Set animation Frequency.

```
int32_t slcd_sync_set_animation_period(
    struct slcd_sync_descriptor *const descr,
    const uint32_t period
)
```

Parameters

descr	Type: struct 35.1.3.1 slcd_sync_descriptor Struct *const SLCD descriptor
period	Type: const uint32_t Period (million second) of each segment to animation

Returns

Type: int32_t

36. Temperature Sensor Drivers

This Temperature Sensor (TSENS) driver provides an interface for getting the operating temperature of the device.

The following driver variants are available:

- 36.2 Temperature Sensor Synchronous Driver: The driver supports polling for hardware changes, functionality is synchronous to the main clock of the MCU.
- 36.1 Temperature Sensor Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. Functionality is asynchronous to the main clock of the MCU.

36.1 Temperature Sensor Asynchronous Driver

In the Temperature Sensor (TSENS) asynchronous driver, a callback function can be registered in the driver by the application and triggered when temperature measurement complete or window monitor condition happens to let the application know the result.

36.1.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable the TSENS hardware
- Temperature Measurement (Celsius)
- Hook callback functions on temperature measurement complete or window monitor condition

36.1.2 Summary of Configuration Options

The main TSENS parameters can be configured in START. Many of these parameters are used by the 36.1.9.1 temp_async_init function when initializing the driver and underlying hardware.

36.1.3 Driver Implementation Description

The driver supports temperature measurement, and window monitor. The window monitor can be used to monitor temperature and compare to predefined threshold. The threshold include two values, lower and upper temperature value. The threshold value should be setup by application before starting window monitor. There are several monitor modes that can be selected in the driver configuration. Typical one includes inside, outside, beyond upper threshold or below the lower threshold. For different MCU/MPU device, the supported monitor modes maybe different, please refer to driver's configuration. A callback function can be registered to window monitor, once the monitor condition happens, the callback function is invoked to notify the application.

The temperature unit used in this driver is Celsius.

36.1.4 Example of Usage

The following shows a simple example of using the TSENS driver to get device temperature. The TSENS must have been initialized by 36.1.9.1 temp_async_init.

The example registers a callback function for temperature data complete and will be invoked when temperature measurement is done.

```
        static int32_t temp;
```

```
        static int32_t result;

static void read_cb_TEMPERATURE_SENSOR_0(const struct temp_async_descriptor
 *const descr, int32_t state)
        {
            result = state;
        }
        /**
         * Example of using TEMPERATURE_SENSOR_0 to generate waveform.
         */
        void TEMPERATURE_SENSOR_0_example(void)
        {
            result = -1;
            temp_async_enable(&TEMPERATURE_SENSOR_0);

    temp_async_register_callback(&TEMPERATURE_SENSOR_0, TEMP_ASYNC_READY_CB
, read_cb_TEMPERATURE_SENSOR_0);
            temp_async_read(&TEMPERATURE_SENSOR_0, &temp);
            while (result != ERR_NONE)
                ;
        }
```

36.1.5 Dependencies

- The Temperature Sensor peripheral and its related I/O lines and clocks
- The NVIC must be configured so that AC interrupt requests are periodically serviced

36.1.6 Structs

36.1.6.1 temp_async_callbacks Struct

Temperature Sensor callbacks.

Members

ready	ready
window	window condition

36.1.6.2 temp_async_descriptor Struct

Asynchronous Temperature Sensor descriptor structure.

Members

dev	Temperature HPL descriptor
cb	Temperature Callback handlers

36.1.7 Enums

36.1.7.1 temp_async_callback_type Enum

TEMP_ASYNC_READY_CB	Temperature measure complete
TEMP_ASYNC_WINDOW_CB	Temperature value reaches the window condition

36.1.8 Typedefs

36.1.8.1 temp_ready_cb_t typedef

typedef void(* temp_ready_cb_t) (const struct temp_async_descriptor *const descr, int32_t state)

Temperature read ready callback type.

Parameters

descr	Direction: in The pointer to the Temperature Sensor Descriptor
state	Direction: in Read state, ERR_NONE for read success

36.1.8.2 temp_window_cb_t typedef

typedef void(* temp_window_cb_t) (const struct temp_async_descriptor *const descr)

Temperature window callback type.

Parameters

descr	Direction: in The pointer to the Temperature Sensor Descriptor

36.1.9 Functions

36.1.9.1 temp_async_init

Initialize Temperature Sensor.

```
int32_t temp_async_init(
    struct temp_async_descriptor *const descr,
    void *const hw
)
```

Parameters

descr	Type: struct 36.1.6.2 temp_async_descriptor Struct *const Temperature Sensor Descriptor to be initialized
hw	Type: void *const The pointer to the hardware instance

Returns

Type: int32_t

36.1.9.2 temp_async_deinit

Deinitialize Temperature Sensor.

```
int32_t temp_async_deinit(
    struct temp_async_descriptor *const descr
)
```

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Parameters

descr	Type: struct 36.1.6.2 temp_async_descriptor Struct *const Temperature Sensor Descriptor to be deinitialized

Returns
Type: int32_t

36.1.9.3 temp_async_enable

Enable Temperature Sensor.

```
int32_t temp_async_enable(
    struct temp_async_descriptor *const desc
)
```

Parameters

descr	Temperature Sensor Descriptor

Returns
Type: int32_t

36.1.9.4 temp_async_disable

Disable Temperature Sensor.

```
int32_t temp_async_disable(
    struct temp_async_descriptor *const desc
)
```

Parameters

descr	Temperature Sensor Descriptor

Returns
Type: int32_t

36.1.9.5 temp_async_read

Read Temperature Value.

```
int32_t temp_async_read(
    struct temp_async_descriptor *const descr,
    int32_t *const temp
)
```

Parameters

descr	Type: struct 36.1.6.2 temp_async_descriptor Struct *const Temperature Sensor Descriptor
temp	Type: int32_t *const Temperature Value (Celsius)

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Returns

Type: int32_t

36.1.9.6 temp_async_set_window_monitor

Set temperature window monitor threshold.

```
int32_t temp_async_set_window_monitor(
    struct temp_async_descriptor *const descr,
    const int32_t lower,
    const int32_t upper
)
```

Parameters

descr Type: struct 36.1.6.2 temp_async_descriptor Struct *const

Temperature Sensor Descriptor

lower Type: const int32_t

Lower temperature value threshold (Celsius)

upper Type: const int32_t

Upper temperature value threshold (Celsius)

Returns

Type: int32_t

36.1.9.7 temp_async_start_window_monitor

Start temperature window monitor.

```
int32_t temp_async_start_window_monitor(
    struct temp_async_descriptor *const descr
)
```

Parameters

descr Type: struct 36.1.6.2 temp_async_descriptor Struct *const

Temperature Sensor Descriptor

Returns

Type: int32_t

36.1.9.8 temp_async_stop_window_monitor

Stop temperature window monitor.

```
int32_t temp_async_stop_window_monitor(
    struct temp_async_descriptor *const descr
)
```

Parameters

descr Type: struct 36.1.6.2 temp_async_descriptor Struct *const

Temperature Sensor Descriptor

Returns

Type: int32_t

36.1.9.9 temp_async_register_callback

Register callback function.

```
int32_t temp_async_register_callback(
    struct temp_async_descriptor *const descr,
    const enum temp_async_callback_type type,
    const FUNC_PTR cb
)
```

Parameters

descr	Type: struct 36.1.6.2 temp_async_descriptor Struct *const Temperature Sensor Descriptor
type	Type: const enum 36.1.7.1 temp_async_callback_type Enum Callback type
cb	Type: const 40.3.2.1 FUNC_PTR typedef A callback function, passing NULL will de-register any registered callback

Returns

Type: int32_t

36.1.9.10 temp_async_get_version

Retrieve the current driver version.

```
uint32_t temp_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

36.2 Temperature Sensor Synchronous Driver

The functions in the Temperature Sensor (TSENS) synchronous driver will block (i.e. not return) until the operation is done.

The temperature result can be get by 36.2.7.5 temp_sync_read, if the return is ERR_NONE then it's the result of the operating temperature of the device.

36.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable the TSENS hardware
- Temperature Measurement (Celsius)

36.2.2 Summary of Configuration Options

The main TSENS parameters can be configured in START. Many of these parameters are used by the 36.2.7.1 temp_sync_init function when initializing the driver and underlying hardware.

36.2.3 Driver Implementation Description

After the TSENS hardware initialization, the operating temperature of the device can be get by 36.2.7.5 temp_sync_read.

The temperature unit used in this driver is Celsius.

36.2.4 Example of Usage

The following shows a simple example of using the TSENS driver to get device temperature. The TSENS must have been initialized by tsens_sync_init().

```
/**
 * Example of using TEMPERATURE_SENSOR_0 to generate waveform.
 */
void TEMPERATURE_SENSOR_0_example(void)
{
    int32_t temp;
    temp_sync_enable(&TEMPERATURE_SENSOR_0);
    temp_sync_read(&TEMPERATURE_SENSOR_0, &temp);
}
```

36.2.5 Dependencies

- The Temperature Sensor peripheral and its related I/O lines and clocks

36.2.6 Structs

36.2.6.1 temp_sync_descriptor Struct

Members

dev	Temperature Sensor HPL device descriptor

36.2.7 Functions

36.2.7.1 temp_sync_init

Initialize Temperature Sensor Descriptor.

```
int32_t temp_sync_init(
    struct temp_sync_descriptor *const descr,
    void *const hw
)
```

Parameters

desc	Temperature Sensor Descriptor to be initialized
hw	Type: void *const The pointer to the hardware instance

Returns

Type: int32_t

36.2.7.2 temp_sync_deinit

Deinitialize Temperature Sensor Descriptor.

```
int32_t temp_sync_deinit(
    struct temp_sync_descriptor *const descr
)
```

Parameters

desc	Temperature Sensor Descriptor to be deinitialized

Returns

Type: int32_t

36.2.7.3 temp_sync_enable

Enable Temperature Sensor.

```
int32_t temp_sync_enable(
    struct temp_sync_descriptor *const descr
)
```

Parameters

desc	Temperature Sensor Descriptor

Returns

Type: int32_t

36.2.7.4 temp_sync_disable

Disable Temperature Sensor.

```
int32_t temp_sync_disable(
    struct temp_sync_descriptor *const descr
)
```

Parameters

desc	Temperature Sensor Descriptor

Returns

Type: int32_t

36.2.7.5 temp_sync_read

Read Temperature Value.

```
int32_t temp_sync_read(
    struct temp_sync_descriptor *const descr,
    int32_t *const temp
)
```

Parameters

desc	Temperature Sensor Descriptor
temp	Type: int32_t *const Temperature Value (Celsius)

Returns

Type: int32_t

36.2.7.6 temp_sync_get_version

Retrieve the current driver version.

```
uint32_t temp_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

37. Timer Driver

The Timer driver provides means for delayed and periodical function invocation.

37.1 Timer Basics and Best Practice

A timer task is a piece of code (function) executed at a specific time or periodically by the timer after the task has been added to the timers task queue. The execution delay or period is set in ticks, where one tick is defined as a configurable number of clock cycles in the hardware timer. Changing the number of clock cycles in a tick automatically changes execution delays and periods for all tasks in the timers task queue.

A task has two operation modes, single-shot or repeating mode. In single-shot mode the task is removed from the task queue and then executed once. In repeating mode the task reschedules itself automatically after it has executed based on the period set in the task configuration. In single-shot mode a task is removed from the task queue before its callback is invoked. It allows an application to reuse the memory of expired tasks in the callback.

Each instance of the Timer driver supports an infinite number of timer tasks, only limited by the amount of RAM available.

37.2 Summary of the API's Functional Features

The API provides functions to:

- Initialization and deinitialization
- Starting and stopping
- Timer tasks - periodical invocation of functions
- Changing and obtaining of the period of a timer

37.3 Summary of Configuration Options

A hardware timer is needed for this timer driver, and can be configured in START. Take SAM D21 for example, one of TC, TCC, RTC can be selected as hardware timer instance, and can configure timer tick in START.

37.4 Driver Implementation Description

37.4.1 Concurrency

The Timer driver is an interrupt driven driver.This means that the interrupt that triggers a task may occur during the process of adding or removing a task via the driver's API. In such case the interrupt processing is postponed until the task adding or removing is complete.

The task queue is not protected from the access by interrupts not used by the driver. Due to this it is not recommended to add or remove a task from such interrupts: in case if a higher priority interrupt supersedes the driver's interrupt, adding or removing a task may cause an unpredictable behavior of the driver.

37.4.2 Limitations

- The driver is designed to work outside of an operating system environment. The task queue is therefore processed in interrupt context which may delay execution of other interrupts
- If there are a lot of frequently called interrupts with a priority higher than the driver's one, it may cause delay for triggering of a task

37.5 Example of Usage

The following shows a simple example of using the Timer. The Timer driver must have been initialized by 37.10.1 timer_init. This initialization will configure the operation of the hardware timer instance, such as ticks for this timer.

