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Chapter 1
About This Manual

1.1 Audience

This reference manual is intended for system software and hardware developers and applications programmers who want to develop products with this device. It assumes that the reader understands operating systems, microprocessor system design, and basic principles of software and hardware.

1.2 Organization

This manual has two main sets of chapters.

1. Chapters in the first set contain information that applies to all components on the chip.
2. Chapters in the second set are organized into functional groupings that detail particular areas of functionality.
   - Examples of these groupings are clocking, timers, and communication interfaces.
   - Each grouping includes chapters that provide a technical description of individual modules.

1.3 Module descriptions

Each module chapter has two main parts:

- **Chip-specific:** The first section, *Chip-specific [module name] information*, includes the number of module instances on the chip and possible implementation differences between the module instances, such as differences in FIFO depths or the number of

channels supported. It may also include functional connections between the module instances and other modules. Read this section *first* because its content is crucial to understanding the information in other sections of the chapter.

- **General:** The subsequent sections provide general information about the module, including its signals, registers, and functional description.

NOTE

If there is a conflict between the chip-specific module information (first section) and the general module information (subsequent sections), the chip-specific information supersedes the general information.

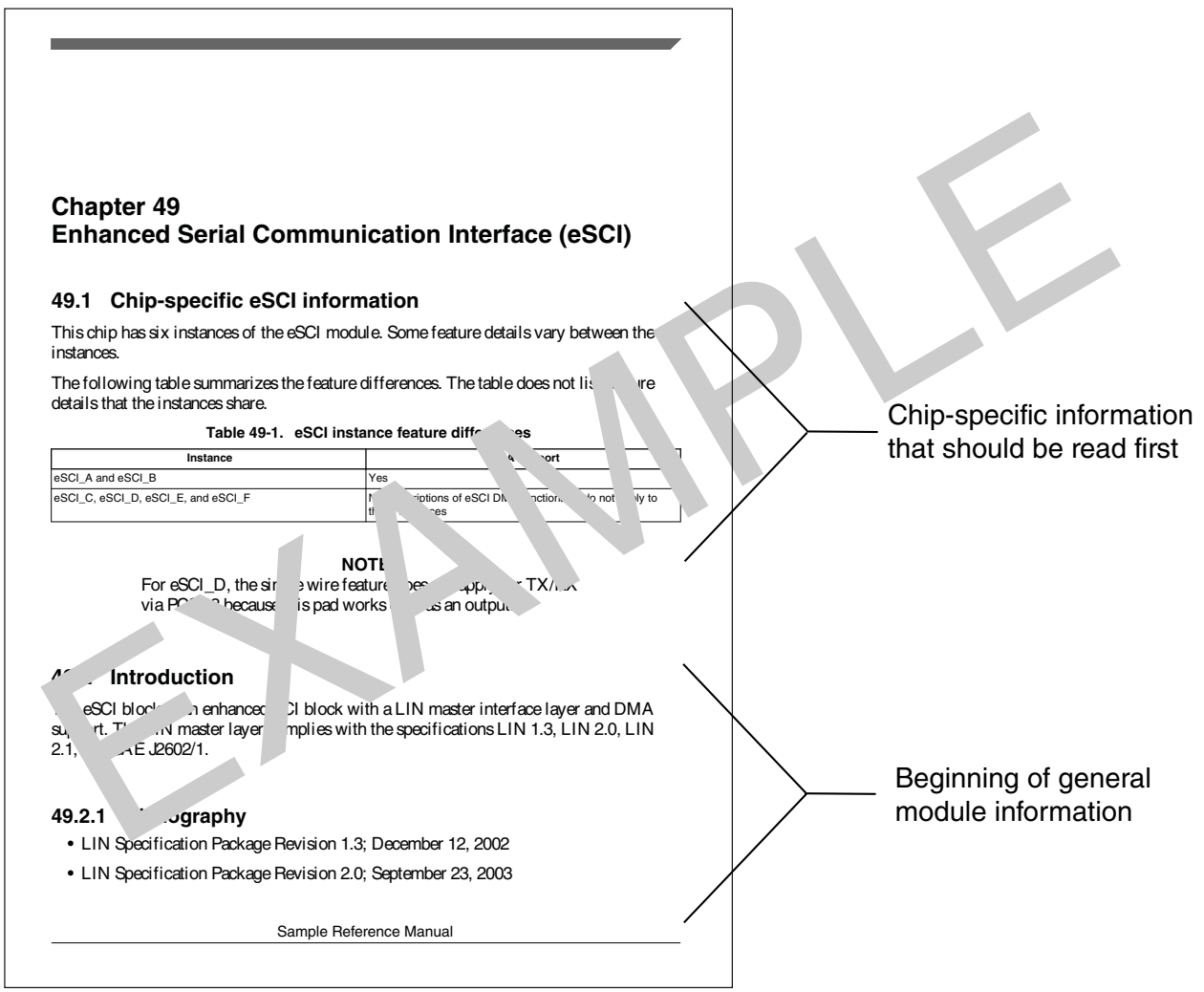
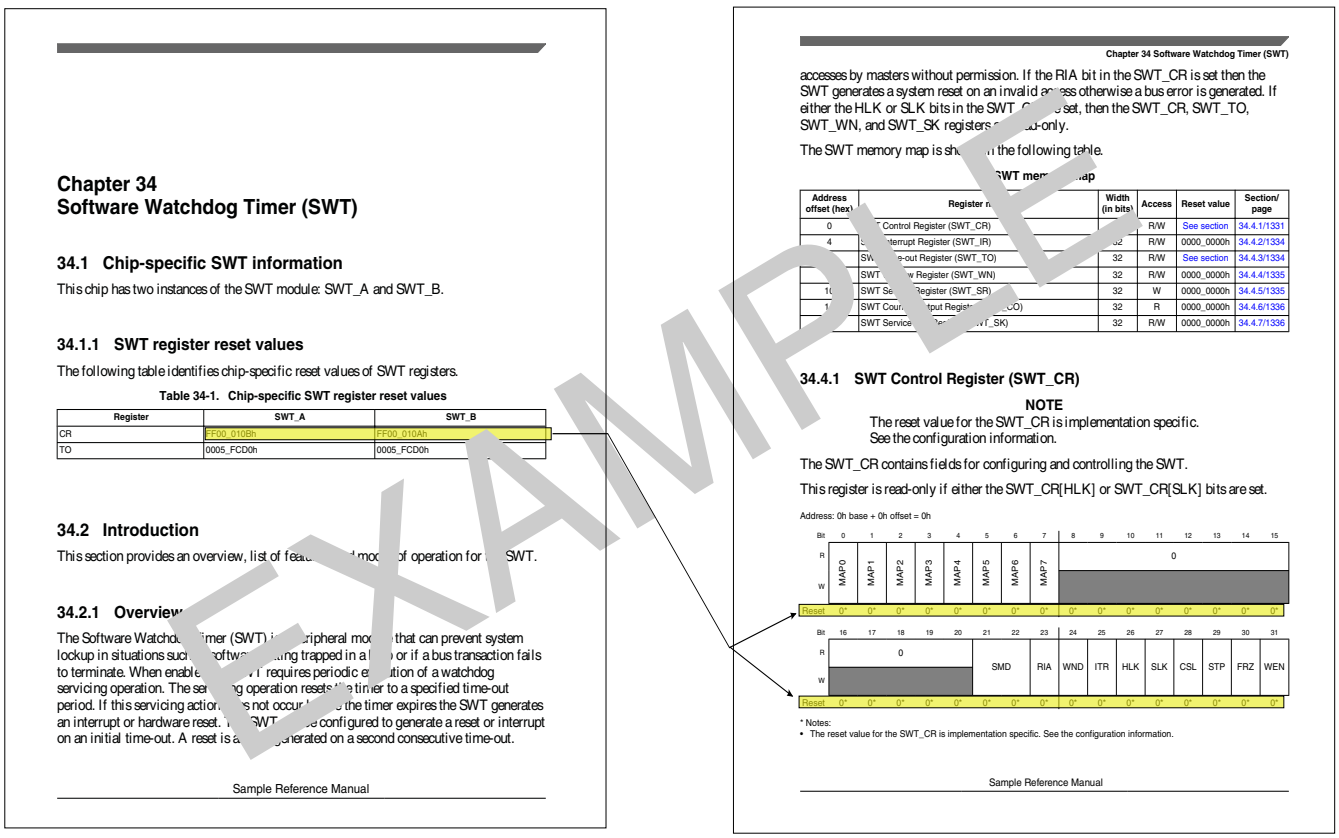


Figure 1-1. Example: chapter chip-specific information and general module information

EXAMPLE

1.3.1 Example: chip-specific information that supersedes content in the same chapter

The example below shows chip-specific information that supersedes general module information presented later in the chapter. In this case, the chip-specific register reset values supersede the reset values that appear in the register diagram.



Chapter 34
Software Watchdog Timer (SWT)

34.1 Chip-specific SWT information

This chip has two instances of the SWT module: SWT_A and SWT_B.

34.1.1 SWT register reset values

The following table identifies chip-specific reset values of SWT registers.

Table 34-1. Chip-specific SWT register reset values

Register	SWT_A	SWT_B
CR	FF00_010Bh	FF00_010Ah
TO	0005_FCD0h	0005_FCD0h

34.2 Introduction

This section provides an overview, list of feat... mod... of operation for ... SWT.

34.2.1 Overview

The Software Watchd... imer (SWT) i... ripheral mo... that can prevent system lockup in situations suc... softw... ting trapped in a l... or if a bus transaction fails to terminate. When enable... T requires periodic e... tion of a watchdog servicing operation. The se... g operation resets ... timer to a specified time-out period. If this servicing actio... s not occur ... the timer expires the SWT generates an interrupt or hardware reset. ... SWT ... e configured to generate a reset or interrupt on an initial time-out. A reset is a... enerated on a second consecutive time-out.

Sample Reference Manual

Chapter 34 Software Watchdog Timer (SWT)

accesses by masters without permission. If the RIA bit in the SWT_CR is set then the SWT generates a system reset on an invalid a... ess otherwise a bus error is generated. If either the HLK or SLK bits in the SWT_C... set, then the SWT_CR, SWT_TO, SWT_WN, and SWT_SK registers ... -only.

The SWT memory map is sh... n the following table.

SWT mem... ap

Address offset (hex)	Register n...	Width (in bits)	Access	Reset value	Section/ page
0	... Control Register (SWT_CR)		R/W	See section	34.4.1/1331
4	S... terrupt Register (SWT_IR)	...2	R/W	0000_0000h	34.4.2/1334
8	SW... e-out Register (SWT_TO)	32	R/W	See section	34.4.3/1334
C	SWT ... w Register (SWT_WN)	32	R/W	0000_0000h	34.4.4/1335
10	SWT Se... Register (SWT_SR)	32	W	0000_0000h	34.4.5/1335
1...	SWT Coun... tput Regis... CO)	32	R	0000_0000h	34.4.6/1336
...	SWT Service ... WT_SK)	32	R/W	0000_0000h	34.4.7/1336

34.4.1 SWT Control Register (SWT_CR)

NOTE
The reset value for the SWT_CR is implementation specific.
See the configuration information.

The SWT_CR contains fields for configuring and controlling the SWT.

This register is read-only if either the SWT_CR[HLK] or SWT_CR[SLK] bits are set.

Address: 0h base + 0h offset = 0h

Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R	MAP0	MAP1	MAP2	MAP3	MAP4	MAP5	MAP6	MAP7	0							
W																
Reset	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*

Bit	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
R	0					SMD	RIA	WND	ITR	HLK	SLK	CSL	STP	FRZ	WEN	
W																
Reset	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*

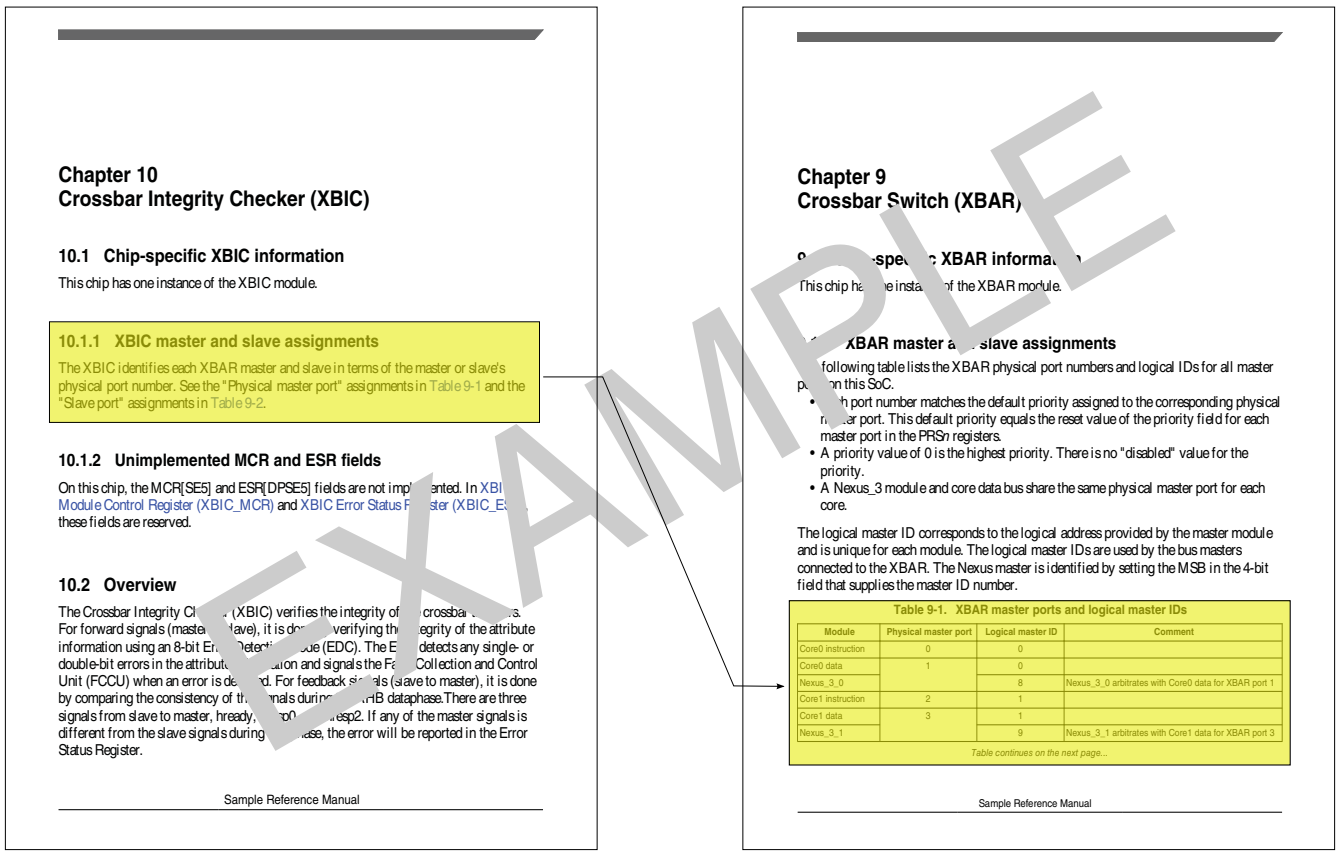
* Notes:
- The reset value for the SWT_CR is implementation specific. See the configuration information.

Sample Reference Manual

Figure 1-2. Example: chip-specific information that supersedes content in the same chapter

1.3.2 Example: chip-specific information that refers to a different chapter

The chip-specific information below refers to another chapter's chip-specific information. In this case, read both sets of chip-specific information before reading further in the chapter.



Chapter 10
Crossbar Integrity Checker (XBIC)

10.1 Chip-specific XBIC information

This chip has one instance of the XBIC module.

10.1.1 XBIC master and slave assignments

The XBIC identifies each XBAR master and slave in terms of the master or slave's physical port number. See the "Physical master port" assignments in Table 9-1 and the "Slave port" assignments in Table 9-2.

10.1.2 Unimplemented MCR and ESR fields

On this chip, the MCR[SE5] and ESR[DPSE5] fields are not implemented. In XBIC Module Control Register (XBIC_MCR) and XBIC Error Status Register (XBIC_ES... these fields are reserved.

10.2 Overview

The Crossbar Integrity Ch... (XBIC) verifies the integrity of ... crossbar ... For forward signals (maste... lave), it is do... verifying th... egrity of the attribute information using an 8-bit Er... Detecti... ue (EDC). The E... detects any single- or double-bit errors in the attribut... ion and signals the Fa... Collection and Control Unit (FCCU) when an error is de... d. For feedback si... ls (slave to master), it is done by comparing the consistency of th... nals duri... hB dataphase.There are three signals from slave to master, hready, ... so0, ... esp2. If any of the master signals is different from the slave signals during ... ase, the error will be reported in the Error Status Register.

Sample Reference Manual

Chapter 9
Crossbar Switch (XBAR)

9 ...-spe... : XBAR informa...

This chip ha... e insta... of the XBAR module.

... XBAR master a... slave assignments

The following table lists the XBAR physical port numbers and logical IDs for all master p... on this SoC.

- ...h port number matches the default priority assigned to the corresponding physical ... er port. This default priority equals the reset value of the priority field for each master port in the PRSn registers.
- A priority value of 0 is the highest priority. There is no "disabled" value for the priority.
- A Nexus_3 module and core data bus share the same physical master port for each core.

The logical master ID corresponds to the logical address provided by the master module and is unique for each module. The logical master IDs are used by the bus masters connected to the XBAR. The Nexus master is identified by setting the MSB in the 4-bit field that supplies the master ID number.

Table 9-1. XBAR master ports and logical master IDs

Module	Physical master port	Logical master ID	Comment
Core0 instruction	0	0	
Core0 data	1	0	
Nexus_3_0		8	Nexus_3_0 arbitrates with Core0 data for XBAR port 1
Core1 instruction	2	1	
Core1 data	3	1	
Nexus_3_1		9	Nexus_3_1 arbitrates with Core1 data for XBAR port 3

Table continues on the next page...

Sample Reference Manual

EXAMPLE

Figure 1-3. Example: chip-specific information that refers to a different chapter

1.4 Register descriptions

Module chapters present register information in:

- Memory maps including:
  - Addresses
  - The name and acronym/abbreviation of each register
  - The width of each register (in bits)
  - Each register's reset value
  - The page number on which each register is described
- Register figures
- Field-description tables
- Associated text

The register figures show the field structure using the conventions in the following figure.

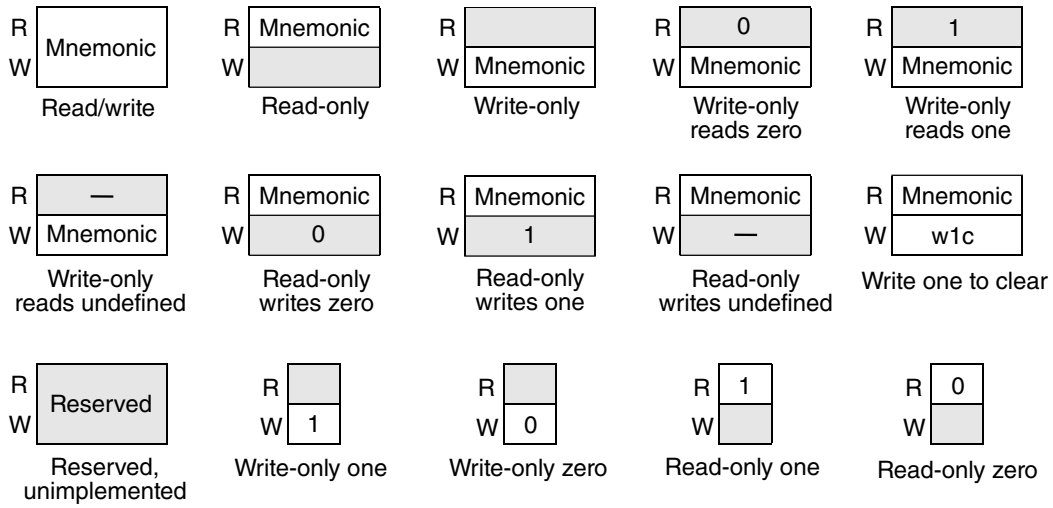


Figure 1-4. Register figure conventions

1.5 Conventions

1.5.1 Numbering systems

The following suffixes identify different numbering systems:

This suffix	Identifies a
b	Binary number. For example, the binary equivalent of the number 5 is written 101b. In some cases, binary numbers are shown with the prefix *0b*.
d	Decimal number. Decimal numbers are followed by this suffix only when the possibility of confusion exists. In general, decimal numbers are shown without a suffix.
h	Hexadecimal number. For example, the hexadecimal equivalent of the number 60 is written 3Ch. In some cases, hexadecimal numbers are shown with the prefix *0x*.

1.5.2 Typographic notation

The following typographic notation is used throughout this document:

Example	Description
placeholder, x	Items in italics are placeholders for information that you provide. Italicized text is also used for the titles of publications and for emphasis. Plain lowercase letters are also used as placeholders for single letters and numbers.
`code`	Fixed-width type indicates text that must be typed exactly as shown. It is used for instruction mnemonics, directives, symbols, subcommands, parameters, and operators. Fixed-width type

Table continues on the next page...

Example	Description
	is also used for example code. Instruction mnemonics and directives in text and tables are shown in all caps; for example, BSR.
SR[SCM]	A mnemonic in brackets represents a named field in a register. This example refers to the Scaling Mode (SCM) field in the Status Register (SR).
REVNO[6:4], XAD[7:0]	Numbers in brackets and separated by a colon represent either: • A subset of a register's named field For example, REVNO[6:4] refers to bits 6–4 that are part of the COREREV field that occupies bits 6–0 of the REVNO register. • A continuous range of individual signals of a bus For example, XAD[7:0] refers to signals 7–0 of the XAD bus.

1.5.3 Special terms

The following terms have special meanings:

Term	Meaning
asserted	Refers to the state of a signal as follows: • An active-high signal is asserted when high (1). • An active-low signal is asserted when low (0).
deasserted	Refers to the state of a signal as follows: • An active-high signal is deasserted when low (0). • An active-low signal is deasserted when high (1). In some cases, deasserted signals are described as *negated*.
reserved	Refers to a memory space, register, field, or programming setting. Writes to a reserved location can result in unpredictable functionality or behavior. • Do not modify the default value of a reserved programming setting, such as the reset value of a reserved register field. • Consider undefined locations in memory to be reserved.
w1c	Write 1 to clear: Refers to a register bitfield that must be written as 1 to be "cleared."

Chapter 2
Introduction

2.1 Overview

Information found here provides an overview of this MCU, which is a part of Kinetis E-series of ARM® Cortex®-M0+ MCUs and product family. It also presents high-level descriptions of the modules available on the device covered by this document.

2.2 Block Diagram

The following figure shows a top-level block diagram of the MCU superset device.

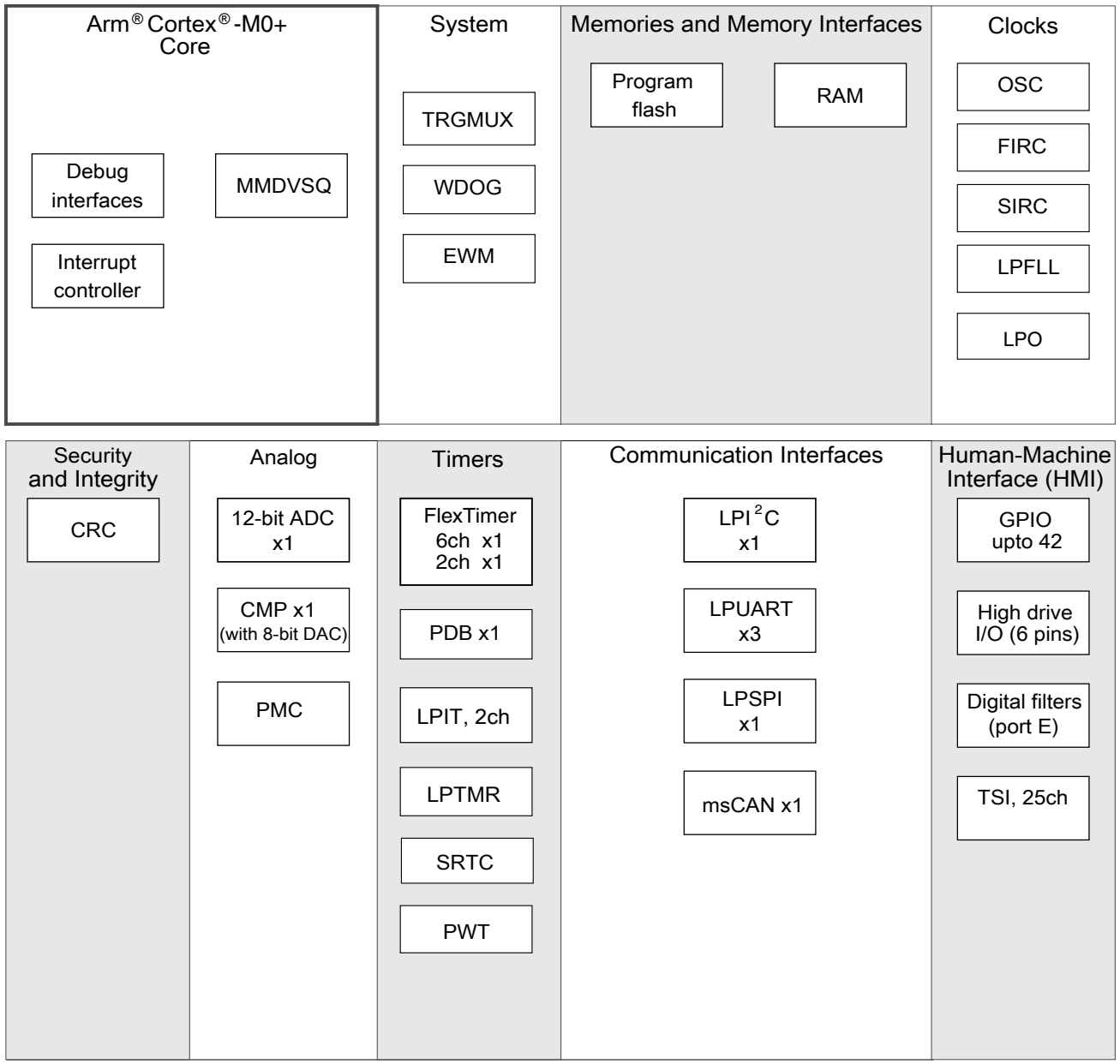


Figure 2-1. MCU block diagram

2.3 Module Functional Categories

The modules on this device are grouped into functional categories. The following sections describe the modules assigned to each category in more detail.

Table 2-1. Module functional categories

Module category	Description

ARM® Cortex®-M0+ core and related modules	• 32-bit MCU core from ARM's Cortex-M class, 1.77 CoreMark®/MHz from single-cycle access memories, 48 MHz CPU frequency
	• Debug interfaces
	  • Serial Wire Debug (SWD)
	  • Micro Trace Buffer (MTB)
	• MMDVSQ

System modules	• System integration module (SIM) • System mode controller (SMC) • Miscellaneous control module (MCM) • Crossbar switch (AXBS-Lite) • Peripheral bridge (AIPS-Lite) • Watchdog (WDOG) • External watchdog monitor (EWM)

Memories and memory interfaces	• Internal memories include:
	  • Program flash memory
	  • On devices with program flash only
	  • SRAM

Clocks	• System clock generator (SCG)
	  • Low-Power-Frequency-locked loop (LPFLL)
	  • Fast internal reference clock (FIRC)
	  • Slow internal reference clock (SIRC)
	  • System oscillator (OSC)
	• Low Power Oscillator (LPO)
	• Peripheral Clock Control (PCC)

Security and integrity modules	• Cyclic Redundancy Check (CRC) module for error detection • 128-bit unique identification (ID) number • ADC self-test and calibration feature
Analog modules	• High speed analog-to-digital converter (ADC) • Comparator (CMP) • Bandgap voltage reference (1V reference voltage) • Power management controllers (PMC) • Multiple power modes available based on run, wait, stop, and power-down modes
Timer modules	• Programmable delay block (PDB) • FlexTimers (FTM) • Low-power periodic interrupt timer (LPIT) • Low power timer (LPTMR) • Independent real time clock (RTC)
Communication interfaces	• MSCAN • Low-power Serial peripheral interface (LPSPI) • Low-power Inter-integrated circuit (LPI^{2}C) • Low-power UART (LPUART)
Human-machine interfaces (HMI)	• General purpose input/output controller (GPIO) • Capacitive touch sense input (TSI) interface enabled in hardware • High drive I/O pins, see the "Pin properties" section in DataSheet. • Digital filters, see "Ports summary" table in Port control and interrupt module features.

Chapter 3
Core Overview

3.1 ARM Cortex-M0+

The ARM Cortex-M0+ is the member of the Cortex-M Series of processors targeting the micro-controller market. It is an entry-level 32-bit processor designed for very cost sensitive, low power applications. The Cortex-M0+ has a 2-stage pipeline von Neumann architecture. The processor delivers exceptional energy efficiency through extensively optimized design and provides high-end processing hardware including a single-cycle multiplier. It also has an I/O port which supports single cycle loads and stores to tightly-coupled peripherals (e.g. GPIO).

The Cortex-M0+ processor implements the ARMv6-M architecture, which is upward compatible with other Cortex-M profile processors. It is based on the 16-bit Thumb® instruction set and includes Thumb-2 technology (including all but three 16-bit Thumb opcodes plus seven 32-bit instructions). The Cortex-M0+ instruction set provides the exceptional performance expected of a modern 32-bit architecture, with a higher code density than 8-bit and 16-bit microcontrollers.

Cortex-M0+ Processor Features

- Thumb instruction set with Thumb-2 technology
- Nested Vectored Interrupt Controller (NVIC)
- Single-cycle 32-bit hardware multiplier
- Single-cycle I/O port
- Serial-Wire Debug port (SWD)
- Breakpoint & Watchpoint Units
- Micro Trace Buffer (MTB)
- 24-bit system tick timer (SysTick)

The detailed architecture and programming model of Cortex-M0+ processor are discussed in the following documents from ARM.

- Cortex-M0+ Devices Generic User Guide

- Cortex-M0+ Technical Reference Manual
- ARMv6-M Architecture Reference Manual

3.2 Core Buses and Interfaces

The Cortex-M0+ processor provides a single system-level interface using AMBA® technology to provide memory and peripheral accesses, a single-cycle I/O port for high speed access to tightly-coupled peripherals (such as GPIO), a NVIC interface for interrupt handling, a Debug Access Port (DAP) for SWD debug and a Micro Trace Buffer (MTB) interface for trace.

The following interfaces are implemented on the Cortex-M0+ processor of this device.

- A single AHB-Lite bus
- A single-cycle IO port
- PPB bus
- NVIC interface
- MTB interface
- Debug port interface

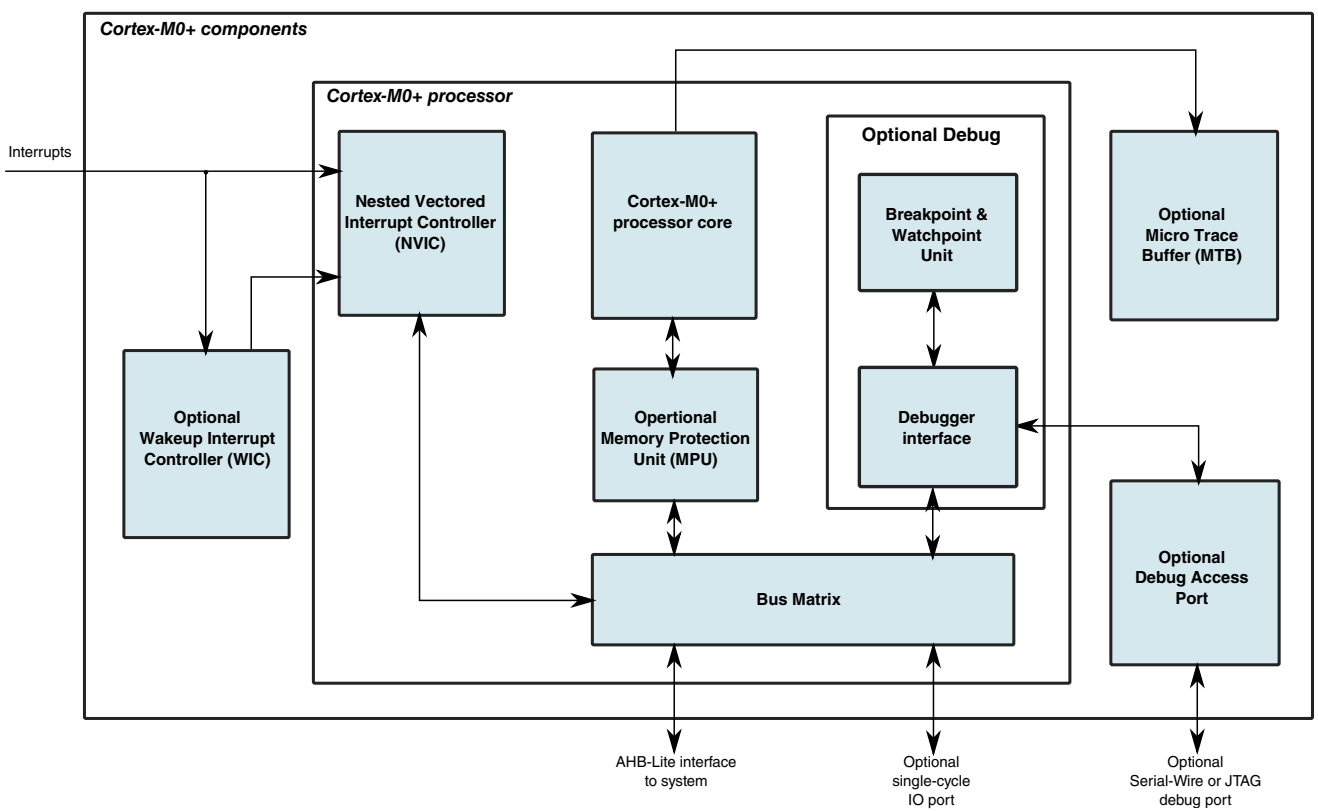


Figure 3-1. Cortex-M0+ core interfaces

3.3 Core Component Configuration

The processor supports optional tightly-coupled system components. The following table lists the specific configuration of the Cortex-M0+ core on this device.

Component name	Present on this device	Note
Single-cycle Multiplier	YES	
Single-cycle IO Port	YES	
SysTick	YES	
Halting debug	YES	
Watchpoint	YES	Include 2 comparators
Breakpoint	YES	Include 2 comparators
MTB	YES	
WIC	YES	
Vector Table Offset Support	YES	
Unprivileged/Privileged Support	YES	
SWD	YES	
MPU	Not present	

3.4 SysTick Clock Configuration

The System Tick Timer's clock source is always the core clock (CORE_CLK) on this device. This results in the following:

- The CLKSOURCE bit in SysTick Control and Status Register (SYST_CSR) is always set to select the core clock.
- Because the timing reference (CORE_CLK) is a variable frequency, the TENMS bit in the SysTick Calibration Value Register (SYST_CALIB) is always zero.
- The NOREF bit in SysTick Calibration Value Register (SYST_CALIB) is always set, implying that CORE_CLK is the only available source of reference timing.

Chapter 4
Interrupts

4.1 Introduction

The ARM Cortex-M0+ processor includes an interrupt controller called the Nested Vectored Interrupt Controller (NVIC). It is closely coupled to the processor core to provide outstanding interrupt handling abilities and low latency interrupt processing. The NVIC supports nested interrupt, dynamic priority changes, interrupt masking and interrupt tail-chaining. In addition, the NVIC also supports re-locatable vector table and an external Nonmaskable Interrupt (NMI).

The NVIC registers are located within the processor's internal System Control Space (SCS) with base address of 0xE000E000. Most of the NVIC registers are accessible only in privileged mode. The detailed NVIC functionalities and registers descriptions are discussed in the following documents from ARM web.

- Cortex-M0+ Devices Generic User Guide
- Cortex-M0+ Technical Reference Manual

4.2 NVIC configuration

The NVIC supports configurable interrupt number and level of priority. The following sections speficy the exact priority level and interrupt vectors implemented on this device.

4.2.1 Interrupt priority levels

The NVIC on this device supports 4 interrupt priority levels. Therefore, the NVIC_IPR registers contains 2 bits for each interrupt request (IRQ). For example, NVIC_IPR0 is shown below:

	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	IRQ3		0	0	0	0	0	0	IRQ2		0	0	0	0	0	0	IRQ1		0	0	0	0	0	0	IRQ0		0	0	0	0	0	0
W																																

4.2.2 Non-maskable interrupt

This device supports non-maskable interrupt (NMI) to the NVIC. It is controlled by the external NMI signal from the pin. The pin which the NMI signal is multiplexed on, must be configured for the NMI function to generate the non-maskable interrupt request.

4.3 Interrupt channel assignments

The interrupt source assignments are defined in the following table.

- Vector number — the value stored on the stack when an interrupt is serviced.
- IRQ number — non-core interrupt source count, which is the vector number minus 16.

The IRQ number is used within ARM's NVIC documentation.

Table 4-2. Interrupt vector assignments

Address	Vector	IRQ[1]	NVIC IPR register number[2]	Source module	Source description
ARM Core System Handler Vectors					
0x0000_0000	0	–	–	ARM core	Initial Stack Pointer
0x0000_0004	1	–	–	ARM core	Initial Program Counter
0x0000_0008	2	–	–	ARM core	Non-maskable Interrupt (NMI)
0x0000_000C	3	–	–	ARM core	Hard Fault
0x0000_0010	4	–	–	—	—
0x0000_0014	5	–	–	—	—
0x0000_0018	6	–	–	—	—
0x0000_001C	7	–	–	—	—

Table continues on the next page...

Table 4-2. Interrupt vector assignments (continued)

Address	Vector	IRQ[1]	NVIC IPR register number[2]	Source module	Source description
0x0000_0020	8	–	–	—	—
0x0000_0024	9	–	–	—	—
0x0000_0028	10	–	–	—	—
0x0000_002C	11	–	–	ARM core	Supervisor call (SVCall)
0x0000_0030	12	–	–	—	—
0x0000_0034	13	–	–	—	—
0x0000_0038	14	–	–	ARM core	Pendable request for system service (PendableSrvReq)
0x0000_003C	15	–	–	ARM core	System tick timer (SysTick)
Non-Core Vectors					
0x0000_0040	16	0	0	—	—
0x0000_0044	17	1	0	—	—
0x0000_0048	18	2	0	—	—
0x0000_004C	19	3	0	—	—
0x0000_0050	20	4	1	—	—
0x0000_0054	21	5	1	Flash memory	Single interrupt vector for all sources
0x0000_0058	22	6	1	PMC	Low-voltage detect, low-voltage warning
0x0000_005C	23	7	1	Port control module	Pin detect (Port A, E)
0x0000_0060	24	8	2	LPI^{2}C0	Single interrupt vector for all sources
0x0000_0064	25	9	2	—	—
0x0000_0068	26	10	2	LPSPI0	Single interrupt vector for all sources
0x0000_006C	27	11	2	—	—
0x0000_0070	28	12	3	LPUART0	Single interrupt vector for all sources
0x0000_0074	29	13	3	LPUART1	Single interrupt vector for all sources
0x0000_0078	30	14	3	LPUART2	Single interrupt vector for all sources
0x0000_007C	31	15	3	ADC0	—
0x0000_0080	32	16	4	CMP0	—
0x0000_0084	33	17	4	FTM0	Single interrupt vector for all sources
0x0000_0088	34	18	4	FTM1	Single interrupt vector for all sources
0x0000_008C	35	19	4		
0x0000_0090	36	20	5	RTC	Single interrupt vector for all sources
0x0000_0094	37	21	5	—	—
0x0000_0098	38	22	5	LPIT	LPIT channel 0-1
0x0000_009C	39	23	5	—	—
0x0000_00A0	40	24	6	TSI	—
0x0000_00A4	41	25	6	PDB0	—
0x0000_00A8	42	26	6	Port control module	Pin detect (Port B, C, D)

Table continues on the next page...

Table 4-2. Interrupt vector assignments (continued)

Address	Vector	IRQ[1]	NVIC IPR register number[2]	Source module	Source description
0x0000_00AC	43	27	6	SCG or RCM	Single interrupt vector for all sources
0x0000_00B0	44	28	7	WDOG or EWM	Both watchdog modules share this interrupt.
0x0000_00B4	45	29	7	PWT or LPTMR	Single interrupt vector for all sources
0x0000_00B8	46	30	7	MSCAN	MSCAN Rx interrupt
0x0000_00BC	47	31	7	MSCAN	MSCAN Tx, Err and Wake-up interrupt

1. Indicates the NVIC's interrupt source number.
2. Indicates the NVIC's IPR register number used for this IRQ. The equation to calculate this value is: IRQ div 4

4.3.1 Determining the bitfield and register location for configuring a particular interrupt

Suppose you need to configure the low-power timer (LPTMR) interrupt. The following table is an excerpt of the LPTMR row from Interrupt channel assignments (value number as example only).

Table 4-3. LPTMR interrupt vector assignment (example only)

Address	Vector	IRQ[1]	NVIC non-IPR register number[2]	NVIC IPR register number[3]	Source module	Source description
0x0000_0128	74	58	1	14	Low Power Timer	—

1. Indicates the NVIC's interrupt source number.
2. Indicates the NVIC's ISER, ICER, ISPR, ICPR, and IABR register number used for this IRQ. The equation to calculate this value is: IRQ div 32
3. Indicates the NVIC's IPR register number used for this IRQ. The equation to calculate this value is: IRQ div 4

- The NVIC registers you would use to configure the interrupt are:
  - NVIC_ISER1
  - NVIC_ICER1
  - NVIC_ISPR1
  - NVIC_ICPR1
  - NVIC_IABR1
  - NVIC_IPR14
- To determine the particular IRQ's bitfield location within these particular registers:
  - NVIC_ISER1, NVIC_ICER1, NVIC_ISPR1, NVIC_ICPR1, NVIC_IABR1 bit location = IRQ mod 32 = 26
  - NVIC_IPR14 bitfield starting location = 8 × (IRQ mod 4) + 4 = 20

Since the NVIC_IPR bitfields are 2-bit wide (4 priority levels), the NVIC_IPR14 bitfield range is 20-21

Therefore, the following bitfield locations are used to configure the LPTMR interrupts:

- NVIC_ISER1[26]
- NVIC_ICER1[26]
- NVIC_ISPR1[26]
- NVIC_ICPR1[26]
- NVIC_IABR1[26]
- NVIC_IPR14[21:20]

Chapter 5
System Integration Module (SIM)

5.1 Introduction

The System Integration Module (SIM) provides system control and chip configuration registers.

5.1.1 Features

Features of the SIM include:

- System clocking configuration
- Flash and system RAM size configuration
- FlexTimer clock and channel selection and configuration
- ADC trigger selection
- Flash configuration
- System device unique identification (UID)

5.2 Memory map and register definition

NOTE

The SIM registers can only be written in the supervisor mode. In the user mode, write accesses are blocked and will result in a bus error.

SIM memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_8004	Chip Control register (SIM_CHIPCTL)	32	R/W	0000_0000h	5.2.1/60

Table continues on the next page...

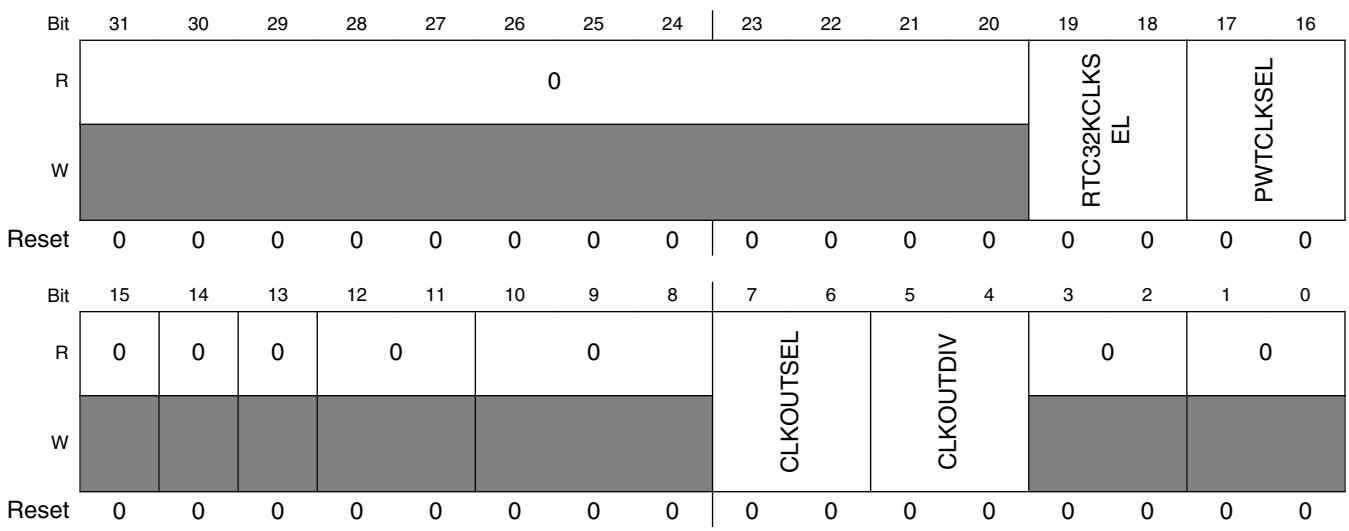
SIM memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_800C	FTM Option Register 0 (SIM_FTMOPT0)	32	R/W	0000_0000h	5.2.2/62
4004_8018	ADC Options Register (SIM_ADCOPT)	32	R/W	0000_0000h	5.2.3/63
4004_801C	FTM Option Register 1 (SIM_FTMOPT1)	32	R/W	0000_0000h	5.2.4/64
4004_8024	System Device Identification Register (SIM_SDID)	32	R	See section	5.2.5/65
4004_804C	Flash Configuration Register 1 (SIM_FCFG1)	32	R/W	See section	5.2.6/66
4004_8050	Flash Configuration Register 2 (SIM_FCFG2)	32	R	See section	5.2.7/68
4004_8054	Unique Identification Register High (SIM_UIDH)	32	R	See section	5.2.8/69
4004_8058	Unique Identification Register Mid-High (SIM_UIDMH)	32	R	See section	5.2.9/69
4004_805C	Unique Identification Register Mid Low (SIM_UIDML)	32	R	See section	5.2.10/70
4004_8060	Unique Identification Register Low (SIM_UIDL)	32	R	See section	5.2.11/70
4004_806C	Miscellaneous Control register (SIM_MISCTRL)	32	R/W	0000_0000h	5.2.12/71

5.2.1 Chip Control register (SIM_CHIPCTL)

SIM_CHIPCTL contains the controls for selecting PWT alternative clock source, ADC COCO trigger, trace clock, and clock out source.

Address: 4004_8000h base + 4h offset = 4004_8004h



SIM_CHIPCTL field descriptions

Field	Description
31–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–18 RTC32KCLKSEL	RTC 32K clock input select

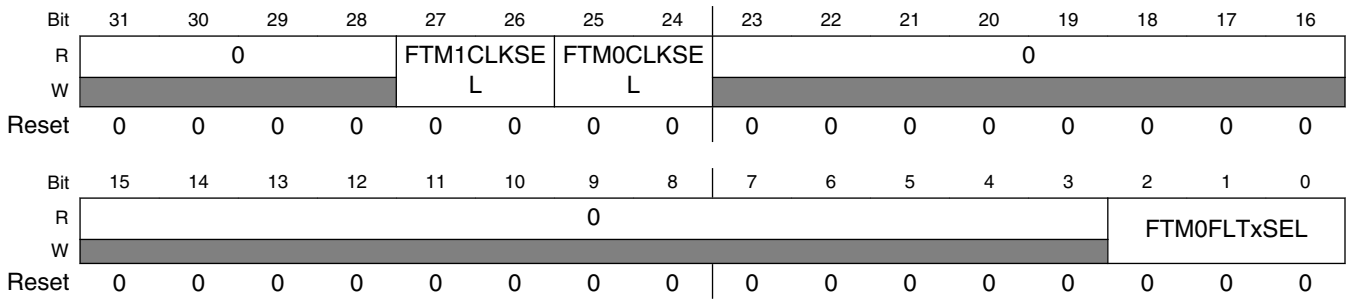
Table continues on the next page...

SIM_CHIPCTL field descriptions (continued)

Field	Description
	00 SOSC 32 kHZ high gain clock 01 RTC_CLKIN 10 LPO 32 kHZ clock output 11 Reserved
17–16 PWTCLKSEL	PWT clock source select 00 PWT alternative clock is from the TCLK0 pin. 01 PWT alternative clock is from the TCLK1 pin. 10 PWT alternative clock is from the TCLK2 pin. 11 Reserved
15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
12–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7–6 CLKOUTSEL	CLKOUT Select Selects the clock to output on the CLKOUT pin. 00 Reserved 01 SCGCLKOUT(SIRC/FIRC/SOSC/LPFLL), see SCG_CLKOUTCNFG register. 10 Reserved 11 LPO clock (128 kHz)
5–4 CLKOUTDIV	CLKOUT divider ratio 00 Divided by 1 01 Divided by 2 10 Divided by 4 11 Divided by 8
3–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

5.2.2 FTM Option Register 0 (SIM_FTMOPT0)

Address: 4004_8000h base + Ch offset = 4004_800Ch

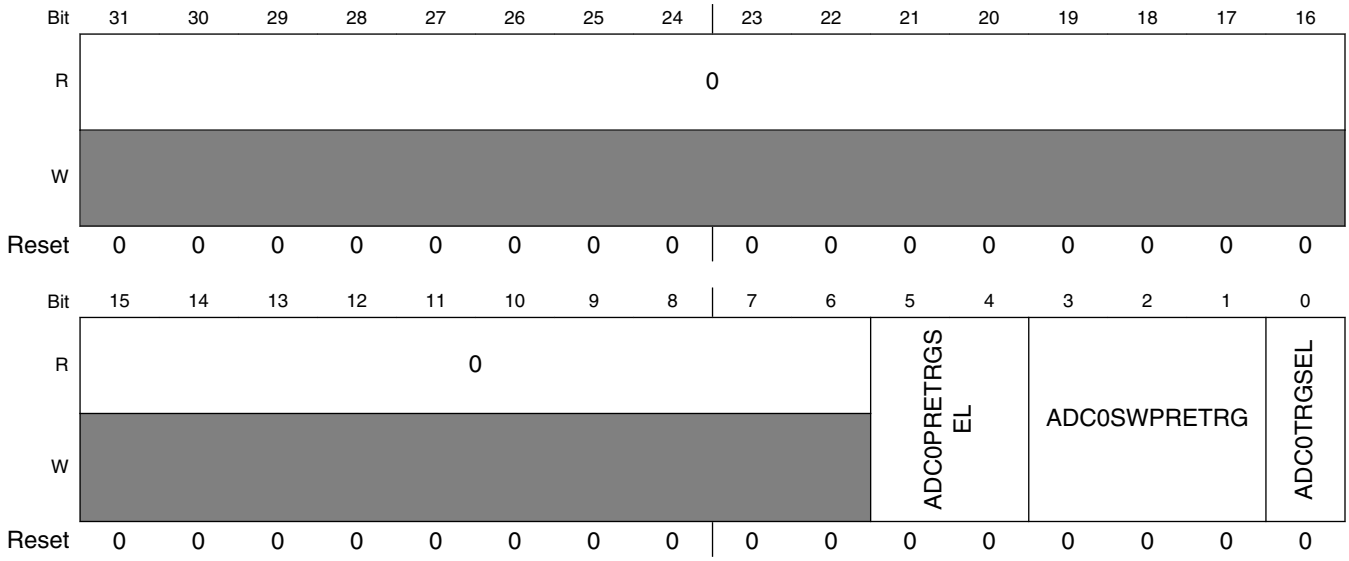


SIM_FTMOPT0 field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–26 FTM1CLKSEL	FTM1 External Clock Pin Select Selects the external pin used to drive the clock to the FTM1 module. **NOTE:** The selected pin must also be configured for the FTM external clock function through the appropriate Pin Control Register in the Port Control module. 00 FTM1 external clock driven by TCLK0 pin. 01 FTM1 external clock driven by TCLK1 pin. 10 FTM1 external clock driven by TCLK2 pin. 11 No clock input
25–24 FTM0CLKSEL	FTM0 External Clock Pin Select Selects the external pin used to drive the clock to the FTM0 module. **NOTE:** The selected pin must also be configured for the FTM external clock function through the appropriate Pin Control Register in the Port Control module. 00 FTM0 external clock driven by TCLK0 pin. 01 FTM0 external clock driven by TCLK1 pin. 10 FTM0 external clock driven by TCLK2 pin. 11 No clock input
23–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
FTM0FLTxSEL	FTM0 Fault x Select Selects the source of FTM0 fault. Every bit means one fault input respectively. **NOTE:** The pin source for fault must be configured for the FTM module fault function through the appropriate pin control register in the port control module when it comes from external fault pin. TRGMUX_FTM0 SELx is corresponding to FTM0 Fault x input. Bit value = 0: FTM0_FLTx pin Bit value = 1: TRGMUX_FTM0 out

5.2.3 ADC Options Register (SIM_ADCOPT)

Address: 4004_8000h base + 18h offset = 4004_8018h

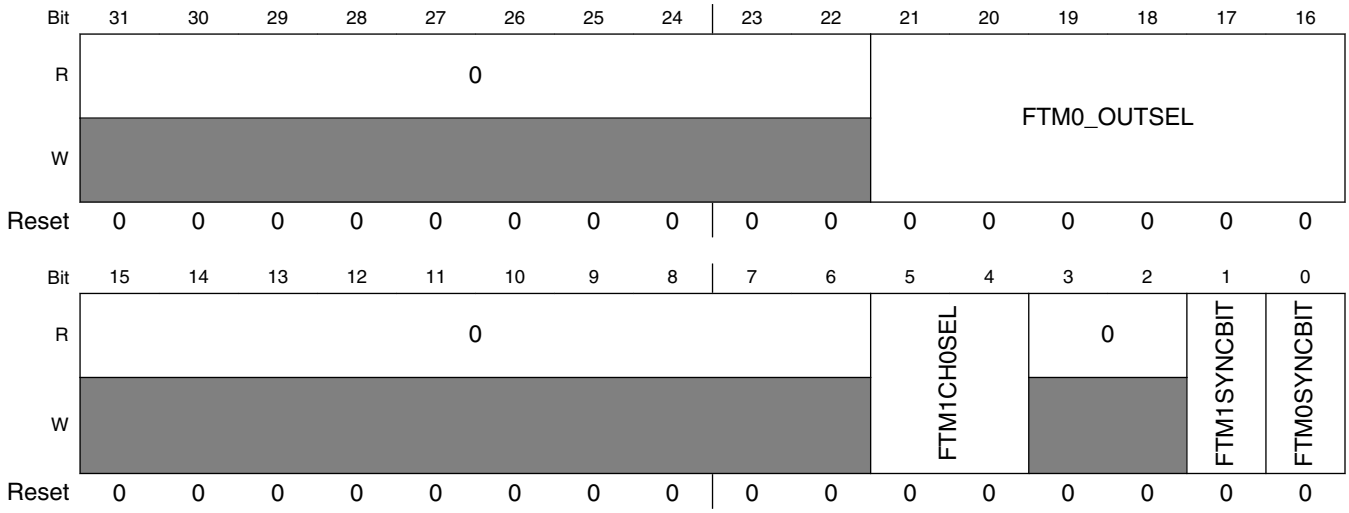


SIM_ADCOPT field descriptions

Field	Description
31–6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
5–4 ADC0PRETRGSEL	ADC0 pre-trigger source select Selects pre-trigger source for ADC0. 00 PDB output 01 TRGMUX output 10 ADC0 software pre-trigger 11 Reserved
3–1 ADC0SWPRETRG	ADC0 software pre-trigger sources 000 software pre-trigger disabled 001 - 011 Reserved (do not use) 100 software pre-trigger 0 101 software pre-trigger 1 110 software pre-trigger 2 111 software pre-trigger 3
0 ADC0TRGSEL	ADC0 trigger source select Selects trigger source for ADC0. 0 PDB output 1 TRGMUX output

5.2.4 FTM Option Register 1 (SIM_FTMOPT1)

Address: 4004_8000h base + 1Ch offset = 4004_801Ch



SIM_FTMOPT1 field descriptions

Field	Description
31–22 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
21–16 FTM0_OUTSEL	FTM0 channel modulation select with FTM1_CH1 Bit 5 to 0 are for channel 5 to 0 respectively. 0 No modulation with FTM1_CH1 1 Modulation with FTM1_CH1
15–6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
5–4 FTM1CH0SEL	FTM1 CH0 Select Selects FTM1 CH0 input 00 FTM1_CH0 input 01 CMP0 output 10 Reserved 11 Reserved
3–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 FTM1SYNCBIT	FTM1 Sync Bit Software control for FTM1 hardware trigger synchronization 0 No effect. 1 Write 1 to assert the TRIG1 input to FTM1. Software must clear this bit to allow other trigger sources to assert.

Table continues on the next page...

SIM_FTMOPT1 field descriptions (continued)

Field	Description
0 FTM0SYNCBIT	FTM0 Sync Bit Software control for FTM0 hardware trigger synchronization 0 No effect. 1 Write 1 to assert the TRIG1 input to FTM0. Software must clear this bit to allow other trigger sources to assert.

5.2.5 System Device Identification Register (SIM_SDID)

NOTE

Reset value loaded during System Reset from Flash IFR.

Address: 4004_8000h base + 24h offset = 4004_8024h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FAMILYID				SUBFAMID				SERIESID				RAMSIZE				REVID				PROJECTID					PINID						
W																																
Reset	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	0	0	0	1	0	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

SIM_SDID field descriptions

Field	Description
31–28 FAMILYID	Kinetis E-series Family ID Specifies the Kinetis E-series family of the device. 0001 KE1x Family (Enhanced features)
27–24 SUBFAMID	Kinetis E-series Sub-Family ID Specifies the Kinetis E-series sub-family of the device.
23–20 SERIESID	Kinetis Series ID Specifies the Kinetis series of the device. 0010 Kinetis E+ series
19–16 RAMSIZE	RAM size This field specifies the amount of system RAM available on the device. 0011 4 KB 0100 8 KB Others Reserved

Table continues on the next page...

SIM_SDID field descriptions (continued)

Field	Description
15–12 REVID	Device revision number Specifies the silicon implementation number for the device.
11–7 PROJECTID	Project ID Specifies the silicon feature set identication number for the device. 00011 for this device.
PINID	Pin identification Specifies the pin count of the device. 0000100 32-pin 0000101 44-pin 0000110 48-pin

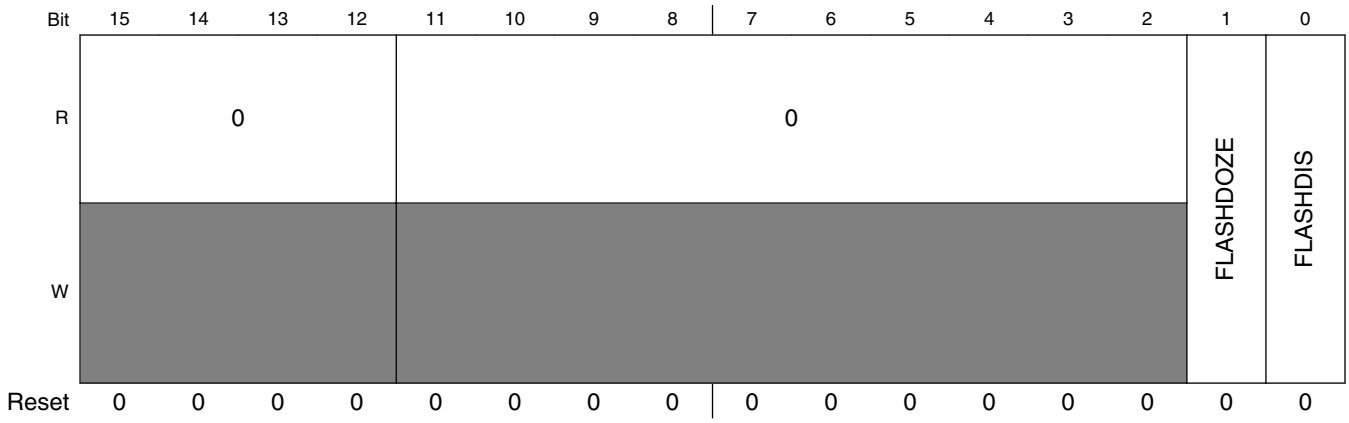
5.2.6 Flash Configuration Register 1 (SIM_FCFG1)

NOTE

Reset value of PFSIZE is loaded during System Reset from Flash IFR.

Address: 4004_8000h base + 4Ch offset = 4004_804Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0				PFSIZE				0							
W																
Reset	0	0	0	0	x*	x*	x*	x*	0	0	0	0	0	0	0	0



* Notes:
- x = Undefined at reset.

SIM_FCFG1 field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 PFSIZE	Program flash size This field specifies the amount of program flash memory available on the device . Undefined values are reserved. 0000 8 KB of program flash memory, 1 KB protection region 0001 16 KB of program flash memory, 1 KB protection region 0011 32 KB of program flash memory, 1 KB protection region 0101 64 KB of program flash memory, 2 KB protection region
23–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 FLASHDOZE	Flash Doze When set, Flash memory is disabled for the duration of Doze mode. An attempt by the bus master to access the Flash when the Flash is disabled will result in a bus error. This bit should be clear during VLP modes. The Flash will be automatically enabled again at the end of Doze mode so interrupt vectors do not need to be relocated out of Flash memory. The wakeup time from Doze mode is extended when this bit is set. 0 Flash remains enabled during Doze mode 1 Flash is disabled for the duration of Doze mode
0 FLASHDIS	Flash Disable Flash accesses are disabled (and generate a bus error) and the Flash memory is placed in a low power state. This bit should not be changed during VLP modes. Relocate the interrupt vectors out of Flash memory before disabling the Flash.

Table continues on the next page...

SIM_FCFG1 field descriptions (continued)

Field	Description
	0 Flash is enabled 1 Flash is disabled

5.2.7 Flash Configuration Register 2 (SIM_FCFG2)

NOTE

Reset values of MAXADDR0 are loaded during System Reset from Flash IFR.

Address: 4004_8000h base + 50h offset = 4004_8050h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	MAXADDR0							1	Reserved						
W																
Reset	0*	1*	1*	1*	1*	1*	1*	1*	1*	0*	0*	0*	0*	0*	0*	0*

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W																
Reset	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*

SIM_FCFG2 field descriptions

Field	Description
31 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
30–24 MAXADDR0	Max address block 0 This field concatenated with 13 trailing zeros indicates the first invalid address of program flash (block 0). For example, if MAXADDR0 = 0x10, the first invalid address of program flash (block 0) is 0x0002_0000. This would be the MAXADDR0 value for a device with 64 KB program flash in flash block 0.
23 Reserved	This field is reserved. This read-only field is reserved and always has the value 1.
22–16 Reserved	This field is reserved.
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

5.2.8 Unique Identification Register High (SIM_UIDH)

Address: 4004_8000h base + 54h offset = 4004_8054h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	UID127_96																															
W																																
Reset	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*

* Notes:
- Reset value loaded during System Reset from Flash IFR.

SIM_UIDH field descriptions

Field	Description
UID127_96	Unique Identification Unique identification for the device.

5.2.9 Unique Identification Register Mid-High (SIM_UIDMH)

Address: 4004_8000h base + 58h offset = 4004_8058h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	UID95_64																															
W																																
Reset	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*	0*

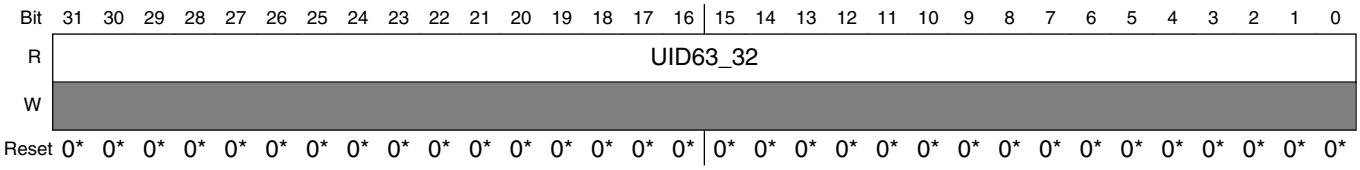
* Notes:
- Reset value loaded during System Reset from Flash IFR.

SIM_UIDMH field descriptions

Field	Description
UID95_64	Unique Identification Unique identification for the device.

5.2.10 Unique Identification Register Mid Low (SIM_UIDML)

Address: 4004_8000h base + 5Ch offset = 4004_805Ch



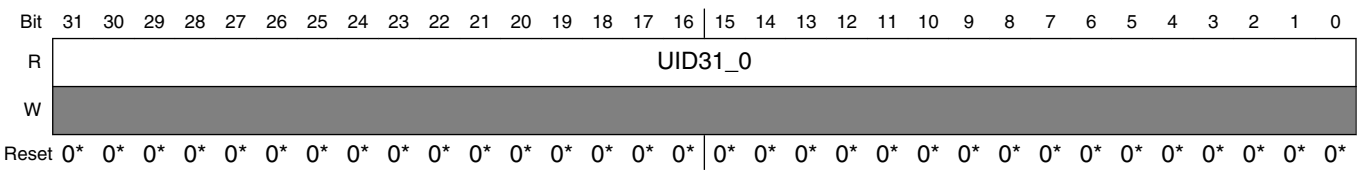
* Notes:
- Reset value loaded during System Reset from Flash IFR.

SIM_UIDML field descriptions

Field	Description
UID63_32	Unique Identification Unique identification for the device.

5.2.11 Unique Identification Register Low (SIM_UIDL)

Address: 4004_8000h base + 60h offset = 4004_8060h



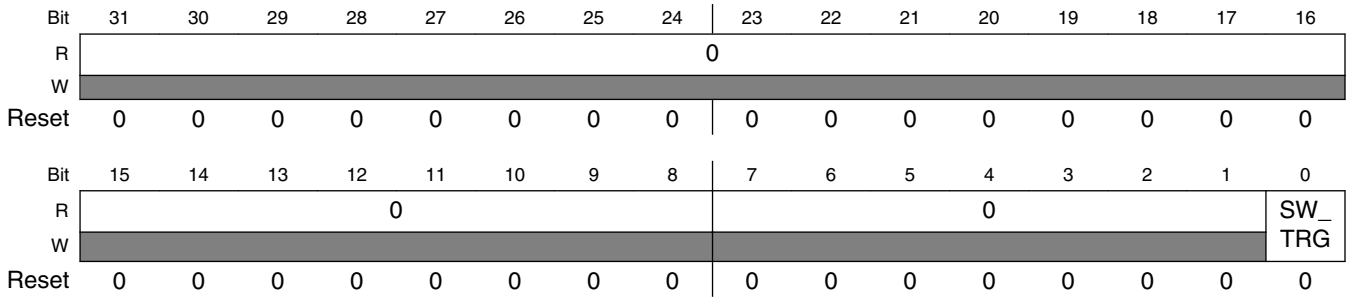
* Notes:
- Reset value loaded during System Reset from Flash IFR.

SIM_UIDL field descriptions

Field	Description
UID31_0	Unique Identification Unique identification for the device.

5.2.12 Miscellaneous Control register (SIM_MISCTRL)

Address: 4004_8000h base + 6Ch offset = 4004_806Ch



SIM_MISCTRL field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7–1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 SW_TRG	Software Trigger bit to TRGMUX

Chapter 6
Memory-Mapped Divide and Square Root (MMDVSQ)

6.1 Chip-specific Information for this Module

In this block chapter, PBRIDGE stands for the Peripheral Bridge, with the same meaning as AIPS-Lite.

NOTE

BME is not supported in this device.

NOTE

DMA is not supported in this device.

6.2 Introduction

Arm processor cores in the Cortex-M family implementing the Armv6-M instruction set architecture do not include hardware support for integer divide operations. The affected processors include the Cortex-M0+ core. However, in certain deeply embedded application spaces, hardware support for this class of arithmetic operation (along with an unsigned square root function) is important to maximize system performance and minimize device power dissipation. Accordingly, the MMDVSQ module is included in select microcontrollers, to serve as a memory-mapped co-processor located in a special address space (within the system memory map) that is accessible only to the processor core.

The MMDVSQ module supports execution of the integer divide operations defined in the Armv7-M instruction set architecture, plus an unsigned integer square root operation. The supported integer divide operations include 32/32 signed (SDIV) and unsigned (UDIV) calculations.

6.2.1 Features

The key features of the MMDVSQ include:

- Lightweight implementation of 32-bit integer divide and square root arithmetic operations
  - Supports 32/32 signed and unsigned divide (or remainder) calculations
  - Supports 32-bit unsigned square root calculations
- Simple programming model includes input data and result registers plus a control/status register
- Programming model interface optimized for activation from inline code or software library call
  - "Fast Start" configuration minimizes the memory-mapped register write overhead
  - Supports two methods to determine when result is valid, including software polling
  - Configurable divide-by-zero response
- Pipelined design processes 2 bits per cycle with early termination exit for minimum execution time

6.2.2 Block diagram

A generic block diagram of the processor core and platform for this class of ultra low-end microcontrollers is shown in Figure 6-1. The MMDVSQ module's location as a memory-mapped co-processor is highlighted.

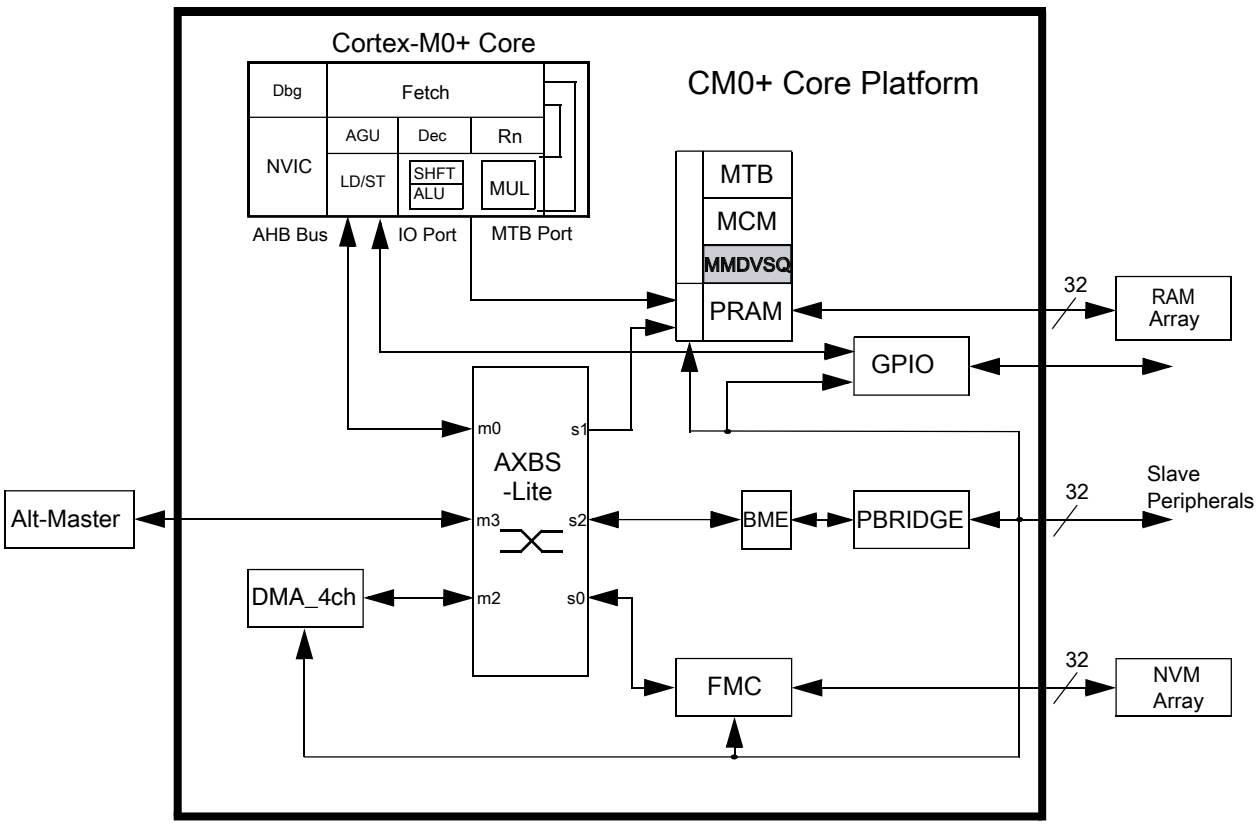


Figure 6-1. Generic Cortex-M0+ Core Platform Block Diagram

Next, a block diagram of the internal structure of the MMDVSQ module is presented. See Figure 6-2.

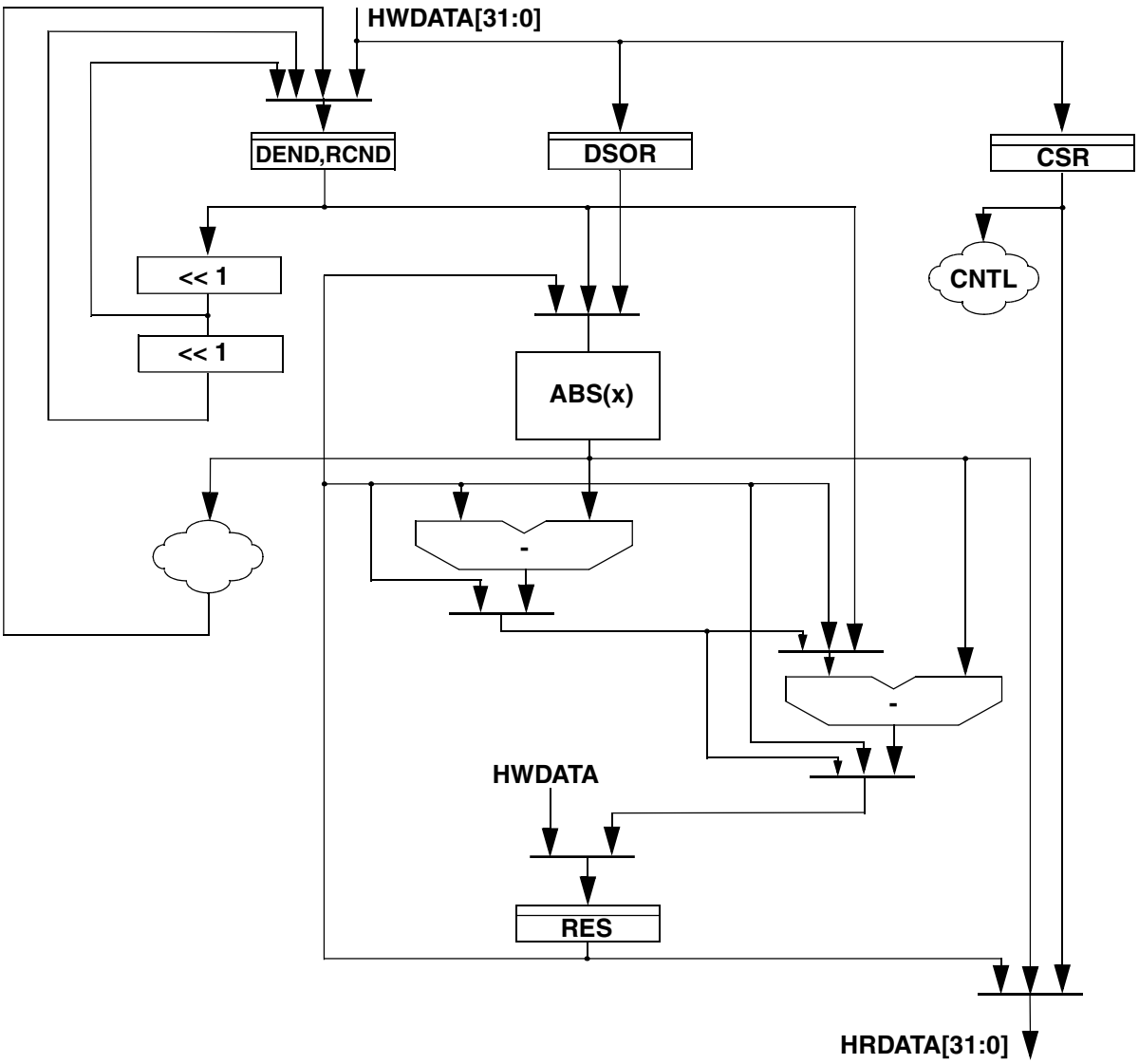


Figure 6-2. MMDVSQ Block Diagram

6.2.3 Modes of operation

The MMDVSQ module does not support any special modes of operation. As a memory-mapped device located on a crossbar slave AHB system bus port, MMDVSQ responds based strictly on memory addresses to its programming model.

All functionality associated with the MMDVSQ module resides in the core platform's clock domain; this includes its connections with the crossbar slave port. To minimize power dissipation, the design supports an architectural clock gate for the entire module, that is, the MMDVSQ is only clocked when responding to bus requests to its programming model or is busy performing a calculation.

6.3 External signal description

The MMDVSQ module does not directly support any external interfaces.

The internal interface includes a standard 32-bit AHB bus as shown in Figure 6-1.

6.4 Memory map and register definition

The MMDVSQ module supports a small number of program-visible registers used for passing input operands and retrieving the output result plus a configuration/status register.

The programming model occupies the first 20 bytes of a standard 4 Kb address slot. It can only be accessed via word-sized (32 bit) accesses. Attempted accesses using smaller data sizes, reading the write-only location or to reserved space are terminated with an error.

At any instant in time, the MMDVSQ can perform either a divide or square root calculation. The basic integer operations supported by the MMDVSQ are:

For divide:

```
MMDVSQ_RES = quotient  (MMDVSQ_DEND / MMDVSQ_DSOR)

MMDVSQ_RES = remainder (MMDVSQ_DEND % MMDVSQ_DSOR)
```

For square root:

```
MMDVSQ_RES = integer   (√MMDVSQ_RCND)
```

The register usage, based on the operation (divide, square root), is detailed in Table 6-1.

Table 6-1. Register Usage = f(Divide, Square Root)

Register	Divide	Square Root	Description
Dividend (MMDVSQ_DEND)	Yes	No	Input dividend (numerator) for the divide
Divisor (MMDVSQ_DSOR)	Yes	No	Input divisor (denominator) for the divide
Control/Status (MMDVSQ_CSR)	Yes	Yes	Control for divide, status for divide and square root
Result (MMDVSQ_RES)	Yes	Yes	Output result
Radicand (MMDVSQ_RCND)	No	Yes	Input "square" data

MMDVSQ memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F000_4000	Dividend Register (MMDVSQ_DEND)	32	R/W	Undefined	6.4.1/78
F000_4004	Divisor Register (MMDVSQ_DSOR)	32	R/W	Undefined	6.4.2/78
F000_4008	Control/Status Register (MMDVSQ_CSR)	32	R/W	See section	6.4.3/80
F000_400C	Result Register (MMDVSQ_RES)	32	R/W	Undefined	6.4.4/83
F000_4010	Radicand Register (MMDVSQ_RCND)	32	W	Undefined	6.4.5/83

6.4.1 Dividend Register (MMDVSQ_DEND)

This register is loaded with the input dividend operand before a divide operation is initiated. The register is updated by the MMDVSQ hardware during the execution of a divide or square root calculation. Any memory access (read or write) of the DEND register while the module is busy during a calculation causes the access to be stalled (using wait states) until the calculation completes.

Address: F000_4000h base + 0h offset = F000_4000h

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

* Notes:
- x = Undefined at reset.

MMDVSQ_DEND field descriptions

Field	Description
DIVIDEND	Dividend This is the input dividend operand for divide calculations.

6.4.2 Divisor Register (MMDVSQ_DSOR)

This register is loaded with the input divisor operand before a divide operation is initiated. If CSR[DFS] = 0, a write to this register inititates a divide operation. Any memory access (read or write) of the DSOR register while the module is busy during a calculation causes the access to be stalled (using wait states) until the calculation completes.

If a divide operation is inititated with DSOR = 0, the hardware signals a divide-by-zero condition and sets RES = 0 and CSR[DZ] = 1. If CSR[DZE] = 1, an attempted read of the RES result is error terminated.

Address: F000_4000h base + 4h offset = F000_4004h

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

* Notes:
- x = Undefined at reset.

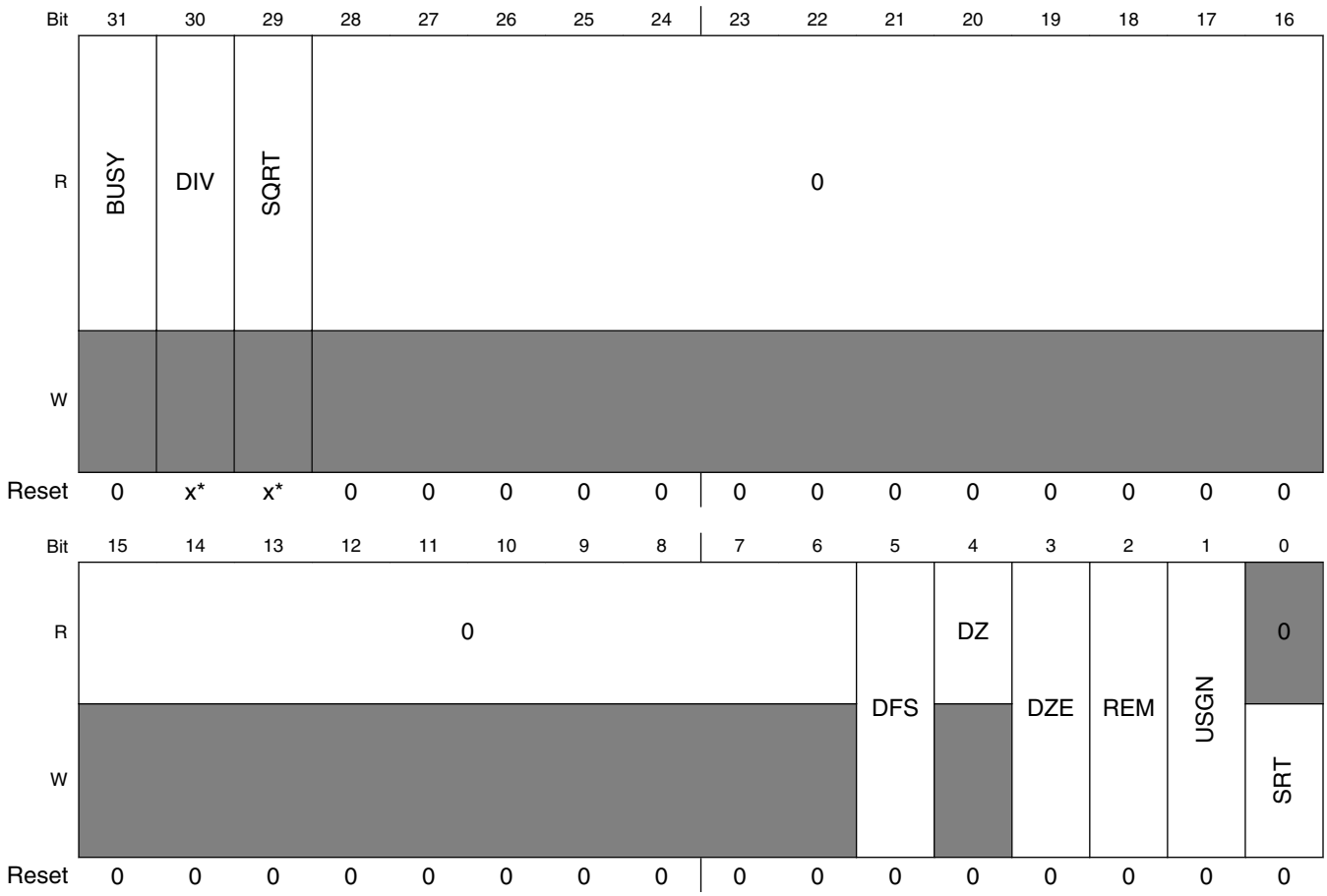
MMDVSQ_DSOR field descriptions

Field	Description
DIVISOR	Divisor This is the input divisor operand for divide calculations.

6.4.3 Control/Status Register (MMDVSQ_CSR)

This register defines the operating configuration of divide operations and provides status information. The upper 3 bits provide busy status indicators, while the low-order byte defines the configuration for divide operations. The read-only status bits in CSR[31:29] are valid for both divide and square root operations; the configuration and status bit in CSR[5:0] are only valid for divides. A memory write access of the CSR register while the module is busy during a calculation causes the access to be stalled (using wait states) until the calculation completes.

Address: F000_4000h base + 8h offset = F000_4008h



* Notes:
- x = Undefined at reset.

MMDVSQ_CSR field descriptions

Field	Description
31 BUSY	BUSY This read-only bit is asserted when the MMDVSQ is performing a divide or square root. When an operation is initiated, the hardware sets this flag. It remains asserted until the operation completes and the

Table continues on the next page...

MMDVSQ_CSR field descriptions (continued)

Field	Description
	hardware automatically clears the indicator. This bit can be used to poll the DVSQ's execution status. The combined CSR[BUSY, DIV, SQRT] indicators provide an encoded module status: • If 0b001, then MMDVSQ is idle and the last calculation was a square root • If 0b010, then MMDVSQ is idle and the last calculation was a divide • If 0b101, then MMDVSQ is busy processing a square root calculation • If 0b110, then MMDVSQ is busy processing a divide calculation The remaining encodings of CSR[BUSY, DIV, SQRT] are reserved. 0 MMDVSQ is idle 1 MMDVSQ is busy performing a divide or square root calculation
30 DIV	DIVIDE Current or last operation was a divide. This read-only indicator bit signals if the current or last operation performed by the MMDVSQ was a divide. 0 Current or last MMDVSQ operation was not a divide 1 Current or last MMDVSQ operation was a divide
29 SQRT	SQUARE ROOT Current or last operation was a square root. This read-only indicator bit signals if the current or last operation performed by the MMDVSQ was a square root. 0 Current or last MMDVSQ operation was not a square root 1 Current or last MMDVSQ operation was a square root
28–6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
5 DFS	Disable Fast Start The MMDVSQ supports 2 mechanisms for initiating a divide operation. The default mechanism is a "fast start" where a write to the DSOR register begins the divide. Alternatively, the start mechanism can begin after a write to the CSR register with CSR[SRT] set. The CSR[DFS] indicator selects the divide start mechanism. 0 A divide operation is initiated by a write to the DSOR register 1 A divide operation is initiated by a write to the CSR register with CSR[SRT] = 1
4 DZ	Divide-by-Zero This read-only status indicator signals the last divide operation had a zero divisor, that is, DSOR = 0x0000_0000. For this case, RES is set to 0x0000_0000 and this indicator bit set. After a divide-by-zero operation, a read of the RES register returns either the zero result, or, if CSR[DZE] = 1, terminates the read with an error. The CSR[DZ] indicator is cleared by the hardware at the beginning of each operation. 0 The last divide operation had a non-zero divisor, that is, DSOR != 0 1 The last divide operation had a zero divisor, that is, DSOR = 0
3 DZE	Divide-by-Zero-Enable This indicator configures the MMDVSQ's response to divide-by-zero calculations. If both CSR[DZ] and CSR[DZE] are set, then a subsequent read of the RES register is error terminated to signal the processor of the attempted divide-by-zero.

Table continues on the next page...

MMDVSQ_CSR field descriptions (continued)

Field	Description
	0 Reads of the RES register return the register contents 1 If CSR[DZ] = 1, an attempted read of RES register is error terminated to signal a divide-by-zero, else the register contents are returned
2 REM	REMainder calculation This indicator selects whether the quotient or the remainder is returned in the RES register. The combined CSR[REM] and CSR[USGN] bits define four possible divide operations: • If CSR[REM, USGN] = 0b00, perform a signed divide, returning the quotient • If CSR[REM, USGN] = 0b01, perform an unsigned divide, returning the quotient • If CSR[REM, USGN] = 0b10, perform a signed divide, returning the remainder • If CSR[REM, USGN] = 0b11, perform an unsigned divide, returning the remainder 0 Return the quotient in the RES for the divide calculation 1 Return the remainder in the RES for the divide calculation
1 USGN	Unsigned calculation This indicator selects whether a signed (default) or unsigned divide is performed. See the CSR[REM] description for the encoding of the four possible divide operations. 0 Perform a signed divide 1 Perform an unsigned divide
0 SRT	Start When written with a logical one and CSR[DFS] = 1, this flag initiates a divide operation. If written as a logical one with CSR[DFS] = 0, it is ignored. This bit always reads as a zero. The state of the register write data defines this bit's function. 0 No operation initiated 1 If CSR[DFS] = 1, then initiate a divide calculation, else ignore

6.4.4 Result Register (MMDVSQ_RES)

This register is loaded with the result of the divide or square root calculation. It is updated by the MMDVSQ hardware at the completion of the calculation. When a square root operation is performed (on an unsigned 32-bit number), the result is limited to a 16-bit value with RES[31:16] = 0x0000. Any memory access (read or write) of the RES register while the module is busy during a calculation causes the access to be stalled (using wait states) until the calculation completes and the new result written into the register.

Address: F000_4000h base + Ch offset = F000_400Ch

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

* Notes:
- x = Undefined at reset.

MMDVSQ_RES field descriptions

Field	Description
RESULT	Result This is the output result for a divide or square root calculation.

6.4.5 Radicand Register (MMDVSQ_RCND)

The write-only radicand register is loaded with the input “square” number. A memory write to the radicand register initiates a square root calculation. While the MMDVSQ module is busy performing a square root calculation, any memory write access to the RCND register causes the write access to be stalled (using wait states) until the square root calculation finishes. Any attempted read of the radicand register terminates with an error.

Address: F000_4000h base + 10h offset = F000_4010h

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

* Notes:
- x = Undefined at reset.

MMDVSQ_RCND field descriptions

Field	Description
RADICAND	Radicand This is the input radicand for a square root calculation, that is, the input "square" number.

6.5 Functional description

This section details the algorithms, execution times of the MMDVSQ, and the software interface to the module.

6.5.1 Algorithms

This section provides more details on the integer divide and square root algorithms.

6.5.1.1 Integer divide including special cases

6.5.1.1.1 Overview

The MMDVSQ module implements a "shift, test, and restore" radix-2 algorithm for unsigned integer divide operations. When performing a signed divide calculation, negative input operands are converted into 2's complement positive numbers first, an unsigned divide performed, and the sign of the results based on the input operand signs, namely:

- The sign of the remainder is the same as the sign of the dividend
- The quotient is negated if the signs of the dividend and divisor are different

The hardware implementation processes two bits per machine cycle and includes "early termination" logic where the execution time is data dependent, based on the magnitude of the positive dividend. See Table 6-4 for more execution time details.

6.5.1.1.2 Special case: Overflow

There is a single "special overflow case" affecting signed integer divides. If the dividend = 0x8000_0000 and the divisor = 0xFFFF_FFFF, the result of this ($-2^{31}/-1$) operation cannot be expressed as a 32-bit 2's complement number. For this case, the MMDVSQ exactly follows the Arm Cortex-Mx definition and returns 0x8000_0000 (the lower 32 bits of the $+2^{31}$ result) as the quotient with no indication of the overflow condition. If the remainder is selected as the output of this calculation, it returns 0x0000_0000.

6.5.1.1.3 Special case: Divide-by-Zero

For both signed and unsigned divides, if the divisor is zero, the MMDVSQ hardware detects this condition and the CSR[DZ] indicator set. The quotient result is forced to 0x0000_0000. If the remainder is selected as the output of this calculation, it also returns 0x0000_0000. Additionally, if CSR[DZE] = 1, then an attempted read of the Result register (RES) is error terminated to provide a simple mechanism to signal software of the divide-by-zero condition.

6.5.1.2 Integer square root

6.5.1.2.1 Overview

The unsigned square root algorithm begins by creating a 32-bit “one-hot” bit vector signaling the highest power of four of the contents of the Radicand register (RCND). It then iterates through an algorithm involving magnitude comparisons of the RCND register versus the working result plus bit vector summation, conditional decrementing of the radicand, a 1-bit right shift of the result, and a 2-bit right shift of the one-hot bit vector.

Processing two bits of the radicand per cycle, the result register finishes with the integer portion of the square root calculation. The module includes early termination logic so that the execution time is data dependent, based on the magnitude of the input radicand. See Table 6-5 for more execution time details. Since both algorithms share common hardware structures, the incremental cost of the square root logic is an extremely small delta to the basic divide hardware.

The square root algorithm was exhaustively compared (that is, all 2^{32} possible input values) against the standard GNU C library implementation, which converts the unsigned integer input into a double-precision floating-point number, calculates the double-precision square root and then converts it back into an unsigned integer. Each input value calculated identical square root results.

6.5.1.2.2 Square root using Q notation

Consider the use of Q notation for square root calculations returning fractional values. The following description is taken from http://en.wikipedia.org/wiki/Q_(number_format).

Q is a fixed point number format where the number of fractional bits (and optionally the number of integer bits) is specified. For example, a Q15 number has 15 fractional bits; a Q1.14 number has 1 integer bit and 14 fractional bits. Q format is often used in hardware that does not have a floating-point unit and in applications that require constant resolution.

Q format numbers are (notionally) fixed point numbers (but not actually a number itself); that is, they are stored and operated upon as regular binary numbers (i.e. signed integers), thus allowing standard integer hardware/ALU to perform rational number calculations. The number of integer bits, fractional bits and the underlying word size are to be chosen by the programmer on an application-specific basis - the programmer's choices of the foregoing will depend on the range and resolution needed for the numbers. The machine itself remains oblivious to the notional fixed point representation being employed - it merely performs integer arithmetic the way it knows how. Ensuring that the computational results are valid in the Q format representation is the responsibility of the programmer.

The Q notation is written as Qm.n, where:

- *Q designates that the number is in the Q format notation - the Texas Instruments representation for signed fixed-point numbers (the "Q" being reminiscent of the standard symbol for the set of rational numbers).*
- *m is the number of bits set aside to designate the two's complement integer portion of the number, exclusive of the sign bit (therefore if m is not specified it is taken as zero).*
- *n is the number of bits used to designate the fractional portion of the number, i.e. the number of bits to the right of the binary point. (If n = 0, the Q numbers are integers - the degenerate case).*

Note that the most significant bit is always designated as the sign bit (the number is stored as a two's complement number) in order to allow standard arithmetic-logic hardware to manipulate Q numbers. Representing a signed fixed-point data type in Q format therefore always requires m+n+1 bits to account for the sign bit. Hence the smallest machine word size required to accommodate a Qm.n number is m+n+1, with the Q number left justified in the machine word.

For a given Qm.n format, using an m+n+1 bit signed integer container with n fractional bits:

- *its range is $[-2^m, 2^m - 2^{-n}]$*
- *its resolution is 2^{-n}*

For the unsigned integer format used in the MMDVSQ's square root calculation, an u(nsigned)Qm.n notation requires m+n bits (m+n = 32) for the input radicand. An uQm.n format produces an uQ(m/2).(n/2) square root. As examples, consider the following tables involving the square root of 2 and square root of "pi" calculations. As expected, as the number of fractional bits (n) increases, the error between the calculated square root and the "actual" result decreases.

Table 6-2. Square Root of 2 Calculations (√2 = 1.4142135623)

RCND [Hex]	RCND Q format	Results [Hex]	RES Q Format	Decimal	% Error
0x0000_0002	uQ32.00	0x0000_0001	uQ16.00	1.0	-29.289%
0x0002_0000	uQ16.16	0x0000_016A	uQ08.08	1.4140625	-0.011%
0x0200_0000	uQ08.24	0x0000_16A0	uQ04.12	1.4140625	-0.011%
0x2000_0000	uQ04.28	0x0000_5A82	uQ02.14	1.4141845703	-0.002%
0x8000_0000	uQ02.30	0x0000_B504	uQ01.15	1.4141845703	-0.002%

Table 6-3. Square Root of Pi Calculations (√Pi = 1.7724538509)

RCND [Hex]	RCND Q format	Results [Hex]	RES Q Format	Decimal	% Error
0x0000_0003	uQ32.0	0x0000_0001	uQ16.00	1.0	-43.581%
0x0003_243F	uQ16.16	0x0000_01C5	uQ08.08	1.76953125	-0.165%
0x0324_3F6A	uQ08.24	0x0000_1C5B	uQ04.12	1.772216769	-0.013%
0x3243_F6A8	uQ04.28	0x0000_716F	uQ02.14	1.7723999023	-0.003%
0xC90F_DAA0	uQ02.30	0x0000_E2DF	uQ01.15	1.7724304199	-0.001%

The application of the Q notation for square root calculations provides a powerful extension for these types of fractional numeric computations using fixed-point integer processing hardware.

6.5.2 Execution times

The MMDVSQ module includes early termination logic to finish both divide and square root calculations as quickly as possible, based on the magnitude of the input operand. Accordingly, the execution time for the calculations is data dependent as defined in Table 6-4 and Table 6-5. In this context, the execution time is defined from the register write to initiate the calculation until the result register has been updated and available to read. Stated differently, it represents the time CSR[BUSY] is asserted for a given calculation. In the following two tables, "x" signals a bit with a don't care value.

Table 6-4. Divide Execution Times

CSR[USGN] ? DEND[31:0] // unsigned divide : abs(DEND[31:0]) // signed divide	Execution Time with CSR[BUSY] = 1 [cycles]
(01,1x)xx_xxxx_xxxx_xxxx__xxxx_xxxx_xxxx_xxxx	17
00(01,1x)_xxxx_xxxx_xxxx__xxxx_xxxx_xxxx_xxxx	16
0000_(01,1x)xx_xxxx_xxxx__xxxx_xxxx_xxxx_xxxx	15
0000_00(01,1x)_xxxx_xxxx__xxxx_xxxx_xxxx_xxxx	14
0000_0000_(01,1x)xx_xxxx__xxxx_xxxx_xxxx_xxxx	13
0000_0000_00(01,1x)_xxxx__xxxx_xxxx_xxxx_xxxx	12
0000_0000_0000_(01,1x)xx__xxxx_xxxx_xxxx_xxxx	11
0000_0000_0000_00(01,1x)__xxxx_xxxx_xxxx_xxxx	10
0000_0000_0000_0000__(01,1x)xx_xxxx_xxxx_xxxx	9
0000_0000_0000_0000__00(01,1x)_xxxx_xxxx_xxxx	8
0000_0000_0000_0000__0000_(01,1x)xx_xxxx_xxxx	7
0000_0000_0000_0000__0000_00(01,1x)_xxxx_xxxx	6
0000_0000_0000_0000__0000_0000_(01,1x)xx_xxxx	5
0000_0000_0000_0000__0000_0000_00(01,1x)_xxxx	4
0000_0000_0000_0000__0000_0000_0000_(01,1x)xx	3
0000_0000_0000_0000__0000_0000_0000_00(01,1x)	2
0000_0000_0000_0000__0000_0000_0000_0000	1

Table 6-5. Square Root Execution Times

RCND[31:0]	Execution Time with CSR[BUSY] = 1 [cycles]
(01,1x)xx_xxxx_xxxx_xxxx__xxxx_xxxx_xxxx_xxxx	17
00(01,1x)_xxxx_xxxx_xxxx_x_xxx_xxxx_xxxx_xxxx	16
0000_(01,1x)xx_xxxx_xxxx__xxxx_xxxx_xxxx_xxxx	15
0000_00(01,1x)_xxxx_xxxx__xxxx_xxxx_xxxx_xxxx	14
0000_0000_(01,1x)xx_xxxx__xxxx_xxxx_xxxx_xxxx	13
0000_0000_00(01,1x)_xxxx__xxxx_xxxx_xxxx_xxxx	12
0000_0000_0000_(01,1x)xx__xxxx_xxxx_xxxx_xxxx	11
0000_0000_0000_00(01,1x)__xxxx_xxxx_xxxx_xxxx	10
0000_0000_0000_0000__(01,1x)xx_xxxx_xxxx_xxxx	9
0000_0000_0000_0000__00(01,1x)_xxxx_xxxx_xxxx	8
0000_0000_0000_0000__0000_(01,1x)xx_xxxx_xxxx	7
0000_0000_0000_0000__0000_00(01,1x)_xxxx_xxxx	6
0000_0000_0000_0000__0000_0000_(01,1x)xx_xxxx	5
0000_0000_0000_0000__0000_0000_00(01,1x)_xxxx	4
0000_0000_0000_0000__0000_0000_0000_(01,1x)xx	3
0000_0000_0000_0000__0000_0000_0000_00(01,1x)	2
0000_0000_0000_0000__0000_0000_0000_0000	2

6.5.3 Software interface

The programming model of the MMDVSQ is organized to be similar to the input arguments passed to software libraries for integer divide and square root functions.

6.5.3.1 Operation activation and result retrieval

The MMDVSQ supports 2 mechanisms for initiating a divide operation:

- The default mechanism is a "fast start" where a write to the DSOR register begins the divide.
- Alternatively, the start mechanism can begin after a write to the CSR register with the CSR[SRT] set.

The CSR[DFS] indicator selects the divide start mechanism.

```
if CSR[DFS] = 0
   then a divide is initiated by a write to the DSOR register
   else a divide is initiated by a write to the CSR register with CSR[SRT] = 1
```

A square root calculation is initiated by a write to the RCND register.

For both divide and square root calculations, the result of the operation is retrieved by reading the RES register. A memory read of this register while the calculation is still being performed causes the access to be stalled via the insertion of bus wait states until the new result is loaded into the register. Note a stalled bus cycle cannot be interrupted, so if system interrupt latency is a concern, the processor should execute a simple wait loop, for example, polling CSR[BUSY], before reading the RES register. This code construct is fully interruptible, so interrupt latency is minimized.

6.5.3.2 Context save and restore

Given that multiple memory-mapped register accesses are needed for each divide and square root calculation, interrupts may occur during the required sequence of operations. As a result, the MMDVSQ's programming model can be saved at entry to an interrupt service routine (ISR) and then restored when redispatching to the interrupted task.

The module's context can be saved by reading the DEND, DSOR, CSR, and RES registers and storing them as part of the task state. There is one special consideration for the task state save. If the last calculation was a zero divide and the divide-by-zero enable is set (CSR[DZE] = 1), then a read of the RES register is error terminated. To avoid a zero-divide error termination during a context save, the following sequence can be used:

1. Read DEND, DSOR, and CSR registers and save the values as part of the task state.

2. Clear CSR[DZE].
3. Read the RES register and save its value as part of the task state.

When restoring the context, special care must be taken to not initiate another divide calculation. Specifically, CSR[DFS] must be set first before reloading the DEND and DSOR registers. For example, the following sequence can be used for the context reload:

1. Write 0x0000_0020 to the CSR to disable the fast start mechanism.
2. Reload DEND, DSOR, CSR, and RES registers from the saved state.

Since the original context save of the control/status register is guaranteed to have CSR[SRT] = 0, there is no divide operation initiated when this register is reloaded in step 2.

Chapter 7
Miscellaneous Control Module (MCM)

7.1 Chip-specific Information for this Module

A generic block diagram of the processor core and platform for this class of microcontrollers is shown in the following figure. The MCM module's location is highlighted.

NOTE

BME is not supported in this device.

NOTE

DMA is not supported in this device.

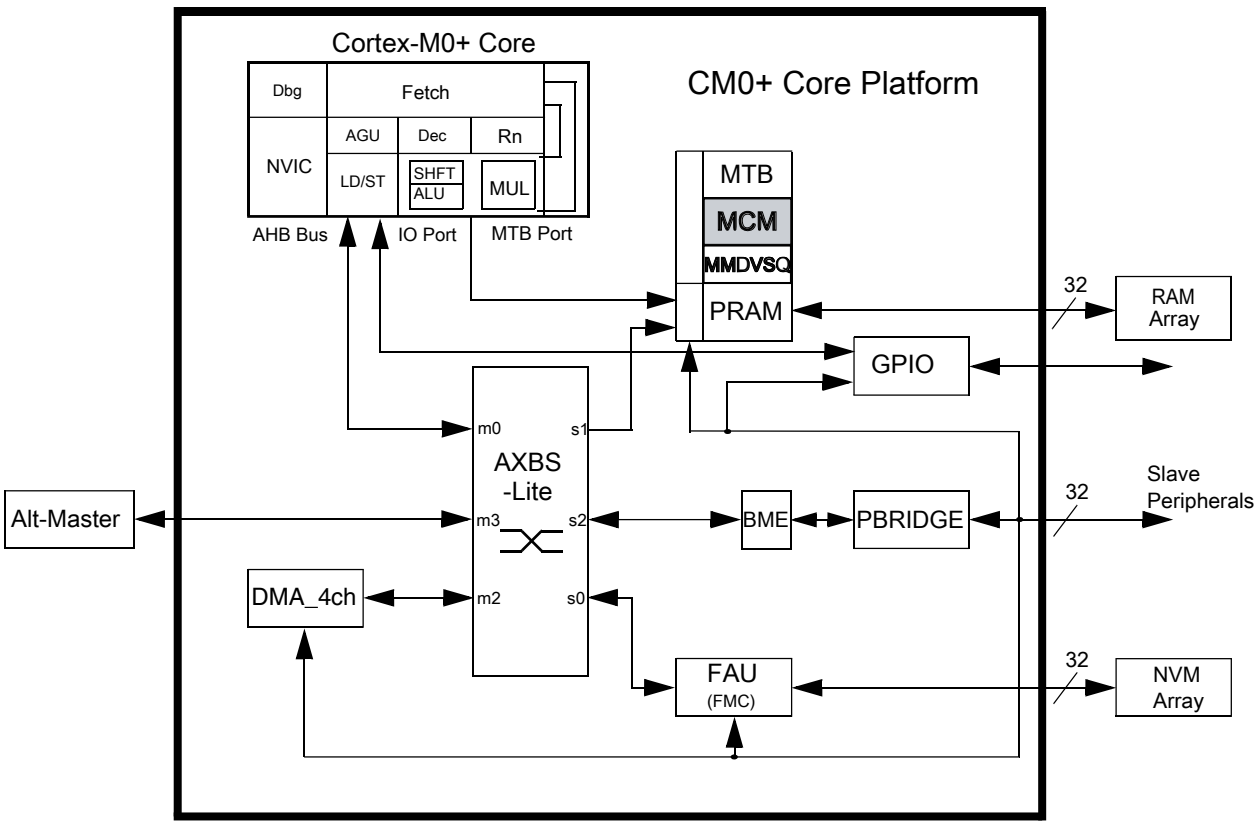


Figure 7-1. Cortex-M0+ core platform block diagram

7.2 Introduction

The Miscellaneous Control Module (MCM) provides a myriad of miscellaneous control functions.

7.2.1 Features

The MCM includes the following features:

- Program-visible information on the platform configuration
- Crossbar master arbitration policy selection
- Flash controller speculation buffer and cache configurations

7.3 Memory map/register descriptions

The memory map and register descriptions found here describe the registers using byte addresses. The registers can be written only when in supervisor mode.

MCM memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F000_3008	Crossbar Switch (AXBS) Slave Configuration (MCM_PLASC)	16	R	0007h	7.3.1/93
F000_300A	Crossbar Switch (AXBS) Master Configuration (MCM_PLAMC)	16	R	0005h	7.3.2/94
F000_300C	Platform Control Register (MCM_PLACR)	32	R/W	0000_0250h	7.3.3/94
F000_3040	Compute Operation Control Register (MCM_CPO)	32	R/W	0000_0000h	7.3.4/97

7.3.1 Crossbar Switch (AXBS) Slave Configuration (MCM_PLASC)

PLASC is a 16-bit read-only register identifying the presence/absence of bus slave connections to the device's crossbar switch.

Address: F000_3000h base + 8h offset = F000_3008h

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0								ASC							
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1

MCM_PLASC field descriptions

Field	Description
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
ASC	Each bit in the ASC field indicates whether there is a corresponding connection to the crossbar switch's slave input port. 0 A bus slave connection to AXBS input port *n* is absent. 1 A bus slave connection to AXBS input port *n* is present.

7.3.2 Crossbar Switch (AXBS) Master Configuration (MCM_PLAMC)

PLAMC is a 16-bit read-only register identifying the presence/absence of bus master connections to the device's crossbar switch.

Address: F000_3000h base + Ah offset = F000_300Ah

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0								AMC							
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

MCM_PLAMC field descriptions

Field	Description
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
AMC	Each bit in the AMC field indicates whether there is a corresponding connection to the AXBS master input port. 0 A bus master connection to AXBS input port *n* is absent 1 A bus master connection to AXBS input port *n* is present

7.3.3 Platform Control Register (MCM_PLACR)

The PLACR register selects the arbitration policy for the crossbar masters and configures the flash memory controller.

The speculation buffer and cache in the flash memory controller is configurable via PLACR[15:10].

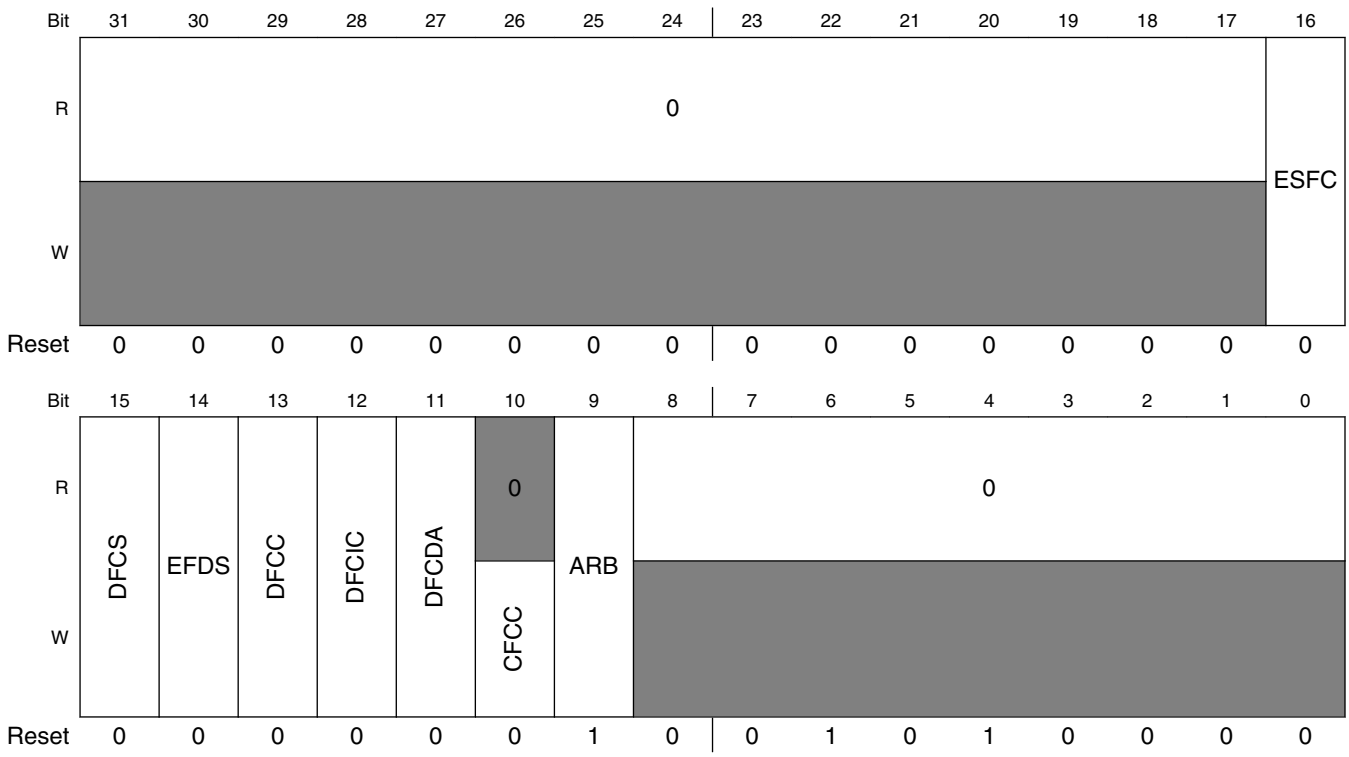
The speculation buffer is enabled only for instructions after reset. It is possible to have these states for the speculation buffer:

DFCS	EFDS	Description
0	0	Speculation buffer is on for instruction and off for data.
0	1	Speculation buffer is on for instruction and on for data.
1	X	Speculation buffer is off.

The cache in flash controller is enabled and caching both instruction and data type fetches after reset. It is possible to have these states for the cache:

DFCC	DFCIC	DFCDA	Description
0	0	0	Cache is on for both instruction and data.
0	0	1	Cache is on for instruction and off for data.
0	1	0	Cache is off for instruction and on for data.
0	1	1	Cache is off for both instruction and data.
1	X	X	Cache is off.

Address: F000_3000h base + Ch offset = F000_300Ch



MCM_PLACR field descriptions

Field	Description
31–17 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
16 ESFC	Enable Stalling Flash Controller Enables stalling flash controller when flash is busy.

Table continues on the next page...

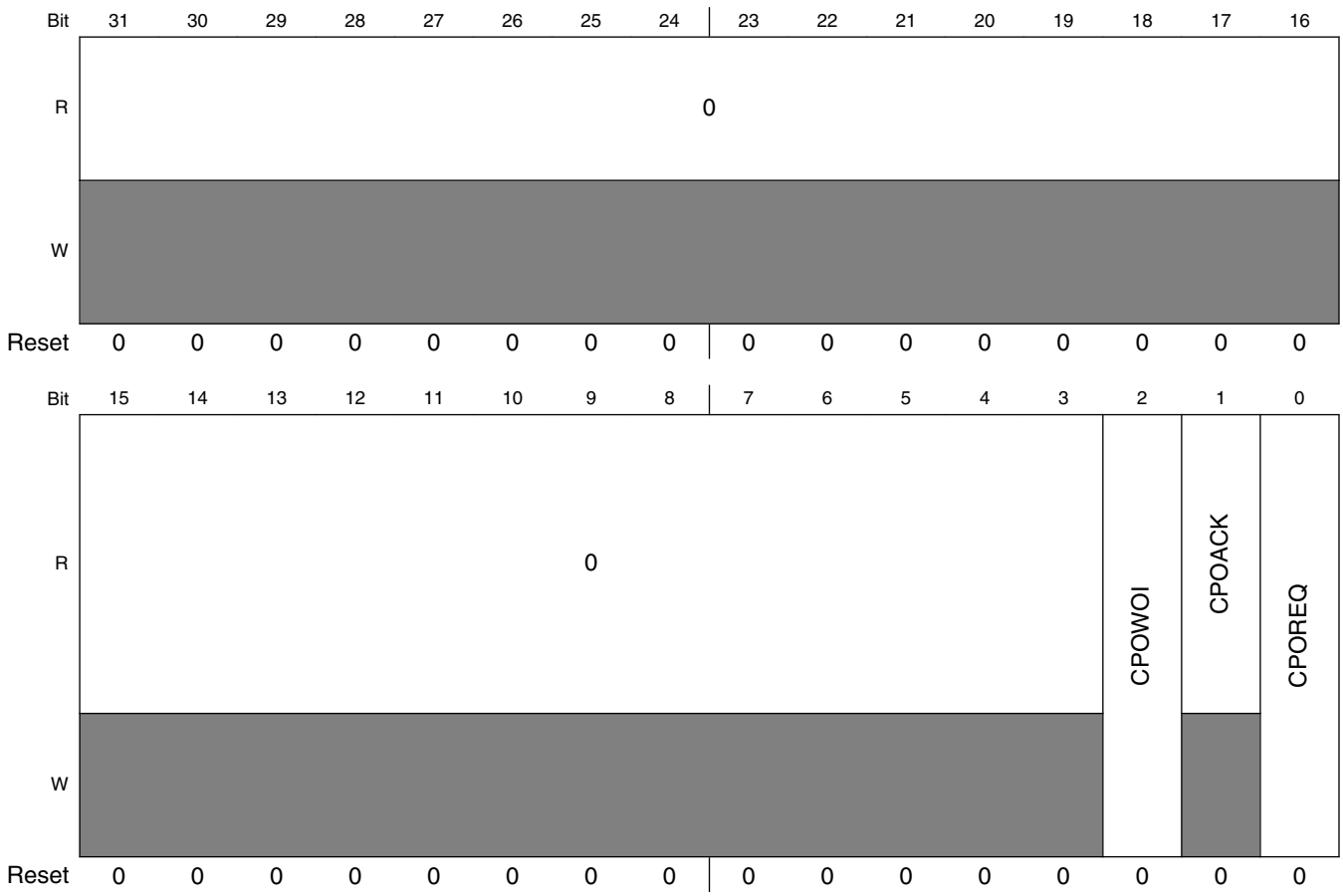
MCM_PLACR field descriptions (continued)

Field	Description
	When software needs to access the flash memory while a flash memory resource is being manipulated by a flash command, software can enable a stall mechanism to avoid a read collision. The stall mechanism allows software to execute code from the same block on which flash operations are being performed. However, software must ensure the sector the flash operations are being performed on is not the same sector from which the code is executing. ESFC enables the stall mechanism. This bit must be set only just before the flash operation is executed and must be cleared when the operation completes. 0 Disable stalling flash controller when flash is busy. 1 Enable stalling flash controller when flash is busy.
15 DFCS	Disable Flash Controller Speculation Disables flash controller speculation. 0 Enable flash controller speculation. 1 Disable flash controller speculation.
14 EFDS	Enable Flash Data Speculation Enables flash data speculation. 0 Disable flash data speculation. 1 Enable flash data speculation.
13 DFCC	Disable Flash Controller Cache Disables flash controller cache. 0 Enable flash controller cache. 1 Disable flash controller cache.
12 DFCIC	Disable Flash Controller Instruction Caching Disables flash controller instruction caching. 0 Enable flash controller instruction caching. 1 Disable flash controller instruction caching.
11 DFCDA	Disable Flash Controller Data Caching Disables flash controller data caching. 0 Enable flash controller data caching 1 Disable flash controller data caching.
10 CFCC	Clear Flash Controller Cache Writing a 1 to this field clears the cache. Writing a 0 to this field is ignored. This field always reads as 0.
9 ARB	Arbitration select 0 Fixed-priority arbitration for the crossbar masters 1 Round-robin arbitration for the crossbar masters
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

7.3.4 Compute Operation Control Register (MCM_CPO)

This register controls the Compute Operation.

Address: F000_3000h base + 40h offset = F000_3040h



MCM_CPO field descriptions

Field	Description
31–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 CPOWOI	Compute Operation Wake-up on Interrupt 0 No effect. 1 When set, the CPOREQ is cleared on any interrupt or exception vector fetch.
1 CPOACK	Compute Operation Acknowledge 0 Compute operation entry has not completed or compute operation exit has completed. 1 Compute operation entry has completed or compute operation exit has not completed.
0 CPOREQ	Compute Operation Request This bit is auto-cleared by vector fetching if CPOWOI = 1.

Table continues on the next page...

MCM_CPO field descriptions (continued)

Field	Description
	0 Request is cleared. 1 Request Compute Operation.

Chapter 8
Crossbar Switch Lite (AXBS-Lite)

8.1 Chip-specific Information for this Module

A generic block diagram of the processor core and platform for this class of microcontrollers is shown in the following figure. The AXBS module's location is highlighted.

NOTE

BME and DMA are not supported in this device.

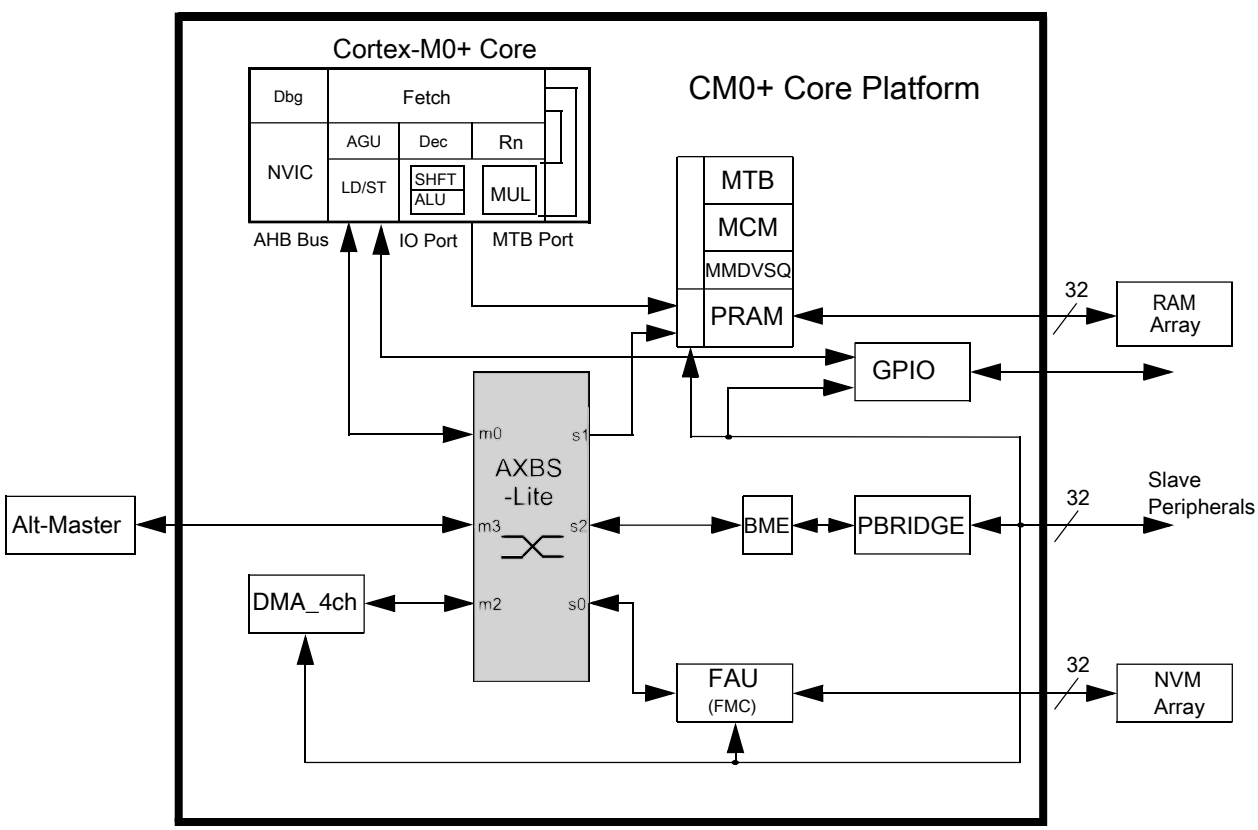


Figure 8-1. Cortex-M0+ core platform block diagram

The masters connected to the crossbar switch are assigned as follows:

Master module	Master port number
ARM core I/D bus	0
ARM core system bus	1
DMA	2

The slaves connected to the crossbar switch are assigned as follows:

Slave module	Slave port number
Flash memory controller	0
SRAM controllers	1
Peripheral bridge 0 / GPIO[1]	2

1. See System memory map for access restrictions.

NOTE

This crossbar switch has no memory mapped configuration registers. The arbitration method in the crossbar switch is programmable by MCM registers.

NOTE

The AXBS master and slave configuration information can be read from MCM registers.

8.2 Introduction

The information found here provides information on the layout, configuration, and programming of the crossbar switch.

The crossbar switch connects bus masters and bus slaves using a crossbar switch structure. This structure allows up to four bus masters to access different bus slaves simultaneously, while providing arbitration among the bus masters when they access the same slave.

8.2.1 Features

The crossbar switch includes these features:

- Symmetric crossbar bus switch implementation

    - Allows concurrent accesses from different masters to different slaves
- Up to single-clock 32-bit transfer
- Programmable configuration for fixed-priority or round-robin slave port arbitration (see the chip-specific information).

8.3 Memory Map / Register Definition

This crossbar switch is designed for minimal gate count. It, therefore, has no memory-mapped configuration registers.

Please see the chip-specific information for information on whether the arbitration method in the crossbar switch is programmable, and by which module.

8.4 Functional Description

8.4.1 General operation

When a master accesses the crossbar switch, the access is immediately taken. If the targeted slave port of the access is available, then the access is immediately presented on the slave port. Single-clock or zero-wait-state accesses are possible through the crossbar. If the targeted slave port of the access is busy or parked on a different master port, the requesting master simply sees wait states inserted until the targeted slave port can service the master's request. The latency in servicing the request depends on each master's priority level and the responding slave's access time.

Because the crossbar switch appears to be just another slave to the master device, the master device has no knowledge of whether it actually owns the slave port it is targeting. While the master does not have control of the slave port it is targeting, it simply waits.

After the master has control of the slave port it is targeting, the master remains in control of the slave port until it relinquishes the slave port by running an IDLE cycle or by targeting a different slave port for its next access.

The master can also lose control of the slave port if another higher-priority master makes a request to the slave port.

The crossbar terminates all master IDLE transfers, as opposed to allowing the termination to come from one of the slave buses. Additionally, when no master is requesting access to a slave port, the crossbar drives IDLE transfers onto the slave bus, even though a default master may be granted access to the slave port.

When a slave bus is being idled by the crossbar, it remains parked with the last master to use the slave port. This is done to save the initial clock of arbitration delay that otherwise would be seen if the same master had to arbitrate to gain control of the slave port.

8.4.2 Arbitration

The crossbar switch supports two arbitration algorithms:

- Fixed priority
- Round-robin

The selection of the global slave port arbitration algorithm is described in the crossbar switch chip-specific information.

8.4.2.1 Arbitration during undefined length bursts

All lengths of burst accesses lock out arbitration until the last beat of the burst.

8.4.2.2 Fixed-priority operation

When operating in fixed-priority mode, each master is assigned a unique priority level with the highest numbered master having the highest priority (for example, in a system with 5 masters, master 1 has lower priority than master 3). If two masters request access to the same slave port, the master with the highest priority gains control over the slave port.

NOTE

In this arbitration mode, a higher-priority master can monopolize a slave port, preventing accesses from any lower-priority master to the port.

When a master makes a request to a slave port, the slave port checks whether the new requesting master's priority level is higher than that of the master that currently has control over the slave port, unless the slave port is in a parked state. The slave port performs an arbitration check at every clock edge to ensure that the proper master, if any, has control of the slave port.

The following table describes possible scenarios based on the requesting master port:

Table 8-1. How the Crossbar Switch grants control of a slave port to a master

When	Then the Crossbar Switch grants control to the requesting master
Both of the following are true: • The current master is not running a transfer. • The new requesting master's priority level is higher than that of the current master.	At the next clock edge
The requesting master's priority level is lower than the current master.	At the conclusion of one of the following cycles: • An IDLE cycle • A non-IDLE cycle to a location other than the current slave port

8.4.2.3 Round-robin priority operation

When operating in round-robin mode, each master is assigned a relative priority based on the master port number. This relative priority is compared to the master port number (ID) of the last master to perform a transfer on the slave bus. The highest priority requesting master becomes owner of the slave bus at the next transfer boundary. Priority is based on how far ahead the ID of the requesting master is to the ID of the last master.

After granted access to a slave port, a master may perform as many transfers as desired to that port until another master makes a request to the same slave port. The next master in line is granted access to the slave port at the next transfer boundary, or possibly on the next clock cycle if the current master has no pending access request.

As an example of arbitration in round-robin mode, assume the crossbar is implemented with master ports 0, 1, 4, and 5. If the last master of the slave port was master 1, and master 0, 4, and 5 make simultaneous requests, they are serviced in the order: 4 then 5 then 0.

The round-robin arbitration mode generally provides a more fair allocation of the available slave-port bandwidth (compared to fixed priority) as the fixed master priority does not affect the master selection.

8.5 Initialization/application information

No initialization is required for the crossbar switch. See the chip-specific crossbar switch information for the reset state of the arbitration scheme.

Chapter 9
Peripheral Bridge (AIPS-Lite)

9.1 Chip-specific information for this module

9.1.1 Instantiation Information

This device contains one peripheral bridge.

A generic block diagram of the processor core and platform for this class of microcontrollers is shown in the following figure. The AIPS (PBRIDGE) module's location is highlighted.

NOTE

BME and DMA are not supported in this device.

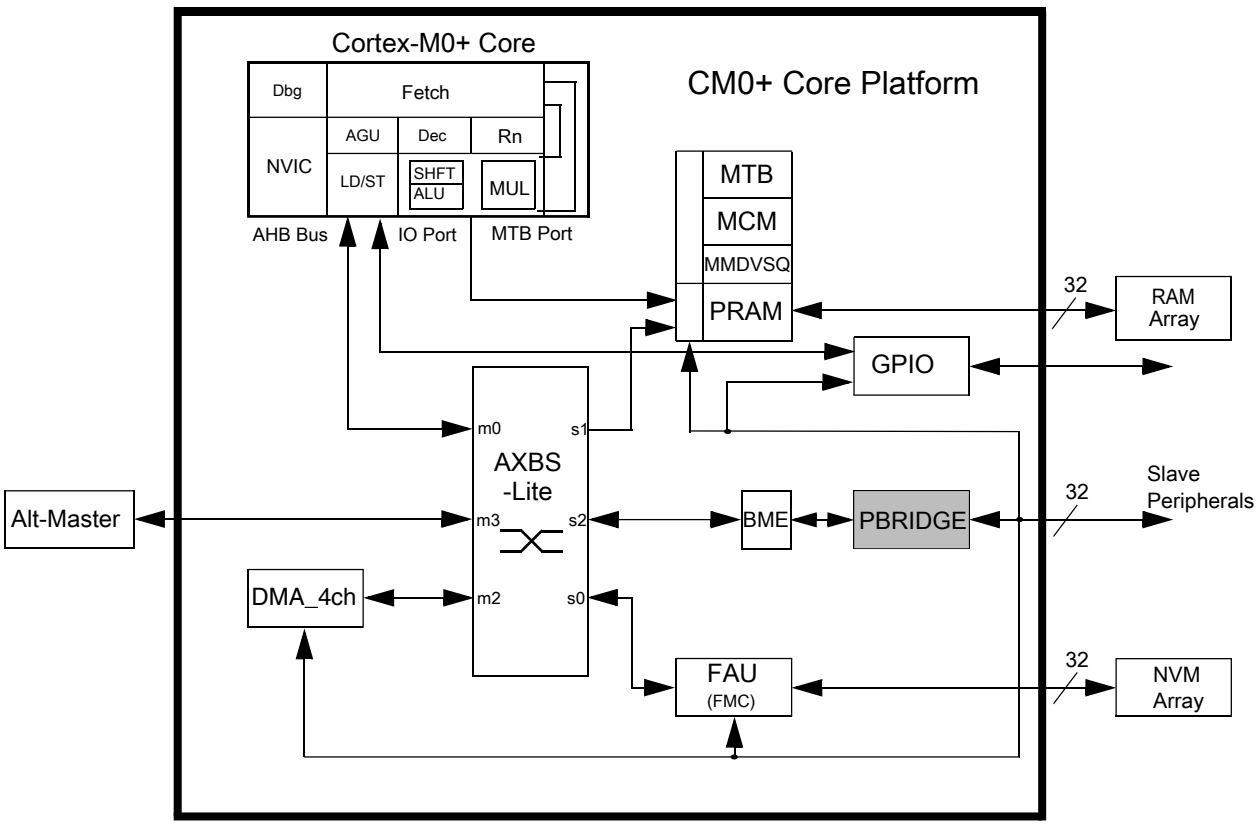


Figure 9-1. Cortex-M0+ core platform block diagram

9.1.1.1 Peripheral slot assignment

The peripheral bridge is used to access the registers of most of the modules on this device. See Peripheral Bridge (AIPS-Lite) Memory Map for the memory slot assignment.

9.2 Introduction

The peripheral bridge converts the crossbar switch interface to an interface that can access most of the slave peripherals on this chip.

The peripheral bridge occupies 64 MB of the address space, which is divided into peripheral slots of 4 KB. (It might be possible that all the peripheral slots are not used. See the memory map chapter for details on slot assignments.) The bridge includes separate clock enable inputs for each of the slots to accommodate slower peripherals.

9.2.1 Features

Key features of the peripheral bridge are:

- Supports peripheral slots with 8-, 16-, and 32-bit datapath width

9.2.2 General operation

The slave devices connected to the peripheral bridge are modules which contain a programming model of control and status registers. The system masters read and write these registers through the peripheral bridge.

The register maps of the peripherals are located on 4-KB boundaries. Each peripheral is allocated one or more 4-KB block(s) of the memory map. Two global external module enables are available for the remaining address space to allow for customization and expansion of addressed peripheral devices.

9.3 Memory map/register definition

The AIPS module(s) on this device do(es) not contain any user-programmable registers.

9.4 Functional description

The peripheral bridge functions as a bus protocol translator between the crossbar switch and the slave peripheral bus.

The peripheral bridge manages all transactions destined for the attached slave devices and generates select signals for modules on the peripheral bus by decoding accesses within the attached address space.

9.4.1 Access support

Aligned and misaligned 32-bit, 16-bit, and byte accesses are supported for 32-bit peripherals. Misaligned accesses are supported to allow memory to be placed on the slave peripheral bus. Peripheral registers must not be misaligned, although no explicit checking is performed by the peripheral bridge. All accesses are performed with a single transfer.

All accesses to the peripheral slots must be sized less than or equal to the designated peripheral slot size. If an access is attempted that is larger than the targeted port, an error response is generated.

Chapter 10
Trigger MUX Control (TRGMUX)

10.1 Chip-specific information for this module

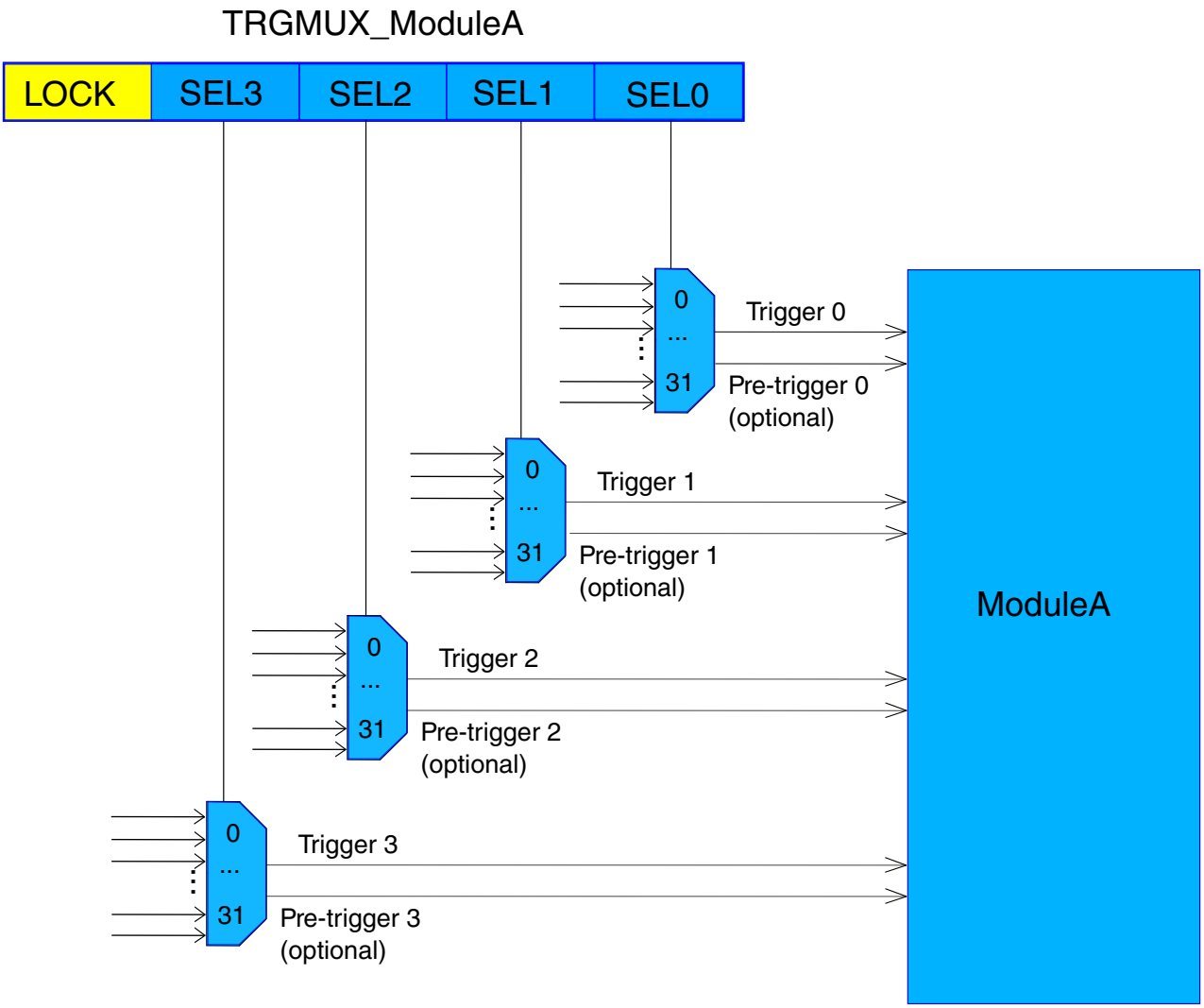
10.1.1 Module Interconnectivity

The module interconnectivity scheme is based on the TRGMUX. The TRGMUX introduces an extremely flexible methodology for connecting various trigger sources to multiple pins/peripherals. This TRGMUX design has removed some trigger inputs, and added one pre-stage trigger source TRGMUX1 for the TRGMUX0. TRGMUX1 supports up to 32 trigger sources and has 8 outputs. These 8 outputs will be the trigger inputs of TRGMUX0. TRGMUX0 supports up to 32 input sources, and its output will be the target modules.

With the TRGMUX, each peripheral which accepts external triggers will usually have one specific 32-bit trigger control register. Each control register supports up to 4 triggers, and each trigger can be selected from up to 32 inputs.

For some trigger sources, there is optional pre-trigger. The trigger and the pre-trigger are 1-1 paired up, and are both selected by the same trigger control register. Not every module has pre-trigger input, please refer to the respective module chapter for details.

Following is the main structure of TRGMUX, and take ModuleA as an example.



NOTE

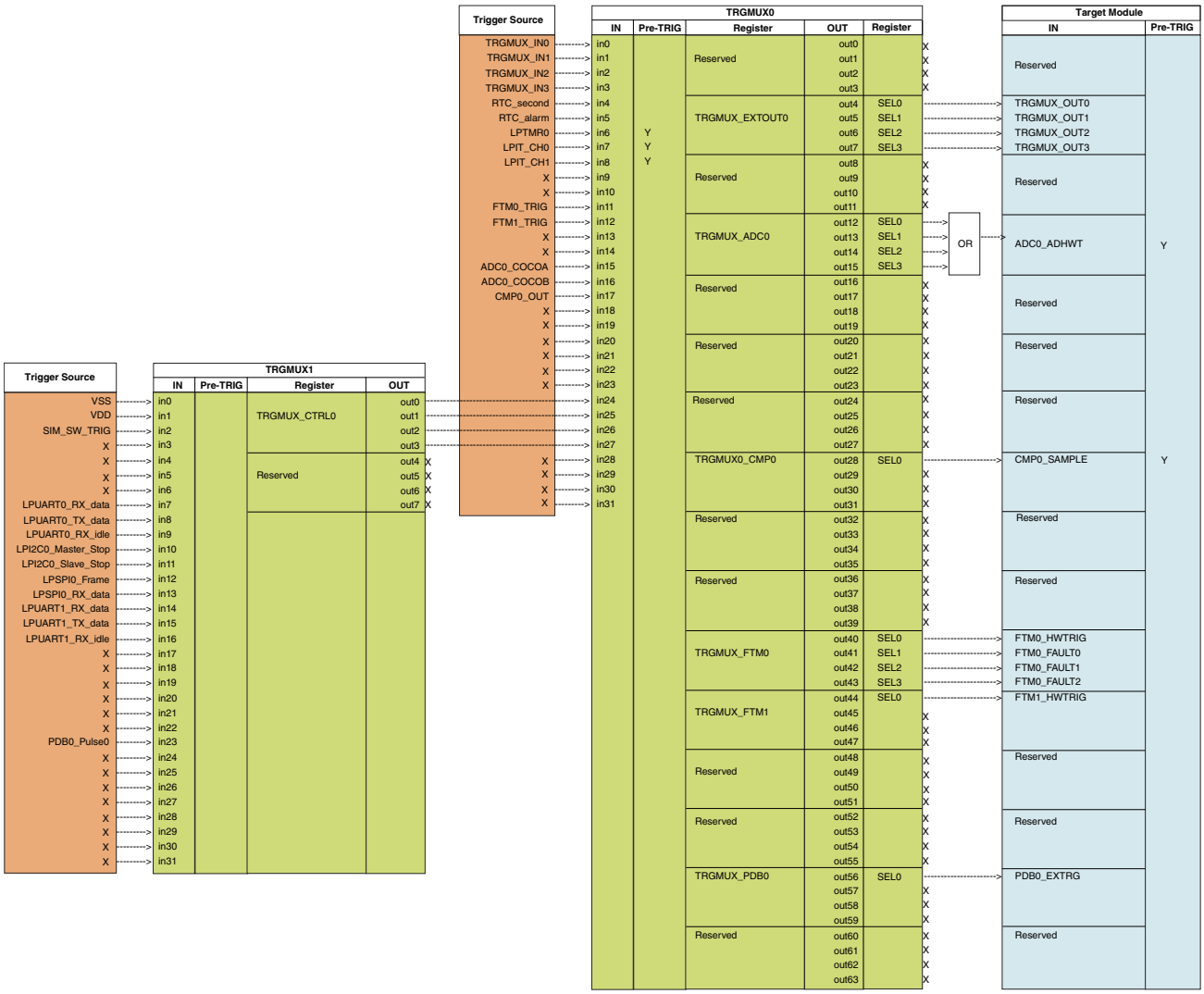
Each TRGMUX control register supports up to 4 trigger channels, but it's not necessary for each module to implement all of the 4 triggers. For those modules (e.g. external output, etc.) which needs more than 4 trigger inputs, multiple control registers are created to support that.

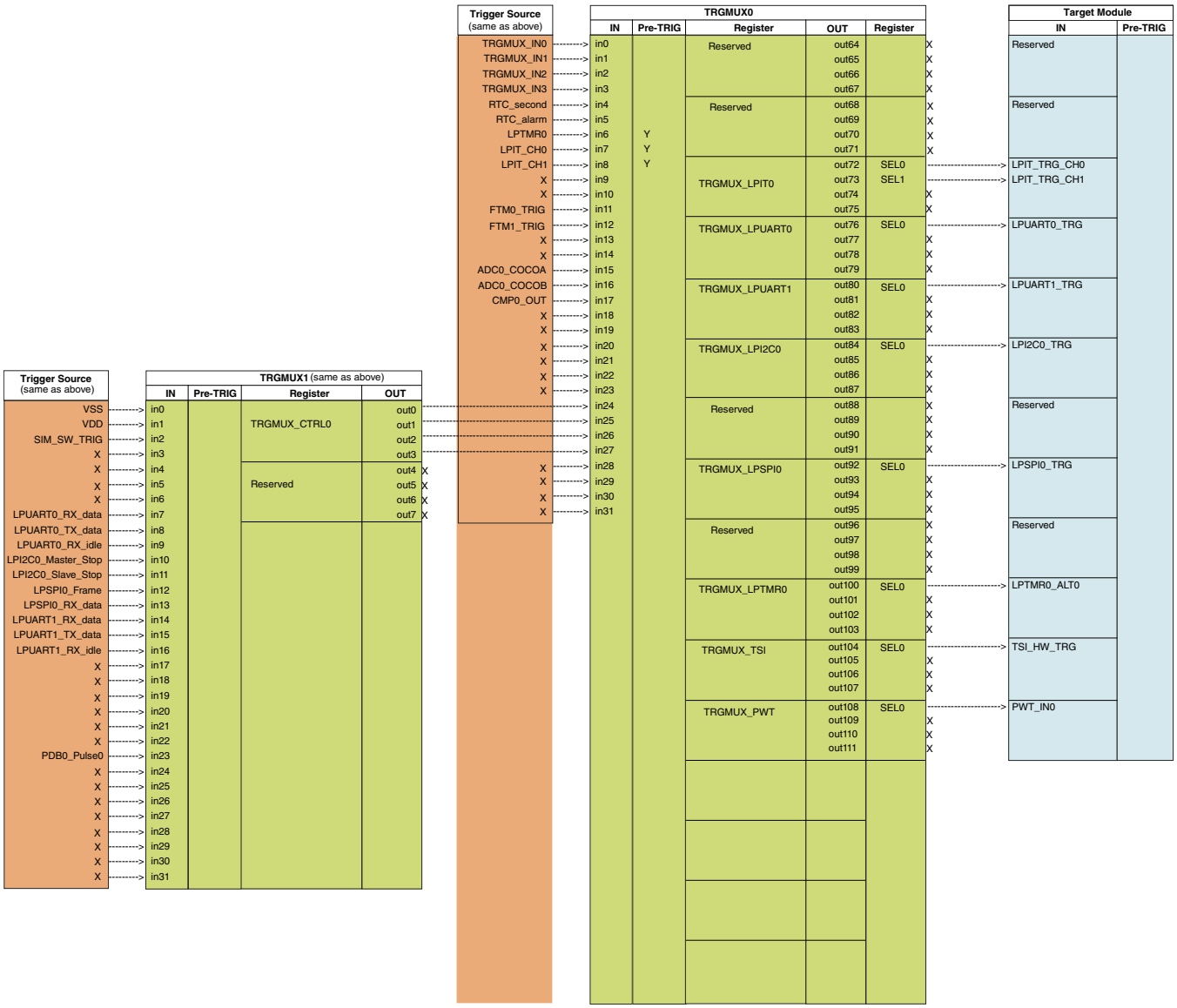
The trigger input and peripheral trigger control are assigned as the following figure indication.

Trigger source	Explanation
VSS	VSS trigger
VDD	VDD trigger
SIM_SW_TRG	Software trigger controlled by SIM module
TRGMUX_INx	TRGMUX external trigger input x
LPUARTx_RX_data	LPUARTx receive end of word trigger

Table continues on the next page...

LPUARTx_TX_data	LPUARTx transmit end of word trigger
LPUARTx_RX_idle	LPUARTx receive idle detected trigger
LPI2Cx_Master_Stop	LPI2Cx master stop or repeated start trigger
LPI2Cx_Slave_Stop	LPI2Cx slave stop or repeated start trigger
LPSPIx_Frame	LPSPIx end of frame trigger
LPSPIx_RX_data	LPSPIx receive data trigger
ADCx_COCOA	ADCx conversion complete trigger for data result A
ADCx_COCOB	ADCx conversion complete trigger for data result B
PDBx_Pulse0	PDBx pulse0 trigger
RTC_second	RTC second trigger
RTC_alarm	RTC alarm trigger
LPTMRx	LPTMRx timer counter match trigger
LPIT_CHx	LPIT channel x timer counter match trigger
FTMx_TRIG	FTMx counter initialization trigger (init_trig) and channel match trigger (ext_trig)
CMPx_OUT	CMPx output trigger


Trigger Source
VSS
VDD
SIM_SW_TRIG
LPUART0_RX_data
LPUART0_TX_data
LPUART0_RX_idle
LPI2C0_Master_Stop
LPI2C0_Slave_Stop
LPSPI0_Frame
LPSPI0_RX_data
LPUART1_RX_data
LPUART1_TX_data
LPUART1_RX_idle
PDB0_Pulse0
TRGMUX1
IN
Pre-TRIG
Register
OUT
TRGMUX_CTRL0
Reserved
Trigger Source
TRGMUX_IN0
TRGMUX_IN1
TRGMUX_IN2
TRGMUX_IN3
RTC_second
RTC_alarm
LPTMR0
LPIT_CH0
LPIT_CH1
FTM0_TRIG
FTM1_TRIG
ADC0_COCOA
ADC0_COCOB
CMP0_OUT
TRGMUX0
Reserved
TRGMUX_EXTOUT0
TRGMUX_ADC0
TRGMUX0_CMP0
TRGMUX_FTM0
TRGMUX_FTM1
TRGMUX_PDB0
SEL0
SEL1
SEL2
SEL3
OR
Target Module
TRGMUX_OUT0
TRGMUX_OUT1
TRGMUX_OUT2
TRGMUX_OUT3
ADC0_ADHWT
CMP0_SAMPLE
FTM0_HWTRIG
FTM0_FAULT0
FTM0_FAULT1
FTM0_FAULT2
FTM1_HWTRIG
PDB0_EXTRG



NOTE

For each ADC, the triggers are OR'ed together to provide a flexible trigger scheme for the hardware trigger of each ADC, while the pre-triggers are not OR'ed. The LPIT pre-triggers can be pre-triggers for each ADC. There is another PDB pre-trigger scheme existing on this device, which is not through TRGMUX. Please refer to the ADC chapter for details on ADC trigger implementation on this device.

10.2 Introduction

The trigger multiplexer (TRGMUX) module allows software to configure the trigger inputs for various peripherals.

10.3 Features

The TRGMUX module allows software to select the trigger source for peripherals. The block diagram below shows the trigger selection logic of the TRGMUX module.

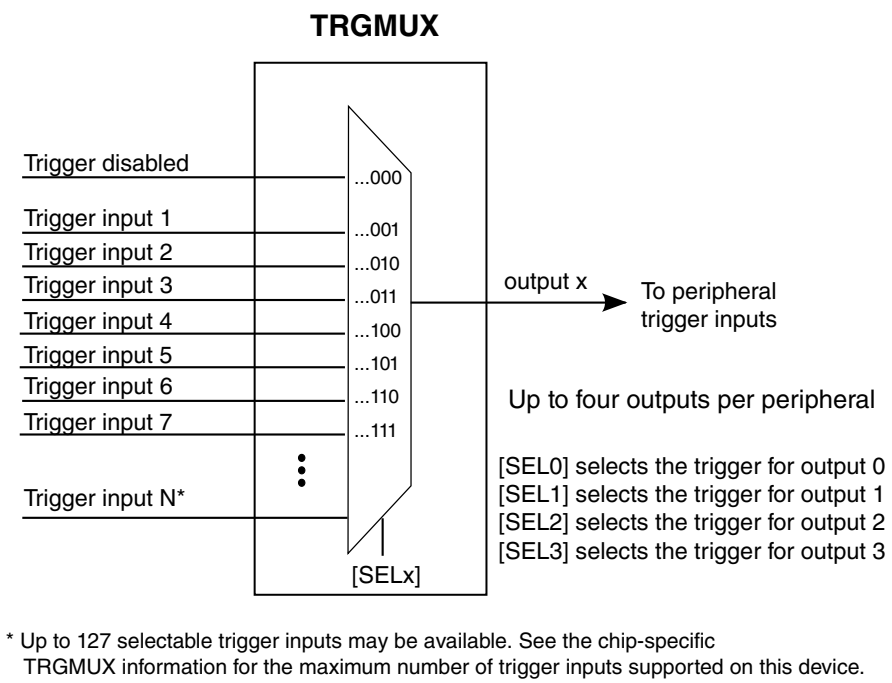


Figure 10-1. TRGMUX block diagram

Each peripheral has its own dedicated TRGMUX register. See each peripheral's TRGMUX register for details.

10.4 Memory map and register definition

The TRGMUX registers contain fields for selecting trigger sources for peripheral modules.

TRGMUX registers can be written only in supervisor mode.

10.4.1 TRGMUX0 register descriptions

10.4.1.1 TRGMUX Memory map

Table 10-1. Select Bit Fields

Field	Function
SELx	This read/write field is used to configure the MUX select for the peripheral trigger inputs. 000_0000 - (0x00) TRGMUX_IN0 is selected. 000_0001 - (0x01) TRGMUX_IN1 is selected. 000_0010 - (0x02) TRGMUX_IN2 is selected. 000_0011 - (0x03) TRGMUX_IN3 is selected. 000_0100 - (0x04) RTC_second is selected. 000_0101 - (0x05) RTC_alarm is selected. 000_0110 - (0x06) LPTMR0 is selected. 000_0111 - (0x07) LPIT_CH0 is selected. 000_1000 - (0x08) LPIT_CH1 is selected. 000_1001 - (0x09) Unused 000_1010 - (0x0A) Unused 000_1011 - (0x0B) FTM0_TRIG is selected. 000_1100 - (0x0C) FTM1_TRIG is selected. 000_1101 - (0x0D) Unused 000_1110 - (0x0E) Unused 000_1111 - (0x0F) ADC0_COCOA is selected. 001_0000 - (0x10) ADC0_COCOB is selected. 001_0001 - (0x11) CMP0_OUT is selected. 001_0010 - (0x12) Unused 001_0011 - (0x13) Unused 001_0100 - (0x14) Unused 001_0101 - (0x15) Unused 001_0110 - (0x16) Unused 001_0111 - (0x17) Unused 001_1000 - (0x18) TRGMUX1 Output 0 is selected. 001_1001 - (0x19) TRGMUX1 Output 1 is selected. 001_1010 - (0x1A) TRGMUX1 Output 2 is selected. 001_1011 - (0x1B) TRGMUX1 Output 3 is selected. 001_1100 - (0x1C) Unused 001_1101 - (0x1D) Unused

Table 10-1. Select Bit Fields

Field	Function
	001_1110 - (0x1E) Unused 001_1111 - (0x1F) Unused

TRGMUX0 base address: 4006_2000h

Offset	Register	Width (In bits)	Access	Reset value
4h	TRGMUX EXTOUT0 Register (EXTOUT0)	32	RW	0000_0000h
Ch	TRGMUX ADC0 Register (ADC0)	32	RW	0000_0000h
1Ch	TRGMUX CMP0 Register (CMP0)	32	RW	0000_0000h
28h	TRGMUX FTM0 Register (FTM0)	32	RW	0000_0000h
2Ch	TRGMUX FTM1 Register (FTM1)	32	RW	0000_0000h
38h	TRGMUX PDB0 Register (PDB0)	32	RW	0000_0000h
48h	TRGMUX LPIT0 Register (LPIT0)	32	RW	0000_0000h
4Ch	TRGMUX LPUART0 Register (LPUART0)	32	RW	0000_0000h
50h	TRGMUX LPUART1 Register (LPUART1)	32	RW	0000_0000h
54h	TRGMUX LPI2C0 Register (LPI2C0)	32	RW	0000_0000h
5Ch	TRGMUX LPSPI0 Register (LPSPI0)	32	RW	0000_0000h
64h	TRGMUX LPTMR0 Register (LPTMR0)	32	RW	0000_0000h
68h	TRGMUX TSI Register (TSI)	32	RW	0000_0000h
6Ch	TRGMUX PWT Register (PWT)	32	RW	0000_0000h

10.4.1.2 TRGMUX EXTOUT0 Register (EXTOUT0)

10.4.1.2.1 Offset

Register	Offset
EXTOUT0	4h

10.4.1.2.2 Function

TRGMUX Register

10.4.1.2.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0		SEL3					0	0		SEL2				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0		SEL1					0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.2.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-29 —	This read-only bit field is reserved and always has the value 0.
28-24 SEL3	Trigger MUX Input 3 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 3. For the field setting definitions, see Memory map and register definition.
23 —	This read-only bit field is reserved and always has the value 0.
22-21 —	This read-only bit field is reserved and always has the value 0.
20-16 SEL2	Trigger MUX Input 2 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 2. For the field setting definitions, see Memory map and register definition.
15 —	This read-only bit field is reserved and always has the value 0.
14-13 —	This read-only bit field is reserved and always has the value 0.
12-8 SEL1	Trigger MUX Input 1 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 1. For the field setting definitions, see Memory map and register definition.
7 —	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.3 TRGMUX ADC0 Register (ADC0)

10.4.1.3.1 Offset

Register	Offset
ADC0	Ch

10.4.1.3.2 Function

TRGMUX Register

10.4.1.3.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0		SEL3					0	0		SEL2				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0		SEL1					0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.3.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written.

Table continues on the next page...

Field	Function
	1b - Register cannot be written until the next system Reset.
30-29 —	This read-only bit field is reserved and always has the value 0.
28-24 SEL3	Trigger MUX Input 3 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 3. For the field setting definitions, see Memory map and register definition.
23 —	This read-only bit field is reserved and always has the value 0.
22-21 —	This read-only bit field is reserved and always has the value 0.
20-16 SEL2	Trigger MUX Input 2 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 2. For the field setting definitions, see Memory map and register definition.
15 —	This read-only bit field is reserved and always has the value 0.
14-13 —	This read-only bit field is reserved and always has the value 0.
12-8 SEL1	Trigger MUX Input 1 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 1. For the field setting definitions, see Memory map and register definition.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.4 TRGMUX CMP0 Register (CMP0)

10.4.1.4.1 Offset

Register	Offset
CMP0	1Ch

10.4.1.4.2 Function

TRGMUX Register

10.4.1.4.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.4.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.5 TRGMUX FTM0 Register (FTM0)

10.4.1.5.1 Offset

Register	Offset
FTM0	28h

10.4.1.5.2 Function

TRGMUX Register

10.4.1.5.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0		SEL3					0	0		SEL2				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0		SEL1					0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.5.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-29 —	This read-only bit field is reserved and always has the value 0.
28-24 SEL3	Trigger MUX Input 3 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 3. For the field setting definitions, see Memory map and register definition.
23 —	This read-only bit field is reserved and always has the value 0.
22-21	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
—	
20-16 SEL2	Trigger MUX Input 2 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 2. For the field setting definitions, see Memory map and register definition.
15 —	This read-only bit field is reserved and always has the value 0.
14-13 —	This read-only bit field is reserved and always has the value 0.
12-8 SEL1	Trigger MUX Input 1 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 1. For the field setting definitions, see Memory map and register definition.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.6 TRGMUX FTM1 Register (FTM1)

10.4.1.6.1 Offset

Register	Offset
FTM1	2Ch

10.4.1.6.2 Function

TRGMUX Register

10.4.1.6.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.6.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.7 TRGMUX PDB0 Register (PDB0)

10.4.1.7.1 Offset

Register	Offset
PDB0	38h

10.4.1.7.2 Function

TRGMUX Register

10.4.1.7.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.7.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.8 TRGMUX LPIT0 Register (LPIT0)

10.4.1.8.1 Offset

Register	Offset
LPIT0	48h

10.4.1.8.2 Function

TRGMUX Register

10.4.1.8.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0		SEL1					0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.8.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.
14-13 —	This read-only bit field is reserved and always has the value 0.
12-8 SEL1	Trigger MUX Input 1 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 1. For the field setting definitions, see Memory map and register definition.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.9 TRGMUX LPUART0 Register (LPUART0)

10.4.1.9.1 Offset

Register	Offset
LPUART0	4Ch

10.4.1.9.2 Function

TRGMUX Register

10.4.1.9.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.9.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.10 TRGMUX LPUART1 Register (LPUART1)

10.4.1.10.1 Offset

Register	Offset
LPUART1	50h

10.4.1.10.2 Function

TRGMUX Register

10.4.1.10.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.10.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.11 TRGMUX LPI2C0 Register (LPI2C0)

10.4.1.11.1 Offset

Register	Offset
LPI2C0	54h

10.4.1.11.2 Function

TRGMUX Register

10.4.1.11.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.11.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.12 TRGMUX LPSPI0 Register (LPSPI0)

10.4.1.12.1 Offset

Register	Offset
LPSPI0	5Ch

10.4.1.12.2 Function

TRGMUX Register

10.4.1.12.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.12.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.13 TRGMUX LPTMR0 Register (LPTMR0)

10.4.1.13.1 Offset

Register	Offset
LPTMR0	64h

10.4.1.13.2 Function

TRGMUX Register

10.4.1.13.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.13.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.14 TRGMUX TSI Register (TSI)

10.4.1.14.1 Offset

Register	Offset
TSI	68h

10.4.1.14.2 Function

TRGMUX Register

10.4.1.14.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.14.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.1.15 TRGMUX PWT Register (PWT)

10.4.1.15.1 Offset

Register	Offset
PWT	6Ch

10.4.1.15.2 Function

TRGMUX Register

10.4.1.15.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0							0	0						
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0							0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.1.15.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written. 1b - Register cannot be written until the next system Reset.
30-24 —	This read-only bit field is reserved and always has the value 0.
23 —	This read-only bit field is reserved and always has the value 0.
22-16 —	This read-only bit field is reserved and always has the value 0.
15 —	This read-only bit field is reserved and always has the value 0.
14-8 —	This read-only bit field is reserved and always has the value 0.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.4.2 TRGMUX1 register descriptions

10.4.2.1 TRGMUX Memory map

Table 10-2. Select Bit Fields

Field	Function
SELx	This read/write field is used to configure the MUX select for the peripheral trigger inputs. 000_0000 - (0x00) VSS is selected. 000_0001 - (0x01) VDD is selected. 000_0010 - (0x02) SIM_SW_TRIG is selected. 000_0011 - (0x03) Unused 000_0100 - (0x04) Unused 000_0101 - (0x05) Unused 000_0110 - (0x06) Unused 000_0111 - (0x07) LPUART0_RX_data is selected. 000_1000 - (0x08) LPUART0_TX_data is selected. 000_1001 - (0x09) LPUART0_RX_idle is selected. 000_1010 - (0x0A) LPI2C0_Master_Stop is selected. 000_1011 - (0x0B) LPI2C0_Slave_Stop is selected. 000_1100 - (0x0C) LPSPI0_Frame is selected. 000_1101 - (0x0D) LPSPI0_RX_data is selected. 000_1110 - (0x0E) LPUART1_RX_data is selected. 000_1111 - (0x0F) LPUART1_TX_data is selected. 001_0000 - (0x10) LPUART1_RX_idle is selected. 001_0001 - (0x11) Unused 001_0010 - (0x12) Unused 001_0011 - (0x13) Unused 001_0100 - (0x14) Unused 001_0101 - (0x15) Unused 001_0110 - (0x16) Unused 001_0111 - (0x17) PDB0_Pulse0 is selected. 001_1000 - (0x18) Unused 001_1001 - (0x19) Unused 001_1010 - (0x1A) Unused 001_1011 - (0x1B) Unused 001_1100 - (0x1C) Unused 001_1101 - (0x1D) Unused 001_1110 - (0x1E) Unused 001_1111 - (0x1F) Unused

TRGMUX1 base address: 4006_3000h

Offset	Register	Width (In bits)	Access	Reset value
0h	TRGMUX CTRL0 Register (CTRL0)	32	RW	0000_0000h

10.4.2.2 TRGMUX CTRL0 Register (CTRL0)

10.4.2.2.1 Offset

Register	Offset
CTRL0	0h

10.4.2.2.2 Function

TRGMUX Register

10.4.2.2.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LK	0		SEL3					0	0		SEL2				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0		SEL1					0	0		SEL0				
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

10.4.2.2.4 Fields

Field	Function
31 LK	TRGMUX register lock. This bit shows whether the register can be written or not. The LK bit can only be written once after any system reset. Once LK is set, the SELx bits in this TRGMUX register cannot be changed until the next system reset clears LK. 0b - Register can be written.

Table continues on the next page...

Field	Function
	1b - Register cannot be written until the next system Reset.
30-29 —	This read-only bit field is reserved and always has the value 0.
28-24 SEL3	Trigger MUX Input 3 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 3. For the field setting definitions, see Memory map and register definition.
23 —	This read-only bit field is reserved and always has the value 0.
22-21 —	This read-only bit field is reserved and always has the value 0.
20-16 SEL2	Trigger MUX Input 2 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 2. For the field setting definitions, see Memory map and register definition.
15 —	This read-only bit field is reserved and always has the value 0.
14-13 —	This read-only bit field is reserved and always has the value 0.
12-8 SEL1	Trigger MUX Input 1 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 1. For the field setting definitions, see Memory map and register definition.
7 —	This read-only bit field is reserved and always has the value 0.
6-5 —	This read-only bit field is reserved and always has the value 0.
4-0 SEL0	Trigger MUX Input 0 Source Select This read/write bit field is used to configure the MUX select for peripheral trigger input 0. For the field setting definitions, see Memory map and register definition.

10.5 Usage Guide

The TRGMUX is an extremely flexible module interconnectivity scheme. The trigger source could be from various peripherals and external input pins, to multiple pins/peripherals. The module level interconnections and trigger scheme offload the intervention of CPU, which is also useful when CPU is in WAIT/STOP mode. The following are some typical use-cases for TRGMUX.

10.5.1 ADC Trigger Source

The following triggers are via the TRGMUX:

- CMP out to trigger each ADC
- LPIT capable to trigger each ADC
- RTC capable to trigger each ADC
- LPTMR capable to trigger each ADC

For details, please refer to “ADC Trigger Sources” section.

FTM module support counter init trigger and channel match trigger, these triggers could be used as trigger input of PDB, PDB then be used to trigger other modules like ADC.

For details, please refer to “ADC Trigger Concept – Use Case ” section.

10.5.2 CMP Window/Sample Input

PDB and LPIT could be used to generate pulse output which can be used as sampling windows of CMP block via TRGMUX.

For details, please refer to “Window Mode” section in the CMP chapter.

10.5.3 FTM Fault Detection Input / Hardware Triggers and Synchronization

Please refer to the FTM chapter for more details.

Chapter 11
Memory and memory map

11.1 Introduction

This device contains various memories and memory-mapped peripherals which are located in one 4G bytes (32-bit address) contiguous memory space. This chapter describes the memory and peripheral locations within that memory space.

The following figure shows the system memory and peripheral locations.

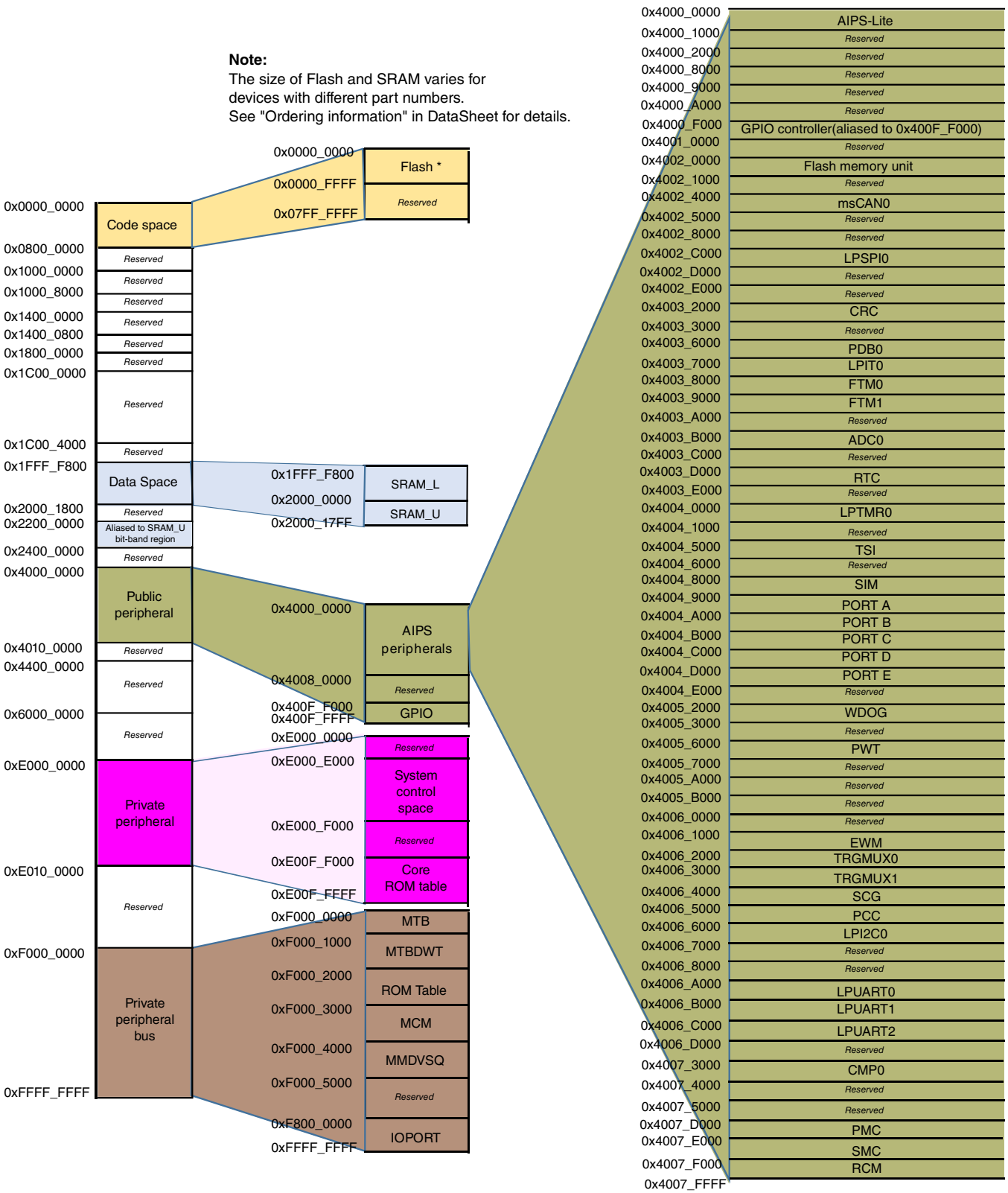


Figure 11-1. Memory map

11.2 Flash memory

11.2.1 Flash memory types

This device contains the following types of flash memory:

- Program flash memory — non-volatile flash memory that can execute program code

11.2.2 Flash Memory Sizes

The devices covered in this document contain:

- 1 block (64 KB) of program flash consisting of 1 KB sectors

The amounts of flash memory and the address range for the devices is shown in following table.

Device	Program flash (KB)	Block 0 address range
KE1xZ64Vxx4	64	0x0000_0000–0x0000_FFFF
KE1xZ32Vxx4	32	0x0000_0000–0x0000_7FFF

11.3 SRAM memory

11.3.1 SRAM sizes

This device contains SRAM The on-chip SRAM is split into SRAM_L and SRAM_U regions where the SRAM_L and SRAM_U ranges form a contiguous block in the memory map anchored at address 0x2000_0000. As such:

- SRAM_L is anchored to 0x1FFF_FFFF and occupies the space before this ending address.
- SRAM_U is anchored to 0x2000_0000 and occupies the space after this beginning address.

NOTE

Burst-access cannot occur across the 0x2000_0000 boundary that separates the two SRAM arrays. The two arrays should be treated as separate memory ranges for burst accesses.

The amount of SRAM for the devices covered in this document is shown in the following table.

Device	SRAM_L size (KB)	SRAM_U size (KB)	Total SRAM (KB)	Address Range
KE1xZ64Vxx4	2	6	8	0x1FFF_F800 - 0x2000_17FF
KE1xZ32Vxx4	1	3	4	0x1FFF_FC00 - 0x2000_0BFF

11.3.2 SRAM retention in low power modes

The SRAM is retained power on to all power modes on this device.

11.4 System memory map

The following table shows the high-level device memory map. This map provides the complete architectural address space definition for the various sections. Based on the physical sizes of the memories and peripherals, the actual address regions used may be smaller.

Table 11-1. System memory map

System 32-bit Address Range	Destination Slave	Access
0x0000_0000–0x07FF_FFFF [1]	Program flash and read-only data (Includes exception vectors in first 1024 bytes)	All masters
0x0800_0000–0x0FFF_FFFF	Reserved	–
0x1000_0000–0x13FF_FFFF	Reserved	Reserved
0x1400_0000–0x17FF_FFFF	Reserved	Reserved
0x1800_0000–0x1BFF_FFFF	Reserved	–
0x1C00_0000–0x1C00_3FFF	Reserved	Reserved
0x1C00_4000–0x1FEF_FFFF	Reserved	–
0x1FF0_0000–0x1FFF_FFFF [2]	SRAM_L: Lower SRAM	All masters
0x2000_0000–0x200F_FFFF [2]	SRAM_U: Upper SRAM bitband region	All masters
0x2010_0000–0x201F_FFFF	Reserved	–
0x2020_0000–0x21FF_FFFF	Reserved	–

Table continues on the next page...

Table 11-1. System memory map (continued)

System 32-bit Address Range	Destination Slave	Access
0x2200_0000–0x23FF_FFFF	Aliased SRAM_U bit-band region	Cortex-M0+ core only
0x2400_0000-0x2FFF_FFFF	Reserved	–
0x3000_0000-0x33FF_FFFF	Reserved	–
0x3400_0000-0x3FFF_FFFF	Reserved	–
0x4000_0000–0x4007_FFFF	AIPS Peripherals	Cortex-M0+ core
0x4008_0000–0x400F_EFFF	Reserved	–
0x400F_F000–0x400F_FFFF	General purpose input/output (GPIO)	Cortex-M0+ core
0x4010_0000–0x41FF_FFFF	Reserved	–
0x4200_0000–0x43FF_FFFF	Reserved	–
0x4400_0000–0x5FFF_FFFF	Reserved	Reserved
0x6000_0000–0xDFFF_FFFF	Reserved	–
0xE000_0000–0xE00F_FFFF	Private peripherals	Cortex-M0+ core only
0xE010_0000–0xEFFF_FFFF	Reserved	–
0xF000_0000–0xF000_0FFF	Micro Trace Buffer (MTB) registers	Cortex-M0+ core only
0xF000_1000–0xF000_1FFF	MTB Data Watchpoint and Trace (MTBDWT) registers	Cortex-M0+ core only
0xF000_2000–0xF000_2FFF	ROM table	Cortex-M0+ core only
0xF000_3000–0xF000_3FFF	Miscellaneous Control Module (MCM)	Cortex-M0+ core only
0xF000_4000–0xF000_4FFF	Memory Mapped Divide and Square Root (MMDVSQ)	Cortex-M0+ core only
0xF000_5000–0xF7FF_FFFF	Reserved	–
0xF800_0000–0xFFFF_FFFF	IOPORT: RGPIO (single cycle)	Cortex-M0+ core only

1. This map provides the complete architectural address space definition for the flash. Based on the physical sizes of the memories implemented for a particular device, the actual address regions used may be smaller. See Flash Memory Sizes for details.
2. This range varies depending on amount of SRAM implemented for a particular device. See SRAM sizes for details.

NOTE

1. Access rights to AIPS-Lite peripheral bridge and general purpose input/output (GPIO) module address space is limited to the core.
2. The SRAM on this device could be accessed through normal way with 32-bit operation, and also could be accessed with bit operation through aliased bit-band region.

11.4.1 Aliased bit-band regions

The device supports aliased SRAM_U bit-band region with Cortex M0+ core. A 32-bit write in the alias region has the same result as a read-modify-write operation on the targeted bit in the bit-band region, but with only one cycle time. Aliased bit-band region is much more efficient for bit operation.

Bit 0 of the value written to the alias region determines what value is written to the target bit:

- Writing a value with bit 0 set writes a 1 to the target bit.
- Writing a value with bit 0 clear writes a 0 to the target bit.

A 32-bit read in the alias region returns either:

- a value of 0x0000_0000 to indicate the target bit is clear
- a value of 0x0000_0001 to indicate the target bit is set

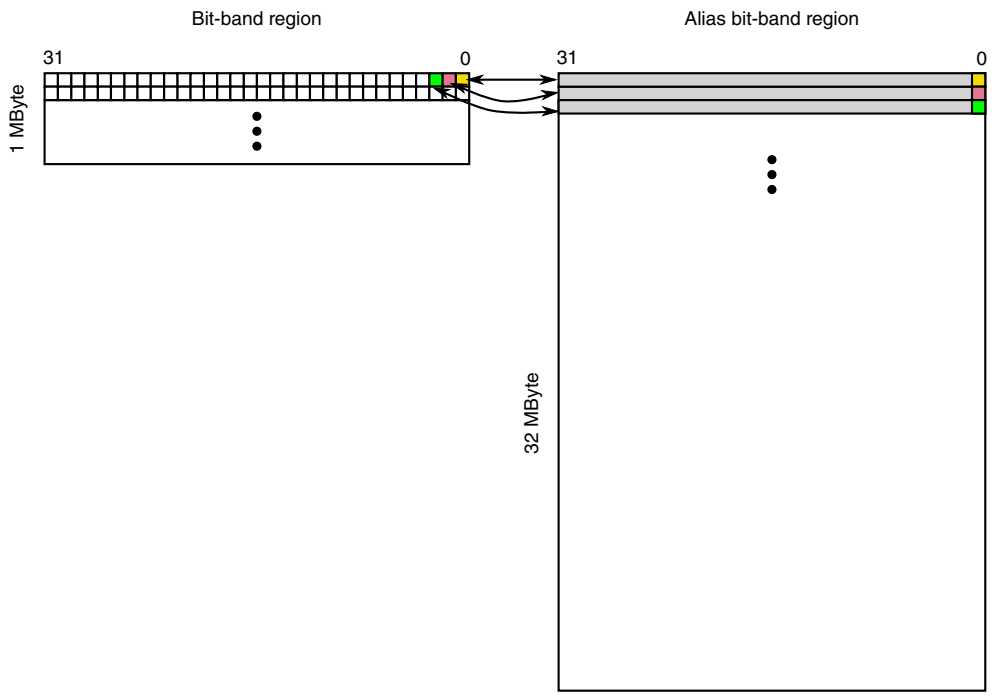


Figure 11-2. Alias bit-band mapping

NOTE

Each bit in bit-band region has an equivalent bit that can be manipulated through bit 0 in a corresponding long word in the alias bit-band region.

11.5 Peripheral memory map

The peripheral memory map is accessible via a crossbar slave port and the AIPS peripheral bridge. The peripheral bridge converts register access from AHB bus domain to peripheral bus domain.

For peripherals that have clock gating control bits (CGC bit) in PCC module, the associated peripherals could be enabled/disabled by these control bits. Access to a disabled peripheral or unimplemented AIPS slot results in a transfer error termination.

For programming model accesses via the peripheral bridges, there is generally only a small range within the 4 KB slots that is implemented. Accessing an address that is not implemented in the peripheral results in a transfer error termination.

11.5.1 Peripheral Bridge (AIPS-Lite) Memory Map

Table 11-2. Peripheral bridge slot assignments

System 32-bit base address	Slot number	Module
0x4000_0000	0	—
0x4000_1000	1	—
0x4000_2000	2	—
0x4000_3000	3	—
0x4000_4000	4	—
0x4000_5000	5	—
0x4000_6000	6	—
0x4000_7000	7	—
0x4000_8000	8	—
0x4000_9000	9	—
0x4000_A000	10	—
0x4000_B000	11	—
0x4000_C000	12	—
0x4000_D000	13	—
0x4000_E000	14	—
0x4000_F000	15	RGPIO controller (aliased to 0x400F_F000)
0x4001_0000	16	—
0x4001_1000	17	—
0x4001_2000	18	—
0x4001_3000	19	—
0x4001_4000	20	—

Table continues on the next page...

Table 11-2. Peripheral bridge slot assignments (continued)

System 32-bit base address	Slot number	Module
0x4001_5000	21	—
0x4001_6000	22	—
0x4001_7000	23	—
0x4001_8000	24	—
0x4001_9000	25	—
0x4001_A000	26	—
0x4001_B000	27	—
0x4001_C000	28	—
0x4001_D000	29	—
0x4001_E000	30	—
0x4001_F000	31	—
0x4002_0000	32	Flash memory
0x4002_1000	33	—
0x4002_2000	34	—
0x4002_3000	35	—
0x4002_4000	36	MSCAN 0
0x4002_5000	37	—
0x4002_6000	38	—
0x4002_7000	39	—
0x4002_8000	40	—
0x4002_9000	41	—
0x4002_A000	42	—
0x4002_B000	43	—
0x4002_C000	44	Low Power SPI (LPSPI) 0
0x4002_D000	45	—
0x4002_E000	46	—
0x4002_F000	47	—
0x4003_0000	48	—
0x4003_1000	49	—
0x4003_2000	50	CRC
0x4003_3000	51	—
0x4003_4000	52	—
0x4003_5000	53	—
0x4003_6000	54	Programmable delay block (PDB) 0
0x4003_7000	55	Low-power Periodic interrupt timer (LPIT0)
0x4003_8000	56	FlexTimer (FTM) 0
0x4003_9000	57	FlexTimer (FTM) 1
0x4003_A000	58	
0x4003_B000	59	Analog-to-digital converter (ADC) 0

Table continues on the next page...

Table 11-2. Peripheral bridge slot assignments (continued)

System 32-bit base address	Slot number	Module
0x4003_C000	60	—
0x4003_D000	61	Real-time clock (RTC)
0x4003_E000	62	—
0x4003_F000	63	—
0x4004_0000	64	Low-power timer (LPTMR0)
0x4004_1000	65	—
0x4004_2000	66	—
0x4004_3000	67	—
0x4004_4000	68	—
0x4004_5000	69	Touch sense interface (TSI)
0x4004_6000	70	—
0x4004_7000	71	—
0x4004_8000	72	System integration module (SIM)
0x4004_9000	73	Port A multiplexing control
0x4004_A000	74	Port B multiplexing control
0x4004_B000	75	Port C multiplexing control
0x4004_C000	76	Port D multiplexing control
0x4004_D000	77	Port E multiplexing control
0x4004_E000	78	—
0x4004_F000	79	—
0x4005_0000	80	—
0x4005_1000	81	—
0x4005_2000	82	Software watchdog (WDOG)
0x4005_3000	83	—
0x4005_4000	84	—
0x4005_5000	85	—
0x4005_6000	86	Pulse Width Timer (PWT)
0x4005_7000	87	—
0x4005_8000	88	—
0x4005_9000	89	—
0x4005_A000	90	—
0x4005_B000	91	—
0x4005_C000	92	—
0x4005_D000	93	—
0x4005_E000	94	—
0x4005_F000	95	—
0x4006_0000	96	—
0x4006_1000	97	External watchdog (EWM)
0x4006_2000	98	Trigger Multiplexing Control (TRGMUX 0)

Table continues on the next page...

Table 11-2. Peripheral bridge slot assignments (continued)

System 32-bit base address	Slot number	Module
0x4006_3000	99	Trigger Multiplexing Control (TRGMUX 1)
0x4006_4000	100	System Clock Generator (SCG)
0x4006_5000	101	Peripheral Clock Control (PCC)
0x4006_6000	102	Low Power I^2C (LPI^2C 0)
0x4006_7000	103	—
0x4006_8000	104	—
0x4006_9000	105	—
0x4006_A000	106	Low Power UART (LPUART 0)
0x4006_B000	107	Low Power UART (LPUART 1)
0x4006_C000	108	Low Power UART (LPUART 2)
0x4006_D000	109	—
0x4006_E000	110	—
0x4006_F000	111	—
0x4007_0000	112	—
0x4007_1000	113	—
0x4007_2000	114	—
0x4007_3000	115	Analog comparator (CMP 0)
0x4007_4000	116	—
0x4007_5000	117	—
0x4007_6000	118	—
0x4007_7000	119	—
0x4007_8000	120	—
0x4007_9000	121	—
0x4007_A000	122	—
0x4007_B000	123	—
0x4007_C000	124	—
0x4007_D000	125	Power management controller (PMC)
0x4007_E000	126	System Mode controller (SMC)
0x4007_F000	127	Reset Control Module (RCM)
0x400F_F000		GPIO controller

11.6 Private Peripheral Bus (PPB) memory map

The PPB is part of the defined ARM bus architecture and provides access to select processor-local modules. These resources are only accessible from the core; other system masters do not have access to them.

Table 11-3. PPB memory map

System 32-bit Address Range	Resource	Additional Range Detail	Resource
0xE000_0000–0xE000_DFFF	Reserved		
0xE000_E000–0xE000_EFFF	System Control Space (SCS)	0xE000_E000–0xE000_E00F	Reserved
		0xE000_E010–0xE000_E0FF	SysTick
		0xE000_E100–0xE000_ECFF	NVIC
		0xE000_ED00–0xE000_ED8F	System Control Block
		0xE000_ED90–0xE000_EDEF	Reserved
		0xE000_EDF0–0xE000_EEFF	Debug
		0xE000_EF00–0xE000_EFFF	Reserved
0xE000_F000–0xE00F_EFFF	Reserved		
0xE00F_F000–0xE00F_FFFF	Core ROM Space (CRS)		

Chapter 12
Flash Acceleration Unit (FAU)

12.1 Flash Acceleration Unit (FAU)

12.1.1 Introduction

The Flash Acceleration Unit (FAU) is a memory acceleration unit. It includes a buffer and a cache that can accelerate program flash memory data transfers. In addition, this module provides two separate mechanisms for accelerating the interface between bus masters and program flash memory. A 32-bit speculation buffer can prefetch the next 32-bit flash memory location, and a 4-way, 4-set program flash memory cache can store previously accessed program flash memory data for quick access times.

12.1.2 Modes of operation

The FAU operates only when a bus master accesses the program flash memory or FlexMemory.

In terms of chip power modes:

- The FAU operates only in Run and Wait modes, including VLPR and VLPW modes.
- For any power mode where the program flash memory or FlexMemory cannot be accessed, the FAU is disabled.

12.1.3 External signal description

The FAU has no external (off-chip) signals.

12.1.4 Memory map and register descriptions

The MCM's programming model provides control and configuration of the FAU's features. For details, see the description of the MCM's Platform Control Register (PLACR).

12.1.5 Functional description

The FAU is a flash acceleration unit with flexible buffers for user configuration.

Besides managing the interface between bus masters and the program flash memory and FlexMemory, the FAU can be used to customize the program flash memory cache and buffer to provide single-cycle system clock data access times. Whenever a hit occurs for the prefetch speculation buffer or the cache (when enabled), the requested data is transferred within a single system clock.

Upon system reset, the FAU is configured as follows:

- Flash cache is enabled.
- Instruction speculation and caching are enabled.
- Data speculation is disabled.
- Data caching is enabled.

Though the default configuration provides flash acceleration, advanced users may desire to customize the FAU buffer configurations to maximize throughput for their use cases. For example, the user may adjust the controls to enable buffering per access type (data or instruction).

NOTE

When reconfiguring the FAU, do not program the control and configuration inputs to the FAU while the program flash memory or FlexMemory is being accessed. Instead, change them with a routine executing from RAM in supervisor mode.

12.2 Usage Guide

For many systems the on-chip flash is the main memory. The Flash Acceleration Unit (FAU) is the interface between the flash memory blocks and the system. In a typical configuration, the core and system bus clock speeds are clock significantly faster than the flash memory clock. The FAU includes features designed to accelerate flash accesses.

For more detailed information, refer to the FMC (same module as FAU) section in AN4745: Optimizing Performance on Kinetis K-series MCUs.

Chapter 13
Flash Memory Module (FTFA)

13.1 Introduction

The flash memory module includes the following accessible memory regions:

- Program flash memory for vector space and code store

Flash memory is ideal for single-supply applications, permitting in-the-field erase and reprogramming operations without the need for any external high voltage power sources.

The flash memory module includes a memory controller that executes commands to modify flash memory contents. An erased bit reads '1' and a programmed bit reads '0'. The programming operation is unidirectional; it can only move bits from the '1' state (erased) to the '0' state (programmed). Only the erase operation restores bits from '0' to '1'; bits cannot be programmed from a '0' to a '1'.

CAUTION

A flash memory location must be in the erased state before being programmed. Cumulative programming of bits (back-to-back program operations without an intervening erase) within a flash memory location is not allowed. Re-programming of existing 0s to 0 is not allowed as this overstresses the device.

The standard shipping condition for flash memory is erased with security disabled. Data loss over time may occur due to degradation of the erased ('1') states and/or programmed ('0') states. Therefore, it is recommended that each flash block or sector be re-erased immediately prior to factory programming to ensure that the full data retention capability is achieved.

13.1.1 Features

The flash memory module includes the following features.

13.1.1.1 Program Flash Memory Features

- Sector size of 1 KB
- Program flash protection scheme prevents accidental program or erase of stored data
- Automated, built-in, program and erase algorithms with verify

13.1.1.2 Other Flash Memory Module Features

- Internal high-voltage supply generator for flash memory program and erase operations
- Optional interrupt generation upon flash command completion
- Supports MCU security mechanisms which prevent unauthorized access to the flash memory contents

13.1.2 Block Diagram

The block diagram of the flash memory module is shown in the following figure.

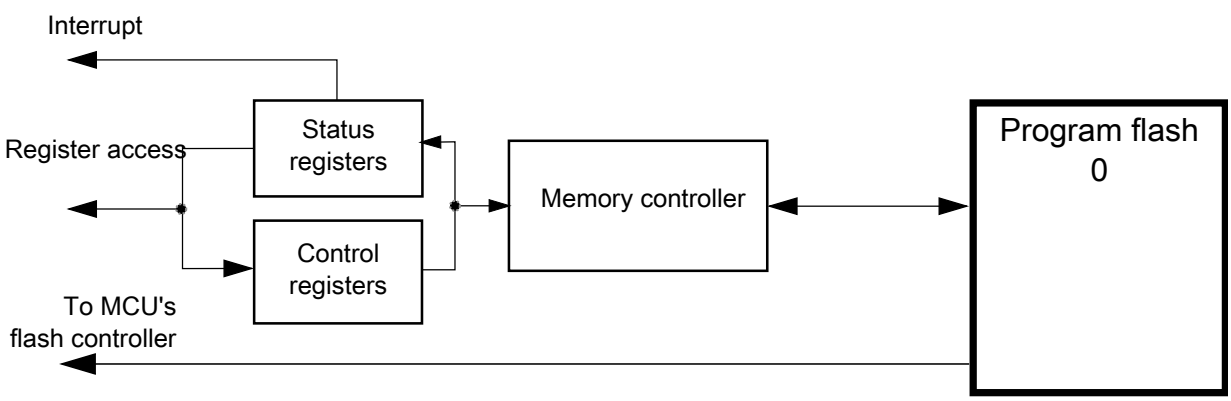


Figure 13-1. Flash Block Diagram

13.1.3 Glossary

Command write sequence — A series of MCU writes to the flash FCCOB register group that initiates and controls the execution of flash algorithms that are built into the flash memory module.

Endurance — The number of times that a flash memory location can be erased and reprogrammed.

FCCOB (Flash Common Command Object) — A group of flash registers that are used to pass command, address, data, and any associated parameters to the memory controller in the flash memory module.

Flash block — A macro within the flash memory module which provides the nonvolatile memory storage.

Flash Memory Module — All flash blocks plus a flash management unit providing high-level control and an interface to MCU buses.

IFR — Nonvolatile information register found in each flash block, separate from the main memory array.

Longword — 32 bits of data with an aligned longword having byte-address[1:0] = 00.

NVM — Nonvolatile memory. A memory technology that maintains stored data during power-off. The flash array is an NVM using NOR-type flash memory technology.

NVM Normal Mode — An NVM mode that provides basic user access to flash memory module resources. The CPU or other bus masters initiate flash program and erase operations (or other flash commands) using writes to the FCCOB register group in the flash memory module.

Program flash — The program flash memory provides nonvolatile storage for vectors and code store.

Program flash Sector — The smallest portion of the program flash memory (consecutive addresses) that can be erased.

Retention — The length of time that data can be kept in the NVM without experiencing errors upon readout. Since erased (1) states are subject to degradation just like programmed (0) states, the data retention limit may be reached from the last erase operation (not from the programming time).

RWW— Read-While-Write. The ability to simultaneously read from one memory resource while commanded operations are active in another memory resource.

Secure — An MCU state conveyed to the flash memory module as described in the Chip Configuration details for this device. In the secure state, reading and changing NVM contents is restricted.

Word — 16 bits of data with an aligned word having byte-address[0] = 0.

13.2 External Signal Description

The flash memory module contains no signals that connect off-chip.

13.3 Memory Map and Registers

This section describes the memory map and registers for the flash memory module.

Data read from unimplemented memory space in the flash memory module is undefined. Writes to unimplemented or reserved memory space (registers) in the flash memory module are ignored.

13.3.1 Flash Configuration Field Description

The program flash memory contains a 16-byte flash configuration field that stores default protection settings (loaded on reset) and security information that allows the MCU to restrict access to the flash memory module.

Flash Configuration Field Offset Address	Size (Bytes)	Field Description
0x0_0400–0x0_0407	8	Backdoor Comparison Key. Refer to Verify Backdoor Access Key Command and Unsecuring the Chip Using Backdoor Key Access.
0x0_0408–0x0_040B	4	Program flash protection bytes. Refer to the description of the Program Flash Protection Registers (FPROT0-3).
0x0_040F	1	Reserved
0x0_040E	1	Reserved
0x0_040D	1	Flash nonvolatile option byte. Refer to the description of the Flash Option Register (FOPT).
0x0_040C	1	Flash security byte. Refer to the description of the Flash Security Register (FSEC).

13.3.2 Program Flash IFR Map

The program flash IFR is nonvolatile information memory that can be read freely, but the user has no erase and limited program capabilities (see the Read Once, Program Once, and Read Resource commands in Read Once Command, Program Once Command and Read Resource Command).

The contents of the program flash IFR are summarized in the table found here and further described in the subsequent paragraphs.

The program flash IFR is located within the program flash 0 memory block .

Address Range	Size (Bytes)	Field Description
0x00 – 0xBF	192	Reserved
0xC0 – 0xFF	64	Program Once Field

13.3.2.1 Program Once Field

The Program Once Field in the program flash IFR provides 64 bytes of user data storage separate from the program flash main array. The user can program the Program Once Field one time only as there is no program flash IFR erase mechanism available to the user. The Program Once Field can be read any number of times. This section of the program flash IFR is accessed in 4-byte records using the Read Once and Program Once commands (see Read Once Command and Program Once Command).

13.3.3 Register Descriptions

The flash memory module contains a set of memory-mapped control and status registers.

NOTE

While a command is running (FSTAT[CCIF]=0), register writes are not accepted to any register except FCNFG and FSTAT. The no-write rule is relaxed during the start-up reset sequence, prior to the initial rise of CCIF. During this initialization period the user may write any register. All register writes are also disabled (except for registers FCNFG and FSTAT) whenever an erase suspend request is active (FCNFG[ERSSUSP]=1).

FTFA memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4002_0000	Flash Status Register (FTFA_FSTAT)	8	R/W	00h	13.3.3.1/162
4002_0001	Flash Configuration Register (FTFA_FCNFG)	8	R/W	00h	13.3.3.2/164
4002_0002	Flash Security Register (FTFA_FSEC)	8	R	Undefined	13.3.3.3/165
4002_0003	Flash Option Register (FTFA_FOPT)	8	R	Undefined	13.3.3.4/166
4002_0004	Flash Common Command Object Registers (FTFA_FCCOB3)	8	R/W	00h	13.3.3.5/167
4002_0005	Flash Common Command Object Registers (FTFA_FCCOB2)	8	R/W	00h	13.3.3.5/167
4002_0006	Flash Common Command Object Registers (FTFA_FCCOB1)	8	R/W	00h	13.3.3.5/167
4002_0007	Flash Common Command Object Registers (FTFA_FCCOB0)	8	R/W	00h	13.3.3.5/167
4002_0008	Flash Common Command Object Registers (FTFA_FCCOB7)	8	R/W	00h	13.3.3.5/167
4002_0009	Flash Common Command Object Registers (FTFA_FCCOB6)	8	R/W	00h	13.3.3.5/167
4002_000A	Flash Common Command Object Registers (FTFA_FCCOB5)	8	R/W	00h	13.3.3.5/167
4002_000B	Flash Common Command Object Registers (FTFA_FCCOB4)	8	R/W	00h	13.3.3.5/167
4002_000C	Flash Common Command Object Registers (FTFA_FCCOBB)	8	R/W	00h	13.3.3.5/167
4002_000D	Flash Common Command Object Registers (FTFA_FCCOBA)	8	R/W	00h	13.3.3.5/167
4002_000E	Flash Common Command Object Registers (FTFA_FCCOB9)	8	R/W	00h	13.3.3.5/167
4002_000F	Flash Common Command Object Registers (FTFA_FCCOB8)	8	R/W	00h	13.3.3.5/167
4002_0010	Program Flash Protection Registers (FTFA_FPROT3)	8	R/W	Undefined	13.3.3.6/168
4002_0011	Program Flash Protection Registers (FTFA_FPROT2)	8	R/W	Undefined	13.3.3.6/168
4002_0012	Program Flash Protection Registers (FTFA_FPROT1)	8	R/W	Undefined	13.3.3.6/168
4002_0013	Program Flash Protection Registers (FTFA_FPROT0)	8	R/W	Undefined	13.3.3.6/168

13.3.3.1 Flash Status Register (FTFA_FSTAT)

The FSTAT register reports the operational status of the flash memory module.

The CCIF, RDCOLERR, ACCERR, and FPVIOL bits are readable and writable. The MGSTAT0 bit is read only. The unassigned bits read 0 and are not writable.

NOTE

When set, the Access Error (ACCERR) and Flash Protection Violation (FPVIOL) bits in this register prevent the launch of any more commands until the flag is cleared (by writing a one to it).

Address: 4002_0000h base + 0h offset = 4002_0000h

Bit	7	6	5	4	3	2	1	0
Read	CCIF	RDCOLERR	ACCERR	FPVIOL	0			MGSTAT0
Write	w1c	w1c	w1c	w1c				
Reset	0	0	0	0	0	0	0	0

FTFA_FSTAT field descriptions

Field	Description
7 CCIF	Command Complete Interrupt Flag Indicates that a flash command has completed. The CCIF flag is cleared by writing a 1 to CCIF to launch a command, and CCIF stays low until command completion or command violation. CCIF is reset to 0 but is set to 1 by the memory controller at the end of the reset initialization sequence. Depending on how quickly the read occurs after reset release, the user may or may not see the 0 hardware reset value. 0 Flash command in progress 1 Flash command has completed
6 RDCOLERR	Flash Read Collision Error Flag Indicates that the MCU attempted a read from a flash memory resource that was being manipulated by a flash command (CCIF=0). Any simultaneous access is detected as a collision error by the block arbitration logic. The read data in this case cannot be guaranteed. The RDCOLERR bit is cleared by writing a 1 to it. Writing a 0 to RDCOLERR has no effect. 0 No collision error detected 1 Collision error detected
5 ACCERR	Flash Access Error Flag Indicates an illegal access has occurred to a flash memory resource caused by a violation of the command write sequence or issuing an illegal flash command. While ACCERR is set, the CCIF flag cannot be cleared to launch a command. The ACCERR bit is cleared by writing a 1 to ACCERR while CCIF is set. Writing a 0 to the ACCERR bit has no effect. 0 No access error detected 1 Access error detected
4 FPVIOL	Flash Protection Violation Flag Indicates an attempt was made to program or erase an address in a protected area of program flash memory during a command write sequence . While FPVIOL is set, the CCIF flag cannot be cleared to launch a command. The FPVIOL bit is cleared by writing a 1 to FPVIOL while CCIF is set. Writing a 0 to the FPVIOL bit has no effect. 0 No protection violation detected 1 Protection violation detected

Table continues on the next page...

FTFA_FSTAT field descriptions (continued)

Field	Description
3–1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 MGSTAT0	Memory Controller Command Completion Status Flag The MGSTAT0 status flag is set if an error is detected during execution of a flash command or during the flash reset sequence. As a status flag, this field cannot (and need not) be cleared by the user like the other error flags in this register. The value of the MGSTAT0 bit for "command-N" is valid only at the end of the "command-N" execution when CCIF=1 and before the next command has been launched. At some point during the execution of "command-N+1," the previous result is discarded and any previous error is cleared.

13.3.3.2 Flash Configuration Register (FTFA_FCNFG)

This register provides information on the current functional state of the flash memory module.

The erase control bits (ERSAREQ and ERSSUSP) have write restrictions. The unassigned bits read as noted and are not writable.

Address: 4002_0000h base + 1h offset = 4002_0001h

Bit	7	6	5	4	3	2	1	0
Read	CCIE	RDCOLLIE	ERSAREQ	ERSSUSP	0	0	0	0
Write								
Reset	0	0	0	0	0	0	0	0

FTFA_FCNFG field descriptions

Field	Description
7 CCIE	Command Complete Interrupt Enable Controls interrupt generation when a flash command completes. 0 Command complete interrupt disabled 1 Command complete interrupt enabled. An interrupt request is generated whenever the FSTAT[CCIF] flag is set.
6 RDCOLLIE	Read Collision Error Interrupt Enable Controls interrupt generation when a flash memory read collision error occurs. 0 Read collision error interrupt disabled 1 Read collision error interrupt enabled. An interrupt request is generated whenever a flash memory read collision error is detected (see the description of FSTAT[RDCOLERR]).
5 ERSAREQ	Erase All Request

Table continues on the next page...

FTFA_FCNFG field descriptions (continued)

Field	Description
	Issues a request to the memory controller to execute the Erase All Blocks command and release security. ERSAREQ is not directly writable but is under indirect user control. Refer to the device's Chip Configuration details on how to request this command. ERSAREQ sets when an erase all request is triggered external to the flash memory module and CCIF is set (no command is currently being executed). ERSAREQ is cleared by the flash memory module when the operation completes. 0 No request or request complete 1 Request to: 1. run the Erase All Blocks command, 2. verify the erased state, 3. program the security byte in the Flash Configuration Field to the unsecure state, and 4. release MCU security by setting the FSEC[SEC] field to the unsecure state.
4 ERSSUSP	Erase Suspend Allows the user to suspend (interrupt) the Erase Flash Sector command while it is executing. 0 No suspend requested 1 Suspend the current Erase Flash Sector command execution.
3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

13.3.3.3 Flash Security Register (FTFA_FSEC)

This read-only register holds all bits associated with the security of the MCU and flash memory module.

During the reset sequence, the register is loaded with the contents of the flash security byte in the Flash Configuration Field located in program flash memory. The flash basis for the values is signified by X in the reset value.

Address: 4002_0000h base + 2h offset = 4002_0002h

Bit	7	6	5	4	3	2	1	0
Read	KEYEN		MEEN		FSLACC		SEC	
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

FTFA_FSEC field descriptions

Field	Description
7–6 KEYEN	Backdoor Key Security Enable Enables or disables backdoor key access to the flash memory module. 00 Backdoor key access disabled 01 Backdoor key access disabled (preferred KEYEN state to disable backdoor key access) 10 Backdoor key access enabled 11 Backdoor key access disabled
5–4 MEEN	Mass Erase Enable Enables and disables mass erase capability of the flash memory module. When SEC is set to unsecure, the MEEN setting does not matter. 00 Mass erase is enabled 01 Mass erase is enabled 10 Mass erase is disabled 11 Mass erase is enabled
3–2 FSLACC	Factory Security Level Access Code Enables or disables access to the flash memory contents during returned part failure analysis at NXP. When SEC is secure and FSLACC is denied, access to the program flash contents is denied and any failure analysis performed by NXP factory test must begin with a full erase to unsecure the part. When access is granted (SEC is unsecure, or SEC is secure and FSLACC is granted), NXP factory testing has visibility of the current flash contents. The state of the FSLACC bits is only relevant when SEC is set to secure. When SEC is set to unsecure, the FSLACC setting does not matter. 00 NXP factory access granted 01 NXP factory access denied 10 NXP factory access denied 11 NXP factory access granted
SEC	Flash Security Defines the security state of the MCU. In the secure state, the MCU limits access to flash memory module resources. The limitations are defined per device and are detailed in the Chip Configuration details. If the flash memory module is unsecured using backdoor key access, SEC is forced to 10b. 00 MCU security status is secure. 01 MCU security status is secure. 10 MCU security status is unsecure. (The standard shipping condition of the flash memory module is unsecure.) 11 MCU security status is secure.

13.3.3.4 Flash Option Register (FTFA_FOPT)

The flash option register allows the MCU to customize its operations by examining the state of these read-only bits, which are loaded from NVM at reset. The function of the bits is defined in the device's Chip Configuration details.

All bits in the register are read-only .

During the reset sequence, the register is loaded from the flash nonvolatile option byte in the Flash Configuration Field located in program flash memory. The flash basis for the values is signified by X in the reset value. However, the register is written to 0xFF if the contents of the flash nonvolatile option byte are 0x00.

Address: 4002_0000h base + 3h offset = 4002_0003h

Bit	7	6	5	4	3	2	1	0
Read	OPT							
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

FTFA_FOPT field descriptions

Field	Description
OPT	Nonvolatile Option These bits are loaded from flash to this register at reset. Refer to the device's Chip Configuration details for the definition and use of these bits.

13.3.3.5 Flash Common Command Object Registers (FTFA_FCCOB*n*)

The FCCOB register group provides 12 bytes for command codes and parameters. The individual bytes within the set append a 0-B hex identifier to the FCCOB register name: FCCOB0, FCCOB1, ..., FCCOBB.

Address: 4002_0000h base + 4h offset + (1d × i), where i=0d to 11d

Bit	7	6	5	4	3	2	1	0
Read Write	CCOBn							
Reset	0	0	0	0	0	0	0	0

FTFA_FCCOB*n* field descriptions

Field	Description
CCOBn	The FCCOB register provides a command code and relevant parameters to the memory controller. The individual registers that compose the FCCOB data set can be written in any order, but you must provide all needed values, which vary from command to command. First, set up all required FCCOB fields and then initiate the command's execution by writing a 1 to the FSTAT[CCIF] bit. This clears the CCIF bit, which locks all FCCOB parameter fields and they cannot be changed by the user until the command completes (CCIF returns to 1). No command buffering or queueing is provided; the next command can be loaded only after the current command completes. Some commands return information to the FCCOB registers. Any values returned to FCCOB are available for reading after the FSTAT[CCIF] flag returns to 1 by the memory controller.

FTFA_FCCOB*n* field descriptions (continued)

Field	Description
	The following table shows a generic flash command format. The first FCCOB register, FCCOB0, always contains the command code. This 8-bit value defines the command to be executed. The command code is followed by the parameters required for this specific flash command, typically an address and/or data values. **NOTE:** The command parameter table is written in terms of FCCOB Number (which is equivalent to the byte number). This number is a reference to the FCCOB register name and is not the register address.

FCCOB Number	Typical Command Parameter Contents [7:0]
0	FCMD (a code that defines the flash command)
1	Flash address [23:16]
2	Flash address [15:8]
3	Flash address [7:0]
4	Data Byte 0
5	Data Byte 1
6	Data Byte 2
7	Data Byte 3
8	Data Byte 4
9	Data Byte 5
A	Data Byte 6
B	Data Byte 7

FCCOB Endianness and Multi-Byte Access :

The FCCOB register group uses a big endian addressing convention. For all command parameter fields larger than 1 byte, the most significant data resides in the lowest FCCOB register number. The FCCOB register group may be read and written as individual bytes, aligned words (2 bytes) or aligned longwords (4 bytes).

13.3.3.6 Program Flash Protection Registers (FTFA_FPROT*n*)

The FPROT registers define which program flash regions are protected from program and erase operations. Protected flash regions cannot have their content changed; that is, these regions cannot be programmed and cannot be erased by any flash command. Unprotected regions can be changed by program and erase operations.

The four FPROT registers allow up to 32 protectable regions. Each bit protects a 1/32 region of the program flash memory except for memory configurations with less than 32 KB of program flash where each assigned bit protects 1 KB. For configurations with 24 KB of program flash memory or less, FPROT0 is not used. For configurations with 16

KB of program flash memory or less, FPROT1 is not used. For configurations with 8 KB of program flash memory, FPROT2 is not used. The bitfields are defined in each register as follows:

Program flash protection register	Program flash protection bits
FPROT0	PROT[31:24]
FPROT1	PROT[23:16]
FPROT2	PROT[15:8]
FPROT3	PROT[7:0]

During the reset sequence, the FPROT registers are loaded with the contents of the program flash protection bytes in the Flash Configuration Field as indicated in the following table.

Program flash protection register	Flash Configuration Field offset address
FPROT0	0x000B
FPROT1	0x000A
FPROT2	0x0009
FPROT3	0x0008

To change the program flash protection that is loaded during the reset sequence, unprotect the sector of program flash memory that contains the Flash Configuration Field. Then, reprogram the program flash protection byte.

Address: 4002_0000h base + 10h offset + (1d × i), where i=0d to 3d

Bit	7	6	5	4	3	2	1	0
Read Write	PROT							
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

FTFA_FPROT*n* field descriptions

Field	Description
PROT	Program Flash Region Protect Each program flash region can be protected from program and erase operations by setting the associated PROT bit. The protection can only be increased, meaning that currently unprotected memory can be protected, but currently protected memory cannot be unprotected. Since unprotected regions are marked with a 1 and protected regions use a 0, only writes changing 1s to 0s are accepted. This 1-to-0 transition check is performed on a bit-by-bit basis. Those FPROT bits with 1-to-0 transitions are accepted while all bits with 0-to-1 transitions are ignored. **Restriction:** The user must never write to any FPROT register while a command is running (CCIF=0).

FTFA_FPROT*n* field descriptions (continued)

Field	Description
	Trying to alter data in any protected area in the program flash memory results in a protection violation error and sets the FSTAT[FPVIOL] bit. A full block erase of a program flash block is not possible if it contains any protected region. Each bit in the 32-bit protection register represents 1/32 of the total program flash except for memory configurations with less than 32 KB of program flash where each assigned bit protects 1 KB . 0 Program flash region is protected. 1 Program flash region is not protected

13.4 Functional Description

The information found here describes functional details of the flash memory module.

13.4.1 Flash Protection

Individual regions within the flash memory can be protected from program and erase operations.

Protection is controlled by the following registers:

- FPROT*n* —
  - For 2^n program flash sizes, four registers typically protect 32 regions of the program flash memory as shown in the following figure

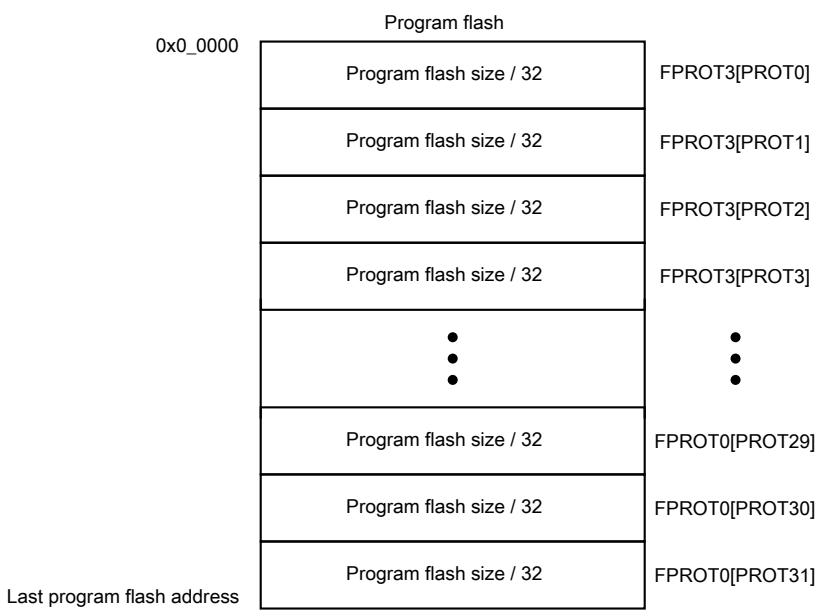


Figure 13-2. Program flash protection

NOTE

Flash protection features are discussed further in AN4507: Using the Kinetis Security and Flash Protection Features . Not all features described in the application note are available on this device.

13.4.2 Interrupts

The flash memory module can generate interrupt requests to the MCU upon the occurrence of various flash events.

These interrupt events and their associated status and control bits are shown in the following table.

Table 13-1. Flash Interrupt Sources

Flash Event	Readable Status Bit	Interrupt Enable Bit
Flash Command Complete	FSTAT[CCIF]	FCNFG[CCIE]
Flash Read Collision Error	FSTAT[RDCOLERR]	FCNFG[RDCOLLIE]

Note

Vector addresses and their relative interrupt priority are determined at the MCU level.

Some devices also generate a bus error response as a result of a Read Collision Error event. See the chip configuration information to determine if a bus error response is also supported.

13.4.3 Flash Operation in Low-Power Modes

13.4.3.1 Wait Mode

When the MCU enters wait mode, the flash memory module is not affected. The flash memory module can recover the MCU from wait via the command complete interrupt (see Interrupts).

13.4.3.2 Stop Mode

When the MCU requests stop mode, if a flash command is active (CCIF = 0) the command execution completes before the MCU is allowed to enter stop mode.

CAUTION

The MCU should never enter stop mode while any flash command is running (CCIF = 0).

NOTE

While the MCU is in very-low-power modes (VLPR, VLPW, VLPS), the flash memory module does not accept flash commands.

13.4.4 Flash Reads and Ignored Writes

The flash memory module requires only the flash address to execute a flash memory read.

The MCU must not read from the flash memory while commands are running (as evidenced by CCIF=0) on that block. Read data cannot be guaranteed from a flash block while any command is processing within that block. The block arbitration logic detects any simultaneous access and reports this as a read collision error (see the FSTAT[RDCOLERR] bit).

13.4.5 Read While Write (RWW)

The following simultaneous accesses are not allowed:

- Reading from program flash memory space while a flash command is active (CCIF=0).

13.4.6 Flash Program and Erase

All flash functions except read require the user to setup and launch a flash command through a series of peripheral bus writes.

The user cannot initiate any further flash commands until notified that the current command has completed. The flash command structure and operation are detailed in Flash Command Operations.

13.4.7 Flash Command Operations

Flash command operations are typically used to modify flash memory contents.

The next sections describe:

- The command write sequence used to set flash command parameters and launch execution
- A description of all flash commands available

13.4.7.1 Command Write Sequence

Flash commands are specified using a command write sequence illustrated in Figure 13-3. The flash memory module performs various checks on the command (FCCOB) content and continues with command execution if all requirements are fulfilled.

Before launching a command, the ACCERR and FPVIOL bits in the FSTAT register must be zero and the CCIF flag must read 1 to verify that any previous command has completed. If CCIF is zero, the previous command execution is still active, a new command write sequence cannot be started, and all writes to the FCCOB registers are ignored.

Attempts to launch a flash command in VLP mode will be ignored.

13.4.7.1.1 Load the FCCOB Registers

The user must load the FCCOB registers with all parameters required by the desired flash command. The individual registers that make up the FCCOB data set can be written in any order.

13.4.7.1.2 Launch the Command by Clearing CCIF

Once all relevant command parameters have been loaded, the user launches the command by clearing FSTAT[CCIF] by writing a '1' to it. FSTAT[CCIF] remains 0 until the flash command completes.

The FSTAT register contains a blocking mechanism that prevents a new command from launching (can't clear FSTAT[CCIF]) if the previous command resulted in an access error (FSTAT[ACCERR]=1) or a protection violation (FSTAT[FPVIOL]=1). In error scenarios, two writes to FSTAT are required to initiate the next command: the first write clears the error flags, the second write clears CCIF.

13.4.7.1.3 Command Execution and Error Reporting

The command processing has several steps:

1. The flash memory module reads the command code and performs a series of parameter checks and protection checks, if applicable, which are unique to each command.

   If the parameter check fails, the FSTAT[ACCERR] (access error) flag is set. FSTAT[ACCERR] reports invalid instruction codes and out-of bounds addresses. Usually, access errors suggest that the command was not set-up with valid parameters in the FCCOB register group.

   Program and erase commands also check the address to determine if the operation is requested to execute on protected areas. If the protection check fails, FSTAT[FPVIOL] (protection error) flag is set.

   Command processing never proceeds to execution when the parameter or protection step fails. Instead, command processing is terminated after setting FSTAT[CCIF].

2. If the parameter and protection checks pass, the command proceeds to execution. Run-time errors, such as failure to erase verify, may occur during the execution phase. Run-time errors are reported in FSTAT[MGSTAT0]. A command may have access errors, protection errors, and run-time errors, but the run-time errors are not seen until all access and protection errors have been corrected.
3. Command execution results, if applicable, are reported back to the user via the FCCOB and FSTAT registers.
4. The flash memory module sets FSTAT[CCIF] signifying that the command has completed.

The flow for a generic command write sequence is illustrated in the following figure.

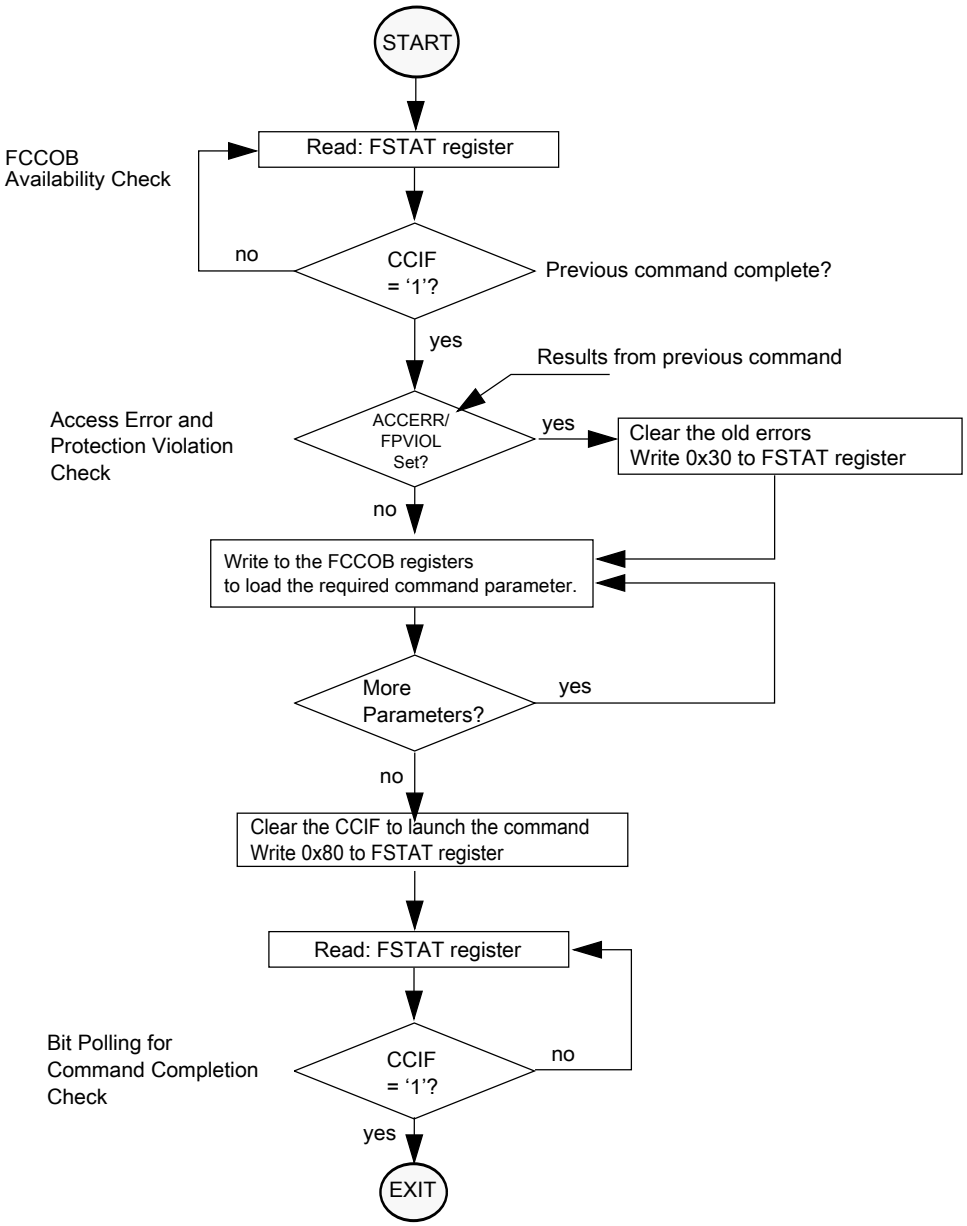


Figure 13-3. Generic flash command write sequence flowchart

13.4.7.2 Flash Commands

The following table summarizes the function of all flash commands.

FCMD	Command	Program flash	Function
0x01	Read 1s Section	×	Verify that a given number of program flash locations from a starting address are erased.

Table continues on the next page...

FCMD	Command	Program flash	Function
0x02	Program Check	×	Tests previously-programmed locations at margin read levels.
0x03	Read Resource	IFR, ID	Read 4 bytes from program flash IFR or version ID.
0x06	Program Longword	×	Program 4 bytes in a program flash block.
0x09	Erase Flash Sector	×	Erase all bytes in a program flash sector.
0x40	Read 1s All Blocks	×	Verify that the program flash block is erased then release MCU security.
0x41	Read Once	IFR	Read 4 bytes of a dedicated 64 byte field in the program flash 0 IFR.
0x43	Program Once	IFR	One-time program of 4 bytes of a dedicated 64-byte field in the program flash 0 IFR.
0x44	Erase All Blocks	×	Erase the program flash block, verify-erase and release MCU security. **NOTE:** An erase is only possible when all memory locations are unprotected.
0x45	Verify Backdoor Access Key	×	Release MCU security after comparing a set of user-supplied security keys to those stored in the program flash.
0x49	Erase All Blocks Unsecure	×	Erase the program flash block, verify-erase, program security byte to unsecure state, release MCU security.

13.4.8 Margin Read Commands

The Read-1s commands (Read 1s All Blocks, Read 1s Section) and the Program Check command have a margin choice parameter that allows the user to apply non-standard read reference levels to the program flash array reads performed by these commands. Using the preset 'user' and 'factory' margin levels, these commands perform their associated read operations at tighter tolerances than a 'normal' read. These non-standard read levels are applied only during the command execution. Basic flash array reads use the standard, un-margined, read reference level.

Only the 'normal' read level should be employed during normal flash usage. The non-standard, 'user' and 'factory' margin levels should be employed only in special cases. They can be used during special diagnostic routines to gain confidence that the device is not suffering from the end-of-life data loss customary of flash memory devices.

Erased ('1') and programmed ('0') bit states can degrade due to elapsed time and data cycling (number of times a bit is erased and re-programmed). The lifetime of the erased states is relative to the last erase operation. The lifetime of the programmed states is measured from the last program time.

The 'user' and 'factory' levels become, in effect, a minimum safety margin; i.e. if the reads pass at the tighter tolerances of the 'user' and 'factory' margins, then the 'normal' reads have at least this much safety margin before they experience data loss.

The 'user' margin is a small delta to the normal read reference level. 'User' margin levels can be employed to check that flash memory contents have adequate margin for normal level read operations. If unexpected read results are encountered when checking flash memory contents at the 'user' margin levels, loss of information might soon occur during 'normal' readout.

The 'factory' margin is a bigger deviation from the norm, a more stringent read criteria that should only be attempted immediately (or very soon) after completion of an erase or program command, early in the cycling life. 'Factory' margin levels can be used to check that flash memory contents have adequate margin for long-term data retention at the normal level setting. If unexpected results are encountered when checking flash memory contents at 'factory' margin levels, the flash memory contents should be erased and reprogrammed.

CAUTION

Factory margin levels must only be used during verify of the initial factory programming.

13.4.9 Flash Command Description

This section describes all flash commands that can be launched by a command write sequence.

The flash memory module sets the FSTAT[ACCERR] bit and aborts the command execution if any of the following illegal conditions occur:

- There is an unrecognized command code in the FCCOB FCMD field.
- There is an error in a FCCOB field for the specific commands. Refer to the error handling table provided for each command.

Ensure that FSTAT[ACCERR] and FSTAT[FPVIOL] are cleared prior to starting the command write sequence. As described in Launch the Command by Clearing CCIF, a new command cannot be launched while these error flags are set.

Do not attempt to read a flash block while the flash memory module is running a command (FSTAT[CCIF] = 0) on that same block. The flash memory module may return invalid data to the MCU with the collision error flag (FSTAT[RDCOLERR]) set.

CAUTION

Flash data must be in the erased state before being programmed. Cumulative programming of bits (adding more zeros) is not allowed.

13.4.9.1 Read 1s Section Command

The Read 1s Section command checks if a section of program flash memory is erased to the specified read margin level. The Read 1s Section command defines the starting address and the number of longwords to be verified.

Table 13-2. Read 1s Section Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x01 (RD1SEC)
1	Flash address [23:16] of the first longword to be verified
2	Flash address [15:8] of the first longword to be verified
3	Flash address [7:0][1] of the first longword to be verified
4	Number of longwords to be verified [15:8]
5	Number of longwords to be verified [7:0]
6	Read-1 Margin Choice

1. Must be longword aligned (Flash address [1:0] = 00).

Upon clearing CCIF to launch the Read 1s Section command, the flash memory module sets the read margin for 1s according to Table 13-3 and then reads all locations within the specified section of flash memory. If the flash memory module fails to read all 1s (that is, the flash section is not erased), FSTAT[MGSTAT0] is set. FSTAT[CCIF] sets after the Read 1s Section operation completes.

Table 13-3. Margin Level Choices for Read 1s Section

Read Margin Choice	Margin Level Description
0x00	Use the 'normal' read level for 1s
0x01	Apply the 'User' margin to the normal read-1 level
0x02	Apply the 'Factory' margin to the normal read-1 level

Table 13-4. Read 1s Section Command Error Handling

Error condition	Error bit
Command not available in current mode/security	FSTAT[ACCERR]
An invalid margin code is supplied.	FSTAT[ACCERR]
An invalid flash address is supplied.	FSTAT[ACCERR]
Flash address is not longword aligned.	FSTAT[ACCERR]
The requested section crosses a Flash block boundary.	FSTAT[ACCERR]
The requested number of longwords is 0.	FSTAT[ACCERR]
Read-1s fails.	FSTAT[MGSTAT0]

13.4.9.2 Program Check Command

The Program Check command tests a previously programmed program flash longword to see if it reads correctly at the specified margin level.

Table 13-5. Program Check Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x02 (PGMCHK)
1	Flash address [23:16]
2	Flash address [15:8]
3	Flash address [7:0][1]
4	Margin Choice
8	Byte 0 expected data
9	Byte 1 expected data
A	Byte 2 expected data
B	Byte 3 expected data

1. Must be longword aligned (Flash address [1:0] = 00).

Upon clearing CCIF to launch the Program Check command, the flash memory module sets the read margin for 1s according to Table 13-6, reads the specified longword, and compares the actual read data to the expected data provided by the FCCOB. If the comparison at margin-1 fails, FSTAT[MGSTAT0] is set.

The flash memory module then sets the read margin for 0s, re-reads, and compares again. If the comparison at margin-0 fails, FSTAT[MGSTAT0] is set. FSTAT[CCIF] is set after the Program Check operation completes.

The supplied address must be longword aligned (the lowest two bits of the byte address must be 00):

- Byte 3 data is written to the supplied byte address ('start'),
- Byte 2 data is programmed to byte address start+0b01,
- Byte 1 data is programmed to byte address start+0b10,
- Byte 0 data is programmed to byte address start+0b11.

NOTE

See the description of margin reads, Margin Read Commands

Table 13-6. Margin Level Choices for Program Check

Read Margin Choice	Margin Level Description
0x01	Read at 'User' margin-1 and 'User' margin-0
0x02	Read at 'Factory' margin-1 and 'Factory' margin-0

Table 13-7. Program Check Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
An invalid flash address is supplied	FSTAT[ACCERR]
Flash address is not longword aligned	FSTAT[ACCERR]
An invalid margin choice is supplied	FSTAT[ACCERR]
Either of the margin reads does not match the expected data	FSTAT[MGSTAT0]

13.4.9.3 Read Resource Command

The Read Resource command allows the user to read data from special-purpose memory resources located within the flash memory module. The special-purpose memory resources available include program flash IFR space and the Version ID field. Each resource is assigned a select code as shown in Table 13-9.

Table 13-8. Read Resource Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x03 (RDRSRC)
1	Flash address [23:16]
2	Flash address [15:8]

Table continues on the next page...

Table 13-8. Read Resource Command FCCOB Requirements (continued)

FCCOB Number	FCCOB Contents [7:0]
3	Flash address [7:0][1]
Returned Values	
4	Read Data [31:24]
5	Read Data [23:16]
6	Read Data [15:8]
7	Read Data [7:0]
User-provided values	
8	Resource Select Code (see Table 13-9)

1. Must be longword aligned (Flash address [1:0] = 00).

Table 13-9. Read Resource Select Codes

Resource Select Code	Description	Resource Size	Local Address Range
0x00	Program Flash 0 IFR	256 Bytes	0x00_0000–0x00_00FF
0x01[1]	Version ID	8 Bytes	0x00_0000–0x00_0007

1. Located in program flash 0 reserved space.

After clearing CCIF to launch the Read Resource command, four consecutive bytes are read from the selected resource at the provided relative address and stored in the FCCOB register. The CCIF flag sets after the Read Resource operation completes. The Read Resource command exits with an access error if an invalid resource code is provided or if the address for the applicable area is out-of-range.

Table 13-10. Read Resource Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
An invalid resource code is entered	FSTAT[ACCERR]
Flash address is out-of-range for the targeted resource.	FSTAT[ACCERR]
Flash address is not longword aligned	FSTAT[ACCERR]

13.4.9.4 Program Longword Command

The Program Longword command programs four previously-erased bytes in the program flash memory using an embedded algorithm.

CAUTION

A flash memory location must be in the erased state before being programmed. Cumulative programming of bits (back-to-back program operations without an intervening erase) within a flash memory location is not allowed. Re-programming of existing 0s to 0 is not allowed as this overstresses the device.

Table 13-11. Program Longword Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x06 (PGM4)
1	Flash address [23:16]
2	Flash address [15:8]
3	Flash address [7:0][1]
4	Byte 0 program value
5	Byte 1 program value
6	Byte 2 program value
7	Byte 3 program value

1. Must be longword aligned (Flash address [1:0] = 00).

Upon clearing CCIF to launch the Program Longword command, the flash memory module programs the data bytes into the flash using the supplied address. The targeted flash locations must be currently unprotected (see the description of the FPROT registers) to permit execution of the Program Longword operation.

The programming operation is unidirectional. It can only move NVM bits from the erased state ('1') to the programmed state ('0'). Erased bits that fail to program to the '0' state are flagged as errors in FSTAT[MGSTAT0]. The CCIF flag is set after the Program Longword operation completes.

The supplied address must be longword aligned (flash address [1:0] = 00):

- Byte 3 data is written to the supplied byte address ('start'),
- Byte 2 data is programmed to byte address start+0b01,
- Byte 1 data is programmed to byte address start+0b10, and
- Byte 0 data is programmed to byte address start+0b11.

Table 13-12. Program Longword Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
An invalid flash address is supplied	FSTAT[ACCERR]
Flash address is not longword aligned	FSTAT[ACCERR]
Flash address points to a protected area	FSTAT[FPVIOL]

Table continues on the next page...

Table 13-12. Program Longword Command Error Handling (continued)

Error Condition	Error Bit
Any errors have been encountered during the verify operation	FSTAT[MGSTAT0]

13.4.9.5 Erase Flash Sector Command

The Erase Flash Sector operation erases all addresses in a flash sector.

Table 13-13. Erase Flash Sector Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x09 (ERSSCR)
1	Flash address [23:16] in the flash sector to be erased
2	Flash address [15:8] in the flash sector to be erased
3	Flash address [7:0][1] in the flash sector to be erased

1. Must be longword aligned (Flash address [1:0] = 00).

After clearing CCIF to launch the Erase Flash Sector command, the flash memory module erases the selected program flash sector and then verifies that it is erased. The Erase Flash Sector command aborts if the selected sector is protected (see the description of the FPROT registers). If the erase-verify fails the FSTAT[MGSTAT0] bit is set. The CCIF flag is set after the Erase Flash Sector operation completes. The Erase Flash Sector command is suspendable (see the FCNFG[ERSSUSP] bit and Figure 13-4).

Table 13-14. Erase Flash Sector Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
An invalid Flash address is supplied	FSTAT[ACCERR]
Flash address is not longword aligned	FSTAT[ACCERR]
The selected program flash sector is protected	FSTAT[FPVIOL]
Any errors have been encountered during the verify operation[1]	FSTAT[MGSTAT0]

1. User margin read may be run using the Read 1s Section command to verify all bits are erased.

13.4.9.5.1 Suspending an Erase Flash Sector Operation

To suspend an Erase Flash Sector operation set the FCNFG[ERSSUSP] bit when CCIF, ACCERR, and FPVIOL are clear and the CCOB command field holds the code for the Erase Flash Sector command. During the Erase Flash Sector operation (see Erase Flash Sector Command), the flash memory module samples the state of the ERSSUSP bit at convenient points. If the flash memory module detects that the ERSSUSP bit is set, the

Erase Flash Sector operation is suspended and the flash memory module sets CCIF. While ERSSUSP is set, all writes to flash registers are ignored except for writes to the FSTAT and FCNFG registers.

If an Erase Flash Sector operation effectively completes before the flash memory module detects that a suspend request has been made, the flash memory module clears the ERSSUSP bit prior to setting CCIF. When an Erase Flash Sector operation has been successfully suspended, the flash memory module sets CCIF and leaves the ERSSUSP bit set. While CCIF is set, the ERSSUSP bit can only be cleared to prevent the withdrawal of a suspend request before the flash memory module has acknowledged it.

13.4.9.5.2 Resuming a Suspended Erase Flash Sector Operation

If the ERSSUSP bit is still set when CCIF is cleared to launch the next command, the previous Erase Flash Sector operation resumes. The flash memory module acknowledges the request to resume a suspended operation by clearing the ERSSUSP bit. A new suspend request can then be made by setting ERSSUSP. A single Erase Flash Sector operation can be suspended and resumed multiple times.

There is a minimum elapsed time limit of 4.3 msec between the request to resume the Erase Flash Sector operation (CCIF is cleared) and the request to suspend the operation again (ERSSUSP is set). This minimum time period is required to ensure that the Erase Flash Sector operation will eventually complete. If the minimum period is continually violated, i.e. the suspend requests come repeatedly and too quickly, no forward progress is made by the Erase Flash Sector algorithm. The resume/suspend sequence runs indefinitely without completing the erase.

13.4.9.5.3 Aborting a Suspended Erase Flash Sector Operation

The user may choose to abort a suspended Erase Flash Sector operation by clearing the ERSSUSP bit prior to clearing CCIF for the next command launch. When a suspended operation is aborted, the flash memory module starts the new command using the new FCCOB contents.

Note

Aborting the erase leaves the bitcells in an indeterminate, partially-erased state. Data in this sector is not reliable until a new erase command fully completes.

The following figure shows how to suspend and resume the Erase Flash Sector operation.

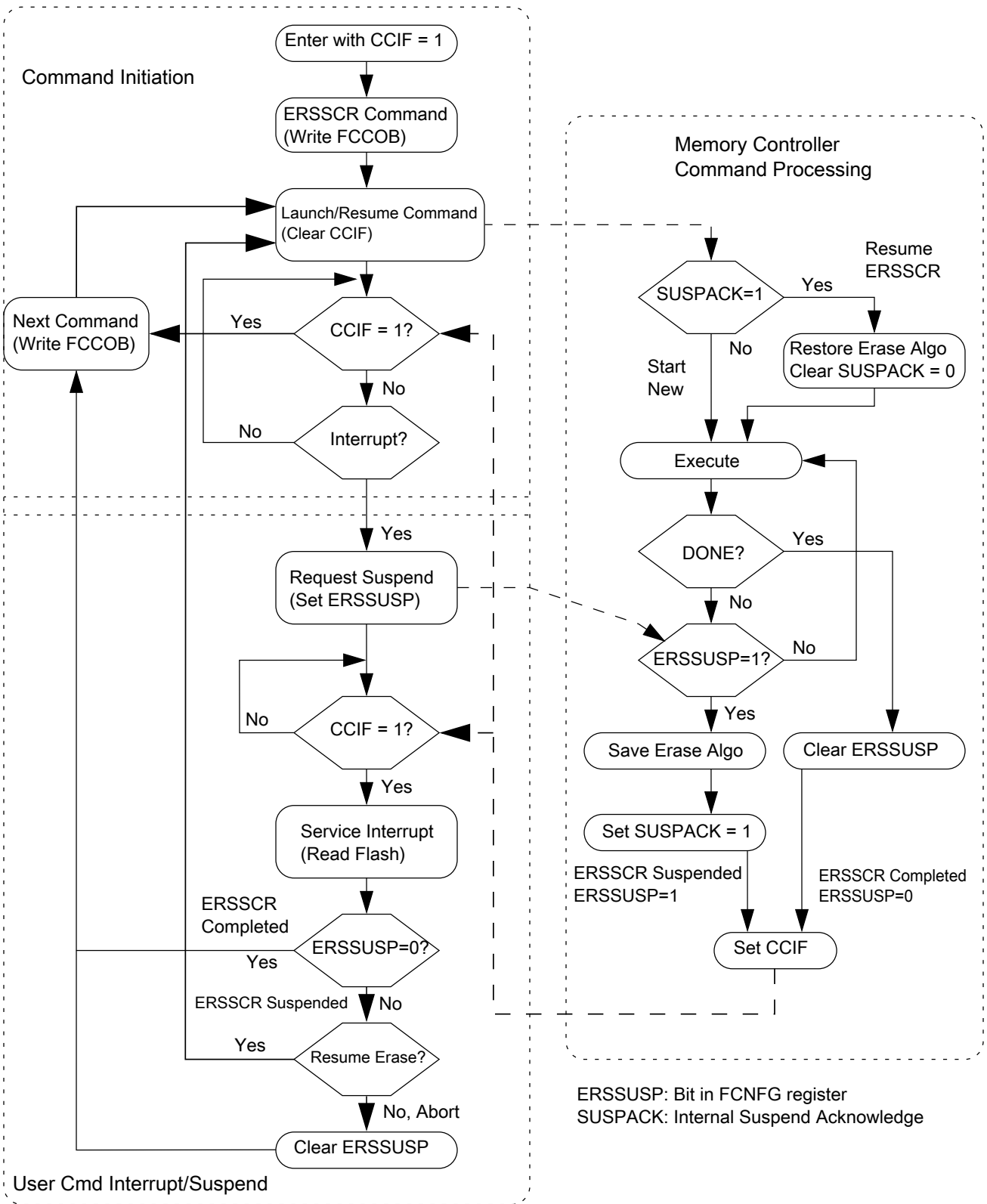


Figure 13-4. Suspend and Resume of Erase Flash Sector Operation

13.4.9.6 Read 1s All Blocks Command

The Read 1s All Blocks command checks if the program flash blocks have been erased to the specified read margin level, if applicable, and releases security if the readout passes, i.e. all data reads as '1'.

