nRF9151

Product Specification

v1.0

NORDIC® SEMICONDUCTOR

nRF9151 features

Features:

Microcontroller:

- Arm® Cortex®-M33
  - 247 EEMBC CoreMark score running from flash memory
  - Data watchpoint and trace (DWT), embedded trace macrocell (ETM), and instrumentation trace macrocell (ITM)
  - Serial wire debug (SWD)
  - Trace port
- 1 MB flash
- 256 kB low leakage RAM
- Arm TrustZone®
- Arm CryptoCell™ 310
- Up to 4x SPI master/slave with EasyDMA
- Up to 4x I2C compatible two-wire master/slave with EasyDMA
- Up to 4x UART (CTS/RTS) with EasyDMA
- I2S with EasyDMA
- Digital microphone interface (PDM) with EasyDMA
- 4x pulse width modulator (PWM) unit with EasyDMA
- 12-bit, 200 ksps ADC with EasyDMA - eight configurable channels with programmable gain
- 3x 32-bit timer with counter mode
- 2x real-time counter (RTC)
- Programmable peripheral interconnect (PPI)
- 32 general purpose I/O pins
- Single supply voltage: 3.0 – 5.5 V
- All necessary clock sources integrated
- Package: 12.1 × 11.1 × 1.2 mm LGA

LTE modem:

- Transceiver and baseband
- 3GPP LTE release 14 Cat-M1 compliant
- 3GPP LTE release 14 Cat-NB1 and Cat-NB2 compliant
- GPS receiver
  - GPS L1 C/A supported
  - QZSS L1 C/A supported
- RF transceiver for global coverage
  - Power Class 3 up to 23 dBm output power
  - Power Class 5 up to 20 dBm output power
  - -108 dBm sensitivity (Cat-M1) for low band, -107 dBm for mid band
  - Single 50 Ω antenna interface
- LTE band support in hardware:
  - Cat-M1: B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B25, B26, B28, B66, B85
  - Cat-NB1/NB2: B1, B2, B3, B4, B5, B8, B12, B13, B17, B19, B20, B25, B26, B28, B65, B66, B85
- Supports SIM and eSIM with an ETSI TS 102 221 compatible UICC interface
- Power saving features: DRX, eDRX, PSM
- IP v4/v6 stack
- Secure socket (TLS/DTLS) API

DECT NR+:

- NR+ band: 1, 2, 9, 22

Current consumption @ 3.7 V:

- LTE power saving mode (PSM) floor current: 2.7 µA
- eDRX @ 81.92s: 18 µA in Cat-M1, 32 µA in Cat-NB1 (UICC included)

Applications:

- Sensor networks
- Logistics and asset tracking
- Smart energy
- Smart building automation
- Smart agriculture
- Industrial
- Retail and monitor devices
- Medical devices
- Wearables

Contents

1 Revision history

Date	Version	Description
July 2024	1.0	First release

2 About this document

This document is organized into chapters that are based on the modules and peripherals available in the IC.

2.1 Document status

The document status reflects the level of maturity of the document.

Document name	Description
Objective Product Specification (OPS)	Applies to document versions up to 1.0. This document contains target specifications for product development.
Product Specification (PS)	Applies to document versions 1.0 and higher. This document contains final product specifications. Nordic Semiconductor ASA reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.

Table 1: Defined document names

2.2 Peripheral chapters

Every peripheral has a unique capitalized name or an abbreviation of its name, e.g. TIMER, used for identification and reference. This name is used in chapter headings and references, and it will appear in the Arm Cortex Microcontroller Software Interface Standard (CMSIS) hardware abstraction layer to identify the peripheral.

The peripheral instance name, which is different from the peripheral name, is constructed using the peripheral name followed by a numbered postfix, starting with 0, for example, TIMER0. A postfix is normally only used if a peripheral can be instantiated more than once. The peripheral instance name is also used in the CMSIS to identify the peripheral instance.

The chapters describing peripherals may include the following information:

- A detailed functional description of the peripheral.
- The register configuration for the peripheral.
- The electrical specification tables, containing performance data which apply for the operating conditions described in Operating conditions on page 523.

2.2.2 Peripheral instantiation

The peripherals have a set of security capabilities listed in the instantiation tables.

The following table describes the abbreviations used.

Abbreviation	Description
NS	Trustzone/security attribute is Non-secure - The peripheral is always accessible as a Non-secure peripheral.
S	Trustzone/security attribute is Secure - The peripheral is always accessible as a Secure peripheral.
US	Trustzone Map is user selectable - The Trustzone/security attribute of the peripheral is configurable.
HF	Trustzone Map is Hardware Fixed - The Trustzone/security attribute of the peripheral cannot be changed.
NA	Not Applicable - Peripheral has no DMA capability.
NSA	NoSeparateAttribute - Peripheral with DMA and DMA transfer has the same security attribute as assigned to the peripheral.
SA	SeparateAttribute - Peripheral with DMA and DMA transfers can have a different security attribute than the one assigned to the peripheral.

Table 2: Instantiation table abbreviations

The Secure mapping column in the peripheral instantiation table defines configuration capabilities for the Arm TrustZone for Armv8-M secure attribute. The DMA security column describes the DMA capabilities of the peripheral.

The instantiation table has the following columns:

- Instance Column - Indicates the peripheral instance name followed by optional Trustzone attribute. A corresponding address is listed in Base address column indicating the base address for Secure and Non-secure Trustzone attribute. This optional Trustzone attribute is separated by a colon (:).
- Trustzone Column - This has 3 sub-columns indicating the Trustzone map, Trustzone attribute and DMA capability. The options are as listed in Instantiation table abbreviations on page 12.

2.3 Register tables

Individual registers are described using register tables. These tables are built up of two sections. The first three colored rows describe the position and size of the different fields in the register. The following rows describe the fields in more detail.

2.3.1 Fields and values

The **Id (Field Id)** row specifies the bits that belong to the different fields in the register. If a field has enumerated values, then every value will be identified with a unique value id in the **Value Id** column.

A blank space means that the field is reserved and read as undefined, and it also must be written as `0` to secure forward compatibility. If a register is divided into more than one field, a unique field name is specified for each field in the **Field** column. The **Value Id** may be omitted in the single-bit bit fields when values can be substituted with a Boolean type enumerator range, e.g. true/false, disable(d)/enable(d), on/off, and so on.

Values are usually provided as decimal or hexadecimal. Hexadecimal values have a `0x` prefix, decimal values have no prefix.

The **Value** column can be populated in the following ways:

- Individual enumerated values, for example 1, 3, 9.
- Range of values, e.g. [0..4], indicating all values from and including 0 and 4.

- Implicit values. If no values are indicated in the **Value** column, all bit combinations are supported, or alternatively the field's translation and limitations are described in the text instead.

If two or more fields are closely related, the **Value Id**, **Value**, and **Description** may be omitted for all but the first field. Subsequent fields will indicate inheritance with '..'.

A feature marked **Deprecated** should not be used for new designs.

2.3.2 Permissions

Different fields in a register might have different access permissions enforced by hardware.

The access permission for each register field is documented in the **Access** column in the following ways:

Access	Description	Hardware behavior
RO	Read-only	Field can only be read. A write will be ignored.
WO	Write-only	Field can only be written. A read will return an undefined value.
RW	Read-write	Field can be read and written multiple times.
W1	Write-once	Field can only be written once per reset. Any subsequent write will be ignored. A read will return an undefined value.
RW1	Read-write-once	Field can be read multiple times, but only written once per reset. Any subsequent write will be ignored.
W1C	Write 1 to clear	Field can be read multiple times. A one clears (set to zero) the corresponding bit in the register. Bits set to zero are ignored.
W1S	Write 1 to set	Field can be read multiple times. A one sets the corresponding bit in the register. Bits set to zero are ignored.

Table 3: Register field permission schemes

2.4 Registers

Register overview

Register	Offset	Description
DUMMY	0x514	Example of a register controlling a dummy feature

2.4.1 DUMMY

Address offset: 0x514

Example of a register controlling a dummy feature

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID								D	D	D	D					C	C	C								B								A	
Reset 0x00050002				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**
ID	R/W	Field	Value ID	Value																															
-A	RW	FIELD0																																	
			Disabled	0																															
			NormalMode	1																															
			ExtendedMode	2																															
B	RW	FIELD1																																	
				This field is deprecated.																															
			Disabled	0																															
			Enabled	1																															
C	RW	FIELD2																																	
			ValidRange	[2..7]																															
D	RW	FIELD3																																	

3 Product overview

The nRF9151 System-in-Package (SiP) is a low-power Internet of Things (IoT) solution integrating an Arm Cortex-M33 processor with advanced security features, a range of peripherals and a Low-Power Wide-Area (LPWA) network processor. The LPWA network processor can operate as a 5G DECT NR+ (NR+) device, independent of cellular network provider or as an LTE modem compliant with 3GPP LTE release 14 Cat-M1 and Cat-NB1/NB2 standards.

The LPWA network processor integrates a flexible transceiver with frequency range 700 MHz to 2200 MHz, through a single 50 Ω antenna pin and a baseband processor. NR+ or LTE operation is supported depending on which network protocol firmware the customer installs on the LPWA network processor of the nRF9151. Nordic Semiconductor provides firmware to support NR+ or LTE, layers L1-L3 and upper IP layers, providing a secure socket API to the application.

The nRF9151 LPWA network processor also integrate a GPS receiver, enabling local positioning support when supported by the installed firmware.

The Arm Cortex-M33 processor is exclusively for the user application, with 1 MB of flash and 256 kB of RAM dedicated for this. The M33 application processor shares the power, clock, and peripheral architecture with Nordic Semiconductor nRF5 Series of PAN/LAN SoCs, ensuring minimal porting efforts.

The peripheral set offers a variety of analog and digital functionality enabling single-chip implementation of a wide range of IoT applications. Arm TrustZone technology, CryptoCell 310 and supporting blocks for system protection and key management, are embedded to enable advanced security needed for IoT applications.

3.1 Block diagram

The block diagram illustrates the overall system. Arrows with white heads indicate signals that share physical pins with other signals.

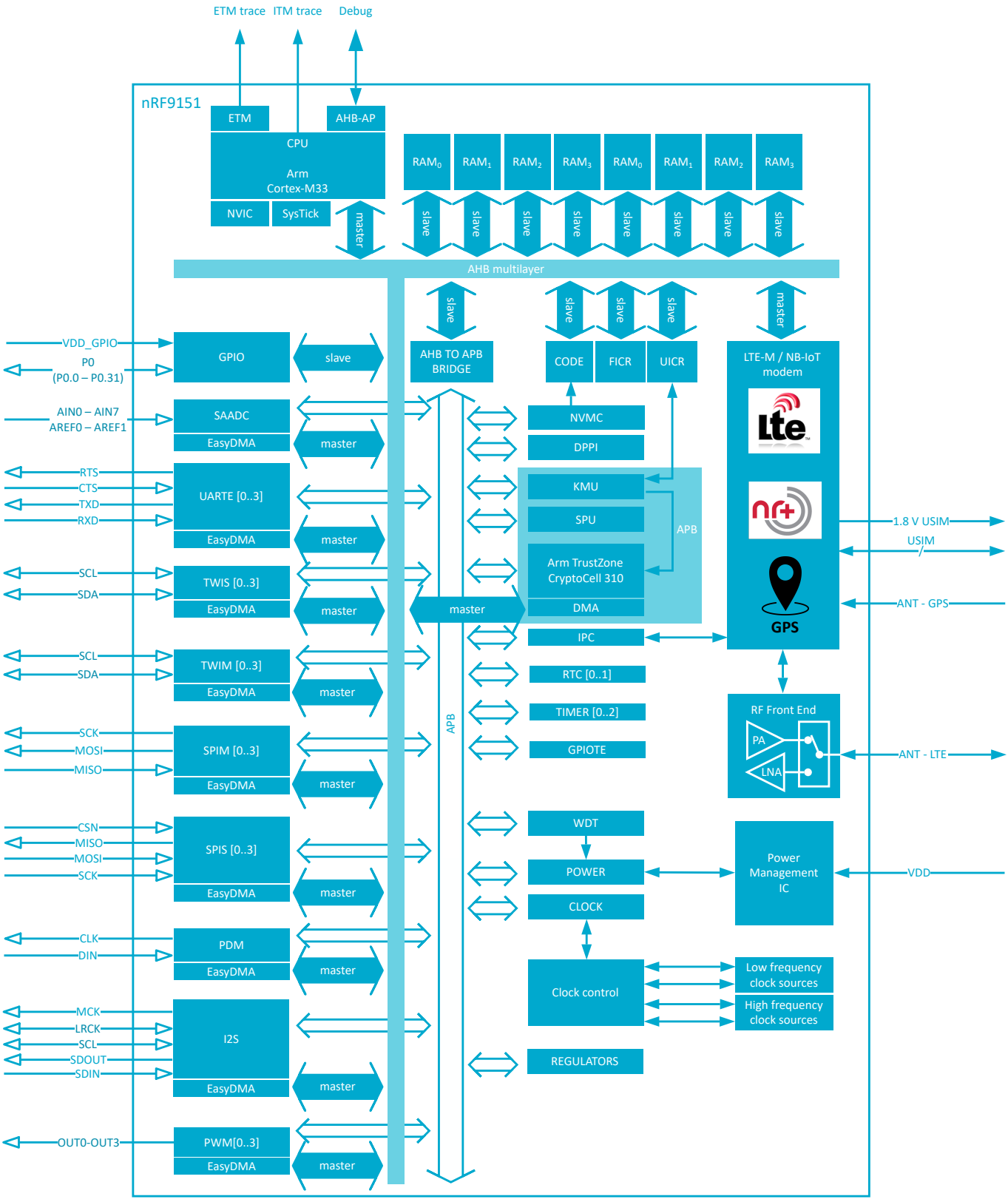

Figure 1: Block diagram

3.2 Peripheral interface

Peripherals are controlled by the CPU through configuration registers, as well as task and event registers. Task registers are inputs, enabling the CPU and other peripherals to initiate a functionality. Event registers

are outputs, enabling a peripheral to trigger tasks in other peripherals and/or the CPU by tying events to CPU interrupts.

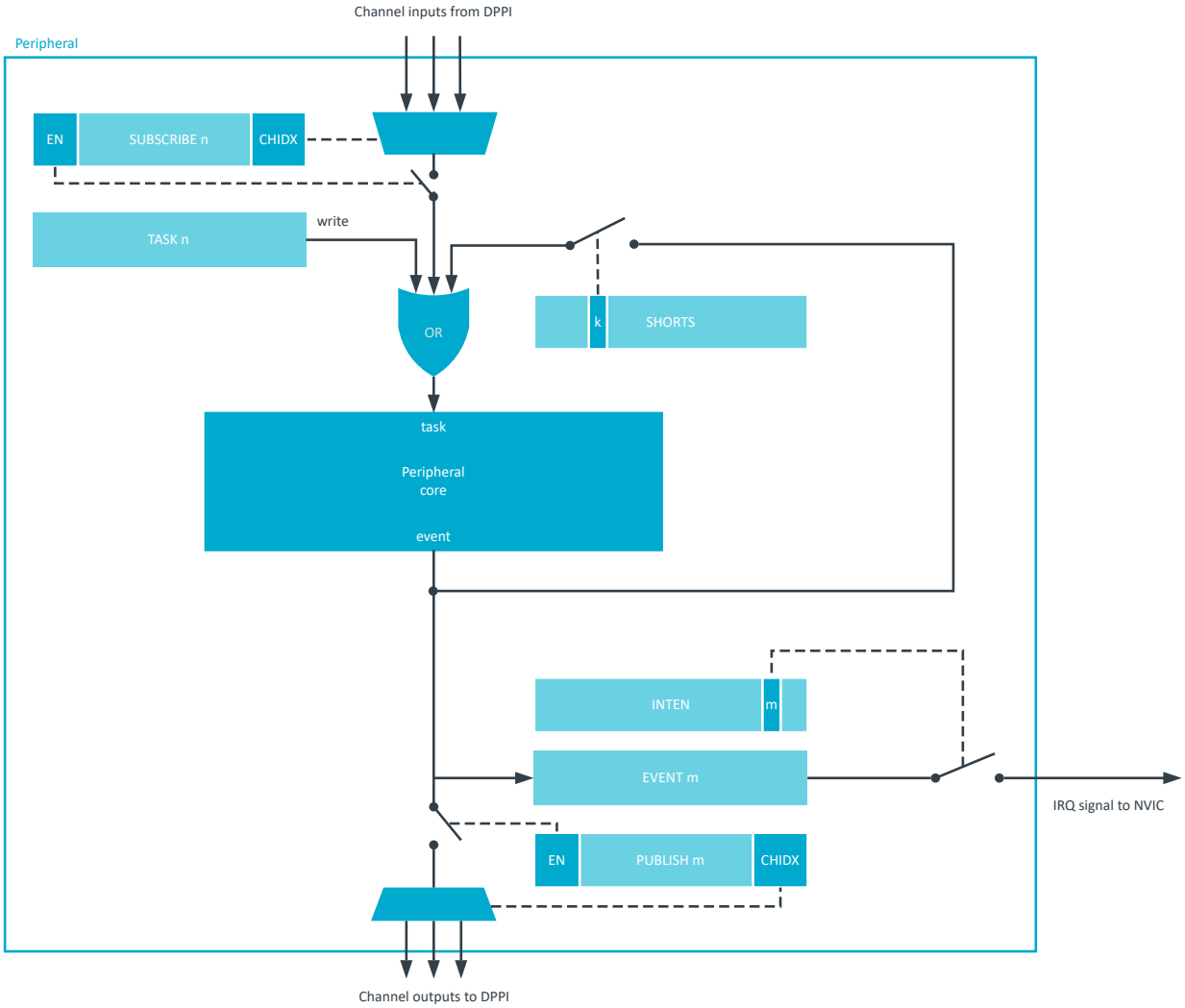

Figure 2: Peripheral interface

The distributed programmable peripheral interconnect (DPPI) feature enables peripherals to connect events to tasks without CPU intervention. For more information on DPPI and the DPPI channels, see DPPI - Distributed programmable peripheral interconnect on page 152.

3.2.1 Peripheral ID

Every peripheral is assigned a fixed block of 0x1000 bytes of address space, which is equal to 1024 x 32-bit registers.

See Instantiation on page 25 for more information about which peripherals are available and where they are located in the address map.

There is a direct relationship between peripheral ID and base address. For example, a peripheral with base address 0x40000000 is assigned ID=0, a peripheral with base address 0x40001000 is assigned ID=1, and a peripheral with base address 0x4001F000 is assigned ID=31.

Peripherals may share the same ID, which may impose one or more of the following limitations:

- Shared registers or common resources
- Limited availability due to mutually exclusive operation; only one peripheral in use at a time

- Enforced peripheral behavior when switching between peripherals (disable the first peripheral before enabling the second)

3.2.2 Peripherals with shared ID

In general (with the exception of ID 0), peripherals sharing an ID and base address may not be used simultaneously. Only one peripheral can be enabled at a given ID.

When switching between two peripherals sharing an ID, the following should be performed to prevent unwanted behavior:

1. Disable the previously used peripheral.
2. Disable any publish/subscribe connection to the DPPI system for the peripheral that is being disabled.
3. Clear all bits in the INTEN register, i.e. INTENCLR = 0xFFFFFFFF.
4. Explicitly configure the peripheral being enabled. Do not rely on inherited configuration from the disabled peripheral.
5. Enable the now configured peripheral.

For a list of which peripherals that share an ID see Instantiation on page 25.

3.2.3 Peripheral registers

Most peripherals feature an ENABLE register. Unless otherwise specified, the peripheral registers must be configured before enabling the peripheral.

PSEL registers need to be set before a peripheral is enabled or started. Updating PSEL registers while the peripheral is running has no effect. To connect a peripheral to a different GPIO, the following must be performed:

1. Disable the peripheral.
2. Update the PSEL register.
3. Re-enable the peripheral.

It takes four CPU cycles between the PSEL register update and the connection between a peripheral and a GPIO becoming effective.

Note: The peripheral must be enabled before tasks and events can be used.

Most of the register values are lost during System OFF or when a reset is triggered. Some registers will retain their values in System OFF or for some specific reset sources. These registers are marked as retained in the register description for a given peripheral. For more information on their behavior, see chapter Reset on page 59.

3.2.4 Bit set and clear

Registers with multiple single-bit bit fields may implement the set-and-clear pattern. This pattern enables firmware to set and clear individual bits in a register without having to perform a read-modify-write operation on the main register.

This pattern is implemented using three consecutive addresses in the register map, where the main register is followed by dedicated SET and CLR registers (in that exact order).

In the main register, the SET register sets individual bits and the CLR register clears them. Writing `1` to a bit in the SET or CLR register will set or clear the same bit in the main register respectively. Writing `0` to a bit in the SET or CLR register has no effect. Reading the SET or CLR register returns the value of the main register.

Note: The main register may not be visible and therefore not directly accessible in all cases.

3.2.5 Tasks

Tasks are used to trigger actions in a peripheral, such as to start a particular behavior. A peripheral can implement multiple tasks with each task having a separate register in that peripheral's task register group.

A task is triggered when firmware writes `1` to the task register, or when the peripheral itself or another peripheral toggles the corresponding task signal. See the figure Peripheral interface on page 16.

3.2.6 Events

Events are used to notify peripherals and the CPU about events that have happened, for example a state change in a peripheral. A peripheral may generate multiple events, where each event has a separate register in that peripheral's event register group.

An event is generated when the peripheral itself toggles the corresponding event signal, and the event register is updated to reflect that the event has been generated, see figure Peripheral interface on page 16. An event register is cleared when a `0` is written to it by firmware. Events can be generated by the peripheral even when the event register is set to `1`.

3.2.7 Publish and subscribe

Events and tasks from different peripherals can be connected together through the DPPI system using the PUBLISH and SUBSCRIBE registers in each peripheral. See Peripheral interface on page 16. An event can be published onto a DPPI channel by configuring the event's PUBLISH register. Similarly, a task can subscribe to a DPPI channel by configuring the task's SUBSCRIBE register.

See DPPI - Distributed programmable peripheral interconnect on page 152 for details.

3.2.8 Shortcuts

A shortcut is a direct connection between an event and a task within the same peripheral. If a shortcut is enabled, the associated task is automatically triggered when its associated event is generated.

Using shortcuts is equivalent to making the connection outside the peripheral and through the DPPI. However, the propagation delay when using shortcuts is usually shorter than the propagation delay through the DPPI.

Shortcuts are predefined, which means that their connections cannot be configured by firmware. Each shortcut can be individually enabled or disabled through the shortcut register, one bit per shortcut, giving a maximum of 32 shortcuts for each peripheral.

3.2.9 Interrupts

All peripherals support interrupts which are generated by events.

A peripheral only occupies one interrupt, and the interrupt number follows the peripheral ID. For example, the peripheral with ID=4 is connected to interrupt number 4 in the nested vectored interrupt controller (NVIC).

Using registers INTEN, INTENSET, and INTENCLR, every event generated by a peripheral can be configured to generate that peripheral's interrupt. Multiple events can be enabled to generate interrupts simultaneously. To resolve the correct interrupt source, the event registers in the event group of peripheral registers will indicate the source.

Some peripherals implement only INTENSET and INTENCLR registers, and the INTEN register is not available on those peripherals. See the individual peripheral chapters for details. In all cases, reading back the INTENSET or INTENCLR register returns the same information as in INTEN.

Each event implemented in the peripheral is associated with a specific bit position in the INTEN, INTENSET, and INTENCLR registers.

The relationship between tasks, events, shortcuts, and interrupts is illustrated in figure Peripheral interface on page 16.

3.2.9.1 Interrupt clearing and disabling

Interrupts should always be cleared by writing `0` to the corresponding EVENT register.

Until cleared, interrupts will immediately be re-triggered and cause software interrupt service routines to be executed repeatedly.

Because the clearing of the EVENT register may take a number of CPU clock cycles, the program should perform a read from the EVENT register that has been cleared before exiting the interrupt service routine. This will ensure that the EVENT clearing has taken place before the interrupt service routine is exited. Care should be taken to ensure that the compiler does not remove the read operation as an optimization.

Similarly, when disabling an interrupt inside an interrupt service routine, the program should perform a read from the INTEN or INTENCLR registers to ensure that the interrupt is disabled before exiting the interrupt service routine.

3.2.10 Secure/non-secure peripherals

For some peripherals, the security configuration can change from secure to non-secure, or vice versa. Care must be taken when changing the security configuration of a peripheral, to prevent security information leakage and ensure correct operation.

The following sequence should be followed, where applicable, when configuring and changing the security settings of a peripheral in the SPU — System protection unit on page 323.

1. Stop peripheral operation.
2. Disable the peripheral.
3. Remove pin connections.
4. Disable DPPI connections.
5. Clear sensitive registers (e.g. writing back default values).
6. Change peripheral security setting in the SPU — System protection unit on page 323.
7. Re-enable the peripheral.

4 Application core

The nRF9151 application core has a modern and powerful Arm Cortex-M33 with on-chip flash and RAM exclusively for application use.

4.1 CPU

The Arm Cortex-M33 processor has a 32-bit instruction set (Thumb®-2 technology) that implements a superset of 16 and 32-bit instructions to maximize code density and performance.

This processor implements several features that enable energy-efficient arithmetic and high-performance signal processing, including:

- Digital signal processing (DSP) instructions
- Single-cycle multiply and accumulate (MAC) instructions
- Hardware divide
- 8- and 16-bit single instruction, multiple data (SIMD) instructions
- Single-precision floating-point unit (FPU)
- Memory Protection Unit (MPU)
- Arm TrustZone for ARMv8-M

The Arm Cortex Common Microcontroller Software Interface Standard (CMSIS) hardware abstraction layer for the Arm Cortex processor series is implemented and available for the M33 CPU.

Real-time execution is highly deterministic in thread mode, to and from sleep modes, and when handling events at configurable priority levels via the nested vectored interrupt controller (NVIC).

Executing code from internal or external flash will have a wait state penalty. The instruction cache can be enabled to minimize flash wait states when fetching instructions. For more information on cache, see Cache on page 32. The section Electrical specification on page 21 shows CPU performance parameters including the wait states in different modes, CPU current and efficiency, and processing power and efficiency based on the CoreMark® benchmark.

4.1.1 Floating-point interrupt

The floating-point unit (FPU) might generate exceptions when used (for example, due to overflow or underflow), which trigger the FPU interrupt.

See Instantiation on page 25 for more information about which exception number (peripheral ID) is triggered by an FPU exception.

The FPU is not affected by any security configuration. It is presented as non-secure in register PERIPHID[n].PERM. See SPU — System protection unit on page 323 for more information.

To clear the IRQ (interrupt request) line when an exception occurs, the relevant exception bit within the floating-point status and control register (FPSCR) must be cleared. For more information about the FPSCR or other FPU registers, see the *Arm Cortex-M33 Devices Generic User Guide*.

4.1.2 CPU and support module configuration

The Arm Cortex-M33 processor has a number of CPU options and support modules implemented on the device.

Option / Module	Description	Implemented
Core options		
NVIC	Nested vectored interrupt controller	YES
PRIORITIES	Priority bits	3
WIC	Wake-up interrupt controller	NO
Endianness	Memory system endianness	Little endian
DWT	Data watchpoint and trace	YES
Modules		
MPU_NS	Number of non-secure memory protection unit (MPU) regions	16
MPU_S	Number of secure MPU regions	16
SAU	Number of security attribution unit (SAU) regions	0, see SPU for more information about secure regions.
FPU	Floating-point unit	YES
DSP	Digital signal processing extension	YES
ARMv8-M TrustZone	ARMv8-M security extensions	YES
CPIF	Co-processor interface	NO
ETM	Embedded trace macrocell	YES
ITM	Instrumentation trace macrocell	YES
MTB	Micro trace buffer	NO
CTI	Cross trigger interface	YES
BPU	Breakpoint unit	YES
HTM	AMBA® AHB trace macrocell	NO

4.1.3 Electrical specification

4.1.3.1 CPU performance

The CPU clock speed is 64 MHz. Current and efficiency data is taken when in System ON and the CPU is executing the CoreMark benchmark. It includes power regulator and clock base currents. All other blocks are IDLE.

Symbol	Description	Min.	Typ.	Max.	Units
W_{FLASH}	CPU wait states, running from flash, cache disabled	0		4	
$W_{FLASHCACHE}$	CPU wait states, running from flash, cache enabled	0		2	
W_{RAM}	CPU wait states, running from RAM			0	
CM_{FLASH}	CoreMark[1], running from flash, cache enabled		247		CoreMark
$CM_{FLASH/MHz}$	CoreMark per MHz, running from flash, cache enabled		3.86		CoreMark/MHz
$CM_{FLASH/mA}$	CoreMark per mA, running from flash, cache enabled		91		CoreMark/mA

4.2 Memory

The application microcontroller has embedded 1024 kB flash and 256 kB RAM for application code and data storage.

As illustrated in Memory layout on page 22, both CPU and EasyDMA are able to access RAM via the AHB multilayer interconnect. See AHB multilayer interconnect on page 48 and EasyDMA on page 46 for more information about AHB multilayer interconnect and EasyDMA respectively. The LTE modem can access all application MCU memory, but typically a small portion of RAM is dedicated to data exchange between application MCU and the modem baseband controller.

[1] Using armclang compiler

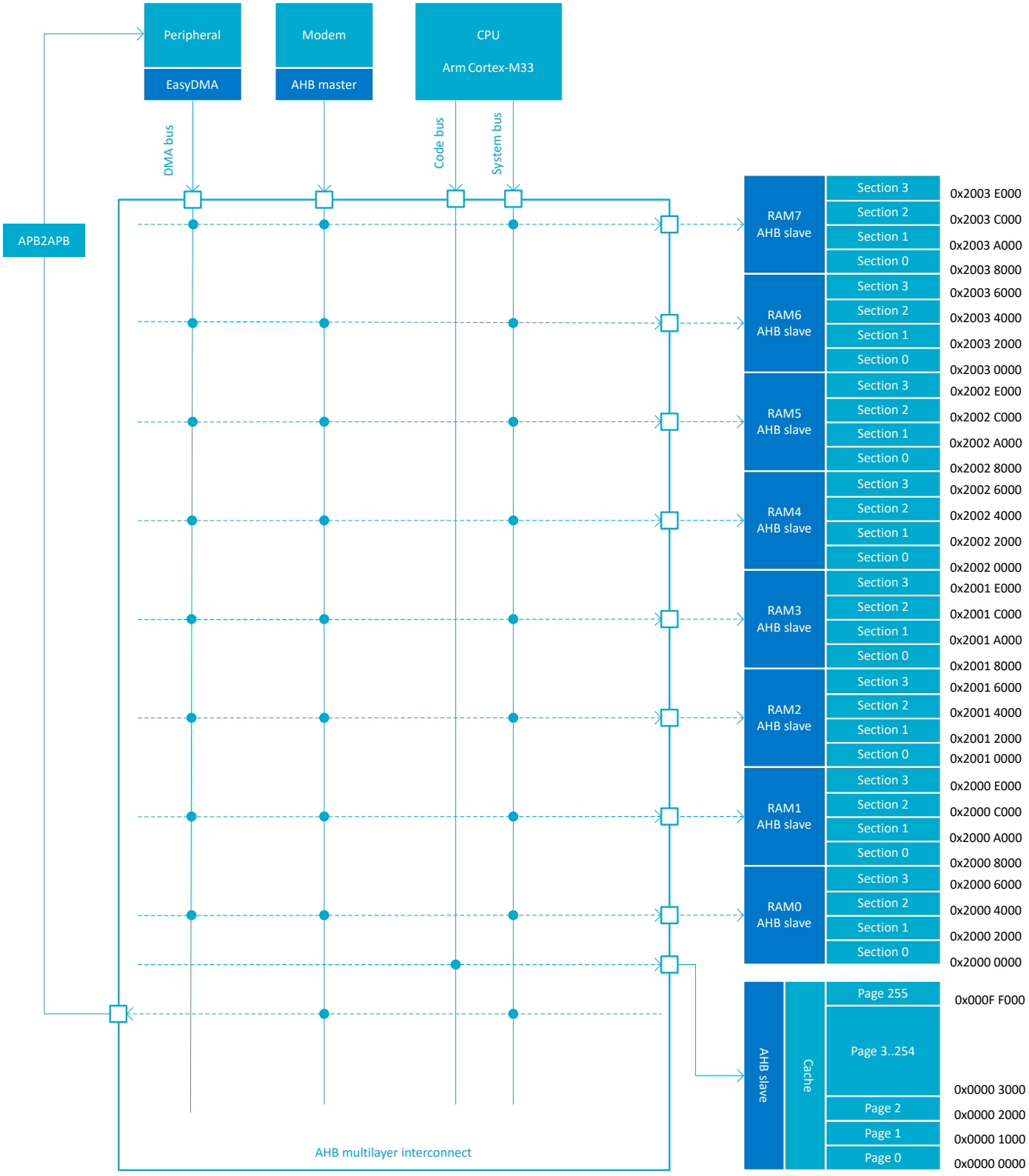

Figure 3: Memory layout

RAM - Random access memory

RAM can be read and written an unlimited number of times by the CPU and the EasyDMA.

Each RAM AHB slave is connected to one or more RAM sections. See Memory layout on page 22 for more information.

The RAM blocks power states and retention states in System ON and System OFF modes are controlled by the VMC.

Flash - Non-volatile memory

Flash can be read an unlimited number of times by the CPU and is accessible via the AHB interface connected to the CPU, see Memory layout on page 22 for more information. There are restrictions on the number of times flash can be written and erased, and also on how it can be written. For more information, see Absolute maximum ratings on page 524. Writing to flash is managed by the non-volatile memory controller (NVMC).

4.2.1 Memory map

All memory and registers are found in the same address space, as illustrated in the device memory map below.

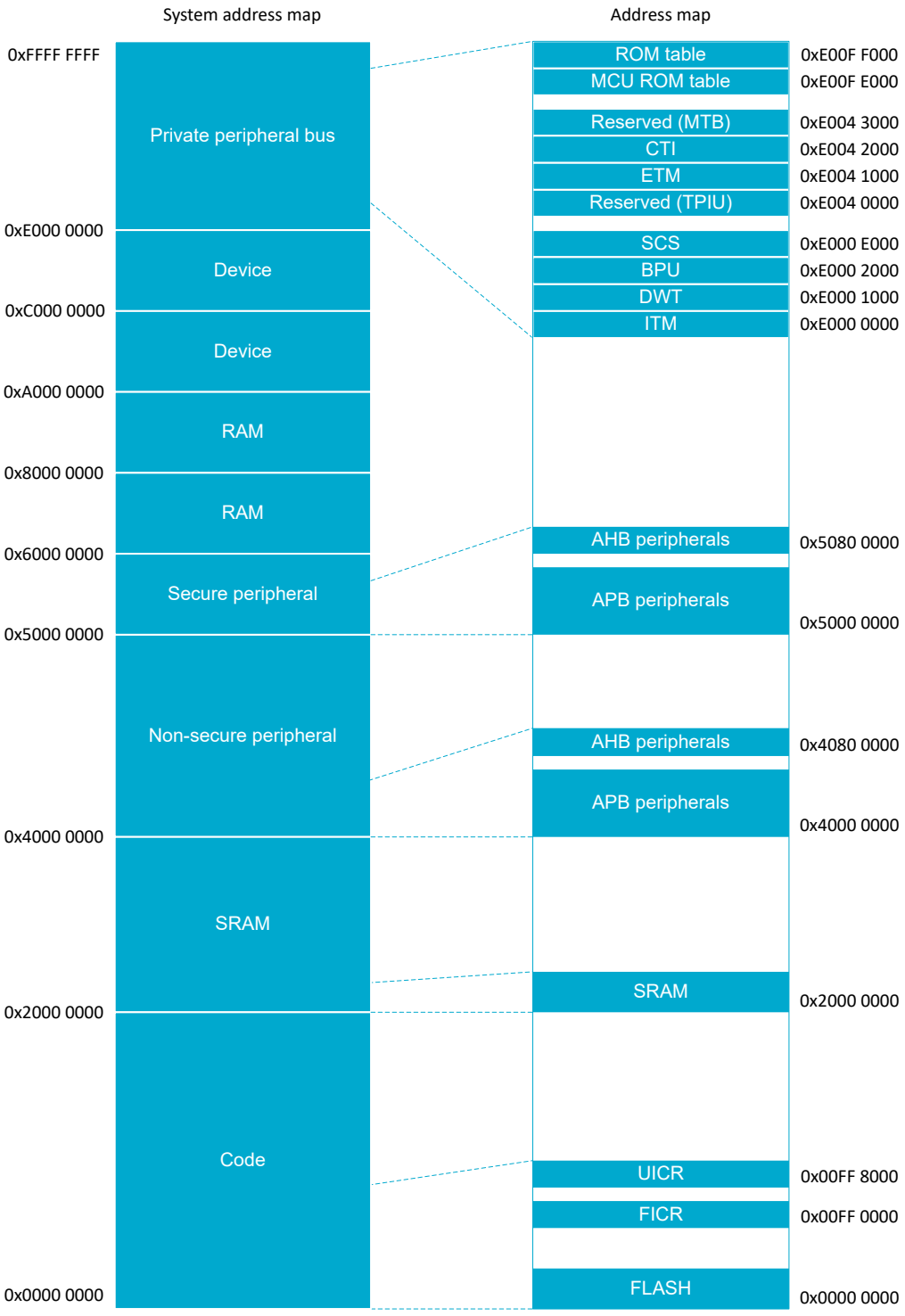

Figure 4: Memory map

Some of the registers are retained (their values kept). Read more about retained registers in Retained registers on page 60 and Reset behavior on page 60.

4.2.2 Instantiation

ID	Base address	Instance	TrustZone			Split access	Description
			Map	Att	DMA		
3	0x50003000	SPU	HF	S	NA	No	System Protection Unit
4	0x50004000 0x40004000	REGULATORS : S REGULATORS : NS	US	NS	NA	No	Regulator configuration
5	0x50005000 0x40005000	CLOCK : S CLOCK : NS	US	NS	NA	No	Clock control
5	0x50005000 0x40005000	POWER : S POWER : NS	US	NS	NA	No	Power control
6	0x50006000	CTRL_AP_PERI	HF	S	NA	No	CTRL-AP-PERI
8	0x50008000 0x40008000	SPIM0 : S SPIM0 : NS	US	NS	SA	No	SPI master 0
8	0x50008000 0x40008000	SPIS0 : S SPIS0 : NS	US	NS	SA	No	SPI slave 0
8	0x50008000 0x40008000	TWIM0 : S TWIM0 : NS	US	NS	SA	No	Two-wire interface master 0
8	0x50008000 0x40008000	TWIS0 : S TWIS0 : NS	US	NS	SA	No	Two-wire interface slave 0
8	0x50008000 0x40008000	UARTE0 : S UARTE0 : NS	US	NS	SA	No	Universal asynchronous receiver/transmitter with EasyDMA 0
9	0x50009000 0x40009000	SPIM1 : S SPIM1 : NS	US	NS	SA	No	SPI master 1
9	0x50009000 0x40009000	SPIS1 : S SPIS1 : NS	US	NS	SA	No	SPI slave 1
9	0x50009000 0x40009000	TWIM1 : S TWIM1 : NS	US	NS	SA	No	Two-wire interface master 1
9	0x50009000 0x40009000	TWIS1 : S TWIS1 : NS	US	NS	SA	No	Two-wire interface slave 1
9	0x50009000 0x40009000	UARTE1 : S UARTE1 : NS	US	NS	SA	No	Universal asynchronous receiver/transmitter with EasyDMA 1
10	0x5000A000 0x4000A000	SPIM2 : S SPIM2 : NS	US	NS	SA	No	SPI master 2
10	0x5000A000 0x4000A000	SPIS2 : S SPIS2 : NS	US	NS	SA	No	SPI slave 2
10	0x5000A000 0x4000A000	TWIM2 : S TWIM2 : NS	US	NS	SA	No	Two-wire interface master 2
10	0x5000A000 0x4000A000	TWIS2 : S TWIS2 : NS	US	NS	SA	No	Two-wire interface slave 2
10	0x5000A000 0x4000A000	UARTE2 : S UARTE2 : NS	US	NS	SA	No	Universal asynchronous receiver/transmitter with EasyDMA 2
11	0x5000B000 0x4000B000	SPIM3 : S SPIM3 : NS	US	NS	SA	No	SPI master 3
11	0x5000B000 0x4000B000	SPIS3 : S SPIS3 : NS	US	NS	SA	No	SPI slave 3
11	0x5000B000 0x4000B000	TWIM3 : S TWIM3 : NS	US	NS	SA	No	Two-wire interface master 3
11	0x5000B000 0x4000B000	TWIS3 : S TWIS3 : NS	US	NS	SA	No	Two-wire interface slave 3
11	0x5000B000 0x4000B000	UARTE3 : S UARTE3 : NS	US	NS	SA	No	Universal asynchronous receiver/transmitter with EasyDMA 3
13	0x5000D000	GPIOTE0	HF	S	NA	No	Secure GPIO tasks and events

ID	Base address	Instance	TrustZone			Split access	Description
			Map	Att	DMA		
14	0x5000E000 0x4000E000	SAADC : S SAADC : NS	US	NS	SA	No	Analog to digital converter
15	0x5000F000 0x4000F000	TIMER0 : S TIMER0 : NS	US	NS	NA	No	Timer 0
16	0x50010000 0x40010000	TIMER1 : S TIMER1 : NS	US	NS	NA	No	Timer 1
17	0x50011000 0x40011000	TIMER2 : S TIMER2 : NS	US	NS	NA	No	Timer 2
20	0x50014000 0x40014000	RTC0 : S RTC0 : NS	US	NS	NA	No	Real time counter 0
21	0x50015000 0x40015000	RTC1 : S RTC1 : NS	US	NS	NA	No	Real time counter 1
23	0x50017000 0x40017000	DPPIC : S DPPIC : NS	HF	NS	NA	Yes	DPPI configuration
24	0x50018000 0x40018000	WDT : S WDT : NS	US	NS	NA	No	Watchdog timer
27	0x5001B000 0x4001B000	EGU0 : S EGU0 : NS	US	NS	NA	No	Event generator unit 0
28	0x5001C000 0x4001C000	EGU1 : S EGU1 : NS	US	NS	NA	No	Event generator unit 1
29	0x5001D000 0x4001D000	EGU2 : S EGU2 : NS	US	NS	NA	No	Event generator unit 2
30	0x5001E000 0x4001E000	EGU3 : S EGU3 : NS	US	NS	NA	No	Event generator unit 3
31	0x5001F000 0x4001F000	EGU4 : S EGU4 : NS	US	NS	NA	No	Event generator unit 4
32	0x50020000 0x40020000	EGU5 : S EGU5 : NS	US	NS	NA	No	Event generator unit 5
33	0x50021000 0x40021000	PWM0 : S PWM0 : NS	US	NS	SA	No	Pulse width modulation unit 0
34	0x50022000 0x40022000	PWM1 : S PWM1 : NS	US	NS	SA	No	Pulse width modulation unit 1
35	0x50023000 0x40023000	PWM2 : S PWM2 : NS	US	NS	SA	No	Pulse width modulation unit 2
36	0x50024000 0x40024000	PWM3 : S PWM3 : NS	US	NS	SA	No	Pulse width modulation unit 3
38	0x50026000 0x40026000	PDM : S PDM : NS	US	NS	SA	No	Pulse density modulation (digital microphone) interface
40	0x50028000 0x40028000	I2S : S I2S : NS	US	NS	SA	No	Inter-IC Sound
42	0x5002A000 0x4002A000	IPC : S IPC : NS	US	NS	NA	No	Interprocessor communication
44	0x4002C000	FPU	HF	NS	NA	No	Floating-point unit
49	0x40031000	GPIOTE1	HF	NS	NA	No	Non Secure GPIO tasks and events
57	0x50039000 0x40039000	APPROTECT : S APPROTECT : NS	HF	NS	NA	Yes	APPROTECT control
57	0x50039000 0x40039000	KMU : S KMU : NS	HF	NS	NA	Yes	Key management unit
57	0x50039000 0x40039000	NVMC : S NVMC : NS	HF	NS	NA	Yes	Non-volatile memory controller
58	0x5003A000 0x4003A000	VMC : S VMC : NS	US	NS	NA	No	Volatile memory controller

ID	Base address	Instance	TrustZone			Split access	Description
			Map	Att	DMA		
64	0x50840000	CRYPTOCELL	HF	S	NSA	No	CRYPTOCELL 310 security subsystem
65	0x50841000	CC_AES	HF	S	NSA	No	CRYPTOCELL AES engine
65	0x50841000	CC_AHB	HF	S	NSA	No	CRYPTOCELL AHB interface
65	0x50841000	CC_CHACHA	HF	S	NSA	No	CRYPTOCELL CHACHA engine
65	0x50841000	CC_CTL	HF	S	NSA	No	CRYPTOCELL CTL interface
65	0x50841000	CC_DIN	HF	S	NSA	No	CRYPTOCELL DIN DMA engine
65	0x50841000	CC_DOUT	HF	S	NSA	No	CRYPTOCELL DOUT DMA engine
65	0x50841000	CC_HASH	HF	S	NSA	No	CRYPTOCELL HASH engine
65	0x50841000	CC_HOST_RGF	HF	S	NSA	No	CRYPTOCELL HOST register interface
65	0x50841000	CC_MISC	HF	S	NSA	No	CRYPTOCELL MISC interface
65	0x50841000	CC_PKA	HF	S	NSA	No	CRYPTOCELL PKA engine
65	0x50841000	CC_RNG	HF	S	NSA	No	CRYPTOCELL RNG engine
65	0x50841000	CC_RNG_SRAM	HF	S	NSA	No	CRYPTOCELL RNG SRAM interface
66	0x50842500 0x40842500	P0 : S P0 : NS	HF	NS	NA	Yes	General purpose input and output
N/A	0x00FF0000	FICR	HF	S	NA	No	Factory information configuration
N/A	0x00FF8000	UICR	HF	S	NA	No	User information configuration
N/A	0xE0041000	ETM	HF	NS	NA	No	ETM
N/A	0xE0051000	ETB	HF	NS	NA	No	ETB
N/A	0xE0054000	TPIU	HF	NS	NA	No	TPIU
N/A	0xE0058000	ATBREPLICATOR	HF	NS	NA	No	ATBREPLICATOR
N/A	0xE005A000	ATBFUNNEL1	HF	NS	NA	No	ATBFUNNEL unit 1
N/A	0xE005B000	ATBFUNNEL2	HF	NS	NA	No	ATBFUNNEL unit 2
N/A	0xE0080000	TAD	HF	S	NA	No	Trace and debug control

Table 4: Instantiation table

4.2.3 Peripheral access control capabilities

Information about the peripheral access control capabilities can be found in the instantiation table.

The instantiation table has two columns containing the information about access control capabilities for a peripheral:

- Secure mapping: This column defines configuration capabilities for TrustZone-M secure attribute.
- DMA security: This column indicates whether the peripheral has DMA capabilities, and if DMA transfer can be assigned to a different security attribute than the peripheral itself.

For details on options in secure mapping column and DMA security column, see the following tables respectively.

Abbreviation	Description
NS	Non-secure: This peripheral is always accessible as a non-secure peripheral.
S	Secure: This peripheral is always accessible as a secure peripheral.
US	User-selectable: Non-secure or secure attribute for this peripheral is defined by the PERIPHID[0].PERM register.
SPLIT	Both non-secure and secure: The same resource is shared by both secure and non-secure code.

Table 5: Secure mapping column options

Abbreviation	Description
NA	Not applicable: Peripheral has no DMA capability.
NSA	No separate attribute: Peripheral has DMA, and DMA transfers always have the same security attribute as assigned to the peripheral.
SA	Separate attribute: Peripheral has DMA, and DMA transfers can have a different security attribute than the one assigned to the peripheral.

Table 6: DMA security column options

4.3 VMC — Volatile memory controller

The volatile memory controller (VMC) provides power control of RAM blocks.

Each of the available RAM blocks, which can contain multiple RAM sections, can be turned on or off independently in System ON mode, using the RAM[n]registers. These registers also control if a RAM block, or some of its sections, is retained in System OFF mode. See Memory chapter for more information about RAM blocks and sections.

Note: Powering up a RAM block takes typically 10 cycles. Thus, it is recommended reading the POWER register before accessing a RAM block that has been recently powered on.

4.3.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
VMC : S	0x5003A000	US	NS	NA	No	Volatile memory controller
VMC : NS	0x4003A000					

Register overview

Register	Offset	TZ	Description
RAM[n].POWER	0x600		RAMn power control register
RAM[n].POWERSET	0x604		RAMn power control set register
RAM[n].POWERCLR	0x608		RAMn power control clear register

4.3.1.1 RAM[n].POWER (n=0..7)

Address offset: 0x600 + (n × 0x10)

RAMn power control register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x0000FFFF				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A-D	RW	S[i]POWER (i=0..3)			Keep RAM section Si of RAM n on or off in System ON mode All RAM sections will be switched off in System OFF mode
			Off	0	Off
			On	1	On
E-H	RW	S[i]RETENTION (i=0..3)			Keep retention on RAM section Si of RAM n when RAM section is switched off
			Off	0	Off
			On	1	On

4.3.1.2 RAM[n].POWERSET (n=0..7)

Address offset: 0x604 + (n × 0x10)

RAMn power control set register

When read, this register will return the value of the POWER register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x0000FFFF				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A-D	W	S[i]POWER (i=0..3)			Keep RAM section Si of RAM n on or off in System ON mode
			On	1	On
E-H	W	S[i]RETENTION (i=0..3)			Keep retention on RAM section Si of RAM n when RAM section is switched off
			On	1	On

4.3.1.3 RAM[n].POWERCLR (n=0..7)

Address offset: 0x608 + (n × 0x10)

RAMn power control clear register

When read, this register will return the value of the POWER register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x0000FFFF				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A-D	W	S[i]POWER (i=0..3)			Keep RAM section Si of RAM n on or off in System ON mode
			Off	1	Off
E-H	W	S[i]RETENTION (i=0..3)			Keep retention on RAM section Si of RAM n when RAM section is switched off
			Off	1	Off

4.4 NVMC — Non-volatile memory controller

The non-volatile memory controller (NVMC) is used for writing and erasing of the internal flash memory and the user information configuration register (UICR).

The NVMC is a split security peripheral. This means that when the NVMC is configured as non-secure, only a subset of the registers is available from the non-secure code. See SPU — System protection unit on page 323 and Registers on page 32 for more details.

When the NVMC is configured to be a secure peripheral, only secure code has access.

Before a write can be performed, the NVMC must be enabled for writing in CONFIG.WEN. Similarly, before an erase can be performed, the NVMC must be enabled for erasing in CONFIG.EEN, see CONFIG on page 33. The user must make sure that writing and erasing are not enabled at the same time. Failing to do so may result in unpredictable behavior.

4.4.1 Writing to flash

When writing is enabled, in CONFIG register for secure region, or in CONFIGNS register for non-secure region, flash is written by writing a full 32-bit word to a word-aligned address in flash.

Secure code has access to both secure and non-secure regions, by using the appropriate configuration of CONFIG and CONFIGNS registers. Non-secure code, in contrast, has access to non-secure regions only. Thus, non-secure code only needs CONFIGNS.

The NVMC is only able to write '0' to erased bits in flash, that is bits set to '1'. It cannot write a bit back to '1'.

As illustrated in Memory on page 21, flash is divided into multiple pages. The same address in flash can only be written n_{WRITE} number of times before a page erase must be performed.

Only full 32-bit words can be written to flash using the NVMC interface. To write less than 32 bits to flash, write the data as a word, and set all the bits that should remain unchanged in the word to '1'. Note that the restriction about the number of writes (see above) still applies in this case.

The time it takes to write a word to flash is specified by t_{WRITE}. If CPU executes code from flash while the NVMC is writing to flash, the CPU will be stalled.

Only word-aligned writes are allowed. Byte or half-word-aligned writes will result in a bus fault.

4.4.2 Erasing a secure page in flash

When secure region erase is enabled (in CONFIG register), a flash page can be erased by writing 0xFFFFFFFF into the first 32-bit word in a flash page.

Page erase is only applicable to the code area in the flash and does not work with UICR.

After erasing a flash page, all bits in the page are set to '1'. The time it takes to erase a page is specified by $t_{ERASEPAGE}$. The CPU is stalled if the CPU executes code from the flash while the NVMC performs the erase operation.

See Partial erase of a page in flash for information on splitting the erase time in smaller chunks.

4.4.3 Erasing a non-secure page in flash

When non-secure region erase is enabled, a non-secure flash page can be erased by writing 0xFFFFFFFF into the first 32-bit word of the flash page.

Page erase is only applicable to the code area in the flash and does not work with UICR.

After erasing a flash page, all bits in the page are set to '1'. The time it takes to erase a page is specified by $t_{ERASEPAGE}$. The CPU is stalled if the CPU executes code from the flash while the NVMC performs the erase operation.

4.4.4 Writing to user information configuration registers (UICR)

User information configuration registers (UICR) are written in the same way as flash. After UICR has been written, the new UICR configuration only takes effect after a reset.

UICR is only accessible by secure code. Any write from non-secure code will be faulted.

In order to lock the chip after uploading non-secure code, a simple sequence must be followed:

1. Block access to secure code by setting UICR register SECUREAPPROTECT on page 44 to protected
2. Use the WRITEUICRNS on page 35 register, via non-secure debugger, in order to set APPROTECT (APPROTECT is automatically written to 0x00000000 by the NVMC)

UICR can only be written n_{WRITE} number of times before an erase must be performed using ERASEALL.

The time it takes to write a word to the UICR is specified by t_{WRITE}. The CPU is stalled if the CPU executes code from the flash while the NVMC is writing to the UICR.

4.4.5 Erase all

When erase is enabled, the whole flash and UICR can be erased in one operation by using the ERASEALL register. ERASEALL does not erase the factory information configuration registers (FICR).

This functionality can be blocked by some configuration of the UICR protection bits, see the table NVMC protection (1 - Enabled, 0 - Disabled, X - Don't care) on page 31.

The time it takes to perform an ERASEALL on page 33 command is specified by $t_{ERASEALL}$. The CPU is stalled if the CPU executes code from the flash while the NVMC performs the erase operation.

4.4.6 NVMC protection mechanisms

This chapter describes the different protection mechanisms for the non-volatile memory.

4.4.6.1 NVMC blocking

UICR integrity is assured through use of multiple levels of protection. UICR protection bits can be configured to allow or block certain operations.

The table below shows the different statuses of UICR protection bits, and which operations are allowed or blocked.

UICR protection bit status			NVMC protection	
SECUREAPPROTECT	APPROTECT	ERASEPROTECT	CTRL-AP ERASEALL	NVMC ERASEALL
0	0	0	Available	Available
1	X	0	Available	Blocked
X	1	0	Available	Blocked
X	X	1	Blocked	Blocked

Table 7: NVMC protection (1 - Enabled, 0 - Disabled, X - Don't care)

Note: Erase can still be performed through CTRL-AP, regardless of the above settings. See CTRL-AP - Control access port on page 503 for more information.

Uploading code with secure debugging blocked

Non-secure code can program non-secure flash regions. In order to perform these operations, the NVMC has the following non-secure registers: CONFIGNS, READY and READYNEXT.

Register CONFIGNS on page 35 works as the CONFIG register but it is used only for non-secure transactions. Both page erase and writing to flash require a write transaction (see Erasing a secure page in flash on page 30 or Erasing a non-secure page in flash on page 30). The SPU — System protection unit on page 323 prevents non-secure code from writing to a secure page since the transaction will never reach the NVMC controller.

4.4.6.2 NVMC power failure protection

NVMC power failure protection is possible using a power-fail comparator which monitors the power supply. If the power-fail comparator is enabled, and the power supply voltage is below V_{POF} threshold, the comparator prevents the NVMC from performing erase or write operations in non-volatile memory (NVM).

If a power failure warning is present at the start of an NVM write or erase operation, the NVMC blocks the operation and a bus error is signaled.

If the power failure warning occurs during an ongoing NVM write operation, the NVMC will try to finish the operation. However, if the power failure warning persists, consecutive NVM write operations are blocked by the NVMC, and a bus error is signaled.

If a power failure warning occurs during an NVM erase operation, the operation is aborted and a bus error is signaled.

4.4.7 Cache

An instruction cache (I-Cache) can be enabled for the ICODE bus in the NVMC.

See Memory map on page 23 for the location of flash.

A cache hit is an instruction fetch from the cache, and it has a 0 wait-state delay. The number of wait-states for a cache miss, where the instruction is not available in the cache and needs to be fetched from flash, depends on the processor frequency, see CPU parameter W_FLASHCACHE.

Enabling the cache can increase the CPU performance and reduce power consumption, by reducing the number of wait cycles and the number of flash accesses. This depends on the cache hit rate. Cache draws current when enabled. If the reduction in average current due to reduced flash accesses is larger than the cache power requirement, the average current to execute the program code is reduced.

When disabled, the cache does not draw current and its content is not retained.

It is possible to enable cache profiling to analyze the performance of the cache for your program using the register ICACHECNF. When profiling is enabled, registers IHIT and IMISS are incremented for every instruction cache hit or miss respectively.

4.4.8 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
NVMC : S	0x50039000	HF	NS	NA	Yes	Non-volatile memory controller
NVMC : NS	0x40039000					

Register overview

Register	Offset	TZ	Description
READY	0x400	NS	Ready flag
READYNEXT	0x408	NS	Ready flag
CONFIG	0x504	S	Configuration register
ERASEALL	0x50C	S	Register for erasing all non-volatile user memory
ERASEPAGEPARTIALCFG	0x51C	S	Register for partial erase configuration
ICACHECNF	0x540	S	I-code cache configuration register
IHIT	0x548	S	I-code cache hit counter
IMISS	0x54C	S	I-code cache miss counter

Register	Offset	TZ	Description
CONFIGNS	0x584	NS	
WRITEUICRNS	0x588	NS	Non-secure APPROTECT enable register

4.4.8.1 READY

Address offset: 0x400

Ready flag

Bit number					31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																				A
Reset 0x00000001					**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	TZ	Field	Value ID	Value																															
A	R		READY																																	
				Busy	0																															
				Ready	1																															

4.4.8.2 READYNEXT

Address offset: 0x408

Ready flag

Bit number					31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																				A
Reset 0x00000001					**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	TZ	Field	Value ID	Value																															
A	R		READYNEXT																																	
				Busy	0																															
				Ready	1																															

4.4.8.3 CONFIG

Address offset: 0x504

Configuration register

Note: This register is one hot

Bit number					31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A	A	A
Reset 0x00000000					**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	TZ	Field	Value ID	Value																															
A	RW		WEN																																	
				Ren	0																															
				Wen	1																															
				Een	2																															
				PEen	4																															

Read only access

Write enabled

Erase enabled

Partial erase enabled

4.4.8.4 ERASEALL

Address offset: 0x50C

Register for erasing all non-volatile user memory

Bit number						31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID						A
Reset 0x00000000						**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	TZ	Field	Value ID	Value	Description
A	W		ERASEALL			Erase all non-volatile memory including UICR registers. Note that erasing must be enabled by setting CONFIG.WEN = Een before the non-volatile memory can be erased.
				NoOperation	0	No operation
				Erase	1	Start chip erase

4.4.8.5 ERASEPAGEPARTIALCFG

Address offset: 0x51C

Register for partial erase configuration

Bit number						31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID						A A A A A A A A
Reset 0x0000000A						**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0**
ID	R/W	TZ	Field	Value ID	Value	Description
A	RW		DURATION			Duration of the partial erase in milliseconds The user must ensure that the total erase time is long enough for a complete erase of the flash page

4.4.8.6 ICACHECNF

Address offset: 0x540

I-code cache configuration register

Bit number						31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID						B A
Reset 0x00000000						**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	TZ	Field	Value ID	Value	Description
A	RW		CACHEEN			Cache enable
				Disabled	0	Disable cache. Invalidates all cache entries.
				Enabled	1	Enable cache
B	RW		CACHEPROFEN			Cache profiling enable
				Disabled	0	Disable cache profiling
				Enabled	1	Enable cache profiling

4.4.8.7 IHIT

Address offset: 0x548

I-code cache hit counter

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	TZ	Field	Value ID	Value	Description
A	RW		HITS			Number of cache hits Write zero to clear

4.4.8.8 IMISS

Address offset: 0x54C

I-code cache miss counter

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	TZ	Field	Value ID	Value	Description
A	RW		MISSES			Number of cache misses Write zero to clear

4.4.8.9 CONFIGNS

Address offset: 0x584

Note: This register is one hot

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	TZ	Field	Value ID	Value	Description
A	RW		WEN			Program memory access mode. It is strongly recommended to only activate erase and write modes when they are actively used. Enabling write or erase will invalidate the cache and keep it invalidated.
				Ren	0	Read only access
				Wen	1	Write enabled
				Een	2	Erase enabled

4.4.8.10 WRITEUICRNS

Address offset: 0x588

Non-secure APPROTECT enable register

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					B B B B B B B B B B B B B B B B B B B B B B B B B B B B A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	TZ	Field	Value ID	Value	Description
A	W		SET			Allow non-secure code to set APPROTECT
				Set	1	Set value
B	W		KEY			Key to write in order to validate the write operation
				Keyvalid	0xAFBE5A7	Key value

4.4.9 Electrical specification

4.4.9.1 Flash programming

Symbol	Description	Min.	Typ.	Max.	Units
n_{WRITE}	Number of times a 32-bit word can be written before erase			2	
$n_{ENDURANCE}$	Erase cycles per page	10,000			
t_{WRITE}	Time to write one 32-bit word			43	µs
$t_{ERASEPAGE}$	Time to erase one page			87	ms
$t_{ERASEALL}$	Time to erase all flash			173	ms
$t_{ERASEPAGEPARTIAL,setup}$	Setup time for one partial erase			1.08	ms

4.4.9.2 Cache size

Symbol	Description	Min.	Typ.	Max.	Units
$Size_{ICODE}$	I-Code cache size		2048		Bytes

4.5 FICR — Factory information configuration registers

Factory information configuration registers (FICR) are pre-programmed in factory and cannot be erased by the user. These registers contain chip-specific information and configuration.

4.5.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
FICR	0x00FF0000	HF	S	NA	No	Factory information configuration

Register overview

Register	Offset	TZ	Description
SIPINFO.PARTNO	0x140		SIP part number
SIPINFO.HWREVISION[n]	0x144		SIP hardware revision, encoded in ASCII, for example B0A or B1A
SIPINFO.VARIANT[n]	0x148		SIP VARIANT, encoded in ASCII, for example LACA. See Ordering information for details.
INFO.DEVICEID[n]	0x204		Device identifier
INFO.RAM	0x218		RAM variant
INFO.FLASH	0x21C		Flash variant
INFO.CODEPAGESIZE	0x220		Code memory page size
INFO.CODESIZE	0x224		Code memory size
INFO.DEVICETYPE	0x228		Device type
TRIMCNF[n].ADDR	0x300		Address
TRIMCNF[n].DATA	0x304		Data
TRNG90B.BYTES	0xC00		Amount of bytes for the required entropy bits
TRNG90B.RCCUTOFF	0xC04		Repetition counter cutoff
TRNG90B.APCUTOFF	0xC08		Adaptive proportion cutoff
TRNG90B.STARTUP	0xC0C		Amount of bytes for the startup tests
TRNG90B.ROSC1	0xC10		Sample count for ring oscillator configuration 1

Register	Offset	TZ	Description
TRNG90B.ROSC2	0xC14		Sample count for ring oscillator configuration 2
TRNG90B.ROSC3	0xC18		Sample count for ring oscillator configuration 3
TRNG90B.ROSC4	0xC1C		Sample count for ring oscillator configuration 4

4.5.1.1 SIPINFO

SIP-specific device information is provided in the following chapters.

4.5.1.1.1 SIPINFO.PARTNO

Address offset: 0x140

SIP part number

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	PARTNO			
			9161	0x00009161	Device is an nRF9161 sip
			9160	0x00009160	Device is an nRF9160 sip
			9151	0x00009151	Device is an nRF9151 sip
			9131	0x00009131	Device is an nRF9131 sip

4.5.1.1.2 SIPINFO.HWREVISION[n] (n=0..3)

Address offset: 0x144 + (n × 0x1)

SIP hardware revision, encoded in ASCII, for example B0A or B1A

Note: When treated as a c-string, content is not NULL-terminated.

Bit number	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A
Reset 0xFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	HWREVISION			

4.5.1.1.3 SIPINFO.VARIANT[n] (n=0..3)

Address offset: 0x148 + (n × 0x1)

SIP VARIANT, encoded in ASCII, for example LACA. See Ordering information for details.

Note: When treated as a c-string, content is not NULL-terminated.

Bit number						7	6	5	4	3	2	1	0
ID						A	A	A	A	A	A	A	A
Reset 0xFF						**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value	Description								
A	R	VARIANT			VARIANT[0] contains the most significant character of the SIP VARIANT. VARIANT[3] contains the least significant character of the SIP VARIANT.								
			A	0x41									
			B	0x42									
			C	0x43									
			I	0x49									
			L	0x4C									
			S	0x53									

4.5.1.2 INFO

Device info

4.5.1.2.1 INFO.DEVICEID[n] (n=0..1)

Address offset: 0x204 + (n × 0x4)

Device identifier

Bit number						31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID						A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF						**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value	Description																																
A	R	DEVICEID			64 bit unique device identifier DEVICEID[0] contains the least significant bits of the device identifier. DEVICEID[1] contains the most significant bits of the device identifier.																																		

4.5.1.2.2 INFO.RAM

Address offset: 0x218

RAM variant

Bit number						31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID						A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000100						**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value	Description																																
A	R	RAM			RAM variant																																
			K256	0x100	256 kByte RAM																																
			Unspecified	0xFFFFFFFF	Unspecified																																

4.5.1.2.3 INFO.FLASH

Address offset: 0x21C

Flash variant

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000400				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	FLASH			Flash variant
			K1024	0x400	1 MByte FLASH

4.5.1.2.4 INFO.CODEPAGESIZE

Address offset: 0x220

Code memory page size

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00001000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	CODEPAGESIZE			Code memory page size
			K4096	0x1000	4 kByte

4.5.1.2.5 INFO.CODESIZE

Address offset: 0x224

Code memory size

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000100				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	CODESIZE			Code memory size in number of pages
					Total code space is: CODEPAGESIZE * CODESIZE
			P256	256	256 pages

4.5.1.2.6 INFO.DEVICETYPE

Address offset: 0x228

Device type

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	R	DEVICETYPE			Device type
			Die	0x0000000	Device is an physical DIE
			FPGA	0xFFFFFFFF	Device is an FPGA

4.5.1.3 TRIMCNF[n].ADDR (n=0..255)

Address offset: 0x300 + (n × 0x8)

Address

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	Address			Address

4.5.1.4 TRIMCNF[n].DATA (n=0..255)

Address offset: 0x304 + (n × 0x8)

Data

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	Data			Data

4.5.1.5 TRNG90B

NIST800-90B RNG calibration data

4.5.1.5.1 TRNG90B.BYTES

Address offset: 0xC00

Amount of bytes for the required entropy bits

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	BYTES			Amount of bytes for the required entropy bits

4.5.1.5.2 TRNG90B.RCCUTOFF

Address offset: 0xC04

Repetition counter cutoff

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	RCCUTOFF			Repetition counter cutoff

4.5.1.5.3 TRNG90B.APCUTOFF

Address offset: 0xC08

Adaptive proportion cutoff

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	APCUTOFF			Adaptive proportion cutoff

4.5.1.5.4 TRNG90B.STARTUP

Address offset: 0xC0C

Amount of bytes for the startup tests

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	STARTUP			Amount of bytes for the startup tests

4.5.1.5.5 TRNG90B.ROSC1

Address offset: 0xC10

Sample count for ring oscillator configuration 1

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	ROSC1			Sample count for ring oscillator configuration 1

4.5.1.5.6 TRNG90B.ROSC2

Address offset: 0xC14

Sample count for ring oscillator configuration 2

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	ROSC2			Sample count for ring oscillator configuration 2

4.5.1.5.7 TRNG90B.ROSC3

Address offset: 0xC18

Sample count for ring oscillator configuration 3

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	R	ROSC3			Sample count for ring oscillator configuration 3

4.5.1.5.8 TRNG90B.ROSC4

Address offset: 0xC1C

Sample count for ring oscillator configuration 4

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value																															
A	R	ROSC4																																	
				Sample count for ring oscillator configuration 4																															

4.6 UICR — User information configuration registers

The user information configuration registers (UICRs) are non-volatile memory (NVM) registers for configuring user specific settings.

For information on writing UICR registers, see the NVMC — Non-volatile memory controller on page 29 and Memory on page 21 chapters.

4.6.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
UICR	0x00FF8000	HF	S	NA	No	User information configuration

Register overview

Register	Offset	TZ	Description
APPROTECT	0x000		Access port protection
XOSC32M	0x014		Oscillator control
HFXOSRC	0x01C		HFXO clock source selection
HFXOCNT	0x020		HFXO startup counter
APPNVMCPOFGUARD	0x024		Enable blocking NVM WRITE and aborting NVM ERASE for Application NVM in POFWARN condition.
SECUREAPPROTECT	0x02C		Secure access port protection
ERASEPROTECT	0x030		Erase protection
OTP[n]	0x108		One time programmable memory
KEYSLOT.CONFIG[n].DEST	0x400		Destination address where content of the key value registers (KEYSLOT.KEYn.VALUE[0-3]) will be pushed by KMU. Note that this address must match that of a peripheral's APB mapped write-only key registers, otherwise the KMU can push this key value into an address range which the CPU can potentially read.
KEYSLOT.CONFIG[n].PERM	0x404		Define permissions for the key slot. Bits 0-15 and 16-31 can only be written when equal to 0xFFFF.
KEYSLOT.KEY[n].VALUE[o]	0x800		Define bits [31+o*32:0+o*32] of value assigned to KMU key slot.

4.6.1.1 APPROTECT

Address offset: 0x000

Access port protection

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	PALL																																	
			HwUnprotected	0x50FA50FA																															
			Protected	0x00000000																															

				Description
				Blocks debugger read/write access to all CPU registers and memory mapped addresses
				Any value different to HwUnprotected will make access port protected.
			HwUnprotected	HwUnprotected
			Protected	Protected

4.6.1.2 XOSC32M

Address offset: 0x014

Oscillator control

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																														A	A	A	A	A	A
Reset 0xFFFFFFCF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	CTRL																																	

				Description
				Pierce current DAC control signals

4.6.1.3 HFXOSRC

Address offset: 0x01C

HFXO clock source selection

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0xFFFFFFFF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	HFXOSRC																																	
			XTAL	1																															
			TCXO	0																															

				Description
				HFXO clock source selection
			XTAL	32 MHz crystal oscillator
			TCXO	32 MHz temperature compensated crystal oscillator (TCXO)

4.6.1.4 HFXOCNT

Address offset: 0x020

HFXO startup counter

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																												A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	HFXOCNT																																	
			MinDebounceTime	0																															
			MaxDebounceTime	255																															

				Description
				HFXO startup counter. Total debounce time = HFXOCNT*64 us + 0.5 us
			MinDebounceTime	Min debounce time = (0*64 us + 0.5 us)
			MaxDebounceTime	Max debounce time = (255*64 us + 0.5 us)

4.6.1.5 APPNVMCPOFGUARD

Address offset: 0x024

Enable blocking NVM WRITE and aborting NVM ERASE for Application NVM in POFWARN condition.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**

ID	R/W	Field	Value ID	Value	Description
A	RW	NVMCPOFGUARDEN			Enable blocking NVM WRITE and aborting NVM ERASE in POFWARN condition
			Disabled	0	NVM WRITE and NVM ERASE are not blocked in POFWARN condition
			Enabled	1	NVM WRITE and NVM ERASE are blocked in POFWARN condition

4.6.1.6 SECUREAPPROTECT

Address offset: 0x02C

Secure access port protection

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**

ID	R/W	Field	Value ID	Value	Description
A	RW	PALL			Blocks debugger read/write access to all secure CPU registers and secure memory mapped addresses
					Any value different to HwUnprotected will make access port protected.
			HwUnprotected	0x50FA50FA	HwUnprotected
			Protected	0x00000000	Protected

4.6.1.7 ERASEPROTECT

Address offset: 0x030

Erase protection

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**

ID	R/W	Field	Value ID	Value	Description
A	RW	PALL			Blocks NVMC ERASEALL and CTRLAP ERASEALL functionality
			Unprotected	0xFFFFFFFF	Unprotected
			Protected	0x00000000	Protected

4.6.1.8 OTP[n] (n=0..189)

Address offset: 0x108 + (n × 0x4)

One time programmable memory

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	RW1	LOWER			Lower half word
					Note: Can only be written to a non 0xFFFF value once.
B	RW1	UPPER			Upper half word
					Note: Can only be written to a non 0xFFFF value once.

4.6.1.9 KEYSLOT.CONFIG[n].DEST (n=0..127)

Address offset: 0x400 + (n × 0x8)

Destination address where content of the key value registers (KEYSLOT.KEYn.VALUE[0-3]) will be pushed by KMU. Note that this address must match that of a peripheral's APB mapped write-only key registers, otherwise the KMU can push this key value into an address range which the CPU can potentially read.

Note: Writing/reading this register requires the KMU SELECTKEYSLOT register to be set to n+1.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	RW	DEST			Secure APB destination address

4.6.1.10 KEYSLOT.CONFIG[n].PERM (n=0..127)

Address offset: 0x404 + (n × 0x8)

Define permissions for the key slot. Bits 0-15 and 16-31 can only be written when equal to 0xFFFF.

Note: Writing/reading this register requires the KMU SELECTKEYSLOT register to be set to n+1.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																D														C	B	A
Reset 0xFFFFFFFF	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	RW	WRITE			Write permission for key slot
			Disabled	0	Disable write to the key value registers
			Enabled	1	Enable write to the key value registers
B	RW	READ			Read permission for key slot
			Disabled	0	Disable read from key value registers
			Enabled	1	Enable read from key value registers
C	RW	PUSH			Push permission for key slot
			Disabled	0	Disable pushing of key value registers over secure APB, but can be read if field READ is Enabled
			Enabled	1	Enable pushing of key value registers over secure APB. Register KEYSLOT.CONFIGn.DEST must contain a valid destination address!

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
D	RW	STATE			Revocation state for the key slot Note that it is not possible to undo a key revocation by writing the value '1' to this field
			Revoked	0	Key value registers can no longer be read or pushed
			Active	1	Key value registers are readable (if enabled) and can be pushed (if enabled)

4.6.1.11 KEYSLOT.KEY[n].VALUE[o] (n=0..127) (o=0..3)

Address offset: 0x800 + (n × 0x10) + (o × 0x4)

Define bits [31+o*32:0+o*32] of value assigned to KMU key slot.

Note: Writing/reading this register requires the KMU SELECTKEYSLOT register to be set to n+1.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			Define bits [31+o*32:0+o*32] of value assigned to KMU key slot

4.7 EasyDMA

EasyDMA is a module implemented by some peripherals to gain direct access to Data RAM.

EasyDMA is an AHB bus master similar to CPU and is connected to the AHB multilayer interconnect for direct access to Data RAM. EasyDMA is not able to access flash.

A peripheral can implement multiple EasyDMA instances to provide dedicated channels. For example, for reading and writing of data between the peripheral and RAM. This concept is illustrated in EasyDMA example on page 46.

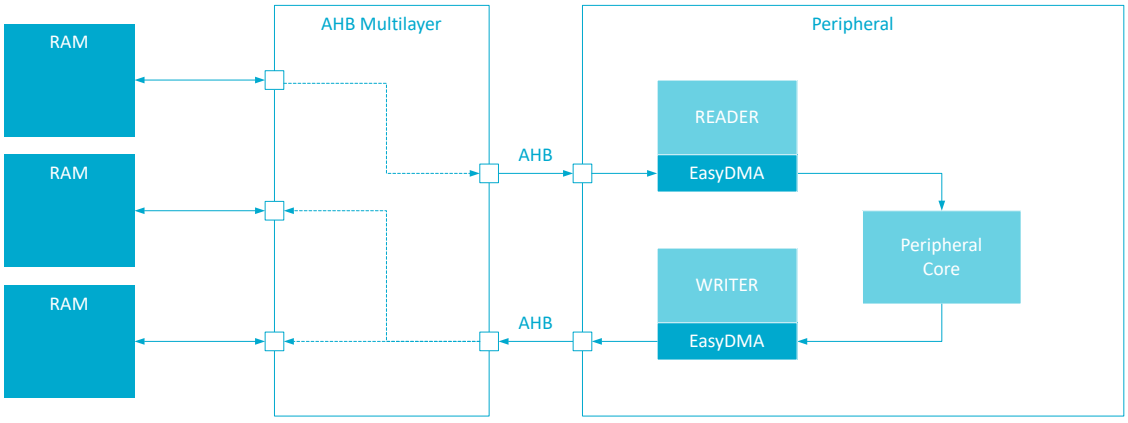

Figure 5: EasyDMA example

An EasyDMA channel is implemented in the following way, but some variations may occur:

```
READERBUFFER_SIZE 5
WRITERBUFFER_SIZE 6

uint8_t readerBuffer[READERBUFFER_SIZE]  __at__ 0x20000000;
uint8_t writerBuffer[WRITERBUFFER_SIZE]  __at__ 0x20000005;

// Configuring the READER channel
MYPERIPHERAL->READER.MAXCNT = READERBUFFER_SIZE;
MYPERIPHERAL->READER.PTR = &readerBuffer;

// Configure the WRITER channel
MYPERIPHERAL->WRITER.MAXCNT = WRITEERBUFFER_SIZE;
MYPERIPHERAL->WRITER.PTR = &writerBuffer;
```

This example shows a peripheral called MYPERIPHERAL that implements two EasyDMA channels - one for reading called READER, and one for writing called WRITER. When the peripheral is started, it is assumed that the peripheral will perform the following tasks:

- Read 5 bytes from the readerBuffer located in RAM at address 0x20000000
- Process the data
- Write no more than 6 bytes back to the writerBuffer located in RAM at address 0x20000005

The memory layout of these buffers is illustrated in EasyDMA memory layout on page 47.

0x20000000	readerBuffer[0]	readerBuffer[1]	readerBuffer[2]	readerBuffer[3]
0x20000004	readerBuffer[4]	writerBuffer[0]	writerBuffer[1]	writerBuffer[2]
0x20000008	writerBuffer[3]	writerBuffer[4]	writerBuffer[5]	

Figure 6: EasyDMA memory layout

The WRITER.MAXCNT register should not be specified larger than the actual size of the buffer (writerBuffer). Otherwise, the channel would overflow the writerBuffer.

Once an EasyDMA transfer is completed, the AMOUNT register can be read by the CPU to see how many bytes were transferred. For example, CPU can read MYPERIPHERAL->WRITER.AMOUNT register to see how many bytes WRITER wrote to RAM.

Note: The PTR register of a READER or WRITER must point to a valid memory region before use. The reset value of a PTR register is not guaranteed to point to valid memory. See Memory on page 21 for more information about the different memory regions and EasyDMA connectivity.

4.7.1 EasyDMA error handling

Some errors may occur during DMA handling.

If READER.PTR or WRITER.PTR is not pointing to a valid memory region, an EasyDMA transfer may result in a HardFault or RAM corruption. See Memory on page 21 for more information about the different memory regions.

If several AHB bus masters try to access the same AHB slave at the same time, AHB bus congestion might occur. An EasyDMA channel is an AHB master. Depending on the peripheral, the peripheral might either stall and wait for access to be granted, or lose data.

4.7.2 EasyDMA array list

EasyDMA can operate in Array List mode.

The Array List mode is implemented in channels where the LIST register is available.

The array list does not provide a mechanism to explicitly specify where the next item in the list is located. Instead, it assumes that the list is organized as a linear array where items are located one after the other in RAM.

The EasyDMA Array List can be implemented by using the data structure ArrayList_type as illustrated in the code example below using a READER EasyDMA channel as an example:

```
#define BUFFER_SIZE  4

typedef struct ArrayList
{
  uint8_t buffer[BUFFER_SIZE];
} ArrayList_type;

ArrayList_type ReaderList[3]  __at__ 0x20000000;

MYPERIPHERAL->READER.MAXCNT = BUFFER_SIZE;
MYPERIPHERAL->READER.PTR = &ReaderList;
MYPERIPHERAL->READER.LIST = MYPERIPHERAL_READER_LIST_ArrayList;
```

The data structure only includes a buffer of size equal to the size of READER.MAXCNT register. EasyDMA uses the READER.MAXCNT register to determine when the buffer is full.

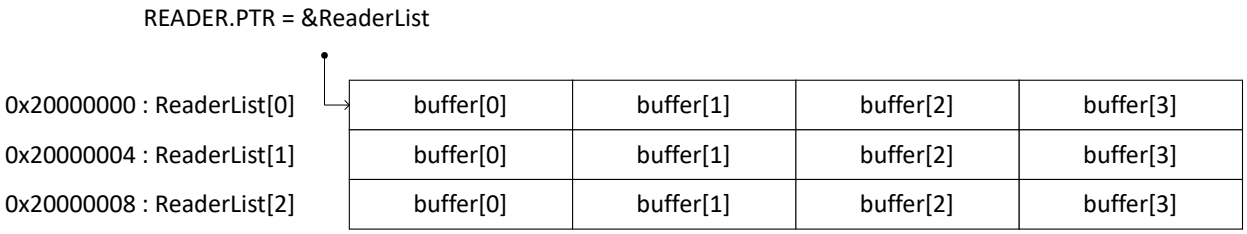

Figure 7: EasyDMA array list

4.8 AHB multilayer interconnect

On the AHB multilayer interconnect, the application CPU and all EasyDMA instances are AHB bus masters while RAM, cache, and peripherals are AHB slaves. External MCU subsystems can be seen both as master and slave on the AHB multilayer interconnect.

Multiple AHB masters can access slave resources within the AHB multilayer interconnect as illustrated in Memory on page 21. Access rights to each of the AHB slaves are resolved using the default natural priority of the different bus masters in the system.

4.8.1 AHB multilayer priorities

Each master connected to the AHB multilayer is assigned a default natural priority.

Bus master name	Natural relative priority	In/Out
System (CPU)	Highest priority	I/O
LTE Modem		I/O
I2S		I/O
PDM		I
SPIM0/SPIS0/TWIM0/TWIS0/UARTE0		I/O
SPIM1/SPIS1/TWIM1/TWIS1/UARTE1		I/O
SPIM2/SPIS2/TWIM2/TWIS2/UARTE2		I/O
SPIM3/SPIS3/TWIM3/TWIS3/UARTE3		I/O
SAADC		I
PWM0		O
PWM1		O
PWM2		O
PWM3		O
CC310	Lowest priority	I/O

Table 8: AHB bus masters (listed from highest to lowest priority)

5 Power and clock management

The power and clock management system automatically ensures maximum power efficiency.

The nRF9151 has three power modes - System Disabled, System ON and System OFF. The System ON and System OFF are internal (automatically handled by the device) and the System Disabled is external (driven by the ENABLE pin and overriding internal ones).

The core of the automatic power and clock management is the power management unit (PMU) illustrated in the following image.

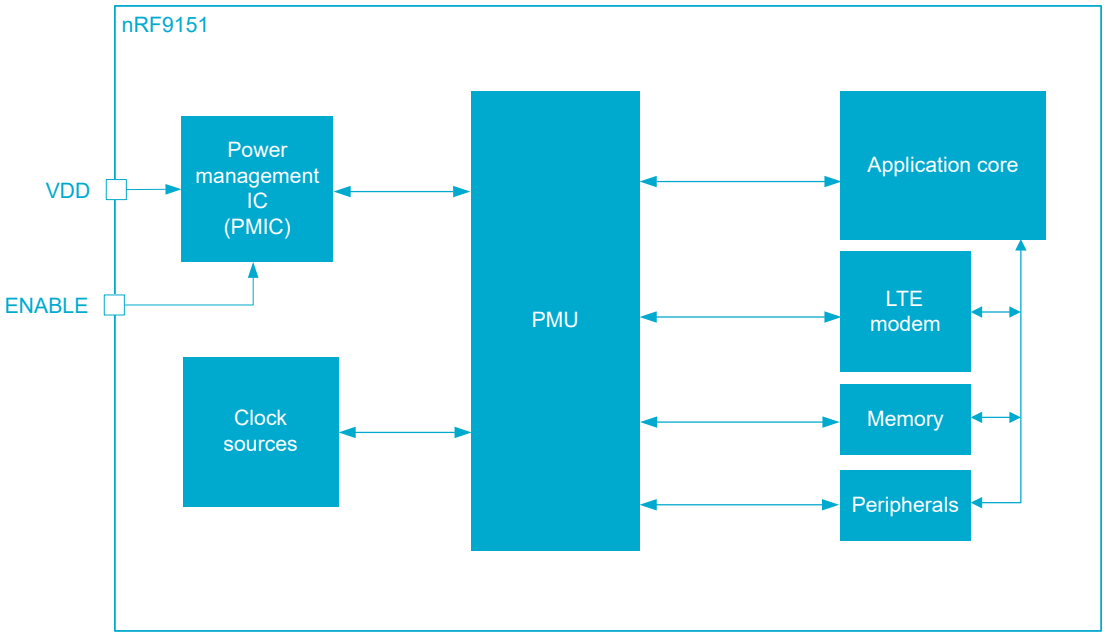

Figure 8: Power management unit

When the device is powered and enabled, the PMU automatically tracks the power and clock resources required by the different components in the system. It then starts/stops and chooses operation modes in supply regulators and clock sources, without user interaction, to achieve the lowest power consumption possible.

5.1 Power management

The two internal modes are handled by the power management unit (PMU), whereas the external is handled by the user via the ENABLE pin.

The System Disabled mode provides a way to override the PMU by manipulating voltages presented to the ENABLE pin.

The PMU steers system-wide clock and power in order to provide the power modes - System ON and System OFF. Under the various modes, internal blocks are automatically powered by the PMU as required by the application.

5.1.1 System Disabled mode

The entire device can be powered down by presenting the appropriate voltage to the externally available ENABLE pin.

The nRF9151 provides a feature to be able disable power throughout the entire device externally. This can be useful when the device is operating as slave processor where it does not need to be powered on at all times, then it is possible to avoid unnecesary current leaking by driving the ENABLE pin to low. The nRF9151 will not start if is not enabled. Moreover, a change from disable to enable, will result in a power-on-reset behavior inside the device.

Note: VDD_GPIO input must be driven low when device is disabled, failing to do so could result in increased leakage. For more information, see VDD_GPIO considerations in Operating conditions on page 523.

Note: If System Disabled mode is not used, ENABLE must be connected to VDD.

Pin Value	Power status	description
Low	Disabled	Device's internal power regulator disabled
High	Enabled	Device's internal power regulator enabled

Table 9: ENABLE pin configuration

5.1.2 System OFF mode

System OFF is the deepest internal power saving mode the system can enter.

In this mode, the core system functionality is powered down and ongoing tasks terminated, and only the reset and the wakeup functions are available and responsive.

The device is put into System OFF mode using the REGULATORS register interface. When in System OFF mode, one of the following signals/actions will wake up the device:

1. DETECT signal, generated by the GPIO peripheral
2. RESET
3. Debug session start

When the device wakes up from System OFF mode, a system reset is performed.

One or more RAM blocks can be retained in System OFF mode depending on the settings in the RAM[n].POWER registers in VMC. RAM[n].POWER are retained registers, see Reset behavior on page 60. Note that these registers are usually overwritten by the startup code provided with the nRF application examples.

Before entering System OFF mode, the user must make sure that all on-going EasyDMA transactions have completed. This can be done by making sure that EasyDMA enabled peripherals have stopped and END events from them received. The LTE modem must also be stopped, by issuing a command through the modem API, before entering System OFF mode. Once the command is issued, wait for the modem to respond that it actually has stopped, as there may be a delay until the modem is disconnected from the network.

5.1.2.1 Emulated System OFF mode

If the device is in debug interface mode, System OFF will be emulated to ensure that all resources required for debugging are available during System OFF.

See Debug and trace on page 434 chapter for more information. Resources required for debugging include the following key components: Debug and trace on page 434, CLOCK — Clock control on page 74, POWER — Power control on page 68, NVMC — Non-volatile memory controller on page 29, CPU on page 20, flash, and RAM. To prevent the CPU from executing unwanted code, an infinite loop must be added directly after entering System OFF mode.

5.1.3 System ON mode

System ON is the power mode entered after a power-on reset.

While in System ON, the system can reside in one of two sub modes:

- Low power
- Constant latency

The low power mode is default after power-on reset.

In low power mode, whenever no application or wireless activity takes place, function blocks like the application CPU, LTE modem and all peripherals are in IDLE state. That particular state is referred to as System ON IDLE. In this state, all function blocks retain their state and configuration, so they are ready to become active once configured by the CPU.

If any application or modem activity occurs, the system leaves the System ON IDLE state. Once a given activity in a function block is completed, the system automatically returns to IDLE, retaining its configuration.

As long as the system resides in low power mode, the PMU ensures that the appropriate regulators and clock sources are started or stopped based on the needs of the function blocks active at any given time.

This automatic power management can be overridden by switching to constant latency mode. In this mode, the CPU wakeup latency and the PPI task response are constant and kept at a minimum. This is secured by keeping a set of base resources that are always enabled. The advantage of having a constant and predictable latency will be at the cost of having significantly increased power consumption compared to the low power mode. The constant latency mode is enabled by triggering the CONSTLAT task (TASKS_CONSTLAT on page 69).

While the system is in constant latency mode, the low power mode can be enabled by triggering LOWPWR task (TASKS_LOWPWR on page 69).

To reduce power consumption while in System ON IDLE, RAM blocks can be turned off in System ON mode while enabling the retention of these RAM blocks in RAM[n].POWER registers in VMC. RAM[n].POWER are retained registers, see Reset behavior on page 60. Note that these registers are usually overwritten by the startup code provided with the nRF application examples.

5.1.4 Electrical specification

5.1.4.1 ENABLE pin

Symbol	Description	Min.	Typ.	Max.	Units
$V_{SYSTEM\_DISABLED\_ON}$	Operational voltage to enforce System-Disabled power mode.	0.8*VDD			V
$V_{SYSTEM\_DISABLED\_OFF}$	Operational voltage to cancel System-Disabled power mode.			0.4	V
$t_{HOLDENABLE}$	ENABLE pin hold time	TBA			ms

5.2 Power supply

The nRF9151 has a single main power supply VDD, and the internal components are powered by integrated voltage regulators. The PMU manages these regulators automatically, no voltage regulator control needs to be included in application firmware.

5.2.1 General purpose I/O supply

The input/output (I/O) drivers of P0.00 - P0.31 pins are supplied independently of VDD through VDD_GPIO. This enables easy match to signal voltage levels in the printed circuit board design.

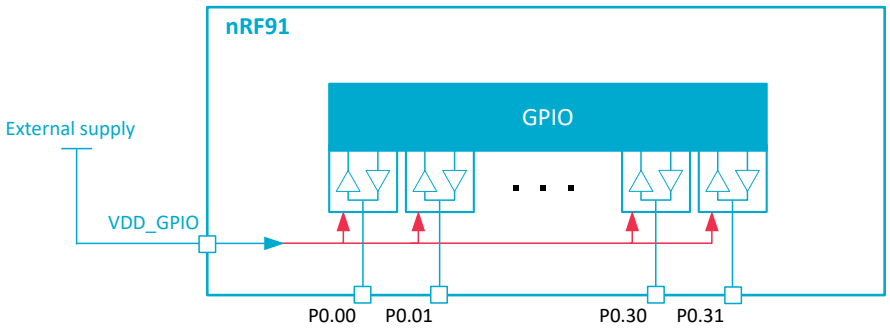

Figure 9: GPIO supply input (VDD_GPIO)

The I/Os are supplied via VDD_GPIO pin as shown in figure above. VDD_GPIO pin supports voltage levels within range given in table Operating conditions on page 523. See VDD_GPIO considerations on page 523 for more information on how to control VDD_GPIO power supply.

5.3 Power supply monitoring

Power monitor solutions are available in the device, in order to survey the VDD (battery voltage).

5.3.1 Power supply supervisor

The power supply supervisor enables monitoring of the connected power supply.

Two functionalities are implemented:

- Power-on reset (POR): Generates a reset when the supply is applied to the device, and ensures that the device starts up in a known state
- Brownout reset (BOR): Generates a reset when the supply drops below the minimum voltage required for safe operations

Two BOR levels are used:

- V_{BOROFF}, used in System OFF
- V_{BORON}, used in System ON

The power supply supervisor is illustrated in the image below.

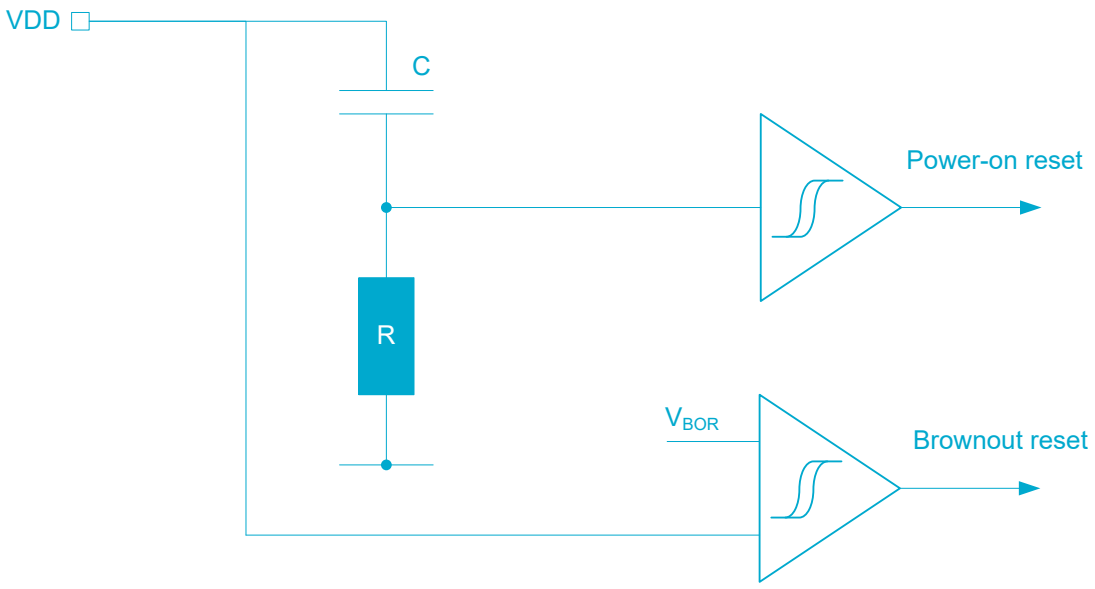

Figure 10: Power supply supervisor

5.3.2 External power failure warning

The external power failure (EXTPOF) warning can provide the CPU an early warning of an imminent power failure. It does not reset the system, but gives the CPU time to prepare for an orderly power-down. EXTPOF detects power failures external to PMU from the device internal PMIC.

> **Note:** All nRF9151 modem firmware versions support this feature.

The user can start and stop the PMIC EXTPOF feature and set the battery voltage low threshold level through the modem API.

For application core to receive the power failure warning events, EXTPOFCON on page 83 register in REGULATORS — Voltage regulators control on page 82 must be enabled. If this is disabled, the state of the PMIC warning input is ignored and the power failure warning events are not delivered to application core.

The available time for the CPU to prepare for a power-down depends on the set warning threshold level, the load of the running tasks, and the type of power source used.

> **Note:** For details on services provided by the modem AT command interface, see nRF Connect SDK AT interface and nRF91 AT Commands.

The EXTPOF functional overview is shown in the following figure.

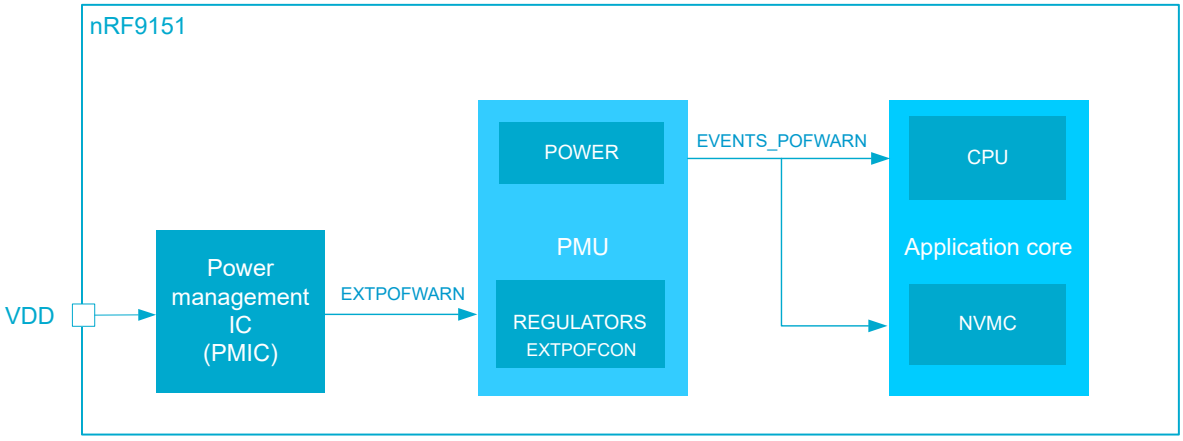

Figure 11: External power failure warning arrangement

If EXTPOF is enabled and the device's internal PMIC detects that battery voltage has dropped below the low threshold level, an POFWARN event is generated (see EVENTS_POFWARN on page 70). The POFWARN event to the CPU can be cleared in the event register, however the PMIC input continues to indicate a warning as long as the battery voltage remains below the low threshold level.

POFWARN event also sets the LTE modem in offline mode.

Note: If a power failure warning occurs during an ongoing NVM write operation, the NVMC tries to finish the operation. Consecutive NVM write operations will be blocked by the NVMC as long as the PMIC input indicates a warning. The CPU interprets a blocked NVM write as a fault, which needs to be handled by the application. If a power failure warning occurs during an ongoing NVM erase operation, the operation will be aborted. Blocking NVM writes and aborting NVM erase operations can be disabled in APPNVMCPOFGUARD on page 44.

The external power failure warning doesn't trigger wakeup from System OFF.

The external power failure warning is disabled in System OFF mode.

5.3.3 Battery monitoring on VDD

A battery voltage (VDD) monitoring capability is provided via a modem API.

Note: For details on services provided by the modem AT command interface, see nRF Connect SDK AT interface and nRF91 AT Commands.

5.3.4 Electrical specification

5.3.4.1 Device startup times

Symbol	Description	Min.	Typ.	Max.	Units
t_{POR}	Time in power-on reset after VDD has reached 3V, ENABLE is tied to VDD.		1.2		ms
t_{PINR}	The maximum time taken to pull up the nRESET pin and release reset after power-on reset. Dependent on the pin capacitive load (C)[2]: t=TRC; Typical: T=2 R=13 kΩ; Max: T=5 R=16 kΩ.	..	..	..	
$t_{PINR,500nF}$	C=500 nF		13	40	ms
$t_{PINR,10uF}$	C=10 µF		260	800	ms
t_{R2ON}	Time from reset to ON (CPU execute)		127	135	µs

[2] To decrease the maximum time a device can be held in reset, a strong external pull-up resistor can be used.

Symbol	Description	Min.	Typ.	Max.	Units
t_{OFF2ON}	Time from OFF to CPU execute		73	92	µs
$t_{WFE2CPU}$	Time from WFE to CPU execute		70	90	µs
$t_{WFI2CPU}$	Time from WFI to CPU execute		69	90	µs
$t_{EVTSET,CL1}$	Time from HW event to PPI event in constant latency System ON mode		0.1	0.1	µs
$t_{EVTSET,CL0}$	Time from HW event to PPI event in low power System ON mode		0.1	0.7	µs
$t_{LTEMODEM,TYP}$	LTE modem typical startup time. Time from application core powering up the modem until the modem is ready to receive the first AT command.			200	ms
$t_{LTEMODEM,WORSTCASE}$	LTE modem worst case startup time. Time from application core powering up the modem until the modem is ready to receive the first AT command, with modem firmware variable elements included.			250	ms
$t_{LTEMODEM,FOTA}$	LTE modem startup time after modem FOTA update. Time from application core powering up the modem after a modem FOTA update until the modem is ready to receive the first AT command.			7.5	s
$t_{LTEMODEM,FOTAREJECT}$	LTE modem startup time after a rejected modem FOTA update. Time from application core powering up the modem after a rejected modem FOTA update until the modem is ready to receive the first AT command. Modem will revert back to original firmware image.			90	s
$t_{LTEMODEM,STOP,TYP}$	LTE modem typical shutdown time. Time from application core calling bsd_shutdown command until bsd_shutdown returns.			1.6	s
$t_{LTEMODEM,STOP,WORSTCASE}$	LTE modem worst case shutdown time. Time from application core calling bsd_shutdown command until bsd_shutdown returns, including modem firmware variable elements.			79	s

5.3.4.2 Power supply supervisor

Symbol	Description	Min.	Typ.	Max.	Units
V_{BOR}	Brownout reset voltage threshold.		2.80		V
V_{POR}	Voltage threshold at which the device enters power-on reset (POR) when VDD is ramping up.			3.0	V

5.4 Clock management

The clock control system can source the system clocks from a range of high and low frequency oscillators, and distribute them to modules based upon a module's individual requirements.

Clock generation and distribution is handled automatically by PMU to optimize current consumption. This optimization will affect the predictability of the oscillators' startup times under different device operating conditions. However, it is possible to bypass some of the power saving mechanisms by explicitly keeping the system on constant latency sub mode (more about constant latency in System ON mode on page 52) and/or manipulating START/STOP clock task registers.

The following are the available clock signal sources:

- 64 MHz oscillator (HFINT)
- 64 MHz high accuracy oscillator (HFXO)
- 32.768 kHz RC oscillator (LFRC)
- 32.768 kHz high accuracy oscillator (LFXO)

The clock and oscillator resources are configured and controlled via the CLOCK peripheral as illustrated below.

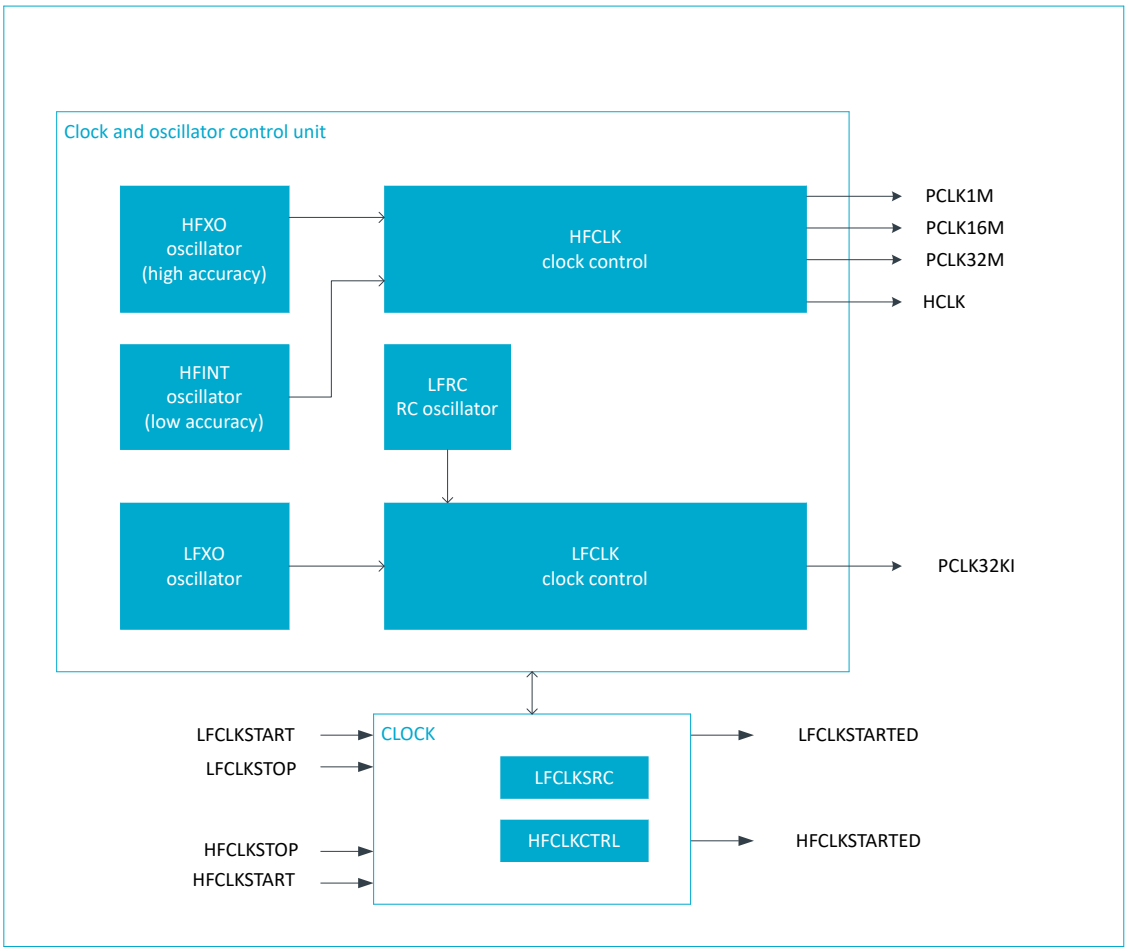

Figure 12: Clock and oscillator setup

5.4.1 HFCLK clock controller

The HFCLK clock controller provides several clocks in the system.

These are as follows:

- HCLK: 64 MHz CPU clock
- PCLK1M: 1 MHz peripheral clock
- PCLK16M: 16 MHz peripheral clock
- PCLK32M: 32 MHz peripheral clock

The HFCLK controller uses the following high frequency clock (HFCLK) sources:

- 64 MHz oscillator (HFINT)
- 64 MHz high accuracy oscillator (HFXO)

For illustration, see Clock and oscillator setup on page 57.

The HFCLK controller automatically provides the clock(s) requested by the system. If the system does not request any clocks from the HFCLK controller, the controller switches off all its clock sources and enters a power saving mode.

The HFINT source is used when HFCLK is requested and HFXO has not been started.

The HFXO is started by triggering the HFCLKSTART task and stopped using the HFCLKSTOP task. A HFCLKSTARTED event is generated when the HFXO has started and its frequency is stable.

5.4.2 LFCLK clock controller

The system supports several low frequency clock sources.

As illustrated in Clock and oscillator setup on page 57, the system supports the following low frequency clock sources:

- LFXO: 32.768 kHz high accuracy oscillator
- LFRC: 32.768 kHz RC oscillator

The LFCLK clock controller and all LFCLK clock sources are always switched off when in System OFF mode.

The LFCLK clock is started by first selecting the preferred clock source in the LFCLKSRC on page 82 register and then triggering the LFCLKSTART task. LFXO is highly recommended as the LFCLK clock source, since the LFRC has a large frequency variation.

Note: The LTE modem requires use of LFXO as the LFCLK source.

Switching between LFCLK clock sources can be done without stopping the LFCLK clock. A LFCLK clock source which is running prior to triggering the LFCLKSTART task continues to run until the selected clock source is available. After that the clock sources will be switched. Switching between clock sources will stretch a clock pulse by 0.5 to 1.0 clock cycle (i.e. will delay rising edge by 0.5 to 1.0 clock cycle).

Note: If the watchdog timer (WDT) is running, the default LFCLK clock source (LFRC - see LFCLKSRC on page 82) is started automatically (LFCLKSTART task doesn't have to be triggered).

A LFCLKSTARTED event will be generated when the selected LFCLK clock source has started.

Note: The first time LFXO is selected, LFRC quality is provided until LFXO is stable.

A LFCLKSTOP task will prevent global requesting of the LFCLK clock, unless a system component such as WDT or modem requires the LFCLK, in which case the clock is not stopped. The LFCLKSTOP task should only be triggered after the STATE field in the LFCLKSTAT register indicates a LFCLK running state.

5.4.2.1 32.768 kHz RC oscillator (LFRC)

The default source of the low frequency clock (LFCLK) is the 32.768 kHz RC oscillator (LFRC).

The LFRC frequency is affected by variation in temperature.

5.4.3 Electrical specification

5.4.3.1 64 MHz internal oscillator (HFINT)

Symbol	Description	Min.	Typ.	Max.	Units
f_{NOM_HFINT}	Nominal output frequency		64		MHz
f_{TOL_HFINT}	Frequency tolerance		±1	±5	%
t_{START_HFINT}	Startup time		3.2		µs

5.4.3.2 64 MHz high accuracy oscillator (HFXO)

Symbol	Description	Min.	Typ.	Max.	Units
f_{NOM_HFXO}	Nominal output frequency		64		MHz
f_{TOL_HFXO}	Frequency tolerance		±1		ppm
t_{START_HFXO}	Startup time		2		ms

5.4.3.3 32.768 kHz high accuracy oscillator (LFXO)

Symbol	Description	Min.	Typ.	Max.	Units
f_{NOM_LFXO}	Frequency		32.768		kHz
f_{TOL_LFXO}	Frequency tolerance		±20		ppm
t_{START_LFXO}	Startup time		450		ms

5.4.3.4 32.768 kHz RC oscillator (LFRC)

Symbol	Description	Min.	Typ.	Max.	Units
f_{NOM_LFRC}	Nominal frequency		32.768		kHz
f_{TOL_LFRC}	Frequency tolerance		30		%
t_{START_LFRC}	Startup time		600		µs

5.5 Reset

A system reset can be triggered by multiple sources. After a reset the CPU can query the RESETREAS (reset reason register) to find out which source generated the reset.

5.5.1 Power-on reset

The power-on reset generator initializes the system at power-on. The system is held in reset state until the supply has reached the minimum operating voltage and the internal voltage regulators have started.

5.5.2 Pin reset

A pin reset is generated when the physical reset pin (nRESET) on the device is pulled low.

To ensure that reset is issued correctly, the reset pin should be held low for the time specified in Pin reset on page 61.

nRESET pin has an always-on internal pull-up resistor connected to nRF9151 internal voltage typically of 2.2 V level, as illustrated in the following figure. The value of the pull-up resistor is given in Pin reset on page 61.

Note: Driving nRESET high with a voltage lower than 2.2V will result in additional leakage.

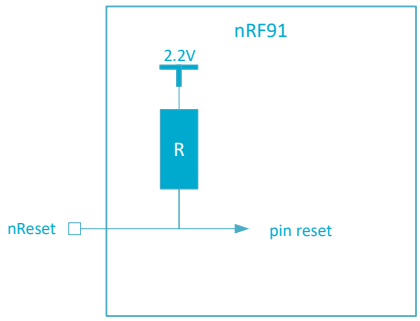

Figure 13: Pin reset internal generation

5.5.3 Wakeup from System OFF mode reset

The device is reset when it wakes up from System OFF mode.

The Debug access port is not reset following a wake up from System OFF mode if the device is in debug interface mode, see Debug and trace on page 434 chapter for more information.

5.5.4 Soft reset

A soft reset is generated when the SYSRESETREQ bit of the application interrupt and reset control register (AIRCR register) in the Arm core is set.

5.5.5 Watchdog reset

A watchdog reset is generated when the watchdog timer (WDT) times out.

See WDT — Watchdog timer on page 417 chapter for more information.

5.5.6 Brownout reset

The brownout reset generator puts the system in reset state if the supply voltage drops below the brownout reset threshold.

5.5.7 Retained registers

A retained register is a register that will retain its value in System OFF mode, and through a reset depending on reset source. For information on which peripheral registers are retained, see the corresponding peripheral's chapter.

5.5.8 Reset behavior

Reset behavior depends on the reset source.

The reset behavior is summarized in the table below.

Reset source	Reset target							
	CPU	Modem	Debug[3]	SWJ-DP	Not retained RAM[4]	Retained RAM[4]	WDT	RESETREAS
CPU lockup [5]	x	x						
Soft reset	x	x						
Wakeup from System OFF mode reset	x	x	x [6]		x		x	
Watchdog reset [7]	x	x	x		x	x	x	
Pin reset	x	x	x	x	x	x	x	
Brownout reset	x	x	x	x	x	x	x	x
Power-on reset	x	x	x	x	x	x	x	

Table 10: Reset behavior for the main components

Note: The RAM is never reset but its content might be corrupted after reset in the cases given in the table above.

[3] All debug components excluding SWJ-DP. See Debug and trace on page 434 chapter for more information about the different debug components in the system.

[4] RAM can be configured to be retained using registers in VMC — Volatile memory controller on page 28.

[5] Reset from CPU lockup is disabled if the device is in debug interface mode. CPU lockup is not possible in System OFF.

[6] The debug components will not be reset if the device is in debug interface mode.

[7] Watchdog reset is not available in System OFF.

Reset source	Reset target					
	Regular peripheral registers	GPIO, SPU	NVMC WAITSTATENUM	NVMC IFCREADDELAY	REGULATORS, OSCILLATORS	POWER.GPREGRET
CPU lockup[5]	x	x	x			
Soft reset	x	x	x			
Wakeup from System OFF mode reset	x		x			
Watchdog reset[7]	x	x	x		x	
Pin reset	x	x	x		x	
Brownout reset	x	x	x	x	x	x
Power-on reset	x	x	x	x	x	x

Table 11: Reset behavior for the retained registers

5.5.9 Electrical specification

5.5.9.1 Pin reset

Symbol	Description	Min.	Typ.	Max.	Units
$t_{HOLDRESET}$	Hold time for reset pin when doing a pin reset	5			µs
$R_{PULL-UP}$	Value of the internal pull-up resistor		13		kΩ

5.6 Current consumption

As the system is constantly tuned by the PMU described in Power and clock management on page 50, estimating the current consumption of an application can be challenging if the designer cannot perform measurements directly on the hardware. To facilitate the estimation process, a set of current consumption scenarios are provided to show the typical current drawn from the VDD supply.

Each scenario specifies a set of operations and conditions that apply to the given scenario. The following table shows a set of common conditions used in all scenarios, unless otherwise is stated in the scenario's description. Similarly, Current consumption scenarios, common conditions for LTE modem on page 62 describes the conditions used for the modem current consumption specifications. For a list of all scenarios, see Electrical specification on page 63.

Peripherals typically share one or more power sources. This results in a current consumption that does not scale linearly with the number of peripherals enabled. For example, the current consumption for an application with two peripherals enabled, is not the sum of the currents reported by their individual peripherals.

Condition	Value
Supply	3.7 V
Temperature	25 °C
CPU	WFI (wait for interrupt)/WFE (wait for event) sleep
Peripherals	All idle[8]
Clock	HFCLK=HFINT Not running LFCLK=Not running
RAM	No retention
Cache enabled	Yes

Table 12: Current consumption scenarios, common conditions

Condition
Cat-M1 and Cat-NB1 HD FDD mode
Good channel, RF cable, no errors in DL/UL communication
Minimum network response times
Wideband radio communication tester used. [9]
Output power at antenna port, single-ended 50 Ω
Modem eDRX current consumption quoted with UICC that allows UICC supply shut down at eDRX intervals. [10] [11] [12]
Modem PSM TAU event energy is measured from the modem PSM wake-up until end of RX inactivity time
All LTE modem current consumption numbers include application core idle mode consumption [13]

Table 13: Current consumption scenarios, common conditions for LTE modem

[8] Except for currents reported for a given peripheral. Peripherals' currents are estimated during momentary transmission.

[9] Key network parameters can differ between every network and live network measurements may differ from Product Specification.

[10] Required UICC restart current consumption is included.

[11] If the UICC used does not support supply shut down, then UICC will remain in clock stop mode. Depending on the UICC used, a clock stop current in the range of 20 µA to 60 µA@3.7 V must be added to get the total average consumption.

[12] Minimum UICC supply shut down interval and clock stop mode current consumption must be obtained from the UICC supplier.

[13] Application RAM leakage not included. Application RAM leakage quoted separately under Sleep on page 63.

5.6.1 Electrical specification

5.6.1.1 Current consumption during System Disabled

Symbol	Description	Min.	Typ.	Max.	Units
$I_{SYSTEM\_DISABLED}$	ENABLE and VDD_GPIO pins grounded		150		nA

5.6.1.2 Sleep

Symbol	Description	Min.	Typ.	Max.	Units
$I_{MCUOFF0}$	MCU off, modem off, wake on GPIO and reset		1.4		µA
I_{MCUON0}	MCU on IDLE, modem off, RTC off		1.8		µA
I_{MCUON1}	MCU on IDLE, modem off, RTC on		2.2		µA
I_{MCUON2}	MCU on IDLE, modem off, wake on GPIOTE input (event mode), Constant latency System ON mode		600		µA
I_{MCUON3}	MCU on IDLE, modem off, wake on GPIOTE input (event mode), Low power System ON mode		18		µA
I_{MCUON4}	MCU on IDLE, modem off, wake on GPIOTE input (port event)		1.8		µA
I_{RAM}	RAM retention leakage current of a 32kB block		0.1		µA

5.6.1.3 Application CPU active current consumption

The application CPU running parameters are obtained using the following compiler version:

Compiler: Arm version 6.16 (armclang)

Compiler flags:

```
-Wno-unused-command-line-argument --target=arm-arm-none-eabi -c -g -masm=auto -Wno-unused-value -mcpu=cortex-m33 -mfpu=fpv5-sp-d16 -mfloat-abi=hard -fno-rtti -flto -funsigned-char -mcmse -Omax -ffunction-sections
```

Symbol	Description	Min.	Typ.	Max.	Units
I_{CPU0_FLASH}	CPU running CoreMark @64 MHz from flash, clock = HFINT, cache enabled		2.7		mA
$I_{COREMARK\_PER\_MA\_FLASH}$	CoreMark per mA, executing from flash, CoreMark=247		91		CoreMark/mA
I_{CPU0_RAM}	CPU running CoreMark @64 MHz from RAM, clock = HFINT		2.1		mA
$I_{COREMARK\_PER\_MA\_RAM}$	CoreMark per mA, executing from RAM, CoreMark=239		114		CoreMark/mA

5.6.1.4 I2S

Symbol	Description	Min.	Typ.	Max.	Units
I_{I2S0}	I2S transferring data left-channel (mono) @ 16 bit x 16 kHz (CONFIG.MCKFREQ = 32MDIV8, CONFIG.RATIO = 256X), Clock = HFINT		600		µA
I_{I2S1}	I2S transferring data left-channel (mono) @ 16 bit x 16 kHz (CONFIG.MCKFREQ = 32MDIV8, CONFIG.RATIO = 256X), Clock = HFXO		1620		µA

5.6.1.5 PDM

Symbol	Description	Min.	Typ.	Max.	Units
I_{PDM}	PDM receiving and processing data 16KHz, with FREQ = 1.28MHz, MODE.OPERATION = mono		620		µA
I_{PDM}	PDM receiving and processing data 16KHz, with FREQ = 1.28MHz, MODE.OPERATION = mono, clock HFXO		1630		µA

5.6.1.6 PWM

Symbol	Description	Min.	Typ.	Max.	Units
I_{PWM0}	PWM running @ 125 kHz, fixed duty cycle		510		µA
I_{PWM1}	PWM running @ 16 MHz, fixed duty cycle		680		µA

5.6.1.7 SAADC

Symbol	Description	Min.	Typ.	Max.	Units
I_{SAADC_HFXO}	SAADC sampling @ 16 ksps, with high accuracy clock HFXO, acquisition time = 20 µs		1550		µA
I_{SAADC_HFINT}	SAADC sampling @ 16 ksps, with low accuracy clock HFINT, acquisition time = 20 µs		540		µA

5.6.1.8 TIMER

Symbol	Description	Min.	Typ.	Max.	Units
I_{TIMER0}	TIMER running @ 1 MHz		390		µA
I_{TIMER1}	TIMER running @ 16 MHz		440		µA

5.6.1.9 SPIM

Symbol	Description	Min.	Typ.	Max.	Units
I_{SPIM0}	SPIM transferring data @ 2 Mbps, Clock = HFINT		610		µA
I_{SPIM1}	SPIM transferring data @ 2 Mbps, Clock = HFXO		1620		µA
I_{SPIM2}	SPIM transferring data @ 8 Mbps, Clock = HFINT		640		µA
I_{SPIM3}	SPIM transferring data @ 8 Mbps, Clock = HFXO		1660		µA

5.6.1.10 SPIS

Symbol	Description	Min.	Typ.	Max.	Units
I_{SPIS_2M}	SPIS receiving data @ 2 Mbps, Clock=HFINT		500		µA
I_{SPIS_2MXO}	SPIS receiving data @ 2 Mbps, Clock=HFXO		1510		µA
I_{SPIS_8M}	SPIS receiving data @ 8 Mbps, Clock=HFINT		510		µA
I_{SPIS_8MXO}	SPIS receiving data @ 8 Mbps, Clock=HFXO		1520		µA

5.6.1.11 TWIM

Symbol	Description	Min.	Typ.	Max.	Units
I_{TWIM_100}	TWIM running @ 100 kbps, Clock=HFINT		590		µA
I_{TWIM_400}	TWIM running @ 400 kbps, Clock = HFINT		590		µA
I_{TWIM_100XO}	TWIM running @ 100 kbps, Clock = HFXO		1600		µA
I_{TWIM_400XO}	TWIM running @ 400 kbps, Clock = HFXO		1610		µA

5.6.1.12 TWIS

Symbol	Description	Min.	Typ.	Max.	Units
I_{TWIS,RUN_100}	TWIS transferring data @ 100 kbps, Clock=HFINT		590		µA
I_{TWIS1,RUN_400}	TWIS transferring data @ 400 kbps, Clock=HFINT		510		µA
I_{TWIS,RUN_100XO}	TWIS transferring data @ 100 kbps, Clock = HFXO		1480		µA
I_{TWIS,RUN_400XO}	TWIS transferring data @ 400 kbps, Clock = HFXO		1370		µA

5.6.1.13 UARTE

Symbol	Description	Min.	Typ.	Max.	Units
$I_{UARTE,1M}$	UARTE transferring data @ 1Mbps		700		µA
$I_{UARTE,115K}$	UARTE transferring data @ 115200 bps		510		µA

5.6.1.14 WDT

Symbol	Description	Min.	Typ.	Max.	Units
I_{WDT}	WDT started		2.5		µA

5.6.1.15 Power Class 3 modem current consumption

To estimate specific use cases, see Online Power Profiler for LTE

Symbol	Description	B13 (typ.)	B20 (typ.)	B3 (typ.)	B4 (typ.)	Units
Sleep current consumption, Cat-M1 and Cat-NB1						
I_{PSM}	PSM floor current	2.7	2.7	2.7	2.7	µA
PSM TAU event energy and duration, Cat-M1						
E_{PSM_TAU}	Pout 23 dBm, QPSK, resource blocks 6, TBS index 9, UICC included	91	97	95	94	mJ
T_{PSM_TAU}	Pout 23 dBm, QPSK, resource blocks 6, TBS index 9, UICC included	1.0	1.0	1.0	1.0	s
PSM TAU event energy and duration, Cat-NB1						
E_{PSM_TAU}	Pout 23 dBm, QPSK, UICC included; UL: 12SC, MCS Index 5 Resource Units 1, Repetitions 1; DL, 12SC, MCS Index 6, Subframes 3, Repetitions 1	343	376	357	347	mJ
T_{PSM_TAU}	Pout 23 dBm, QPSK, UICC included; UL: 12SC, MCS Index 5 Resource Units 1, Repetitions 1; DL, 12SC, MCS Index 6, Subframes 3, Repetitions 1	2.3	2.4	2.3	2.4	s
Average current consumption, radio resource control (RRC) mode, Cat-M1						
I_{EDRX}	eDRX average current, 81.92 s, one PO/PTW, PTW = 2.56 s	18	-	18	-	µA
I_{IEDRX}	Idle eDRX average current, 655 s, one PO/PTW, PTW = 2.56 s	5	-	5	-	µA
I_{RMC_0DBM}	Pout 0 dBm, QPSK, 1RB, 5MHz, RMC settings as per 3GPP TS 36.521-1 Annex A.2	45	45	45	45	mA
I_{RMC_10DBM}	Pout 10 dBm, QPSK, 1RB, 5MHz, RMC settings as per 3GPP TS 36.521-1 Annex A.2	50	50	55	55	mA
I_{RMC_23DBM}	Pout 23 dBm, QPSK, 1RB, 5MHz, RMC settings as per 3GPP TS 36.521-1 Annex A.2	115	125	120	120	mA
Average current consumption, radio resource control (RRC) mode, Cat-NB1						
I_{EDRX}	eDRX average current, 81.92 s, one PO/PTW, PTW = 2.56 s	32	-	33	-	µA
I_{IEDRX}	Idle eDRX average current, 655 s, one PO/PTW, PTW = 2.56 s	7	-	7	-	µA
I_{RMC_0DBM}	Pout 0 dBm, QPSK, 1SC, 15 kHz, TX 33% RX 33%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	30	30	30	35	mA
I_{RMC_10DBM}	Pout 10 dBm, QPSK, 1SC, 15 kHz, TX 33% RX 33%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	40	40	40	45	mA
I_{RMC_23DBM}	Pout 23 dBm, QPSK, 1SC, 15 kHz, TX 33% RX 33%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	100	120	110	115	mA
I_{RMC_0DBM}	Pout 0 dBm, BPSK, 1SC, 3.75 kHz, TX 80% RX 10%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	50	50	55	55	mA
I_{RMC_10DBM}	Pout 10 dBm, BPSK, 1SC, 3.75 kHz, TX 80% RX 10%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	70	70	80	80	mA
I_{RMC_23DBM}	Pout 23 dBm, BPSK, 1SC, 3.75 kHz, TX 80% RX 10%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	215	240	235	230	mA

5.6.1.16 Power Class 5 modem current consumption

To estimate specific use cases, see Online Power Profiler for LTE

Symbol	Description	B13 (typ.)	B20 (typ.)	B3 (typ.)	B4 (typ.)	Units
Sleep current consumption, Cat-M1 and Cat-NB1						
I_{PSM}	PSM floor current	2.7	2.7	2.7	2.7	µA
PSM TAU event energy and duration, Cat-M1						
E_{PSM_TAU}	Pout 20 dBm, QPSK, resource blocks 6, TBS index 9, UICC included	84	87	87	86	mJ
T_{PSM_TAU}	Pout 20 dBm, QPSK, resource blocks 6, TBS index 9, UICC included	1.0	1.0	1.0	1.0	s
PSM TAU event energy and duration, Cat-NB1						
E_{PSM_TAU}	Pout 20 dBm, QPSK, UICC included; UL: 12SC, MCS Index 5 Resource Units 1, Repetitions 1; DL, 12SC, MCS Index 6, Subframes 3, Repetitions 1	260	276	280	290	mJ
T_{PSM_TAU}	Pout 20 dBm, QPSK, UICC included; UL: 12SC, MCS Index 5 Resource Units 1, Repetitions 1; DL, 12SC, MCS Index 6, Subframes 3, Repetitions 1	2.3	2.4	2.4	2.4	s
Average current consumption, radio resource control (RRC) mode, Cat-M1						
I_{EDRX}	eDRX average current, 81.92 s, one PO/PTW, PTW = 2.56 s	18	-	18	-	µA
I_{IEDRX}	Idle eDRX average current, 655 s, one PO/PTW, PTW = 2.56 s	5	-	5	-	µA
I_{RMC_0DBM}	Pout 0 dBm, QPSK, 1RB, 5MHz, RMC settings as per 3GPP TS 36.521-1 Annex A.2	45	45	45	45	mA
I_{RMC_10DBM}	Pout 10 dBm, QPSK, 1RB, 5MHz, RMC settings as per 3GPP TS 36.521-1 Annex A.2	50	50	55	55	mA
I_{RMC_20DBM}	Pout 20 dBm, QPSK, 1RB, 5MHz, RMC settings as per 3GPP TS 36.521-1 Annex A.2	90	90	90	90	mA
Average current consumption, radio resource control (RRC) mode, Cat-NB1						
I_{EDRX}	eDRX average current, 81.92 s, one PO/PTW, PTW = 2.56 s	32	-	33	-	µA
I_{IEDRX}	Idle eDRX average current, 655 s, one PO/PTW, PTW = 2.56 s	7	-	7	-	µA
I_{RMC_0DBM}	Pout 0 dBm, QPSK, 1SC, 15 kHz, TX 33% RX 33%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	30	30	30	35	mA
I_{RMC_10DBM}	Pout 10 dBm, QPSK, 1SC, 15 kHz, TX 33% RX 33%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	40	40	40	45	mA
I_{RMC_20DBM}	Pout 20 dBm, QPSK, 1SC, 15 kHz, TX 33% RX 33%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	70	75	80	80	mA
I_{RMC_0DBM}	Pout 0 dBm, BPSK, 1SC, 3.75 kHz, TX 80% RX 10%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	50	50	55	55	mA
I_{RMC_10DBM}	Pout 10 dBm, BPSK, 1SC, 3.75 kHz, TX 80% RX 10%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	70	70	80	80	mA
I_{RMC_20DBM}	Pout 20 dBm, BPSK, 1SC, 3.75 kHz, TX 80% RX 10%, RMC settings as per 3GPP TS 36.101 Annex A.2.4	145	150	160	160	mA

5.6.1.17 DECT NR+ current consumption

Symbol	Description	B1, B2, B9, B22 (typ.)	Units
Average current during active transmission, nominal operating conditions			
$I_{TX\_PL13\_LOW\_LATENCY}$	Minimum latency mode[14], any modulation, Power level[15] 13 (19 dBm)	235	mA
Average current during active reception, nominal operating conditions			
$I_{RX\_-90DBM\_LOW\_LATENCY}$	Minimum latency mode[14], Received signal -90 dBm	47	mA
Average current during idle[16], nominal operating conditions			
$I_{IDLE\_LOW\_LATENCY}$	Minimum latency mode[14], modem waiting for TX or RX operation	37	mA

14 Modem is configured to mode where lowest possible latency TX or RX operations can be achieved. In this mode certain circuit blocks which are slow to power-up are kept powered ON constantly. This will increase the current consumption during TX, RX, and especially idle operation.