The example enables two repeat timer tasks at different time intervals.

```
        /**
         * Example of using TIMER_0.
         */

static void TIMER_0_task1_cb(const struct timer_task *const timer_task)
        {
        }

static void TIMER_0_task2_cb(const struct timer_task *const timer_task)
        {
        }
        void TIMER_0_example(void)
        {
            TIMER_0_task1.interval = 100;
            TIMER_0_task1.cb       = TIMER_0_task1_cb;
            TIMER_0_task1.mode     = TIMER_TASK_REPEAT;
            TIMER_0_task2.interval = 200;
            TIMER_0_task2.cb       = TIMER_0_task2_cb;
            TIMER_0_task2.mode     = TIMER_TASK_REPEAT;
            timer_add_task(&TIMER_0, &TIMER_0_task1);
            timer_add_task(&TIMER_0, &TIMER_0_task2);
            timer_start(&TIMER_0);
        }
```

37.6 Dependencies

- Each instance of the driver requires separate hardware timer capable of generating periodic interrupt

37.7 Structs

37.7.1 timer_task Struct

Timer task structure.

Members

elem

time_label	List element.
interval	Absolute timer start time.
cb	Number of timer ticks before calling the task.
mode	Function pointer to the task.

37.7.2 timer_descriptor Struct

Timer structure.

Members

func	
device	
time	
tasks	
flags	Timer tasks list.

37.8 Enums

37.8.1 timer_task_mode Enum

TIMER_TASK_ONE_SHOT

TIMER_TASK_REPEAT

37.9 Typedefs

37.9.1 timer_cb_t typedef

typedef void(* timer_cb_t) (const struct timer_task *const timer_task)

Timer task callback function type.

37.10 Functions

37.10.1 timer_init

Initialize timer.

```
int32_t timer_init(
    struct timer_descriptor *const descr,
    void *const hw,
    struct _timer_hpl_interface *const func
)
```

This function initializes the given timer. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

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Parameters

descr	Type: struct 37.7.2 timer_descriptor Struct *const A timer descriptor to initialize
hw	Type: void *const The pointer to the hardware instance
func	Type: struct _timer_hpl_interface *const The pointer to a set of function pointers

Returns

Type: int32_t

Initialization status.

37.10.2 timer_deinit

Deinitialize timer.

```
int32_t timer_deinit(
    struct timer_descriptor *const descr
)
```

This function deinitializes the given timer. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr	Type: struct 37.7.2 timer_descriptor Struct *const A timer descriptor to deinitialize

Returns

Type: int32_t

De-initialization status.

37.10.3 timer_start

Start timer.

```
int32_t timer_start(
    struct timer_descriptor *const descr
)
```

This function starts the given timer. It checks if the given hardware is initialized.

Parameters

descr	Type: struct 37.7.2 timer_descriptor Struct *const The timer descriptor of a timer to start

Returns

Type: int32_t

Timer starting status.

37.10.4 timer_stop

Stop timer.

```
int32_t timer_stop(
    struct timer_descriptor *const descr
)
```

This function stops the given timer. It checks if the given hardware is initialized.

Parameters

descr	Type: struct 37.7.2 timer_descriptor Struct *const The timer descriptor of a timer to stop

Returns

Type: int32_t

Timer stopping status.

37.10.5 timer_set_clock_cycles_per_tick

Set amount of clock cycles per timer tick.

```
int32_t timer_set_clock_cycles_per_tick(
    struct timer_descriptor *const descr,
    const uint32_t clock_cycles
)
```

This function sets the amount of clock cycles per timer tick for the given timer. It checks if the given hardware is initialized.

Parameters

descr	Type: struct 37.7.2 timer_descriptor Struct *const The timer descriptor of a timer to stop
clock_cycles	Type: const uint32_t The amount of clock cycles per tick to set

Returns

Type: int32_t

Setting clock cycles amount status.

37.10.6 timer_get_clock_cycles_in_tick

Retrieve the amount of clock cycles in a tick.

```
int32_t timer_get_clock_cycles_in_tick(
    const struct timer_descriptor *const descr,
```

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```
    uint32_t *const cycles
)
```

This function retrieves how many clock cycles there are in a single timer tick. It checks if the given hardware is initialized.

Parameters

descr Type: const struct 37.7.2 timer_descriptor Struct *const

The timer descriptor of a timer to convert ticks to clock cycles

cycles Type: uint32_t *const

The amount of clock cycles

Returns

Type: int32_t

The status of clock cycles retrieving.

37.10.7 timer_add_task

Add timer task.

```
int32_t timer_add_task(
    struct timer_descriptor *const descr,
    struct timer_task *const task
)
```

This function adds the given timer task to the given timer. It checks if the given hardware is initialized.

Parameters

descr Type: struct 37.7.2 timer_descriptor Struct *const

The timer descriptor of a timer to add task to

task Type: struct 37.7.1 timer_task Struct *const

A task to add

Returns

Type: int32_t

Timer's task adding status.

37.10.8 timer_remove_task

Remove timer task.

```
int32_t timer_remove_task(
    struct timer_descriptor *const descr,
    const struct timer_task *const task
)
```

This function removes the given timer task from the given timer. It checks if the given hardware is initialized.

Parameters

descr	Type: struct 37.7.2 timer_descriptor Struct *const The timer descriptor of a timer to remove task from
task	Type: const struct 37.7.1 timer_task Struct *const A task to remove

Returns
Type: int32_t

Timer's task removing status.

37.10.9 timer_get_version

Retrieve the current driver version.

```
uint32_t timer_get_version(
    void
)
```

Returns
Type: uint32_t

Current driver version.

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38. USART Drivers

Four driver variants are available for the USART: Synchronous, Asynchronous, RTOS, and DMA.

- 38.5 USART Synchronous Driver: The driver supports polling for hardware changes, the functionality is synchronous to the main clock of the MCU.
- 38.2 USART Asynchronous Driver: The driver supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.
- 38.4 USART RTOS Driver: The driver supports a Real-Time operating system, i.e. is thread safe.
- 38.3 USART DMA Driver: The driver uses a DMA system to transfer and receive data between the USART and a memory buffer. It supports a callback handler for the IRQ caused by hardware state changes. The functionality is asynchronous to the main clock of the MCU.

38.1 USART Basics and Best Practice

The universal synchronous and asynchronous receiver and transmitter (USART) is normally used to transfer data from one device to the other.

The USART provides one full duplex universal synchronous asynchronous serial link. Data frame format is widely programmable (data length, parity, number of stop bits) to support a maximum of standards. The receiver implements parity error, framing error, and overrun error detection. The receiver timeout enables handling variable-length frames and the transmitter timeguard facilitates communications with slow remote devices. Multidrop communications are also supported through address bit handling in reception and transmission.

38.2 USART Asynchronous Driver

The universal synchronous and asynchronous receiver and transmitter (USART) is normally used to transfer data from one device to the other.

The USART driver uses a ring buffer to store received data. When the USART raise the data received interrupt, this data will be stored in the ring buffer at the next free location. When the ring buffer is full, the next reception will overwrite the oldest data stored in the ring buffer. There is one USART_BUFFER_SIZE macro per used hardware instance, e.g. for SERCOM0 the macro is called SERCOM0_USART_BUFFER_SIZE.

On the other hand, when sending data over USART, the data is not copied to an internal buffer, but the data buffer supplied by the user is used. The callback will only be generated at the end of the buffer and not for each byte.

The user can set an action for flow control pins by 38.2.10.7 usart_async_set_flow_control function, if the flow control is enabled. All the available states are defined in 38.2.10.14 usart_async_flow_control_status union.

Note that user can set state of flow control pins only if automatic support of the flow control is not supported by the hardware.

38.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware

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- Register I/O descriptor
- Enable or disable USART
- Hookup callback handlers on transfer complete, or error events
- Data transfer: transmission and reception

38.2.2 Summary of Configuration Options

Below is a list of the main USART parameters that can be configured in START. Many of these are used by the 38.2.10.1 usart_async_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Set USART baudrate
- Select UART or USART communication mode
- Select character size
- Set Data order
- Flow control
- Which clock source is used

38.2.3 Driver Implementation Description

After USART hardware initialization, the 38.2.10.5 usart_async_get_io_descriptor function is needed to register an I/O descriptor. Then use 38.2.10.6 usart_async_register_callback to register the callback function for transfer, and enable the USART hardware. After that, start the read/write operation.

38.2.3.1 Concurrency

- The write buffer should not be changed while data is being sent

38.2.3.2 Limitations

- The driver does not support 9-bit character size
- The "USART with ISO7816" mode can be used only in ISO7816 capable devices, and the SCK pin can't be set directly. The application can use a GCLK output pin to generate SCK. For example, to communicate with a SMARTCARD with ISO7816 (F = 372; D = 1), and baudrate=9600, the SCK pin output frequency should be configured as 372*9600=3571200Hz. For more information, refer to the ISO7816 Specification.

38.2.4 Example of Usage

The following shows a simple example of using the USART. The USART master must have been initialized by 38.2.10.1 usart_async_init. This initialization will configure the operation of the USART.

The example registers an I/O descriptor and enables the hardware. Then it registers a callback, and finally starts a writing operation.

```
         /**
          * Example of using USART_0 to write "Hello World" using the I/
O abstraction.


 * Since the driver is asynchronous we need to use statically allocated mem
ory for string

 * because driver initiates transfer and then returns before the transmissi
on is completed.


 * Once transfer has been completed the tx_cb function will be called.
```

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```
          */
        static uint8_t example_USART_0[12] = "Hello World!";

static void tx_cb_USART_0(const struct usart_async_descriptor *const io_des
cr)
        {
            /* Transfer completed */
        }
        void USART_0_example(void)
        {
            struct io_descriptor *io;

    usart_async_register_callback(&USART_0, USART_ASYNC_TXC_CB, tx_cb_USART
_0);
            /
*usart_async_register_callback(&USART_0, USART_ASYNC_RXC_CB, rx_cb);

    usart_async_register_callback(&USART_0, USART_ASYNC_ERROR_CB, err_cb);*
/
            usart_async_get_io_descriptor(&USART_0, &io);
            usart_async_enable(&USART_0);
            io_write(io, example_USART_0, 12);
        }
```

38.2.5 Dependencies

- The USART peripheral and its related I/O lines and clocks
- The NVIC must be configured so that USART interrupt requests are periodically serviced

38.2.6 Structs

38.2.6.1 usart_async_callbacks Struct

USART callbacks.

Members

tx_done

rx_done

error

38.2.6.2 usart_async_status Struct

USART status Status descriptor holds the current status of transfer.

Members

flags	Status flags
txcnt	Number of characters transmitted
rxcnt	Number of characters receviced

38.2.6.3 usart_async_descriptor Struct

Asynchronous USART descriptor structure.

Members

io

device

usart_cb

stat

rx

tx_por

tx_buffer

tx_buffer_length

38.2.7 Defines

38.2.7.1 USART_ASYNC_STATUS_BUSY

#define USART_ASYNC_STATUS_BUSY( ) 0x0001

USART write busy

38.2.8 Enums

38.2.8.1 usart_async_callback_type Enum

USART_ASYNC_RXC_CB

USART_ASYNC_TXC_CB

USART_ASYNC_ERROR_CB

38.2.9 Typedefs

38.2.9.1 usart_cb_t typedef

typedef void(* usart_cb_t) (const struct usart_async_descriptor *const descr)

USART callback type.

38.2.10 Functions

38.2.10.1 usart_async_init

Initialize USART interface.

```
int32_t usart_async_init(
    struct usart_async_descriptor *const descr,
    void *const hw,
    uint8_t *const rx_buffer,
    const uint16_t rx_buffer_length,
    void *const func
)
```

This function initializes the given I/O descriptor to be used as USART interface descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via the USART
hw	Type: void *const The pointer to the hardware instance
rx_buffer	Type: uint8_t *const An RX buffer
rx_buffer_length	Type: const uint16_t The length of the buffer above
func	Type: void *const The pointer to a set of function pointers

Returns

Type: int32_t

Initialization status.

-1	Passed parameters were invalid or the interface is already initialized
0	The initialization is completed successfully

38.2.10.2 usart_async_deinit

Deinitialize USART interface.

```
int32_t usart_async_deinit(
    struct usart_async_descriptor *const descr
)
```

This function deinitializes the given I/O descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

De-initialization status.

38.2.10.3 usart_async_enable

Enable USART interface.

```
int32_t usart_async_enable(
    struct usart_async_descriptor *const descr
)
```

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Enables the USART interface

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

Enabling status.