Table 13-15. Read 1s All Blocks Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x40 (RD1ALL)
1	Read-1 Margin Choice

After clearing CCIF to launch the Read 1s All Blocks command, the flash memory module :

- sets the read margin for 1s according to Table 13-16,
- checks the contents of the program flash are in the erased state.

If the flash memory module confirms that these memory resources are erased, security is released by setting the FSEC[SEC] field to the unsecure state. The security byte in the flash configuration field (see Flash Configuration Field Description) remains unaffected by the Read 1s All Blocks command. If the read fails, i.e. all memory resources are not in the fully erased state, the FSTAT[MGSTAT0] bit is set.

The CCIF flag sets after the Read 1s All Blocks operation has completed.

Table 13-16. Margin Level Choices for Read 1s All Blocks

Read Margin Choice	Margin Level Description
0x00	Use the 'normal' read level for 1s
0x01	Apply the 'User' margin to the normal read-1 level
0x02	Apply the 'Factory' margin to the normal read-1 level

Table 13-17. Read 1s All Blocks Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
An invalid margin choice is specified	FSTAT[ACCERR]
Read-1s fails	FSTAT[MGSTAT0]

13.4.9.7 Read Once Command

The Read Once command provides read access to special 64-byte fields located in the program flash 0 IFR (see Program Flash IFR Map and Program Once Field). Access to the Program Once field is via 16 records (index values 0x00 - 0x0F), each 4 bytes long. These fields are programmed using the Program Once command described in Program Once Command.

Table 13-18. Read Once Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x41 (RDONCE)
1	Program Once record index (0x00 - 0x0F)
2	Not used
3	Not used
Returned Values	
4	Program Once byte 0 value
5	Program Once byte 1 value
6	Program Once byte 2 value
7	Program Once byte 3 value

After clearing CCIF to launch the Read Once command, a 4-byte Program Once record is read and stored in the FCCOB register. The CCIF flag is set after the Read Once operation completes. Valid record index values for the Read Once command range from 0x00 - 0x0F. During execution of the Read Once command, any attempt to read addresses within the program flash block containing the selected record index returns invalid data. The Read Once command can be executed any number of times.

Table 13-19. Read Once Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
An invalid record index is supplied	FSTAT[ACCERR]

13.4.9.8 Program Once Command

The Program Once command enables programming to special 64-byte fields in the program flash 0 IFR (see Program Flash IFR Map and Program Once Field). Access to the Program Once field is via 16 records (index values 0x00 - 0x0F), each 4 bytes long. These records can be read using the Read Once command (see Read Once Command) or using the Read Resource command (see Read Resource Command). These records can be programmed only once since the program flash 0 IFR cannot be erased.

Table 13-20. Program Once Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x43 (PGMONCE)
1	Program Once record index (0x00 - 0x0F)
2	Not Used
3	Not Used
4	Program Once byte 0 value
5	Program Once byte 1 value
6	Program Once byte 2 value
7	Program Once byte 3 value

After clearing CCIF to launch the Program Once command, the flash memory module first verifies that the selected record is erased. If erased, then the selected record is programmed using the values provided. The Program Once command also verifies that the programmed values read back correctly. The CCIF flag is set after the Program Once operation has completed.

Any attempt to program one of these records when the existing value is not Fs (erased) is not allowed. Valid record index values for the Program Once command range from 0x00 - 0x0F. During execution of the Program Once command, any attempt to read addresses within the program flash block containing the selected record index returns invalid data.

Table 13-21. Program Once Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
An invalid record index is supplied	FSTAT[ACCERR]
The requested record has already been programmed to a non-FFFF value[1]	FSTAT[ACCERR]
Any errors have been encountered during the verify operation	FSTAT[MGSTAT0]

1. If a Program Once record is initially programmed to 0xFFFF_FFFF, the Program Once command is allowed to execute again on that same record.

13.4.9.9 Erase All Blocks Command

The Erase All Blocks operation erases all flash memory, verifies all memory contents, and releases MCU security.

Table 13-22. Erase All Blocks Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x44 (ERSALL)

After clearing CCIF to launch the Erase All Blocks command, the flash memory module erases all program flash memory, then verifies that all are erased.

If the flash memory module verifies that all flash memories were properly erased, security is released by setting the FSEC[SEC] field to the unsecure state. The Erase All Blocks command aborts if any flash region is protected. The security byte and all other contents of the flash configuration field (see Flash Configuration Field Description) are erased by the Erase All Blocks command. If the erase-verify fails, the FSTAT[MGSTAT0] bit is set. The CCIF flag is set after the Erase All Blocks operation completes.

Table 13-23. Erase All Blocks Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
Any region of the program flash memory is protected	FSTAT[FPVIOL]
Any errors have been encountered during the verify operation[1]	FSTAT[MGSTAT0]

1. User margin read may be run using the Read 1s All Blocks command to verify all bits are erased.

13.4.9.9.1 Triggering an Erase All External to the Flash Memory Module

The functionality of the Erase All Blocks/Erase All Blocks Unsecure command is also available in an uncommanded fashion outside of the flash memory. Refer to the device's Chip Configuration details for information on this functionality.

Before invoking the external erase all function, the FSTAT[ACCERR and PVIOL] flags must be cleared and the FCCOB0 register must not contain 0x44. When invoked, the erase-all function erases all program flash memory regardless of the protection settings. If the post-erase verify passes, the routine then releases security by setting the FSEC[SEC] field register to the unsecure state. The security byte in the Flash Configuration Field is also programmed to the unsecure state. The status of the erase-all request is reflected in the FCNFG[ERSAREQ] bit. The FCNFG[ERSAREQ] bit is cleared once the operation completes and the normal FSTAT error reporting is available, except FPVIOL, as described in Erase All Blocks Command/Erase All Blocks Unsecure Command.

13.4.9.10 Verify Backdoor Access Key Command

The Verify Backdoor Access Key command only executes if the mode and security conditions are satisfied (see Flash Commands by Mode). Execution of the Verify Backdoor Access Key command is further qualified by the FSEC[KEYEN] bits. The Verify Backdoor Access Key command releases security if user-supplied keys in the FCCOB match those stored in the Backdoor Comparison Key bytes of the Flash

Configuration Field (see Flash Configuration Field Description). The column labelled Flash Configuration Field offset address shows the location of the matching byte in the Flash Configuration Field.

Table 13-24. Verify Backdoor Access Key Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]	Flash Configuration Field Offset Address
0	0x45 (VFYKEY)	
1-3	Not Used	
4	Key Byte 0	0x0_0003
5	Key Byte 1	0x0_0002
6	Key Byte 2	0x0_0001
7	Key Byte 3	0x0_0000
8	Key Byte 4	0x0_0007
9	Key Byte 5	0x0_0006
A	Key Byte 6	0x0_0005
B	Key Byte 7	0x0_0004

After clearing CCIF to launch the Verify Backdoor Access Key command, the flash memory module checks the FSEC[KEYEN] bits to verify that this command is enabled. If not enabled, the flash memory module sets the FSTAT[ACCERR] bit and terminates. If the command is enabled, the flash memory module compares the key provided in FCCOB to the backdoor comparison key in the Flash Configuration Field. If the backdoor keys match, the FSEC[SEC] field is changed to the unsecure state and security is released. If the backdoor keys do not match, security is not released and all future attempts to execute the Verify Backdoor Access Key command are immediately aborted and the FSTAT[ACCERR] bit is (again) set to 1 until a reset of the flash memory module module occurs. If the entire 8-byte key is all zeros or all ones, the Verify Backdoor Access Key command fails with an access error. The CCIF flag is set after the Verify Backdoor Access Key operation completes.

Table 13-25. Verify Backdoor Access Key Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
The supplied key is all-0s or all-Fs	FSTAT[ACCERR]
An incorrect backdoor key is supplied	FSTAT[ACCERR]
Backdoor key access has not been enabled (see the description of the FSEC register)	FSTAT[ACCERR]
This command is launched and the backdoor key has mismatched since the last power down reset	FSTAT[ACCERR]

13.4.9.11 Erase All Blocks Unsecure Command

The Erase All Blocks Unsecure operation erases all flash memory, verifies all memory contents, programs the security byte in the Flash Configuration Field to the unsecure state, and releases MCU security.

Table 13-26. Erase All Blocks Unsecure Command FCCOB Requirements

FCCOB Number	FCCOB Contents [7:0]
0	0x49 (ERSALLU)

After clearing CCIF to launch the Erase All Blocks Unsecure command, the flash memory module erases all program flash memory, then verifies that all are erased.

If the flash memory module verifies that all program flash memory was properly erased, security is released by setting the FSEC[SEC] field to the unsecure state, and the security byte (see Flash Configuration Field Description) is programmed to the unsecure state by the Erase All Blocks Unsecure command. If the erase or program verify fails, the FSTAT[MGSTAT0] bit is set. The CCIF flag is set after the Erase All Blocks Unsecure operation completes.

Table 13-27. Erase All Blocks Unsecure Command Error Handling

Error Condition	Error Bit
Command not available in current mode/security	FSTAT[ACCERR]
Any errors have been encountered during erase or program verify operations	FSTAT[MGSTAT0]

13.4.10 Security

The flash memory module provides security information to the MCU based on contents of the FSEC security register.

The MCU then limits access to flash memory resources as defined in the device's Chip Configuration details. During reset, the flash memory module initializes the FSEC register using data read from the security byte of the Flash Configuration Field (see Flash Configuration Field Description).

The following fields are available in the FSEC register. The settings are described in the Flash Security Register (FTFA_FSEC) details.

Flash security features are discussed further in AN4507: Using the Kinetis Security and Flash Protection Features . Note that not all features described in the application note are available on this device.

Table 13-28. FSEC register fields

FSEC field	Description
KEYEN	Backdoor Key Access
MEEN	Mass Erase Capability
FSLACC	Factory Security Level Access
SEC	MCU security

13.4.10.1 Changing the Security State

The security state out of reset can be permanently changed by programming the security byte of the flash configuration field. This assumes that you are starting from a mode where the necessary program flash erase and program commands are available and that the region of the program flash containing the flash configuration field is unprotected. If the flash security byte is successfully programmed, its new value takes affect after the next chip reset.

13.4.10.1.1 Unsecuring the Chip Using Backdoor Key Access

The chip can be unsecured by using the backdoor key access feature, which requires knowledge of the contents of the 8-byte backdoor key value stored in the Flash Configuration Field (see Flash Configuration Field Description). If the FSEC[KEYEN] bits are in the enabled state, the Verify Backdoor Access Key command (see Verify Backdoor Access Key Command) can be run; it allows the user to present prospective keys for comparison to the stored keys. If the keys match, the FSEC[SEC] bits are changed to unsecure the chip. The entire 8-byte key cannot be all 0s or all 1s; that is, 0000_0000_0000_0000h and FFFF_FFFF_FFFF_FFFFh are not accepted by the Verify Backdoor Access Key command as valid comparison values. While the Verify Backdoor Access Key command is active, program flash memory is not available for read access and returns invalid data.

The user code stored in the program flash memory must have a method of receiving the backdoor keys from an external stimulus. This external stimulus would typically be through one of the on-chip serial ports.

If the KEYEN bits are in the enabled state, the chip can be unsecured by the following backdoor key access sequence:

1. Follow the command sequence for the Verify Backdoor Access Key command as explained in Verify Backdoor Access Key Command

2. If the Verify Backdoor Access Key command is successful, the chip is unsecured and the FSEC[SEC] bits are forced to the unsecure state

An illegal key provided to the Verify Backdoor Access Key command prohibits further use of the Verify Backdoor Access Key command. A reset of the chip is the only method to re-enable the Verify Backdoor Access Key command when a comparison fails.

After the backdoor keys have been correctly matched, the chip is unsecured by changing the FSEC[SEC] bits. A successful execution of the Verify Backdoor Access Key command changes the security in the FSEC register only. It does not alter the security byte or the keys stored in the Flash Configuration Field (Flash Configuration Field Description). After the next reset of the chip, the security state of the flash memory module reverts back to the flash security byte in the Flash Configuration Field. The Verify Backdoor Access Key command sequence has no effect on the program and erase protections defined in the program flash protection registers.

If the backdoor keys successfully match, the unsecured chip has full control of the contents of the Flash Configuration Field. The chip may erase the sector containing the Flash Configuration Field and reprogram the flash security byte to the unsecure state and change the backdoor keys to any desired value.

13.4.11 Reset Sequence

On each system reset the flash memory module executes a sequence which establishes initial values for the flash block configuration parameters, FPROT, FOPT, and FSEC registers.

FSTAT[CCIF] is cleared throughout the reset sequence. The flash memory module holds off CPU access during the reset sequence. Flash reads are possible when the hold is removed. Completion of the reset sequence is marked by setting CCIF which enables flash user commands.

If a reset occurs while any flash command is in progress, that command is immediately aborted. The state of the word being programmed or the sector/block being erased is not guaranteed. Commands and operations do not automatically resume after exiting reset.

Chapter 14
Clock Distribution

14.1 Introduction

This chapter presents the clock architecture overview of this device, the clock distribution and module clocks, and a clock terminology section. The clocking generation and configuration can be divided into 3 parts:

1. Clock sources generation
   - FIRC, SIRC, SOSC, LPFLL, all from the SCG module
   - LPO from PMC
2. Peripheral Clock Controller (PCC)
3. Module level clock control (Inside specific peripherals)

The System Clock Generator (SCG) module is used on this device for main system clock generation. It generates clock sources like Fast IRC (FIRC, 48 MHz, within 1% accuracy), Slow IRC (SIRC, 2/8 MHz, within 3% accuracy), System Oscillator (SOSC) and LPFLL. It controls which clock source is used to derive the system clocks. The SCG also divides the selected clock source into a variety of clock domains, including the clocks for the system bus masters, system bus slaves, and flash memory .

Besides the clocks generated by SCG, there are other clock generator: LPO from PMC.

Clock selection for most modules is controlled by the Peripheral Clock Controller (PCC) module. The PCC also implements module-specific clock gating to allow granular shutoff of modules.

Various modules have module-specific clocks that can be generated from the FIRC_CLK, SIRC_CLK, SOSC_CLK, FLL_CLK clock. In addition, there are various other module-specific clocks that have other alternate sources. While clock selection for most modules is controlled by the PCC module, some peripherals have clock source selection/divider inside the module, for details, please see the "Peripheral Clock Summary" table for more information.

14.2 High-level clocking diagram

The following diagram shows the high-level clocking architecture and various clock sources for this device.

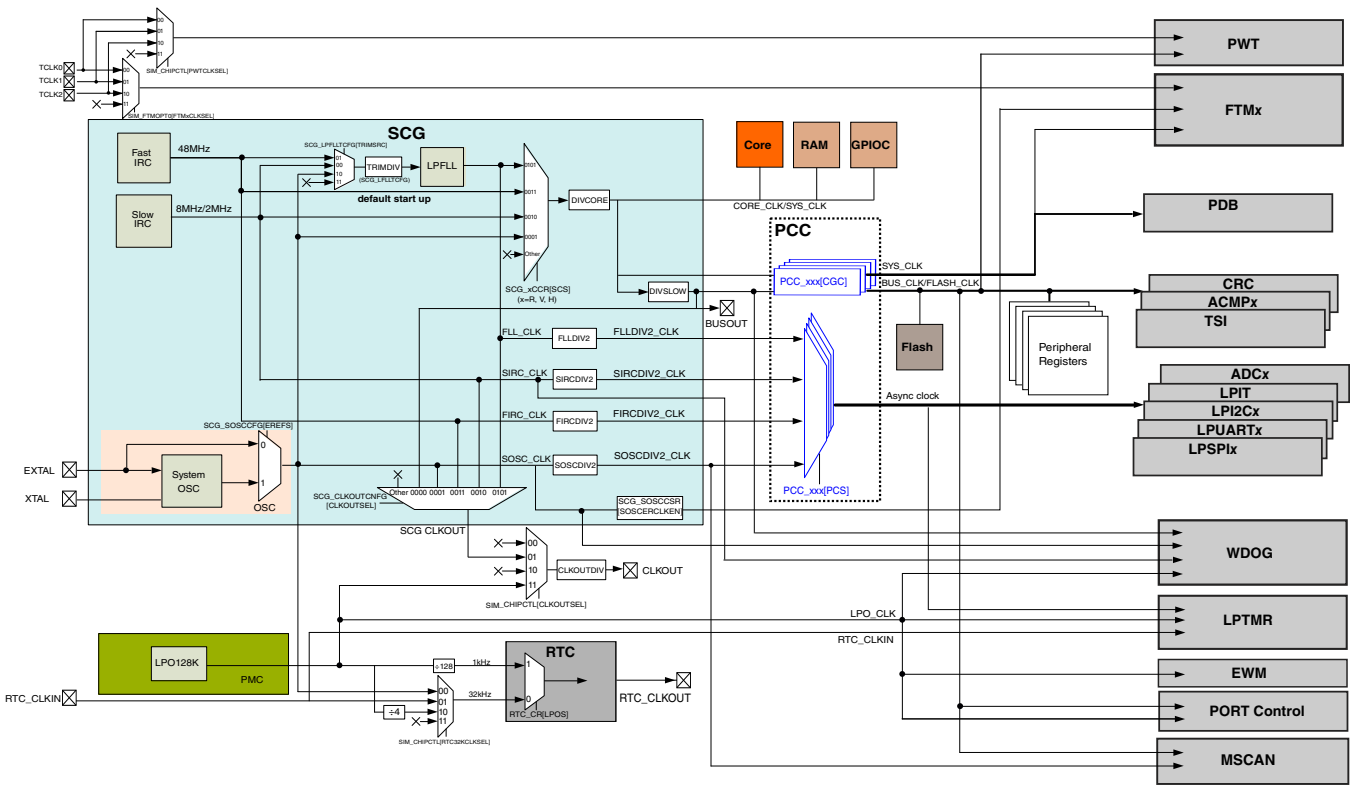


Figure 14-1. Clocking Diagram

14.3 Clock definitions

The following table describes the clocks in the previous block diagram and other sections of this document.

Clock name	Description
CORE_CLK	Clocks the ARM core, divided by DIVCORE bits inside SCG
SYS_CLK	Clocks the Crossbar, NVIC, Flash controller, FTM and PDB, etc. SYS_CLK can run up to CORE_CLK and divided by DIVCORE bits inside SCG.
BUS_CLK	Clocks the Peripherals, divided by bits inside SCG
FLASH_CLK	Clocks the flash module, divided by DIVSLOW bits inside SCG

Table continues on the next page...

Clock name	Description
FLL_CLK	Optional divided FLL source for peripherals
SIRC_CLK	Optional divided SIRC source for peripherals
FIRC_CLK	Optional divided FIRC source for peripherals
SOSC_CLK[1]	Optional divided System Oscillator clock for peripherals. **NOTE:** SOSC_CLK/ERCLK/OSCERCLK stands for the same clock source, in some module chapters.
LPO_CLK	Always on low power oscillator clock inside PMC
RTC_CLKOUT	Clock output from RTC module for both internal and external
CLKOUT	Optional output clock source for external devices
BUSOUT	Optional output bus clock through pin for external devices or diagnostics

1.
- For WDOG, its SOSC_CLK is with no dividers.
- For FTM, its SOSC_CLK is with no dividers, but gated by SCG_SOSCCSR[SOSCERCLKEN].
- For other peripherals (LPUART etc.), its SOSC_CLK is divided by DIVx.

14.4 Typical Clock Configuration

The clock dividers are programmed via the SCG module's clock divider registers. The following requirements must be met when configuring the clocks for this device:

The following are a few of the more common clock configurations for this device:

Clock	Normal Run (Using LPFLL)	Normal Run (Typically using FIRC)	VLPR (Using SIRC or SOSC)
CORE_CLK	48 MHz	48 MHz	4 MHz
SYS_CLK	48 MHz	48 MHz	4 MHz
BUS_CLK	24 MHz	24 MHz	1 MHz
FLASH_CLK	24 MHz	24 MHz	1 MHz

14.4.1 Default start-up clock

In default out of reset, the CPU is clocked from internal Fast IRC (IRC48M). The clocks, e.g. core clock and bus clock, are programmed via the SCG module. For the default reset value of divider, please refer to SCG chapter for details.

The flash memory's FTFA_FOPT[LPBOOT] bit provides an option to control the reset value of the core clock, system clock divider as shown below:

FTFA_FOPT [LPBOOT]	Core/system clock	Description
0	divide by 2	Low power boot
1	divide by 1	Normal boot

This gives the user flexibility for a lower frequency, low-power boot option. The flash erased state defaults to fast clocking mode, since where the low power boot (FTFA_FOPT[LPBOOT]) bit resides in flash is logic 1 in the flash erased state.

To enable the low power boot option program FTFA_FOPT[LPBOOT] to zero. During the reset sequence, if LPBOOT is cleared, the system is in a slow clock configuration. Upon any system reset, the clock dividers return to this configurable reset state.

14.4.2 VLPR mode clocking

The clock dividers should not be changed while in VLPR mode. They must be programmed prior to entering VLPR mode to guarantee:

- the core/system clocks are less than or equal to 4 MHz
- the flash memory clock is less than or equal to 1 MHz

14.5 Clock Gating

The clock to most of the modules can be individually gated on and off using the PCC module. After any reset, PCC disables part of the clock to the corresponding module to conserve power. Prior to initializing a module, set the corresponding clock gating control bits in PCC register to enable the clock. Before turning off the clock, make sure to disable the module.

Any bus access to a peripheral that has its bus interface clock disabled (CGC=0 in PCC module) will generate a bus fault. While any bus access to a peripheral that has its functional clock disabled (PCS=0 in PCC module) will not return a fault, but the module cannot work properly.

NOTE

Changes to clock source should be done when clock is gated by PCC to avoid glitches to output clock.

14.6 Module clocks

The following table summarizes the clocks associated with each module.

Table 14-1. Peripheral Clock Summary

Module Name	Bus Interface Clock Gating	Peripheral Functional Clock		Max Frequency of Clock Source
	Gated by [CGC] bit of PCC	Clocks controlled by [PCS] bits of PCC [1]	Clocks controlled by registers inside module	
Communications				
LPUART0 – LPUART2	Yes	FIRC_CLK, SIRC_CLK, FLL_CLK, SOSC_CLK	-	Max: 48 MHz
LPSPI0	Yes	FIRC_CLK, SIRC_CLK, FLL_CLK, SOSC_CLK	-	Max: 48 MHz SCK clock Max: 25 MHz
LPI^{2}C0	Yes	FIRC_CLK, SIRC_CLK, FLL_CLK, SOSC_CLK	-	Max: 48 MHz
MSCAN0	Yes	-	BUS_CLK, SOSC_CLK	Max: 40 MHz
Timers				
LPTMR	Yes	FIRC_CLK, SIRC_CLK, FLL_CLK, SOSC_CLK	LPO_CLK,RTC_CLKIN	Max: 48 MHz LPO_CLK: 128kHz
LPIT	Yes	FIRC_CLK, SIRC_CLK, FLL_CLK, SOSC_CLK	-	Max: 48 MHz
RTC	Yes	-	LPO_CLK, SOSC_CLK,RTC_CLKIN	Max: BUS_CLK LPO_CLK: 1kHz, 32kHz
PDB0	Yes	SYS_CLK		Max: SYS_CLK
FlexTimer0 - FlexTimer1	Yes	-	SYS_CLK, SOSC_CLK, TCLKx	Max: SYS_CLK
PWT	Yes	-	BUS_CLK, TCLKx	Max: BUS_CLK
System Modules				
Watchdog	No	-	BUS_CLK, SIRC_CLK, LPO_CLK, SOSC_CLK	Max: BUS_CLK LPO_CLK: 128kHz
EWM	Yes	-	LPO_CLK	LPO_CLK: 128kHz
PMC	No	-	BUS_CLK, LPO_CLK	Max: BUS_CLK
RCM	No	-	BUS_CLK, LPO_CLK	Max: BUS_CLK

Table continues on the next page...

Table 14-1. Peripheral Clock Summary (continued)

Module Name	Bus Interface Clock Gating	Peripheral Functional Clock		Max Frequency of Clock Source
	Gated by [CGC] bit of PCC	Clocks controlled by [PCS] bits of PCC [1]	Clocks controlled by registers inside module	
				LPO_CLK: 1kHz
Port Control	Yes	-	BUS_CLK, LPO_CLK	Max: BUS_CLK LPO_CLK: 128kHz
SIM	No	BUS_CLK		Max: BUS_CLK
CRC	Yes	BUS_CLK		Max: BUS_CLK
GPIOC	No	SYS_CLK		Max: SYS_CLK
Memory Modules				
FTFA	Yes	FLASH_CLK		Max: FLASH_CLK
SYS RAM	No	SYS_CLK		Max: SYS_CLK
Analog Modules				
ADC0	Yes	FIRC_CLK, SIRC_CLK, FLL_CLK, SOSC_CLK	-	Max: 48 MHz
ACMP0	Yes	BUS_CLK		Max: BUS_CLK
TSI	Yes	BUS_CLK		Max: BUS_CLK

1. The clock sources undergo clock divider DIV*x* in SCG (output to PCC). For details, see the "High-Level clocking diagram" section in Clocking chapter and the "Chip-specific information" section in each module chapter.

14.6.1 LPO clock distribution

See the section "High-Level clocking diagram" for details.

14.6.2 EWM clocks

This table shows the EWM clocks and the corresponding chip clocks.

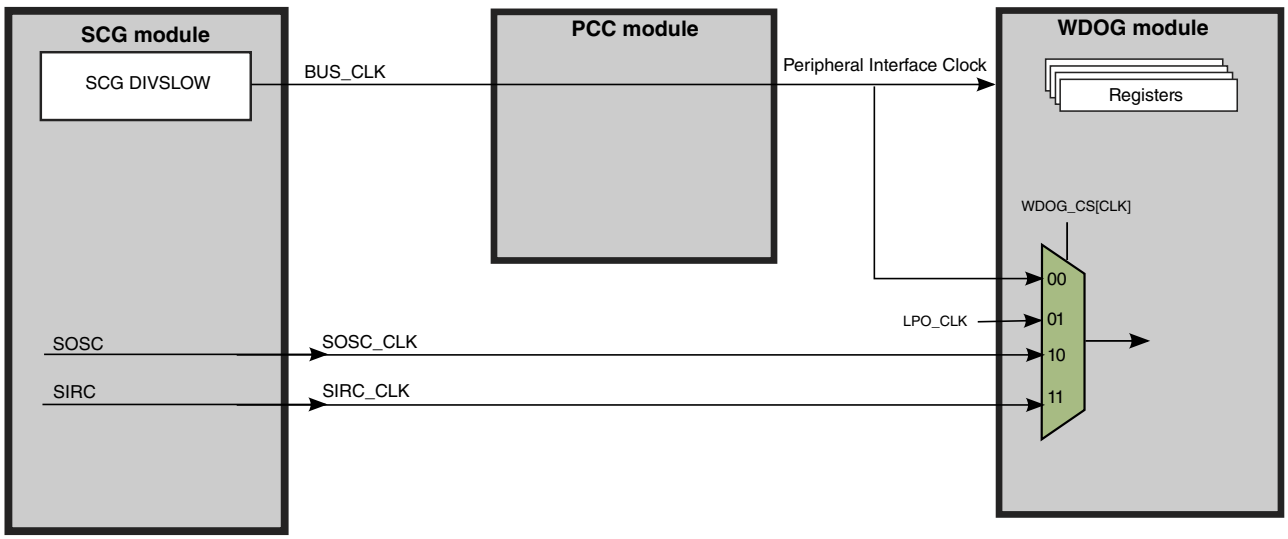
Table 14-2. EWM clock connections

Module clock	Chip clock
Low Power Clock	128 kHz LPO Clock (LPO_CLK)

14.6.3 WDOG Clocking Information

The following figure shows the input clock sources available for this module.

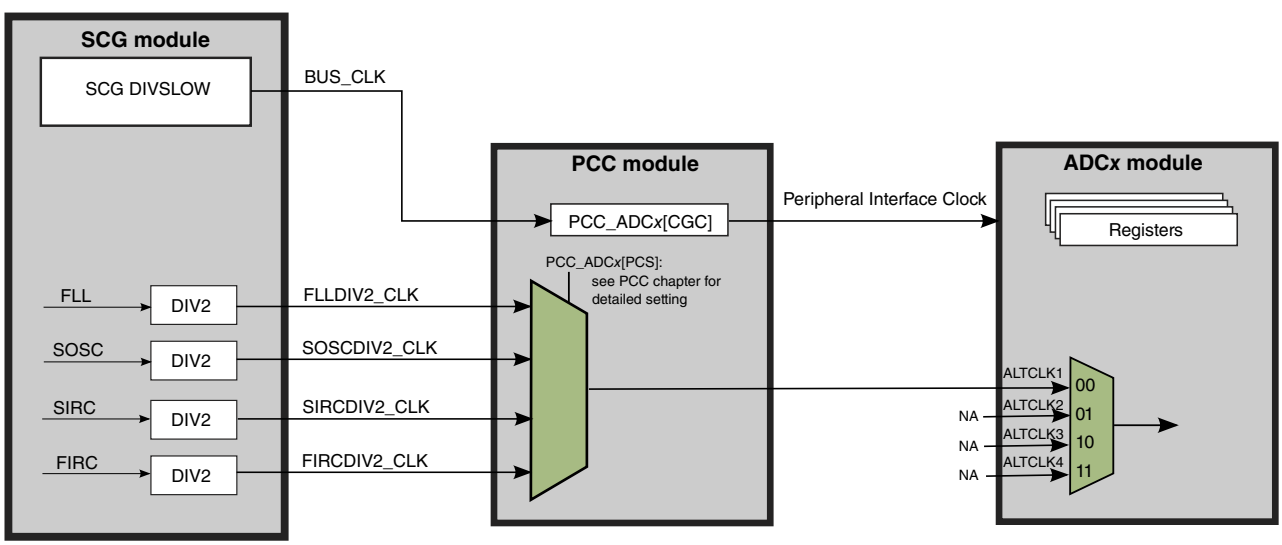
Peripheral Clocking - WDOG



14.6.4 ADC Clocking Information

The following figure shows the input clock sources available for this module.

Peripheral Clocking - ADC



NOTE

ALTCLK2~4 are not connected on this chip.

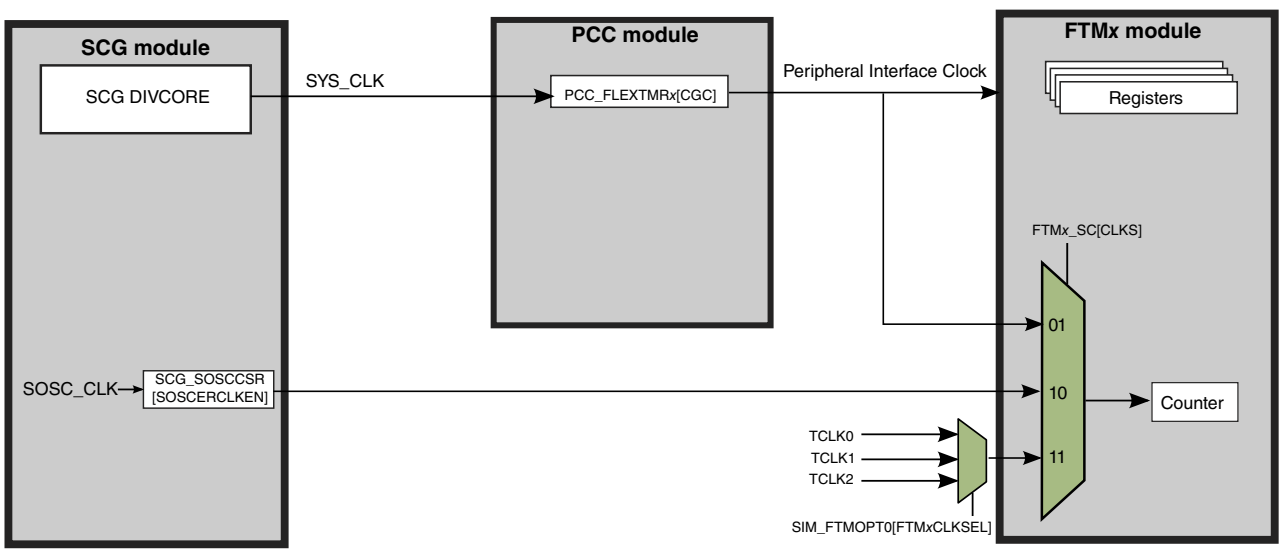
14.6.5 PDB Clock Options

The PDB module is clocked by the system clock (SYS_CLK). The SYS_CLK could run up to CPU frequency which provides higher timing resolution and more precise delay control with the PDB counter.

14.6.6 FTM Clocking Information

The following figure shows the input clock sources available for this module.

Peripheral Clocking - FTM



NOTE

Due to FTM hardware implementation limitations, the frequency of the fixed frequency clock must not exceed 1/2 of the FTM system clock frequency (SYS_CLK).

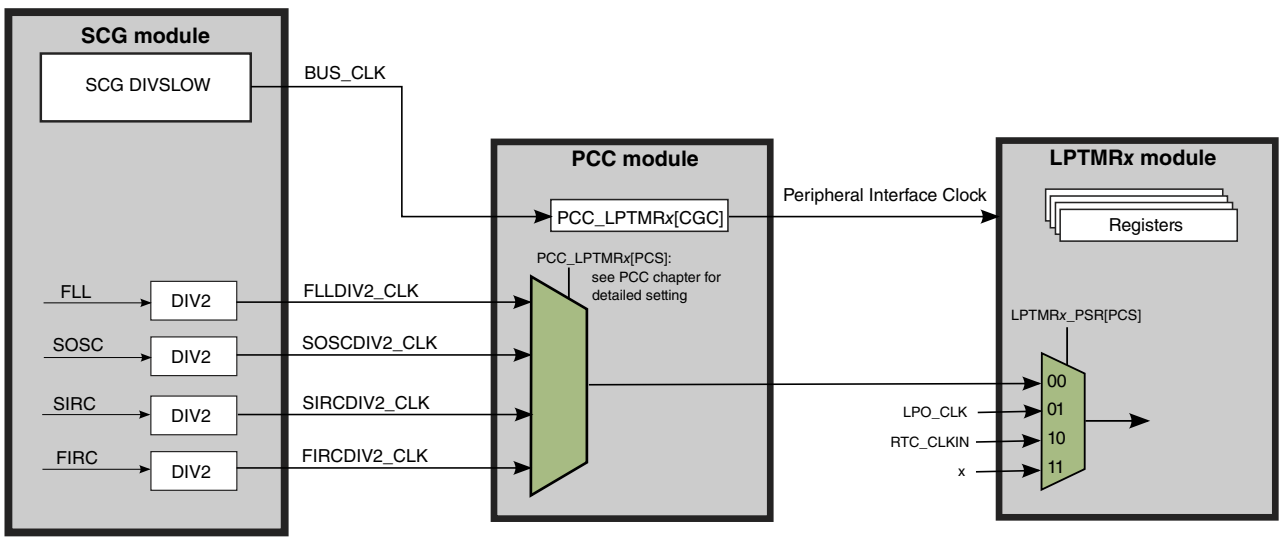
NOTE

The external clock are synchronized by FTM system clock (SYS_CLK). Therefore, to meet Nyquist criteria considering also jitter, the frequency of the external clock source must not exceed 1/4 of the system clock frequency.

14.6.7 LPTMR prescaler/glitch filter clocking options

The following figure shows the input clock sources available for this module.

Peripheral Clocking - LPTMR



NOTE

The chosen clock must remain enabled if the LPTMR is to continue operating in all required low-power modes.

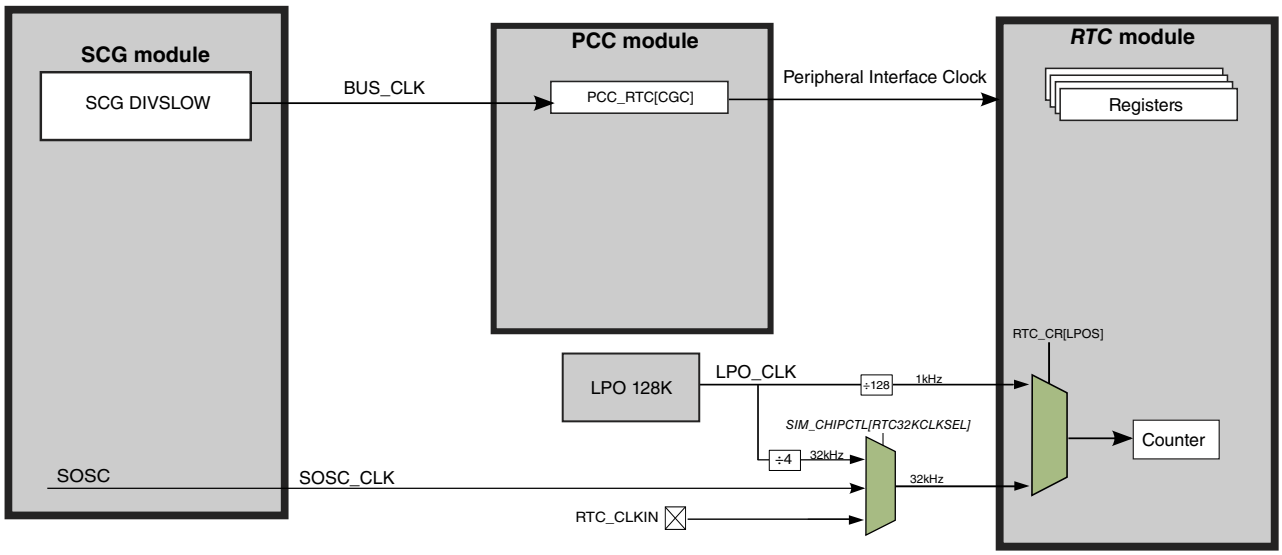
14.6.8 RTC Clocking Information

The following figure shows the input clock sources available for this module.

NOTE

No 32 kHz crystal in this device. See the clocking figure below, for more details about RTC clock source.

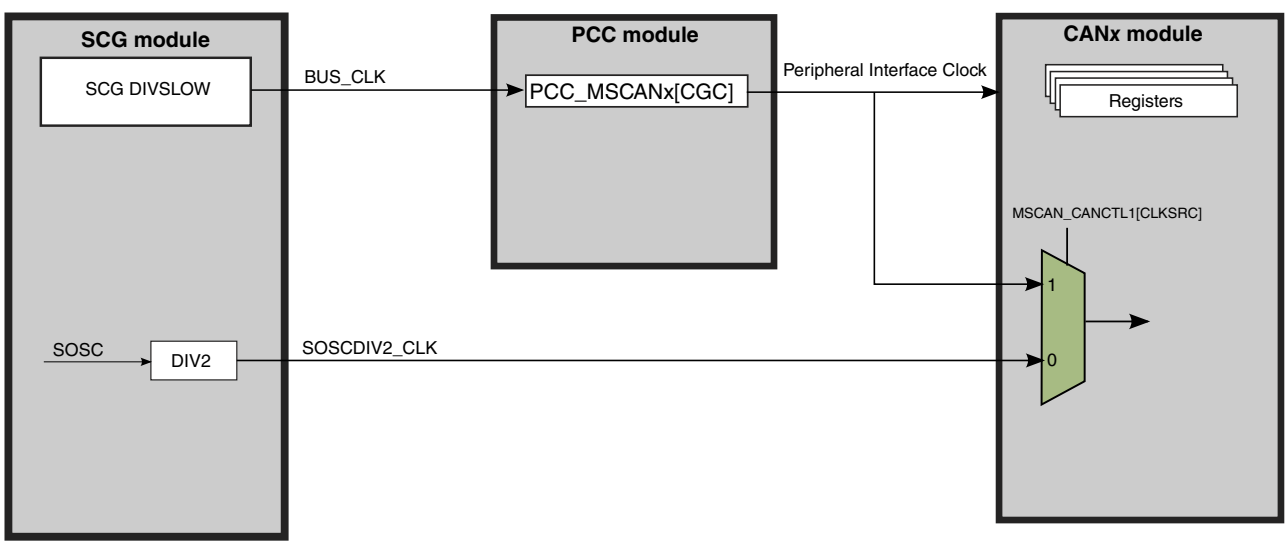
Peripheral Clocking - RTC



14.6.9 MSCAN clocking

The MSCAN module has programmable clock source. It could be clocked by bus clock or external oscillator clock (SOSCDIV2_CLK). User can configure MSCAN_CANCTL1[CLKSRC] to select the clock used.

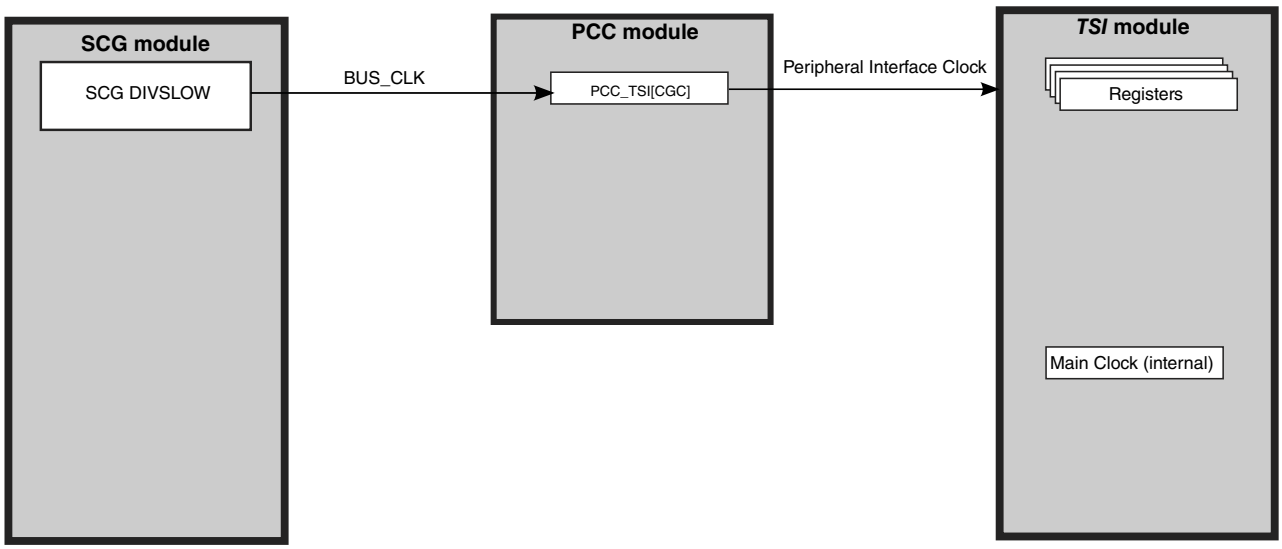
Peripheral Clocking - MSCAN



14.6.10 TSI Clocking Information

This following figure shows the TSI clocks.

Peripheral Clocking - TSI

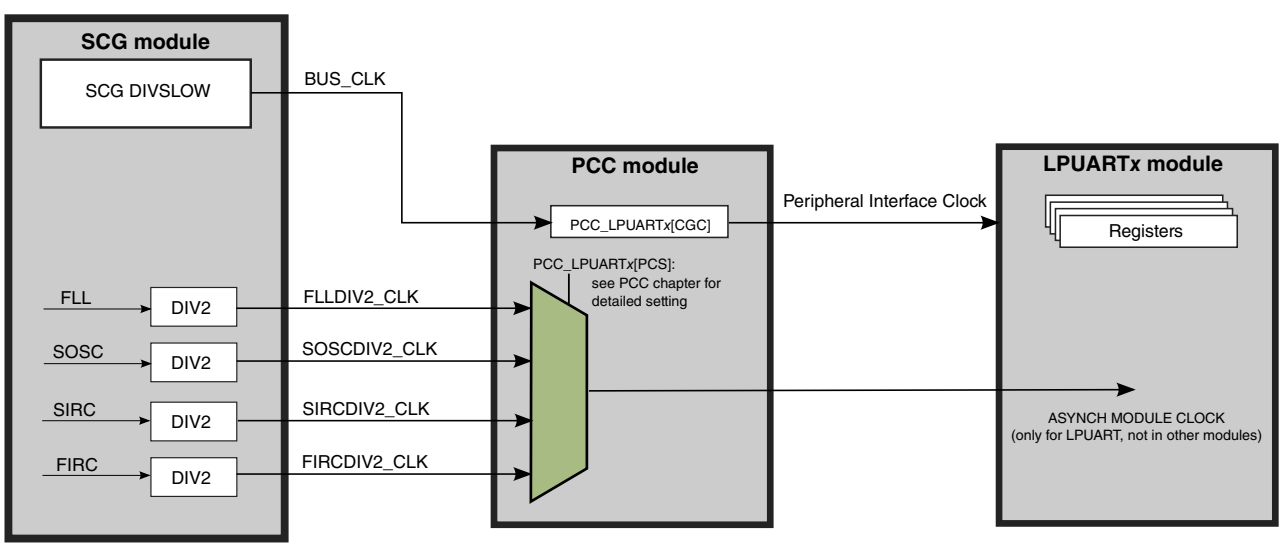


14.6.11 Module Clocking Information for LPUART, LPSPI, LPI2C and LPIT

The following figure shows the input clock sources available for this module.

Peripheral Clocking - LPUART, etc.

Note: this example figure also applies similarly to the clocking for LPSPI, LPI2C, LPIT, etc.



Chapter 15
System Clock Generator (SCG)

15.1 Chip-specific information for this module

15.1.1 Instantiation Information

15.1.1.1 Information of SCG on this device

NOTE

For the clocking dividers, DIV1 is not used on this device, and DIV2 is used in SCG for peripheral clocking. See the "High-Level clocking diagram" in the Clock Distribution chapter.

NOTE

FIRC is trimmed to 48 MHz only, in this device. Other values are reserved in SCG_FIRCCFG[RANGE].

Writing to SCG_FIRCSTAT register can cause hard fault when auto trim is disabled.

ERCLK (External Reference Clock) is either from an external pin or from the SCG internal OSC (SOSC), and configured with the SCG_SOSCCFG[EREFS] bit.

For the supported frequency range of OSC, see the "Oscillator electrical specifications" section in the Data Sheet. For this device, low frequency range: 32 kHz - 40 kHz; medium frequency range: 4 MHz - 8 MHz; high frequency range: 8 MHz - 40 MHz.

15.1.1.1.1 SCG clock mode transitions

The following figure shows the valid clock mode transitions supported by SCG, for this device. For more information, see the Functional description section.

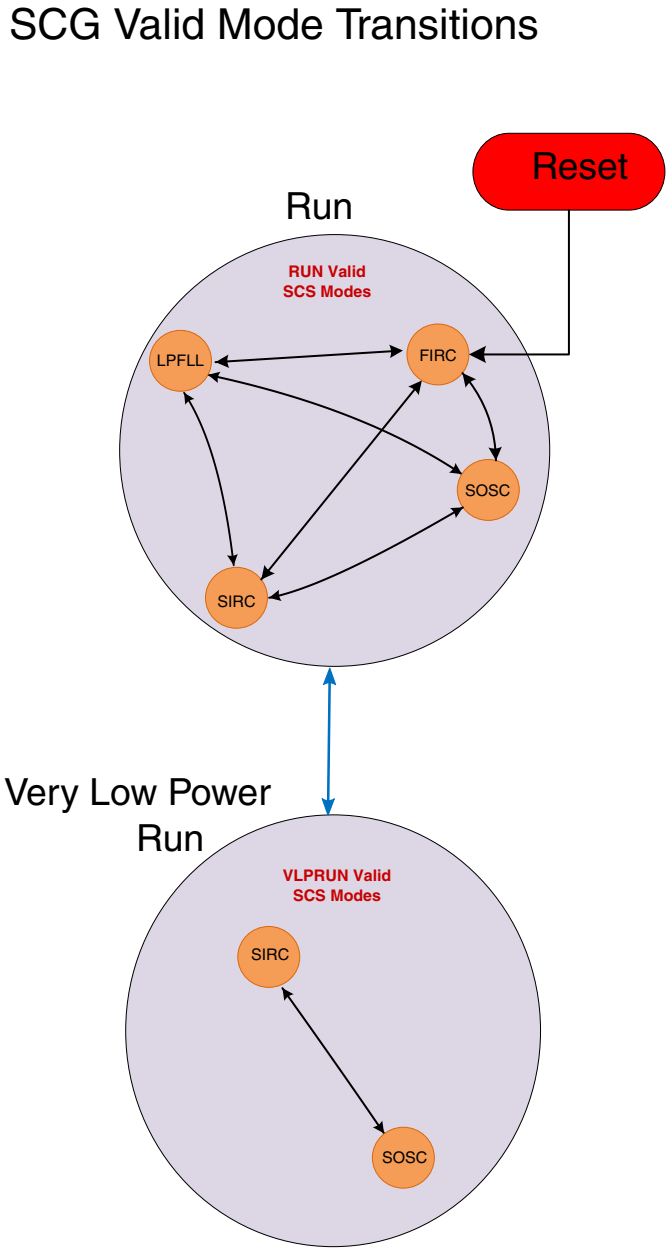


Figure 15-1. SCG Valid Mode Transition Diagram

15.2 Introduction

The system clock generator (SCG) module provides the system clocks of the MCU. The SCG contains a frequency-locked loop (LPFLL), a slow internal reference clock (SIRC), a fast internal reference clock (FIRC), and the system oscillator clock (SOSC). The LPFLL trimming is controlled by the either the SOSC reference clock, SIRC reference

clock or FIRC reference clock. The SCG can select either the output clock of the LPFLL, or a SCG reference clock (SIRC, FIRC, and SOSC) as the source for the MCU system clocks. The SCG also supports operation with crystal oscillators, which allows an external crystal, ceramic resonator, or another external clock source to produce the external reference clock (which are also available as clock sources for the MCU systems clocks).

15.2.1 Features

Key features of the SCG module are:

- Low Power Frequency Locked-Loop (LPFLL):
  - Programmable multiplier for up to 4 different frequency ranges
  - Internal reference clocks or oscillators reference clocks can be used as the LPFLL source for trimming purposes
  - Can be selected as the clock source for the MCU system clocks
  - 3 programmable post-divider clock outputs, which can be used as a clock source for other on-chip peripherals
- 2 Internal reference clock (IRC) generators:
  - Fast IRC clock with programmable High and Low frequency range
  - Either the slow or the fast clock can be selected as the clock source for the MCU system clocks
  - 2 programmable post-divider clock outputs for each IRC, which can be used as clock sources for other on-chip peripherals
- System Crystal Oscillator:
  - Can be used as a source for the LPFLL
  - Can be selected as the clock source for the MCU system clocks
- Clock monitor with reset and interrupt request capability for SOSC, clocks

See the Clock Distribution Chapter for more information.

15.3 Memory Map/Register Definition

This section includes the memory map and register definition.

The SCG registers can only be written when in supervisor mode. Write accesses when in user mode will result in a bus transfer error. Read accesses may be performed in both supervisor and user mode.

NOTE

For any writeable SCG registers, only 32-bit writes are allowed. 8-bit or 16-bit writes will result in transfer errors.

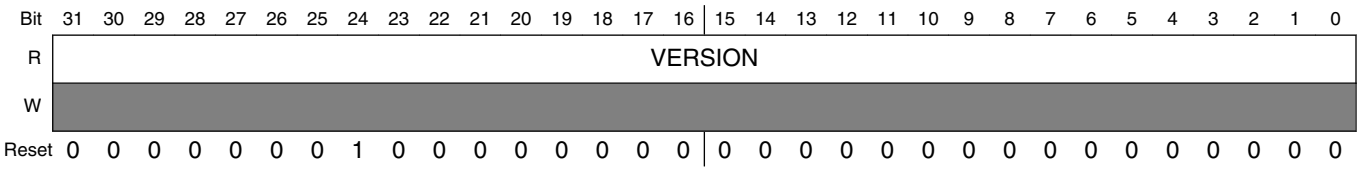
SCG memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4006_4000	Version ID Register (SCG_VERID)	32	R	0100_0000h	15.3.1/211
4006_4004	Parameter Register (SCG_PARAM)	32	R	See section	15.3.2/211
4006_4010	Clock Status Register (SCG_CSR)	32	R	See section	15.3.3/212
4006_4014	Run Clock Control Register (SCG_RCCR)	32	R/W	See section	15.3.4/214
4006_4018	VLPR Clock Control Register (SCG_VCCR)	32	R/W	See section	15.3.5/216
4006_4020	SCG CLKOUT Configuration Register (SCG_CLKOUTCNFG)	32	R/W	0300_0000h	15.3.6/218
4006_4100	System OSC Control Status Register (SCG_SOSCCSR)	32	R/W	See section	15.3.7/219
4006_4104	System OSC Divide Register (SCG_SOSCDIV)	32	R/W	0000_0000h	15.3.8/221
4006_4108	System Oscillator Configuration Register (SCG_SOSCCFG)	32	R/W	0000_0010h	15.3.9/222
4006_4200	Slow IRC Control Status Register (SCG_SIRCCSR)	32	R/W	0100_0005h	15.3.10/224
4006_4204	Slow IRC Divide Register (SCG_SIRCDIV)	32	R/W	0000_0000h	15.3.11/225
4006_4208	Slow IRC Configuration Register (SCG_SIRCCFG)	32	R/W	0000_0001h	15.3.12/226
4006_4300	Fast IRC Control Status Register (SCG_FIRCCSR)	32	R/W	See section	15.3.13/227
4006_4304	Fast IRC Divide Register (SCG_FIRCDIV)	32	R/W	0000_0000h	15.3.14/229
4006_4308	Fast IRC Configuration Register (SCG_FIRCCFG)	32	R/W	0000_0000h	15.3.15/230
4006_430C	Fast IRC Trim Configuration Register (SCG_FIRCTCFG)	32	R/W	0000_0000h	15.3.16/230
4006_4318	Fast IRC Status Register (SCG_FIRCSTAT)	32	R/W	See section	15.3.17/232
4006_4500	Low Power FLL Control Status Register (SCG_LPFLLCSR)	32	R/W	0000_0000h	15.3.18/233
4006_4504	Low Power FLL Divide Register (SCG_LPFLLDIV)	32	R/W	0000_0000h	15.3.19/235
4006_4508	Low Power FLL Configuration Register (SCG_LPFLLCFG)	32	R/W	0000_0000h	15.3.20/236
4006_450C	Low Power FLL Trim Configuration Register (SCG_LPFLLTCFG)	32	R/W	0000_0000h	15.3.21/237
4006_4514	Low Power FLL Status Register (SCG_LPFLLSTAT)	32	R/W	See section	15.3.22/238

15.3.1 Version ID Register (SCG_VERID)

Note: Writing to this register will result in a transfer error.

Address: 4006_4000h base + 0h offset = 4006_4000h



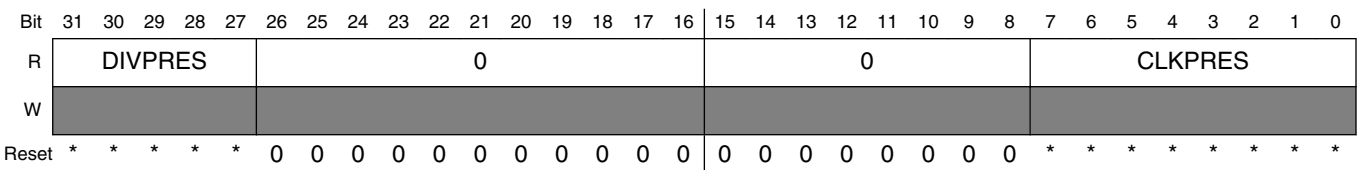
SCG_VERID field descriptions

Field	Description
VERSION	SCG Version Number

15.3.2 Parameter Register (SCG_PARAM)

Note: Writing to this register will result in a transfer error.

Address: 4006_4000h base + 4h offset = 4006_4004h



* Notes:
- DIVPRES field: The reset value is controlled by which SCG System Dividers are used by Soc.
- CLKPRES field: The reset value is controlled by which SCG Clock Sources are used by Soc. Please reference the Reference manual clocking chapter.

SCG_PARAM field descriptions

Field	Description
31–27 DIVPRES	Divider Present Indicates which system clock dividers are present in this instance of SCG. DIVPRES[27]=1 System DIVSLOW is present. DIVPRES[29]=1 Reserved DIVPRES[30]=1 Reserved DIVPRES[31]=1 System DIVCORE is present
26–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

SCG_PARAM field descriptions (continued)

Field	Description
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
CLKPRES	Clock Present Indicates which clock sources are present in this instance of SCG. Any bits not defined in this bit field are Reserved and always has the value 0 when read. CLKPRES[0] Reserved CLKPRES[1]=1 System OSC (SOSC) is present CLKPRES[2]=1 Slow IRC (SIRC) is present CLKPRES[3]=1 Fast IRC (FIRC) is present CLKPRES[5]=1 Low Power FLL (LPFLL) is present

15.3.3 Clock Status Register (SCG_CSR)

This register returns the currently configured system clock source and the system clock dividers for the core (DIVCORE) and peripheral interface clock (DIVSLOW). The SCG_CSR reflects the configuration set by one of three clock control registers SCG_RCCR, SCG_VCCR.

Note: Writing to this register will result in a transfer error.

Address: 4006_4000h base + 10h offset = 4006_4010h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				SCS				0				DIVCORE				0				0				0				DIVSLOW			
W																																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	*	*	*	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

* Notes:

- DIVCORE field: The reset value is controlled by user FOPT bits that get uploaded during reset. The valid reset values are div-by-1 or div-by-2 when resetting into RUN mode or div-by-4 or div-by-8 when resetting into VLPR mode.

SCG_CSR field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 SCS	System Clock Source Returns the currently configured clock source generating the system clock. 0000 Reserved 0001 System OSC (SOSC_CLK) 0010 Slow IRC (SIRC_CLK) 0011 Fast IRC (FIRC_CLK)

Table continues on the next page...

SCG_CSR field descriptions (continued)

Field	Description
	0100 Reserved 0101 Low Power FLL (LPFLL_CLK) 0110 Reserved 0111 Reserved
23–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–16 DIVCORE	Core Clock Divide Ratio 0000 Divide-by-1 0001 Divide-by-2 0010 Divide-by-3 0011 Divide-by-4 0100 Divide-by-5 0101 Divide-by-6 0110 Divide-by-7 0111 Divide-by-8 1000 Divide-by-9 1001 Divide-by-10 1010 Divide-by-11 1011 Divide-by-12 1100 Divide-by-13 1101 Divide-by-14 1110 Divide-by-15 1111 Divide-by-16
15–12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DIVSLOW	Slow Clock Divide Ratio 0000 Reserved 0001 Divide-by-2 0010 Divide-by-3 0011 Divide-by-4 0100 Divide-by-5 0101 Divide-by-6 0110 Divide-by-7 0111 Divide-by-8 1000 Reserved 1001 Reserved 1010 Reserved 1011 Reserved 1100 Reserved 1101 Reserved

Table continues on the next page...

SCG_CSR field descriptions (continued)

Field	Description
	1110 Reserved 1111 Reserved

15.3.4 Run Clock Control Register (SCG_RCCR)

This register controls the system clock source and the system clock dividers for the core, platform, external and bus clock domains when in Run mode only. This register can only be written using a 32-bit write. Selecting a different clock source when in RUN requires that clock source to be enabled first and be valid before system clocks switch to that clock source. If system clock divide ratios also change when selecting a different clock mode when in RUN, new system clock divide ratios will not take affect until new clock source is valid.

Address: 4006_4000h base + 14h offset = 4006_4014h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				SCS				0				DIVCORE				Reserved				0				0				DIVSLOW			
W																																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	*	*	*	*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

* Notes:
- DIVCORE field: The reset value is controlled by user FOPT bits that get uploaded during reset. The two valid reset values are div-by-1 and div-by-2

SCG_RCCR field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 SCS	System Clock Source Selects the clock source generating the system clock in Run mode. Attempting to select a clock that is not valid will be ignored. Selecting a different clock source when in Run mode requires that clock source to be enabled first and be valid before system clocks are allowed to switch to that clock source. 0000 Reserved 0001 System OSC (SOSC_CLK) 0010 Slow IRC (SIRC_CLK) 0011 Fast IRC (FIRC_CLK) 0100 Reserved 0101 Low Power FLL (LPFLL_CLK) 0110 Reserved 0111 Reserved
23–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

SCG_RCCR field descriptions (continued)

Field	Description
19–16 DIVCORE	Core Clock Divide Ratio 0000 Divide-by-1 0001 Divide-by-2 0010 Divide-by-3 0011 Divide-by-4 0100 Divide-by-5 0101 Divide-by-6 0110 Divide-by-7 0111 Divide-by-8 1000 Divide-by-9 1001 Divide-by-10 1010 Divide-by-11 1011 Divide-by-12 1100 Divide-by-13 1101 Divide-by-14 1110 Divide-by-15 1111 Divide-by-16
15–12 Reserved	This field is reserved. Software should write 0 to these bits to maintain compatibility. This field is reserved.
11–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DIVSLOW	Slow Clock Divide Ratio 0000 Reserved 0001 Divide-by-2 0010 Divide-by-3 0011 Divide-by-4 0100 Divide-by-5 0101 Divide-by-6 0110 Divide-by-7 0111 Divide-by-8 1000 Reserved 1001 Reserved 1010 Reserved 1011 Reserved 1100 Reserved 1101 Reserved 1110 Reserved 1111 Reserved

15.3.5 VLPR Clock Control Register (SCG_VCCR)

This register controls the system clock source and the system clock dividers for the core, platform, external and bus clock domains when in VLPR mode only. This register can only be written using a 32-bit write. Selecting a different clock source when in VLPR requires that clock source to be enabled first and be valid before system clocks switch to that clock source. If system clock divide ratios also change when selecting a different clock mode when in VLPR, new system clock divide ratios will not take affect until new clock source is valid.

Address: 4006_4000h base + 18h offset = 4006_4018h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				SCS				0				DIVCORE				Reserved				0				0				DIVSLOW			
W																																
Reset	0	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	1

* Notes:

- DIVCORE field: The reset value is controlled by user FOPT bits that get uploaded during reset. The two option reset values are div-by-4 and div-by-8.

SCG_VCCR field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 SCS	System Clock Source Selects the clock source generating the system clock in VLPR mode. Attempting to select a clock that is not valid will be ignored. Selects the clock source generating the system clock. Selecting a different clock source when in VLPR mode requires that clock source to be enabled first and be valid before system clocks switch to that clock source. 0000 Reserved 0001 System OSC (SOSC_CLK) 0010 Slow IRC (SIRC_CLK) 0011 Reserved 0100 Reserved 0101 Reserved 0110 Reserved 0111 Reserved
23–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–16 DIVCORE	Core Clock Divide Ratio 0000 Divide-by-1 0001 Divide-by-2 0010 Divide-by-3

Table continues on the next page...

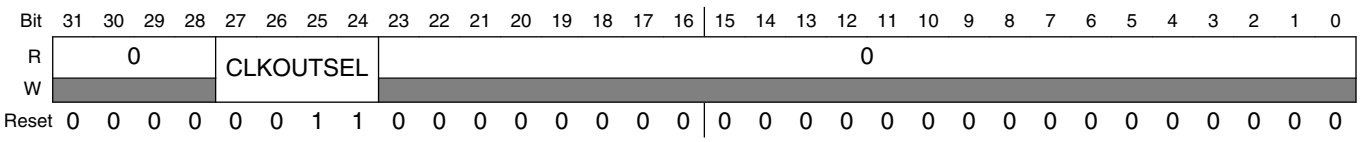
SCG_VCCR field descriptions (continued)

Field	Description
	0011 Divide-by-4 0100 Divide-by-5 0101 Divide-by-6 0110 Divide-by-7 0111 Divide-by-8 1000 Divide-by-9 1001 Divide-by-10 1010 Divide-by-11 1011 Divide-by-12 1100 Divide-by-13 1101 Divide-by-14 1110 Divide-by-15 1111 Divide-by-16
15–12 Reserved	This field is reserved. Software should write 0 to these bits to maintain compatibility. This field is reserved.
11–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DIVSLOW	Slow Clock Divide Ratio 0000 Reserved 0001 Divide-by-2 0010 Divide-by-3 0011 Divide-by-4 0100 Divide-by-5 0101 Divide-by-6 0110 Divide-by-7 0111 Divide-by-8 1000 Reserved 1001 Reserved 1010 Reserved 1011 Reserved 1100 Reserved 1101 Reserved 1110 Reserved 1111 Reserved

15.3.6 SCG CLKOUT Configuration Register (SCG_CLKOUTCNFG)

This register controls which SCG clock source is selected to be ported out to the CLKOUT pin.

Address: 4006_4000h base + 20h offset = 4006_4020h

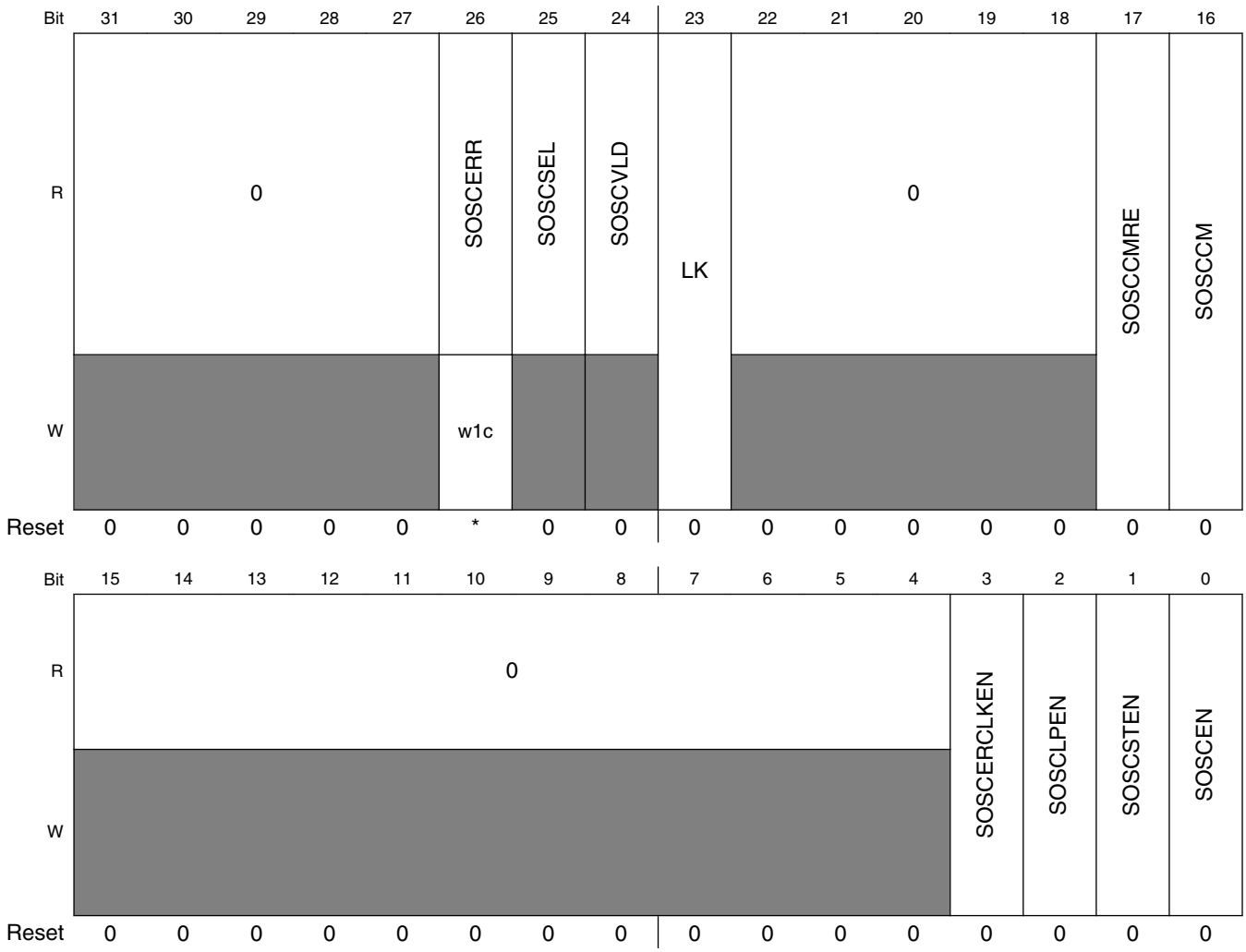


SCG_CLKOUTCNFG field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 CLKOUTSEL	SCG Clkout Select Selects the SCG system clock. 0000 SCG SLOW Clock 0001 System OSC (SOSC_CLK) 0010 Slow IRC (SIRC_CLK) 0011 Fast IRC (FIRC_CLK) 0100 Reserved 0101 Low Power FLL (LPFLL_CLK) 0110 Reserved 0111 Reserved 1111 Reserved
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

15.3.7 System OSC Control Status Register (SCG_SOSCCSR)

Address: 4006_4000h base + 100h offset = 4006_4100h



* Notes:
- SOSCERR field: This flag is reset on Chip POR only

SCG_SOSCCSR field descriptions

Field	Description
31–27 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
26 SOSCERR	System OSC Clock Error This flag is reset on Chip POR only, software can also clear this flag by writing a logic one. 0 System OSC Clock Monitor is disabled or has not detected an error 1 System OSC Clock Monitor is enabled and detected an error

Table continues on the next page...

SCG_SOSCCSR field descriptions (continued)

Field	Description
25 SOSCSEL	System OSC Selected 0 System OSC is not the system clock source 1 System OSC is the system clock source
24 SOSCVLD	System OSC Valid The SOSC is considered valid after 4096 xtal counts. 0 System OSC is not enabled or clock is not valid 1 System OSC is enabled and output clock is valid
23 LK	Lock Register This bit field can be cleared/set at any time. 0 This Control Status Register can be written. 1 This Control Status Register cannot be written.
22–18 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
17 SOSCCMRE	System OSC Clock Monitor Reset Enable 0 Clock Monitor generates interrupt when error detected 1 Clock Monitor generates reset when error detected
16 SOSCCM	System OSC Clock Monitor Enables the clock monitor when SOSCVLD is set. If the clock source is disabled in a low power mode then the clock monitor is also disabled in the low power mode. When the clock monitor is disabled in a low power mode, it remains disabled until the clock valid flag is set following exit from the low power mode. 0 System OSC Clock Monitor is disabled 1 System OSC Clock Monitor is enabled
15–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 SOSCERCLKEN	System OSC 3V ERCLK Enable SOSCERCLKEN is required for stop modes. 0 System OSC 3V ERCLK output clock is disabled. 1 System OSC 3V ERCLK output clock is enabled when SYSOSC is enabled.
2 SOSCLPEN	System OSC Low Power Enable SOSCLPEN is required for low power modes. In VLPS mode (low power stop mode), if you want the clock to remain ON, then both SOSCLPEN and SOSCSTEN bits must be enabled. 0 System OSC is disabled in VLP modes 1 System OSC is enabled in VLP modes
1 SOSCSTEN	System OSC Stop Enable 0 System OSC is disabled in Stop modes 1 System OSC is enabled in Stop modes if SOSCEN=1.

Table continues on the next page...

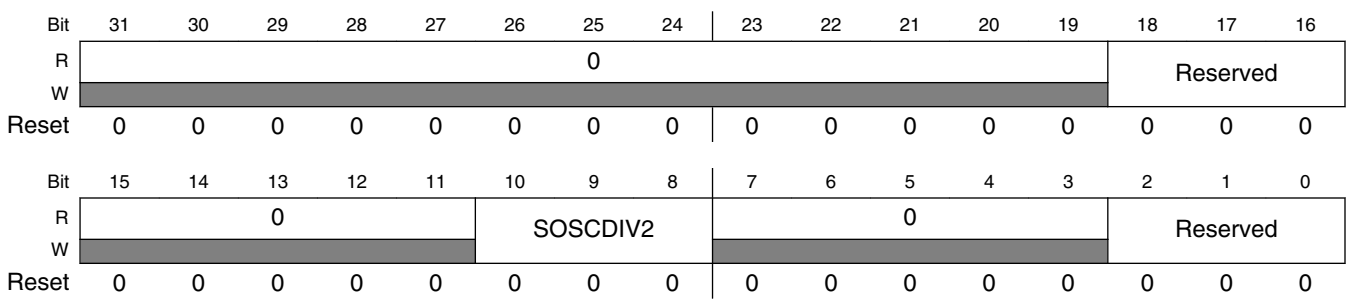
SCG_SOSCCSR field descriptions (continued)

Field	Description
0 SOSCEN	System OSC Enable If this bit written during clock switching, it should be read back and confirmed before proceeding. 0 System OSC is disabled 1 System OSC is enabled

15.3.8 System OSC Divide Register (SCG_SOSCDIV)

The SCG_SOSCDIV register provides the control of clock trees which can be used to provide optional peripheral functional clocks, or alternative module clocks. Each clock tree has optional dividers of the input SOSC clock. Changes to SOSCDIV should be done when System OSC is disabled to prevent glitches to output divided clock.

Address: 4006_4000h base + 104h offset = 4006_4104h



SCG_SOSCDIV field descriptions

Field	Description
31–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
18–16 Reserved	This field is reserved. This bit field is reserved. Software should write 0 to this bit field to maintain compatibility.
15–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10–8 SOSCDIV2	System OSC Clock Divide 2 Clock divider 2 for System OSC. Used by modules that need an asynchronous clock source. 000 Output disabled 001 Divide by 1 010 Divide by 2 011 Divide by 4 100 Divide by 8 101 Divide by 16

Table continues on the next page...

SCG_SOSCDIV field descriptions (continued)

Field	Description
	110 Divide by 32 111 Divide by 64
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
Reserved	This field is reserved. This bit field is reserved. Software should write 0 to this bit field to maintain compatibility.

15.3.9 System Oscillator Configuration Register (SCG_SOSCCFG)

The SOSCCFG register cannot be changed when the System OSC is enabled. When the System OSC is enabled, writes to this register are ignored, and there is no transfer error.

Address: 4006_4000h base + 108h offset = 4006_4108h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				Reserved				0		RANGE		HGO	EREFS	0	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

SCG_SOSCCFG field descriptions

Field	Description
31–12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11–8 Reserved	This field is reserved. This bit is reserved. Software should write 0 to this bit field.
7–6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
5–4 RANGE	System OSC Range Select Selects the frequency range for the system crystal oscillator (OSC) **See chip-specific information for supported crystal oscillator ranges.** 00 Reserved 01 Low frequency range selected for the crystal oscillator

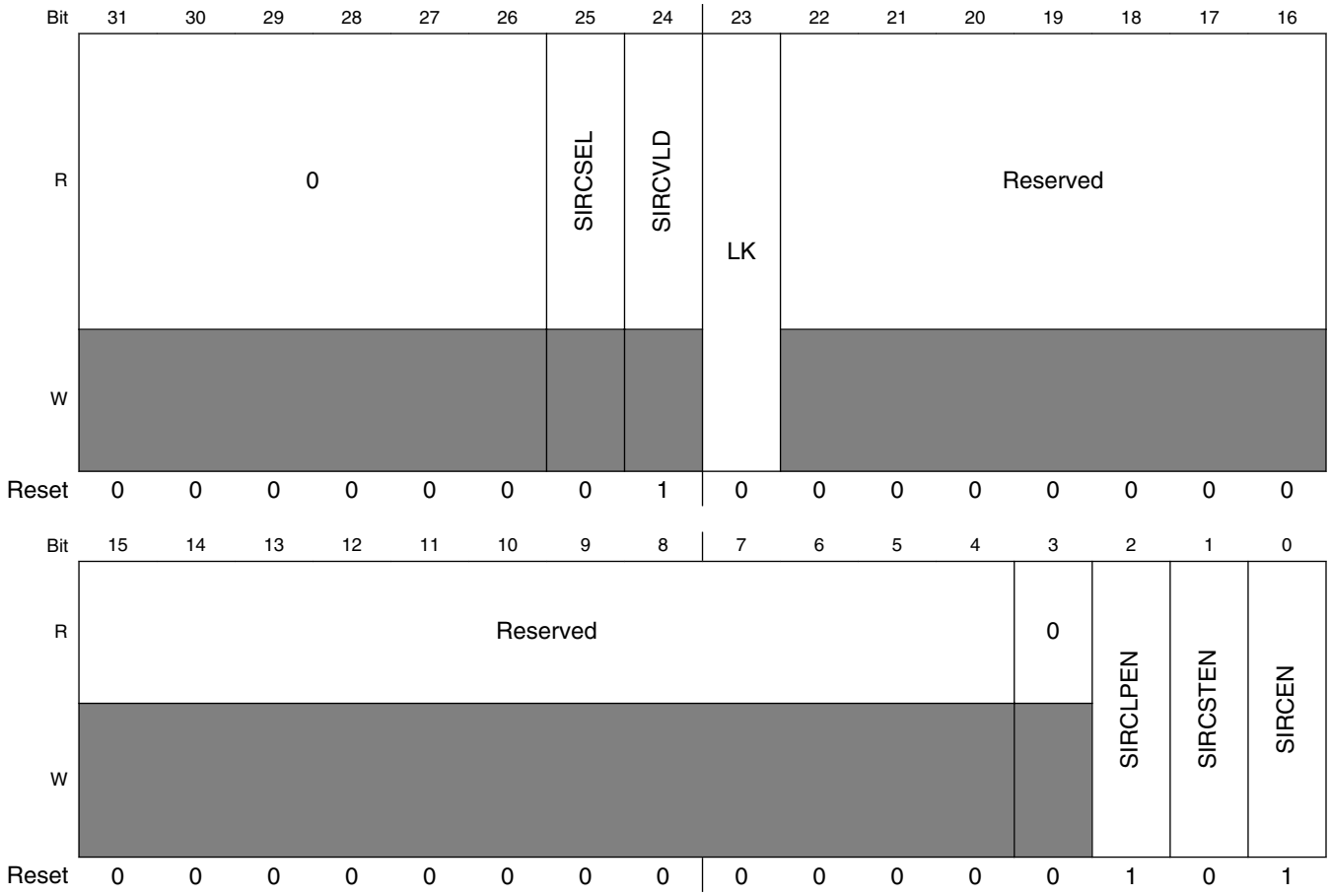
Table continues on the next page...

SCG_SOSCCFG field descriptions (continued)

Field	Description
	10 Medium frequency range selected for the crytstal oscillator 11 High frequency range selected for the crystal oscillator
3 HGO	High Gain Oscillator Select Controls the crystal oscillator power mode of operations. 0 Configure crystal oscillator for low-gain operation 1 Configure crystal oscillator for high-gain operation
2 EREFS	External Reference Select Selects the source for the external reference clock. This bit selects which clock is output from the System OSC (SOSC) into the SCG, thus either the crystal oscillator or from an external clock input 0 External reference clock selected 1 Internal crystal oscillator of OSC selected.
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

15.3.10 Slow IRC Control Status Register (SCG_SIRCCSR)

Address: 4006_4000h base + 200h offset = 4006_4200h



SCG_SIRCCSR field descriptions

Field	Description
31–26 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
25 SIRCSEL	Slow IRC Selected 0 Slow IRC is not the system clock source 1 Slow IRC is the system clock source
24 SIRCVLD	Slow IRC Valid 0 Slow IRC is not enabled or clock is not valid 1 Slow IRC is enabled and output clock is valid
23 LK	Lock Register This bit field can be cleared/set at any time.

Table continues on the next page...

SCG_SIRCCSR field descriptions (continued)

Field	Description
	0 Control Status Register can be written. 1 Control Status Register cannot be written.
22–4 Reserved	This field is reserved and is always has the value 0 This field is reserved.
3 Reserved	This field is reserved and is always has the value 0 This field is reserved. This read-only field is reserved and always has the value 0.
2 SIRCLPEN	Slow IRC Low Power Enable 0 Slow IRC is disabled in VLP modes 1 Slow IRC is enabled in VLP modes
1 SIRCSTEN	Slow IRC Stop Enable 0 Slow IRC is disabled in supported Stop modes 1 Slow IRC is enabled in supported Stop modes
0 SIRCEN	Slow IRC Enable If this bit written during clock switching, it should be read back and confirmed before proceeding. 0 Slow IRC is disabled 1 Slow IRC is enabled

15.3.11 Slow IRC Divide Register (SCG_SIRCDIV)

To prevent glitches to the output divided clock, change SIRDIV when the Slow IRC is disabled.

Address: 4006_4000h base + 204h offset = 4006_4204h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0													Reserved		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0					SIRCDIV2			0					Reserved		
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SCG_SIRCDIV field descriptions

Field	Description
31–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

SCG_SIRCDIV field descriptions (continued)

Field	Description
18–16 Reserved	This field is reserved. This bit field is reserved. Software should write 0 to this bit field to maintain compatibility.
15–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10–8 SIRCDIV2	Slow IRC Clock Divide 2 Clock divider 2 for Slow IRC. Used by modules that need an asynchronous clock source. 000 Output disabled 001 Divide by 1 010 Divide by 2 011 Divide by 4 100 Divide by 8 101 Divide by 16 110 Divide by 32 111 Divide by 64
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
Reserved	This field is reserved. This bit field is reserved. Software should write 0 to this bit field to maintain compatibility.

15.3.12 Slow IRC Configuration Register (SCG_SIRCCFG)

The SIRCCFG register cannot be changed when the slow IRC clock is enabled. When the slow IRC clock is enabled, writes to this register are ignored, and there is no transfer error.

Address: 4006_4000h base + 208h offset = 4006_4208h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

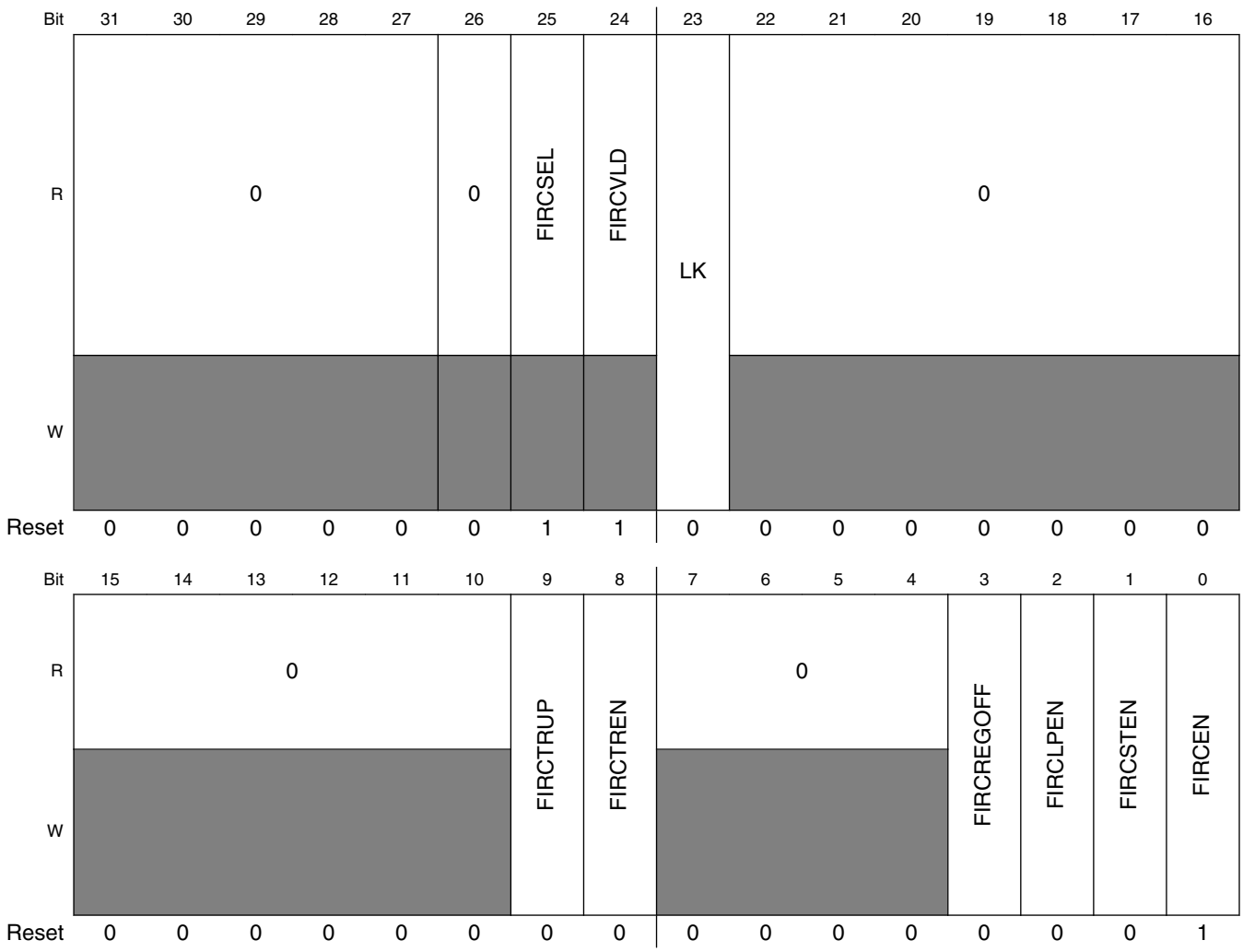
Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															RANGE
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

SCG_SIRCCFG field descriptions

Field	Description
31–1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 RANGE	Frequency Range **See chip-specific information for supported frequency ranges.** 0 Slow IRC low range clock (2 MHz) 1 Slow IRC high range clock (8 MHz)

15.3.13 Fast IRC Control Status Register (SCG_FIRCCSR)

Address: 4006_4000h base + 300h offset = 4006_4300h



SCG_FIRCCSR field descriptions

Field	Description
31–27 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
26 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
25 FIRCSEL	Fast IRC Selected status 0 Fast IRC is not the system clock source 1 Fast IRC is the system clock source
24 FIRCVLD	Fast IRC Valid status 0 Fast IRC is not enabled or clock is not valid. 1 Fast IRC is enabled and output clock is valid. The clock is valid once there is an output clock from the FIRC analog.
23 LK	Lock Register This bit field can be cleared/set at any time. 0 Control Status Register can be written. 1 Control Status Register cannot be written.
22–10 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
9 FIRCTRUP	Fast IRC Trim Update 0 Disable Fast IRC trimming updates 1 Enable Fast IRC trimming updates
8 FIRCTREN	Fast IRC Trim Enable 0 Disable trimming Fast IRC to an external clock source 1 Enable trimming Fast IRC to an external clock source
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 FIRCREGOFF	Fast IRC Regulator Enable **NOTE:** When Fast IRC is used, FIRCREGOFF must be 0. Fast IRC cannot be operated with FIRCREGOFF=1. 0 Fast IRC Regulator is enabled. 1 Fast IRC Regulator is disabled.
2 FIRCLPEN	Fast IRC Low Power Enable 0 Fast IRC is disabled in VLP modes 1 Fast IRC is enabled in VLP modes
1 FIRCSTEN	Fast IRC Stop Enable 0 Fast IRC is disabled in Stop modes. 1 Fast IRC is enabled in Stop modes
0 FIRCEN	Fast IRC Enable If this bit written during clock switching, it should be read back and confirmed before proceeding.

Table continues on the next page...

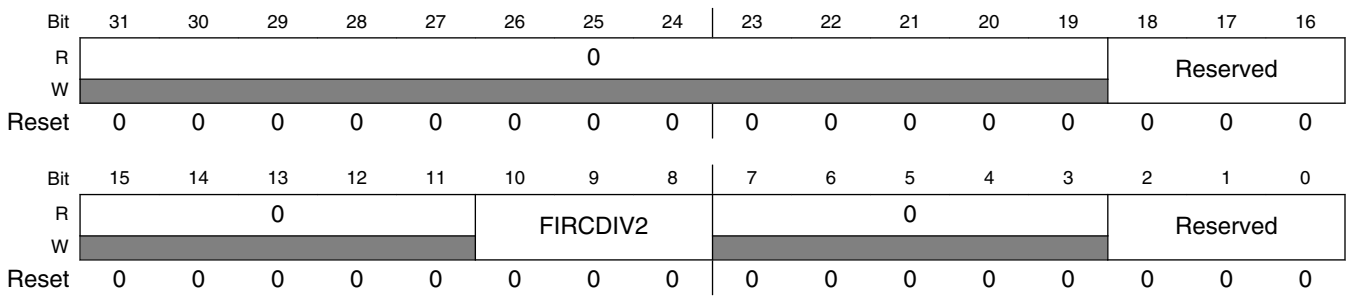
SCG_FIRCCSR field descriptions (continued)

Field	Description
	FIRCEN should not toggle when FIRCTREN = 1. 0 Fast IRC is disabled 1 Fast IRC is enabled

15.3.14 Fast IRC Divide Register (SCG_FIRCDIV)

Changes to FIRCDIV should be done when FAST IRC is disabled to prevent glitches to output divided clock.

Address: 4006_4000h base + 304h offset = 4006_4304h



SCG_FIRCDIV field descriptions

Field	Description
31–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
18–16 Reserved	This field is reserved. This bit field is reserved. Software should write 0 to this bit field to maintain compatibility.
15–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10–8 FIRCDIV2	Fast IRC Clock Divide 2 Clock divider 2 for the Fast IRC. Used by modules that need an asynchronous clock source. 000 Output disabled 001 Divide by 1 010 Divide by 2 011 Divide by 4 100 Divide by 8 101 Divide by 16 110 Divide by 32 111 Divide by 64
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
Reserved	This field is reserved. This bit field is reserved. Software should write 0 to this bit field to maintain compatibility.

15.3.15 Fast IRC Configuration Register (SCG_FIRCCFG)

The FIRCCFG register cannot be changed when the Fast IRC is enabled. When the Fast IRC is enabled, writes to this register are ignored, and there is no transfer error.

Address: 4006_4000h base + 308h offset = 4006_4308h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0														RANGE	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SCG_FIRCCFG field descriptions

Field	Description
31–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
RANGE	Frequency Range **See chip-specific information for supported frequency ranges.** 00 Fast IRC is trimmed to 48 MHz 01 Reserved 10 Reserved 11 Reserved

15.3.16 Fast IRC Trim Configuration Register (SCG_FIRCTCFG)

The FIRCTCFG register cannot be changed when Fast IRC tuning is enabled. When the Fast IRC tuning is enabled, writes to this register are ignored, and there is no transfer error.

Address: 4006_4000h base + 30Ch offset = 4006_430Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0					TRIMDIV			0						TRIMSRC	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SCG_FIRCTCFG field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10–8 TRIMDIV	Fast IRC Trim Predivide Divide the System OSC down for Fast IRC trimming. 000 Divide by 1 001 Divide by 128 010 Divide by 256 011 Divide by 512 100 Divide by 1024 101 Divide by 2048 110 Reserved. Writing this value will result in Divide by 1. 111 Reserved. Writing this value will result in a Divide by 1.
7–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TRIMSRC	Trim Source Configures the external clock source to tune the Fast IRC. TRMSRC must be configured before programming FIRCSTAT register for trim update 00 Reserved 01 Reserved 10 System OSC 11 Reserved

15.3.17 Fast IRC Status Register (SCG_FIRCSTAT)

This register is loaded from IFR during reset. These register gets uploaded with the trim values generated by FIRC auto trimming which is enabled when FIRC is enabled and FIRCTREN=1 and FIRCTRUP=1. When FIRC auto trimming is enabled and FIRCTRUP is off (Note: TRIMSRC needs to be programmed to TRIMSRC=10 or TRIMSRC=11), writes to this register is allowed and values written to this register are used to trim FIRC clock.

Address: 4006_4000h base + 318h offset = 4006_4318h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		TRIMCOAR						0	TRIMFINE						
W																
Reset	0	0	*	*	*	*	*	*	0	*	*	*	*	*	*	*

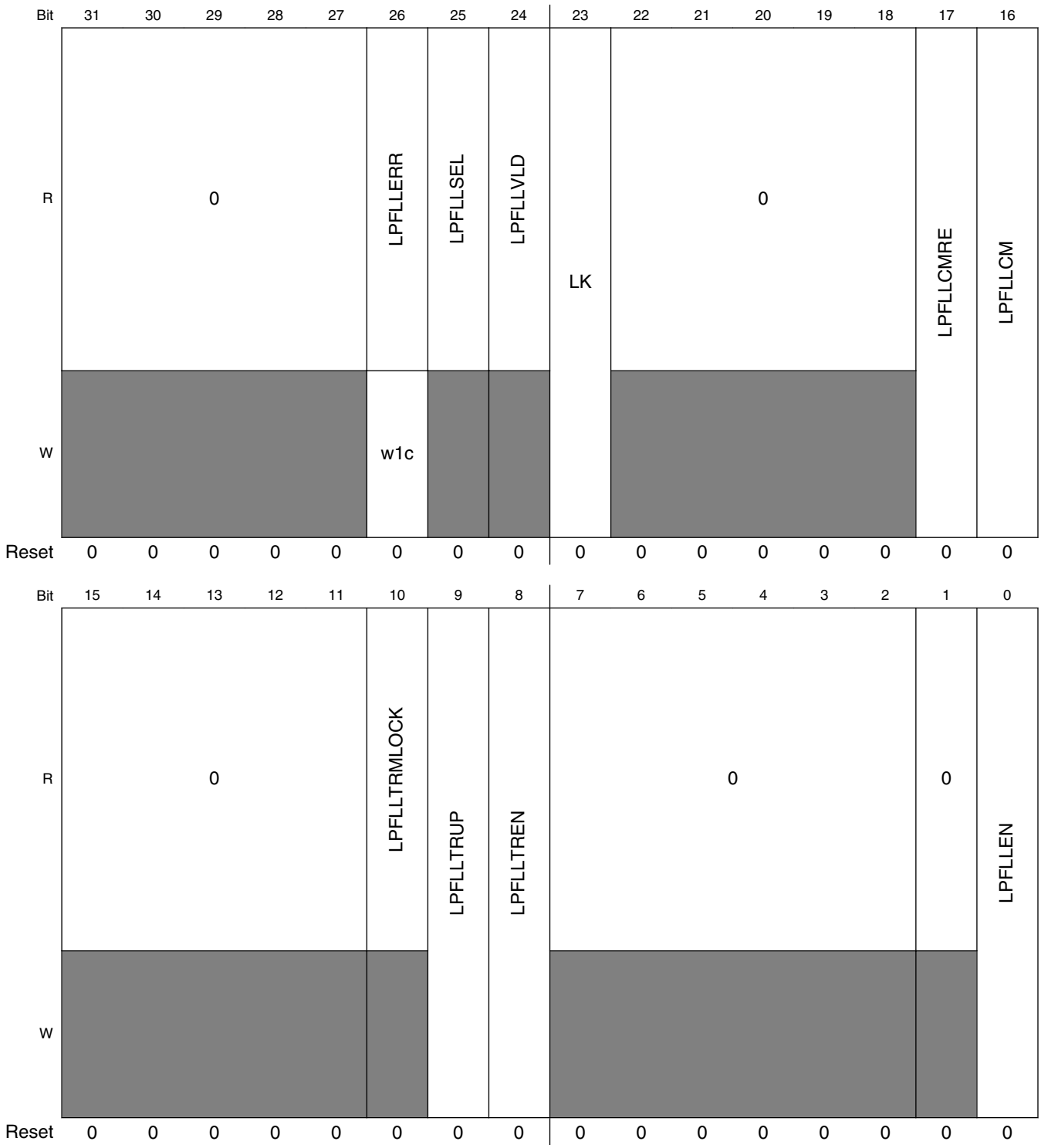
* Notes:
- TRIMCOAR field: Reset values are loaded out of IFR.
- TRIMFINE field: Reset values are loaded out of IFR.

SCG_FIRCSTAT field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13–8 TRIMCOAR	Trim Coarse TRIMCOAR bits are used to coursely trim the Fast IRC Clock to within approximately ±0.7% of the target frequency. When FIRC is enabled and auto trimming is enabled (FIRCTREN=1 and FIRCTRUP=1), then TRIMCOAR register gets uploaded with the trimmed coarse value. When FIRCTRUP=0, TRIMCOAR bitfield is writable, to allow user programming of coarse trim values.
7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TRIMFINE	Trim Fine Status Once the Fast IRC Clock is trimmed to ±0.7% of the target frequency using the TRIMCOAR bits, the TRIMFINE bits can be used to trim the Fast IRC Clock to within ±0.04% of the target frequency. When FIRC is enabled and auto trimming is enabled (FIRCTREN=1 and FIRCTRUP=1), TRIMFINE register gets uploaded with the trimmed fine value. When FIRCTRUP=0, TRIMFINE bitfield is writeable, to allow user programming of fine trim values.

15.3.18 Low Power FLL Control Status Register (SCG_LPFLLCSR)

Address: 4006_4000h base + 500h offset = 4006_4500h



SCG_LPFLLCSR field descriptions

Field	Description
31–27 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
26 LPFLLERR	LPFLL Clock Error This flag is reset on Chip POR only, software can also clear this flag by writing a logic one When LPFLLTREN=1 and LPFLLTRUP=1, LPFLLERR=1 if the LPFLL can't lock the reference clock. This occurs when the reference clock is too fast/slow or LPFLL clock is stopped. LPFLLERR indicates a loss of lock or loss of clock. To change the reference clock frequency to re-lock, the LPFLLTREN or LPFLLTRUP bits must also be re-enabled (LPFLLTREN=1 or LPFLLTRUP=1). 0 Error not detected with the LPFLL trimming. 1 Error detected with the LPFLL trimming.
25 LPFLLSEL	LPFLL Selected 0 LPFLL is not the system clock source 1 LPFLL is the system clock source
24 LPFLLVLD	LPFLL Valid 0 LPFLL is not enabled or clock is not valid. 1 LPFLL is enabled and output clock is valid.
23 LK	Lock Register This bit field can be cleared/set at any time. 0 Control Status Register can be written. 1 Control Status Register cannot be written.
22–18 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
17 LPFLLCMRE	LPFLL Clock Monitor Reset Enable 0 Clock Monitor generates interrupt when error detected 1 Clock Monitor generates reset when error detected
16 LPFLLCM	LPFLL Clock Monitor Enables the clock monitor when LPFLLTREN is set and LPFLL is enabled. The clock monitor is always disabled in low power modes. When the clock monitor is disabled in a low power mode, it remains disabled until the clock valid flag is set following exit from the low power mode. 0 LPFLL Clock Monitor is disabled 1 LPFLL Clock Monitor is enabled
15–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10 LPFLLTRMLOCK	LPFLL Trim LOCK Asserts only when LPFLLTREN=1 and LPFLLTRUP=1 and LPFLL has locked to target frequency. [1] 0 LPFLL not Locked 1 LPFLL trimmed and Locked

Table continues on the next page...

SCG_LPFLLCSR field descriptions (continued)

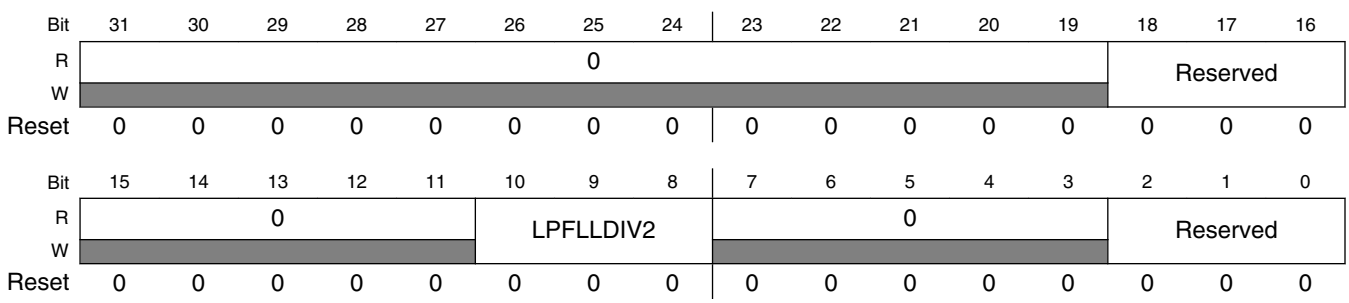
Field	Description
9 LPFLLTRUP	LPFLL Trim Update 0 Disable LPFLL trimming updates. LPFLL frequency determined by AUTOTRIM written value. 1 Enable LPFLL trimming updates. LPFLL frequency determined by reference clock multiplication
8 LPFLLTREN	LPFLL Trim Enable 0 Disable trimming LPFLL to an reference clock source 1 Enable trimming LPFLL to an reference clock source
7–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 LPFLLEN	LPFLL Enable If this bit written during clock switching, it should be read back and confirmed before proceeding. 0 LPFLL is disabled 1 LPFLL is enabled

1. In open-loop mode (LPFLLTRUP=0), lock conditions cannot be checked.

15.3.19 Low Power FLL Divide Register (SCG_LPFLLDIV)

Changes to LPFLLDIV should be done when LPFLL is disabled to prevent glitches to output divided clock.

Address: 4006_4000h base + 504h offset = 4006_4504h



SCG_LPFLLDIV field descriptions

Field	Description
31–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
18–16 Reserved	This field is reserved. This bit field is reserved. Software should write 0 to this bit field to maintain compatibility.
15–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

SCG_LPFLLDIV field descriptions (continued)

Field	Description
10–8 LPFLLDIV2	LPFLL Clock Divide 2 Clock divider 2 for the LPFLL. Used by modules that need an asynchronous clock source. 000 Output disabled 001 Divide by 1 010 Divide by 2 011 Divide by 4 100 Divide by 8 101 Divide by 16 110 Divide by 32 111 Divide by 64
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
Reserved	This field is reserved. This bit field is reserved. Software should write 0 to this bit field to maintain compatibility.

15.3.20 Low Power FLL Configuration Register (SCG_LPFLLCFG)

The LPFLLCFG register cannot be changed when the LPFLL is enabled. When the LPFLL is enabled, writes to this register are ignored, and there is no transfer error.

Address: 4006_4000h base + 508h offset = 4006_4508h

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

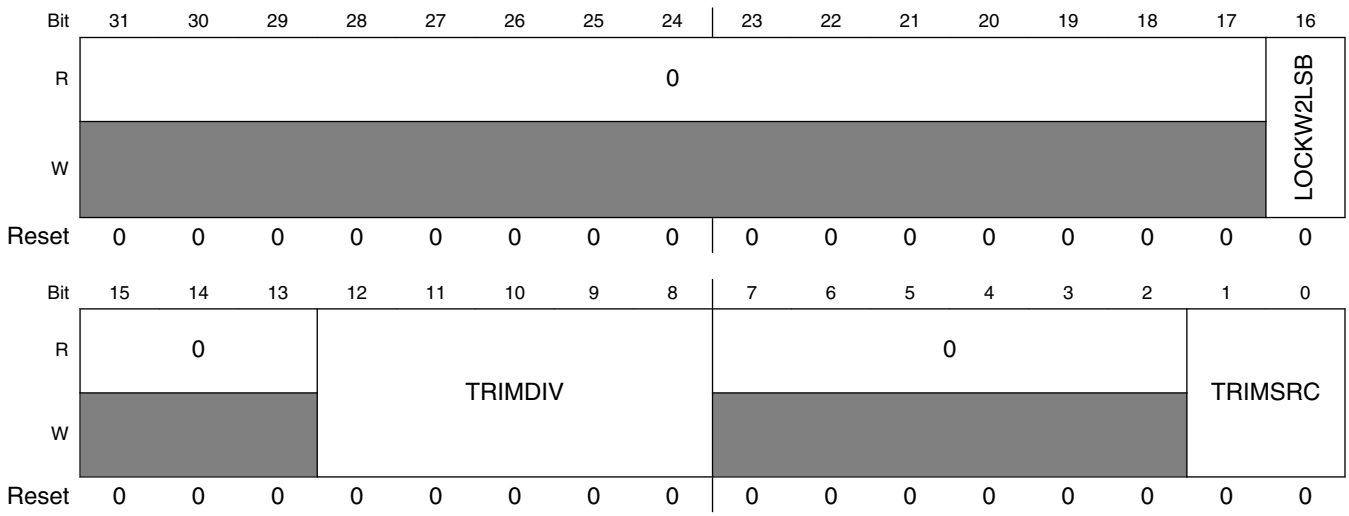
SCG_LPFLLCFG field descriptions

Field	Description
31–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
FSEL	Frequency Select 00 LPFLL is trimmed to 48 MHz 01 Reserved 10 Reserved 11 Reserved

15.3.21 Low Power FLL Trim Configuration Register (SCG_LPFLLTCFG)

The LPFLLTCFG register cannot be changed when LPFLL tuning is enabled. When the LPFLL tuning is enabled, writes to this register are ignored, and there is no transfer error.

Address: 4006_4000h base + 50Ch offset = 4006_450Ch



SCG_LPFLLTCFG field descriptions

Field	Description
31–17 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
16 LOCKW2LSB	Lock LPFLL with 2 LSBS This bitfield is used to control the condition to set LPFLLTRMLOCK: difference between LPFLL actual clock and target clock (48 MHz) is within 0.8% or 0.4%; 0 LPFLL locks within 1LSB (0.4%) 1 LPFLL locks within 2LSB (0.8%)
15–13 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
12–8 TRIMDIV	LPFLL Trim Predivide Use to divide the reference clock down for LPFLL trimming by 1,2,3,4…..31,32. The divided frequency should be either 32.768 KHz or 2 MHz. 00000 Divide by 1 00001 Divide by 2 00010 Divide by 3 .... 11110 Divide by 31 11111 Divide by 32

Table continues on the next page...

SCG_LPFLLTCFG field descriptions (continued)

Field	Description
7–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TRIMSRC	Trim Source Configures the reference clock source to tune the LPFLL. 00 SIRC 01 FIRC 10 System OSC 11 Reserved

15.3.22 Low Power FLL Status Register (SCG_LPFLLSTAT)

This register is loaded from IFR during reset. This register gets uploaded with the trim values generated by LPFLL auto trimming which is enabled when LPFLL is enabled and LPFLLTREN=1 and LPFLLTRUP=1. When LPFLL auto trimming is enabled and LPFLLTRUP is off, writes to this register is allowed and values written to this register are used to trim LPFLL clock.

Address: 4006_4000h base + 514h offset = 4006_4514h

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

* Notes:
- AUTOTRIM field: Reset values are loaded out of IFR.

SCG_LPFLLSTAT field descriptions

Field	Description
31–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
AUTOTRIM	Auto Tune Trim Status When LPFLL is enabled and auto trimming is enabled (LPFLLTREN=1 and LPFLLTRUP=1), this register gets uploaded with the trimmed value. When LPFLLTRUP=0, this register is writeable to allow user programming of trim values.

15.4 Functional description

15.4.1 SCG Clock Mode Transitions

The following figure shows the valid clock mode transitions supported by SCG.

Slow IRC (SIRC) boot mode is not supported on this device.

See SCG Specific Chip information for the SCG Valid Mode Transition Diagram.

NOTE

When a transition between run modes (RUN, VLRUN) is required, the SCG should complete the switch to the clock mode as defined in the SCG clock control register first. Once the switch to the clock mode is completed, the system can then initiate the request for the selected run mode.

For example, if a transition from RUN mode to VLRUN is required, first complete any required clock change. Initiate the VLRUN request **after** the clock change has completed.

The power modes are chip specific. For more details about power mode assignments, see power management and system mode control information.

The modes of operation listed in the following table are the valid modes for this implementation of the SCG.

Table 15-1. SCG modes of operation

Mode	Description
System Oscillator Clock (SOSC)	System Oscillator Clock (SOSC) mode is entered when all the following conditions occur: • RUN MODE: 0001 is written to RCCR[SCS]. VLRUN MODE: 0001 is written to VCCR[SCS]. • SOSCEN = 1 • SOSCVLD = 1 In SOSC mode, SCGCLKOUT and system clocks are derived from the external System Oscillator Clock (SOSC). Information regarding SOSC operation during normal and low power stop modes is found in the "Stop" row of this table.
Slow Internal Reference Clock (SIRC)	Slow Internal Reference Clock (SIRC) mode is entered when all the following conditions occur: • RUN MODE: 0010 is written to RCCR[SCS]. VLRUN MODE: 0010 is written to VCCR[SCS] and 1 is written to SIRCCSR[SIRCLPEN]. • SIRCEN = 1 • SIRCVLD = 1

Table continues on the next page...

Table 15-1. SCG modes of operation (continued)

Mode	Description
	In SIRC mode, SCGCLKOUT and system clocks are derived from the slow internal reference clock. Two frequency ranges are available for SIRC clock as described in the SIRCCFG[RANGE] register definition. Changes to SIRC range settings will be ignored when SIRC clock is enabled. Information regarding SIRC operation during normal and low power stop modes is found in the "Stop" row of this table. See chip-specific information for supported frequency ranges.
Fast Internal Reference Clock (FIRC)	Fast Internal Reference Clock (FIRC) mode is the default clock mode of operation and is entered when all the following conditions occur: • RUN MODE: 0011 is written to RCCR[SCS]. VLRUN MODE: Invalid mode. Programming SCG into FIRC mode will be ingored. • FIRCEN = 1 • FIRCREGOFF = 0 • FIRCVLD = 1 In FIRC mode, SCGCLKOUT and system clocks are derived from the fast internal reference clock. Four frequency range settings are available for FIRC clock as described in the FIRC[RANGE] register definition. Changes to FIRC range settings will be ignored when FIRC clock is enabled. Information regarding FIRC operation during normal and low power stop modes is found in the "Stop" row of this table. See chip-specific information for supported frequency ranges.
Low Power FLL (LPFLL)	Low Power FLL (LPFLL) mode is entered when all the following conditions occur: • RUN MODE: 0101 is written to RCCR[SCS]. VLRUN MODE: Invalid mode. Programming SCG into LPFLL mode will be ingored. • LPFLLEN = 1 • LPFLLVLD = 1 In LPFLL mode, SCGCLKOUT and system clocks are derived from the Low Power FLL (LPFLL). By default the LPFLL will be running in open-loop mode using default trim values. In closed-loop mode (LPFLLTREN=1 and LPFLLTRUP=1) LPFLL will be auto trimmed using a selectable reference clock as specified by its corresponding SCG_LPFLLTCFG[TRIMSRC]. The LPFLL will lock its frequency to the LPFLL factor, as specified by the SCG_LPFLLCFG[FSEL]. Information regarding LPFLL operation during normal and low power stop modes is found in the "Stop" row of this table.
Stop	Entered whenever the MCU enters a Stop state. The power modes are chip specific. For power mode assignments, see the chapter that describes how modules are configured and SCG behaviour during Stop recovery. Entering Stop mode, all SCG clock signals are static except the following clocks which can continue to run and stay enabled in the following cases: SIRCCLK is available in Normal Stop and VLPS mode when all the following conditions become true: • SIRCCSR[SIRCEN] = 1 • SIRCCSR[SIRCSTEN] = 1 • SIRCCSR[SIRCLPEN] = 1 in VLPS FIRCCLK is available only in Normal Stop mode when all the following conditions become true:

Table 15-1. SCG modes of operation

Mode	Description
	• FIRCCSR[FIRCEN] = 1 • FIRCCSR[FIRCSTEN] = 1 SOSCLK is available in following low power stop modes (Normal Stop, VLPS) when all the below conditions are true. • SOSCCSR[SOSCEN] = 1 • SOSCCSR[SOSCSTEN] = 1 • SOSCCSR[SOSCLPEN] = 1 (required only for Low Power Stop modes (VLPS)

Chapter 16
Peripheral Clock Controller (PCC)

16.1 Chip-specific information for this module

16.1.1 Information of PCC on this device

The clock connection information for this module is as follows.

Clock Source : SCG	Clock Source Descriptions	PCS Clock Names of PCC
SOSCDIV2_CLK	SOSCDIV2 of system OSC clock	OSCCLK
SIRCDIV2_CLK	SIRCDIV2 of slow IRC clock	SCGIRCLK
FIRCDIV2_CLK	FIRCDIV2 of fast IRC clock	SCGFIRCLK
SFLLDIV2_CLK	FLLDIV2 of LPFLL clock	SCGFLLCLK

For PCS bitfield, the following clock source select options are applicable in this device:

- 000 - Clock is off .
- 001 - System Oscillator Bus Clock.
- 010 - Slow IRC Clock.
- 011 - Fast IRC Clock.
- 100 - Reserved.
- 101 - Low-power FLL (LPFLL) clock.
- 110 - Reserved.
- 111 - Reserved.

16.2 Introduction

The Peripheral Clock Control (PCC) module provides clock control and configuration for on-chip peripherals. Each peripheral has its own clock control and configuration register.

16.3 Features

The PCC module enables software to configure the following clocking options for each peripheral:

- Interface clock gating
- Functional clock source selection
- Functional clock divide values

Below is a block diagram of the PCC module:

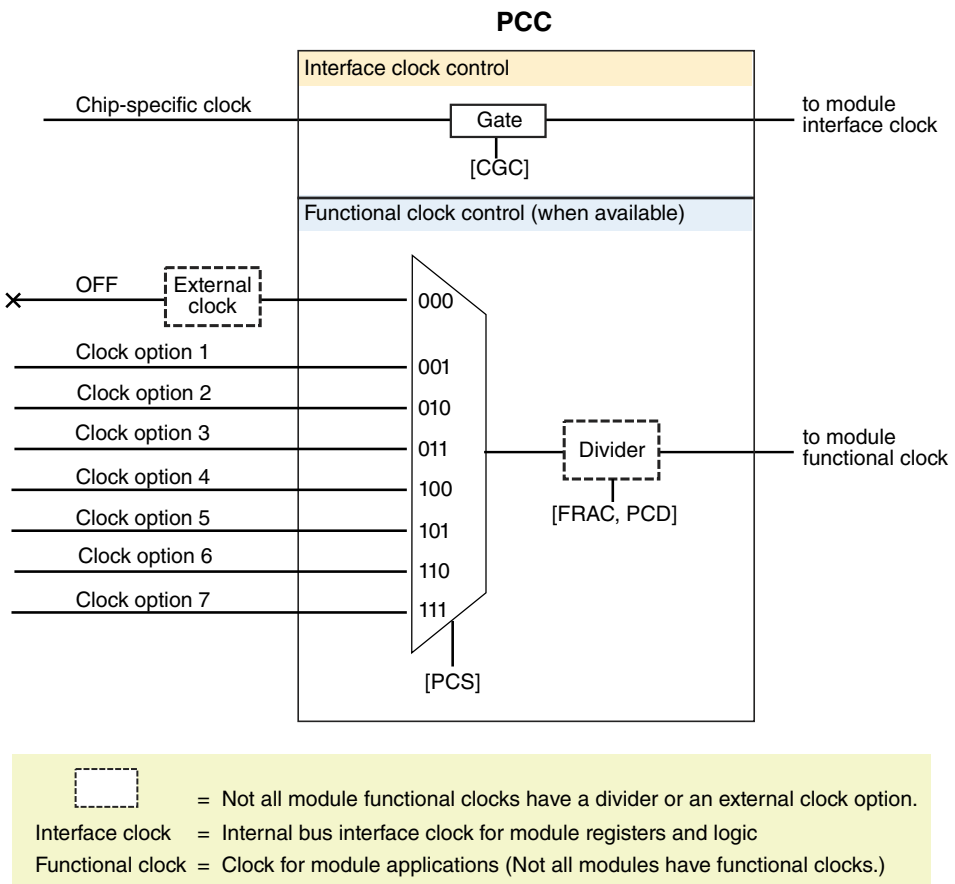


Figure 16-1. PCC Block Diagram

16.4 Functional description

The PCC module provides on-chip peripherals (modules) their own dedicated PCC registers for clock gating and configuration options. Each module's PCC register contains a clock gating control bit (CGC) for the module's interface clock. Before a module can be used, its interface clock must be enabled (CGC = 1) in the module's PCC register.

If a module has a functional clock, its PCC register may provide options for the clock source, selected by programming the Peripheral Clock Select (PCS) field. Optionally, a module may also have a clock divider, selected by programming the Peripheral Clock Divider (PCD) field along with a Fraction (FRAC) field. Before configuring a functional clock, the module's interface clock must be disabled (CGC = 0).

16.5 Memory map and register definition

Each module has its own dedicated PCC register, which controls the clock gating, clock source and divider (when applicable) for that specific module. See each module's PCC register for details.

PCC registers can be written only in supervisor mode using 32-bit accesses.

NOTE

To configure the clocking options available to a given module or to modify an existing configuration, first disable the module's interface clock by writing 0 to its CGC bit.

16.6 PCC register descriptions

16.6.1 PCC Memory map

PCC base address: 4006_5000h

Offset	Register	Width (In bits)	Access	Reset value
80h	PCC FLASH Register (PCC_FLASH)	32	RW	C000_0000h

Table continues on the next page...

Offset	Register	Width (In bits)	Access	Reset value
90h	PCC MSCAN0 Register (PCC_MSCAN0)	32	RW	8000_0000h
B0h	PCC LPSPI0 Register (PCC_LPSPI0)	32	RW	8000_0000h
C8h	PCC CRC Register (PCC_CRC)	32	RW	8000_0000h
D8h	PCC PDB0 Register (PCC_PDB0)	32	RW	8000_0000h
DCh	PCC LPIT0 Register (PCC_LPIT0)	32	RW	8000_0000h
E0h	PCC FLEXTMR0 Register (PCC_FLEXTMR0)	32	RW	8000_0000h
E4h	PCC FLEXTMR1 Register (PCC_FLEXTMR1)	32	RW	8000_0000h
ECh	PCC ADC0 Register (PCC_ADC0)	32	RW	C000_0000h
F4h	PCC RTC Register (PCC_RTC)	32	RW	8000_0000h
100h	PCC LPTMR0 Register (PCC_LPTMR0)	32	RW	8000_0000h
114h	PCC TSI Register (PCC_TSI)	32	RW	8000_0000h
124h	PCC PORTA Register (PCC_PORTA)	32	RW	8000_0000h
128h	PCC PORTB Register (PCC_PORTB)	32	RW	8000_0000h
12Ch	PCC PORTC Register (PCC_PORTC)	32	RW	8000_0000h
130h	PCC PORTD Register (PCC_PORTD)	32	RW	8000_0000h
134h	PCC PORTE Register (PCC_PORTE)	32	RW	8000_0000h
158h	PCC PWT Register (PCC_PWT)	32	RW	8000_0000h
184h	PCC EWM Register (PCC_EWM)	32	RW	8000_0000h
198h	PCC LPI2C0 Register (PCC_LPI2C0)	32	RW	8000_0000h
1A8h	PCC LPUART0 Register (PCC_LPUART0)	32	RW	8000_0000h
1ACh	PCC LPUART1 Register (PCC_LPUART1)	32	RW	8000_0000h
1B0h	PCC LPUART2 Register (PCC_LPUART2)	32	RW	8000_0000h
1CCh	PCC CMP0 Register (PCC_CMP0)	32	RW	8000_0000h

16.6.2 PCC FLASH Register (PCC_FLASH)

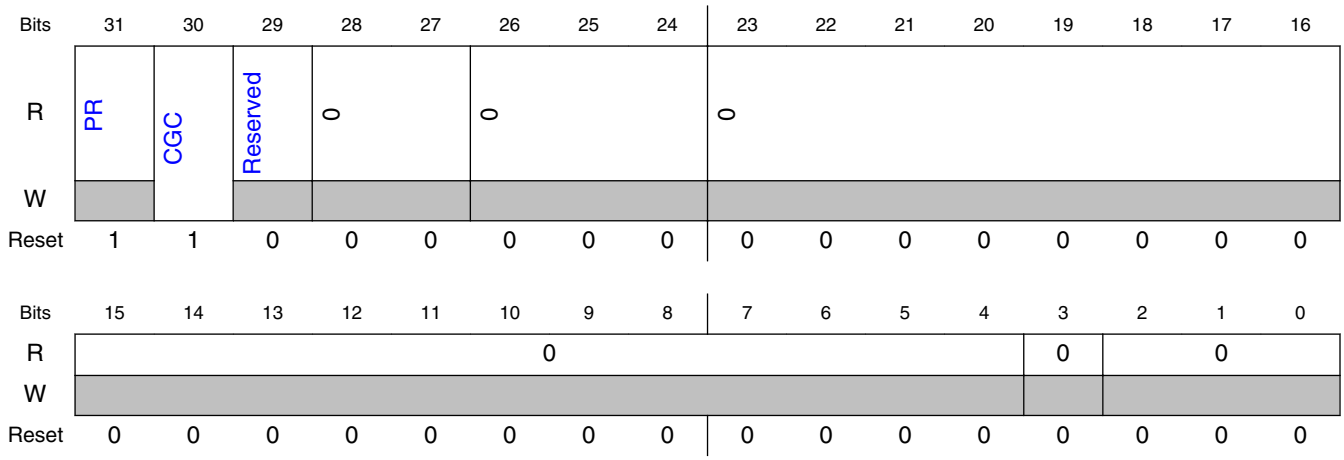
16.6.2.1 Offset

Register	Offset
PCC_FLASH	80h

16.6.2.2 Function

PCC Register

16.6.2.3 Diagram



16.6.2.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.3 PCC MSCAN0 Register (PCC_MSCAN0)

16.6.3.1 Offset

Register	Offset
PCC_MSCAN0	90h

16.6.3.2 Function

PCC Register

16.6.3.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	PR	CGC	Reserved	0		0			0							
W																
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												0		0	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

16.6.3.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral.

Table continues on the next page...

Field	Function
	0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.4 PCC LPSPI0 Register (PCC_LPSPI0)

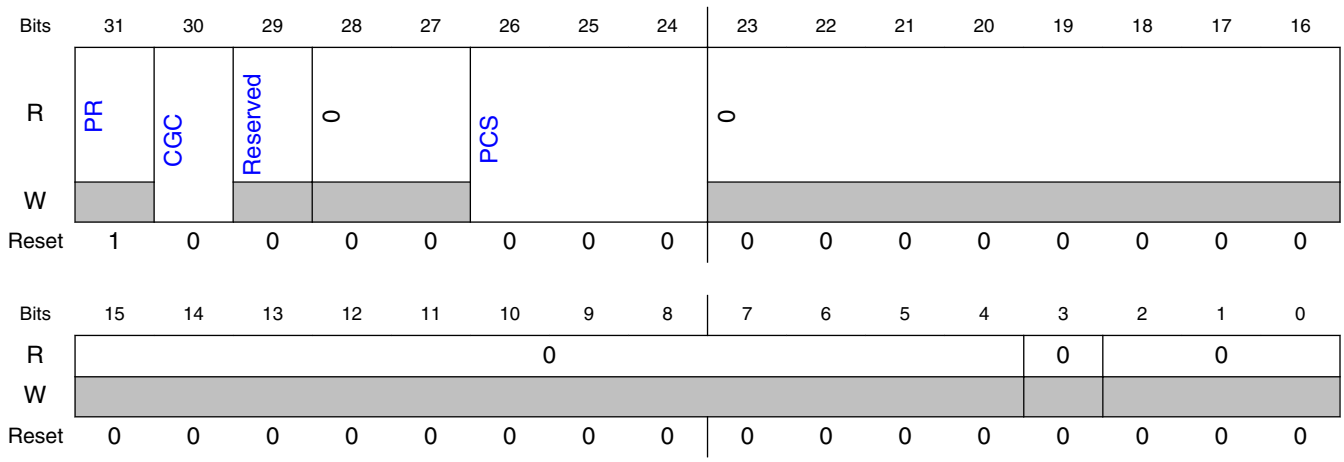
16.6.4.1 Offset

Register	Offset
PCC_LPSPI0	B0h

16.6.4.2 Function

PCC Register

16.6.4.3 Diagram



16.6.4.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 PCS	Peripheral Clock Source Select This read/write bit field is used for peripherals that support various clock selections. This field can be written only when the clock is disabled (CGC = 0). 000b - Clock is off. 001b - Clock option 1 010b - Clock option 2 011b - Clock option 3 100b - Clock option 4 101b - Clock option 5 110b - Clock option 6 111b - Clock option 7
23-4	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
—	
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.5 PCC CRC Register (PCC_CRC)

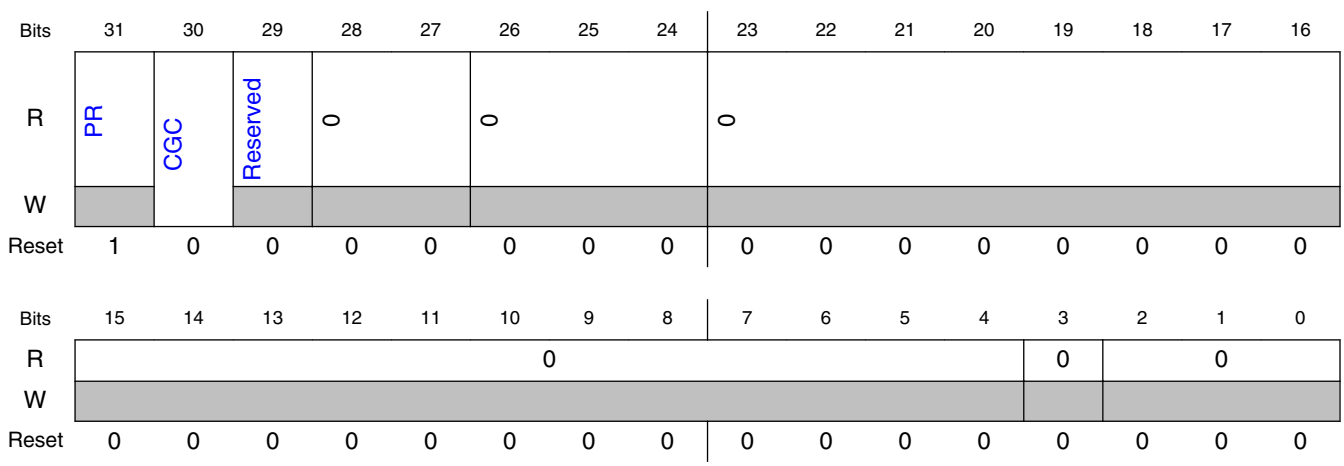
16.6.5.1 Offset

Register	Offset
PCC_CRC	C8h

16.6.5.2 Function

PCC Register

16.6.5.3 Diagram



16.6.5.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.6 PCC PDB0 Register (PCC_PDB0)

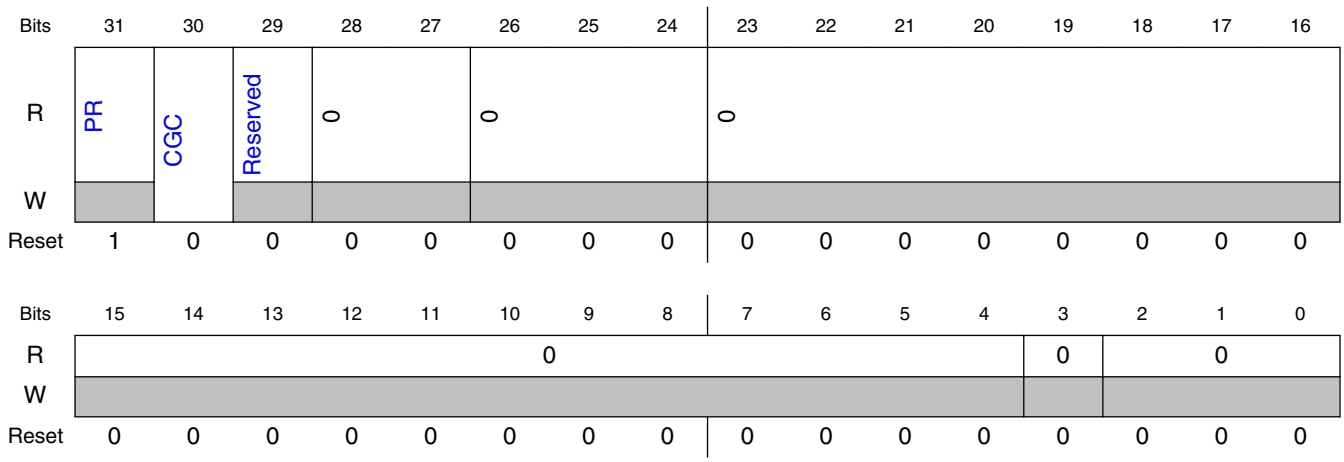
16.6.6.1 Offset

Register	Offset
PCC_PDB0	D8h

16.6.6.2 Function

PCC Register

16.6.6.3 Diagram



16.6.6.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.7 PCC LPIT0 Register (PCC_LPIT0)

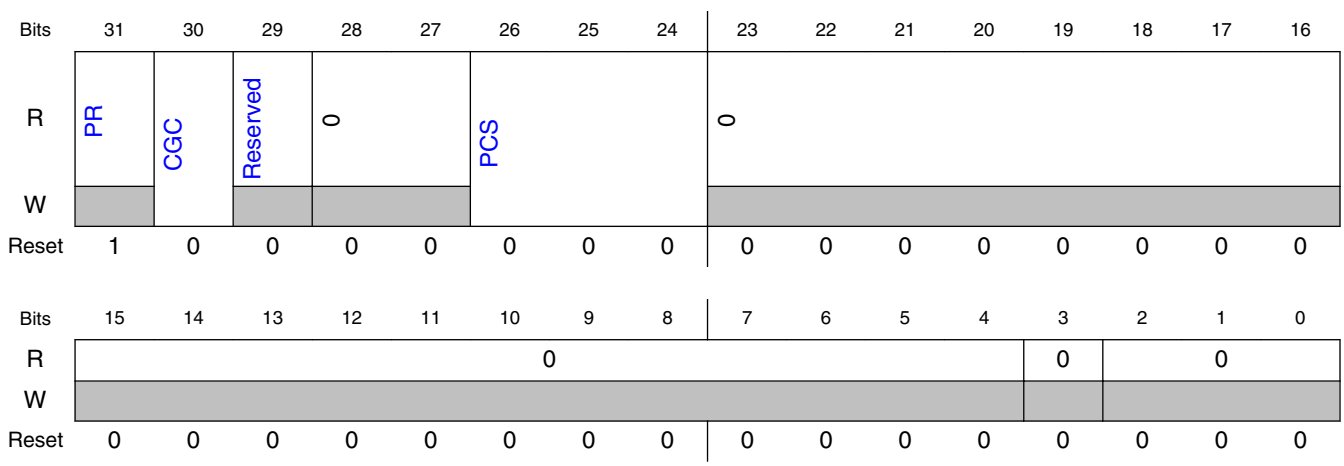
16.6.7.1 Offset

Register	Offset
PCC_LPIT0	DCh

16.6.7.2 Function

PCC Register

16.6.7.3 Diagram



16.6.7.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral.

Table continues on the next page...

Field	Function
	0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 PCS	Peripheral Clock Source Select This read/write bit field is used for peripherals that support various clock selections. This field can be written only when the clock is disabled (CGC = 0). 000b - Clock is off. 001b - Clock option 1 010b - Clock option 2 011b - Clock option 3 100b - Clock option 4 101b - Clock option 5 110b - Clock option 6 111b - Clock option 7
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.8 PCC FLEXTMR0 Register (PCC_FLEXTMR0)

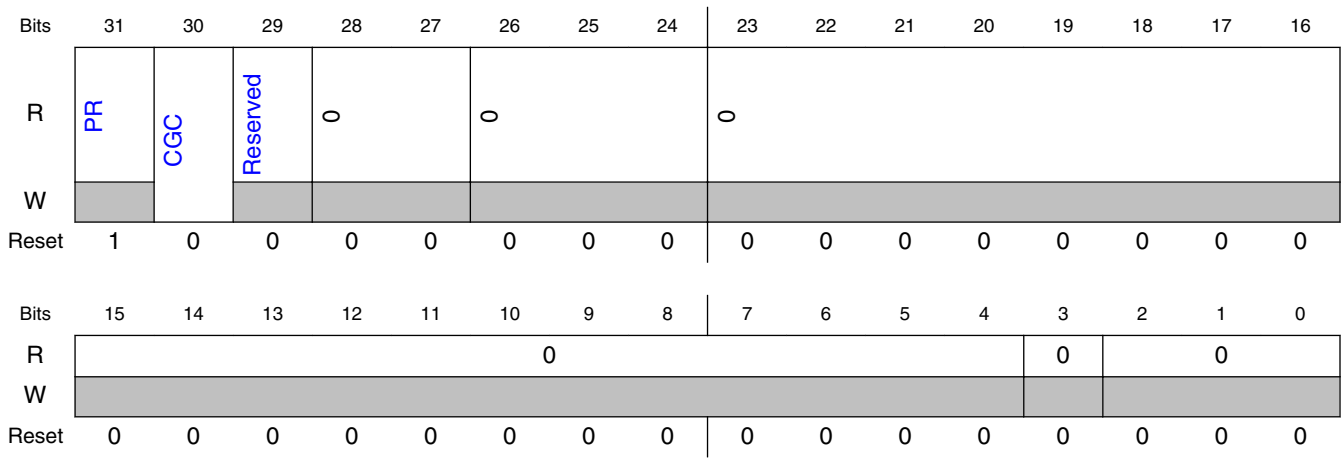
16.6.8.1 Offset

Register	Offset
PCC_FLEXTMR0	E0h

16.6.8.2 Function

PCC Register

16.6.8.3 Diagram



16.6.8.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.9 PCC FLEXTMR1 Register (PCC_FLEXTMR1)

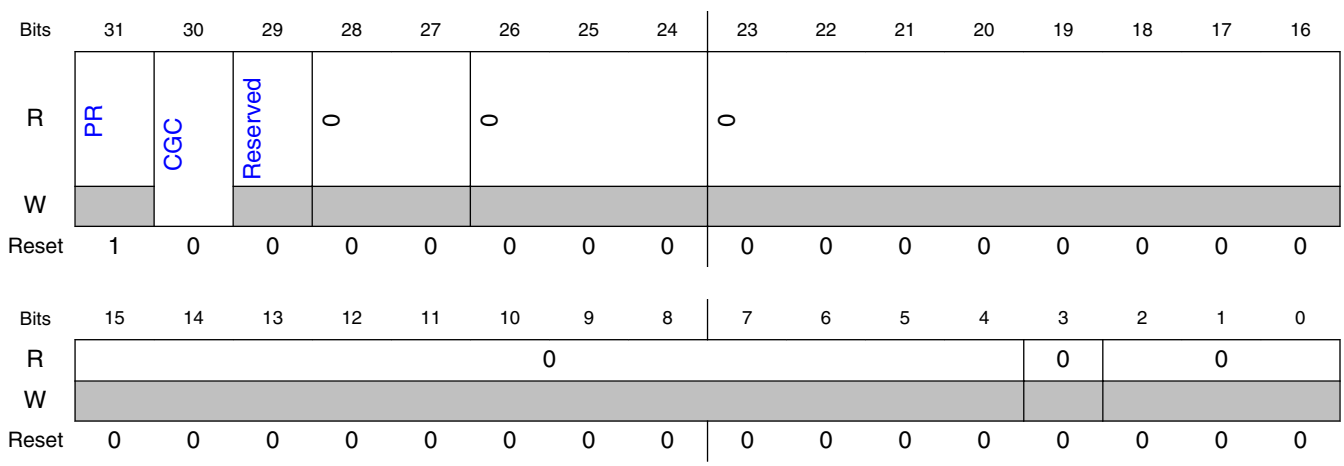
16.6.9.1 Offset

Register	Offset
PCC_FLEXTMR1	E4h

16.6.9.2 Function

PCC Register

16.6.9.3 Diagram



16.6.9.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral.

Table continues on the next page...

Field	Function
	0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.10 PCC ADC0 Register (PCC_ADC0)

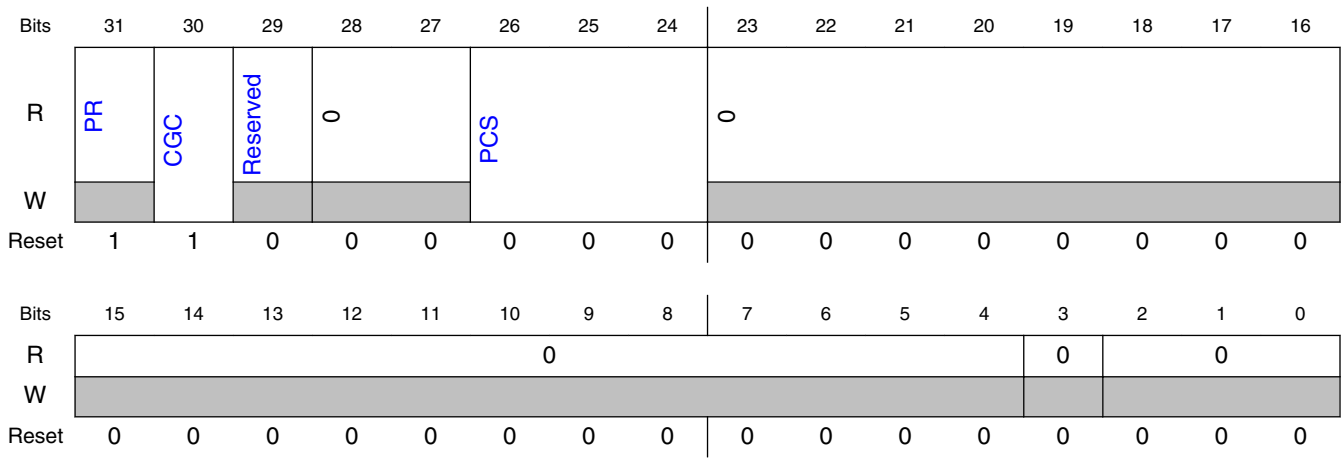
16.6.10.1 Offset

Register	Offset
PCC_ADC0	ECh

16.6.10.2 Function

PCC Register

16.6.10.3 Diagram



16.6.10.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 PCS	Peripheral Clock Source Select This read/write bit field is used for peripherals that support various clock selections. This field can be written only when the clock is disabled (CGC = 0). 000b - Clock is off. 001b - Clock option 1 010b - Clock option 2 011b - Clock option 3 100b - Clock option 4 101b - Clock option 5 110b - Clock option 6 111b - Clock option 7
23-4	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
—	
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.11 PCC RTC Register (PCC_RTC)

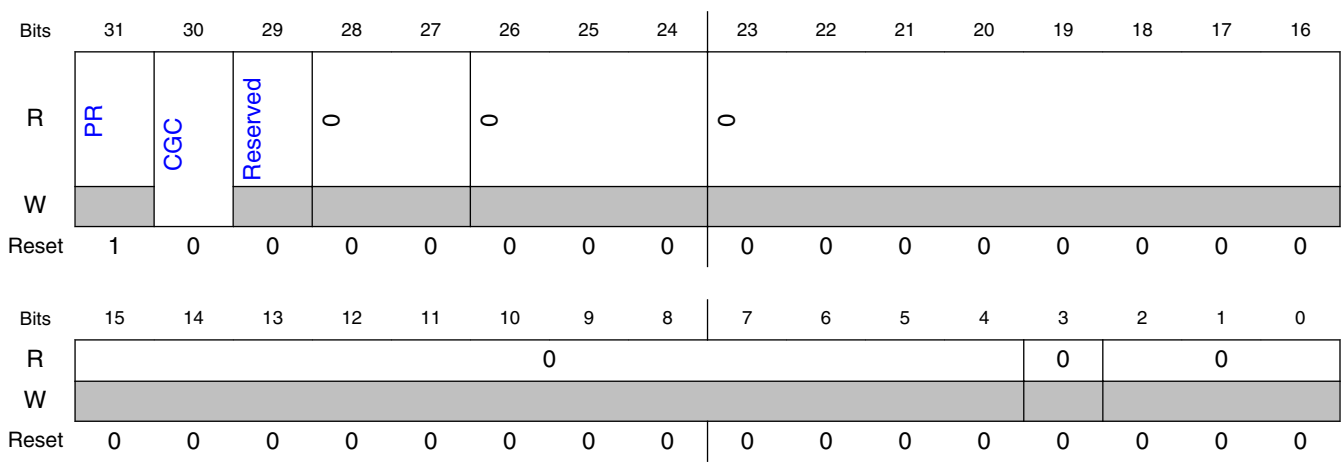
16.6.11.1 Offset

Register	Offset
PCC_RTC	F4h

16.6.11.2 Function

PCC Register

16.6.11.3 Diagram



16.6.11.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.12 PCC LPTMR0 Register (PCC_LPTMR0)

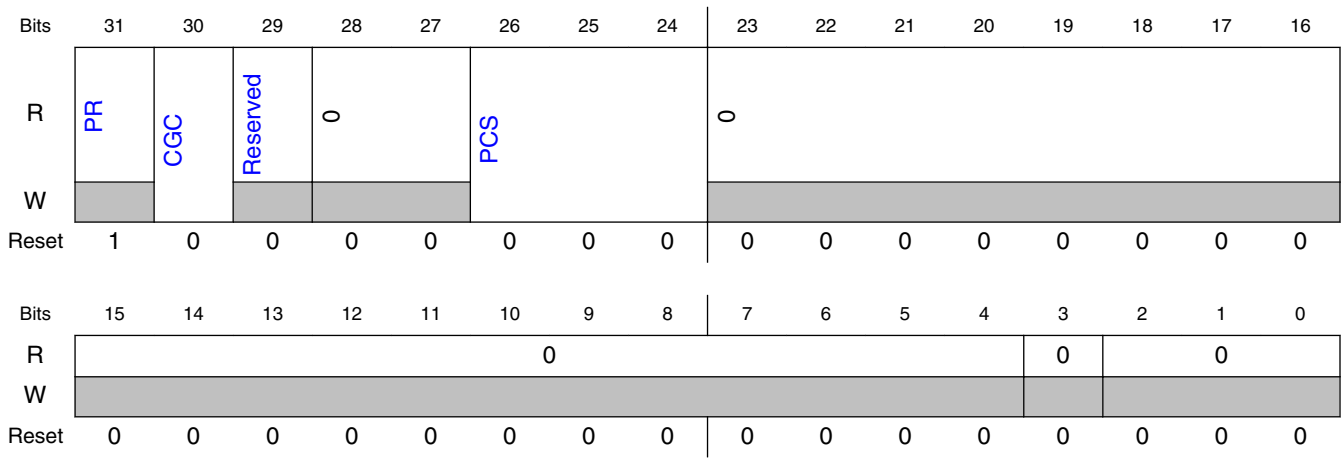
16.6.12.1 Offset

Register	Offset
PCC_LPTMR0	100h

16.6.12.2 Function

PCC Register

16.6.12.3 Diagram



16.6.12.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 PCS	Peripheral Clock Source Select This read/write bit field is used for peripherals that support various clock selections. This field can be written only when the clock is disabled (CGC = 0). 000b - Clock is off. 001b - Clock option 1 010b - Clock option 2 011b - Clock option 3 100b - Clock option 4 101b - Clock option 5 110b - Clock option 6 111b - Clock option 7
23-4	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
—	
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.13 PCC TSI Register (PCC_TSI)

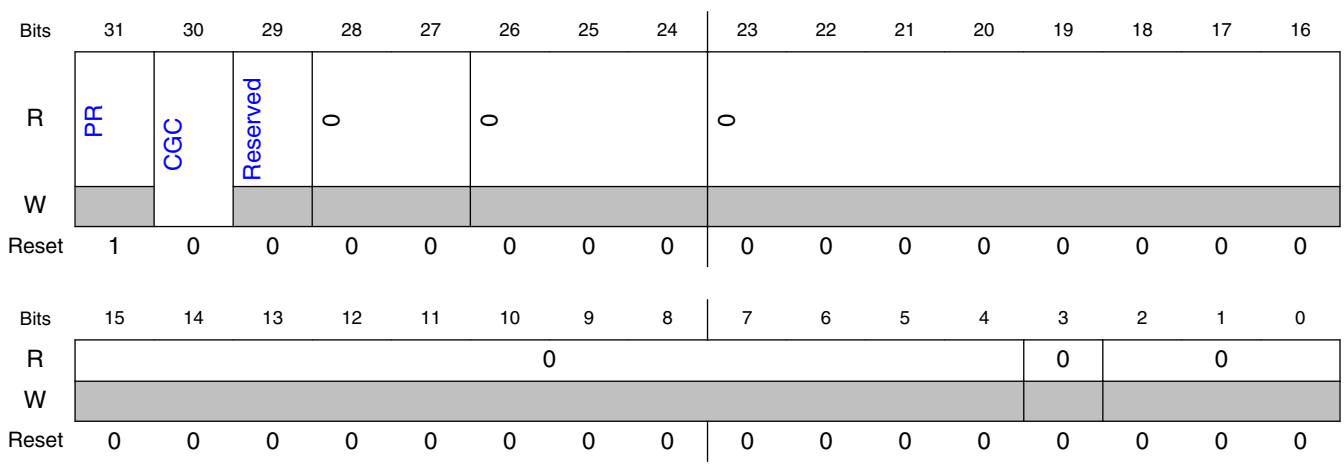
16.6.13.1 Offset

Register	Offset
PCC_TSI	114h

16.6.13.2 Function

PCC Register

16.6.13.3 Diagram



16.6.13.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.14 PCC PORTA Register (PCC_PORTA)

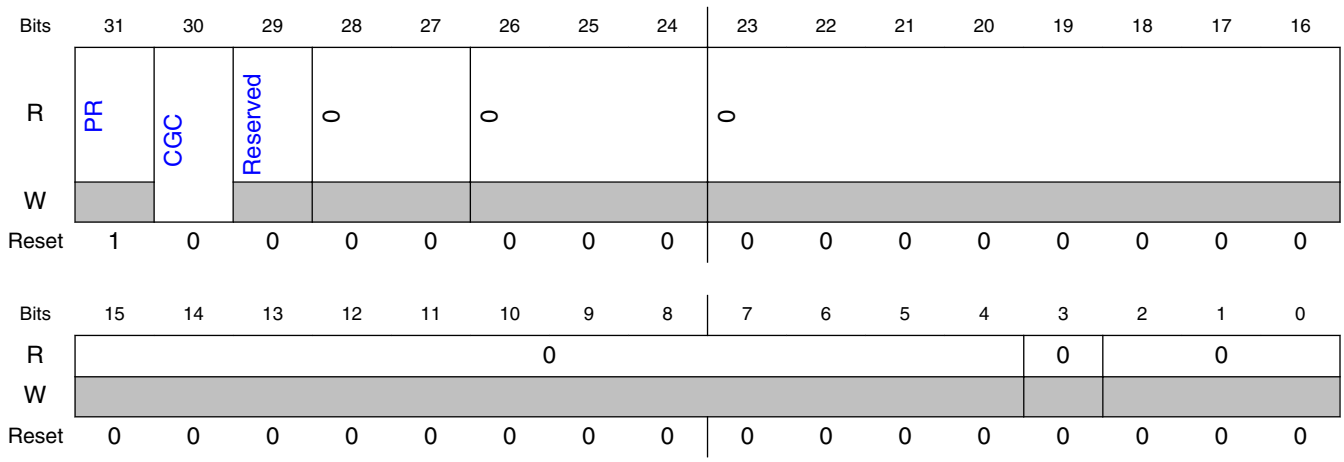
16.6.14.1 Offset

Register	Offset
PCC_PORTA	124h

16.6.14.2 Function

PCC Register

16.6.14.3 Diagram



16.6.14.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.15 PCC PORTB Register (PCC_PORTB)

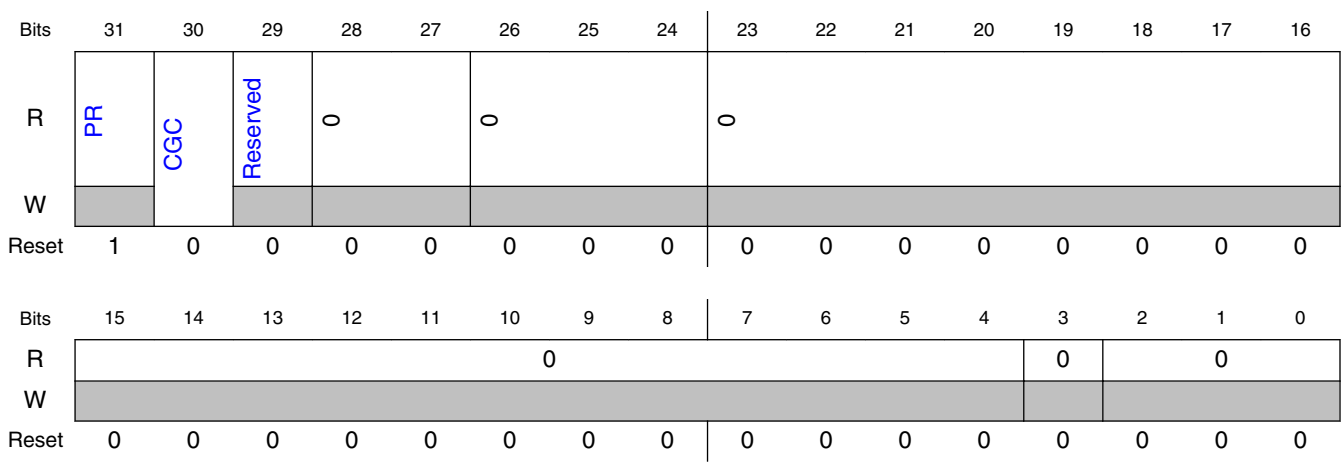
16.6.15.1 Offset

Register	Offset
PCC_PORTB	128h

16.6.15.2 Function

PCC Register

16.6.15.3 Diagram



16.6.15.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral.

Table continues on the next page...

Field	Function
	0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.16 PCC PORTC Register (PCC_PORTC)

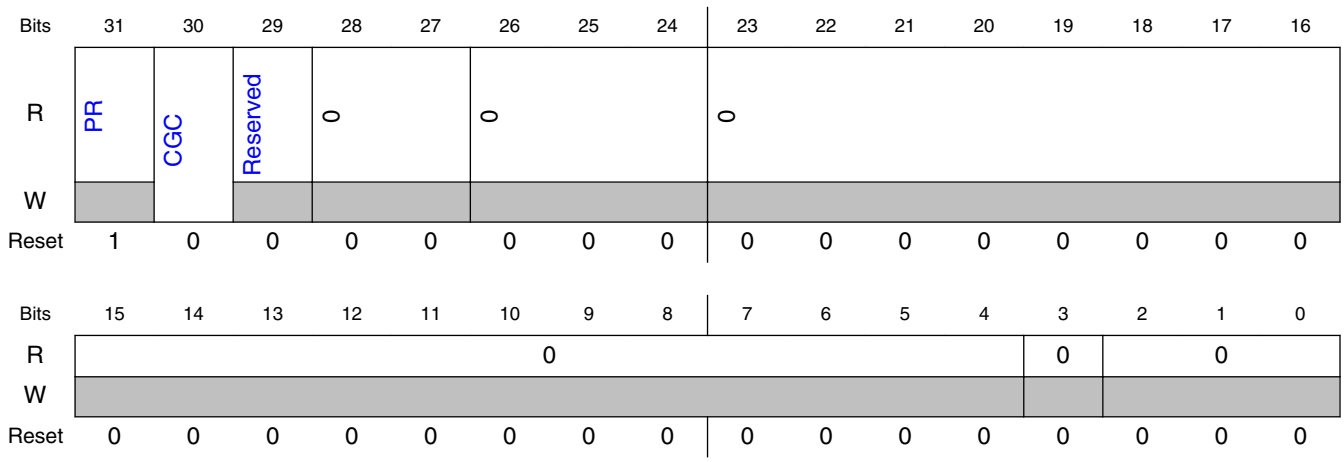
16.6.16.1 Offset

Register	Offset
PCC_PORTC	12Ch

16.6.16.2 Function

PCC Register

16.6.16.3 Diagram



16.6.16.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.17 PCC PORTD Register (PCC_PORTD)

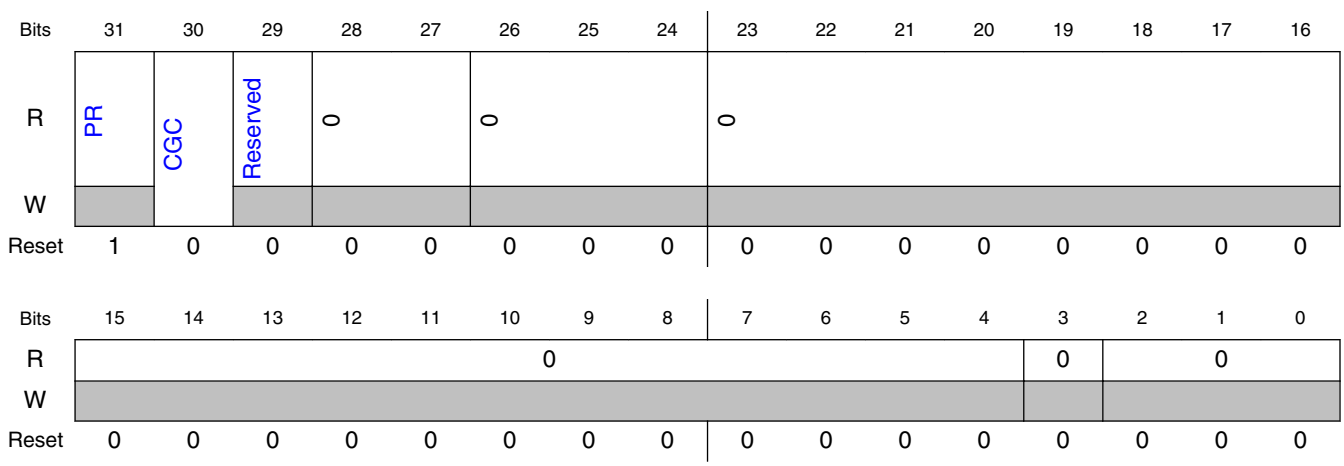
16.6.17.1 Offset

Register	Offset
PCC_PORTD	130h

16.6.17.2 Function

PCC Register

16.6.17.3 Diagram



16.6.17.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral.

Table continues on the next page...

Field	Function
	0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.18 PCC PORTE Register (PCC_PORTE)

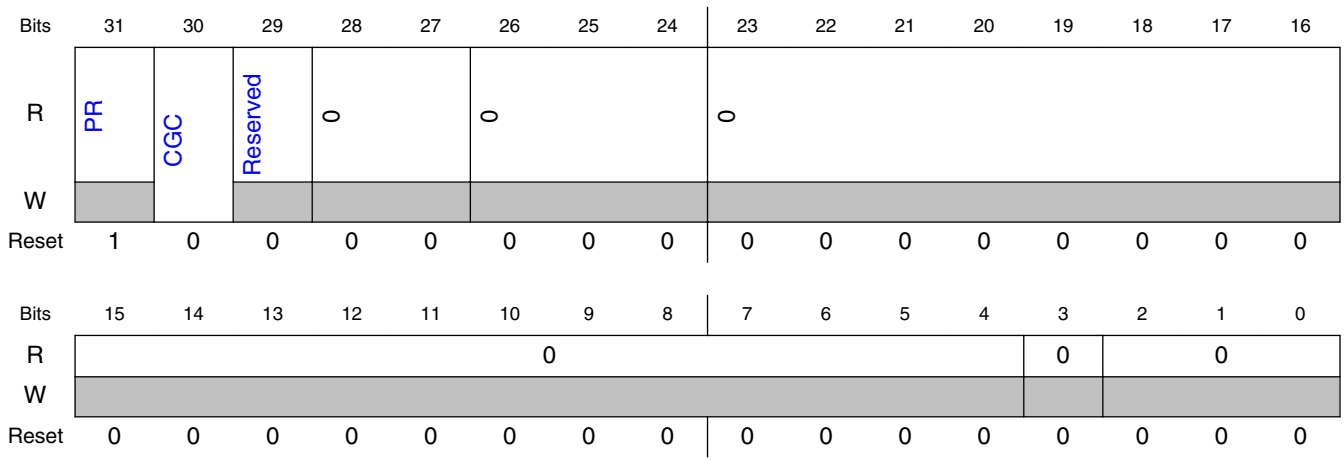
16.6.18.1 Offset

Register	Offset
PCC_PORTE	134h

16.6.18.2 Function

PCC Register

16.6.18.3 Diagram



16.6.18.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.19 PCC PWT Register (PCC_PWT)

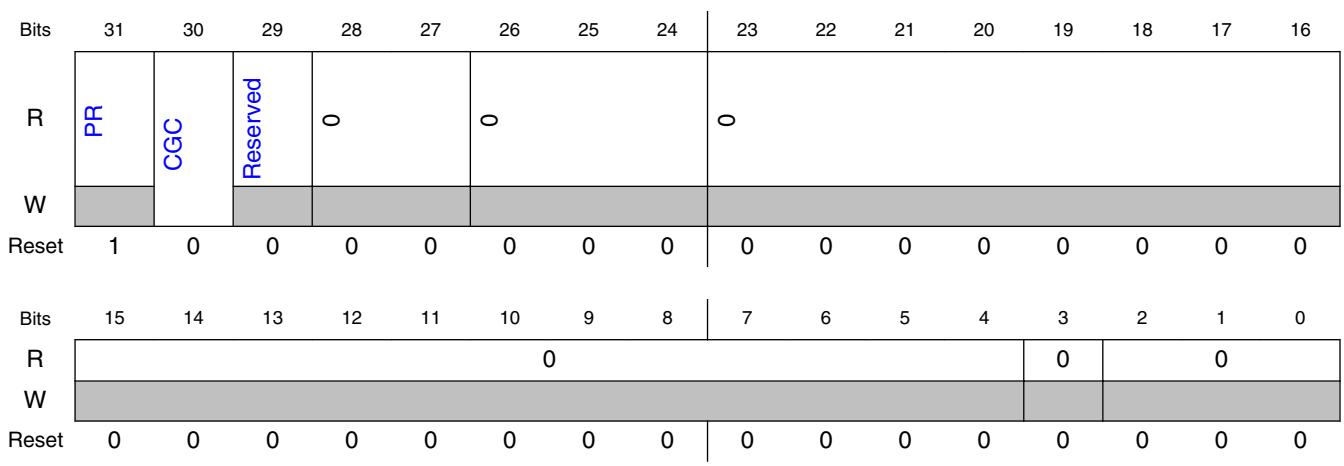
16.6.19.1 Offset

Register	Offset
PCC_PWT	158h

16.6.19.2 Function

PCC Register

16.6.19.3 Diagram



16.6.19.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral.

Table continues on the next page...

Field	Function
	0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.20 PCC EWM Register (PCC_EWM)

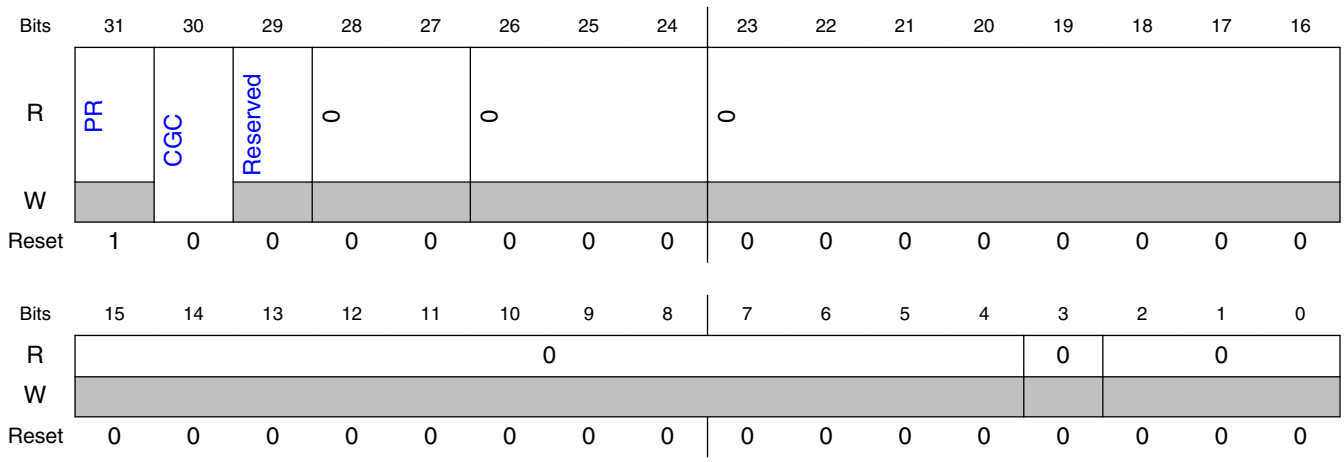
16.6.20.1 Offset

Register	Offset
PCC_EWM	184h

16.6.20.2 Function

PCC Register

16.6.20.3 Diagram



16.6.20.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.21 PCC LPI2C0 Register (PCC_LPI2C0)

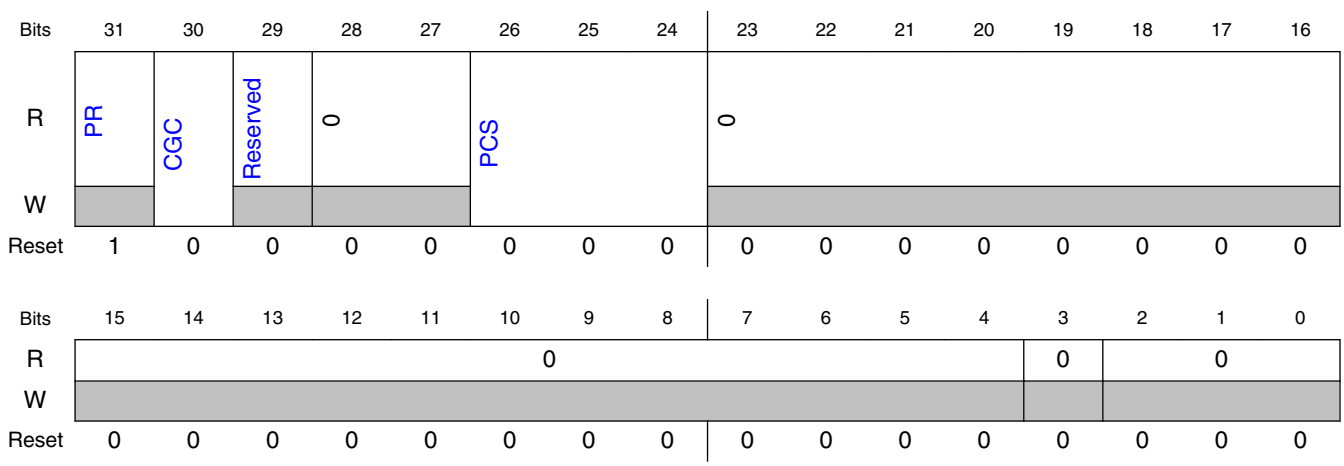
16.6.21.1 Offset

Register	Offset
PCC_LPI2C0	198h

16.6.21.2 Function

PCC Register

16.6.21.3 Diagram



16.6.21.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral.

Table continues on the next page...

Field	Function
	0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 PCS	Peripheral Clock Source Select This read/write bit field is used for peripherals that support various clock selections. This field can be written only when the clock is disabled (CGC = 0). 000b - Clock is off. 001b - Clock option 1 010b - Clock option 2 011b - Clock option 3 100b - Clock option 4 101b - Clock option 5 110b - Clock option 6 111b - Clock option 7
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.22 PCC LPUART0 Register (PCC_LPUART0)

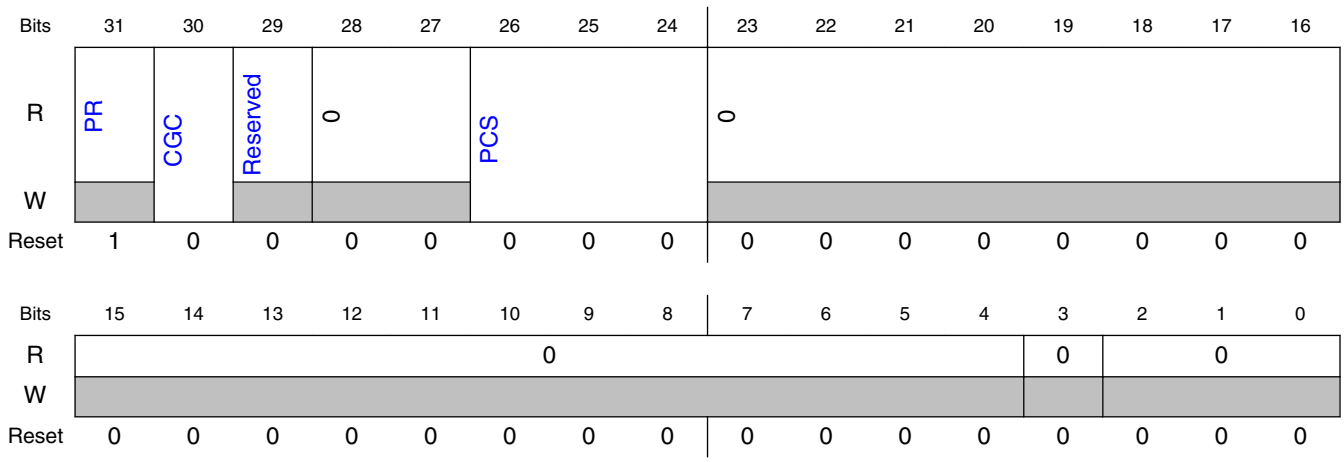
16.6.22.1 Offset

Register	Offset
PCC_LPUART0	1A8h

16.6.22.2 Function

PCC Register

16.6.22.3 Diagram



16.6.22.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 PCS	Peripheral Clock Source Select This read/write bit field is used for peripherals that support various clock selections. This field can be written only when the clock is disabled (CGC = 0). 000b - Clock is off. 001b - Clock option 1 010b - Clock option 2 011b - Clock option 3 100b - Clock option 4 101b - Clock option 5 110b - Clock option 6 111b - Clock option 7
23-4	This read-only bit field is reserved and always has the value 0.

Table continues on the next page...

Field	Function
—	
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.23 PCC LPUART1 Register (PCC_LPUART1)

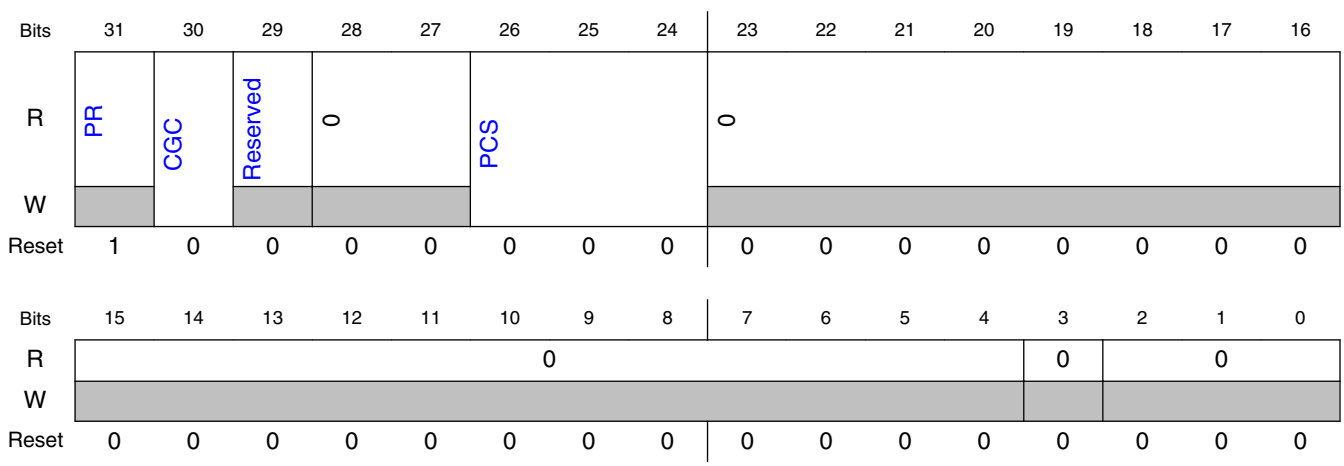
16.6.23.1 Offset

Register	Offset
PCC_LPUART1	1ACh

16.6.23.2 Function

PCC Register

16.6.23.3 Diagram



16.6.23.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 PCS	Peripheral Clock Source Select This read/write bit field is used for peripherals that support various clock selections. This field can be written only when the clock is disabled (CGC = 0). 000b - Clock is off. 001b - Clock option 1 010b - Clock option 2 011b - Clock option 3 100b - Clock option 4 101b - Clock option 5 110b - Clock option 6 111b - Clock option 7
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.24 PCC LPUART2 Register (PCC_LPUART2)

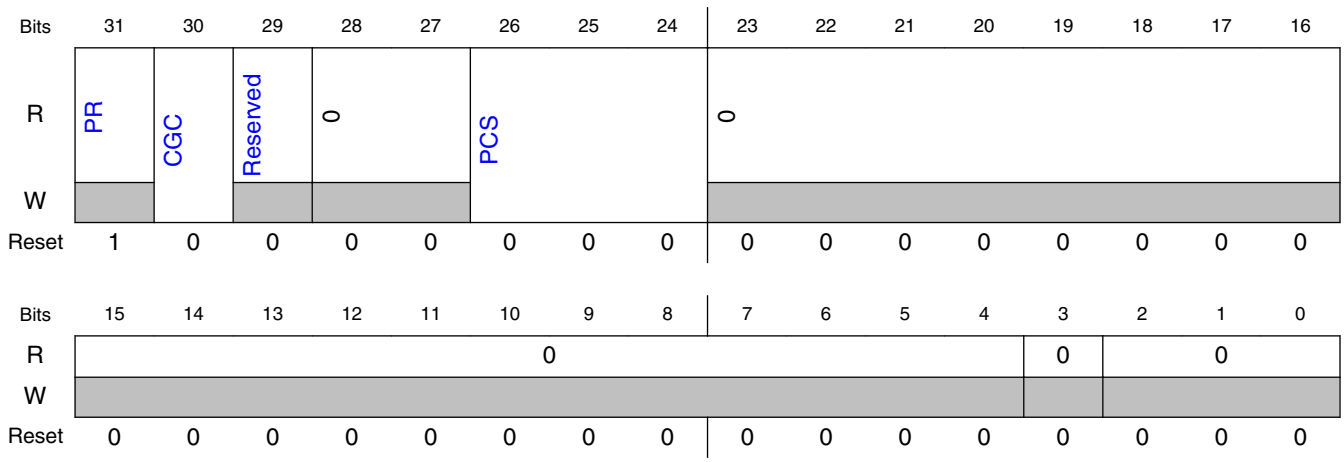
16.6.24.1 Offset

Register	Offset
PCC_LPUART2	1B0h

16.6.24.2 Function

PCC Register

16.6.24.3 Diagram



16.6.24.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 PCS	Peripheral Clock Source Select This read/write bit field is used for peripherals that support various clock selections. This field can be written only when the clock is disabled (CGC = 0). 000b - Clock is off. 001b - Clock option 1

Table continues on the next page...

Field	Function
	010b - Clock option 2 011b - Clock option 3 100b - Clock option 4 101b - Clock option 5 110b - Clock option 6 111b - Clock option 7
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

16.6.25 PCC CMP0 Register (PCC_CMP0)

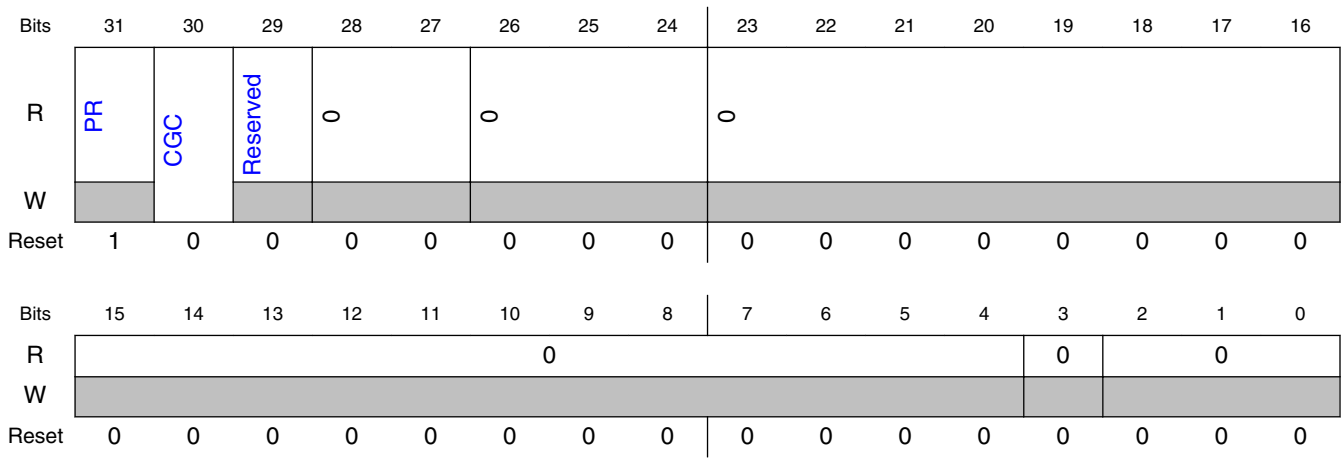
16.6.25.1 Offset

Register	Offset
PCC_CMP0	1CCh

16.6.25.2 Function

PCC Register

16.6.25.3 Diagram



16.6.25.4 Fields

Field	Function
31 PR	Present This bit shows whether the peripheral is present on this device. 0b - Peripheral is not present. 1b - Peripheral is present.
30 CGC	Clock Gate Control This read/write bit enables the clock for the peripheral. 0b - Clock disabled 1b - Clock enabled. The current clock selection and divider options are locked.
29 —	This read-only bit field is reserved. This bit can change values but is a don't-care.
28-27 —	This read-only bit field is reserved and always has the value 0.
26-24 —	This read-only bit field is reserved and always has the value 0.
23-4 —	This read-only bit field is reserved and always has the value 0.
3 —	This read-only bit field is reserved and always has the value 0.
2-0 —	This read-only bit field is reserved and always has the value 0.

Chapter 17
Reset and Boot

17.1 Introduction

The following reset sources are supported in this MCU:

Table 17-1. Reset sources

Reset sources	Description
POR reset	• Power-on reset (POR)
System resets	• External pin reset (PIN) • Low voltage detect (LVD) • Software watchdog reset (WDOG) • Clock generator loss of clock (LOC) reset • Clock generator loss of lock (LOL) reset • Stop mode acknowledge error (SACKERR) • Software reset (SW) • Lockup reset (LOCKUP) • MDM DAP system reset
Debug reset	• Debug reset

Each of the reset sources has an associated bit in the system reset status (RCM_SRS) register. Besides immediate reset, the RCM module also supports optional delays of the system resets for a period of time with an interrupt generated. This provides software an option to perform a graceful shutdown. See the Reset Control Module (RCM) chapter for register details.

The MCU exits reset in functional mode where the CPU is executing code. See Boot options for more details.

The following figure shows a block diagram of the reset sources for this device.

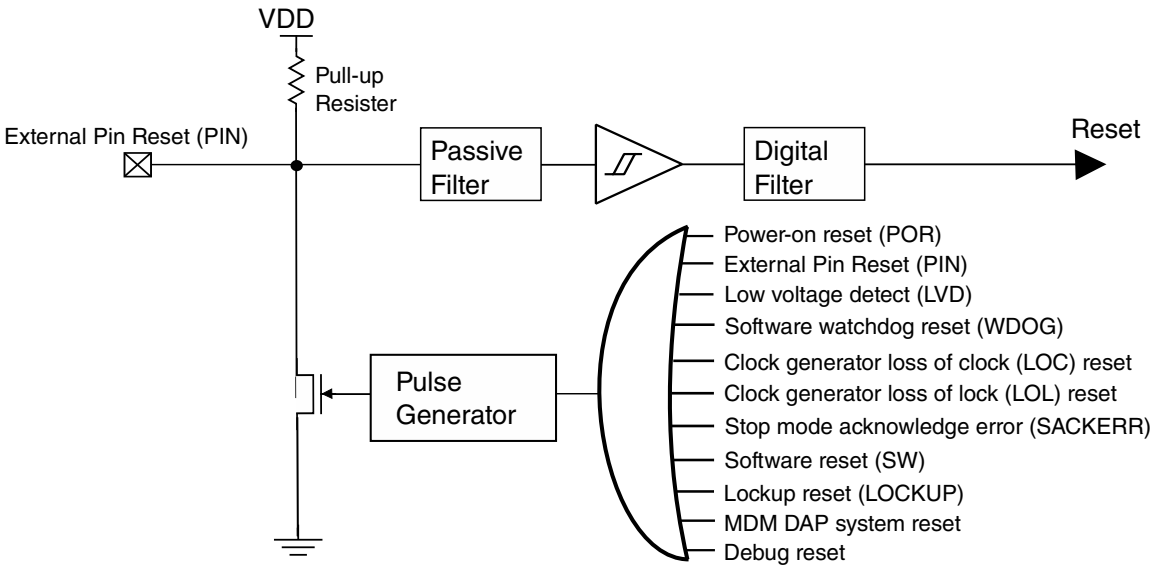


Figure 17-1. Reset Sources

17.2 Reset

This section discusses basic reset mechanisms and sources. Some modules that cause resets can be configured to cause interrupts instead. Consult the individual peripheral chapters for more information.

17.2.1 Power-on reset (POR)

When power is initially applied to the MCU or when the supply voltage drops below the power-on reset re-arm voltage level (V_{POR}), the POR circuit causes a POR reset condition.

As the supply voltage rises, the LVR circuit holds the MCU in reset until the supply has risen above the LVR threshold (V_{LVR}). The POR and LVD bits in RCM_SRS register are set following a POR.

17.2.2 System resets

Resetting the MCU provides a way to start processing from a known set of initial conditions. System reset begins with the on-chip regulator in full regulation and system clocking generation from an internal reference. When the processor exits reset, it performs the following:

- Reads the start SP (SP_main) from vector-table offset 0

- Reads the start program counter (PC) from vector-table offset 4
- Link register (LR) is set to 0xFFFF_FFFF

The on-chip peripheral modules are disabled and the non-analog I/O pins are initially configured as disabled. The pins with analog functions assigned to them are assigned by default to their analog functions after reset.

During and following a reset, the SWD pins have their associated input pins configured as:

- SWD_CLK in pull-down (PD)
- SWD_DIO in pull-up (PU)

17.2.2.1 External pin reset (PIN)

On this device, asserting $\overline{\text{RESET}}$ wakes and resets the device from any mode. During a pin reset, RCM_SRS[PIN] is set.

The $\overline{\text{RESET}}$ pin filter supports filtering from both the 1 kHz LPO clock and the bus clock. RCM_RPC[RSTFLTSS], RCM_RPC[RSTFLTSRW], and RCM_RPC[RSTFLTSEL] control this functionality; see the RCM chapter. The filters are asynchronously reset by Chip POR. The reset value for each filter assumes the $\overline{\text{RESET}}$ pin is negated.

For all stop modes where LPO clock is still active, the only filtering option is the LPO-based digital filter. The filtering logic either switches to bypass operation or has continued filtering operation depending on the filtering mode selected.

The LPO filter has a fixed filter value of 3. Due to a synchronizer on the input data, there is also some associated latency (2 cycles). As a result, 5 cycles are required to complete a transition from low to high or high to low.

17.2.2.2 Low voltage detect (LVD)

The chip includes a system for managing low voltage conditions to protect memory contents and control MCU system states during supply voltage variations. The system consists of a power-on reset (POR) circuit and an LVD circuit. The LVD system can always be enabled in normal Run, or Wait mode. The LVD system is disabled (LVR active only) when entering VLPx modes or Stop mode.

The LVD can be configured to generate a reset upon detection of a low voltage condition by setting the PMC_LVDSC1[LVDRE] bit to 1. After an LVD reset has occurred, the LVD system holds the MCU in reset until the supply voltage has risen above the low voltage detection threshold. The RCM_SRS[LVD] bit is set following either an LVD reset or POR.

Refer to the "Low-voltage Detect (LVD) System" section in the Power Management Controller (PMC) chapter for more information. For LVR related content, see Low Voltage Reset (LVR) Operation.

17.2.2.3 Watchdog timer (WDOG)

The watchdog timer (WDOG) monitors the operation of the system by expecting periodic communication from the software. This communication is generally known as servicing (or refreshing) the watchdog. If this periodic refreshing does not occur, the watchdog issues a system reset. The reset causes the RCM_SRS[WDOG] bit to set.

17.2.2.4 Clock generator loss-of-clock (LOC)

The SCG module contains a clock monitor with reset and interrupt request capability for SOSC clocks.

NOTE

To prevent unexpected loss of clock reset events, all clock monitors should be disabled before entering any low power modes, including VLPR and VLPW.

17.2.2.5 Loss-of-lock (LOL) reset

The SCG module contains a loss-of-lock detector, to indicate a reset has been caused by a loss of lock in the SCG PLL/FLL.

NOTE

This reset source does not cause a reset if the chip is in VLPR/ VLPW/VLPS mode.

17.2.2.6 Stop mode acknowledge error (SACKERR)

This reset is generated if the core attempts to enter stop mode, but not all modules acknowledge stop mode within 1025 cycles of the LPO clock.

A module might not acknowledge the entry to stop mode if an error condition occurs. The error can be caused by a failure of an external clock input to a module.

The RCM_SRS[SACKERR] bit is set to indicate this reset source.

17.2.2.7 Software reset (SW)

The SYSRESETREQ bit in the System Control Block's (SCB) application interrupt and reset control register can be set to force a software reset on the device. (See ARM's Cortex-M user guide for the full description of the register fields, especially the VECTKEY field requirements.) Setting SYSRESETREQ generates a software reset request. This reset forces a system reset of all major components except for the debug module. A software reset causes the RCM_SRS[SW] bit to set.

17.2.2.8 Lockup reset (LOCKUP)

The LOCKUP gives immediate indication of seriously errant kernel software. This is the result of the core being locked because of an unrecoverable exception following the activation of the processor’s built in system state protection hardware.

The LOCKUP condition causes a system reset and also causes the RCM_SRS[LOCKUP] bit to set.

17.2.2.9 MDM-AP system reset request

Set the system reset request bit in the MDM-AP control register to initiate a system reset. This is the primary method for resets via the SWD interface. The system reset is held until this bit is cleared.

Set the core hold reset bit in the MDM-AP control register to hold the core in reset as the rest of the chip comes out of system reset.

17.2.3 MCU Resets

A variety of resets are generated by the MCU to reset different modules.

17.2.3.1 POR Only

The POR Only reset asserts on the POR reset source only. It resets the PMC registers.

The POR Only reset also causes all other reset types to occur.

17.2.3.2 Chip POR

The Chip POR asserts on POR, LVD Wakeup reset sources. It resets the Reset Pin Filter registers and parts of the SIM and SCG .

The Chip POR also causes the Chip Reset (including Early Chip Reset) to occur.

17.2.3.3 Early Chip Reset

The Early Chip Reset asserts on all reset sources. It resets only the flash memory module. It negates before flash memory initialization begins ("earlier" than when the Chip Reset negates).

17.2.3.4 Chip Reset

Chip Reset asserts on all reset sources and only negates after flash initialization has completed and the RESET_b pin has also negated. It resets the remaining modules (the modules not reset by other reset types).

17.2.4 Reset Pin

For all reset sources, the RESET_b pin is driven low by the MCU for at least 128 bus clock cycles and until flash initialization has completed.

After flash initialization has completed, the RESET_b pin is released, and the internal Chip Reset negates after the RESET_b pin is pulled high. Keeping the RESET_b pin asserted externally delays the negation of the internal Chip Reset.

17.3 Boot

This section describes the boot sequence, including sources and options.

17.3.1 Boot options

The Flash Option (FOPT) register in the Flash Memory module (FTFA_FOPT) allows the user to customize the operation of the MCU at boot time. The register contains read-only bits that are loaded from the NVM's option byte in the flash configuration field. The default setting for all values in the FTFA_FOPT register is logic 1 since it is copied from the option byte residing in flash, which has all bits as logic 1 in the flash erased state. To configure for alternate settings, program the appropriate bits in the NVM option byte. The new settings will take effect on subsequent POR and any system reset. For more details on programming the option byte, see the flash memory chapter.

The MCU uses FTFA_FOPT to configure the device at reset as shown in the following table.

Table 17-2. Flash Option Register (FTFA_FOPT) definition

Bit Num	Field	Value	Definition
7	Reserved	Reserved for future expansion	
6	Reserved	Reserved for future expansion	
5-4	Reserved	Reserved for future expansion	
3	RESET_PIN_CFG	Enables/disables control for the RESET pin.	
		0	RESET_b pin is disabled following a POR and cannot be enabled as reset function. When this option is selected, there could be a short period of contention during a POR ramp where the device drives the pin low prior to establishing the setting of this option and releasing the reset function on the pin. When the RESET pin is disabled and configured as a GPIO output, it operates as a pseudo open drain output. This bit is preserved through system resets and low-power modes. When RESET_b pin function is disabled, it cannot be used as a source for low-power mode wake-up. **NOTE:** When the reset pin has been disabled and security has been enabled by means of the FSEC register, a mass erase can be performed only by setting both the Mass Erase and System Reset Request fields in the MDM-AP register.
		1	RESET_b pin is dedicated. The port is configured with pullup enabled, open drain, passive filter enabled.
2	NMI_DIS	Enables/disables control for the NMI function.	
		0	NMI interrupts are always blocked. The associated pin continues to default to NMI_b pin controls with internal pullup enabled. When NMI_b pin function is disabled, it cannot be used as a source for low-power mode wake-up. If the NMI function is not required, either for an interrupt or wake up source, it is recommended that the NMI function be disabled by clearing NMI_DIS.
		1	NMI_b pin/interrupts reset default to enabled.
1	Reserved	Reserved for future expansion	

Table continues on the next page...

Table 17-2. Flash Option Register (FTFA_FOPT) definition (continued)

Bit Num	Field	Value	Definition
0	LPBOOT	Controls the reset value of clock divider of IRC48M to feed the core clock. Larger divide value selections produce lower average power consumption during POR and reset sequencing and after reset exit. The recovery times are also extended .	
		0	Low-power boot: Core and system clock divider (DIVCORE) is 0x1 (divide by 2).
		1	Normal boot: Core and system clock divider (DIVCORE) is 0x0 (divide by 1).

This device supports cold booting from either internal flash.

When the device boots from internal flash, the reset vectors are located at address 0x0 (initial SP_main) and 0x4 (initial PC).

The device also supports relocating the exception vector table to RAM. This is implemented through a programmable Vector Table Offset Register (VTOR) in SCB module.

17.3.2 Boot sequence

At power up, the on-chip regulator holds the system in a POR state until the input supply is above the POR threshold. The system continues to be held in this static state until the internally regulated supplies have reached a safe operating voltage as determined by the LVR. The Mode Controller reset logic then controls a sequence to exit reset.

1. A system reset is held on internal logic, the RESET_b pin is driven out low, and the SCG is enabled in its default clocking mode.
2. Required clocks are enabled (Core Clock, System Clock, Flash Clock, and any Bus Clocks that do not have clock gate control reset to disabled).
3. The system reset on internal logic continues to be held, but the Flash Controller is released from reset and begins initialization operation while the Reset Control logic continues to drive the RESET_b pin out low.
4. Early in reset sequencing the NVM option byte is read and stored to the Flash Memory module's FOPT register.If the LPBOOT is programmed for an alternate clock divider reset value, the system/core clock is switched to a slower clock speed.
5. When Flash Initialization completes, the RESET_b pin is released. If RESET_b continues to be asserted (an indication of a slow rise time on the RESET_b pin or external drive in low), the system continues to be held in reset. Once the RESET_b pin is detected high, the Core clock is enabled and the system is released from reset.
6. When the system exits reset, the processor sets up the stack, program counter (PC), and link register (LR). The processor reads the start SP (SP_main) from vector-table offset 0. The core reads the start PC from vector-table offset 4. LR is set to

0xFFFF_FFFF. What happens next depends on the NMI input and the FOPT[NMI_DIS] field in the Flash Memory module:

- If the NMI input is high or the NMI function is disabled in the NMI_DIS field, the CPU begins execution at the PC location.
- If the NMI input is low and the NMI function is enabled in the NMI_DIS field, this results in an NMI interrupt. The processor executes an Exception Entry and reads the NMI interrupt handler address from vector-table offset 8. The CPU begins execution at the NMI interrupt handler.

Subsequent system resets follow this same reset flow.

The following figure shows the boot sequence.

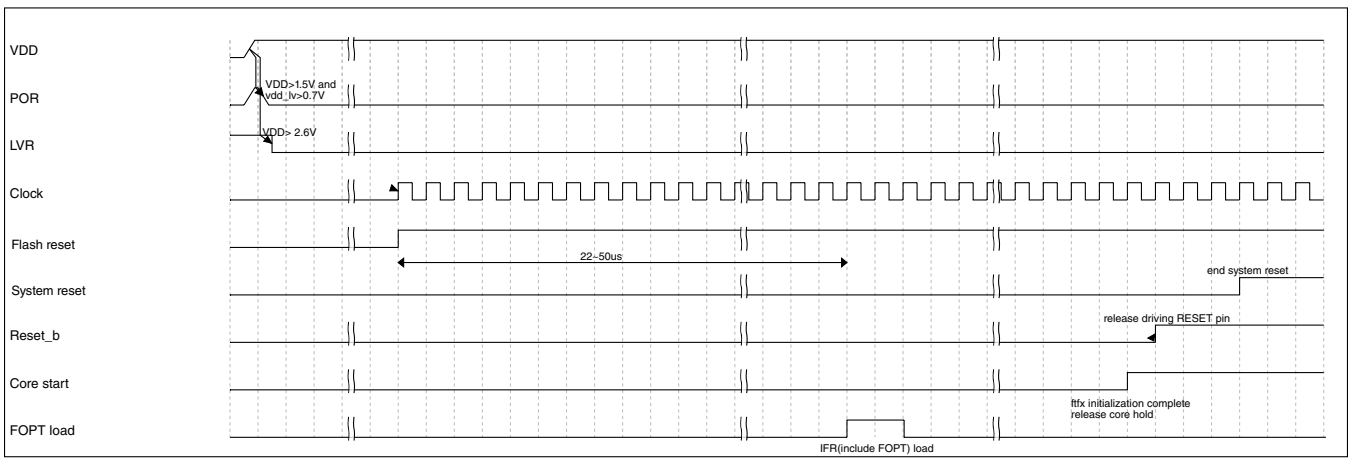


Figure 17-2. Boot Sequence

Chapter 18
Reset Control Module (RCM)

18.1 Chip-specific information for this module

18.1.1 Instantiation Information

18.1.1.1 Information of RCM on this device

NOTE

The RCM registers can be written only in supervisor mode. Write accesses in user mode are blocked and will result in a bus error. A bus error will generate a hard fault interrupt on this device.

NOTE

High-Voltage Detect (HVD) is not supported on this device. Therefore, HVD related descriptions are not applicable in RCM_SRS[LVD].

18.2 Introduction

Information found here describes the registers of the Reset Control Module (RCM). The RCM implements many of the reset functions for the chip. See the chip's reset chapter for more information.

See AN4503: Power Management for Kinetis and ColdFire+ MCUs for further details on using the RCM.

18.3 Reset memory map and register descriptions

The RCM Memory Map/Register Definition can be found here.

The Reset Control Module (RCM) registers provide reset status information and reset filter control.

NOTE

The RCM registers can be written only in supervisor mode. Write accesses in user mode are blocked and will result in a bus error.

RCM memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4007_F000	Version ID Register (RCM_VERID)	32	R	0300_0003h	18.3.1/294
4007_F008	System Reset Status Register (RCM_SRS)	32	R	0000_0082h	18.3.2/295
4007_F00C	Reset Pin Control register (RCM_RPC)	32	R/W	0000_0000h	18.3.3/298
4007_F010	Mode Register (RCM_MR)	32	R/W	See section	18.3.4/299
4007_F014	Force Mode Register (RCM_FM)	32	R/W	0000_0000h	18.3.5/300
4007_F018	Sticky System Reset Status Register (RCM_SSRS)	32	R/W	0000_0082h	18.3.6/301
4007_F01C	System Reset Interrupt Enable Register (RCM_SRIE)	32	R/W	0000_0000h	18.3.7/303

18.3.1 Version ID Register (RCM_VERID)

Address: 4007_F000h base + 0h offset = 4007_F000h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MAJOR								MINOR								FEATURE															
W																																
Reset	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

RCM_VERID field descriptions

Field	Description
31–24 MAJOR	Major Version Number This read only field returns the major version number for the specification.
23–16 MINOR	Minor Version Number This read only field returns the minor version number for the specification.

Table continues on the next page...

RCM_VERID field descriptions (continued)

Field	Description
FEATURE	Feature Specification Number This read only field returns the feature set number. 0x0003 Standard feature set.

18.3.2 System Reset Status Register (RCM_SRS)

This register includes read-only status flags to indicate the source of the most recent reset. Note that multiple flags can be set if multiple reset events occur at the same time. The reset state of these bits depends on what caused the MCU to reset.

NOTE

The reset value of this register depends on the reset source:
- POR (including LVD) — 0x82
- LVD (without POR) — 0x02
- Other reset — a bit is set if its corresponding reset source caused the reset

Address: 4007_F000h base + 8h offset = 4007_F008h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	SACKERR	0	MDM_AP	SW	LOCKUP	0	POR	PIN	WDOG	0	LOL	LOC	LVD	0
W																
Reset	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0

RCM_SRS field descriptions

Field	Description
31–17 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13 SACKERR	Stop Acknowledge Error Indicates that after an attempt to enter Stop mode, a reset has been caused by a failure of one or more peripherals to acknowledge within approximately one second to enter stop mode. 0 Reset not caused by peripheral failure to acknowledge attempt to enter stop mode 1 Reset caused by peripheral failure to acknowledge attempt to enter stop mode
12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11 MDM_AP	MDM-AP System Reset Request Indicates a reset has been caused by the host debugger system setting of the System Reset Request bit in the MDM-AP Control Register. 0 Reset was not caused by host debugger system setting of the System Reset Request bit 1 Reset was caused by host debugger system setting of the System Reset Request bit
10 SW	Software Indicates a reset has been caused by software setting of SYSRESETREQ bit in Application Interrupt and Reset Control Register in the Arm core. 0 Reset not caused by software setting of SYSRESETREQ bit 1 Reset caused by software setting of SYSRESETREQ bit
9 LOCKUP	Core Lockup

Table continues on the next page...

RCM_SRS field descriptions (continued)

Field	Description
	Indicates a reset has been caused by the Arm core indication of a LOCKUP event. 0 Reset not caused by core LOCKUP event 1 Reset caused by core LOCKUP event
8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 POR	Power-On Reset Indicates a reset has been caused by the power-on detection logic. Because the internal supply voltage was ramping up at the time, the low-voltage reset (LVD) status bit is also set to indicate that the reset occurred while the internal supply was below the LVD threshold. 0 Reset not caused by POR 1 Reset caused by POR
6 PIN	External Reset Pin Indicates a reset has been caused by an active-low level on the external $\overline{\text{RESET}}$ (RESET_b) pin. 0 Reset not caused by external reset pin 1 Reset caused by external reset pin
5 WDOG	Watchdog Indicates a reset has been caused by the watchdog timer timing out. This reset source can be blocked by disabling the watchdog. 0 Reset not caused by watchdog timeout 1 Reset caused by watchdog timeout
4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 LOL	Loss-of-Lock Reset Indicates a reset has been caused by a loss of lock in the SCG PLL/FLL. 0 Reset not caused by a loss of lock in the PLL/FLL 1 Reset caused by a loss of lock in the PLL/FLL
2 LOC	Loss-of-Clock Reset Indicates a reset has been caused by a loss of external clock. The SCG SOSC clock monitor must be enabled for a loss of clock to be detected. Refer to the detailed SCG description for information on enabling the clock monitor. 0 Reset not caused by a loss of external clock. 1 Reset caused by a loss of external clock.
1 LVD	Low-Voltage Detect Reset or High-Voltage Detect Reset If PMC_LVDSC1[LVDRE] is set and the supply drops below the LVD trip voltage, an LVD reset occurs. If PMC_HVDSC1[HVDRE] is set and the supply rises above the HVD trip voltage, an HVD reset occurs. This field is also set by POR. 0 Reset not caused by LVD trip, HVD trip or POR 1 Reset caused by LVD trip, HVD trip or POR

Table continues on the next page...

RCM_SRS field descriptions (continued)

Field	Description
0 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

18.3.3 Reset Pin Control register (RCM_RPC)

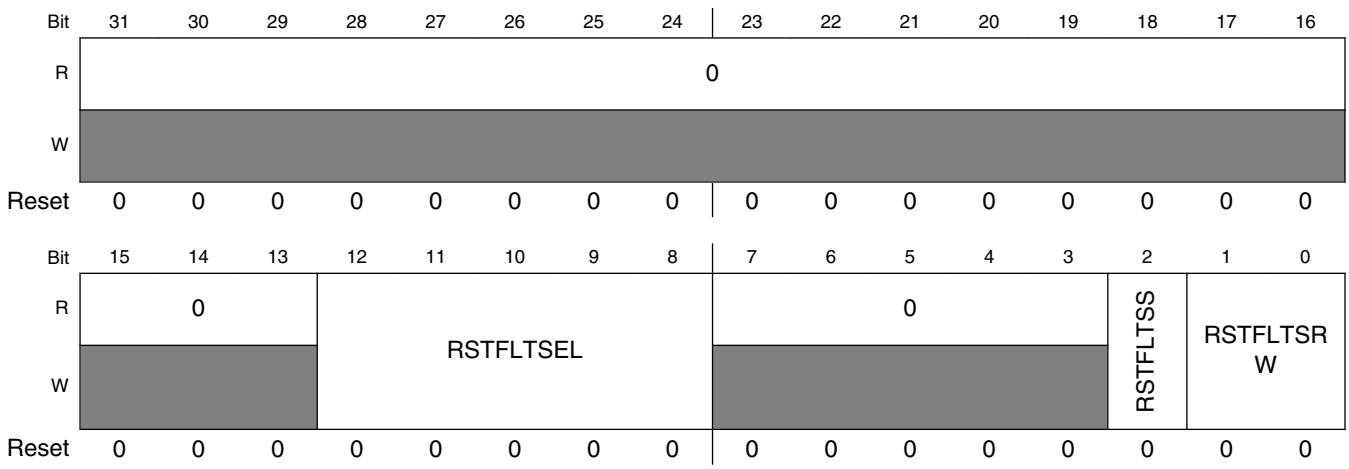
NOTE

This register is reset on Chip POR only, it is unaffected by other reset types.

NOTE

The bus clock filter is reset when disabled or when entering stop mode. The LPO filter is reset when disabled.

Address: 4007_F000h base + Ch offset = 4007_F00Ch



RCM_RPC field descriptions

Field	Description
31–13 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
12–8 RSTFLTSEL	Reset Pin Filter Bus Clock Select Selects the reset pin bus clock filter width: • Transition lengths less than RSTFLTSEL cycles are filtered. • Transition lengths between RSTFLTSEL and (RSTFLTSEL+1) cycles (inclusive) may be filtered. • Transition lengths greater than (RSTFLTSEL+1) cycles are not filtered.
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 RSTFLTSS	Reset Pin Filter Select in Stop Mode Selects how the reset pin filter is enabled in any stop mode.

Table continues on the next page...

RCM_RPC field descriptions (continued)

Field	Description
	0 All filtering disabled 1 LPO clock filter enabled
RSTFLTSRW	Reset Pin Filter Select in Run and Wait Modes Selects how the reset pin filter is enabled in run and wait modes. 00 All filtering disabled 01 Bus clock filter enabled for normal operation 10 LPO clock filter enabled for normal operation 11 Reserved

18.3.4 Mode Register (RCM_MR)

This register includes status flags to indicate the state of the mode pins during the last Chip Reset.

Address: 4007_F000h base + 10h offset = 4007_F010h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0													BOOTROM		0
W														w1c		
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	*	*	0

* Notes:
- BOOTROM field: The reset state of this register depends on the boot mode.

RCM_MR field descriptions

Field	Description
31–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2–1 BOOTROM	Boot ROM Configuration Indicates the boot source, the boot source remains set until the next System Reset or software can write logic one to clear the corresponding mode bit. While either bit is set, the NMI input is disabled and the vector table is relocated to the ROM base address at $1C00_0000. These bits should be cleared by writing logic one before executing any code from either Flash or SRAM.

Table continues on the next page...

RCM_MR field descriptions (continued)

Field	Description
	00 Boot from Flash 01 Boot from ROM due to BOOTCFG0 pin assertion / Reserved if no Boot pin 10 Boot form ROM due to FOPT[7] configuration 11 Boot from ROM due to both BOOTCFG0 pin assertion and FOPT[7] configuration
0 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

18.3.5 Force Mode Register (RCM_FM)

NOTE

The reset values of the bits in the FORCEROM field are for Chip POR only. They are unaffected by other reset types.

Address: 4007_F000h base + 14h offset = 4007_F014h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0													FORCEROM		0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RCM_FM field descriptions

Field	Description
31–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2–1 FORCEROM	Force ROM Boot When either bit is set, will force boot from ROM during all subsequent system resets. 00 No effect 01 Force boot from ROM with RCM_MR[1] set. 10 Force boot from ROM with RCM_MR[2] set. 11 Force boot from ROM with RCM_MR[2:1] set.
0 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

18.3.6 Sticky System Reset Status Register (RCM_SSRS)

This register includes status flags to indicate all reset sources since the last POR or LVD that have not been cleared by software. Software can clear the status flags by writing a logic one to a flag.

Address: 4007_F000h base + 18h offset = 4007_F018h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	SSACKERR	0	SMDM_AP	SSW	SLOCKUP	0	SPOR	SPIN	SWDOG	0	SLOL	SLOC	SLVD	0
W			w1c		w1c	w1c	w1c		w1c	w1c	w1c		w1c	w1c	w1c	
Reset	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0

RCM_SSRS field descriptions

Field	Description
31–17 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13 SSACKERR	Sticky Stop Acknowledge Error

Table continues on the next page...

RCM_SSRS field descriptions (continued)

Field	Description
	Indicates that after an attempt to enter Stop mode, a reset has been caused by a failure of one or more peripherals to acknowledge within approximately one second to enter stop mode. 0 Reset not caused by peripheral failure to acknowledge attempt to enter stop mode 1 Reset caused by peripheral failure to acknowledge attempt to enter stop mode
12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11 SMDM_AP	Sticky MDM-AP System Reset Request Indicates a reset has been caused by the host debugger system setting of the System Reset Request bit in the MDM-AP Control Register. 0 Reset was not caused by host debugger system setting of the System Reset Request bit 1 Reset was caused by host debugger system setting of the System Reset Request bit
10 SSW	Sticky Software Indicates a reset has been caused by software setting of SYSRESETREQ bit in Application Interrupt and Reset Control Register in the Arm core. 0 Reset not caused by software setting of SYSRESETREQ bit 1 Reset caused by software setting of SYSRESETREQ bit
9 SLOCKUP	Sticky Core Lockup Indicates a reset has been caused by the Arm core indication of a LOCKUP event. 0 Reset not caused by core LOCKUP event 1 Reset caused by core LOCKUP event
8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 SPOR	Sticky Power-On Reset Indicates a reset has been caused by the power-on detection logic. Because the internal supply voltage was ramping up at the time, the low-voltage reset (LVD) status bit is also set to indicate that the reset occurred while the internal supply was below the LVD threshold. 0 Reset not caused by POR 1 Reset caused by POR
6 SPIN	Sticky External Reset Pin Indicates a reset has been caused by an active-low level on the external $\overline{\text{RESET}}$ (RESET_b) pin. 0 Reset not caused by external reset pin 1 Reset caused by external reset pin
5 SWDOG	Sticky Watchdog Indicates a reset has been caused by the watchdog timer timing out. This reset source can be blocked by disabling the watchdog. 0 Reset not caused by watchdog timeout 1 Reset caused by watchdog timeout
4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

RCM_SSRS field descriptions (continued)

Field	Description
3 SLOL	Sticky Loss-of-Lock Reset Indicates a reset has been caused by a loss of lock in the SCG PLL/FLL. See the SCG description for information on the loss-of-lock event. 0 Reset not caused by a loss of lock in the PLL/FLL 1 Reset caused by a loss of lock in the PLL/FLL
2 SLOC	Sticky Loss-of-Clock Reset Indicates a reset has been caused by a loss of external clock. The SCG SOSC clock monitor must be enabled for a loss of clock to be detected. Refer to the detailed SCG description for information on enabling the clock monitor. 0 Reset not caused by a loss of external clock. 1 Reset caused by a loss of external clock.
1 SLVD	Sticky Low-Voltage Detect Reset If PMC_LVDSC1[LVDRE] is set and the supply drops below the LVD trip voltage, an LVD reset occurs. This field is also set by POR. 0 Reset not caused by LVD trip or POR 1 Reset caused by LVD trip or POR
0 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

18.3.7 System Reset Interrupt Enable Register (RCM_SRIE)

This register provides the option to delay the assertion of a system reset for a period of time (DELAY field) while an interrupt is generated. When an interrupt for a reset source is enabled, software has time to perform a graceful shutdown. A Chip POR source cannot be delayed by this feature. The SRS updates only after the system reset occurs.

NOTE

This register is reset on Chip POR only, it is unaffected by other reset types.

Address: 4007_F000h base + 1Ch offset = 4007_F01Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	0	SACKERR	0	MDM_AP	SW	LOCKUP	0	GIE	PIN	WDOG	0	LOL	LOC	DELAY	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RCM_SRIE field descriptions

Field	Description
31–17 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13 SACKERR	Stop Acknowledge Error Interrupt 0 Interrupt disabled. 1 Interrupt enabled.
12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11 MDM_AP	MDM-AP System Reset Request 0 Interrupt disabled. 1 Interrupt enabled.
10 SW	Software Interrupt 0 Interrupt disabled. 1 Interrupt enabled.
9 LOCKUP	Core Lockup Interrupt **NOTE:** The LOCKUP bit is useful only in devices with more than one core processor. 0 Interrupt disabled. 1 Interrupt enabled.
8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 GIE	Global Interrupt Enable 0 All interrupt sources disabled. 1 All interrupt sources enabled. Note that the individual interrupt-enable bits still need to be set to generate interrupts.
6 PIN	External Reset Pin Interrupt 0 Reset not caused by external reset pin 1 Reset caused by external reset pin

Table continues on the next page...

RCM_SRIE field descriptions (continued)

Field	Description
5 WDOG	Watchdog Interrupt 0 Interrupt disabled. 1 Interrupt enabled.
4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 LOL	Loss-of-Lock Interrupt 0 Interrupt disabled. 1 Interrupt enabled.
2 LOC	Loss-of-Clock Interrupt 0 Interrupt disabled. 1 Interrupt enabled.
DELAY	Reset Delay Time Configures the maximum reset delay time from when the interrupt is asserted and the system reset occurs. 00 10 LPO cycles 01 34 LPO cycles 10 130 LPO cycles 11 514 LPO cycles

Chapter 19
Power Management

19.1 Introduction

This chapter describes the various chip power modes and functionality of the individual modules in these modes. Following stated are general power modes, which are supported additionally by certain clocking mode options. Clock gating technique is used for general power modes and for the additional clocking mode options.

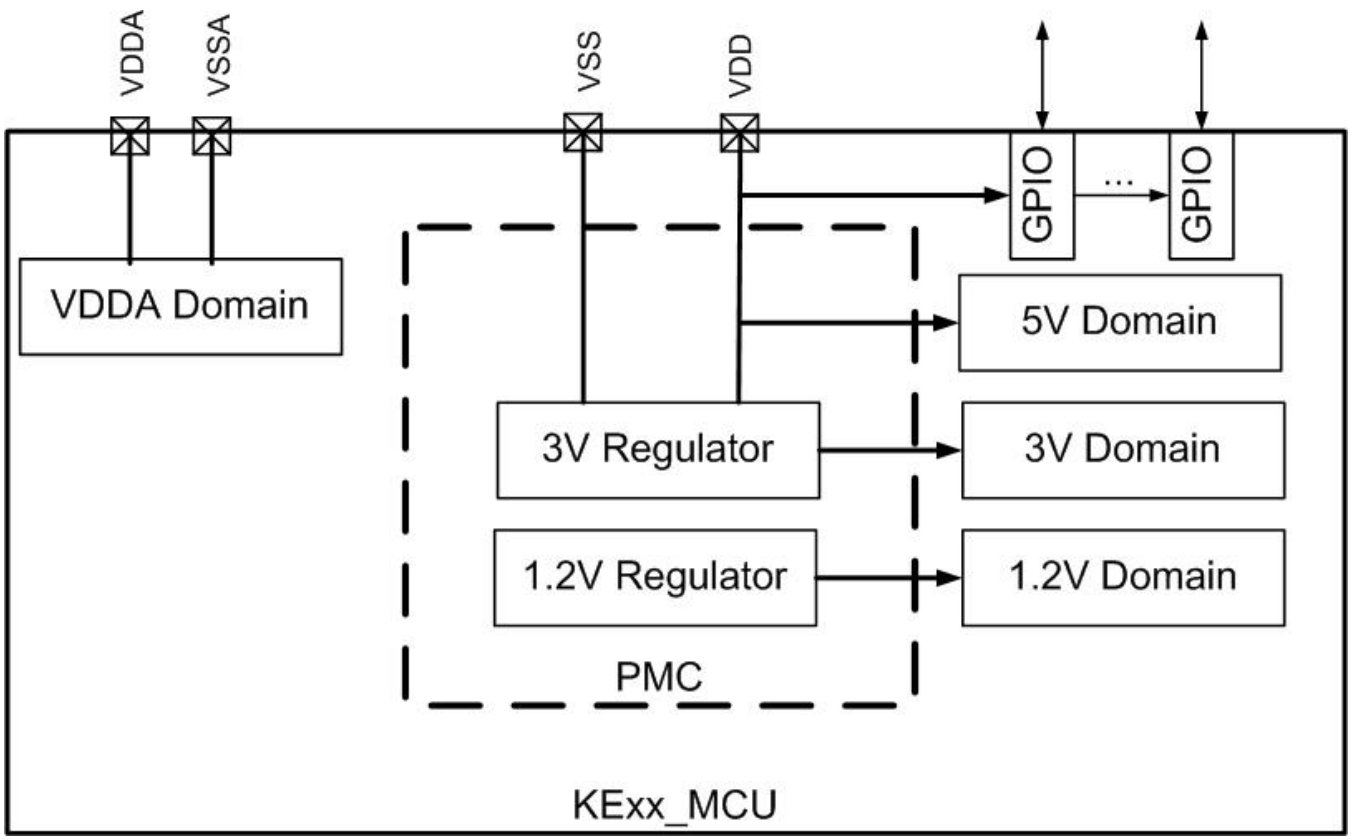


Figure 19-1. Power Infrastructure

19.2 Power Modes Description

The power management controller (PMC) provides multiple power options to allow the user to optimize power consumption for the level of functionality needed.

Depending on the stop requirements of the user application, a variety of stop modes are available that provide state retention, partial power down or full power down of certain logic and/or memory. I/O states are held in all modes of operation. The following table compares the various power modes available.

For Run and VLPR mode there is a corresponding wait and stop mode. Wait modes are similar to ARM sleep modes. Stop modes (VLPS, STOP) are similar to ARM sleep deep mode. The Very Low Power Run (VLPR) operating mode can drastically reduce runtime power when the maximum bus frequency is not required to handle the application needs.

The three primary modes of operation are Run, Wait and Stop. The WFI instruction invokes both wait and stop modes for the chip. The primary modes are augmented in a number of ways to provide lower power based on application needs.

Table 19-1. Chip power modes

Chip mode	Description	Core mode	Normal recovery method
Normal Run	Allows maximum performance of chip. Default mode out of reset; on-chip voltage regulator is on.	Run	-
Normal Wait - via WFI	Allows peripherals to function while the core is in sleep mode, reducing power. NVIC remains sensitive to interrupts; peripherals continue to be clocked.	Sleep	Interrupt
Normal Stop - via WFI	Places chip in static state. On-chip voltage regulator is in a low power mode. LVD is off while maintaining LVR and POR protection. NVIC is disabled; AWIC is used to wake up from interrupt; Peripheral clocks are stopped. All SRAM is operating (content retained and I/O state held). ADC and CMP are optional on.	Sleep Deep	Interrupt
VLPR (Very Low Power Run)	On-chip voltage regulator is in a low power mode that supplies only enough power to run the chip at a reduced frequency. Reduced frequency Flash access mode (); LVD off; internal oscillator provides a low power MHz source for the core, the bus and the peripheral clocks.	Run	-
VLPW (Very Low Power Wait) -via WFI	Same as VLPR but with the core in sleep mode to further reduce power; NVIC remains sensitive to interrupts (FCLK = ON). On-chip voltage regulator is in a low power mode that supplies only enough power to run the chip at a reduced frequency.	Sleep	Interrupt
VLPS (Very Low Power Stop)-via WFI	Same as Stop mode, but PMC_REGSC register provides options to gate off unused modules and further reduce power in low power mode.	Sleep Deep	Interrupt

19.2.1 Run mode

Run mode is the default mode after reset, and refers to any mode in which CPU execution is possible. Depending on the on-chip regulator settings, Run mode has the following configurations:

- Normal RUN mode — The on-chip regulator voltage output is normal. The 1.2V domain is powered by 1.2V. This allows the MCU digital modules to operate at a normal frequency.
- Very Low Power RUN mode — The on-chip regulator voltage is in Low Power mode. The MCU digital modules should operate at a limited frequency but with much lower power.

Run mode configurations can be selected by configuring SMC_PMCTRL.

The following sections describe optimizing power in Run modes.

19.2.1.1 Clock Gating

To conserve power, the clocks to most modules can be turned off using CGC bit of the peripheral control registers in the PCC module. These bits are cleared after any reset, which disables the clock to the corresponding module. Prior to initializing a module, set the corresponding bit in the PCC peripheral control register to enable the clock. Before turning off the clock, make sure to disable the module. For more details, refer to the clock distribution and PCC chapters.

19.2.1.2 Compute Operation

Compute Operation is an execution or compute-only mode of operation that keeps the CPU enabled with full access to the SRAM and Flash read port, but places all other bus masters and bus slaves into their stop mode. Compute Operation can be enabled in Run mode or VLPR mode.

NOTE

Do not enter any stop mode without first exiting Compute Operation.

Because Compute Operation reuses the stop mode logic (including the staged entry with bus masters disabled before bus slaves), any bus master or bus slave that can remain functional in stop mode also remains functional in Compute Operation, including generation of asynchronous interrupts requests. When enabling Compute Operation in

Run mode, module functionality for bus masters and slaves is the equivalent of STOP mode. When enabling Compute Operation in VLPR mode, module functionality for bus masters and slaves is the equivalent of VLPS mode. SCG, PMC, SRAM and Flash read port are not affected by Compute Operation, although the Flash register interface is disabled.

During Compute Operation, the AIPS peripheral space is disabled and attempted accesses generate bus errors. The private peripheral bus (PPB) remains accessible during Compute Operation, including the MCM, System Control Space (SCS) (for NVIC), and SysTick. Although access to the GPIO registers is supported, the GPIO port data input registers do not return valid data since clocks are disabled to the Port Control and Interrupt modules. By writing to the GPIO port data output registers, it is possible to control those GPIO ports that are configured as output pins.

Compute Operation is controlled by the CPO register in the MCM, which is only accessible to the CPU. Setting or clearing the CPOREQ bit in the MCM initiates entry or exit into Compute Operation. Compute Operation can also be configured to exit automatically on detection of an interrupt, which is required in order to service most interrupts. Only the core system interrupts (exceptions, including NMI and SysTick) and any edge sensitive interrupts can be serviced without exiting Compute Operation.

When entering Compute Operation, the CPOACK status bit indicates when entry has completed. When exiting Compute Operation in Run mode, the CPOACK status bit negates immediately. When exiting Compute Operation in VLPR mode, the exit is delayed to allow the PMC to handle the change in power consumption. This delay means the CPOACK bit is polled to determine when the AIPS peripheral space can be accessed without generating a bus error.

19.2.2 Wait mode

Wait mode refers to a power modes in which the CPU execution is halted. The core clock is gated off. The system clock continues to operate. Bus clocks, if enabled, continue to operate.

Depending on the on-chip regulator settings, Wait mode has the following configurations:

- Normal Wait mode — The on-chip regulator voltage output is normal. The 1.2V domain is powered by 1.2V. This allows the MCU digital modules to operate at a normal frequency.
- Very Low Power Wait mode — The on-chip regulator voltage is in Low Power mode. The MCU digital modules must operate at a limited frequency but with much lower power.

After the CPU executes the WFI/WFE instruction, VLPW mode is entered when MCU is in VLPR mode and Normal Wait mode is entered when MCU is in Normal Run mode. Run mode configurations can be selected by configuring SMC_PMCTRL.

Clock gating can be used to optimize the power in Wait mode. Any interrupt can be used as a wake up source from the Wait mode. See the "Interrupt vector assignments" table in Interrupts chapter for all the available interrupt sources.

19.2.3 Stop mode

Stop mode refers to power modes in which the CPU and most peripherals are static. The SRAM and all registers are retained. The core clock, system clock, and the bus clock are gated off. NVIC is disabled; AWIC is used to wake up from interrupt. In the Stop mode, some peripherals can remain operational with asynchronous clock and can wake up the MCU as needed.

Stop mode configurations can be selected by configuring SMC_PMCTRL.

In Stop mode, the bus clock is gated as core clock and system clock. This device supports a partial Stop mode that permits peripherals to run with the bus clock.

19.2.3.1 Partial Stop

Partial Stop is a clocking option that can be taken instead of entering Stop mode and is configured in the SMC Stop Control Register (SMC_STOPCTRL). The Stop mode is only partially entered, which leaves some additional functionality alive at the expense of higher power consumption. Partial Stop can be entered from either Run mode or VLP Run mode.

When configured for PSTOP2, only the core and system clocks are gated and the bus clock remains active. The bus masters and bus slaves clocked by the system clock enter Stop mode, but the bus slaves clocked by bus clock remain in Run (or VLP Run) mode. The clock generators in the SCG and the on-chip regulator in the PMC also remain in Run (or VLP Run) mode. Exit from PSTOP2 can be initiated by a reset, an asynchronous interrupt from a bus master or bus slave clocked by the system clock, or a synchronous interrupt from a bus slave clocked by the bus clock.

PSTOP2 is functionally similar to WAIT mode, but offers additional power savings through the gating of the System clock. All the bus masters are disabled.

Any AWIC interrupt can be used as a wake up source from Stop (normal Stop and VLPS) mode. See Table 19-4 for all the available wake up source.

19.2.4 Power domains

The following table describe the power domain of this device.

Table 19-2. Power domain summary

Domain name	Description
5V	5V domain is powered by VDD/VSS directly. It contains GPIO and PMC.
VDDA	Analog domain is powered by VDDA/VSSA. It contains analog modules such as ADC and CMP.
3V	3V domain is powered by the PMC 3V regulator. It contains TSI, OSC, and Flash memory.
1.2V	1.2V domain is powered by the PMC 1.2V regulator. It contains all digital logics and SRAM.

19.2.5 Entering and exiting power modes

The WFI instruction invokes wait and stop modes for the chip. The processor exits the low-power mode via an interrupt. The "Interrupt vector assignments" table in the Interrupts chapter describes interrupt operation and what peripherals can cause interrupts.

NOTE

The WFE instruction can have the side effect of entering a low-power mode, but that is not its intended usage. See ARM documentation for more on the WFE instruction.

19.3 Power mode transitions

The following figure shows the power mode transitions. Any reset always brings the chip back to the normal run state. In run, wait, and stop modes active power regulation is enabled. The VLPx modes offer a lower power operating mode than normal modes. VLPR and VLPW are limited in frequency.

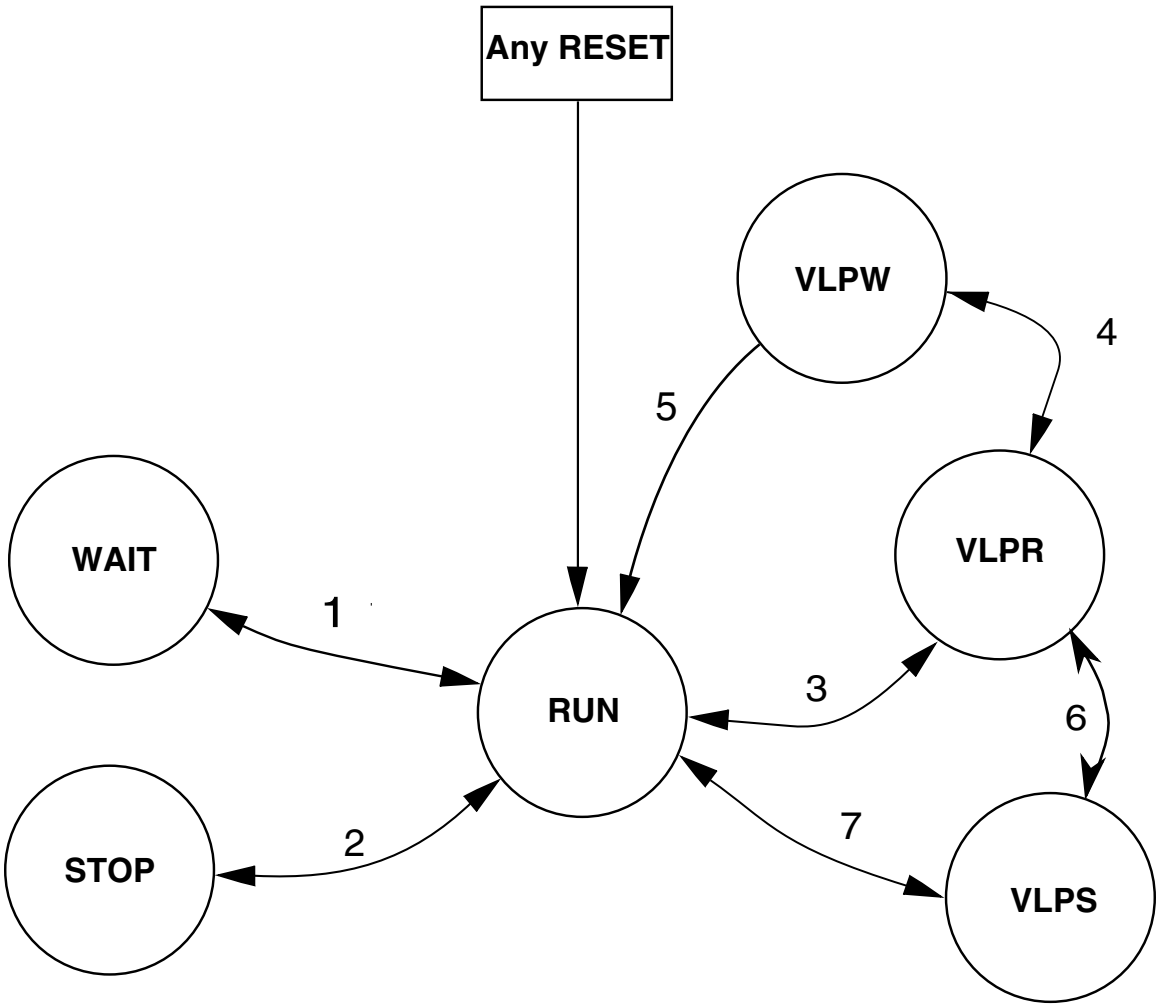


Figure 19-2. Power mode state transition diagram

NOTE

See Table 20-2 in the SMC chapter for more detailed mode transition conditions.

19.4 Power modes shutdown sequencing

When entering stop or other low-power modes, the clocks are shut off in an orderly sequence to safely place the chip in the targeted low-power state. All low-power entry sequences are initiated by the core executing an WFI instruction. The ARM core's outputs, SLEEPDEEP and SLEEPING, trigger entry to the various low-power modes:

- System level wait and VLPW modes equate to: SLEEPING & $\overline{\text{SLEEPDEEP}}$
- All other low power modes equate to: SLEEPING & SLEEPDEEP

When entering the non-wait modes, the chip performs the following sequence:

- Shuts off Core Clock and System Clock to the ARM Cortex-M core immediately.
- Polls stop acknowledge indications from the supporting peripherals (SPI, PIT) and the Flash Controller for indications that System Clocks, Bus Clock and/or Flash Clock need to be left enabled to complete a previously initiated operation, effectively stalling entry to the targeted low power mode. When all acknowledges are detected, System Clock, Bus Clock and Flash Clock are turned off at the same time.
- SCG and Mode Controller shut off clock sources and/or the internal supplies driven from the on-chip regulator as defined for the targeted low power mode.

In wait modes, most of the system clocks are not affected by the low power mode entry. The Core Clock to the ARM Cortex-M core is shut off. Some modules support stop-in-wait functionality and have their clocks disabled under these configurations.

The debugger modules support a transition from stop, wait, VLPS, and VLPW back to a halted state when the debugger is enabled. This transition is initiated by setting the Debug Request bit in MDM-AP control register. As part of this transition, system clocking is re-established and is equivalent to normal run/VLPR mode clocking configuration.

19.5 Module Operation in Low Power Modes

The following table illustrates the functionality of each module while the chip is in each of the low power modes. The standard behavior is shown with some exceptions for Compute Operation (CPO) and Partial Stop2 (PSTOP2).

(Debug modules are discussed separately; see Debug in Low Power Modes.) Number ratings (such as 2 MHz and 1 Mbit/s) represent the maximum frequencies or maximum data rates per mode. Also, these terms are used:

- FF = Full functionality. In VLPR and VLPW the system frequency is limited, but if a module does not have a limitation in its functionality, it is still listed as FF.
- Async operation = Fully functional with alternate clock source, provided the selected clock source remains enabled
- static = Module register states and associated memories are retained.
- powered = Memory is powered to retain contents.
- low power = Memory is powered to retain contents in a lower power state
- OFF = Modules are powered off; module is in reset state upon wakeup. For clocks, OFF means disabled.
- wakeup = Modules can serve as a wakeup source for the chip.

Table 19-3. Module operation in low power modes

Modules	VLPR	VLPW	Stop	VLPS
Core modules				

Table continues on the next page...

Table 19-3. Module operation in low power modes (continued)

Modules	VLPR	VLPW	Stop	VLPS
NVIC	FF	FF	static	static
System modules				
System Mode Controller	FF	FF	FF	FF
Regulator	low power	low power	low power	low power
LVD/LVR	disabled (LVR active only)	disabled (LVR active only)	disabled (LVR active only)	disabled (LVR active only)
POR (Brown-out Detection)	FF	FF	FF	FF
Watchdog	FF	FF	FF	FF
EWM	FF static in CPO	static	static FF in PSTOP2	static
Clocks				
128 kHz LPO	FF	FF	FF	FF
System oscillator (OSC)	SOSC_CLK max of 16 MHz crystal	SOSC_CLK max of 16 MHz crystal	SOSC_CLK optional	SOSC_CLK max of 16 MHz crystal
SCG	SOSC, SIRC optional ON	SOSC, SIRC optional ON	SOSC, SIRC, FIRC optional ON	SOSC, SIRC optional ON
Core clock	4 MHz max	OFF	OFF	OFF
Platform clock	4 MHz max	4 MHz max	OFF	OFF
System clock	4 MHz max OFF in CPO	4 MHz max	OFF	OFF
Bus clock	4 MHz max OFF in CPO	4 MHz max	OFF FF in PSTOP2	OFF
Memory and memory interfaces				
Flash	1 MHz max access - no program/erase No register access in CPO	low power	low power	low power
System RAM (SRAM_U and SRAM_L)	low power [1]	low power	low power	low power
Communication interfaces				
LPUART	FF Async operation in CPO	FF	Async operation FF in PSTOP2	Async operation
LPSPI	FF Async operation in CPO	FF	Async operation FF in PSTOP2	Async operation
LPI^{2}C	FF Async operation in CPO	FF	Async operation FF in PSTOP2	Async operation
CAN	FF wakeup in CPO	FF	wakeup FF in PSTOP2	wakeup
Security				

Table continues on the next page...

Table 19-3. Module operation in low power modes (continued)

Modules	VLPR	VLPW	Stop	VLPS
CRC	FF static in CPO	FF	static FF in PSTOP2	static
Timers				
FTM	FF static in CPO	FF	static	static
LPIT	FF static in CPO	FF	Async operation FF in PSTOP2	Async operation
PWT	FF static in CPO	FF	static FF in PSTOP2	static
PDB	FF static in CPO	FF	static	static
LPTMR	FF	FF	Async operation FF in PSTOP2	Async operation
Analog				
12-bit ADC	FF SIRC and SOSC clocks only	FF SIRC and SOSC clocks only	FF	FF SIRC and SOSC clocks only
CMP [2]	LS compare only	LS compare only	LS compare FF in PSTOP2	LS compare only
Human-machine interfaces				
GPIO	FF IOPORT write only in CPO	FF	static output, wakeup input FF in PSTOP2	static output, wakeup input
TSI	FF Async operation in CPO	FF	Async operation FF in PSTOP2	Async operation

1. SRAM is writable and readable in VLPR mode.
2. CMP in stop or VLPS supports low speed external pin to pin or external pin to DAC compares. Windowed, sampled & filtered modes of operation are not available while in stop or VLPS modes.

19.5.1 Peripheral doze

Several peripherals support a Peripheral Doze mode, where a register bit can be used to disable the peripheral for the duration of a low-power mode. The flash memory can also be placed in a low-power state during Peripheral Doze via a register bit in the SIM.

Peripheral Doze is defined to include all of the modes of operation listed below.

- The CPU is in Wait mode.
- The CPU is in Stop mode, including the entry sequence.
- The CPU is in Compute Operation, including the entry sequence.

Peripheral Doze can therefore be used to disable selected bus masters or slaves for the duration of WAIT or VLPW mode. It can also be used to disable selected bus slaves immediately on entry into any stop mode (or Compute Operation), instead of waiting for the bus masters to acknowledge the entry as part of the stop entry sequence.

If the flash memory is not being accessed during WAIT and PSTOP modes, then the Flash Doze mode can be used to reduce power consumption, at the expense of a slightly longer wake-up when executing code and vectors from flash. It can also be used to reduce power consumption during Compute Operation when executing code and vectors from SRAM.

19.6 Low-power wake-up sources

Table 19-4. AWIC Stop and VLPS Wake-up Sources

Wake-up source	Description
Available system resets	RESET pin, WDOG , loss of clock(LOC) reset and loss of lock (LOL) reset
Pin interrupts	Port Control Module - Any enabled pin interrupt is capable of waking the system
ADC	ADC is optional functional with clock source from SIRC or OSC
CMP	Functional in Stop/VLPS modes with clock source from SIRC or OSC
LPI2C	Functional in Stop/VLPS modes with clock source from SIRC or OSC
LPUART	Functional in Stop/VLPS modes with clock source from SIRC or OSC
LPSPI	Functional in Stop/VLPS modes with clock source from SIRC or OSC
LPIT	Functional in Stop/VLPS modes with clock source from SIRC or OSC
LPTMR	Functional in Stop/VLPS modes
RTC	Functional in Stop/VLPS modes
SCG	Functional in Stop mode
RCM	Reset wakeup
CAN	CAN stop wakeup
TSI	Touch sense wakeup
NMI	Non-maskable interrupt

19.7 Power supply supervisor

This device integrates the following power supervisor circuits:

- Power-on reset (POR)
- Low voltage detection (LVD)

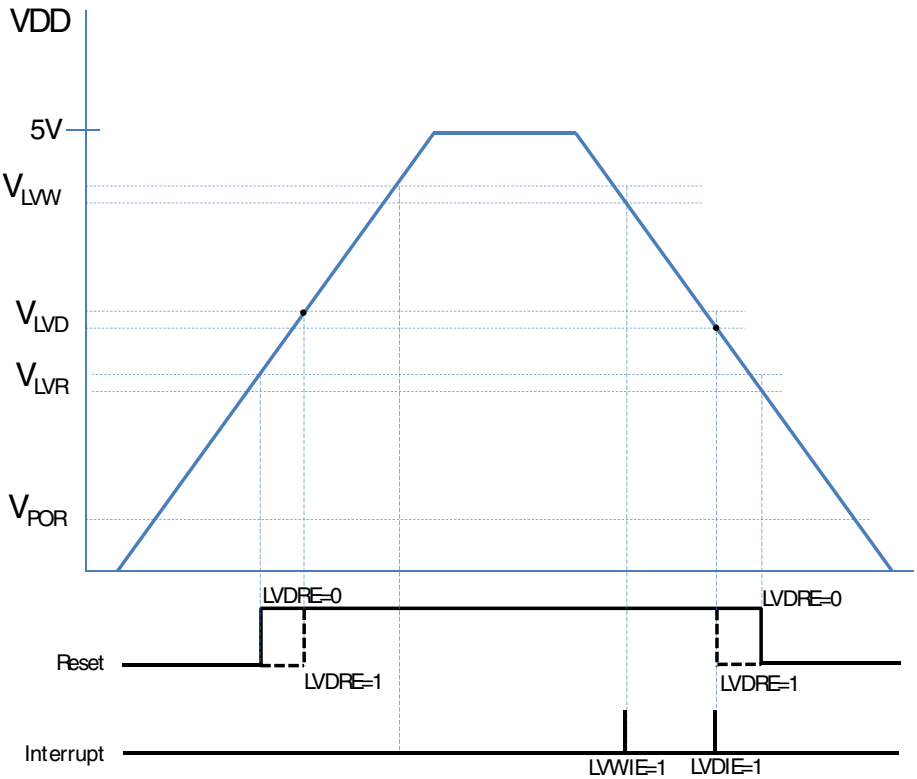


Figure 19-3. Power Supply Supervisor

NOTE

When VDD ramps up above V_{LVR} , the RESET pin is released (indicating MCU quits POR reset state), and it starts to run code immediately.

If LVDRE bit is not operated in code, the LVDRE bit is 0 after POR reset by default, then LVD does not take effect.

If LVDRE bit is configured as 1 in user's code, and the current VDD still below V_{LVD}, then LVD takes effect, and holds MCU in system reset state, keeps the RESET pin low until VDD increases above V_{LVD}.

During power-on, the POR keeps the device under reset until the supply voltage V_{DD} reaches the specified threshold. When V_{DD} is above the threshold, the device reset is released and the system can start.

The LVD circuit can be used to monitor the power supply voltage by comparing it to a configurable threshold. User can choose to generate LVD reset or LVW interrupt when power supply voltage drops below the threshold. See PMC chapters for details.

For more details on the POR/LVD reset and the LVW interrupt thresholds, see the electrical characteristics (LVR, LVD and POR) section in the Data Sheet.

Chapter 20
System Mode Controller (SMC)

20.1 Introduction

The System Mode Controller (SMC) is responsible for sequencing the system into and out of all low-power Stop and Run modes.

Specifically, it monitors events to trigger transitions between power modes while controlling the power, clocks, and memories of the system to achieve the power consumption and functionality of that mode.

This chapter describes all the available low-power modes, the sequence followed to enter/exit each mode, and the functionality available while in each of the modes.