15 Transmit power level requested from modem according to ETSI TS 103 636-4 Table 6.2.1-3a.

16 DECT NR+ enabled and waiting for TX or RX operations.

5.6.1.18 GPS current consumption

Symbol	Description	Min.	Typ.	Max.	Units
$I_{GPS\_CONTINUOUS}$	Continuous tracking, without power saving mode		43.1		mA
$I_{GPS\_CONTINUOUS\_PSM}$	Continuous tracking, power saving mode		7.8		mA
$I_{GPS\_PERIODIC}$	Periodic fix average current with A-GPS[17], one fix every 2 minutes		0.5		mA

5.7 Register description

5.7.1 POWER — Power control

The POWER module provides an interface to tasks, events, interrupt, and reset related configuration settings of the power management unit.

Note: Registers INTEN on page 71, INTENSET on page 72, and INTENCLR on page 72 are the same registers (at the same address) as corresponding registers in CLOCK — Clock control on page 74.

5.7.1.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
POWER : S	0x50005000	US	NS	NA	No	Power control
POWER : NS	0x40005000					

Register overview

Register	Offset	TZ	Description
TASKS_CONSTLAT	0x78		Enable constant latency mode.
TASKS_LOWPWR	0x7C		Enable low power mode (variable latency)
SUBSCRIBE_CONSTLAT	0xF8		Subscribe configuration for task CONSTLAT
SUBSCRIBE_LOWPWR	0xFC		Subscribe configuration for task LOWPWR
EVENTS_POFWARN	0x108		Power failure warning
EVENTS_SLEEPENTER	0x114		CPU entered WFI/WFE sleep
EVENTS_SLEEPEXIT	0x118		CPU exited WFI/WFE sleep
PUBLISH_POFWARN	0x188		Publish configuration for event POFWARN
PUBLISH_SLEEPENTER	0x194		Publish configuration for event SLEEPENTER
PUBLISH_SLEEPEXIT	0x198		Publish configuration for event SLEEPEXIT
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
RESETREAS	0x400		Reset reason
POWERSTATUS	0x440		Modem domain power status
GPREGRET[n]	0x51C		General purpose retention register
LTEMODEM.STARTN	0x610		Start LTE modem
LTEMODEM.FORCEOFF	0x614		Force off LTE modem

[17] Including LTE current consumption.

5.7.1.1.1 TASKS_CONSTLAT

Address offset: 0x78

Enable constant latency mode.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_CONSTLAT			Enable constant latency mode.
			Trigger	1	Trigger task

5.7.1.1.2 TASKS_LOWPWR

Address offset: 0x7C

Enable low power mode (variable latency)

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_LOWPWR			Enable low power mode (variable latency)
			Trigger	1	Trigger task

5.7.1.1.3 SUBSCRIBE_CONSTLAT

Address offset: 0xF8

Subscribe configuration for task CONSTLAT

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task CONSTLAT will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

5.7.1.1.4 SUBSCRIBE_LOWPWR

Address offset: 0xFC

Subscribe configuration for task LOWPWR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task LOWPWR will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

5.7.1.1.5 EVENTS_POFWARN

Address offset: 0x108

Power failure warning

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	EVENTS_POFWARN																																	
			NotGenerated	0																															
			Generated	1																															

5.7.1.1.6 EVENTS_SLEEPENTER

Address offset: 0x114

CPU entered WFI/WFE sleep

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	EVENTS_SLEEPENTER																																	
			NotGenerated	0																															
			Generated	1																															

5.7.1.1.7 EVENTS_SLEEPEXIT

Address offset: 0x118

CPU exited WFI/WFE sleep

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	EVENTS_SLEEPEXIT																																	
			NotGenerated	0																															
			Generated	1																															

5.7.1.1.8 PUBLISH_POFWARN

Address offset: 0x188

Publish configuration for event POFWARN

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event POFWARN will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

5.7.1.1.9 PUBLISH_SLEEPENTER

Address offset: 0x194

Publish configuration for event SLEEPENTER

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event SLEEPENTER will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

5.7.1.1.10 PUBLISH_SLEEPEXIT

Address offset: 0x198

Publish configuration for event SLEEPEXIT

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event SLEEPEXIT will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

5.7.1.1.11 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	POFWARN			Enable or disable interrupt for event POFWARN
			Disabled	0	Disable
			Enabled	1	Enable
D	RW	SLEEPENTER			Enable or disable interrupt for event SLEEPENTER
			Disabled	0	Disable
			Enabled	1	Enable

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
E	RW	SLEEPEXIT			Enable or disable interrupt for event SLEEPEXIT
			Disabled	0	Disable
			Enabled	1	Enable

5.7.1.1.12 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	POFWARN			Write '1' to enable interrupt for event POFWARN
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
D	RW	SLEEPENTER			Write '1' to enable interrupt for event SLEEPENTER
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	SLEEPEXIT			Write '1' to enable interrupt for event SLEEPEXIT
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

5.7.1.1.13 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	POFWARN			Write '1' to disable interrupt for event POFWARN
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
D	RW	SLEEPENTER			Write '1' to disable interrupt for event SLEEPENTER
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	SLEEPEXIT			Write '1' to disable interrupt for event SLEEPEXIT
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

5.7.1.1.14 RESETREAS

Address offset: 0x400

Reset reason

> **Note:** Unless cleared, the RESETREAS register will be cumulative. A field is cleared by writing '1' to it. If none of the reset sources are flagged, this indicates that the chip was reset from the on-chip reset generator, which will indicate a power-on reset or a brownout reset.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	RESETPIN			Reset from pin reset detected
			NotDetected	0	Not detected
			Detected	1	Detected
B	RW	DOG			Reset from global watchdog detected
			NotDetected	0	Not detected
			Detected	1	Detected
C	RW	OFF			Reset due to wakeup from System OFF mode, when wakeup is triggered by DETECT signal from GPIO
			NotDetected	0	Not detected
			Detected	1	Detected
D	RW	DIF			Reset due to wakeup from System OFF mode, when wakeup is triggered by entering debug interface mode
			NotDetected	0	Not detected
			Detected	1	Detected
E	RW	SREQ			Reset from AIRCR.SYSRESETREQ detected
			NotDetected	0	Not detected
			Detected	1	Detected
F	RW	LOCKUP			Reset from CPU lock-up detected
			NotDetected	0	Not detected
			Detected	1	Detected
G	RW	CTRLAP			Reset triggered through CTRL-AP
			NotDetected	0	Not detected
			Detected	1	Detected

5.7.1.1.15 POWERSTATUS

Address offset: 0x440

Modem domain power status

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	LTEMODEM			LTE modem domain status
			OFF	0	LTE modem domain is powered off
			ON	1	LTE modem domain is powered on

5.7.1.1.16 GPREGRET[n] (n=0..1)

Address offset: 0x51C + (n × 0x4)

General purpose retention register

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																												A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	GPREGRET																																	

					General purpose retention register
					This register is a retained register

5.7.1.1.17 LTEMODEM

LTE Modem

5.7.1.1.17.1 LTEMODEM.STARTN

Address offset: 0x610

Start LTE modem

Note: Starting and stopping LTE modem must only be done through the LTE modem API to guarantee correct sequence in FW and HW and to avoid possible malfunctions.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	STARTN																																	
			Start	0																															
			Hold	1																															

					Start LTE modem
				0	Start LTE modem
				1	Hold LTE modem disabled

5.7.1.1.17.2 LTEMODEM.FORCEOFF

Address offset: 0x614

Force off LTE modem

Note: Starting and stopping LTE modem must only be done through the LTE modem API to guarantee correct sequence in FW and HW and to avoid possible malfunctions.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	FORCEOFF																																	
			Release	0																															
			Hold	1																															

					Force off LTE modem
				0	Release force off
				1	Hold force off active

5.7.2 CLOCK — Clock control

The CLOCK module provides one of the interfaces to power and clock management configuration settings.

Through CLOCK module it is able to configure the following:

- LFCLK clock source setup
- LFCLK and HFCLK status

- Tasks and events
- Interrupts
- Reset

Note: Registers INTEN on page 79, INTENSET on page 79, and INTENCLR on page 79 are the same registers (at the same address) as corresponding registers in POWER — Power control on page 68.

5.7.2.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CLOCK : S CLOCK : NS	0x50005000 0x40005000	US	NS	NA	No	Clock control

Register overview

Register	Offset	TZ	Description
TASKS_HFCLKSTART	0x000		Start HFCLK source
TASKS_HFCLKSTOP	0x004		Stop HFCLK source
TASKS_LFCLKSTART	0x008		Start LFCLK source
TASKS_LFCLKSTOP	0x00C		Stop LFCLK source
SUBSCRIBE_HFCLKSTART	0x080		Subscribe configuration for task HFCLKSTART
SUBSCRIBE_HFCLKSTOP	0x084		Subscribe configuration for task HFCLKSTOP
SUBSCRIBE_LFCLKSTART	0x088		Subscribe configuration for task LFCLKSTART
SUBSCRIBE_LFCLKSTOP	0x08C		Subscribe configuration for task LFCLKSTOP
EVENTS_HFCLKSTARTED	0x100		HFCLK oscillator started
EVENTS_LFCLKSTARTED	0x104		LFCLK started
PUBLISH_HFCLKSTARTED	0x180		Publish configuration for event HFCLKSTARTED
PUBLISH_LFCLKSTARTED	0x184		Publish configuration for event LFCLKSTARTED
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
INTPEND	0x30C		Pending interrupts
HFCLKRUN	0x408		Status indicating that HFCLKSTART task has been triggered
HFCLKSTAT	0x40C		The register shows if HFXO has been requested by triggering HFCLKSTART task and if it has been started (STATE).
LFCLKRUN	0x414		Status indicating that LFCLKSTART task has been triggered
LFCLKSTAT	0x418		The register shows which LFCLK source has been requested (SRC) when triggering LFCLKSTART task and if the source has been started (STATE).
LFCLKSRCCOPY	0x41C		Copy of LFCLKSRC register, set after LFCLKSTART task has been triggered
LFCLKSRC	0x518		Clock source for the LFCLK. LFCLKSTART task starts a clock source selected with this register.

5.7.2.1.1 TASKS_HFCLKSTART

Address offset: 0x000

Start HFCLK source

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_HFCLKSTART			Start HFCLK source
			Trigger	1	Trigger task

5.7.2.1.2 TASKS_HFCLKSTOP

Address offset: 0x004

Stop HFCLK source

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_HFCLKSTOP			Stop HFCLK source
			Trigger	1	Trigger task

5.7.2.1.3 TASKS_LFCLKSTART

Address offset: 0x008

Start LFCLK source

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_LFCLKSTART			Start LFCLK source
			Trigger	1	Trigger task

5.7.2.1.4 TASKS_LFCLKSTOP

Address offset: 0x00C

Stop LFCLK source

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_LFCLKSTOP			Stop LFCLK source
			Trigger	1	Trigger task

5.7.2.1.5 SUBSCRIBE_HFCLKSTART

Address offset: 0x080

Subscribe configuration for task HFCLKSTART

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task HFCLKSTART will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

5.7.2.1.6 SUBSCRIBE_HFCLKSTOP

Address offset: 0x084

Subscribe configuration for task HFCLKSTOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task HFCLKSTOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

5.7.2.1.7 SUBSCRIBE_LFCLKSTART

Address offset: 0x088

Subscribe configuration for task LFCLKSTART

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task LFCLKSTART will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

5.7.2.1.8 SUBSCRIBE_LFCLKSTOP

Address offset: 0x08C

Subscribe configuration for task LFCLKSTOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task LFCLKSTOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

5.7.2.1.9 EVENTS_HFCLKSTARTED

Address offset: 0x100

HFCLK oscillator started

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	EVENTS_HFCLKSTARTED																																	
			NotGenerated	0																															
			Generated	1																															

5.7.2.1.10 EVENTS_LFCLKSTARTED

Address offset: 0x104

LFCLK started

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	EVENTS_LFCLKSTARTED																																	
			NotGenerated	0																															
			Generated	1																															

5.7.2.1.11 PUBLISH_HFCLKSTARTED

Address offset: 0x180

Publish configuration for event HFCLKSTARTED

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				B																								A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	CHIDX		[0..255]																															
B	RW	EN																																	
			Disabled	0																															
			Enabled	1																															

5.7.2.1.12 PUBLISH_LFCLKSTARTED

Address offset: 0x184

Publish configuration for event LFCLKSTARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event LFCLKSTARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

5.7.2.1.13 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	HFCLKSTARTED			Enable or disable interrupt for event HFCLKSTARTED
			Disabled	0	Disable
			Enabled	1	Enable
B	RW	LFCLKSTARTED			Enable or disable interrupt for event LFCLKSTARTED
			Disabled	0	Disable
			Enabled	1	Enable

5.7.2.1.14 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	HFCLKSTARTED			Write '1' to enable interrupt for event HFCLKSTARTED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	LFCLKSTARTED			Write '1' to enable interrupt for event LFCLKSTARTED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

5.7.2.1.15 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	HFCLKSTARTED			Write '1' to disable interrupt for event HFCLKSTARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	LFCLKSTARTED			Write '1' to disable interrupt for event LFCLKSTARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

5.7.2.1.16 INTPEND

Address offset: 0x30C

Pending interrupts

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	HFCLKSTARTED			Read pending status of interrupt for event HFCLKSTARTED
			NotPending	0	Read: Not pending
			Pending	1	Read: Pending
B	R	LFCLKSTARTED			Read pending status of interrupt for event LFCLKSTARTED
			NotPending	0	Read: Not pending
			Pending	1	Read: Pending

5.7.2.1.17 HFCLKRUN

Address offset: 0x408

Status indicating that HFCLKSTART task has been triggered

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			HFCLKSTART task triggered or not
			NotTriggered	0	Task not triggered
			Triggered	1	Task triggered

5.7.2.1.18 HFCLKSTAT

Address offset: 0x40C

The register shows if HFXO has been requested by triggering HFCLKSTART task and if it has been started (STATE).

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	SRC			Active clock source
			HFINT	0	HFINT - 64 MHz on-chip oscillator
			HFXO	1	HFXO - 64 MHz clock derived from external 32 MHz crystal oscillator
B	R	STATE			HFCLK state
			NotRunning	0	HFXO has not been started or HFCLKSTOP task has been triggered
			Running	1	HFXO has been started (HFCLKSTARTED event has been generated)

5.7.2.1.19 LFCLKRUN

Address offset: 0x414

Status indicating that LFCLKSTART task has been triggered

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			LFCLKSTART task triggered or not
			NotTriggered	0	Task not triggered
			Triggered	1	Task triggered

5.7.2.1.20 LFCLKSTAT

Address offset: 0x418

The register shows which LFCLK source has been requested (SRC) when triggering LFCLKSTART task and if the source has been started (STATE).

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	SRC			Active clock source
			RFU	0	Reserved for future use
			LFRC	1	32.768 kHz RC oscillator
			LFXO	2	32.768 kHz crystal oscillator
B	R	STATE			LFCLK state
			NotRunning	0	Requested LFCLK source has not been started or LFCLKSTOP task has been triggered
			Running	1	Requested LFCLK source has been started (LFCLKSTARTED event has been generated)

5.7.2.1.21 LFCLKSRCCOPY

Address offset: 0x41C

Copy of LFCLKSRC register, set after LFCLKSTART task has been triggered

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	SRC			Clock source
			RFU	0	Reserved for future use
			LFRC	1	32.768 kHz RC oscillator
			LFXO	2	32.768 kHz crystal oscillator

5.7.2.1.22 LFCLKSRC

Address offset: 0x518

Clock source for the LFCLK. LFCLKSTART task starts a clock source selected with this register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	SRC			Clock source
			RFU	0	Reserved for future use (equals selecting LFRC)
			LFRC	1	32.768 kHz RC oscillator
			LFXO	2	32.768 kHz crystal oscillator

5.7.3 REGULATORS — Voltage regulators control

The REGULATORS module provides an interface to certain configuration settings of on-chip voltage regulators.

5.7.3.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
REGULATORS : S	0x50004000	US	NS	NA	No	Regulator configuration
REGULATORS : NS	0x40004000					

Register overview

Register	Offset	TZ	Description
SYSTEMOFF	0x500		System OFF register
EXTPOFCON	0x514		External power failure warning configuration
DCDCEN	0x578		Enable a step-down DC/DC voltage regulator.

5.7.3.1.1 SYSTEMOFF

Address offset: 0x500

System OFF register

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	SYSTEMOFF																																	Enable System OFF mode
			Enable	1																															Enable System OFF mode

5.7.3.1.2 EXTPOFCON

Address offset: 0x514

External power failure warning configuration

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	POF																																	Enable or disable external power failure warning
			Disabled	0																															Disable
			Enabled	1																															Enable

5.7.3.1.3 DCDCEN

Address offset: 0x578

Enable a step-down DC/DC voltage regulator.

Note: DCDCEN must be set to 1 (enabled) before the LTE modem is started.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	DCDCEN																																	Enable DC/DC buck regulator
			Disabled	0																															DC/DC buck regulator is disabled
			Enabled	1																															DC/DC buck regulator is enabled

6 Peripherals

The nRF9151 application core peripherals are found in Instantiation on page 25.

6.1 CRYPTOCELL — Arm TrustZone CryptoCell 310

Arm TrustZone CryptoCell 310 (CRYPTOCELL) is a security subsystem providing root of trust (RoT) and cryptographic services for a device.

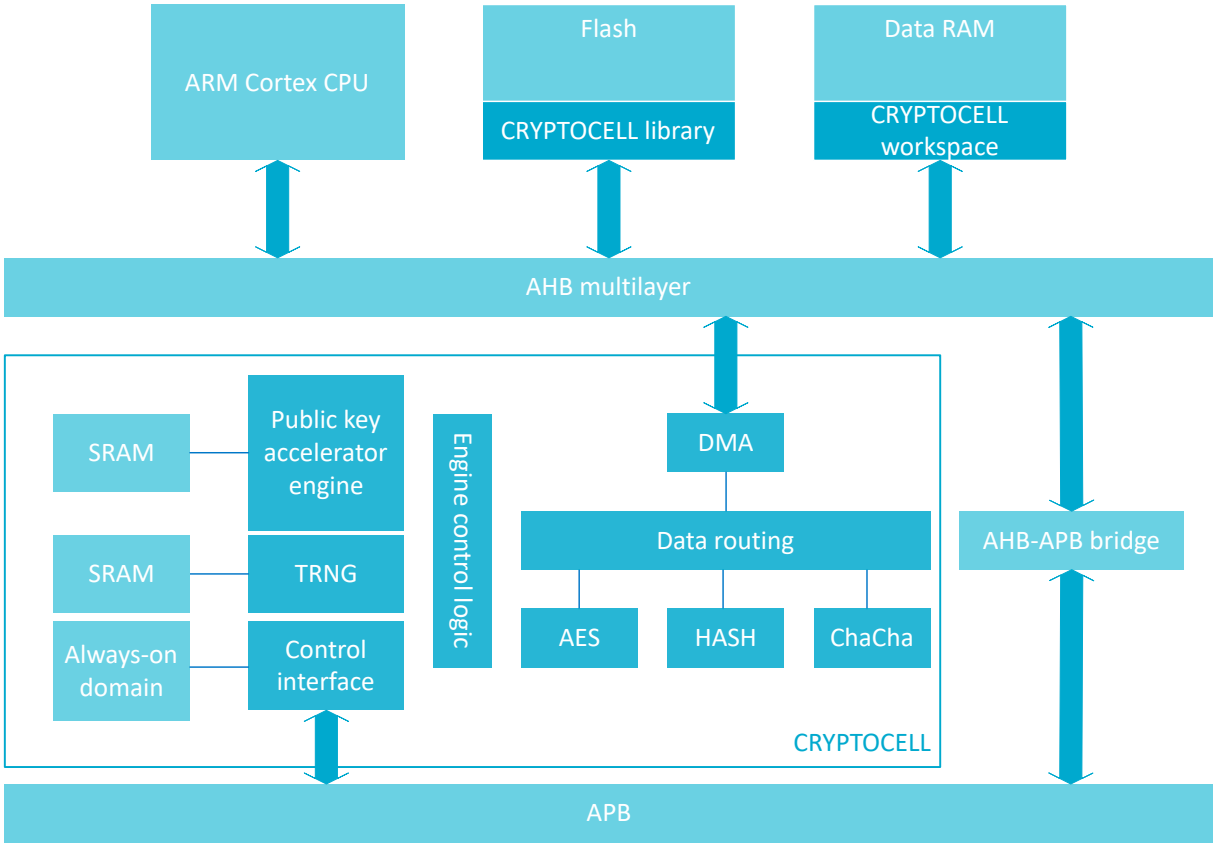

Figure 14: CRYPTOCELL block diagram

The following cryptographic features are among the functionality that can be supported:

- True random number generator (TRNG) compliant with FIPS 140-2, BSI AIS-31, and NIST 800-90B.
- Pseudorandom number generator (PRNG) using underlying AES engine compliant with NIST 800-90A
- RSA public key cryptography
  - Signature verification up to key sizes of 2048 bits
  - Key generation up to key sizes of 2048 bits
  - PKCS#1 v2.1/v1.5
- Elliptic curve cryptography (ECC)
  - NIST FIPS 186-4 recommended curves using pseudorandom parameters, up to 521 bits:
    - Prime field: P-192, P-224, P-256, P-384, P-521
  - SEC 2 recommended curves using pseudorandom parameters, up to 521 bits:
    - Prime field: secp160r1, secp192r1, secp224r1, secp256r1, secp384r1, secp521r1

- Koblitz curves using fixed parameters, up to 256 bits:
  - Prime field: secp160k1, secp192k1, secp224k1, secp256k1
- Brainpool curves:
  - Prime field: BrainpoolP256r1
- Edwards/Montgomery curves:
  - Ed25519, Curve25519
- ECDH/ECDSA support
- Secure remote password protocol (SRP), up to 3072 bits operations
- Hashing functions
  - SHA-1, SHA-2 up to 256 bits
  - Keyed-hash message authentication code (HMAC)
- AES symmetric encryption
  - General purpose AES engine (encrypt/decrypt, sign/verify)
  - 128 bits key size
  - Supported encryption modes: ECB, CBC, CMAC/CBC-MAC, CTR, CCM/CCM*
- ChaCha20/Poly1305 symmetric encryption
  - 128 and 256 bits key size
  - Authenticated encryption with associated data (AEAD) mode

6.1.1 Disclaimer

This section contains an important disclaimer about the CRYPTOCELL subsystem documentation.

The CRYPTOCELL subsystem is recommended for use with the libraries in the Nordic Semiconductor ASA SDK. These libraries are tested and verified to work with the CRYPTOCELL subsystem hardware. The CRYPTOCELL subsystem documentation and register descriptions are for reference only and can be used for modifying the Nordic supplied SDK libraries or implementing new features.

Nordic Semiconductor ASA reserves the right to change the CRYPTOCELL documentation and register descriptions without further notice. Changes will not trigger erratas and will not be seen as changing form/fit/function of the device.

Please note that Nordic cannot support questions directly related to the register interface or modification of the source code implementation. Nordic provide support for the top-level API in the software library distributed as part of the device SDK.

6.1.2 Usage

The CRYPTOCELL subsystem is a hardware and software solution where software is delivered as libraries in Nordic device SDKs. Recommended usage of the CRYPTOCELL subsystem is to use the SDK library implementation available for the device. The CRYPTOCELL subsystem is documented for reference purpose only, please see section Disclaimer on page 85 for more information.

To enable CRYPTOCELL, use register ENABLE on page 91. The device will not enter the System ON IDLE mode until CRYPTOCELL has been disabled, see POWER — Power control on page 68 for more information. The Nordic SDK software library automatically controls enabling and disabling of the CRYPTOCELL subsystem as a part of its function calls.

6.1.3 Security configuration

CRYPTOCELL has internal storage for its security configuration, which is preserved even if CRYPTOCELL is disabled.

The following configuration settings are retained:

- Device life cycle state (LCS)
- Various lock bits
- 128 bits device root key, K_{DR}, see Device root key on page 87

Any reset source will erase the CRYPTOCELL internal storage, see Reset on page 59 for more information.

6.1.3.1 Lifecycle state (LCS)

Lifecycle refers to the multiple states a device goes through during its lifetime. `DebugEnable` and `Secure` are the two CRYPTOCELL lifecycle states available to the device.

The CRYPTOCELL lifecycle state (LCS) is controlled through register HOST_IOT_LCS on page 149. The LCS is configured by writing either `DebugEnable` or `Secure` to the LCS field of this register. To validate that the register is configured correctly, read back the read-only field LCS_IS_VALID from the register HOST_IOT_LCS on page 149. The LCS_IS_VALID field will change from `Invalid` to `Valid` once a valid LCS value is written.

The following debug override functionality is available if LCS is configured as `DebugEnable`:

- Registers HOST_IOT_KDR0 through HOST_IOT_KDR3 can be written multiple times.
- The TRNG output can be overridden. This is done by writing the desired value to register EHR_DATA[0] through EHR_DATA[5] in RNG engine. If LCS is configured as `Secure`, registers EHR_DATA are read-only and its content is randomly generated by the RNG engine.

LCS field value	LCS_IS_VALID field value	Description
Secure	Invalid	Default reset value indicating that LCS has not been configured.
Secure	Valid	LCS set to `Secure` mode, and LCS is valid. Registers HOST_IOT_KDR0 through HOST_IOT_KDR3 can only be written once. Any additional writes are ignored.
DebugEnable	Valid	LCS set to `DebugEnable` mode, and LCS is valid. Registers HOST_IOT_KDR0 through HOST_IOT_KDR3 can be written multiple times.

Table 14: Lifecycle states

6.1.4 Cryptographic flow

The following section describe a typical cryptographic flow for the CRYPTOCELL subsystem.

1. Enable CRYPTOCELL subsystem as described in Usage on page 85.
2. Perform clock control for the desired cryptographic engine(s) as described in Power and clock on page 88.
3. Configure the desired cryptographic mode as described in CTL interface on page 134.
4. Depending on the selected cryptographic mode the active engine(s) must be configured, including which cryptographic key to use as described in Cryptographic key selection on page 86.
5. Optionally configure DMA engines as described in Direct memory access (DMA) on page 88.
6. Initiate the operation, and wait for an event as described in Interrupt handling on page 89.
7. Check status register(s) for the active engine(s).

6.1.5 Cryptographic key selection

The CRYPTOCELL subsystem can operate on different cryptographic keys.

6.1.5.1 Hardware unique keys

The AES engine can be instructed to use different key input sources.

The cryptographic key input for the AES engine on page 91 can either be a hard-coded RTL key referred to as K_{PRTL}, a device root key referred to as K_{DR} which is typically programmed into CRYPTOCELL during boot by an immutable bootloader, or a session key provided runtime by the application or the KMU — Key management unit on page 205.

Register HOST_CRYPTOKEY_SEL on page 147 selects one of the following keys for the AES cryptographic operations:

- RTL key K_{PRTL}
- Device root key K_{DR}
- Session key

6.1.5.1.1 RTL key

CRYPTOCELL contains one hard-coded RTL key referred to as K_{PRTL}. This key is set to the same value for all devices with the same part code and cannot be changed.

CRYPTOCELL can perform cryptographic operations using the K_{PRTL} key without a bootloader or application having access to the key value itself. Usage of K_{PRTL} can be disabled until next reset by writing to register HOST_IOT_KPRTL_LOCK on page 147. If a locked K_{PRTL} key is requested, a zero vector key will be used by the AES engine instead.

6.1.5.1.2 Device root key

The device root key, K_{DR}, is a 128 bits AES key typically programmed by an immutable bootloader as part of the CRYPTOCELL initialization process during device boot sequence. It is kept in the CRYPTOCELL internal storage until the next reset.

To configure the K_{DR} key, write the key value into registers HOST_IOT_KDR0 through HOST_IOT_KDR3. These registers are write-only when LCS is set to `DebugEnable` mode, and write-once when LCS is set to `Secure` mode. The K_{DR} key value is kept when the read-back value of register HOST_IOT_KDR0 is `Retained`. Once configured, CRYPTOCELL can perform cryptographic operations using the K_{DR} key without an updatable bootloader or application having access to the key value itself.

The K_{DR} key should be protected by the KMU — Key management unit on page 205.

6.1.5.2 Session keys

Session keys are supported by the AES and CHACHA engine.

Before starting a cryptographic operation using a session key, the desired key value must be written in clear-text by the CPU into the write-only key registers of the corresponding engine. One session key can be overwritten by another as long as the write order of the write-only key registers are respected. Please refer to the corresponding chapter of each cryptographic engine for more information about write order.

The AES engine on page 91 supports 128 bits session keys, and CHACHA engine on page 97 supports 128/256 bits session keys.

The last written session key for each engine is retained until CRYPTOCELL is disabled, the engine is reset, or the device is reset.

6.1.5.3 Key Management Unit (KMU) keys

The KMU — Key management unit on page 205 is designed to securely transfer symmetric encryption keys directly into the dedicated write-only key registers of the AES and CHACHA cryptographic engines upon request from the CPU.

Pushing a symmetric key value stored in a KMU key slot into either the AES or CHACHA engine will replace the need for software to write a session key in clear-text into registers AES_KEY_0[n] (n=0..7) on page 93 for 128 bits AES keys or registers CHACHA_KEY[n] (n=0..7) on page 100 for 128/256 bits CHACHA keys.

The symmetric key value pushed from a KMU key slot into the AES or CHACHA engine will be retained until CRYPTOCELL is disabled or the device is reset.

6.1.5.4 Asymmetric keys

Asymmetric cryptographic keys are supported by the PKA engine.

Before starting a cryptographic operation using an asymmetric key, the desired key value must be written into the PKA SRAM together with the payload.

See PKA engine on page 110 for more information.

6.1.6 Internal memories

CRYPTOCELL contains two dedicated memory blocks; one 4 kB SRAM block for the PKA engine calculations, and one 2 kB SRAM block for the RNG engine entropy collector.

See PKA SRAM on page 114 and RNG SRAM on page 122 for more information about these dedicated memory blocks.

6.1.7 Direct memory access (DMA)

CRYPTOCELL support direct memory access (DMA) to allow cryptographic operations on memory mapped regions without involving the CPU.

The following table indicates which memory is accessible by CRYPTOCELL DMA engines.

Memory type	Read	Write
SRAM	Yes	Yes
Flash	No	No

Table 15: DMA transaction types

Data stored in a memory type not accessible by CRYPTOCELL DMA engines must be copied to an accessible memory type before it can be processed by the CRYPTOCELL subsystem. Maximum DMA transaction size is limited to 2^{16}-1 bytes.

The CRYPTOCELL DMA engine can also run in Bypass mode, meaning data is read and written without being piped through a cryptographic engine. Thus CRYPTOCELL can act as a general purpose DMA engine for moving data.

Operating the DMA engines in Bypass mode involve the following steps:

1. Enable DMA engines clock using register DMA_CLK on page 151.
2. Configure cryptographic control for `Bypass` mode using register CRYPTO_CTL on page 134.
3. Set the the output destination address and size of the receiving buffer.
4. Start the DMA transaction by configuring the input source address and the number of bytes to transfer.
5. Status of the DMA transaction can be monitored by either polling register DOUT_DMA_MEM_BUSY on page 140, or by unmasking the interrupt for field `DOUT_TO_MEM_MASK` in register IMR on page 144.

See DIN DMA engine on page 135 and DOUT DMA engine on page 139 for more information.

6.1.8 Power and clock

Power and clock management of the CRYPTOCELL subsystem is handled automatically in hardware, as long as the neccessary conditions are fulfilled by software.

Clock gating

CRYPTOCELL implements separate clock domains for each cryptographic engine. Internal clock gating control is handled through the MISC interface on page 150, as well as register RNG_CLK on page 130. The registers of a cryptographic engine are only accessible when its clock is enabled.

Power gating

CRYPTOCELL must be disabled to ensure lowest possible power consumption when the subsystem is not needed.

The CRYPTOCELL subsystem power is controlled through register ENABLE on page 91. Even though external clock input is gated away automatically by hardware, the CRYPTOCELL subsystem power will still be enabled. To initiate a full power-down sequence software must perform the following steps:

1. Make sure there are no pending tasks
2. Clear all pending interrupts in register RNG_ICR on page 126 and register ICR on page 145.
3. Disable CRYPTOCELL subsystem using register ENABLE on page 91.

6.1.9 Interrupt handling

CRYPTOCELL triggers interrupt once processing is complete.

See register IRR on page 144 for more information on which CRYPTOCELL subsystem components are able to trigger an interrupt request.

To clear the IRQ line when an interrupt has occurred, the relevant interrupt bit in register ICR on page 145 must be cleared. Interrupt sources can be masked using register IMR on page 144. If an interrupt source is masked, no interrupt request will be triggered.

In addition if field `RNG_INT` in register IRR on page 144 is asserted, the relevant RNG engine interrupt bit in register RNG_ICR on page 126 must be cleared *before* clearing that interrupt bit in register ICR on page 145 as described above.

The figure below shows how the CRYPTOCELL subsystem interrupt handling is designed and how it is connected to the NVIC module in the CPU.

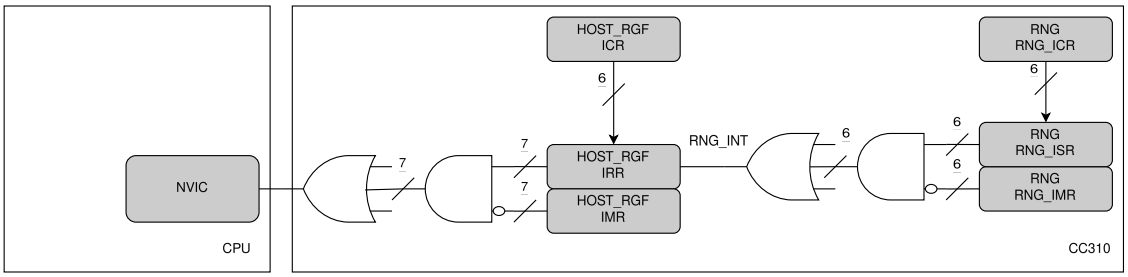

Figure 15: CRYPTOCELL interrupt handling

6.1.10 Standards

Arm TrustZone CryptoCell 310 (CRYPTOCELL) is compliant with the protocol specifications and standards shown in the following table.

Algorithm family	Identification code	Document title
TRNG	NIST SP 800-90B	*Recommendation for the Entropy Sources Used for Random Bit Generation*
	BSI AIS-31	*Functionality Classes and Evaluation Methodology for True Random Number Generators*
	FIPS 140-2	*Security Requirements for Cryptographic Modules*
PRNG	NIST SP 800-90A	*Recommendation for Random Number Generation Using Deterministic Random Bit Generators*
Stream cipher	Chacha	*ChaCha, a variant of Salsa20*, Daniel J. Bernstein, January 28th 2008
MAC	Poly1305	*The Poly1305-AES message-authentication code*, Daniel J. Bernstein *Cryptography in NaCl*, Daniel J. Bernstein
Key agreement	SRP	*The Secure Remote Password Protocol*, Thomas Wu, November 11th 1997
Key derivation	NIST SP 800-108	*Recommendation for Key Derivation Using Pseudorandom Functions.*
AES	FIPS-197	*Advanced Encryption Standard (AES)*. Compliant with 128 bits key size only
	NIST SP 800-38A	*Recommendation for Block Cipher Modes of Operation - Methods and Techniques*
	NIST SP 800-38B	*Recommendation for Block Cipher Modes of Operation: The CMAC Mode for Authentication*
	NIST SP 800-38C	*Recommendation for Block Cipher Modes of Operation: The CCM Mode for Authentication and Confidentiality*
	ISO/IEC 9797-1	AES CBC-MAC per ISO/IEC 9797-1 MAC algorithm 1
	IEEE 802.15.4-2011	*IEEE Standard for Local and metropolitan area networks - Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)*, Annex B.4: *Specification of generic CCM* mode of operation*
Hash	FIPS 180-4	Secure Hash Standard (SHA1, SHA-224, SHA-256)
	RFC2104	*HMAC: Keyed-Hashing for Message Authentication*
RSA	PKCS#1	*Public-Key Cryptography Standards (PKCS) #1: RSA Cryptography Specifications* v1.5/2.1. RSA signature verification supported up to key sizes of 2048 bits. RSA key generation supported up to key sizes of 2048 bits.
Diffie-Hellman	ANSI X9.42	*Public Key Cryptography for the Financial Services Industry: Agreement of Symmetric Keys Using Discrete Logarithm Cryptography*
	PKCS#3	*Diffie-Hellman Key-Agreement Standard*
ECC	ANSI X9.63	*Public Key Cryptography for the Financial Services Industry - Key Agreement and Key Transport Using Elliptic Curve Cryptography*
	IEEE 1363	*Standard Specifications for Public-Key Cryptography*
	ANSI X9.62	*Public Key Cryptography For The Financial Services Industry: The Elliptic Curve Digital Signature Algorithm (ECDSA)*
	Ed25519	Edwards-curve, *Ed25519: high-speed high-security signatures*, Daniel J. Bernstein, Niels Duif, Tanja Lange, Peter Schwabe, and Bo-Yin Yang
	Curve25519	Montgomery curve, *Curve25519: new Diffie-Hellman speed records*, Daniel J. Bernstein
	FIPS 186-4	*Digital Signature Standard (DSS)*
	SEC 2	*Recommended Elliptic Curve Domain Parameters*, Certicom Research
	NIST SP 800-56A rev. 2	*Recommendation for Pair-Wise Key Establishment Schemes Using Discrete Logarithm Cryptography*

Table 16: CRYPTOCELL cryptography standards

6.1.11 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CRYPTOCELL	0x50840000	HF	S	NSA	No	CRYPTOCELL 310 security subsystem

Register overview

Register	Offset	TZ	Description
ENABLE	0x500		Enable CRYPTOCELL subsystem.

6.1.11.1 ENABLE

Address offset: 0x500

Enable CRYPTOCELL subsystem.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field		Value ID			Value					Description																							
A	RW	ENABLE										Enable or disable the CRYPTOCELL subsystem.																							
				Disabled			0					CRYPTOCELL subsystem disabled.																							
				Enabled			1					CRYPTOCELL subsystem enabled.																							

6.1.12 Accelerators

This chapter contains register interfaces for each of the hardware accelerator engines.

6.1.12.1 AES engine

The Advanced Encryption Standard (AES) hardware engine is designed according to FIPS197 for use in encrypt/decrypt and sign/verify operations for 128 bits key sizes.

The following cipher modes are supported:

- ECB
- CBC
- CBC-MAC
- CMAC
- CTR
- CCM
- CCM*

Note:

To ensure proper operation when writing 128 bits AES keys, the write-only key registers of the AES engine must be written in ascending order, starting with:

- AES_KEY_0[0]
- AES_KEY_0[1]
- AES_KEY_0[2]
- AES_KEY_0[3]

6.1.12.1.1 Cryptographic flow

The following section describe a simple cryptographic flow for this engine.

```
uint8_t buf_dst[16] = { 0 };
uint8_t buf_src[16] = { 0x81, 0x02, 0xF2, 0x40, 0xD5, 0xB9, 0x44, 0x59,
                        0xA2, 0xEB, 0x6F, 0xF2, 0x49, 0xF5, 0xEB, 0x94 };

/* Enable CRYPTOCELL subsystem */
NRF_CRYPTOCELL->ENABLE =  CRYPTOCELL_ENABLE_ENABLE_Enabled;

/* Enable engine and DMA clock */
NRF_CC_MISC->AES_CLK = CC_MISC_AES_CLK_ENABLE_Enable;
NRF_CC_MISC->DMA_CLK = CC_MISC_DMA_CLK_ENABLE_Enable;

/* Wait until crypto engine is Idle  */
while (NRF_CC_CTL->CRYPTO_BUSY == CC_CTL_CRYPTO_BUSY_STATUS_Busy) { }

/* Configure AES as cryptographic flow */
NRF_CC_CTL->CRYPTO_CTL = CC_CTL_CRYPTO_CTL_MODE_AESActive;

/* Configure AES engine control for decryption using ECB mode (default) */
NRF_CC_AES->AES_CONTROL = CC_AES_AES_CONTROL_DEC_KEY0_Decrypt;

/* Load the AES key value into the engine */
NRF_CC_AES->AES_KEY_0[0] = 0x51515151;
NRF_CC_AES->AES_KEY_0[1] = 0x52525252;
NRF_CC_AES->AES_KEY_0[2] = 0x53535353;
NRF_CC_AES->AES_KEY_0[3] = 0x54545454;

/* Configure default init vector */
NRF_CC_AES->AES_IV_0[0] = 0x0;
NRF_CC_AES->AES_IV_0[1] = 0x0;
NRF_CC_AES->AES_IV_0[2] = 0x0;
NRF_CC_AES->AES_IV_0[3] = 0x0;

/* Configure DMA output destination address */
NRF_CC_DOUT->DST_MEM_ADDR = (uint32_t) buf_dst;
NRF_CC_DOUT->DST_MEM_SIZE = (uint32_t) sizeof(buf_dst);

/* Configure DMA input source address to start the cryptographic operation */
NRF_CC_DIN->SRC_MEM_ADDR = (uint32_t) buf_src;
NRF_CC_DIN->SRC_MEM_SIZE = (uint32_t) sizeof(buf_src);

/* Wait on DOUT DMA interrupt */
while(!(NRF_CC_HOST_RGF->IRR & CC_HOST_RGF_IRR_DOUT_TO_MEM_INT_Msk)) {}
```

6.1.12.1.2 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_AES	0x50841000	HF	S	NSA	No	CRYPTOCELL AES engine

Register overview

Register	Offset	TZ	Description
AES_KEY_0[n]	0x400		AES key value to use. The initial AES_KEY_0[0] register holds the least significant bits [31:0] of the key value.
AES_IV_0[n]	0x440		AES Initialization Vector (IV) to use. The initial AES_IV_0[0] register holds the least significant bits [31:0] of the IV.
AES_CTR[n]	0x460		AES counter (CTR) to use. The initial AES_CTR[0] register holds the least significant bits [31:0] of the CTR.
AES_BUSY	0x470		Status register for AES engine activity.
AES_SK	0x478		Writing to this address trigger sampling of the HW key to the AES_KEY_0 register
AES_CMAC_INIT	0x47C		Writing to this address triggers the AES engine to generate K1 and K2 for AES-CMAC operations.
AES_REMAINING_BYTES	0x4BC		This register should be set with the amount of remaining bytes until the end of the current AES operation.
AES_CONTROL	0x4C0		Control the AES engine behavior.
AES_HW_FLAGS	0x4C8		Hardware configuration of the AES engine. Reset value holds the supported features.
AES_CTR_NO_INCREMENT	0x4D8		This register enables the AES CTR no increment mode in which the counter mode is not incremented between two blocks
AES_SW_RESET	0x4F4		Reset the AES engine.
AES_CMAC_SIZE0_KICK	0x524		Writing to this address triggers the AES engine to perform a CMAC operation with size 0. The CMAC result can be read from the AES_IV_0 register.

6.1.12.1.2.1 AES_KEY_0[n] (n=0..7)

Address offset: 0x400 + (n × 0x4)

AES key value to use. The initial AES_KEY_0[0] register holds the least significant bits [31:0] of the key value.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	VALUE			AES key value.

6.1.12.1.2.2 AES_IV_0[n] (n=0..3)

Address offset: 0x440 + (n × 0x4)

AES Initialization Vector (IV) to use. The initial AES_IV_0[0] register holds the least significant bits [31:0] of the IV.

AES_IV_0 must be configured according to the selected AES mode:

- AES CBC/CBC-MAC : Loaded with the IV.

This register is a 'R/W change' register, as the written register values changes during processing.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			AES non-tunneling or first tunnel stage IV value.

6.1.12.1.2.3 AES_CTR[n] (n=0..3)

Address offset: 0x460 + (n × 0x4)

AES counter (CTR) to use. The initial AES_CTR[0] register holds the least significant bits [31:0] of the CTR.

AES_CTR must be configured according to the selected AES mode:

- AES CTR : Loaded with the counter value.

This register is a 'R/W change' register, as the written register values changes during processing.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			AES CTR value.

6.1.12.1.2.4 AES_BUSY

Address offset: 0x470

Status register for AES engine activity.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			AES engine status.
			Idle	0	AES engine is idle
			Busy	1	AES engine is busy

6.1.12.1.2.5 AES_SK

Address offset: 0x478

Writing to this address trigger sampling of the HW key to the AES_KEY_0 register

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	AES_SK			Sample HW key to AES_KEY_0 registers.

6.1.12.1.2.6 AES_CMAC_INIT

Address offset: 0x47C

Writing to this address triggers the AES engine to generate K1 and K2 for AES-CMAC operations.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ENABLE			Generate K1 and K2 for the AES-CMAC operations.
			Enable	1	Initialize AES-CMAC operations.

6.1.12.1.2.7 AES_REMAINING_BYTES

Address offset: 0x4BC

This register should be set with the amount of remaining bytes until the end of the current AES operation.

The AES engine counts down from this value to determine the last block or the block before the last blocks in mode AES CMAC and mode AES CCM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			Remaining bytes util the end of the current AES operation.

6.1.12.1.2.8 AES_CONTROL

Address offset: 0x4C0

Control the AES engine behavior.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C C B B B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	DEC_KEY0			Set AES encrypt or decrypt mode in non-tunneling operations.
			Encrypt	0	Perform AES encryption
			Decrypt	1	Perform AES decryption
B	RW	MODE_KEY0			Set the AES mode.
			ECB	0x0	Electronic codebook mode
			CBC	0x1	Cipher block chaining mode
			CTR	0x2	Counter mode
			CBC_MAC	0x3	Cipher Block Chaining Message Authentication Code
			CMAC	0x7	Cipher-based Message Authentication Code
C	RW	NK_KEY0			Set the AES key length.
			128Bits	0x0	128 bits key length
D	RW	AES_XOR_CRYPTOKEY			This field determines the value that is written to AES_KEY_0, when AES_SK is kicked.
			Disable	0	The value that is written to AES_KEY_0 is the value of the HW cryptokey as is.
			Enable	1	The value that is written to AES_KEY_0 is the value of the HW cryptokey XOR with the current value of AES_KEY_0.
E	RW	DIRECT_ACCESS			Using direct access and not the DIN-DOUT DMA interface
			Disable	0	Access using the DIN-DOUT DMA interface
			Enable	1	Access using direct access

6.1.12.1.2.9 AES_HW_FLAGS

Address offset: 0x4C8

Hardware configuration of the AES engine. Reset value holds the supported features.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																							K	J	I	H	G			F	E	D	C	B	A
Reset 0x00000108				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	SUPPORT_256_192_KEY																																	
				If this flag is set, the engine support 192 bits and 256 bits key size.																																	
B	R	AES_LARGE_RKEK																																	
				If this flag is set, the engine support AES_LARGE_RKEK.																																	
C	R	DPA_CNTRMSR_EXIST																																	
				If this flag is set, the engine support DPA countermeasures.																																	
D	R	CTR_EXIST																																	
				If this flag is set, the engine support AES CTR mode.																																	
E	R	ONLY_ENCRYPT																																	
				If this flag is set, the engine only support encrypt operations.																																	
F	R	USE_SBOX_TABLE																																	
				If this flag is set, the engine uses SBOX tables.																																	
G	R	USE_5_SBOXES																																	
				If this flag is set, the engine uses 5 SBOX where each AES round takes 4 cycles.																																	
H	R	AES_SUPPORT_PREV_IV																																	
				If this flag is set, the engine contains the PREV_IV register for faster AES XCBC MAC calculation.																																	
I	R	AES_TUNNEL_EXIST																																	
				If this flag is set, the engine support tunneling operations.																																	
J	R	SECOND_REGS_SET_EXIST																																	
				If this flag is set, the engine support a second register set for tunneling operations.																																	
K	R	DFA_CNTRMSR_EXIST																																	
				If this flag is set, the engine support DFA countermeasures.																																	

6.1.12.1.2.10 AES_CTR_NO_INCREMENT

Address offset: 0x4D8

This register enables the AES CTR no increment mode in which the counter mode is not incremented between two blocks

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ENABLE																																	
				This field enables the AES CTR no increment mode in which the counter mode is not incremented between two blocks																																	
			Disable	0																															
				Counter always incremented between blocks																																	
			Enable	1																															
				Do not increment counter between blocks																																	

6.1.12.1.2.11 AES_SW_RESET

Address offset: 0x4F4

Reset the AES engine.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	RESET																																	
				Writing any value to this address resets the AES engine. The reset takes 4 CPU clock cycles to complete.																																	
			Enable	1																															
				Reset AES engine.																																	

6.1.12.1.2.12 AES_CMAC_SIZE0_KICK

Address offset: 0x524

Writing to this address triggers the AES engine to perform a CMAC operation with size 0. The CMAC result can be read from the AES_IV_0 register.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	ENABLE																																	
			Disable	0																															
			Enable	1																															

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	ENABLE																																	
			Disable	0																															
			Enable	1																															

6.1.12.2 CHACHA engine

The ChaCha algorithm is a family of stream ciphers.

The ChaCha family of stream ciphers can be used as both a stand-alone algorithm, and in combination with the Poly1305 authenticator to form an Authenticated Encryption with Associated Data (AEAD) algorithm as defined in RFC7539 for IETF protocols.

The CHACHA engine provide acceleration for the stream encryption, while the PKA engine is used for acceleration of the Poly1305 authenticator. The core of the ChaCha algorithm is a hash function which is based on rotation operations. In the default configuration the hash function consist of 20 rounds of rotation permutations. The implementation support ChaCha stream ciphers using key sizes up to 256 bits in 8, 12 and 20 rounds. The ChaCha20/Poly1305 combination is perfectly suited for embedded environments, and can achieve much higher throughput than AES using similar power consumption and execution time.

Note: To ensure proper operation when writing 128 bits CHACHA keys, the write-only key registers of the CHACHA engine must be written in ascending order, starting with:

- CHACHA_KEY[0]
- CHACHA_KEY[1]
- CHACHA_KEY[2]
- CHACHA_KEY[3]

For 256 bits CHACHA keys, this must be followed by:

- CHACHA_KEY[4]
- CHACHA_KEY[5]
- CHACHA_KEY[6]
- CHACHA_KEY[7]

6.1.12.2.1 Cryptographic flow

The following section describe a simple cryptographic flow for this engine.

```
uint8_t buf_dst[16] = { 0 };
uint8_t buf_src[16] = { 0x18, 0x35, 0x9B, 0x75, 0x18, 0x6F, 0x33, 0xBE,
                        0x22, 0x0A, 0x3D, 0xB7, 0x66, 0xFD, 0x98, 0x35 };

/* Enable CRYPTOCELL subsystem */
NRF_CRYPTOCELL->ENABLE = CRYPTOCELL_ENABLE_ENABLE_Enabled;

/* Enable engine and DMA clock */
NRF_CC_MISC->CHACHA_CLK = CC_MISC_CHACHA_CLK_ENABLE_Enable;
NRF_CC_MISC->DMA_CLK = CC_MISC_DMA_CLK_ENABLE_Enable;

/* Wait until crypto engine is Idle  */
while (NRF_CC_CTL->CRYPTO_BUSY == CC_CTL_CRYPTO_BUSY_STATUS_Busy) { }

/* Configure CHACHA as cryptographic flow */
NRF_CC_CTL->CRYPTO_CTL = CC_CTL_CRYPTO_CTL_MODE_ChaChaActive;

/* Configure testing NONCE */
NRF_CC_CHACHA->CHACHA_IV[0] = 0xBBBBAAAA;
NRF_CC_CHACHA->CHACHA_IV[1] = 0x22221111;

/* Load the CHACHA test key value into the engine */
NRF_CC_CHACHA->CHACHA_KEY[0] = 0x51515151;
NRF_CC_CHACHA->CHACHA_KEY[1] = 0x52525252;
NRF_CC_CHACHA->CHACHA_KEY[2] = 0x53535353;
NRF_CC_CHACHA->CHACHA_KEY[3] = 0x54545454;
NRF_CC_CHACHA->CHACHA_KEY[4] = 0x51515151;
NRF_CC_CHACHA->CHACHA_KEY[5] = 0x52525252;
NRF_CC_CHACHA->CHACHA_KEY[6] = 0x53535353;
NRF_CC_CHACHA->CHACHA_KEY[7] = 0x54545454;

/* Configure CHACHA mode - using default (0x0), adding new message init */
NRF_CC_CHACHA->CHACHA_CONTROL =
  (CC_CHACHA_CHACHA_CONTROL_INIT_Enable <<
   CC_CHACHA_CHACHA_CONTROL_INIT_Pos);

/* Configure DMA output destination address */
NRF_CC_DOUT->DST_MEM_ADDR = (uint32_t) buf_dst;
NRF_CC_DOUT->DST_MEM_SIZE = (uint32_t) sizeof(buf_dst);

/* Configure DMA input source address to start the cryptographic operation */
NRF_CC_DIN->SRC_MEM_ADDR = (uint32_t) buf_src;
NRF_CC_DIN->SRC_MEM_SIZE = (uint32_t) sizeof(buf_src);

/* Wait on DOUT DMA interrupt */
while(!(NRF_CC_HOST_RGF->IRR & CC_HOST_RGF_IRR_DOUT_TO_MEM_INT_Msk)) {}
```

6.1.12.2.2 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_CHACHA	0x50841000	HF	S	NSA	No	CRYPTOCELL CHACHA engine

Register overview

Register	Offset	TZ	Description
CHACHA_CONTROL	0x380		Control the CHACHA engine behavior.
CHACHA_VERSION	0x384		CHACHA engine HW version
CHACHA_KEY[n]	0x388		CHACHA key value to use. The initial CHACHA_KEY[0] register holds the least significant bits [31:0] of the key value.
CHACHA_IV[n]	0x3A8		CHACHA Initialization Vector (IV) to use. The IV is also known as the nonce.
CHACHA_BUSY	0x3B0		Status register for CHACHA engine activity.
CHACHA_HW_FLAGS	0x3B4		Hardware configuration of the CHACHA engine. Reset value holds the supported features.
CHACHA_BLOCK_CNT_LSB	0x3B8		Store the LSB value of the block counter, in order to support suspend/resume of operation
CHACHA_BLOCK_CNT_MSB	0x3BC		Store the MSB value of the block counter, in order to support suspend/resume of operation
CHACHA_SW_RESET	0x3C0		Reset the CHACHA engine.
CHACHA_POLY1305_KEY[n]	0x3C4		The auto-generated key to use in Poly1305 MAC calculation. The initial CHACHA_POLY1305_KEY[0] register holds the least significant bits [31:0] of the key value.
CHACHA_ENDIANNESS	0x3E4		CHACHA engine data order configuration.
CHACHA_DEBUG	0x3E8		Debug register for the CHACHA engine

6.1.12.2.2.1 CHACHA_CONTROL

Address offset: 0x380

Control the CHACHA engine behavior.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																						G	F				E	E	D	C	B	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHACHA_OR_SALSA			Run engine in ChaCha or Salsa mode
			ChaCha	0	Run engine in ChaCha mode
			Salsa	1	Run engine in Salsa mode
B	RW	INIT			Perform initialization for a new message
			Disable	0	Message already initialized
			Enable	1	Initialize new message
C	RW	GEN_KEY_POLY1305			Generate the key to use in Poly1305 message authentication code calculation.
			Disable	0	Do not generate Poly1305 key
			Enable	1	Generate Poly1305 key
D	RW	KEY_LEN			Key length selection.
			256Bits	0	Use 256 bits key length
			128Bits	1	Use 128 bits key length
E	RW	NUM_OF_ROUNDS			Set number of permutation rounds, default value is 20.
			Default	0	Use 20 rounds of rotation (default)

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																									G	F				E	E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
			12Rounds	1																															
			8Rounds	2																															
F	RW	RESET_BLOCK_CNT																																	
			Disable	0																															
			Enable	1																															
G	RW	USE_IV_96BIT																																	
			Disable	0																															
			Enable	1																															

6.1.12.2.2.2 CHACHA_VERSION

Address offset: 0x384

CHACHA engine HW version

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
A	R	CHACHA_VERSION																																	

6.1.12.2.2.3 CHACHA_KEY[n] (n=0..7)

Address offset: 0x388 + (n × 0x4)

CHACHA key value to use. The initial CHACHA_KEY[0] register holds the least significant bits [31:0] of the key value.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	VALUE																																	
																																			CHACHA key value.

6.1.12.2.2.4 CHACHA_IV[n] (n=0..1)

Address offset: 0x3A8 + (n × 0x4)

CHACHA Initialization Vector (IV) to use. The IV is also known as the nonce.

The size of the nonce is controlled from register CHACHA_CONTROL on page 99.

For 64 bits IV size the nonce value must be encoded using:

- CHACHA_IV[0] : Bits [31:0] of the nonce
- CHACHA_IV[1] : Bits [63:32] of the nonce

For 96 bits IV size the nonce value must be encoded using:

- CHACHA_BLOCK_CNT_MSB on page 101 : Bits [31:0] of the nonce
- CHACHA_IV[0] : Bits [63:32] of the nonce
- CHACHA_IV[1] : Bits [95:64] of the nonce

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			CHACHA IV value.

6.1.12.2.2.5 CHACHA_BUSY

Address offset: 0x3B0

Status register for CHACHA engine activity.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			CHACHA engine status.
			Idle	0	CHACHA engine is idle
			Busy	1	CHACHA engine is busy

6.1.12.2.2.6 CHACHA_HW_FLAGS

Address offset: 0x3B4

Hardware configuration of the CHACHA engine. Reset value holds the supported features.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	CHACHA_EXISTS			If this flag is set, the engine include ChaCha support
B	R	SALSA_EXISTS			If this flag is set, the engine include Salsa support
C	R	FAST_CHACHA			If this flag is set, the next matrix calculated when the current one is written to data output path.

6.1.12.2.2.7 CHACHA_BLOCK_CNT_LSB

Address offset: 0x3B8

Store the LSB value of the block counter, in order to support suspend/resume of operation

The two first words (n) in the last row of the cipher matrix are the block counter. At the end of each block (512b), the block counter for the next block is written by HW to register CHACHA_BLOCK_CNT_LSB on page 101 and register CHACHA_BLOCK_CNT_MSB on page 101. If starting a new message the block counter must also be reset.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			This register holds the ChaCha block counter bits [31:0] and must be read and written during respectively suspend and resume operations.

6.1.12.2.2.8 CHACHA_BLOCK_CNT_MSB

Address offset: 0x3BC

Store the MSB value of the block counter, in order to support suspend/resume of operation

For the description of register CHACHA_BLOCK_CNT_MSB on page 101, see register CHACHA_BLOCK_CNT_LSB on page 101.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			This register holds the ChaCha block counter bits [63:32] and must be read and written during respectively suspend and resume operations.

6.1.12.2.2.9 CHACHA_SW_RESET

Address offset: 0x3C0

Reset the CHACHA engine.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	RESET			Writing any value to this address resets the CHACHA engine. The reset takes 4 CPU clock cycles to complete.
			Enable	1	Reset CHACHA engine.

6.1.12.2.2.10 CHACHA_POLY1305_KEY[n] (n=0..7)

Address offset: 0x3C4 + (n × 0x4)

The auto-generated key to use in Poly1305 MAC calculation.

The initial CHACHA_POLY1305_KEY[0] register holds the least significant bits [31:0] of the key value.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	R	VALUE			Poly1305 key value.

6.1.12.2.2.11 CHACHA_ENDIANNESS

Address offset: 0x3E4

CHACHA engine data order configuration.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																												E	D	C	B	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHACHA_DIN_WORD_ORDER			Change the word order of the input data.
			Default	0	Use default word order for 128-bits input, where words are ordered as follows: w0, w1, w2, w3.
			Reverse	1	Reverses the word order for 128-bits input, where words are re-ordered as follows: w3, w2, w1, w0.
B	RW	CHACHA_DIN_BYTE_ORDER			Change the byte order of the input data.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Default	0	Use default byte order within each input word, where bytes are ordered as follows: B0, B1, B2, B3.
			Reverse	1	Reverse the byte order within each input word, where bytes are re-ordered as follows: B3, B2, B1, B0.
C	RW	CHACHA_CORE_MATRIX_LBE_ORDER			Change the quarter of a matrix order in the engine.
			Default	0	Use default quarter of matrix order, where quarters are ordered as follows: q0, q1, q2, q3. Each quarter represents a 128-bits section of the matrix.
			Reverse	1	Reverse the order of matrix quarters, where quarters are re-ordered as follows: q3, q2, q1, q0. Each quarter represents a 128-bits section of the matrix.
D	RW	CHACHA_DOUT_WORD_ORDER			Change the word order of the output data.
			Default	0	Uses default word order for 128-bits output, where words are ordered as follows: w0, w1, w2, w3.
			Reverse	1	Reverse the word order for 128-bits output, where words are re-ordered as follows: w3, w2, w1, w0.
E	RW	CHACHA_DOUT_BYTE_ORDER			Change the byte order of the output data.
			Default	0	Use default byte order within each output word, where bytes are ordered as follows: B0, B1, B2, B3.
			Reverse	1	Reverse the byte order within each output word, where bytes are re-ordered as follows: B3, B2, B1, B0.

6.1.12.2.2.12 CHACHA_DEBUG

Address offset: 0x3E8

Debug register for the CHACHA engine

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	FSM_STATE			Reflects the debug state of the CHACHA FSM.
			IDLE_STATE	0	CHACHA FSM is in idle state
			INIT_STATE	1	CHACHA FSM is in init state
			ROUNDS_STATE	2	CHACHA FSM is in rounds state
			FINAL_STATE	3	CHACHA FSM is in final state

6.1.12.3 HASH engine

The HASH engine is designed according to FIPS 180-4, and support both the SHA1 and SHA2 family of digest algorithms up to 256 bits.

The following SHA modes are supported:

- SHA-1
- SHA-224
- SHA-256

Note:

To ensure proper operation, the FIPS 180-4 defined initial hash values written to the registers of the HASH engine must be written in descending order, starting with:

- HASH_H[7] for SHA-256, and SHA-224.
- HASH_H[6] for SHA-256, and SHA-224.
- HASH_H[5] for SHA-256, and SHA-224.
- HASH_H[4] for SHA-256, SHA-224, and SHA-1.
- HASH_H[3] for SHA-256, SHA-224, and SHA-1.
- HASH_H[2] for SHA-256, SHA-224, and SHA-1.
- HASH_H[1] for SHA-256, SHA-224, and SHA-1.
- HASH_H[0] for SHA-256, SHA-224, and SHA-1.

6.1.12.3.1 Cryptographic flow

The following section describe a simple cryptographic flow for this engine.

```
uint8_t buf_src[32] =  {
      0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,
      0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,
      0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,
      0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,0xFA,0xFA };

/* Enable CRYPTOCELL subsystem */
NRF_CRYPTOCELL->ENABLE = CRYPTOCELL_ENABLE_ENABLE_Enabled;

/* Enable engine and DMA clock */
NRF_CC_MISC->HASH_CLK = CC_MISC_HASH_CLK_ENABLE_Enable;
NRF_CC_MISC->DMA_CLK = CC_MISC_DMA_CLK_ENABLE_Enable;

/* Wait until hash engine is Idle  */
while (NRF_CC_CTL->HASH_BUSY == CC_CTL_HASH_BUSY_STATUS_Busy) {}

/* Clear all interrupts */
NRF_CC_HOST_RGF->ICR = 0xFFFFFFFF;

/* Configure HASH as cryptographic flow */
NRF_CC_CTL->CRYPTO_CTL = CC_CTL_CRYPTO_CTL_MODE_HashActive;

/* Configure engine for SHA256 */
NRF_CC_HASH->HASH_CONTROL = CC_HASH_HASH_CONTROL_MODE_SHA256;

/* Configure initial SHA256 values */
NRF_CC_HASH->HASH_H[7] = 0x5BE0CD19;
NRF_CC_HASH->HASH_H[6] = 0x1F83D9AB;
NRF_CC_HASH->HASH_H[5] = 0x9B05688C;
NRF_CC_HASH->HASH_H[4] = 0x510E527F;
NRF_CC_HASH->HASH_H[3] = 0xA54FF53A;
NRF_CC_HASH->HASH_H[2] = 0x3C6EF372;
NRF_CC_HASH->HASH_H[1] = 0xBB67AE85;
NRF_CC_HASH->HASH_H[0] = 0x6A09E667;

/* Configure DMA input source address to start the cryptographic operation */
NRF_CC_DIN->SRC_MEM_ADDR = (uint32_t) buf_src;
NRF_CC_DIN->SRC_MEM_SIZE = (uint32_t) sizeof(buf_src);

/* Wait on DIN DMA interrupt indicating data has been fetched */
while(!(NRF_CC_HOST_RGF->IRR & CC_HOST_RGF_IRR_MEM_TO_DIN_INT_Msk)) {}

/* Wait until hash engine is Idle */
while (NRF_CC_CTL->HASH_BUSY == CC_CTL_HASH_BUSY_STATUS_Busy) {}

/* Calculated SHA256 digest now available in
NRF_CC_HASH->HASH_H[0] to NRF_CC_HASH->HASH_H[7]  */
```

6.1.12.3.2 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_HASH	0x50841000	HF	S	NSA	No	CRYPTOCELL HASH engine

Register overview

Register	Offset	TZ	Description
HASH_H[n]	0x640		HASH_H value registers. The initial HASH_H[0] register holds the least significant bits [31:0] of the value.
HASH_PAD_AUTO	0x684		Configure the HASH engine to automatically pad data at the end of the DMA transfer to complete the digest operation.
HASH_INIT_STATE	0x694		Configure HASH engine initial state registers.
HASH_VERSION	0x7B0		HASH engine HW version
HASH_CONTROL	0x7C0		Control the HASH engine behavior.
HASH_PAD	0x7C4		Enable the hardware padding feature of the HASH engine.
HASH_PAD_FORCE	0x7C8		Force the hardware padding operation to trigger if the input data length is zero bytes.
HASH_CUR_LEN_0	0x7CC		Bits [31:0] of the number of bytes that have been digested so far.
HASH_CUR_LEN_1	0x7D0		Bits [63:32] of the number of bytes that have been digested so far.
HASH_HW_FLAGS	0x7DC		Hardware configuration of the HASH engine. Reset value holds the supported features.
HASH_SW_RESET	0x7E4		Reset the HASH engine.
HASH_ENDIANNESS	0x7E8		Configure the endianness of HASH data and padding generation.

6.1.12.3.2.1 HASH_H[n] (n=0..7)

Address offset: 0x640 + (n × 0x4)

HASH_H value registers. The initial HASH_H[0] register holds the least significant bits [31:0] of the value.

This register is a 'R/W change' register, as the written register values changes during processing.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			Write the initial hash value before start of digest operation, and read the final hash value result after the digest operation has been completed.

6.1.12.3.2.2 HASH_PAD_AUTO

Address offset: 0x684

Configure the HASH engine to automatically pad data at the end of the DMA transfer to complete the digest operation.

This feature can only be used if HASH_PAD on page 108 is enabled, and must be disabled after a digest operation is completed. In the event of zero bytes input data length the hardware padding must be manually triggered using register HASH_PAD_FORCE on page 108.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	HWPAD			Enable automatic padding in hardware. Disable this register when the digest operation is completed.
			Disable	0	Do not enable automatic hardware padding.
			Enable	1	Enable automatic hardware padding.

6.1.12.3.2.3 HASH_INIT_STATE

Address offset: 0x694

Configure HASH engine initial state registers.

Data fetched using the DIN DMA engine will be loaded into initial hash value registers HASH_H[n] (n=0..7) on page 106 or used as IV for AES MAC.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	LOAD			Enable loading of data to initial state registers. Digest/IV for HASH/ AES_MAC. Disable this register when loading of data using DIN DMA is done.
			Disable	0	Disable loading of data to initial state registers.
			Enable	1	Enable loading of data to initial state registers.

6.1.12.3.2.4 HASH_VERSION

Address offset: 0x7B0

HASH engine HW version

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C C C C B B B B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	PATCH			
B	R	MINOR_VERSION_NUMBER			Minor version number
C	R	MAJOR_VERSION_NUMBER			Major version number

6.1.12.3.2.5 HASH_CONTROL

Address offset: 0x7C0

Control the HASH engine behavior.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MODE			Select HASH mode to execute
			SHA1	1	Select SHA1 mode
			SHA256	2	Select SHA256 mode
			SHA224	10	Select SHA224 mode

6.1.12.3.2.6 HASH_PAD

Address offset: 0x7C4

Enable the hardware padding feature of the HASH engine.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	ENABLE																																	
			Disable	0																															
			Enable	1																															

6.1.12.3.2.7 HASH_PAD_FORCE

Address offset: 0x7C8

Force the hardware padding operation to trigger if the input data length is zero bytes.

This feature can only be used if HASH_PAD on page 108 is enabled, and must be disabled after a digest operation is completed.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																	A		
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ENABLE																																	
				Disable this register when the digest operation is completed.																																	
			Disable	0																															
			Enable	1																															

6.1.12.3.2.8 HASH_CUR_LEN_0

Address offset: 0x7CC

Bits [31:0] of the number of bytes that have been digested so far.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	VALUE																																	

6.1.12.3.2.9 HASH_CUR_LEN_1

Address offset: 0x7D0

Bits [63:32] of the number of bytes that have been digested so far.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	VALUE																																	

6.1.12.3.2.10 HASH_HW_FLAGS

Address offset: 0x7DC

Hardware configuration of the HASH engine. Reset value holds the supported features.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																	J	I	H	G	F	E	D	C	C	C	B	B	B	B	A	A	A	A
Reset 0x00012001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
A	R	CW																																	
			One	1																															
			Two	2																															
B	R	CH																																	
			One	0																															
			All	1																															
C	R	DW																																	
			32Bits	0																															
			64Bits	1																															
D	R	SHA_512_EXISTS																																	
E	R	PAD_EXISTS																																	
F	R	MD5_EXISTS																																	
G	R	HMAC_EXISTS																																	
H	R	SHA_256_EXISTS																																	
I	R	HASH_COMPARE_EXISTS																																	
J	R	DUMP_HASH_TO_DOUT_EXISTS																																	

6.1.12.3.2.11 HASH_SW_RESET

Address offset: 0x7E4

Reset the HASH engine.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	RESET																																	
			Enable	1																															

6.1.12.3.2.12 HASH_ENDIANNESS

Address offset: 0x7E8

Configure the endianness of HASH data and padding generation.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENDIAN			Endianness of HASH data and padding generation. The default value is little-endian.
			LittleEndian	0	Use little-endian format for data and padding
			BigEndian	1	Use big-endian format for data and padding

6.1.12.4 PKA engine

The Public Key Accelerator (PKA) engine is designed to accelerate asymmetric cryptographic algorithms.

The PKA design is a general purpose bignum modular ALU capable of supporting operand sizes between 128-3136 bits in the following operations:

- Modular exponentiation/inversion
- Modular/regular addition/subtraction
- Modular/regular increment/decrement
- Modular/regular multiplication/division
- Logical operations (AND, OR, XOR, SHIFT)

The PKA engine can be used to hardware accelerate various arithmentic regular and modular mathematical operations involving very large numbers which are used in both RSA and Elliptic Curve Cryptographic (ECC) public-key cryptosystems.

6.1.12.4.1 Virtual memory mapping

The PKA engine uses virtual register mapping to facilitate flexible data management across a variety of cryptographic algorithms.

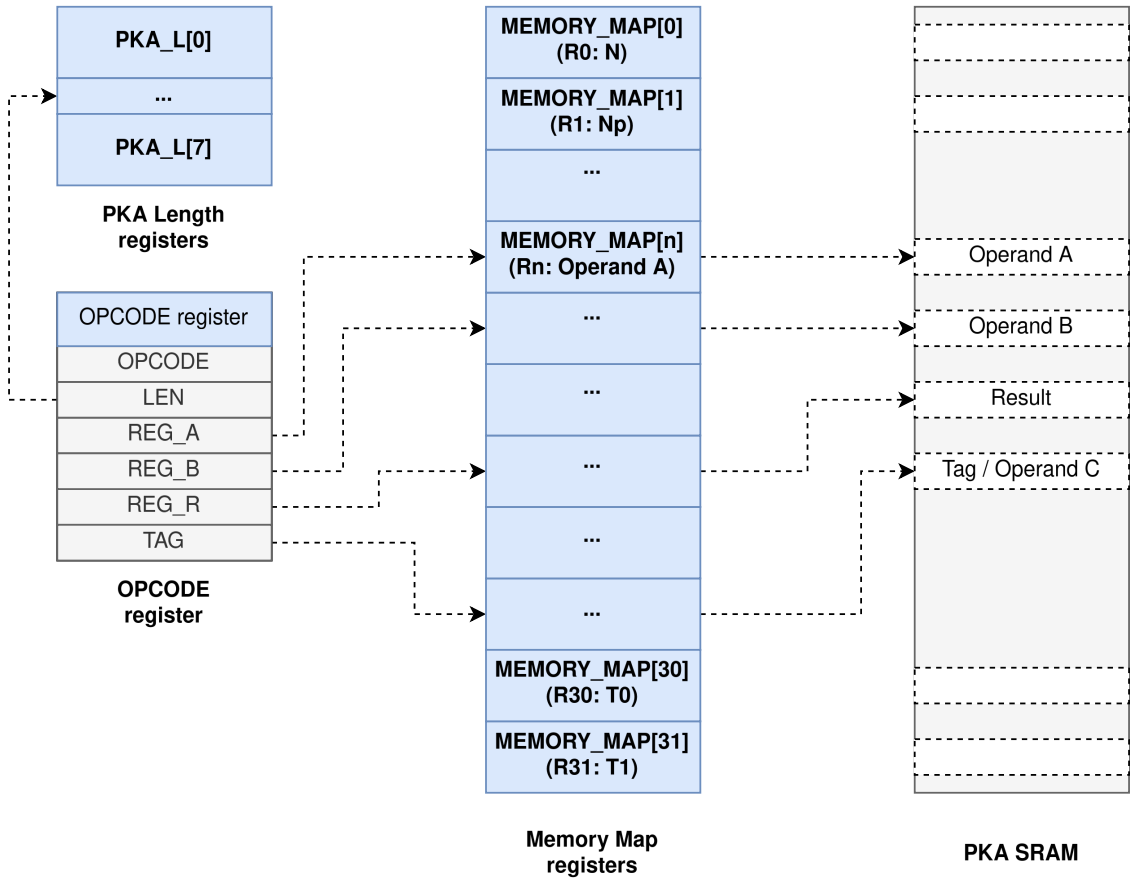

Figure 16: Virtual register mapping

All virtual registers must be defined and configured in the dedicated PKA SRAM on page 114 before they can be accessed by the PKA engine during processing. This SRAM acts as a private memory pool for the PKA engine, where all other access is blocked during processing. The virtual registers are used as input for the PKA calculation and as a placeholder for intermediate and final results.

The PKA engine can be configured to perform multiple operations on virtual operand registers and store the result of the operation in a virtual result or intermediate result register. During the next iteration the PKA engine can then use an intermediate result register from a previous operation as a virtual operand register for further calculations. This re-mapping strategy enables the PKA engine to efficiently handle complex cryptographic operations.

In total there are 32 virtual registers that can be mapped to different PKA SRAM regions using register MEMORY_MAP[n] (n=0..31) on page 116, denoted as virtual register R0 - R31. Four of these 32 virtual registers are special registers, and their register index mapping can be changed using register N_NP_T0_T1_ADDR on page 117:

- N - holds the modulus number, by default mapped to virtual register R0. This register is used by the PKA engine for modular operations, and its modulus N value does not change during processing.
- Np - holds the inverse modulus number, by default mapped to virtual register R1. This register is used by the PKA engine for the Barrett reduction algorithm, and its inverse modulus Np value does not change during processing.
- T0 - temporary register, by default mapped to virtual register R30. This register is for internal use by the PKA engine.
- T1 - temporary register, by default mapped to virtual register R31. This register is for internal use by the PKA engine.

All virtual registers must be 64 bits word size aligned, and the size of the virtual registers must be at least the size of the largest operand plus an extra 64 bits for internal PKA calculations. These extra 64 bits must be initialized to zero. This is applicable for all virtual registers R0 - R31. The configured virtual register size does not define the size of the operation, it only limits the largest operand size that can be used with the corresponding virtual register.

The memory map configuration can be altered dynamically by the PKA engine, depending on the operation. Not all virtual registers need to be configured for each operation. It is recommended to re-write the memory map configuration after a reset.

6.1.12.4.2 Engine operations

The PKA engine can perform multiple operations on operands stored in virtual registers.

PKA processing is triggered by writing to register OPCODE on page 117. This register contains both the PKA operation to perform, and which virtual register indexes to use as operand inputs, tag, and intermediate or final result output of the operation. Register PKA_DONE on page 119 will indicate `Processing` until the PKA operation is done, after which the result can be read from the result register in PKA SRAM.

The following OPCODE virtual register indexes must be configured prior to starting the PKA engine:

- Field `REG_R` configure which virtual register to use for storing an intermediate or final result.
- Field `REG_A` and `REG_B` configure which virtual registers to use as operand input. The operand input fields can be interpreted by the PKA engine as constants instead of virtual register indexes by setting fields `CONST_A` and `CONST_B` for certain operations, as documented in the table below.
- The size of the operands are set in field `LEN`, which must point to one of the pre-configured operand sizes in bits configured in register PKA_L[n] (n=0..7) on page 118.

6.1.12.4.2.1 OPCODE overview

Supported PKA operation codes and the corresponding required virtual register configurations.

OPCODE	Operation
Terminate	Terminate ongoing PKA operation
AddInc	Add or Increment • ADD: `REG_R = REG_A + REG_B` • INC: `REG_R = REG_A + 0x1`, when `REG_B` and `CONST_B` are 0x1
SubDecNeg	Subtract, Decrement, or Negate • SUB: `REG_R = REG_A - REG_B` • DEC: `REG_R = REG_A - 0x1`, when `REG_B` and `CONST_B` are 0x1 • NEG: `REG_R = 0x0 - REG_B`, when `REG_A` is 0x0 and `CONST_A` is 0x1
ModAddInc	Modular Add or Modular Increment • ModADD: `REG_R = (REG_A + REG_B) % REG_N` • ModINC: `REG_R = (REG_A + 0x1) % REG_N`, when `REG_B` and `CONST_B` are 0x1
ModSubDecNeg	Modular Subtract, Modular Decrement, or Modular Negate • ModSUB: `REG_R = (REG_A - REG_B) % REG_N` • ModDEC: `REG_R = (REG_A - 0x1) % REG_N`, when `REG_B` and `CONST_B` is 0x1 • ModNEG: `REG_R = (0x0 - REG_B) % REG_N`, when `REG_A` is 0x0
ANDTST0CLR0	And, Test bit 0, or Clear • AND: `REG_R = REG_A & REG_B` • TST0: `REG_R = REG_A & 0x1`, when `REG_B` is 0x1, and `CONST_B` is 0x1 • CLR: `REG_R = 0x0`, when `REG_B` is 0x0 and `CONST_B` is 0x1. `REG_A` is ignored.
ORCOPYSET0	Or, Copy, or Set bit 0 • OR: `REG_R = REG_A | REG_B` • COPY: `REG_R = REG_A`, when `REG_B` is 0x0 and `CONST_B` is 0x1. • SET0: `REG_R = REG_A | 0x1`, when `REG_B` and `CONST_B` is 0x1.
XORFLP0INVCMP	XOR, Flip bit 0, Invert, or Compare • XOR: `REG_R = REG_A XOR REG_B` • FLP0: `REG_R = REG_A XOR 0x1`, when `REG_B` and `CONST_B` is 0x1. • INV: `REG_R = REG_A XOR 0xFFFFFFFF`, when `REG_B` is 0x1F and `CONST_B` is 0x1. • CMP: `REG_A XOR REG_B`, when `DISCARD_R` is 0x1, result of comparison is provided by the `ALU_OUT_ZERO` flag in PKA_STATUS register.
SHR0	Shift right 0. This operation performs a logical right shift on the contents of `REG_A` by a specified number of bit positions and stores the result in `REG_R`. The leftmost bits of `REG_R` that are vacated by the shift operation are filled with zeros. `REG_R = REG_A >> s`, `CONST_B` must be set to 0x1. To perform `s` shifts, `REG_B` should be set to `s - 1` (where `1 <= s <= 31`).
SHR1	Shift right 1. This operation performs a logical right shift on the contents of `REG_A` by a specified number of bit positions and stores the result in `REG_R`. The leftmost bits of `REG_R` that are vacated by the shift operation are filled with ones. `REG_R = REG_A >> s`, `CONST_B` must be set to 0x1. To perform `s` shifts, `REG_B` should be set to `s - 1` (where `1 <= s <= 31`).
SHL0	Shift left 0. This operation performs a logical left shift on the contents of `REG_A` by a specified number of bit positions and stores the result in `REG_R`. The leftmost bits of `REG_R` that are vacated by the shift operation are filled with zeros. `REG_R = REG_A << s`, `CONST_B` must be set to 0x1. To perform `s` shifts, `REG_B` should be set to `s - 1` (where `1 <= s <= 31`).
SHL1	Shift left 1. This operation performs a logical left shift on the contents of `REG_A` by a specified number of bit positions and stores the result in `REG_R`. The leftmost bits of `REG_R` that are vacated by the shift operation are filled with ones. `REG_R = REG_A << s`, `CONST_B` must be set to 0x1. To perform `s` shifts, `REG_B` should be set to `s - 1` (where `1 <= s <= 31`).
MulLow	Multiply Low. This operation performs a multiplication of the values in `REG_A` and `REG_B` and stores the result in the destination register `REG_R`. Any bits of the product that exceed the operand size are discarded, effectively keeping only the least significant bits (LSBs) that fit within the operand size.

OPCODE	Operation
	`REG_R = (REG_A * REG_B) & operand size mask`
ModMul	Modular Multiply. `REG_R = (REG_A * REG_B) % REG_N`
ModMulN	The output of this operation is a number that is potentially larger than the modulus `N`, but guaranteed to be smaller than `2N`. Assuming `REG_A` and `REG_B` are already reduced modulo `N` or are less than `N`, the operation is simply `REG_R = (REG_A * REG_B)`.
ModExp	Modular Exponentiation. `REG_R = (REG_A ^ REG_B) % REG_N`
Division	Integer Division. This operation performs integer division of the value in `REG_A` by the value in `REG_B`. The quotient of the division is stored in `REG_R`, and the remainder is stored back in `REG_A`. • `REG_R = REG_A / REG_B` • `REG_A = REG_A % REG_B` If `REG_B` is zero (0x0), the operation is invalid, and the divide by zero bit in the status register is set to indicate a division error.
ModInv	Modular Inversion. `REG_R = 1/REG_B % REG_N`
ModDiv	Modular division is done by calculating the modular inverse of the divisor, check that the inverse value exists by examining the GCD, and then use modular multiplication to multiply the inverse result by the divided. `REG_A = (REG_A * REG_B^(-1)) % REG_N`
MulHigh	Multiply High. This operation multiplies `REG_A` by `REG_B` and captures the high-order bits of the result that exceed the operand size. It places these significant bits, along with an additional `PKA_WORD` number of bits, into the destination register `REG_R`. `REG_R = (REG_A * REG_B) >> operand size`
ModMLAC	Modular Multiplication Acceleration. Performs a modular multiplication and addition. `REG_C` is defined using the operation tag. `REG_R = ((REG_A * REG_B) + REG_C) % REG_N`
ModMLACNR	Modular Multiplication Acceleration No Reduction. Same as ModMLAC, but this omits the final reduction of the result.
Reduction	Reduction. This operation performs a modular reduction, where the result `REG_R` is the remainder of `REG_A` divided by `REG_N`. The length of the operation is flexible and can be chosen based on the specific requirements of the use case. `REG_R = REG_A % REG_N`

Table 17: PKA OPCODE descriptions

6.1.12.4.3 Pipeline configuration

The following section describe how the PKA engine is used to accelerate asymmetric cryptographic algorithms.

The PKA engine supports pipelined operations; the pipeline depth is one opcode, thus the next operation can be set up while the previous operation is executing. Register PKA_PIPE on page 119 will indicate if the pipeline is ready for a new opcode and register PKA_DONE on page 119 will indicate when the PKA operation has been completed and no operation is waiting in the pipeline.

1. Enable CRYPTOCELL subsystem as described in Cryptographic flow on page 86.
2. Initialize the PKA engine to accommodate the maximum bit size of all intended operations
   a. Configure registers PKA_L[n] (n=0..7) on page 118 for all required operand bit sizes. The desired operand length is selected using field `LEN` in register OPCODE on page 117.
   b. Define the PKA SRAM memory map partitioning using register MEMORY_MAP[n] (n=0..31) on page 116 for register `N`, `Np`, `T0`, and `T1`, as well as any other virtual registers intended to be used in the operations. The PKA SRAM memory map partitioning must allow for the max operand bit size plus an additional 64 bits reserved for PKA engine internal calculations.
3. For all operations

   a. Load the PKA SRAM virtual registers `N` and `Np` as required
   b. Load the remaining PKA SRAM virtual registers as required
   c. Execute the operation by writing register OPCODE on page 117
   d. Prepare the next opcode once register PKA_PIPE on page 119 is ready.
   e. Handle any status bits in register PKA_STATUS on page 118
   f. Re-use intermediate results of the previous operation as needed.
4. Wait for the operation to complete by either polling register PKA_DONE on page 119, or by unmasking the interrupt for field `PKA_MASK` in register IMR on page 144
5. Read the result from the result register.

6.1.12.4.4 PKA SRAM

The 4 kB PKA SRAM memory connected to the PKA engine is used exclusively by the engine during cryptographic operations. All access to this memory is blocked while the PKA engine is processing.

The PKA SRAM memory is not directly mapped to the device memory map. Instead, any read or write operation to this memory region must be done using the PKA engine on page 110.

Writing data to the PKA SRAM involves the following steps:

1. **Set the Address Offset**: Specify the starting byte address for writing by setting register PKA_SRAM_WADDR on page 119. An offset value of `0x0` points to the first 32-bits word in the PKA SRAM memory. An offset value of `0x10` points to the fourth 32-bits word in the PKA SRAM memory.
2. **Write Data**: After setting the address offset, data is written to register PKA_SRAM_WDATA on page 120. The address will automatically increment after each write, allowing writes to the next word without needing to set the offset again.

Reading data from the PKA SRAM involves the following steps:

1. **Set the Read Address**: Specify the starting byte address for reading by setting register PKA_SRAM_RADDR on page 120
2. **Read Data**: Retrieve the data from register PKA_SRAM_RDATA on page 120. Similar to the write address, the read address will auto-increment with each read, setting it to the next word.

Note: Before switching from writing to reading operations (or vice versa), the PKA SRAM write buffer must be cleared. This is done using register PKA_SRAM_WCLEAR on page 120. Clearing the buffer ensures that the next operation starts cleanly without any leftover data from the previous operation.

6.1.12.4.5 Cryptographic flow

The following section describe a simple cryptographic flow for this engine.

```
/* Enable CRYPTOCELL and its PKA engine */
NRF_CRYPTOCELL->ENABLE = CRYPTOCELL_ENABLE_ENABLE_Enabled;
NRF_CC_MISC->PKA_CLK = CC_MISC_PKA_CLK_ENABLE_Enable;

/* Define the operand bit size as 2048 */
NRF_CC_PKA->PKA_L[1] = 0x800;

/* Define the 32-bits PKA SRAM address of the selected R4 and R5 */
NRF_CC_PKA->MEMORY_MAP[4] = 0x108;
NRF_CC_PKA->MEMORY_MAP[5] = 0x14A;

/* Initialize the SRAM registers with one word of data */
NRF_CC_PKA->PKA_SRAM_WADDR = NRF_CC_PKA->MEMORY_MAP[4];
NRF_CC_PKA->PKA_SRAM_WDATA = 0x5;
NRF_CC_PKA->PKA_SRAM_WADDR = NRF_CC_PKA->MEMORY_MAP[5];
NRF_CC_PKA->PKA_SRAM_WDATA = 0x2;

/* Execute subtract, OPCODE SubDecNeg: R4 = R4 - R5 */
NRF_CC_PKA->OPCODE =
    (4 << CC_PKA_OPCODE_REG_R_Pos) |
    (5 << CC_PKA_OPCODE_REG_B_Pos) |
    (4 << CC_PKA_OPCODE_REG_A_Pos) |
    (1 << CC_PKA_OPCODE_LEN_Pos)   |
    (CC_PKA_OPCODE_OPCODE_SubDecNeg << CC_PKA_OPCODE_OPCODE_Pos);

/* Wait for operation to complete, result will be in R4 */
while (!NRF_CC_PKA->PKA_DONE) { }
```

This cryptographic flow example perform a subtract operation with the following assumptions:

- All PKA SRAM registers, including the special virtual registers `N`, `Np`, `T0`, and `T1`, have been cleared before the operation is run.
- The operation is using index 1 in register PKA_L[n] (n=0..7) on page 118, which is set to accommodate an operand size of 2048 bits.
- Register `R4` and `R5` have been selected to run this operation. Register `R4` is used both as the operand A register and the result register.
- The memory map is configured to allow operands of 2048 bits plus an additional 64 bits for the internal PKA engine calculations. The configuration of the MEMORY_MAP[n] (n=0..31) on page 116 for virtual register `N`, `Np`, `T0`, and `T1` is not included in the example. The memory map is thus configured with 66 words per register, leading to the following:

Virtual register	Memory map register	PKA SRAM address
N (R0)	MEMORY_MAP[0]	0x0
Np (R1)	MEMORY_MAP[1]	0x42
...	...	...
R4	MEMORY_MAP[4]	0x108
R5	MEMORY_MAP[5]	0x14A
...	...	...

6.1.12.4.6 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_PKA	0x50841000	HF	S	NSA	No	CRYPTOCELL PKA engine

Register overview

Register	Offset	TZ	Description
MEMORY_MAP[n]	0x0		Register for mapping the virtual register R[n] to a physical address in the PKA SRAM.
OPCODE	0x80		Operation code to be executed by the PKA engine. Writing to this register triggers the PKA operation.
N_NP_T0_T1_ADDR	0x84		This register defines the N, Np, T0, and T1 virtual register index.
PKA_STATUS	0x88		This register holds the status for the PKA pipeline.
PKA_SW_RESET	0x8C		Reset the PKA engine.
PKA_L[n]	0x90		This register holds the operands bit size.
PKA_PIPE	0xB0		Status register indicating if the PKA pipeline is ready to receive a new OPCODE.
PKA_DONE	0xB4		Status register indicating if the PKA operation has been completed.
PKA_VERSION	0xC4		PKA engine HW version. Reset value holds the version.
PKA_SRAM_WADDR	0xD4		Start address in PKA SRAM for subsequent write transactions.
PKA_SRAM_WDATA	0xD8		Write data to PKA SRAM. Writing to this register triggers a DMA transaction writing data into PKA SRAM. The DMA address offset is automatically incremented during write.
PKA_SRAM_RDATA	0xDC		Read data from PKA SRAM. Reading from this register triggers a DMA transaction read data from PKA SRAM. The DMA address offset is automatically incremented during read.
PKA_SRAM_WCLEAR	0xE0		Register for clearing PKA SRAM write buffer.
PKA_SRAM_RADDR	0xE4		Start address in PKA SRAM for subsequent read transactions.

6.1.12.4.6.1 MEMORY_MAP[n] (n=0..31)

Address offset: 0x0 + (n × 0x4)

Register for mapping the virtual register R[n] to a physical address in the PKA SRAM.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																							A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ADDR			The physical word address used for the virtual register.

6.1.12.4.6.2 OPCODE

Address offset: 0x80

Operation code to be executed by the PKA engine.

Writing to this register triggers the PKA operation.

Bit number					31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID					I	I	I	I	I	H	H	H	G	F	F	F	F	F	E	D	D	D	D	D	C	B	B	B	B	B	A	A	A	A	A	A
Reset 0x00000000					**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field		Value ID																																
A	RW	TAG																																		
B	RW	REG_R																																		
C	RW	DISCARD_R																																		
				Register																																
				Discard																																
D	RW	REG_B																																		
E	RW	CONST_B																																		
				Register																																
				Constant																																
F	RW	REG_A																																		
G	RW	CONST_A																																		
				Register																																
				Constant																																
H	RW	LEN																																		
I	RW	OPCODE																																		
				Terminate																																
				AddInc																																
				SubDecNeg																																
				ModAddInc																																
				ModSubDecNeg																																
				ANDTST0CLR0																																
				ORCOPYSET0																																
				XORFLP0INVCMP																																
				SHR0																																
				SHR1																																
				SHL0																																
				SHL1																																
				MulLow																																
				ModMul																																
				ModMulN																																
				ModExp																																
				Division																																
				ModInv																																
				ModDiv																																
				MulHigh																																
				ModMLAC																																
				ModMLACNR																																
				Reduction																																

ID	R/W	Field	Value ID	Value	Description
A	RW	TAG			Holds the operation tag or the operand C virtual register index.
B	RW	REG_R			Result register virtual register index.
C	RW	DISCARD_R			This field controls the interpretation of REG_R.
			Register	0x0	REG_R is intepreted as a register index.
			Discard	0x1	Result is discarded.
D	RW	REG_B			Operand B virtual register index.
E	RW	CONST_B			This field controls the interpretation of REG_B.
			Register	0x0	REG_B is intepreted as a register index.
			Constant	0x1	REG_B is intepreted as a constant.
F	RW	REG_A			Operand A virtual register index.
G	RW	CONST_A			This field controls the interpretation of REG_A.
			Register	0x0	REG_A is intepreted as a register index.
			Constant	0x1	REG_A is intepreted as a constant.
H	RW	LEN			The length of the operands. This value serves as an PKA length register index. E.g.: if LEN field value is set to 0, PKA_L[0] holds the size of the operands.
I	RW	OPCODE			Operation code to be executed by the PKA engine
			Terminate	0x0	Terminate operation
			AddInc	0x4	Add or Increment
			SubDecNeg	0x5	Subtract, Decrement, or Negate
			ModAddInc	0x6	Modular Add or Modular Increment
			ModSubDecNeg	0x7	Modular Subtract, Modular Decrement, or Modular Negate
			ANDTST0CLR0	0x8	Perform AND, test, or clear
			ORCOPYSET0	0x9	Perform OR, copy, or set bits
			XORFLP0INVCMP	0xA	Perform XOR, flip bits, invert, or compare
			SHR0	0xC	Shift right 0 operation
			SHR1	0xD	Shift right 1 operation
			SHL0	0xE	Shift left 0 operation
			SHL1	0xF	Shift left 1 operation
			MulLow	0x10	Multiply low operation
			ModMul	0x11	Modular multiply operation
			ModMulN	0x12	Modular multiply N operation
			ModExp	0x13	Modular exponentiation operation
			Division	0x14	Division operation
			ModInv	0x15	Modular inversion operation
			ModDiv	0x16	Modular division operation
			MulHigh	0x17	Multiply high operation
			ModMLAC	0x18	Modular multiplication acceleration
			ModMLACNR	0x19	Modular multiplication acceleration where final reduction is omitted
			Reduction	0x1B	Reduction operation

6.1.12.4.6.3 N_NP_T0_T1_ADDR

Address offset: 0x84

This register defines the N, Np, T0, and T1 virtual register index.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																D	D	D	D	D	C	C	C	C	C	B	B	B	B	B	A	A	A	A	A
Reset 0x000FF820				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	N_VIRTUAL_ADDR																																	
B	RW	NP_VIRTUAL_ADDR																																	
C	RW	T0_VIRTUAL_ADDR																																	
D	RW	T1_VIRTUAL_ADDR																																	

6.1.12.4.6.4 PKA_STATUS

Address offset: 0x88

This register holds the status for the PKA pipeline.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																K	K	K	K	J	I	H	G	F	E	D	C	B	B	B	B	A	A	A	A
Reset 0x00001000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	ALU_MSB_4BITS																																	
B	R	ALU_LSB_4BITS																																	
C	R	ALU_SIGN_OUT																																	
D	R	ALU_CARRY																																	
E	R	ALU_CARRY_MOD																																	
F	R	ALU_SUB_IS_ZERO																																	
G	R	ALU_OUT_ZERO																																	
H	R	ALU_MODOVRFLW																																	
I	R	DIV_BY_ZERO																																	
J	R	MODINV_OF_ZERO																																	
K	R	OPCODE																																	

6.1.12.4.6.5 PKA_SW_RESET

Address offset: 0x8C

Reset the PKA engine.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	RESET																																	
			Enable	1																															

6.1.12.4.6.6 PKA_L[n] (n=0..7)

Address offset: 0x90 + (n × 0x4)

This register holds the operands bit size.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	OpSize			Operand bit size.

6.1.12.4.6.7 PKA_PIPE

Address offset: 0xB0

Status register indicating if the PKA pipeline is ready to receive a new OPCODE.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			PKA pipeline status.
			NotReady	0	PKA pipeline is not ready for a new OPCODE
			Ready	1	PKA pipeline is ready for a new OPCODE

6.1.12.4.6.8 PKA_DONE

Address offset: 0xB4

Status register indicating if the PKA operation has been completed.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			PKA operation status.
			Processing	0	PKA operation is processing
			Completed	1	PKA operation is completed and pipeline is empty

6.1.12.4.6.9 PKA_VERSION

Address offset: 0xC4

PKA engine HW version. Reset value holds the version.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x16110215				**0 0 0 1 0 1 1 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 1 0 1 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	PKA_VERSION			

6.1.12.4.6.10 PKA_SRAM_WADDR

Address offset: 0xD4

Start address in PKA SRAM for subsequent write transactions.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	ADDR																																	
				PKA SRAM start address for write transaction																															

6.1.12.4.6.11 PKA_SRAM_WDATA

Address offset: 0xD8

Write data to PKA SRAM. Writing to this register triggers a DMA transaction writing data into PKA SRAM. The DMA address offset is automatically incremented during write.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	DATA																																	
				Data to write to PKA SRAM.																															

6.1.12.4.6.12 PKA_SRAM_RDATA

Address offset: 0xDC

Read data from PKA SRAM. Reading from this register triggers a DMA transaction read data from PKA SRAM. The DMA address offset is automatically incremented during read.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	DATA																																	
				Data to read from PKA SRAM																															

6.1.12.4.6.13 PKA_SRAM_WCLEAR

Address offset: 0xE0

Register for clearing PKA SRAM write buffer.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	CLEAR																																	
				Clear the PKA SRAM write buffer.																															

6.1.12.4.6.14 PKA_SRAM_RADDR

Address offset: 0xE4

Start address in PKA SRAM for subsequent read transactions.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	ADDR																																	
				PKA SRAM start address for read transaction																															

6.1.12.5 RNG engine

CRYPTOCELL implements a Random Number Generator (RNG) engine which uses a True Random Number Generator (TRNG) for its entropy collection.

The TRNG is a full entropy design compliant with:

- FIPS 140-2: *Security requirements for Cryptographic Modules*
- BSI AIS-31: *Functionality Classes and Evaluation Methodology for True Random Number Generators*
- NIST SP 800-90B: *Recommendation for the Entropy Sources Used for Random Bit Generation*

where a ring-oscillator is used as the noise source.

The entropy collected using the RNG engine can in turn be used for seeding a Pseudo Random Number Generator (PRNG) as defined in NIST SP 800-90A: *Recommendation for Random Number Generation Using Deterministic Random Bit Generators.*

NIST SP 800-90A define three Deterministic Random Bit Generator (DRBG) that are considered cryptographically secure pseudorandom number generators for use in cryptography: Hash DRBG, HMAC DRBG, and CTR DRBG.

The CRYPTOCELL DRBG implementation is a combination of hardware and software, where CTR DRBG is implemented using the the AES engine running AES encryption in counter (CTR) mode as the underlying cipher. This DRBG instance is seeded with random entropy from the RNG engine.

6.1.12.5.1 Ring oscillator length configuration

The RNG engine must be configured with specific parameters to ensure correct operation in order to output random bits with sufficient entropy.

The noise source used for collecting entropy is based on inverter timing jitter that is collected from a dedicated on-chip free-running ring oscillator. The ring oscillator length, i.e. the number of inverters in the chain, can be configured using register TRNG_CONFIG on page 127.

In total there are four different ring oscillator lengths that can be selected, referred to as ROSC1 through ROSC4. For each of these four configurable lengths a corresponding sample count value is provided in register TRNG90B.ROSC1 on page 41 through register TRNG90B.ROSC4 on page 42.

The sampling frequency is configured using register SAMPLE_CNT on page 128, and the programmed value defines the number of CPU clock cycles between two consecutive ring oscillator samples. The configured sample count value is the minimum number of clock cycles that is enough to get independent outputs from the ring oscillator and must match that of the configured ROSC length.

The following steps describe how to set the RNG engine parameters described above:

1. Enable RNG engine clock using register RNG_CLK on page 130.
2. Reset the RNG engine using register RNG_SW_RESET on page 129.
3. Re-enable RNG engine clock and select a device-specific sample count from registers TRNG90B.ROSC1 on page 41 through TRNG90B.ROSC4 on page 42 starting with the smallest one, and program the value into register SAMPLE_CNT on page 128.
4. Perform a readback of the selected sample count value.
5. Set the corresponding ROSC length in register TRNG_CONFIG on page 127 to match the selected sample count selection.
6. Enable the noise source using register NOISE_SOURCE on page 127.
7. Wait until event `EHR_VALID_INT` in register RNG_ISR on page 126 trigger to indicate successful collection of 192 bits of random data. The result can be read from registers EHR_DATA[n] (n=0..5) on page 127.
8. If events `AUTOCORR_ERR_INT`, `CRNGT_ERR_INT`, or `VNC_ERR_INT` in register RNG_ISR on page 126 trigger, the RNG engine must be re-configured starting from step 2 above. Increase the ROSC length by a factor of one, and pick the corresponding sample count value from FICR. This step must be

repeated until the collection of 192 bits of random data can be collected without an error event being triggered.

It is recommended to always try the shortest ROSC length first, allowing the RNG engine to complete the entropy collection in a shorter time and keep the ring oscillator turned off for longer periods in order to save power.

6.1.12.5.2 RNG SRAM

The 2 kB SRAM memory connected to the RNG engine can be used for storing a large pool of random entropy.

The RNG SRAM memory is not directly mapped to the device memory map. Instead, any read or write operation using word granularity to this memory region must be done using RNG SRAM interface on page 149. Larger payloads than word granularity can be processed using the DIN DMA engine on page 135 and DOUT DMA engine on page 139.

Before any RNG SRAM read or write transaction can be performed, the CRYPTOCELL must be enabled.

Writing data to the RNG SRAM involves the following steps:

1. **Set the Address Offset**: Specify the starting byte address for writing by setting register SRAM_ADDR on page 149. An offset value of `0x0` points to the first 32-bits word in the RNG SRAM memory. An offset value of `0x10` points to the fourth 32-bits word in the RNG SRAM memory.
2. **Write Data**: When register SRAM_DATA_READY on page 150 indicates DMA engine is idle, data is written to register SRAM_DATA on page 149. The address will automatically increment after each write, allowing writes to the next word without needing to set the offset again.

Reading data from the RNG SRAM involves the following steps:

1. **Set the Read Address**: Specify the starting byte address for reading by setting register SRAM_ADDR on page 149
2. **Discard first read**: Read and discard the first value from register SRAM_DATA on page 149, as it will contain the previous value pointed to by register SRAM_ADDR on page 149.
3. **Read Data**: When register SRAM_DATA_READY on page 150 indicates DMA engine is idle, retrieve the data from register SRAM_DATA on page 149. Similar to the write address, the read address will auto-increment with each read, setting it to the next word.

Note: Once the address register reaches the last RNG SRAM address, the automatic address incrementation halts. Any subsequent read or write transaction will cause the DMA engine to continue operating on the last 32-bits word in the RNG SRAM memory.

6.1.12.5.3 TRNG hardware tests

The RNG engine has a number of built-in hardware tests for making sure the collected entropy from the TRNG is of sufficient quality.

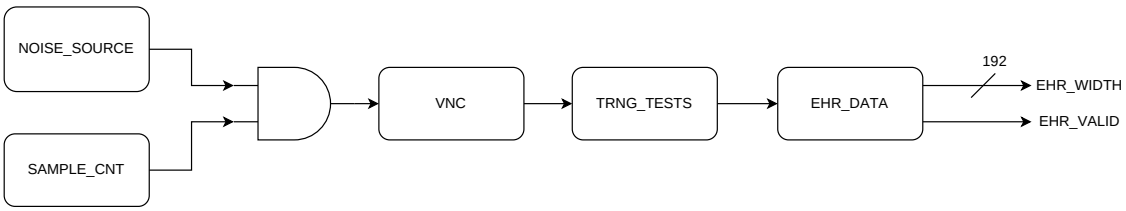

Figure 17: CRYPTOCELL True Random Number Generator

The TRNG collects random bits from the noise source according to the programmed sample counter value in register SAMPLE_CNT on page 128. The sampled bits are post-processed in a von Neumann corrector (VNC) before being subjected to a continuous random number generation test (CRNGT) and autocorrelation test.

192 bits of random data can be read from the entropy holding registers EHR_DATA[n] (n=0..5) on page 127 once interrupt EHR_VALID_INT in register RNG_ISR on page 126 trigger. If this interrupt is masked away in register RNG_IMR on page 125, the status register TRNG_VALID on page 127 contains field EHR_DATA which can be polled when the random data is valid. Reading the most significant word from EHR_DATA registers will reset register TRNG_VALID and a new 192 bits collection period will start.

Note:

To ensure proper operation when reading 192 bits of random data from the EHR_DATA registers of the RNG engine the data must be read in ascending order, starting with:

- EHR_DATA[0]
- EHR_DATA[1]
- EHR_DATA[2]
- EHR_DATA[3]
- EHR_DATA[4]
- EHR_DATA[5]

6.1.12.5.3.1 von Neumann Corrector

The von Neumann Corrector (VNC) is designed to balance the succession of '1' and '0' bits being output by the TRNG noise source.

The input bits to the VNC is tested for bit equality, meaning a sequence of 32 consequtive bits with the same bit value will trigger event VNC_ERR_INT in register RNG_ISR on page 126.

If no error event is triggered, the input bits will be balanced using the VNC as shown in the figure below, and the resulting output bits will be subjected to additional TRNG tests. The VNC produce output only if the noise source is active, see register NOISE_SOURCE on page 127.

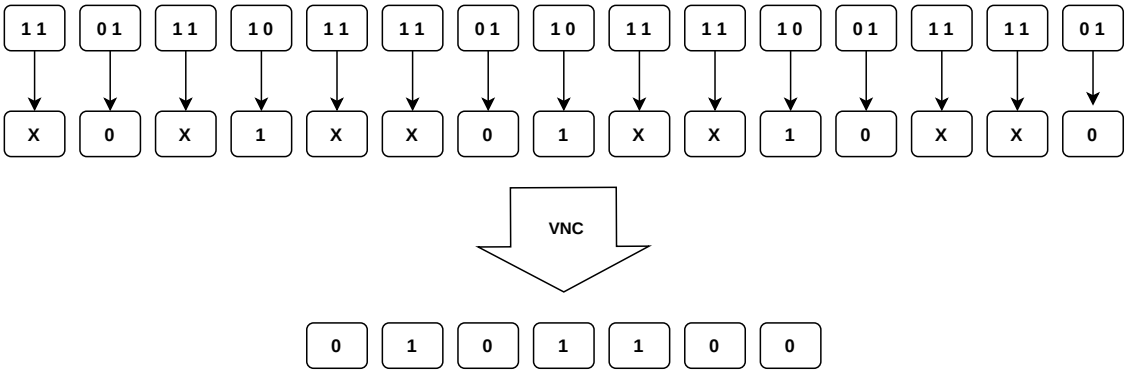

Figure 18: CRYPTOCELL von Neumann corrector

The VNC statistically output one bit for each 4 input bits sampled, meaning the average output rate of the TRNG is 1/(SAMPLE_CNT * 4) bits per CPU clock cycle.

6.1.12.5.3.2 Continuous random number generation test

The Continuous random number generation test (CRNGT) process the balanced output of random data from the von Neumann corrector.

In the event that two consecutive blocks of 16 collected bits are equal, the CRNGT will trigger event CRNGT_ERR_INT in register RNG_ISR on page 126.

6.1.12.5.3.3 Autocorrelation test

The Autocorrelation test determine if there over time is a bias in the random bit sequences towards certain values or patterns, or if the bits in the sequence are truly independent.

If a bias in the collected bit stream is detected, the output will be discarded and the error flagged in register AUTOCORR_STATISTIC on page 128. If a bias is detected four consecutive times in a row, the autocorrelation test will trigger event AUTOCORR_ERR_INT in register RNG_ISR on page 126. In this situation the TRNG will cease to function until manually reset using register RNG_SW_RESET on page 129.

6.1.12.5.4 Cryptographic flow

The following section describe a simple cryptographic flow for this engine.

```
/* Enable CRYPTOCELL subsystem */
NRF_CRYPTOCELL->ENABLE = CRYPTOCELL_ENABLE_ENABLE_Enabled;

/* Enable engine clock */
NRF_CC_RNG->RNG_CLK = CC_RNG_RNG_CLK_ENABLE_Enable;

/* Reset engine */
NRF_CC_RNG->RNG_SW_RESET = CC_RNG_RNG_SW_RESET_RESET_Enable;

/* Configure sampling rate between consecutive bits */
do {
    NRF_CC_RNG->RNG_CLK = CC_RNG_RNG_CLK_ENABLE_Enable;
    NRF_CC_RNG->SAMPLE_CNT = NRF_FICR->TRNG90B.ROSC1;
} while ( NRF_CC_RNG->SAMPLE_CNT != NRF_FICR->TRNG90B.ROSC1 );

/* Configure ROSC length */
NRF_CC_RNG->TRNG_CONFIG = CC_RNG_TRNG_CONFIG_ROSC_LEN_ROSC1;

/* Enable noise source */
NRF_CC_RNG->NOISE_SOURCE = CC_RNG_NOISE_SOURCE_ENABLE_Enabled;

/* Wait for random data to be sampled */
while ((NRF_CC_RNG->RNG_ISR & CC_RNG_RNG_ISR_EHR_VALID_INT_Msk) == 0) {}

/* 192 bits of random data now available in
   NRF_CC_RNG->EHR_DATA[0] to NRF_CC_RNG->EHR_DATA[5] */
```

6.1.12.5.5 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_RNG	0x50841000	HF	S	NSA	No	CRYPTOCELL RNG engine

Register overview

Register	Offset	TZ	Description
RNG_IMR	0x100		Interrupt mask register. Each bit of this register holds the mask of a single interrupt source.

Register	Offset	TZ	Description
RNG_ISR	0x104		Interrupt status register. Each bit of this register holds the interrupt status of a single interrupt source. If corresponding RNG_IMR bit is unmasked, an interrupt is generated.
RNG_ICR	0x108		Interrupt clear register. Writing a 1 bit into a field in this register will clear the corresponding bit in RNG_ISR.
TRNG_CONFIG	0x10C		TRNG ring oscillator length configuration
TRNG_VALID	0x110		This register indicates if TRNG entropy collection is valid.
EHR_DATA[n]	0x114		The entropy holding registers (EHR) hold 192-bits random data collected by the TRNG. The initial EHR_DATA[0] register holds the least significant bits [31:0] of the random data value.
NOISE_SOURCE	0x12C		This register controls the ring oscillator circuit used as a noise source.
SAMPLE_CNT	0x130		Sample count defining the number of CPU clock cycles between two consecutive noise source samples.
AUTOCORR_STATISTIC	0x134		Statistics counter for autocorrelation test activations. Statistics collection is stopped if one of the counters reach its limit of all ones.
TRNG_DEBUG	0x138		Debug register for the TRNG. This register is used to bypass TRNG tests in hardware.
RNG_SW_RESET	0x140		Reset the RNG engine.
RNG_BUSY	0x1B8		Status register for RNG engine activity.
TRNG_RESET	0x1BC		Reset the TRNG, including internal counter of collected bits and registers EHR_DATA and TRNG_VALID.
RNG_HW_FLAGS	0x1C0		Hardware configuration of RNG engine. Reset value holds the supported features.
RNG_CLK	0x1C4		Control clock for the RNG engine.
RNG_DMA	0x1C8		Writing to this register enables the RNG DMA engine.
RNG_DMA_ROSC_LEN	0x1CC		This register defines which ring oscillator length configuration should be used when using the RNG DMA engine.
RNG_DMA_SRAM_ADDR	0x1D0		This register defines the start address in TRNG SRAM for the TRNG data to be collected by the RNG DMA engine.
RNG_DMA_SAMPLES_NUM	0x1D4		This register defines the number of 192-bits samples that the RNG DMA engine collects per run.
RNG_WATCHDOG_VAL	0x1D8		This register defines the maximum number of CPU clock cycles per TRNG collection of 192-bits samples. If the number of cycles for a collection exceeds this threshold the WATCHDOG interrupt is triggered.
RNG_DMA_BUSY	0x1DC		Status register for RNG DMA engine activity.

6.1.12.5.5.1 RNG_IMR

Address offset: 0x100

Interrupt mask register. Each bit of this register holds the mask of a single interrupt source.

Bit number																																
ID																											F	E	D	C	B	A
Reset 0x0000003F									**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field		Value ID		Value																										
A	RW	EHR_VALID_MASK																														
				IRQEnable		0																										
				IRQDisable		1																										
B	RW	AUTOCORR_ERR_MASK																														
				IRQEnable		0																										
				IRQDisable		1																										
C	RW	CRNGT_ERR_MASK																														
				IRQEnable		0																										
				IRQDisable		1																										
D	RW	VNC_ERR_MASK																														

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x0000003F				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
			IRQEnable	0	Do not mask the von Neumann corrector error interrupt i.e. interrupt is generated
			IRQDisable	1	Mask the von Neumann corrector error interrupt i.e. no interrupt is generated
E	RW	WATCHDOG_MASK			See RNG_ISR for explanation on this interrupt.
			IRQEnable	0	Do not mask the watchdog interrupt i.e. interrupt is generated
			IRQDisable	1	Mask the watchdog interrupt i.e. no interrupt is generated
F	RW	DMA_DONE_MASK			See RNG_ISR for explanation on this interrupt.
			IRQEnable	0	Do not mask the RNG DMA completion interrupt i.e. interrupt is generated
			IRQDisable	1	Mask the RNG DMA completion interrupt i.e. no interrupt is generated

6.1.12.5.5.2 RNG_ISR

Address offset: 0x104

Interrupt status register. Each bit of this register holds the interrupt status of a single interrupt source. If corresponding RNG_IMR bit is unmasked, an interrupt is generated.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	EHR_VALID_INT			192-bits have been collected and are ready to be read.
B	R	AUTOCORR_ERR_INT			Autocorrelation error. Failure occurs when autocorrelation test has failed four times in a row. Once set, the TRNG ceases to function until next reset.
C	R	CRNGT_ERR_INT			Continuous random number generator test error. Failure occurs when two consecutive blocks of 16 collected bits are equal.
D	R	VNC_ERR_INT			von Neumann corrector error. Failure occurs if 32 consecutive collected bits are identical, ZERO, or ONE.
E	R	WATCHDOG_INT			Maximum number of CPU clock cycles per sample have been exceeded. See RNG_WATCHDOG_VAL for more information.
F	R	DMA_DONE_INT			RNG DMA to SRAM is completed.

6.1.12.5.5.3 RNG_ICR

Address offset: 0x108

Interrupt clear register. Writing a 1 bit into a field in this register will clear the corresponding bit in RNG_ISR.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	EHR_VALID_CLEAR			Writing value '1' clears corresponding bit in RNG_ISR
B	W	AUTOCORR_ERR_CLEAR			Cannot be cleared by software! Only RNG reset clears this bit.
C	W	CRNGT_ERR_CLEAR			Writing value '1' clears corresponding bit in RNG_ISR
D	W	VNC_ERR_CLEAR			Writing value '1' clears corresponding bit in RNG_ISR
E	W	WATCHDOG_CLEAR			Writing value '1' clears corresponding bit in RNG_ISR
F	W	DMA_DONE_CLEAR			Writing value '1' clears corresponding bit in RNG_ISR

6.1.12.5.5.4 TRNG_CONFIG

Address offset: 0x10C

TRNG ring oscillator length configuration

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																		A	
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
-A	RW	ROSC_LEN																																	
			ROSC1	0																															
			ROSC2	1																															
			ROSC3	2																															
			ROSC4	3																															

Set the length of the oscillator ring (= the number of inverters) out of four possible configurations.

Use shortest ROSC1 ring oscillator configuration.

Use ROSC2 ring oscillator configuration.

Use ROSC3 ring oscillator configuration.

Use longest ROSC4 ring oscillator configuration.

6.1.12.5.5.5 TRNG_VALID

Address offset: 0x110

This register indicates if TRNG entropy collection is valid.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	EHR_DATA																																	
			NotValid	0																															
			Valid	1																															

A value of 1 indicates that collection of bits in the TRNG is completed, and data can be read from EHR_DATA registers.

Collection of bits not valid.

Collection of bits valid.

6.1.12.5.5.6 EHR_DATA[n] (n=0..5)

Address offset: 0x114 + (n × 0x4)

The entropy holding registers (EHR) hold 192-bits random data collected by the TRNG.

The initial EHR_DATA[0] register holds the least significant bits [31:0] of the random data value.

These registers are readable if register TRNG_VALID on page 127 is `Valid`. Reading register EHR_DATA[5] will clear the content, reset TRNG_VALID, and start a new 192 bits collection period.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	VALUE																																	

Random data value.

6.1.12.5.5.7 NOISE_SOURCE

Address offset: 0x12C

This register controls the ring oscillator circuit used as a noise source.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			Enable or disable the noise source.
			Disabled	0	Noise source is disabled
			Enabled	1	Noise source is enabled

6.1.12.5.5.8 SAMPLE_CNT

Address offset: 0x130

Sample count defining the number of CPU clock cycles between two consecutive noise source samples.

After selecting the desired ring oscillator length configuration in TRNG_CONFIG on page 127 this register must be set to the corresponding value from FICR.TRNG90B.ROSC1-4.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x0000FFFF				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE			Number of CPU clock cycles between two consecutive noise source samples. If the von Neumann corrector is bypassed, the minimum value set in this register must not be smaller than decimal 17.

6.1.12.5.5.9 AUTOCORR_STATISTIC

Address offset: 0x134

Statistics counter for autocorrelation test activations. Statistics collection is stopped if one of the counters reach its limit of all ones.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B B B B B A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	AUTOCORR_TRYS			Count each time an autocorrelation test starts. Any write to the field resets the counter.
B	RW	AUTOCORR_FAILS			Count each time an autocorrelation test fails. Any write to the field resets the counter.

6.1.12.5.5.10 TRNG_DEBUG

Address offset: 0x138

Debug register for the TRNG. This register is used to bypass TRNG tests in hardware.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	VNC_BYPASS			Bypass the von Neumann corrector post-processing test, including the 32 consecutive bits test.
			Disabled	0	von Neumann corrector post-processing is active
			Enabled	1	Bypass the von Neumann corrector
B	RW	CRNGT_BYPASS			Bypass the Continuous Random Number Generator Test (CRNGT).
			Disabled	0	CRNGT is active
			Enabled	1	Bypass CRNGT
C	RW	AUTOCORR_BYPASS			Bypass the autocorrelation test.
			Disabled	0	Autocorrelation test is active
			Enabled	1	Bypass the autocorrelation test

6.1.12.5.5.11 RNG_SW_RESET

Address offset: 0x140

Reset the RNG engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	RESET			Writing any value to this address resets the RNG engine. The reset takes 4 CPU clock cycles to complete.
			Enable	1	Reset RNG engine.

6.1.12.5.5.12 RNG_BUSY

Address offset: 0x1B8

Status register for RNG engine activity.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
	R	STATUS			RNG engine status.
			Idle	0	RNG engine is idle
			Busy	1	RNG engine is busy
B	R	TRNG_STATUS			TRNG status.
			Idle	0	TRNG is idle
			Busy	1	TRNG is busy

6.1.12.5.5.13 TRNG_RESET

Address offset: 0x1BC

Reset the TRNG, including internal counter of collected bits and registers EHR_DATA and TRNG_VALID.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	RESET			Writing any value to this address resets the internal bits counter and registers EHR_DATA and TRNG_VALID. Register NOISE_SOURCE must be disabled in order for the reset to take place.
			Enable	1	Reset TRNG.

6.1.12.5.5.14 RNG_HW_FLAGS

Address offset: 0x1C0

Hardware configuration of RNG engine. Reset value holds the supported features.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x0000000F				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1**

ID	R/W	Field	Value ID	Value	Description
A	R	EHR_WIDTH			Data width supported by the entropy collector
			128Bits	0	128 bits EHR width
			192Bits	1	192 bits EHR width
B	R	CRNGT_EXISTS			If this flag is set, the engine include support for continuous random number generator test.
C	R	AUTOCORR_EXISTS			If this flag is set, the engine include support for autocorrelation test.
D	R	BYPASS_EXISTS			If this flag is set, the engine include support for bypassing TRNG tests.
E	R	PRNG_EXISTS			If this flag is set, the engine include a pseudo-random number generator.
F	R	KAT_EXISTS			If this flag is set, the engine include support for known answer tests.
G	R	RESEEDING_EXISTS			If this flag is set, the engine include support for automatic reseeding.
H	R	RNG_USE_5_SBOXES			
			Disable	0	20 SBOX AES
			Enable	1	5 SBOX AES

6.1.12.5.5.15 RNG_CLK

Address offset: 0x1C4

Control clock for the RNG engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	ENABLE			Enables clock for the RNG engine.
			Disable	0	Disable clock for RNG engine.
			Enable	1	Enable clock for RNG engine.

6.1.12.5.5.16 RNG_DMA

Address offset: 0x1C8

Writing to this register enables the RNG DMA engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			
			Disable	0	Disable RNG DMA engine
			Enable	1	Enable RNG DMA engine
					This value is cleared when the RNG DMA engine completes its operation.