38.2.10.4 usart_async_disable

Disable USART interface.

```
int32_t usart_async_disable(
    struct usart_async_descriptor *const descr
)
```

Disables the USART interface

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

Disabling status.

38.2.10.5 usart_async_get_io_descriptor

Retrieve I/O descriptor.

```
int32_t usart_async_get_io_descriptor(
    struct usart_async_descriptor *const descr,
    struct io_descriptor ** io
)
```

This function retrieves the I/O descriptor of the given USART descriptor.

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART
io	Type: struct 25.2.1.1 io_descriptor Struct ** An I/O descriptor to retrieve

Returns

Type: int32_t

The status of I/O descriptor retrieving.

38.2.10.6 usart_async_register_callback

Register USART callback.

```
int32_t usart_async_register_callback(
    struct usart_async_descriptor *const descr,
    const enum usart_async_callback_type type,
    usart_cb_t cb
)
```

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART
type	Type: const enum 38.2.8.1 usart_async_callback_type Enum Callback type
cb	Type: 38.2.9.1 usart_cb_t typedef A callback function

Returns

Type: int32_t

The status of callback assignment.

-1	Passed parameters were invalid or the interface is not initialized
0	A callback is registered successfully

38.2.10.7 usart_async_set_flow_control

Specify action for flow control pins.

```
int32_t usart_async_set_flow_control(
    struct usart_async_descriptor *const descr,
    const union usart_flow_control_state state
)
```

This function sets action (or state) for flow control pins if the flow control is enabled. It sets state of flow control pins only if automatic support of the flow control is not supported by the hardware.

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART
state	Type: const union usart_flow_control_state A state to set the flow control pins

Returns

Type: int32_t

The status of flow control action setup.

38.2.10.8 usart_async_set_baud_rate

Set USART baud rate.

```
int32_t usart_async_set_baud_rate(
    struct usart_async_descriptor *const descr,
    const uint32_t baud_rate
)
```

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART
baud_rate	Type: const uint32_t A baud rate to set

Returns

Type: int32_t

The status of baud rate setting.

38.2.10.9 usart_async_set_data_order

Set USART data order.

```
int32_t usart_async_set_data_order(
    struct usart_async_descriptor *const descr,
    const enum usart_data_order data_order
)
```

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART
data_order	Type: const enum usart_data_order A data order to set

Returns

Type: int32_t

The status of data order setting.

38.2.10.10 usart_async_set_mode

Set USART mode.

```
int32_t usart_async_set_mode(
    struct usart_async_descriptor *const descr,
    const enum usart_mode mode
)
```

Parameters

descr Type: struct 38.2.6.3 usart_async_descriptor Struct *const

A USART descriptor which is used to communicate via USART

mode Type: const enum usart_mode

A mode to set

Returns

Type: int32_t

The status of mode setting.

38.2.10.11 usart_async_set_parity

Set USART parity.

```
int32_t usart_async_set_parity(
    struct usart_async_descriptor *const descr,
    const enum usart_parity parity
)
```

Parameters

descr Type: struct 38.2.6.3 usart_async_descriptor Struct *const

A USART descriptor which is used to communicate via USART

parity Type: const enum usart_parity

A parity to set

Returns

Type: int32_t

The status of parity setting.

38.2.10.12 usart_async_set_stopbits

Set USART stop bits.

```
int32_t usart_async_set_stopbits(
    struct usart_async_descriptor *const descr,
    const enum usart_stop_bits stop_bits
)
```

Parameters

descr Type: struct 38.2.6.3 usart_async_descriptor Struct *const

A USART descriptor which is used to communicate via USART

stop_bits Type: const enum usart_stop_bits

Stop bits to set

Returns

Type: int32_t

The status of stop bits setting.

38.2.10.13 usart_async_set_character_size

Set USART character size.

```
int32_t usart_async_set_character_size(
    struct usart_async_descriptor *const descr,
    const enum usart_character_size size
)
```

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART
size	Type: const enum usart_character_size A character size to set

Returns

Type: int32_t

The status of character size setting.

38.2.10.14 usart_async_flow_control_status

Retrieve the state of flow control pins.

```
int32_t usart_async_flow_control_status(
    const struct usart_async_descriptor *const descr,
    union usart_flow_control_state *const state
)
```

This function retrieves the flow control pins if the flow control is enabled.

The function can return USART_FLOW_CONTROL_STATE_UNAVAILABLE in case if the flow control is done by the hardware and the pins state cannot be read out.

Parameters

descr	Type: const struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART
state	Type: union usart_flow_control_state *const The state of flow control pins

Returns

Type: int32_t

The status of flow control state reading.

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38.2.10.15 usart_async_is_tx_empty

Check if the USART transmitter is empty.

```
int32_t usart_async_is_tx_empty(
    const struct usart_async_descriptor *const descr
)
```

Parameters

descr	Type: const struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

The status of USART TX empty checking.

0	The USART transmitter is not empty
1	The USART transmitter is empty

38.2.10.16 usart_async_is_rx_not_empty

Check if the USART receiver is not empty.

```
int32_t usart_async_is_rx_not_empty(
    const struct usart_async_descriptor *const descr
)
```

Parameters

descr	Type: const struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

The status of the USART RX empty checking.

1	The USART receiver is not empty
0	The USART receiver is empty

38.2.10.17 usart_async_get_status

Retrieve the current interface status.

```
int32_t usart_async_get_status(
    struct usart_async_descriptor *const descr,
    struct usart_async_status *const status
)
```

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Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const A USART descriptor which is used to communicate via USART
status	Type: struct 38.2.6.2 usart_async_status Struct *const The state of USART

Returns

Type: int32_t

The status of USART status retrieving.

38.2.10.18 usart_async_flush_rx_buffer

flush USART ringbuf

```
int32_t usart_async_flush_rx_buffer(
    struct usart_async_descriptor *const descr
)
```

This function flush USART RX ringbuf.

Parameters

descr	Type: struct 38.2.6.3 usart_async_descriptor Struct *const The pointer to USART descriptor

Returns

Type: int32_t

ERR_NONE

38.2.10.19 usart_async_get_version

Retrieve the current driver version.

```
uint32_t usart_async_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

38.3 USART DMA Driver

The universal synchronous and asynchronous receiver and transmitter (USART) is normally used to transfer data from one device to the other.

When receiving data over USART DMA, the data buffer supplied by the user is used. The RX done callback will only be generated at the end of the buffer and not for each byte.

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On the other hand, when sending data over USART DMA, the data is stored in a buffer defined by the user, the TX done callback will be generated only at the end of the buffer and not for each byte.

38.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable USART
- Hookup callback handlers on transfer complete, or error events
- Data transfer: transmission, reception

38.3.2 Summary of configuration options

Below is a list of the main USART parameters that can be configured in START. Many of these are used by the 38.3.7.1 usart_dma_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Select USART DMA TX channel
- Select USART DMA RX channel
- Set USART baudrate
- Select UART or USART communication mode
- Select character size
- Set Data order
- Flow control
- Which clock source is used

38.3.3 Driver Implementation Description

After USART hardware initialization, the 38.3.7.5 usart_dma_get_io_descriptor function is needed to register an I/O descriptor. Then use 38.3.7.6 usart_dma_register_callback to register the callback function for transfer, and enable USART hardware complete. After that, start the read/write operation.

38.3.3.1 Concurrency

- The write buffer should not be changed while data is being sent

38.3.3.2 Limitations

- The driver does not support 9-bit character size

38.3.4 Example of Usage

The following shows a simple example of using the USART DMA. The USART must have been initialized by 38.3.7.1 usart_dma_init. This initialization will configure the operation of the USART.

The example registers an I/O descriptor and enables the hardware. Then it registers a callback, and finally starts a writing operation.

```
        /**
         * Example of using USART_0 to write "Hello World" using the I/
O abstraction.

 * Once transfer has been completed the tx_cb function will be called.
         */
        static uint8_t example_USART_0[12] = "Hello World!";
```

```
        static void tx_cb_USART_0(struct _dma_resource *resource)
        {
            /* Transfer completed */
        }
        void USART_0_example(void)
        {
            struct io_descriptor *io;

    usart_dma_register_callback(&USART_0, USART_DMA_TX_DONE, tx_cb_USART_0)
;
            usart_dma_get_io_descriptor(&USART_0, &io);
            usart_dma_enable(&USART_0);
            io_write(io, example_USART_0, 12);
        }
```

38.3.5 Dependencies

- The USART peripheral and its related I/O lines and clocks
- The NVIC must be configured so that USART interrupt requests are periodically serviced
- DMA

38.3.6 Structs

38.3.6.1 usart_dma_descriptor Struct

DMA USART descriptor structure.

Members

device

io

resource

38.3.7 Functions

38.3.7.1 usart_dma_init

Initialize USART interface.

```
int32_t usart_dma_init(
    struct usart_dma_descriptor *const descr,
    void *const hw,
    void *const func
)
```

This function initializes the given I/O descriptor to be used as USART interface descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr Type: struct 38.3.6.1 usart_dma_descriptor Struct *const

A USART descriptor which is used to communicate via the USART

hw Type: void *const

The pointer to the hardware instance

func	Type: void *const The pointer to as set of functions pointers

Returns

Type: int32_t

Initialization status.

-1	Passed parameters were invalid or the interface is already initialized
0	The initialization is completed successfully

38.3.7.2 usart_dma_deinit

Deinitialize USART interface.

```
int32_t usart_dma_deinit(
    struct usart_dma_descriptor *const descr
)
```

This function deinitializes the given I/O descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr	Type: struct 38.3.6.1 usart_dma_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

De-initialization status.

38.3.7.3 usart_dma_enable

Enable USART interface.

```
int32_t usart_dma_enable(
    struct usart_dma_descriptor *const descr
)
```

Enables the USART interface

Parameters

descr	Type: struct 38.3.6.1 usart_dma_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

Enabling status.

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38.3.7.4 usart_dma_disable

Disable USART interface.

```
int32_t usart_dma_disable(
    struct usart_dma_descriptor *const descr
)
```

Disables the USART interface

Parameters

descr	Type: struct 38.3.6.1 usart_dma_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

Disabling status.

38.3.7.5 usart_dma_get_io_descriptor

Retrieve I/O descriptor.

```
int32_t usart_dma_get_io_descriptor(
    struct usart_dma_descriptor *const descr,
    struct io_descriptor ** io
)
```

This function retrieves the I/O descriptor of the given USART descriptor.

Parameters

descr	Type: struct 38.3.6.1 usart_dma_descriptor Struct *const A USART descriptor which is used to communicate via USART
io	Type: struct 25.2.1.1 io_descriptor Struct ** An I/O descriptor to retrieve

Returns

Type: int32_t

The status of I/O descriptor retrieving.

38.3.7.6 usart_dma_register_callback

Register USART callback.

```
int32_t usart_dma_register_callback(
    struct usart_dma_descriptor *const descr,
    const enum usart_dma_callback_type type,
    usart_dma_cb_t cb
)
```

Parameters

descr	Type: struct 38.3.6.1 usart_dma_descriptor Struct *const

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A USART descriptor which is used to communicate via USART

type Type: const enum usart_dma_callback_type

Callback type

cb Type: usart_dma_cb_t

A callback function

Returns
Type: int32_t

The status of callback assignment.

-1 Passed parameters were invalid or the interface is not initialized

0 A callback is registered successfully

38.3.7.7 usart_dma_set_baud_rate

Set USART baud rate.

```
int32_t usart_dma_set_baud_rate(
    struct usart_dma_descriptor *const descr,
    const uint32_t baud_rate
)
```

Parameters

descr Type: struct 38.3.6.1 usart_dma_descriptor Struct *const

A USART descriptor which is used to communicate via USART

baud_rate Type: const uint32_t

A baud rate to set

Returns
Type: int32_t

The status of baud rate setting.

38.3.7.8 usart_dma_set_data_order

Set USART data order.

```
int32_t usart_dma_set_data_order(
    struct usart_dma_descriptor *const descr,
    const enum usart_data_order data_order
)
```

Parameters

descr Type: struct 38.3.6.1 usart_dma_descriptor Struct *const

A USART descriptor which is used to communicate via USART

data_order Type: const enum usart_data_order

A data order to set

Returns

Type: int32_t

The status of data order setting.

38.3.7.9 usart_dma_set_mode

Set USART mode.

```
int32_t usart_dma_set_mode(
    struct usart_dma_descriptor *const descr,
    const enum usart_mode mode
)
```

Parameters

descr Type: struct 38.3.6.1 usart_dma_descriptor Struct *const

A USART descriptor which is used to communicate via USART

mode Type: const enum usart_mode

A mode to set

Returns

Type: int32_t

The status of mode setting.

38.3.7.10 usart_dma_set_parity

Set USART parity.