The SMC is able to function during even the deepest low power modes.

See AN4503: Power Management for Kinetis MCUs for further details on using the SMC.

20.2 Modes of operation

The Arm CPU has three primary modes of operation:

- Run
- Sleep
- Deep Sleep

The WFI or WFE instruction is used to invoke Sleep and Deep Sleep modes. Run, Wait, and Stop are the common terms used for the primary operating modes of Kinetis microcontrollers.

The following table shows the translation between the Arm CPU modes and the Kinetis MCU power modes.

Arm CPU mode	MCU mode
Sleep	Wait
Deep Sleep	Stop

Accordingly, the Arm CPU documentation refers to sleep and deep sleep, while the Kinetis MCU documentation normally uses wait and stop.

In addition, Kinetis MCUs also augment Stop, Wait, and Run modes in a number of ways. The power management controller (PMC) contains a run and a stop mode regulator. Run regulation is used in normal run, wait and stop modes. Stop mode regulation is used during all very low power and low leakage modes. During stop mode regulation, the bus frequencies are limited in the very low power modes.

The SMC provides the user with multiple power options. The Very Low Power Run (VLPR) mode can drastically reduce run time power when maximum bus frequency is not required to handle the application needs. From Normal Run mode, the Run Mode (RUNM) field can be modified to change the MCU into VLPR mode when limited frequency is sufficient for the application. From VLPR mode, a corresponding wait (VLPW) and stop (VLPS) mode can be entered.

Depending on the needs of the user application, a variety of stop modes are available that allow the state retention, partial power down or full power down of certain logic and/or memory. I/O states are held in all modes of operation. Several registers are used to configure the various modes of operation for the device.

The following table describes the power modes available for the device.

Table 20-1. Power modes

Mode	Description
RUN	The MCU can be run at full speed and the internal supply is fully regulated, that is, in run regulation. This mode is also referred to as Normal Run mode.
WAIT	The core clock is gated off. The system clock continues to operate. Bus clocks, if enabled, continue to operate. Run regulation is maintained.
STOP	The core clock is gated off. System clocks to other masters and bus clocks are gated off after all stop acknowledge signals from supporting peripherals are valid.
VLPR	The core, system, bus, and flash clock maximum frequencies are restricted in this mode. See the Power Management chapter for details about the maximum allowable frequencies.
VLPW	The core clock is gated off. The system, bus, and flash clocks continue to operate, although their maximum frequency is restricted. See the Power Management chapter for details on the maximum allowable frequencies.
VLPS	The core clock is gated off. System clocks to other masters and bus clocks are gated off after all stop acknowledge signals from supporting peripherals are valid.

20.3 Memory map and register descriptions

Information about the registers related to the system mode controller can be found here.

Different SMC registers reset on different reset types. Each register's description provides details. For more information about the types of reset on this chip, refer to the Reset section details.

NOTE

The SMC registers can be written only in supervisor mode. Write accesses in user mode are blocked and will result in a bus error.

NOTE

Before executing the WFI instruction, the last register written to must be read back. This ensures that all register writes associated with setting up the low power mode being entered have completed before the MCU enters the low power mode. Failure to do this may result in the low power mode not being entered correctly.

SMC memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4007_E000	SMC Version ID Register (SMC_VERID)	32	R	0100_0000h	20.3.1/321
4007_E004	SMC Parameter Register (SMC_PARAM)	32	R	See section	20.3.2/322
4007_E008	Power Mode Protection register (SMC_PMPROT)	32	R/W	0000_0000h	20.3.3/323
4007_E00C	Power Mode Control register (SMC_PMCTRL)	32	R/W	0000_0000h	20.3.4/325
4007_E010	Stop Control Register (SMC_STOPCTRL)	32	R/W	0000_0003h	20.3.5/326
4007_E014	Power Mode Status register (SMC_PMSTAT)	32	R	0000_0001h	20.3.6/328

20.3.1 SMC Version ID Register (SMC_VERID)

Address: 4007_E000h base + 0h offset = 4007_E000h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MAJOR								MINOR								FEATURE															
W																																
Reset	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	0	0	0	0	0	0	0

SMC_VERID field descriptions

Field	Description
31–24 MAJOR	Major Version Number This read only field returns the major version number for the module specification.
23–16 MINOR	Minor Version Number This read only field returns the minor version number for the module specification.
FEATURE	Feature Specification Number This read only field returns the feature set number. 0x0000 Standard features implemented

20.3.2 SMC Parameter Register (SMC_PARAM)

Address: 4007_E000h base + 4h offset = 4007_E004h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								0	EVLLS0	ELLS2	0	ELLS	0		EHSRUN
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SMC_PARAM field descriptions

Field	Description
31–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
6 EVLLS0	Existence of VLLS0 feature This static bit states whether or not the feature is available on the device. 0 The feature is not available. 1 The feature is available.
5 ELLS2	Existence of LLS2 feature This static bit states whether or not the feature is available on the device. 0 The feature is not available. 1 The feature is available.
4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 ELLS	Existence of LLS feature This static bit states whether or not the feature is available on the device. 0 The feature is not available. 1 The feature is available.
2–1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 EHSRUN	Existence of HSRUN feature This static bit states whether or not the feature is available on the device. 0 The feature is not available. 1 The feature is available.

20.3.3 Power Mode Protection register (SMC_PMPROT)

This register provides protection for entry into any low-power run or stop mode. The enabling of the low-power run or stop mode occurs by configuring the Power Mode Control register (PMCTRL).

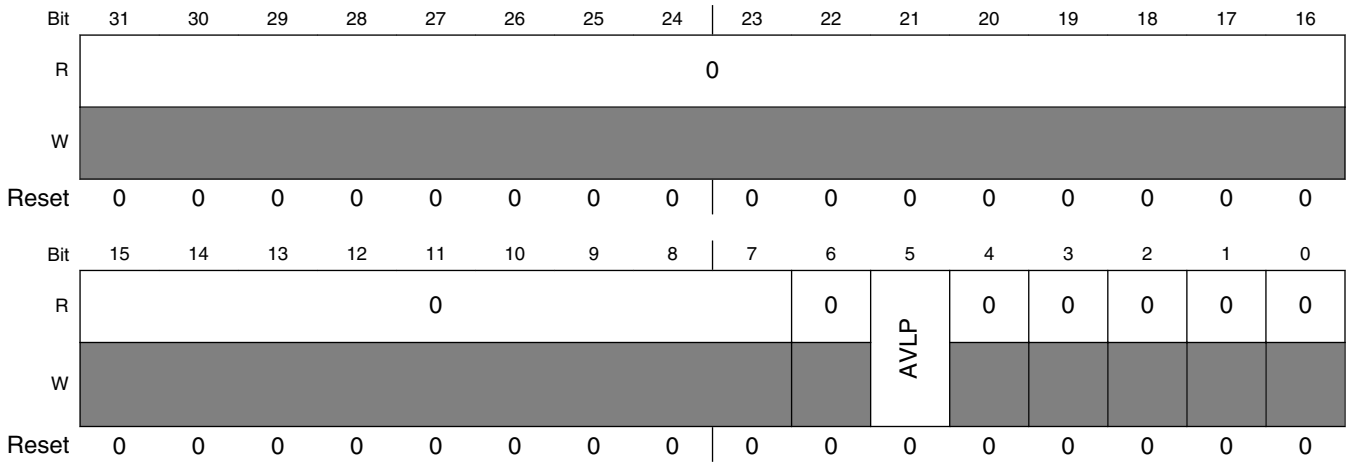
The PMPROT register can be written only once after any system reset.

If the MCU is configured for a disallowed or reserved power mode, the MCU remains in its current power mode. For example, if the MCU is in normal RUN mode and AVLP is 0, an attempt to enter VLPR mode using PMCTRL[RUNM] is blocked and PMCTRL[RUNM] remains 00b, indicating the MCU is still in Normal Run mode.

NOTE

This register is reset on Chip Reset and by reset types that trigger Chip Reset. It is unaffected by reset types that do not trigger Chip Reset. See the Reset section details for more information.

Address: 4007_E000h base + 8h offset = 4007_E008h



SMC_PMPROT field descriptions

Field	Description
31–7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
5 AVLP	Allow Very-Low-Power Modes Provided the appropriate control bits are set up in PMCTRL, this write-once field allows the MCU to enter any very-low-power mode (VLPR, VLPW, and VLPS). 0 VLPR, VLPW, and VLPS are not allowed. 1 VLPR, VLPW, and VLPS are allowed.
4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

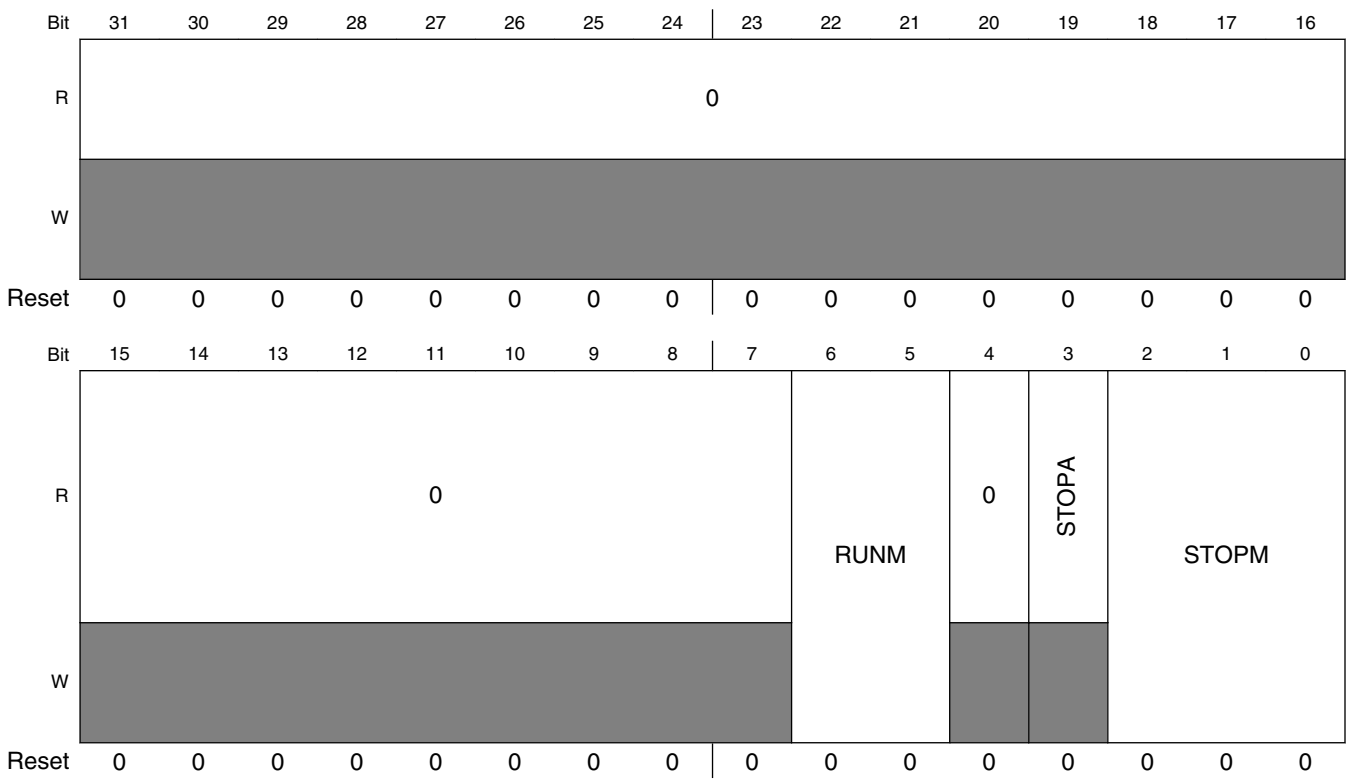
20.3.4 Power Mode Control register (SMC_PMCTRL)

The PMCTRL register controls entry into low-power Run and Stop modes, provided that the selected power mode is allowed via an appropriate setting of the protection (PMPROT) register.

NOTE

This register is reset on Chip POR and by reset types that trigger Chip POR. It is unaffected by reset types that do not trigger Chip POR. See the Reset section details for more information.

Address: 4007_E000h base + Ch offset = 4007_E00Ch



SMC_PMCTRL field descriptions

Field	Description
31–7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
6–5 RUNM	Run Mode Control When written, causes entry into the selected run mode. Writes to this field are blocked if the protection level has not been enabled using the PMPROT register.

Table continues on the next page...

SMC_PMCTRL field descriptions (continued)

Field	Description
	NOTE: RUNM may be set to VLPR only when PMSTAT=RUN. After being written to VLPR, RUNM should not be written back to RUN until PMSTAT=VLPR. 00 Normal Run mode (RUN) 01 Reserved 10 Very-Low-Power Run mode (VLPR) 11 Reserved
4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 STOPA	Stop Aborted When set, this read-only status bit indicates an interrupt occured during the previous stop mode entry sequence, preventing the system from entering that mode. This field is cleared by reset or by hardware at the beginning of any stop mode entry sequence and is set if the sequence was aborted. 0 The previous stop mode entry was successful. 1 The previous stop mode entry was aborted.
STOPM	Stop Mode Control When written, controls entry into the selected stop mode when Sleep-Now or Sleep-On-Exit mode is entered with SLEEPDEEP=1 . Writes to this field are blocked if the protection level has not been enabled using the PMPROT register. After any system reset, this field is cleared by hardware on any successful write to the PMPROT register. **NOTE:** When set to STOP, the PSTOPO bits in the STOPCTRL register can be used to select a Partial Stop mode if desired. 000 Normal Stop (STOP) 001 Reserved 010 Very-Low-Power Stop (VLPS) 011 Reserved 101 Reserved 110 Reseved 111 Reserved

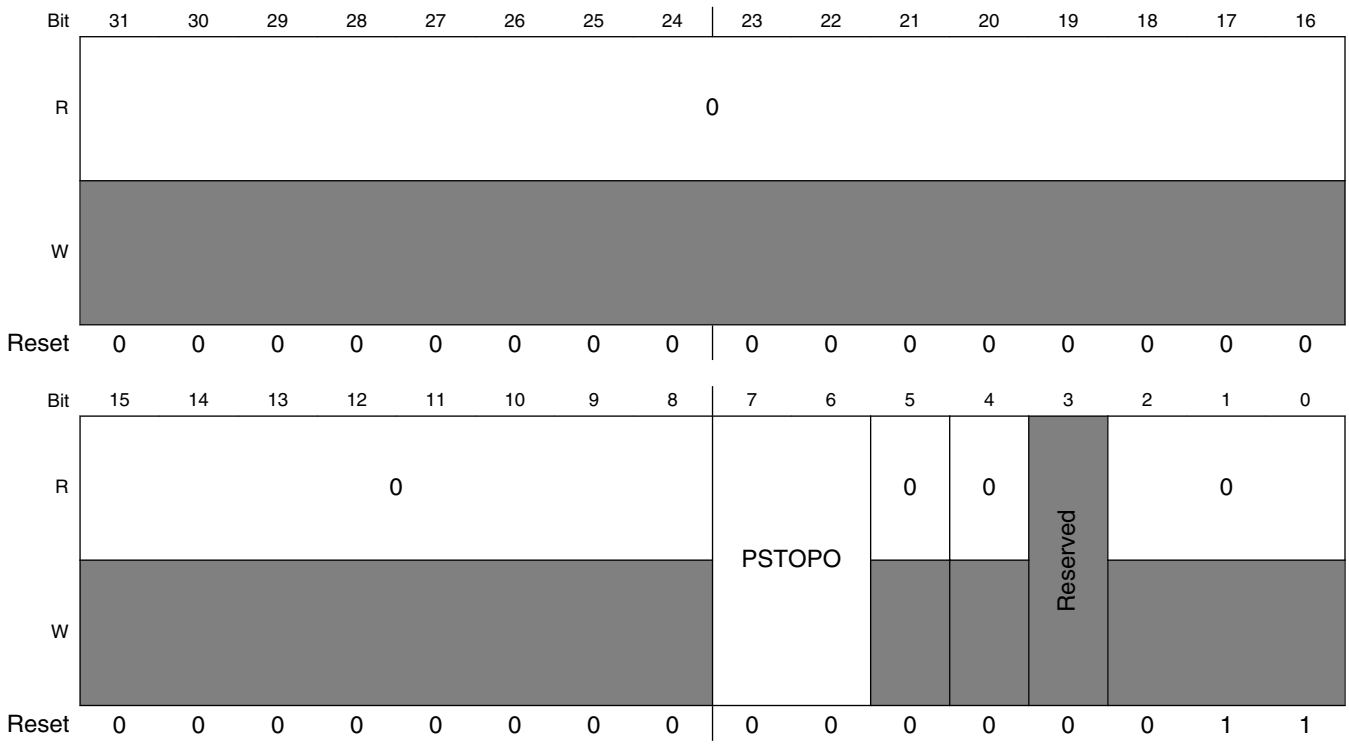
20.3.5 Stop Control Register (SMC_STOPCTRL)

The STOPCTRL register provides various control bits allowing the user to fine tune power consumption during the stop mode selected by the STOPM field.

NOTE

This register is reset on Chip POR and by reset types that trigger Chip POR. It is unaffected by reset types that do not trigger Chip POR. See the Reset section details for more information.

Address: 4007_E000h base + 10h offset = 4007_E010h



SMC_STOPCTRL field descriptions

Field	Description
31–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7–6 PSTOPO	Partial Stop Option These bits control whether a Partial Stop mode is entered when STOPM=STOP. When entering a Partial Stop mode from RUN mode, the PMC, SCG and flash remain fully powered, allowing the device to wakeup almost instantaneously at the expense of higher power consumption. In PSTOP2, only system clocks are gated allowing peripherals running on bus clock to remain fully functional. In PSTOP1, both system and bus clocks are gated. 00 STOP - Normal Stop mode 01 PSTOP1 - Partial Stop with both system and bus clocks disabled 10 PSTOP2 - Partial Stop with system clock disabled and bus clock enabled 11 Reserved
5 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 Reserved	This field is reserved. This bit is reserved for future expansion. Software should write 0 to this bit to maintain compatibility.
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

20.3.6 Power Mode Status register (SMC_PMSTAT)

PMSTAT is a read-only, one-hot register which indicates the current power mode of the system.

NOTE

This register is reset on Chip POR and by reset types that trigger Chip POR. It is unaffected by reset types that do not trigger Chip POR. See the Reset section details for more information.

Address: 4007_E000h base + 14h offset = 4007_E014h

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

SMC_PMSTAT field descriptions

Field	Description
31–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
PMSTAT	Power Mode Status **NOTE:** When debug is enabled, the PMSTAT will not update to STOP or VLPS **NOTE:** When a PSTOP mode is enabled, the PMSTAT will not update to STOP or VLPS 0000_0001 Current power mode is RUN. 0000_0010 Current power mode is STOP. 0000_0100 Current power mode is VLPR. 0000_1000 Current power mode is VLPW. 0001_0000 Current power mode is VLPS. 0010_0000 Reserved 0100_0000 Reserved 1000_0000 Reserved

20.4 Functional description

20.4.1 Power mode transitions

The following figure shows the power mode state transitions available on the chip. Any reset always brings the MCU back to the normal RUN state.

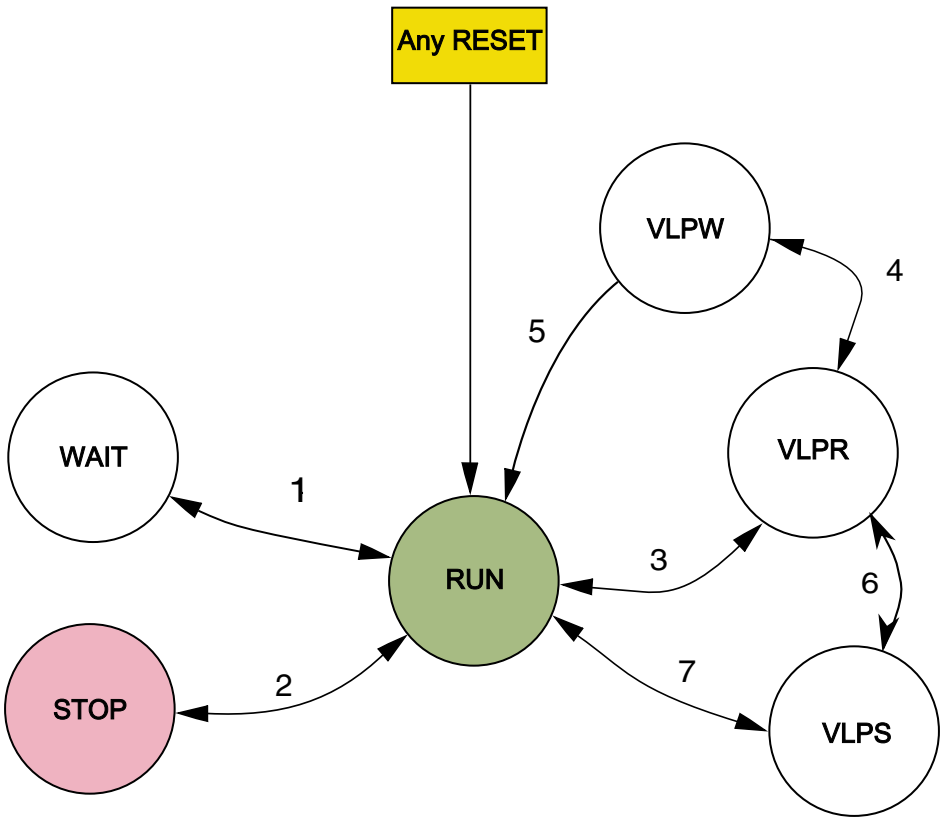


Figure 20-1. Power mode state diagram

The following table defines triggers for the various state transitions shown in the previous figure.

Table 20-2. Power mode transition triggers

Transition #	From	To	Trigger conditions
1	RUN	WAIT	Sleep-now or sleep-on-exit modes entered with SLEEPDEEP clear, controlled in System Control Register in Arm core. See note.[1]
	WAIT	RUN	Interrupt or Reset
2	RUN	STOP	PMCTRL[RUNM]=00, PMCTRL[STOPM]=000[2] Sleep-now or sleep-on-exit modes entered with SLEEPDEEP set, which is controlled in System Control Register in Arm core.

Table continues on the next page...

Table 20-2. Power mode transition triggers (continued)

Transition #	From	To	Trigger conditions
			See note.[1]
	STOP	RUN	Interrupt or Reset
3	RUN	VLPR	The core, system, bus and flash clock frequencies and SCG clocking mode are restricted in this mode. See the Power Management chapter for the maximum allowable frequencies and SCG modes supported. Set PMPROT[AVLP]=1, PMCTRL[RUNM]=10.
	VLPR	RUN	Set PMCTRL[RUNM]=00 or Reset.
4	VLPR	VLPW	Sleep-now or sleep-on-exit modes entered with SLEEPDEEP clear, which is controlled in System Control Register in Arm core. See note.[1]
	VLPW	VLPR	Interrupt
5	VLPW	RUN	Reset
6	VLPR	VLPS	PMCTRL[STOPM]=000[3] or 010, Sleep-now or sleep-on-exit modes entered with SLEEPDEEP set, which is controlled in System Control Register in Arm core. See note.[1]
	VLPS	VLPR	Interrupt **NOTE:** If VLPS was entered directly from RUN (transition #7), hardware forces exit back to RUN and does not allow a transition to VLPR.
7	RUN	VLPS	PMPROT[AVLP]=1, PMCTRL[STOPM]=010, Sleep-now or sleep-on-exit modes entered with SLEEPDEEP set, which is controlled in System Control Register in Arm core. See note.[1]
	VLPS	RUN	Interrupt and VLPS mode was entered directly from RUN or Reset

1. If debug is enabled, the core clock remains to support debug.
2. If PMCTRL[STOPM]=000 and STOPCTRL[PSTOPO]=01 or 10, then only a Partial Stop mode is entered instead of STOP
3. If PMCTRL[STOPM]=000 and STOPCTRL[PSTOPO]=00, then VLPS mode is entered instead of STOP. If PMCTRL[STOPM]=000 and STOPCTRL[PSTOPO]=01 or 10, then only a Partial Stop mode is entered instead of VLPS

20.4.2 Power mode entry/exit sequencing

When entering or exiting low-power modes, the system must conform to an orderly sequence to manage transitions safely.

The SMC manages the system's entry into and exit from all power modes. This diagram illustrates the connections of the SMC with other system components in the chip that are necessary to sequence the system through all power modes.

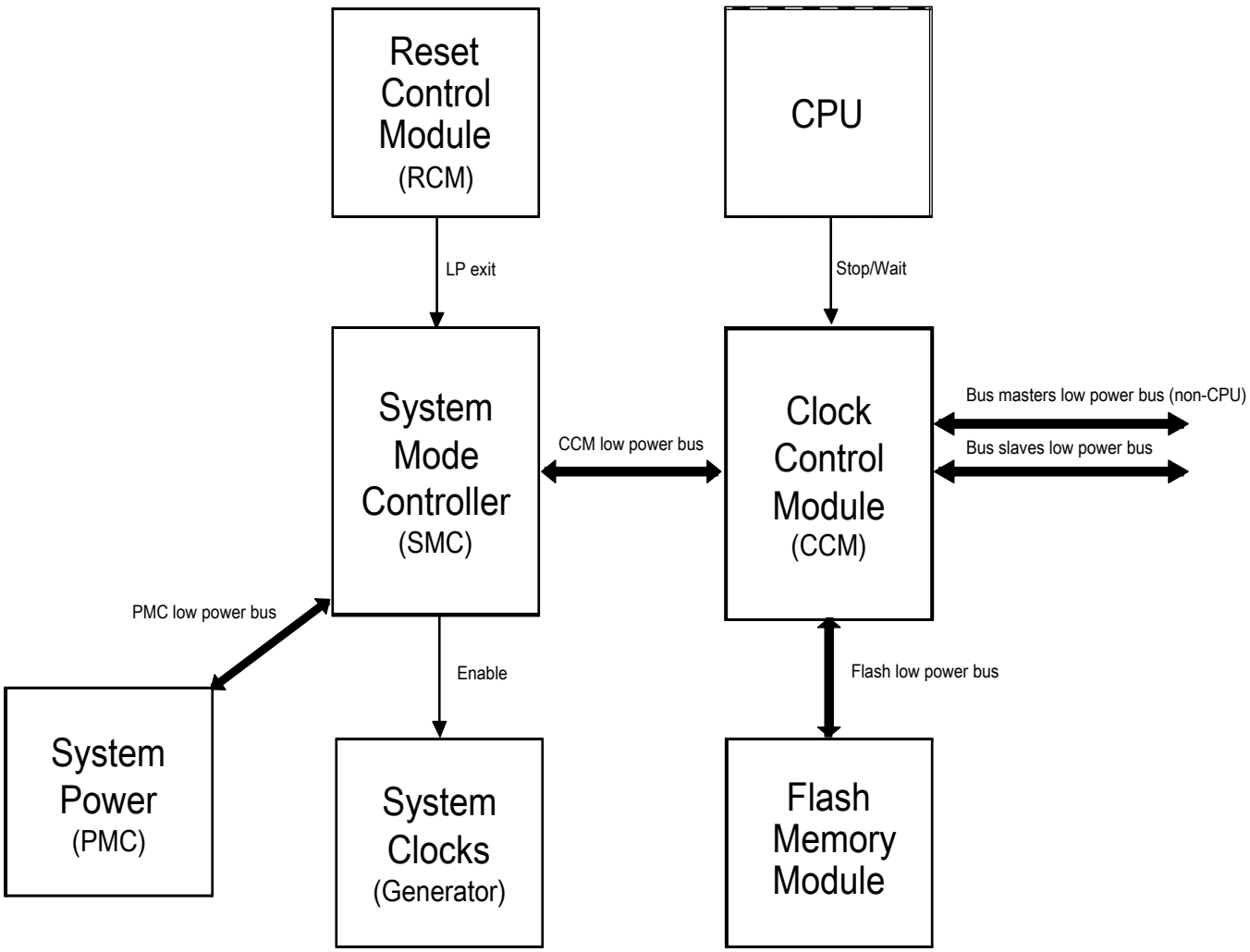


Figure 20-2. Low-power system components and connections

20.4.2.1 Stop mode entry sequence

Entry into a low-power stop mode (Stop, VLPS) is initiated by a CPU executing the WFI instruction. After the instruction is executed, the following sequence occurs:

1. The CPU clock is gated off immediately.
2. Requests are made to all non-CPU bus masters to enter Stop mode.
3. After all masters have acknowledged they are ready to enter Stop mode, requests are made to all bus slaves to enter Stop mode.
4. After all slaves have acknowledged they are ready to enter Stop mode, all system and bus clocks are gated off.

5. Clock generators are disabled in the SCG unless configured to be enabled in Stop mode. See the SCG module information for the programming options.
6. The on-chip regulator in the PMC and internal power switches are configured to meet the power consumption goals for the targeted low-power mode.

20.4.2.2 Stop mode exit sequence

Exit from a low-power stop mode is initiated either by a reset or an interrupt event. The following sequence then executes to restore the system to a run mode (RUN or VLPR):

1. The on-chip regulator in the PMC and internal power switches are restored.
2. Clock generators are enabled in the SCG.
3. System and bus clocks are enabled to all masters and slaves.
4. The CPU clock is enabled and the CPU begins servicing the reset or interrupt that initiated the exit from the low-power stop mode.

20.4.2.3 Aborted stop mode entry

If an interrupt occurs during a stop entry sequence, the SMC can abort the transition early and return to RUN mode without completely entering the stop mode. An aborted entry is possible only if the interrupt occurs before the PMC begins the transition to stop mode regulation. After this point, the interrupt is ignored until the PMC has completed its transition to stop mode regulation. When an aborted stop mode entry sequence occurs, SMC_PMCTRL[STOPA] is set to 1.

20.4.2.4 Transition to wait modes

For wait modes (WAIT and VLPW), the CPU clock is gated off while all other clocking continues, as in RUN and VLPR mode operation. Some modules that support stop-in-wait functionality have their clocks disabled in these configurations.

20.4.2.5 Transition from stop modes to Debug mode

The debugger module supports a transition from STOP, WAIT, VLPS, and VLPW back to a Halted state when the debugger has been enabled. As part of this transition, system clocking is re-established and is equivalent to the normal RUN and VLPR mode clocking configuration.

20.4.3 Run modes

The run modes supported by this device can be found here.

- Run (RUN)
- Very Low-Power Run (VLPR)

20.4.3.1 RUN mode

This is the normal operating mode for the device.

This mode is selected after any reset. When the Arm processor exits reset, it sets up the stack, program counter (PC), and link register (LR):

- The processor reads the start SP (SP_main) from vector-table offset 0x000
- The processor reads the start PC from vector-table offset 0x004
- LR is set to 0xFFFF_FFFF.

To reduce power in this mode, disable the clocks to unused modules.

20.4.3.2 Very-Low Power Run (VLPR) mode

In VLPR mode, the on-chip voltage regulator is put into a stop mode regulation state. In this state, the regulator is designed to supply enough current to the MCU over a reduced frequency. To further reduce power in this mode, disable the clocks to unused modules using their corresponding clock gating control bits in the PCC's registers.

Before entering this mode, the following conditions must be met:

- All clock monitors in the SCG must be disabled.
- The maximum frequencies of the system, bus, flash, and core are restricted. See the Power Management details about which frequencies are supported.
- Mode protection must be set to allow VLP modes, that is, PMPROT[AVLP] is 1.
- PMCTRL[RUNM] must be set to 10b to enter VLPR.
- Flash programming/erasing is not allowed.

NOTE

Do not increase the clock frequency while in VLPR mode, because the regulator is slow in responding and cannot manage fast load transitions. In addition, do not modify the clock source in the SCG module or any clock divider registers. Module clock enables in the PCC can be set, but not cleared.

To reenter Normal Run mode, clear PMCTRL[RUNM]. PMSTAT is a read-only status register that can be used to determine when the system has completed an exit to RUN mode. When PMSTAT=RUN, the system is in run regulation and the MCU can run at full speed in any clock mode. If a higher execution frequency is desired, poll PMSTAT until it is set to RUN when returning from VLPR mode.

Any reset always causes an exit from VLPR and returns the device to RUN mode after the MCU exits its reset flow.

20.4.4 Wait modes

This device contains two different wait modes which are listed here.

- Wait
- Very-Low Power Wait (VLPW)

20.4.4.1 WAIT mode

WAIT mode is entered when the Arm core enters the Sleep-Now or Sleep-On-Exit modes while SLEEPDEEP is cleared. The Arm CPU enters a low-power state in which it is not clocked, but peripherals continue to be clocked provided they are enabled.

When an interrupt request occurs, the CPU exits WAIT mode and resumes processing in RUN mode, beginning with the stacking operations leading to the interrupt service routine.

A system reset causes an exit from WAIT mode, returning the device to normal RUN mode.

20.4.4.2 Very-Low-Power Wait (VLPW) mode

VLPW mode is entered by entering the Sleep-Now or Sleep-On-Exit mode while SLEEPDEEP is cleared and the device is in VLPR mode.

In VLPW, the on-chip voltage regulator remains in its stop regulation state. In this state, the regulator is designed to supply enough current to the device at a reduced frequency. To further reduce power in this mode, disable the clocks to unused modules.

VLPR mode restrictions also apply to VLPW.

When an interrupt from VLPW occurs, the device returns to VLPR mode to execute the interrupt service routine.

A system reset causes an exit from VLPW mode, returning the device to normal RUN mode.

20.4.5 Stop modes

This device contains a variety of stop modes to meet your application needs.

The stop modes range from:

- a stopped CPU, with all I/O, logic, and memory states retained, and certain asynchronous mode peripherals operating

to:

- a powered down CPU, with only I/O and a small register file retained, very few asynchronous mode peripherals operating, while the remainder of the MCU is powered down.

The choice of stop mode depends upon the user's application, and how power usage and state retention versus functional needs and recovery time may be traded off.

The various stop modes are selected by setting the appropriate fields in PMPROT and PMCTRL. The selected stop mode is entered during the sleep-now or sleep-on-exit entry with the SLEEPDEEP bit set in the System Control Register in the Arm core.

The available stop modes are:

- Normal Stop (STOP)
- Very-Low Power Stop (VLPS)

20.4.5.1 STOP mode

STOP mode is entered via the sleep-now or sleep-on-exit with the SLEEPDEEP bit set in the System Control Register in the Arm core.

The SCG module can be configured to leave the reference clocks running.

A module capable of providing an asynchronous interrupt to the device takes the device out of STOP mode and returns the device to normal RUN mode. Refer to the device's Power Management chapter for peripheral, I/O, and memory operation in STOP mode. When an interrupt request occurs, the CPU exits STOP mode and resumes processing, beginning with the stacking operations leading to the interrupt service routine.

A system reset will cause an exit from STOP mode, returning the device to normal RUN mode via an MCU reset.

20.4.5.2 Very-Low-Power Stop (VLPS) mode

The two ways in which VLPS mode can be entered are listed here.

- Entry into stop via the sleep-now or sleep-on-exit with the SLEEPDEEP bit set in the System Control Register in the Arm core while the MCU is in VLPR mode and PMCTRL[STOPM] = 010 or 000.
- Entry into stop via the sleep-now or sleep-on-exit with the SLEEPDEEP bit set in the System Control Register in the Arm core while the MCU is in normal RUN mode and PMCTRL[STOPM] = 010. When VLPS is entered directly from RUN mode, exit to VLPR is disabled by hardware and the system will always exit back to RUN.

In VLPS, the on-chip voltage regulator remains in its stop regulation state as in VLPR.

A module capable of providing an asynchronous interrupt to the device takes the device out of VLPS and returns the device to VLPR mode.

A system reset will also cause a VLPS exit, returning the device to normal RUN mode.

20.4.6 Debug in low power modes

When the MCU is secure, the device disables/limits debugger operation. When the MCU is unsecure, the Arm debugger can assert two power-up request signals:

- System power up, via SYSPWR in the Debug Port Control/Stat register
- Debug power up, via CDBGPWRUPREQ in the Debug Port Control/Stat register

When asserted while in RUN, WAIT, VLPR, or VLPW the mode controller drives a corresponding acknowledge for each signal, that is, both CDBGPWRUPACK and CSYSPWRUPACK. When both requests are asserted, the mode controller handles attempts to enter STOP and VLPS by entering an emulated stop state. In this emulated stop state:

- the regulator is in run regulation,
- the SCG-generated clock source is enabled,
- all system clocks, except the core clock, are disabled,
- the debug module has access to core registers, and
- access to the on-chip peripherals is blocked.

Chapter 21
Power Management Controller (PMC)

21.1 Chip-specific Information for this Module

NOTE

If needed in some case, PMC_REGSC[CLKBIASDIS] should be set manually before entering STOP or VLPS mode. See CLKBIASDIS for more information. In the bitfield description, "RPM" is an alias of Low Power Mode (LPM).

21.2 Introduction

The PMC contains the internal voltage regulator, power on reset (POR), the low voltage reset (LVR) and the low voltage detect (LVD) systems.

21.3 Features

The PMC features include:

- Internal voltage regulator offering a variety of power modes
- Active POR providing brown-out detect
- Low voltage reset (LVR)
- Low voltage detect supporting two low voltage trip points (V_{LVD} and V_{LVW}) and interrupt
- Low power oscillator (LPO) with a typical frequency of 128 kHz

21.4 Modes of Operation

21.4.1 Full Performance Mode (FPM)

For the following Chip Power Modes, the internal voltage regulator is in full performance mode: HSRUN, RUN, WAIT.

21.4.2 Low Power Mode (LPM)

For the following Chip Power Modes, the internal voltage regulator is in low power mode: STOP, VLPR, VLPW, VLPS.

21.5 Low Voltage Detect (LVD) System

NOTE

The low voltage detect system (Low voltage detect flag, Low voltage warning flag and Low voltage detect reset generation) is disabled in low power mode.

This device includes a system to guard against low voltage conditions. This protects memory contents and controls MCU system states during supply voltage variations. The system is comprised of a power-on reset (POR) circuit, a low voltage reset (LVR) circuit and a low voltage detect (LVD) circuit with two trip points (V_{LVD} and V_{LVW}). The LVD is disabled upon entering low power mode.

Two flags are available to indicate the status of the low voltage detect system:

- The low voltage detect flag (LVDF) operates in a level sensitive manner. The LVDF bit is set when the supply voltage falls below the trip point (V_{LVD}). The LVDF bit is cleared by writing one to the LVDACK bit, but only if the internal supply has returned above the trip point; otherwise, the LVDF bit remains set.
- The low voltage warning flag (LVWF) operates in a level sensitive manner. The LVWF bit is set when the supply voltage falls below the selected monitor trip point (V_{LVW}). The LVWF bit is cleared by writing one to the LVWACK bit, but only if the internal supply has returned above the trip point; otherwise, the LVWF bit remains set.

NOTE

This flag (LVDF/LVWF) gets cleared on reset. The flag is only valid after the device has come out of the reset, at which point the flag will be set accordingly to the voltage level. If supply level is higher than LVD/LVW threshold then this flag stay cleared, else this flag gets set.

21.5.1 Low Voltage Reset (LVR) Operation

If the supply voltage falls below the reset trip point (V_{LVR}), a system reset will be generated.

If PMC_LVDSC1[LVDRE] is set and the supply voltage falls below V_{LVD}, a system reset will be generated.

PMC_LVDSC1[LVDF] will be cleared by system reset, so after recovery PMC_LVDSC1[LVDF] will read zero. Usage of PMC_LVDSC1[LVDF] is intended for LVD interrupt opteration only (for example, PMC_LVDSC1[LVDIE] = 1 and PMC_LVDSC1[LVDRE] = 0).

21.5.2 LVD Interrupt Operation

By configuring the LVD circuit for interrupt operation (LVDIE set), PMC_LVDSC1[LVDF] is set and an LVD interrupt request occurs upon detection of a low voltage condition. The LVDF bit is cleared by writing one to the PMC_LVDSC1[LVDACK] bit, when the supply returns to above the trip point.

21.5.3 Low-voltage warning (LVW) interrupt operation

The LVD system contains a low-voltage warning flag (LVWF) to indicate that the supply voltage is approaching, but is above, the LVD voltage. The LVW also has an interrupt, which is enabled by setting the PMC_LVDSC2[LVWIE] bit. If enabled, an LVW interrupt request occurs when the LVWF is set. LVWF is cleared by writing one to the PMC_LVDSC2[LVWACK] bit, when the supply returns to above the trip point.

21.6 Memory Map and Register Definition

This sections provides the detailed information of all registers for the PMC module.

NOTE

Different portions of PMC registers are reset only by particular reset types. Each register's description provides details.

NOTE

The PMC registers can be written only in supervisor mode. Write accesses in user mode are blocked and will result in a bus error.

PMC memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4007_D000	Low Voltage Detect Status and Control 1 Register (PMC_LVDSC1)	8	R/W	See section	21.6.1/340
4007_D001	Low Voltage Detect Status and Control 2 Register (PMC_LVDSC2)	8	R/W	00h	21.6.2/341
4007_D002	Regulator Status and Control Register (PMC_REGSC)	8	R/W	See section	21.6.3/342
4007_D004	Low Power Oscillator Trim Register (PMC_LPOTRIM)	8	R/W	See section	21.6.4/343

21.6.1 Low Voltage Detect Status and Control 1 Register (PMC_LVDSC1)

This register contains status and control bits to support the low voltage detect function.

NOTE

When the internal voltage regulator is in low power mode, the LVD system is disabled, regardless of the PMC_LVDSC1 settings.

Address: 4007_D000h base + 0h offset = 4007_D000h

Bit	7	6	5	4	3	2	1	0
Read	LVDF		LVDIE	LVDRE	0			
Write		LVDACK						
Reset	0	0	0	u*	0	0	0	0
POR	0	0	0	0	0	0	0	0

* Notes:
- u = Unaffected by reset.

PMC_LVDSC1 field descriptions

Field	Description
7 LVDF	Low Voltage Detect Flag This bit's read-only status bit indicates a low-voltage detect event. The threshold voltage is V_{LVD}. 0 Low-voltage event not detected 1 Low-voltage event detected
6 LVDACK	Low Voltage Detect Acknowledge This write-only bit is used to acknowledge low voltage detection errors. Write 1 to clear LVDF. Read always return 0.
5 LVDIE	Low Voltage Detect Interrupt Enable This bit enables hardware interrupt requests for LVDF. 0 Hardware interrupt disabled (use polling) 1 Request a hardware interrupt when LVDF = 1
4 LVDRE	Low Voltage Detect Reset Enable This bit enables the low voltage detect events to generate a system reset. 0 No system resets on low voltage detect events. 1 If the supply voltage falls below V_{LVD}, a system reset will be generated.
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

21.6.2 Low Voltage Detect Status and Control 2 Register (PMC_LVDSC2)

This register contains status and control bits to support the low voltage warning (LVW) function.

NOTE

When the internal voltage regulator is in low power mode, the LVD system is disabled regardless of the PMC_LVDSC2 settings.

Address: 4007_D000h base + 1h offset = 4007_D001h

Bit	7	6	5	4	3	2	1	0
Read	LVWF		LVWIE	0				
Write		LVWACK						
Reset	0	0	0	0	0	0	0	0

PMC_LVDSC2 field descriptions

Field	Description
7 LVWF	Low-Voltage Warning Flag This bit read-only status bit indicates a low-voltage detect event. The threshold voltage is V_{LVW}. 0 Low-voltage warning event not detected 1 Low-voltage warning event detected
6 LVWACK	Low-Voltage Warning Acknowledge This write-only bit is used to acknowledge low voltage warning errors. Write 1 to clear LVWF. Reads always return 0.
5 LVWIE	Low-Voltage Warning Interrupt Enable This bit enables hardware interrupt requests for LVWF. 0 Hardware interrupt disabled (use polling) 1 Request a hardware interrupt when LVWF=1
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

21.6.3 Regulator Status and Control Register (PMC_REGSC)

This register contains general control and status bits for the regulator and the LPO.

Address: 4007_D000h base + 2h offset = 4007_D002h

Bit	7	6	5	4	3	2	1	0
Read	LPODIS	LPOSTAT	0			REGFPM	CLKBIASDIS	BIASEN
Write								
Reset	u*	*	0	0	0	1	0	0
POR	0	*	0	0	0	1	0	0

* Notes:
- u = Unaffected by reset.
- LPOSTAT field: Reset value is undefined.

PMC_REGSC field descriptions

Field	Description
7 LPODIS	LPO Disable Bit This bit enables or disable the low power oscillator. **NOTE:** After disabling the LPO a time of 2 LPO clock cycles is required before it is allowed to enable it again. Violating this waiting time of 2 cycles can result in malfunction of the LPO. 0 Low power oscillator enabled 1 Low power oscillator disabled

Table continues on the next page...

PMC_REGSC field descriptions (continued)

Field	Description
6 LPOSTAT	LPO Status Bit This bit shows the status of the LPO clock to be either in high phase (logic 1) or low phase (logic 0) of the clock period. Software can poll this status bit to measure actual LPO clock frequency and eventually use the LPOTRIM[4:0] register to change the LPO frequency. 0 Low power oscillator in low phase 1 Low power oscillator in high phase
5–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 REGFPM	Regulator in Full Performance Mode Status Bit This read-only bit provides the current status of the internal voltage regulator. 0 Regulator is in low power mode or transition to/from 1 Regulator is in full performance mode
1 CLKBIASDIS	Clock Bias Disable Bit This bit disables the bias currents and reference voltages for some clock modules in order to further reduce power consumption in STOP or VLPS mode if all clocks are disabled. The bias currents and reference voltages for LPFLL (if available on device) are always disabled in LPM. **Note: Using this bit it must be ensured that respective clock modules are disabled in STOP or VLPS mode. Else severe malfunction of clock modules will happen.** 0 No effect 1 In STOP or VLPS mode the bias currents and reference voltages for the following clock modules are disabled: SIRC, FIRC, PLL. (if available on device)
0 BIASEN	Bias Enable Bit This bit enables source and well biasing for the core logic in low power mode. In full performance mode this bit has no effect. This is useful to further reduce MCU power consumption in low power mode. 0 Biasing disabled, core logic can run in full performance 1 Biasing enabled, core logic is slower and there are restrictions in allowed system clock speed (see *Data Sheet* for details)

21.6.4 Low Power Oscillator Trim Register (PMC_LPOTRIM)

This register contains the period trimming bits for the low power oscillator.

Table 21-1. Trimming effect of LPOTRIM[4:0]

LPOTRIM[4:0]	Decimal	Period of LPO clock
10000	–16	lowest
10001	–15	increasing
...	...	
11110	–2	
11111	–1	

Table continues on the next page...

Table 21-1. Trimming effect of LPOTRIM[4:0] (continued)

LPOTRIM[4:0]	Decimal	Period of LPO clock
00000	0	typical 128 kHz
00001	+1	increasing
...	...	
01110	+14	
01111	+15	highest

NOTE

The LPO trimming bits represent signed values. Starting from -16 the period of the LPO clock will increase monotonically (for example, frequency decreases monotonically).

Address: 4007_D000h base + 4h offset = 4007_D004h

Bit	7	6	5	4	3	2	1	0
Read	0			LPOTRIM				
Write								
Reset	0	0	0	*	*	*	*	*
POR	0	0	0	0*	0*	0*	0*	0*

* Notes:
- LPOTRIM field: After POR reset, automatically loaded from Flash Memory IFR after Reset (normal system reset).

PMC_LPOTRIM field descriptions

Field	Description
7–5 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
LPOTRIM	LPO trimming bits These bits are used for trimming the frequency of the low power oscillator. See the table above for trimming effect.

Chapter 22
Security

22.1 Introduction

This chapter summarizes all security related features of this device.

22.2 Flash Security

The flash module provides security information to the MCU based on the state held by the FSEC[SEC] bits. The MCU, in turn, confirms the security request and limits access to flash resources. During reset, the flash module initializes the FSEC register using data read from the security byte of the flash configuration field.

NOTE

The security features apply only to external accesses via debug. CPU accesses to the flash are not affected by the status of FSEC.

In the unsecured state all flash commands are available to the programming interfaces (), as well as user code execution of Flash Controller commands. When the flash is secured (FSEC[SEC] = 00, 01, or 11), programmer interfaces are only allowed to launch mass erase operations and have no access to memory locations.

Further information regarding the flash security options and enabling/disabling flash security is available in the "Flash Memory Module" chapter.

22.3 Security Interactions with other Modules

The flash security settings are used by the SoC to determine what resources are available. The following sections describe the interactions between modules and the flash security settings or the impact that the flash security has on non-flash modules.

22.3.1 Security Interactions with Debug

Although most debug functions are disabled, the debugger can write to the Flash Mass Erase in Progress bit in the MDM-AP Control register to trigger a mass erase (Erase All Blocks) command. A mass erase via the debugger is allowed even when some memory locations are protected.

When mass erase is disabled, mass erase via the debugger is blocked.

Chapter 23
External Watchdog Monitor (EWM)

23.1 Introduction

For safety, a redundant watchdog system, External Watchdog Monitor (EWM), is designed to monitor external circuits, as well as the MCU software flow. This provides a back-up mechanism to the internal watchdog that resets the MCU's CPU and peripherals.

The watchdog is generally used to monitor the flow and execution of embedded software within an MCU. The watchdog consists of a counter that if allowed to overflow, forces an internal reset (asynchronous) to all on-chip peripherals and optionally assert the $\overline{\text{RESET}}$ pin to reset external devices/circuits. The overflow of the watchdog counter must not occur if the software code works well and services the watchdog to re-start the actual counter.

The EWM differs from the internal watchdog in that it does not reset the MCU's CPU and peripherals. The EWM provides an independent $\overline{\text{EWM_out}}$ signal that when asserted resets or places an external circuit into a safe mode. The $\overline{\text{EWM_out}}$ signal is asserted upon the EWM counter time-out. An optional external input EWM_in is provided to allow additional control of the assertion of $\overline{\text{EWM_out}}$ signal.

23.1.1 Features

Features of EWM module include:

- Independent LPO_CLK clock source
- Programmable time-out period specified in terms of number of EWM LPO_CLK clock cycles.
- Windowed refresh option
    - Provides robust check that program flow is faster than expected.

- Programmable window.
- Refresh outside window leads to assertion of $\overline{\text{EWM_out}}$.

- Robust refresh mechanism
  - Write values of 0xB4 and 0x2C to EWM Refresh Register within 15 (*EWM_refresh_time*) peripheral bus clock cycles.
- One output port, $\overline{\text{EWM_out}}$, when asserted is used to reset or place the external circuit into safe mode.
- One Input port, EWM_in, allows an external circuit to control the assertion of the $\overline{\text{EWM_out}}$ signal.

23.1.2 Modes of Operation

This section describes the module's operating modes.

23.1.2.1 Stop Mode

When the EWM is in stop mode, the CPU refreshes to the EWM cannot occur. On entry to stop mode, the EWM's counter freezes.

There are two possible ways to exit from Stop mode:

- On exit from stop mode through a reset, the EWM remains disabled.
- On exit from stop mode by an interrupt, the EWM is re-enabled, and the counter continues to be clocked from the same value prior to entry to stop mode.

Note the following if the EWM enters the stop mode during CPU refresh mechanism: At the exit from stop mode by an interrupt, refresh mechanism state machine starts from the previous state which means, if first refresh command is written correctly and EWM enters the stop mode immediately, the next command has to be written within the next 15 (*EWM_refresh_time*) peripheral bus clocks after exiting from stop mode. User must mask all interrupts prior to executing EWM refresh instructions.

23.1.2.2 Wait Mode

The EWM module treats the stop and wait modes as the same. EWM functionality remains the same in both of these modes.

23.1.2.3 Debug Mode

Entry to debug mode has no effect on the EWM.

- If the EWM is enabled prior to entry of debug mode, it remains enabled.
- If the EWM is disabled prior to entry of debug mode, it remains disabled.

23.1.3 Block Diagram

This figure shows the EWM block diagram.

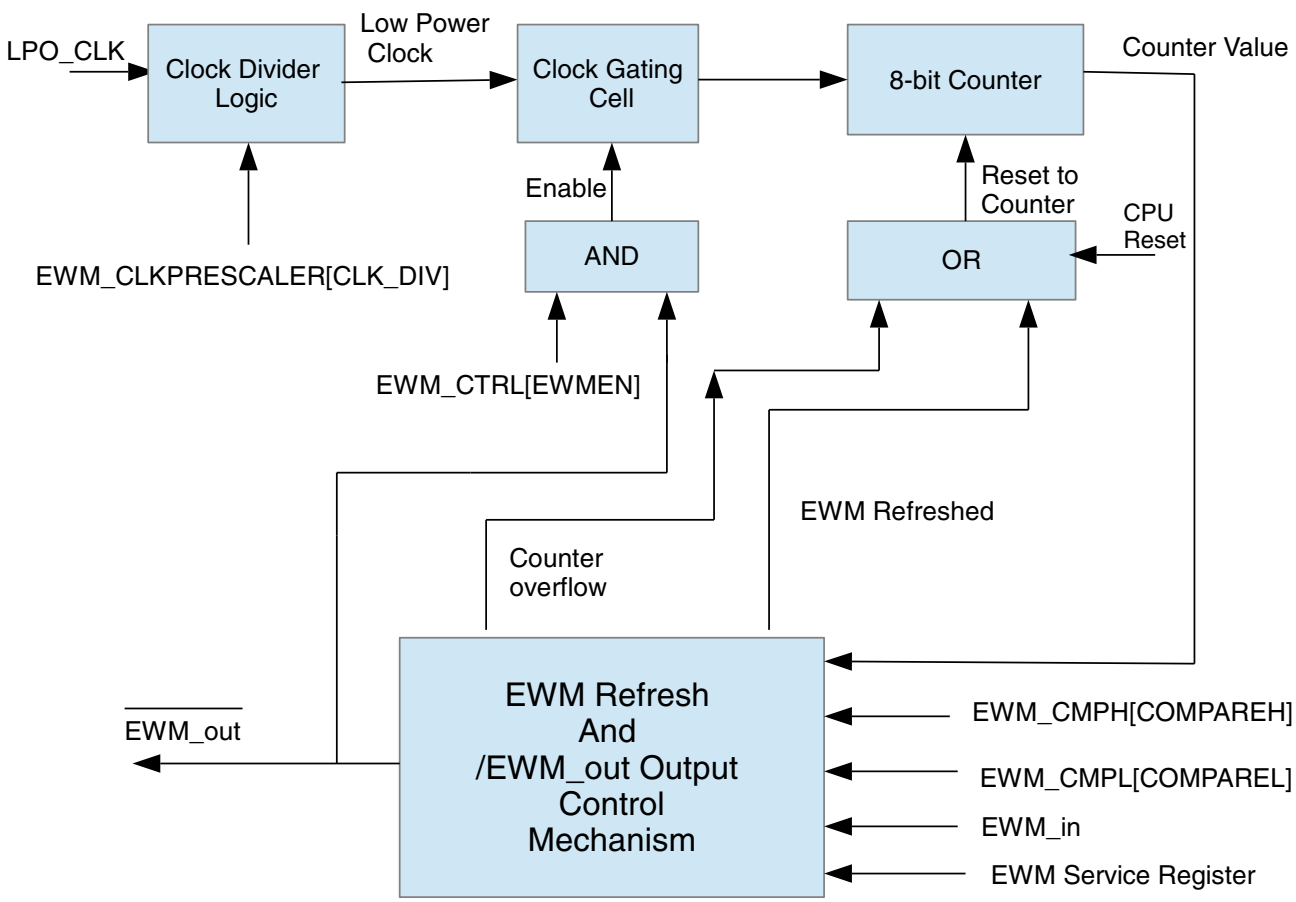


Figure 23-1. EWM Block Diagram

23.2 EWM Signal Descriptions

The EWM has two external signals, as shown in the following table.

Table 23-1. EWM Signal Descriptions

Signal	Description	I/O
EWM_in	EWM input for safety status of external safety circuits. The polarity of EWM_in is programmable using the EWM_CTRL[ASSIN] bit. The default polarity is active-low.	I
$\overline{\text{EWM_out}}$	EWM reset out signal	O

23.3 Memory Map/Register Definition

This section contains the module memory map and registers.

EWM memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4006_1000	Control Register (EWM_CTRL)	8	R/W	00h	23.3.1/350
4006_1001	Service Register (EWM_SERV)	8	W (always reads 0)	00h	23.3.2/351
4006_1002	Compare Low Register (EWM_CMPL)	8	R/W	00h	23.3.3/351
4006_1003	Compare High Register (EWM_CMPH)	8	R/W	FFh	23.3.4/352
4006_1005	Clock Prescaler Register (EWM_CLKPRESCALER)	8	R/W	00h	23.3.5/353

23.3.1 Control Register (EWM_CTRL)

The CTRL register is cleared by any reset.

NOTE

INEN, ASSIN and EWMEN bits can be written once after a CPU reset. Modifying these bits more than once, generates a bus transfer error.

Address: 4006_1000h base + 0h offset = 4006_1000h

Bit	7	6	5	4	3	2	1	0
Read	0				INTEN	INEN	ASSIN	EWMEN
Write								
Reset	0	0	0	0	0	0	0	0

EWM_CTRL field descriptions

Field	Description
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 INTEN	Interrupt Enable. This bit when set and $\overline{\text{EWM_out}}$ is asserted, an interrupt request is generated. To de-assert interrupt request, user should clear this bit by writing 0.
2 INEN	Input Enable. This bit when set, enables the EWM_in port.
1 ASSIN	EWM_in's Assertion State Select. Default assert state of the EWM_in signal is logic zero. Setting the ASSIN bit inverts the assert state of EWM_in signal to a logic one.
0 EWMEN	EWM enable. This bit when set, enables the EWM module. This resets the EWM counter to zero and deasserts the $\overline{\text{EWM_out}}$ signal. This bit when unset, keeps the EWM module disabled. It cannot be re-enabled until a next reset, due to the write-once nature of this bit.

23.3.2 Service Register (EWM_SERV)

The SERV register provides the interface from the CPU to the EWM module. It is write-only and reads of this register return zero.

Address: 4006_1000h base + 1h offset = 4006_1001h

Bit	7	6	5	4	3	2	1	0
Read	0							
Write	SERVICE							
Reset	0	0	0	0	0	0	0	0

EWM_SERV field descriptions

Field	Description
SERVICE	The EWM refresh mechanism requires the CPU to write two values to the SERV register: a first data byte of 0xB4, followed by a second data byte of 0x2C. The EWM refresh is invalid if either of the following conditions is true. • The first or second data byte is not written correctly. • The second data byte is not written within a fixed number of peripheral bus cycles of the first data byte. This fixed number of cycles is called *EWM_refresh_time*.

23.3.3 Compare Low Register (EWM_CMPL)

The CMPL register is reset to zero after a CPU reset. This provides no minimum time for the CPU to refresh the EWM counter.

NOTE

This register can be written only once after a CPU reset. Writing this register more than once generates a bus transfer error.

Address: 4006_1000h base + 2h offset = 4006_1002h

Bit	7	6	5	4	3	2	1	0
Read Write	COMPAREL							
Reset	0	0	0	0	0	0	0	0

EWM_CMPL field descriptions

Field	Description
COMPAREL	To prevent runaway code from changing this field, software should write to this field after a CPU reset even if the (default) minimum refresh time is required.

23.3.4 Compare High Register (EWM_CMPH)

The CMPH register is reset to 0xFF after a CPU reset. This provides a maximum of 256 clocks time, for the CPU to refresh the EWM counter.

NOTE

This register can be written only once after a CPU reset. Writing this register more than once generates a bus transfer error.

NOTE

The valid values for CMPH are up to 0xFE because the EWM counter never expires when CMPH = 0xFF. The expiration happens only if EWM counter is greater than CMPH.

Address: 4006_1000h base + 3h offset = 4006_1003h

Bit	7	6	5	4	3	2	1	0
Read Write	COMPAREH							
Reset	1	1	1	1	1	1	1	1

EWM_CMPH field descriptions

Field	Description
COMPAREH	To prevent runaway code from changing this field, software should write to this field after a CPU reset even if the (default) maximum refresh time is required.

23.3.5 Clock Prescaler Register (EWM_CLKPRESCALER)

This CLKPRESCALER register is reset to 0x00 after a CPU reset.

NOTE

This register can be written only once after a CPU reset. Writing this register more than once generates a bus transfer error.

NOTE

Write the required prescaler value before enabling the EWM.

NOTE

The implementation of this register is chip-specific. See the chip-specific information for details.

Address: 4006_1000h base + 5h offset = 4006_1005h

Bit	7	6	5	4	3	2	1	0
Read Write	CLK_DIV							
Reset	0	0	0	0	0	0	0	0

EWM_CLKPRESCALER field descriptions

Field	Description
CLK_DIV	Selected low power clock source for running the EWM counter can be prescaled as below. • Prescaled clock frequency = low power clock source frequency / (1 + CLK_DIV)

23.4 Functional Description

The following sections describe functional details of the EWM module.

NOTE

When the BUS_CLK is lost, then EWM module doesn't generate the $\overline{\text{EWM_out}}$ signal and no refresh operation is possible

23.4.1 The $\overline{\text{EWM_out}}$ Signal

The $\overline{\text{EWM_out}}$ is a digital output signal used to gate an external circuit (application specific) that controls critical safety functions. For example, the $\overline{\text{EWM_out}}$ could be connected to the high voltage transistors circuits.

The $\overline{\text{EWM_out}}$ signal remains deasserted when the EWM is being regularly refreshed by the CPU within the programmable refresh window, indicating that the application code is executed as expected.

The $\overline{\text{EWM_out}}$ signal is asserted in any of the following conditions:

- The EWM refresh occurs when the counter value is less than CMPL value.
- The EWM counter value reaches the CMPH value, and no EWM refresh has occurred.
- If functionality of EWM_in pin is enabled and EWM_in pin is asserted while refreshing the EWM.
- After any reset (by the virtue of the external pull-down mechanism on the $\overline{\text{EWM_out}}$ pin)

The $\overline{\text{EWM_out}}$ is asserted after any reset by the virtue of the external pull-down mechanism on the $\overline{\text{EWM_out}}$ signal. Then, to deassert the $\overline{\text{EWM_out}}$ signal, set EWMEN bit in the CTRL register to enable the EWM.

If the $\overline{\text{EWM_out}}$ signal shares its pad with a digital I/O pin, on reset this actual pad defers to being an input signal. The pad state is controlled by the $\overline{\text{EWM_out}}$ signal only after the EWM is enabled by the EWMEN bit in the CTRL register.

Note

$\overline{\text{EWM_out}}$ pad must be in pull down state when EWM functionality is used and when EWM is under Reset.

23.4.2 The EWM_in Signal

The EWM_in is a digital input signal for safety status of external safety circuits, that allows an external circuit to control the assertion of the $\overline{\text{EWM_out}}$ signal. For example, in the application, an external circuit monitors a critical safety function, and if there is fault with safety function, the external circuit can then actively initiate the $\overline{\text{EWM_out}}$ signal that controls the gating circuit.

The EWM_in signal is ignored if the EWM is disabled, or if INEN bit of CTRL register is cleared, as after any reset.

On enabling the EWM (setting the CTRL[EWMEN] bit) and enabling EWM_in functionality (setting the CTRL[INEN] bit), the EWM_in signal must be in the deasserted state prior to the CPU start refreshing the EWM. This ensures that the $\overline{\text{EWM_out}}$ stays in the deasserted state; otherwise, the $\overline{\text{EWM_out}}$ output signal is asserted.

Note

The user must update the CMPH and CMPL registers prior to enabling the EWM. After enabling the EWM, the counter resets to zero, therefore the user shall provide a reasonable time after a power-on reset for the external monitoring circuit to stabilize. The user shall also ensure that the EWM_in pin is deasserted.

23.4.3 EWM Counter

It is an 8-bit ripple counter fed from a clock source that is independent of the peripheral bus clock source. As the preferred time-out is between 1 ms and 100 ms the actual clock source should be in the kHz range.

The counter is reset to zero after the CPU reset, or when EWM refresh action completes, or at counter overflow. The counter value is not accessible to the CPU.

23.4.4 EWM Compare Registers

The compare registers CMPL and CMPH are write-once after a CPU reset and cannot be modified until another CPU reset occurs.

The EWM compare registers are used to create a refresh window to refresh the EWM module.

It is illegal to program CMPL and CMPH with same value. In this case, as soon as counter reaches (CMPL + 1), $\overline{\text{EWM_out}}$ is asserted.

23.4.5 EWM Refresh Mechanism

Other than the initial configuration of the EWM, the CPU can only access the EWM by the EWM Service Register. The CPU must access the EWM service register with correct write of unique data within the windowed time frame as determined by the CMPL and CMPH registers for correct EWM refresh operation. Therefore, three possible conditions can occur:

Table 23-2. EWM Refresh Mechanisms

Condition	Mechanism
An EWM refresh action completes when: CMPL < Counter < CMPH.	The software behaves as expected and the EWM counter is reset to zero. The $\overline{\text{EWM_out}}$ output signal remains in the deasserted state if, during the EWM refresh action, the EWM_in input has been in deasserted state..
An EWM refresh action completes when Counter < CMPL	The software refreshes the EWM before the windowed time frame, the counter is reset to zero and the $\overline{\text{EWM_out}}$ output signal is asserted irrespective of the input $\overline{\text{EWM_in}}$.
Counter value reaches CMPH prior to completion of EWM refresh action.	Software has not refreshed the EWM. The EWM counter is reset to zero and the $\overline{\text{EWM_out}}$ output signal is asserted irrespective of the input $\overline{\text{EWM_in}}$.

23.4.6 EWM Interrupt

When $\overline{\text{EWM_out}}$ is asserted, an interrupt request is generated to indicate the assertion of the EWM reset out signal. This interrupt is enabled when CTRL[INTEN] is set. Clearing this bit clears the interrupt request but does not affect $\overline{\text{EWM_out}}$. The $\overline{\text{EWM_out}}$ signal can be deasserted only by forcing a system reset.

23.4.7 Counter clock prescaler

The EWM counter clock source can be prescaled by a clock divider, by programming CLKPRESCALER[CLK_DIV]. This divided clock is used to run the EWM counter.

NOTE

The divided clock used to run the EWM counter must be no more than half the frequency of the bus clock.

23.5 Usage Guide

23.5.1 EWM low-power modes

This table shows the EWM low-power modes and the corresponding chip low-power modes.

Table 23-3. EWM low-power modes

Module mode	Chip mode
Wait	Wait, VLPW
Stop	Stop, VLPS

23.5.2 $\overline{\text{EWM_out}}$ pin state in low power modes

During Wait, Stop, and Power Down modes the $\overline{\text{EWM_out}}$ pin preserve its state before entering Wait or Stop mode. When the CPU enters a Run mode from Wait or Stop recovery, the pin resumes its previous state before entering Wait or Stop mode. When the CPU enters Run mode from Power Down, the pin returns to its reset state.

23.5.3 Example code

23.5.3.1 Initializing the EWM

The following code segment shows the initialize sequence of the EWM module. It enables EWM_in pin input with assert state logic zero, enables interrupt when EWM_out is assert. The compare value is also set into CMPL/H register before enabling EWM.

```
// Initialize the EWM module
EWM_CMPL = compareValue & 0xFF;
EWM_CMPH = (compareValue >> 8) 0xFF;
EWM_CTRL = EWM_CTRL_INEN(1) | EWM_CTRL_ASSIN(0) |
           EWM_CTRL_INTEN(1) | EWM_CTRL_EWMEN(1);
```

23.5.3.2 Refreshing the EWM

The following code segment shows the refresh write sequence of the EWM module.

```
// Refresh EWM
DisableInterrupts; // disable global interrupt
EWM_SERV= 0xB4; // write the 1st refresh words
EWM_SERV= 0x2C; // write the 2nd refresh words
EnableInterrupts; // enable global interrupt
```

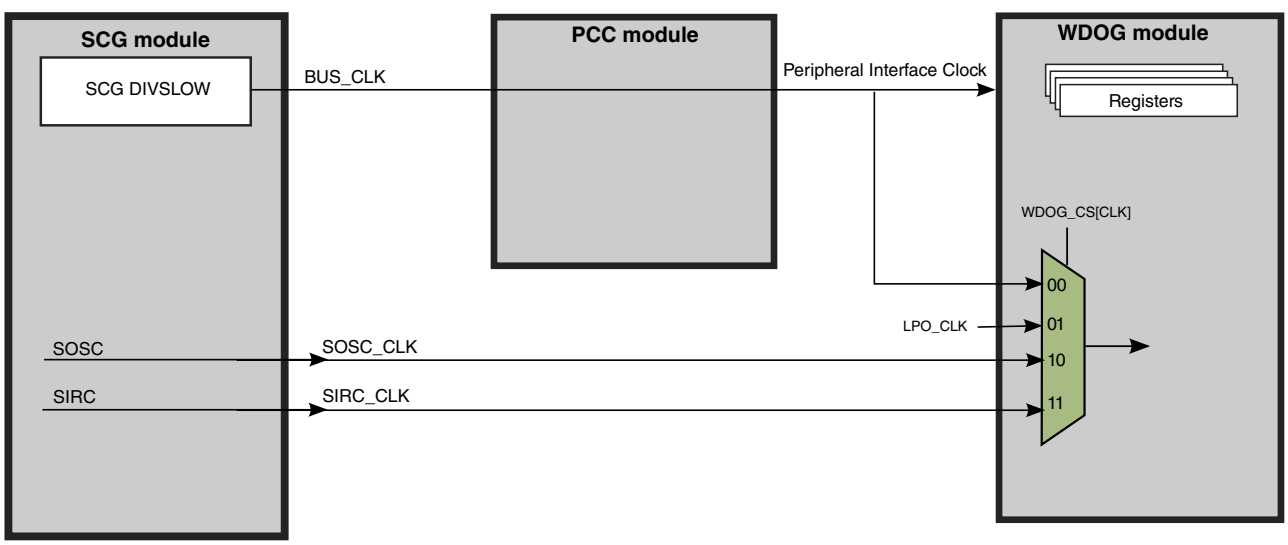
Chapter 24
Watchdog timer (WDOG)

24.1 Chip-specific information for this module

24.1.1 WDOG Clocking Information

The following figure shows the input clock sources available for this module.

Peripheral Clocking - WDOG



24.1.2 WDOG low-power modes

This table shows the WDOG low-power modes and the corresponding chip low-power modes.

Table 24-1. WDOG low-power modes

Module mode	Chip mode
Wait	Wait, VLPW
Stop	Stop, VLPS

24.2 Introduction

The Watchdog Timer (WDOG) module is an independent timer that is available for system use. It provides a safety feature to ensure that software is executing as planned and that the CPU is not stuck in an infinite loop or executing unintended code. If the WDOG module is not serviced (refreshed) within a certain period, it resets the MCU.

24.2.1 Features

Features of the WDOG module include:

- Configurable clock source inputs independent from the bus clock
  - Bus clock (slow clock)
  - LPO clock (from PMC)
  - SIRC (8 MHz IRC from SCG)
  - ERCLK (external reference clock from SCG)
- Programmable timeout period
  - Programmable 16-bit timeout value
  - Optional fixed 256 clock prescaler when longer timeout periods are needed
- Robust write sequence for counter refresh
  - Refresh sequence of writing 0xA602 and then 0xB480
- Window mode option for the refresh mechanism
  - Programmable 16-bit window value
  - Provides robust check that program flow is faster than expected
  - Early refresh attempts trigger a reset.
- Optional timeout interrupt to allow post-processing diagnostics

- Interrupt request to CPU with interrupt vector for an interrupt service routine (ISR)
- Forced reset occurs 128 bus clocks after the interrupt vector fetch.

- Configuration bits are write-once-after-reset to ensure watchdog configuration cannot be mistakenly altered.
- Robust write sequence for unlocking write-once configuration bits
  - Unlock sequence of writing 0xC520 and then 0xD928 for allowing updates to write-once configuration bits
  - Software must make updates within 128 bus clocks after unlocking and before WDOG closing unlock window.

24.2.2 Block diagram

The following figure shows a block diagram of the WDOG module.

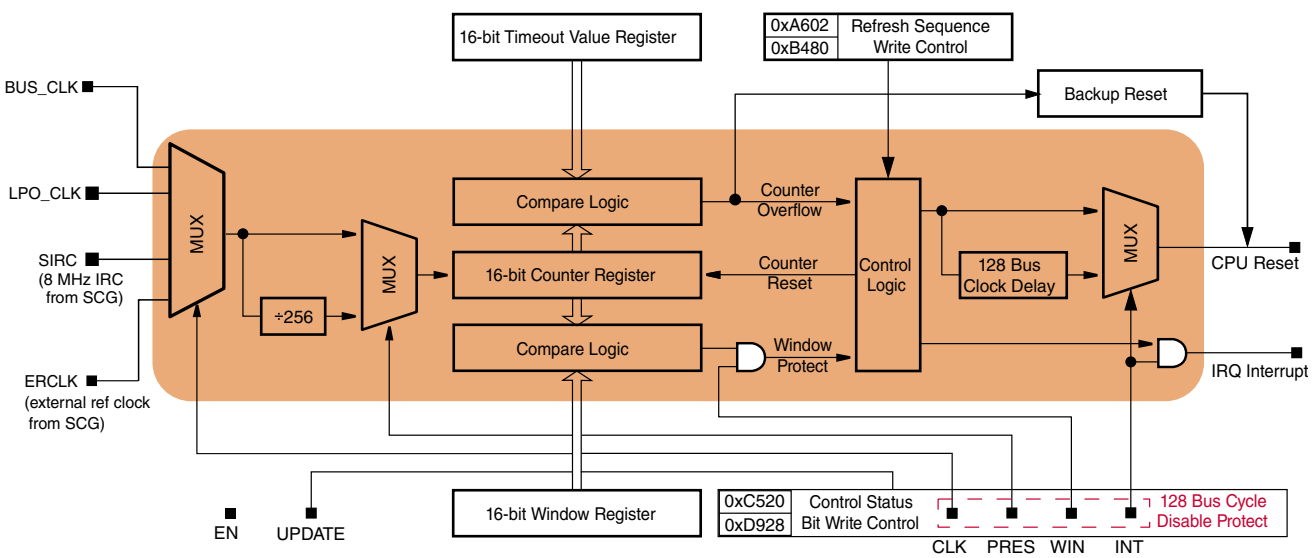


Figure 24-1. WDOG block diagram

24.3 Memory map and register definition

WDOG memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4005_2000	Watchdog Control and Status Register (WDOG_CS)	32	R/W	See section	24.3.1/362
4005_2004	Watchdog Counter Register (WDOG_CNT)	32	R/W	0000_0000h	24.3.2/365
4005_2008	Watchdog Timeout Value Register (WDOG_TOVAL)	32	R/W	0000_0400h	24.3.3/365
4005_200C	Watchdog Window Register (WDOG_WIN)	32	R/W	0000_0000h	24.3.4/366

24.3.1 Watchdog Control and Status Register (WDOG_CS)

This section describes the function of Watchdog Control and Status Register.

NOTE

TST is cleared (0:0) on POR only. Any other reset does not affect the value of this field.

Address: 4005_2000h base + 0h offset = 4005_2000h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	WIN	FLG	CMD32EN	PRES	ULK	RCS	CLK		EN	INT	UPDATE	TST		DBG	WAIT	STOP
W		w1c														
Reset	0	0	1	0	1	0	0	1	1	0	0	0	0	0	0	0

WDOG_CS field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15 WIN	Watchdog Window This write-once bit enables window mode. See the Window mode section. 0 Window mode disabled. 1 Window mode enabled.
14 FLG	Watchdog Interrupt Flag This bit is an interrupt indicator when INT is set in control and status register 1. Write 1 to clear it. 0 No interrupt occurred. 1 An interrupt occurred.
13 CMD32EN	Enables or disables WDOG support for 32-bit (otherwise 16-bit or 8-bit) refresh/unlock command write words This is write-once field, and the user needs to unlock WDOG after writing this field for reconfiguration. 0 Disables support for 32-bit refresh/unlock command write words. Only 16-bit or 8-bit is supported. 1 Enables support for 32-bit refresh/unlock command write words. 16-bit or 8-bit is NOT supported.
12 PRES	Watchdog prescaler This write-once bit enables a fixed 256 pre-scaling of watchdog counter reference clock. (The block diagram shows this clock divider option.) 0 256 prescaler disabled. 1 256 prescaler enabled.
11 ULK	Unlock status This read-only bit indicates whether WDOG is unlocked or not. Default reset value is 1. 0 WDOG is locked. 1 WDOG is unlocked.
10 RCS	Reconfiguration Success This read-only bit indicates whether the reconfiguration is successful or not. Default reset value is 0.This bit is set when new configuration takes effect, and is cleared by successful unlock command. 0 Reconfiguring WDOG. 1 Reconfiguration is successful.
9–8 CLK	Watchdog Clock This write-once field indicates the clock source that feeds the watchdog counter. See the Clock source section. 00 Bus clock 01 LPO clock 10 System oscillator clock (SOSC, from SCG) 11 Slow internal reference clock (SIRC, from SCG)
7 EN	Watchdog Enable

Table continues on the next page...

WDOG_CS field descriptions (continued)

Field	Description
	This write-once bit enables the watchdog counter to start counting. 0 Watchdog disabled. 1 Watchdog enabled.
6 INT	Watchdog Interrupt This write-once bit configures the watchdog to immediately generate an interrupt request upon a reset-triggering event (timeout or illegal write to the watchdog), before forcing a reset. After the interrupt vector fetch (which comes after the reset-triggering event), the reset occurs after a delay of 128 bus clocks. 0 Watchdog interrupts are disabled. Watchdog resets are not delayed. 1 Watchdog interrupts are enabled. Watchdog resets are delayed by 128 bus clocks from the interrupt vector fetch.
5 UPDATE	Allow updates This write-once bit allows software to reconfigure the watchdog without a reset. 0 Updates not allowed. After the initial configuration, the watchdog cannot be later modified without forcing a reset. 1 Updates allowed. Software can modify the watchdog configuration registers within 128 bus clocks after performing the unlock write sequence.
4–3 TST	Watchdog Test Enables the fast test mode. The test mode allows software to exercise all bits of the counter to demonstrate that the watchdog is functioning properly. See the Fast testing of the watchdog section. This write-once field is cleared (0:0) on POR only. Any other reset does not affect the value of this field. 00 Watchdog test mode disabled. 01 Watchdog user mode enabled. (Watchdog test mode disabled.) After testing the watchdog, software should use this setting to indicate that the watchdog is functioning normally in user mode. 10 Watchdog test mode enabled, only the low byte is used. CNT[CNTLOW] is compared with TOVAL[TOVALLOW]. 11 Watchdog test mode enabled, only the high byte is used. CNT[CNTHIGH] is compared with TOVAL[TOVALHIGH].
2 DBG	Debug Enable This write-once bit enables the watchdog to operate when the chip is in debug mode. 0 Watchdog disabled in chip debug mode. 1 Watchdog enabled in chip debug mode.
1 WAIT	Wait Enable This write-once bit enables the watchdog to operate when the chip is in wait mode. 0 Watchdog disabled in chip wait mode. 1 Watchdog enabled in chip wait mode.
0 STOP	Stop Enable This write-once bit enables the watchdog to operate when the chip is in stop mode. 0 Watchdog disabled in chip stop mode. 1 Watchdog enabled in chip stop mode.

24.3.2 Watchdog Counter Register (WDOG_CNT)

This section describes the watchdog counter register.

The watchdog counter register provides access to the value of the free-running watchdog counter. Software can read the counter register at any time.

Software cannot write directly to the watchdog counter; however, two write sequences to these registers have special functions:

1. The *refresh sequence* resets the watchdog counter to 0x0000. See the "Refreshing the Watchdog" section.
2. The *unlock sequence* allows the watchdog to be reconfigured without forcing a reset (when CS[UPDATE] = 1). See the "Configure for reconfigurable" section.

NOTE

All other writes to this register are illegal and force a reset.

Address: 4005_2000h base + 4h offset = 4005_2004h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0																CNTHIGH								CNTLOW							
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

WDOG_CNT field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–8 CNTHIGH	High byte of the Watchdog Counter
CNTLOW	Low byte of the Watchdog Counter

24.3.3 Watchdog Timeout Value Register (WDOG_TOVAL)

This section describes the watchdog timeout value register. TOVAL contains the 16-bit value used to set the timeout period of the watchdog.

The watchdog counter (CNT) is continuously compared with the timeout value (TOVAL). If the counter reaches the timeout value, the watchdog forces a reset triggering event.

NOTE

Do not write 0 to the Watchdog Timeout Value Register; otherwise, the watchdog always generates a reset.

Address: 4005_2000h base + 8h offset = 4005_2008h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0																TOVALHIGH								TOVALLOW							
W																																
Reset	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

WDOG_TOVAL field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–8 TOVALHIGH	High byte of the timeout value
TOVALLOW	Low byte of the timeout value

24.3.4 Watchdog Window Register (WDOG_WIN)

This section describes the watchdog window register. When window mode is enabled (CS[WIN] is set), The WIN register determines the earliest time that a refresh sequence is considered valid. See the Watchdog refresh mechanism section.

The WIN register value must be less than the TOVAL register value.

Address: 4005_2000h base + Ch offset = 4005_200Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0																WINHIGH								WINLOW							
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

WDOG_WIN field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–8 WINHIGH	High byte of Watchdog Window
WINLOW	Low byte of Watchdog Window

24.4 Functional description

The WDOG module provides a fail safe mechanism to ensure the system can be reset to a known state of operation in case of system failure, such as the CPU clock stopping or there being a run away condition in the software code. The watchdog counter runs continuously off a selectable clock source and expects to be serviced (refreshed) periodically. If it is not, it generates a reset triggering event.

The timeout period, window mode, and clock source are all programmable but must be configured within 128 bus clocks after a reset.

24.4.1 Clock source

The watchdog counter has the following clock source options selected by programming CS[CLK]:

- bus clock
- internal Low-Power Oscillator clock (LPO_CLK) (This is the default source.)
- internal 8 MHz clock (SIRC)
- external clock (SOSC)

The options allow software to select a clock source independent of the bus clock for applications that need to meet more robust safety requirements. Using a clock source other than the bus clock ensures that the watchdog counter continues to run if the bus clock is somehow halted; see Backup reset.

An optional fixed prescaler for all clock sources allows for longer timeout periods. When CS[PRES] is set, the clock source is prescaled by 256 before clocking the watchdog counter.

The following table summarizes the different watchdog timeout periods available.

Table 24-2. Watchdog timeout availability

Reference clock	Prescaler	Watchdog time-out availability
Internal LPO_CLK	Pass through	~1 ms–65.5 s (if LPO_CLK = 1 kHz); (~1 ms–65.5 s)/128 (if LPO_CLK = 128 kHz). [1]
	÷256	~256 ms–16,777.2 s (if LPO_CLK = 1 kHz); ~2 ms–131.1 s (if LPO_CLK = 128 kHz).
Internal 8 MHz (SIRC)	Pass through	125 ns–8.1925 ms
	÷256	32 µs–2.09728 s
1 MHz (from bus or external)	Pass through	1 µs–65.54 ms

Table continues on the next page...

Table 24-2. Watchdog timeout availability (continued)

Reference clock	Prescaler	Watchdog time-out availability
	÷256	256 µs–16.777 s
20 MHz (from bus or external)	Pass through	50 ns–3.277 ms
	÷256	12.8 µs–838.8 ms

1. The default timeout value after reset is approximately 1 s (if LPO_CLK = 1 kHz), or 1/128 s (if LPO_CLK = 128 kHz).

NOTE

When the programmer switches clock sources during reconfiguration, the watchdog hardware holds the counter at zero for 2.5 periods of the previous clock source and 2.5 periods of the new clock source after the configuration time period (128 bus clocks) ends. This delay ensures a smooth transition before restarting the counter with the new configuration.

24.4.2 Watchdog refresh mechanism

The watchdog resets the MCU if the watchdog counter is not refreshed. A robust refresh mechanism makes it very unlikely that the watchdog can be refreshed by runaway code.

To refresh the watchdog counter, software must execute a refresh write sequence before the timeout period expires. In addition, if window mode is used, software must not start the refresh sequence until after the time value set in the WIN register. See the following figure.

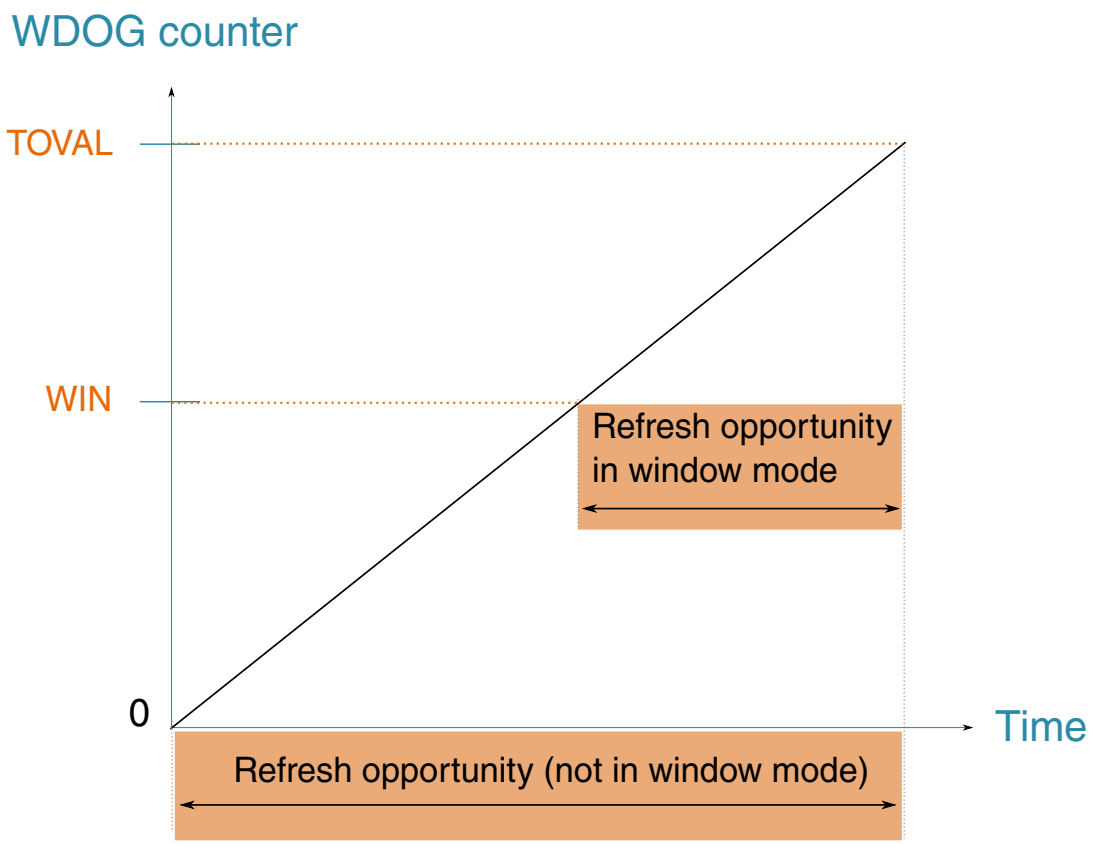


Figure 24-2. Refresh opportunity for the Watchdog counter

24.4.2.1 Window mode

Software finishing its main control loop faster than expected could be an indication of a problem. Depending on the requirements of the application, the WDOG can be programmed to force a reset when refresh attempts are early.

When Window mode is enabled, the watchdog must be refreshed after the counter has reached a minimum expected time value; otherwise, the watchdog resets the MCU. The minimum expected time value is specified in the WIN register. Setting CS[WIN] enables Window mode.

24.4.2.2 Refreshing the Watchdog

The refresh write sequence can be

- either two 16-bit writes (0xA602, 0xB480) or four 8-bit writes (0xA6, 0x02, 0xB4, 0x80) if WDOG_CS[CMD32EN] is 0;
- one 32-bit write (0xB480_A602) if WDOG_CS[CMD32EN] is 1.

to the CNT register. Both methods must occur before the WDG timeout; otherwise, the watchdog resets the MCU.

Note

Before starting the refresh sequence, disable the global interrupts. Otherwise, an interrupt could effectively invalidate the refresh sequence, if the interrupt occurs before the refresh writes finish. After the sequence finishes, restore the global interrupt control state.

The example codes can be found in the "Application Information" section of this chapter.

24.4.3 Configuring the Watchdog

24.4.3.1 Configuring the Watchdog Once

All watchdog control bits, timeout value, and window value are write-once after reset *within 128 bus clocks*. This means that after a write has occurred they cannot be changed unless a reset occurs. This is guaranteed by the user configuring the window and timeout value first, followed by the other control bits, and ensuring that CS[UPDATE] is also set to 0.

This provides a robust mechanism to configure the watchdog and ensure that a runaway condition cannot mistakenly disable or modify the watchdog configuration after configured.

The new configuration takes effect only after all registers except CNT are written after reset. Otherwise, the WDOG uses the reset values by default. If window mode is not used (CS[WIN] is 0), writing to WIN is not required to make the new configuration take effect.

24.4.3.2 Reconfiguring the Watchdog

In some cases (like when supporting a bootloader function), you may want to reconfigure or disable the watchdog, *without forcing a reset first*.

- By setting CS[UPDATE] to 1 on the initial configuration of the watchdog after a reset, you can reconfigure the watchdog at any time by executing an unlock sequence.
- Conversely, if CS[UPDATE] remains 0, the only way to reconfigure the watchdog is by initiating a reset.

The unlock sequence is similar to the refresh sequence but uses different values.

24.4.3.2.1 Unlocking the Watchdog

The unlock sequence is a write to the CNT register of 0xC520 followed by 0xD928 within 16 bus clocks at any time after the watchdog has been configured. On completing the unlock sequence, the user must reconfigure the watchdog within 128 bus clocks; otherwise, the watchdog closes the unlock window.

NOTE

Due to the 128 bus clocks requirement for reconfiguring the watchdog, some delays must be inserted before executing STOP or WAIT instructions after reconfiguring the watchdog. This ensures that the watchdog's new configuration takes effect before the MCU enters low power mode. Otherwise, the MCU may not be waken up from low power mode.

The example codes can be found at end of this chapter.

24.4.4 Using interrupts to delay resets

- **When interrupts are enabled (CS[INT] = 1):** After a reset-triggering event (like a counter timeout or invalid refresh attempt), the watchdog first generates an interrupt request. Next, the watchdog delays 128 bus clocks (from the interrupt vector fetch, not the reset-triggering event) before forcing a reset, to allow the interrupt service routine (ISR) to perform tasks (like analyzing the stack to debug code).
- **When interrupts are disabled (CS[INT] = 0):** the watchdog does not delay the forcing a reset.

24.4.5 Backup reset

NOTE

A clock source other than the bus clock must be used as the reference clock for the counter; otherwise, the backup reset function is not available.

The backup reset function is a safeguard feature that independently generates a reset in case the main WDOG logic loses its clock (the bus clock) and can no longer monitor the counter. If the watchdog counter overflows twice in succession (without an intervening reset), the backup reset function takes effect and generates a reset.

24.4.6 Functionality in debug and low-power modes

By default, the watchdog is not functional in Debug mode, Wait mode, or Stop mode. However, the watchdog can remain functional in these modes as follows:

- **For Debug mode,** set CS[DBG]. (This way the watchdog is functional in Debug mode even when the CPU is held by the Debug module.)
- **For Wait mode,** set CS[WAIT].
- **For Stop mode,** set CS[STOP], CS[WAIT], and ensure the clock source is active in STOP mode.

NOTE

For Debug mode and Stop mode, in addition to the above configurations, a clock source other than the bus clock must be used as the reference clock for the counter; otherwise, the watchdog cannot function.

24.4.7 Fast testing of the watchdog

Before executing application code in safety critical applications, users are required to test that the watchdog works as expected and resets the MCU. Testing every bit of a 16-bit counter by letting it run to the overflow value takes a relatively long time (64 kHz clocks).

To help minimize the startup delay for application code after reset, the watchdog has a feature to test the watchdog more quickly by splitting the counter into its constituent byte-wide stages. The low and high bytes are run independently and tested for timeout against the corresponding byte of the timeout value register. (For complete coverage when testing the high byte of the counter, the test feature feeds the input clock via the 8th bit of the low byte, thus ensuring that the overflow connection from the low byte to the high byte is tested.)

Using this test feature reduces the test time to 512 clocks (not including overhead, such as user configuration and reset vector fetches). To further speed testing, use a faster clock (such as the bus clock) for the counter reference.

On a power-on reset, the POR bit in the system reset register is set, indicating the user should perform the WDOG fast test.

24.4.7.1 Testing each byte of the counter

The test procedure follows these steps:

1. Program the preferred watchdog timeout value in the TOVAL register during the watchdog configuration time period.
2. Select a byte of the counter to test using the CS[TST] = 10b for the low byte; CS[TST] = 11b for the high byte.
3. Wait for the watchdog to timeout. Optionally, in the idle loop, increment RAM locations as a parallel software counter for later comparison. Because the RAM is not affected by a watchdog reset, the timeout period of the watchdog counter can be compared with the software counter to verify the timeout period has occurred as expected.
4. The watchdog counter times out and forces a reset.
5. Confirm the WDOG flag in the system reset register is set, indicating that the watchdog caused the reset. (The POR flag remains clear.)
6. Confirm that CS[TST] shows a test (10b or 11b) was performed.

If confirmed, the count and compare functions work for the selected byte. Repeat the procedure, selecting the other byte in step 2.

NOTE

CS[TST] is cleared by a POR only and not affected by other resets.

24.4.7.2 Entering user mode

After successfully testing the low and high bytes of the watchdog counter, the user can configure CS[TST] to 01b to indicate the watchdog is ready for use in application user mode. Thus if a reset occurs again, software can recognize the reset trigger as a real watchdog reset caused by runaway or faulty application code.

As an ongoing test when using the default LPO clock source, software can periodically read the CNT register to ensure the counter is being incremented.

24.5 Application Information

The watchdog is enabled by default after reset. To disable or reconfigure the watchdog, it is better to be done before the first watchdog timeout. It is suggested to disable or reconfigure the watchdog at the very beginning of the software code, e.g. beginning of the startup or main function.

NOTE

When the watchdog is configured by user, it needs at least 2.5 periods of watchdog clock to take effect. This means interval between two configures by user must be larger than 2.5 clocks.

To disable or reconfigure the watchdog without forcing a reset, the unlock sequence must be done.

24.5.1 Disable Watchdog

To disable the watchdog, first do unlock sequence, then unset the WDOG_CS[EN] bit.

```
DisableInterrupts; // disable global interrupt
WDOG_CNT = 0xD928C520; // unlock watchdog
WDOG_CS &= ~WDOG_CS_EN_MASK; // disable watchdog
EnableInterrupts; // enable global interrupt
```

24.5.2 Configure Watchdog

The watchdog can be configured once by set the WDOG_CS[UPDATE]=0. After that, the watchdog cannot be reconfigured until a reset.If set WDOG_CS[UPDATE]=1 when configuring the watchdog, the watchdog can be reconfigured without forcing a reset.The following example code shows how to configure the watchdog without window mode, clock source as LPO, interrupt enabled and timeout value to 256 clocks.

Configure once

```
DisableInterrupts; //disable global interrupt
WDOG_CNT = 0xD928C520; //unlock watchdog
while(WDOG_CS[ULK]==0);  //wait until registers are unlocked
WDOG_TOVAL = 256; //set timeout value
WDOG_CS = WDOG_CS_EN(1) | WDOG_CS_CLK(1) | WDOG_CS_INT(1) |
          WDOG_CS_WIN(0) | WDOG_CS_UPDATE(0);
while(WDOG_CS[RCS]==0); //wait until new configuration takes effect
EnableInterrupts; //enable global interrupt
```

Configure for reconfigurable

```
DisableInterrupts; //disable global interrupt
WDOG_CNT = 0xD928C520; //unlock watchdog
while(WDOG_CS[ULK]==0);  //wait until registers are unlocked
WDOG_TOVAL = 256; //set timeout value
WDOG_CS = WDOG_CS_EN(1) | WDOG_CS_CLK(1) | WDOG_CS_INT(1) |
          WDOG_CS_WIN(0) | WDOG_CS_UPDATE(1);
while(WDOG_CS[RCS]==0); //wait until new configuration takes effect
EnableInterrupts; //enable global interrupt
```

24.5.3 Refreshing the Watchdog

To refresh the watchdog and reset the watchdog counter to zero, a refresh sequence is required:

```
DisableInterrupts; // disable global interrupt
WDOG_CNT = 0xB480A602; // refresh watchdog
EnableInterrupts; // enable global interrupt
```

Chapter 25
Cyclic Redundancy Check (CRC)

25.1 Introduction

The cyclic redundancy check (CRC) module generates 16/32-bit CRC code for error detection.

The CRC module provides a programmable polynomial and other parameters required to implement a 16-bit or 32-bit CRC standard.

The 16/32-bit code is calculated for 32 bits of data at a time.

25.1.1 Features

Features of the CRC module include:

- Hardware CRC generator circuit using a 16-bit or 32-bit programmable shift register
- Programmable initial seed value and polynomial
- Option to transpose input data or output data (the CRC result) bitwise or bytewise. This option is required for certain CRC standards. A bytewise transpose operation is not possible when accessing the CRC data register via 8-bit accesses. In this case, the user's software must perform the bytewise transpose function.
- Option for inversion of final CRC result
- 32-bit CPU register programming interface

25.1.2 Block diagram

The following is a block diagram of the CRC.

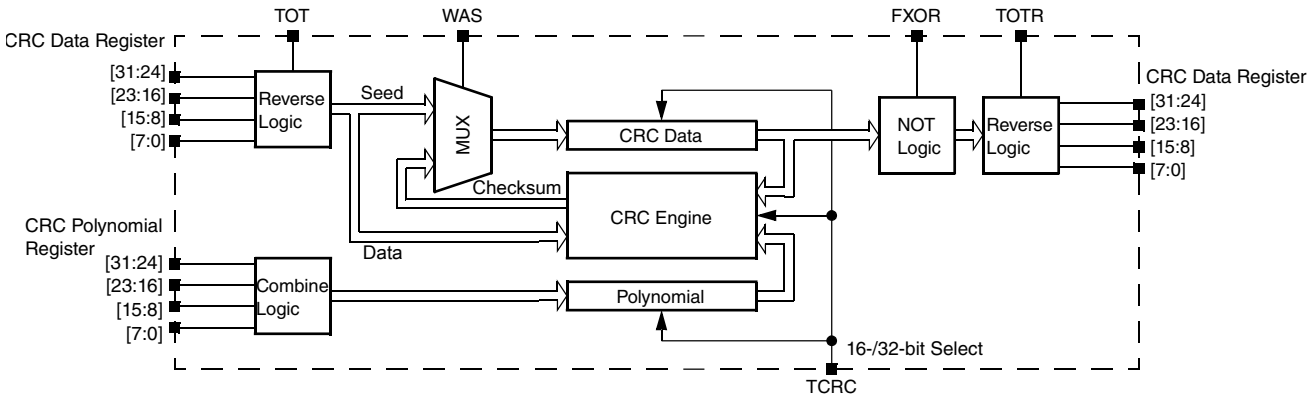


Figure 25-1. Programmable cyclic redundancy check (CRC) block diagram

25.1.3 Modes of operation

Various MCU modes affect the CRC module's functionality.

25.1.3.1 Run mode

This is the basic mode of operation.

25.1.3.2 Low-power modes (Wait or Stop)

Any CRC calculation in progress stops when the MCU enters a low-power mode that disables the module clock. It resumes after the clock is enabled or via the system reset for exiting the low-power mode. Clock gating for this module is dependent on the MCU.

25.2 Memory map and register descriptions

CRC memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4003_2000	CRC Data register (CRC_DATA)	32	R/W	FFFF_FFFFh	25.2.1/379
4003_2004	CRC Polynomial register (CRC_GPOLY)	32	R/W	0000_1021h	25.2.2/380
4003_2008	CRC Control register (CRC_CTRL)	32	R/W	0000_0000h	25.2.3/380

25.2.1 CRC Data register (CRC_DATA)

The CRC Data register contains the value of the seed, data, and checksum. When CTRL[WAS] is set, any write to the data register is regarded as the seed value. When CTRL[WAS] is cleared, any write to the data register is regarded as data for general CRC computation.

In 16-bit CRC mode, the HU and HL fields are not used for programming the seed value, and reads of these fields return an indeterminate value. In 32-bit CRC mode, all fields are used for programming the seed value.

When programming data values, the values can be written 8 bits, 16 bits, or 32 bits at a time, provided all bytes are contiguous; with MSB of data value written first.

After all data values are written, the CRC result can be read from this data register. In 16-bit CRC mode, the CRC result is available in the LU and LL fields. In 32-bit CRC mode, all fields contain the result. Reads of this register at any time return the intermediate CRC value, provided the CRC module is configured.

Address: 4003_2000h base + 0h offset = 4003_2000h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	HU								HL								LU								LL							
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

CRC_DATA field descriptions

Field	Description
31–24 HU	CRC High Upper Byte In 16-bit CRC mode (CTRL[TCRC] is 0), this field is not used for programming a seed value. In 32-bit CRC mode (CTRL[TCRC] is 1), values written to this field are part of the seed value when CTRL[WAS] is 1. When CTRL[WAS] is 0, data written to this field is used for CRC checksum generation in both 16-bit and 32-bit CRC modes.
23–16 HL	CRC High Lower Byte In 16-bit CRC mode (CTRL[TCRC] is 0), this field is not used for programming a seed value. In 32-bit CRC mode (CTRL[TCRC] is 1), values written to this field are part of the seed value when CTRL[WAS] is 1. When CTRL[WAS] is 0, data written to this field is used for CRC checksum generation in both 16-bit and 32-bit CRC modes.
15–8 LU	CRC Low Upper Byte When CTRL[WAS] is 1, values written to this field are part of the seed value. When CTRL[WAS] is 0, data written to this field is used for CRC checksum generation.
LL	CRC Low Lower Byte When CTRL[WAS] is 1, values written to this field are part of the seed value. When CTRL[WAS] is 0, data written to this field is used for CRC checksum generation.

25.2.2 CRC Polynomial register (CRC_GPOLY)

This register contains the value of the polynomial for the CRC calculation. The HIGH field contains the upper 16 bits of the CRC polynomial, which are used only in 32-bit CRC mode. Writes to the HIGH field are ignored in 16-bit CRC mode. The LOW field contains the lower 16 bits of the CRC polynomial, which are used in both 16- and 32-bit CRC modes.

Address: 4003_2000h base + 4h offset = 4003_2004h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	HIGH																LOW															
Reset	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	1	0	0	0	0	1

CRC_GPOLY field descriptions

Field	Description
31–16 HIGH	High Polynominal Half-word Writable and readable in 32-bit CRC mode (CTRL[TCRC] is 1). This field is not writable in 16-bit CRC mode (CTRL[TCRC] is 0).
LOW	Low Polynominal Half-word Writable and readable in both 32-bit and 16-bit CRC modes.

25.2.3 CRC Control register (CRC_CTRL)

This register controls the configuration and working of the CRC module. Appropriate bits must be set before starting a new CRC calculation. A new CRC calculation is initialized by asserting CTRL[WAS] and then writing the seed into the CRC data register.

Address: 4003_2000h base + 8h offset = 4003_2008h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	TOT		TOTR		0	FXOR	WAS	TCRC	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CRC_CTRL field descriptions

Field	Description
31–30 TOT	Type Of Transpose For Writes Defines the transpose configuration of the data written to the CRC data register. See the description of the transpose feature for the available transpose options. 00 No transposition. 01 Bits in bytes are transposed; bytes are not transposed. 10 Both bits in bytes and bytes are transposed. 11 Only bytes are transposed; no bits in a byte are transposed.
29–28 TOTR	Type Of Transpose For Read Identifies the transpose configuration of the value read from the CRC Data register. See the description of the transpose feature for the available transpose options. 00 No transposition. 01 Bits in bytes are transposed; bytes are not transposed. 10 Both bits in bytes and bytes are transposed. 11 Only bytes are transposed; no bits in a byte are transposed.
27 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
26 FXOR	Complement Read Of CRC Data Register Some CRC protocols require the final checksum to be XORed with 0xFFFFFFFF or 0xFFFF. Asserting this bit enables on the fly complementing of read data. 0 No XOR on reading. 1 Invert or complement the read value of the CRC Data register.
25 WAS	Write CRC Data Register As Seed When asserted, a value written to the CRC data register is considered a seed value. When deasserted, a value written to the CRC data register is taken as data for CRC computation. 0 Writes to the CRC data register are data values. 1 Writes to the CRC data register are seed values.
24 TCRC	Width of CRC protocol. 0 16-bit CRC protocol. 1 32-bit CRC protocol.
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

25.3 Functional description

25.3.1 CRC initialization/reinitialization

To enable the CRC calculation, the user must program CRC_CTRL[WAS], CRC_GPOLY,necessary parameters for transposition and CRC result inversion in the applicable registers. Asserting CRC_CTRL[WAS] enables the programming of the seed value into the CRC_DATA register.

After a completed CRC calculation, the module can be reinitialized for a new CRC computation by reasserting CRC_CTRL[WAS] and programming a new, or previously used, seed value. All other parameters must be set before programming the seed value and subsequent data values.

25.3.2 CRC calculations

In 16-bit and 32-bit CRC modes, data values can be programmed 8 bits, 16 bits, or 32 bits at a time, provided all bytes are contiguous. Noncontiguous bytes can lead to an incorrect CRC computation.

25.3.2.1 16-bit CRC

To compute a 16-bit CRC:

1. Clear CRC_CTRL[TCRC] to enable 16-bit CRC mode.
2. Program the transpose and complement options in the CTRL register as required for the CRC calculation. See Transpose feature and CRC result complement for details.
3. Write a 16-bit polynomial to the CRC_GPOLY[LOW] field. The CRC_GPOLY[HIGH] field is not usable in 16-bit CRC mode.
4. Set CRC_CTRL[WAS] to program the seed value.
5. Write a 16-bit seed to CRC_DATA[LU:LL]. CRC_DATA[HU:HL] are not used.
6. Clear CRC_CTRL[WAS] to start writing data values.
7. Write data values into CRC_DATA[HU:HL:LU:LL]. A CRC is computed on every data value write, and the intermediate CRC result is stored back into CRC_DATA[LU:LL].
8. When all values have been written, read the final CRC result from CRC_DATA[LU:LL].

Transpose and complement operations are performed on the fly while reading or writing values. See Transpose feature and CRC result complement for details.

25.3.2.2 32-bit CRC

To compute a 32-bit CRC:

1. Set CRC_CTRL[TCRC] to enable 32-bit CRC mode.
2. Program the transpose and complement options in the CTRL register as required for the CRC calculation. See Transpose feature and CRC result complement for details.
3. Write a 32-bit polynomial to CRC_GPOLY[HIGH:LOW].
4. Set CRC_CTRL[WAS] to program the seed value.
5. Write a 32-bit seed to CRC_DATA[HU:HL:LU:LL].
6. Clear CRC_CTRL[WAS] to start writing data values.
7. Write data values into CRC_DATA[HU:HL:LU:LL]. A CRC is computed on every data value write, and the intermediate CRC result is stored back into CRC_DATA[HU:HL:LU:LL].
8. When all values have been written, read the final CRC result from CRC_DATA[HU:HL:LU:LL]. The CRC is calculated bytewise, and two clocks are required to complete one CRC calculation.

Transpose and complement operations are performed on the fly while reading or writing values. See Transpose feature and CRC result complement for details.

25.3.3 Transpose feature

By default, the transpose feature is not enabled. However, some CRC standards require the input data and/or the final checksum to be transposed. The user software has the option to configure each transpose operation separately, as desired by the CRC standard. The data is transposed on the fly while being read or written.

Some protocols use little endian format for the data stream to calculate a CRC. In this case, the transpose feature usefully flips the bits. This transpose option is one of the types supported by the CRC module.

25.3.3.1 Types of transpose

The CRC module provides several types of transpose functions to flip the bits and/or bytes, for both writing input data and reading the CRC result, separately using the CTRL[TOT] or CTRL[TOTR] fields, according to the CRC calculation being used.

The following types of transpose functions are available for writing to and reading from the CRC data register:

1. CTRL[TOT] or CTRL[TOTR] is 00.

No transposition occurs.

2. CTRL[TOT] or CTRL[TOTR] is 01

   Bits in a byte are transposed, while bytes are not transposed.

   reg[31:0] becomes {reg[24:31], reg[16:23], reg[8:15], reg[0:7]}

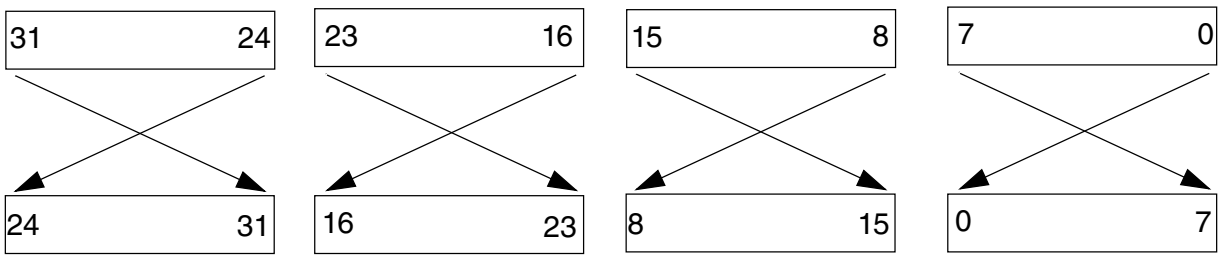


Figure 25-2. Transpose type 01

3. CTRL[TOT] or CTRL[TOTR] is 10.

   Both bits in bytes and bytes are transposed.

   reg[31:0] becomes = {reg[0:7], reg[8:15],reg[16:23], reg[24:31]}

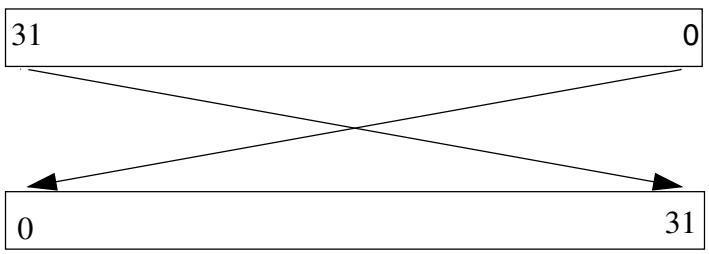


Figure 25-3. Transpose type 10

4. CTRL[TOT] or CTRL[TOTR] is 11.

   Bytes are transposed, but bits are not transposed.

   reg[31:0] becomes {reg[7:0], reg[15:8], reg[23:16], reg[31:24]}

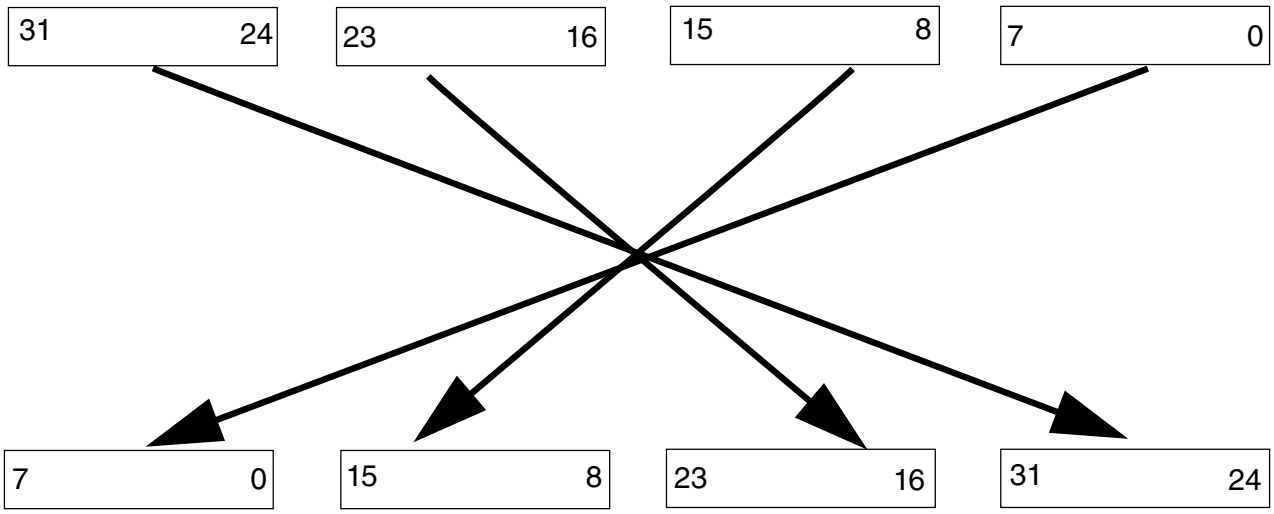


Figure 25-4. Transpose type 11

NOTE

- For 8-bit and 16-bit write accesses to the CRC data register, the data is transposed with zeros on the unused byte or bytes (taking 32 bits as a whole), but the CRC is calculated on the valid byte(s) only.
- When reading the CRC data register for a 16-bit CRC result and using transpose options 10 and 11, the resulting value after transposition resides in the CRC[HU:HL] fields. The user software must account for this situation when reading the 16-bit CRC result, so reading 32 bits is preferred.

25.3.4 CRC result complement

When CTRL[FXOR] is set, the checksum is complemented. The CRC result complement function outputs the complement of the checksum value stored in the CRC data register every time the CRC data register is read. When CTRL[FXOR] is cleared, reading the CRC data register accesses the raw checksum value.

25.4 Usage Guide

When programming data values, the values can be written 8 bits, 16 bits, or 32 bits at a time, provided all bytes are contiguous. The DATA register is written with MSB of data value first, thus the application with little-endian configured, the data write bytes transpose should be enabled when writing a 32bit value from variable to DATA register.

After all data values are written, the CRC result can be read from this data register. For a 16-bit CRC result, if transpose options 10 and 11 is used, the resulting value after transposition resides in the CRC[HU:HL] fields.

This section shows two examples of using CRC module to implement typical CRC algorithms, including both 32-bit and 16-bit algorithms.

25.4.1 32-bit POSIX CRC

CRC-32/POSIX: width=32 poly=0x04c11db7 init=0x00000000 refin=false refout=false xorout=0xffffffff check=0x765e7680

```
uint32_t checksum32, dataSize;
uint8_t data[] = "123456789";
uint32_t *data32;

// Transport Bytes for data write, as the CRC_DATA requires MSB write first
// No transport for checksum read, enable complement read as xorout not zero
CRC_CTRL = CRC_CTRL_TOT(3) | CRC_CTRL_TOTR(0) | CRC_CTRL_FXOR(1) |
           CRC_CTRL_TCRC(1) | CRC_CTRL_WAS(0);
// write polynomial register
CRC_GPOLY = 0x04c11bd7;
// write pre-computed control register value along with WAS to start checksum computation
CRC_CTRL |= CRC_CTRL_WAS(1);
// write seed (initial checksum)
CRC_DATA = 0;
// deassert WAS by writing pre-computed CRC control register value
CRC_CTRL &= ~CRC_CTRL_WAS(1);

// write data
dataSize = sizeof(data);
// 8-bit reads and writes till source address is aligned 4 bytes */
while ((data) && ((uint32_t)data & 3U))
{
    CRC_DATA = *data;
    data++;
    dataSize--;
}

// use 32-bit reads and writes as long as possible
data32 = (uint32_t *)data;
while (dataSize >= sizeof(uint32_t))
{
    CRC_DATA = *data32;
    data32++;
    dataSize -= sizeof(uint32_t);
}

data = (uint8_t *)data32;

// 8-bit reads and writes till end of data buffer
while (dataSize)
{
    CRC_DATA = *data;
    data++;
    dataSize--;
}

// read 32bit checksum result
checksum32 = CRC_DATA;
```

25.4.2 16-bit KERMIT CRC

CRC-16/KERMIT: width=16 poly=0x1021 init=0x0000 refin=true refout=true xorout=0x0000 check=0x2189

```
uint32_t checksum16, dataSize;
uint8_t data[] = "123456789";
uint32_t *data32;

// Transport Bytes and Bits for both data write and read
// Bytes transport is because of the CRC_DATA requires MSB write first
// Bits transport is because of the KERMIT algorithm requirement
// No complement for checksum result
CRC_CTRL = CRC_CTRL_TOT(2) | CRC_CTRL_TOTR(2) | CRC_CTRL_FXOR(0) |
           CRC_CTRL_TCRC(0) | CRC_CTRL_WAS(0);
// write polynomial register
CRC_GPOLY = 0x1021;
// write pre-computed control register value along with WAS to start checksum computation
CRC_CTRL |= CRC_CTRL_WAS(1);
// write seed (initial checksum)
CRC_DATA = 0;
// deassert WAS by writing pre-computed CRC control register value
CRC_CTRL &= ~CRC_CTRL_WAS(1);

// write data
dataSize = sizeof(data);
// 8-bit reads and writes till source address is aligned 4 bytes */
while ((data) && ((uint32_t)data & 3U))
{
    CRC_DATA = *data;
    data++;
    dataSize--;
}

// use 32-bit reads and writes as long as possible
data32 = (uint32_t *)data;
while (dataSize >= sizeof(uint32_t))
{
    CRC_DATA = *data32;
    data32++;
    dataSize -= sizeof(uint32_t);
}

data = (uint8_t *)data32;

// 8-bit reads and writes till end of data buffer
while (dataSize)
{
    CRC_DATA = *data;
    data++;
    dataSize--;
}

// due to the transport option TOTR >= 2
// read 16bit checksum result from CRC_DATA[HU:HL]
// otherwise, read checksum from CRC_DATA[LU:LL]
checksum16 = (CRC_DATA & 0xFFFF0000) >> 16;
```

Chapter 26
Debug

26.1 Introduction

This device's debug is based on the ARM CoreSight architecture and is configured to provide the maximum flexibility as allowed by the restrictions of the pinout and other available resources.

It provides register and memory accessibility from the external debugger interface, basic run/halt control plus 2 breakpoints and 2 watchpoints. Additionally, it supports ARM's Basic BranchBuffer (BBB) capability to provide simple program trace.

This device supports only one debug interface, Serial Wire Debug (SWD).

26.2 Debug port pin descriptions

The debug port pins default to their SWD functionality after power-on-reset (POR).

Table 26-1. Serial wire debug pin description

Pin Name	Type	Description
SWD_CLK	Input	Serial Wire Clock. This pin is the clock for debug logic when in the Serial Wire Debug mode.
SWD_DIO	Input / Output	Serial Wire Debug Data input/output. The SWD_DIO pin is used by an external debug tool for communication and device control. This pin is pulled up internally.

26.3 SWD status and control registers

Through the ARM Debug Access Port (DAP), the debugger has access to the status and control elements, implemented as registers on the DAP bus as shown in Figure 26-1. These registers provide additional control and status for low-power mode recovery and

typical run-control scenarios. The status register bits also provide a means for the debugger to get updated status of the core without having to initiate a bus transaction across the crossbar switch, thus remaining less intrusive during a debug session.

A miscellaneous debug module (MDM) is implemented on this device, which contains the DAP control and status registers. It is important to note that these DAP control and status registers are not memory-mapped within the system memory map and are only accessible via the Debug Access Port using SWD. The MDM-AP is accessible as Debug Access Port 1 with the available registers shown in the table below.

Table 26-2. MDM-AP register summary

Address	Register	Description
0x0100_0000	Status	See MDM-AP status register
0x0100_0004	Control	See MDM-AP Control register
0x0100_00FC	IDR	Read-only identification register that always reads as 0x001C_0020

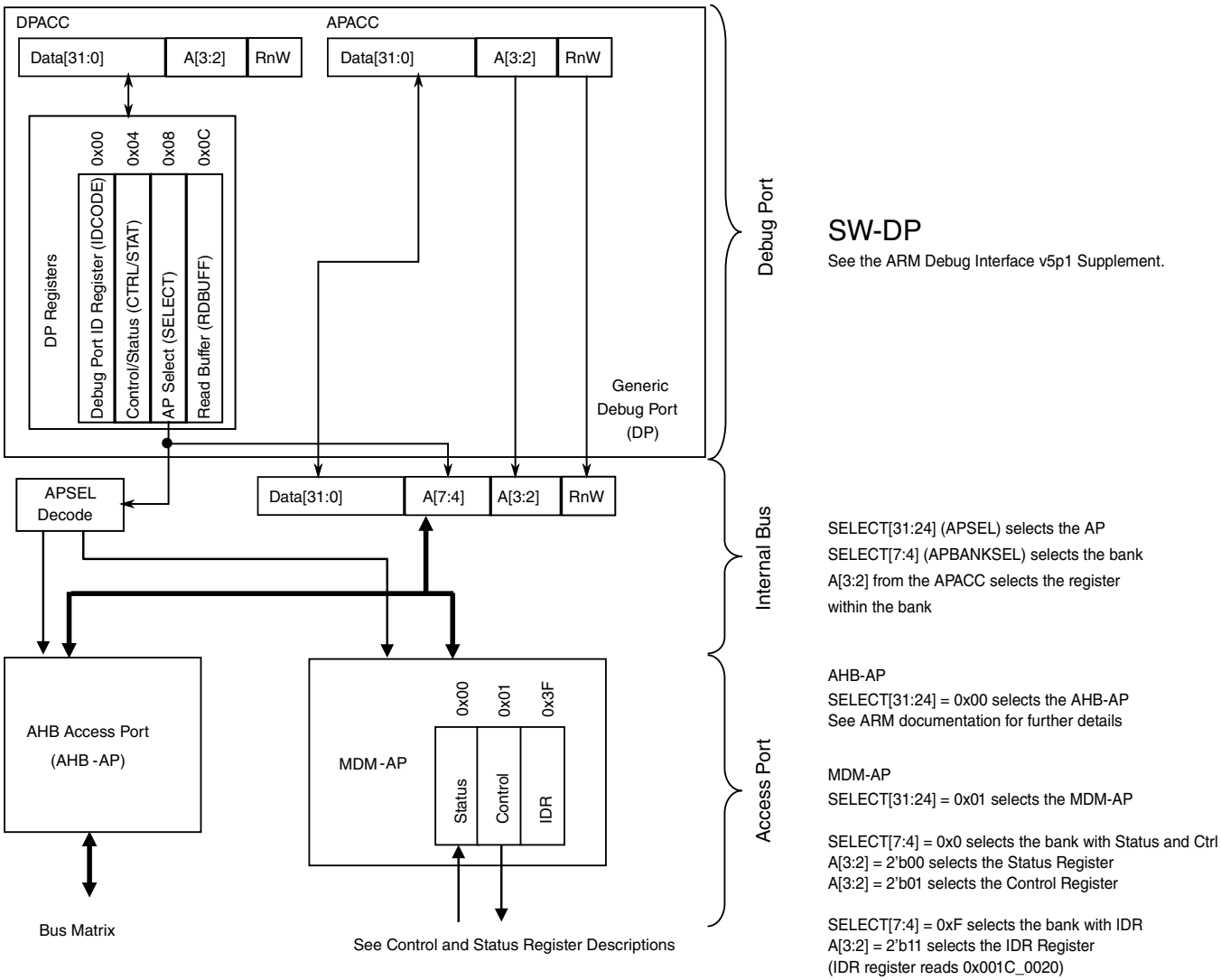


Figure 26-1. MDM AP addressing

26.3.1 MDM-AP status register

Table 26-3. MDM-AP status register assignments

Bit	Name	Description
0	Flash Mass Erase Acknowledge	The Flash Mass Erase Acknowledge field is cleared after POR reset. The field is also cleared at launch of a mass erase command due to write of Flash Mass Erase in Progress field in MDM AP Control Register. The Flash Mass Erase Acknowledge is set after Flash control logic has started the mass erase operation.
1	Flash Ready	Indicates that flash memory has been initialized and debugger can be configured even if system is continuing to be held in reset via the debugger. 0 Flash is under initialization.

Table continues on the next page...

Table 26-3. MDM-AP status register assignments (continued)

Bit	Name	Description
		1 Flash is ready.
2	System Security	Indicates the security state. When secure, the debugger does not have access to the system bus or any memory mapped peripherals. This field indicates when the part is locked and no system bus access is possible. **NOTE:** This bit is not valid until Flash Ready bit set. 0 Device is unsecured. 1 Device is secured.
3	System Reset	Indicates the system reset state. 0 System is in reset. 1 System is not in reset.
4	Reserved	
5 – 15	Reserved for future use	Always read 0.
16	Core Halted	Indicates the core has entered Debug Halt mode 0 Core is not halted. 1 Core is halted.
17	Core SLEEPDEEP	SLEEPDEEP=1 indicates the core has entered Stop mode.
18	Core SLEEPING	SLEEPING=1 indicates the core has entered Wait mode.
19 – 31	Reserved for future use	Always reads 0.

26.3.2 MDM-AP Control register

Table 26-4. MDM-AP Control register assignments

Bit	Name	Secure[1]	Description
0	Flash Mass Erase in Progress	Y	Set to cause mass erase. Cleared by hardware after mass erase operation completes.
1	Debug Disable	N	Set to disable debug. Clear to allow debug operation. When set, it overrides the C_DEBUGEN field within the DHCSR[2] and forces to disable Debug logic.
2	Debug Request	N	Set to force the core to halt. If the core is in Stop or Wait mode, this field can be used to wake the core and transition to a halted state.
3	System Reset Request	Y	Set to force a system reset. The system remains held in reset until this field is cleared. When this bit is set, $\overline{\text{RESET}}$ pin does not reflect the status of system reset and does not keep low.
4	Core Hold	N	Configuration field to control core operation at the end of system reset sequencing. 0 Normal operation—release the core from reset along with the rest of the system at the end of system reset sequencing.

Table continues on the next page...

Table 26-4. MDM-AP Control register assignments (continued)

Bit	Name	Secure[1]	Description
			1 Suspend operation—hold the core in reset at the end of reset sequencing. Once the system enters this suspended state, clearing this control bit immediately releases the core from reset and CPU operation begins.
5– 31	Reserved for future use	N	

1. Command available in secure mode
2. DHCSR: refer to the Debug Halting Control and Status Register in the ARMv6-M Architecture Reference Mannual.

26.4 Debug resets

The debug system receives the following sources of reset:

- System POR reset

Conversely, the debug system is capable of generating system reset using the following mechanism:

- A system reset in the DAP control register which allows the debugger to hold the system in reset.
- Writing 1 to the SYSRESETREQ field in the NVIC Application Interrupt and Reset Control register
- A system reset in the DAP control register which allows the debugger to hold the core in reset.

26.5 Micro Trace Buffer (MTB)

The Micro Trace Buffer (MTB) provides a simple execution trace capability for the Cortex-M0+ processor. When enabled, the MTB records changes in program flow reported by the Cortex-M0+ processor, via the execution trace interface, into a configurable region of the SRAM. Subsequently an off-chip debugger may extract the trace information, which would allow reconstruction of an instruction flow trace. The MTB does not include any form of load/store data trace capability or tracing of any other information.

In addition to providing the trace capability, the MTB also operates as a simple AHB-Lite SRAM controller. The system bus masters, including the processor, have read/write access to all of the SRAM via the AHB-Lite interface, allowing the memory to also be used to store program and data information. The MTB simultaneously stores the trace

information into an attached SRAM and allows bus masters to access the memory. The MTB ensures that trace information write accesses to the SRAM take priority over accesses from the AHB-Lite interface.

The MTB includes trace control registers for configuring and triggering the MTB functions. The MTB also supports triggering via TSTART and TSTOP control functions in the MTB DWT module.

26.6 Debug in low-power modes

In low-power modes in which the debug modules are kept static or powered off, the debugger cannot gather any debug data for the duration of the low-power mode.

- If the debugger is held static, the debug port returns to full functionality as soon as the low-power mode exits and the system returns to a state with active debug.
- If the debugger logic is powered off, the debugger is reset on recovery and must be reconfigured once the low-power mode is exited.

The active debug will prevent the chip from entering low-power mode. In case the chip is already in low-power mode, a debug request from MDM-AP control register will wake the chip from low-power mode.

26.7 Debug and security

When flash security is enabled, the debug port capabilities are limited in order to prevent exploitation of secure data. In the secure state, the debugger still has access to the status register and can determine the current security state of the device. In the case of a secure device, the debugger has the capability of performing only a mass erase operation.

Chapter 27
Micro Trace Buffer (MTB)

27.1 Introduction

Microcontrollers using the Cortex-M0+ processor core include support for a CoreSight Micro Trace Buffer to provide program trace capabilities.

The proper name for this function is the CoreSight Micro Trace Buffer for the Cortex-M0+ Processor; in this document, it is simply abbreviated as the MTB.

The simple program trace function creates instruction address change-of-flow data packets in a user-defined region of the system RAM. Accordingly, the system RAM controller manages requests from two sources:

- AMBA-AHB reads and writes from the system bus
- program trace packet writes from the processor

As part of the MTB functionality, there is a DWT (Data Watchpoint and Trace) module that allows the user to define watchpoint addresses, or optionally, an address and data value, that when triggered, can be used to start or stop the program trace recording.

This document details the functionality of both the MTB_RAM and MTB_DWT capabilities.

27.1.1 Overview

A generic block diagram of the processor core and platform for this class of ultra low-end microcontrollers is shown as follows:

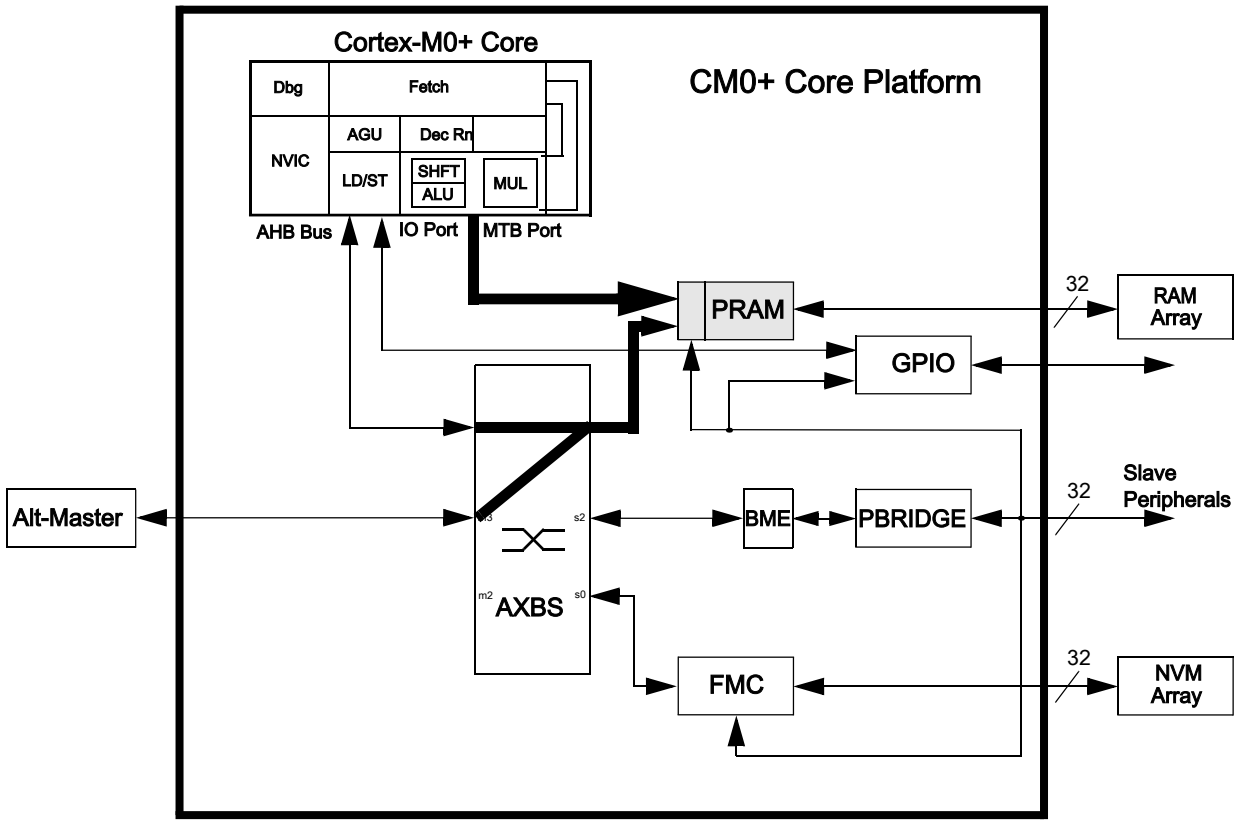


Figure 27-1. Generic Cortex-M0+ core platform block diagram

As shown in the block diagram, the platform RAM (PRAM) controller connects to two input buses:

- the crossbar slave port for system bus accesses
- a "private execution MTB port" from the core

The logical paths from the crossbar master input ports to the PRAM controller are highlighted along with the private execution trace port from the processor core. The private MTB port signals the instruction address information needed for the 64-bit program trace packets written into the system RAM. The PRAM controller output interfaces to the attached RAM array. In this document, the PRAM controller is the MTB_RAM controller.

The following information is taken from the Arm CoreSight Micro Trace Buffer documentation.

"The execution trace packet consists of a pair of 32-bit words that the MTB generates when it detects the processor PC value changes non-sequentially. A non-sequential PC change can occur during branch instructions or during exception entry.

The processor can cause a trace packet to be generated for any instruction.

The following figure shows how the execution trace information is stored in memory as a sequence of packets.

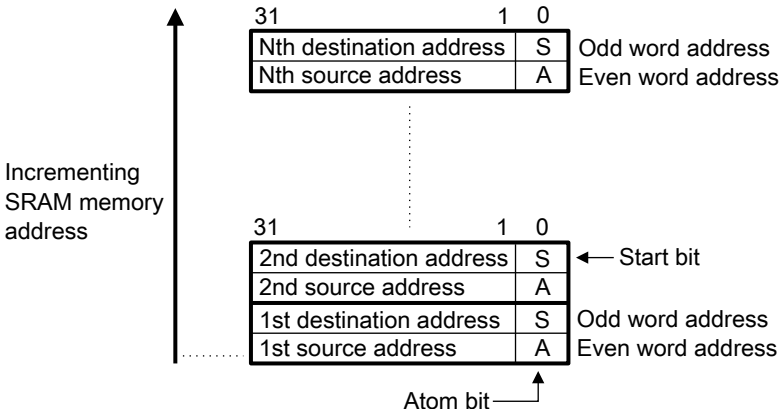


Figure 27-2. MTB execution trace storage format

The first, lower addressed, word contains the source of the branch, the address it branched from. The value stored only records bits[31:1] of the source address, because Thumb instructions are at least halfword aligned. The least significant bit of the value is the A-bit. The A-bit indicates the atomic state of the processor at the time of the branch, and can differentiate whether the branch originated from an instruction in a program, an exception, or a PC update in Debug state. When it is zero the branch originated from an instruction, when it is one the branch originated from an exception or PC update in Debug state. This word is always stored at an even word location.

The second, higher addressed word contains the destination of the branch, the address it branched to. The value stored only records bits[31:1] of the branch address. The least significant bit of the value is the S-bit. The S-bit indicates where the trace started. An S-bit value of 1 indicates where the first packet after the trace started and a value of 0 is used for other packets. Because it is possible to start and stop tracing multiple times in a trace session, the memory might contain several packets with the S-bit set to 1. This word is always stored in the next higher word in memory, an odd word address.

When the A-bit is set to 1, the source address field contains the architecturally-preferred return address for the exception. For example, if an exception was caused by an SVC instruction, then the source address field contains the address of the following instruction. This is different from the case where the A-bit is set to 0. In this case, the source address contains the address of the branch instruction.

For an exception return operation, two packets are generated:

- The first packet has the:
  - Source address field set to the address of the instruction that causes the exception return, BX or POP.

    - Destination address field set to bits[31:1] of the EXC_RETURN value. See the Arm v6-M Architecture Reference Manual.
    - The A-bit set to 0.

- The second packet has the:
    - Source address field set to bits[31:1] of the EXC_RETURN value.
    - Destination address field set to the address of the instruction where execution commences.
    - A-bit set to 1."

Given the recorded change-of-flow trace packets in system RAM and the memory image of the application, a debugger can read out the data and create an instruction-by-instruction program trace. In keeping with the low area and power implementation cost design targets, the MTB trace format is less efficient than other CoreSight trace modules, for example, the ETM (Embedded Trace Macrocell). Since each branch packet is 8 bytes in size, a 1 KB block of system RAM can contain 128 branches. Using the Dhrystone 2.1 benchmark's dynamic runtime as an example, this corresponds to about 875 instructions per KB of trace RAM, or with a zero wait state memory, this corresponds to approximately 1600 processor cycles per KB. This metric is obviously very sensitive to the runtime characteristics of the user code.

The MTB_DWT function (not shown in the core platform block diagram) monitors the processor address and data buses so that configurable watchpoints can be detected to trigger the appropriate response in the MTB recording.

27.1.2 Features

The key features of the MTB_RAM and MTB_DWT include:

- Memory controller for system RAM and Micro Trace Buffer for program trace packets
- Read/write capabilities for system RAM accesses, write-only for program trace packets
- Supports zero wait state response to system bus accesses when no trace data is being written
- Can buffer two AHB address phases and one data write for system RAM accesses
- Supports 64-bit program trace packets including source and destination instruction addresses
- Program trace information in RAM available to MCU's application code or external debugger
- Program trace watchpoint configuration accessible by MCU's application code or debugger
- Location and size of RAM trace buffer is configured by software

- Two DWT comparators (addresses or address + data) provide programmable start/ stop recording
- CoreSight compliant debug functionality

27.1.3 Modes of operation

The MTB_RAM and MTB_DWT functions do not support any special modes of operation. The MTB_RAM controller, as a memory-mapped device located on the platform's slave AHB system bus, responds strictly on the basis of memory addresses for accesses to its attached RAM array. The MTB private execution bus provides program trace packet write information to the RAM controller. Both the MTB_RAM and MTB_DWT modules are memory-mapped, so their programming models can be accessed.

All functionality associated with the MTB_RAM and MTB_DWT modules resides in the core platform's clock domain; this includes its connections with the RAM array.

27.2 External signal description

The MTB_RAM and MTB_DWT modules do not directly support any external interfaces.

The internal interface includes a standard AHB bus with a 32-bit datapath width from the appropriate crossbar slave port plus the private execution trace bus from the processor core. The signals in the private execution trace bus are detailed in the following table taken from the Arm CoreSight Micro Trace Buffer documentation. The signal direction is defined as viewed by the MTB_RAM controller.

Table 27-1. Private execution trace port from the core to MTB_RAM

Signal	Direction	Description
LOCKUP	Input	Indicates the processor is in the Lockup state. This signal is driven LOW for cycles when the processor is executing normally and driven HIGH for every cycle the processor is waiting in the Lockup state. This signal is valid on every cycle.
IAESEQ	Input	Indicates the next instruction address in execute, IAEX, is sequential, that is non-branching.
IAEXEN	Input	IAEX register enable.
IAEX[30:0]	Input	Registered address of the instruction in the execution stage, shifted right by one bit, that is, PC >> 1.
ATOMIC	Input	Indicates the processor is performing non-instruction related activities.
EDBGRQ	Output	Request for the processor to enter the Debug state, if enabled, and halt.

In addition, there are two signals formed by the MTB_DWT module and driven to the MTB_RAM controller: TSTART (trace start) and TSTOP (trace stop). These signals can be configured using the trace watchpoints to define programmable addresses and data values to affect the program trace recording state.

27.3 Memory map and register definition

The MTB_RAM and MTB_DWT modules each support a sparsely-populated 4 KB address space for their programming models. For each address space, there are a variety of control and configurable registers near the base address, followed by a large unused address space and finally a set of CoreSight registers to support dynamic determination of the debug configuration for the device.

Accesses to the programming model follow standard Arm conventions. Taken from the Arm CoreSight Micro Trace Buffer documentation, these are:

- Do not attempt to access reserved or unused address locations. Attempting to access these locations can result in UNPREDICTABLE behavior.
- The behavior of the MTB is UNPREDICTABLE if the registers with UNKNOWN reset values are not programmed prior to enabling trace.
- Unless otherwise stated in the accompanying text:
  - Do not modify reserved register bits
  - Ignore reserved register bits on reads
  - All register bits are reset to a logic 0 by a system or power-on reset
  - Use only word size, 32-bit, transactions to access all registers

27.3.1 MTB_RAM Memory Map

MTB memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F000_0000	MTB Position Register (MTB_POSITION)	32	R/W	Undefined	27.3.1.1/402
F000_0004	MTB Master Register (MTB_MASTER)	32	R/W	See section	27.3.1.2/403
F000_0008	MTB Flow Register (MTB_FLOW)	32	R/W	Undefined	27.3.1.3/405
F000_000C	MTB Base Register (MTB_BASE)	32	R	Undefined	27.3.1.4/407
F000_0F00	Integration Mode Control Register (MTB_MODECTRL)	32	R	0000_0000h	27.3.1.5/407
F000_0FA0	Claim TAG Set Register (MTB_TAGSET)	32	R	0000_0000h	27.3.1.6/408
F000_0FA4	Claim TAG Clear Register (MTB_TAGCLEAR)	32	R	0000_0000h	27.3.1.7/408
F000_0FB0	Lock Access Register (MTB_LOCKACCESS)	32	R	0000_0000h	27.3.1.8/409

Table continues on the next page...

MTB memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F000_0FB4	Lock Status Register (MTB_LOCKSTAT)	32	R	0000_0000h	27.3.1.9/409
F000_0FB8	Authentication Status Register (MTB_AUTHSTAT)	32	R	0000_0000h	27.3.1.10/ 409
F000_0FBC	Device Architecture Register (MTB_DEVICEARCH)	32	R	4770_0A31h	27.3.1.11/ 410
F000_0FC8	Device Configuration Register (MTB_DEVICECFG)	32	R	0000_0000h	27.3.1.12/ 411
F000_0FCC	Device Type Identifier Register (MTB_DEVICETYPID)	32	R	0000_0031h	27.3.1.13/ 411
F000_0FD0	Peripheral ID Register (MTB_PERIPHID4)	32	R	See section	27.3.1.14/ 412
F000_0FD4	Peripheral ID Register (MTB_PERIPHID5)	32	R	See section	27.3.1.14/ 412
F000_0FD8	Peripheral ID Register (MTB_PERIPHID6)	32	R	See section	27.3.1.14/ 412
F000_0FDC	Peripheral ID Register (MTB_PERIPHID7)	32	R	See section	27.3.1.14/ 412
F000_0FE0	Peripheral ID Register (MTB_PERIPHID0)	32	R	See section	27.3.1.14/ 412
F000_0FE4	Peripheral ID Register (MTB_PERIPHID1)	32	R	See section	27.3.1.14/ 412
F000_0FE8	Peripheral ID Register (MTB_PERIPHID2)	32	R	See section	27.3.1.14/ 412
F000_0FEC	Peripheral ID Register (MTB_PERIPHID3)	32	R	See section	27.3.1.14/ 412
F000_0FF0	Component ID Register (MTB_COMPID0)	32	R	See section	27.3.1.15/ 412
F000_0FF4	Component ID Register (MTB_COMPID1)	32	R	See section	27.3.1.15/ 412
F000_0FF8	Component ID Register (MTB_COMPID2)	32	R	See section	27.3.1.15/ 412
F000_0FFC	Component ID Register (MTB_COMPID3)	32	R	See section	27.3.1.15/ 412

27.3.1.1 MTB Position Register (MTB_POSITION)

The MTB_POSITION register contains the Trace Write Address Pointer and Wrap fields. This register can be modified by the explicit programming model writes. It is also automatically updated by the MTB hardware when trace packets are being recorded.

The base address of the system RAM in the memory map dictates special consideration for the placement of the MTB. Consider the following guidelines:

For the standard configuration where the size of the MTB is ≤ 25% of the total RAM capacity, it is recommended the MTB be based at the address defined by the MTB_BASE register. The read-only MTB_BASE register is defined by the expression (0x2000_0000 - (RAM_Size/4)). For this configuration, the MTB_POSITION register is initialized to MTB_BASE & 0x0000_7FF8.

If the size of the MTB is more than 25% but less than or equal to 50% of the total RAM capacity, it is recommended the MTB be based at address 0x2000_0000. In this configuration, the MTB_POSITION register is initialized to (0x2000_0000 & 0x0000_7FF8) = 0x0000_00000.

Following these two suggested placements provides a full-featured circular memory buffer containing program trace packets.

In the unlikely event an even larger trace buffer is required, a write-once capacity of 75% of the total RAM capacity can be based at address 0x2000_0000. The MTB_POSITION register is initialized to (0x2000_0000 & 0x0000_7FF8) = 0x0000_0000. However, this configuration cannot support operation as a circular queue and instead requires the use of the MTB_FLOW[WATERMARK] capability to automatically disable tracing or halting the processor as the number of packet writes approach the buffer capacity. See the MTB_FLOW register description for more details.

Address: F000_0000h base + 0h offset = F000_0000h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	POINTER															
W																
Reset	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	POINTER													WRAP	0	
W																
Reset	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	0	0

* Notes:
- x = Undefined at reset.

MTB_POSITION field descriptions

Field	Description
31–3 POINTER	Trace Packet Address Pointer[28:0] Because a packet consists of two words, the POINTER field is the address of the first word of a packet. This field contains bits[31:3] of the RAM address where the next trace packet is written. Therefore, it points to an unused location and is automatically incremented.

Table continues on the next page...

MTB_POSITION field descriptions (continued)

Field	Description

	A debug agent can calculate the system memory map address for the current location in the MTB using the following "generic" equation:
	Given mtb_size = 1 << (MTB_MASTER[MASK] + 4),
	systemAddress = MTB_BASE + (((MTB_POSITION & 0xFFFF_FFF8) + (mtb_size - (MTB_BASE & (mtb_size-1)))) & 0x0000_7FF8);
	For this device, a simpler expression also applies. See the following pseudo-code:
	if ((MTB_POSITION >> 13) == 0x3) systemAddress = (0x1FFF << 16) + (0x1 << 15) + (MTB_POSITION & 0x7FF8); else systemAddress = (0x2000 << 16) + (0x0 << 15) + (MTB_POSITION & 0x7FF8);
	NOTE: The size of the RAM is parameterized and the most significant bits of the POINTER field are RAZ/WI.
	For these devices, POSITION[31:15] == POSITION[POINTER[28:12]] are RAZ/WI. Therefore, the active bits in this field are POSITION[14:3] == POSITION[POINTER[11:0]].

2 WRAP	WRAP This field is set to 1 automatically when the POINTER value wraps as determined by the MTB_MASTER[MASK] field in the MASTER Trace Control Register. A debug agent might use the WRAP field to determine whether the trace information above and below the pointer address is valid.
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

27.3.1.2 MTB Master Register (MTB_MASTER)

The MTB_MASTER register contains the main program trace enable plus other trace controls. This register can be modified by the explicit programming model writes. MTB_MASTER[EN] and MTB_MASTER[HALTREQ] fields are also automatically updated by the MTB hardware.

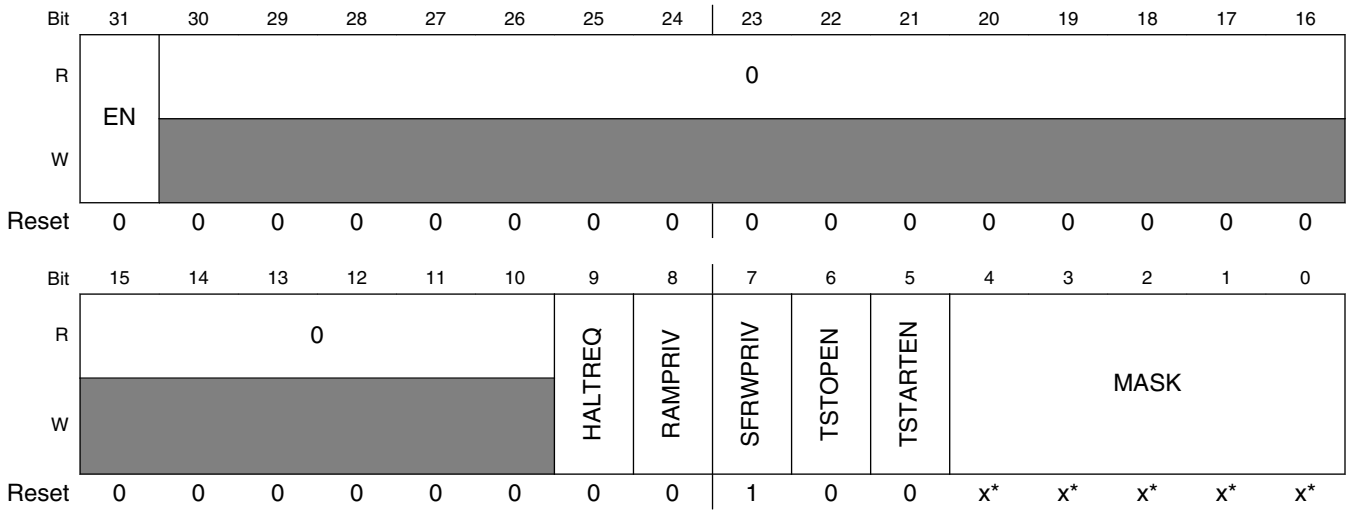
Before MTB_MASTER[EN] or MTB_MASTER[TSTARTEN] are set to 1, the software must initialize the MTB_POSITION and MTB_FLOW registers.

If MTB_FLOW[WATERMARK] is used to stop tracing or to halt the processor, MTB_MASTER[MASK] must still be set to a value that prevents MTB_POSITION[POINTER] from wrapping before it reaches the MTB_FLOW[WATERMARK] value.

NOTE

The format of this mask field is different than MTBDWT_MASKn[MASK].

Address: F000_0000h base + 4h offset = F000_0004h



* Notes:
- x = Undefined at reset.

MTB_MASTER field descriptions

Field	Description
31 EN	Main Trace Enable When this field is 1, trace data is written into the RAM memory location addressed by MTB_POSITION[POINTER]. The MTB_POSITION[POINTER] value auto increments after the trace data packet is written. EN can be automatically set to 0 using the MTB_FLOW[WATERMARK] field and the MTB_FLOW[AUTOSTOP] bit. EN is automatically set to 1 if TSTARTEN is 1 and the TSTART signal is HIGH. EN is automatically set to 0 if TSTOPEN is 1 and the TSTOP signal is HIGH. **NOTE:** If EN is set to 0 because MTB_FLOW[WATERMARK] is set, then it is not automatically set to 1 if TSTARTEN is 1 and the TSTART input is HIGH. In this case, tracing can only be restarted if MTB_FLOW[WATERMARK] or MTB_POSITION[POINTER] value is changed by software.
30–10 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
9 HALTREQ	Halt Request This field is connected to the halt request signal of the trace logic, EDBGRQ. When HALTREQ is set to 1, the EDBFGRQ is asserted if DBGEN (invasive debug enable, one of the debug authentication interface signals) is also HIGH. HALTREQ can be automatically set to 1 using MTB_FLOW[WATERMARK].
8 RAMPRIV	RAM Privilege If this field is 0, then user or privileged AHB read and write accesses to the RAM are permitted. If this field is 1, then only privileged AHB read and write accesses to the RAM are permitted and user accesses are RAZ/WI. The HPROT[1] signal determines if an access is a user or privileged mode reference.
7 SFRWPRIV	Special Function Register Write Privilege If this field is 0, then user or privileged AHB read and write accesses to the MTB_RAM Special Function Registers (programming model) are permitted. If this field is 1, then only privileged write accesses are

Table continues on the next page...

MTB_MASTER field descriptions (continued)

Field	Description
	permitted; user write accesses are ignored. The HPROT[1] signal determines if an access is user or privileged. Note MTB_RAM SFR read access are not controlled by this bit and are always permitted.
6 TSTOPEN	Trace Stop Input Enable If this field is 1 and the TSTOP signal is HIGH, then EN is set to 0. If a trace packet is being written to memory, the write is completed before tracing is stopped.
5 TSTARTEN	Trace Start Input Enable If this field is 1 and the TSTART signal is HIGH, then EN is set to 1. Tracing continues until a stop condition occurs.
MASK	Mask This value determines the maximum size of the trace buffer in RAM. It specifies the most-significant bit of the MTB_POSITION[POINTER] field that can be updated by automatic increment. If the trace tries to advance past this power of 2, the MTB_POSITION[WRAP] bit is set to 1, the MTB_POSITION[MASK+3:3] == MTB_POSITION[POINTER[MASK:0]] bits are set to 0, and the MTB_POSITION[14:MASK+3] == MTB_POSITION[POINTER[11:MASK+1]] bits remain unchanged. This field causes the trace packet information to be stored in a circular buffer of size 2^[MASK+4] bytes, that can be positioned in memory at multiples of this size. As detailed in the MTB_POSITION description, typical "upper limits" for the MTB size are RAM_Size/4 or RAM_Size/2. Values greater than the maximum have the same effect as the maximum.

27.3.1.3 MTB Flow Register (MTB_FLOW)

The MTB_FLOW register contains the watermark address and the autostop/autohalt control bits.

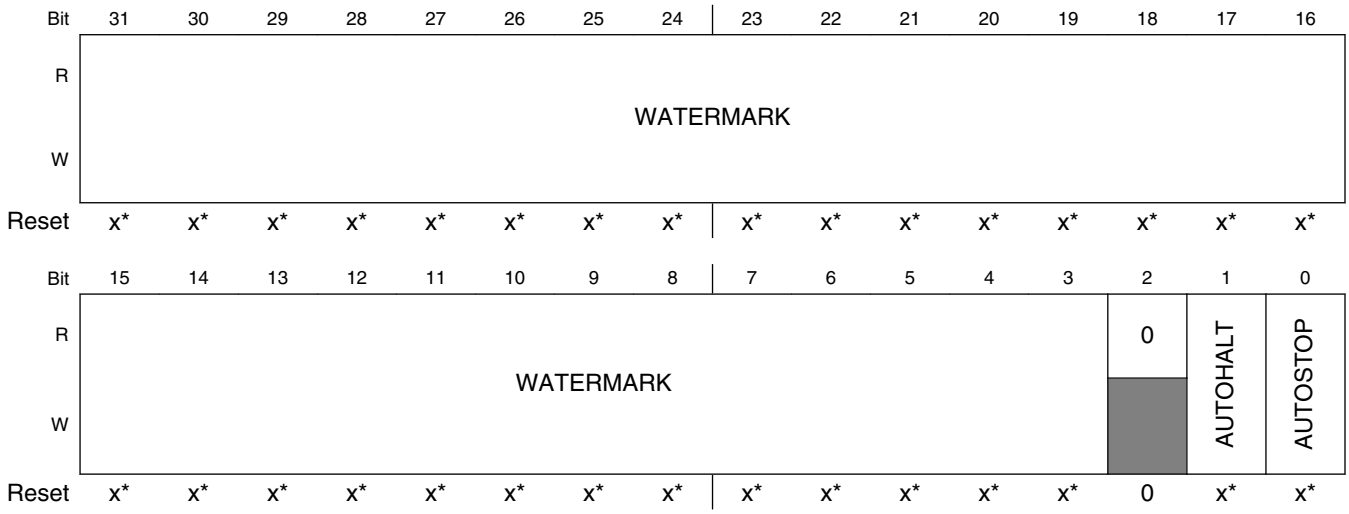
If tracing is stopped using the watermark autostop feature, it cannot be restarted until software clears the watermark autostop. This can be achieved in one of the following ways:

- Changing the MTB_POSITION[POINTER] field value to point to the beginning of the trace buffer, or
- Setting MTB_FLOW[AUTOSTOP] = 0.

A debug agent can use MTB_FLOW[AUTOSTOP] to fill the trace buffer once only without halting the processor.

A debug agent can use MTB_FLOW[AUTOHALT] to fill the trace buffer once before causing the Cortex-M0+ processor to enter the Debug state. To enter Debug state, the Cortex-M0+ processor might have to perform additional branch type operations. Therefore, the MTB_FLOW[WATERMARK] field must be set below the final entry in the trace buffer region.

Address: F000_0000h base + 8h offset = F000_0008h



* Notes:
- x = Undefined at reset.

MTB_FLOW field descriptions

Field	Description
31–3 WATERMARK	WATERMARK[28:0] This field contains an address in the same format as the MTB_POSITION[POINTER] field. When MTB_POSITION[POINTER] matches the WATERMARK field value, actions defined by the AUTOHALT and AUTOSTOP bits are performed.
2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 AUTOHALT	AUTOHALT If this field is 1 and WATERMARK is equal to MTB_POSITION[POINTER], then MTB_MASTER[HALTREQ] is automatically set to 1. If the DBGEN signal is HIGH, the MTB asserts this halt request to the Cortex-M0+ processor by asserting the EDBGRQ signal.
0 AUTOSTOP	AUTOSTOP If this field is 1 and WATERMARK is equal to MTB_POSITION[POINTER], then MTB_MASTER[EN] is automatically set to 0. This stops tracing.

27.3.1.4 MTB Base Register (MTB_BASE)

The read-only MTB_BASE Register indicates where the RAM is located in the system memory map. This register is provided to enable auto discovery of the MTB RAM location, by a debug agent and is defined by a hardware design parameter. For this device, the base address is defined by the expression: MTB_BASE[BASEADDR] = 0x2000_0000 - (RAM_Size/4)

Address: F000_0000h base + Ch offset = F000_000Ch

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

* Notes:
- x = Undefined at reset.

MTB_BASE field descriptions

Field	Description
BASEADDR	BASEADDR This value is defined with a hardwired signal and the expression: 0x2000_0000 - (RAM_Size/4). For example, if the total RAM capacity is 16 KB, this field is 0x1FFF_F000.

27.3.1.5 Integration Mode Control Register (MTB_MODECTRL)

This register enables the device to switch from a functional mode, or default behavior, into integration mode. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + F00h offset = F000_0F00h

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

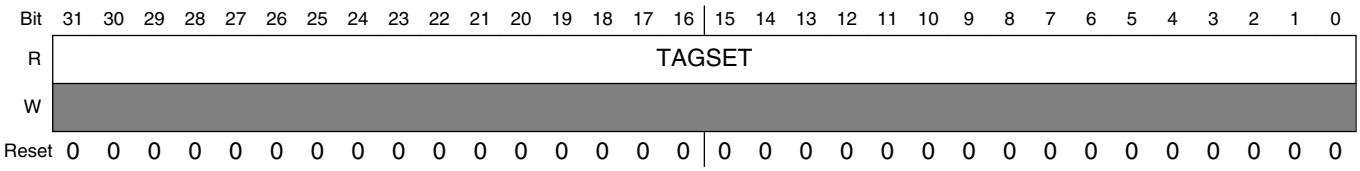
MTB_MODECTRL field descriptions

Field	Description
MODECTRL	MODECTRL Hardwired to 0x0000_0000

27.3.1.6 Claim TAG Set Register (MTB_TAGSET)

The Claim Tag Set Register returns the number of bits that can be set on a read, and enables individual bits to be set on a write. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FA0h offset = F000_0FA0h



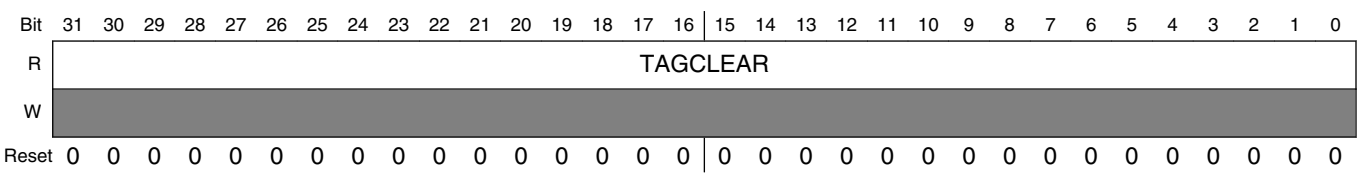
MTB_TAGSET field descriptions

Field	Description
TAGSET	TAGSET Hardwired to 0x0000_0000

27.3.1.7 Claim TAG Clear Register (MTB_TAGCLEAR)

The read/write Claim Tag Clear Register is used to read the claim status on debug resources. A read indicates the claim tag status. Writing 1 to a specific bit clears the corresponding claim tag to 0. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FA4h offset = F000_0FA4h



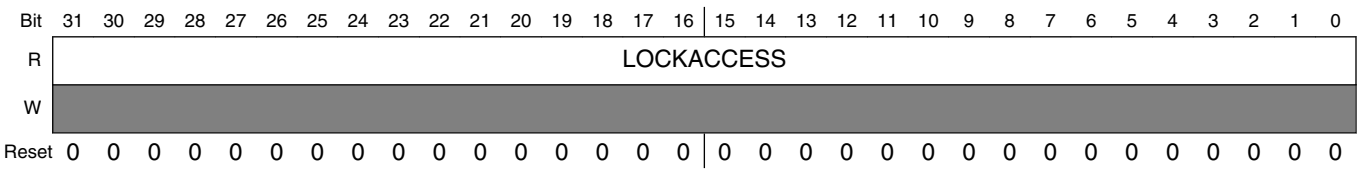
MTB_TAGCLEAR field descriptions

Field	Description
TAGCLEAR	TAGCLEAR Hardwired to 0x0000_0000

27.3.1.8 Lock Access Register (MTB_LOCKACCESS)

The Lock Access Register enables a write access to component registers. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FB0h offset = F000_0FB0h



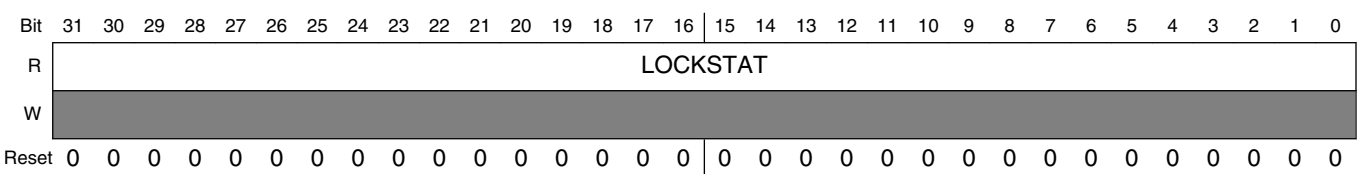
MTB_LOCKACCESS field descriptions

Field	Description
LOCKACCESS	Hardwired to 0x0000_0000

27.3.1.9 Lock Status Register (MTB_LOCKSTAT)

The Lock Status Register indicates the status of the lock control mechanism. This register is used in conjunction with the Lock Access Register. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FB4h offset = F000_0FB4h



MTB_LOCKSTAT field descriptions

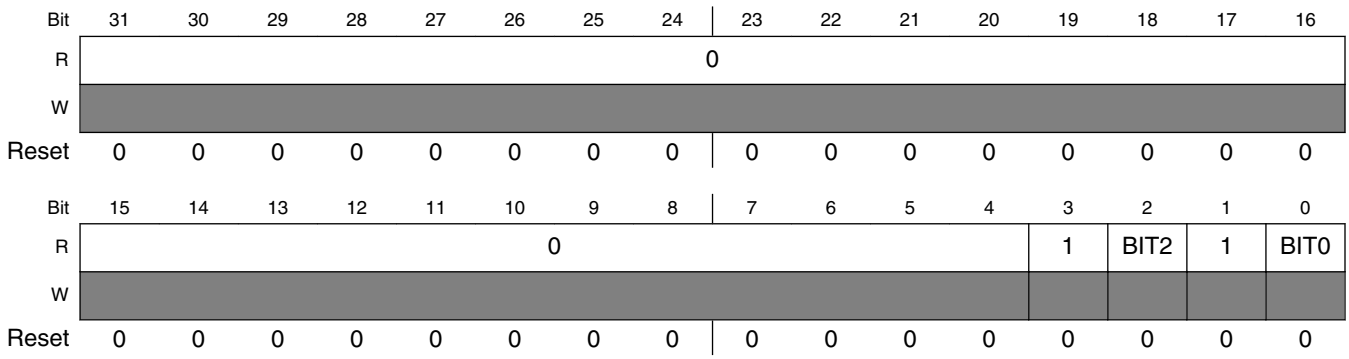
Field	Description
LOCKSTAT	LOCKSTAT Hardwired to 0x0000_0000

27.3.1.10 Authentication Status Register (MTB_AUTHSTAT)

The Authentication Status Register reports the required security level and current status of the security enable bit pairs. Where functionality changes on a given security level, this change must be reported in this register. It is connected to specific signals used during the auto-discovery process by an external debug agent.

MTB_AUTHSTAT[3:2] indicates if nonsecure, noninvasive debug is enabled or disabled, while MTB_AUTHSTAT[1:0] indicates the enabled/disabled state of nonsecure, invasive debug. For both 2-bit fields, 0b10 indicates the functionality is disabled and 0b11 indicates it is enabled.

Address: F000_0000h base + FB8h offset = F000_0FB8h



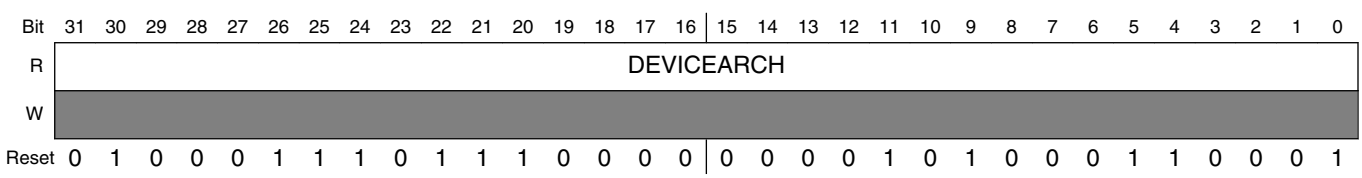
MTB_AUTHSTAT field descriptions

Field	Description
31–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 Reserved	This field is reserved. This read-only field is reserved and always has the value 1.
2 BIT2	BIT2 Connected to NIDEN or DBGEN signal.
1 Reserved	This field is reserved. This read-only field is reserved and always has the value 1.
0 BIT0	Connected to DBGEN.

27.3.1.11 Device Architecture Register (MTB_DEVICEARCH)

This register indicates the device architecture. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FBCh offset = F000_0FBCh



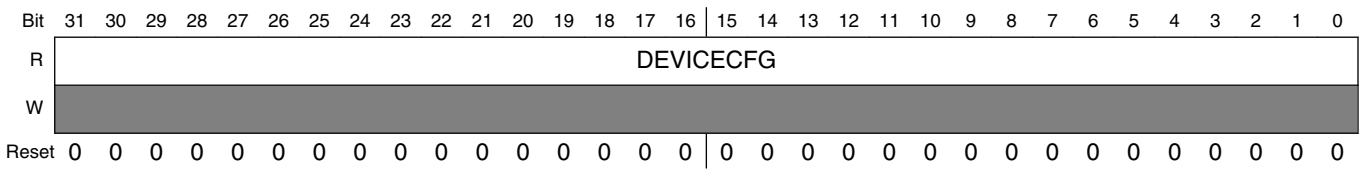
MTB_DEVICEARCH field descriptions

Field	Description
DEVICEARCH	DEVICEARCH Hardwired to 0x4770_0A31.

27.3.1.12 Device Configuration Register (MTB_DEVICECFG)

This register indicates the device configuration. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FC8h offset = F000_0FC8h



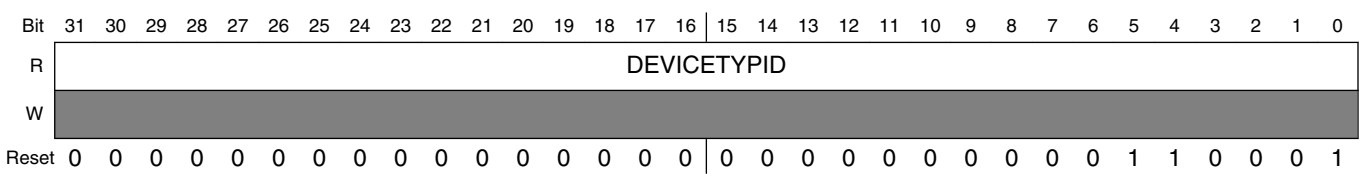
MTB_DEVICECFG field descriptions

Field	Description
DEVICECFG	DEVICECFG Hardwired to 0x0000_0000.

27.3.1.13 Device Type Identifier Register (MTB_DEVICETYPID)

This register indicates the device type ID. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FCCh offset = F000_0FCCh



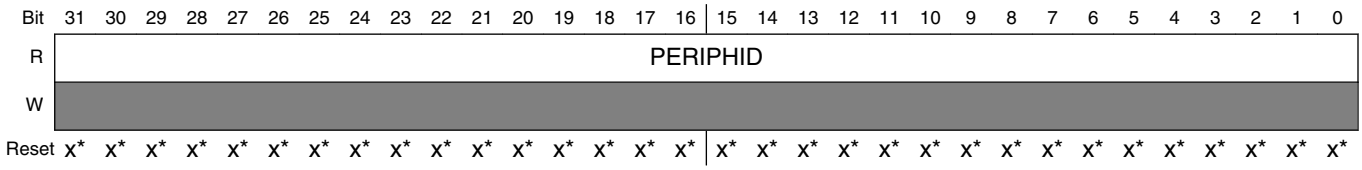
MTB_DEVICETYPID field descriptions

Field	Description
DEVICETYPID	DEVICETYPID Hardwired to 0x0000_0031.

27.3.1.14 Peripheral ID Register (MTB_PERIPHID*n*)

These registers indicate the peripheral IDs. They are hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FD0h offset + (4d × i), where i=0d to 7d



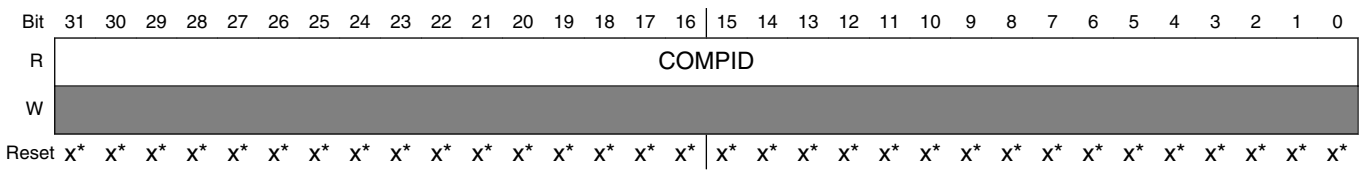
MTB_PERIPHID*n* field descriptions

Field	Description
PERIPHID	PERIPHID Peripheral ID4 is hardwired to 0x0000_0004; ID0 to 0x0000_0032; ID1 to 0x0000_00B9; ID2 to 0x0000_001B; and all the others to 0x0000_0000.

27.3.1.15 Component ID Register (MTB_COMPID*n*)

These registers indicate the component IDs. They are hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_0000h base + FF0h offset + (4d × i), where i=0d to 3d



MTB_COMPID*n* field descriptions

Field	Description
COMPID	Component ID Component ID0 is hardwired to 0x0000_000D; ID1 to 0x0000_0090; ID2 to 0x0000_0005; ID3 to 0x0000_00B1.

27.3.2 MTB_DWT Memory Map

The MTB_DWT programming model supports a very simplified subset of the v7M debug architecture and follows the standard Arm DWT definition.

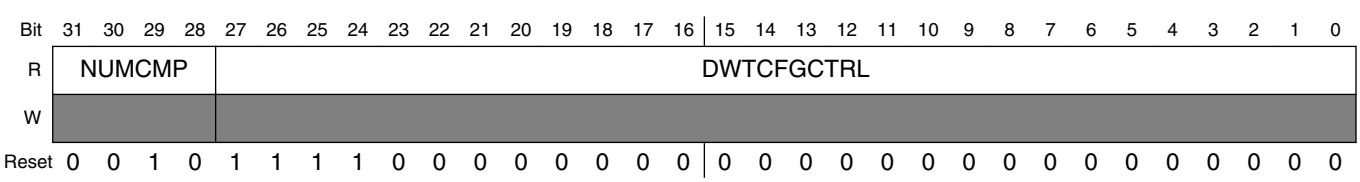
MTBDWT memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F000_1000	MTB DWT Control Register (MTBDWT_CTRL)	32	R	2F00_0000h	27.3.2.1/414
F000_1020	MTB_DWT Comparator Register (MTBDWT_COMP0)	32	R/W	0000_0000h	27.3.2.2/415
F000_1024	MTB_DWT Comparator Mask Register (MTBDWT_MASK0)	32	R/W	0000_0000h	27.3.2.3/415
F000_1028	MTB_DWT Comparator Function Register 0 (MTBDWT_FCT0)	32	R/W	0000_0000h	27.3.2.4/416
F000_1030	MTB_DWT Comparator Register (MTBDWT_COMP1)	32	R/W	0000_0000h	27.3.2.2/415
F000_1034	MTB_DWT Comparator Mask Register (MTBDWT_MASK1)	32	R/W	0000_0000h	27.3.2.3/415
F000_1038	MTB_DWT Comparator Function Register 1 (MTBDWT_FCT1)	32	R/W	0000_0000h	27.3.2.5/418
F000_1200	MTB_DWT Trace Buffer Control Register (MTBDWT_TBCTRL)	32	R/W	2000_0000h	27.3.2.6/419
F000_1FC8	Device Configuration Register (MTBDWT_DEVICECFG)	32	R	0000_0000h	27.3.2.7/421
F000_1FCC	Device Type Identifier Register (MTBDWT_DEVICETYPID)	32	R	0000_0004h	27.3.2.8/421
F000_1FD0	Peripheral ID Register (MTBDWT_PERIPHID4)	32	R	See section	27.3.2.9/422
F000_1FD4	Peripheral ID Register (MTBDWT_PERIPHID5)	32	R	See section	27.3.2.9/422
F000_1FD8	Peripheral ID Register (MTBDWT_PERIPHID6)	32	R	See section	27.3.2.9/422
F000_1FDC	Peripheral ID Register (MTBDWT_PERIPHID7)	32	R	See section	27.3.2.9/422
F000_1FE0	Peripheral ID Register (MTBDWT_PERIPHID0)	32	R	See section	27.3.2.9/422
F000_1FE4	Peripheral ID Register (MTBDWT_PERIPHID1)	32	R	See section	27.3.2.9/422
F000_1FE8	Peripheral ID Register (MTBDWT_PERIPHID2)	32	R	See section	27.3.2.9/422
F000_1FEC	Peripheral ID Register (MTBDWT_PERIPHID3)	32	R	See section	27.3.2.9/422
F000_1FF0	Component ID Register (MTBDWT_COMPID0)	32	R	See section	27.3.2.10/ 422
F000_1FF4	Component ID Register (MTBDWT_COMPID1)	32	R	See section	27.3.2.10/ 422
F000_1FF8	Component ID Register (MTBDWT_COMPID2)	32	R	See section	27.3.2.10/ 422
F000_1FFC	Component ID Register (MTBDWT_COMPID3)	32	R	See section	27.3.2.10/ 422

27.3.2.1 MTB DWT Control Register (MTBDWT_CTRL)

The MTBDWT_CTRL register provides read-only information on the watchpoint configuration for the MTB_DWT.

Address: F000_1000h base + 0h offset = F000_1000h



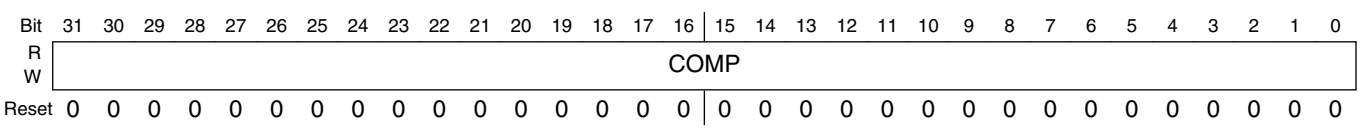
MTBDWT_CTRL field descriptions

Field	Description
31–28 NUMCMP	Number of comparators The MTB_DWT implements two comparators.
DWTCFGCTRL	DWT configuration controls This field is hardwired to 0xF00_0000, disabling all the remaining DWT functionality. The specific fields and their state are: MTBDWT_CTRL[27] = NOTRCPKT = 1, trace sample and exception trace is not supported MTBDWT_CTRL[26] = NOEXTTRIG = 1, external match signals are not supported MTBDWT_CTRL[25] = NOCYCCNT = 1, cycle counter is not supported MTBDWT_CTRL[24] = NOPRFCNT = 1, profiling counters are not supported MTBDWT_CTRL[22] = CYCEBTENA = 0, no POSTCNT underflow packets generated MTBDWT_CTRL[21] = FOLDEVTENA = 0, no folded instruction counter overflow events MTBDWT_CTRL[20] = LSUEVTENA = 0, no LSU counter overflow events MTBDWT_CTRL[19] = SLEEPEVTENA = 0, no sleep counter overflow events MTBDWT_CTRL[18] = EXCEVTENA = 0, no exception overhead counter events MTBDWT_CTRL[17] = CPIEVTENA = 0, no CPI counter overflow events MTBDWT_CTRL[16] = EXCTRCENA = 0, generation of exception trace disabled MTBDWT_CTRL[12] = PCSAMPLENA = 0, no periodic PC sample packets generated MTBDWT_CTRL[11:10] = SYNCTAP = 0, no synchronization packets MTBDWT_CTRL[9] = CYCTAP = 0, cycle counter is not supported MTBDWT_CTRL[8:5] = POSTINIT = 0, cycle counter is not supported MTBDWT_CTRL[4:1] = POSTPRESET = 0, cycle counter is not supported MTBDWT_CTRL[0] = CYCCNTENA = 0, cycle counter is not supported

27.3.2.2 MTB_DWT Comparator Register (MTBDWT_COMP*n*)

The MTBDWT_COMPn registers provide the reference value for comparator n.

Address: F000_1000h base + 20h offset + (16d × i), where i=0d to 1d



MTBDWT_COMP*n* field descriptions

Field	Description
COMP	Reference value for comparison If MTBDWT_COMP0 is used for a data value comparator and the access size is byte or halfword, the data value must be replicated across all appropriate byte lanes of this register. For example, if the data is a

MTBDWT_COMP*n* field descriptions (continued)

Field	Description
	byte-sized "x" value, then COMP[31:24] = COMP[23:16] = COMP[15:8] = COMP[7:0] = "x". Likewise, if the data is a halfword-size "y" value, then COMP[31:16] = COMP[15:0] = "y".

27.3.2.3 MTB_DWT Comparator Mask Register (MTBDWT_MASK*n*)

The MTBDWT_MASKn registers define the size of the ignore mask applied to the reference address for address range matching by comparator n. Note the format of this mask field is different than the MTB_MASTER[MASK].

Address: F000_1000h base + 24h offset + (16d × i), where i=0d to 1d

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

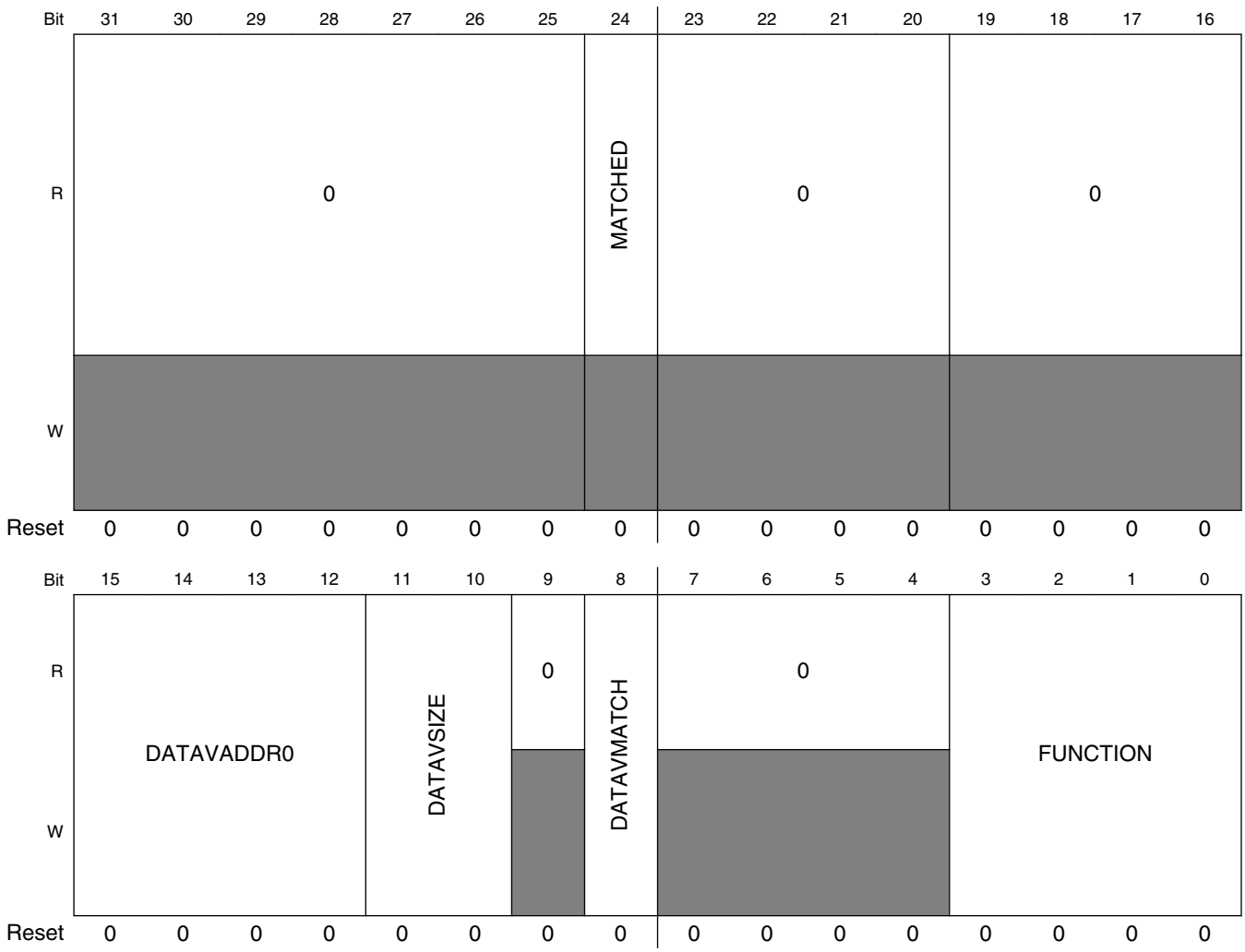
MTBDWT_MASK*n* field descriptions

Field	Description
31–5 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
MASK	MASK The value of the ignore mask, 0-31 bits, is applied to address range matching. MASK = 0 is used to include all bits of the address in the comparison, except if MASK = 0 and the comparator is configured to watch instruction fetch addresses, address bit [0] is ignored by the hardware since all fetches must be at least halfword aligned. For MASK != 0 and regardless of watch type, address bits [x-1:0] are ignored in the address comparison. Using a mask means the comparator matches on a range of addresses, defined by the unmasked most significant bits of the address, bits [31:x]. The maximum MASK value is 24, producing a 16 Mbyte mask. An attempted write of a MASK value > 24 is limited by the MTBDWT hardware to 24. If MTBDWT_COMP0 is used as a data value comparator, then MTBDWT_MASK0 should be programmed to zero.

27.3.2.4 MTB_DWT Comparator Function Register 0 (MTBDWT_FCT0)

The MTBDWT_FCTn registers control the operation of comparator n.

Address: F000_1000h base + 28h offset = F000_1028h



MTBDWT_FCT0 field descriptions

Field	Description
31–25 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
24 MATCHED	Comparator match If this read-only flag is asserted, it indicates the operation defined by the FUNCTION field occurred since the last read of the register. Reading the register clears this bit. 0 No match. 1 Match occurred.

Table continues on the next page...

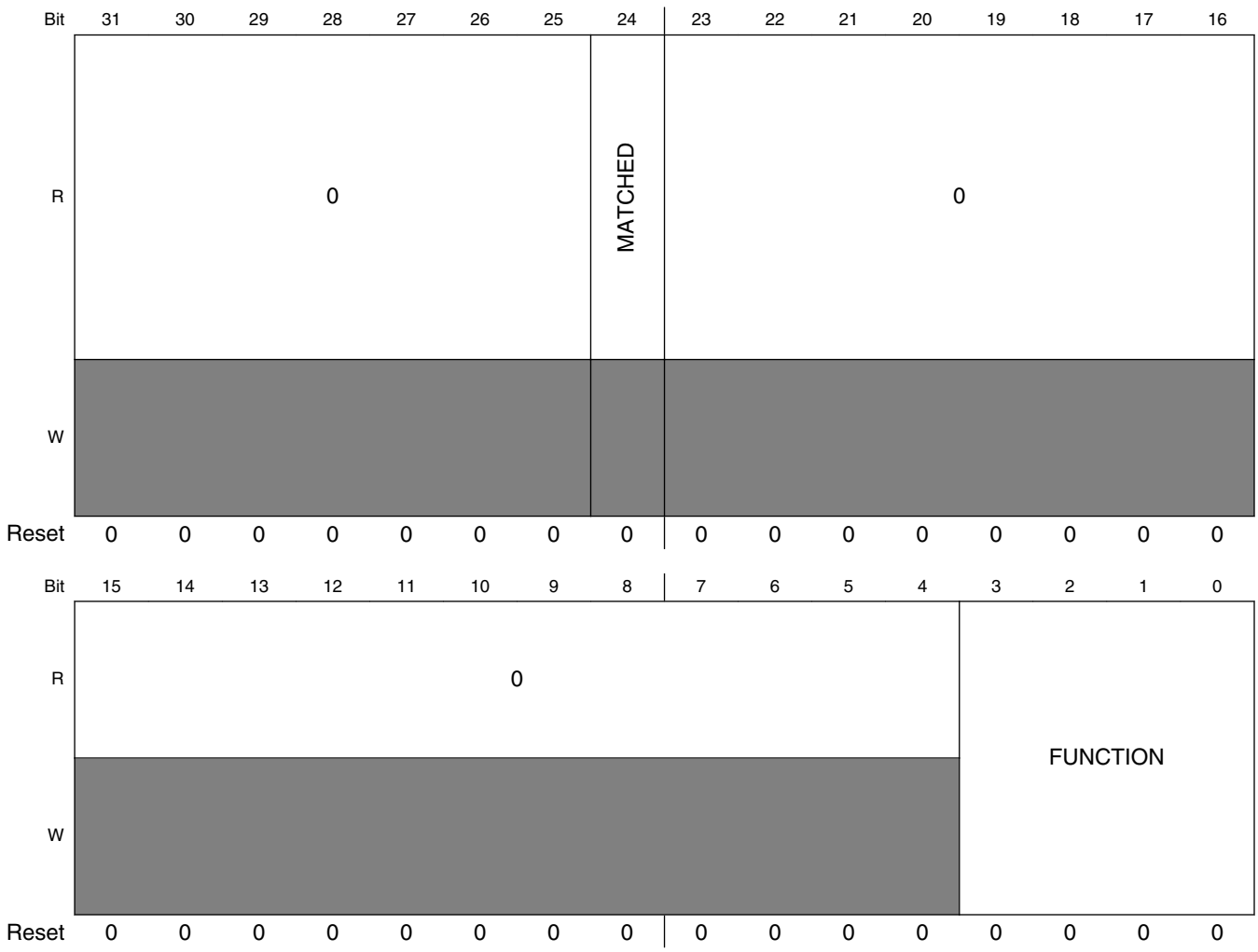
MTBDWT_FCT0 field descriptions (continued)

Field	Description
23–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–12 DATAVADDR0	Data Value Address 0 Since the MTB_DWT implements two comparators, the DATAVADDR0 field is restricted to values {0,1}. When the DATAVMATCH bit is asserted, this field defines the comparator number to use for linked address comparison. If MTBDWT_COMP0 is used as a data watchpoint and MTBDWT_COMP1 as an address watchpoint, DATAVADDR0 must be set.
11–10 DATAVSIZE	Data Value Size For data value matching, this field defines the size of the required data comparison. 00 Byte. 01 Halfword. 10 Word. 11 Reserved. Any attempts to use this value results in UNPREDICTABLE behavior.
9 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
8 DATAVMATCH	Data Value Match When this field is 1, it enables data value comparison. For this implementation, MTBDWT_COMP0 supports address or data value comparisons; MTBDWT_COMP1 only supports address comparisons. 0 Perform address comparison. 1 Perform data value comparison.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
FUNCTION	Function Selects the action taken on a comparator match. If MTBDWT_COMP0 is used for a data value and MTBDWT_COMP1 for an address value, then MTBDWT_FCT1[FUNCTION] must be set to zero. For this configuration, MTBDWT_MASK1 can be set to a non-zero value, so the combined comparators match on a range of addresses. 0000 Disabled. 0100 Instruction fetch. 0101 Data operand read. 0110 Data operand write. 0111 Data operand (read + write). others Reserved. Any attempts to use this value results in UNPREDICTABLE behavior.

27.3.2.5 MTB_DWT Comparator Function Register 1 (MTBDWT_FCT1)

The MTBDWT_FCTn registers control the operation of comparator n. Since the MTB_DWT only supports data value comparisons on comparator 0, there are several fields in the MTBDWT_FCT1 register that are RAZ/WI (bits 12, 11:10, 8).

Address: F000_1000h base + 38h offset = F000_1038h



MTBDWT_FCT1 field descriptions

Field	Description
31–25 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
24 MATCHED	Comparator match If this read-only flag is asserted, it indicates the operation defined by the FUNCTION field occurred since the last read of the register. Reading the register clears this bit.

Table continues on the next page...

MTBDWT_FCT1 field descriptions (continued)

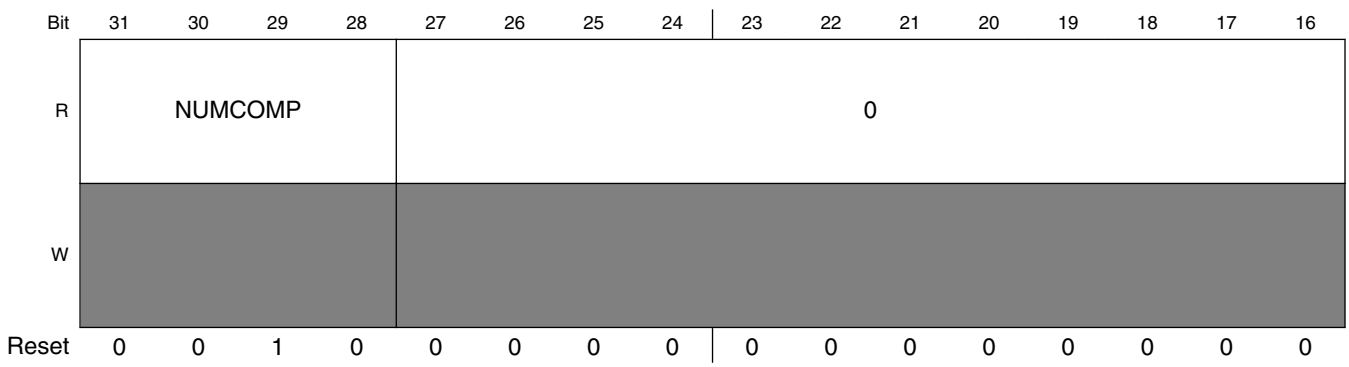
Field	Description
	0 No match. 1 Match occurred.
23–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
FUNCTION	Function Selects the action taken on a comparator match. If MTBDWT_COMP0 is used for a data value and MTBDWT_COMP1 for an address value, then MTBDWT_FCT1[FUNCTION] must be set to zero. For this configuration, MTBDWT_MASK1 can be set to a non-zero value, so the combined comparators match on a range of addresses. 0000 Disabled. 0100 Instruction fetch. 0101 Data operand read. 0110 Data operand write. 0111 Data operand (read + write). others Reserved. Any attempts to use this value results in UNPREDICTABLE behavior.

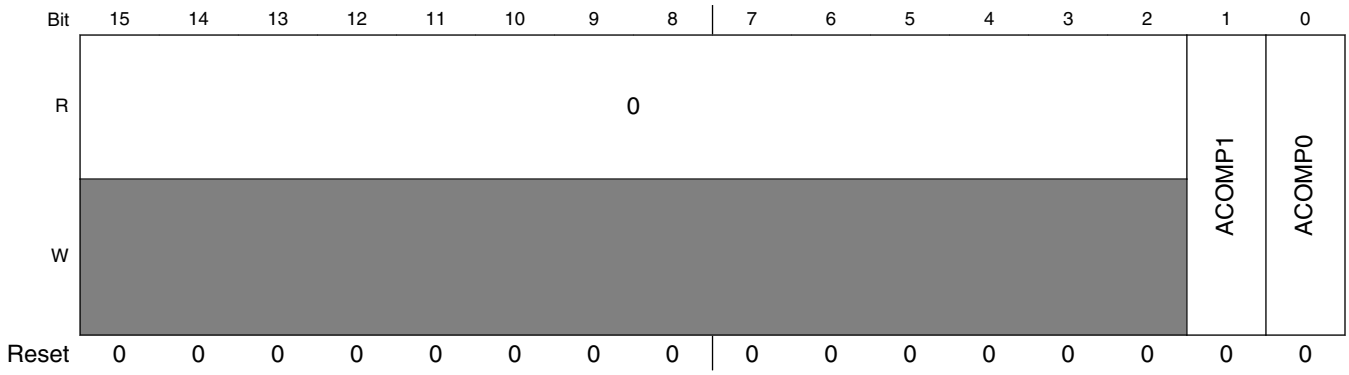
27.3.2.6 MTB_DWT Trace Buffer Control Register (MTBDWT_TBCTRL)

The MTBDWT_TBCTRL register defines how the watchpoint comparisons control the actual trace buffer operation.

Recall the MTB supports starting and stopping the program trace based on the watchpoint comparisons signaled via TSTART and TSTOP. The watchpoint comparison signals are enabled in the MTB's control logic by setting the appropriate enable bits, MTB_MASTER[TSTARTEN, TSTOPEN]. In the event of simultaneous assertion of both TSTART and TSTOP, TSTART takes priority.

Address: F000_1000h base + 200h offset = F000_1200h





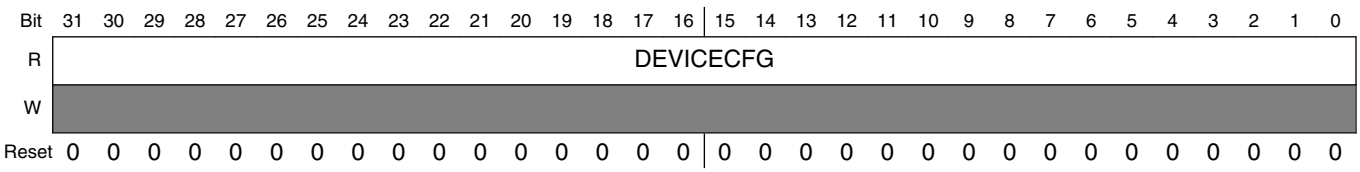
MTBDWT_TBCTRL field descriptions

Field	Description
31–28 NUMCOMP	Number of Comparators This read-only field specifies the number of comparators in the MTB_DWT. This implementation includes two registers.
27–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 ACOMP1	Action based on Comparator 1 match When the MTBDWT_FCT1[MATCHED] is set, it indicates MTBDWT_COMP1 address compare has triggered and the trace buffer's recording state is changed. 0 Trigger TSTOP based on the assertion of MTBDWT_FCT1[MATCHED]. 1 Trigger TSTART based on the assertion of MTBDWT_FCT1[MATCHED].
0 ACOMP0	Action based on Comparator 0 match When the MTBDWT_FCT0[MATCHED] is set, it indicates MTBDWT_COMP0 address compare has triggered and the trace buffer's recording state is changed. The assertion of MTBDWT_FCT0[MATCHED] is caused by the following conditions: • Address match in MTBDWT_COMP0 when MTBDWT_FCT0[DATAVMATCH] = 0 • Data match in MTBDWT_COMP0 when MTBDWT_FCT0[DATAVMATCH, DATAVADDR0] = {1,0} • Data match in MTBDWT_COMP0 and address match in MTBDWT_COMP1 when MTBDWT_FCT0[DATAVMATCH, DATAVADDR0] = {1,1} 0 Trigger TSTOP based on the assertion of MTBDWT_FCT0[MATCHED]. 1 Trigger TSTART based on the assertion of MTBDWT_FCT0[MATCHED].

27.3.2.7 Device Configuration Register (MTBDWT_DEVICECFG)

This register indicates the device configuration. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_1000h base + FC8h offset = F000_1FC8h



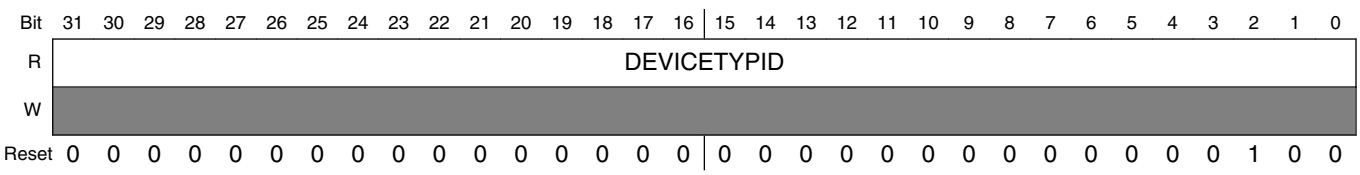
MTBDWT_DEVICECFG field descriptions

Field	Description
DEVICECFG	DEVICECFG Hardwired to 0x0000_0000.

27.3.2.8 Device Type Identifier Register (MTBDWT_DEVICETYPID)

This register indicates the device type ID. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_1000h base + FCCh offset = F000_1FCCh



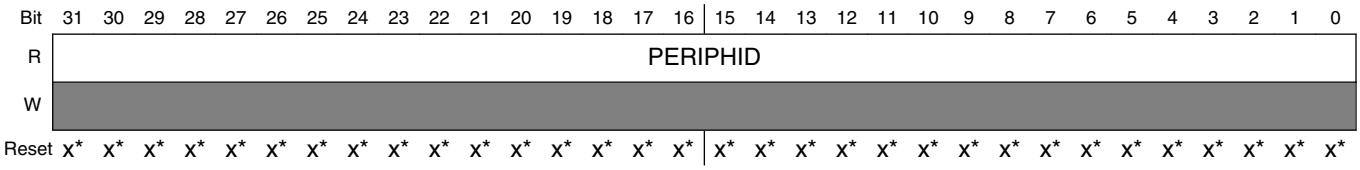
MTBDWT_DEVICETYPID field descriptions

Field	Description
DEVICETYPID	DEVICETYPID Hardwired to 0x0000_0004.

27.3.2.9 Peripheral ID Register (MTBDWT_PERIPHID*n*)

These registers indicate the peripheral IDs. They are hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_1000h base + FD0h offset + (4d × i), where i=0d to 7d



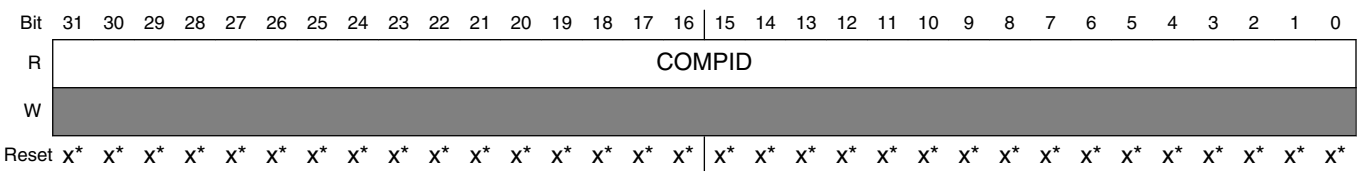
MTBDWT_PERIPHID*n* field descriptions

Field	Description
PERIPHID	PERIPHID Peripheral ID1 is hardwired to 0x0000_00E0; ID2 to 0x0000_0008; and all the others to 0x0000_0000.

27.3.2.10 Component ID Register (MTBDWT_COMPID*n*)

These registers indicate the component IDs. They are hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_1000h base + FF0h offset + (4d × i), where i=0d to 3d



MTBDWT_COMPID*n* field descriptions

Field	Description
COMPID	Component ID Component ID0 is hardwired to 0x0000_000D; ID1 to 0x0000_0090; ID2 to 0x0000_0005; ID3 to 0x0000_00B1.

27.3.3 System ROM Memory Map

The System ROM Table registers are also mapped into a sparsely-populated 4 KB address space.

For core configurations like that supported by Cortex-M0+, Arm recommends that a debugger identifies and connects to the debug components using the CoreSight debug infrastructure.

Arm recommends that a debugger follows the flow as shown in the following figure to discover the components in the CoreSight debug infrastructure. In this case, a debugger reads the peripheral and component ID registers for each CoreSight component in the CoreSight system.

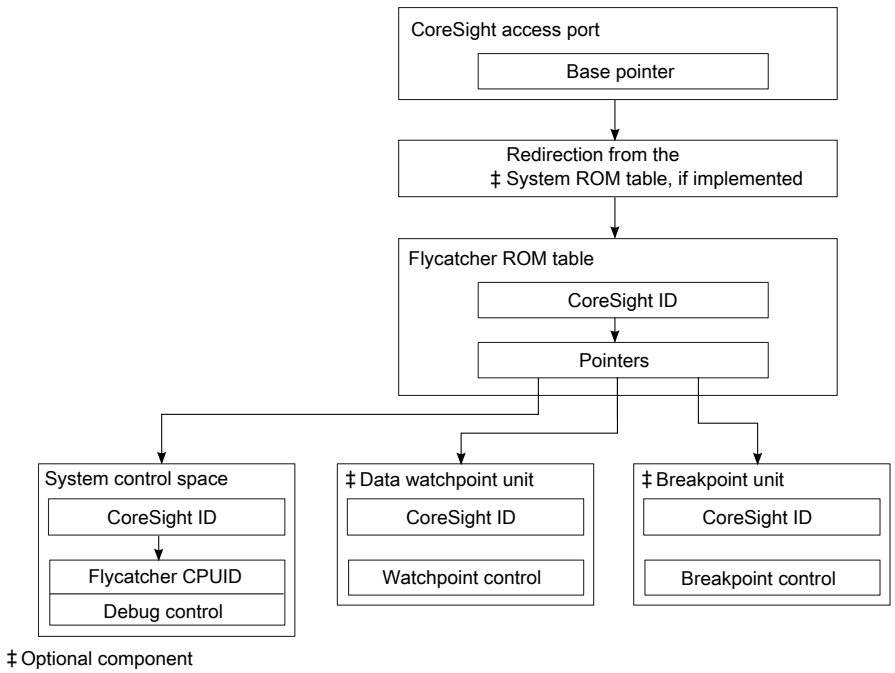


Figure 27-3. CoreSight discovery process

ROM memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F000_2000	Entry (ROM_ENTRY0)	32	R	See section	27.3.3.1/424
F000_2004	Entry (ROM_ENTRY1)	32	R	See section	27.3.3.1/424
F000_2008	Entry (ROM_ENTRY2)	32	R	See section	27.3.3.1/424
F000_200C	End of Table Marker Register (ROM_TABLEMARK)	32	R	0000_0000h	27.3.3.2/425
F000_2FCC	System Access Register (ROM_SYSACCESS)	32	R	0000_0001h	27.3.3.3/425
F000_2FD0	Peripheral ID Register (ROM_PERIPHID4)	32	R	See section	27.3.3.4/426
F000_2FD4	Peripheral ID Register (ROM_PERIPHID5)	32	R	See section	27.3.3.4/426
F000_2FD8	Peripheral ID Register (ROM_PERIPHID6)	32	R	See section	27.3.3.4/426
F000_2FDC	Peripheral ID Register (ROM_PERIPHID7)	32	R	See section	27.3.3.4/426
F000_2FE0	Peripheral ID Register (ROM_PERIPHID0)	32	R	See section	27.3.3.4/426

Table continues on the next page...

ROM memory map (continued)

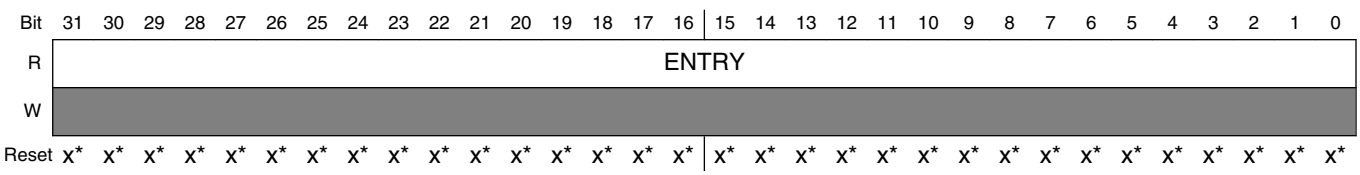
Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F000_2FE4	Peripheral ID Register (ROM_PERIPHID1)	32	R	See section	27.3.3.4/426
F000_2FE8	Peripheral ID Register (ROM_PERIPHID2)	32	R	See section	27.3.3.4/426
F000_2FEC	Peripheral ID Register (ROM_PERIPHID3)	32	R	See section	27.3.3.4/426
F000_2FF0	Component ID Register (ROM_COMPID0)	32	R	See section	27.3.3.5/426
F000_2FF4	Component ID Register (ROM_COMPID1)	32	R	See section	27.3.3.5/426
F000_2FF8	Component ID Register (ROM_COMPID2)	32	R	See section	27.3.3.5/426
F000_2FFC	Component ID Register (ROM_COMPID3)	32	R	See section	27.3.3.5/426

27.3.3.1 Entry (ROM_ENTRY*n*)

The System ROM Table begins with "n" relative 32-bit addresses, one for each debug component present in the device and terminating with an all-zero value signaling the end of the table at the "n+1"-th value.

It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_2000h base + 0h offset + (4d × i), where i=0d to 2d



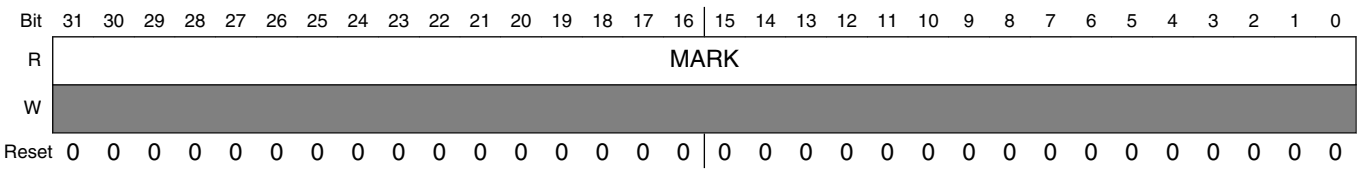
ROM_ENTRY*n* field descriptions

Field	Description
ENTRY	ENTRY Entry 0 (MTB) is hardwired to 0xFFFF_E003; Entry 1 (MTBDWT) to 0xFFFF_F003; Entry 2 (CM0+ ROM Table) to 0xF00F_D003.

27.3.3.2 End of Table Marker Register (ROM_TABLEMARK)

This register indicates end of table marker. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_2000h base + Ch offset = F000_200Ch



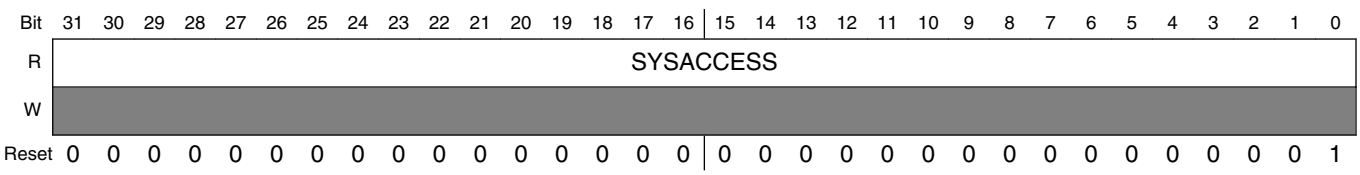
ROM_TABLEMARK field descriptions

Field	Description
MARK	MARK Hardwired to 0x0000_0000

27.3.3.3 System Access Register (ROM_SYSACCESS)

This register indicates system access. It is hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_2000h base + FCCh offset = F000_2FCCh



ROM_SYSACCESS field descriptions

Field	Description
SYSACCESS	SYSACCESS Hardwired to 0x0000_0001

27.3.3.4 Peripheral ID Register (ROM_PERIPHID*n*)

These registers indicate the peripheral IDs. They are hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_2000h base + FD0h offset + (4d × i), where i=0d to 7d

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

ROM_PERIPHID*n* field descriptions

Field	Description
PERIPHID	PERIPHID Peripheral ID1 is hardwired to 0x0000_00E0; ID2 to 0x0000_0008; and all the others to 0x0000_0000.

27.3.3.5 Component ID Register (ROM_COMPID*n*)

These registers indicate the component IDs. They are hardwired to specific values used during the auto-discovery process by an external debug agent.

Address: F000_2000h base + FF0h offset + (4d × i), where i=0d to 3d

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

ROM_COMPID*n* field descriptions

Field	Description
COMPID	Component ID Component ID0 is hardwired to 0x0000_000D; ID1 to 0x0000_0010; ID2 to 0x0000_0005; ID3 to 0x0000_00B1.

27.4 Usage Guide

27.4.1 ARM reference

For more information about MTB, please refer to the ARM document ARM Debug Interface Architecture Specification .

Chapter 28
Signal Multiplexing and Pin Assignment

28.1 Package types

Below is a list of package types for this device.

- 48-pin LQFP (7 × 7 mm^2, 0.5mm pitch)
- 44-pin LQFP (10 × 10 mm^2, 0.8mm pitch)
- 40-pin QFN (5 × 5 mm^2, 0.4mm pitch)

28.2 Introduction

To optimize functionality in small packages, pins have several functions available via signal multiplexing. This chapter illustrates which of the device's signals are multiplexed on which external pin.

The Port Control block controls which signal is present on the external pin. Refer to that chapter to find which register controls the operation of a specific pin.

For more information about how the Port Control block is integrated into this device, refer to the Signal multiplexing integration section.

28.3 Pinouts

28.3.1 KE1xZ64 Signal Multiplexing and Pin Assignments

The following table shows the signals available on each pin and the locations of these pins on the devices supported by this document. The Port Control Module is responsible for selecting which ALT functionality is available on each pin.

48 LQFP	44 LQFP	40 QFN	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7
—	—	5	TSI0_CH0	TSI0_CH0	PTE5	TCLK2					EWM_IN
—	—	6	TSI0_CH1	TSI0_CH1	PTE4	BUSOUT					EWM_OUT_b
—	—	32	TSI0_CH16	TSI0_CH16	PTC7	LPUART1_TX					
—	—	33	TSI0_CH15	TSI0_CH15	PTC6	LPUART1_RX					
1	1	1	TSI0_CH5	TSI0_CH5	PTD1	FTM0_CH3					TRGMUX_ OUT2
2	2	2	TSI0_CH4	TSI0_CH4	PTD0	FTM0_CH2					TRGMUX_ OUT1
3	—	3	TSI0_CH3	TSI0_CH3	PTE11	PWT_IN1	LPTMR0_ALT1				
4	—	4	TSI0_CH2	TSI0_CH2	PTE10	CLKOUT					
5	3	—	TSI0_CH0	TSI0_CH0	PTE5	TCLK2			CAN0_TX		EWM_IN
6	4	—	TSI0_CH1	TSI0_CH1	PTE4	BUSOUT			CAN0_RX		EWM_OUT_b
7	5	7	VDD	VDD							
8	6	7	VDDA	VDDA							
9	7	7	VREFH	VREFH							
10	8	—	VSS/ VREFL	VSS/ VREFL							
11	9	8	EXTAL	EXTAL	PTB7	LPI2C0_SCL					
12	10	9	XTAL	XTAL	PTB6	LPI2C0_SDA					
13	11	—	TSI0_CH24	TSI0_CH24	PTE3	FTM0_FLT0	LPUART2_RTS				
14	—	10	ACMP0_IN3/ TSI0_CH11	ACMP0_IN3/ TSI0_CH11	PTE8						
15	12	11	TSI0_CH9	TSI0_CH9	PTB5	FTM0_CH5	LPSPI0_PCS1			TRGMUX_IN0	
16	13	12	TSI0_CH8	TSI0_CH8	PTB4	FTM0_CH4	LPSPI0_SOUT			TRGMUX_IN1	
17	14	13	ADC0_SE11/ ACMP0_IN4	ADC0_SE11/ ACMP0_IN4	PTC3	FTM0_CH3					
18	15	14	ADC0_SE10/ ACMP0_IN5	ADC0_SE10/ ACMP0_IN5	PTC2	FTM0_CH2					
19	16	15	TSI0_CH10	TSI0_CH10	PTD7	LPUART2_TX					
20	17	16	TSI0_CH7	TSI0_CH7	PTD6	LPUART2_RX					
21	18	17	TSI0_CH6	TSI0_CH6	PTD5		LPTMR0_ALT2		PWT_IN2		LPUART2_CTS
22	19	18	ADC0_SE9/ TSI0_CH23	ADC0_SE9/ TSI0_CH23	PTC1	FTM0_CH1					
23	20	19	ADC0_SE8/ TSI0_CH22	ADC0_SE8/ TSI0_CH22	PTC0	FTM0_CH0					
24	21	20	ADC0_SE7/ TSI0_CH21	ADC0_SE7/ TSI0_CH21	PTB3	FTM1_CH1	LPSPI0_SIN	FTM1_QD_PHA		TRGMUX_IN2	
25	22	22	ADC0_SE6/ TSI0_CH20	ADC0_SE6/ TSI0_CH20	PTB2	FTM1_CH0	LPSPI0_SCK	FTM1_QD_PHB		TRGMUX_IN3	
26	23	23	ADC0_SE5	ADC0_SE5	PTB1	LPUART0_TX	LPSPI0_SOUT	TCLK0			
27	24	24	ADC0_SE4	ADC0_SE4	PTB0	LPUART0_RX	LPSPI0_PCS0	LPTMR0_ALT3	PWT_IN3		
28	25	25	ADC0_SE3	ADC0_SE3	PTA7	FTM0_FLT2	LPSPI0_PCS3	RTC_CLKIN		LPUART1_RTS	
29	26	—	ADC0_SE2	ADC0_SE2	PTA6	FTM0_FLT1				LPUART1_CTS	

48 LQFP	44 LQFP	40 QFN	Default	ALT0	ALT1	ALT2	ALT3	ALT4	ALT5	ALT6	ALT7
30	27	21, 40 and EP	VSS	VSS							
31	28	26	VDD	VDD							
32	29	—	DISABLED		PTD4	FTM0_FLT3					
33	30	27	NMI_b		PTD3						NMI_b
34	31	—	DISABLED		PTD2						
35	32	28	DISABLED		PTA3		LPI2C0_SCL	EWM_IN		LPUART0_TX	
36	33	29	DISABLED		PTA2		LPI2C0_SDA	EWM_OUT_b		LPUART0_RX	
37	34	30	ADC0_SE1/ ACMP0_IN1/ TSI0_CH18	ADC0_SE1/ ACMP0_IN1/ TSI0_CH18	PTA1	FTM1_CH1	LPI2C0_SDAS		FTM1_QD_PHA	LPUART0_RTS	TRGMUX_ OUT0
38	35	31	ADC0_SE0/ ACMP0_IN0/ TSI0_CH17	ADC0_SE0/ ACMP0_IN0/ TSI0_CH17	PTA0		LPI2C0_SCLS			LPUART0_CTS	TRGMUX_ OUT3
39	36	—	TSI0_CH16	TSI0_CH16	PTC7	LPUART1_TX			CAN0_TX		
40	37	—	TSI0_CH15	TSI0_CH15	PTC6	LPUART1_RX			CAN0_RX		
41	—	—	DISABLED		PTE6	LPSPI0_PCS2				LPUART1_RTS	
42	38	—	TSI0_CH19	TSI0_CH19	PTE2	LPSPI0_SOUT	LPTMR0_ALT3		PWT_IN3	LPUART1_CTS	
43	39	34	TSI0_CH14	TSI0_CH14	PTE1	LPSPI0_SIN	LPI2C0_HREQ				
44	40	35	TSI0_CH13	TSI0_CH13	PTE0	LPSPI0_SCK	TCLK1				
45	41	36	TSI0_CH12	TSI0_CH12	PTC5		RTC_CLKOUT				
46	42	37	SWD_CLK	ACMP0_IN2	PTC4	FTM1_CH0	RTC_CLKOUT		EWM_IN	FTM1_QD_PHB	SWD_CLK
47	43	38	RESET_b		PTA5		TCLK1				RESET_b
48	44	39	SWD_DIO		PTA4			ACMP0_OUT	EWM_OUT_b		SWD_DIO

28.3.2 Pin properties

NOTE

For some pins, for example I2C SDA and SCL, they can be configure as pesudo opendrain pins via its module itself or the SIM module. Please see the respective module chapter and Port control and interrupt module features for details.

48 LQFP	44 LQFP	40 QFN	Pin Name	Driver strength	Default status after POR	Pullup/ pulldown setting after POR	Slew rate after POR	Passive pin filter after POR	True Open Drain	Pin interrupt
1	1	1	PTD1	HD	Hi-Z	—	—	—	—	Y
2	2	2	PTD0	HD	Hi-Z	—	—	—	—	Y
3	—	3	PTE11	ND	Hi-Z	—	—	—	—	Y

Table continues on the next page...

48 LQFP	44 LQFP	40 QFN	Pin Name	Driver strength	Default status after POR	Pullup/ pulldown setting after POR	Slew rate after POR	Passive pin filter after POR	True Open Drain	Pin interrupt
4	—	4	PTE10	ND	Hi-Z	—	—	—	—	Y
5	3	5	PTE5	ND	Hi-Z	—	—	—	—	Y
6	4	6	PTE4	ND	Hi-Z	—	—	—	—	Y
7	5	7	VDD	—	—	—	—	—	—	—
8	6		VDDA	—	—	—	—	—	—	—
9	7		VREFH	—	—	—	—	—	—	—
10	8	—	VREFL	—	—	—	—	—	—	—
			VSS	—	—	—	—	—	—	—
11	9	8	PTB7	ND	Hi-Z	—	—	—	—	Y
12	10	9	PTB6	ND	Hi-Z	—	—	—	—	Y
13	11	—	PTE3	ND	Hi-Z	—	—	—	—	Y
14	—	10	PTE8	ND	Hi-Z	—	—	—	—	Y
15	12	11	PTB5	HD	Hi-Z	—	—	—	—	Y
16	13	12	PTB4	HD	Hi-Z	—	—	—	—	Y
17	14	13	PTC3	ND	Hi-Z	—	—	—	—	Y
18	15	14	PTC2	ND	Hi-Z	—	—	—	—	Y
19	16	15	PTD7	ND	Hi-Z	—	—	—	—	Y
20	17	16	PTD6	ND	Hi-Z	—	—	—	—	Y
21	18	17	PTD5	ND	Hi-Z	—	—	—	—	Y
22	19	18	PTC1	ND	Hi-Z	—	—	—	—	Y
23	20	19	PTC0	ND	Hi-Z	—	—	—	—	Y
24	21	20	PTB3	ND	Hi-Z	—	—	—	—	Y
25	22	22	PTB2	ND	Hi-Z	—	—	—	—	Y
26	23	23	PTB1	ND	Hi-Z	—	—	—	—	Y
27	24	24	PTB0	ND	Hi-Z	—	—	—	—	Y
28	25	25	PTA7	ND	Hi-Z	—	—	—	—	Y
29	26	—	PTA6	ND	Hi-Z	—	—	—	—	Y
30	27	21, 40 and EP (exposed pad)	VSS	—	—	—	—	—	—	—
31	28	26	VDD	—	—	—	—	—	—	—
32	29	—	PTD4	ND	Hi-Z	—	—	—	—	Y
33	30	27	PTD3	ND	H	PU	—	N	—	Y
34	31	—	PTD2	ND	Hi-Z	—	—	—	—	Y
35	32	28	PTA3	ND	Hi-Z	—	—	—	—	Y
36	33	29	PTA2	ND	Hi-Z	—	—	—	—	Y
37	34	30	PTA1	ND	Hi-Z	—	—	—	—	Y
38	35	31	PTA0	ND	Hi-Z	—	—	—	—	Y

Table continues on the next page...

48 LQFP	44 LQFP	40 QFN	Pin Name	Driver strength	Default status after POR	Pullup/ pulldown setting after POR	Slew rate after POR	Passive pin filter after POR	True Open Drain	Pin interrupt
39	36	32	PTC7	ND	Hi-Z	—	—	—	—	Y
40	37	33	PTC6	ND	Hi-Z	—	—	—	—	Y
41	—	—	PTE6	ND	Hi-Z	—	—	—	—	Y
42	38	—	PTE2	ND	Hi-Z	—	—	—	—	Y
43	39	34	PTE1	HD	Hi-Z	—	—	—	—	Y
44	40	35	PTE0	HD	Hi-Z	—	—	—	—	Y
45	41	36	PTC5	ND	H	PU	—	—	—	Y
46	42	37	PTC4	ND	L	PD	—	—	—	Y
47	43	38	PTA5	ND	H	PU	—	Y	—	Y
48	44	39	PTA4	ND	H	PU	—	—	—	Y

Properties	Abbreviation	Descriptions
Driver strength	ND	Normal drive
	HD	High drive
Default status after POR	Hi-Z	High impendence
	H	High level
	L	Low level
Pullup/ pulldown setting after POR	PU	Pullup
	PD	Pulldown
Slew rate after POR	FS	Fast slew rate
	SS	Slow slew rate
Passive Pin Filter after POR	N	Disabled
	Y	Enabled
Open drain	N	Disabled
	Y	Enabled
Pin interrupt	Y	Yes

28.3.3 Pinout diagram

The following figure shows the pinout diagram for the devices supported by this document. Many signals may be multiplexed onto a single pin. To determine what signals can be used on which pin, see the previous table of Pin Assignments.

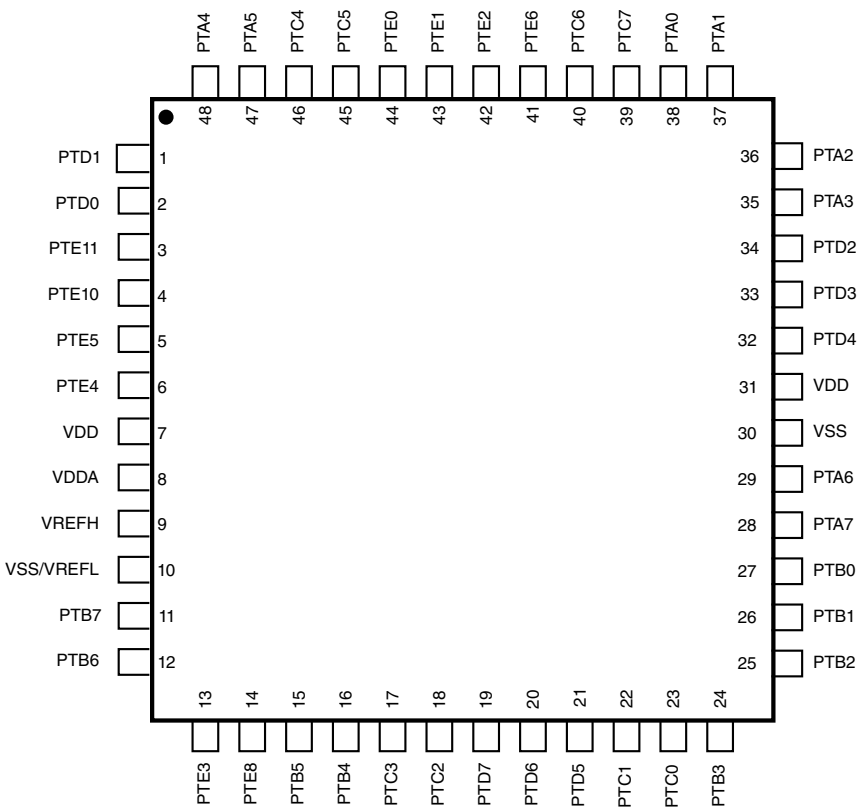


Figure 28-1. 48 LQFP Pinout Diagram

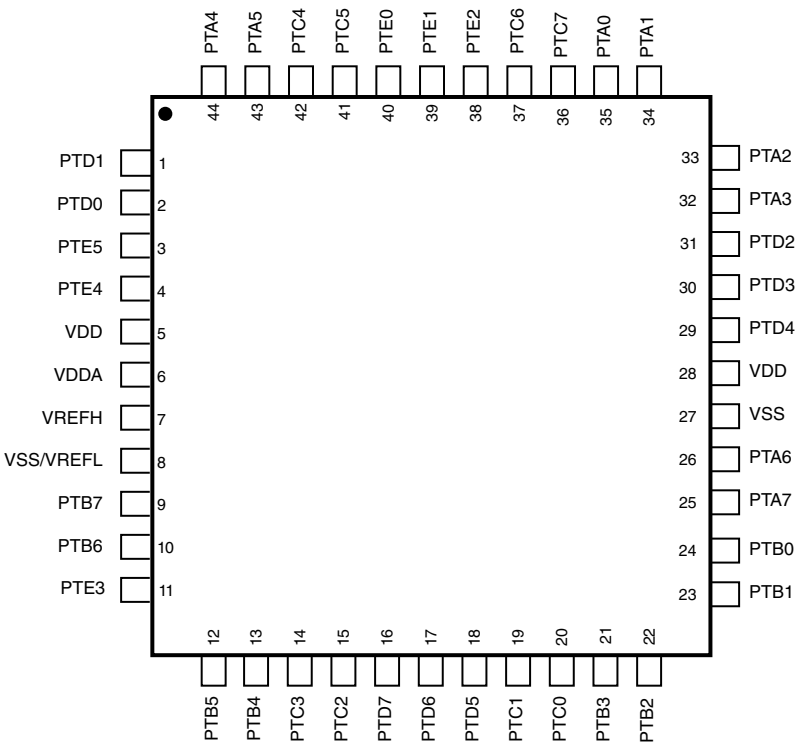


Figure 28-2. 44 LQFP Pinout Diagram

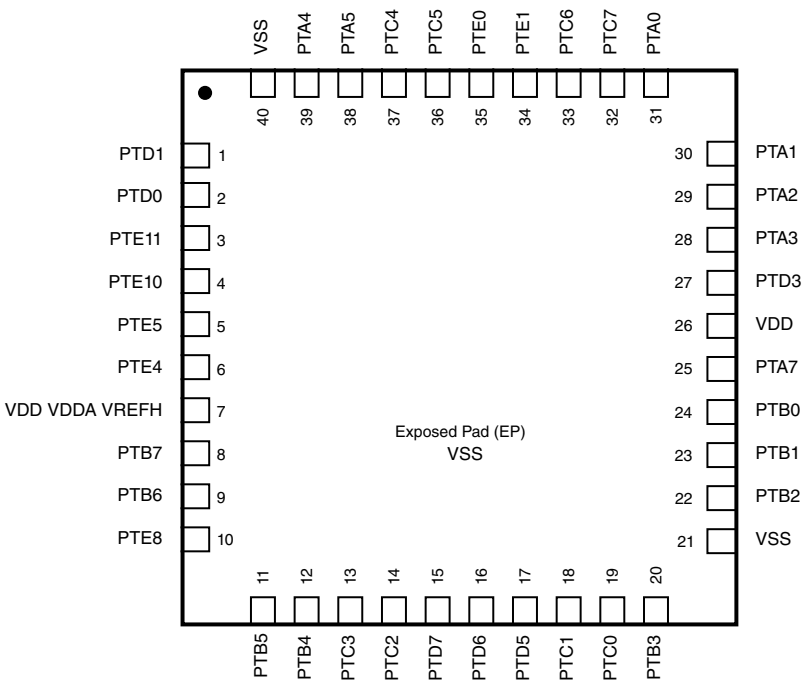


Figure 28-3. 40 QFN Pinout Diagram

28.4 Module Signal Description Tables

The following sections correlate the chip-level signal name with the signal name used in the module's chapter. They also briefly describe the signal function and direction.

28.4.1 Core Modules

Table 28-1. SWD Signal Descriptions

Chip signal name	Module signal name	Description	I/O
SWD_CLK	SWD_CLK	Serial Wire Clock	I
SWD_DIO	SWD_DIO	Serial Wire Data	I/O

28.4.2 System Modules

Table 28-2. System Signal Descriptions

Chip signal name	Module signal name	Description	I/O
NMI_b	—	Non-maskable interrupt NOTE: Driving the NMI signal low forces a non-maskable interrupt, if the NMI function is selected on the corresponding pin.	I
RESET_b	—	Reset bidirectional signal	I/O
VDD	—	MCU power	I
VSS	—	MCU ground	I

Table 28-3. EWM Signal Descriptions

Chip signal name	Module signal name	Description	I/O
EWM_IN	EWM_in	EWM input for safety status of external safety circuits. The polarity of EWM_IN is programmable using the EWM_CTRL[ASSIN] bit. The default polarity is active-low.	I
EWM_OUT_b	$\overline{\text{EWM_out}}$	EWM reset out signal	O

28.4.3 Clock Modules

Table 28-4. OSC (in SCG) Signal Descriptions

Chip signal name	Module signal name	Description	I/O
EXTAL	EXTAL	External clock/Oscillator input	I
XTAL	XTAL	Oscillator output	O

28.4.4 Analog

Table 28-5. ADC*0* Signal Descriptions

Chip signal name	Module signal name	Description	I/O
ADC*0*_SE[11:0]	AD[11:0]	Single-Ended Analog Channel Inputs	I
VREFH	V_{REFSH}	Voltage Reference Select High	I
VREFL	V_{REFSL}	Voltage Reference Select Low	I
VDDA	V_{DDA}	Analog Power Supply	I

Table 28-6. ACMP*0* Signal Descriptions

Chip signal name	Module signal name	Description	I/O
ACMP*0*_IN[5:0]	IN[5:0]	Analog voltage inputs	I
ACMP*0*_OUT	CMPO	Comparator output	O

28.4.5 Timer Modules

Table 28-7. LPTMR0 Signal Descriptions

Chip signal name	Module signal name	Description	I/O
LPTMR0_ALT[3:1]	LPTMR_ALT*n*	Pulse Counter Input pin	I

Table 28-8. RTC Signal Descriptions

Chip signal name	Module signal name	Description	I/O
RTC_CLKOUT	RTC_CLKOUT	1 Hz square-wave output or 32 kHz clock	O

Table 28-9. FTM*0* Signal Descriptions

Chip signal name	Module signal name	Description	I/O
FTM*0*_CH[5:0]	CHn	FTM channel (n), where n can be 5-0	I/O
FTM*0*_FLT[3:0]	FAULTj	Fault input (j), where j can be 3-0	I
TCLK[2:0]	EXTCLK	External clock. FTM external clock can be selected to drive the FTM counter.	I

Table 28-10. FTM*1* Signal Descriptions

Chip signal name	Module signal name	Description	I/O
FTM*1*_CH[1:0]	CHn	FTM channel (n), where n can be 1-0	I/O
FTM*1*_QD_PHA	PHA	Quadrature decoder phase A input. Input pin associated with quadrature decoder phase A.	I
FTM*1*_QD_PHB	PHB	Quadrature decoder phase B input. Input pin associated with quadrature decoder phase B.	I

28.4.6 Communication Interfaces

Table 28-11. CAN*n* Signal Descriptions

Chip signal name	Module signal name	Description	I/O
CAN*n*_RX	CAN Rx	CAN Receive Pin	I
CAN*n*_TX	CAN Tx	CAN Transmit Pin	O

Table 28-12. LPSPI*n* Signal Descriptions

Chip signal name	Module signal name	Description	I/O
LPSPI*n*_SOUT	SOUT	Serial Data Out	O
LPSPI*n*_SIN	SIN	Serial Data In	I
LPSPI*n*_SCK	SCK	Serial Clock	I/O
LPSPI*n*_PCS[3:0]	PCS[3:0]	Peripheral Chip Select 0-3	I/O

Table 28-13. LPI2C*n* Signal Descriptions

Chip signal name	Module signal name	Description	I/O
LPI2C*n*_SCL	SCL	Bidirectional serial clock line of the I2C system.	I/O
LPI2C*n*_SDA	SDA	Bidirectional serial data line of the I2C system.	I/O
LPI2C*n*_HREQ	HREQ	Host request, can initiate an LPI2C master transfer if asserted and the I2C bus is idle.	I
LPI2C*n*_SCLS	SCLS	Secondary I2C clock line.	I/O
LPI2C*n*_SDAS	SDAS	Secondary I2C data line.	I/O

Table 28-14. LPUART*n* Signal Descriptions

Chip signal name	Module signal name	Description	I/O
LPUART*n*_TX	LPUART_TXD	Transmit data	I/O

Table continues on the next page...

Table 28-14. LPUART*n* Signal Descriptions (continued)

Chip signal name	Module signal name	Description	I/O
LPUART*n*_RX	LPUART_RXD	Receive data	I
LPUART*n*_CTS	LPUART_CTS	Clear to send	I
LPUART*n*_RTS	LPUART_RTS	Request to send	O

28.4.7 Human-Machine Interfaces (HMI)

Table 28-15. GPIO Signal Descriptions

Chip signal name	Module signal name	Description	I/O
PTA[7:0]	PORTA7–PORTA0	General-purpose input/output	I/O
PTB[7:0]	PORTB7–PORTB0	General-purpose input/output	I/O
PTC[7:0]	PORTC7–PORTC0	General-purpose input/output	I/O
PTD[7:0]	PORTD7–PORTD0	General-purpose input/output	I/O
PTE[11:10], PTE[8], PTE[6:0]	PORTE11–PORTE10 PORTE8 PORTE6–PORTE0	General-purpose input/output	I/O

Table 28-16. TSI0 Signal Descriptions

Chip signal name	Module signal name	Description	I/O
TSI0_CH[24:0]	TSI[24:0]	TSI sensing pins or GPIO pins	I/O

Chapter 29
Port Control and Interrupts (PORT)

29.1 Chip-specific information for this module

29.1.1 I/O pin structure

The following figure shows the structure of normal I/O pin.

See the "Pin properties" section in DataSheet for properties on each pin.

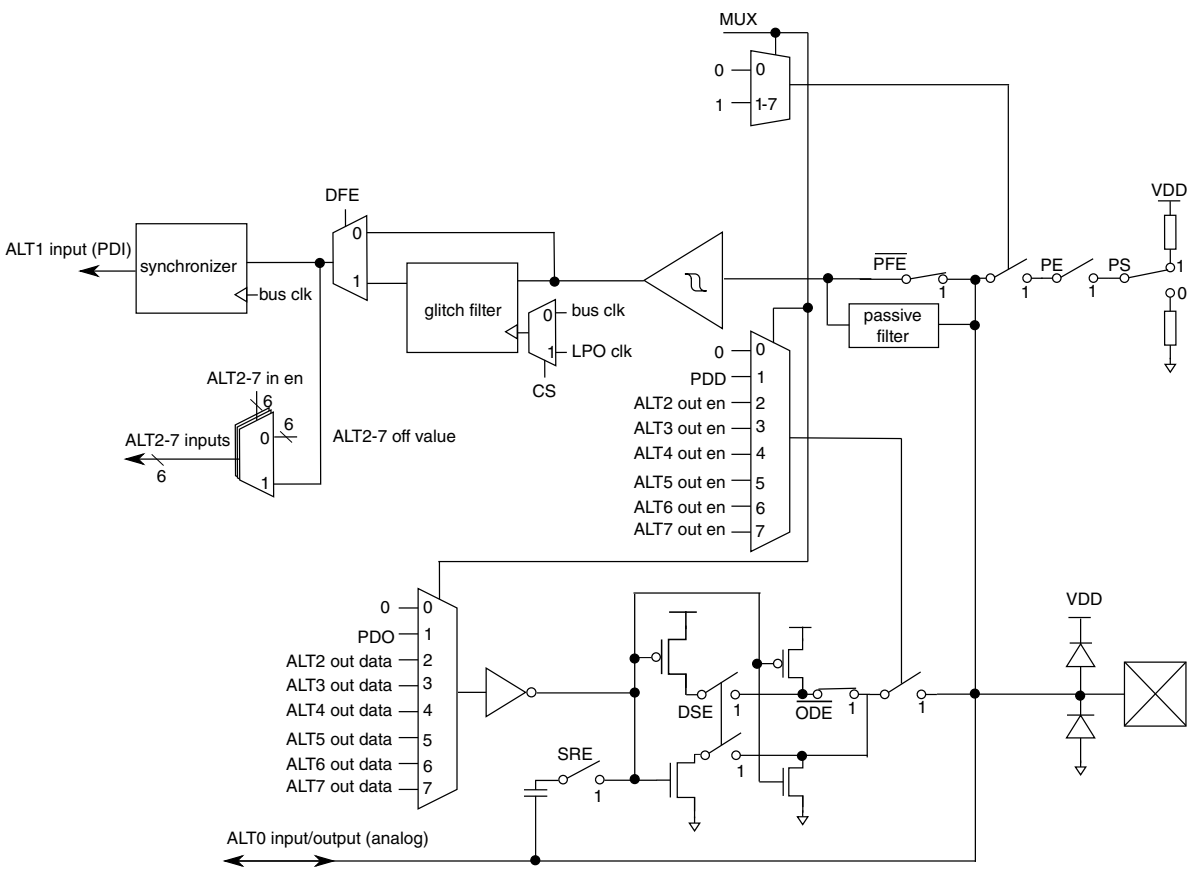


Figure 29-1. Normal I/O structure

29.1.2 Port control and interrupt module features

- 32-pin ports

NOTE

Not all pins are available on the device. See the "GPIO Signal Descriptions" table in DataSheet, and the following section for details.