6.1.12.5.5.17 RNG_DMA_ROSC_LEN

Address offset: 0x1CC

This register defines which ring oscillator length configuration should be used when using the RNG DMA engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ROSC1			Use shortest ROSC1 ring oscillator configuration.
			Disable	0	Disable ROSC1
			Enable	1	Enable ROSC1
B	RW	ROSC2			Use ROSC2 ring oscillator configuration.
			Disable	0	Disable ROSC2
			Enable	1	Enable ROSC2
C	RW	ROSC3			Use ROSC3 ring oscillator configuration.
			Disable	0	Disable ROSC3
			Enable	1	Enable ROSC3
D	RW	ROSC4			Use longest ROSC4 ring oscillator configuration.
			Disable	0	Disable ROSC4
			Enable	1	Enable ROSC4

6.1.12.5.5.18 RNG_DMA_SRAM_ADDR

Address offset: 0x1D0

This register defines the start address in TRNG SRAM for the TRNG data to be collected by the RNG DMA engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RNG_SRAM_DMA_ADDR			Start address of the TRNG data in TRNG SRAM.

6.1.12.5.5.19 RNG_DMA_SAMPLES_NUM

Address offset: 0x1D4

This register defines the number of 192-bits samples that the RNG DMA engine collects per run.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																									A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	RNG_SAMPLES_NUM			Defines the number of 192-bits samples that the DMA engine collects per run.

6.1.12.5.5.20 RNG_WATCHDOG_VAL

Address offset: 0x1D8

This register defines the maximum number of CPU clock cycles per TRNG collection of 192-bits samples. If the number of cycles for a collection exceeds this threshold the WATCHDOG interrupt is triggered.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	RNG_WATCHDOG_VAL			Defines the maximum number of CPU clock cycles per TRNG collection of 192-bits samples. If the number of cycles for a collection exceeds this threshold the WATCHDOG interrupt is triggered.

6.1.12.5.5.21 RNG_DMA_BUSY

Address offset: 0x1DC

Status register for RNG DMA engine activity.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																						C	C	C	C	C	C	C	C	B	B	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			RNG DMA engine status.
			Idle	0	RNG DMA engine is idle
			Busy	1	RNG DMA engine is busy
B	R	ROSC_LEN			The active ring oscillator length configuration used by the RNG DMA engine.
			ROSC1	0	Shortest ROSC1 ring oscillator configuration used.
			ROSC2	1	ROSC2 ring oscillator configuration used.
			ROSC3	2	ROSC3 ring oscillator configuration used.
			ROSC4	3	Longest ROSC4 ring oscillator configuration used.
C	R	NUM_OF_SAMPLES			Number of samples already collected using the current ring oscillator configuration.

6.1.13 Host integration

This chapter describes host registers used to control CRYPTOCELL behavior.

6.1.13.1 AHB interface

The AHB interface controls CRYPTOCELL bus master behavior.

6.1.13.1.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_AHB	0x50841000	HF	S	NSA	No	CRYPTOCELL AHB interface

Register overview

Register	Offset	TZ	Description
AHBM_SINGLES	0xB00		This register forces the AHB transactions from CRYPTOCELL master to be always singles.
AHBM_HPROT	0xB04		This register holds the AHB HPROT value
AHBM_HMASTLOCK	0xB08		This register holds AHB HMASTLOCK value
AHBM_HNONSEC	0xB0C		This register holds AHB HNONSEC value

6.1.13.1.1.1 AHBM_SINGLES

Address offset: 0xB00

This register forces the AHB transactions from CRYPTOCELL master to be always singles.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	AHB_SINGLES			Force AHB singles

6.1.13.1.1.2 AHBM_HPROT

Address offset: 0xB04

This register holds the AHB HPROT value

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																													A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	AHB_HPROT			The AHB HPROT value

6.1.13.1.1.3 AHBM_HMASTLOCK

Address offset: 0xB08

This register holds AHB HMASTLOCK value

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	AHB_HMASTLOCK			The AHB HMASTLOCK value.

6.1.13.1.1.4 AHBM_HNONSEC

Address offset: 0xB0C

This register holds AHB HNONSEC value

Bit number																															
ID																														B	A
Reset 0x00000000																														**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	AHB_WRITE_HNONSEC			The AHB HNONSEC value for write transaction.
B	RW	AHB_READ_HNONSEC			The AHB HNONSEC value for read transaction.

6.1.13.2 CTL interface

The CTL interface controls the cryptographic flow and provide busy status for individual components in the CRYPTOCELL subsystem.

6.1.13.2.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_CTL	0x50841000	HF	S	NSA	No	CRYPTOCELL CTL interface

Register overview

Register	Offset	TZ	Description
CRYPTO_CTL	0x900		Defines the cryptographic flow.
CRYPTO_BUSY	0x910		Status register for cryptographic cores engine activity.
HASH_BUSY	0x91C		Status register for HASH engine activity.
CONTEXT_ID	0x930		A general-purpose read/write register.

6.1.13.2.1.1 CRYPTO_CTL

Address offset: 0x900

Defines the cryptographic flow.

Bit number																															
ID																														A	A	A	A	A
Reset 0x00000000																														**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	MODE			Configure the cryptographic engine mode.
			Bypass	0	Bypass cryptographic engine
			AESActive	1	Use AES engine
			AESToHashActive	2	Pipe AES engine output to HASH engine input
			AESAndHashActive	3	Process input using both AES and HASH engine in parallell
			HashActive	7	Use HASH engine
			AESMACAndBypassActive	9	Calculate AES MAC and bypass
			AESToHashAndDOUTActive	10	Pipe AES engine output to HASH engine input. The resulting digest output is piped to DOUT buffer.
			ChaChaActive	16	Use CHACHA engine

6.1.13.2.1.2 CRYPTO_BUSY

Address offset: 0x910

Status register for cryptographic cores engine activity.

This register will be asserted whenever register AES_BUSY on page 94 or register HASH_BUSY on page 135 is asserted or when register DIN_FIFO_EMPTY on page 139 indicate that the DIN FIFO is not empty.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			Cryptographic core engines status.
			Idle	0	Cryptographic core engines are idle
			Busy	1	Cryptographic core engines are busy

6.1.13.2.1.3 HASH_BUSY

Address offset: 0x91C

Status register for HASH engine activity.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			Hash engine status.
			Idle	0	HASH engine is idle
			Busy	1	HASH engine is busy

6.1.13.2.1.4 CONTEXT_ID

Address offset: 0x930

A general-purpose read/write register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CONTEXT_ID			Context ID

6.1.13.3 DIN DMA engine

The Data IN (DIN) DMA engine transfers data into the CRYPTOCELL subsystem and its various cryptographic engines.

The DIN DMA engine provides a comprehensive interface for to facilitate the transfer of data from the CPU or memory to the cryptographic engines. It includes a variety of registers that control direct data buffering, DMA operations, and data flow management.

Maximum DMA transaction size is limited to 2^{16}-1 bytes. If a DMA transaction is configured with a payload size above the maximum DMA transaction size limit, the DMA engine must be reset before being functional again using register DIN_SW_RESET on page 138.

The flow demonstrated in Cryptographic flow on page 92 shows how the DIN DMA engine is configured to provide data to the AES engine using registers SRC_MEM_ADDR on page 137 and

SRC_MEM_SIZE on page 137 to define the input source address and number of input bytes, respectively.

6.1.13.3.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_DIN	0x50841000	HF	S	NSA	No	CRYPTOCELL DIN DMA engine

Register overview

Register	Offset	TZ	Description
DIN_BUFFER	0xC00		Used by CPU to write data directly to the DIN buffer, which is then sent to the cryptographic engines for processing.
DIN_DMA_MEM_BUSY	0xC20		Status register for DIN DMA engine activity when accessing memory.
SRC_MEM_ADDR	0xC28		Data source address in memory.
SRC_MEM_SIZE	0xC2C		The number of bytes to be read from memory. Writing to this register triggers the DMA operation.
SRC_SRAM_ADDR	0xC30		Data source address in RNG SRAM.
SRC_SRAM_SIZE	0xC34		The number of bytes to be read from RNG SRAM. Writing to this register triggers the DMA operation.
DIN_DMA_SRAM_BUSY	0xC38		Status register for DIN DMA engine activity when accessing RNG SRAM.
DIN_DMA_SRAM_ENDIANNESS	0xC3C		Configure the endianness of DIN DMA transactions towards RNG SRAM.
DIN_SW_RESET	0xC44		Reset the DIN DMA engine.
DIN_CPU_DATA	0xC48		Specifies the number of bytes the CPU will write to the DIN_BUFFER, ensuring the cryptographic engine processes the correct amount of data.
DIN_WRITE_ALIGN	0xC4C		Indicates that the next CPU write to the DIN_BUFFER is the last in the sequence. This is needed only when the data size is NOT modulo 4 (e.g. HASH padding).
DIN_FIFO_EMPTY	0xC50		Register indicating if DIN FIFO is empty and if more data can be accepted.
DIN_FIFO_RESET	0xC58		Reset the DIN FIFO, effectively clearing the FIFO for new data.

6.1.13.3.1.1 DIN_BUFFER

Address offset: 0xC00

Used by CPU to write data directly to the DIN buffer, which is then sent to the cryptographic engines for processing.

The number of bytes to write is defined in DIN_CPU_DATA on page 138.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	DATA			This register is mapped into 8 addresses in order to enable a CPU burst.

6.1.13.3.1.2 DIN_DMA_MEM_BUSY

Address offset: 0xC20

Status register for DIN DMA engine activity when accessing memory.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			DIN memory DMA engine status.
			Idle	0	DIN memory DMA engine is idle
			Busy	1	DIN memory DMA engine is busy

6.1.13.3.1.3 SRC_MEM_ADDR

Address offset: 0xC28

Data source address in memory.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ADDR			Source address in memory.

6.1.13.3.1.4 SRC_MEM_SIZE

Address offset: 0xC2C

The number of bytes to be read from memory. Writing to this register triggers the DMA operation.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	SIZE			Total number of bytes to read from memory.
B	W	FIRST			This field is reserved
C	W	LAST			This field is reserved

6.1.13.3.1.5 SRC_SRAM_ADDR

Address offset: 0xC30

Data source address in RNG SRAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ADDR			Source address in RNG SRAM.

6.1.13.3.1.6 SRC_SRAM_SIZE

Address offset: 0xC34

The number of bytes to be read from RNG SRAM. Writing to this register triggers the DMA operation.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	SIZE																																	
																																			Total number of bytes to read from RNG SRAM.

6.1.13.3.1.7 DIN_DMA_SRAM_BUSY

Address offset: 0xC38

Status register for DIN DMA engine activity when accessing RNG SRAM.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	STATUS																																	
			Idle	0																															DIN RNG SRAM DMA engine is idle
			Busy	1																															DIN RNG SRAM DMA engine is busy

6.1.13.3.1.8 DIN_DMA_SRAM_ENDIANNESS

Address offset: 0xC3C

Configure the endianness of DIN DMA transactions towards RNG SRAM.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ENDIAN																																	
																																			Endianness of DIN DMA transactions towards RNG SRAM. The default value is little-endian.
			LittleEndian	0																															Use little-endian format for RNG SRAM DMA transactions
			BigEndian	1																															Use big-endian format for RNG SRAM DMA transactions

6.1.13.3.1.9 DIN_SW_RESET

Address offset: 0xC44

Reset the DIN DMA engine.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	RESET																																	
																																			Writing any value to this address resets the DIN DMA engine. The reset takes 4 CPU clock cycles to complete.
			Enable	1																															Reset DIN DMA engine.

6.1.13.3.1.10 DIN_CPU_DATA

Address offset: 0xC48

Specifies the number of bytes the CPU will write to the DIN_BUFFER, ensuring the cryptographic engine processes the correct amount of data.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	SIZE			When using CPU direct write to the DIN_BUFFER, the size of input data in bytes should be written to this register.

6.1.13.3.1.11 DIN_WRITE_ALIGN

Address offset: 0xC4C

Indicates that the next CPU write to the DIN_BUFFER is the last in the sequence. This is needed only when the data size is NOT modulo 4 (e.g. HASH padding).

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	LAST			Next CPU write to the DIN_BUFFER is the last word.
			Confirm	1	The next CPU write is the last in the sequence.

6.1.13.3.1.12 DIN_FIFO_EMPTY

Address offset: 0xC50

Register indicating if DIN FIFO is empty and if more data can be accepted.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			DIN FIFO status
			NotEmpty	0	DIN FIFO is not empty
			Empty	1	DIN FIFO is empty, and more data can be accepted

6.1.13.3.1.13 DIN_FIFO_RESET

Address offset: 0xC58

Reset the DIN FIFO, effectively clearing the FIFO for new data.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	RESET			Writing any value to this address resets the DIN FIFO.
			Enable	1	Reset DIN FIFO.

6.1.13.4 DOUT DMA engine

The Data OUT (DOUT) DMA engine transfers data from the CRYPTOCELL subsystem and its various cryptographic engines.

The DOUT DMA engine provides a comprehensive interface for to facilitate the transfer of data to the CPU or memory from the cryptographic engines. It includes a variety of registers that control direct data buffering, DMA operations, and data flow management.

Maximum DMA transaction size is limited to 2^{16}-1 bytes. If a DMA transaction is configured with a payload size above the maximum DMA transaction size limit, the DMA engine must be reset before being functional again using register DOUT_SW_RESET on page 143.

The flow demonstrated in Cryptographic flow on page 92 shows how the DOUT DMA engine is configured to output data from the AES engine using registers DST_MEM_ADDR on page 141 and DST_MEM_SIZE on page 141 to define the output source address and number of output bytes, respectively.

6.1.13.4.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_DOUT	0x50841000	HF	S	NSA	No	CRYPTOCELL DOUT DMA engine

Register overview

Register	Offset	TZ	Description
DOUT_BUFFER	0xC00		Cryptographic results directly accessible by the CPU.
DOUT_DMA_MEM_BUSY	0xD20		Status register for DOUT DMA engine activity when accessing memory.
DST_MEM_ADDR	0xD28		Data destination address in memory.
DST_MEM_SIZE	0xD2C		The number of bytes to be written to memory.
DST_SRAM_ADDR	0xD30		Data destination address in RNG SRAM.
DST_SRAM_SIZE	0xD34		The number of bytes to be written to RNG SRAM.
DOUT_DMA_SRAM_BUSY	0xD38		Status register for DOUT DMA engine activity when accessing RNG SRAM.
DOUT_DMA_SRAM_ENDIANNESS	0xD3C		Configure the endianness of DOUT DMA transactions towards RNG SRAM.
DOUT_READ_ALIGN	0xD44		Indication that the next CPU read from the DOUT_BUFFER is the last in the sequence. This is needed only when the data size is NOT modulo 4 (e.g. HASH padding).
DOUT_FIFO_EMPTY	0xD50		Register indicating if DOUT FIFO is empty or if more data will come.
DOUT_SW_RESET	0xD58		Reset the DOUT DMA engine.

6.1.13.4.1.1 DOUT_BUFFER

Address offset: 0xC00

Cryptographic results directly accessible by the CPU.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	R	DATA			This address can be used by the CPU to read data directly from the DOUT buffer.

6.1.13.4.1.2 DOUT_DMA_MEM_BUSY

Address offset: 0xD20

Status register for DOUT DMA engine activity when accessing memory.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	STATUS																																	
			Idle	0																															
			Busy	1																															

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	ADDR																																	

6.1.13.4.1.3 DST_MEM_ADDR

Address offset: 0xD28

Data destination address in memory.

6.1.13.4.1.4 DST_MEM_SIZE

Address offset: 0xD2C

The number of bytes to be written to memory.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				C	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	SIZE																																	
B	W	FIRST																																	
C	W	LAST																																	

6.1.13.4.1.5 DST_SRAM_ADDR

Address offset: 0xD30

Data destination address in RNG SRAM.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ADDR																																	

6.1.13.4.1.6 DST_SRAM_SIZE

Address offset: 0xD34

The number of bytes to be written to RNG SRAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	SIZE			Total number of bytes to write to RNG SRAM.

6.1.13.4.1.7 DOUT_DMA_SRAM_BUSY

Address offset: 0xD38

Status register for DOUT DMA engine activity when accessing RNG SRAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			DOUT RNG SRAM DMA engine status.
			Idle	0	DOUT RNG SRAM DMA engine is idle
			Busy	1	DOUT RNG SRAM DMA engine is busy

6.1.13.4.1.8 DOUT_DMA_SRAM_ENDIANNESS

Address offset: 0xD3C

Configure the endianness of DOUT DMA transactions towards RNG SRAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENDIAN			Endianness of DOUT DMA transactions towards RNG SRAM. The default value is little-endian.
			LittleEndian	0	Use little-endian format for RNG SRAM DMA transactions
			BigEndian	1	Use big-endian format for RNG SRAM DMA transactions

6.1.13.4.1.9 DOUT_READ_ALIGN

Address offset: 0xD44

Indication that the next CPU read from the DOUT_BUFFER is the last in the sequence. This is needed only when the data size is NOT modulo 4 (e.g. HASH padding).

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	LAST			Next CPU read from the DOUT_BUFFER is the last word, and the remaining read aligned content can be flushed.
			Flush	1	Flush the remaining read aligned content.

6.1.13.4.1.10 DOUT_FIFO_EMPTY

Address offset: 0xD50

Register indicating if DOUT FIFO is empty or if more data will come.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			DOUT FIFO status
			NotEmpty	0	DOUT FIFO is not empty, and more data will come
			Empty	1	DOUT FIFO is empty

6.1.13.4.1.11 DOUT_SW_RESET

Address offset: 0xD58

Reset the DOUT DMA engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	RESET			Writing any value to this address resets the DOUT DMA engine. The reset takes 4 CPU clock cycles to complete.
			Enable	1	Reset DOUT DMA engine.

6.1.13.5 HOST register interface

The HOST_RGF interface contains registers for CRYPTOCELL interrupt handling, configuring CRYPTOCELL lifecycle state and CRYPTOCELL key management where different cryptographic key inputs can be connected to the AES engine.

Use of the CRYPTOCELL K_{PRTL} key or the device root key K_{DR} is selected using this interface. Availability and configuration of these two key types are typically controlled from an immutable bootloader. Once CRYPTOCELL has been correctly configured it will be possible for an application to either use session keys directly or perform cryptographic operations with the device root key key K_{DR} without having access to the key value.

6.1.13.5.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_HOST_RGF	0x50841000	HF	S	NSA	No	CRYPTOCELL HOST register interface

Register overview

Register	Offset	TZ	Description
IRR	0xA00		Interrupt request register. Each bit of this register holds the interrupt status of a single interrupt source. If corresponding IMR bit is unmasked, an interrupt is generated.
IMR	0xA04		Interrupt mask register. Each bit of this register holds the mask of a single interrupt source.
ICR	0xA08		Interrupt clear register. Writing a 1 bit into a field in this register will clear the corresponding bit in IRR.
ENDIANNESS	0xA0C		This register defines the endianness of the Host-accessible registers, and can only be written once.
HOST_SIGNATURE	0xA24		This register holds the CRYPTOCELL subsystem signature. See reset value.

Register	Offset	TZ	Description
HOST_BOOT	0xA28		Hardware configuration of the CRYPTOCELL subsystem. Reset value holds the supported features.
HOST_CRYPTOKEY_SEL	0xA38		AES hardware key select.
HOST_IOT_KPRTL_LOCK	0xA4C		This write-once register is the K_PRTL lock register. When this register is set, K_PRTL cannot be used and a zeroed key will be used instead. The value of this register is saved in the CRYPTOCELL AO power domain.
HOST_IOT_KDR0	0xA50		This register holds bits 31:0 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain. Reading from this address returns the K_DR valid status indicating if K_DR is successfully retained.
HOST_IOT_KDR1	0xA54		This register holds bits 63:32 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain.
HOST_IOT_KDR2	0xA58		This register holds bits 95:64 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain.
HOST_IOT_KDR3	0xA5C		This register holds bits 127:96 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain.
HOST_IOT_LCS	0xA60		Controls life-cycle state (LCS) for CRYPTOCELL subsystem

6.1.13.5.1.1 IRR

Address offset: 0xA00

Interrupt request register. Each bit of this register holds the interrupt status of a single interrupt source. If corresponding IMR bit is unmasked, an interrupt is generated.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																						G	F	E	D	C	B	A				
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	R	SRAM_TO_DIN_INT			The RNG SRAM to DIN DMA done interrupt status. This interrupt is asserted when all data was delivered from RNG SRAM to DIN buffer.
B	R	DOUT_TO_SRAM_INT			The DOUT to RNG SRAM DMA done interrupt status. This interrupt is asserted when all data was delivered from DOUT buffer to RNG SRAM.
C	R	MEM_TO_DIN_INT			The memory to DIN DMA done interrupt status. This interrupt is asserted when all data was delivered from memory to DIN buffer.
D	R	DOUT_TO_MEM_INT			The DOUT to memory DMA done interrupt status. This interrupt is asserted when all data was delivered from DOUT buffer to memory.
E	R	AHB_ERR_INT			The AHB error interrupt status.
F	R	PKA_INT			The PKA end of operation interrupt status.
G	R	RNG_INT			The RNG interrupt status.

6.1.13.5.1.2 IMR

Address offset: 0xA04

Interrupt mask register. Each bit of this register holds the mask of a single interrupt source.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																						G	F	E	D	C	B	A				
Reset 0x01FFFFFF	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

ID	R/W	Field	Value ID	Value	Description
A	RW	SRAM_TO_DIN_MASK			The RNG SRAM to DIN DMA done interrupt mask.
			IRQEnable	0	Do not mask RNG SRAM to DIN DMA done interrupt i.e. interrupt is generated
			IRQDisable	1	Mask RNG SRAM to DIN DMA done interrupt i.e. no interrupt is generated

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				G F E D C B A
Reset 0x01FFFFFF				**0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
B	RW	DOUT_TO_SRAM_MASK			The DOUT to RNG SRAM DMA done interrupt mask.
			IRQEnable	0	Do not mask DOUT to RNG SRAM DMA done interrupt i.e. interrupt is generated
			IRQDisable	1	Mask DOUT to RNG SRAM DMA done interrupt i.e. no interrupt is generated
C	RW	MEM_TO_DIN_MASK			The memory to DIN DMA done interrupt mask.
			IRQEnable	0	Do not mask memory to DIN DMA done interrupt i.e. interrupt is generated
			IRQDisable	1	Mask memory to DIN DMA done interrupt i.e. no interrupt is generated
D	RW	DOUT_TO_MEM_MASK			The DOUT to memory DMA done interrupt mask.
			IRQEnable	0	Do not mask DOUT to memory DMA done interrupt i.e. interrupt is generated
			IRQDisable	1	Mask DOUT to memory DMA done interrupt i.e. no interrupt is generated
E	RW	AHB_ERR_MASK			The AHB error interrupt mask.
			IRQEnable	0	Do not mask AHB error interrupt i.e. interrupt is generated
			IRQDisable	1	Mask AHB error interrupt i.e. no interrupt is generated
F	RW	PKA_MASK			The PKA end of operation interrupt mask.
			IRQEnable	0	Do not mask PKA end of operation interrupt i.e. interrupt is generated
			IRQDisable	1	Mask PKA end of operation interrupt i.e. no interrupt is generated
G	RW	RNG_MASK			The RNG interrupt mask.
			IRQEnable	0	Do not mask RNG interrupt i.e. interrupt is generated
			IRQDisable	1	Mask RNG interrupt i.e. no interrupt is generated

6.1.13.5.1.3 ICR

Address offset: 0xA08

Interrupt clear register. Writing a 1 bit into a field in this register will clear the corresponding bit in IRR.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	SRAM_TO_DIN_CLEAR			The RNG SRAM to DIN DMA done interrupt clear.
B	W	DOUT_TO_SRAM_CLEAR			The DOUT to RNG SRAM DMA done interrupt clear.
C	W	MEM_TO_DIN_CLEAR			The memory to DIN DMA done interrupt clear.
D	W	DOUT_TO_MEM_CLEAR			The DOUT to memory DMA done interrupt clear.
E	W	AHB_ERR_CLEAR			The AHB error interrupt clear.
F	W	PKA_CLEAR			The PKA end of operation interrupt clear.
G	W	RNG_CLEAR			The RNG interrupt clear. Register RNG_ISR in the RNG engine must be cleared before this interrupt can be cleared.

6.1.13.5.1.4 ENDIANNESS

Address offset: 0xA0C

This register defines the endianness of the Host-accessible registers, and can only be written once.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	DOUT_WR_BG			DOUT write endianness.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			LittleEndian	0	Configure DOUT write as little-endian
			BigEndian	1	Configure DOUT write as big-endian
B	RW	DIN_RD_BG			DIN read endianness.
			LittleEndian	0	Configure DIN read as little-endian
			BigEndian	1	Configure DIN read as big-endian
C	RW	DOUT_WR_WBG			DOUT write word endianness.
			LittleEndian	0	Configure DOUT write word as little-endian
			BigEndian	1	Configure DOUT write word as big-endian
D	RW	DIN_RD_WBG			DIN read word endianness.
			LittleEndian	0	Configure DIN read word as little-endian
			BigEndian	1	Configure DIN read word as big-endian

6.1.13.5.1.5 HOST_SIGNATURE

Address offset: 0xA24

This register holds the CRYPTOCELL subsystem signature. See reset value.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x20E00000				**0 0 1 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	VALUE			Fixed-value identification signature used by host driver to verify CRYPTOCELL presence at this address.

6.1.13.5.1.6 HOST_BOOT

Address offset: 0xA28

Hardware configuration of the CRYPTOCELL subsystem. Reset value holds the supported features.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				b a Z Y X W V U T S R Q P O N M L K J I H G F F F E D C B A
Reset 0x4622982C				**0 1 0 0 0 1 1 0 0 0 1 0 0 0 1 0 1 0 0 1 1 0 0 0 0 0 1 0 1 1 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	POWER_GATING_EXISTS_LOCAL			If this flag is set, full power gating is implemented
B	R	LARGE_RKEK_LOCAL			If this flag is set, large RKEK is supported
C	R	HASH_IN_FUSES_LOCAL			If this flag is set, HASH in fuses is supported
D	R	EXT_MEM_SECURED_LOCAL			If this flag is set, external secure memory is supported
E	R	RKEK_ECC_EXISTS_LOCAL_N			If this flag is set, RKEK ECC is supported
F	R	SRAM_SIZE_LOCAL			SRAM size
G	R	DSCRPTR_EXISTS_LOCAL			If this flag is set, Descriptors are supported
H	R	PAU_EXISTS_LOCAL			If this flag is set, PAU is supported
I	R	RNG_EXISTS_LOCAL			If this flag is set, the RNG engine is present
J	R	PKA_EXISTS_LOCAL			If this flag is set, the PKA engine is present
K	R	RC4_EXISTS_LOCAL			If this flag is set, the RC4 engine is present
L	R	SHA_512_PRSNT_LOCAL			If this flag is set, the HASH engine supports SHA512
M	R	SHA_256_PRSNT_LOCAL			If this flag is set, the HASH engine supports SHA256
N	R	MD5_PRSNT_LOCAL			If this flag is set, the HASH engine supports MD5
O	R	HASH_EXISTS_LOCAL			If this flag is set, the HASH engine is present
P	R	C2_EXISTS_LOCAL			If this flag is set, the C2 engine is present

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID		b	a	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	F	F	E		D	C	B	A
Reset 0x4622982C	**0**	**1**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
Q	R	DES_EXISTS_LOCAL			If this flag is set, the DES engine is present
R	R	AES_XCBC_MAC_EXISTS_LOCAL			If this flag is set, AES XCBC-MAC mode is supported
S	R	AES_CMAC_EXISTS_LOCAL			If this flag is set, AES CMAC mode is supported
T	R	AES_CCM_EXISTS_LOCAL			If this flag is set, AES CCM mode is supported
U	R	AES_XEX_HW_T_CALC_LOCAL			If this flag is set, AES XEX mode T-value calculation in HW is supported
V	R	AES_XEX_EXISTS_LOCAL			If this flag is set, AES XEX mode is supported
W	R	CTR_EXISTS_LOCAL			If this flag is set, AES CTR mode is supported
X	R	AES_DIN_BYTE_RESOLUTION_LOCAL			If this flag is set, the AES engine data input support byte size resolution
Y	R	TUNNELING_ENB_LOCAL			If this flag is set, the AES engine supports tunneling operations
Z	R	SUPPORT_256_192_KEY_LOCAL			If this flag is set, the AES engine supports 192/256 bits key sizes
a	R	ONLY_ENCRYPT_LOCAL			If this flag is set, the AES engine only support encryption
b	R	AES_EXISTS_LOCAL			If this flag is set, the AES engine is present

6.1.13.5.1.7 HOST_CRYPTOKEY_SEL

Address offset: 0xA38

AES hardware key select.

If the HOST_IOT_KPRTL_LOCK register is set, and the HOST_CRYPTOKEY_SEL register set to 1, then the HW key that is connected to the AES engine is zero

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																															A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	HOST_CRYPTOKEY_SEL			Select the source of the HW key that is used by the AES engine
			K_DR	0	Use device root key K_DR from CRYPTOCELL AO power domain
			K_PRTL	1	Use hard-coded RTL key K_PRTL
			Session	2	Use provided session key

6.1.13.5.1.8 HOST_IOT_KPRTL_LOCK

Address offset: 0xA4C

This write-once register is the K_PRTL lock register. When this register is set, K_PRTL cannot be used and a zeroed key will be used instead. The value of this register is saved in the CRYPTOCELL AO power domain.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW1	HOST_IOT_KPRTL_LOCK			This register is the K_PRTL lock register. When this register is set, K_PRTL cannot be used and a zeroed key will be used instead. The value of this register is saved in the CRYPTOCELL AO power domain.
			Disabled	0	K_PRTL can be selected for use from register HOST_CRYPTOKEY_SEL
			Enabled	1	K_PRTL has been locked until next power-on reset (POR). If K_PRTL is selected anyway, a zeroed key will be used instead.

6.1.13.5.1.9 HOST_IOT_KDR0

Address offset: 0xA50

This register holds bits 31:0 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain. Reading from this address returns the K_DR valid status indicating if K_DR is successfully retained.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW1	HOST_IOT_KDR0																																	
			NotRetained	0																															
			Retained	1																															

ID	R/W	Field	Value ID	Value	Description
A	RW1	HOST_IOT_KDR0			This register holds bits 31:0 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain. Reading from this address returns the K_DR valid status indicating if K_DR is successfully retained. Write: K_DR bits 31:0.
			NotRetained	0	Read: 128 bits K_DR key value is not yet retained in the CRYPTOCELL AO power domain.
			Retained	1	Read: 128 bits K_DR key value is successfully retained in the CRYPTOCELL AO power domain.

6.1.13.5.1.10 HOST_IOT_KDR1

Address offset: 0xA54

This register holds bits 63:32 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W1	HOST_IOT_KDR1																																	

ID	R/W	Field	Value ID	Value	Description
A	W1	HOST_IOT_KDR1			K_DR bits 63:32

6.1.13.5.1.11 HOST_IOT_KDR2

Address offset: 0xA58

This register holds bits 95:64 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W1	HOST_IOT_KDR2																																	

ID	R/W	Field	Value ID	Value	Description
A	W1	HOST_IOT_KDR2			K_DR bits 95:64

6.1.13.5.1.12 HOST_IOT_KDR3

Address offset: 0xA5C

This register holds bits 127:96 of K_DR. The value of this register is saved in the CRYPTOCELL AO power domain.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W1	HOST_IOT_KDR3																																	

ID	R/W	Field	Value ID	Value	Description
A	W1	HOST_IOT_KDR3			K_DR bits 127:96

6.1.13.5.1.13 HOST_IOT_LCS

Address offset: 0xA60

Controls life-cycle state (LCS) for CRYPTOCELL subsystem

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A
Reset 0x00000002				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0**

ID	R/W	Field	Value ID	Value	Description
A	RW1	LCS			Life-cycle state value. This field is write-once per reset.
			DebugEnable	0	CC310 operates in debug mode
			Secure	2	CC310 operates in secure mode
B	R	LCS_IS_VALID			Read-only field. Indicates if CRYPTOCELL LCS has been successfully configured since last reset.
			Invalid	0	Valid LCS not yet retained in the CRYPTOCELL AO power domain
			Valid	1	Valid LCS successfully retained in the CRYPTOCELL AO power domain

6.1.13.6 RNG SRAM interface

The RNG_SRAM interface enable reading and writing data to RNG SRAM.

6.1.13.6.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_RNG_SRAM	0x50841000	HF	S	NSA	No	CRYPTOCELL RNG SRAM interface

Register overview

Register	Offset	TZ	Description
SRAM_DATA	0xF00		Read/Write data from RNG SRAM
SRAM_ADDR	0xF04		First address given to RNG SRAM DMA for read/write transactions from/to RNG SRAM.
SRAM_DATA_READY	0xF08		RNG SRAM DMA engine is ready to read/write from/to RNG SRAM.

6.1.13.6.1.1 SRAM_DATA

Address offset: 0xF00

Read/Write data from RNG SRAM

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	SRAM_DATA			32 bits DMA read/write from/to RNG SRAM. A 'read' or 'write' operation to this register will trigger the DMA address to be automatically incremented.

6.1.13.6.1.2 SRAM_ADDR

Address offset: 0xF04

First address given to RNG SRAM DMA for read/write transactions from/to RNG SRAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	SRAM_ADDR			RNG SRAM starting address

6.1.13.6.1.3 SRAM_DATA_READY

Address offset: 0xF08

RNG SRAM DMA engine is ready to read/write from/to RNG SRAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	SRAM_READY			RNG SRAM DMA status.
			Busy	0	DMA is busy
			Idle	1	DMA is idle

6.1.13.7 MISC interface

The MISC interface controls clocks for the individual engines within the CRYPTOCELL subsystem.

Each cryptographic engine has an individual register for performing clock gating. Engine clock status is displayed in register CLK_STATUS on page 151.

> **Note:** Clock control for the RNG engine on page 121 is handled by register RNG_CLK on page 130 and not through the MISC interface.

6.1.13.7.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CC_MISC	0x50841000	HF	S	NSA	No	CRYPTOCELL MISC interface

Register overview

Register	Offset	TZ	Description
AES_CLK	0x810		Clock control for the AES engine.
HASH_CLK	0x818		Clock control for the HASH engine.
PKA_CLK	0x81C		Clock control for the PKA engine.
DMA_CLK	0x820		Clock control for the DMA engines.
CLK_STATUS	0x824		CRYPTOCELL clocks status register.
CHACHA_CLK	0x858		Clock control for the CHACHA engine.

6.1.13.7.1.1 AES_CLK

Address offset: 0x810

Clock control for the AES engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ENABLE			Enables clock for the AES engine.
			Disable	0	Disable clock for the AES engine.
			Enable	1	Enable clock for the AES engine.

6.1.13.7.1.2 HASH_CLK

Address offset: 0x818

Clock control for the HASH engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ENABLE			Enables clock for the HASH engine.
			Disable	0	Disable clock for the HASH engine.
			Enable	1	Enable clock for the HASH engine.

6.1.13.7.1.3 PKA_CLK

Address offset: 0x81C

Clock control for the PKA engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ENABLE			Enables clock for the PKA engine.
			Disable	0	Disable clock for the PKA engine.
			Enable	1	Enable clock for the PKA engine.

6.1.13.7.1.4 DMA_CLK

Address offset: 0x820

Clock control for the DMA engines.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ENABLE			Enables clock for the DMA engines.
			Disable	0	Disable clock for the DMA engines.
			Enable	1	Enable clock for the DMA engines.

6.1.13.7.1.5 CLK_STATUS

Address offset: 0x824

CRYPTOCELL clocks status register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000100				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	AES_CLK			Status of AES engine clock.
			Disabled	0	Clock for AES engine is disabled
			Enabled	1	Clock for AES engine is enabled
B	R	HASH_CLK			Status of HASH engine clock.
			Disabled	0	Clock for HASH engine is disabled
			Enabled	1	Clock for HASH engine is enabled
C	R	PKA_CLK			Status of PKA engine clock.
			Disabled	0	Clock for PKA engine is disabled
			Enabled	1	Clock for PKA engine is enabled
D	R	CHACHA_CLK			Status of CHACHA engine clock.
			Disabled	0	Clock for CHACHA engine is disabled
			Enabled	1	Clock for CHACHA engine is enabled
E	R	DMA_CLK			Status of DMA engines clock.
			Disabled	0	Clocks for DMA engines are disabled
			Enabled	1	Clocks for DMA engines are enabled

6.1.13.7.1.6 CHACHA_CLK

Address offset: 0x858

Clock control for the CHACHA engine.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ENABLE			Enables clock for the CHACHA engine.
			Disable	0	Disable clock for the CHACHA engine.
			Enable	1	Enable clock for the CHACHA engine.

6.2 DPPI - Distributed programmable peripheral interconnect

The distributed programmable peripheral interconnect (DPPI) enables peripherals to interact autonomously with each other by using tasks and events, without any intervention from the CPU. DPPI allows precise synchronization between peripherals when real-time application constraints exist and eliminates the need for CPU involvement to implement behavior which can be predefined using the DPPI.

Note: For more information on tasks, events, publish/subscribe, interrupts, and other concepts, see Peripheral interface on page 15.

The DPPI has the following features:

- Peripheral tasks can subscribe to channels
- Peripheral events can be published on channels
- Publish/subscribe pattern enabling multiple connection options that include the following:
  - One-to-one
  - One-to-many

- Many-to-one
- Many-to-many

The DPPI consists of several PPIBus modules, which are connected to a fixed number of DPPI channels and a DPPI configuration (DPPIC).

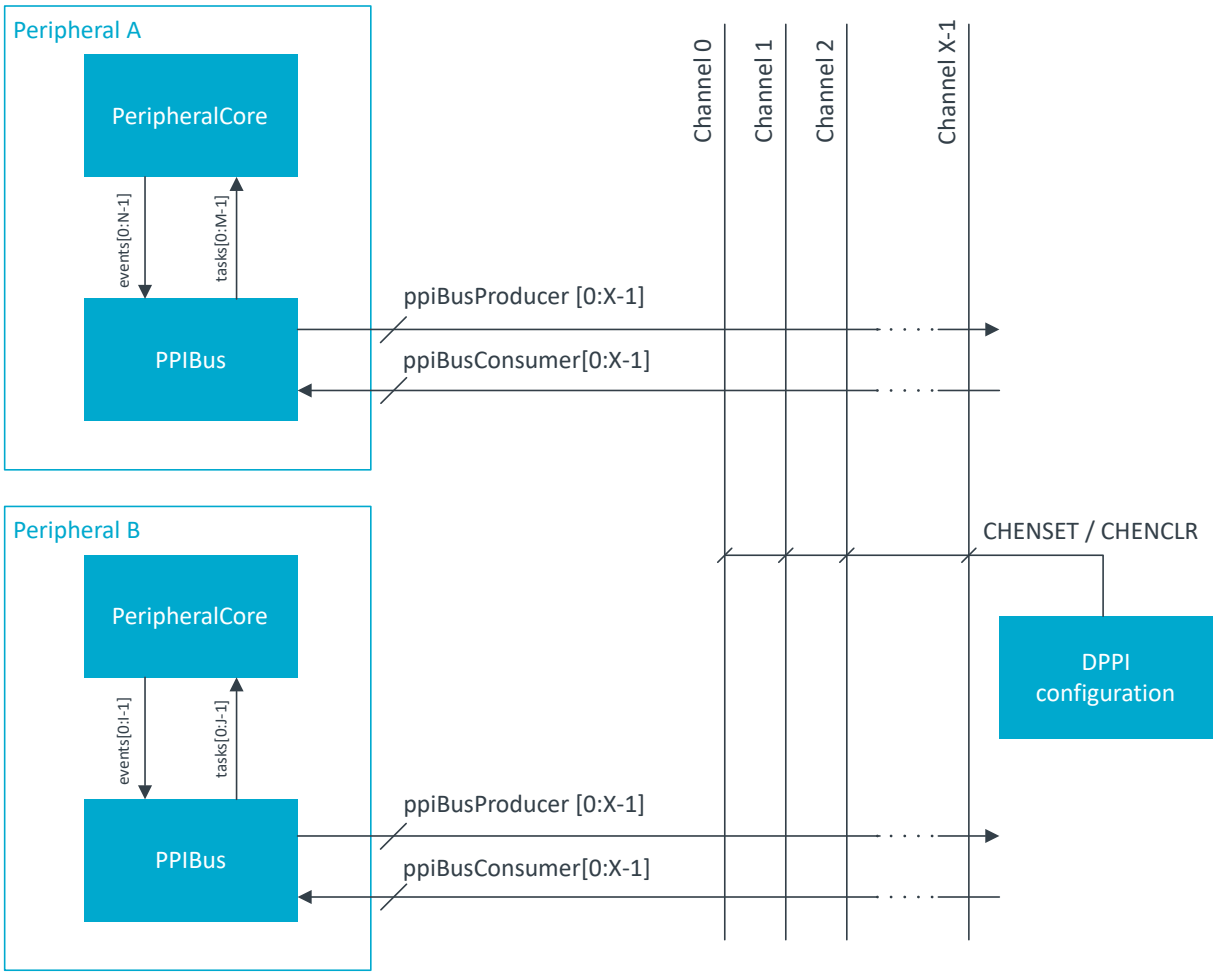

Figure 19: DPPI overview

6.2.1 Subscribing to and publishing on channels

The PPIBus can route peripheral events onto the channels (publishing), or route events from the channels into peripheral tasks (subscribing).

All peripherals include the following:

- One subscribe register per task
- One publish register per event

Publish and subscribe registers use a channel index field to determine the channel to which the event is published or tasks subscribed. In addition, there is an enable bit for the subscribe and publish registers that needs to be enabled before the subscription or publishing takes effect.

Writing non-existing channel index (CHIDX) numbers into a peripheral's publish or subscribe registers will yield unexpected results.

One event can trigger multiple tasks by subscribing different tasks to the same channel. Similarly, one task can be triggered by multiple events by publishing different events to the same channel. For advanced use cases, multiple events and multiple tasks can connect to the same channel forming a many-to-many connection. If multiple events are published on the same channel at the same time, the events are merged and only one event is routed through the DPPI.

How peripheral events are routed onto different channels based on publish registers is illustrated in the following figure.

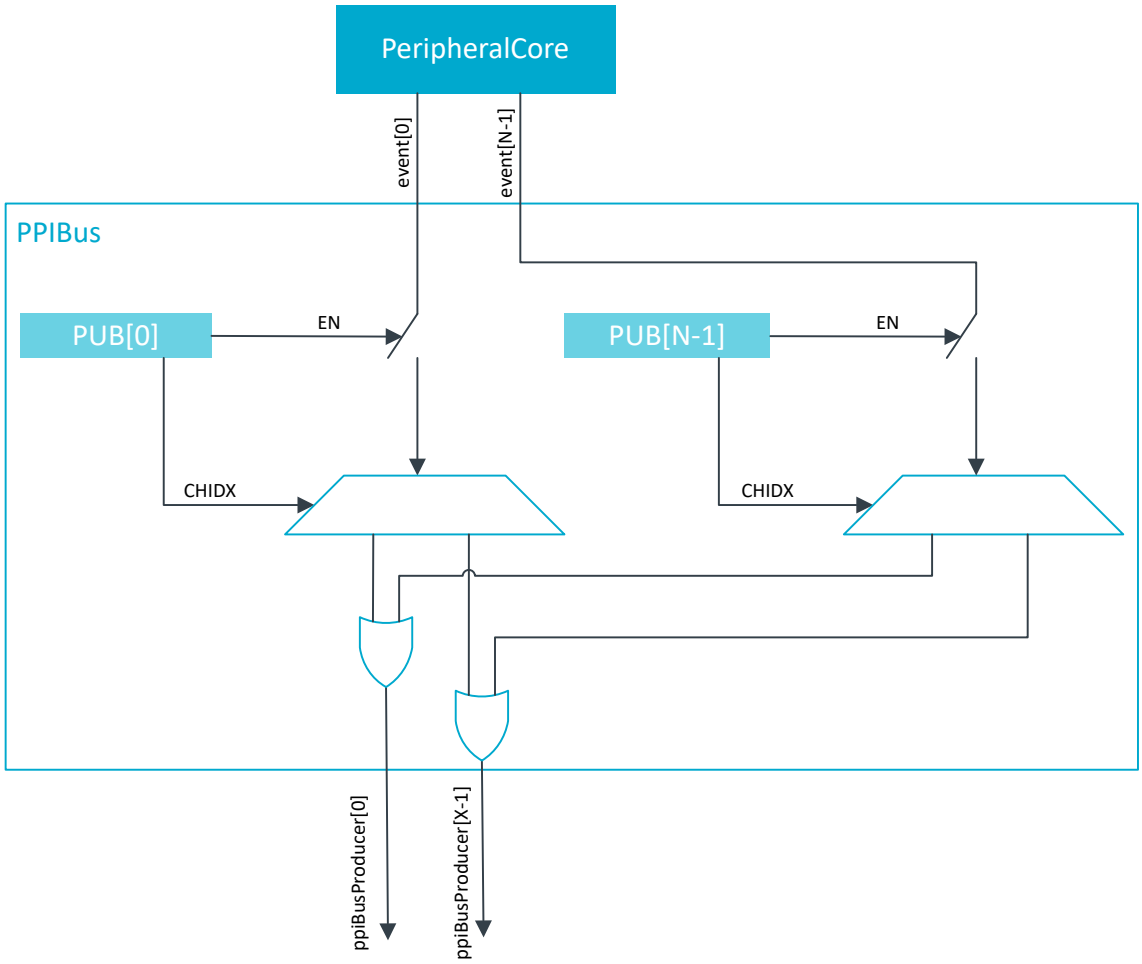

Figure 20: DPPI events flow

The following figure illustrates how peripheral tasks are triggered from different channels based on subscribe registers.

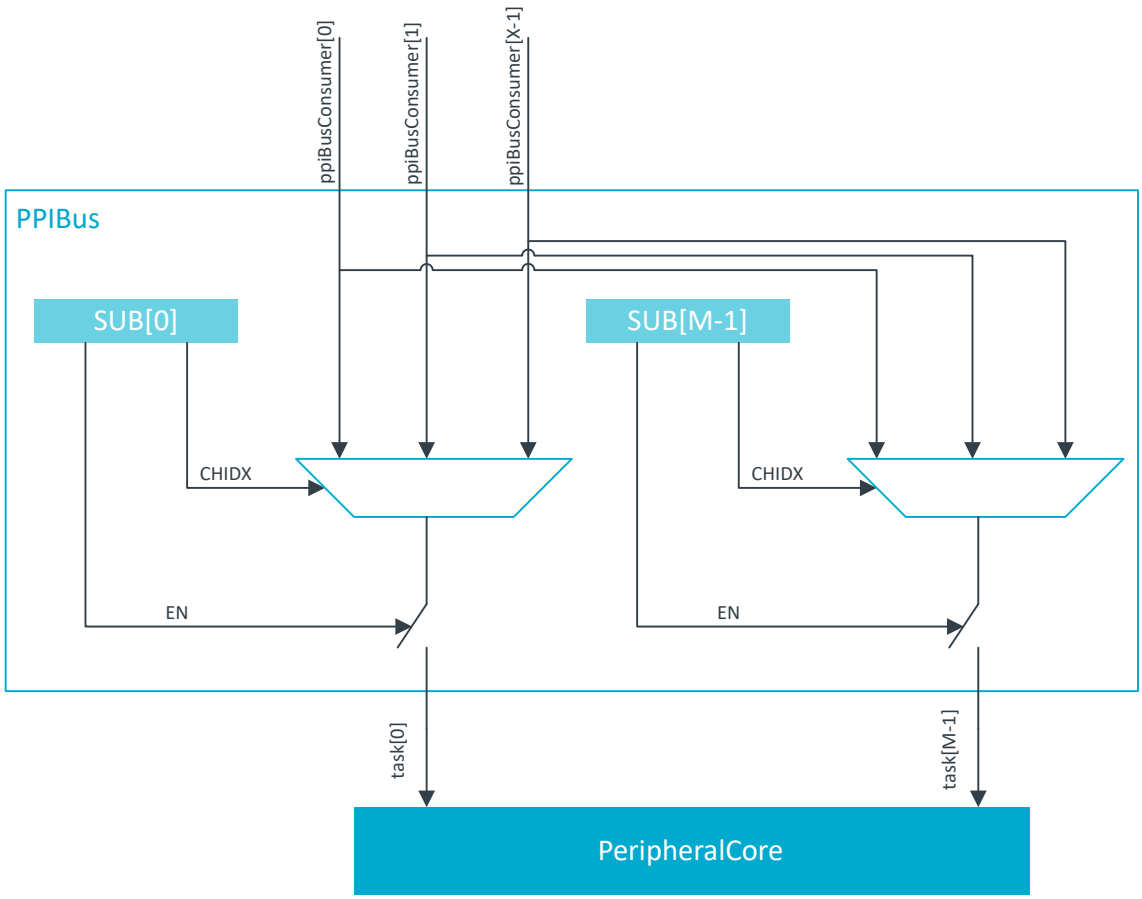

Figure 21: DPPI tasks flow

6.2.2 DPPI configuration (DPPIC)

Enabling and disabling of channels globally is handled through the DPPI configuration (DPPIC). Connection (connect/disconnect) between a channel and a peripheral is handled locally by the PPIBus.

There are two ways of enabling and disabling global channels using the DPPI configuration:

- Enable or disable channels individually using registers CHEN, CHENSET, and CHENCLR.
- Enable or disable channels in channel groups using the groups' tasks ENABLE and DISABLE. It needs to be defined which channels belong to which channel groups before these tasks are triggered.

Note: ENABLE tasks are prioritized over DISABLE tasks. When a channel belongs to two or more groups, for example group m and n, and the tasks CHG[m].EN and CHG[n].DIS occur simultaneously (m and n can be equal or different), the CHG[m].EN task on that channel is prioritized.

The DPPI configuration tasks (for example CHG[0].EN) can be triggered through DPPI like any other task, which means they can be linked to a DPPI channel through the subscribe registers.

In order to write to CHG[x], the corresponding CHG[x].EN and CHG[x].DIS subscribe registers must be disabled. Writes to CHG[x] are ignored if any of the two subscribe registers are enabled.

6.2.3 Connection examples

DPPI offers several connection options. Examples are given for how to create one-to-one and many-to-many connections.

One-to-one connection

This example shows how to create a one-to-one connection between TIMER compare register and SAADC start task.

The channel configuration is set up first. TIMER0 will publish its COMPARE0 event on channel 0, and SAADC will subscribe its START task to events on the same channel. After that, the channel is enabled through the DPPIC.

```
NRF_TIMER0->PUBLISH_COMPARE0 = (DPPI_PUB_CHIDX_Ch0) |
                               (DPPI_PUB_EN_Msk);
NRF_SAADC->SUBSCRIBE_START   = (DPPI_SUB_CHIDX_Ch0) |
                               (DPPI_SUB_EN_Msk);

NRF_DPPIC->CHENSET = (DPPI_CHENSET_CH0_Set << DPPI_CHENSET_CH0_Pos);
```

Many-to-many connection

The example shows how to create a many-to-many connection, showcasing the DPPIC's channel group functionality.

A channel group that includes only channel 0 is set up first. Then the GPIOTE and TIMER0 configure their IN0 and COMPARE0 events respectively to be published on channel 0, while the SAADC configures its START task to subscribe to events on channel 0. Through DPPIC, the CHG0 DISABLE task is configured to subscribe to events on channel 0. After an event is received on channel 0 it will be disabled. Finally, channel 0 is enabled using the DPPIC task to enable a channel group.

```
NRF_DPPIC->CHG[0] = (DPPI_CHG_CH0_Included << PPI_CHG_CH0_Pos);

NRF_GPIOTE->PUBLISH_IN0         = (DPPI_PUB_CHIDX_Ch0) |
                                  (DPPI_PUB_EN_Msk);
NRF_TIMER0->PUBLISH_COMPARE0    = (DPPI_PUB_CHIDX_Ch0) |
                                  (DPPI_PUB_EN_Msk);
NRF_SAADC->SUBSCRIBE_START      = (DPPI_SUB_CHIDX_Ch0) |
                                  (DPPI_SUB_EN_Msk);
NRF_DPPIC->SUBSCRIBE_CHG[0].DIS = (DPPI_SUB_CHIDX_Ch0) |
                                  (DPPI_SUB_EN_Msk);

NRF_DPPIC->TASK_CHG[0].EN = 1;
```

6.2.4 Special considerations for a system implementing TrustZone for Cortex-M processors

DPPI is implemented with split security, meaning it handles both secure and non-secure accesses. In a system implementing the TrustZone for Cortex-M technology, DPPI channels can be defined as secure or non-secure using the SPU.

A peripheral configured as non-secure will only be able to subscribe to or publish on non-secure DPPI channels. A peripheral configured as secure will be able to access all DPPI channels. DPPI handles both secure and non-secure accesses, but behaves differently depending on the access type:

- A non-secure peripheral access can only configure and control the DPPI channels defined as non-secure in the SPU.DPPI.PERM[] register(s)

- A secure peripheral access can control all the DPPI channels, independently of the SPU.DPPI.PERM[] register(s)

A group of channels can be created, making it possible to simultaneously enable or disable all channels within the group. The security attribute of a group of channels (secure or non-secure) is defined as follows:

- If all channels (enabled or not) within a group are non-secure, then the group is considered non-secure
- If at least one of the channels (enabled or not) within the group is secure, then the group is considered secure

A non-secure access to a DPPI register, or a bit field, controlling a channel marked as secure in SPU.DPPI[].PERM register(s) will be ignored. Write accesses will have no effect, and read accesses will always return a zero value.

No exceptions are triggered when non-secure accesses target a register or a bit field controlling a secure channel. For example, if the bit `i` is set in the SPU.DPPI[0].PERM register (declaring DPPI channel i as secure), then:

- Non-secure write accesses to registers CHEN, CHENSET, and CHENCLR cannot write bit `i` of these registers
- Non-secure write accesses to TASK_CHG[j].EN and TASK_CHG[j].DIS registers are ignored if the channel group `j` contains at least one channel defined as secure (it can be the channel i itself or any channel declared as secure)
- Non-secure read accesses to registers CHEN, CHENSET, and CHENCLR always read 0 for the bit at position `i`

For the channel configuration registers (CHG[]), access from non-secure code is only possible if the included channels are all non-secure, whether the channels are enabled or not. If a CHG[g] register included one or more secure channel(s), then the group `g` is considered as secure, and only secure transfers can read to or write from CHG[g]. A non-secure write access is ignored, and a non-secure read access returns 0.

The DPPI can subscribe to secure and non-secure channels through the SUBSCRIBE_CHG[] registers, in order to trigger the task for enabling or disabling groups of channels. An event from a secure channel will be ignored if the group subscribing to this channel is non-secure. A secure group can subscribe to a non-secure channel or a secure channel.

6.2.5 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
DPPIC : S	0x50017000	HF	NS	NA	Yes	DPPI configuration
DPPIC : NS	0x40017000					

Register overview

Register	Offset	TZ	Description
TASKS_CHG[n].EN	0x000		Enable channel group n
TASKS_CHG[n].DIS	0x004		Disable channel group n
SUBSCRIBE_CHG[n].EN	0x080		Subscribe configuration for task CHG[n].EN
SUBSCRIBE_CHG[n].DIS	0x084		Subscribe configuration for task CHG[n].DIS
CHEN	0x500		Channel enable register
CHENSET	0x504		Channel enable set register
CHENCLR	0x508		Channel enable clear register
CHG[n]	0x800		Channel group n Note: Writes to this register are ignored if either SUBSCRIBE_CHG[n].EN or SUBSCRIBE_CHG[n].DIS is enabled

6.2.5.1 TASKS_CHG[n] (n=0..5)

Channel group tasks

6.2.5.1.1 TASKS_CHG[n].EN (n=0..5)

Address offset: 0x000 + (n × 0x8)

Enable channel group n

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	EN			Enable channel group n
			Trigger	1	Trigger task

6.2.5.1.2 TASKS_CHG[n].DIS (n=0..5)

Address offset: 0x004 + (n × 0x8)

Disable channel group n

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	DIS			Disable channel group n
			Trigger	1	Trigger task

6.2.5.2 SUBSCRIBE_CHG[n] (n=0..5)

Subscribe configuration for tasks

6.2.5.2.1 SUBSCRIBE_CHG[n].EN (n=0..5)

Address offset: 0x080 + (n × 0x8)

Subscribe configuration for task CHG[n].EN

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task CHG[n].EN will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.2.5.2.2 SUBSCRIBE_CHG[n].DIS (n=0..5)

Address offset: 0x084 + (n × 0x8)

Subscribe configuration for task CHG[n].DIS

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task CHG[n].DIS will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.2.5.3 CHEN

Address offset: 0x500

Channel enable register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-P	RW	CH[i] (i=0..15)			Enable or disable channel i
			Disabled	0	Disable channel
			Enabled	1	Enable channel

6.2.5.4 CHENSET

Address offset: 0x504

Channel enable set register

Note: Read: Reads value of CHi field in CHEN register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-P	RW	CH[i] (i=0..15)			Channel i enable set register. Writing 0 has no effect.
	W1S				
			Disabled	0	Read: Channel disabled
			Enabled	1	Read: Channel enabled
			Set	1	Write: Enable channel

6.2.5.5 CHENCLR

Address offset: 0x508

Channel enable clear register

Note: Read: Reads value of CHi field in CHEN register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-P	RW	CH[i] (i=0..15)			Channel i enable clear register. Writing 0 has no effect.
	W1C				
			Disabled	0	Read: Channel disabled
			Enabled	1	Read: Channel enabled
			Clear	1	Write: Disable channel

6.2.5.6 CHG[n] (n=0..5)

Address offset: 0x800 + (n × 0x4)

Channel group n

Note: Writes to this register are ignored if either SUBSCRIBE_CHG[n].EN or SUBSCRIBE_CHG[n].DIS is enabled

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-P	RW	CH[i] (i=0..15)			Include or exclude channel i
			Excluded	0	Exclude
			Included	1	Include

6.3 EGU — Event generator unit

Event generator unit (EGU) provides support for interlayer signaling. This means providing support for atomic triggering of both CPU execution and hardware tasks, from both firmware (by CPU) and hardware (by PPI). This feature can, for instance, be used for triggering CPU execution at a lower priority execution from a higher priority execution, or to handle a peripheral's interrupt service routine (ISR) execution at a lower priority for some of its events. However, triggering any priority from any priority is possible.

Listed here are the main EGU features:

- Software-enabled interrupt triggering
- Separate interrupt vectors for every EGU instance
- Up to 16 separate event flags per interrupt for multiplexing

Each instance of EGU implements a set of tasks which can individually be triggered to generate the corresponding event, for example, the corresponding event for TASKS_TRIGGER[n] is EVENTS_TRIGGERED[n]. See Instances on page 161 for a list of EGU instances.

6.3.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
EGU0 : S	0x5001B000	US	NS	NA	No	Event generator unit 0
EGU0 : NS	0x4001B000					
EGU1 : S	0x5001C000	US	NS	NA	No	Event generator unit 1
EGU1 : NS	0x4001C000					
EGU2 : S	0x5001D000	US	NS	NA	No	Event generator unit 2
EGU2 : NS	0x4001D000					
EGU3 : S	0x5001E000	US	NS	NA	No	Event generator unit 3
EGU3 : NS	0x4001E000					
EGU4 : S	0x5001F000	US	NS	NA	No	Event generator unit 4
EGU4 : NS	0x4001F000					
EGU5 : S	0x50020000	US	NS	NA	No	Event generator unit 5
EGU5 : NS	0x40020000					

Register overview

Register	Offset	TZ	Description
TASKS_TRIGGER[n]	0x000		Trigger n for triggering the corresponding TRIGGERED[n] event
SUBSCRIBE_TRIGGER[n]	0x080		Subscribe configuration for task TRIGGER[n]
EVENTS_TRIGGERED[n]	0x100		Event number n generated by triggering the corresponding TRIGGER[n] task
PUBLISH_TRIGGERED[n]	0x180		Publish configuration for event TRIGGERED[n]
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt

6.3.1.1 TASKS_TRIGGER[n] (n=0..15)

Address offset: 0x000 + (n × 0x4)

Trigger n for triggering the corresponding TRIGGERED[n] event

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_TRIGGER			Trigger n for triggering the corresponding TRIGGERED[n] event
			Trigger	1	Trigger task

6.3.1.2 SUBSCRIBE_TRIGGER[n] (n=0..15)

Address offset: 0x080 + (n × 0x4)

Subscribe configuration for task TRIGGER[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task TRIGGER[n] will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.3.1.3 EVENTS_TRIGGERED[n] (n=0..15)

Address offset: 0x100 + (n × 0x4)

Event number n generated by triggering the corresponding TRIGGER[n] task

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_TRIGGERED			Event number n generated by triggering the corresponding TRIGGER[n] task
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.3.1.4 PUBLISH_TRIGGERED[n] (n=0..15)

Address offset: 0x180 + (n × 0x4)

Publish configuration for event TRIGGERED[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TRIGGERED[n] will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.3.1.5 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-P	RW	TRIGGERED[i] (i=0..15)			Enable or disable interrupt for event TRIGGERED[i]
			Disabled	0	Disable
			Enabled	1	Enable

6.3.1.6 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-P	RW	TRIGGERED[i] (i=0..15)			Write '1' to enable interrupt for event TRIGGERED[i]
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.3.1.7 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-P	RW	TRIGGERED[i] (i=0..15)			Write '1' to disable interrupt for event TRIGGERED[i]
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.3.2 Electrical specification

6.3.2.1 EGU Electrical Specification

Symbol	Description	Min.	Typ.	Max.	Units
$t_{EGU,EVT}$	Latency between setting an EGU event flag and the system setting an interrupt		1		cycles

6.4 GPIO — General purpose input/output

The general purpose input/output pins (GPIOs) are grouped as one or more ports with each port having up to 32 GPIOs.

The number of ports and GPIOs per port may vary with product variant and package. Refer to Registers on page 168 and Pin assignments on page 516 for more information about the number of GPIOs that are supported.

GPIO has the following user-configurable features:

- Up to 32 GPIO pins per GPIO port
- Configurable output drive strength
- Internal pull-up and pull-down resistors
- Wake-up from high or low level triggers on all pins
- Trigger interrupt on state changes on any pin
- All pins can be used by the PPI task/event system
- One or more GPIO outputs can be controlled through PPI and GPIOTE channels
- All pins can be individually mapped to interface blocks for layout flexibility
- GPIO state changes captured on SENSE signal can be stored by LATCH register
- Support for secure and non-secure attributes for pins in conjunction with the system protection unit (SPU — System protection unit on page 323)

GPIO port and the GPIO pin details on page 164 illustrates the GPIO port containing 32 individual pins, where `PIN0` is illustrated in more detail as a reference. All signals on the left side in the illustration are used by other peripherals in the system and therefore not directly available to the CPU.

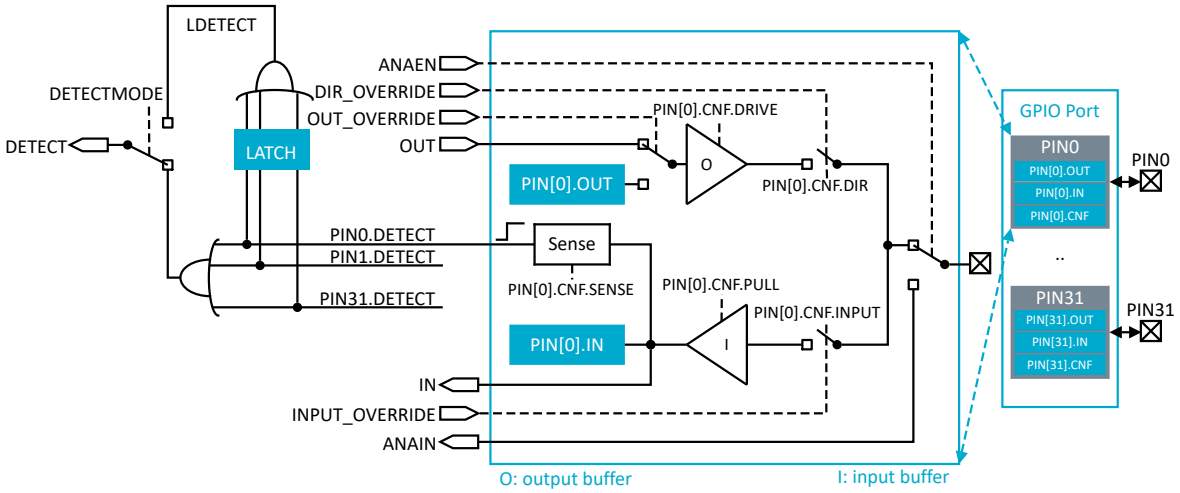

Figure 22: GPIO port and the GPIO pin details

6.4.1 Pin configuration

The GPIO port peripheral implements up to 32 pins, `PIN0` through `PIN31`. Each of these pins can be individually configured in the PIN_CNF[n] registers (n=0..31).

The following parameters can be configured through these registers:

- Direction
- Drive strength
- Enabling of pull-up and pull-down resistors
- Pin sensing
- Input buffer disconnect
- Analog input (for selected pins)

Note: All write-capable registers are retained registers, see POWER — Power control on page 68 for more information.

The input buffer of a GPIO pin can be disconnected from the pin to enable power savings when the pin is not used as an input, see GPIO port and the GPIO pin details on page 164. Inputs must be connected to get a valid input value in the IN register, and for the sense mechanism to get access to the pin.

Other peripherals in the system can connect to GPIO pins and override their output value and configuration, or read their analog or digital input value. See GPIO port and the GPIO pin details on page 164.

Selected pins also support analog input signals, see ANAIN in GPIO port and the GPIO pin details on page 164. The assignment of the analog pins can be found in Pin assignments on page 516.

The following delays should be taken into considerations:

- There is a delay of 2 CPU clock cycles from the GPIO pad to the IN register.
- The GPIO pad must be low (or high depending on the SENSE polarity) for 3 CPU clock cycles after DETECT has gone high to generate a new DETECT signal.

Note: When a pin is configured as digital input, care has been taken to minimize increased current consumption when the input voltage is between V_{IL} and V_{IH}. However, it is a good practice to ensure that the external circuitry does not drive that pin to levels between V_{IL} and V_{IH} for a long period of time.

6.4.2 Pin sense mechanism

Pins sensitivity can be individually configured, through the SENSE field in the PIN_CNF[n] register, to detect either a high level or a low level on their input.

When the correct level is detected on any such configured pin, the sense mechanism will set the DETECT signal high. Each pin has a separate DETECT signal. Default behavior, defined by the DETECTMODE register, is that the DETECT signals from all pins in the GPIO port are combined into one common DETECT signal that is routed throughout the system, which then can be utilized by other peripherals. This mechanism is functional in both System ON and System OFF modes.

DETECTMODE and DETECTMODE_SEC are provided to handle secure and non-secure pins. DETECTMODE_SEC register is available to control the behavior associated to pin marked as secure, while the DETECTMODE register is restricted to pin marked as non-secure. Please refer to GPIO security on page 166 for more details.

Make sure that a pin is in a level that cannot trigger the sense mechanism before enabling it. The DETECT signal will go high immediately if the SENSE condition configured in the PIN_CNF registers is met when the sense mechanism is enabled. This will trigger a PORT event if the DETECT signal was low before enabling the sense mechanism.

The DETECT signal is also used by power and clock management system to exit from System OFF mode, and by GPIOTE to generate the PORT event. In addition GPIOTE_SEC is used for PORT event related to secure pins). See POWER — Power control on page 68 and GPIOTE — GPIO tasks and events on page 173 for more information about how the DETECT signal is used.

When a pin's PINx.DETECT signal goes high, a flag will be set in the LATCH register. For example, when the PIN0.DETECT signal goes high, bit 0 in the LATCH register will be set to '1'. If the CPU performs a clear operation on a bit in the LATCH register when the associated PINx.DETECT signal is high, the bit in the LATCH register will not be cleared. The LATCH register will only be cleared if the CPU explicitly clears it by writing a '1' to the bit that shall be cleared, i.e. the LATCH register will not be affected by a PINx.DETECT signal being set low.

The LDETECT signal will be set high when one or more bits in the LATCH register are '1'. The LDETECT signal will be set low when all bits in the LATCH register are successfully cleared to '0'.

If one or more bits in the LATCH register are '1' after the CPU has performed a clear operation on the LATCH registers, a rising edge will be generated on the LDETECT signal. This is illustrated in DETECT signal behavior on page 166.

Note: The CPU can read the LATCH register at any time to check if a SENSE condition has been met on one or more of the GPIO pins, even if that condition is no longer met at the time the CPU queries the LATCH register. This mechanism will work even if the LDETECT signal is not used as the DETECT signal.

The LDETECT signal is by default not connected to the GPIO port's DETECT signal, but via the DETECTMODE register it is possible to change from default behavior to DETECT signal being derived directly from the LDETECT signal instead. See GPIO port and the GPIO pin details on page 164. DETECT signal behavior on page 166 illustrates the DETECT signal behavior for these two alternatives.

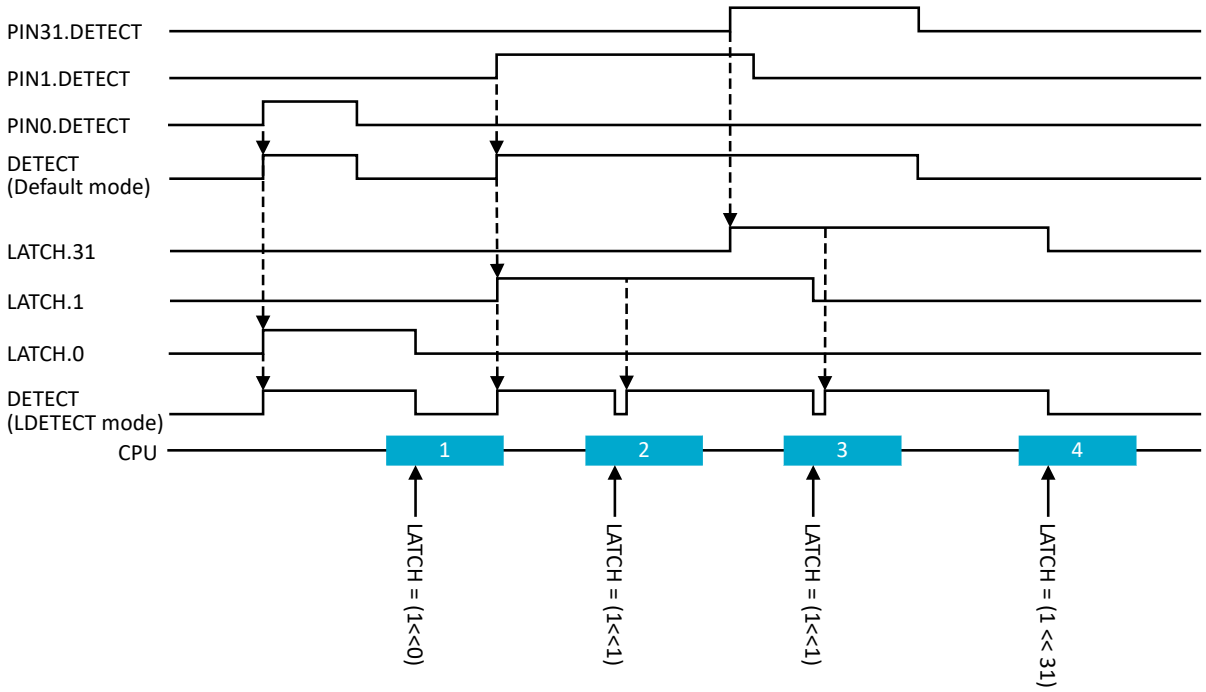

Figure 23: DETECT signal behavior

6.4.3 GPIO security

The general purpose input/output (GPIO) peripheral is implemented as a *split-security* peripheral. If marked as non-secure, it can be accessed by both secure and non-secure accesses but will behave differently depending on the access type.

A non-secure peripheral access will only be able to configure and control pins defined as non-secure in the system protection unit (SPU) GPIOPORT.PERM[] register(s).

A non-secure access to a register or a bitfield controlling a pin marked as secure in GPIO.PERM[] register(s) will be ignored. Write access will have no effect and read access will return a zero value.

No exception is triggered when a non-secure access targets a register or bitfield controlling a secure pin. For example, if the bit `i` is set in the SPU.GPIO.PERM[0] register (declaring Pin P0.`i` as secure), then

- non-secure write accesses to OUT, OUTSET, OUTCLR, DIR, DIRSET, DIRCLR and LATCH registers will not be able to write to bit `i` of those registers
- non-secure write accesses to registers PIN[`i`].OUT and PIN_CNF[`i`] will be ignored

- non-secure read accesses to registers OUT, OUTSET, OUTCLR, IN, DIR, DIRSET, DIRCLR and LATCH will always read a '0' for the bit at position `i`
- non-secure read accesses to registers PIN[`i`].OUT, PIN[`i`].OUT and PIN_CNF[`i`] will always return 0

The GPIO.DETECTMODE and GPIO.DETECTMODE_SEC registers are handled differently than the other registers mentioned before. When accessed by a secure access, the DETECTMODE_SEC register control the source for the DETECT_SEC signal for the pins marked as secure. When accessed by a non-secure access, the DETECTMODE_SEC is read as zero and write accesses are ignored. The GPIO.DETECTMODE register controls the source for the DETECT_NSEC signal for the pins defined as non-secure.

The DETECT_NSEC signal is routed to the GPIOTE peripheral, allowing generation of events and interrupts from pins marked as non-secure. The DETECT_SEC signal is routed to the GPIOTESEC peripheral, allowing generation of events and interrupts from pins marked as secure. Principle of direct pin access on page 167 illustrates how the DETECT_NSEC and DETECT_SEC signals are generated from the GPIO PIN[].DETECT signals.

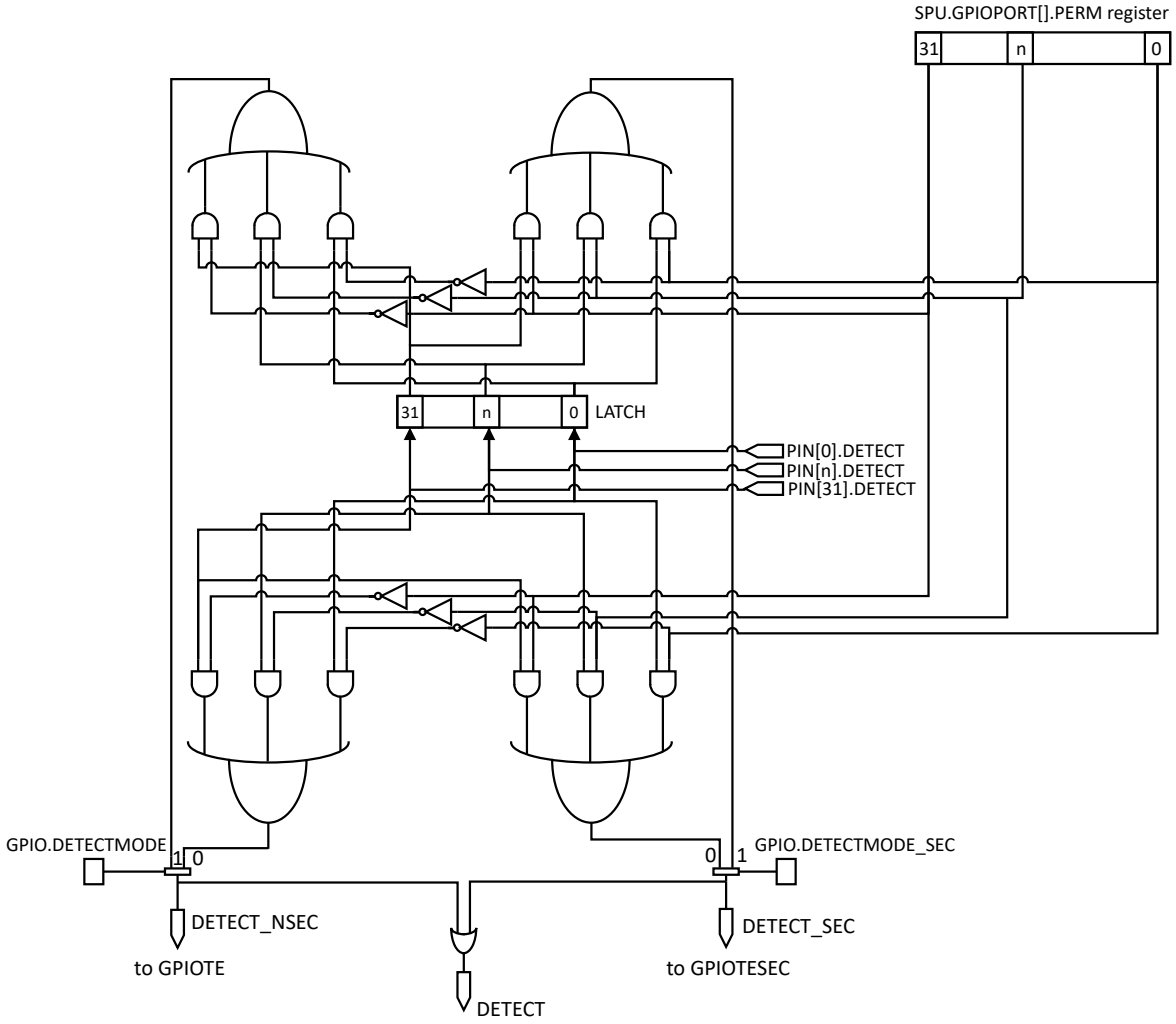

Figure 24: Principle of direct pin access

6.4.4 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
P0 : S	0x50842500	HF	NS	NA	Yes	General purpose input and output
P0 : NS	0x40842500					

Register overview

Register	Offset	TZ	Description
OUT	0x004		Write GPIO port This register is retained.
OUTSET	0x008		Set individual bits in GPIO port
OUTCLR	0x00C		Clear individual bits in GPIO port
IN	0x010		Read GPIO port
DIR	0x014		Direction of GPIO pins This register is retained.
DIRSET	0x018		DIR set register
DIRCLR	0x01C		DIR clear register
LATCH	0x020		Latch register indicating what GPIO pins that have met the criteria set in the PIN_CNF[n].SENSE registers This register is retained.
DETECTMODE	0x024		Select between default DETECT signal behavior and LDETECT mode (For non-secure pin only) This register is retained.
DETECTMODE_SEC	0x028		Select between default DETECT signal behavior and LDETECT mode (For secure pin only) This register is retained.
PIN_CNF[n]	0x200		Configuration of GPIO pins This register is retained.

6.4.4.1 OUT (Retained)

Address offset: 0x004

Write GPIO port

This register is retained.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	f	e	d	c	b	a	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A-f	RW	PIN[i] (i=0..31)			Pin i
			Low	0	Pin driver is low
			High	1	Pin driver is high

6.4.4.2 OUTSET

Address offset: 0x008

Set individual bits in GPIO port

Read: reads value of OUT register.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				f	e	d	c	b	a	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-f	RW	PIN[i] (i=0..31)																																	
	W1S																																		
			Low	0																															
			High	1																															
			Set	1																															

Write: writing a '1' sets the pin high; writing a '0' has no effect

6.4.4.3 OUTCLR

Address offset: 0x00C

Clear individual bits in GPIO port

Read: reads value of OUT register.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				f	e	d	c	b	a	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-f	RW	PIN[i] (i=0..31)																																	
	W1C																																		
			Low	0																															
			High	1																															
			Clear	1																															

Write: writing a '1' sets the pin low; writing a '0' has no effect

6.4.4.4 IN

Address offset: 0x010

Read GPIO port

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				f	e	d	c	b	a	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-f	R	PIN[i] (i=0..31)																																	
			Low	0																															
			High	1																															

6.4.4.5 DIR (Retained)

Address offset: 0x014

Direction of GPIO pins

This register is retained.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				f e d c b a Z Y X W V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-f	RW	PIN[i] (i=0..31)			Pin i
			Input	0	Pin set as input
			Output	1	Pin set as output

6.4.4.6 DIRSET

Address offset: 0x018

DIR set register

Read: reads value of DIR register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				f e d c b a Z Y X W V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-f	RW	PIN[i] (i=0..31)			Set as output pin i
	W1S				
			Input	0	Read: pin set as input
			Output	1	Read: pin set as output
			Set	1	Write: writing a '1' sets pin to output; writing a '0' has no effect

6.4.4.7 DIRCLR

Address offset: 0x01C

DIR clear register

Read: reads value of DIR register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				f e d c b a Z Y X W V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-f	RW	PIN[i] (i=0..31)			Set as input pin i
	W1C				
			Input	0	Read: pin set as input
			Output	1	Read: pin set as output
			Clear	1	Write: writing a '1' sets pin to input; writing a '0' has no effect

6.4.4.8 LATCH (Retained)

Address offset: 0x020

Latch register indicating what GPIO pins that have met the criteria set in the PIN_CNF[n].SENSE registers

This register is retained.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				f e d c b a Z Y X W V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-f	RW	PIN[i] (i=0..31)			Status on whether PIN[i] has met criteria set in PIN_CNF[i].SENSE register.
					Write '1' to clear.
			NotLatched	0	Criteria has not been met
			Latched	1	Criteria has been met

6.4.4.9 DETECTMODE (Retained)

Address offset: 0x024

Select between default DETECT signal behavior and LDETECT mode (For non-secure pin only)

This register is retained.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	DETECTMODE			Select between default DETECT signal behavior and LDETECT mode
			Default	0	DETECT directly connected to PIN DETECT signals
			LDETECT	1	Use the latched LDETECT behavior

6.4.4.10 DETECTMODE_SEC (Retained)

Address offset: 0x028

Select between default DETECT signal behavior and LDETECT mode (For secure pin only)

This register is retained.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	DETECTMODE			Select between default DETECT signal behavior and LDETECT mode
			Default	0	DETECT directly connected to PIN DETECT signals
			LDETECT	1	Use the latched LDETECT behavior

6.4.4.11 PIN_CNF[n] (n=0..31) (Retained)

Address offset: 0x200 + (n × 0x4)

Configuration of GPIO pins

This register is retained.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E E D D D C C B
Reset 0x00000002				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0**
ID	R/W	Field	Value ID	Value	Description
	RW	DIR			Pin direction. Same physical register as DIR register
			Input	0	Configure pin as an input pin
			Output	1	Configure pin as an output pin

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E E D D D C C B
Reset 0x00000002				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0**
ID	R/W	Field	Value ID	Value	Description
B	RW	INPUT			Connect or disconnect input buffer
			Connect	0	Connect input buffer
			Disconnect	1	Disconnect input buffer
C	RW	PULL			Pull configuration
			Disabled	0	No pull
			Pulldown	1	Pull down on pin
			Pullup	3	Pull up on pin
D-	RW	DRIVE			Drive configuration
			S0S1	0	Standard '0', standard '1'
			H0S1	1	High drive '0', standard '1'
			S0H1	2	Standard '0', high drive '1'
			H0H1	3	High drive '0', high 'drive '1''
			D0S1	4	Disconnect '0', standard '1' (normally used for wired-or connections)
			D0H1	5	Disconnect '0', high drive '1' (normally used for wired-or connections)
			S0D1	6	Standard '0', disconnect '1' (normally used for wired-and connections)
			H0D1	7	High drive '0', disconnect '1' (normally used for wired-and connections)
E	RW	SENSE			Pin sensing mechanism
			Disabled	0	Disabled
			High	2	Sense for high level
			Low	3	Sense for low level

6.4.5 Electrical specification

6.4.5.1 GPIO Electrical Specification

Note: VDD in the following table refers to VDD_GPIO.

Symbol	Description	Min.	Typ.	Max.	Units
V_{IH}	Input high voltage	0.7 x VDD		VDD	V
V_{IL}	Input low voltage	VSS		0.3 x VDD	V
$V_{OH,SD}$	Output high voltage, standard drive, 0.5 mA, VDD ≥ 1.7 V	VDD-0.4		VDD	V
$V_{OH,HDH}$	Output high voltage, high drive, 5 mA, VDD ≥ 2.7 V	VDD-0.4		VDD	V
$V_{OH,HDL}$	Output high voltage, high drive, 3 mA, VDD ≥ 1.7 V	VDD-0.4		VDD	V
$V_{OL,SD}$	Output low voltage, standard drive, 0.5 mA, VDD ≥ 1.7 V	VSS		VSS+0.4	V
$V_{OL,HDH}$	Output low voltage, high drive, 5 mA, VDD ≥ 2.7 V	VSS		VSS+0.4	V
$V_{OL,HDL}$	Output low voltage, high drive, 3 mA, VDD ≥ 1.7 V	VSS		VSS+0.4	V
$I_{OL,SD}$	Current at VSS + 0.4 V, output set low, standard drive, VDD ≥ 1.7 V	1	2	4	mA
$I_{OL,HDH}$	Current at VSS + 0.4 V, output set low, high drive, VDD ≥ 2.7 V	6	10	15	mA
$I_{OL,HDL}$	Current at VSS + 0.4 V, output set low, high drive, VDD ≥ 1.7 V	3			mA
$I_{OH,SD}$	Current at VDD - 0.4 V, output set high, standard drive, VDD ≥1.7	1	2	4	mA
$I_{OH,HDH}$	Current at VDD - 0.4 V, output set high, high drive, VDD ≥ 2.7 V	6	9	14	mA
$I_{OH,HDL}$	Current at VDD - 0.4 V, output set high, high drive, VDD ≥ 1.7 V	3			mA
$t_{RF,15pF}$	Rise/fall time, standard drive mode, 10 to 90%, 15 pF load[1]	6	9	19	ns
$t_{RF,25pF}$	Rise/fall time, standard drive mode, 10 to 90%, 25 pF load[1]	10	13	30	ns
$t_{RF,50pF}$	Rise/fall time, standard drive mode, 10 to 90%, 50 pF load[1]	18	25	61	ns
$t_{HRF,15pF}$	Rise/Fall time, high drive mode, 10 to 90%, 15 pF load[1]	2	4	8	ns

[1] Rise and fall times based on simulations

Symbol	Description	Min.	Typ.	Max.	Units
$t_{HRF,25pF}$	Rise/Fall time, high drive mode, 10 to 90%, 25 pF load[1]	3	5	11	ns
$t_{HRF,50pF}$	Rise/Fall time, high drive mode, 10 to 90%, 50 pF load[1]	5	8	19	ns
R_{PU}	Pull-up resistance	11	13	16	kΩ
R_{PD}	Pull-down resistance	11	13	16	kΩ
C_{PAD}	Pad capacitance		3		pF

6.5 GPIOTE — GPIO tasks and events

The GPIO tasks and events (GPIOTE) module provides functionality for accessing GPIO pins using tasks and events. Each GPIOTE channel can be assigned to one pin.

A GPIOTE block enables GPIOs to generate events on pin state change which can be used to carry out tasks through the PPI system. A GPIO can also be driven to change state on system events using the PPI system. Tasks and events are briefly introduced in Peripheral interface on page 15, and GPIO is described in more detail in GPIO — General purpose input/output on page 163.

Low power detection of pin state changes is possible when in System ON or System OFF.

Instance	Number of GPIOTE channels
GPIOTE	8

Table 18: GPIOTE properties

Up to three tasks can be used in each GPIOTE channel for performing write operations to a pin. Two tasks are fixed (SET and CLR), and one (OUT) is configurable to perform following operations:

- Set
- Clear
- Toggle

An event can be generated in each GPIOTE channel from one of the following input conditions:

- Rising edge
- Falling edge
- Any change

6.5.1 Pin events and tasks

The GPIOTE module has a number of tasks and events that can be configured to operate on individual GPIO pins.

The tasks SET[n], CLR[n], and OUT[n] can write to individual pins, and events IN[n] can be generated from input changes of individual pins.

The SET task will set the pin selected in GPIOTE.CONFIG[n].PSEL to high. The CLR task will set the pin low.

The effect of the OUT task on the pin is configurable in CONFIG[n].POLARITY. It can set the pin high, set it low, or toggle it.

Tasks and events are configured using the CONFIG[n] registers. One CONFIG[n] register is associated with a set of SET[n], CLR[n], and OUT[n] tasks and IN[n] events.

As long as a SET[n], CLR[n], and OUT[n] task or an IN[n] event is configured to control pin **n**, the pin's output value will only be updated by the GPIOTE module. The pin's output value, as specified in the GPIO, will be ignored as long as the pin is controlled by GPIOTE. Attempting to write to the pin as a normal GPIO pin will have no effect. When the GPIOTE is disconnected from a pin, the associated pin gets the output and configuration values specified in the GPIO module, see MODE field in CONFIG[n] register.

When conflicting tasks are triggered simultaneously (i.e. during the same clock cycle) in one channel, the priority of the tasks is as described in the following table.

Priority	Task
1	OUT
2	CLR
3	SET

Table 19: Task priorities

When setting the CONFIG[n] registers, MODE=Disabled does not have the same effect as MODE=Task and POLARITY=None. In the latter case, a CLR or SET task occurring at the exact same time as OUT will end up with no change on the pin, based on the priorities described in the table above.

When a GPIOTE channel is configured to operate on a pin as a task, the initial value of that pin is configured in the OUTINIT field of CONFIG[n].

6.5.2 Port event

PORT is an event that can be generated from multiple input pins using the GPIO DETECT signal.

The event will be generated on the rising edge of the DETECT signal. See GPIO — General purpose input/output on page 163 for more information about the DETECT signal.

The GPIO DETECT signal will not wake the system up again if the system is put into System ON IDLE while the DETECT signal is high. Clear all DETECT sources before entering sleep. If the LATCH register is used as a source, a new rising edge will be generated on DETECT if any bit in LATCH is still high after clearing all or part of the register. This could occur if one of the PINx.DETECT signals is still high, for example. See Pin sense mechanism on page 165 for more information.

Setting the system to System OFF while DETECT is high will cause a wakeup from System OFF reset.

This feature can be used to wake up the CPU from a WFI or WFE type sleep in System ON when all peripherals and the CPU are idle, meaning the lowest power consumption in System ON mode.

To prevent spurious interrupts from the PORT event while configuring the sources, the following steps must be performed:

1. Disable interrupts on the PORT event (through INTENCLR.PORT).
2. Configure the sources (PIN_CNF[n].SENSE).
3. Clear any potential event that could have occurred during configuration (write `0` to EVENTS_PORT).
4. Enable interrupts (through INTENSET.PORT).

6.5.3 Tasks and events pin configuration

Each GPIOTE channel is associated with one physical GPIO pin through the CONFIG.PSEL field.

When Event mode is selected in CONFIG.MODE, the pin specified by CONFIG.PSEL will be configured as an input, overriding the DIR setting in GPIO. Similarly, when Task mode is selected in CONFIG.MODE, the pin specified by CONFIG.PSEL will be configured as an output overriding the DIR setting and OUT value in GPIO. When Disabled is selected in CONFIG.MODE, the pin specified by CONFIG.PSEL will use its configuration from the PIN[n].CNF registers in GPIO. CONFIG.MODE must be disabled in order to be able to change the value of the PSEL field.

Note: A pin can only be assigned to one GPIOTE channel at a time. Failing to do so may result in unpredictable behavior.

6.5.4 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
GPIOTE0	0x5000D000	HF	S	NA	No	Secure GPIO tasks and events
GPIOTE1	0x40031000	HF	NS	NA	No	Non Secure GPIO tasks and events

Register overview

Register	Offset	TZ	Description
TASKS_OUT[n]	0x000		Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is configured in CONFIG[n].POLARITY.
TASKS_SET[n]	0x030		Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is to set it high.
TASKS_CLR[n]	0x060		Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is to set it low.
SUBSCRIBE_OUT[n]	0x080		Subscribe configuration for task OUT[n]
SUBSCRIBE_SET[n]	0x0B0		Subscribe configuration for task SET[n]
SUBSCRIBE_CLR[n]	0x0E0		Subscribe configuration for task CLR[n]
EVENTS_IN[n]	0x100		Event generated from pin specified in CONFIG[n].PSEL
EVENTS_PORT	0x17C		Event generated from multiple input GPIO pins with SENSE mechanism enabled
PUBLISH_IN[n]	0x180		Publish configuration for event IN[n]
PUBLISH_PORT	0x1FC		Publish configuration for event PORT
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
CONFIG[n]	0x510		Configuration for OUT[n], SET[n], and CLR[n] tasks and IN[n] event

6.5.4.1 TASKS_OUT[n] (n=0..7)

Address offset: 0x000 + (n × 0x4)

Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is configured in CONFIG[n].POLARITY.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_OUT			Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is configured in CONFIG[n].POLARITY.
			Trigger	1	Trigger task

6.5.4.2 TASKS_SET[n] (n=0..7)

Address offset: 0x030 + (n × 0x4)

Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is to set it high.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_SET			Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is to set it high.
			Trigger	1	Trigger task

6.5.4.3 TASKS_CLR[n] (n=0..7)

Address offset: 0x060 + (n × 0x4)

Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is to set it low.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_CLR			Task for writing to pin specified in CONFIG[n].PSEL. Action on pin is to set it low.
			Trigger	1	Trigger task

6.5.4.4 SUBSCRIBE_OUT[n] (n=0..7)

Address offset: 0x080 + (n × 0x4)

Subscribe configuration for task OUT[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task OUT[n] will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.5.4.5 SUBSCRIBE_SET[n] (n=0..7)

Address offset: 0x0B0 + (n × 0x4)

Subscribe configuration for task SET[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task SET[n] will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.5.4.6 SUBSCRIBE_CLR[n] (n=0..7)

Address offset: 0x0E0 + (n × 0x4)

Subscribe configuration for task CLR[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task CLR[n] will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.5.4.7 EVENTS_IN[n] (n=0..7)

Address offset: 0x100 + (n × 0x4)

Event generated from pin specified in CONFIG[n].PSEL

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_IN			Event generated from pin specified in CONFIG[n].PSEL
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.5.4.8 EVENTS_PORT

Address offset: 0x17C

Event generated from multiple input GPIO pins with SENSE mechanism enabled

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_PORT			Event generated from multiple input GPIO pins with SENSE mechanism enabled
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.5.4.9 PUBLISH_IN[n] (n=0..7)

Address offset: 0x180 + (n × 0x4)

Publish configuration for event IN[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event IN[n] will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.5.4.10 PUBLISH_PORT

Address offset: 0x1FC

Publish configuration for event PORT

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event PORT will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.5.4.11 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-H	RW	IN[i] (i=0..7)			Write '1' to enable interrupt for event IN[i]
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
I	RW	PORT			Write '1' to enable interrupt for event PORT
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.5.4.12 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-H	RW	IN[i] (i=0..7)			Write '1' to disable interrupt for event IN[i]
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
I	RW	PORT			Write '1' to disable interrupt for event PORT
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.5.4.13 CONFIG[n] (n=0..7)

Address offset: 0x510 + (n × 0x4)

Configuration for OUT[n], SET[n], and CLR[n] tasks and IN[n] event

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID															D			C	C				B	B	B	B	B							A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	MODE																																	
			Disabled	0																															
			Event	1																															
				The pin specified by PSEL will be configured as an input and the IN[n] event will be generated if operation specified in POLARITY occurs on the pin.																																
			Task	3																															
				The GPIO specified by PSEL will be configured as an output and triggering the SET[n], CLR[n] or OUT[n] task will perform the operation specified by POLARITY on the pin. When enabled as a task the GPIOTE module will acquire the pin and the pin can no longer be written as a regular output pin from the GPIO module.																																
B	RW	PSEL		[0..31]																															
				GPIO number associated with SET[n], CLR[n], and OUT[n] tasks and IN[n] event																															
C	RW	POLARITY																																	
				When In task mode: Operation to be performed on output when OUT[n] task is triggered. When In event mode: Operation on input that shall trigger IN[n] event.																																
			None	0																															
				Task mode: No effect on pin from OUT[n] task. Event mode: no IN[n] event generated on pin activity.																																
			LoToHi	1																															
				Task mode: Set pin from OUT[n] task. Event mode: Generate IN[n] event when rising edge on pin.																																
			HiToLo	2																															
				Task mode: Clear pin from OUT[n] task. Event mode: Generate IN[n] event when falling edge on pin.																																
			Toggle	3																															
				Task mode: Toggle pin from OUT[n]. Event mode: Generate IN[n] when any change on pin.																																
D	RW	OUTINIT																																	
				When in task mode: Initial value of the output when the GPIOTE channel is configured. When in event mode: No effect.																																
			Low	0																															
				Task mode: Initial value of pin before task triggering is low																																
			High	1																															
				Task mode: Initial value of pin before task triggering is high																																

6.6 IPC — Interprocessor communication

The interprocessor communication (IPC) peripheral is used to send and receive events between MCUs in the system.

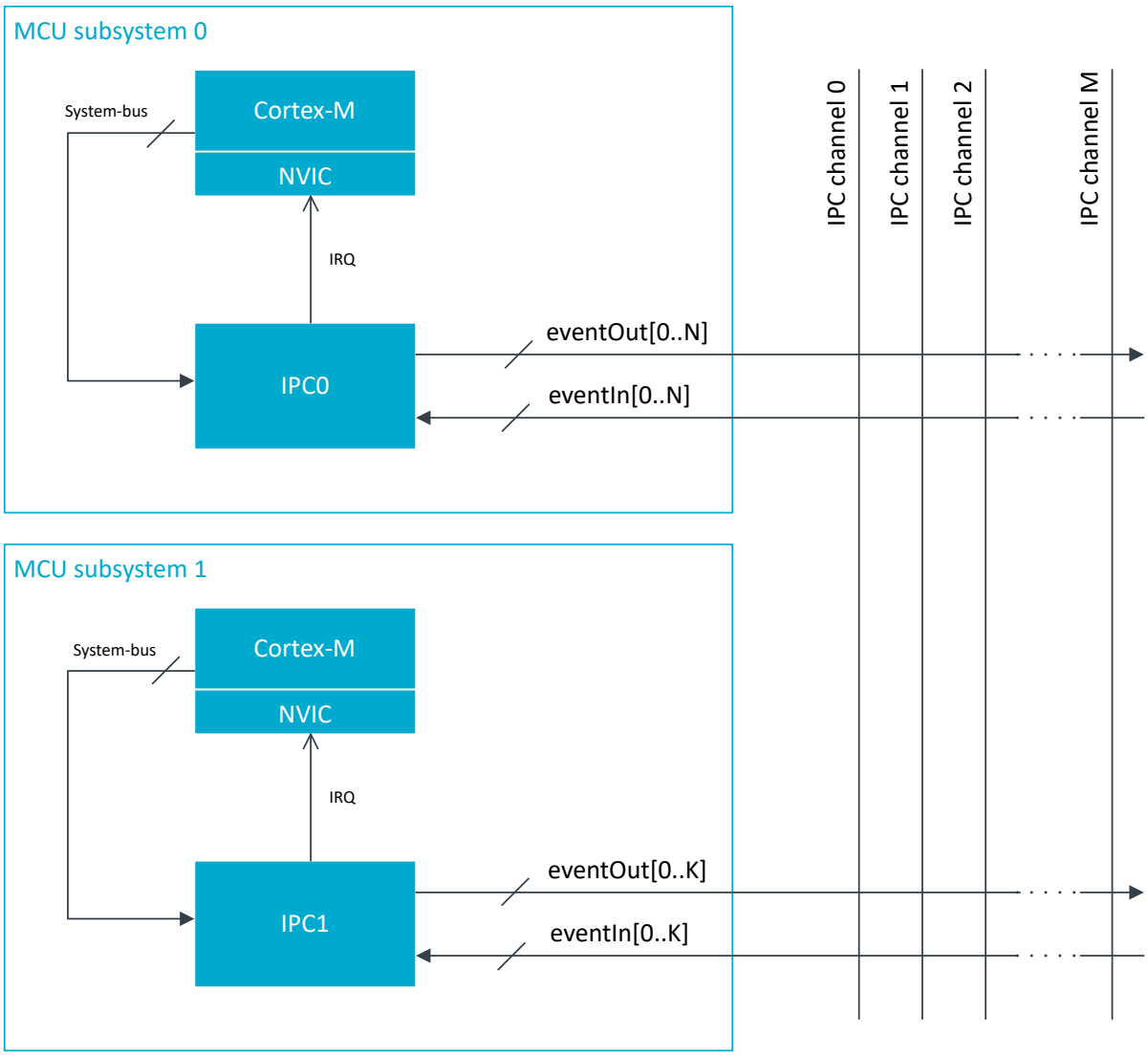

Figure 25: IPC block diagram

Functional description

IPC block diagram on page 180 illustrates the interprocessor communication (IPC) peripheral. In a multi-MCU system, each MCU has one dedicated IPC peripheral. The IPC peripheral can be used to send and receive events to and from other IPC peripherals. An instance of the IPC peripheral can have multiple SEND tasks and RECEIVE events. A single SEND task can be configured to signal an event on one or more IPC channels, and a RECEIVE event can be configured to listen on one or more IPC channels. The IPC channels that are triggered in a SEND task can be configured through the SEND_CNF registers, and the IPC channels that trigger a RECEIVE event are configured through the RECEIVE_CNF registers. The figure below illustrates how the SEND_CNF and RECEIVE_CNF registers work. Both the SEND task and the RECEIVE event can be connected to all IPC channels.

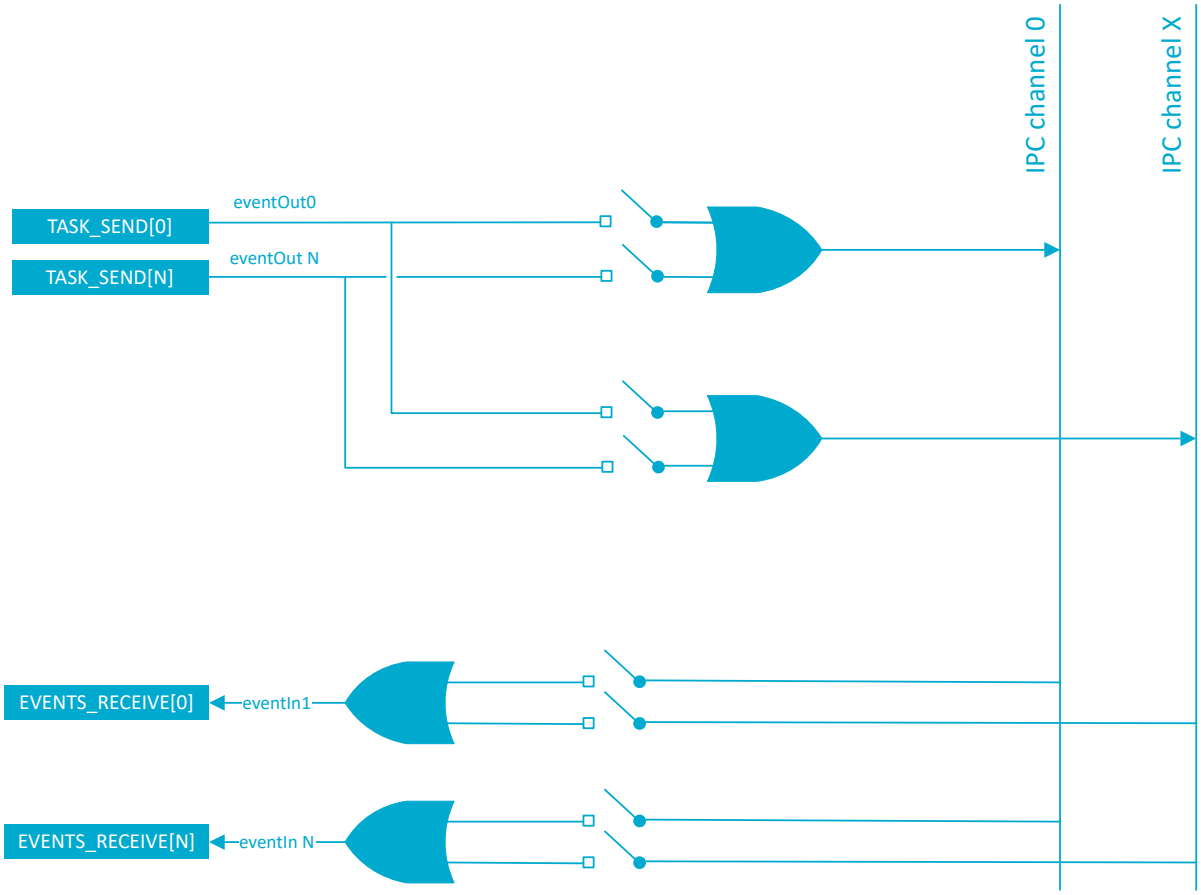

Figure 26: IPC registers SEND_CNF and RECEIVE_CNF

A SEND task can be viewed as broadcasting events onto one or more IPC channels, and a RECEIVE event can be seen as subscribing to a subset of IPC channels. It is possible for multiple IPCs to trigger events onto the same channel at the same time. When two or more events on the same channel occur within t_{IPC}, the events may be merged into a single event seen from the IPC receiver. One of the events can therefore be lost. To prevent this, the user must ensure that events on the same IPC channel do not occur within t_{IPC} of each other. When implementing firmware data structures, such as queues or mailboxes, this can be done by using one channel for acknowledgements.

An IPC event often does not contain any data itself, it is used to signal other MCUs that something has occurred. Data can be shared through shared memory, for example in the form of a software implemented mailbox, or command/event queues. It is up to software to assign a logical functionality to an IPC channel. For instance, one IPC channel can be used to signal that a command is ready to be executed, and any processor in the system can subscribe to that particular channel and decode/execute the command.

General purpose memory

The GPMEM registers can be used freely to store information. These registers are accessed like any other of the IPC peripheral's registers.

6.6.1 IPC and PPI connections

The IPC SEND tasks and RECEIVE events can be connected through PPI channels. This makes it possible to relay events from peripherals in one MCU to another, without CPU involvement.

Figure below illustrates a timer COMPARE event that is relayed from one MCU to IPC using PPI, then back into a timer CAPTURE event in another MCU.

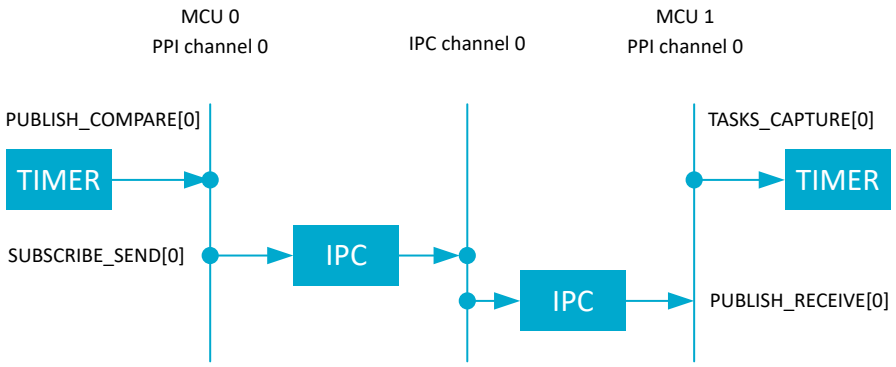

Figure 27: Example of PPI and IPC connections

6.6.2 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
IPC : S	0x5002A000	US	NS	NA	No	Interprocessor communication
IPC : NS	0x4002A000					

Register overview

Register	Offset	TZ	Description
TASKS_SEND[n]	0x000		Trigger events on IPC channel enabled in SEND_CNF[n]
SUBSCRIBE_SEND[n]	0x080		Subscribe configuration for task SEND[n]
EVENTS_RECEIVE[n]	0x100		Event received on one or more of the enabled IPC channels in RECEIVE_CNF[n]
PUBLISH_RECEIVE[n]	0x180		Publish configuration for event RECEIVE[n]
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
INTPEND	0x30C		Pending interrupts
SEND_CNF[n]	0x510		Send event configuration for TASKS_SEND[n]
RECEIVE_CNF[n]	0x590		Receive event configuration for EVENTS_RECEIVE[n]
GPMEM[n]	0x610		General purpose memory

6.6.2.1 TASKS_SEND[n] (n=0..7)

Address offset: 0x000 + (n × 0x4)

Trigger events on IPC channel enabled in SEND_CNF[n]

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_SEND			Trigger events on IPC channel enabled in SEND_CNF[n]
			Trigger	1	Trigger task

6.6.2.2 SUBSCRIBE_SEND[n] (n=0..7)

Address offset: 0x080 + (n × 0x4)

Subscribe configuration for task SEND[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task SEND[n] will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.6.2.3 EVENTS_RECEIVE[n] (n=0..7)

Address offset: 0x100 + (n × 0x4)

Event received on one or more of the enabled IPC channels in RECEIVE_CNF[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RECEIVE			Event received on one or more of the enabled IPC channels in RECEIVE_CNF[n]
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.6.2.4 PUBLISH_RECEIVE[n] (n=0..7)

Address offset: 0x180 + (n × 0x4)

Publish configuration for event RECEIVE[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event RECEIVE[n] will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.6.2.5 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	RECEIVE[i] (i=0..7)			Enable or disable interrupt for event RECEIVE[i]
			Disabled	0	Disable
			Enabled	1	Enable

6.6.2.6 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	RECEIVE[i] (i=0..7)			Write '1' to enable interrupt for event RECEIVE[i]
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.6.2.7 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	RECEIVE[i] (i=0..7)			Write '1' to disable interrupt for event RECEIVE[i]
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.6.2.8 INTPEND

Address offset: 0x30C

Pending interrupts

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	R	RECEIVE[i] (i=0..7)			Read pending status of interrupt for event RECEIVE[i]
			NotPending	0	Read: Not pending
			Pending	1	Read: Pending

6.6.2.9 SEND_CNF[n] (n=0..7)

Address offset: 0x510 + (n × 0x4)

Send event configuration for TASKS_SEND[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	CHEN[i] (i=0..7)			Enable broadcasting on IPC channel i
			Disable	0	Disable broadcast
			Enable	1	Enable broadcast

6.6.2.10 RECEIVE_CNF[n] (n=0..7)

Address offset: 0x590 + (n × 0x4)

Receive event configuration for EVENTS_RECEIVE[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	CHEN[i] (i=0..7)			Enable subscription to IPC channel i
			Disable	0	Disable events
			Enable	1	Enable events

6.6.2.11 GPMEM[n] (n=0..3)

Address offset: 0x610 + (n × 0x4)

General purpose memory

Retained only in System ON mode

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	GPMEM			General purpose memory

6.6.3 Electrical specification

6.6.3.1 IPC Electrical Specification

Symbol	Description	Min.	Typ.	Max.	Units
t_{IPC}	Time window during which IPC events can be merged			165	µs

6.7 I2S — Inter-IC sound interface

The I2S (Inter-IC Sound) module, supports the original two-channel I2S format, and left or right-aligned formats. It implements EasyDMA for sample transfer directly to and from RAM without CPU intervention.

The I2S peripheral has the following main features:

- Master and Slave mode

- Simultaneous bi-directional (TX and RX) audio streaming
- Original I2S and left- or right-aligned format
- 8, 16 and 24-bit sample width
- Low-jitter Master Clock generator
- Various sample rates

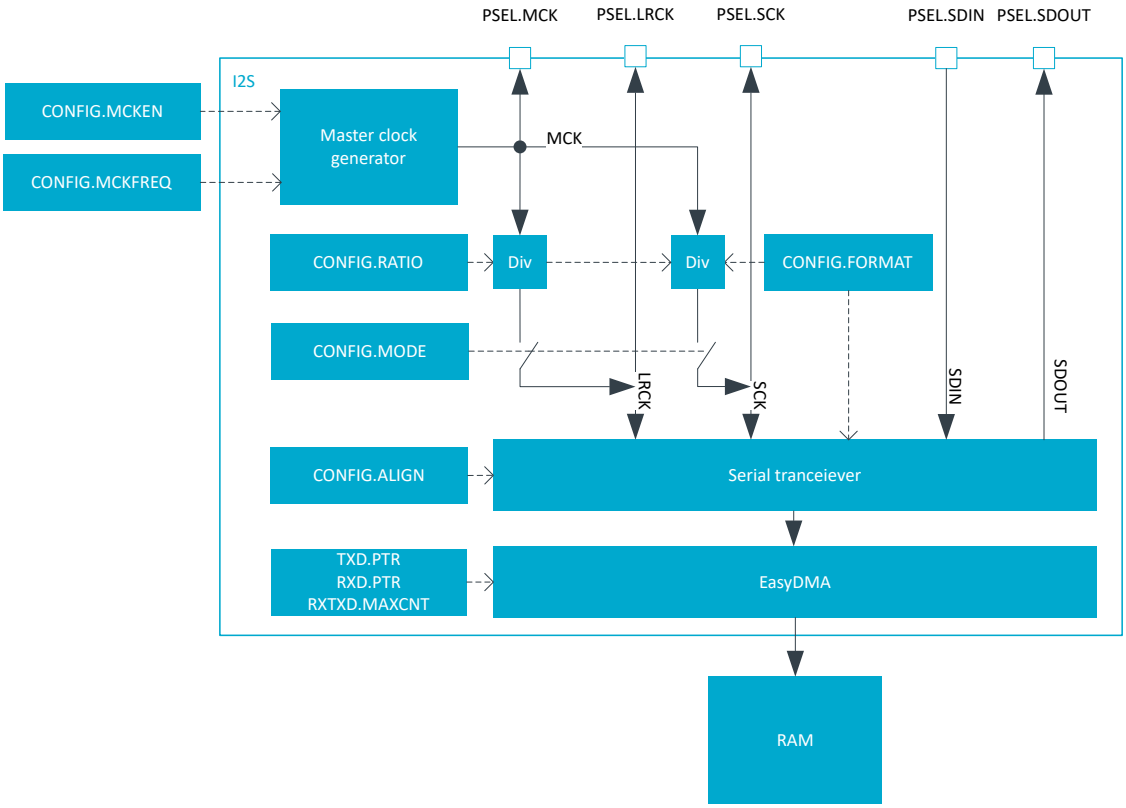

Figure 28: I2S master

6.7.1 Mode

The I2S protocol specification defines two modes of operation, Master and Slave.

The I2S mode decides which of the two sides (Master or Slave) shall provide the clock signals LRCK and SCK, and these signals are always supplied by the Master to the Slave.

6.7.2 Transmitting and receiving

The I2S module supports both transmission (TX) and reception (RX) of serial data. In both cases the serial data is shifted synchronously to the clock signals SCK and LRCK.

TX data is written to the SDOUT pin on the falling edge of SCK, and RX data is read from the SDIN pin on the rising edge of SCK. The most significant bit (MSB) is always transmitted first.

Note: When starting a transmission in master mode, two frames (two left-and-right sample pairs) of value zero will be transmitted after triggering the START task, prior to the RXTXD.MAXCNT samples specified by the TXD.PTR pointer.

TX and RX are available in both Master and Slave modes and can be enabled/disabled independently in the CONFIG.TXEN on page 200 and CONFIG.RXEN on page 200.

Transmission and/or reception is started by triggering the START task. When started and transmission is enabled (in CONFIG.TXEN on page 200), the TXPTRUPD event will be generated for every

RXTXD.MAXCNT on page 203 number of transmitted data words (containing one or more samples). Similarly, when started and reception is enabled (in CONFIG.RXEN on page 200), the RXPTRUPD event will be generated for every RXTXD.MAXCNT on page 203 received data words.

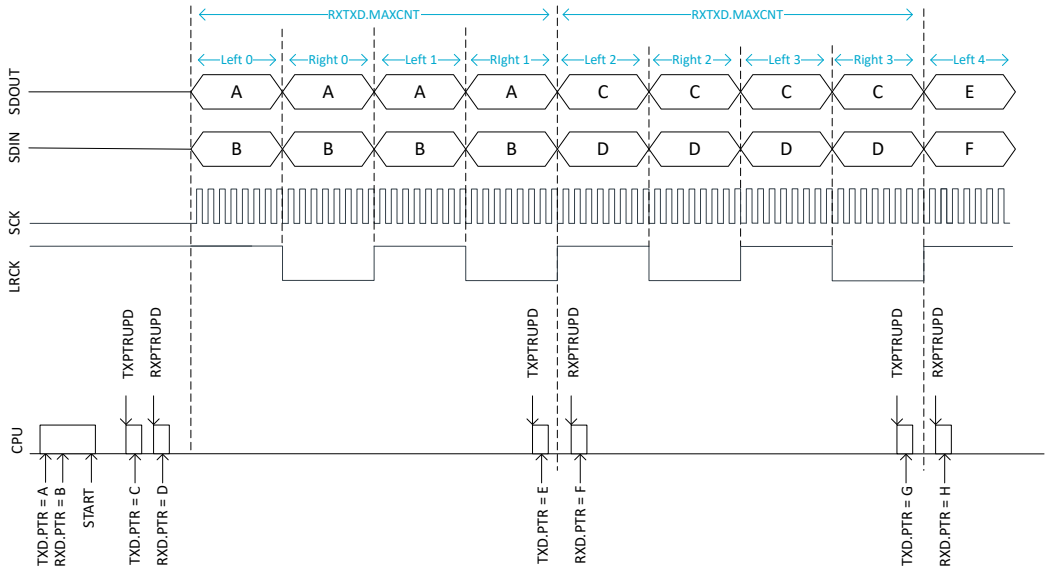

Figure 29: Transmitting and receiving. CONFIG.FORMAT = Aligned, CONFIG.SWIDTH = 8Bit, CONFIG.CHANNELS = Stereo, RXTXD.MAXCNT = 1.

6.7.3 Left right clock (LRCK)

The Left Right Clock (LRCK), often referred to as "word clock", "sample clock" or "word select" in I2S context, is the clock defining the frames in the serial bit streams sent and received on SDOUT and SDIN, respectively.

In I2S mode, each frame contains one left and right sample pair, with the left sample being transferred during the low half period of LRCK followed by the right sample being transferred during the high period of LRCK.

In Aligned mode, each frame contains one left and right sample pair, with the left sample being transferred during the high half period of LRCK followed by the right sample being transferred during the low period of LRCK.

Consequently, the LRCK frequency is equivalent to the audio sample rate.

When operating in Master mode, the LRCK is generated from the MCK, and the frequency of LRCK is then given as:

```
LRCK = MCK / CONFIG.RATIO
```

LRCK always toggles around the falling edge of the serial clock SCK.

6.7.4 Serial clock (SCK)

The serial clock (SCK), often referred to as the serial bit clock, pulses once for each data bit being transferred on the serial data lines SDIN and SDOUT.

When operating in Master mode the SCK is generated from the MCK, and the frequency of SCK is then given as:

```
SCK = 2 * LRCK * CONFIG.SWIDTH
```

The falling edge of the SCK falls on the toggling edge of LRCK.

When operating in Slave mode SCK is provided by the external I2S master.

6.7.5 Master clock (MCK)

The master clock (MCK) is the clock from which LRCK and SCK are derived when operating in Master mode.

The MCK is generated by an internal MCK generator. This generator always needs to be enabled when in Master mode, but the generator can also be enabled when in Slave mode. Enabling the generator when in slave mode can be useful in the case where the external Master is not able to generate its own master clock.

The MCK generator is enabled/disabled in the register CONFIG.MCKEN on page 200, and the generator is started or stopped by the START or STOP tasks.

In Master mode the LRCK and the SCK frequencies are closely related, as both are derived from MCK and set indirectly through CONFIG.RATIO on page 201 and CONFIG.SWIDTH on page 202.

When configuring these registers, the user is responsible for fulfilling the following requirements:

1. SCK frequency can never exceed the MCK frequency, which can be formulated as:

```
CONFIG.RATIO >= 2 * CONFIG.SWIDTH
```

2. The MCK/LRCK ratio shall be a multiple of 2 * CONFIG.SWIDTH, which can be formulated as:

```
Integer = (CONFIG.RATIO / (2 * CONFIG.SWIDTH))
```

The MCK signal can be routed to an output pin (specified in PSEL.MCK) to supply external I2S devices that require the MCK to be supplied from the outside.

When operating in Slave mode, the I2S module does not use the MCK and the MCK generator does not need to be enabled.

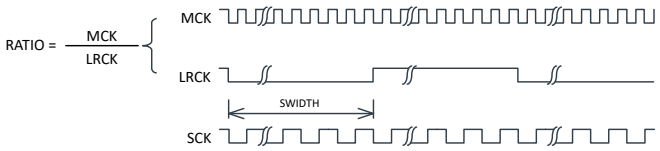

Figure 30: Relation between RATIO, MCK and LRCK.

Desired LRCK [Hz]	CONFIG.SWID	CONFIG.RATIO	CONFIG.MCKF	MCK [Hz]	LRCK [Hz]	LRCK error [%]
16000	16Bit	32X	32MDIV63	507936.5	15873.0	-0.8
16000	16Bit	64X	32MDIV31	1032258.1	16129.0	0.8
16000	16Bit	256X	32MDIV8	4000000.0	15625.0	-2.3
32000	16Bit	32X	32MDIV31	1032258.1	32258.1	0.8
32000	16Bit	64X	32MDIV16	2000000.0	31250.0	-2.3
44100	16Bit	32X	32MDIV23	1391304.3	43478.3	-1.4
44100	16Bit	64X	32MDIV11	2909090.9	45454.5	3.1

Table 20: Configuration examples

6.7.6 Width, alignment, and format

The CONFIG.SWIDTH register primarily defines the sample width of the data written to memory. In master mode, it then also sets the amount of bits per frame. In Slave mode it controls padding/trimming if required. Left, right, transmitted, and received samples always have the same width. The CONFIG.FORMAT register specifies the position of the data frames with respect to the LRCK edges in both Master and Slave modes.

When using I2S format, the first bit in a half-frame (containing one left or right sample) gets sampled on the second rising edge of the SCK after a LRCK edge. When using Aligned mode, the first bit in a half-frame gets sampled on the first rising edge of SCK following a LRCK edge.

For data being received on SDIN the sample value can be either right or left-aligned inside a half-frame, as specified in CONFIG.ALIGN on page 202. CONFIG.ALIGN on page 202 affects only the decoding of the incoming samples (SDIN), while the outgoing samples (SDOUT) are always left-aligned (or justified).

When using left-alignment, each half-frame starts with the MSB of the sample value (both for data being sent on SDOUT and received on SDIN).

When using right-alignment, each half-frame of data being received on SDIN ends with the LSB of the sample value, while each half-frame of data being sent on SDOUT starts with the MSB of the sample value (same as for left-alignment).

In Master mode, the size of a half-frame (in number of SCK periods) equals the sample width (in number of bits), and in this case the alignment setting does not care as each half-frame in any case will start with the MSB and end with the LSB of the sample value.

In slave mode, however, the sample width does not need to equal the frame size. This means you might have extra or fewer SCK pulses per half-frame than what the sample width specified in CONFIG.SWIDTH requires.

In the case where we use **left-alignment** and the number of SCK pulses per half-frame is **higher** than the sample width, the following will apply:

- For data received on SDIN, all bits after the LSB of the sample value will be discarded.
- For data sent on SDOUT, all bits after the LSB of the sample value will be 0.

In the case where we use **left-alignment** and the number of SCK pulses per frame is **lower** than the sample width, the following will apply:

- Data sent and received on SDOUT and SDIN will be truncated with the LSBs being removed first.

In the case where we use **right-alignment** and the number of SCK pulses per frame is **higher** than the sample width, the following will apply:

- For data received on SDIN, all bits before the MSB of the sample value will be discarded.
- For data sent on SDOUT, all bits after the LSB of the sample value will be 0 (same behavior as for left-alignment).

In the case where we use **right-alignment** and the number of SCK pulses per frame is **lower** than the sample width, the following will apply:

- Data received on SDIN will be sign-extended to "sample width" number of bits before being written to memory.
- Data sent on SDOUT will be truncated with the LSBs being removed first (same behavior as for left-alignment).

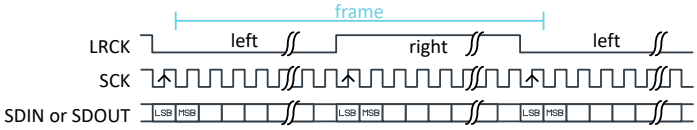

Figure 31: I2S format. CONFIG.SWIDTH equaling half-frame size.

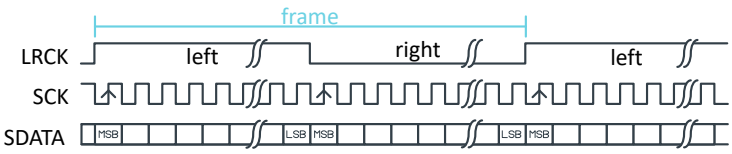

Figure 32: Aligned format. CONFIG.SWIDTH equaling half-frame size.

6.7.7 EasyDMA

The I2S module implements EasyDMA for accessing internal Data RAM without CPU intervention.

The source and destination pointers for the TX and RX data are configured in TXD.PTR on page 203 and RXD.PTR on page 203. The memory pointed to by these pointers will only be read or written when TX or RX are enabled in CONFIG.TXEN on page 200 and CONFIG.RXEN on page 200.

The addresses written to the pointer registers TXD.PTR on page 203 and RXD.PTR on page 203 are double-buffered in hardware, and these double buffers are updated for every RXTXD.MAXCNT on page 203 words (containing one or more samples) read/written from/to memory. The events TXPTRUPD and RXPTRUPD are generated whenever the TXD.PTR and RXD.PTR are transferred to these double buffers.

If TXD.PTR on page 203 is not pointing to the Data RAM region when transmission is enabled, or RXD.PTR on page 203 is not pointing to the Data RAM region when reception is enabled, an EasyDMA transfer may result in a HardFault and/or memory corruption. See Memory on page 21 for more information about the different memory regions.

Due to the nature of I2S, where the number of transmitted samples always equals the number of received samples (at least when both TX and RX are enabled), one common register RXTXD.MAXCNT on page 203 is used for specifying the sizes of these two memory buffers. The size of the buffers is specified in a number of 32-bit words. Such a 32-bit memory word can either contain four 8-bit samples, two 16-bit samples or one right-aligned 24-bit sample sign extended to 32 bit.