```
int32_t usart_dma_set_parity(
    struct usart_dma_descriptor *const descr,
    const enum usart_parity parity
)
```

Parameters

descr Type: struct 38.3.6.1 usart_dma_descriptor Struct *const

A USART descriptor which is used to communicate via USART

parity Type: const enum usart_parity

A parity to set

Returns

Type: int32_t

The status of parity setting.

38.3.7.11 usart_dma_set_stopbits

Set USART stop bits.

```
int32_t usart_dma_set_stopbits(
    struct usart_dma_descriptor *const descr,
    const enum usart_stop_bits stop_bits
)
```

Parameters

descr	Type: struct 38.3.6.1 usart_dma_descriptor Struct *const A USART descriptor which is used to communicate via USART
stop_bits	Type: const enum usart_stop_bits Stop bits to set

Returns

Type: int32_t

The status of stop bits setting.

38.3.7.12 usart_dma_set_character_size

Set USART character size.

```
int32_t usart_dma_set_character_size(
    struct usart_dma_descriptor *const descr,
    const enum usart_character_size size
)
```

Parameters

descr	Type: struct 38.3.6.1 usart_dma_descriptor Struct *const A USART descriptor which is used to communicate via USART
size	Type: const enum usart_character_size A character size to set

Returns

Type: int32_t

The status of character size setting.

38.3.7.13 _usart_dma_set_flow_control_state

Set the state of flow control pins.

```
void _usart_dma_set_flow_control_state(
    struct _usart_dma_device *const device,
    const union usart_flow_control_state state
)
```

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Parameters

device	Type: struct _usart_dma_device *const The pointer to USART device instance
state	Type: const union usart_flow_control_state A state of flow control pins to set

Returns
Type: void

38.3.7.14 usart_dma_get_version

Retrieve the current driver version.

```
uint32_t usart_dma_get_version(
    void
)
```

Returns
Type: uint32_t

Current driver version.

38.4 USART RTOS Driver

The universal synchronous and asynchronous receiver and transmitter (USART) is normally used to transfer data from one device to the other.

The transfer functions of the USART RTOS driver are optimized for RTOS support. That is, the transfer functions will not work without RTOS, the transfer functions should be called only in an RTOS task or thread.

The USART RTOS driver use a ring buffer to store received data. When the USART raise the data received interrupt, the data will be stored in the ring buffer at the next free location. When the ring buffer is full, the next reception will overwrite the oldest data stored in the ring buffer. When initialize the driver, the ring buffer must be allocated and passed to driver for use. The size of the buffer must be the power of two, e.g., 32 or 64. When reading data through the USART RTOS API, and if the number of bytes asked for are more than currently available in the ring buffer or more than the ringbuf size, the task/thread will be blocked until read is done. If the number of bytes asked for is less than the available bytes in the ring buffer, the remaining bytes will be kept until a new call.

On the other hand, when sending data over USART, the data is not copied to an internal buffer. The data buffer supplied by the user is used. Then the task/thread will be blocked to wait until all data is sent.

During data transfer, the USART TX/RX process is not protected, so that a more flexible way can be chosen in the application.

The user can set an action for the flow control pins by the driver API if the flow control is enabled. All the available states are defined in the 38.4.7.13 usart_os_flow_control_status union.

Note that the user can set the state of the flow control pins only if the automatic support of the flow control is not supported by the hardware.

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38.4.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable USART
- Hookup callback handlers on transfer complete, or error events
- Data transfer: transmission, reception

38.4.2 Summary of Configuration Options

Below is a list of the main USART parameters that can be configured in START. Many of these parameters are used by the 38.4.7.1 usart_os_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Set USART baudrate
- Select UART or USART communication mode
- Select character size
- Set Data order
- Flow control
- Which clock source is used

38.4.3 Driver Implementation Description

After USART hardware initialization, the usart_os_get_io_descriptor() function is needed to register an I/O descriptor. Then start the read/write operation.

38.4.3.1 Concurrency

- The write buffer should not be changed while data is being sent

38.4.3.2 Limitations

- The driver does not support 9-bit character size

38.4.4 Example of Usage

The following shows a simple example of using the USART. The USART must have been initialized by 38.4.7.1 usart_os_init. This initialization will configure the operation of the USART.

The example registers an I/O descriptor and then starts a reading operation.

```
/** * Example task of using USART_0 to echo using the I/O abstraction. */
static void USART_0_example_task(void *p)
{    struct io_descriptor *io;    uint16_t              data;    (void)p;
  usart_os_get_io(&USART_0, &io);    for (;;) {        if (io_read(io, (uin
t8_t *)&data, 2) == 2) {            io_write(io, (uint8_t *)&data, 2);
   }    }}#define TASK_TRANSFER_STACK_SIZE          ( 256/
sizeof( portSTACK_TYPE ))#define TASK_TRANSFER_STACK_PRIORITY        ( tskI
DLE_PRIORITY + 0 )static TaskHandle_t xCreatedTransferTask;static void task
_transfer_create(void){    /
* Create the task that handles the CLI. */    if (xTaskCreate(USART_0_examp
le_task, "transfer", TASK_TRANSFER_STACK_SIZE, NULL,    TASK_TRANSFER_STACK
_PRIORITY, &xCreatedTransferTask) !
= pdPASS) {        while(1) {;        }    }}static void tasks_run(void)
{    vTaskStartScheduler();}int main(void){    /
* Initializes MCU, drivers and middleware */    atmel_start_init();    task
_transfer_create();    tasks_run();    /
* Replace with your application code */    while (1) {    }}
```

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38.4.5 Dependencies

- The USART peripheral and its related I/O lines and clocks
- The NVIC must be configured so that USART interrupt requests are periodically serviced
- RTOS

38.4.6 Structs

38.4.6.1 usart_os_descriptor Struct

Asynchronous USART descriptor structure.

Members

io

device

rx

rx_buffer

rx_size

rx_length

tx_buffer

tx_por

tx_buffer_length

rx_sem

tx_sem

38.4.7 Functions

38.4.7.1 usart_os_init

Initialize USART interface.

```
int32_t usart_os_init(
    struct usart_os_descriptor *const descr,
    void *const hw,
    uint8_t *const rx_buffer,
    const uint16_t rx_buffer_length,
    void *const func
)
```

This function initializes the given I/O descriptor to be used as USART interface descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr	Type: struct 38.4.6.1 usart_os_descriptor Struct *const A USART descriptor which is used to communicate via the USART
hw	Type: void *const The pointer to the hardware instance

rx_buffer Type: uint8_t *const

An RX buffer

rx_buffer_length Type: const uint16_t

The length of the buffer above

Returns

Type: int32_t

Initialization status.

-1 Passed parameters were invalid or the interface is already initialized

0 The initialization is completed successfully

38.4.7.2 usart_os_deinit

Deinitialize USART interface.

```
int32_t usart_os_deinit(
    struct usart_os_descriptor *const descr
)
```

This function deinitializes the given I/O descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr Type: struct 38.4.6.1 usart_os_descriptor Struct *const

A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

De-initialization status.

-1 Passed parameters were invalid or the interface is already deinitialized

0 The de-initialization is completed successfully

38.4.7.3 usart_os_enable

Enable USART interface.

```
int32_t usart_os_enable(
    struct usart_os_descriptor *const descr
)
```

Enables the USART interface

Parameters

descr Type: struct 38.4.6.1 usart_os_descriptor Struct *const

A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

Enabling status.

38.4.7.4 usart_os_disable

Disable USART interface.

```
int32_t usart_os_disable(
    struct usart_os_descriptor *const descr
)
```

Disables the USART interface

Parameters

descr Type: struct 38.4.6.1 usart_os_descriptor Struct *const

A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

Disabling status.

38.4.7.5 usart_os_get_io

Retrieve I/O descriptor.

```
int32_t usart_os_get_io(
    struct usart_os_descriptor *const descr,
    struct io_descriptor ** io
)
```

This function retrieves the I/O descriptor of the given USART descriptor.

Parameters

descr Type: struct 38.4.6.1 usart_os_descriptor Struct *const

A USART descriptor which is used to communicate via USART

io Type: struct 25.2.1.1 io_descriptor Struct **

An I/O descriptor to retrieve

Returns

Type: int32_t

The status of I/O descriptor retrieving.

-1 Passed parameters were invalid or the interface is already deinitialized

0 The retrieving is completed successfully

38.4.7.6 usart_os_set_flow_control

Specify action for flow control pins.

```
int32_t usart_os_set_flow_control(
    struct usart_os_descriptor *const descr,
    const union usart_flow_control_state state
)
```

This function sets the action (or state) for flow control pins if the flow control is enabled. It sets the state of flow control pins only if the automatic support of the flow control is not supported by the hardware.

Parameters

descr	Type: struct 38.4.6.1 usart_os_descriptor Struct *const A USART descriptor which is used to communicate via USART
state	Type: const union usart_flow_control_state A state to set the flow control pins

Returns

Type: int32_t

The status of the flow control action setup.

-1	Passed parameters were invalid or the interface is not initialized
0	The flow control action is set successfully

38.4.7.7 usart_os_set_baud_rate

Set USART baud rate.

```
int32_t usart_os_set_baud_rate(
    struct usart_os_descriptor *const descr,
    const uint32_t baud_rate
)
```

Parameters

descr	Type: struct 38.4.6.1 usart_os_descriptor Struct *const A USART descriptor which is used to communicate via USART
baud_rate	Type: const uint32_t A baud rate to set

Returns

Type: int32_t

The status of the baudrate setting.

-1	Passed parameters were invalid or the interface is not initialized
0	The flow control action is set successfully

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38.4.7.8 usart_os_set_data_order

Set USART data order.

```
int32_t usart_os_set_data_order(
    struct usart_os_descriptor *const descr,
    const enum usart_data_order data_order
)
```

Parameters

descr	Type: struct 38.4.6.1 usart_os_descriptor Struct *const A USART descriptor which is used to communicate via USART
data_order	Type: const enum usart_data_order A data order to set

Returns

Type: int32_t

The status of data order setting.

-1	Passed parameters were invalid or the interface is not initialized
0	The flow control action is set successfully

38.4.7.9 usart_os_set_mode

Set USART mode.

```
int32_t usart_os_set_mode(
    struct usart_os_descriptor *const descr,
    const enum usart_mode mode
)
```

Parameters

descr	Type: struct 38.4.6.1 usart_os_descriptor Struct *const A USART descriptor which is used to communicate via USART
mode	Type: const enum usart_mode A mode to set

Returns

Type: int32_t

The status of mode setting.

-1	Passed parameters were invalid or the interface is not initialized
0	The flow control action is set successfully

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38.4.7.10 usart_os_set_parity

Set USART parity.

```
int32_t usart_os_set_parity(
    struct usart_os_descriptor *const descr,
    const enum usart_parity parity
)
```

Parameters

descr Type: struct 38.4.6.1 usart_os_descriptor Struct *const

A USART descriptor which is used to communicate via USART

parity Type: const enum usart_parity

A parity to set

Returns

Type: int32_t

The status of parity setting.

-1 Passed parameters were invalid or the interface is not initialized

0 The flow control action is set successfully

38.4.7.11 usart_os_set_stopbits

Set USART stop bits.

```
int32_t usart_os_set_stopbits(
    struct usart_os_descriptor *const descr,
    const enum usart_stop_bits stop_bits
)
```

Parameters

descr Type: struct 38.4.6.1 usart_os_descriptor Struct *const

A USART descriptor which is used to communicate via USART

stop_bits Type: const enum usart_stop_bits

Stop bits to set

Returns

Type: int32_t

The status of stop bits setting.

-1 Passed parameters were invalid or the interface is not initialized

0 The flow control action is set successfully

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38.4.7.12 usart_os_set_character_size

Set USART character size.

```
int32_t usart_os_set_character_size(
    struct usart_os_descriptor *const descr,
    const enum usart_character_size size
)
```

Parameters

descr Type: struct 38.4.6.1 usart_os_descriptor Struct *const

A USART descriptor which is used to communicate via USART

size Type: const enum usart_character_size

A character size to set

Returns

Type: int32_t

The status of character size setting.

-1 Passed parameters were invalid or the interface is not initialized

0 The flow control action is set successfully

38.4.7.13 usart_os_flow_control_status

Retrieve the state of flow control pins.