- Each 32-pin port is assigned one interrupt.

Table 29-1. Ports summary

Feature	Port A	Port B	Port C	Port D	Port E
Pull select control	Yes	Yes	Yes	Yes	Yes
Pull select at reset	PTA4/PTA5=Pull up, Others=No	No	PTC4=Pull down, Others=No	PTD3=Pull up, Others=No	No
Pull enable control	Yes	Yes	Yes	Yes	Yes
Pull enable at reset	PTA4/ PTA5=Enabled; Others=Disabled	Disabled	PTC4=Enabled; Others=Disabled	PTD3=Enabled; Others=Disabled	Disabled
Passive filter enable control	PTA5=Yes; Others=No	No	No	PTD3=Yes; Others=No	No
Passive filter enable at reset	PTA5=Enabled; Others=Disabled	Disabled	Disabled	Disabled	Disabled
Open drain enable control	I2C and UART Tx=Enabled; Others=Disabled	I2C and UART Tx=Enabled; Others=Disabled	I2C and UART Tx=Enabled; Others=Disabled	I2C and UART Tx=Enabled; Others=Disabled	I2C and UART Tx=Enabled; Others=Disabled
Open drain enable at reset	Disabled	Disabled	Disabled	Disabled	Disabled
Drive strength enable control	No	PTB4/PTB5 only	No	PTD0/PTD1 only	PTE0/PTE1 only
Drive strength enable at reset	Disabled	Disabled	Disabled	Disabled	Disabled
Pin mux control	Yes	Yes	Yes	Yes	Yes
Pin mux at reset	PTA4/PTA5=ALT7; Others=ALT0	ALT0	PTC4=ALT7; Others=ALT0	PTD3=ALT7; Others=ALT0	ALT0
Lock bit	Yes	Yes	Yes	Yes	Yes
Interrupt request	Yes	Yes	Yes	Yes	Yes
Digital glitch filter	No	No	No	No	Yes

29.1.3 Application-related Information

1. A given peripheral function must be assigned to a maximum of one package pin. Do not program the same function to more than one pin.
2. To ensure the best signal timing for a given peripheral's interface, choose the pins in closest proximity to each other.
3. The clock to the port control module can be gated on and off using the PCC_PORTx register. These bits are cleared after any reset, which disables the clock to the corresponding module to conserve power. Prior to initializing the corresponding module, set PCC_PORTx[CGC] to enable the clock. Before turning off the clock, make sure to disable the module. For more details, refer to the clock distribution chapter.

29.2 Introduction

29.2.1 Overview

The Port Control and Interrupt (PORT) module provides support for port control, digital filtering, and external interrupt functions.

Most functions can be configured independently for each pin in the 32-bit port and affect the pin regardless of its pin muxing state.

There is one instance of the PORT module for each port. Not all pins within each port are implemented on a specific device.

29.2.2 Features

The PORT module has the following features:

- Pin interrupt
  - Interrupt flag and enable registers for each pin
  - Support for edge sensitive (rising, falling, both) or level sensitive (low, high) configured per pin
  - Support for interrupt request configured per pin
  - Asynchronous wake-up in low-power modes
  - Pin interrupt is functional in all digital pin muxing modes
- Digital input filter
  - Digital input filter for each pin, usable by any digital peripheral muxed onto the pin
  - Individual enable or bypass control field per pin

- Selectable clock source for digital input filter with a five bit resolution on filter size
- Functional in all digital pin multiplexing modes

- Port control
  - Individual pull control fields with pullup, pulldown, and pull-disable support
  - Individual drive strength field supporting high and low drive strength
  - Individual input passive filter field supporting enable and disable of the individual input passive filter
  - Individual mux control field supporting analog or pin disabled, GPIO, and up to six chip-specific digital functions
  - Pad configuration fields are functional in all digital pin muxing modes.

29.2.3 Modes of operation

29.2.3.1 Run mode

In Run mode, the PORT operates normally.

29.2.3.2 Wait mode

In Wait mode, PORT continues to operate normally and may be configured to exit the Low-Power mode if an enabled interrupt is detected.

29.2.3.3 Stop mode

In Stop mode, the PORT can be configured to exit the Low-Power mode via an asynchronous wake-up signal if an enabled interrupt is detected.

In Stop mode, the digital input filters are bypassed unless they are configured to run from the LPO clock source.

29.2.3.4 Debug mode

In Debug mode, PORT operates normally.

29.3 External signal description

The table found here describes the PORT external signal.

Table 29-2. Signal properties

Name	Function	I/O	Reset	Pull
PORTx[31:0]	External interrupt	I/O	0	-

NOTE

Not all pins within each port are implemented on each device.

29.4 Detailed signal description

The table found here contains the detailed signal description for the PORT interface.

Table 29-3. PORT interface—detailed signal description

Signal	I/O	Description	
PORTx[31:0]	I/O	External interrupt.	
		State meaning	Asserted—pin is logic 1. Negated—pin is logic 0.
		Timing	Assertion—may occur at any time and can assert asynchronously to the system clock. Negation—may occur at any time and can assert asynchronously to the system clock.

29.5 Memory map and register definition

Any read or write access to the PORT memory space that is outside the valid memory map results in a bus error. All register accesses complete with zero wait states.

PORT memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_9000	Pin Control Register n (PORTA_PCR0)	32	R/W	See section	29.5.1/452
4004_9004	Pin Control Register n (PORTA_PCR1)	32	R/W	See section	29.5.1/452
4004_9008	Pin Control Register n (PORTA_PCR2)	32	R/W	See section	29.5.1/452

Table continues on the next page...

PORT memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_900C	Pin Control Register n (PORTA_PCR3)	32	R/W	See section	29.5.1/452
4004_9010	Pin Control Register n (PORTA_PCR4)	32	R/W	See section	29.5.1/452
4004_9014	Pin Control Register n (PORTA_PCR5)	32	R/W	See section	29.5.1/452
4004_9018	Pin Control Register n (PORTA_PCR6)	32	R/W	See section	29.5.1/452
4004_901C	Pin Control Register n (PORTA_PCR7)	32	R/W	See section	29.5.1/452
4004_9020	Pin Control Register n (PORTA_PCR8)	32	R/W	See section	29.5.1/452
4004_9024	Pin Control Register n (PORTA_PCR9)	32	R/W	See section	29.5.1/452
4004_9028	Pin Control Register n (PORTA_PCR10)	32	R/W	See section	29.5.1/452
4004_902C	Pin Control Register n (PORTA_PCR11)	32	R/W	See section	29.5.1/452
4004_9030	Pin Control Register n (PORTA_PCR12)	32	R/W	See section	29.5.1/452
4004_9034	Pin Control Register n (PORTA_PCR13)	32	R/W	See section	29.5.1/452
4004_9038	Pin Control Register n (PORTA_PCR14)	32	R/W	See section	29.5.1/452
4004_903C	Pin Control Register n (PORTA_PCR15)	32	R/W	See section	29.5.1/452
4004_9040	Pin Control Register n (PORTA_PCR16)	32	R/W	See section	29.5.1/452
4004_9044	Pin Control Register n (PORTA_PCR17)	32	R/W	See section	29.5.1/452
4004_9048	Pin Control Register n (PORTA_PCR18)	32	R/W	See section	29.5.1/452
4004_904C	Pin Control Register n (PORTA_PCR19)	32	R/W	See section	29.5.1/452
4004_9050	Pin Control Register n (PORTA_PCR20)	32	R/W	See section	29.5.1/452
4004_9054	Pin Control Register n (PORTA_PCR21)	32	R/W	See section	29.5.1/452
4004_9058	Pin Control Register n (PORTA_PCR22)	32	R/W	See section	29.5.1/452
4004_905C	Pin Control Register n (PORTA_PCR23)	32	R/W	See section	29.5.1/452
4004_9060	Pin Control Register n (PORTA_PCR24)	32	R/W	See section	29.5.1/452
4004_9064	Pin Control Register n (PORTA_PCR25)	32	R/W	See section	29.5.1/452
4004_9068	Pin Control Register n (PORTA_PCR26)	32	R/W	See section	29.5.1/452
4004_906C	Pin Control Register n (PORTA_PCR27)	32	R/W	See section	29.5.1/452
4004_9070	Pin Control Register n (PORTA_PCR28)	32	R/W	See section	29.5.1/452
4004_9074	Pin Control Register n (PORTA_PCR29)	32	R/W	See section	29.5.1/452
4004_9078	Pin Control Register n (PORTA_PCR30)	32	R/W	See section	29.5.1/452
4004_907C	Pin Control Register n (PORTA_PCR31)	32	R/W	See section	29.5.1/452
4004_9080	Global Pin Control Low Register (PORTA_GPCLR)	32	W (always reads 0)	0000_0000h	29.5.2/454
4004_9084	Global Pin Control High Register (PORTA_GPCHR)	32	W (always reads 0)	0000_0000h	29.5.3/455
4004_90A0	Interrupt Status Flag Register (PORTA_ISFR)	32	w1c	0000_0000h	29.5.4/456
4004_90C0	Digital Filter Enable Register (PORTA_DFER)	32	R/W	0000_0000h	29.5.5/456
4004_90C4	Digital Filter Clock Register (PORTA_DFCR)	32	R/W	0000_0000h	29.5.6/457
4004_90C8	Digital Filter Width Register (PORTA_DFWR)	32	R/W	0000_0000h	29.5.7/457

PORT memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_A000	Pin Control Register n (PORTB_PCR0)	32	R/W	See section	29.5.1/452
4004_A004	Pin Control Register n (PORTB_PCR1)	32	R/W	See section	29.5.1/452
4004_A008	Pin Control Register n (PORTB_PCR2)	32	R/W	See section	29.5.1/452
4004_A00C	Pin Control Register n (PORTB_PCR3)	32	R/W	See section	29.5.1/452
4004_A010	Pin Control Register n (PORTB_PCR4)	32	R/W	See section	29.5.1/452
4004_A014	Pin Control Register n (PORTB_PCR5)	32	R/W	See section	29.5.1/452
4004_A018	Pin Control Register n (PORTB_PCR6)	32	R/W	See section	29.5.1/452
4004_A01C	Pin Control Register n (PORTB_PCR7)	32	R/W	See section	29.5.1/452
4004_A020	Pin Control Register n (PORTB_PCR8)	32	R/W	See section	29.5.1/452
4004_A024	Pin Control Register n (PORTB_PCR9)	32	R/W	See section	29.5.1/452
4004_A028	Pin Control Register n (PORTB_PCR10)	32	R/W	See section	29.5.1/452
4004_A02C	Pin Control Register n (PORTB_PCR11)	32	R/W	See section	29.5.1/452
4004_A030	Pin Control Register n (PORTB_PCR12)	32	R/W	See section	29.5.1/452
4004_A034	Pin Control Register n (PORTB_PCR13)	32	R/W	See section	29.5.1/452
4004_A038	Pin Control Register n (PORTB_PCR14)	32	R/W	See section	29.5.1/452
4004_A03C	Pin Control Register n (PORTB_PCR15)	32	R/W	See section	29.5.1/452
4004_A040	Pin Control Register n (PORTB_PCR16)	32	R/W	See section	29.5.1/452
4004_A044	Pin Control Register n (PORTB_PCR17)	32	R/W	See section	29.5.1/452
4004_A048	Pin Control Register n (PORTB_PCR18)	32	R/W	See section	29.5.1/452
4004_A04C	Pin Control Register n (PORTB_PCR19)	32	R/W	See section	29.5.1/452
4004_A050	Pin Control Register n (PORTB_PCR20)	32	R/W	See section	29.5.1/452
4004_A054	Pin Control Register n (PORTB_PCR21)	32	R/W	See section	29.5.1/452
4004_A058	Pin Control Register n (PORTB_PCR22)	32	R/W	See section	29.5.1/452
4004_A05C	Pin Control Register n (PORTB_PCR23)	32	R/W	See section	29.5.1/452
4004_A060	Pin Control Register n (PORTB_PCR24)	32	R/W	See section	29.5.1/452
4004_A064	Pin Control Register n (PORTB_PCR25)	32	R/W	See section	29.5.1/452
4004_A068	Pin Control Register n (PORTB_PCR26)	32	R/W	See section	29.5.1/452
4004_A06C	Pin Control Register n (PORTB_PCR27)	32	R/W	See section	29.5.1/452
4004_A070	Pin Control Register n (PORTB_PCR28)	32	R/W	See section	29.5.1/452
4004_A074	Pin Control Register n (PORTB_PCR29)	32	R/W	See section	29.5.1/452
4004_A078	Pin Control Register n (PORTB_PCR30)	32	R/W	See section	29.5.1/452
4004_A07C	Pin Control Register n (PORTB_PCR31)	32	R/W	See section	29.5.1/452
4004_A080	Global Pin Control Low Register (PORTB_GPCLR)	32	W (always reads 0)	0000_0000h	29.5.2/454
4004_A084	Global Pin Control High Register (PORTB_GPCHR)	32	W (always reads 0)	0000_0000h	29.5.3/455
4004_A0A0	Interrupt Status Flag Register (PORTB_ISFR)	32	w1c	0000_0000h	29.5.4/456

Table continues on the next page...

PORT memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_A0C0	Digital Filter Enable Register (PORTB_DFER)	32	R/W	0000_0000h	29.5.5/456
4004_A0C4	Digital Filter Clock Register (PORTB_DFCR)	32	R/W	0000_0000h	29.5.6/457
4004_A0C8	Digital Filter Width Register (PORTB_DFWR)	32	R/W	0000_0000h	29.5.7/457
4004_B000	Pin Control Register n (PORTC_PCR0)	32	R/W	See section	29.5.1/452
4004_B004	Pin Control Register n (PORTC_PCR1)	32	R/W	See section	29.5.1/452
4004_B008	Pin Control Register n (PORTC_PCR2)	32	R/W	See section	29.5.1/452
4004_B00C	Pin Control Register n (PORTC_PCR3)	32	R/W	See section	29.5.1/452
4004_B010	Pin Control Register n (PORTC_PCR4)	32	R/W	See section	29.5.1/452
4004_B014	Pin Control Register n (PORTC_PCR5)	32	R/W	See section	29.5.1/452
4004_B018	Pin Control Register n (PORTC_PCR6)	32	R/W	See section	29.5.1/452
4004_B01C	Pin Control Register n (PORTC_PCR7)	32	R/W	See section	29.5.1/452
4004_B020	Pin Control Register n (PORTC_PCR8)	32	R/W	See section	29.5.1/452
4004_B024	Pin Control Register n (PORTC_PCR9)	32	R/W	See section	29.5.1/452
4004_B028	Pin Control Register n (PORTC_PCR10)	32	R/W	See section	29.5.1/452
4004_B02C	Pin Control Register n (PORTC_PCR11)	32	R/W	See section	29.5.1/452
4004_B030	Pin Control Register n (PORTC_PCR12)	32	R/W	See section	29.5.1/452
4004_B034	Pin Control Register n (PORTC_PCR13)	32	R/W	See section	29.5.1/452
4004_B038	Pin Control Register n (PORTC_PCR14)	32	R/W	See section	29.5.1/452
4004_B03C	Pin Control Register n (PORTC_PCR15)	32	R/W	See section	29.5.1/452
4004_B040	Pin Control Register n (PORTC_PCR16)	32	R/W	See section	29.5.1/452
4004_B044	Pin Control Register n (PORTC_PCR17)	32	R/W	See section	29.5.1/452
4004_B048	Pin Control Register n (PORTC_PCR18)	32	R/W	See section	29.5.1/452
4004_B04C	Pin Control Register n (PORTC_PCR19)	32	R/W	See section	29.5.1/452
4004_B050	Pin Control Register n (PORTC_PCR20)	32	R/W	See section	29.5.1/452
4004_B054	Pin Control Register n (PORTC_PCR21)	32	R/W	See section	29.5.1/452
4004_B058	Pin Control Register n (PORTC_PCR22)	32	R/W	See section	29.5.1/452
4004_B05C	Pin Control Register n (PORTC_PCR23)	32	R/W	See section	29.5.1/452
4004_B060	Pin Control Register n (PORTC_PCR24)	32	R/W	See section	29.5.1/452
4004_B064	Pin Control Register n (PORTC_PCR25)	32	R/W	See section	29.5.1/452
4004_B068	Pin Control Register n (PORTC_PCR26)	32	R/W	See section	29.5.1/452
4004_B06C	Pin Control Register n (PORTC_PCR27)	32	R/W	See section	29.5.1/452
4004_B070	Pin Control Register n (PORTC_PCR28)	32	R/W	See section	29.5.1/452
4004_B074	Pin Control Register n (PORTC_PCR29)	32	R/W	See section	29.5.1/452
4004_B078	Pin Control Register n (PORTC_PCR30)	32	R/W	See section	29.5.1/452
4004_B07C	Pin Control Register n (PORTC_PCR31)	32	R/W	See section	29.5.1/452
4004_B080	Global Pin Control Low Register (PORTC_GPCLR)	32	W (always reads 0)	0000_0000h	29.5.2/454

Table continues on the next page...

PORT memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_B084	Global Pin Control High Register (PORTC_GPCHR)	32	W (always reads 0)	0000_0000h	29.5.3/455
4004_B0A0	Interrupt Status Flag Register (PORTC_ISFR)	32	w1c	0000_0000h	29.5.4/456
4004_B0C0	Digital Filter Enable Register (PORTC_DFER)	32	R/W	0000_0000h	29.5.5/456
4004_B0C4	Digital Filter Clock Register (PORTC_DFCR)	32	R/W	0000_0000h	29.5.6/457
4004_B0C8	Digital Filter Width Register (PORTC_DFWR)	32	R/W	0000_0000h	29.5.7/457
4004_C000	Pin Control Register n (PORTD_PCR0)	32	R/W	See section	29.5.1/452
4004_C004	Pin Control Register n (PORTD_PCR1)	32	R/W	See section	29.5.1/452
4004_C008	Pin Control Register n (PORTD_PCR2)	32	R/W	See section	29.5.1/452
4004_C00C	Pin Control Register n (PORTD_PCR3)	32	R/W	See section	29.5.1/452
4004_C010	Pin Control Register n (PORTD_PCR4)	32	R/W	See section	29.5.1/452
4004_C014	Pin Control Register n (PORTD_PCR5)	32	R/W	See section	29.5.1/452
4004_C018	Pin Control Register n (PORTD_PCR6)	32	R/W	See section	29.5.1/452
4004_C01C	Pin Control Register n (PORTD_PCR7)	32	R/W	See section	29.5.1/452
4004_C020	Pin Control Register n (PORTD_PCR8)	32	R/W	See section	29.5.1/452
4004_C024	Pin Control Register n (PORTD_PCR9)	32	R/W	See section	29.5.1/452
4004_C028	Pin Control Register n (PORTD_PCR10)	32	R/W	See section	29.5.1/452
4004_C02C	Pin Control Register n (PORTD_PCR11)	32	R/W	See section	29.5.1/452
4004_C030	Pin Control Register n (PORTD_PCR12)	32	R/W	See section	29.5.1/452
4004_C034	Pin Control Register n (PORTD_PCR13)	32	R/W	See section	29.5.1/452
4004_C038	Pin Control Register n (PORTD_PCR14)	32	R/W	See section	29.5.1/452
4004_C03C	Pin Control Register n (PORTD_PCR15)	32	R/W	See section	29.5.1/452
4004_C040	Pin Control Register n (PORTD_PCR16)	32	R/W	See section	29.5.1/452
4004_C044	Pin Control Register n (PORTD_PCR17)	32	R/W	See section	29.5.1/452
4004_C048	Pin Control Register n (PORTD_PCR18)	32	R/W	See section	29.5.1/452
4004_C04C	Pin Control Register n (PORTD_PCR19)	32	R/W	See section	29.5.1/452
4004_C050	Pin Control Register n (PORTD_PCR20)	32	R/W	See section	29.5.1/452
4004_C054	Pin Control Register n (PORTD_PCR21)	32	R/W	See section	29.5.1/452
4004_C058	Pin Control Register n (PORTD_PCR22)	32	R/W	See section	29.5.1/452
4004_C05C	Pin Control Register n (PORTD_PCR23)	32	R/W	See section	29.5.1/452
4004_C060	Pin Control Register n (PORTD_PCR24)	32	R/W	See section	29.5.1/452
4004_C064	Pin Control Register n (PORTD_PCR25)	32	R/W	See section	29.5.1/452
4004_C068	Pin Control Register n (PORTD_PCR26)	32	R/W	See section	29.5.1/452
4004_C06C	Pin Control Register n (PORTD_PCR27)	32	R/W	See section	29.5.1/452
4004_C070	Pin Control Register n (PORTD_PCR28)	32	R/W	See section	29.5.1/452
4004_C074	Pin Control Register n (PORTD_PCR29)	32	R/W	See section	29.5.1/452
4004_C078	Pin Control Register n (PORTD_PCR30)	32	R/W	See section	29.5.1/452

Table continues on the next page...

PORT memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_C07C	Pin Control Register n (PORTD_PCR31)	32	R/W	See section	29.5.1/452
4004_C080	Global Pin Control Low Register (PORTD_GPCLR)	32	W (always reads 0)	0000_0000h	29.5.2/454
4004_C084	Global Pin Control High Register (PORTD_GPCHR)	32	W (always reads 0)	0000_0000h	29.5.3/455
4004_C0A0	Interrupt Status Flag Register (PORTD_ISFR)	32	w1c	0000_0000h	29.5.4/456
4004_C0C0	Digital Filter Enable Register (PORTD_DFER)	32	R/W	0000_0000h	29.5.5/456
4004_C0C4	Digital Filter Clock Register (PORTD_DFCR)	32	R/W	0000_0000h	29.5.6/457
4004_C0C8	Digital Filter Width Register (PORTD_DFWR)	32	R/W	0000_0000h	29.5.7/457
4004_D000	Pin Control Register n (PORTE_PCR0)	32	R/W	See section	29.5.1/452
4004_D004	Pin Control Register n (PORTE_PCR1)	32	R/W	See section	29.5.1/452
4004_D008	Pin Control Register n (PORTE_PCR2)	32	R/W	See section	29.5.1/452
4004_D00C	Pin Control Register n (PORTE_PCR3)	32	R/W	See section	29.5.1/452
4004_D010	Pin Control Register n (PORTE_PCR4)	32	R/W	See section	29.5.1/452
4004_D014	Pin Control Register n (PORTE_PCR5)	32	R/W	See section	29.5.1/452
4004_D018	Pin Control Register n (PORTE_PCR6)	32	R/W	See section	29.5.1/452
4004_D01C	Pin Control Register n (PORTE_PCR7)	32	R/W	See section	29.5.1/452
4004_D020	Pin Control Register n (PORTE_PCR8)	32	R/W	See section	29.5.1/452
4004_D024	Pin Control Register n (PORTE_PCR9)	32	R/W	See section	29.5.1/452
4004_D028	Pin Control Register n (PORTE_PCR10)	32	R/W	See section	29.5.1/452
4004_D02C	Pin Control Register n (PORTE_PCR11)	32	R/W	See section	29.5.1/452
4004_D030	Pin Control Register n (PORTE_PCR12)	32	R/W	See section	29.5.1/452
4004_D034	Pin Control Register n (PORTE_PCR13)	32	R/W	See section	29.5.1/452
4004_D038	Pin Control Register n (PORTE_PCR14)	32	R/W	See section	29.5.1/452
4004_D03C	Pin Control Register n (PORTE_PCR15)	32	R/W	See section	29.5.1/452
4004_D040	Pin Control Register n (PORTE_PCR16)	32	R/W	See section	29.5.1/452
4004_D044	Pin Control Register n (PORTE_PCR17)	32	R/W	See section	29.5.1/452
4004_D048	Pin Control Register n (PORTE_PCR18)	32	R/W	See section	29.5.1/452
4004_D04C	Pin Control Register n (PORTE_PCR19)	32	R/W	See section	29.5.1/452
4004_D050	Pin Control Register n (PORTE_PCR20)	32	R/W	See section	29.5.1/452
4004_D054	Pin Control Register n (PORTE_PCR21)	32	R/W	See section	29.5.1/452
4004_D058	Pin Control Register n (PORTE_PCR22)	32	R/W	See section	29.5.1/452
4004_D05C	Pin Control Register n (PORTE_PCR23)	32	R/W	See section	29.5.1/452
4004_D060	Pin Control Register n (PORTE_PCR24)	32	R/W	See section	29.5.1/452
4004_D064	Pin Control Register n (PORTE_PCR25)	32	R/W	See section	29.5.1/452
4004_D068	Pin Control Register n (PORTE_PCR26)	32	R/W	See section	29.5.1/452
4004_D06C	Pin Control Register n (PORTE_PCR27)	32	R/W	See section	29.5.1/452

Table continues on the next page...

PORT memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_D070	Pin Control Register n (PORTE_PCR28)	32	R/W	See section	29.5.1/452
4004_D074	Pin Control Register n (PORTE_PCR29)	32	R/W	See section	29.5.1/452
4004_D078	Pin Control Register n (PORTE_PCR30)	32	R/W	See section	29.5.1/452
4004_D07C	Pin Control Register n (PORTE_PCR31)	32	R/W	See section	29.5.1/452
4004_D080	Global Pin Control Low Register (PORTE_GPCLR)	32	W (always reads 0)	0000_0000h	29.5.2/454
4004_D084	Global Pin Control High Register (PORTE_GPCHR)	32	W (always reads 0)	0000_0000h	29.5.3/455
4004_D0A0	Interrupt Status Flag Register (PORTE_ISFR)	32	w1c	0000_0000h	29.5.4/456
4004_D0C0	Digital Filter Enable Register (PORTE_DFER)	32	R/W	0000_0000h	29.5.5/456
4004_D0C4	Digital Filter Clock Register (PORTE_DFCR)	32	R/W	0000_0000h	29.5.6/457
4004_D0C8	Digital Filter Width Register (PORTE_DFWR)	32	R/W	0000_0000h	29.5.7/457

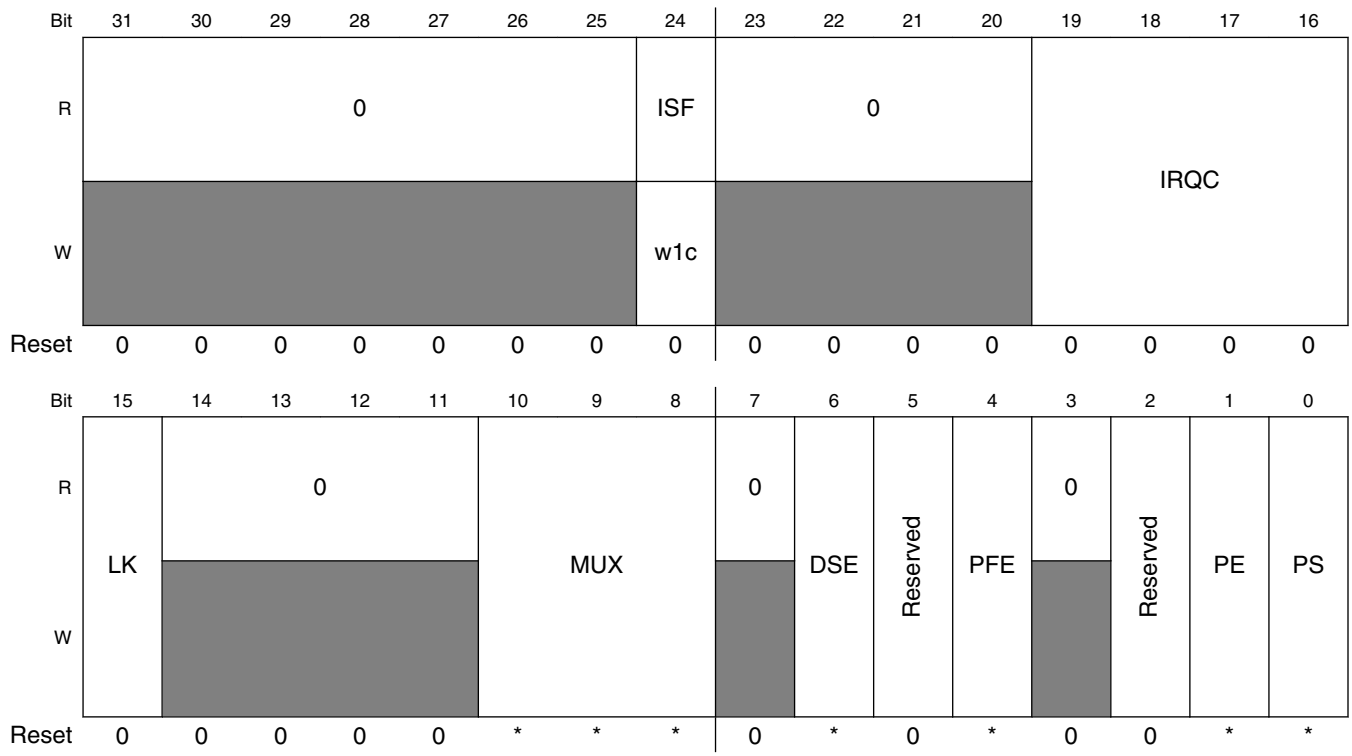
29.5.1 Pin Control Register n (PORTx_PCR*n*)

NOTE

See the GPIO Configuration section for details on the available functions for each pin.

Do not modify pin configuration registers associated with pins that are not available in a reduced-pin package offering. Unbonded pins not available in a package are disabled by default to prevent them from consuming power.

Address: Base address + 0h offset + (4d × i), where i=0d to 31d



* Notes:
- MUX field: Varies by port. See Signal Multiplexing and Signal Descriptions chapter for reset values per port.
- DSE field: Varies by port. See Signal Multiplexing and Signal Descriptions chapter for reset values per port.
- PFE field: Varies by port. See Signal Multiplexing and Signal Descriptions chapter for reset values per port.
- PE field: Varies by port. See Signal Multiplexing and Signal Descriptions chapter for reset values per port.
- PS field: Varies by port. See Signal Multiplexing and Signal Descriptions chapter for reset values per port.

PORTx_PCR*n* field descriptions

Field	Description
31–25 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
24 ISF	Interrupt Status Flag The pin interrupt configuration is valid in all digital pin muxing modes. 0 Configured interrupt is not detected. 1 Configured interrupt is detected. The flag remains set until a logic 1 is written to the flag. If the pin is configured for a level sensitive interrupt and the pin remains asserted, then the flag is set again immediately after it is cleared.
23–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–16 IRQC	Interrupt Configuration The pin interrupt configuration is valid in all digital pin muxing modes. The corresponding pin is configured to generate interrupt request as follows: 0000 Interrupt Status Flag (ISF) is disabled. 0100 Reserved. 0101 Reserved. 0110 Reserved. 0111 Reserved. 1000 ISF flag and Interrupt when logic 0. 1001 ISF flag and Interrupt on rising-edge. 1010 ISF flag and Interrupt on falling-edge. 1011 ISF flag and Interrupt on either edge. 1100 ISF flag and Interrupt when logic 1. 1101 Reserved. 1110 Reserved. 1111 Reserved.
15 LK	Lock Register 0 Pin Control Register fields [15:0] are not locked. 1 Pin Control Register fields [15:0] are locked and cannot be updated until the next system reset.
14–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10–8 MUX	Pin Mux Control Not all pins support all pin muxing slots. Unimplemented pin muxing slots are reserved and may result in configuring the pin for a different pin muxing slot. The corresponding pin is configured in the following pin muxing slot as follows: 000 Pin disabled (Alternative 0) (analog). 001 Alternative 1 (GPIO). 010 Alternative 2 (chip-specific). 011 Alternative 3 (chip-specific). 100 Alternative 4 (chip-specific). 101 Alternative 5 (chip-specific). 110 Alternative 6 (chip-specific). 111 Alternative 7 (chip-specific).

Table continues on the next page...

PORTx_PCR*n* field descriptions (continued)

Field	Description
7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
6 DSE	Drive Strength Enable Drive strength configuration is valid in all digital pin muxing modes. 0 Low drive strength is configured on the corresponding pin, if pin is configured as a digital output. 1 High drive strength is configured on the corresponding pin, if pin is configured as a digital output.
5 Reserved	This field is reserved.
4 PFE	Passive Filter Enable Passive filter configuration is valid in all digital pin muxing modes. 0 Passive input filter is disabled on the corresponding pin. 1 Passive input filter is enabled on the corresponding pin, if the pin is configured as a digital input. Refer to the device data sheet for filter characteristics.
3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 Reserved	This field is reserved.
1 PE	Pull Enable Pull configuration is valid in all digital pin muxing modes. 0 Internal pullup or pulldown resistor is not enabled on the corresponding pin. 1 Internal pullup or pulldown resistor is enabled on the corresponding pin, if the pin is configured as a digital input.
0 PS	Pull Select Pull configuration is valid in all digital pin muxing modes. 0 Internal pulldown resistor is enabled on the corresponding pin, if the corresponding PE field is set. 1 Internal pullup resistor is enabled on the corresponding pin, if the corresponding PE field is set.

29.5.2 Global Pin Control Low Register (PORTx_GPCLR)

Only 32-bit writes are supported to this register.

Address: Base address + 80h offset

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0																0															
W	GPWE																GPWD															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PORTx_GPCLR field descriptions

Field	Description
31–16 GPWE	Global Pin Write Enable Selects which Pin Control Registers (15 through 0) bits [15:0] update with the value in GPWD. If a selected Pin Control Register is locked then the write to that register is ignored. 0 Corresponding Pin Control Register is not updated with the value in GPWD. 1 Corresponding Pin Control Register is updated with the value in GPWD.
GPWD	Global Pin Write Data Write value that is written to all Pin Control Registers bits [15:0] that are selected by GPWE.

29.5.3 Global Pin Control High Register (PORTx_GPCHR)

Only 32-bit writes are supported to this register.

Address: Base address + 84h offset

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0																0															
W	GPWE																GPWD															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PORTx_GPCHR field descriptions

Field	Description
31–16 GPWE	Global Pin Write Enable Selects which Pin Control Registers (31 through 16) bits [15:0] update with the value in GPWD. If a selected Pin Control Register is locked then the write to that register is ignored. 0 Corresponding Pin Control Register is not updated with the value in GPWD. 1 Corresponding Pin Control Register is updated with the value in GPWD.
GPWD	Global Pin Write Data Write value that is written to all Pin Control Registers bits [15:0] that are selected by GPWE.

29.5.4 Interrupt Status Flag Register (PORTx_ISFR)

The pin interrupt configuration is valid in all digital pin muxing modes. The Interrupt Status Flag for each pin is also visible in the corresponding Pin Control Register, and each flag can be cleared in either location.

Address: Base address + A0h offset

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	ISF																															
W	w1c																															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PORTx_ISFR field descriptions

Field	Description
ISF	Interrupt Status Flag Each bit in the field indicates the detection of the configured interrupt of the same number as the field. 0 Configured interrupt is not detected. 1 Configured interrupt is detected. The flag remains set until a logic 1 is written to the flag. If the pin is configured for a level sensitive interrupt and the pin remains asserted, then the flag is set again immediately after it is cleared.

29.5.5 Digital Filter Enable Register (PORTx_DFER)

The digital filter configuration is valid in all digital pin muxing modes.

Address: Base address + C0h offset

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

PORTx_DFER field descriptions

Field	Description
DFE	Digital Filter Enable The digital filter configuration is valid in all digital pin muxing modes. The output of each digital filter is reset to zero at system reset and whenever the digital filter is disabled. Each bit in the field enables the digital filter of the same number as the field.

PORTx_DFER field descriptions (continued)

Field	Description
	0 Digital filter is disabled on the corresponding pin and output of the digital filter is reset to zero. 1 Digital filter is enabled on the corresponding pin, if the pin is configured as a digital input.

29.5.6 Digital Filter Clock Register (PORTx_DFCR)

The digital filter configuration is valid in all digital pin muxing modes.

Address: Base address + C4h offset

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0															CS
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PORTx_DFCR field descriptions

Field	Description
31–1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 CS	Clock Source The digital filter configuration is valid in all digital pin muxing modes. Configures the clock source for the digital input filters. Changing the filter clock source must be done only when all digital filters are disabled. 0 Digital filters are clocked by the bus clock. 1 Digital filters are clocked by the LPO clock.

29.5.7 Digital Filter Width Register (PORTx_DFWR)

The digital filter configuration is valid in all digital pin muxing modes.

Address: Base address + C8h offset

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

PORTx_DFWR field descriptions

Field	Description
31–5 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
FILT	Filter Length The digital filter configuration is valid in all digital pin muxing modes. Configures the maximum size of the glitches, in clock cycles, that the digital filter absorbs for the enabled digital filters. Glitches that are longer than this register setting will pass through the digital filter, and glitches that are equal to or less than this register setting are filtered. Changing the filter length must be done only after all filters are disabled.

29.6 Functional description

29.6.1 Pin control

Each port pin has a corresponding Pin Control register, PORT_PCRn, associated with it.

The upper half of the Pin Control register configures the pin's capability to interrupt the CPU on a rising/falling edge or both edges as well as a logic level occurring on the port pin. It also includes a flag to indicate that an interrupt has occurred.

The lower half of the Pin Control register configures the following functions for each pin within the 32-bit port.

- Pullup or pulldown enable
- Drive strength
- Passive input filter enable
- Pin Muxing mode

The functions apply across all digital pin muxing modes and individual peripherals do not override the configuration in the Pin Control register. For example, if an I^2C function is enabled on a pin, that does not override the pullup configuration for that pin.

When the Pin Muxing mode is configured for analog or is disabled, all the digital functions on that pin are disabled. This includes the pullup and pulldown enables, output buffer enable, input buffer enable, and passive filter enable.

The LK bit (bit 15 of Pin Control Register PCR*n*) allows the configuration for each pin to be locked until the next system reset. When locked, writes to the lower half of that pin control register are ignored, although a bus error is not generated on an attempted write to a locked register.

The configuration of each Pin Control register is retained when the PORT module is disabled.

Whenever a pin is configured in any digital pin muxing mode, the input buffer for that pin is enabled allowing the pin state to be read via the corresponding GPIO Port Data Input Register (GPIO_PDIR) or allowing a pin interrupt to be generated. If a pin is ever floating when its input buffer is enabled, then this can cause an increase in power consumption and must be avoided. A pin can be floating due to an input pin that is not connected or an output pin that has tri-stated (output buffer is disabled).

Enabling the internal pull resistor (or implementing an external pull resistor) will ensure a pin does not float when its input buffer is enabled; note that the internal pull resistor is automatically disabled whenever the output buffer is enabled allowing the Pull Enable bit to remain set. Configuring the Pin Muxing mode to disabled or analog will disable the pin's input buffer and results in the lowest power consumption.

29.6.2 Global pin control

The two global pin control registers allow a single register write to update the lower half of the pin control register on up to 16 pins, all with the same value. Registers that are locked cannot be written using the global pin control registers.

The global pin control registers are designed to enable software to quickly configure multiple pins within the one port for the same peripheral function. However, the interrupt functions cannot be configured using the global pin control registers.

The global pin control registers are write-only registers, that always read as 0.

29.6.3 External interrupts

The external interrupt capability of the PORT module is available in all digital pin muxing modes provided the PORT module is enabled.

Each pin can be individually configured for any of the following external interrupt modes:

- Interrupt disabled, default out of reset
- Active high level sensitive interrupt
- Active low level sensitive interrupt
- Rising edge sensitive interrupt
- Falling edge sensitive interrupt
- Rising and falling edge sensitive interrupt

The interrupt status flag is set when the configured edge or level is detected on the pin or at the output of the digital input filter, if the digital input digital filter is enabled. When not in Stop mode, the input is first synchronized to the bus clock to detect the configured level or edge transition.

The PORT module generates a single interrupt that asserts when the interrupt status flag is set for any enabled interrupt for that port. The interrupt negates after the interrupt status flags for all enabled interrupts have been cleared by writing a logic 1 to the ISF flag in either the PORT_ISFR or PORT_PCRn registers.

During Stop mode, the interrupt status flag for any enabled interrupt is asynchronously set if the required level or edge is detected. This also generates an asynchronous wake-up signal to exit the Low-Power mode.

29.6.4 Digital filter

The digital filter capabilities of the PORT module are available in all digital Pin Muxing modes if the PORT module is enabled.

The clock used for all digital filters within one port can be configured between the bus clock or the LPO clock. This selection must be changed only when all digital filters for that port are disabled. If the digital filters for a port are configured to use the bus clock, then the digital filters are bypassed for the duration of Stop mode. While the digital filters are bypassed, the output of each digital filter always equals the input pin, but the internal state of the digital filters remains static and does not update due to any change on the input pin.

The filter width in clock size is the same for all enabled digital filters within one port and must be changed only when all digital filters for that port are disabled.

The output of each digital filter is logic zero after system reset and whenever a digital filter is disabled. After a digital filter is enabled, the input is synchronized to the filter clock, either the bus clock or the LPO clock. If the synchronized input and the output of the digital filter remain different for a number of filter clock cycles equal to the filter width register configuration, then the output of the digital filter updates to equal the synchronized filter input.

The maximum latency through a digital filter equals three filter clock cycles plus the filter width configuration register.

Chapter 30
General-Purpose Input/Output (GPIO)

30.1 Chip-specific information for this module

30.1.1 Instantiation Information

The number of GPIO signals available on the devices covered by this document are detailed in the "Ordering information" section and the "GPIO Signal Descriptions" table of the Data Sheet.

See "Pin properties" in the Data Sheet for features of each pins.

Port control and interrupt module features are supported, each 32-pin port will support a single interrupt. The pins of PORT_E support digital filter functions.

30.1.2 GPIO accessibility in the memory map

The GPIO is multi-ported and can be accessed directly by the core with zero wait states at base address 0xF800_0000. It can also be accessed by the core through the cross bar/ AIPS interface at 0x400F_F000 and at an aliased slot (15) at address 0x4000_F000.

30.2 Introduction

The GPIO registers support 8-bit, 16-bit or 32-bit accesses.

The GPIO data direction and output data registers control the direction and output data of each pin when the pin is configured for the GPIO function. The GPIO input data register displays the logic value on each pin when the pin is configured for any digital function, provided the corresponding Port Control and Interrupt module for that pin is enabled.

Efficient bit manipulation of the general-purpose outputs is supported through the addition of set, clear, and toggle write-only registers for each port output data register.

30.2.1 Features

Features of the GPIO module include:

- Port Data Input register visible in all digital pin-multiplexing modes
- Port Data Output register with corresponding set/clear/toggle registers
- Port Data Direction register
- Zero wait state access to GPIO registers through IOPORT

NOTE

The GPIO module is clocked by system clock.

30.2.2 Modes of operation

The following table depicts different modes of operation and the behavior of the GPIO module in these modes.

Table 30-1. Modes of operation

Modes of operation	Description
Run	The GPIO module operates normally.
Wait	The GPIO module operates normally.
Stop	The GPIO module is disabled.
Debug	The GPIO module operates normally.

30.2.3 GPIO signal descriptions

Table 30-2. GPIO signal descriptions

GPIO signal descriptions	Description	I/O
PORTA31–PORTA0	General-purpose input/output	I/O
PORTB31–PORTB0	General-purpose input/output	I/O
PORTC31–PORTC0	General-purpose input/output	I/O
PORTD31–PORTD0	General-purpose input/output	I/O
PORTE31–PORTE0	General-purpose input/output	I/O

NOTE

Not all pins within each port are implemented on each device.
See the "Signal Multiplexing" section and the "GPIO Signal

Descriptions" table in DataSheet, for the number of GPIO ports available in the device.

30.2.3.1 Detailed signal description

Table 30-3. GPIO interface-detailed signal descriptions

Signal	I/O	Description	
PORTA31–PORTA0 PORTB31–PORTB0 PORTC31–PORTC0 PORTD31–PORTD0 PORTE31–PORTE0	I/O	General-purpose input/output	
		State meaning	Asserted: The pin is logic 1. Deasserted: The pin is logic 0.
		Timing	Assertion: When output, this signal occurs on the rising-edge of the system clock. For input, it may occur at any time and input may be asserted asynchronously to the system clock. Deassertion: When output, this signal occurs on the rising-edge of the system clock. For input, it may occur at any time and input may be asserted asynchronously to the system clock.

30.3 Memory map and register definition

Any read or write access to the GPIO memory space that is outside the valid memory map results in a bus error.

GPIO memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
400F_F000	Port Data Output Register (GPIOA_PDOR)	32	R/W	0000_0000h	30.3.1/465
400F_F004	Port Set Output Register (GPIOA_PSOR)	32	W (always reads 0)	0000_0000h	30.3.2/466
400F_F008	Port Clear Output Register (GPIOA_PCOR)	32	W (always reads 0)	0000_0000h	30.3.3/466
400F_F00C	Port Toggle Output Register (GPIOA_PTOR)	32	W (always reads 0)	0000_0000h	30.3.4/467

Table continues on the next page...

GPIO memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
400F_F010	Port Data Input Register (GPIOA_PDIR)	32	R	0000_0000h	30.3.5/467
400F_F014	Port Data Direction Register (GPIOA_PDDR)	32	R/W	0000_0000h	30.3.6/468
400F_F040	Port Data Output Register (GPIOB_PDOR)	32	R/W	0000_0000h	30.3.1/465
400F_F044	Port Set Output Register (GPIOB_PSOR)	32	W (always reads 0)	0000_0000h	30.3.2/466
400F_F048	Port Clear Output Register (GPIOB_PCOR)	32	W (always reads 0)	0000_0000h	30.3.3/466
400F_F04C	Port Toggle Output Register (GPIOB_PTOR)	32	W (always reads 0)	0000_0000h	30.3.4/467
400F_F050	Port Data Input Register (GPIOB_PDIR)	32	R	0000_0000h	30.3.5/467
400F_F054	Port Data Direction Register (GPIOB_PDDR)	32	R/W	0000_0000h	30.3.6/468
400F_F080	Port Data Output Register (GPIOC_PDOR)	32	R/W	0000_0000h	30.3.1/465
400F_F084	Port Set Output Register (GPIOC_PSOR)	32	W (always reads 0)	0000_0000h	30.3.2/466
400F_F088	Port Clear Output Register (GPIOC_PCOR)	32	W (always reads 0)	0000_0000h	30.3.3/466
400F_F08C	Port Toggle Output Register (GPIOC_PTOR)	32	W (always reads 0)	0000_0000h	30.3.4/467
400F_F090	Port Data Input Register (GPIOC_PDIR)	32	R	0000_0000h	30.3.5/467
400F_F094	Port Data Direction Register (GPIOC_PDDR)	32	R/W	0000_0000h	30.3.6/468
400F_F0C0	Port Data Output Register (GPIOD_PDOR)	32	R/W	0000_0000h	30.3.1/465
400F_F0C4	Port Set Output Register (GPIOD_PSOR)	32	W (always reads 0)	0000_0000h	30.3.2/466
400F_F0C8	Port Clear Output Register (GPIOD_PCOR)	32	W (always reads 0)	0000_0000h	30.3.3/466
400F_F0CC	Port Toggle Output Register (GPIOD_PTOR)	32	W (always reads 0)	0000_0000h	30.3.4/467
400F_F0D0	Port Data Input Register (GPIOD_PDIR)	32	R	0000_0000h	30.3.5/467
400F_F0D4	Port Data Direction Register (GPIOD_PDDR)	32	R/W	0000_0000h	30.3.6/468
400F_F100	Port Data Output Register (GPIOE_PDOR)	32	R/W	0000_0000h	30.3.1/465
400F_F104	Port Set Output Register (GPIOE_PSOR)	32	W (always reads 0)	0000_0000h	30.3.2/466

Table continues on the next page...

GPIO memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
400F_F108	Port Clear Output Register (GPIOE_PCOR)	32	W (always reads 0)	0000_0000h	30.3.3/466
400F_F10C	Port Toggle Output Register (GPIOE_PTOR)	32	W (always reads 0)	0000_0000h	30.3.4/467
400F_F110	Port Data Input Register (GPIOE_PDIR)	32	R	0000_0000h	30.3.5/467
400F_F114	Port Data Direction Register (GPIOE_PDDR)	32	R/W	0000_0000h	30.3.6/468

30.3.1 Port Data Output Register (GPIOx_PDOR)

This register configures the logic levels that are driven on each general-purpose output pins.

NOTE

Do not modify pin configuration registers associated with pins not available in your selected package. All unbonded pins not available in your package will default to DISABLE state for lowest power consumption.

Address: Base address + 0h offset

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

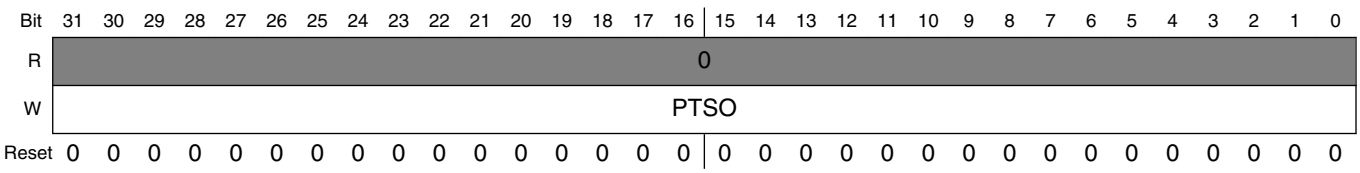
GPIOx_PDOR field descriptions

Field	Description
PDO	Port Data Output Register bits for unbonded pins return a undefined value when read. 0 Logic level 0 is driven on pin, provided pin is configured for general-purpose output. 1 Logic level 1 is driven on pin, provided pin is configured for general-purpose output.

30.3.2 Port Set Output Register (GPIOx_PSOR)

This register configures whether to set the fields of the PDOR.

Address: Base address + 4h offset



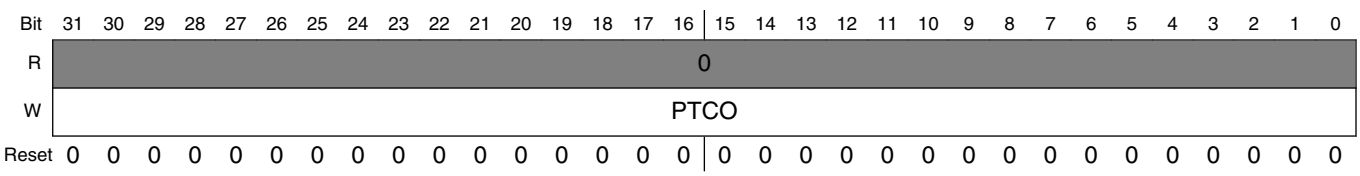
GPIOx_PSOR field descriptions

Field	Description
PTSO	Port Set Output Writing to this register will update the contents of the corresponding bit in the PDOR as follows: 0 Corresponding bit in PDORn does not change. 1 Corresponding bit in PDORn is set to logic 1.

30.3.3 Port Clear Output Register (GPIOx_PCOR)

This register configures whether to clear the fields of PDOR.

Address: Base address + 8h offset



GPIOx_PCOR field descriptions

Field	Description
PTCO	Port Clear Output Writing to this register will update the contents of the corresponding bit in the Port Data Output Register (PDOR) as follows: 0 Corresponding bit in PDORn does not change. 1 Corresponding bit in PDORn is cleared to logic 0.

30.3.4 Port Toggle Output Register (GPIOx_PTOR)

Address: Base address + Ch offset

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

GPIOx_PTOR field descriptions

Field	Description
PTTO	Port Toggle Output Writing to this register will update the contents of the corresponding bit in the PDOR as follows: 0 Corresponding bit in PDORn does not change. 1 Corresponding bit in PDORn is set to the inverse of its existing logic state.

30.3.5 Port Data Input Register (GPIOx_PDIR)

NOTE

Do not modify pin configuration registers associated with pins not available in your selected package. All unbonded pins not available in your package will default to DISABLE state for lowest power consumption.

Address: Base address + 10h offset

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

GPIOx_PDIR field descriptions

Field	Description
PDI	Port Data Input Reads 0 at the unimplemented pins for a particular device. Pins that are not configured for a digital function read 0. If the Port Control and Interrupt module is disabled, then the corresponding bit in PDIR does not update. 0 Pin logic level is logic 0, or is not configured for use by digital function. 1 Pin logic level is logic 1.

30.3.6 Port Data Direction Register (GPIOx_PDDR)

The PDDR configures the individual port pins for input or output.

Address: Base address + 14h offset

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

GPIOx_PDDR field descriptions

Field	Description
PDD	Port Data Direction Configures individual port pins for input or output. 0 Pin is configured as general-purpose input, for the GPIO function. 1 Pin is configured as general-purpose output, for the GPIO function.

30.4 FGPIO memory map and register definition

The GPIO registers are also aliased to the IOPORT interface on the Cortex-M0+ from address 0xF800_0000.

Accesses via the IOPORT interface occur in parallel with any instruction fetches and will therefore complete in a single cycle. This aliased Fast GPIO memory map is called FGPIO.

Any read or write access to the FGPIO memory space that is outside the valid memory map results in a bus error. All register accesses complete with zero wait states, except error accesses which complete with one wait state.

FGPIO memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F800_0000	Port Data Output Register (FGPIOA_PDOR)	32	R/W	0000_0000h	30.4.1/470
F800_0004	Port Set Output Register (FGPIOA_PSOR)	32	W (always reads 0)	0000_0000h	30.4.2/470
F800_0008	Port Clear Output Register (FGPIOA_PCOR)	32	W (always reads 0)	0000_0000h	30.4.3/471

Table continues on the next page...

FGPIO memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F800_000C	Port Toggle Output Register (FGPIOA_PTOR)	32	W (always reads 0)	0000_0000h	30.4.4/471
F800_0010	Port Data Input Register (FGPIOA_PDIR)	32	R	0000_0000h	30.4.5/472
F800_0014	Port Data Direction Register (FGPIOA_PDDR)	32	R/W	0000_0000h	30.4.6/472
F800_0040	Port Data Output Register (FGPIOB_PDOR)	32	R/W	0000_0000h	30.4.1/470
F800_0044	Port Set Output Register (FGPIOB_PSOR)	32	W (always reads 0)	0000_0000h	30.4.2/470
F800_0048	Port Clear Output Register (FGPIOB_PCOR)	32	W (always reads 0)	0000_0000h	30.4.3/471
F800_004C	Port Toggle Output Register (FGPIOB_PTOR)	32	W (always reads 0)	0000_0000h	30.4.4/471
F800_0050	Port Data Input Register (FGPIOB_PDIR)	32	R	0000_0000h	30.4.5/472
F800_0054	Port Data Direction Register (FGPIOB_PDDR)	32	R/W	0000_0000h	30.4.6/472
F800_0080	Port Data Output Register (FGPIOC_PDOR)	32	R/W	0000_0000h	30.4.1/470
F800_0084	Port Set Output Register (FGPIOC_PSOR)	32	W (always reads 0)	0000_0000h	30.4.2/470
F800_0088	Port Clear Output Register (FGPIOC_PCOR)	32	W (always reads 0)	0000_0000h	30.4.3/471
F800_008C	Port Toggle Output Register (FGPIOC_PTOR)	32	W (always reads 0)	0000_0000h	30.4.4/471
F800_0090	Port Data Input Register (FGPIOC_PDIR)	32	R	0000_0000h	30.4.5/472
F800_0094	Port Data Direction Register (FGPIOC_PDDR)	32	R/W	0000_0000h	30.4.6/472
F800_00C0	Port Data Output Register (FGPIOD_PDOR)	32	R/W	0000_0000h	30.4.1/470
F800_00C4	Port Set Output Register (FGPIOD_PSOR)	32	W (always reads 0)	0000_0000h	30.4.2/470
F800_00C8	Port Clear Output Register (FGPIOD_PCOR)	32	W (always reads 0)	0000_0000h	30.4.3/471
F800_00CC	Port Toggle Output Register (FGPIOD_PTOR)	32	W (always reads 0)	0000_0000h	30.4.4/471
F800_00D0	Port Data Input Register (FGPIOD_PDIR)	32	R	0000_0000h	30.4.5/472
F800_00D4	Port Data Direction Register (FGPIOD_PDDR)	32	R/W	0000_0000h	30.4.6/472
F800_0100	Port Data Output Register (FGPIOE_PDOR)	32	R/W	0000_0000h	30.4.1/470

Table continues on the next page...

FGPIO memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
F800_0104	Port Set Output Register (FGPIOE_PSOR)	32	W (always reads 0)	0000_0000h	30.4.2/470
F800_0108	Port Clear Output Register (FGPIOE_PCOR)	32	W (always reads 0)	0000_0000h	30.4.3/471
F800_010C	Port Toggle Output Register (FGPIOE_PTOR)	32	W (always reads 0)	0000_0000h	30.4.4/471
F800_0110	Port Data Input Register (FGPIOE_PDIR)	32	R	0000_0000h	30.4.5/472
F800_0114	Port Data Direction Register (FGPIOE_PDDR)	32	R/W	0000_0000h	30.4.6/472

30.4.1 Port Data Output Register (FGPIOx_PDOR)

This register configures the logic levels that are driven on each general-purpose output pins.

Address: Base address + 0h offset

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

FGPIOx_PDOR field descriptions

Field	Description
PDO	Port Data Output Unimplemented pins for a particular device read as zero. 0 Logic level 0 is driven on pin, provided pin is configured for general-purpose output. 1 Logic level 1 is driven on pin, provided pin is configured for general-purpose output.

30.4.2 Port Set Output Register (FGPIOx_PSOR)

This register configures whether to set the fields of the PDOR.

Address: Base address + 4h offset

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

FGPIOx_PSOR field descriptions

Field	Description
PTSO	Port Set Output Writing to this register will update the contents of the corresponding bit in the PDOR as follows: 0 Corresponding bit in PDORn does not change. 1 Corresponding bit in PDORn is set to logic 1.

30.4.3 Port Clear Output Register (FGPIOx_PCOR)

This register configures whether to clear the fields of PDOR.

Address: Base address + 8h offset

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

FGPIOx_PCOR field descriptions

Field	Description
PTCO	Port Clear Output Writing to this register will update the contents of the corresponding bit in the Port Data Output Register (PDOR) as follows: 0 Corresponding bit in PDORn does not change. 1 Corresponding bit in PDORn is cleared to logic 0.

30.4.4 Port Toggle Output Register (FGPIOx_PTOR)

Address: Base address + Ch offset

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

FGPIOx_PTOR field descriptions

Field	Description
PTTO	Port Toggle Output Writing to this register will update the contents of the corresponding bit in the PDOR as follows:

FGPIOx_PTOR field descriptions (continued)

Field	Description
	0 Corresponding bit in PDORn does not change. 1 Corresponding bit in PDORn is set to the inverse of its existing logic state.

30.4.5 Port Data Input Register (FGPIOx_PDIR)

Address: Base address + 10h offset

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

FGPIOx_PDIR field descriptions

Field	Description
PDI	Port Data Input Reads 0 at the unimplemented pins for a particular device. Pins that are not configured for a digital function read 0. If the Port Control and Interrupt module is disabled, then the corresponding bit in PDIR does not update. 0 Pin logic level is logic 0, or is not configured for use by digital function. 1 Pin logic level is logic 1.

30.4.6 Port Data Direction Register (FGPIOx_PDDR)

The PDDR configures the individual port pins for input or output.

Address: Base address + 14h offset

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

FGPIOx_PDDR field descriptions

Field	Description
PDD	Port Data Direction Configures individual port pins for input or output. 0 Pin is configured as general-purpose input, for the GPIO function. 1 Pin is configured as general-purpose output, for the GPIO function.

30.5 Functional description

30.5.1 General-purpose input

The logic state of each pin is available via the Port Data Input registers, provided the pin is configured for a digital function and the corresponding Port Control and Interrupt module is enabled.

The Port Data Input registers return the synchronized pin state after any enabled digital filter in the Port Control and Interrupt module. The input pin synchronizers are shared with the Port Control and Interrupt module, so that if the corresponding Port Control and Interrupt module is disabled, then synchronizers are also disabled. This reduces power consumption when a port is not required for general-purpose input functionality.

30.5.2 General-purpose output

The logic state of each pin can be controlled via the port data output registers and port data direction registers, provided the pin is configured for the GPIO function. The following table depicts the conditions for a pin to be configured as input/output.

If	Then
A pin is configured for the GPIO function and the corresponding port data direction register bit is clear.	The pin is configured as an input.
A pin is configured for the GPIO function and the corresponding port data direction register bit is set.	The pin is configured as an output and and the logic state of the pin is equal to the corresponding port data output register.

To facilitate efficient bit manipulation on the general-purpose outputs, pin data set, pin data clear, and pin data toggle registers exist to allow one or more outputs within one port to be set, cleared, or toggled from a single register write.

The corresponding Port Control and Interrupt module does not need to be enabled to update the state of the port data direction registers and port data output registers including the set/clear/toggle registers.

30.5.3 IOPORT

The GPIO registers are also aliased to the IOPORT interface on the Cortex-M0+ from address 0xF800_0000. Accesses via the IOPORT interface occur in parallel with any instruction fetches and will therefore complete in a single cycle.

Chapter 31
Analog-to-Digital Converter (ADC)

31.1 Chip-specific information for this module

31.1.1 Instantiation information

Number of ADC	1
Number of result registers per ADC	4

31.1.1.1 Number of ADC channels

Each SAR ADC supports up to 16 external analog input channels, but the exact ADC channel number present on the device is different with packages as indicated in following table.

For details regarding a specific ADC channel available on a particular package, refer to the Pinout section in DataSheet.

Table 31-1. ADC external channels per package

ADC Module	48LQFP	44LQFP	40QFN	
ADC0	12	12	12	

31.1.1.2 ADC Connections/Channel Assignment

31.1.1.2.1 ADC0 channel assignment

The ADC0 channel assignments for the device are shown in following table. Reserved channels convert to an unknown value.

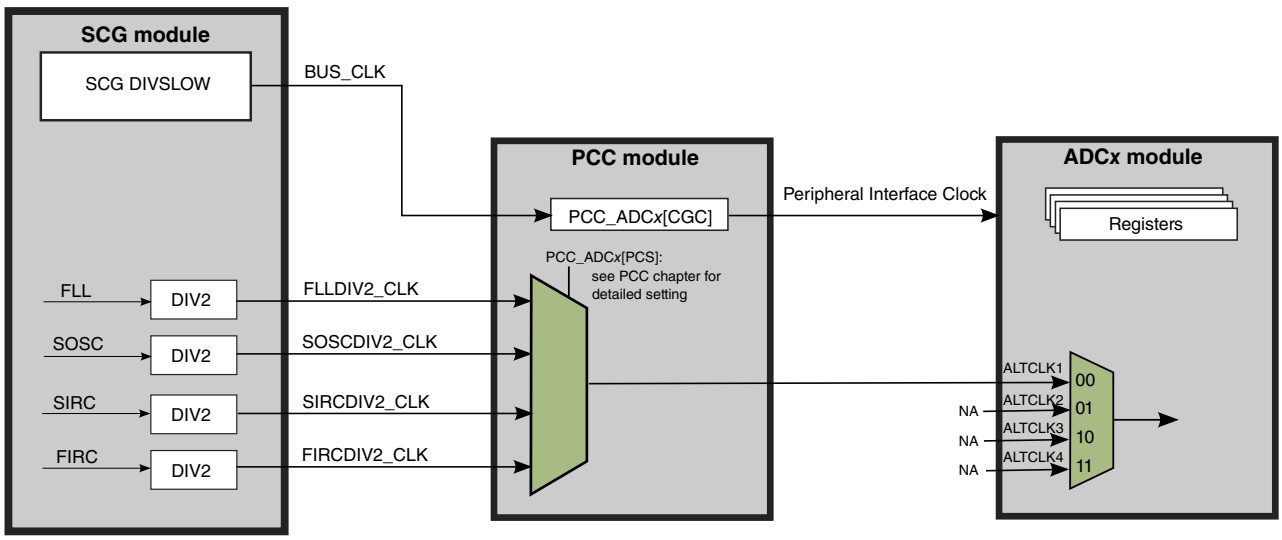
Table 31-2. ADC0 channel assignment

ADCH Value	Channel	Input
00000	AD0	PTA0/ADC0_SE0
00001	AD1	PTA1/ADC0_SE1
00010	AD2	PTA6/ADC0_SE2
00011	AD3	PTA7/ADC0_SE3
00100	AD4	PTB0/ADC0_SE4
00101	AD5	PTB1/ADC0_SE5
00110	AD6	PTB2/ADC0_SE6
00111	AD7	PTB3/ADC0_SE7
01000	AD8	PTC0/ADC0_SE8
01001	AD9	PTC1/ADC0_SE9
01010	AD10	PTC2/ADC0_SE10
01011	AD11	PTC3/ADC0_SE11
01100	AD12	Reserved
01101	AD13	Reserved
01110	AD14	Reserved
01111	AD15	Reserved
10000	AD16	Reserved
10001	AD17	Reserved
10010	AD18	Reserved
10011	AD19	Reserved
10100	AD20	Reserved
10101	AD21	Reserved
10110	AD22	Reserved
10111	AD23	CMP0 8-bit DAC out
11000	AD24	Reserved
11001	AD25	Reserved
11010	AD26	Temperature Sensor
11011	AD27	Bandgap (1V reference voltage)
11100	AD28	Reserved
11101	AD29	VREFH
11110	AD30	VREFL
11111	Module disabled	None

31.1.2 ADC Clocking Information

The following figure shows the input clock sources available for this module.

Peripheral Clocking - ADC



NOTE

ALTCLK2~4 are not connected on this chip.

31.1.3 Application-related Information

31.1.3.1 ADC Reference Options

The ADC supports the following references:

- VREFH/VREFL - connected as the primary reference option

NOTE

VREFH pin on the PCB should use 3 bypass capacitors in the range: 1 μF, 100 nF and 1 nF. Capacitors should be placed to the VREFH pin as close as possible.

- Bandgap from PMC connected as the V_{ALT2} reference option. The V_{ALT2} input is also connected within the ADC module as ADC channel 27

ADCx_SC2[REFSEL] bit selects the voltage reference sources for ADC. Refer to REFSEL description in ADC chapter for more details.

31.1.3.2 ADC Trigger Sources

The ADC support multiple trigger sources. There is two kinds of trigger: pre-trigger and trigger. The pre-trigger precondition the ADC block and selects the specific data result register, before the ADC trigger is asserted. The trigger initiate the ADC conversion as soon as it's asserted. The trigger and pre-trigger sources are described as following:

- Hardware pre-triggers/triggers are connected through PDB and TRGMUX. The pre-triggers can also be controlled by software to provide flexible trigger schemes (by controlling SIM_ADCOPT[ADCxSWPRETRG] registers). Besides the hardware triggers through ADHWT, the ADC module itself also supports software trigger mode by setting SC2[ADTRG]=0. Following a write to SC1A register, a conversion is initiated.
- 1×PDB can generate triggers and pre-triggers for 1×ADC, each PDB channel will have up to 4 pre-triggers for ADC channel control, which provides an automatically trigger scheme so that the CPU involvement is not necessary.
- TRGMUX can provide triggers for each ADC, while the pre-triggers need to be controlled by software to determine relative priority. It should not trigger the ADC again before a single conversion has not completed.

The following triggers are via the TRGMUX:

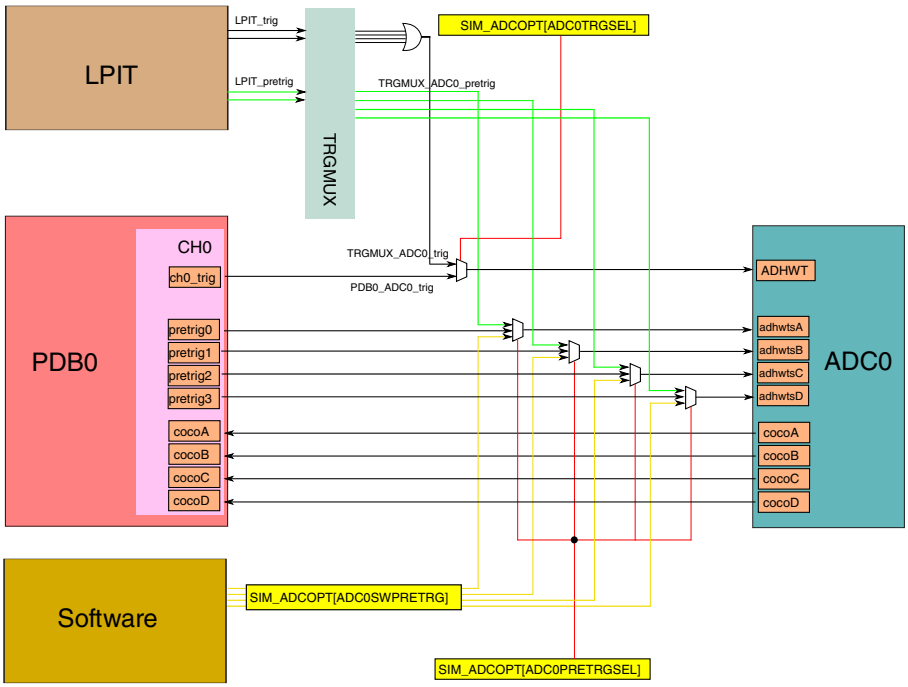
- CMP out to trigger each ADC
- RTC capable to trigger each ADC
- LPTMR capable to trigger each ADC
- Software trigger capable to trigger each ADC

NOTE

The software trigger/pre-trigger through TRGMUX, the ADC's own software trigger mode and the software pre-trigger controlled by SIM are different concepts.

Following specification and diagram are just giving an example to help understanding the ADC trigger scheme. Generally, the ADC support two kind of hardware triggering scheme:

- The default hardware triggering scheme is using PDB to trigger ADC (suggested).
- Another optional hardware triggering scheme is using TRGMUX.
- SIM_ADCOPT[ADCxTRGSEL] bit is used to control the ADC triggering source/ scheme.
  - When ADCxTRGSEL=0, the ADC pre-trigger is coming from PDB directly.
  - When ADCxTRGSEL=1, the ADC pre-trigger is coming from TRGMUX, e.g. LPIT.



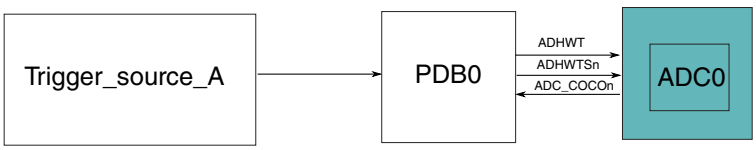
PDB triggering scheme:

PDB triggering scheme is the default and suggested trigger method for ADC. ADC and one PDB work as one pair, the implementation on this device is: PDB0-ADC0. Here we take PDB0-ADC0 as an example to specify the triggering scheme.

- Set SIM_ADCOPT[ADC*x*TRGSEL]=0. PDB0 channel0 is selected as ADC trigger source.
- Set SIM_ADCOPT[ADCxPRETRGSEL]=00. PDB0 pre-triggers will connect directly to ADC0 ADHWTS ports to control the channels.
- The ADC0 COCO signals are directly feed-backed to PDB0 to deactivate the PDB lock state.

Following are typical case for ADC triggering using PDB:

Case 1:



TRGMUX triggering scheme:

TRGMUX supports many trigger sources, here we take LPIT as an example (typical), but the trigger source can also be others which mentioned above. LPIT supports up to 2 channels, each channel have a trigger and pre-trigger.

- Set SIM_ADCOPT[ADC*x*TRGSEL]=1. TRGMUX out is selected as ADC trigger source.
- Configure TRGMUX to select LPIT triggers as ADC trigger and pre-trigger source.
- Set SIM_ADCOPT[ADCxPRETRGSEL]=01. LPIT pre-triggers will connect directly to ADC0 ADHWTS ports to control the channels.
- ADC COCO is not required in this case. Software need to take care of the intermission time between each ADC conversion.
- With TRGMUX, a single LPIT could be used to trigger 1 ADC at same time.

NOTE

For other trigger sources other than PDB and LPIT, software engagement is required to configure ADC pre-trigger selection. That means it must select pre-trigger source from software (it is required SIM_ADCOPT[ADCxPRETRGSEL] is set to 10 in this case, to make sure that software pre-triggers connect directly to ADC0 ADHWTS ports), and which ADC channel to use (by setting ADCxSWPRETRG).

Software triggering scheme:

It also supports to configure ADC pre-trigger/trigger by software.

- By setting SC2[ADTRG]=0, ADC software trigger mode is selected. A conversion is initiated following a write to SC1A register.

NOTE

ADC software trigger mode only support SC1A and data register A.

- Configure SC2[ADTRG]=1, ADC is in hardware triggering mode. By setting SIM_ADCOPT[ADCxSWPRETRG], the pre-trigger for ADC is selected. The software trigger trough TRGMUX can trigger the ADC conversion. This mechanism supports multiple data registers.

31.2 Introduction

The 12-bit analog-to-digital converter (ADC) is a successive approximation ADC designed for operation within an integrated microcontroller system-on-chip.

NOTE

For the chip specific modes of operation, see the power management information of the device.

31.2.1 Features

Following are the features of the ADC module:

- Linear successive approximation algorithm with up to 12-bit resolution
- Up to 4 single-ended external analog inputs
- Single-ended 12-bit, 10-bit, and 8-bit output modes
- Output in right-justified unsigned format for single-ended
- Single or continuous conversion modes
- Automatic return to idle after single conversion
- Configurable sample time and conversion speed/power
- Conversion complete/hardware average complete flag and interrupt
- Input clock selectable from up to four sources
- Operation in low-power modes for lower noise
- Selectable hardware conversion trigger with hardware channel select
- Automatic compare with interrupt for less-than, greater-than or equal-to, within range, or out-of-range, programmable value
- Temperature sensor
- Hardware average function
- Selectable voltage reference: external or alternate
- Self-Calibration mode

31.2.2 Block diagram

The following figure is the ADC module block diagram.

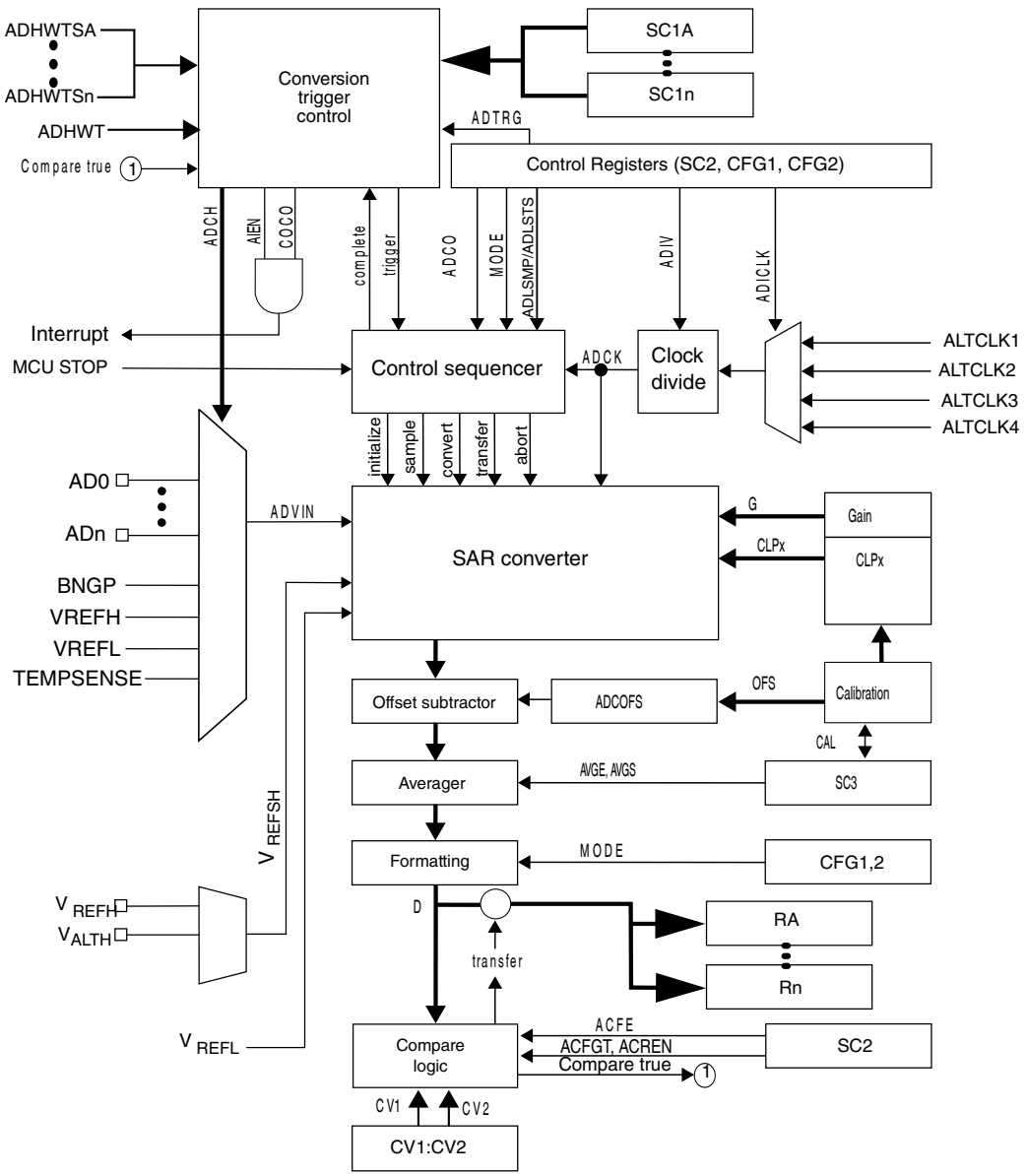


Figure 31-1. ADC block diagram

31.3 ADC signal descriptions

Each ADC module supports up to 4 single-ended inputs.

The ADC also requires four supply/reference/ground connections.

NOTE

For the number of channels supported on this device, see the chip-specific ADC information.

The ADC does not produce any output signals.

Table 31-3. ADC input signal descriptions

Signal	Description
AD*n*	Single-Ended Analog Channel Inputs
V_{REFSH}	Voltage Reference Select High
V_{REFSL}	Voltage Reference Select Low
V_{DDA}	Analog Power Supply
V_{SSA}	Analog Ground

31.3.1 Analog Power (V_{DDA})

The ADC analog portion uses V_{DDA} as its power connection. In some packages, V_{DDA} is connected internally to V_{DD}. If externally available, connect the V_{DDA} pin to the same voltage potential as V_{DD}. External filtering may be necessary to ensure clean V_{DDA} for good results.

31.3.2 Analog Ground (V_{SSA})

The ADC analog portion uses V_{SSA} as its ground connection.statement In some packages, V_{SSA} is connected internally to V_{SS}.statement If externally available, connect the V_{SSA} pin to the same voltage potential as V_{SS}.

31.3.3 Voltage Reference Select

V_{REFSH} and V_{REFSL} are the high and low reference voltages for the ADC module.

The ADC can be configured to accept one of the voltage reference pairs for V_{REFSH} and V_{REFSL} by configuring V_{REFSH} as V_{REFH} or V_{ALTH}. Each pair contains a positive reference that must be between the minimum Ref Voltage High and V_{DDA}, and a ground reference that must be at the same potential as V_{SSA}. The two pairs are external (V_{REFH} and V_{REFL}) alternate (V_{ALTLH} and V_{REFL}). These voltage references are selected by configuring SC2[REFSEL]. The alternate voltage reference, V_{ALTH} may select additional external pin or internal source depending on MCU configuration. See the chip configuration information on the Voltage References specific to this MCU.

In some packages, V_{REFH} is internally connected to V_{DDA} and V_{REFL} to V_{SSA}. If externally available, the positive reference(s) may be connected to the same potential as V_{DDA} or may be driven by an external source to a level between the minimum V_{REFH} and the V_{DDA} potential. V_{REFH} must never exceed V_{DDA}. Connect the ground references to the same voltage potential as V_{SSA}.

31.3.4 Analog Channel Inputs (ADx)

The ADC module supports up to 4 analog inputs. An analog input is selected for conversion through the SC1[ADCH] channel select field.

31.4 ADC register descriptions

This section describes the ADC registers. All ADC registers support 8-bit, 16-bit, and 32-bit reads, but only 32-bit writes are supported. Executing an 8-bit or a 16-bit write will result in a transfer error.

31.4.1 ADC Memory map

ADC base address: 4003_B000h

Offset	Register	Width (In bits)	Access	Reset value
0h - Ch	ADC Status and Control Register 1 (SC1A - SC1D)	32	RW	0000_001Fh
40h	ADC Configuration Register 1 (CFG1)	32	RW	0000_0000h
44h	ADC Configuration Register 2 (CFG2)	32	RW	0000_000Ch
48h - 54h	ADC Data Result Registers (RA - RD)	32	RW	0000_0000h
88h - 8Ch	Compare Value Registers (CV1 - CV2)	32	RW	0000_0000h
90h	Status and Control Register 2 (SC2)	32	RW	0000_0000h
94h	Status and Control Register 3 (SC3)	32	RW	0000_0000h
98h	BASE Offset Register (BASE_OFS)	32	RW	0000_0040h
9Ch	ADC Offset Correction Register (OFS)	32	RW	See description.
A0h	USER Offset Correction Register (USR_OFS)	32	RW	0000_0000h
A4h	ADC X Offset Correction Register (XOFS)	32	RW	0000_0030h
A8h	ADC Y Offset Correction Register (YOFS)	32	RW	0000_0037h

Table continues on the next page...

Offset	Register	Width (In bits)	Access	Reset value
ACh	ADC Gain Register (G)	32	RW	See description.
B0h	ADC User Gain Register (UG)	32	RW	0000_0004h
B4h	ADC General Calibration Value Register S (CLPS)	32	RW	See description.
B8h	ADC Plus-Side General Calibration Value Register 3 (CLP3)	32	RW	See description.
BCh	ADC Plus-Side General Calibration Value Register 2 (CLP2)	32	RW	See description.
C0h	ADC Plus-Side General Calibration Value Register 1 (CLP1)	32	RW	See description.
C4h	ADC Plus-Side General Calibration Value Register 0 (CLP0)	32	RW	See description.
C8h	ADC Plus-Side General Calibration Value Register X (CLPX)	32	RW	See description.
CCh	ADC Plus-Side General Calibration Value Register 9 (CLP9)	32	RW	See description.
D0h	ADC General Calibration Offset Value Register S (CLPS_OFS)	32	RW	0000_0000h
D4h	ADC Plus-Side General Calibration Offset Value Register 3 (CLP3_OFS)	32	RW	0000_0000h
D8h	ADC Plus-Side General Calibration Offset Value Register 2 (CLP2_OFS)	32	RW	0000_0000h
DCh	ADC Plus-Side General Calibration Offset Value Register 1 (CLP1_OFS)	32	RW	0000_0000h
E0h	ADC Plus-Side General Calibration Offset Value Register 0 (CLP0_OFS)	32	RW	0000_0000h
E4h	ADC Plus-Side General Calibration Offset Value Register X (CLPX_OFS)	32	RW	0000_0440h
E8h	ADC Plus-Side General Calibration Offset Value Register 9 (CLP9_OFS)	32	RW	0000_0240h

31.4.2 ADC Status and Control Register 1 (SC1A - SC1D)

31.4.2.1 Offset

Register	Offset
SC1A	0h
SC1B	4h
SC1C	8h
SC1D	Ch

31.4.2.2 Function

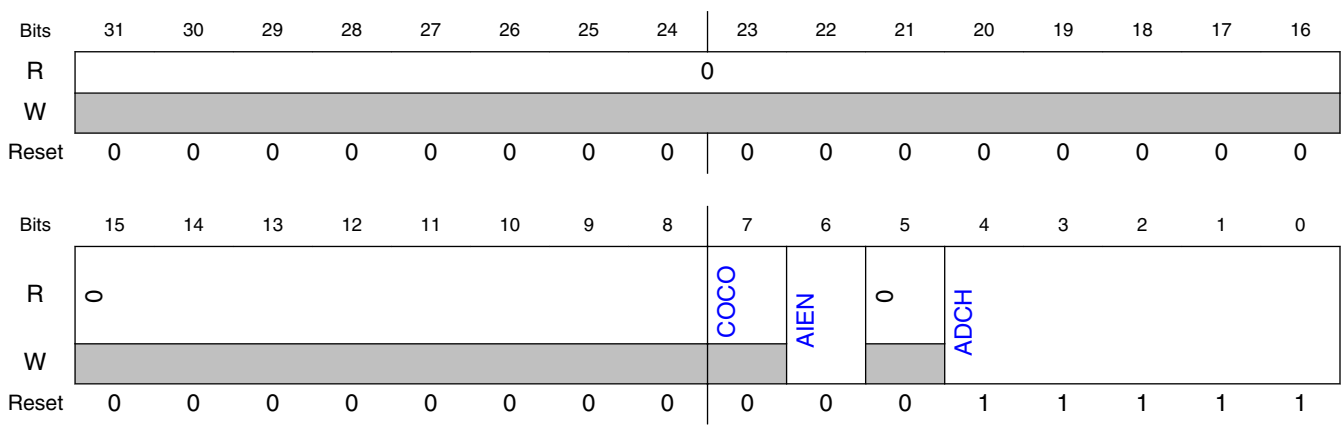
SC1A is used for both software and hardware trigger modes of operation.

At any one point in time, only one of the SC1*n* registers is actively controlling ADC sequential conversions. Updating SC1A while SC1*n* is actively controlling a conversion is allowed, and vice versa for any of the SC1*n* registers specific to this MCU.

Writing 11111 to the SC1A ADCH field while SC1A is actively controlling a conversion aborts the current conversion. In Software Trigger mode (when SC2[ADTRG] = 0), writes to SC1A initiate a new conversion. This is valid for all values of SC1A[ADCH] other than 11111 (module disabled).

Writing any of the SC1*n* registers while that specific SC1*n* register is actively controlling a conversion aborts the current conversion. None of the SC1B-SC1*n* registers are used for software trigger operation and therefore writes to the SC1B-SC1*n* registers do not initiate a new conversion.

31.4.2.3 Diagram



31.4.2.4 Fields

Field	Function
31-8 —	Reserved
7 COCO	Conversion Complete Flag

Table continues on the next page...

Field	Function
	This is a read-only field that is set each time a conversion is completed when one or more of the following is true: • The compare function is disabled • SC2[ACFE]=0 and the hardware average function is disabled • SC3[AVGE]=0 If the compare result is true, then COCO is set upon completion of a conversion if one or more of the following is true: • The compare function is enabled • SC2[ACFE]=1 COCO is set upon completion of the selected number of conversions (determined by AVGS) if one or more of the following is true: • The hardware average function is enabled • SC3[AVGE]=1 COCO in SC1A is also set at the completion of a calibration sequence. COCO is cleared when one of the following is true: • The respective SC1n register is written • The respective Rn register is read 0b - Conversion is not complete. 1b - Conversion is complete.
6 AIEN	Interrupt Enable Enables conversion complete interrupts. When COCO becomes set while the respective AIEN is high, an interrupt is asserted. 0b - Conversion complete interrupt is disabled. 1b - Conversion complete interrupt is enabled.
5 —	Reserved
4-0 ADCH	Input channel select Selects one of the input channels. **NOTE:** Some of the input channel options in the bitfield-setting descriptions might not be available for your chip. For the actual ADC channel assignments for your device, see the chip-specific information. The successive approximation converter subsystem is turned off when the channel bits are all set (i.e. ADCH set to all 1s). This feature allows explicit disabling of the ADC and isolation of the input channel from all sources. Terminating continuous conversions this way prevents an additional single conversion from being performed. It is not necessary to set ADCH to all 1s to place the ADC in a low-power state when continuous conversions are not enabled because the module automatically enters a low-power state when a conversion completes. 00000b - External channel 0 is selected as input. 00001b - External channel 1 is selected as input. 00010b - External channel 2 is selected as input. 00011b - External channel 3 is selected as input. 00100b - External channel 4 is selected as input. 00101b - External channel 5 is selected as input. 00110b - External channel 6 is selected as input. 00111b - External channel 7 is selected as input. 01000b - External channel 8 is selected as input. 01001b - External channel 9 is selected as input. 01010b - External channel 10 is selected as input. 01011b - External channel 11 is selected as input.

Field	Function
	01100b - External channel 12 is selected as input. 01101b - External channel 13 is selected as input. 01110b - External channel 14 is selected as input. 01111b - External channel 15 is selected as input. 10000b - Reserved 10001b - Reserved 10010b - External channel 18 is selected as input. 10011b - External channel 19 is selected as input. 10100b - Reserved. 10101b - Internal channel 0 is selected as input. 10110b - Internal channel 1 is selected as input. 10111b - Internal channel 2 is selected as input. 11000b - Reserved 11001b - Reserved 11010b - Temp Sensor 11011b - Band Gap 11100b - Internal channel 3 is selected as input. 11101b - V_{REFSH} is selected as input. Voltage reference selected is determined by SC2[REFSEL]. 11110b - V_{REFSL} is selected as input. Voltage reference selected is determined by SC2[REFSEL]. 11111b - Module is disabled

31.4.3 ADC Configuration Register 1 (CFG1)

31.4.3.1 Offset

Register	Offset
CFG1	40h

31.4.3.2 Function

Configuration Register 1 (CFG1) selects the mode of operation, clock source, clock divide.

31.4.3.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0							0	0	ADIV		0	MODE		ADICLK	
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31.4.3.4 Fields

Field	Function
31-9 —	Reserved
8 —	Reserved
7 —	Reserved
6-5 ADIV	Clock Divide Select Selects the divide ratio used by the ADC to generate the internal clock ADCK. 00b - The divide ratio is 1 and the clock rate is input clock. 01b - The divide ratio is 2 and the clock rate is (input clock)/2. 10b - The divide ratio is 4 and the clock rate is (input clock)/4. 11b - The divide ratio is 8 and the clock rate is (input clock)/8.
4 —	Reserved
3-2 MODE	Conversion mode selection Selects the ADC resolution. 00b - 8-bit conversion. 01b - 12-bit conversion. 10b - 10-bit conversion. 11b - Reserved
1-0 ADICLK	Input Clock Select Selects the input clock source to generate the internal clock, ADCK. See the clock distribution/clocking chapter of your device for details on which alternate clocks are supported. 00b - Alternate clock 1 (ALTCLK1) 01b - Alternate clock 2 (ALTCLK2) 10b - Alternate clock 3 (ALTCLK3) 11b - Alternate clock 4 (ALTCLK4)

31.4.4 ADC Configuration Register 2 (CFG2)

31.4.4.1 Offset

Register	Offset
CFG2	44h

31.4.4.2 Function

Configuration Register 2 (CFG2) selects the long sample time duration during long sample mode.

NOTE

Writing 0 is not supported on this register.

31.4.4.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								SMPLTS							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

31.4.4.4 Fields

Field	Function
31-8 —	Reserved
7-0 SMPLTS	Sample Time Select

Field	Function
	Selects a sample time of 2 to 256 ADCK clock cycles. The value written to this register field is the desired sample time minus 1. A sample time of 1 is not supported. Allows higher impedance inputs to be accurately sampled or conversion speed to be maximized for lower impedance inputs. Longer sample times can also be used to lower overall power consumption when continuous conversions are enabled if high conversion rates are not required.

31.4.5 ADC Data Result Registers (RA - RD)

31.4.5.1 Offset

Register	Offset
RA	48h
RB	4Ch
RC	50h
RD	54h

31.4.5.2 Function

The data result registers (Rn) contain the result of an ADC conversion of the channel selected by the corresponding status and channel control register (SC1A:SC1n). For every status and channel control register, there is a corresponding data result register.

Unused bits in R*n* are cleared.

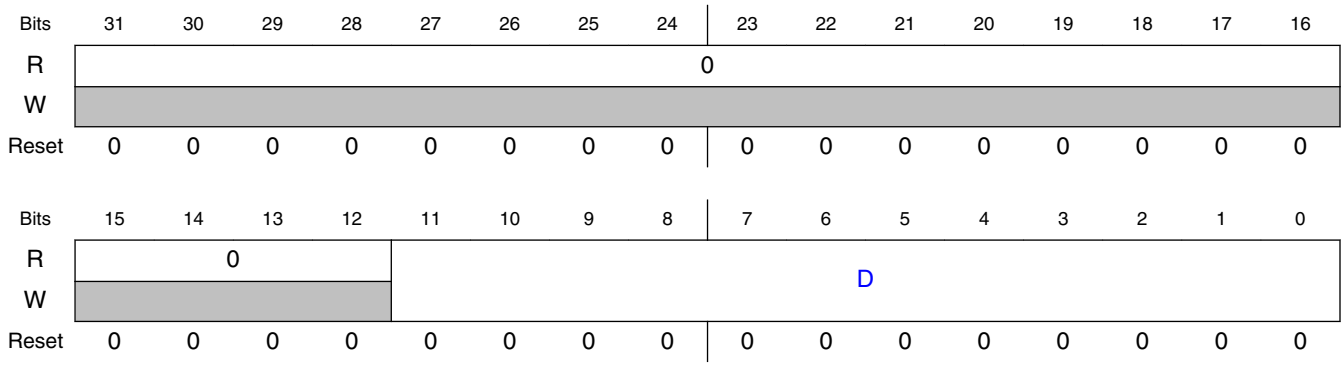
The following table describes the behavior of the data result registers in the different modes of operation.

Table 31-4. Data result register description

Conversion mode	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	Format
12-bit single-ended	D												Unsigned right-justified
10-bit single-ended	0		D										
8-bit single-ended	0				D								

D: Data. The data result registers are read-only; writing to these registers generates a transfer error.

31.4.5.3 Diagram



31.4.5.4 Fields

Field	Function
31-12 —	Reserved
11-0 D	Data result

31.4.6 Compare Value Registers (CV1 - CV2)

31.4.6.1 Offset

Register	Offset
CV1	88h
CV2	8Ch

31.4.6.2 Function

The Compare Value Registers (CV1 and CV2) contain a compare value used to compare the conversion result when the compare function is enabled, that is, SC2[ACFE]=1. This register is formatted in the same way as the Rn registers. Therefore, the compare function

uses only the CVn fields that are related to the ADC mode of operation. CV2 is used only when the compare range function is enabled, that is, SC2[ACREN]=1.

31.4.6.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CV															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31.4.6.4 Fields

Field	Function
31-16 —	Reserved
15-0 CV	Compare Value.

31.4.7 Status and Control Register 2 (SC2)

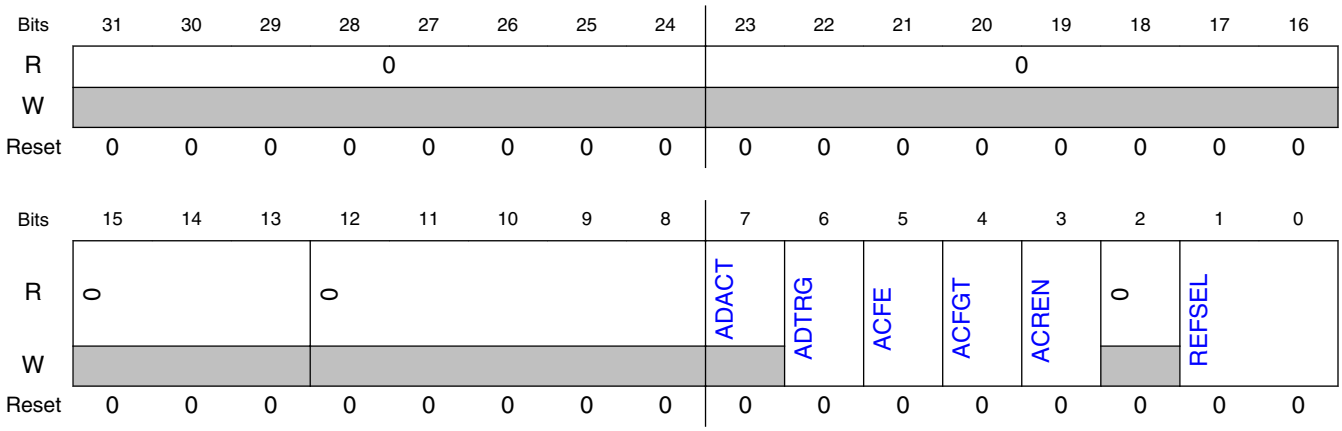
31.4.7.1 Offset

Register	Offset
SC2	90h

31.4.7.2 Function

The status and control register 2 (SC2) contains the conversion active, hardware/software trigger select, compare function, and voltage reference select of the ADC module.

31.4.7.3 Diagram



31.4.7.4 Fields

Field	Function
31-24 —	Reserved
23-16 —	Reserved
15-13 —	Reserved
12-8 —	Reserved
7 ADACT	Conversion Active Indicates that a conversion or hardware averaging is in progress. ADACT is set when a conversion is initiated and cleared when a conversion is completed or aborted. 0b - Conversion not in progress. 1b - Conversion in progress.
6 ADTRG	Conversion Trigger Select Selects the type of trigger used for initiating a conversion. Two types of triggers can be selected: • Software trigger: When software trigger is selected, a conversion is initiated following a write to SC1A. • Hardware trigger: When hardware trigger is selected, a conversion is initiated following the assertion of the ADHWT input after a pulse of the ADHWTSn input. 0b - Software trigger selected. 1b - Hardware trigger selected.
5 ACFE	Compare Function Enable Enables the compare function. 0b - Compare function disabled.

Table continues on the next page...

Field	Function
	1b - Compare function enabled.
4 ACFGT	Compare Function Greater Than Enable Configures the compare function to check the conversion result relative to CV1 and CV2 based upon the value of ACREN. ACFE must be set for ACFGT to have any effect. See Table 31-6 "Compare modes" for further details.
3 ACREN	Compare Function Range Enable Configures the compare function to check if the conversion result of the input being monitored is either between or outside the range formed by CV1 and CV2 determined by the value of ACFGT. ACFE must be set for ACFGT to have any effect. See Table 31-6 "Compare modes" for further details.
2 —	Reserved
1-0 REFSEL	Voltage Reference Selection Selects the voltage reference source used for conversions. 00b - Default voltage reference pin pair, that is, external pins V_{REFH} and V_{REFL} 01b - Alternate reference voltage, that is, V_{ALTH}. This voltage may be additional external pin or internal source depending on the MCU configuration. See the chip configuration information for details specific to this MCU. 10b - Reserved 11b - Reserved

31.4.8 Status and Control Register 3 (SC3)

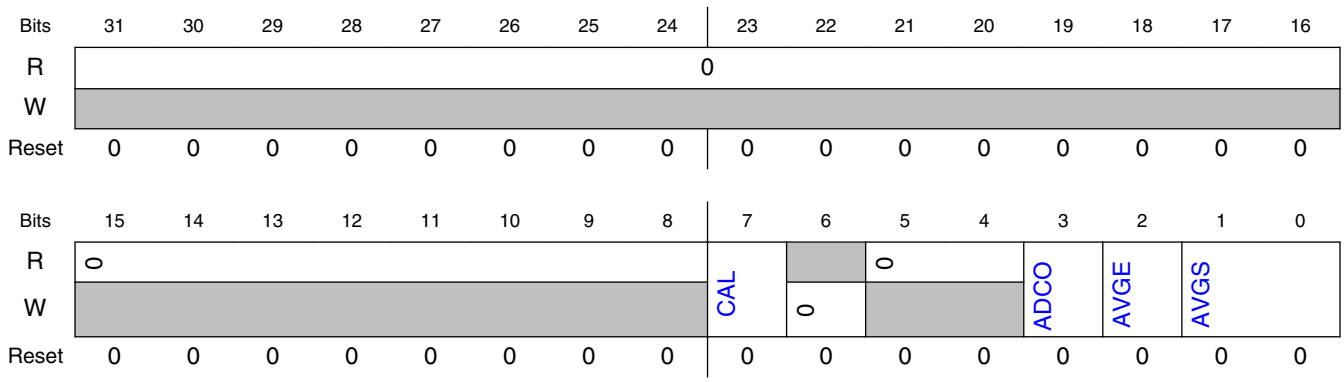
31.4.8.1 Offset

Register	Offset
SC3	94h

31.4.8.2 Function

The Status and Control Register 3 (SC3) controls the calibration, continuous conversion, and hardware averaging functions of the ADC module.

31.4.8.3 Diagram



31.4.8.4 Fields

Field	Function
31-8 —	Reserved
7 CAL	Calibration When CAL=1, the ADC begins the calibration sequence. This field stays set while the calibration is in progress and is cleared when the calibration sequence is completed. After it is started, the calibration routine cannot be interrupted by writes to the ADC registers or the results will be invalid. Setting CAL will abort any current conversion. **NOTE:** For calibration, it is mandatory to use averaging and average number 32. **NOTE:** If several ADCs are on a device, they should be calibrated sequentially. No parallel calibrations of ADCs are allowed because they will disturb each other.
6 —	Reserved
5-4 —	Reserved
3 ADCO	Continuous Conversion Enable Enables continuous conversions. 0b - One conversion will be performed (or one set of conversions, if AVGE is set) after a conversion is initiated. 1b - Continuous conversions will be performed (or continuous sets of conversions, if AVGE is set) after a conversion is initiated.
2 AVGE	Hardware Average Enable Enables the hardware average function of the ADC. 0b - Hardware average function disabled. 1b - Hardware average function enabled.
1-0 AVGS	Hardware Average Select Determines how many ADC conversions will be averaged to create the ADC average result.

Field	Function
	00b - 4 samples averaged. 01b - 8 samples averaged. 10b - 16 samples averaged. 11b - 32 samples averaged.

31.4.9 BASE Offset Register (BASE_OFS)

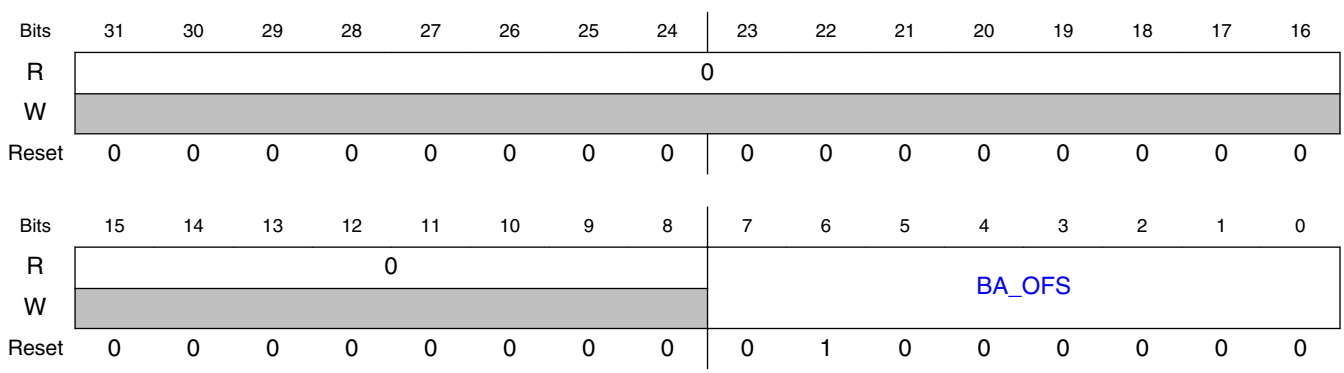
31.4.9.1 Offset

Register	Offset
BASE_OFS	98h

31.4.9.2 Function

The BASE Offset Register (BASE_OFS) contains the offset value used by the calibration algorithm to determine the Offset Calibration Value (OFS).

31.4.9.3 Diagram



31.4.9.4 Fields

Field	Function
31-8	Reserved

Table continues on the next page...

Field	Function
—	
7-0 BA_OFS	Base Offset Error Correction Value

31.4.10 ADC Offset Correction Register (OFS)

31.4.10.1 Offset

Register	Offset
OFS	9Ch

31.4.10.2 Function

The ADC Offset Correction Register (OFS) contains the calibration-generated offset error correction value (OFS). The value in BA_OFS is used in the calibration algorithm to calculate the offset correction value that gets stored in the OFS register. The value in OFS is subtracted from the conversion and the result is transferred into the result registers, Rn. If the result is greater than the maximum or less than the minimum result value, it is forced to the appropriate limit for the current mode of operation.

NOTE

If offset register is set to a negative value and it is lower than or equal to 0xFFF8, the ADC will not result code 0. If offset register is set to a negative value and it is lower than or equal to 0xFFF0, the ADC will not result code 1.

31.4.10.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	OFS															
W																
Reset	u[1]	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u

1. Reset values are loaded out of IFR.

31.4.10.4 Fields

Field	Function
31-16 —	Reserved
15-0 OFS	Offset Error Correction Value

31.4.11 USER Offset Correction Register (USR_OFS)

31.4.11.1 Offset

Register	Offset
USR_OFS	A0h

31.4.11.2 Function

The ADC USER Offset Correction Register (USR_OFS) contains the user defined offset error correction value used in the conversion result error correction algorithm.

31.4.11.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								USR_OFS							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31.4.11.4 Fields

Field	Function
31-8 —	Reserved
7-0 USR_OFS	USER Offset Error Correction Value

31.4.12 ADC X Offset Correction Register (XOFS)

31.4.12.1 Offset

Register	Offset
XOFS	A4h

31.4.12.2 Function

The ADC X Offset Correction Register (XOFS) contains the X offset used in the conversion result error correction algorithm.

31.4.12.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0										XOFS					
W																
Reset	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0

31.4.12.4 Fields

Field	Function
31-6 —	Reserved
5-0 XOFS	X offset error correction value

31.4.13 ADC Y Offset Correction Register (YOFS)

31.4.13.1 Offset

Register	Offset
YOFS	A8h

31.4.13.2 Function

The ADC Y Offset Correction Register (YOFS) contains the Y offset used in the conversion result error correction algorithm.

31.4.13.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								YOFS							
W																
Reset	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1

31.4.13.4 Fields

Field	Function
31-8 —	Reserved
7-0 YOFS	Y offset error correction value

31.4.14 ADC Gain Register (G)

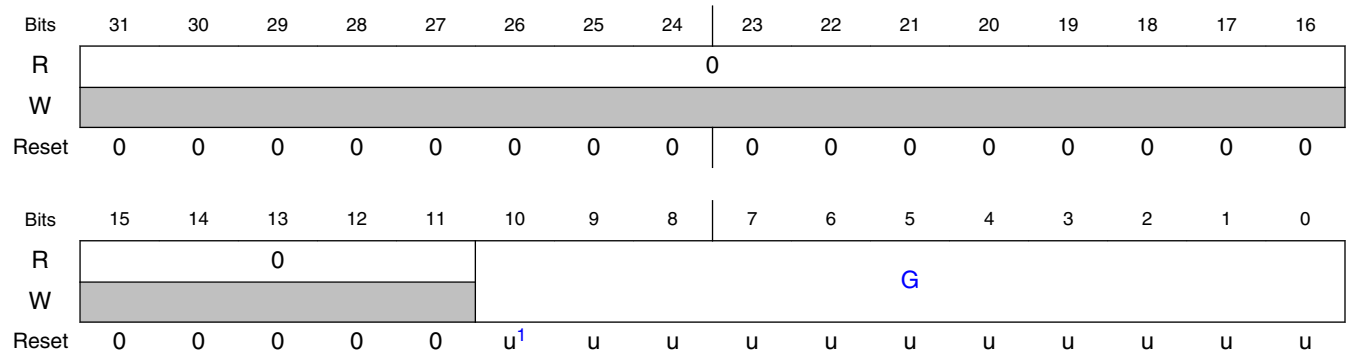
31.4.14.1 Offset

Register	Offset
G	ACh

31.4.14.2 Function

The Gain Register (G) contains the gain error correction for the overall conversion. G, a 11-bit real number in binary format, is the gain adjustment factor. This register value is determined and uploaded by the calibration algorithm.

31.4.14.3 Diagram



1. Reset values are loaded out of IFR.

31.4.14.4 Fields

Field	Function
31-11 —	Reserved
10-0 G	G Gain error adjustment factor for the overall conversion

31.4.15 ADC User Gain Register (UG)

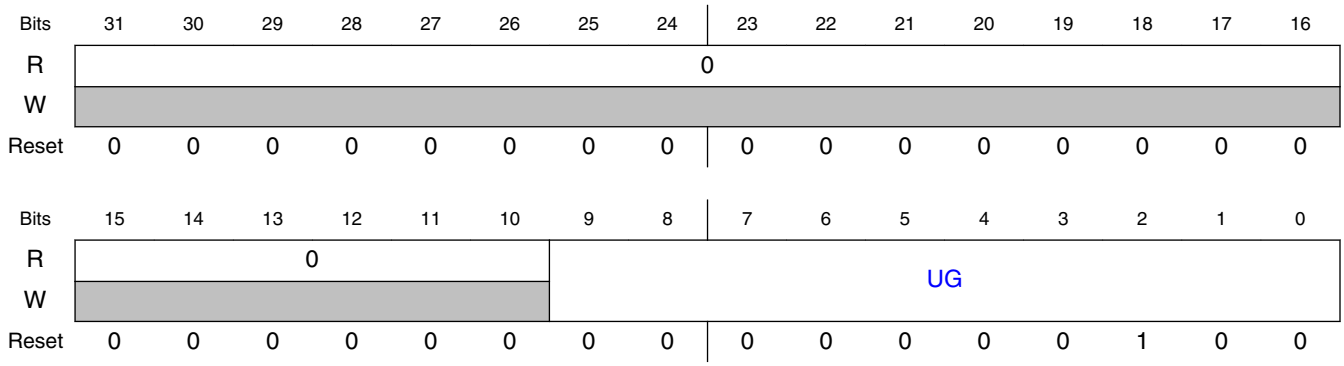
31.4.15.1 Offset

Register	Offset
UG	B0h

31.4.15.2 Function

The User Gain Register (UG) contains the user gain error correction. It allows you to adjust the final calibration gain value.

31.4.15.3 Diagram



31.4.15.4 Fields

Field	Function
31-10 —	Reserved
9-0 UG	UG User gain error correction value

31.4.16 ADC General Calibration Value Register S (CLPS)

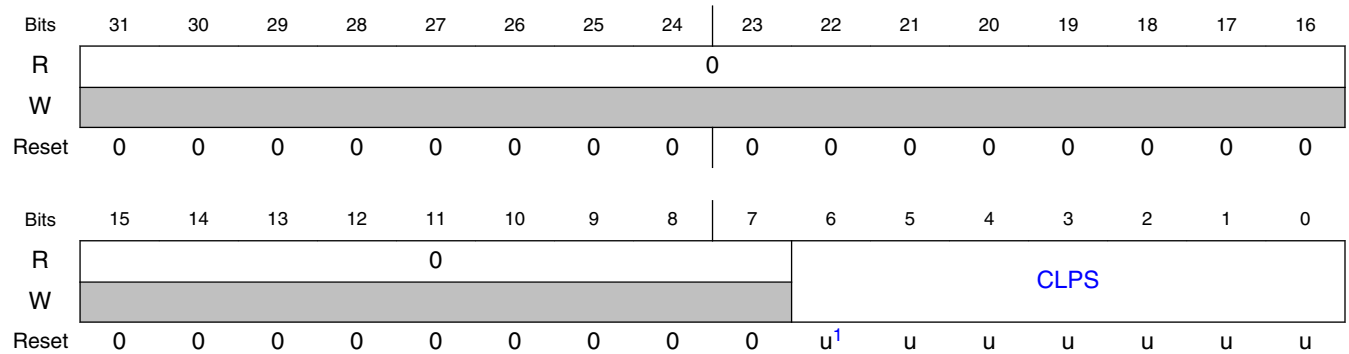
31.4.16.1 Offset

Register	Offset
CLPS	B4h

31.4.16.2 Function

The General Calibration Value Registers (CLPx) contain calibration information that is generated by the calibration function. These registers contain seven signed calibration values of varying widths in two's complement format. CLPx are automatically set when the self-calibration sequence is done, that is, CAL is cleared. If these registers are written by the user after calibration, the linearity error specifications may not be met.

31.4.16.3 Diagram



1. Reset values are loaded out of IFR.

31.4.16.4 Fields

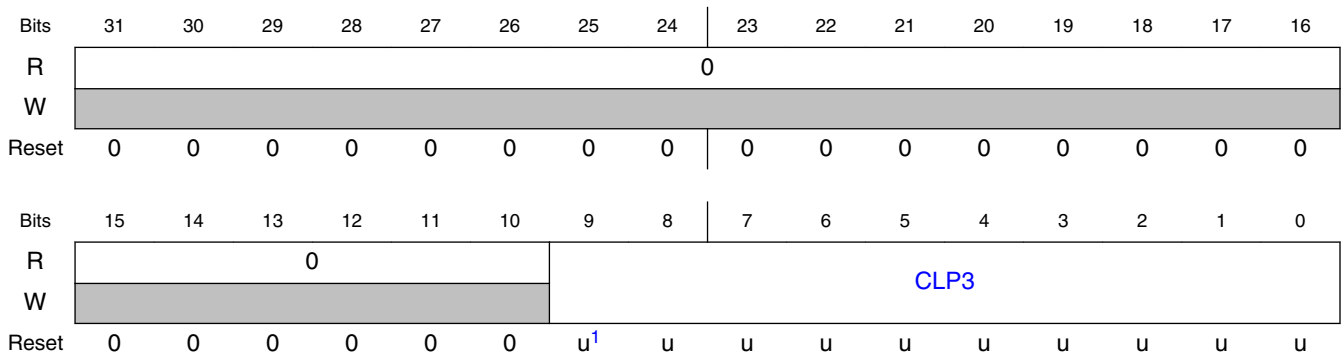
Field	Function
31-7 —	Reserved
6-0 CLPS	CLPS Calibration Value

31.4.17 ADC Plus-Side General Calibration Value Register 3 (CLP3)

31.4.17.1 Offset

Register	Offset
CLP3	B8h

31.4.17.2 Diagram



1. Reset values are loaded out of IFR.

31.4.17.3 Fields

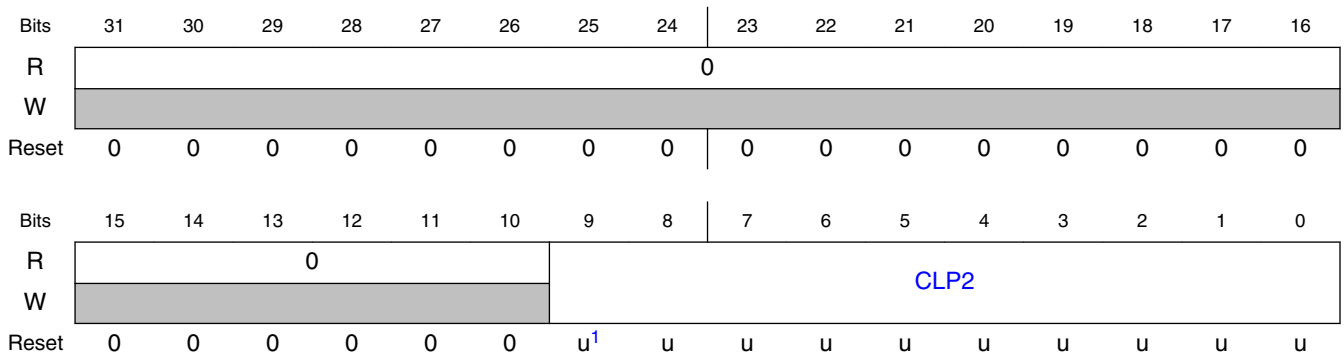
Field	Function
31-10 —	Reserved
9-0 CLP3	CLP3 Calibration Value

31.4.18 ADC Plus-Side General Calibration Value Register 2 (CLP2)

31.4.18.1 Offset

Register	Offset
CLP2	BCh

31.4.18.2 Diagram



1. Reset values are loaded out of IFR.

31.4.18.3 Fields

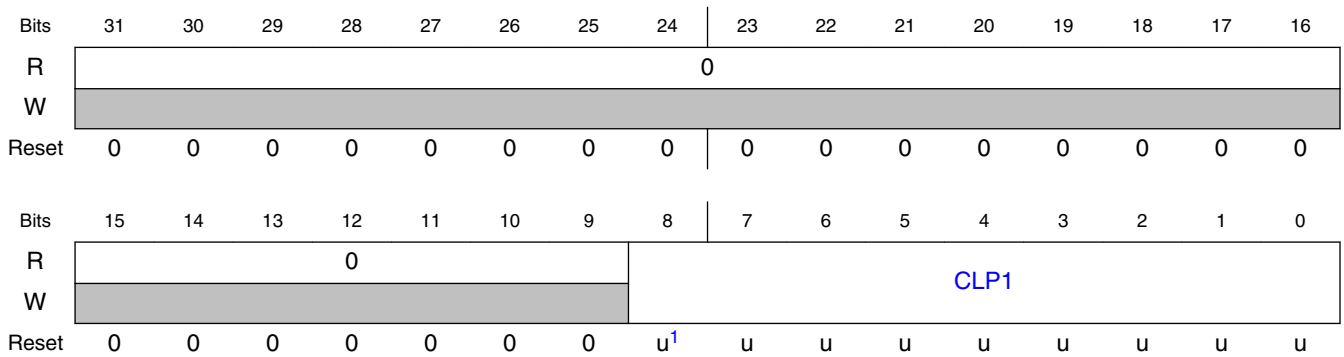
Field	Function
31-10 —	Reserved
9-0 CLP2	CLP2 Calibration Value

31.4.19 ADC Plus-Side General Calibration Value Register 1 (CLP1)

31.4.19.1 Offset

Register	Offset
CLP1	C0h

31.4.19.2 Diagram



1. Reset values are loaded out of IFR.

31.4.19.3 Fields

Field	Function
31-9 —	Reserved
8-0 CLP1	CLP1 Calibration Value

31.4.20 ADC Plus-Side General Calibration Value Register 0 (CLP0)

31.4.20.1 Offset

Register	Offset
CLP0	C4h

31.4.20.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								CLP0							
W																
Reset	0	0	0	0	0	0	0	0	u[1]	u	u	u	u	u	u	u

1. Reset values are loaded out of IFR.

31.4.20.3 Fields

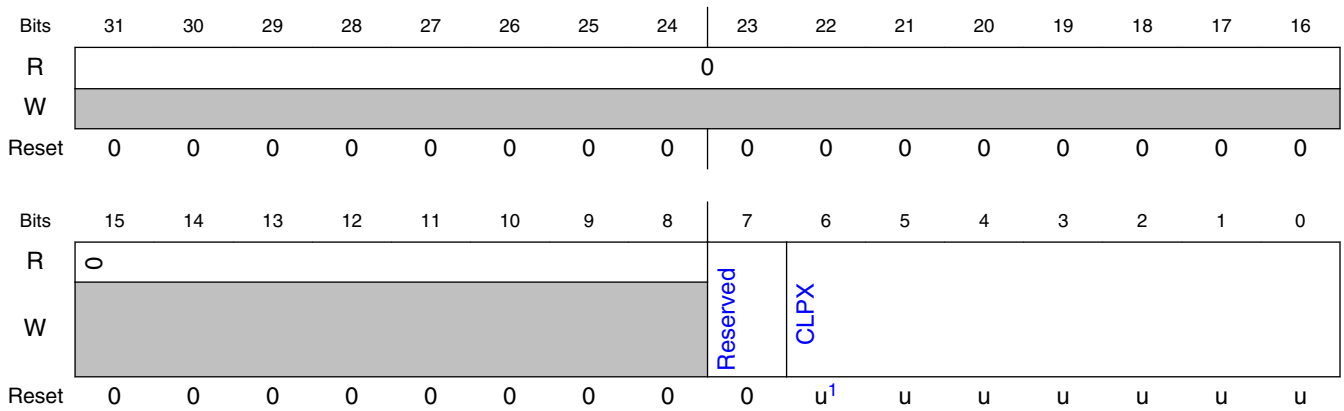
Field	Function
31-8 —	Reserved
7-0 CLP0	CLP0 Calibration Value

31.4.21 ADC Plus-Side General Calibration Value Register X (CLPX)

31.4.21.1 Offset

Register	Offset
CLPX	C8h

31.4.21.2 Diagram



1. Reset values are loaded out of IFR.

31.4.21.3 Fields

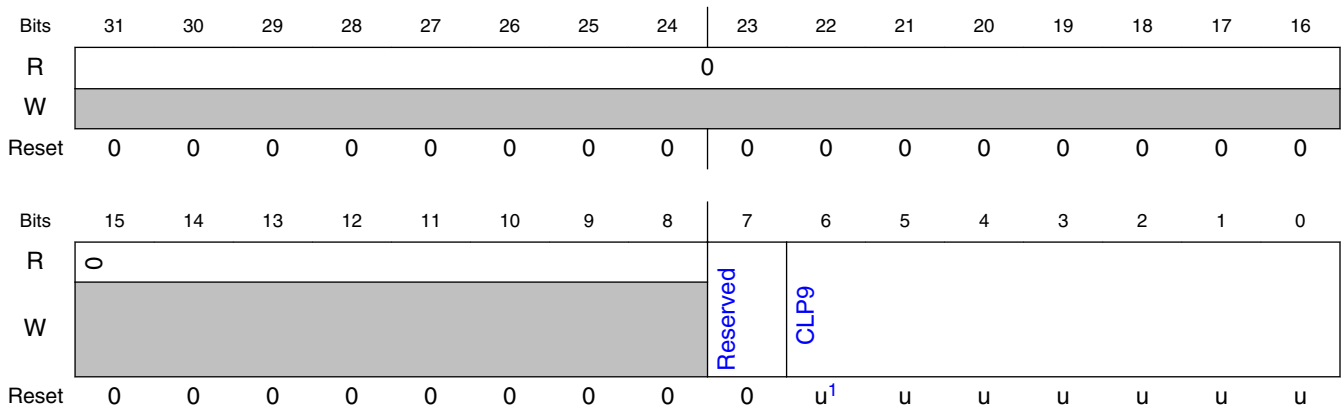
Field	Function
31-8 —	Reserved
7 —	Reserved
6-0 CLPX	CLPX Calibration Value

31.4.22 ADC Plus-Side General Calibration Value Register 9 (CLP9)

31.4.22.1 Offset

Register	Offset
CLP9	CCh

31.4.22.2 Diagram



1. Reset values are loaded out of IFR.

31.4.22.3 Fields

Field	Function
31-8 —	Reserved
7 —	Reserved
6-0 CLP9	CLP9 Calibration Value

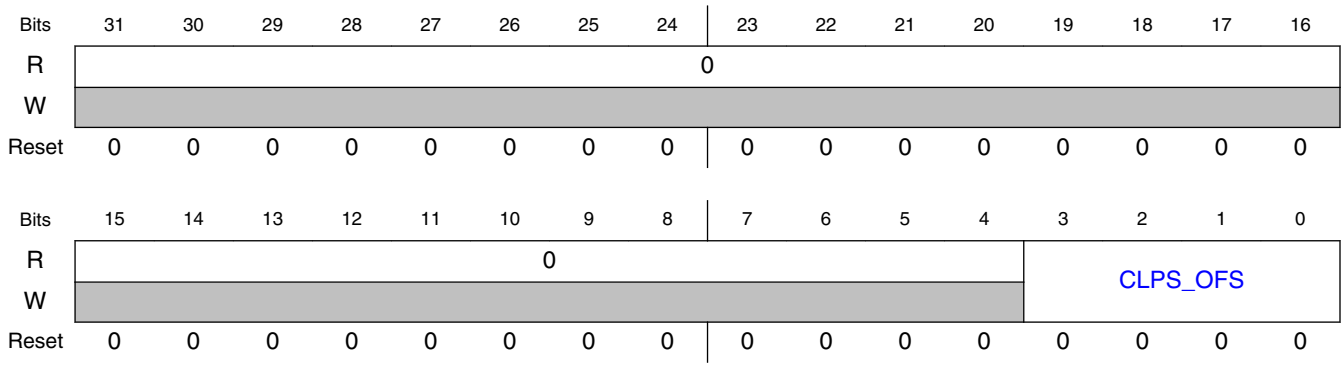
31.4.23 ADC General Calibration Offset Value Register S (CLPS_OFS)

31.4.23.1 Offset

Register	Offset
CLPS_OFS	D0h

31.4.23.2 Function

31.4.23.3 Diagram



31.4.23.4 Fields

Field	Function
31-4 —	Reserved
3-0 CLPS_OFS	CLPS Offset Capacitor offset correction value

31.4.24 ADC Plus-Side General Calibration Offset Value Register 3 (CLP3_OFS)

31.4.24.1 Offset

Register	Offset
CLP3_OFS	D4h

31.4.24.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												CLP3_OFS			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31.4.24.3 Fields

Field	Function
31-4 —	Reserved
3-0 CLP3_OFS	CLP3 Offset Capacitor offset correction value

31.4.25 ADC Plus-Side General Calibration Offset Value Register 2 (CLP2_OFS)

31.4.25.1 Offset

Register	Offset
CLP2_OFS	D8h

31.4.25.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												CLP2_OFS			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31.4.25.3 Fields

Field	Function
31-4 —	Reserved
3-0 CLP2_OFS	CLP2 Offset Capacitor offset correction value

31.4.26 ADC Plus-Side General Calibration Offset Value Register 1 (CLP1_OFS)

31.4.26.1 Offset

Register	Offset
CLP1_OFS	DCh

31.4.26.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												CLP1_OFS			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31.4.26.3 Fields

Field	Function
31-4 —	Reserved
3-0 CLP1_OFS	CLP1 Offset Capacitor offset correction value

31.4.27 ADC Plus-Side General Calibration Offset Value Register 0 (CLP0_OFS)

31.4.27.1 Offset

Register	Offset
CLP0_OFS	E0h

31.4.27.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												CLP0_OFS			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

31.4.27.3 Fields

Field	Function
31-4 —	Reserved
3-0 CLP0_OFS	CLP0 Offset Capacitor offset correction value

31.4.28 ADC Plus-Side General Calibration Offset Value Register X (CLPX_OFS)

31.4.28.1 Offset

Register	Offset
CLPX_OFS	E4h

31.4.28.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				CLPX_OFS											
W																
Reset	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0

31.4.28.3 Fields

Field	Function
31-12 —	Reserved
11-0 CLPX_OFS	CLPX Offset Capacitor offset correction value

31.4.29 ADC Plus-Side General Calibration Offset Value Register 9 (CLP9_OFS)

31.4.29.1 Offset

Register	Offset
CLP9_OFS	E8h

31.4.29.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0				CLP9_OFS											
W																
Reset	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0

31.4.29.3 Fields

Field	Function
31-12 —	Reserved
11-0 CLP9_OFS	CLP9 Offset Capacitor offset correction value

31.5 Functional description

The ADC module is disabled during reset, or when SC1*n*[ADCH] are all high; see the power management information for details. The module is idle when a conversion has completed and another conversion has not been initiated. When it is idle the module is in its lowest power state. The ADC can perform an analog-to-digital conversion on any of the software selectable channels. All modes perform conversion by a successive approximation algorithm.

To meet accuracy specifications, the ADC module must be calibrated using the on-chip calibration function.

See Calibration function for details on how to perform calibration.

When the conversion is completed, the result is placed in the Rn data registers. The respective SC1*n*[COCO] is then set and an interrupt is generated if the respective conversion complete interrupt has been enabled, or when SC1*n*[AIEN]=1.

The ADC module has the capability of automatically comparing the result of a conversion with the contents of the CV1 and CV2 registers. The compare function is enabled by setting SC2[ACFE] and operates in any of the conversion modes and configurations.

The ADC module has the capability of automatically averaging the result of multiple conversions. The hardware average function is enabled by setting SC3[AVGE] and operates in any of the conversion modes and configurations.

NOTE

For the chip-specific modes of operation, see the power management information of this chip.

31.5.1 Clock select and divide control

One of four clock sources can be selected as the clock source for the ADC module. This clock source is then divided by a configurable value to generate the input clock ADCK, to the module. The clock is selected by configuring CFG1[ADICLK]. ALTCLK*x*, as defined for this MCU. See the chip configuration information. Conversions are possible using ALTCLK*x* as the input clock source while the MCU is in Normal Stop mode. ALTCLK1 is the default selection following reset.

Whichever clock is selected, its frequency must fall within the specified frequency range for ADCK. If the available clocks are too slow, the ADC may not perform as in the specifications. If the available clocks are too fast, the clock must be divided to the appropriate frequency. This divider is specified by CFG1[ADIV] and can be divided by 1, 2, 4, or 8. The ADC bus clock frequency must be greater than or equal to the ADC ALT clock frequency. Please refer to the device *Data Sheet* for ADC specifications.

31.5.2 Voltage reference selection

The ADC can be configured to accept one of the two voltage reference pairs as the reference voltage (V_{REFSH} and V_{REFSL}) used for conversions.

Each pair contains a positive reference that must be between the minimum Ref Voltage High and V_{DDA}, and a ground reference that must be at the same potential as V_{SSA}. The two pairs are external (V_{REFH} and V_{REFL}) and alternate (V_{ALTH}). These voltage references are selected using SC2[REFSEL]. The alternate V_{ALTH} voltage reference may select additional external pin or internal source depending on MCU configuration. See the chip configuration information for the voltage references specific to this MCU.

31.5.3 Hardware trigger and channel selects

The ADC module has a selectable asynchronous hardware conversion trigger, ADHWT, that is enabled when SC2[ADTRG] is set and a hardware trigger select event, ADHWTS*n*, has occurred. This source is not available on all MCUs. See the chip-specific ADC information for information on the ADHWT source and the ADHWTS*n* configurations specific to this MCU.

When an ADHWT source is available and hardware trigger is enabled, that is SC2[ADTRG] = 1, a conversion is initiated on the rising edge of ADHWT after a hardware trigger select event, ADHWTS*n*, has occurred. If a conversion is in progress when a rising edge of a trigger occurs, the rising edge is ignored. In continuous conversionn configuration, only the initial rising edge to launch continuous conversions is observed, and until conversion is aborted, the ADC continues to do conversions on the same SCn register that initiated the conversion. The hardware trigger function operates in conjunction with any of the conversion modes and configurations.

The hardware trigger select event, ADHWTS*n*, must be set prior to the receipt of the ADHWT signal. If these conditions are not met, the converter may ignore the trigger or use an incorrect configuration. If a hardware trigger select event is asserted during a conversion, it must stay asserted until the end of current conversion and remain set until the receipt of the ADHWT signal to trigger a new conversion. The channel and status fields selected for the conversion depend on the active trigger select signal:

- ADHWTSA active selects SC1A.
- ADHWTS*n* active selects SC1*n*.

When the conversion is completed, the result is placed in the R*n* registers associated with the ADHWTS*n* received. For example:

- ADHWTSA active selects RA register
- ADHWTS*n* active selects R*n* register

The conversion complete flag associated with the ADHWTS*n* received, that is, SC1*n*[COCO], is then set and an interrupt is generated if the respective conversion complete interrupt has been enabled, that is, SC1[AIEN]=1.

31.5.4 Conversion control

Conversion mode is selected by configuring CFG1[MODE].

Conversions can be initiated by a software or hardware trigger.

In addition, the ADC module can be configured for:

- Low-power operation
- Long sample time
- Continuous conversion
- Hardware average
- Automatic compare of the conversion result to a software-determined compare value

31.5.4.1 Initiating conversions

A conversion is initiated:

- Following a write to SC1A, if software-triggered operation is selected, that is, when SC2[ADTRG] = 0.
- Following a hardware trigger, or ADHWT event, if hardware-triggered operation is selected, that is, SC2[ADTRG] = 1, and a hardware trigger select event, ADHWTS*n*, has occurred. The channel and status fields that are selected depend on the active trigger select signal:
  - ADHWTSA active selects SC1A.
  - ADHWTS*n* active selects SC1*n*.
  - if neither is active, the off condition is selected

Note

Selecting more than one ADHWTS*n* prior to a conversion completion will cause unpredictable results. To avoid this, select only one ADHWTS*n* prior to a conversion completion.

- Following the transfer of the result to the data registers when continuous conversion is enabled, that is, when SC3[ADCO] = 1.

If continuous conversions are enabled, a new conversion is automatically initiated after the completion of the current conversion. In software-triggered operation, that is, when SC2[ADTRG] = 0, continuous conversions begin after SC1A is written and continue until aborted. In hardware-triggered operation, that is, when SC2[ADTRG] = 1 and one ADHWTSn event has occurred, continuous conversions begin after a hardware trigger event and continue until aborted.

If hardware averaging is enabled, a new conversion is automatically initiated after the completion of the current conversion until the correct number of conversions are completed. In software-triggered operation, conversions begin after SC1A is written. In hardware-triggered operation, conversions begin after a hardware trigger. If continuous conversions are also enabled, a new set of conversions to be averaged are initiated following the last of the selected number of conversions.

31.5.4.2 Completing conversions

A conversion is completed when the result of the conversion is transferred into the data result registers, R*n*, as indicated in the following table.

Table 31-5. Indication of conversion completion

Compare functions	Hardware averaging	Conversion status	Is SC1*n*[COCO] set to 1, and is the conversion result transferred into the data result registers?
Disabled	Disabled	Not completed	No
Disabled	Disabled	Completed	Yes
Disabled	Enabled	Not completed	No
Disabled	Enabled	Completed	Yes, if the last of the selected number of conversions is completed
Enabled	Disabled	Not completed	No
Enabled	Disabled	Completed	Yes, if the compare condition is true
Enabled	Enabled	Not completed	No
Enabled	Enabled	Completed	Yes, if [(the last of the selected number of conversions is completed) AND (the compare condition is true)]

An interrupt is generated if the respective SC1*n*[AIEN] is high at the time that the respective SC1*n*[COCO] is set.

31.5.4.3 Aborting conversions

Any conversion in progress is aborted when:

- Writing to SC1A while it is actively controlling a conversion aborts the current conversion. In Software Trigger mode, when SC2[ADTRG] = 0, a write to SC1A initiates a new conversion if SC1A[ADCH] is equal to a value other than all 1s. Writing to any of the SC1B-SC1*n* registers while that specific SC1B-SC1*n* register is actively controlling a conversion aborts the current conversion. The SC1B-SC1*n* registers are not used for software trigger operation and therefore writes to the SC1B-SC1*n* registers do not initiate a new conversion.
- A write to any ADC register besides the SC1A-SC1*n* registers occurs. This indicates that a change in mode of operation has occurred and the current conversion is therefore invalid.
- The MCU is reset.

When a conversion is aborted, the contents of the data registers, R*n*, are not altered. The data registers continue to be the values transferred after the completion of the last successful conversion. If the conversion was aborted by a reset, RA and R*n* return to their reset states.

31.5.4.4 Power control

The ADC module remains in its Idle state until a conversion is initiated. The Idle state implies that ADC conversion routine is held in reset.

31.5.4.5 Sample time and total conversion time

The total conversion time depends upon:

- The sample time as determined by CFG2[SMPLTS]
- The MCU bus frequency
- The conversion mode, as determined by CFG1[MODE]
- The frequency of the conversion clock, that is, f_{ADCK}.

After the module becomes active, sampling of the input begins.

1. CFG2[SMPLTS] selects between sample times based on the conversion mode that is selected.
2. When sampling is completed, the converter is isolated from the input channel and a successive approximation algorithm is applied to determine the digital value of the analog signal.
3. The result of the conversion is transferred to Rn upon completion of the conversion algorithm.

The maximum total conversion time is determined by the clock source chosen and the divide ratio selected. The clock source is selectable by CFG1[ADICLK], and the divide ratio is specified by CFG1[ADIV]. To calculate total conversion time the following formula is applied:

ADC TOTAL CONVERSION TIME = Sample Phase Time (set by SMPLTS + 1) + Hold Phase (1 ADC Cycle) + Compare Phase Time (8-bit Mode = 20 ADC Cycles, 10-bit Mode = 24 ADC Cycles, 12-bit Mode = 28 ADC Cycles) + Single or First continuous time adder (5 ADC cycles + 5 bus clock cycles)

31.5.4.6 Hardware average function

The hardware average function can be enabled by setting SC3[AVGE] = 1 to perform a hardware average of multiple conversions. The number of conversions is determined by the AVGS[1:0] bits, which can select 4, 8, 16, or 32 conversions to be averaged. While the hardware average function is in progress, SC2[ADACT] will be set.

After the selected input is sampled and converted, the result is placed in an accumulator from which an average is calculated after the selected number of conversions have been completed. When hardware averaging is selected, the completion of a single conversion will not set SC1*n*[COCO].

If the compare function is either disabled or evaluates true, after the selected number of conversions are completed, the average conversion result is transferred into the data result registers, R*n*, and SC1*n*[COCO] is set. An ADC interrupt is generated upon the setting of SC1*n*[COCO] if the respective ADC interrupt is enabled, that is, SC1*n*[AIEN] = 1.

Note

The hardware average function can perform conversions on a channel while the MCU is in Wait or Normal Stop mode. The ADC interrupt wakes the MCU when the hardware average is completed if SC1*n*[AIEN] is set.

31.5.5 Automatic compare function

The compare function can be configured to check whether the result is less than or greater-than-or-equal-to a single compare value, or, if the result falls within or outside a range determined by two compare values.

The compare mode is determined by SC2[ACFGT], SC2[ACREN], and the values in the Compare Value registers (CV1 and CV2). After the input is sampled and converted, the compare values in CV1 and CV2 are used as described in the following table. There are six Compare modes as shown in the following table.

Table 31-6. Compare modes

SC2[ACFGT]	SC2[ACREN]	CV1 relative to CV2	Function	Compare mode description
0	0	—	Less than threshold	Compare true if the result is less than the CV1 registers.
1	0	—	Greater than or equal to threshold	Compare true if the result is greater than **OR** equal to CV1 registers.

Table continues on the next page...

Table 31-6. Compare modes (continued)

SC2[ACFGT]	SC2[ACREN]	CV1 relative to CV2	Function	Compare mode description
0	1	Less than or equal	Outside range, not inclusive	Compare true if the result is less than CV1 **OR** the result is greater than CV2.
0	1	Greater than	Inside range, not inclusive	Compare true if the result is less than CV1 **AND** the result is greater than CV2.
1	1	Less than or equal	Inside range, inclusive	Compare true if the result is greater than or equal to CV1 **AND** the result is less than or equal to CV2.
1	1	Greater than	Outside range, inclusive	Compare true if the result is greater than or equal to CV1 **OR** the result is less than or equal to CV2.

With SC2[ACREN] = 1, and if the value of CV1 is less than or equal to the value of CV2, then setting SC2[ACFGT] will select a trigger-if-inside-compare-range inclusive-of-endpoints function. Clearing SC2[ACFGT] will select a trigger-if-outside-compare-range, not-inclusive-of-endpoints function.

If CV1 is greater than CV2, setting SC2[ACFGT] will select a trigger-if-outside-compare-range, inclusive-of-endpoints function. Clearing SC2[ACFGT] will select a trigger-if-inside-compare-range, not-inclusive-of-endpoints function.

If the condition selected evaluates true, SC1*n*[COCO] is set.

Upon completion of a conversion while the compare function is enabled, if the compare condition is not true, SC1*n*[COCO] is not set and the conversion result data will not be transferred to the result register, R*n*. If the hardware averaging function is enabled, the compare function compares the averaged result to the compare values. The same compare function definitions apply. An ADC interrupt is generated when SC1*n*[COCO] is set and the respective ADC interrupt is enabled, that is, SC1*n*[AIEN] = 1.

Note

The compare function can monitor the voltage on a channel while the MCU is in Wait or Normal Stop mode. The ADC interrupt wakes the MCU when the compare condition is met.

31.5.6 Calibration function

The ADC is equipped with a calibration mechanism to provide high accuracy as specified in the data sheet.

NOTE

It is mandatory to calibrate the ADC after power up or reset. Not doing this can result in ADC conversion results with lower than specified accuracy.

In order to calibrate the ADC correctly, the following has to be done:

- On startup, wait until the reference voltage (VREFH) has stabilized.
- ADC has to be recalibrated after each system reset.
- Calibrate only one ADC instance at a time. So, when calibrating instance ADC0, the instances ADC1, ADC2, and so on, are required to be idle.
- Set ADCK (ADC clock) to a value less than or equal to half of the maximum specified frequency.
- Before starting calibration, the calibration registers (CLPS, CLP3, CLP2, CLP1, CLP0, CLPX, and CLP9) must be cleared by writing 0000_0000h into each of them.
- Start ADC calibration by writing SC3[CAL] = 1, SC3[AVGE] = 1, and SC3[AVGS] = 11b.
- Wait for calibration to finish. This will be indicated by conversion complete flag (SC1*n*[COCO] = 1).
- Now you can run ADC conversions with high accuracy in your application. Please make sure to reconfigure the ADCK clock speed and reconfigure AVGE and AVGS to your desired settings. (Maximum clock speed and no use of hardware averaging is possible.)

The total calibration conversion time is: 12 × (# of AVERAGE × [Sample time (sample + 1) + 1 cycle for hold + 34 cycles for compare phase]) + 1st conversion synchronization (~5 ADC cycles + 5 module clocks).

For high accuracy of the ADC (as specified in data sheet) on your application board (PCB), the following requirements should be met:

- Bypass caps between VREFH and VREFL. Suggested cap sizes: 1 nF, 100 nF, 10 µF.
- Place caps on PCB as close as possible to the device pins VREFH and VREFL.
- Bypass caps between VDDA and VSSA. Suggested cap sizes: 1 nF, 100 nF, 10 µF.
- Place caps on PCB as close as possible to the device pins VDDA and VSSA.
- Routing of VDDA, VSSA, VREFH, and VREFL on PCB:
  - Low impedance between the bypass caps and the MCU pins.
  - Keep routing distant from noisy signal routes like switching I/Os.

31.5.7 User-defined offset function

OFS is a two's-complement, left-justified register that contains the calibration-generated offset error correction value.

The value in OFS is subtracted from the conversion and the result is transferred into the result registers, R*n*. If the result is greater than the maximum or less than the minimum result value, it is forced to the appropriate limit for the current mode of operation.

The formatting of OFS is different from the data result register, R*n*, to preserve the resolution of the calibration value regardless of the conversion mode selected. Lower order bits are ignored in lower resolution modes. For example, in 8-bit single-ended mode, OFS[14:7] are subtracted from D[7:0]; OFS[15] indicates the sign (negative numbers are effectively added to the result) and OFS[6:0] are ignored.

OFS is automatically set according to calibration requirements after the self-calibration sequence is done, that is, SC3[CAL] is cleared. You can write to OFS to override the calibration result if desired. If you write an OFS value that is different from the calibration value, the ADC error specifications may not be met. You should store the value generated by the calibration function in memory before overwriting with a user-specified value.

Note

There is an effective limit to the values of offset that you can set. If the magnitude of the offset is too high, the results of the conversions will cap off at the limits.

You can use the offset calibration function to remove application offsets or DC bias values. USR_OFS may be written with a number in two's-complement format and this offset will be subtracted from the result or hardware averaged value. To add an offset, store the negative offset in two's-complement format and the effect will be an addition. An offset correction that results in an out-of-range value will be forced to the minimum or maximum value. The minimum value for single-ended conversions is 0000h.

31.5.8 MCU wait mode operation

Wait mode is a lower-power consumption Standby mode from which recovery is fast because the clock sources remain active.

If a conversion is in progress when the MCU enters Wait mode, it continues until completion. Conversions can be initiated while the MCU is in Wait mode by means of the hardware trigger or if continuous conversions are enabled.

The Alternate Clock sources are available as conversion clock sources while in Wait mode. The use of ALTCLK as the conversion clock source in Wait is dependent on the definition of ALTCLK for this MCU. See the Chip Configuration information on ALTCLK specific to this MCU.

If the compare and hardware averaging functions are disabled, a conversion complete event sets SC1*n*[COCO] and generates an ADC interrupt to wake the MCU from Wait mode if the respective ADC interrupt is enabled, that is, when SC1*n*[AIEN]=1. If the hardware averaging function is enabled, SC1*n*[COCO] will set, and generate an interrupt if enabled, when the selected number of conversions are completed. If the compare function is enabled, SC1*n*[COCO] will set, and generate an interrupt if enabled, only if the compare conditions are met. If a single conversion is selected and the compare trigger is not met, the ADC will return to its idle state and cannot wake the MCU from Wait mode unless a new conversion is initiated by the hardware trigger.

31.5.9 MCU Normal Stop mode operation

Stop mode is a low-power consumption Standby mode during which most or all clock sources on the MCU are disabled.

31.5.9.1 Normal Stop mode with Alternate clock sources enabled

If Alternate clock source selected for the conversion clock is enabled, the ADC continues operation during Normal Stop mode. See the chip-specific ADC information for configuration information for this device.

If a conversion is in progress when the MCU enters Normal Stop mode, it continues until completion. Conversions can be initiated while the MCU is in Normal Stop mode by means of the hardware trigger or if continuous conversions are enabled.

If the compare and hardware averaging functions are disabled, a conversion complete event sets SC1*n*[COCO] and generates an ADC interrupt to wake the MCU from Normal Stop mode if the respective ADC interrupt is enabled, that is, when SC1*n*[AIEN]=1. The result register, R*n*, will contain the data from the first completed conversion that occurred during Normal Stop mode. If the hardware averaging function is enabled, SC1*n*[COCO] will set, and generate an interrupt if enabled, when the selected number of conversions are completed. If the compare function is enabled, SC1*n*[COCO] will set, and generate an interrupt if enabled, only if the compare conditions are met. If a single conversion is selected and the compare is not true, the ADC will return to its idle state and cannot wake the MCU from Normal Stop mode unless a new conversion is initiated by another hardware trigger.

31.6 Usage Guide

31.6.1 ADC module initialization sequence

Before the ADC module can be used to complete conversions, an initialization procedure must be performed. A typical sequence is as below:

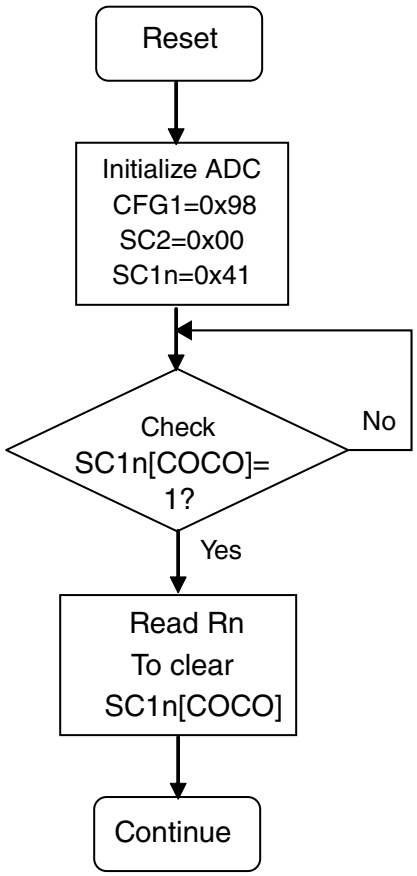
1. Calibrate the ADC by following the calibration instructions in Calibration function.
2. Update CFG to select the input clock source and the divide ratio used to generate ADCK.
3. Update SC2 to select the conversion trigger, hardware or software, and compare function options, if enabled.
4. Update SC3 to select whether conversions will be continuous or completed only once (ADCO) and whether to perform hardware averaging.
5. Update SC1:SC1*n* registers to enable or disable conversion complete interrupts.

Also, select the input channel which can be used to perform conversions.

31.6.2 Pseudo-code example

In this example, the ADC module is set up with interrupts enabled to perform a single 10-bit conversion at low-power with a long sample time on input channel 1, where ADCK is derived from the bus clock divided by 1.

```
ADC_CFG1 = ADC_CFG1_ADLPC_MASK |
ADC_CFG1_ADLSMP_MASK | ADC_CFG1_MODE(0x10);
// Bit 7 ADLPC 1 Configures for low power, lowers maximum clock speed.
// Bit 6:5 ADIV 00 Sets the ADCK to the input clock ÷ 1.
// Bit 4 ADLSMP 1 Configures for long sample time.
// Bit 3:2 MODE 10 Selects the single-ended 10-bit conversion.
// Bit 1:0 ADICLK 00 Selects the bus clock.
ADC_SC2 = 0x00;
// Bit 7 ADACT 0 Flag indicates if a conversion is in progress.
// Bit 6 ADTRG 0 Software trigger selected.
// Bit 5 ACFE 0 Compare function disabled.
// Bit 4 ACFGT 0 Not used in this example.
// Bit 3 ACREN 0 Compare range disabled.
// Bit 2 DMAEN 0 DMA request disabled.
// Bit 1:0 REFSEL 00 Selects default voltage reference pin pair (External pins VREFH and
VREFL ).
ADC_SC1A = ADC_SC1_AIEN_MASK | ADC_SC1_ADCH(0x1);
// Bit 7 COCO 0 Read-only flag which is set when a conversion completes.
// Bit 6 AIEN 1 Conversion complete interrupt enabled.
// Bit 4:0 ADCH 00001 Input channel 1 selected as ADC input channel.
ADC_RA = 0xxx
// Holds results of conversion.
ADC_CV = 0xxx
// Holds compare value when compare function enabled.
```



31.6.3 Calibration

The ADC contains a self-calibration function that is required to achieve the specified accuracy. Calibration must be run, or valid calibration values written, after any reset and before a conversion is initiated. Not doing this can result in ADC conversion results with lower than specified accuracy.

In order to calibrate ADC correctly the following steps have to be done:

- On startup, wait until reference voltage (VREFH/VREFL) has stabilized, use 3 bypass capacitance in the range: 1 μF, 100 nF and 1 nF.
- Calibrate only one ADC instance at a time, no parallel calibration of ADCs because they will disturb each other.
- Set ADCK (ADC clock) to half the maximum specified frequency, e.g. 25 MHz.
- Start ADC calibration by writing ADC_SC3 register with: CAL=1, AVGE=1, AVGS=11.

- Wait for calibration to finish. This will be indicated by conversion complete flag (COCO in ADC_SC1A).
- Run ADC conversions with high accuracy in your application. Make sure to re-configure ADCK clock speed and to re-configure AVGE and AVGS to the desired settings.

For more detailed information about calibration guidelines, refer to the application note AN5314: ADC Calibration on Kinetis E+ Microcontrollers.

NOTE

In the OFS, CLPX and CLP9 registers, the calibration values are signed numbers (in 2's complement format).

31.6.4 Application hints

The ADC has been designed to be integrated into a microcontroller for use in embedded control applications requiring an ADC. For guidance on selecting optimum external component values and converter parameters, refer to the application note AN5250: How to Increase the Analog-to-Digital Converter Accuracy in an Application.

31.6.5 ADC low-power modes

The ADC will be available in STOP, VLPR, VLPW, and VLPS mode.

NOTE

When in VLPx mode, the ADC clock source is only limited to OSC and SIRC.

31.6.6 ADC Trigger Concept – Use Case

FTM module support counter init trigger and channel match trigger, these triggers could be used as trigger input of PDB, PDB then be used to trigger other modules like ADC. Each ADC channel in PDB module supports up to 4 pre-triggers, which could be used as ADC hardware channel selection to precondition the ADC block prior to actual trigger. The ADC trigger is initiated after pre-trigger to trigger ADC conversion. The waveforms shown in following diagram illustrate the pre-trigger and trigger output of PDB to ADC. Every time when one PDB pre-trigger and trigger output starts an ADC conversion, an internal lock associated with the corresponding pre-trigger is activated. This lock becomes inactive when receiving COCO signal from ADC.

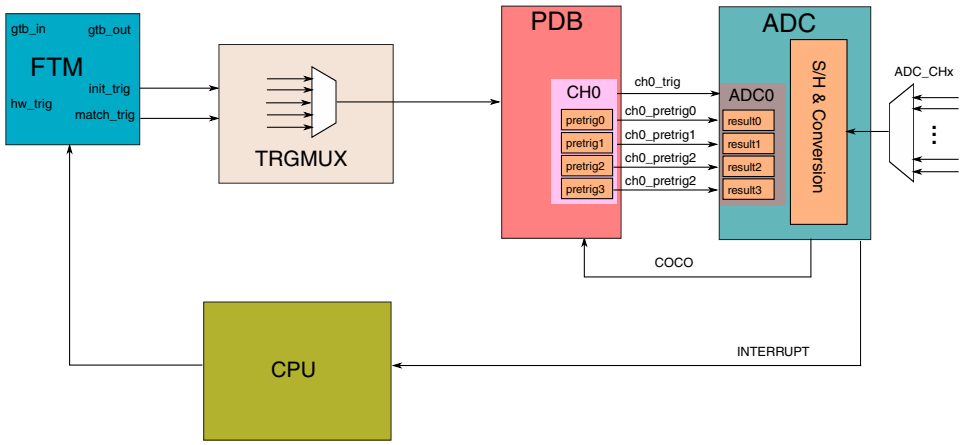


Figure 31-2. PWM Load Diagnosis – ADC Trigger Concept (block diagram)

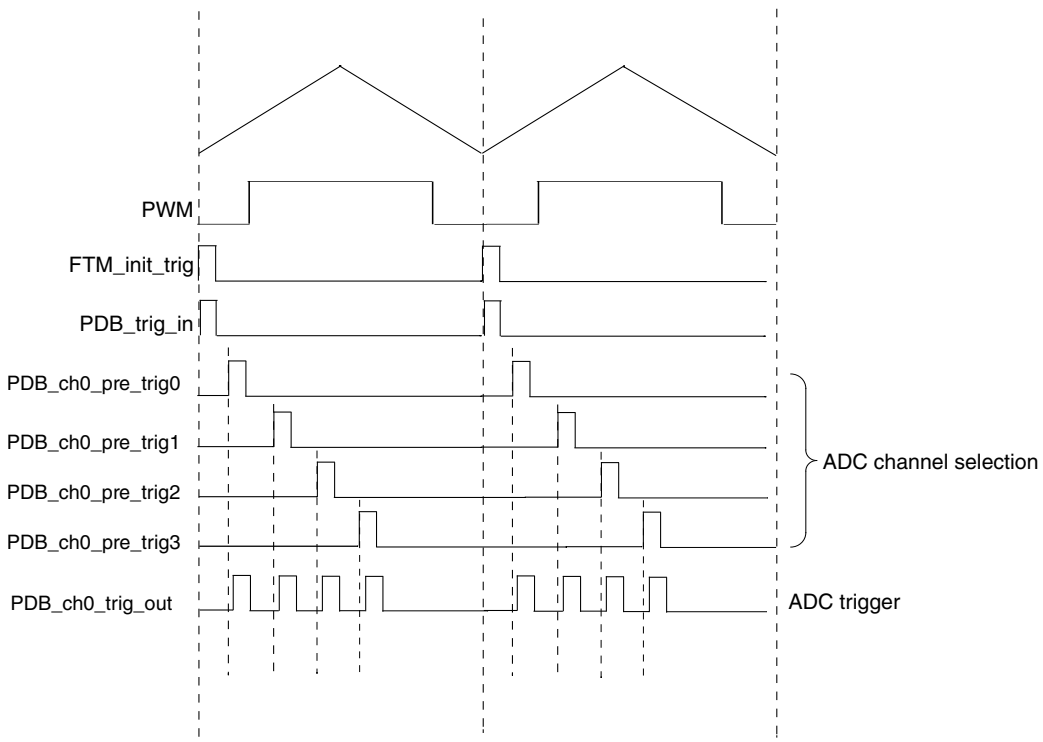


Figure 31-3. PWM Load Diagnosis – ADC Trigger Concept 1 (Timing)

31.6.7 ADC self-test and calibration scheme

ADC calibration needs to be initiated by setting the ADCx_SC3[CAL] bit.

The ADC contains a self-calibration function that is required to achieve the specified accuracy. Calibration must be run, or valid calibration values written, after any reset and before a conversion is initiated. Not doing this can result in ADC conversion results with lower than specified accuracy. Calibration needs to be initiated manually by setting the CAL bit. For more details, please refer to "Calibration" section.

Chapter 32
Comparator (CMP)

32.1 Chip-specific information for this module

32.1.1 Instantiation information

Number of CMP	1
8-bit DAC sub-block	Each CMP has its own independent 8-bit DAC.
Analog inputs	Each CMP supports up to 6 analog inputs from external pins.
Internal reference	Each CMP is able to convert an internal reference from the bandgap (1 V reference voltage).
Round-robin mode	Each CMP supports the round-robin sampling scheme.[1]

1. In summary, this allow the CMP to operate independently in STOP and VLPS mode, whilst being triggered periodically to sample up to 6 inputs. Only if an input changes state is a full wakeup generated.

NOTE

DMA is not supported in this device.

32.1.1.1 CMP input connections

The following table shows the input connections to the CMP.

Table 32-1. CMP input connections

CMP Inputs	CMP0
IN0	ACMP0_IN0
IN1	ACMP0_IN1
IN2	ACMP0_IN2
IN3	ACMP0_IN3
IN4	ACMP0_IN4

Table continues on the next page...

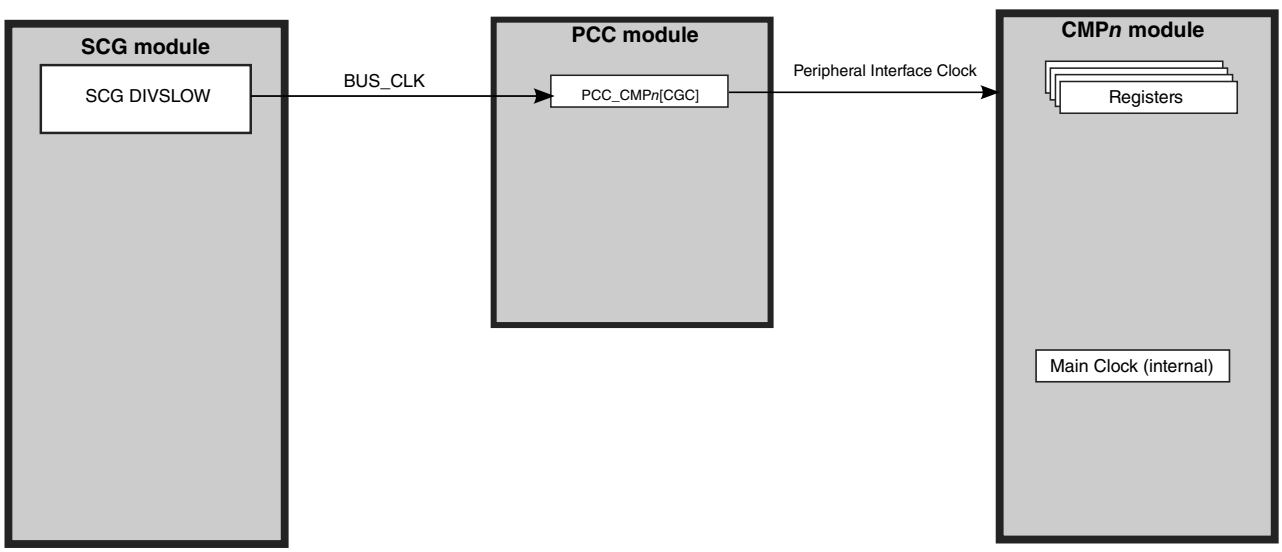
Table 32-1. CMP input connections (continued)

CMP Inputs	CMP0
IN5	ACMP0_IN5
IN6	Reserved
IN7	Reserved

32.1.2 CMP Clocking Information

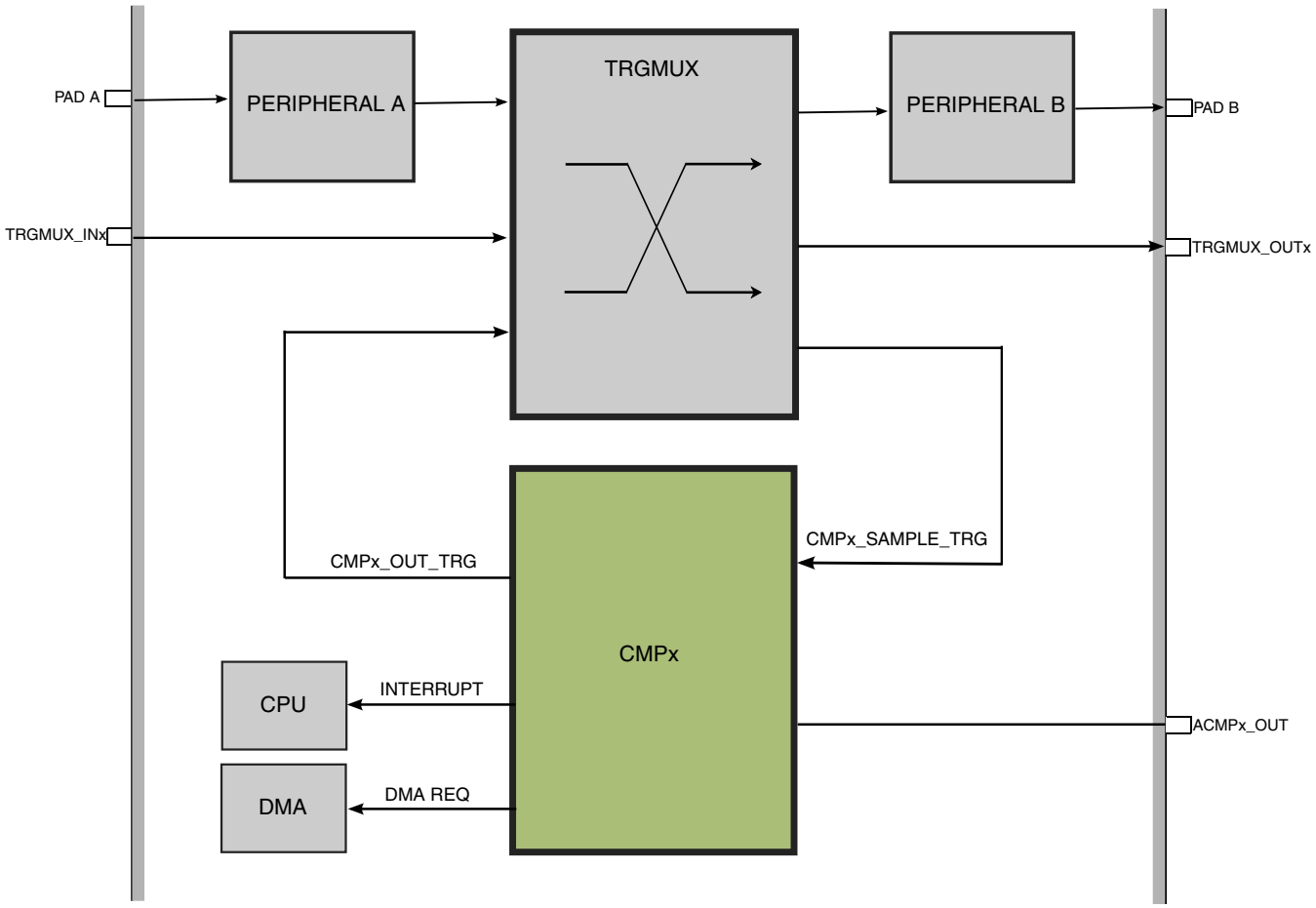
The CMP clocking input is as below.

Peripheral Clocking - CMP



32.1.3 Inter-connectivity Information

The CMP inter-connectivity is shown in following diagram.



32.1.4 Application-related Information

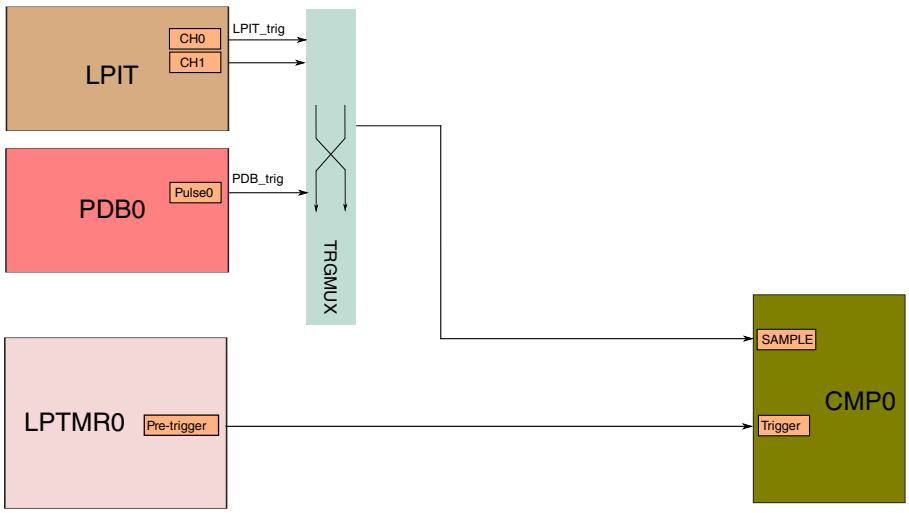
32.1.4.1 CMP external references

The CMP could get external reference through the tightly integrated 8-bit DAC sub-block. The 8-bit DAC sub-block supports selection of two references. For this device, the references are connected as follows:

- VDDA -- connected to V_{in1} of CMP
- PMC bandgap buffer out (1V reference voltage) -- connected to V_{in2} of CMP

32.1.4.2 External window/sample input

PDB and LPIT could be used to generate pulse output which can be used as sampling windows of CMP block via TRGMUX.



32.1.4.3 CMP trigger mode

The CMP and 8-bit DAC sub-block supports trigger mode operation when the chip is in STOP or VLPS mode. When trigger mode is enabled, the trigger source will provide a low power clock and the triggers to the CMP. The trigger event will initiate a compare sequence that must first enable the CMP and DAC prior to performing a CMP operation and capturing the output.

In this device, control for this two-staged sequencing is provided from, for example, LPTMR. The LPTMR provides a single trigger output to all implemented comparators. Through configuration of the CMPx_C2[RRE] bits the trigger can be used to trigger a single comparator or multiple comparators concurrently. The LPTMR only offers single wire trigger to CMP. And the configuration must be done by LPTMR itself (round robin) before entering low power mode.

32.2 Introduction

The comparator (CMP) module provides a circuit for comparing two analog input voltages. The comparator circuit is designed to operate across the full range of the supply voltage, known as rail-to-rail operation.

The Analog MUX (ANMUX) provides a circuit for selecting an analog input signal from eight channels. One signal is provided by the 8-bit digital-to-analog converter (DAC). The mux circuit is designed to operate across the full range of the supply voltage.

The DAC is a 256-tap resistor ladder network that provides a selectable voltage reference for applications requiring a voltage reference. The 256-tap resistor ladder network divides the supply reference V_{in} into 256 voltage levels. A 8-bit digital signal input selects the output voltage level, which varies from V_{in} to $V_{in}/256$. V_{in} can be selected from two voltage sources, V_{in1} and V_{in2}. The DAC from a comparator is available as an on-chip internal signal only and is not available externally to a pin.

32.3 Features

The following subsections list the features of the CMP, the DAC, and the ANMUX.

32.3.1 CMP features

The CMP has the following features:

- Operational over the entire supply range
- Inputs may range from rail to rail
- Programmable hysteresis control
- Selectable interrupt on rising-edge, falling-edge, or both rising or falling edges of the comparator output
- Selectable inversion on comparator output
- Capability to produce a wide range of outputs such as:
  - Sampled
  - Windowed, which is ideal for certain PWM zero-crossing-detection applications
  - Digitally filtered:
    - Filter can be bypassed
    - Can be clocked via external SAMPLE signal or scaled bus clock
- External hysteresis can be used at the same time that the output filter is used for internal functions
- Two software selectable performance levels:

  - Shorter propagation delay at the expense of higher power
  - Low power, with longer propagation delay
- Functional in all power modes available on this MCU
- The window and filter functions are not available in STOP modes
- The comparator can be triggered by other peripherals to work for only a small fraction of the time

32.3.2 8-bit DAC key features

The DAC has the following features:

- 8-bit resolution
- Selectable supply reference source
- Power Down mode to conserve power when not in use
- Option to route the output to internal comparator input

32.3.3 ANMUX key features

The ANMUX has the following features:

- Two 8-to-1 channel MUXes
- Operational over the entire supply range

32.4 CMP, DAC, and ANMUX diagram

The following figure shows the block diagram for the High-Speed Comparator, DAC, and ANMUX modules.

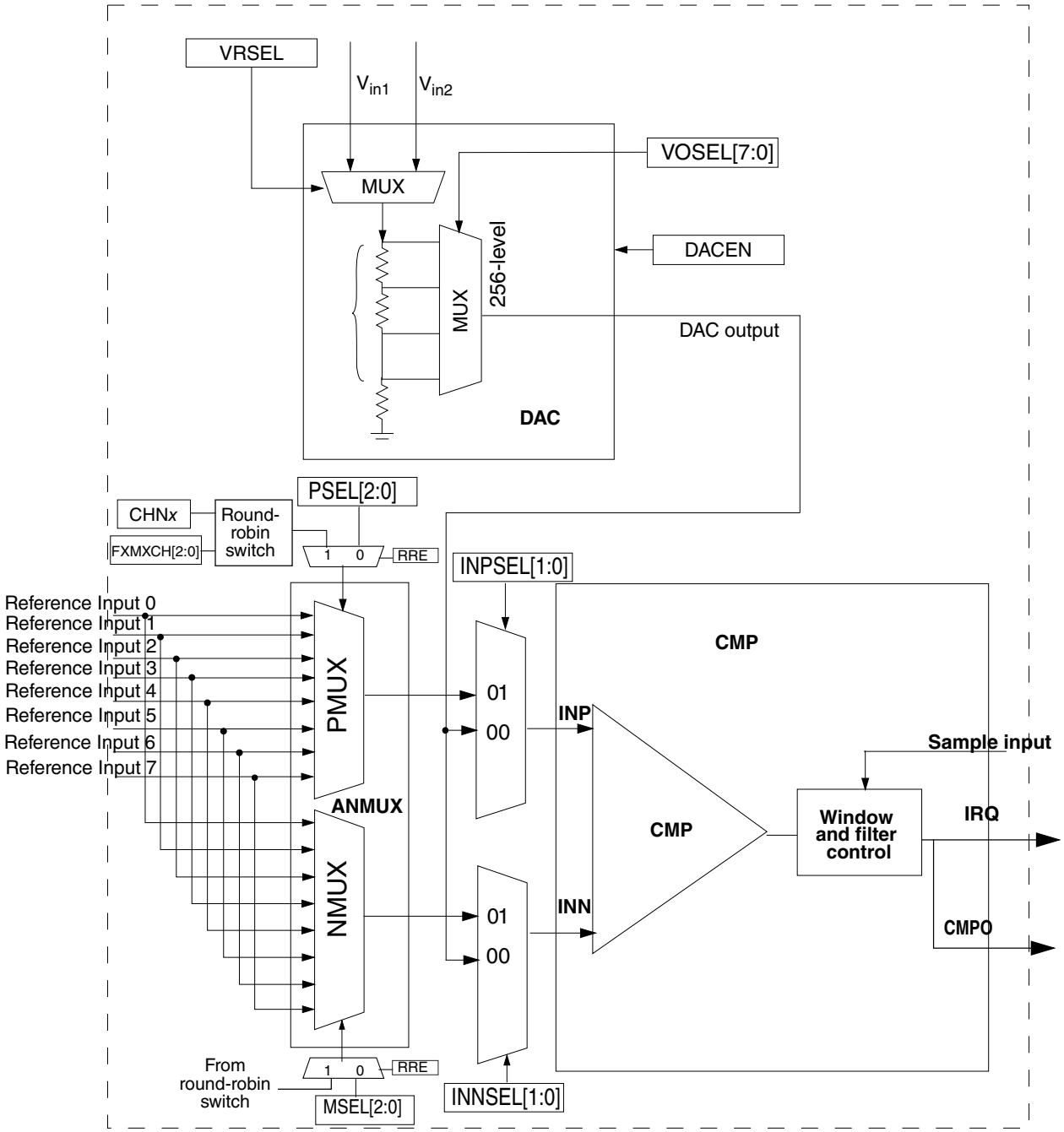


Figure 32-1. CMP high level diagram

32.5 CMP block diagram

The following figure shows the block diagram for the CMP module.

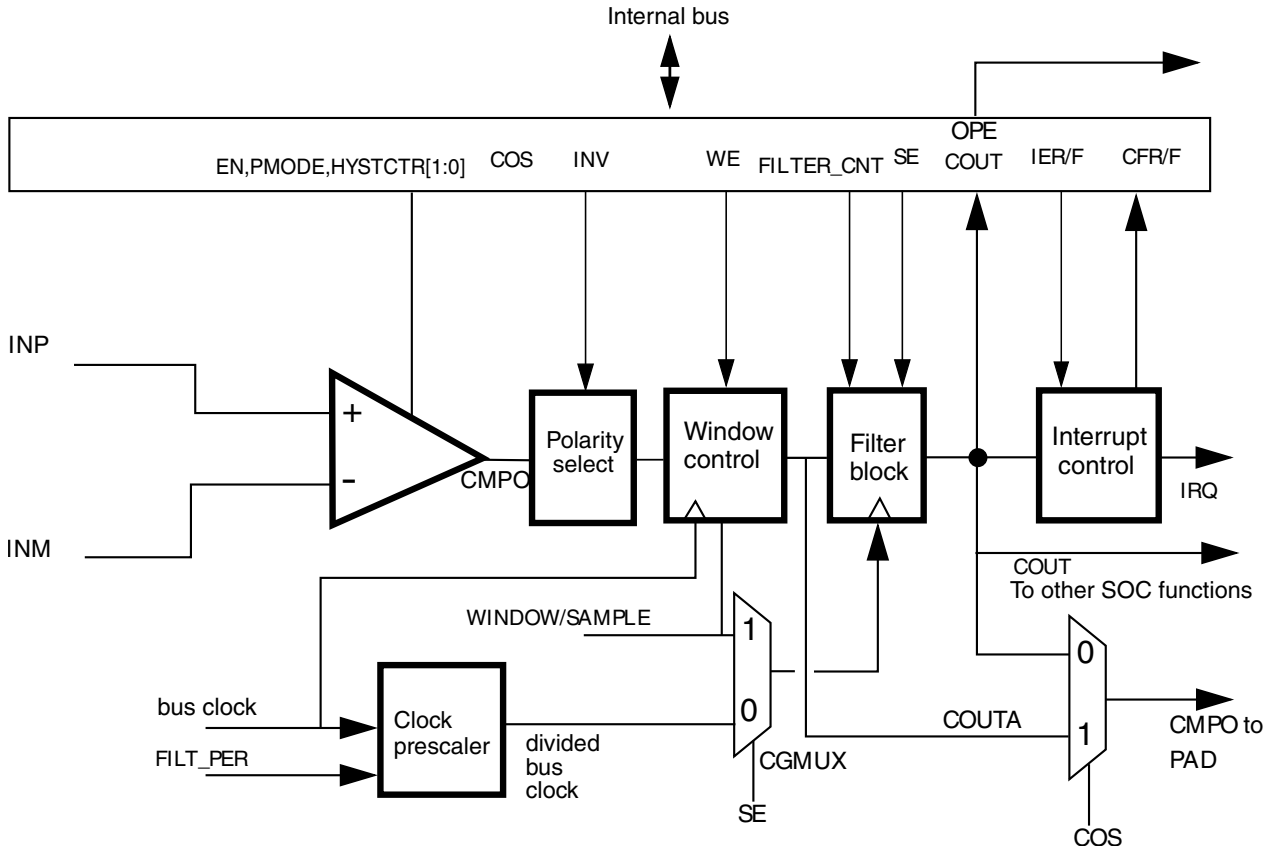


Figure 32-2. Comparator module block diagram

In the CMP block diagram:

- The Window Control block is bypassed when C0[WE] = 0.
- If C0[WE] = 1, the comparator output is sampled on every bus clock when WINDOW=1 to generate COUTA. Sampling does NOT occur when WINDOW = 0.
- The Filter block is bypassed when not in use.

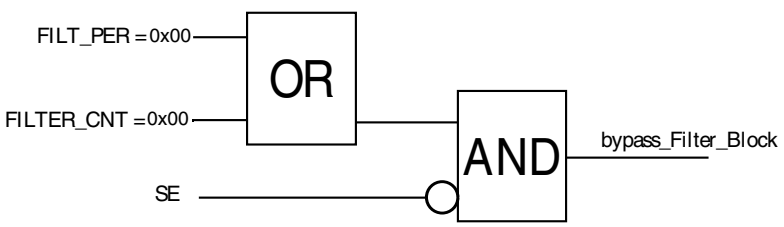


Figure 32-3. Filter block bypass logic

- The Filter block acts as a simple sampler if the filter is bypassed and C0[FILTER_CNT] is set to 0x01.
- The Filter block filters based on multiple samples when the filter is bypassed and C0[FILTER_CNT] is set greater than 0x01.

  - If C0[SE] = 1, the external SAMPLE input is used as the sampling clock.
  - IF C0[SE] = 0, the divided bus clock is used as the sampling clock.
- If enabled, the Filter block will incur up to one bus clock additional latency penalty on COUT due to the fact that COUT, which crosses clock domain boundaries, must be resynchronized to the bus clock.
- C0[WE] and C0[SE] are mutually exclusive.
- If enabled, the filter clock and the sample period must be at least 4 times slower than the system clock to the comparator.

32.6 CMP pin descriptions

This section provides the comparator pin descriptions. The external inputs IN[7:0] are muxed by CMP_C1[PSEL] and CMP_C1[MSEL] beforehand and multiplexed output will then go to the second stage of multiplex with the input of 8-bit DAC and other two internal reserved test signals, determined by CMP_C1[INPSEL] and CMP_C1[INNSEL]. The output of the second multiplex will finally go to the positive and negative ports of the comparator respectively.

Table 32-2. CMP signal descriptions

Signal	Description	I/O
IN[7:0]	Analog voltage inputs	I

NOTE

If comparing one input channel with the DAC output, and if there is injection or over-voltage in the input channels, the DAC output may be corrupted. For such case, the software workaround is to configure the DAC side SEL[2:0] same as the non-DAC side, i.e. configuration of MSEL and PSEL register bits must be the same.

32.6.1 External pins

The CMP has two analog inputs: INP and INM. Each of these pins can accept an input voltage that varies across the full operating range of the MCU. If the module is not enabled, each pin can be used as a digital input or output. Consult the specific MCU documentation to determine what functions are shared with these analog inputs.

The user can select either filtered or unfiltered comparator outputs for use on an external I/O pad.

32.7 CMP functional modes

There are three main sub-blocks to the CMP module:

- The comparator itself
- The window function
- The filter function

The filter, C0[FILTER_CNT], can be clocked from an internal or external clock source. The filter is programmable with respect to the number of samples that must agree before a change in the output is registered. In the simplest case, only one sample must agree. In this case, the filter acts as a simple sampler.

The external sample input is enabled using C0[SE]. When set, the output of the comparator is sampled only on rising edges of the sample input.

The "windowing mode" is enabled by setting C0[WE]. When set, the comparator output is sampled only when WINDOW=1. This feature can be used to ignore the comparator output during time periods in which the input voltages are not valid. This is especially useful when implementing zero-crossing-detection for certain PWM applications.

The comparator filter and sampling features can be combined as shown in the following table. Individual modes are discussed below.

Table 32-3. Comparator sample/filter controls

Mode #	C0[EN]	C0[WE]	C0[SE]	C0[FILTER_CNT]	C0[FPR]	Operation
1	0	X	X	X	X	**Disabled** See the Disabled mode (# 1).
2A	1	0	0	0x00	X	**Continuous Mode** See the Continuous mode (#s 2A & 2B).
2B	1	0	0	X	0x00	
3A	1	0	1	0x01	X	**Sampled, Non-Filtered mode** See the Sampled, Non-Filtered mode (#s 3A & 3B).
3B	1	0	0	0x01	> 0x00	
4A	1	0	1	> 0x01	X	**Sampled, Filtered mode**
4B	1	0	0	> 0x01	> 0x04	

Table continues on the next page...

Table 32-3. Comparator sample/filter controls (continued)

Mode #	C0[EN]	C0[WE]	C0[SE]	C0[FILTER_CNT]	C0[FPR]	Operation
						See the Sampled, Filtered mode (#s 4A & 4B).
5A	1	1	0	0x00	X	**Windowed mode** Comparator output is sampled on every rising bus clock edge when SAMPLE=1 to generate COUTA. See the Windowed mode (#s 5A & 5B).
5B	1	1	0	X	0x00	
6	1	1	0	0x01	0x01–0xFF	**Windowed/Resampled mode** Comparator output is sampled on every rising bus clock edge when SAMPLE=1 to generate COUTA, which is then resampled on an interval determined by C0[FPR] to generate COUT. See the Windowed/Resampled mode (# 6).
7	1	1	0	> 0x01	0x01–0xFF	**Windowed/Filtered mode** Comparator output is sampled on every rising bus clock edge when SAMPLE=1 to generate COUTA, which is then resampled and filtered to generate COUT. See the Windowed/Filtered mode (#7).
All other combinations of C0[EN], C0[WE], C0[SE], C0[FILTER_CNT], and C0[FPR] are illegal.						

For cases where a comparator is used to drive a fault input, for example, for a motor-control module such as FTM, it must be configured to operate in Continuous mode so that an external fault can immediately pass through the comparator to the target fault circuitry.

Note

Filtering and sampling settings must be changed only after setting C0[SE]=0, C0[FPR] =0 and C0[FILTER_CNT]=0x00. This resets the filter to a known state.

32.7.1 Disabled mode (# 1)

In Disabled mode, the analog comparator is non-functional and consumes no power. CMPO is 0 in this mode.

32.7.2 Continuous mode (#s 2A & 2B)

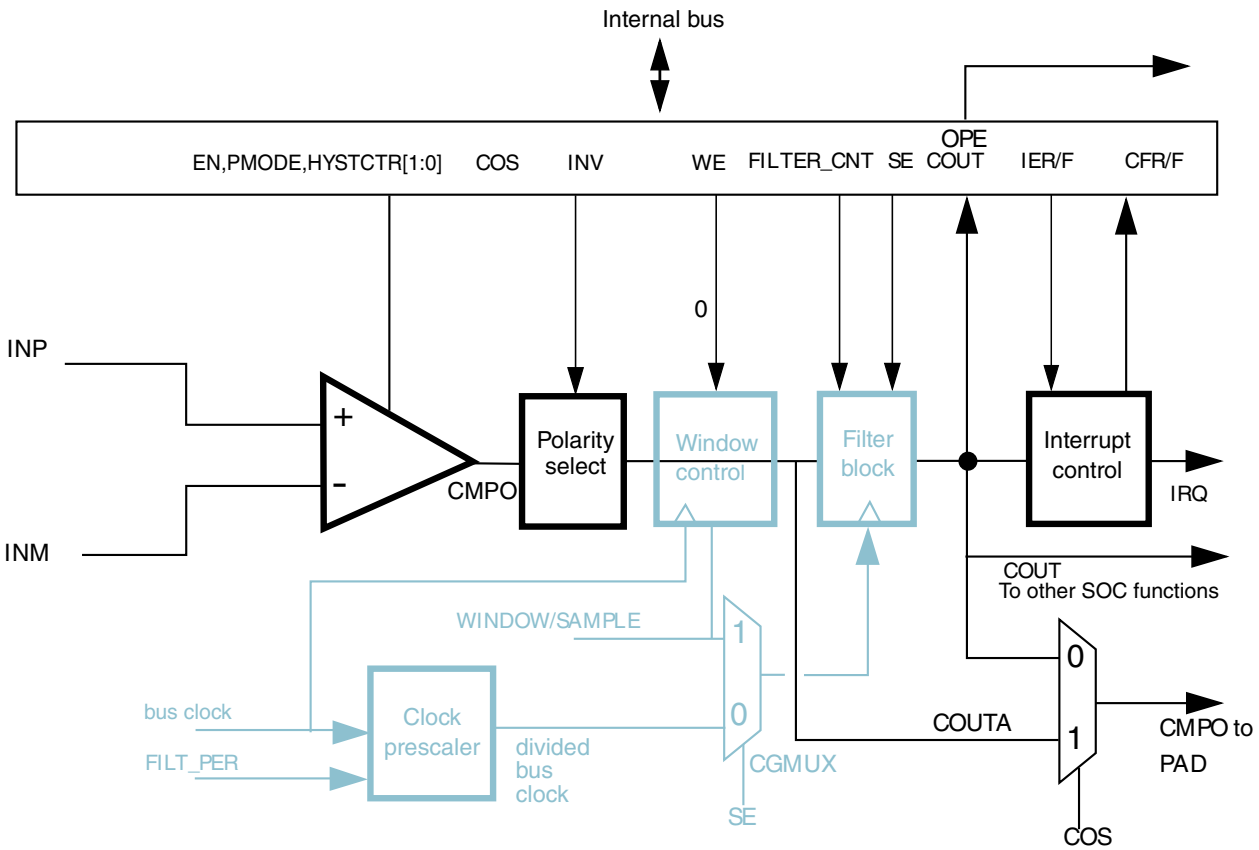


Figure 32-4. Comparator operation in Continuous mode

NOTE

See the chip configuration section for the source of sample/ window input.

The analog comparator block is powered and active. CMPO may be optionally inverted, but is not subject to external sampling or filtering. Both window control and filter blocks are completely bypassed (as the grey-colored parts in the figure). C0[COUT] is updated continuously. The path from comparator input pins to output pin is operating in combinational unclocked mode. COUT and COUTA are identical.

For control configurations that result in disabling the filter block, see Figure 32-3.

32.7.3 Sampled, Non-Filtered mode (#s 3A & 3B)

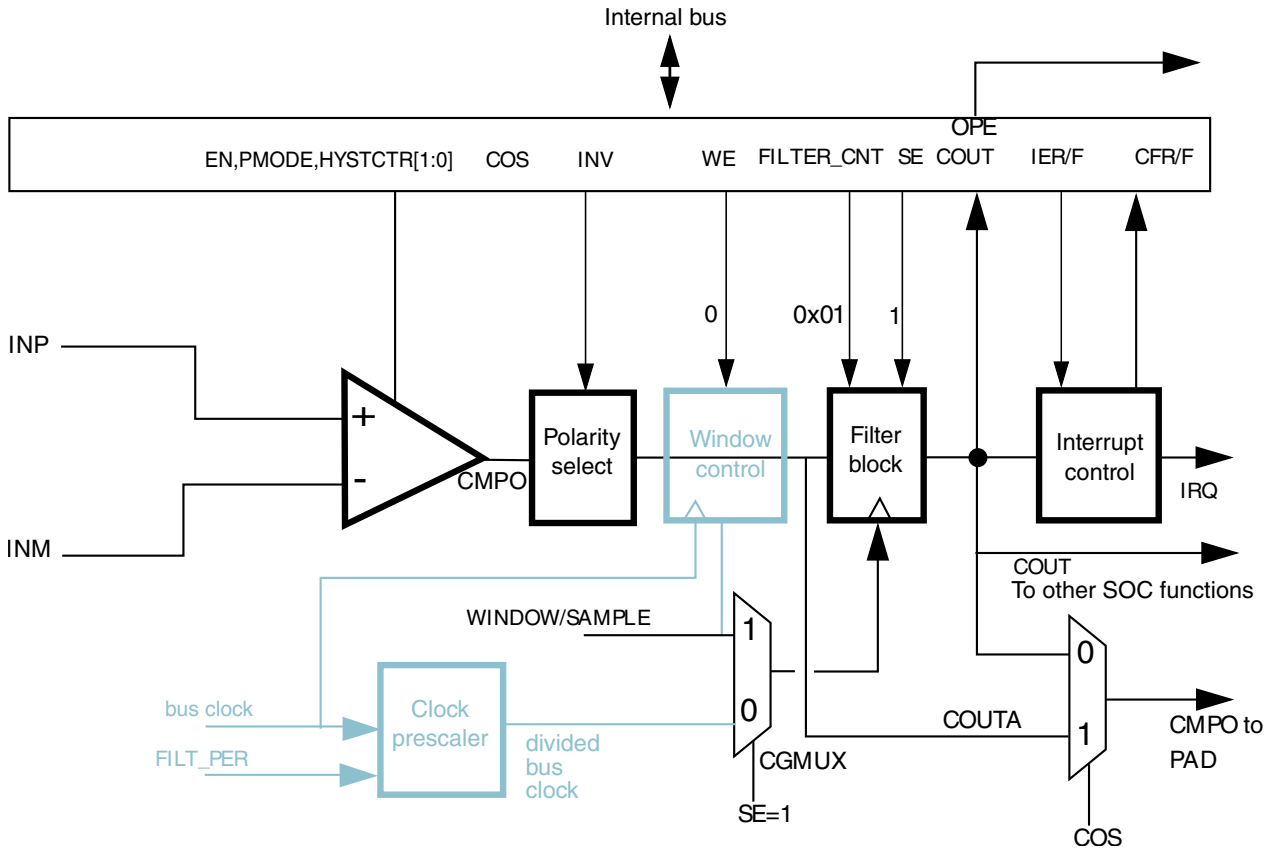


Figure 32-5. Sampled, Non-Filtered (# 3A): sampling point externally driven

In Sampled, Non-Filtered mode, the analog comparator block is powered and active. The path from analog inputs to COUTA is combinational unclocked. Windowing control is completely bypassed. COUTA is sampled whenever a rising edge is detected on the filter block clock input.

The only difference in operation between Sampled, Non-Filtered (# 3A) and Sampled, Non-Filtered (# 3B) is in how the clock to the filter block is derived. In #3A, the clock to filter block is externally derived while in #3B, the clock to filter block is internally derived.

The comparator filter has no other function than sample/hold of the comparator output in this mode (# 3B).

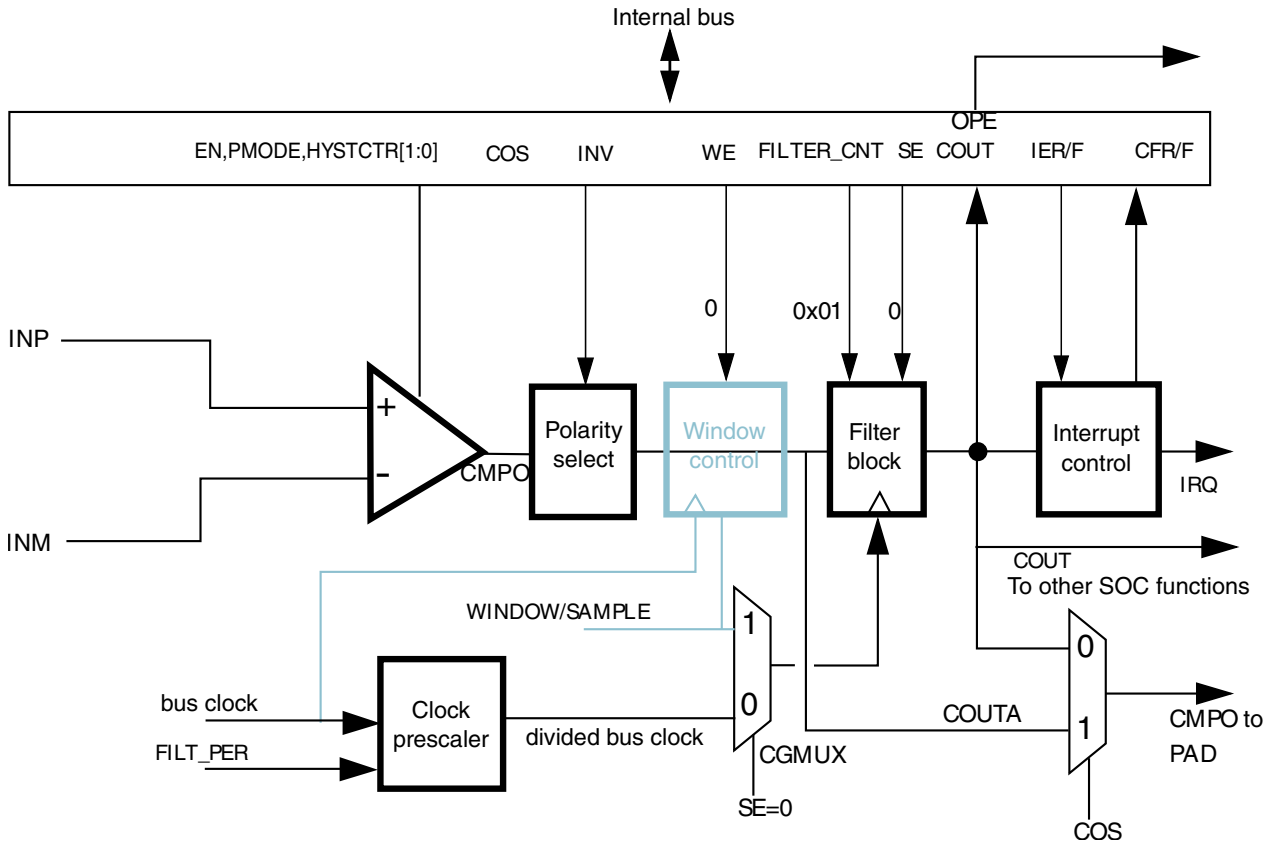


Figure 32-6. Sampled, Non-Filtered (# 3B): sampling interval internally derived

The following figure illustrates comparator operation in this mode, assuming the polarity select is set to non-inverting state.

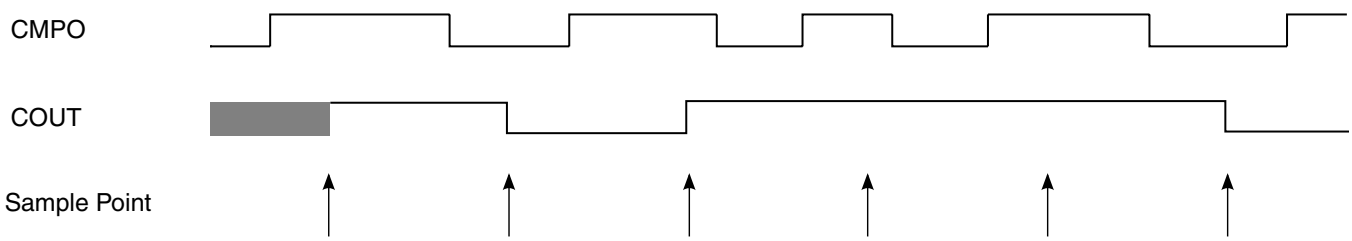


Figure 32-7. Sampled, Non-Filtered Mode Timing Diagram

32.7.4 Sampled, Filtered mode (#s 4A & 4B)

In Sampled, Filtered mode, the analog comparator block is powered and active. The path from analog inputs to COUTA is combinational unclocked. Windowing control is completely bypassed. COUTA is sampled whenever a rising edge is detected on the filter block clock input.

The only difference in operation between Sampled, Non-Filtered (# 3A) and Sampled, Filtered (# 4A) is that, now, C0[FILTER_CNT]>1, which activates filter operation.

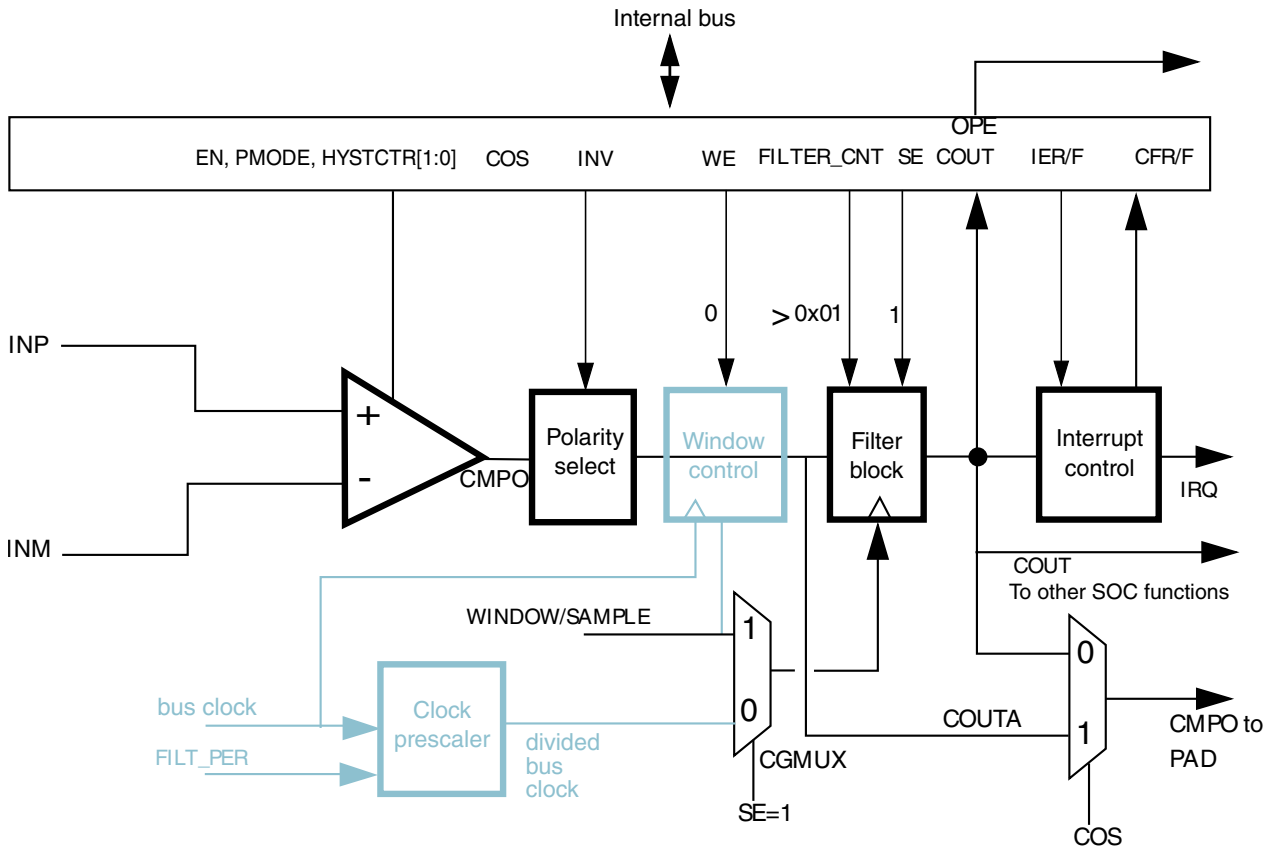


Figure 32-8. Sampled, Filtered (# 4A): sampling point externally driven

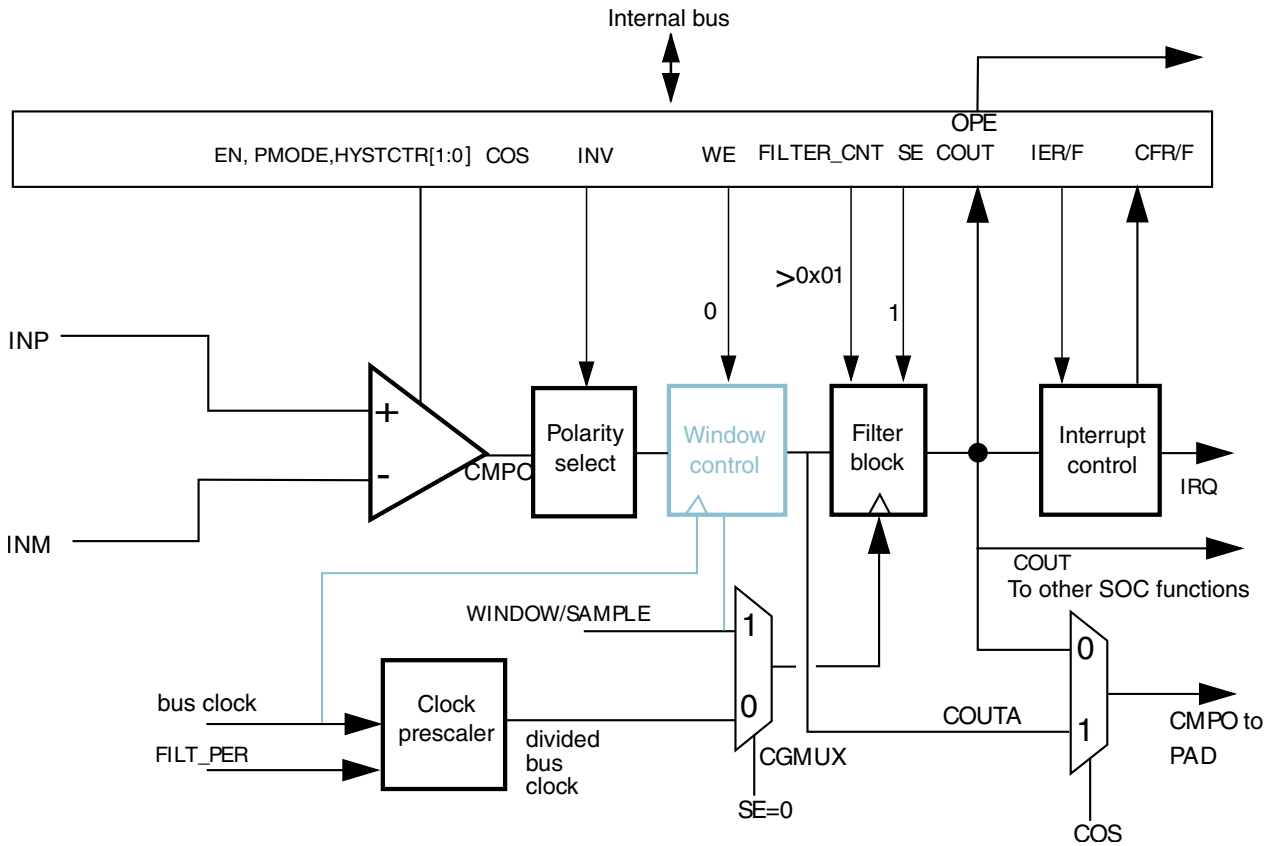


Figure 32-9. Sampled, Filtered (# 4B): sampling point internally derived

The only difference in operation between Sampled, Non-Filtered (# 3B) and Sampled, Filtered (# 4B) is that now, C0[FILTER_CNT]>1, which activates filter operation.

32.7.5 Windowed mode (#s 5A & 5B)

The following figure illustrates comparator operation in the Windowed mode, ignoring latency of the analog comparator, polarity select, and window control block. It also assumes that the polarity select is set to non-inverting state.

NOTE

The analog comparator output is passed to COUTA only when the WINDOW signal is high.

In actual operation, COUTA may lag the analog inputs by up to one bus clock cycle plus the combinational path delay through the comparator and polarity select logic.

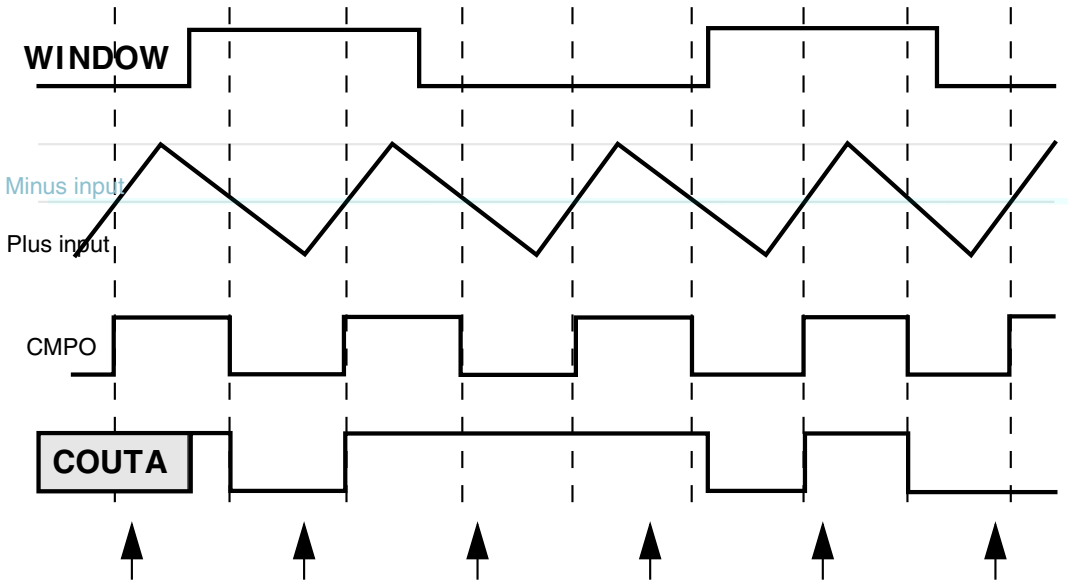


Figure 32-10. Windowed mode timing diagram

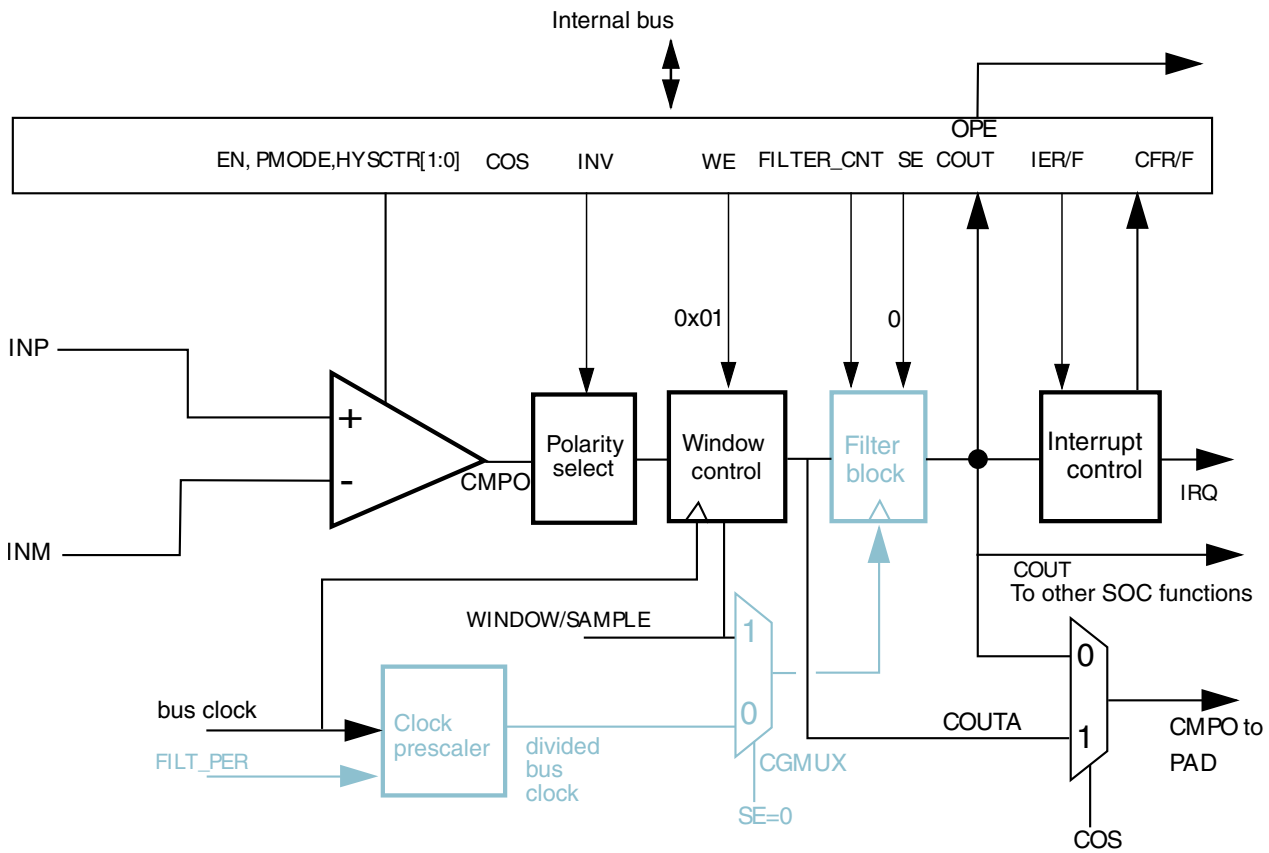


Figure 32-11. Windowed mode

For control configurations which result in disabling the filter block, see Figure 32-3.

When any windowed mode is active, COUTA is clocked by the bus clock whenever WINDOW = 1. The last latched value is held when WINDOW = 0.

NOTE

The sample input must be high for ≥ 2.5 CMP bus clock cycles to ensure no sampling event is missed.

32.7.6 Windowed/Resampled mode (# 6)

The following figure uses the same input stimulus shown in Figure 32-10, and adds resampling of COUTA to generate COUT. Samples are taken at the time points indicated by the arrows in the figure. Again, prop delays and latency are ignored for the sake of clarity.

This example was generated solely to demonstrate operation of the comparator in windowed/resampled mode, and does not reflect any specific application. Depending upon the sampling rate and window placement, COUT may not see zero-crossing events detected by the analog comparator. Sampling period and/or window placement must be carefully considered for a given application.

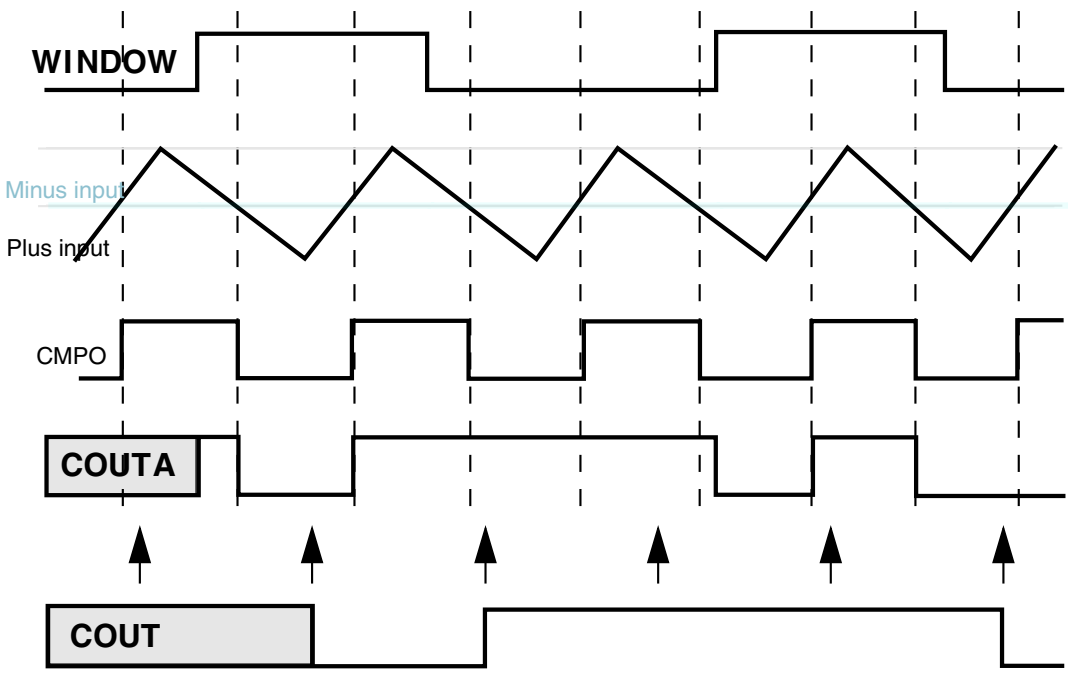


Figure 32-12. Windowed/resampled mode operation

This mode of operation results in an unfiltered string of comparator samples where the interval between the samples is determined by FPR[FILT_PER] and the bus clock rate. Configuration for this mode is virtually identical to that for the Windowed/Filtered Mode shown in the next section. The only difference is that the value of C0[FILTER_CNT] must be 1.

NOTE

The sample input must be high for ≥ 2.5 CMP bus clock cycles to ensure no sampling event is missed.

32.7.7 Windowed/Filtered mode (#7)

This is the most complex mode of operation for the comparator block, as it uses both windowing and filtering features. It also has the highest latency of any of the modes. This can be approximated: up to 1 bus clock synchronization in the window function + [(C0[FILTER_CNT] × C0[FPR]) + 1] × bus clock for the filter function.

When any windowed mode is active, COUTA is clocked by the bus clock whenever WINDOW = 1. The last latched value is held when WINDOW = 0.

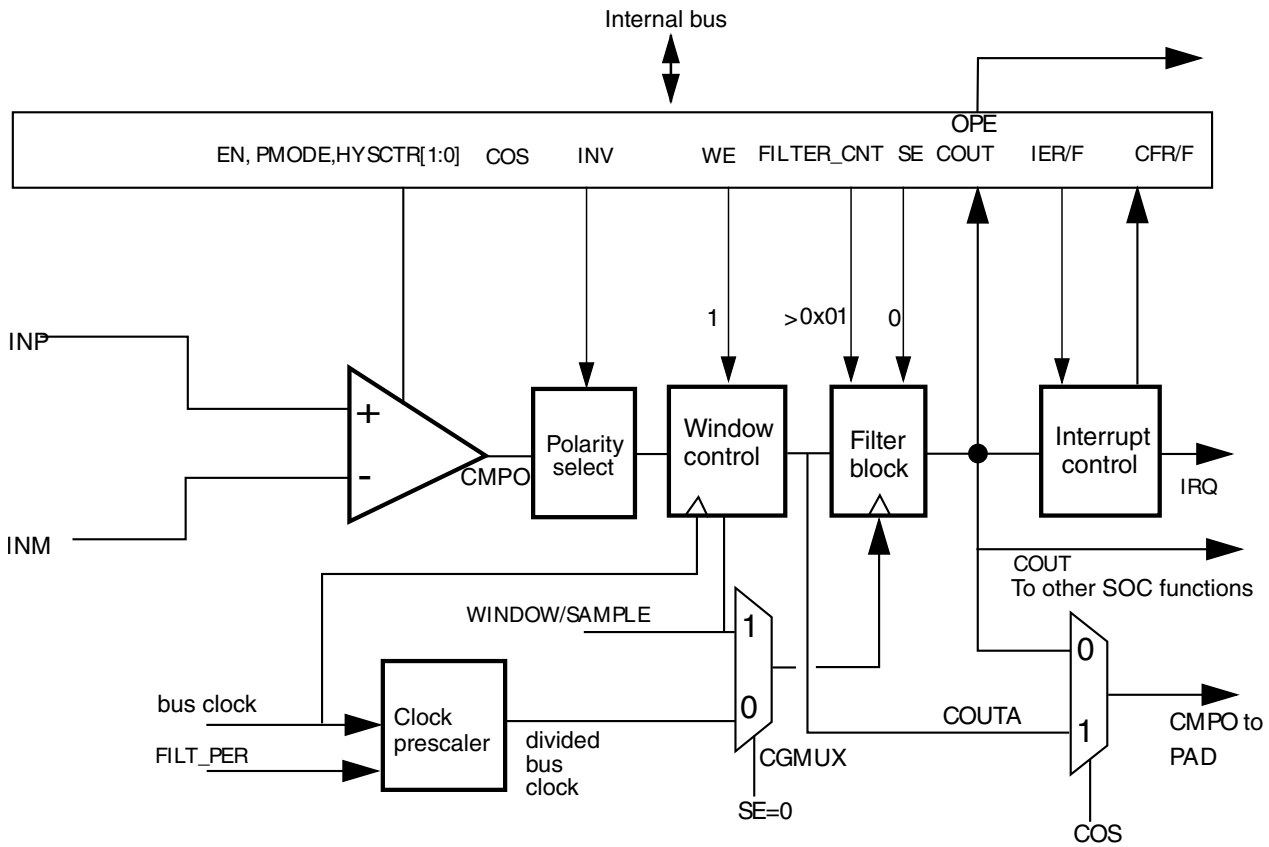


Figure 32-13. Windowed/Filtered mode

The following figure shows the operation timing for this mode, considering uncertainty is introduced by the internal synchronization for the filter block.

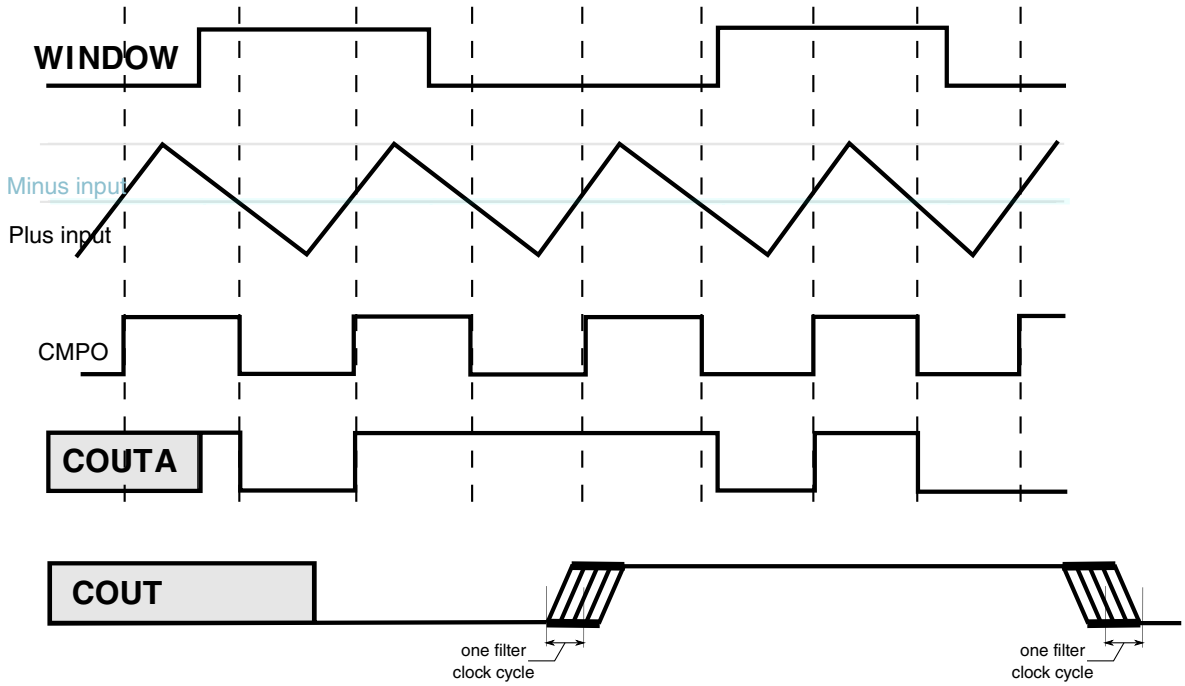


Figure 32-14. Windowed/Filtered mode operation

32.8 Memory map/register definitions

CMP memory map

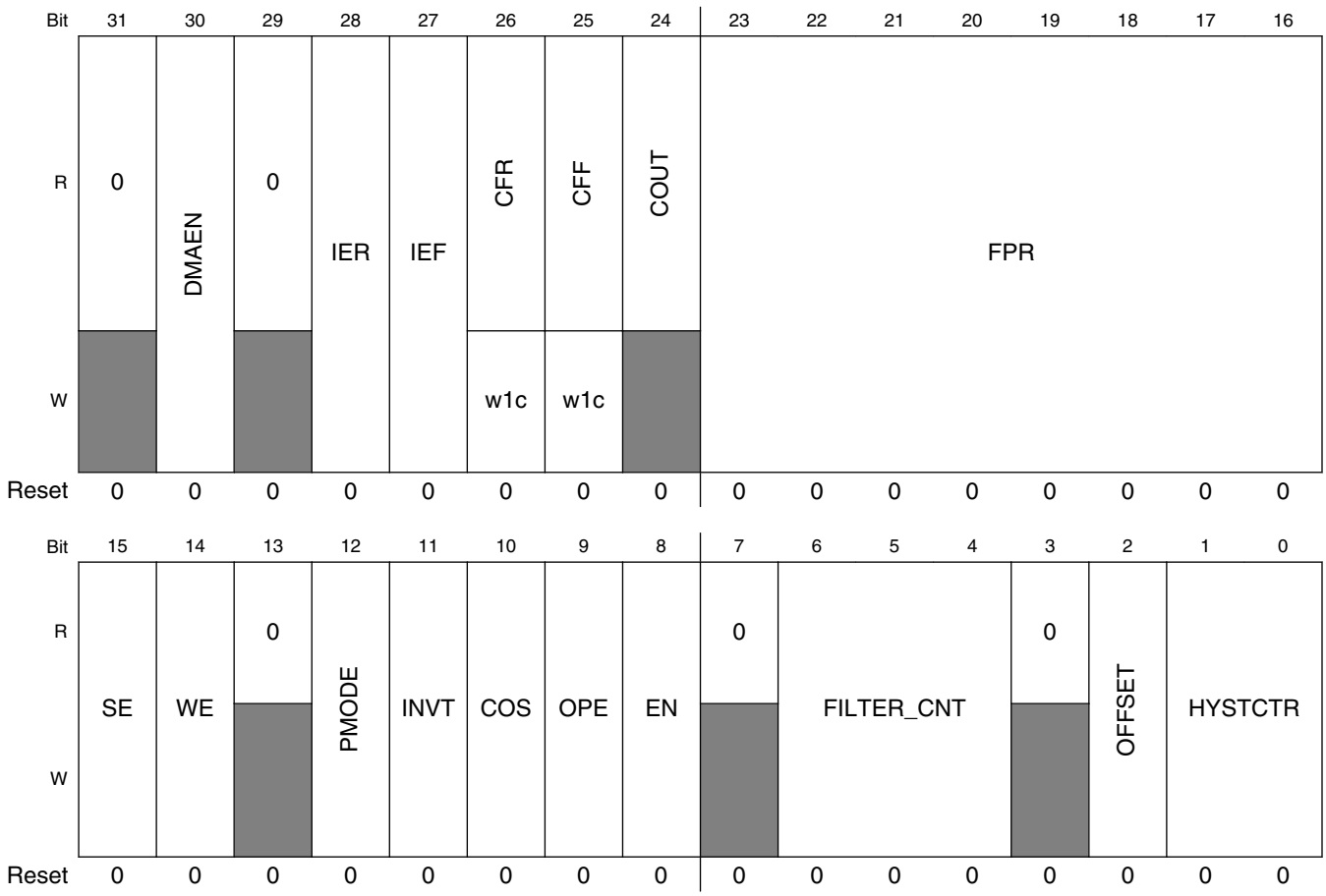
Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4007_3000	CMP Control Register 0 (CMP0_C0)	32	R/W	0000_0000h	32.8.1/554
4007_3004	CMP Control Register 1 (CMP0_C1)	32	R/W	0000_0000h	32.8.2/558
4007_3008	CMP Control Register 2 (CMP0_C2)	32	R/W	0000_0000h	32.8.3/561

32.8.1 CMP Control Register 0 (CMPx_C0)

Access:

- Supervisor read/write
- User read/write

Address: 4007_3000h base + 0h offset = 4007_3000h



CMPx_C0 field descriptions

Field	Description
31 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
30 DMAEN	DMA Enable Enables the DMA transfer triggered from the CMP module. When this field is set, a DMA request is asserted when CFR or CFF is set. 0 DMA is disabled. 1 DMA is enabled.
29 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
28 IER	Comparator Interrupt Enable Rising Enables the CFR interrupt from the CMP. When this field is set, an interrupt will be asserted when CFR is set. 0 Interrupt is disabled. 1 Interrupt is enabled.
27 IEF	Comparator Interrupt Enable Falling

Table continues on the next page...

CMPx_C0 field descriptions (continued)

Field	Description
	Enables the CFF interrupt from the CMP. When this field is set, an interrupt will be asserted when CFF is set. 0 Interrupt is disabled. 1 Interrupt is enabled.
26 CFR	Analog Comparator Flag Rising Detects a rising-edge on COUT, when set, during normal operation. CFR is cleared by writing 1 to it. During Stop modes, CFR is level sensitive 0 A rising edge has not been detected on COUT. 1 A rising edge on COUT has occurred.
25 CFF	Analog Comparator Flag Falling Detects a falling-edge on COUT, when set, during normal operation. CFF is cleared by writing 1 to it. During Stop modes, CFF is level sensitive . 0 A falling edge has not been detected on COUT. 1 A falling edge on COUT has occurred.
24 COUT	Analog Comparator Output Returns the current value of the Analog Comparator output, when read. The field is reset to 0 and will read as C0[INVT] when the Analog Comparator module is disabled, that is, when C0[EN] = 0. Writes to this field are ignored.
23–16 FPR	Filter Sample Period Specifies the sampling period, in bus clock cycles, of the comparator output filter, when C0[SE] = 0. Setting FPR to 0x0 disables the filter. Filter programming and latency details are provided in the CMP functional description. This field has no effect when C0[SE]= 1. In that case, the external SAMPLE signal is used to determine the sampling period.
15 SE	Sample Enable At any given time, either SE or WE can be set. If a write to this register attempts to set both, then SE is set and WE is cleared. However, avoid writing ones to both bit locations because this "11" case is reserved. 0 Sampling mode is not selected. 1 Sampling mode is selected.
14 WE	Windowing Enable At any given time, either SE or WE can be set. If a write to this register attempts to set both, then SE is set and WE is cleared. However, avoid writing ones to both bit locations because this "11" case is reserved. 0 Windowing mode is not selected. 1 Windowing mode is selected.
13 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
12 PMODE	Power Mode Select 0 Low Speed (LS) comparison mode is selected. 1 High Speed (HS) comparison mode is selected, in VLPx mode, or Stop mode switched to Low Speed (LS) mode.

Table continues on the next page...

CMPx_C0 field descriptions (continued)

Field	Description
11 INVT	Comparator invert This bit allows selecting the polarity of the analog comparator function. It is also driven to the COUT output (on both the device pin and as C0[COUT]) when C0[OPE]=0. 0 Does not invert the comparator output. 1 Inverts the comparator output.
10 COS	Comparator Output Select 0 Set CMPO to equal COUT (filtered comparator output). 1 Set CMPO to equal COUTA (unfiltered comparator output).
9 OPE	Comparator Output Pin Enable The OPE bit enables the path from the comparator output to a selected pin. 0 When OPE is 0, the comparator output (after window/filter settings dependent on software configuration) is not available to a packaged pin. 1 When OPE is 1, and if the software has configured the comparator to own a packaged pin, the comparator is available in a packaged pin.
8 EN	Comparator Module Enable The EN bit enables the Analog Comparator Module. When the module is not enabled, the analog part remains in the off state, and consumes no power. 0 Analog Comparator is disabled. 1 Analog Comparator is enabled.
7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
6–4 FILTER_CNT	Filter Sample Count This field specifies the number of consecutive samples that must agree prior to the comparator output filter accepting a new output state. For information regarding filter programming and latency, please see the Functional Description. 000 Filter is disabled. If SE = 1, then COUT is a logic zero (this is not a legal state, and is not recommended). If SE = 0, COUT = COUTA. 001 1 consecutive sample must agree (comparator output is simply sampled). 010 2 consecutive samples must agree. 011 3 consecutive samples must agree. 100 4 consecutive samples must agree. 101 5 consecutive samples must agree. 110 6 consecutive samples must agree. 111 7 consecutive samples must agree.
3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 OFFSET	Comparator hard block offset control. See chip data sheet to get the actual offset value with each level

Table continues on the next page...

CMPx_C0 field descriptions (continued)

Field	Description
	NOTE: • If OFFSET = 1, then there will be no hysteresis in the case of INP crossing INN in the positive direction (or INN crossing INP in the negative direction). A Half Hysteresis value still exists for INP crossing INN in the falling direction. • If OFFSET = 0, then the hysteresis selected by HYSTCTR is valid for both directions. 0 The comparator hard block output has level 0 offset internally. 1 The comparator hard block output has level 1 offset internally.
HYSTCTR	Comparator hard block hysteresis control. See chip data sheet to get the actual hysteresis value with each level 00 The hard block output has level 0 hysteresis internally. 01 The hard block output has level 1 hysteresis internally. 10 The hard block output has level 2 hysteresis internally. 11 The hard block output has level 3 hysteresis internally.

32.8.2 CMP Control Register 1 (CMPx_C1)

Access:

- Supervisor read/write
- User read/write

Address: 4007_3000h base + 4h offset = 4007_3004h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0		0	INPSEL		0	INNSEL		CHN7	CHN6	CHN5	CHN4	CHN3	CHN2	CHN1	CHN0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	DACEN	VRSEL	PSEL			MSEL			VOSEL							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CMPx_C1 field descriptions

Field	Description
31–30 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
29 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

CMPx_C1 field descriptions (continued)

Field	Description
28–27 INPSEL	Selection of the input to the positive port of the comparator Determines which input is selected for the plus input of the comparator. NOTE: These selections is used to select the final positive input to the comparator. Note: For the round robin mode of operation, the MSEL and PSEL bitfields in CMP*x*_C1 register must have different values. 00 IN0, from the 8-bit DAC output 01 IN1, from the analog 8-1 mux 10 Reserved 11 Reserved
26 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
25–24 INNSEL	Selection of the input to the negative port of the comparator Determines which input is selected for the minus input of the comparator. NOTE: These selections is used to select the final negative input to the comparator. Note: For the round robin mode of operation, the MSEL and PSEL bitfields in CMP*x*_C1 register must have different values. 00 IN0, from the 8-bit DAC output 01 IN1, from the analog 8-1 mux 10 Reserved 11 Reserved
23 CHN7	Channel 7 input enable Channel 7 of the input enable for the round-robin checker. If CHN7 is set, then the corresponding channel to the non-fixed mux port is enabled to check its voltage value in the round-robin mode. If the same channel is selected as the reference voltage, this bit has no effect.
22 CHN6	Channel 6 input enable Channel 6 of the input enable for the round-robin checker. If CHN6 is set, then the corresponding channel to the non-fixed mux port is enabled to check its voltage value in the round-robin mode. If the same channel is selected as the reference voltage, this bit has no effect.
21 CHN5	Channel 5 input enable Channel 5 of the input enable for the round-robin checker. If CHN5 is set, then the corresponding channel to the non-fixed mux port is enabled to check its voltage value in the round-robin mode. If the same channel is selected as the reference voltage, this bit has no effect.
20 CHN4	Channel 4 input enable Channel 4 of the input enable for the round-robin checker. If CHN4 is set, then the corresponding channel to the non-fixed mux port is enabled to check its voltage value in the round-robin mode. If the same channel is selected as the reference voltage, this bit has no effect.
19 CHN3	Channel 3 input enable Channel 3 of the input enable for the round-robin checker. If CHN3 is set, then the corresponding channel to the non-fixed mux port is enabled to check its voltage value in the round-robin mode. If the same channel is selected as the reference voltage, this bit has no effect.

Table continues on the next page...

CMPx_C1 field descriptions (continued)

Field	Description
18 CHN2	Channel 2 input enable Channel 2 of the input enable for the round-robin checker. If CHN2 is set, then the corresponding channel to the non-fixed mux port is enabled to check its voltage value in the round-robin mode. If the same channel is selected as the reference voltage, this bit has no effect.
17 CHN1	Channel 1 input enable Channel 1 of the input enable for the round-robin checker. If CHN1 is set, then the corresponding channel to the non-fixed mux port is enabled to check its voltage value in the round-robin mode. If the same channel is selected as the reference voltage, this bit has no effect.
16 CHN0	Channel 0 input enable Channel 0 of the input enable for the round-robin checker. If CHN0 is set, then the corresponding channel to the non-fixed mux port is enabled to check its voltage value in the round-robin mode. If the same channel is selected as the reference voltage, this bit has no effect.
15 DACEN	DAC Enable This bit is used to enable the DAC. When the DAC is disabled, it is powered down to conserve power. 0 DAC is disabled. 1 DAC is enabled.
14 VRSEL	Supply Voltage Reference Source Select 0 Vin1 is selected as resistor ladder network supply reference Vin. 1 Vin2 is selected as resistor ladder network supply reference Vin.
13–11 PSEL	Plus Input MUX Control Determines which input is selected for the plus mux. NOTE: These bits are used to select the external 8 inputs for the plus mux, the actual input to the positive port of the comparator is selected between this mux out and other inputs finally, see the definition in INPSEL. Note: For the round robin mode of operation, the MSEL and PSEL bitfields in CMPx_C1 register must have different values. 000 IN0 001 IN1 010 IN2 011 IN3 100 IN4 101 IN5 110 IN6 111 IN7
10–8 MSEL	Minus Input MUX Control Determines which input is selected for the minus mux. NOTE: These bits are used to select the external 8 inputs for the minus mux, the actual input to the negative port of the comparator is selected between this mux out and other inputs finally, see the definition in INNSEL. Note: For the round robin mode of operation, the MSEL and PSEL bitfields in CMPx_C1 register must have different values.

Table continues on the next page...

CMPx_C1 field descriptions (continued)

Field	Description
	000 IN0 001 IN1 010 IN2 011 IN3 100 IN4 101 IN5 110 IN6 111 IN7
VOSEL	DAC Output Voltage Select This bit selects an output voltage from one of 256 distinct levels. DACO = (Vin/256) × (VOSEL[7:0] + 1), so the DACO range is from Vin/256 to Vin.

32.8.3 CMP Control Register 2 (CMPx_C2)

Access:

- Supervisor read/write
- User read/write

Address: 4007_3000h base + 8h offset = 4007_3008h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	RRE	RRIE	FXMP	0	FXMXCH			0	CH7F	CH6F	CH5F	CH4F	CH3F	CH2F	CH1F	CH0F
W									w1c	w1c	w1c	w1c	w1c	w1c	w1c	w1c
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	NSAM		INITMOD						ACOn							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CMPx_C2 field descriptions

Field	Description
31 RRE	Round-Robin Enable This bit enables the round-robin operation. 0 Round-robin operation is disabled. 1 Round-robin operation is enabled.
30 RRIE	Round-Robin interrupt enable This bit enables the interrupt/wake-up when the comparison result changes for a given channel. 0 The round-robin interrupt is disabled. 1 The round-robin interrupt is enabled when a comparison result changes from the last sample.
29 FXMP	Fixed MUX Port This bit is used to fix the analog mux port for the round-robin mode. 0 The Plus port is fixed. Only the inputs to the Minus port are swept in each round. 1 The Minus port is fixed. Only the inputs to the Plus port are swept in each round.
28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–25 FXMXCH	Fixed channel selection This field indicates which channel in the mux port is fixed in a given round-robin mode. 000 Channel 0 is selected as the fixed reference input for the fixed mux port. 001 Channel 1 is selected as the fixed reference input for the fixed mux port. 010 Channel 2 is selected as the fixed reference input for the fixed mux port. 011 Channel 3 is selected as the fixed reference input for the fixed mux port. 100 Channel 4 is selected as the fixed reference input for the fixed mux port. 101 Channel 5 is selected as the fixed reference input for the fixed mux port. 110 Channel 6 is selected as the fixed reference input for the fixed mux port. 111 Channel 7 is selected as the fixed reference input for the fixed mux port.
24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23 CH7F	Channel 7 input changed flag. This bit is set if the channel 7 input changed from the last comparison with the fixed mux port.
22 CH6F	Channel 6 input changed flag. This bit is set if the channel 6 input changed from the last comparison with the fixed mux port.
21 CH5F	Channel 5 input changed flag. This bit is set if the channel 5 input changed from the last comparison with the fixed mux port.
20 CH4F	Channel 4 input changed flag. This bit is set if the channel 4 input changed from the last comparison with the fixed mux port.
19 CH3F	Channel 3 input changed flag. This bit is set if the channel 3 input changed from the last comparison with the fixed mux port.
18 CH2F	Channel 2 input changed flag. This bit is set if the channel 2 input changed from the last comparison with the fixed mux port.
17 CH1F	Channel 1 input changed flag. This bit is set if the channel 1 input changed from the last comparison with the fixed mux port.

Table continues on the next page...