In stereo mode (CONFIG.CHANNELS=Stereo), the samples are stored as "left and right sample pairs" in memory. Figure Memory mapping for 8 bit stereo. CONFIG.SWIDTH = 8Bit, CONFIG.CHANNELS = Stereo. on page 190, Memory mapping for 16 bit stereo. CONFIG.SWIDTH = 16Bit, CONFIG.CHANNELS = Stereo. on page 191 and Memory mapping for 24 bit stereo. CONFIG.SWIDTH = 24Bit, CONFIG.CHANNELS = Stereo. on page 191 show how the samples are mapped to memory in this mode. The mapping is valid for both RX and TX.

In mono mode (CONFIG.CHANNELS=Left or Right), RX sample from only one channel in the frame is stored in memory, the other channel sample is ignored. Illustrations Memory mapping for 8 bit mono. CONFIG.SWIDTH = 8Bit, CONFIG.CHANNELS = Left. on page 191, Memory mapping for 16 bit mono, left channel only. CONFIG.SWIDTH = 16Bit, CONFIG.CHANNELS = Left. on page 191 and Memory mapping for 24 bit mono, left channel only. CONFIG.SWIDTH = 24Bit, CONFIG.CHANNELS = Left. on page 192 show how RX samples are mapped to memory in this mode.

For TX, the same outgoing sample read from memory is transmitted on both left and right in a frame, resulting in a mono output stream.

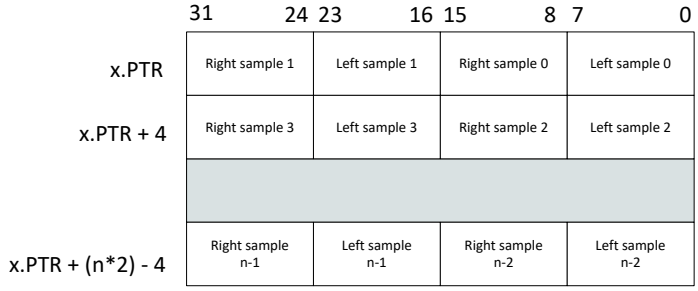

Figure 33: Memory mapping for 8 bit stereo. CONFIG.SWIDTH = 8Bit, CONFIG.CHANNELS = Stereo.

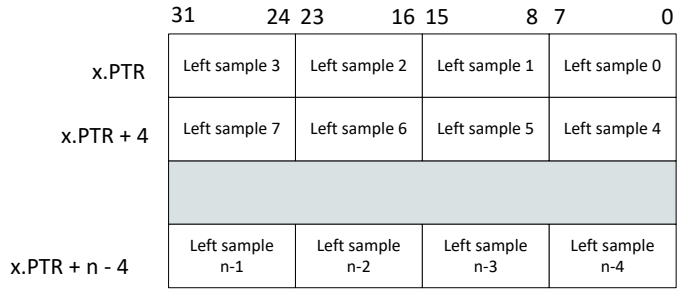

Figure 34: Memory mapping for 8 bit mono. CONFIG.SWIDTH = 8Bit, CONFIG.CHANNELS = Left.

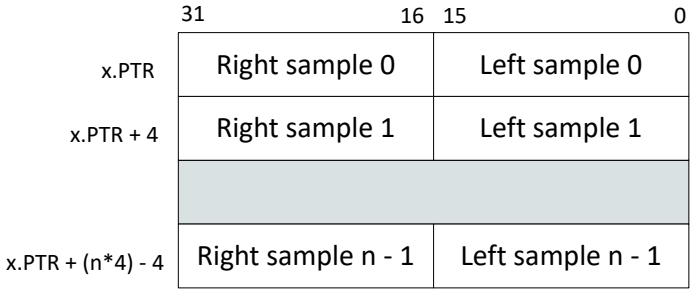

Figure 35: Memory mapping for 16 bit stereo. CONFIG.SWIDTH = 16Bit, CONFIG.CHANNELS = Stereo.

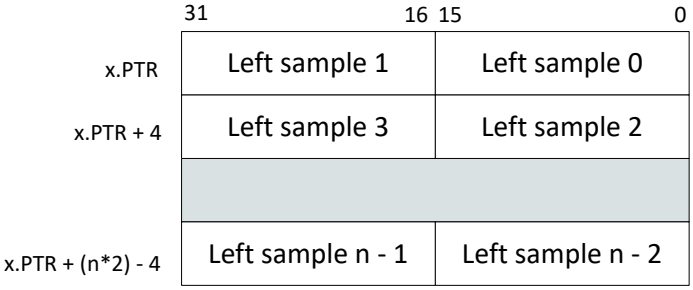

Figure 36: Memory mapping for 16 bit mono, left channel only. CONFIG.SWIDTH = 16Bit, CONFIG.CHANNELS = Left.

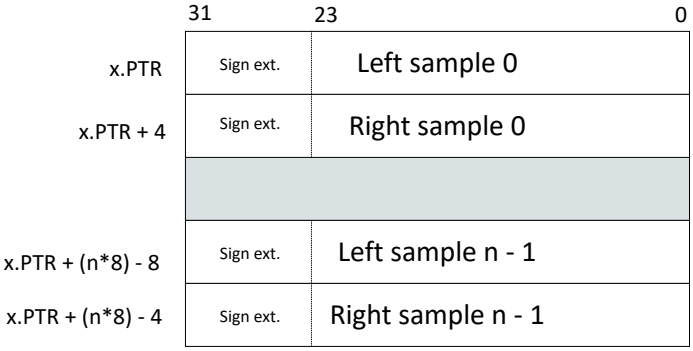

Figure 37: Memory mapping for 24 bit stereo. CONFIG.SWIDTH = 24Bit, CONFIG.CHANNELS = Stereo.

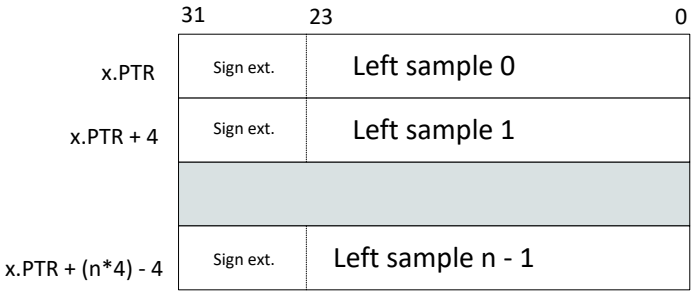

Figure 38: Memory mapping for 24 bit mono, left channel only. CONFIG.SWIDTH = 24Bit, CONFIG.CHANNELS = Left.

6.7.8 Module operation

Described here is a typical operating procedure for the I2S module.

1. Configure the I2S module using the CONFIG registers

```
// Enable reception
NRF_I2S->CONFIG.RXEN = (I2S_CONFIG_RXEN_RXEN_Enabled <<
                                        I2S_CONFIG_RXEN_RXEN_Pos);
// Enable transmission
NRF_I2S->CONFIG.TXEN = (I2S_CONFIG_TXEN_TXEN_Enabled <<
                                        I2S_CONFIG_TXEN_TXEN_Pos);
// Enable MCK generator
NRF_I2S->CONFIG.MCKEN = (I2S_CONFIG_MCKEN_MCKEN_Enabled <<
                                        I2S_CONFIG_MCKEN_MCKEN_Pos);
// MCKFREQ = 4 MHz
NRF_I2S->CONFIG.MCKFREQ = I2S_CONFIG_MCKFREQ_MCKFREQ_32MDIV8 <<
                                        I2S_CONFIG_MCKFREQ_MCKFREQ_Pos;
// Ratio = 256
NRF_I2S->CONFIG.RATIO = I2S_CONFIG_RATIO_RATIO_256X <<
                                        I2S_CONFIG_RATIO_RATIO_Pos;
// MCKFREQ = 4 MHz and Ratio = 256 gives sample rate = 15.625 ks/s
// Sample width = 16 bit
NRF_I2S->CONFIG.SWIDTH = I2S_CONFIG_SWIDTH_SWIDTH_16Bit <<
                                        I2S_CONFIG_SWIDTH_SWIDTH_Pos;
// Alignment = Left
NRF_I2S->CONFIG.ALIGN = I2S_CONFIG_ALIGN_ALIGN_Left <<
                                        I2S_CONFIG_ALIGN_ALIGN_Pos;
// Format = I2S
NRF_I2S->CONFIG.FORMAT = I2S_CONFIG_FORMAT_FORMAT_I2S <<
                                        I2S_CONFIG_FORMAT_FORMAT_Pos;
// Use stereo
NRF_I2S->CONFIG.CHANNELS = I2S_CONFIG_CHANNELS_CHANNELS_Stereo <<
                                        I2S_CONFIG_CHANNELS_CHANNELS_Pos;
```

2. Map IO pins using the PINSEL registers

```
// MCK routed to pin 0
NRF_I2S->PSEL.MCK = (0 << I2S_PSEL_MCK_PIN_Pos) |
                    (I2S_PSEL_MCK_CONNECT_Connected <<
                                                I2S_PSEL_MCK_CONNECT_Pos);
// SCK routed to pin 1
NRF_I2S->PSEL.SCK = (1 << I2S_PSEL_SCK_PIN_Pos) |
                    (I2S_PSEL_SCK_CONNECT_Connected <<
                                                I2S_PSEL_SCK_CONNECT_Pos);
// LRCK routed to pin 2
NRF_I2S->PSEL.LRCK = (2 << I2S_PSEL_LRCK_PIN_Pos) |
                     (I2S_PSEL_LRCK_CONNECT_Connected <<
                                                I2S_PSEL_LRCK_CONNECT_Pos);
// SDOUT routed to pin 3
NRF_I2S->PSEL.SDOUT = (3 << I2S_PSEL_SDOUT_PIN_Pos) |
                      (I2S_PSEL_SDOUT_CONNECT_Connected <<
                                                I2S_PSEL_SDOUT_CONNECT_Pos);
// SDIN routed on pin 4
NRF_I2S->PSEL.SDIN = (4 << I2S_PSEL_SDIN_PIN_Pos) |
                     (I2S_PSEL_SDIN_CONNECT_Connected <<
                                                I2S_PSEL_SDIN_CONNECT_Pos);
```

3. Configure TX and RX data pointers using the TXD, RXD and RXTXD registers

```
NRF_I2S->TXD.PTR = my_tx_buf;
NRF_I2S->RXD.PTR = my_rx_buf;
NRF_I2S->TXD.MAXCNT = MY_BUF_SIZE;
```

4. Enable the I2S module using the ENABLE register

```
NRF_I2S->ENABLE = 1;
```

5. Start audio streaming using the START task

```
NRF_I2S->TASKS_START = 1;
```

6. Handle received and transmitted data when receiving the TXPTRUPD and RXPTRUPD events

```
if(NRF_I2S->EVENTS_TXPTRUPD  != 0)
{
    NRF_I2S->TXD.PTR = my_next_tx_buf;
    NRF_I2S->EVENTS_TXPTRUPD = 0;
}

if(NRF_I2S->EVENTS_RXPTRUPD != 0)
{
    NRF_I2S->RXD.PTR = my_next_rx_buf;
    NRF_I2S->EVENTS_RXPTRUPD = 0;
}
```

6.7.9 Pin configuration

The MCK, SCK, LRCK, SDIN and SDOUT signals associated with the I2S module are mapped to physical pins according to the pin numbers specified in the PSEL.x registers.

These pins are acquired whenever the I2S module is enabled through the register ENABLE on page 199.

When a pin is acquired by the I2S module, the direction of the pin (input or output) will be configured automatically, and any pin direction setting done in the GPIO module will be overridden. The directions for the various I2S pins are shown below in GPIO configuration before enabling peripheral (master mode) on page 194 and GPIO configuration before enabling peripheral (slave mode) on page 194.

To secure correct signal levels on the pins when the system is in OFF mode, and when the I2S module is disabled, these pins must be configured in the GPIO peripheral directly.

I2S signal	I2S pin	Direction	Output value	Comment
MCK	As specified in PSEL.MCK	Output	0	
LRCK	As specified in PSEL.LRCK	Output	0	
SCK	As specified in PSEL.SCK	Output	0	
SDIN	As specified in PSEL.SDIN	Input	Not applicable	
SDOUT	As specified in PSEL.SDOUT	Output	0	

Table 21: GPIO configuration before enabling peripheral (master mode)

I2S signal	I2S pin	Direction	Output value	Comment
MCK	As specified in PSEL.MCK	Output	0	
LRCK	As specified in PSEL.LRCK	Input	Not applicable	
SCK	As specified in PSEL.SCK	Input	Not applicable	
SDIN	As specified in PSEL.SDIN	Input	Not applicable	
SDOUT	As specified in PSEL.SDOUT	Output	0	

Table 22: GPIO configuration before enabling peripheral (slave mode)

6.7.10 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
I2S : S	0x50028000	US	NS	SA	No	Inter-IC Sound
I2S : NS	0x40028000					

Register overview

Register	Offset	TZ	Description
TASKS_START	0x000		Starts continuous I2S transfer. Also starts MCK generator when this is enabled.
TASKS_STOP	0x004		Stops I2S transfer. Also stops MCK generator. Triggering this task will cause the STOPPED event to be generated.
SUBSCRIBE_START	0x080		Subscribe configuration for task START
SUBSCRIBE_STOP	0x084		Subscribe configuration for task STOP
EVENTS_RXPTRUPD	0x104		The RXD.PTR register has been copied to internal double-buffers. When the I2S module is started and RX is enabled, this event will be generated for every RXTXD.MAXCNT words that are received on the SDIN pin.

Register	Offset	TZ	Description
EVENTS_STOPPED	0x108		I2S transfer stopped.
EVENTS_TXPTRUPD	0x114		The TDX.PTR register has been copied to internal double-buffers. When the I2S module is started and TX is enabled, this event will be generated for every RXTXD.MAXCNT words that are sent on the SDOUT pin.
PUBLISH_RXPTRUPD	0x184		Publish configuration for event RXPTRUPD
PUBLISH_STOPPED	0x188		Publish configuration for event STOPPED
PUBLISH_TXPTRUPD	0x194		Publish configuration for event TXPTRUPD
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
ENABLE	0x500		Enable I2S module.
CONFIG.MODE	0x504		I2S mode.
CONFIG.RXEN	0x508		Reception (RX) enable.
CONFIG.TXEN	0x50C		Transmission (TX) enable.
CONFIG.MCKEN	0x510		Master clock generator enable.
CONFIG.MCKFREQ	0x514		Master clock generator frequency.
CONFIG.RATIO	0x518		MCK / LRCK ratio.
CONFIG.SWIDTH	0x51C		Sample width.
CONFIG.ALIGN	0x520		Alignment of sample within a frame.
CONFIG.FORMAT	0x524		Frame format.
CONFIG.CHANNELS	0x528		Enable channels.
RXD.PTR	0x538		Receive buffer RAM start address.
TXD.PTR	0x540		Transmit buffer RAM start address.
RXTXD.MAXCNT	0x550		Size of RXD and TXD buffers.
PSEL.MCK	0x560		Pin select for MCK signal.
PSEL.SCK	0x564		Pin select for SCK signal.
PSEL.LRCK	0x568		Pin select for LRCK signal.
PSEL.SDIN	0x56C		Pin select for SDIN signal.
PSEL.SDOUT	0x570		Pin select for SDOUT signal.

6.7.10.1 TASKS_START

Address offset: 0x000

Starts continuous I2S transfer. Also starts MCK generator when this is enabled.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_START			Starts continuous I2S transfer. Also starts MCK generator when this is enabled.
			Trigger	1	Trigger task

6.7.10.2 TASKS_STOP

Address offset: 0x004

Stops I2S transfer. Also stops MCK generator. Triggering this task will cause the STOPPED event to be generated.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stops I2S transfer. Also stops MCK generator. Triggering this task will cause the STOPPED event to be generated.
			Trigger	1	Trigger task

6.7.10.3 SUBSCRIBE_START

Address offset: 0x080

Subscribe configuration for task START

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task START will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.7.10.4 SUBSCRIBE_STOP

Address offset: 0x084

Subscribe configuration for task STOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.7.10.5 EVENTS_RXPTRUPD

Address offset: 0x104

The RXD.PTR register has been copied to internal double-buffers. When the I2S module is started and RX is enabled, this event will be generated for every RXTXD.MAXCNT words that are received on the SDIN pin.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RXPTRUPD			The RXD.PTR register has been copied to internal double-buffers. When the I2S module is started and RX is enabled, this event will be generated for every RXTXD.MAXCNT words that are received on the SDIN pin.
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.7.10.6 EVENTS_STOPPED

Address offset: 0x108

I2S transfer stopped.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	EVENTS_STOPPED																																	
			NotGenerated	0																															
			Generated	1																															

6.7.10.7 EVENTS_TXPTRUPD

Address offset: 0x114

The TDX.PTR register has been copied to internal double-buffers. When the I2S module is started and TX is enabled, this event will be generated for every RXTXD.MAXCNT words that are sent on the SDOUT pin.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	EVENTS_TXPTRUPD																																	
				The TDX.PTR register has been copied to internal double-buffers. When the I2S module is started and TX is enabled, this event will be generated for every RXTXD.MAXCNT words that are sent on the SDOUT pin.																																
			NotGenerated	0																															
			Generated	1																															

6.7.10.8 PUBLISH_RXPTRUPD

Address offset: 0x184

Publish configuration for event RXPTRUPD

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				B																								A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	CHIDX		[0..255]																															
B	RW	EN																																	
			Disabled	0																															
			Enabled	1																															

6.7.10.9 PUBLISH_STOPPED

Address offset: 0x188

Publish configuration for event STOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STOPPED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.7.10.10 PUBLISH_TXPTRUPD

Address offset: 0x194

Publish configuration for event TXPTRUPD

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TXPTRUPD will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.7.10.11 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F C B
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
B	RW	RXPTRUPD			Enable or disable interrupt for event RXPTRUPD
			Disabled	0	Disable
			Enabled	1	Enable
C	RW	STOPPED			Enable or disable interrupt for event STOPPED
			Disabled	0	Disable
			Enabled	1	Enable
F	RW	TXPTRUPD			Enable or disable interrupt for event TXPTRUPD
			Disabled	0	Disable
			Enabled	1	Enable

6.7.10.12 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F C B
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
B	RW	RXPTRUPD			Write '1' to enable interrupt for event RXPTRUPD

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F C B
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	STOPPED			Write '1' to enable interrupt for event STOPPED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
F	RW	TXPTRUPD			Write '1' to enable interrupt for event TXPTRUPD
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.7.10.13 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F C B
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
B	RW	RXPTRUPD			Write '1' to disable interrupt for event RXPTRUPD
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	STOPPED			Write '1' to disable interrupt for event STOPPED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
F	RW	TXPTRUPD			Write '1' to disable interrupt for event TXPTRUPD
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.7.10.14 ENABLE

Address offset: 0x500

Enable I2S module.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			Enable I2S module.
			Disabled	0	Disable
			Enabled	1	Enable

6.7.10.15 CONFIG.MODE

Address offset: 0x504

I2S mode.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	MODE																																	
			Master	0																															
			Slave	1																															

6.7.10.16 CONFIG.RXEN

Address offset: 0x508

Reception (RX) enable.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	RXEN																																	
			Disabled	0																															
			Enabled	1																															

6.7.10.17 CONFIG.TXEN

Address offset: 0x50C

Transmission (TX) enable.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	TXEN																																	
			Disabled	0																															
			Enabled	1																															

6.7.10.18 CONFIG.MCKEN

Address offset: 0x510

Master clock generator enable.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	MCKEN			Master clock generator enable.
			Disabled	0	Master clock generator disabled and PSEL.MCK not connected(available as GPIO).
			Enabled	1	Master clock generator running and MCK output on PSEL.MCK.

6.7.10.19 CONFIG.MCKFREQ

Address offset: 0x514

Master clock generator frequency.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x20000000				**0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MCKFREQ			Master clock generator frequency.
			32MDIV8	0x20000000	32 MHz / 8 = 4.0 MHz
			32MDIV10	0x18000000	32 MHz / 10 = 3.2 MHz
			32MDIV11	0x16000000	32 MHz / 11 = 2.9090909 MHz
			32MDIV15	0x11000000	32 MHz / 15 = 2.1333333 MHz
			32MDIV16	0x10000000	32 MHz / 16 = 2.0 MHz
			32MDIV21	0x0C000000	32 MHz / 21 = 1.5238095
			32MDIV23	0x0B000000	32 MHz / 23 = 1.3913043 MHz
			32MDIV30	0x08800000	32 MHz / 30 = 1.0666667 MHz
			32MDIV31	0x08400000	32 MHz / 31 = 1.0322581 MHz
			32MDIV32	0x08000000	32 MHz / 32 = 1.0 MHz
			32MDIV42	0x06000000	32 MHz / 42 = 0.7619048 MHz
			32MDIV63	0x04100000	32 MHz / 63 = 0.5079365 MHz
			32MDIV125	0x020C0000	32 MHz / 125 = 0.256 MHz

6.7.10.20 CONFIG.RATIO

Address offset: 0x518

MCK / LRCK ratio.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000006				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RATIO			MCK / LRCK ratio.
			32X	0	LRCK = MCK / 32
			48X	1	LRCK = MCK / 48
			64X	2	LRCK = MCK / 64
			96X	3	LRCK = MCK / 96
			128X	4	LRCK = MCK / 128
			192X	5	LRCK = MCK / 192
			256X	6	LRCK = MCK / 256
			384X	7	LRCK = MCK / 384
			512X	8	LRCK = MCK / 512

6.7.10.21 CONFIG.SWIDTH

Address offset: 0x51C

Sample width.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																		A	A
Reset 0x00000001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	SWIDTH																																	
			8Bit	0																															
			16Bit	1																															
			24Bit	2																															

6.7.10.22 CONFIG.ALIGN

Address offset: 0x520

Alignment of sample within a frame.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ALIGN																																	
			Left	0																															
			Right	1																															

6.7.10.23 CONFIG.FORMAT

Address offset: 0x524

Frame format.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	FORMAT																																	
			I2S	0																															
			Aligned	1																															

6.7.10.24 CONFIG.CHANNELS

Address offset: 0x528

Enable channels.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHANNELS			Enable channels.
			Stereo	0	Stereo.
			Left	1	Left only.
			Right	2	Right only.

6.7.10.25 RXD.PTR

Address offset: 0x538

Receive buffer RAM start address.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Receive buffer Data RAM start address. When receiving, words containing samples will be written to this address. This address is a word aligned Data RAM address.

6.7.10.26 TXD.PTR

Address offset: 0x540

Transmit buffer RAM start address.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Transmit buffer Data RAM start address. When transmitting, words containing samples will be fetched from this address. This address is a word aligned Data RAM address.

6.7.10.27 RXTXD.MAXCNT

Address offset: 0x550

Size of RXD and TXD buffers.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT			Size of RXD and TXD buffers in number of 32 bit words.

6.7.10.28 PSEL.MCK

Address offset: 0x560

Pin select for MCK signal.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.7.10.29 PSEL.SCK

Address offset: 0x564

Pin select for SCK signal.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.7.10.30 PSEL.LRCK

Address offset: 0x568

Pin select for LRCK signal.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.7.10.31 PSEL.SDIN

Address offset: 0x56C

Pin select for SDIN signal.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.7.10.32 PSEL.SDOUT

Address offset: 0x570

Pin select for SDOUT signal.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.7.11 Electrical specification

6.7.11.1 I2S timing specification

Symbol	Description	Min.	Typ.	Max.	Units
t_{S_SDIN}	SDIN setup time before SCK rising	20			ns
t_{H_SDIN}	SDIN hold time after SCK rising	15			ns
t_{S_SDOUT}	SCK falling edge to SDOUT valid	40			ns
t_{H_SDOUT}	SDOUT hold time after SCK falling	6			ns
t_{SCK_LRCK}	SCLK falling to LRCK edge	-5	0	5	ns
f_{MCK}	MCK frequency			4000	kHz
f_{LRCK}	LRCK frequency			48	kHz
f_{SCK}	SCK frequency			2000	kHz
DC_{CK}	Clock duty cycle (MCK, LRCK, SCK)	45		55	%

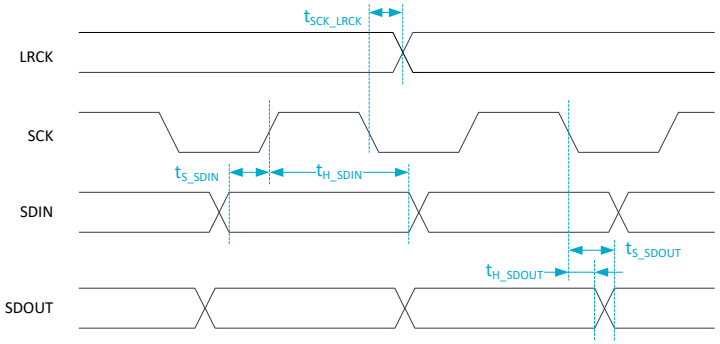

Figure 39: I2S timing diagram

6.8 KMU — Key management unit

The key management unit (KMU) enforces access policies to a subset region of user information configuration register (UICR). This subset region is used for storing cryptographic key values inside the key slots, which the CPU has no access to.

In total there are 128 key slots available, where each key slot can store one 128-bit key value together with an access policy and a destination address for the key value. Multiple key slots can be combined in order to support key sizes larger than 128 bits. The access policy of a key slot governs if and how a key value can

be used, while the destination address determines where in the memory map the KMU pushes the key value upon a request from the CPU.

Key slots can be configured to be pushed directly into write-only key registers in cryptographic accelerators, like e.g. CryptoCell, without exposing the key value itself to the CPU. This enables the CPU to use the key values stored inside the key slots for cryptographic operations without being exposed to the key value.

Access to the KMU, and the key slots in the UICR, is only allowed from secure mode.

6.8.1 Functional view

From a functional view the UICR is divided into two different regions, one-time programmable (OTP) memory and key storage.

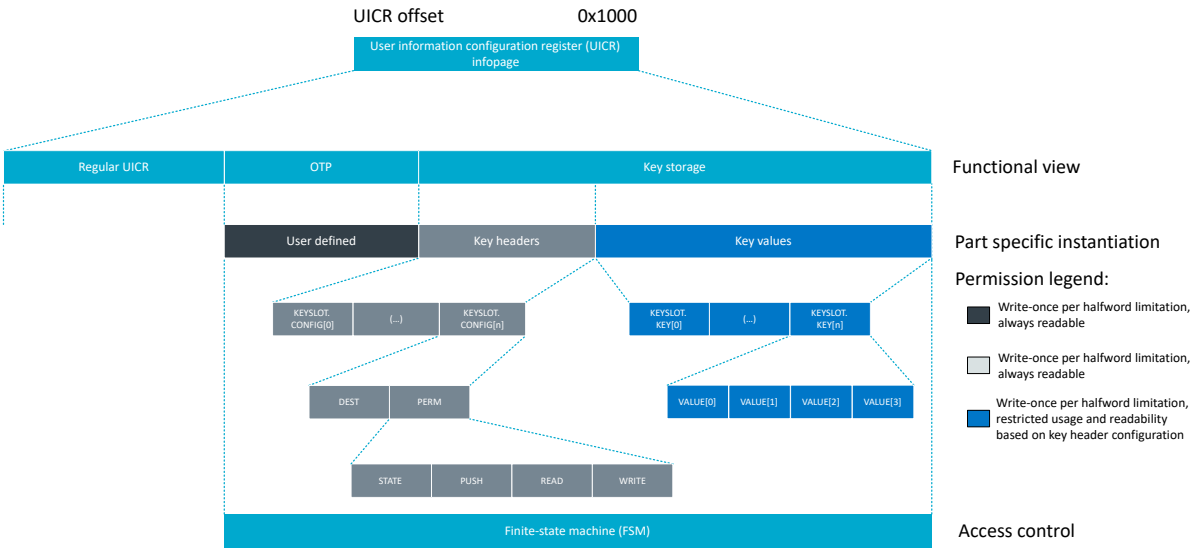

Figure 40: Memory map overview

OTP

One-time programmable (OTP) memory is typically used for holding values that are written once, and then never to be changed again throughout the product lifetime. The OTP region of UICR is emulated by placing a write-once per halfword limitation on registers defined here.

Key storage

The key storage region contains multiple key slots, where each slot consists of a key header and an associated key value. The key value is limited to 128 bits. Any key size greater than 128 bits must be divided and distributed over multiple key slot instances.

Key headers are allocated an address range of 0x400 in the UICR memory map, allowing a total of 128 keys to be addressable inside the key storage region.

Note: The use of the key storage region in UICR should be limited to keys with a certain life span, and not per-session derived keys where the CPU is involved in the key exchange.

6.8.2 Access control

Access control to the underlying UICR infopage in flash is enforced by a hardware finite-state machine (FSM). The FSM can allow or block transactions, depending both on the security of the transaction (secure or non-secure) and on the type of register being written and/or read.

Access type	Key headers	Key values
Read	Allowed	Restricted
Write	Restricted	Restricted

Table 23: Access control

Any restricted access requires an explicit key slot selection through the KMU register interface. Any illegal access to restricted key slot registers will be blocked and word `0xDEADDEAD` will be returned on the AHB.

The OTP region has individual access control behavior, while access control to the key storage region is configured on a per key slot basis. The KMU FSM operates on only one key slot instance at a time, and the permissions and the usage restriction for a key value associated with a key slot can be configured individually.

Note: Even if the KMU can be configured as non-secure, all non-secure transactions will be blocked.

6.8.3 Protecting the UICR content

The UICR content can be protected against device-internal NVMC.ERASEALL requests, in addition to device-external ERASEALL requests, through the CTRL-AP interface. This feature is useful if the firmware designers want to prevent the OTP region from being erased.

Since enabling this step will permanently disable erase for the UICR, the procedure requires an implementation defined 32-bit word to be written into the UICR's ERASEPROTECT register.

In case of a field return handling, it is still possible to erase the UICR even if the ERASEPROTECT is set. If this functionality is desired, the secure boot code must implement a secure communication channel over the CTRL-AP mailbox interface. Upon successful authentication of the external party, the secure boot code can temporarily re-enable the CTRL-AP ERASEALL functionality.

6.8.4 Usage

This section describes the specific KMU and UICR behavior in more detail, to help the reader get a better overview of KMU's features and the intended usage.

6.8.4.1 OTP

The OTP region of the UICR contains a user-defined static configuration of the device. The KMU emulates the OTP functionality by placing a write-once per halfword limitation of registers defined in this region, i.e. only halfwords containing all '1's can be written.

An OTP write transaction must consist of a full 32-bit word. Both halfwords can either be written simultaneously or one at a time. The KMU FSM will block any write to a halfword in the OTP region, if the initial value of this halfword is not 0xFFFF. When writing halfwords one at a time, the non-active halfword must be masked as 0xFFFF, otherwise the request will be blocked. For example, writing 0x1234XXXX to an OTP destination address which already contains the value 0xFFFFAABB, must be configured as 0x1234FFFF. The OTP destination address will contain the value 0x1234AABB after both write transactions have been processed.

The KMU will also only allow secure AHB write transactions into the OTP region of the UICR. Any AHB write transaction to this region that does not satisfy the above requirements will be ignored, and the STATUS.BLOCKED register will be set to '1'.

6.8.4.2 Key storage

The key storage region of the UICR can contain multiple keys of different type, including symmetrical keys, hashes, public/private key pairs and other device secrets. One of the key features of the KMU, is that these

device secrets can be installed and made available for use in cryptographic operations without revealing the actual secret values.

Keys in this region will typically have a certain life span. The region is not designed to be used for per-session derived keys where the non-secure side (i.e. application) is participating in the key exchange.

All key storage is done through the concept of multiple key slots, where each key slot instance consists of one key header and an associated key value. Each key header supports the configuration of usage permissions and an optional secure destination address.

The key header secure destination address option enables the KMU to push the associated key value over a dedicated secure APB to a pre-configured secure location within the memory map. Such locations typically include a write-only key register of the hardware cryptographic accelerator, allowing the KMU to distribute keys within the system without compromising the key values.

One key slot instance can store a key value of maximum 128 bits. If a key size exceeds this limit, the key value itself must be split over multiple key slot instances.

The following usage and read permissions scheme is applicable for each key slot:

State	Push	Read	Write	Description
Active (1)	Enabled (1)	Enabled (1)	Enabled (1)	Default flash erase value. Key slot cannot be pushed, write is enabled.
Active (1)	Enabled (1)	Enabled (1)	Disabled (0)	Key slot is active, push is enabled. Key slot VALUE registers can be read, but write is disabled.
Active (1)	Enabled (1)	Disabled (0)	Disabled (0)	Key slot is active, push is enabled. Read and write to key slot VALUE registers are disabled.
Active (1)	Disabled (0)	Enabled (1)	Disabled (0)	Key slot is active, push is disabled. Key slot VALUE registers can be read, but write is disabled.
Revoked (0)	-	-	-	Key slot is revoked. Cannot be read or pushed over secure APB regardless of the permission settings.

Table 24: Valid key slot permission schemes

6.8.4.2.1 Selecting a key slot

The KMU FSM is designed to process only one key slot at a time, effectively operating as a memory protection unit for the key storage region. Whenever a key slot is selected, the KMU will allow access to writing, reading, and/or pushing the associated key value according to the selected slot configuration.

A key slot must be selected prior to use, by writing the key slot ID into the KMU SELECTKEYSLOT register. Because the reset value of this register is 0x00000000, there is no key slot associated with ID=0 and no slot is selected by default. All key slots are addressed using IDs from 1 to 128.

SELECTED status is set when a key slot is selected, and a read or write access to that keyslot occurs.

BLOCKED status is set when any illegal access to key slot registers is detected.

When the use of the particular key slot is stopped, the key slot selection in SELECTKEYSLOT must be set back to '0'.

By default, all KMU key slots will consist of a 128-bit key value of '1's, where the key headers have no secure destination address, or any usage and read restrictions.

6.8.4.2.2 Writing to a key slot

Writing a key slot into UICR is a five-step process.

1. Select which key slot the KMU shall operate on by writing the desired key slot ID into KMU->SELECTKEYSLOT. The selected key slot must be empty in order to add a new entry to UICR.
2. If the key value shall be pushable over secure APB, the destination address of the recipient must be configured in register KEYSLOT.CONFIG[ID-1].DEST.

3. Write the 128-bit key value into KEYSLOT.KEY[ID-1].VALUE[0-3].
4. Write the desired key slot permissions into KEYSLOT.CONFIG[ID-1].PERM, including any applicable usage restrictions.
5. Select key slot 0.

In case the total key size is greater than 128 bits, the key value itself must be split into 128-bit segments and written to multiple key slot instances. Steps 1 through 5 above must be repeated for the entire key size.

Note: If a key slot is configured as readable, and KEYSLOT.CONFIG[ID-1].DEST is not to be used, it is recommended to disable the push bit in KEYSLOT.CONFIG[ID-1].PERM when configuring key slot permissions.

Note: A key value distributed over multiple key slots should use the same key slot configuration in its key headers, but the secure destination address for each key slot instance must be incremented by 4 words (128 bits) for each key slot instance spanned.

Note: Write to flash must be enabled in NVMC->CONFIG prior to writing keys to flash, and subsequently disabled once writing is complete.

Steps 1 through 5 above will be blocked if any of the following violations are detected:

- No key slot selected
- Non-empty key slot selected
- NVM destination address not empty
- AHB write to KEYSLOT.KEY[ID-1].VALUE[0-3] registers not belonging to selected key slot

6.8.4.2.3 Reading a key value

Key slots that are configured as readable can have their key value read directly from the UICR memory map by the CPU.

Readable keys are typically used during the secure boot sequence, where the CPU is involved in falsifying or verifying the integrity of the system. Since the CPU is involved in this decision process, it makes little sense not to trust the CPU having access to the actual key value but ultimately trust the decision of the integrity check. Another use-case for readable keys is if the key type in question does not have a HW peripheral in the platform that is able to accept such keys over secure APB.

Reading a key value from the UICR is a three-step process:

1. Select the key slot which the KMU shall operate on by writing the desired key slot ID into KMU->SELECTKEYSLOT.
2. If STATE and READ permission requirements are fulfilled as defined in KEYSLOT.CONFIG[ID-1].PERM, the key value can be read from region KEYSLOT.KEY[ID-1].VALUE[0-3] for selected key slot.
3. Select key slot 0.

Step 2 will be blocked and word 0xDEADDEAD will be returned on AHB if any of the following violations are detected:

- No key slot selected
- Key slot not configured as readable
- Key slot is revoked
- AHB read to KEYSLOT.KEY[ID-1].VALUE[0-3] registers not belonging to selected key slot

6.8.4.2.4 Push over secure APB

Key slots that are configured as non-readable cannot be read by the CPU regardless of the mode the system is in and must be pushed over secure APB in order to use the key value for cryptographic operations.

The secure APB destination address is set in the key slot configuration DEST register. Such destination addresses are typically write-only key registers in a hardware cryptographic accelerators memory map. The secure APB allows key slots to be utilized by the software side, without exposing the key value itself.

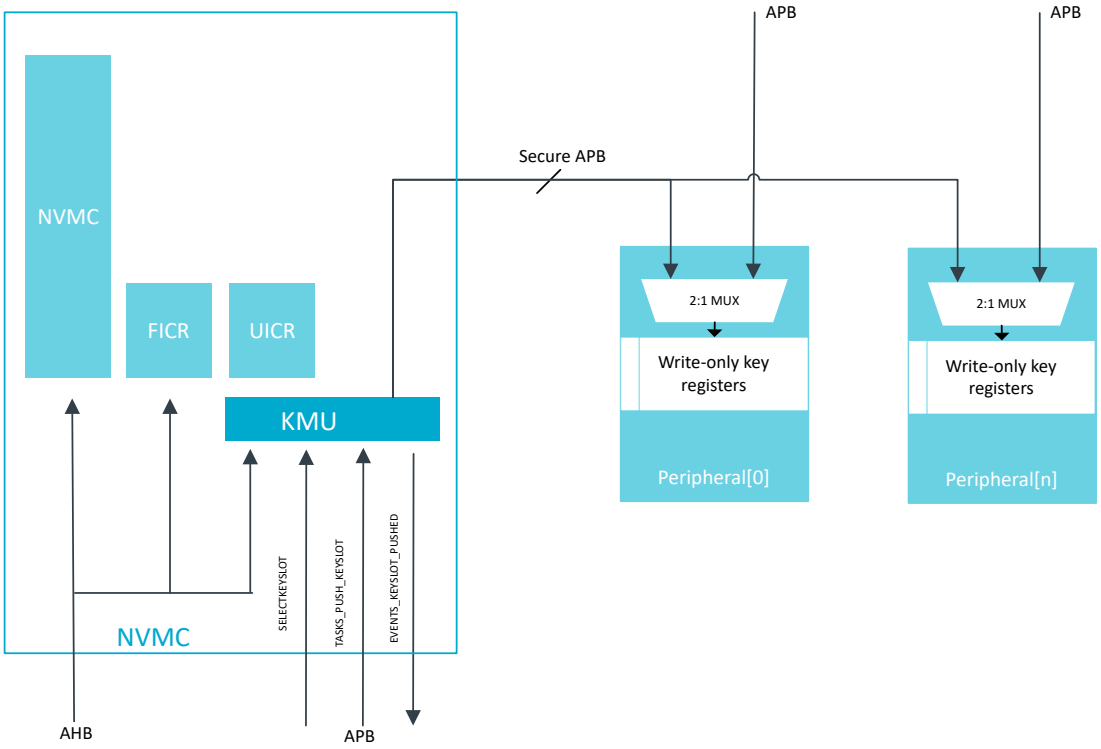

Figure 41: Tasks and events pattern for key slots

Pushing a key slot over secure APB is a four-step process:

1. Select the key slot on which the KMU shall operate by writing the desired key slot ID into KMU->SELECTKEYSLOT.
2. Start TASKS_PUSH_KEYSLOT to initiate a secure APB transaction, writing the 128-bit key value associated with the selected key slot into address defined in KEYSLOT.CONFIG[ID-1].DEST.
3. After completing the secure APB transaction, the 128-bit key value is ready for use by the peripheral and EVENTS_KEYSLOT_PUSHED is triggered.
4. Select key slot 0.

> **Note:** If a key value is distributed over multiple key slots due to its key size, exceeding the maximum 128-bit key value limitation, then each distributed key slot must be pushed individually in order to transfer the entire key value over secure APB.

Step 3 will trigger other events than EVENTS_KEYSLOT_PUSHED if the following violations are detected:

- EVENTS_KEYSLOT_ERROR:
  - If no key slot is selected
  - If a key slot has no destination address configured
  - If when pushing a key slot, flash, or peripheral returns an error
  - If pushing a key slot when push permissions are disabled

- If attempting to push a key slot with default permissions
- EVENTS_KEYSLOT_REVOKED if a key slot is marked as revoked in its key header configuration

6.8.4.2.5 Revoking the key slots

All key slots within the key storage area can be marked as revoked.

To revoke any key slots, write to the STATE field in the KEYSLOT.CONFIG[ID-1].PERM register. The following rules apply to keys that have been revoked:

1. Key slots that have the PUSH field enabled in PERM register can no longer be pushed. If a revoked key slot is selected and task TASKS_PUSH_KEYSLOT is started, the event EVENTS_KEYSLOT_REVOKED is triggered.
2. Key slots that have the READ field enabled in PERM register can no longer be read. Any read operation to a revoked key value will return word 0xDEADDEAD.
3. Previously pushed key values stored in a peripheral write-only key register are not affected by key revocation. If secure code wants to enforce that a revoked key is no longer usable by a peripheral for cryptographic operations, the secure code should disable or reset the peripheral in question.

6.8.4.3 STATUS register

The KMU uses a STATUS register to indicate its status of operation. The SELECTED bit will be asserted whenever the currently selected key slot is successfully read from or written to.

All read or write operations to other key slots than what is currently selected in KMU->SELECTKEYSLOT will assert the BLOCKED bit. The BLOCKED bit will also be asserted if the KMU fails to select a key slot, or if a request has been blocked due to an access violation. Normal operation using the KMU should never trigger the BLOCKED bit. If this bit is triggered during the development phase, it indicates that the code is using the KMU incorrectly.

The STATUS register is reset every time register SELECTKEYSLOT is written.

6.8.5 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
KMU : S KMU : NS	0x50039000 0x40039000	HF	NS	NA	Yes	Key management unit

Register overview

Register	Offset	TZ	Description
TASKS_PUSH_KEYSLOT	0x0000		Push a key slot over secure APB
EVENTS_KEYSLOT_PUSHED	0x100		Key slot successfully pushed over secure APB
EVENTS_KEYSLOT_REVOKED	0x104		Key slot has been revoked and cannot be tasked for selection
EVENTS_KEYSLOT_ERROR	0x108		No key slot selected, no destination address defined, or error during push operation
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
INTPEND	0x30C		Pending interrupts
STATUS	0x40C		Status bits for KMU operation
SELECTKEYSLOT	0x500		Select key slot to be read over AHB or pushed over secure APB when TASKS_PUSH_KEYSLOT is started

6.8.5.1 TASKS_PUSH_KEYSLOT

Address offset: 0x0000

Push a key slot over secure APB

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_PUSH_KEYSLOT			Push a key slot over secure APB
			Trigger	1	Trigger task

6.8.5.2 EVENTS_KEYSLOT_PUSHED

Address offset: 0x100

Key slot successfully pushed over secure APB

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_KEYSLOT_PUSHED			Key slot successfully pushed over secure APB
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.8.5.3 EVENTS_KEYSLOT_REVOKED

Address offset: 0x104

Key slot has been revoked and cannot be tasked for selection

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_KEYSLOT_REVOKED			Key slot has been revoked and cannot be tasked for selection
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.8.5.4 EVENTS_KEYSLOT_ERROR

Address offset: 0x108

No key slot selected, no destination address defined, or error during push operation

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_KEYSLOT_ERROR			No key slot selected, no destination address defined, or error during push operation
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.8.5.5 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	KEYSLOT_PUSHED			Enable or disable interrupt for event KEYSLOT_PUSHED
			Disabled	0	Disable
			Enabled	1	Enable
B	RW	KEYSLOT_REVOKED			Enable or disable interrupt for event KEYSLOT_REVOKED
			Disabled	0	Disable
			Enabled	1	Enable
C	RW	KEYSLOT_ERROR			Enable or disable interrupt for event KEYSLOT_ERROR
			Disabled	0	Disable
			Enabled	1	Enable

6.8.5.6 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	KEYSLOT_PUSHED			Write '1' to enable interrupt for event KEYSLOT_PUSHED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	KEYSLOT_REVOKED			Write '1' to enable interrupt for event KEYSLOT_REVOKED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	KEYSLOT_ERROR			Write '1' to enable interrupt for event KEYSLOT_ERROR
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.8.5.7 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	KEYSLOT_PUSHED			Write '1' to disable interrupt for event KEYSLOT_PUSHED
			Clear	1	Disable

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	KEYSLOT_REVOKED			Write '1' to disable interrupt for event KEYSLOT_REVOKED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	KEYSLOT_ERROR			Write '1' to disable interrupt for event KEYSLOT_ERROR
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.8.5.8 INTPEND

Address offset: 0x30C

Pending interrupts

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	KEYSLOT_PUSHED			Read pending status of interrupt for event KEYSLOT_PUSHED
			NotPending	0	Read: Not pending
			Pending	1	Read: Pending
B	R	KEYSLOT_REVOKED			Read pending status of interrupt for event KEYSLOT_REVOKED
			NotPending	0	Read: Not pending
			Pending	1	Read: Pending
C	R	KEYSLOT_ERROR			Read pending status of interrupt for event KEYSLOT_ERROR
			NotPending	0	Read: Not pending
			Pending	1	Read: Pending

6.8.5.9 STATUS

Address offset: 0x40C

Status bits for KMU operation

This register is reset and re-written by the KMU whenever SELECTKEYSLOT is written

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	SELECTED			Key slot ID successfully selected by the KMU
			Disabled	0	No key slot ID selected by KMU
			Enabled	1	Key slot ID successfully selected by KMU
B	R	BLOCKED			Violation status
			Disabled	0	No access violation detected
			Enabled	1	Access violation detected and blocked

6.8.5.10 SELECTKEYSLOT

Address offset: 0x500

Select key slot to be read over AHB or pushed over secure APB when TASKS_PUSH_KEYSLOT is started

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																									A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ID			Select key slot ID to be read over AHB, or pushed over secure APB, when TASKS_PUSH_KEYSLOT is started. NOTE: ID=0 is not a valid key slot ID. The 0 ID should be used when the KMU is idle or not in use. NOTE: Index N in UICR->KEYSLOT.KEY[N] and UICR->KEYSLOT.CONFIG[N] corresponds to KMU key slot ID=N+1.

6.9 PDM — Pulse density modulation interface

The pulse density modulation (PDM) module enables input of pulse density modulated signals from external audio frontends, for example, digital microphones. The PDM module generates the PDM clock and supports single-channel or dual-channel (left and right) data input. Data is transferred directly to RAM buffers using EasyDMA.

Listed here are the main features for PDM:

- Up to two PDM microphones configured as a left/right pair using the same data input
- 16 kHz output sample rate, 16-bit samples
- EasyDMA support for sample buffering
- HW decimation filters
- Selectable ratio of 64 or 80 between PDM_CLK and output sample rate

The PDM module illustrated below is interfacing up to two digital microphones with the PDM interface. EasyDMA is implemented to relieve the real-time requirements associated with controlling of the PDM slave from a low priority CPU execution context. It also includes all the necessary digital filter elements to produce pulse code modulation (PCM) samples. The PDM module allows continuous audio streaming.

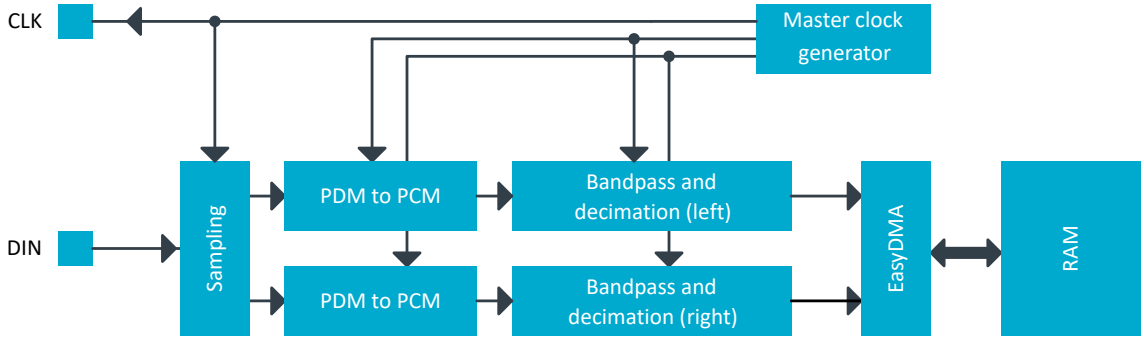

Figure 42: PDM module

6.9.1 Master clock generator

The master clock generator's PDMCLKCTRL register allows adjusting the PDM clock's frequency.

The master clock generator does not add any jitter to the HFCLK source chosen. It is recommended (but not mandatory) to use the Xtal as HFCLK source.

6.9.2 Module operation

By default, bits from the left PDM microphone are sampled on PDM_CLK falling edge, and bits for the right are sampled on the rising edge of PDM_CLK, resulting in two bitstreams. Each bitstream is fed into a digital filter which converts the PDM stream into 16-bit PCM samples, then filters and down-samples them to reach the appropriate sample rate.

The EDGE field in the MODE register allows swapping left and right, so that left will be sampled on rising edge, and right on falling.

The PDM module uses EasyDMA to store the samples coming out from the filters into one buffer in RAM. Depending on the mode chosen in the OPERATION field in the MODE register, memory either contains alternating left and right 16-bit samples (Stereo), or only left 16-bit samples (Mono). To ensure continuous PDM sampling, it is up to the application to update the EasyDMA destination address pointer as the previous buffer is filled.

The continuous transfer can be started or stopped by sending the START and STOP tasks. STOP becomes effective after the current frame has finished transferring, which will generate the STOPPED event. The STOPPED event indicates that all activity in the module is finished, and that the data is available in RAM (EasyDMA has finished transferring as well). Attempting to restart before receiving the STOPPED event may result in unpredictable behavior.

6.9.3 Decimation filter

In order to convert the incoming data stream into PCM audio samples, a decimation filter is included in the PDM interface module.

The input of the filter is the two-channel PDM serial stream (with left channel on clock high, right channel on clock low). Depending on the RATIO selected, its output is 2 × 16-bit PCM samples at a sample rate either 64 times or 80 times (depending on the RATIO register) lower than the PDM clock rate.

The filter stage of each channel is followed by a digital volume control, to attenuate or amplify the output samples in a range of -20 dB to +20 dB around the default (reset) setting, defined by $G_{PDM,default}$. The gain is controlled by the GAINL and GAINR registers.

As an example, if the goal is to achieve 2500 RMS output samples (16-bit) with a 1 kHz 90 dBA signal into a -26 dBFS sensitivity PDM microphone, do the following:

- Sum the PDM module's default gain ($G_{PDM,default}$) and the gain introduced by the microphone and acoustic path of his implementation (an attenuation would translate into a negative gain)
- Adjust GAINL and GAINR by the above summed amount. Assuming that only the PDM module influences the gain, GAINL and GAINR must be set to $-G_{PDM,default}$ dB to achieve the requirement.

With $G_{PDM,default}$=3.2 dB, and as GAINL and GAINR are expressed in 0.5 dB steps, the closest value to program would be 3.0 dB, which can be calculated as:

```
GAINL = GAINR = (DefaultGain - (2 * 3))
```

Remember to check that the resulting values programmed into GAINL and GAINR fall within MinGain and MaxGain.

6.9.4 EasyDMA

Samples will be written directly to RAM, and EasyDMA must be configured accordingly.

The address pointer for the EasyDMA channel is set in SAMPLE.PTR register. If the destination address set in SAMPLE.PTR is not pointing to the Data RAM region, an EasyDMA transfer may result in a HardFault or RAM corruption. See Memory on page 21 for more information about the different memory regions.

DMA supports Stereo (Left+Right 16-bit samples) and Mono (Left only) data transfer, depending on the setting in the OPERATION field in the MODE register. The samples are stored little endian.

MODE.OPERATION	Bits per sample	Result stored per RAM word	Physical RAM allocated (32-bit words)	Result boundary indexes in RAM	Note
Stereo	32 (2x16)	L+R	ceil(SAMPLE.MAXCNT/2)	R0=[31:16]; L0=[15:0]	Default
Mono	16	2xL	ceil(SAMPLE.MAXCNT/2)	L1=[31:16]; L0=[15:0]	

Table 25: DMA sample storage

The destination buffer in RAM consists of one block, the size of which is set in SAMPLE.MAXCNT register. Format is number of 16-bit samples. The physical RAM allocated is always:

```
(RAM allocation, in bytes) = SAMPLE.MAXCNT * 2;
```

(but the mapping of the samples depends on MODE.OPERATION).

If OPERATION=Stereo, RAM will contain a succession of left and right samples.

If OPERATION=Mono, RAM will contain a succession of left only samples.

For a given value of SAMPLE.MAXCNT, the buffer in RAM can contain half the stereo sampling time as compared to the mono sampling time.

The PDM acquisition can be started by the START task, after the SAMPLE.PTR and SAMPLE.MAXCNT registers have been written. When starting the module, it will take some time for the filters to start outputting valid data. Transients from the PDM microphone itself may also occur. The first few samples (typically around 50) might hence contain invalid values or transients. It is therefore advised to discard the first few samples after a PDM start.

As soon as the STARTED event is received, the firmware can write the next SAMPLE.PTR value (this register is double-buffered), to ensure continuous operation.

When the buffer in RAM is filled with samples, an END event is triggered. The firmware can start processing the data in the buffer. Meanwhile, the PDM module starts acquiring data into the new buffer pointed to by SAMPLE.PTR, and sends a new STARTED event, so that the firmware can update SAMPLE.PTR to the next buffer address.

6.9.5 Hardware example

PDM can be configured with a single microphone (mono), or with two microphones.

When a single microphone is used, connect the microphone clock to CLK, and data to DIN.

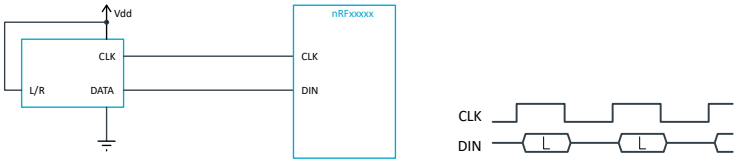

Figure 43: Example of a single PDM microphone, wired as left

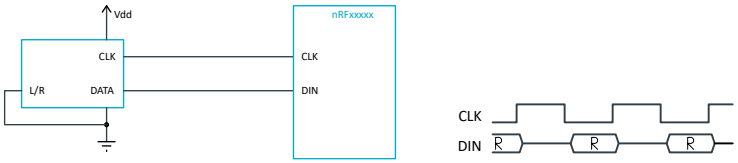

Figure 44: Example of a single PDM microphone, wired as right

Note that in a single-microphone (mono) configuration, depending on the microphone's implementation, either the left or the right channel (sampled at falling or rising CLK edge respectively) will contain reliable data.

If two microphones are used, one of them must be set as left, the other as right (L/R pin tied high or to GND on the respective microphone). It is strongly recommended to use two microphones of exactly the same brand and type so that their timings in left and right operation match.

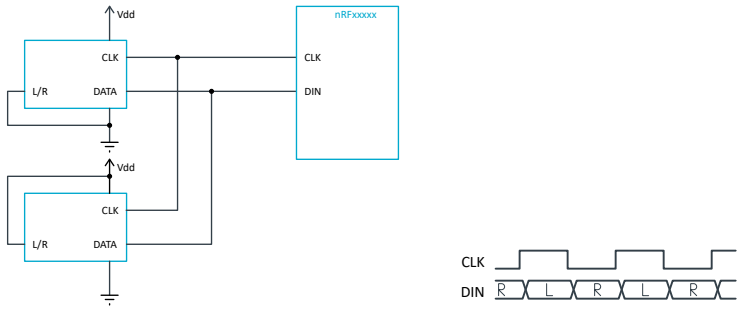

Figure 45: Example of two PDM microphones

6.9.6 Pin configuration

The CLK and DIN signals associated to the PDM module are mapped to physical pins according to the configuration specified in the PSEL.CLK and PSEL.DIN registers respectively. If the CONNECT field in any PSEL register is set to Disconnected, the associated PDM module signal will not be connected to the required physical pins and will not operate properly.

The PSEL.CLK and PSEL.DIN registers and their configurations are only used as long as the PDM module is enabled, and retained only as long as the device is in System ON mode. See POWER — Power control on page 68 for more information about power modes. When the peripheral is disabled, the pins will behave as regular GPIOs, and use the configuration in their respective OUT bit field and PIN_CNF[n] register.

To ensure correct behavior in the PDM module, the pins used by the PDM module must be configured in the GPIO peripheral as described in GPIO configuration before enabling peripheral on page 218 before enabling the PDM module. This is to ensure that the pins used by the PDM module are driven correctly if the PDM module itself is temporarily disabled or the device temporarily enters System OFF. This configuration must be retained in the GPIO for the selected I/Os as long as the PDM module is supposed to be connected to an external PDM circuit.

Only one peripheral can be assigned to drive a particular GPIO pin at a time. Failing to do so may result in unpredictable behavior.

PDM signal	PDM pin	Direction	Output value	Comment
CLK	As specified in PSEL.CLK	Output	0	
DIN	As specified in PSEL.DIN	Input	Not applicable	

Table 26: GPIO configuration before enabling peripheral

6.9.7 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
PDM : S PDM : NS	0x50026000 0x40026000	US	NS	SA	No	Pulse density modulation (digital microphone) interface

Register overview

Register	Offset	TZ	Description
TASKS_START	0x000		Starts continuous PDM transfer
TASKS_STOP	0x004		Stops PDM transfer
SUBSCRIBE_START	0x080		Subscribe configuration for task START
SUBSCRIBE_STOP	0x084		Subscribe configuration for task STOP
EVENTS_STARTED	0x100		PDM transfer has started
EVENTS_STOPPED	0x104		PDM transfer has finished
EVENTS_END	0x108		The PDM has written the last sample specified by SAMPLE.MAXCNT (or the last sample after a STOP task has been received) to Data RAM
PUBLISH_STARTED	0x180		Publish configuration for event STARTED
PUBLISH_STOPPED	0x184		Publish configuration for event STOPPED
PUBLISH_END	0x188		Publish configuration for event END
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
ENABLE	0x500		PDM module enable register
PDMCLKCTRL	0x504		PDM clock generator control
MODE	0x508		Defines the routing of the connected PDM microphones' signals
GAINL	0x518		Left output gain adjustment
GAINR	0x51C		Right output gain adjustment
RATIO	0x520		Selects the ratio between PDM_CLK and output sample rate. Change PDMCLKCTRL accordingly.
PSEL.CLK	0x540		Pin number configuration for PDM CLK signal
PSEL.DIN	0x544		Pin number configuration for PDM DIN signal
SAMPLE.PTR	0x560		RAM address pointer to write samples to with EasyDMA
SAMPLE.MAXCNT	0x564		Number of samples to allocate memory for in EasyDMA mode

6.9.7.1 TASKS_START

Address offset: 0x000

Starts continuous PDM transfer

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_START			Starts continuous PDM transfer
			Trigger	1	Trigger task

6.9.7.2 TASKS_STOP

Address offset: 0x004

Stops PDM transfer

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stops PDM transfer
			Trigger	1	Trigger task

6.9.7.3 SUBSCRIBE_START

Address offset: 0x080

Subscribe configuration for task START

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task START will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.9.7.4 SUBSCRIBE_STOP

Address offset: 0x084

Subscribe configuration for task STOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.9.7.5 EVENTS_STARTED

Address offset: 0x100

PDM transfer has started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STARTED			PDM transfer has started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.9.7.6 EVENTS_STOPPED

Address offset: 0x104

PDM transfer has finished

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STOPPED			PDM transfer has finished
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.9.7.7 EVENTS_END

Address offset: 0x108

The PDM has written the last sample specified by SAMPLE.MAXCNT (or the last sample after a STOP task has been received) to Data RAM

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_END			The PDM has written the last sample specified by SAMPLE.MAXCNT (or the last sample after a STOP task has been received) to Data RAM
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.9.7.8 PUBLISH_STARTED

Address offset: 0x180

Publish configuration for event STARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.9.7.9 PUBLISH_STOPPED

Address offset: 0x184

Publish configuration for event STOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STOPPED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.9.7.10 PUBLISH_END

Address offset: 0x188

Publish configuration for event END

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event END will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.9.7.11 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	STARTED			Enable or disable interrupt for event STARTED
			Disabled	0	Disable
			Enabled	1	Enable
B	RW	STOPPED			Enable or disable interrupt for event STOPPED
			Disabled	0	Disable
			Enabled	1	Enable
C	RW	END			Enable or disable interrupt for event END
			Disabled	0	Disable
			Enabled	1	Enable

6.9.7.12 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	STARTED			Write '1' to enable interrupt for event STARTED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	STOPPED			Write '1' to enable interrupt for event STOPPED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	END			Write '1' to enable interrupt for event END
			Set	1	Enable

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.9.7.13 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	STARTED			Write '1' to disable interrupt for event STARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	STOPPED			Write '1' to disable interrupt for event STOPPED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	END			Write '1' to disable interrupt for event END
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.9.7.14 ENABLE

Address offset: 0x500

PDM module enable register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			Enable or disable PDM module
			Disabled	0	Disable
			Enabled	1	Enable

6.9.7.15 PDMCLKCTRL

Address offset: 0x504

PDM clock generator control

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x08400000				**0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	FREQ			PDM_CLK frequency configuration.
			1000K	0x08000000	PDM_CLK = 32 MHz / 32 = 1.000 MHz
			Default	0x08400000	PDM_CLK = 32 MHz / 31 = 1.032 MHz. Nominal clock for RATIO=Ratio64.
			1067K	0x08800000	PDM_CLK = 32 MHz / 30 = 1.067 MHz
			1231K	0x09800000	PDM_CLK = 32 MHz / 26 = 1.231 MHz
			1280K	0x0A000000	PDM_CLK = 32 MHz / 25 = 1.280 MHz. Nominal clock for RATIO=Ratio80.
			1333K	0x0A800000	PDM_CLK = 32 MHz / 24 = 1.333 MHz

6.9.7.16 MODE

Address offset: 0x508

Defines the routing of the connected PDM microphones' signals

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	OPERATION			Mono or stereo operation
			Stereo	0	Sample and store one pair (left + right) of 16-bit samples per RAM word R=[31:16]; L=[15:0]
			Mono	1	Sample and store two successive left samples (16 bits each) per RAM word L1=[31:16]; L0=[15:0]
B	RW	EDGE			Defines on which PDM_CLK edge left (or mono) is sampled
			LeftFalling	0	Left (or mono) is sampled on falling edge of PDM_CLK
			LeftRising	1	Left (or mono) is sampled on rising edge of PDM_CLK

6.9.7.17 GAINL

Address offset: 0x518

Left output gain adjustment

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A
Reset 0x00000028				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	GAINL			Left output gain adjustment, in 0.5 dB steps, around the default module gain (see electrical parameters) 0x00 -20 dB gain adjust 0x01 -19.5 dB gain adjust (...) 0x27 -0.5 dB gain adjust 0x28 0 dB gain adjust 0x29 +0.5 dB gain adjust (...) 0x4F +19.5 dB gain adjust 0x50 +20 dB gain adjust
			MinGain	0x00	-20 dB gain adjustment (minimum)
			DefaultGain	0x28	0 dB gain adjustment
			MaxGain	0x50	+20 dB gain adjustment (maximum)

6.9.7.18 GAINR

Address offset: 0x51C

Right output gain adjustment

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A
Reset 0x00000028				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	GAINR			Right output gain adjustment, in 0.5 dB steps, around the default module gain (see electrical parameters)
			MinGain	0x00	-20 dB gain adjustment (minimum)
			DefaultGain	0x28	0 dB gain adjustment
			MaxGain	0x50	+20 dB gain adjustment (maximum)

6.9.7.19 RATIO

Address offset: 0x520

Selects the ratio between PDM_CLK and output sample rate. Change PDMCLKCTRL accordingly.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RATIO			Selects the ratio between PDM_CLK and output sample rate
			Ratio64	0	Ratio of 64
			Ratio80	1	Ratio of 80

6.9.7.20 PSEL.CLK

Address offset: 0x540

Pin number configuration for PDM CLK signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.9.7.21 PSEL.DIN

Address offset: 0x544

Pin number configuration for PDM DIN signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.9.7.22 SAMPLE.PTR

Address offset: 0x560

RAM address pointer to write samples to with EasyDMA

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	SAMPLEPTR			Address to write PDM samples to over DMA

Note: See the memory chapter for details about which memories are available for EasyDMA.

6.9.7.23 SAMPLE.MAXCNT

Address offset: 0x564

Number of samples to allocate memory for in EasyDMA mode

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	BUFFSIZE		[0..32767]	Length of DMA RAM allocation in number of samples

6.9.8 Electrical specification

6.9.8.1 PDM Electrical Specification

Symbol	Description	Min.	Typ.	Max.	Units
$f_{PDM,CLK,64}$	PDM clock speed. PDMCLKCTRL = Default (Setting needed for 16 MHz sample frequency @ RATIO = Ratio64)		1.032		MHz
$f_{PDM,CLK,80}$	PDM clock speed. PDMCLKCTRL = 1280K (Setting needed for 16 MHz sample frequency @ RATIO = Ratio80)		1.28		MHz
$t_{PDM,JITTER}$	Jitter in PDM clock output			20	ns
$T_{dPDM,CLK}$	PDM clock duty cycle	40	50	60	%
$t_{PDM,DATA}$	Decimation filter delay			5	ms
$t_{PDM,cv}$	Allowed clock edge to data valid			125	ns
$t_{PDM,ci}$	Allowed (other) clock edge to data invalid	0			ns
$t_{PDM,s}$	Data setup time at $f_{PDM,CLK}$=1.024 MHz or 1.280 MHz	65			ns
$t_{PDM,h}$	Data hold time at $f_{PDM,CLK}$=1.024 MHz or 1.280 MHz	0			ns
$G_{PDM,default}$	Default (reset) absolute gain of the PDM module		3.2		dB

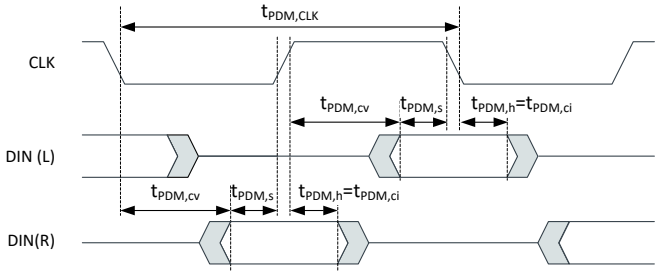

Figure 46: PDM timing diagram

6.10 PWM — Pulse width modulation

The pulse width modulation (PWM) module enables the generation of pulse width modulated signals on GPIO. The module implements an up or up-and-down counter with four PWM channels that drive assigned GPIOs.

The following are the main features of a PWM module:

- Programmable PWM frequency
- Up to four PWM channels with individual polarity and duty cycle values
- Edge or center-aligned pulses across PWM channels
- Multiple duty cycle arrays (sequences) defined in RAM
- Autonomous and glitch-free update of duty cycle values directly from memory through EasyDMA (no CPU involvement)
- Change of polarity, duty cycle, and base frequency possibly on every PWM period
- RAM sequences can be repeated or connected into loops

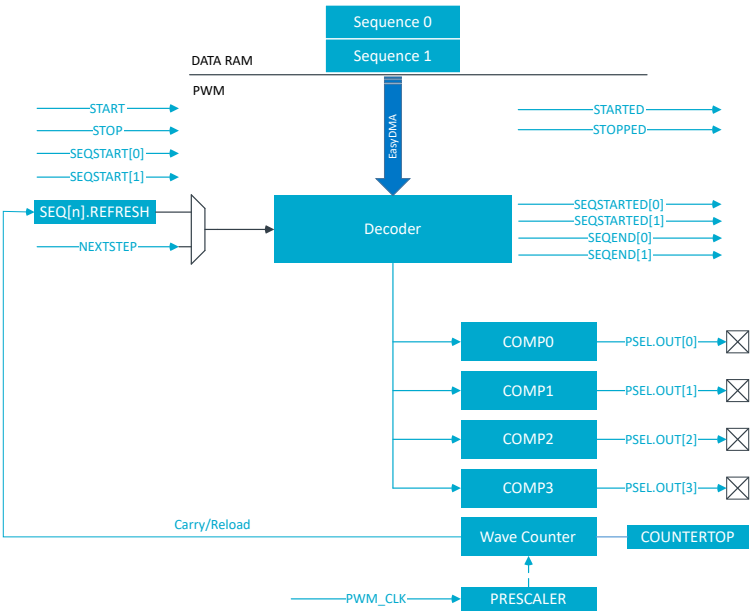

Figure 47: PWM module

6.10.1 Wave counter

The wave counter is responsible for generating the pulses, at a duty cycle that depends on the compare values and at a frequency that depends on COUNTERTOP.

There is one common 15-bit counter with four compare channels. Thus, all four channels will share the same period (PWM frequency) but can have individual duty cycle and polarity. The polarity is set by the most significant bit (MSB) of the value read from RAM (see figure Decoder memory access modes on page 231). When the MSB bit is high (FallingEdge polarity), OUT[n] starts high to become low during the given PWM cycle, whereas the inverse occurs for RisingEdge polarity. Whether the counter counts up, or up and down, is controlled by the MODE register.

The timer top value is controlled by the COUNTERTOP register. This register value, in conjunction with the selected PRESCALER of the PWM_CLK, will result in a given PWM period. A COUNTERTOP value smaller than the compare setting will result in a state where no PWM edges are generated. OUT[n] is held high, given that the polarity is set to FallingEdge. All compare registers are internal and can only be configured through decoder presented later. COUNTERTOP can be safely written at any time.

Sampling follows the START task. If DECODER.LOAD=WaveForm, the register value is ignored and taken from RAM instead (see section Decoder with EasyDMA on page 231 for more details). If DECODER.LOAD is anything else than the WaveForm, it is sampled following a STARTSEQ[n] task and when loading a new value from RAM during a sequence playback.

The following figure shows the counter operating in up mode (MODE=PWM_MODE_Up), with two PWM channels with the same frequency but different duty cycle:

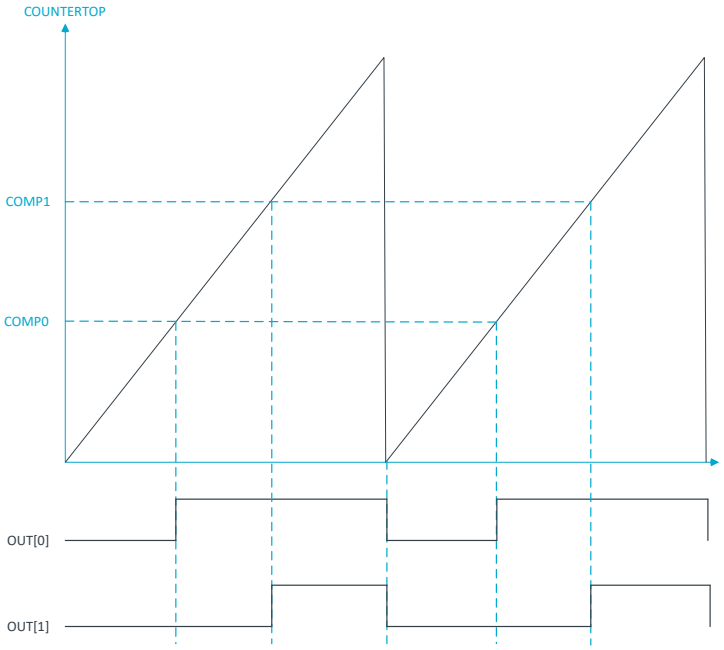

Figure 48: PWM counter in up mode example - RisingEdge polarity

The counter is automatically reset to zero when COUNTERTOP is reached and OUT[n] will invert. OUT[n] is held low if the compare value is 0 and held high if set to COUNTERTOP, given that the polarity is set to FallingEdge. Counter running in up mode results in pulse widths that are edge-aligned. The following is the code for the counter in up mode example:

```
uint16_t pwm_seq[4] = {PWM_CH0_DUTY, PWM_CH1_DUTY, PWM_CH2_DUTY, PWM_CH3_DUTY};
NRF_PWM0->PSEL.OUT[0] = (first_pin << PWM_PSEL_OUT_PIN_Pos) |
                        (PWM_PSEL_OUT_CONNECT_Connected <<
                                                PWM_PSEL_OUT_CONNECT_Pos);
NRF_PWM0->PSEL.OUT[1] = (second_pin << PWM_PSEL_OUT_PIN_Pos) |
                        (PWM_PSEL_OUT_CONNECT_Connected <<
                                                PWM_PSEL_OUT_CONNECT_Pos);
NRF_PWM0->ENABLE      = (PWM_ENABLE_ENABLE_Enabled << PWM_ENABLE_ENABLE_Pos);
NRF_PWM0->MODE        = (PWM_MODE_UPDOWN_Up << PWM_MODE_UPDOWN_Pos);
NRF_PWM0->PRESCALER   = (PWM_PRESCALER_PRESCALER_DIV_1 <<
                                                PWM_PRESCALER_PRESCALER_Pos);
NRF_PWM0->COUNTERTOP  = (16000 << PWM_COUNTERTOP_COUNTERTOP_Pos); //1 msec
NRF_PWM0->LOOP        = (PWM_LOOP_CNT_Disabled << PWM_LOOP_CNT_Pos);
NRF_PWM0->DECODER   = (PWM_DECODER_LOAD_Individual << PWM_DECODER_LOAD_Pos) |
                      (PWM_DECODER_MODE_RefreshCount << PWM_DECODER_MODE_Pos);
NRF_PWM0->SEQ[0].PTR  = ((uint32_t)(pwm_seq) << PWM_SEQ_PTR_PTR_Pos);
NRF_PWM0->SEQ[0].CNT  = ((sizeof(pwm_seq) / sizeof(uint16_t)) <<
                                                PWM_SEQ_CNT_CNT_Pos);
NRF_PWM0->SEQ[0].REFRESH  = 0;
NRF_PWM0->SEQ[0].ENDDELAY = 0;
NRF_PWM0->TASKS_SEQSTART[0] = 1;
```

When the counter is running in up mode, the following formula can be used to compute the PWM period and the step size:

PWM period: $T_{PWM(Up)} = T_{PWM\_CLK} * COUNTERTOP$

Step width/Resolution: $T_{steps} = T_{PWM\_CLK}$

The following figure shows the counter operating in up-and-down mode (MODE=PWM_MODE_UpAndDown), with two PWM channels with the same frequency but different duty cycle and output polarity:

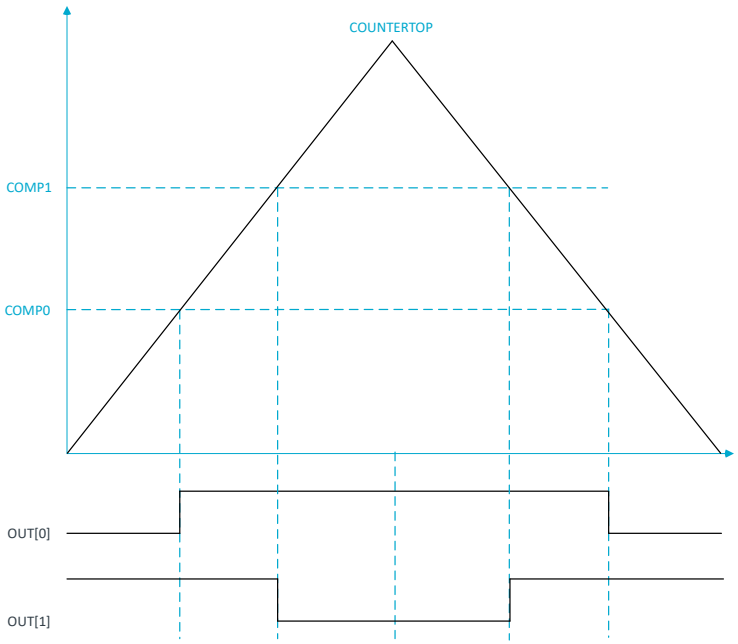

Figure 49: PWM counter in up-and-down mode example

The counter starts decrementing to zero when COUNTERTOP is reached and will invert the OUT[n] when compare value is hit for the second time. This results in a set of pulses that are center-aligned. The following is the code for the counter in up-and-down mode example:

```
uint16_t pwm_seq[4] = {PWM_CH0_DUTY, PWM_CH1_DUTY, PWM_CH2_DUTY, PWM_CH3_DUTY};
NRF_PWM0->PSEL.OUT[0] = (first_pin << PWM_PSEL_OUT_PIN_Pos) |
                        (PWM_PSEL_OUT_CONNECT_Connected <<
                                                PWM_PSEL_OUT_CONNECT_Pos);
NRF_PWM0->PSEL.OUT[1] = (second_pin << PWM_PSEL_OUT_PIN_Pos) |
                        (PWM_PSEL_OUT_CONNECT_Connected <<
                                                PWM_PSEL_OUT_CONNECT_Pos);
NRF_PWM0->ENABLE      = (PWM_ENABLE_ENABLE_Enabled << PWM_ENABLE_ENABLE_Pos);
NRF_PWM0->MODE        = (PWM_MODE_UPDOWN_UpAndDown << PWM_MODE_UPDOWN_Pos);
NRF_PWM0->PRESCALER   = (PWM_PRESCALER_PRESCALER_DIV_1 <<
                                                PWM_PRESCALER_PRESCALER_Pos);
NRF_PWM0->COUNTERTOP  = (16000 << PWM_COUNTERTOP_COUNTERTOP_Pos); //1 msec
NRF_PWM0->LOOP        = (PWM_LOOP_CNT_Disabled << PWM_LOOP_CNT_Pos);
NRF_PWM0->DECODER   = (PWM_DECODER_LOAD_Individual << PWM_DECODER_LOAD_Pos) |
                      (PWM_DECODER_MODE_RefreshCount << PWM_DECODER_MODE_Pos);
NRF_PWM0->SEQ[0].PTR  = ((uint32_t)(pwm_seq) << PWM_SEQ_PTR_PTR_Pos);
NRF_PWM0->SEQ[0].CNT  = ((sizeof(pwm_seq) / sizeof(uint16_t)) <<
                                                PWM_SEQ_CNT_CNT_Pos);
NRF_PWM0->SEQ[0].REFRESH  = 0;
NRF_PWM0->SEQ[0].ENDDELAY = 0;
NRF_PWM0->TASKS_SEQSTART[0] = 1;
```

When the counter is running in up-and-down mode, the following formula can be used to compute the PWM period and the step size:

$T_{PWM(Up\ And\ Down)} = T_{PWM\_CLK} * 2 * COUNTERTOP$

Step width/Resolution: $T_{steps} = T_{PWM\_CLK} * 2$

6.10.2 Decoder with EasyDMA

The decoder uses EasyDMA to take PWM parameters stored in RAM and update the internal compare registers of the wave counter, based on the mode of operation.

PWM parameters are organized into a sequence containing at least one half word (16 bit). Its most significant bit[15] denotes the polarity of the OUT[n] while bit[14:0] is the 15-bit compare value.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Id				B A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
Id	RW	Field	Value Id	Value	Description
A	RW	COMPARE			Duty cycle setting - value loaded to internal compare register
B	RW	POLARITY			Edge polarity of GPIO.
			RisingEdge	0	First edge within the PWM period is rising
			FallingEdge	1	First edge within the PWM period is falling

The DECODER register controls how the RAM content is interpreted and loaded into the internal compare registers. The LOAD field controls if the RAM values are loaded to all compare channels, or to update a group or all channels with individual values. The following figure illustrates how parameters stored in RAM are organized and routed to various compare channels in different modes:

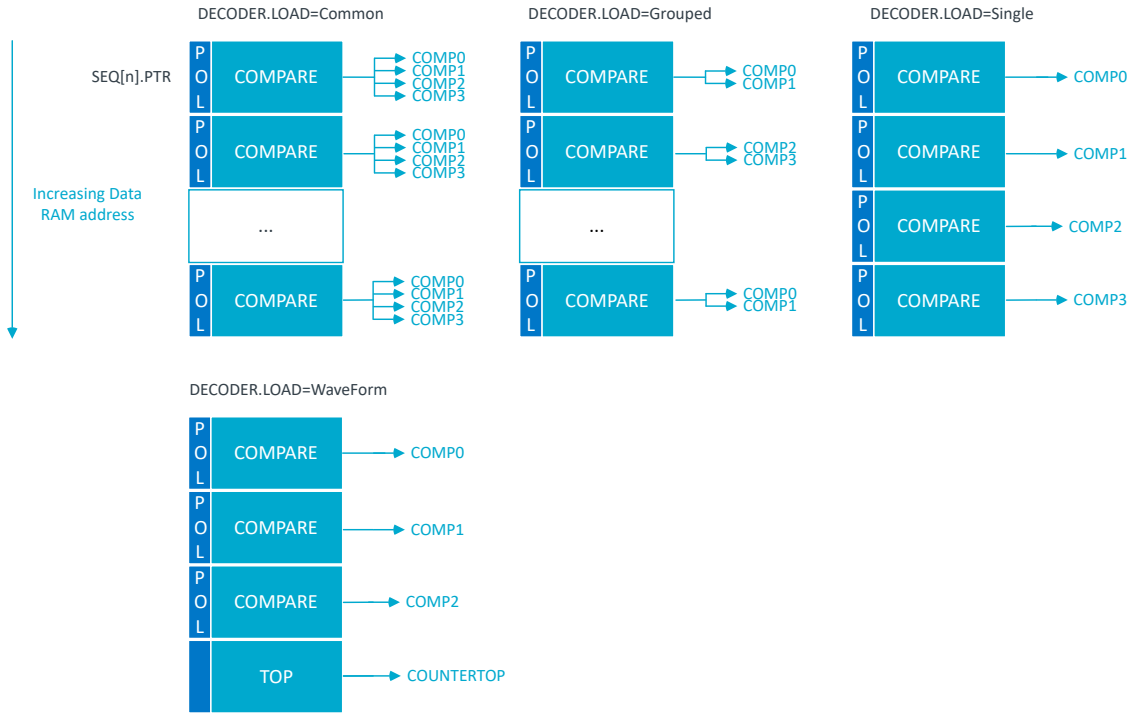

Figure 50: Decoder memory access modes

A special mode of operation is available when DECODER.LOAD is set to WaveForm. In this mode, up to three PWM channels can be enabled - OUT[0] to OUT[2]. In RAM, four values are loaded at a time: the first, second and third location are used to load the values, and the fourth RAM location is used to load

the COUNTERTOP register. This way one can have up to three PWM channels with a frequency base that changes on a per PWM period basis. This mode of operation is useful for arbitrary wave form generation in applications, such as LED lighting.

The register SEQ[n].REFRESH=N (one per sequence n=0 or 1) will instruct a new RAM stored pulse width value on every (N+1)th PWM period. Setting the register to zero will result in a new duty cycle update every PWM period, as long as the minimum PWM period is observed.

Note that registers SEQ[n].REFRESH and SEQ[n].ENDDELAY are ignored when DECODER.MODE=NextStep. The next value is loaded upon every received NEXTSTEP task.

SEQ[n].PTR is the pointer used to fetch COMPARE values from RAM. If the SEQ[n].PTR is not pointing to a RAM region, an EasyDMA transfer may result in a HardFault or RAM corruption. See Memory on page 21 for more information about the different memory regions. After the SEQ[n].PTR is set to the desired RAM location, the SEQ[n].CNT register must be set to the number of 16-bit half words in the sequence. It is important to observe that the Grouped mode requires one half word per group, while the Single mode requires one half word per channel, thus increasing the RAM size occupation. If PWM generation is not running when the SEQSTART[n] task is triggered, the task will load the first value from RAM and then start the PWM generation. A SEQSTARTED[n] event is generated as soon as the EasyDMA has read the first PWM parameter from RAM and the wave counter has started executing it. When LOOP.CNT=0, sequence n=0 or 1 is played back once. After the last value in the sequence has been loaded and started executing, a SEQEND[n] event is generated. The PWM generation will then continue with the last loaded value. The following figure illustrates an example of a simple playback.

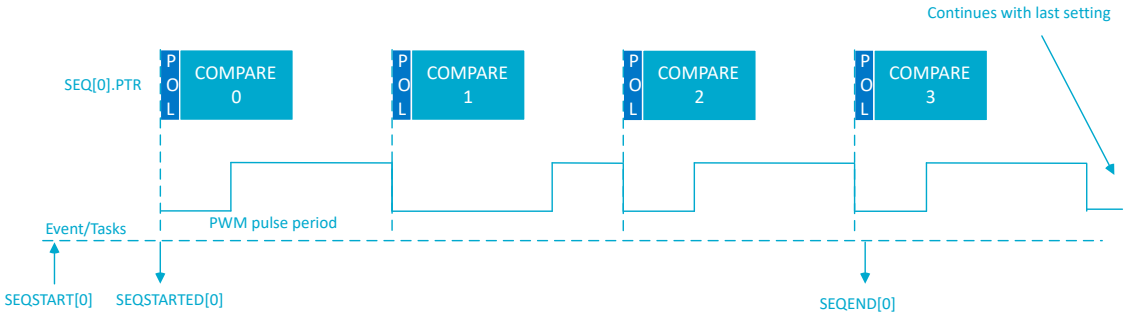

Figure 51: Simple sequence example

The following source code is used for configuration and timing details in a sequence where only sequence 0 is used and only run once with a new PWM duty cycle for each period.

```
NRF_PWM0->PSEL.OUT[0] = (first_pin << PWM_PSEL_OUT_PIN_Pos) |
                        (PWM_PSEL_OUT_CONNECT_Connected <<
                                                PWM_PSEL_OUT_CONNECT_Pos);
NRF_PWM0->ENABLE      = (PWM_ENABLE_ENABLE_Enabled << PWM_ENABLE_ENABLE_Pos);
NRF_PWM0->MODE        = (PWM_MODE_UPDOWN_Up << PWM_MODE_UPDOWN_Pos);
NRF_PWM0->PRESCALER   = (PWM_PRESCALER_PRESCALER_DIV_1 <<
                                                PWM_PRESCALER_PRESCALER_Pos);
NRF_PWM0->COUNTERTOP  = (16000 << PWM_COUNTERTOP_COUNTERTOP_Pos); //1 msec
NRF_PWM0->LOOP        = (PWM_LOOP_CNT_Disabled << PWM_LOOP_CNT_Pos);
NRF_PWM0->DECODER   = (PWM_DECODER_LOAD_Common << PWM_DECODER_LOAD_Pos) |
                      (PWM_DECODER_MODE_RefreshCount << PWM_DECODER_MODE_Pos);
NRF_PWM0->SEQ[0].PTR  = ((uint32_t)(seq0_ram) << PWM_SEQ_PTR_PTR_Pos);
NRF_PWM0->SEQ[0].CNT  = ((sizeof(seq0_ram) / sizeof(uint16_t)) <<
                                                PWM_SEQ_CNT_CNT_Pos);
NRF_PWM0->SEQ[0].REFRESH  = 0;
NRF_PWM0->SEQ[0].ENDDELAY = 0;
NRF_PWM0->TASKS_SEQSTART[0] = 1;
```

To completely stop the PWM generation and force the associated pins to a defined state, a STOP task can be triggered at any time. A STOPPED event is generated when the PWM generation has stopped at the end of the currently running PWM period, and the pins go into their idle state as defined in GPIO OUT register. PWM generation can then only be restarted through a SEQSTART[n] task. SEQSTART[n] will resume PWM generation after having loaded the first value from the RAM buffer defined in the SEQ[n].PTR register.

The following table indicates when specific registers get sampled by the hardware. Care should be taken when updating these registers to avoid that values are applied earlier than expected.

Register	Taken into account by hardware	Recommended (safe) update
SEQ[n].PTR	When sending the SEQSTART[n] task	After having received the SEQSTARTED[n] event
SEQ[n].CNT	When sending the SEQSTART[n] task	After having received the SEQSTARTED[n] event
SEQ[0].ENDDELAY	When sending the SEQSTART[0] task	Before starting sequence [0] through a SEQSTART[0] task
	Every time a new value from sequence [0] has been loaded from RAM and gets applied to the Wave Counter (indicated by the PWMPERIODEND event)	When no more value from sequence [0] gets loaded from RAM (indicated by the SEQEND[0] event)
		At any time during sequence [1] (which starts when the SEQSTARTED[1] event is generated)
SEQ[1].ENDDELAY	When sending the SEQSTART[1] task	Before starting sequence [1] through a SEQSTART[1] task
	Every time a new value from sequence [1] has been loaded from RAM and gets applied to the Wave Counter (indicated by the PWMPERIODEND event)	When no more value from sequence [1] gets loaded from RAM (indicated by the SEQEND[1] event)
		At any time during sequence [0] (which starts when the SEQSTARTED[0] event is generated)
SEQ[0].REFRESH	When sending the SEQSTART[0] task	Before starting sequence [0] through a SEQSTART[0] task
	Every time a new value from sequence [0] has been loaded from RAM and gets applied to the Wave Counter (indicated by the PWMPERIODEND event)	At any time during sequence [1] (which starts when the SEQSTARTED[1] event is generated)
SEQ[1].REFRESH	When sending the SEQSTART[1] task	Before starting sequence [1] through a SEQSTART[1] task
	Every time a new value from sequence [1] has been loaded from RAM and gets applied to the Wave Counter (indicated by the PWMPERIODEND event)	At any time during sequence [0] (which starts when the SEQSTARTED[0] event is generated)
COUNTERTOP	In DECODER.LOAD=WaveForm: this register is ignored.	Before starting PWM generation through a SEQSTART[n] task
	In all other LOAD modes: at the end of current PWM period (indicated by the PWMPERIODEND event)	After a STOP task has been triggered, and the STOPPED event has been received.
MODE	Immediately	Before starting PWM generation through a SEQSTART[n] task
		After a STOP task has been triggered, and the STOPPED event has been received.
DECODER	Immediately	Before starting PWM generation through a SEQSTART[n] task
		After a STOP task has been triggered, and the STOPPED event has been received.
PRESCALER	Immediately	Before starting PWM generation through a SEQSTART[n] task
		After a STOP task has been triggered, and the STOPPED event has been received.
LOOP	Immediately	Before starting PWM generation through a SEQSTART[n] task
		After a STOP task has been triggered, and the STOPPED event has been received.
PSEL.OUT[n]	Immediately	Before enabling the PWM instance through the ENABLE register

Table 27: When to safely update PWM registers

Note: SEQ[n].REFRESH and SEQ[n].ENDDELAY are ignored at the end of a complex sequence, indicated by a LOOPSDONE event. The reason for this is that the last value loaded from RAM is maintained until further action from software (restarting a new sequence or stopping PWM generation).

The following figure shows a more complex example using the register LOOP on page 249.

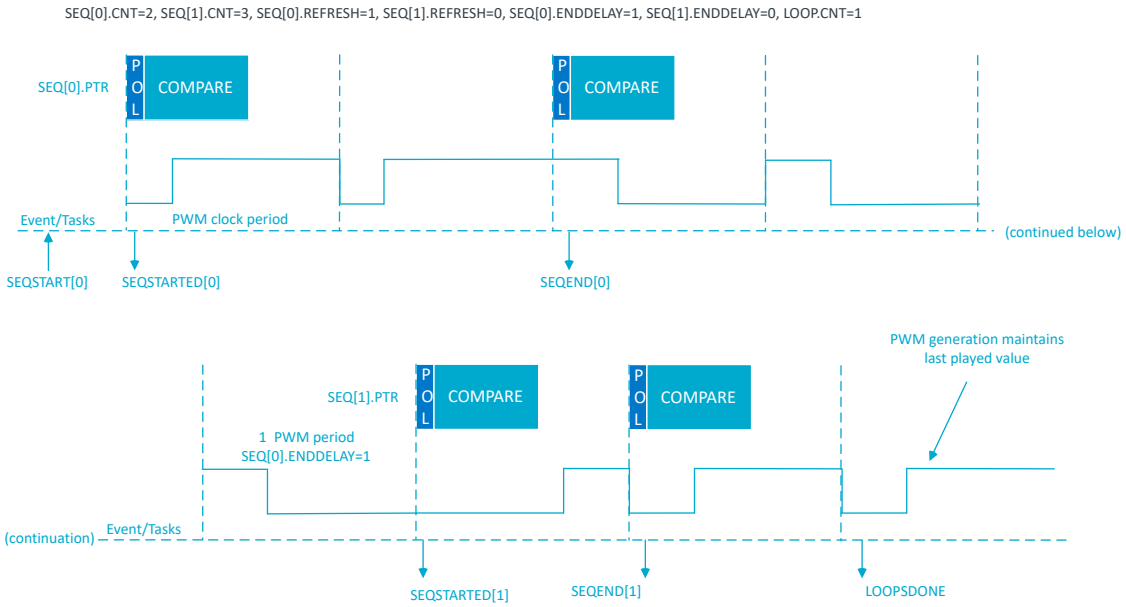

Figure 52: Example using two sequences

In this case, an automated playback takes place, consisting of SEQ[0], delay 0, SEQ[1], delay 1, then again SEQ[0], etc. The user can choose to start a complex playback with SEQ[0] or SEQ[1] through sending the SEQSTART[0] or SEQSTART[1] task. The complex playback always ends with delay 1.

The two sequences 0 and 1 are defined by the addresses of value tables in RAM (pointed to by SEQ[n].PTR) and the buffer size (SEQ[n].CNT). The rate at which a new value is loaded is defined individually for each sequence by SEQ[n].REFRESH. The chaining of sequence 1 following the sequence 0 is implicit, the LOOP.CNT register allows the chaining of sequence 1 to sequence 0 for a determined number of times. In other words, it allows to repeat a complex sequence a number of times in a fully automated way.

In the following code example, sequence 0 is defined with SEQ[0].REFRESH set to 1, meaning that a new PWM duty cycle is pushed every second PWM period. This complex sequence is started with the SEQSTART[0] task, so SEQ[0] is played first. Since SEQ[0].ENDDELAY=1 there will be one PWM period delay between last period on sequence 0 and the first period on sequence 1. Since SEQ[1].ENDDELAY=0 there is no delay 1, so SEQ[0] would be started immediately after the end of SEQ[1]. However, as LOOP.CNT is

1, the playback stops after having played SEQ[1] only once, and both SEQEND[1] and LOOPSDONE are generated (their order is not guaranteed in this case).

```
NRF_PWM0->PSEL.OUT[0] = (first_pin << PWM_PSEL_OUT_PIN_Pos) |
                        (PWM_PSEL_OUT_CONNECT_Connected <<
                                                  PWM_PSEL_OUT_CONNECT_Pos);
NRF_PWM0->ENABLE      = (PWM_ENABLE_ENABLE_Enabled << PWM_ENABLE_ENABLE_Pos);
NRF_PWM0->MODE        = (PWM_MODE_UPDOWN_Up << PWM_MODE_UPDOWN_Pos);
NRF_PWM0->PRESCALER   = (PWM_PRESCALER_PRESCALER_DIV_1 <<
                                                  PWM_PRESCALER_PRESCALER_Pos);
NRF_PWM0->COUNTERTOP  = (16000 << PWM_COUNTERTOP_COUNTERTOP_Pos); //1 msec
NRF_PWM0->LOOP        = (1 << PWM_LOOP_CNT_Pos);
NRF_PWM0->DECODER   = (PWM_DECODER_LOAD_Common << PWM_DECODER_LOAD_Pos) |
                      (PWM_DECODER_MODE_RefreshCount << PWM_DECODER_MODE_Pos);
NRF_PWM0->SEQ[0].PTR  = ((uint32_t)(seq0_ram) << PWM_SEQ_PTR_PTR_Pos);
NRF_PWM0->SEQ[0].CNT  = ((sizeof(seq0_ram) / sizeof(uint16_t)) <<
                                                  PWM_SEQ_CNT_CNT_Pos);
NRF_PWM0->SEQ[0].REFRESH  = 1;
NRF_PWM0->SEQ[0].ENDDELAY = 1;
NRF_PWM0->SEQ[1].PTR  = ((uint32_t)(seq1_ram) << PWM_SEQ_PTR_PTR_Pos);
NRF_PWM0->SEQ[1].CNT  = ((sizeof(seq1_ram) / sizeof(uint16_t)) <<
                                                  PWM_SEQ_CNT_CNT_Pos);
NRF_PWM0->SEQ[1].REFRESH  = 0;
NRF_PWM0->SEQ[1].ENDDELAY = 0;
NRF_PWM0->TASKS_SEQSTART[0] = 1;
```

The decoder can also be configured to asynchronously load new PWM duty cycle. If the DECODER.MODE register is set to NextStep, then the NEXTSTEP task will cause an update of internal compare registers on the next PWM period.

The following figures provide an overview of each part of an arbitrary sequence, in various modes (LOOP.CNT=0 and LOOP.CNT>0). In particular, the following are represented:

- Initial and final duty cycle on the PWM output(s)
- Chaining of SEQ[0] and SEQ[1] if LOOP.CNT>0
- Influence of registers on the sequence
- Events generated during a sequence
- DMA activity (loading of next value and applying it to the output(s))

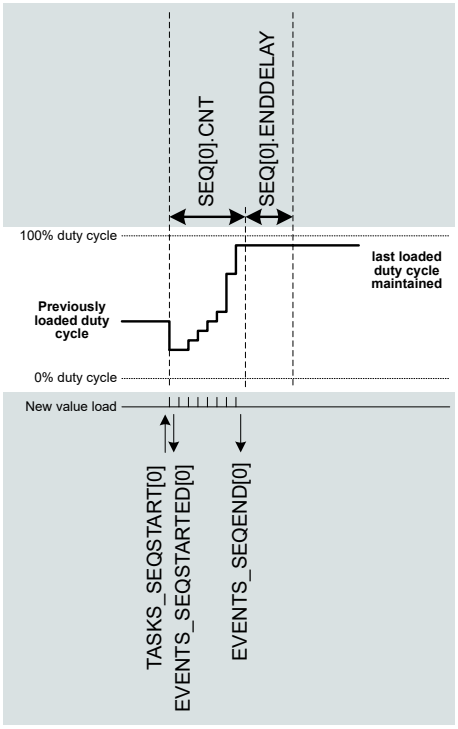

Figure 53: Single shot (LOOP.CNT=0)

Note: The single-shot example also applies to SEQ[1]. Only SEQ[0] is represented for simplicity.

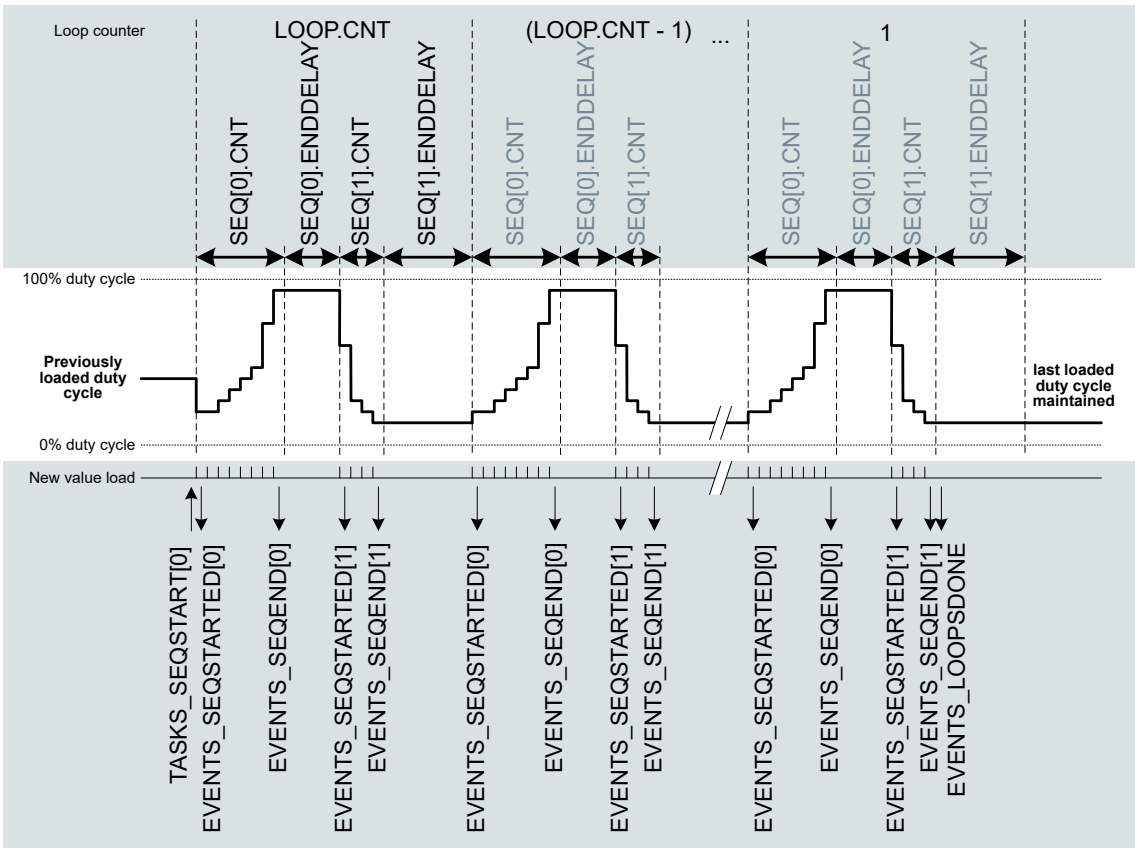

Figure 54: Complex sequence (LOOP.CNT>0) starting with SEQ[0]

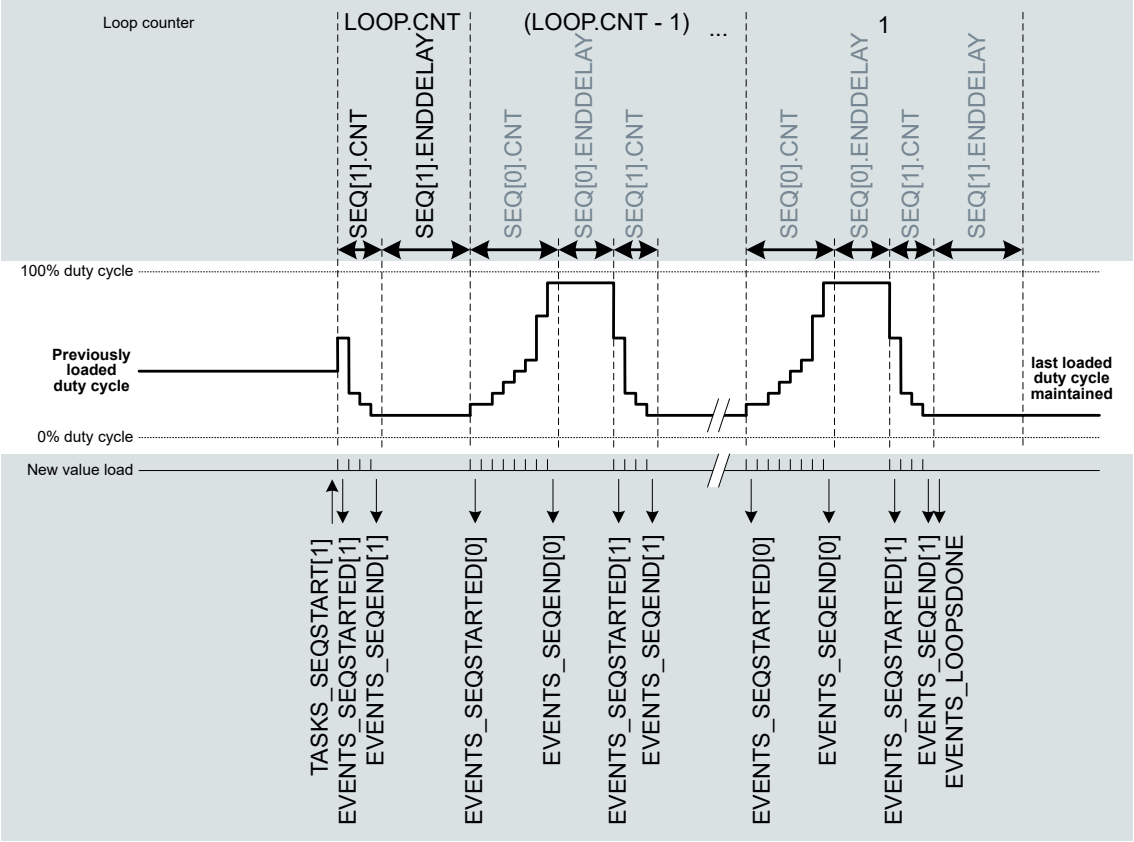

Figure 55: Complex sequence (LOOP.CNT>0) starting with SEQ[1]

Note: If a sequence is in use in a simple or complex sequence, it must have a length of SEQ[n].CNT > 0.

This example shows how the PWM module can be configured to repeat a single sequence until stopped.

```
NRF_PWM0->PSEL.OUT[0] = (first_pin << PWM_PSEL_OUT_PIN_Pos) |
                        (PWM_PSEL_OUT_CONNECT_Connected <<
                                                PWM_PSEL_OUT_CONNECT_Pos);
NRF_PWM0->ENABLE      = (PWM_ENABLE_ENABLE_Enabled << PWM_ENABLE_ENABLE_Pos);
NRF_PWM0->MODE        = (PWM_MODE_UPDOWN_Up << PWM_MODE_UPDOWN_Pos);
NRF_PWM0->PRESCALER   = (PWM_PRESCALER_PRESCALER_DIV_1 <<
                                                PWM_PRESCALER_PRESCALER_Pos);
NRF_PWM0->COUNTERTOP  = (16000 << PWM_COUNTERTOP_COUNTERTOP_Pos); //1 msec
// Enable the shortcut from LOOPSDONE event to SEQSTART1 task for infinite loop
NRF_PWM0->SHORTS      = (PWM_SHORTS_LOOPSDONE_SEQSTART1_Enabled <<
                                            PWM_SHORTS_LOOPSDONE_SEQSTART1_Pos);
// LOOP_CNT must be greater than 0 for the LOOPSDONE event to trigger and enable looping
NRF_PWM0->LOOP        = (1 << PWM_LOOP_CNT_Pos);
NRF_PWM0->DECODER     = (PWM_DECODER_LOAD_Common << PWM_DECODER_LOAD_Pos) |
                       (PWM_DECODER_MODE_RefreshCount << PWM_DECODER_MODE_Pos);
// To repeat a single sequence until stopped, it must be configured in SEQ[1]
NRF_PWM0->SEQ[1].PTR  = ((uint32_t)(seq0_ram) << PWM_SEQ_PTR_PTR_Pos);
NRF_PWM0->SEQ[1].CNT  = ((sizeof(seq0_ram) / sizeof(uint16_t)) <<
                                                PWM_SEQ_CNT_CNT_Pos);
NRF_PWM0->SEQ[1].REFRESH  = 0;
NRF_PWM0->SEQ[1].ENDDELAY = 0;
NRF_PWM0->TASKS_SEQSTART[1] = 1;
```

6.10.3 Limitations

The previous compare value is repeated if the PWM period is shorter than the time it takes for the EasyDMA to retrieve from RAM and update the internal compare registers. This is to ensure a glitch-free operation even for very short PWM periods.

Only SEQ[1] can trigger the LOOPSDONE event upon completion, not SEQ[0]. This requires looping to be enabled (LOOP > 0) and SEQ[1].CNT > 0 when sequence playback starts.

6.10.4 Pin configuration

The OUT[n] (n=0..3) signals associated with each PWM channel are mapped to physical pins according to the configuration of PSEL.OUT[n] registers. If PSEL.OUT[n].CONNECT is set to Disconnected, the associated PWM module signal will not be connected to any physical pins.

The PSEL.OUT[n] registers and their configurations are used as long as the PWM module is enabled and the PWM generation active (wave counter started). They are retained only as long as the device is in System ON mode (see the POWER section for more information about power modes).

To ensure correct behavior in the PWM module, the pins that are used must be configured in the GPIO peripheral in the following way before the PWM module is enabled:

PWM signal	PWM pin	Direction	Output value	Comment
OUT[n]	As specified in PSEL.OUT[n] (n=0..3)	Output	0	Idle state defined in GPIO OUT register

Table 28: Recommended GPIO configuration before starting PWM generation

The idle state of a pin is defined by the OUT register in the GPIO module, to ensure that the pins used by the PWM module are driven correctly. If PWM generation is stopped by triggering a STOP task, the PWM module itself is temporarily disabled or the device temporarily enters System OFF. This configuration must be retained in the GPIO for the selected pins (I/Os) for as long as the PWM module is supposed to be connected to an external PWM circuit.

Only one peripheral can be assigned to drive a particular GPIO pin at a time. Failing to do so may result in unpredictable behavior.

6.10.5 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
PWM0 : S PWM0 : NS	0x50021000 0x40021000	US	NS	SA	No	Pulse width modulation unit 0
PWM1 : S PWM1 : NS	0x50022000 0x40022000	US	NS	SA	No	Pulse width modulation unit 1
PWM2 : S PWM2 : NS	0x50023000 0x40023000	US	NS	SA	No	Pulse width modulation unit 2
PWM3 : S PWM3 : NS	0x50024000 0x40024000	US	NS	SA	No	Pulse width modulation unit 3

Register overview

Register	Offset	TZ	Description
TASKS_STOP	0x004		Stops PWM pulse generation on all channels at the end of current PWM period, and stops sequence playback
TASKS_SEQSTART[n]	0x008		Loads the first PWM value on all enabled channels from sequence n, and starts playing that sequence at the rate defined in SEQ[n]REFRESH and/or DECODER.MODE. Causes PWM generation to start if not running.
TASKS_NEXTSTEP	0x010		Steps by one value in the current sequence on all enabled channels if DECODER.MODE=NextStep. Does not cause PWM generation to start if not running.
SUBSCRIBE_STOP	0x084		Subscribe configuration for task STOP
SUBSCRIBE_SEQSTART[n]	0x088		Subscribe configuration for task SEQSTART[n]
SUBSCRIBE_NEXTSTEP	0x090		Subscribe configuration for task NEXTSTEP
EVENTS_STOPPED	0x104		Response to STOP task, emitted when PWM pulses are no longer generated
EVENTS_SEQSTARTED[n]	0x108		First PWM period started on sequence n
EVENTS_SEQEND[n]	0x110		Emitted at end of every sequence n, when last value from RAM has been applied to wave counter
EVENTS_PWMPERIODEND	0x118		Emitted at the end of each PWM period
EVENTS_LOOPSDONE	0x11C		Concatenated sequences have been played the amount of times defined in LOOP.CNT
PUBLISH_STOPPED	0x184		Publish configuration for event STOPPED
PUBLISH_SEQSTARTED[n]	0x188		Publish configuration for event SEQSTARTED[n]
PUBLISH_SEQEND[n]	0x190		Publish configuration for event SEQEND[n]
PUBLISH_PWMPERIODEND	0x198		Publish configuration for event PWMPERIODEND
PUBLISH_LOOPSDONE	0x19C		Publish configuration for event LOOPSDONE
SHORTS	0x200		Shortcuts between local events and tasks
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
ENABLE	0x500		PWM module enable register
MODE	0x504		Selects operating mode of the wave counter
COUNTERTOP	0x508		Value up to which the pulse generator counter counts
PRESCALER	0x50C		Configuration for PWM_CLK
DECODER	0x510		Configuration of the decoder
LOOP	0x514		Number of playbacks of a loop
SEQ[n].PTR	0x520		Beginning address in RAM of this sequence
SEQ[n].CNT	0x524		Number of values (duty cycles) in this sequence
SEQ[n].REFRESH	0x528		Number of additional PWM periods between samples loaded into compare register
SEQ[n].ENDDELAY	0x52C		Time added after the sequence
PSEL.OUT[n]	0x560		Output pin select for PWM channel n

6.10.5.1 TASKS_STOP

Address offset: 0x004

Stops PWM pulse generation on all channels at the end of current PWM period, and stops sequence playback

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stops PWM pulse generation on all channels at the end of current PWM period, and stops sequence playback
			Trigger	1	Trigger task

6.10.5.2 TASKS_SEQSTART[n] (n=0..1)

Address offset: 0x008 + (n × 0x4)

Loads the first PWM value on all enabled channels from sequence n, and starts playing that sequence at the rate defined in SEQ[n]REFRESH and/or DECODER.MODE. Causes PWM generation to start if not running.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_SEQSTART			Loads the first PWM value on all enabled channels from sequence n, and starts playing that sequence at the rate defined in SEQ[n]REFRESH and/or DECODER.MODE. Causes PWM generation to start if not running.
			Trigger	1	Trigger task

6.10.5.3 TASKS_NEXTSTEP

Address offset: 0x010

Steps by one value in the current sequence on all enabled channels if DECODER.MODE=NextStep. Does not cause PWM generation to start if not running.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_NEXTSTEP			Steps by one value in the current sequence on all enabled channels if DECODER.MODE=NextStep. Does not cause PWM generation to start if not running.
			Trigger	1	Trigger task

6.10.5.4 SUBSCRIBE_STOP

Address offset: 0x084

Subscribe configuration for task STOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.10.5.5 SUBSCRIBE_SEQSTART[n] (n=0..1)

Address offset: 0x088 + (n × 0x4)

Subscribe configuration for task SEQSTART[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task SEQSTART[n] will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.10.5.6 SUBSCRIBE_NEXTSTEP

Address offset: 0x090

Subscribe configuration for task NEXTSTEP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task NEXTSTEP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.10.5.7 EVENTS_STOPPED

Address offset: 0x104

Response to STOP task, emitted when PWM pulses are no longer generated

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STOPPED			Response to STOP task, emitted when PWM pulses are no longer generated
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.10.5.8 EVENTS_SEQSTARTED[n] (n=0..1)

Address offset: 0x108 + (n × 0x4)

First PWM period started on sequence n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_SEQSTARTED			First PWM period started on sequence n
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.10.5.9 EVENTS_SEQEND[n] (n=0..1)

Address offset: 0x110 + (n × 0x4)

Emitted at end of every sequence n, when last value from RAM has been applied to wave counter

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_SEQEND			Emitted at end of every sequence n, when last value from RAM has been applied to wave counter
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.10.5.10 EVENTS_PWMPERIODEND

Address offset: 0x118

Emitted at the end of each PWM period

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_PWMPERIODEND			Emitted at the end of each PWM period
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.10.5.11 EVENTS_LOOPSDONE

Address offset: 0x11C

Concatenated sequences have been played the amount of times defined in LOOP.CNT

This event triggers after the last SEQ[1] completion of the loop, and only if looping was enabled (LOOP > 0) when the sequence playback was started.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_LOOPSDONE			Concatenated sequences have been played the amount of times defined in LOOP.CNT This event triggers after the last SEQ[1] completion of the loop, and only if looping was enabled (LOOP > 0) when the sequence playback was started.
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.10.5.12 PUBLISH_STOPPED

Address offset: 0x184

Publish configuration for event STOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STOPPED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.10.5.13 PUBLISH_SEQSTARTED[n] (n=0..1)

Address offset: 0x188 + (n × 0x4)

Publish configuration for event SEQSTARTED[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event SEQSTARTED[n] will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.10.5.14 PUBLISH_SEQEND[n] (n=0..1)

Address offset: 0x190 + (n × 0x4)

Publish configuration for event SEQEND[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event SEQEND[n] will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.10.5.15 PUBLISH_PWMPERIODEND

Address offset: 0x198

Publish configuration for event PWMPERIODEND

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event PWMPERIODEND will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.10.5.16 PUBLISH_LOOPSDONE

Address offset: 0x19C

Publish configuration for event LOOPSDONE

This event triggers after the last SEQ[1] completion of the loop, and only if looping was enabled (LOOP > 0) when the sequence playback was started.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event LOOPSDONE will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.10.5.17 SHORTS

Address offset: 0x200

Shortcuts between local events and tasks

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	SEQEND0_STOP			Shortcut between event SEQEND[0] and task STOP
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
B	RW	SEQEND1_STOP			Shortcut between event SEQEND[1] and task STOP
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
C	RW	LOOPSDONE_SEQSTART0			Shortcut between event LOOPSDONE and task SEQSTART[0]
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
D	RW	LOOPSDONE_SEQSTART1			Shortcut between event LOOPSDONE and task SEQSTART[1]
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
E	RW	LOOPSDONE_STOP			Shortcut between event LOOPSDONE and task STOP
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut

6.10.5.18 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
B	RW	STOPPED			Enable or disable interrupt for event STOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Disabled	0	Disable
			Enabled	1	Enable
C-D	RW	SEQSTARTED[i] (i=0..1)			Enable or disable interrupt for event SEQSTARTED[i]
			Disabled	0	Disable
			Enabled	1	Enable
E-F	RW	SEQEND[i] (i=0..1)			Enable or disable interrupt for event SEQEND[i]
			Disabled	0	Disable
			Enabled	1	Enable
G	RW	PWMPERIODEND			Enable or disable interrupt for event PWMPERIODEND
			Disabled	0	Disable
			Enabled	1	Enable
H	RW	LOOPSDONE			Enable or disable interrupt for event LOOPSDONE This event triggers after the last SEQ[1] completion of the loop, and only if looping was enabled (LOOP > 0) when the sequence playback was started.
			Disabled	0	Disable
			Enabled	1	Enable

6.10.5.19 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
B	RW	STOPPED			Write '1' to enable interrupt for event STOPPED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C-D	RW	SEQSTARTED[i] (i=0..1)			Write '1' to enable interrupt for event SEQSTARTED[i]
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E-F	RW	SEQEND[i] (i=0..1)			Write '1' to enable interrupt for event SEQEND[i]
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
G	RW	PWMPERIODEND			Write '1' to enable interrupt for event PWMPERIODEND
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
H	RW	LOOPSDONE			Write '1' to enable interrupt for event LOOPSDONE This event triggers after the last SEQ[1] completion of the loop, and only if looping was enabled (LOOP > 0) when the sequence playback was started.
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.10.5.20 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																												H	G	F	E	D	C	B	
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
B	RW	STOPPED																																	
			Clear	1																															
			Disabled	0																															
			Enabled	1																															
C-D	RW	SEQSTARTED[i] (i=0..1)																																	
			Clear	1																															
			Disabled	0																															
			Enabled	1																															
E-F	RW	SEQEND[i] (i=0..1)																																	
			Clear	1																															
			Disabled	0																															
			Enabled	1																															
G	RW	PWMPERIODEND																																	
			Clear	1																															
			Disabled	0																															
			Enabled	1																															
H	RW	LOOPSDONE																																	
			Clear	1																															
			Disabled	0																															
			Enabled	1																															

Write '1' to disable interrupt for event STOPPED

Write '1' to disable interrupt for event SEQSTARTED[i]

Write '1' to disable interrupt for event SEQEND[i]

Write '1' to disable interrupt for event PWMPERIODEND

Write '1' to disable interrupt for event LOOPSDONE

This event triggers after the last SEQ[1] completion of the loop, and only if looping was enabled (LOOP > 0) when the sequence playback was started.

6.10.5.21 ENABLE

Address offset: 0x500

PWM module enable register

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ENABLE																																	
			Disabled	0																															
			Enabled	1																															

Enable or disable PWM module

6.10.5.22 MODE

Address offset: 0x504

Selects operating mode of the wave counter

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	UPDOWN			Selects up mode or up-and-down mode for the counter
			Up	0	Up counter, edge-aligned PWM duty cycle
			UpAndDown	1	Up and down counter, center-aligned PWM duty cycle

6.10.5.23 COUNTERTOP

Address offset: 0x508

Value up to which the pulse generator counter counts

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A
Reset 0x000003FF				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	COUNTERTOP		[3..32767]	Value up to which the pulse generator counter counts. This register is ignored when DECODER.MODE=WaveForm and only values from RAM are used.

6.10.5.24 PRESCALER

Address offset: 0x50C

Configuration for PWM_CLK

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PRESCALER			Prescaler of PWM_CLK
			DIV_1	0	Divide by 1 (16 MHz)
			DIV_2	1	Divide by 2 (8 MHz)
			DIV_4	2	Divide by 4 (4 MHz)
			DIV_8	3	Divide by 8 (2 MHz)
			DIV_16	4	Divide by 16 (1 MHz)
			DIV_32	5	Divide by 32 (500 kHz)
			DIV_64	6	Divide by 64 (250 kHz)
			DIV_128	7	Divide by 128 (125 kHz)

6.10.5.25 DECODER

Address offset: 0x510

Configuration of the decoder

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	LOAD			How a sequence is read from RAM and spread to the compare register
			Common	0	1st half word (16-bit) used in all PWM channels 0..3
			Grouped	1	1st half word (16-bit) used in channel 0..1; 2nd word in channel 2..3
			Individual	2	1st half word (16-bit) in ch.0; 2nd in ch.1; ...; 4th in ch.3
			WaveForm	3	1st half word (16-bit) in ch.0; 2nd in ch.1; ...; 4th in COUNTERTOP
B	RW	MODE			Selects source for advancing the active sequence
			RefreshCount	0	SEQ[n].REFRESH is used to determine loading internal compare registers
			NextStep	1	NEXTSTEP task causes a new value to be loaded to internal compare registers

6.10.5.26 LOOP

Address offset: 0x514

Number of playbacks of a loop

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CNT			Number of playbacks of pattern cycles
			Disabled	0	Looping disabled (stop at the end of the sequence)

6.10.5.27 SEQ[n].PTR (n=0..1)

Address offset: 0x520 + (n × 0x20)

Beginning address in RAM of this sequence

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Beginning address in RAM of this sequence

Note: See the memory chapter for details about which memories are available for EasyDMA.

6.10.5.28 SEQ[n].CNT (n=0..1)

Address offset: 0x524 + (n × 0x20)

Number of values (duty cycles) in this sequence

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CNT			Number of values (duty cycles) in this sequence
			Disabled	0	Sequence is disabled, and shall not be started as it is empty

6.10.5.29 SEQ[n].REFRESH (n=0..1)

Address offset: 0x528 + (n × 0x20)

Number of additional PWM periods between samples loaded into compare register

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID												A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value								Description																							
A	RW	CNT										Number of additional PWM periods between samples loaded into compare register (load every REFRESH.CNT+1 PWM periods)																							
			Continuous	0								Update every PWM period																							

6.10.5.30 SEQ[n].ENDDELAY (n=0..1)

Address offset: 0x52C + (n × 0x20)

Time added after the sequence

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID												A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value								Description																							
A	RW	CNT										Time added after the sequence in PWM periods																							

6.10.5.31 PSEL.OUT[n] (n=0..3)

Address offset: 0x560 + (n × 0x4)

Output pin select for PWM channel n

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				B																													A	A	A	A	A
Reset 0xFFFFFFFF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value								Description																							
A	RW	PIN		[0..31]								Pin number																							
B	RW	CONNECT										Connection																							
			Disconnected	1								Disconnect																							
			Connected	0								Connect																							

6.11 RTC — Real-time counter

The real-time counter (RTC) module provides a generic, low-power timer on the low frequency clock source (LFCLK).

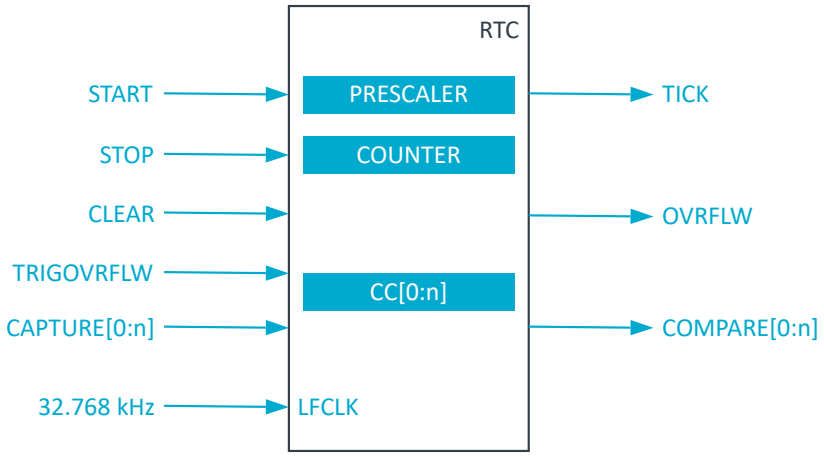

Figure 56: RTC block diagram

The RTC module features a 24-bit COUNTER, a 12-bit (1/X) prescaler, compare registers, and a tick event generator.

6.11.1 Clock source

The RTC will run off the LFCLK.

When started, the RTC will automatically request the LFCLK source with RC oscillator if the LFCLK is not already running.

See CLOCK — Clock control on page 74 for more information about clock sources.

6.11.2 Resolution versus overflow and the prescaler

The relationship between the prescaler, counter resolution, and overflow is summarized in the following table.

Prescaler	Counter resolution	Overflow
0	30.517 µs	512 seconds
2^8-1	7812.5 µs	131072 seconds
2^{12}-1	125 ms	582.542 hours

Table 29: RTC resolution versus overflow

The counter increment frequency is given by the following equation:

$$f_{RTC}\ [kHz] = 32.768\ /\ (PRESCALER + 1\ )$$

The PRESCALER register can only be written when the RTC is stopped.

The prescaler is restarted on tasks START, CLEAR and TRIGOVRFLW. That is, the prescaler value is latched to an internal register (<<PRESC>>) on these tasks.