```
int32_t usart_os_flow_control_status(
    const struct usart_os_descriptor *const descr,
    union usart_flow_control_state *const state
)
```

This function retrieves the flow control pins if the flow control is enabled. The function can return UASRT_OS_FLOW_CONTROL_STATE_UNAVAILABLE in case if the flow control is done by the hardware and pins state cannot be read out.

Parameters

descr Type: const struct 38.4.6.1 usart_os_descriptor Struct *const

A USART descriptor which is used to communicate via USART

state Type: union usart_flow_control_state *const

The state of flow control pins

Returns

Type: int32_t

The status of flow control state reading.

-1 Passed parameters were invalid or the interface is not initialized

0 The flow control state is retrieved successfully

38.4.7.14 usart_os_flush_rx_buffer

flush USART ringbuf

```
int32_t usart_os_flush_rx_buffer(
    struct usart_os_descriptor *const descr
)
```

This function flush USART RX ringbuf.

Parameters

descr	Type: struct 38.4.6.1 usart_os_descriptor Struct *const The pointer to USART descriptor

Returns

Type: int32_t

ERR_NONE

38.4.7.15 usart_os_get_version

Retrieve the current driver version.

```
uint32_t usart_os_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

38.5 USART Synchronous Driver

The universal synchronous and asynchronous receiver and transmitter (USART) is normally used to transfer data from one device to the other.

The user can set the action for flow control pins by the 38.5.7.6 usart_sync_set_flow_control function, if the flow control is enabled. All the available states are defined in the 38.5.7.13 usart_sync_flow_control_status union.

Note that the user can set the state of the flow control pins only if automatic support of the flow control is not supported by the hardware.

38.5.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Register I/O descriptor
- Enable or disable USART
- Data transfer: transmission, reception

38.5.2 Summary of Configuration Options

Below is a list of the main USART parameters that can be configured in START. Many of these parameters are used by the 38.5.7.1 usart_sync_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

- Set USART baudrate
- Select UART or USART communication mode
- Select character size
- Set Data order
- Flow control
- Which clock source is used

38.5.3 Driver Implementation Description

After the USART hardware initialization, the 38.5.7.5 usart_sync_get_io_descriptor function is needed to register an I/O descriptor. Then enable USART hardware, and start the read/write operation.

38.5.3.1 Concurrency

- Write buffer should not be changed while data is being sent

38.5.3.2 Limitations

- The driver does not support 9-bit character size
- The "USART with ISO7816" mode can be only used in ISO7816 capable devices. And the SCK pin can't be set directly. Application can use a GCLK output PIN to generate SCK. For example to communicate with a SMARTCARD with ISO7816 (F = 372; D = 1), and baudrate=9600, the SCK pin output frequency should be config as 372*9600=3571200Hz. More information can be refer to ISO7816 Specification.

38.5.4 Example of Usage

The following shows a simple example of using the USART. The USART must have been initialized by 38.5.7.1 usart_sync_init. This initialization will configure the operation of the USART.

The example enables USART, and finally starts a writing operation.

```
/** * Example of using USART_0 to write "Hello World" using the I/
O abstraction. */void USART_0_example(void)
{     struct io_descriptor *io;     usart_sync_get_io_descriptor(&USART_0, &i
o);     usart_sync_enable(&USART_0);     io_write(io, (uint8_t *)"Hello World
!", 12);}
```

38.5.5 Dependencies

- USART peripheral and its related I/O lines and clocks

38.5.6 Structs

38.5.6.1 usart_sync_descriptor Struct

Synchronous USART descriptor.

Members

io

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device

38.5.7 Functions

38.5.7.1 usart_sync_init

Initialize USART interface.

```
int32_t usart_sync_init(
    struct usart_sync_descriptor *const descr,
    void *const hw,
    void *const func
)
```

This function initializes the given I/O descriptor to be used as USART interface descriptor. It checks if the given hardware is not initialized and if the given hardware is permitted to be initialized.

Parameters

descr Type: struct 38.5.6.1 usart_sync_descriptor Struct *const

A USART descriptor which is used to communicate via USART

hw Type: void *const

The pointer to hardware instance

func Type: void *const

The pointer to as set of functions pointers

Returns

Type: int32_t

Initialization status.

38.5.7.2 usart_sync_deinit

Deinitialize USART interface.

```
int32_t usart_sync_deinit(
    struct usart_sync_descriptor *const descr
)
```

This function deinitializes the given I/O descriptor. It checks if the given hardware is initialized and if the given hardware is permitted to be deinitialized.

Parameters

descr Type: struct 38.5.6.1 usart_sync_descriptor Struct *const

A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

De-initialization status.

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38.5.7.3 usart_sync_enable

Enable USART interface.

```
int32_t usart_sync_enable(
    struct usart_sync_descriptor *const descr
)
```

Enables the USART interface

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

Enabling status.

38.5.7.4 usart_sync_disable

Disable USART interface.

```
int32_t usart_sync_disable(
    struct usart_sync_descriptor *const descr
)
```

Disables the USART interface

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

Disabling status.

38.5.7.5 usart_sync_get_io_descriptor

Retrieve I/O descriptor.

```
int32_t usart_sync_get_io_descriptor(
    struct usart_sync_descriptor *const descr,
    struct io_descriptor ** io
)
```

This function retrieves the I/O descriptor of the given USART descriptor.

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART
io	Type: struct 25.2.1.1 io_descriptor Struct **

An I/O descriptor to retrieve

Returns

Type: int32_t

The status of the I/O descriptor retrieving.

38.5.7.6 usart_sync_set_flow_control

Specify action for flow control pins.

```
int32_t usart_sync_set_flow_control(
    struct usart_sync_descriptor *const descr,
    const union usart_flow_control_state state
)
```

This function sets the action (or state) for the flow control pins if the flow control is enabled. It sets the state of flow control pins only if the automatic support of the flow control is not supported by the hardware.

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART
state	Type: const union usart_flow_control_state A state to set the flow control pins

Returns

Type: int32_t

The status of flow control action setup.

38.5.7.7 usart_sync_set_baud_rate

Set USART baud rate.

```
int32_t usart_sync_set_baud_rate(
    struct usart_sync_descriptor *const descr,
    const uint32_t baud_rate
)
```

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART
baud_rate	Type: const uint32_t A baud rate to set

Returns

Type: int32_t

The status of baud rate setting.

38.5.7.8 usart_sync_set_data_order

Set USART data order.

```
int32_t usart_sync_set_data_order(
    struct usart_sync_descriptor *const descr,
    const enum usart_data_order data_order
)
```

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART
data_order	Type: const enum usart_data_order A data order to set

Returns

Type: int32_t

The status of data order setting.

38.5.7.9 usart_sync_set_mode

Set USART mode.

```
int32_t usart_sync_set_mode(
    struct usart_sync_descriptor *const descr,
    const enum usart_mode mode
)
```

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART
mode	Type: const enum usart_mode A mode to set

Returns

Type: int32_t

The status of mode setting.

38.5.7.10 usart_sync_set_parity

Set USART parity.

```
int32_t usart_sync_set_parity(
    struct usart_sync_descriptor *const descr,
    const enum usart_parity parity
)
```

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Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART
parity	Type: const enum usart_parity A parity to set

Returns

Type: int32_t

The status of parity setting.

38.5.7.11 usart_sync_set_stopbits

Set USART stop bits.

```
int32_t usart_sync_set_stopbits(
    struct usart_sync_descriptor *const descr,
    const enum usart_stop_bits stop_bits
)
```

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART
stop_bits	Type: const enum usart_stop_bits Stop bits to set

Returns

Type: int32_t

The status of stop bits setting.

38.5.7.12 usart_sync_set_character_size

Set USART character size.

```
int32_t usart_sync_set_character_size(
    struct usart_sync_descriptor *const descr,
    const enum usart_character_size size
)
```

Parameters

descr	Type: struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART
size	Type: const enum usart_character_size A character size to set

Returns

Type: int32_t

The status of character size setting.

38.5.7.13 usart_sync_flow_control_status

Retrieve the state of flow control pins.

```
int32_t usart_sync_flow_control_status(
    const struct usart_sync_descriptor *const descr,
    union usart_flow_control_state *const state
)
```

This function retrieves the of flow control pins if the flow control is enabled. Function can return USART_FLOW_CONTROL_STATE_UNAVAILABLE in case if the flow control is done by the hardware and the pins state cannot be read out.

Parameters

descr Type: const struct 38.5.6.1 usart_sync_descriptor Struct *const

A USART descriptor which is used to communicate via USART

state Type: union usart_flow_control_state *const

The state of flow control pins

Returns

Type: int32_t

The status of flow control state reading.

38.5.7.14 usart_sync_is_tx_empty

Check if the USART transmitter is empty.

```
int32_t usart_sync_is_tx_empty(
    const struct usart_sync_descriptor *const descr
)
```

Parameters

descr Type: const struct 38.5.6.1 usart_sync_descriptor Struct *const

A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

The status of USART TX empty checking.

0 The USART transmitter is not empty

1 The USART transmitter is empty

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38.5.7.15 usart_sync_is_rx_not_empty

Check if the USART receiver is not empty.

```
int32_t usart_sync_is_rx_not_empty(
    const struct usart_sync_descriptor *const descr
)
```

Parameters

descr	Type: const struct 38.5.6.1 usart_sync_descriptor Struct *const A USART descriptor which is used to communicate via USART

Returns

Type: int32_t

The status of USART RX empty checking.