CMPx_C2 field descriptions (continued)

Field	Description
16 CH0F	Channel 0 input changed flag. This bit is set if the channel 0 input changed from the last comparison with the fixed mux port.
15–14 NSAM	Number of sample clocks For a given channel, this field specifies how many round-robin clock cycles later the sample takes place. 00 The comparison result is sampled as soon as the active channel is scanned in one round-robin clock. 01 The sampling takes place 1 round-robin clock cycle after the next cycle of the round-robin clock. 10 The sampling takes place 2 round-robin clock cycles after the next cycle of the round-robin clock. 11 The sampling takes place 3 round-robin clock cycles after the next cycle of the round-robin clock.
13–8 INITMOD	Comparator and DAC initialization delay modulus. These values specify the round robin clock cycles used to determine the comparator and DAC initialization delays specified by the datasheet. For example the initialization delay is 80us and the round robin clock is 100kHz, then INITMOD should be set to 80us/10us = 8. 000000 The modulus is set to 64 (same with 111111). other values Initialization delay is set to INITMOD × round robin clock period
ACOn	The result of the input comparison for channel *n* . This field stores the latest comparison result of the input channel *n* with the fixed mux port. Reading this bit returns the latest comparison result. Writing this field defines the pre-set state of channel *n*.

32.9 CMP functional description

The CMP module can be used to compare two analog input voltages applied to INP and INM. CMPO is high when the non-inverting input is greater than the inverting input, and is low when the non-inverting input is less than the inverting input. This signal can be selectively inverted by setting C0[INVT] = 1.

C0[IER] and C0[IEF] are used to select the condition that causes the CMP module to assert an interrupt to the processor. C0[CFF] is set on a falling edge, and C0[CFR] is set on a rising edge of the comparator output. The optionally filtered CMPO can be read directly through C0[COUT].

32.9.1 Initialization

A typical startup sequence is as follows.

The time required to stabilize COUT is the power-on delay of the comparators plus the largest propagation delay from a selected analog source through the analog comparator, windowing function, and filter. See the datasheet for power-on delays of the comparators. The windowing function has a maximum of one bus clock period delay. The filter delay is specified in the Low-pass filter section.

During operation, the propagation delay of the selected data paths must always be considered. It may take many bus clock cycles for COUT and C0[CFR]/C0[CFF] to reflect an input change or a configuration change to one of the components involved in the data path.

When programmed for filtering modes, COUT initially equals 0 until sufficient clock cycles have elapsed to fill all stages of the filter. This occurs even if COUTA is at a logic 1.

32.9.2 Low-pass filter

The low-pass filter operates on the unfiltered and unsynchronized and optionally inverted comparator output COUTA and generates the filtered and synchronized output COUT. Both COUTA and COUT can be configured as module outputs and are used for different purposes within the system.

Synchronization and edge detection are always used to determine status register bit values. They also apply to COUT for all sampling and windowed modes. Filtering can be performed using an internal timebase defined by FPR[FILT_PER], or using an external SAMPLE input to determine sample time.

The need for digital filtering and the amount of filtering is dependent on user requirements. Filtering can become more useful in the absence of an external hysteresis circuit. Without external hysteresis, high-frequency oscillations can be generated at COUTA when the selected INM and INP input voltages differ by less than the offset voltage of the differential comparator.

32.9.2.1 Enabling filter modes

Filter modes can be enabled by:

- Setting C0[FILTER_CNT] > 0x01 and
- Setting C0[FPR] to a nonzero value or setting C0[SE]=1

If using the divided bus clock to drive the filter, it samples COUTA every C0[FPR] bus clock cycles.

The filter output is at logic 0 when first initalized, and subsequently changes when all the consecutive C0[FILTER_CNT] samples agree that the output value has changed. In other words, C0[COUT] is 0 for some initial period, even when COUTA is at logic 1.

Setting all of C0[SE], C0[FPR] and C0[FILTER_CNT] to 0 disables the filter and eliminates switching current associated with the filtering process.

Note

Always switch to this setting prior to making any changes in filter parameters. This resets the filter to a known state. Switching C0[FILTER_CNT] on the fly without this intermediate step can result in unexpected behavior.

If C0[SE]=1, the filter samples COUTA on each positive transition of the sample input. The output state of the filter changes when all the consecutive C0[FILTER_CNT] samples agree that the output value has changed.

32.9.2.2 Latency issues

The value of C0[FPR] or SAMPLE period must be set such that the sampling period is just longer than the period of the expected noise. This way a noise spike will corrupt only one sample. The value of C0[FILTER_CNT] must be chosen to reduce the probability of noisy samples causing an incorrect transition to be recognized. The probability of an incorrect transition is defined as the probability of an incorrect sample raised to the power of C0[FILTER_CNT].

The values of C0[FPR] or SAMPLE period and C0[FILTER_CNT] must also be traded off against the desire for minimal latency in recognizing actual comparator output transitions. The probability of detecting an actual output change within the nominal latency is the probability of a correct sample raised to the power of C0[FILTER_CNT].

The following table summarizes maximum latency values for the various modes of operation *in the absence of noise*. Filtering latency is restarted each time an actual output transition is masked by noise.

Table 32-4. Comparator sample/filter maximum latencies

Mode #	C0[EN]	C0[WE]	C0[SE]	C0[FILTER_CNT]	Co[FPR]	Operation	Maximum latency[1]
1	0	X	X	X	X	Disabled	N/A
2A	1	0	0	0x00	X	Continuous Mode	T_{PD}
2B	1	0	0	X	0x00		
3A	1	0	1	0x01	X	Sampled, Non-Filtered mode	$T_{PD} + T_{SAMPLE} + T_{per}$

Table continues on the next page...

Table 32-4. Comparator sample/filter maximum latencies (continued)

Mode #	C0[EN]	C0[WE]	C0[SE]	C0[FILTER_CNT]	Co[FPR]	Operation	Maximum latency[1]
3B	1	0	0	0x01	> 0x00		T_{PD} + (C0[FPR] * T_{per}) + T_{per}
4A	1	0	1	> 0x01	X	Sampled, Filtered mode	T_{PD} + (C0[FILTER_CNT] * T_{SAMPLE}) + T_{per}
4B	1	0	0	> 0x01	> 0x00		T_{PD} + (C0[FILTER_CNT] * C0[FPR] x T_{per}) + T_{per}
5A	1	1	0	0x00	X	Windowed mode	T_{PD} + T_{per}
5B	1	1	0	X	0x00		T_{PD} + T_{per}
6	1	1	0	0x01	0x01 - 0xFF	Windowed / Resampled mode	T_{PD} + (C0[FPR] * T_{per}) + $2T_{per}$
7	1	1	0	> 0x01	0x01 - 0xFF	Windowed / Filtered mode	T_{PD} + (C0[FILTER_CNT] * C0[FPR] x T_{per}) + $2T_{per}$

1. T_{PD} represents the intrinsic delay of the analog component plus the polarity select logic. T_{SAMPLE} is the clock period of the external sample clock. T_{per} is the period of the bus clock.

32.10 Interrupts

The CMP module is capable of generating an interrupt on either the rising- or falling-edge of the comparator output, or both. Assuming the CMP DMA enable bit is not set, the following table gives the conditions in which the interrupt request is asserted and deasserted.

Table 32-5. CMP interrupt generations

When	Then
C0[IER] and C0[CFR] are set	The interrupt request is asserted
C0[IEF] and C0[CFF] are set	The interrupt request is asserted
C0[IER] and C0[CFR] are cleared for a rising-edge interrupt	The interrupt request is deasserted
C0[IEF] and C0[CFF] are cleared for a falling-edge interrupt	The interrupt request is deasserted

32.11 DAC functional description

This section provides DAC functional description.

32.11.1 Digital-to-analog converter block diagram

The following figure shows the block diagram of the DAC module. It contains a 256-tap resistor ladder network and a 256-to-1 multiplexer, which selects an output voltage from one of 256 distinct levels that outputs from DACO. It is controlled through the Control register 1 (CMP_C1). Its supply reference source can be selected from two sources V_{in1} and V_{in2}. The module can be powered down or disabled when not in use. When in the Disabled mode, DACO is connected to the analog ground.

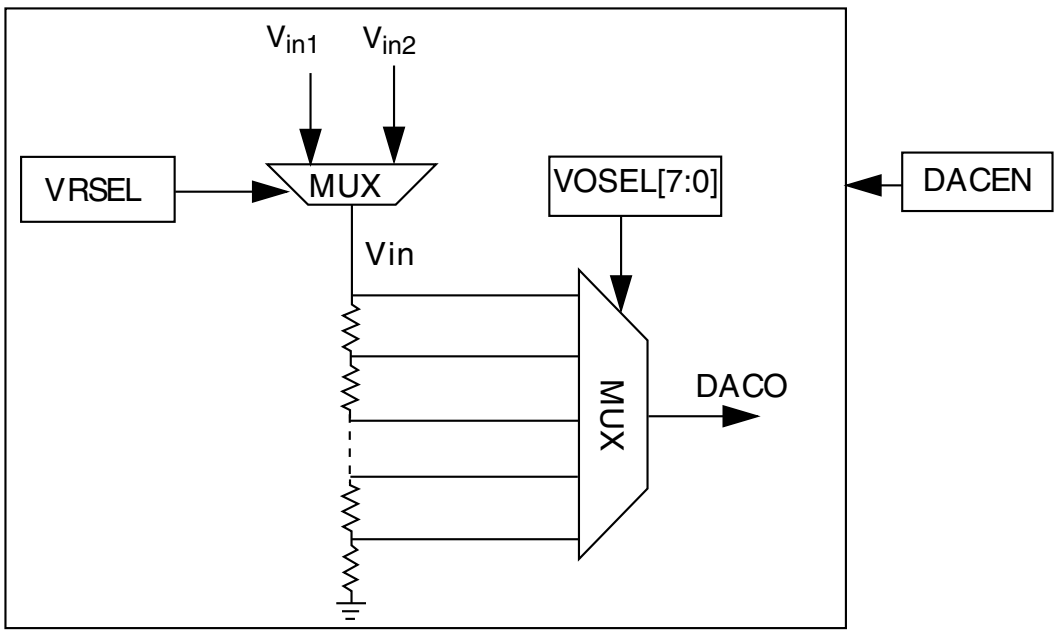


Figure 32-15. 8-bit DAC block diagram

32.11.2 DAC resets

This module has a single reset input, corresponding to the chip-wide peripheral reset.

32.11.3 DAC clocks

This module has a single clock input, the bus clock.

32.11.4 DAC interrupts

This module has no interrupts.

32.12 Trigger mode

The CMP and the 8-bit DAC are designed to support the trigger mode operation, which is enabled when the MCU enters STOP modes with C2[RRE] and C0[EN] are set.

With this mode enabled, the trigger events that include the operation clock and a trigger start signal will initiate a compare sequence that must first enable the CMP and DAC prior to performing a CMP operation and capturing the output. A fixed channel for either the plus-side mux or the minus-side mux is selected by software via C2[FXMP] and C2[FXMXCH]. It is a mandatory request that the round-robin cycling period must be set longer than the time that all the active channels complete the specified comparison cycles set by C2[NSAM].

The active channels selected by C1[CHN*n*] are then routed to the non-fixed channel mux and compared with the reference input in a round-robin manner. In order to meet the comparator stabilization time, after the configurable number of operation clocks defined by C2[NSAM], the comparison result is sampled for the selected channel. A software pre-programmed state for each channel is configured by writing to C2[ACO*n*] field. After all the active channels are sampled, if the comparison result changes from its pre-programmed state, the corresponding flag in C2[CH*n*F] is set. If C2[RRIE] is set, an asynchronous reset is asserted to bring the MCU out of STOP mode.

NOTE

These flags do not support generating a DMA transfer event.

This mode is active when the MCU is in STOP mode, so none of the window/filter functions are available. A basic assumption of this mode is that the selected inputs are changing at a much slower rate than the operation clock. It is suggested to configure the comparator in low power comparison mode as well. In programming the C2[INITMOD] registers, the INITMOD × round-robin clock period must be longer than the initialization delay, which can be referred from the chip datasheet.

The following diagram shows the basic flow of this mode. In the diagram, C1[CHN1], C1[CHN3], and C1[CHN7] are set, so channels #1, #3, and #7 are selected for round-robin. C2[NSAM] is set to 2'b01, so one clock later the comparison result of the selected channel is sampled. When channel #7 is compared, the result is sampled, and round-robin ends. If any of the comparison results from channel #1, #3, or #7 changed from their programmed value (written to C2[ACO1], C2[ACO3], and C2[ACO7]), an interrupt is generated to wake up the MCU from the STOP mode. Software can then poll the C2[CH*n*F] to see which channel input(s) changed value during the STOP mode.

NOTE

In round-robin mode, it should be ensured that the RTC_CLK period is greater than the comparison time corresponding to the value of C0[PMODE]. It is also required to **not** select the internal reserved channels for round-robin by INPSEL and INNSEL.

NOTE

In round-robin mode, it is suggested to always configure the DAC output as the fixed port reference.

NOTE

In round-robin mode, current injection or over-voltage is not supported on the input channels.

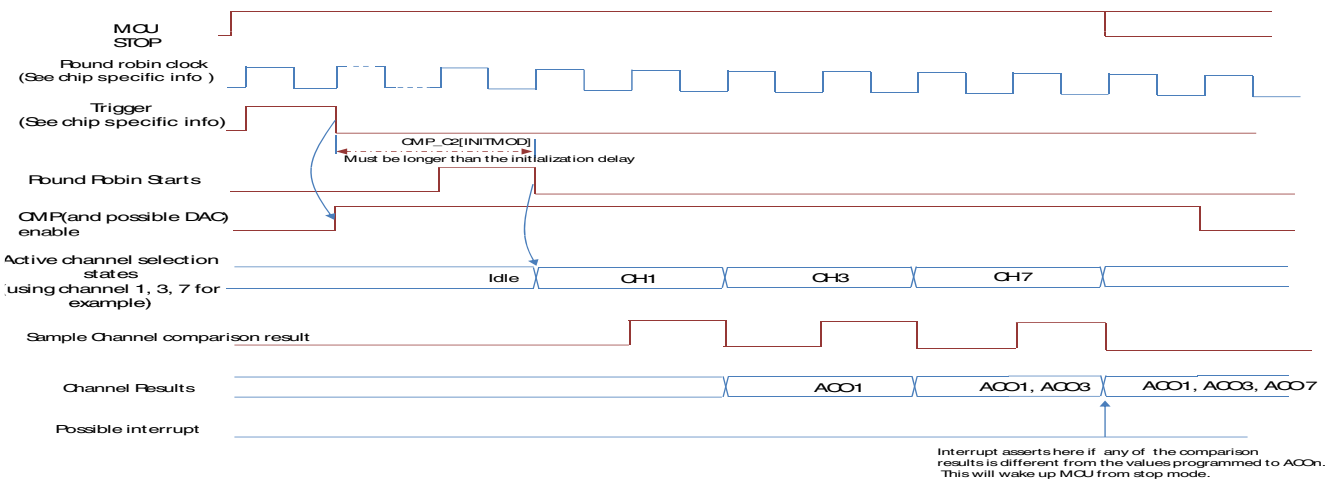


Figure 32-16. Trigger mode

The following table shows the channel decoding in both functional mode and trigger mode. Other cases not listed in the table are illegal.

Table 32-6. CMP channel decoding in functional mode and trigger mode

Mode	RRE	PSEL[2:0]	MSEL[2:0]	INPSEL[1:0]	INNSEL[1:0]	FXMP	FXMXCH[2:0]	CHNx	INP	INN	CMP Behavior
Functional Mode	0	x[1]	0~7	0	1	x	x	x	DAC	Channel decoded from MSEL[2:0]	Channel 0~7 can be compared with DAC

Table continues on the next page...

Table 32-6. CMP channel decoding in functional mode and trigger mode (continued)

Mode	RRE	PSEL[2:0]	MSEL[2:0]	INPSEL[1:0]	INNSEL[1:0]	FXMP	FXMXCH[2:0]	CHN*x*	INP	INN	CMP Behavior
		0~7	x	1	0	x	x	x	Channel decoded from PSEL[2:0]	DAC	Channel 0~7 can be compared with DAC
		0~7	0~7	1	1	x	x	x	Channel decoded from PSEL[2:0]	Channel decoded from MSEL[2:0]	Channel 0~7 can be compared with channel 0~7[2]
Trigger Mode	1	x	x	0	1	0	x	0~7	DAC	Channel sweep (CHN*x*)	Channel 0~7 can be swept with DAC
		x	x	1	0	1	x	0~7	Channel sweep (CHN*x*)	DAC	Channel 0~7 can be swept with DAC
		x	x	1	1	0	0~7	0~7	Channel fixed by FXMXCH[2:0]	Channel sweep (CHN*x*)	Channel 0~7 can be swept with a fixed channel (0~7)[3]
		x	x	1	1	1	0~7	0~7	Channel sweep (CHN*x*)	Channel fixed by FXMXCH[2:0]	Channel 0~7 can be swept with a fixed channel (0~7)[3]

1. "x" means "do not care".
2. PSEL should not be set the same as MSEL.
3. Channel in the sweep side should not be the same as the fixed side.

32.13 Usage Guide

32.13.1 Zero Crossing Detection

A zero-crossing is a point where the sign of a signal's mathematical function changes (e.g. from positive to negative), represented by a crossing of the axis (zero value) in the graph of the signal function. It is a commonly used in electronics application especially for systems which send digital data over AC circuits.

When in some cases, the “Zero point” could be other voltage than actual 0 V. This “Zero point” would be used to judge whether the indicated voltage level is reached. In this situation, the internal DAC could generate the reference voltage level for “Zero point” to make the comparison with the other input channel of CMP module, and then output the result of logic “0” and “1”.

To enable the internal DAC and set it as the comparator’s input of minus side, the code could be as follow:

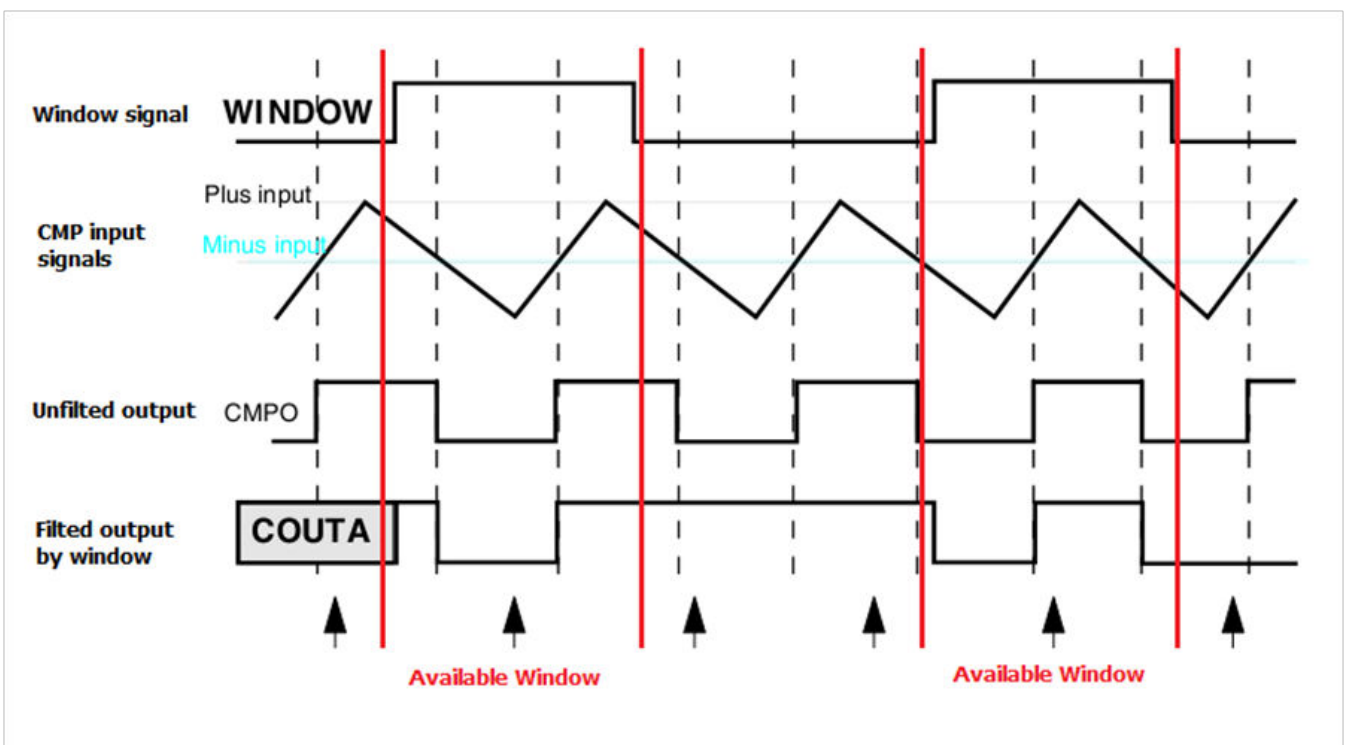
```
/* Set internal DAC as minus input. */
CMPx_C1 &= ~CMP_C1_ INNSEL_MASK;

/* Set input channel 3 as plus input. */
CMPx_C1 = (CMPx_C1 & ~(CMP_C1_ INPSEL_MASK | CMP_C1_PSEL_MASK))
          | CMP_C1_INPSEL(1) | CMP_C1_PSEL(3);
```

Then, the CMP output interrupts with their flags would be used to indicate the event of Zero Crossing Detection.

32.13.2 Window Mode

This mode could be used to create a kind of filter for input signal. When enabling the window mode, the compare would only launch the comparison in available window, which could be generated by some timer modules (e.g. PDB or LPIT). And output of CMP in unavailable window would be hold.



To enable the window mode for CMP, the code could be as follows:

```
/* Enable the window mode and disable the sample mode. */
CMPx_C0 = (CMPx_C0 & ~ CMP_C0_SE_MASK ) | CMP_C0_WE_MASK;
```

Then enable the window's generator (to produce the WINDOW signal) of related module.

For detailed information about CMP's window feature, please see to section "Windowed mode" in this chapter.

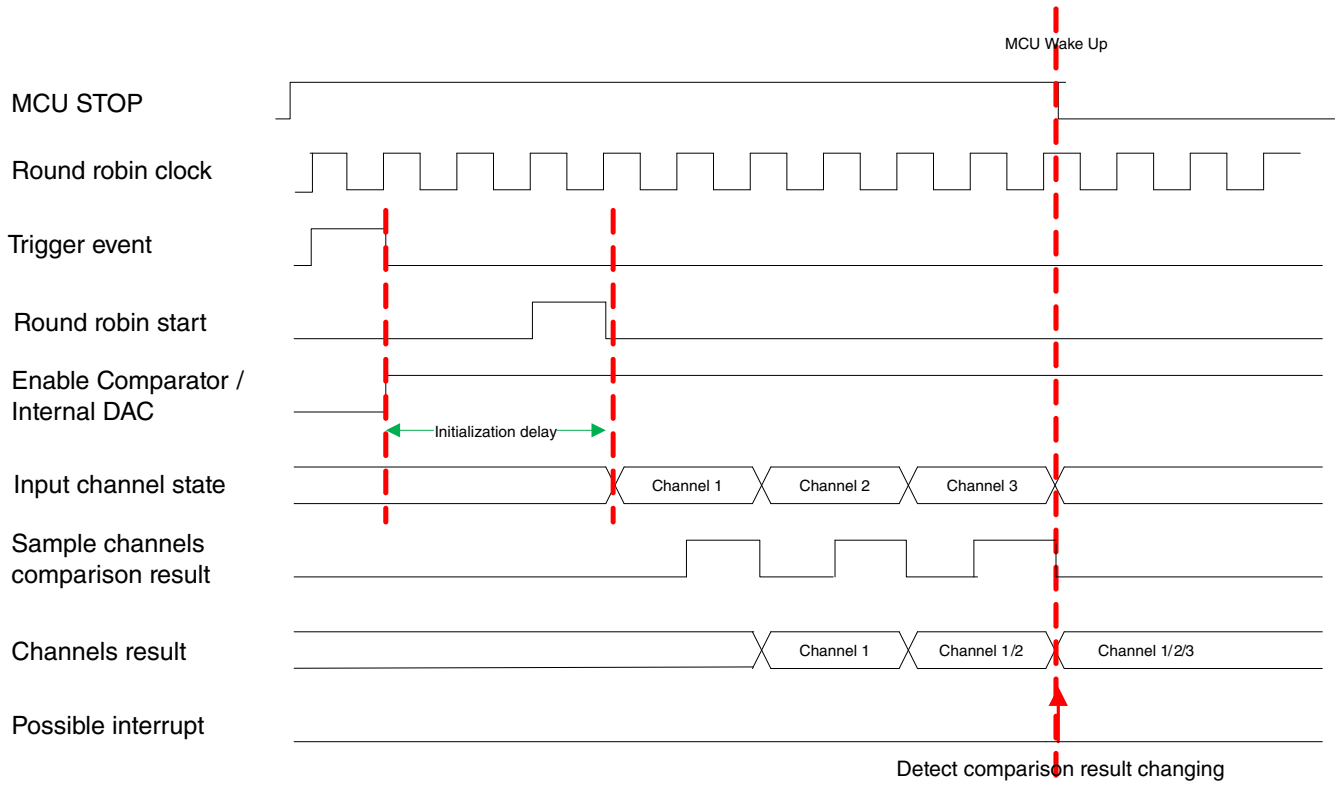
32.13.3 Round Robin Mode

This mode compares multiple input channels with the reference input channel (fixed) in a round-robin manner. It is commonly used to provide a trigger mode to wake up the MCU in STOP mode.

This mode needs some trigger events to work. The trigger events include the operation clock and a trigger start signal which can be provided by other module (e.g. LPTMR).

Round robin mode works as follows:

1. The trigger start signal will enable the comparator and internal DAC in the initialization delay period;
2. The comparator will then compare the multiple input channels with the reference input channel in turn under the operation clock until all input channels complete comparison;
3. If current comparison result is different with the pre-set state or the previous comparison result and round robin interrupt is enabled, an interrupt will generate to bring the MCU out of STOP mode.



The code snippet to enable the round robin mode is:

```
/* Set the positive port input from DAC and negative port input from minus mux input */
/* Plus mux input must be different from minus mux input even though they aren't functional
in round robin mode. */
CMPx_C1 = ((CMPx_C1 & (~(CMP_C1_INPSEL_MASK | CMP_C1_INNSEL_MASK | CMP_C1_PSEL_MASK |
CMP_C1_MSEL_MASK)))
          | (CMP_C1_INPSEL(0) | CMP_C1_INNSEL(1) | CMP_C1_PSEL(0) | CMP_C1_MSEL(1)));

/* Set following round robin attribute:
positive port as fixed port.
All channel0~7 as the round robin checker channel in non-fixed port.
The comparison result is sampled as soon as the active channel is scanned in one round-robin
clock.
The initialization delay modulus is set to 64.
Enable round robin mode.
Enable round robin interrupt.
*/
CMPx_C1 = ((CMPx_C1 & (~(CMP_C1_CHN0_MASK | CMP_C1_CHN1_MASK | CMP_C1_CHN2_MASK |
CMP_C1_CHN3_MASK |
           CMP_C1_CHN4_MASK | CMP_C1_CHN5_MASK | CMP_C1_CHN6_MASK | CMP_C1_CHN7_MASK)))
           |(0xFF << CMP_C1_CHN0_SHIFT));

CMPx_C2 = ((CMPx_C2 & (~(CMP_C2_FXMP_MASK | CMP_C2_FXMXCH_MASK | CMP_C2_NSAM_MASK
          | CMP_C2_INITMOD_MASK | CMP_C2_CHnF_MASK))) | (CMP_C2_FXMP(0)
          | CMP_C2_FXMXCH(0) | CMP_C2_NSAM(0)
          | CMP_C2_INITMOD(0) | CMP_C2_RRE_MASK | CMP_C2_RRIE_MASK));

/* Set all the pre-state of round robin checker channel0~7 to 1. */
CMPx ->C2 = ((CMPx ->C2 & (~CMP_C2_ACOn_MASK | CMP_C2_CHnF_MASK)) | (0xFF <<
CMP_C2_ACOn_SHIFT));

/* Set round robin comparison trigger. See the chip configuration about the available
trigger in the SoC. */
```

```
/* Set SoC enter into STOP mode. See the power management chapter. */

/* Change the voltage of input channel to wake up the SoC. */
```

Chapter 33
Programmable Delay Block (PDB)

33.1 Chip-specific information for this module

33.1.1 Instantiation Information

33.1.1.1 PDB Configuration

There are 1 PDB modules on this device.

Number of ADC channel	1
Number of pre-triggers per ADC channel	4
Number of Pulse Out	1

NOTE

DMA is not supported in this device.

33.1.1.2 PDB Input Trigger Connections

On this device, the PDB trigger source selection is implemented through the TRGMUX module. For each PDB unit, there is only one trigger input from TRGMUX, but it supports different trigger sources. The internal trigger mux inside PDB is not used any more.

PDB Trigger	PDB Input
0000	TRGMUX_PDB0_EXTRG

33.1.2 Back-to-back acknowledgement connections

Back-to-back operation enables the ADC conversions complete to trigger the next PDB channel pre-trigger and trigger output.

The PDB back-to-back operation acknowledgement connections are implemented inside each PDB unit as a ring. The following list is an example for PDB0.

- PDB0 channel 0 pre-trigger 0 acknowledgement input: ADC0SC1D_COCO
- PDB0 channel 0 pre-trigger 1 acknowledgement input: ADC0SC1A_COCO
- PDB0 channel 0 pre-trigger 2 acknowledgement input: ADC0SC1B_COCO
- PDB0 channel 0 pre-trigger 3 acknowledgement input: ADC0SC1C_COCO

The back-to-back chain diagram is as follows:

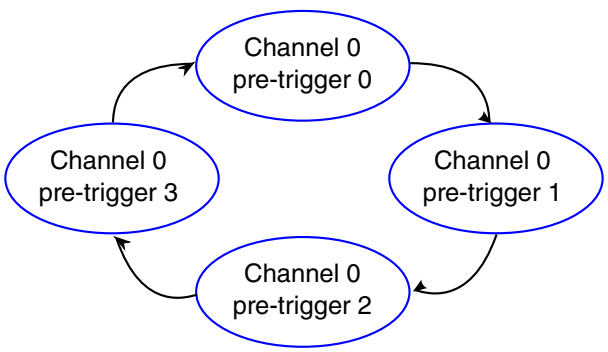


Figure 33-1. PDB0 back-to-back chain

33.2 Introduction

The Programmable Delay Block (PDB) provides controllable delays from either an internal or an external trigger, or a programmable interval tick, to the hardware trigger inputs of ADCs. The PDB can optionally provide pulse outputs (Pulse-Out's) that are used as the sample window in the CMP block.

33.2.1 Features

- Up to 15 trigger input sources and one software trigger source
- Up to 8 configurable PDB channels for ADC hardware trigger
  - One PDB channel is associated with one ADC
  - One trigger output for ADC hardware trigger and up to 8 pre-trigger outputs for ADC trigger select per PDB channel

  - Trigger outputs can be enabled or disabled independently
  - One 16-bit delay register per pre-trigger output
  - Optional bypass of the delay registers of the pre-trigger outputs
  - Operation in One-Shot or Continuous modes
  - Optional back-to-back mode operation, which enables the ADC conversions complete to trigger the next PDB channel
  - One programmable delay interrupt
  - One sequence error interrupt
  - One channel flag and one sequence error flag per pre-trigger
  - DMA support
- Up to 8 pulse outputs (pulse-out's)
  - Pulse-out's can be enabled or disabled independently
  - Programmable pulse width

NOTE

The number of PDB input and output triggers are chip-specific. See the chip-specific PDB information for details.

33.2.2 Implementation

In this section, the following letters refer to the number of output triggers:

- N—Total available number of PDB channels.
- n—PDB channel number, valid from 0 to *N*-1.
- M—Total available pre-trigger per PDB channel.
- m—Pre-trigger number, valid from 0 to *M*-1.
- Y—Total number of Pulse-Out's.
- y—Pulse-Out number, valid value is from 0 to *Y*-1.

NOTE

The number of module output triggers to core is chip-specific. For module to core output triggers implementation, see the chip configuration information.

33.2.3 Back-to-back acknowledgment connections

PDB back-to-back operation acknowledgment connections are chip-specific. For implementation, see the chip configuration information.

33.2.4 Block diagram

This diagram illustrates the major components of the PDB.

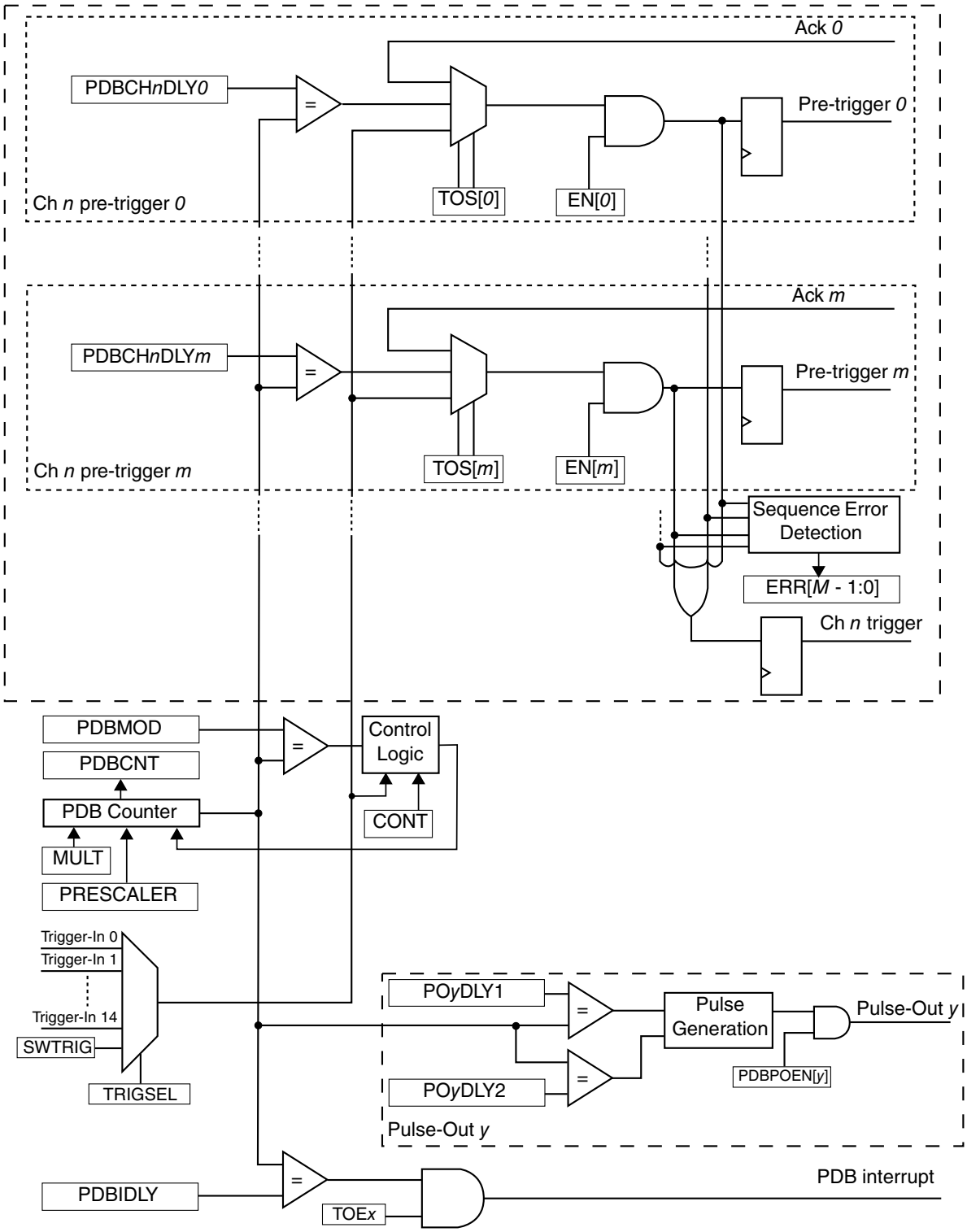


Figure 33-2. PDB block diagram

In this diagram, only one PDB channel *n*, and one Pulse-Out *y* are shown. The PDB-enabled control logic and the sequence error interrupt logic are not shown.

33.2.5 Modes of operation

PDB ADC trigger operates in the following modes:

- Disabled—Counter is off, all pre-trigger and trigger outputs are low if PDB is not in back-to-back operation of Bypass mode.
- Debug—Counter is paused when processor is in Debug mode.
- Enabled One-Shot—Counter is enabled and restarted at count zero upon receiving a positive edge on the selected trigger input source or software trigger is selected and SC[SWTRIG] is written with 1. In each PDB channel, an enabled pre-trigger asserts once per trigger input event. The trigger output asserts whenever any of the pre-triggers is asserted.
- Enabled Continuous—Counter is enabled and restarted at count zero. The counter is rolled over to zero again when the count reaches the value specified in the modulus register, and the counting is restarted. This enables a continuous stream of pre-triggers/trigger outputs as a result of a single trigger input event.
- Enabled Bypassed—The pre-trigger and trigger outputs assert immediately after a positive edge on the selected trigger input source or software trigger is selected and SC[SWTRIG] is written with 1, that is the delay registers are bypassed. It is possible to bypass any one or more of the delay registers; therefore, this mode can be used in conjunction with One-Shot or Continuous mode.

33.3 PDB signal descriptions

This table shows the detailed description of the external signal.

Table 33-1. PDB signal descriptions

Signal	Description	I/O
EXTRG	External Trigger Input Source If the PDB is enabled and external trigger input source is selected, a positive edge on the EXTRG signal resets and starts the counter.	I

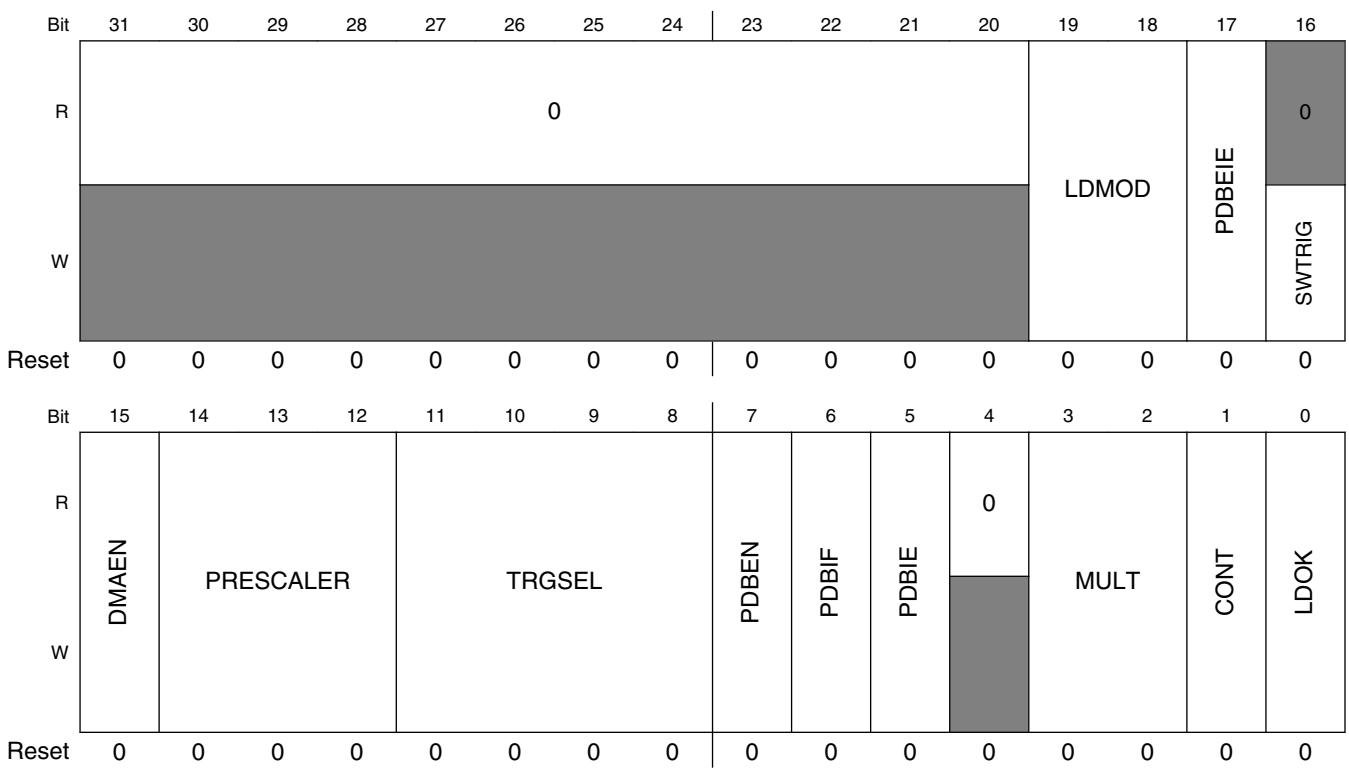
33.4 Memory map and register definition

PDB memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4003_6000	Status and Control register (PDB0_SC)	32	R/W	0000_0000h	33.4.1/581
4003_6004	Modulus register (PDB0_MOD)	32	R/W	0000_FFFFh	33.4.2/584
4003_6008	Counter register (PDB0_CNT)	32	R	0000_0000h	33.4.3/585
4003_600C	Interrupt Delay register (PDB0_IDLY)	32	R/W	0000_FFFFh	33.4.4/585
4003_6010	Channel n Control register 1 (PDB0_CH0C1)	32	R/W	0000_0000h	33.4.5/586
4003_6014	Channel n Status register (PDB0_CH0S)	32	R/W	0000_0000h	33.4.6/587
4003_6018	Channel n Delay 0 register (PDB0_CH0DLY0)	32	R/W	0000_0000h	33.4.7/587
4003_601C	Channel n Delay 1 register (PDB0_CH0DLY1)	32	R/W	0000_0000h	33.4.8/588
4003_6020	Channel n Delay 2 register (PDB0_CH0DLY2)	32	R/W	0000_0000h	33.4.9/589
4003_6024	Channel n Delay 3 register (PDB0_CH0DLY3)	32	R/W	0000_0000h	33.4.10/589
4003_6190	Pulse-Out n Enable register (PDB0_POEN)	32	R/W	0000_0000h	33.4.11/590
4003_6194	Pulse-Out n Delay register (PDB0_PO0DLY)	32	R/W	0000_0000h	33.4.12/590

33.4.1 Status and Control register (PDBx_SC)

Address: 4003_6000h base + 0h offset = 4003_6000h



PDBx_SC field descriptions

Field	Description
31–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–18 LDMOD	Load Mode Select Selects the mode to load the MOD, IDLY, CH*n*DLY*m*, INT*x*, and PO*y*DLY registers, after 1 is written to LDOK. 00 The internal registers are loaded with the values from their buffers, immediately after 1 is written to LDOK. 01 The internal registers are loaded with the values from their buffers when the PDB counter (CNT) = MOD + 1 CNT delay elapsed, after 1 is written to LDOK. 10 The internal registers are loaded with the values from their buffers when a trigger input event is detected, after 1 is written to LDOK. 11 The internal registers are loaded with the values from their buffers when either the PDB counter (CNT) = MOD + 1 CNT delay elapsed, or a trigger input event is detected, after 1 is written to LDOK.
17 PDBEIE	PDB Sequence Error Interrupt Enable Enables the PDB sequence error interrupt. When PDBEIE is set, any of the PDB channel sequence error flags generates a PDB sequence error interrupt. 0 PDB sequence error interrupt disabled. 1 PDB sequence error interrupt enabled.
16 SWTRIG	Software Trigger When PDB is enabled and the software trigger is selected as the trigger input source, writing 1 to SWTRIG resets and restarts the counter. Writing 0 to SWTRIG has no effect. Reading SWTRIG yields 0.
15 DMAEN	DMA Enable When DMA is enabled, the PDBIF flag generates a DMA request instead of an interrupt. 0 DMA disabled. 1 DMA enabled.
14–12 PRESCALER	Prescaler Divider Select Counting uses the peripheral clock divided by the product of a factor (selected by MULT field) and an integer factor (set by PRESCALAR field), or in other words, (peripheral clock)/(MULT x PRESCALAR). 000 Counting uses the peripheral clock divided by MULT (the multiplication factor). 001 Counting uses the peripheral clock divided by 2 x MULT (the multiplication factor). 010 Counting uses the peripheral clock divided by 4 x MULT (the multiplication factor). 011 Counting uses the peripheral clock divided by 8 x MULT (the multiplication factor). 100 Counting uses the peripheral clock divided by 16 x MULT (the multiplication factor). 101 Counting uses the peripheral clock divided by 32 x MULT (the multiplication factor). 110 Counting uses the peripheral clock divided by 64 x MULT (the multiplication factor). 111 Counting uses the peripheral clock divided by 128 x MULT (the multiplication factor).
11–8 TRGSEL	Trigger Input Source Select Selects the trigger input source for the PDB. The trigger input source can be internal or external (EXTRG pin), or the software trigger. Refer to chip configuration details for the actual PDB input trigger connections. 0000 Trigger-In 0 is selected.

Table continues on the next page...

PDBx_SC field descriptions (continued)

Field	Description
	0001 Trigger-In 1 is selected. 0010 Trigger-In 2 is selected. 0011 Trigger-In 3 is selected. 0100 Trigger-In 4 is selected. 0101 Trigger-In 5 is selected. 0110 Trigger-In 6 is selected. 0111 Trigger-In 7 is selected. 1000 Trigger-In 8 is selected. 1001 Trigger-In 9 is selected. 1010 Trigger-In 10 is selected. 1011 Trigger-In 11 is selected. 1100 Trigger-In 12 is selected. 1101 Trigger-In 13 is selected. 1110 Trigger-In 14 is selected. 1111 Software trigger is selected.
7 PDBEN	PDB Enable 0 PDB disabled. Counter is off. 1 PDB enabled.
6 PDBIF	PDB Interrupt Flag PDBIF is set when the counter value is equal to the IDLY register + 1. • Write zero to clear PDBIF. • Writing 1 to PDBIF has no effect.
5 PDBIE	PDB Interrupt Enable Enables the PDB interrupt. When PDBIE is set and DMAEN is cleared, PDBIF generates a PDB interrupt. 0 PDB interrupt disabled. 1 PDB interrupt enabled.
4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3–2 MULT	Multiplication Factor Select for Prescaler Selects the multiplication factor of the prescaler divider for the counter clock. 00 Multiplication factor is 1. 01 Multiplication factor is 10. 10 Multiplication factor is 20. 11 Multiplication factor is 40.
1 CONT	Continuous Mode Enable Enables the PDB operation in Continuous mode. 0 PDB operation in One-Shot mode 1 PDB operation in Continuous mode
0 LDOK	Load OK

Table continues on the next page...

PDBx_SC field descriptions (continued)

Field	Description
	Writing 1 to LDOK bit updates the MOD, IDLY, CHnDLYm, and POyDLY registers with the values previously written to their internal buffers (and stored there). The new values of MOD, IDLY, CHnDLYm, and POyDLY registers will take effect according to the setting of the LDMOD field (Load Mode Select). Before 1 is written to the LDOK field, the values in the internal buffers of these registers are not effective, and new values cannot be written to the internal buffers until the existing values in the internal buffers are loaded into their corresponding registers. • LDOK can be written only when PDBEN is set, or LDOK can be written at the same time when PDBEN is written to 1. • LDOK is automatically cleared when the values in the internal buffers are loaded into the registers or when PDBEN bit (PDB Enable) is cleared. • Writing 0 to LDOK has no effect.

33.4.2 Modulus register (PDBx_MOD)

Note: This register is internally buffered, and any values written to the register are written to its internal buffer instead; in other words, the internal device bus does not write directly to this register. The value in this register's internal buffer is loaded into this register only after "1" is written to the SC[LDOK] bit.

Address: 4003_6000h base + 4h offset = 4003_6004h

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

PDBx_MOD field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
MOD	PDB Modulus Specifies the period of the counter. When the counter reaches this value, it will be reset back to zero. If the PDB is in Continuous mode, the count begins anew. Reading this field returns the value of the internal register that is effective for the current cycle of PDB.

33.4.3 Counter register (PDBx_CNT)

NOTE

Writing to this read-only register will generate a transfer error (and possibly a hard fault).

Address: 4003_6000h base + 8h offset = 4003_6008h

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

PDBx_CNT field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
CNT	PDB Counter Contains the current value of the counter.

33.4.4 Interrupt Delay register (PDBx_IDLY)

Note: This register is internally buffered, and any values written to the register are written to its internal buffer instead; in other words, the internal device bus does not write directly to this register. The value in this register's internal buffer is loaded into this register only after "1" is written to the SC[LDOK] bit.

Address: 4003_6000h base + Ch offset = 4003_600Ch

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

PDBx_IDLY field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
IDLY	PDB Interrupt Delay

Table continues on the next page...

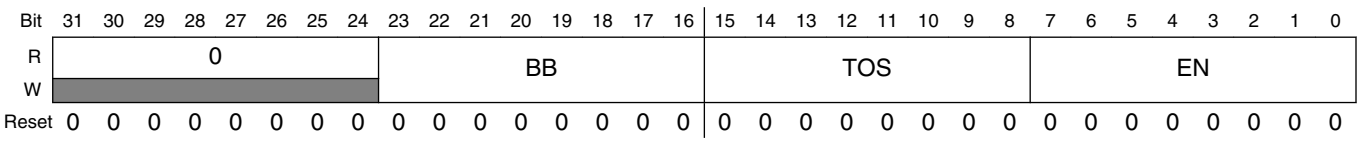
PDBx_IDLY field descriptions (continued)

Field	Description
	Specifies the delay value to schedule the PDB interrupt. It can be used to schedule an independent interrupt at some point in the PDB cycle. If enabled, a PDB interrupt is generated, when the counter is equal to the IDLY. Reading this field returns the value of internal register that is effective for the current cycle of the PDB.

33.4.5 Channel n Control register 1 (PDBx_CH*n*C1)

Each PDB channel has one control register, CHnC1. The fields in this register control the functionality of each PDB channel operation.

Address: 4003_6000h base + 10h offset + (40d × i), where i=0d to 0d

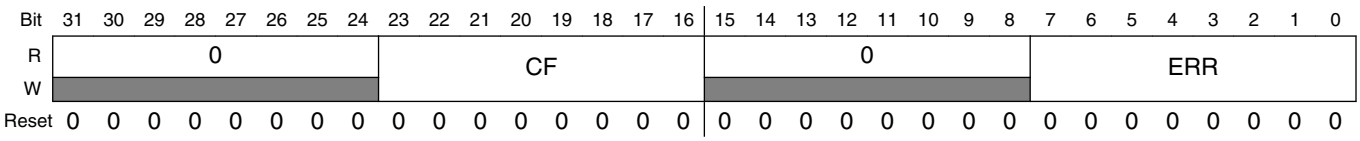


PDBx_CH*n*C1 field descriptions

Field	Description
31–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23–16 BB	PDB Channel Pre-Trigger Back-to-Back Operation Enable Enables the PDB ADC pre-trigger operation as back-to-back mode. Only lower M pre-trigger bits are implemented in this MCU. Back-to-back operation enables the ADC conversions complete to trigger the next PDB channel pre-trigger and trigger output, so that the ADC conversions can be triggered on the next set of configuration and results registers. Application code must enable only the back-to-back operation of the PDB pre-triggers at the leading of the back-to-back connection chain. 0 PDB channel's corresponding pre-trigger back-to-back operation disabled. 1 PDB channel's corresponding pre-trigger back-to-back operation enabled.
15–8 TOS	PDB Channel Pre-Trigger Output Select These bits select the PDB ADC pre-trigger outputs. Only lower M pre-trigger bits are implemented in this MCU. 0 PDB channel's corresponding pre-trigger is in bypassed mode. The pre-trigger asserts one peripheral clock cycle after a rising edge is detected on selected trigger input source or software trigger is selected and SWTRIG is written with 1. 1 PDB channel's corresponding pre-trigger asserts when the counter reaches the channel delay register plus one peripheral clock cycle after a rising edge is detected on selected trigger input source or software trigger is selected and SWTRIG is written with 1.
EN	PDB Channel Pre-Trigger Enable Enables the PDB ADC pre-trigger outputs. Only lower M pre-trigger fields are implemented in this MCU. 0 PDB channel's corresponding pre-trigger disabled. 1 PDB channel's corresponding pre-trigger enabled.

33.4.6 Channel n Status register (PDBx_CHnS)

Address: 4003_6000h base + 14h offset + (40d × i), where i=0d to 0d



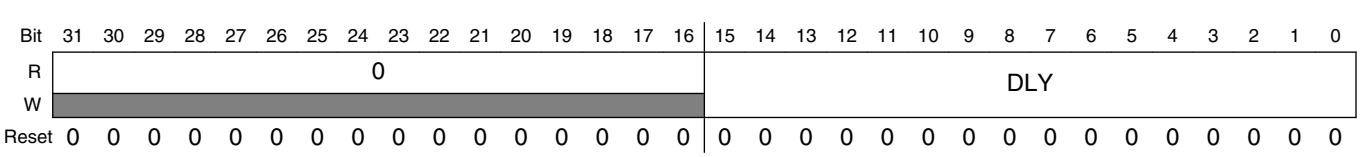
PDBx_CHnS field descriptions

Field	Description
31–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23–16 CF	PDB Channel Flags The CF[*m*] field is set when the PDB counter (PDB_CNT) matches the value CHnDLY*m* + 1. Write 0 to clear CF.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
ERR	PDB Channel Sequence Error Flags Only the lower M bits are implemented in this MCU. 0 Sequence error not detected on PDB channel's corresponding pre-trigger. 1 Sequence error detected on PDB channel's corresponding pre-trigger. ADCn block can be triggered for a conversion by one pre-trigger from PDB channel *n*. When one conversion, which is triggered by one of the pre-triggers from PDB channel *n*, is in progress, new trigger from PDB channel's corresponding pre-trigger m cannot be accepted by ADCn, and ERR[m] is set. Writing 0's to clear the sequence error flags.

33.4.7 Channel n Delay 0 register (PDBx_CHnDLY0)

Note: This register is internally buffered, and any values written to the register are written to its internal buffer instead; in other words, the internal device bus does not write directly to this register. The value in this register's internal buffer is loaded into this register only after "1" is written to the SC[LDOK] bit.

Address: 4003_6000h base + 18h offset + (40d × i), where i=0d to 0d



PDBx_CHnDLY0 field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DLY	PDB Channel Delay Specifies the delay value for the channel's corresponding pre-trigger. The pre-trigger asserts when the counter is equal to DLY. Reading this field returns the value of internal register that is effective for the current PDB cycle.

33.4.8 Channel n Delay 1 register (PDBx_CHnDLY1)

Note: This register is internally buffered, and any values written to the register are written to its internal buffer instead; in other words, the internal device bus does not write directly to this register. The value in this register's internal buffer is loaded into this register only after "1" is written to the SC[LDOK] bit.

Address: 4003_6000h base + 1Ch offset + (40d × i), where i=0d to 0d

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

PDBx_CHnDLY1 field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DLY	PDB Channel Delay These bits specify the delay value for the channel's corresponding pre-trigger. The pre-trigger asserts when the counter is equal to DLY. Reading these bits returns the value of internal register that is effective for the current PDB cycle.

33.4.9 Channel n Delay 2 register (PDB*x*_CH*n*DLY2)

Note: This register is internally buffered, and any values written to the register are written to its internal buffer instead; in other words, the internal device bus does not write directly to this register. The value in this register's internal buffer is loaded into this register only after "1" is written to the SC[LDOK] bit.

Address: 4003_6000h base + 20h offset + (40d × i), where i=0d to 0d

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

PDB*x*_CH*n*DLY2 field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DLY	PDB Channel Delay These bits specify the delay value for the channel's corresponding pre-trigger. The pre-trigger asserts when the counter is equal to DLY. Reading these bits returns the value of internal register that is effective for the current PDB cycle.

33.4.10 Channel n Delay 3 register (PDB*x*_CH*n*DLY3)

Note: This register is internally buffered, and any values written to the register are written to its internal buffer instead; in other words, the internal device bus does not write directly to this register. The value in this register's internal buffer is loaded into this register only after "1" is written to the SC[LDOK] bit.

Address: 4003_6000h base + 24h offset + (40d × i), where i=0d to 0d

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

PDBx_CHnDLY3 field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DLY	PDB Channel Delay These bits specify the delay value for the channel's corresponding pre-trigger. The pre-trigger asserts when the counter is equal to DLY. Reading these bits returns the value of internal register that is effective for the current PDB cycle.

33.4.11 Pulse-Out n Enable register (PDBx_POEN)

Address: 4003_6000h base + 190h offset = 4003_6190h

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

PDBx_POEN field descriptions

Field	Description
31–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
POEN	PDB Pulse-Out Enable Enables the pulse output. Only lower 8 bits are implemented in this MCU. 0 PDB Pulse-Out disabled 1 PDB Pulse-Out enabled

33.4.12 Pulse-Out n Delay register (PDBx_POnDLY)

Note: This register is internally buffered, and any values written to the register are written to its internal buffer instead; in other words, the internal device bus does not write directly to this register. The value in this register's internal buffer is loaded into this register only after "1" is written to the SC[LDOK] bit.

Address: 4003_6000h base + 194h offset + (4d × i), where i=0d to 0d

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	DLY1																DLY2															
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

PDBx_PO*n*DLY field descriptions

Field	Description
31–16 DLY1	PDB Pulse-Out Delay 1 These bits specify the delay 1 value for the PDB Pulse-Out. Pulse-Out goes high when the PDB counter is equal to the DLY1. Reading these bits returns the value of internal register that is effective for the current PDB cycle.
DLY2	PDB Pulse-Out Delay 2 These bits specify the delay 2 value for the PDB Pulse-Out. Pulse-Out goes low when the PDB counter is equal to the DLY2. Reading these bits returns the value of internal register that is effective for the current PDB cycle.

33.5 Functional description

33.5.1 PDB pre-trigger and trigger outputs

The PDB contains a counter whose output is compared to several different digital values. If the PDB is enabled, then a trigger input event will reset the counter and make it start to count. A trigger input event is defined as a rising edge being detected on a selected trigger input source, or if a software trigger is selected and the Software Trigger bit (SC[SWTRIG]) is written with 1. For each channel, a delay *m* determines the time between assertion of the trigger input event to the time at which changes in the pre-trigger *m* output signal are started. The time is defined as:

- Trigger input event to pre-trigger *m* = (prescaler × multiplication factor × delay *m*) + 2 peripheral clock cycles
- Add 1 additional peripheral clock cycle to determine the time when the channel trigger output changes.

Each channel is associated with 1 ADC block. PDB channel n pre-trigger outputs 0 to *M*; each pre-trigger output is connected to ADC hardware trigger select and hardware trigger inputs. The pre-triggers are used to precondition the ADC block before the actual trigger occurs. When the ADC receives the rising edge of the trigger, the ADC will start the conversion according to the precondition determined by the pre-triggers. The ADC contains *M* sets of configuration and result registers, allowing it to alternate conversions between *M* different analog sources (like a ping-pong game). The pre-trigger outputs are used to specify which signal will be sampled next. When a pre-trigger *m* is asserted, the ADC conversion is triggered with set *m* of the configuration and result registers.

The waveforms shown in the following diagram show the pre-trigger and trigger outputs of PDB channel *n*. The delays can be independently set using the channel delay registers (CH*n*DLY*m*), and the pre-triggers can be enabled or disabled using the PDB Channel Pre-Trigger Enables (CH*n*C1[EN[*m*]]).

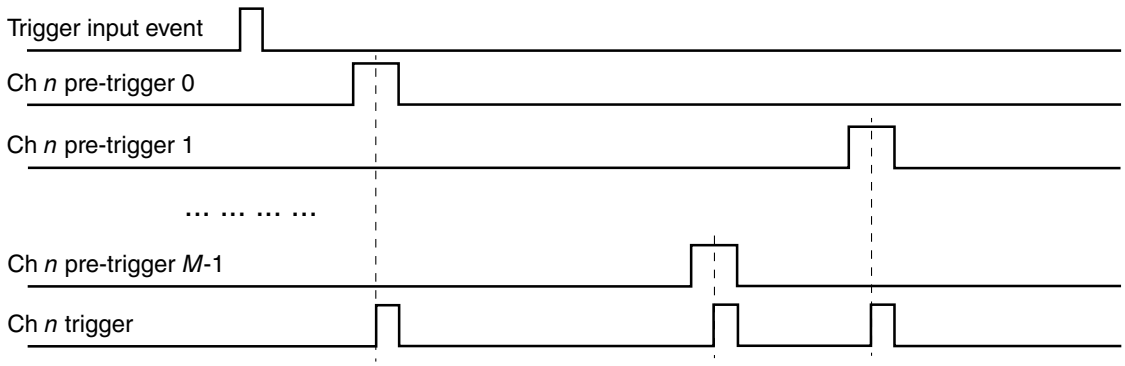


Figure 33-3. Pre-trigger and trigger outputs

The delay in the channel delay register (CH*n*DLY*m*) can be optionally bypassed, if the PDB Channel Pre-Trigger Output Select (CH*n*C1[TOS[*m*]]) is cleared. In this case, when the trigger input event occurs, the pre-trigger *m* is asserted after 2 peripheral clock cycles.

The PDB can be configured for back-to-back operation. Back-to-back operation enables the ADC conversion completions to trigger the next PDB channel pre-trigger and trigger outputs, so that the ADC conversions can be triggered on the next set of configuration and results registers. When back-to-back operation is enabled by setting the PDB Channel Pre-Trigger Back-to-Back Operation Enable (CH*n*C1[BB[*m*]]), then the delay *m* is ignored and the pre-trigger *m* is asserted 2 peripheral cycles after the acknowledgment *m* is received. The acknowledgment connections in this MCU are described in Back-to-back acknowledgment connections.

When a pre-trigger from a PDB channel *n* is asserted, the associated lock of the pre-trigger becomes active. The associated lock is released by the rising edge of the corresponding ADC*n*SC1[COCO]; the ADC*n*SC1[COCO] should be cleared after the conversion result is read, so that the next rising edge of ADC*n*SC1[COCO] can be generated to clear the lock later. The lock becomes inactive when:

- the rising edge of corresponding ADC*n*SC1[COCO] occurs,
- or the corresponding PDB pre-trigger is disabled,
- or the PDB is disabled

The channel *n* trigger output is suppressed when any of the locks of the pre-triggers in channel *n* is active.

- If a new pre-trigger *m* asserts when there is active lock in the PDB channel *n*, then a PDB Channel Sequence Error Flag (CH*n*S[ERR[*m*]], associated with the pre-trigger *m*) is set. If the PDB Sequence Error Interrupt Enable (SC[PDBEIE]) is set, then the

sequence error interrupt is generated. A sequence error typically happens because the delay *m* is set too short and the pre-trigger *m* asserts before the previously triggered ADC conversion finishes.
- If the pre-trigger delay is 0 cycles, then both channels will flag a PDB channel sequence error and ADC will not perform a conversion.

The PDB reports PDB channel sequence errors only for pre-triggers in same PDB channel. For situations when PDB triggering is done through different PDB channels, software must ensure sufficient delays in between the pre-triggers.

When the PDB counter reaches the value (CNT + 1), the PDB Interrupt Flag (SC[PDBIF]) is set. A PDB interrupt can be generated if the PDB Sequence Error Interrupt Enable (SC[PDBEIE]) is set and the DMA Enable (SC[DMAEN]) is cleared. If the DMA Enable (SC[DMAEN]) is set, then the PDB requests a DMA transfer when the PDB Interrupt Flag (SC[PDBIF]) is set.

The modulus value in the Modulus register (MOD) is used to reset the counter back to zero at the end of the count. If the Continuous Mode Enable (SC[CONT]) is set, then the counter will then resume a new count; otherwise, the counter operation will stop until the next trigger input event occurs.

33.5.2 PDB trigger input source selection

The PDB has up to 15 trigger input sources, namely Trigger-In 0 to Trigger-In 14. They are connected to on-chip or off-chip event sources. The PDB can be triggered by software through SC[SWTRIG].

For the trigger input sources implemented in this MCU, see chip configuration information.

33.5.3 Pulse-Out's

PDB can generate pulse outputs of configurable width.
- When the PDB counter reaches the value set in PO*y*DLY[DLY1], then the Pulse-Out goes high.
- When the PDB counter reaches PO*y*DLY[DLY2], then it goes low.

PO*y*DLY[DLY2] can be set either greater or less than PO*y*DLY[DLY1].

ADC pre-trigger/trigger outputs and Pulse-Out generation have the same time base, because they both share the PDB counter. The pulse-out connections implemented in this MCU are described in the device's chip configuration details.

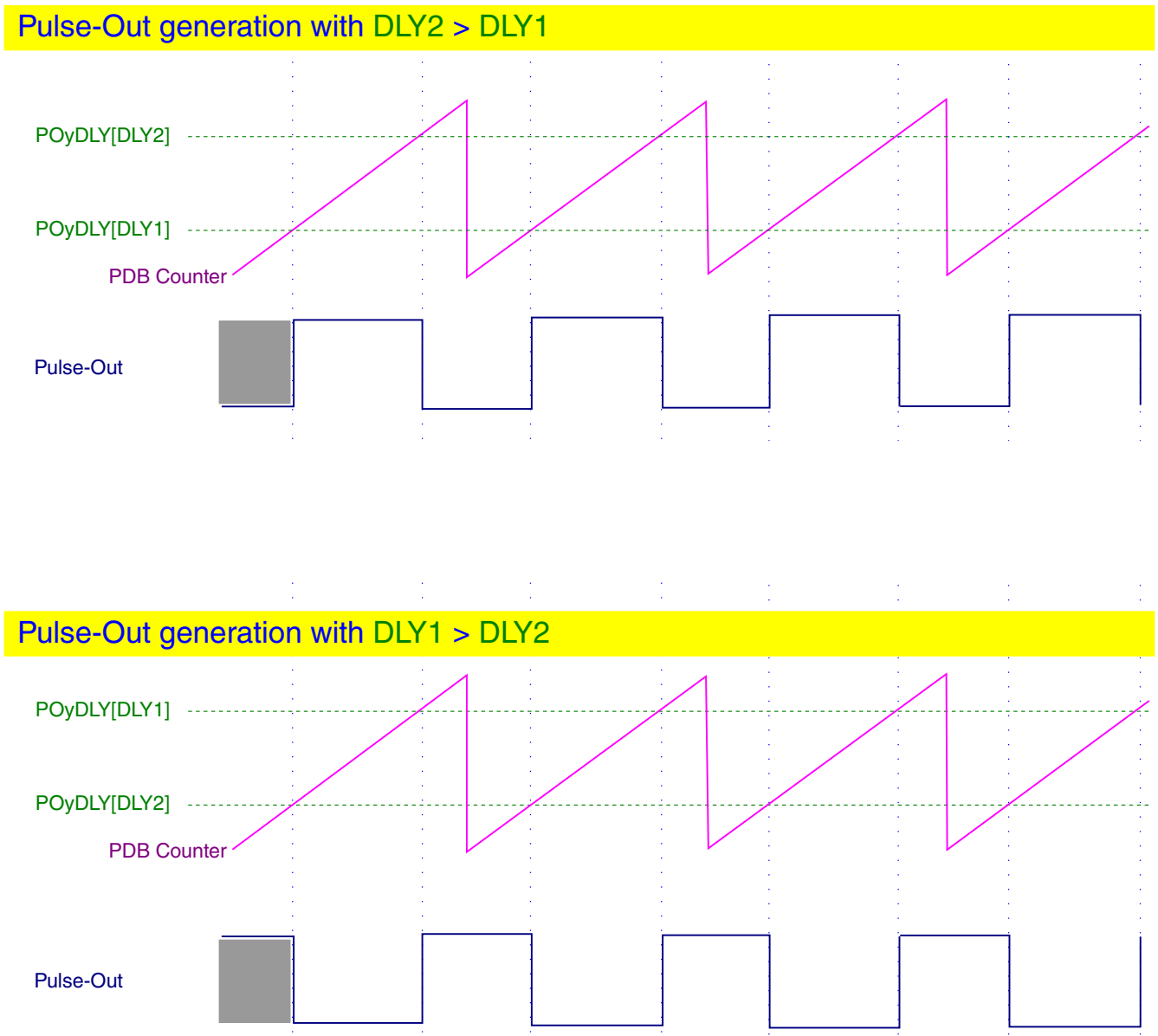


Figure 33-4. How Pulse Out is generated

33.5.4 Updating the delay registers

The following registers control the timing of the PDB operation; and in some of the applications, they may need to become effective at the same time.

- PDB Modulus register (MOD)
- PDB Interrupt Delay register (IDLY)

- PDB Channel *n* Delay *m* register (CH*n*DLY*m*)
- PDB Pulse-Out *y* Delay register (PO*y*DLY)

The internal registers of them are buffered and any values written to them are written first to their buffers. The circumstances that cause their internal registers to be updated with the values from the buffers are summarized in the next table.

Table 33-2. When delay registers are updated

SC[LDMOD]	Update to the delay registers
00	The internal registers are loaded with the values from their buffers immediately after 1 is written to SC[LDOK].
01	The PDB counter reaches PDB_MOD[MOD] + 1 value, after 1 is written to SC[LDOK].
10	A trigger input event is detected after 1 is written to SC[LDOK].
11	Either the PDB counter reaches PDB_MOD[MOD] + 1 value or a trigger input event is detected, after 1 is written to SC[LDOK].

After 1 is written to SC[LDOK], the buffers cannot be written until the values in buffers are loaded into their internal registers. SC[LDOK] is self-cleared when the internal registers are loaded, so the application code can read it to determine the updates to the internal registers.

The following diagrams show the cases of the internal registers being updated with SC[LDMOD] is 00 and x1.

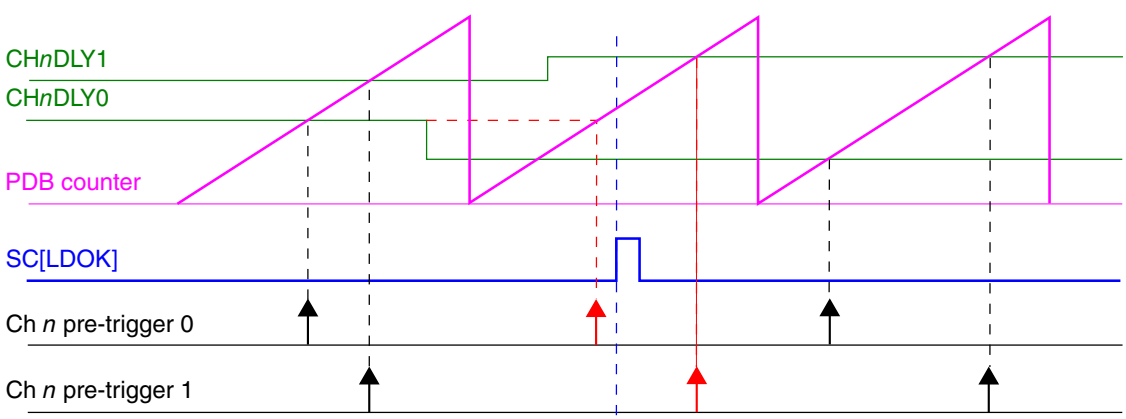


Figure 33-5. Registers update with SC[LDMOD] = 00

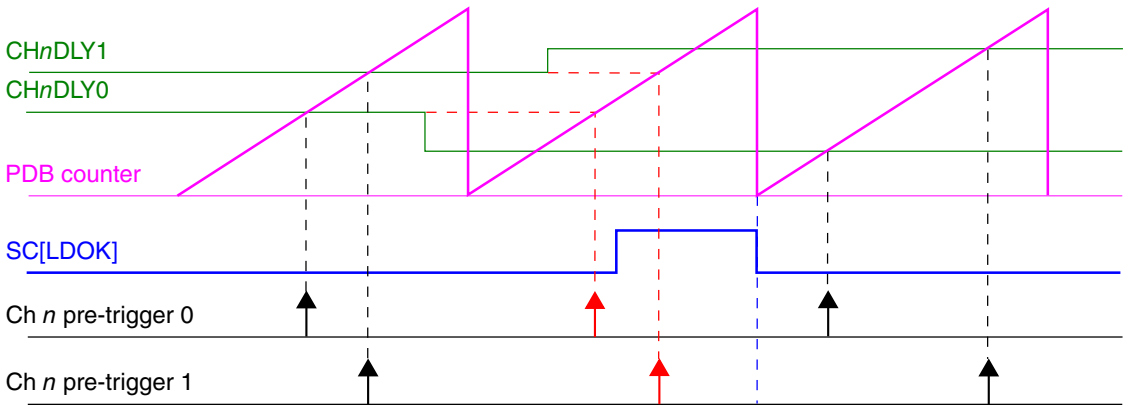


Figure 33-6. Registers update with SC[LDMOD] = x1

33.5.5 Interrupts

PDB can generate two interrupts: PDB interrupt and PDB sequence error interrupt. The following table summarizes the interrupts.

Table 33-3. PDB interrupt summary

Interrupt	Flags	Enable bit
PDB Interrupt	SC[PDBIF]	SC[PDBIE] = 1 and SC[DMAEN] = 0
PDB Sequence Error Interrupt	CH*n*S[ERR*m*]	SC[PDBEIE] = 1

33.5.6 DMA

If SC[DMAEN] is set, PDB can generate a DMA transfer request when SC[PDBIF] is set. When DMA is enabled, the PDB interrupt is not issued.

33.6 Application information

33.6.1 Impact of using the prescaler and multiplication factor on timing resolution

Use of prescaler and multiplication factor greater than 1 limits the count/delay accuracy in terms of peripheral clock cycles (to the modulus of the prescaler X multiplication factor). If the multiplication factor is set to 1 and the prescaler is set to 2 then the only values of total peripheral clocks that can be detected are even values; if prescaler is set to 4 then the only values of total peripheral clocks that can be decoded as detected are mod(4) and so forth. If the applications need a really long delay value and use a prescaler set to 128, then the resolution would be limited to 128 peripheral clock cycles.

Therefore, use the lowest possible prescaler and multiplication factor for a given application.

33.7 Usage Guide

33.7.1 Using PDB to precisely control ADC conversion

For detailed information, see the ADC trigger sections in the ADC chapter.

Chapter 34
FlexTimer Module (FTM)

34.1 Chip-specific information for this module

34.1.1 Instantiation Information

This device contains FlexTimer modules.

The following table shows how these modules are configured.

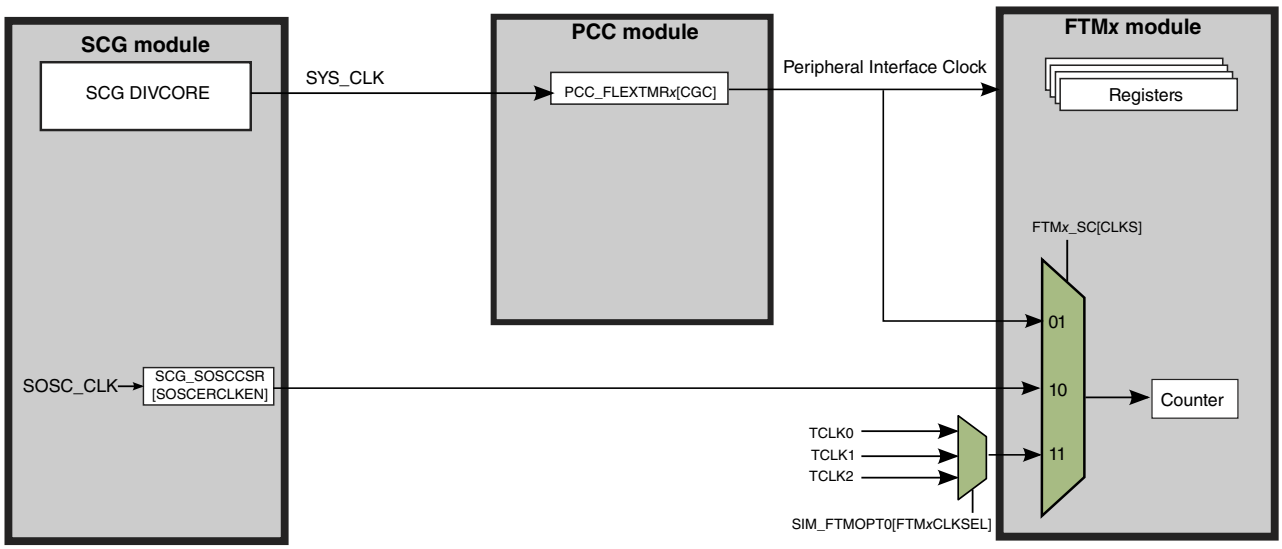
Table 34-1. FTM Instantiations

FTM instance	Number of channels	Features/usage
FTM0	6	• FTM enhanced features • Global time base • Fault Control supported in FTM0
FTM1	2	• FTM enhanced features • Global time base • Quadrature Decoder • **Without** Fault Control in FTM1

34.1.2 FTM Clocking Information

The following figure shows the input clock sources available for this module.

Peripheral Clocking - FTM



NOTE

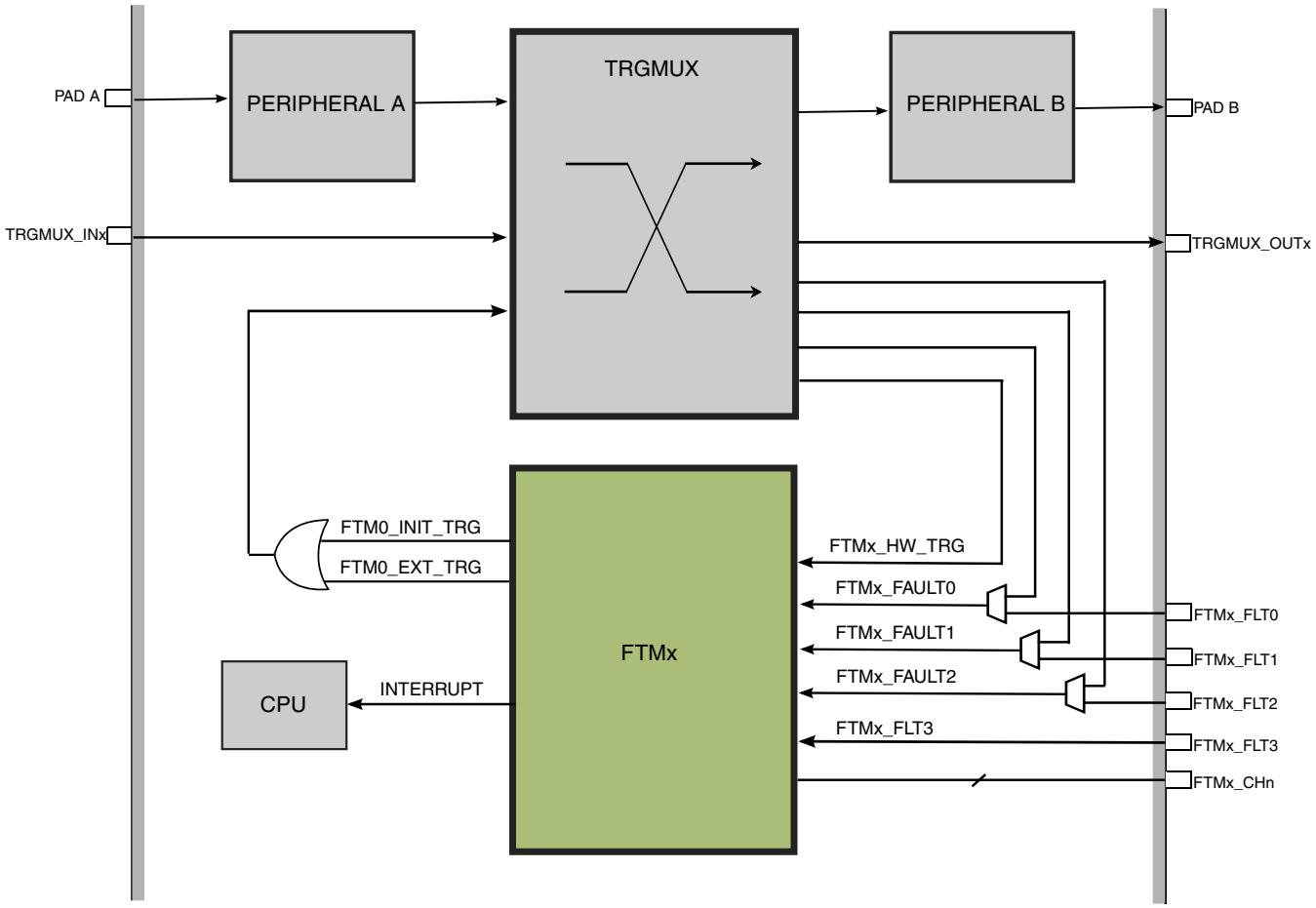
Due to FTM hardware implementation limitations, the frequency of the fixed frequency clock must not exceed 1/2 of the FTM system clock frequency (SYS_CLK).

NOTE

The external clock are synchronized by FTM system clock (SYS_CLK). Therefore, to meet Nyquist criteria considering also jitter, the frequency of the external clock source must not exceed 1/4 of the system clock frequency.

34.1.3 Inter-connectivity Information

The FTM inter-connectivity is shown in the following diagram.



NOTE

The diagram only shows some possible fault input sources. For the actual connections of each FTM, see FTM Fault Detection Inputs for details.

34.1.3.1 FTM Fault Detection Inputs

The following fault detection input options for the FTM modules are selected via the SIM_FTMOPT0 register. The external pin option is selected by default.

- FTM0 FAULT0 = FTM0_FLT0 pin or TRGMUX output
- FTM0 FAULT1 = FTM0_FLT1 pin or TRGMUX output
- FTM0 FAULT2 = FTM0_FLT2 pin or TRGMUX output
- FTM0 FAULT3 = FTM0_FLT3 pin

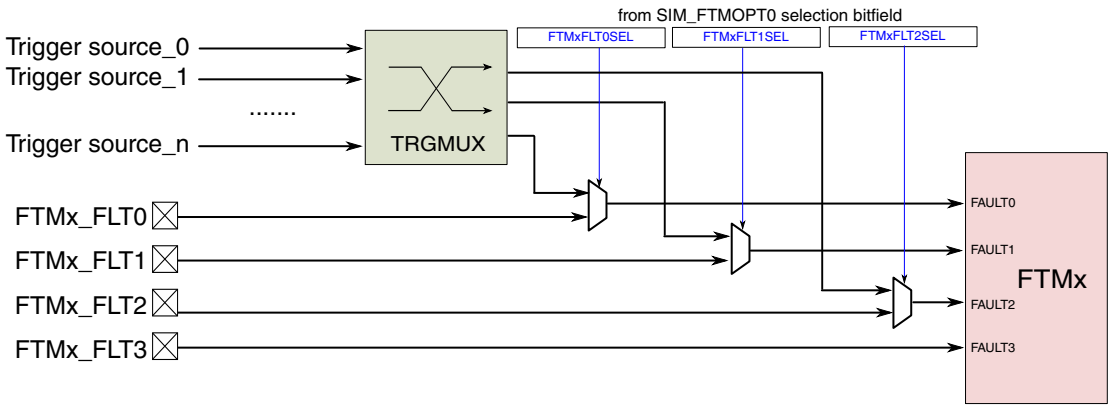


Figure 34-1. FTM0 Fault Detection Inputs

34.1.3.2 FTM Hardware Triggers and Synchronization

The FlexTimer support external hardware trigger input which can be used for timer dynamic synchronization between multiple FlexTimers or counter reset. The FlexTimer hardware trigger are implemented as following.

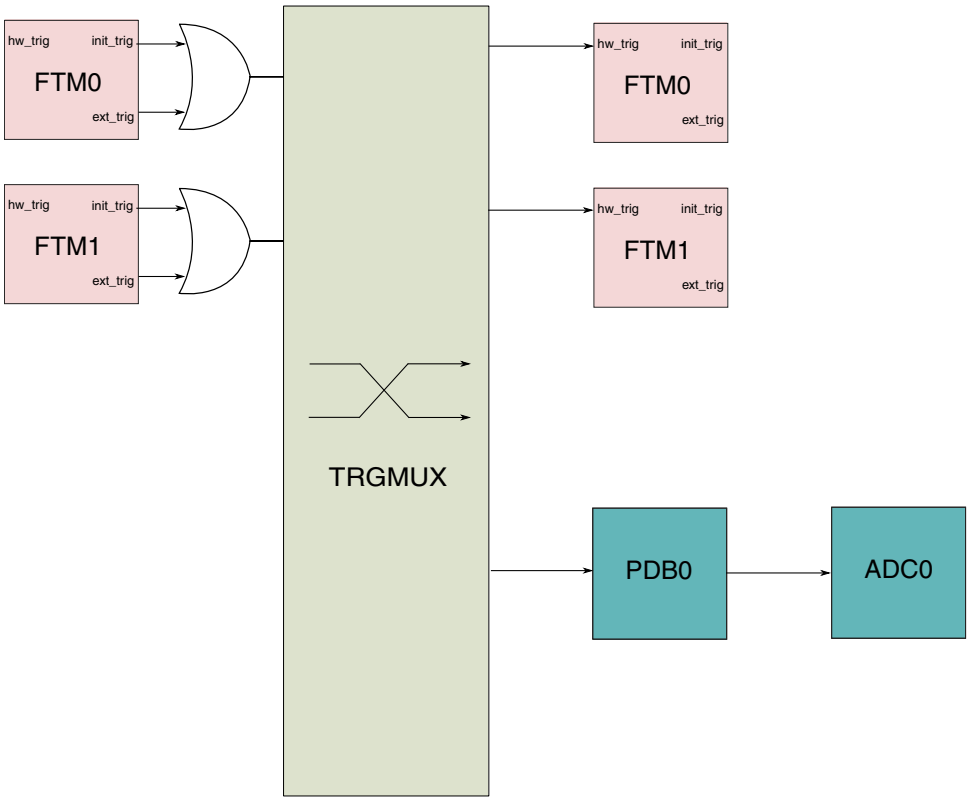
FTM0:

- FTM0 hardware trigger 0 = TRGMUX trigger output
- FTM0 hardware trigger 1 = SIM_FTMOPT1[FTM0SYNCBIT]
- FTM0 hardware trigger 2 = FTM0_FLT0 pin

FTM1:

- FTM1 hardware trigger 0 = TRGMUX trigger output
- FTM1 hardware trigger 1 = SIM_FTMOPT1[FTM1SYNCBIT]

The hardware trigger source can be from many other modules via TRGMUX, like LPIT, Low Power Timer, CMP, etc. It also supports FlexTimer's self trigger outputs, e.g. counter initialization trigger (init_trig) and channel match trigger (ext_trig), through the flexible TRGMUX module.



The FlexTimer trigger outputs are also usually used as trigger source by other modules, for example, the above diagram shows a case of triggering PDB and ADC. See "Chip-specific Information" in PDB chapter andADC Trigger Sources in ADC chapter for details.

34.1.3.3 FTM Input Capture Options

The following channel 0 input capture source options are selected via SIM_FTMOPT1. The external pin option is selected by default.

- FTM1 channel 0 input capture = FTM1_CH0 pin or CMP0 output

34.2 Introduction

The FlexTimer module (FTM) is a two-to-six channel timer that supports input capture, output compare, and the generation of PWM signals to control electric motor and power management applications. The FTM time reference is a 16-bit counter that can be used as an unsigned or signed counter.

34.2.1 Features

The FTM features include:

- FTM source clock is selectable
  - Source clock can be the FTM input clock, the fixed frequency clock, or an external clock
  - Fixed frequency clock is an additional clock input to allow the selection of an on chip clock source other than the FTM input clock
  - Selecting external clock connects FTM clock to a chip level input pin therefore allowing to synchronize the FTM counter with an off chip clock source
- Prescaler divide-by 1, 2, 4, 8, 16, 32, 64, or 128
- 16-bit counter
  - It can be a free-running counter or a counter with initial and final value
  - The counting can be up or up-down
- Each channel can be configured for input capture, output compare, or edge-aligned PWM mode
- In Input Capture mode:
  - The capture can occur on rising edges, falling edges or both edges
  - An input filter can be selected for some channels.
- In Output Compare mode the output signal can be set, cleared, or toggled on match
- All channels can be configured for center-aligned PWM mode
- Each pair of channels can be combined to generate a PWM signal with independent control of both edges of PWM signal
- The FTM channels can operate as pairs with equal outputs, pairs with complementary outputs, or independent channels with independent outputs
- The deadtime insertion is available for each complementary pair
- Generation of match triggers
- Software control of PWM outputs
- Up to 4 fault inputs for global fault control
- The polarity of each channel is configurable

- The generation of an interrupt per channel
- The generation of an interrupt when the counter overflows
- The generation of an interrupt when the fault condition is detected
- The generation of an interrupt when a register reload point occurs
- Synchronized loading of write buffered FTM registers
- Half cycle and Full cycle register reload capacity
- Write protection for critical registers
- Backwards compatible with TPM
- Testing of input capture mode
- Direct access to input pin states
- Dual edge capture for pulse and period width measurement
- Quadrature decoder with input filters, relative position counting, and interrupt on position count or capture of position count on external event
- The FTM channels can be selected to generate a trigger pulse on channel output instead of a PWM
- Dithering capability to simulate fine edge control for both PWM period or PWM duty cycle

34.2.2 Modes of operation

When the chip is in an active Debug mode, the FTM temporarily suspends all counting until the chip returns to normal user operating mode. During Stop mode, all FTM input clocks are stopped, so the FTM is effectively disabled until clocks resume. During Wait mode, the FTM continues to operate normally. If the FTM does not need to produce a real time reference or provide the interrupt sources needed to wake the chip from Wait mode, the power can then be saved by disabling FTM functions before entering Wait mode.

34.2.3 Block Diagram

The FTM uses one input/output (I/O) pin per channel, CHn (FTM channel (n)) where n is the channel number (0–7).

NOTE

The number of channels supported can vary for each instance of the FTM module on a chip. See the chip-specific FTM information to see how many channels are supported for each module instance. For example, if a module instance supports only six channels, references to channel numbers 6 and 7 do not apply for that instance.

The following figure shows the FTM structure. The central component of the FTM is the 16-bit counter with programmable initial and final values and its counting can be up or up-down.

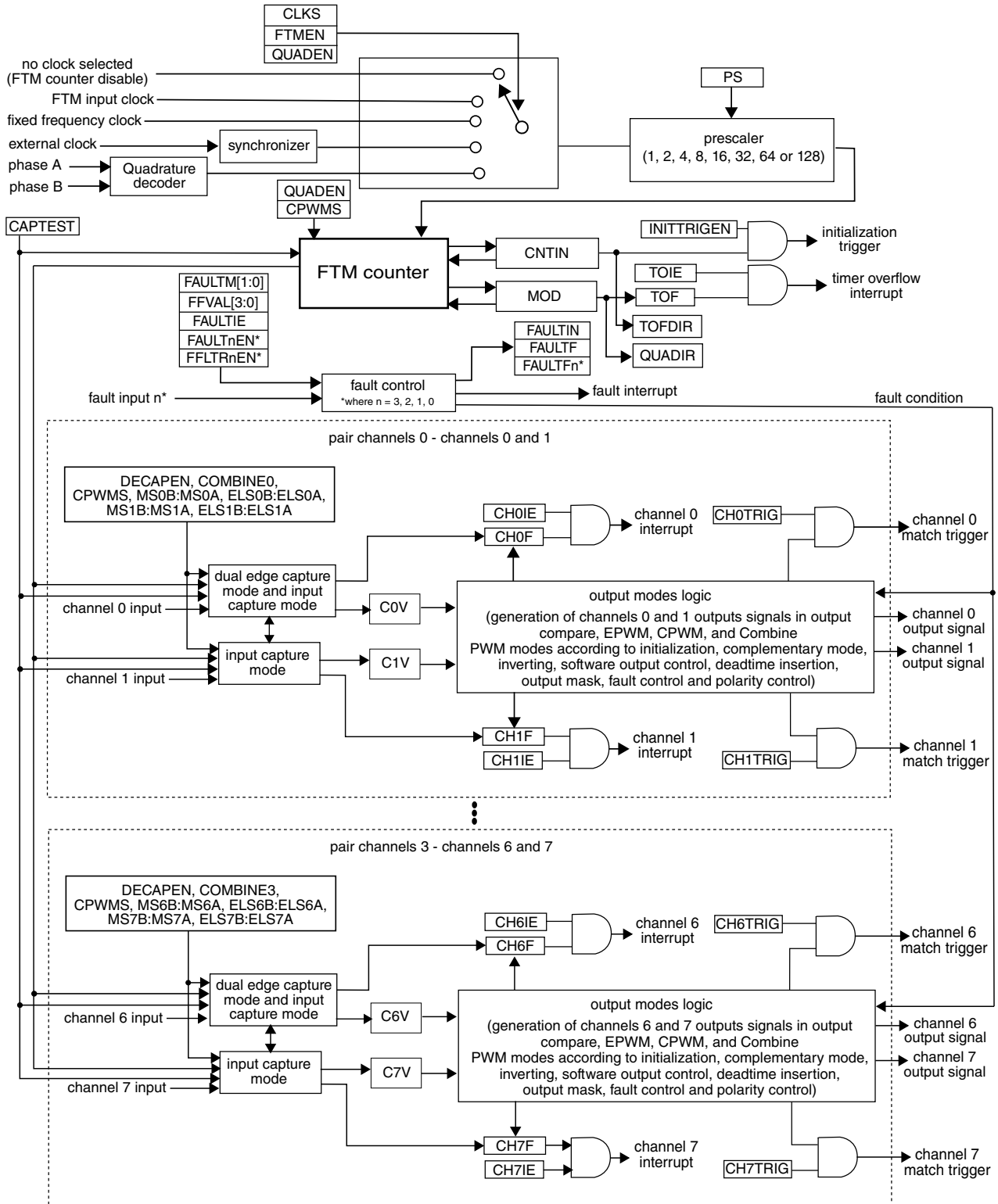


Figure 34-2. FTM Block Diagram

34.3 FTM signal descriptions

Table 34-2 shows the user-accessible signals for the FTM.

Table 34-2. FTM signal descriptions

Signal	Description	I/O	Function
EXTCLK	External clock. FTM external clock can be selected to drive the FTM counter.	I	The external clock input signal is used as the FTM counter clock if selected by CLKS[1:0] bits in the SC register. This clock signal must not exceed 1/4 of FTM input clock frequency. The FTM counter prescaler selection and settings are also used when an external clock is selected.
CHn	FTM channel (n), where n can be 7-0	I/O	Each FTM channel can be configured to operate either as input or output. The direction associated with each channel, input or output, is selected according to the mode assigned for that channel.
FAULTj	Fault input (j), where j can be 3-0	I	The fault input signals are used to control the CHn channel output state. If a fault is detected, the FAULTj signal is asserted and the channel output is put in a safe state. The behavior of the fault logic is defined by the FAULTM[1:0] control bits in the MODE register and FAULTEN bit in the COMBINE register. Note that each FAULTj input may affect all channels selectively since FAULTM[1:0] and FAULTEN control bits are defined for each pair of channels. Because there are several FAULTj inputs, maximum of 4 for the FTM module, each one of these inputs is activated by the FAULTjEN bit in the FLTCTRL register.
PHA	Quadrature decoder phase A input. Input pin associated with quadrature decoder phase A.	I	The quadrature decoder phase A input is used as the Quadrature Decoder mode is selected. The phase A input signal is one of the signals that control the FTM counter increment or decrement in the Quadrature Decoder Mode.
PHB	Quadrature decoder phase B input. Input pin associated with quadrature decoder phase B.	I	The quadrature decoder phase B input is used as the Quadrature Decoder mode is selected. The phase B input signal is one of the signals that control the FTM counter increment or decrement in the Quadrature Decoder Mode.

34.4 Memory map and register definition

34.4.1 Memory map

This section presents a high-level summary of the FTM registers and how they are mapped.

The registers and bits of an unavailable function in the FTM remain in the memory map and in the reset value, but they have no active function.

NOTE

The number of channels supported can vary for each instance of the FTM module on a chip. See the chip-specific FTM information to see how many channels are supported for each module instance.

Note

Do not write in the region from the CNTIN register when FTMEN = 0.

34.4.2 Register descriptions

Accesses to reserved addresses result in transfer errors. Registers for absent channels are considered reserved. Double buffered register writes must be done using 32-bit operations.

34.4.3 FTM register descriptions

34.4.3.1 FTM Memory map

FTM0 base address: 4003_8000h

FTM1 base address: 4003_9000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Status And Control (SC)	32	RW	0000_0000h
4h	Counter (CNT)	32	RW	0000_0000h
8h	Modulo (MOD)	32	RW	0000_0000h
Ch	Channel (n) Status And Control (C0SC)	32	RW	0000_0000h
10h	Channel (n) Value (C0V)	32	RW	0000_0000h
14h	Channel (n) Status And Control (C1SC)	32	RW	0000_0000h
18h	Channel (n) Value (C1V)	32	RW	0000_0000h
1Ch	Channel (n) Status And Control (C2SC)	32	RW	0000_0000h
20h	Channel (n) Value (C2V)	32	RW	0000_0000h
24h	Channel (n) Status And Control (C3SC)	32	RW	0000_0000h
28h	Channel (n) Value (C3V)	32	RW	0000_0000h

Table continues on the next page...

Offset	Register	Width (In bits)	Access	Reset value
2Ch	Channel (n) Status And Control (C4SC)	32	RW	0000_0000h
30h	Channel (n) Value (C4V)	32	RW	0000_0000h
34h	Channel (n) Status And Control (C5SC)	32	RW	0000_0000h
38h	Channel (n) Value (C5V)	32	RW	0000_0000h
4Ch	Counter Initial Value (CNTIN)	32	RW	0000_0000h
50h	Capture And Compare Status (STATUS)	32	RW	0000_0000h
54h	Features Mode Selection (MODE)	32	RW	0000_0004h
58h	Synchronization (SYNC)	32	RW	0000_0000h
5Ch	Initial State For Channels Output (OUTINIT)	32	RW	0000_0000h
60h	Output Mask (OUTMASK)	32	RW	0000_0000h
64h	Function For Linked Channels (COMBINE)	32	RW	0000_0000h
68h	Deadtime Configuration (DEADTIME)	32	RW	0000_0000h
6Ch	FTM External Trigger (EXTTRIG)	32	RW	0000_0000h
70h	Channels Polarity (POL)	32	RW	0000_0000h
74h	Fault Mode Status (FMS)	32	RW	0000_0000h
78h	Input Capture Filter Control (FILTER)	32	RW	0000_0000h
7Ch	Fault Control (FLTCTRL)	32	RW	0000_0000h
80h	Quadrature Decoder Control And Status (QDCTRL)	32	RW	0000_0000h
84h	Configuration (CONF)	32	RW	0000_0000h
88h	FTM Fault Input Polarity (FLTPOL)	32	RW	0000_0000h
8Ch	Synchronization Configuration (SYNCONF)	32	RW	0000_0000h
90h	FTM Inverting Control (INVCTRL)	32	RW	0000_0000h
94h	FTM Software Output Control (SWOCTRL)	32	RW	0000_0000h
98h	FTM PWM Load (PWMLOAD)	32	RW	0000_0000h
9Ch	Half Cycle Register (HCR)	32	RW	0000_0000h
200h	Mirror of Modulo Value (MOD_MIRROR)	32	RW	0000_0000h
204h - 218h	Mirror of Channel (n) Match Value (C0V_MIRROR - C5V_MIRROR)	32	RW	0000_0000h

34.4.3.2 Status And Control (SC)

34.4.3.2.1 Offset

Register	Offset
SC	0h

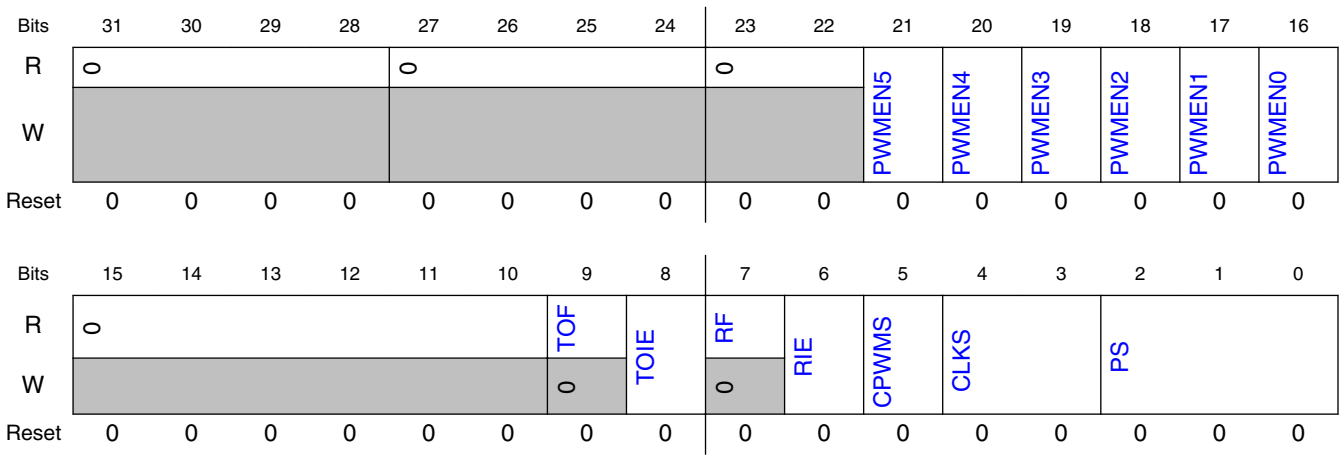
34.4.3.2.2 Function

SC contains the overflow status flag and control bits used to configure the interrupt enable, FTM configuration, clock source, and prescaler factor.

This register also contains the output enable control bits and the reload opportunity flag control.

These controls relate to all channels within this module.

34.4.3.2.3 Diagram



34.4.3.2.4 Fields

Field	Function
31-28 —	Reserved
27-24 —	Reserved
23-22 —	Reserved
21-16 PWMENn	Channel 0 PWM enable bit This bit enables the PWM channel output. This bit should be set to 0 (output disabled) when an input mode is used. 0b - Channel output port is disabled. 1b - Channel output port is enabled.
15-10 —	Reserved
9 TOF	Timer Overflow Flag

Table continues on the next page...

Field	Function
	Set by hardware when the FTM counter passes the value in the MOD register. The TOF bit is cleared by reading the SC register while TOF is set and then writing a 0 to TOF bit. Writing a 1 to TOF has no effect. If another FTM overflow occurs between the read and write operations, the write operation has no effect; therefore, TOF remains set indicating an overflow has occurred. In this case, a TOF interrupt request is not lost due to the clearing sequence for a previous TOF. 0b - FTM counter has not overflowed. 1b - FTM counter has overflowed.
8 TOIE	Timer Overflow Interrupt Enable Enables FTM overflow interrupts. 0b - Disable TOF interrupts. Use software polling. 1b - Enable TOF interrupts. An interrupt is generated when TOF equals one.
7 RF	Reload Flag The RF bit is set at each selected reload point. See Reload Points. The RF bit is cleared by reading the SC register while RF is set and then writing a 0 to RF bit. Writing 1 to RF has no effect. If another selected reload point happens between the read and write operations, the write operation has no effect; therefore, RF remains set. 0b - A selected reload point did not happen. 1b - A selected reload point happened.
6 RIE	Reload Point Interrupt Enable Enables the reload point interrupt. 0b - Reload point interrupt is disabled. 1b - Reload point interrupt is enabled.
5 CPWMS	Center-Aligned PWM Select Selects CPWM mode. This mode configures the FTM to operate in Up-Down Counting mode. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - FTM counter operates in Up Counting mode. 1b - FTM counter operates in Up-Down Counting mode.
4-3 CLKS	Clock Source Selection Selects one of the three FTM counter clock sources. This field is write protected. It can be written only when MODE[WPDIS] = 1. 00b - No clock selected. This in effect disables the FTM counter. 01b - FTM input clock 10b - Fixed frequency clock 11b - External clock
2-0 PS	Prescale Factor Selection Selects one of 8 division factors for the clock source selected by CLKS. The new prescaler factor affects the clock source on the next FTM input clock cycle after the new value is updated into the register bits. This field is write protected. It can be written only when MODE[WPDIS] = 1. 000b - Divide by 1 001b - Divide by 2 010b - Divide by 4 011b - Divide by 8 100b - Divide by 16 101b - Divide by 32 110b - Divide by 64 111b - Divide by 128

34.4.3.3 Counter (CNT)

34.4.3.3.1 Offset

Register	Offset
CNT	4h

34.4.3.3.2 Function

The CNT register contains the FTM counter value.

Reset clears the CNT register. Writing any value to COUNT updates the counter with its initial value, CNTIN.

34.4.3.3.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	COUNT															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

34.4.3.3.4 Fields

Field	Function
31-16 —	Reserved
15-0 COUNT	Counter Value

34.4.3.4 Modulo (MOD)

34.4.3.4.1 Offset

Register	Offset
MOD	8h

34.4.3.4.2 Function

The Modulo register contains the modulo value for the FTM counter. After the FTM counter reaches the modulo value, the overflow flag (TOF) becomes set at the next clock cycle, and the next value of FTM counter depends on the selected counting method; see Counter.

Writes to the MOD register are done on its write buffer. The MOD register is updated with its write buffer value according to Registers updated from write buffers. If FTMEN = 0, a write to SC register resets manually this write coherency mechanism.

Initialize the FTM counter, by writing to CNT, before writing to the MOD register to avoid confusion about when the first counter overflow will occur.

34.4.3.4.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MOD															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

34.4.3.4.4 Fields

Field	Function
31-16 —	Reserved
15-0 MOD	MOD Modulo Value

34.4.3.5 Channel (n) Status And Control (C0SC - C5SC)

34.4.3.5.1 Offset

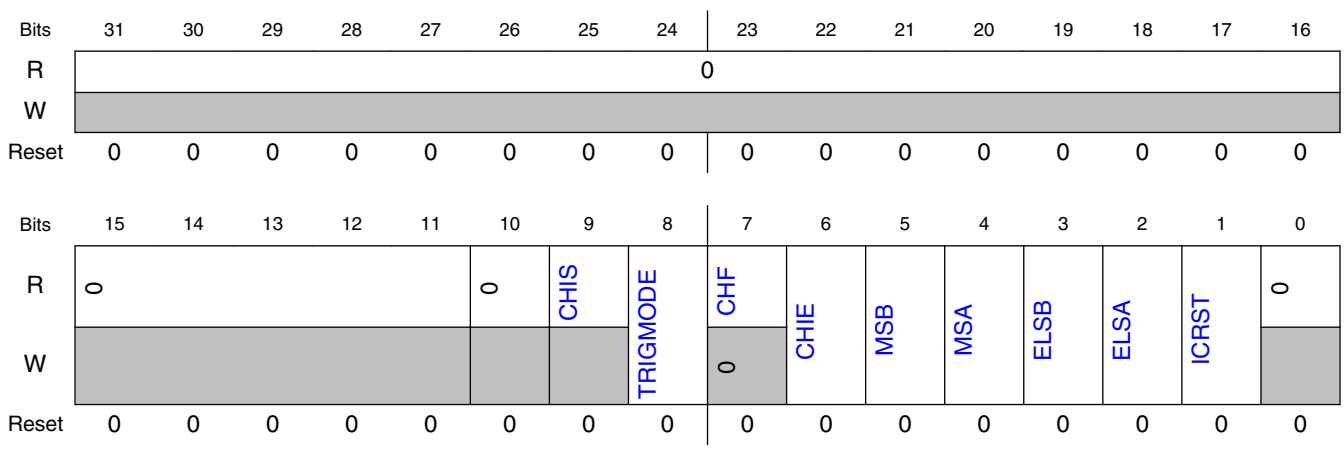
For a = 0 to 5:

Register	Offset
CaSC	Ch + (a × 8h)

34.4.3.5.2 Function

CnSC contains channel (n) status bits and control bits that select the channel (n) mode and its functionality.

34.4.3.5.3 Diagram



34.4.3.5.4 Fields

Field	Function
31-11 —	Reserved
10 —	Reserved
9	Channel (n) Input State

Table continues on the next page...

Field	Function
CHIS	The CHIS bit has the value of the channel (n) input after the double-sampling or the filtering (if the channel (n) filter is enabled) both them are inside the FTM. **NOTE:** The CHIS bit should be ignored when the channel (n) is not in an input mode. **NOTE:** When the pair channels is on dual edge mode, the channel (n+1) CHIS bit is the channel (n+1) input value and not the channel (n) input value (this signal is the input signal used by the dual edge mode). 0b - The channel (n) input is zero. 1b - The channel (n) input is one.
8 TRIGMODE	Trigger mode control This bit controls the trigger generation on FTM channel outputs. This mode is allowed only if when FTM channel is configured to EPWM or CPWM modes. If a match in the channel occurs, a trigger pulse with one FTM clock cycle width will be generated in the channel output. See Channel trigger output. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Channel outputs will generate the normal PWM outputs without generating a pulse. 1b - If a match in the channel occurs, a trigger generation on channel output will happen. The trigger pulse width has one FTM clock cycle.
7 CHF	Channel (n) Flag Set by hardware when an event occurs on the channel (n). CHF is cleared by reading the CnSC register while CHF is set and then writing a 0 to the CHF bit. Writing a 1 to CHF has no effect. If another event occurs between the read and write operations, the write operation has no effect; therefore, CHF remains set indicating an event has occurred. In this case a CHF interrupt request is not lost due to the clearing sequence for a previous CHF. 0b - No channel (n) event has occurred. 1b - A channel (n) event has occurred.
6 CHIE	Channel (n) Interrupt Enable Enables channel (n) interrupt. 0b - Disable channel (n) interrupt. Use software polling. 1b - Enable channel (n) interrupt.
5 MSB	Channel (n) Mode Select Used on the selection of the channel (n) mode. See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.
4 MSA	Channel (n) Mode Select Used on the selection of the channel (n) mode. See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.
3 ELSB	Channel (n) Edge or Level Select Used on the selection of the channel (n) mode. See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.
2 ELSA	Channel (n) Edge or Level Select Used on the selection of the channel (n) mode. See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.
1 ICRST	FTM counter reset by the selected input capture event. FTM counter reset is driven by the selected event of the channel (n) in the Input Capture mode. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - FTM counter is not reset when the selected channel (n) input event is detected.

Table continues on the next page...

Field	Function
	1b - FTM counter is reset when the selected channel (n) input event is detected.
0 —	Reserved

34.4.3.6 Channel (n) Value (C0V - C5V)

34.4.3.6.1 Offset

For a = 0 to 5:

Register	Offset
CaV	10h + (a × 8h)

34.4.3.6.2 Function

These registers contain the captured FTM counter value for the input modes or the match value for the output modes.

In Input Capture, Capture Test, and Dual Edge Capture modes, any write to a CnV register is ignored.

In output modes, writes to the CnV register are done on its write buffer. The CnV register is updated with its write buffer value according to Registers updated from write buffers. If FTMEN = 0, a write to CnSC register resets manually this write coherency mechanism.

34.4.3.6.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	VAL															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

34.4.3.6.4 Fields

Field	Function
31-16 —	Reserved
15-0 VAL	Channel Value Captured FTM counter value of the input modes or the match value for the output modes

34.4.3.7 Counter Initial Value (CNTIN)

34.4.3.7.1 Offset

Register	Offset
CNTIN	4Ch

34.4.3.7.2 Function

The Counter Initial Value register contains the initial value for the FTM counter.

Writing to the CNTIN register latches the value into a buffer. The CNTIN register is updated with the value of its write buffer according to Registers updated from write buffers.

When the FTM clock is initially selected, by writing a non-zero value to the CLKS bits, the FTM counter starts with the value 0x0000. To avoid this behavior, before the first write to select the FTM clock, write the new value to the CNTIN register and then initialize the FTM counter by writing any value to the CNT register.

34.4.3.7.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	INIT															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

34.4.3.7.4 Fields

Field	Function
31-16 —	Reserved
15-0 INIT	INIT Initial Value Of The FTM Counter

34.4.3.8 Capture And Compare Status (STATUS)

34.4.3.8.1 Offset

Register	Offset
STATUS	50h

34.4.3.8.2 Function

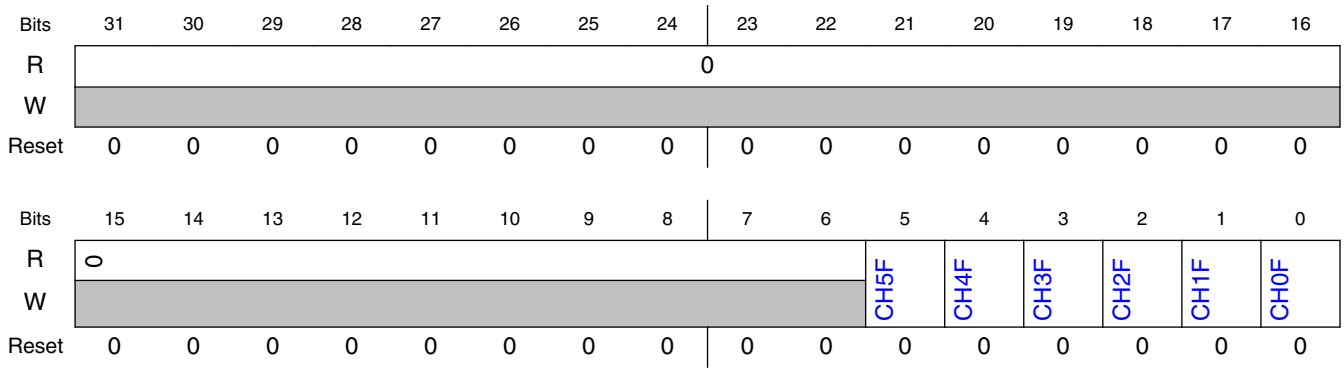
The STATUS register contains a copy of the status flag CHF bit in CnSC for each FTM channel for software convenience.

Each CHF bit in STATUS is a mirror of CHF bit in CnSC. All CHF bits can be checked using only one read of STATUS. All CHF bits can be cleared by reading STATUS followed by writing 0x00 to STATUS.

Hardware sets the individual channel flags when an event occurs on the channel. CHF is cleared by reading STATUS while CHF is set and then writing a 0 to the CHF bit. Writing a 1 to CHF has no effect.

If another event occurs between the read and write operations, the write operation has no effect; therefore, CHF remains set indicating an event has occurred. In this case, a CHF interrupt request is not lost due to the clearing sequence for a previous CHF.

34.4.3.8.3 Diagram



34.4.3.8.4 Fields

Field	Function
31-6 —	Reserved
5-0 CHnF	Channel 0 Flag See the register description. 0b - No channel event has occurred. 1b - A channel event has occurred.

34.4.3.9 Features Mode Selection (MODE)

34.4.3.9.1 Offset

Register	Offset
MODE	54h

34.4.3.9.2 Function

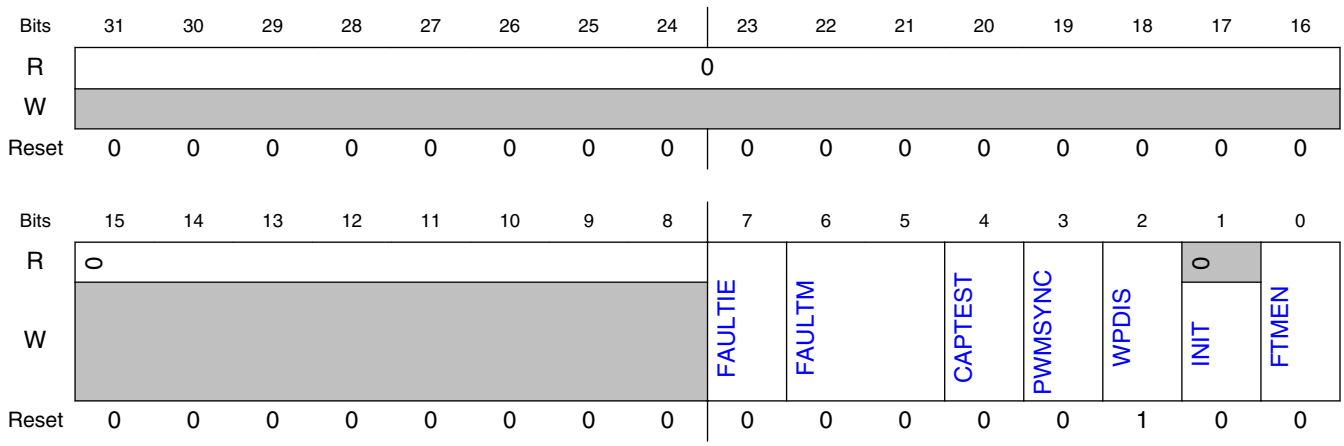
This register contains the global enable bit for FTM-specific features and the control bits used to configure:

- Fault control mode and interrupt
- Capture Test mode
- PWM synchronization

- Write protection
- Channel output initialization

These controls relate to all channels within this module.

34.4.3.9.3 Diagram



34.4.3.9.4 Fields

Field	Function
31-8 —	Reserved
7 FAULTIE	Fault Interrupt Enable Enables the generation of an interrupt when a fault is detected by FTM and the FTM fault control is enabled. 0b - Fault control interrupt is disabled. 1b - Fault control interrupt is enabled.
6-5 FAULTM	Fault Control Mode Defines the FTM fault control mode. This field is write protected. It can be written only when MODE[WPDIS] = 1. 00b - Fault control is disabled for all channels. 01b - Fault control is enabled for even channels only (channels 0, 2, 4, and 6), and the selected mode is the manual fault clearing. 10b - Fault control is enabled for all channels, and the selected mode is the manual fault clearing. 11b - Fault control is enabled for all channels, and the selected mode is the automatic fault clearing.
4 CAPTEST	Capture Test Mode Enable Enables the capture test mode. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Capture test mode is disabled. 1b - Capture test mode is enabled.

Table continues on the next page...

Field	Function
3 PWMSYNC	PWM Synchronization Mode Selects which triggers can be used by MOD, CnV, OUTMASK, and FTM counter synchronization. See PWM synchronization. The PWMSYNC bit configures the synchronization when SYNCMODE is 0. 0b - No restrictions. Software and hardware triggers can be used by MOD, CnV, OUTMASK, and FTM counter synchronization. 1b - Software trigger can only be used by MOD and CnV synchronization, and hardware triggers can only be used by OUTMASK and FTM counter synchronization.
2 WPDIS	Write Protection Disable When write protection is enabled (WPDIS = 0), write protected bits cannot be written. When write protection is disabled (WPDIS = 1), write protected bits can be written. The WPDIS bit is the negation of the WPEN bit. WPDIS is cleared when 1 is written to WPEN. WPDIS is set when WPEN bit is read as a 1 and then 1 is written to WPDIS. Writing 0 to WPDIS has no effect. 0b - Write protection is enabled. 1b - Write protection is disabled.
1 INIT	Initialize The Channels Output When a 1 is written to INIT bit the channels output is initialized according to the state of their corresponding bit in the OUTINIT register. Writing a 0 to INIT bit has no effect. The INIT bit is always read as 0.
0 FTMEN	FTM Enable This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - TPM compatibility. Free running counter and synchronization compatible with TPM. 1b - Free running counter and synchronization are different from TPM behavior.

34.4.3.10 Synchronization (SYNC)

34.4.3.10.1 Offset

Register	Offset
SYNC	58h

34.4.3.10.2 Function

This register configures the PWM synchronization.

A synchronization event can perform the synchronized update of MOD, CnV, and OUTMASK registers with the value of their write buffer and the FTM counter initialization.

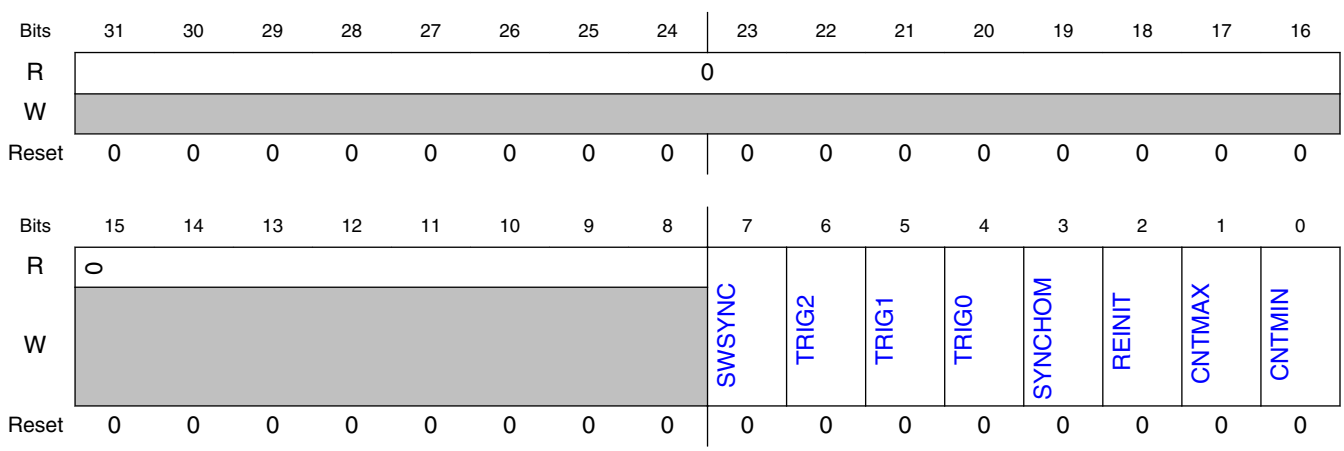
NOTE

The software trigger, SWSYNC bit, and hardware triggers TRIG0, TRIG1, and TRIG2 bits have a potential conflict if used together when SYNCMODE = 0. Use only hardware or software triggers but not both at the same time, otherwise unpredictable behavior is likely to happen.

The selection of the loading point, CNTMAX and CNTMIN bits, is intended to provide the update of MOD, CNTIN, and CnV registers across all enabled channels simultaneously. The use of the loading point selection together with SYNCMODE = 0 and hardware trigger selection, TRIG0, TRIG1, or TRIG2 bits, is likely to result in unpredictable behavior.

The synchronization event selection also depends on the PWMSYNC (MODE register) and SYNCMODE (SYNCONF register) bits. See PWM synchronization.

34.4.3.10.3 Diagram



34.4.3.10.4 Fields

Field	Function
31-8 —	Reserved
7 SWSYNC	PWM Synchronization Software Trigger Selects the software trigger as the PWM synchronization trigger. The software trigger happens when a 1 is written to SWSYNC bit.

Table continues on the next page...

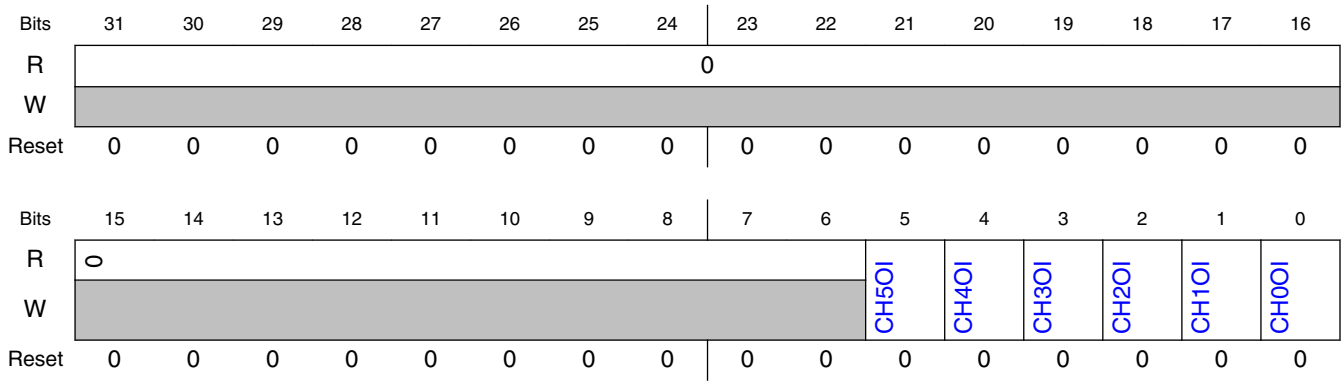
Field	Function
	0b - Software trigger is not selected. 1b - Software trigger is selected.
6 TRIG2	PWM Synchronization Hardware Trigger 2 Enables hardware trigger 2 to the PWM synchronization. Hardware trigger 2 happens when a rising edge is detected at the trigger 2 input signal. 0b - Trigger is disabled. 1b - Trigger is enabled.
5 TRIG1	PWM Synchronization Hardware Trigger 1 Enables hardware trigger 1 to the PWM synchronization. Hardware trigger 1 happens when a rising edge is detected at the trigger 1 input signal. 0b - Trigger is disabled. 1b - Trigger is enabled.
4 TRIG0	PWM Synchronization Hardware Trigger 0 Enables hardware trigger 0 to the PWM synchronization. Hardware trigger 0 occurs when a rising edge is detected at the trigger 0 input signal. 0b - Trigger is disabled. 1b - Trigger is enabled.
3 SYNCHOM	Output Mask Synchronization Selects when the OUTMASK register is updated with the value of its buffer. 0b - OUTMASK register is updated with the value of its buffer in all rising edges of the FTM input clock. 1b - OUTMASK register is updated with the value of its buffer only by the PWM synchronization.
2 REINIT	FTM Counter Reinitialization by Synchronization Determines if the FTM counter is reinitialized when the selected trigger for the synchronization is detected (FTM counter synchronization). The REINIT bit configures the synchronization when SYNCMODE is zero. 0b - FTM counter continues to count normally. 1b - FTM counter is updated with its initial value when the selected trigger is detected.
1 CNTMAX	Maximum Loading Point Enable Selects the maximum loading point to PWM synchronization (Synchronization Points). If CNTMAX is 1, the selected loading point is when the FTM counter reaches its maximum value (MOD register). 0b - The maximum loading point is disabled. 1b - The maximum loading point is enabled.
0 CNTMIN	Minimum Loading Point Enable Selects the minimum loading point to PWM synchronization (Synchronization Points). If CNTMIN is 1, the selected loading point is when the FTM counter reaches its minimum value (CNTIN register). 0b - The minimum loading point is disabled. 1b - The minimum loading point is enabled.

34.4.3.11 Initial State For Channels Output (OUTINIT)

34.4.3.11.1 Offset

Register	Offset
OUTINIT	5Ch

34.4.3.11.2 Diagram



34.4.3.11.3 Fields

Field	Function
31-6 —	Reserved
5-0 CHnOI	Channel 0 Output Initialization Value Selects the value that is forced into the channel output when the initialization occurs. 0b - The initialization value is 0. 1b - The initialization value is 1.

34.4.3.12 Output Mask (OUTMASK)

34.4.3.12.1 Offset

Register	Offset
OUTMASK	60h

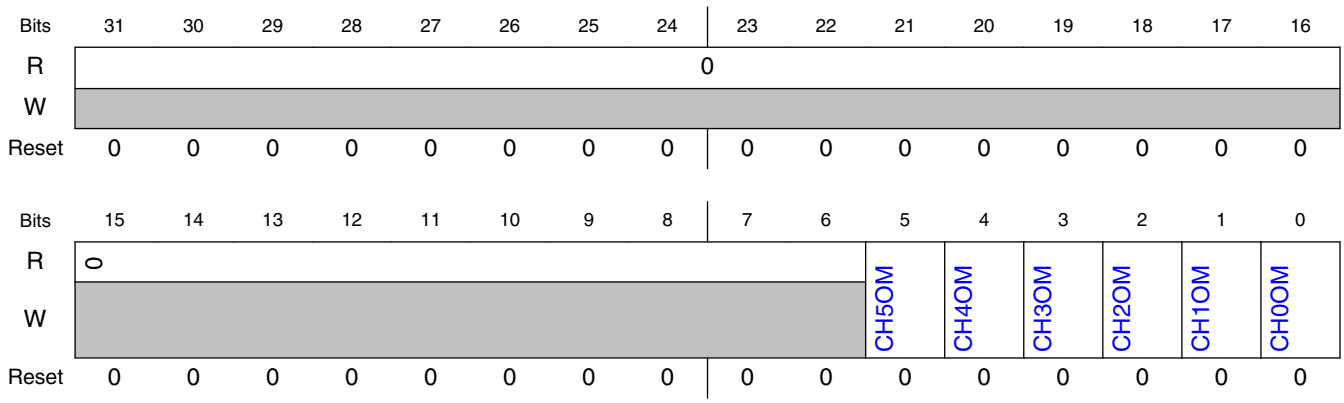
34.4.3.12.2 Function

This register provides a mask for each FTM channel. The mask of a channel determines if its output responds, that is, it is masked or not, when a match occurs. This feature is used for BLDC control where the PWM signal is presented to an electric motor at specific times to provide electronic commutation.

Any write to the OUTMASK register, stores the value in its write buffer. The register is updated with the value of its write buffer according to PWM synchronization.

Output Mask bits must not be set for trigger mode.

34.4.3.12.3 Diagram



34.4.3.12.4 Fields

Field	Function
31-6 —	Reserved
5-0 CHnOM	Channel 0 Output Mask Defines if the channel output is masked or unmasked. 0b - Channel output is not masked. It continues to operate normally. 1b - Channel output is masked. It is forced to its inactive state.

34.4.3.13 Function For Linked Channels (COMBINE)

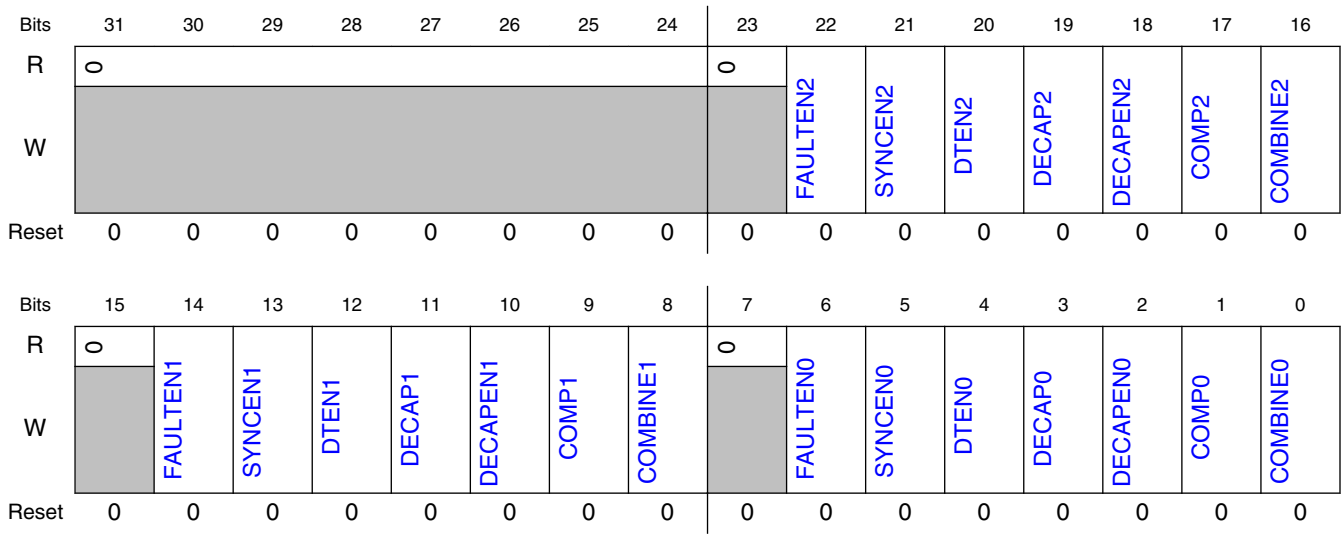
34.4.3.13.1 Offset

Register	Offset
COMBINE	64h

34.4.3.13.2 Function

This register contains the configuration bits for each pair of channels.

34.4.3.13.3 Diagram



34.4.3.13.4 Fields

Field	Function
31-24 —	Reserved
23 —	Reserved
22 FAULTEN2	Fault Control Enable For n = 4 Enables the fault control in channels (n) and (n+1). This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The fault control in this pair of channels is disabled. 1b - The fault control in this pair of channels is enabled.
21 SYNCEN2	Synchronization Enable For n = 4 Enables PWM synchronization of registers C(n)V and C(n+1)V. 0b - The PWM synchronization in this pair of channels is disabled. 1b - The PWM synchronization in this pair of channels is enabled.
20 DTEN2	Deadtime Enable For n = 4 Enables the deadtime insertion in the channels (n) and (n+1). This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The deadtime insertion in this pair of channels is disabled. 1b - The deadtime insertion in this pair of channels is enabled.
19 DECAP2	Dual Edge Capture Mode Captures For n = 4 Enables the capture of the FTM counter value according to the channel (n) input event and the configuration of the dual edge capture bits.

Table continues on the next page...

Field	Function
	This field applies only when DECAPEN = 1. DECAP bit is cleared automatically by hardware if dual edge capture – one-shot mode is selected and when the capture of channel (n+1) event is made. 0b - The dual edge captures are inactive. 1b - The dual edge captures are active.
18 DECAPEN2	Dual Edge Capture Mode Enable For n = 4 Enables the Dual Edge Capture mode in the channels (n) and (n+1). See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.
17 COMP2	Complement Of Channel (n) For n = 4 In Complementary mode the channel (n+1) output is the inverse of the channel (n) output. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The channel (n+1) output is the same as the channel (n) output. 1b - The channel (n+1) output is the complement of the channel (n) output.
16 COMBINE2	Combine Channels For n = 4 Used on the selection of the combine mode for channels (n) and (n+1). See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.
15 —	Reserved
14 FAULTEN1	Fault Control Enable For n = 2 Enables the fault control in channels (n) and (n+1). This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The fault control in this pair of channels is disabled. 1b - The fault control in this pair of channels is enabled.
13 SYNCEN1	Synchronization Enable For n = 2 Enables PWM synchronization of registers C(n)V and C(n+1)V. 0b - The PWM synchronization in this pair of channels is disabled. 1b - The PWM synchronization in this pair of channels is enabled.
12 DTEN1	Deadtime Enable For n = 2 Enables the deadtime insertion in the channels (n) and (n+1). This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The deadtime insertion in this pair of channels is disabled. 1b - The deadtime insertion in this pair of channels is enabled.
11 DECAP1	Dual Edge Capture Mode Captures For n = 2 Enables the capture of the FTM counter value according to the channel (n) input event and the configuration of the dual edge capture bits. This field applies only when DECAPEN = 1. DECAP bit is cleared automatically by hardware if Dual Edge Capture – One-Shot mode is selected and when the capture of channel (n+1) event is made. 0b - The dual edge captures are inactive. 1b - The dual edge captures are active.
10 DECAPEN1	Dual Edge Capture Mode Enable For n = 2 Enables the Dual Edge Capture mode in the channels (n) and (n+1). See Channel Modes.

Table continues on the next page...

Field	Function
	This field is write protected. It can be written only when MODE[WPDIS] = 1.
9 COMP1	Complement Of Channel (n) For n = 2 In Complementary mode the channel (n+1) output is the inverse of the channel (n) output. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The channel (n+1) output is the same as the channel (n) output. 1b - The channel (n+1) output is the complement of the channel (n) output.
8 COMBINE1	Combine Channels For n = 2 Used on the selection of the combine mode for channels (n) and (n+1). See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.
7 —	Reserved
6 FAULTEN0	Fault Control Enable For n = 0 Enables the fault control in channels (n) and (n+1). This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The fault control in this pair of channels is disabled. 1b - The fault control in this pair of channels is enabled.
5 SYNCEN0	Synchronization Enable For n = 0 Enables PWM synchronization of registers C(n)V and C(n+1)V. 0b - The PWM synchronization in this pair of channels is disabled. 1b - The PWM synchronization in this pair of channels is enabled.
4 DTEN0	Deadtime Enable For n = 0 Enables the deadtime insertion in the channels (n) and (n+1). This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The deadtime insertion in this pair of channels is disabled. 1b - The deadtime insertion in this pair of channels is enabled.
3 DECAP0	Dual Edge Capture Mode Captures For n = 0 Enables the capture of the FTM counter value according to the channel (n) input event and the configuration of the dual edge capture bits. This field applies only when DECAPEN = 1. DECAP bit is cleared automatically by hardware if dual edge capture – one-shot mode is selected and when the capture of channel (n+1) event is made. 0b - The dual edge captures are inactive. 1b - The dual edge captures are active.
2 DECAPEN0	Dual Edge Capture Mode Enable For n = 0 Enables the Dual Edge Capture mode in the channels (n) and (n+1). See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.
1 COMP0	Complement Of Channel (n) For n = 0 In Complementary mode the channel (n+1) output is the inverse of the channel (n) output. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The channel (n+1) output is the same as the channel (n) output. 1b - The channel (n+1) output is the complement of the channel (n) output.
0	Combine Channels For n = 0

Field	Function
COMBINE0	Used on the selection of the combine mode for channels (n) and (n+1). See Channel Modes. This field is write protected. It can be written only when MODE[WPDIS] = 1.

34.4.3.14 Deadtime Configuration (DEADTIME)

34.4.3.14.1 Offset

Register	Offset
DEADTIME	68h

34.4.3.14.2 Function

This register selects the deadtime prescaler and value for all pair of channels.

34.4.3.14.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0												0			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								DTPS		DTVAL					
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

34.4.3.14.4 Fields

Field	Function
31-20 —	Reserved
19-16 —	Reserved
15-8 —	Reserved

Table continues on the next page...

Field	Function
7-6 DTPS	Deadtime Prescaler Value Selects the division factor of the FTM input clock. This prescaled clock is used by the deadtime counter. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0xb - Divide the FTM input clock by 1. 10b - Divide the FTM input clock by 4. 11b - Divide the FTM input clock by 16.
5-0 DTVAL	Deadtime Value Selects the deadtime value. Deadtime insert value = (DTPS × DTVAL). This field is write protected. It can be written only when MODE[WPDIS] = 1.

34.4.3.15 FTM External Trigger (EXTTRIG)

34.4.3.15.1 Offset

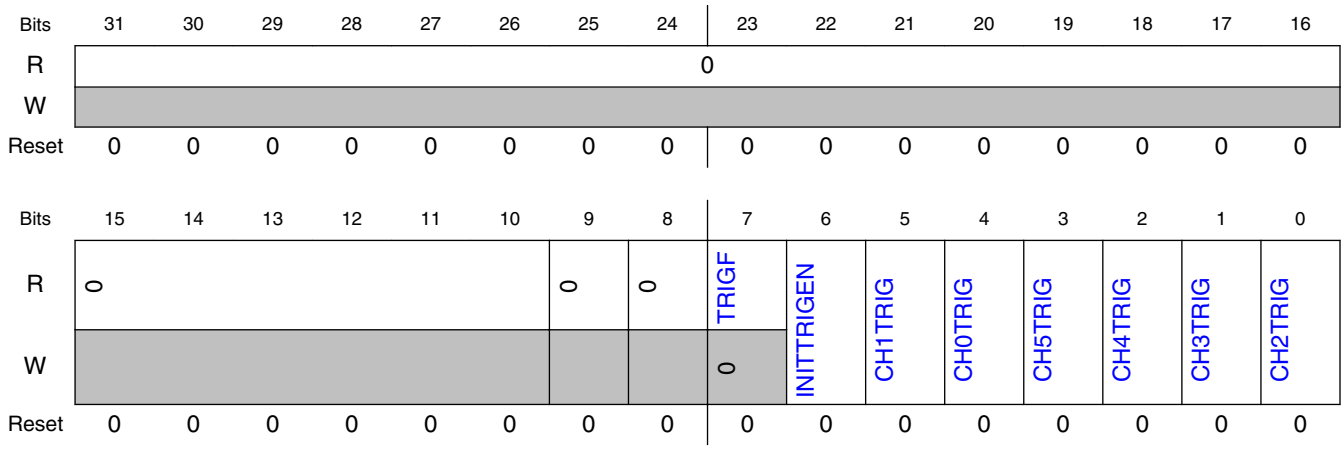
Register	Offset
EXTTRIG	6Ch

34.4.3.15.2 Function

This register:

- Indicates when the external trigger was generated
- Enables the generation of a trigger when the FTM counter is equal to its initial value
- Selects which channels are used in the generation of the external trigger

34.4.3.15.3 Diagram



34.4.3.15.4 Fields

Field	Function
31-10 —	Reserved
9 —	Reserved
8 —	Reserved
7 TRIGF	Channel Trigger Flag Set by hardware when a channel trigger is generated. Clear TRIGF by reading EXTTRIG while TRIGF is set and then writing a 0 to TRIGF. Writing a 1 to TRIGF has no effect. If another channel trigger is generated before the clearing sequence is completed, the sequence is reset so TRIGF remains set after the clear sequence is completed for the earlier TRIGF. 0b - No channel trigger was generated. 1b - A channel trigger was generated.
6 INITTRIGEN	Initialization Trigger Enable Enables the generation of the trigger when the FTM counter is equal to the CNTIN register. 0b - The generation of initialization trigger is disabled. 1b - The generation of initialization trigger is enabled.
5 CH1TRIG	Channel 1 External Trigger Enable Enables the generation of the external trigger when FTM counter = C1V. 0b - The generation of this external trigger is disabled. 1b - The generation of this external trigger is enabled.
4 CH0TRIG	Channel 0 External Trigger Enable Enables the generation of the external trigger when FTM counter = C0V. 0b - The generation of this external trigger is disabled. 1b - The generation of this external trigger is enabled.
3	Channel 5 External Trigger Enable

Table continues on the next page...

Field	Function
CH5TRIG	Enables the generation of the external trigger when FTM counter = C5V. 0b - The generation of this external trigger is disabled. 1b - The generation of this external trigger is enabled.
2 CH4TRIG	Channel 4 External Trigger Enable Enables the generation of the external trigger when FTM counter = C4V. 0b - The generation of this external trigger is disabled. 1b - The generation of this external trigger is enabled.
1 CH3TRIG	Channel 3 External Trigger Enable Enables the generation of the external trigger when FTM counter = C3V. 0b - The generation of this external trigger is disabled. 1b - The generation of this external trigger is enabled.
0 CH2TRIG	Channel 2 External Trigger Enable Enables the generation of the external trigger when FTM counter = C2V. 0b - The generation of this external trigger is disabled. 1b - The generation of this external trigger is enabled.

34.4.3.16 Channels Polarity (POL)

34.4.3.16.1 Offset

Register	Offset
POL	70h

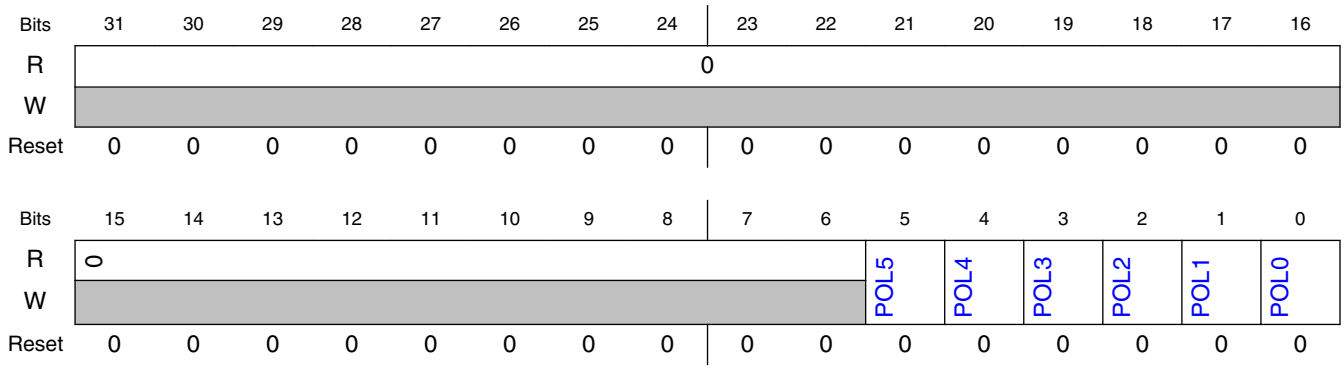
34.4.3.16.2 Function

This register defines the output polarity of the FTM channels.

NOTE

The channel safe value is the value of its POL bit.The channel safe value is driven on the channel output when the fault control is enabled and a fault condition is detected.

34.4.3.16.3 Diagram



34.4.3.16.4 Fields

Field	Function
31-6 —	Reserved
5-0 POLn	Channel 0 Polarity Defines the polarity of the channel output. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The channel polarity is active high. 1b - The channel polarity is active low.

34.4.3.17 Fault Mode Status (FMS)

34.4.3.17.1 Offset

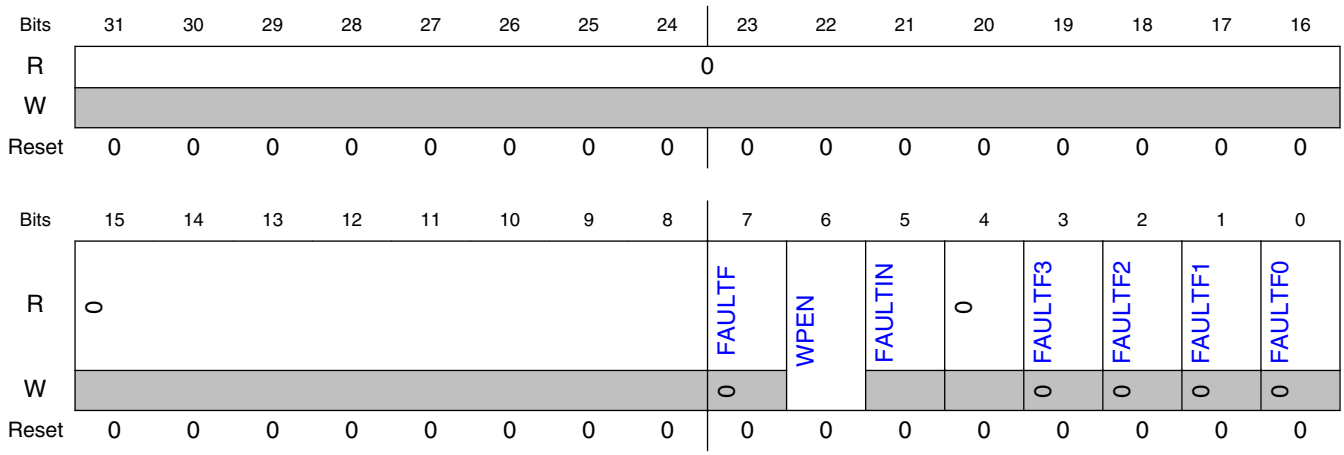
Register	Offset
FMS	74h

34.4.3.17.2 Function

This register contains:

- the write protection enable bit
- the fault detection flags
- the logic OR of the enabled fault inputs

34.4.3.17.3 Diagram



34.4.3.17.4 Fields

Field	Function
31-8 —	Reserved
7 FAULTF	Fault Detection Flag Represents the logic OR of the FAULTF bit of each enabled fault input. Clear FAULTF by reading the FMS register while FAULTF is set and then writing a 0 to FAULTF while there is no existing fault condition at the enabled fault inputs. Writing a 1 to FAULTF has no effect. If another fault condition is detected in an enabled fault input before the clearing sequence is completed, the sequence is reset so FAULTF remains set after the clearing sequence is completed for the earlier fault condition. FAULTF is also cleared when FAULTF bit of each enabled fault input is cleared. 0b - No fault condition was detected. 1b - A fault condition was detected.
6 WPEN	Write Protection Enable The WPEN bit is the negation of the WPDIS bit. WPEN is set when 1 is written to it. WPEN is cleared when WPEN bit is read as a 1 and then 1 is written to WPDIS. Writing 0 to WPEN has no effect. 0b - Write protection is disabled. Write protected bits can be written. 1b - Write protection is enabled. Write protected bits cannot be written.
5 FAULTIN	Fault Inputs Represents the logic OR of the enabled fault inputs after their filter (if their filter is enabled) when fault control is enabled. 0b - The logic OR of the enabled fault inputs is 0. 1b - The logic OR of the enabled fault inputs is 1.
4 —	Reserved
3 FAULTF3	Fault Detection Flag 3 Set by hardware when fault control is enabled, the corresponding fault input is enabled and a fault condition is detected at the fault input.

Table continues on the next page...

Field	Function
	Clear FAULTF3 by reading the FMS register while FAULTF3 is set and then writing a 0 to FAULTF3 while there is no existing fault condition at the corresponding fault input. Writing a 1 to FAULTF3 has no effect. FAULTF3 bit is also cleared when FAULTF bit is cleared. If another fault condition is detected at the corresponding fault input before the clearing sequence is completed, the sequence is reset so FAULTF3 remains set after the clearing sequence is completed for the earlier fault condition. 0b - No fault condition was detected at the fault input. 1b - A fault condition was detected at the fault input.
2 FAULTF2	Fault Detection Flag 2 Set by hardware when fault control is enabled, the corresponding fault input is enabled and a fault condition is detected at the fault input. Clear FAULTF2 by reading the FMS register while FAULTF2 is set and then writing a 0 to FAULTF2 while there is no existing fault condition at the corresponding fault input. Writing a 1 to FAULTF2 has no effect. FAULTF2 bit is also cleared when FAULTF bit is cleared. If another fault condition is detected at the corresponding fault input before the clearing sequence is completed, the sequence is reset so FAULTF2 remains set after the clearing sequence is completed for the earlier fault condition. 0b - No fault condition was detected at the fault input. 1b - A fault condition was detected at the fault input.
1 FAULTF1	Fault Detection Flag 1 Set by hardware when fault control is enabled, the corresponding fault input is enabled and a fault condition is detected at the fault input. Clear FAULTF1 by reading the FMS register while FAULTF1 is set and then writing a 0 to FAULTF1 while there is no existing fault condition at the corresponding fault input. Writing a 1 to FAULTF1 has no effect. FAULTF1 bit is also cleared when FAULTF bit is cleared. If another fault condition is detected at the corresponding fault input before the clearing sequence is completed, the sequence is reset so FAULTF1 remains set after the clearing sequence is completed for the earlier fault condition. 0b - No fault condition was detected at the fault input. 1b - A fault condition was detected at the fault input.
0 FAULTF0	Fault Detection Flag 0 Set by hardware when fault control is enabled, the corresponding fault input is enabled and a fault condition is detected at the fault input. Clear FAULTF0 by reading the FMS register while FAULTF0 is set and then writing a 0 to FAULTF0 while there is no existing fault condition at the corresponding fault input. Writing a 1 to FAULTF0 has no effect. FAULTF0 bit is also cleared when FAULTF bit is cleared. If another fault condition is detected at the corresponding fault input before the clearing sequence is completed, the sequence is reset so FAULTF0 remains set after the clearing sequence is completed for the earlier fault condition. 0b - No fault condition was detected at the fault input. 1b - A fault condition was detected at the fault input.

34.4.3.18 Input Capture Filter Control (FILTER)

34.4.3.18.1 Offset

Register	Offset
FILTER	78h

34.4.3.18.2 Function

This register selects the filter value for the inputs of channels.

Channels 4, 5, 6 and 7 do not have an input filter.

NOTE

Writing to the FILTER register has immediate effect and must be done only when the channels 0, 1, 2, and 3 are not in input modes. Failure to do this could result in a missing valid signal.

34.4.3.18.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CH3FVAL				CH2FVAL				CH1FVAL				CH0FVAL			
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

34.4.3.18.4 Fields

Field	Function
31-16 —	Reserved
15-12 CH3FVAL	Channel 3 Input Filter Selects the filter value for the channel input. The filter is disabled when the value is zero.
11-8 CH2FVAL	Channel 2 Input Filter Selects the filter value for the channel input. The filter is disabled when the value is zero.
7-4	Channel 1 Input Filter

Table continues on the next page...

Field	Function
CH1FVAL	Selects the filter value for the channel input. The filter is disabled when the value is zero.
3-0 CH0FVAL	Channel 0 Input Filter Selects the filter value for the channel input. The filter is disabled when the value is zero.

34.4.3.19 Fault Control (FLTCTRL)

34.4.3.19.1 Offset

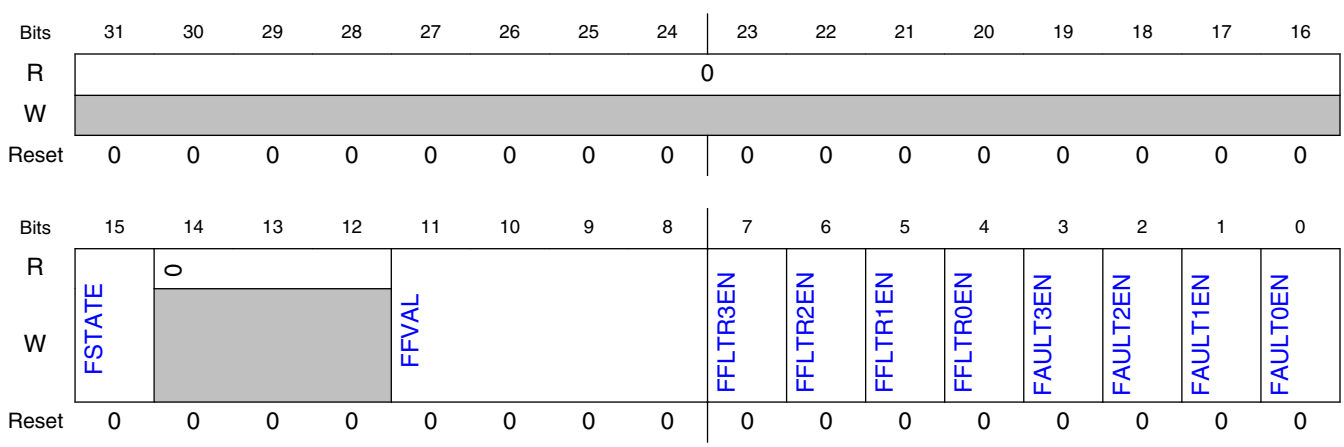
Register	Offset
FLTCTRL	7Ch

34.4.3.19.2 Function

This register contains:

- the state of channels output when a fault event happens
- the enable for each fault input
- the filter enable for each fault input
- the filter value for enabled fault inputs and with filter

34.4.3.19.3 Diagram



34.4.3.19.4 Fields

Field	Function
31-16 —	Reserved
15 FSTATE	Fault output state This configuration allows to put the FTM outputs tri-stated when a fault event is ongoing. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - FTM outputs will be placed into safe values when fault events in ongoing (defined by POL bits). 1b - FTM outputs will be tri-stated when fault event is ongoing
14-12 —	Reserved
11-8 FFVAL	Fault Input Filter Selects the filter value for the fault inputs. The fault filter is disabled when the value is zero. **NOTE:** Writing to this field has immediate effect and must be done only when the fault control or all fault inputs are disabled. Failure to do this could result in a missing fault detection.
7 FFLTR3EN	Fault Input 3 Filter Enable Enables the filter for the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Fault input filter is disabled. 1b - Fault input filter is enabled.
6 FFLTR2EN	Fault Input 2 Filter Enable Enables the filter for the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Fault input filter is disabled. 1b - Fault input filter is enabled.
5 FFLTR1EN	Fault Input 1 Filter Enable Enables the filter for the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Fault input filter is disabled. 1b - Fault input filter is enabled.
4 FFLTR0EN	Fault Input 0 Filter Enable Enables the filter for the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Fault input filter is disabled. 1b - Fault input filter is enabled.
3 FAULT3EN	Fault Input 3 Enable Enables the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Fault input is disabled. 1b - Fault input is enabled.
2	Fault Input 2 Enable

Table continues on the next page...

Field	Function
FAULT2EN	Enables the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Fault input is disabled. 1b - Fault input is enabled.
1 FAULT1EN	Fault Input 1 Enable Enables the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Fault input is disabled. 1b - Fault input is enabled.
0 FAULT0EN	Fault Input 0 Enable Enables the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Fault input is disabled. 1b - Fault input is enabled.

34.4.3.20 Quadrature Decoder Control And Status (QDCTRL)

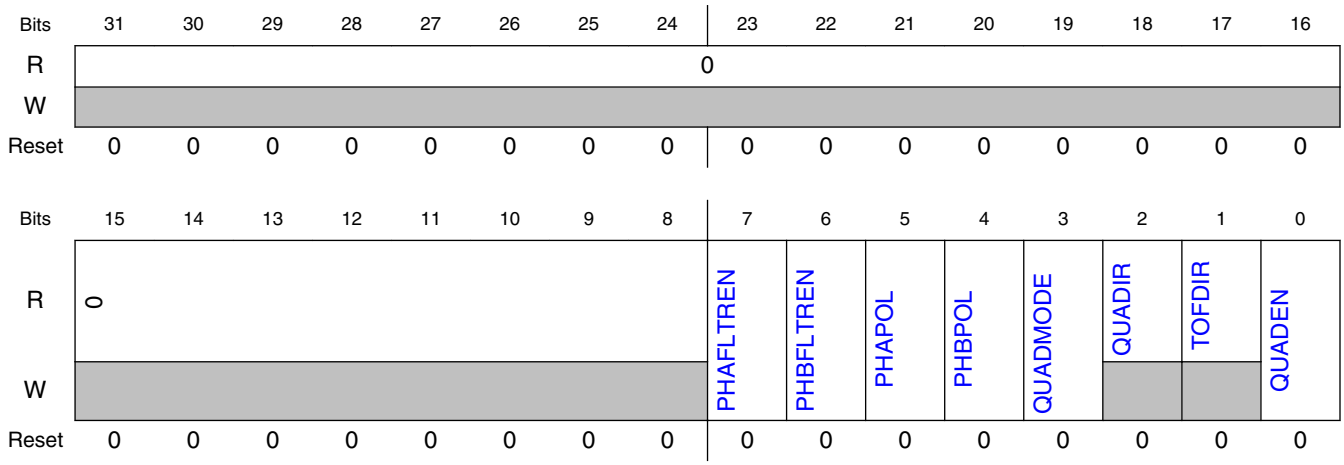
34.4.3.20.1 Offset

Register	Offset
QDCTRL	80h

34.4.3.20.2 Function

This register has the control and status bits for the Quadrature Decoder mode.

34.4.3.20.3 Diagram



34.4.3.20.4 Fields

Field	Function
31-8 —	Reserved
7 PHAFLTREN	Phase A Input Filter Enable Enables the filter for the quadrature decoder phase A input. The filter value for the phase A input is defined by the CH0FVAL field of FILTER. The phase A filter is also disabled when CH0FVAL is zero. 0b - Phase A input filter is disabled. 1b - Phase A input filter is enabled.
6 PHBFLTREN	Phase B Input Filter Enable Enables the filter for the quadrature decoder phase B input. The filter value for the phase B input is defined by the CH1FVAL field of FILTER. The phase B filter is also disabled when CH1FVAL is zero. 0b - Phase B input filter is disabled. 1b - Phase B input filter is enabled.
5 PHAPOL	Phase A Input Polarity Selects the polarity for the quadrature decoder phase A input. 0b - Normal polarity. Phase A input signal is not inverted before identifying the rising and falling edges of this signal. 1b - Inverted polarity. Phase A input signal is inverted before identifying the rising and falling edges of this signal.
4 PHBPOL	Phase B Input Polarity Selects the polarity for the quadrature decoder phase B input. 0b - Normal polarity. Phase B input signal is not inverted before identifying the rising and falling edges of this signal. 1b - Inverted polarity. Phase B input signal is inverted before identifying the rising and falling edges of this signal.
3 QUADMODE	Quadrature Decoder Mode Selects the encoding mode used in the Quadrature Decoder mode. 0b - Phase A and phase B encoding mode. 1b - Count and direction encoding mode.

Table continues on the next page...

Field	Function
2 QUADIR	FTM Counter Direction In Quadrature Decoder Mode Indicates the counting direction. 0b - Counting direction is decreasing (FTM counter decrement). 1b - Counting direction is increasing (FTM counter increment).
1 TOFDIR	Timer Overflow Direction In Quadrature Decoder Mode Indicates if the TOF bit was set on the top or the bottom of counting. 0b - TOF bit was set on the bottom of counting. There was an FTM counter decrement and FTM counter changes from its minimum value (CNTIN register) to its maximum value (MOD register). 1b - TOF bit was set on the top of counting. There was an FTM counter increment and FTM counter changes from its maximum value (MOD register) to its minimum value (CNTIN register).
0 QUADEN	Quadrature Decoder Mode Enable Enables the Quadrature Decoder mode. In this mode, the phase A and B input signals control the FTM counter direction. The Quadrature Decoder mode has precedence over the other modes. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - Quadrature Decoder mode is disabled. 1b - Quadrature Decoder mode is enabled.

34.4.3.21 Configuration (CONF)

34.4.3.21.1 Offset

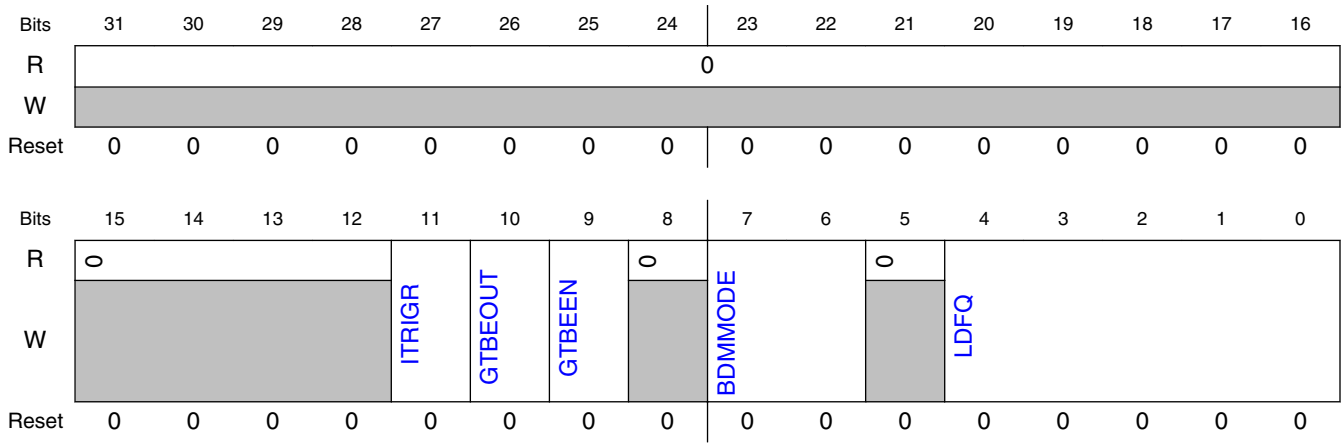
Register	Offset
CONF	84h

34.4.3.21.2 Function

This register selects the frequency of the reload opportunities, the FTM behavior in Debug mode, the use of an external global time base, and the global time base signal generation.

This register also controls if initialization trigger should be generated when a reload point is reached.

34.4.3.21.3 Diagram



34.4.3.21.4 Fields

Field	Function
31-12 —	Reserved
11 ITRIGR	Initialization trigger on Reload Point This bit controls whether an initialization trigger is generated when a reload point configured by PWMLOAD register is reached considering the FTM_CONF[LDFQ] settings. 0b - Initialization trigger is generated on counter wrap events. 1b - Initialization trigger is generated when a reload point is reached.
10 GTBEOUT	Global Time Base Output Enables the global time base signal generation to other FTMs. 0b - A global time base signal generation is disabled. 1b - A global time base signal generation is enabled.
9 GTBEEN	Global Time Base Enable Configures the FTM to use an external global time base signal that is generated by another FTM. 0b - Use of an external global time base is disabled. 1b - Use of an external global time base is enabled.
8 —	Reserved
7-6 BDMMODE	Debug Mode Selects the FTM behavior in Debug mode. See Debug mode.
5 —	Reserved
4-0 LDFQ	Frequency of the Reload Opportunities The LDFQ[4:0] bits define the number of enabled reload opportunities should happen until an enabled reload opportunity becomes a reload point. See Reload Points LDFQ = 0: All reload opportunities are reload points.

Field	Function
	LDFQ = 1: There is a reload point each 2 reload oportunities. LDFQ = 2: There is a reload point each 3 reload oportunities. LDFQ = 3: There is a reload point each 4 reload oportunities. This pattern continues up to a maximum of 32.

34.4.3.22 FTM Fault Input Polarity (FLTPOL)

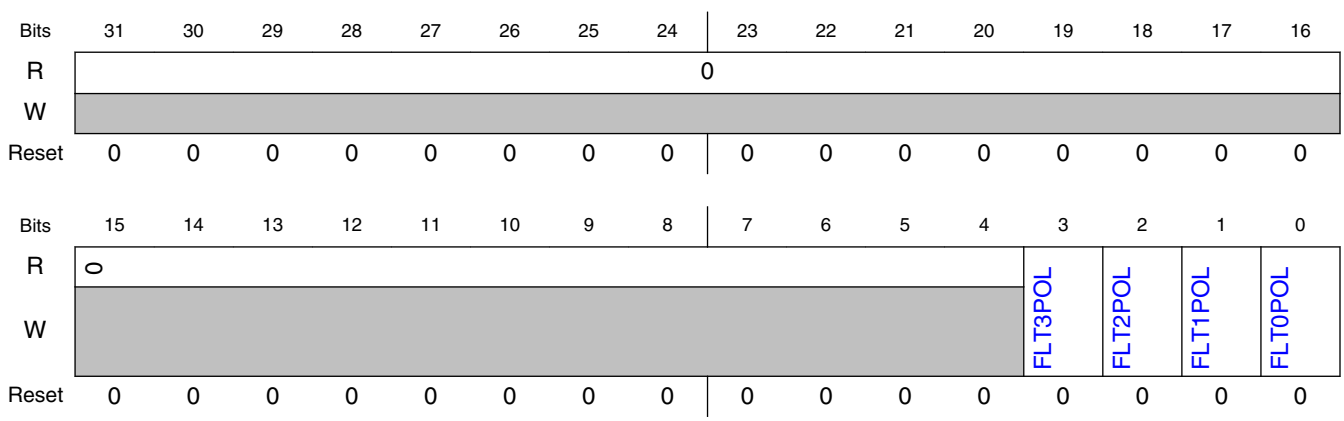
34.4.3.22.1 Offset

Register	Offset
FLTPOL	88h

34.4.3.22.2 Function

This register defines the fault inputs polarity.

34.4.3.22.3 Diagram



34.4.3.22.4 Fields

Field	Function
31-4 —	Reserved
3	Fault Input 3 Polarity

Table continues on the next page...

Field	Function
FLT3POL	Defines the polarity of the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The fault input polarity is active high. A 1 at the fault input indicates a fault. 1b - The fault input polarity is active low. A 0 at the fault input indicates a fault.
2 FLT2POL	Fault Input 2 Polarity Defines the polarity of the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The fault input polarity is active high. A 1 at the fault input indicates a fault. 1b - The fault input polarity is active low. A 0 at the fault input indicates a fault.
1 FLT1POL	Fault Input 1 Polarity Defines the polarity of the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The fault input polarity is active high. A 1 at the fault input indicates a fault. 1b - The fault input polarity is active low. A 0 at the fault input indicates a fault.
0 FLT0POL	Fault Input 0 Polarity Defines the polarity of the fault input. This field is write protected. It can be written only when MODE[WPDIS] = 1. 0b - The fault input polarity is active high. A 1 at the fault input indicates a fault. 1b - The fault input polarity is active low. A 0 at the fault input indicates a fault.

34.4.3.23 Synchronization Configuration (SYNCONF)

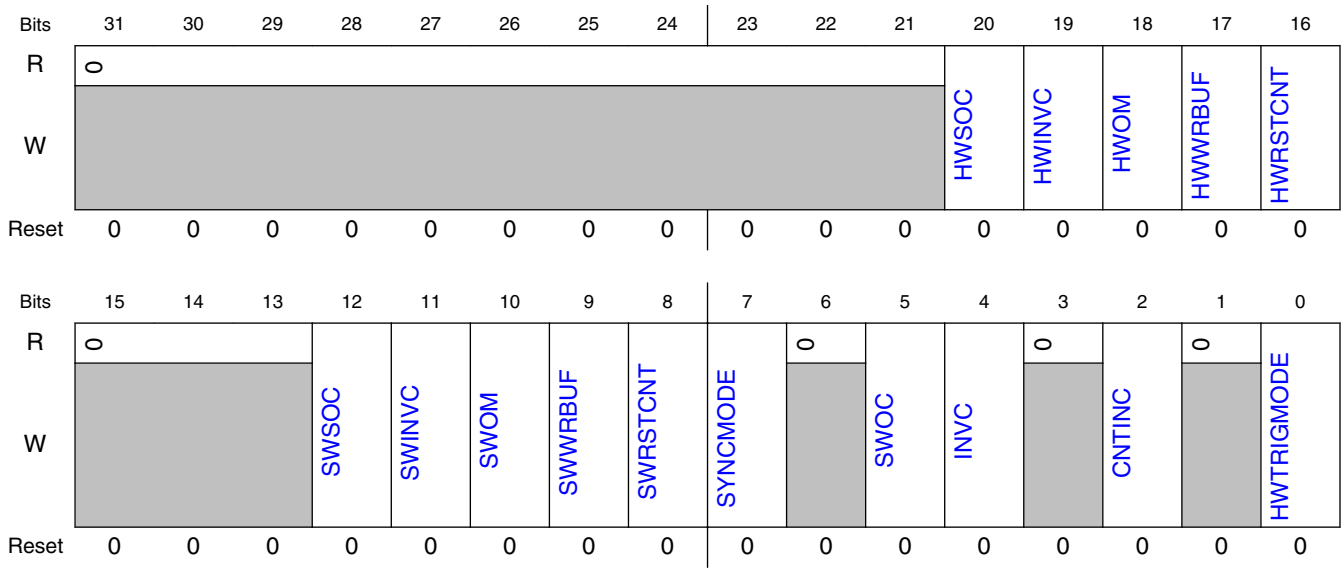
34.4.3.23.1 Offset

Register	Offset
SYNCONF	8Ch

34.4.3.23.2 Function

This register selects the PWM synchronization configuration, SWOCTRL, INVCTRL and CNTIN registers synchronization, if FTM clears the TRIGj bit, where j = 0, 1, 2, when the hardware trigger j is detected.

34.4.3.23.3 Diagram



34.4.3.23.4 Fields

Field	Function
31-21 —	Reserved
20 HWSOC	Software output control synchronization is activated by a hardware trigger 0b - A hardware trigger does not activate the SWOCTRL register synchronization. 1b - A hardware trigger activates the SWOCTRL register synchronization.
19 HWINVC	Inverting control synchronization is activated by a hardware trigger 0b - A hardware trigger does not activate the INVCTRL register synchronization. 1b - A hardware trigger activates the INVCTRL register synchronization.
18 HWOM	Output mask synchronization is activated by a hardware trigger 0b - A hardware trigger does not activate the OUTMASK register synchronization. 1b - A hardware trigger activates the OUTMASK register synchronization.
17 HWWRBUF	MOD, HCR, CNTIN, and CV registers synchronization is activated by a hardware trigger 0b - A hardware trigger does not activate MOD, HCR, CNTIN, and CV registers synchronization. 1b - A hardware trigger activates MOD, HCR, CNTIN, and CV registers synchronization.
16 HWRSTCNT	FTM counter synchronization is activated by a hardware trigger 0b - A hardware trigger does not activate the FTM counter synchronization. 1b - A hardware trigger activates the FTM counter synchronization.
15-13 —	Reserved
12 SWSOC	Software output control synchronization is activated by the software trigger 0b - The software trigger does not activate the SWOCTRL register synchronization. 1b - The software trigger activates the SWOCTRL register synchronization.
11 SWINVC	Inverting control synchronization is activated by the software trigger 0b - The software trigger does not activate the INVCTRL register synchronization. 1b - The software trigger activates the INVCTRL register synchronization.

Table continues on the next page...

Field	Function
10 SWOM	Output mask synchronization is activated by the software trigger 0b - The software trigger does not activate the OUTMASK register synchronization. 1b - The software trigger activates the OUTMASK register synchronization.
9 SWWRBUF	MOD, HCR, CNTIN, and CV registers synchronization is activated by the software trigger 0b - The software trigger does not activate MOD, HCR, CNTIN, and CV registers synchronization. 1b - The software trigger activates MOD, HCR, CNTIN, and CV registers synchronization.
8 SWRSTCNT	FTM counter synchronization is activated by the software trigger 0b - The software trigger does not activate the FTM counter synchronization. 1b - The software trigger activates the FTM counter synchronization.
7 SYNCMODE	Synchronization Mode Selects the PWM Synchronization mode. 0b - Legacy PWM synchronization is selected. 1b - Enhanced PWM synchronization is selected.
6 —	Reserved
5 SWOC	SWOCTRL Register Synchronization 0b - SWOCTRL register is updated with its buffer value at all rising edges of FTM input clock. 1b - SWOCTRL register is updated with its buffer value by the PWM synchronization.
4 INVC	INVCTRL Register Synchronization 0b - INVCTRL register is updated with its buffer value at all rising edges of FTM input clock. 1b - INVCTRL register is updated with its buffer value by the PWM synchronization.
3 —	Reserved
2 CNTINC	CNTIN Register Synchronization 0b - CNTIN register is updated with its buffer value at all rising edges of FTM input clock. 1b - CNTIN register is updated with its buffer value by the PWM synchronization.
1 —	Reserved
0 HWTRIGMODE	Hardware Trigger Mode 0b - FTM clears the TRIGj bit when the hardware trigger j is detected, where j = 0, 1,2. 1b - FTM does not clear the TRIGj bit when the hardware trigger j is detected, where j = 0, 1,2.

34.4.3.24 FTM Inverting Control (INVCTRL)

34.4.3.24.1 Offset

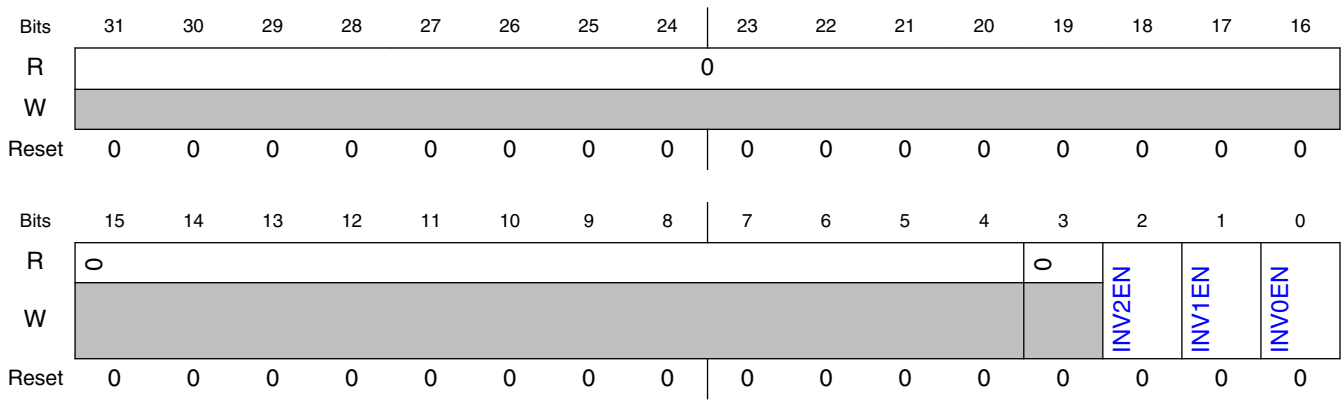
Register	Offset
INVCTRL	90h

34.4.3.24.2 Function

This register controls when the channel (n) output becomes the channel (n+1) output, and channel (n+1) output becomes the channel (n) output. Each INVmEN bit enables the inverting operation for the corresponding pair channels m.

This register has a write buffer. The INVmEN bit is updated by the INVCTRL register synchronization.

34.4.3.24.3 Diagram



34.4.3.24.4 Fields

Field	Function
31-4 —	Reserved
3 —	Reserved
2 INV2EN	Pair Channels 2 Inverting Enable 0b - Inverting is disabled. 1b - Inverting is enabled.
1 INV1EN	Pair Channels 1 Inverting Enable 0b - Inverting is disabled. 1b - Inverting is enabled.
0 INV0EN	Pair Channels 0 Inverting Enable 0b - Inverting is disabled. 1b - Inverting is enabled.

34.4.3.25 FTM Software Output Control (SWOCTRL)

34.4.3.25.1 Offset

Register	Offset
SWOCTRL	94h

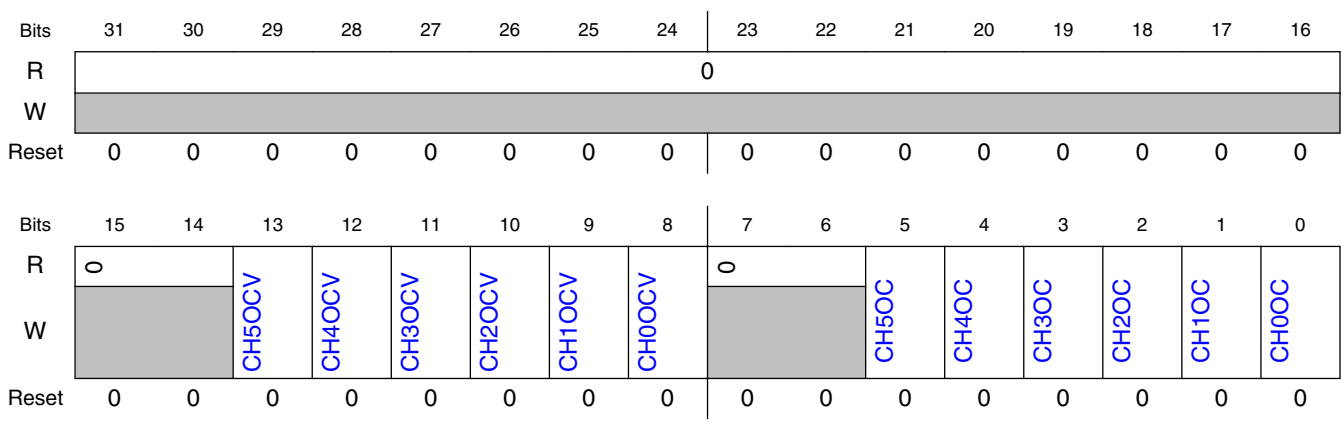
34.4.3.25.2 Function

This register enables software control of channel (n) output and defines the value forced to the channel (n) output:

- The CH(n)OC bits enable the control of the corresponding channel (n) output by software.
- The CH(n)OCV bits select the value that is forced at the corresponding channel (n) output.

This register has a write buffer. The fields are updated by the SWOCTRL register synchronization.

34.4.3.25.3 Diagram



34.4.3.25.4 Fields

Field	Function
31-16 —	Reserved
15-14 —	Reserved
13-8	Channel 0 Software Output Control Value 0b - The software output control forces 0 to the channel output.

Table continues on the next page...

Field	Function
CHnOCV	1b - The software output control forces 1 to the channel output.
7-6 —	Reserved
5-0 CHnOC	Channel 0 Software Output Control Enable 0b - The channel output is not affected by software output control. 1b - The channel output is affected by software output control.

34.4.3.26 FTM PWM Load (PWMLOAD)

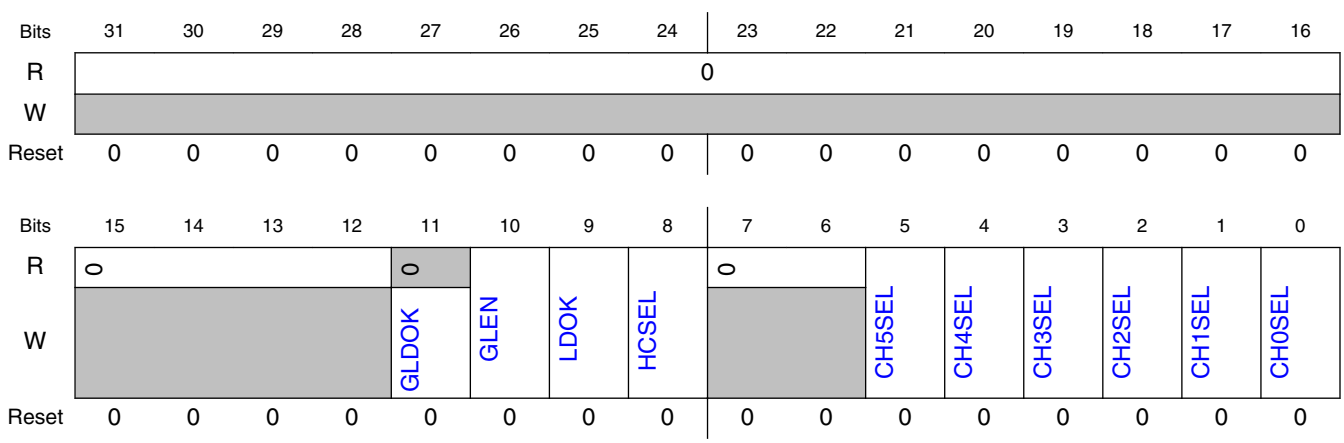
34.4.3.26.1 Offset

Register	Offset
PWMLOAD	98h

34.4.3.26.2 Function

Enables the reload of the MOD, HCR, CNTIN, C(n)V, and C(n+1)V registers with the values of their write buffers when the FTM counter changes from the MOD register value to its next value or when a channel (j) match occurs. A match occurs for channel (j) when FTM counter = C(j)V. A reload can also occurs when FTM counter = HCR register at a half cycle match. This register also controls the local and global load mechanisms.

34.4.3.26.3 Diagram



34.4.3.26.4 Fields

Field	Function
31-12 —	Reserved
11 GLDOK	Global Load OK This bit controls the global load mechanism. It generates a pulse at FTM module global load output with one FTM clock cycle width, which is used to set LDOK bits of FTM and other modules (including other FTMs). This bit is self-cleared and read value is always zero. The global load mechanism depends on SoC specific information. Refer to FTM SoC specific information to more details. 0b - No action. 1b - LDOK bit is set.
10 GLEN	Global Load Enable This bit enables the global load mechanism implemented by GLDOK. If GLEN bit is set, then an external event on the FTM global load input sets the LDOK bit. The clear of the LDOK bit is done by CPU writes '0' to the bit. 0b - Global Load Ok disabled. 1b - Global Load OK enabled. A pulse event on the module global load input sets the LDOK bit.
9 LDOK	Load Enable Enables the loading of the MOD, CNTIN, HCR and CV registers with the values of their buffers. The LDOK bit can also be set by the Global Load mechanism if GLEN bit is enabled. 0b - Loading updated values is disabled. 1b - Loading updated values is enabled.
8 HCSEL	Half Cycle Select This bit enables the half cycle match as a reload oportunity. A half cycle is defined by when the FTM counter matches the HCR register. 0b - Half cycle reload is disabled and it is not considered as a reload opportunity. 1b - Half cycle reload is enabled and it is considered as a reload opportunity.
7-6 —	Reserved
5-0 CHnSEL	Channel 0 Select 0b - Channel match is not included as a reload opportunity. 1b - Channel match is included as a reload opportunity.

34.4.3.27 Half Cycle Register (HCR)

34.4.3.27.1 Offset

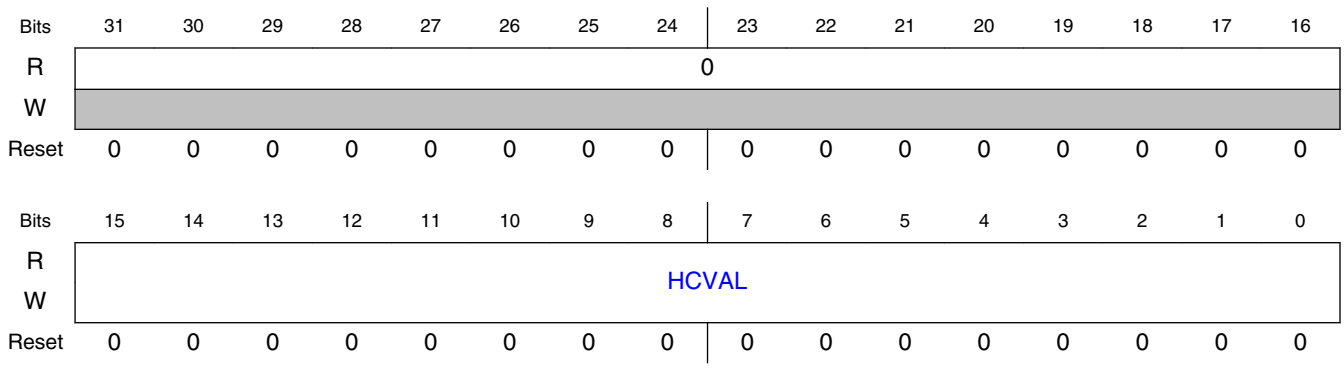
Register	Offset
HCR	9Ch

34.4.3.27.2 Function

The Half Cycle Register contains the match value for FTM half cycle reload feature. After FTM counter reaches this value, a reload opportunity is generated if FTM_PWMLOAD[HCSEL] is enabled.

Writing to the HCR register latches the value into a buffer. The HCR register is updated with the value of its write buffer according to Registers updated from write buffers.

34.4.3.27.3 Diagram



34.4.3.27.4 Fields

Field	Function
31-16 —	Reserved
15-0 HCVAL	Half Cycle Value

34.4.3.28 Mirror of Modulo Value (MOD_MIRROR)

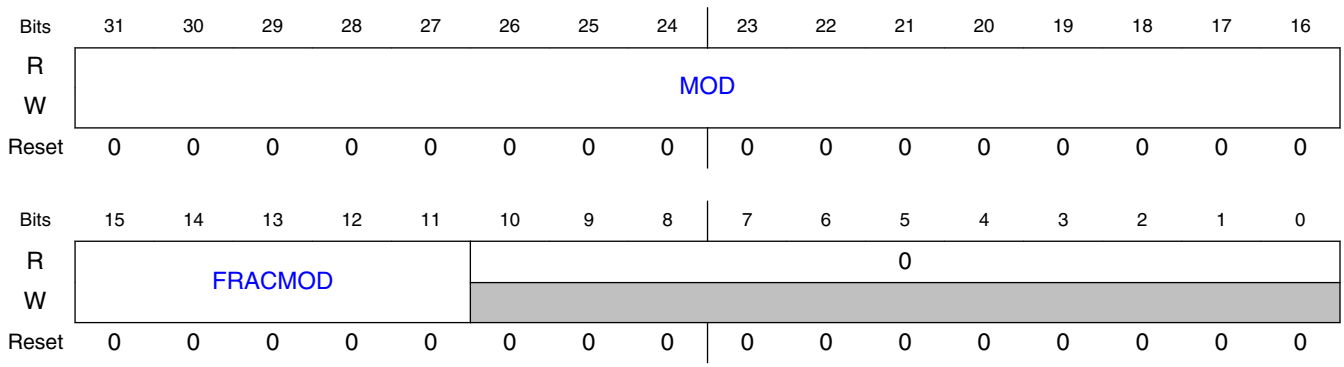
34.4.3.28.1 Offset

Register	Offset
MOD_MIRROR	200h

34.4.3.28.2 Function

This register contains the integer and fractional modulo value for the FTM counter.

34.4.3.28.3 Diagram



34.4.3.28.4 Fields

Field	Function
31-16 MOD	Mirror of the Modulo Integer Value See the field MOD of the register MOD.
15-11 FRACMOD	Modulo Fractional Value The modulo fractional value is used in the PWM period dithering. This value is added to an internal accumulator at the end of each PWM period. Writes to the field FRACMOD are done on its write buffer. The FRACMOD is updated with its write buffer value according to Registers updated from write buffers. If FTMEN = 0, a write to SC register resets manually this write coherency mechanism.
10-0 —	Reserved

34.4.3.29 Mirror of Channel (n) Match Value (C0V_MIRROR - C5V_MIRROR)

34.4.3.29.1 Offset

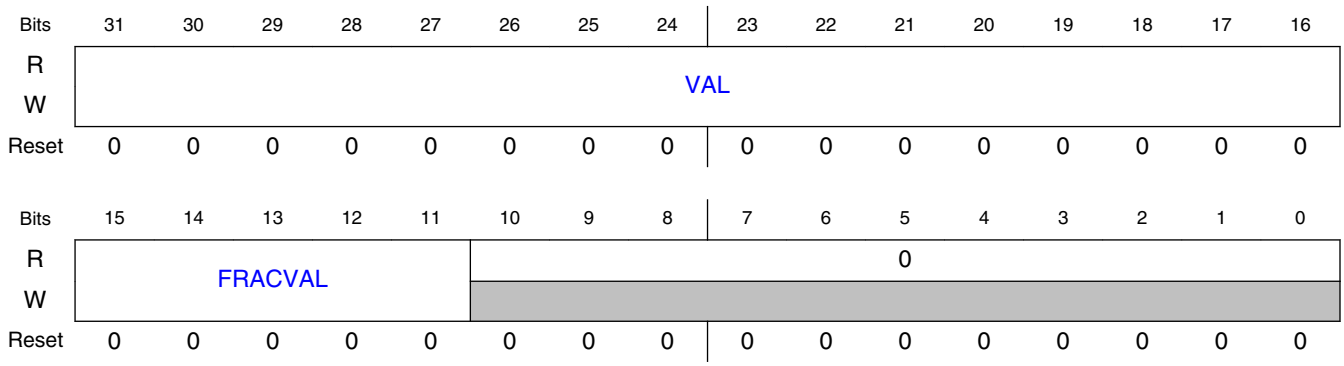
For a = 0 to 5:

Register	Offset
CaV_MIRROR	204h + (a × 4h)

34.4.3.29.2 Function

This register contains the integer and fractional value of the channel (n) match.

34.4.3.29.3 Diagram



34.4.3.29.4 Fields

Field	Function
31-16 VAL	Mirror of the Channel (n) Match Integer Value See the field VAL of the register CnV.
15-11 FRACVAL	Channel (n) Match Fractional Value The channel (n) match fractional value is used in the PWM edge dithering. This value is added to the channel (n) internal accumulator at the end of each PWM period. Writes to the field FRACVAL are done on its write buffer. The FRACVAL is updated with its write buffer value according to Registers updated from write buffers. If FTMEN = 0, a write to CnSC register resets manually this write coherency mechanism.
10-0 —	Reserved

34.5 Functional Description

34.5.1 Clock source

The FTM has only one clock domain: the FTM input clock.

34.5.1.1 Counter clock source

The CLKS[1:0] bits select one of three possible clock sources for the FTM counter or disable the FTM counter. After any chip reset, CLKS[1:0] = 0:0 so no clock source is selected.

The CLKS[1:0] bits may be read or written at any time. Disabling the FTM counter by writing 0:0 to the CLKS[1:0] bits does not affect the FTM counter value or other registers.

The fixed frequency clock is an alternative clock source for the FTM counter that allows the selection of a clock other than the FTM input clock or an external clock. This clock input is defined by chip integration. Refer to the chip specific documentation for further information. Due to FTM hardware implementation limitations, the frequency of the fixed frequency clock must not exceed 1/2 of the FTM input clock frequency.

The external clock passes through a synchronizer clocked by the FTM input clock to assure that counter transitions are properly aligned to FTM input clock transitions.Therefore, to meet Nyquist criteria considering also jitter, the frequency of the external clock source must not exceed 1/4 of the FTM input clock frequency.

34.5.2 Prescaler

The selected counter clock source passes through a prescaler that is a 7-bit counter. The value of the prescaler is selected by the PS[2:0] bits. The following figure shows an example of the prescaler counter and FTM counter.

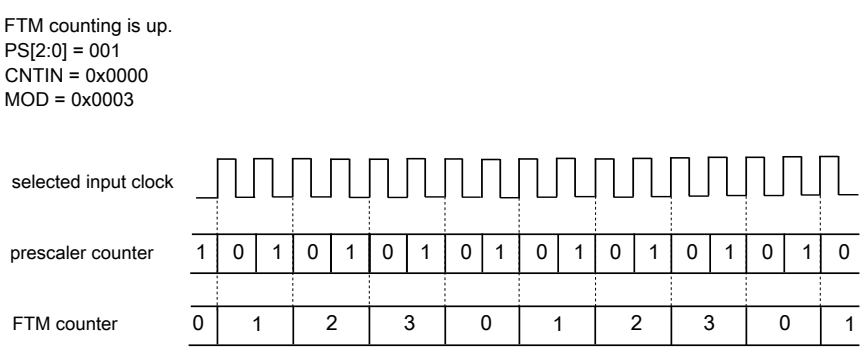


Figure 34-3. Example of the prescaler counter

34.5.3 Counter

The FTM has a 16-bit counter that is used by the channels either for input or output modes. The FTM counter clock is the selected clock divided by the prescaler.

The FTM counter has these modes of operation:

- Up counting
- Up-down counting
- Quadrature Decoder Mode

34.5.3.1 Up counting

Up counting is selected when:

- QUADEN = 0, and
- CPWMS = 0

CNTIN defines the starting value of the count and MOD defines the final value of the count, see the following figure. The value of CNTIN is loaded into the FTM counter, and the counter increments until the value of MOD is reached, at which point the counter is reloaded with the value of CNTIN.

The FTM period when using up counting is (MOD – CNTIN + 0x0001) × period of the FTM counter clock.

The TOF bit is set when the FTM counter changes from MOD to CNTIN.

A counter event happens at the same time of TOF bit set when the FTM counter changes from MOD to CNTIN. See Counter events for more details.

FTM counting is up.
CNTIN = 0xFFFC (in two's complement is equal to -4)
MOD = 0x0004

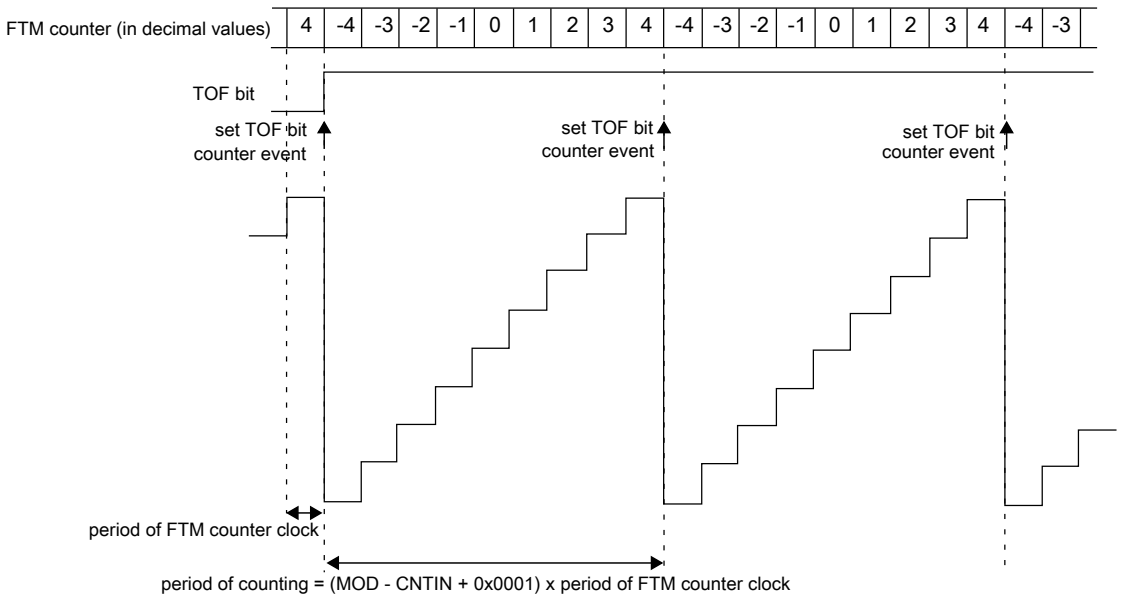


Figure 34-4. Example of FTM up and signed counting

Table 34-3. FTM counting based on CNTIN value

When	Then
CNTIN = 0x0000	The FTM counting is equivalent to TPM up counting, that is, up and unsigned counting. See the following figure.
CNTIN[15] = 1	The initial value of the FTM counter is a negative number in two's complement, so the FTM counting is up and signed.
CNTIN[15] = 0 and CNTIN ≠ 0x0000	The initial value of the FTM counter is a positive number, so the FTM counting is up and unsigned.

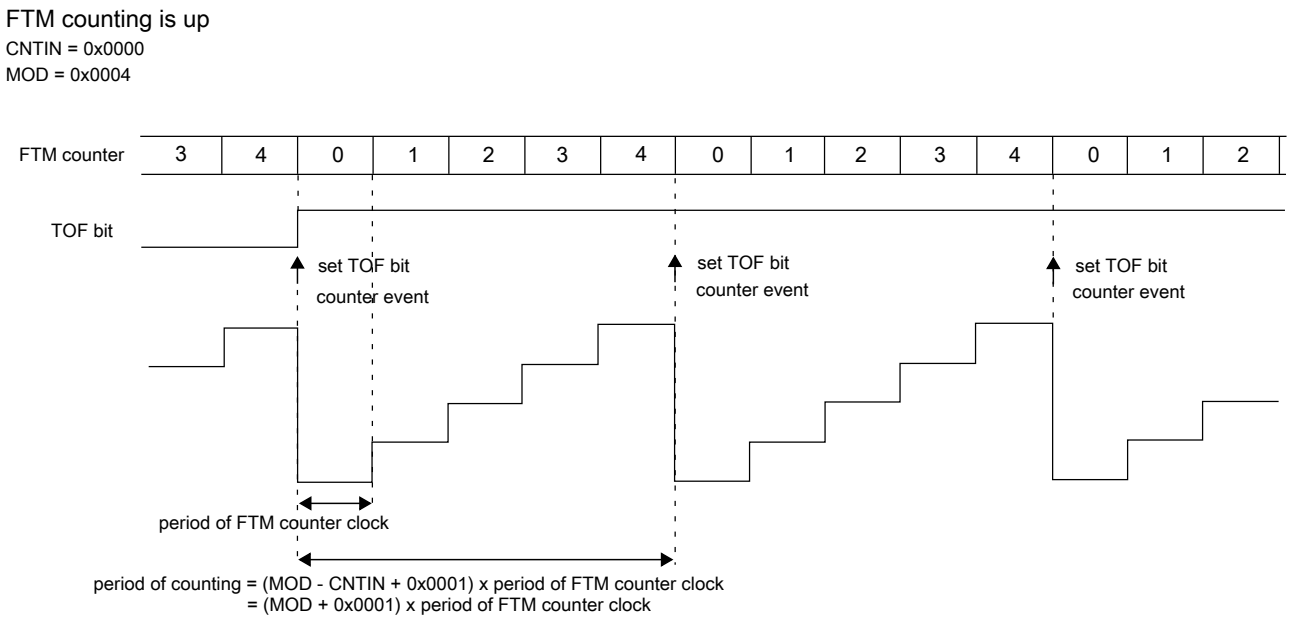


Figure 34-5. Example of FTM up counting with CNTIN = 0x0000

Note

- FTM operation is only valid when the value of the CNTIN register is less than the value of the MOD register, either in the unsigned counting or signed counting. It is the responsibility of the software to ensure that the values in the CNTIN and MOD registers meet this requirement. Any values of CNTIN and MOD that do not satisfy this criteria can result in unpredictable behavior.
- MOD = CNTIN is a redundant condition. In this case, the FTM counter is always equal to MOD and the TOF bit is set in each rising edge of the FTM counter clock.
- When MOD = 0x0000, CNTIN = 0x0000, for example after reset, and FTMEN = 1, the FTM counter remains stopped at 0x0000 until a non-zero value is written into the MOD or CNTIN registers.
- Setting CNTIN to be greater than the value of MOD is not recommended as this unusual setting may make the FTM operation difficult to comprehend. However, there is no restriction on this configuration, and an example is shown in the following figure.

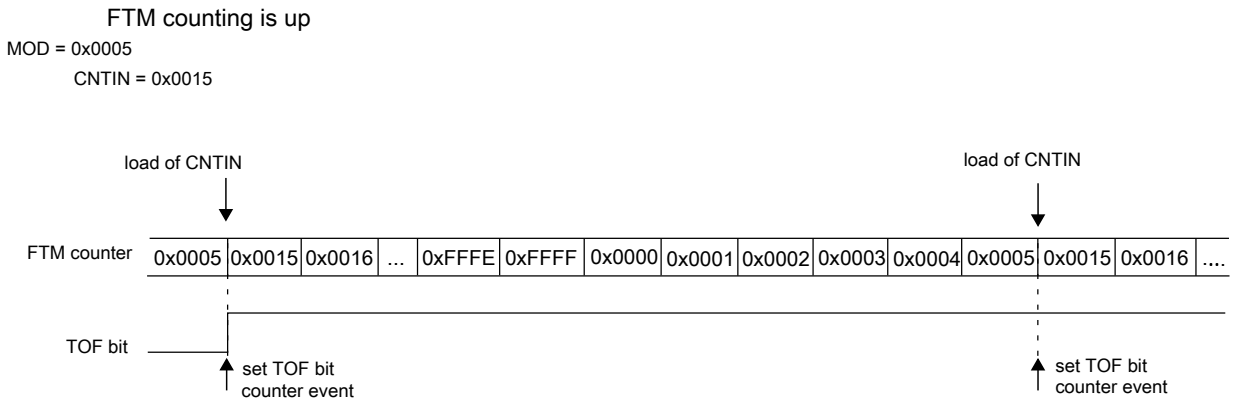


Figure 34-6. Example of up counting when the value of CNTIN is greater than the value of MOD

34.5.3.2 Up-down counting

Up-down counting is selected when:

- QUADEN = 0, and
- CPWMS = 1

CNTIN defines the starting value of the count and MOD defines the final value of the count. The value of CNTIN is loaded into the FTM counter, and the counter increments until the value of MOD is reached, at which point the counter is decremented until it returns to the value of CNTIN and the up-down counting restarts.

The FTM period when using up-down counting is 2 × (MOD – CNTIN) × period of the FTM counter clock.

The TOF bit is set when the FTM counter changes from MOD to (MOD – 1).

If (CNTIN = 0x0000), the FTM counting is equivalent to TPM up-down counting, that is, up-down and unsigned counting. See the following figure.

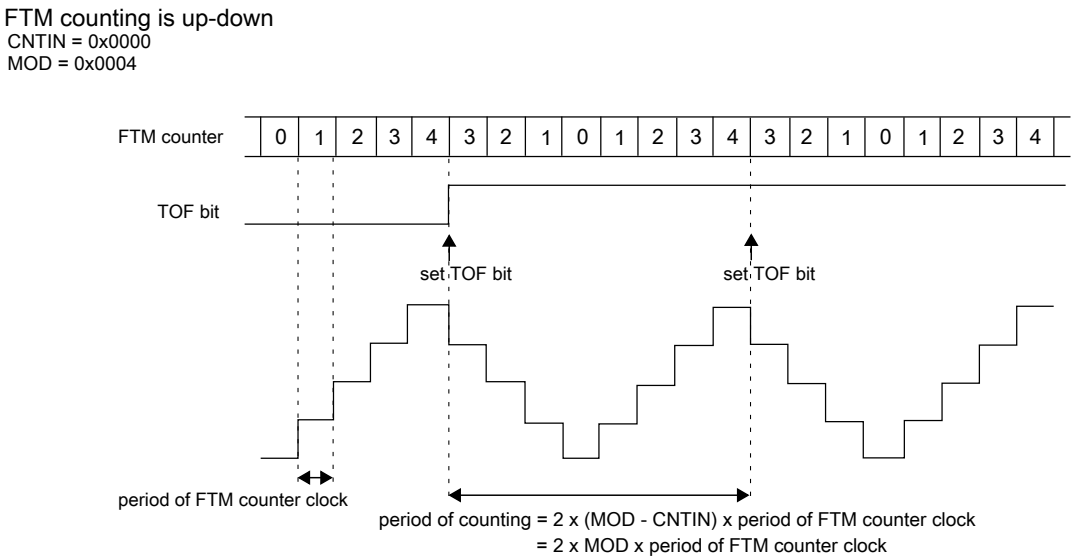


Figure 34-7. Example of up-down counting when CNTIN = 0x0000

Note

When CNTIN is different from zero in the up-down counting, a valid CPWM signal is generated:

- if CnV > CNTIN, or
- if CnV = 0 or if CnV[15] = 1. In this case, 0% CPWM is generated.

The figure below shows the possible counter events when in up-down counting mode. See Counter events for more details.

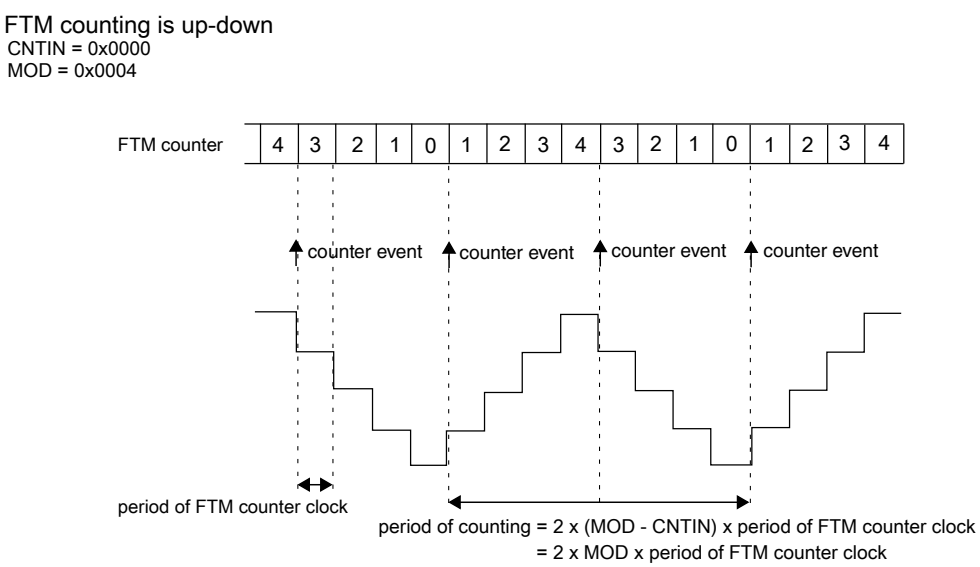


Figure 34-8. Example of counter events in up-down counting mode when CNTIN = 0x0000

34.5.3.3 Free running counter

If (FTMEN = 0) and (MOD = 0x0000 or MOD = 0xFFFF), the FTM counter is a free running counter. In this case, the FTM counter runs free from 0x0000 through 0xFFFF and the TOF bit is set when the FTM counter changes from 0xFFFF to 0x0000. See the following figure.

A counter event occurs at the same time of TOF bit set when the FTM counter changes from 0xFFFF to 0x0000. See Counter events for more details.

Figure 34-9. Example when the FTM counter is free running

The FTM counter is also a free running counter when:

- FTMEN = 1
- QUADEN = 0
- CPWMS = 0
- CNTIN = 0x0000, and
- MOD = 0xFFFF

34.5.3.4 Counter reset

Any one of the following cases resets the FTM counter to the value in the CNTIN register and the channels output to its initial value, except for channels in Output Compare mode.

- Any write to CNT.
- FTM counter synchronization.
- A channel in Input Capture mode with ICRST = 1 (FTM Counter Reset in Input Capture Mode).

Note that reseting the counter also generates a counter event. See Counter events for more details.

34.5.3.5 Counter events

Counter events can be used as reload opportunities to FTM register sychronization mechanism. See Reload Points for more details. There are some possible counter events depending on the counter mode. Please see the table below for more details.

Table 34-4. FTM counter events

When	Then
FTM counter is in up counting mode or freerunning	• A counter event happens at the same time of TOF bit set when the FTM counter changes from MOD to CNTIN (counter wrap). Figure at Up counting shows the counter event generation. • When in freerunning, there is a counter event when FTM counter changes from 0xFFFF to 0x0000. Figure at Free running counter shows the counter event generation.
FTM counter is in up-down counting mode	• In up-down counting mode, there are two possible counter events when FTM counter turns from down to up counting and when counter turns from up to down counting. User can select which point will be used to generate the counter event. Figure at Up-down counting shows the possible counter events.
FTM counter is reseted (see Counter reset) or a value different from zero is written at CLKS field	• In up-counting mode, all counter reset events or a write in the CLKS with a value different from zero generates a counter event. • In up-down counting mode, counter reset events only generates a counter event if the minimum load point when FTM counter turns from down to up counting is configured. A write in the CLKS with a value different from zero always generates a counter event in up-down counting mode.

34.5.4 Channel Modes

The following table shows the channel modes selection.

Table 34-5. Channel Modes Selection

DECAPEN	COMBINE	CPWMS	MSB:MSA	ELSB:ELSA	Mode	Configuration
X	X	X	XX	00	Pin not used for FTM—revert the channel pin to general purpose I/O or other peripheral control	
0	0	0	00	01	Input Capture	Capture on Rising Edge Only
				10		Capture on Falling Edge Only

Table continues on the next page...

Table 34-5. Channel Modes Selection (continued)

DECAPEN	COMBINE	CPWMS	MSB:MSA	ELSB:ELSA	Mode	Configuration
				11		Capture on Rising or Falling Edge
			01	01	Output Compare	Toggle Output on match
				10		Clear Output on match
				11		Set Output on match
			1X	10	Edge-Aligned PWM	High-true pulses (clear Output on match)
				X1		Low-true pulses (set Output on match)
		1	XX	10	Center-Aligned PWM	High-true pulses (clear Output on match-up)
				X1		Low-true pulses (set Output on match-up)
	1	0	XX	10	Combine PWM	High-true pulses (set on channel (n) match, and clear on channel (n+1) match)
				X1		Low-true pulses (clear on channel (n) match, and set on channel (n +1) match)
1	0	0	X0	See Table 34-6.	Dual Edge Capture	One-Shot Capture mode
			X1			Continuous Capture mode

Table 34-6. Dual Edge Capture Mode — Edge Polarity Selection

ELSB	ELSA	Channel Port Enable	Detected Edges
0	0	Disabled	No edge
0	1	Enabled	Rising edge
1	0	Enabled	Falling edge
1	1	Enabled	Rising and falling edges

34.5.5 Input Capture Mode

The Input Capture mode is selected when:

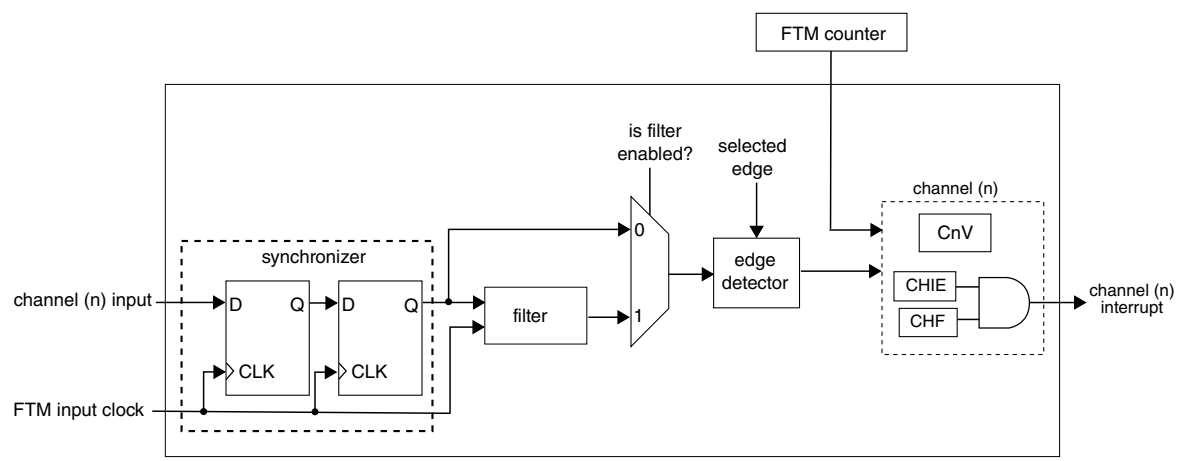
- DECAPEN = 0
- COMBINE = 0
- CPWMS = 0
- MSB:MSA = 0:0, and
- ELSB:ELSA ≠ 0:0

When a selected edge occurs on the channel input, the current value of the FTM counter is captured into the CnV register, at the same time the CHF bit is set and the channel interrupt is generated if enabled by CHIE = 1. See the following figure.

When a channel is configured for input capture, the FTMxCHn pin is an edge-sensitive input. ELSB:ELSA bits determine which edge, falling or rising, triggers input-capture event.

Writes to the CnV register are ignored in input capture mode.

While in Debug mode, the input capture function works as configured. When a selected edge event occurs, the FTM counter value, which is frozen because of Debug, is captured into the CnV register and the CHF bit is set.



Note: The filter is only available for the channels 0, 1, 2, and 3 inputs.

Figure 34-10. Diagram for Input Capture Mode

34.5.5.1 Filter for Input Capture Mode

The filter is only available on channels 0, 1, 2, and 3.

The channel input after being synchronized by FTM input clock (Figure 34-10) is the filter input.

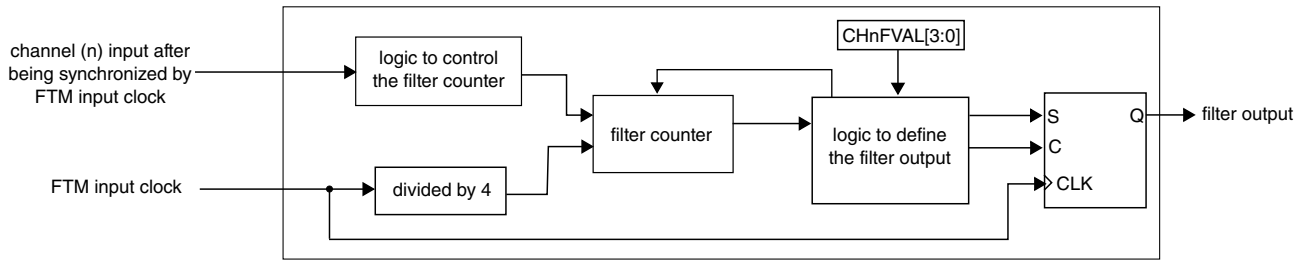


Figure 34-11. Channel Input Filter

NOTE

The maximum frequency for the channel input to be detected correctly is FTM input clock divided by 4, which is required to meet Nyquist criteria for signal sampling.

When there is a state change in the channel input, the counter is reset and starts counting up. As long as the new state is stable on the channel input, the counter continues to increment. When the counter is equal to CHnFVAL[3:0], the new channel input signal value is validated. It is then transmitted as a pulse to the edge detector.

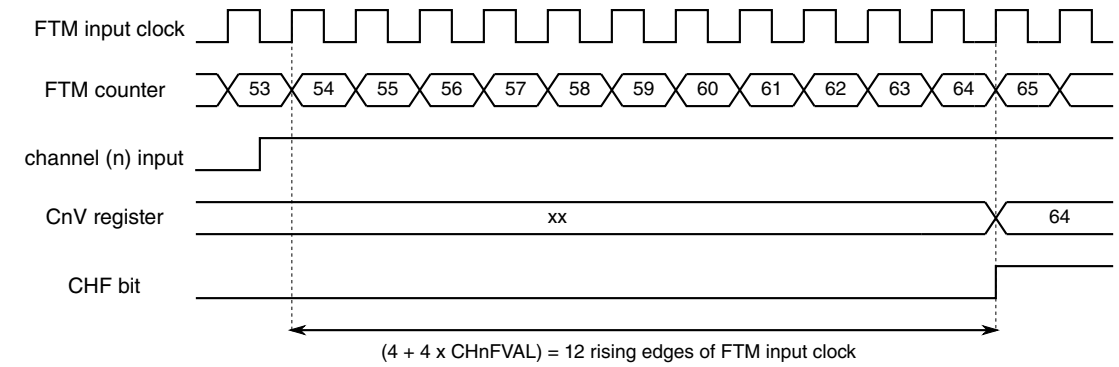
If the opposite edge appears on the channel input signal before it can be validated, the counter is reset. At the next input transition, the counter starts counting again. If a pulse is sampled as a value less than (CHnFVAL[3:0] x 4) consecutive rising edges of FTM input clock, it is regarded as a glitch and is not passed on to the edge detector.

The table below shows the delay that is added by the FTM channel input filter according to its configuration.

Table 34-7. FTM Channel Input Filter Delay

FTM channel input filter	Number of rising edges between the selected edge on channel input and setting CHF bit
• channel does not have the input filter, or • channel input filter is disabled (CHnFVAL[3:0] = 0)	• 3 rising edges of FTM input clock
• channel has the input filter, and • channel input filter is enabled (CHnFVAL[3:0] ≠ 0)	• (4 + 4 × CHnFVAL[3:0]) rising edges of FTM input clock

The following figure illustrates an example of channel input filter.



Note:
PS[2:0] = 3'b000
channel (n) in input capture mode with capture only on rising edges
CHnFVAL[3:0] = 4'h2 (channel (n) input filter is enabled)

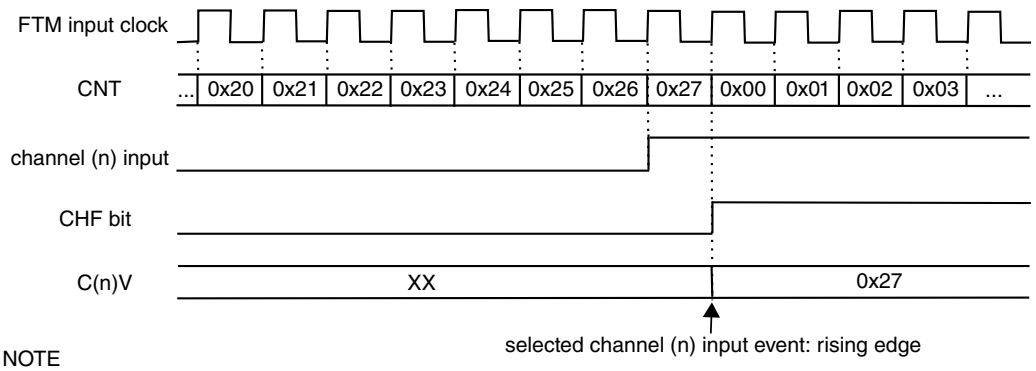
Figure 34-12. Example of Channel Input Filter

34.5.5.2 FTM Counter Reset in Input Capture Mode

If the channel (n) is in input capture mode and CnSC[ICRST = 1], then when the selected input capture event occurs in the channel (n) input signal, the current value of the FTM counter is captured into the CnV register, the CHF bit is set, the channel (n) interrupt is generated (if CHIE = 1) and the FTM counter is reset to the CNTIN register value.

This allows the FTM to measure a period/pulse being applied to the channel (n) input (number of the FTM input clocks) without having to implement a subtraction calculation in software subsequent to the event occurring.

The figure below shows the FTM counter reset when the selected input capture event is detected in a channel in input capture mode with ICRST = 1.



NOTE
Channel (n) input after its synchronizer and filter
MOD = 0xFFFF
CNTIN = 0x0000
PS[2:0] = 3'b000
ICRST = 1'b1

Figure 34-13. Example of the Input Capture mode with ICRST = 1

NOTE

- It is expected that the ICRST bit be set only when the channel is in input capture mode.
- If the FTM counter is reset because the channel is in input capture mode with ICRST = 1, then the prescaler counter (Prescaler) is also reset.

34.5.6 Output Compare mode

The Output Compare mode is selected when:

- DECAPEN = 0
- COMBINE = 0
- CPWMS = 0, and
- MSB:MSA = 0:1

In Output Compare mode, the FTM can generate timed pulses with programmable position, polarity, duration, and frequency. When the counter matches the value in the CnV register of an output compare channel, the channel (n) output can be set, cleared, or toggled.

When a channel is initially configured to Toggle mode, the previous value of the channel output is held until the first output compare event occurs.

The CHF bit is set and the channel (n) interrupt is generated if CHIE = 1 at the channel (n) match (FTM counter = CnV).

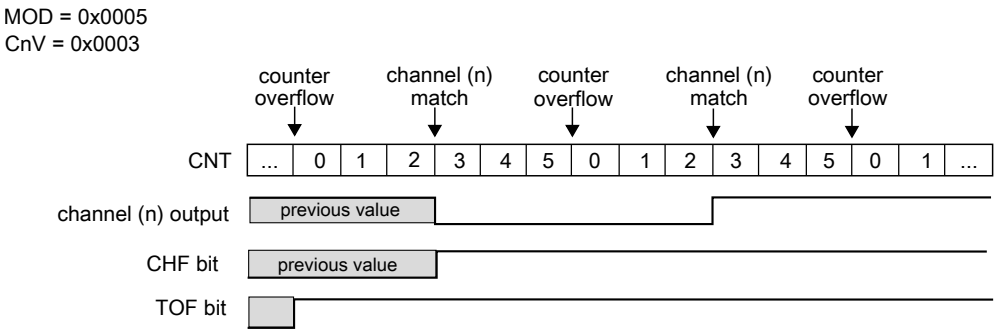


Figure 34-14. Example of the Output Compare mode when the match toggles the channel output

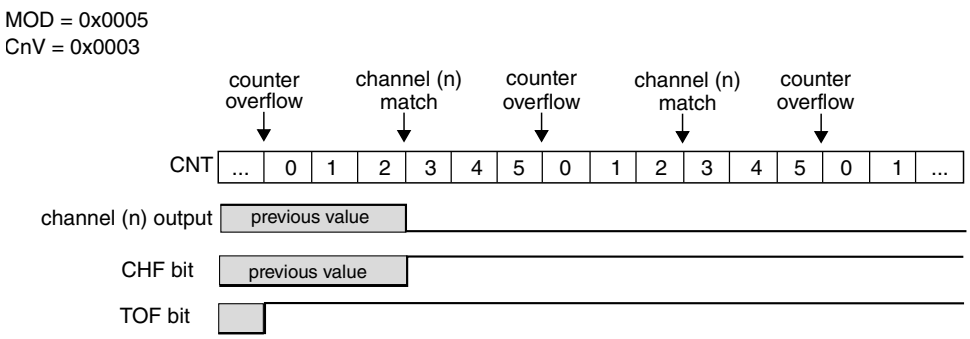


Figure 34-15. Example of the Output Compare mode when the match clears the channel output

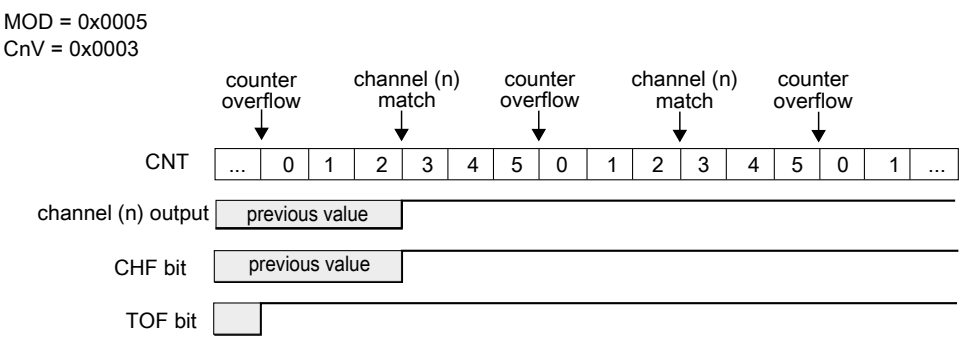


Figure 34-16. Example of the Output Compare mode when the match sets the channel output

If (ELSB:ELSA = 0:0) when the counter reaches the value in the CnV register, the CHF bit is set and the channel (n) interrupt is generated if CHIE = 1, however the channel (n) output is not modified and controlled by FTM.

34.5.7 Edge-Aligned PWM (EPWM) mode

The Edge-Aligned mode is selected when:

- QUADEN = 0

- DECAPEN = 0
- COMBINE = 0
- CPWMS = 0, and
- MSB = 1

The EPWM period is determined by (MOD − CNTIN + 0x0001) and the pulse width (duty cycle) is determined by (CnV − CNTIN).

The CHF bit is set and the channel (n) interrupt is generated if CHIE = 1 at the channel (n) match (FTM counter = CnV), that is, at the end of the pulse width.

This type of PWM signal is called edge-aligned because the leading edges of all PWM signals are aligned with the beginning of the period, which is the same for all channels within an FTM.

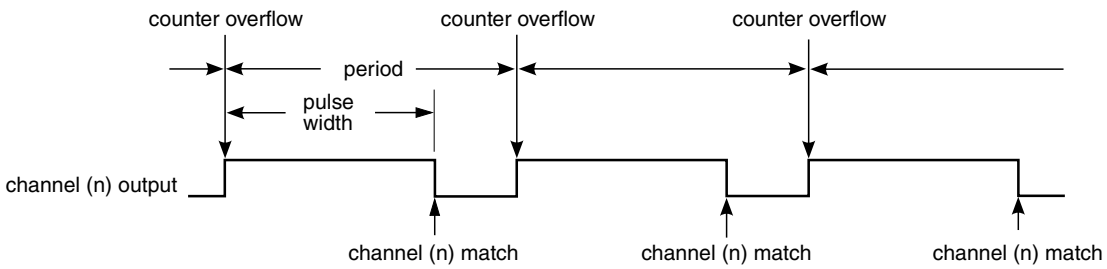


Figure 34-17. EPWM period and pulse width with ELSB:ELSA = 1:0

If (ELSB:ELSA = 0:0) when the counter reaches the value in the CnV register, the CHF bit is set and the channel (n) interrupt is generated if CHIE = 1, however the channel (n) output is not controlled by FTM.

If (ELSB:ELSA = 1:0), then the channel (n) output is forced high at the counter overflow when the CNTIN register value is loaded into the FTM counter, and it is forced low at the channel (n) match (FTM counter = CnV). See the following figure.

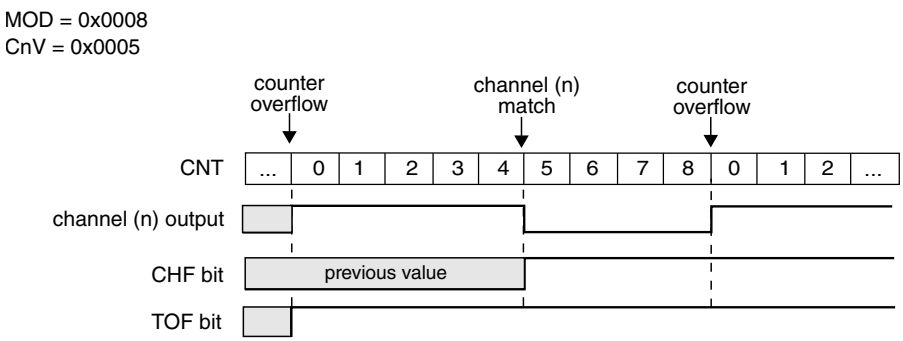


Figure 34-18. EPWM signal with ELSB:ELSA = 1:0

If (ELSB:ELSA = X:1), then the channel (n) output is forced low at the counter overflow when the CNTIN register value is loaded into the FTM counter, and it is forced high at the channel (n) match (FTM counter = CnV). See the following figure.

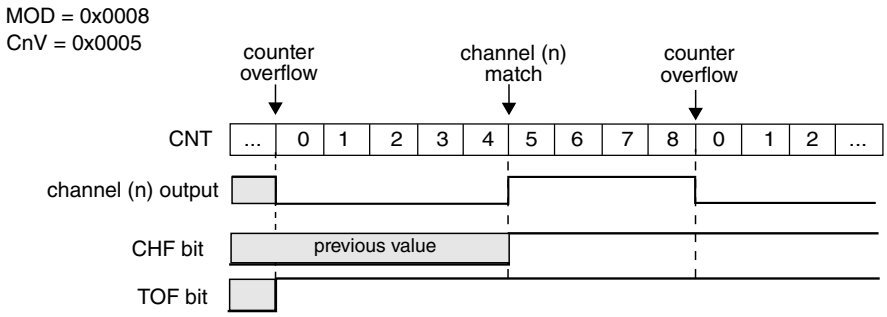


Figure 34-19. EPWM signal with ELSB:ELSA = X:1

If (CnV = 0x0000), then the channel (n) output is a 0% duty cycle EPWM signal and CHF bit is not set even when there is the channel (n) match.

If (CnV > MOD), then the channel (n) output is a 100% duty cycle EPWM signal and CHF bit is not set. Therefore, MOD must be less than 0xFFFF in order to get a 100% duty cycle EPWM signal.

Note

When CNTIN is different from zero the following EPWM signals can be generated:

- 0% EPWM signal if CnV = CNTIN,
- EPWM signal between 0% and 100% if CNTIN < CnV <= MOD,
- 100% EPWM signal when CNTIN > CnV or CnV > MOD.

34.5.8 Center-Aligned PWM (CPWM) mode

The Center-Aligned mode is selected when:

- QUADEN = 0
- DECAPEN = 0
- COMBINE = 0, and
- CPWMS = 1

The CPWM pulse width (duty cycle) is determined by 2 × (CnV − CNTIN) and the period is determined by 2 × (MOD − CNTIN). See the following figure. MOD must be kept in the range of 0x0001 to 0x7FFF because values outside this range can produce ambiguous results.

In the CPWM mode, the FTM counter counts up until it reaches MOD and then counts down until it reaches CNTIN.

The CHF bit is set and channel (n) interrupt is generated (if CHIE = 1) at the channel (n) match (FTM counter = CnV) when the FTM counting is down (at the begin of the pulse width) and when the FTM counting is up (at the end of the pulse width).

This type of PWM signal is called center-aligned because the pulse width centers for all channels are aligned with the value of CNTIN.

The other channel modes are not compatible with the up-down counter (CPWMS = 1). Therefore, all FTM channels must be used in CPWM mode when (CPWMS = 1).

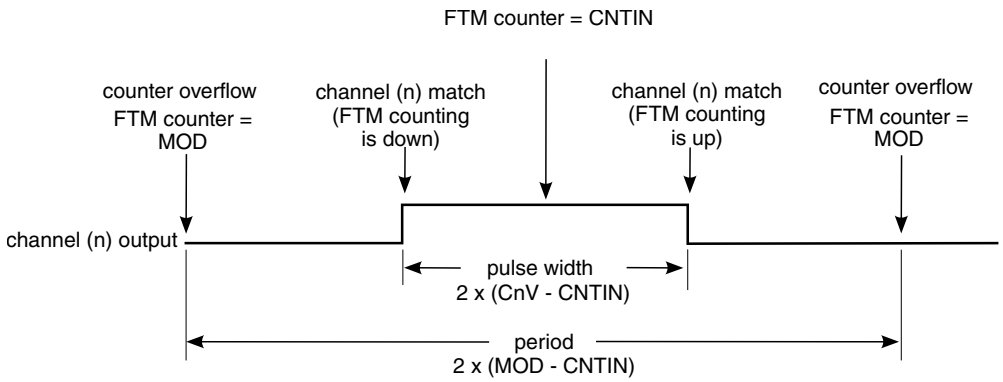


Figure 34-20. CPWM period and pulse width with ELSB:ELSA = 1:0

If (ELSB:ELSA = 0:0) when the FTM counter reaches the value in the CnV register, the CHF bit is set and the channel (n) interrupt is generated (if CHIE = 1), however the channel (n) output is not controlled by FTM.

If (ELSB:ELSA = 1:0), then the channel (n) output is forced high at the channel (n) match (FTM counter = CnV) when counting down, and it is forced low at the channel (n) match when counting up. See the following figure.

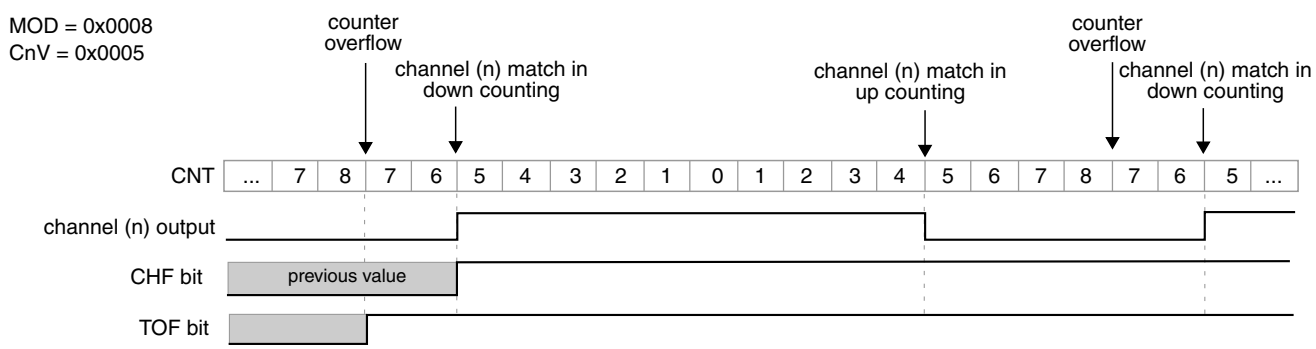


Figure 34-21. CPWM signal with ELSB:ELSA = 1:0

If (ELSB:ELSA = X:1), then the channel (n) output is forced low at the channel (n) match (FTM counter = CnV) when counting down, and it is forced high at the channel (n) match when counting up. See the following figure.

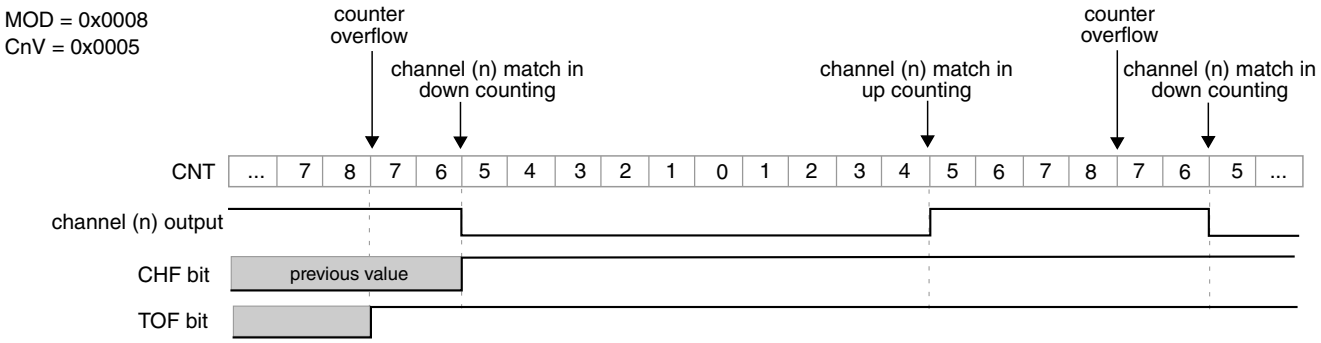


Figure 34-22. CPWM signal with ELSB:ELSA = X:1

If (CnV = 0x0000) or CnV is a negative value, that is (CnV[15] = 1), then the channel (n) output is a 0% duty cycle CPWM signal and CHF bit is not set even when there is the channel (n) match.

If CnV is a positive value, that is (CnV[15] = 0), (CnV ≥ MOD), and (MOD ≠ 0x0000), then the channel (n) output is a 100% duty cycle CPWM signal and CHF bit is not set even when there is the channel (n) match. This implies that the usable range of periods set by MOD is 0x0001 through 0x7FFE, 0x7FFF if you do not need to generate a 100% duty cycle CPWM signal. This is not a significant limitation because the resulting period is much longer than required for normal applications.

The CPWM mode must not be used when the FTM counter is a free running counter.

34.5.9 Combine mode

The Combine mode is selected when:

- QUADEN = 0
- DECAPEN = 0
- COMBINE = 1, and
- CPWMS = 0

In Combine mode, an even channel (n) and adjacent odd channel (n+1) are combined to generate a PWM signal in the channel (n) output.

In the Combine mode, the PWM period is determined by (MOD − CNTIN + 0x0001) and the PWM pulse width (duty cycle) is determined by (|C(n+1)V − C(n)V|).

The channel (n) CHF bit is set and its interrupt is generated, if channel (n) CHIE = 1, at the channel (n) match (FTM counter = C(n)V). The channel (n+1) CHF bit is set and its interrupt is generated, if channel (n+1) CHIE = 1, at the channel (n+1) match (FTM counter = C(n+1)V).

If channel (n) ELSB:ELSA = 1:0, then the channel (n) output is forced low at the beginning of the period (FTM counter = CNTIN) and at the channel (n+1) match (FTM counter = C(n+1)V). It is forced high at the channel (n) match (FTM counter = C(n)V). See the following figure.

If channel (n) ELSB:ELSA = X:1, then the channel (n) output is forced high at the beginning of the period (FTM counter = CNTIN) and at the channel (n+1) match (FTM counter = C(n+1)V). It is forced low at the channel (n) match (FTM counter = C(n)V). See the following figure.