Examples:

1. Desired COUNTER frequency 100 Hz (10 ms counter period)

   PRESCALER = round(32.768 kHz / 100 Hz) - 1 = 327

   f_{RTC} = 99.9 Hz

   10009.576 µs counter period

2. Desired COUNTER frequency 8 Hz (125 ms counter period)

PRESCALER = round(32.768 kHz / 8 Hz) – 1 = 4095

f_{RTC} = 8 Hz

125 ms counter period

6.11.3 Counter register

The internal <<COUNTER>> register increments on LFCLK when the internal PRESCALER register (<<PRESC>>) is 0x00. <<PRESC>> is reloaded from the PRESCALER register. If enabled, the TICK event occurs on each increment of the COUNTER.

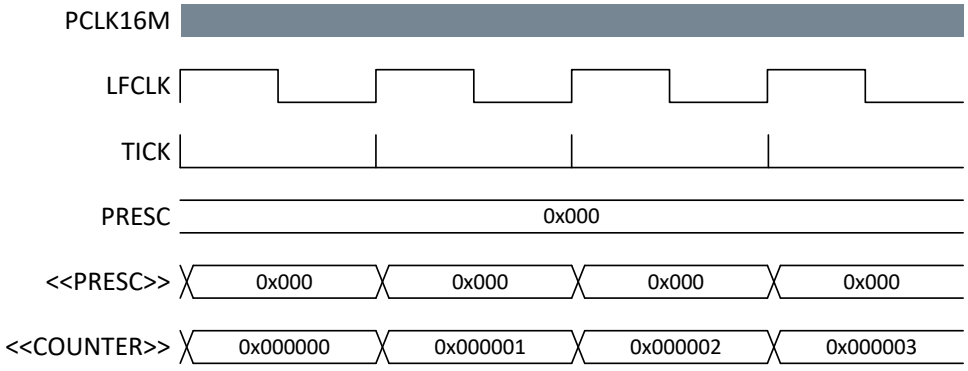

Figure 57: Timing diagram - COUNTER_PRESCALER_0

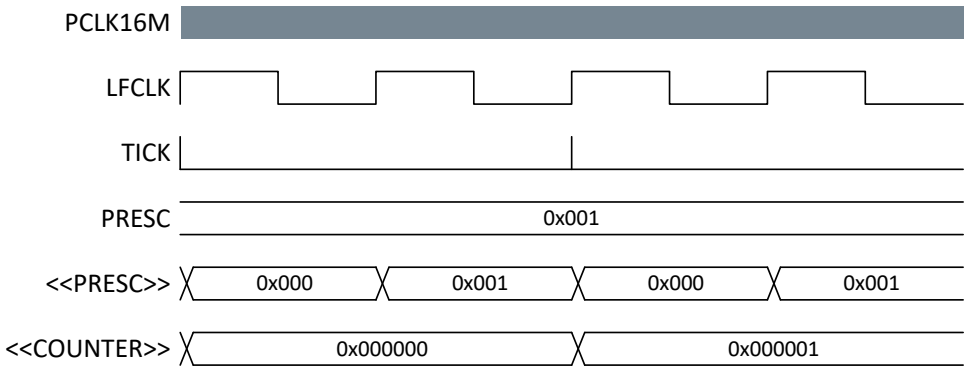

Figure 58: Timing diagram - COUNTER_PRESCALER_1

6.11.3.1 Reading the counter register

To read the COUNTER register, the internal <<COUNTER>> value is sampled.

To ensure that the <<COUNTER>> is safely sampled (considering that an LFCLK transition may occur during a read), the CPU and core memory bus are halted for PCLK16M cycles. In addition, the read takes the CPU two PCLK16M cycles, resulting in the COUNTER register read taking maximum six PCLK16M clock cycles.

6.11.4 Overflow

An OVRFLW event is generated on COUNTER register overflow (overflowing from 0xFFFFFF to 0).

The TRIGOVRFLW task will set the COUNTER value to 0xFFFFF0, to allow software test of the overflow condition.

Note: The OVRFLW event is disabled by default.

6.11.5 Tick event

The TICK event enables low-power tickless RTOS implementation, as it optionally provides a regular interrupt source for an RTOS with no need for use of the ARM SysTick feature.

Using the TICK event, rather than the SysTick, allows the CPU to be powered down while keeping RTOS scheduling active.

Note: The TICK event is disabled by default.

6.11.6 Event control

To optimize the RTC power consumption, events in the RTC can be individually disabled to prevent PCLK16M and HFCLK from being requested when those events are triggered. This is managed using the EVTEN register.

This means that the RTC implements a slightly different task and event system compared to the standard system described in Peripheral interface on page 15. The RTC task and event system is illustrated in the following figure.

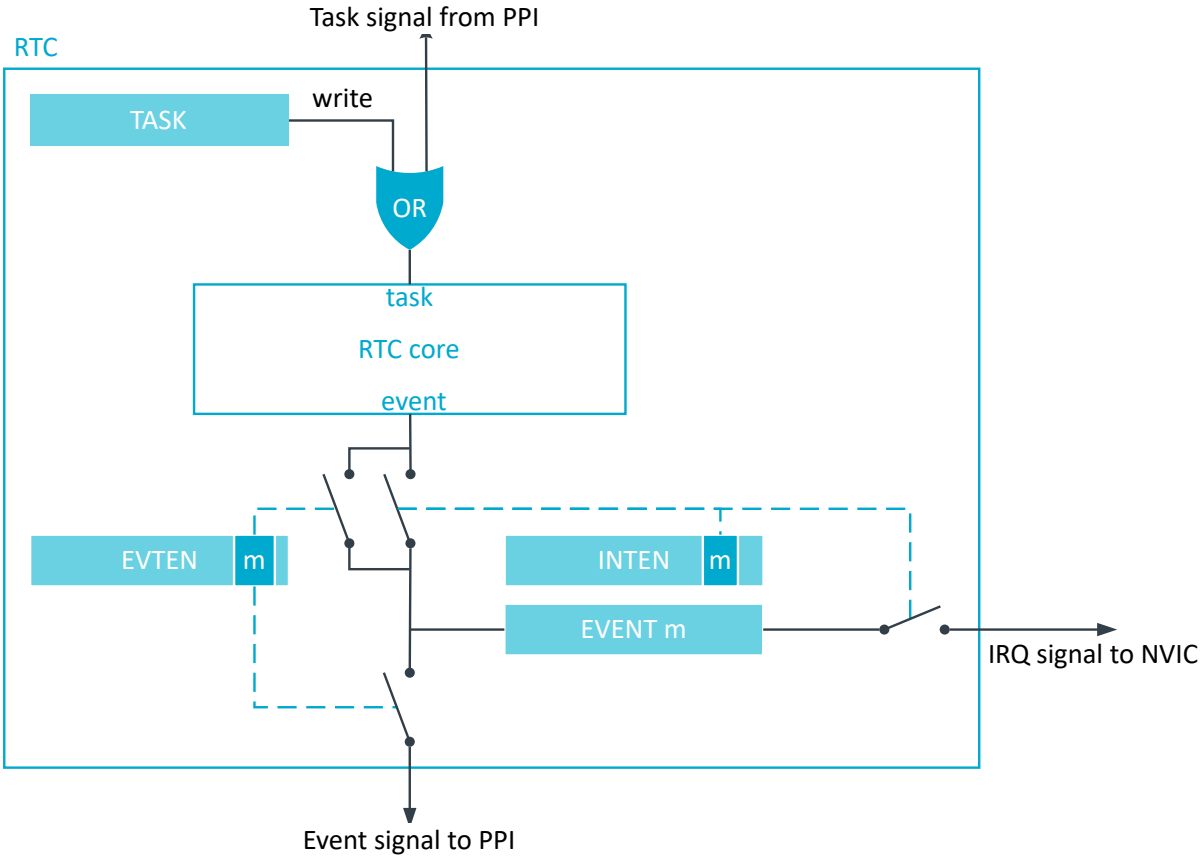

Figure 59: Tasks, events, and interrupts in the RTC

6.11.7 Compare

The RTC implements one COMPARE event for every available compare register.

When the COUNTER is incremented and then becomes equal to the value specified in the register CC[n], the corresponding compare event COMPARE[n] is generated.

When writing a CC[n] register, the RTC COMPARE event exhibits several behaviors. See the following figures for more information.

If a CC value is 0 when a CLEAR task is set, this will not trigger a COMPARE event.

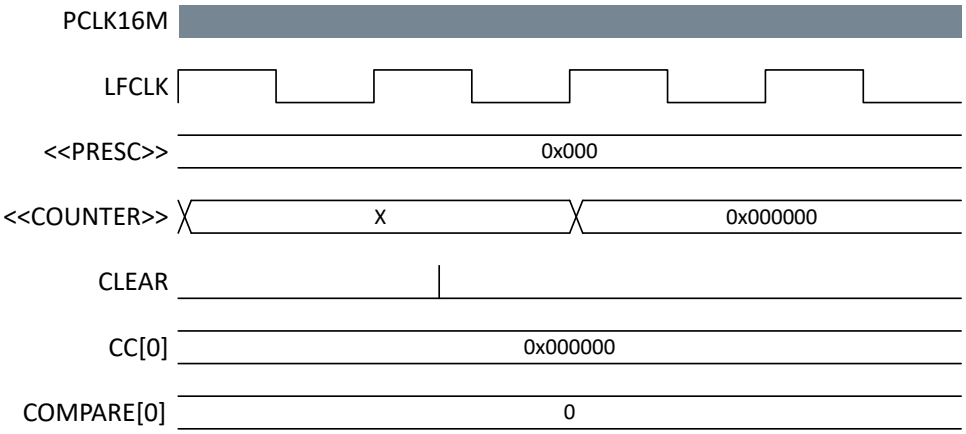

Figure 60: Timing diagram - COMPARE_CLEAR

If a CC value is N and the COUNTER value is N when the START task is set, this will not trigger a COMPARE event.

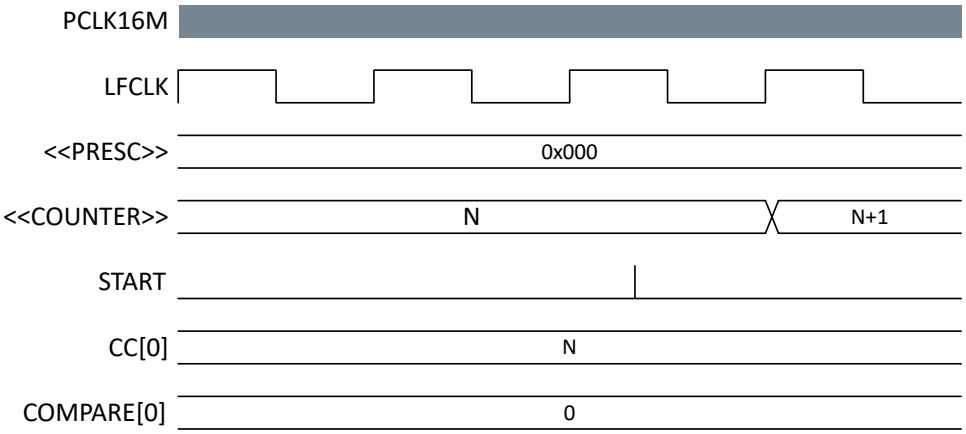

Figure 61: Timing diagram - COMPARE_START

A COMPARE event occurs when a CC value is N, and the COUNTER value transitions from N-1 to N.

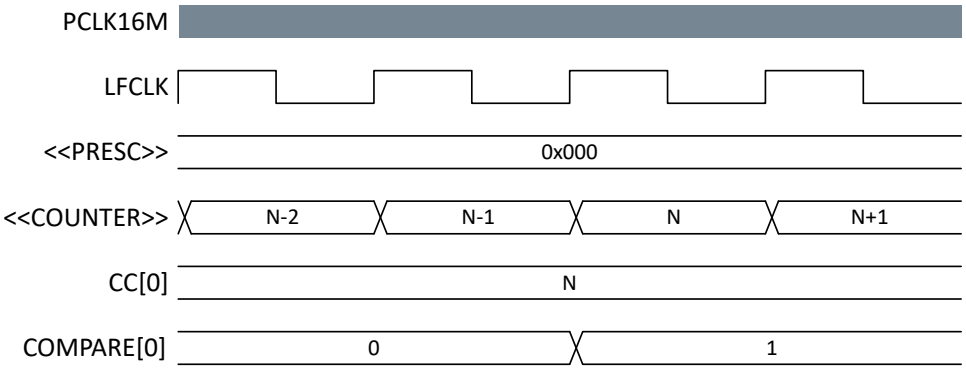

Figure 62: Timing diagram - COMPARE

If the COUNTER value is N, writing N+2 to a CC register is guaranteed to trigger a COMPARE event at N+2.

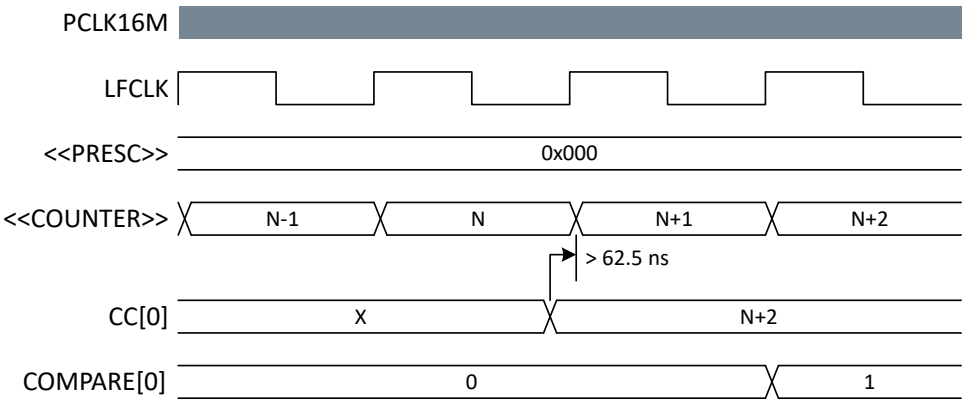

Figure 63: Timing diagram - COMPARE_N+2

If the COUNTER value is N, writing N or N+1 to a CC register may not trigger a COMPARE event.

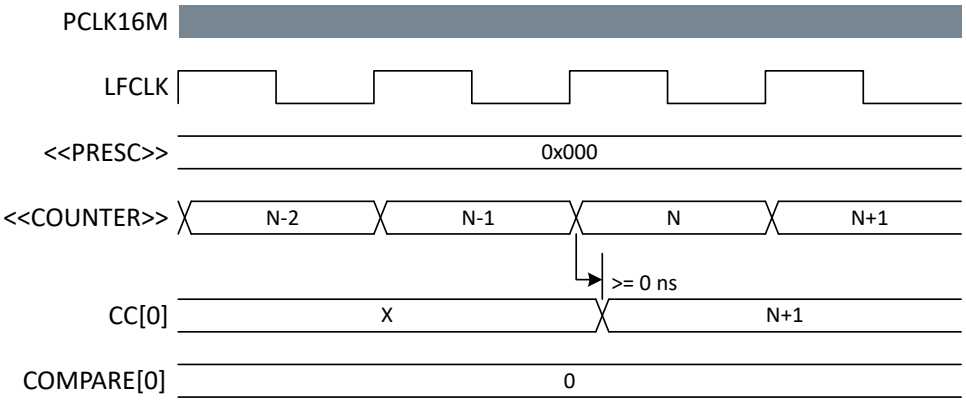

Figure 64: Timing diagram - COMPARE_N+1

If the COUNTER value is N, and the current CC value is N+1 or N+2 when a new CC value is written, a match may trigger on the previous CC value before the new value takes effect. If the current CC value is greater than N+2 when the new value is written, there will be no event due to the old value.

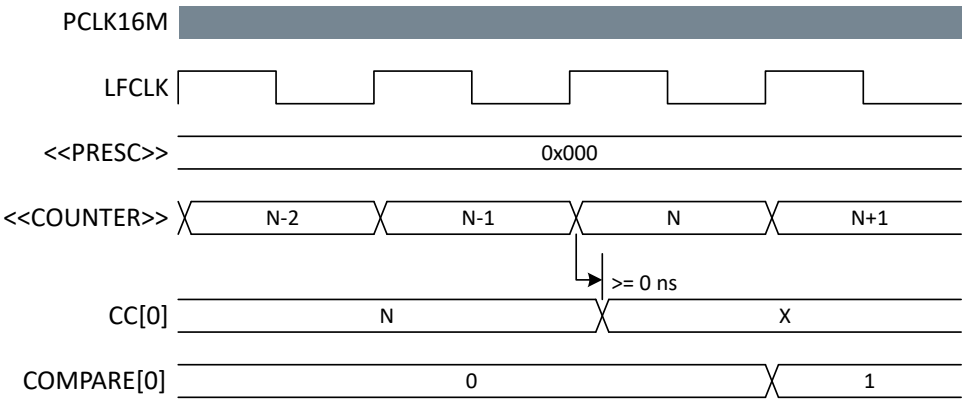

Figure 65: Timing diagram - COMPARE_N-1

6.11.8 Task and event jitter/delay

Jitter or delay in the RTC is due to the peripheral clock being a low frequency clock (LFCLK), which is not synchronous to the faster PCLK16M.

Registers in the peripheral interface that are part of the PCLK16M domain, have a set of mirrored registers in the LFCLK domain. For example, the COUNTER value accessible from the CPU is in the PCLK16M domain and is latched on a read from an internal COUNTER register in the LFCLK domain. The COUNTER register

is modified each time the RTC ticks. The registers are synchronised between the two clock domains (PCLK16M and LFCLK).

CLEAR and STOP (and TRIGOVRFLW, which is not shown) will be delayed as long as it takes for the peripheral to clock a falling edge and a rising edge of the LFCLK. This is between 15.2585 µs and 45.7755 µs – rounded to 15 µs and 46 µs for the remainder of the section.

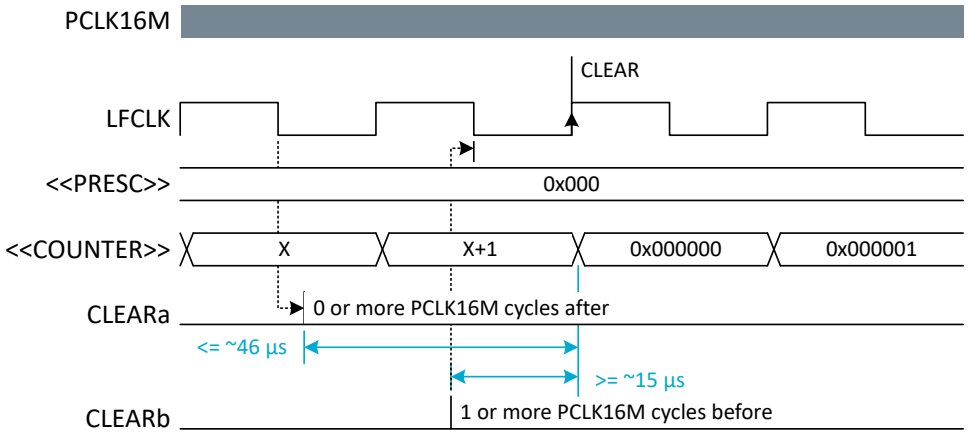

Figure 66: Timing diagram - DELAY_CLEAR

When a STOP task is triggered, the PCLK16M domain will immediately prevent the generation of any EVENTS from the RTC. However, as seen in the following figure, the COUNTER value can still increment one final time.

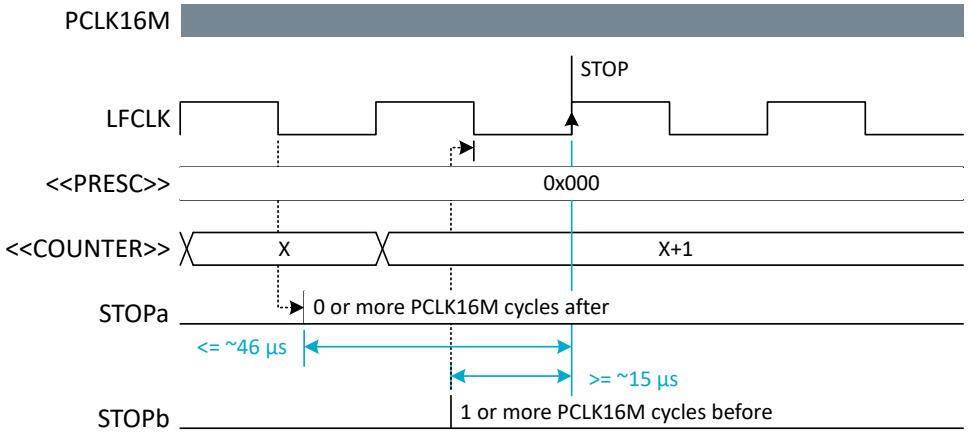

Figure 67: Timing diagram - DELAY_STOP

The START task will start the RTC. Assuming that the LFCLK was previously running and stable, the first increment of COUNTER (and instance of TICK event) will be typically after 30.5 µs +/-15 µs. Additional delay will occur if the RTC is started before the LFCLK is running, see CLOCK — Clock control on page 74 for LFLK startup times. The software should therefore wait for the first TICK if it has to make sure that the RTC is running. Sending a TRIGOVRFLW task sets the COUNTER to a value close to overflow. However, since the update of COUNTER relies on a stable LFCLK, sending this task while LFCLK is not running will also add additional delay as previously described. The figures show the smallest and largest delays on the START task, appearing as a +/-15 µs jitter on the first COUNTER increment.

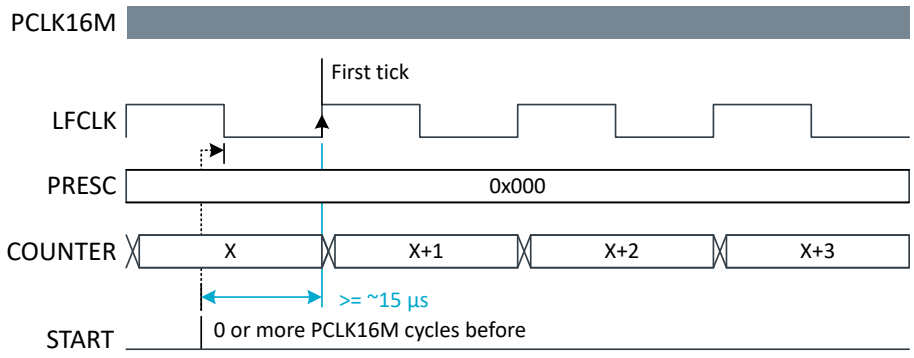

Figure 68: Timing diagram - JITTER_START-

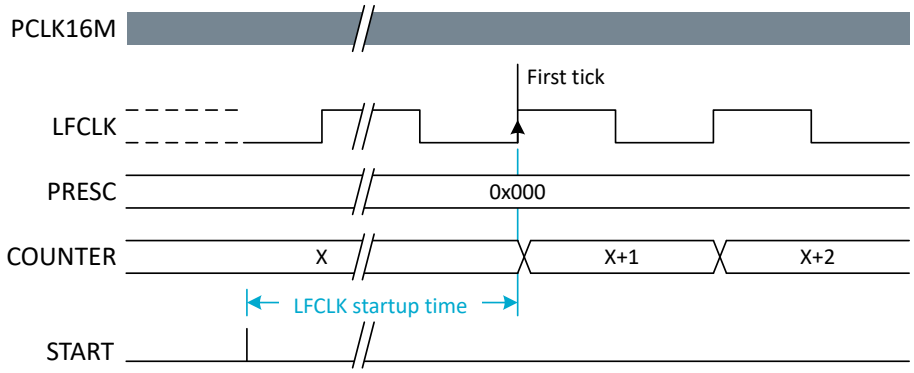

Figure 69: Timing diagram - JITTER_START+

The following tables summarize jitter introduced for tasks and events. Any 32.768 kHz clock jitter will come in addition to these numbers.

Task	Delay
CLEAR, START, STOP, TRIGOVRFLOW	+15 to 46 µs

Table 30: RTC jitter magnitudes on tasks

Operation/Function	Jitter
START to COUNTER increment	± 15 µs
COMPARE to COMPARE [18]	± 62.5 ns

Table 31: RTC jitter magnitudes on events

6.11.9 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
RTC0 : S	0x50014000	US	NS	NA	No	Real time counter 0
RTC0 : NS	0x40014000					
RTC1 : S	0x50015000	US	NS	NA	No	Real time counter 1
RTC1 : NS	0x40015000					

[18] Assumes RTC runs continuously between these events.

Register overview

Register	Offset	TZ	Description
TASKS_START	0x000		Start RTC counter
TASKS_STOP	0x004		Stop RTC counter
TASKS_CLEAR	0x008		Clear RTC counter
TASKS_TRIGOVRFLW	0x00C		Set counter to 0xFFFFF0
SUBSCRIBE_START	0x080		Subscribe configuration for task START
SUBSCRIBE_STOP	0x084		Subscribe configuration for task STOP
SUBSCRIBE_CLEAR	0x088		Subscribe configuration for task CLEAR
SUBSCRIBE_TRIGOVRFLW	0x08C		Subscribe configuration for task TRIGOVRFLW
EVENTS_TICK	0x100		Event on counter increment
EVENTS_OVRFLW	0x104		Event on counter overflow
EVENTS_COMPARE[n]	0x140		Compare event on CC[n] match
PUBLISH_TICK	0x180		Publish configuration for event TICK
PUBLISH_OVRFLW	0x184		Publish configuration for event OVRFLW
PUBLISH_COMPARE[n]	0x1C0		Publish configuration for event COMPARE[n]
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
EVTEN	0x340		Enable or disable event routing
EVTENSET	0x344		Enable event routing
EVTENCLR	0x348		Disable event routing
COUNTER	0x504		Current counter value
PRESCALER	0x508		12-bit prescaler for counter frequency (32768/(PRESCALER+1)). Must be written when RTC is stopped.
CC[n]	0x540		Compare register n

6.11.9.1 TASKS_START

Address offset: 0x000

Start RTC counter

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_START			Start RTC counter
			Trigger	1	Trigger task

6.11.9.2 TASKS_STOP

Address offset: 0x004

Stop RTC counter

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stop RTC counter
			Trigger	1	Trigger task

6.11.9.3 TASKS_CLEAR

Address offset: 0x008

Clear RTC counter

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	TASKS_CLEAR																																	
			Trigger	1																															

6.11.9.4 TASKS_TRIGOVRFLW

Address offset: 0x00C

Set counter to 0xFFFFF0

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	TASKS_TRIGOVRFLW																																	
			Trigger	1																															

6.11.9.5 SUBSCRIBE_START

Address offset: 0x080

Subscribe configuration for task START

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				B																								A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	CHIDX		[0..255]																															
B	RW	EN																																	
			Disabled	0																															
			Enabled	1																															

6.11.9.6 SUBSCRIBE_STOP

Address offset: 0x084

Subscribe configuration for task STOP

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				B																								A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	CHIDX		[0..255]																															
B	RW	EN																																	
			Disabled	0																															
			Enabled	1																															

6.11.9.7 SUBSCRIBE_CLEAR

Address offset: 0x088

Subscribe configuration for task CLEAR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task CLEAR will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.11.9.8 SUBSCRIBE_TRIGOVRFLW

Address offset: 0x08C

Subscribe configuration for task TRIGOVRFLW

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task TRIGOVRFLW will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.11.9.9 EVENTS_TICK

Address offset: 0x100

Event on counter increment

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_TICK			Event on counter increment
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.11.9.10 EVENTS_OVRFLW

Address offset: 0x104

Event on counter overflow

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_OVRFLW			Event on counter overflow
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.11.9.11 EVENTS_COMPARE[n] (n=0..3)

Address offset: 0x140 + (n × 0x4)

Compare event on CC[n] match

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_COMPARE			Compare event on CC[n] match
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.11.9.12 PUBLISH_TICK

Address offset: 0x180

Publish configuration for event TICK

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TICK will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.11.9.13 PUBLISH_OVRFLW

Address offset: 0x184

Publish configuration for event OVRFLW

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event OVRFLW will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.11.9.14 PUBLISH_COMPARE[n] (n=0..3)

Address offset: 0x1C0 + (n × 0x4)

Publish configuration for event COMPARE[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event COMPARE[n] will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.11.9.15 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TICK			Write '1' to enable interrupt for event TICK
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	OVRFLW			Write '1' to enable interrupt for event OVRFLW
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C-F	RW	COMPARE[i] (i=0..3)			Write '1' to enable interrupt for event COMPARE[i]
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.11.9.16 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TICK			Write '1' to disable interrupt for event TICK
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	OVRFLW			Write '1' to disable interrupt for event OVRFLW
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C-F	RW	COMPARE[i] (i=0..3)			Write '1' to disable interrupt for event COMPARE[i]
			Clear	1	Disable

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.11.9.17 EVTEN

Address offset: 0x340

Enable or disable event routing

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TICK			Enable or disable event routing for event TICK
			Disabled	0	Disable
			Enabled	1	Enable
B	RW	OVRFLW			Enable or disable event routing for event OVRFLW
			Disabled	0	Disable
			Enabled	1	Enable
C-F	RW	COMPARE[i] (i=0..3)			Enable or disable event routing for event COMPARE[i]
			Disabled	0	Disable
			Enabled	1	Enable

6.11.9.18 EVTENSET

Address offset: 0x344

Enable event routing

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TICK			Write '1' to enable event routing for event TICK
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
			Set	1	Enable
B	RW	OVRFLW			Write '1' to enable event routing for event OVRFLW
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
			Set	1	Enable
C-F	RW	COMPARE[i] (i=0..3)			Write '1' to enable event routing for event COMPARE[i]
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
			Set	1	Enable

6.11.9.19 EVTENCLR

Address offset: 0x348

Disable event routing

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TICK			Write '1' to disable event routing for event TICK
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
			Clear	1	Disable
B	RW	OVRFLW			Write '1' to disable event routing for event OVRFLW
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
			Clear	1	Disable
C-F	RW	COMPARE[i] (i=0..3)			Write '1' to disable event routing for event COMPARE[i]
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
			Clear	1	Disable

6.11.9.20 COUNTER

Address offset: 0x504

Current counter value

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	COUNTER			Counter value

6.11.9.21 PRESCALER

Address offset: 0x508

12-bit prescaler for counter frequency (32768/(PRESCALER+1)). Must be written when RTC is stopped.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PRESCALER			Prescaler value

6.11.9.22 CC[n] (n=0..3)

Address offset: 0x540 + (n × 0x4)

Compare register n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	COMPARE			Compare value

6.12 SAADC — Successive approximation analog-to-digital converter

The SAADC is a differential successive approximation register (SAR) analog-to-digital converter.

Listed here are the main features of SAADC:

- 8/10/12-bit resolution, 14-bit resolution with oversampling
- Multiple analog inputs:
  - AIN0 to AIN7 pins
  - VDD_GPIO pin
- Up to eight input channels:
  - One channel per single-ended input and two channels per differential input
  - Scan mode can be configured with both single-ended channels and differential channels
  - Each channel can be configured to select any of the above analog inputs
- Full scale input range (0 to VDD_GPIO)
- Sampling triggered via a task from software or a PPI channel for full flexibility on sample frequency source from low-power 32.768 kHz RTC or more accurate 1/16 MHz timers
- One-shot conversion mode to sample a single channel
- Scan mode to sample a series of channels in sequence with configurable sample delay
- Support for direct sample transfer to RAM using EasyDMA
- Interrupts on single sample and full buffer events
- Samples stored as 16-bit two's complement values for differential and single-ended sampling
- Continuous sampling without the need of an external timer
- Internal resistor string
- On-the-fly limit checking

6.12.1 Overview

The ADC supports up to eight external analog input channels. It can be operated in One-shot mode with sampling under software control, or Continuous mode with a programmable sampling rate.

The analog inputs can be configured as eight single-ended inputs, four differential inputs or a combination of these. Each channel can be configured to select:

- `AIN0` to `AIN7` pins
- `VDD_GPIO` pin

Channels can be sampled individually in one-shot or continuous sampling modes, or, using scan mode, multiple channels can be sampled in sequence. Channels can also be oversampled to improve noise performance.

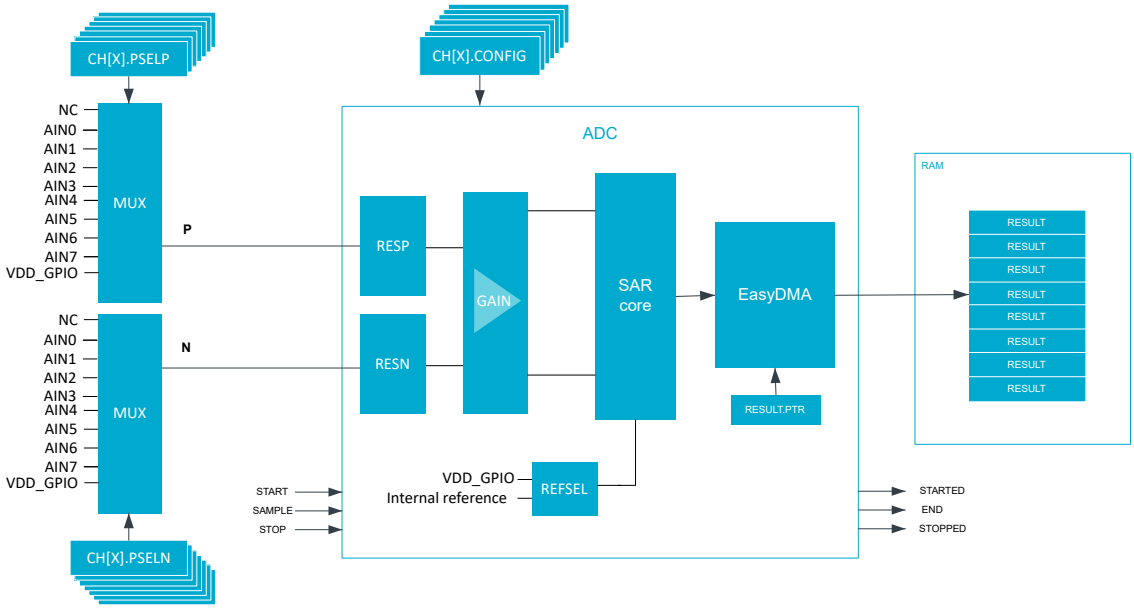

Figure 70: Simplified ADC block diagram

Internally, the ADC is always a differential analog-to-digital converter, but by default it is configured with single-ended input in the MODE field of the CH[n].CONFIG register. In single-ended mode, the negative input will be shorted to ground internally.

The assumption in single-ended mode is that the internal ground of the ADC is the same as the external ground that the measured voltage is referred to. The ADC is thus sensitive to ground bounce on the PCB in single-ended mode. If this is a concern, we recommend using differential measurement.

6.12.2 Digital output

The output result of the ADC depends on the settings in the CH[n].CONFIG and RESOLUTION registers as follows:

$$RESULT = [V(P) - V(N)] * GAIN/REFERENCE * 2^{(RESOLUTION - m)}$$

where

V(P)

is the voltage at input P

V(N)

is the voltage at input N

GAIN

is the selected gain setting

m

is the mode setting. Use m=0 if CONFIG.MODE=SE, or m=1 if CONFIG.MODE=Diff

REFERENCE

is the selected reference voltage

The result generated by the ADC will deviate from the expected due DC errors like offset, gain, differential non-linearity (DNL), and integral non-linearity (INL). See Electrical specification for details on these parameters. The result can also vary due to AC errors like non-linearities in the GAIN block, settling errors

due to high source impedance and sampling jitter. For battery measurement, the DC errors are most noticeable.

The ADC has a wide selection of gains controlled in the GAIN field of the CH[n].CONFIG register. If CH[n].CONFIG.REFSEL=0, the input range of the ADC core is nominally ±0.6 V differential and the input must be scaled accordingly.

Calibration

The ADC has a temperature dependent offset. If the ADC is to operate over a large temperature range, we recommend running TASKS_CALIBRATEOFFSET at regular intervals.

The DONE, RESULTDONE, and CALIBRATEDONE events are fired when the calibration has been completed.

The offset calibration must be run when the SAADC is stopped. If the TASKS_CALIBRATEOFFSET is run when the SAADC is started, then RAM may contain values not related to the ADC input.

6.12.3 Analog inputs and channels

Up to eight analog input channels, CH[n](n=0..7), can be configured.

Any one of the available channels can be enabled for the ADC to operate in one-shot mode. If more than one CH[n] is configured, the ADC enters scan mode.

An analog input is selected as a positive converter input if CH[n].PSELP is set, setting CH[n].PSELP also enables the particular channel.

An analog input is selected as a negative converter input if CH[n].PSELN is set. The CH[n].PSELN register will have no effect unless differential mode is enabled, see MODE field in CH[n].CONFIG register.

If more than one of the CH[n].PSELP registers is set, the device enters scan mode. Input selections in scan mode are controlled by the CH[n].PSELP and CH[n].PSELN registers, where CH[n].PSELN is only used if the particular scan channel is specified as differential, see MODE field in CH[n].CONFIG register.

6.12.4 Operation modes

The ADC input configuration supports one-shot mode, continuous mode, and scan mode.

Note: Scan mode and oversampling cannot be combined.

The ADC indicates a single ongoing conversion via the register STATUS on page 286. During scan mode, oversampling, or continuous modes, more than a single conversion take place in the ADC. As consequence, the value reflected in STATUS register will toggle at the end of each single conversion.

6.12.4.1 One-shot mode

One-shot operation is configured by enabling only one of the available channels defined by CH[n].PSELP, CH[n].PSELN, and CH[n].CONFIG registers.

Upon a SAMPLE task, the ADC starts to sample the input voltage. The CH[n].CONFIG.TACQ controls the acquisition time.

A DONE event signals that one sample has been taken.

In this mode, the RESULTDONE event has the same meaning as DONE when no oversampling takes place. Note that both events may occur before the actual value has been transferred into RAM by EasyDMA. For more information, see EasyDMA on page 269.

6.12.4.2 Continuous mode

Continuous sampling can be achieved by using the internal timer in the ADC, or triggering the SAMPLE task from one of the general purpose timers through the PPI system.

Care shall be taken to ensure that the sample rate fulfils the following criteria, depending on how many channels are active:

$$f_{SAMPLE} < 1/(t_{ACQ} + t_{conv})$$

The SAMPLERATE register can be used as a local timer instead of triggering individual SAMPLE tasks. When SAMPLERATE.MODE is set to Timers, it is sufficient to trigger SAMPLE task only once in order to start the SAADC and triggering the STOP task will stop sampling. The SAMPLERATE.CC field controls the sample rate.

The SAMPLERATE timer mode cannot be combined with SCAN mode, and only one channel can be enabled in this mode.

A DONE event signals that one sample has been taken.

In this mode, the RESULTDONE event has the same meaning as DONE when no oversampling takes place. Note that both events may occur before the actual value has been transferred into RAM by EasyDMA.

6.12.4.3 Oversampling

An accumulator in the ADC can be used to average noise on the analog input. In general, oversampling improves the signal-to-noise ratio (SNR). However, oversampling does not improve the integral non-linearity (INL) nor the differential non-linearity (DNL).

Oversampling and scan should not be combined, since oversampling and scan will average over input channels.

The accumulator is controlled in the OVERSAMPLE register. The SAMPLE task must be set $2^{OVERSAMPLE}$ number of times before the result is written to RAM. This can be achieved by:

- Configuring a fixed sampling rate using the local timer or a general purpose timer and the PPI system to trigger a SAMPLE task
- Triggering SAMPLE $2^{OVERSAMPLE}$ times from software
- Enabling BURST mode

CH[n].CONFIG.BURST can be enabled to avoid setting SAMPLE task $2^{OVERSAMPLE}$ times. With BURST = 1 the ADC will sample the input $2^{OVERSAMPLE}$ times as fast as it can (actual timing: $<(t_{ACQ}+t_{CONV})\times 2^{OVERSAMPLE}$). Thus, for the user it will just appear like the conversion took a bit longer time, but other than that, it is similar to one-shot mode.

A DONE event signals that one sample has been taken.

In this mode, the RESULTDONE event signals that enough conversions have taken place for an oversampled result to get transferred into RAM. Note that both events may occur before the actual value has been transferred into RAM by EasyDMA.

6.12.4.4 Scan mode

A channel is considered enabled if CH[n].PSELP is set. If more than one channel, CH[n], is enabled, the ADC enters scan mode.

In scan mode, one SAMPLE task will trigger one conversion per enabled channel. The time it takes to sample all channels is:

$$Total\ time < Sum(CH[x].t_{ACQ}+t_{CONV}),\ x=0..enabled\ channels$$

A DONE event signals that one sample has been taken.

In this mode, the RESULTDONE event signals has the same meaning as DONE when no oversampling takes place. Note that both events may occur before the actual values have been transferred into RAM by EasyDMA.

The following figure shows an example of results placement in Data RAM, with an even RESULT.MAXCNT. In this example, channels 1, 2, and 5 are enabled, all others are disabled.

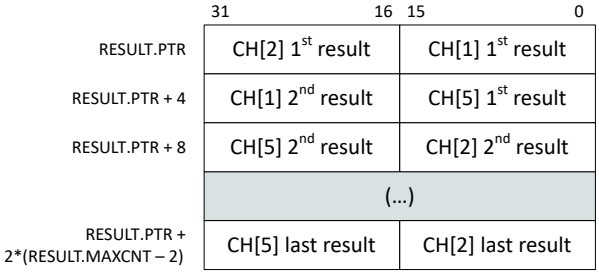

Figure 71: Example of RAM placement (even RESULT.MAXCNT), channels 1, 2 and 5 enabled

The following figure shows an example of results placement in Data RAM, with an odd RESULT.MAXCNT. In this example, channels 1, 2, and 5 are enabled, all others are disabled. The last 32-bit word is populated only with one 16-bit result.

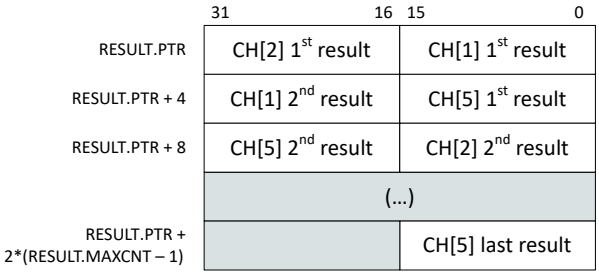

Figure 72: Example of RAM placement (odd RESULT.MAXCNT), channels 1, 2 and 5 enabled

6.12.5 EasyDMA

After configuring RESULT.PTR and RESULT.MAXCNT, the ADC resources are started by triggering the START task. The ADC is using EasyDMA to store results in a Result buffer in RAM.

The Result buffer is located at the address specified in the RESULT.PTR register. The RESULT.PTR register is double-buffered and it can be updated and prepared for the next START task immediately after the STARTED event is generated. The size of the Result buffer is specified in the RESULT.MAXCNT register and the ADC will generate an END event when it has filled up the Result buffer, see ADC on page 270. Results are stored in little-endian byte order in Data RAM. Every sample will be sign extended to 16 bit before stored in the Result buffer.

The ADC is stopped by triggering the STOP task. The STOP task will terminate an ongoing sampling. The ADC will generate a STOPPED event when it has stopped. If the ADC is already stopped when the STOP task is triggered, the STOPPED event will still be generated.

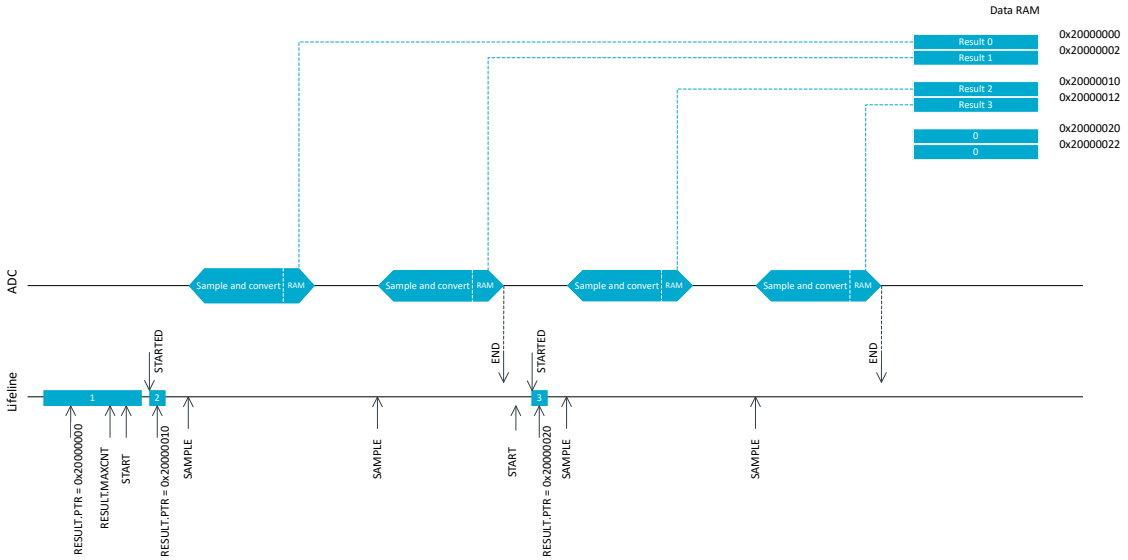

Figure 73: ADC

If the RESULT.PTR is not pointing to a RAM region accessible from the peripheral, an EasyDMA transfer may result in a HardFault and/or memory corruption. See Memory on page 21 for more information about the different memory regions.

The EasyDMA will have finished accessing the RAM when the END or STOPPED event has been generated.

The RESULT.AMOUNT register can be read following an END event or a STOPPED event to see how many results have been transferred to the Result buffer in RAM since the START task was triggered.

In scan mode, SAMPLE tasks can be triggered once the START task is triggered. The END event is generated when the number of samples transferred to memory reaches the value specified by RESULT.MAXCNT. After an END event, the START task needs to be triggered again before new samples can be taken. Also make sure that the size of the Result buffer is large enough to have space for minimum one result from each of the enabled channels, by specifying RESULT.MAXCNT >= number of channels enabled. For more information about the scan mode, see Scan mode on page 268.

6.12.6 Resistor ladder

The ADC has an internal resistor string for positive and negative input.

See Resistor ladder for positive input (negative input is equivalent, using RESN instead of RESP) on page 271. The resistors are controlled in the CH[n].CONFIG.RESP and CH[n].CONFIG.RESN registers.

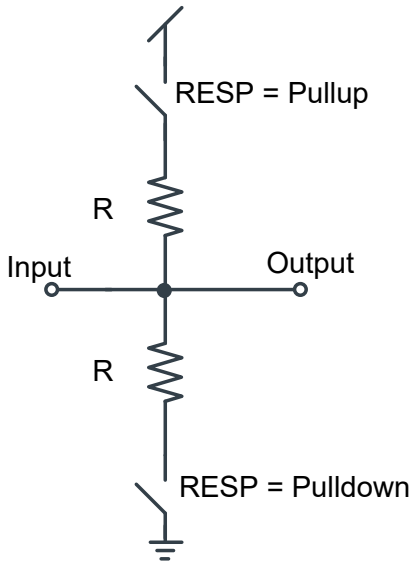

Figure 74: Resistor ladder for positive input (negative input is equivalent, using RESN instead of RESP)

6.12.7 Reference

The ADC can use two different references, controlled in the REFSEL field of the CH[n].CONFIG register.

These are:

- Internal reference
- VDD_GPIO as reference

The internal reference results in an input range of ±0.6 V on the ADC core. VDD_GPIO as reference results in an input range of ±VDD_GPIO/4 on the ADC core. The gain block can be used to change the effective input range of the ADC.

```
Input range = (± 0.6 V or ±VDD_GPIO/4)/Gain
```

For example, choosing VDD_GPIO as reference, single ended input (grounded negative input), and a gain of 1/4 the input range will be:

```
Input range = (VDD_GPIO/4)/(1/4) = VDD_GPIO
```

With internal reference, single ended input (grounded negative input), and a gain of 1/6 the input range will be:

```
Input range = (0.6 V)/(1/6) = 3.6 V
```

The AIN0-AIN7 inputs cannot exceed VDD_GPIO, or be lower than VSS.

6.12.8 Acquisition time

To sample the input voltage, the ADC connects a capacitor to the input.

For illustration, see Simplified ADC sample network on page 272. The acquisition time indicates how long the capacitor is connected, see TACQ field in CH[n].CONFIG register. The required acquisition time depends on the source (R_{source}) resistance. For high source resistance the acquisition time should be increased, see Acquisition time on page 272.

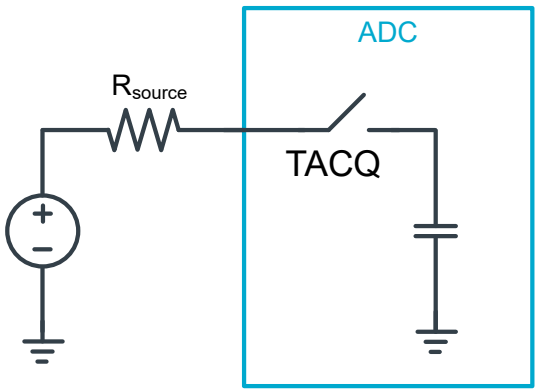

Figure 75: Simplified ADC sample network

TACQ [µs]	Maximum source resistance [kOhm]
3	10
5	40
10	100
15	200
20	400
40	800

Table 32: Acquisition time

6.12.9 Limits event monitoring

A channel can be event monitored by configuring limit register CH[n].LIMIT.

If the conversion result is higher than the defined high limit, or lower than the defined low limit, the appropriate event will get fired.

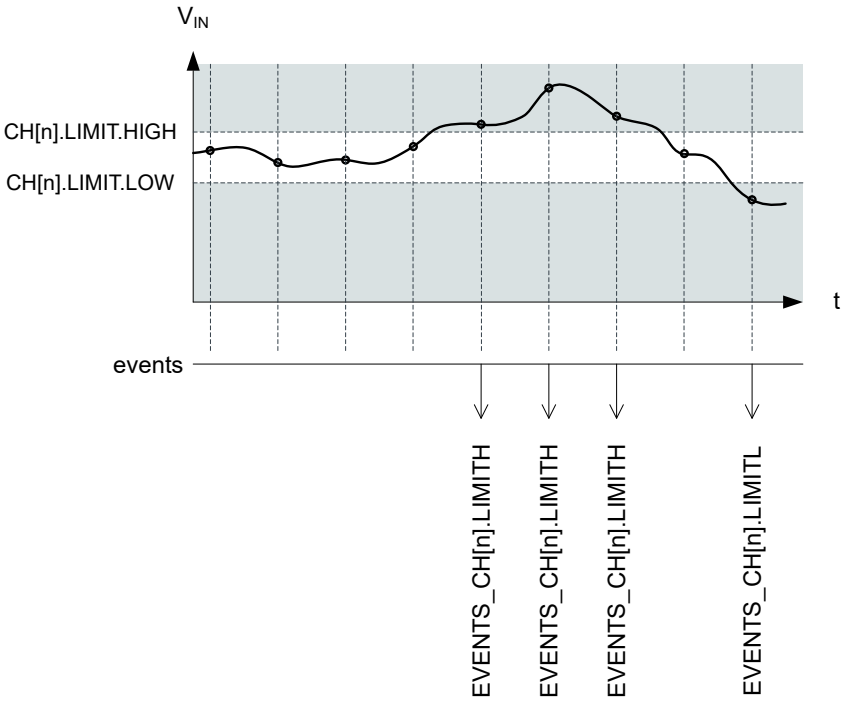

Figure 76: Example of limits monitoring on channel 'n'

Note that when setting the limits, CH[n].LIMIT.HIGH shall always be higher than or equal to CH[n].LIMIT.LOW . In other words, an event can be fired only when the input signal has been sampled outside of the defined limits. It is not possible to fire an event when the input signal is inside a defined range by swapping high and low limits.

The comparison to limits always takes place, there is no need to enable it. If comparison is not required on a channel, the software shall simply ignore the related events. In that situation, the value of the limits registers is irrelevant, so it does not matter if CH[n].LIMIT.LOW is lower than CH[n].LIMIT.HIGH or not.

6.12.10 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
SAADC : S	0x5000E000	US	NS	SA	No	Analog to digital converter
SAADC : NS	0x4000E000					

Register overview

Register	Offset	TZ	Description
TASKS_START	0x000		Start the ADC and prepare the result buffer in RAM
TASKS_SAMPLE	0x004		Take one ADC sample, if scan is enabled all channels are sampled
TASKS_STOP	0x008		Stop the ADC and terminate any on-going conversion
TASKS_CALIBRATEOFFSET	0x00C		Starts offset auto-calibration
SUBSCRIBE_START	0x080		Subscribe configuration for task START
SUBSCRIBE_SAMPLE	0x084		Subscribe configuration for task SAMPLE
SUBSCRIBE_STOP	0x088		Subscribe configuration for task STOP
SUBSCRIBE_CALIBRATEOFFSET	0x08C		Subscribe configuration for task CALIBRATEOFFSET
EVENTS_STARTED	0x100		The ADC has started
EVENTS_END	0x104		The ADC has filled up the Result buffer
EVENTS_DONE	0x108		A conversion task has been completed. Depending on the mode, multiple conversions might be needed for a result to be transferred to RAM.
EVENTS_RESULTDONE	0x10C		A result is ready to get transferred to RAM.
EVENTS_CALIBRATEDONE	0x110		Calibration is complete
EVENTS_STOPPED	0x114		The ADC has stopped
EVENTS_CH[n].LIMITH	0x118		Last results is equal or above CH[n].LIMIT.HIGH
EVENTS_CH[n].LIMITL	0x11C		Last results is equal or below CH[n].LIMIT.LOW
PUBLISH_STARTED	0x180		Publish configuration for event STARTED
PUBLISH_END	0x184		Publish configuration for event END
PUBLISH_DONE	0x188		Publish configuration for event DONE
PUBLISH_RESULTDONE	0x18C		Publish configuration for event RESULTDONE
PUBLISH_CALIBRATEDONE	0x190		Publish configuration for event CALIBRATEDONE
PUBLISH_STOPPED	0x194		Publish configuration for event STOPPED
PUBLISH_CH[n].LIMITH	0x198		Publish configuration for event CH[n].LIMITH
PUBLISH_CH[n].LIMITL	0x19C		Publish configuration for event CH[n].LIMITL
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
STATUS	0x400		Status
ENABLE	0x500		Enable or disable ADC
CH[n].PSELP	0x510		Input positive pin selection for CH[n]
CH[n].PSELN	0x514		Input negative pin selection for CH[n]

Register	Offset	TZ	Description
CH[n].CONFIG	0x518		Input configuration for CH[n]
CH[n].LIMIT	0x51C		High/low limits for event monitoring a channel
RESOLUTION	0x5F0		Resolution configuration
OVERSAMPLE	0x5F4		Oversampling configuration. OVERSAMPLE should not be combined with SCAN. The RESOLUTION is applied before averaging, thus for high OVERSAMPLE a higher RESOLUTION should be used.
SAMPLERATE	0x5F8		Controls normal or continuous sample rate
RESULT.PTR	0x62C		Data pointer
RESULT.MAXCNT	0x630		Maximum number of buffer words to transfer
RESULT.AMOUNT	0x634		Number of buffer words transferred since last START

6.12.10.1 TASKS_START

Address offset: 0x000

Start the ADC and prepare the result buffer in RAM

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_START			Start the ADC and prepare the result buffer in RAM
			Trigger	1	Trigger task

6.12.10.2 TASKS_SAMPLE

Address offset: 0x004

Take one ADC sample, if scan is enabled all channels are sampled

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_SAMPLE			Take one ADC sample, if scan is enabled all channels are sampled
			Trigger	1	Trigger task

6.12.10.3 TASKS_STOP

Address offset: 0x008

Stop the ADC and terminate any on-going conversion

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stop the ADC and terminate any on-going conversion
			Trigger	1	Trigger task

6.12.10.4 TASKS_CALIBRATEOFFSET

Address offset: 0x00C

Starts offset auto-calibration

Do not trigger when the ADC has been started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_CALIBRATEOFFSET			Starts offset auto-calibration
					Do not trigger when the ADC has been started
			Trigger	1	Trigger task

6.12.10.5 SUBSCRIBE_START

Address offset: 0x080

Subscribe configuration for task START

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task START will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.12.10.6 SUBSCRIBE_SAMPLE

Address offset: 0x084

Subscribe configuration for task SAMPLE

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task SAMPLE will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.12.10.7 SUBSCRIBE_STOP

Address offset: 0x088

Subscribe configuration for task STOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.12.10.8 SUBSCRIBE_CALIBRATEOFFSET

Address offset: 0x08C

Subscribe configuration for task CALIBRATEOFFSET

Do not trigger when the ADC has been started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task CALIBRATEOFFSET will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.12.10.9 EVENTS_STARTED

Address offset: 0x100

The ADC has started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STARTED			The ADC has started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.12.10.10 EVENTS_END

Address offset: 0x104

The ADC has filled up the Result buffer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_END			The ADC has filled up the Result buffer
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.12.10.11 EVENTS_DONE

Address offset: 0x108

A conversion task has been completed. Depending on the mode, multiple conversions might be needed for a result to be transferred to RAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_DONE			A conversion task has been completed. Depending on the mode, multiple conversions might be needed for a result to be transferred to RAM.
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.12.10.12 EVENTS_RESULTDONE

Address offset: 0x10C

A result is ready to get transferred to RAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RESULTDONE			A result is ready to get transferred to RAM.
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.12.10.13 EVENTS_CALIBRATEDONE

Address offset: 0x110

Calibration is complete

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_CALIBRATEDONE			Calibration is complete
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.12.10.14 EVENTS_STOPPED

Address offset: 0x114

The ADC has stopped

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STOPPED			The ADC has stopped
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.12.10.15 EVENTS_CH[n] (n=0..7)

Peripheral events.

6.12.10.15.1 EVENTS_CH[n].LIMITH (n=0..7)

Address offset: 0x118 + (n × 0x8)

Last results is equal or above CH[n].LIMIT.HIGH

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIMITH			Last results is equal or above CH[n].LIMIT.HIGH
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.12.10.15.2 EVENTS_CH[n].LIMITL (n=0..7)

Address offset: 0x11C + (n × 0x8)

Last results is equal or below CH[n].LIMIT.LOW

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIMITL			Last results is equal or below CH[n].LIMIT.LOW
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.12.10.16 PUBLISH_STARTED

Address offset: 0x180

Publish configuration for event STARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.12.10.17 PUBLISH_END

Address offset: 0x184

Publish configuration for event END

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event END will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.12.10.18 PUBLISH_DONE

Address offset: 0x188

Publish configuration for event DONE

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event DONE will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.12.10.19 PUBLISH_RESULTDONE

Address offset: 0x18C

Publish configuration for event RESULTDONE

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event RESULTDONE will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.12.10.20 PUBLISH_CALIBRATEDONE

Address offset: 0x190

Publish configuration for event CALIBRATEDONE

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event CALIBRATEDONE will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.12.10.21 PUBLISH_STOPPED

Address offset: 0x194

Publish configuration for event STOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STOPPED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.12.10.22 PUBLISH_CH[n] (n=0..7)

Publish configuration for events

6.12.10.22.1 PUBLISH_CH[n].LIMITH (n=0..7)

Address offset: 0x198 + (n × 0x8)

Publish configuration for event CH[n].LIMITH

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event CH[n].LIMITH will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.12.10.22.2 PUBLISH_CH[n].LIMITL (n=0..7)

Address offset: 0x19C + (n × 0x8)

Publish configuration for event CH[n].LIMITL

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event CH[n].LIMITL will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.12.10.23 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	STARTED			Enable or disable interrupt for event STARTED
			Disabled	0	Disable
			Enabled	1	Enable
B	RW	END			Enable or disable interrupt for event END
			Disabled	0	Disable
			Enabled	1	Enable
C	RW	DONE			Enable or disable interrupt for event DONE
			Disabled	0	Disable
			Enabled	1	Enable
D	RW	RESULTDONE			Enable or disable interrupt for event RESULTDONE
			Disabled	0	Disable
			Enabled	1	Enable
E	RW	CALIBRATEDONE			Enable or disable interrupt for event CALIBRATEDONE
			Disabled	0	Disable
			Enabled	1	Enable
F	RW	STOPPED			Enable or disable interrupt for event STOPPED
			Disabled	0	Disable
			Enabled	1	Enable
G	RW	CH0LIMITH			Enable or disable interrupt for event CH0LIMITH
			Disabled	0	Disable
			Enabled	1	Enable
H	RW	CH0LIMITL			Enable or disable interrupt for event CH0LIMITL
			Disabled	0	Disable
			Enabled	1	Enable
I	RW	CH1LIMITH			Enable or disable interrupt for event CH1LIMITH
			Disabled	0	Disable
			Enabled	1	Enable
J	RW	CH1LIMITL			Enable or disable interrupt for event CH1LIMITL
			Disabled	0	Disable
			Enabled	1	Enable
K	RW	CH2LIMITH			Enable or disable interrupt for event CH2LIMITH
			Disabled	0	Disable
			Enabled	1	Enable
L	RW	CH2LIMITL			Enable or disable interrupt for event CH2LIMITL
			Disabled	0	Disable
			Enabled	1	Enable
M	RW	CH3LIMITH			Enable or disable interrupt for event CH3LIMITH
			Disabled	0	Disable
			Enabled	1	Enable
N	RW	CH3LIMITL			Enable or disable interrupt for event CH3LIMITL
			Disabled	0	Disable
			Enabled	1	Enable
O	RW	CH4LIMITH			Enable or disable interrupt for event CH4LIMITH
			Disabled	0	Disable
			Enabled	1	Enable
P	RW	CH4LIMITL			Enable or disable interrupt for event CH4LIMITL
			Disabled	0	Disable
			Enabled	1	Enable
Q	RW	CH5LIMITH			Enable or disable interrupt for event CH5LIMITH
			Disabled	0	Disable

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Enabled	1	Enable
R	RW	CH5LIMITL			Enable or disable interrupt for event CH5LIMITL
			Disabled	0	Disable
			Enabled	1	Enable
S	RW	CH6LIMITH			Enable or disable interrupt for event CH6LIMITH
			Disabled	0	Disable
			Enabled	1	Enable
T	RW	CH6LIMITL			Enable or disable interrupt for event CH6LIMITL
			Disabled	0	Disable
			Enabled	1	Enable
U	RW	CH7LIMITH			Enable or disable interrupt for event CH7LIMITH
			Disabled	0	Disable
			Enabled	1	Enable
V	RW	CH7LIMITL			Enable or disable interrupt for event CH7LIMITL
			Disabled	0	Disable
			Enabled	1	Enable

6.12.10.24 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	STARTED			Write '1' to enable interrupt for event STARTED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	END			Write '1' to enable interrupt for event END
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	DONE			Write '1' to enable interrupt for event DONE
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
D	RW	RESULTDONE			Write '1' to enable interrupt for event RESULTDONE
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	CALIBRATEDONE			Write '1' to enable interrupt for event CALIBRATEDONE
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
F	RW	STOPPED			Write '1' to enable interrupt for event STOPPED
			Set	1	Enable
			Disabled	0	Read: Disabled

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID											V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
			Enabled	1	Read: Enabled
G	RW	CH0LIMITH			Write '1' to enable interrupt for event CH0LIMITH
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
H	RW	CH0LIMITL			Write '1' to enable interrupt for event CH0LIMITL
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
I	RW	CH1LIMITH			Write '1' to enable interrupt for event CH1LIMITH
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
J	RW	CH1LIMITL			Write '1' to enable interrupt for event CH1LIMITL
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
K	RW	CH2LIMITH			Write '1' to enable interrupt for event CH2LIMITH
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
L	RW	CH2LIMITL			Write '1' to enable interrupt for event CH2LIMITL
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
M	RW	CH3LIMITH			Write '1' to enable interrupt for event CH3LIMITH
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
N	RW	CH3LIMITL			Write '1' to enable interrupt for event CH3LIMITL
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
O	RW	CH4LIMITH			Write '1' to enable interrupt for event CH4LIMITH
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
P	RW	CH4LIMITL			Write '1' to enable interrupt for event CH4LIMITL
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
Q	RW	CH5LIMITH			Write '1' to enable interrupt for event CH5LIMITH
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
R	RW	CH5LIMITL			Write '1' to enable interrupt for event CH5LIMITL
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
S	RW	CH6LIMITH			Write '1' to enable interrupt for event CH6LIMITH

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
T	RW	CH6LIMITL			Write '1' to enable interrupt for event CH6LIMITL
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
U	RW	CH7LIMITH			Write '1' to enable interrupt for event CH7LIMITH
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
V	RW	CH7LIMITL			Write '1' to enable interrupt for event CH7LIMITL
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.12.10.25 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	STARTED			Write '1' to disable interrupt for event STARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	END			Write '1' to disable interrupt for event END
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	DONE			Write '1' to disable interrupt for event DONE
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
D	RW	RESULTDONE			Write '1' to disable interrupt for event RESULTDONE
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	CALIBRATEDONE			Write '1' to disable interrupt for event CALIBRATEDONE
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
F	RW	STOPPED			Write '1' to disable interrupt for event STOPPED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
G	RW	CH0LIMITH			Write '1' to disable interrupt for event CH0LIMITH
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
H	RW	CH0LIMITL			Write '1' to disable interrupt for event CH0LIMITL
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
I	RW	CH1LIMITH			Write '1' to disable interrupt for event CH1LIMITH
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
J	RW	CH1LIMITL			Write '1' to disable interrupt for event CH1LIMITL
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
K	RW	CH2LIMITH			Write '1' to disable interrupt for event CH2LIMITH
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
L	RW	CH2LIMITL			Write '1' to disable interrupt for event CH2LIMITL
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
M	RW	CH3LIMITH			Write '1' to disable interrupt for event CH3LIMITH
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
N	RW	CH3LIMITL			Write '1' to disable interrupt for event CH3LIMITL
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
O	RW	CH4LIMITH			Write '1' to disable interrupt for event CH4LIMITH
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
P	RW	CH4LIMITL			Write '1' to disable interrupt for event CH4LIMITL
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
Q	RW	CH5LIMITH			Write '1' to disable interrupt for event CH5LIMITH
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
R	RW	CH5LIMITL			Write '1' to disable interrupt for event CH5LIMITL
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
S	RW	CH6LIMITH			Write '1' to disable interrupt for event CH6LIMITH
			Clear	1	Disable

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				V U T S R Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
T	RW	CH6LIMITL			Write '1' to disable interrupt for event CH6LIMITL
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
U	RW	CH7LIMITH			Write '1' to disable interrupt for event CH7LIMITH
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
V	RW	CH7LIMITL			Write '1' to disable interrupt for event CH7LIMITL
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.12.10.26 STATUS

Address offset: 0x400

Status

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	STATUS			Status
			Ready	0	ADC is ready. No on-going conversion.
			Busy	1	ADC is busy. Single conversion in progress.

6.12.10.27 ENABLE

Address offset: 0x500

Enable or disable ADC

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			Enable or disable ADC
			Disabled	0	Disable ADC
			Enabled	1	Enable ADC
					When enabled, the ADC will acquire access to the analog input pins specified in the CH[n].PSELP and CH[n].PSELN registers.

6.12.10.28 CH[n].PSELP (n=0..7)

Address offset: 0x510 + (n × 0x10)

Input positive pin selection for CH[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PSELP			Analog positive input channel
			NC	0	Not connected
			AnalogInput0	1	AIN0
			AnalogInput1	2	AIN1
			AnalogInput2	3	AIN2
			AnalogInput3	4	AIN3
			AnalogInput4	5	AIN4
			AnalogInput5	6	AIN5
			AnalogInput6	7	AIN6
			AnalogInput7	8	AIN7
			VDDGPIO	9	VDD_GPIO

6.12.10.29 CH[n].PSELN (n=0..7)

Address offset: 0x514 + (n × 0x10)

Input negative pin selection for CH[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PSELN			Analog negative input, enables differential channel
			NC	0	Not connected
			AnalogInput0	1	AIN0
			AnalogInput1	2	AIN1
			AnalogInput2	3	AIN2
			AnalogInput3	4	AIN3
			AnalogInput4	5	AIN4
			AnalogInput5	6	AIN5
			AnalogInput6	7	AIN6
			AnalogInput7	8	AIN7
			VDD_GPIO	9	VDD_GPIO

6.12.10.30 CH[n].CONFIG (n=0..7)

Address offset: 0x518 + (n × 0x10)

Input configuration for CH[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				G F E E E D C C C B B A A
Reset 0x00020000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RESP			Positive channel resistor control
			Bypass	0	Bypass resistor ladder
			Pulldown	1	Pull-down to GND
			Pullup	2	Pull-up to VDD_GPIO
			VDD1_2	3	Set input at VDD_GPIO/2
B	RW	RESN			Negative channel resistor control
			Bypass	0	Bypass resistor ladder

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				G F E E E D C C C B B A A
Reset 0x00020000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Pulldown	1	Pull-down to GND
			Pullup	2	Pull-up to VDD_GPIO
			VDD1_2	3	Set input at VDD_GPIO/2
C	RW	GAIN			Gain control
			Gain1_6	0	1/6
			Gain1_5	1	1/5
			Gain1_4	2	1/4
			Gain1_3	3	1/3
			Gain1_2	4	1/2
			Gain1	5	1
			Gain2	6	2
			Gain4	7	4
D-	RW	REFSEL			Reference control
			Internal	0	Internal reference (0.6 V)
			VDD1_4	1	VDD_GPIO/4 as reference
E	RW	TACQ			Acquisition time, the time the ADC uses to sample the input voltage
			3us	0	3 us
			5us	1	5 us
			10us	2	10 us
			15us	3	15 us
			20us	4	20 us
			40us	5	40 us
F	RW	MODE			Enable differential mode
			SE	0	Single ended, PSELN will be ignored, negative input to ADC shorted to GND
			Diff	1	Differential
G	RW	BURST			Enable burst mode
			Disabled	0	Burst mode is disabled (normal operation)
			Enabled	1	Burst mode is enabled. SAADC takes 2^OVERSAMPLE number of samples as fast as it can, and sends the average to Data RAM.

6.12.10.31 CH[n].LIMIT (n=0..7)

Address offset: 0x51C + (n × 0x10)

High/low limits for event monitoring a channel

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B B B B B B B B B B B B B A A A A A A A A A A A A A A
Reset 0x7FFF8000				**0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LOW		[-32768 to +32767]	Low level limit
B	RW	HIGH		[-32768 to +32767]	High level limit

6.12.10.32 RESOLUTION

Address offset: 0x5F0

Resolution configuration

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**

ID	R/W	Field	Value ID	Value	Description
A	RW	VAL			Set the resolution
			8bit	0	8 bit
			10bit	1	10 bit
			12bit	2	12 bit
			14bit	3	14 bit

6.12.10.33 OVERSAMPLE

Address offset: 0x5F4

Oversampling configuration. OVERSAMPLE should not be combined with SCAN. The RESOLUTION is applied before averaging, thus for high OVERSAMPLE a higher RESOLUTION should be used.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	OVERSAMPLE			Oversample control
			Bypass	0	Bypass oversampling
			Over2x	1	Oversample 2x
			Over4x	2	Oversample 4x
			Over8x	3	Oversample 8x
			Over16x	4	Oversample 16x
			Over32x	5	Oversample 32x
			Over64x	6	Oversample 64x
			Over128x	7	Oversample 128x
			Over256x	8	Oversample 256x

6.12.10.34 SAMPLERATE

Address offset: 0x5F8

Controls normal or continuous sample rate

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CC		[80..2047]	Capture and compare value. Sample rate is 16 MHz/CC
B	RW	MODE			Select mode for sample rate control
			Task	0	Rate is controlled from SAMPLE task
			Timers	1	Rate is controlled from local timer (use CC to control the rate)

6.12.10.35 RESULT

RESULT EasyDMA channel

6.12.10.35.1 RESULT.PTR

Address offset: 0x62C

Data pointer

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Data pointer

Note: See the memory chapter for details about which memories are available for EasyDMA.

6.12.10.35.2 RESULT.MAXCNT

Address offset: 0x630

Maximum number of buffer words to transfer

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT			Maximum number of buffer words to transfer

6.12.10.35.3 RESULT.AMOUNT

Address offset: 0x634

Number of buffer words transferred since last START

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																		A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT			Number of buffer words transferred since last START. This register can be read after an END or STOPPED event.

6.12.11 Electrical specification

6.12.11.1 SAADC Electrical Specification

Symbol	Description	Min.	Typ.	Max.	Units
DNL_{10}	Differential non-linearity, 10-bit resolution	-0.95	<1		LSB10b
INL_{10}	Integral non-linearity, 10-bit resolution		1		LSB10b
V_{OS}	Differential offset error (calibrated), 10-bit resolution [a]		±2		LSB10b
C_{EG}	Gain error temperature coefficient	-0.05	0.02	0.05	%/°C
f_{SAMPLE}	Maximum sampling rate			200	kHz
$t_{ACQ,10k}$	Acquisition time (configurable), source Resistance <= 10 kOhm		3		µs
$t_{ACQ,40k}$	Acquisition time (configurable), source Resistance <= 40 kOhm		5		µs
$t_{ACQ,100k}$	Acquisition time (configurable), source Resistance <= 100 kOhm		10		µs
$t_{ACQ,200k}$	Acquisition time (configurable), source Resistance <= 200 kOhm		15		µs
$t_{ACQ,400k}$	Acquisition time (configurable), source Resistance <= 400 kOhm		20		µs
$t_{ACQ,800k}$	Acquisition time (configurable), source Resistance <= 800 kOhm		40		µs
t_{CONV}	Conversion time		<2		µs

[a] Digital output code at zero volt differential input.

Symbol	Description	Min.	Typ.	Max.	Units
$E_{G1/6}$	Error[b] for Gain = 1/6	-3		3	%
$E_{G1/4}$	Error[b] for Gain = 1/4	-3		3	%
$E_{G1/2}$	Error[b] for Gain = 1/2. Internal reference	-3		4	%
E_{G1}	Error[b] for Gain = 1. Internal reference	-3		4	%
$E_{G1/2\_VDD\_GPIO}$	Error[b] for Gain = 1/2. VDD_GPIO as reference	-4		4	%
$E_{G1\_VDD\_GPIO}$	Error[b] for Gain = 1. VDD_GPIO as reference	-4		4	%
C_{SAMPLE}	Sample and hold capacitance at maximum gain[19]		2.5		pF
R_{INPUT}	Input resistance		>1		MΩ
E_{NOB}	Effective number of bits, differential mode, 12-bit resolution, 1/1 gain, 3 µs acquisition time, HFXO, 200 ksps		9		Bit
S_{NDR}	Peak signal to noise and distortion ratio, differential mode, 12-bit resolution, 1/1 gain, 3 µs acquisition time, HFXO, 200 ksps		56		dB
S_{FDR}	Spurious free dynamic range, differential mode, 12-bit resolution, 1/1 gain, 3 µs acquisition time, HFXO, 200 ksps		70		dBc
R_{LADDER}	Ladder resistance		160		kΩ

6.12.12 Performance factors

Clock jitter, affecting sample timing accuracy, and circuit noise can affect ADC performance.

Jitter can be between START tasks or from START task to acquisition. START timer accuracy and startup times of regulators and references will contribute to variability. Sources of circuit noise may include CPU activity and the DC/DC regulator. Best ADC performance is achieved using START timing based on the TIMER module, HFXO clock source, and Constant Latency mode.

6.13 SPIM — Serial peripheral interface master with EasyDMA

The SPI master can communicate with multiple slaves using individual chip select signals for each of the slave devices attached to a bus.

Listed here are the main features for the SPIM

- SPI mode 0-3
- EasyDMA direct transfer to/from RAM for both SPI Slave and SPI Master
- Individual selection of IO pin for each SPI signal

[b] Does not include temperature drift

[19] Maximum gain corresponds to highest capacitance.

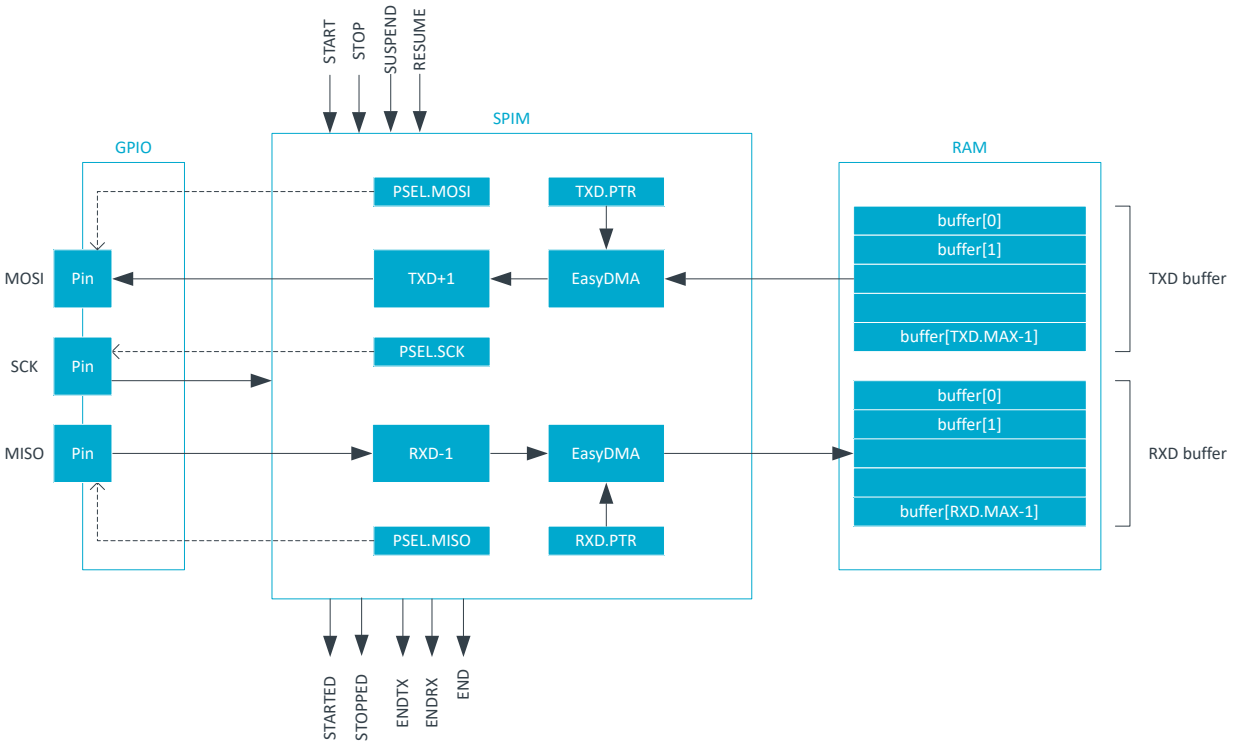

Figure 77: SPIM — SPI master with EasyDMA

The SPIM does not implement support for chip select directly. Therefore, the CPU must use available GPIOs to select the correct slave and control this independently of the SPI master. The SPIM supports SPI modes 0 through 3. The CONFIG register allows setting CPOL and CPHA appropriately.

Mode	Clock polarity	Clock phase
	CPOL	CPHA
SPI_MODE0	0 (Active High)	0 (Leading)
SPI_MODE1	0 (Active High)	1 (Trailing)
SPI_MODE2	1 (Active Low)	0 (Leading)
SPI_MODE3	1 (Active Low)	1 (Trailing)

Table 33: SPI modes

6.13.1 SPI master transaction sequence

An SPI master transaction consists of a sequence started by the START task followed by a number of events, and finally the STOP task.

An SPI master transaction is started by triggering the START task. The ENDTX event will be generated when the transmitter has transmitted all bytes in the TXD buffer as specified in the TXD.MAXCNT register. The ENDRX event will be generated when the receiver has filled the RXD buffer, i.e. received the last possible byte as specified in the RXD.MAXCNT register.

Following a START task, the SPI master will generate an END event when both ENDRX and ENDTX have been generated.

The SPI master is stopped by triggering the STOP task. A STOPPED event is generated when the SPI master has stopped.

If the ENDRX event has not already been generated when the SPI master has come to a stop, the SPI master will generate the ENDRX event explicitly even though the RX buffer is not full.

If the ENDTX event has not already been generated when the SPI master has come to a stop, the SPI master will generate the ENDTX event explicitly even though all bytes in the TXD buffer, as specified in the TXD.MAXCNT register, have not been transmitted.

The SPI master is a synchronous interface, and for every byte that is sent, a different byte will be received at the same time; this is illustrated in SPI master transaction on page 293.

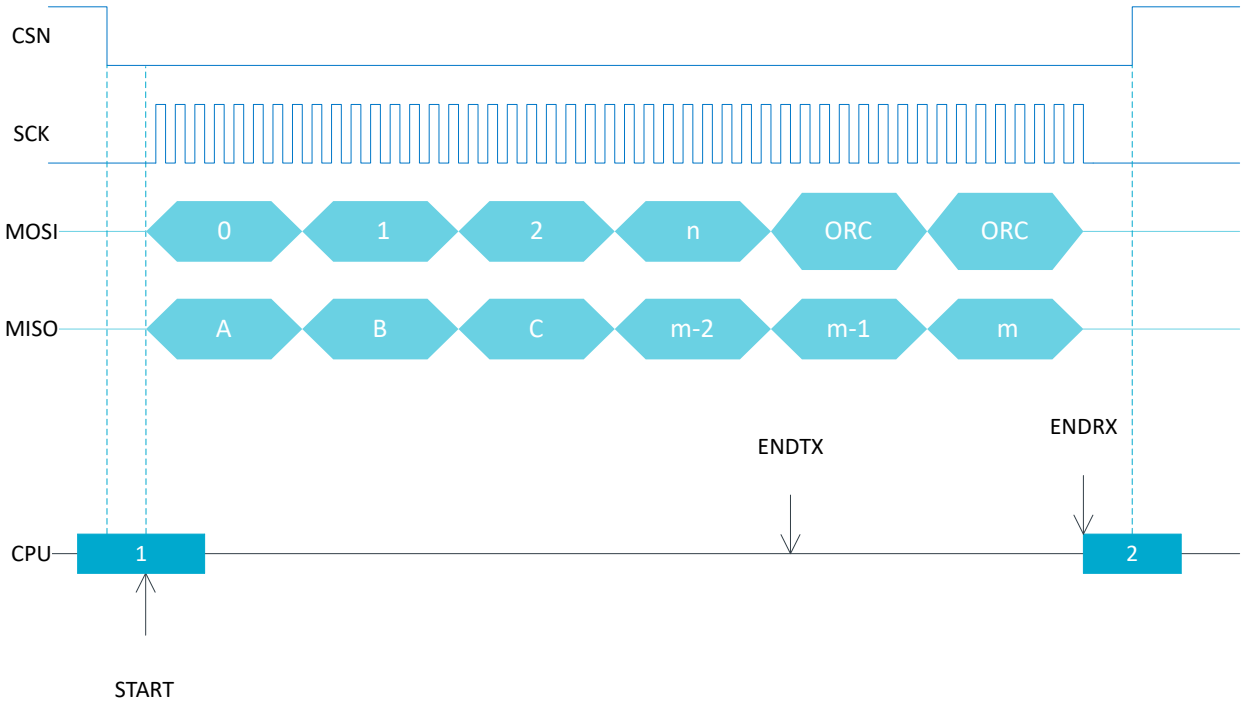

Figure 78: SPI master transaction

6.13.2 Master mode pin configuration

The SCK, MOSI, and MISO signals associated with the SPI master are mapped to physical pins according to the configuration specified in the PSEL.SCK, PSEL.MOSI, and PSEL.MISO registers respectively.

The PSEL.SCK, PSEL.MOSI, and PSEL.MISO registers and their configurations are only used as long as the SPI master is enabled, and retained only as long as the device is in ON mode. PSEL.SCK, PSEL.MOSI and PSEL.MISO must only be configured when the SPI master is disabled.

To secure correct behavior in the SPI, the pins used by the SPI must be configured in the GPIO peripheral as described in GPIO configuration on page 293 prior to enabling the SPI. This configuration must be retained in the GPIO for the selected IOs as long as the SPI is enabled.

Only one peripheral can be assigned to drive a particular GPIO pin at a time. Failing to do so may result in unpredictable behavior.

SPI master signal	SPI master pin	Direction	Output value
SCK	As specified in PSEL.SCK	Output	Same as CONFIG.CPOL
MOSI	As specified in PSEL.MOSI	Output	0
MISO	As specified in PSEL.MISO	Input	Not applicable

Table 34: GPIO configuration

6.13.3 Shared resources

The SPI shares registers and other resources with other peripherals that have the same ID as the SPI. Therefore, the user must disable all peripherals that have the same ID as the SPI before the SPI can be configured and used.

Disabling a peripheral that has the same ID as the SPI will not reset any of the registers that are shared with the SPI. It is therefore important to configure all relevant SPI registers explicitly to secure that it operates correctly.

See the Instantiation table in Instantiation on page 25 for details on peripherals and their IDs.

6.13.4 EasyDMA

The SPIM implements EasyDMA for accessing RAM without CPU involvement.

The SPIM peripheral implements the following EasyDMA channels:

Channel	Type	Register Cluster
TXD	READER	TXD
RXD	WRITER	RXD

Table 35: SPIM EasyDMA Channels

For detailed information regarding the use of EasyDMA, see EasyDMA on page 46.

The .PTR and .MAXCNT registers are double-buffered. They can be updated and prepared for the next transmission immediately after having received the STARTED event.

The SPI master will automatically stop transmitting after TXD.MAXCNT bytes have been transmitted and RXD.MAXCNT bytes have been received. If RXD.MAXCNT is larger than TXD.MAXCNT, the remaining transmitted bytes will contain the value defined in the ORC register. If TXD.MAXCNT is larger than RXD.MAXCNT, the superfluous received bytes will be discarded.

The ENDRX/ENDTX event indicate that EasyDMA has finished accessing respectively the RX/TX buffer in RAM. The END event gets generated when both RX and TX are finished accessing the buffers in RAM.

In the case of bus congestion as described in AHB multilayer interconnect on page 48, data loss may occur.

6.13.5 Low power

When putting the system in low power and the peripheral is not needed, lowest possible power consumption is achieved by stopping, and then disabling the peripheral.

The STOP task may not be always needed (the peripheral might already be stopped), but if it is sent, software shall wait until the STOPPED event was received as a response before disabling the peripheral through the ENABLE register.

6.13.6 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
SPIM0 : S	0x50008000	US	NS	SA	No	SPI master 0
SPIM0 : NS	0x40008000					
SPIM1 : S	0x50009000	US	NS	SA	No	SPI master 1
SPIM1 : NS	0x40009000					
SPIM2 : S	0x5000A000	US	NS	SA	No	SPI master 2
SPIM2 : NS	0x4000A000					
SPIM3 : S	0x5000B000	US	NS	SA	No	SPI master 3
SPIM3 : NS	0x4000B000					

Register overview

Register	Offset	TZ	Description
TASKS_START	0x010		Start SPI transaction
TASKS_STOP	0x014		Stop SPI transaction
TASKS_SUSPEND	0x01C		Suspend SPI transaction
TASKS_RESUME	0x020		Resume SPI transaction
SUBSCRIBE_START	0x090		Subscribe configuration for task START
SUBSCRIBE_STOP	0x094		Subscribe configuration for task STOP
SUBSCRIBE_SUSPEND	0x09C		Subscribe configuration for task SUSPEND
SUBSCRIBE_RESUME	0x0A0		Subscribe configuration for task RESUME
EVENTS_STOPPED	0x104		SPI transaction has stopped
EVENTS_ENDRX	0x110		End of RXD buffer reached
EVENTS_END	0x118		End of RXD buffer and TXD buffer reached
EVENTS_ENDTX	0x120		End of TXD buffer reached
EVENTS_STARTED	0x14C		Transaction started
PUBLISH_STOPPED	0x184		Publish configuration for event STOPPED
PUBLISH_ENDRX	0x190		Publish configuration for event ENDRX
PUBLISH_END	0x198		Publish configuration for event END
PUBLISH_ENDTX	0x1A0		Publish configuration for event ENDTX
PUBLISH_STARTED	0x1CC		Publish configuration for event STARTED
SHORTS	0x200		Shortcuts between local events and tasks
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
ENABLE	0x500		Enable SPIM
PSEL.SCK	0x508		Pin select for SCK
PSEL.MOSI	0x50C		Pin select for MOSI signal
PSEL.MISO	0x510		Pin select for MISO signal
FREQUENCY	0x524		SPI frequency. Accuracy depends on the HFCLK source selected.
RXD.PTR	0x534		Data pointer
RXD.MAXCNT	0x538		Maximum number of bytes in receive buffer
RXD.AMOUNT	0x53C		Number of bytes transferred in the last transaction
RXD.LIST	0x540		EasyDMA list type
TXD.PTR	0x544		Data pointer
TXD.MAXCNT	0x548		Maximum number of bytes in transmit buffer
TXD.AMOUNT	0x54C		Number of bytes transferred in the last transaction
TXD.LIST	0x550		EasyDMA list type

Register	Offset	TZ	Description
CONFIG	0x554		Configuration register
ORC	0x5C0		Over-read character. Character clocked out in case an over-read of the TXD buffer.

6.13.6.1 TASKS_START

Address offset: 0x010

Start SPI transaction

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_START			Start SPI transaction
			Trigger	1	Trigger task

6.13.6.2 TASKS_STOP

Address offset: 0x014

Stop SPI transaction

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stop SPI transaction
			Trigger	1	Trigger task

6.13.6.3 TASKS_SUSPEND

Address offset: 0x01C

Suspend SPI transaction

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_SUSPEND			Suspend SPI transaction
			Trigger	1	Trigger task

6.13.6.4 TASKS_RESUME

Address offset: 0x020

Resume SPI transaction

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_RESUME			Resume SPI transaction
			Trigger	1	Trigger task

6.13.6.5 SUBSCRIBE_START

Address offset: 0x090

Subscribe configuration for task START

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task START will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.13.6.6 SUBSCRIBE_STOP

Address offset: 0x094

Subscribe configuration for task STOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.13.6.7 SUBSCRIBE_SUSPEND

Address offset: 0x09C

Subscribe configuration for task SUSPEND

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task SUSPEND will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.13.6.8 SUBSCRIBE_RESUME

Address offset: 0x0A0

Subscribe configuration for task RESUME

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task RESUME will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.13.6.9 EVENTS_STOPPED

Address offset: 0x104

SPI transaction has stopped

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STOPPED			SPI transaction has stopped
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.13.6.10 EVENTS_ENDRX

Address offset: 0x110

End of RXD buffer reached

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ENDRX			End of RXD buffer reached
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.13.6.11 EVENTS_END

Address offset: 0x118

End of RXD buffer and TXD buffer reached

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_END			End of RXD buffer and TXD buffer reached
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.13.6.12 EVENTS_ENDTX

Address offset: 0x120

End of TXD buffer reached

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ENDTX			End of TXD buffer reached
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.13.6.13 EVENTS_STARTED

Address offset: 0x14C

Transaction started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STARTED			Transaction started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.13.6.14 PUBLISH_STOPPED

Address offset: 0x184

Publish configuration for event STOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STOPPED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.13.6.15 PUBLISH_ENDRX

Address offset: 0x190

Publish configuration for event ENDRX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ENDRX will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.13.6.16 PUBLISH_END

Address offset: 0x198

Publish configuration for event END

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event END will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.13.6.17 PUBLISH_ENDTX

Address offset: 0x1A0

Publish configuration for event ENDTX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ENDTX will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.13.6.18 PUBLISH_STARTED

Address offset: 0x1CC

Publish configuration for event STARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.13.6.19 SHORTS

Address offset: 0x200

Shortcuts between local events and tasks

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	END_START			Shortcut between event END and task START
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut

6.13.6.20 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																E											D		C		B			A	
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field		Value ID				Value																			Description									
A	RW	STOPPED																									Write '1' to enable interrupt for event STOPPED									
				Set				1																			Enable									
				Disabled				0																			Read: Disabled									
				Enabled				1																			Read: Enabled									
B	RW	ENDRX																									Write '1' to enable interrupt for event ENDRX									
				Set				1																			Enable									
				Disabled				0																			Read: Disabled									
				Enabled				1																			Read: Enabled									
C	RW	END																									Write '1' to enable interrupt for event END									
				Set				1																			Enable									
				Disabled				0																			Read: Disabled									
				Enabled				1																			Read: Enabled									
D	RW	ENDTX																									Write '1' to enable interrupt for event ENDTX									
				Set				1																			Enable									
				Disabled				0																			Read: Disabled									
				Enabled				1																			Read: Enabled									
E	RW	STARTED																									Write '1' to enable interrupt for event STARTED									
				Set				1																			Enable									
				Disabled				0																			Read: Disabled									
				Enabled				1																			Read: Enabled									

6.13.6.21 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																E											D		C		B			A	
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field		Value ID				Value																			Description									
A	RW	STOPPED																									Write '1' to disable interrupt for event STOPPED									
				Clear				1																			Disable									
				Disabled				0																			Read: Disabled									
				Enabled				1																			Read: Enabled									
B	RW	ENDRX																									Write '1' to disable interrupt for event ENDRX									
				Clear				1																			Disable									
				Disabled				0																			Read: Disabled									
				Enabled				1																			Read: Enabled									
C	RW	END																									Write '1' to disable interrupt for event END									
				Clear				1																			Disable									
				Disabled				0																			Read: Disabled									
				Enabled				1																			Read: Enabled									
D	RW	ENDTX																									Write '1' to disable interrupt for event ENDTX									
				Clear				1																			Disable									

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	STARTED			Write '1' to disable interrupt for event STARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.13.6.22 ENABLE

Address offset: 0x500

Enable SPIM

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			Enable or disable SPIM
			Disabled	0	Disable SPIM
			Enabled	7	Enable SPIM

6.13.6.23 PSEL.SCK

Address offset: 0x508

Pin select for SCK

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.13.6.24 PSEL.MOSI

Address offset: 0x50C

Pin select for MOSI signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.13.6.25 PSEL.MISO

Address offset: 0x510

Pin select for MISO signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.13.6.26 FREQUENCY

Address offset: 0x524

SPI frequency. Accuracy depends on the HFCLK source selected.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x04000000				**0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	FREQUENCY			SPI master data rate
			K125	0x02000000	125 kbps
			K250	0x04000000	250 kbps
			K500	0x08000000	500 kbps
			M1	0x10000000	1 Mbps
			M2	0x20000000	2 Mbps
			M4	0x40000000	4 Mbps
			M8	0x80000000	8 Mbps

6.13.6.27 RXD

RXD EasyDMA channel

6.13.6.27.1 RXD.PTR

Address offset: 0x534

Data pointer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Data pointer

Note: See the memory chapter for details about which memories are available for EasyDMA.

6.13.6.27.2 RXD.MAXCNT

Address offset: 0x538

Maximum number of bytes in receive buffer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in receive buffer

6.13.6.27.3 RXD.AMOUNT

Address offset: 0x53C

Number of bytes transferred in the last transaction

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transferred in the last transaction

6.13.6.27.4 RXD.LIST

Address offset: 0x540

EasyDMA list type

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIST			List type
			Disabled	0	Disable EasyDMA list
			ArrayList	1	Use array list

6.13.6.28 TXD

TXD EasyDMA channel

6.13.6.28.1 TXD.PTR

Address offset: 0x544

Data pointer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Data pointer

Note: See the memory chapter for details about which memories are available for EasyDMA.

6.13.6.28.2 TXD.MAXCNT

Address offset: 0x548

Maximum number of bytes in transmit buffer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in transmit buffer

6.13.6.28.3 TXD.AMOUNT

Address offset: 0x54C

Number of bytes transferred in the last transaction

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transferred in the last transaction

6.13.6.28.4 TXD.LIST

Address offset: 0x550

EasyDMA list type

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIST			List type
			Disabled	0	Disable EasyDMA list
			ArrayList	1	Use array list

6.13.6.29 CONFIG

Address offset: 0x554

Configuration register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ORDER			Bit order
			MsbFirst	0	Most significant bit shifted out first
			LsbFirst	1	Least significant bit shifted out first
B	RW	CPHA			Serial clock (SCK) phase
			Leading	0	Sample on leading edge of clock, shift serial data on trailing edge
			Trailing	1	Sample on trailing edge of clock, shift serial data on leading edge
C	RW	CPOL			Serial clock (SCK) polarity
			ActiveHigh	0	Active high
			ActiveLow	1	Active low

6.13.6.30 ORC

Address offset: 0x5C0

Over-read character. Character clocked out in case an over-read of the TXD buffer.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ORC			Over-read character. Character clocked out in case an over-read of the TXD buffer.

6.13.7 Electrical specification

6.13.7.1 SPIM master interface electrical specifications

Symbol	Description	Min.	Typ.	Max.	Units
f_{SPIM}	Bit rates for SPIM[20]			8	Mbps
$t_{SPIM,START}$	Time from START task to transmission started		1		µs

6.13.7.2 Serial Peripheral Interface Master (SPIM) timing specifications

Symbol	Description	Min.	Typ.	Max.	Units
$t_{SPIM,CSCK}$	SCK period		125		ns
$t_{SPIM,RSCK,LD}$	SCK rise time, standard drive[a]			$t_{RF,25pF}$	
$t_{SPIM,RSCK,HD}$	SCK rise time, high drive[a]			$t_{HRF,25pF}$	
$t_{SPIM,FSCK,LD}$	SCK fall time, standard drive[a]			$t_{RF,25pF}$	
$t_{SPIM,FSCK,HD}$	SCK fall time, high drive[a]			$t_{HRF,25pF}$	
$t_{SPIM,WHSCK}$	SCK high time[a]	$(0.5*t_{CSCK}) - t_{RSCK}$			
$t_{SPIM,WLSCK}$	SCK low time[a]	$(0.5*t_{CSCK}) - t_{FSCK}$			
$t_{SPIM,SUMI}$	MISO to CLK edge setup time	19			ns
$t_{SPIM,HMI}$	CLK edge to MISO hold time	18			ns

[20] High bit rates may require GPIOs to be set as High Drive, see GPIO chapter for more details.

[a] At 25pF load, including GPIO pin capacitance, see GPIO spec.

Symbol	Description	Min.	Typ.	Max.	Units
$t_{SPIM,VMO}$	CLK edge to MOSI valid			59	ns
$t_{SPIM,HMO}$	MOSI hold time after CLK edge	20			ns

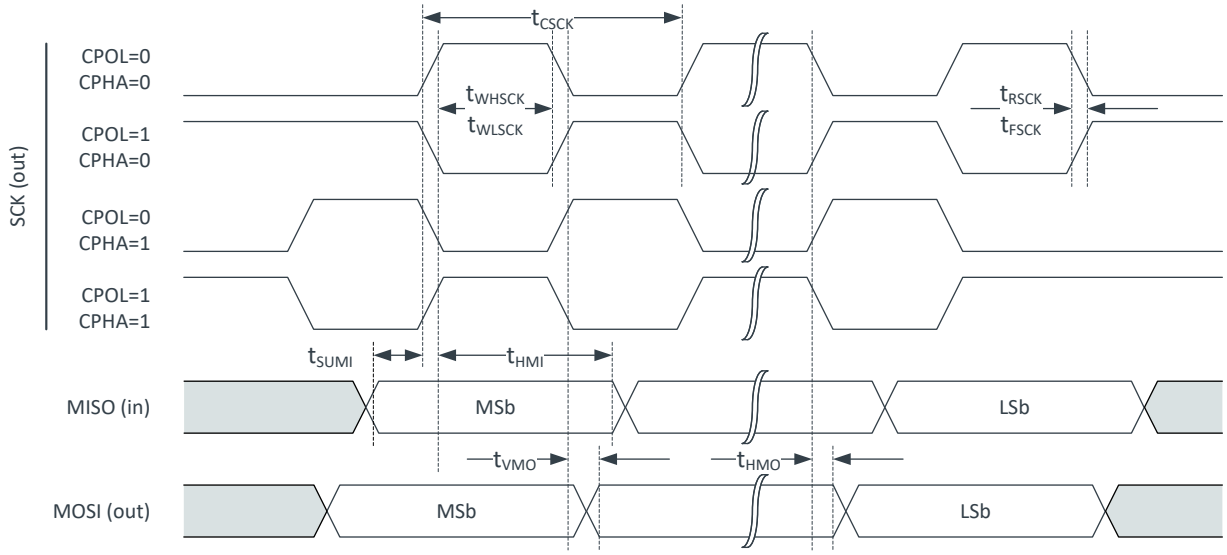

Figure 79: SPIM timing diagram

6.14 SPIS — Serial peripheral interface slave with EasyDMA

SPI slave (SPIS) is implemented with EasyDMA support for ultra low power serial communication from an external SPI master. EasyDMA in conjunction with hardware-based semaphore mechanisms removes all real-time requirements associated with controlling the SPI slave from a low priority CPU execution context.

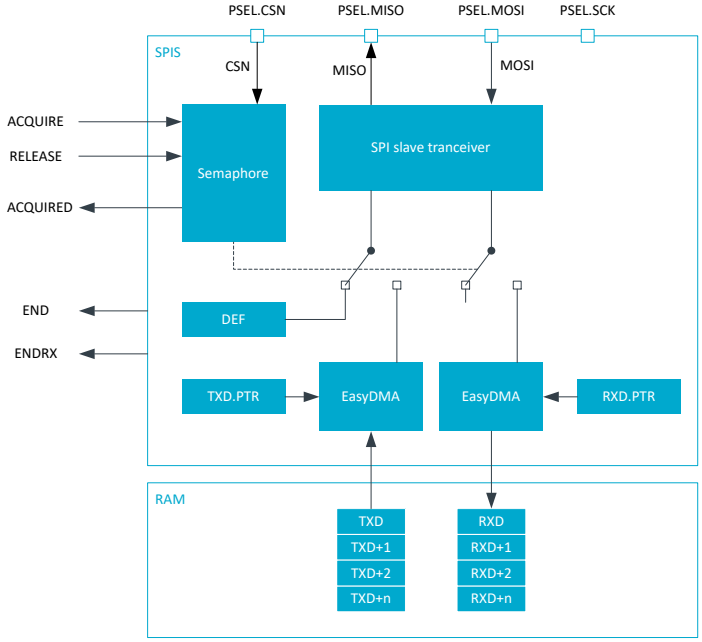

Figure 80: SPI slave

The SPIS supports SPI modes 0 through 3. The CONFIG register allows setting CPOL and CPHA appropriately.

Mode	Clock polarity	Clock phase
	CPOL	CPHA
SPI_MODE0	0 (Active High)	0 (Sample on Leading)
SPI_MODE1	0 (Active High)	1 (Sample on Trailing)
SPI_MODE2	1 (Active Low)	0 (Sample on Leading)
SPI_MODE3	1 (Active Low)	1 (Sample on Trailing)

Table 36: SPI modes

6.14.1 Shared resources

The SPI slave shares registers and other resources with other peripherals that have the same ID as the SPI slave. Therefore, you must disable all peripherals that have the same ID as the SPI slave before the SPI slave can be configured and used.

Disabling a peripheral that has the same ID as the SPI slave will not reset any of the registers that are shared with the SPI slave. It is important to configure all relevant SPI slave registers explicitly to secure that it operates correctly.

The Instantiation table in Instantiation on page 25 shows which peripherals have the same ID as the SPI slave.

6.14.2 EasyDMA

The SPIS implements EasyDMA for accessing RAM without CPU involvement.

The SPIS peripheral implements the following EasyDMA channels:

Channel	Type	Register Cluster
TXD	READER	TXD
RXD	WRITER	RXD

Table 37: SPIS EasyDMA Channels

For detailed information regarding the use of EasyDMA, see EasyDMA on page 46.

If RXD.MAXCNT is larger than TXD.MAXCNT, the remaining transmitted bytes will contain the value defined in the ORC register.

The END event indicates that EasyDMA has finished accessing the buffer in RAM.

6.14.3 SPI slave operation

SPI slave uses two memory pointers, RXD.PTR and TXD.PTR, that point to the RXD buffer (receive buffer) and TXD buffer (transmit buffer) respectively. Since these buffers are located in RAM, which can be accessed by both the SPI slave and the CPU, a hardware based semaphore mechanism is implemented to enable safe sharing.

Before the CPU can safely update the RXD.PTR and TXD.PTR pointers it must first acquire the SPI semaphore. The CPU can acquire the semaphore by triggering the ACQUIRE task and then receiving the ACQUIRED event. When the CPU has updated the RXD.PTR and TXD.PTR pointers the CPU must release the semaphore before the SPI slave will be able to acquire it.

The CPU releases the semaphore by triggering the RELEASE task, this is illustrated in SPI transaction when shortcut between END and ACQUIRE is enabled on page 309. Triggering the RELEASE task when the semaphore is not granted to the CPU will have no effect. See Semaphore operation on page 310 for more information

If the CPU is not able to reconfigure the TXD.PTR and RXD.PTR between granted transactions, the same TX data will be clocked out and the RX buffers will be overwritten. To prevent this from happening, the END_ACQUIRE shortcut can be used. With this shortcut enabled the semaphore will be handed over to the CPU automatically after the granted transaction has completed, giving the CPU the ability to update the TXPTR and RXPTR between every granted transaction.

The ENDRX event is generated when the RX buffer has been filled.

The RXD.MAXCNT register specifies the maximum number of bytes the SPI slave can receive in one granted transaction. If the SPI slave receives more than RXD.MAXCNT number of bytes, an OVERFLOW will be indicated in the STATUS register and the incoming bytes will be discarded.

The TXD.MAXCNT parameter specifies the maximum number of bytes the SPI slave can transmit in one granted transaction. If the SPI slave is forced to transmit more than TXD.MAXCNT number of bytes, an OVERREAD will be indicated in the STATUS register and the ORC character will be clocked out.

The RXD.AMOUNT and TXD.AMOUNT registers are updated when a granted transaction is completed. The TXD.AMOUNT register indicates how many bytes were read from the TX buffer in the last transaction, that is, ORC (over-read) characters are not included in this number. Similarly, the RXD.AMOUNT register indicates how many bytes were written into the RX buffer in the last transaction.

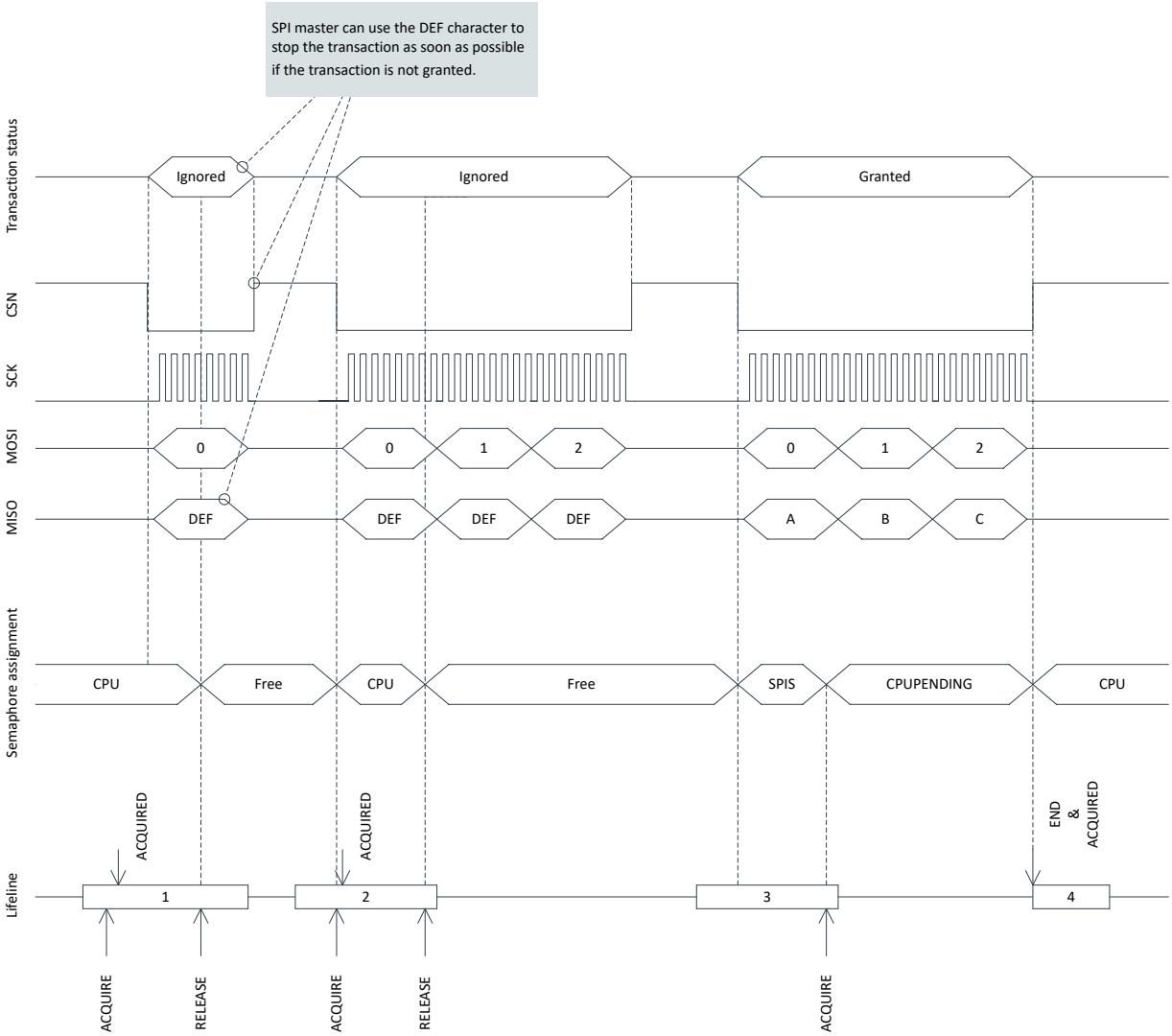

Figure 81: SPI transaction when shortcut between END and ACQUIRE is enabled

6.14.4 Semaphore operation

The semaphore is a mechanism implemented inside the SPI slave that prevents simultaneous access to the data buffers by the SPI slave and CPU.

The semaphore is by default assigned to the CPU after the SPI slave is enabled. No ACQUIRED event will be generated for this initial semaphore handover. An ACQUIRED event will be generated immediately if the ACQUIRE task is triggered while the semaphore is assigned to the CPU. The figure SPI semaphore FSM on page 310 illustrates the transitions between states in the semaphore based on the relevant tasks and events.

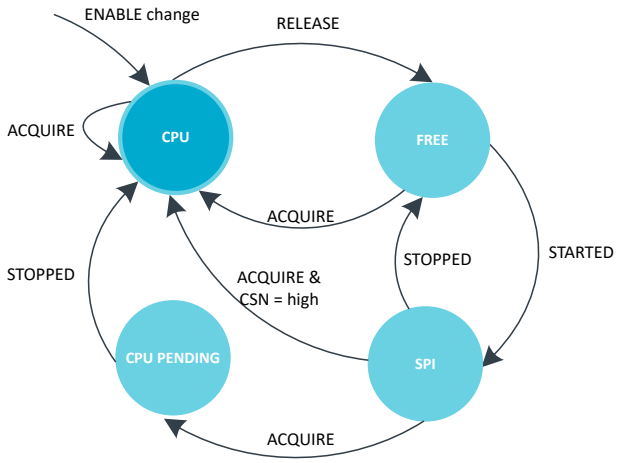

Figure 82: SPI semaphore FSM

Note: The semaphore mechanism does not, at any time, prevent the CPU from performing read or write access to the RXD.PTR register, the TXD.PTR registers, or the RAM that these pointers are pointing to. The semaphore is only telling when these can be updated by the CPU so that safe sharing is achieved.

The SPI slave will try to acquire the semaphore when STARTED event is detected, the event also indicates that CSN is currently low. If the SPI slave does not manage to acquire the semaphore at this point (i.e., it is under CPU's control), the transaction will be ignored. This means that all incoming data on MOSI will be discarded, and the DEF (default) character will be clocked out on the MISO line throughout the whole transaction. This will also be the case even if the semaphore is released by the CPU during the transaction. In case of a race condition where the CPU and the SPI slave try to acquire the semaphore at the same time, as illustrated in lifeline item 2 in figure SPI transaction when shortcut between END and ACQUIRE is enabled on page 309, the semaphore will be granted to the CPU.

If the SPI slave acquires the semaphore, the transaction will be granted. The incoming data on MOSI will be stored in the RXD buffer and the data in the TXD buffer will be clocked out on MISO.

When a granted transaction is completed and CSN goes high, the SPI slave will automatically release the semaphore and generate the END event.

As long as the semaphore is available, the SPI slave can be granted multiple transactions one after the other.

If the CPU tries to acquire the semaphore while it is assigned to the SPI slave, an immediate handover will not be granted. However, the semaphore will be handed over to the CPU as soon as the SPI slave has released the semaphore after the granted transaction is completed. If the END_ACQUIRE shortcut is enabled and the CPU has triggered the ACQUIRE task during a granted transaction, only one ACQUIRE request will be served following the END event.

6.14.5 Pin configuration

The CSN, SCK, MOSI, and MISO signals associated with the SPI slave are mapped to physical pins according to the configuration specified in the PSEL.CSN, PSEL.SCK, PSEL.MOSI, and PSEL.MISO registers respectively. If the CONNECT field of any of these registers is set to Disconnected, the associated SPI slave signal will not be connected to any physical pins.

The PSEL.CSN, PSEL.SCK, PSEL.MOSI, and PSEL.MISO registers and their configurations are only used as long as the SPI slave is enabled, and retained only as long as the device is in System ON mode, see POWER — Power control on page 68 chapter for more information about power modes. When the peripheral is disabled, the pins will behave as regular GPIOs, and use the configuration in their respective OUT bit field and PIN_CNF[n] register. PSEL.CSN, PSEL.SCK, PSEL.MOSI, and PSEL.MISO must only be configured when the SPI slave is disabled.

To secure correct behavior in the SPI slave, the pins used by the SPI slave must be configured in the GPIO peripheral as described in GPIO configuration before enabling peripheral on page 311 before enabling the SPI slave. This is to secure that the pins used by the SPI slave are driven correctly if the SPI slave itself is temporarily disabled, or if the device temporarily enters System OFF. This configuration must be retained in the GPIO for the selected I/Os as long as the SPI slave is to be recognized by an external SPI master.

The MISO line is set in high impedance as long as the SPI slave is not selected with CSN.

Only one peripheral can be assigned to drive a particular GPIO pin at a time. Failing to do so may result in unpredictable behavior.

SPI signal	SPI pin	Direction	Output value	Comment
CSN	As specified in PSEL.CSN	Input	Not applicable	
SCK	As specified in PSEL.SCK	Input	Not applicable	
MOSI	As specified in PSEL.MOSI	Input	Not applicable	
MISO	As specified in PSEL.MISO	Input	Not applicable	Emulates that the SPI slave is not selected.

Table 38: GPIO configuration before enabling peripheral

6.14.6 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
SPIS0 : S	0x50008000	US	NS	SA	No	SPI slave 0
SPIS0 : NS	0x40008000					
SPIS1 : S	0x50009000	US	NS	SA	No	SPI slave 1
SPIS1 : NS	0x40009000					
SPIS2 : S	0x5000A000	US	NS	SA	No	SPI slave 2
SPIS2 : NS	0x4000A000					
SPIS3 : S	0x5000B000	US	NS	SA	No	SPI slave 3
SPIS3 : NS	0x4000B000					

Register overview

Register	Offset	TZ	Description
TASKS_ACQUIRE	0x024		Acquire SPI semaphore
TASKS_RELEASE	0x028		Release SPI semaphore, enabling the SPI slave to acquire it
SUBSCRIBE_ACQUIRE	0x0A4		Subscribe configuration for task ACQUIRE

Register	Offset	TZ	Description
SUBSCRIBE_RELEASE	0x0A8		Subscribe configuration for task RELEASE
EVENTS_END	0x104		Granted transaction completed
EVENTS_ENDRX	0x110		End of RXD buffer reached
EVENTS_ACQUIRED	0x128		Semaphore acquired
PUBLISH_END	0x184		Publish configuration for event END
PUBLISH_ENDRX	0x190		Publish configuration for event ENDRX
PUBLISH_ACQUIRED	0x1A8		Publish configuration for event ACQUIRED
SHORTS	0x200		Shortcuts between local events and tasks
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
SEMSTAT	0x400		Semaphore status register
STATUS	0x440		Status from last transaction
ENABLE	0x500		Enable SPI slave
PSEL.SCK	0x508		Pin select for SCK
PSEL.MISO	0x50C		Pin select for MISO signal
PSEL.MOSI	0x510		Pin select for MOSI signal
PSEL.CSN	0x514		Pin select for CSN signal
RXD.PTR	0x534		RXD data pointer
RXD.MAXCNT	0x538		Maximum number of bytes in receive buffer
RXD.AMOUNT	0x53C		Number of bytes received in last granted transaction
RXD.LIST	0x540		EasyDMA list type
TXD.PTR	0x544		TXD data pointer
TXD.MAXCNT	0x548		Maximum number of bytes in transmit buffer
TXD.AMOUNT	0x54C		Number of bytes transmitted in last granted transaction
TXD.LIST	0x550		EasyDMA list type
CONFIG	0x554		Configuration register
DEF	0x55C		Default character. Character clocked out in case of an ignored transaction.
ORC	0x5C0		Over-read character

6.14.6.1 TASKS_ACQUIRE

Address offset: 0x024

Acquire SPI semaphore

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_ACQUIRE			Acquire SPI semaphore
			Trigger	1	Trigger task

6.14.6.2 TASKS_RELEASE

Address offset: 0x028

Release SPI semaphore, enabling the SPI slave to acquire it

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_RELEASE			Release SPI semaphore, enabling the SPI slave to acquire it
			Trigger	1	Trigger task

6.14.6.3 SUBSCRIBE_ACQUIRE

Address offset: 0x0A4

Subscribe configuration for task ACQUIRE

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task ACQUIRE will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.14.6.4 SUBSCRIBE_RELEASE

Address offset: 0x0A8

Subscribe configuration for task RELEASE

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task RELEASE will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.14.6.5 EVENTS_END

Address offset: 0x104

Granted transaction completed

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_END			Granted transaction completed
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.14.6.6 EVENTS_ENDRX

Address offset: 0x110

End of RXD buffer reached

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ENDRX			End of RXD buffer reached
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.14.6.7 EVENTS_ACQUIRED

Address offset: 0x128

Semaphore acquired

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ACQUIRED			Semaphore acquired
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.14.6.8 PUBLISH_END

Address offset: 0x184

Publish configuration for event END

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event END will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.14.6.9 PUBLISH_ENDRX

Address offset: 0x190

Publish configuration for event ENDRX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ENDRX will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.14.6.10 PUBLISH_ACQUIRED

Address offset: 0x1A8

Publish configuration for event ACQUIRED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ACQUIRED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.14.6.11 SHORTS

Address offset: 0x200

Shortcuts between local events and tasks

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	END_ACQUIRE			Shortcut between event END and task ACQUIRE
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut

6.14.6.12 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	END			Write '1' to enable interrupt for event END
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	ENDRX			Write '1' to enable interrupt for event ENDRX
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	ACQUIRED			Write '1' to enable interrupt for event ACQUIRED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.14.6.13 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	END			Write '1' to disable interrupt for event END
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	ENDRX			Write '1' to disable interrupt for event ENDRX
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	ACQUIRED			Write '1' to disable interrupt for event ACQUIRED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.14.6.14 SEMSTAT

Address offset: 0x400

Semaphore status register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**

ID	R/W	Field	Value ID	Value	Description
A	R	SEMSTAT			Semaphore status
			Free	0	Semaphore is free
			CPU	1	Semaphore is assigned to CPU
			SPIS	2	Semaphore is assigned to SPI slave
			CPUPending	3	Semaphore is assigned to SPI but a handover to the CPU is pending

6.14.6.15 STATUS

Address offset: 0x440

Status from last transaction

Note: Individual bits are cleared by writing a '1' to the bits that shall be cleared

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	OVERREAD			TX buffer over-read detected, and prevented
			NotPresent	0	Read: error not present
			Present	1	Read: error present
			Clear	1	Write: clear error on writing '1'
B	RW	OVERFLOW			RX buffer overflow detected, and prevented
			NotPresent	0	Read: error not present
			Present	1	Read: error present
			Clear	1	Write: clear error on writing '1'

6.14.6.16 ENABLE

Address offset: 0x500

Enable SPI slave

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ENABLE																																	
			Disabled	0																															
			Enabled	2																															

6.14.6.17 PSEL.SCK

Address offset: 0x508

Pin select for SCK

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				B																											A	A	A	A	A
Reset 0xFFFFFFFF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	PIN		[0..31]																															
B	RW	CONNECT																																	
			Disconnected	1																															
			Connected	0																															

6.14.6.18 PSEL.MISO

Address offset: 0x50C

Pin select for MISO signal

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				B																											A	A	A	A	A
Reset 0xFFFFFFFF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	PIN		[0..31]																															
B	RW	CONNECT																																	
			Disconnected	1																															
			Connected	0																															

6.14.6.19 PSEL.MOSI

Address offset: 0x510

Pin select for MOSI signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.14.6.20 PSEL.CSN

Address offset: 0x514

Pin select for CSN signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.14.6.21 RXD.PTR

Address offset: 0x534

RXD data pointer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			RXD data pointer See the Memory chapter for details about which memories are available for EasyDMA.

6.14.6.22 RXD.MAXCNT

Address offset: 0x538

Maximum number of bytes in receive buffer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in receive buffer

6.14.6.23 RXD.AMOUNT

Address offset: 0x53C

Number of bytes received in last granted transaction

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																				A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes received in the last granted transaction

6.14.6.24 RXD.LIST

Address offset: 0x540

EasyDMA list type

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																															A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	LIST			List type
			Disabled	0	Disable EasyDMA list
			ArrayList	1	Use array list

6.14.6.25 TXD.PTR

Address offset: 0x544

TXD data pointer

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			TXD data pointer See the Memory chapter for details about which memories are available for EasyDMA.

6.14.6.26 TXD.MAXCNT

Address offset: 0x548

Maximum number of bytes in transmit buffer

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																				A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in transmit buffer

6.14.6.27 TXD.AMOUNT

Address offset: 0x54C

Number of bytes transmitted in last granted transaction

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transmitted in last granted transaction

6.14.6.28 TXD.LIST

Address offset: 0x550

EasyDMA list type

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIST			List type
			Disabled	0	Disable EasyDMA list
			ArrayList	1	Use array list

6.14.6.29 CONFIG

Address offset: 0x554

Configuration register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ORDER			Bit order
			MsbFirst	0	Most significant bit shifted out first
			LsbFirst	1	Least significant bit shifted out first
B	RW	CPHA			Serial clock (SCK) phase
			Leading	0	Sample on leading edge of clock, shift serial data on trailing edge
			Trailing	1	Sample on trailing edge of clock, shift serial data on leading edge
C	RW	CPOL			Serial clock (SCK) polarity
			ActiveHigh	0	Active high
			ActiveLow	1	Active low

6.14.6.30 DEF

Address offset: 0x55C

Default character. Character clocked out in case of an ignored transaction.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	DEF			Default character. Character clocked out in case of an ignored transaction.

6.14.6.31 ORC

Address offset: 0x5C0

Over-read character

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																									A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ORC			Over-read character. Character clocked out after an over-read of the transmit buffer.

6.14.7 Electrical specification

6.14.7.1 SPIS slave interface electrical specifications

Symbol	Description	Min.	Typ.	Max.	Units
f_{SPIS}	Bit rates for SPIS[21]			8[22]	Mbps
$t_{SPIS,START}$	Time from RELEASE task to receive/transmit (CSN active)		0.125		µs

6.14.7.2 Serial Peripheral Interface Slave (SPIS) timing specifications

Symbol	Description	Min.	Typ.	Max.	Units
$t_{SPIS,CSCKIN}$	SCK input period	125			ns
$t_{SPIS,RFSCKIN}$	SCK input rise/fall time			30	ns
$t_{SPIS,WHSCKIN}$	SCK input high time	30			ns
$t_{SPIS,WLSCKIN}$	SCK input low time	30			ns
$t_{SPIS,SUCSN}$	CSN to CLK setup time	1000			ns
$t_{SPIS,HCSN}$	CLK to CSN hold time	2000			ns
$t_{SPIS,ASA}$	CSN to MISO driven	0			ns
$t_{SPIS,ASO}$	CSN to MISO valid[a]			1000	ns
$t_{SPIS,DISSO}$	CSN to MISO disabled[a]			68	ns
$t_{SPIS,CWH}$	CSN inactive time	300			ns
$t_{SPIS,VSO}$	CLK edge to MISO valid			59	ns
$t_{SPIS,HSO}$	MISO hold time after CLK edge	20[23]			ns
$t_{SPIS,SUSI}$	MOSI to CLK edge setup time	19			ns
$t_{SPIS,HSI}$	CLK edge to MOSI hold time	18			ns

21 High bit rates may require GPIOs to be set as High Drive, see GPIO chapter for more details.

22 The actual maximum data rate depends on the master's CLK to MISO and MOSI setup and hold timings.

a At 25pF load, including GPIO capacitance, see GPIO spec.