1	The USART receiver is not empty
0	The USART receiver is empty

38.5.7.16 usart_sync_get_version

Retrieve the current driver version.

```
uint32_t usart_sync_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

39. USB Drivers

39.1 USB Driver Basics and Best Practice

The Universal Serial Bus (USB) is an industry standard that defines the cables, connectors, and communication protocols used in a bus for connection, communication, and power supply between computers and electronic devices.

The following driver variants are available:

- 39.2 USB Device Driver
- 39.3 USB Host Driver

39.2 USB Device Driver

The Universal Serial Bus (USB) is an industry standard that defines the cables, connectors, and communication protocols used in a bus for connection, communication, and power supply between computers and electronic devices.

The USB device driver provides necessary APIs to support USB Device states and USB data flow, so that the USB Device enumeration, class, and vendor support can be implemented based on it. The driver is asynchronous, which means that all USB data processing is done in callbacks.

To be recognized by a host, a USB device must handle a subset of the USB events. The USB device should build up control communication to report its descriptors to the host and accept host's requests. An application or upper stack that uses the USB device driver should have its descriptors prepared, catch the callbacks, monitor the control requests and handle them correctly. Usually, a USB device application that can be enumerated may use the following sequence:

- Initialize
- Register callback and handle Reset event, where:
  - Initialize endpoint 0
  - Register callbacks for endpoint 0, where some of the standard requests defined in Chapter 9, USB specification (see USB 2.0 Documents http://www.usb.org/developers/docs/usb20_docs_) are handled
    - Setup request handling callback
      - On **GetDeviceDescriptor** request, sends device descriptor
      - On **GetConfigurationDescriptor** request, sends configuration descriptors
      - On **SetAddress** request sends no data, just goes to status phase
      - On **SetConfigure** request initialize and enable other endpoints, sends no data, just goes to status phase
    - Transfer done handling callback
      - On **SetAddress** request apply the new address
      - On **SetConfigure** request a global variable can be set to indicates that the host driver is loaded and device is ready to work
  - Enable endpoint 0
- Enable

- Attach device

To support USB transfer on endpoints, endpoints information is stored by the driver internally, including control request data, endpoint status, callbacks and transfer data pointers. The number of endpoints that the driver can support is defined through configuration. To optimize RAM usage, the number of endpoints the driver needs to support should be minimized.

39.2.1 Summary of the API's Functional Features

The API provides functions to:

- Initialization/de-initialization
- Enabling/disabling
- USB device attachment/detachment
- USB device address control
- USB working speed status
- USB device frame number and micro frame number status
- Sending remote wakeup to host
- Callback management for following USB events:
  - Start of Frame (SOF)
  - Other USB events:
    - VBus change
    - Reset
    - Wakeup
    - Linked Power Management (LPM) Suspend
    - Suspend
    - Error
- Endpoints management:
  - Endpoint initialization/de-initialization
  - Endpoint enabling/disabling
  - Control endpoint setup request packet
  - Data transfer and abort
  - Endpoint halt state control
  - Endpoint status, including:
    - Endpoint address
    - Last transfer result status code
    - Last error status code
    - Current transfer state
    - Transfer size and done count
  - Endpoint callback management for endpoint and its transfer events:
    - In case a setup request received on control endpoint
    - In case transfer finished with/without error

39.2.2 Driver Implementation Description

39.2.2.1 Limitations

- When a buffer is used by a USB endpoint to transfer data, it must be kept unchanged while the transfer is in progress.

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- After receiving a request that has no data expected, the transfer function must be called with data length zero to complete control status phase.

39.2.3 Dependencies

- The USB device capable hardware
- 48MHz clock for low-speed and full-speed and 480MHz clock for high-speed

39.2.4 Considerations for SAM D21 USB

39.2.4.1 Clocks

DFLL must be used to generate 48MHz clock for USB device with either of the following mode:

- USB Clock Recovery Mode
  - Set "DFLL Enable", "Bypass Coarse Lock", "Chill Cycle Disable", "USB Clock Recovery Mode", "Stable DFLL Frequency"
  - Clear "Wait Lock"
  - Leave "Operating Mode Selection" to "Closed Loop Mode"
- Closed Loop Mode
  - Set "DFLL Enable"
  - Clear "USB Clock Recovery Mode", "Stable DFLL Frequency"
  - Select "Closed Loop Mode" of "Operating Mode Selection"
  - Set "DFLL Multiply Factor" to 1464 or 1465 (48000000/32768)
  - Select "Reference Clock Source" to use 32768Hz source, e.g., use GCLK1 and for GCLK1 settings:
    - Set "Generic Clock Generator Enable"
    - Select "XOSC32K" of "Generic clock generator 1 source", and for XOSC32K settings:
      - Set "External 32K Oscillator Enable", "Enable 32KHz Output", "Enable XTAL"
      - Set a right value for "Startup time for the 32K Oscillator", e.g., 1125092 us

39.2.4.2 Endpoints

Each USB device endpoint number supports two endpoint addresses, corresponding to IN and OUT endpoint. E.g., for endpoint 1, the endpoint IN has address 0x81 and endpoint OUT has address 0x01. Thus, the possible supported endpoint addresses are almost two times of max endpoint number (endpoint 0 must be used as control endpoint instead of dedicated IN and OUT endpoints).

39.2.4.3 Buffering and RAM usage optimization

When transferring data through USB device endpoints, buffer pointers can be used to let endpoint get access to the buffer, but there are some limits:

- For control endpoint there must always be a buffer available to put received setup packet.
- For IN endpoint (transmit to host) the data must in RAM.
- For OUT endpoint (receive from host) the data pointer must be aligned, and the data size must be aligned by max endpoint size and not zero.

The driver has option for each endpoint to allocate internal static buffer as cache to buffer input/output data, to remove upper limits. The configuration affects the parameter check of transfer functions, and the RAM usage.

- For control endpoints, cache buffer must be enabled to fill setup packet. In addition, to support unaligned OUT packet and IN packet inside flash, the buffer size must be equal to or larger than max endpoint size.

- For OUT endpoints, if the cache is allocated, it's possible to pass unaligned buffer address and buffer size to transfer function. Else the transfer function only accepts aligned buffer with it's size multiple of endpoint packet size.
- For IN endpoints, if the cache is allocated, it's possible to pass buffer pointer to internal flash or other memory part other than RAM to the transfer function.

To optimize the RAM usage, the configuration of max endpoint number, max number of endpoints supported and the buffer usage of used input and/or output endpoints can be adjusted.

39.2.5 Structs

39.2.5.1 usb_d_ep_status Struct

Members

ep	Endpoint address, including direction.
code	Endpoint transfer status code that triggers the callback. usb_xfer_code.
error	Endpoint error, if `code` is USB_TRANS_ERROR.
state	Transfer state, usb_ep_state.
count	Transfer count.
size	Transfer size.

39.2.5.2 usb_d_callbacks Struct

Members

sof	Callback that is invoked on SOF.
event	Callback that is invoked on USB RESET/WAKEUP/RESUME/SUSPEND.

39.2.6 Typedefs

39.2.6.1 usb_d_sof_cb_t typedef

typedef void(* usb_d_sof_cb_t) (void)

39.2.6.2 usb_d_event_cb_t typedef

typedef void(* usb_d_event_cb_t) (const enum usb_event event, const uint32_t param)

39.2.6.3 usb_d_ep_cb_setup_t typedef

typedef bool(* usb_d_ep_cb_setup_t) (const uint8_t ep, const uint8_t *req)

39.2.6.4 usb_d_ep_cb_more_t typedef

typedef bool(* usb_d_ep_cb_more_t) (const uint8_t ep, const uint32_t count)

39.2.6.5 usb_d_ep_cb_xfer_t typedef

typedef bool(* usb_d_ep_cb_xfer_t) (const uint8_t ep, const enum usb_xfer_code code, void *param)

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39.2.7 Functions

39.2.7.1 usb_d_init

Initialize the USB device driver.

```
int32_t usb_d_init(
    void
)
```

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

39.2.7.2 usb_d_deinit

Deinitialize the USB device driver.

```
void usb_d_deinit(
    void
)
```

Returns

Type: void

39.2.7.3 usb_d_register_callback

Register the USB device callback.

```
void usb_d_register_callback(
    const enum usb_d_cb_type type,
    const FUNC_PTR func
)
```

Parameters

type	Type: const enum usb_d_cb_type The callback type to register.
func	Type: const 40.3.2.1 FUNC_PTR typedef The callback function, NULL to disable callback.

Returns

Type: void

39.2.7.4 usb_d_enable

Enable the USB device driver.

```
int32_t usb_d_enable(
    void
)
```

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Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

39.2.7.5 usb_d_disable

Disable the USB device driver.

```
void usb_d_disable(
    void
)
```

Returns

Type: void

39.2.7.6 usb_d_attach

Attach the USB device.

```
void usb_d_attach(
    void
)
```

Returns

Type: void

39.2.7.7 usb_d_detach

Detach the USB device.

```
void usb_d_detach(
    void
)
```

Returns

Type: void

39.2.7.8 usb_d_get_speed

Retrieve current USB working speed.

```
enum usb_speed usb_d_get_speed(
    void
)
```

Returns

Type: enum usb_speed

USB Speed. See usb_speed.

39.2.7.9 usb_d_get_frame_num

Retrieve current USB frame number.

```
uint16_t usb_d_get_frame_num(
    void
)
```

Returns

Type: uint16_t

Frame number.

39.2.7.10 usb_d_get_uframe_num

Retrieve current USB micro frame number.

```
uint8_t usb_d_get_uframe_num(
    void
)
```

Returns

Type: uint8_t

Micro frame number inside a frame (0~7). 0 if not available (not HS).

39.2.7.11 usb_d_set_address

Set the USB address that is used.

```
void usb_d_set_address(
    const uint8_t addr
)
```

Parameters

addr	Type: const uint8_t The address to set.

Returns

Type: void

39.2.7.12 usb_d_send_remotewakeup

Send remote wakeup to host.

```
void usb_d_send_remotewakeup(
    void
)
```

Returns

Type: void

Operation status.

39.2.7.13 usb_d_ep0_init

Initialize the endpoint 0.

```
int32_t usb_d_ep0_init(
    const uint8_t max_pkt_size
)
```

Note that endpoint 0 must be initialized as control endpoint.

Parameters

max_pkt_size	Type: const uint8_t Max. packet size of EP0.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

39.2.7.14 usb_d_ep_init

Initialize the endpoint.

```
int32_t usb_d_ep_init(
    const uint8_t ep,
    const uint8_t attr,
    const uint16_t max_pkt_size
)
```

Parameters

ep	Type: const uint8_t The endpoint address.
attr	Type: const uint8_t The endpoint attributes.
max_pkt_size	Type: const uint16_t Max. packet size of EP0.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

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39.2.7.15 usb_d_ep_deinit

Disable and deinitialize the endpoint.

```
void usb_d_ep_deinit(
    const uint8_t ep
)
```

Parameters

ep Type: const uint8_t

The endpoint address to deinitialize.

Returns

Type: void

39.2.7.16 usb_d_ep_register_callback

Register the USB device endpoint callback on initialized endpoint.

```
void usb_d_ep_register_callback(
    const uint8_t ep,
    const enum usb_d_ep_cb_type type,
    const FUNC_PTR func
)
```

Parameters

ep Type: const uint8_t

The endpoint address.

type Type: const enum usb_d_ep_cb_type

The callback type to register.

func Type: const 40.3.2.1 FUNC_PTR typedef

The callback function, NULL to disable callback.

Returns

Type: void

39.2.7.17 usb_d_ep_enable

Enabled the initialized endpoint.

```
int32_t usb_d_ep_enable(
    const uint8_t ep
)
```

Setup request will be monitored after enabling a control endpoint.

Parameters

ep Type: const uint8_t

The endpoint address.

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Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

39.2.7.18 usb_d_ep_disable

Disable the initialized endpoint.

```
void usb_d_ep_disable(
    const uint8_t ep
)
```

Parameters

ep	Type: const uint8_t The endpoint address.

Returns

Type: void

39.2.7.19 usb_d_ep_get_req

Get request data pointer to access received setup request packet.

```
uint8_t* usb_d_ep_get_req(
    const uint8_t ep
)
```

Parameters

ep	Type: const uint8_t The endpoint address.

Returns

Type: uint8_t *

Pointer to the request data.

NULL	The endpoint is not a control endpoint.

39.2.7.20 usb_d_ep_transfer

Endpoint transfer.

```
int32_t usb_d_ep_transfer(
    const struct usb_d_transfer * xfer
)
```

For control endpoints, start the transfer according to the direction in the bmRequest type, and finish with STATUS stage. For non-control endpoints, the transfer will be unique direction. Defined by bit 8 of the endpoint address.

Parameters

xfer	Type: const struct usb_d_transfer * Pointer to the transfer description.

Returns

Type: int32_t

Operation status.

0	Success.
<0	Error code.

39.2.7.21 usb_d_ep_abort

Abort an on-going transfer on a specific endpoint.

```
void usb_d_ep_abort(
    const uint8_t ep
)
```

Parameters

ep	Type: const uint8_t The endpoint address.

Returns

Type: void

39.2.7.22 usb_d_ep_get_status

Retrieve the endpoint status.

```
int32_t usb_d_ep_get_status(
    const uint8_t ep,
    struct usb_d_ep_status * stat
)
```

Parameters

ep	Type: const uint8_t The endpoint address.
stat	Type: struct 39.2.5.1 usb_d_ep_status Struct * Pointer to the buffer to fill the status description.

Returns

Type: int32_t

Endpoint status.

1	Busy.
0	Idle.
<0	Error code.

39.2.7.23 usb_d_ep_halt

Endpoint halt control.

```
int32_t usb_d_ep_halt(
    const uint8_t ep,
    const enum usb_ep_halt_ctrl ctrl
)
```

Parameters

ep	Type: const uint8_t The endpoint address.
ctrl	Type: const enum usb_ep_halt_ctrl Control code (SET/CLEAR/GET).

Returns

Type: int32_t

Operation status or HALT state (if `ctrl` is USB_EP_HALT_GET).

39.2.7.24 usb_d_get_version

Retrieve the current driver version.

```
uint32_t usb_d_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

39.3 USB Host Driver

The Universal Serial Bus (USB) is an industry standard that defines the cables, connectors, and communication protocols used in a bus for connection, communication, and power supply between computers and electronic devices.

The USB host driver provides necessary APIs to support USB states and USB data flow. So that the USB Device enumeration, class and vendor support can be implemented base on it. The driver is asynchronous, which means that all USB data processing is done in callbacks.

To recognized a device, a USB host must handle a subset of the USB events. The USB host should turn on VBus supply, monitor root hub events, build up control communication to request descriptors of attached device. An application or upper stack that uses the USB host driver should have its descriptors buffer prepared, issue the control requests, analyze the returned descriptors and handle them correctly.