In Combine mode, the channel (n+1) ELSB:ELSA bits are not used in the generation of the channels (n) and (n+1) output. However, if channel (n) ELSB:ELSA = 0:0, then the channel (n) output is not controlled by FTM, and if channel (n+1) ELSB:ELSA = 0:0, then the channel (n+1) output is not controlled by FTM.

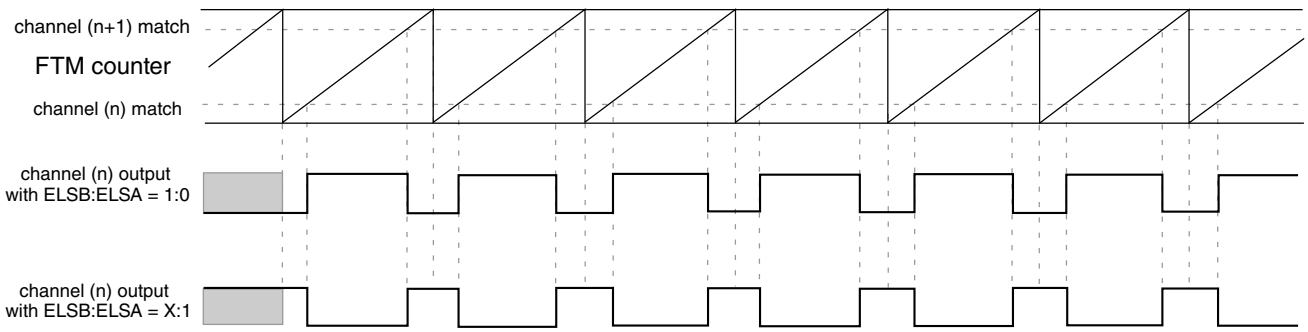


Figure 34-23. Combine mode

The following figures illustrate the PWM signals generation using Combine mode.

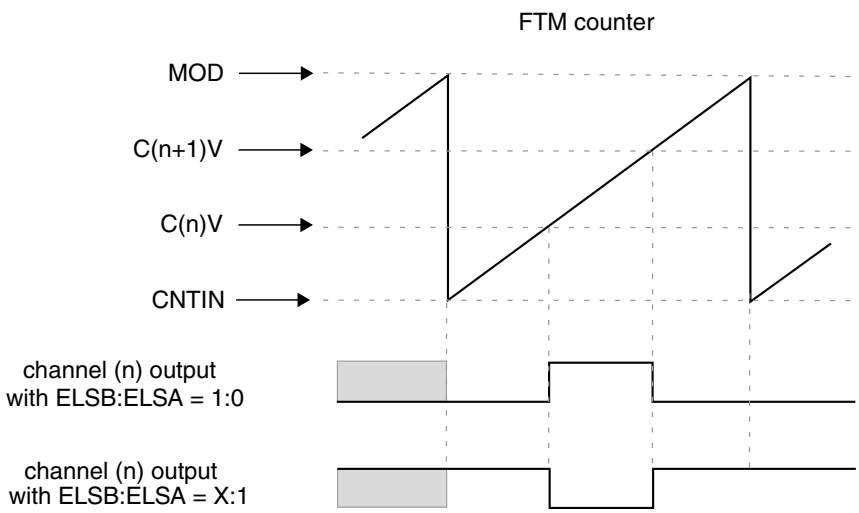


Figure 34-24. Channel (n) output if (CNTIN < C(n)V < MOD) and (CNTIN < C(n+1)V < MOD) and (C(n)V < C(n+1)V)

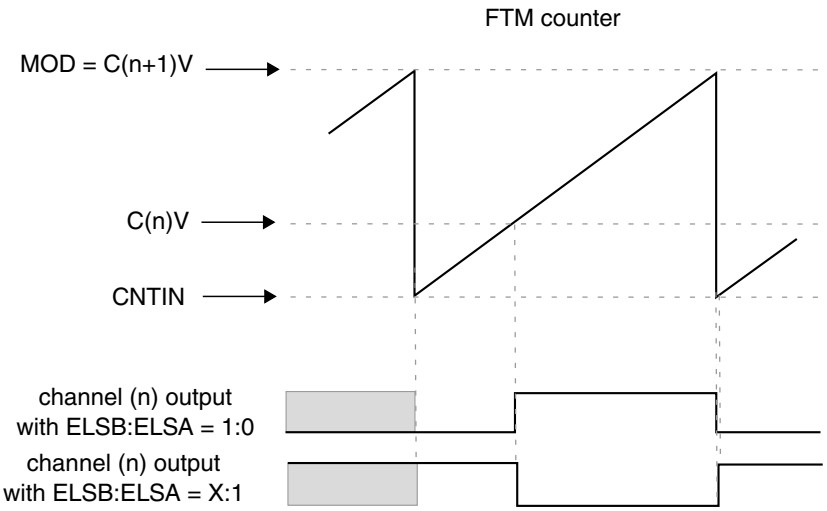


Figure 34-25. Channel (n) output if (CNTIN < C(n)V < MOD) and (C(n+1)V = MOD)

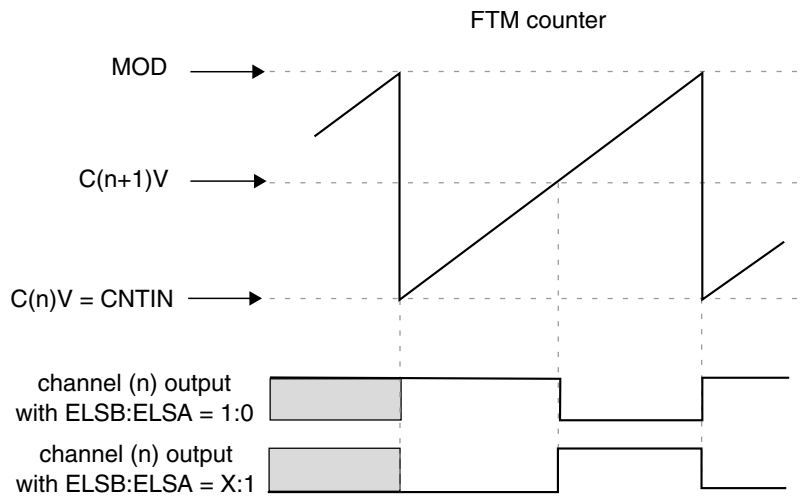


Figure 34-26. Channel (n) output if (C(n)V = CNTIN) and (CNTIN < C(n+1)V < MOD)

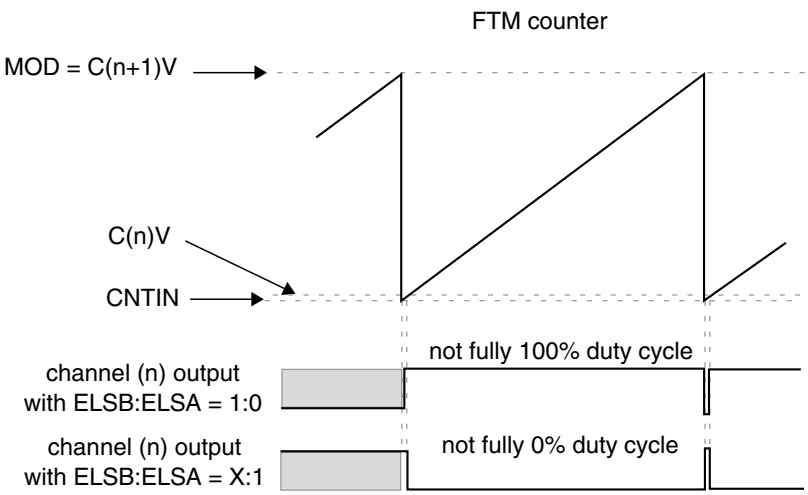


Figure 34-27. Channel (n) output if (CNTIN < C(n)V < MOD) and (C(n)V is Almost Equal to CNTIN) and (C(n+1)V = MOD)

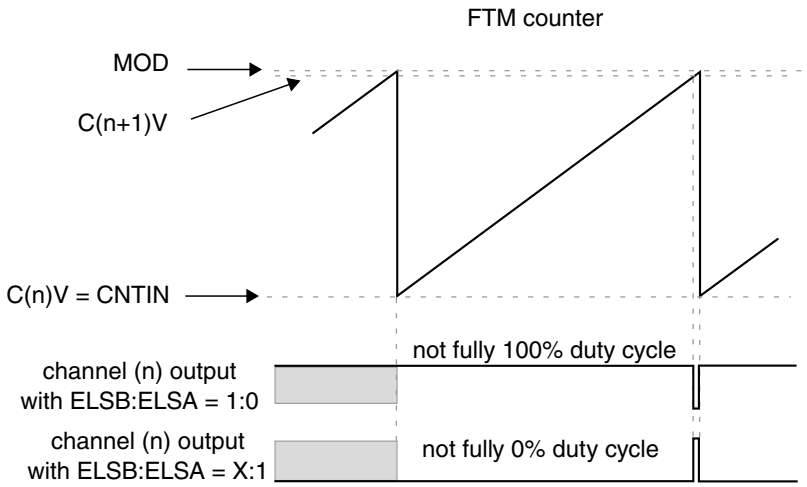


Figure 34-28. Channel (n) output if (C(n)V = CNTIN) and (CNTIN < C(n+1)V < MOD) and (C(n+1)V is Almost Equal to MOD)

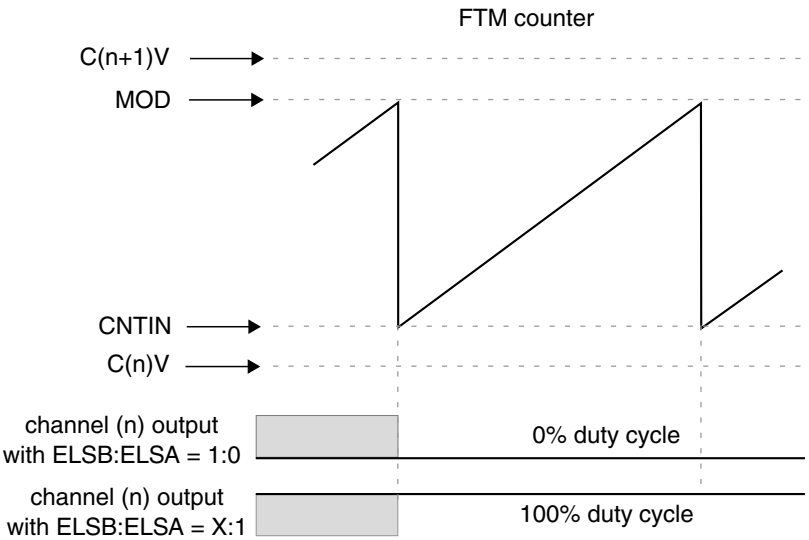


Figure 34-29. Channel (n) output if C(n)V and C(n+1)V are not between CNTIN and MOD

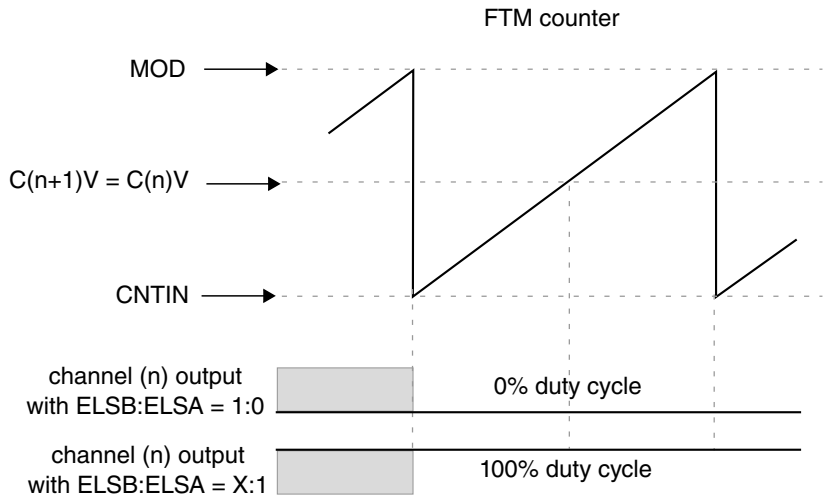


Figure 34-30. Channel (n) output if (CNTIN < C(n)V < MOD) and (CNTIN < C(n+1)V < MOD) and (C(n)V = C(n+1)V)

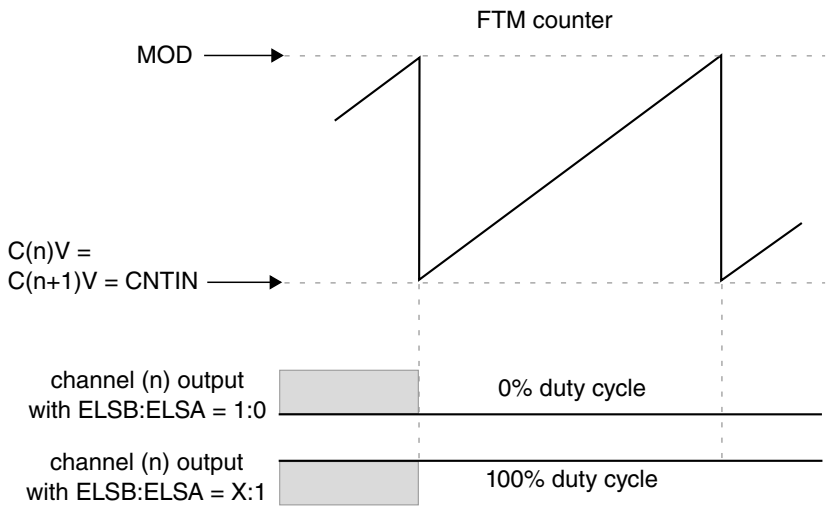


Figure 34-31. Channel (n) output if (C(n)V = C(n+1)V = CNTIN)

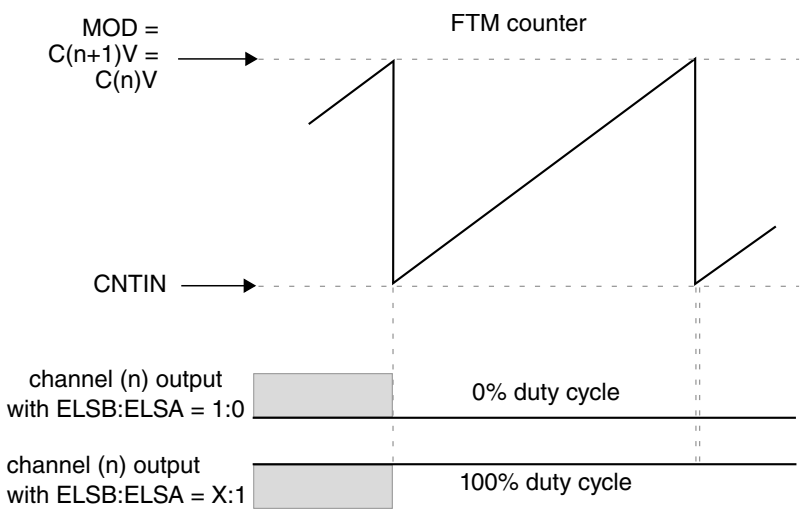


Figure 34-32. Channel (n) output if (C(n)V = C(n+1)V = MOD)

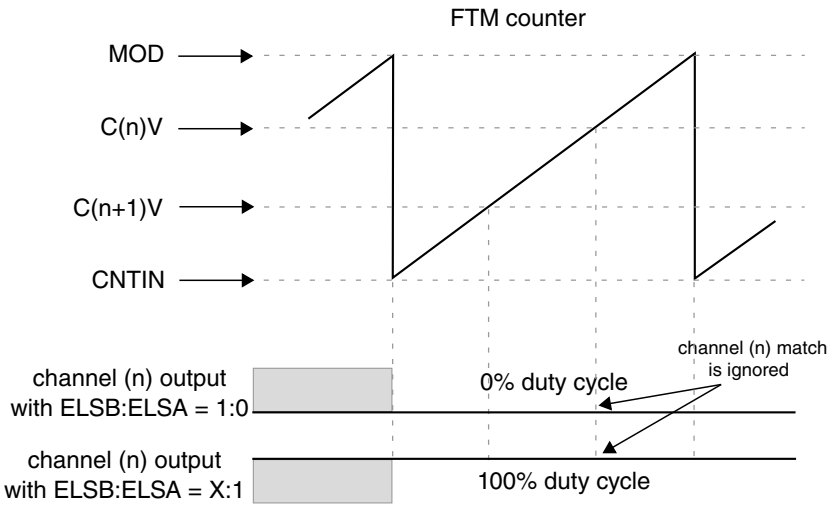


Figure 34-33. Channel (n) output if (CNTIN < C(n)V < MOD) and (CNTIN < C(n+1)V < MOD) and (C(n)V > C(n+1)V)

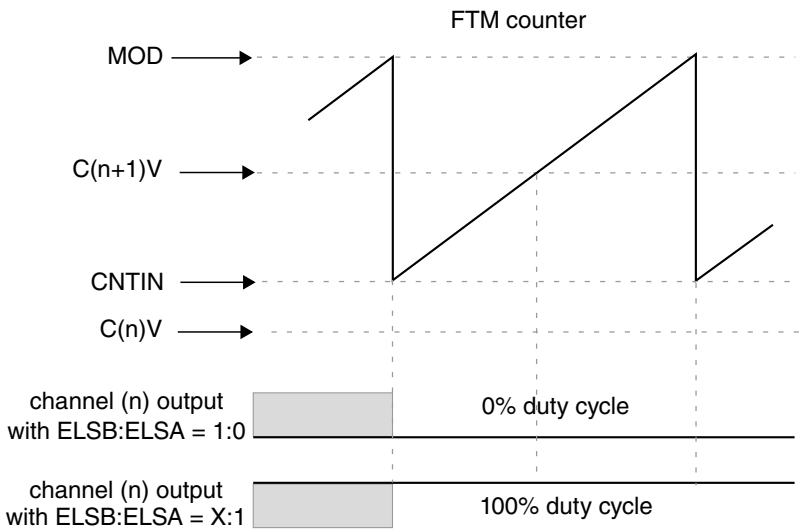


Figure 34-34. Channel (n) output if (C(n)V < CNTIN) and (CNTIN < C(n+1)V < MOD)

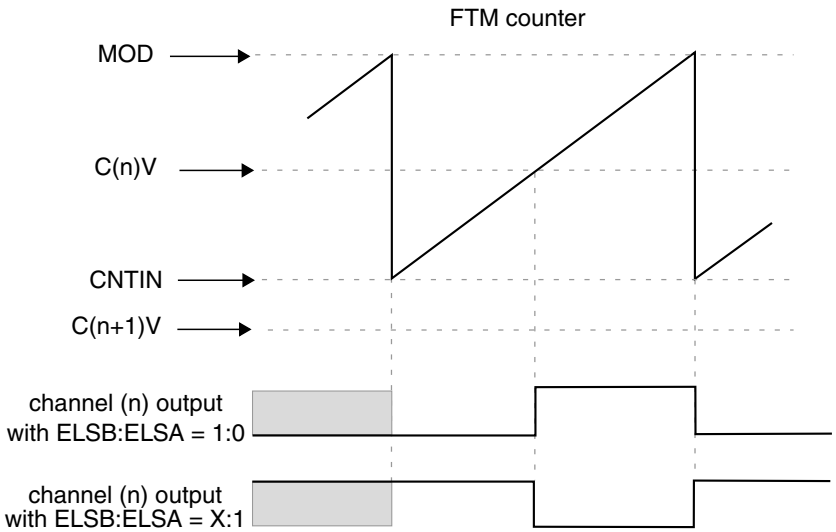


Figure 34-35. Channel (n) output if (C(n+1)V < CNTIN) and (CNTIN < C(n)V < MOD)

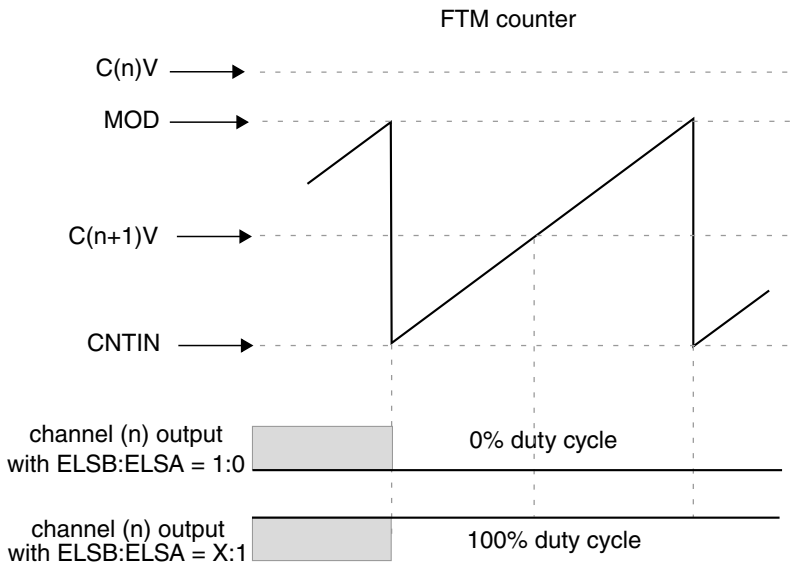


Figure 34-36. Channel (n) output if (C(n)V > MOD) and (CNTIN < C(n+1)V < MOD)

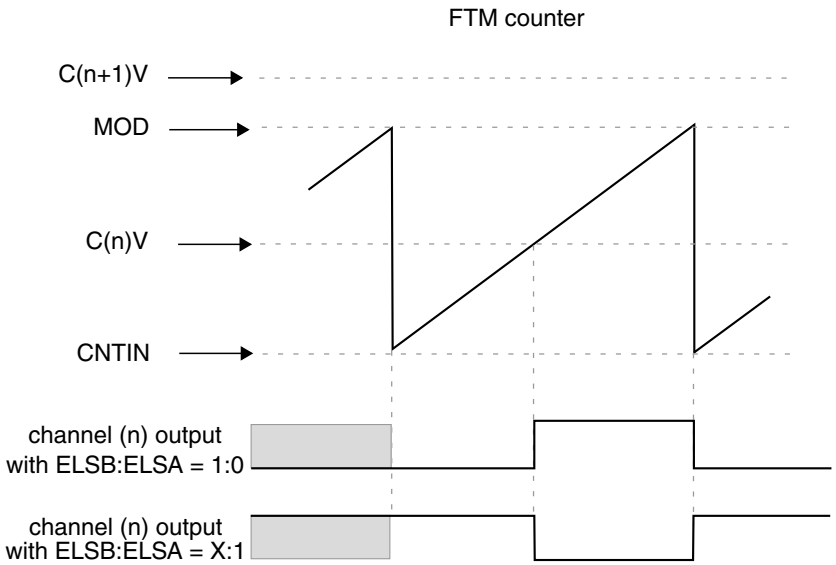


Figure 34-37. Channel (n) output if (C(n+1)V > MOD) and (CNTIN < C(n)V < MOD)

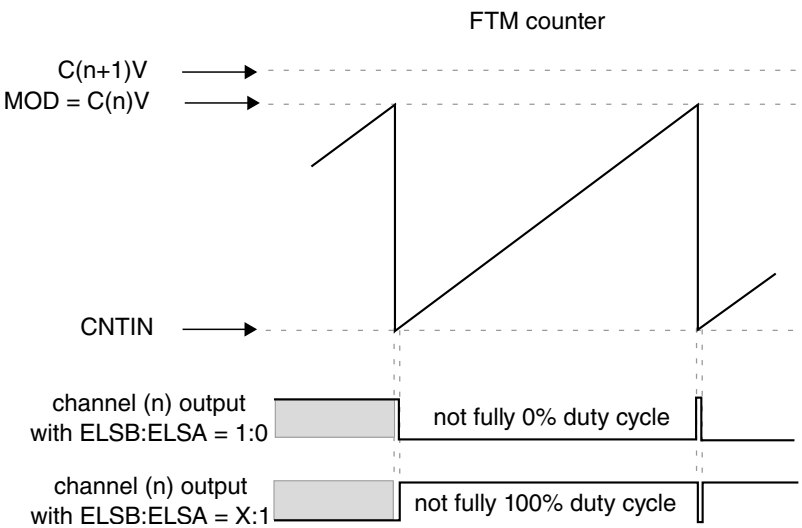


Figure 34-38. Channel (n) output if (C(n+1)V > MOD) and (CNTIN < C(n)V = MOD)

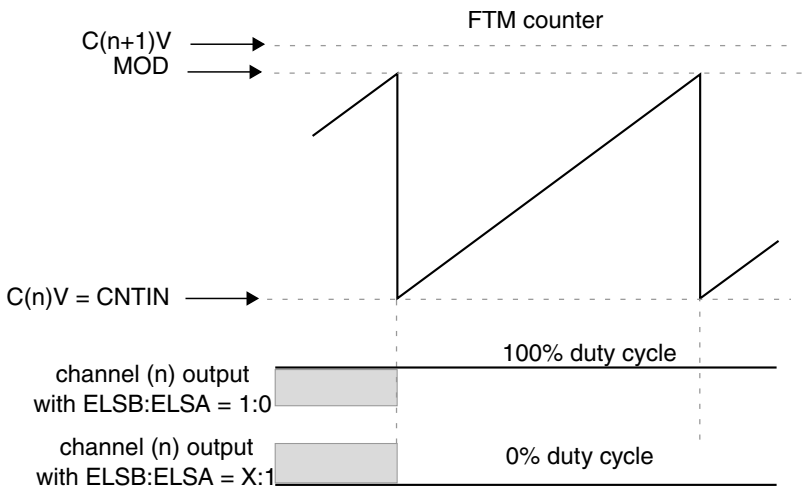


Figure 34-39. Channel (n) output if (C(n)V = CNTIN) and (C(n+1)V > MOD)

34.5.9.1 Asymmetrical PWM

In Combine mode, the PWM first edge (channel (n) match: FTM counter = C(n)V) is independent of the PWM second edge (channel (n+1) match: FTM counter = C(n+1)V).

34.5.10 Complementary Mode

The Complementary mode is selected when:

- QUADEN = 0
- DECAPEN = 0
- COMP = 1

In Complementary mode, the channel (n+1) output is the inverse of the channel (n) output.

So, the channel (n+1) output is the same as the channel (n) output when:

- QUADEN = 0
- DECAPEN = 0
- COMP = 0

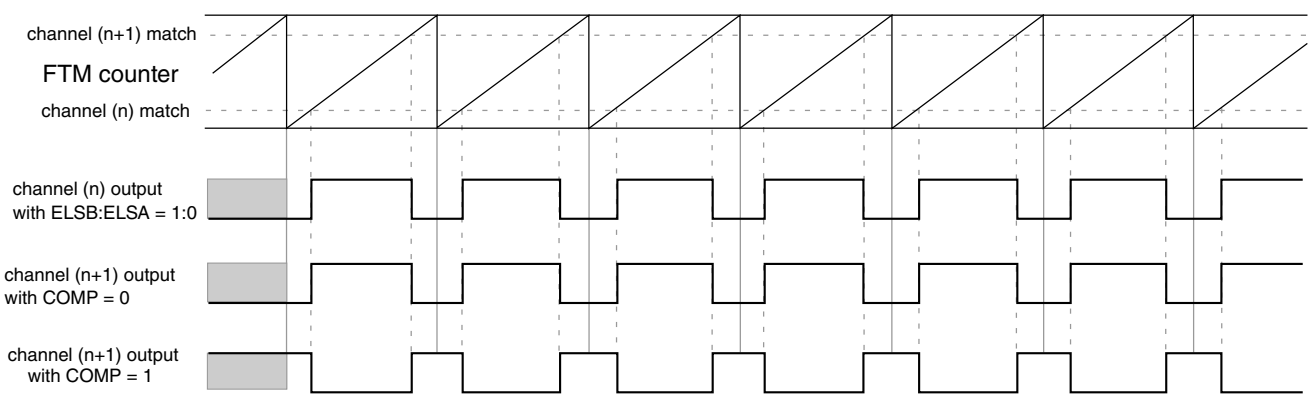


Figure 34-40. Channel (n+1) output in Complementary mode with (ELSB:ELSA = 1:0)

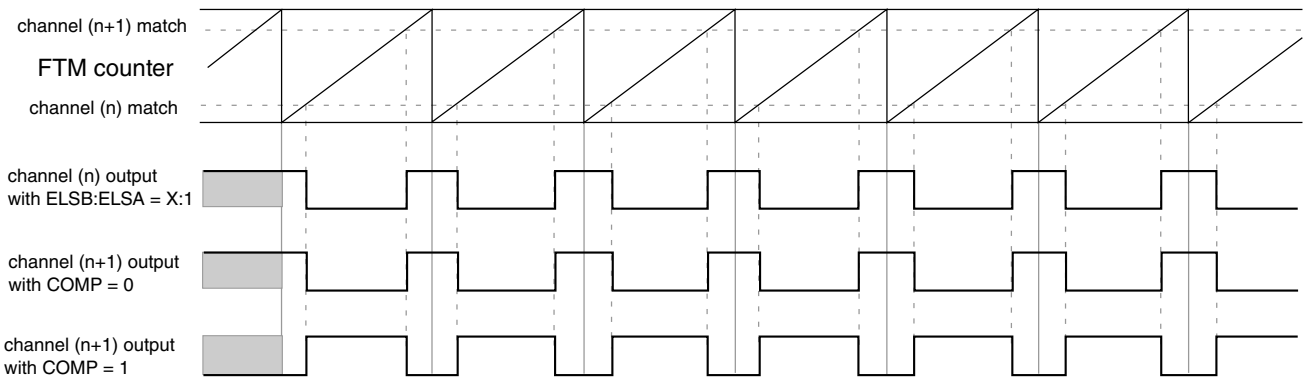


Figure 34-41. Channel (n+1) output in Complementary mode with (ELSB:ELSA = X:1)

NOTE

The Complementary Mode is not available on Output Compare mode.

34.5.11 Registers updated from write buffers

34.5.11.1 CNTIN register update

The following table describes when CNTIN register is updated:

Table 34-8. CNTIN register update

When	Then CNTIN register is updated
CLKS[1:0] = 0:0	When CNTIN register is written, independent of FTMEN bit.
• FTMEN = 0, or • CNTINC = 0	At the next FTM input clock after CNTIN was written.
• FTMEN = 1, • SYNCMODE = 1, and • CNTINC = 1	By the CNTIN register synchronization.
• CNTINC = 1, and • LDOK = 1	By the Reload Points.

34.5.11.2 MOD and HCR registers update

The following table describes when MOD or HCR registers are updated:

Table 34-9. MOD and HCR updates

When	Then MOD or HCR is updated
CLKS[1:0] = 0:0	When MOD (or HCR) is written, independent of FTMEN bit.
• CLKS[1:0] ≠ 0:0, and • FTMEN = 0	According to the CPWMS bit, that is: • If the selected mode is not CPWM then MOD (or HCR) is updated after MOD (or HCR) register was written and the FTM counter changes from MOD to CNTIN. If the FTM counter is at free-running counter mode then this update occurs when the FTM counter changes from 0xFFFF to 0x0000. • If the selected mode is CPWM then MOD (or HCR) register is updated after MOD (or HCR) register was written and the FTM counter changes from MOD to (MOD – 0x0001).
• CLKS[1:0] ≠ 0:0, and • FTMEN = 1	By the MOD register synchronization. HCR follows the same procedure of MOD register in this case.
• LDOK = 1	By the Reload Points.

34.5.11.3 CnV register update

The following table describes when CnV register is updated:

Table 34-10. CnV register update

When	Then CnV register is updated
CLKS[1:0] = 0:0	When CnV register is written, independent of FTMEN bit.
• CLKS[1:0] ≠ 0:0, and • FTMEN = 0	According to the selected mode, that is: • If the selected mode is Output Compare, then CnV register is updated on the next FTM counter change, end of the prescaler counting, after CnV register was written. • If the selected mode is EPWM, then CnV register is updated after CnV register was written and the FTM counter changes from MOD to CNTIN. If the FTM counter is at free-running counter mode then this update occurs when the FTM counter changes from 0xFFFF to 0x0000. • If the selected mode is CPWM, then CnV register is updated after CnV register was written and the FTM counter changes from MOD to (MOD – 0x0001).
• CLKS[1:0] ≠ 0:0, and • FTMEN = 1	According to the selected mode, that is: • If the selected mode is output compare then CnV register is updated according to the SYNCEN bit. If (SYNCEN = 0) then CnV register is updated after CnV register was written at the next change of the FTM counter, the end of the prescaler counting. If (SYNCEN = 1) then CnV register is updated by the C(n)V and C(n+1)V register synchronization. • If the selected mode is not output compare and (SYNCEN = 1) then CnV register is updated by the C(n)V and C(n+1)V register synchronization.
• SYNCEN = 1, and • LDOK = 1	By the Reload Points.

34.5.12 PWM synchronization

The PWM synchronization provides an opportunity to update the MOD, HCR, CNTIN, CnV, OUTMASK, INVCTRL and SWOCTRL registers with their buffered value and force the FTM counter to the CNTIN register value.

Note

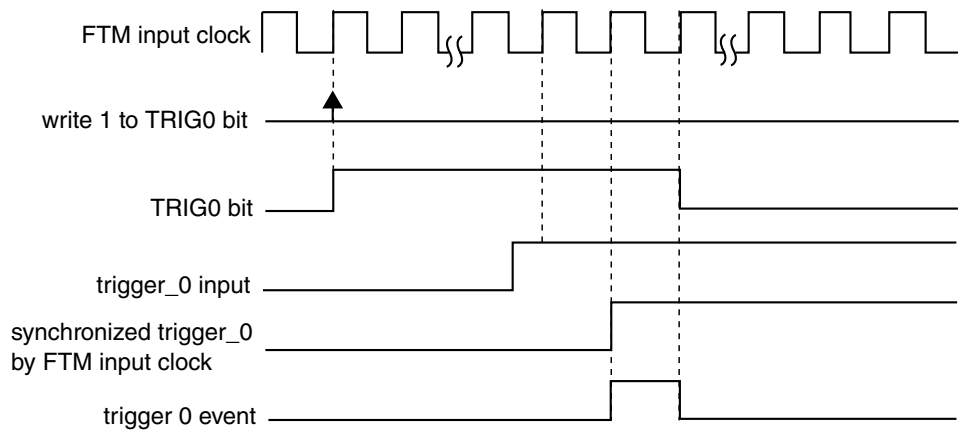
The legacy PWM synchronization (SYNCMODE = 0) is a subset of the enhanced PWM synchronization (SYNCMODE = 1). Thus, only the enhanced PWM synchronization must be used.

34.5.12.1 Hardware trigger

Three hardware trigger signal inputs of the FTM module are enabled when TRIGn = 1, where n = 0, 1 or 2 corresponding to each one of the input signals, respectively. The hardware trigger input n is synchronized by the FTM input clock. The PWM synchronization with hardware trigger is initiated when a rising edge is detected at the enabled hardware trigger inputs.

If (HWTRIGMODE = 0) then the TRIGn bit is cleared when 0 is written to it or when the trigger n event is detected.

In this case, if two or more hardware triggers are enabled (for example, TRIG0 and TRIG1 = 1) and only trigger 1 event occurs, then only TRIG1 bit is cleared. If a trigger n event occurs together with a write setting TRIGn bit, then the synchronization is initiated, but TRIGn bit remains set due to the write operation.



Note
All hardware trigger inputs have the same behavior.

Figure 34-42. Hardware trigger event with HWTRIGMODE = 0

If HWTRIGMODE = 1, then the TRIGn bit is only cleared when 0 is written to it.

NOTE

The HWTRIGMODE bit must be 1 only with enhanced PWM synchronization (SYNCMODE = 1).

34.5.12.2 Software trigger

A software trigger event occurs when 1 is written to the SYNC[SWSYNC] bit. The SWSYNC bit is cleared when 0 is written to it or when the PWM synchronization, initiated by the software event, is completed.

If another software trigger event occurs (by writing another 1 to the SWSYNC bit) at the same time the PWM synchronization initiated by the previous software trigger event is ending, a new PWM synchronization is started and the SWSYNC bit remains equal to 1.

If SYNCMODE = 0 then the SWSYNC bit is also cleared by FTM according to PWMSYNC and REINIT bits. In this case if (PWMSYNC = 1) or (PWMSYNC = 0 and REINIT = 0) then SWSYNC bit is cleared at the next selected loading point after that the software trigger event occurred; see Synchronization Points and the following figure. If (PWMSYNC = 0) and (REINIT = 1) then SWSYNC bit is cleared when the software trigger event occurs.

If SYNCMODE = 1 then the SWSYNC bit is also cleared by FTM according to the SWRSTCNT bit. If SWRSTCNT = 0 then SWSYNC bit is cleared at the next selected loading point after that the software trigger event occurred; see the following figure. If SWRSTCNT = 1 then SWSYNC bit is cleared when the software trigger event occurs.

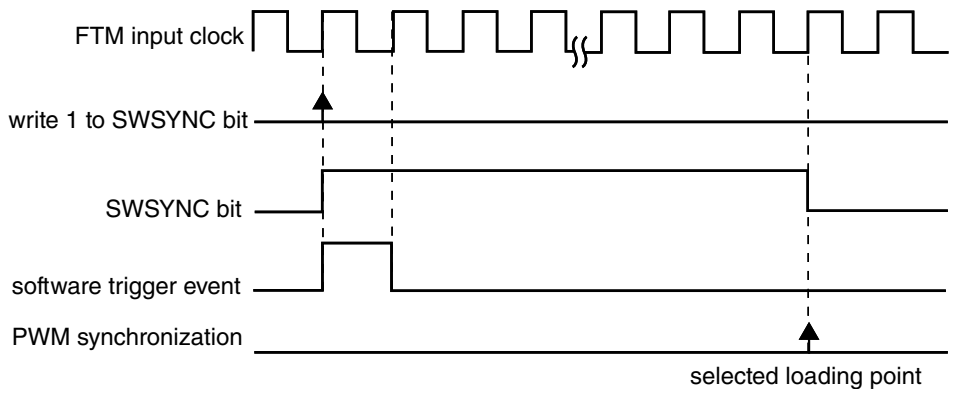


Figure 34-43. Software trigger event

34.5.12.3 Synchronization Points

The synchronization points are points where the registers can be updated with their write buffer by PWM synchronization. These synchronization points are safe points because guarantee smooth transitions in the generated PWM signals.

In Up counting, the synchronization points are when the FTM counter changes from MOD to CNTIN. In this case, the synchronization points are enabled if (CNTMIN = 1) or (CNTMAX = 1).

In Up-down counting, the synchronization points are:

- if (CNTMAX = 1), when the FTM counter changes from (MOD) to (MOD - 1);
- if (CNTMIN = 1), when the FTM counter changes from (CNTIN) to (CNTIN + 1).

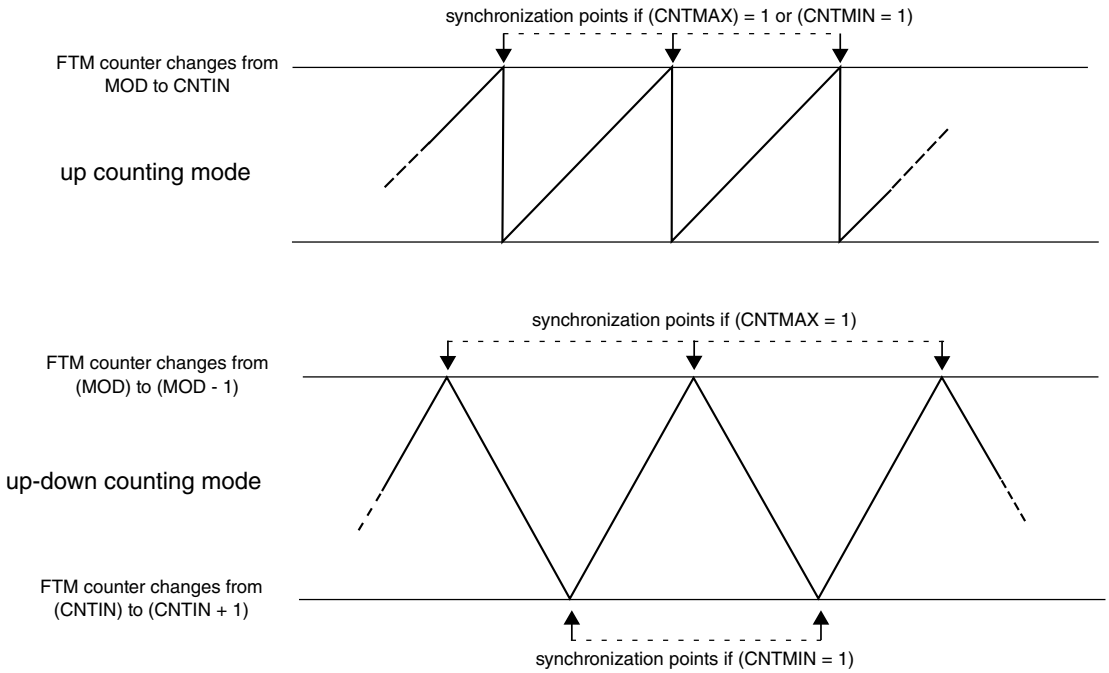


Figure 34-44. Synchronization Points

34.5.12.4 MOD register synchronization

The MOD register synchronization updates the MOD register with its buffer value. This synchronization is enabled if (FTMEN = 1).

The MOD register synchronization can be done by either the enhanced PWM synchronization (SYNCMODE = 1) or the legacy PWM synchronization (SYNCMODE = 0). However, it is expected that the MOD register be synchronized only by the enhanced PWM synchronization.

In the case of enhanced PWM synchronization, the MOD register synchronization depends on SWWRBUF, SWRSTCNT, HWWRBUF, and HWRSTCNT bits according to this flowchart:

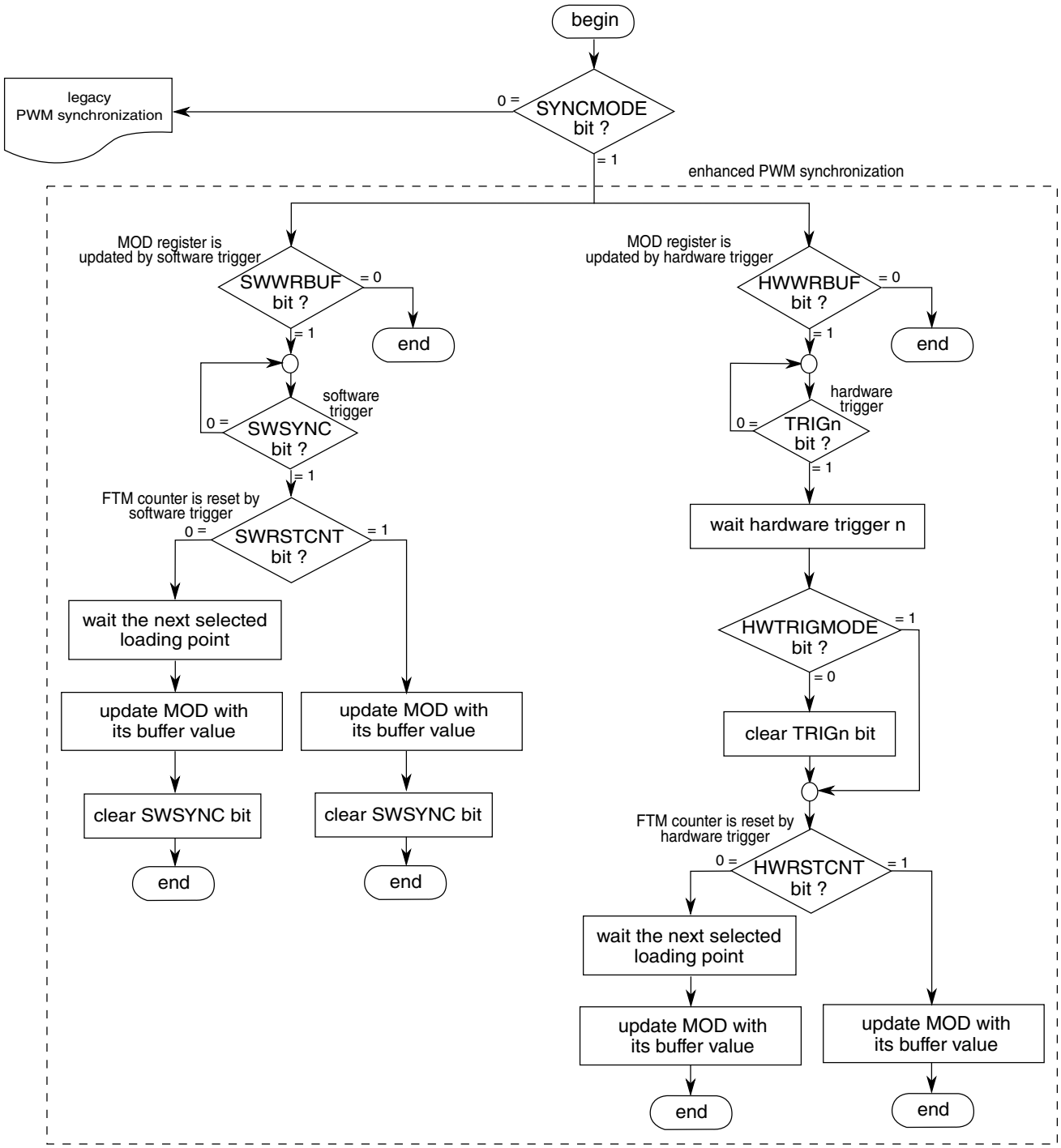


Figure 34-45. MOD register synchronization flowchart

In the case of legacy PWM synchronization, the MOD register synchronization depends on PWMSYNC and REINIT bits according to the following description.

If (SYNCMODE = 0), (PWMSYNC = 0), and (REINIT = 0), then this synchronization is made on the next selected loading point after an enabled trigger event takes place. If the trigger event was a software trigger, then the SWSYNC bit is cleared on the next selected

loading point. If the trigger event was a hardware trigger, then the trigger enable bit (TRIGn) is cleared according to Hardware trigger. Examples with software and hardware triggers follow.

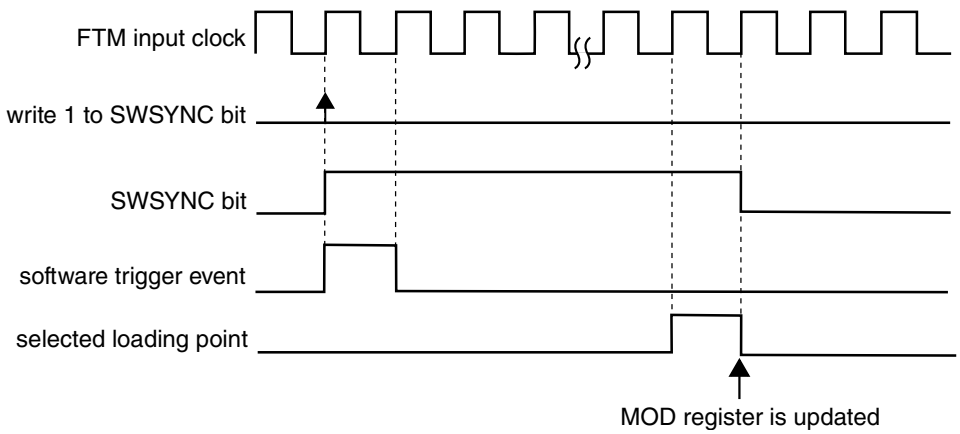


Figure 34-46. MOD synchronization with (SYNCMODE = 0), (PWMSYNC = 0), (REINIT = 0), and software trigger was used

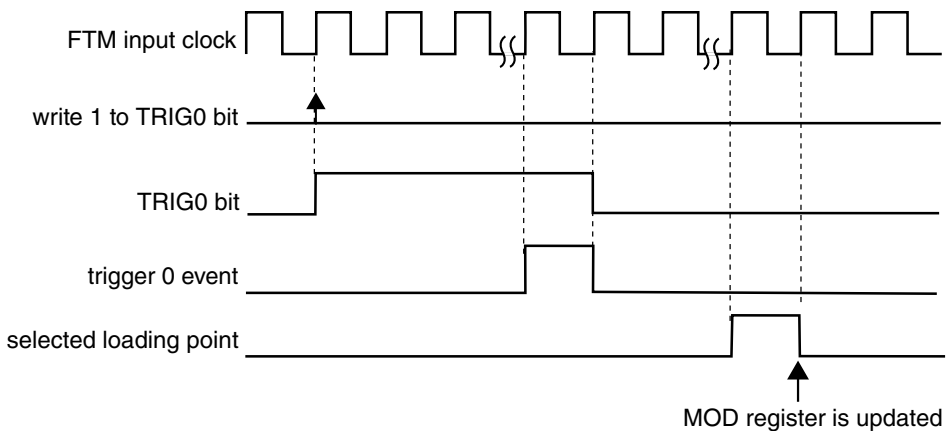


Figure 34-47. MOD synchronization with (SYNCMODE = 0), (HWTRIGMODE = 0), (PWMSYNC = 0), (REINIT = 0), and a hardware trigger was used

If (SYNCMODE = 0), (PWMSYNC = 0), and (REINIT = 1), then this synchronization is made on the next enabled trigger event. If the trigger event was a software trigger, then the SWSYNC bit is cleared according to the following example. If the trigger event was a hardware trigger, then the TRIGn bit is cleared according to Hardware trigger. Examples with software and hardware triggers follow.

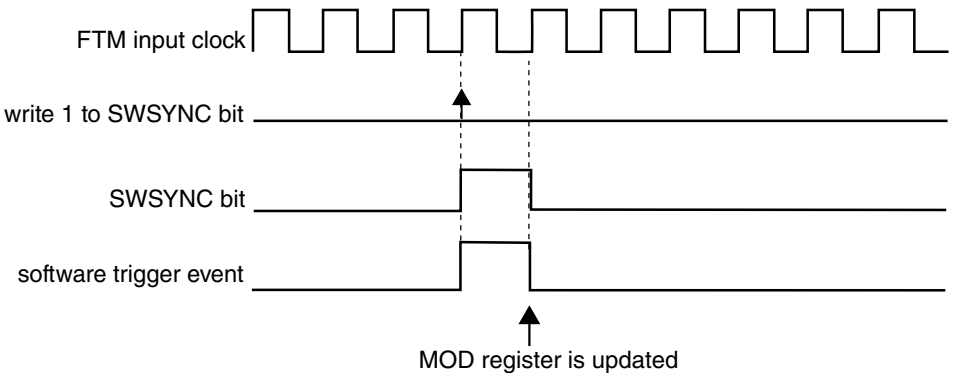


Figure 34-48. MOD synchronization with (SYNCMODE = 0), (PWMSYNC = 0), (REINIT = 1), and software trigger was used

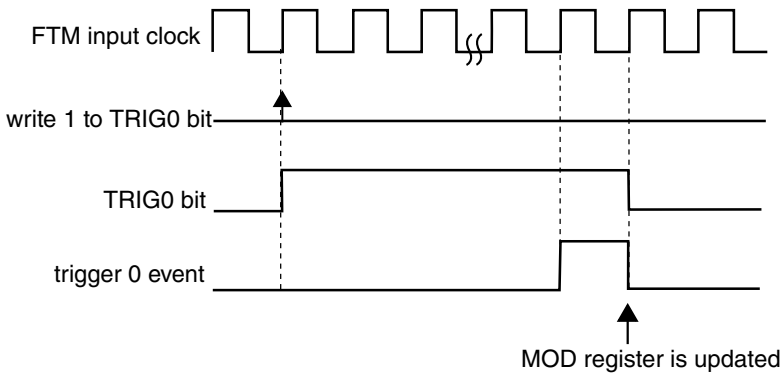


Figure 34-49. MOD synchronization with (SYNCMODE = 0), (HWTRIGMODE = 0), (PWMSYNC = 0), (REINIT = 1), and a hardware trigger was used

If (SYNCMODE = 0) and (PWMSYNC = 1), then this synchronization is made on the next selected loading point after the software trigger event takes place. The SWSYNC bit is cleared on the next selected loading point:

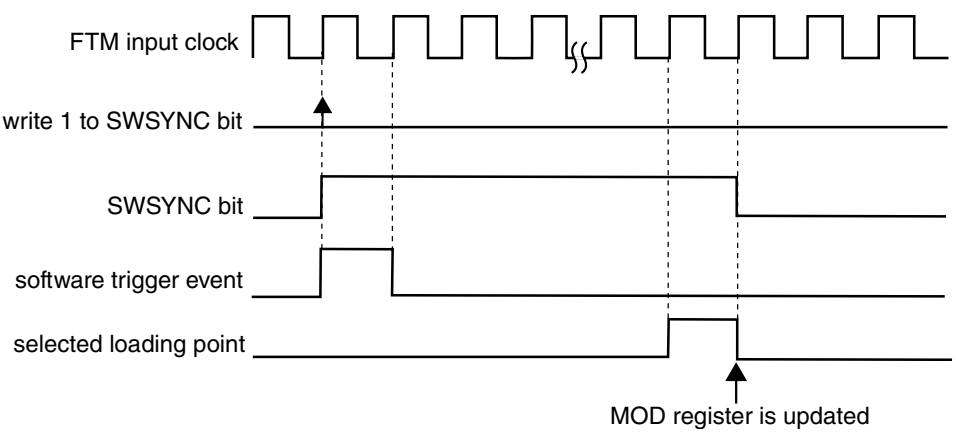


Figure 34-50. MOD synchronization with (SYNCMODE = 0) and (PWMSYNC = 1)

34.5.12.5 CNTIN register synchronization

The CNTIN register synchronization updates the CNTIN register with its buffer value.

This synchronization is enabled if (FTMEN = 1), (SYNCMODE = 1), and (CNTINC = 1). The CNTIN register synchronization can be done only by the enhanced PWM synchronization (SYNCMODE = 1). The synchronization mechanism is the same as the MOD register synchronization done by the enhanced PWM synchronization; see MOD register synchronization.

34.5.12.6 C(n)V and C(n+1)V register synchronization

The C(n)V and C(n+1)V registers synchronization updates the C(n)V and C(n+1)V registers with their buffer values.

This synchronization is enabled if (FTMEN = 1) and (SYNCEN = 1). The synchronization mechanism is the same as the MOD register synchronization. However, it is expected that the C(n)V and C(n+1)V registers be synchronized only by the enhanced PWM synchronization (SYNCMODE = 1).

34.5.12.7 OUTMASK register synchronization

The OUTMASK register synchronization updates the OUTMASK register with its buffer value.

The OUTMASK register can be updated at each rising edge of FTM input clock (SYNCHOM = 0), by the enhanced PWM synchronization (SYNCHOM = 1 and SYNCMODE = 1) or by the legacy PWM synchronization (SYNCHOM = 1 and SYNCMODE = 0). However, it is expected that the OUTMASK register be synchronized only by the enhanced PWM synchronization.

In the case of enhanced PWM synchronization, the OUTMASK register synchronization depends on SWOM and HWOM bits. See the following flowchart:

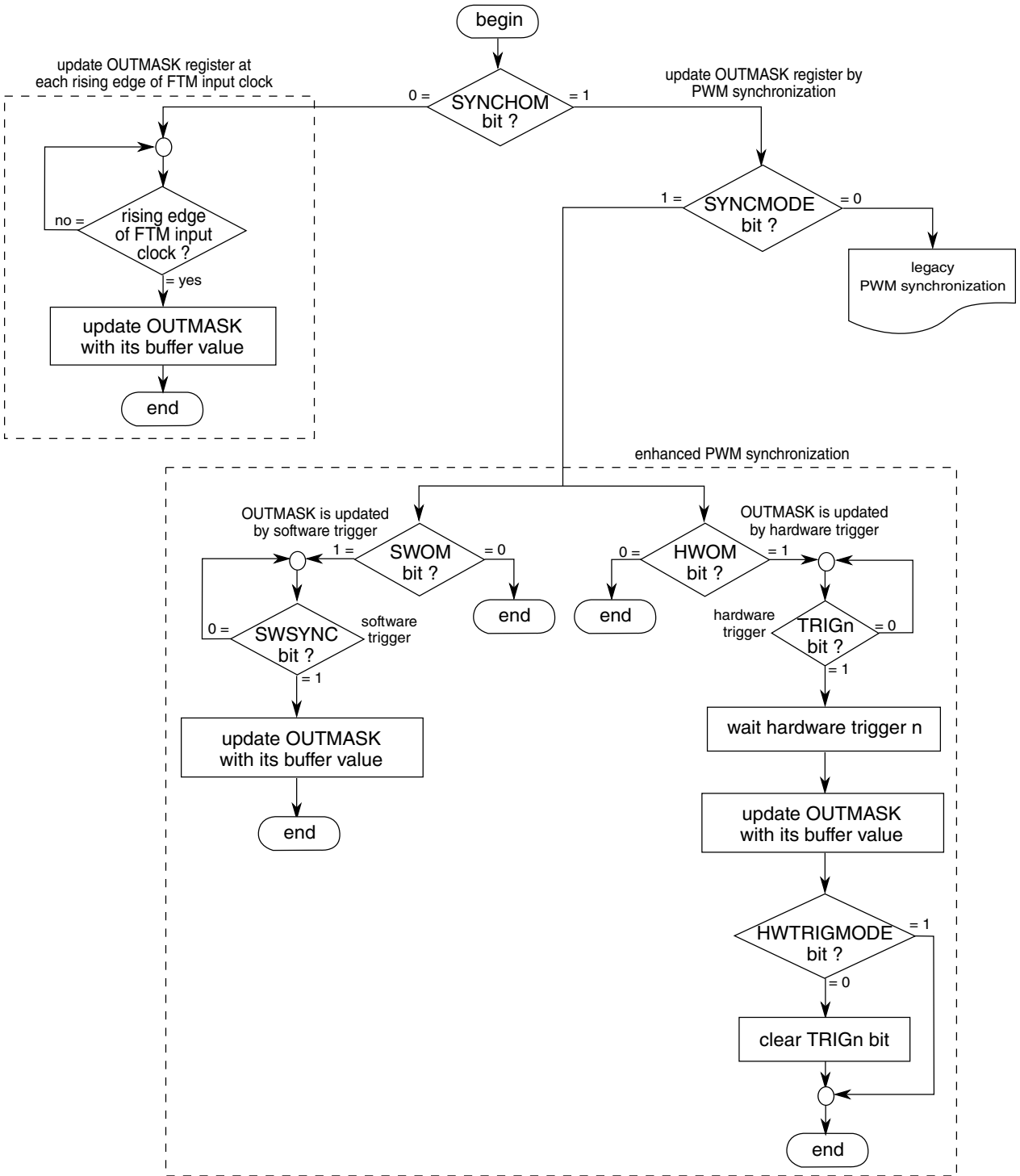


Figure 34-51. OUTMASK register synchronization flowchart

In the case of legacy PWM synchronization, the OUTMASK register synchronization depends on PWMSYNC bit according to the following description.

If (SYNCMODE = 0), (SYNCHOM = 1), and (PWMSYNC = 0), then this synchronization is done on the next enabled trigger event. If the trigger event was a software trigger, then the SWSYNC bit is cleared on the next selected loading point. If the trigger event was a hardware trigger, then the TRIGn bit is cleared according to Hardware trigger. Examples with software and hardware triggers follow.

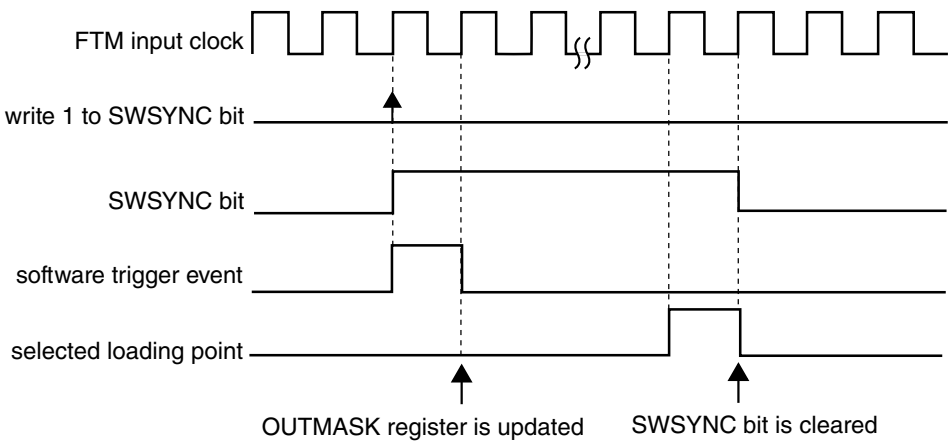


Figure 34-52. OUTMASK synchronization with (SYNCMODE = 0), (SYNCHOM = 1), (PWMSYNC = 0) and software trigger was used

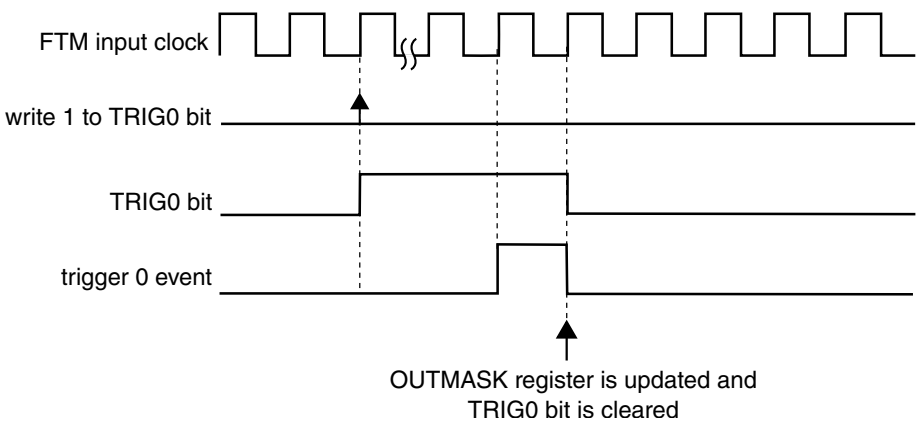


Figure 34-53. OUTMASK synchronization with (SYNCMODE = 0), (HWTRIGMODE = 0), (SYNCHOM = 1), (PWMSYNC = 0), and a hardware trigger was used

If (SYNCMODE = 0), (SYNCHOM = 1), and (PWMSYNC = 1), then this synchronization is made on the next enabled hardware trigger. The TRIGn bit is cleared according to Hardware trigger. An example with a hardware trigger follows.

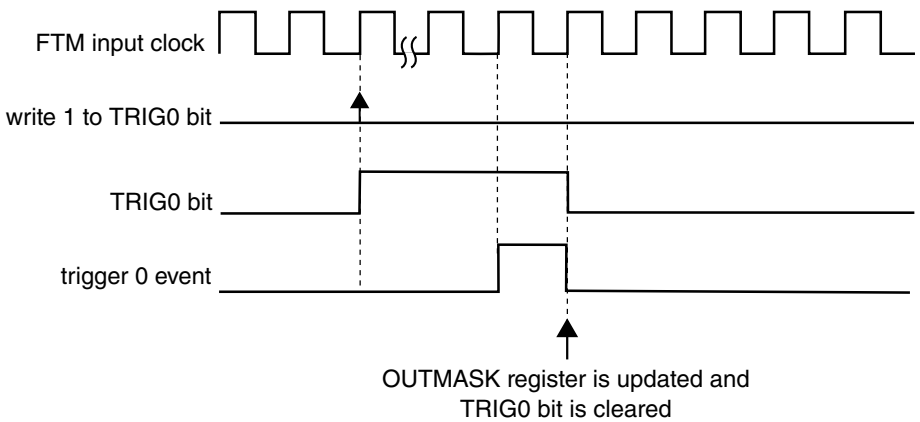


Figure 34-54. OUTMASK synchronization with (SYNCMODE = 0), (HWTRIGMODE = 0), (SYNCHOM = 1), (PWMSYNC = 1), and a hardware trigger was used

34.5.12.8 INVCTRL register synchronization

The INVCTRL register synchronization updates the INVCTRL register with its buffer value.

The INVCTRL register can be updated at each rising edge of FTM input clock (INVC = 0) or by the enhanced PWM synchronization (INVC = 1 and SYNCMODE = 1) according to the following flowchart.

In the case of enhanced PWM synchronization, the INVCTRL register synchronization depends on SWINVC and HWINVC bits.

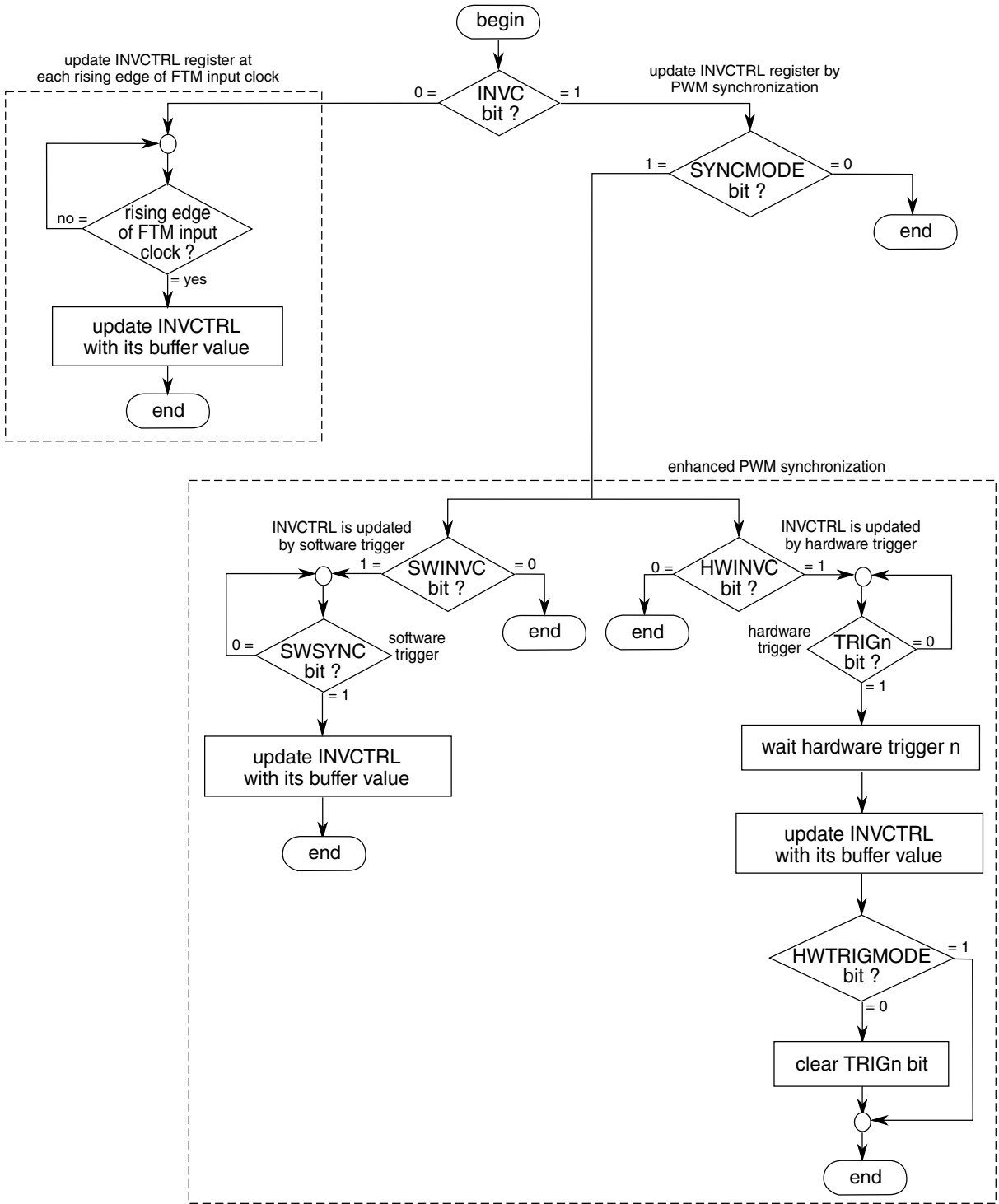


Figure 34-55. INVCTRL register synchronization flowchart

34.5.12.9 SWOCTRL register synchronization

The SWOCTRL register synchronization updates the SWOCTRL register with its buffer value.

The SWOCTRL register can be updated at each rising edge of FTM input clock (SWOC = 0) or by the enhanced PWM synchronization (SWOC = 1 and SYNCMODE = 1) according to the following flowchart.

In the case of enhanced PWM synchronization, the SWOCTRL register synchronization depends on SWSOC and HWSOC bits.

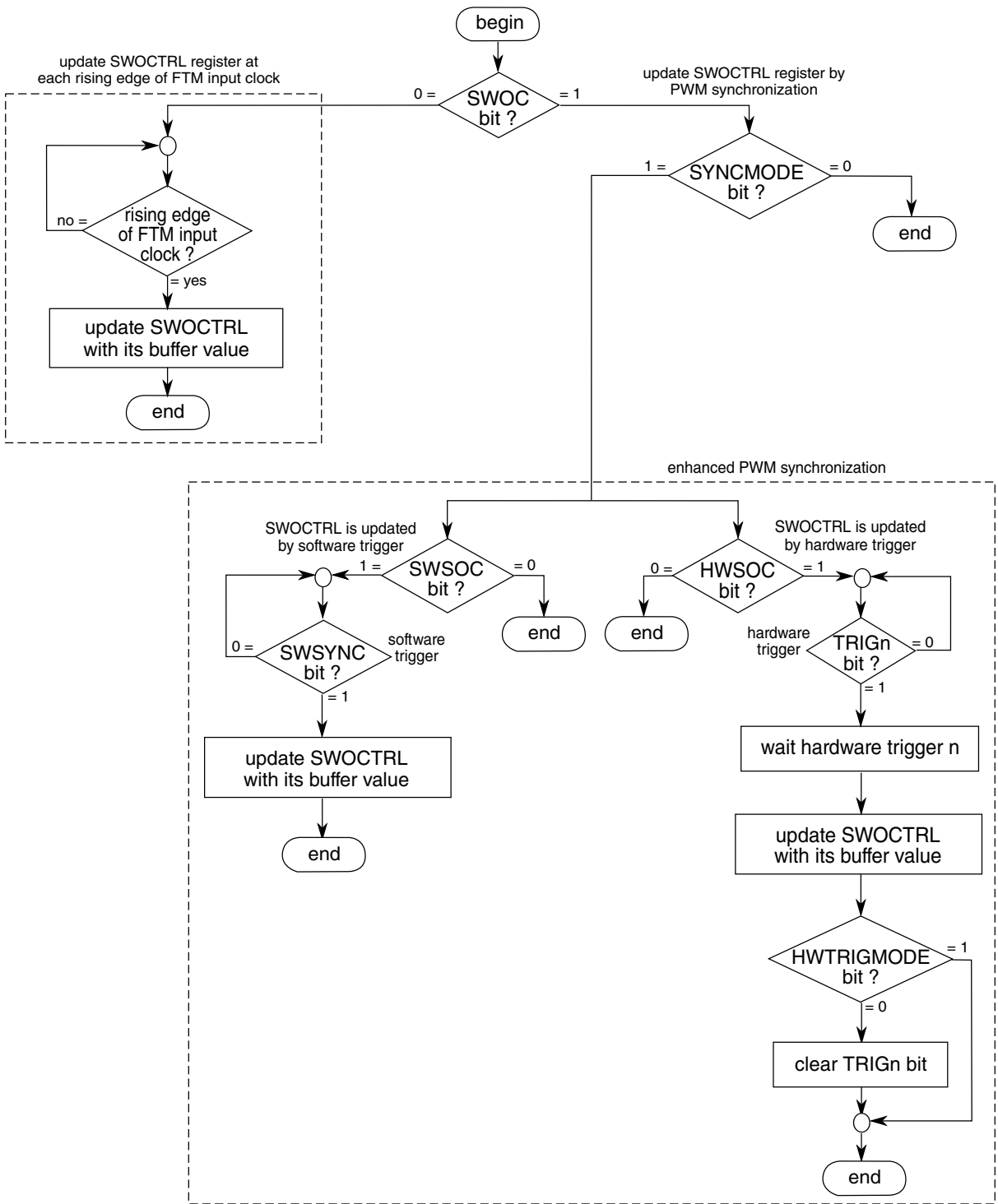


Figure 34-56. SWOCTRL register synchronization flowchart

34.5.12.10 FTM counter synchronization

The FTM counter synchronization is a mechanism that allows the FTM to restart the PWM generation at a certain point in the PWM period. The channels outputs are forced to their initial value, except for channels in Output Compare mode, and the FTM counter is forced to its initial counting value defined by CNTIN register.

The following figure shows the FTM counter synchronization. Note that after the synchronization event occurs, the channel (n) is set to its initial value and the channel (n +1) is not set to its initial value due to a specific timing of this figure in which the deadtime insertion prevents this channel output from transitioning to 1. If no deadtime insertion is selected, then the channel (n+1) transitions to logical value 1 immediately after the synchronization event occurs.

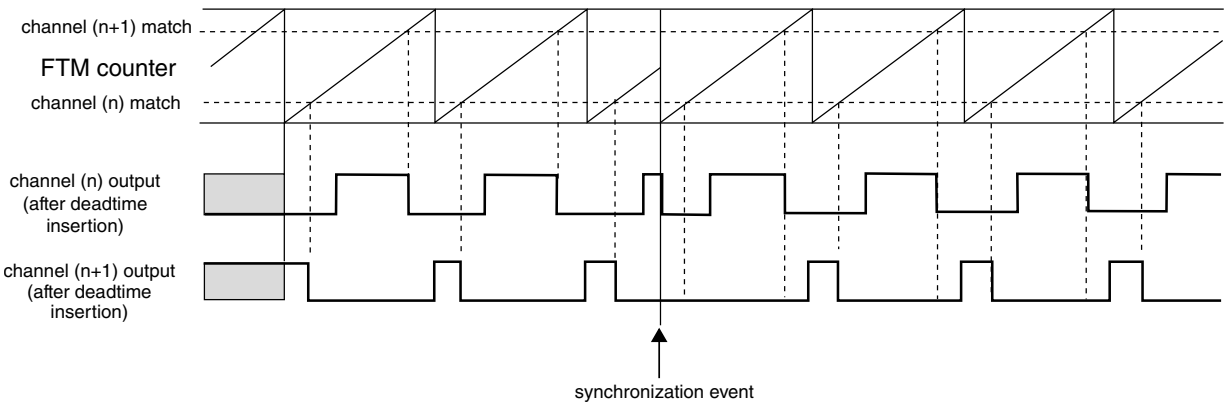


Figure 34-57. FTM counter synchronization

The FTM counter synchronization can be done by either the enhanced PWM synchronization (SYNCMODE = 1) or the legacy PWM synchronization (SYNCMODE = 0). However, the FTM counter must be synchronized only by the enhanced PWM synchronization.

In the case of enhanced PWM synchronization, the FTM counter synchronization depends on SWRSTCNT and HWRSTCNT bits according to the following flowchart.

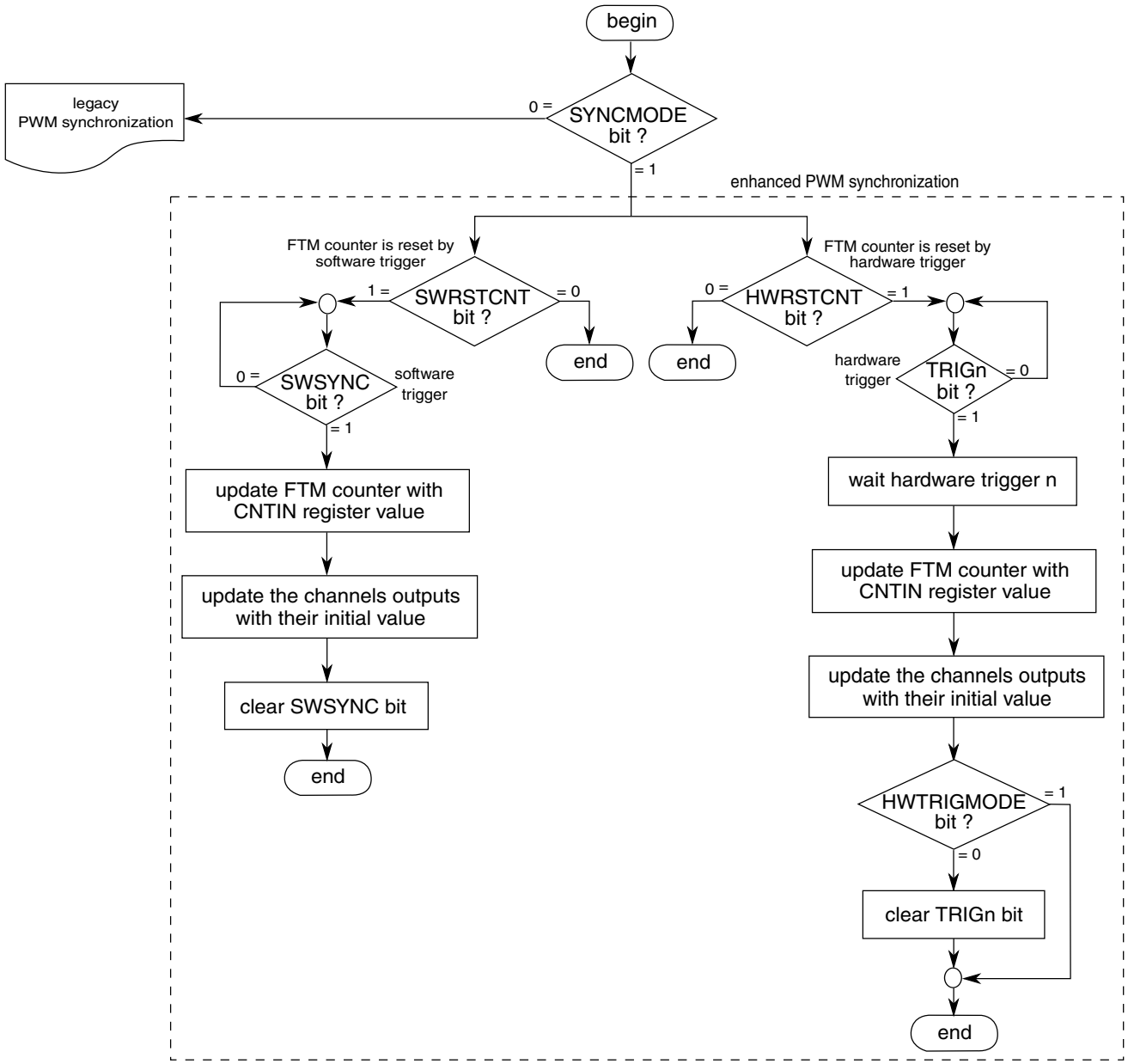


Figure 34-58. FTM counter synchronization flowchart

In the case of legacy PWM synchronization, the FTM counter synchronization depends on REINIT and PWMSYNC bits according to the following description.

If (SYNCMODE = 0), (REINIT = 1), and (PWMSYNC = 0) then this synchronization is made on the next enabled trigger event. If the trigger event was a software trigger then the SWSYNC bit is cleared according to the following example. If the trigger event was a hardware trigger then the TRIGn bit is cleared according to Hardware trigger. Examples with software and hardware triggers follow.

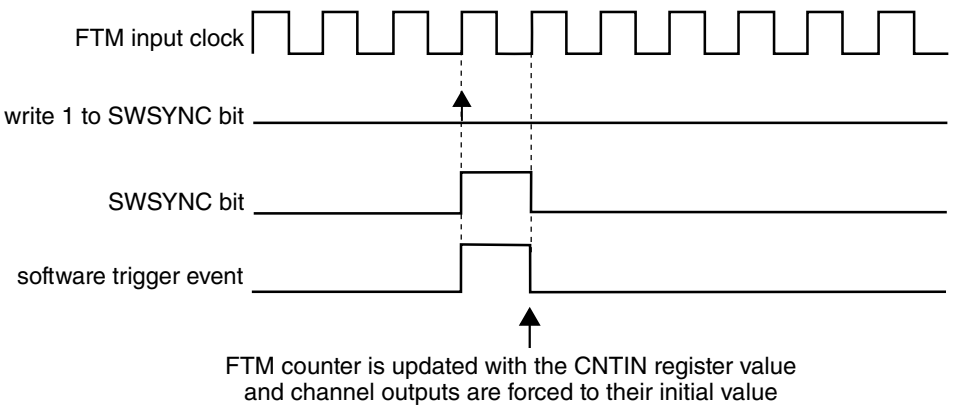


Figure 34-59. FTM counter synchronization with (SYNCMODE = 0), (REINIT = 1), (PWMSYNC = 0), and software trigger was used

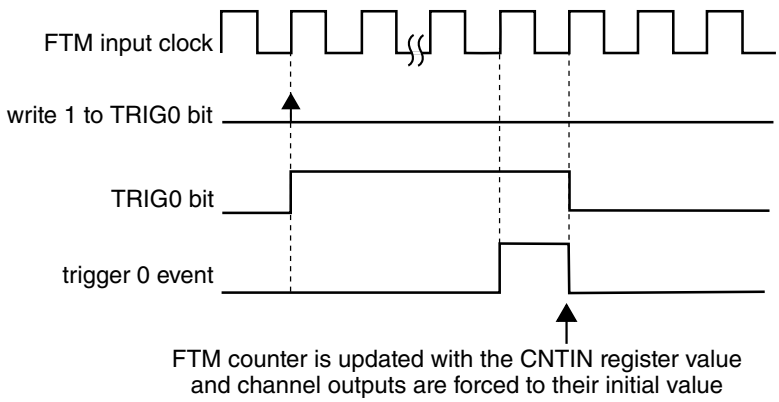


Figure 34-60. FTM counter synchronization with (SYNCMODE = 0), (HWTRIGMODE = 0), (REINIT = 1), (PWMSYNC = 0), and a hardware trigger was used

If (SYNCMODE = 0), (REINIT = 1), and (PWMSYNC = 1) then this synchronization is made on the next enabled hardware trigger. The TRIGn bit is cleared according to Hardware trigger.

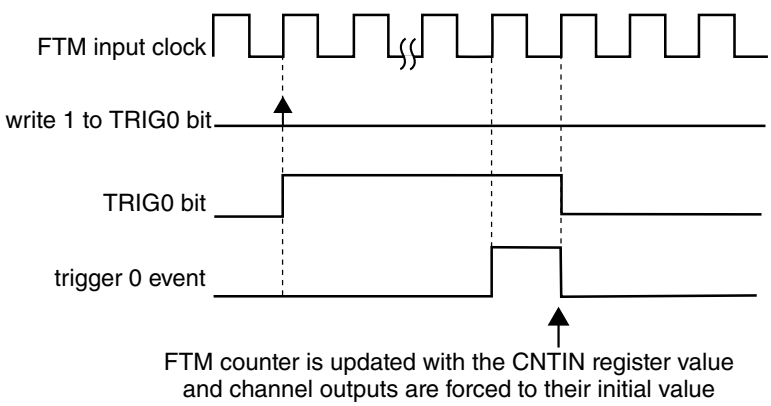


Figure 34-61. FTM counter synchronization with (SYNCMODE = 0), (HWTRIGMODE = 0), (REINIT = 1), (PWMSYNC = 1), and a hardware trigger was used

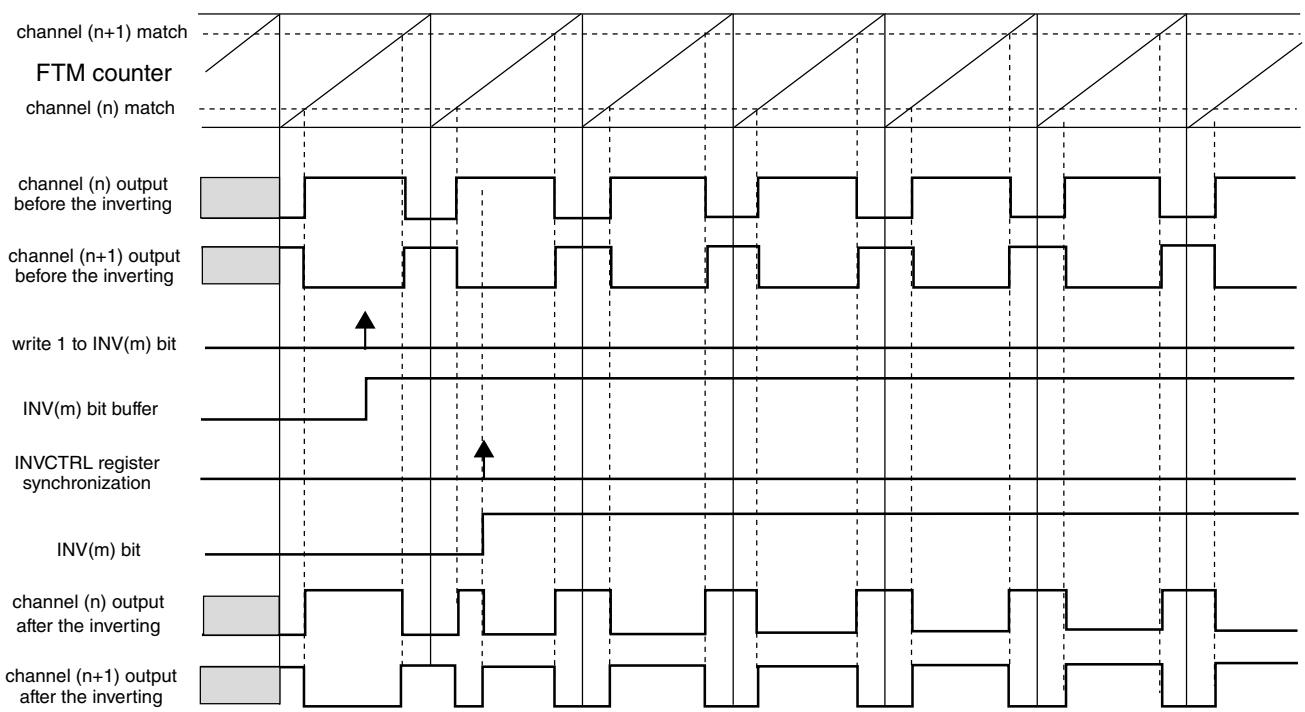
34.5.13 Inverting

The invert functionality swaps the signals between channel (n) and channel (n+1) outputs. The inverting operation is selected when:

- QUADEN = 0
- DECAPEN = 0
- COMP = 1, and
- INVm = 1 (where m represents a channel pair)

The INVm bit in INVCTRL register is updated with its buffer value according to INVCTRL register synchronization.

In combine mode with channel (n) ELSB:ELSA = 1:0, the channel (n) output is forced low at the beginning of the period (FTM counter = CNTIN), forced high at the channel (n) match and forced low at the channel (n+1) match. If the inverting is selected, the channel (n) output behavior is changed to force high at the beginning of the PWM period, force low at the channel (n) match and force high at the channel (n+1) match. See the following figure.



NOTE
INV(m) bit selects the inverting to the pair channels (n) and (n+1).

Figure 34-62. Channels (n) and (n+1) outputs after the inverting in combine mode with channel (n) ELSB:ELSA = 1:0

Note that the channel (n) ELSB:ELSA bits should be considered because they define the active state of the channels outputs. In combine mode with channel (n) ELSB:ELSA = X:1, the channel (n) output is forced high at the beginning of the period, forced low at the channel (n) match and forced high at the channel (n+1) match. When inverting is selected, the channels (n) and (n+1) present waveforms as shown in the following figure.

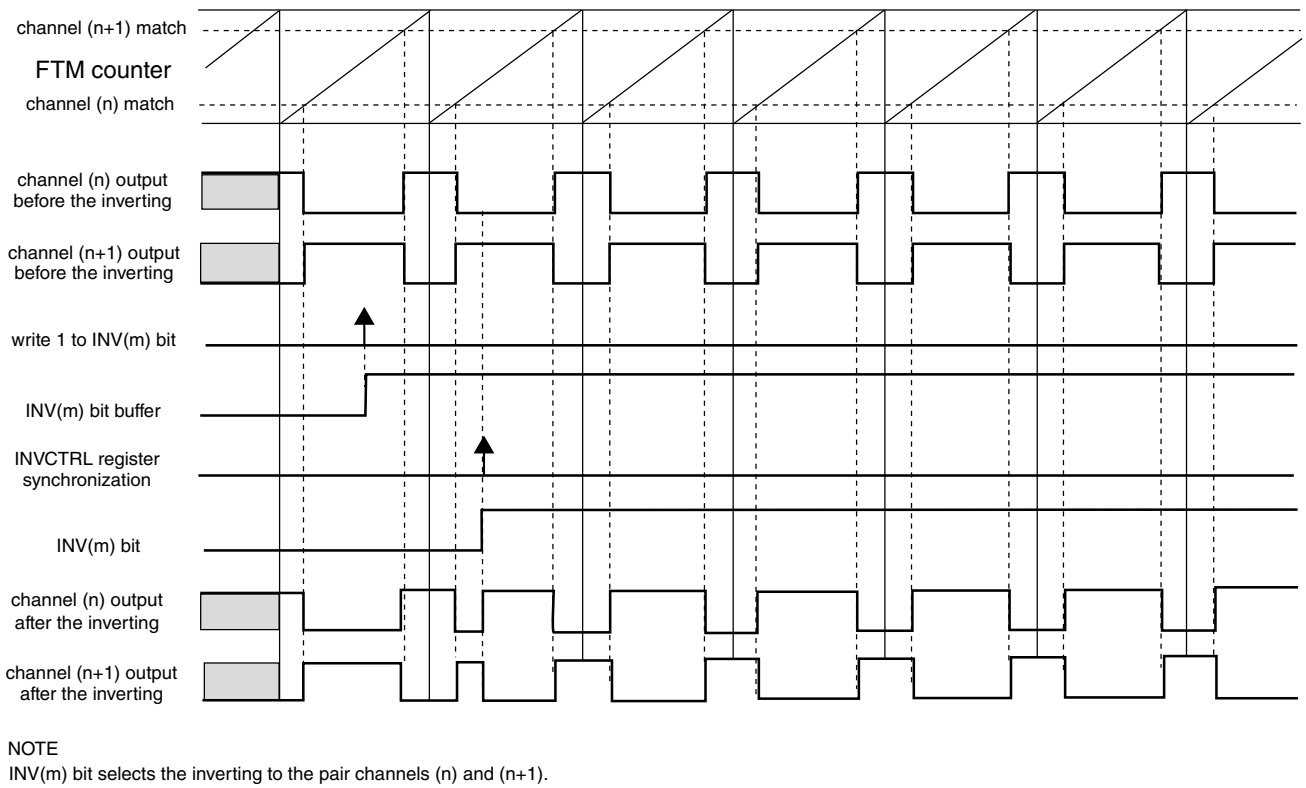


Figure 34-63. Channels (n) and (n+1) outputs after the inverting in combine mode with channel (n) ELSB:ELSA = X:1

NOTE

The Inverting is not available in Output Compare mode.

34.5.14 Software Output Control Mode

The software output control forces the channel output according to software defined values at a specific time in the PWM generation.

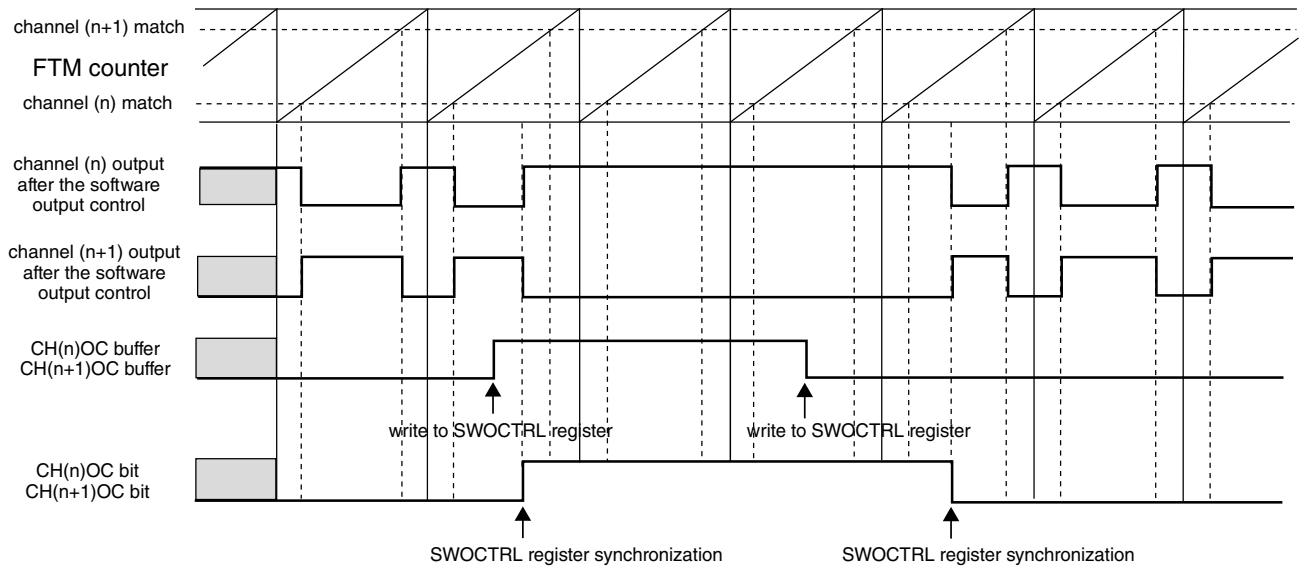
The software output control is selected when:

- QUADEN = 0
- DECAPEN = 0, and
- CH(n)OC = 1

The CH(n)OC bit enables the software output control for a specific channel output and the CH(n)OCV selects the value that is forced to this channel output.

Both CH(n)OC and CH(n)OCV bits in SWOCTRL register are buffered and updated with their buffer value according to SWOCTRL register synchronization.

The following figure shows the channels (n) and (n+1) outputs signals when the software output control is used. In this case the channels (n) and (n+1) are set to Combine and Complementary mode.



NOTE
Channel (n) ELSB:ELSA = X:1, CH(n)OCV = 1 and CH(n+1)OCV = 0.

Figure 34-64. Example of software output control in Combine and Complementary mode

Software output control forces the following values on channels (n) and (n+1) when the COMP bit is zero.

Table 34-11. Software ouput control behavior when (COMP = 0)

CH(n)OC	CH(n+1)OC	CH(n)OCV	CH(n+1)OCV	Channel (n) Output	Channel (n+1) Output
0	0	X	X	is not modified by SWOC	is not modified by SWOC
1	1	0	0	is forced to zero	is forced to zero
1	1	0	1	is forced to zero	is forced to one
1	1	1	0	is forced to one	is forced to zero
1	1	1	1	is forced to one	is forced to one

Software output control forces the following values on channels (n) and (n+1) when the COMP bit is one.

Table 34-12. Software ouput control behavior when (COMP = 1)

CH(n)OC	CH(n+1)OC	CH(n)OCV	CH(n+1)OCV	Channel (n) Output	Channel (n+1) Output
0	0	X	X	is not modified by SWOC	is not modified by SWOC
1	1	0	0	is forced to zero	is forced to zero
1	1	0	1	is forced to zero	is forced to one
1	1	1	0	is forced to one	is forced to zero
1	1	1	1	is forced to one	is forced to zero

Note

- The CH(n)OC and CH(n+1)OC bits should be equal.
- The COMP bit must not be modified when software output control is enabled, that is, CH(n)OC = 1 and/or CH(n +1)OC = 1.
- Software output control has the same behavior with disabled or enabled FTM counter (see the CLKS field description in the Status and Control register).

34.5.15 Deadtime insertion

The deadtime insertion is enabled when DTEN is set and DTVAL[5:0] is non-zero.

DEADTIME register defines the deadtime delay that can be used for all FTM channels. The clock for the DEADTIME delay is the FTM input clock divided by DTPS bits, and the DTVAL[5:0] bits define the deadtime modulo, that is, the number of the deadtime prescaler clocks.

The deadtime delay insertion ensures that no two complementary signals (channels (n) and (n+1)) drive the active state at the same time.

If POL(n) = 0, POL(n+1) = 0, and the deadtime is enabled, then when the channel (n) match (FTM counter = C(n)V) occurs, the channel (n) output remains at the low value until the end of the deadtime delay when the channel (n) output is set. Similarly, when the channel (n+1) match (FTM counter = C(n+1)V) occurs, the channel (n+1) output remains at the low value until the end of the deadtime delay when the channel (n+1) output is set. See the following figures.

If POL(n) = 1, POL(n+1) = 1, and the deadtime is enabled, then when the channel (n) match (FTM counter = C(n)V) occurs, the channel (n) output remains at the high value until the end of the deadtime delay when the channel (n) output is cleared. Similarly,

when the channel (n+1) match (FTM counter = C(n+1)V) occurs, the channel (n+1) output remains at the high value until the end of the deadtime delay when the channel (n +1) output is cleared.

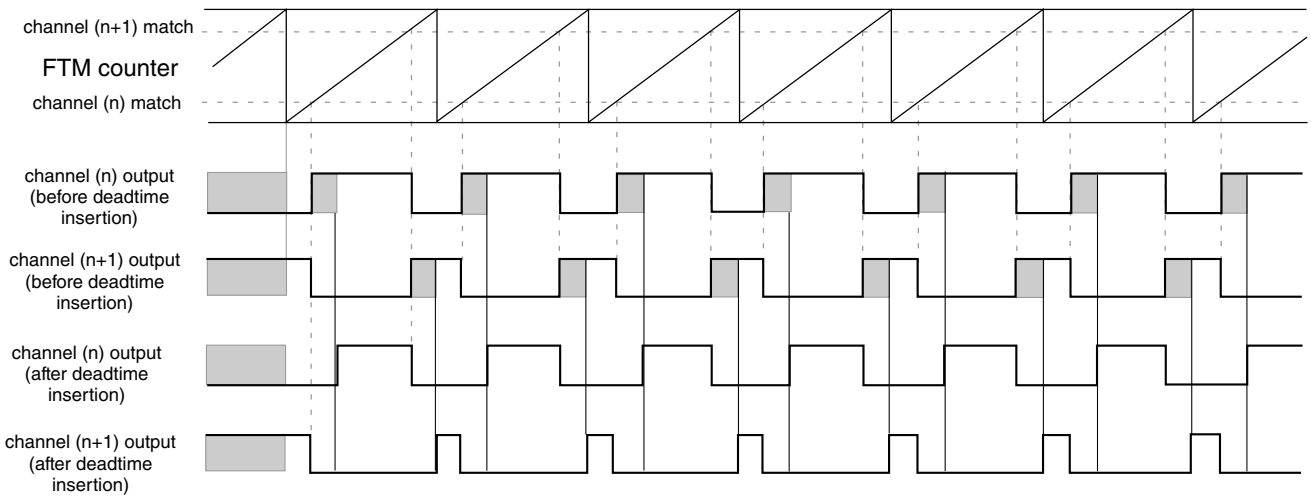


Figure 34-65. Deadtime insertion with ELSB:ELSA = 1:0, POL(n) = 0, and POL(n+1) = 0

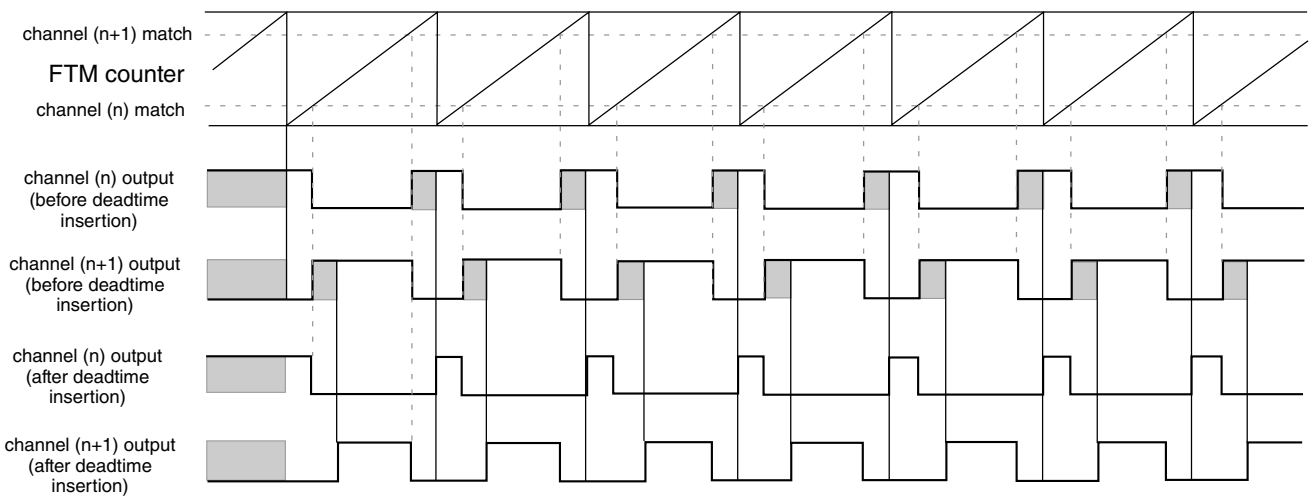


Figure 34-66. Deadtime insertion with ELSB:ELSA = X:1, POL(n) = 0, and POL(n+1) = 0

NOTE

- The deadtime feature must be used only in Complementary mode.
- The deadtime feature is not available in Output Compare mode.

34.5.15.1 Deadtime insertion corner cases

If (PS[2:0] is cleared), (DTPS[1:0] = 0:0 or DTPS[1:0] = 0:1):

- and the deadtime delay is greater than or equal to the channel (n) duty cycle ((C(n +1)V – C(n)V) × FTM input clock), then the channel (n) output is always the inactive value (POL(n) bit value).
- and the deadtime delay is greater than or equal to the channel (n+1) duty cycle ((MOD – CNTIN + 1 – (C(n+1)V – C(n)V)) × FTM input clock), then the channel (n+1) output is always the inactive value (POL(n+1) bit value).

Although, in most cases the deadtime delay is not comparable to channels (n) and (n+1) duty cycle, the following figures show examples where the deadtime delay is comparable to the duty cycle.

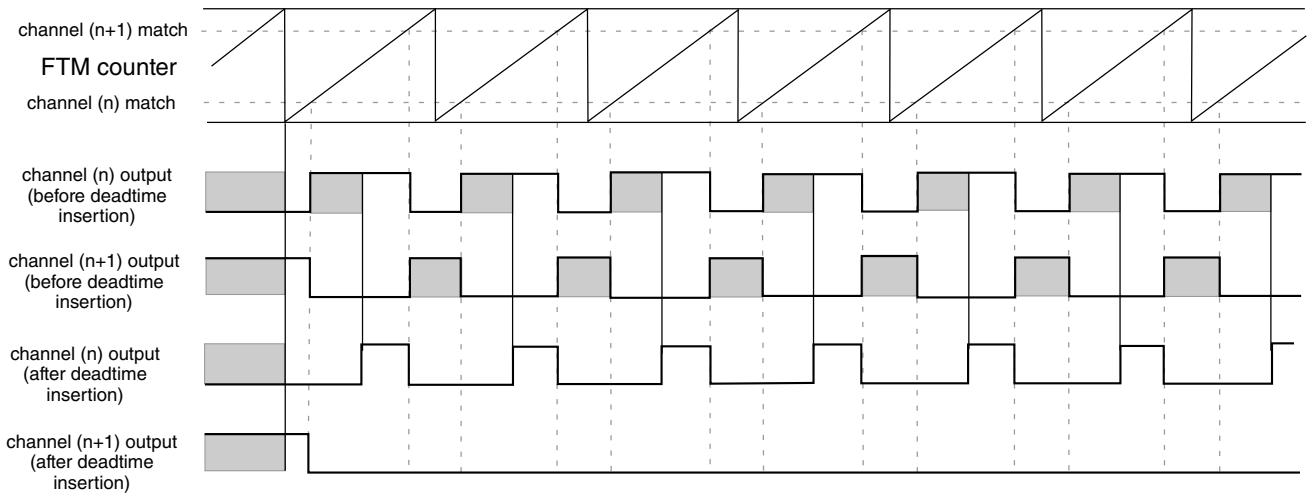


Figure 34-67. Example of the deadtime insertion (channel (n) ELSB:ELSA = 1:0, POL(n) = 0, and POL(n+1) = 0) when the deadtime delay is comparable to channel (n+1) duty cycle

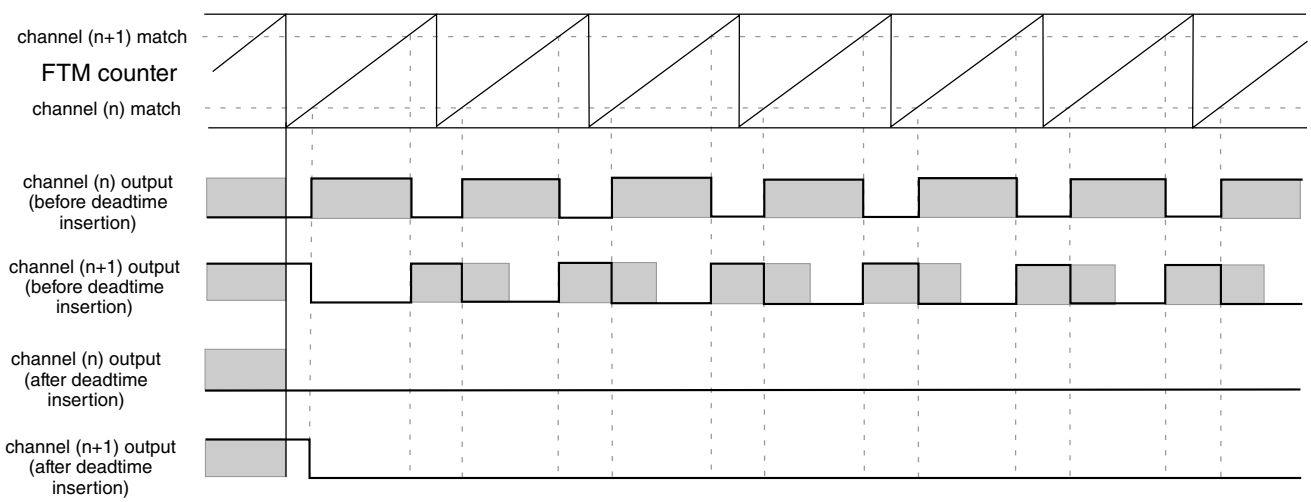


Figure 34-68. Example of the deadtime insertion (channel (n) ELSB:ELSA = 1:0, POL(n) = 0, and POL(n+1) = 0) when the deadtime delay is comparable to channels (n) and (n+1) duty cycle

34.5.16 Output mask

The output mask can be used to force channels output to their inactive state through software. For example: to control a BLDC motor.

Any write to the OUTMASK register updates its write buffer. The OUTMASK register is updated with its buffer value by PWM synchronization; see OUTMASK register synchronization.

If CH(n)OM = 1, then the channel (n) output is forced to its inactive state (POLn bit value). If CH(n)OM = 0, then the channel (n) output is unaffected by the output mask. See the following figure.

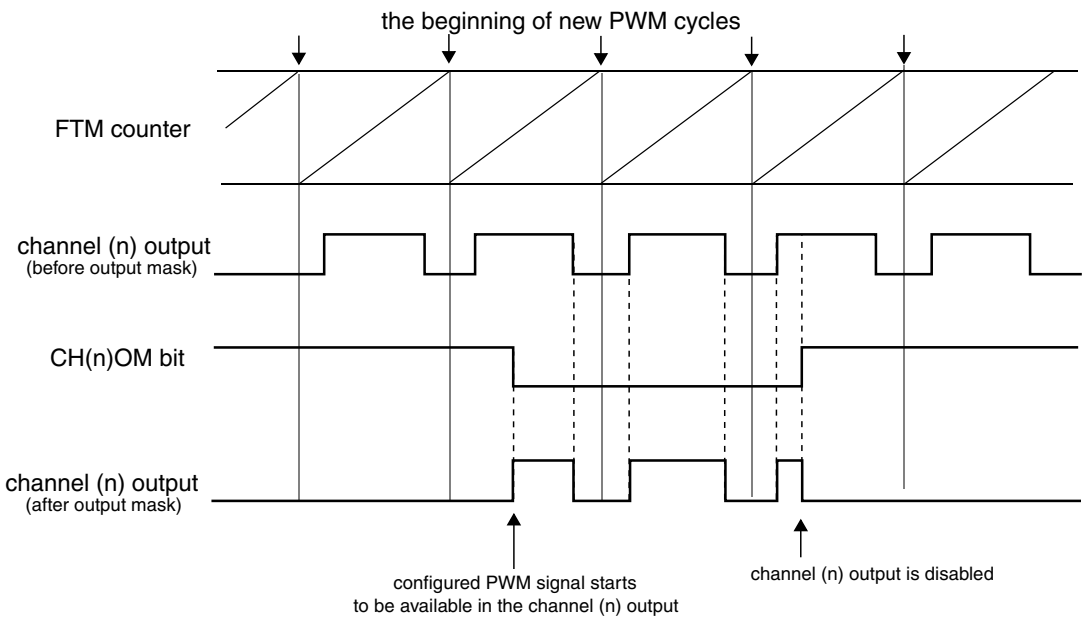


Figure 34-69. Output mask with POLn = 0

The following table shows the output mask result before the polarity control.

Table 34-13. Output mask result for channel (n) before the polarity control

CH(n)OM	Output Mask Input	Output Mask Result
0	inactive state	inactive state
	active state	active state
1	inactive state	inactive state
	active state	

34.5.17 Fault Control

The fault control is enabled if FAULTM[1:0] ≠ 0:0.

FTM can have up to four fault inputs. FAULTnEN bit (where n = 0, 1, 2, 3) enables the fault input n and FFLTRnEN bit enables the fault input n filter. FFVAL[3:0] bits select the value of the enabled filter in each enabled fault input.

The fault input after being synchronized by FTM input clock is the filter input.

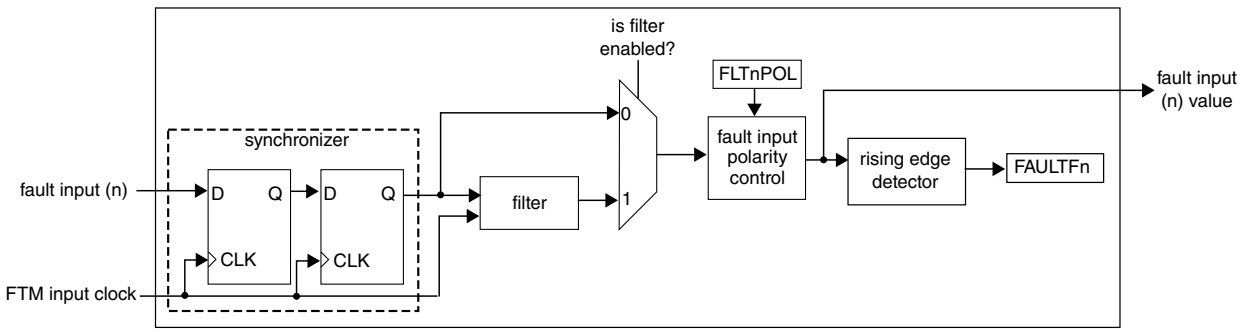


Figure 34-70. Diagram for Fault Control

When there is a state change in the fault input (n), the counter is reset and starts counting up. As long as the new state is stable on the fault input (n), the counter continues to increment. When the counter is equal to FFVAL[3:0] bits, the new fault input (n) value is validated. It is then transmitted as a pulse to the edge detector.

If the opposite edge appears on the fault input (n) before it can be validated, the counter is reset. At the next input transition, the counter starts counting again. If a pulse is sampled as a value less than FFVAL[3:0] consecutive rising edges of FTM input clock, it is regarded as a glitch and is not passed on to the edge detector.

The table below shows the delay that is added by the FTM fault input filter according to its configuration.

Table 34-14. FTM Fault Input Filter Delay

FTM fault input filter	Number of rising edges between the selected edge on fault input and forcing the channels outputs to their safe values
• fault input does not have the input filter, or • fault input filter is disabled (FFLTRnEN = 0 or FFVAL[3:0] = 0)	• 3 rising edges of FTM input clock
• fault input has the input filter, and • fault input filter is enabled (FFLTRnEN = 1 and FFVAL[3:0] ≠ 0)	• (4 + FFVAL[3:0]) rising edges of FTM input clock

If the fault control and fault input (n) are enabled, and the selected edge at the fault input (n) is detected, then a fault condition has occurred and the FAULTFn bit is set. The FAULTF bit is the logic OR of FAULTFn[3:0] bits. See the following figure.

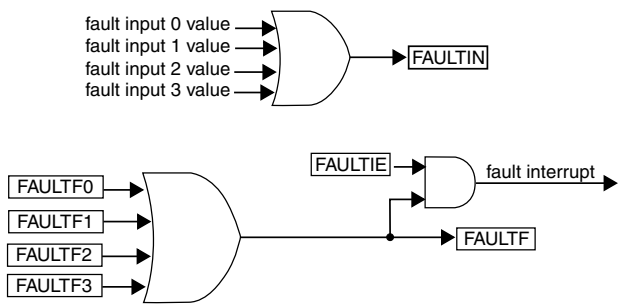


Figure 34-71. FAULTF and FAULTIN bits and fault interrupt

If the fault control is enabled (FAULTM[1:0] ≠ 0:0), a fault condition has occurred, and (FAULTENj = 1, where j is the pair j of the channels), then the channels (n) and (n+1) outputs are forced to their safe values:

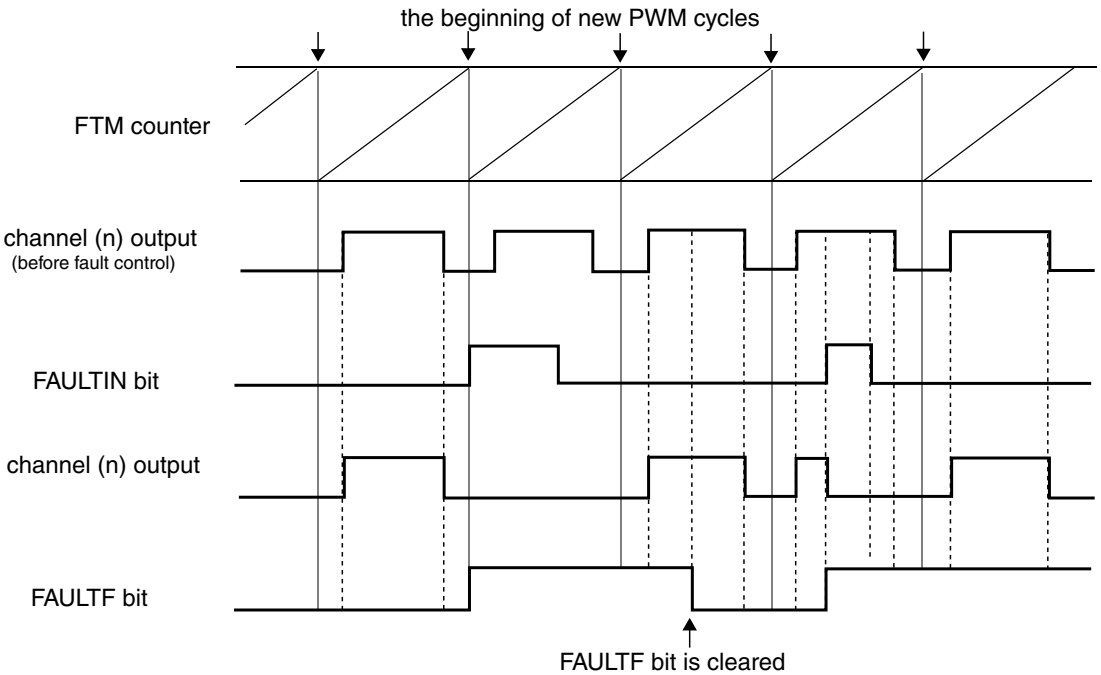
- channel (n) output takes the POL(n) bit value
- channel (n+1) output takes the POL(n+1) bit value

The fault interrupt is generated when (FAULTF = 1) and (FAULTIE = 1). This interrupt request remains set until:

- Software clears the FAULTF bit by reading FAULTF bit as 1 and writing 0 to it
- Software clears the FAULTIE bit
- A reset occurs

34.5.17.1 Automatic fault clearing

If the automatic fault clearing is selected (FAULTM[1:0] = 1:1), then the channels output disabled by fault control is again enabled when the fault input signal (FAULTIN) returns to zero and a new PWM cycle begins. See the following figure.

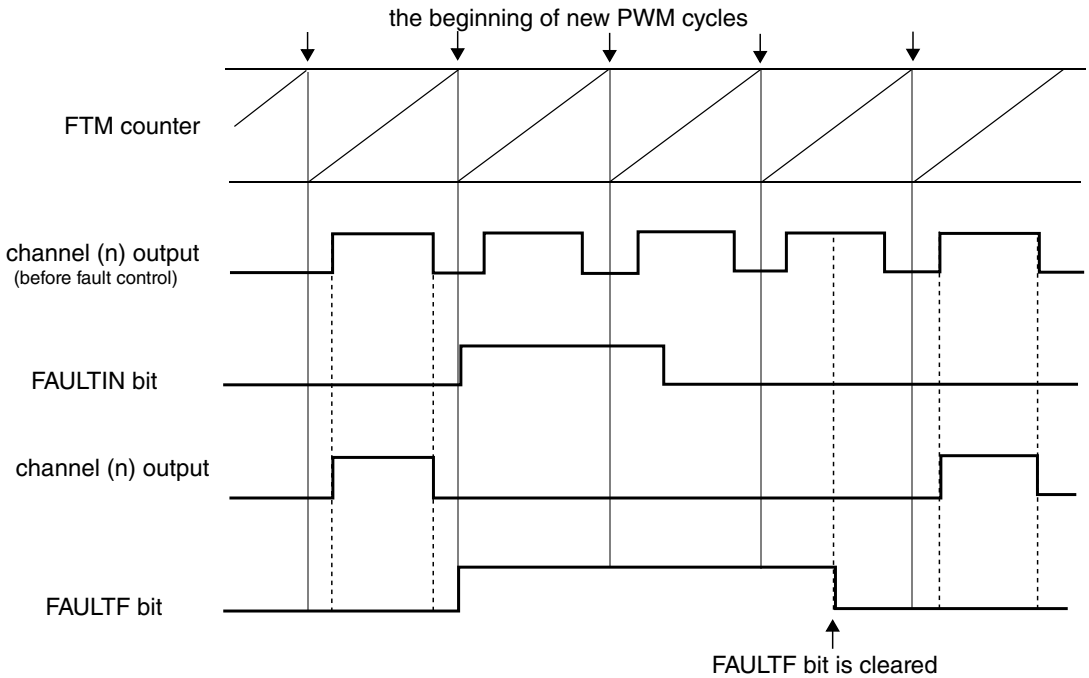


NOTE
The channel (n) output is after the fault control with automatic fault clearing and POLn = 0.

Figure 34-72. Fault control with automatic fault clearing

34.5.17.2 Manual fault clearing

If the manual fault clearing is selected (FAULTM[1:0] = 0:1 or 1:0), then the channels output disabled by fault control is again enabled when the FAULTF bit is cleared and a new PWM cycle begins. See the following figure.



NOTE
The channel (n) output is after the fault control with manual fault clearing and POLn = 0.

Figure 34-73. Fault control with manual fault clearing

34.5.17.3 Fault inputs polarity control

The FLTjPOL bit selects the fault input j polarity, where j = 0, 1, 2, 3:

- If FLTjPOL = 0, the fault j input polarity is high, so the logical one at the fault input j indicates a fault.
- If FLTjPOL = 1, the fault j input polarity is low, so the logical zero at the fault input j indicates a fault.

34.5.18 Polarity Control

The POLn bit selects the channel (n) output polarity:

- If POLn = 0, the channel (n) output polarity is high, so the logical one is the active state and the logical zero is the inactive state.
- If POLn = 1, the channel (n) output polarity is low, so the logical zero is the active state and the logical one is the inactive state.

34.5.19 Initialization

The initialization forces the CH(n)OI bit value to the channel (n) output when 1 is written to the INIT bit.

The initialization depends on COMP and DTEN bits. The following table shows the values that channels (n) and (n+1) are forced by initialization when the COMP and DTEN bits are zero.

Table 34-15. Initialization behavior when (COMP = 0 and DTEN = 0)

CH(n)OI	CH(n+1)OI	Channel (n) Output	Channel (n+1) Output
0	0	is forced to zero	is forced to zero
0	1	is forced to zero	is forced to one
1	0	is forced to one	is forced to zero
1	1	is forced to one	is forced to one

The following table shows the values that channels (n) and (n+1) are forced by initialization when (COMP = 1) or (DTEN = 1).

Table 34-16. Initialization behavior when (COMP = 1 or DTEN = 1)

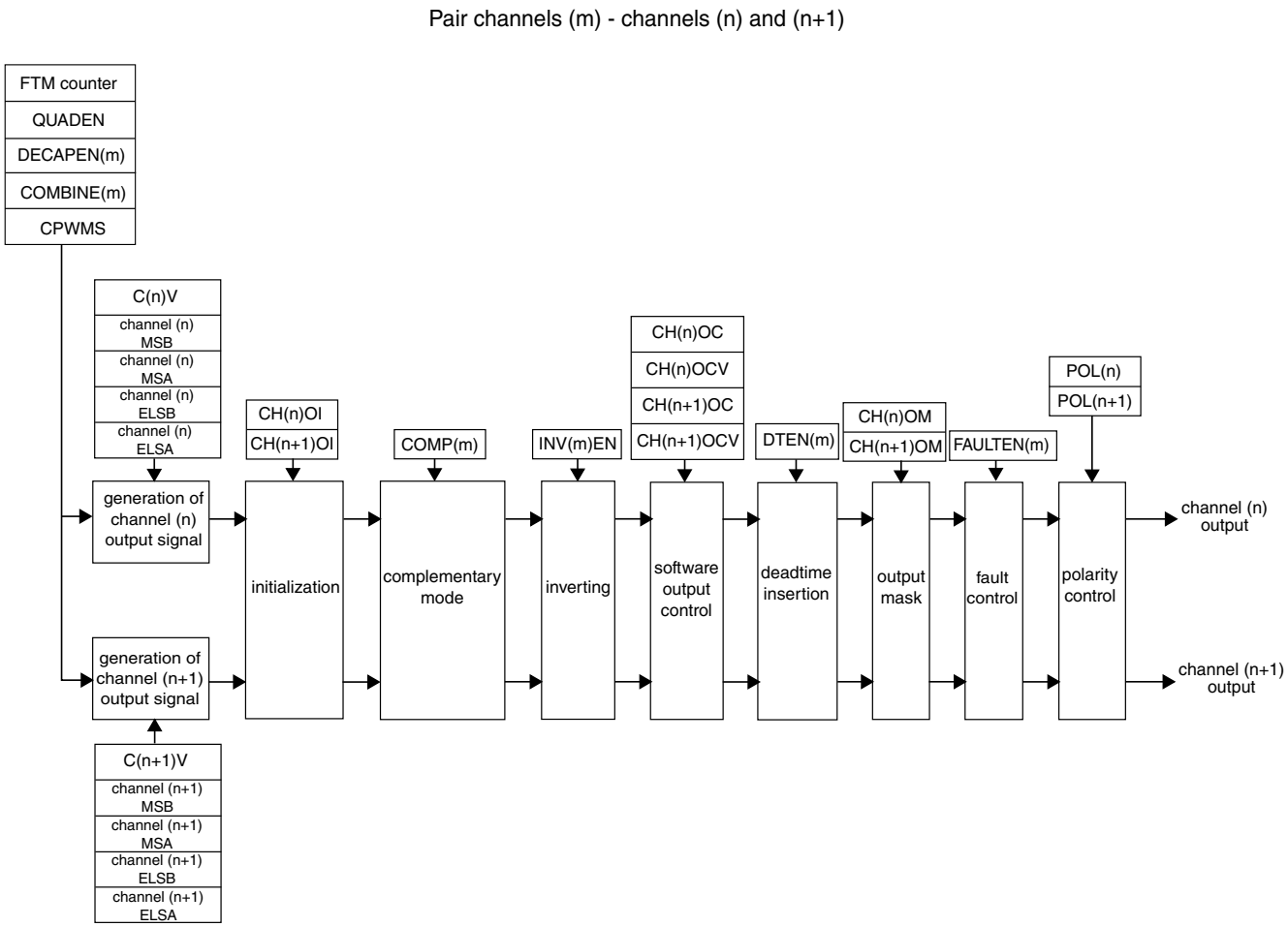
CH(n)OI	CH(n+1)OI	Channel (n) Output	Channel (n+1) Output
0	X	is forced to zero	is forced to one
1	X	is forced to one	is forced to zero

Note

The initialization feature must be used only with disabled FTM counter. See the description of the CLKS field in the Status and Control register.

34.5.20 Features Priority

The following figure shows the priority of the features used at the generation of channels (n) and (n+1) outputs signals.



Note:
The channels (n) and (n+1) are in Output Compare, EPWM, CPWM or Combine modes.

Figure 34-74. Priority of the features usead at the generation of channels (n) and (n+1) output

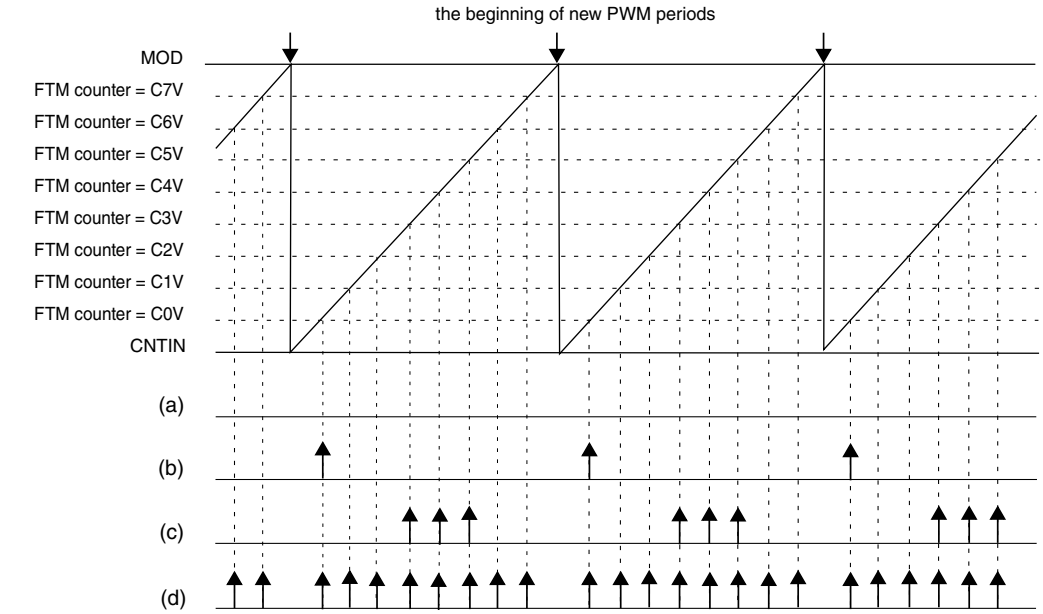
NOTE

The Initialization must not be used with Inverting and Software Output Control Mode.

34.5.21 External Trigger

If the CH(n)TRIG bit (register EXTTRIG) is set, where n = 0, 1, 2, 3, 4, 5, 6 or 7, then the FTM generates a trigger when the channel (n) match occurs (FTM counter = C(n)V) at the FTM external trigger output.

The width of a channel (n) trigger is one FTM input clock and the FTM is able to generate multiple triggers in one PWM period. See the figure below.



Note
(a) CH0TRIG = 0, CH1TRIG = 0, CH2TRIG = 0, CH3TRIG = 0, CH4TRIG = 0, CH5TRIG = 0, CH6TRIG = 0, CH7TRIG = 0
(b) CH0TRIG = 1, CH1TRIG = 0, CH2TRIG = 0, CH3TRIG = 0, CH4TRIG = 0, CH5TRIG = 0, CH6TRIG = 0, CH7TRIG = 0
(c) CH0TRIG = 0, CH1TRIG = 0, CH2TRIG = 0, CH3TRIG = 1, CH4TRIG = 1, CH5TRIG = 1, CH6TRIG = 0, CH7TRIG = 0
(d) CH0TRIG = 1, CH1TRIG = 1, CH2TRIG = 1, CH3TRIG = 1, CH4TRIG = 1, CH5TRIG = 1, CH6TRIG = 1, CH7TRIG = 1

Figure 34-75. External Trigger

34.5.22 Initialization Trigger

Initialization trigger allows FTM to generate a trigger in some specific points of FTM counter cycle. This feature is controlled by the bits INITTRIGEN and ITRIGR. The INITTRIGEN bit enables the initialization trigger generation and the ITRIGR bit selects when the initialization trigger is generated.

If INITTRIGEN = 1 and ITRIGR = 1, then the initialization trigger is generated when FTM counter reaches a reload point according to the frequency of the reload opportunities (Reload Points).

NOTE

For this configuration of initilization trigger and in CPWM mode, the bits CNTMAX and CNTMIN select where the initialization trigger is generated.

If INITTRIGEN = 1 and ITRIGR = 0, then the initialization trigger is generated when FTM counter is updated with the CNTIN register value. See the cases below.

1. When FTM counter is updated with CNTIN register value automatically.

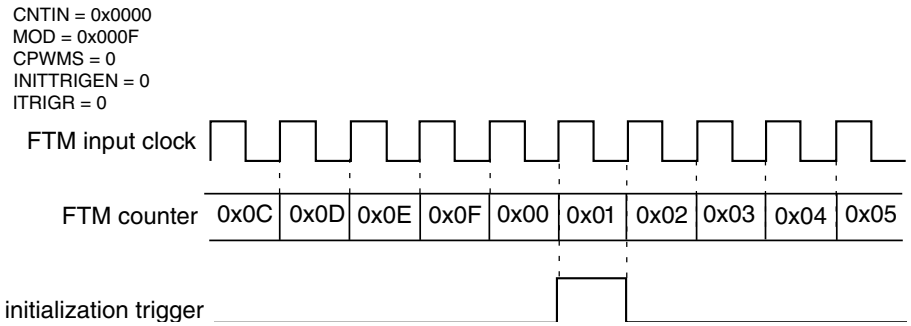


Figure 34-76. Example of the generation of the initialization trigger in the case 1.

2. When there is a write to CNT register.

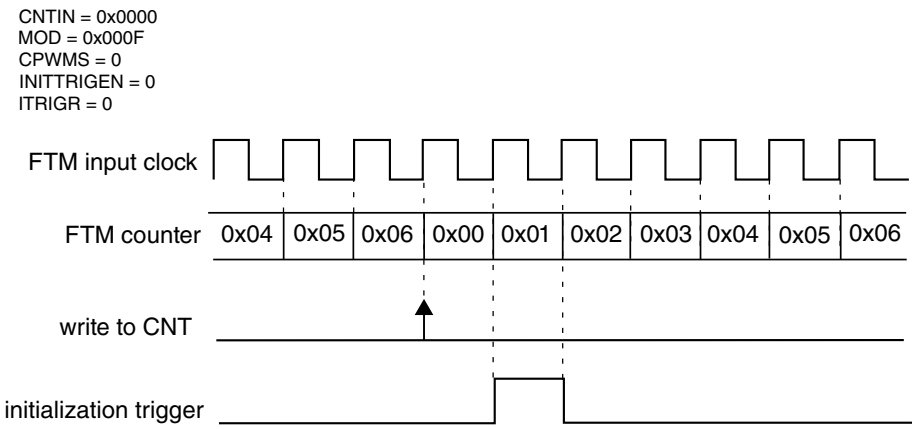


Figure 34-77. Example of the generation of the initialization trigger in the case 2.

NOTE

This behavior is not available in CPWM mode.

3. When there is the FTM counter synchronization.

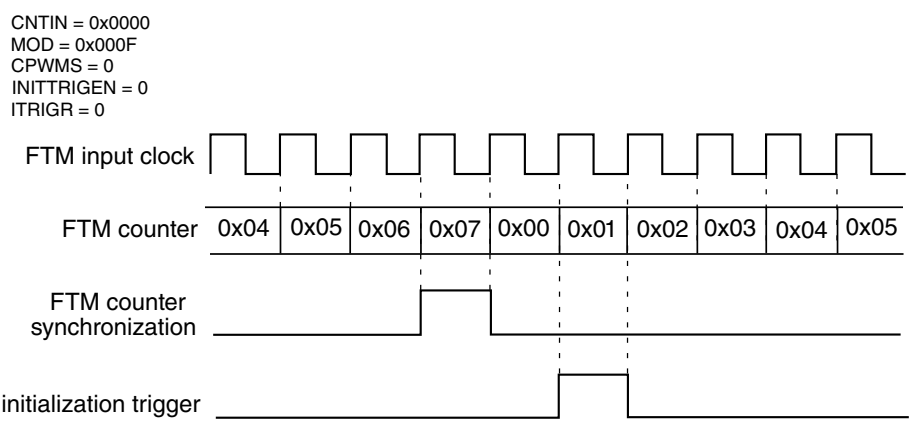


Figure 34-78. Example of the generation of the initialization trigger in the case 3.

NOTE

This behavior is not available in CPWM mode.

4. If (CNT = CNTIN), (CLKS[1:0] = 0:0), and a value different from zero is written to CLKS[1:0] bits.

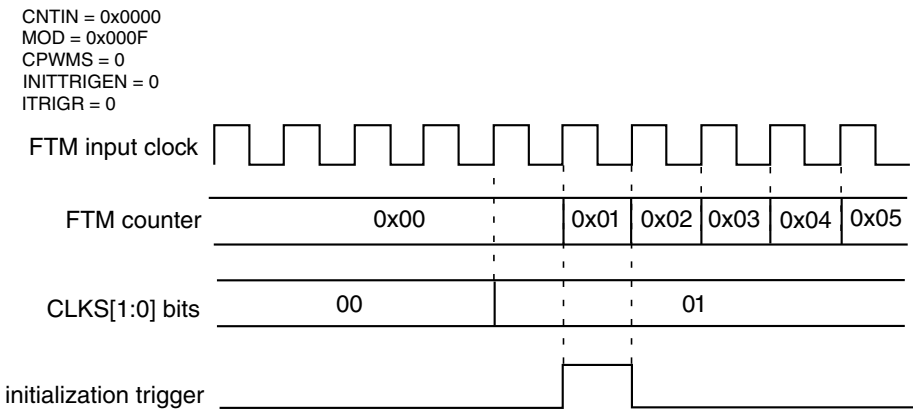


Figure 34-79. Example of the generation of the initialization trigger in the case 4.

NOTE

This behavior is not available in CPWM mode.

5. If the channel (n) is in Input Capture mode, (ICRST = 1) and the selected input capture event occurs in the channel (n) input.

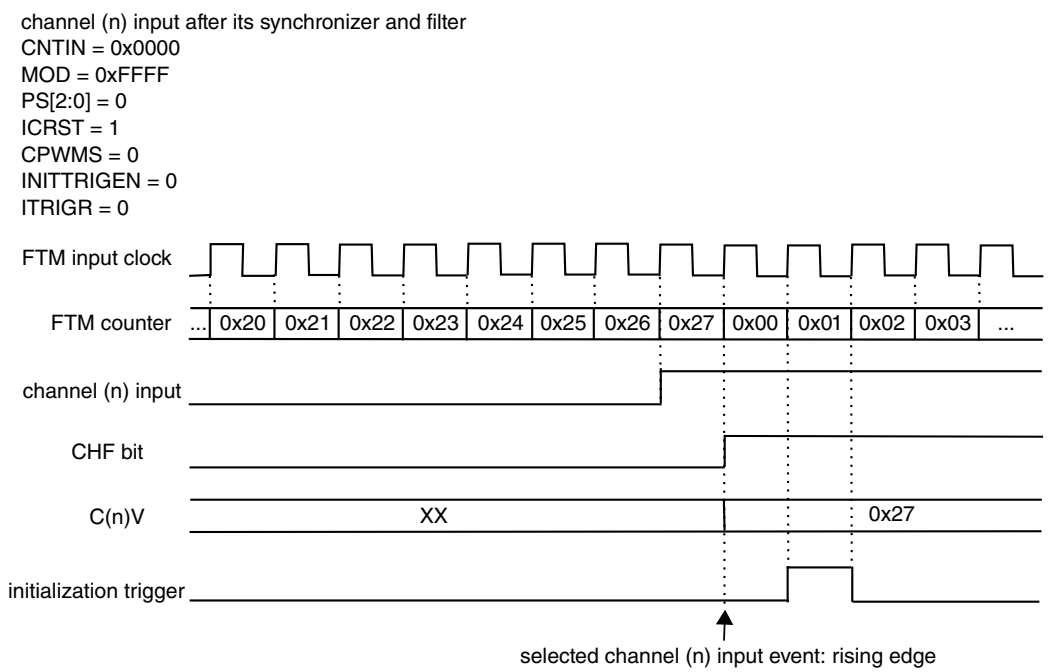


Figure 34-80. Example of the generation of the initialization trigger in the case 5.

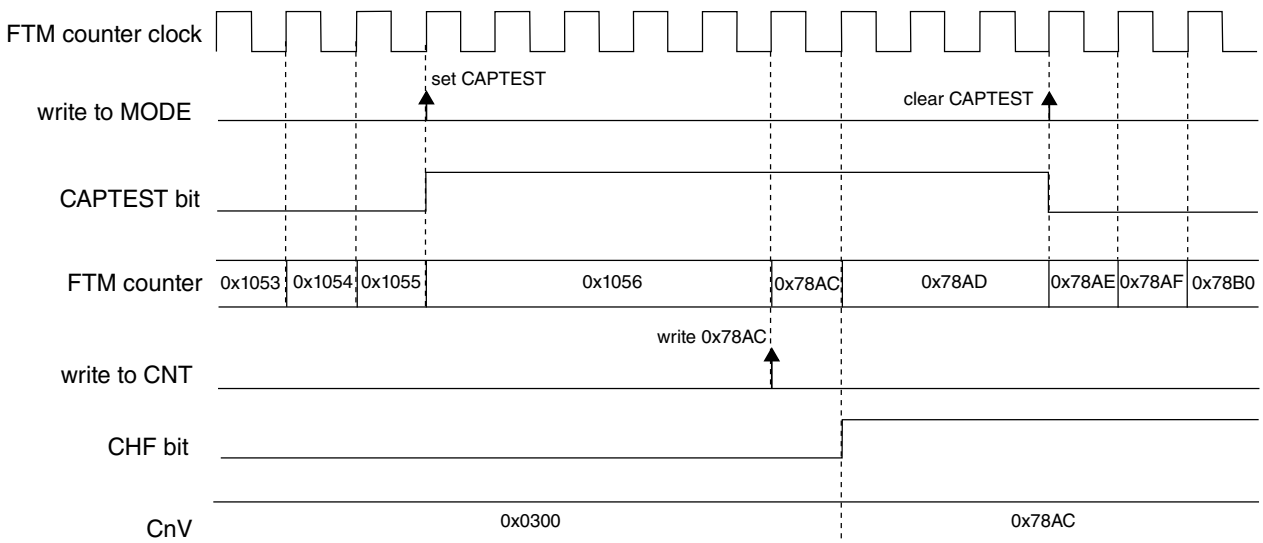
34.5.23 Capture Test Mode

The Capture Test mode allows to test the CnV registers, the FTM counter and the interconnection logic between the FTM counter and CnV registers.

In this test mode, all channels must be configured for Input Capture Mode and FTM counter must be configured to the Up counting.

When the Capture Test mode is enabled (CAPTEST = 1), the FTM counter is frozen and any write to CNT register updates directly the FTM counter; see the following figure. After it was written, all CnV registers are updated with the written value to CNT register and CHF bits are set. Therefore, the FTM counter is updated with its next value according to its configuration. Its next value depends on CNTIN, MOD, and the written value to FTM counter.

The next reads of CnV registers return the written value to the FTM counter and the next reads of CNT register return FTM counter next value.



Note:
- FTM counter is in free running
- FTMEN = 1
- FTM channel (n) is in Input Capture Mode

Figure 34-81. Capture Test Mode

34.5.24 Dual Edge Capture Mode

The dual edge capture mode is enabled if DECAPEN = 1. This mode allows to measure a pulse width or period of the channel (n) input where n = 0, 2, 4 or 6. The channel (n) filter can be enabled for n = 0 or 2.

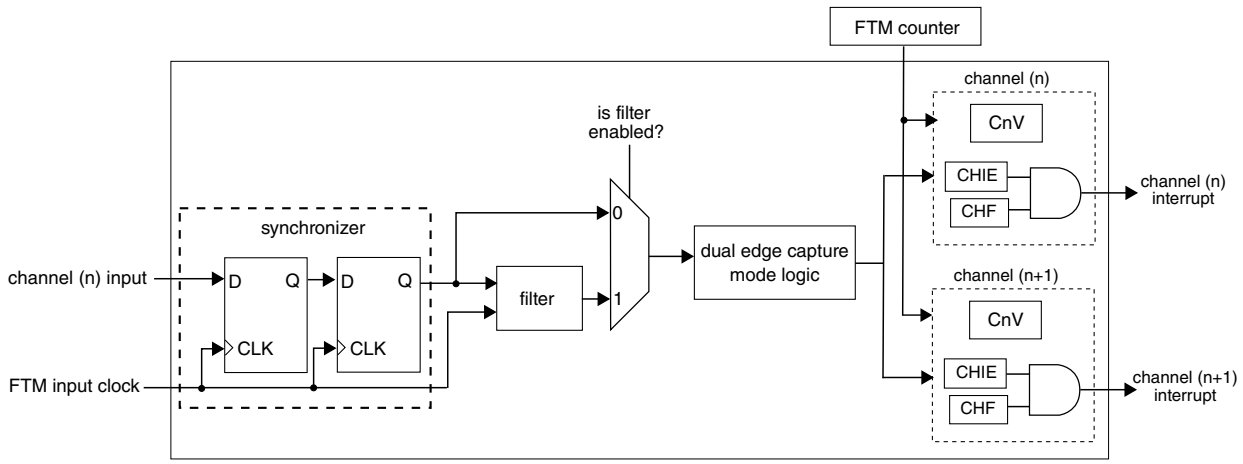


Figure 34-82. Diagram for Dual Edge Capture Mode

The channel (n) MSA bit defines if the dual edge capture mode is one-shot or continuous.

The channel (n) ELSB:ELSA bits select the edge that is captured by channel (n), and channel (n+1) ELSB:ELSA bits select the edge that is captured by channel (n+1). If both channel (n) ELSB:ELSA and channel (n+1) ELSB:ELSA bits select the same edge, then it is the period measurement. If these bits select different edges, then it is a pulse width measurement.

In the dual edge capture mode, only channel (n) input is used and channel (n+1) input is ignored.

If the selected edge by channel (n) bits is detected at channel (n) input, then channel (n) CHF bit is set and the channel (n) interrupt is generated (if channel (n) CHIE = 1). If the selected edge by channel (n+1) bits is detected at channel (n) input and (channel (n) CHF = 1), then channel (n+1) CHF bit is set and the channel (n+1) interrupt is generated (if channel (n+1) CHIE = 1).

The C(n)V register stores the FTM counter value when the selected edge by channel (n) is detected at channel (n) input. The C(n+1)V register stores the FTM counter value when the selected edge by channel (n+1) is detected at channel (n) input.

In this mode, a coherency mechanism (for channels (n) and (n+1)) ensures coherent data when the C(n)V and C(n+1)V registers are read. The only requirement is that C(n)V must be read before C(n+1)V.

Note

- The dual edge capture mode must be used with channel (n) ELSB:ELSA = 0:1 or 1:0, channel (n+1) ELSB:ELSA = 0:1 or 1:0 and the FTM counter in Free running counter.

34.5.24.1 One-Shot Capture mode

The One-Shot Capture mode is selected when (DECAPEN = 1), and (channel (n) MSA = 0). In this capture mode, only one pair of edges at the channel (n) input is captured. The channel (n) ELSB:ELSA bits select the first edge to be captured, and channel (n+1) ELSB:ELSA bits select the second edge to be captured.

The edge captures are enabled while DECAP bit is set. For each new measurement in One-Shot Capture mode, first the channel (n) CHF and channel (n+1) CHF bits must be cleared, and then the DECAP bit must be set.

In this mode, the DECAP bit is automatically cleared by FTM when the edge selected by channel (n+1) is captured. Therefore, while DECAP bit is set, the one-shot capture is in process. When this bit is cleared, both edges were captured and the captured values are ready for reading in the C(n)V and C(n+1)V registers.

Similarly, when the channel (n+1) CHF bit is set, both edges were captured and the captured values are ready for reading in the C(n)V and C(n+1)V registers.

34.5.24.2 Continuous Capture mode

The Continuous Capture mode is selected when (DECAPEN = 1), and (channel (n) MSA = 1). In this capture mode, the edges at the channel (n) input are captured continuously. The channel (n) ELSB:ELSA bits select the initial edge to be captured, and channel (n+1) ELSB:ELSA bits select the final edge to be captured.

The edge captures are enabled while DECAP bit is set. For the initial use, first the channel (n) CHF and channel (n+1) CHF bits must be cleared, and then DECAP bit must be set to start the continuous measurements.

When the channel (n+1) CHF bit is set, both edges were captured and the captured values are ready for reading in the C(n)V and C(n+1)V registers. The latest captured values are always available in these registers even after the DECAP bit is cleared.

In this mode, it is possible to clear only the channel (n+1) CHF bit. Therefore, when the channel (n+1) CHF bit is set again, the latest captured values are available in C(n)V and C(n+1)V registers.

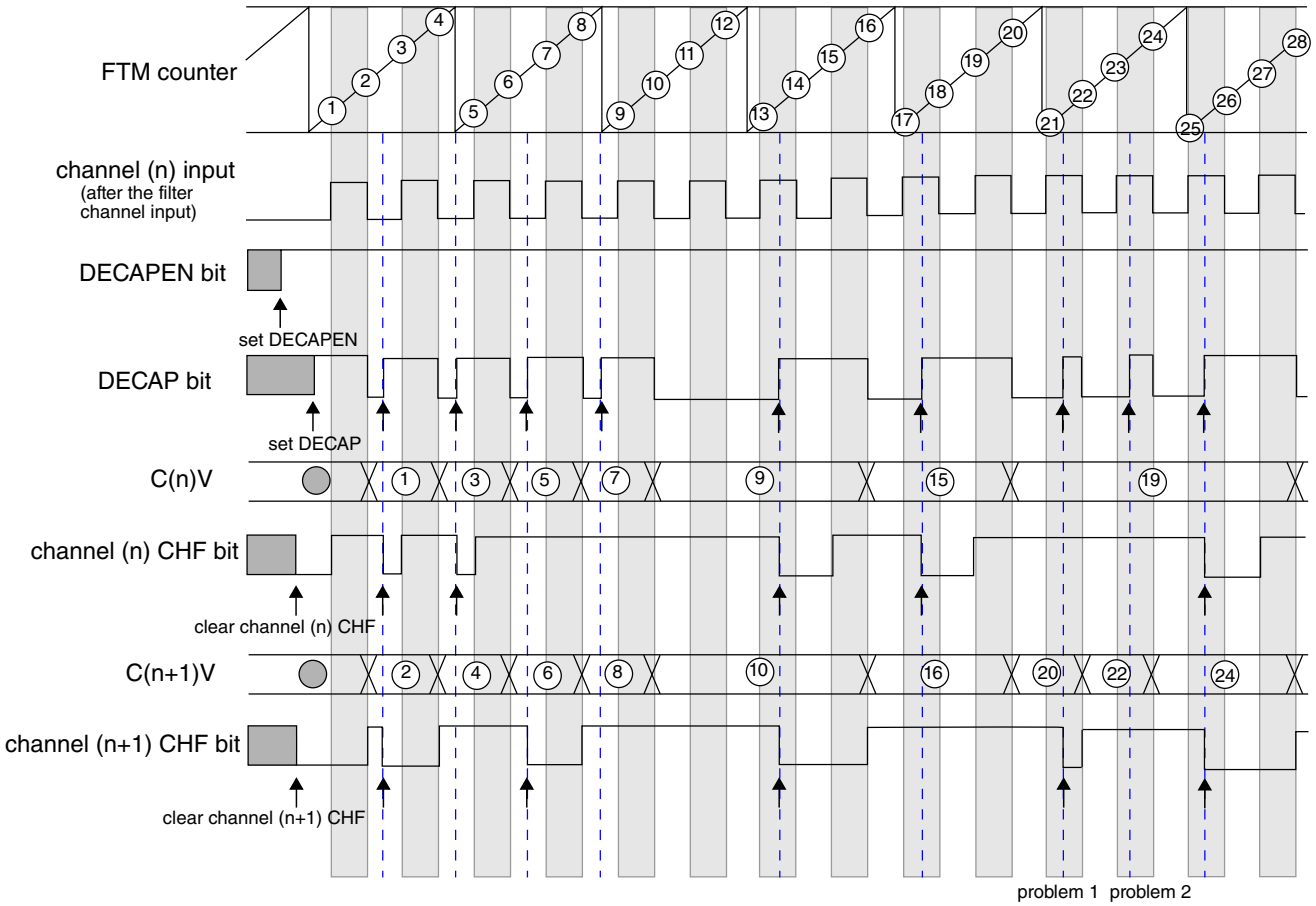
For a new sequence of the measurements in the Dual Edge Capture – Continuous mode, clear the channel (n) CHF and channel (n+1) CHF bits to start new measurements.

34.5.24.3 Pulse width measurement

If the channel (n) is configured to capture rising edges (channel (n) ELSB:ELSA = 0:1) and the channel (n+1) to capture falling edges (channel (n+1) ELSB:ELSA = 1:0), then the positive polarity pulse width is measured. If the channel (n) is configured to capture falling edges (channel (n) ELSB:ELSA = 1:0) and the channel (n+1) to capture rising edges (channel (n+1) ELSB:ELSA = 0:1), then the negative polarity pulse width is measured.

The pulse width measurement can be made in One-Shot Capture mode or Continuous Capture mode.

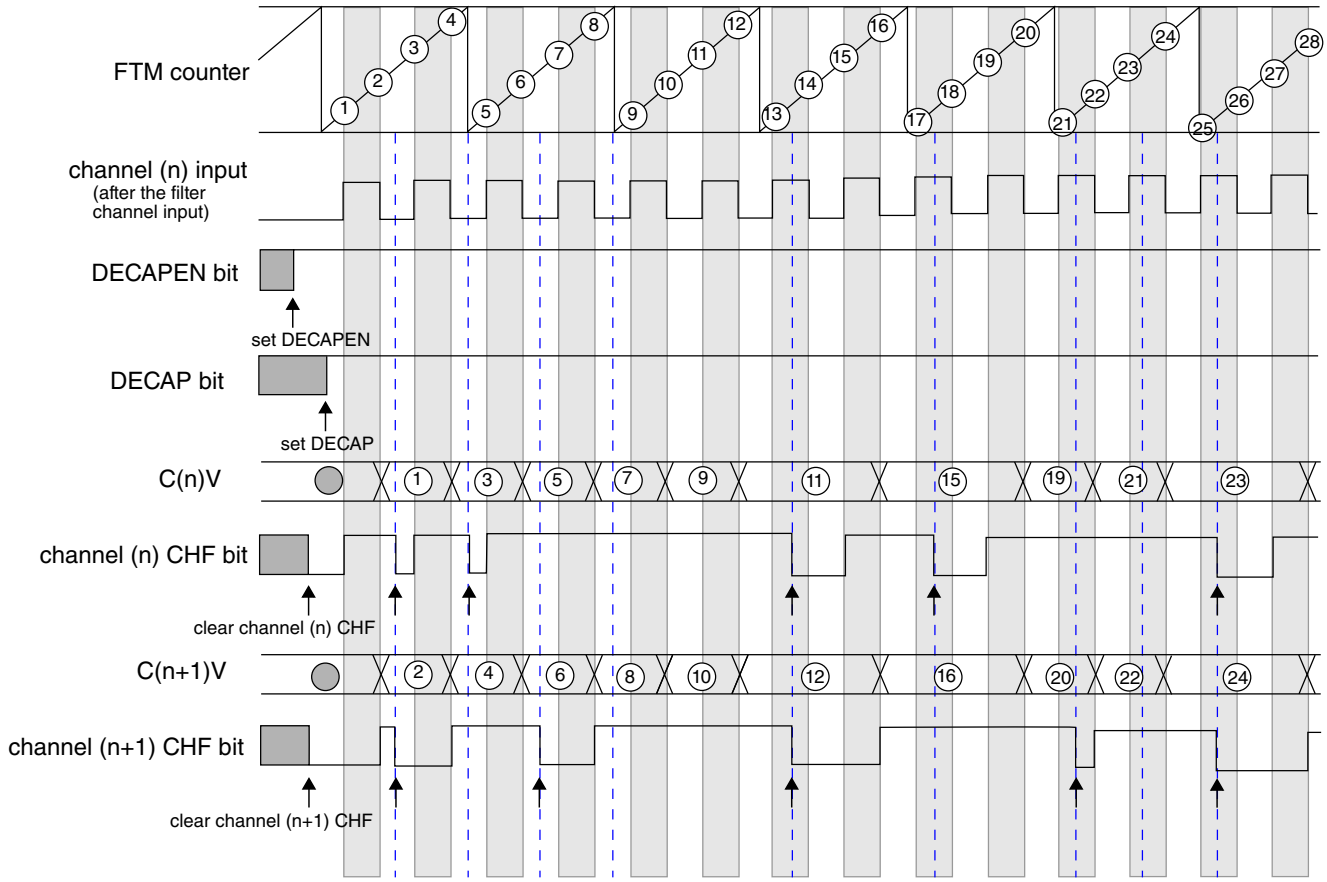
The following figure shows an example of the Dual Edge Capture – One-Shot mode used to measure the positive polarity pulse width. The DECAPEN bit selects the Dual Edge Capture mode, so it remains set. The DECAP bit is set to enable the measurement of next positive polarity pulse width. The channel (n) CHF bit is set when the first edge of this pulse is detected, that is, the edge selected by channel (n) ELSB:ELSA bits. The channel (n+1) CHF bit is set and DECAP bit is cleared when the second edge of this pulse is detected, that is, the edge selected by channel (n+1) ELSB:ELSA bits. Both DECAP and channel (n+1) CHF bits indicate when two edges of the pulse were captured and the C(n)V and C(n+1)V registers are ready for reading.



Note
- The commands set DECAPEN, set DECAP, clear channel (n) CHF, and clear channel (n+1) CHF are made by the user.
- Problem 1: channel (n) input = 1, set DECAP, not clear channel (n) CHF, and clear channel (n+1) CHF.
- Problem 2: channel (n) input = 1, set DECAP, not clear channel (n) CHF, and not clear channel (n+1) CHF.

Figure 34-83. Dual Edge Capture – One-Shot mode for positive polarity pulse width measurement

The following figure shows an example of the Dual Edge Capture – Continuous mode used to measure the positive polarity pulse width. The DECAPEN bit selects the Dual Edge Capture mode, so it remains set. While the DECAP bit is set the configured measurements are made. The channel (n) CHF bit is set when the first edge of the positive polarity pulse is detected, that is, the edge selected by channel (n) ELSB:ELSA bits. The channel (n+1) CHF bit is set when the second edge of this pulse is detected, that is, the edge selected by channel (n+1) ELSB:ELSA bits. The channel (n+1) CHF bit indicates when two edges of the pulse were captured and the C(n)V and C(n+1)V registers are ready for reading.



Note
- The commands set DECAPEN, set DECAP, clear channel (n) CHF, and clear channel (n+1) CHF are made by the user.

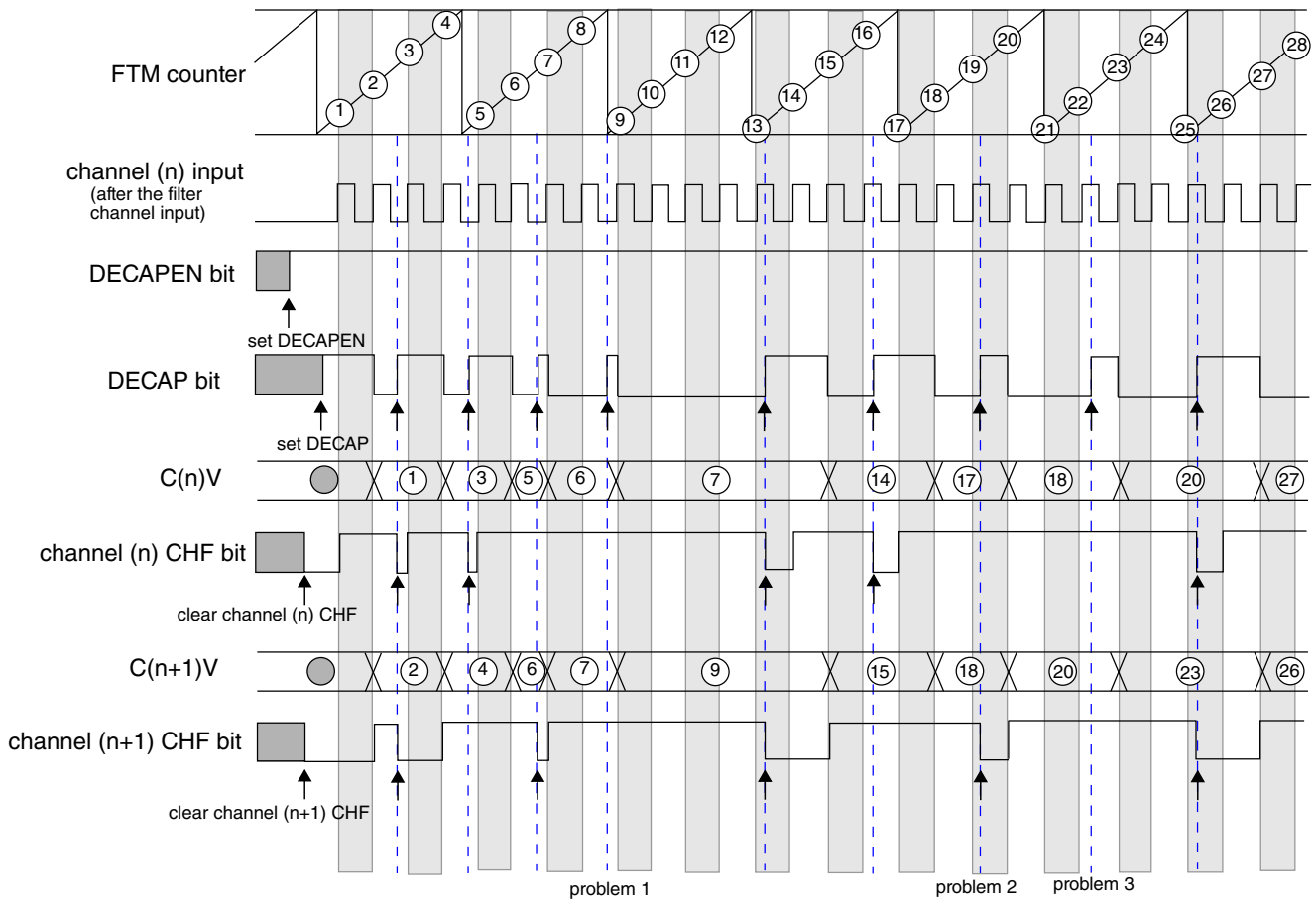
Figure 34-84. Dual Edge Capture – Continuous mode for positive polarity pulse width measurement

34.5.24.4 Period measurement

If the channels (n) and (n+1) are configured to capture consecutive edges of the same polarity, then the period of the channel (n) input signal is measured. If both channels (n) and (n+1) are configured to capture rising edges (channel (n) ELSB:ELSA = 0:1 and channel (n+1) ELSB:ELSA = 0:1), then the period between two consecutive rising edges is measured. If both channels (n) and (n+1) are configured to capture falling edges (channel (n) ELSB:ELSA = 1:0 and channel (n+1) ELSB:ELSA = 1:0), then the period between two consecutive falling edges is measured.

The period measurement can be made in One-Shot Capture mode or Continuous Capture mode.

The following figure shows an example of the Dual Edge Capture – One-Shot mode used to measure the period between two consecutive rising edges. The DECAPEN bit selects the Dual Edge Capture mode, so it remains set. The DECAP bit is set to enable the measurement of next period. The channel (n) CHF bit is set when the first rising edge is detected, that is, the edge selected by channel (n) ELSB:ELSA bits. The channel (n+1) CHF bit is set and DECAP bit is cleared when the second rising edge is detected, that is, the edge selected by channel (n+1) ELSB:ELSA bits. Both DECAP and channel (n+1) CHF bits indicate when two selected edges were captured and the C(n)V and C(n+1)V registers are ready for reading.

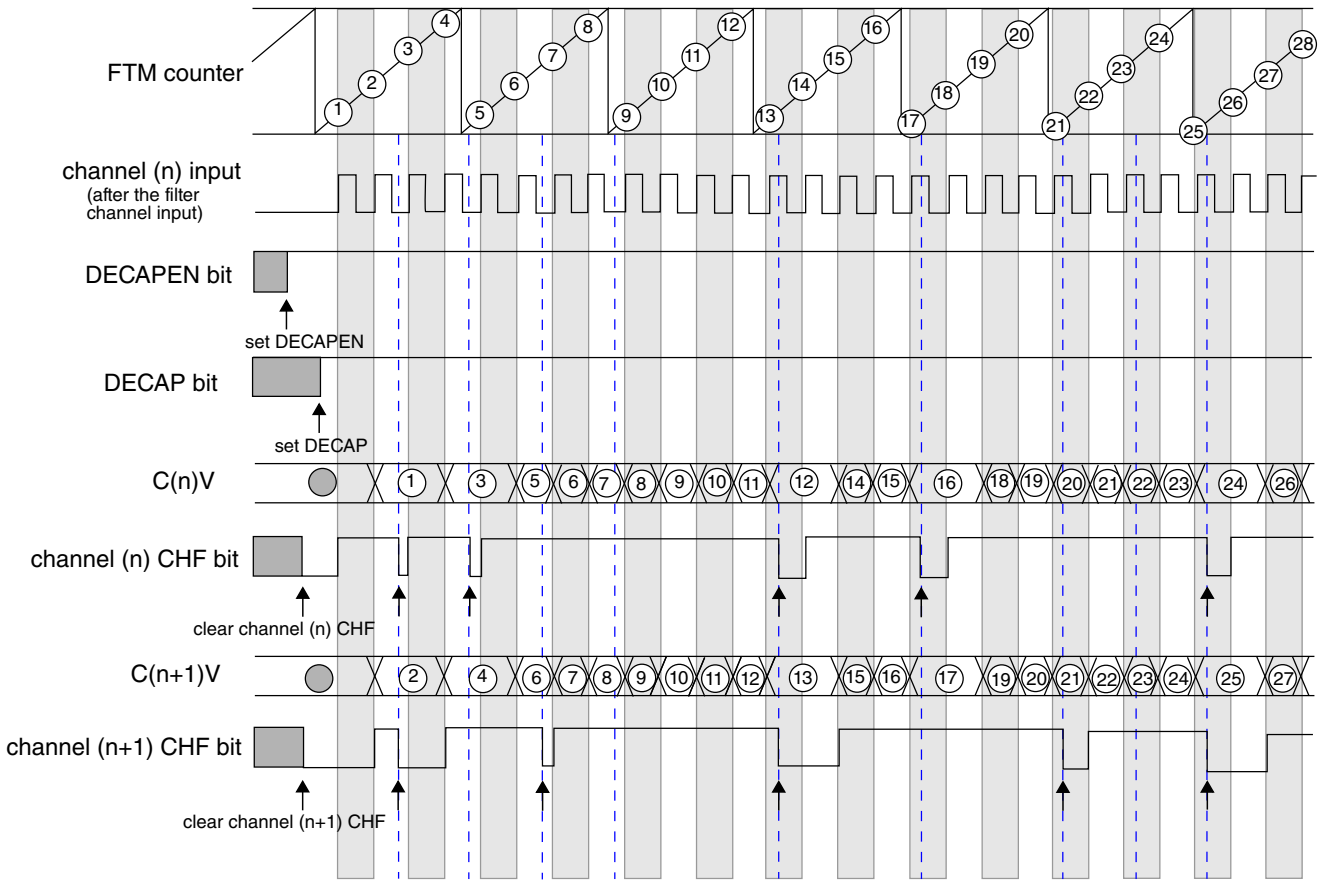


Note
- The commands set DECAPEN, set DECAP, clear channel (n) CHF, and clear channel (n+1) CHF are made by the user.
- Problem 1: channel (n) input = 0, set DECAP, not clear channel (n) CHF, and not clear channel (n+1) CHF.
- Problem 2: channel (n) input = 1, set DECAP, not clear channel (n) CHF, and clear channel (n+1) CHF.
- Problem 3: channel (n) input = 1, set DECAP, not clear channel (n) CHF, and not clear channel (n+1) CHF.

Figure 34-85. Dual Edge Capture – One-Shot mode to measure of the period between two consecutive rising edges

The following figure shows an example of the Dual Edge Capture – Continuous mode used to measure the period between two consecutive rising edges. The DECAPEN bit selects the Dual Edge Capture mode, so it remains set. While the DECAP bit is set the configured measurements are made. The channel (n) CHF bit is set when the first rising

edge is detected, that is, the edge selected by channel (n) ELSB:ELSA bits. The channel (n+1) CHF bit is set when the second rising edge is detected, that is, the edge selected by channel (n+1) ELSB:ELSA bits. The channel (n+1) CHF bit indicates when two edges of the period were captured and the C(n)V and C(n+1)V registers are ready for reading.



Note
- The commands set DECAPEN, set DECAP, clear channel (n) CHF, and clear channel (n+1) CHF are made by the user.

Figure 34-86. Dual Edge Capture – Continuous mode to measure of the period between two consecutive rising edges

34.5.24.5 Read coherency mechanism

The Dual Edge Capture mode implements a read coherency mechanism between the FTM counter value captured in C(n)V and C(n+1)V registers. The read coherency mechanism is illustrated in the following figure. In this example, the channels (n) and (n +1) are in Dual Edge Capture – Continuous mode for positive polarity pulse width measurement. Thus, the channel (n) is configured to capture the FTM counter value when there is a rising edge at channel (n) input signal, and channel (n+1) to capture the FTM counter value when there is a falling edge at channel (n) input signal.

When a rising edge occurs in the channel (n) input signal, the FTM counter value is captured into channel (n) capture buffer. The channel (n) capture buffer value is transferred to C(n)V register when a falling edge occurs in the channel (n) input signal. C(n)V register has the FTM counter value when the previous rising edge occurred, and the channel (n) capture buffer has the FTM counter value when the last rising edge occurred.

When a falling edge occurs in the channel (n) input signal, the FTM counter value is captured into channel (n+1) capture buffer. The channel (n+1) capture buffer value is transferred to C(n+1)V register when the C(n)V register is read.

In the following figure, the read of C(n)V returns the FTM counter value when the event 1 occurred and the read of C(n+1)V returns the FTM counter value when the event 2 occurred.

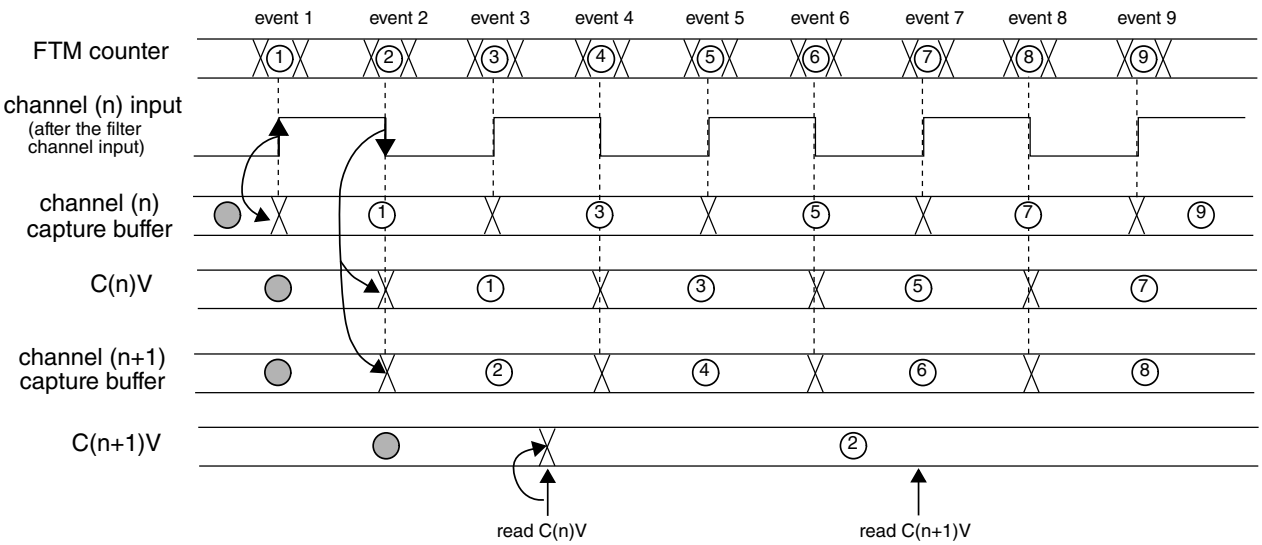


Figure 34-87. Dual Edge Capture mode read coherency mechanism

C(n)V register must be read prior to C(n+1)V register in dual edge capture one-shot and continuous modes for the read coherency mechanism works properly.

34.5.25 Quadrature Decoder Mode

The quadrature decoder mode is enabled if QUADEN = 1. The quadrature decoder mode uses the input signals phase A and B to control the FTM counter increment and decrement.

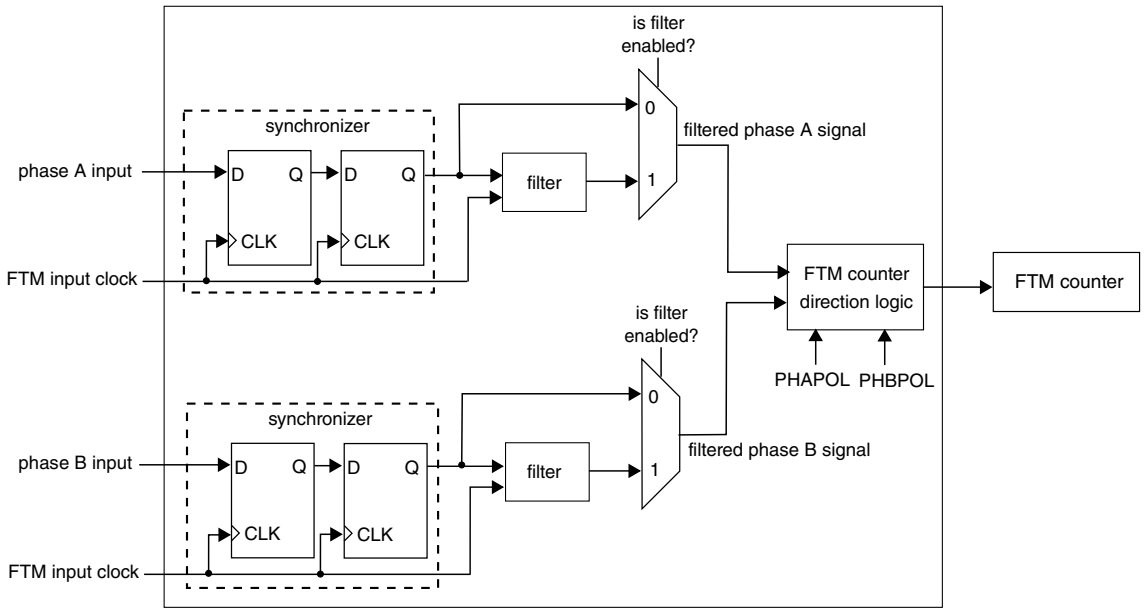


Figure 34-88. Diagram for Quadrature Decoder

Each one of input signals phase A and B has a filter that is equivalent to the channel input filter (Filter for Input Capture Mode). The phase A input filter is enabled by PHAFLTREN bit and its value is defined by CH0FVAL[3:0] bits. The phase B input filter is enabled by PHBFLTREN bit and its value is defined by CH1FVAL[3:0] bits.

Except for CH0FVAL[3:0] and CH1FVAL[3:0] bits, no channel logic is used in quadrature decoder mode.

Note

The FTM counter is clocked by the phase A and B input signals when quadrature decoder mode is enabled. Therefore it is expected that the quadrature decoder mode be used only with the FTM channels in input capture or output compare modes.

Note

An edge at phase A must not occur together an edge at phase B and vice-versa.

The PHAPOL bit selects the polarity of the phase A input, and the PHBPOL bit selects the polarity of the phase B input.

The QUADMODE selects the encoding mode used in the quadrature decoder mode. If QUADMODE = 1, then the count and direction encoding mode is enabled; see the following figure. In this mode, the phase B input value indicates the counting direction, and the phase A input defines the counting rate.

- If PHAPOL = 0 and PHBPOL = 0, then the FTM counter is incremented when there is a rising edge at phase A input and phase B input = 1; the FTM counter is decremented when there is a rising edge at phase A input and phase B input = 0.
- If PHAPOL = 1 and PHBPOL = 0, then the FTM counter is incremented when there is a falling edge at phase A input and phase B input = 1; the FTM counter is decremented when there is a falling edge at phase A input and phase B input = 0.

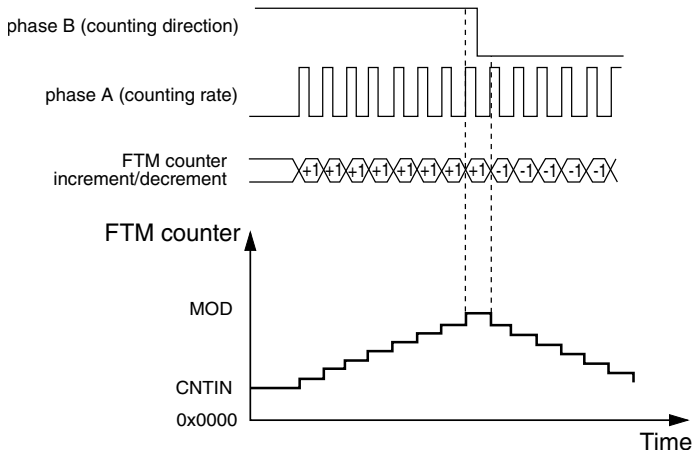


Figure 34-89. Quadrature Decoder – Count and Direction Encoding mode

If QUADMODE = 0, then the phase A and phase B Encoding mode is enabled; see the following figure. In this mode, the relationship between phase A and B signals indicates the counting direction, and phase A and B signals define the counting rate. The FTM counter is updated when there is an edge either at the phase A or phase B signals.

If PHAPOL = 0 and PHBPOL = 0, then the FTM counter increment happens when:

- there is a rising edge at phase A signal and phase B signal is at logic zero;
- there is a rising edge at phase B signal and phase A signal is at logic one;
- there is a falling edge at phase B signal and phase A signal is at logic zero;
- there is a falling edge at phase A signal and phase B signal is at logic one;

and the FTM counter decrement happens when:

- there is a falling edge at phase A signal and phase B signal is at logic zero;
- there is a falling edge at phase B signal and phase A signal is at logic one;
- there is a rising edge at phase B signal and phase A signal is at logic zero;
- there is a rising edge at phase A signal and phase B signal is at logic one.

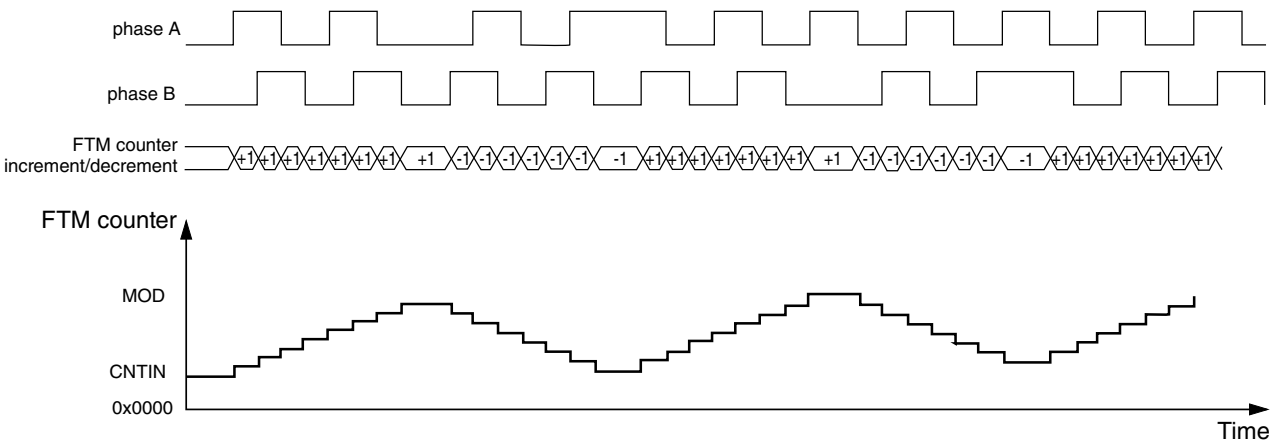


Figure 34-90. Quadrature Decoder – Phase A and Phase B Encoding Mode

The following figure shows the FTM counter overflow in up counting. In this case, when the FTM counter changes from MOD to CNTIN, TOF and TOFDIR bits are set. TOF bit indicates the FTM counter overflow occurred. TOFDIR indicates the counting was up when the FTM counter overflow occurred.

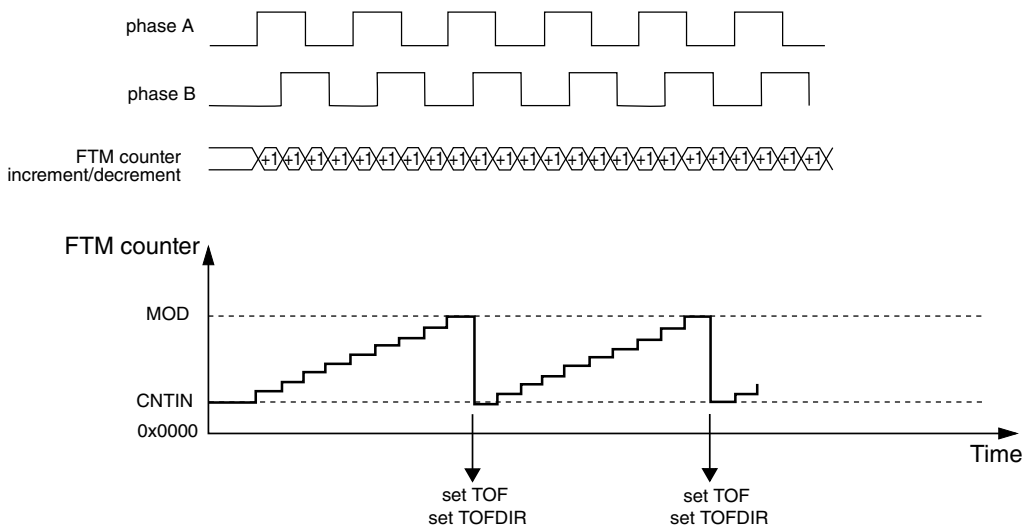


Figure 34-91. FTM Counter Overflow in Up Counting for Quadrature Decoder Mode

The following figure shows the FTM counter overflow in down counting. In this case, when the FTM counter changes from CNTIN to MOD, TOF bit is set and TOFDIR bit is cleared. TOF bit indicates the FTM counter overflow occurred. TOFDIR indicates the counting was down when the FTM counter overflow occurred.

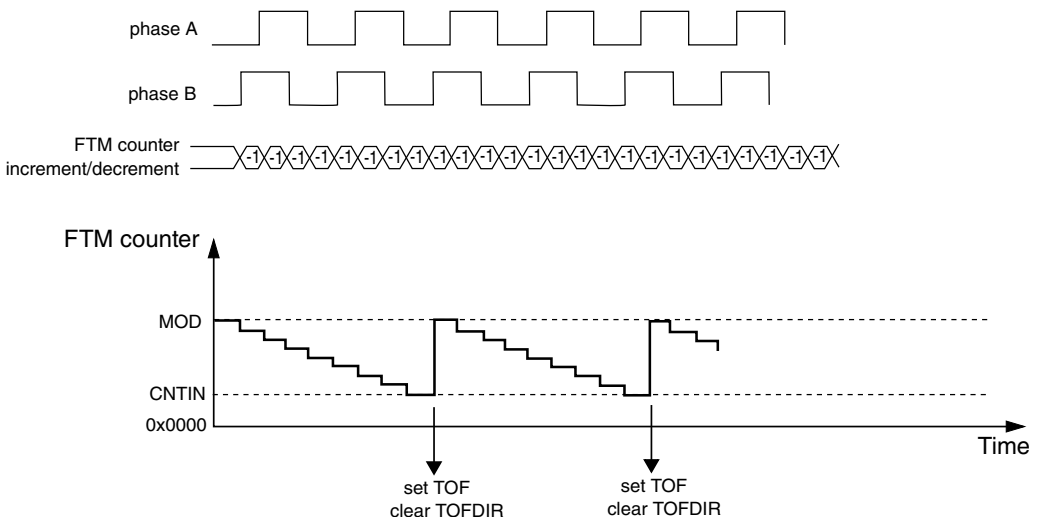


Figure 34-92. FTM Counter Overflow in Down Counting for Quadrature Decoder Mode

34.5.25.1 Quadrature Decoder boundary conditions

The following figures show the FTM counter responding to motor jittering typical in motor position control applications.

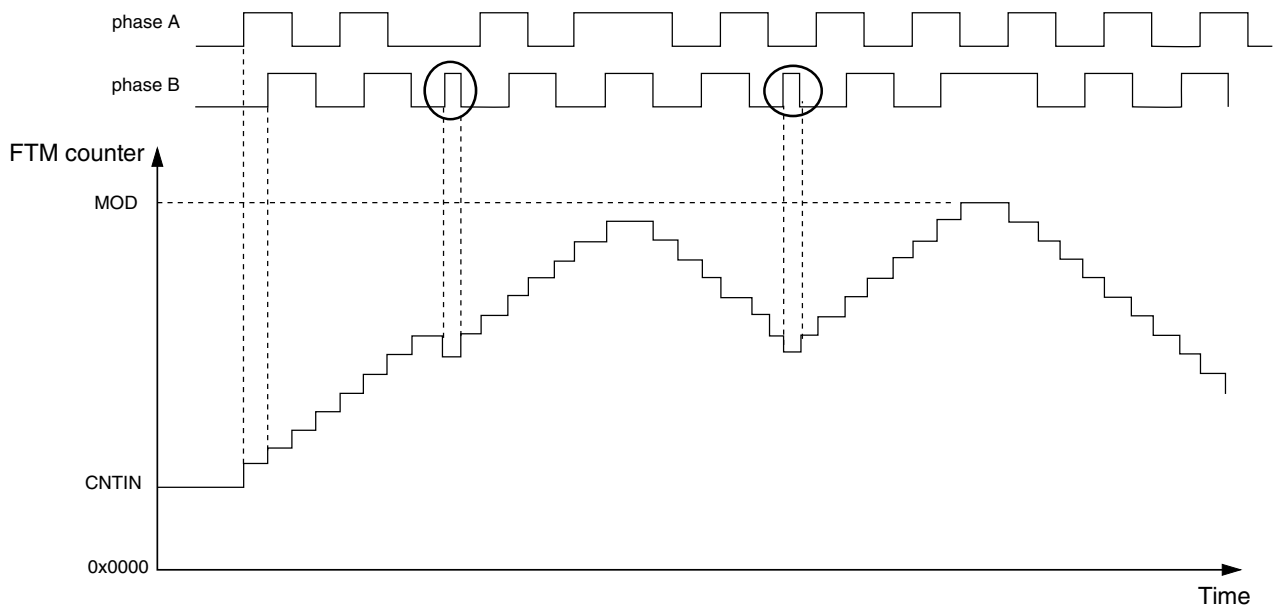


Figure 34-93. Motor position jittering in a mid count value

The following figure shows motor jittering produced by the phase B and A pulses respectively:

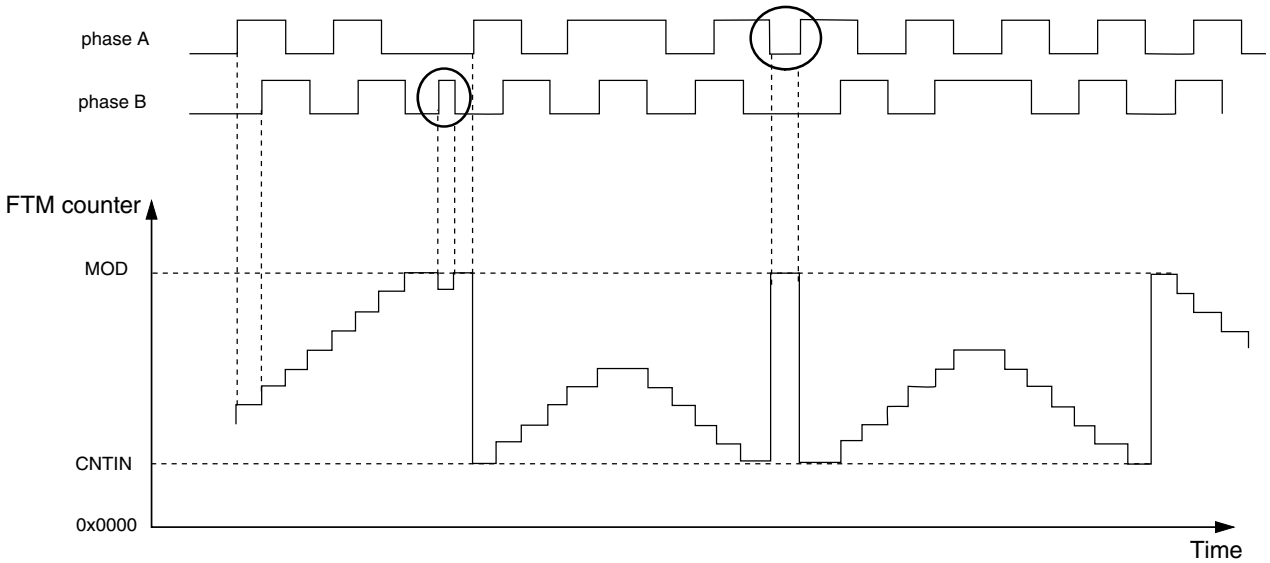


Figure 34-94. Motor position jittering near maximum and minimum count value

The first highlighted transition causes a jitter on the FTM counter value near the maximum count value (MOD). The second indicated transition occurs on phase A and causes the FTM counter transition between the maximum and minimum count values which are defined by MOD and CNTIN registers.

The appropriate settings of the phase A and phase B input filters are important to avoid glitches that may cause oscillation on the FTM counter value. The preceding figures show examples of oscillations that can be caused by poor input filter setup. Thus, it is important to guarantee a minimum pulse width to avoid these oscillations.

34.5.26 Debug mode

When the chip is in Debug mode, the BDMMODE[1:0] bits select the behavior of the FTM counter, the channel (n) CHF bit, the channels output, and the writes to the MOD, CNTIN, and C(n)V registers according to the following table.

Table 34-17. FTM behavior when the chip Is in Debug mode

BDMMODE	FTM Counter	channel (n) CHF bit	FTM Channels Output	Writes to MOD, CNTIN, and C(n)V Registers
00	Stopped	can be set	Functional mode	Writes to these registers bypass the registers buffers
01	Stopped	is not set	The channels outputs are forced to their safe value according to POLn bit	Writes to these registers bypass the registers buffers
10	Stopped	is not set	The channels outputs are frozen when the chip enters in Debug mode	Writes to these registers bypass the registers buffers

Table continues on the next page...

Table 34-17. FTM behavior when the chip Is in Debug mode (continued)

BDMMODE	FTM Counter	channel (n) CHF bit	FTM Channels Output	Writes to MOD, CNTIN, and C(n)V Registers
11	Functional mode	can be set	Functional mode	Functional mode

Note that if BDMMODE[1:0] = 2’b00 then the channels outputs remain at the value when the chip enters in Debug mode, because the FTM counter is stopped. However, the following situations modify the channels outputs in this Debug mode.

- Write any value to CNT register; see Counter reset. In this case, the FTM counter is updated with the CNTIN register value and the channels outputs are updated to the initial value – except for those channels set to Output Compare mode.
- FTM counter is reset by PWM Synchronization mode; see FTM counter synchronization. In this case, the FTM counter is updated with the CNTIN register value and the channels outputs are updated to the initial value – except for channels in Output Compare mode.
- In the channels outputs initialization, the channel (n) output is forced to the CH(n)OI bit value when the value 1 is written to INIT bit. See Initialization.

Note

The BDMMODE[1:0] = 2’b00 must not be used with the Fault Control. Even if the fault control is enabled and a fault condition exists, the channels outputs are updated as above.

Note

If CLKS[1:0] = 2'b00 in Debug, a non-zero value is written to CLKS in Debug, and CnV = CNTIN when the Debug is disabled, then the CHF bit is set (since if the channel is a 0% EPWM signal) when the Debug is disabled.

34.5.27 Reload Points

This feature allows to update the registers CNTIN, HCR, MOD and C(n)V with the value of their write buffer at the selected reload point.

NOTE

- This feature is independent of the PWM synchronization.
- At these reload points neither the channels outputs nor the FTM counter are changed. Software must select these reload points at the safe points in time.

34.5.27.1 Reload Opportunities

The reload opportunities are:

1. At the half cycle

   This reload opportunity is enabled if (HCSEL = 1) and it happens at the half cycle (FTM counter = HCR register). The software should calculate the half cycle value according to the FTM counter configuration, then writes this value to the register HCR.

2. At the channel (n) match

   This reload opportunity is enabled if (CH(n)SEL = 1) and it happens at the channel (n) match (FTM counter = C(n)V).

3. When the FTM counter is an up counter

   This reload opportunity is when the FTM counter changes from (MOD) to (CNTIN - 1) and it is always enabled.

   The following figure shows an example of the reload opportunities at the half cycle, at the channels match, and when the FTM counter is an up counter.

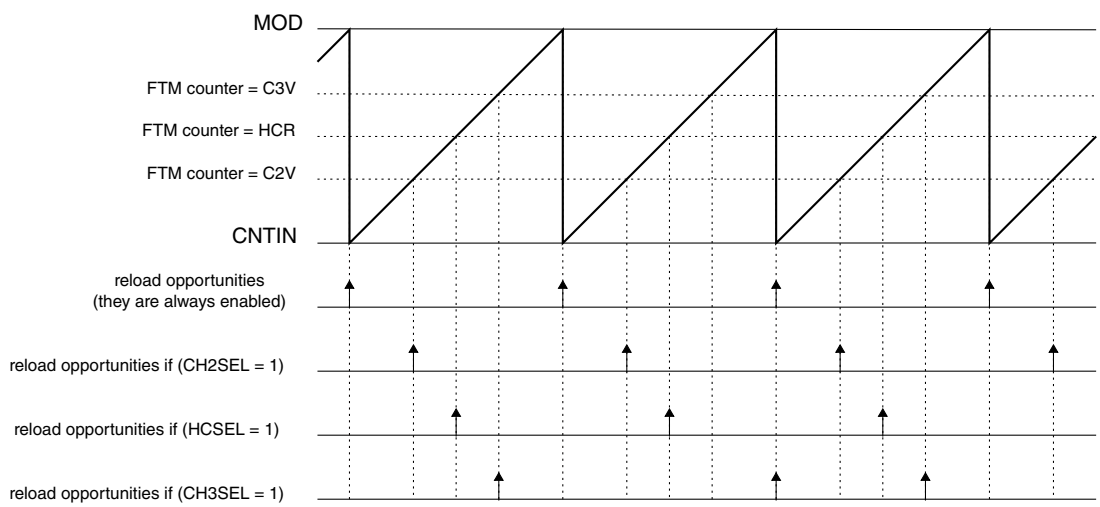


Figure 34-95. Reload opportunities when the FTM counter is an up counter

4. When the FTM counter is an up-down counter

   In this case, the reload opportunities are enabled by the bits CNTMAX and CNTMIN according to Table 34-18.

Table 34-18. Reload opportunities enabled by the bits CNTMAX and CNTMIN when the FTM counter is up-down counter

CNTMAX	CNTMIN	Reload Opportunities
0	0	when the FTM counter changes from (MOD) to (MOD - 1)
0	1	when the FTM counter changes from (CNTMIN) to (CNTMIN + 1)
1	0	when the FTM counter changes from (MOD) to (MOD - 1)
1	1	• when the FTM counter changes from (MOD) to (MOD - 1), and • when the FTM counter changes from (CNTMIN) to (CNTMIN + 1)

The following figure shows an example of the reload opportunities at the half cycle, at the channels match, and when the FTM counter is an up-down counter.

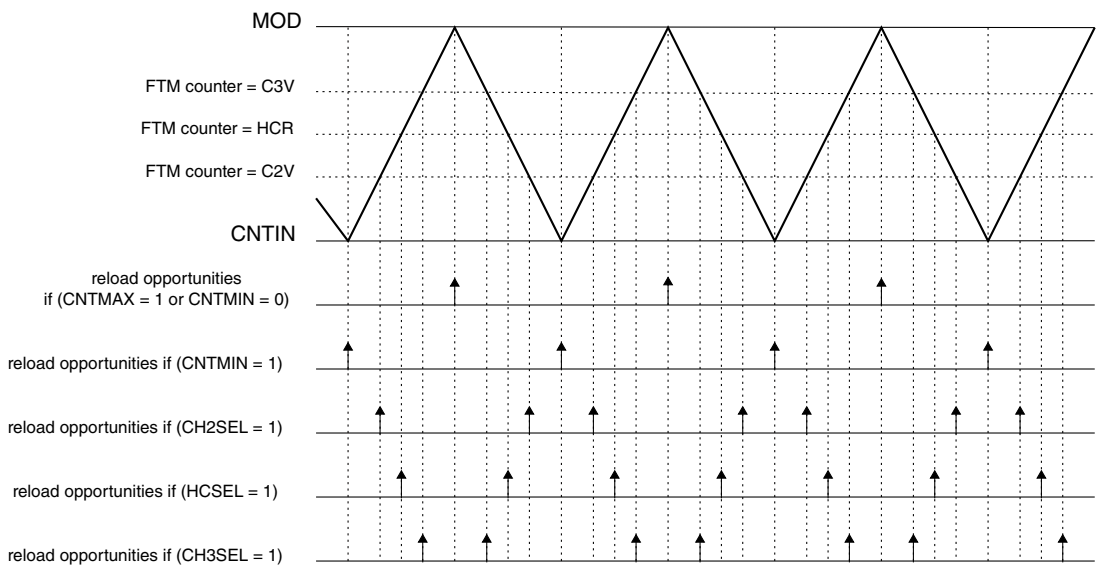


Figure 34-96. Reload opportunities when the FTM counter is an up-down counter

34.5.27.2 Frequency of Reload Opportunities

The LDFQ[4:0] bits define the number of enabled reload opportunities should happen until an enabled reload opportunity becomes a reload point. The following figure shows an example when the LDFQ[4:0] = 4.

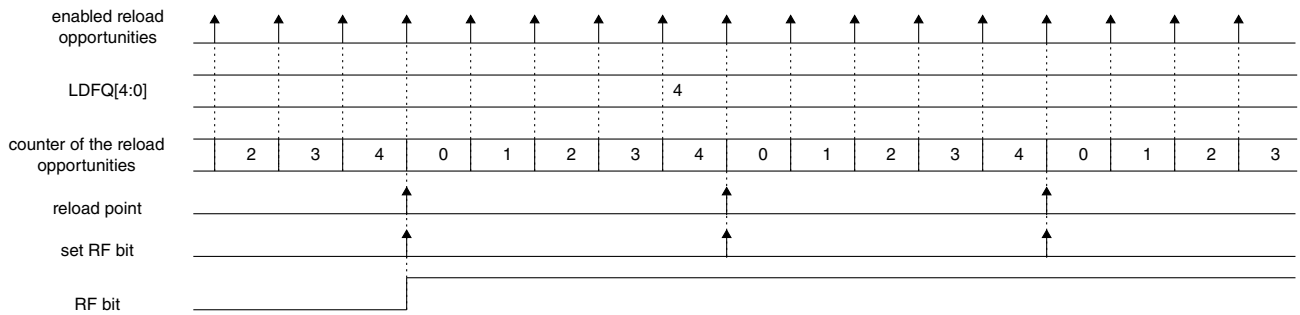


Figure 34-97. Frequency of Reload Opportunities with LDFQ[4:0] = 4

If LDFQ[4:0] = 0, then all reload opportunities are reload points.

The counter of the reload opportunities is reset when there is a write to the register CNT.

The RF bit is set at each reload point (see the figure above) independent of LDOK bit value. The reload point interrupt is generated when (RF = 1) and (RIE = 1).

34.5.27.3 Update of the Registers

After writing new value to the registers with write buffer, selecting which of them will be updated (according to Table 34-19), selecting the reload opportunities, selecting the frequency of the reload opportunities, thus the LDOK bit should be set to enable the update of these registers at the next reload point.

Table 34-19. Additional conditions to update the registers

Register	Additional Condition
CNTIN	CNTINC = 1
HCR	-
MOD	-
C(n)V and C(n+1)V	SYNCENm = 1, where m is the pair of the channels (n) and (n +1)

34.5.28 Global Load

The global load mechanism allows several modules to have their double buffered registers synchronously reloaded after a synchronization event if a write to one operation is performed in the global load OK (GLDOK) bit in the PWMLOAD register. Global load may be enabled or disabled configuring the global load enable (GLEN) bit in the

PWMLOAD register. Writing one in the GLDOK bit with GLEN enabled has the same effect of writing one in the LDOK bit. Refer to SoC specific information about global load connections.

Global load mechanism allows MOD, HCR, CNTIN, and C(n)V registers to be updated with the content of the register buffer at configurable reload point. The figure below shows an example of connection between FTM global load inputs and outputs considering that GLDOK bit is implemented outside from FTM module.

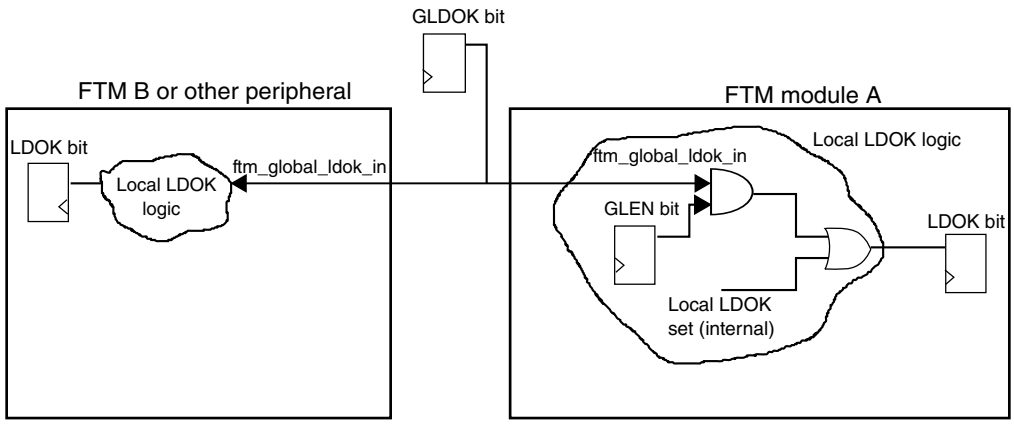


Figure 34-98. Global load logic

34.5.29 Global time base (GTB)

The global time base (GTB) is a FTM function that allows the synchronization of multiple FTM modules on a chip. The following figure shows an example of the GTB feature used to synchronize two FTM modules. In this case, the FTM A and B channels can behave as if just one FTM module was used, that is, a global time base.

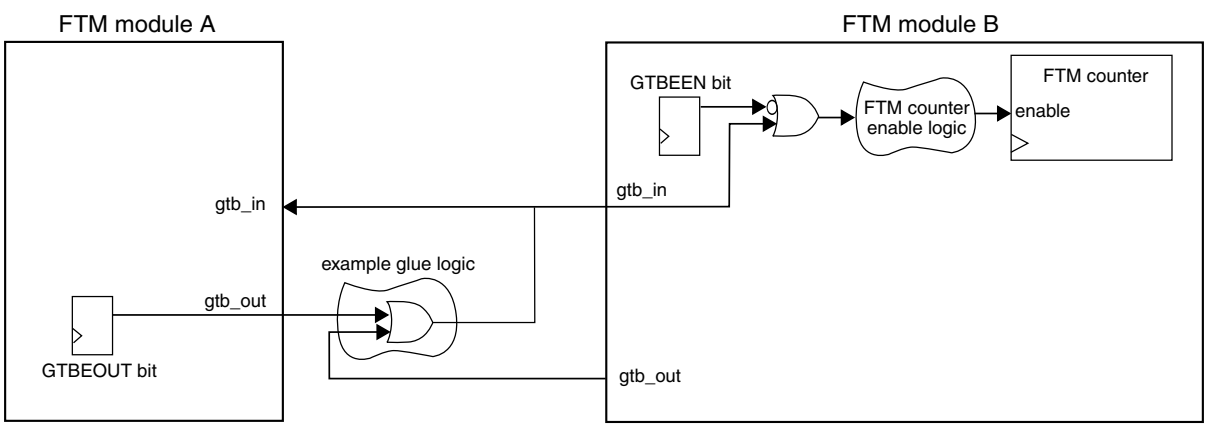


Figure 34-99. Global time base (GTB) block diagram

The GTB functionality is implemented by the GTBEEN and GTBEOUT bits in the CONF register, the input signal *gtb_in*, and the output signal *gtb_out*. The GTBEEN bit enables gtb_in to control the FTM counter enable signal:

- If GTBEEN = 0, each one of FTM modules works independently according to their configured mode.
- If GTBEEN = 1, the FTM counter update is enabled only when gtb_in is 1.

In the configuration described in the preceding figure, FTM modules A and B have their FTM counters enabled if at least one of the gtb_out signals from one of the FTM modules is 1. There are several possible configurations for the interconnection of the gtb_in and gtb_out signals, represented by the example glue logic shown in the figure. Note that these configurations are chip-dependent and implemented outside of the FTM modules. See the chip-specific FTM information for the chip's specific implementation.

NOTE

- In order to use the GTB signals to synchronize the FTM counter of different FTM modules, the configuration of each FTM module should guarantee that its FTM counter starts counting as soon as the gtb_in signal is 1.
- The GTB feature does not provide continuous synchronization of FTM counters, meaning that the FTM counters may lose synchronization during FTM operation. The GTB feature only allows the FTM counters to *start* their operation synchronously.

34.5.29.1 Enabling the global time base (GTB)

To enable the GTB feature, follow these steps for each participating FTM module:

1. Stop the FTM counter: Write 00b to SC[CLKS].
2. Program the FTM to the intended configuration. The FTM counter mode needs to be consistent across all participating modules.
3. Write 1 to CONF[GTBEEN] and write 0 to CONF[GTBEOUT] at the same time.
4. Select the intended FTM counter clock source in SC[CLKS]. The clock source needs to be consistent across all participating modules.
5. Reset the FTM counter: Write any value to the CNT register.

To initiate the GTB feature in the configuration described in the preceding figure, write 1 to CONF[GTBEOUT] in the FTM module used as the time base.

34.5.30 Channel trigger output

The channel trigger output provides a trigger signal which has one FTM input clock period width in the channel (n) output.

If the TRIGMODE bit of the CnSC register is set (TRIGMODE = 1), a trigger pulse with one FTM input clock width is generated in the channel (n) output when a match occurs. It is only allowed to use trigger mode when channel (n) is in EPWM or CPWM modes.

The figures below show some cases of channel (n) trigger generation in the channel (n) output.

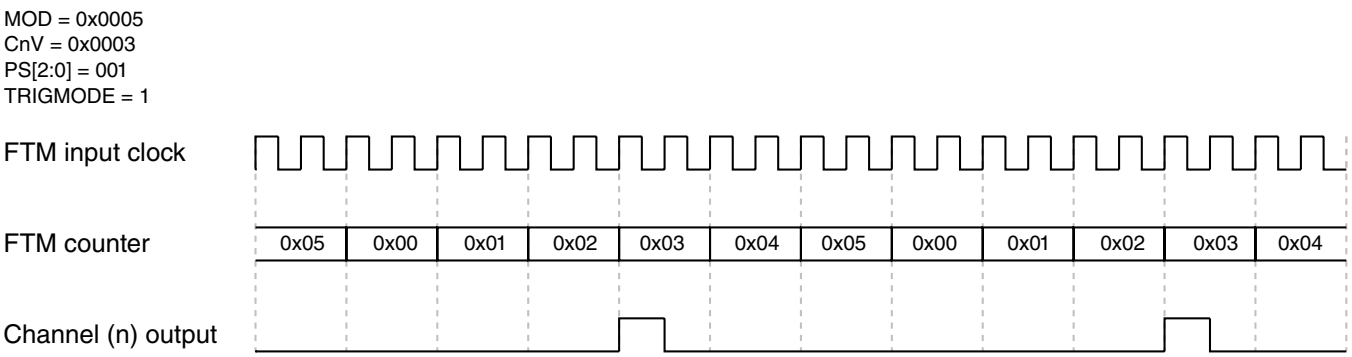


Figure 34-100. Example of channel (n) trigger at the channel (n) output in EPWM mode

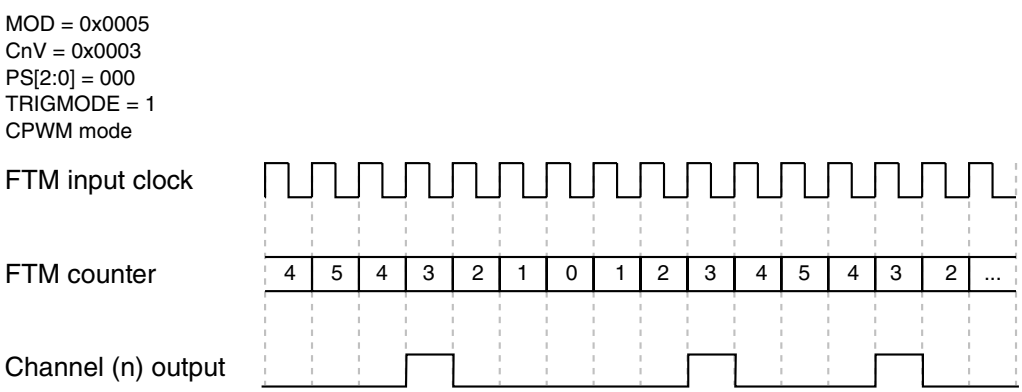


Figure 34-101. Example of channel (n) trigger at the channel (n) output in CPWM mode

34.5.31 External Control of Channels Output

The channel (n) PWMEN bit can be used in an FTM external logic to control the final value of the channel (n) output. This same logic can also control the channel (n) output when FSTATE = 1 and the channel (n) output is disabled by the Fault Control. The following figure shows an example of this external logic.

The term "channel (n) output" means the channel (n) output value after the Polarity Control. See Features Priority and Polarity Control for more details.

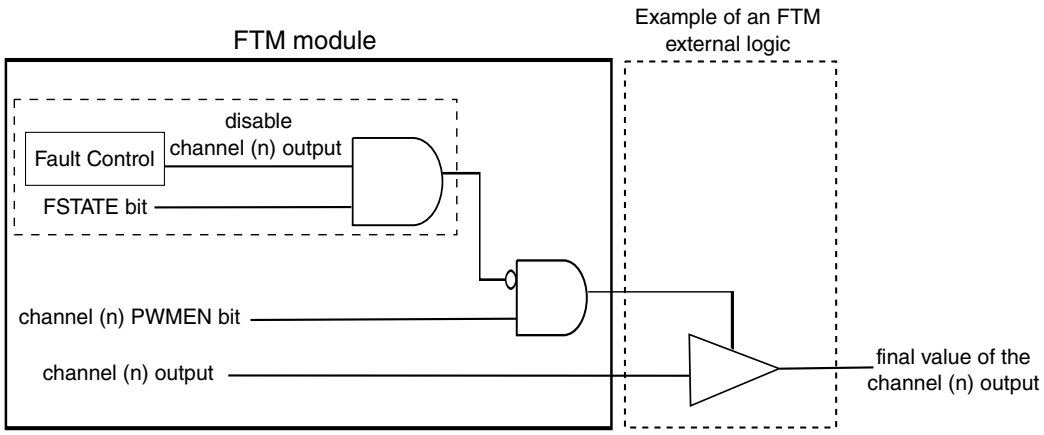


Figure 34-102. Example of the External Control of the Channel (n) Output

34.5.32 Dithering

FTM implements a fractional delay to achieve fine resolution on the generated PWM signals using dithering. The dithering can be used by applications where more resolution than one unit of the FTM counter is needed.

Two kinds of dithering are available: PWM period dithering and edge dithering.

34.5.32.1 PWM Period Dithering

The PWM period dithering is enabled when a non-zero value is written to FRACMOD.

The internal accumulator used in the PWM period dithering is reset when:

- the field MOD of the register MOD_MIRROR is updated with the value of its write buffer,
- the FRACMOD is updated with the value of its write buffer, or
- the FTM counter is stopped.

NOTE

For the PWM period dithering, the register MOD_MIRROR should be used instead of the register MOD.

To avoid inconsistencies, the field FRACMOD is cleared when the field MOD of the register MOD is updated with the value of its write buffer.

The PWM period dithering is not available:

- when the FTM counter is a free running counter
- when the FTM is in quadrature decoder mode

34.5.32.1.1 Up Counting

When the FTM counter is an up counter and the PWM period dithering is enabled, at the end of each PWM period, the FRACMOD value is added to an internal 5-bit accumulator. When this accumulator overflows (that is, the result of the adding is greater or equal than 0x20), then one unit of FTM counter is added to the end of the current PWM period, and the accumulator remains with the rest of the subtraction: (the result of this adding - 0x20).

Due to one unit of FTM counter that can be added to the PWM period, the largest valid value for MOD is 0xFFFE for PWM period dithering with unsigned counting and 0x7FFE for PWM period dithering with signed counting.

The following figures show some examples of PWM period dithering when the FTM counter is an up counter.

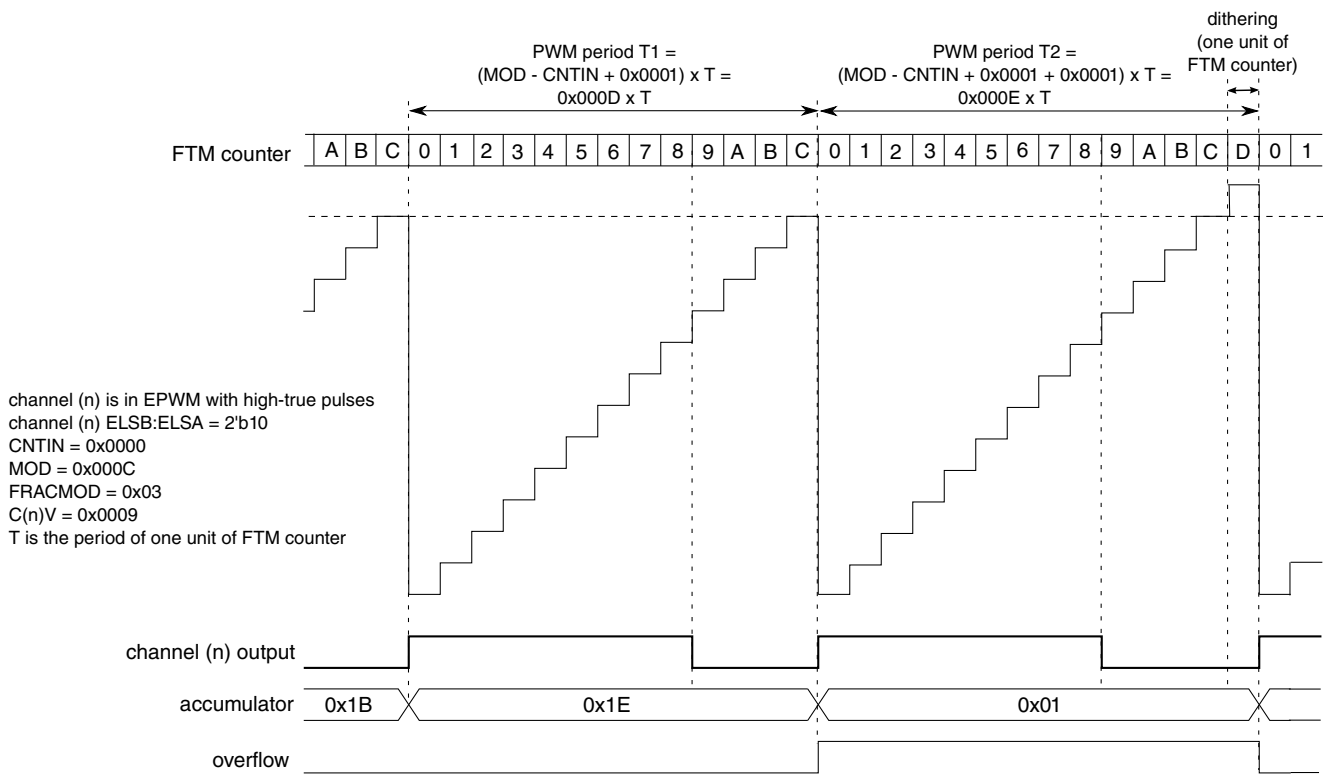


Figure 34-103. PWM Period Dithering with Up Counting

Assuming:

- the FTM counter is an up counter,
- T is one unit of FTM counter,

- the PWM period without period dithering is [(MOD - CNTIN + 1) x T],
- the number of PWM periods with period dithering is FRACMOD,
- the PWM period with period dithering is [(MOD - CNTIN + 1 + 1) x T],

thus, the average period (in decimal) is [(MOD - CNTIN + 1) + (FRACMOD/32)] x T, where the integer value is (MOD - CNTIN + 1) and the fractional value is (FRACMOD/32). See the example below.

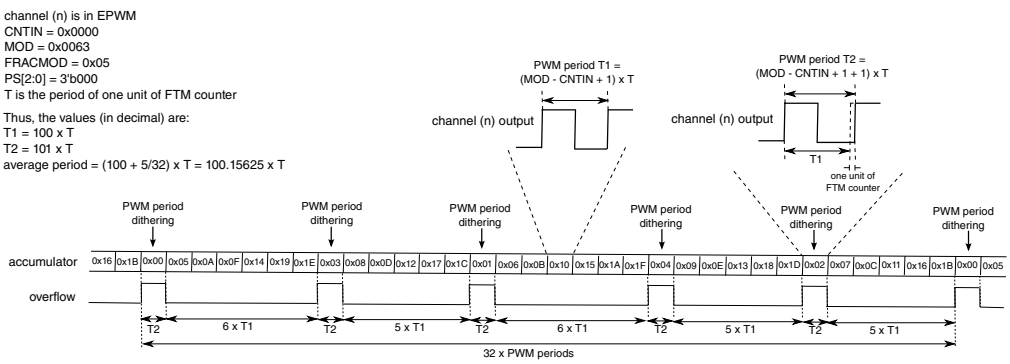


Figure 34-104. Example of Average Period when the PWM Period Dithering is used with the Up Counting

NOTE

For the generation of 100% PWM signal in the channel (n) (with channel (n) ELSB:ELSA = 2'b10) using EPWM mode and PWM Period Dithering, it is recommended to use (C(n) > MOD + 1).

For the generation of PWM signals in the channel (n) (with channel (n) ELSB:ELSA = 2'b10) using Combine mode and PWM Period Dithering, it is recommended to use:

- For 0% PWM signal: (C(n)V > MOD + 1) and (C(n+1)V > MOD + 1);
- For 100% PWM signal: (C(n)V = CNTIN) and (C(n+1)V > MOD + 1).

34.5.32.1.2 Up-Down Counting

When the FTM counter is an up-down counter and the PWM period dithering is enabled, at the end of each PWM period, the FRACMOD value is added to an internal 5-bit accumulator. When this accumulator overflows (that is, the result of the adding is greater or equal than 0x20), then one unit of FTM counter is added to the end of the current

PWM period and other unit is added to the begin of the next PWM period (see the figure below). After the accumulator overflows, the accumulator remains with the rest of the subtraction: (the result of this adding - 0x20).

Due to one unit of FTM counter that can be added to the PWM period, the largest valid value for MOD is 0x7FFE for PWM period dithering in up-down counting (CPWM mode).

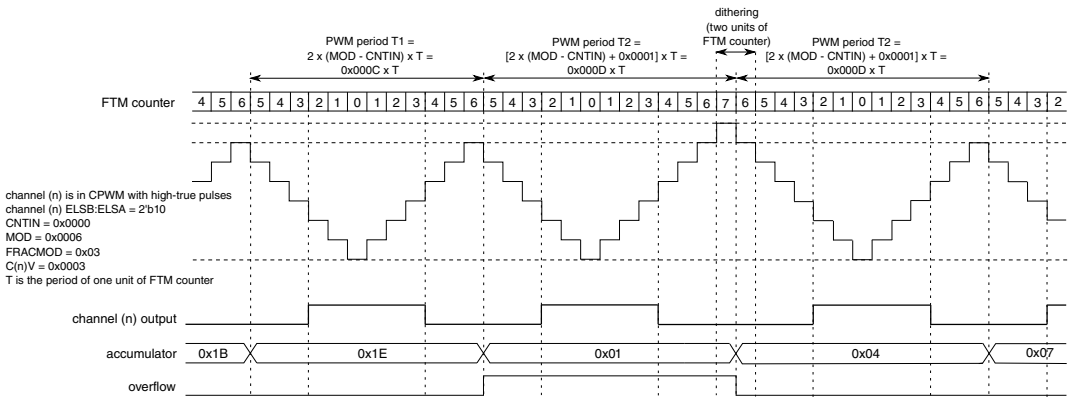


Figure 34-105. PWM Period Dithering with Up-Down Counting

NOTE

For the generation of 100% PWM signal in the channel (n) (with channel (n) ELSB:ELSA = 2'b10) using CPWM mode and PWM Period Dithering, it is recommended to use (C(n)V[15] = 0) and (C(n)V > MOD + 1) and (MOD ≠ 0x0000).

34.5.32.2 PWM Edge Dithering

The channel (n) internal accumulator used in the PWM edge dithering is reset when:

- the field VAL of the register C(n)V_MIRROR is updated with the value of its write buffer,
- the FRACVAL is updated with the value of its write buffer, or
- the FTM counter is stopped.

NOTE

For the PWM edge dithering, the register C(n)V_MIRROR should be used instead of the register C(n)V.

To avoid inconsistencies, the field FRACVAL is cleared when the field VAL of the register C(n)V is updated with the value of its write buffer.

The PWM edge dithering is not available:

- to the channel in input modes, and
- to the channel in output compare mode.

34.5.32.2.1 EPWM Mode

The PWM edge dithering for channel (n) in EPWM mode is enabled when a non-zero value is written to the channel (n) FRACVAL.

If the channel (n) is in EPWM mode and the PWM edge dithering is enabled, at the end of each EPWM period, the channel (n) FRACVAL value is added to the channel (n) internal 5-bit accumulator. When this accumulator overflows (that is, the result of the adding is greater or equal than 0x20), the accumulator remains with the rest of the subtraction: (the result of this adding - 0x20).

In this configuration, the initial edge of EPWM duty cycle happens when (FTM counter = CNTIN), its position is not modified by the PWM edge dithering. If there was not the overflow of the channel (n) accumulator in the current EPWM period, then the final edge of EPWM duty cycle happens on the channel (n) match (FTM counter = C(n)V), that is, its position is not modified by the edge dithering. However, if there was the overflow of the channel (n) accumulator in the current EPWM period, then the final edge of EPWM duty cycle happens when (FTM counter = C(n)V + 0x0001).

The following figures show some examples of PWM edge dithering when the channel (n) is in EPWM mode.

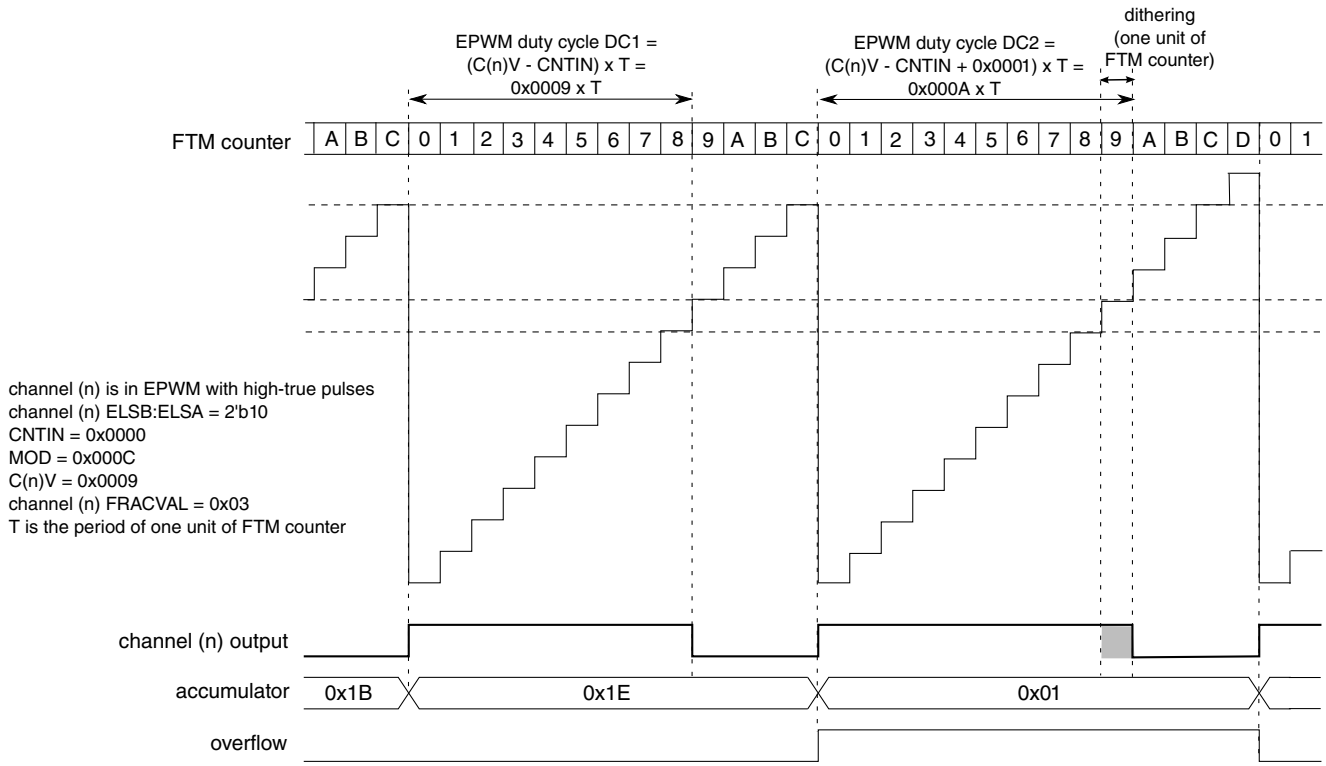


Figure 34-106. Channel (n) is in EPWM Mode with PWM Edge Dithering

Assuming:

- the channel (n) is in EPWM mode,
- T is one unit of FTM counter,
- the EPWM duty cycle without edge dithering is [(C(n)V - CNTIN) x T],
- the number of PWM periods which duty cycle that has edge dithering is FRACVAL,
- the EWM duty cycle with edge dithering is [(C(n)V - CNTIN + 1) x T],

thus, the average duty cycle (in decimal) is [(C(n)V - CNTIN) + (FRACVAL/32)] x T, where the integer value is (C(n)V - CNTIN) and the fractional value is (FRACVAL/32). See the example below.

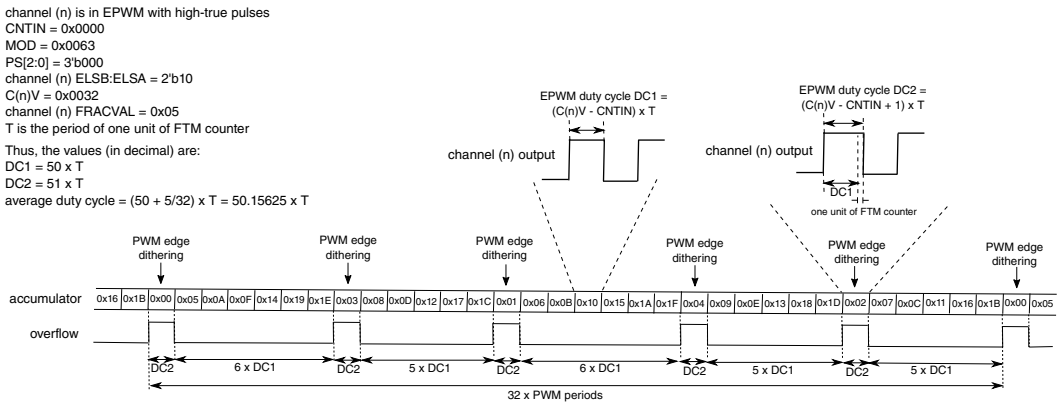


Figure 34-107. Example of Average Duty Cyle when the Channel (n) is in EPWM Mode with PWM Edge Dithering

34.5.32.2.2 CPWM Mode

The PWM edge dithering for channel (n) in CPWM mode is enabled when a non-zero value is written to the channel (n) FRACVAL.

If the channel (n) is in CPWM mode and the PWM edge dithering is enabled, at the end of each CPWM period, the channel (n) FRACVAL value is added to the channel (n) internal 5-bit accumulator. When this accumulator overflows (that is, the result of the adding is greater or equal than 0x20), the accumulator remains with the rest of the subtraction: (the result of this adding - 0x20).

In this configuration, if there was not the overflow of the channel (n) accumulator in the current CPWM period, then the duty cycle is not modified by the PWM edge dithering, that is, the initial edge of CPWM duty cycle happens on channel (n) match (FTM counter = C(n)V) when the FTM counter is decrementing, and the final edge of CPWM duty cycle on channel (n) match when the FTM counter is incrementing.

However, if there was the overflow of the channel (n) accumulator in the current CPWM period, then the initial edge of CPWM duty cycle happens when (FTM counter = C(n)V + 0x0001) and the FTM counter is decrementing, and the final edge of CPWM duty cycle when (FTM counter = C(n)V + 0x0001) and the FTM counter is incrementing.

The following figure shows an example of PWM edge dithering when the channel (n) is in CPWM mode.

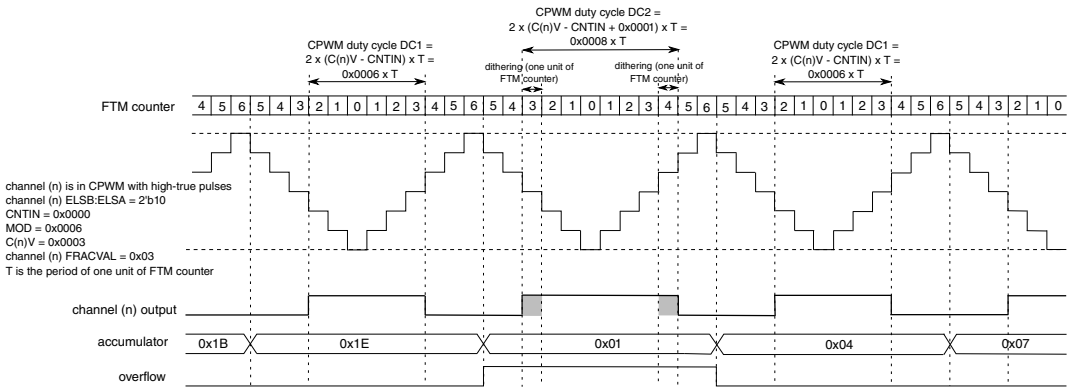


Figure 34-108. Channel (n) is in CPWM Mode with PWM Edge Dithering

34.5.32.2.3 Combine Mode

In the Combine mode, the PWM edge dithering can be done:

- in the channel (n) match (FTM counter = C(n)V) edge or
- in the channel (n+1) match (FTM counter = C(n+1)V) edge.

The channel (n) match edge dithering is enabled when a non-zero value is written to the channel (n) FRACVAL.

For the channel (n) match edge dithering, the channel (n) has an internal 5-bit accumulator. At the end of each PWM period, the channel (n) FRACVAL value is added to the channel (n) accumulator. When this accumulator overflows (that is, the result of the adding is greater or equal than 0x20), the accumulator remains with the rest of the subtraction: (the result of this adding - 0x20).

If there was not the overflow of the channel (n) accumulator in the current PWM period, the channel (n) match edge is not modified, that is, it happens on channel (n) match. However, if there was the overflow of the channel (n) accumulator, the channel (n) match edge happens when (FTM counter = C(n)V + 0x0001).

The following figure shows an example of the channel (n) match edge dithering when the channels (n) and (n+1) are in Combine mode.

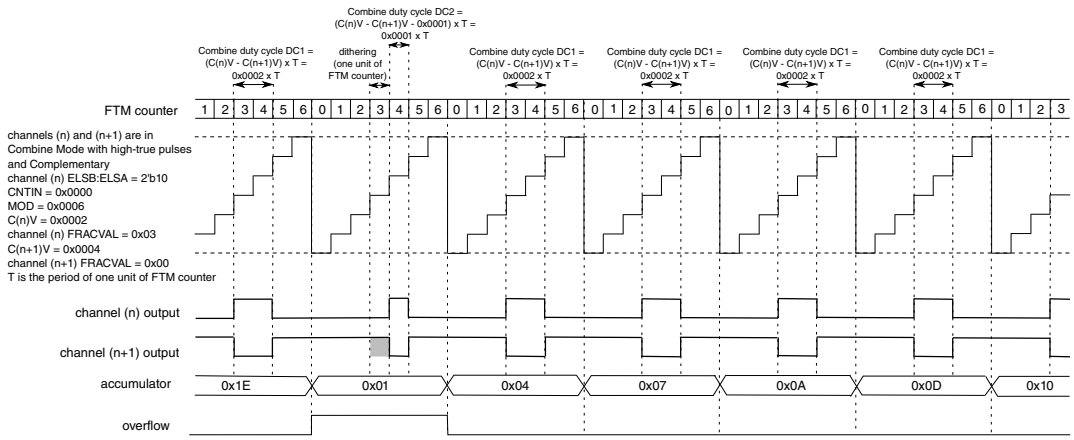


Figure 34-109. Channel (n) Match Edge Dithering in Combine Mode

The channel (n+1) match edge dithering is enabled when a non-zero value is written to the channel (n+1) FRACVAL.

For the channel (n+1) match edge dithering, the channel (n+1) has an internal 5-bit accumulator. At the end of each PWM period, the channel (n+1) FRACVAL value is added to the channel (n+1) accumulator. When this accumulator overflows (that is, the result of the adding is greater or equal than 0x20), the accumulator remains with the rest of the subtraction: (the result of this adding - 0x20).

If there was not the overflow of the channel (n+1) accumulator in the current PWM period, the channel (n+1) match edge is not modified, that is, it happens on channel (n+1) match. However, if there was the overflow of the channel (n+1) accumulator, the channel (n+1) match edge happens when (FTM counter = C(n+1)V + 0x0001).

The following figure shows an example of the channel (n+1) match edge dithering when the channels (n) and (n+1) are in Combine mode.

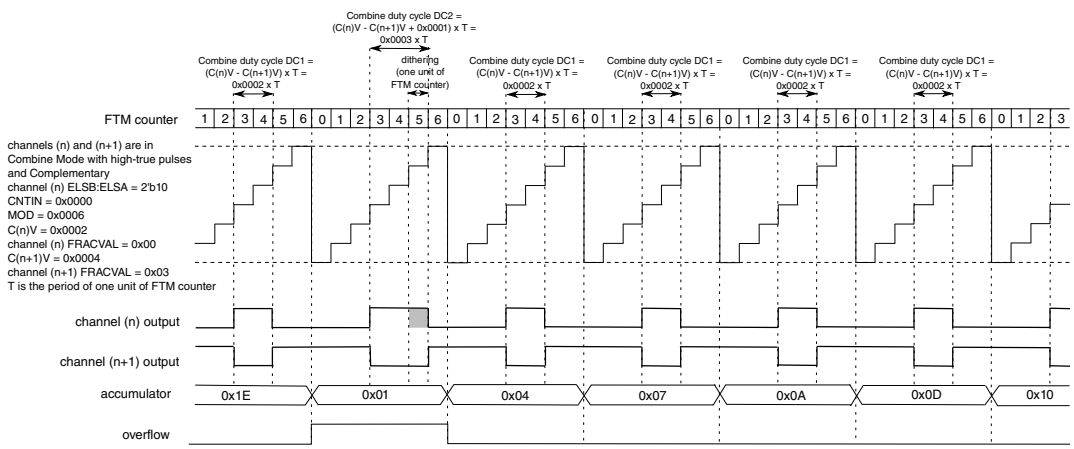


Figure 34-110. Channel (n+1) Match Edge Dithering in Combine Mode

NOTE

It is recommended to use only one PWM Edge Dithering (channel (n) PWM Edge Dithering or channel (n+1) PWM Edge Dithering) at a time.

For the generation of 0% PWM in the channel (n) (with channel (n) ELSB:ELSA = 2'b10) using Combine mode and PWM Edge Dithering, it is recommended to use:

- (C(n)V < CNTIN or C(n)V > MOD) and (channel (n) FRACVAL is zero) and
- (channel (n+1) FRACVAL is zero).

For the generation of 100% PWM in the channel (n) (with channel (n) ELSB:ELSA = 2'b10) using Combine mode and PWM Edge Dithering, it is recommended to use:

- (C(n)V = CNTIN) and (channel (n) FRACVAL is zero) and
- (C(n+1)V < CNTIN or C(n+1)V > MOD) and (channel (n +1) FRACVAL is zero).

34.6 Reset Overview

The FTM is reset whenever any chip reset occurs.

When the FTM exits from reset:

- the FTM counter and the prescaler counter are zero and are stopped (CLKS[1:0] = 2'b00);
- the timer overflow interrupt is zero (Timer Overflow Interrupt);
- the channels interrupts are zero (Channel (n) Interrupt);
- the fault interrupt is zero (Fault Interrupt);
- the channels are in input capture mode (Input Capture Mode);
- the channels outputs are zero;
- the channels ELSB:ELSA = 0:0 (Channel Modes) and PWMEN = 0 (External Control of Channels Output).

The following figure shows the FTM behavior after the reset. At the reset (item 1), the FTM counter is disabled (CLKS[1:0] = 2'b00), its value is updated to zero and the pins are not controlled by FTM (Channel Modes).

After the reset, the FTM should be configurated (item 2). It is necessary to define the FTM counter mode, the FTM counting limits (MOD and CNTIN registers value), the channels mode and CnV registers value according to the channels mode.

Thus, it is recommended to write any value to CNT register (item 3). This write updates the FTM counter with the CNTIN register value and the channels output with its initial value (except for channels in output compare mode) (Counter reset).

The next step is to select the FTM counter clock by the CLKS[1:0] bits (item 4). It is important to highlight that the pins are only controlled by FTM when CLKS[1:0] bits are different from zero.