23 This is to ensure compatibility to SPI masters sampling MISO on the same edge as MOSI is output

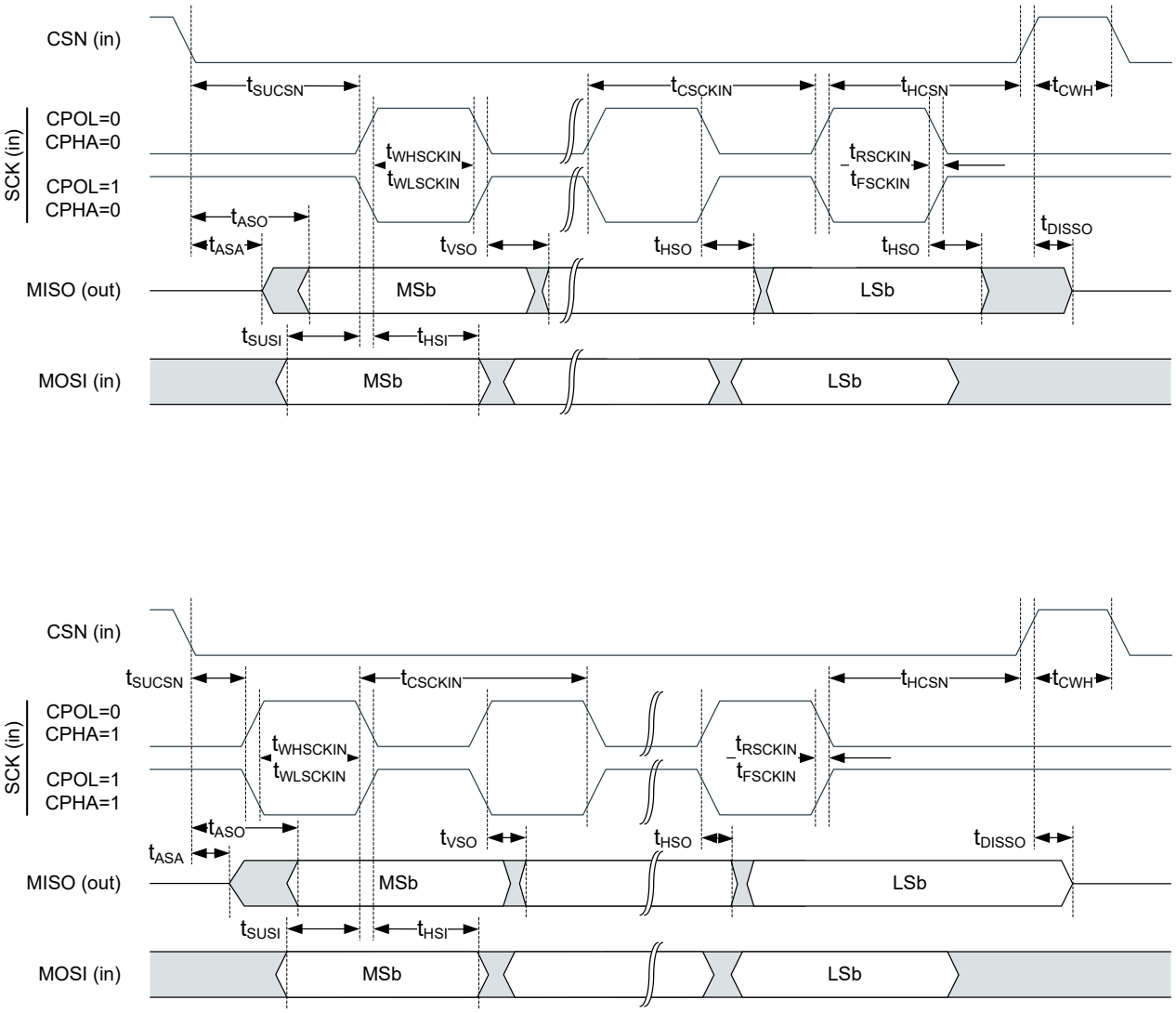

Figure 83: SPIS timing diagram

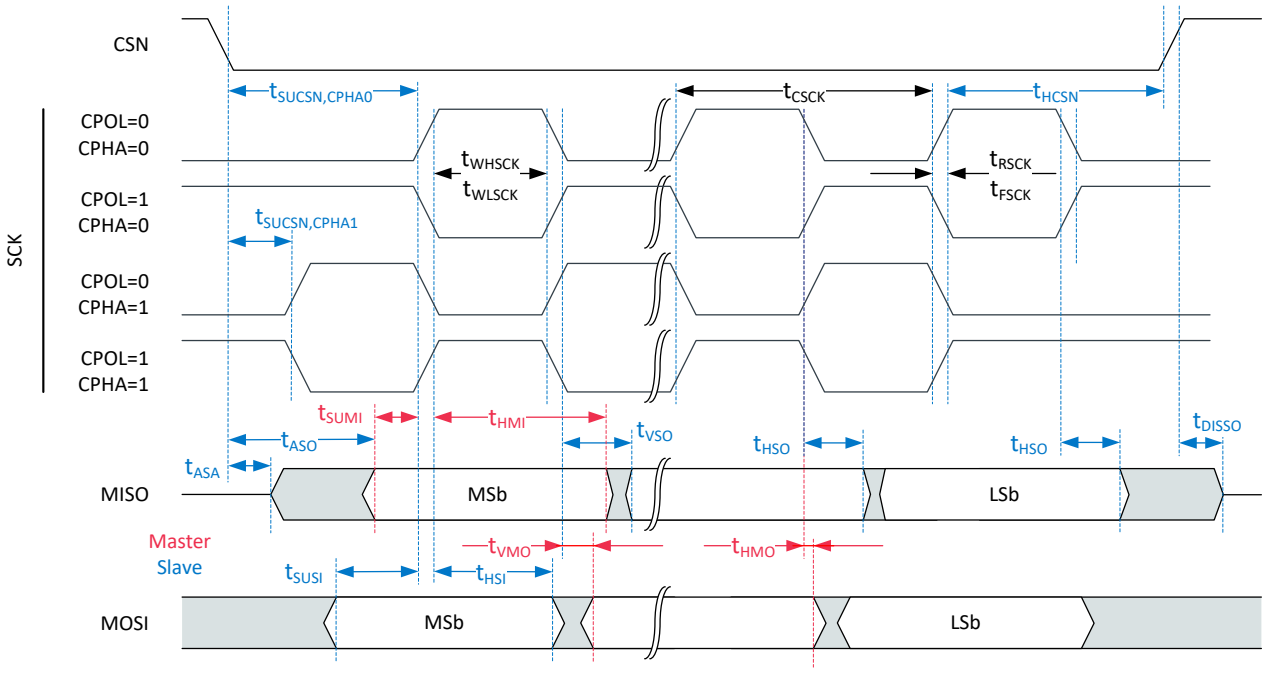

Figure 84: Common SPIM and SPIS timing diagram

6.15 SPU — System protection unit

SPU is the central point in the system to control access to memories, peripherals and other resources.

Listed here are the main features of the SPU:

- ARM TrustZone support, allowing definition of secure, non-secure and non-secure callable memory regions
- Extended ARMTrustZone, protecting memory regions and peripherals from non-CPU devices like EasyDMA transfer
- Pin access protection, preventing non-secure code and peripherals from accessing secure pin resources
- DPPI access protection, realized by preventing non-secure code and peripherals to publish from or subscribe to secured DPPI channels
- External domain access protection, controlling access rights from other MCUs

6.15.1 General concepts

SPU provides a register interface to control the various internal logic blocks that monitor access to memory-mapped slave devices (RAM, flash, peripherals, etc) and other resources (device pins, DPPI channels, etc).

For memory-mapped devices like RAM, flash and peripherals, the internal logic checks the address and attributes (e.g. read, write, execute, secure) of the incoming transfer to block it if necessary. Whether a secure resource can be accessed by a given master is defined:

For a CPU-type master

By the security state of the CPU and the security state reported by the SPU, for the address in the bus transfer

For a non-CPU master

By the security attribute of the master that initiates the transfer, defined by a SPU register

The Simplified view of the protection of RAM, flash and peripherals using SPU on page 323 shows a simplified view of the SPU registers controlling several internal modules.

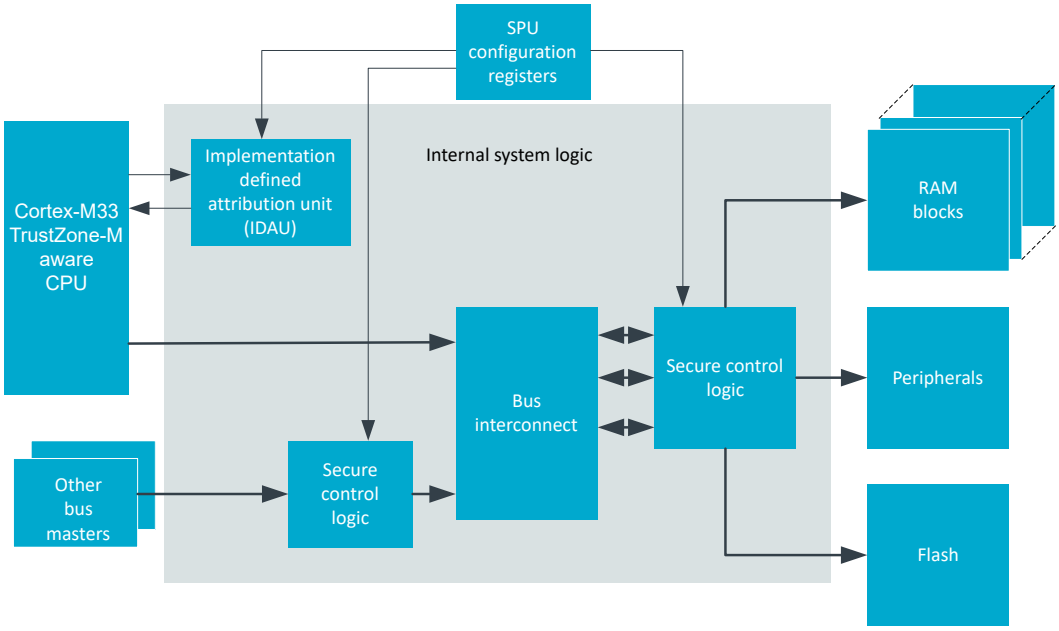

Figure 85: Simplified view of the protection of RAM, flash and peripherals using SPU

The protection logic implements a read-as-zero/write-ignore (RAZ/WI) policy:

- A blocked read operation will always return a zero value on the bus, preventing information leak
- A write operation to a forbidden region or peripheral will be ignored

An error is reported through dedicated error signals. For security state violations from an M33 master this will be a SecureFault exception, for other violations this will be an SPU event. The SPU event can be configured to generate an interrupt towards the CPU.

Other resources like pins and DPPI channels are protected by comparing the security attributes of the protected resource with the security attribute of the peripheral that wants to access it. The SPU is the only place where those security attributes can be configured.

6.15.1.1 Special considerations for ARM TrustZone for Cortex-M enabled system

For a ARM TrustZone for Cortex-M enabled CPU, the SPU also controls custom logic.

Custom logic is shown as the implementation defined attribution unit (IDAU) in figure Simplified view of the protection of RAM, flash and peripherals using SPU on page 323. Full support is provided for:

- ARM TrustZone for Cortex-M related instructions, like test target (TT) for reporting the security attributes of a region
- Non-secure callable (NSC) regions, to implement secure entry points from non-secure code

The SPU provides the necessary registers to configure the security attributes for memory regions and peripherals. However, as a requirement to use the SPU, the secure attribution unit (SAU) needs to be disabled and all memory set as non-secure in the ARM core. This will allow the SPU to control the IDAU and set the security attribution of all addresses as originally intended.

6.15.2 Flash access control

The flash memory space is divided in regions, each of them with configurable permissions settings.

The flash memory space is divided into 32 regions of 32 KiB .

For each region, four different types of permissions can be configured:

Read
Allows data read access to the region. Note that code fetch from this region is not controlled by the read permission but by the execute permission described below.

Write
Allows write or page erase access to the region

Execute
Allows code fetch from this region, even if data read is disabled

Secure
Allows only bus accesses with the security attribute set to access the region

Permissions can be set independently. For example, it is possible to configure a flash region to be accessible only through secure transfer, being read-only (no write allowed) and non-executable (no code fetch allowed). For each region, permissions can be set and then locked by using the FLASHREGION[n].PERM.LOCK bit, to prevent subsequent modifications.

Note that the debugger is able to step through execute-protected memory regions.

The following figure shows the flash memory space and the divided regions:

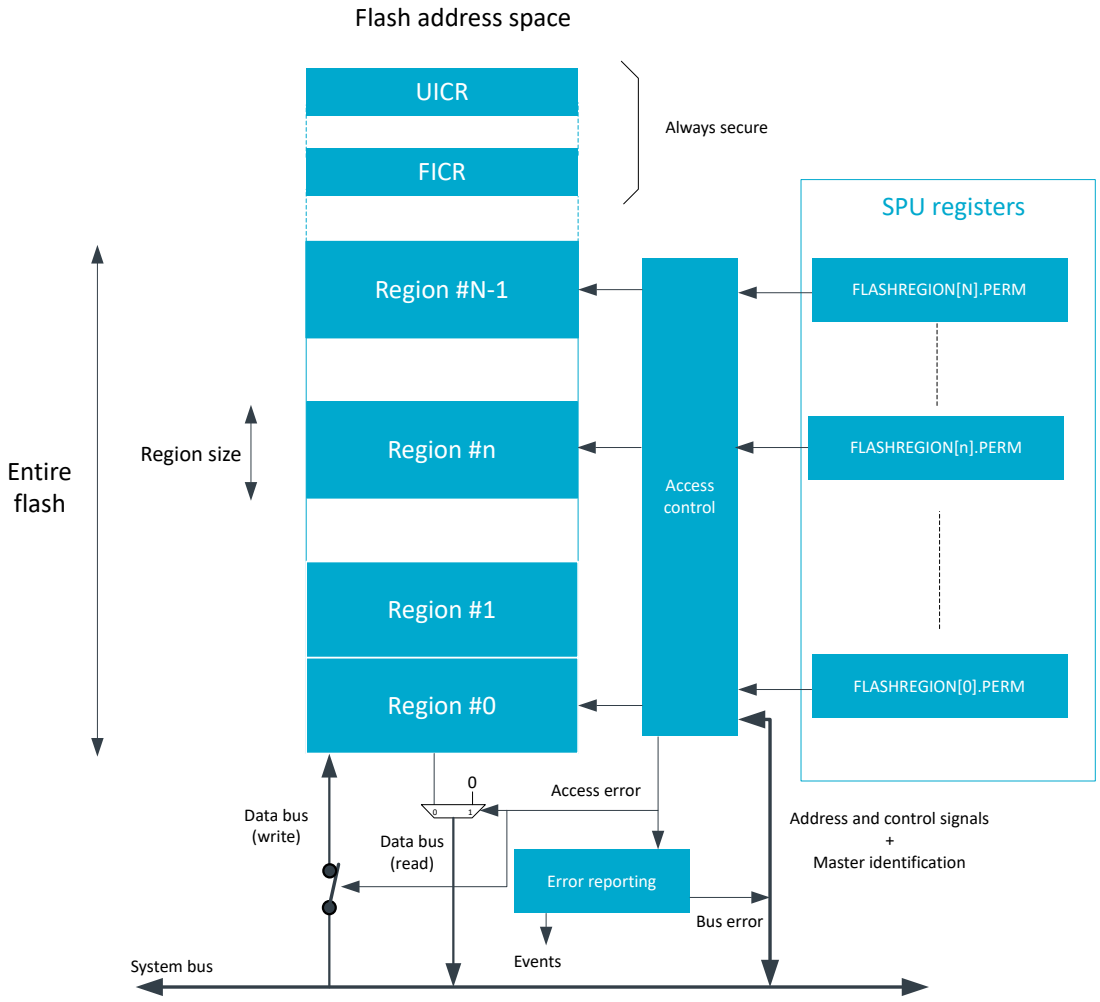

Figure 86: Definition of the N=32 regions, each of 32 KiB, in the flash memory space

6.15.2.1 Non-secure callable (NSC) region definition in flash

The SPU provides support for the definition of non-secure callable (NSC) sub-regions to allow non-secure to secure function calls.

A non-secure callable sub-region can only exist within an existing secure region and its definition is done using two registers:

- FLASHNSC[n].REGION, used to select the secure region that will contain the NSC sub-region
- FLASHNSC[n].SIZE, used to define the size of the NSC sub-region within the secure region

The NSC sub-region will be defined from the highest address in that region, going downwards. Figure below illustrates the NSC sub-regions and the registers used for their definition:

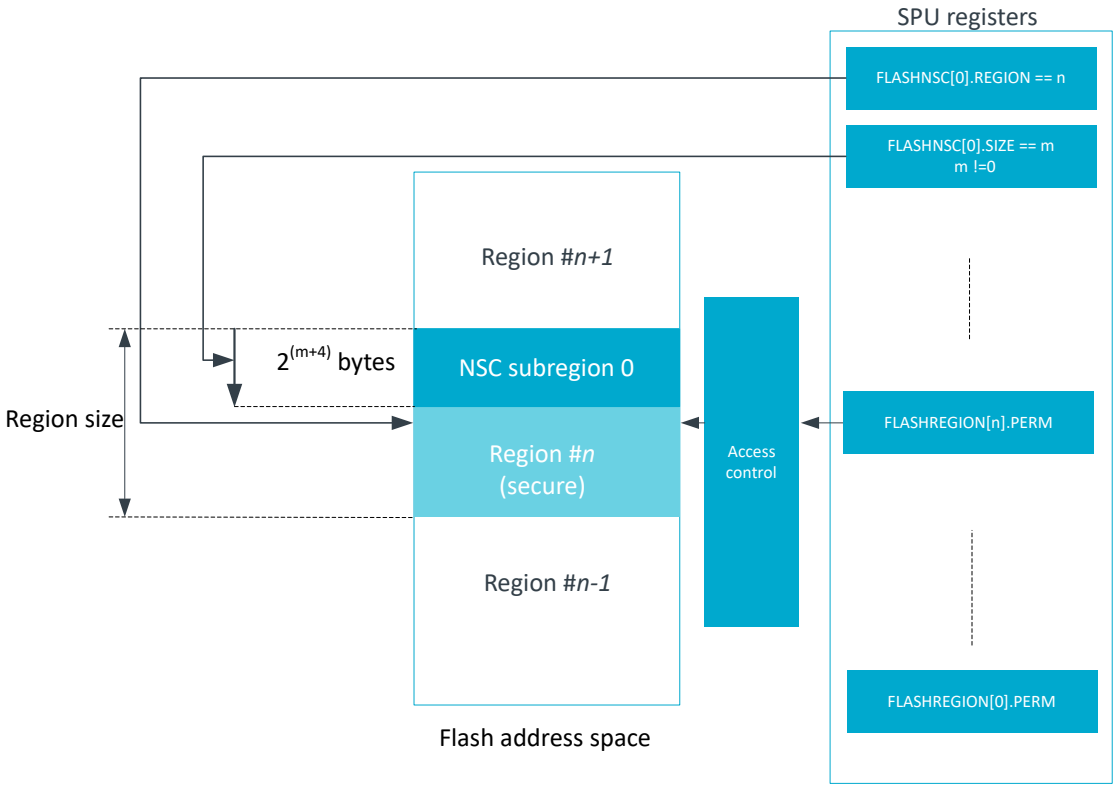

Figure 87: Non-secure callable region definition in the flash memory space

The NSC sub-region will only be defined if:

- FLASHNSC[*i*].SIZE value is non zero
- FLASHNSC[*i*].REGION defines a secure region

If FLASHNSC[*i*].REGION and FLASHNSC[*j*].REGION have the same value, there is only one sub-region defined as NSC, with the size given by the maximum of FLASHNSC[*i*].SIZE and FLASHNSC[*j*].SIZE.

If FLASHNSC[*i*].REGION defines a non-secure region, then there is no non-secure callable region defined and the selected region stays non-secure.

6.15.2.2 Flash access error reporting

The SPU and the logic controlled by it will respond with a certain behavior once an access violation is detected.

The following will happen once the logic controlled by the SPU detects an access violation on one of the flash ports:

- The faulty transfer will be blocked
- In case of a read transfer, the bus will be driven to zero
- Feedback will be sent to the master through specific bus error signals, if this is supported by the master. Moreover, the SPU will receive an event that can optionally trigger an interrupt towards the CPU.
- SecureFault exception will be triggered if security violation is detected for access from Cortex-M33
- BusFault exception will be triggered when read/write/execute protection violation is detected for Cortex-M33
- FLASHACCERR event will be triggered if any access violations are detected for all master types except for Cortex-M33 security violation

The following table summarizes the SPU behavior based on the type of initiator and access violation:

Master type	Security violation	Read/Write/Execute protection violation
Cortex-M33	SecureFault exception	BusFault exception, FLASHACCERR event
EasyDMA	RAZ/WI, FLASHACCERR event	RAZ/WI, FLASHACCERR event
Other masters	RAZ/WI, FLASHACCERR event	RAZ/WI, FLASHACCERR event

Table 39: Error reporting for flash access errors

For a Cortex-M33 master, the SecureFault exception will take precedence over the BusFault exception if a security violation occurs simultaneously with another type of violation.

6.15.2.3 UICR and FICR protections

The user information configuration registers (UICR) and factory information configuration registers (FICR) are always considered as secure. FICR registers are read-only. UICR registers can be read and written by secure code only.

Writing new values to user information configuration registers must follow the procedure described in NVMC — Non-volatile memory controller on page 29. Code execution from FICR and UICR address spaces will always be reported as access violation, an exception to this rule applies during a debug session.

6.15.3 RAM access control

The RAM memory space is divided in regions, each of them with configurable permissions settings.

The RAM memory space is divided into 32 regions of 8 KiB.

For each region, four different types of permissions can be configured:

Read
Allows data read access to the region. Code fetch from this region is not controlled by the read permission but by the execute permission described below.

Write
Allows write access to the region

Execute
Allows code fetch from this region

Secure
Allows only bus accesses with the security attribute set to access the region

Permissions can be set independently. For example, it is possible to configure a RAM region to be accessible only through secure transfer, being read-only (no write allowed) and non-executable (no code fetch allowed). For each region, permissions can be set and then locked to prevent subsequent modifications by using the RAMREGION[n].PERM.LOCK bit.

The following figure shows the RAM memory space and the devided regions:

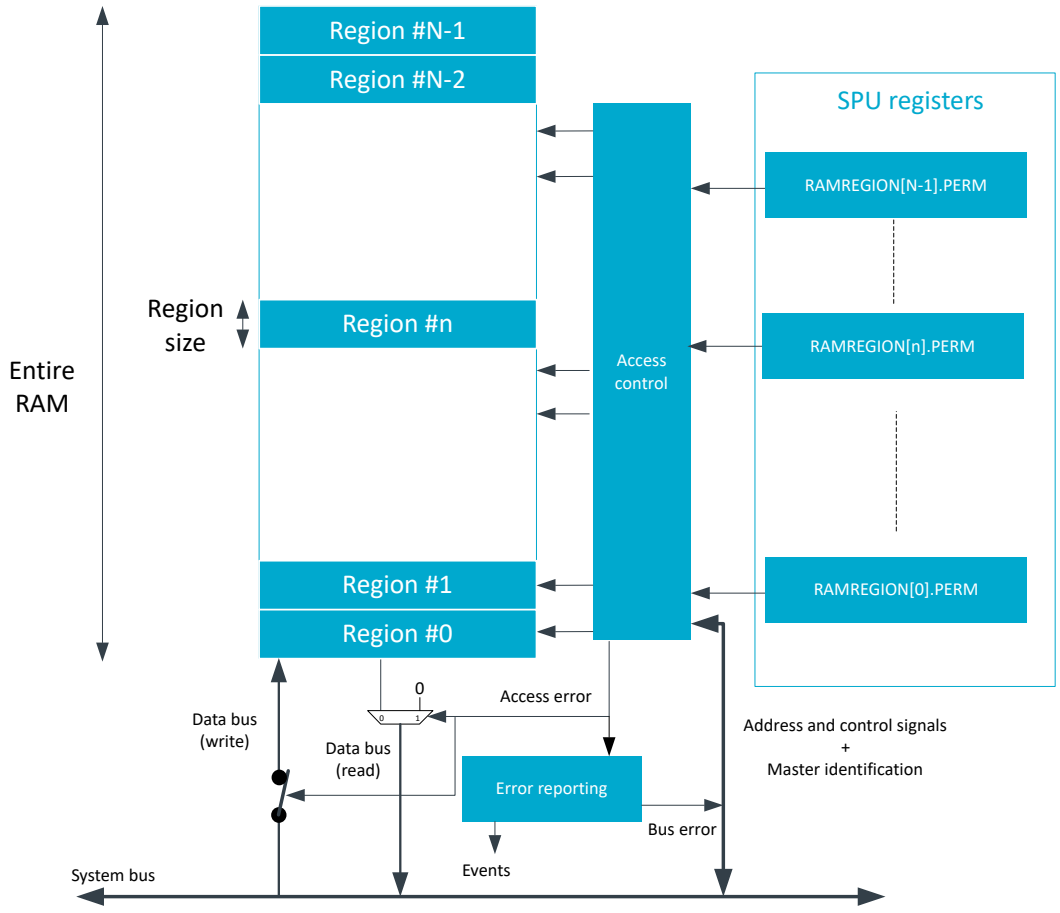

Figure 88: Definition of the N=32 regions, each of 8 KiB, in the RAM memory space

6.15.3.1 Non-secure callable (NSC) region definition in RAM

The SPU provides support for the definition of non-secure callable (NSC) sub-regions to allow non-secure to secure function calls.

A non-secure callable sub-region can only exist within an existing secure region and its definition is done using two registers:

- RAMNSC[n].REGION, used to select the secure region that will contain the NSC sub-region
- RAMNSC[n].SIZE, used to define the size of the NSC sub-region within the secure region

The NSC sub-region will be defined from the highest address in that region, going downwards. Figure below illustrates the NSC sub-regions and the registers used for their definition:

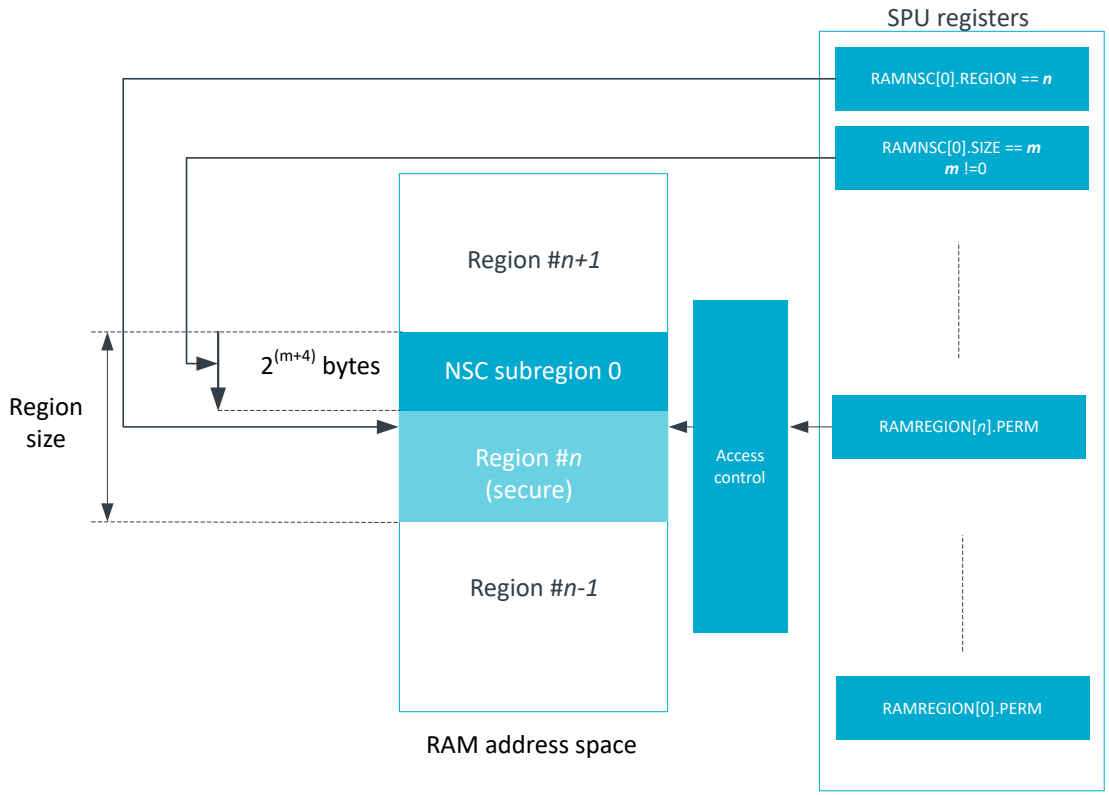

Figure 89: Non-secure callable region definition in the RAM memory space

The NSC sub-region will only be defined if:

- RAMNSC[*i*].SIZE value is non zero
- RAMNSC[*i*].REGION defines a secure region

If RAMNSC[*i*].REGION and RAMNSC[*j*].REGION have the same value, there is only one sub-region defined as NSC, with the size given by the maximum of RAMNSC[*i*].SIZE and RAMNSC[*j*].SIZE.

If RAMNSC[*i*].REGION defines a non-secure region, then there is no non-secure callable region defined and the selected region stays non-secure.

6.15.3.2 RAM access error reporting

The SPU and the logic controlled by it will respond with a certain behavior once an access violation is detected.

The following will happen once the logic controlled by the SPU detects an access violation on one of the RAM ports:

- The faulty transfer will be blocked
- In case of a read transfer, the bus will be driven to zero
- Feedback will be sent to the master through specific bus error signals, if this is supported by the master
- SecureFault exception will be triggered if security violation is detected for access from Cortex-M33
- BusFault exception will be triggered when read/write/execute protection violation is detected for Cortex-M33. The SPU will also generate an event that can optionally trigger an interrupt towards the CPU.
- RAMACCERR event will be triggered if any access violations are detected for all master types but for Cortex-M33 security violation

The following table summarizes the SPU behavior based on the type of initiator and access violation:

Master type	Security violation	Read/Write/Execute protection violation
Cortex-M33	SecureFault exception	BusFault exception, RAMACCERR event
EasyDMA	RAZ/WI, RAMACCERR event	RAZ/WI, RAMACCERR event
Other masters	RAZ/WI, RAMACCERR event	RAZ/WI, RAMACCERR event

Table 40: Error reporting for RAM access errors

For a Cortex-M33 master, the SecureFault exception will take precedence over the BusFault exception if a security violation occurs simultaneously with another type of violation.

6.15.4 Peripheral access control

Access controls are defined by the characteristics of the peripheral.

Peripherals can have their security attribute set as:

Always secure
For a peripheral related to system control

Always non-secure
For some general-purpose peripherals

Configurable
For general-purpose peripherals that may be configured for secure only access

The full list of peripherals and their corresponding security attributes can be found in Memory map on page 23. For each peripheral with ID *n*, PERIPHID[*n*]. PERM will show whether the security attribute for this peripheral is configurable or not.

If not hardcoded, the security attribute can configured using the PERIPHID[*id*].PERM.

At reset, all user-selectable and split security peripherals are set to be secure, with secure DMA where present.

Secure code can access both secure peripherals and non-secure peripherals.

6.15.4.1 Peripherals with split security

Peripherals with split security are defined to handle use-cases when both secure and non-secure code needs to control the same resource.

When peripherals with split security have their security attribute set to non-secure, access to specific registers and bitfields within some registers is dependent on the security attribute of the bus transfer. For example, some registers will not be accessible for a non-secure transfer.

When peripherals with split security have their security attribute set to secure, then only secure transfers can access their registers.

See Instantiation on page 25 for an overview of split security peripherals. Respective peripheral chapters explain the specific security behavior of each peripheral.

6.15.4.2 Peripheral address mapping

Peripherals that have non-secure security mapping have their address starting with 0x4XXX_XXXX. Peripherals that have secure security mapping have their address starting with 0x5XXX_XXXX.

Peripherals with a user-selectable security mapping are available at an address starting with:

- 0x4XXX_XXXX, if the peripheral security attribute is set to non-secure
- 0x5XXX_XXXX, if the peripheral security attribute is set to secure

Note: Accesses to the 0x4XXX_XXXX address range from secure or non-secure code for a peripheral marked as secure will result in a bus-error.

Secure code accessing the 0x5XXX_XXXX address range of a peripheral marked as non-secure will also result in a bus-error.

Peripherals with a split security mapping are available at an address starting with:

- 0x4XXX_XXXX for non-secure access and 0x5XXX_XXXX for secure access, if the peripheral security attribute is set to non-secure
  - Secure registers in the 0x4XXX_XXXX range are not visible for secure or non-secure code, and an attempt to access such a register will result in write-ignore, read-as-zero behavior
  - Secure code can access both non-secure and secure registers in the 0x5XXX_XXXX range
- 0x5XXX_XXXX, if the peripheral security attribute is set to secure

Any attempt to access the 0x5000_0000-0x5FFF_FFFF address range from non-secure code will be ignored and generate a SecureFault exception.

The table below illustrates the address mapping for the three peripheral types, in all possible configurations

Security-features and configuration	Is mapped at 0x4XXX_XXXX?	Is mapped at 0x5XXX_XXXX?
Secure peripheral	No	Yes
Non-secure peripheral	Yes	No
Split-security peripheral, with attribute=secure	No	Yes
Split-security peripheral, with attribute=non-secure	Yes, restricted functionality	Yes

Table 41: Peripheral's address mapping in relation to its security-features and configuration

6.15.4.3 Special considerations for peripherals with DMA master

Peripherals containing a DMA master can be configured so the security attribute of the DMA transfers is different from the security attribute of the peripheral itself. This allows a secure peripheral to do non-secure data transfers to or from the system memories.

The following conditions must be met:

- The DMA field of PERIPHID[n].PERM.SECURITYMAPPING should read as "SeparateAttribute"
- The peripheral itself should be secure (PERIPHID[n].PERM.SECATTR == 1)

Then it is possible to select the security attribute of the DMA transfers using the field DMASEC (PERIPHID[n].PERM.DMASEC == Secure and PERIPHID[n].PERM.DMASEC == NonSecure) in PERIPHID[n].PERM.

6.15.4.4 Peripheral access error reporting

Peripherals send error reports once access violation is detected.

The following will happen if the logic controlled by the SPU detects an access violation on one of the peripherals:

- The faulty transfer will be blocked
- In case of a read transfer, the bus will be driven to zero
- Feedback is sent to the master through specific bus error signals, if this is supported by the master. If the master is a processor supporting ARM TrustZone for Cortex-M, a SecureFault exception will be generated for security related errors.
- The PERIPHACCERR event will be triggered

6.15.5 Pin access control

Access to device pins can be controlled by the SPU. A pin can be declared as secure so that only secure peripherals or secure code can access it. Pins declared as non-secure can be accessed by both secure and non-secure peripherals or code.

The security attribute of each pin can be individually configured in SPU's GPIOPORT[n].PERM register. When the secure attribute is set for a pin, only peripherals that have the secure attribute set will be able to read the value of the pin or change it.

Peripherals can select the pin(s) they need access to through their PSEL register(s). If a peripheral has its attribute set to non-secure, but one of its PSEL registers selects a pin with the attribute set to secure, the SPU controlled logic will ensure that the pin selection is not propagated. In addition, the pin value will always be read as zero, to prevent a non-secure peripheral from obtaining a value from a secure pin. Whereas access to other pins with attribute set as non-secure will not be blocked.

Pins can be assigned to other domains than the application domain by changing the MCUSEL value in the GPIO PIN_CNF[n] register. Domains that do not have a pin assigned to them can neither control that pin nor read its status. Any pin configuration set in a domain that doesn't have ownership of that pin will not take effect until the MCUSEL is updated to assign that pin to the domain. Within each domain, pin access is controlled by that domain's local security configuration and peripheral PSEL registers. This is illustrated in the following figure:

Note: The SPU setting will still count when the APP domain accesses its local GPIO peripheral, as local registers are still writable even though MCUSEL is set to a different domain. Any changes in the APP GPIO peripheral done to a GPIO controlled by another domain will not affect the GPIO pad until MCUSEL is changed to APP.

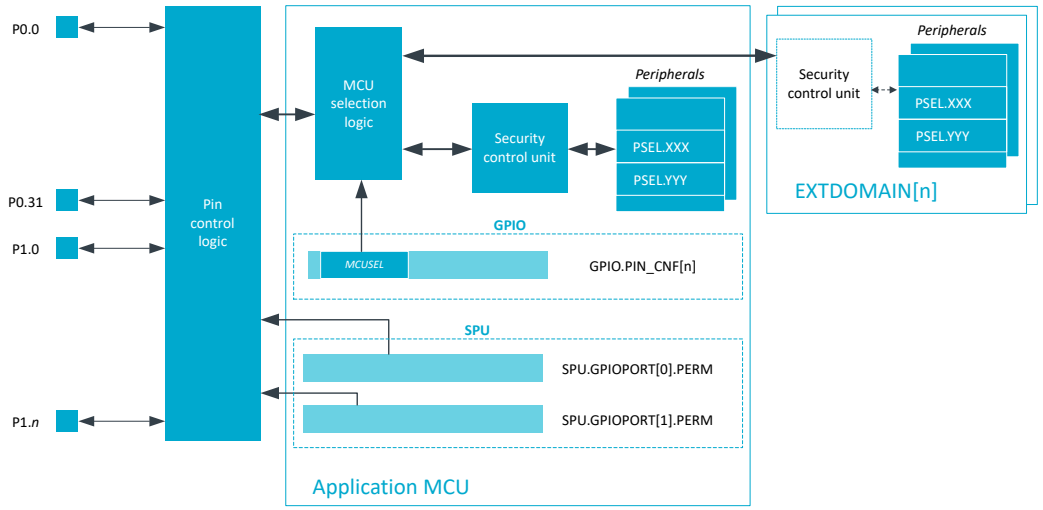

Figure 90: Pin access for domains other than the application domain

6.15.6 DPPI access control

Access to DPPI channels can be restricted. A channel can be declared as secure so that only secure peripherals can access it.

The security attribute of a DPPI channel is configured in DPPI[n].PERM (n=0..0) on page 340. When the secure attribute is set for a channel, only peripherals that have the secure attribute set will be able to publish events to this channel or subscribe to this channel to receive tasks.

The DPPI controller peripheral (DPPIC) is a split security peripheral, i.e., its security behavior depends on the security attributes of both the DPPIC and the accessing party. See Special considerations regarding the DPPIC configuration registers on page 333 for more information about the DPPIC security behavior.

If a non-secure peripheral wants to publish an event on a secure DPPI channel, the channel will ignore the event. If a non-secure peripheral subscribes to a secure DPPI channel, it will not receive any events from this channel. The following figure illustrates the principle of operation of the security logic for a subscribed channel:

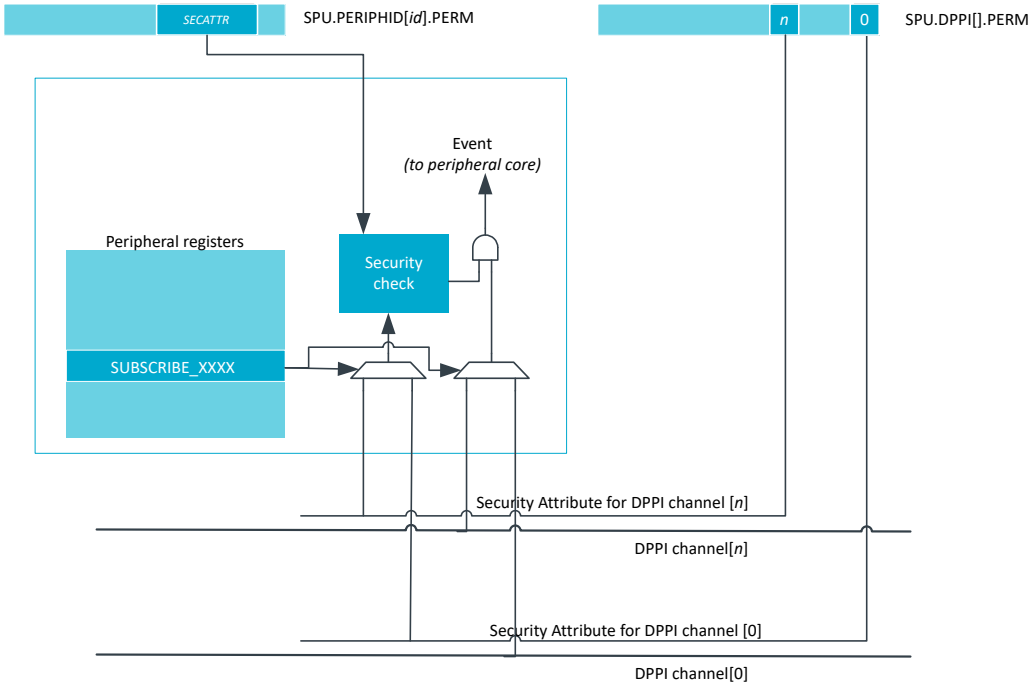

Figure 91: Subscribed channel security concept

No error reporting mechanism is associated with the DPPI access control logic.

6.15.6.1 Special considerations regarding the DPPIC configuration registers

DPPI channels can be enabled, disabled and grouped through the DPPI controller (DPPIC). The DPPIC is a split-security peripheral, and handles both secure and non-secure accesses.

A non-secure peripheral access will only be able to configure and control DPPI channels defined as non-secure in SPU's DPPI[n].PERM register(s). A secure peripheral access can control all DPPI channels, independently of the configuration in the DPPI[n].PERM register(s).

The DPPIC allows the creation of group of channels to be able to enable or disable all channels within a group simultaneously. The security attribute of a group of channels (secure or non-secure) is defined as follows:

- If all channels (enabled or not) in the group are non-secure, then the group is considered non-secure
- If at least one of the channels (enabled or not) in the group is secure, then the group is considered secure

A non-secure access to a DPPIC register, or a bitfield controlling a channel marked as secure in DPPI[n].PERM register(s), will be ignored:

- Write accesses will have no effect
- Read will always return a zero value

No exceptions are thrown when a non-secure access targets a register or bitfield controlling a secure channel. For example, if the bit *i* is set in the DPPI[n].PERM register (declaring the DPPI channel *i* as secure), then:

- Non-secure write accesses to registers CHEN, CHENSET and CHENCLR will not be able to write to bit *i* of those registers
- Non-secure write accesses to registers TASK_CHG[*j*].EN and TASK_CHG[*j*].DIS will be ignored if the channel group *j* contains at least one channel defined as secure (it can be the channel *i* itself or any channel declared as secured)
- Non-secure read accesses to registers CHEN, CHENSET and CHENCLR will always read zero for the bit at position *i*

For the channel configuration registers (DPPIC.CHG[n]), access from non-secure code is only possible if the included channels are all non-secure, whether the channels are enabled or not. If a DPPIC.CHG[*g*] register included one or more secure channels, then the group *g*is considered as secure and only a secure transfer can read or write DPPIC.CHG[*g*]. A non-secure write will be ignored and a non-secure read will return zero.

The DPPIC can subscribe to secure or non-secure channels through SUBSCRIBE_CHG[n] registers in order to trigger task for enabling or disabling groups of channels. But an event from a non-secure channel will be ignored if the group subscribing to this channel is secure. An event from a secure channel can trigger both secure and non-secure tasks.

6.15.7 External domain access control

Other domains with their own CPUs can access peripherals, flash, and RAM memories. The SPU allows controlling accesses from those bus masters.

The external domains can access application MCU memories and peripherals. External domains are assigned security attributes as described in register EXTDOMAIN[n].PERM.

Domain	Capability register	Permission register
LTE modem	Modem is always a non-secure domain	Not applicable

Table 42: Register mapping for external domains

The figure below illustrates how the security control units are used to assign security attributes to transfers initiated by the external domains:

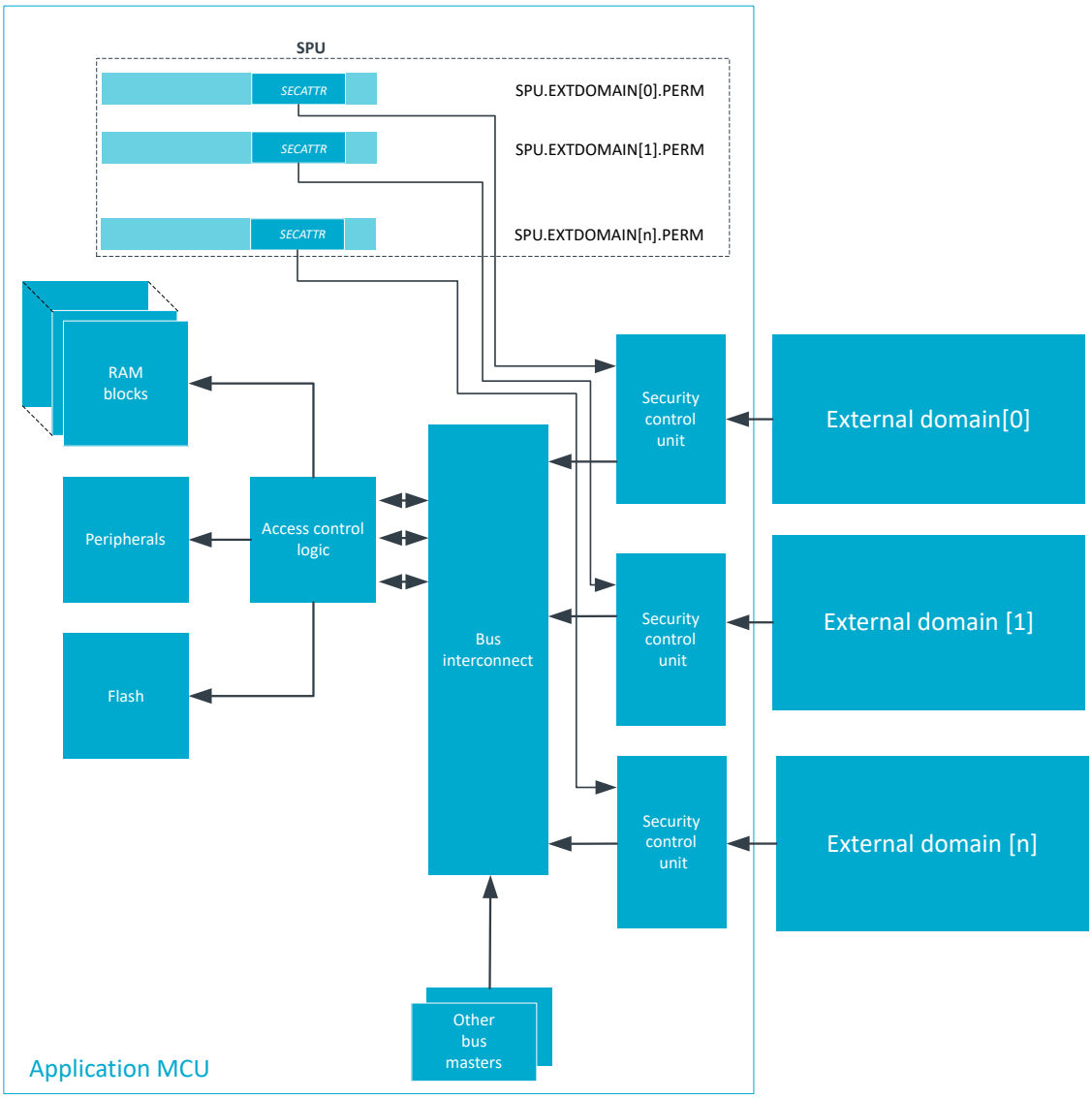

Figure 92: Access control from external domains

6.15.8 TrustZone for Cortex-M ID allocation

Flash and RAM regions, as well as non-secure and secure peripherals, are assigned unique TrustZone IDs.

> **Note:** TrustZone ID should not be confounded with the peripheral ID used to identify peripherals.

The table below shows the TrustZone ID allocation:

Regions	TrustZone Cortex-M ID
Flash regions 0..31	0..31
RAM regions 0..15	64..79
Non-secure peripherals	253
Secure peripherals	254

Table 43: TrustZone ID allocation

6.15.9 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
SPU	0x50003000	HF	S	NA	No	System Protection Unit

Register overview

Register	Offset	TZ	Description
EVENTS_RAMACCERR	0x100		A security violation has been detected for the RAM memory space
EVENTS_FLASHACCERR	0x104		A security violation has been detected for the flash memory space
EVENTS_PERIPHACCERR	0x108		A security violation has been detected on one or several peripherals
PUBLISH_RAMACCERR	0x180		Publish configuration for event RAMACCERR
PUBLISH_FLASHACCERR	0x184		Publish configuration for event FLASHACCERR
PUBLISH_PERIPHACCERR	0x188		Publish configuration for event PERIPHACCERR
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
CAP	0x400		Show implemented features for the current device
EXTDOMAIN[n].PERM	0x440		Access for bus access generated from the external domain n List capabilities of the external domain n
DPPI[n].PERM	0x480		Select between secure and non-secure attribute for the DPPI channels.
DPPI[n].LOCK	0x484		Prevent further modification of the corresponding PERM register
GPIOPORT[n].PERM	0x4C0		Select between secure and non-secure attribute for pins 0 to 31 of port n. This register is retained.
GPIOPORT[n].LOCK	0x4C4		Prevent further modification of the corresponding PERM register
FLASHNSC[n].REGION	0x500		Define which flash region can contain the non-secure callable (NSC) region n
FLASHNSC[n].SIZE	0x504		Define the size of the non-secure callable (NSC) region n
RAMNSC[n].REGION	0x540		Define which RAM region can contain the non-secure callable (NSC) region n
RAMNSC[n].SIZE	0x544		Define the size of the non-secure callable (NSC) region n
FLASHREGION[n].PERM	0x600		Access permissions for flash region n
RAMREGION[n].PERM	0x700		Access permissions for RAM region n
PERIPHID[n].PERM	0x800		List capabilities and access permissions for the peripheral with ID n

6.15.9.1 EVENTS_RAMACCERR

Address offset: 0x100

A security violation has been detected for the RAM memory space

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RAMACCERR			A security violation has been detected for the RAM memory space
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.15.9.2 EVENTS_FLASHACCERR

Address offset: 0x104

A security violation has been detected for the flash memory space

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_FLASHACCERR			A security violation has been detected for the flash memory space
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.15.9.3 EVENTS_PERIPHACCERR

Address offset: 0x108

A security violation has been detected on one or several peripherals

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_PERIPHACCERR			A security violation has been detected on one or several peripherals
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.15.9.4 PUBLISH_RAMACCERR

Address offset: 0x180

Publish configuration for event RAMACCERR

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					B A A A A A A A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event RAMACCERR will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.15.9.5 PUBLISH_FLASHACCERR

Address offset: 0x184

Publish configuration for event FLASHACCERR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event FLASHACCERR will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.15.9.6 PUBLISH_PERIPHACCERR

Address offset: 0x188

Publish configuration for event PERIPHACCERR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event PERIPHACCERR will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.15.9.7 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RAMACCERR			Enable or disable interrupt for event RAMACCERR
			Disabled	0	Disable
			Enabled	1	Enable
B	RW	FLASHACCERR			Enable or disable interrupt for event FLASHACCERR
			Disabled	0	Disable
			Enabled	1	Enable
C	RW	PERIPHACCERR			Enable or disable interrupt for event PERIPHACCERR
			Disabled	0	Disable
			Enabled	1	Enable

6.15.9.8 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	RAMACCERR			Write '1' to enable interrupt for event RAMACCERR
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	FLASHACCERR			Write '1' to enable interrupt for event FLASHACCERR
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	PERIPHACCERR			Write '1' to enable interrupt for event PERIPHACCERR
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.15.9.9 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	RAMACCERR			Write '1' to disable interrupt for event RAMACCERR
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	FLASHACCERR			Write '1' to disable interrupt for event FLASHACCERR
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	PERIPHACCERR			Write '1' to disable interrupt for event PERIPHACCERR
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.15.9.10 CAP

Address offset: 0x400

Show implemented features for the current device

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**

ID	R/W	Field	Value ID	Value	Description
A	R	TZM			Show ARM TrustZone status
			NotAvailable	0	ARM TrustZone support not available
			Enabled	1	ARM TrustZone support is available

6.15.9.11 EXTDOMAIN[n].PERM (n=0..0)

Address offset: 0x440 + (n × 0x4)

Access for bus access generated from the external domain n

List capabilities of the external domain n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	SECUREMAPPING			Define configuration capabilities for TrustZone Cortex-M secure attribute
					Note: This does not affect DPPI in the external domain
			NonSecure	0	The bus access from this external domain always have the non-secure attribute set
			Secure	1	The bus access from this external domain always have the secure attribute set
			UserSelectable	2	Non-secure or secure attribute for bus access from this domain is defined by the EXTDOMAIN[n].PERM register
B	RW	SECATTR			Peripheral security mapping
					Note: This bit has effect only if EXTDOMAIN[n].PERM.SECUREMAPPING reads as UserSelectable
			NonSecure	0	Bus accesses from this domain have the non-secure attribute set
			Secure	1	Bus accesses from this domain have secure attribute set
C	RW	LOCK			
			Unlocked	0	This register can be updated
			Locked	1	The content of this register can't be changed until the next reset

6.15.9.12 DPPI[n].PERM (n=0..0)

Address offset: 0x480 + (n × 0x8)

Select between secure and non-secure attribute for the DPPI channels.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x0000FFFF				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**

ID	R/W	Field	Value ID	Value	Description
A-P	RW	CHANNEL[i] (i=0..15)			Select secure attribute.
			Secure	1	Channeli has its secure attribute set
			NonSecure	0	Channeli has its non-secure attribute set

6.15.9.13 DPPI[n].LOCK (n=0..0)

Address offset: 0x484 + (n × 0x8)

Prevent further modification of the corresponding PERM register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LOCK			
			Locked	1	DPPI[n].PERM register can't be changed until next reset
			Unlocked	0	DPPI[n].PERM register content can be changed

6.15.9.14 GPIOPORT[n].PERM (n=0..0) (Retained)

Address offset: 0x4C0 + (n × 0x8)

Select between secure and non-secure attribute for pins 0 to 31 of port n.

This register is retained.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				f e d c b a Z Y X W V U T S R Q P O N M L K J I H G F E D C B A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A-f	RW	PIN[i] (i=0..31)			Select secure attribute attribute for PIN i.
			Secure	1	Pin i has its secure attribute set
			NonSecure	0	Pin i has its non-secure attribute set

6.15.9.15 GPIOPORT[n].LOCK (n=0..0)

Address offset: 0x4C4 + (n × 0x8)

Prevent further modification of the corresponding PERM register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LOCK			
			Locked	1	GPIOPORT[n].PERM register can't be changed until next reset
			Unlocked	0	GPIOPORT[n].PERM register content can be changed

6.15.9.16 FLASHNSC[n].REGION (n=0..1)

Address offset: 0x500 + (n × 0x8)

Define which flash region can contain the non-secure callable (NSC) region n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-	RW	REGION			Region number
B	RW	LOCK			
			Unlocked	0	This register can be updated
			Locked	1	The content of this register can't be changed until the next reset

6.15.9.17 FLASHNSC[n].SIZE (n=0..1)

Address offset: 0x504 + (n × 0x8)

Define the size of the non-secure callable (NSC) region n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	SIZE			Size of the non-secure callable (NSC) region n
			Disabled	0	The region n is not defined as a non-secure callable region. Normal security attributes (secure or non-secure) are enforced.
			32	1	The region n is defined as non-secure callable with a 32-byte size
			64	2	The region n is defined as non-secure callable with a 64-byte size
			128	3	The region n is defined as non-secure callable with a 128-byte size
			256	4	The region n is defined as non-secure callable with a 256-byte size
			512	5	The region n is defined as non-secure callable with a 512-byte size
			1024	6	The region n is defined as non-secure callable with a 1024-byte size
			2048	7	The region n is defined as non-secure callable with a 2048-byte size
			4096	8	The region n is defined as non-secure callable with a 4096-byte size
B	RW	LOCK			
			Unlocked	0	This register can be updated
			Locked	1	The content of this register can't be changed until the next reset

6.15.9.18 RAMNSC[n].REGION (n=0..1)

Address offset: 0x540 + (n × 0x8)

Define which RAM region can contain the non-secure callable (NSC) region n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-	RW	REGION			Region number
B	RW	LOCK			
			Unlocked	0	This register can be updated
			Locked	1	The content of this register can't be changed until the next reset

6.15.9.19 RAMNSC[n].SIZE (n=0..1)

Address offset: 0x544 + (n × 0x8)

Define the size of the non-secure callable (NSC) region n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	SIZE			Size of the non-secure callable (NSC) region n
			Disabled	0	The region n is not defined as a non-secure callable region. Normal security attributes (secure or non-secure) are enforced.
			32	1	The region n is defined as non-secure callable with a 32-byte size
			64	2	The region n is defined as non-secure callable with a 64-byte size
			128	3	The region n is defined as non-secure callable with a 128-byte size
			256	4	The region n is defined as non-secure callable with a 256-byte size
			512	5	The region n is defined as non-secure callable with a 512-byte size

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			1024	6	The region n is defined as non-secure callable with a 1024-byte size
			2048	7	The region n is defined as non-secure callable with a 2048-byte size
			4096	8	The region n is defined as non-secure callable with a 4096-byte size
B	RW	LOCK			
			Unlocked	0	This register can be updated
			Locked	1	The content of this register can't be changed until the next reset

6.15.9.20 FLASHREGION[n].PERM (n=0..31)

Address offset: 0x600 + (n × 0x4)

Access permissions for flash region n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000017				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	EXECUTE			Configure instruction fetch permissions from flash region n
			Enable	1	Allow instruction fetches from flash region n
			Disable	0	Block instruction fetches from flash region n
B	RW	WRITE			Configure write permission for flash region n
			Enable	1	Allow write operation to region n
			Disable	0	Block write operation to region n
C	RW	READ			Configure read permissions for flash region n
			Enable	1	Allow read operation from flash region n
			Disable	0	Block read operation from flash region n
D	RW	SECATTR			Security attribute for flash region n
			Non_Secure	0	Flash region n security attribute is non-secure
			Secure	1	Flash region n security attribute is secure
E	RW	LOCK			
			Unlocked	0	This register can be updated
			Locked	1	The content of this register can't be changed until the next reset

6.15.9.21 RAMREGION[n].PERM (n=0..31)

Address offset: 0x700 + (n × 0x4)

Access permissions for RAM region n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000017				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	EXECUTE			Configure instruction fetch permissions from RAM region n
			Enable	1	Allow instruction fetches from RAM region n
			Disable	0	Block instruction fetches from RAM region n
B	RW	WRITE			Configure write permission for RAM region n
			Enable	1	Allow write operation to RAM region n
			Disable	0	Block write operation to RAM region n
C	RW	READ			Configure read permissions for RAM region n
			Enable	1	Allow read operation from RAM region n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000017				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1**
ID	R/W	Field	Value ID	Value	Description
			Disable	0	Block read operation from RAM region n
D	RW	SECATTR			Security attribute for RAM region n
			Non_Secure	0	RAM region n security attribute is non-secure
			Secure	1	RAM region n security attribute is secure
E	RW	LOCK			
			Unlocked	0	This register can be updated
			Locked	1	The content of this register can't be changed until the next reset

6.15.9.22 PERIPHID[n].PERM (n=0..66)

Address offset: 0x800 + (n × 0x4)

List capabilities and access permissions for the peripheral with ID n

Note: Reset values are unique per peripheral instantiation. Please refer to the peripheral instantiation table. Entries not listed in the instantiation table are undefined.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B B A A
Reset 0x00000012				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0**
ID	R/W	Field	Value ID	Value	Description
A	R	SECUREMAPPING			Define configuration capabilities for TrustZone Cortex-M secure attribute
			NonSecure	0	This peripheral is always accessible as a non-secure peripheral
			Secure	1	This peripheral is always accessible as a secure peripheral
			UserSelectable	2	Non-secure or secure attribute for this peripheral is defined by the PERIPHID[n].PERM register
			Split	3	This peripheral implements the split security mechanism. Non-secure or secure attribute for this peripheral is defined by the PERIPHID[n].PERM register.
B	R	DMA			Indicate if the peripheral has DMA capabilities and if DMA transfer can be assigned to a different security attribute than the peripheral itself
			NoDMA	0	Peripheral has no DMA capability
			NoSeparateAttribute	1	Peripheral has DMA and DMA transfers always have the same security attribute as assigned to the peripheral
			SeparateAttribute	2	Peripheral has DMA and DMA transfers can have a different security attribute than the one assigned to the peripheral
C	RW	SECATTR			Peripheral security mapping **Note:** This bit has effect only if PERIPHID[n].PERM.SECUREMAPPING reads as UserSelectable or Split
			Secure	1	Peripheral is mapped in secure peripheral address space
			NonSecure	0	If SECUREMAPPING == UserSelectable: Peripheral is mapped in non-secure peripheral address space. If SECUREMAPPING == Split: Peripheral is mapped in non-secure and secure peripheral address space.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B B A A
Reset 0x00000012				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0**
ID	R/W	Field	Value ID	Value	Description
D	RW	DMASEC			Security attribution for the DMA transfer
					Note: This bit has effect only if PERIPHID[n].PERM.SECATTR is set to secure
			Secure	1	DMA transfers initiated by this peripheral have the secure attribute set
			NonSecure	0	DMA transfers initiated by this peripheral have the non-secure attribute set
E	RW	LOCK			
			Unlocked	0	This register can be updated
			Locked	1	The content of this register can't be changed until the next reset
F	R	PRESENT			Indicate if a peripheral is present with ID n
			NotPresent	0	Peripheral is not present
			IsPresent	1	Peripheral is present

6.16 TIMER — Timer/counter

This peripheral is a general purpose timer designed to keep track of time in user-selective time intervals, it can operate in two modes: timer and counter.

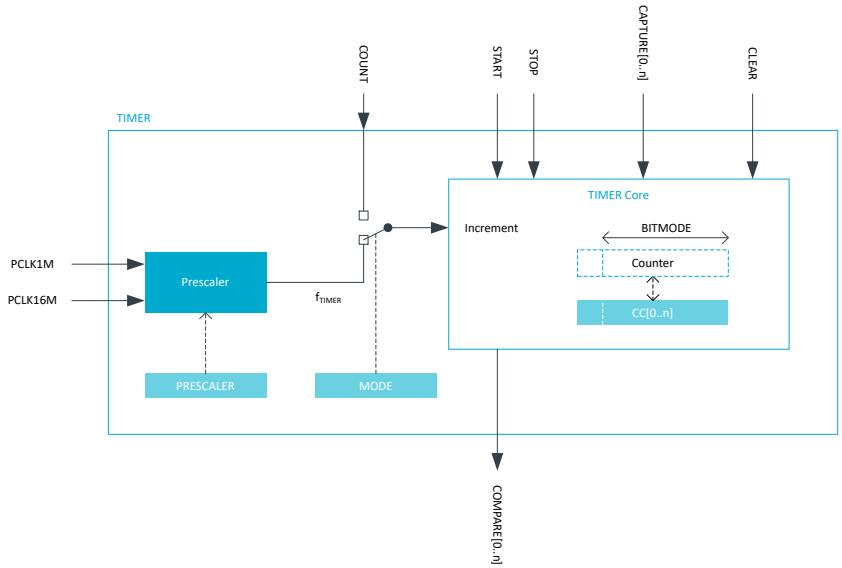

Figure 93: Block schematic for timer/counter

The timer/counter runs on the high-frequency clock source (HFCLK) and includes a four-bit (1/2X) prescaler that can divide the timer input clock from the HFCLK controller. Clock source selection between PCLK16M and PCLK1M is automatic according to TIMER base frequency set by the prescaler. The TIMER base frequency is always given as 16 MHz divided by the prescaler value.

The PPI system allows a TIMER event to trigger a task of any other system peripheral of the device. The PPI system also enables the TIMER task/event features to generate periodic output and PWM signals to any GPIO. The number of input/outputs used at the same time is limited by the number of GPIOTE channels.

TIMER can operate in two modes: Timer mode and Counter mode. In both modes, TIMER is started by triggering the START task, and stopped by triggering the STOP task. After the timer is stopped the timer can resume timing/counting by triggering the START task again. When timing/counting is resumed, the timer will continue from the value it had prior to being stopped.

In Timer mode, the TIMER's internal Counter register is incremented by one for every tick of the timer frequency f_{TIMER} as illustrated in Block schematic for timer/counter on page 345. The timer frequency is derived from PCLK16M as shown in the following example, using the values specified in the PRESCALER register.

$$f_{TIMER} = 16\ MHz\ /\ (2^{PRESCALER})$$

When $f_{TIMER} \leq 1$ MHz, TIMER will use PCLK1M instead of PCLK16M for reduced power consumption.

In counter mode, the TIMER's internal Counter register is incremented by one each time the COUNT task is triggered, meaning the timer frequency and the prescaler are not utilized in counter mode. Similarly, the COUNT task has no effect in Timer mode.

The TIMER's maximum value is configured by changing the bit-width of the timer in register BITMODE on page 352.

PRESCALER on page 353 and BITMODE on page 352 must only be updated when the timer is stopped. If these registers are updated while the timer is started, unpredictable behavior may occur.

When the timer is incremented beyond its maximum value, the Counter register will overflow and the timer will automatically start over from zero.

The Counter register can be cleared by triggering the CLEAR task. This will explicitly set the internal value to zero.

TIMER implements multiple capture/compare registers.

Independent of prescaler setting, the accuracy of TIMER is equivalent to one tick of the timer frequency f_{TIMER} as illustrated in Block schematic for timer/counter on page 345.

6.16.1 Capture

TIMER implements one capture task for every available capture/compare register.

Every time the CAPTURE[n] task is triggered, the Counter value is copied to the CC[n] register.

6.16.2 Compare

TIMER implements one COMPARE event for every available capture/compare register.

A COMPARE event is generated when the Counter is incremented and then becomes equal to the value specified in one of the capture compare registers. When the Counter value becomes equal to the value specified in a capture compare register CC[n], the corresponding compare event COMPARE[n] is generated.

BITMODE on page 352 specifies how many bits of the Counter register and the capture/compare register that are used when the comparison is performed. Other bits will be ignored.

The COMPARE event can be configured to operate in one-shot mode by configuring the corresponding ONESHOTEN[n] register. COMPARE[n] event is generated the first time the Counter matches CC[n] after CC[n] has been written.

6.16.3 Task delays

After TIMER is started, the CLEAR, COUNT, and STOP tasks are guaranteed to take effect within one clock cycle of the PCLK16M.

6.16.4 Task priority

If the START task and the STOP task are triggered at the same time, meaning within the same period of PCLK16M, the STOP task will be prioritized.

If one or more of the CAPTURE tasks and the CLEAR task is triggered at the same time, that is, within the same period of PCLK16M, the CLEAR task will be prioritized. This means that the CC register for the relevant CAPTURE task will be set to 0.

6.16.5 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
TIMER0 : S	0x5000F000	US	NS	NA	No	Timer 0
TIMER0 : NS	0x4000F000					
TIMER1 : S	0x50010000	US	NS	NA	No	Timer 1
TIMER1 : NS	0x40010000					
TIMER2 : S	0x50011000	US	NS	NA	No	Timer 2
TIMER2 : NS	0x40011000					

Register overview

Register	Offset	TZ	Description
TASKS_START	0x000		Start Timer
TASKS_STOP	0x004		Stop Timer
TASKS_COUNT	0x008		Increment Timer (Counter mode only)
TASKS_CLEAR	0x00C		Clear time
TASKS_SHUTDOWN	0x010		Shut down timer This register is deprecated.
TASKS_CAPTURE[n]	0x040		Capture Timer value to CC[n] register
SUBSCRIBE_START	0x080		Subscribe configuration for task START
SUBSCRIBE_STOP	0x084		Subscribe configuration for task STOP
SUBSCRIBE_COUNT	0x088		Subscribe configuration for task COUNT
SUBSCRIBE_CLEAR	0x08C		Subscribe configuration for task CLEAR
SUBSCRIBE_SHUTDOWN	0x090		Subscribe configuration for task SHUTDOWN This register is deprecated.
SUBSCRIBE_CAPTURE[n]	0x0C0		Subscribe configuration for task CAPTURE[n]
EVENTS_COMPARE[n]	0x140		Compare event on CC[n] match
PUBLISH_COMPARE[n]	0x1C0		Publish configuration for event COMPARE[n]
SHORTS	0x200		Shortcuts between local events and tasks
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
MODE	0x504		Timer mode selection
BITMODE	0x508		Configure the number of bits used by the TIMER
PRESCALER	0x510		Timer prescaler register
ONESHOTEN[n]	0x514		Enable one-shot operation for Capture/Compare channel n
CC[n]	0x540		Capture/Compare register n

6.16.5.1 TASKS_START

Address offset: 0x000

Start Timer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_START			Start Timer
			Trigger	1	Trigger task

6.16.5.2 TASKS_STOP

Address offset: 0x004

Stop Timer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stop Timer
			Trigger	1	Trigger task

6.16.5.3 TASKS_COUNT

Address offset: 0x008

Increment Timer (Counter mode only)

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_COUNT			Increment Timer (Counter mode only)
			Trigger	1	Trigger task

6.16.5.4 TASKS_CLEAR

Address offset: 0x00C

Clear time

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_CLEAR			Clear time
			Trigger	1	Trigger task

6.16.5.5 TASKS_SHUTDOWN (Deprecated)

Address offset: 0x010

Shut down timer

This register is deprecated.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_SHUTDOWN			Shut down timer This field is deprecated.
			Trigger	1	Trigger task

6.16.5.6 TASKS_CAPTURE[n] (n=0..5)

Address offset: 0x040 + (n × 0x4)

Capture Timer value to CC[n] register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_CAPTURE			Capture Timer value to CC[n] register
			Trigger	1	Trigger task

6.16.5.7 SUBSCRIBE_START

Address offset: 0x080

Subscribe configuration for task START

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task START will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.16.5.8 SUBSCRIBE_STOP

Address offset: 0x084

Subscribe configuration for task STOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.16.5.9 SUBSCRIBE_COUNT

Address offset: 0x088

Subscribe configuration for task COUNT

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task COUNT will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.16.5.10 SUBSCRIBE_CLEAR

Address offset: 0x08C

Subscribe configuration for task CLEAR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task CLEAR will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.16.5.11 SUBSCRIBE_SHUTDOWN (Deprecated)

Address offset: 0x090

Subscribe configuration for task SHUTDOWN

This register is deprecated.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task SHUTDOWN will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.16.5.12 SUBSCRIBE_CAPTURE[n] (n=0..5)

Address offset: 0x0C0 + (n × 0x4)

Subscribe configuration for task CAPTURE[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task CAPTURE[n] will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.16.5.13 EVENTS_COMPARE[n] (n=0..5)

Address offset: 0x140 + (n × 0x4)

Compare event on CC[n] match

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_COMPARE			Compare event on CC[n] match
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.16.5.14 PUBLISH_COMPARE[n] (n=0..5)

Address offset: 0x1C0 + (n × 0x4)

Publish configuration for event COMPARE[n]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event COMPARE[n] will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.16.5.15 SHORTS

Address offset: 0x200

Shortcuts between local events and tasks

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-F	RW	COMPARE[i]_CLEAR (i=0..5)			Shortcut between event COMPARE[i] and task CLEAR
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
G-L	RW	COMPARE[i]_STOP (i=0..5)			Shortcut between event COMPARE[i] and task STOP
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut

6.16.5.16 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-F	RW	COMPARE[i] (i=0..5)			Write '1' to enable interrupt for event COMPARE[i]
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.16.5.17 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-F	RW	COMPARE[i] (i=0..5)			Write '1' to disable interrupt for event COMPARE[i]
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.16.5.18 MODE

Address offset: 0x504

Timer mode selection

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MODE			Timer mode
			Timer	0	Select Timer mode
			Counter	1	Select Counter mode
					This enumerator is deprecated.
			LowPowerCounter	2	Select Low Power Counter mode

6.16.5.19 BITMODE

Address offset: 0x508

Configure the number of bits used by the TIMER

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	BITMODE			Timer bit width
			16Bit	0	16 bit timer bit width
			08Bit	1	8 bit timer bit width
			24Bit	2	24 bit timer bit width
			32Bit	3	32 bit timer bit width

6.16.5.20 PRESCALER

Address offset: 0x510

Timer prescaler register

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000004				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PRESCALER		[0..9]	Prescaler value

6.16.5.21 ONESHOTEN[n] (n=0..5)

Address offset: 0x514 + (n × 0x4)

Enable one-shot operation for Capture/Compare channel n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ONESHOTEN			Enable one-shot operation
					Configures the corresponding compare-channel for one-shot operation
			Disable	0	Disable one-shot operation
					Compare event is generated every time the Counter matches CC[n]
			Enable	1	Enable one-shot operation
					Compare event is generated the first time the Counter matches CC[n] after CC[n] has been written

6.16.5.22 CC[n] (n=0..5)

Address offset: 0x540 + (n × 0x4)

Capture/Compare register n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CC			Capture/Compare value
					Only the number of bits indicated by BITMODE will be used by the TIMER.

6.17 TWIM — I²C compatible two-wire interface master with EasyDMA

TWI master with EasyDMA (TWIM) is a two-wire half-duplex master which can communicate with multiple slave devices connected to the same bus.

Listed here are the main features for TWIM:

- I²C compatible
- Supported baud rates: 100, 250, 400 kbps
- Support for clock stretching (non I²C compliant)
- EasyDMA

The two-wire interface can communicate with a bi-directional wired-AND bus with two lines (SCL, SDA). The protocol makes it possible to interconnect up to 127 individually addressable devices. TWIM is not compatible with CBUS.

The GPIOs used for each two-wire interface line can be chosen from any GPIO on the device and are independently configurable. This enables great flexibility in device pinout and efficient use of board space and signal routing.

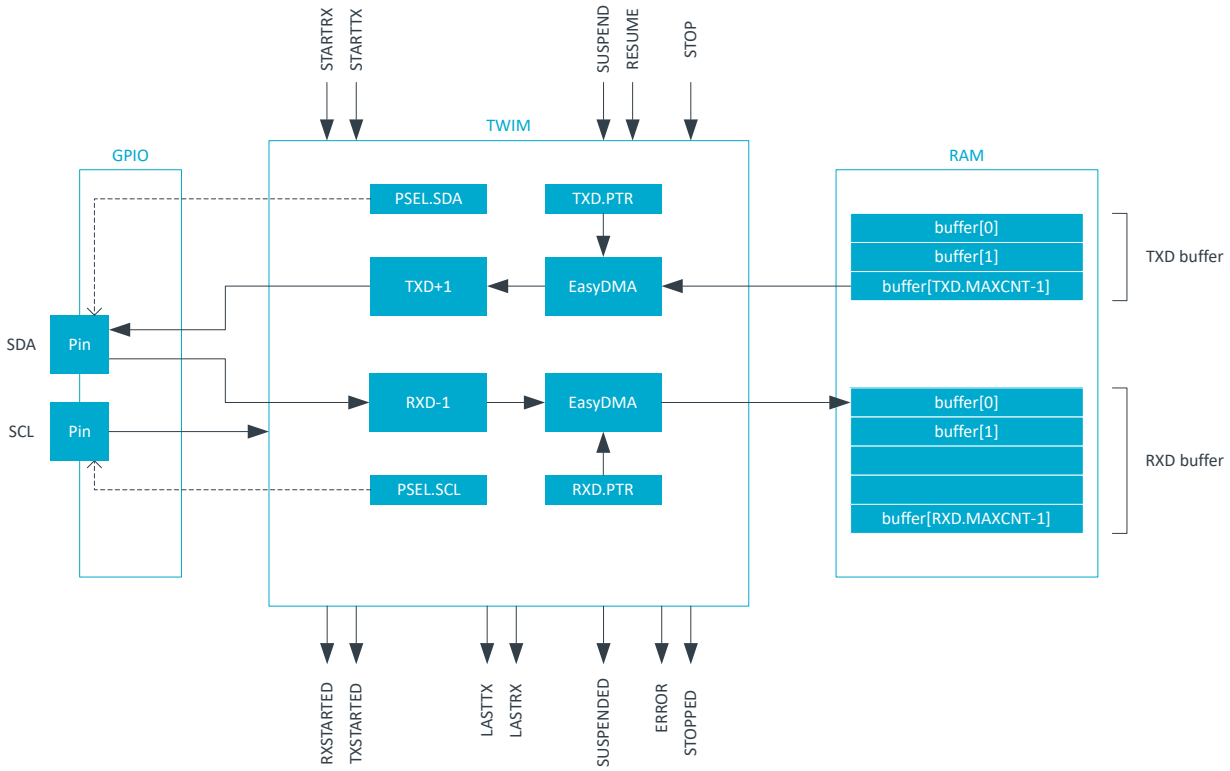

Figure 94: TWI master with EasyDMA

A typical TWI setup consists of one master and one or more slaves. For an example, see the following figure. This TWIM is only able to operate as a single master on the TWI bus. Multi-master bus configuration is not supported.

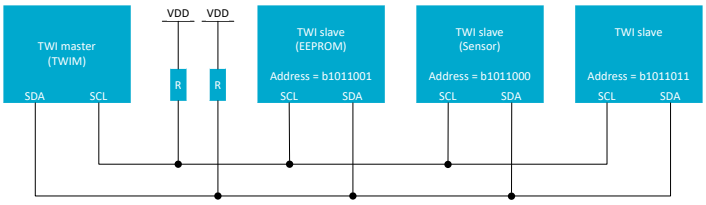

Figure 95: A typical TWI setup comprising one master and three slaves

This TWI master supports clock stretching performed by the slaves. The SCK pulse following a stretched clock cycle may be shorter than specified by the I2C specification.

The TWI master is started by triggering the STARTTX or STARTRX tasks and stopped by triggering the STOP task. The TWI master will generate a STOPPED event when it has stopped following a STOP task.

After the TWI master is started, the STARTTX or STARTRX tasks should not be triggered again until the TWI master has issued a LASTRX, LASTTX, or STOPPED event.

The TWI master can be suspended using the SUSPEND task, this can be used when using the TWI master in a low priority interrupt context. When the TWIM enters suspend state, will automatically issue a SUSPENDED event while performing a continuous clock stretching until it is instructed to resume operation via a RESUME task. The TWI master cannot be stopped while it is suspended, thus the STOP task must be issued after the TWI master has been resumed.

Note: Any ongoing byte transfer will be allowed to complete before the suspend is enforced. A SUSPEND task has no effect unless the TWI master is actively involved in a transfer.

If a NACK is clocked in from the slave, the TWI master will generate an ERROR event.

6.17.1 Shared resources

The TWI master shares registers and other resources with other peripherals that have the same ID as the TWI master. Therefore, you must disable all peripherals that have the same ID as the TWI master before the TWI master can be configured and used.

Disabling a peripheral that has the same ID as the TWI master will not reset any of the registers that are shared with the TWI master. It is therefore important to configure all relevant registers explicitly to secure that the TWI master operates correctly.

The Instantiation table in Instantiation on page 25 shows which peripherals have the same ID as the TWI.

6.17.2 EasyDMA

The TWIM implements EasyDMA for accessing RAM without CPU involvement.

The TWIM peripheral implements the EasyDMA channels found in the following table.

Channel	Type	Register Cluster
TXD	READER	TXD
RXD	WRITER	RXD

Table 44: TWIM EasyDMA Channels

For detailed information regarding the use of EasyDMA, see EasyDMA on page 46.

The .PTR and .MAXCNT registers are double-buffered. They can be updated and prepared for the next RX/TX transmission immediately after having received the RXSTARTED/TXSTARTED event.

The STOPPED event indicates that EasyDMA has finished accessing the buffer in RAM.

6.17.3 Master write sequence

A TWI master write sequence is started by triggering the STARTTX task. After the STARTTX task has been triggered, the TWI master will generate a start condition on the TWI bus, followed by clocking out the address and the READ/WRITE bit set to 0 (WRITE=0, READ=1).

The address must match the address of the slave device that the master wants to write to. The READ/WRITE bit is followed by an ACK/NACK bit (ACK=0 or NACK=1) generated by the slave.

After receiving the ACK bit, the TWI master will clock out the data bytes found in the transmit buffer located in RAM at the address specified in the TXD.PTR register. Each byte clocked out from the master will be followed by an ACK/NACK bit clocked in from the slave.

A typical TWI master write sequence is shown in the following figure. Occurrence 2 in the figure illustrates clock stretching performed by the TWI master following a SUSPEND task.

A SUSPENDED event indicates that the SUSPEND task has taken effect. This event can be used to synchronize the software.

The TWI master will generate a LASTTX event when it starts to transmit the last byte, this is shown in the following figure.

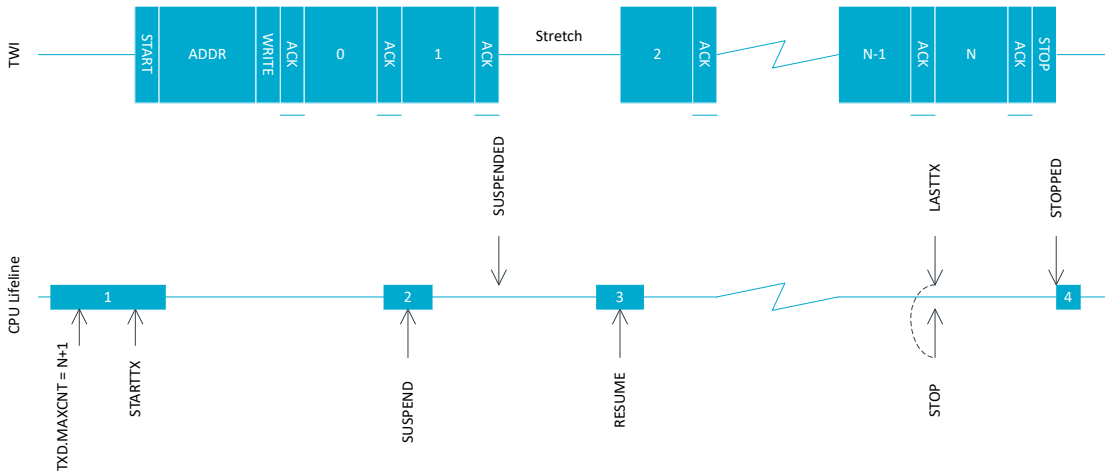

Figure 96: TWI master writing data to a slave

The TWI master is stopped by triggering the STOP task. This task should be triggered during the transmission of the last byte to secure that the TWI master will stop as fast as possible after sending the last byte. The shortcut between LASTTX and STOP can alternatively be used to accomplish this.

Note: The TWI master does not stop by itself when the entire RAM buffer has been sent, or when an error occurs. The STOP task must be issued, using a local or PPI shortcut, or in software as part of the error handler.

6.17.4 Master read sequence

A TWI master read sequence is started by triggering the STARTRX task. After the STARTRX task has been triggered, the TWI master will generate a start condition on the TWI bus, followed by clocking out the address and the READ/WRITE bit set to 1 (WRITE = 0, READ = 1). The address must match the address of the slave device that the master wants to read from. The READ/WRITE bit is followed by an ACK/NACK bit (ACK=0 or NACK = 1) generated by the slave.

After sending the ACK bit, the TWI slave will send data to the master using the clock generated by the master.

Data received will be stored in RAM at the address specified in the RXD.PTR register. The TWI master will generate an ACK after all but the last byte have been received from the slave. The TWI master will generate a NACK after the last byte received to indicate that the read sequence shall stop.

A typical TWI master read sequence is illustrated in The TWI master reading data from a slave on page 357. Occurrence 2 in the figure illustrates clock stretching performed by the TWI master following a SUSPEND task.

A SUSPENDED event indicates that the SUSPEND task has taken effect. This event can be used to synchronize the software.

The TWI master will generate a LASTRX event when it is ready to receive the last byte, as shown in The TWI master reading data from a slave on page 357. If RXD.MAXCNT > 1, the LASTRX event is generated after sending the ACK of the previously received byte. If RXD.MAXCNT = 1, the LASTRX event is generated after receiving the ACK following the address and READ bit.

The TWI master is stopped by triggering the STOP task. This task must be triggered before the NACK bit is supposed to be transmitted. The STOP task can be triggered at any time during the reception of the last byte. It is recommended to use the shortcut between LASTRX and STOP to accomplish this.

The TWI master does not stop by itself when the RAM buffer is full, or when an error occurs. The STOP task must be issued, using a local or PPI shortcut, or in software as part of the error handler.

The TWI master cannot be stopped while suspended, so the STOP task must be issued after the TWI master has been resumed.

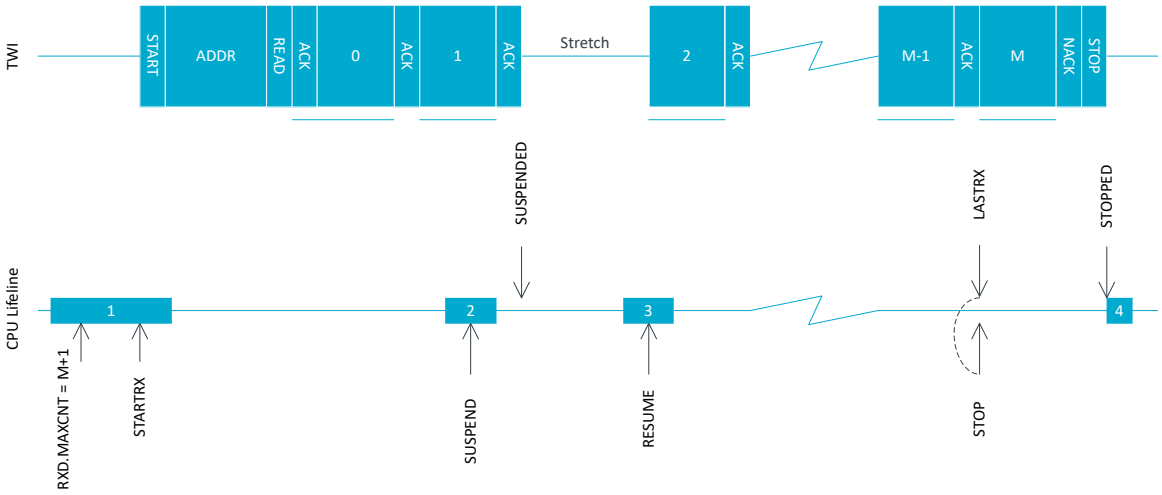

Figure 97: The TWI master reading data from a slave

6.17.5 Master repeated start sequence

A typical repeated start sequence is one in which the TWI master writes two bytes to the slave followed by reading four bytes from the slave. This example uses shortcuts to perform the simplest type of repeated start sequence, i.e. one write followed by one read. The same approach can be used to perform a repeated start sequence where the sequence is read followed by write.

The following figure shows an example of a repeated start sequence where the TWI master writes two bytes followed by reading four bytes from the slave.

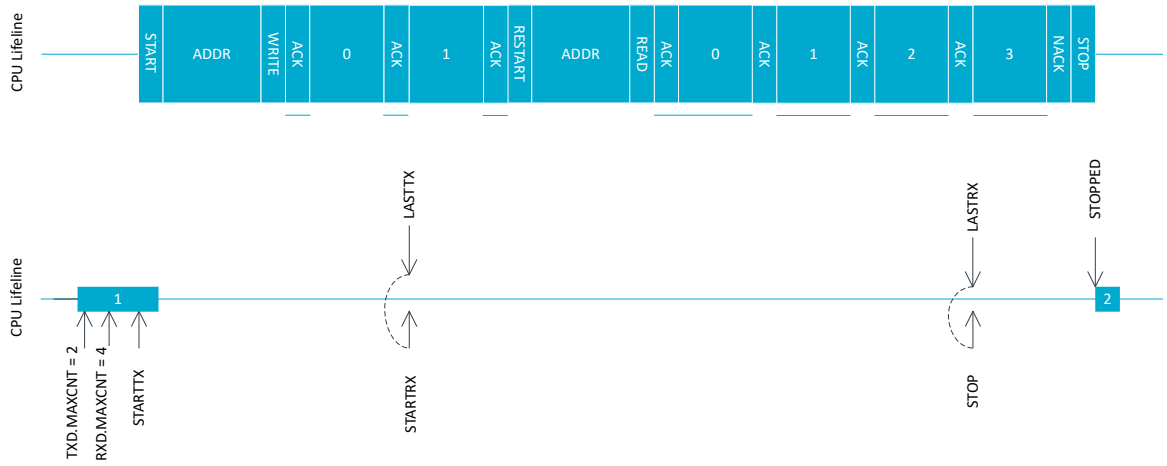

Figure 98: Master repeated start sequence

If a more complex repeated start sequence is needed, and the TWI firmware drive is serviced in a low priority interrupt, it may be necessary to use the SUSPEND task and SUSPENDED event to guarantee that the correct tasks are generated at the correct time. A double repeated start sequence using the SUSPEND task to secure safe operation in low priority interrupts is shown in the following figure.

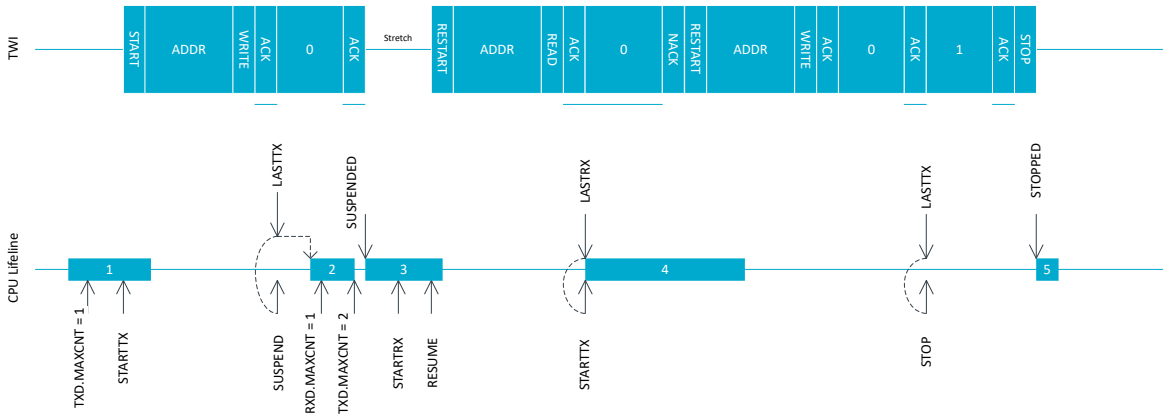

Figure 99: Double repeated start sequence

6.17.6 Low power

When putting the system in low power and the peripheral is not needed, lowest possible power consumption is achieved by stopping, and then disabling the peripheral.

When the STOP task is sent, the software shall wait until the STOPPED event is received as a response before disabling the peripheral through the ENABLE register. If the peripheral is already stopped, the STOP task is not required.

6.17.7 Master mode pin configuration

The SCL and SDA signals associated with the TWI master are mapped to physical pins according to the configuration specified in the PSEL.SCL and PSEL.SDA registers respectively.

The PSEL.SCL and PSEL.SDA registers and their configurations are only used as long as the TWI master is enabled, and retained only as long as the device is in ON mode. When the peripheral is disabled, the pins will behave as regular GPIOs, and use the configuration in their respective OUT bit field and PIN_CNF[n] register. PSEL.SCL, PSEL.SDA must only be configured when the TWI master is disabled.

To secure correct signal levels on the pins used by the TWI master when the system is in OFF mode, and when the TWI master is disabled, these pins must be configured in the GPIO peripheral as described in the following table.

Only one peripheral can be assigned to drive a particular GPIO pin at a time. Failing to do so may result in unpredictable behavior.

TWI master signal	TWI master pin	Direction	Output value	Drive strength
SCL	As specified in PSEL.SCL	Input	Not applicable	S0D1
SDA	As specified in PSEL.SDA	Input	Not applicable	S0D1

Table 45: GPIO configuration before enabling peripheral

6.17.8 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
TWIM0 : S	0x50008000	US	NS	SA	No	Two-wire interface master 0
TWIM0 : NS	0x40008000					
TWIM1 : S	0x50009000	US	NS	SA	No	Two-wire interface master 1
TWIM1 : NS	0x40009000					
TWIM2 : S	0x5000A000	US	NS	SA	No	Two-wire interface master 2
TWIM2 : NS	0x4000A000					
TWIM3 : S	0x5000B000	US	NS	SA	No	Two-wire interface master 3
TWIM3 : NS	0x4000B000					

Register overview

Register	Offset	TZ	Description
TASKS_STARTRX	0x000		Start TWI receive sequence
TASKS_STARTTX	0x008		Start TWI transmit sequence
TASKS_STOP	0x014		Stop TWI transaction. Must be issued while the TWI master is not suspended.
TASKS_SUSPEND	0x01C		Suspend TWI transaction
TASKS_RESUME	0x020		Resume TWI transaction
SUBSCRIBE_STARTRX	0x080		Subscribe configuration for task STARTRX
SUBSCRIBE_STARTTX	0x088		Subscribe configuration for task STARTTX
SUBSCRIBE_STOP	0x094		Subscribe configuration for task STOP
SUBSCRIBE_SUSPEND	0x09C		Subscribe configuration for task SUSPEND
SUBSCRIBE_RESUME	0x0A0		Subscribe configuration for task RESUME
EVENTS_STOPPED	0x104		TWI stopped
EVENTS_ERROR	0x124		TWI error
EVENTS_SUSPENDED	0x148		SUSPEND task has been issued, TWI traffic is now suspended.
EVENTS_RXSTARTED	0x14C		Receive sequence started
EVENTS_TXSTARTED	0x150		Transmit sequence started
EVENTS_LASTRX	0x15C		Byte boundary, starting to receive the last byte
EVENTS_LASTTX	0x160		Byte boundary, starting to transmit the last byte
PUBLISH_STOPPED	0x184		Publish configuration for event STOPPED
PUBLISH_ERROR	0x1A4		Publish configuration for event ERROR
PUBLISH_SUSPENDED	0x1C8		Publish configuration for event SUSPENDED
PUBLISH_RXSTARTED	0x1CC		Publish configuration for event RXSTARTED

Register	Offset	TZ	Description
PUBLISH_TXSTARTED	0x1D0		Publish configuration for event TXSTARTED
PUBLISH_LASTRX	0x1DC		Publish configuration for event LASTRX
PUBLISH_LASTTX	0x1E0		Publish configuration for event LASTTX
SHORTS	0x200		Shortcuts between local events and tasks
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
ERRORSRC	0x4C4		Error source
ENABLE	0x500		Enable TWIM
PSEL.SCL	0x508		Pin select for SCL signal
PSEL.SDA	0x50C		Pin select for SDA signal
FREQUENCY	0x524		TWI frequency. Accuracy depends on the HFCLK source selected.
RXD.PTR	0x534		Data pointer
RXD.MAXCNT	0x538		Maximum number of bytes in receive buffer
RXD.AMOUNT	0x53C		Number of bytes transferred in the last transaction
RXD.LIST	0x540		EasyDMA list type
TXD.PTR	0x544		Data pointer
TXD.MAXCNT	0x548		Maximum number of bytes in transmit buffer
TXD.AMOUNT	0x54C		Number of bytes transferred in the last transaction
TXD.LIST	0x550		EasyDMA list type
ADDRESS	0x588		Address used in the TWI transfer

6.17.8.1 TASKS_STARTRX

Address offset: 0x000

Start TWI receive sequence

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STARTRX			Start TWI receive sequence
			Trigger	1	Trigger task

6.17.8.2 TASKS_STARTTX

Address offset: 0x008

Start TWI transmit sequence

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STARTTX			Start TWI transmit sequence
			Trigger	1	Trigger task

6.17.8.3 TASKS_STOP

Address offset: 0x014

Stop TWI transaction. Must be issued while the TWI master is not suspended.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stop TWI transaction. Must be issued while the TWI master is not suspended.
			Trigger	1	Trigger task

6.17.8.4 TASKS_SUSPEND

Address offset: 0x01C

Suspend TWI transaction

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_SUSPEND			Suspend TWI transaction
			Trigger	1	Trigger task

6.17.8.5 TASKS_RESUME

Address offset: 0x020

Resume TWI transaction

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_RESUME			Resume TWI transaction
			Trigger	1	Trigger task

6.17.8.6 SUBSCRIBE_STARTRX

Address offset: 0x080

Subscribe configuration for task STARTRX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STARTRX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.17.8.7 SUBSCRIBE_STARTTX

Address offset: 0x088

Subscribe configuration for task STARTTX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STARTTX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.17.8.8 SUBSCRIBE_STOP

Address offset: 0x094

Subscribe configuration for task STOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.17.8.9 SUBSCRIBE_SUSPEND

Address offset: 0x09C

Subscribe configuration for task SUSPEND

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task SUSPEND will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.17.8.10 SUBSCRIBE_RESUME

Address offset: 0x0A0

Subscribe configuration for task RESUME

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task RESUME will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.17.8.11 EVENTS_STOPPED

Address offset: 0x104

TWI stopped

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STOPPED			TWI stopped
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.17.8.12 EVENTS_ERROR

Address offset: 0x124

TWI error

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ERROR			TWI error
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.17.8.13 EVENTS_SUSPENDED

Address offset: 0x148

SUSPEND task has been issued, TWI traffic is now suspended.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_SUSPENDED			SUSPEND task has been issued, TWI traffic is now suspended.
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.17.8.14 EVENTS_RXSTARTED

Address offset: 0x14C

Receive sequence started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RXSTARTED			Receive sequence started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.17.8.15 EVENTS_TXSTARTED

Address offset: 0x150

Transmit sequence started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_TXSTARTED			Transmit sequence started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.17.8.16 EVENTS_LASTRX

Address offset: 0x15C

Byte boundary, starting to receive the last byte

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_LASTRX			Byte boundary, starting to receive the last byte
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.17.8.17 EVENTS_LASTTX

Address offset: 0x160

Byte boundary, starting to transmit the last byte

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_LASTTX			Byte boundary, starting to transmit the last byte
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.17.8.18 PUBLISH_STOPPED

Address offset: 0x184

Publish configuration for event STOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STOPPED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.17.8.19 PUBLISH_ERROR

Address offset: 0x1A4

Publish configuration for event ERROR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ERROR will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.17.8.20 PUBLISH_SUSPENDED

Address offset: 0x1C8

Publish configuration for event SUSPENDED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event SUSPENDED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.17.8.21 PUBLISH_RXSTARTED

Address offset: 0x1CC

Publish configuration for event RXSTARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event RXSTARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.17.8.22 PUBLISH_TXSTARTED

Address offset: 0x1D0

Publish configuration for event TXSTARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TXSTARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.17.8.23 PUBLISH_LASTRX

Address offset: 0x1DC

Publish configuration for event LASTRX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event LASTRX will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.17.8.24 PUBLISH_LASTTX

Address offset: 0x1E0

Publish configuration for event LASTTX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event LASTTX will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.17.8.25 SHORTS

Address offset: 0x200

Shortcuts between local events and tasks

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LASTTX_STARTRX			Shortcut between event LASTTX and task STARTRX
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
B	RW	LASTTX_SUSPEND			Shortcut between event LASTTX and task SUSPEND
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
C	RW	LASTTX_STOP			Shortcut between event LASTTX and task STOP
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
D	RW	LASTRX_STARTTX			Shortcut between event LASTRX and task STARTTX
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
F	RW	LASTRX_STOP			Shortcut between event LASTRX and task STOP
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut

6.17.8.26 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				J I H G F D A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	STOPPED			Enable or disable interrupt for event STOPPED
			Disabled	0	Disable
			Enabled	1	Enable
D	RW	ERROR			Enable or disable interrupt for event ERROR
			Disabled	0	Disable
			Enabled	1	Enable
F	RW	SUSPENDED			Enable or disable interrupt for event SUSPENDED
			Disabled	0	Disable
			Enabled	1	Enable
G	RW	RXSTARTED			Enable or disable interrupt for event RXSTARTED
			Disabled	0	Disable
			Enabled	1	Enable
H	RW	TXSTARTED			Enable or disable interrupt for event TXSTARTED
			Disabled	0	Disable
			Enabled	1	Enable
I	RW	LASTRX			Enable or disable interrupt for event LASTRX
			Disabled	0	Disable
			Enabled	1	Enable
J	RW	LASTTX			Enable or disable interrupt for event LASTTX
			Disabled	0	Disable
			Enabled	1	Enable

6.17.8.27 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID											J	I			H	G	F									D								A	
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	STOPPED																																	
			Set	1																															
			Disabled	0																															
			Enabled	1																															
D	RW	ERROR																																	
			Set	1																															
			Disabled	0																															
			Enabled	1																															
F	RW	SUSPENDED																																	
			Set	1																															
			Disabled	0																															
			Enabled	1																															
G	RW	RXSTARTED																																	
			Set	1																															
			Disabled	0																															
			Enabled	1																															
H	RW	TXSTARTED																																	
			Set	1																															
			Disabled	0																															
			Enabled	1																															
I	RW	LASTRX																																	
			Set	1																															
			Disabled	0																															
			Enabled	1																															
J	RW	LASTTX																																	
			Set	1																															
			Disabled	0																															
			Enabled	1																															

6.17.8.28 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID											J	I			H	G	F									D								A	
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	STOPPED																																	
			Clear	1																															
			Disabled	0																															
			Enabled	1																															
D	RW	ERROR																																	
			Clear	1																															
			Disabled	0																															
			Enabled	1																															
F	RW	SUSPENDED																																	

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				J I H G F D A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
G	RW	RXSTARTED			Write '1' to disable interrupt for event RXSTARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
H	RW	TXSTARTED			Write '1' to disable interrupt for event TXSTARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
I	RW	LASTRX			Write '1' to disable interrupt for event LASTRX
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
J	RW	LASTTX			Write '1' to disable interrupt for event LASTTX
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.17.8.29 ERRORSRC

Address offset: 0x4C4

Error source

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW W1C	OVERRUN			Overrun error A new byte was received before previous byte got transferred into RXD buffer. (Previous data is lost)
			NotReceived	0	Error did not occur
			Received	1	Error occurred
B	RW W1C	ANACK			NACK received after sending the address (write '1' to clear)
			NotReceived	0	Error did not occur
			Received	1	Error occurred
C	RW W1C	DNACK			NACK received after sending a data byte (write '1' to clear)
			NotReceived	0	Error did not occur
			Received	1	Error occurred

6.17.8.30 ENABLE

Address offset: 0x500

Enable TWIM

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			Enable or disable TWIM
			Disabled	0	Disable TWIM
			Enabled	6	Enable TWIM

6.17.8.31 PSEL.SCL

Address offset: 0x508

Pin select for SCL signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.17.8.32 PSEL.SDA

Address offset: 0x50C

Pin select for SDA signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.17.8.33 FREQUENCY

Address offset: 0x524

TWI frequency. Accuracy depends on the HFCLK source selected.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x04000000				**0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	FREQUENCY			TWI master clock frequency
			K100	0x01980000	100 kbps
			K250	0x04000000	250 kbps
			K400	0x06400000	400 kbps

6.17.8.34 RXD

RXD EasyDMA channel

6.17.8.34.1 RXD.PTR

Address offset: 0x534

Data pointer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Data pointer See the memory chapter for details about which memories are available for EasyDMA.

6.17.8.34.2 RXD.MAXCNT

Address offset: 0x538

Maximum number of bytes in receive buffer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in receive buffer

6.17.8.34.3 RXD.AMOUNT

Address offset: 0x53C

Number of bytes transferred in the last transaction

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transferred in the last transaction. In case of NACK error, includes the NACK'ed byte.

6.17.8.34.4 RXD.LIST

Address offset: 0x540

EasyDMA list type

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIST			List type
			Disabled	0	Disable EasyDMA list
			ArrayList	1	Use array list

6.17.8.35 TXD

TXD EasyDMA channel

6.17.8.35.1 TXD.PTR

Address offset: 0x544

Data pointer

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Data pointer See the memory chapter for details about which memories are available for EasyDMA.

6.17.8.35.2 TXD.MAXCNT

Address offset: 0x548

Maximum number of bytes in transmit buffer

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A A A A A A A A A A A A A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in transmit buffer

6.17.8.35.3 TXD.AMOUNT

Address offset: 0x54C

Number of bytes transferred in the last transaction

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A A A A A A A A A A A A A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transferred in the last transaction. In case of NACK error, includes the NACK'ed byte.

6.17.8.35.4 TXD.LIST

Address offset: 0x550

EasyDMA list type

Bit number					31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID					A A
Reset 0x00000000					**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIST			List type
			Disabled	0	Disable EasyDMA list
			ArrayList	1	Use array list

6.17.8.36 ADDRESS

Address offset: 0x588

Address used in the TWI transfer

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																										A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ADDRESS			Address used in the TWI transfer

6.17.9 Electrical specification

6.17.9.1 TWIM interface electrical specifications

Symbol	Description	Min.	Typ.	Max.	Units
$f_{TWIM,SCL}$	Bit rates for TWIM[24]	100		400	kbps
$t_{TWIM,START}$	Time from STARTRX/STARTTX task to transmission started		1.615		µs

6.17.9.2 Two Wire Interface Master (TWIM) timing specifications

Symbol	Description	Min.	Typ.	Max.	Units
t_{TWIM,SU_DAT}	Data setup time before positive edge on SCL – all modes	300			ns
t_{TWIM,HD_DAT}	Data hold time after negative edge on SCL – 100, 250 and 400 kbps	500			ns
$t_{TWIM,HD\_STA,100kbps}$	TWIM master hold time for START and repeated START condition, 100 kbps	10000			ns
$t_{TWIM,HD\_STA,250kbps}$	TWIM master hold time for START and repeated START condition, 250 kbps	4000			ns
$t_{TWIM,HD\_STA,400kbps}$	TWIM master hold time for START and repeated START condition, 400 kbps	2500			ns
$t_{TWIM,SU\_STO,100kbps}$	TWIM master setup time from SCL high to STOP condition, 100 kbps	5000			ns
$t_{TWIM,SU\_STO,250kbps}$	TWIM master setup time from SCL high to STOP condition, 250 kbps	2000			ns
$t_{TWIM,SU\_STO,400kbps}$	TWIM master setup time from SCL high to STOP condition, 400 kbps	1250			ns
$t_{TWIM,BUF,100kbps}$	TWIM master bus free time between STOP and START conditions, 100 kbps	5800			ns
$t_{TWIM,BUF,250kbps}$	TWIM master bus free time between STOP and START conditions, 250 kbps	2700			ns
$t_{TWIM,BUF,400kbps}$	TWIM master bus free time between STOP and START conditions, 400 kbps	2100			ns

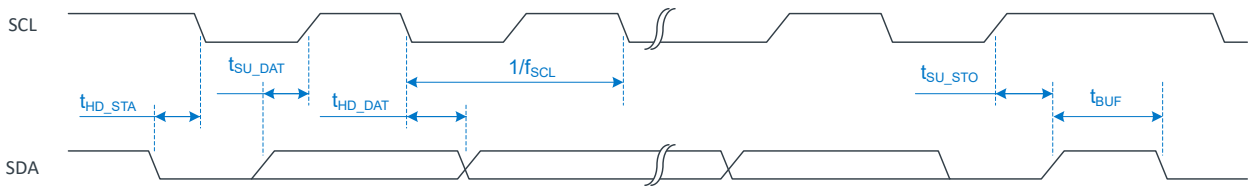

Figure 100: TWIM timing diagram, 1 byte transaction

[24] High bit rates or stronger pull-ups may require GPIOs to be set as High Drive, see GPIO — General purpose input/output on page 163 for more details.

6.17.10 Pullup resistor

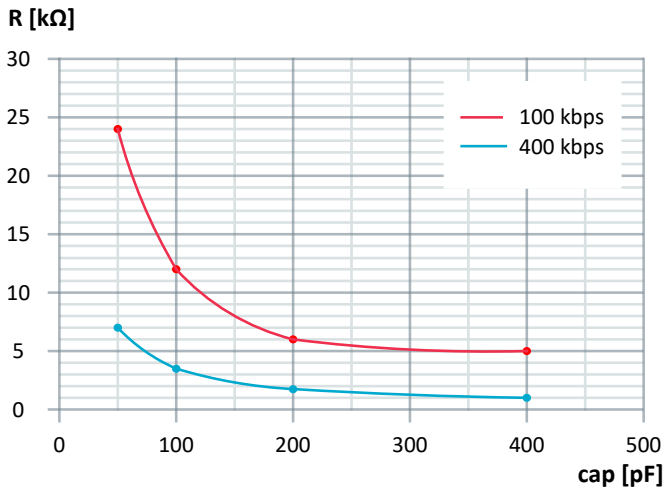

Figure 101: Recommended TWIM pullup value vs. line capacitance

- The I2C specification allows a line capacitance of 400 pF at most.
- The value of internal pullup resistor (R_{PU}) for nRF9151 can be found in GPIO — General purpose input/output on page 163.

6.18 TWIS — I²C compatible two-wire interface slave with EasyDMA

TWI slave with EasyDMA (TWIS) is compatible with I²C operating at 100 kHz and 400 kHz. The TWI transmitter and receiver implement EasyDMA.

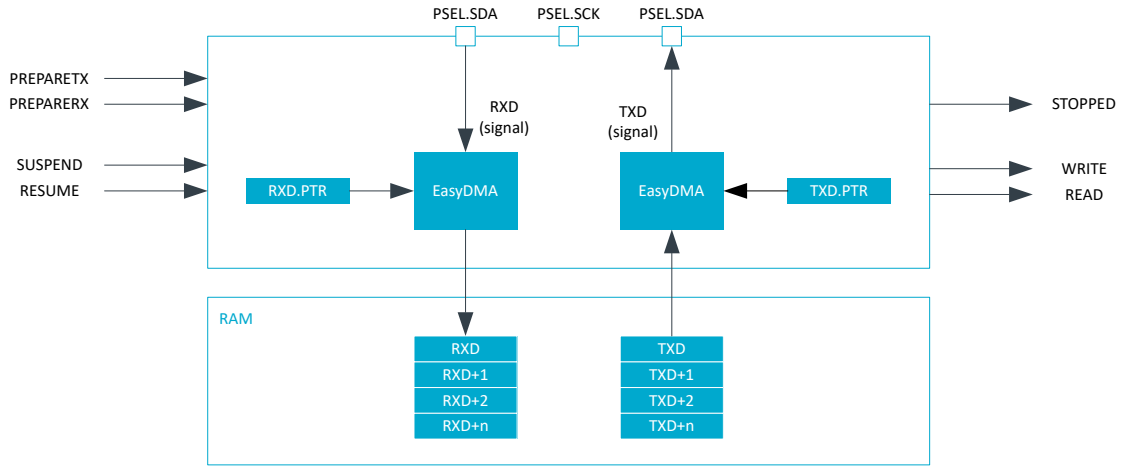

Figure 102: TWI slave with EasyDMA

A typical TWI setup consists of one master and one or more slaves. For an example, see the following figure. TWIS is only able to operate with a single master on the TWI bus.

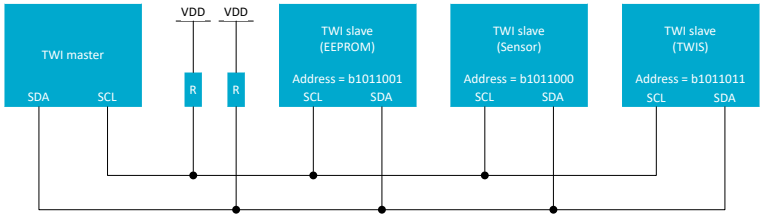

Figure 103: A typical TWI setup comprising one master and three slaves

The following figure shows the TWI slave state machine.

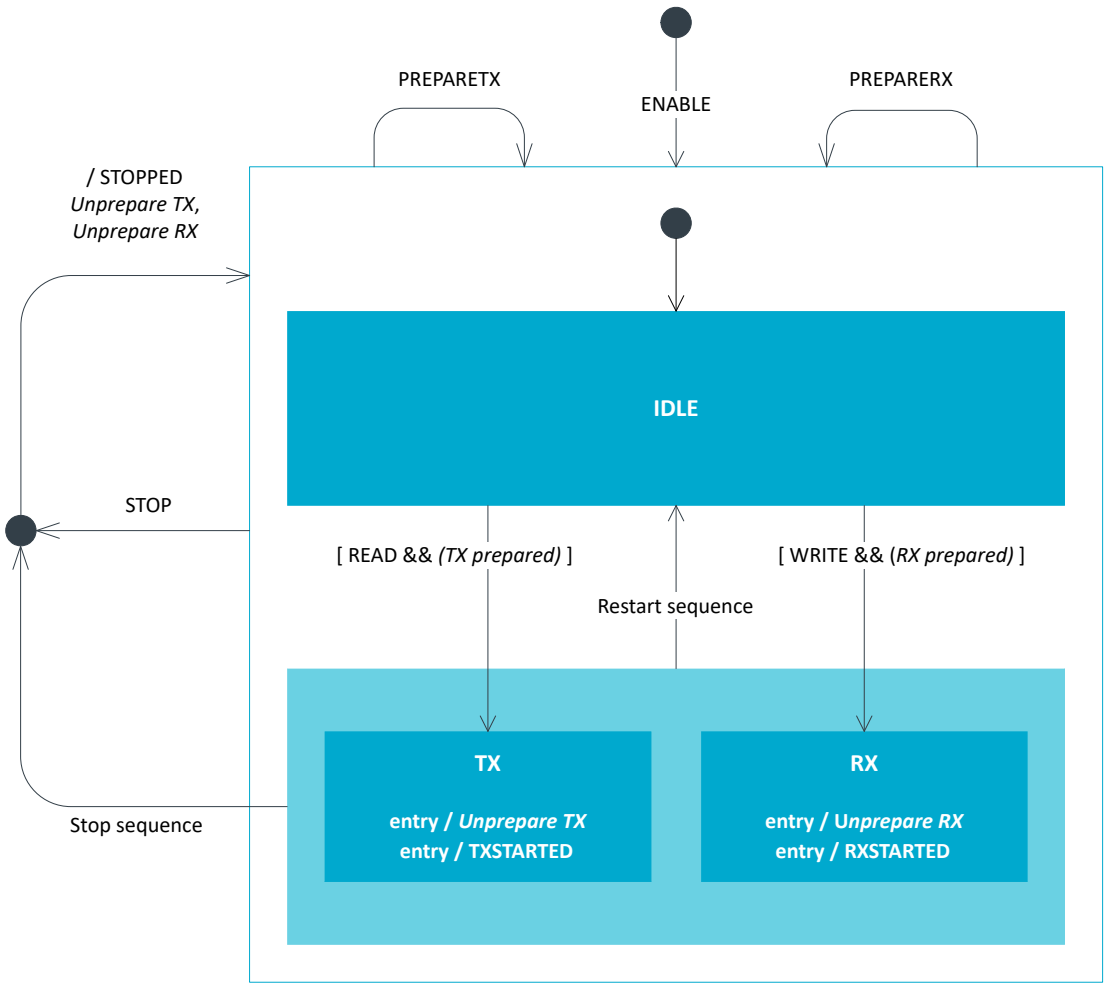

Figure 104: TWI slave state machine

The following table contains descriptions of the symbols used in the state machine.

Symbol	Type	Description
ENABLE	Register	The TWI slave has been enabled via the ENABLE register.
PREPARETX	Task	The TASKS_PREPARETX task has been triggered.
STOP	Task	The TASKS_STOP task has been triggered.
PREPARERX	Task	The TASKS_PREPARERX task has been triggered.
STOPPED	Event	The EVENTS_STOPPED event was generated.
RXSTARTED	Event	The EVENTS_RXSTARTED event was generated.
TXSTARTED	Event	The EVENTS_TXSTARTED event was generated.
TX prepared	Internal	Internal flag indicating that a TASKS_PREPARETX task has been triggered. This flag is not visible to the user.
RX prepared	Internal	Internal flag indicating that a TASKS_PREPARERX task has been triggered. This flag is not visible to the user.
Unprepare TX	Internal	Clears the internal 'TX prepared' flag until next TASKS_PREPARETX task.
Unprepare RX	Internal	Clears the internal 'RX prepared' flag until next TASKS_PREPARERX task.
Stop condition	TWI protocol	A TWI stop condition was detected.
Restart condition	TWI protocol	A TWI restart condition was detected.

Table 46: TWI slave state machine symbols

The TWI slave can perform clock stretching, with the premise that the master is able to support it.

The TWI slave operates in a low power mode while waiting for a TWI master to initiate a transfer. As long as the TWI slave is not addressed, it will remain in this low power mode.

To secure correct behavior of the TWI slave, PSEL.SCL, PSEL.SDA, CONFIG, and the ADDRESS[n] registers must be configured prior to enabling the TWI slave through the ENABLE register. Similarly, changing these settings must be performed while the TWI slave is disabled. Failing to do so may result in unpredictable behavior.

6.18.1 Shared resources

The TWI slave shares registers and other resources with other peripherals that have the same ID as the TWI slave.

Therefore, you must disable all peripherals that have the same ID as the TWI slave before the TWI slave can be configured and used. Disabling a peripheral that has the same ID as the TWI slave will not reset any of the registers that are shared with the TWI slave. It is therefore important to configure all relevant registers explicitly to secure that the TWI slave operates correctly.

The Instantiation table in Instantiation on page 25 shows which peripherals have the same ID as the TWI slave.

6.18.2 EasyDMA

The TWIS implements EasyDMA for accessing RAM without CPU involvement.

The following table shows the Easy DMA channels that the TWIS peripheral implements.

Channel	Type	Register Cluster
TXD	READER	TXD
RXD	WRITER	RXD

Table 47: TWIS EasyDMA Channels

For detailed information regarding the use of EasyDMA, see EasyDMA on page 46.

The STOPPED event indicates that EasyDMA has finished accessing the buffer in RAM.

6.18.3 TWI slave responding to a read command

Before the TWI slave can respond to a read command, the TWI slave must be configured correctly and enabled via the ENABLE register. When enabled, the TWI slave will be in its IDLE state. .

A read command is started when the TWI master generates a start condition on the TWI bus, followed by clocking out the address and the READ/WRITE bit set to 1 (WRITE=0, READ=1). The READ/WRITE bit is followed by an ACK/NACK bit (ACK=0 or NACK=1) response from the TWI slave.

The TWI slave can listen for up to two addresses at the same time. This is configured in the ADDRESS registers and the CONFIG register.

The TWI slave will only acknowledge (ACK) the read command if the address presented by the master matches one of the addresses the slave is configured to listen for. The TWI slave will generate a READ event when it acknowledges the read command.

The TWI slave can only detect a read command from the IDLE state.

The TWI slave will set an internal 'TX prepared' flag when the PREPARETX task is triggered.

When the read command is received, the TWI slave will enter the TX state if the internal 'TX prepared' flag is set.

If the internal 'TX prepared' flag is not set when the read command is received, the TWI slave will stretch the master's clock until the PREPARETX task is triggered and the internal 'TX prepared' flag is set.

The TWI slave will generate the TXSTARTED event and clear the 'TX prepared' flag ('unprepare TX') when it enters the TX state. In this state the TWI slave will send the data bytes found in the transmit buffer to the master using the master's clock.

The TWI slave will go back to the IDLE state if the TWI slave receives a restart command when it is in the TX state.

The TWI slave is stopped when it receives the stop condition from the TWI master. A STOPPED event will be generated when the transaction has stopped. The TWI slave will clear the 'TX prepared' flag ('unprepare TX') and go back to the IDLE state when it has stopped.

The transmit buffer is located in RAM at the address specified in the TXD.PTR register. The TWI slave will only be able to send TXD.MAXCNT bytes from the transmit buffer for each transaction. If the TWI master forces the slave to send more than TXD.MAXCNT bytes, the slave will send the byte specified in the ORC register to the master instead. If this happens, an ERROR event will be generated.

The EasyDMA configuration registers, see TXD.PTR etc., are latched when the TXSTARTED event is generated.

The TWI slave can be forced to stop by triggering the STOP task. A STOPPED event will be generated when the TWI slave has stopped. The TWI slave will clear the 'TX prepared' flag and go back to the IDLE state when it has stopped, see also Terminating an ongoing TWI transaction on page 380.

Each byte sent from the slave will be followed by an ACK/NACK bit sent from the master. The TWI master will generate a NACK following the last byte that it wants to receive to tell the slave to release the bus so that the TWI master can generate the stop condition. The TXD.AMOUNT register can be queried after a transaction to see how many bytes were sent.

A typical TWI slave read command response is shown in the following figure. Occurrence 2 in the figure illustrates clock stretching performed by the TWI slave following a SUSPEND task.

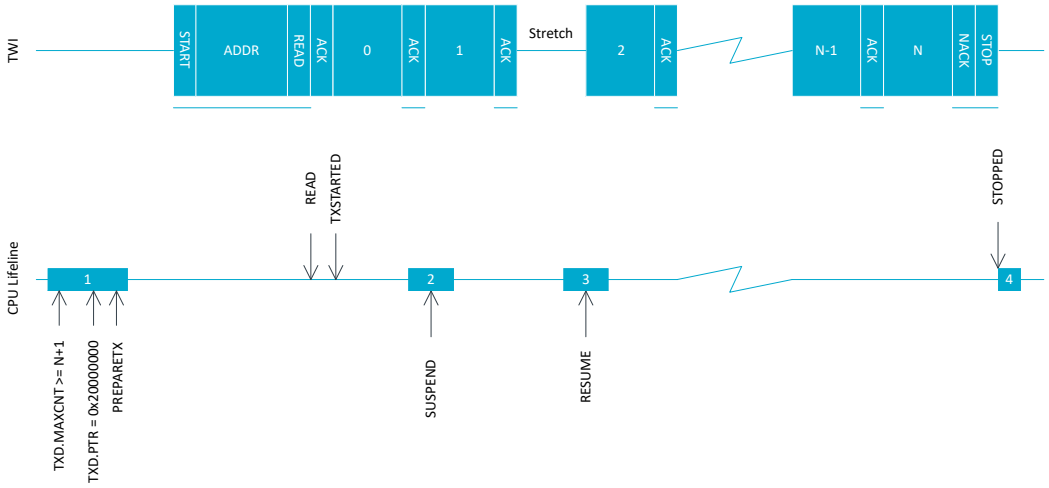

Figure 105: The TWI slave responding to a read command

6.18.4 TWI slave responding to a write command

Before the TWI slave can respond to a write command, the TWI slave must be configured correctly and enabled via the ENABLE register. When enabled, the TWI slave will be in its IDLE state.

A write command is started when the TWI master generates a start condition on the TWI bus, followed by clocking out the address and the READ/WRITE bit set to 0 (WRITE=0, READ=1). The READ/WRITE bit is followed by an ACK/NACK bit (ACK=0 or NACK=1) response from the slave.

The TWI slave can listen for up to two addresses at the same time. This is configured in the ADDRESS registers and the CONFIG register.

The TWI slave will only acknowledge (ACK) the write command if the address presented by the master matches one of the addresses the slave is configured to listen for. The TWI slave will generate a WRITE event if it acknowledges the write command.

The TWI slave can only detect a write command from the IDLE state.

The TWI slave will set an internal 'RX prepared' flag when the PREPARERX task is triggered.

When the write command is received, the TWI slave will enter the RX state if the internal 'RX prepared' flag is set.

If the internal 'RX prepared' flag is not set when the write command is received, the TWI slave will stretch the master's clock until the PREPARERX task is triggered and the internal 'RX prepared' flag is set.

The TWI slave will generate the RXSTARTED event and clear the internal 'RX prepared' flag ('unprepare RX') when it enters the RX state. In this state, the TWI slave will be able to receive the bytes sent by the TWI master.

The TWI slave will go back to the IDLE state if the TWI slave receives a restart command when it is in the RX state.

The TWI slave is stopped when it receives the stop condition from the TWI master. A STOPPED event will be generated when the transaction has stopped. The TWI slave will clear the internal 'RX prepared' flag ('unprepare RX') and go back to the IDLE state when it has stopped.

The receive buffer is located in RAM at the address specified in the RXD.PTR register. The TWI slave will only be able to receive as many bytes as specified in the RXD.MAXCNT register. If the TWI master tries to send more bytes to the slave than it can receive, the extra bytes are discarded and NACKed by the slave. If this happens, an ERROR event will be generated.

The EasyDMA configuration registers, see RXD.PTR etc., are latched when the RXSTARTED event is generated.

The TWI slave can be forced to stop by triggering the STOP task. A STOPPED event will be generated when the TWI slave has stopped. The TWI slave will clear the internal 'RX prepared' flag and go back to the IDLE state when it has stopped, see also Terminating an ongoing TWI transaction on page 380.

The TWI slave will generate an ACK after every byte received from the master. The RXD.AMOUNT register can be queried after a transaction to see how many bytes were received.

A typical TWI slave write command response is show in the following figure. Occurrence 2 in the figure illustrates clock stretching performed by the TWI slave following a SUSPEND task.

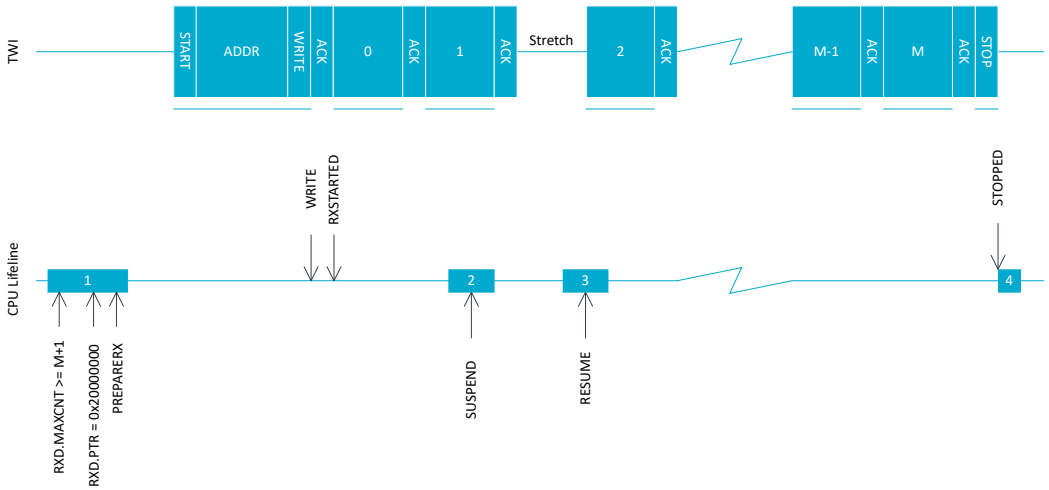

Figure 106: The TWI slave responding to a write command

6.18.5 Master repeated start sequence

An example of a repeated start sequence is one in which the TWI master writes two bytes to the slave followed by reading four bytes from the slave.

This is illustrated in the following figure.

In this example, the receiver does not know what the master wants to read in advance. This information is in the first two received bytes of the write in the repeated start sequence. To guarantee that the CPU is able to process the received data before the TWI slave starts to reply to the read command, the SUSPEND task is triggered via a shortcut from the READ event generated when the read command is received. When the CPU has processed the incoming data and prepared the correct data response, the CPU will resume the transaction by triggering the RESUME task.