Usually, a USB host application that can enumerates USB device may use the following sequence:

- Initialize
- Register callback and handle root hub events, where:
  - On connection, issue USB Reset
  - On USB Reset end, initialize pipe 0, register request end callback and issue *GetDeviceDescriptor- request
  - On disconnection, free all allocated pipes
- In pipe 0 request done handling callback:
  - On *GetDeviceDescriptor- OK, modify pipe 0 endpoint size according to the descriptor returned, issue *SetAddress- request
  - On *SetAddress- request OK, issue *GetConfigurationDescriptor- request
  - On *GetConfigurationDescriptor- request OK, create pipes based on returned configuration descriptor; issue *SetConfigure- request
- Enable
- After the *SetConfigure- request is done correctly, the created pipes should be OK to communicate with the USB device

39.3.1 Summary of the API's Functional Features

The API provides functions to:

- Initialization/de-initialization
- Enabling/disabling
- USB root hub control
  - Attach/detach detection
  - Reset
  - Suspend/resume
  - Connection speed detection
- USB host frame number and micro frame number status
- Callback management for:
  - Start of Frame (SOF)
  - Root hub events
- Pipes management:
  - Pipe allocation/free
  - Control pipe request
  - Bulk, interrupt and ISO pipe transfer
  - Pipe callback management for transfer done

39.3.2 Dependencies

- The USB host capable hardware
- 48MHz clock for low-speed and full-speed and 480MHz clock for high-speed

39.3.3 Functions

39.3.3.1 usb_h_init

USB HCD Initialization.

```
static int32_t usb_h_init(
    struct usb_h_desc * drv,
    void * hw,
    void * prvt
)
```

Parameters

drv	Type: struct usb_h_desc * Pointer to the HCD driver instance
hw	Type: void * Pointer to hardware base
prvt	Type: void * The private driver data (implement specific)

Returns

Type: int32_t

Operation result status

ERR_DENIED	Hardware has been enabled
ERR_NONE	Operation done successfully

39.3.3.2 usb_h_deinit

USB HCD de-initialization.

```
static void usb_h_deinit(
    struct usb_h_desc * drv
)
```

Parameters

drv	Type: struct usb_h_desc * The driver

Returns

Type: void

39.3.3.3 usb_h_enable

USB HCD enable.

```
static void usb_h_enable(
    struct usb_h_desc * drv
)
```

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Parameters

drv	Type: struct usb_h_desc * The driver

Returns
Type: void

39.3.3.4 usb_h_disable

USB HCD disable.

```
static void usb_h_disable(
    struct usb_h_desc * drv
)
```

Parameters

drv	Type: struct usb_h_desc * The driver

Returns
Type: void

39.3.3.5 usb_h_register_callback

Register callbacks for USB HCD.

```
static int32_t usb_h_register_callback(
    struct usb_h_desc * drv,
    enum usb_h_cb_type type,
    FUNC_PTR cb
)
```

Parameters

drv	Type: struct usb_h_desc * The driver
type	Type: enum usb_h_cb_type The callback type
cb	Type: 40.3.2.1 FUNC_PTR typedef The callback function entry

Returns
Type: int32_t

Operation result status

ERR_INVALID_ARG	Argument error

ERR_NONE	Operation done successfully

39.3.3.6 usb_h_get_frame_n

Return current frame number.

```
static uint16_t usb_h_get_frame_n(
    struct usb_h_desc * drv
)
```

Parameters

drv	Type: struct usb_h_desc * The driver

Returns

Type: uint16_t

Current frame number

39.3.3.7 usb_h_get_microframe_n

Return current micro frame number.

```
static uint8_t usb_h_get_microframe_n(
    struct usb_h_desc * drv
)
```

Parameters

drv	Type: struct usb_h_desc * The driver

Returns

Type: uint8_t

Current micro frame number

39.3.3.8 usb_h_suspend

Suspend the USB bus.

```
static void usb_h_suspend(
    struct usb_h_desc * drv
)
```

Parameters

drv	Type: struct usb_h_desc * The driver

Returns

Type: void

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39.3.3.9 usb_h_resume

Resume the USB bus.

```
static void usb_h_resume(
    struct usb_h_desc * drv
)
```

Parameters

drv	Type: struct usb_h_desc * The driver

Returns

Type: void

39.3.3.10 usb_h_rh_reset

Reset the root hub port.

```
static void usb_h_rh_reset(
    struct usb_h_desc * drv,
    uint8_t port
)
```

Parameters

drv	Type: struct usb_h_desc * Pointer to the USB HCD driver
port	Type: uint8_t Root hub port, ignored if there is only one port

Returns

Type: void

39.3.3.11 usb_h_rh_suspend

Suspend the root hub port.

```
static void usb_h_rh_suspend(
    struct usb_h_desc * drv,
    uint8_t port
)
```

Parameters

drv	Type: struct usb_h_desc * Pointer to the USB HCD driver
port	Type: uint8_t Root hub port, ignored if there is only one port

Returns

Type: void

39.3.3.12 usb_h_rh_resume

Resume the root hub port.

```
static void usb_h_rh_resume(
    struct usb_h_desc * drv,
    uint8_t port
)
```

Parameters

drv	Type: struct usb_h_desc * Pointer to the USB HCD driver
port	Type: uint8_t Root hub port, ignored if there is only one port

Returns

Type: void

39.3.3.13 usb_h_rh_check_status

Root hub or port feature status check.

```
static bool usb_h_rh_check_status(
    struct usb_h_desc * drv,
    uint8_t port,
    uint8_t ftr
)
```

Check USB Spec. for hub status and feature selectors.

Parameters

drv	Type: struct usb_h_desc * Pointer to the USB HCD driver
port	Type: uint8_t Set to 0 to get hub status, otherwise to get port status
ftr	Type: uint8_t Feature selector (0: connection, 2: suspend, 4: reset, 9: LS, 10: HS)

Returns

Type: bool

`true` if the status bit is 1

39.3.3.14 usb_h_pipe_allocate

Allocate a pipe for the USB host communication.

```
static struct usb_h_pipe* usb_h_pipe_allocate(
    struct usb_h_desc * drv,
    uint8_t dev,
    uint8_t ep,
    uint16_t max_pkt_size,
    uint8_t attr,
    uint8_t interval,
    uint8_t speed,
    bool minimum_rsc
)
```

Parameters

drv	Type: struct usb_h_desc * The USB HCD driver
dev	Type: uint8_t The device address
ep	Type: uint8_t The endpoint address
max_pkt_size	Type: uint16_t The endpoint maximum packet size
attr	Type: uint8_t The endpoint attribute
interval	Type: uint8_t The endpoint interval (bInterval of USB Endpoint Descriptor)
speed	Type: uint8_t The transfer speed of the endpoint
minimum_rsc	Type: bool Minimum resource usage,

Returns

Type: struct usb_h_pipe *

Pointer to the allocated pipe structure instance

NULL	allocation fail

39.3.3.15 usb_h_pipe_free

Free an allocated pipe.

```
static int32_t usb_h_pipe_free(
    struct usb_h_pipe * pipe
)
```

Parameters

pipe	Type: struct usb_h_pipe * The pipe

Returns

Type: int32_t

Operation result status

ERR_BUSY	Pipe is busy, use _usb_h_pipe_abort to abort
ERR_NONE	Operation done successfully

39.3.3.16 usb_h_pipe_set_control_param

Modify parameters of an allocated control pipe.

```
static int32_t usb_h_pipe_set_control_param(
    struct usb_h_pipe * pipe,
    uint8_t dev,
    uint8_t ep,
    uint16_t max_pkt_size,
    uint8_t speed
)
```

Parameters

pipe	Type: struct usb_h_pipe * The pipe
dev	Type: uint8_t The device address
ep	Type: uint8_t The endpoint address
max_pkt_size	Type: uint16_t The maximum packet size, must be equal or less than the allocated size
speed	Type: uint8_t The working speed

Returns

Type: int32_t

Operation result status

ERR_NOT_INITIALIZED	The pipe is not allocated
ERR_BUSY	The pipe is busy transferring
ERR_INVALID_ARG	Argument error
ERR_UNSUPPORTED_OP	The pipe is not control pipe
ERR_NONE	The operation is done successfully

39.3.3.17 usb_h_pipe_register_callback

Register transfer callback on a pipe.

```
static int32_t usb_h_pipe_register_callback(
    struct usb_h_pipe * pipe,
    usb_h_pipe_cb_xfer_t cb
)
```

Parameters

pipe	Type: struct usb_h_pipe * The pipe
cb	Type: usb_h_pipe_cb_xfer_t Transfer callback function

Returns

Type: int32_t

Operation result status

ERR_INVALID_ARG	Argument error
ERR_NONE	Operation done successfully

39.3.3.18 usb_h_control_xfer

Issue a control transfer (request) on a pipe.

```
static int32_t usb_h_control_xfer(
    struct usb_h_pipe * pipe,
    uint8_t * setup,
    uint8_t * data,
    uint16_t length,
    int16_t timeout
)
```

Parameters

pipe	Type: struct usb_h_pipe * The pipe
setup	Type: uint8_t *

	Pointer to the setup packet
data	Type: uint8_t *
	Pointer to the data buffer
length	Type: uint16_t
	The data length
timeout	Type: int16_t
	Timeout for whole request in ms

Returns

Type: int32_t

Operation result status

ERR_NOT_INITIALIZED	Pipe is not allocated
ERR_BUSY	Pipe is busy transferring
ERR_INVALID_ARG	Argument error
ERR_UNSUPPORTED_OP	Pipe is not control pipe
ERR_NONE	Operation done successfully

39.3.3.19 usb_h_bulk_int_iso_xfer

Issue a bulk/interrupt/iso transfer on a pipe.

```
static int32_t usb_h_bulk_int_iso_xfer(
    struct usb_h_pipe * pipe,
    uint8_t * data,
    uint32_t length,
    bool auto_zlp
)
```

Parameters

pipe	Type: struct usb_h_pipe *
	The pipe
data	Type: uint8_t *
	Pointer to the data buffer
length	Type: uint32_t
	The data length
auto_zlp	Type: bool
	Auto append ZLP for OUT

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Returns

Type: int32_t

Operation result status

ERR_NOT_INITIALIZED	The pipe is not allocated
ERR_BUSY	The pipe is busy transferring
ERR_INVALID_ARG	Argument error
ERR_UNSUPPORTED_OP	The pipe is control pipe
ERR_NONE	The operation is done successfully

39.3.3.20 usb_h_high_bw_out

Issue a periodic high bandwidth output on a pipe.

```
static int32_t usb_h_high_bw_out(
    struct usb_h_pipe * pipe,
    uint8_t * data,
    uint32_t length,
    uint16_t trans_pkt_size
)
```

Parameters

pipe	Type: struct usb_h_pipe * The pipe
data	Type: uint8_t * Pointer to the data buffer
length	Type: uint32_t The data length
trans_pkt_size	Type: uint16_t The transaction packet sizes in a micro frame, 0 to use endpoint max packet size

Returns

Type: int32_t

Operation result status

ERR_NOT_INITIALIZED	The pipe is not allocated
ERR_BUSY	The pipe is busy transferring
ERR_INVALID_ARG	Argument error
ERR_UNSUPPORTED_OP	The pipe is not a high bandwidth periodic pipe, or the DMA feature is not enabled, or high bandwidth not enabled

ERR_NONE	The operation is done successfully

39.3.3.21 usb_h_pipe_is_busy

Check if the pipe is busy transferring.

```
static bool usb_h_pipe_is_busy(
    struct usb_h_pipe * pipe
)
```

Parameters

pipe	Type: struct usb_h_pipe * The pipe

Returns

Type: bool

`true` if pipe is busy

39.3.3.22 usb_h_pipe_abort

Abort pending transfer on a pipe.

```
static void usb_h_pipe_abort(
    struct usb_h_pipe * pipe
)
```

Parameters

pipe	Type: struct usb_h_pipe * The pipe

Returns

Type: void

Operation result status

39.3.3.23 usb_h_get_version

Return version of the driver.

```
static uint32_t usb_h_get_version(
    void
)
```

Returns

Type: uint32_t

40. Utility Drivers

The following utility drivers are available:

- 40.1 List
- 40.2 Ring Buffer
- 40.3 Utility Macros

40.1 List

The List driver provides a basic operation (insert, remove, find) on a linked list.

A linked list is a linear collection of data elements, called nodes, each pointing to the next node by means of a pointer. It is a data structure consisting of a group of nodes which together represent a sequence.

The principal benefit of a linked list over a conventional array is that the list elements can easily be inserted or removed without reallocation or reorganization of the entire structure because the data items need not be stored contiguously in memory or on disk, while an array has to be declared in the source code, before compiling and running the program.

40.1.1 Structs

40.1.1.1 list_element Struct

List element type.

Members

next

40.1.1.2 list_descriptor Struct

List head type.

Members

head

40.1.2 Functions

40.1.2.1 list_reset

Reset list.

```
static void list_reset(
    struct list_descriptor *const list
)
```

Parameters

list Type: struct 40.1.1.2 list_descriptor Struct *const

The pointer to a list descriptor

Returns

Type: void

40.1.2.2 list_get_head

Retrieve list head.

```
static void* list_get_head(
    const struct list_descriptor *const list
)
```

Parameters

list	Type: const struct 40.1.1.2 list_descriptor Struct *const The pointer to a list descriptor

Returns

Type: void *

A pointer to the head of the given list or NULL if the list is empty

40.1.2.3 list_get_next_element

Retrieve next list head.

```
static void* list_get_next_element(
    const void *const element
)
```

Parameters

list	The pointer to a list element

Returns

Type: void *

A pointer to the next list element or NULL if there is not next element

40.1.2.4 list_insert_as_head

Insert an element as list head.

```
void list_insert_as_head(
    struct list_descriptor *const list,
    void *const element
)
```

Parameters

list	Type: struct 40.1.1.2 list_descriptor Struct *const The pointer to a list element
element	Type: void *const An element to insert to the given list

Returns

Type: void

40.1.2.5 list_insert_after

Insert an element after the given list element.

```
void list_insert_after(
    void *const after,
    void *const element
)
```

Parameters

after	Type: void *const An element to insert after
element	Type: void *const Element to insert to the given list

Returns

Type: void

40.1.2.6 list_insert_at_end

Insert an element at list end.

```
void list_insert_at_end(
    struct list_descriptor *const list,
    void *const element
)
```

Parameters

after	An element to insert after
element	Type: void *const Element to insert to the given list

Returns

Type: void

40.1.2.7 is_list_element

Check whether an element belongs to a list.

```
bool is_list_element(
    const struct list_descriptor *const list,
    const void *const element
)
```

Parameters

list	Type: const struct 40.1.1.2 list_descriptor Struct *const

	The pointer to a list
element	Type: const void *const
	An element to check

Returns

Type: bool

The result of checking

true	If the given element is an element of the given list
false	Otherwise

40.1.2.8 list_remove_head

Removes list head.

```
void* list_remove_head(
    struct list_descriptor *const list
)
```

This function removes the list head and sets the next element after the list head as a new list head.