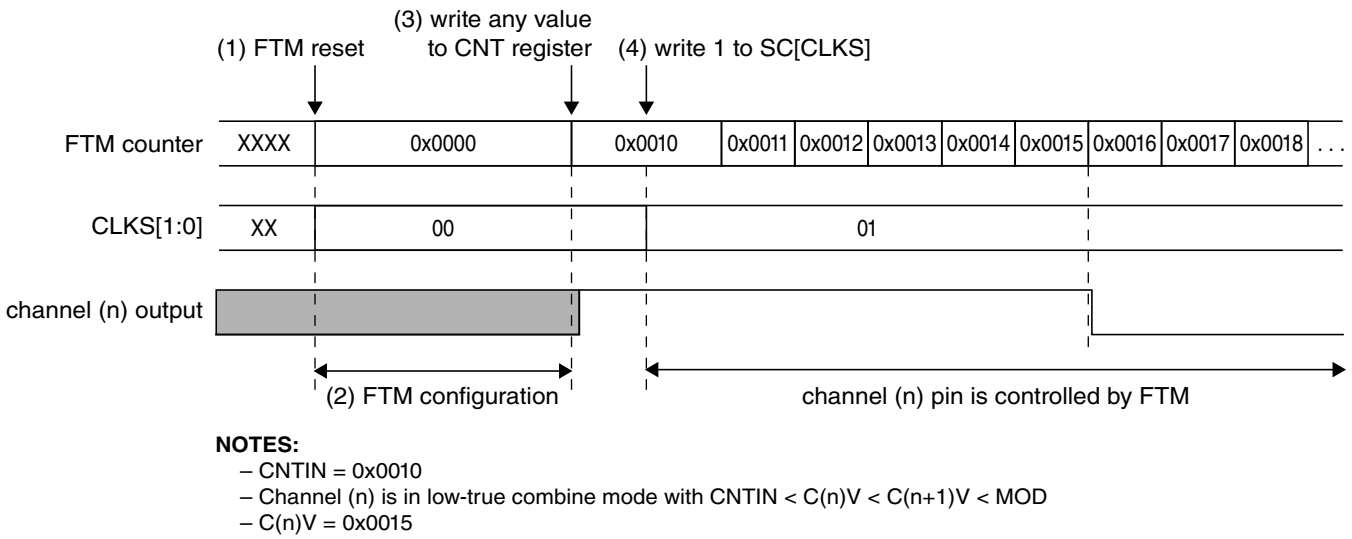
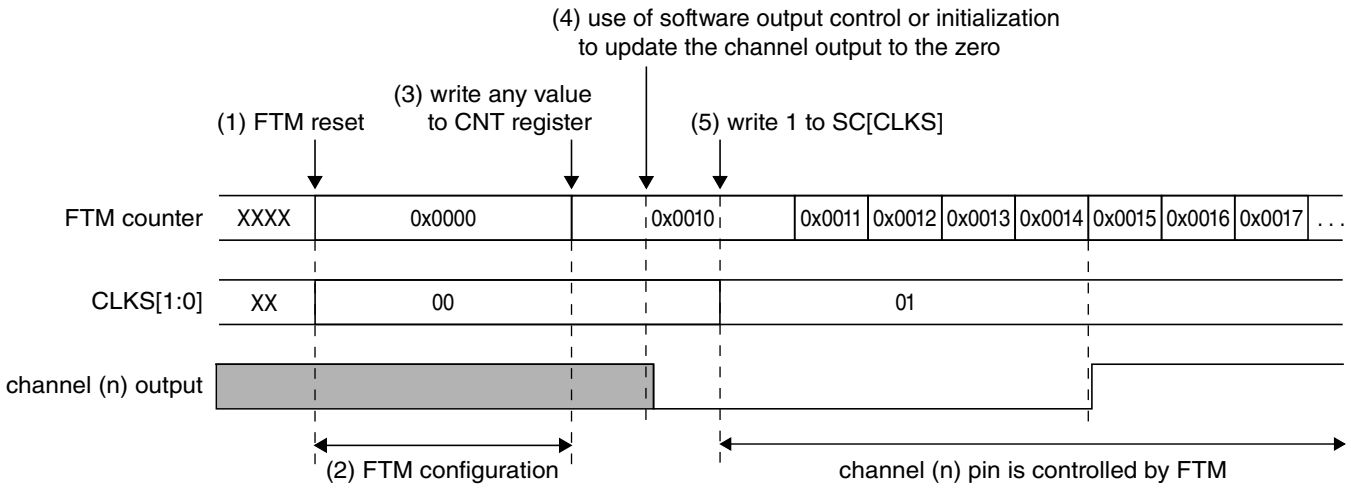


Figure 34-111. FTM behavior after reset when the channel (n) is in Combine mode

The following figure shows an example when the channel (n) is in Output Compare mode and the channel (n) output is toggled when there is a match. In the Output Compare mode, the channel output is not updated to its initial value when there is a write to CNT register (item 3). In this case, use the software output control (Software Output Control Mode) or the initialization (Initialization) to update the channel output to the selected value (item 4).



NOTES:
- CNTIN = 0x0010
- Channel (n) is in output compare and the channel (n) output is toggled when there is a match
- C(n)V = 0x0014

Figure 34-112. FTM behavior after reset when the channel (n) is in Output Compare mode

34.7 FTM Interrupts

34.7.1 Timer Overflow Interrupt

The timer overflow interrupt is generated when (TOIE = 1) and (TOF = 1).

34.7.2 Reload Point Interrupt

The Reload Point interrupt is generated when (RIE = 1) and (RF = 1).

34.7.3 Channel (n) Interrupt

The channel (n) interrupt is generated when (CHIE = 1) and (CHF = 1).

34.7.4 Fault Interrupt

The fault interrupt is generated when (FAULTIE = 1) and (FAULTF = 1).

34.8 Initialization Procedure

The following initialization procedure is recommended to configure the FlexTimer. This procedure can also be used to do a new configuration.

1. Define the POL bits.
2. Mask the channels outputs using SYNCHOM = 0. Two clocks after the write to OUTMASK, the channels outputs are in the safe value.
3. (Re)Configuration FTM counter and channels to generation of periodic signals:
   a. Disable the clock. Disable the Quadrature Decoder mode.
   b. Examples of (re)configuration:
   - Write to MOD
   - Write to CNTIN
   - Configure the channels that will be used
   - Write to CnV for the channels in output modes
   - (Re)Configure deadtime and fault control
   - Do not use the SWOC without SW synchronization (see item 6)
   - Do not use the Inverting without SW synchronization (see item 6)
   - Do not use the Initialization
   - Do not change the polarity control
   - Do not configure the HW synchronization
4. Write any value to CNT. The FTM Counter is reset and the channels outputs are updated according to new configuration.
5. Enable the clock. Write to CLKS[1:0] bits a value different from zero. Enable the Quadrature Decoder mode (if it is desired).
6. Configure the SW synchronization for SWOC (if it is necessary), Inverting (if it is necessary) and Output Mask (always)
   a. Select synchronization for Output Mask
      - Write to SYNC (SWSYNC = 0, TRIG2 = 0, TRIG1 = 0, TRIG0 = 0, SYNCHOM = 1, REINIT = 0, CNTMAX = 0, CNTMIN = 0)
   b. Write to SYNCONF
      - HW Synchronization can not be enabled (HWSOC = 0, HWINVC = 0, HWOM = 0, HWWRBUF = 0, HWRSTCNT = 0, HWTRIGMODE = 0)
      - SW Synchronization for SWOC (if it is necessary): SWSOC = [0/1] and SWOC = [0/1]
      - SW Synchronization for Inverting (if it is necessary): SWINVC = [0/1] and INVC = [0/1]
      - SW Synchronization for SWOM (always): SWOM = 1

- No enable the SW Synchronization for write buffers (because the writes to registers with write buffer are done using CLKS[1:0] = 2’b00): SWWRBUF = 0 and CNTINC = 0
- SW Synchronization for counter reset (always): SWRSTCNT = 1
- Enhanced synchronization (always): SYNCMODE = 1

c. If the SWOC is used (SWSOC = 1 and SWOC = 1), then write to SWOCTRL register.
d. If the Inverting is used (SWINVC = 1 and INVC = 1), then write to INVCTRL register.
e. Write to OUTMASK to enable the masked channels.

7. Generate the Software Trigger
   - Write to SYNC (SWSYNC = 1, TRIG2 = 0, TRIG1 = 0, TRIG0 = 0, SYNCHOM = 1, REINIT = 0, CNTMAX = 0, CNTMIN = 0)
8. Configure PWMEN bits (External Control of Channels Output).

34.9 Usage Guide

34.9.1 FTM Interrupts

The FlexTimer has multiple sources of interrupt. However, these sources are OR'd together to generate a single interrupt request to the interrupt controller. When an FTM interrupt occurs, read the FTM status registers (FMS, SC, and STATUS) to determine the exact interrupt source.

34.9.2 FTM Modulation Implementation

FTM0 support a modulation function where the output channels when configured as PWM or Output Compare mode modulate another timer output when the channel signal is asserted. Any of the 6 channels of FTM0 can be configured to support this modulation function.

The SIM_FTMOPT1 register has control bits (FTMxCHySEL) that allow the user to select normal PWM/Output Compare mode on the corresponding FTM timer channel or modulate with FTM1_CH1. The diagram below shows the implementation for FTM0. See SIM Block Guide for further information.

When FTM1_CH1 is used to modulate an FTM0 channel, then the user must configure FTM1_CH1 to provide a signal that has a higher frequency than the modulated FTM0 channel output. Also it limits the use of the FTM1_CH0 function, as the FTM1_CH1 will be programmed to provide a 50% duty PWM signal and limit the start and modulus values for the free running counter.

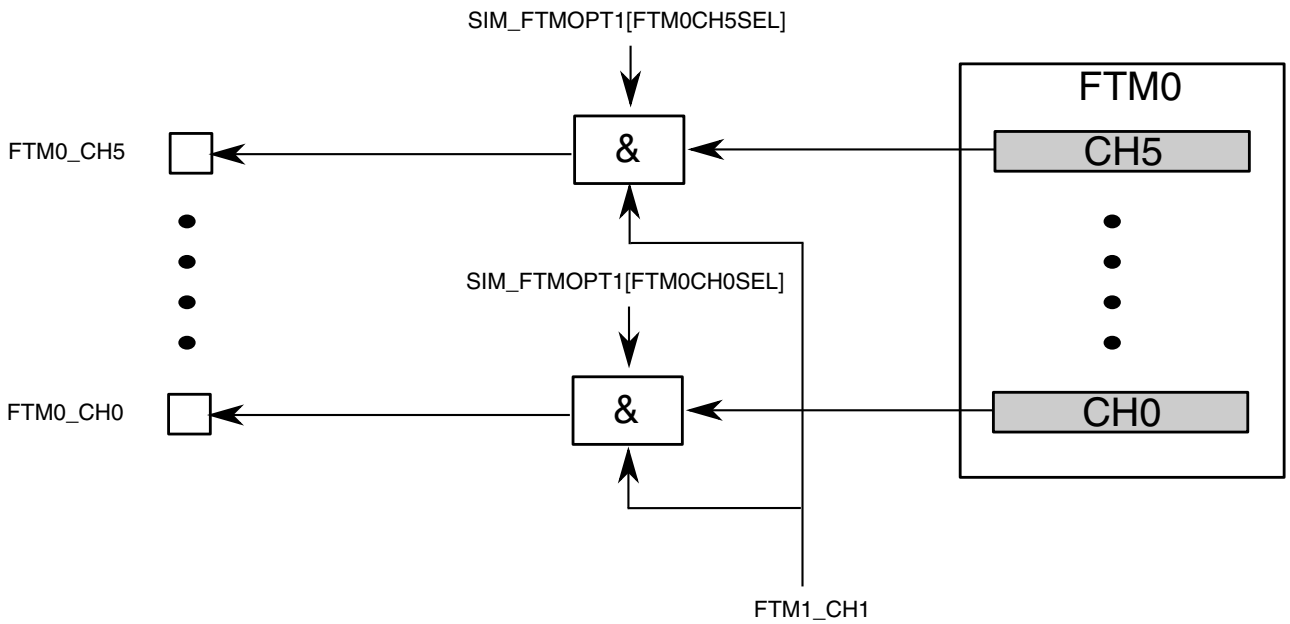
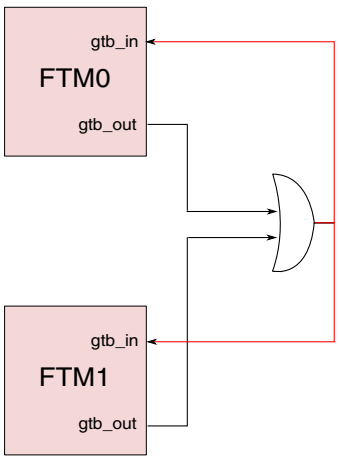


Figure 34-113. FTM Output Modulation

34.9.3 FTM Global Time Base

This chip provides the optional FTM global time base feature, see Global time base (GTB).

FTM supports global timer base through the GTB feature. Any of the FTM module could be used as the GTB_EN source. The global timer base only allows the FTM counters to start their operation synchronously, it does not automatically provide continuous synchronization of FTM counters, meaning that the FTM counters may lose synchronization during misc FTM operation.



34.9.4 FTM BDM and debug halt mode

In the FTM chapter, references to the chip being in "BDM" are the same as the chip being in “debug halt mode".

Chapter 35
Low-power Periodic Interrupt Timer (LPIT)

35.1 Chip-specific Information for this Module

35.1.1 Instantiation Information

This device contains one LPIT module with two channels.

NOTE

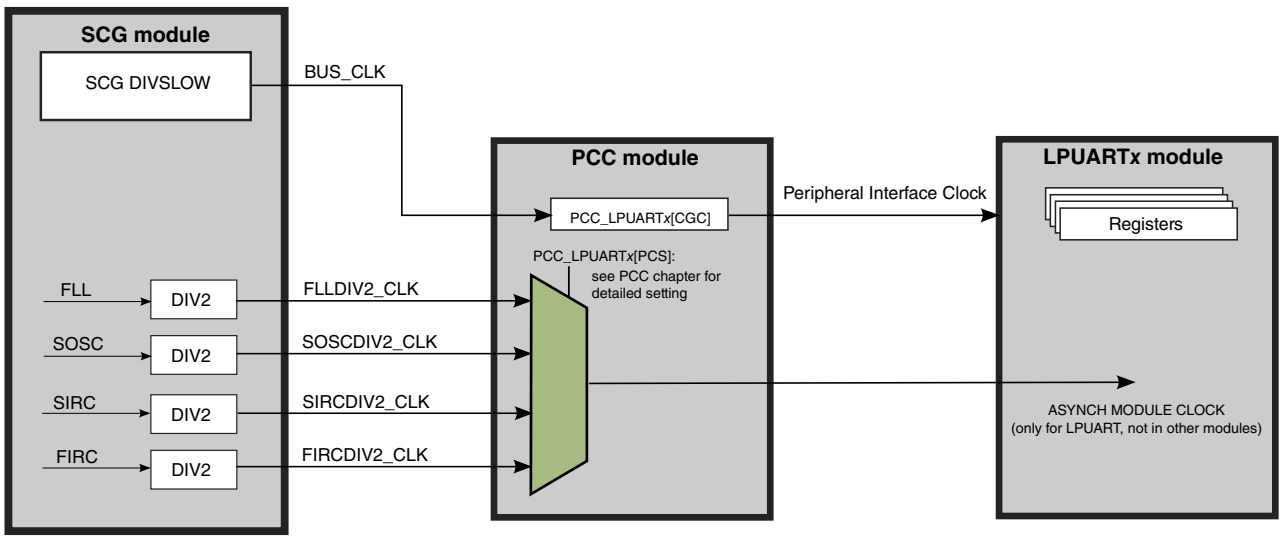
The reset value of PARAM register is 0000_0202h, for this device. 2 timer channels (ch0 and ch1) and 2 external triggers, others (ch2 and ch3) not applicable to this device.

35.1.2 LPIT Clocking Information

The LPIT module is only clocked by system clock shown in following diagram.

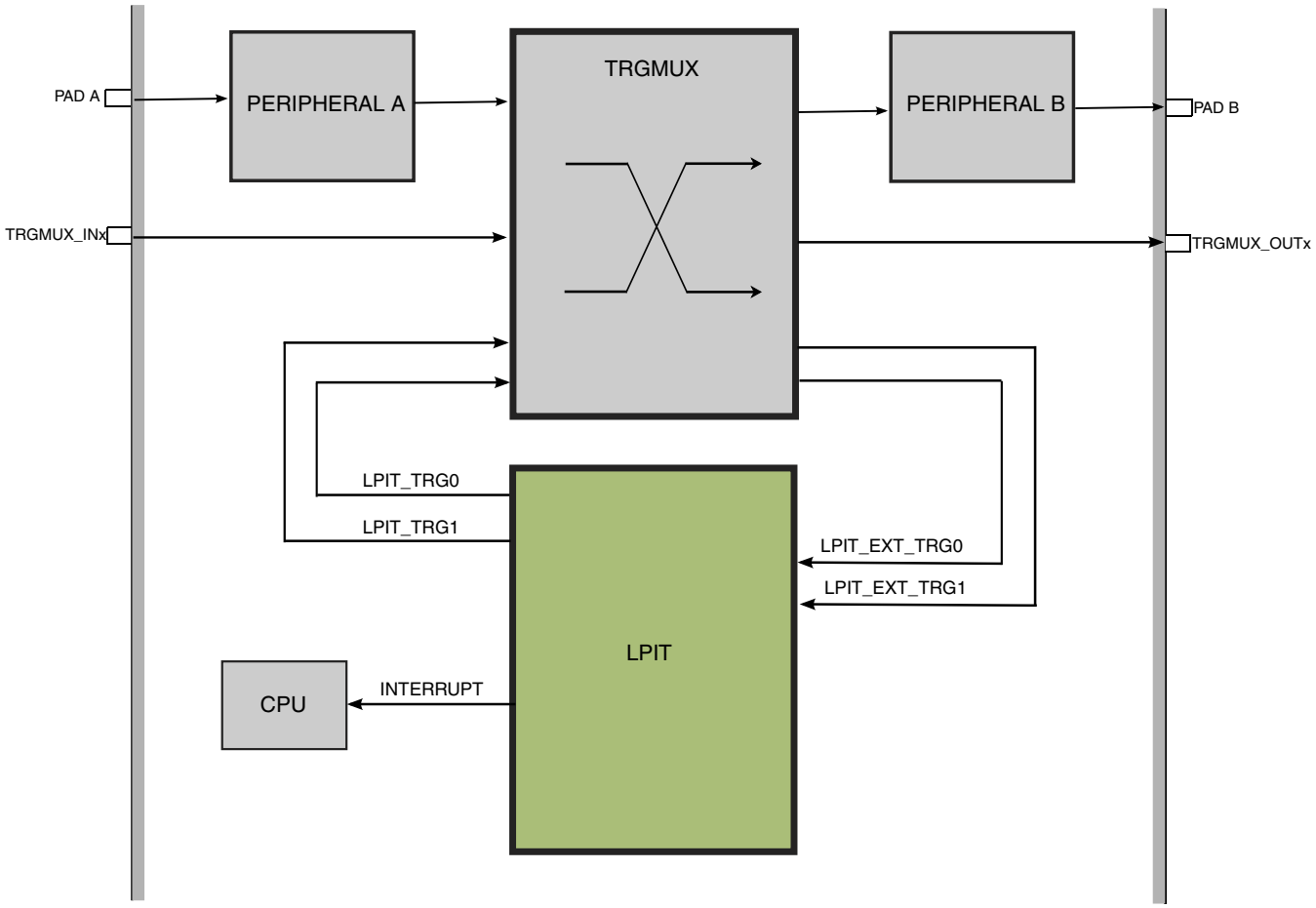
Peripheral Clocking - LPUART, etc.

Note: this example figure also applies similarly to the clocking for LPSPI, LPI2C, LPIT, FlexIO, etc.



35.1.3 Inter-connectivity Information

The LPIT module interconnectivity with other peripherals is based on the TRGMUX.



35.2 Introduction

35.2.1 Overview

The Low Power Periodic Interrupt Timer (LPIT) is a multi-channel timer module generating independent pre-trigger and trigger outputs. These timer channels can operate individually or can be chained together. The LPIT can operate in low power modes if configured to do so. The pre-trigger and trigger outputs can be used to trigger other modules on the device.

Each timer channel can be configured to run independently and made to work in either compare or capture modes. In compare mode, the timers decrement when enabled and generate an output pre-trigger and timeout pulse. The trigger output is 1 clock cycle delayed of the pre-trigger pulse. Each timer channel start, reload and restart can be

controlled via control bits. The timer can be configured to always decrement, or decrement on selected trigger inputs or previous channel timeout (when channels are chained). By chaining timer channels, applications can achieve larger timeout durations. In capture mode, the timer can be used to perform measurements as the timer value is captured (in the timer value register) when a selected trigger input is asserted. In capture mode, the timer can support once-off or multiple measurements (for example, frequency measurements).

The timer channels operate on an asynchronous clock, which is independent from the register read/write access clock. Clock synchronization between the clock domains ensures normal operations.

35.2.2 Block Diagram

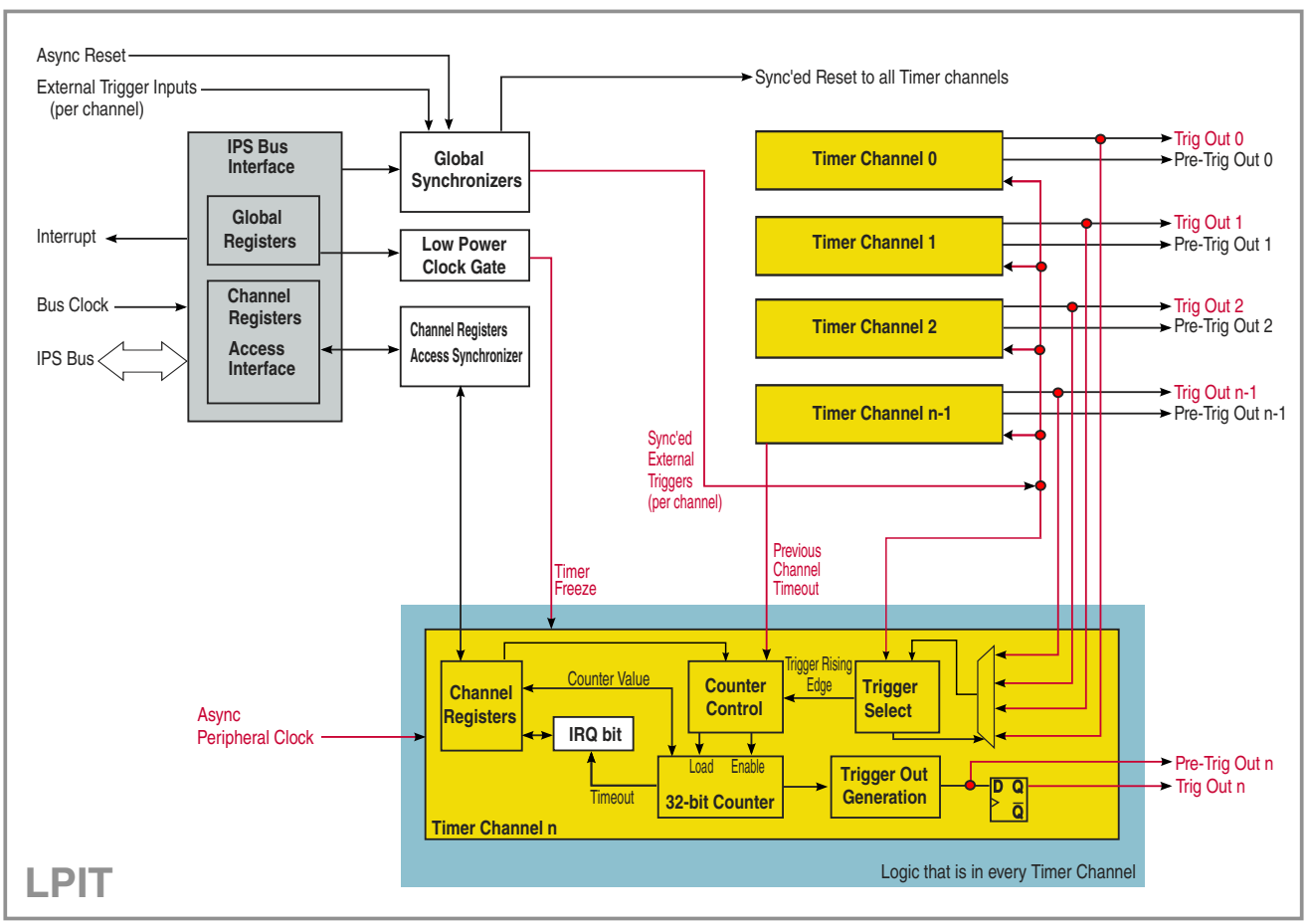


Figure 35-1. Top Level Block Diagram

35.3 Modes of operation

The LPIT module supports the chip modes described in the following table.

Table 35-1. Chip modes supported by the LPIT module

Chip mode	LPIT Operation
Run	Normal operation
Stop/Wait	Can continue operating provided the Doze Enable bit (MCR[DOZE_EN]) is set and the LPIT is using an external or internal clock source which remains operating during stop/wait modes.
Debug	Can continue operating provided the Debug Enable bit (MCR[DBG_EN]) is set.

35.4 Memory Map and Registers

The memory map comprises of 32-bit aligned registers which can be accessed via 8-bit, 16-bit, or 32-bit accesses. Write access to reserved locations will generate a transfer error. Read access to reserved locations will also generate a transfer error and the read data bus will show all 0s. The Memory Map and complete module is in Big Endian format.

The module will not check for correctness of programmed values in the registers and software must ensure that correct values are being written.

LPIT memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4003_7000	Version ID Register (LPIT0_VERID)	32	R	0100_0000h	35.4.1/758
4003_7004	Parameter Register (LPIT0_PARAM)	32	R	See section	35.4.2/759
4003_7008	Module Control Register (LPIT0_MCR)	32	R/W	0000_0000h	35.4.3/759
4003_700C	Module Status Register (LPIT0_MSR)	32	w1c	0000_0000h	35.4.4/760
4003_7010	Module Interrupt Enable Register (LPIT0_MIER)	32	R/W	0000_0000h	35.4.5/761
4003_7014	Set Timer Enable Register (LPIT0_SETTEN)	32	R/W	0000_0000h	35.4.6/763
4003_7018	Clear Timer Enable Register (LPIT0_CLRTEN)	32	W (always reads 0)	0000_0000h	35.4.7/764
4003_7020	Timer Value Register (LPIT0_TVAL0)	32	R/W	0000_0000h	35.4.8/765
4003_7024	Current Timer Value (LPIT0_CVAL0)	32	R	FFFF_FFFFh	35.4.9/766
4003_7028	Timer Control Register (LPIT0_TCTRL0)	32	R/W	0000_0000h	35.4.10/767

Table continues on the next page...

LPIT memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4003_7030	Timer Value Register (LPIT0_TVAL1)	32	R/W	0000_0000h	35.4.8/765
4003_7034	Current Timer Value (LPIT0_CVAL1)	32	R	FFFF_FFFFh	35.4.9/766
4003_7038	Timer Control Register (LPIT0_TCTRL1)	32	R/W	0000_0000h	35.4.10/767

35.4.1 Version ID Register (LPITx_VERID)

Address: 4003_7000h base + 0h offset = 4003_7000h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MAJOR								MINOR								FEATURE															
W																																
Reset	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	0	0	0	0	0	0	0

LPITx_VERID field descriptions

Field	Description
31–24 MAJOR	Major Version Number This read only field returns the major version number for the module specification
23–16 MINOR	Minor Version Number This read only field returns the minor version number for the module specification
FEATURE	Feature Number This read only field returns the feature set number.

35.4.2 Parameter Register (LPITx_PARAM)

This register provides details on the parameter settings that were used while including this module in the device.

Address: 4003_7000h base + 4h offset = 4003_7004h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0																EXT_TRIG								CHANNEL							
W																																
Reset	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*	u*

* Notes:

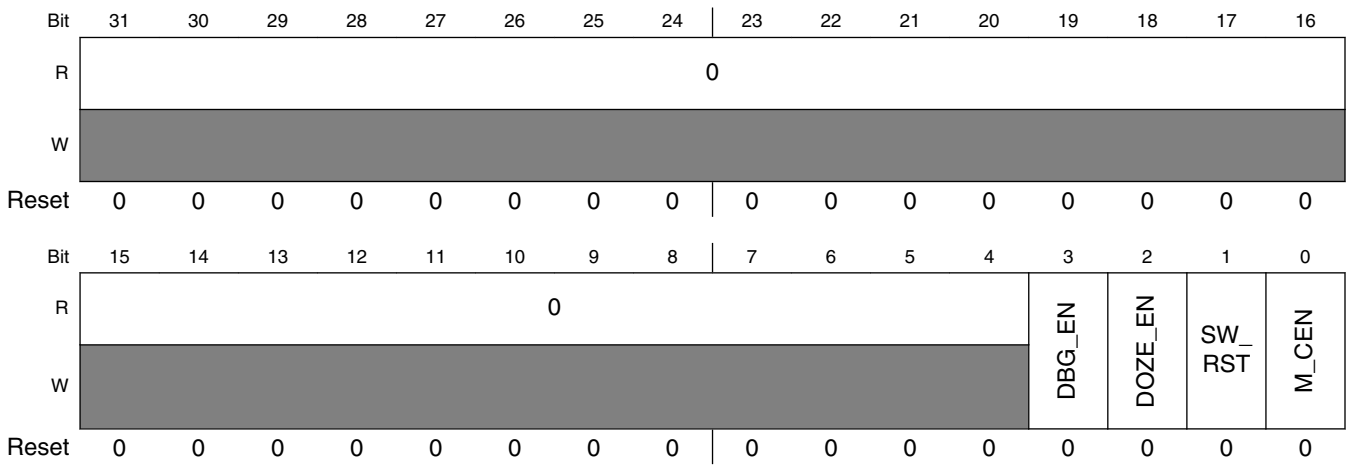
- The reset value is chip-specific.u = Unaffected by reset.

LPITx_PARAM field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–8 EXT_TRIG	Number of External Trigger Inputs Number of external triggers implemented.
CHANNEL	Number of Timer Channels Number of timer channels implemented.

35.4.3 Module Control Register (LPITx_MCR)

Address: 4003_7000h base + 8h offset = 4003_7008h



LPITx_MCR field descriptions

Field	Description
31–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 DBG_EN	Debug Enable Bit Allows the timer channels to be stopped when the device enters the Debug mode 0 Timer channels are stopped in Debug mode 1 Timer channels continue to run in Debug mode
2 DOZE_EN	DOZE Mode Enable Bit Allows the timer channels to be stopped or continue to run when the device enters the DOZE mode 0 Timer channels are stopped in DOZE mode 1 Timer channels continue to run in DOZE mode
1 SW_RST	Software Reset Bit

Table continues on the next page...

LPITx_MCR field descriptions (continued)

Field	Description
	Resets all channels and registers, except the Module Control Register. Remains set until cleared by software. 0 Timer channels and registers are not reset 1 Timer channels and registers are reset
0 M_CEN	Module Clock Enable Enables the peripheral clock to the module timers. M_CEN bit must be asserted when writing to timer registers. Both clocks (bus clock and peripheral clock) must be enabled, to allow for clock synchronization and update of register bits. **NOTE:** Writing to the MSR, SETTEN , CLRTEN, TCTRL, and TVAL registers while M_CEN = 0, will lead to the assertion of a transfer error for that bus cycle. Writing to CVAL and reserved registers will always generate a transfer error. 0 Protocol clock to timers is disabled 1 Protocol clock to timers is enabled

35.4.4 Module Status Register (LPITx_MSR)

Address: 4003_7000h base + Ch offset = 4003_700Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												TIF3	TIF2	TIF1	TIF0
W													w1c	w1c	w1c	w1c
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPITx_MSR field descriptions

Field	Description
31–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 TIF3	Channel 3 Timer Interrupt Flag In compare modes, sets to 1 at the end of the timer period. In capture modes, sets to 1 when the trigger asserts. Writing logic 1 to this flag clears it. Writing 0 has no effect. 0 Timer has not timed out 1 Timeout has occurred
2 TIF2	Channel 2 Timer Interrupt Flag In compare modes, sets to 1 at the end of the timer period. In capture modes, sets to 1 when the trigger asserts. Writing logic 1 to this flag clears it. Writing 0 has no effect.

Table continues on the next page...

LPITx_MSR field descriptions (continued)

Field	Description
	0 Timer has not timed out 1 Timeout has occurred
1 TIF1	Channel 1 Timer Interrupt Flag In compare modes, sets to 1 at the end of the timer period. In capture modes, sets to 1 when the trigger asserts. Writing logic 1 to this flag clears it. Writing 0 has no effect. 0 Timer has not timed out 1 Timeout has occurred
0 TIF0	Channel 0 Timer Interrupt Flag In compare modes, sets to 1 at the end of the timer period. In capture modes, sets to 1 when the trigger asserts. Writing logic 1 to this flag clears it. Writing 0 has no effect. 0 Timer has not timed out 1 Timeout has occurred

35.4.5 Module Interrupt Enable Register (LPITx_MIER)

Address: 4003_7000h base + 10h offset = 4003_7010h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												TIE3	TIE2	TIE1	TIE0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPITx_MIER field descriptions

Field	Description
31–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 TIE3	Channel 3 Timer Interrupt Enable Enables interrupt generation when this bit is set to 1 and if corresponding Timer Interrupt Flag is asserted. 0 Interrupt generation is disabled 1 Interrupt generation is enabled
2 TIE2	Channel 2 Timer Interrupt Enable Enables interrupt generation when this bit is set to 1 and if corresponding Timer Interrupt Flag is asserted. 0 Interrupt generation is disabled 1 Interrupt generation is enabled

Table continues on the next page...

LPITx_MIER field descriptions (continued)

Field	Description
1 TIE1	Channel 1 Timer Interrupt Enable Enables interrupt generation when this bit is set to 1 and if corresponding Timer Interrupt Flag is asserted. 0 Interrupt generation is disabled 1 Interrupt generation is enabled
0 TIE0	Channel 0 Timer Interrupt Enable Enables interrupt generation when this bit is set to 1 and if corresponding Timer Interrupt Flag is asserted. 0 Interrupt generation is disabled 1 Interrupt generation is enabled

35.4.6 Set Timer Enable Register (LPITx_SETTEN)

This register allows simulataneous enabling of timer channels. Timer channels can be enabled either by writing '1' to T_EN in respective TCTRLn register or setting the corresponding bit in this register. Writing a '0' to this register has no effect. CLRTEN register should be used to disable timer channels simultaneously.

Address: 4003_7000h base + 14h offset = 4003_7014h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0												SET_T_EN_3	SET_T_EN_2	SET_T_EN_1	SET_T_EN_0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPITx_SETTEN field descriptions

Field	Description
31–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 SET_T_EN_3	Set Timer 3 Enable

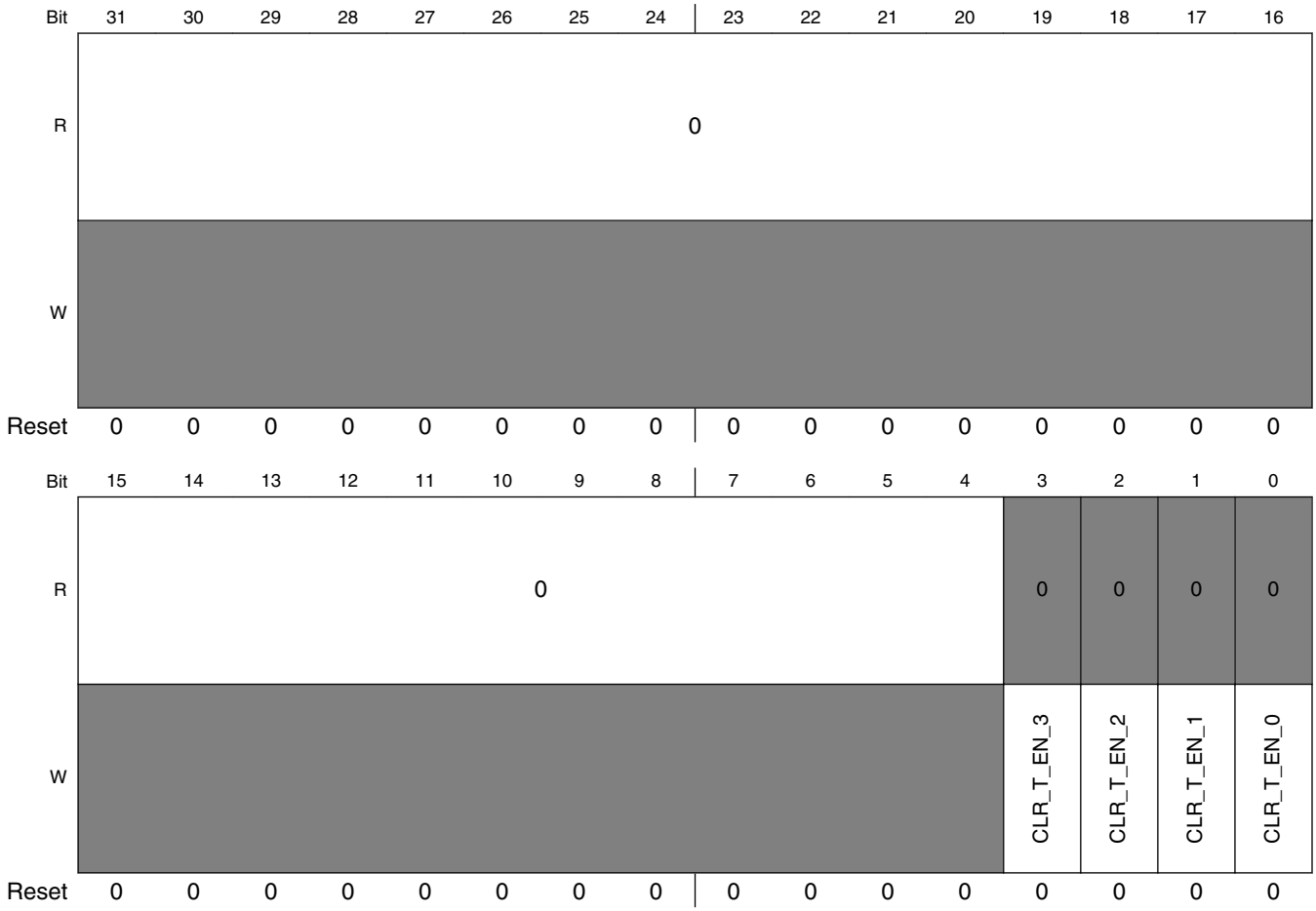
Table continues on the next page...

LPITx_SETTEN field descriptions (continued)

Field	Description
	Writing '1' to this bit will enable the timer channel 3. This bit can be used in addition to T_EN bit in TCTRL3 register. Writing a 0 will not disable the counter. This bit will be cleared when T_EN bit in TCTRL3 is set to '0' or '1' is written to the CLR_T_EN_3 bit in CLRTEN register. 0 No effect 1 Enables the Timer Channel 3
2 SET_T_EN_2	Set Timer 2 Enable Writing '1' to this bit will enable the timer channel 2. This bit can be used in addition to T_EN bit in TCTRL2 register. Writing a 0 will not disable the counter. This bit will be cleared when T_EN bit in TCTRL2 is set to '0' or '1' is written to the CLR_T_EN_2 bit in CLRTEN register. 0 No Effect 1 Enables the Timer Channel 2
1 SET_T_EN_1	Set Timer 1 Enable Writing '1' to this bit will enable the timer channel 1. This bit can be used in addition to T_EN bit in TCTRL1 register. Writing a 0 will not disable the counter. This bit will be cleared when T_EN bit in TCTRL1 is set to '0' or '1' is written to the CLR_T_EN_1 bit in CLRTEN register. 0 No Effect 1 Enables the Timer Channel 1
0 SET_T_EN_0	Set Timer 0 Enable Writing '1' to this bit will enable the timer channel 0. This bit can be used in addition to T_EN bit in TCTRL0 register. Writing a 0 will not disable the counter. This bit will be cleared when T_EN bit in TCTRL0 is set to 0 or '1' is written to the CLR_T_EN_0 bit in CLRTEN register. 0 No effect 1 Enables the Timer Channel 0

35.4.7 Clear Timer Enable Register (LPITx_CLRTEN)

Address: 4003_7000h base + 18h offset = 4003_7018h



LPITx_CLRTEN field descriptions

Field	Description
31–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 CLR_T_EN_3	Clear Timer 3 Enable Writing a '1' to this bit will disable the timer channel 3. This bit can be used in addition to T_EN bit in TCTRL3 register. Writing a 1 will not enable the counter. This bit is self clearing and will always read 0. 0 No Action 1 Clear T_EN bit for Timer Channel 3
2 CLR_T_EN_2	Clear Timer 2 Enable Writing a '1' to this bit will disable the timer channel 2. This bit can be used in addition to T_EN bit in TCTRL2 register. Writing a 1 will not enable the counter. This bit is self clearing and will always read 0.

Table continues on the next page...

LPITx_CLRTEN field descriptions (continued)

Field	Description
	0 No Action 1 Clear T_EN bit for Timer Channel 2
1 CLR_T_EN_1	Clear Timer 1 Enable Writing a '1' to this bit will disable the timer channel 1. This bit can be used in addition to T_EN bit in TCTRL1 register. Writing a 1 will not enable the counter. This bit is self clearing and will always read 0. 0 No Action 1 Clear T_EN bit for Timer Channel 1
0 CLR_T_EN_0	Clear Timer 0 Enable Writing a '1' to this bit will disable the timer channel 0. This bit can be used in addition to T_EN bit in TCTRL0 register. Writing a 1 will not enable the counter. This bit is self clearing and will always read 0. 0 No action 1 Clear T_EN bit for Timer Channel 0

35.4.8 Timer Value Register (LPITx_TVAL*n*)

In compare modes, these registers select the timeout period for the timer channels. In capture modes, these registers are loaded with the value of the counter when the trigger asserts.

Address: 4003_7000h base + 20h offset + (16d × i), where i=0d to 1d

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

LPITx_TVAL*n* field descriptions

Field	Description
TMR_VAL	Timer Value In compare modes, sets the timer channel start value. The timer will count down until it reaches 0, then it will generate an interrupt and load this register value again. Writing a new value to this register will not restart the timer channel; instead the value will be loaded after the timer expires. To abort the current cycle and start a timer period with the new value, the timer channel must be disabled and enabled again. In capture modes, this register stores the inverse of the counter whenever the trigger asserts. 0 Invalid load value in compare modes >0 Value to be loaded (Compare Mode) or Value of Timer (Capture Mode)

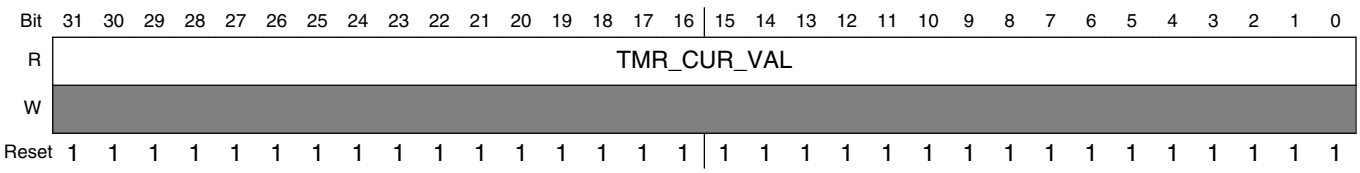
35.4.9 Current Timer Value (LPITx_CVALn)

These registers indicate the current timer counter value.

NOTE

While the timer is running, CVALn register reads may not return the real value.

Address: 4003_7000h base + 24h offset + (16d × i), where i=0d to 1d



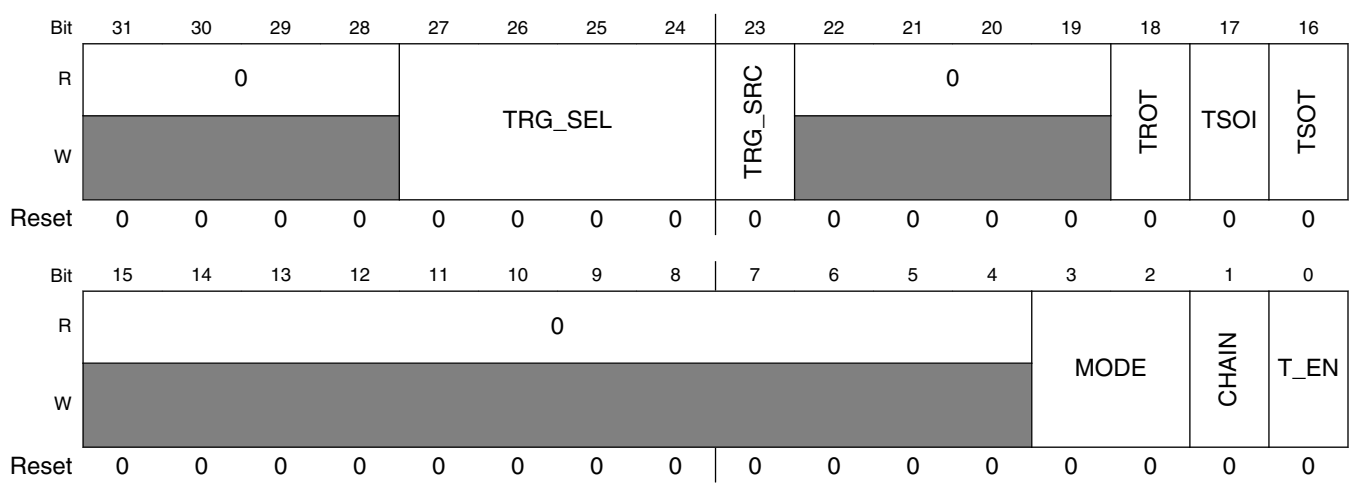
LPITx_CVALn field descriptions

Field	Description
TMR_CUR_VAL	Current Timer Value Represents the current timer value, if the timer is enabled.

35.4.10 Timer Control Register (LPITx_TCTRLn)

These registers contain the control bits for each timer channel

Address: 4003_7000h base + 28h offset + (16d × i), where i=0d to 1d



LPITx_TCTRL*n* field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 TRG_SEL	Trigger Select Selects the trigger to use for starting and/or reloading the LPIT timer. This field should only be changed when the LPIT timer channel is disabled. The TRG_SRC bit selects between internal and external trigger signals for each channel. The TRG_SEL bits select one trigger from the set of internal or external triggers selected by TRG_SRC. 0 Timer channel 0 trigger source is selected 1 Timer channel 1 trigger source is selected 2 Timer channel 2 trigger source is selected . . . . . . n Timer channel 'n' trigger source is selected
23 TRG_SRC	Trigger Source Selects between internal or external trigger sources. The final trigger is selected by TRG_SEL depending on which trigger source out of internal triggers or external triggers are selected by TRG_SRC. Refer to the chip configuration section for available external trigger options. If a channel does not have an associated external trigger then this bit for that channel should be set to 1. 0 Trigger source selected in external 1 Trigger source selected is the internal trigger
22–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
18 TROT	Timer Reload On Trigger When set, the LPIT timer will reload when a rising edge is detected on the selected trigger input. The trigger input is ignored if the LPIT is disabled during debug mode or DOZE mode (DOZE_EN or DBGEN = 0) 0 Timer will not reload on selected trigger 1 Timer will reload on selected trigger
17 TSOI	Timer Stop On Interrupt This bit controls whether the channel timer will stop after it times out and when it can restart (when TSOT = 0). If TSOT = 1, then the timer will stop on timeout and will restart after a rising edge on the selected trigger is detected. If TSOT = 0, then this bit controls when the timer restarts. 0 Timer does not stop after timeout 1 Timer will stop after timeout and will restart after rising edge on the T_EN bit is detected (i.e. timer channel is disabled and then enabled)
16 TSOT	Timer Start On Trigger This bit controls when the timer starts decrementing. 0 Timer starts to decrement immediately based on restart condition (controlled by TSOI bit) 1 Timer starts to decrement when rising edge on selected trigger is detected
15–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

LPITx_TCTRL*n* field descriptions (continued)

Field	Description
3–2 MODE	Timer Operation Mode Configures the Channel Timer Mode of Operation. The mode bits control how the timer decrements. See Functional Description for more details. 00 32-bit Periodic Counter 01 Dual 16-bit Periodic Counter 10 32-bit Trigger Accumulator 11 32-bit Trigger Input Capture
1 CHAIN	Chain Channel When enabled, timer channel will decrement when channel N-1 trigger asserts. Channel 0 cannot be chained. 0 Channel Chaining is disabled. Channel Timer runs independently. 1 Channel Chaining is enabled. Timer decrements on previous channel's timeout
0 T_EN	Timer Enable Enables or disables the Timer Channel 0 Timer Channel is disabled 1 Timer Channel is enabled

35.5 Functional description

35.5.1 Initialization

The following steps can be used to initialize the LPIT module

- Enable the protocol clock by setting the M_CEN bit in the MCR register.

NOTE

Writing to certain registers while M_CEN = 0 will lead to assertion of transfer error for that bus access. These registers are MSR, SETTEN, CLRTEN, TVAL, and TCTRL. Writing to CVAL and Reserved registers will generate a transfer error irrespective of M_CEN bit value. Reads to these registers can happen irrespective of M_CEN bit value.

- Wait for 4 protocol clock cycles to allow time for clock synchronization and reset de-assertion.

- For each timer channel that is to be enabled, configure the timer mode of operation (MODE bits), Trigger source selection (TRG_SEL & TRG_SRC) and Trigger control bits (TROT, TSOT, TSOI bits) in the TCTRLn register.
- Configure the channels that are to be chained by setting the CHAIN bit in the corresponding channel's TCTRLn register.
- For channels configured in Compare Mode, set the timer timeout value by programming the appropriate value in TVAL register for those channels.
- Configure TIEn bits in MIER register for those channels which are required to generate interrupt on timer timeout.
- Configure the low power mode functionality of the module by setting the DBG_EN and DOZE_EN bits in the MCR register. This is common to all timer channels.
- Enable the channel timers by setting the corresponding T_EN bit in the corresponding channel's TCRTLn register.
- For channels configured in Capture Mode, the timer value can be read from TVALn register when channel timeout occurs.
- At any time, the current value of the timer for any channel can be read by reading the corresponding channel's CVALn register.
- The timer interrupt flag bits (TIFn) in MSR register get asserted on timer timeout. These bits can be cleared by writing '1' to them.

35.5.2 Timer Modes

The timer mode is configured by setting an appropriate value in the MODE bits in TCTRLn register. The timer modes supported are:

- *32-bit Periodic Counter:* In this mode the counter will load and then decrement down to zero. It will then set the timer interrupt flag and assert the output pre-trigger.
- *Dual 16-bit Periodic Counter:* In this mode, the counter will load and then the lower 16-bits will decrement down to zero, which will assert the output pre-trigger. The upper 16-bits will then decrement down to zero, which will negate the output pre-trigger and set the timer interrupt flag.
- *32-bit Trigger Accumulator:* In this mode, the counter will load on the first trigger rising edge and then decrement down to zero on each trigger rising edge. It will then set the timer interrupt flag and assert the output pre-trigger.
- *32-bit Trigger Input Capture:* In this mode, the counter will load with 0xFFFF_FFFF and then decrement down to zero. If a trigger rising edge is detected, it will store the inverse of the current counter value in the load value register, set the timer interrupt flag and assert the output pre-trigger.

The timer operation is further controlled by Trigger Control bits (TSOT, TSOI, TROT) which control the timer load, reload, start and restart of the timers.

NOTE

- The trigger output is asserted one Protocol Timer Clock cycle later than pre-trigger output. The trigger output and the pre-trigger output de-assert at the same time.
- The pre-trigger output is asserted for two clock cycles and trigger output is asserted for one clock cycle (except in 16-bit Periodic Counter mode where both pre-trigger and trigger are asserted for many cycles depending on TMR_VAL[31:16]).

35.5.3 Trigger Control for Timers

The TSOT, TROT, TSOI and TRG_SEL, TRG_SRC bits control how the trigger input affects the timer operation. The TRG_SEL selects the input trigger for the channel from all other channel's trigger outputs. The TRG_SRC further selects between the selected internal trigger and the external trigger input to the channel.

The selected trigger affects the timer operation based on TROT, TSOI & TSOT bits. The behavior due to these bits is as follows:

- If TSOI = 1, counter stops on TIF assertion. Requires trigger (if TSOT = 1) or T_EN rising edge (if TSOT = 0), to reload and decrement. If TSOI = 0, counter does not stop after timeout.
- If TROT = 1, counter is loaded on each trigger; else, counter is loaded on every T_EN rising edge or timeout rising edge (timeout not used in Capture modes).
- If TSOT = 1, counter will start to decrement on trigger. Subsequent triggers are ignored till a counter timeout. If TSOT = 0, counter decrements immediately from the next clock edge. TSOT has no effect when channel is Chained or in Capture mode.

These bits affect the timer operation differently in different timer modes:

- In 32-bit Periodic Counter and Dual 16-bit Periodic Counter modes, all bits (TSOT, TSOI & TROT) affect the timer operation as described above.
- In 32-bit Trigger Accumulator mode, only TSOI bit controls the timer function. TROT & TSOT bits have no effect on timer operation.
- In 32-bit Input Trigger Capture mode, TSOI and TROT bits control the timer function. TSOT bit has no effect on timer operation.

35.5.4 Channel Chaining

Individual timer channels can be chained together to achieve a larger value of timeout. Chaining the timer channel causes them to work in a *'nested loop'* manner thereby leading to an effective timeout value of $TVAL_{CHn} \times (TVAL_{CHn-1} + 1)$.

The channels are chained by setting the CHAIN bit in corresponding channel's TCTRLn register. When a channel is chained, that channel's timer decrements on previous channel's timeout pulse, irrespective of the timer mode (MODE bits). The TSOT bit does not have any effect if the channel timer (Channel 'n') is chained to previous channel's timer (Channel 'n-1').

35.6 Usage Guide

35.6.1 Periodic timer/counter

LPIT typical usage is to generate periodic trigger pulses and interrupts.

Example: LPIT channel0 trigger a periodic interrupt every 1 second

- Enable the LPIT module clock;
- Reset the timer channels and registers;
- Setup timer operation in debug and doze modes and enable the module;
- Setup the channel counters operation mode to "32-bit Periodic Counter",and keep default values for the trigger source;
- Set timer period for channel 0 as 1 second;
- Enable channel0 interrupt;
- Starts the timer counting afer all configuration;
- In the channel interrupt rountine, clear the channel flag every 1 second.

The following pseudo-code matches the described setup above:

```
CLOCK_EnableClock(LPIT0);
LPIT0_MCR |= LPIT_MCR_SW_RST_MASK;
LPIT0_MCR &= ~LPIT_MCR_SW_RST_MASK;
LPIT0_MCR |= (LPIT_MCR_DBG_EN(1) | LPIT_MCR_DOZE_EN(1) | LPIT_MCR_M_CEN_MASK);
LPIT0_TCTRL0 |= LPIT_TCTRL_MODE(0);
LPIT0_TVAL0 = ONE_SECOND_VALUE;
LPIT0_MIER |= LPIT_MIER_TIE0_MASK;
NVIC_EnableIRQ(LPIT0_IRQ);
LPIT0_SETTEN |= LPIT_SETTEN_SET_T_EN_0_MASK;
```

35.6.2 LPIT/ADC Trigger

The LPIT could be used as an alternate ADC hardware trigger source, whose implementation is via TRGMUX. Each LPIT channel supports one pre-trigger and one trigger. The LPIT channels are implemented based on independent counters. When used as ADC trigger source, the channel outputs are ORed together to generate the ADC hardware trigger. The following diagram shows an example of using LPIT triggering ADC0.

Example: LPIT hardware trigger via TRGMUX for ADC conversion

- ADC module initialization and enable its hardware trigger;
- Enable the LPIT module clock;
- Reset the LPIT timer channels and registers;
- Setup timer operation in debug and doze modes and enable LPIT module;
- Setup the LPIT_CH0 and LPIT_CH1 counters mode to "32-bit Periodic Counter",and keep default values for the trigger source;
- Set timer period for LPIT_CH0 and LPIT_CH1,they are used as ADC pre-trigger delay;
- Starts the timer counting after all configuration;
- In SIM register, select TRGMUX output as ADC pre-trigger and trigger source;
- Configure LPIT_CH0 and LPIT_CH1 as ADC hardware trigger by TRGMUX;
- In the ADC interrupt routine, clear the COCO flag and read the conversion value. (If Rn is read, the COCO flag will be cleared automatically.)

The following pseudo-code matches the described setup above:

```
ADC_Config();
CLOCK_EnableClock(LPIT0);
LPIT0_MCR |= LPIT_MCR_SW_RST_MASK;
LPIT0_MCR &= ~LPIT_MCR_SW_RST_MASK;
LPIT0_MCR |= (LPIT_MCR_DBG_EN(1) | LPIT_MCR_DOZE_EN(1) | LPIT_MCR_M_CEN_MASK);
LPIT0_TCTRL0 |= LPIT_TCTRL_MODE(0);
LPIT0_TCTRL1 |= LPIT_TCTRL_MODE(0);
LPIT0_TVAL0 = ADC_PRETRG_DELAY_VALUE1;
LPIT0_TVAL1 = ADC_PRETRG_DELAY_VALUE2;
LPIT0_SETTEN |= LPIT_SETTEN_SET_T_EN_0_MASK|LPIT_SETTEN_SET_T_EN_1_MASK;
SIM_ADCOPT |= SIM_ADCOPT_ADC0TRGSEL(1)|SIM_ADCOPT_ADC0PRETRGSEL(1);
TRGMUX0_ADC0 = TRGMUX_TRGCFG_SEL0(7)|TRGMUX_TRGCFG_SEL1(8);
```

Chapter 36
Pulse Width Timer (PWT)

36.1 Chip-specific information for this module

36.1.1 Instantiation Information

The Pulse Width Timer (PWT) module on this device consists of one 16-bit counter, which can be used to capture or measure the pulse width mapping on its input channels.

The counter of PWT has two selectable clocks sources, and support up to BUS_CLK with internal timer clock. PWT module supports programmable positive or negative pulse edges, and programmable interrupt generation upon pulse width values or counter overflow.

36.1.2 PWT Clocking Information

Two software selectable clock sources are available for input to pre-scaler divider of PWT module:

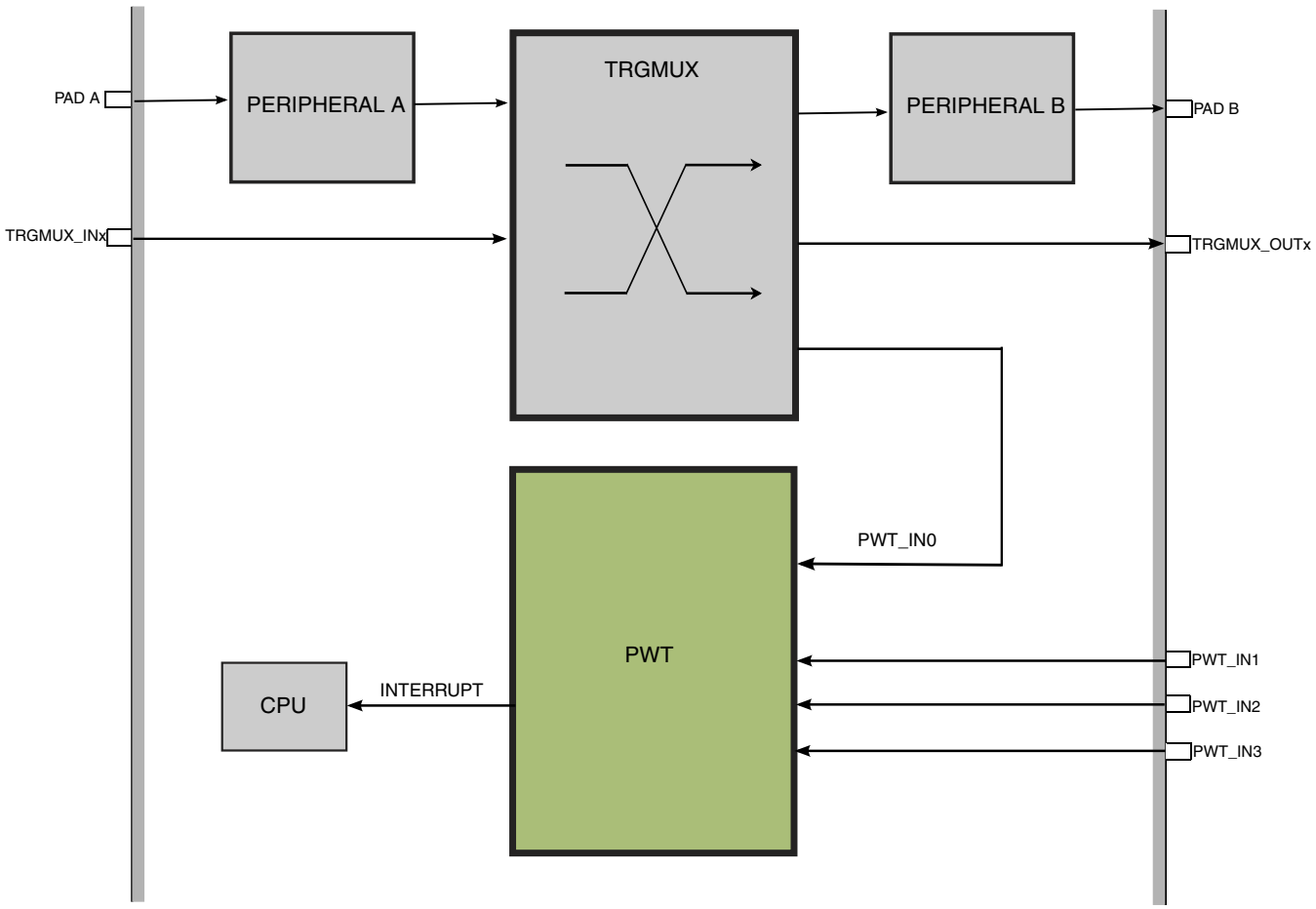
- Bus clock
- External clock from pins (TCLKx)

36.1.3 Inter-connectivity Information

PWT module has four input channels, which is connected as shown in the following table:

Table 36-1. PWT input connections

PWT input channel	Connection
0	TRGMUX output
1	PWT_IN1 pin
2	PWT_IN2 pin
3	PWT_IN3 pin



36.2 Introduction

36.2.1 Features

The pulse width timer (PWT) includes the following features:

- Automatic measurement of pulse width with 16 bit resolution
- Separate positive and negative pulse width measurements

- Programmable measuring time between successive alternating edges, rising edges or falling edges
- Programmable pre-scaler from clock input as 16-bit counter time base
- Two selectable clock sources — bus clock and alternative clock
- Four selectable pulse inputs
- Programmable interrupt generation upon pulse width value updated and counter overflows

36.2.2 Modes of operation

This module supports the following mode:

- Run Mode

  When enabled, the pulse width timer module is active.

- Wait Mode

  When enabled, the pulse width timer module is active and can perform the waking up function if the corresponding interrupt is enabled.

- Stop Mode

  The pulse width timer module is halted when entering stop and the register contents and operating status is preserved. If stop exits with reset then the module resets. If stop exits with another source, the module resumes operation based on module status upon exit.

- Active Background Mode

  Upon entering BDM mode, the PWT suspends all counting and pulse edge detection until the microcontroller returns to normal user operating mode. Counting and edge detection resume from the suspended value when normal user operating mode returns as long as the PWTSR bit (PWT software reset) is not written to 1 and the PWT module is still enabled.

36.2.3 Block diagram

The following figure show the block diagram of the PWT.

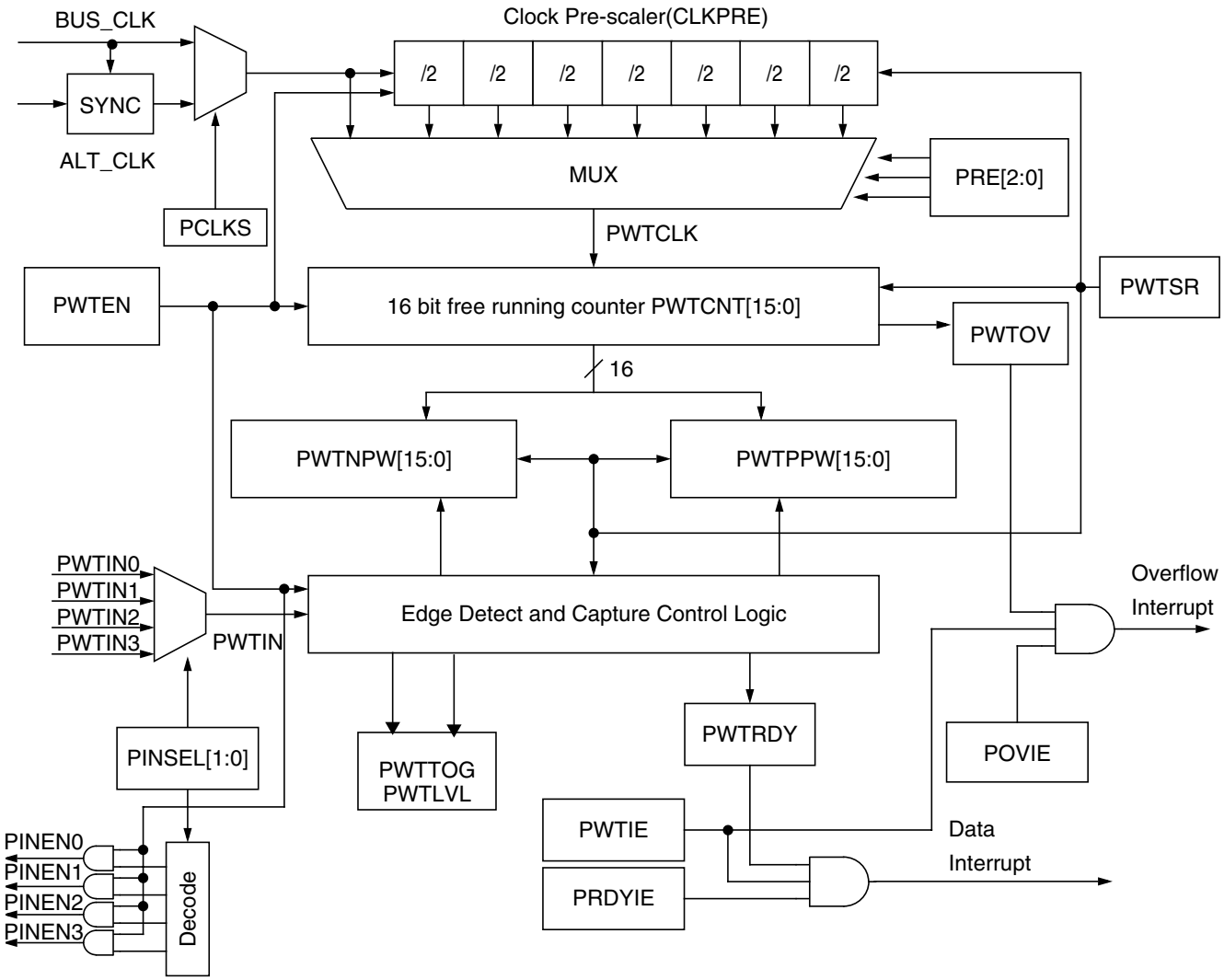


Figure 36-1. Pulse width timer (PWT) block diagram

36.3 External signal description

36.3.1 Overview

PWT has the following signal.

Table 36-2. PWT signal properties

Signal	Pullup	Description	I/O
PWTIN[3:0]	No	Pulse inputs	I
ALTCLK	No	Alternative clock source for the counter	I

36.3.2 PWTIN[3:0] — pulse width timer capture inputs

The input signals are pulse capture inputs which can come from internal or external. The PWT input is selected by PINSEL[1:0] to be routed to the pulse width timer. If the input comes from external and is selected as the PWT input, the input port is enabled for PWT function by PINSEL[1:0] automatically. The minimum pulse width to be measured is 1 PWTCLK cycle, any pulse narrower than this value is ignored by PWT module. The PWTCLK cycle time depends on the PWT clock source selection and pre-scaler rate setting.

36.3.3 ALTCLK— alternative clock source for counter

The PWT has an alternative clock input ALTCLK which can be selected as the clock source of the counter when the PCLKS bit is set. The ALTCLK input must be synchronized by the bus clock. Variations in duty cycle and clock jitter must also be accommodated so that the ALTCLK signal must not exceed one-fourth of the bus frequency. The ALTCLK pin can be shared with a general-purpose port pin. See the Pins and Connections chapter for the pin location and priority of this function.

36.4 Memory Map and Register Descriptions

PWT memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4005_6000	Pulse Width Timer Control and Status Register (PWT_CS)	8	R/W	00h	36.4.1/780
4005_6001	Pulse Width Timer Control Register (PWT_CR)	8	R/W	00h	36.4.2/781
4005_6002	Pulse Width Timer Positive Pulse Width Register: High (PWT_PPH)	8	R	00h	36.4.3/782
4005_6003	Pulse Width Timer Positive Pulse Width Register: Low (PWT_PPL)	8	R	00h	36.4.4/782
4005_6004	Pulse Width Timer Negative Pulse Width Register: High (PWT_NPH)	8	R	00h	36.4.5/783
4005_6005	Pulse Width Timer Negative Pulse Width Register: Low (PWT_NPL)	8	R	00h	36.4.6/783
4005_6006	Pulse Width Timer Counter Register: High (PWT_CNTH)	8	R	00h	36.4.7/784
4005_6007	Pulse Width Timer Counter Register: Low (PWT_CNTL)	8	R	00h	36.4.8/784

36.4.1 Pulse Width Timer Control and Status Register (PWT_CS)

Address: 4005_6000h base + 0h offset = 4005_6000h

Bit	7	6	5	4	3	2	1	0
Read	PWTEN	PWTIE	PRDYIE	POVIE	0	FCTLE	PWTRDY	PWTOV
Write					PWTSR			
Reset	0	0	0	0	0	0	0	0

PWT_CS field descriptions

Field	Description
7 PWTEN	PWT Module Enable Enables/disables the PWT module. To avoid unexpected behavior, do not change any PWT configurations as long as PWTEN is set. 0 The PWT is disabled. 1 The PWT is enabled.
6 PWTIE	PWT Module Interrupt Enable Enables the PWT module to generate an interrupt. 0 Disables the PWT to generate interrupt. 1 Enables the PWT to generate interrupt.
5 PRDYIE	PWT Pulse Width Data Ready Interrupt Enable Enables/disables the PWT to generate an interrupt when PWTRDY is set as long as PWTIE is set. 0 Disable PWT to generate interrupt when PWTRDY is set. 1 Enable PWT to generate interrupt when PWTRDY is set.
4 POVIE	PWT Counter Overflow Interrupt Enable Enables/disables the PWT to generate an interrupt when PWTOV is set due to PWT counter overflow. 0 Disable PWT to generate interrupt when PWTOV is set. 1 Enable PWT to generate interrupt when PWTOV is set.
3 PWTSR	PWT Soft Reset Performs a soft reset to the PWT. This field always reads as 0. 0 No action taken. 1 Writing 1 to this field will perform soft reset to PWT.
2 FCTLE	First counter load enable after enable This bit determines if the counter value should be loaded to the corresponding PWTx_PPW{H,L}, PWTx_NPW{H,L} after first enable. 0 Do not load the first counter values to corresponding registers 1 Load the first coutner value to corresponding registers depended by the PWTIN level

Table continues on the next page...

PWT_CS field descriptions (continued)

Field	Description
1 PWTRDY	PWT Pulse Width Valid Indicates that the PWT Pulse Width register(s) has been updated and is ready to be read. This field is cleared by reading PWTRDY and then writing 0 to PWTRDY bit when PWTRDY is set.Writing 1 to this field has no effect. 0 PWT pulse width register(s) is not up-to-date. 1 PWT pulse width register(s) has been updated.
0 PWTOV	PWT Counter Overflow Indicates that the PWT counter has run from 0x0000_0xFFFF to 0x0000_0x0000. This field is cleared by writing 0 to PWTOV when PWTOV is set. Writing 1 to this field has no effect. If another overflow occurs when this field is being cleared, the clearing fails. 0 PWT counter no overflow. 1 PWT counter runs from 0xFFFF to 0x0000.

36.4.2 Pulse Width Timer Control Register (PWT_CR)

Address: 4005_6000h base + 1h offset = 4005_6001h

Bit	7	6	5	4	3	2	1	0
Read	PCLKS	PINSEL		TGL	LVL	PRE		
Write				w1c				
Reset	0	0	0	0	0	0	0	0

PWT_CR field descriptions

Field	Description
7 PCLKS	PWT Clock Source Selection Controls the selection of clock source for the PWT counter. 0 PWT_CLK is selected as the clock source of PWT counter. 1 Alternative clock is selected as the clock source of PWT counter.
6–5 PINSEL	PWT Pulse Inputs Selection Enables the corresponding PWT input port, if this PWT input comes from an external source. 00 PWTIN[0] is enabled. 01 PWTIN[1] is enabled. 10 PWTIN[2] enabled. 11 PWTIN[3] enabled.
4 TGL	PWTIN states Toggled from last state This flag indicates if the selected PWTIN has toggled its state since last time this bit has cleared to 0.

Table continues on the next page...

PWT_CR field descriptions (continued)

Field	Description
	0 The selected PWTIN hasn't changed its original states from last time. 1 The selected PWTIN has toggled its states.
3 LVL	PWTIN Level when Overflows This Read Only bit signalizes the selected PWTIN states when the coutner overflows to read out.
PRE	PWT Clock Prescaler (CLKPRE) Setting Selects the value by which the clock is divided to clock the PWT counter. 000 Clock divided by 1. 001 Clock divided by 2. 010 Clock divided by 4. 011 Clock divided by 8. 100 Clock divided by 16. 101 Clock divided by 32. 110 Clock divided by 64. 111 Clock divided by 128.

36.4.3 Pulse Width Timer Positive Pulse Width Register: High (PWT_PPH)

Address: 4005_6000h base + 2h offset = 4005_6002h

Bit	7	6	5	4	3	2	1	0
Read	PPWH							
Write								
Reset	0	0	0	0	0	0	0	0

PWT_PPH field descriptions

Field	Description
PPWH	Positive Pulse Width[15:8] High byte of captured positive pulse width value.

36.4.4 Pulse Width Timer Positive Pulse Width Register: Low (PWT_PPL)

Address: 4005_6000h base + 3h offset = 4005_6003h

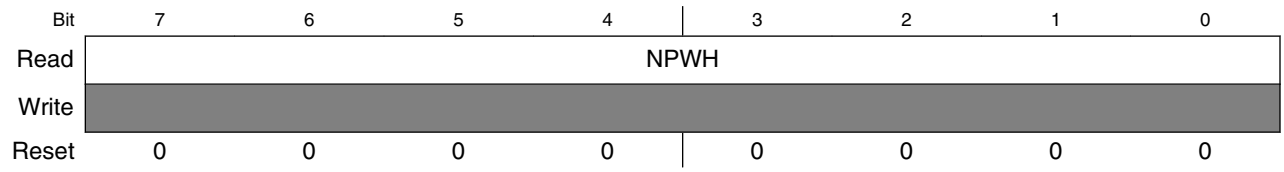
Bit	7	6	5	4	3	2	1	0
Read	PPWL							
Write								
Reset	0	0	0	0	0	0	0	0

PWT_PPL field descriptions

Field	Description
PPWL	Positive Pulse Width[7:0] Low byte of captured positive pulse width value.

36.4.5 Pulse Width Timer Negative Pulse Width Register: High (PWT_NPH)

Address: 4005_6000h base + 4h offset = 4005_6004h

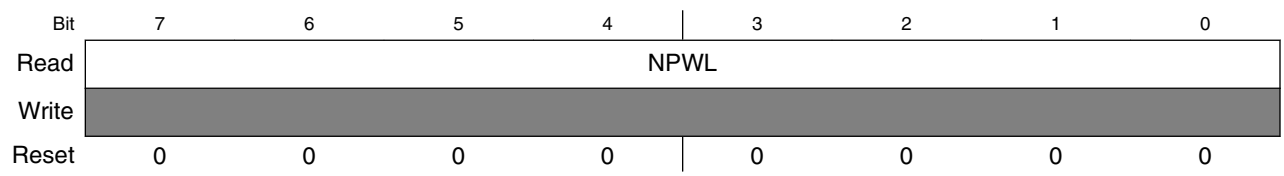


PWT_NPH field descriptions

Field	Description
NPWH	Negative Pulse Width[15:8] High byte of captured negative pulse width value.

36.4.6 Pulse Width Timer Negative Pulse Width Register: Low (PWT_NPL)

Address: 4005_6000h base + 5h offset = 4005_6005h



PWT_NPL field descriptions

Field	Description
NPWL	Negative Pulse Width[7:0] Low byte of captured negative pulse width value.

36.4.7 Pulse Width Timer Counter Register: High (PWT_CNTH)

Address: 4005_6000h base + 6h offset = 4005_6006h

Bit	7	6	5	4	3	2	1	0
Read	PWTH							
Write								
Reset	0	0	0	0	0	0	0	0

PWT_CNTH field descriptions

Field	Description
PWTH	PWT counter[15:8] High byte of PWT counter register.

36.4.8 Pulse Width Timer Counter Register: Low (PWT_CNTL)

Address: 4005_6000h base + 7h offset = 4005_6007h

Bit	7	6	5	4	3	2	1	0
Read	PWTL							
Write								
Reset	0	0	0	0	0	0	0	0

PWT_CNTL field descriptions

Field	Description
PWTL	PWT counter[7:0] Low byte of PWT counter register.

36.5 Functional description

36.5.1 PWT counter and PWT clock pre-scaler

The pulse width timer (PWT) measures duration of a pulse or the period of a signal input to the PWTIN by a 16-bit free running counter (PWT_CNTH:L). There is a clock pre-scaler (CLKPRE) in PWT module that provides the frequency divided clock to the PWT_CNTH:L.. The clock pre-scaler can select clock input from bus clock and alternative clock by PWT_CR[PCLKS].

The PWT counter uses the frequency divided clock from CLKPRE for counter advancing. The frequency of pre-scaler is programmable as the clock frequency divided by 1, 2, 4, 8, 16, 32, 64, 128 (depending on the setting of PRE[2:0]).

When PWT_CNT is running, any edge to be measured after the trigger edge causes the value of the PWT_CNT to be uploaded to the appropriate pulse width registers. At the same time, PWT_CNT will be reset to $0000 and the clock pre-scaler output will also be reset together. PWT_CNT will then start advancing again with the input clock. If the PWTxCNT runs from 0xFFFF to 0x0000, the PWTOV bit is set.

36.5.2 Edge detection and capture control

The edge detection and capture control part detects measurement trigger edges and controls when and which pulse width register(s) will be updated.

The edge detection logic determines from which edge appeared on PWTIN the pulse width starts to be measured, when and which pulse width registers should be updated.

The PWTIN can be selected from one of four sources by configuring PINSEL[1:0].

As soon as the PWT is enabled, the 16-bit free counter will begin to count up until a edge transistion on the selected PWTIN. Determined by PWT_CS[FCTLE] and PWTIN state, the counter contents can be uploaded to the corresponding registers.

If PWT_CS[FCTLE] is cleared to 0, the first 16-bit free counter content will just be ignored and not uploaded to neither PWT_PPH:L nor PWT_NPH:L. Otherwise, detemined by current PWTIN state(as signalized by PWT_CR[LVL]), the counter content will be uploaded to PWT_PPH:L if PWT_CR[LVL] is 1 and PWT_NPH:L if PWT_CR[LVL] is 0.

In normal measurement, when the PWT_CS[PWTRDY] is set, software can then read out the positive pulse width and negative pulse width values from PWT_PPH:L and PWT_NPH:L respectively and the selected PWTIN duty ratio can then be calculated. The exception is when overflow happens, software need to check PWT_CR[TGL] and PWT_CR[LVL] to determine if it is low overflow(0 duty ratio) ,high overflow(100% duty ratio), toggled low overflow or toggled high overflow. Below table 1 shows the meaning:

Table 36-3. Abnormal PWTIN duty ratio

Flag	PWT_CR[TGL]	PWT_CR[LVL]	Description
PWT_CS[PWTOV]	0	0	Low overflow
	0	1	High overflow
	1	0	Toggled low overflow

Table continues on the next page...

Table 36-3. Abnormal PWTIN duty ratio (continued)

Flag	PWT_CR[TGL]	PWT_CR[LVL]	Description
	1	1	Toggled high overflow

The following figure illustrates the trigger edge detection and pulse width registers update of PWT.

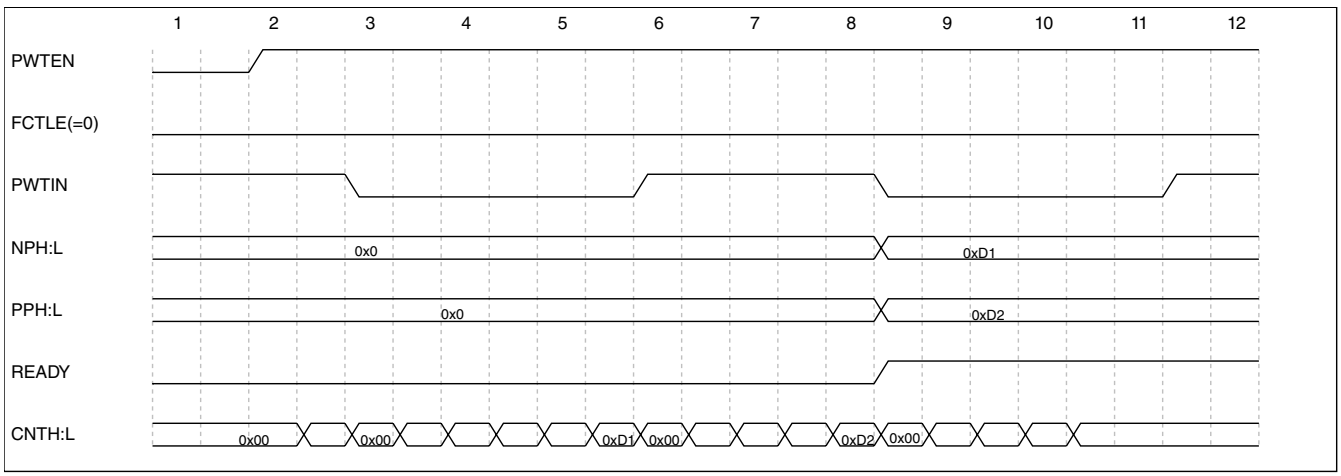


Figure 36-2. PWT normal measurement with FCTLE = 0

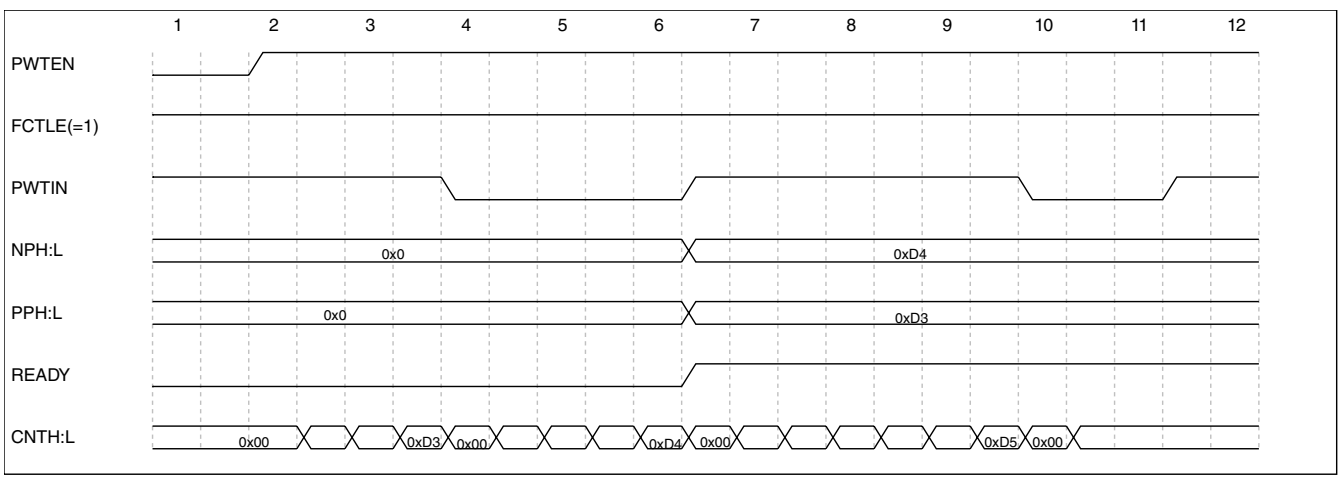


Figure 36-3. PWT normal measurement with FCTLE = 1

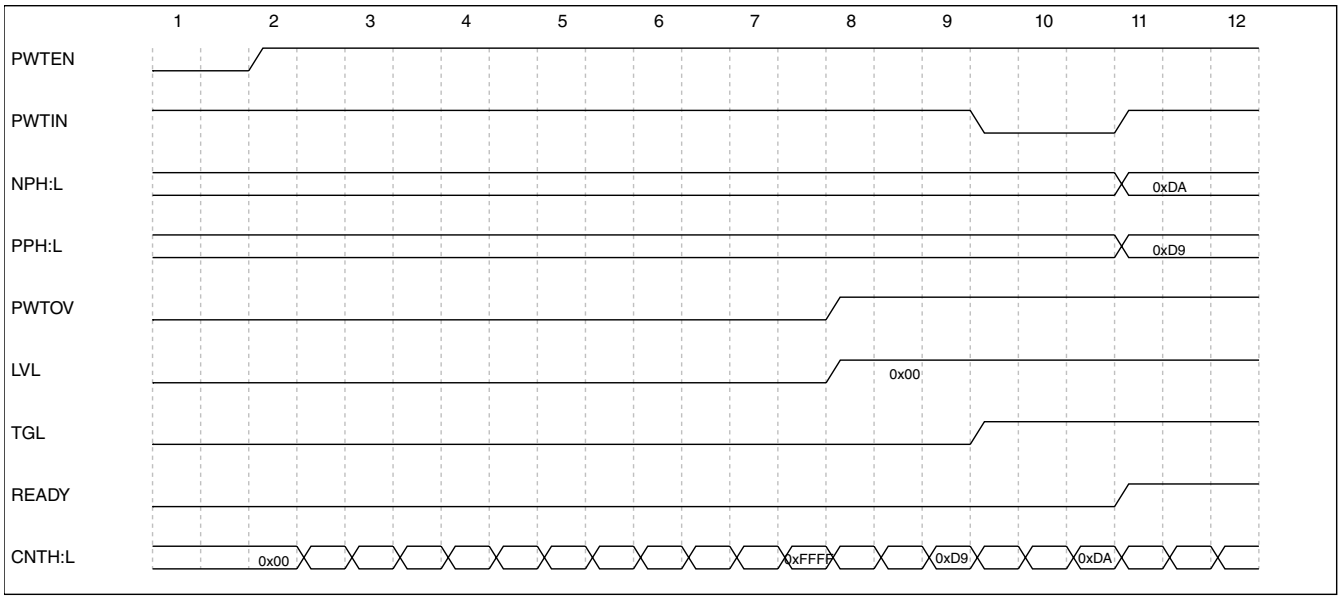


Figure 36-4. PWT measurement overflows at high level with FCTLE = 1

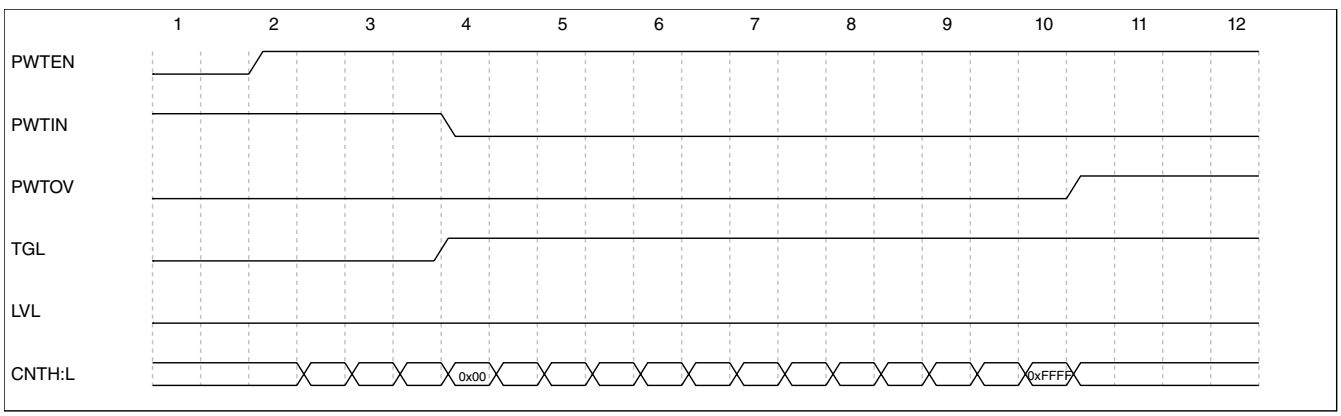


Figure 36-5. PWT measurement overflows with PWTIN toggles

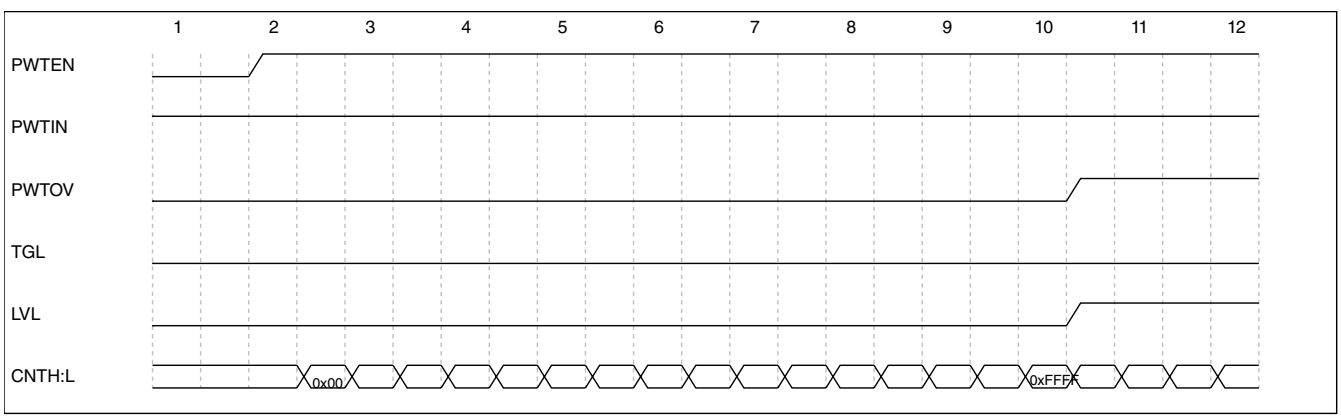


Figure 36-6. PWT measurement overflows without PWTIN toggles

The PWTRDY flag bit indicates that the data can be read in PWTxPPH:L and/or PWTxNPH:L, whenever there is a valid edge transition happened on the selected PWTIN.

When PWTRDY bit is set, the updated pulse width register(s) transfers the data to corresponding 16-bit read buffer(s). The read value of pulse width registers actually comes from the corresponding read buffers, whenever the chip is in normal run mode or BDM mode. Reading followed by writing 0 to the PWTRDY flag clears this bit. Until the PWTRDY bit is cleared, the 16-bit read buffer(s) cannot be updated. But this does not affect the upload of pulse width registers from the PWT counter.

If another pulse measurement is completed and the pulse width registers are updated, the clearing of the PWTRDY flag fails, i.e., the PWTRDY will still be set, but the 16-bit read buffer(s) will be updated again as long as the action is cleared. The user should complete the pulse width data reading before clearing the PWTRDY flag to avoid missing data. This mechanism assures that the second pulse measurement will not be lost in case the MCU does not have enough time to read the first one ready for read. The mechanism is automatically restarted by an MCU reset , writing 1 to PWTSR bit or writing a 0 to PWTEN bit followed by writing a 1 to it.

The following figure illustrates the buffering mechanism of pulse width register:

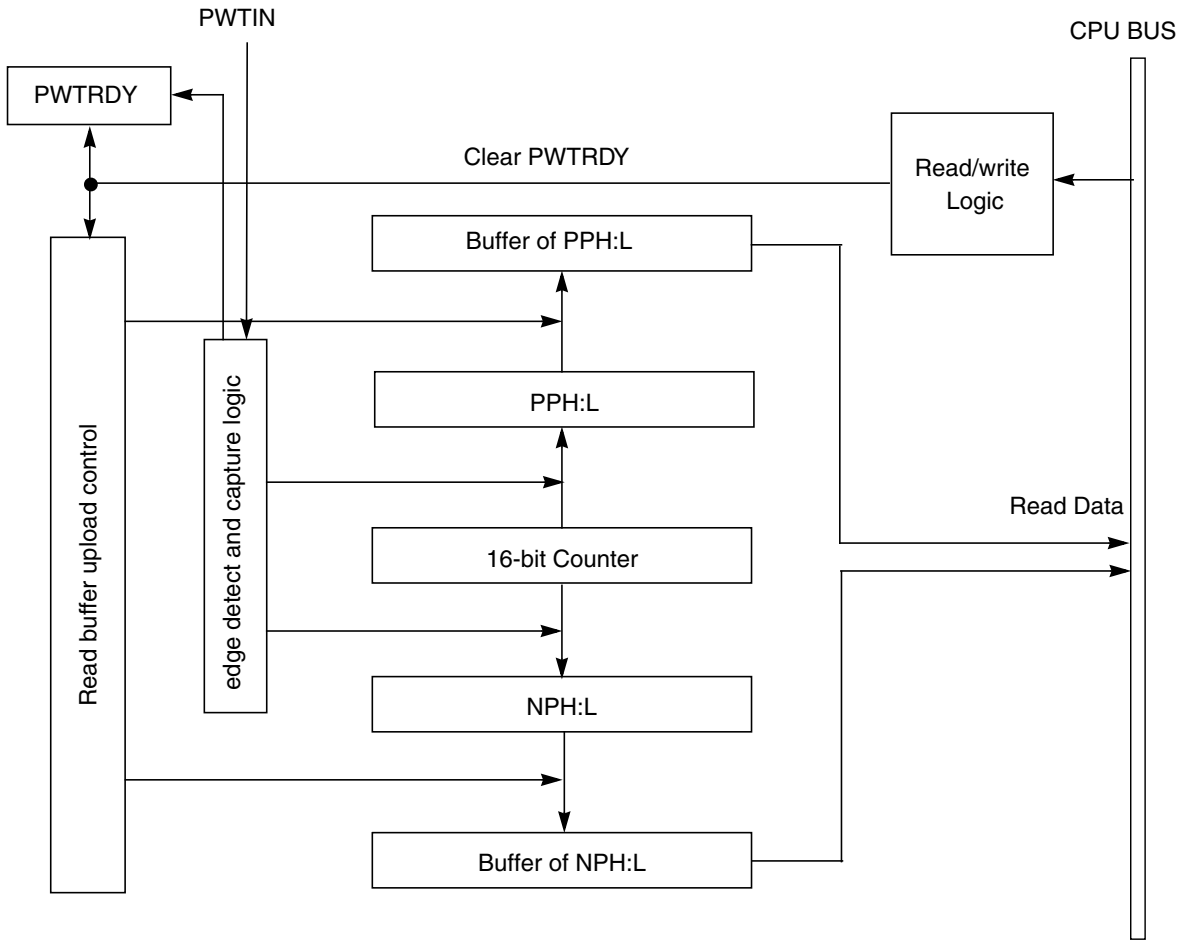


Figure 36-7. Buffering mechanism of pulse width register

When PWT completes any pulse width measurement, a signal is generated to reset PWTxCNTH:L and the clock pre-scaler output after the data has been uploaded to the pulse width registers.. To assure that there is no missing count, the PWTxCNTH:L and the clock pre-scaler output are reset in a bus clock cycle after the completion of a pulse width measurement.

36.6 Reset overview

36.6.1 Description of reset operation

PWT soft reset is built into PWT as a mechanism used to reset/restart the pulse width timer. The PWT soft reset is triggered by writing 1 to the PWTSR bit. (This bit always reads 0). Unlike reset by the CPU, the PWT reset does not restore everything in the PWT to its reset state. The following occurs

1. The PWT counter is set to 0x0000

2. The 16-bit buffer of PWT counter is reset and the reading coherency mechanism is restarted
3. The PWT clock pre-scaler output is reset
4. The edge detection logic is reset
5. The capture logic is reset and the latching mechanism of pulse width registers is also restarted.
6. PWTxPPH, PWTxPPL, PWTxNPH, PWTxNPL are set to 0x00
7. PWTOV, PWTRDY, TGL and LVL status are set to 0
8. All other PWT register settings are not changed

Writing a 0 to PWTEN bit also has the above effects except that the reset state will be held until the PWTEN bit is set to 1.

36.7 Interrupts

36.7.1 Description of interrupt operation

The other major component of the PWT is the interrupts control logic. When the PWTOV bit and POVIE bit of PWTxCS are set, a PWT overflow interrupt can be generated. When PWTRDY bit and PRDYIE bit of PWTxCS are set, a pulse width data ready interrupt can be generated. The PWTIE bit of PWTxCS controls the interrupt generation of the PWT module. The functionality of the PWT is not affected while the interrupt is being generated.

36.7.2 Application examples

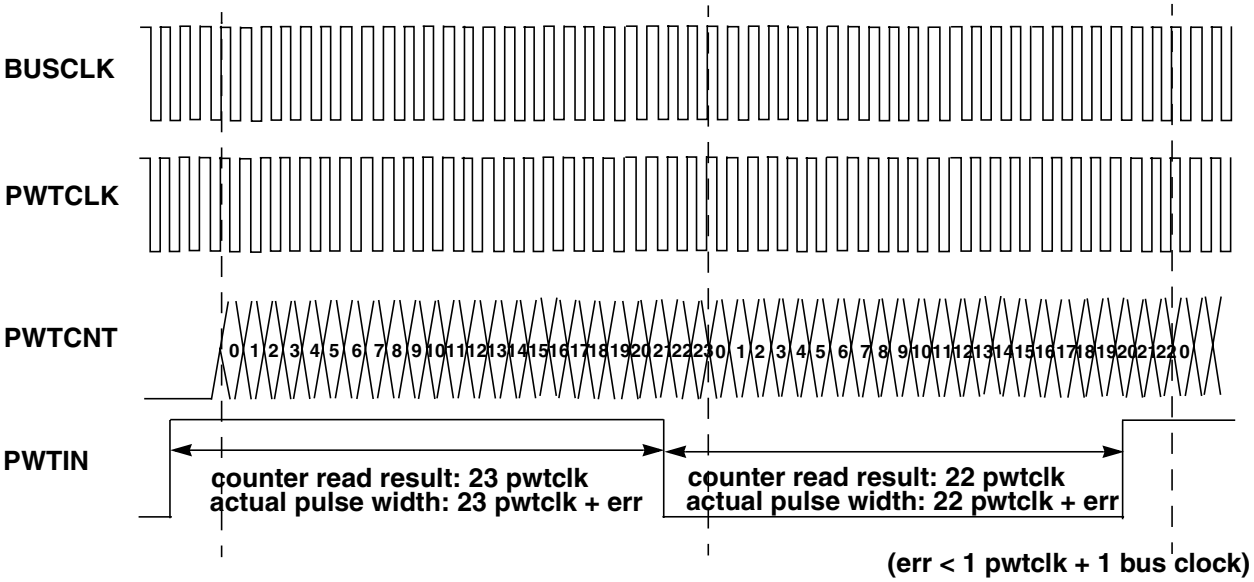


Figure 36-8. Example at PWTCLK is bus clock divided by 1

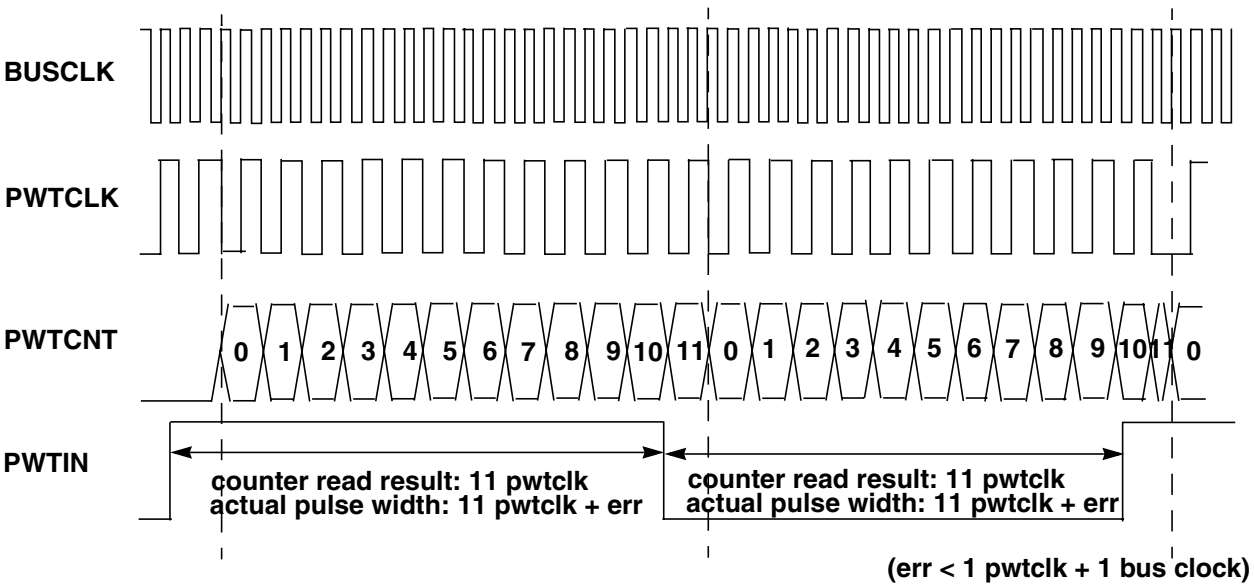


Figure 36-9. Example at PWTCLK is Bus Clock divided by 2

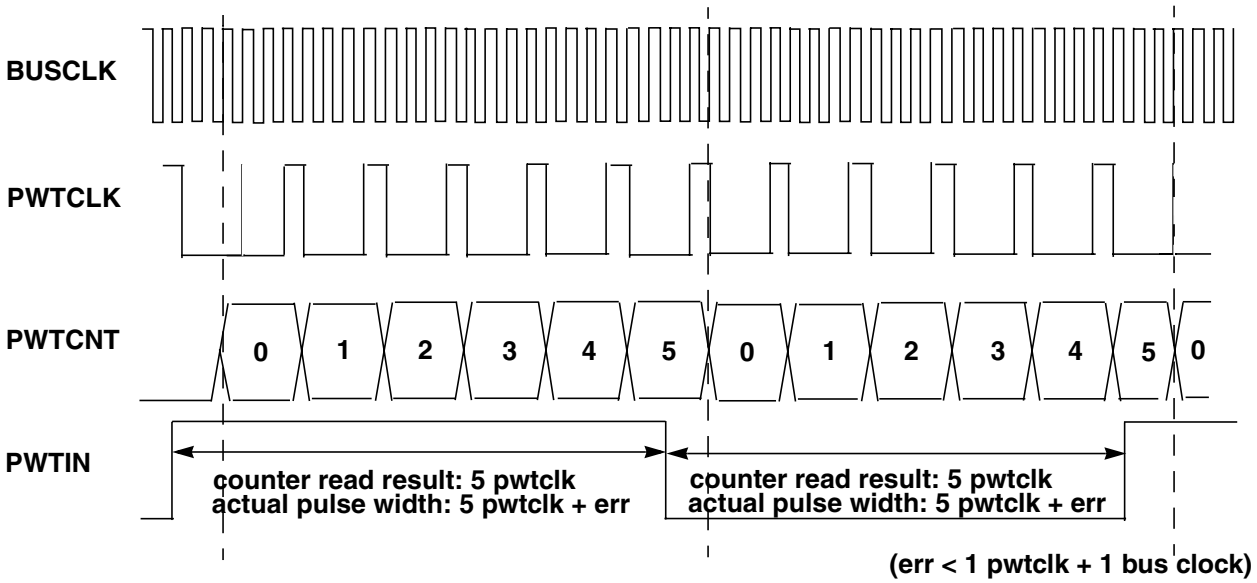


Figure 36-10. Example at PWTCLK is bus clock divided by 4

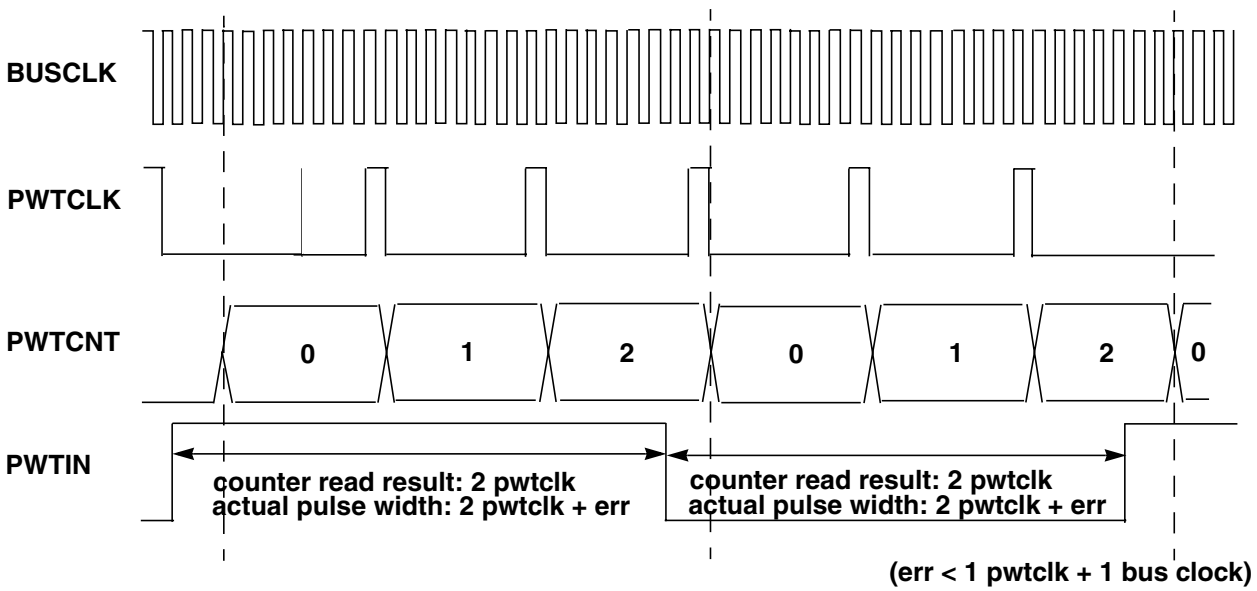


Figure 36-11. Example at PWTCLK is bus clock divided by 8

36.8 Initialization/Application information

Following are the recommended steps to initialize the PWT module:

1. Configure PWTxCR to select clock source, set pre-scaler rate, select PWT input pin and edge detection mode.
2. Set PWTIE, PRDYIE and POVIE bits in PWTxCS if corresponding interrupt is desired to be generated.
3. Set PWTEN bit in PWTxCS to enable the pulse width measurement.

The step 1 and 2 can be sequential or not, but they must be completed before step 3 to ensure all settings are ready before pulse width measurement is enabled.

36.9 Usage Guide

PWT provides an accurate signal frequency measurement for both the positive and negative portions of a periodic signal, useful for applications such as motor control. In conjunction with a Pulse Width Modulated signal it can effectively be used to implement a highly accurate closed loop motor control system, or any other system in which it might be necessary to measure a periodic signal frequency and duty cycle, providing not only accuracy but also high flexibility.

36.9.1 Edge detection, capture control and period measurement

PWT typical usage is external signal input capture and time period measurement.

Example: PWT input channel 1 capture external signal and measure its time period

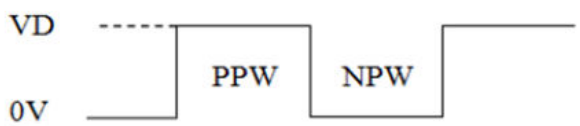


Figure Input pulse capture

The frequency (Hz) is PWT Clock / (PPW ? NPW), PWT Clock = PWT clock source / presacler.

- Enable the PWT module clock;
- Reset the timer channels and registers;
- Configure not to load the first counter values to corresponding registers, enable the PWT interrupt;
- Select bus clock as clock source and enable PWT_IN1 as input source;
- Set the module enable bit to start PWT;
- Wait for the pulse width valid flag (PWTRDY) in interrupt routinue, then get the positive and negative value(PPW, NPW) to calculate the period.

The following pseudo-code matches the described setup above:

```
CLOCK_EnableClock(PWT);
PWT_CS|= PWT_CS_PWTSR_MASK;
PWT_CS|= PWT_CS_FCTLE(0)|PWT_CS_PWTIE_MASK|PWT_CS_PRDYIE_MASK;
```

```
PWT_CR|= PWT_CR_PCLKS(0)|PWT_CR_PRE(0)|PWT_CR_PINSEL(1);
PWT_CS|= PWT_CS_PWTEN_MASK;
EnableIRQ(PWT_IRQ);
```

Chapter 37
Low Power Timer (LPTMR)

37.1 Chip-specific information for this module

37.1.1 Instantiation Information

This device contains one LPTMR module with 1-channel, 16-bit pulse counter.

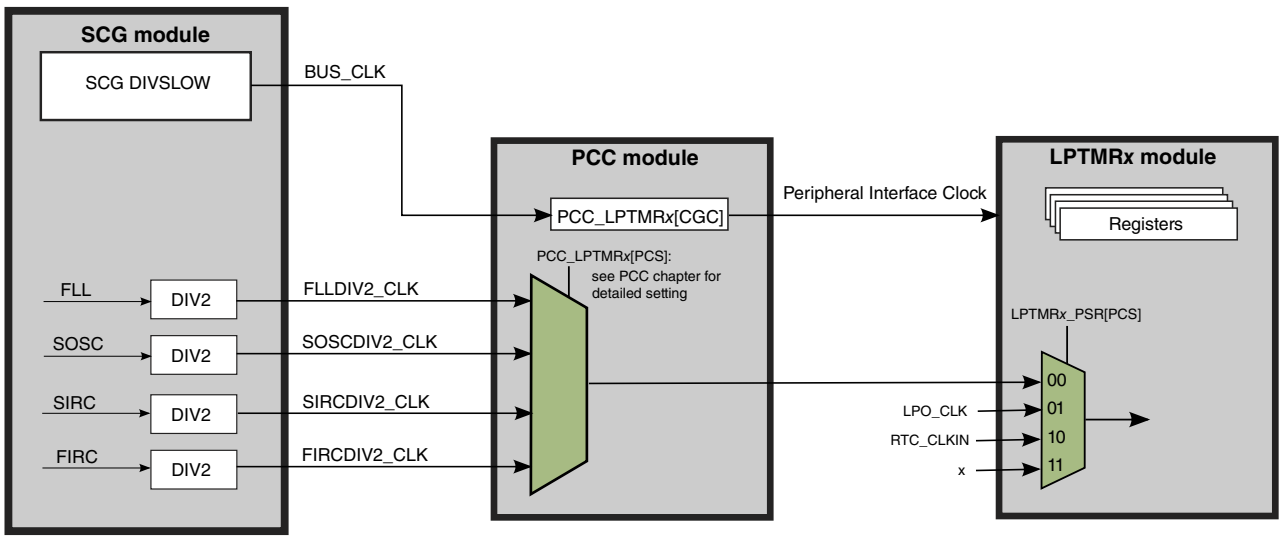
NOTE

DMA is not supported in this device.

37.1.2 LPTMR Clocking Information

The following figure shows the input clock sources available for this module.

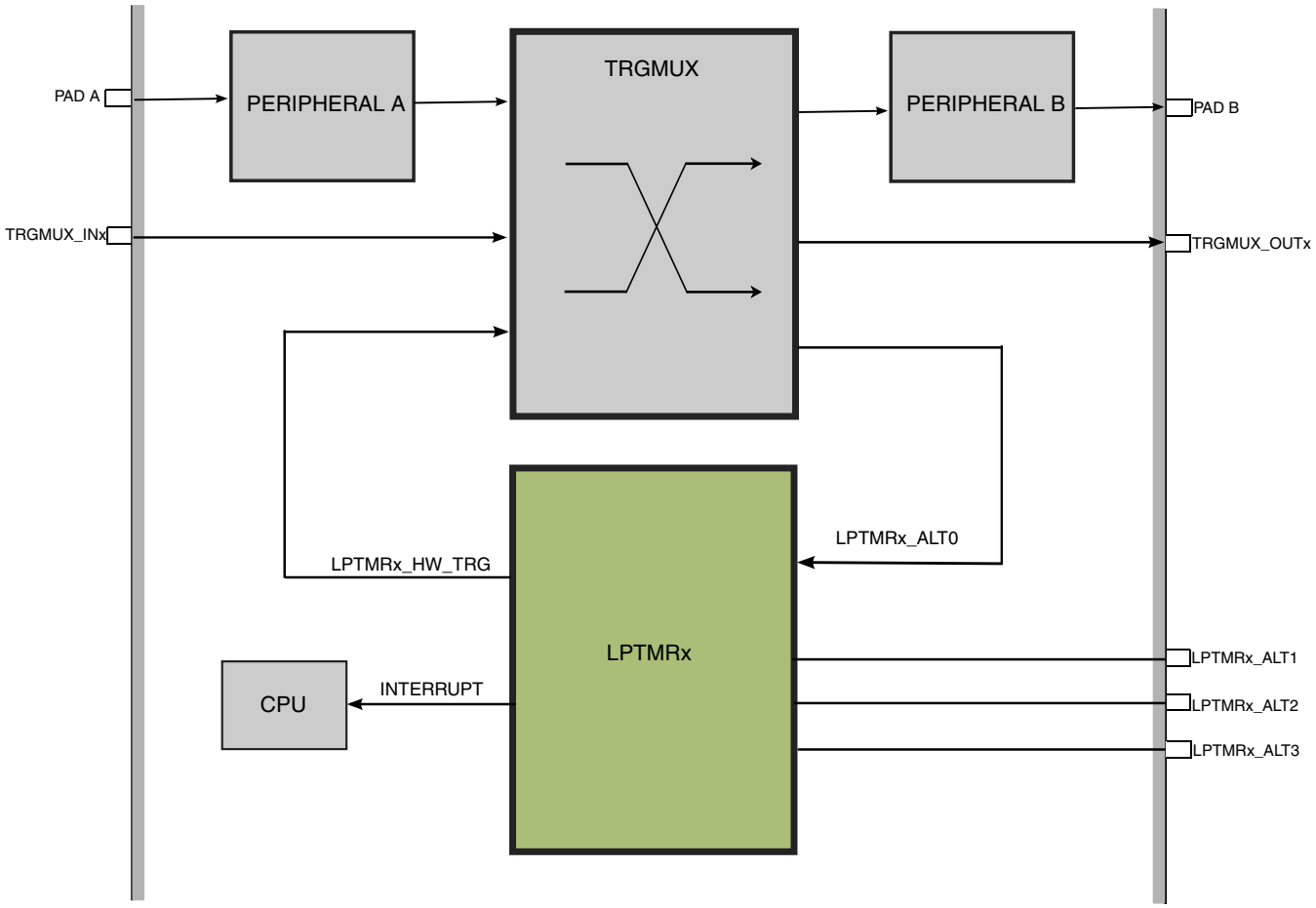
Peripheral Clocking - LPTMR



37.1.3 Inter-connectivity Information

The LPTMRx_CSR[TPS] bitfield configures the input source used in pulse counter mode. The following table shows the chip-specific input assignments for this bitfield.

LPTMRx_CSR[TPS]	Pulse counter input number	Chip input
00	0	TRGMUX output
01	1	LPTMR0_ALT1 pin
10	2	LPTMR0_ALT2 pin
11	3	LPTMR0_ALT3 pin



37.2 Introduction

The low-power timer (LPTMR) can be configured to operate as a time counter with optional prescaler, or as a pulse counter with optional glitch filter, across all power modes. It can also continue operating through most system reset events, allowing it to be used as a time of day counter.

37.2.1 Features

The features of the LPTMR module include:

- 16-bit time counter or pulse counter with compare
  - Optional interrupt can generate asynchronous wakeup from any low-power mode
  - Hardware trigger output
  - Counter supports free-running mode or reset on compare

- Configurable clock source for prescaler/glitch filter
- Configurable input source for pulse counter
  - Rising-edge or falling-edge

37.2.2 Modes of operation

The following table describes the operation of the LPTMR module in various modes.

Table 37-1. Modes of operation

Modes	Description
Run	The LPTMR operates normally.
Wait	The LPTMR continues to operate normally and can be configured to exit the low-power mode by generating an interrupt request.
Stop	The LPTMR continues to operate normally and can be configured to exit the low-power mode by generating an interrupt request.
Debug	The LPTMR operates normally in Pulse Counter mode, but the counter does not increment in Time Counter mode.

37.3 LPTMR signal descriptions

Table 37-2. LPTMR signal descriptions

Signal	I/O	Description
LPTMR_ALT*n*	I	Pulse Counter Input pin

37.3.1 Detailed signal descriptions

Table 37-3. LPTMR interface—detailed signal descriptions

Signal	I/O	Description	
LPTMR_ALT*n*	I	Pulse Counter Input The LPTMR can select one of the input pins to be used in Pulse Counter mode.	
		State meaning	Assertion—If configured for pulse counter mode with active-high input, then assertion causes the CNR to increment. Deassertion—If configured for pulse counter mode with active-low input, then deassertion causes the CNR to increment.

Table continues on the next page...

Table 37-3. LPTMR interface—detailed signal descriptions (continued)

Signal	I/O	Description	
		Timing	Assertion or deassertion may occur at any time; input may assert asynchronously to the bus clock.

37.4 Memory map and register definition

NOTE

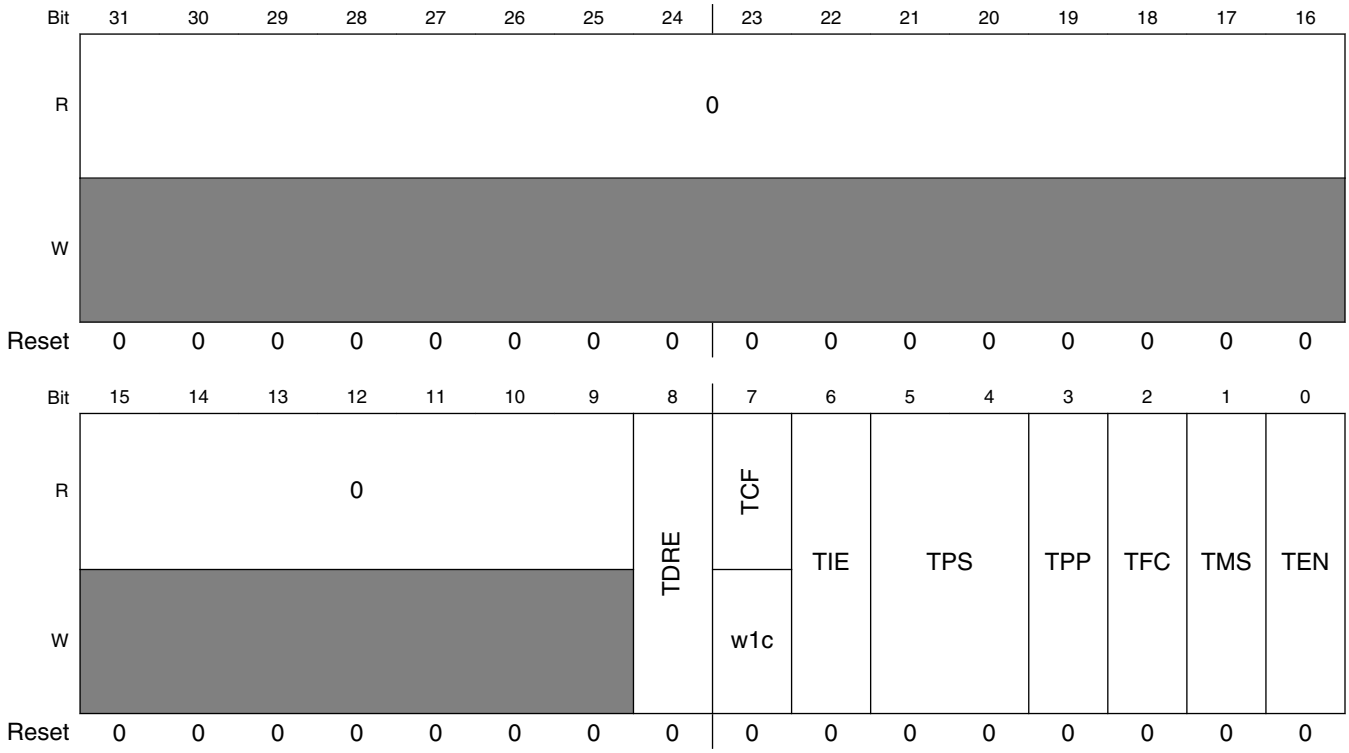
The LPTMR registers are reset only on a POR or LVD event.
See LPTMR power and reset for more details.

LPTMR memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_0000	Low Power Timer Control Status Register (LPTMR0_CSR)	32	R/W	0000_0000h	37.4.1/800
4004_0004	Low Power Timer Prescale Register (LPTMR0_PSR)	32	R/W	0000_0000h	37.4.2/802
4004_0008	Low Power Timer Compare Register (LPTMR0_CMR)	32	R/W	0000_0000h	37.4.3/803
4004_000C	Low Power Timer Counter Register (LPTMR0_CNR)	32	R/W	0000_0000h	37.4.4/804

37.4.1 Low Power Timer Control Status Register (LPTMRx_CSR)

Address: 4004_0000h base + 0h offset = 4004_0000h



LPTMRx_CSR field descriptions

Field	Description
31–9 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
8 TDRE	Timer DMA Request Enable When TDRE is set, the LPTMR DMA Request is generated whenever TCF is also set and the TCF is cleared when the DMA Controller is done. 0 Timer DMA Request disabled. 1 Timer DMA Request enabled.
7 TCF	Timer Compare Flag TCF is set when the LPTMR is enabled and the CNR equals the CMR and increments. TCF is cleared when the LPTMR is disabled or a logic 1 is written to it. 0 The value of CNR is not equal to CMR and increments. 1 The value of CNR is equal to CMR and increments.
6 TIE	Timer Interrupt Enable When TIE is set, the LPTMR Interrupt is generated whenever TCF is also set.

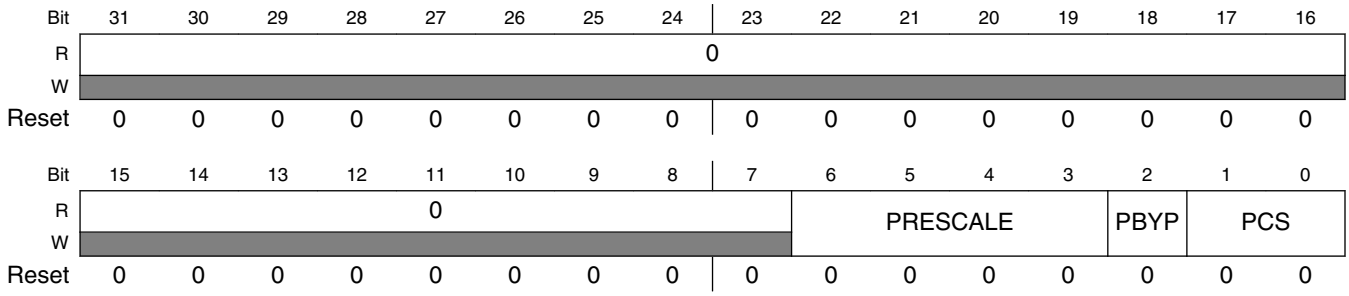
Table continues on the next page...

LPTMRx_CSR field descriptions (continued)

Field	Description
	0 Timer interrupt disabled. 1 Timer interrupt enabled.
5–4 TPS	Timer Pin Select Configures the input source to be used in Pulse Counter mode. TPS must be altered only when the LPTMR is disabled. The input connections vary by device. See the chip configuration information about connections to these inputs. 00 Pulse counter input 0 is selected. 01 Pulse counter input 1 is selected. 10 Pulse counter input 2 is selected. 11 Pulse counter input 3 is selected.
3 TPP	Timer Pin Polarity Configures the polarity of the input source in Pulse Counter mode. TPP must be changed only when the LPTMR is disabled. 0 Pulse Counter input source is active-high, and the CNR will increment on the rising-edge. 1 Pulse Counter input source is active-low, and the CNR will increment on the falling-edge.
2 TFC	Timer Free-Running Counter When clear, TFC configures the CNR to reset whenever TCF is set. When set, TFC configures the CNR to reset on overflow. TFC must be altered only when the LPTMR is disabled. 0 CNR is reset whenever TCF is set. 1 CNR is reset on overflow.
1 TMS	Timer Mode Select Configures the mode of the LPTMR. TMS must be altered only when the LPTMR is disabled. 0 Time Counter mode. 1 Pulse Counter mode.
0 TEN	Timer Enable When TEN is clear, it resets the LPTMR internal logic, including the CNR and TCF. When TEN is set, the LPTMR is enabled. While writing 1 to this field, CSR[5:1] must not be altered. 0 LPTMR is disabled and internal logic is reset. 1 LPTMR is enabled.

37.4.2 Low Power Timer Prescale Register (LPTMRx_PSR)

Address: 4004_0000h base + 4h offset = 4004_0004h



LPTMRx_PSR field descriptions

Field	Description
31–7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
6–3 PRESCALE	Prescale Value Configures the size of the Prescaler in Time Counter mode or width of the glitch filter in Pulse Counter mode. PRESCALE must be altered only when the LPTMR is disabled. 0000 Prescaler divides the prescaler clock by 2; glitch filter does not support this configuration. 0001 Prescaler divides the prescaler clock by 4; glitch filter recognizes change on input pin after 2 rising clock edges. 0010 Prescaler divides the prescaler clock by 8; glitch filter recognizes change on input pin after 4 rising clock edges. 0011 Prescaler divides the prescaler clock by 16; glitch filter recognizes change on input pin after 8 rising clock edges. 0100 Prescaler divides the prescaler clock by 32; glitch filter recognizes change on input pin after 16 rising clock edges. 0101 Prescaler divides the prescaler clock by 64; glitch filter recognizes change on input pin after 32 rising clock edges. 0110 Prescaler divides the prescaler clock by 128; glitch filter recognizes change on input pin after 64 rising clock edges. 0111 Prescaler divides the prescaler clock by 256; glitch filter recognizes change on input pin after 128 rising clock edges. 1000 Prescaler divides the prescaler clock by 512; glitch filter recognizes change on input pin after 256 rising clock edges. 1001 Prescaler divides the prescaler clock by 1024; glitch filter recognizes change on input pin after 512 rising clock edges. 1010 Prescaler divides the prescaler clock by 2048; glitch filter recognizes change on input pin after 1024 rising clock edges. 1011 Prescaler divides the prescaler clock by 4096; glitch filter recognizes change on input pin after 2048 rising clock edges. 1100 Prescaler divides the prescaler clock by 8192; glitch filter recognizes change on input pin after 4096 rising clock edges. 1101 Prescaler divides the prescaler clock by 16,384; glitch filter recognizes change on input pin after 8192 rising clock edges.

Table continues on the next page...

LPTMRx_PSR field descriptions (continued)

Field	Description
	1110 Prescaler divides the prescaler clock by 32,768; glitch filter recognizes change on input pin after 16,384 rising clock edges. 1111 Prescaler divides the prescaler clock by 65,536; glitch filter recognizes change on input pin after 32,768 rising clock edges.
2 PBYP	Prescaler Bypass When PBYP is set, the selected prescaler clock in Time Counter mode or selected input source in Pulse Counter mode directly clocks the CNR. When PBYP is clear, the CNR is clocked by the output of the prescaler/glitch filter. PBYP must be altered only when the LPTMR is disabled. 0 Prescaler/glitch filter is enabled. 1 Prescaler/glitch filter is bypassed.
PCS	Prescaler Clock Select Selects the clock to be used by the LPTMR prescaler/glitch filter. PCS must be altered only when the LPTMR is disabled. The clock connections vary by device. **NOTE:** See the chip configuration details for information on the connections to these inputs. 00 Prescaler/glitch filter clock 0 selected. 01 Prescaler/glitch filter clock 1 selected. 10 Prescaler/glitch filter clock 2 selected. 11 Prescaler/glitch filter clock 3 selected.

37.4.3 Low Power Timer Compare Register (LPTMRx_CMR)

Address: 4004_0000h base + 8h offset = 4004_0008h

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

LPTMRx_CMR field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
COMPARE	Compare Value When the LPTMR is enabled and the CNR equals the value in the CMR and increments, TCF is set and the hardware trigger asserts until the next time the CNR increments. If the CMR is 0, the hardware trigger will remain asserted until the LPTMR is disabled. If the LPTMR is enabled, the CMR must be altered only when TCF is set.

37.4.4 Low Power Timer Counter Register (LPTMRx_CNR)

Address: 4004_0000h base + Ch offset = 4004_000Ch

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

LPTMRx_CNR field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
COUNTER	Counter Value The CNR returns the current value of the LPTMR counter at the time this register was last written.

37.5 Functional description

37.5.1 LPTMR power and reset

The LPTMR remains powered in all power modes. If the LPTMR is not required to remain operating during a low-power mode, then it must be disabled before entering the mode.

The LPTMR is reset only on global Power On Reset (POR) or Low Voltage Detect (LVD). When configuring the LPTMR registers, the CSR must be initially written with the timer disabled, before configuring the PSR and CMR. Then, CSR[TIE] must be set as the last step in the initialization. This ensures the LPTMR is configured correctly and the LPTMR counter is reset to zero following a warm reset.

37.5.2 LPTMR clocking

The LPTMR prescaler/glitch filter can be clocked by one of the four clocks. The clock source must be enabled before the LPTMR is enabled.

NOTE

The clock source selected may need to be configured to remain enabled in low-power modes, otherwise the LPTMR will not operate during low-power modes.

In Pulse Counter mode with the prescaler/glitch filter bypassed, the selected input source directly clocks the CNR and no other clock source is required. To minimize power in this case, configure the prescaler clock source for a clock that is not toggling.

NOTE

The clock source or pulse input source selected for the LPTMR should not exceed the frequency f_{LPTMR} defined in the device datasheet.

37.5.3 LPTMR prescaler/glitch filter

The LPTMR prescaler and glitch filter share the same logic which operates as a prescaler in Time Counter mode and as a glitch filter in Pulse Counter mode.

NOTE

The prescaler/glitch filter configuration must not be altered when the LPTMR is enabled.

37.5.3.1 Prescaler enabled

In Time Counter mode, when the prescaler is enabled, the output of the prescaler directly clocks the CNR. When the LPTMR is enabled, the CNR will increment every 2^2 to 2^{16} prescaler clock cycles. After the LPTMR is enabled, the first increment of the CNR will take an additional one or two prescaler clock cycles due to synchronization logic.

37.5.3.2 Prescaler bypassed

In Time Counter mode, when the prescaler is bypassed, the selected prescaler clock increments the CNR on every clock cycle. When the LPTMR is enabled, the first increment will take an additional one or two prescaler clock cycles due to synchronization logic.

37.5.3.3 Glitch filter

In Pulse Counter mode, when the glitch filter is enabled, the output of the glitch filter directly clocks the CNR. When the LPTMR is first enabled, the output of the glitch filter is asserted, that is, logic 1 for active-high and logic 0 for active-low. The following table shows the change in glitch filter output with the selected input source.

If	Then
The selected input source remains deasserted for at least 2^1 to 2^{15} consecutive prescaler clock rising edges	The glitch filter output will also deassert.
The selected input source remains asserted for at least 2^1 to 2^{15} consecutive prescaler clock rising-edges	The glitch filter output will also assert.

NOTE

The input is only sampled on the rising clock edge.

The CNR will increment each time the glitch filter output asserts. In Pulse Counter mode, the maximum rate at which the CNR can increment is once every 2^2 to 2^{16} prescaler clock edges. When first enabled, the glitch filter will wait an additional one or two prescaler clock edges due to synchronization logic.

37.5.3.4 Glitch filter bypassed

In Pulse Counter mode, when the glitch filter is bypassed, the selected input source increments the CNR every time it asserts. Before the LPTMR is first enabled, the selected input source is forced to be asserted. This prevents the CNR from incrementing if the selected input source is already asserted when the LPTMR is first enabled.

37.5.4 LPTMR compare

When the CNR equals the value of the CMR and increments, the following events occur:

- CSR[TCF] is set.
- LPTMR interrupt is generated if CSR[TIE] is also set.
- LPTMR hardware trigger is generated.
- CNR is reset if CSR[TFC] is clear.

When the LPTMR is enabled, the CMR can be altered only when CSR[TCF] is set. When updating the CMR, the CMR must be written and CSR[TCF] must be cleared before the LPTMR counter has incremented past the new LPTMR compare value.

37.5.5 LPTMR counter

The CNR increments by one on every:

- Prescaler clock in Time Counter mode with prescaler bypassed
- Prescaler output in Time Counter mode with prescaler enabled
- Input source assertion in Pulse Counter mode with glitch filter bypassed
- Glitch filter output in Pulse Counter mode with glitch filter enabled

The CNR is reset when the LPTMR is disabled or if the counter register overflows. If CSR[TFC] is cleared, then the CNR is also reset whenever CSR[TCF] is set.

When the core is halted in Debug mode:

- If configured for Pulse Counter mode, the CNR continues incrementing.
- If configured for Time Counter mode, the CNR stops incrementing.

The CNR cannot be initialized, but can be read at any time. On each read of the CNR, software must first write to the CNR with any value. This will synchronize and register the current value of the CNR into a temporary register. The contents of the temporary register are returned on each read of the CNR.

When reading the CNR, the bus clock must be at least two times faster than the rate at which the LPTMR counter is incrementing, otherwise incorrect data may be returned.

37.5.6 LPTMR hardware trigger

The LPTMR hardware trigger asserts at the same time the CSR[TCF] is set and can be used to trigger hardware events in other peripherals without software intervention. The hardware trigger is always enabled.

When	Then
The CMR is set to 0 with CSR[TFC] clear	The LPTMR hardware trigger will assert on the first compare and does not deassert.
The CMR is set to a nonzero value, or, if CSR[TFC] is set	The LPTMR hardware trigger will assert on each compare and deassert on the following increment of the CNR.

37.5.7 LPTMR interrupt

The LPTMR interrupt is generated whenever CSR[TIE] and CSR[TCF] are set. CSR[TCF] is cleared by disabling the LPTMR or by writing a logic 1 to it.

CSR[TIE] can be altered and CSR[TCF] can be cleared while the LPTMR is enabled.

The LPTMR interrupt is generated asynchronously to the system clock and can be used to generate a wakeup from any low-power mode, provided the LPTMR is enabled as a wakeup source.

37.6 Usage Guide

LPTMR is very useful in low power situations. It can be used as a wake-up timer to wake the MCU out of sleep modes after a certain amount of time. If used as pulse counter mode with the glitch filter enabled, then there is no need for a clock to be on. The MCU can wakeup based on counting pulses.

37.6.1 Time Counter mode

The typical usage of LPTMR is as Time Counter mode to generate periodic trigger pulses and interrupts.

Example: LPTMR trigger a periodic interrupt every 1 second

- Enable the LPTMR module clock;
- Configure LPTMR to Timer counter mode by default, use LPO 128K as clock source, bypass the prescaler;
- Set the compare value register to 1 second value;
- Enable timer interrupt ;
- Starts the timer counting after all configuration;
- In the interrupt routine, clear the channel compare flag TCF every 1 second.

The following pseudo-code matches the described setup above:

```
CLOCK_EnableClock(LPTMR0);
LPTMR0_CSR = 0;
LPTMR0_PSR |= LPTMR_PSR_PBYP_MASK|LPTMR_PSR_PCS(1);
LPTMR0_CMR = ONE_SECOND_VALUE;
LPTMR0_CSR |= LPTMR_CSR_TIE_MASK;
EnableIRQ(LPTMR0_IRQn);
LPTMR0_CSR |= LPTMR_CSR_TEN_MASK;
```

37.6.2 Pulse Counter mode

LPTMR another option is used as Pulse Counter mode to count the input pulses.

Example: LPTMR count the input pulses on LPTMR0_ALT1 pin

- Enable the LPTMR module clock;

- Configure LPTMR to Pulse counter mode, use LPO 128K as clock source, bypass the glitch filter
- Set the compare value register to the value you want to compare the numbers of pulse
- Enable the pulse counter input enable on LPTMR0_ALT1
- Enable timer interrupt
- Starts the pulse counting after all configuration;
- In the interrupt routine, clear the channel compare flag TCF when the counter reaches the value in compare register;

The following pseudo-code matches the described setup above:

```
CLOCK_EnableClock(LPTMR0);
LPTMR0_CSR |= LPTMR_CSR_TPS(1)|LPTMR_CSR_TMS_MASK;
LPTMR0_PSR |= LPTMR_PSR_PBYP_MASK|LPTMR_PSR_PCS(1);
LPTMR0_CMR = PULSE_COMPARE_VALUE;
LPTMR0_CSR |= LPTMR_CSR_TIE_MASK;
EnableIRQ(LPTMR0_IRQn);
LPTMR0_CSR |= LPTMR_CSR_TEN_MASK;
```

Chapter 38
Real Time Clock (SRTC)

38.1 Chip-specific information for this module

38.1.1 RTC Instantiation

NOTE

RTC_CR[OSCE] bit is not applicable for this device, as no embeded 32 kHz crystal oscillator.

NOTE

The wakeup pin is not available for RTC on this device, therefore the related register bitfields are not applicable (e.g. RTC_CR[WPS], RTC_CR[WPE], and RTC_IER[WPON]).

NOTE

Also there is no integrated capacitor for this device, therefore no tunable capacitors (included in the crystal oscillator) can be configured by software.

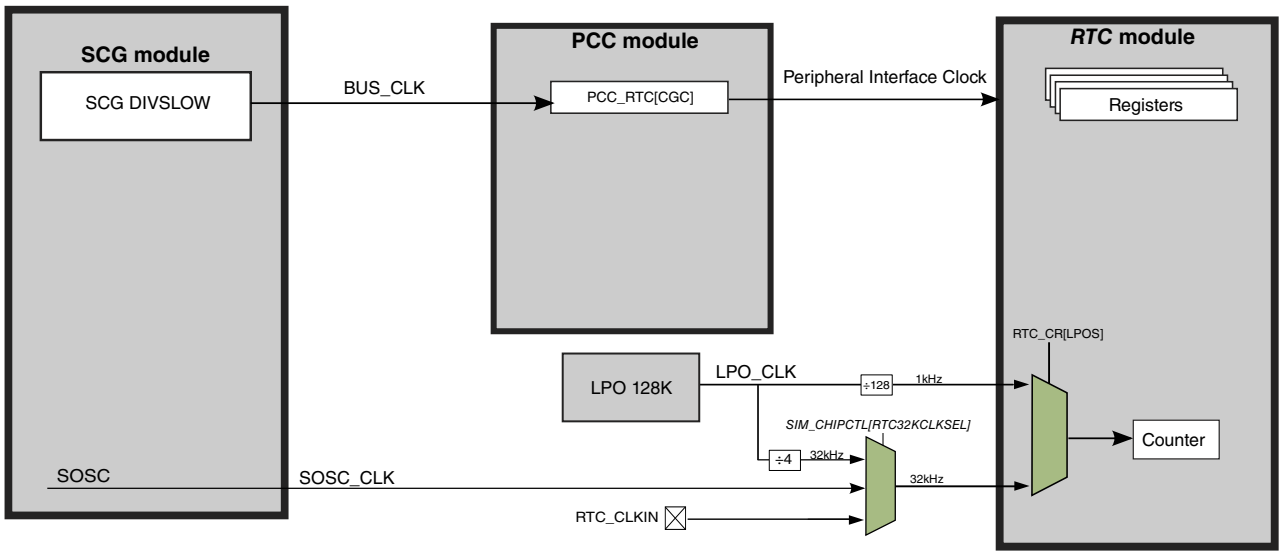
38.1.2 RTC Clocking Information

The following figure shows the input clock sources available for this module.

NOTE

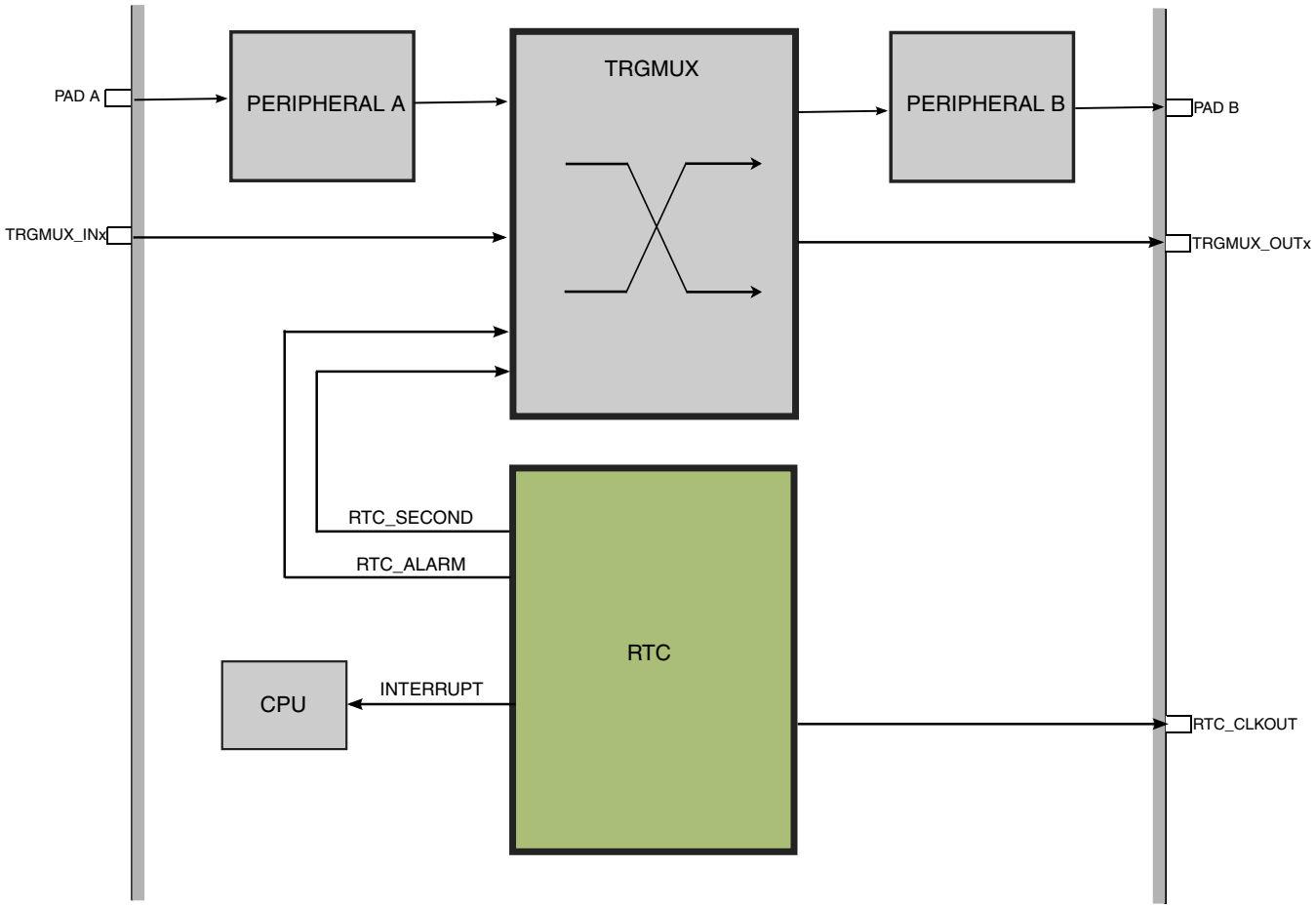
No 32 kHz crystal in this device. See the clocking figure below, for more details about RTC clock source.

Peripheral Clocking - RTC



38.1.3 Inter-connectivity Information

The SRTC inter-connectivity is shown in following diagram..



38.2 Introduction

38.2.1 Features

The RTC module features include:

- 32-bit seconds counter with roll-over protection and 32-bit alarm
- 16-bit prescaler with compensation that can correct errors between 0.12 ppm and 3906 ppm
- Option to increment prescaler using the LPO (prescaler increments by 32 every clock edge)
- Register write protection

- Lock register requires POR or software reset to enable write access
- Access control registers require system reset to enable read and/or write access

- Configurable 1, 2, 4, 8, 16, 32, 64 or 128 Hz square wave output with optional interrupt

38.2.2 Modes of operation

The RTC remains functional in all low power modes and can generate an interrupt to exit any low power mode.

38.2.3 RTC signal descriptions

Table 38-1. RTC signal descriptions

Signal	Description	I/O
RTC_CLKOUT	Prescaler square-wave output or 32kHz crystal clock	O

38.2.3.1 RTC clock output

The RTC_CLKOUT signal can output either a square wave prescaler output (configurable to 1, 2, 4, 8, 16, 32, 64 or 128 Hz) or the 32 kHz crystal clock.

38.3 Register definition

All registers must be accessed using 32-bit writes and all register accesses incur three wait states.

Write accesses to any register by non-supervisor mode software, when the supervisor access bit in the control register is clear, will terminate with a bus error.

Read accesses by non-supervisor mode software complete as normal.

Writing to a register protected by the write access register or lock register does not generate a bus error, but the write will not complete.

Reading a register protected by the read access register does not generate a bus error, but the register will read zero.

RTC memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4003_D000	RTC Time Seconds Register (RTC_TSR)	32	R/W	0000_0000h	38.3.1/815
4003_D004	RTC Time Prescaler Register (RTC_TPR)	32	R/W	0000_0000h	38.3.2/815
4003_D008	RTC Time Alarm Register (RTC_TAR)	32	R/W	0000_0000h	38.3.3/816
4003_D00C	RTC Time Compensation Register (RTC_TCR)	32	R/W	0000_0000h	38.3.4/816
4003_D010	RTC Control Register (RTC_CR)	32	R/W	0000_0000h	38.3.5/818
4003_D014	RTC Status Register (RTC_SR)	32	R/W	0000_0001h	38.3.6/820
4003_D018	RTC Lock Register (RTC_LR)	32	R/W	0000_00FFh	38.3.7/821
4003_D01C	RTC Interrupt Enable Register (RTC_IER)	32	R/W	0000_0007h	38.3.8/822
4003_D800	RTC Write Access Register (RTC_WAR)	32	R/W	0000_00FFh	38.3.9/824
4003_D804	RTC Read Access Register (RTC_RAR)	32	R/W	0000_00FFh	38.3.10/825

38.3.1 RTC Time Seconds Register (RTC_TSR)

Address: 4003_D000h base + 0h offset = 4003_D000h

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

RTC_TSR field descriptions

Field	Description
TSR	Time Seconds Register When the time counter is enabled, the TSR is read only and increments once a second provided SR[TOF] or SR[TIF] are not set. The time counter will read as zero when SR[TOF] or SR[TIF] are set. When the time counter is disabled, the TSR can be read or written. Writing to the TSR when the time counter is disabled will clear the SR[TOF] and/or the SR[TIF]. Writing to TSR with zero is supported, but not recommended because TSR will read as zero when SR[TIF] or SR[TOF] are set (indicating the time is invalid).

38.3.2 RTC Time Prescaler Register (RTC_TPR)

Address: 4003_D000h base + 4h offset = 4003_D004h

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

RTC_TPR field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TPR	Time Prescaler Register When the time counter is enabled, the TPR is read only and increments every 32.768 kHz clock cycle. The time counter will read as zero when SR[TOF] or SR[TIF] are set. When the time counter is disabled, the TPR can be read or written. The TSR[TSR] increments when bit 14 of the TPR transitions from a logic one to a logic zero.

38.3.3 RTC Time Alarm Register (RTC_TAR)

Address: 4003_D000h base + 8h offset = 4003_D008h

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

RTC_TAR field descriptions

Field	Description
TAR	Time Alarm Register When the time counter is enabled, the SR[TAF] is set whenever the TAR[TAR] equals the TSR[TSR] and the TSR[TSR] increments. Writing to the TAR clears the SR[TAF].

38.3.4 RTC Time Compensation Register (RTC_TCR)

Address: 4003_D000h base + Ch offset = 4003_D00Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	CIC								TCV								CIR								TCR							
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RTC_TCR field descriptions

Field	Description
31–24 CIC	Compensation Interval Counter Current value of the compensation interval counter. If the compensation interval counter equals zero then it is loaded with the contents of the CIR. If the CIC does not equal zero then it is decremented once a second.
23–16 TCV	Time Compensation Value

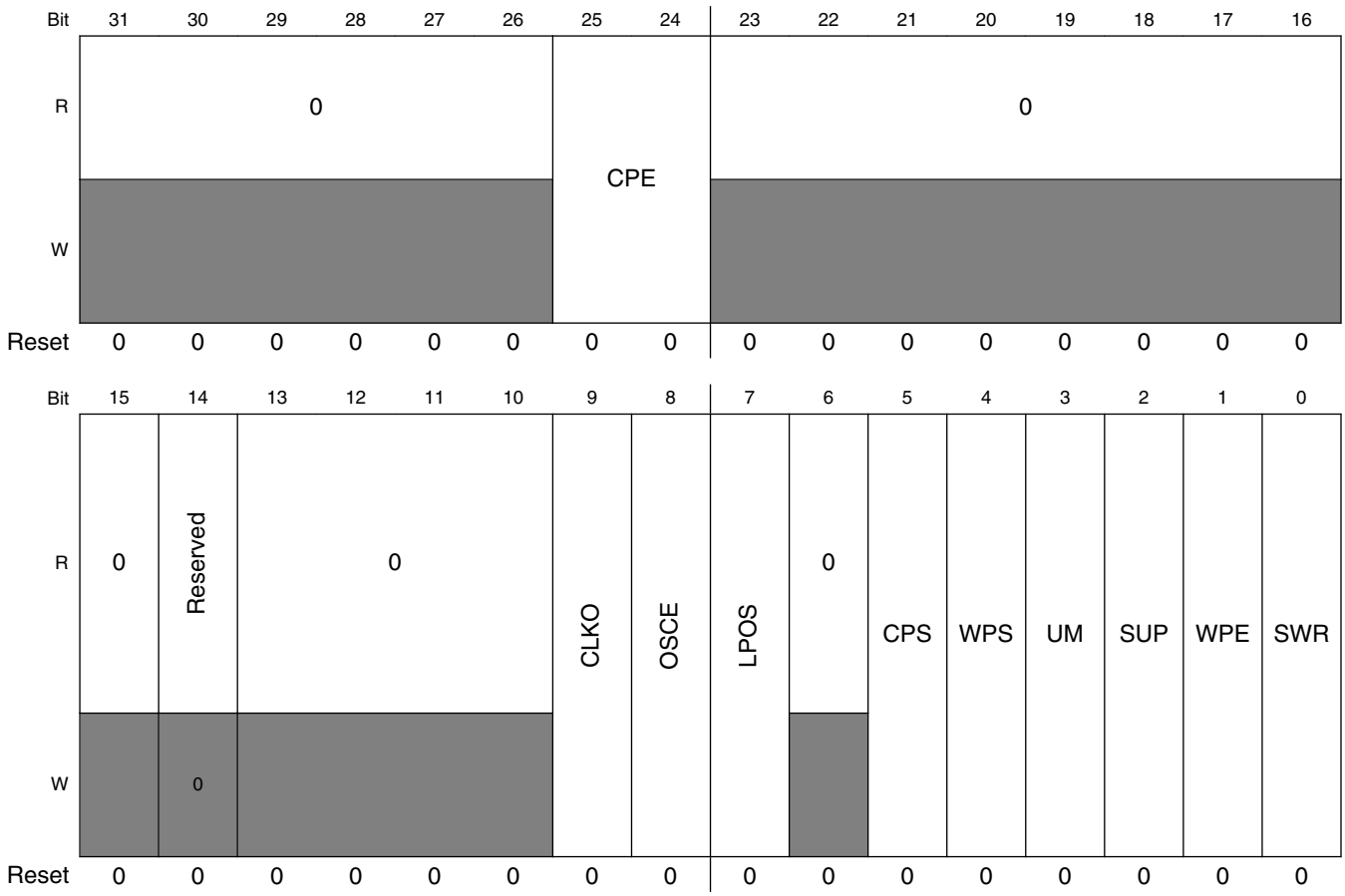
Table continues on the next page...

RTC_TCR field descriptions (continued)

Field	Description
	Current value used by the compensation logic for the present second interval. Updated once a second if the CIC equals 0 with the contents of the TCR field. If the CIC does not equal zero then it is loaded with zero (compensation is not enabled for that second increment).
15–8 CIR	Compensation Interval Register Configures the compensation interval in seconds from 1 to 256 to control how frequently the TCR should adjust the number of 32.768 kHz cycles in each second. The value written should be one less than the number of seconds. For example, write zero to configure for a compensation interval of one second. This register is double buffered and writes do not take affect until the end of the current compensation interval.
TCR	Time Compensation Register Configures the number of 32.768 kHz clock cycles in each second. This register is double buffered and writes do not take affect until the end of the current compensation interval. 80h Time Prescaler Register overflows every 32896 clock cycles. ... ... FFh Time Prescaler Register overflows every 32769 clock cycles. 00h Time Prescaler Register overflows every 32768 clock cycles. 01h Time Prescaler Register overflows every 32767 clock cycles. .... 7Fh Time Prescaler Register overflows every 32641 clock cycles.

38.3.5 RTC Control Register (RTC_CR)

Address: 4003_D000h base + 10h offset = 4003_D010h



RTC_CR field descriptions

Field	Description
31–26 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
25–24 CPE	Clock Pin Enable **NOTE:** The CPE field should be configured to 01 or 11 (i.e. CPE[0] = 1), if we want the RTC_CLKOUT signal as output. 00 RTC_CLKOUT is disabled. 01 RTC_CLKOUT is enabled. 10 Reserved. 11 Reserved.
23–15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 Reserved	This field is reserved. It must always be written to 0.

Table continues on the next page...

RTC_CR field descriptions (continued)

Field	Description
13–10 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
9 CLKO	Clock Output 0 The 32 kHz clock is allowed to output on RTC_CLKOUT. 1 The 32 kHz clock is not allowed to output on RTC_CLKOUT.
8 OSCE	Oscillator Enable 0 32.768 kHz oscillator is disabled. 1 32.768 kHz oscillator is enabled. After setting this bit, wait the oscillator startup time before enabling the time counter to allow the 32.768 kHz clock time to stabilize.
7 LPOS	LPO Select When set, the RTC prescaler increments using the LPO clock and not the RTC 32 kHz clock. The LPO increments the prescaler from bit TPR[5] (TPR[4:0] are ignored), supporting close to 1 second increment of the seconds register. Although compensation is supported when clocked from the LPO, TCR[4:0] of the compensation register are also ignored and only TCR[7:5] set the compensation value (can overflow after 1020 to 1027 cycles). 0 RTC prescaler increments using 32 kHz clock. 1 RTC prescaler increments using LPO, bits [4:0] of the prescaler are bypassed.
6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
5 CPS	Clock Pin Select 0 The prescaler output clock (as configured by TSIC) is output on RTC_CLKOUT. 1 The RTC 32kHz clock is output on RTC_CLKOUT.
4 WPS	Wakeup Pin Select The wakeup pin is optional and not available on all devices. 0 Wakeup pin asserts (active low, open drain) if the RTC interrupt asserts or the wakeup pin is turned on. 1 Wakeup pin instead outputs the RTC 32kHz clock, provided the wakeup pin is turned on and the 32kHz clock is output to other peripherals.
3 UM	Update Mode Allows SR[TCE] to be written even when the Status Register is locked. When set, the SR[TCE] can always be written if the SR[TIF] or SR[TOF] are set or if the SR[TCE] is clear. 0 Registers cannot be written when locked. 1 Registers can be written when locked under limited conditions.
2 SUP	Supervisor Access 0 Non-supervisor mode write accesses are not supported and generate a bus error. 1 Non-supervisor mode write accesses are supported.
1 WPE	Wakeup Pin Enable The wakeup pin is optional and not available on all devices.

Table continues on the next page...

RTC_CR field descriptions (continued)

Field	Description
	0 Wakeup pin is disabled. 1 Wakeup pin is enabled and wakeup pin asserts if the RTC interrupt asserts or the wakeup pin is turned on.
0 SWR	Software Reset 0 No effect. 1 Resets all RTC registers except for the SWR bit and the RTC_WAR and RTC_RAR registers . The SWR bit is cleared by POR and by software explicitly clearing it.

38.3.6 RTC Status Register (RTC_SR)

Address: 4003_D000h base + 14h offset = 4003_D014h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0											TCE	0	TAF	TOF	TIF
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

RTC_SR field descriptions

Field	Description
31–5 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
4 TCE	Time Counter Enable When time counter is disabled the TSR register and TPR register are writeable, but do not increment. When time counter is enabled the TSR register and TPR register are not writeable, but increment. 0 Time counter is disabled. 1 Time counter is enabled.
3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 TAF	Time Alarm Flag Time alarm flag is set when the TAR[TAR] equals the TSR[TSR] and the TSR[TSR] increments. This bit is cleared by writing the TAR register. 0 Time alarm has not occurred. 1 Time alarm has occurred.
1 TOF	Time Overflow Flag

Table continues on the next page...

RTC_SR field descriptions (continued)

Field	Description
	Time overflow flag is set when the time counter is enabled and overflows. The TSR and TPR do not increment and read as zero when this bit is set. This bit is cleared by writing the TSR register when the time counter is disabled. 0 Time overflow has not occurred. 1 Time overflow has occurred and time counter is read as zero.
0 TIF	Time Invalid Flag The time invalid flag is set on POR or software reset. The TSR and TPR do not increment and read as zero when this bit is set. This bit is cleared by writing the TSR register when the time counter is disabled. 0 Time is valid. 1 Time is invalid and time counter is read as zero.

38.3.7 RTC Lock Register (RTC_LR)

Address: 4003_D000h base + 18h offset = 4003_D018h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								1	LRL	SRL	CRL	TCL	1		
W																
Reset	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

RTC_LR field descriptions

Field	Description
31–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 Reserved	This field is reserved. This read-only field is reserved and always has the value 1.
6 LRL	Lock Register Lock After being cleared, this bit can be set only by POR or software reset. 0 Lock Register is locked and writes are ignored. 1 Lock Register is not locked and writes complete as normal.
5 SRL	Status Register Lock After being cleared, this bit can be set only by POR or software reset. 0 Status Register is locked and writes are ignored. 1 Status Register is not locked and writes complete as normal.
4 CRL	Control Register Lock

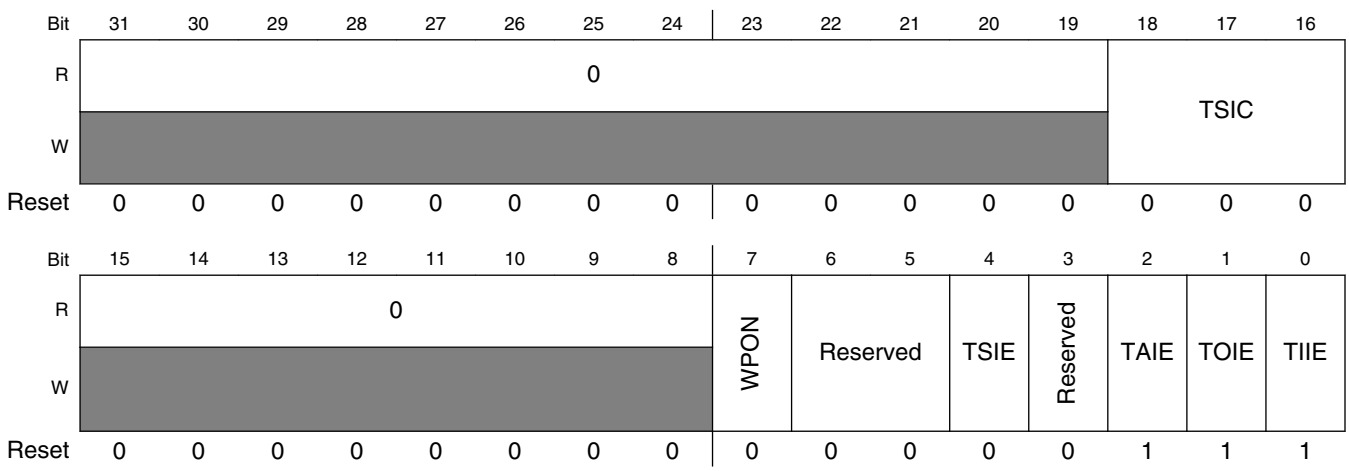
Table continues on the next page...

RTC_LR field descriptions (continued)

Field	Description
	After being cleared, this bit can only be set by POR. 0 Control Register is locked and writes are ignored. 1 Control Register is not locked and writes complete as normal.
3 TCL	Time Compensation Lock After being cleared, this bit can be set only by POR or software reset. 0 Time Compensation Register is locked and writes are ignored. 1 Time Compensation Register is not locked and writes complete as normal.
Reserved	This field is reserved. This read-only field is reserved and always has the value 1.

38.3.8 RTC Interrupt Enable Register (RTC_IER)

Address: 4003_D000h base + 1Ch offset = 4003_D01Ch



RTC_IER field descriptions

Field	Description
31–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
18–16 TSIC	Timer Seconds Interrupt Configuration Configures the frequency of the RTC Seconds interrupt and the RTC_CLKOUT prescaler output. This field should only be altered when TSIE is clear. 000 1 Hz. 001 2 Hz. 010 4 Hz. 011 8 Hz. 100 16 Hz. 101 32 Hz.

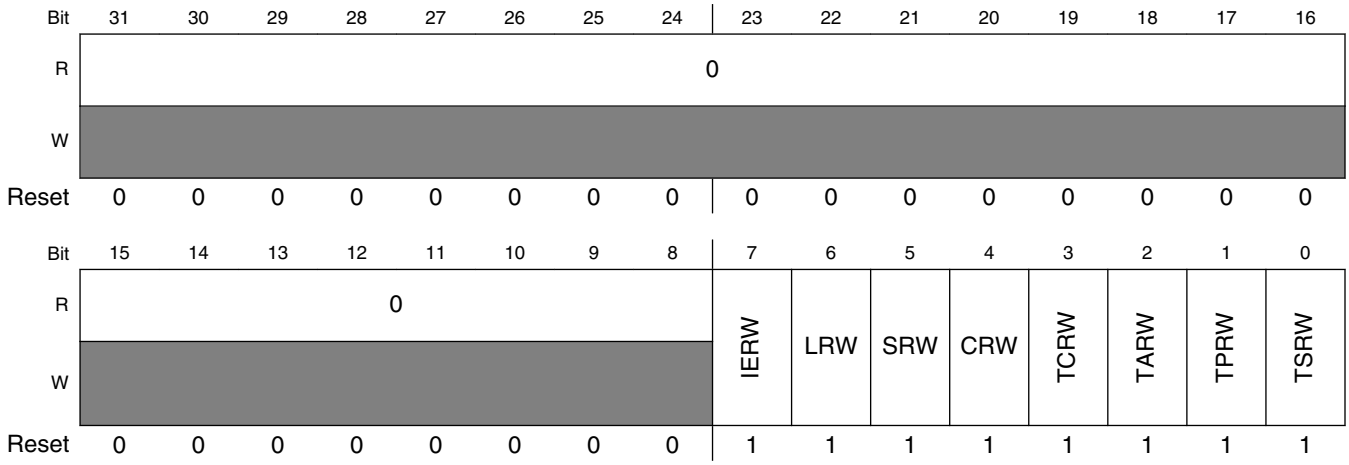
Table continues on the next page...

RTC_IER field descriptions (continued)

Field	Description
	110 64 Hz. 111 128 Hz.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 WPON	Wakeup Pin On The wakeup pin is optional and not available on all devices. Whenever the wakeup pin is enabled and this bit is set, the wakeup pin will assert. 0 No effect. 1 If the wakeup pin is enabled, then the wakeup pin will assert.
6–5 Reserved	This field is reserved.
4 TSIE	Time Seconds Interrupt Enable The seconds interrupt is an edge-sensitive interrupt with a dedicated interrupt vector. It is generated once a second and requires no software overhead (there is no corresponding status flag to clear). 0 Seconds interrupt is disabled. 1 Seconds interrupt is enabled.
3 Reserved	This field is reserved.
2 TAIE	Time Alarm Interrupt Enable 0 Time alarm flag does not generate an interrupt. 1 Time alarm flag does generate an interrupt.
1 TOIE	Time Overflow Interrupt Enable 0 Time overflow flag does not generate an interrupt. 1 Time overflow flag does generate an interrupt.
0 TIIE	Time Invalid Interrupt Enable 0 Time invalid flag does not generate an interrupt. 1 Time invalid flag does generate an interrupt.

38.3.9 RTC Write Access Register (RTC_WAR)

Address: 4003_D000h base + 800h offset = 4003_D800h



RTC_WAR field descriptions

Field	Description
31–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 IERW	Interrupt Enable Register Write After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Writes to the Interupt Enable Register are ignored. 1 Writes to the Interrupt Enable Register complete as normal.
6 LRW	Lock Register Write After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Writes to the Lock Register are ignored. 1 Writes to the Lock Register complete as normal.
5 SRW	Status Register Write After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Writes to the Status Register are ignored. 1 Writes to the Status Register complete as normal.
4 CRW	Control Register Write After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Writes to the Control Register are ignored. 1 Writes to the Control Register complete as normal.
3 TCRW	Time Compensation Register Write After being cleared, this bit is set only by system reset. It is not affected by software reset.

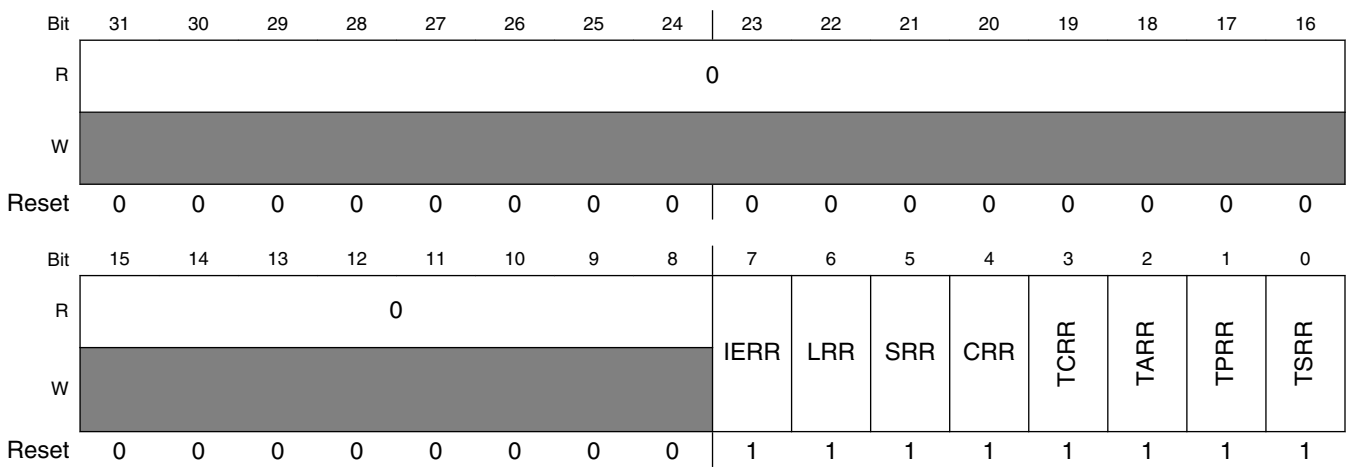
Table continues on the next page...

RTC_WAR field descriptions (continued)

Field	Description
	0 Writes to the Time Compensation Register are ignored. 1 Writes to the Time Compensation Register complete as normal.
2 TARW	Time Alarm Register Write After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Writes to the Time Alarm Register are ignored. 1 Writes to the Time Alarm Register complete as normal.
1 TPRW	Time Prescaler Register Write After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Writes to the Time Prescaler Register are ignored. 1 Writes to the Time Prescaler Register complete as normal.
0 TSRW	Time Seconds Register Write After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Writes to the Time Seconds Register are ignored. 1 Writes to the Time Seconds Register complete as normal.

38.3.10 RTC Read Access Register (RTC_RAR)

Address: 4003_D000h base + 804h offset = 4003_D804h



RTC_RAR field descriptions

Field	Description
31–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 IERR	Interrupt Enable Register Read After being cleared, this bit is set only by system reset. It is not affected by software reset.

Table continues on the next page...

RTC_RAR field descriptions (continued)

Field	Description
	0 Reads to the Interrupt Enable Register are ignored. 1 Reads to the Interrupt Enable Register complete as normal.
6 LRR	Lock Register Read After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Reads to the Lock Register are ignored. 1 Reads to the Lock Register complete as normal.
5 SRR	Status Register Read After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Reads to the Status Register are ignored. 1 Reads to the Status Register complete as normal.
4 CRR	Control Register Read After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Reads to the Control Register are ignored. 1 Reads to the Control Register complete as normal.
3 TCRR	Time Compensation Register Read After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Reads to the Time Compensation Register are ignored. 1 Reads to the Time Compensation Register complete as normal.
2 TARR	Time Alarm Register Read After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Reads to the Time Alarm Register are ignored. 1 Reads to the Time Alarm Register complete as normal.
1 TPRR	Time Prescaler Register Read After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Reads to the Time Pprescaler Register are ignored. 1 Reads to the Time Prescaler Register complete as normal.
0 TSRR	Time Seconds Register Read After being cleared, this bit is set only by system reset. It is not affected by software reset. 0 Reads to the Time Seconds Register are ignored. 1 Reads to the Time Seconds Register complete as normal.

38.4 Functional description

38.4.1 Power, clocking, and reset

The RTC is an always powered block that remains active in all low power modes.

The time counter within the RTC is clocked by a 32.768 kHz clock sourced from an external crystal using the oscillator. Alternatively, the time counter can be clocked by the LPO and the prescaler will increment by 32 for each LPO clock.

The power-on-reset signal initializes all RTC registers to their default state. A software reset bit can also initialize all RTC registers.

38.4.1.1 Oscillator control

The 32.768 kHz crystal oscillator is disabled at POR and must be enabled by software. After enabling the cystal oscillator, wait the oscillator startup time before setting SR[TCE] or using the oscillator clock external to the RTC.

38.4.1.2 Software reset

Writing 1 to CR[SWR] forces the equivalent of a POR to the rest of the RTC module. CR[SWR] is not affected by the software reset and must be cleared by software. The access control registers are not affected by either VBAT POR or the software reset; they are reset by the chip reset.

38.4.1.3 Supervisor access

When the supervisor access control bit is clear, only supervisor mode software can write to the RTC registers, non-supervisor mode software will generate a bus error. Both supervisor and non-supervisor mode software can always read the RTC registers.

38.4.2 Time counter

The time counter consists of a 32-bit seconds counter that increments once every second and a 16-bit prescaler register that increments once every 32.768 kHz clock cycle. There is also the option to clock the prescaler using a 1 kHz LPO that increments the prescaler by 32 on every clock cycle.

Reading the time counter (either seconds or prescaler) while it is incrementing may return invalid data due to synchronization of the read data bus. If it is necessary for software to read the prescaler or seconds counter when they could be incrementing, it is recommended that two read accesses are performed and that software verifies that the same data was returned for both reads.

The time seconds register and time prescaler register can be written only when SR[TCE] is clear. Always write to the prescaler register before writing to the seconds register, because the seconds register increments on the falling edge of bit 14 of the prescaler register.

The time prescaler register increments provided SR[TCE] is set, SR[TIF] is clear, SR[TOF] is clear, and the 32.768 kHz (or 1 kHz) clock source is present. After enabling the oscillator, wait the oscillator startup time before setting SR[TCE] to allow time for the oscillator clock output to stabilize.

If the time seconds register overflows then the SR[TOF] will set and the time prescaler register will stop incrementing. Clear SR[TOF] by initializing the time seconds register. The time seconds register and time prescaler register read as zero whenever SR[TOF] is set.

SR[TIF] is set on POR and software reset and is cleared by initializing the time seconds register. The time seconds register and time prescaler register read as zero whenever SR[TIF] is set.

38.4.3 Compensation

The compensation logic provides an accurate and wide compensation range and can correct errors as high as 3906 ppm and as low as 0.12 ppm. The compensation factor must be calculated externally to the RTC and supplied by software to the compensation register. The RTC itself does not calculate the amount of compensation that is required, although the 1 Hz clock is output to an external pin in support of external calibration logic.

Crystal compensation can be supported by using firmware and crystal characteristics to determine the compensation amount. Temperature compensation can be supported by firmware that periodically measures the external temperature via ADC and updates the compensation register based on a look-up table that specifies the change in crystal frequency over temperature.

The compensation logic alters the number of 32.768 kHz clock cycles it takes for the prescaler register to overflow and increment the time seconds counter. The time compensation value is used to adjust the number of clock cycles between -127 and +128.

Cycles are added or subtracted from the prescaler register when the prescaler register equals 0x3FFF and then increments. The compensation interval is used to adjust the frequency at which the time compensation value is used, that is, from once a second to once every 256 seconds.

Updates to the time compensation register will not take effect until the next time the time seconds register increments and provided the previous compensation interval has expired. When the compensation interval is set to other than once a second then the compensation is applied in the first second interval and the remaining second intervals receive no compensation.

Compensation is disabled by configuring the time compensation register to zero.

When the prescaler is configured to increment using the 1 kHz LPO, the effective compensation value is divided by 32 and can only adjust the number of clock cycles between -4 and +3.

38.4.4 Time alarm

The Time Alarm register (TAR), SR[TAF], and IER[TAIE] allow the RTC to generate an interrupt at a predefined time. The 32-bit TAR is compared with the 32-bit Time Seconds register (TSR) each time it increments. SR[TAF] will set when TAR equals TSR and TSR increments.

SR[TAF] is cleared by writing TAR. This will usually be the next alarm value, although writing a value that is less than TSR, such as 0, will prevent SR[TAF] from setting again. SR[TAF] cannot otherwise be disabled, although the interrupt it generates is enabled or disabled by IER[TAIE].

38.4.5 Update mode

The Update Mode field in the Control register (CR[UM]) configures software write access to the Time Counter Enable (SR[TCE]) field. When CR[UM] is clear, SR[TCE] can be written only when LR[SRL] is set. When CR[UM] is set, SR[TCE] can also be written when SR[TCE] is clear or when SR[TIF] or SR[TOF] are set. This allows the time seconds and prescaler registers to be initialized whenever time is invalidated, while preventing the time seconds and prescaler registers from being changed on the fly. When LR[SRL] is set, CR[UM] has no effect on SR[TCE].

38.4.6 Register lock

The Lock register (LR) can be used to block write accesses to certain registers until the next POR or software reset. Locking the Control register (CR) will disable the software reset. Locking LR will block future updates to LR.

Write accesses to a locked register are ignored and do not generate a bus error.

38.4.7 Access control

The read access and write access registers are implemented in the chip power domain and reset on the chip reset. They are not affected by the POR or the software reset. They are used to block read or write accesses to each register until the next chip system reset.

38.4.8 Interrupt

The RTC interrupt is asserted whenever a status flag and the corresponding interrupt enable bit are both set. It is always asserted on POR, and software reset. The RTC interrupt is enabled at the chip level by enabling the chip-specific RTC clock gate control bit. The RTC interrupt can be used to wakeup the chip from any low-power mode.

The optional RTC seconds interrupt is an edge-sensitive interrupt with a dedicated interrupt vector that is generated once a second and requires no software overhead (there is no corresponding status flag to clear). It is enabled in the RTC by the time seconds interrupt enable bit and enabled at the chip level by setting the chip-specific RTC clock gate control bit. The frequency of the seconds interrupt defaults to 1 Hz, but can instead be configured to trigger every 2, 4, 8, 16, 32, 64 or 128 Hz. This interrupt is optional and may not be implemented on all devices.

38.5 Usage Guide

38.5.1 Clock source information

To get an accuracy clock for RTC, an external 32.768 kHz crystal should be connected to EXTAL32/XTAL32 pin, or a 32.768 kHz clock signal to RTC_CLKIN pin.
Alternatively, the time counter can be clocked by the LPO 1 kHz and the prescaler will increment by 32 for each LPO clock, which is not that precisely.

38.5.2 Usage examples

This section shows the application examples of initializing the RTC module, setting the data time and alarm.

RTC Module Initialization

The RTC module is reset by a POR or a software reset (The access control registers are not affected by either VBAT POR or the software reset).

Before using the RTC module, a software reset is recommend by setting the RTC_CR[SWR] bit. And the 32.768 kHz external crystal should be enabled to provide clock to RTC.

```
// Reset the RTC by set RTC_CR[SWR] bit, and wait
// for the TIF flag cleared by writing the TSR
while (RTC_SR & RTC_SR_TIF_MASK)
{
    RTC_CR |= RTC_CR_SWR_MASK;
    RTC_CR &= ~RTC_CR_SWR_MASK;
    RTC_TSR = 1;
}

// Setup the update mode and supervisor access mode
// enable 32.768 kHz oscillator timer
RTC_CR = RTC_CR_CPE(0) | RTC_CR_LPOS(0) | RTC_CR_CPS(1) |
         RTC_CR_UM(0) | RTC_CR_SUP(0)| RTC_CR_OSCE(1);
// disable all the interrupts first
RTC_IER = 0;
// stop timer first
RTC_SR &= ~RTC_SR_TCE_MASK;
```

Set Date Time

After RTC initialized, user can set the date time before starting the timer. Please make sure the timer is stopped when setting the date time by RTC_TSR register.

```
// stop timer first
RTC_SR &= ~RTC_SR_TCE_MASK;
// convert the date time to secs first, then write to RTC_TSR register
RTC_TSR = datetime_in_secs;
// start the timer
RTC_SR |= RTC_SR_TCE_MASK;
```

Set Alarm

To set an alarm and trigger alarm interrupt, user should enable the alarm interrupt, write the alarm seconds into RTC_TAR.

```
uint32_t datetime_in_secs;

// assume the timer is running
// enable the interrupt
RTC_IER |= RTC_IER_TAIE_MASK;
// enable the RTC IRQ in NVIC
NVIC_EnableIRQ(RTC_IRQn);

// get the current date time in secs
datetime_in_secs = RTC_TSR;
```

```
datatime_in_secs += 10;
// set alarm 10s later
RTC_TAR = datetime_in_secs;
```

After 10 seconds, the RTC Alarm IRQ would be triggered and IRQ Handler called. In the IRQ Handler, user should first clear the interrupt status:

```
if (RTC_SR & RTC_SR_TAF_MASK)
{
    // clear the TAF flag by writing the RTC_TAR register
    RTC_TAR = 0;
}
// Then doing the alarm task in this IRQ Handler
……
```

38.5.3 RTC_CLKOUT signal

When the RTC is enabled and the port control module selects the RTC_CLKOUT function, the RTC_CLKOUT signal output either a square wave prescaler output (configurable to 1, 2, 4, 8, 16, 32, 64 or 128 Hz) or 32 kHz output derived from RTC oscillator as shown below.

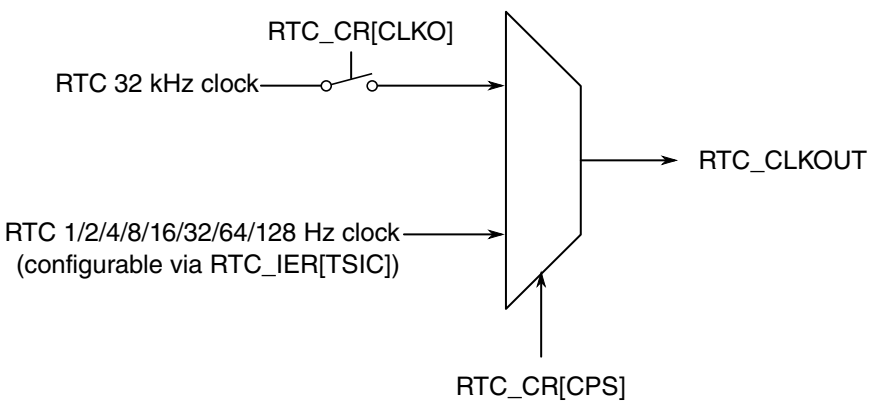


Figure 38-1. RTC_CLKOUT generation

NOTE

When using LPO 1kHz as RTC clock source, it cannot directly output to pad. But RTC can normally output 1/2/4/8/…/64/128 Hz clock using prescaler.

Chapter 39
Low Power Serial Peripheral Interface (LPSPI)

39.1 Chip-specific information for this module

39.1.1 Instantiation Information

NOTE

DMA is not supported in this device.

This device contains one LPSPI module. The LPSPI can remain functional in Stop and VLPS mode provided the clock it is using remains enabled.

Table 39-1. LPSPI Configuration

	TX FIFO (word/32bit)	RX FIFO (word/32bit)	Chip Selects
LPSPI0	4	4	4

NOTE

The TX/RX FIFO "word" does not refer to system bus width 32-bit, and it varies for different communication module. For example:

- LPSPI: 32-bit
- LPI2C: 8-bit (except CMD)
- LPUART: 10-bit

NOTE

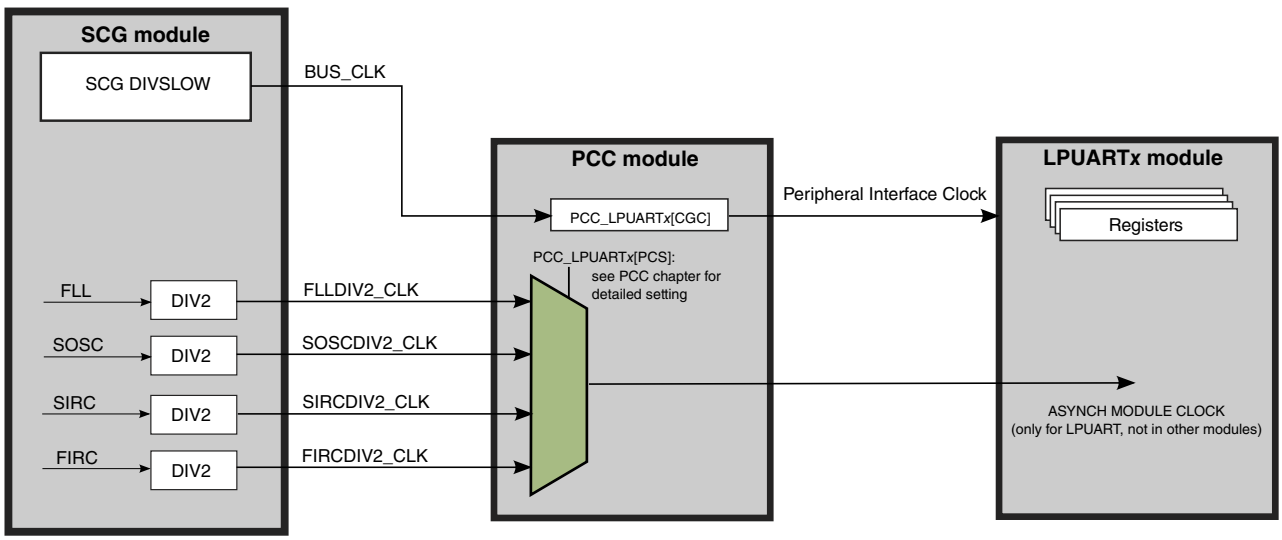
The exact number of chip select for each module is depending on the package, not all of the chip selects are available on different packages.

39.1.2 Module Clocking Information for LPUART, LPSPI, LPI2C and LPIT

The following figure shows the input clock sources available for this module.

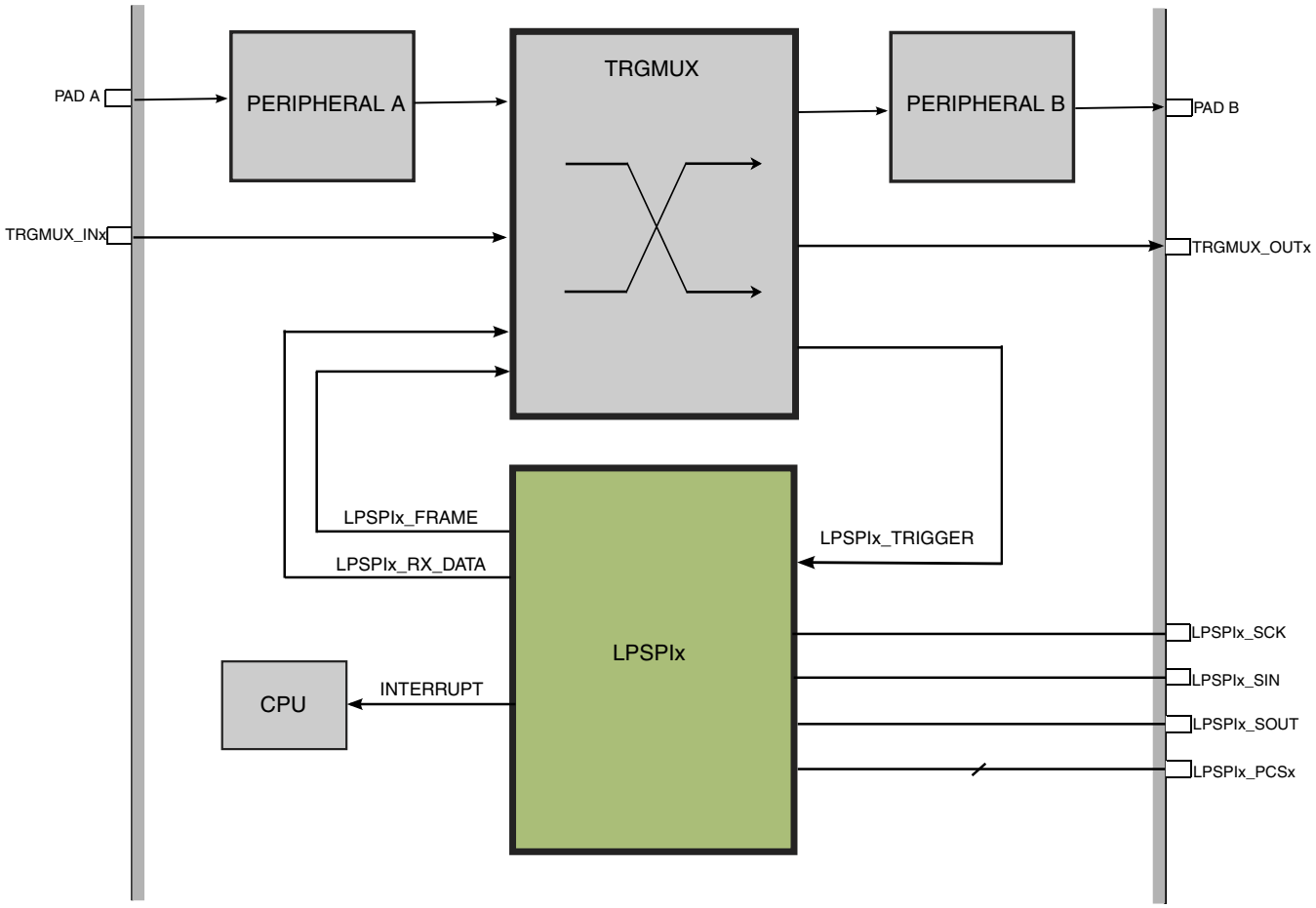
Peripheral Clocking - LPUART, etc.

Note: this example figure also applies similarly to the clocking for LPSPI, LPI2C, LPIT, etc.



39.1.3 Inter-connectivity Information

The LPSPI inter-connectivity is shown in following diagram.



39.2 Introduction

39.2.1 Overview

The LPSPI is a low power Serial Peripheral Interface (SPI) module that supports an efficient interface to an SPI bus as a master and/or a slave. The LPSPI can continue operating in stop modes provided an appropriate clock is available and is designed for low CPU overhead with DMA offloading of FIFO register accesses.

39.2.2 Features

The LPSPI supports the following features:

- Word size = 32 bits
- Command/transmit FIFO of 4 words.
- Receive FIFO of 4 words.
- Host request input can be used to control the start time of an SPI bus transfer.

39.2.3 Block Diagram

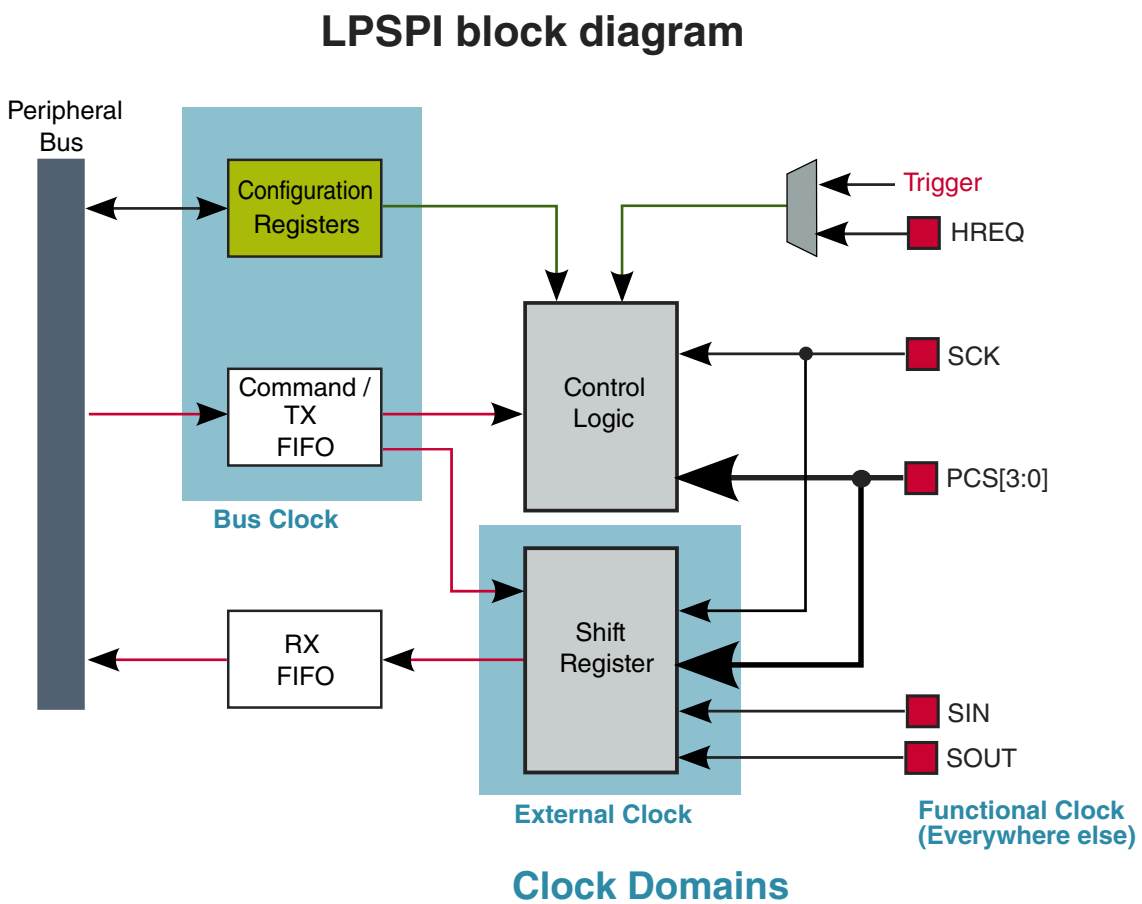


Figure 39-1. Block Diagram

39.2.4 Modes of operation

The LPSPI module supports the chip modes described in the following table.

Table 39-2. Chip modes supported by the LPSPI module

Chip mode	LPSPI Operation
Run	Normal operation

Table continues on the next page...

Table 39-2. Chip modes supported by the LPSPI module (continued)

Chip mode	LPSPI Operation
Stop/Wait	Can continue operating if the Doze Enable bit (CR[DOZEN]) is set and the LPSPI is using an external or internal clock source, which remains operating during stop/ wait modes.
Debug	Can continue operating if the Debug Enable bit (CR[DBGEN]) is set.

39.2.5 Signal Descriptions

Signal	Description	I/O
SCK	Serial clock. Input in slave mode, output in master mode.	I/O
PCS[0]	Peripheral Chip Select. Input in slave mode, output in master mode.	I/O
PCS[1] / HREQ	Peripheral Chip Select or Host Request. Host Request pin is selected when HREN=1 and HRSEL=0. Input in either slave mode or when used as Host Request, output in master mode.	I/O
PCS[2] / DATA[2]	Peripheral Chip Select or data pin 2 during quad-data transfers. Input in slave mode, output in master mode, input in quad-data receive transfers, output in quad-data transmit transfers.	I/O
PCS[3] / DATA[3]	Peripheral Chip Select or data pin 3 during quad-data transfers. Input in slave mode, output in master mode, input in quad-data receive transfers, output in quad-data transmit transfers.	I/O
SOUT / DATA[0]	Serial Data Output. Can be configured as serial data input signal. Used as data pin 0 in quad-data and dual-data transfers.	I/O
SIN / DATA[1]	Serial Data Input. Can be configured as serial data output signal. Used as data pin 1 in quad-data and dual-data transfers.	I/O

39.3 Memory Map and Registers

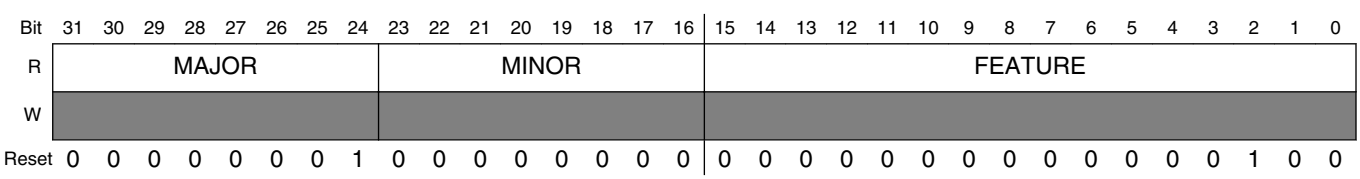
LPSPI memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4002_C000	Version ID Register (LPSPI0_VERID)	32	R	0100_0004h	39.3.1/838
4002_C004	Parameter Register (LPSPI0_PARAM)	32	R	See section	39.3.2/839
4002_C010	Control Register (LPSPI0_CR)	32	R/W	0000_0000h	39.3.3/840
4002_C014	Status Register (LPSPI0_SR)	32	R/W	0000_0001h	39.3.4/841
4002_C018	Interrupt Enable Register (LPSPI0_IER)	32	R/W	0000_0000h	39.3.5/843
4002_C01C	DMA Enable Register (LPSPI0_DER)	32	R/W	0000_0000h	39.3.6/844
4002_C020	Configuration Register 0 (LPSPI0_CFGR0)	32	R/W	0000_0000h	39.3.7/845
4002_C024	Configuration Register 1 (LPSPI0_CFGR1)	32	R/W	0000_0000h	39.3.8/846
4002_C030	Data Match Register 0 (LPSPI0_DMR0)	32	R/W	0000_0000h	39.3.9/848
4002_C034	Data Match Register 1 (LPSPI0_DMR1)	32	R/W	0000_0000h	39.3.10/848
4002_C040	Clock Configuration Register (LPSPI0_CCR)	32	R/W	0000_0000h	39.3.11/849
4002_C058	FIFO Control Register (LPSPI0_FCR)	32	R/W	0000_0000h	39.3.12/850
4002_C05C	FIFO Status Register (LPSPI0_FSR)	32	R	0000_0000h	39.3.13/850
4002_C060	Transmit Command Register (LPSPI0_TCR)	32	R/W	0000_001Fh	39.3.14/851
4002_C064	Transmit Data Register (LPSPI0_TDR)	32	W	0000_0000h	39.3.15/854
4002_C070	Receive Status Register (LPSPI0_RSR)	32	R	0000_0002h	39.3.16/855
4002_C074	Receive Data Register (LPSPI0_RDR)	32	R	0000_0000h	39.3.17/856

39.3.1 Version ID Register (LPSPIx_VERID)

.

Address: 4002_C000h base + 0h offset = 4002_C000h



LPSPIx_VERID field descriptions

Field	Description
31–24 MAJOR	Major Version Number This read only field returns the major version number for the module specification.

Table continues on the next page...

LPSPIx_VERID field descriptions (continued)

Field	Description
23–16 MINOR	Minor Version Number This read only field returns the minor version number for the module specification.
FEATURE	Module Identification Number This read only field returns the feature set number. 0x0004 Standard feature set supporting 32-bit shift register.

39.3.2 Parameter Register (LPSPIx_PARAM)

.

Address: 4002_C000h base + 4h offset = 4002_C004h

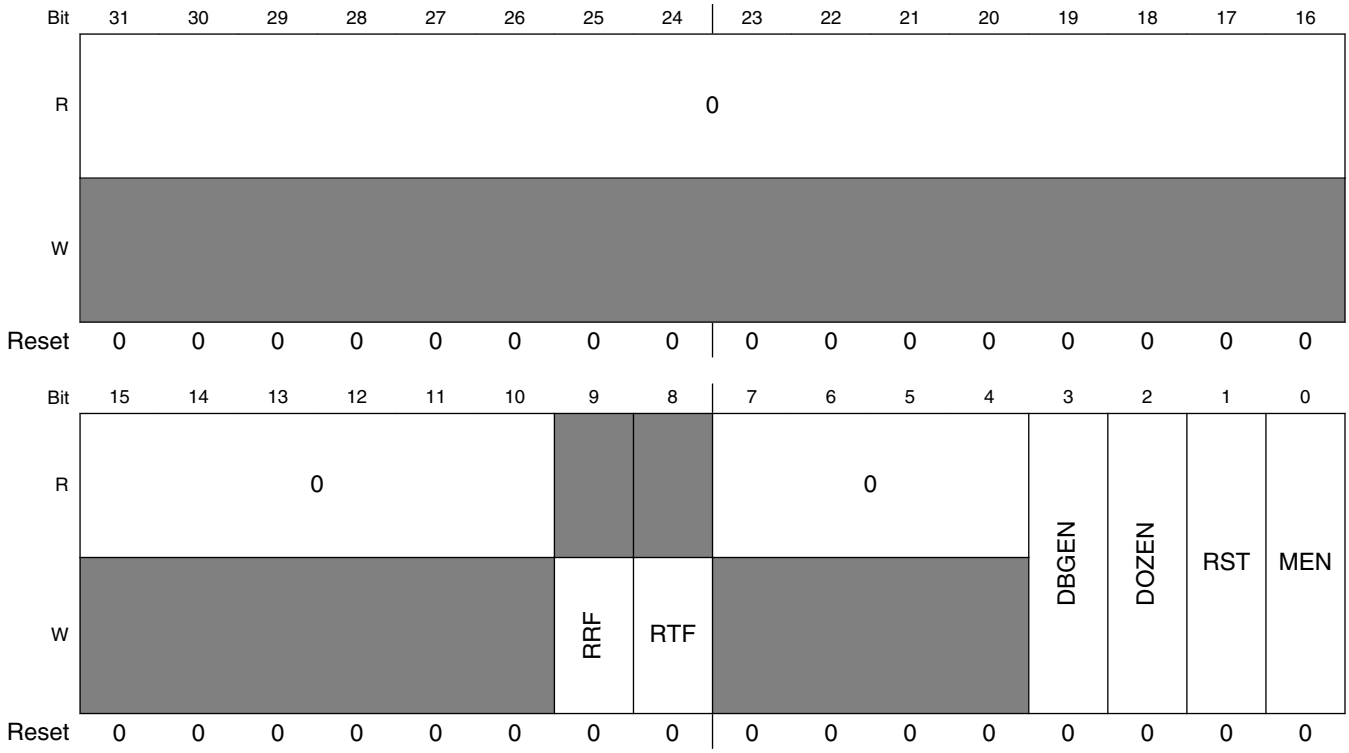
Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0																RXFIFO								TXFIFO							
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0

LPSPIx_PARAM field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–8 RXFIFO	Receive FIFO Size The number of words in the receive FIFO is 2^RXFIFO.
TXFIFO	Transmit FIFO Size The number of words in the transmit FIFO is 2^TXFIFO.

39.3.3 Control Register (LPSPIx_CR)

Address: 4002_C000h base + 10h offset = 4002_C010h



LPSPIx_CR field descriptions

Field	Description
31–10 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
9 RRF	Reset Receive FIFO 0 No effect. 1 Receive FIFO is reset.
8 RTF	Reset Transmit FIFO 0 No effect. 1 Transmit FIFO is reset.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 DBGEN	Debug Enable 0 Module is disabled in debug mode. 1 Module is enabled in debug mode.
2 DOZEN	Doze mode enable Enables or disables Doze mode

Table continues on the next page...

LPSPIx_CR field descriptions (continued)

Field	Description
	0 Module is enabled in Doze mode. 1 Module is disabled in Doze mode.
1 RST	Software Reset Reset all internal logic and registers, except the Control Register. Remains set until cleared by software. 0 Master logic is not reset. 1 Master logic is reset.
0 MEN	Module Enable 0 Module is disabled. 1 Module is enabled.

39.3.4 Status Register (LPSPIx_SR)

Address: 4002_C000h base + 14h offset = 4002_C014h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0							MBF	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		DMF	REF	TEF	TCF	FCF	WCF	0						RDF	TDF
W			w1c	w1c	w1c	w1c	w1c	w1c								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

LPSPIx_SR field descriptions

Field	Description
31–25 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
24 MBF	Module Busy Flag 0 LPSPI is idle. 1 LPSPI is busy.
23–14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13 DMF	Data Match Flag Indicates that the received data has matched the MATCH0 and/or MATCH1 fields as configured by MATCFG. 0 Have not received matching data. 1 Have received matching data.

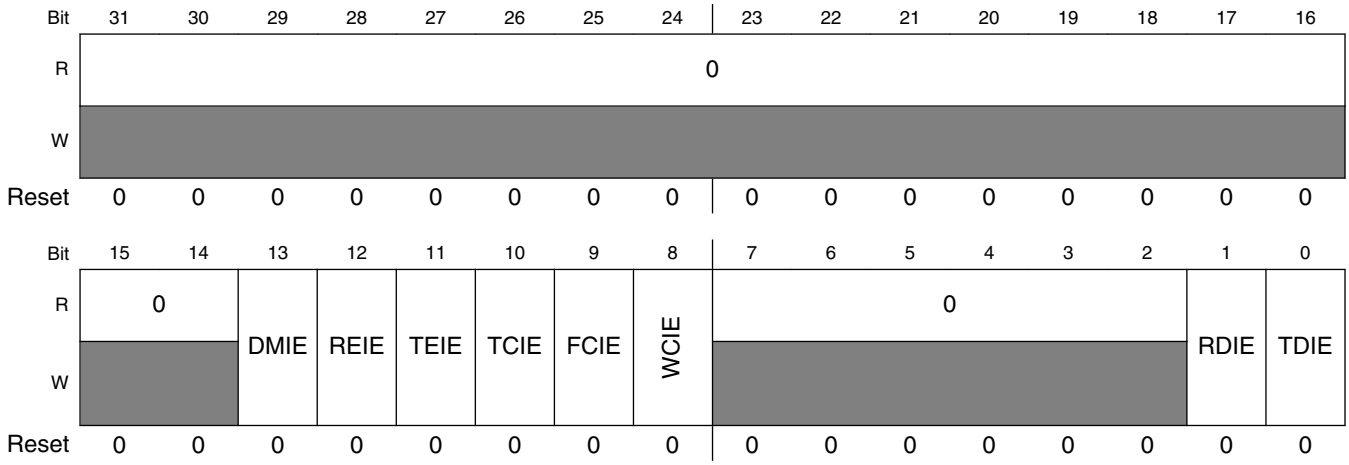
Table continues on the next page...

LPSPIx_SR field descriptions (continued)

Field	Description
12 REF	Receive Error Flag This flag will set when the Receiver FIFO overflows. 0 Receive FIFO has not overflowed. 1 Receive FIFO has overflowed.
11 TEF	Transmit Error Flag This flag will set when the Transmit FIFO underruns. 0 Transmit FIFO underrun has not occurred. 1 Transmit FIFO underrun has occurred
10 TCF	Transfer Complete Flag This flag will set in master mode when the LPSPI returns to idle state with the transmit FIFO empty. 0 All transfers have not completed. 1 All transfers have completed.
9 FCF	Frame Complete Flag This flag will set at the end of each frame transfer, when the PCS negates. 0 Frame transfer has not completed. 1 Frame transfer has completed.
8 WCF	Word Complete Flag This flag will set when the last bit of a received word is sampled. 0 Transfer word not completed. 1 Transfer word completed.
7–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 RDF	Receive Data Flag The Receive Data Flag is set whenever the number of words in the receive FIFO is greater than RXWATER. 0 Receive Data is not ready. 1 Receive data is ready.
0 TDF	Transmit Data Flag The Transmit Data Flag is set whenever the number of words in the transmit FIFO is equal or less than TXWATER. 0 Transmit data not requested. 1 Transmit data is requested.

39.3.5 Interrupt Enable Register (LPSPIx_IER)

Address: 4002_C000h base + 18h offset = 4002_C018h



LPSPIx_IER field descriptions

Field	Description
31–14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13 DMIE	Data Match Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
12 REIE	Receive Error Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
11 TEIE	Transmit Error Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
10 TCIE	Transfer Complete Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
9 FCIE	Frame Complete Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
8 WCIE	Word Complete Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
7–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

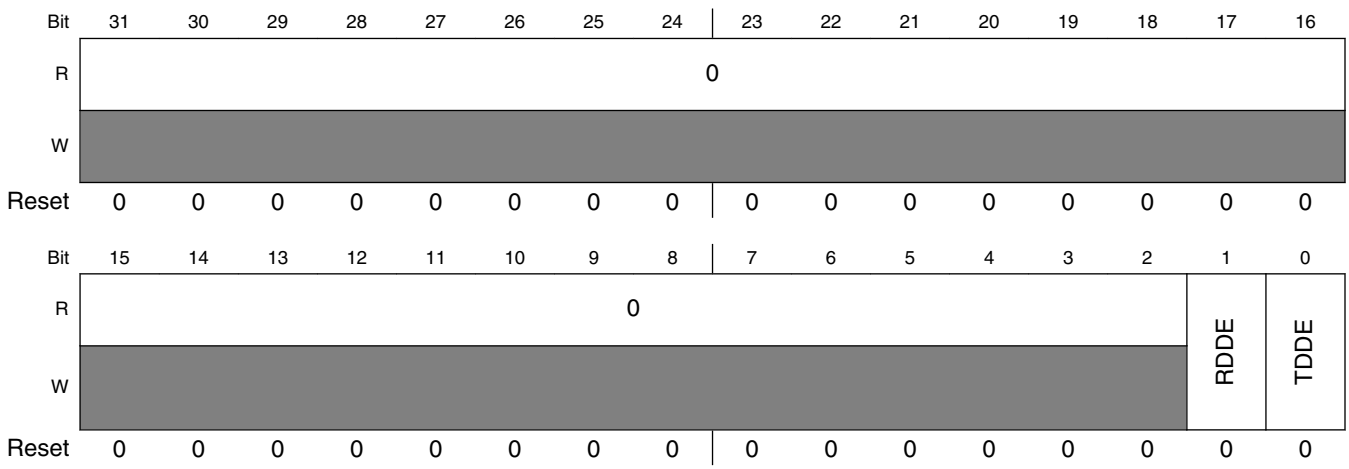
Table continues on the next page...

LPSPIx_IER field descriptions (continued)

Field	Description
1 RDIE	Receive Data Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
0 TDIE	Transmit Data Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled

39.3.6 DMA Enable Register (LPSPIx_DER)

Address: 4002_C000h base + 1Ch offset = 4002_C01Ch

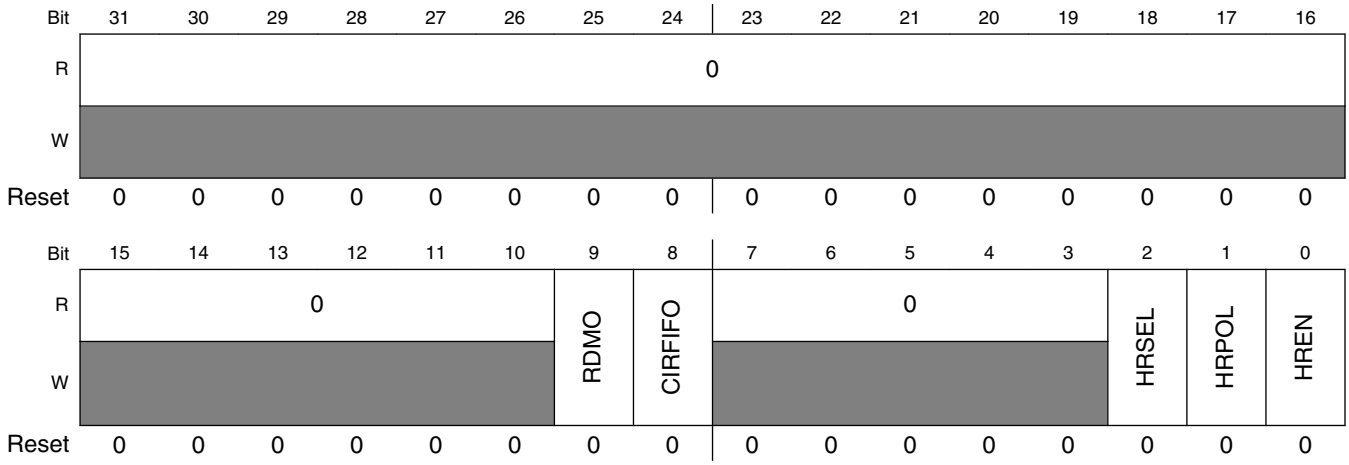


LPSPIx_DER field descriptions

Field	Description
31–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 RDDE	Receive Data DMA Enable 0 DMA request disabled. 1 DMA request enabled.
0 TDDE	Transmit Data DMA Enable 0 DMA request disabled. 1 DMA request enabled

39.3.7 Configuration Register 0 (LPSPIx_CFGR0)

Address: 4002_C000h base + 20h offset = 4002_C020h



LPSPIx_CFGR0 field descriptions

Field	Description
31–10 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
9 RDMO	Receive Data Match Only When enabled, all received data that does not cause DMF to set is discarded. Once DMF is set, the RDMO configuration is ignored. When disabling RDMO, clear RDMO before clearing DMF to ensure no receive data is lost. 0 Received data is stored in the receive FIFO as normal. 1 Received data is discarded unless the DMF is set.
8 CIRFIFO	Circular FIFO Enable When enabled, the transmit FIFO read pointer is saved to a temporary register. The transmit FIFO will be emptied as normal, but once the LPSPI is idle and the transmit FIFO is empty, then the read pointer value will be restored from the temporary register. This will cause the contents of the transmit FIFO to be cycled through repeatedly. 0 Circular FIFO is disabled. 1 Circular FIFO is enabled.
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 HRSEL	Host Request Select Selects the source of the host request input. When the host request function is enabled with the LPSPI_HREQ pin, the LPSPI_PCS[1] function is disabled. 0 Host request input is pin LPSPI_HREQ. 1 Host request input is input trigger.
1 HRPOL	Host Request Polarity

Table continues on the next page...

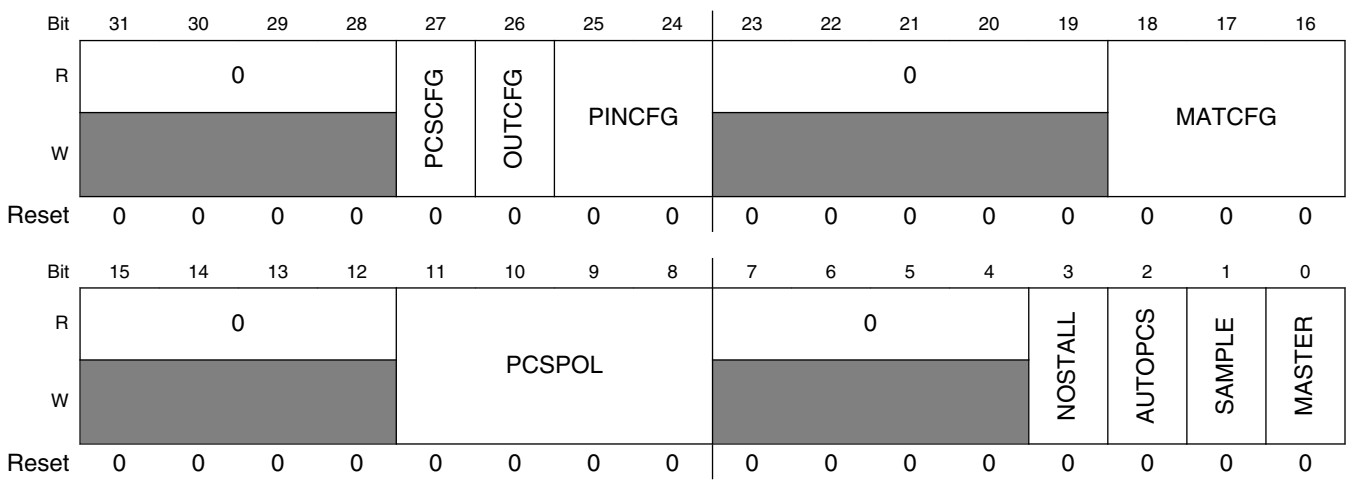
LPSPIx_CFGR0 field descriptions (continued)

Field	Description
	Configures the polarity of the host request pin. 0 Active low. 1 Active high.
0 HREN	Host Request Enable When enabled in master mode, the LPSPI will only initiate a SPI bus transfer if the host request input is asserted. 0 Host request is disabled. 1 Host request is enabled.

39.3.8 Configuration Register 1 (LPSPIx_CFGR1)

The CFGR1 should only be written when the LPSPI is disabled.

Address: 4002_C000h base + 24h offset = 4002_C024h



LPSPIx_CFGR1 field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27 PCSCFG	Peripheral Chip Select Configuration PCSCFG must be set if performing 4-bit transfers. 0 PCS[3:2] are enabled. 1 PCS[3:2] are disabled.
26 OUTCFG	Output Config Configures if the output data is tristated between accesses (LPSPI_PCS is negated).

Table continues on the next page...

LPSPIx_CFGR1 field descriptions (continued)

Field	Description
	0 Output data retains last value when chip select is negated. 1 Output data is tristated when chip select is negated.
25–24 PINCFG	Pin Configuration Configures which pins are used for input and output data during single bit transfers. 00 SIN is used for input data and SOUT for output data. 01 SIN is used for both input and output data. 10 SOUT is used for both input and output data. 11 SOUT is used for input data and SIN for output data.
23–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
18–16 MATCFG	Match Configuration Configures the condition that will cause the DMF to set. 000 Match disabled. 001 Reserved 010 Match enabled (1st data word equals MATCH0 OR MATCH1). 011 Match enabled (any data word equals MATCH0 OR MATCH1). 100 Match enabled (1st data word equals MATCH0 AND 2nd data word equals MATCH1). 101 Match enabled (any data word equals MATCH0 AND next data word equals MATCH1) 110 Match enabled (1st data word AND MATCH1 equals MATCH0 AND MATCH1) 111 Match enabled (any data word AND MATCH1 equals MATCH0 AND MATCH1).
15–12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11–8 PCSPOL	Peripheral Chip Select Polarity Configures the polarity of each Peripheral Chip Select pin. 0 The PCSx is active low. 1 The PCSx is active high.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 NOSTALL	No Stall In master mode, the LPSPI will stall transfers when the transmit FIFO is empty or receive FIFO is full ensuring that no transmit FIFO underrun or receive FIFO overrun can occur. Setting this bit will disable this functionality. 0 Transfers will stall when transmit FIFO is empty or receive FIFO is full. 1 Transfers will not stall, allowing transmit FIFO underrun or receive FIFO overrun to occur.
2 AUTOPCS	Automatic PCS The LPSPI slave normally requires the PCS to negate between frames for correct operation. Setting this bit will cause the LPSPI to generate an internal PCS signal at the end of each transfer word when CPHA=1. When this bit is set, the SCK must remain idle for at least 4 LPSPI functional clock cycles (divided by PRESCALE configuration) between each word to ensure correct operation. This bit is ignored in master mode.

Table continues on the next page...

LPSPIx_CFGR1 field descriptions (continued)

Field	Description
	0 Automatic PCS generation disabled. 1 Automatic PCS generation enabled.
1 SAMPLE	Sample Point When set, the LPSPI master will sample the input data on a delayed LPSPI_SCK edge. This improves the setup time when sampling data. The input data setup time in master mode with delayed LPSPI_SCK edge is equal to the input data setup time in slave mode. This bit is ignored in slave mode. 0 Input data sampled on SCK edge. 1 Input data sampled on delayed SCK edge.
0 MASTER	Master Mode Configures the LPSPI in master or slave mode. This bit directly controls the direction of the LPSPI_SCK and LPCPI_PCS pins. 0 Slave mode. 1 Master mode.

39.3.9 Data Match Register 0 (LPSPIx_DMR0)

Address: 4002_C000h base + 30h offset = 4002_C030h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	MATCH0																															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPSPIx_DMR0 field descriptions

Field	Description
MATCH0	Match 0 Value Compared against the received data when receive data match is enabled.

39.3.10 Data Match Register 1 (LPSPIx_DMR1)

Address: 4002_C000h base + 34h offset = 4002_C034h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	MATCH1																															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPSPIx_DMR1 field descriptions

Field	Description
MATCH1	Match 1 Value

LPSPIx_DMR1 field descriptions (continued)

Field	Description
	Compared against the received data when receive data match is enabled.

39.3.11 Clock Configuration Register (LPSPIx_CCR)

The CCR is only used in master mode and cannot be changed when the LPSPI is enabled.

Address: 4002_C000h base + 40h offset = 4002_C040h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	SCKPCS								PCSSCK								DBT								SCKDIV							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPSPIx_CCR field descriptions

Field	Description
31–24 SCKPCS	SCK to PCS Delay Configures the delay in master mode from the last SCK edge to the PCS negation. The delay is equal to (SCKPCS + 1) cycles of the LPSPI functional clock divided by the PRESCALE configuration, and the minimum delay is 1 cycle.
23–16 PCSSCK	PCS to SCK Delay Configures the delay in master mode from the PCS assertion to the first SCK edge. The delay is equal to (PCSSCK + 1) cycles of the LPSPI functional clock divided by the PRESCALE configuration, and the minimum delay is 1 cycle.
15–8 DBT	Delay Between Transfers Configures the delay in master mode from the PCS negation to the next PCS assertion. The delay is equal to (DBT + 2) cycles of the LPSPI functional clock divided by the PRESCALE configuration, and the minimum delay is 2 cycles. Note that half the delay occurs before PCS assertion and the other half of the delay occurs after PCS negation; the full command word can only update in the middle. Also configures the delay in master mode from the last SCK edge of a transfer word and the first SCK edge of the next transfer word in a continuous transfer. The delay is equal to (DBT + 1) cycles of the LPSPI functional clock divided by the PRESCALE configuration, and the minimum delay is 1 cycle.
SCKDIV	SCK Divider Configures the divide ratio of the SCK pin in master mode. The SCK period is equal to (SCKDIV+2) cycles of the LPSPI functional clock divided by the PRESCALE configuration, and the minimum period is 2 cycles. If the period is an odd number of cycles, then the first half of the period will be one cycle longer than the second half of the period.

39.3.12 FIFO Control Register (LPSPIx_FCR)

Address: 4002_C000h base + 58h offset = 4002_C058h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								RXWATER								0								TXWATER							
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPSPIx_FCR field descriptions

Field	Description
31–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23–16 RXWATER	Receive FIFO Watermark The Receive Data Flag is set whenever the number of words in the receive FIFO is greater than RXWATER. Writing a value equal or greater than the FIFO size will be truncated.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TXWATER	Transmit FIFO Watermark The Transmit Data Flag is set whenever the number of words in the transmit FIFO is equal or less than TXWATER. Writing a value equal or greater than the FIFO size will be truncated.

39.3.13 FIFO Status Register (LPSPIx_FSR)

Address: 4002_C000h base + 5Ch offset = 4002_C05Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								RXCOUNT								0								TXCOUNT							
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPSPIx_FSR field descriptions

Field	Description
31–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23–16 RXCOUNT	Receive FIFO Count Returns the number of words in the receive FIFO.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TXCOUNT	Transmit FIFO Count Returns the number of words in the transmit FIFO.

39.3.14 Transmit Command Register (LPSPIx_TCR)

Writes to either the Transmit Command Register or Transmit Data Register will push the data into the transmit FIFO in the order they are written. Command Register writes will be tagged and cause the command register to update once that entry reaches the top of the FIFO. This allows changes to the command word and the transmit data itself to be interleaved. Changing the command word will cause all subsequent SPI bus transfer to be performed using the new command word.

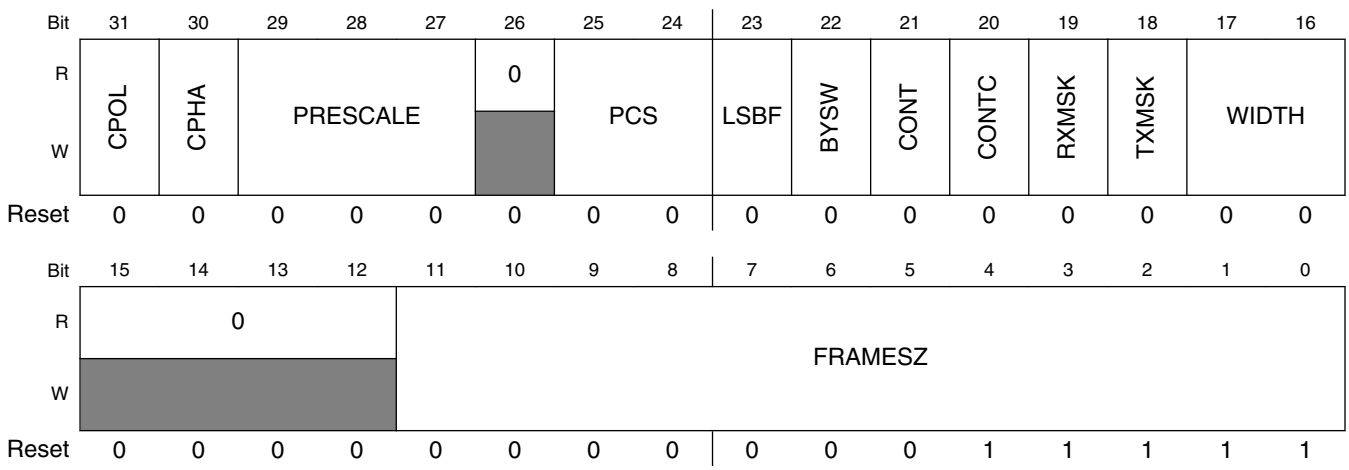
In master mode, writing a new command word does not initiate a new transfer, unless TXMSK is set. Transfers are initiated by transmit data in the transmit FIFO, or a new command word with TXMSK set. Hardware will clear TXMSK when the LPSPI_PCS negates.

In master mode if the command word is changed before an existing frame has completed, then the existing frame will terminate and the command word will then update. The command word can be changed during a continuous transfer, provided CONTC of the new command word is set and the command word is written on a frame size boundary.

In slave mode, the command word should be changed only when the LPSPI is idle and there is no SPI bus transfer.

Reading the Transmit Command Register will return the current state of the command register.

Address: 4002_C000h base + 60h offset = 4002_C060h



LPSPIx_TCR field descriptions

Field	Description
31 CPOL	Clock Polarity This field is only updated between frames.

Table continues on the next page...

LPSPIx_TCR field descriptions (continued)

Field	Description
	0 The inactive state value of SCK is low. 1 The inactive state value of SCK is high.
30 CPHA	Clock Phase This field is only updated between frames. 0 Data is captured on the leading edge of SCK and changed on the following edge. 1 Data is changed on the leading edge of SCK and captured on the following edge.
29–27 PRESCALE	Prescaler Value Prescaler applied to the clock configuration register for all SPI bus transfers. This field is only updated between frames. 000 Divide by 1. 001 Divide by 2. 010 Divide by 4. 011 Divide by 8. 100 Divide by 16. 101 Divide by 32. 110 Divide by 64. 111 Divide by 128.
26 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
25–24 PCS	Peripheral Chip Select Configures the peripheral chip select used for the transfer. This field is only updated between frames. 00 Transfer using LPSPI_PCS[0] 01 Transfer using LPSPI_PCS[1] 10 Transfer using LPSPI_PCS[2] 11 Transfer using LPSPI_PCS[3]
23 LSBF	LSB First 0 Data is transferred MSB first. 1 Data is transferred LSB first.
22 BYSW	Byte Swap Byte swap will swap the contents of [31:24] with [7:0] and [23:16] with [15:8] for each transmit data word read from the FIFO and each received data word stored to the FIFO (or compared with match registers). 0 Byte swap disabled. 1 Byte swap enabled.
21 CONT	Continuous Transfer In master mode, continuous transfer will keep the PCS asserted at the end of the frame size, until a command word is received that starts a new frame. In slave mode, when continuous transfer is enabled the LPSPI will only transmit the first FRAMESZ bits, after which it will transmit received data assuming a 32-bit shift register.

Table continues on the next page...

LPSPIx_TCR field descriptions (continued)

Field	Description
	0 Continuous transfer disabled. 1 Continuous transfer enabled.
20 CONTC	Continuing Command In master mode, this bit allows the command word to be changed within a continuous transfer. The initial command word must enable continuous transfer (CONT=1), the continuing command must set this bit (CONTC=1) and the continuing command word must be loaded on a frame size boundary. For example, if the continuous transfer has a frame size of 64-bits, then a continuing command word must be loaded on a 64-bit boundary. 0 Command word for start of new transfer. 1 Command word for continuing transfer.
19 RXMSK	Receive Data Mask When set, receive data is masked (receive data is not stored in receive FIFO). 0 Normal transfer. 1 Receive data is masked.
18 TXMSK	Transmit Data Mask When set, transmit data is masked (no data is loaded from transmit FIFO and output pin is tristated). In master mode, this bit will initiate a new transfer which cannot be aborted by another command word and the bit will be cleared by hardware at the end of the transfer. 00 Normal transfer. 01 Mask transmit data.
17–16 WIDTH	Transfer Width Either RXMSK or TXMSK must be set for 2-bit or 4-bit transfers. 00 Single bit transfer. 01 Two bit transfer. 10 Four bit transfer. 11 Reserved.
15–12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
FRAMESZ	Frame Size Configures the frame size in number of bits equal to (FRAMESZ + 1). The minimum frame size is 8 bits. If the frame size is larger than 32 bits, data will be loaded from the transmit FIFO and stored to the receive FIFO every 32 bits. If the size of the transfer word is not divisible by 32, then the last load of the transmit FIFO and store of the receive FIFO will contain the remainder bits (e.g.: a 72-bit transfer will load/store 32-bits from the FIFO and then another 32-bits from the FIFO and then the final 8-bits from the FIFO).

39.3.15 Transmit Data Register (LPSPIx_TDR)

Writes to either the Transmit Command Register or Transmit Data Register will push the data into the transmit FIFO in the order it was written.

Address: 4002_C000h base + 64h offset = 4002_C064h

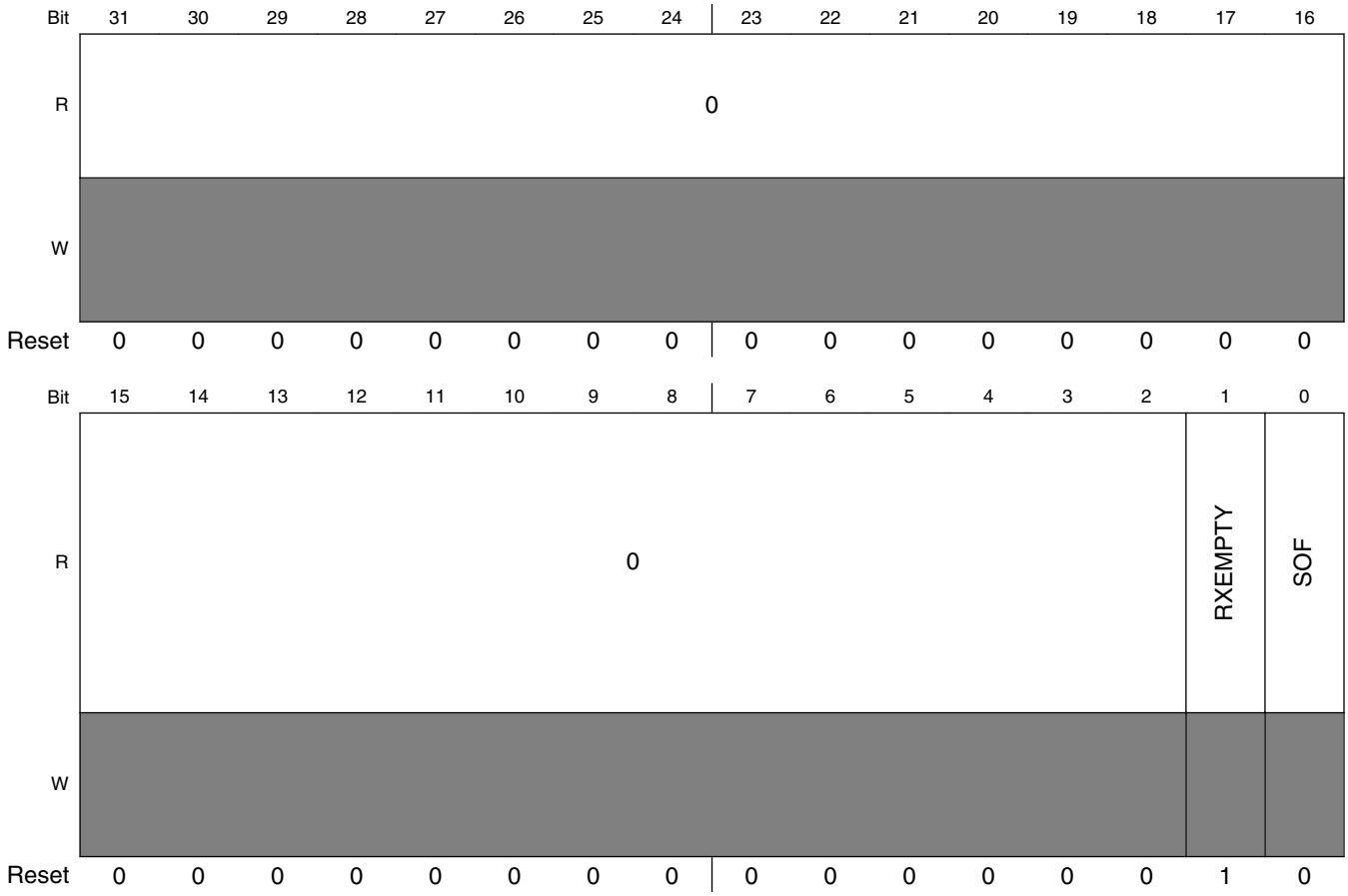
Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R																																
W	DATA																															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPSPIx_TDR field descriptions

Field	Description
DATA	Transmit Data Both 8-bit and 16-bit writes of transmit data will zero extend the data written and push the data into the transmit FIFO.

39.3.16 Receive Status Register (LPSPIx_RSR)

Address: 4002_C000h base + 70h offset = 4002_C070h

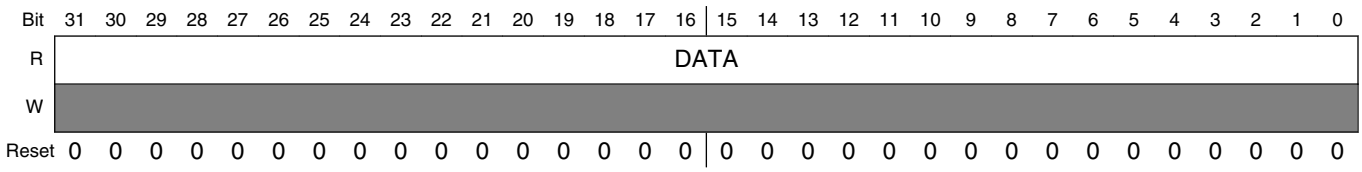


LPSPIx_RSR field descriptions

Field	Description
31–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 RXEMPTY	RX FIFO Empty 0 RX FIFO is not empty. 1 RX FIFO is empty.
0 SOF	Start Of Frame Indicates that this is the first data word received after LPSPI_PCS assertion. 0 Subsequent data word received after LPSPI_PCS assertion. 1 First data word received after LPSPI_PCS assertion.

39.3.17 Receive Data Register (LPSPIx_RDR)

Address: 4002_C000h base + 74h offset = 4002_C074h



LPSPIx_RDR field descriptions

Field	Description
DATA	Receive Data

39.4 Functional description

39.4.1 Clocking and Resets

39.4.1.1 Functional clock

The LPSPI functional clock is asynchronous to the bus clock and can remain enabled in low power modes to support SPI bus transfers in both master and slave modes. If the functional clock is disabled in slave mode, the LPSPI can transfer a single word before the functional clock needs to be enabled. The LPSPI divides the functional clock by a prescaler and the resulting frequency must be at least two times faster than the SPI clock frequency.

39.4.1.2 External clock

The LPSPI shift register is clocked directly by the external pins. This allows the LPSPI slave to remain operational in low power modes, even when the LPSPI functional clock is disabled, although this is limited to a single word transfer.

39.4.1.3 Bus clock

The bus clock is only used for bus accesses to the control and configuration registers. The bus clock frequency must be sufficient to support the data bandwidth requirements of the LPSPI registers, including FIFOs.

39.4.1.4 Chip reset

The logic and registers for the LPSPI are reset to their default state on a chip reset.

39.4.1.5 Software reset

The LPSPI implements a software reset bit in the Control Register. The CR[RST] will reset all logic and registers to their default state, except for the CR itself.

39.4.1.6 FIFO reset

The LPSPI implements write-only control bits that resets the transmit/command FIFO (CR[RTF] and receive FIFO (CR[RRF]). A FIFO is empty after being reset.

39.4.2 Master Mode

39.4.2.1 Transmit and Command FIFO

The transmit and command FIFO is a combined FIFO that includes both transmit data and command words. Command words are stored to the transmit/command FIFO by writing the transmit command register. Transmit data words are stored to the transmit/command FIFO by writing the transmit data register.

When a command word is at the top of the transmit/command FIFO, the following actions can occur:

- If the LPSPI is between frames, the command word is pulled from the FIFO and controls all subsequent transfers.
- If the LPSPI is busy and either the existing CONT bit is clear or the new CONTC value is clear, the SPI frame will complete at the end of the existing word, ignoring

the FRAMESZ configuration. The command word is then pulled from the FIFO and controls all subsequent transfers (or until the next update to the command word).

- If the LPSPI is busy and the existing CONT bit is set and the new CONTC value is set, the command word is pulled from the FIFO during the last LPSPI_SCK pulse of the existing frame (based on FRAMESZ configuration) and the frame continues using the new command value for the rest of the frame (or until the next update to the command word). When CONTC is set, only the lower 24-bits of the command word are updated.

The current state of the existing command word can be read by reading the transmit command register. It requires at least three LPSPI functional clock cycles for the transmit command register to update after it is written (assuming an empty FIFO) and the LPSPI must be enabled (CR[MEN] is set).

Writing the transmit command register does not initiate a SPI bus transfer, unless the TXMSK bit is set. When TXMSK is set, a new command word will not be loaded until the end of the existing frame (based on FRAMESZ configuration) and the TXMSK bit will be cleared at the end of the transfer.

The following table describes the attributes that are controlled by the command word.

Table 39-3. LPSPI Command Word

Field	Description	Modify During Transfer
CPOL	Configures polarity of the LPSPI_SCK pin. Any change of CPOL value will cause a transition on the LPSPI_SCK pin.	N
CPHA	Configures clock phase of transfer.	N
PRESCALE	Configures prescaler used to divide the LPSPI functional clock to generate the timing parameters of the SPI bus transfer. Changing PRESCALE in conjunction with PCS allows the LPSPI to connect to different slave devices at different frequencies.	N
PCS	Configures which LPSPI_PCS asserts for the transfer, the polarity of LPSPI_PCS is static and configured by PCSPOL. If PCSCFG is set, then PCS[3:2] should not be selected.	N
LSBF	Configures if LSB (bit 0) or MSB (bit 31 for a 32-bit word) is transmitted/received first.	Y
BYSW	Enables byte swap on each 32-bit word when transmitting and receiving data. Can be useful when interfacing to devices that organize data as big endean.	Y

Table continues on the next page...