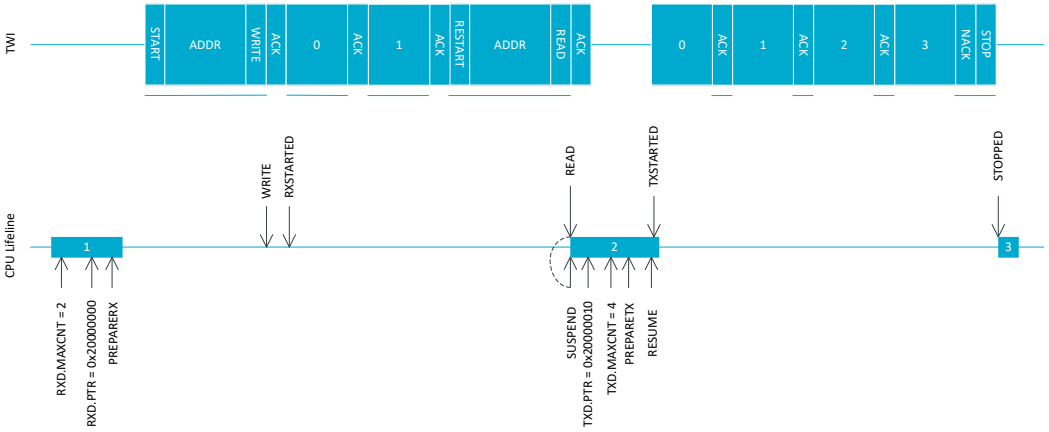

Figure 107: Repeated start sequence

6.18.6 Terminating an ongoing TWI transaction

In some situations, e.g. if the external TWI master is not responding correctly, it may be required to terminate an ongoing transaction.

This can be achieved by triggering the STOP task. In this situation, a STOPPED event will be generated when the TWI has stopped independent of whether or not a STOP condition has been generated on the TWI bus. The TWI slave will release the bus when it has stopped and go back to its IDLE state.

6.18.7 Low power

When putting the system in low power and the peripheral is not needed, lowest possible power consumption is achieved by stopping, and then disabling the peripheral.

The STOP task may not be always needed (the peripheral might already be stopped), but if it is sent, software shall wait until the STOPPED event was received as a response before disabling the peripheral through the ENABLE register.

6.18.8 Slave mode pin configuration

The SCL and SDA signals associated with the TWI slave are mapped to physical pins according to the configuration specified in the PSEL.SCL and PSEL.SDA registers respectively.

The PSEL.SCL and PSEL.SDA registers and their configurations are only used as long as the TWI slave is enabled, and retained only as long as the device is in ON mode. When the peripheral is disabled, the pins will behave as regular GPIOs, and use the configuration in their respective OUT bit field and PIN_CNF[n] register. PSEL.SCL and PSEL.SDA must only be configured when the TWI slave is disabled.

To secure correct signal levels on the pins used by the TWI slave when the system is in OFF mode, and when the TWI slave is disabled, these pins must be configured in the GPIO peripheral as described in the following table.

Only one peripheral can be assigned to drive a particular GPIO pin at a time. Failing to do so may result in unpredictable behavior.

TWI slave signal	TWI slave pin	Direction	Output value	Drive strength
SCL	As specified in PSEL.SCL	Input	Not applicable	S0D1
SDA	As specified in PSEL.SDA	Input	Not applicable	S0D1

Table 48: GPIO configuration before enabling peripheral

6.18.9 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
TWIS0 : S TWIS0 : NS	0x50008000 0x40008000	US	NS	SA	No	Two-wire interface slave 0
TWIS1 : S TWIS1 : NS	0x50009000 0x40009000	US	NS	SA	No	Two-wire interface slave 1
TWIS2 : S TWIS2 : NS	0x5000A000 0x4000A000	US	NS	SA	No	Two-wire interface slave 2
TWIS3 : S TWIS3 : NS	0x5000B000 0x4000B000	US	NS	SA	No	Two-wire interface slave 3

Register overview

Register	Offset	TZ	Description
TASKS_STOP	0x014		Stop TWI transaction
TASKS_SUSPEND	0x01C		Suspend TWI transaction
TASKS_RESUME	0x020		Resume TWI transaction
TASKS_PREPARERX	0x030		Prepare the TWI slave to respond to a write command
TASKS_PREPARETX	0x034		Prepare the TWI slave to respond to a read command
SUBSCRIBE_STOP	0x094		Subscribe configuration for task STOP
SUBSCRIBE_SUSPEND	0x09C		Subscribe configuration for task SUSPEND
SUBSCRIBE_RESUME	0x0A0		Subscribe configuration for task RESUME
SUBSCRIBE_PREPARERX	0x0B0		Subscribe configuration for task PREPARERX
SUBSCRIBE_PREPARETX	0x0B4		Subscribe configuration for task PREPARETX
EVENTS_STOPPED	0x104		TWI stopped
EVENTS_ERROR	0x124		TWI error
EVENTS_RXSTARTED	0x14C		Receive sequence started
EVENTS_TXSTARTED	0x150		Transmit sequence started
EVENTS_WRITE	0x164		Write command received
EVENTS_READ	0x168		Read command received
PUBLISH_STOPPED	0x184		Publish configuration for event STOPPED
PUBLISH_ERROR	0x1A4		Publish configuration for event ERROR
PUBLISH_RXSTARTED	0x1CC		Publish configuration for event RXSTARTED
PUBLISH_TXSTARTED	0x1D0		Publish configuration for event TXSTARTED
PUBLISH_WRITE	0x1E4		Publish configuration for event WRITE
PUBLISH_READ	0x1E8		Publish configuration for event READ
SHORTS	0x200		Shortcuts between local events and tasks
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
ERRORSRC	0x4D0		Error source
MATCH	0x4D4		Status register indicating which address had a match
ENABLE	0x500		Enable TWIS
PSEL.SCL	0x508		Pin select for SCL signal
PSEL.SDA	0x50C		Pin select for SDA signal
RXD.PTR	0x534		RXD Data pointer
RXD.MAXCNT	0x538		Maximum number of bytes in RXD buffer
RXD.AMOUNT	0x53C		Number of bytes transferred in the last RXD transaction
RXD.LIST	0x540		EasyDMA list type
TXD.PTR	0x544		TXD Data pointer
TXD.MAXCNT	0x548		Maximum number of bytes in TXD buffer
TXD.AMOUNT	0x54C		Number of bytes transferred in the last TXD transaction
TXD.LIST	0x550		EasyDMA list type
ADDRESS[n]	0x588		TWI slave address n
CONFIG	0x594		Configuration register for the address match mechanism
ORC	0x5C0		Over-read character. Character sent out in case of an over-read of the transmit buffer.

6.18.9.1 TASKS_STOP

Address offset: 0x014

Stop TWI transaction

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOP			Stop TWI transaction
			Trigger	1	Trigger task

6.18.9.2 TASKS_SUSPEND

Address offset: 0x01C

Suspend TWI transaction

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_SUSPEND			Suspend TWI transaction
			Trigger	1	Trigger task

6.18.9.3 TASKS_RESUME

Address offset: 0x020

Resume TWI transaction

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_RESUME			Resume TWI transaction
			Trigger	1	Trigger task

6.18.9.4 TASKS_PREPARERX

Address offset: 0x030

Prepare the TWI slave to respond to a write command

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_PREPARERX			Prepare the TWI slave to respond to a write command
			Trigger	1	Trigger task

6.18.9.5 TASKS_PREPARETX

Address offset: 0x034

Prepare the TWI slave to respond to a read command

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_PREPARETX			Prepare the TWI slave to respond to a read command
			Trigger	1	Trigger task

6.18.9.6 SUBSCRIBE_STOP

Address offset: 0x094

Subscribe configuration for task STOP

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOP will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.18.9.7 SUBSCRIBE_SUSPEND

Address offset: 0x09C

Subscribe configuration for task SUSPEND

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task SUSPEND will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.18.9.8 SUBSCRIBE_RESUME

Address offset: 0x0A0

Subscribe configuration for task RESUME

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task RESUME will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.18.9.9 SUBSCRIBE_PREPARERX

Address offset: 0x0B0

Subscribe configuration for task PREPARERX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task PREPARERX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.18.9.10 SUBSCRIBE_PREPARETX

Address offset: 0x0B4

Subscribe configuration for task PREPARETX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task PREPARETX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.18.9.11 EVENTS_STOPPED

Address offset: 0x104

TWI stopped

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_STOPPED			TWI stopped
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.18.9.12 EVENTS_ERROR

Address offset: 0x124

TWI error

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ERROR			TWI error
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.18.9.13 EVENTS_RXSTARTED

Address offset: 0x14C

Receive sequence started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RXSTARTED			Receive sequence started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.18.9.14 EVENTS_TXSTARTED

Address offset: 0x150

Transmit sequence started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_TXSTARTED			Transmit sequence started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.18.9.15 EVENTS_WRITE

Address offset: 0x164

Write command received

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_WRITE			Write command received
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.18.9.16 EVENTS_READ

Address offset: 0x168

Read command received

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_READ			Read command received
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.18.9.17 PUBLISH_STOPPED

Address offset: 0x184

Publish configuration for event STOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event STOPPED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.18.9.18 PUBLISH_ERROR

Address offset: 0x1A4

Publish configuration for event ERROR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ERROR will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.18.9.19 PUBLISH_RXSTARTED

Address offset: 0x1CC

Publish configuration for event RXSTARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event RXSTARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.18.9.20 PUBLISH_TXSTARTED

Address offset: 0x1D0

Publish configuration for event TXSTARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TXSTARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.18.9.21 PUBLISH_WRITE

Address offset: 0x1E4

Publish configuration for event WRITE

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event WRITE will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.18.9.22 PUBLISH_READ

Address offset: 0x1E8

Publish configuration for event READ

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event READ will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.18.9.23 SHORTS

Address offset: 0x200

Shortcuts between local events and tasks

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	WRITE_SUSPEND			Shortcut between event WRITE and task SUSPEND
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
B	RW	READ_SUSPEND			Shortcut between event READ and task SUSPEND
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut

6.18.9.24 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	STOPPED			Enable or disable interrupt for event STOPPED
			Disabled	0	Disable
			Enabled	1	Enable
B	RW	ERROR			Enable or disable interrupt for event ERROR
			Disabled	0	Disable
			Enabled	1	Enable
E	RW	RXSTARTED			Enable or disable interrupt for event RXSTARTED
			Disabled	0	Disable
			Enabled	1	Enable
F	RW	TXSTARTED			Enable or disable interrupt for event TXSTARTED
			Disabled	0	Disable
			Enabled	1	Enable
G	RW	WRITE			Enable or disable interrupt for event WRITE
			Disabled	0	Disable
			Enabled	1	Enable
H	RW	READ			Enable or disable interrupt for event READ
			Disabled	0	Disable
			Enabled	1	Enable

6.18.9.25 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	STOPPED			Write '1' to enable interrupt for event STOPPED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	ERROR			Write '1' to enable interrupt for event ERROR
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	RXSTARTED			Write '1' to enable interrupt for event RXSTARTED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
F	RW	TXSTARTED			Write '1' to enable interrupt for event TXSTARTED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
G	RW	WRITE			Write '1' to enable interrupt for event WRITE
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
H	RW	READ			Write '1' to enable interrupt for event READ
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.18.9.26 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	STOPPED			Write '1' to disable interrupt for event STOPPED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	ERROR			Write '1' to disable interrupt for event ERROR
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	RXSTARTED			Write '1' to disable interrupt for event RXSTARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
F	RW	TXSTARTED			Write '1' to disable interrupt for event TXSTARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
G	RW	WRITE			Write '1' to disable interrupt for event WRITE
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
H	RW	READ			Write '1' to disable interrupt for event READ
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.18.9.27 ERRORSRC

Address offset: 0x4D0

Error source

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW W1C	OVERFLOW			RX buffer overflow detected, and prevented
			NotDetected	0	Error did not occur
			Detected	1	Error occurred
B	RW W1C	DNACK			NACK sent after receiving a data byte
			NotReceived	0	Error did not occur
			Received	1	Error occurred
C	RW W1C	OVERREAD			TX buffer over-read detected, and prevented
			NotDetected	0	Error did not occur
			Detected	1	Error occurred

6.18.9.28 MATCH

Address offset: 0x4D4

Status register indicating which address had a match

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	MATCH		[0..1]	Indication of which address in ADDRESS that matched the incoming address

6.18.9.29 ENABLE

Address offset: 0x500

Enable TWIS

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			Enable or disable TWIS
			Disabled	0	Disable TWIS
			Enabled	9	Enable TWIS

6.18.9.30 PSEL.SCL

Address offset: 0x508

Pin select for SCL signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.18.9.31 PSEL.SDA

Address offset: 0x50C

Pin select for SDA signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.18.9.32 RXD

RXD EasyDMA channel

6.18.9.32.1 RXD.PTR

Address offset: 0x534

RXD Data pointer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			RXD Data pointer See the memory chapter for details about which memories are available for EasyDMA.

6.18.9.32.2 RXD.MAXCNT

Address offset: 0x538

Maximum number of bytes in RXD buffer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in RXD buffer

6.18.9.32.3 RXD.AMOUNT

Address offset: 0x53C

Number of bytes transferred in the last RXD transaction

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transferred in the last RXD transaction

6.18.9.32.4 RXD.LIST

Address offset: 0x540

EasyDMA list type

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIST			List type
			Disabled	0	Disable EasyDMA list
			ArrayList	1	Use array list

6.18.9.33 TXD

TXD EasyDMA channel

6.18.9.33.1 TXD.PTR

Address offset: 0x544

TXD Data pointer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			TXD Data pointer See the memory chapter for details about which memories are available for EasyDMA.

6.18.9.33.2 TXD.MAXCNT

Address offset: 0x548

Maximum number of bytes in TXD buffer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in TXD buffer

6.18.9.33.3 TXD.AMOUNT

Address offset: 0x54C

Number of bytes transferred in the last TXD transaction

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transferred in the last TXD transaction

6.18.9.33.4 TXD.LIST

Address offset: 0x550

EasyDMA list type

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LIST			List type
			Disabled	0	Disable EasyDMA list
			ArrayList	1	Use array list

6.18.9.34 ADDRESS[n] (n=0..1)

Address offset: 0x588 + (n × 0x4)

TWI slave address n

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ADDRESS			TWI slave address

6.18.9.35 CONFIG

Address offset: 0x594

Configuration register for the address match mechanism

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A-B	RW	ADDRESS[i] (i=0..1)			Enable or disable address matching on ADDRESS[i]
			Disabled	0	Disabled
			Enabled	1	Enabled

6.18.9.36 ORC

Address offset: 0x5C0

Over-read character. Character sent out in case of an over-read of the transmit buffer.

Bit number																															
ID																															
Reset 0x00000000																															
ID	R/W	Field	Value ID	Value	Description																										
A	RW	ORC			Over-read character. Character sent out in case of an over-read of the transmit buffer.																										

6.18.10 Electrical specification

6.18.10.1 TWIS slave timing specifications

Symbol	Description	Min.	Typ.	Max.	Units
$f_{TWIS,SCL}$	Bit rates for TWIS[25]	100		400	kbps
$t_{TWIS,START}$	Time from PREPARERX/PREPARETX task to ready to receive/transmit		1.5		µs
t_{TWIS,SU_DAT}	Data setup time before positive edge on SCL – all modes	300			ns
t_{TWIS,HD_DAT}	Data hold time after negative edge on SCL – all modes	500			ns
$t_{TWIS,HD\_STA,100kbps}$	TWI slave hold time from for START condition (SDA low to SCL low), 100 kbps	5200			ns
$t_{TWIS,HD\_STA,400kbps}$	TWI slave hold time from for START condition (SDA low to SCL low), 400 kbps	1300			ns
$t_{TWIS,SU\_STO,100kbps}$	TWI slave setup time from SCL high to STOP condition, 100 kbps	5200			ns
$t_{TWIS,SU\_STO,400kbps}$	TWI slave setup time from SCL high to STOP condition, 400 kbps	1300			ns
$t_{TWIS,BUF,100kbps}$	TWI slave bus free time between STOP and START conditions, 100 kbps		4700		ns
$t_{TWIS,BUF,400kbps}$	TWI slave bus free time between STOP and START conditions, 400 kbps		1300		ns

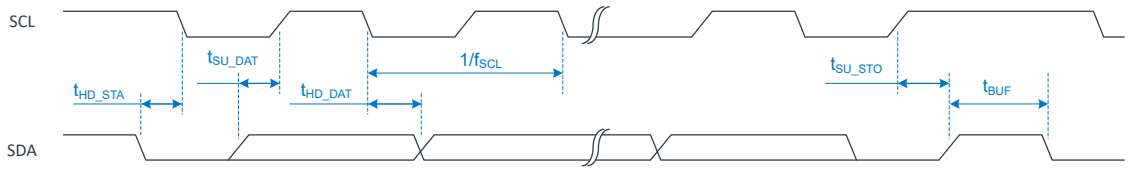

Figure 108: TWIS timing diagram, 1 byte transaction

6.19 UARTE — Universal asynchronous receiver/transmitter with EasyDMA

The Universal asynchronous receiver/transmitter with EasyDMA (UARTE) offers fast, full-duplex, asynchronous serial communication with built-in flow control (CTS, RTS) support in hardware at a rate up to 1 Mbps, and EasyDMA data transfer from/to RAM.

Listed here are the main features for UARTE:

- Full-duplex operation
- Automatic hardware flow control
- Optional even parity bit checking and generation
- EasyDMA
- Up to 1 Mbps baudrate
- Return to IDLE between transactions supported (when using HW flow control)
- One or two stop bit

[25] High bit rates or stronger pull-ups may require GPIOs to be set as High Drive, see GPIO chapter for more details.

- Least significant bit (LSB) first

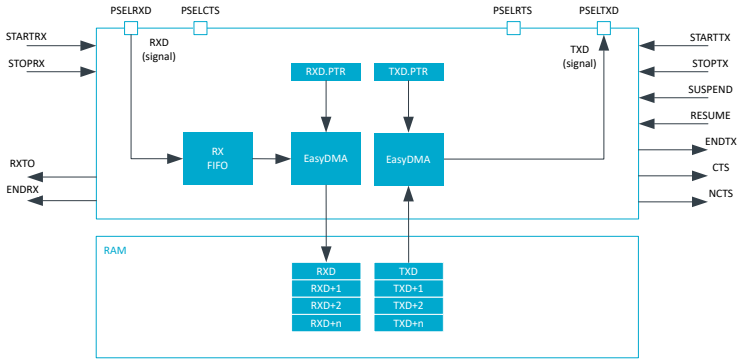

Figure 109: UARTE configuration

The GPIOs used for each UART interface can be chosen from any GPIO on the device and are independently configurable. This enables great flexibility in device pinout and efficient use of board space and signal routing.

Note: The external crystal oscillator must be enabled to obtain sufficient clock accuracy for stable communication. See CLOCK — Clock control on page 74 for more information.

6.19.1 EasyDMA

The UARTE implements EasyDMA for reading and writing to and from the RAM.

If the TXD.PTR and the RXD.PTR are not pointing to the Data RAM region, an EasyDMA transfer may result in a HardFault or RAM corruption. See Memory on page 21 for more information about the different memory regions.

The .PTR and .MAXCNT registers are double-buffered. They can be updated and prepared for the next RX/TX transmission immediately after having received the RXSTARTED/TXSTARTED event.

The ENDRX and ENDTX events indicate that the EasyDMA is finished accessing the RX or TX buffer in RAM.

6.19.2 Transmission

The first step of a DMA transmission is storing bytes in the transmit buffer and configuring EasyDMA. This is achieved by writing the initial address pointer to TXD.PTR, and the number of bytes in the RAM buffer to TXD.MAXCNT. The UARTE transmission is started by triggering the STARTTX task.

After each byte has been sent over the TXD line, a TXDRDY event will be generated.

When all bytes in the TXD buffer, as specified in the TXD.MAXCNT register, have been transmitted, the UARTE transmission will end automatically and an ENDTX event will be generated.

A UARTE transmission sequence is stopped by triggering the STOPTX task. A TXSTOPPED event will be generated when the UARTE transmitter has stopped.

If the ENDTX event has not already been generated when the UARTE transmitter has come to a stop, the UARTE will generate the ENDTX event explicitly even though all bytes in the TXD buffer, as specified in the TXD.MAXCNT register, have not been transmitted.

If flow control is enabled through the HWFC field in the CONFIG register, a transmission will be automatically suspended when CTS is deactivated and resumed when CTS is activated again, as shown in the following figure. A byte that is in transmission when CTS is deactivated will be fully transmitted before the transmission is suspended.

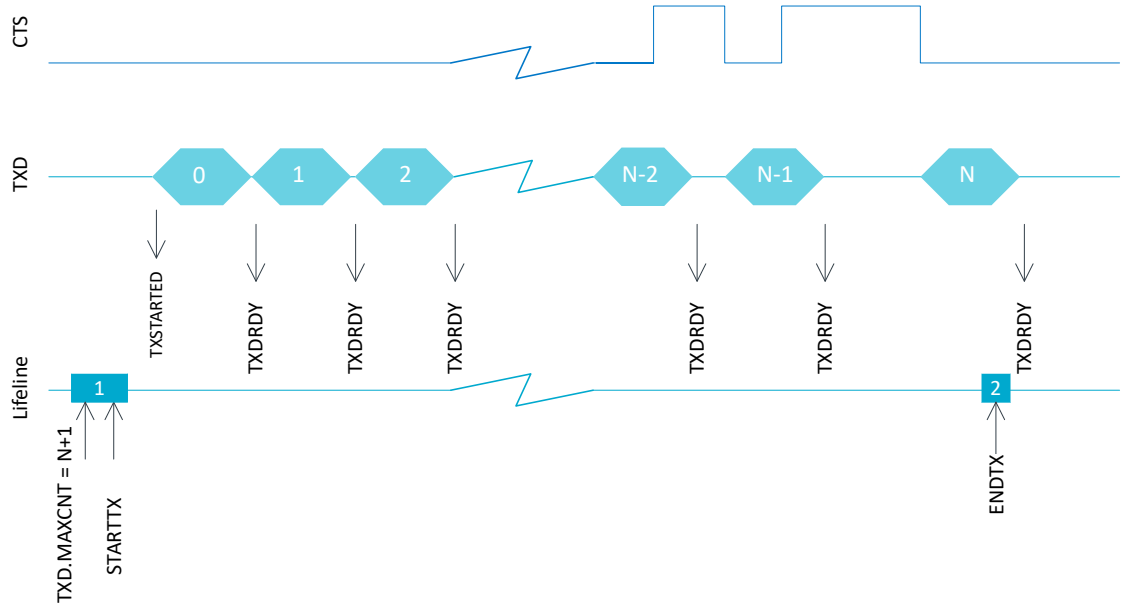

Figure 110: UARTE transmission

The UARTE transmitter will be in its lowest activity level, and consume the least amount of energy, when it is stopped, i.e. before it is started via STARTTX or after it has been stopped via STOPTX and the TXSTOPPED event has been generated. See POWER — Power control on page 68 for more information about power modes.

6.19.3 Reception

The UARTE receiver is started by triggering the STARTRX task. The UARTE receiver is using EasyDMA to store incoming data in an RX buffer in RAM.

The RX buffer is located at the address specified in the RXD.PTR register. The RXD.PTR register is double-buffered and it can be updated and prepared for the next STARTRX task immediately after the RXSTARTED event is generated. The size of the RX buffer is specified in the RXD.MAXCNT register. The UARTE generates an ENDRX event when it has filled up the RX buffer, as seen in the following figure.

For each byte received over the RXD line, an RXDRDY event will be generated. This event is likely to occur before the corresponding data has been transferred to Data RAM.

The RXD.AMOUNT register can be queried following an ENDRX event to see how many new bytes have been transferred to the RX buffer in RAM since the previous ENDRX event.

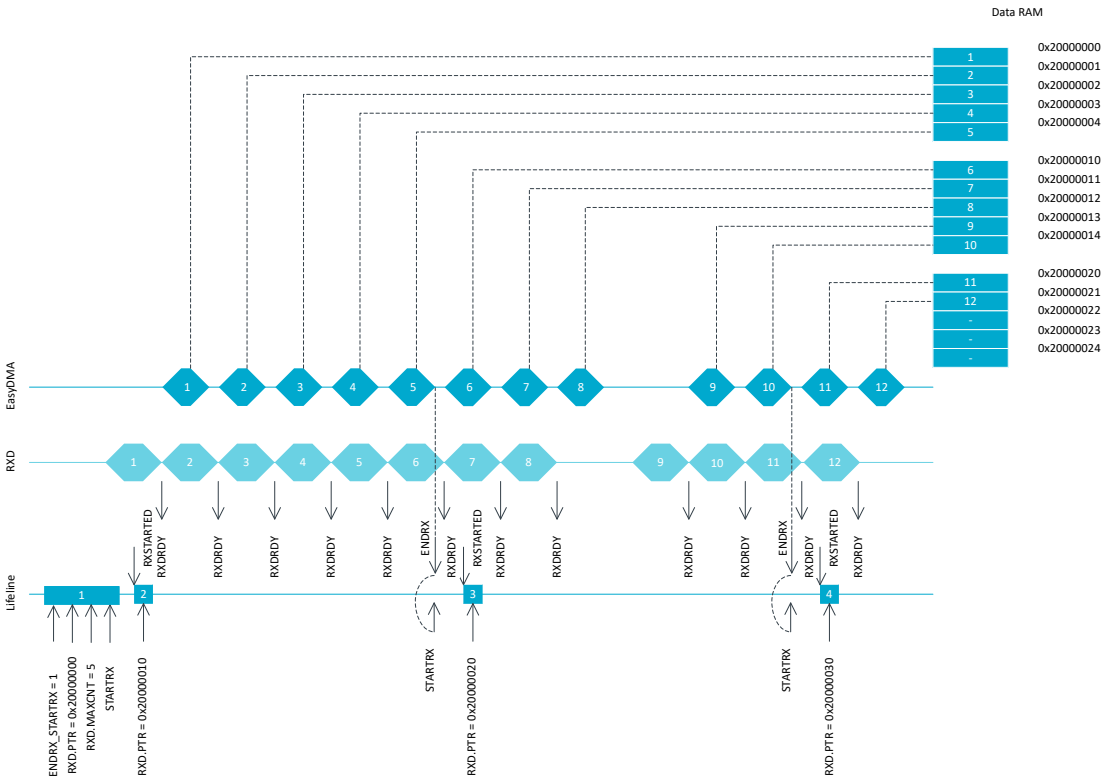

Figure 111: UARTE reception

The UARTE receiver is stopped by triggering the STOPRX task. An RXTO event is generated when the UARTE has stopped. The UARTE will make sure that an impending ENDRX event will be generated before the RXTO event is generated. This means that the UARTE will guarantee that no ENDRX event will be generated after RXTO, unless the UARTE is restarted or a FLUSHRX command is issued after the RXTO event is generated.

Note: If the ENDRX event has not been generated when the UARTE receiver stops, indicating that all pending content in the RX FIFO has been moved to the RX buffer, the UARTE will generate the ENDRX event explicitly even though the RX buffer is not full. In this scenario the ENDRX event will be generated before the RXTO event is generated.

To determine the amount of bytes the RX buffer has received, the CPU can read the RXD.AMOUNT register following the ENDRX event or the RXTO event.

The UARTE is able to receive up to four bytes after the STOPRX task has been triggered, as long as these are sent in succession immediately after the RTS signal is deactivated. After the RTS is deactivated, the UART is able to receive bytes for a period of time equal to the time needed to send four bytes on the configured baud rate.

After the RXTO event is generated the internal RX FIFO may still contain data, and to move this data to RAM the FLUSHRX task must be triggered. To make sure that this data does not overwrite data in the RX buffer, the RX buffer should be emptied or the RXD.PTR should be updated before the FLUSHRX task is triggered. To make sure that all data in the RX FIFO is moved to the RX buffer, the RXD.MAXCNT register must be set to RXD.MAXCNT > 4, as seen in the following figure. The UARTE will generate the ENDRX event after completing the FLUSHRX task even if the RX FIFO was empty or if the RX buffer does not get filled up. To be able to know how many bytes have actually been received into the RX buffer in this case, the CPU can read the RXD.AMOUNT register following the ENDRX event.

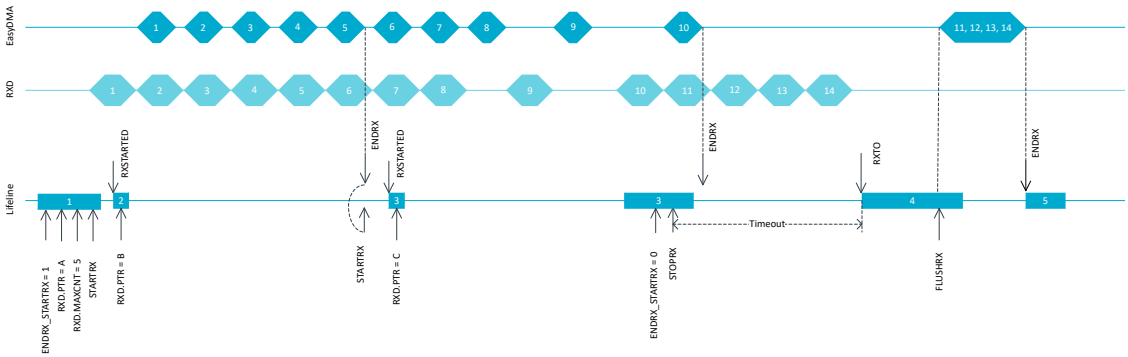

Figure 112: UARTE reception with forced stop via STOPRX

If HW flow control is enabled through the HWFC field in the CONFIG register, the RTS signal will be deactivated when the receiver is stopped via the STOPRX task or when the UARTE is only able to receive four more bytes in its internal RX FIFO.

With flow control disabled, the UARTE will function in the same way as when the flow control is enabled except that the RTS line will not be used. This means that no signal will be generated when the UARTE has reached the point where it is only able to receive four more bytes in its internal RX FIFO. Data received when the internal RX FIFO is filled up, will be lost.

The UARTE receiver will be in its lowest activity level, and consume the least amount of energy, when it is stopped, i.e. before it is started via STARTRX or after it has been stopped via STOPRX and the RXTO event has been generated. See POWER — Power control on page 68 for more information about power modes.

6.19.4 Error conditions

An ERROR event, in the form of a framing error, will be generated if a valid stop bit is not detected in a frame. Another ERROR event, in the form of a break condition, will be generated if the RXD line is held active low for longer than the length of a data frame. Effectively, a framing error is always generated before a break condition occurs.

An ERROR event will not stop reception. If the error was a parity error, the received byte will still be transferred into Data RAM, and so will following incoming bytes. If there was a framing error (wrong stop bit), that specific byte will NOT be stored into Data RAM, but following incoming bytes will.

6.19.5 Using the UARTE without flow control

If flow control is not enabled, the interface will behave as if the CTS and RTS lines are kept active all the time.

6.19.6 Parity and stop bit configuration

Automatic even parity generation for both transmission and reception can be configured using the register CONFIG on page 416. See the register description for details.

The amount of stop bits can also be configured through the register CONFIG on page 416.

6.19.7 Low power

When putting the system in low power and the peripheral is not needed, lowest possible power consumption is achieved by stopping, and then disabling the peripheral.

The STOPTX and STOPRX tasks may not be always needed (the peripheral might already be stopped), but if STOPTX and/or STOPRX is sent, software shall wait until the TXSTOPPED and/or RXTO event is received in response, before disabling the peripheral through the ENABLE register.

6.19.8 Pin configuration

The different signals RXD, CTS (Clear To Send, active low), RTS (Request To Send, active low), and TXD associated with the UARTE are mapped to physical pins according to the configuration specified in the PSEL.RXD, PSEL.CTS, PSEL.RTS, and PSEL.TXD registers respectively.

The PSEL.RXD, PSEL.CTS, PSEL.RTS, and PSEL.TXD registers and their configurations are only used as long as the UARTE is enabled, and retained only for the duration the device is in ON mode. PSEL.RXD, PSEL.RTS, PSEL.RTS, and PSEL.TXD must only be configured when the UARTE is disabled.

To secure correct signal levels on the pins by the UARTE when the system is in OFF mode, the pins must be configured in the GPIO peripheral as described in the following table.

Only one peripheral can be assigned to drive a particular GPIO pin at a time. Failing to do so may result in unpredictable behavior.

UARTE signal	UARTE pin	Direction	Output value
RXD	As specified in PSEL.RXD	Input	Not applicable
CTS	As specified in PSEL.CTS	Input	Not applicable
RTS	As specified in PSEL.RTS	Output	1
TXD	As specified in PSEL.TXD	Output	1

Table 49: GPIO configuration before enabling peripheral

6.19.9 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
UARTE0 : S UARTE0 : NS	0x50008000 0x40008000	US	NS	SA	No	Universal asynchronous receiver/ transmitter with EasyDMA 0
UARTE1 : S UARTE1 : NS	0x50009000 0x40009000	US	NS	SA	No	Universal asynchronous receiver/ transmitter with EasyDMA 1
UARTE2 : S UARTE2 : NS	0x5000A000 0x4000A000	US	NS	SA	No	Universal asynchronous receiver/ transmitter with EasyDMA 2
UARTE3 : S UARTE3 : NS	0x5000B000 0x4000B000	US	NS	SA	No	Universal asynchronous receiver/ transmitter with EasyDMA 3

Register overview

Register	Offset	TZ	Description
TASKS_STARTRX	0x000		Start UART receiver
TASKS_STOPRX	0x004		Stop UART receiver
TASKS_STARTTX	0x008		Start UART transmitter
TASKS_STOPTX	0x00C		Stop UART transmitter
TASKS_FLUSHRX	0x02C		Flush RX FIFO into RX buffer
SUBSCRIBE_STARTRX	0x080		Subscribe configuration for task STARTRX
SUBSCRIBE_STOPRX	0x084		Subscribe configuration for task STOPRX
SUBSCRIBE_STARTTX	0x088		Subscribe configuration for task STARTTX
SUBSCRIBE_STOPTX	0x08C		Subscribe configuration for task STOPTX
SUBSCRIBE_FLUSHRX	0x0AC		Subscribe configuration for task FLUSHRX
EVENTS_CTS	0x100		CTS is activated (set low). Clear To Send.
EVENTS_NCTS	0x104		CTS is deactivated (set high). Not Clear To Send.

Register	Offset	TZ	Description
EVENTS_RXDRDY	0x108		Data received in RXD (but potentially not yet transferred to Data RAM)
EVENTS_ENDRX	0x110		Receive buffer is filled up
EVENTS_TXDRDY	0x11C		Data sent from TXD
EVENTS_ENDTX	0x120		Last TX byte transmitted
EVENTS_ERROR	0x124		Error detected
EVENTS_RXTO	0x144		Receiver timeout
EVENTS_RXSTARTED	0x14C		UART receiver has started
EVENTS_TXSTARTED	0x150		UART transmitter has started
EVENTS_TXSTOPPED	0x158		Transmitter stopped
PUBLISH_CTS	0x180		Publish configuration for event CTS
PUBLISH_NCTS	0x184		Publish configuration for event NCTS
PUBLISH_RXDRDY	0x188		Publish configuration for event RXDRDY
PUBLISH_ENDRX	0x190		Publish configuration for event ENDRX
PUBLISH_TXDRDY	0x19C		Publish configuration for event TXDRDY
PUBLISH_ENDTX	0x1A0		Publish configuration for event ENDTX
PUBLISH_ERROR	0x1A4		Publish configuration for event ERROR
PUBLISH_RXTO	0x1C4		Publish configuration for event RXTO
PUBLISH_RXSTARTED	0x1CC		Publish configuration for event RXSTARTED
PUBLISH_TXSTARTED	0x1D0		Publish configuration for event TXSTARTED
PUBLISH_TXSTOPPED	0x1D8		Publish configuration for event TXSTOPPED
SHORTS	0x200		Shortcuts between local events and tasks
INTEN	0x300		Enable or disable interrupt
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
ERRORSRC	0x480		Error source This register is read/write one to clear.
ENABLE	0x500		Enable UART
PSEL.RTS	0x508		Pin select for RTS signal
PSEL.TXD	0x50C		Pin select for TXD signal
PSEL.CTS	0x510		Pin select for CTS signal
PSEL.RXD	0x514		Pin select for RXD signal
BAUDRATE	0x524		Baud rate. Accuracy depends on the HFCLK source selected.
RXD.PTR	0x534		Data pointer
RXD.MAXCNT	0x538		Maximum number of bytes in receive buffer
RXD.AMOUNT	0x53C		Number of bytes transferred in the last transaction
TXD.PTR	0x544		Data pointer
TXD.MAXCNT	0x548		Maximum number of bytes in transmit buffer
TXD.AMOUNT	0x54C		Number of bytes transferred in the last transaction
CONFIG	0x56C		Configuration of parity and hardware flow control

6.19.9.1 TASKS_STARTRX

Address offset: 0x000

Start UART receiver

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STARTRX			Start UART receiver
			Trigger	1	Trigger task

6.19.9.2 TASKS_STOPRX

Address offset: 0x004

Stop UART receiver

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOPRX			Stop UART receiver
			Trigger	1	Trigger task

6.19.9.3 TASKS_STARTTX

Address offset: 0x008

Start UART transmitter

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STARTTX			Start UART transmitter
			Trigger	1	Trigger task

6.19.9.4 TASKS_STOPTX

Address offset: 0x00C

Stop UART transmitter

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_STOPTX			Stop UART transmitter
			Trigger	1	Trigger task

6.19.9.5 TASKS_FLUSHRX

Address offset: 0x02C

Flush RX FIFO into RX buffer

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_FLUSHRX			Flush RX FIFO into RX buffer
			Trigger	1	Trigger task

6.19.9.6 SUBSCRIBE_STARTRX

Address offset: 0x080

Subscribe configuration for task STARTRX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STARTRX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.19.9.7 SUBSCRIBE_STOPRX

Address offset: 0x084

Subscribe configuration for task STOPRX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOPRX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.19.9.8 SUBSCRIBE_STARTTX

Address offset: 0x088

Subscribe configuration for task STARTTX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STARTTX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.19.9.9 SUBSCRIBE_STOPTX

Address offset: 0x08C

Subscribe configuration for task STOPTX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task STOPTX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.19.9.10 SUBSCRIBE_FLUSHRX

Address offset: 0x0AC

Subscribe configuration for task FLUSHRX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task FLUSHRX will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.19.9.11 EVENTS_CTS

Address offset: 0x100

CTS is activated (set low). Clear To Send.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_CTS			CTS is activated (set low). Clear To Send.
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.12 EVENTS_NCTS

Address offset: 0x104

CTS is deactivated (set high). Not Clear To Send.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_NCTS			CTS is deactivated (set high). Not Clear To Send.
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.13 EVENTS_RXDRDY

Address offset: 0x108

Data received in RXD (but potentially not yet transferred to Data RAM)

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RXDRDY			Data received in RXD (but potentially not yet transferred to Data RAM)
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.14 EVENTS_ENDRX

Address offset: 0x110

Receive buffer is filled up

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ENDRX			Receive buffer is filled up
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.15 EVENTS_TXDRDY

Address offset: 0x11C

Data sent from TXD

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_TXDRDY			Data sent from TXD
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.16 EVENTS_ENDTX

Address offset: 0x120

Last TX byte transmitted

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ENDTX			Last TX byte transmitted
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.17 EVENTS_ERROR

Address offset: 0x124

Error detected

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_ERROR			Error detected
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.18 EVENTS_RXTO

Address offset: 0x144

Receiver timeout

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RXTO			Receiver timeout
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.19 EVENTS_RXSTARTED

Address offset: 0x14C

UART receiver has started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_RXSTARTED			UART receiver has started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.20 EVENTS_TXSTARTED

Address offset: 0x150

UART transmitter has started

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_TXSTARTED			UART transmitter has started
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.21 EVENTS_TXSTOPPED

Address offset: 0x158

Transmitter stopped

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_TXSTOPPED			Transmitter stopped
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.19.9.22 PUBLISH_CTS

Address offset: 0x180

Publish configuration for event CTS

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event CTS will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.23 PUBLISH_NCTS

Address offset: 0x184

Publish configuration for event NCTS

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event NCTS will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.24 PUBLISH_RXDRDY

Address offset: 0x188

Publish configuration for event RXDRDY

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event RXDRDY will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.25 PUBLISH_ENDRX

Address offset: 0x190

Publish configuration for event ENDRX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ENDRX will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.26 PUBLISH_TXDRDY

Address offset: 0x19C

Publish configuration for event TXDRDY

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TXDRDY will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.27 PUBLISH_ENDTX

Address offset: 0x1A0

Publish configuration for event ENDTX

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ENDTX will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.28 PUBLISH_ERROR

Address offset: 0x1A4

Publish configuration for event ERROR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event ERROR will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.29 PUBLISH_RXTO

Address offset: 0x1C4

Publish configuration for event RXTO

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event RXTO will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.30 PUBLISH_RXSTARTED

Address offset: 0x1CC

Publish configuration for event RXSTARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event RXSTARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.31 PUBLISH_TXSTARTED

Address offset: 0x1D0

Publish configuration for event TXSTARTED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TXSTARTED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.32 PUBLISH_TXSTOPPED

Address offset: 0x1D8

Publish configuration for event TXSTOPPED

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TXSTOPPED will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.19.9.33 SHORTS

Address offset: 0x200

Shortcuts between local events and tasks

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
C	RW	ENDRX_STARTRX			Shortcut between event ENDRX and task STARTRX
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut
D	RW	ENDRX_STOPRX			Shortcut between event ENDRX and task STOPRX
			Disabled	0	Disable shortcut
			Enabled	1	Enable shortcut

6.19.9.34 INTEN

Address offset: 0x300

Enable or disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CTS			Enable or disable interrupt for event CTS
			Disabled	0	Disable
			Enabled	1	Enable
B	RW	NCTS			Enable or disable interrupt for event NCTS
			Disabled	0	Disable
			Enabled	1	Enable
C	RW	RXDRDY			Enable or disable interrupt for event RXDRDY
			Disabled	0	Disable
			Enabled	1	Enable
D	RW	ENDRX			Enable or disable interrupt for event ENDRX
			Disabled	0	Disable
			Enabled	1	Enable
E	RW	TXDRDY			Enable or disable interrupt for event TXDRDY

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Disabled	0	Disable
			Enabled	1	Enable
F	RW	ENDTX			Enable or disable interrupt for event ENDTX
			Disabled	0	Disable
			Enabled	1	Enable
G	RW	ERROR			Enable or disable interrupt for event ERROR
			Disabled	0	Disable
			Enabled	1	Enable
H	RW	RXTO			Enable or disable interrupt for event RXTO
			Disabled	0	Disable
			Enabled	1	Enable
I	RW	RXSTARTED			Enable or disable interrupt for event RXSTARTED
			Disabled	0	Disable
			Enabled	1	Enable
J	RW	TXSTARTED			Enable or disable interrupt for event TXSTARTED
			Disabled	0	Disable
			Enabled	1	Enable
L	RW	TXSTOPPED			Enable or disable interrupt for event TXSTOPPED
			Disabled	0	Disable
			Enabled	1	Enable

6.19.9.35 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CTS			Write '1' to enable interrupt for event CTS
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	NCTS			Write '1' to enable interrupt for event NCTS
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	RXDRDY			Write '1' to enable interrupt for event RXDRDY
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
D	RW	ENDRX			Write '1' to enable interrupt for event ENDRX
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	TXDRDY			Write '1' to enable interrupt for event TXDRDY
			Set	1	Enable
			Disabled	0	Read: Disabled

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Enabled	1	Read: Enabled
F	RW	ENDTX			Write '1' to enable interrupt for event ENDTX
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
G	RW	ERROR			Write '1' to enable interrupt for event ERROR
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
H	RW	RXTO			Write '1' to enable interrupt for event RXTO
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
I	RW	RXSTARTED			Write '1' to enable interrupt for event RXSTARTED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
J	RW	TXSTARTED			Write '1' to enable interrupt for event TXSTARTED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
L	RW	TXSTOPPED			Write '1' to enable interrupt for event TXSTOPPED
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.19.9.36 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CTS			Write '1' to disable interrupt for event CTS
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
B	RW	NCTS			Write '1' to disable interrupt for event NCTS
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
C	RW	RXDRDY			Write '1' to disable interrupt for event RXDRDY
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
D	RW	ENDRX			Write '1' to disable interrupt for event ENDRX
			Clear	1	Disable

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
E	RW	TXDRDY			Write '1' to disable interrupt for event TXDRDY
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
F	RW	ENDTX			Write '1' to disable interrupt for event ENDTX
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
G	RW	ERROR			Write '1' to disable interrupt for event ERROR
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
H	RW	RXTO			Write '1' to disable interrupt for event RXTO
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
I	RW	RXSTARTED			Write '1' to disable interrupt for event RXSTARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
J	RW	TXSTARTED			Write '1' to disable interrupt for event TXSTARTED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled
L	RW	TXSTOPPED			Write '1' to disable interrupt for event TXSTOPPED
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.19.9.37 ERRORSRC

Address offset: 0x480

Error source

This register is read/write one to clear.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW W1C	OVERRUN			Overrun error A start bit is received while the previous data still lies in RXD. (Previous data is lost.)
			NotPresent	0	Read: error not present
			Present	1	Read: error present
B	RW W1C	PARITY			Parity error A character with bad parity is received, if HW parity check is enabled.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			NotPresent	0	Read: error not present
			Present	1	Read: error present
C	RW W1C	FRAMING			Framing error occurred A valid stop bit is not detected on the serial data input after all bits in a character have been received.
			NotPresent	0	Read: error not present
			Present	1	Read: error present
D	RW W1C	BREAK			Break condition The serial data input is '0' for longer than the length of a data frame. (The data frame length is 10 bits without parity bit, and 11 bits with parity bit).
			NotPresent	0	Read: error not present
			Present	1	Read: error present

6.19.9.38 ENABLE

Address offset: 0x500

Enable UART

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			Enable or disable UARTE
			Disabled	0	Disable UARTE
			Enabled	8	Enable UARTE

6.19.9.39 PSEL.RTS

Address offset: 0x508

Pin select for RTS signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.19.9.40 PSEL.TXD

Address offset: 0x50C

Pin select for TXD signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.19.9.41 PSEL.CTS

Address offset: 0x510

Pin select for CTS signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.19.9.42 PSEL.RXD

Address offset: 0x514

Pin select for RXD signal

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN		[0..31]	Pin number
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

6.19.9.43 BAUDRATE

Address offset: 0x524

Baud rate. Accuracy depends on the HFCLK source selected.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x04000000				**0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	BAUDRATE			Baud rate
			Baud1200	0x0004F000	1200 baud (actual rate: 1205)
			Baud2400	0x0009D000	2400 baud (actual rate: 2396)
			Baud4800	0x0013B000	4800 baud (actual rate: 4808)
			Baud9600	0x00275000	9600 baud (actual rate: 9598)
			Baud14400	0x003AF000	14400 baud (actual rate: 14401)

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x04000000				**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
			Baud19200	0x004EA000																															
			Baud28800	0x0075C000																															
			Baud31250	0x00800000																															
			Baud38400	0x009D0000																															
			Baud56000	0x00E50000																															
			Baud57600	0x00EB0000																															
			Baud76800	0x013A9000																															
			Baud115200	0x01D60000																															
			Baud230400	0x03B00000																															
			Baud250000	0x04000000																															
			Baud460800	0x07400000																															
			Baud921600	0x0F000000																															
			Baud1M	0x10000000																															

6.19.9.44 RXD

RXD EasyDMA channel

6.19.9.44.1 RXD.PTR

Address offset: 0x534

Data pointer

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	PTR																																	

Data pointer

See the memory chapter for details about which memories are available for EasyDMA.

6.19.9.44.2 RXD.MAXCNT

Address offset: 0x538

Maximum number of bytes in receive buffer

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																							A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	MAXCNT		[1..0x1FFF]																															

Maximum number of bytes in receive buffer

6.19.9.44.3 RXD.AMOUNT

Address offset: 0x53C

Number of bytes transferred in the last transaction

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	A A A A A A A A A A A A A A A A
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transferred in the last transaction

6.19.9.45 TXD

TXD EasyDMA channel

6.19.9.45.1 TXD.PTR

Address offset: 0x544

Data pointer

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PTR			Data pointer See the memory chapter for details about which memories are available for EasyDMA.

6.19.9.45.2 TXD.MAXCNT

Address offset: 0x548

Maximum number of bytes in transmit buffer

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	A A A A A A A A A A A A A A A A
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	MAXCNT		[1..0x1FFF]	Maximum number of bytes in transmit buffer

6.19.9.45.3 TXD.AMOUNT

Address offset: 0x54C

Number of bytes transferred in the last transaction

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	A A A A A A A A A A A A A A A A
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	AMOUNT		[1..0x1FFF]	Number of bytes transferred in the last transaction

6.19.9.46 CONFIG

Address offset: 0x56C

Configuration of parity and hardware flow control

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	C B B B
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
	RW	HWFC			Hardware flow control
			Disabled	0	Disabled
			Enabled	1	Enabled
B	RW	PARITY			Parity
			Excluded	0x0	Exclude parity bit
			Included	0x7	Include even parity bit
C	RW	STOP			Stop bits
			One	0	One stop bit
			Two	1	Two stop bits

6.19.10 Electrical specification

6.19.10.1 UARTE electrical specification

Symbol	Description	Min.	Typ.	Max.	Units
f_{UARTE}	Baud rate for UARTE[26].			1000	kbps
$t_{UARTE,CTSH}$	CTS high time	1			µs
$t_{UARTE,START}$	Time from STARTRX/STARTTX task to transmission started		0.25		µs

6.20 WDT — Watchdog timer

A countdown watchdog timer using the low-frequency clock source (LFCLK) offers configurable and robust protection against application lock-up.

The watchdog timer is started by triggering the START task.

The watchdog can be paused during long CPU sleep periods for low power applications and when the debugger has halted the CPU. The watchdog is implemented as a down-counter that generates a TIMEOUT event when it wraps over after counting down to 0. When the watchdog timer is started through the START task, the watchdog counter is loaded with the value specified in the CRV register. This counter is also reloaded with the value specified in the CRV register when a reload request is granted.

The watchdog's timeout period is given by:

```
timeout [s] = ( CRV + 1 ) / 32768
```

When started, the watchdog will automatically force the 32.768 kHz RC oscillator on as long as no other 32.768 kHz clock source is running and generating the 32.768 kHz system clock, see chapter CLOCK — Clock control on page 74.

6.20.1 Reload criteria

The watchdog has eight separate reload request registers, which shall be used to request the watchdog to reload its counter with the value specified in the CRV register. To reload the watchdog counter, the special value 0x6E524635 needs to be written to all enabled reload registers.

One or more RR registers can be individually enabled through the RREN register.

[26] High baud rates may require GPIOs to be set as High Drive, see GPIO chapter for more details.

6.20.2 Temporarily pausing the watchdog

By default, the watchdog will be active counting down the down-counter while the CPU is sleeping and when it is halted by the debugger. It is however possible to configure the watchdog to automatically pause while the CPU is sleeping as well as when it is halted by the debugger.

6.20.3 Watchdog reset

A TIMEOUT event will automatically lead to a watchdog reset.

See Reset on page 59 for more information about reset sources. If the watchdog is configured to generate an interrupt on the TIMEOUT event, the watchdog reset will be postponed with two 32.768 kHz clock cycles after the TIMEOUT event has been generated. Once the TIMEOUT event has been generated, the impending watchdog reset will always be effectuated.

The watchdog must be configured before it is started. After it is started, the watchdog's configuration registers, which comprise registers CRV, RREN, and CONFIG, will be blocked for further configuration.

The watchdog can be reset from several reset sources, see Reset behavior on page 60.

When the device starts running again, after a reset, or waking up from OFF mode, the watchdog configuration registers will be available for configuration again.

6.20.4 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
WDT : S	0x50018000	US	NS	NA	No	Watchdog timer
WDT : NS	0x40018000					

Register overview

Register	Offset	TZ	Description
TASKS_START	0x000		Start the watchdog
SUBSCRIBE_START	0x080		Subscribe configuration for task START
EVENTS_TIMEOUT	0x100		Watchdog timeout
PUBLISH_TIMEOUT	0x180		Publish configuration for event TIMEOUT
INTENSET	0x304		Enable interrupt
INTENCLR	0x308		Disable interrupt
RUNSTATUS	0x400		Run status
REQSTATUS	0x404		Request status
CRV	0x504		Counter reload value
RREN	0x508		Enable register for reload request registers
CONFIG	0x50C		Configuration register
RR[n]	0x600		Reload request n

6.20.4.1 TASKS_START

Address offset: 0x000

Start the watchdog

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_START			Start the watchdog
			Trigger	1	Trigger task

6.20.4.2 SUBSCRIBE_START

Address offset: 0x080

Subscribe configuration for task START

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that task START will subscribe to
B	RW	EN			
			Disabled	0	Disable subscription
			Enabled	1	Enable subscription

6.20.4.3 EVENTS_TIMEOUT

Address offset: 0x100

Watchdog timeout

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENTS_TIMEOUT			Watchdog timeout
			NotGenerated	0	Event not generated
			Generated	1	Event generated

6.20.4.4 PUBLISH_TIMEOUT

Address offset: 0x180

Publish configuration for event TIMEOUT

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CHIDX		[0..255]	DPPI channel that event TIMEOUT will publish to
B	RW	EN			
			Disabled	0	Disable publishing
			Enabled	1	Enable publishing

6.20.4.5 INTENSET

Address offset: 0x304

Enable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TIMEOUT			Write '1' to enable interrupt for event TIMEOUT
			Set	1	Enable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.20.4.6 INTENCLR

Address offset: 0x308

Disable interrupt

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TIMEOUT			Write '1' to disable interrupt for event TIMEOUT
			Clear	1	Disable
			Disabled	0	Read: Disabled
			Enabled	1	Read: Enabled

6.20.4.7 RUNSTATUS

Address offset: 0x400

Run status

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
	R	RUNSTATUSWDT			Indicates whether or not the watchdog is running
			NotRunning	0	Watchdog not running
			Running	1	Watchdog is running

6.20.4.8 REQSTATUS

Address offset: 0x404

Request status

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000001				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A-H	R	RR[i] (i=0..7)			Request status for RR[i] register
			DisabledOrRequested	0	RR[i] register is not enabled, or are already requesting reload
			EnabledAndUnrequested	1	RR[i] register is enabled, and are not yet requesting reload

6.20.4.9 CRV

Address offset: 0x504

Counter reload value

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0xFFFFFFFF				**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
ID	R/W	Field	Value ID	Value																															
A	RW	CRV		[0x0000000F..0xFFFFFFFF]																															
				Counter reload value in number of cycles of the 32.768 kHz clock																																

6.20.4.10 RREN

Address offset: 0x508

Enable register for reload request registers

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																												H	G	F	E	D	C	B	A
Reset 0x00000001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
A-H	RW	RR[i] (i=0..7)																																	
				Enable or disable RR[i] register																																	
			Disabled	0																																	
				Disable RR[i] register																																	
			Enabled	1																																	
				Enable RR[i] register																																	

6.20.4.11 CONFIG

Address offset: 0x50C

Configuration register

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																C			
Reset 0x00000001				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
	RW	SLEEP																																	
				Configure the watchdog to either be paused, or kept running, while the CPU is sleeping																																	
			Pause	0																																	
				Pause watchdog while the CPU is sleeping																																	
			Run	1																																	
				Keep the watchdog running while the CPU is sleeping																																	
C	RW	HALT																																	
				Configure the watchdog to either be paused, or kept running, while the CPU is halted by the debugger																																	
			Pause	0																																	
				Pause watchdog while the CPU is halted by the debugger																																	
			Run	1																																	
				Keep the watchdog running while the CPU is halted by the debugger																																	

6.20.4.12 RR[n] (n=0..7)

Address offset: 0x600 + (n × 0x4)

Reload request n

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	RR																																	
				Reload request register																																	
			Reload	0x6E524635																																	
				Value to request a reload of the watchdog timer																																	

6.20.5 Electrical specification

6.20.5.1 Watchdog Timer Electrical Specification

Symbol	Description	Min.	Typ.	Max.	Units
t_{WDT}	Time out interval	31 µs		36 h	

7 LTE modem

The nRF9151 SiP contains a Low-Power Wide-Area (LPWA) network processor with dedicated flash/RAM, which controls the radio and baseband hardware components. LTE capabilities are provided by installing Nordic Semiconductor firmware, which complies with 3GPP LTE release 14 Cat-M1 and Cat-NB1/NB2 standards.

The following is an overview of the LTE modem, with a figure showing key components:

- RF transceiver
- Modem baseband (BB)
- Embedded flash/RAM
- LPWA network processor and peripherals

They provide functions for the LTE L1, L2, and L3 (layers 1, 2, and 3 respectively) as well as IP communication layers. Peripherals provide hardware services for the LPWA network processor operating system and secure execution environment.

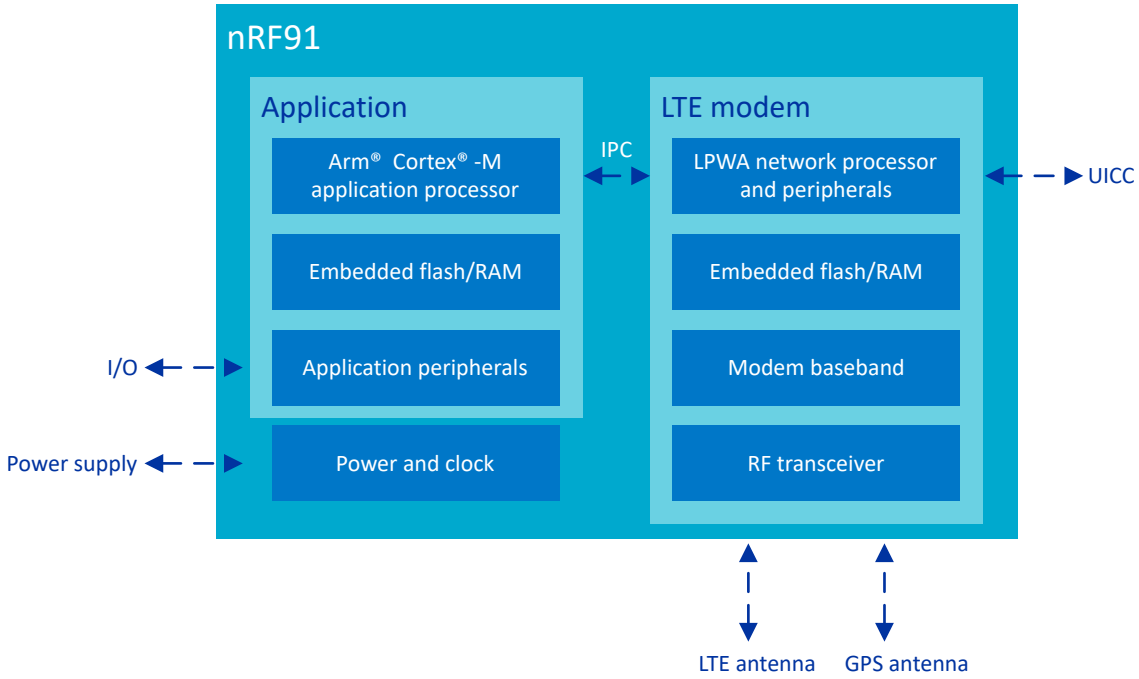

Figure 113: nRF9151 LTE modem functional overview

Application and LPWA network domains interact through the interprocessor communication (IPC) mechanism. The LTE modem is accessible to users through the modem API.

The application processor is the system master and is responsible for starting and stopping the LTE modem. The LPWA network processor enables the clocks and power required for its own operation. The platform handles shared resources, such as clocks, and does not need user participation. In cases where a hard fault is detected in the modem, the application domain will perform a hard reset of the modem.

The nRF9151 LTE modem feature set depends on the modem firmware version and the application firmware. For more information on the LTE modem API, see nRF Connect SDK API documentation and nRF91 AT Commands.

The key features of the LTE modem are:

- Complete modem with baseband and RF transceiver

- 3GPP release 14 compliant LTE categories:
  - Cat-M1 (eMTC - enhanced machine type communication)
  - Cat-NB1 (NB-IoT - narrowband Internet of things)
  - Cat-NB2 (NB-IoT)
- Power saving modes
- Supports LTE bands from 700 MHz to 2.2 GHz through a single 50 Ω antenna pin
  - ANT antenna pin is DC grounded
- RX sensitivity: -108 dBm for Cat-M1 and -114 dBm for Cat-NB1 and Cat-NB2
  - As defined in 3GPP conformance test specification TS 36.521-1
- 1.8 V MIPI RF Front-End (MIPI RFFE) digital control interface and MAGPIO control interface for external RF applications.
- LTE modem internal ADC that is also used for some AT command interface services, for example, for battery monitoring
- 1.8 V UICC (universal integrated circuit card) interface, based on ISO/IEC 7816-3 and compliant with:
  - UICC (ETSI TS 102 221)
  - eUICC (ETSI TS 103 383)

Note: The nRF9151 modem feature set depends on the modem firmware version and the application firmware.

7.1 SIM card interface

The LTE modem supports the universal integrated circuit card (UICC) interface.

Only UICCs with electrical interfaces specified in ISO/IEC 7816-3 are supported. UICCs with IC-USB, CLF or MMC interfaces are not supported.

The supported UICC/eUICC interface is compliant with:

- ETSI TS 102 221: Smart Cards; UICC-Terminal interface; Physical and logical characteristics
- ETSI TS 103 383: Smart Cards; Embedded UICC; Requirements Specification

The physical interface towards the eUICC is the same as that towards the removable UICC.

By default, only the class C (supply voltage 1.8 V nominal) operation is supported. Support for legacy class B (supply voltage 3.0 V nominal) operation must be built with external components, including an external power supply and the level shifters towards the LTE modem UICC interface.

The LTE modem supports powering down the UICC during PSM and eDRX idle mode if the UICC supports this feature as specified in 3GPP TS 24.301. To reach the lowest total power consumption of the complete cellular IoT product, only UICCs supporting power down mode during PSM and eDRX idle mode sleep intervals should be considered.

The LTE modem controls the physical interfaces towards the UICC and implements the transport protocol over the four-pin ISO/IEC 7816-3 interface:

- VCC (power supply) – LTE modem drives this
- CLK (clock signal) – LTE modem drives this
- RST (reset signal) – LTE modem drives this
- I/O (input/output serial data) – Bi-directional

The interface between the LTE modem, the UICC (SIM card) connector, and the ESD device is shown in the following figure.

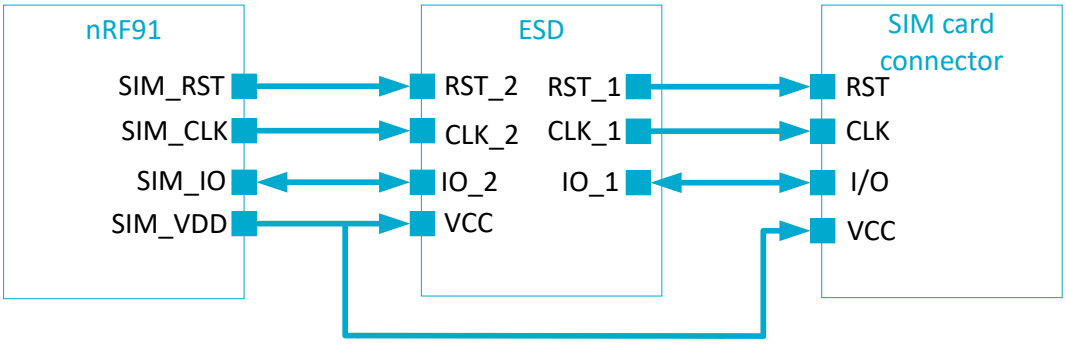

Figure 114: Connections between LTE modem, card connector, and the ESD device

Only standard transmission speeds are supported as specified in ETSI TS 102 221.

Note: Before removing the UICC, the LTE modem must be stopped through the modem API.

An electrostatic discharge (ESD) protection device compatible with UICC cards must be used between the removable card and the LTE modem, to protect LTE modem against harmful ESD from the card connector.

7.2 LTE coexistence interface

The LTE modem uses a dedicated three-pin interface for RF interference avoidance towards a companion radio device such as an external positioning device or *Bluetooth*® Low Energy device.

The interface has the following outputs:

- COEX0 – Output from the LTE modem to the external device. When internal GPS is used, COEX0 can be used as active high control for the external LNA component.
- COEX1 – Output from the LTE modem to the external device. When internal GPS is used, COEX1 delivers the GPS 1PPS (one pulse per second) time mark pulse. The 1PPS feature must not be used when LTE is enabled.
- COEX2 – Output from the LTE modem to the external device. When active high, this indicates that the LTE modem transceiver is turned on. COEX2 can also be treated as an active low grant from the LTE modem to the external device, indicating permission to transmit and receive.

Note: Using the COEX2 pin requires an external pull-down resistor in the 100 kΩ size range.

The COEX interface timing in relation to the LTE modem state is shown in the following figure.

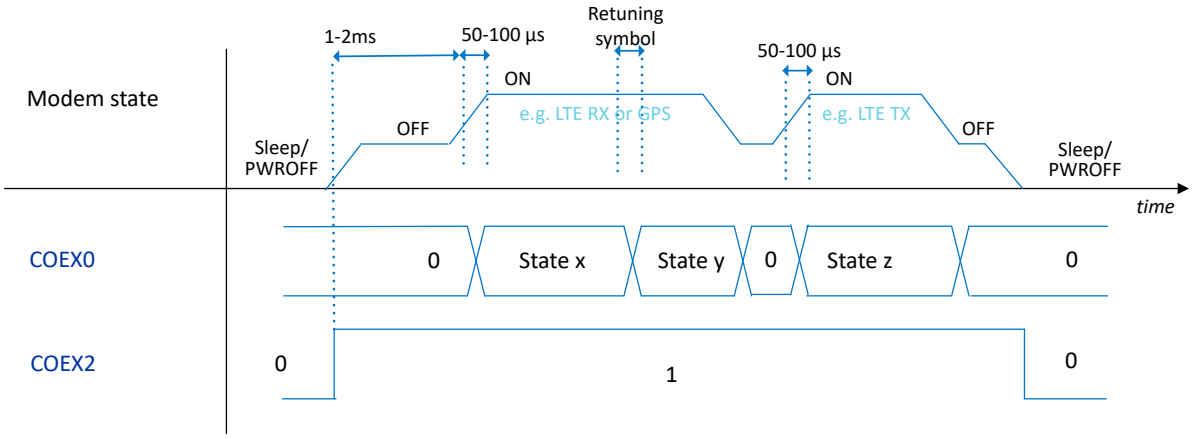

Figure 115: COEX interface timing

7.3 LTE RF control external interface

The LTE modem provides dedicated 1.8 V digital interfaces for controlling external RF applications, such as antenna tuner devices.

The LTE modem supports the following pins:

- MIPI RFFE interface pins – VIO, SCLK, SDATA
- MAGPIO interface pins – MAGPIO0, MAGPIO1, MAGPIO2

The LTE modem accurately drives the timing of these outputs according to the LTE protocol, to set the correct antenna tuner settings per used frequency, for example. The LTE modem API must be used to inform the LTE modem about the external RF application, so that LTE modem knows to drive it.

Note: For details regarding the modem API and supported RF external control features, see nRF91 AT Commands.

Note: The MIPI RFFE capacitive load at SCLK or SDATA pins must not exceed 15 pF.

The MIPI RFFE interface timing in relation to modem state is shown in the following figure.

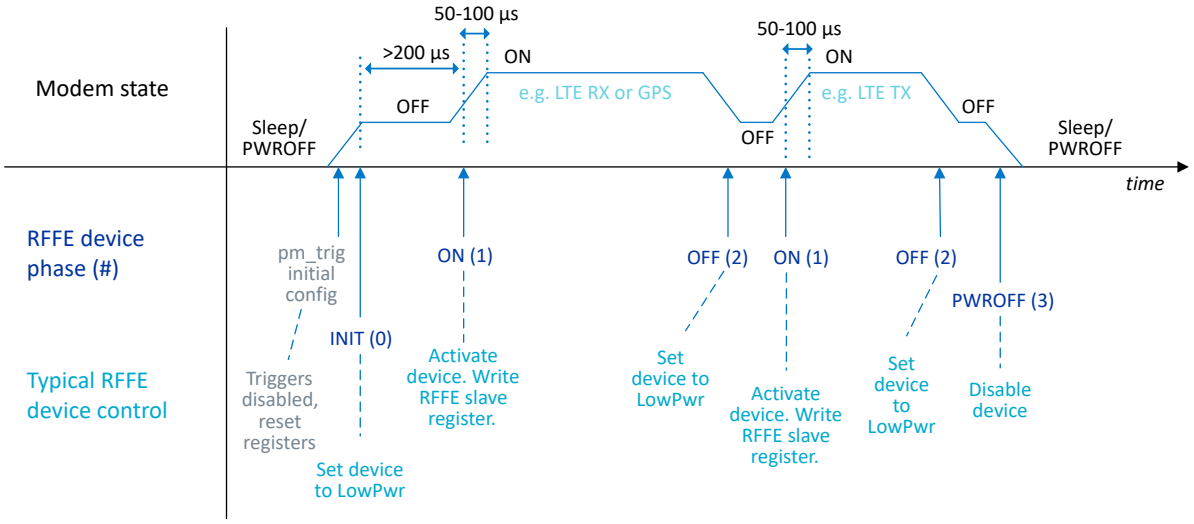

Figure 116: MIPI RFFE interface timing

The MAGPIO interface timing in relation to the LTE modem state is shown in the following figure.

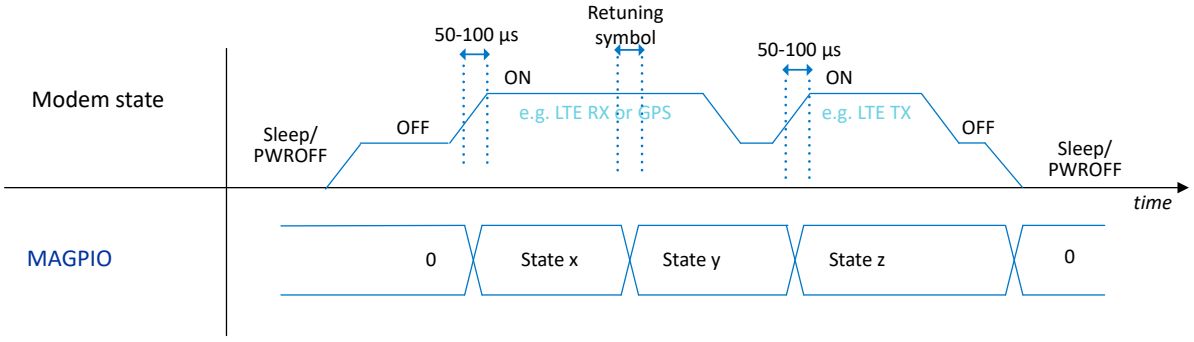

Figure 117: MAGPIO interface timing

7.4 RF front-end interface

The nRF9151 has a single-ended (SE) 50 Ω antenna interface to which an antenna is directly connected.

7.5 Electrical specification

7.5.1 Key RF parameters for Cat-M1

Note: For certification status, please refer to Regulatory information on page 530.

Symbol	Description	Min.	Typ.	Max.	Units
Supported LTE	Supported LTE standards		LTE Rel-14 Cat-M1 HD-FDD		
Bands supported	Bands supported		B1, B2, B3, B4, B5, B8, B12, B13, B18, B19, B20, B25, B26, B28, B66, B85		
Transmission bandwidth	Maximum bandwidth		1.4		MHz

7.5.2 Key RF parameters for Cat-NB1 and Cat-NB2

Note: For certification status, please refer to Regulatory information on page 530.

Note: There is no foreseen NB-IoT network deployment for FCC bands closer than 200 kHz from band edge, hence our device will not transmit in FCC bands on channels that are closer than 200kHz to band edge.

Symbol	Description	Min.	Typ.	Max.	Units
Supported LTE	Supported LTE standards		LTE Rel-14 Cat-NB1 and Cat-NB2 HD-FDD		
Bands supported	Bands supported		B1, B2, B3, B4, B5, B8, B12, B13, B17, B19, B20, B25, B26, B28, B65, B66, B85		
Transmission bandwidth	Maximum bandwidth		200		kHz

7.5.3 Receiver parameters for Cat-M1

Symbol	Description	Min.	Typ.	Max.	Units
$Freq_{range\_ANT\_RX}$	RX operation frequency range at ANT pin	728		2200	MHz
Z_{in}	Input impedance, single-ended		50		Ω
Sensitivity, low band	LTE 1.4 MHz without coverage extension	-103	-108		dBm
Sensitivity, mid band	LTE 1.4 MHz without coverage extension	-103	-107		dBm

7.5.4 Receiver parameters for Cat-NB1 and Cat-NB2

Symbol	Description	Min.	Typ.	Max.	Units
$Freq_{range\_ANT\_RX}$	RX operation frequency range at ANT pin	728		2200	MHz
Z_{in}	Input impedance, single-ended		50		Ω
Sensitivity, low band	NB 200 kHz without coverage extension	-108	-114		dBm
Sensitivity, mid band	NB 200 kHz without coverage extension	-108	-113		dBm

7.5.5 Transmitter parameters for Cat-M1

Symbol	Description	Min.	Typ.	Max.	Units
$Freq_{range\_ANT\_TX}$	TX operation frequency range at ANT pin	698		1980	MHz
Z_{out}	Output impedance, single-ended		50		Ω
PC3 maximum output power	Power Class 3 maximum output power		23		dBm
PC5 maximum output power	Power Class 5 maximum output power		20		dBm
Minimum output power	Minimum output power		-40		dBm
Pout maximum accuracy	Pout maximum accuracy		±2		dB

7.5.6 Transmitter parameters for Cat-NB1 and Cat-NB2

Symbol	Description	Min.	Typ.	Max.	Units
$Freq_{range\_ANT\_TX}$	TX operation frequency range at ANT pin	698		2010	MHz
Z_{out}	Output impedance, single-ended		50		Ω
PC3 maximum output power	Power Class 3 maximum output power		23		dBm
PC5 maximum output power	Power Class 5 maximum output power		20		dBm
Minimum output power	Minimum output power		-40		dBm
Pout maximum accuracy	Pout maximum accuracy		±2		dB

8 DECT NR+

The nRF9151 SiP contains a Low-Power Wide-Area (LPWA) network processor with dedicated flash/RAM, which controls the radio and baseband hardware components. DECT NR+ (NR+) capabilities are provided by installing Nordic Semiconductor firmware, that implements the physical layer (PHY) level operation of the NR+ radio protocol stack according to ETSI specifications (TS 103 636-2 and TS 103 636-3).

NR+ is a non-cellular radio standard included as part of the 5G standards by the International Telecommunication Union (ITU). It is designed for massive Machine Type Communication (mMTC) and for Ultra-Reliable Low Latency Communication (URLLC).

NR+ operates on the global and license-exempt 1.9 GHz band, which significantly cuts deployment costs by eliminating the need for frequency planning or heavy certification. The NR+ device developer can design optimal radio behavior since there is no need for third-party cellular infrastructure. Additionally, the range and dense topology properties of NR+ make it highly scalable. A square kilometer can be covered by as little as 100 devices or scaled up to over 1 million devices while maintaining the same reliable, low-latency communication.

The physical radio layer in NR+ reuses known techniques from cellular radios, reaching the same level of reliability that is proven by billions of devices already in the field.

The following are key features of NR+:

- License-exempt global band
- Built-in coexistence of multiple networks in the same location
- Flexible, low-latency system and network architectures
- High reliability, using hybrid ARQ
- Possibility of hiding the network, using AES-128 encryption and integrity protection
- Data rate up to 3.4 Mbps, depending on modulation

See ETSI TS 103 636-1 for more information.

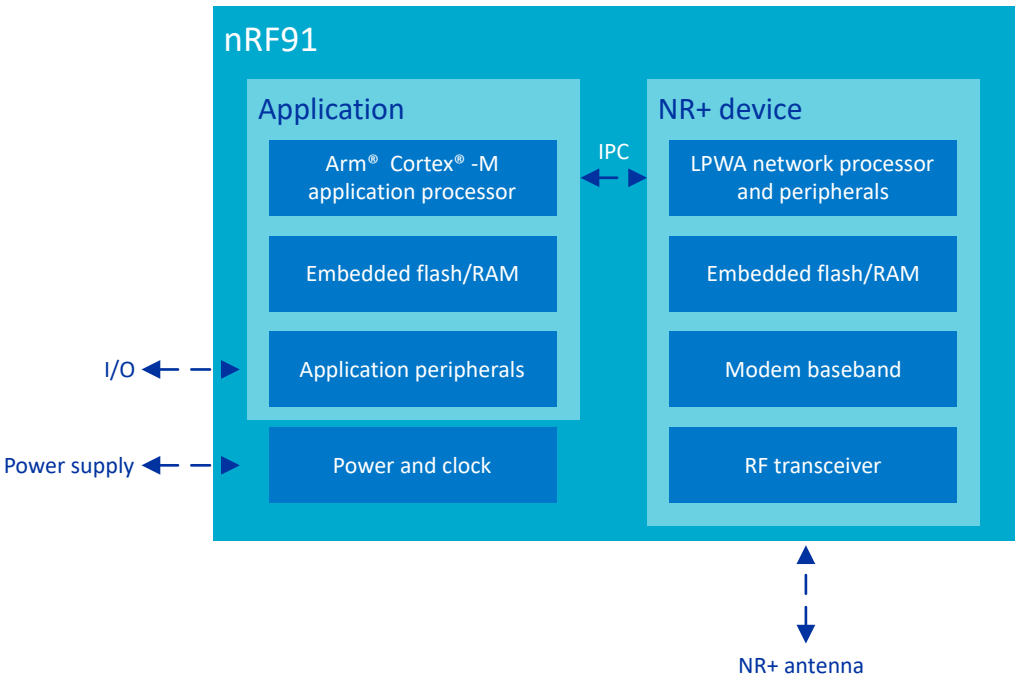

Figure 118: nRF9151 NR+ device functional overview

Application and LPWA network domains interact through the interprocessor communication (IPC) mechanism. The application processor is the system master and is responsible for starting and stopping the NR+ device. The LPWA network processor enables the clocks and power required for its own operation. The platform handles shared resources, such as clocks, and does not need user participation.

8.1 massive Machine Type Communication (mMTC)

mMTC is used for large networks with machine-type devices, connecting tens of billions of nodes that operate for many years using small batteries and transmit small amounts of data.

Typical use cases involve collecting measurements from many sensors, such as smart metering, which requires a low-maintenance and low-cost autonomous network structure.

A key feature of NR+ is its self-healing and self-organizing properties. Each node can function as a router to an access point with a connection to the internet. Nodes can change to a routing role based on the needs of the network. Multiple access points to the internet can be supported in a single network. These properties eliminates single points of failure and resolves high-traffic situations that can occur in dense IoT networks.

8.2 Ultra-Reliable Low-Latency Communication (URLLC)

URLLC enables mission-critical wireless use cases where failure is not an option.

Examples include management of self-driving factory vehicles, high-speed robots working alongside human operators in warehouses, and critical infrastructure in buildings, cities, and utilities.

NR+ is designed to reach one-millisecond latency between devices, opening the possibility for low-latency systems to consider wireless operation, even where ranges are over a kilometer. This makes NR+ an open, standardized alternative to existing proprietary technology.

8.3 DECT NR+ on the nRF9151

Nordic Semiconductor provides NR+ firmware that implements the physical layer (PHY) level operation of the NR+ radio protocol stack according to ETSI specifications (*TS 103 636-2 and TS 103 636-3*).

The NR+ standard and stack are still in development, contact the Nordic Semiconductor sales department for more information on the NR+ firmware.

The nRF9151 SiP supports NR+ bands 1, 2, and 9. The antenna interface and recommendations are the same as for the LTE modem. NR+ does not require a SIM or eSIM.

Note: While running DECT NR+ firmware, the nRF9151 SiP does not support LTE modem. See the LTE modem section for more information on alternative firmware.

8.4 Key RF Parameters

NR+ RF performance parameters are shown in the following table.

Description	Min	Typ	Max	Unit
Bands supported		1, 2, 9, 22		
Transmission Bandwidth		1.728		MHz
Occupied Bandwidth		1.539		MHz
Antenna impedance, single-ended		50		Ω
RX: Sensitivity[27], modulation MCS1		-103		dBm
TX: Maximum output power		19		dBm
TX: Minimum output power		-40		dBm

Table 50: Common parameters

8.5 DECT NR+ coexistence interface

NR+ uses a dedicated two-pin coexistence interface to avoid RF interference to a companion radio device such as an external positioning device or a Bluetooth Low Energy device.

The user can configure COEX0 and COEX2 pin functions through the NR+ AT commands.

Note: Using the COEX2 pin requires an external pull-down resistor in the 100 kΩ range.

[27] The sensitivity level has not been measured using the same method as decribed in ETSI TS 103 636-2 chapter "7.2 Reference sensitivity". The reported sensitivity level is the signal level where 10% packet error rate (PER) occurs. This measurement method does not measure the throughput and does not include HARQ.

9 GPS receiver

The LPWA network processor supports GPS reception, if the onboard network protocol firmware supports it.

GPS receiver operation is time multiplexed with the LTE modem, and GPS and QZSS position can be received while the LTE modem is in RRC Idle mode, power saving mode (PSM), or completely deactivated.

The application processor is the system master and responsible for starting and stopping the GPS receiver. GPS can be run standalone or concurrently with QZSS. The GPS and QZSS reception can be configured through the GNSS interface API.

Note: For details regarding the GNSS API, refer to nRF Connect SDK API documentation.

Key features of the GPS receiver are as follows:

- GPS L1 C/A reception
- QZSS L1 C/A reception
- Optimized for low-power and low-cost IoT applications
- Modes of operation:
  - Single shot
  - Position fix per fixed interval, configurable to a value between 10 s to 65536 s
  - Continuous tracking
- Power saving mode:
  - Duty-cycled continuous tracking operation
- One pulse per second (1PPS) signal:
  - A pulse repeating once per second, accurately synchronized to coordinated universal time (UTC) full seconds
  - For more details on 1PPS programmability and power vs. accuracy trade-offs, see GNSS API documentation
  - Available on device COEX1 pin
    - For more details, see LTE modem on page 423, coexistence interface
- Antenna interface:
  - External low-noise amplifier (LNA) with SAW filter recommended on the GPS antenna input
  - Dedicated GPS antenna, or shared antenna with LTE
  - GPS antenna pin is DC grounded

Note: There must be minimum 27dB attenuation to out of band power to avoid blocking high power RF signals to GPS receiver input. This can be achieved by using a SAW filter, for example, at the external LNA output.

9.1 Electrical specification

The following is a summary of GPS receiver performance parameters.

Condition	Value
Environment	Open sky
Temperature	25°C
GPS sleep clock source	TCXO

Table 51: Common typical conditions

Note: Local and temporal conditions might lead to considerable variation in TTFF, positioning accuracy, 1PPS signal accuracy.

The figures in the following table assume the use of an external low-noise amplifier (LNA) with SAW filter.

Symbol	Description	Value	Unit
Sensitivity, cold	Acquisition sensitivity, cold start	-146.5	dBm
Sensitivity, hot	Acquisition sensitivity, hot start	-152.5	dBm
Sensitivity, tracking	Tracking sensitivity	-156.5	dBm
TTFF, cold	Time to first fix (TTFF), cold start	30.5	s
TTFF, hot	TTFF, hot start	1.3	s
TTFF, A-GPS	TTFF, A-GPS start	1.3	s
Accuracy, 2D, periodic	Positioning accuracy (CEP50), periodic tracking[28]	3.4	m
Accuracy, 2D, periodic, A-GPS	Positioning accuracy (CEP50), periodic tracking[28] with A-GPS[29]	3.1	m
Accuracy, 2D, continuous	Positioning accuracy (CEP50), continuous tracking	2.0	m
Accuracy, 2D, continuous, A-GPS	Positioning accuracy (CEP50), continuous tracking with A-GPS[29]	1.8	m
1PPS accuracy	1PPS signal accuracy, continuous tracking	±35	ns

Table 52: GPS electrical specification

[28] Fix interval 2 min.
[29] Including NeQuick ionospheric model parameters.

10 Debug and trace

The debug and trace system offers a flexible and powerful mechanism for non-intrusive debugging.

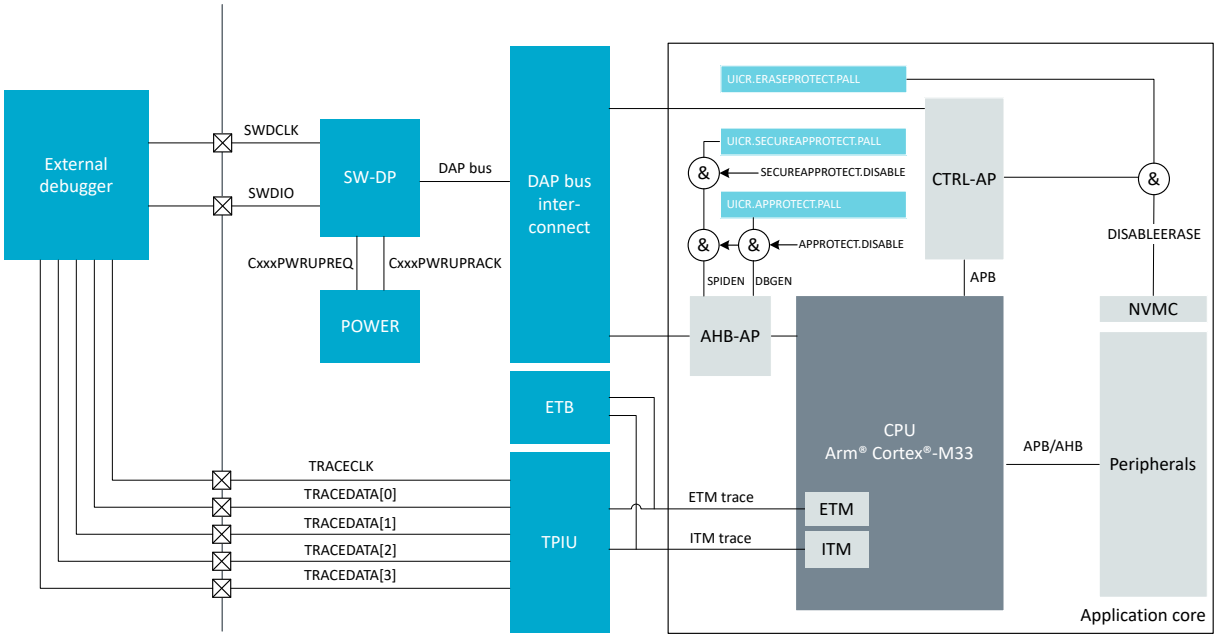

Figure 119: Debug and trace overview

The main features of the debug and trace system include:

- Two-pin serial wire debug (SWD) interface, protocol version 1
- Access port connection
  - Breakpoint unit (BPU) supports eight hardware breakpoint comparators
  - Data watchpoint and trace (DWT) unit supports four watchpoint comparators
  - Instrumentation trace macrocell (ITM)
  - Embedded trace macrocell (ETM)
  - Access protection through APPROTECT, ERASEPROTECT and SECUREAPPROTECT
- Embedded trace buffer (ETB)
- Trace port interface unit (TPIU)
  - 4-bit parallel trace of ITM and ETM trace data

Note: When a system contains multiple CPU domains, it is important to be aware that if one domain (subsystem A) has master rights on another domain (subsystem B), the master subsystem can access some data from the slave subsytem. In this example, even if subsystem B is locked by APPROTECT or ERASEPROTECT, subsystem A can access some data for subsystem B. Consequently, even if the security permissions are managed per subsystem, it is mandatory to have a global approach to the protection. Protecting a slave subsystem does not guarantee system security if the master subsystem is not protected.

10.1 DAP - Debug access port

An external debugger can access the device via the debug access port (DAP).

The DAP implements a standard Arm CoreSight serial wire debug port (SW-DP). The SW-DP implements the serial wire debug (SWD) protocol that is a two-pin serial interface, see SWDCLK and SWDIO illustrated in figure Debug and trace overview on page 434.

In addition to the default access port in the application CPU (AHB-AP), the DAP includes a custom control access port (CTRL-AP), described in more detail in CTRL-AP - Control access port on page 503.

Note:

- The SWDIO line has an internal pull-up resistor.
- The SWDCLK line has an internal pull-down resistor.

There are several access ports that connect to different parts of the system. An overview is given in the table below.

AP ID	Type	Description
0	AHB-AP	Application subsystem access port
3	APB-AP	CoreSight subsystem access port
4	CTRL-AP	Application subsystem control access port

Table 53: Access port overview

The standard Arm components are documented in *Arm CoreSight SoC-400 Technical Reference Manual, revision r3p2*. The control access port (CTRL-AP) is proprietary, and described in more detail in CTRL-AP - Control access port on page 503.

10.2 Access port protection

Access port protection blocks the debugger from read and write access to all CPU registers and memory-mapped addresses when enabled. If needed, a debugger can be restricted to debug non-secure code only and access non-secure memory regions and peripherals using register SECUREAPPROTECT on page 44. Register APPROTECT on page 42 blocks all debugger access.

The following table gives an overview of the access port protection methods.

Debugging capability	Description
Non-secure code	The application core AHB-AP DBGEN signal controls all non-secure access through the application core AHB-AP. This can be used to provide readback protection of the flash contents. See Debugger access control for non-secure debug access on page 436. For more information about the DBGEN signal, see the *Arm CoreSight SoC-400 Technical Reference Manual, Revision r3p2*.
Secure code	The application core AHB-AP SPIDEN signal controls all secure access through the application core AHB-AP. This means that only the non-secure code can be debugged and accessed when secure accesses are blocked. To enable access to the secure access port, non-secure code must be unprotected. See Debugger access control for secure debug access on page 436. For more information about the SPIDEN signal, see the *Arm CoreSight SoC-400 Technical Reference Manual, Revision r3p2*.

Table 54: Application core access port protection overview

If a RAM or flash region has its permission set to allow code execution, the content of this region is visible to the debugger even if the read permission is not set. This allows a debugger to display the content of the code being executed. For more information on configuring permissions, see SPU — System protection unit on page 323.

Access port protection controlled by hardware and software

By default, access port protection is enabled.

The following table describes how non-secure debugger access is controlled.

Debugging capability	UICR.APPROTECT.PALL	APPROTECT.DISABLE	APPROTECT.FORCEPROTECT	Secure debug access
Non-secure code	HwUnprotected	SwUnprotected	Reset value	-
No debugging possible	Protected	Reset value	Force	-

Table 55: Debugger access control for non-secure debug access

The following table describes how secure debugger access is controlled.

Debugging capability	UICR.SECUREAPPROTECT.PALL	SECUREAPPROTECT.DISABLE	SECUREAPPROTECT.FORCEPROTECT	Non-secure debug access
Secure code	HwUnprotected	SwUnprotected	Reset value	Permitted
No debugging possible	Protected	Reset value	Force	Permitted
No debugging possible	-	-	-	Not permitted

Table 56: Debugger access control for secure debug access

Access port protection is enabled when the hardware and software disabling conditions are not present. For additional security, it is recommended to write `Protected` to UICR.SECUREAPPROTECT and UICR.APPROTECT, and have firmware write `Force` to SECUREAPPROTECT.FORCEPROTECT and APPROTECT.FORCEPROTECT.

Note: Registers SECUREAPPROTECT.FORCEPROTECT and APPROTECT.FORCEPROTECT are reset in System ON IDLE or after any reset.

Access port protection is disabled by issuing an ERASEALL command through CTRL-AP. Read ERASEALLSTATUS until the ERASEALL sequence is ready. When ERASEALL is ready, trigger and then release soft reset from the RESET register. Read APPROTECT.STATUS to ensure that access port protection is disabled. If access port is not disabled, do a reset and repeat the ERASEALL command. This command erases the flash, UICR, and RAM, including UICR.SECUREAPPROTECT and UICR.APPROTECT. CTRL-AP is described in more detail in CTRL-AP - Control access port on page 503. Access port protection remains disabled until one of the following occurs:

- Pin reset
- Power or brownout reset

- Watchdog reset
- Wake from System OFF if not in Emulated System OFF

To keep access port protection disabled, the following actions must be performed:

- Program UICR.SECUREAPPROTECT and UICR.APPROTECT to `HwUnprotected`. This disables the hardware part of the access port protection scheme after the first reset of any type. The hardware part of the access port protection stays disabled as long as UICR.SECUREAPPROTECT and UICR.APPROTECT are not overwritten.
- Firmware must write SECUREAPPROTECT.DISABLE and APPROTECT.DISABLE to `SwUnprotected`. This disables the software part of the access port protection scheme.

Note: Register SECUREAPPROTECT.DISABLE and APPROTECT.DISABLE are reset in System ON IDLE or after pin reset, power or brownout reset, watchdog reset, or wake from System OFF as mentioned above.

The following figure shows how a device with access port protection enabled is erased, programmed, and configured to allow debugging. Operations sent from the debugger and registers written by firmware affects the access port state.

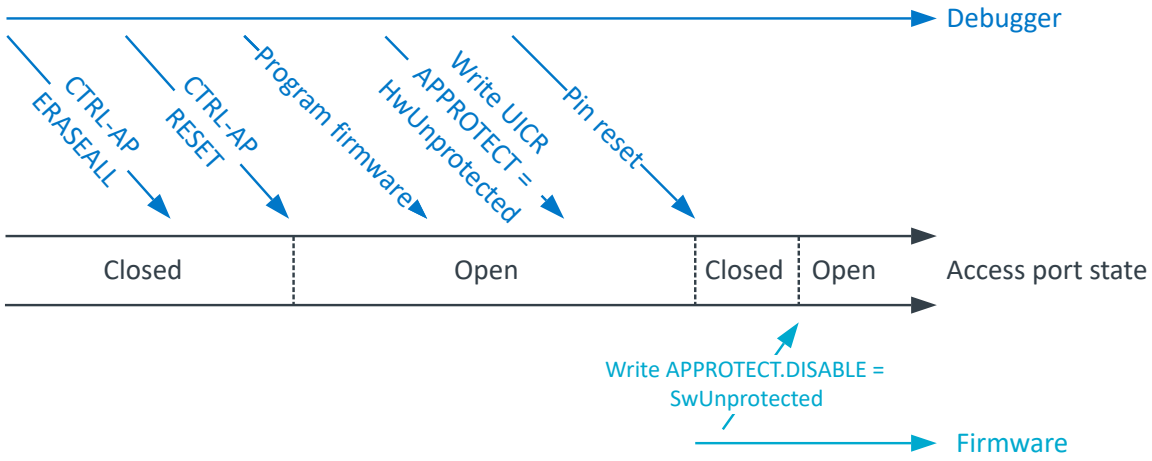

Figure 120: Access port unlocking

10.2.2 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
APPROTECT : S	0x50039000	HF	NS	NA	Yes	APPROTECT control
APPROTECT : NS	0x40039000					

Register overview

Register	Offset	TZ	Description
SECUREAPPROTECT.DISABLE	0xE00	S	Software disable SECUREAPPROTECT mechanism
SECUREAPPROTECT.FORCEPROTECT	0xE00	S	Software force SECUREAPPROTECT mechanism
APPROTECT.DISABLE	0xE10	NS	Software disable APPROTECT mechanism
APPROTECT.FORCEPROTECT	0xE10	NS	Software force APPROTECT mechanism

10.2.2.1 SECUREAPPROTECT.DISABLE

Address offset: 0xE00

Software disable SECUREAPPROTECT mechanism

Bit number							31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID							A A A A A A A A
Reset 0x00000001							**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	TZ	Field	Value ID	Value	Description	
A	RW		DISABLE			Software disable SECUREAPPROTECT mechanism	
				SwUnprotected	0x5A	Software disable SECUREAPPROTECT mechanism	

10.2.2.2 SECUREAPPROTECT.FORCEPROTECT

Address offset: 0xE00

Software force SECUREAPPROTECT mechanism

Bit number							31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID							A
Reset 0x00000001							**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	TZ	Field	Value ID	Value	Description	
A	RW W1S		FORCEPROTECT			Write 0x1 to force enable SECUREAPPROTECT mechanism	
				Force	0x1	Software force enable SECUREAPPROTECT mechanism	

10.2.2.3 APPROTECT.DISABLE

Address offset: 0xE10

Software disable APPROTECT mechanism

Bit number							31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID							A A A A A A A A
Reset 0x00000001							**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	TZ	Field	Value ID	Value	Description	
A	RW		DISABLE			Software disable APPROTECT mechanism	
				SwUnprotected	0x5A	Software disable APPROTECT mechanism	

10.2.2.4 APPROTECT.FORCEPROTECT

Address offset: 0xE10

Software force APPROTECT mechanism

Bit number							31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID							A
Reset 0x00000001							**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1**
ID	R/W	TZ	Field	Value ID	Value	Description	
A	RW W1S		FORCEPROTECT			Write 0x1 to force enable APPROTECT mechanism	
				Force	0x1	Software force enable APPROTECT mechanism	

10.3 Debug interface mode

Before the external debugger can access the CPU's access port (AHB-AP) or the control access port (CTRL-AP), the debugger must first request the device to power up via CxxxPWRUPREQ in the SWJ-DP.

As long as the debugger is requesting power via CxxxPWRUPREQ, the device will be in debug interface mode. Otherwise, the device is in normal mode. When a debug session is over, the external debugger must make sure to put the device back into normal mode and then a pin reset should be performed. The reason is that the overall power consumption is higher in debug interface mode compared to normal mode.

Some peripherals behave differently in debug interface mode compared to normal mode. The differences are described in more detail in the chapters of the affected peripherals.

For details on how to use the debug capabilities, please read the debug documentation of your IDE.

If the device is in System OFF when power is requested via CxxxPWRUPREQ, the system will wake up and the DIF flag in RESETREAS on page 73 will be set.

10.4 Real-time debug

The device supports real-time debugging, which allows interrupts to execute to completion in real time when breakpoints are set in thread mode or lower priority interrupts.

Real-time debugging thus enables the developer to set a breakpoint and single-step through their code without a failure of the real-time event-driven threads running at higher priority. For example, this enables the device to continue to service the high-priority interrupts of an external controller or sensor without failure or loss of state synchronization while the developer steps through code in a low-priority thread.

10.5 Registers

Register overview

Register	Offset	Description
TARGETID	0x042	The TARGETID register provides information about the target when the host is connected to a single device. The TARGETID register is accessed by a read of DP register 0x4 when the DPBANKSEL bit in the SELECT register is set to 0x2.

10.5.1 TARGETID

Address offset: 0x042

The TARGETID register provides information about the target when the host is connected to a single device.

The TARGETID register is accessed by a read of DP register 0x4 when the DPBANKSEL bit in the SELECT register is set to 0x2.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				D	D	D	D	C	C	C	C	C	C	C	C	C	C	C	C					B	B	B	B	B	B	B	B	B	B	A	
Reset 0x10090289				**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**1**
ID	R/W	Field	Value ID	Value																															
A	R	UNUSED																																	
				Reserved, read-as-one																																	
B	R	TDESIGNER																																	
				An 11-bit code: JEDEC JEP106 continuation code and identity code. The ID identifies the designer of the part.																																	
			NordicSemi	0x144																																	
				Nordic Semiconductor ASA																																	
C	R	TPARTNO																																	
				Part number																																	
D	R	TREVISION																																	
				Target revision																																	

10.6 Electrical specification

10.6.1 Trace port

Symbol	Description	Min.	Typ.	Max.	Units
T_{cyc}	Clock period, as defined by ARM (See ARM Infocenter, Embedded Trace Macrocell Architecture Specification, Trace Port Physical Interface, Timing specifications)	62.5			ns

10.7 Trace

The nRF9151 supports ETM and ITM trace.

Available trace sinks:

- 2 kB internal embedded trace buffer (ETB)
- External trace port interface through TPIU

Trace data from the ETM and the ITM can be sent to an internal embedded trace buffer (ETB) or an external debugger via a 4-bit wide parallel trace port (TPIU), see TRACEDATA[0] through TRACEDATA[3], and TRACECLK in Debug and trace overview on page 434.

The following diagram shows the trace components architecture of the device's embedded Arm CoreSight subsystem.

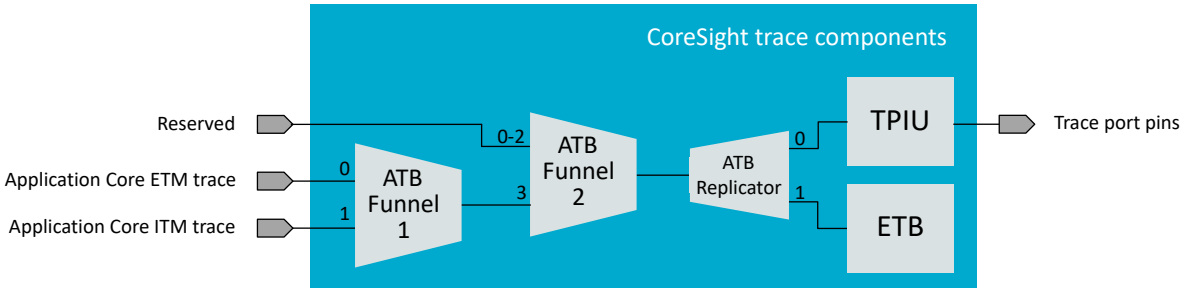

Figure 121: Trace components architecture

The standard Arm components are documented in *Arm CoreSight SoC-400 Technical Reference Manual, revision r3p2*. For details on how to use the trace capabilities, please read the debug documentation of your IDE.

TPIU's trace pins are multiplexed with GPIOs, see Pin assignments on page 516 for more information.

Note: To configure the trace data delivery to the device trace port, use the MDK system start-up file included as of MDK version 8.26.0.

Trace speed is configured in the TRACEPORTSPEED (Retained) on page 514 register. The speed of the trace pins depends on the DRIVE setting of the GPIOs that the trace pins are multiplexed with. See GPIO — General purpose input/output on page 163 for information about how to set drive settings. Only S0S1 and H0H1 drives are suitable for debugging. S0S1 is the default DRIVE at reset. If parallel or serial trace port signals are not fast enough in the debugging conditions, all GPIOs in use for tracing should be set to high drive (H0H1). The user shall make sure that DRIVE setting for these GPIOs is not overwritten by software during the debugging session.

10.7.1 ATB Funnel

The ARM® ATB Funnel funnels trace bus mesages from several sources into one output bus.

This document only provides a register-level description of this ARM component. See the ARM® CoreSight™ SoC-400 Technical Reference Manual for more details

10.7.1.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
ATBFUNNEL1	0xE005A000	HF	NS	NA	No	ATBFUNNEL unit 1
ATBFUNNEL2	0xE005B000	HF	NS	NA	No	ATBFUNNEL unit 2

Register overview

Register	Offset	TZ	Description
CTRLREG	0x000		The IDFILTER0 register enables the programming of ID filtering for master port 0.
PRIORITYCTRLREG	0x004		The Priority_Ctrl_Reg register defines the order in which inputs are selected. Each 3-bit field is a priority for each particular slave interface.
ITATBDATA0	0xEEC		The ITATBDATA0 register performs different functions depending on whether the access is a read or a write.
ITATBCTR2	0xEF0		The ITATBCTR2 register performs different functions depending on whether the access is a read or a write.
ITATBCTR1	0xEF4		The ITATBCTR1 register performs different functions depending on whether the access is a read or a write.
ITATBCTR0	0xEF8		The ITATBCTR0 register performs different functions depending on whether the access is a read or a write.
ITCTRL	0xF00		The ITCTRL register enables the component to switch from a functional mode, which is the default behavior, to integration mode where the inputs and outputs of the component can be directly controlled for the purposes of integration testing and topology detection.
CLAIMSET	0xFA0		Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMSET register sets bits in the claim tag, and determines the number of claim bits implemented.
CLAIMCLR	0xFA4		Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMCLR register sets the bits in the claim tag to 0 and determines the current value of the claim tag.
LAR	0xFB0		This is used to enable write access to device registers.

Register	Offset	TZ	Description
LSR	0xFB4		This indicates the status of the lock control mechanism. This lock prevents accidental writes by code under debug. Accesses to the extended stimulus port registers are not affected by the lock mechanism. This register must always be present although there might not be any lock access control mechanism. The lock mechanism, where present and locked, must block write accesses to any control register, except the Lock Access Register. For most components this covers all registers except for the Lock Access Register.
AUTHSTATUS	0xFB8		Indicates the current level of tracing permitted by the system
DEVID	0xFC8		Indicates the capabilities of the component.
DEVTYPE	0xFCC		The DEVTYPE register provides a debugger with information about the component when the Part Number field is not recognized. The debugger can then report this information.
PIDR4	0xFD0		Coresight peripheral identification registers.
PIDR[0]	0xFE0		Coresight peripheral identification registers.
PIDR[1]	0xFE4		Coresight peripheral identification registers.
PIDR[2]	0xFE8		Coresight peripheral identification registers.
PIDR[3]	0xFEC		Coresight peripheral identification registers.
CIDR[0]	0xFF0		Coresight component identification registers.
CIDR[1]	0xFF4		Coresight component identification registers.
CIDR[2]	0xFF8		Coresight component identification registers.
CIDR[3]	0xFFC		Coresight component identification registers.

10.7.1.1.1 CTRLREG

Address offset: 0x000

The IDFILTER0 register enables the programming of ID filtering for master port 0.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																								I	I	I	I	H	G	F	E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field		Value ID				Value				Description																							
A-H	RW	ENS[i] (i=0..7)										Enable slave port i.																							
				Disabled				0				Slave port disabled. This excludes the port from the priority selection scheme.																							
				Enabled				1				Slave port enabled.																							
I	RW	HT						[0:14]				Hold Time. The formatting scheme can become inefficient when fast switching occurs, and you can use this setting to minimize switching. When a source has nothing to transmit, then another source is selected irrespective of the minimum number of transactions. The ATB funnel holds for the minimum hold time and one additional transaction. The actual hold time is the register value plus 1. The maximum value that can be entered is 0b1110 and this equates to 15 transactions. 0b1111 is reserved.																							

10.7.1.1.2 PRIORITYCTRLREG

Address offset: 0x004

The Priority_Ctrl_Reg register defines the order in which inputs are selected. Each 3-bit field is a priority for each particular slave interface.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID												H	H	H	G	G	G	F	F	F	E	E	E	D	D	D	C	C	C	B	B	B	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field		Value ID				Value				Description																							
A-H	RW	PRIPORT[i] (i=0..7)						[0:7]				Priority value of port number i.																							

10.7.1.1.3 ITATBDATA0

Address offset: 0xEEC

The ITATBDATA0 register performs different functions depending on whether the access is a read or a write.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				Q P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-Q	RW	ATDATA[i] (i=0..16)			A read access returns the value of a pin on atdatas_x of the enabled port. A write access writes to the corresponding atdatam pin of the enabled port.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.1.1.4 ITATBCTR2

Address offset: 0xEF0

The ITATBCTR2 register performs different functions depending on whether the access is a read or a write.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ATREADY			A read access returns the value of atreadym. A write access outputs the data to afvalids[n], where the value of the CTRLREG at 0x000 defines n.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.
B	RW	AFVALID			A read access returns the value of afvalidm. A write access outputs the data to atreadys[n], where the value of the CTRLREG at 0x000 defines n.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.1.1.5 ITATBCTR1

Address offset: 0xEF4

The ITATBCTR1 register performs different functions depending on whether the access is a read or a write.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ATVALIDM0			A read returns the value of the atids[n] signals, where the value of the Control Register at 0x000 defines n. A write outputs the value to the atidm port.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.1.1.6 ITATBCTR0

Address offset: 0xEF8

The ITATBCTR0 register performs different functions depending on whether the access is a read or a write.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ATVALID			A read returns the value of the atvalids[n] signal, where the value of the CTRLREG at 0x000 defines n. A write outputs the value to atvalidm.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.
B	RW	AFREADY			A read returns the value of the afreadys[n] signal, where the value of the Ctrl_Reg at 0x000 defines n. A write outputs the value to afreadym.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.
C	RW	ATBYTES			A read returns the value of the atbytess[n] signal, where the value of the Ctrl_Reg at 0x000 defines n. A write outputs the value to atbytesm.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.1.1.7 ITCTRL

Address offset: 0xF00

The ITCTRL register enables the component to switch from a functional mode, which is the default behavior, to integration mode where the inputs and outputs of the component can be directly controlled for the purposes of integration testing and topology detection.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	IME			Integration Mode Enable.
			Disabled	0	Integration mode disabled.
			Enabled	1	Integration mode enabled.

10.7.1.1.8 CLAIMSET

Address offset: 0xFA0

Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMSET register sets bits in the claim tag, and determines the number of claim bits implemented.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-D	RW	BIT[i] (i=0..3)			Set claim bit i and check if bit is implemented or not.
			NotImplemented	0	Claim bit i is not implemented.
			Implemented	1	Claim bit i is implemented.
			Set	1	Set claim bit i.

10.7.1.1.9 CLAIMCLR

Address offset: 0xFA4

Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMCLR register sets the bits in the claim tag to 0 and determines the current value of the claim tag.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-D	RW	BIT[i] (i=0..3)			Read or clear claim bit i.
			Cleared	0	Claim bit i is not set.
			Set	1	Claim bit i is set.
			Clear	1	Clear claim bit i.

10.7.1.1.10 LAR

Address offset: 0xFB0

This is used to enable write access to device registers.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ACCESS			A write of 0xC5ACCE55 enables further write access to this device. Any other write removes write access.
			UnLock	0xC5ACCE55	Unlock register interface.

10.7.1.1.11 LSR

Address offset: 0xFB4

This indicates the status of the lock control mechanism. This lock prevents accidental writes by code under debug. Accesses to the extended stimulus port registers are not affected by the lock mechanism. This register must always be present although there might not be any lock access control mechanism. The lock mechanism, where present and locked, must block write accesses to any control register, except the Lock Access Register. For most components this covers all registers except for the Lock Access Register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PRESENT			Indicates that a lock control mechanism exists for this device.
			NotImplemented	0	No lock control mechanism exists, writes to the Lock Access Register are ignored.
			Implemented	1	Lock control mechanism is present.
B	RW	LOCKED			Returns the current status of the Lock.
			UnLocked	0	Write access is allowed to this device.
			Locked	1	Write access to the component is blocked. All writes to control registers are ignored. Reads are permitted.
C	RW	TYPE			Indicates if the Lock Access Register is implemented as 8-bit or 32-bit.
			Bits32	0	This component implements a 32-bit Lock Access Register.
			Bits8	1	This component implements an 8-bit Lock Access Register.

10.7.1.1.12 AUTHSTATUS

Address offset: 0xFB8

Indicates the current level of tracing permitted by the system

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																												D	D	C	C	B	B	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	NSID																																	
			NotImplemented	0																															
			Implemented	1																															
B	RW	NSNID																																	
			NotImplemented	0																															
			Implemented	1																															
C	RW	SID																																	
			NotImplemented	0																															
			Implemented	1																															
D	RW	SNID																																	
			NotImplemented	0																															
			Implemented	1																															

10.7.1.1.13 DEVID

Address offset: 0xFC8

Indicates the capabilities of the component.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	PORTCOUNT		[2:8]																															
				Indicates the number of input ports connected. 0x0 and 0x1 are illegal values.																																

10.7.1.1.14 DEVTYPE

Address offset: 0xFCC

The DEVTYPE register provides a debugger with information about the component when the Part Number field is not recognized. The debugger can then report this information.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																												B	B	B	B	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	MAJOR																																	
			InputOutputDevice	2																															
B	R	SUB																																	
			Replicator	1																															

10.7.1.1.15 PIDR4

Address offset: 0xFD0

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.1.1.16 PIDR[0]

Address offset: 0xFE0

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.1.1.17 PIDR[1]

Address offset: 0xFE4

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.1.1.18 PIDR[2]

Address offset: 0xFE8

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.1.1.19 PIDR[3]

Address offset: 0xFEC

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.1.1.20 CIDR[0]

Address offset: 0xFF0

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.1.1.21 CIDR[1]

Address offset: 0xFF4

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.1.1.22 CIDR[2]

Address offset: 0xFF8

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.1.1.23 CIDR[3]

Address offset: 0xFFC

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.2 ATB Replicator

The ARM® ATB Replicator replicates incoming trace bus mesages across its outputs.

This document only provides a register-level description of this ARM component. See the ARM® CoreSight™ SoC-400 Technical Reference Manual for more details

10.7.2.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
ATBREPLICATOR	0xE0058000	HF	NS	NA	No	ATBREPLICATOR

Register overview

Register	Offset	TZ	Description
IDFILTER0	0x000		The IDFILTER0 register enables the programming of ID filtering for master port 0.
IDFILTER1	0x004		The IDFILTER1 register enables the programming of ID filtering for master port 1.
ITATBCTR1	0xEF8		The ITATBCTR1 register returns the value of the atreadym0, atreadym1, and atvalids inputs in integration mode.
ITATBCTR0	0xEFC		The ITATBCTR0 register controls the value of the atvalidm0, atvalidm1, and atreadys outputs in integration mode.
ITCTRL	0xF00		The ITCTRL register enables the component to switch from a functional mode, which is the default behavior, to integration mode where the inputs and outputs of the component can be directly controlled for the purposes of integration testing and topology detection.
CLAIMSET	0xFA0		Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMSET register sets bits in the claim tag, and determines the number of claim bits implemented.
CLAIMCLR	0xFA4		Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMCLR register sets the bits in the claim tag to 0 and determines the current value of the claim tag.
LAR	0xFB0		This is used to enable write access to device registers.
LSR	0xFB4		This indicates the status of the lock control mechanism. This lock prevents accidental writes by code under debug. Accesses to the extended stimulus port registers are not affected by the lock mechanism. This register must always be present although there might not be any lock access control mechanism. The lock mechanism, where present and locked, must block write accesses to any control register, except the Lock Access Register. For most components this covers all registers except for the Lock Access Register.
AUTHSTATUS	0xFB8		Indicates the current level of tracing permitted by the system
DEVID	0xFC8		Indicates the capabilities of the component.
DEVTYPE	0xFCC		The DEVTYPE register provides a debugger with information about the component when the Part Number field is not recognized. The debugger can then report this information.
PIDR4	0xFD0		Coresight peripheral identification registers.
PIDR[0]	0xFE0		Coresight peripheral identification registers.
PIDR[1]	0xFE4		Coresight peripheral identification registers.
PIDR[2]	0xFE8		Coresight peripheral identification registers.
PIDR[3]	0xFEC		Coresight peripheral identification registers.
CIDR[0]	0xFF0		Coresight component identification registers.
CIDR[1]	0xFF4		Coresight component identification registers.
CIDR[2]	0xFF8		Coresight component identification registers.
CIDR[3]	0xFFC		Coresight component identification registers.

10.7.2.1.1 IDFILTER0

Address offset: 0x000

The IDFILTER0 register enables the programming of ID filtering for master port 0.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																									H	G	F	E	D	C	B	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A-H	RW	ID0_[i]0_[i]F (i=0..7)			Enable or disable ID filtering for IDs 0xi0_0xiF.
			NotFiltered	0	Transactions with these IDs are passed on to ATB master port 0.
			Selected	1	Transactions with these IDs are discarded by the replicator.

10.7.2.1.2 IDFILTER1

Address offset: 0x004

The IDFILTER1 register enables the programming of ID filtering for master port 1.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																												H	G	F	E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-H	RW	ID1_[i]0_[i]F (i=0..7)																																	
			NotFiltered	0																															
			Selected	1																															

10.7.2.1.3 ITATBCTR1

Address offset: 0xEF8

The ITATBCTR1 register returns the value of the atreadym0, atreadym1, and atvalids inputs in integration mode.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																C		B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ATREADYM0																																	
			Low	0																															
			High	1																															
B	RW	ATREADYM1																																	
			Low	0																															
			High	1																															
C	RW	ATVALIDS																																	
			Low	0																															
			High	1																															

10.7.2.1.4 ITATBCTR0

Address offset: 0xEFC

The ITATBCTR0 register controls the value of the atvalidm0, atvalidm1, and atreadys outputs in integration mode.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																C	B		A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ATVALIDM0																																	
			Low	0																															
			High	1																															
B	RW	ATVALIDM1																																	
			Low	0																															
			High	1																															
C	RW	ATREADYS																																	
			Low	0																															
			High	1																															

10.7.2.1.5 ITCTRL

Address offset: 0xF00

The ITCTRL register enables the component to switch from a functional mode, which is the default behavior, to integration mode where the inputs and outputs of the component can be directly controlled for the purposes of integration testing and topology detection.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	IME			Integration Mode Enable.
			Disabled	0	Integration mode disabled.
			Enabled	1	Integration mode enabled.

10.7.2.1.6 CLAIMSET

Address offset: 0xFA0

Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMSET register sets bits in the claim tag, and determines the number of claim bits implemented.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-D	RW	BIT[i] (i=0..3)			Set claim bit i and check if bit is implemented or not.
			NotImplemented	0	Claim bit i is not implemented.
			Implemented	1	Claim bit i is implemented.
			Set	1	Set claim bit i.

10.7.2.1.7 CLAIMCLR

Address offset: 0xFA4

Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMCLR register sets the bits in the claim tag to 0 and determines the current value of the claim tag.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-D	RW	BIT[i] (i=0..3)			Read or clear claim bit i.
			Cleared	0	Claim bit i is not set.
			Set	1	Claim bit i is set.
			Clear	1	Clear claim bit i.

10.7.2.1.8 LAR

Address offset: 0xFB0

This is used to enable write access to device registers.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ACCESS			A write of 0xC5ACCE55 enables further write access to this device. Any other write removes write access.
			UnLock	0xC5ACCE55	Unlock register interface.

10.7.2.1.9 LSR

Address offset: 0xFB4

This indicates the status of the lock control mechanism. This lock prevents accidental writes by code under debug. Accesses to the extended stimulus port registers are not affected by the lock mechanism. This register must always be present although there might not be any lock access control mechanism. The lock mechanism, where present and locked, must block write accesses to any control register, except the Lock Access Register. For most components this covers all registers except for the Lock Access Register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PRESENT			Indicates that a lock control mechanism exists for this device.
			NotImplemented	0	No lock control mechanism exists, writes to the Lock Access Register are ignored.
			Implemented	1	Lock control mechanism is present.
B	RW	LOCKED			Returns the current status of the Lock.
			UnLocked	0	Write access is allowed to this device.
			Locked	1	Write access to the component is blocked. All writes to control registers are ignored. Reads are permitted.
C	RW	TYPE			Indicates if the Lock Access Register is implemented as 8-bit or 32-bit.
			Bits32	0	This component implements a 32-bit Lock Access Register.
			Bits8	1	This component implements an 8-bit Lock Access Register.

10.7.2.1.10 AUTHSTATUS

Address offset: 0xFB8

Indicates the current level of tracing permitted by the system

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D D C C B B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	NSID			Non-secure Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
B	RW	NSNID			Non-secure Non-Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
C	RW	SID			Secure Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
D	RW	SNID			Secure Non-Invasive Debug
			NotImplemented	0	The feature is not implemented.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D D C C B B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Implemented	1	The feature is implemented.

10.7.2.1.11 DEVID

Address offset: 0xFC8

Indicates the capabilities of the component.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	PORTNUM		[0:15]	Indicates the number of master ports implemented.

10.7.2.1.12 DEVTYPE

Address offset: 0xFCC

The DEVTYPE register provides a debugger with information about the component when the Part Number field is not recognized. The debugger can then report this information.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	MAJOR			The main type of the component
			InputOutputDevice	2	Indicates that this component has ATB inputs and outputs.
B	R	SUB			The sub-type of the component
			Replicator	2	Indicates that this component replicates trace from a single source to multiple targets.

10.7.2.1.13 PIDR4

Address offset: 0xFD0

Coresight peripheral identification registers.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description

10.7.2.1.14 PIDR[0]

Address offset: 0xFE0

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.2.1.15 PIDR[1]

Address offset: 0xFE4

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.2.1.16 PIDR[2]

Address offset: 0xFE8

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.2.1.17 PIDR[3]

Address offset: 0xFEC

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.2.1.18 CIDR[0]

Address offset: 0xFF0

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.2.1.19 CIDR[1]

Address offset: 0xFF4

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.2.1.20 CIDR[2]

Address offset: 0xFF8

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.2.1.21 CIDR[3]

Address offset: 0xFFC

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.3 ETB — Embedded trace buffer

The ARM embedded trace buffer captures trace and stores it in an on-chip RAM for later inspection.

This document only provides a register-level description of this ARM component. See the Arm® CoreSight SoC-400 Technical Reference Manual for more details.

10.7.3.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
ETB	0xE0051000	HF	NS	NA	No	ETB

Register overview

Register	Offset	TZ	Description
RDP	0x4		ETB RAM Depth Register
STS	0xC		ETB Status Register
RRD	0x10		ETB RAM Read Data Register
RRP	0x14		ETB RAM Read Pointer Register
RWP	0x18		ETB RAM Write Pointer Register
TRG	0x1C		ETB Trigger Counter Register
CTL	0x20		ETB Control Register
RWD	0x24		ETB RAM Write Data Register
FFSR	0x300		ETB Formatter and Flush Status Register

Register	Offset	TZ	Description
FFCR	0x304		ETB Formatter and Flush Control Register
ITMISCOP0	0xEE0		Integration Test Miscellaneous Output Register 0
ITTRFLINACK	0xEE4		Integration Test Trigger In and Flush In Acknowledge Register
ITTRFLIN	0xEE8		Integration Test Trigger In and Flush In Register
ITATBDATA0	0xEEC		Integration Test ATB Data Register 0
ITATBCTR2	0xEF0		Integration Test ATB Control Register 2
ITATBCTR1	0xEF4		Integration Test ATB Control Register 1
ITATBCTR0	0xEF8		Integration Test ATB Control Register 0
ITCTRL	0xF00		Integration Mode Control Register
CLAIMSET	0xFA0		Claim Tag Set Register
CLAIMCLR	0xFA4		Claim Tag Clear Register
LAR	0xFB0		Lock Access Register
LSR	0xFB4		Lock Status Register
AUTHSTATUS	0xFB8		Authentication Status Register
DEVID	0xFC8		Device Configuration Register
DEVTYPE	0xFCC		Device Type Identifier Register
PERIPHID4	0xFD0		Peripheral ID4 Register
PERIPHID0	0xFE0		Peripheral ID0 Register
PERIPHID1	0xFE4		Peripheral ID1 Register
PERIPHID2	0xFE8		Peripheral ID2 Register
PERIPHID3	0xFEC		Peripheral ID3 Register
COMPID0	0xFF0		Component ID0 Register
COMPID1	0xFF4		Component ID1 Register
COMPID2	0xFF8		Component ID2 Register
COMPID3	0xFFC		Component ID3 Register

10.7.3.1.1 RDP

Address offset: 0x4

ETB RAM Depth Register

Defines the depth, in words, of the trace RAM. This value is configurable in the RTL, but fixed at synthesis. Supported depth in powers of 2 only.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	R	ETB_RAM_DEPTH			Defines the depth, in words, of the trace RAM.

10.7.3.1.2 STS

Address offset: 0xC

ETB Status Register

This register indicates the status of the ETB.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000008				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	FULL			RAM Full. The flag indicates when the RAM write pointer has wrapped around.
B	R	TRIGGERED			The Triggered bit is set when a trigger has been observed. This does not indicate that a trigger has been embedded in the trace data by the formatter, but is determined by the programming of the Formatter and Flush Control Register.
C	R	ACQCOMP			The acquisition complete flag indicates that capture has been completed when the formatter stops because of any of the methods defined in the Formatter and Flush Control Register, or TraceCaptEn = 0. This also results in FtStopped in the Formatter and Flush Status Register going HIGH.
D	R	FTEMPTY			Formatter pipeline empty. All data stored to RAM.

10.7.3.1.3 RRD

Address offset: 0x10

ETB RAM Read Data Register

When trace capture is disabled, the contents of the ETB Trace RAM at the location addressed by the RAM Read Pointer Registers are placed in this register. Reading this register increments the RAM Read Pointer Register and triggers a RAM access cycle. If trace capture is enabled (FtStopped=0, TraceCaptEn=1), and ETB RAM reading is attempted, a read from this register outputs 0xFFFFFFFF and the RAM Read Pointer Register does not auto-increment. A constant stream of 1s being output corresponds to a synchronization output in the formatter protocol, which is not applicable to the ETB, and so can be used to signify a read error, when formatting is enabled.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	RAM_READ_DATA			Data read from the ETB Trace RAM.

10.7.3.1.4 RRP

Address offset: 0x14

ETB RAM Read Pointer Register

The RAM Read Pointer Register sets the read pointer used to read entries from the Trace RAM over the APB interface. When this register is written to, a RAM access is initiated. The RAM Read Data Register is then updated. The register can also be read to determine the current memory location being referenced. This register must not be written to when trace capture is enabled (FtStopped=0, TraceCaptEn=1). If access is attempted, the register is not updated.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RAM_READ_POINTER			Sets the read pointer used to read entries from the Trace RAM over the APB interface.

10.7.3.1.5 RWP

Address offset: 0x18

ETB RAM Write Pointer Register

The RAM Write Pointer Register sets the write pointer used to write entries from the CoreSight bus into Trace RAM. During trace capture the pointer increments when the DataValid flag is asserted by the Formatter. When this register increments from its maximum value back to zero, the Full flag is set. This register can also be written to over APB to set the pointer for write accesses carried out through the APB interface. This register must not be written to when trace capture is enabled (FtStopped=0, TraceCaptEn=1). If access is attempted, the register is not updated. The register can also be read to determine the current memory location being referenced. It is recommended that addresses are 128-bit aligned when the formatter is used in normal or continuous modes.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RAM_WRITE_POINTER			Sets the write pointer used to write entries from the CoreSight bus into the Trace RAM.