Parameters

list	Type: struct 40.1.1.2 list_descriptor Struct *const
	The pointer to a list

Returns

Type: void *

The pointer to the new list head of NULL if the list head is NULL

40.1.2.9 list_delete_element

Removes the list element.

```
bool list_delete_element(
    struct list_descriptor *const list,
    const void *const element
)
```

Parameters

list	Type: struct 40.1.1.2 list_descriptor Struct *const
	The pointer to a list
element	Type: const void *const
	An element to remove

Returns

Type: bool

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The result of element removing

true	The given element is removed from the given list
false	The given element is not an element of the given list

40.2 Ring Buffer

The ring buffer driver provides basic operation (get, put, etc.) on a uint8_t type ring buffer.

The ring buffer is a circular software queue with two indexes to the elements within the buffer. This queue has a first-in-first-out (FIFO) data characteristic. The ring buffer's first-in first-out data structure is useful tool for transmitting data between asynchronous processes.

40.2.1 Structs

40.2.1.1 ringbuffer Struct

Ring buffer element type.

Members

buf	
size	Buffer base address
read_index	Buffer size
write_index	Buffer read index

40.2.2 Functions

40.2.2.1 ringbuffer_init

Ring buffer init.

```
int32_t ringbuffer_init(
    struct ringbuffer *const rb,
    void * buf,
    uint32_t size
)
```

Parameters

rb	Type: struct 40.2.1.1 ringbuffer Struct *const The pointer to a ring buffer structure instance
buf	Type: void * Space to store the data
size	Type: uint32_t The buffer length, must be aligned with power of 2

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Returns

Type: int32_t

ERR_NONE on success, or an error code on failure.

40.2.2.2 ringbuffer_get

Get one byte from ring buffer, the user needs to handle the concurrent access on buffer via put/get/flush.

```
int32_t ringbuffer_get(
    struct ringbuffer *const rb,
    uint8_t * data
)
```

Parameters

rb	Type: struct 40.2.1.1 ringbuffer Struct *const The pointer to a ring buffer structure instance
data	Type: uint8_t * One byte space to store the read data

Returns

Type: int32_t

ERR_NONE on success, or an error code on failure.

40.2.2.3 ringbuffer_put

Put one byte to ring buffer, the user needs to handle the concurrent access on buffer via put/get/flush.

```
int32_t ringbuffer_put(
    struct ringbuffer *const rb,
    uint8_t data
)
```

Parameters

rb	Type: struct 40.2.1.1 ringbuffer Struct *const The pointer to a ring buffer structure instance
data	Type: uint8_t One byte data to be put into ring buffer

Returns

Type: int32_t

ERR_NONE on success, or an error code on failure.

40.2.2.4 ringbuffer_num

Return the element number of ring buffer.

```
uint32_t ringbuffer_num(
    const struct ringbuffer *const rb
)
```

Parameters

rb Type: const struct 40.2.1.1 ringbuffer Struct *const

The pointer to a ring buffer structure instance

Returns

Type: uint32_t

The number of elements in ring buffer [0, rb->size]

40.2.2.5 ringbuffer_flush

Flush ring buffer, the user needs to handle the concurrent access on buffer via put/get/flush.

```
uint32_t ringbuffer_flush(
    struct ringbuffer *const rb
)
```

Parameters

rb Type: struct 40.2.1.1 ringbuffer Struct *const

The pointer to a ring buffer structure instance

Returns

Type: uint32_t

ERR_NONE on success, or an error code on failure.

40.3 Utility Macros

Different macros used in ASF4.

40.3.1 Defines

40.3.1.1 CONTAINER_OF

#define CONTAINER_OF( ) ((type *) (((uint8_t *)ptr) - offsetof(type, field_name)))

Retrieve pointer to parent structure.

40.3.1.2 ARRAY_SIZE

#define ARRAY_SIZE( ) (sizeof(a) / sizeof((a)[0]))

Retrieve array size.

40.3.1.3 COMPILER_PRAGMA

#define COMPILER_PRAGMA( ) _Pragma(#arg)

Emit the compiler pragma **arg**.

Parameters

arg The pragma directive as it would appear after **#pragma** (i.e. not stringified).

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40.3.1.4 COMPILER_PACK_SET

```
#define COMPILER_PACK_SET( ) COMPILER_PRAGMA(pack(alignment))
```

Set maximum alignment for subsequent struct and union definitions to **alignment**.

40.3.1.5 COMPILER_PACK_RESET

```
#define COMPILER_PACK_RESET( ) COMPILER_PRAGMA(pack())
```

Set default alignment for subsequent struct and union definitions.

40.3.1.6 LE_BYTE0

```
#define LE_BYTE0( ) ((uint8_t)(a))
```

40.3.1.7 LE_BYTE1

```
#define LE_BYTE1( ) ((uint8_t)((a) >> 8))
```

40.3.1.8 LE_BYTE2

```
#define LE_BYTE2( ) ((uint8_t)((a) >> 16))
```

40.3.1.9 LE_BYTE3

```
#define LE_BYTE3( ) ((uint8_t)((a) >> 24))
```

40.3.1.10 LE_2_U16

```
#define LE_2_U16( ) ((p)[0] + ((p)[1] << 8))
```

40.3.1.11 LE_2_U32

```
#define LE_2_U32( ) ((p)[0] + ((p)[1] << 8) + ((p)[2] << 16) + ((p)[3] << 24))
```

40.3.1.12 size_of_mask

```
#define size_of_mask( ) (32 - clz(mask) - ctz(mask))
```

Counts the number of bits in a mask (no more than 32 bits)

Parameters

mask	Mask of which to count the bits.

40.3.1.13 pos_of_mask

```
#define pos_of_mask( ) ctz(mask)
```

Retrieve the start position of bits mask (no more than 32 bits)

Parameters

mask	Mask of which to retrieve the start position.

40.3.1.14 round_up

```
#define round_up( ) (((a) - 1) / (b) + 1)
```

Return division result of a/b and round up the result to the closest number divisible by "b".

40.3.1.15 min

#define min( ) ((x)>(y)?(y):(x))

Get the minimum of x and y.

40.3.1.16 max

#define max( ) ((x)>(y)?(x):(y))

Get the maximum of x and y.

40.3.2 Typedefs

40.3.2.1 FUNC_PTR typedef

typedef void(* FUNC_PTR) (void)

Set aligned boundary.

40.3.3 Zero-Bit Counting

40.3.3.1 clz

#define clz( )

Counts the leading zero bits of the given value considered as a 32-bit integer.

Parameters

u	Value of which to count the leading zero bits.

40.3.3.2 ctz

#define ctz( )

Counts the trailing zero bits of the given value considered as a 32-bit integer.

Parameters

u	Value of which to count the trailing zero bits.

41. WDT Driver

This Watchdog Timer (WDT) driver provides an interface to prevent system lock-up if the software becomes trapped in a deadlock. It is a system function for monitoring correct operation.

WDT makes it possible to recover from error situations such as runway or deadlocked code. The WDT is configured to a predefined timeout period, and is constantly running when enabled. If the WDT is not reset within the timeout period, it will issue a system reset.

41.1 Summary of the API's Functional Features

The API provides functions to:

- Initialize and deinitialize the driver and associated hardware
- Enable or disable WDT
- Reset the watchdog (wdt_feed)
- Timeout period set/get

41.2 Summary of Configuration Options

The main WDT parameters can be configured in START. Many of these parameters are used by the 41.7.1 wdt_init function when initializing the driver and underlying hardware. Most of the initial values can be overridden and changed runtime by calling the appropriate API functions.

41.3 Driver Implementation Description

41.3.1 Limitations

Available timeout period is device specific, the user must refer the corresponding device to set the timeout period.

Timeout period can not be changed when WDT is enabled.

41.4 Example of Usage

The following shows a simple example of using the WDT. The WDT driver must have been initialized by 41.7.1 wdt_init. This initialization will configure the operation of the hardware WDT instance.

The example sets the timeout period, and then enables the WDT. When running the project on the board, the system restarts at regular intervals.

```
/**
 * Example of using WDT_0.
 */
void WDT_0_example(void)
{
    uint32_t clk_rate;
    uint16_t timeout_period;
    clk_rate       = 1000;
    timeout_period = 4096;
    wdt_set_timeout_period(&WDT_0, clk_rate, timeout_period);
```

```
            wdt_enable(&WDT_0);
        }
```

41.5 Dependencies

- WDT peripheral and clocks

41.6 Structs

41.6.1 wdt_descriptor Struct

WDT HAL driver struct.

Members

dev

41.7 Functions

41.7.1 wdt_init

Initialize the WDT HAL instance and hardware.

```
static int32_t wdt_init(
    struct wdt_descriptor *const wdt,
    const void * hw
)
```

Initialize WDT HAL.

Parameters

wdt Type: struct 41.6.1 wdt_descriptor Struct *const

The pointer to the HAL WDT instance.

hw Type: const void *

The pointer to the hardware instance.

Returns

Type: int32_t

Operation status of init

0 Completed sucessfully.

-1 Always on or enabled, don't need init again.

41.7.2 wdt_deinit

Deinitialize the WDT HAL instance and hardware.

```
static int32_t wdt_deinit(
    struct wdt_descriptor *const wdt
)
```

Deinitialize WDT HAL.

Parameters

wdt	Type: struct 41.6.1 wdt_descriptor Struct *const The pointer to the HAL WDT instance.

Returns

Type: int32_t

Operation status of init

0	Completed sucessfully.
-1	Always on, can't deinitialize.

41.7.3 wdt_set_timeout_period

Config the timeout period for WDT HAL instance and hardware.

```
static int32_t wdt_set_timeout_period(
    struct wdt_descriptor *const wdt,
    const uint32_t clk_rate,
    const uint16_t timeout_period
)
```

Set the timeout period to WDT instance.

Parameters

wdt	Type: struct 41.6.1 wdt_descriptor Struct *const The pointer to the HAL WDT instance.
clk_rate	Type: const uint32_t The current clock rate of generic clock(GCLK_WDT) in HZ
timeout_period	Type: const uint16_t The desired timeout period(ms).

Returns

Type: int32_t

Operation status of init

0	Completed sucessfully.

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-1	Always on or enabled, can't set again.
-2	Invalid timeout period.

41.7.4 wdt_get_timeout_period

Get the timeout period for WDT HAL instance and hardware.

```
static uint32_t wdt_get_timeout_period(
    struct wdt_descriptor *const wdt,
    const uint32_t clk_rate
)
```

Parameters

wdt	Type: struct 41.6.1 wdt_descriptor Struct *const The pointer to the HAL WDT instance.
clk_rate	Type: const uint32_t The current clock rate of generic clock (GCLK_WDT) in Hz

Returns

Type: uint32_t

Current timeout period(ms)

-1	Invalid timeout period

41.7.5 wdt_enable

Enbale watchdog timer.

```
static int32_t wdt_enable(
    struct wdt_descriptor *const wdt
)
```

Parameters

wdt	Type: struct 41.6.1 wdt_descriptor Struct *const The pointer to the HAL WDT instance.

Returns

Type: int32_t

Operation status of init

0	Completed sucessfully.

41.7.6 wdt_disable

Disable watchdog timer.

```
static int32_t wdt_disable(
    struct wdt_descriptor *const wdt
)
```

Parameters

wdt	Type: struct 41.6.1 wdt_descriptor Struct *const The pointer to the HAL WDT instance.

Returns

Type: int32_t

Operation status of init

0	Completed sucessfully.
-1	Always on, can't disable.

41.7.7 wdt_feed

Feed watchdog timer to make WDT kick from start.

```
static int32_t wdt_feed(
    struct wdt_descriptor *const wdt
)
```

Parameters

wdt	Type: struct 41.6.1 wdt_descriptor Struct *const The pointer to the HAL WDT instance.

Returns

Type: int32_t

Operation status of init

0	Completed sucessfully.

41.7.8 wdt_get_version

Retrieve the current driver version.

```
uint32_t wdt_get_version(
    void
)
```

Returns

Type: uint32_t

Current driver version.

42. Revision History

Doc. Rev.	Date	Comments
B	04/2018	Updated AVR and SAM Development tools overview section.
A	09/2017	Initial document release.

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