10.7.3.1.6 TRG

Address offset: 0x1C

ETB Trigger Counter Register

The Trigger Counter Register disables write access to the Trace RAM by stopping the Formatter after a defined number of words have been stored following the trigger event. The number of 32-bit words written into the Trace RAM following the trigger event is equal to the value stored in this register+1.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TRIGGER_COUNTER			The counter is used as follows:Trace after - The counter is set to a large value, slightly less than the number of entries in the RAM. Trace before - The counter is set to a small value. Trace about - The counter is set to half the depth of the Trace RAM. This register must not be written to when trace capture is enabled (FtStopped=0, TraceCaptEn=1). If a write is attempted, the register is not updated. A read access is permitted with trace capture enabled.

10.7.3.1.7 CTL

Address offset: 0x20

ETB Control Register

This register controls trace capture by the ETB.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TRACECAPTEN			ETB Trace Capture Enable. This is the master enable bit forcing FtStopped HIGH when TraceCaptEn is LOW. When capture is disabled, any remaining data in the ATB formatter is stored to RAM. When all data is stored the formatter outputs FtStopped. Capture is fully disabled, or complete, when FtStopped goes HIGH. See ETB Formatter and Flush Status Register, FFSR, 0x300.

10.7.3.1.8 RWD

Address offset: 0x24

ETB RAM Write Data Register

Data written to the ETB Trace RAM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RAM_WRITE_DATA			Data written to the ETB Trace RAM. When trace capture is disabled, the contents of this register are placed into the ETB Trace RAM when this register is written to. Writing to this register increments the RAM Write Pointer Register. If trace capture is enabled, and this register is accessed, then a read from this register outputs 0xFFFFFFFF. Reads of this register never increment the RAM Write Pointer Register. A constant stream of 1s being output corresponds to a synchronization output from the ETB. If a write access is attempted, the data is not written into Trace RAM.

10.7.3.1.9 FFSR

Address offset: 0x300

ETB Formatter and Flush Status Register

This register indicates the implemented Trigger Counter multipliers and other supported features of the trigger system.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000002				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0**
ID	R/W	Field	Value ID	Value	Description
A	R	FLINPROG			Flush In Progress. This is an indication of the current state of afvalids.
B	R	FTSTOPPED			Formatter stopped. The formatter has received a stop request signal and all trace data and post-amble has been output. Any more trace data on the ATB interface is ignored and atreadys goes HIGH.

10.7.3.1.10 FFCR

Address offset: 0x304

ETB Formatter and Flush Control Register

This register controls the generation of stop, trigger, and flush events. To disable formatting and put the formatter into bypass mode, bits 1 and 0 must be clear. If both bits are set, then the formatter inserts triggers into the formatted stream. All three flush generating conditions can be enabled together. However, if a second or third flush event is generated then the current flush completes before the next flush is serviced. Flush from flushin takes priority over flush from Trigger, which in turn completes before a manually activated flush. All Trigger indication conditions can be enabled simultaneously although this can cause the appearance of multiple triggers if flush using trigger is also enabled. Both 'Stop On' settings can be enabled, although if flush on trigger, FOnTrig, is set up then none of the flushed data is stored. When the system stops, it returns ATREADY and does not store the accepted data packets. This is to avoid stalling of any other connected devices using a Trace Replicator. If an event in the Formatter and Flush Control Register is required, it must be enabled before the originating event starts. Because requests from flushes and triggers can originate in an asynchronous clock domain, the exact time the component acts on the request cannot be determined with respect to configuring the control. Note - To perform a stop on flush completion through a manually-generated flush request, two write operations to the register are required: one to enable the stop event, if it is not already enabled; one to generate the manual flush.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																						J	I		H	G	F		E	D	C			B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ENFTC																																	
				Do not embed Triggers into the formatted stream. Trace disable cycles and triggers are indicated by TRACECTL, where fitted. Can only be changed when FtStopped is HIGH. This bit is clear on reset.																																	
B	RW	ENFCONT																																	
				Continuous mode in the ETB corresponds to normal mode with the embedding of triggers. Can only be changed when FtStopped is HIGH. This bit is clear on reset.																																	
C	RW	FONFLIN																																	
				Set this bit to enable use of the flushin connection. This is clear on reset.																																	
D	RW	FONTRIG																																	
				Generate flush using Trigger event. Set this bit to cause a flush of data in the system when a Trigger Event occurs. This bit is clear on reset. A Trigger Event is defined as when the Trigger counter reaches zero (where fitted) or, in the case of the trigger counter being zero (or not fitted), when trigin is HIGH.																																	
E	RW	FONMAN																																	
				Setting this bit causes a flush to be generated. This is cleared when this flush has been serviced. This bit is clear on reset.																																	
F	RW	TRIGIN																																	
				Indicate a trigger on trigin being asserted.																																	
G	RW	TRIGEVT																																	
				Indicate a trigger on a Trigger Event.																																	
H	RW	TRIGFL																																	
				Indicates a trigger on Flush completion (afreadys being returned).																																	
I	RW	STOPFL																																	
				This forces the FIFO to drain off any part-completed packets. Setting this bit enables this function but this is clear on reset (disabled).																																	
J	RW	STOPTRIG																																	
				Stop the formatter after a Trigger Event is observed. Reset to disabled (zero).																																	

10.7.3.1.11 ITMISCOP0

Address offset: 0xEE0

Integration Test Miscellaneous Output Register 0

The Integration Test Miscellaneous Output Register 0 controls the values of some outputs from the ETB.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ACQCOMP			Set the value of acqcomp.
B	W	FULL			Set the value of full output port.

10.7.3.1.12 ITTRFLINACK

Address offset: 0xEE4

Integration Test Trigger In and Flush In Acknowledge Register

The Integration Test Trigger In and Flush In Acknowledge Register enables control of the triginack and flushinack outputs from the ETB.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TRIGINACK			Set the value of triginack.
B	W	FLUSHINACK			Set the value of flushinack.

10.7.3.1.13 ITTRFLIN

Address offset: 0xEE8

Integration Test Trigger In and Flush In Register

The Integration Test Trigger In and Flush In Register contains the values of the flushin and trigin inputs to the ETB.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	TRIGIN			Read the value of trigin.
B	R	FLUSHIN			Read the value of flushin.

10.7.3.1.14 ITATBDATA0

Address offset: 0xEEC

Integration Test ATB Data Register 0

The Integration Test ATB Data Register 0 contains the value of the atdatas inputs to the ETB. The values are only valid when atvalids is HIGH.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																															E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	ATDATA_0																																	

Description
Read the value of atdatas[0].
Read the value of atdatas[7].
Read the value of atdatas[15].
Read the value of atdatas[23].
Read the value of atdatas[31].

10.7.3.1.15 ITATBCTR2

Address offset: 0xEF0

Integration Test ATB Control Register 2

The Integration Test ATB Control Register 2 enables control of the atreadys and afvalids outputs of the ETB.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																		B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	W	ATREADYS																																	
B	W	AFVALIDS																																	

Description
Set the value of atreadys.
Set the value of afvalids.

10.7.3.1.16 ITATBCTR1

Address offset: 0xEF4

Integration Test ATB Control Register 1

The Integration Test ATB Control Register 1 contains the value of the atids input to the ETB. This is only valid when atvalids is HIGH.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																													A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	R	ATID																																	

Description
Read the value of atids.

10.7.3.1.17 ITATBCTR0

Address offset: 0xEF8

Integration Test ATB Control Register 0

The Integration Test ATB Control Register 0 captures the values of the atvalids, afreadys, and atbytess inputs to the ETB. To ensure the integration registers work correctly in a system, the value of atbytess is only valid when atvalids, bit [0], is HIGH.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	C C B A
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	ATVALID			Read the value of atvalids.
B	R	AFREADY			Read the value of afreadys.
C	R	ATBYTES			Read the value of atbytess.

10.7.3.1.18 ITCTRL

Address offset: 0xF00

Integration Mode Control Register

This register is used to enable topology detection. For more information see the CoreSight Architecture Specification. This register enables the component to switch from a functional mode, the default behavior, to integration mode where the inputs and outputs of the component can be directly controlled for the purpose of integration testing and topology solving. Note: When a device has been in integration mode, it might not function with the original behavior. After performing integration or topology detection, you must reset the system to ensure correct behavior of CoreSight and other connected system components that are affected by the integration or topology detection.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	A
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	INTEGRATION_MODE			Allows the component to switch from functional mode to integration mode or back.

10.7.3.1.19 CLAIMSET

Address offset: 0xFA0

Claim Tag Set Register

This is used in conjunction with Claim Tag Clear Register, CLAIMCLR. This register forms one half of the Claim Tag value. This location allows individual bits to be set, write, and returns the number of bits that can be set, read.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	A A A A
Reset 0x0000000F	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1**

ID	R/W	Field	Value ID	Value	Description
A	RW	CLAIMSET			This claim tag bit is implemented

10.7.3.1.20 CLAIMCLR

Address offset: 0xFA4

Claim Tag Clear Register

This register is used in conjunction with Claim Tag Set Register, CLAIMSET. This register forms one half of the Claim Tag value. This location enables individual bits to be cleared, write, and returns the current Claim Tag value, read.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CLAIMCLR			The value present reflects the current setting of the Claim Tag.

10.7.3.1.21 LAR

Address offset: 0xFB0

Lock Access Register

This is used to enable write access to device registers. External accesses from a debugger (paddrdbg31 = 1) are not subject to the Lock Registers. A debugger does not have to unlock the component in order to write and modify the registers in the component.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	ACCESS_W			A write of 0xC5ACCE55 enables further write access to this device. A write of any value other than 0xC5ACCE55 will have the affect of removing write access.

10.7.3.1.22 LSR

Address offset: 0xFB4

Lock Status Register

This indicates the status of the Lock control mechanism. This lock prevents accidental writes by code under debug. When locked, write access is blocked to all registers, except the Lock Access Register. External accesses from a debugger (paddrdbg31 = 1) are not subject to the Lock Registers. This register reads as 0 when read from an external debugger (paddrdbg31 = 1).

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000003				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1**
ID	R/W	Field	Value ID	Value	Description
A	R	LOCKEXIST			Indicates that a lock control mechanism exists for this device. This bit reads as 0 when read from an external debugger (paddrdbg31 = 1) since external debugger accesses are not subject to Lock Registers.
B	R	LOCKGRANT			Returns the current status of the Lock. This bit reads as 0 when read from an external debugger (paddrdbg31 = 1) since external debugger accesses are not subject to Lock Registers.
C	R	LOCKTYPE			Indicates if the Lock Access Register (0xFB0) is implemented as 8-bit or 32-bit

10.7.3.1.23 AUTHSTATUS

Address offset: 0xFB8

Authentication Status Register

Reports what functionality is currently permitted by the authentication interface.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D D C C B B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	NSID			Indicates the security level for non-secure invasive debug
B	R	NSNID			Indicates the security level for non-secure non-invasive debug
C	R	SID			Indicates the security level for secure invasive debug
D	R	SNID			Indicates the security level for secure non-invasive debug

10.7.3.1.24 DEVID

Address offset: 0xFC8

Device Configuration Register

This register indicates the capabilities of the ETB.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	EXTMUXNUM			When non-zero this value indicates the type/number of ATB multiplexing present on the input to the ATB.
B	R	RAMCLK			This bit returns 0 on reads indicating that the ETB RAM operates synchronously to atclk.

10.7.3.1.25 DEVTYPE

Address offset: 0xFCC

Device Type Identifier Register

It provides a debugger with information about the component when the Part Number field is not recognized. The debugger can then report this information.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B A A A A
Reset 0x00000021				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	MAJOR_TYPE			Major classification grouping for this debug/trace component
B	R	SUB_TYPE			Sub-classification within the major category

10.7.3.1.26 PERIPHID4

Address offset: 0xFD0

Peripheral ID4 Register

Part of the set of Peripheral Identification registers. Contains part of the designer identity and the memory footprint indicator.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B A A A A
Reset 0x00000004				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	DES_2			JEDEC continuation code indicating the designer of the component (along with the identity code)
B	R	SIZE			This is a 4-bit value that indicates the total contiguous size of the memory window used by this component in powers of 2 from the standard 4KB. If a component only requires the standard 4KB then this should read as 0x0, 4KB only, for 8KB set to 0x1, 16KB == 0x2, 32KB == 0x3, and so on.

10.7.3.1.27 PERIPHID0

Address offset: 0xFE0

Peripheral ID0 Register

Part of the set of Peripheral Identification registers. Contains part of the designer specific part number.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000007				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	R	PART_0			Bits [7:0] of the component's part number. This is selected by the designer of the component.

10.7.3.1.28 PERIPHID1

Address offset: 0xFE4

Peripheral ID1 Register

Part of the set of Peripheral Identification registers. Contains part of the designer specific part number and part of the designer identity.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B A A A A
Reset 0x000000B9				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	PART_1			Bits [11:8] of the component's part number. This is selected by the designer of the component.
B	R	DES_0			Bits 3:0 of the JEDEC identity code indicating the designer of the component (along with the continuation code)

10.7.3.1.29 PERIPHID2

Address offset: 0xFE8

Peripheral ID2 Register

Part of the set of Peripheral Identification registers. Contains part of the designer identity and the product revision.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C C C C B A A A
Reset 0x0000004B				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 1 1**
ID	R/W	Field	Value ID	Value	Description
A	R	DES_1			Bits 6:4 of the JEDEC identity code indicating the designer of the component (along with the continuation code)
B	R	JEDEC			Always set. Indicates that a JEDEC assigned value is used
C	R	REVISION			The Revision field is an incremental value starting at 0x0 for the first design of this component. This only increases by 1 for both major and minor revisions and is simply used as a look-up to establish the exact major/minor revision.

10.7.3.1.30 PERIPHID3

Address offset: 0xFEC

Peripheral ID3 Register

Part of the set of Peripheral Identification registers. Contains the RevAnd and Customer Modified fields.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	CMOD			Where the component is reusable IP, this value indicates if the customer has modified the behavior of the component. In most cases this field is zero.
B	R	REVAND			This field indicates minor errata fixes specific to this design, for example metal fixes after implementation. In most cases this field is zero. It is recommended that component designers ensure this field can be changed by a metal fix if required, for example by driving it from registers that reset to zero.

10.7.3.1.31 COMPID0

Address offset: 0xFF0

Component ID0 Register

A component identification register, that indicates that the identification registers are present.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x0000000D				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	PRMBL_0			Contains bits [7:0] of the component identification

10.7.3.1.32 COMPID1

Address offset: 0xFF4

Component ID1 Register

A component identification register, that indicates that the identification registers are present. This register also indicates the component class.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B A A A A
Reset 0x00000090				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	PRMBL_1			Contains bits [11:8] of the component identification
B	R	CLASS			Class of the component. E. g. ROM table, CoreSight component etc. Constitutes bits [15:12] of the component identification.

10.7.3.1.33 COMPID2

Address offset: 0xFF8

Component ID2 Register

A component identification register, that indicates that the identification registers are present.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000005				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	PRMBL_2			Contains bits [23:16] of the component identification

10.7.3.1.34 COMPID3

Address offset: 0xFFC

Component ID3 Register

A component identification register, that indicates that the identification registers are present.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x000000B1				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 0 0 0 1**
ID	R/W	Field	Value ID	Value	Description
A	R	PRMBL_3			Contains bits [31:24] of the component identification

10.7.4 ETM — Embedded trace macrocell

The ARM embedded trace macorcell implements instruction, data and event tracing.

This document only provides a register-level description of this ARM component. See the Arm® Embedded Trace Macrocell Architecture Specification for more details

10.7.4.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
ETM	0xE0041000	HF	NS	NA	No	ETM

Register overview

Register	Offset	TZ	Description
TRCPRGCTLR	0x004		Enables the trace unit.

Register	Offset	TZ	Description
TRCPROCSELR	0x008		Controls which PE to trace. Might ignore writes when the trace unit is enabled or not idle. Before writing to this register, ensure that TRCSTATR.IDLE == 1 so that the trace unit can synchronize with the chosen PE. Implemented if TRCIDR3.NUMPROC is greater than zero.
TRCSTATR	0x00C		Idle status bit
TRCCONFIGR	0x010		Controls the tracing options This register must always be programmed as part of trace unit initialization. Might ignore writes when the trace unit is enabled or not idle.
TRCEVENTCTL0R	0x20		Controls the tracing of arbitrary events. If the selected event occurs a trace element is generated in the trace stream according to the settings in TRCEVENTCTL1R.DATAEN and TRCEVENTCTL1R.INSTEN.
TRCEVENTCTL1R	0x24		Controls the behavior of the events that TRCEVENTCTL0R selects. This register must always be programmed as part of trace unit initialization. Might ignore writes when the trace unit is enabled or not idle.
TRCSTALLCTLR	0x2C		Enables trace unit functionality that prevents trace unit buffer overflows. Might ignore writes when the trace unit is enabled or not idle. Must be programmed if TRCIDR3.STALLCTL == 1.
TRCTSCTLR	0x30		Controls the insertion of global timestamps in the trace streams. When the selected event is triggered, the trace unit inserts a global timestamp into the trace streams. Might ignore writes when the trace unit is enabled or not idle. Must be programmed if TRCCONFIGR.TS == 1.
TRCSYNCPR	0x34		Controls how often trace synchronization requests occur. Might ignore writes when the trace unit is enabled or not idle. If writes are permitted then the register must be programmed.
TRCCCCTLR	0x38		Sets the threshold value for cycle counting. Might ignore writes when the trace unit is enabled or not idle. Must be programmed if TRCCONFIGR.CCI==1.
TRCBBCTLR	0x3C		Controls which regions in the memory map are enabled to use branch broadcasting. Might ignore writes when the trace unit is enabled or not idle. Must be programmed if TRCCONFIGR.BB == 1.
TRCTRACEIDR	0x40		Sets the trace ID for instruction trace. If data trace is enabled then it also sets the trace ID for data trace, to (trace ID for instruction trace) + 1. This register must always be programmed as part of trace unit initialization. Might ignore writes when the trace unit is enabled or not idle.
TRCQCTLR	0x44		Controls when Q elements are enabled. Might ignore writes when the trace unit is enabled or not idle. This register must be programmed if it is implemented and TRCCONFIGR.QE is set to any value other than 0b00.
TRCVICTLR	0x080		Controls instruction trace filtering. Might ignore writes when the trace unit is enabled or not idle. Only returns stable data when TRCSTATR.PMSTABLE == 1. Must be programmed, particularly to set the value of the SSSTATUS bit, which sets the state of the start/stop logic.

Register	Offset	TZ	Description
TRCVIIECTLR	0x084		ViewInst exclude control. Might ignore writes when the trace unit is enabled or not idle. This register must be programmed when one or more address comparators are implemented.
TRCVISSCTLR	0x088		Use this to set, or read, the single address comparators that control the ViewInst start/stop logic. The start/stop logic is active for an instruction which causes a start and remains active up to and including an instruction which causes a stop, and then the start/stop logic becomes inactive. Might ignore writes when the trace unit is enabled or not idle. If implemented then this register must be programmed.
TRCVIPCSSCTLR	0x08C		Use this to set, or read, which PE comparator inputs can control the ViewInst start/stop logic. Might ignore writes when the trace unit is enabled or not idle. If implemented then this register must be programmed.
TRCVDCTLR	0x0A0		Controls data trace filtering. Might ignore writes when the trace unit is enabled or not idle. This register must be programmed when data tracing is enabled, that is, when either TRCCONFIGR.DA == 1 or TRCCONFIGR.DV == 1.
TRCVDSACCTLR	0x0A4		ViewData include / exclude control. Might ignore writes when the trace unit is enabled or not idle. This register must be programmed when one or more address comparators are implemented.
TRCVDARCCTLR	0x0A8		ViewData include / exclude control. Might ignore writes when the trace unit is enabled or not idle. This register must be programmed when one or more address comparators are implemented.
TRCSEQEVR[n]	0x100		Moves the sequencer state according to programmed events. Might ignore writes when the trace unit is enabled or not idle. When the sequencer is used, all sequencer state transitions must be programmed with a valid event.
TRCSEQRSTEVR	0x118		Moves the sequencer to state 0 when a programmed event occurs. Might ignore writes when the trace unit is enabled or not idle. When the sequencer is used, all sequencer state transitions must be programmed with a valid event.
TRCSEQSTR	0x11C		Use this to set, or read, the sequencer state. Might ignore writes when the trace unit is enabled or not idle. Only returns stable data when TRCSTATR.PMSTABLE == 1. When the sequencer is used, all sequencer state transitions must be programmed with a valid event.
TRCEXTINSELR	0x120		Use this to set, or read, which external inputs are resources to the trace unit. Might ignore writes when the trace unit is enabled or not idle. Only returns stable data when TRCSTATR.PMSTABLE == 1. When the sequencer is used, all sequencer state transitions must be programmed with a valid event.
TRCCNTRLDVR[n]	0x140		This sets or returns the reload count value for counter n. Might ignore writes when the trace unit is enabled or not idle.
TRCCNTCTLR[n]	0x150		Controls the operation of counter n. Might ignore writes when the trace unit is enabled or not idle.

Register	Offset	TZ	Description
TRCCNTVR[n]	0x160		This sets or returns the value of counter n. The count value is only stable when TRCSTATR.PMSTABLE == 1. If software uses counter n then it must write to this register to set the initial counter value. Might ignore writes when the trace unit is enabled or not idle.
TRCRSCTLR[n]	0x200		Controls the selection of the resources in the trace unit. Might ignore writes when the trace unit is enabled or not idle. If software selects a non-implemented resource then CONSTRAINED UNPREDICTABLE behavior of the resource selector occurs, so the resource selector might fire unexpectedly or might not fire. Reads of the TRCRSCTLRn might return UNKNOWN.
TRCSSCCR0	0x280		Controls the single-shot comparator.
TRCSSCSR0	0x2A0		Indicates the status of the single-shot comparators. TRCSSCSR0 is sensitive toinstruction addresses.
TRCSSPCICR0	0x2C0		Selects the processor comparator inputs for Single-shot control.
TRCPDCR	0x310		Controls the single-shot comparator.
TRCPDSR	0x314		Indicates the power down status of the ETM.
TRCITATBIDR	0xEE4		Sets the state of output pins.
TRCITIATBINR	0xEF4		Reads the state of the input pins.
TRCITIATBOUTR	0xEFC		Sets the state of the output pins.
TRCITCTRL	0xF00		Enables topology detection or integration testing, by putting ETM-M33 into integration mode.
TRCCLAIMSET	0xFA0		Sets bits in the claim tag and determines the number of claim tag bits implemented.
TRCCLAIMCLR	0xFA4		Clears bits in the claim tag and determines the current value of the claim tag.
TRCAUTHSTATUS	0xFB8		Indicates the current level of tracing permitted by the system
TRCDEVARCH	0xFBC		The TRCDEVARCH identifies ETM-M33 as an ETMv4.2 component
TRCDEVTYPE	0xFCC		Controls the single-shot comparator.
TRCPIDR[n]	0xFD0		Coresight peripheral identification registers.
TRCCIDR[n]	0xFF0		Coresight component identification registers.

10.7.4.1.1 TRCPRGCTLR

Address offset: 0x004

Enables the trace unit.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

ID	R/W	Field	Value ID	Value	Description
A	RW	EN			Trace unit enable bit
			Disabled	0	The trace unit is disabled. All trace resources are inactive and no trace is generated.
			Enabled	1	The trace unit is enabled.

10.7.4.1.2 TRCPROCSELR

Address offset: 0x008

Controls which PE to trace.

Might ignore writes when the trace unit is enabled or not idle.

Before writing to this register, ensure that TRCSTATR.IDLE == 1 so that the trace unit can synchronize with the chosen PE.

Implemented if TRCIDR3.NUMPROC is greater than zero.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PROCSEL			PE select bits that select the PE to trace.

10.7.4.1.3 TRCSTATR

Address offset: 0x00C

Idle status bit

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	IDLE			Trace unit enable bit
			NotIdle	0	The trace unit is not idle.
			Idle	1	The trace unit is idle.
B	RW	PMSTABLE			Programmers' model stable bit
			NotStable	0	The programmers' model is not stable.
			Stable	1	The programmers' model is stable.

10.7.4.1.4 TRCCONFIGR

Address offset: 0x010

Controls the tracing options

This register must always be programmed as part of trace unit initialization.

Might ignore writes when the trace unit is enabled or not idle.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				M L K J J I H G G G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	LOADASP0INST			Instruction P0 load field. This field controls whether load instructions are traced as P0 instructions.
			No	0	Do not trace load instructions as P0 instructions.
			Yes	1	Trace load instructions as P0 instructions.
B	RW	STOREASP0INST			Instruction P0 field. This field controls whether store instructions are traced as P0 instructions.
			No	0	Do not trace store instructions as P0 instructions.
			Yes	1	Trace store instructions as P0 instructions.
C	RW	BB			Branch broadcast mode bit.
			Disabled	0	Branch broadcast mode is disabled.
			Enabled	1	Branch broadcast mode is enabled.
D	RW	CCI			Cycle counting instruction trace bit.
			Disabled	0	Cycle counting in the instruction trace is disabled.
			Enabled	1	Cycle counting in the instruction trace is enabled.
E	RW	CID			Context ID tracing bit.
			Disabled	0	Context ID tracing is disabled.
			Enabled	1	Context ID tracing is enabled.
F	RW	VMID			Virtual context identifier tracing bit.
			Disabled	0	Virtual context identifier tracing is disabled.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				M L K J J I H G G G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Enabled	1	Virtual context identifier tracing is enabled.
G	RW	COND			Conditional instruction tracing bit.
			Disabled	0	Conditional instruction tracing is disabled.
			LoadOnly	1	Conditional load instructions are traced.
			StoreOnly	2	Conditional store instructions are traced.
			LoadAndStore	3	Conditional load and store instructions are traced.
			All	7	All conditional instructions are traced.
H	RW	TS			Global timestamp tracing bit.
			Disabled	0	Global timestamp tracing is disabled.
			Enabled	1	Global timestamp tracing is enabled.
I	RW	RS			Return stack enable bit.
			Disabled	0	Return stack is disabled.
			Enabled	1	Return stack is enabled.
J	RW	QE			Q element enable field.
			Disabled	0	Q elements are disabled.
			OnlyWithoutInstCou	1	Q elements with instruction counts are enabled. Q elements without instruction counts are disabled.
			Enabled	3	Q elements with and without instruction counts are enabled.
K	RW	VMIDOPT			Control bit to select the Virtual context identifier value used by the trace unit, both for trace generation and in the Virtual context identifier comparators.
			VTTBR_EL2	0	VTTBR_EL2.VMID is used. If the trace unit supports a Virtual context identifier larger than the VTTBR_EL2.VMID, the upper unused bits are always zero. If the trace unit supports a Virtual context identifier larger than 8 bits and if the VTCR_EL2.VS bit forces use of an 8-bit Virtual context identifier, bits [15:8] of the trace unit Virtual context identifier are always zero.
			CONTEXTIDR_EL2	1	CONTEXTIDR_EL2 is used.
L	RW	DA			Data address tracing bit.
			Disabled	0	Data address tracing is disabled.
			Enabled	1	Data address tracing is enabled.
M	RW	DV			Data value tracing bit.
			Disabled	0	Data value tracing is disabled.
			Enabled	1	Data value tracing is enabled.

10.7.4.1.5 TRCEVENTCTL0R

Address offset: 0x20

Controls the tracing of arbitrary events.

If the selected event occurs a trace element is generated in the trace stream according to the settings in TRCEVENTCTL1R.DATAEN and TRCEVENTCTL1R.INSTEN.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENT		[0:255]	Select which event should generate trace elements.

10.7.4.1.6 TRCEVENTCTL1R

Address offset: 0x24

Controls the behavior of the events that TRCEVENTCTL0R selects.

This register must always be programmed as part of trace unit initialization.

Might ignore writes when the trace unit is enabled or not idle.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																							G	F								E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-D	RW	INSTEN[i] (i=0..3)																																	
			Disabled	0																															
			Enabled	1																															
E	RW	DATAEN																																	
			Disabled	0																															
			Enabled	1																															
F	RW	ATB																																	
			Disabled	0																															
			Enabled	1																															
G	RW	LPOVERRIDE																																	
			Disabled	0																															
			Enabled	1																															

10.7.4.1.7 TRCSTALLCTLR

Address offset: 0x2C

Enables trace unit functionality that prevents trace unit buffer overflows.

Might ignore writes when the trace unit is enabled or not idle.

Must be programmed if TRCIDR3.STALLCTL == 1.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																							G	F	E	D	C	B				A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	LEVEL		[15:0]																															
				If LEVEL is nonzero then a trace unit might suppress the generation of: Global timestamps in the instruction trace stream and the data trace stream. Cycle counting in the instruction trace stream, although the cumulative cycle count remains correct.																																		
			Min	0																															
			Max	15																															

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				G F E D C B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
B	RW	ISTALL			Instruction stall bit. Controls if a trace unit can stall the PE when the instruction trace buffer space is less than LEVEL.
			Disabled	0	The trace unit must not stall the PE.
			Enabled	1	The trace unit can stall the PE.
C	RW	DSTALL			Data stall bit. Controls if a trace unit can stall the PE when the data trace buffer space is less than LEVEL.
			Disabled	0	The trace unit must not stall the PE.
			Enabled	1	The trace unit can stall the PE.
D	RW	INSTPRIORITY			Prioritize instruction trace bit. Controls if a trace unit can prioritize instruction trace when the instruction trace buffer space is less than LEVEL.
			Disabled	0	The trace unit must not prioritize instruction trace.
			Enabled	1	The trace unit can prioritize instruction trace. A trace unit might prioritize instruction trace by preventing output of data trace, or other means which ensure that the instruction trace has a higher priority than the data trace.
E	RW	DATADISCARDLOAD			Data discard field. Controls if a trace unit can discard data trace elements on a load when the data trace buffer space is less than LEVEL.
			Disabled	0	The trace unit must not discard any data trace elements.
			Enabled	1	The trace unit can discard P1 and P2 elements associated with data loads.
F	RW	DATADISCARDSTORE			Data discard field. Controls if a trace unit can discard data trace elements on a store when the data trace buffer space is less than LEVEL.
			Disabled	0	The trace unit must not discard any data trace elements.
			Enabled	1	The trace unit can discard P1 and P2 elements associated with data stores.
G	RW	NOOVERFLOW			Trace overflow prevention bit.
			Disabled	0	Trace overflow prevention is disabled.
			Enabled	1	Trace overflow prevention is enabled. This might cause a significant performance impact.

10.7.4.1.8 TRCTSCTLR

Address offset: 0x30

Controls the insertion of global timestamps in the trace streams.

When the selected event is triggered, the trace unit inserts a global timestamp into the trace streams.

Might ignore writes when the trace unit is enabled or not idle.

Must be programmed if TRCCONFIGR.TS == 1.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENT		[0:255]	Select which event should generate time stamps.

10.7.4.1.9 TRCSYNCPR

Address offset: 0x34

Controls how often trace synchronization requests occur.

Might ignore writes when the trace unit is enabled or not idle.

If writes are permitted then the register must be programmed.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PERIOD		[31:0]	Controls how many bytes of trace, the sum of instruction and data, that a trace unit can generate before a trace synchronization request occurs. The number of bytes is always a power of two, calculated by 2^PERIOD
			Disabled	0	Trace synchronization requests are disabled. This setting does not disable other types of trace synchronization request.

10.7.4.1.10 TRCCCCTLR

Address offset: 0x38

Sets the threshold value for cycle counting.

Might ignore writes when the trace unit is enabled or not idle.

Must be programmed if TRCCONFIGR.CCI==1.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	THRESHOLD		[2047:0]	Sets the threshold value for instruction trace cycle counting.

10.7.4.1.11 TRCBBCTLR

Address offset: 0x3C

Controls which regions in the memory map are enabled to use branch broadcasting.

Might ignore writes when the trace unit is enabled or not idle.

Must be programmed if TRCCONFIGR.BB == 1.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	RANGE[i] (i=0..7)			Address range field. Selects which address range comparator pairs are in use with branch broadcasting. Each field represents an address range comparator pair, so field[i] controls the selection of address range comparator pair i.
			Disabled	0	The address range that address range comparator pair i defines, is not selected.
			Enabled	1	The address range that address range comparator pair n defines, is selected.

10.7.4.1.12 TRCTRACEIDR

Address offset: 0x40

Sets the trace ID for instruction trace. If data trace is enabled then it also sets the trace ID for data trace, to (trace ID for instruction trace) + 1.

This register must always be programmed as part of trace unit initialization.

Might ignore writes when the trace unit is enabled or not idle.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TRACEID			Trace ID field. Sets the trace ID value for instruction trace. Bit[0] must be zero if data trace is enabled. If data trace is enabled then a trace unit sets the trace ID for data trace, to TRACEID+1.

10.7.4.1.13 TRCQCTLR

Address offset: 0x44

Controls when Q elements are enabled.

Might ignore writes when the trace unit is enabled or not idle.

This register must be programmed if it is implemented and TRCCONFIGR.QE is set to any value other than 0b00.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	RANGE[i] (i=0..7)			Specifies the address range comparators to be used for controlling Q elements.
			Disabled	0	Address range comparator i is disabled.
			Enabled	1	Address range comparator i is selected for use.
I	RW	MODE			Selects whether the address range comparators selected by the RANGE field indicate address ranges where the trace unit is permitted to generate Q elements or address ranges where the trace unit is not permitted to generate Q elements:
			Exclude	0	Exclude mode. The address range comparators selected by the RANGE field indicate address ranges where the trace unit cannot generate Q elements. If no ranges are selected, Q elements are permitted across the entire memory map.
			Include	1	Include mode. The address range comparators selected by the RANGE field indicate address ranges where the trace unit can generate Q elements. If all the implemented bits in RANGE are set to 0 then Q elements are disabled.

10.7.4.1.14 TRCVICTLR

Address offset: 0x080

Controls instruction trace filtering.

Might ignore writes when the trace unit is enabled or not idle.

Only returns stable data when TRCSTATR.PMSTABLE == 1.

Must be programmed, particularly to set the value of the SSSTATUS bit, which sets the state of the start/stop logic.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L K J I H G F E D C B A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENT_SEL			Select which resource number should be filtered.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L K J I H G F E D C B A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Disabled	0	This event is not filtered.
			Enabled	1	This event is filtered.
B	RW	SSSTATUS			When TRCIDR4.NUMACPAIRS > 0 or TRCIDR4.NUMPC > 0, this bit returns the status of the start/stop logic.
			Stopped	0	The start/stop logic is in the stopped state.
			Started	1	The start/stop logic is in the started state.
C	RW	TRCRESET			Controls whether a trace unit must trace a Reset exception.
			Disabled	0	The trace unit does not trace a Reset exception unless it traces the exception or instruction immediately prior to the Reset exception.
			Enabled	1	The trace unit always traces a Reset exception.
D	RW	TRCERR			When TRCIDR3.TRCERR==1, this bit controls whether a trace unit must trace a System error exception.
			Disabled	0	The trace unit does not trace a System error exception unless it traces the exception or instruction immediately prior to the System error exception.
			Enabled	1	The trace unit always traces a System error exception, regardless of the value of ViewInst.
E-H	RW	EXLEVEL[i]_S (i=0..3)			In Secure state, each bit controls whether instruction tracing is enabled for the corresponding Exception level i.
			Disabled	1	The trace unit does not generate instruction trace, in Secure state, for Exception level i.
			Enabled	0	The trace unit generates instruction trace, in Secure state, for Exception level i.
I-L	RW	EXLEVEL[i]_NS (i=0..3)			In Non-secure state, each bit controls whether instruction tracing is enabled for the corresponding Exception level i.
			Disabled	1	The trace unit does not generate instruction trace, in Non-secure state, for Exception level i.
			Enabled	0	The trace unit generates instruction trace, in Non-secure state, for Exception level i.

10.7.4.1.15 TRCVIIECTLR

Address offset: 0x084

ViewInst exclude control.

Might ignore writes when the trace unit is enabled or not idle.

This register must be programmed when one or more address comparators are implemented.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	INCLUDE[i] (i=0..7)			Include range field. Selects which address range comparator pairs are in use with ViewInst include control.
			Disabled	0	The address range that address range comparator pair i defines, is not selected for ViewInst include control.
			Enabled	1	The address range that address range comparator pair i defines, is selected for ViewInst include control.
I-P	RW	EXCLUDE[i] (i=0..7)			Exclude range field. Selects which address range comparator pairs are in use with ViewInst exclude control.
			Disabled	0	The address range that address range comparator pair i defines, is not selected for ViewInst exclude control.
			Enabled	1	The address range that address range comparator pair i defines, is selected for ViewInst exclude control.

10.7.4.1.16 TRCVISSCTLR

Address offset: 0x088

Use this to set, or read, the single address comparators that control the ViewInst start/stop logic. The start/stop logic is active for an instruction which causes a start and remains active up to and including an instruction which causes a stop, and then the start/stop logic becomes inactive.

Might ignore writes when the trace unit is enabled or not idle.

If implemented then this register must be programmed.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	START[i] (i=0..7)			Selects which single address comparators are in use with ViewInst start/stop control, for the purpose of starting trace.
			Disabled	0	The single address comparator i, is not selected as a start resource.
			Enabled	1	The single address comparator i, is selected as a start resource.
I-P	RW	STOP[i] (i=0..7)			Selects which single address comparators are in use with ViewInst start/stop control, for the purpose of stopping trace
			Disabled	0	The single address comparator i, is not selected as a stop resource.
			Enabled	1	The single address comparator i, is selected as a stop resource.

10.7.4.1.17 TRCVIPCSSCTLR

Address offset: 0x08C

Use this to set, or read, which PE comparator inputs can control the ViewInst start/stop logic.

Might ignore writes when the trace unit is enabled or not idle.

If implemented then this register must be programmed.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	START[i] (i=0..7)			Selects which PE comparator inputs are in use with ViewInst start/stop control, for the purpose of starting trace
			Disabled	0	The single PE comparator input i, is not selected as a start resource.
			Enabled	1	The single PE comparator input i, is selected as a start resource.
I-P	RW	STOP[i] (i=0..7)			Selects which PE comparator inputs are in use with ViewInst start/stop control, for the purpose of stopping trace.
			Disabled	0	The single PE comparator input i, is not selected as a stop resource.
			Enabled	1	The single PE comparator input i, is selected as a stop resource.

10.7.4.1.18 TRCVDCTLR

Address offset: 0x0A0

Controls data trace filtering.

Might ignore writes when the trace unit is enabled or not idle.

This register must be programmed when data tracing is enabled, that is, when either TRCCONFIGR.DA == 1 or TRCCONFIGR.DV == 1.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				L K J I I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	EVENT[i] (i=0..7)			Event unit enable bit.
			Disabled	0	The trace event is not selected for trace filtering.
			Enabled	1	The trace event is selected for trace filtering.
I	RW	SPREL			Controls whether a trace unit traces data for transfers that are relative to the Stack Pointer (SP).
			Enabled	0	The trace unit does not affect the tracing of SP-relative transfers.
			DataOnly	2	The trace unit does not trace the address portion of SP-relative transfers. If data value tracing is enabled then the trace unit generates a P1 data address element.
			Disabled	3	The trace unit does not trace the address or value portions of SP-relative transfers.
J	RW	PCREL			Controls whether a trace unit traces data for transfers that are relative to the Program Counter (PC).
			Enabled	0	The trace unit does not affect the tracing of PC-relative transfers.
			Disabled	1	The trace unit does not trace the address or value portions of PC-relative transfers.
K	RW	TBI			Controls which information a trace unit populates in bits[63:56] of the data address.
			SignExtend	0	The trace unit assigns bits[63:56] to have the same value as bit[55] of the data address, that is, it sign-extends the value.
			Copy	1	The trace unit assigns bits[63:56] to have the same value as bits[63:56] of the data address.
L	RW	TRCEXDATA			Controls the tracing of data transfers for exceptions and exception returns on Armv6-M, Armv7-M, and Armv8-M PEs.
			Disabled	0	Exception and exception return data transfers are not traced.
			Enabled	1	Exception and exception return data transfers are traced if the other aspects of ViewData indicate that the data transfers must be traced.

10.7.4.1.19 TRCVDSACCTLR

Address offset: 0x0A4

ViewData include / exclude control.

Might ignore writes when the trace unit is enabled or not idle.

This register must be programmed when one or more address comparators are implemented.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-H	RW	INCLUDE[i] (i=0..7)			Selects which single address comparators are in use with ViewData include control.
			Disabled	0	The single address comparator i, is not selected for ViewData include control.
			Enabled	1	The single address comparator i, is selected for ViewData include control.
I-P	RW	EXCLUDE[i] (i=0..7)			Selects which single address comparators are in use with ViewData exclude control.
			Disabled	0	The single address comparator i, is not selected for ViewData exclude control.
			Enabled	1	The single address comparator i, s selected for ViewData exclude control.

10.7.4.1.20 TRCVDARCCTLR

Address offset: 0x0A8

ViewData include / exclude control.

Might ignore writes when the trace unit is enabled or not idle.

This register must be programmed when one or more address comparators are implemented.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-H	RW	INCLUDE[i] (i=0..7)			Include range field. Selects which address range comparator pairs are in use with ViewData include control.
			Disabled	0	The address range that address range comparator i defines, is not selected for ViewData include control.
			Enabled	1	The address range that address range comparator i defines, is selected for ViewData include control.
I-P	RW	EXCLUDE[i] (i=0..7)			Exclude range field. Selects which address range comparator pairs are in use with ViewData exclude control.
			Disabled	0	The address range that address range comparator i defines, is not selected for ViewData exclude control.
			Enabled	1	The address range that address range comparator i defines, s selected for ViewData exclude control.

10.7.4.1.21 TRCSEQEVR[n] (n=0..2)

Address offset: 0x100 + (n × 0x4)

Moves the sequencer state according to programmed events.

Might ignore writes when the trace unit is enabled or not idle.

When the sequencer is used, all sequencer state transitions must be programmed with a valid event.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				P O N M L K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	F[i] (i=0..7)			Forward field.
			Disabled	0	The trace event does not affect the sequencer.
			Enabled	1	When the event occurs then the sequencer state moves from state n to state n+1.
I-P	RW	B[i] (i=0..7)			Backward field.
			Disabled	0	The trace event does not affect the sequencer.
			Enabled	1	When the event occurs then the sequencer state moves from state n+1 to state n.

10.7.4.1.22 TRCSEQRSTEVR

Address offset: 0x118

Moves the sequencer to state 0 when a programmed event occurs.

Might ignore writes when the trace unit is enabled or not idle.

When the sequencer is used, all sequencer state transitions must be programmed with a valid event.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EVENT		[0:255]	Select which event should reset the sequencer.

10.7.4.1.23 TRCSEQSTR

Address offset: 0x11C

Use this to set, or read, the sequencer state.

Might ignore writes when the trace unit is enabled or not idle.

Only returns stable data when TRCSTATR.PMSTABLE == 1.

When the sequencer is used, all sequencer state transitions must be programmed with a valid event.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	STATE			Sets or returns the state of the sequencer.
			State0	0	The sequencer is in state 0.
			State1	1	The sequencer is in state 1.
			State2	2	The sequencer is in state 2.
			State3	3	The sequencer is in state 3.

10.7.4.1.24 TRCEXTINSELR

Address offset: 0x120

Use this to set, or read, which external inputs are resources to the trace unit.

Might ignore writes when the trace unit is enabled or not idle.

Only returns stable data when TRCSTATR.PMSTABLE == 1.

When the sequencer is used, all sequencer state transitions must be programmed with a valid event.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D D D D D D D D C C C C C C C C B B B B B B B B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-D	RW	SEL[i] (i=0..3)		[0:255]	Each field in this collection selects an external input as a resource for the trace unit.

10.7.4.1.25 TRCCNTRLDVR[n] (n=0..3)

Address offset: 0x140 + (n × 0x4)

This sets or returns the reload count value for counter n.

Might ignore writes when the trace unit is enabled or not idle.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE		[0:65535]	Contains the reload value for counter n. When a reload event occurs for counter n then the trace unit copies the VALUEn field into counter n.

10.7.4.1.26 TRCCNTCTLR[n] (n=0..3)

Address offset: 0x150 + (n × 0x4)

Controls the operation of counter n.

Might ignore writes when the trace unit is enabled or not idle.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B B B B B B B B A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CNTEVENT		[0:255]	Selects an event, that when it occurs causes counter n to decrement.
B	RW	RLDEVENT		[0:255]	Selects an event, that when it occurs causes a reload event for counter n.
C	RW	RLDSELF			Controls whether a reload event occurs for counter n, when counter n reaches zero.
			Disabled	0	The counter is in Normal mode.
			Enabled	1	The counter is in Self-reload mode.
D	RW	CNTCHAIN			For TRCCNTCTLR3 and TRCCNTCTLR1, this bit controls whether counter n decrements when a reload event occurs for counter n-1.
			Disabled	0	Counter n does not decrement when a reload event for counter n-1 occurs.
			Enabled	1	Counter n decrements when a reload event for counter n-1 occurs. This concatenates counter n and counter n-1, to provide a larger count value.

10.7.4.1.27 TRCCNTVR[n] (n=0..3)

Address offset: 0x160 + (n × 0x4)

This sets or returns the value of counter n.

The count value is only stable when TRCSTATR.PMSTABLE == 1.

If software uses counter n then it must write to this register to set the initial counter value.

Might ignore writes when the trace unit is enabled or not idle.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	VALUE		[0:65535]	Contains the count value of counter n.

10.7.4.1.28 TRCRSCTLR[n] (n=2..31)

Address offset: 0x200 + (n × 0x4)

Controls the selection of the resources in the trace unit.

Might ignore writes when the trace unit is enabled or not idle.

If software selects a non-implemented resource then CONSTRAINED UNPREDICTABLE behavior of the resource selector occurs, so the resource selector might fire unexpectedly or might not fire. Reads of the TRCRSCTLRn might return UNKNOWN.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	EN			Trace unit enable bit
			Disabled	0	The trace unit is disabled. All trace resources are inactive and no trace is generated.
			Enabled	1	The trace unit is enabled.

10.7.4.1.29 TRCSSCCR0

Address offset: 0x280

Controls the single-shot comparator.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	RST			Enables the single-shot comparator resource to be reset when it occurs, to enable another comparator match to be detected
			Disabled	0	Multiple matches can not be detected.
			Enabled	1	Multiple matches can occur.

10.7.4.1.30 TRCSSCSR0

Address offset: 0x2A0

Indicates the status of the single-shot comparators. TRCSSCSR0 is sensitive toinstruction addresses.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	INST			Instruction address comparator support
			False	0	Single-shot instruction address comparisons not supported.
			True	1	Single-shot instruction address comparisons supported.
B	RW	DA			Data address comparator support
			False	0	Data address comparisons not supported.
			True	1	Data address comparisons supported.
C	RW	DV			Data value comparator support
			False	0	Data value comparisons not supported.
			True	1	Data value comparisons supported.
D	RW	PC			Process counter value comparator support
			False	0	Process counter value comparisons not supported.
			True	1	Process counter value comparisons supported.
E	RW	STATUS			Single-shot status. This indicates whether any of the selected comparators have matched.
			NoMatch	0	Match has not occurred.
			Match	1	Match has occurred at least once.

10.7.4.1.31 TRCSSPCICR0

Address offset: 0x2C0

Selects the processor comparator inputs for Single-shot control.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-D	RW	PC[i] (i=0..3)			Selects processor comparator i inputs for Single-shot control
			Disabled	0	Processor comparator i is not selected for Single-shot control.
			Enabled	1	Processor comparator i is selected for Single-shot control.

10.7.4.1.32 TRCPDCR

Address offset: 0x310

Controls the single-shot comparator.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PU			Power up request, to request that power to ETM and access to the trace registers is maintained.
			Disabled	0	Power not requested.
			Enabled	1	Power requested.

10.7.4.1.33 TRCPDSR

Address offset: 0x314

Indicates the power down status of the ETM.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	POWER			Indicates ETM is powered up
			NotPoweredUp	0	ETM is not powered up. All registers are not accessible.
			PoweredUp	1	ETM is powered up. All registers are accessible.
B	RW	STICKYPD			Sticky power down state. This bit is set to 1 when power to the ETM registers is removed, to indicate that programming state has been lost. It is cleared after a read of the TRCPDSR
			NotPoweredDown	0	Trace register power has not been removed since the TRCPDSR was last read.
			PoweredDown	1	Trace register power has been removed since the TRCPDSR was last read.

10.7.4.1.34 TRCITATBIDR

Address offset: 0xEE4

Sets the state of output pins.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-G	RW	ID[i] (i=0..6)			Drives the ATIDMI[i] output pin.

10.7.4.1.35 TRCITIATBINR

Address offset: 0xEF4

Reads the state of the input pins.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ATVALID			Returns the value of the ATVALIDMI input pin.
B	RW	AFREADY			Returns the value of the AFREADYMI input pin.

10.7.4.1.36 TRCITIATBOUTR

Address offset: 0xEFC

Sets the state of the output pins.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ATVALID			Drives the ATVALIDMI output pin.
B	RW	AFREADY			Drives the AFREADYMI output pin.

10.7.4.1.37 TRCITCTRL

Address offset: 0xF00

Enables topology detection or integration testing, by putting ETM-M33 into integration mode.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	IME			Integration mode enable
			Disabled	0	ETM is not in integration mode.
			Enabled	1	ETM is in integration mode.

10.7.4.1.38 TRCCLAIMSET

Address offset: 0xFA0

Sets bits in the claim tag and determines the number of claim tag bits implemented.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-D	RW	SET[i] (i=0..3)			Claim tag set register
			NotSet	0	Claim tag i is not set.
			Set	1	Claim tag i is set.
			Claim	1	Set claim tag i.

10.7.4.1.39 TRCCLAIMCLR

Address offset: 0xFA4

Clears bits in the claim tag and determines the current value of the claim tag.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-D	RW	CLR[i] (i=0..3)			Claim tag clear register
			NotSet	0	Claim tag i is not set.
			Set	1	Claim tag i is set.
			Clear	1	Clear claim tag i.

10.7.4.1.40 TRCAUTHSTATUS

Address offset: 0xFB8

Indicates the current level of tracing permitted by the system

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D D C C B B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	NSID			Non-secure Invasive Debug

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D D C C B B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
B	RW	NSNID			Non-secure Non-Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
C	RW	SID			Secure Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
D	RW	SNID			Secure Non-Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.

10.7.4.1.41 TRCDEVARCH

Address offset: 0xFBC

The TRCDEVARCH identifies ETM-M33 as an ETMv4.2 component

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D D D D D D D D D D D C B B B A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	ARCHID			Architecture ID
			ETMv42	0x4A13	Component is an ETMv4 component
B	R	REVISION			Architecture revision
			v2	2	Component is part of architecture 4.2
C	R	PRESENT			This register is implemented
			Absent	0	The register is not implemented.
			Present	1	The register is implemented.
D	R	ARCHITECT			Defines the architect of the component
			Arm	0x23B	This peripheral was architected by Arm.

10.7.4.1.42 TRCDEVTYPE

Address offset: 0xFCC

Controls the single-shot comparator.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	MAJOR			The main type of the component
			TraceSource	3	Peripheral is a trace source.
B	R	SUB			The sub-type of the component
			ProcessorTrace	1	Peripheral is a processor trace source.

10.7.4.1.43 TRCPIDR[n] (n=0..7)

Address offset: 0xFD0 + (n × 0x4)

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.4.1.44 TRCCIDR[n] (n=0..3)

Address offset: 0xFF0 + (n × 0x4)

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.5 TPIU — Trace port interface unit

The ARM® CoreSight™ TPIU connects an ATB to an external trace port.

This document only provides a register-level description of this ARM component. See the ARM® CoreSight™ SoC-400 Technical Reference Manual for more details

10.7.5.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
TPIU	0xE0054000	HF	NS	NA	No	TPIU

Register overview

Register	Offset	TZ	Description
SUPPORTEDPORTSIZES	0x000		Each bit location is a single port size that is supported on the device.
CURRENTPORTSIZE	0x004		Each bit location is a single port size. One bit can be set, and indicates the current port size.
SUPPORTEDTRIGGERMODES	0x100		The Supported_trigger_modes register indicates the implemented trigger counter multipliers and other supported features of the trigger system.
TRIGGERCOUNTERVALUE	0x104		The Trigger_counter_value register enables delaying the indication of triggers to any external connected trace capture or storage devices.
TRIGGERMULTIPLIER	0x108		The Trigger_multiplier register contains the selectors for the trigger counter multiplier.
SUPPPORTEDTESTPATTERNMODES	0x200		The Supported_test_pattern_modes register provides a set of known bit sequences or patterns that can be output over the trace port and can be detected by the TPA or other associated trace capture device.
CURRENTTESTPATTERNMODES	0x204		Current_test_pattern_mode indicates the current test pattern or mode selected.
TPRCR	0x208		The TPRCR register is an 8-bit counter start value that is decremented. A write sets the initial counter value and a read returns the programmed value.
FFSR	0x300		The FFSR register indicates the current status of the formatter and flush features available in the TPIU.
FFCR	0x304		The FFCR register controls the generation of stop, trigger, and flush events.
FSCR	0x308		The FSCR register enables the frequency of synchronization information to be optimized to suit the Trace Port Analyzer (TPA) capture buffer size.

Register	Offset	TZ	Description
EXTCTLINPORT	0x400		Two ports can be used as a control and feedback mechanism for any serializers, pin sharing multiplexers, or other solutions that might be added to the trace output pins either for pin control or a high-speed trace port solution.
EXTCTLOUTPORT	0x404		Two ports can be used as a control and feedback mechanism for any serializers, pin sharing multiplexers, or other solutions that might be added to the trace output pins either for pin control or a high speed trace port solution. These ports are raw register banks that sample or export the corresponding external pins.
ITTRFLINACK	0xEE4		The ITTRFLINACK register enables control of the triginack and flushinack outputs from the TPIU.
ITTRFLIN	0xEE8		The ITTRFLIN register contains the values of the flushin and trigin inputs to the TPIU.
ITATBDATA0	0xEEC		The ITATBDATA0 register contains the value of the atdatas inputs to the TPIU. The values are valid only when atvalids is HIGH.
ITATBCTR2	0xEF0		Enables control of the atreadys and afvalids outputs of the TPIU.
ITATBCTR1	0xEF4		The ITATBCTR1 register contains the value of the atids input to the TPIU. This is only valid when atvalids is HIGH.
ITATBCTR0	0xEF8		The ITATBCTR0 register captures the values of the atvalids, afreadys, and atbytess inputs to the TPIU. To ensure the integration registers work correctly in a system, the value of atbytess is only valid when atvalids, bit[0], is HIGH.
ITCTRL	0xF00		Used to enable topology detection. This register enables the component to switch from a functional mode, the default behavior, to integration mode where the inputs and outputs of the component can be directly controlled for integration testing and topology solving.
CLAIMSET	0xFA0		Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMSET register sets bits in the claim tag, and determines the number of claim bits implemented.
CLAIMCLR	0xFA4		Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMCLR register sets the bits in the claim tag to 0 and determines the current value of the claim tag.
LAR	0xFB0		This is used to enable write access to device registers.
LSR	0xFB4		This indicates the status of the lock control mechanism. This lock prevents accidental writes by code under debug. Accesses to the extended stimulus port registers are not affected by the lock mechanism. This register must always be present although there might not be any lock access control mechanism. The lock mechanism, where present and locked, must block write accesses to any control register, except the Lock Access Register. For most components this covers all registers except for the Lock Access Register.
AUTHSTATUS	0xFB8		Indicates the current level of tracing permitted by the system
DEVID	0xFC8		Indicates the capabilities of the component.
DEVTYPE	0xFCC		The DEVTYPE register provides a debugger with information about the component when the Part Number field is not recognized. The debugger can then report this information.
PIDR4	0xFD0		Coresight peripheral identification registers.
PIDR[0]	0xFE0		Coresight peripheral identification registers.
PIDR[1]	0xFE4		Coresight peripheral identification registers.
PIDR[2]	0xFE8		Coresight peripheral identification registers.
PIDR[3]	0xFEC		Coresight peripheral identification registers.
CIDR[0]	0xFF0		Coresight component identification registers.
CIDR[1]	0xFF4		Coresight component identification registers.
CIDR[2]	0xFF8		Coresight component identification registers.
CIDR[3]	0xFFC		Coresight component identification registers.

10.7.5.1.1 SUPPORTEDPORTSIZES

Address offset: 0x000

Each bit location is a single port size that is supported on the device.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				f	e	d	c	b	a	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-f	RW	PORT_SIZE_[i+1] (i=0..31)																																	
			NotSupported	0																															
			Supported	1																															

				Description
A-f	RW	PORT_SIZE_[i+1] (i=0..31)		Indicates whether the TPIU supports port size of i+1-bit.
			NotSupported	Port size i+1 is not supported.
			Supported	Port size i+1 is supported.

10.7.5.1.2 CURRENTPORTSIZE

Address offset: 0x004

Each bit location is a single port size. One bit can be set, and indicates the current port size.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				f	e	d	c	b	a	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-f	RW	PORT_SIZE_[i+1] (i=0..31)																																	
			NotSelected	0																															
			Selected	1																															

				Description
A-f	RW	PORT_SIZE_[i+1] (i=0..31)		Indicates which port size is currently selected.
			NotSelected	Port size i+1 is not selected.
			Selected	Port size i+1 is selected.

10.7.5.1.3 SUPPORTEDTRIGGERMODES

Address offset: 0x100

The Supported_trigger_modes register indicates the implemented trigger counter multipliers and other supported features of the trigger system.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																		H	G									F			E	D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-E	RW	MULT[i] (i=0..4)																																	
			NotSelected	0																															
			Selected	1																															
F	RW	TCOUNT8																																	
			NotImplemented	0																															
			Implemented	1																															
G	RW	TRIGGERED																																	
			NotOccured	0																															
			Occured	1																															
H	RW	TRGRUN																																	
			NotOccured	0																															
			Occured	1																															

				Description
A-E	RW	MULT[i] (i=0..4)		Indicates whether multiplying the trigger counter by 2^(i+1) is supported.
			NotSelected	Multiplying the trigger counter by 2^(i+1) is supported.
			Selected	Multiplying the trigger counter by 2^(i+1) is supported.
F	RW	TCOUNT8		Indicates whether an 8-bit wide counter register is implemented.
			NotImplemented	An 8-bit wide counter register is implemented.
			Implemented	An 8-bit wide counter register is implemented.
G	RW	TRIGGERED		A trigger has occurred and the counter has reached 0.
			NotOccured	Trigger has not occurred.
			Occured	Trigger has occurred.
H	RW	TRGRUN		A trigger has occurred but the counter is not at 0.
			NotOccured	Either a trigger has not occurred or the counter is at 0.
			Occured	A trigger has occurred but the counter is not at 0.

10.7.5.1.4 TRIGGERCOUNTERVALUE

Address offset: 0x104

The Trigger_counter_value register enables delaying the indication of triggers to any external connected trace capture or storage devices.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TrigCount		[0:255]	8-bit counter value for the number of words to be output from the formatter before a trigger is inserted.

10.7.5.1.5 TRIGGERMULTIPLIER

Address offset: 0x108

The Trigger_multiplier register contains the selectors for the trigger counter multiplier.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-E	RW	MULT[i] (i=0..4)			Multiply the Trigger Counter by 2^n.
			Disabled	0	Multiplier disabled.
			Enabled	1	Multiplier enabled.

10.7.5.1.6 SUPPPORTEDTESTPATTERNMODES

Address offset: 0x200

The Supported_test_pattern_modes register provides a set of known bit sequences or patterns that can be output over the trace port and can be detected by the TPA or other associated trace capture device.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	PATW1			Indicates whether the walking 1s pattern is supported as output over the trace port.
			NotSupported	0	Test pattern is not supported.
			Supported	1	Test pattern is supported.
B	RW	PATW0			Indicates whether the walking 0s pattern is supported as output over the trace port.
			NotSupported	0	Test pattern is not supported.
			Supported	1	Test pattern is supported.
C	RW	PATA5			Indicates whether the AA/55 pattern is supported as output over the trace port.
			NotSupported	0	Test pattern is not supported.
			Supported	1	Test pattern is supported.
D	RW	PATF0			Indicates whether the FF/00 pattern is supported as output over the trace port.
			NotSupported	0	Test pattern is not supported.
			Supported	1	Test pattern is supported.
E	RW	PTIMEEN			Indicates whether timed mode is supported.
			NotSupported	0	Mode is not supported.
			Supported	1	Mode is supported.
F	RW	PCONTEN			Indicates whether continuous mode is supported.
			NotSupported	0	Mode is not supported.
			Supported	1	Mode is supported.

10.7.5.1.7 CURRENTTESTPATTERNMODES

Address offset: 0x204

Current_test_pattern_mode indicates the current test pattern or mode selected.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PATW1			Indicates whether the walking 1s pattern is supported as output over the trace port.
			Disabled	0	Test pattern is disabled.
			Enabled	1	Test pattern is enabled.
B	RW	PATW0			Indicates whether the walking 0s pattern is supported as output over the trace port.
			Disabled	0	Test pattern is disabled.
			Enabled	1	Test pattern is enabled.
C	RW	PATA5			Indicates whether the AA/55 pattern is supported as output over the trace port.
			Disabled	0	Test pattern is disabled.
			Enabled	1	Test pattern is enabled.
D	RW	PATF0			Indicates whether the FF/00 pattern is supported as output over the trace port.
			Disabled	0	Test pattern is disabled.
			Enabled	1	Test pattern is enabled.
E	RW	PTIMEEN			Indicates whether timed mode is supported.
			Disabled	0	Mode is disabled.
			Enabled	1	Mode is enabled.
F	RW	PCONTEN			Indicates whether continuous mode is supported.
			Disabled	0	Mode is disabled.
			Enabled	1	Mode is enabled.

10.7.5.1.8 TPRCR

Address offset: 0x208

The TPRCR register is an 8-bit counter start value that is decremented. A write sets the initial counter value and a read returns the programmed value.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PATTCOUNT		[0:255]	8-bit counter value to indicate the number of traceclkin cycles for which a pattern runs before it switches to the next pattern.

10.7.5.1.9 FFSR

Address offset: 0x300

The FFSR register indicates the current status of the formatter and flush features available in the TPIU.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	FLINPROG			Flush in progress.
			NotInProgress	0	A flush is not in progress.
			InProgress	1	A flush is in progress.
B	RW	FTSTOPPED			The formatter has received a stop request signal and all trace data and post-amble is sent. Any additional trace data on the ATB interface is ignored and atreadys goes HIGH.
			Running	0	Formatter has not stopped.
			Stopped	1	Formatter has stopped.
C	RW	TCPRESENT			Indicates whether the TRACECTL pin is available for use.
			NotPresent	0	TRACECTL pin is not present.
			Present	1	TRACECTL pin is present.

10.7.5.1.10 FFCR

Address offset: 0x304

The FFCR register controls the generation of stop, trigger, and flush events.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ENFTC			Do not embed triggers into the formatted stream. Trace disable cycles and triggers are indicated by tracectl, where present.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
B	RW	ENFCONT			Is embedded in trigger packets and indicates that no cycle is using sync packets.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
C	RW	FONFLIN			Enables the use of the flushin connection.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
D	RW	FONTRIG			Initiates a manual flush of data in the system when a trigger event occurs.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
E	RW	FONMANR			Generates a flush. This bit is set to 0 when this flush is serviced.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
F	RW	FONMANW			Generates a flush. This bit is set to 1 when this flush is serviced.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
G	RW	TRIGIN			Indicates a trigger when trigin is asserted.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
H	RW	TRIGEVT			Indicates a trigger on a trigger event.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
I	RW	TRIGFL			Indicates a trigger when flush completion on afreadys is returned.
			Disabled	0	The formatting feature is disabled.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				K J I H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			Enabled	1	The formatting feature is enabled.
J	RW	STOPFL			Forces the FIFO to drain off any part-completed packets.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.
K	RW	STOPTRIG			Stops the formatter after a trigger event is observed. Reset to disabled or 0.
			Disabled	0	The formatting feature is disabled.
			Enabled	1	The formatting feature is enabled.

10.7.5.1.11 FSCR

Address offset: 0x308

The FSCR register enables the frequency of synchronization information to be optimized to suit the Trace Port Analyzer (TPA) capture buffer size.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	CYCCOUNT		[0:1024]	12-bit counter reload value. Indicates the number of complete frames between full synchronization packets.

10.7.5.1.12 EXTCTLINPORT

Address offset: 0x400

Two ports can be used as a control and feedback mechanism for any serializers, pin sharing multiplexers, or other solutions that might be added to the trace output pins either for pin control or a high-speed trace port solution.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	EXTCTLIN[i] (i=0..7)			EXTCTL inputs.
			Low	0	Input EXTCTLi is low.
			High	1	Input EXTCTLi is high.

10.7.5.1.13 EXTCTLOUTPORT

Address offset: 0x404

Two ports can be used as a control and feedback mechanism for any serializers, pin sharing multiplexers, or other solutions that might be added to the trace output pins either for pin control or a high speed trace port solution. These ports are raw register banks that sample or export the corresponding external pins.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				H G F E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A-H	RW	EXTCTLOUT[i] (i=0..7)			EXTCTL outputs.
			Low	0	Output EXTCTLi is low.
			High	1	Output EXTCTLi is high.

10.7.5.1.14 ITTRFLINACK

Address offset: 0xEE4

The ITTRFLINACK register enables control of the triginack and flushinack outputs from the TPIU.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TRIGINACK			Sets the value of triginack.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.
B	RW	FLUSHINACK			Sets the value of flushinack.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.5.1.15 ITTRFLIN

Address offset: 0xEE8

The ITTRFLIN register contains the values of the flushin and trigin inputs to the TPIU.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TRIGIN			Reads the value of trigin.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.
B	RW	FLUSHIN			Reads the value of flushin.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.5.1.16 ITATBDATA0

Address offset: 0xEEC

The ITATBDATA0 register contains the value of the atdatas inputs to the TPIU. The values are valid only when atvalids is HIGH.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-E	RW	ATDATA[i] (i=0..4)			A read access returns the value of a pin on atdatas_x of the enabled port. A write access writes to the corresponding atdatam pin of the enabled port.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.5.1.17 ITATBCTR2

Address offset: 0xEF0

Enables control of the atreadys and afvalids outputs of the TPIU.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ATREADY			Sets the value of afvalid.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.
B	RW	AFVALID			Sets the value of atready.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.5.1.18 ITATBCTR1

Address offset: 0xEF4

The ITATBCTR1 register contains the value of the atids input to the TPIU. This is only valid when atvalids is HIGH.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ATID			Reads the value of atids.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.5.1.19 ITATBCTR0

Address offset: 0xEF8

The ITATBCTR0 register captures the values of the atvalids, afreadys, and atbytess inputs to the TPIU. To ensure the integration registers work correctly in a system, the value of atbytess is only valid when atvalids, bit[0], is HIGH.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	ATVALID			Reads the value of atvalids.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.
B	RW	AFREADY			Reads the value of afreadys.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.
C	RW	ATBYTES			Reads the value of atbytess.
			Low	0	Pin is logic 0.
			High	1	Pin is logic 1.

10.7.5.1.20 ITCTRL

Address offset: 0xF00

Used to enable topology detection. This register enables the component to switch from a functional mode, the default behavior, to integration mode where the inputs and outputs of the component can be directly controlled for integration testing and topology solving.

Note: When a device has been in integration mode, it might not function with the original behavior. After performing integration or topology detection, you must reset the system to ensure correct behavior of CoreSight and other connected system components that are affected by the integration or topology detection.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	INTEGRATIONMODE			Enables the component to switch from functional mode to integration mode and back. If no integration functionality is implemented, this register must read as zero.
			Disabled	0	Integration mode is disabled.
			Enabled	1	Integration mode is Enabled.

10.7.5.1.21 CLAIMSET

Address offset: 0xFA0

Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMSET register sets bits in the claim tag, and determines the number of claim bits implemented.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A-D	RW	BIT[i] (i=0..3)			Set claim bit i and check if bit is implemented or not.
			NotImplemented	0	Claim bit i is not implemented.
			Implemented	1	Claim bit i is implemented.
			Set	1	Set claim bit i.

10.7.5.1.22 CLAIMCLR

Address offset: 0xFA4

Software can use the claim tag to coordinate application and debugger access to trace unit functionality. The claim tags have no effect on the operation of the component. The CLAIMCLR register sets the bits in the claim tag to 0 and determines the current value of the claim tag.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																D	C	B	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A-D	RW	BIT[i] (i=0..3)																																	
			Cleared	0																															
			Set	1																															
			Clear	1																															

10.7.5.1.23 LAR

Address offset: 0xFB0

This is used to enable write access to device registers.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	ACCESS																																	
			UnLock	0xC5ACCE55																															

10.7.5.1.24 LSR

Address offset: 0xFB4

This indicates the status of the lock control mechanism. This lock prevents accidental writes by code under debug. Accesses to the extended stimulus port registers are not affected by the lock mechanism. This register must always be present although there might not be any lock access control mechanism. The lock mechanism, where present and locked, must block write accesses to any control register, except the Lock Access Register. For most components this covers all registers except for the Lock Access Register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				C B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	PRESENT			Indicates that a lock control mechanism exists for this device.
			NotImplemented	0	No lock control mechanism exists, writes to the Lock Access Register are ignored.
			Implemented	1	Lock control mechanism is present.
B	RW	LOCKED			Returns the current status of the Lock.
			UnLocked	0	Write access is allowed to this device.
			Locked	1	Write access to the component is blocked. All writes to control registers are ignored. Reads are permitted.
C	RW	TYPE			Indicates if the Lock Access Register is implemented as 8-bit or 32-bit.
			Bits32	0	This component implements a 32-bit Lock Access Register.
			Bits8	1	This component implements an 8-bit Lock Access Register.

10.7.5.1.25 AUTHSTATUS

Address offset: 0xFB8

Indicates the current level of tracing permitted by the system

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				D D C C B B A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	RW	NSID			Non-secure Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
B	RW	NSNID			Non-secure Non-Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
C	RW	SID			Secure Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.
D	RW	SNID			Secure Non-Invasive Debug
			NotImplemented	0	The feature is not implemented.
			Implemented	1	The feature is implemented.

10.7.5.1.26 DEVID

Address offset: 0xFC8

Indicates the capabilities of the component.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C C C B A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	MUXNUM			Indicates the hidden level of input multiplexing. When non-zero, this value indicates the type of multiplexing on the input to the ATB. Currently only 0x00 is supported, that is, no multiplexing is present. This value helps detect the ATB structure.
B	R	CLKRELAT			Indicates the relationship between atclk and traceclkin.
			Synchronous	0	atclk and traceclkin are synchronous.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				F E D C C C B A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
			ASynchronous	1	atclk and traceclkin are asynchronous.
C	R	FIFOSIZE			FIFO size in powers of 2.
			Entries4	2	FIFO size of 4 entries, that is, 16 bytes.
D	R	TCLKDATA			Indicates whether trace clock plus data is supported.
			Supported	0	Trace clock and data is supported.
			NotSupported	1	Trace clock and data is not supported.
E	R	SWOMAN			Indicates whether Serial Wire Output, Manchester encoded format, is supported.
			NotSupported	0	Serial Wire Output, Manchester encoded format, is not supported.
			Supported	1	Serial Wire Output, Manchester encoded format, is supported.
F	R	SWOUARTNRZ			Indicates whether Serial Wire Output, UART or NRZ, is supported.
			NotSupported	0	Serial Wire Output, UART or NRZ, is not supported.
			Supported	1	Serial Wire Output, UART or NRZ, is supported.

10.7.5.1.27 DEVTYPE

Address offset: 0xFCC

The DEVTYPE register provides a debugger with information about the component when the Part Number field is not recognized. The debugger can then report this information.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B B B B A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	MAJOR			The main type of the component
			TraceSource	1	Peripheral is a trace sink.
B	R	SUB			The sub-type of the component
			TracePort	1	Indicates that this component is a trace port component.

10.7.5.1.28 PIDR4

Address offset: 0xFD0

Coresight peripheral identification registers.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description

10.7.5.1.29 PIDR[0]

Address offset: 0xFE0

Coresight peripheral identification registers.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description

10.7.5.1.30 PIDR[1]

Address offset: 0xFE4

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.5.1.31 PIDR[2]

Address offset: 0xFE8

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.5.1.32 PIDR[3]

Address offset: 0xFEC

Coresight peripheral identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.5.1.33 CIDR[0]

Address offset: 0xFF0

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.5.1.34 CIDR[1]

Address offset: 0xFF4

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.5.1.35 CIDR[2]

Address offset: 0xFF8

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.7.5.1.36 CIDR[3]

Address offset: 0xFFC

Coresight component identification registers.

Bit number	31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID	
Reset 0x00000000	**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description

10.8 CTRL-AP - Control access port

The control access port (CTRL-AP) is a custom access port that enables control of the device when other debug access ports (DAP) have been disabled by the access port protection.

For an overview of the other debug access ports, see DAP - Debug access port on page 434.

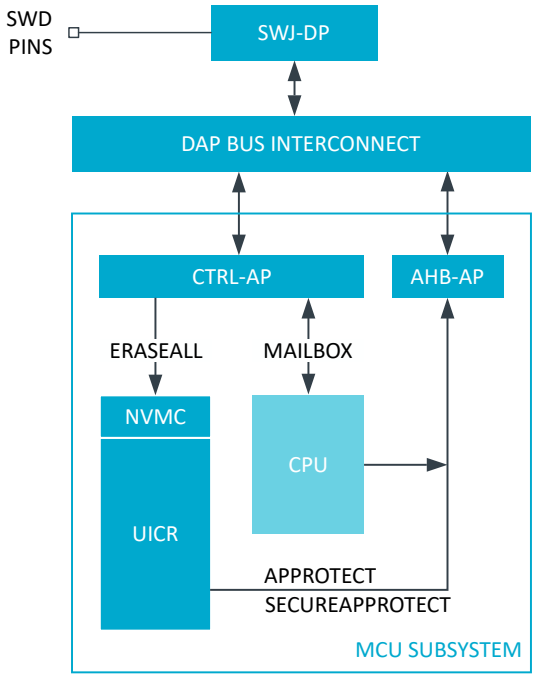

Figure 122: Control access port details

Access port protection (APPROTECT) blocks the debugger access to the AHB-AP, and prevents read and write access to all CPU registers and memory-mapped addresses. To enable port protection access for both secure and non-secure modes, use the registers SECUREAPPROTECT on page 44 and APPROTECT on

page 42 respectively. The debugger can use the register APPROTECT.STATUS on page 507 to read the status of secure and non-secure access port protection.

CTRL-AP has the following features:

- Soft reset
- Erase all
- Mailbox interface
- Debug of protected devices

10.8.1 Reset request

The debugger can request the device to perform a soft reset.

Use the register RESET on page 506 to request a soft reset. Once the soft reset is performed, the reset reason is accessible on the on-chip firmware through the RESETREAS register. For more information about the soft reset, see Reset on page 59.

10.8.2 Erase all

The erase all function lets the debugger trigger an erase of flash, user information configuration registers (UICR), RAM, all peripheral settings, and also removes the access port protection.

To trigger an erase all function, the debugger writes to the register ERASEALL on page 506. The register ERASEALLSTATUS on page 506 will read as busy for the duration of the operation. After the next reset, the access port protection is removed.

If the debugger performs an erase all function on a slave MCU, the erase sequence will always erase the application MCU first, independently of how the application is protected, before erasing the slave MCU.

Erase all protection

It is possible to prevent the debugger from performing an erase all operation by writing to the UICR.ERASEPROTECT register. Once the register is configured and the device is reset, the CTRL-AP ERASEALL operation is disabled, and all flash write and erase operations are restricted to the firmware. In addition, it is still possible to write/erase from the debugger as long as the UICR.APPROTECT register is not set.

Note: Setting the UICR.ERASEPROTECT register only affects the erase all operation and not the debugger access.

The register ERASEPROTECT.STATUS on page 507 holds the status for erase protection.

10.8.3 Mailbox interface

CTRL-AP implements a mailbox interface which enables the CPU to communicate with a debugger over the SWD interface.

The mailbox interface consists of a transmit register MAILBOX.TXDATA on page 508 with its corresponding status register MAILBOX.TXSTATUS on page 508, and a receive register MAILBOX.RXDATA on page 508 with its corresponding status register MAILBOX.RXSTATUS on page 508. Status bits in the TXSTATUS/RXSTATUS registers are set and cleared automatically when the TXDATA/RXDATA registers are written to and read from, independently of the direction.

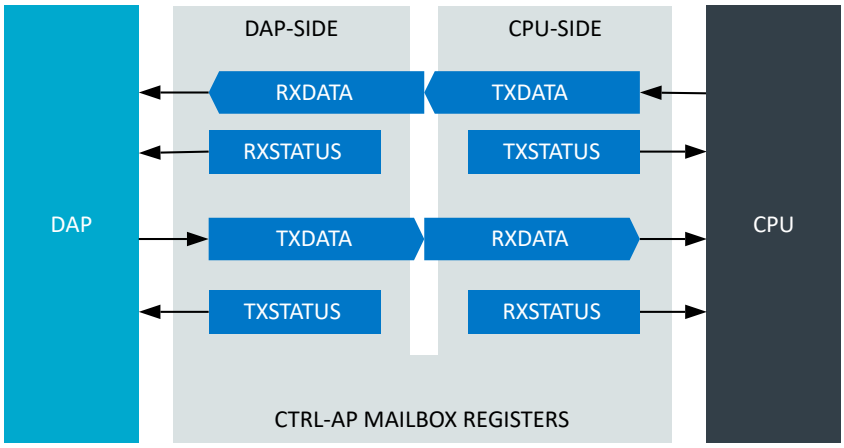

Figure 123: Mailbox register interface

Mailbox transfer sequence

1. Sender writes TXDATA.
2. Hardware sets sender's TXSTATUS to DataPending.
3. Hardware sets receiver's RXSTATUS to DataPending.
4. Receiver reads RXDATA.
5. Hardware sets receiver's RXSTATUS to NoDataPending.
6. Hardware sets sender's TXSTATUS to NoDataPending.

10.8.4 Disabling erase protection

The erase protection mechanism can be disabled to return a device to factory default settings on next reset.

The debugger can read the erase protection status in the register ERASEPROTECT.STATUS on page 507.

If ERASEPROTECT has been enabled, both the debugger and on-chip firmware must write the same non-zero 32-bit KEY value into their respective ERASEPROTECT.DISABLE registers to disable the erase protection. When both registers have been written with the same non-zero 32-bit KEY value, the device is automatically erased as described in Erase all on page 504. The access ports will be re-enabled on the next reset once the secure erase sequence has completed.

The write-once register ERASEPROTECT.LOCK on page 510 should be set to *Locked* as early as possible in the start-up sequence, preferably as soon as the on-chip firmware has determined it does not need to communicate with a debugger over the CTRL-AP mailbox interface. Once written, it will not be possible to remove the erase protection until the next reset.

10.8.5 Debugger registers

CTRL-AP has a set of registers that can only be accessed from the debugger over the SWD interface. These are not accessible from the CPU.

10.8.5.1 Debugger registers

Register overview

Register	Offset	Description
RESET	0x000	System reset request
ERASEALL	0x004	Perform a secure erase of the device, where flash, SRAM and UICR will be erased in sequence. The device will be returned to factory default settings upon next reset.

Register	Offset	Description
ERASEALLSTATUS	0x008	This is the status register for the ERASEALL operation.
APPROTECT.STATUS	0x00C	This is the status register for the UICR access port protection.
ERASEPROTECT.STATUS	0x018	This is the status register for the UICR ERASEPROTECT configuration.
ERASEPROTECT.DISABLE	0x01C	This register disables ERASEPROTECT and performs ERASEALL.
MAILBOX.TXDATA	0x020	Data sent from the debugger to the CPU.
MAILBOX.TXSTATUS	0x024	This register shows a status that indicates if data sent from the debugger to the CPU has been read.
MAILBOX.RXDATA	0x028	Data sent from the CPU to the debugger.
MAILBOX.RXSTATUS	0x02C	This register shows a status that indicates if data sent from the CPU to the debugger has been read.
IDR	0x0FC	CTRL-AP Identification Register, IDR

10.8.5.1.1 RESET

Address offset: 0x000

System reset request

This register is automatically deactivated during an ERASEALL operation.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field		Value ID			Value																			Description									
A	RW	RESET																								System reset request and status									
				NoReset			0																			Write to release reset Reading '0' means reset is not active									
				Reset			1																			Write to hold reset Reading '1' means reset is active									

10.8.5.1.2 ERASEALL

Address offset: 0x004

Perform a secure erase of the device, where flash, SRAM and UICR will be erased in sequence. The device will be returned to factory default settings upon next reset.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field		Value ID			Value																			Description									
A	W	ERASEALL																								Return device to factory default settings									
				NoOperation			0																			No operation									
				Erase			1																			Erase flash, SRAM, and UICR in sequence									

10.8.5.1.3 ERASEALLSTATUS

Address offset: 0x008

This is the status register for the ERASEALL operation.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	ERASEALLSTATUS			Status bit for the ERASEALL operation
			Ready	0	ERASEALL is ready
			Busy	1	ERASEALL is busy (on-going)

10.8.5.1.4 APPROTECT.STATUS

Address offset: 0x00C

This is the status register for the UICR access port protection.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	APPROTECT			Status bit for access port protection
					Note: The reset value is auto read from the APPROTECT register in UICR.
			Enabled	0	APPROTECT is enabled
			Disabled	1	APPROTECT is disabled
B	R	SECUREAPPROTECT			Status bit for secure access port protection
					Note: The reset value is auto read from the SECUREAPPROTECT register in UICR.
			Enabled	0	SECUREAPPROTECT is enabled
			Disabled	1	SECUREAPPROTECT is disabled

10.8.5.1.5 ERASEPROTECT.STATUS

Address offset: 0x018

This is the status register for the UICR ERASEPROTECT configuration.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**

ID	R/W	Field	Value ID	Value	Description
A	R	PALL			Status bit for erase protection
					Note: The reset value is auto read from the ERASEPROTECT register in UICR.
			Enabled	0	ERASEPROTECT is enabled
			Disabled	1	ERASEPROTECT is not enabled and ERASEALL can be performed

10.8.5.1.6 ERASEPROTECT.DISABLE

Address offset: 0x01C

This register disables ERASEPROTECT and performs ERASEALL.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ID	R/W	Field	Value ID	Value	Description
A	RW1	KEY			The ERASEALL sequence will be initiated if value of the KEY fields are non-zero and the KEY fields match on both the CPU and debugger sides.

10.8.5.1.7 MAILBOX.TXDATA

Address offset: 0x020

Data sent from the debugger to the CPU.

Writing to this register will automatically set a DataPending value in the TXSTATUS register.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ID	R/W	Field	Value ID	Value	Description
A	RW	Data			Data sent from debugger

10.8.5.1.8 MAILBOX.TXSTATUS

Address offset: 0x024

This register shows a status that indicates if data sent from the debugger to the CPU has been read.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																A
Reset 0x00000000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ID	R/W	Field	Value ID	Value	Description
A	R	Status			Status of register DATA
			NoDataPending	0	No data pending in register TXDATA
			DataPending	1	Data pending in register TXDATA

10.8.5.1.9 MAILBOX.RXDATA

Address offset: 0x028

Data sent from the CPU to the debugger.

Reading from this register will automatically set a NoDataPending value in the RXSTATUS register.

Bit number	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ID	R/W	Field	Value ID	Value	Description
A	R	Data			Data sent from CPU

10.8.5.1.10 MAILBOX.RXSTATUS

Address offset: 0x02C

This register shows a status that indicates if data sent from the CPU to the debugger has been read.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	Status			Status of register DATA
			NoDataPending	0	No data pending in register RXDATA
			DataPending	1	Data pending in register RXDATA

10.8.5.1.11 IDR

Address offset: 0x0FC

CTRL-AP Identification Register, IDR

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				E E E E D D D D C C C C C C C B B B B B A A A A A A A A
Reset 0x12880000				**0 0 0 1 0 0 1 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	APID			AP Identification
B	R	CLASS			Access Port (AP) class
			NotDefined	0x0	No defined class
			MEMAP	0x8	Memory Access Port
C	R	JEP106ID			JEDEC JEP106 identity code
D	R	JEP106CONT			JEDEC JEP106 continuation code
E	R	REVISION			Revision

10.8.6 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
CTRL_AP_PERI	0x50006000	HF	S	NA	No	CTRL-AP-PERI

Register overview

Register	Offset	TZ	Description
MAILBOX.RXDATA	0x400		Data sent from the debugger to the CPU.
MAILBOX.RXSTATUS	0x404		This register shows a status that indicates if data sent from the debugger to the CPU has been read.
MAILBOX.TXDATA	0x480		Data sent from the CPU to the debugger.
MAILBOX.TXSTATUS	0x484		This register shows a status that indicates if the data sent from the CPU to the debugger has been read.
ERASEPROTECT.LOCK	0x500		This register locks the ERASEPROTECT.DISABLE register from being written until next reset.
ERASEPROTECT.DISABLE	0x504		This register disables the ERASEPROTECT register and performs an ERASEALL operation.

10.8.6.1 MAILBOX.RXDATA

Address offset: 0x400

Data sent from the debugger to the CPU.

Reading from this register will automatically set a NoDataPending value in the RXSTATUS register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	RXDATA			Data received from debugger

10.8.6.2 MAILBOX.RXSTATUS

Address offset: 0x404

This register shows a status that indicates if data sent from the debugger to the CPU has been read.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	RXSTATUS			Status of data in register RXDATA
			NoDataPending	0	No data pending in register RXDATA
			DataPending	1	Data pending in register RXDATA

10.8.6.3 MAILBOX.TXDATA

Address offset: 0x480

Data sent from the CPU to the debugger.

Writing to this register will automatically set a DataPending value in the TXSTATUS register.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	TXDATA			Data sent to debugger

10.8.6.4 MAILBOX.TXSTATUS

Address offset: 0x484

This register shows a status that indicates if the data sent from the CPU to the debugger has been read.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	R	TXSTATUS			Status of data in register TXDATA
			NoDataPending	0	No data pending in register TXDATA
			DataPending	1	Data pending in register TXDATA

10.8.6.5 ERASEPROTECT.LOCK

Address offset: 0x500

This register locks the ERASEPROTECT.DISABLE register from being written until next reset.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																			A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW1	LOCK																																	
			Unlocked	0																															
			Locked	1																															

Description
Lock ERASEPROTECT.DISABLE register from being written until next reset
Register ERASEPROTECT.DISABLE is writeable
Register ERASEPROTECT.DISABLE is read-only

10.8.6.6 ERASEPROTECT.DISABLE

Address offset: 0x504

This register disables the ERASEPROTECT register and performs an ERASEALL operation.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW1	KEY																																	

Description
The ERASEALL sequence is initiated if the value of the KEY fields are non-zero and the KEY fields match on both the CPU and debugger sides.

10.9 TAD - Trace and debug control

Configuration interface for trace and debug

Please refer to the Trace section for more information about how to configure the trace and debug interface.

> **Note:** Although there are PSEL registers for the trace port, each function can only be mapped to a single pin due to pin speed requirements. Setting the PIN field to anything else will not have any effect. See Pin assignment chapter for more information

10.9.1 Registers

Instances

Instance	Base address	TrustZone			Split access	Description
		Map	Att	DMA		
TAD	0xE0080000	HF	S	NA	No	Trace and debug control

Register overview

Register	Offset	TZ	Description
TASKS_CLOCKSTART	0x000		Start all trace and debug clocks.
TASKS_CLOCKSTOP	0x004		Stop all trace and debug clocks.
ENABLE	0x500		Enable debug domain and aquire selected GPIOs
PSEL.TRACECLK	0x504		Pin configuration for TRACECLK
PSEL.TRACEDATA0	0x508		Pin configuration for TRACEDATA[0]
PSEL.TRACEDATA1	0x50C		Pin configuration for TRACEDATA[1]
PSEL.TRACEDATA2	0x510		Pin configuration for TRACEDATA[2]
PSEL.TRACEDATA3	0x514		Pin configuration for TRACEDATA[3]
TRACEPORTSPEED	0x518		Clocking options for the Trace Port debug interface Reset behavior is the same as debug components This register is retained.

10.9.1.1 TASKS_CLOCKSTART

Address offset: 0x000

Start all trace and debug clocks.

Note: The TASKS_CLOCKSTART task asserts the CTRL/STAT.CSYSPWRUPACK and CTRL/STAT.CDBGPWRUPACK (see *Arm CoreSight SoC-400 Technical Reference Manual, revision r3p2*).

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_CLOCKSTART			Start all trace and debug clocks. **Note:** The TASKS_CLOCKSTART task asserts the CTRL/STAT.CSYSPWRUPACK and CTRL/STAT.CDBGPWRUPACK (see *Arm CoreSight SoC-400 Technical Reference Manual, revision r3p2*).
			Trigger	1	Trigger task

10.9.1.2 TASKS_CLOCKSTOP

Address offset: 0x004

Stop all trace and debug clocks.

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	W	TASKS_CLOCKSTOP			Stop all trace and debug clocks.
			Trigger	1	Trigger task

10.9.1.3 ENABLE

Address offset: 0x500

Enable debug domain and aquire selected GPIOs

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				A
Reset 0x00000000				**0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0**
ID	R/W	Field	Value ID	Value	Description
A	RW	ENABLE			
			DISABLED	0	Disable debug domain and release selected GPIOs
			ENABLED	1	Enable debug domain and aquire selected GPIOs

10.9.1.4 PSEL.TRACECLK

Address offset: 0x504

Pin configuration for TRACECLK

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN			Pin number
			Traceclk	21	TRACECLK pin
					Note: Only this pin is valid
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

10.9.1.5 PSEL.TRACEDATA0

Address offset: 0x508

Pin configuration for TRACEDATA[0]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN			Pin number
			Tracedata0	22	TRACEDATA0 pin
					Note: Only this pin is valid
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

10.9.1.6 PSEL.TRACEDATA1

Address offset: 0x50C

Pin configuration for TRACEDATA[1]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN			Pin number
			Tracedata1	23	TRACEDATA1 pin
					Note: Only this pin is valid
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

10.9.1.7 PSEL.TRACEDATA2

Address offset: 0x510

Pin configuration for TRACEDATA[2]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN			Pin number
			Tracedata2	24	TRACEDATA2 pin
					Note: Only this pin is valid
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

10.9.1.8 PSEL.TRACEDATA3

Address offset: 0x514

Pin configuration for TRACEDATA[3]

Bit number				31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
ID				B A A A A A
Reset 0xFFFFFFFF				**1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1**
ID	R/W	Field	Value ID	Value	Description
A	RW	PIN			Pin number
			Tracedata3	25	TRACEDATA3 pin
					Note: Only this pin is valid
B	RW	CONNECT			Connection
			Disconnected	1	Disconnect
			Connected	0	Connect

10.9.1.9 TRACEPORTSPEED (Retained)

Address offset: 0x518

Clocking options for the Trace Port debug interface

Reset behavior is the same as debug components

This register is retained.

Bit number				31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID																																		A	A
Reset 0x00000000				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
ID	R/W	Field	Value ID	Value																															
A	RW	TRACEPORTSPEED																																	
			32MHz	0																															
			16MHz	1																															
			8MHz	2																															
			4MHz	3																															

A	RW	TRACEPORTSPEED			Speed of Trace Port clock. Note that the TRACECLK pin output will be divided again by two from the Trace Port clock.
			32MHz	0	Trace Port clock is: 32MHz
			16MHz	1	Trace Port clock is: 16MHz
			8MHz	2	Trace Port clock is: 8MHz
			4MHz	3	Trace Port clock is: 4MHz

11 Hardware and layout

The following sections describe nRF9151 hardware and layout specifications.

11.1 Pin assignments

This section describes the pin assignment and the pin functions of the nRF9151.

The device provides flexibility when it comes to routing and configuration of the GPIO pins. However, for some pins there are recommendations on pin usage and configuration. See following table for more information about this.

11.1.1 LGA pin assignments

The pin assignment table and figure describe the assignments.

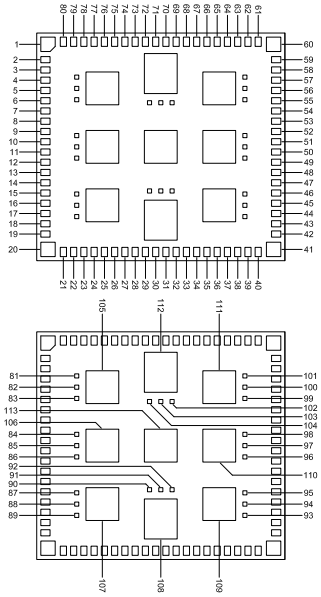

Figure 124: LGA pin assignments, top view

Pin no	Pin name	Function	Description
1	GND	Power	Ground
2	P0.20	Digital I/O (SoC)	General purpose I/O.
	AIN7	Analog input	Analog input.
3	SWDCLK	Digital input	Serial wire debug clock input for debug and programming
4	SWDIO	Digital I/O	Serial wire debug I/O for debug and programming
5	P0.21	Digital I/O (SoC)	General purpose I/O.
	TRACECLK	Trace clock	Trace buffer clock (optional).
6	P0.22	Digital I/O (SoC)	General purpose I/O.
	TRACEDATA[0]	Trace data	Trace buffer TRACEDATA[0] (optional).
7	GND	Power	Ground
8	P0.23	Digital I/O (SoC)	General purpose I/O.
	TRACEDATA[1]	Trace data	Trace buffer TRACEDATA[1] (optional).

Pin no	Pin name	Function	Description
9	nRESET	Digital I/O (SoC)	SoC reset pin[30,31]
10	ENABLE		Enable for the SiP internal regulator for the nRF91 SoC. **Note:** The nRF9151 will not start until this pin is enabled.
11	P0.24 TRACEDATA[2]	Digital I/O (SoC) Trace data	General purpose I/O. Trace buffer TRACEDATA[2] (optional).
12	P0.25 TRACEDATA[3]	Digital I/O (SoC) Trace data	General purpose I/O. Trace buffer TRACEDATA[3] (optional).
13	GND	Power	Ground
14	VDD	Power	Supply voltage
15	GND	Power	Ground
16	SIM_RST	Digital I/O (SoC)	SIM reset
17	SIM_IO	Digital I/O (SoC)	SIM data
18	SIM_CLK	Digital I/O (SoC)	SIM clock
19	SIM_1V8	Power	SIM 1.8 V power supply output
20	GND	Power	Ground
21	MAGPIO0	Digital I/O (SoC)	1.8 V general purpose I/O
22	MAGPIO1	Digital I/O (SoC)	1.8 V general purpose I/O
23	MAGPIO2	Digital I/O (SoC)	1.8 V general purpose I/O
24	DEC0	Power	Power supply decoupling. Reserved for Nordic use.
25	GND	Power	Ground
26	SIM_DET	Digital I/O (SoC)	SIM detect Not used. Must be left floating.
27	SDATA	Digital I/O (SoC)	MIPI RFFE control interface
28	SCLK	Digital I/O (SoC)	MIPI RFFE control interface
29	VIO	Power	MIPI RFFE control interface
30	GND	Power	Ground
31	RESERVED		Connect thermally and mechanically to the application board but leave electrically unconnected.
32	RESERVED		Connect thermally and mechanically to the application board but leave electrically unconnected.
33	RESERVED		Connect thermally and mechanically to the application board but leave electrically unconnected.
34	GND	Power	Ground
35	ANT	RF	Single-ended 50 Ω LTE antenna pin
36	GND	Power	Ground
37	AUX	RF	Single-ended 50 Ω ANT loop-back pin
38	GND	Power	Ground
39	GND	Power	Ground
40	GND	Power	Ground
41	GND	Power	Ground
42	GPS	RF	Single-ended 50 Ω GPS input pin
43	GND	Power	Ground
44	P0.26	Digital I/O (SoC)	General purpose I/O
45	P0.27	Digital I/O (SoC)	General purpose I/O
46	GND	Power	Ground
47	P0.28	Digital I/O (SoC)	General purpose I/O

30 External pull-up not allowed.

31 For implementations that require the ERASEALL functionality, enable access to the nRESET pin. See Erase all on page 504 for more information.

Pin no	Pin name	Function	Description
48	P0.29	Digital I/O (SoC)	General purpose I/O
49	P0.30	Digital I/O (SoC)	General purpose I/O
50	P0.31	Digital I/O (SoC)	General purpose I/O
51	GND	Power	Ground
52	COEX0	Digital I/O (SoC)	Coexistence interface
53	COEX1	Digital I/O (SoC)	Coexistence interface
54	COEX2	Digital I/O (SoC)	Coexistence interface
55	GND	Power	Ground
56	P0.00	Digital I/O (SoC)	General purpose I/O
57	P0.01	Digital I/O (SoC)	General purpose I/O
58	P0.02	Digital I/O (SoC)	General purpose I/O
59	P0.03	Digital I/O (SoC)	General purpose I/O
60	GND	Power	Ground
61	P0.04	Digital I/O (SoC)	General purpose I/O
62	P0.05	Digital I/O (SoC)	General purpose I/O
63	P0.06	Digital I/O (SoC)	General purpose I/O
64	P0.07	Digital I/O (SoC)	General purpose I/O
65	VDD_GPIO	Power	GPIO power supply input and logic level
66	GND	Power	Ground
67	P0.08	Digital I/O (SoC)	General purpose I/O
68	P0.09	Digital I/O (SoC)	General purpose I/O
69	P0.10	Digital I/O (SoC)	General purpose I/O
70	P0.11	Digital I/O (SoC)	General purpose I/O
71	GND	Power	Ground
72	P0.12	Digital I/O (SoC)	General purpose I/O
73	P0.13	Digital I/O (SoC)	General purpose I/O.
	AIN0	Analog input	Analog input.
74	P0.14	Digital I/O (SoC)	General purpose I/O.
	AIN1	Analog input	Analog input.
75	P0.15	Digital I/O (SoC)	General purpose I/O.
	AIN2	Analog input	Analog input.
76	GND	Power	Ground
77	P0.16	Digital I/O (SoC)	General purpose I/O.
	AIN3	Analog input	Analog input.
78	P0.17	Digital I/O (SoC)	General purpose I/O.
	AIN4	Analog input	Analog input.
79	P0.18	Digital I/O (SoC)	General purpose I/O.
	AIN5	Analog input	Analog input.
80	P0.19	Digital I/O (SoC)	General purpose I/O.
	AIN6	Analog input	Analog input.
81	RESERVED		Do not connect/reserved for future use
82	RESERVED		Do not connect/reserved for future use
83	RESERVED		Do not connect/reserved for future use
84	RESERVED		Do not connect/reserved for future use
85	RESERVED		Do not connect/reserved for future use
86	RESERVED		Do not connect/reserved for future use
87	RESERVED		Do not connect/reserved for future use
88	RESERVED		Do not connect/reserved for future use
89	RESERVED		Do not connect/reserved for future use
90	RESERVED		Do not connect/reserved for future use
91	RESERVED		Do not connect/reserved for future use

Pin no	Pin name	Function	Description
92	RESERVED		Do not connect/reserved for future use
93	RESERVED		Do not connect/reserved for future use
94	RESERVED		Do not connect/reserved for future use
95	RESERVED		Do not connect/reserved for future use
96	RESERVED		Do not connect/reserved for future use
97	RESERVED		Do not connect/reserved for future use
98	RESERVED		Do not connect/reserved for future use
99	RESERVED		Do not connect/reserved for future use
100	RESERVED		Do not connect/reserved for future use
101	RESERVED		Do not connect/reserved for future use
102	RESERVED		Do not connect/reserved for future use
103	RESERVED		Do not connect/reserved for future use
104	RESERVED		Do not connect/reserved for future use
105	GND	Power	Ground
106	GND	Power	Ground
107	GND	Power	Ground
108	GND	Power	Ground
109	GND	Power	Ground
110	GND	Power	Ground
111	GND	Power	Ground
112	GND	Power	Ground
113	GND	Power	Ground

Table 57: LGA pin assignments

11.2 Mechanical specifications

The mechanical specifications show the package dimensions in millimeters.

11.2.1 12.1 x 11.1 mm package

Dimensions in millimeters for the nRF9151 LGA 12.1 x 11.1 x 1.2 mm package.

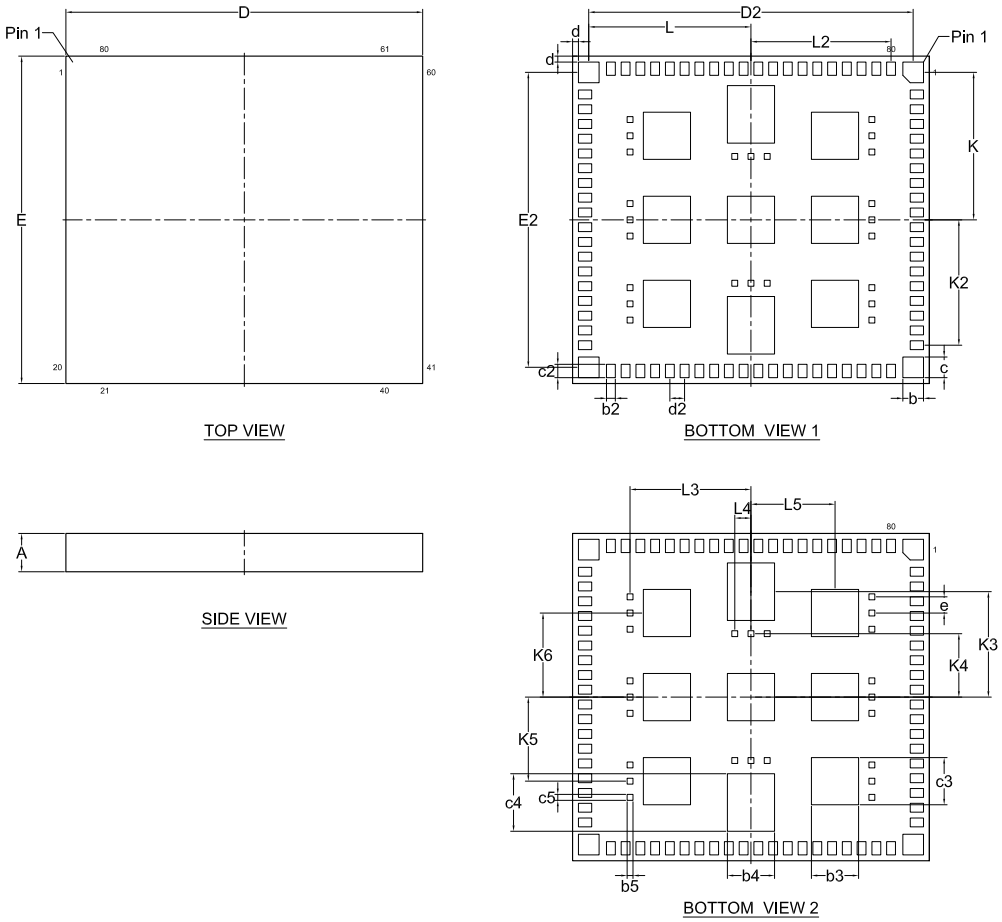

Figure 125: LGA 12.1 x 11.1 mm package

	Min.	Nom.	Max.
A	1.099	1.156	1.3
b	0.65	0.7	0.75
b2	0.25	0.3	0.35
b3	1.55	1.6	1.65
b4	1.55	1.6	1.65
b5	0.15	0.2	0.25
c	0.65	0.7	0.75
c2	0.4	0.45	0.5
c3	1.55	1.6	1.65
c4	1.9	1.95	2.0
c5	0.15	0.2	0.25
D	12	12.1	12.2
D2		11.0	
d		0.2	
d2		0.5	
E	11	11.1	11.2
E2		10.0	
e		0.55	
K		5.0	
K2		4.25	
K3		3.575	
K4		2.15	
K5		2.85	
K6		2.85	
L		5.50	
L2		4.75	
L3		4.1	
L4		0.55	
L5		2.85	

Table 58: LGA dimensions in millimeters

11.3 Reference circuitry

To ensure good RF performance when designing PCBs, using the PCB layouts and component values provided by Nordic Semiconductor is highly recommended .

Documentation for the different package reference circuits, including Altium Designer files, PCB layout files, and PCB production files can be downloaded from the product page at www.nordicsemi.com/nRF9151.

This section contains reference circuitry showing the components to support the design of on-chip features.

> **Note:** This is not a complete list of configurations, but all required circuitry is shown for further configurations.

11.3.1 nRF9151 reference design

Circuit configuration schematic for the nRF9151 SiP.

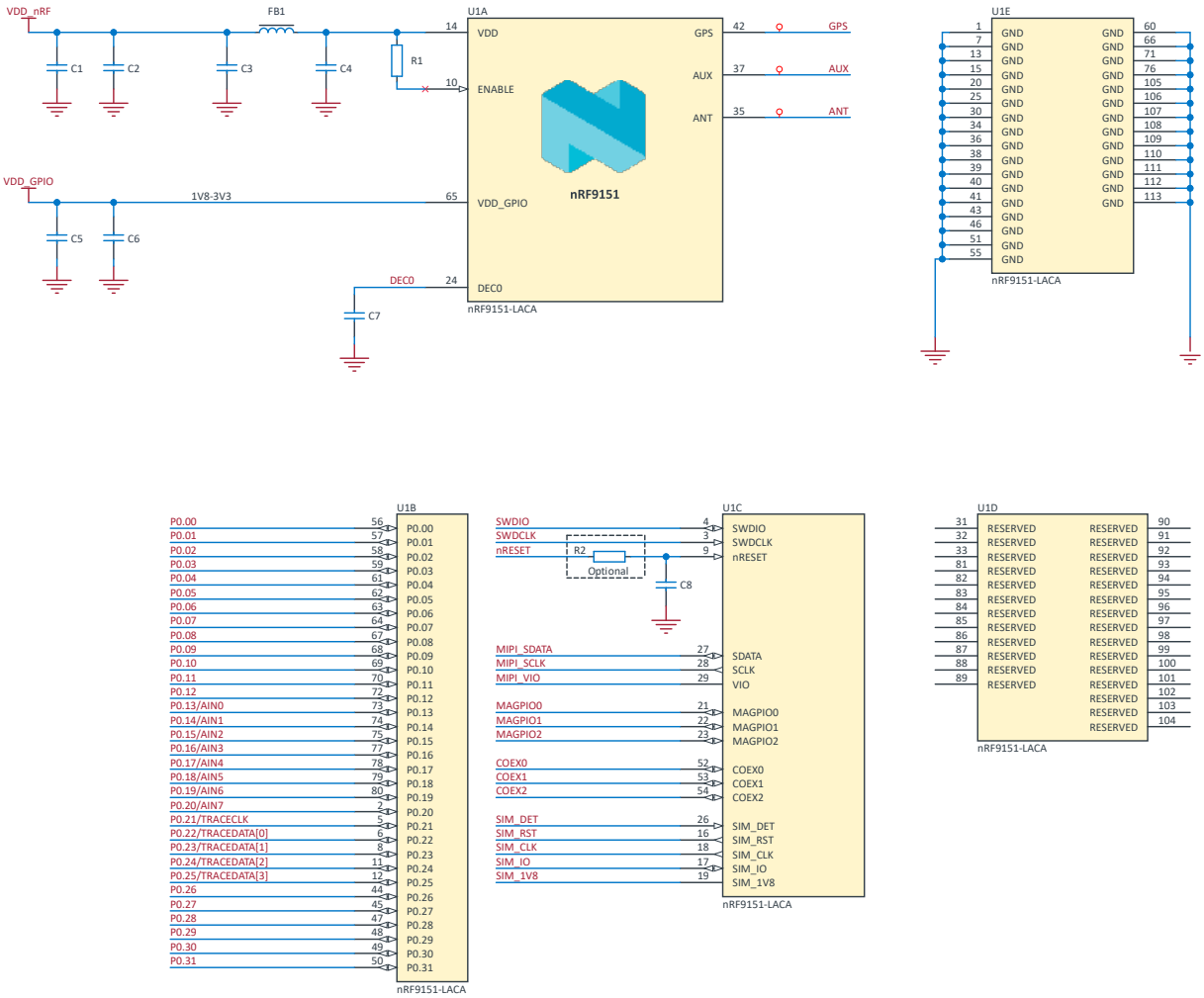

Figure 126: nRF9151 reference design

For Bill of Materials (BOM), PCB layout and thermal design, see the *nRF9151 Hardware Design Guidelines*.

11.4 Reflow conditions

The recommended reflow profile is JEDEC J-STD-020D. The maximum amount of reflows is three.

11.5 Shelf and floor life

If floor life is exceeded, see Shelf Life of Dry Packed Integrated Circuits for shelf and floor life and recommended baking (drying of parts) requirements.

12 Operating conditions

The operating conditions are the physical parameters that the chip can operate within.

Symbol	Parameter	Notes	Min.	Nom.	Max.	Units
VDD	Battery input voltage	Including voltage drop, ripple and spikes.	3.0	3.7	5.5	V
VDD_GPIO	GPIO input voltage		1.7		3.6	V
$GPIO_H$	GPIO high level voltage				VDD_GPIO	V
$MAGPIO_H$	MAGPIO high level voltage	Supply from internal LDO	1.7	1.8	1.9	V
VIO	VIO high level voltage	Supply from internal LDO	1.7	1.8	1.9	V
TA	Operating temperature		-40	25	85	°C
COEX	COEX high level voltage				VDD_GPIO	V
SIMIF	SIMIF output high level voltage	Supply from internal LDO	1.7	1.8	1.9	V

Table 59: Operating conditions

Note: There can be excessive leakage at VDD and/or VDD_GPIO if any of these supply voltages is outside its range given in the table above.

Note: It is not recommended to use high voltage, high drive GPIO outputs ($V_{OH,HDH}$ and $V_{OH,HDL}$) with high frequency, high capacitance loads unless needed, as this may increase noise level and affect radio receiver performance. High drive/high load should especially be avoided on GPIO pins close to the radio front end.

12.1 VDD_GPIO considerations

VDD_GPIO is the supply to the general purpose I/O.

The following restrictions should be taken into considerations:

- VDD_GPIO should be applied after VDD has been supplied
- VDD_GPIO should be removed before removing VDD
- If VDD is supplied and VDD_GPIO is grounded, an extra current consumption can be generated on VDD
- If ENABLE is low, VDD_GPIO should also be low

13 Absolute maximum ratings

Maximum ratings are the extreme limits to which the chip can be exposed for a limited amount of time without permanently damaging it. Exposure to absolute maximum ratings for prolonged periods of time may affect the reliability of the device.

	Note	Min.	Max.	Unit
Supply voltages				
VDD		-0.3	5.5	V
VDD_GPIO		-0.3	3.9	V
SIM_1V8		1.65	1.95	V
VSS			0	V
I/O pin voltage				
$V_{I/O}$, VDD_GPIO ≤ 3.6 V		-0.3	VDD_GPIO + 0.3	V
$V_{I/O}$, VDD_GPIO > 3.6 V		-0.3	3.9	V
Radio				
ANT antenna input level			10	dBm
GPS antenna input level	LNA turned on, max gain		-15	dBm
RF port ruggedness	Maximum deviation from 50 Ω without damaging the module		10:1	VSWR
Environmental (LGA package)				
Storage temperature		-40	95	°C
MSL	Moisture Sensitivity Level		3	
ESD HBM AUX	AUX pin Human Body Model[32]		500	V
ESD HBM AUX Class	AUX pin Human Body Model Class[32]		1B	
ESD HBM	Human Body Model[33]		1.5	kV
ESD HBM Class	Human Body Model Class[33]		1C	
ESD CDM	Charged Device Model		250	V
Flash memory				
Endurance		10 000		Write/erase cycles
Retention		10 years at 85°C		
No internal voltage boost converters				

Table 60: Absolute maximum ratings

[32] The AUX pin is intended for production test.
[33] Exclude the AUX pin.

14 Ordering information

This chapter contains information on IC marking, ordering codes, and container sizes.

14.1 SiP marking

The nRF9151 package is marked as shown in the following figure.

n	R	F	9	1	5	1		L	A	C	A		<H	P>
<Y	Y>	<W	W>	<L	L>	<V	C>	<X	X	X	X	X>	<Z	Z>

Figure 127: SiP package marking

Second line character position may vary depending on product's certification updates.

14.2 Box labels

The following figures show the box labels used for the nRF9151.

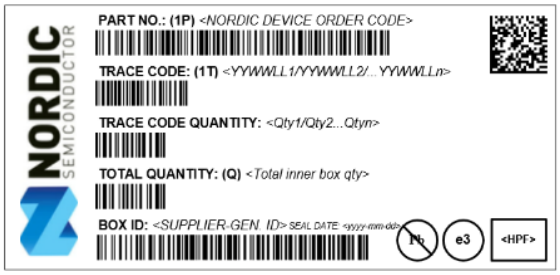

Figure 128: Inner box label

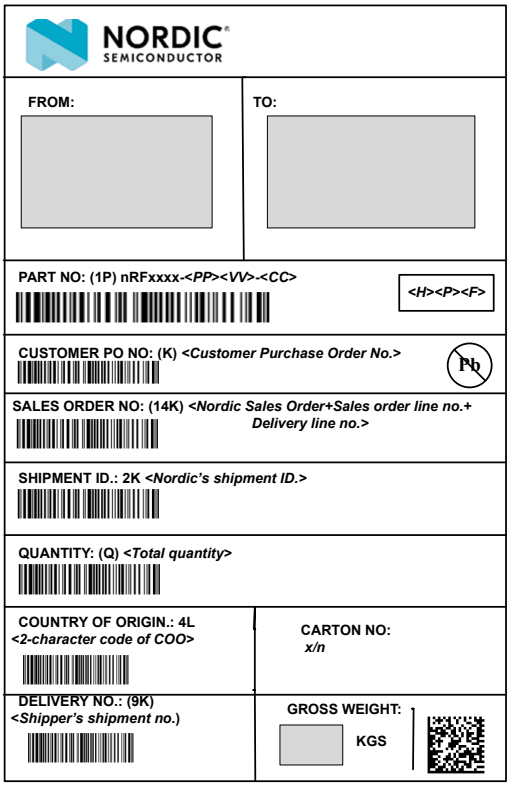

Figure 129: Outer box label

14.3 Order code

The following are the order codes and definitions for the nRF9151.

n	R	F	9	1	5	1	-	<L	A>	<C	A>	-	<C	C>

Figure 130: Order code

Abbreviation	Definition and implemented codes
N91/nRF91	nRF91 Series product
51	Part code
<LA>	Package variant code
<CA>	Function variant code
<H><P><F>	Build code H - Hardware version code P - Production configuration code (production site, etc.) F - Firmware version code (only visible on shipping container label)
<YY><WW><LL> <VC><XXXXX><ZZ>	Serial number YY - Year code WW - Assembly week number LL - Wafer lot code VC - Vendor code XXXXX - Alpha-numeric serial number ZZ - Alpha-numeric serial number checksum
<CC>	Container code

Table 61: Abbreviations

14.4 Code ranges and values

The nRF9151 code ranges and values are defined here.

<H>	Description
[A . . Z]	Hardware version/revision identifier (incremental)

Table 62: Hardware version codes

<P>	Description
[0 . . 9]	Production device identifier (incremental)
[A . . Z]	Engineering device identifier (incremental)

Table 63: Production configuration codes

<F>	Description
[A . . N, P . . Z]	Version of preprogrammed firmware
[0]	Delivered without preprogrammed firmware

Table 64: Production version codes

<YY>	Description
[23 . . 99]	Production year: 2023 to 2099

Table 65: Year codes

<WW>	Description
[01 . . 53]	Week of production

Table 66: Week codes

<LL>	Description
[AA . . ZZ]	Wafer production lot identifier

Table 67: Lot codes

<VC>	Description
[AC]	Vendor Code

Table 68: Vendor code

<XXXXX>	Description
[00000 . . ZZZZZ]	Alpha-numeric serial number

Table 69: Serial Number

<ZZ>	Description
[00 . . ZZ]	Alpha-numeric serial number checksum

Table 70: Serial Number

<CC>	Description
R7	7" Reel
R	13" Reel

Table 71: Container codes

14.5 Ordering options

The nRF9151 SiP ordering codes and minimum ordering quantity are described in the following table.

Order code	Minimum ordering quantity (MOQ)	Comment
nRF9151-LACA-R	2000	
nRF9151-LACA-R7	100	

Table 72: nRF9151 order codes

15 Regulatory information

The nRF9151 undergoes regulatory certifications, ensuring both regional compliances and compatibility with the LTE 3GPP specification.

15.1 Certified bands

The following table shows the FCC and ISED certified Cat-M1 bands for nRF9151.

Band	FCC certification	ISED certification
Band 2	Yes	Yes
Band 4	Yes	Yes
Band 5	Yes	Yes
Band 8	Yes	Yes[34]
Band 12	Yes	Yes
Band 13	Yes	Yes
Band 25	Yes	Yes
Band 26	Yes	No
Band 66	Yes	Yes
Band 85	Yes	Yes

Table 73: FCC and ISED certified Cat-M1 bands

The following table shows the FCC and ISED certified Cat-NB1 and Cat-NB2 bands for nRF9151.

[34] The Band 8 is not supported in Canada.

Band	FCC certification	ISED certification
Band 2	Yes	Yes
Band 4	Yes	Yes
Band 5	Yes	Yes
Band 8	Yes	Yes[34]
Band 12	Yes	Yes
Band 13	Yes	Yes
Band 17	Yes	Yes
Band 25	Yes	Yes
Band 26	Yes	No
Band 66	Yes	Yes
Band 85	Yes	Yes

Table 74: FCC and ISED certified Cat-NB1/NB2 bands

15.2 Supported FCC/ISED rules

The nRF9151 module has been certified to comply with FCC and ISED rules.

The nRF9151 SiP has been certified to comply with the following FCC rules.

- 47 CFR Part 22
- 47 CFR Part 24
- 47 CFR Part 27
- 47 CFR Part 90
- 47 CFR Part 2.1091

The nRF9151 SiP has been certified to comply with the following ISED rules.

- RSS-132 Issue 4
- RSS-130 Issue 2
- RSS-139 Issue 4
- RSS-133 Issue 6

A host manufacturer who integrates the nRF9151 SiP to a host device, can apply the certifications to the host device, except for FCC Part 15 Subpart B which must be retested.

The host manufacturer can use nRF9151's FCC ID if the device meets the conditions of the FCC certificate. Normally, the conditions are the following:

- A minimum of 20 cm distance from the human body.
- No colocation with other transmitters. Typically, this condition needs to be reviewed by the FCC lab.
- Antenna gain below the requirements.

15.3 FCC/ISED regulatory notices

FCC/ISED regulatory notices cover modification and interference statements, wireless and FCC Class B digital device notices, permitted antennas and labeling requirements.

Modification statement

Nordic Semiconductor has not approved any changes or modifications to this device by the user. Any changes or modifications could void the user's authority to operate the equipment.

Nordic Semiconductor n'approuve aucune modification apportée à l'appareil par l'utilisateur, quelle qu'en soit la nature. Tout changement ou modification peuvent annuler le droit d'utilisation de l'appareil par l'utilisateur.

Interference statement

This device complies with Part 15 of the FCC Rules and Industry Canada's licence-exempt RSS standards. Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Wireless notice

This equipment complies with FCC and ISED radiation exposure limits set forth for an uncontrolled environment. The antenna should be installed and operated with minimum distance of 20 cm between the radiator and your body. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

Cet appareil est conforme aux limites d'exposition aux rayonnements de l'ISDE pour un environnement non contrôlé. L'antenne doit être installée de façon à garder une distance minimale de 20 centimètres entre la source de rayonnements et votre corps. L'émetteur ne doit pas être colocalisé ni fonctionner conjointement avec à autre antenne ou autre émetteur.

Permitted antenna

This radio transmitter has been approved by FCC and ISED to operate with the antenna types listed below with the maximum permissible gain indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Band	Max gain
Band 2	9.0 dBi
Band 4	6.0 dBi
Band 5	7.1 dBi
Band 8	10.78 dBi
Band 12	6.6 dBi
Band 13	6.9 dBi
Band 17 (Cat-NB1/NB2)	6.6 dBi
Band 25	9.0 dBi
Band 26	7.0 dBi
Band 66	6.0 dBi
Band 85	6.6 dBi

Le présent émetteur radio a été approuvé par ISDE pour fonctionner avec les types d'antenne énumérés ci dessous et ayant un gain admissible maximal. Les types d'antenne non inclus dans cette liste, et dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

Bande	Gain maximal
Bande 2	9.0 dBi
Bande 4	6.0 dBi
Bande 5	7.1 dBi
Band 8	10.78 dBi
Bande 12	6.6 dBi
Bande 13	6.9 dBi
Bande 17 (Cat-NB1/NB2)	6.6 dBi
Bande 25	9.0 dBi
Bande 26	7.0 dBi
Bande 66	6.0 dBi
Bande 85	6.6 dBi

FCC Class B digital device notice

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna

- Increase the separation between the equipment and receiver
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected
- Consult the dealer or an experienced radio/TV technician for help

CAN ICES-3 (B)/NMB-3 (B)

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de classe B est conforme à la norme canadienne ICES-003.

Labeling requirements for the host device

The host device shall be properly labelled to identify the modules within the host device. The certification label of the module shall be clearly visible at all times when installed in the host device, otherwise the host device must be labelled to display the FCC ID and IC of the module, preceded by the words "Contains transmitter module", or the word "Contains", or similar wording expressing the same meaning, as shown in the following examples:

Contains FCC ID: 2ANPO00NRF9151
Contains IC: 24529-NRF9151

L'équipement hôte doit être correctement étiqueté pour identifier les modules dans l'équipement. L'étiquette de certification du module doit être clairement visible en tout temps lorsqu'il est installé dans l'hôte, l'équipement hôte doit être étiqueté pour afficher le FCC ID et IC du module, précédé des mots "Contient le module émetteur", ou le mot "Contient", ou un libellé similaire exprimant la même signification, comme suit:

Contient FCC ID: 2ANPO00NRF9151
Contient IC: 24529-NRF9151

15.4 RF exposure considerations

The nRF9151 has been tested and certified as a mobile device for use of a minimum of 20 cm distance from the human body with no colocation with other transmitters. If the device is to be used closer than 20 cm from the human body and/or with other transmiters simultaneously, the host product manufacturer is required to perform additional evaluation, testing, or testing and Class 2 permissive change. It is required to take responsibility of the module through a change in the FCC ID (new application). The host product manufacturer must also inform the end user about RF Exposure conditions.

15.5 Host device manufacturer responsibility

The nRF9151 device is only authorized for the rules listed in Supported FCC/ISED rules on page 531.
The host device manufacturer is responsible for compliance to any other FCC rules that apply to the host device not covered by the nRF9151 grant of certification. It is mandatory for the host device manufacturer to assure the final device’s compliance with FCC Part 15 Subpart B even if certification has been granted to nRF9151.

15.6 Antenna interface

The nRF9151 module has a single-ended 50 Ω antenna port where the antenna solution shall be connected. nRF9151 is evaluated with a 50 Ω antenna load. To ensure good overall RF performance,

antenna impedance and the characteristic impedance of the transmission line (i.e. cable) connecting the antenna and antenna port must be 50 Ω. Impedance mismatch may lead to performance degradation. Maximum antenna VSWR 2:1 is recommended but VSWR 3:1 can still be accepted in the final device. Respective minimum return loss values are 9.5 dB and 6.0 dB.

The length of the transmission line from the antenna to the nRF9151 antenna port should be kept as short as possible to minimize losses, as this loss is directly deteriorating the module's transmitted and received power. Additionally, low-loss matching circuit between the antenna and the nRF9151 antenna port is recommended to minimize loss caused by antenna and PCB routing mismatch. Reserving space from device manufacturer's application board for matching components (e.g. π-circuit) is recommended. This is because, for example, catalog antennas are typically tuned on reference board and differences to device mechanics may impact antenna impedance. It is also possible that device mechanics change during the development phase of the final device, and these modifications may impact antenna performance. Matching components can be used to compensate the impact of mechanics change to antenna impedance, and thus it may not be mandatory to modify the antenna itself.

The nRF9151 module has an internal ESD circuit in the antenna port, but additional ESD components at device manufacturer's application board may be used. The design of the ESD circuit shall be such that the impact on RF frequencies is negligible

Note: ESD filtering may be necessary for some active components that can be used at antenna path. Such components can be, for example, RF switches and antenna tuners. For further ESD requirements, see the RF switch and antenna tuner datasheets.

15.7 Antenna port test connector

To run conductive RF tests, a test connector nearby the nRF9151 antenna port in the RF transmission line is needed. The 50 Ω impedance requirement applies also to the test connector, and VSWR and insertion loss should be minimal. Regardless of whether the nRF9151 antenna port is connected to an actual antenna or test equipment, the load at the nRF9151 antenna should remain as close to 50 Ω as possible.

For a test connector, microwave coaxial switch connectors (for example, Murata MM8130-2600) are a good choice for this purpose. For conductive tests, a test cable is plugged in which connects the nRF9151 antenna port to the test equipment instead of the antenna. When the test cable is plugged off, the nRF9151 antenna port is connected to the antenna for real use case or radiated testing. The layout for the connector must be carefully designed to fulfil the 50 Ω requirement. For detailed guidance on this, see the coaxial switch connectors datasheets.

15.8 Reference design

To ensure good RF performance when designing PCBs, it is highly recommended to use the PCB layouts and component values provided by Nordic Seminconductor. See Hardware Design Guidelines for details.

The information on layout of trace design is confidential; host manufacturer shall need to contact module's grantee to obtain this information.

This module can only be used when installed in a host device that follows the required instructions for use of the layout of trace design. Any deviation(s) from the defined parameters of the layout of trace design, as described by the instructions, require that the host product manufacturer must notify the module grantee that they wish to change the layout of trace design. In this case, a Class II permissive change application is required to be filed by the grantee, or the host manufacturer can take responsibility through the change in FCC ID (new application).

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