Table 39-3. LPSPI Command Word (continued)

Field	Description	Modify During Transfer
CONT	Configures for a continuous transfer that keeps PCS asserted between frames (as configured by FRAMESZ). A new command word is required to cause PCS to negate. Also supports changing the command word at frame size boundaries.	Y
CONTC	Indicates this is a new command word for the existing continuous transfer. This bit is ignored when not written to the transmit/command FIFO on a frame boundary.	Y
RXMSK	Masks the receive data and does not store to the receive FIFO or perform receive data matching. Useful for half-duplex transfers or to configure which fields are compared during receive data matching.	Y
TXMSK	Masks the transmit data, so that data is not pulled from transmit FIFO and the output data pin is tristated (unless configured by OUTCFG). Useful for half-duplex transfers.	Y
WIDTH	Configures the number of bits shifted on each LPSPI_SCK pulse. Single bit transfers support traditional SPI bus transfers in either half-duplex or full-duplex data formats. Two and four bit transfers are useful for interfacing to QuadSPI memory devices and only support half-duplex data formats (at least one of TXMSK or RXMSK must also be set).	Y
FRAMESZ	Configures the number of bits in each frame to FRAMESZ+1. The minimum frame size is 8-bits and the maximum frame size is 4096-bits. If the frame size is less than or equal to 32-bits, the word size and frame size are identical. If the frame size is greater than 32-bits, then the word size is 32-bits for each word except the last (the last word contains the remainder bits if the frame size is not divisible by 32). The minimum word size is 2-bits, a frame size of 33-bits (or similar) is not supported.	Y

The LPSPI initiates a SPI bus transfer when data is written to the transmit FIFO, the HREQ pin is asserted (or disabled) and the LPSPI is enabled. The SPI bus transfer uses the attributes configured in the transmit command register and timing parameters from the clock configuration register to perform the transfer. The SPI bus transfer ends once

the FRAMESZ configuration is reached, or at the end of a word when a new transmit command word is at the top of the transmit/command FIFO. The HREQ input is only checked the next time the LPSPI goes idle (completes the current transfer and transmit/command register is empty).

The transmit/command FIFO also supports a Circular FIFO feature. This allows the LPSPI master to (periodically) repeat a short data transfer that can fit within the transmit/command FIFO, without requiring additional FIFO accesses. When the circular FIFO is enabled, the current state of the FIFO read pointer is saved and the status flags do not update. Once the transmit/command FIFO is considered empty and the LPSPI is idle, the FIFO read pointer is restored with the saved version, so the contents of the transmit/command FIFO are not permanently pulled from the FIFO while circular FIFO mode is enabled.

39.4.2.2 Receive FIFO and Data Match

The receive FIFO is used to store receive data during SPI bus transfers. When RXMSK is set, receive data is discarded instead of storing in the receive FIFO.

Receive data supports a receive data match function that can match received data against one of two words or against a masked data word. The data match function can also be configured to compare only the first one or two received data words since the start of the frame. Receive data that is already discarded due to RXMSK bit cannot cause the data match to set and will delay the match on first received data word until after all discarded data is received. The receiver match function can also be configured to discard all receive data until a data match is detected, using the MCFGR0[RDMO] control bit. When clearing the MCFGR0[RDMO] control bit following a data match, clear MCFGR0[RDMO] before clearing MSR[DMF] to allow all subsequent data to be received.

39.4.2.3 Timing Parameters

The following table lists the timing parameters that are used for all SPI bus transfers, these timing parameters are relative to the LPSPI functional clock divided by the PRESCALE configuration. Although the Clock Configuration Register cannot be changed when the LPSPI is busy, the PRESCALE configuration can be altered between transfers using the command register, to support interfacing to different slave devices at different frequencies.

Table 39-4. LPSPI Timing Parameters

Field	Description	Min	Max
SCKDIV	Configures the LPSPI_SCK clock period to (SCKDIV+2) cycles. When configured to an odd number of cycles, the first half of the LPSPI_SCK cycle is one cycle longer than the second half.	0 (2 cycles)	255 (257 cycles)
DBT	Configures the minimum delay between PCS negation and the next PCS assertion to (DBT + 2) cycles. When the command word is updated between transfers, there is a minimum of (DBT/2)+1 cycles between the command word update and any change on LPSPI_PCS pins.	0 (2 cycles)	255 (257 cycles)
DBT	Configures the delay during a continuous transfer between the last SCK edge of a frame and the first SCK edge of the continuing frame to (DBT + 1) cycles. This is useful where the external slave requires a large delay between different words of a SPI bus transfer.	0 (1 cycle)	255 (256 cycles)
PCSSCK	Configures the minimum delay between PCS assertion and the first SCK edge to (PCSSCK + 1) cycles.	0 (1 cycle)	255 (256 cycles)
SCKPCS	Configures the minimum delay between the last SCK edge and the PCS assertion to (SCKPCS + 1) cycles.	0 (1 cycle)	255 (256 cycles)

39.4.2.4 Pin Configuration

The LPSPI_SIN and LPSPI_SOUT pins can be configured via the PINCFG configuration to swap directions or even support half-duplex transfers on the same pin.

The OUTCFG configuration can be used to determine if output data pin (eg: LPSPI_SOUT) will tristate when the LPSPI_PCS is negated, or if it will simply retain the last value. When configuring for half-duplex transfers using the same data pin in single bit transfer mode, or any transfer in 2-bit and 4-bit transfer modes, then the output data pins must be configured to tristate when LPSPI_PCS is negated.

The PCSCFG configuration is used to disable LPSPI_PCS[3:2] functions and to use them for quad-data transfers. This option must be enabled when performing quad-data transfers.

39.4.3 Slave Mode

LPSPI slave mode uses the same shift register and logic as the master mode, but does not use the clock configuration register and the transmit command register must remain static during SPI bus transfers.

39.4.3.1 Transmit and Command FIFO

The transmit command register should be initialized before enabling the LPSPI in slave mode, although the command register will not update until after the LPSPI is enabled. Once enabled, the transmit command register should only be changed if the LPSPI is idle. The following table lists how the command register functions in slave mode.

Table 39-5. LPSPI Command Word in Slave Mode

Field	Description
CPOL	Configures polarity of the external LPSPI_SCK input.
CPHA	Configures clock phase of transfer.
PRESCALE	Configures LPSPI functional clock prescaler.
PCS	Configures which LPSPI_PCS is used, the polarity of LPSPI_PCS is static and configured by PCSPOL. If PCSCFG is set, then PCS[3:2] should not be selected.
LSBF	Configures if LSB (bit 0) or MSB (bit 31 for a 32-bit word) is transmitted/received first.
BYSW	Enables byte swap on each 32-bit word when transmitting and receiving data. Can be useful when interfacing to devices that organize data as big endean.
CONT	When set, only the first FRAMSZ bits will be transmitted/ received by the LPSPI.
CONTC	This bit is reserved in slave mode.
RXMSK	Masks the receive data and does not store to the receive FIFO or perform receive data matching. Useful for half-duplex transfers or to configure which fields are compared during receive data matching.
TXMSK	Masks the transmit data, so that data is not pulled from transmit FIFO and the output data pin is tristated (unless configured by OUTCFG). Useful for half-duplex transfers.
WIDTH	Configures the number of bits shifted on each LPSPI_SCK pulse. Single bit transfers support traditional SPI bus transfers in either half-duplex or full-duplex data formats. Two and four bit transfers are useful for interfacing to QuadSPI memory

Table continues on the next page...

Table 39-5. LPSPI Command Word in Slave Mode (continued)

Field	Description
	devices and only support half-duplex data formats (at least one of TXMSK or RXMSK must also be set).
FRAMESZ	Configures the number of bits in each frame to FRAMESZ+1. The minimum frame size is 8-bits and the maximum frame size is 4096-bits. If the frame size is less than or equal to 32-bits, the word size and frame size are identical. If the frame size is greater than 32-bits, then the word size is 32-bits for each word except the last (the last word contains the remainder bits if the frame size is not divisible by 32). The minimum word size is 2-bits, a frame size of 33-bits (or similar) is not supported.

The transmit FIFO must be filled with transmit data before the LPSPI_PCS input asserts, otherwise the transmit error flag will set.

39.4.3.2 Receive FIFO and Data Match

The receive FIFO is used to store receive data during SPI bus transfers. When RXMSK is set, receive data is discarded instead of storing in the receive FIFO.

Receive data supports a receive data match function that can match received data against one of two words or against a masked data word. The data match function can also be configured to compare only the first one or two received data words since the start of the frame. Receive data that is already discarded due to RXMSK bit cannot cause the data match to set and will delay the match on first received data word until after all discarded data is received. The receiver match function can also be configured to discard all receive data until a data match is detected, using the MCFGR0[RDMO] control bit. When clearing the MCFGR0[RDMO] control bit following a data match, clear MCFGR0[RDMO] before clearing MSR[DMF] to allow all subsequent data to be received.

39.4.3.3 Clocked Interface

The LPSPI supports interfacing to external masters that provide only clock and data pins (LPSPI_PCS is not required). This requires using CPHA=1, configuring the LPSPI_PCS input to be always asserted (configure PCSPOL) and setting the AUTOPCS bit. When AUTOPCS is set, a minimum of four LPSPI functional clock cycles (divided by PRESCALE configuration) is required between the last LPSPI_SCK edge of one word and the first LPSPI_SCK edge of the next word.

39.4.4 Interrupts and DMA Requests

The following table illustrates the status flags that can generate the LPSPI interrupt and LPSPI transmit/receive DMA requests.

Table 39-6. LPSPI Interrupts and DMA Requests

Flag	Description	Interrupt	DMA Request	Low Power Wakeup
TDF	Data can be written to transmit FIFO, as configured by TXWATER.	Y	TX	Y
RDF	Data can be read from the receive FIFO, as configured by RXWATER.	Y	RX	Y
WCF	Word complete, last bit of word has been sampled.	Y	N	Y
FCF	Frame complete, PCS has negated .	Y	N	Y
TCF	Transfer complete, PCS has negated and transmit/command FIFO is empty.	Y	N	Y
TEF	Transmit error flag, indicates transmit/ command FIFO underrun. This bit cannot set in master mode when NOSTALL is clear.	Y	N	Y
REF	Receive error flag, indicates receive FIFO overflow. This bit cannot set in master mode when NOSTALL is clear.	Y	N	Y
DMF	Data match flag, received data has matched the configured data match value.	Y	N	Y
MBF	LPSPI is busy performing a SPI bus transfer.	N	N	N

39.4.5 Peripheral Triggers

The connection of the LPSPI peripheral triggers with other peripherals are device specific.

39.4.5.1 Output Triggers

The LPSPI generates two output triggers that can be connected to other peripherals on the device. The frame output trigger asserts at the end of each frame (when PCS negates) and remains asserted until PCS next asserts. The word output trigger asserts at the end of each received word and remains asserted for one LPSPI_SCK period.

39.4.5.2 Input Trigger

The LPSPI input trigger can be selected in place of the LPSPI_HREQ input to control the start of a LPSPI bus transfer. The input trigger must assert for longer than one LPSPI functional clock cycle to be detected.

Chapter 40
Low Power Inter-Integrated Circuit (LPI2C)

40.1 Chip-specific information for this module

40.1.1 Instantiation Information

This device has LPI2C modules. The LPI2C can remain functional in Stop and VLPS mode provided the clock it is using remains enabled.

Table 40-1. LPI2C Configuration

	TX FIFO (word/8bit)	RX FIFO (word/8bit)	SMBus	Slave mode enable
LPI2C0	4	4	Yes	Yes

NOTE

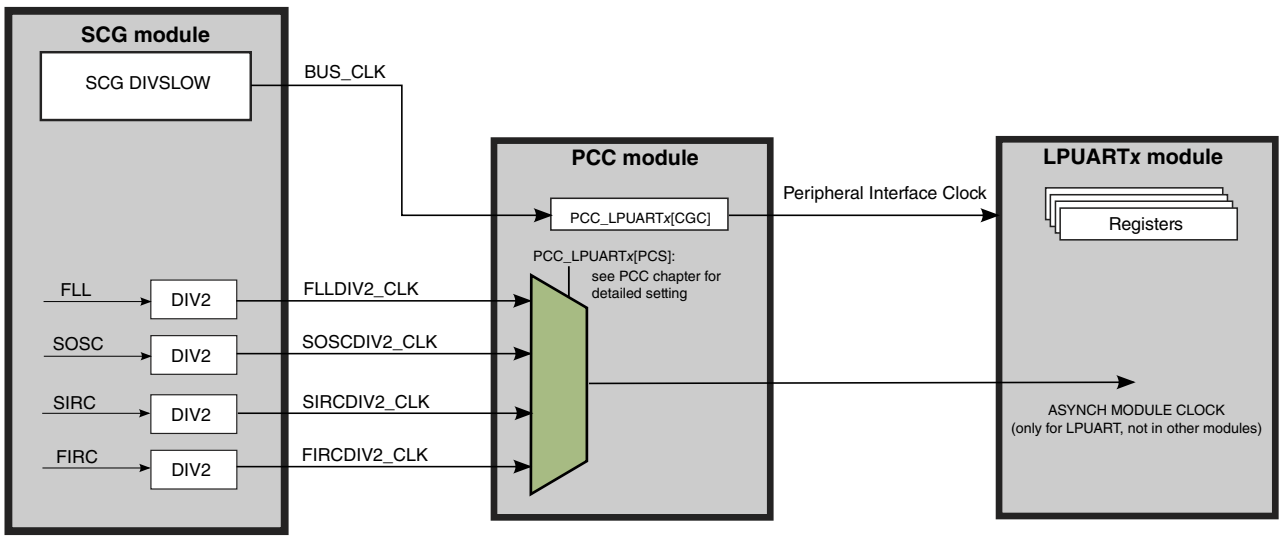
DMA is not supported in this device.

40.1.2 Module Clocking Information for LPUART, LPSPI, LPI2C and LPIT

The following figure shows the input clock sources available for this module.

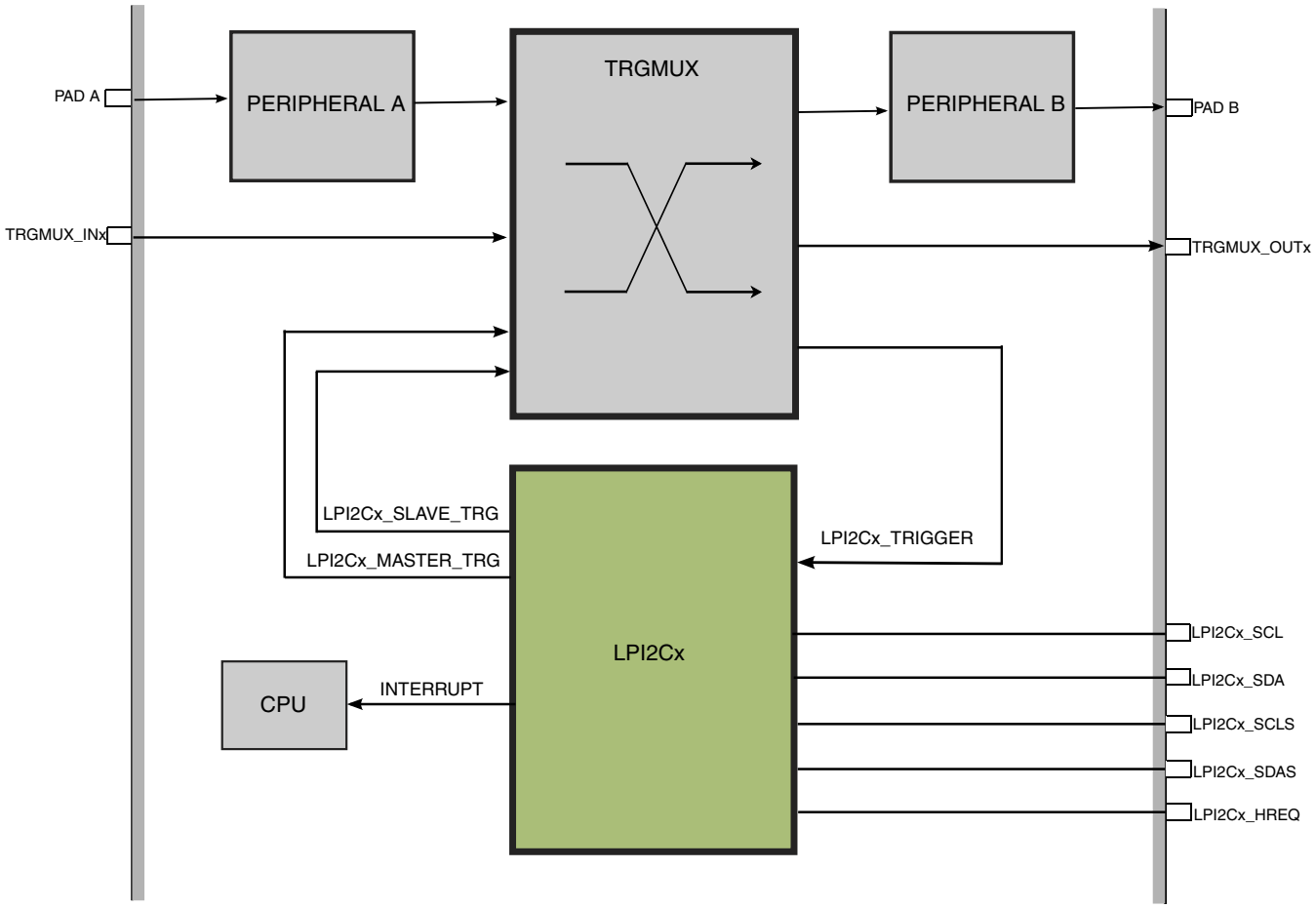
Peripheral Clocking - LPUART, etc.

Note: this example figure also applies similarly to the clocking for LPSPI, LPI2C, LPIT, etc.



40.1.3 Inter-connectivity Information

The LPI2C inter-connectivity is shown in following diagram.



40.2 Introduction

40.2.1 Overview

The LPI2C is a low power Inter-Integrated Circuit (I2C) module that supports an efficient interface to an I2C bus as a master and/or a slave. The LPI2C can continue operating in stop modes provided an appropriate clock is available and is designed for low CPU overhead with DMA offloading of FIFO register accesses. The LPI2C implements logic support for standard-mode, fast-mode, fast-mode plus and ultra-fast modes of operation. The LPI2C module also complies with the System Management Bus (SMBus) Specification, version 2.

40.2.2 Features

The LPI2C supports the following features of the I2C specification:

- Standard, Fast, Fast+ and Ultra Fast modes are supported.
- HS-mode supported in slave mode.
- HS-mode supported for master mode, provided SCL pin implements current source pull-up (device specific).
- Multi-master support including synchronization and arbitration.
- Clock stretching.
- General call, 7-bit and 10-bit addressing.
- Software reset, START byte and Device ID require software support.

The LPI2C master supports the following features:

- Command/transmit FIFO of 4 words.
- Receive FIFO of 4 words.
- Command FIFO will wait for idle I2C bus before initiating transfer
- Command FIFO can initiate (repeated) START and STOP conditions and one or more master-receiver transfers.
- STOP condition can be generated from command FIFO or automatically when the transmit FIFO is empty.
- Host request input can be used to control the start time of an I2C bus transfer.
- Flexible receive data match can generate interrupt on data match and/or discard unwanted data.
- Flag and optional interrupt to signal Repeated START condition, STOP condition, loss of arbitration, unexpected NACK and command word errors.
- Supports configurable bus idle timeout and pin stuck low timeout.

The LPI2C slave supports the following features:

- Separate I2C slave registers to minimize software overhead due to master/slave switching.
- Support for 7-bit or 10-bit addressing, address range, SMBus alert and general call address.
- Transmit data register supporting interrupt or DMA requests.
- Receive data register supporting interrupt or DMA requests.
- Software controllable ACK or NACK, with optional clock stretching on ACK/NACK bit.
- Configurable clock stretching to avoid transmit FIFO underrun and receive FIFO overrun.
- Flag and optional interrupt at end of packet, STOP condition or bit error detection.

40.2.3 Block Diagram

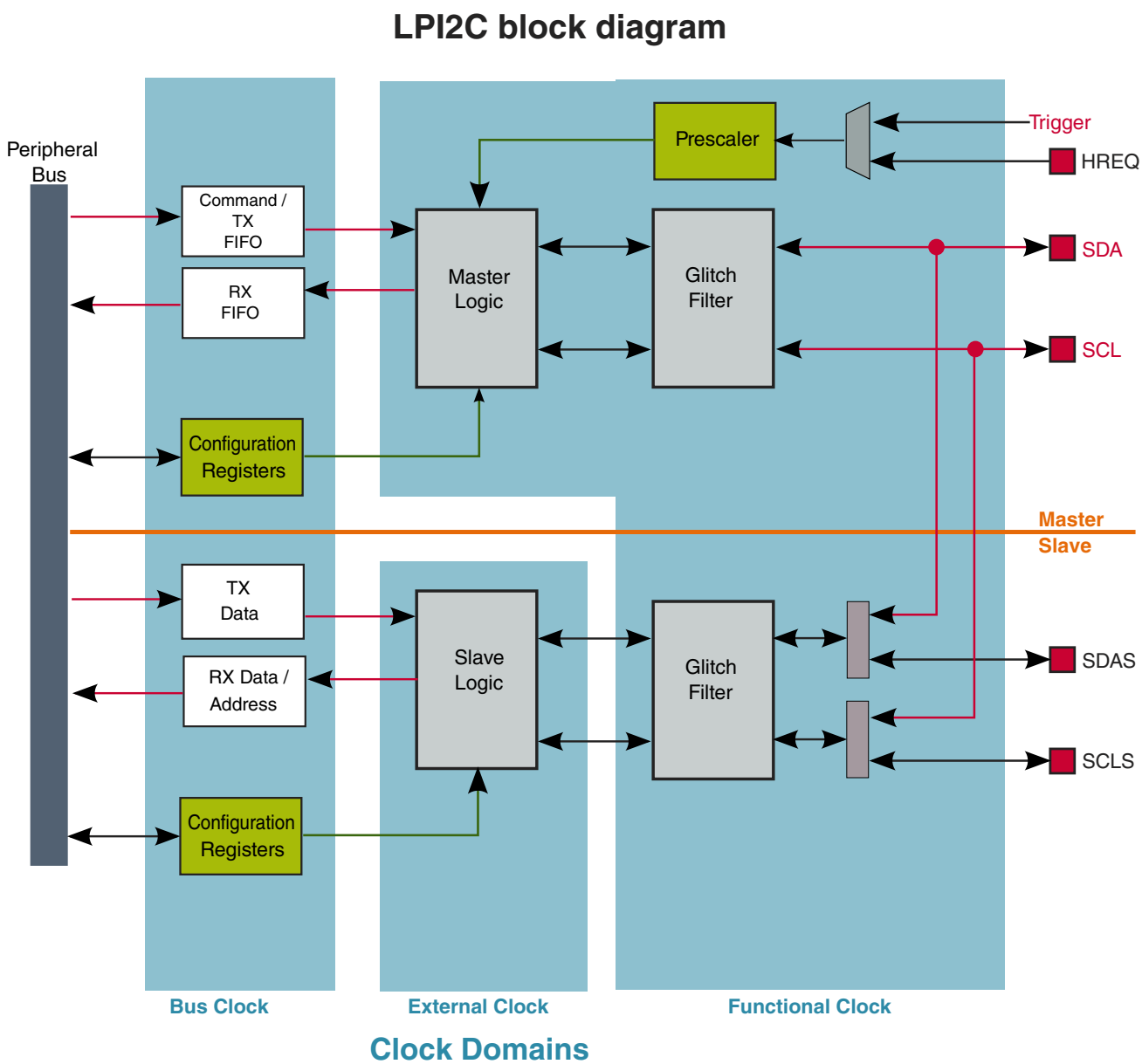


Figure 40-1. LPI2C block diagram

40.2.4 Modes of operation

The LPI2C module supports the chip modes described in the following table.

Table 40-2. Chip modes supported by the LPI2C module

Chip mode	LPI2C Operation
Run	Normal operation
Stop/Wait	Can continue operating provided the Doze Enable bit (MCR[DOZEN]) is set and the LPI2C is using an external or internal clock source which remains operating during stop/wait modes.
Debug	Can continue operating provided the Debug Enable bit (MCR[DBGEN]) is set.

40.2.5 Signal Descriptions

Signal	Description	I/O
SCL	LPI2C clock line. In 4-wire mode, this is the SCL input pin.	I/O
SDA	LPI2C data line. In 4-wire mode, this is the SDA input pin.	I/O
HREQ	Host request, can initiate an LPI2C master transfer if asserted and the I2C bus is idle.	I
SCLS	Secondary I2C clock line. In 4-wire mode, this is the SCL output pin. If LPI2C master/slave are configured to use separate pins, this the LPI2C slave SCL pin.	I/O
SDAS	Secondary I2C data line. In 4-wire mode, this is the SDA output pin. If LPI2C master/slave are configured to use separate pins, this the LPI2C slave SDA pin.	I/O

40.3 Memory Map and Registers

LPI2C memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4006_6000	Version ID Register (LPI2C0_VERID)	32	R	See section	40.3.1/874
4006_6004	Parameter Register (LPI2C0_PARAM)	32	R	See section	40.3.2/874
4006_6010	Master Control Register (LPI2C0_MCR)	32	R/W	0000_0000h	40.3.3/875
4006_6014	Master Status Register (LPI2C0_MSR)	32	R/W	0000_0001h	40.3.4/876
4006_6018	Master Interrupt Enable Register (LPI2C0_MIER)	32	R/W	0000_0000h	40.3.5/878
4006_601C	Master DMA Enable Register (LPI2C0_MDER)	32	R/W	0000_0000h	40.3.6/880

Table continues on the next page...

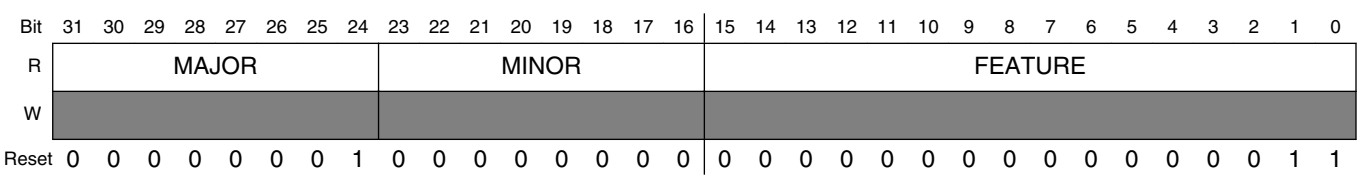
LPI2C memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4006_6020	Master Configuration Register 0 (LPI2C0_MCFGR0)	32	R/W	0000_0000h	40.3.7/881
4006_6024	Master Configuration Register 1 (LPI2C0_MCFGR1)	32	R/W	0000_0000h	40.3.8/882
4006_6028	Master Configuration Register 2 (LPI2C0_MCFGR2)	32	R/W	0000_0000h	40.3.9/884
4006_602C	Master Configuration Register 3 (LPI2C0_MCFGR3)	32	R/W	0000_0000h	40.3.10/885
4006_6040	Master Data Match Register (LPI2C0_MDMR)	32	R/W	0000_0000h	40.3.11/885
4006_6048	Master Clock Configuration Register 0 (LPI2C0_MCCR0)	32	R/W	0000_0000h	40.3.12/886
4006_6050	Master Clock Configuration Register 1 (LPI2C0_MCCR1)	32	R/W	0000_0000h	40.3.13/887
4006_6058	Master FIFO Control Register (LPI2C0_MFCR)	32	R/W	0000_0000h	40.3.14/888
4006_605C	Master FIFO Status Register (LPI2C0_MFSR)	32	R	0000_0000h	40.3.15/888
4006_6060	Master Transmit Data Register (LPI2C0_MTDR)	32	W	0000_0000h	40.3.16/889
4006_6070	Master Receive Data Register (LPI2C0_MRDR)	32	R	0000_4000h	40.3.17/890
4006_6110	Slave Control Register (LPI2C0_SCR)	32	R/W	0000_0000h	40.3.18/891
4006_6114	Slave Status Register (LPI2C0_SSR)	32	R/W	0000_0000h	40.3.19/892
4006_6118	Slave Interrupt Enable Register (LPI2C0_SIER)	32	R/W	0000_0000h	40.3.20/895
4006_611C	Slave DMA Enable Register (LPI2C0_SDER)	32	R/W	0000_0000h	40.3.21/896
4006_6124	Slave Configuration Register 1 (LPI2C0_SCFGR1)	32	R/W	0000_0000h	40.3.22/897
4006_6128	Slave Configuration Register 2 (LPI2C0_SCFGR2)	32	R/W	0000_0000h	40.3.23/899
4006_6140	Slave Address Match Register (LPI2C0_SAMR)	32	R/W	0000_0000h	40.3.24/900
4006_6150	Slave Address Status Register (LPI2C0_SASR)	32	R	0000_4000h	40.3.25/901
4006_6154	Slave Transmit ACK Register (LPI2C0_STAR)	32	R/W	0000_0000h	40.3.26/902
4006_6160	Slave Transmit Data Register (LPI2C0_STDR)	32	W	0000_0000h	40.3.27/902
4006_6170	Slave Receive Data Register (LPI2C0_SRDR)	32	R	0000_4000h	40.3.28/903

40.3.1 Version ID Register (LPI2Cx_VERID)

.

Address: 4006_6000h base + 0h offset = 4006_6000h



LPI2Cx_VERID field descriptions

Field	Description
31–24 MAJOR	Major Version Number This read only field returns the major version number for the specification.

Table continues on the next page...

LPI2Cx_VERID field descriptions (continued)

Field	Description
23–16 MINOR	Minor Version Number This read only field returns the minor version number for the specification.
FEATURE	Feature Specification Number This read only field returns the feature set number. 0x0002 Master only with standard feature set. 0x0003 Master and slave with standard feature set.

40.3.2 Parameter Register (LPI2Cx_PARAM)

.

Address: 4006_6000h base + 4h offset = 4006_6004h

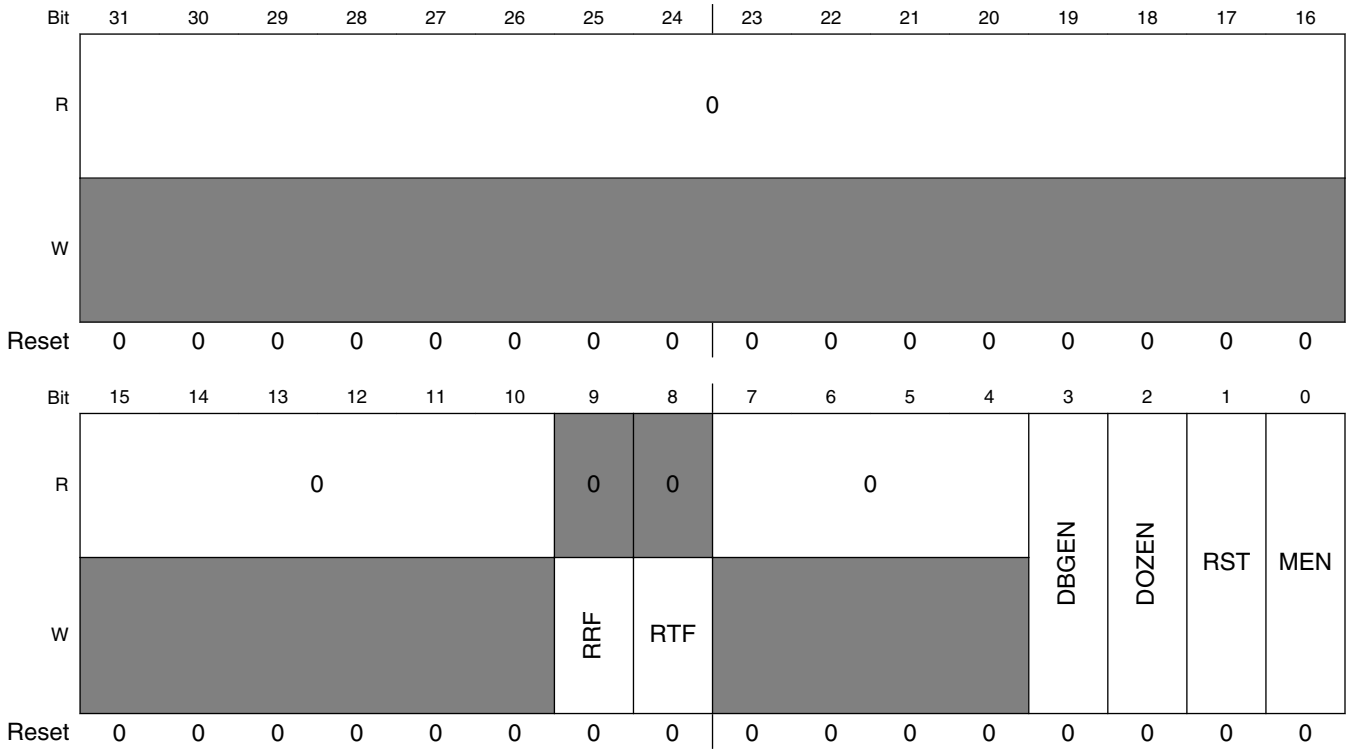
Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0																0				MRXFIFO				0				MTXFIFO			
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0

LPI2Cx_PARAM field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11–8 MRXFIFO	Master Receive FIFO Size The number of words in the master receive FIFO is 2^MRXFIFO.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
MTXFIFO	Master Transmit FIFO Size The number of words in the master transmit FIFO is 2^MTXFIFO.

40.3.3 Master Control Register (LPI2Cx_MCR)

Address: 4006_6000h base + 10h offset = 4006_6010h



LPI2Cx_MCR field descriptions

Field	Description
31–10 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
9 RRF	Reset Receive FIFO 0 No effect. 1 Receive FIFO is reset.
8 RTF	Reset Transmit FIFO 0 No effect. 1 Transmit FIFO is reset.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 DBGEN	Debug Enable 0 Master is disabled in debug mode. 1 Master is enabled in debug mode.
2 DOZEN	Doze mode enable Enables or disables Doze mode for the master.

Table continues on the next page...

LPI2Cx_MCR field descriptions (continued)

Field	Description
	0 Master is enabled in Doze mode. 1 Master is disabled in Doze mode.
1 RST	Software Reset Reset all internal master logic and registers, except the Master Control Register. Remains set until cleared by software. 0 Master logic is not reset. 1 Master logic is reset.
0 MEN	Master Enable 0 Master logic is disabled. 1 Master logic is enabled.

40.3.4 Master Status Register (LPI2Cx_MSR)

Address: 4006_6000h base + 14h offset = 4006_6014h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0						BBF	MBF	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	DMF	PLTF	FEF	ALF	NDF	SDF	EPF	0						RDF	TDF
W		w1c	w1c	w1c	w1c	w1c	w1c	w1c								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

LPI2Cx_MSR field descriptions

Field	Description
31–26 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
25 BBF	Bus Busy Flag 0 I2C Bus is idle. 1 I2C Bus is busy.
24 MBF	Master Busy Flag 0 I2C Master is idle. 1 I2C Master is busy.
23–15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 DMF	Data Match Flag

Table continues on the next page...

LPI2Cx_MSR field descriptions (continued)

Field	Description
	Indicates that the received data has matched the MATCH0 and/or MATCH1 fields as configured by MATCFG. Received data that is discarded due to CMD field does not cause this flag to set. 0 Have not received matching data. 1 Have received matching data.
13 PLTF	Pin Low Timeout Flag Will set when the SCL and/or SDA input is low for more than PINLOW cycles, even when the LPI2C master is idle. Software is responsible for resolving the pin low condition. This flag cannot be cleared for as long as the pin low timeout continues and must be cleared before the LPI2C can initiate a START condition. 0 Pin low timeout has not occurred or is disabled. 1 Pin low timeout has occurred.
12 FEF	FIFO Error Flag Detects an attempt to send or receive data without first generating a (repeated) START condition. This can occur if the transmit FIFO underflows when the AUTOSTOP bit is set. When this flag is set, the LPI2C master will send a STOP condition (if busy) and will not initiate a new START condition until this flag has been cleared. 0 No error. 1 Master sending or receiving data without START condition.
11 ALF	Arbitration Lost Flag This flag will set if the LPI2C master transmits a logic one and detects a logic zero on the I2C bus, or if it detects a START or STOP condition while it is transmitting data. When this flag sets, the LPI2C master will release the bus (go idle) and will not initiate a new START condition until this flag has been cleared. 0 Master has not lost arbitration. 1 Master has lost arbitration.
10 NDF	NACK Detect Flag This flag will set if the LPI2C master detects a NACK when transmitting an address or data. If a NACK is expected for a given address (as configured by the command word) then the flag will set if a NACK is not generated. When set, the master will transmit a STOP condition and will not initiate a new START condition until this flag has been cleared. 0 Unexpected NACK not detected. 1 Unexpected NACK was detected.
9 SDF	STOP Detect Flag This flag will set when the LPI2C master generates a STOP condition. 0 Master has not generated a STOP condition. 1 Master has generated a STOP condition.
8 EPF	End Packet Flag This flag will set when the LPI2C master generates either a repeated START or a STOP condition. It does not set when the master first generates a START condition. 0 Master has not generated a STOP or Repeated START condition. 1 Master has generated a STOP or Repeated START condition.

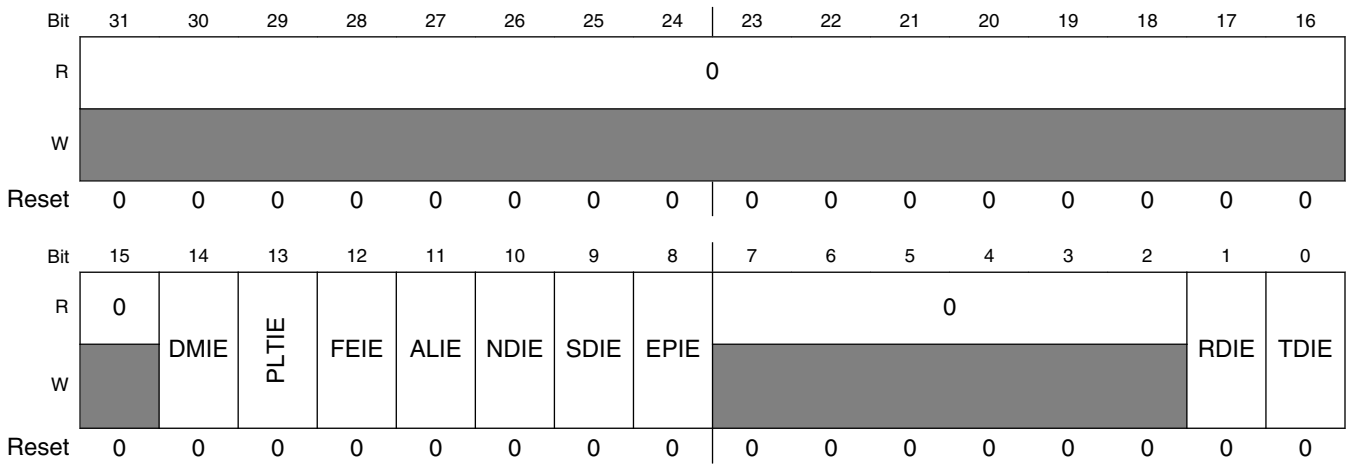
Table continues on the next page...

LPI2Cx_MSR field descriptions (continued)

Field	Description
7–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 RDF	Receive Data Flag The Receive Data Flag is set whenever the number of words in the receive FIFO is greater than RXWATER. 0 Receive Data is not ready. 1 Receive data is ready.
0 TDF	Transmit Data Flag The Transmit Data Flag is set whenever the number of words in the transmit FIFO is equal or less than TXWATER. 0 Transmit data not requested. 1 Transmit data is requested.

40.3.5 Master Interrupt Enable Register (LPI2Cx_MIER)

Address: 4006_6000h base + 18h offset = 4006_6018h



LPI2Cx_MIER field descriptions

Field	Description
31–15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 DMIE	Data Match Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
13 PLTIE	Pin Low Timeout Interrupt Enable

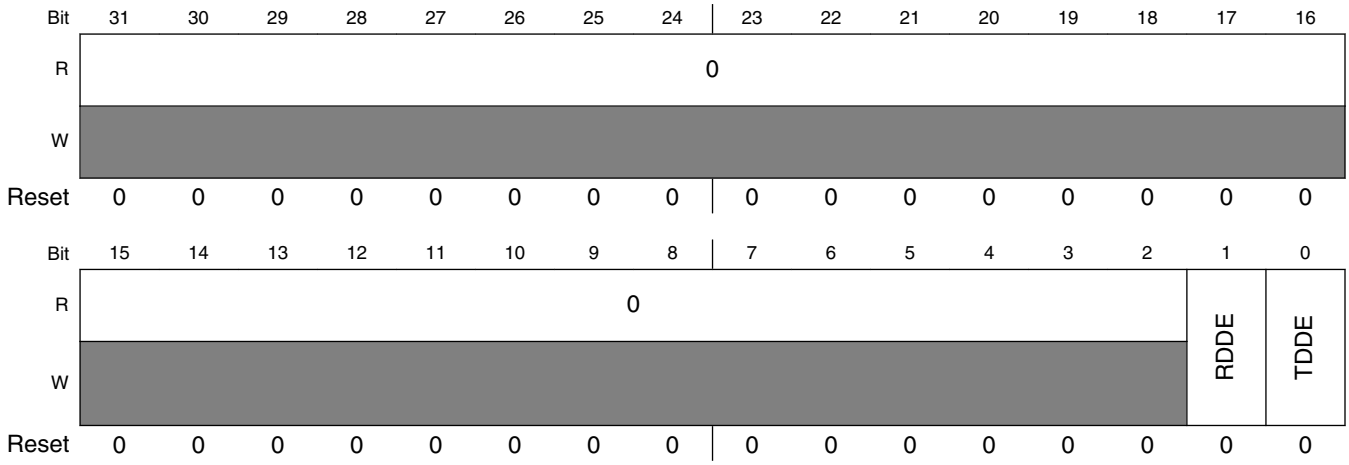
Table continues on the next page...

LPI2Cx_MIER field descriptions (continued)

Field	Description
	0 Interrupt disabled. 1 Interrupt enabled.
12 FEIE	FIFO Error Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
11 ALIE	Arbitration Lost Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
10 NDIE	NACK Detect Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
9 SDIE	STOP Detect Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
8 EPIE	End Packet Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
7–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 RDIE	Receive Data Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
0 TDIE	Transmit Data Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled

40.3.6 Master DMA Enable Register (LPI2Cx_MDER)

Address: 4006_6000h base + 1Ch offset = 4006_601Ch

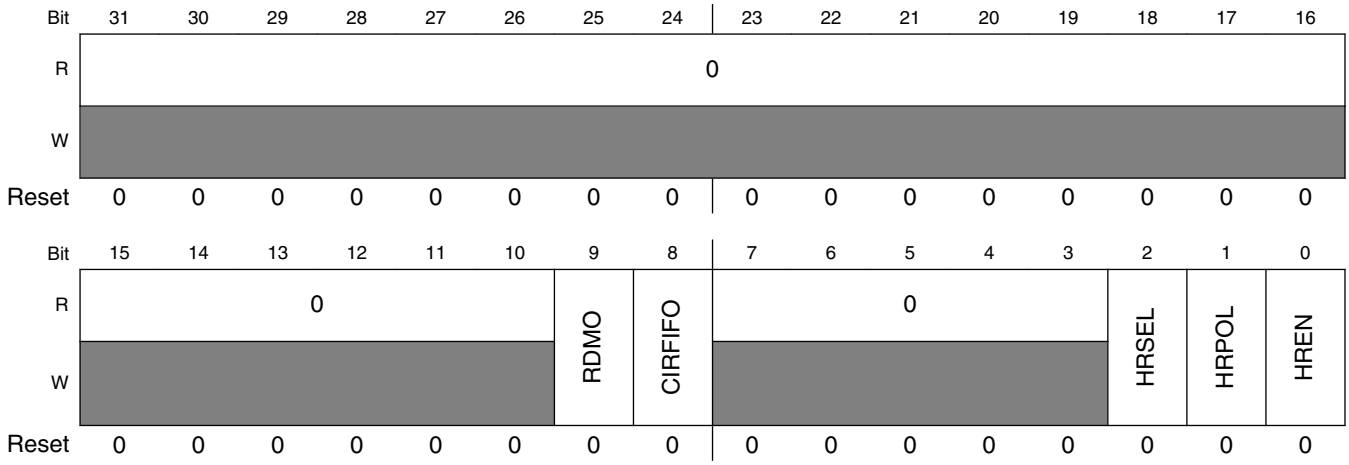


LPI2Cx_MDER field descriptions

Field	Description
31–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 RDDE	Receive Data DMA Enable 0 DMA request disabled. 1 DMA request enabled.
0 TDDE	Transmit Data DMA Enable 0 DMA request disabled. 1 DMA request enabled

40.3.7 Master Configuration Register 0 (LPI2Cx_MCFGR0)

Address: 4006_6000h base + 20h offset = 4006_6020h



LPI2Cx_MCFGR0 field descriptions

Field	Description
31–10 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
9 RDMO	Receive Data Match Only When enabled, all received data that does not cause DMF to set is discarded. Once DMF is set, the RDMO configuration is ignored. When disabling RDMO, clear RDMO before clearing DMF to ensure no receive data is lost. 0 Received data is stored in the receive FIFO as normal. 1 Received data is discarded unless the RMF is set.
8 CIRFIFO	Circular FIFO Enable When enabled, the transmit FIFO read pointer is saved to a temporary register. The transmit FIFO will be emptied as normal, but once the LPI2C master is idle and the transmit FIFO is empty, then the read pointer value will be restored from the temporary register. This will cause the contents of the transmit FIFO to be cycled through repeatedly. If AUTOSTOP is set, a STOP condition will be sent whenever the transmit FIFO is empty and the read pointer is restored. 0 Circular FIFO is disabled. 1 Circular FIFO is enabled.
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 HRSEL	Host Request Select Selects the source of the host request input. 0 Host request input is pin LPI2C_HREQ. 1 Host request input is input trigger.
1 HRPOL	Host Request Polarity

Table continues on the next page...

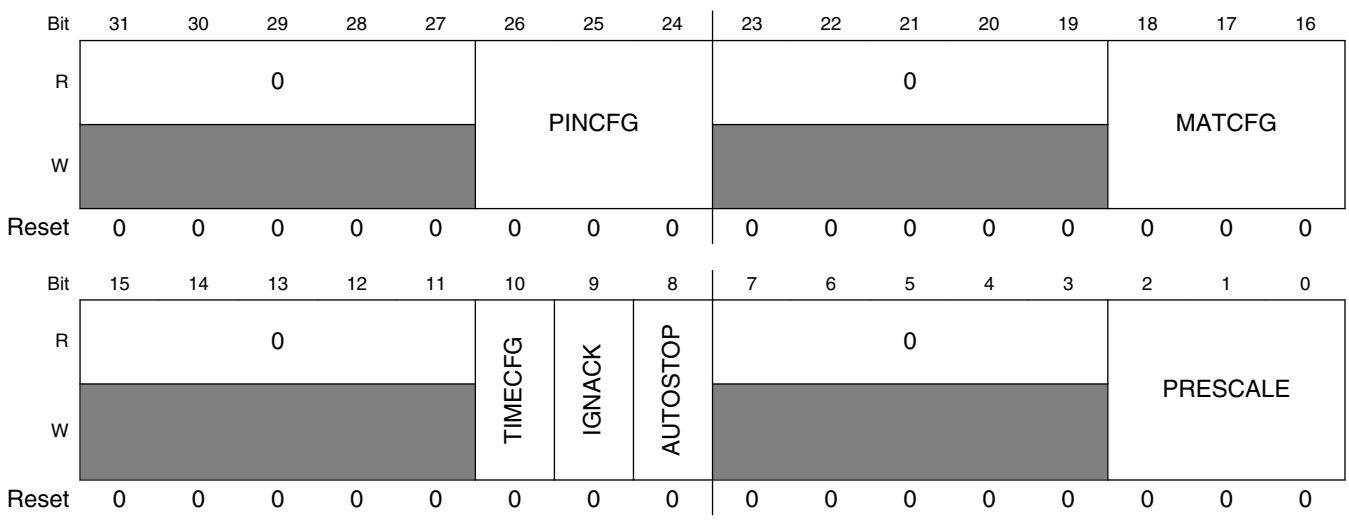
LPI2Cx_MCFGR0 field descriptions (continued)

Field	Description
	Configures the polarity of the host request input pin. 0 Active low. 1 Active high.
0 HREN	Host Request Enable When enabled, the LPI2C master will only initiate a START condition if the host request input is asserted and the bus is idle. A repeated START is not affected by the host request. 0 Host request input is disabled. 1 Host request input is enabled.

40.3.8 Master Configuration Register 1 (LPI2Cx_MCFGR1)

The MCFGR1 should only be written when the I2C Master is disabled.

Address: 4006_6000h base + 24h offset = 4006_6024h



LPI2Cx_MCFGR1 field descriptions

Field	Description
31–27 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
26–24 PINCFG	Pin Configuration Configures the pin mode. 000 LPI2C configured for 2-pin open drain mode. 001 LPI2C configured for 2-pin output only mode (ultra-fast mode). 010 LPI2C configured for 2-pin push-pull mode. 011 LPI2C configured for 4-pin push-pull mode.

Table continues on the next page...

LPI2Cx_MCFGR1 field descriptions (continued)

Field	Description
	100 LPI2C configured for 2-pin open drain mode with separate LPI2C slave. 101 LPI2C configured for 2-pin output only mode (ultra-fast mode) with separate LPI2C slave. 110 LPI2C configured for 2-pin push-pull mode with separate LPI2C slave. 111 LPI2C configured for 4-pin push-pull mode (inverted outputs).
23–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
18–16 MATCFG	Match Configuration Configures the condition that will cause the DMF to set. 000 Match disabled. 001 Reserved. 010 Match enabled (1st data word equals MATCH0 OR MATCH1). 011 Match enabled (any data word equals MATCH0 OR MATCH1). 100 Match enabled (1st data word equals MATCH0 AND 2nd data word equals MATCH1). 101 Match enabled (any data word equals MATCH0 AND next data word equals MATCH1). 110 Match enabled (1st data word AND MATCH1 equals MATCH0 AND MATCH1). 111 Match enabled (any data word AND MATCH1 equals MATCH0 AND MATCH1).
15–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10 TIMECFG	Timeout Configuration 0 Pin Low Timeout Flag will set if SCL is low for longer than the configured timeout. 1 Pin Low Timeout Flag will set if either SCL or SDA is low for longer than the configured timeout.
9 IGNACK	When set, the received NACK field is ignored and assumed to be ACK. This bit is required to be set in Ultra-Fast Mode. 0 LPI2C Master will receive ACK and NACK normally. 1 LPI2C Master will treat a received NACK as if it was an ACK.
8 AUTOSTOP	Automatic STOP Generation When enabled, a STOP condition is generated whenever the LPI2C master is busy and the transmit FIFO is empty. The STOP condition can also be generated using a transmit FIFO command. 0 No effect. 1 STOP condition is automatically generated whenever the transmit FIFO is empty and LPI2C master is busy.
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
PRESCALE	Prescaler Configures the clock prescaler used for all LPI2C master logic, except the digital glitch filters. 000 Divide by 1. 001 Divide by 2. 010 Divide by 4. 011 Divide by 8. 100 Divide by 16. 101 Divide by 32.

Table continues on the next page...

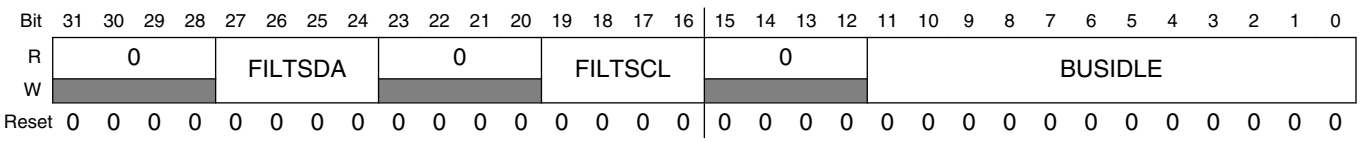
LPI2Cx_MCFGR1 field descriptions (continued)

Field	Description
	110 Divide by 64. 111 Divide by 128.

40.3.9 Master Configuration Register 2 (LPI2Cx_MCFGR2)

The MCFGR2 should only be written when the I2C Master is disabled.

Address: 4006_6000h base + 28h offset = 4006_6028h



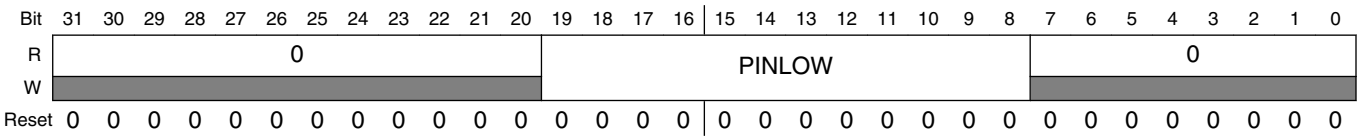
LPI2Cx_MCFGR2 field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 FILTSDA	Glitch Filter SDA Configures the I2C master digital glitch filters for SDA input, a configuration of 0 will disable the glitch filter. Glitches equal to or less than FILTSDA cycles long will be filtered out and ignored. The latency through the glitch filter is equal to FILTSDA cycles and must be configured less than the minimum SCL low or high period. The glitch filter cycle count is not affected by the PRESCALE configuration and is automatically bypassed in High Speed mode.
23–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–16 FILTSCL	Glitch Filter SCL Configures the I2C master digital glitch filters for SCL input, a configuration of 0 will disable the glitch filter. Glitches equal to or less than FILTSCL cycles long will be filtered out and ignored. The latency through the glitch filter is equal to FILTSCL cycles and must be configured less than the minimum SCL low or high period. The glitch filter cycle count is not affected by the PRESCALE configuration and is automatically bypassed in High Speed mode.
15–12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
BUSIDLE	Bus Idle Timeout Configures the bus idle timeout period in clock cycles. If both SCL and SDA are high for longer than BUSIDLE cycles, then the I2C bus is assumed to be idle and the master can generate a START condition. When set to zero, this feature is disabled.

40.3.10 Master Configuration Register 3 (LPI2Cx_MCFGR3)

The MCFGR3 should only be written when the I2C Master is disabled.

Address: 4006_6000h base + 2Ch offset = 4006_602Ch

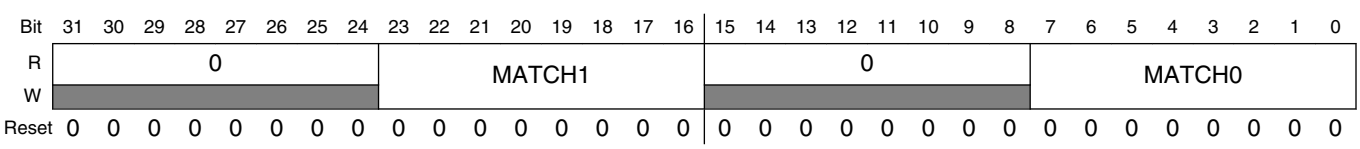


LPI2Cx_MCFGR3 field descriptions

Field	Description
31–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–8 PINLOW	Pin Low Timeout Configures the pin low timeout flag in clock cycles. If SCL and/or SDA is low for longer than (PINLOW * 256) cycles then PLTF is set. When set to zero, this feature is disabled.
Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

40.3.11 Master Data Match Register (LPI2Cx_MDMR)

Address: 4006_6000h base + 40h offset = 4006_6040h



LPI2Cx_MDMR field descriptions

Field	Description
31–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23–16 MATCH1	Match 1 Value Compared against the received data when receive data match is enabled.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
MATCH0	Match 0 Value Compared against the received data when receive data match is enabled.

40.3.12 Master Clock Configuration Register 0 (LPI2Cx_MCCR0)

The MCCR0 cannot be changed when the I2C master is enabled and is used for standard, fast, fast-mode plus and ultra-fast transfers.

Address: 4006_6000h base + 48h offset = 4006_6048h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0		DATAVD						0		SETHOLD						0		CLKHI						0		CLKLO					
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

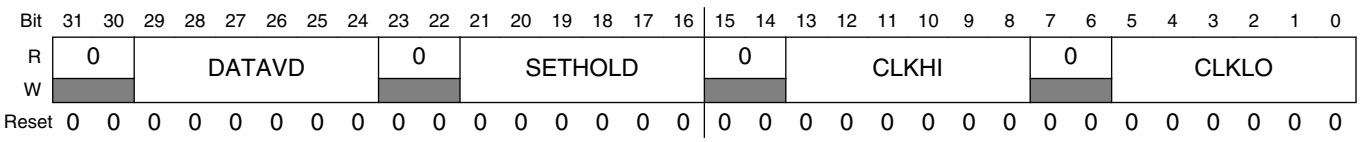
LPI2Cx_MCCR0 field descriptions

Field	Description
31–30 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
29–24 DATAVD	Data Valid Delay Minimum number of cycles (minus one) that is used as the data hold time for SDA. Must be configured less than the minimum SCL low period.
23–22 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
21–16 SETHOLD	Setup Hold Delay Minimum number of cycles (minus one) that is used by the master as the setup and hold time for a (repeated) START condition and setup time for a STOP condition. The setup time is extended by the time it takes to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this is equal to (2 + FILTSCL) / 2^PRESCALE cycles.
15–14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13–8 CLKHI	Clock High Period Minimum number of cycles (minus one) that the SCL clock is driven high by the master. The SCL high time is extended by the time it takes to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this is equal to (2 + FILTSCL) / 2^PRESCALE cycles.
7–6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
CLKLO	Clock Low Period Minimum number of cycles (minus one) that the SCL clock is driven low by the master. This value is also used for the minimum bus free time between a STOP and a START condition.

40.3.13 Master Clock Configuration Register 1 (LPI2Cx_MCCR1)

The MCCR1 cannot be changed when the I2C master is enabled and is used for high speed mode transfers. The separate clock configuration for high speed mode allows arbitration to take place in Fast mode (with timing configured by MCCR0), before switching to high speed mode (with timing configured by MCCR1).

Address: 4006_6000h base + 50h offset = 4006_6050h



LPI2Cx_MCCR1 field descriptions

Field	Description
31–30 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
29–24 DATAVD	Data Valid Delay Minimum number of cycles (minus one) that is used as the data hold time for SDA. Must be configured less than the minimum SCL low period.
23–22 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
21–16 SETHOLD	Setup Hold Delay Minimum number of cycles (minus one) that is used by the master as the setup and hold time for a (repeated) START condition and setup time for a STOP condition. The setup time is extended by the time it takes to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this is equal to (2 + FILTSCL) / 2^PRESCALE cycles.
15–14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13–8 CLKHI	Clock High Period Minimum number of cycles (minus one) that the SCL clock is driven high by the master. The SCL high time is extended by the time it takes to detect a rising edge on the external SCL pin. Ignoring any additional board delay due to external loading, this is equal to (2 + FILTSCL) / 2^PRESCALE cycles.
7–6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
CLKLO	Clock Low Period Minimum number of cycles (minus one) that the SCL clock is driven low by the master. This value is also used for the minimum bus free time between a STOP and a START condition.

40.3.14 Master FIFO Control Register (LPI2Cx_MFCR)

Address: 4006_6000h base + 58h offset = 4006_6058h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								RXWATER								0								TXWATER							
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPI2Cx_MFCR field descriptions

Field	Description
31–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23–16 RXWATER	Receive FIFO Watermark The Receive Data Flag is set whenever the number of words in the receive FIFO is greater than RXWATER. Writing a value equal or greater than the FIFO size will be truncated.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TXWATER	Transmit FIFO Watermark The Transmit Data Flag is set whenever the number of words in the transmit FIFO is equal or less than TXWATER. Writing a value equal or greater than the FIFO size will be truncated.

40.3.15 Master FIFO Status Register (LPI2Cx_MFSR)

Address: 4006_6000h base + 5Ch offset = 4006_605Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0								RXCOUNT								0								TXCOUNT							
W																																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

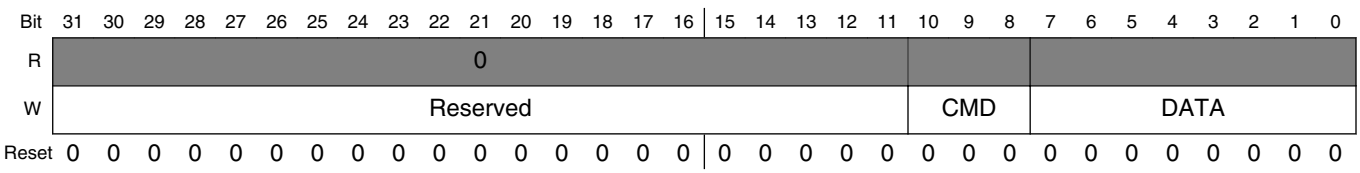
LPI2Cx_MFSR field descriptions

Field	Description
31–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23–16 RXCOUNT	Receive FIFO Count Returns the number of words in the receive FIFO.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TXCOUNT	Transmit FIFO Count Returns the number of words in the transmit FIFO.

40.3.16 Master Transmit Data Register (LPI2Cx_MTDR)

An 8-bit write to the CMD field will store the data in the Command FIFO, but does not increment the FIFO write pointer. An 8-bit write to the DATA field will zero extend the CMD field unless the CMD field has been written separately since the last FIFO write, it also increments the FIFO write pointer. A 16-bit or 32-bit will write both the CMD and DATA fields and increment the FIFO.

Address: 4006_6000h base + 60h offset = 4006_6060h

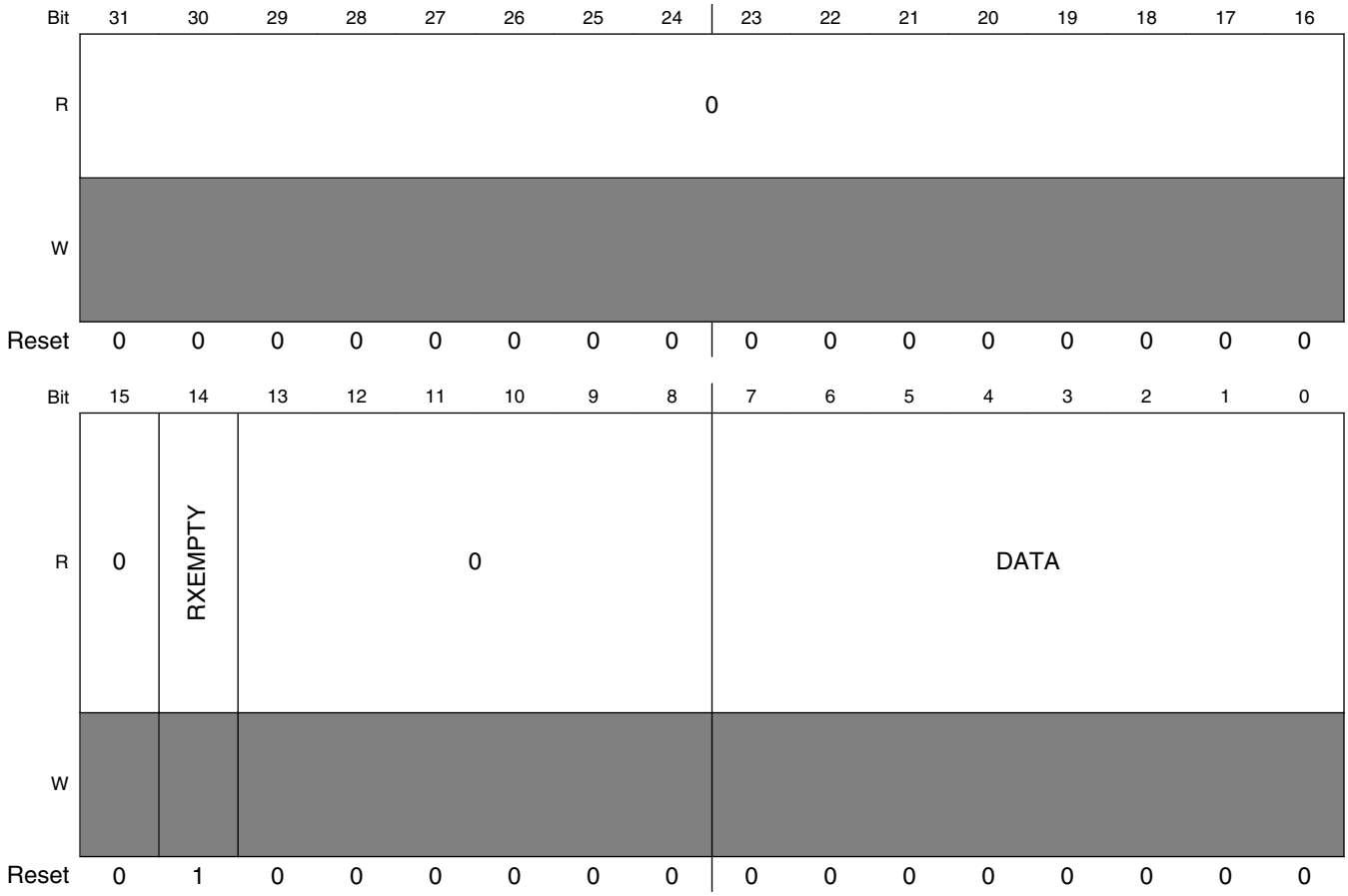


LPI2Cx_MTDR field descriptions

Field	Description
31–11 Reserved	This field is reserved.
10–8 CMD	Command Data 000 Transmit DATA[7:0]. 001 Receive (DATA[7:0] + 1) bytes. 010 Generate STOP condition. 011 Receive and discard (DATA[7:0] + 1) bytes. 100 Generate (repeated) START and transmit address in DATA[7:0]. 101 Generate (repeated) START and transmit address in DATA[7:0]. This transfer expects a NACK to be returned. 110 Generate (repeated) START and transmit address in DATA[7:0] using high speed mode. 111 Generate (repeated) START and transmit address in DATA[7:0] using high speed mode. This transfer expects a NACK to be returned.
DATA	Transmit Data Performing an 8-bit write to DATA will zero extend the CMD field.

40.3.17 Master Receive Data Register (LPI2Cx_MRDR)

Address: 4006_6000h base + 70h offset = 4006_6070h

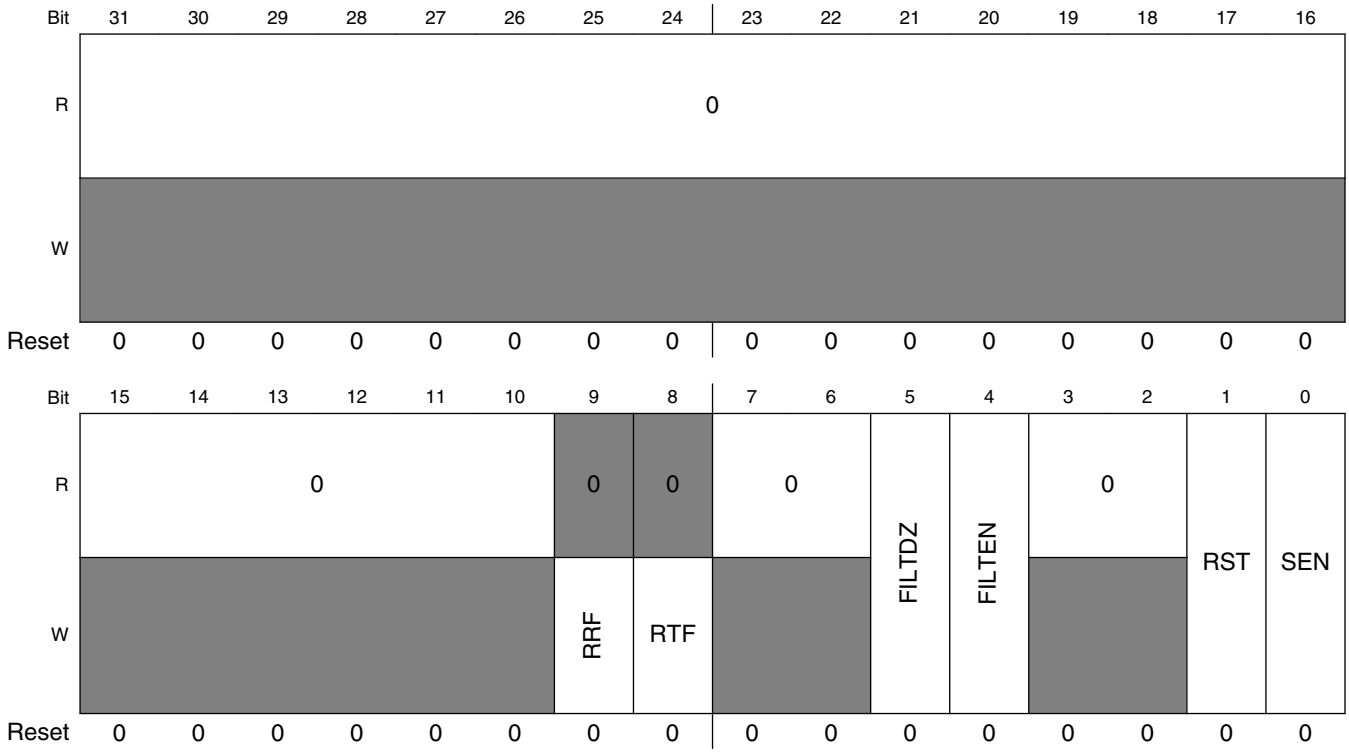


LPI2Cx_MRDR field descriptions

Field	Description
31–15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 RXEMPTY	RX Empty 0 Receive FIFO is not empty. 1 Receive FIFO is empty.
13–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DATA	Receive Data Reading this register returns the data received by the I2C master that has not been discarded. Receive data can be discarded due to the CMD field or the master can be configured to discard non-matching data.

40.3.18 Slave Control Register (LPI2Cx_SCR)

Address: 4006_6000h base + 110h offset = 4006_6110h



LPI2Cx_SCR field descriptions

Field	Description
31–10 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
9 RRF	Reset Receive FIFO 0 No effect. 1 Receive Data Register is now empty.
8 RTF	Reset Transmit FIFO 0 No effect. 1 Transmit Data Register is now empty.
7–6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
5 FILTDZ	Filter Doze Enable 0 Filter remains enabled in Doze mode. 1 Filter is disabled in Doze mode.
4 FILTEN	Filter Enable 0 Disable digital filter and output delay counter for slave mode. 1 Enable digital filter and output delay counter for slave mode.

Table continues on the next page...

LPI2Cx_SCR field descriptions (continued)

Field	Description
3–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 RST	Software Reset 0 Slave logic is not reset. 1 Slave logic is reset.
0 SEN	Slave Enable 0 Slave mode is disabled. 1 Slave mode is enabled.

40.3.19 Slave Status Register (LPI2Cx_SSR)

Address: 4006_6000h base + 114h offset = 4006_6114h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0						BBF	SBF	0							
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	SARF	GCF	AM1F	AM0F	FEF	BEF	SDF	RSF	0				TAF	AVF	RDF	TDF
W					w1c	w1c	w1c	w1c								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPI2Cx_SSR field descriptions

Field	Description
31–26 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
25 BBF	Bus Busy Flag 0 I2C Bus is idle. 1 I2C Bus is busy.
24 SBF	Slave Busy Flag 0 I2C Slave is idle. 1 I2C Slave is busy.
23–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15 SARF	SMBus Alert Response Flag This flag is cleared by reading the Address Status Register. This flag cannot generate an asynchronous wakeup. 0 SMBus Alert Response disabled or not detected. 1 SMBus Alert Response enabled and detected.
14 GCF	General Call Flag This flag is cleared by reading the Address Status Register. This flag cannot generate an asynchronous wakeup. 0 Slave has not detected the General Call Address or General Call Address disabled. 1 Slave has detected the General Call Address.
13 AM1F	Address Match 1 Flag Indicates that the received address has matched the ADDR1 field or ADDR0 to ADDR1 range as configured by ADDRCFG. This flag is cleared by reading the Address Status Register. This flag cannot generate an asynchronous wakeup. 0 Have not received ADDR1 or ADDR0/ADDR1 range matching address. 1 Have received ADDR1 or ADDR0/ADDR1 range matching address.
12 AM0F	Address Match 0 Flag Indicates that the received address has matched the ADDR0 field as configured by ADDRCFG. This flag is cleared by reading the Address Status Register. This flag cannot generate an asynchronous wakeup. 0 Have not received ADDR0 matching address. 1 Have received ADDR0 matching address.
11 FEF	FIFO Error Flag FIFO error flag can only set when clock stretching is disabled. 0 FIFO underflow or overflow not detected. 1 FIFO underflow or overflow detected.
10 BEF	Bit Error Flag This flag will set if the LPI2C slave transmits a logic one and detects a logic zero on the I2C bus. The slave will ignore the rest of the transfer until the next (repeated) START condition.

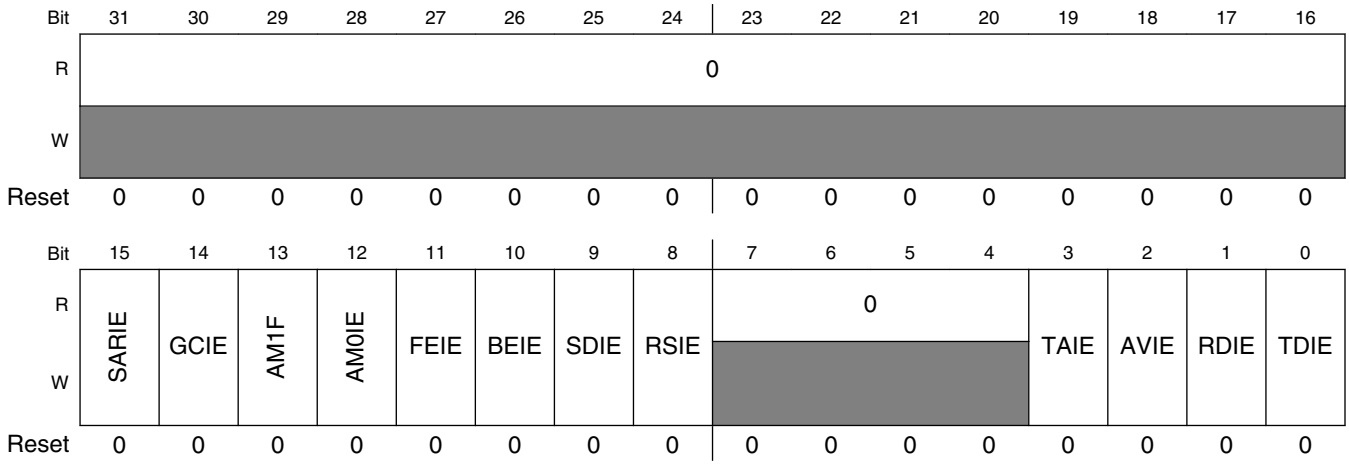
Table continues on the next page...

LPI2Cx_SSR field descriptions (continued)

Field	Description
	0 Slave has not detected a bit error. 1 Slave has detected a bit error.
9 SDF	STOP Detect Flag This flag will set when the LPI2C slave detects a STOP condition, provided the LPI2C slave matched the last address byte. 0 Slave has not detected a STOP condition. 1 Slave has detected a STOP condition.
8 RSF	Repeated Start Flag This flag will set when the LPI2C slave detects a repeated START condition, provided the LPI2C slave matched the last address byte. It does not set when the slave first detects a START condition. 0 Slave has not detected a Repeated START condition. 1 Slave has detected a Repeated START condition.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 TAF	Transmit ACK Flag This flag is cleared by writing the transmit ACK register. 0 Transmit ACK/NACK is not required. 1 Transmit ACK/NACK is required.
2 AVF	Address Valid Flag This flag is cleared by reading the address status register. When RXCFG is set, this flag is also cleared by reading the receive data register. 0 Address Status Register is not valid. 1 Address Status Register is valid.
1 RDF	Receive Data Flag This flag is cleared by reading the receive data register. When RXCFG is set, this flag is not cleared when reading the receive data register and AVF is set. 0 Receive Data is not ready. 1 Receive data is ready.
0 TDF	Transmit Data Flag This flag is cleared by writing the transmit data register. When TXCFG is clear, it is also cleared if a NACK or Repeated START or STOP condition is detected. 0 Transmit data not requested. 1 Transmit data is requested.

40.3.20 Slave Interrupt Enable Register (LPI2Cx_SIER)

Address: 4006_6000h base + 118h offset = 4006_6118h



LPI2Cx_SIER field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15 SARIE	SMBus Alert Response Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
14 GCIE	General Call Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
13 AM1F	Address Match 1 Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
12 AM0IE	Address Match 0 Interrupt Enable 0 Interrupt enabled. 1 Interrupt disabled.
11 FEIE	FIFO Error Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
10 BEIE	Bit Error Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
9 SDIE	STOP Detect Interrupt Enable

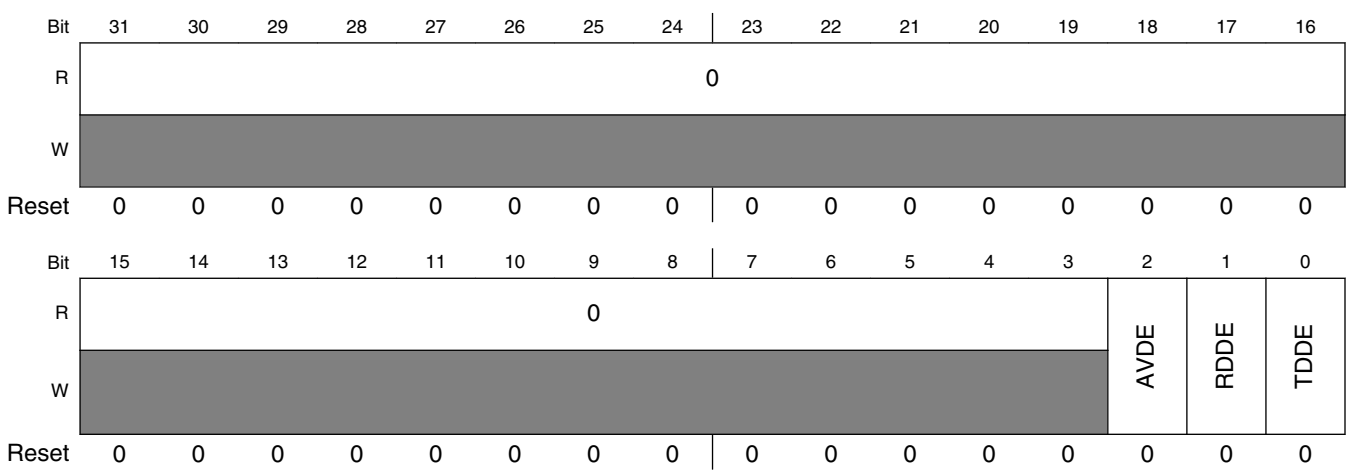
Table continues on the next page...

LPI2Cx_SIER field descriptions (continued)

Field	Description
	0 Interrupt disabled. 1 Interrupt enabled.
8 RSIE	Repeated Start Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 TAIE	Transmit ACK Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
2 AVIE	Address Valid Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
1 RDIE	Receive Data Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled.
0 TDIE	Transmit Data Interrupt Enable 0 Interrupt disabled. 1 Interrupt enabled

40.3.21 Slave DMA Enable Register (LPI2Cx_SDER)

Address: 4006_6000h base + 11Ch offset = 4006_611Ch



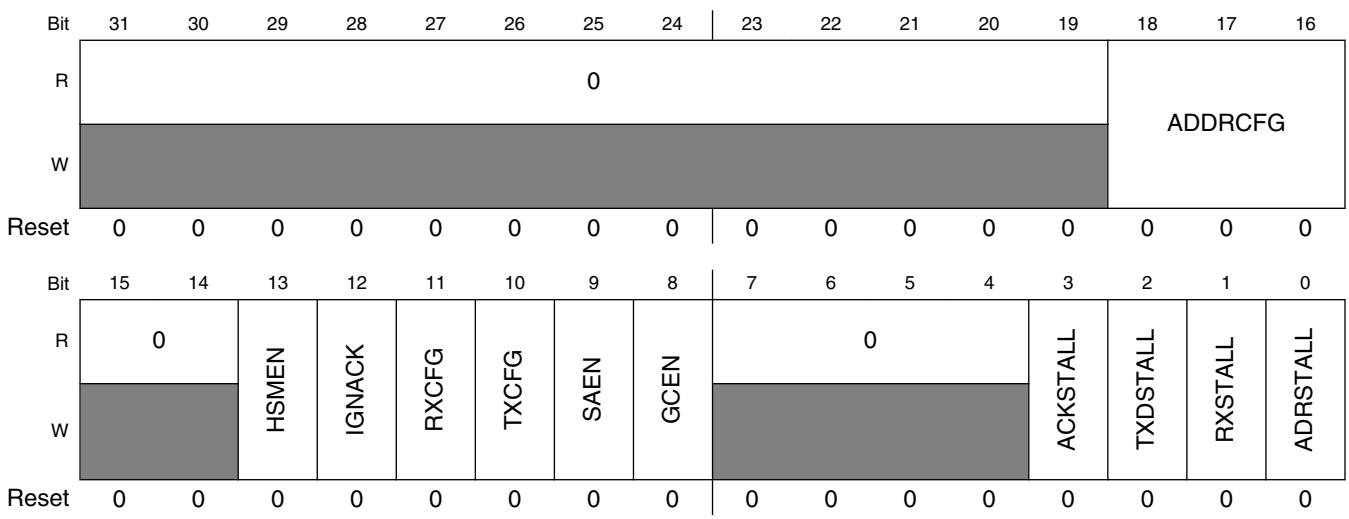
LPI2Cx_SDER field descriptions

Field	Description
31–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
2 AVDE	Address Valid DMA Enable The Address Valid DMA request is shared with the Receive Data DMA request. If both are enabled, then set RXCFG to allow the DMA to read the address from the Receive Data Register. 0 DMA request disabled. 1 DMA request enabled.
1 RDDE	Receive Data DMA Enable 0 DMA request disabled. 1 DMA request enabled.
0 TDDE	Transmit Data DMA Enable 0 DMA request disabled. 1 DMA request enabled

40.3.22 Slave Configuration Register 1 (LPI2Cx_SCFGR1)

The SCFGR1 should only be written when the I2C Slave is disabled.

Address: 4006_6000h base + 124h offset = 4006_6124h



LPI2Cx_SCFGR1 field descriptions

Field	Description
31–19 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
18–16 ADDRCFG	Address Configuration

Table continues on the next page...

LPI2Cx_SCFGR1 field descriptions (continued)

Field	Description
	Configures the condition that will cause an address to match. 000 Address match 0 (7-bit). 001 Address match 0 (10-bit). 010 Address match 0 (7-bit) or Address match 1 (7-bit). 011 Address match 0 (10-bit) or Address match 1 (10-bit). 100 Address match 0 (7-bit) or Address match 1 (10-bit). 101 Address match 0 (10-bit) or Address match 1 (7-bit). 110 From Address match 0 (7-bit) to Address match 1 (7-bit). 111 From Address match 0 (10-bit) to Address match 1 (10-bit).
15–14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13 HSMEN	High Speed Mode Enable Enables detection of the High-speed Mode master code of slave address 0000_1XX, but does not cause an address match on this code. When set and any Hs-mode master code is detected, the FILTEN and ACKSTALL bits are ignored until the next STOP condition is detected. 0 Disables detection of Hs-mode master code. 1 Enables detection of Hs-mode master code.
12 IGNACK	Ignore NACK When set, the LPI2C slave will continue transfers after a NACK is detected. This bit is required to be set in Ultra-Fast Mode. 0 Slave will end transfer when NACK detected. 1 Slave will not end transfer when NACK detected.
11 RXCFG	Receive Data Configuration 0 Reading the receive data register will return receive data and clear the receive data flag. 1 Reading the receive data register when the address valid flag is set will return the address status register and clear the address valid flag. Reading the receive data register when the address valid flag is clear will return receive data and clear the receive data flag.
10 TXCFG	Transmit Flag Configuration The transmit data flag will always assert before a NACK is detected at the end of a slave-transmit transfer. This can cause an extra word to be written to the transmit data FIFO. When TXCFG=0, the transmit data register is automatically emptied when a slave-transmit transfer is detected. This cause the transmit data flag to assert whenever a slave-transmit transfer is detected and negate at the end of the slave-transmit transfer. When TXCFG=1, the transmit data flag will assert whenver the transit data register is empty and negate when the transmit data register is full. This allows the transmit data register to be filled before a slave-transmit transfer is detected, but can cause the transmit data register to be written before a NACK is detected on the last byte of a slave transmit transfer. 0 Transmit Data Flag will only assert during a slave-transmit transfer when the transmit data register is empty. 1 Transmit Data Flag will assert whenever the transmit data register is empty.
9 SAEN	SMBus Alert Enable

Table continues on the next page...

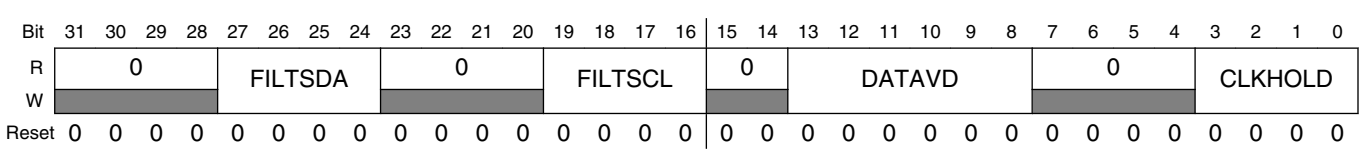
LPI2Cx_SCFGR1 field descriptions (continued)

Field	Description
	0 Disables match on SMBus Alert. 1 Enables match on SMBus Alert.
8 GCEN	General Call Enable 0 General Call address is disabled. 1 General call address is enabled.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 ACKSTALL	ACK SCL Stall Enables SCL clock stretching during slave-transmit address byte(s) and slave-receiver address and data byte(s) to allow software to write the Transmit ACK Register before the ACK or NACK is transmitted. Clock stretching occurs when transmitting the 9th bit and is therefore not compatible with high speed mode. When ACKSTALL is enabled, there is no need to set either RXSTALL or ADRSTALL 0 Clock stretching disabled. 1 Clock stretching enabled.
2 TXDSTALL	TX Data SCL Stall Enables SCL clock stretching when the transmit data flag is set during a slave-transmit transfer. Clock stretching occurs following the 9th bit and is therefore compatible with high speed mode. 0 Clock stretching disabled. 1 Clock stretching enabled.
1 RXSTALL	RX SCL Stall Enables SCL clock stretching when receive data flag is set during a slave-receive transfer. Clock stretching occurs following the 9th bit and is therefore compatible with high speed mode. 0 Clock stretching disabled. 1 Clock stretching enabled.
0 ADRSTALL	Address SCL Stall Enables SCL clock stretching when the address valid flag is asserted. Clock stretching only occurs following the 9th bit and is therefore compatible with high speed mode. 0 Clock stretching disabled. 1 Clock stretching enabled.

40.3.23 Slave Configuration Register 2 (LPI2Cx_SCFGR2)

The SCFGR2 should only be written when the I2C Slave is disabled.

Address: 4006_6000h base + 128h offset = 4006_6128h



LPI2Cx_SCFGR2 field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 FILTSDA	Glitch Filter SDA Configures the I2C slave digital glitch filters for SDA input, a configuration of 0 will disable the glitch filter. Glitches equal to or less than FILTSDA cycles long will be filtered out and ignored. The latency through the glitch filter is equal to FILTSDA+3 cycles and must be configured less than the minimum SCL low or high period. The glitch filter cycle count is not affected by the PRESCALE configuration, and is disabled in high speed mode.
23–20 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
19–16 FILTSCL	Glitch Filter SCL Configures the I2C slave digital glitch filters for SCL input, a configuration of 0 will disable the glitch filter. Glitches equal to or less than FILTSCL cycles long will be filtered out and ignored. The latency through the glitch filter is equal to FILTSCL+3 cycles and must be configured less than the minimum SCL low or high period. The glitch filter cycle count is not affected by the PRESCALE configuration, and is disabled in high speed mode.
15–14 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
13–8 DATAVD	Data Valid Delay Configures the SDA data valid delay time for the I2C slave equal to FILTSCL+DATAVD+3 cycles. This data valid delay must be configured to less than the minimum SCL low period. The I2C slave data valid delay time is not affected by the PRESCALE configuration, and is disabled in high speed mode.
7–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
CLKHOLD	Clock Hold Time Configures the minimum clock hold time for the I2C slave, when clock stretching is enabled. The minimum hold time is equal to CLKHOLD+3 cycles. The I2C slave clock hold time is not affected by the PRESCALE configuration, and is disabled in high speed mode.

40.3.24 Slave Address Match Register (LPI2Cx_SAMR)

Address: 4006_6000h base + 140h offset = 4006_6140h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0					ADDR1										0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0					ADDR0										0
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPI2Cx_SAMR field descriptions

Field	Description
31–27 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
26–17 ADDR1	Address 1 Value Compared against the received address to detect the Slave Address. In 10-bit mode, the first address byte is compared to { 11110, ADDR1[10:9] } and the second address byte is compared to ADDR1[8:1]. In 7-bit mode, the address is compared to ADDR1[7:1].
16–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10–1 ADDR0	Address 0 Value Compared against the received address to detect the Slave Address. In 10-bit mode, the first address byte is compared to { 11110, ADDR0[10:9] } and the second address byte is compared to ADDR0[8:1]. In 7-bit mode, the address is compared to ADDR0[7:1].
0 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

40.3.25 Slave Address Status Register (LPI2Cx_SASR)

Address: 4006_6000h base + 150h offset = 4006_6150h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	ANV	0			RADDR										
W																
Reset	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

LPI2Cx_SASR field descriptions

Field	Description
31–15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14 ANV	Address Not Valid 0 RADDR is valid. 1 RADDR is not valid.
13–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
RADDR	Received Address RADDR updates whenever the AMF is set and the AMF is cleared by reading this register. In 7-bit mode, the address byte is store in RADDR[7:0]. In 10-bit mode, the first address byte is { 11110, RADDR[10:9],

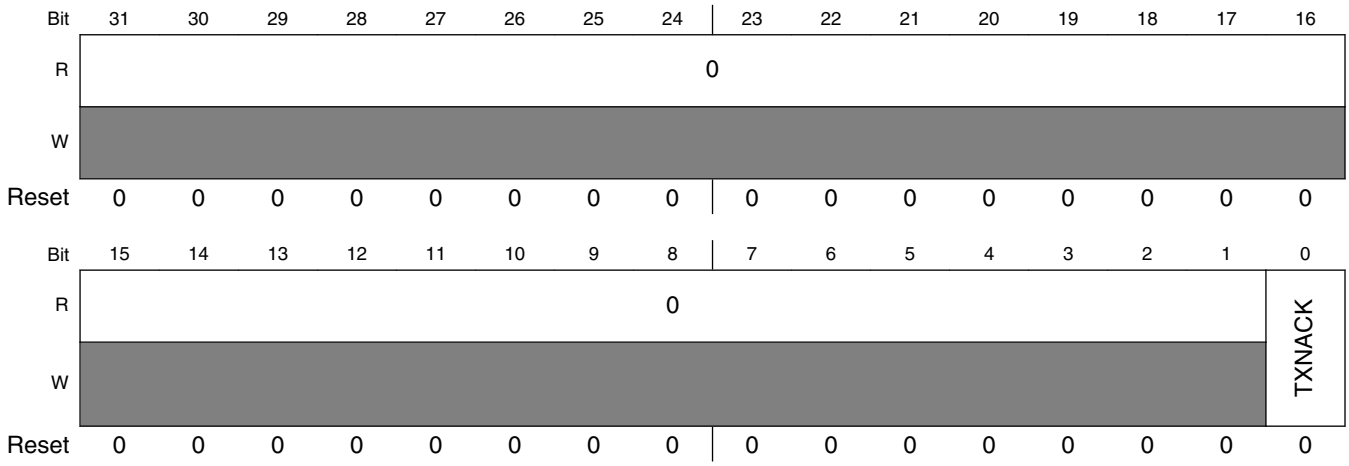
Table continues on the next page...

LPI2Cx_SASR field descriptions (continued)

Field	Description
	RADDR[0] } and the second address byte is RADDR[8:1]. The R/W bit is therefore always stored in RADDR[0].

40.3.26 Slave Transmit ACK Register (LPI2Cx_STAR)

Address: 4006_6000h base + 154h offset = 4006_6154h

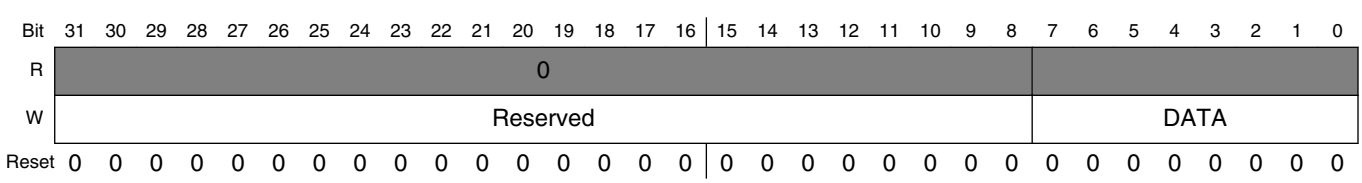


LPI2Cx_STAR field descriptions

Field	Description
31–1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 TXNACK	Transmit NACK When NACKSTALL is set, must be written once for each matching address byte and each received word. Can also be written when LPI2C Slave is disabled or idle to configure the default ACK/NACK. 0 Transmit ACK for received word. 1 Transmit NACK for received word.

40.3.27 Slave Transmit Data Register (LPI2Cx_STDR)

Address: 4006_6000h base + 160h offset = 4006_6160h

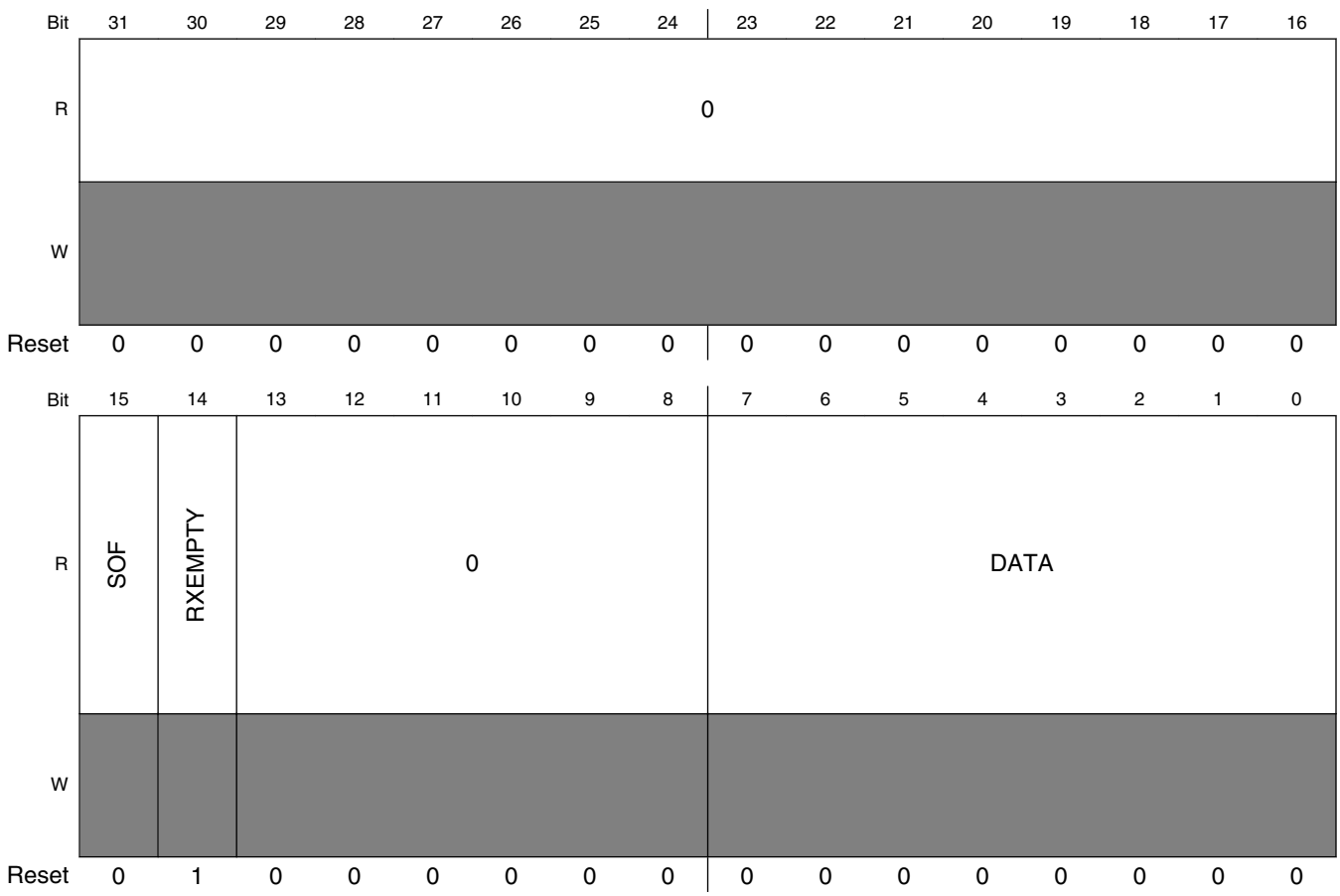


LPI2Cx_STDR field descriptions

Field	Description
31–8 Reserved	This field is reserved.
DATA	Transmit Data Writing this register will store I2C slave transmit data in the transmit register.

40.3.28 Slave Receive Data Register (LPI2Cx_SRDR)

Address: 4006_6000h base + 170h offset = 4006_6170h



LPI2Cx_SRDR field descriptions

Field	Description
31–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15 SOF	Start Of Frame 0 Indicates this is not the first data word since a (repeated) START or STOP condition. 1 Indicates this is the first data word since a (repeated) START or STOP condition.

Table continues on the next page...

LPI2Cx_SRDR field descriptions (continued)

Field	Description
14 RXEMPTY	RX Empty 0 The Receive Data Register is not empty. 1 The Receive Data Register is empty.
13–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
DATA	Receive Data Reading this register returns the data received by the I2C slave.

40.4 Functional description

40.4.1 Clocking and Resets

40.4.1.1 Functional clock

The LPI2C functional clock is asynchronous to the bus clock and can remain enabled in low power modes to support I2C bus transfers by the LPI2C master. It is also used by the LPI2C slave to support digital filter and data hold time configurations. The LPI2C master divides the functional clock by a prescaler and the resulting frequency must be at least eight times faster than the I2C bus bandwidth.

40.4.1.2 External clock

The LPI2C slave logic is clocked directly from the external pins LPI2C_SCL and LPI2C_SDA (or LPI2C_SCLS and LPI2C_SDAS if master and slave are implemented on separate pins). This allows the LPI2C slave to remain operational, even when the LPI2C functional clock is disabled. Note that the LPI2C slave digital filter must be disabled if the LPI2C functional clock is disabled and this can effect compliance with some of the timing parameters of the I2C specification, such as the data hold time.

40.4.1.3 Bus clock

The bus clock is only used for bus accesses to the control and configuration registers. The bus clock frequency must be sufficient to support the data bandwidth requirements of the LPI2C master and slave registers.

40.4.1.4 Chip reset

The logic and registers for the LPI2C master and slave are reset to their default state on a chip reset.

40.4.1.5 Software reset

The LPI2C master implements a software reset bit in its Control Register. The MCR[RST] will reset all master logic and registers to their default state, except for the MCR itself.

The LPI2C slave implements a software reset bit in its Control Register. The SCR[RST] will reset all slave logic and registers to their default state, except for the SCR itself.

40.4.1.6 FIFO reset

The LPI2C master implements write-only control bits that resets the transmit FIFO (MCR[RTF] and receive FIFO (MCR[RRF]). A FIFO is empty after being reset.

The LPI2C slave implements write-only control bits that resets the transmit data register (SCR[RTF] and receive data register (SCR[RRF]). A data register is empty after being reset.

40.4.2 Master Mode

The LPI2C master logic operates independently from the slave logic to perform all master mode transfers on the I2C bus.

40.4.2.1 Transmit and Command FIFO

The transmit FIFO stores command data to initiate the various I2C operations. The following operations can be initiated through commands in the transmit FIFO:

- START or Repeated START condition with address byte and expecting ACK or NACK.
- Transmit data (this is the default for zero extended byte writes to the transmit FIFO).
- Receive 1-256 bytes of data (can also be configured to discard receive data and not store in receive FIFO).
- STOP condition (can also be configured to send STOP condition when transmit FIFO is empty).

Multiple transmit and receive commands can be inserted between the START condition and STOP conditon, transmit and receive commands must not be interleaved in order to comply with the I2C specification. The receive data command and the receive data and discard command can be interleaved to ensure only the desired received data is stored in the receive FIFO (or compared with the data match logic).

The LPI2C master supports 10-bit addressing through a (repeated) START condition, followed by a transmit byte with the second address byte, followed by any number of data bytes with the master-transmit data.

A START or Repeated START condition that is expecting a NACK (for example, hs-mode master code) must be followed by a STOP or (repeated) START condition.

40.4.2.2 Master Operation

Whenever the LPI2C is enabled, it monitors the I2C bus to detect when the I2C bus is idle (MSR[BBF]). The I2C bus is no longer considered idle if either SCL or SDA are low and becomes idle if a STOP condition is detected or if a bus idle timeout is detected (as configured by MCFGR2[BUSIDLE]). Once the I2C bus is idle, the transmit FIFO is not empty, and the host request is either asserted or disabled, then the LPI2C master will initiate a transfer on the I2C bus. This involves the following steps:

- Wait the bus idle time equal to (MCCR0[CLKLO] + 1) multiplied by the prescaler.
- Transmit a START condition and address byte using the timing configuration in MCCR0, if a high speed mode transfer is configured then timing configuration from MCCR1 is used instead.
- Perform master-transmit or master-receive transfers, as configured by the transmit FIFO.
- Transmit a Repeated START or STOP condition as configured by the transmit FIFO and/or MCFGR1[AUTOSTOP]. A repeated START can change which timing configuration register is used.

When the LPI2C master is disabled (either due to MCR[MEN] being clear or automatically due to mode entry), the LPI2C will continue to empty the transmit FIFO until a STOP condition is transmitted. However, it will no longer stall the I2C bus waiting for the transmit or receive FIFO and once the transmit FIFO is empty it will generate a STOP condition automatically.

The LPI2C master can stall the I2C bus under certain conditions, this will result in SCL pulled low continuously on the first bit of a byte until the condition is removed:

- LPI2C master is enabled and busy, transmit FIFO is empty, and MCFGR1[AUTOSTOP] is clear.
- LPI2C master is enabled and receiving data, receive data is not being discarded (due to command or receive data match), and receive FIFO is full.

40.4.2.3 Receive FIFO and Data Match

The receive FIFO is used to store receive data during master-receiver transfers. Receive data can also be configured to discard receive data instead of storing in the receive FIFO, this is configured by the command word in the transmit FIFO.

Receive data supports a receive data match function that can match received data against one of two bytes or against a masked data byte. The data match function can also be configured to compare only the first one or two received data words since the last (repeated) START condition. Receive data that is already discarded due to the command word cannot cause the data match to set and will delay the match on first received data word until after the discarded data is received. The receiver match function can also be configured to discard all receive data until a data match is detected, using the MCFGR0[RDMO] control bit. When clearing the MCFGR0[RDMO] control bit following a data match, clear MCFGR0[RDMO] before clearing MSR[DMF] to allow all subsequent data to be received.

40.4.2.4 Timing Parameters

The following timing parameters can be configured by the LPI2C master. Parameters are configured separately for high speed mode (MCCR1) and other modes (MCCR0). This allows the high speed mode master code to be sent using the regular timing parameters and then switch to the high speed mode timing (following a repeated START) until the next STOP condition.

The LPI2C master timing parameters in LPI2C functional clock cycles are configured as follows. They must be configured to meet the I2C timing specification for the required mode.

- Bus idle time is always (MCCR0[CLKLO] + 1) multiplied by the prescaler. This is extended by the time it takes to detect external SDA rising edge.
- START or repeated START hold time is equal to (MCCR0/1[SETHOLD] + 1) multiplied by the prescaler.
- START, or repeated START, or STOP setup time is equal to (MCCR0/1[SETHOLD] + 1) multiplied by the prescaler. This is extended by the time it takes to detect external SCL rising edge.
- SCL low time (before clock stretching) is equal to (MCCR0/1[CLKLO] + 1) multiplied by the prescaler.
- SCL high time is equal to (MCCR0/1[CLKHI] + 1) multiplied by the prescaler. This is extended by the time it takes to detect external SCL rising edge.
- SDA output delay is equal to (MCCR0/1[DATAVD] + 1) multiplied by the prescaler.

The time taken to detect an external rising edge depends on a number of factors including the bus loading and external pull-up resistor sizing. The minimum delay equals two plus the pin input digital filter setting (which are configured separately for SCL and SDA), divided by the prescaler (since the pin input digital filters are not affected by the prescaler setting).

The following timing restrictions must be enforced to avoid unexpected START or STOP conditions on the I2C bus or unexpected START or STOP conditions detected by the LPI2C master. They can be summarized as SDA cannot change when SCL is high outside of a transmitted (repeated) START or STOP condition.

Table 40-3. Timing Parameters

Timing Parameter	Minimum	Maximum	Comment
CLKLO	0x03	-	CLKLO must also be greater than delay through the SCL filter.
CLKHI	0x01	-	
SETHOLD	0x02	-	
DATAVD	0x01	CLKLO - [(FILTSDA+2) / (2 ^ PRESCALER)]	DATAVD must be less than CLKLO minus delay through the SDA filter.
FILTSCL	0x00	[CLKLO × (2 ^ PRESCALER)] - 3	
FILTSDA	FILTSCL	[CLKLO × (2 ^ PRESCALER)] - 3	Does not apply if compensating for board level skew between SCL and SDA.
BUSIDLE	(CLKLO+SETHOLD+2) × 2	-	Must also be greater than CLKHI+1.

The timing parameters must be configured to meet the requirements of the I2C specification, this will depend on the mode being supported, the frequency of the LPI2C functional clock. Some example configurations are provided below.

Table 40-4. LPI2C Example Timing Configurations

I2C Mode	Clock Frequency	Baud Rate	PRESCALER	FILTSCL/ FILTSDA	SETHOLD	CLKLO	CLKHI	DATAVD
Fast	8 MHz	400 kbps	0x0	0x0/0x0	0x04	0x0B	0x05	0x02
Fast+	8 MHz	1 Mbps	0x0	0x0/0x0	0x02	0x03	0x01	0x01
Fast	48 MHz	400 kbps	0x2	0x1/0x1	0x07	0x11	0x0B	0x03
Fast+	48 MHz	1 Mbps	0x2	0x1/0x1	0x03	0x06	0x04	0x04
Fast+	48 MHz	1 Mbps	0x0	0x1/0x1	0x1D	0x18	0x13	0x0F
HS-mode	48 MHz	3.2 Mbps	0x0	0x0/0x0	0x07	0x08	0x03	0x01
Fast	60 MHz	400 kbps	0x1	0x2/0x2	0x11	0x28	0x21	0x08
Fast+	60 MHz	1 Mbps	0x1	0x2/0x2	0x07	0x0F	0x0B	0x01
HS-mode	60 MHz	3.33 Mbps	0x1	0x0/0x0	0x04	0x03	0x04	0x01
Ultrafast	60 MHz	5 Mbps	0x0	0x0/0x0	0x02	0x05	0x03	0x01

The formula to calculate number of cycles per bit is as follows:

*Baud rate divide = ((CLKLO+CLKHI+2)*2^PRESCALER) + ROUNDDOWN((2+FILTSCL)/2^PRESCALER)*

This assumes SCL will pull high within 1 cycle of the LPI2C functional clock, this will depend on the pullup resistor and loading on the SCL pin.

40.4.2.5 Error Conditions

The LPI2C master will monitor for errors while it is active, the following conditions will generate an error flag and block a new START condition from being sent until the flag is cleared by software:

- START or STOP condition detected and not generated by LPI2C master (sets MSR[ALF]).
- Transmitting data on SDA and different value being received (sets MSR[ALF]).
- NACK detected when transmitting data, provided MCFGR1[IGNACK] is clear (sets MSR[NDF]).
- NACK detected and expecting ACK for address byte, provided MCFGR1[IGNACK] is clear (sets MSR[NDF]).
- ACK detected and expecting NACK for address byte, provided MCFGR1[IGNACK] is clear (sets MSR[NDF]).

- Transmit FIFO requesting to transmit or receive data without a START condition (sets MSR[FEF]).
- SCL (or SDA if MCFGR1[TIMECFG] is set) is low for (MCFGR2[TIMELOW] * 256) prescaler cycles without a pin transition (sets MSR[PLTF]).

Software must respond to the MSR[PTLF] flag to terminate the existing command either cleanly (by clearing MCR[MEN]) or abruptly (by setting MCR[SWRST]).

The MCFGR2[BUSIDLE] field can be used to force the I2C bus to be considered idle when SCL and SDA remain high for (BUSIDLE+1) prescaler cycles. The I2C bus is normally considered idle when the LPI2C master is first enabled, but when BUSIDLE is configured greater than zero then SCL and/or SDA must be high for (BUSIDLE+1) prescaler cycles before the I2C bus is first considered idle.

40.4.2.6 Pin Configuration

The LPI2C master defaults to open-drain configuration of the LPI2C_SDA and LPI2C_SCL pins. Support for true open drain is device specific and requires the pins where LPI2C pins are muxed to support true open drain. Support for high speed mode is also device specific and requires the LPI2C_SCL pin to support the current source pull-up required in the I2C specification.

The LPI2C master also supports the output only push-pull function required for I2C ultra-fast mode using the LPI2C_SDA and LPI2C_SCL pins. Support for ultra-fast mode also requires the IGNACK bit to be set.

A push-pull 2 wire configuration is also available to the LPI2C master that may support a partial high speed mode provided the LPI2C is the only master and all I2C pins on the bus are at the same voltage. This will configure the LPI2C_SCL pin as push-pull for every clock except the 9th clock pulse to allow high speed mode compatible slaves to perform clock stretching. In this mode, the LPI2C_SDA pin is tristated for master-receive data bits and master-transmit ACK/NACK bits.

The push-pull 4 wire configuration separates the SCL input and output and the SDA input and output onto separate pins, with SCL/SDA used as the input pins and SCLS/SDAS used as the output pins with configurable polarity. This simplifies the external connections when connecting the I2C bus to external level shifters. The LPI2C master logic and LPI2C slave logic are not able to connect to separate I2C buses when using this configuration.

40.4.3 Slave Mode

The LPI2C slave logic operates independently from the master logic to perform all slave mode transfers on the I2C bus.

40.4.3.1 Address Match

The LPI2C slave can be configured to match one of two addresses using either 7-bit or 10-bit addressing modes for each address, or to match a range of addresses in either 7-bit or 10-bit addressing modes. Separately, it can be configured to match the General Call Address or the SMBus Alert Address and generate appropriate flags. The LPI2C slave can also be configured to detect the high speed mode master code and to disable the digital filters and output valid delay time until the next STOP condition is detected.

Once a valid address is matched, the LPI2C slave will automatically perform slave-transmit or slave-receive transfers until a NACK is detected (unless IGNACK is set), a bit error is detected (the LPI2C slave is driving SDA, but a different value is sampled), or a (repeated) START or STOP condition is detected.

40.4.3.2 Transmit and Receive

The transmit and receive data registers are double buffered and only update during a slave-transmit and slave-receive transfer respectively. The slave address that was received can be configured to be read from either the receive data register (for example, when using DMA to transfer data) or from the address status register. The transmit data register can be configured to only request data once a slave-transmit transfer is detected or to request new data whenever the transmit data register is empty.

The transmit data register should only be written when the transmit data flag is set. The receive data register should only be read when the received data flag is set (or the address valid flag is set and RXCFG=1). The address status register should only be read when the address valid flag is set.

40.4.3.3 Clock Stretching

The LPI2C slave supports many configurable options for when clock stretching is performed. The following conditions can be configured to perform clock stretching.

- During 9th clock pulse of address byte and address valid flag is set.
- During 9th clock pulse of slave-transmit transfer and transmit data flag is set.
- During 9th clock pulse of slave-receive transfer and receive data flag is set.

- During 8th clock pulse of address byte or slave-receive transfer and transmit ACK flag is set. This is disabled in high speed mode.
- Clock stretching can also be extended for CLKHOLD cycles to allow additional setup time to sample the SDA pin externally. This is disabled in high speed mode.

Unless extended by the CLKHOLD configuration, clock stretching will extend for one peripheral bus clock cycle after SDA updates when clock stretching is enabled.

40.4.3.4 Timing Parameters

The LPI2C slave can configure the following timing parameters, these parameters are disabled when SCR[FILTEN] is clear, when SCR[FILTDZ] is set in Doze mode, and when LPI2C slave detects high speed mode. When disabled, the LPI2C slave is clocked directly from the I2C bus and may not satisfy all timing requirements of the I2C specification (such as SDA minimum hold time in Standard/Fast mode).

- SDA data valid time from SCL negation to SDA update.
- SCL hold time when clock stretching is enabled to increase setup time when sampling SDA externally.
- SCL glitch filter time.
- SDA glitch filter time.

The LPI2C slave imposes the following restrictions on the timing parameters.

- FILTSDA must be configured to greater than or equal to FILTSCL (unless compensating for board level skew between SDA and SCL).
- DATAVD must be configured less than the minimum SCL low period.

40.4.3.5 Error Conditions

The LPI2C slave can detect the following error conditions.

- Bit error flag will set when the LPI2C slave is driving SDA, but samples a different value than what is expected.
- FIFO error flag will set due to a transmit data underrun or a receive data overrun. Clock stretching can be enabled to eliminate the possibility of underrun and overrun occurring.
- FIFO error flag will also set due to an address overrun when RXCFG is set, otherwise an address overrun is not flagged. Clock stretching can be enabled to eliminate the possibility of overrun occurring.

The LPI2C slave does not implement a timeout due to SCL and/or SDA being stuck low. If this detection is required, the LPI2C master logic should be used and software can reset the LPI2C slave when this condition is detected.

40.4.4 Interrupts and DMA Requests

The LPI2C master and slave interrupts may be combined depending on the device.

The LPI2C master and slave transmit DMA requests may be combined depending on the device.

The LPI2C master and slave receive DMA requests may be combined depending on the device.

40.4.4.1 Master mode

The following table illustrates the master mode sources that can generate the LPI2C master interrupt and LPI2C master transmit/receive DMA requests.

Table 40-5. Master Interrupts and DMA Requests

Flag	Description	Interrupt	DMA Request	Low Power Wakeup
TDF	Data can be written to transmit FIFO, as configured by TXWATER.	Y	TX	Y
RDF	Data can be read from the receive FIFO, as configured by RXWATER.	Y	RX	Y
EPF	Master has transmitted Repeated START or STOP condition.	Y	N	Y
SDF	Master has transmitted STOP condition.	Y	N	Y
NDF	Master detected NACK during address byte when expecting ACK, master detected ACK during address byte and expecting NACK, or master detected NACK during master-transmitter data byte.	Y	N	Y
ALF	Master lost arbitration due to START/STOP condition detected at	Y	N	Y

Table continues on the next page...

Table 40-5. Master Interrupts and DMA Requests (continued)

Flag	Description	Interrupt	DMA Request	Low Power Wakeup
	wrong time, or Master was transmitting data but received different data than what was transmitted.			
FEF	Master expecting START condition in command FIFO and next entry in FIFO is not START condition.	Y	N	Y
PLTF	Pin low timeout is enabled and SCL (or SDA if configured) is low for longer than the configured timeout.	Y	N	Y
DMF	Received data matches the configured data match, and receive data not discarded due to command FIFO entry.	Y	N	Y
MBF	LPI2C master is busy transmitting/receiving data.	N	N	N
BBF	LPI2C master is enabled and activity detected on I2C bus, but STOP condition has not been detected and bus idle timeout (if enabled) has not occurred.	N	N	N

40.4.4.2 Slave mode

The following table illustrates the slave mode sources that can generate the LPI2C slave interrupt and the LPI2C slave transmit/receive DMA requests.

Table 40-6. Slave Interrupts and DMA Requests

Flag	Description	Interrupt	DMA Request	Low Power Wakeup
TDF	Data can be written to transmit data register.	Y	TX	Y
RDF	Data can be read from the receive data register.	Y	RX	Y

Table continues on the next page...

Table 40-6. Slave Interrupts and DMA Requests (continued)

Flag	Description	Interrupt	DMA Request	Low Power Wakeup
AVF	Address can be read from the address status register.	Y	RX	Y
TAF	ACK/NACK can be written to the transmit ACK register.	Y	N	Y
RSF	Slave has detected an address match followed by a Repeated START condition.	Y	N	Y
SDF	Slave has detected an address match followed by a STOP condition.	Y	N	Y
BEF	Slave was transmitting data, but received different data than what was transmitted.	Y	N	Y
FEF	Transmit data underrun, receive data overrun or address status overrun (when RXCFG=1). This flag can only set when clock stretching is disabled.	Y	N	Y
AM0F	Slave detected address match with ADDR0 field.	Y	N	N
AM1F	Slave detected address match with ADDR1 field or address range.	Y	N	N
GCF	Slave detected address match with general call address.	Y	N	N
SARF	Slave detected address match with SMBus alert address.	Y	N	N
SBF	LPI2C slave is busy receiving address byte or transmitting/receiving data.	N	N	N
BBF	LPI2C slave is enabled and START condition detected on I2C bus, but STOP condition has not been detected.	N	N	N

40.4.5 Peripheral Triggers

The connection of the LPI2C peripheral triggers with other peripherals are device specific.

40.4.5.1 Master Output Trigger

The LPI2C master generates an output trigger that can be connected to other peripherals on the device. The master output trigger asserts on both a Repeated START or STOP condition and remains asserted for one cycle of the LPI2C functional clock divided by the prescaler.

40.4.5.2 Slave Output Trigger

The LPI2C slave generates an output trigger that can be connected to other peripherals on the device. The slave output trigger asserts on both a Repeated START or STOP condition that occurs following a slave address match. It remains asserted until the next slave SCL pin negation.

40.4.5.3 Input Trigger

The LPI2C input trigger can be selected in place of the LPI2C_HREQ pin to control the start of a LPI2C master bus transfer. The input trigger must assert for longer than one LPI2C functional clock cycle to be detected.

40.5 Usage Guide

For master:

- Configure functional clock source
- Reset LPI2C module by LPI2C0_MCR[RST]
- Configure baudrate
- Set Tx/Rx FIFO watermark by LPI2C0_MFCR
- Enable Master mode by set LPI2C0_MCR[MEN]

For slave:

- Configure functional clock source
- Set the slave address into LPI2C0_SAMR
- Configure the TDF only be set in the Slave-Transmit condition by LPI2C0_SCFGR1[TXCFG]

- Enable the TX Data SCL Stall and RX SCL Stall for clock stretching on SCL
- Enable Slave mode by set LPI2C0_SCR[SEN]

Chapter 41
Low Power Universal Asynchronous Receiver/ Transmitter (LPUART)

41.1 Chip-specific information for this module

41.1.1 Instantiation Information

This device has three LPUART modules. The LPUART can remain functional in Stop and VLPS mode provided the clock it is using remains enabled.

Table 41-1. LPUART Configuration

	TX FIFO (word/10bit)	RX FIFO (word/10bit)	Single-wire mode
LPUART0	4	4	Yes
LPUART1	4	4	Yes
LPUART2	4	4	Yes

NOTE

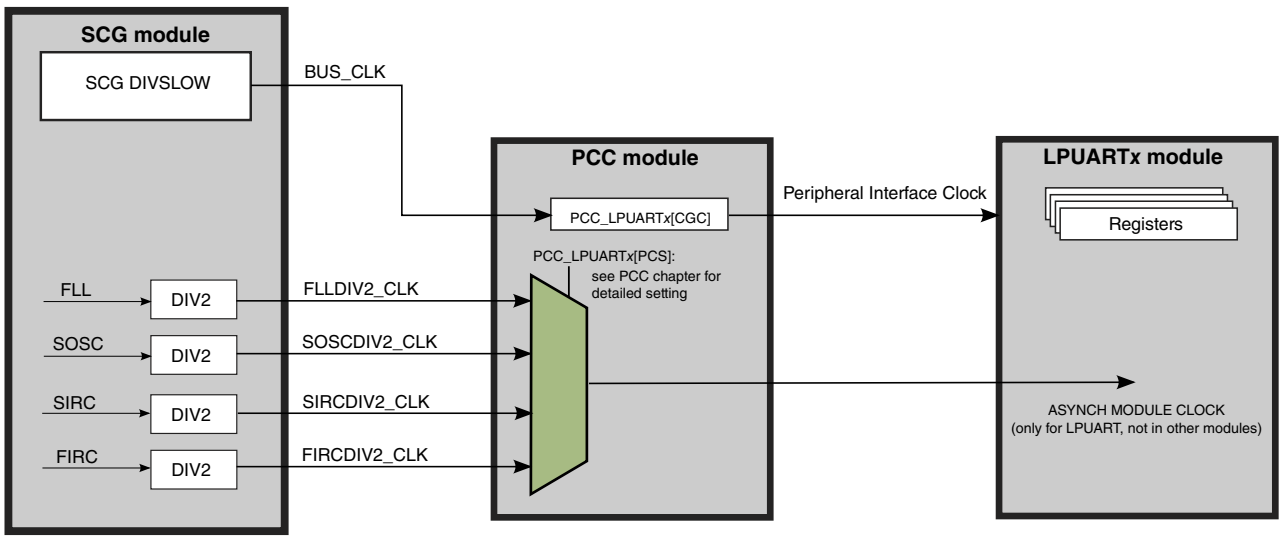
DMA is not supported in this device.

41.1.2 Module Clocking Information for LPUART, LPSPI, LPI2C and LPIT

The following figure shows the input clock sources available for this module.

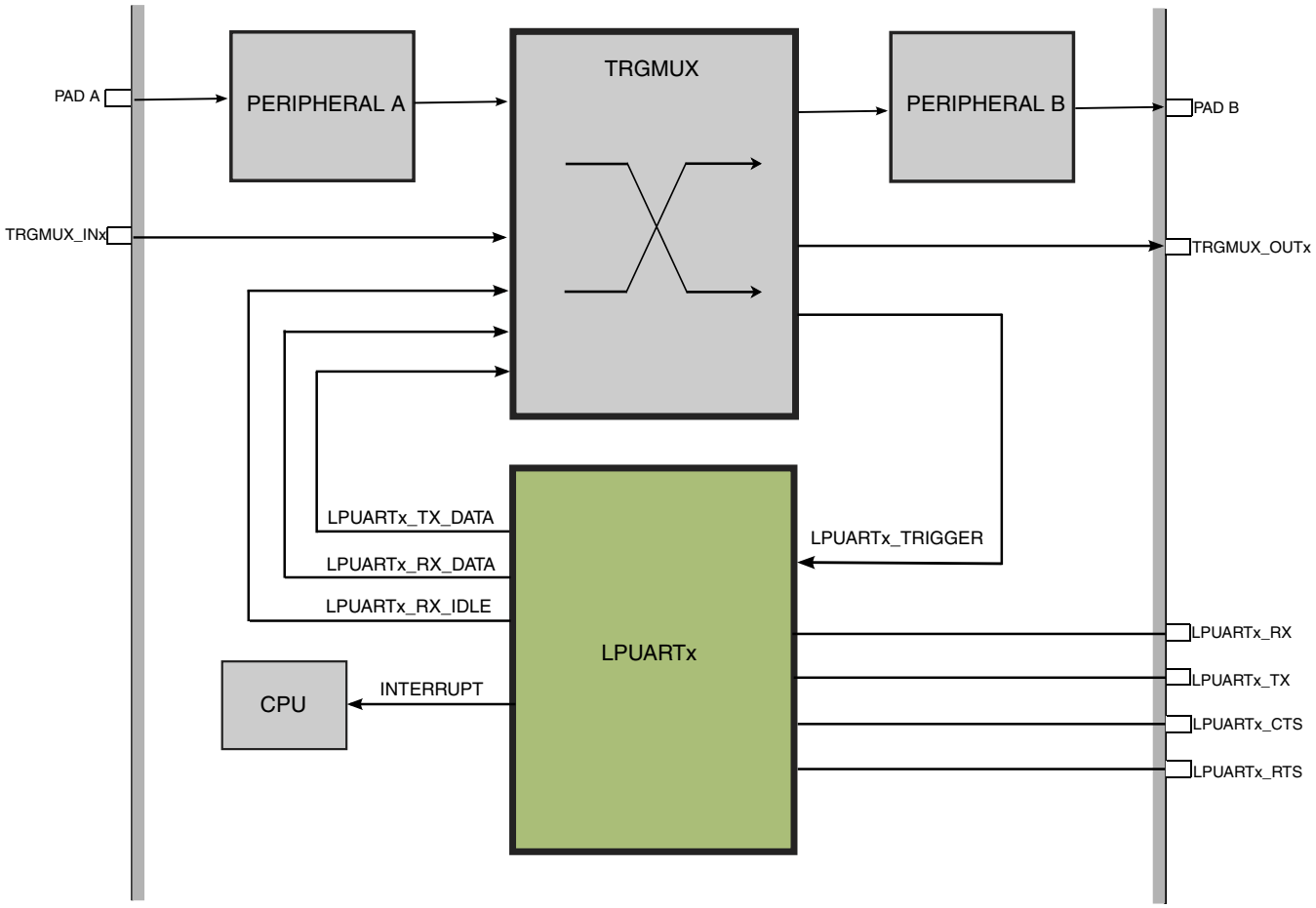
Peripheral Clocking - LPUART, etc.

Note: this example figure also applies similarly to the clocking for LPSPI, LPI2C, LPIT, etc.



41.1.3 Inter-connectivity Information

The LPUART inter-connectivity is shown in following diagram.



41.2 Introduction

41.2.1 Features

Features of the LPUART module include:

- Full-duplex, standard non-return-to-zero (NRZ) format
- Programmable baud rates (13-bit modulo divider) with configurable oversampling ratio from 4x to 32x
- Transmit and receive baud rate can operate asynchronous to the bus clock:
  - Baud rate can be configured independently of the bus clock frequency
  - Supports operation in Stop modes
- Interrupt or polled operation:
  - Transmit data register empty and transmission complete

    - Receive data register full
    - Receive overrun, parity error, framing error, and noise error
    - Idle receiver detect
    - Active edge on receive pin
    - Break detect supporting LIN
    - Receive data match
- Hardware parity generation and checking
- Programmable 7-bit, 8-bit, 9-bit or 10-bit character length
- Programmable 1-bit or 2-bit stop bits
- Three receiver wakeup methods:
    - Idle line wakeup
    - Address mark wakeup
    - Receive data match
- Automatic address matching to reduce ISR overhead:
    - Address mark matching
    - Idle line address matching
    - Address match start, address match end
- Optional 13-bit break character generation / 11-bit break character detection
- Configurable idle length detection supporting 1, 2, 4, 8, 16, 32, 64 or 128 idle characters
- Selectable transmitter output and receiver input polarity
- Hardware flow control support for request to send (RTS) and clear to send (CTS) signals
- Selectable IrDA 1.4 return-to-zero-inverted (RZI) format with programmable pulse width
- Independent FIFO structure for transmit and receive
    - Separate configurable watermark for receive and transmit requests
    - Option for receiver to assert request after a configurable number of idle characters if receive FIFO is not empty

41.2.2 Modes of operation

41.2.2.1 Stop mode

The LPUART remains functional during Stop mode, provided the CTRL[DOZEEN] bit is clear and the asynchronous transmit and receive clock remain enabled. The LPUART can generate an interrupt to cause a wakeup from Stop mode.

If the LPUART is disabled in Stop mode, then it can generate a wakeup via the STAT[RXEDGIF] flag if the receiver detects an active edge.

41.2.2.2 Wait mode

The LPUART can be configured to Stop in Wait modes, when the CTRL[DOZEEN] bit is set. The transmitter and receiver finish transmitting/receiving the current word.

41.2.3 Signal Descriptions

Signal	Description	I/O
TXD	Transmit data. This pin is normally an output, but is an input (tristated) in single wire mode whenever the transmitter is disabled or transmit direction is configured for receive data.	I/O
RXD	Receive data.	I
CTS_B	Clear to send.	I
RTS_B	Request to send.	O

41.2.4 Block diagram

The following figure shows the transmitter portion of the LPUART.

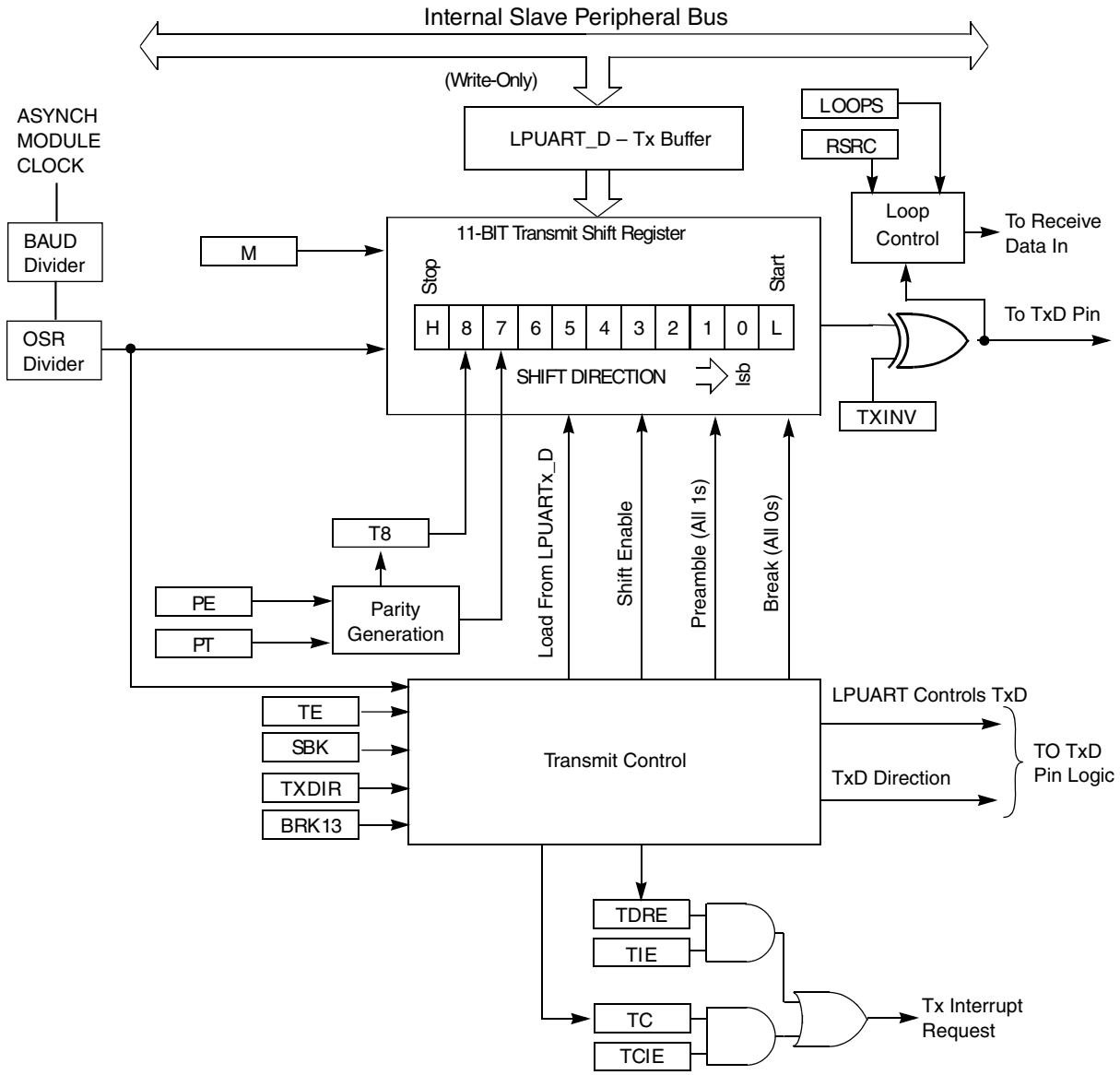


Figure 41-1. LPUART transmitter block diagram

The following figure shows the receiver portion of the LPUART.

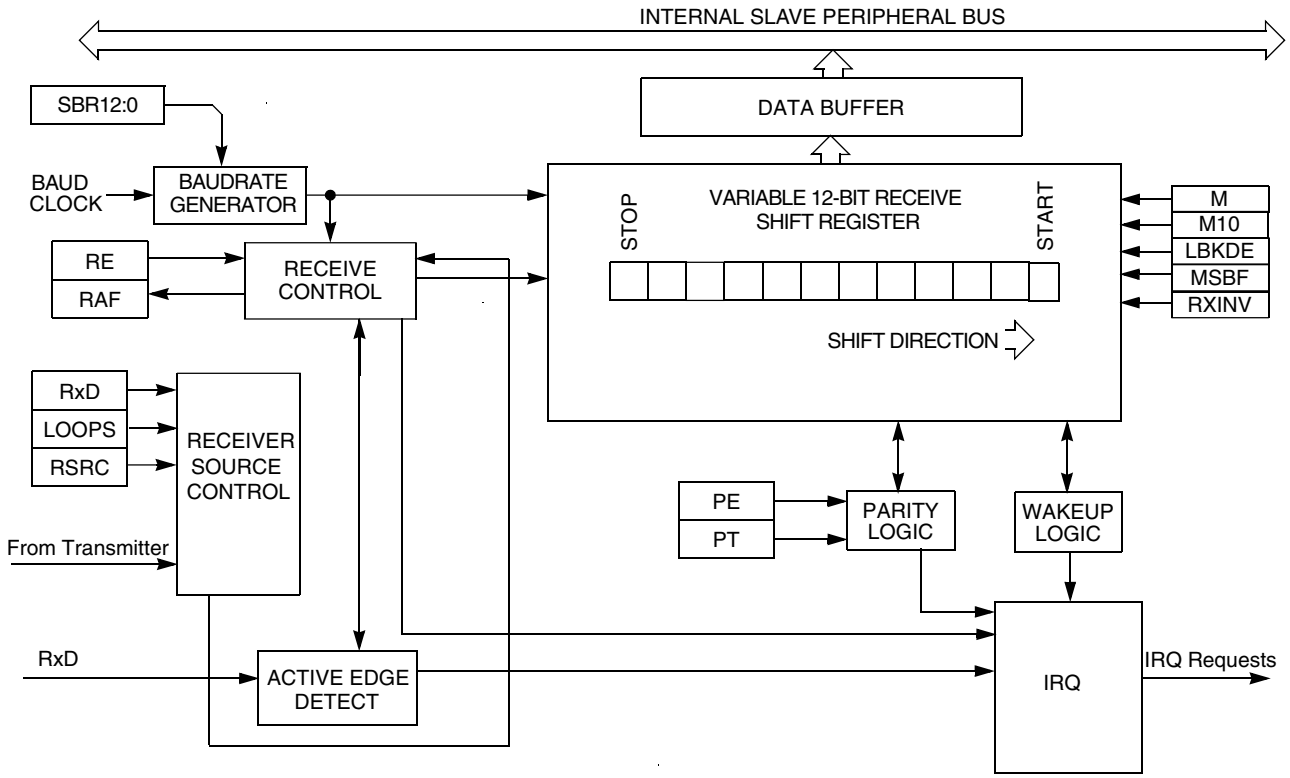


Figure 41-2. LPUART receiver block diagram

41.3 Register definition

The LPUART includes registers to control baud rate, select options, report status, and store transmit/receive data. Access to an address outside the valid memory map generates a bus error.

NOTE

Writing a Read-Only (RO) register or reading a Write-Only (WO) register can cause bus errors. This module does not check if programmed values in the registers are correct; the application software must ensure that valid programmed values are being written.

41.3.1 LPUART register descriptions

41.3.1.1 LPUART memory map

LPUART0 base address: 4006_A000h

LPUART1 base address: 4006_B000h

LPUART2 base address: 4006_C000h

Offset	Register	Width (In bits)	Access	Reset value
0h	Version ID Register (VERID)	32	RO	0401_0003h
4h	Parameter Register (PARAM)	32	RO	0000_0202h
8h	LPUART Global Register (GLOBAL)	32	RW	0000_0000h
Ch	LPUART Pin Configuration Register (PINCFG)	32	RW	0000_0000h
10h	LPUART Baud Rate Register (BAUD)	32	RW	0F00_0004h
14h	LPUART Status Register (STAT)	32	RW	00C0_0000h
18h	LPUART Control Register (CTRL)	32	RW	0000_0000h
1Ch	LPUART Data Register (DATA)	32	RW	0000_1000h
20h	LPUART Match Address Register (MATCH)	32	RW	0000_0000h
24h	LPUART Modem IrDA Register (MODIR)	32	RW	0000_0000h
28h	LPUART FIFO Register (FIFO)	32	RW	00C0_0011h
2Ch	LPUART Watermark Register (WATER)	32	RW	0000_0000h

41.3.1.2 Version ID Register (VERID)

41.3.1.2.1 Offset

Register	Offset
VERID	0h

41.3.1.2.2 Function

The Version ID register indicates the version integrated for this instance on the device and also indicates inclusion/exclusion of several optional features.

41.3.1.2.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	MAJOR								MINOR							
W																
Reset	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	FEATURE															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

41.3.1.2.4 Fields

Field	Function
31-24	Major Version Number
MAJOR	This read only field returns the major version number for the module specification.
23-16	Minor Version Number
MINOR	This read only field returns the minor version number for the module specification.
15-0	Feature Identification Number
FEATURE	This read only field returns the feature set number. 0000000000000001b - Standard feature set. 0000000000000011b - Standard feature set with MODEM/IrDA support.

41.3.1.3 Parameter Register (PARAM)

41.3.1.3.1 Offset

Register	Offset
PARAM	4h

41.3.1.3.2 Function

The Parameter register indicates the parameter configuration for this instance on the device

41.3.1.3.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	RXFIFO								TXFIFO							
W																
Reset	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0

41.3.1.3.4 Fields

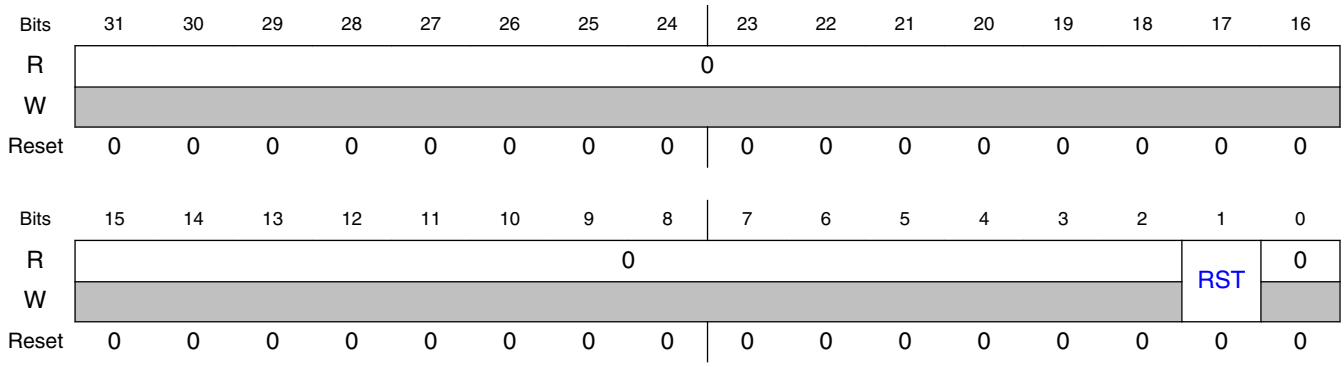
Field	Function
31-16 —	Reserved
15-8 RXFIFO	Receive FIFO Size The number of characters in the receive FIFO is 2^RXFIFO.
7-0 TXFIFO	Transmit FIFO Size The number of characters in the transmit FIFO is 2^TXFIFO.

41.3.1.4 LPUART Global Register (GLOBAL)

41.3.1.4.1 Offset

Register	Offset
GLOBAL	8h

41.3.1.4.2 Diagram



41.3.1.4.3 Fields

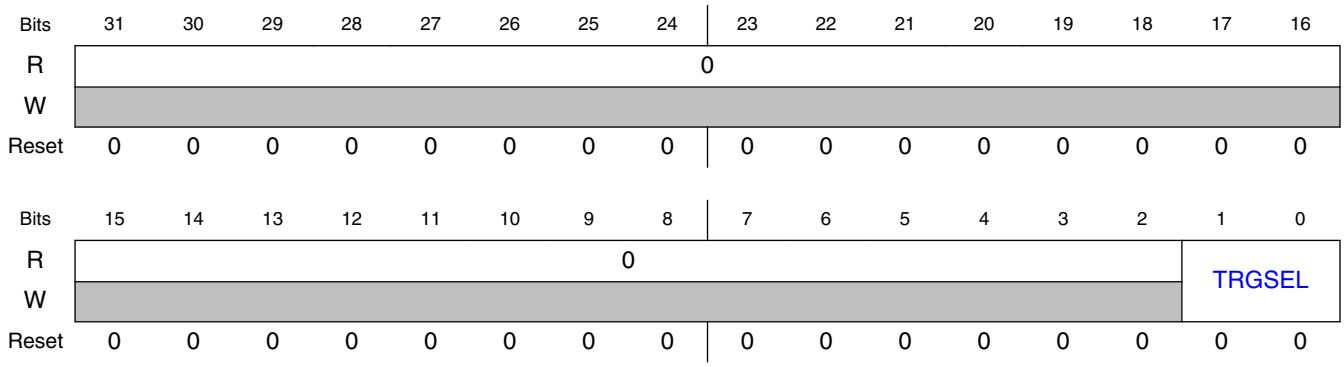
Field	Function
31-2 —	Reserved
1 RST	Software Reset Resets all internal logic and registers, except the Global Register. The reset takes effect immediately and remains asserted until negated by software. There is no minimum delay required before clearing the software reset. 0b - Module is not reset. 1b - Module is reset.
0 —	Reserved

41.3.1.5 LPUART Pin Configuration Register (PINCFG)

41.3.1.5.1 Offset

Register	Offset
PINCFG	Ch

41.3.1.5.2 Diagram



41.3.1.5.3 Fields

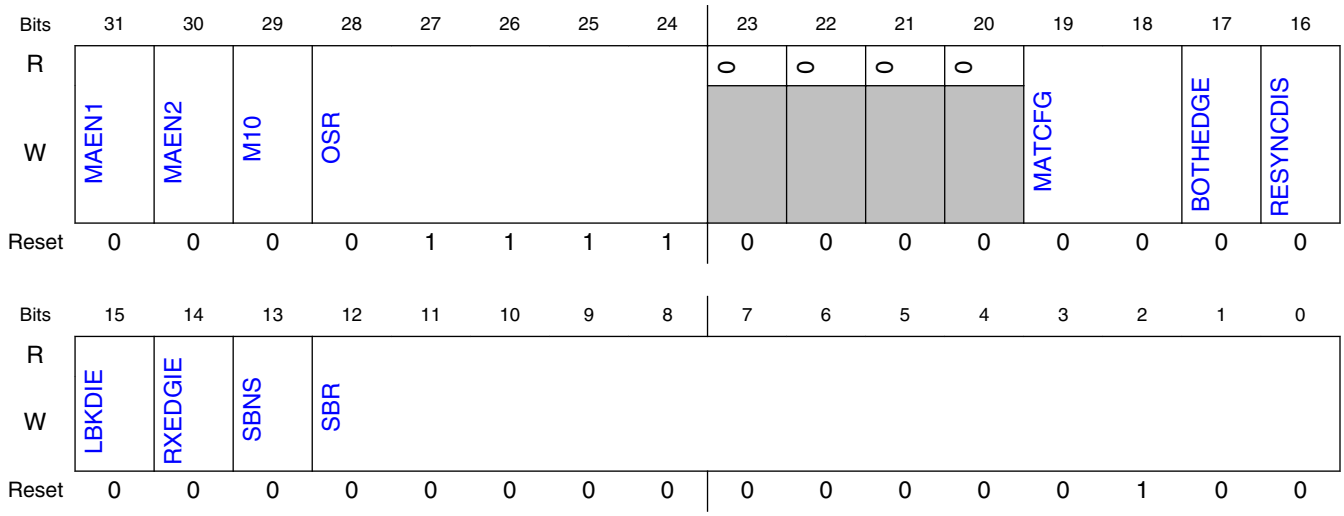
Field	Function
31-2 —	Reserved
1-0 TRGSEL	Trigger Select Configures the input trigger usage. This field should only be changed when the transmitter and receiver are both disabled. 00b - Input trigger is disabled. 01b - Input trigger is used instead of RXD pin input. 10b - Input trigger is used instead of CTS_B pin input. 11b - Input trigger is used to modulate the TXD pin output. The TXD pin output (after TXINV configuration) is ANDed with the input trigger.

41.3.1.6 LPUART Baud Rate Register (BAUD)

41.3.1.6.1 Offset

Register	Offset
BAUD	10h

41.3.1.6.2 Diagram



41.3.1.6.3 Fields

Field	Function
31 MAEN1	Match Address Mode Enable 1 0b - Normal operation. 1b - Enables automatic address matching or data matching mode for MATCH[MA1].
30 MAEN2	Match Address Mode Enable 2 0b - Normal operation. 1b - Enables automatic address matching or data matching mode for MATCH[MA2].
29 M10	10-bit Mode select The M10 bit causes a tenth bit to be part of the serial transmission. This bit should only be changed when the transmitter and receiver are both disabled. 0b - Receiver and transmitter use 7-bit to 9-bit data characters. 1b - Receiver and transmitter use 10-bit data characters.
28-24 OSR	Oversampling Ratio This field configures the oversampling ratio for the receiver. This field should only be changed when the transmitter and receiver are both disabled. 00000b - Writing 0 to this field results in an oversampling ratio of 16 00001b - Reserved 00010b - Reserved 00011b - Oversampling ratio of 4, requires BOTHEDGE to be set. 00100b - Oversampling ratio of 5, requires BOTHEDGE to be set. 00101b - Oversampling ratio of 6, requires BOTHEDGE to be set. 00110b - Oversampling ratio of 7, requires BOTHEDGE to be set. 00111b - Oversampling ratio of 8. 01000b - Oversampling ratio of 9. 01001b - Oversampling ratio of 10. 01010b - Oversampling ratio of 11. 01011b - Oversampling ratio of 12. 01100b - Oversampling ratio of 13. 01101b - Oversampling ratio of 14. 01110b - Oversampling ratio of 15.

Table continues on the next page...

Field	Function
	01111b - Oversampling ratio of 16. 10000b - Oversampling ratio of 17. 10001b - Oversampling ratio of 18. 10010b - Oversampling ratio of 19. 10011b - Oversampling ratio of 20. 10100b - Oversampling ratio of 21. 10101b - Oversampling ratio of 22. 10110b - Oversampling ratio of 23. 10111b - Oversampling ratio of 24. 11000b - Oversampling ratio of 25. 11001b - Oversampling ratio of 26. 11010b - Oversampling ratio of 27. 11011b - Oversampling ratio of 28. 11100b - Oversampling ratio of 29. 11101b - Oversampling ratio of 30. 11110b - Oversampling ratio of 31. 11111b - Oversampling ratio of 32.
23 —	Reserved
22 —	Reserved
21 —	Reserved
20 —	Reserved
19-18 MATCFG	Match Configuration Configures the match addressing mode used. This field should only be changed when the transmitter and receiver are both disabled. 00b - Address Match Wakeup 01b - Idle Match Wakeup 10b - Match On and Match Off 11b - Enables RWU on Data Match and Match On/Off for transmitter CTS input
17 BOTHEDGE	Both Edge Sampling Enables sampling of the received data on both edges of the baud rate clock, effectively doubling the number of times the receiver samples the input data for a given oversampling ratio. This bit must be set for oversampling ratios between x4 and x7 and is optional for higher oversampling ratios. This bit should only be changed when the receiver is disabled. 0b - Receiver samples input data using the rising edge of the baud rate clock. 1b - Receiver samples input data using the rising and falling edge of the baud rate clock.
16 RESYNCDIS	Resynchronization Disable When set, disables the resynchronization of the received data word when a data one followed by data zero transition is detected. This bit should only be changed when the receiver is disabled. 0b - Resynchronization during received data word is supported 1b - Resynchronization during received data word is disabled
15 LBKDIE	LIN Break Detect Interrupt Enable LBKDIE enables the LIN break detect flag, STAT[LBKDIF], to generate interrupt requests. 0b - Hardware interrupts from STAT[LBKDIF] flag are disabled (use polling). 1b - Hardware interrupt requested when STAT[LBKDIF] flag is 1.
14	RX Input Active Edge Interrupt Enable

Table continues on the next page...

Field	Function
RXEDGIE	Enables the receive input active edge, STAT[RXEDGIF], to generate interrupt requests. Changing CTRL[LOOP] or CTRL[RSRC] when RXEDGIE is set can cause the STAT[RXEDGIF] flag to set. 0b - Hardware interrupts from STAT[RXEDGIF] are disabled. 1b - Hardware interrupt is requested when STAT[RXEDGIF] flag is 1.
13 SBNS	Stop Bit Number Select SBNS determines whether data characters have one or two stop bits. This bit should only be changed when the transmitter and receiver are both disabled. 0b - One stop bit. 1b - Two stop bits.
12-0 SBR	Baud Rate Modulo Divisor. The 13 bits in SBR[12:0] set the modulo divide rate for the baud rate generator. When SBR is 1 - 8191, the baud rate equals "baud clock / ((OSR+1) × SBR)". The 13-bit baud rate setting [SBR12:SBR0] must be updated only when the transmitter and receiver are both disabled (CTRL[RE] and CTRL[TE] are both 0).

41.3.1.7 LPUART Status Register (STAT)

41.3.1.7.1 Offset

Register	Offset
STAT	14h

41.3.1.7.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	LBKDIF	RXEDGIF	MSBF	RXINV	RWUID	BRK13	LBKDE	RAF	TDRE	TC	RDRF	IDLE	OR	NF	FE	PF
W	W1C	W1C										W1C	W1C	W1C	W1C	W1C
Reset	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MA1F	MA2F	0												0	
W	W1C	W1C														
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

41.3.1.7.3 Fields

Field	Function
31 LBKDIF	LIN Break Detect Interrupt Flag LBKDIF is set when the LIN break detect circuitry is enabled and a LIN break character is detected. LBKDIF is cleared by writing a 1 to it. 0b - No LIN break character has been detected. 1b - LIN break character has been detected.
30 RXEDGIF	RXD Pin Active Edge Interrupt Flag RXEDGIF is set whenever the receiver is enabled and an active edge, falling if RXINV = 0, rising if RXINV=1, on the RXD pin occurs. RXEDGIF is cleared by writing a 1 to it. 0b - No active edge on the receive pin has occurred. 1b - An active edge on the receive pin has occurred.
29 MSBF	MSB First Setting this bit reverses the order of the bits that are transmitted and received on the wire. This bit does not affect the polarity of the bits, the location of the parity bit or the location of the start or stop bits. This bit should only be changed when the transmitter and receiver are both disabled. 0b - LSB (bit0) is the first bit that is transmitted following the start bit. Further, the first bit received after the start bit is identified as bit0. 1b - MSB (bit9, bit8, bit7 or bit6) is the first bit that is transmitted following the start bit depending on the setting of CTRL[M], CTRL[PE] and BAUD[M10]. Further, the first bit received after the start bit is identified as bit9, bit8, bit7 or bit6 depending on the setting of CTRL[M] and CTRL[PE].
28 RXINV	Receive Data Inversion Setting this bit reverses the polarity of the received data input. This bit should only be changed when the receiver is disabled. **NOTE:** Setting RXINV inverts the RXD input for all cases: data bits, start and stop bits, break, and idle. 0b - Receive data not inverted. 1b - Receive data inverted.
27 RWUID	Receive Wake Up Idle Detect For RWU on idle character, RWUID controls whether the idle character that wakes up the receiver sets the IDLE bit. For address match wakeup, RWUID controls if the IDLE bit is set when the address does not match. This bit should only be changed when the receiver is disabled. 0b - During receive standby state (RWU = 1), the IDLE bit does not get set upon detection of an idle character. During address match wakeup, the IDLE bit does not set when an address does not match. 1b - During receive standby state (RWU = 1), the IDLE bit gets set upon detection of an idle character. During address match wakeup, the IDLE bit does set when an address does not match.
26 BRK13	Break Character Generation Length BRK13 selects a longer transmitted break character length. Detection of a framing error is not affected by the state of this bit. This bit should only be changed when the transmitter is disabled. A break character can be sent by setting CTRL[SBK] or by writing the transmit FIFO with DATA[FRETSC] set and DATA[R9T9] clear. 0b - Break character is transmitted with length of 9 to 13 bit times. 1b - Break character is transmitted with length of 12 to 15 bit times.
25 LBKDE	LIN Break Detection Enable LBKDE selects a longer break character detection length. While LBKDE is set, receive data is not stored in the receive data buffer. **NOTE:** The LBKDE bit enables the LIN break detect circuit and disables writing receive data to FIFO. So it essentially ignores all characters except a LIN break. 0b - LIN break detect is disabled, normal break character can be detected.

Table continues on the next page...

Field	Function
	1b - LIN break detect is enabled. LIN break character is detected at length of 11 bit times (if M = 0) or 12 (if M = 1) or 13 (M10 = 1).
24 RAF	Receiver Active Flag RAF is set when the receiver detects the beginning of a valid start bit, and RAF is cleared automatically when the receiver detects an idle line. 0b - LPUART receiver idle waiting for a start bit. 1b - LPUART receiver active (RXD input not idle).
23 TDRE	Transmit Data Register Empty Flag When the transmit FIFO is enabled, TDRE is set when the number of datawords in the transmit FIFO (DATA register) is equal to or less than the number indicated by WATER[TXWATER]). To clear TDRE, write to the DATA register until the number of words in the transmit FIFO is greater than the number indicated by WATER[TXWATER]. When the transmit FIFO is disabled,TDRE is set when the transmit DATA register is empty. To clear TDRE, write to the DATA register. TDRE is not affected by a character that is in the process of being transmitted; it is updated at the start of each transmitted character. 0b - Transmit data buffer full. 1b - Transmit data buffer empty.
22 TC	Transmission Complete Flag TC is cleared when there is a transmission in progress or when a preamble or break character is loaded. TC is set when the transmit buffer is empty and no data, preamble, or break character is being transmitted. When TC is set, the transmit data output signal becomes idle (logic 1). TC is cleared by writing to the DATA register to transmit new data, queuing a preamble by clearing and then setting CTRL[TE], queuing a break character by writing 1 to CTRL[SBK]. 0b - Transmitter active (sending data, a preamble, or a break). 1b - Transmitter idle (transmission activity complete).
21 RDRF	Receive Data Register Full Flag When the receive FIFO is enabled, RDRF is set when the number of datawords in the receive buffer is greater than the number indicated by WATER[RXWATER]. To clear RDRF, read the DATA register until the number of datawords in the receive data buffer is equal to or less than the number indicated by WATER[RXWATER]. When the receive FIFO is disabled, RDRF is set when the receive buffer (the DATA register) is full. To clear RDRF, read the DATA register. A character that is in the process of being received does not cause a change in RDRF until the entire character is received. Even if RDRF is set, the character continues to be received until an overrun condition occurs once the entire character is received. 0b - Receive data buffer empty. 1b - Receive data buffer full.
20 IDLE	Idle Line Flag IDLE is set when the LPUART receive line becomes idle for a full character time after a period of activity. When CTRL[ILT] is cleared, the receiver starts counting idle bit times after the start bit. If the receive character is all 1s, these bit times and the stop bits time count toward the full character time of logic high, 10 to 13 bit times, needed for the receiver to detect an idle line. When CTRL[ILT] is set, the receiver doesn't start counting idle bit times until after the stop bits. The stop bits and any logic high bit times at the end of the previous character do not count toward the full character time of logic high needed for the receiver to detect an idle line. To clear IDLE, write logic 1 to the IDLE flag. After IDLE has been cleared, it cannot be set again until after a new character has been stored in the receive buffer or a LIN break character has set the LBKDIF flag . IDLE is set only once even if the receive line remains idle for an extended period. 0b - No idle line detected. 1b - Idle line was detected.

Table continues on the next page...

Register definition

Field	Function
19 OR	Receiver Overrun Flag OR is set when software fails to prevent the receive data register from overflowing with data. The OR bit is set immediately after the stop bit has been completely received for the dataword that overflows the buffer and all the other error flags (FE, NF, and PF) are prevented from setting. The data in the shift register is lost, but the data already in the LPUART data registers is not affected. If LBKDE is enabled and a LIN Break is detected, the OR field asserts if LBKDIF is not cleared before the next data character is received. While the OR flag is set, no additional data is stored in the data buffer even if sufficient room exists. To clear OR, write logic 1 to the OR flag. 0b - No overrun. 1b - Receive overrun (new LPUART data lost).
18 NF	Noise Flag The advanced sampling technique used in the receiver takes three samples in each of the received bits. If any of these samples disagrees with the rest of the samples within any bit time in the frame then noise is detected for that character. NF is set whenever the next character to be read from the DATA register was received with noise detected within the character. To clear NF, write logic 1 to the NF field. 0b - No noise detected. 1b - Noise detected in the received character in the DATA register.
17 FE	Framing Error Flag FE is set whenever the next character to be read from the DATA register was received with logic 0 detected where a stop bit was expected. To clear FE, write logic 1 to the FE field. 0b - No framing error detected. This does not guarantee the framing is correct. 1b - Framing error.
16 PF	Parity Error Flag PF is set whenever the next character to be read from the DATA register was received when parity is enabled (PE = 1) and the parity bit in the received character does not agree with the expected parity value. To clear PF, write a logic 1 to the PF field. 0b - No parity error. 1b - Parity error.
15 MA1F	Match 1 Flag MA1F is set whenever the next character to be read from the DATA register matches MA1. To clear MA1F, write a logic 1 to the MA1F field. 0b - Received data is not equal to MA1 1b - Received data is equal to MA1
14 MA2F	Match 2 Flag MA2F is set whenever the next character to be read from the DATA register matches MA2. To clear MA2F, write a logic 1 to the MA2F field. 0b - Received data is not equal to MA2 1b - Received data is equal to MA2
13-2 —	Reserved
1-0 —	Reserved

41.3.1.8 LPUART Control Register (CTRL)

41.3.1.8.1 Offset

Register	Offset
CTRL	18h

41.3.1.8.2 Function

This read/write register controls various optional features of the LPUART system. This register should only be altered when the transmitter and receiver are both disabled.

41.3.1.8.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	R8T9	R9T8	TXDIR	TXINV	ORIE	NEIE	FEIE	PEIE	TIE	TCIE	RIE	ILIE	TE	RE	RWU	SBK
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MA1IE	MA2IE	0		M7	IDLECFG			LOOPS	DOZEEN	RSRC	M	WAKE	ILT	PE	PT
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

41.3.1.8.4 Fields

Field	Function
31 R8T9	Receive Bit 8 / Transmit Bit 9 R8 is the ninth data bit received when the LPUART is configured for 9-bit or 10-bit data formats. When reading 9-bit or 10-bit data, read R8 before reading the DATA register. T9 is the tenth data bit transmitted when the LPUART is configured for 10-bit data formats. When writing 10-bit data, write T9 before writing the DATA register. If T9 does not need to change from its previous value, such as when it is used to generate address mark or parity, they it need not be written each time the DATA register is written. **NOTE:** R8 is a read-only bit and T9 is a write-only bit, the value read is different from the value written.
30 R9T8	Receive Bit 9 / Transmit Bit 8 R9 is the tenth data bit received when the LPUART is configured for 10-bit data formats. When reading 10-bit data, read R9 before reading the DATA register

Table continues on the next page...

Field	Function
	T8 is the ninth data bit transmitted when the LPUART is configured for 9-bit or 10-bit data formats. When writing 9-bit or 10-bit data, write T8 before writing the DATA register. If T8 does not need to change from its previous value, such as when it is used to generate address mark or parity, then it need not be written each time the DATA register is written. **NOTE:** R9 is a read-only bit and T8 is a write-only bit, the value read is different from the value written.
29 TXDIR	TXD Pin Direction in Single-Wire Mode When the LPUART is configured for single-wire half-duplex operation (LOOPS = RSRC = 1), this bit determines the direction of data at the TXD pin. When clearing TXDIR, the transmitter finishes receiving the current character (if any) before the receiver starts receiving data from the TXD pin. 0b - TXD pin is an input in single-wire mode. 1b - TXD pin is an output in single-wire mode.
28 TXINV	Transmit Data Inversion Setting this bit reverses the polarity of the transmitted data output. **NOTE:** Setting TXINV inverts the TXD output for all cases: data bits, start and stop bits, break, and idle. 0b - Transmit data not inverted. 1b - Transmit data inverted.
27 ORIE	Overrun Interrupt Enable This bit enables the overrun flag (OR) to generate hardware interrupt requests. 0b - OR interrupts disabled; use polling. 1b - Hardware interrupt requested when OR is set.
26 NEIE	Noise Error Interrupt Enable This bit enables the noise flag (NF) to generate hardware interrupt requests. 0b - NF interrupts disabled; use polling. 1b - Hardware interrupt requested when NF is set.
25 FEIE	Framing Error Interrupt Enable This bit enables the framing error flag (FE) to generate hardware interrupt requests. 0b - FE interrupts disabled; use polling. 1b - Hardware interrupt requested when FE is set.
24 PEIE	Parity Error Interrupt Enable This bit enables the parity error flag (PF) to generate hardware interrupt requests. 0b - PF interrupts disabled; use polling). 1b - Hardware interrupt requested when PF is set.
23 TIE	Transmit Interrupt Enable Enables STAT[TDRE] to generate interrupt requests. 0b - Hardware interrupts from TDRE disabled; use polling. 1b - Hardware interrupt requested when TDRE flag is 1.
22 TCIE	Transmission Complete Interrupt Enable for TCIE enables the transmission complete flag, TC, to generate interrupt requests. 0b - Hardware interrupts from TC disabled; use polling. 1b - Hardware interrupt requested when TC flag is 1.
21 RIE	Receiver Interrupt Enable Enables STAT[RDRF] to generate interrupt requests. 0b - Hardware interrupts from RDRF disabled; use polling. 1b - Hardware interrupt requested when RDRF flag is 1.
20 ILIE	Idle Line Interrupt Enable ILIE enables the idle line flag, STAT[IDLE], to generate interrupt requests. 0b - Hardware interrupts from IDLE disabled; use polling.

Table continues on the next page...

Field	Function
	1b - Hardware interrupt requested when IDLE flag is 1.
19 TE	Transmitter Enable Enables the LPUART transmitter. TE can also be used to queue an idle preamble by clearing and then setting TE. When TE is cleared, this register bit reads as 1 until the transmitter has completed the current character and the TXD pin is tristated. A single idle character can also be queued by writing to the transmit FIFO with DATA[FRETSC] set and DATA[R9T9] set. 0b - Transmitter disabled. 1b - Transmitter enabled.
18 RE	Receiver Enable Enables the LPUART receiver. When RE is written to 0, this register bit reads as 1 until the receiver finishes receiving the current character (if any). 0b - Receiver disabled. 1b - Receiver enabled.
17 RWU	Receiver Wakeup Control This field can be set to place the LPUART receiver in a standby state. RWU automatically clears when an RWU event occurs, that is, an IDLE event when CTRL[WAKE] is clear or an address match when CTRL[WAKE] is set with STAT[RWUID] is clear. **NOTE:** RWU must be set only with CTRL[WAKE] = 0 (wakeup on idle) if the channel is currently not idle. This can be determined by STAT[RAF]. If the flag is set to wake up an IDLE event and the channel is already idle, it is possible that the LPUART will discard data. This is because the data must be received or a LIN break detected after an IDLE is detected before IDLE is allowed to be reasserted. 0b - Normal receiver operation. 1b - LPUART receiver in standby waiting for wakeup condition.
16 SBK	Send Break Writing a 1 and then a 0 to SBK queues a break character in the transmit data stream. Additional break characters of 9 to 13 bits, or 12 to 15 bits if STAT[BRK13] is set, bit times of logic 0 are queued as long as SBK is set. Depending on the timing of the set and clear of SBK relative to the character currently being transmitted, a second break character may be queued before software clears SBK. A single break character can also be queued by writing to the transmit FIFO with DATA[FRETSC] set and DATA[R9T9] clear. 0b - Normal transmitter operation. 1b - Queue break character(s) to be sent.
15 MA1IE	Match 1 Interrupt Enable 0b - MA1F interrupt disabled 1b - MA1F interrupt enabled
14 MA2IE	Match 2 Interrupt Enable 0b - MA2F interrupt disabled 1b - MA2F interrupt enabled
13-12 —	Reserved
11 M7	7-Bit Mode Select This bit should only be changed when the transmitter and receiver are both disabled. 0b - Receiver and transmitter use 8-bit to 10-bit data characters. 1b - Receiver and transmitter use 7-bit data characters.
10-8	Idle Configuration

Table continues on the next page...

Field	Function
IDLECFG	Configures the number of idle characters that must be received before the IDLE flag is set. 000b - 1 idle character 001b - 2 idle characters 010b - 4 idle characters 011b - 8 idle characters 100b - 16 idle characters 101b - 32 idle characters 110b - 64 idle characters 111b - 128 idle characters
7 LOOPS	Loop Mode Select When LOOPS is set, the RXD pin is disconnected from the LPUART and the transmitter output is internally connected to the receiver input. The transmitter and the receiver must be enabled to use the loop function. 0b - Normal operation - RXD and TXD use separate pins. 1b - Loop mode or single-wire mode where transmitter outputs are internally connected to receiver input (see RSRC bit).
6 DOZEEN	Doze Enable 0b - LPUART is enabled in Doze mode. 1b - LPUART is disabled in Doze mode.
5 RSRC	Receiver Source Select This field has no meaning or effect unless the LOOPS field is set. When LOOPS is set, the RSRC field determines the source for the receiver shift register input. 0b - Provided LOOPS is set, RSRC is cleared, selects internal loop back mode and the LPUART does not use the RXD pin. 1b - Single-wire LPUART mode where the TXD pin is connected to the transmitter output and receiver input.
4 M	9-Bit or 8-Bit Mode Select 0b - Receiver and transmitter use 8-bit data characters. 1b - Receiver and transmitter use 9-bit data characters.
3 WAKE	Receiver Wakeup Method Select Determines which condition wakes the LPUART when RWU=1: • Address mark in the bit preceding the stop bit (or bit preceding the parity bit when parity is enabled) of the received data character, or • An idle condition on the receive pin input signal. 0b - Configures RWU for idle-line wakeup. 1b - Configures RWU with address-mark wakeup.
2 ILT	Idle Line Type Select Determines when the receiver starts counting logic 1s as idle character bits. The count begins either after a valid start bit or after the stop bit. If the count begins after the start bit, then a string of logic 1s preceding the stop bit can cause false recognition of an idle character. Beginning the count after the stop bit avoids false idle character recognition, but requires properly synchronized transmissions. **NOTE:** In case the LPUART is programmed with ILT = 1, a logic 0 is automatically shifted after a received stop bit, therefore resetting the idle count. 0b - Idle character bit count starts after start bit. 1b - Idle character bit count starts after stop bit.
1 PE	Parity Enable Enables hardware parity generation and checking. When parity is enabled, the bit immediately before the stop bit is treated as the parity bit. 0b - No hardware parity generation or checking. 1b - Parity enabled.

Table continues on the next page...

Field	Function
0 PT	Parity Type Provided parity is enabled (PE = 1), this bit selects even or odd parity. Odd parity means the total number of 1s in the data character, including the parity bit, is odd. Even parity means the total number of 1s in the data character, including the parity bit, is even. 0b - Even parity. 1b - Odd parity.

41.3.1.9 LPUART Data Register (DATA)

41.3.1.9.1 Offset

Register	Offset
DATA	1Ch

41.3.1.9.2 Function

NOTE

This register is two separate registers. Reads return the contents of the read-only receive data buffer and writes go to the write-only transmit data buffer.

Reads and writes of this register are also involved in the automatic flag clearing mechanisms for some of the LPUART status flags.

41.3.1.9.3 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0															
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	NOISY	PARITYE	FRETSC	RXEMPT	IDLINE	0	R9T9	R8T8	R7T7	R6T6	R5T5	R4T4	R3T3	R2T2	R1T1	R0T0
W																
Reset	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

41.3.1.9.4 Fields

Field	Function
31-16 —	Reserved
15 NOISY	NOISY The current received dataword contained in DATA[R9:R0] was received with noise. 0b - The dataword was received without noise. 1b - The data was received with noise.
14 PARITYE	PARITYE The current received dataword contained in DATA[R9:R0] was received with a parity error. 0b - The dataword was received without a parity error. 1b - The dataword was received with a parity error.
13 FRETSC	Frame Error / Transmit Special Character For reads, indicates the current received dataword contained in DATA[R9:R0] was received with a frame error. For writes, indicates a break or idle character is to be transmitted instead of the contents in DATA[T9:T0]. T9 is used to indicate a break character when 0 and a idle character when 1, the contents of DATA[T8:T0] should be zero. 0b - The dataword was received without a frame error on read, or transmit a normal character on write. 1b - The dataword was received with a frame error, or transmit an idle or break character on transmit.
12 RXEMPT	Receive Buffer Empty Asserts when there is no data in the receive buffer. This field does not take into account data that is in the receive shift register. 0b - Receive buffer contains valid data. 1b - Receive buffer is empty, data returned on read is not valid.
11 IDLINE	Idle Line Indicates the receiver line was idle before receiving the character in DATA[9:0]. Unlike the IDLE flag, this bit can set for the first character received when the receiver is first enabled. 0b - Receiver was not idle before receiving this character. 1b - Receiver was idle before receiving this character.
10 —	Reserved
9 R9T9	R9T9 Read receive data buffer 9 or write transmit data buffer 9.
8 R8T8	R8T8 Read receive data buffer 8 or write transmit data buffer 8.
7 R7T7	R7T7 Read receive data buffer 7 or write transmit data buffer 7.
6 R6T6	R6T6 Read receive data buffer 6 or write transmit data buffer 6.
5 R5T5	R5T5 Read receive data buffer 5 or write transmit data buffer 5.
4	R4T4

Table continues on the next page...

Field	Function
R4T4	Read receive data buffer 4 or write transmit data buffer 4.
3 R3T3	R3T3 Read receive data buffer 3 or write transmit data buffer 3.
2 R2T2	R2T2 Read receive data buffer 2 or write transmit data buffer 2.
1 R1T1	R1T1 Read receive data buffer 1 or write transmit data buffer 1.
0 R0T0	R0T0 Read receive data buffer 0 or write transmit data buffer 0.

41.3.1.10 LPUART Match Address Register (MATCH)

41.3.1.10.1 Offset

Register	Offset
MATCH	20h

41.3.1.10.2 Diagram

Bits	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0						MA2									
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0						MA1									
W																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

41.3.1.10.3 Fields

Field	Function
31-26 —	Reserved
25-16	Match Address 2

Table continues on the next page...

Field	Function
MA2	The MA1 and MA2 fields are compared to input data addresses when the most significant bit is set and the associated BAUD[MAEN] bit is set. If a match occurs, the following data is transferred to the DATA register. If a match fails, the following data is discarded. Software should only write a MAx field when the associated BAUD[MAEN] bit is clear.
15-10 —	Reserved
9-0 MA1	Match Address 1 The MA1 and MA2 fields are compared to input data addresses when the most significant bit is set and the associated BAUD[MAEN] bit is set. If a match occurs, the following data is transferred to the DATA register. If a match fails, the following data is discarded. Software should only write a MAx field when the associated BAUD[MAEN] bit is clear.

41.3.1.11 LPUART Modem IrDA Register (MODIR)

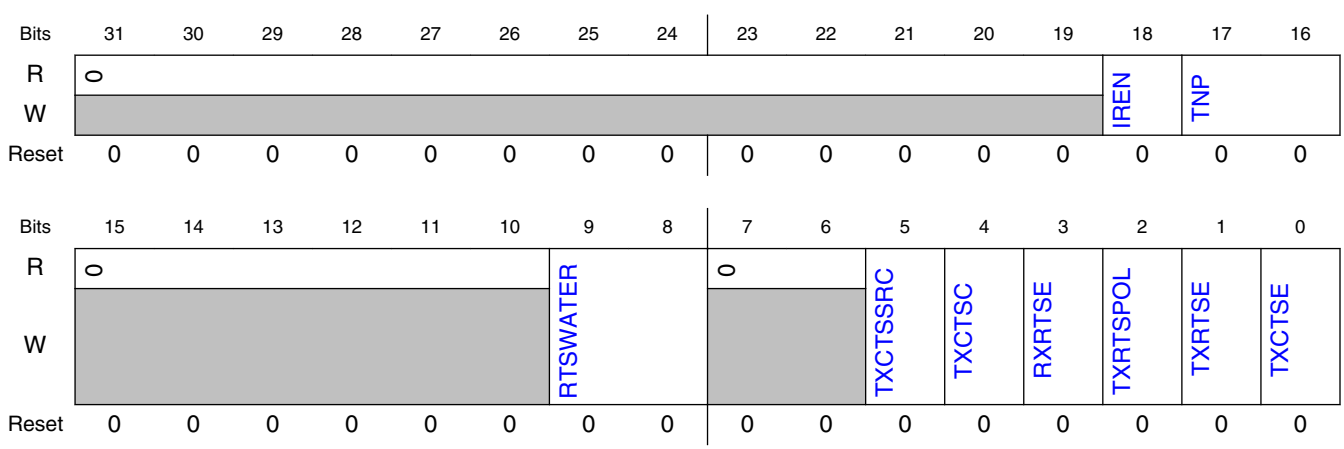
41.3.1.11.1 Offset

Register	Offset
MODIR	24h

41.3.1.11.2 Function

The MODEM register controls options for setting the modem configuration.

41.3.1.11.3 Diagram



41.3.1.11.4 Fields

Field	Function
31-19 —	Reserved
18 IREN	Infrared enable Enables/disables the infrared modulation/demodulation. This bit should only be changed when the transmitter and receiver are both disabled. 0b - IR disabled. 1b - IR enabled.
17-16 TNP	Transmitter narrow pulse Configures whether the LPUART transmits a 1/OSR, 2/OSR, 3/OSR or 4/OSR narrow pulse when IR is enabled. This bit should only be changed when the transmitter and receiver are both disabled. The IR pulse width should be configured to less than half of the oversampling ratio. Common pulse widths are 3/16, 1/16, 1/32 or 1/4 of the bit length. These can be configured by selecting the appropriate oversample ratio and pulse width. 00b - 1/OSR. 01b - 2/OSR. 10b - 3/OSR. 11b - 4/OSR.
15-10 —	Reserved
9-8 RTSWATER	Receive RTS Configuration Configures the assertion and negation of the RX RTS_B output. The RX RTS_B output negates when the number of empty words in the receive FIFO is greater or equal to RTSWATER. If RTSWATER is configured to zero, RTS_B negates when the receive FIFO is full. For the purpose of RX RTS_B generation, the number of words in the receive FIFO updates when a start bit is detected. This supports additional latency between RTS_B negation and the external transmitter ceasing transmission. If both RX RTS_B and address/data matching is enabled, then RTS_B could assert at the end of a character if there is not a match. This field should only be changed when the receiver is disabled.
7-6 —	Reserved
5 TXCTSSRC	Transmit CTS Source Configures the source of the CTS input. 0b - CTS input is the CTS_B pin. 1b - CTS input is the inverted Receiver Match result.
4 TXCTSC	Transmit CTS Configuration Configures if the CTS state is checked at the start of each character or only when the transmitter is idle. 0b - CTS input is sampled at the start of each character. 1b - CTS input is sampled when the transmitter is idle.
3 RXRTSE	Receiver request-to-send enable Allows the RTS output to control the CTS input of the transmitting device to prevent receiver overrun. This bit should only be changed when the receiver is disabled. **NOTE:** Do not set both RXRTSE and TXRTSE. 0b - The receiver has no effect on RTS.

Table continues on the next page...

Field	Function
	1b - RTS is deasserted if the receiver data register is full or a start bit has been detected that would cause the receiver data register to become full. RTS is asserted if the receiver data register is not full and has not detected a start bit that would cause the receiver data register to become full.
2 TXRTSPOL	Transmitter request-to-send polarity Controls the polarity of the transmitter RTS. TXRTSPOL does not affect the polarity of the receiver RTS. RTS remains negated in the active low state unless TXRTSE is set. This bit should only be changed when the transmitter is disabled. 0b - Transmitter RTS is active low. 1b - Transmitter RTS is active high.
1 TXRTSE	Transmitter request-to-send enable Controls RTS before and after a transmission. This bit should only be changed when the transmitter is disabled. 0b - The transmitter has no effect on RTS. 1b - When a character is placed into an empty transmitter data buffer , RTS asserts one bit time before the start bit is transmitted. RTS deasserts one bit time after all characters in the transmitter data buffer and shift register are completely sent, including the last stop bit.
0 TXCTSE	Transmitter clear-to-send enable TXCTSE controls the operation of the transmitter. TXCTSE can be set independently from the state of TXRTSE and RXRTSE. 0b - CTS has no effect on the transmitter. 1b - Enables clear-to-send operation. The transmitter checks the state of CTS each time it is ready to send a character. If CTS is asserted, the character is sent. If CTS is deasserted, the signal TXD remains in the mark state and transmission is delayed until CTS is asserted. Changes in CTS as a character is being sent do not affect its transmission.

41.3.1.12 LPUART FIFO Register (FIFO)

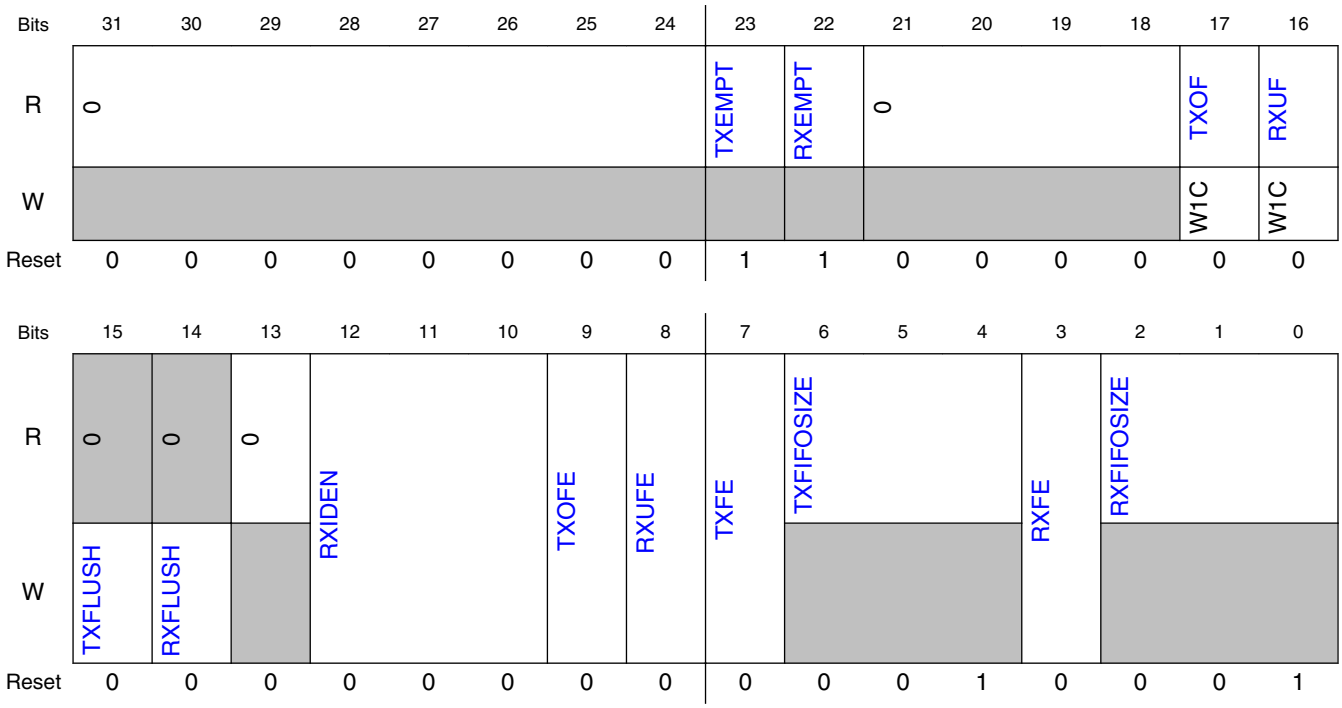
41.3.1.12.1 Offset

Register	Offset
FIFO	28h

41.3.1.12.2 Function

This register provides the ability for the programmer to turn on and off FIFO functionality. It also provides the size of the FIFO that has been implemented. This register may be read at any time. This register must be written only when CTRL[RE] and CTRL[TE] are cleared/not set and when the data buffer/FIFO is empty.

41.3.1.12.3 Diagram



41.3.1.12.4 Fields

Field	Function
31-24 —	Reserved
23 TXEMPT	Transmit Buffer/FIFO Empty Asserts when there is no data in the Transmit FIFO/buffer. This field does not take into account data that is in the transmit shift register. 0b - Transmit buffer is not empty. 1b - Transmit buffer is empty.
22 RXEMPT	Receive Buffer/FIFO Empty Asserts when there is no data in the receive FIFO/Buffer. This field does not take into account data that is in the receive shift register. 0b - Receive buffer is not empty. 1b - Receive buffer is empty.
21-18 —	Reserved
17 TXOF	Transmitter Buffer Overflow Flag Indicates that more data has been written to the transmit buffer than it can hold. This field asserts regardless of the value of TXOFE. However, an interrupt is issued to the host only if TXOFE is set. This flag is cleared by writing a 1. 0b - No transmit buffer overflow has occurred since the last time the flag was cleared. 1b - At least one transmit buffer overflow has occurred since the last time the flag was cleared.

Table continues on the next page...

Field	Function
16 RXUF	Receiver Buffer Underflow Flag Indicates that more data has been read from the receive buffer than was present. This field asserts regardless of the value of RXUFE. However, an interrupt is issued to the host only if RXUFE is set. This flag is cleared by writing a 1. 0b - No receive buffer underflow has occurred since the last time the flag was cleared. 1b - At least one receive buffer underflow has occurred since the last time the flag was cleared.
15 TXFLUSH	Transmit FIFO/Buffer Flush Writing to this field causes all data that is stored in the transmit FIFO/buffer to be flushed. This does not affect data that is in the transmit shift register. 0b - No flush operation occurs. 1b - All data in the transmit FIFO/Buffer is cleared out.
14 RXFLUSH	Receive FIFO/Buffer Flush Writing to this field causes all data that is stored in the receive FIFO/buffer to be flushed. This does not affect data that is in the receive shift register. 0b - No flush operation occurs. 1b - All data in the receive FIFO/buffer is cleared out.
13 —	Reserved
12-10 RXIDEN	Receiver Idle Empty Enable When set, enables the assertion of RDRF when the receiver is idle for a number of idle characters and the FIFO is not empty. 000b - Disable RDRF assertion due to partially filled FIFO when receiver is idle. 001b - Enable RDRF assertion due to partially filled FIFO when receiver is idle for 1 character. 010b - Enable RDRF assertion due to partially filled FIFO when receiver is idle for 2 characters. 011b - Enable RDRF assertion due to partially filled FIFO when receiver is idle for 4 characters. 100b - Enable RDRF assertion due to partially filled FIFO when receiver is idle for 8 characters. 101b - Enable RDRF assertion due to partially filled FIFO when receiver is idle for 16 characters. 110b - Enable RDRF assertion due to partially filled FIFO when receiver is idle for 32 characters. 111b - Enable RDRF assertion due to partially filled FIFO when receiver is idle for 64 characters.
9 TXOFE	Transmit FIFO Overflow Interrupt Enable When this field is set, the TXOF flag generates an interrupt to the host. 0b - TXOF flag does not generate an interrupt to the host. 1b - TXOF flag generates an interrupt to the host.
8 RXUFE	Receive FIFO Underflow Interrupt Enable When this field is set, the RXUF flag generates an interrupt to the host. 0b - RXUF flag does not generate an interrupt to the host. 1b - RXUF flag generates an interrupt to the host.
7 TXFE	Transmit FIFO Enable When this field is set, the built-in FIFO structure for the transmit buffer is enabled. The size of the FIFO structure is indicated by TXFIFOSIZE. If this field is not set, the transmit buffer operates as a FIFO of depth one dataword regardless of the value in TXFIFOSIZE. Both CTRL[TE] and CTRL[RE] must be cleared prior to changing this field. 0b - Transmit FIFO is not enabled. Buffer is depth 1. 1b - Transmit FIFO is enabled. Buffer is depth indicated by TXFIFOSIZE.
6-4 TXFIFOSIZE	Transmit FIFO Buffer Depth The maximum number of transmit datawords that can be stored in the transmit buffer. This field is read only. 000b - Transmit FIFO/Buffer depth = 1 dataword. 001b - Transmit FIFO/Buffer depth = 4 datawords.

Table continues on the next page...

Field	Function
	010b - Transmit FIFO/Buffer depth = 8 datawords. 011b - Transmit FIFO/Buffer depth = 16 datawords. 100b - Transmit FIFO/Buffer depth = 32 datawords. 101b - Transmit FIFO/Buffer depth = 64 datawords. 110b - Transmit FIFO/Buffer depth = 128 datawords. 111b - Transmit FIFO/Buffer depth = 256 datawords
3 RXFE	Receive FIFO Enable When this field is set, the built-in FIFO structure for the receive buffer is enabled. The size of the FIFO structure is indicated by the RXFIFOSIZE field. If this field is not set, the receive buffer operates as a FIFO of depth one dataword regardless of the value in RXFIFOSIZE. Both CTRL[TE] and CTRL[RE] must be cleared prior to changing this field. 0b - Receive FIFO is not enabled. Buffer is depth 1. 1b - Receive FIFO is enabled. Buffer is depth indicted by RXFIFOSIZE.
2-0 RXFIFOSIZE	Receive FIFO Buffer Depth The maximum number of receive datawords that can be stored in the receive buffer before an overrun occurs. This field is read only. 000b - Receive FIFO/Buffer depth = 1 dataword. 001b - Receive FIFO/Buffer depth = 4 datawords. 010b - Receive FIFO/Buffer depth = 8 datawords. 011b - Receive FIFO/Buffer depth = 16 datawords. 100b - Receive FIFO/Buffer depth = 32 datawords. 101b - Receive FIFO/Buffer depth = 64 datawords. 110b - Receive FIFO/Buffer depth = 128 datawords. 111b - Receive FIFO/Buffer depth = 256 datawords.

41.3.1.13 LPUART Watermark Register (WATER)

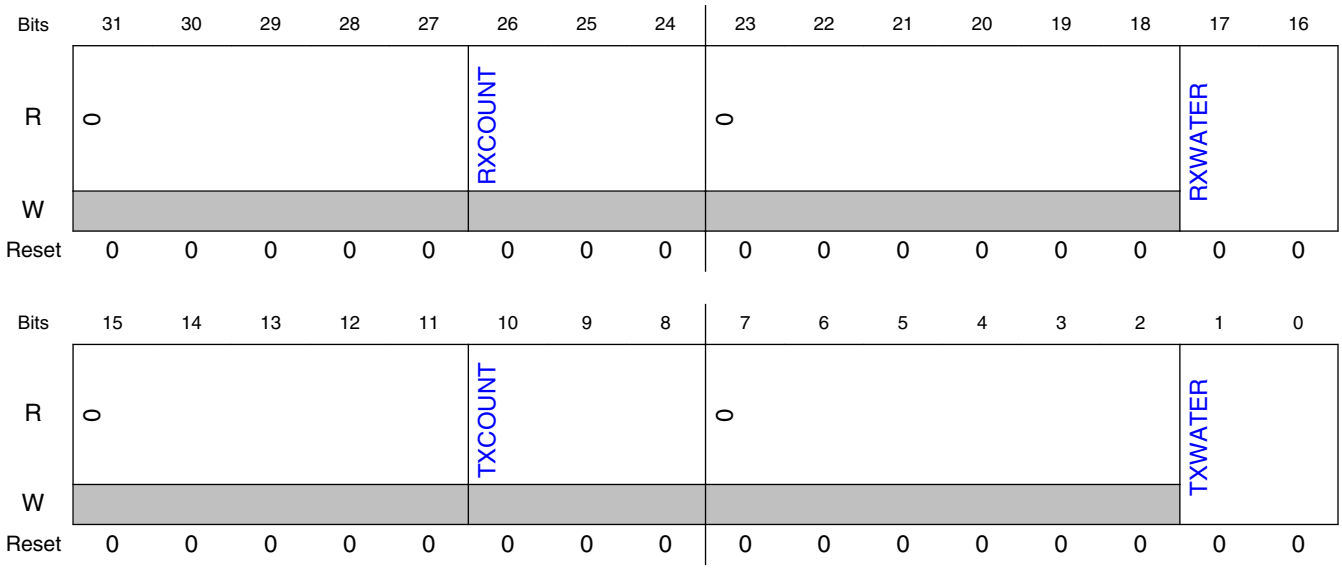
41.3.1.13.1 Offset

Register	Offset
WATER	2Ch

41.3.1.13.2 Function

This register provides the ability to set a programmable threshold for notification of needing additional transmit data. This register may be read at any time but must be written only when CTRL[TE] is not set.

41.3.1.13.3 Diagram



41.3.1.13.4 Fields

Field	Function
31-27 —	Reserved
26-24 RXCOUNT	Receive Counter The value in this register indicates the number of datawords that are in the receive FIFO/buffer. If a dataword is being received, that is, in the receive shift register, it is not included in the count. This value may be used in conjunction with FIFO[RXFIFOSIZE] to calculate how much room is left in the receive FIFO/buffer.
23-18 —	Reserved
17-16 RXWATER	Receive Watermark When the number of datawords in the receive FIFO/buffer is greater than the value in this register field, an interrupt or a DMA request is generated. For proper operation, the value in RXWATER must be set to be less than the receive FIFO/buffer size as indicated by FIFO[RXFIFOSIZE] and FIFO[RXFE].
15-11 —	Reserved
10-8 TXCOUNT	Transmit Counter The value in this register indicates the number of datawords that are in the transmit FIFO/buffer. If a dataword is being transmitted, that is, in the transmit shift register, it is not included in the count. This value may be used in conjunction with FIFO[TXFIFOSIZE] to calculate how much room is left in the transmit FIFO/buffer.
7-2 —	Reserved
1-0	Transmit Watermark

Field	Function
TXWATER	When the number of datawords in the transmit FIFO/buffer is equal to or less than the value in this register field, an interrupt or a DMA request is generated. For proper operation, the value in TXWATER must be set to be less than the size of the transmit buffer/FIFO size as indicated by FIFO[TXFIFOSIZE] and FIFO[TXFE].

41.4 Functional description

The LPUART supports full-duplex, asynchronous, NRZ serial communication and comprises a baud rate generator, transmitter, and receiver block. The transmitter and receiver operate independently, although they use the same baud rate generator. The following describes each of the blocks of the LPUART.

41.4.1 Clocking and Resets

Table 41-2. Clocks

LPUART Functional clock	The LPUART functional clock is asynchronous to the bus clock and can remain enabled in low power modes to support transmit and/or receive, including low power wakeups.
Bus clock	The bus clock is only used for bus accesses to the control and configuration registers. The bus clock frequency must be sufficient to support the data bandwidth requirements of the LPUART transmit and receive registers, including the FIFOs.

Table 41-3. Resets

Chip reset	The logic and registers for the LPUART transmitter and receiver are reset to their default state on a chip reset.
Software reset	Resets the LPUART logic and registers to their default state, except for the Global Register. The LPUART software reset is in the Global Register GLOBAL[RST].
FIFO reset	The LPUART implements write-only control bits that reset the transmit FIFO (FIFO[TXFLUSH]) and receive FIFO (FIFO[RXFLUSH]). After a FIFO is reset, that FIFO is empty.

41.4.2 Baud rate generation

A 13-bit modulus counter in the baud rate generator derives the baud rate for both the receiver and the transmitter. The value from 1 to 8191 written to BAUD[SBR] determines the baud clock divisor for the asynchronous LPUART baud clock. The baud rate clock drives the receiver, while the transmitter is driven by a bit clock which is

generated from baud rate clock divided by the over sampling ratio (OSR). Depending on the over sampling ratio, the receiver has an acquisition rate of 4 to 32 samples per bit time.

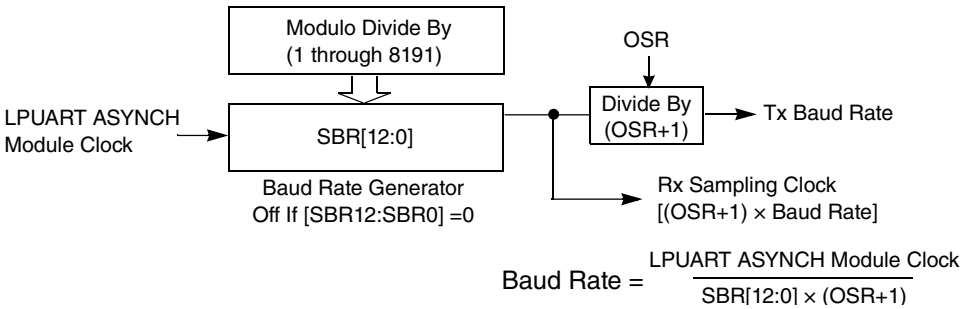


Figure 41-3. LPUART baud rate generation

Baud rate generation is subject to two sources of error:

- Integer division of the asynchronous LPUART baud clock may not give the exact target frequency.
- Synchronization with the asynchronous LPUART baud clock can cause phase shift.

The baud rate generation is a free-running counter that continues whenever the transmitter or receiver is enabled. The transmitter bit clock continues whenever the transmitter is enabled, each transmitted character aligns to the next edge of the transmit bit clock.

In general, configuring OSR for a higher oversampling ratio and/or sampling on both edges of the clock will slightly improve the LPUART tolerance to baud rate mismatch between the received data and the LPUART configured baud rate. However, the three data samples in each bit will also be closer together which may impact noise sensitivity.

41.4.3 Transmitter functional description

This section describes the overall block diagram for the LPUART transmitter, as well as specialized functions for sending break and idle characters.

The transmitter output (TXD) idle state defaults to logic high, CTRL[TXINV] is cleared following reset. The transmitter output is inverted by setting CTRL[TXINV]. The transmitter is enabled by setting the CTRL[TE] bit. This queues a preamble character that is one full character frame of the idle state. The transmitter then remains idle until data is available in the transmit data buffer. Programs store data into the transmit data buffer by writing to the DATA register.

The central element of the LPUART transmitter is the transmit shift register that is 9-bit to 13 bits long depending on the setting in the CTRL[M], CTRL[M7], BAUD[M10] and BAUD[SBNS] control bits. For the remainder of this section, assume CTRL[M], CTRL[M7], BAUD[M10] and BAUD[SBNS] are cleared, selecting the normal 8-bit data mode. In 8-bit data mode, the shift register holds a start bit, eight data bits, and a stop bit. When the transmit shift register is available for a new character, the value waiting in the transmit data register is transferred to the shift register, synchronized with the baud rate clock, and the transmit data register empty (STAT[TDRE]) status flag is set to indicate another character may be written to the transmit data buffer at the DATA register.

If no new character is waiting in the transmit data buffer after a stop bit is shifted out the TXD pin, the transmitter sets the transmit complete flag and enters an idle mode, with TXD high, waiting for more characters to transmit.

Writing 0 to CTRL[TE] does not immediately disable the transmitter. The current transmit activity in progress must first be completed (that could include a data character, idle character or break character), although the transmitter does not start transmitting another character.

41.4.3.1 Send break and queued idle

The CTRL[SBK] bit sends break characters originally used to gain the attention of old teletype receivers. Break characters are a full character time of logic 0, 9-bit to 12-bit times including the start and stop bits. A longer break of 13-bit times can be enabled by setting STAT[BRK13]. Normally, a program would wait for STAT[TDRE] to become set to indicate the last character of a message has moved to the transmit shifter, write 1, and then write 0 to the CTRL[SBK] bit. This action queues a break character to be sent as soon as the shifter is available. If CTRL[SBK] remains 1 when the queued break moves into the shifter, synchronized to the baud rate clock, an additional break character is queued. When the LPUART is the receiving device, a break character is received as 0s in all data bits and a framing error (STAT[FE] = 1) is detected.

A break character can also be transmitted by writing to the DATA register with bit 13 set and the data bits clear. This supports transmitting the break character as part of the normal data stream

When idle-line wakeup is used, a full character time of idle (logic 1) is needed between messages to wake up any sleeping receivers. Normally, a program would wait for STAT[TDRE] to become set to indicate the last character of a message has moved to the transmit shifter, then write 0 and then write 1 to the CTRL[TE] bit. This action queues an

idle character to be sent as soon as the shifter is available. As long as the character in the shifter does not finish while CTRL[TE] is cleared, the LPUART transmitter never actually releases control of the TXD pin.

An idle character can also be transmitted by writing to the DATA register with bit 13 set and the data bits also set. This supports transmitting the idle character as part of the normal data stream.

The length of the break character is affected by the STAT[BRK13], CTRL[M], CTRL[M7], BAUD[M10] and BAUD[SNBS] bits as shown below.

Table 41-4. Break character length

BRK13	M	M10	M7	SBNS	Break character length
0	0	0	0	0	10 bit times
0	0	0	0	1	11 bit times
0	0	0	1	0	9 bit times
0	0	0	1	1	10 bit times
0	1	0	X	0	11 bit times
0	1	0	X	1	12 bit times
0	X	1	X	0	12 bit times
0	X	1	X	1	13 bit times
1	0	0	0	0	13 bit times
1	0	0	0	1	13 bit times
1	0	0	1	0	12 bit times
1	0	0	1	1	12 bit times
1	1	0	X	0	14 bit times
1	1	0	X	1	14 bit times
1	X	1	X	0	15 bit times
1	X	1	X	1	15 bit times

41.4.3.2 Hardware flow control

The transmitter supports hardware flow control by gating the transmission with the value of CTS_B. If the clear-to-send operation is enabled, the character is transmitted when CTS_B is asserted. If CTS_B is deasserted in the middle of a transmission with characters remaining in the transmitter data buffer, the character in the shift register is sent and TXD remains in the mark state until CTS_B is reasserted. The CTS_B pin must assert for longer than one bit period to guarantee a new transmission is started when the transmitter is idle with data to send.

If the clear-to-send operation is disabled, the transmitter ignores the state of CTS_B.

The transmitter's CTS_B signal can also be enabled even if the same LPUART receiver's RTS_B signal is disabled.

41.4.3.3 Transceiver driver enable

The transmitter can use RTS_B as an enable signal for the driver of an external transceiver. See Transceiver driver enable using RTS_B for details. If the request-to-send operation is enabled, when a character is placed into an empty transmitter data buffer, RTS_B asserts one bit time before the start bit is transmitted. RTS_B remains asserted for the whole time that the transmitter data buffer has any characters. RTS_B deasserts one bit time after all characters in the transmitter data buffer and shift register are completely sent, including the last stop bit. Transmitting a break character also asserts RTS_B, with the same assertion and deassertion timing as having a character in the transmitter data buffer.

The transmitter's RTS_B signal asserts only when the transmitter is enabled. However, the transmitter's RTS_B signal is unaffected by its CTS_B signal. RTS_B remains asserted until the transfer is completed, even if the transmitter is disabled mid-way through a data transfer.

41.4.3.4 Transceiver driver enable using RTS_B

RS-485 is a multiple drop communication protocol in which the LPUART transceiver's driver is 3-stated unless the LPUART is driving. The RTS_B signal can be used by the transmitter to enable the driver of a transceiver. The polarity of RTS_B can be matched to the polarity of the transceiver's driver enable signal.

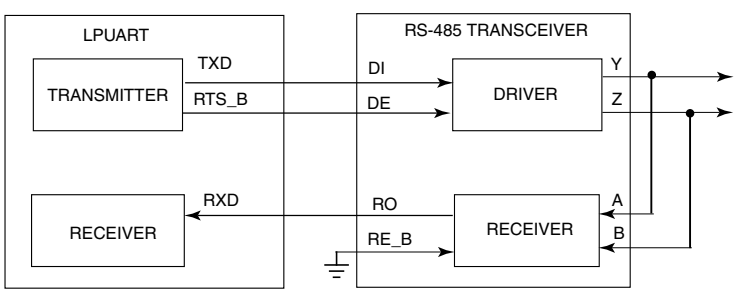


Figure 41-4. Transceiver driver enable using RTS_B

In the figure, the receiver enable signal is asserted. Another option for this connection is to connect RTS_B to both DE and RE_B. The transceiver's receiver is disabled while driving. A pullup can pull RXD to a non-floating value during this time. This option can be refined further by operating the LPUART in single wire mode, freeing the RXD pin for other uses.

41.4.4 Receiver functional description

In this section, the receiver block diagram is a guide for the overall receiver functional description. Next, the data sampling technique used to reconstruct receiver data is described in more detail. Finally, different variations of the receiver wakeup function are explained.

The receiver input is inverted by setting STAT[RXINV]. The receiver is enabled by setting the CTRL[RE] bit. Character frames consist of a start bit of logic 0, seven to ten data bits (msb or lsb first), and one or two stop bits of logic 1. For information about 7-bit, 9-bit or 10-bit data mode, refer to Data Modes. For the remainder of this discussion, assume the LPUART is configured for normal 8-bit data mode.

After receiving the stop bit into the receive shifter, and provided the receive data register is not already full, the data character is transferred to the receive data register and the receive data register full (STAT[RDRF]) status flag is set. If [RDRF] was already set indicating the receive data register (buffer) was already full, the overrun (OR) status flag is set and the new data is lost. Because the LPUART receiver is double-buffered, the program has one full character time after [RDRF] is set before the data in the receive data buffer must be read to avoid a receiver overrun.

When a program detects that the receive data register is full (STAT[RDRF] = 1), it gets the data from the receive data register by reading the DATA register. Refer to Interrupts and status flags for details about flag clearing.

41.4.4.1 Data sampling technique

The LPUART receiver supports a configurable oversampling rate of between 4× and 32× of the baud rate clock for sampling. The receiver starts by taking logic level samples at the oversampling rate times the baud rate to search for a falling edge on the RXD serial data input pin. A falling edge is defined as a logic 0 sample after three consecutive logic 1 samples. The oversampling baud rate clock divides the bit time into 4 to 32 segments from 1 to OSR (where OSR is the configured oversampling ratio). When a falling edge is located, three more samples are taken at (OSR/2), (OSR/2)+1, and (OSR/2)+2 to make sure this was a real start bit and not merely noise. If at least two of these three samples are 0, the receiver assumes it is synchronized to a received character. If another falling edge is detected before the receiver is considered synchronized, the receiver restarts the sampling from the first segment.

The receiver then samples each bit time, including the start and stop bits, at (OSR/2), (OSR/2)+1, and (OSR/2)+2 to determine the logic level for that bit. The logic level is interpreted to be that of the majority of the samples taken during the bit time. If any sample in any bit time, including the start and stop bits, in a character frame fails to agree with the logic level for that bit, the noise flag (STAT[NF]) is set when the received character is transferred to the receive data buffer.

When the LPUART receiver is configured to sample on both edges of the baud rate clock, the number of segments in each received bit is effectively doubled (from 1 to OSR×2). The start and data bits are then sampled at OSR, OSR+1 and OSR+2. Sampling on both edges of the clock must be enabled for oversampling rates of 4× to 7× and is optional for higher oversampling rates.

The "synchronization" is a feature of the LPUART module to synchronize the internal oversampling counter with detected falling edge on Rx signal, and to adjust the data sampling window. The falling edge detection needs three consecutive '1' prior to '1'->'0' transition. After the initial falling edge detection for the start bit, the circuit continuously monitors the next falling edge, and resets the counter once another falling edge is detected. This is called "resynchronization".

- When LPUART_BAUD[RESYNCDIS] = 0, this falling edge detection and resynchronization is performed not only for the start bit but also for the rest of character reception after the start bit.
- When LPUART_BAUD[RESYNCDIS] = 1, the falling edge detection and resynchronization is performed only for the start bit. The use case for disabling the resynchronization is protocols that require this (for example, LIN 2.1 prohibits resynchronization within a byte).

  See the following table and figure.

Table 41-5. LPUART resynchronization

Resynchronization	LPUART_BAUD[RESYNCDIS]=0	LPUART_BAUD[RESYNCDIS]=1
For the starting bit falling edge	Yes	Yes
For every falling edges after the start bit	Yes	No

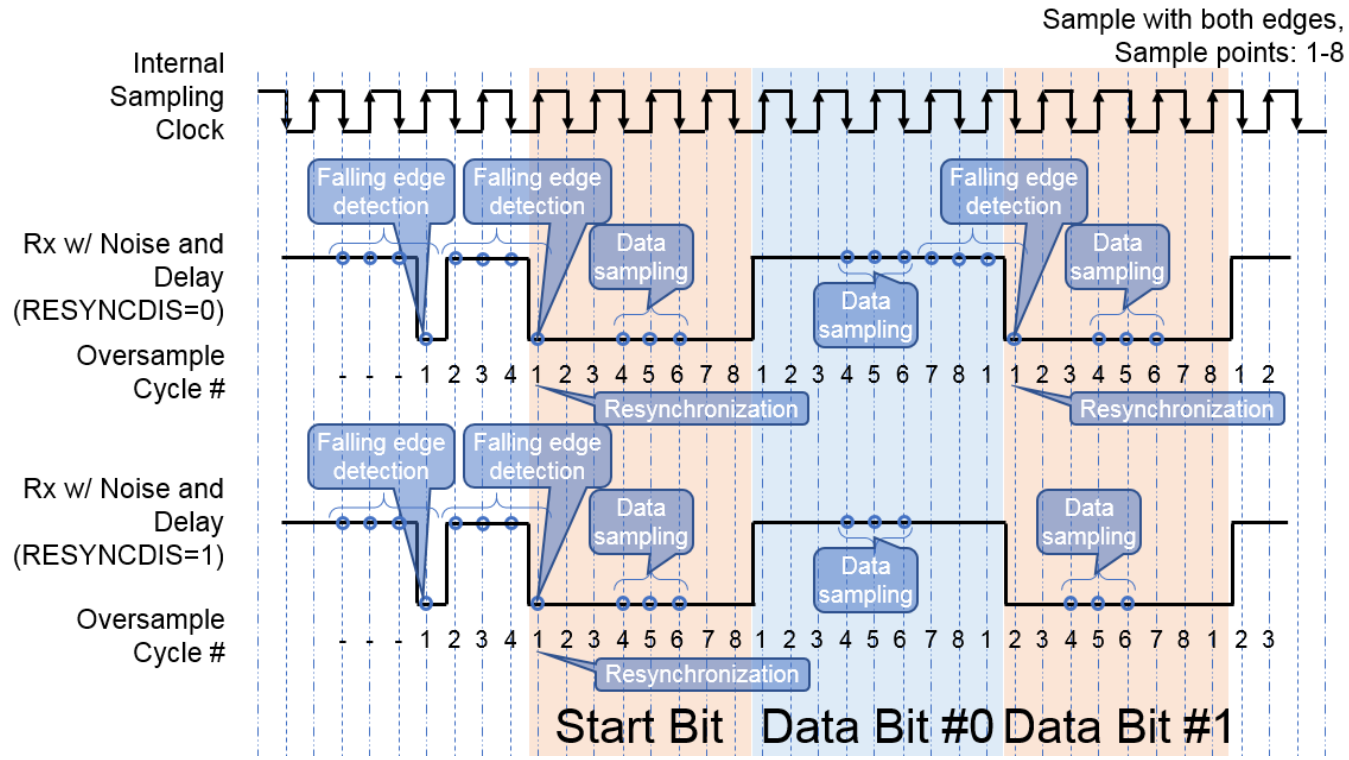


Figure 41-5. LPUART resynchronization

41.4.4.2 Receiver wakeup operation

Receiver wakeup and receiver address matching is a hardware mechanism that allows an LPUART receiver to ignore the characters in a message intended for a different receiver.

During receiver wakeup, all receivers evaluate the first character(s) of each message, and as soon as they determine the message is intended for a different receiver, they write logic 1 to the receiver wake up control bit (CTRL[RWU]). When CTRL[RWU] and STAT[RWUID] bit are set, the status flags associated with the receiver, with the exception of the idle bit, STAT[IDLE], are inhibited from setting, thus eliminating the software overhead for handling the unimportant message characters. At the end of a message, or at the beginning of the next message, all receivers automatically force CTRL[RWU] to 0 so all receivers wake up in time to look at the first character(s) of the next message.

During receiver address matching, the address matching is performed in hardware and the LPUART receiver ignores all characters that do not meet the address match requirements.

Table 41-6. Receiver Wakeup Options

RWU	MA1 | MA2	MATCFG	WAKE:RWUID	Receiver Wakeup
0	0	X	X	Normal operation

Table continues on the next page...

Table 41-6. Receiver Wakeup Options (continued)

RWU	MA1 | MA2	MATCFG	WAKE:RWUID	Receiver Wakeup
1	0	00	00	Receiver wakeup on idle line, IDLE flag not set
1	0	00	01	Receiver wakeup on idle line, IDLE flag set
1	0	00	10	Receiver wakeup on address mark
1	1	11	10	Receiver wakeup on data match
0	1	00	X0	Address mark address match, IDLE flag not set for discarded characters
0	1	00	X1	Address mark address match, IDLE flag set for discarded characters
0	1	01	X0	Idle line address match
0	1	10	X0	Address match on and address match off, IDLE flag not set for discarded characters
0	1	10	X1	Address match on and address match off, IDLE flag set for discarded characters

41.4.4.2.1 Idle-line wakeup

When wake is cleared, the receiver is configured for idle-line wakeup. In this mode, CTRL[RWU] is cleared automatically when the receiver detects a full character time of the idle-line level. The CTRL[M], CTRL[M7] and BAUD[M10] control bit selects 7-bit to 10-bit data mode and the BAUD[SBNS] bit selects 1-bit or 2-bit stop bit number that determines how many bit times of idle are needed to constitute a full character time, 9 to 13 bit times because of the start and stop bits.

When CTRL[RWU] is one and STAT[RWUID] is 0, the idle condition that wakes up the receiver does not set the STAT[IDLE] flag. The receiver wakes up and waits for the first data character of the next message that sets the STAT[RDRF] flag and generates an interrupt if enabled. When STAT[RWUID] is 1, any idle condition sets the STAT[IDLE] flag and generates an interrupt if enabled, regardless of whether CTRL[RWU] is 0 or 1.

The idle-line type (CTRL[ILT]) control bit selects one of two ways to detect an idle line. When CTRL[ILT] is cleared, the idle bit counter starts after the start bit so the stop bit and any logic 1s at the end of a character count toward the full character time of idle. When CTRL[ILT] is set, the idle bit counter does not start until after the stop bit time, so the idle detection is not affected by the data in the last character of the previous message.

41.4.4.2.2 Address-mark wakeup

When CTRL[WAKE] is set, the receiver is configured for address-mark wakeup. In this mode, CTRL[RWU] is cleared automatically when the receiver detects a logic 1 in the most significant bit of the received character. When parity is enabled, the second most significant bit is used for address-mark wakeup.

Address-mark wakeup allows messages to contain idle characters, but requires one bit be reserved for use in address frames. The logic 1 in the most significant bit (or second most significant bit when parity is enabled) of an address frame clears the CTRL[RWU] bit and sets the STAT[RDRF] flag. In this case, the character with the address-mark bit is received even though the receiver was sleeping during most of this character time.

41.4.4.2.3 Data match wakeup

When CTRL[RWU] is set, CTRL[WAKE] is set and BAUD[MATCFG] equals 11, the receiver is configured for data match wakeup. In this mode, CTRL[RWU] is cleared automatically when the receiver detects a character that matches MATCH[MA1] field when BAUD[MAEN1] is set, or that matches MATCH[MA2] when BAUD[MAEN2] is set.

41.4.4.2.4 Address Match operation

Address match operation is enabled when the BAUD[MAEN1] or BAUD[MAEN2] bit is set and BAUD[MATCFG] is equal to 00. In this function, a character received by the RXD pin with a logic 1 in the most significant bit (or second most significant bit when parity is enabled) is considered an address and is compared with the associated MATCH[MA1] or MATCH[MA2] field. The character is only transferred to the receive buffer, and STAT[RDRF] is set, if the comparison matches. All subsequent characters received with a logic 0 in the most significant bit (or second most significant bit when parity is enabled) are considered to be data associated with the address and are transferred to the receive data buffer. If no marked address match occurs then no transfer is made to the receive data buffer, and all following characters with logic zero in the most significant bit (or second most significant bit when parity is enabled) are also discarded. If both the BAUD[MAEN1] and BAUD[MAEN2] bits are negated, the receiver operates normally and all data received is transferred to the receive data buffer.

Address match operation functions in the same way for both MATCH[MA1] and MATCH[MA2] fields.

- If only one of BAUD[MAEN1] and BAUD[MAEN2] is asserted, a marked address is compared only with the associated match register field and data is transferred to the receive data buffer only on a match.
- If BAUD[MAEN1] and BAUD[MAEN2] are asserted, a marked address is compared with both match registers and data is transferred only on a match with either of the MATCH[MA1] or MATCH[MA2] fields.

41.4.4.2.5 Idle Match operation

Idle match operation is enabled when the BAUD[MAEN1] or BAUD[MAEN2] bit is set and BAUD[MATCFG] is equal to 01. In this function, the first character received by the RXD pin after an idle line condition is considered an address and is compared with the associated MATCH[MA1] or MATCH[MA2] field. The character is only transferred to the receive buffer, and STAT[RDRF] is set, if the comparison matches. All subsequent characters are considered to be data associated with the address and are transferred to the receive data buffer until the next idle line condition is detected. If no address match occurs then no transfer is made to the receive data buffer, and all following frames until the next idle condition are also discarded. If both the BAUD[MAEN1] and BAUD[MAEN2] bits are negated, the receiver operates normally and all data received is transferred to the receive data buffer.

Idle match operation functions in the same way for both MATCH[MA1] or MATCH[MA2] fields.

- If only one of BAUD[MAEN1] and BAUD[MAEN2] is asserted, the first character after an idle line is compared only with the associated match register and data is transferred to the receive data buffer only on a match.
- If BAUD[MAEN1] and BAUD[MAEN2] are asserted, the first character after an idle line is compared with both MATCH[MA1] or MATCH[MA2] fields and data is transferred only on a match with either of the fields.

41.4.4.2.6 Match On Match Off operation

Match on, match off operation is enabled when both BAUD[MAEN1] and BAUD[MAEN2] are set and BAUD[MATCFG] is equal to 10. In this function, a character received by the RXD pin that matches MATCH[MA1] is received and transferred to the receive buffer, and STAT[RDRF] is set. All subsequent characters are considered to be data and are also transferred to the receive data buffer, until a character

is received that matches MATCH[MA2] field. The character that matches MATCH[MA2] and all following characters are discarded; this continues until another character that matches MATCH[MA1] is received. If both the BAUD[MAEN1] and BAUD[MAEN2] bits are negated, the receiver operates normally and all data received is transferred to the receive data buffer.

NOTE

Match on, match off operation requires both BAUD[MAEN1] and BAUD[MAEN2] to be asserted.

41.4.4.3 Hardware flow control

To support hardware flow control, the receiver can be programmed to automatically deassert and assert RTS_B.

- RTS_B remains asserted until the transfer is complete, even if the transmitter is disabled midway through a data transfer. See Transceiver driver enable using RTS_B for more details.
- If the receiver request-to-send functionality is enabled, the receiver automatically deasserts RTS_B if the number of characters in the receiver data register is full or a start bit is detected that causes the receiver data register to be full.
- The receiver asserts RTS_B when the number of characters in the receiver data register is not full and has not detected a start bit that causes the receiver data register to be full. It is not affected if STAT[RDRF] is asserted.
- Even if RTS_B is deasserted, the receiver continues to receive characters until the receiver data buffer is overrun.
- If the receiver request-to-send functionality is disabled, the receiver RTS_B remains deasserted.

41.4.4.4 Infrared decoder

The infrared decoder converts the received character from the IrDA format to the NRZ format used by the receiver. It also has a OSR oversampling baud rate clock counter that filters noise and indicates when a 1 is received.

41.4.4.4.1 Start bit detection

When STAT[RXINV] is cleared, the first falling edge of the received character corresponds to the start bit. The infrared decoder resets its counter. At this time, the receiver also begins its start bit detection process. After the start bit is detected, the

receiver synchronizes its bit times to this start bit time. For the rest of the character reception, the infrared decoder's counter and the receiver's bit time counter count independently from each other.

41.4.4.4.2 Noise filtering

Any further rising edges detected during the first half of the infrared decoder counter are ignored by the decoder. Any pulses less than one oversampling baud clock can be undetected by it regardless of whether it is seen in the first or second half of the count.

41.4.4.4.3 Low-bit detection

During the second half of the decoder count, a rising edge is decoded as a 0, which is sent to the receiver. The decoder counter is also reset.

41.4.4.4.4 High-bit detection

At OSR oversampling baud rate clocks after the previous rising edge, if a rising edge is not seen, then the decoder sends a 1 to the receiver.

If the next bit is a 0, which arrives late, then a low-bit is detected according to Low-bit detection. The value sent to the receiver is changed from 1 to a 0. Then, if a noise pulse occurs outside the receiver's bit time sampling period, then the delay of a 0 is not recorded as noise.

41.4.5 Additional LPUART functions

The following sections describe additional LPUART functions.

41.4.5.1 Data Modes

The LPUART transmitter and receiver can be configured to operate in 7-bit data mode by setting CTRL[M7], 9-bit data mode by setting the CTRL[M] or 10-bit data mode by setting BAUD[M10]. In 9-bit mode, there is a ninth data bit and in 10-bit mode, there is a tenth data bit. For the transmit data buffer, these bits are stored in CTRL[T8] and CTRL[T9]. For the receiver, these bits are held in CTRL[R8] and CTRL[R9]. They are also accessible via 16-bit or 32-bit accesses to the DATA register.

For coherent 8-bit writes to the transmit data buffer, write to CTRL[T8] and CTRL[T9] before writing to DATA[7:0]. For 16-bit and 32-bit writes to the DATA register, all 10 transmit bits are written to the transmit data buffer at the same time.

If the bit values to be transmitted as the ninth and tenth bit of a new character are the same as for the previous character, it is not necessary to write to CTRL[T8] and CTRL[T9] again. When data is transferred from the transmit data buffer to the transmit shifter, the value in CTRL[T8] and CTRL[T9] is copied at the same time data is transferred from DATA[7:0] to the shifter.

The 9-bit data mode is typically used with parity to allow eight bits of data plus the parity in the ninth bit, or it is used with address-mark wakeup so the ninth data bit can serve as the wakeup bit. The 10-bit data mode is typically used with parity and address-mark wakeup so the ninth data bit can serve as the wakeup bit and the tenth bit as the parity bit. In custom protocols, the ninth and/or tenth bits can also serve as software-controlled markers.

41.4.5.2 Idle length

An idle character is a character where the start bit, all data bits and stop bits are in the mark position. The CTRL[ILT] bit can be configured to start detecting an idle character from the previous start bit (any data bits and stop bits count towards the idle character detection) or from the previous stop bit.

The number of idle characters that must be received before an idle line condition is detected can also be configured using the CTRL[IDLECFG] field. This field configures the number of idle characters that must be received before the STAT[IDLE] flag is set, the STAT[RAF] flag is cleared and the DATA[IDLINE] flag is set with the next received character.

Idle-line wakeup and idle match operation are also affected by the CTRL[IDLECFG] field. When address match or match on/off operation is enabled, setting the STAT[RWUID] bit causes any discarded characters to be treated as if they were idle characters.

41.4.5.3 Loop mode

When CTRL[LOOPS] is set, the CTRL[RSRC] bit chooses between loop mode (CTRL[RSRC] = 0) or single-wire mode (CTRL[RSRC] = 1). Loop mode is sometimes used to check software, independent of connections in the external system, to help isolate system problems. In this mode, the transmitter output is internally connected to the receiver input and the RXD pin is not used by the LPUART.

41.4.5.4 Single-wire operation

When CTRL[LOOPS] is set, the CTRL[RSRC] bit chooses between loop mode (CTRL[RSRC] = 0) or single-wire mode (CTRL[RSRC] = 1). Single-wire mode implements a half-duplex serial connection. The receiver is internally connected to the transmitter output and to the TXD pin (the RXD pin is not used).

In single-wire mode, the CTRL[TXDIR] bit controls the direction of serial data on the TXD pin. When CTRL[TXDIR] is cleared, the TXD pin is an input to the receiver and the transmitter is temporarily disconnected from the TXD pin so an external device can send serial data to the receiver. When CTRL[TXDIR] is set, the TXD pin is an output driven by the transmitter, the internal loop back connection is disabled, and as a result the receiver cannot receive characters that are sent out by the transmitter.

41.4.6 Infrared interface

The LPUART provides the capability of transmitting narrow pulses to an IR LED and receiving narrow pulses and transforming them to serial bits, which are sent to the LPUART. The IrDA physical layer specification defines a half-duplex infrared communication link for exchanging data. The full standard includes data rates up to 16 Mbits/s. This module covers data rates only between 2.4 kbits/s and 115.2 kbits/s.

The LPUART has an infrared transmit encoder and receive decoder. The LPUART transmits serial bits of data that are encoded by the infrared submodule to transmit a narrow pulse for every zero bit. No pulse is transmitted for every one bit. When receiving data, the IR pulses are detected using an IR photo diode and transformed to CMOS levels by the IR receive decoder, external from the LPUART. The narrow pulses are then stretched by the infrared receive decoder to get back to a serial bit stream to be received by the LPUART. The polarity of transmitted pulses and expected receive pulses can be inverted so that a direct connection can be made to external IrDA transceiver modules that use active high pulses.

The infrared submodule receives its clock sources from the LPUART. One of these two clocks are selected in the infrared submodule to generate either 1/OSR, 2/OSR, 3/OSR, or 4/OSR narrow pulses during transmission.

41.4.6.1 Infrared transmit encoder

The infrared transmit encoder converts serial bits of data from transmit shift register to the TXD signal. A narrow pulse is transmitted for a 0 bit and no pulse for a 1 bit. The narrow pulse is sent at the start of the bit with a duration of 1/OSR, 2/OSR, 3/OSR, or 4/OSR of a bit time. A narrow low pulse is transmitted for a 0 bit when CTRL[TXINV] is cleared, while a narrow high pulse is transmitted for a 0 bit when CTRL[TXINV] is set.

41.4.6.2 Infrared receive decoder

The infrared receive block converts data from the RXD signal to the receive shift register. A narrow pulse is expected for each 0 received and no pulse is expected for each 1 received. A narrow low pulse is expected for a 0 bit when STAT[RXINV] is cleared, while a narrow high pulse is expected for a 0 bit when STAT[RXINV] is set. This receive decoder meets the edge jitter requirement as defined by the IrDA serial infrared physical layer specification.

41.4.7 Interrupts and status flags

The LPUART transmitter has two status flags that can optionally generate hardware interrupt requests. Transmit data register empty STAT[TDRE]) indicates when there is room in the transmit data buffer to write another transmit character to the DATA register. If the transmit interrupt enable CTRL[TIE]) bit is set, a hardware interrupt is requested when STAT[TDRE] is set. Transmit complete (STAT[TC]) indicates that the transmitter is finished transmitting all data, preamble, and break characters and is idle with TXD at the inactive level. This flag is often used in systems with modems to determine when it is safe to turn off the modem. If the transmit complete interrupt enable (CTRL[TCIE]) bit is set, a hardware interrupt is requested when STAT[TC] is set. Instead of hardware interrupts, software polling may be used to monitor the STAT[TDRE] and STAT[TC] status flags if the corresponding CTRL[TIE] or CTRL[TCIE] local interrupt masks are cleared.

When a program detects that the receive data register is full (STAT[RDRF] = 1), it gets the data from the receive data register by reading the DATA register. The STAT[RDRF] flag is cleared by reading the DATA register.

The IDLE status flag includes logic that prevents it from getting set repeatedly when the RXD line remains idle for an extended period of time. IDLE is cleared by writing 1 to the STAT[IDLE] flag. After STAT[IDLE] has been cleared, it cannot become set again until the receiver has received at least one new character and has set STAT[RDRF].

If the associated error was detected in the received character that caused STAT[RDRF] to be set, the error flags - noise flag (STAT[NF]), framing error (STAT[FE]), and parity error flag (STAT[PF]) - are set at the same time as STAT[RDRF]. These flags are not set in overrun cases.

If STAT[RDRF] was already set when a new character is ready to be transferred from the receive shifter to the receive data buffer, the overrun (STAT[OR]) flag is set instead of the data along with any associated NF, FE, or PF condition is lost.

If the received character matches the contents of MATCH[MA1] and/or MATCH[MA2] then the STAT[MA1F] and/or STAT[MA2F] flags are set at the same time that STAT[RDRF] is set.

At any time, an active edge on the RXD serial data input pin causes the STAT[RXEDGIF] flag to set. The STAT[RXEDGIF] flag is cleared by writing a 1 to it. This function depends on the receiver being enabled (CTRL[RE] = 1).

41.4.8 Peripheral Triggers

The connection of the LPUART peripheral triggers with other peripherals are device specific.

41.4.8.1 Output Triggers

The LPUART generates the following output triggers that can be connected to other peripherals on the device.

- The transmit word trigger asserts at the end of each transmitted word, it negates after one bit period.
- The receive word trigger asserts at the end of each received word that is written to the receive FIFO, for one oversampling clock period.
- The receive idle trigger asserts at when the idle flag would set, for one oversampling clock period.

41.4.8.2 Input Trigger

The LPUART supports one peripheral input trigger, that can be configured in one of the following ways.

- The input trigger can be connected in place of the CTS_B pin input. The input trigger must assert for longer than one bit clock period when the transmitter is idle with data to send to guarantee a new transmission.
- The input trigger can modulate the transmit data output (trigger is logically ANDed with the TXD output). The input trigger is expected to be generated from a PWM source with a period that is less than the bit clock frequency.
- The input trigger can be connected in place of the RXD pin input. The input trigger is expected to be generated from a receive data source, such as analog comparator or external pin.

Chapter 42
Modular/Scalable Controller Area Network (MSCAN)

42.1 Chip-specific information for this module

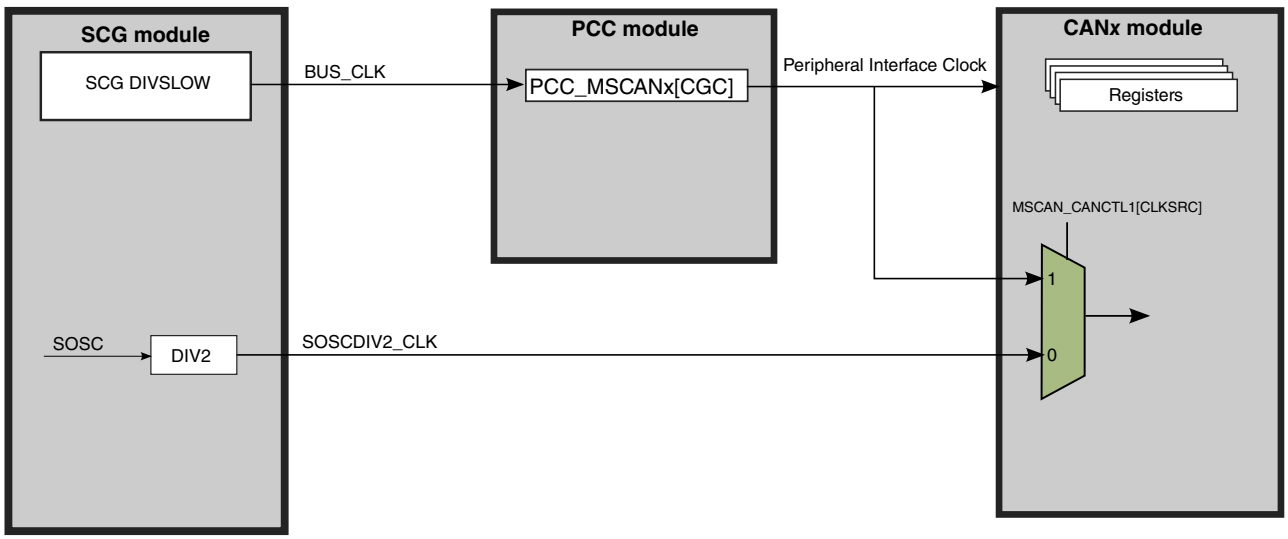
42.1.1 MSCAN overview

This device contains a CAN module. It uses the MSCAN mudule which is a communication controller implementing the CAN 2.0A/B protocol as defined in the Bosch specification dated September 1991.

42.1.2 MSCAN clocking

The MSCAN module has programmable clock source. It could be clocked by bus clock or external oscillator clock (SOSCDIV2_CLK). User can configure MSCAN_CANCTL1[CLKSRC] to select the clock used.

Peripheral Clocking - MSCAN



42.1.3 MSCAN wake-up interrupt and glitch filter

The MSCAN can be programmed to wake from Sleep or Stop mode when the CAN bus activity is detected. The sensitivity to existing CAN bus action can be modified by applying a low-pass filter function to the RXCAN input line by setting MSCAN_CANCTL1[WUPM]. This feature protects the MSCAN from wake-up due to short glitches on the CAN bus lines.

42.2 Introduction

Modular/scalable controller area network (MSCAN) is a communication controller implementing the CAN 2.0A/B protocol as defined in the Bosch specification dated September 1991. For users to fully understand the MSCAN specification, it is recommended that the Bosch specification be read first to familiarize the reader with the terms and concepts contained within this document.

Though not exclusively intended for automotive applications, CAN protocol is designed to meet the specific requirements of a vehicle serial data bus: real-time processing, reliable operation in the EMI environment of a vehicle, cost-effectiveness, and required bandwidth.

MSCAN uses an advanced buffer arrangement resulting in predictable real-time behavior and simplified application software.

42.2.1 Glossary

Table 42-1. Terminology

Term	Description
ACK	Acknowledge of CAN message
CAN	Controller area network
CRC	Cyclic redundancy code
EOF	End of frame
FIFO	First-In-First-Out memory
IFS	Inter-Frame sequence
SOF	Start of Frame
CPU bus	CPU related read/write data bus
CAN bus	CAN protocol related serial bus
oscillator clock	Direct clock from external oscillator
bus clock	CPU bus related clock
CAN clock	CAN protocol related clock

42.2.2 Block diagram

The following figure is the block diagram of the MSCAN

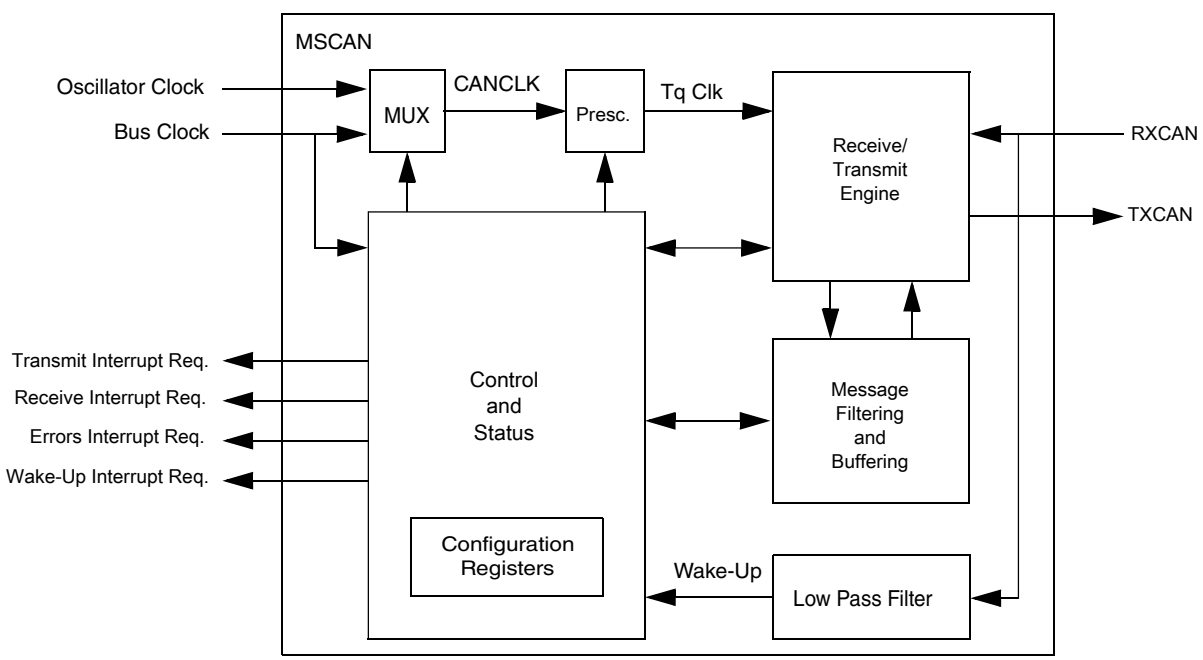


Figure 42-1. MSCAN Block Diagram

42.2.3 Features

The basic features of the MSCAN are as follows:

- Implementation of the CAN protocol - Version 2.0A/B
  - Standard and extended data frames
  - Zero to eight bytes data length
  - Programmable bit rate up to 1 Mbps[1]
  - Support for remote frames
- Five receive buffers with FIFO storage scheme
- Three transmit buffers with internal prioritization using a "local priority" concept
- Flexible maskable identifier filter supports two full-size (32-bit) extended identifier filters, or four 16-bit filters, or eight 8-bit filters
- Programmable wake-up functionality with integrated low-pass filter
- Programmable loopback mode supports self-test operation
- Programmable listen-only mode for monitoring of CAN bus
- Programmable bus-off recovery functionality
- Separate signalling and interrupt capabilities for all CAN receiver and transmitter error states (warning, error passive, bus-off)
- Programmable MSCAN clock source either bus clock or oscillator clock
- Internal timer for time-stamping of received and transmitted messages
- Three low-power modes: sleep, power down, and MSCAN enable
- Global initialization of configuration registers

42.2.4 Modes of operation

42.2.4.1 Normal system operating modes

The MSCAN module behaves as described within this specification in all normal system operating modes. Write restrictions exist for some registers.

42.2.4.2 Special system operating modes

The MSCAN module behaves as described within this specification in all special system operating modes. Write restrictions which exist on specific registers in normal modes are lifted for test purposes in special modes.

1. Depending on the actual bit timing and the clock jitter of the PLL.

42.2.4.3 Emulation modes

In all emulation modes, the MSCAN module behaves just like in normal system operating modes as described within this specification.

42.2.4.4 Listen-only mode

In an optional CAN bus monitoring mode (listen-only), the CAN node is able to receive valid data frames and valid remote frames, but it sends only "recessive" bits on the CAN bus. In addition, it cannot start a transmission.

If the MAC sub-layer is required to send a "dominant" bit (ACK bit, overload flag, or active error flag), the bit is rerouted internally so that the MAC sub-layer monitors this "dominant" bit, although the CAN bus may remain in recessive state externally.

42.2.4.5 MSCAN initialization mode

MSCAN Initialization Mode The MSCAN enters initialization mode when it is enabled (CANE=1).

When entering initialization mode during operation, any on-going transmission or reception is immediately aborted and synchronization to the CAN bus is lost, potentially causing CAN protocol violations. To protect the CAN bus system from fatal consequences of violations, the MSCAN immediately drives TXCAN into a recessive state.

NOTE

The user is responsible for ensuring that the MSCAN is not active when initialization mode is entered. The recommended procedure is to bring the MSCAN into sleep mode (SLPRQ = 1 and SLPAK = 1) before setting the INITRQ bit in the CANCTL0 register. Otherwise, the abort of an on-going message can cause an error condition and can impact other CAN bus devices.

In initialization mode, the MSCAN is stopped. However, interface registers remain accessible. This mode is used to reset the CANCTL0, CANRFLG, CANRIER, CANTFLG, CANTIER, CANTARQ, CANTAAK, and CANTBSEL registers to their

default values. In addition, the MSCAN enables the configuration of the CANBTR0, CANBTR1 bit timing registers; CANIDAC; and the CANIDAR, CANIDMR message filters.

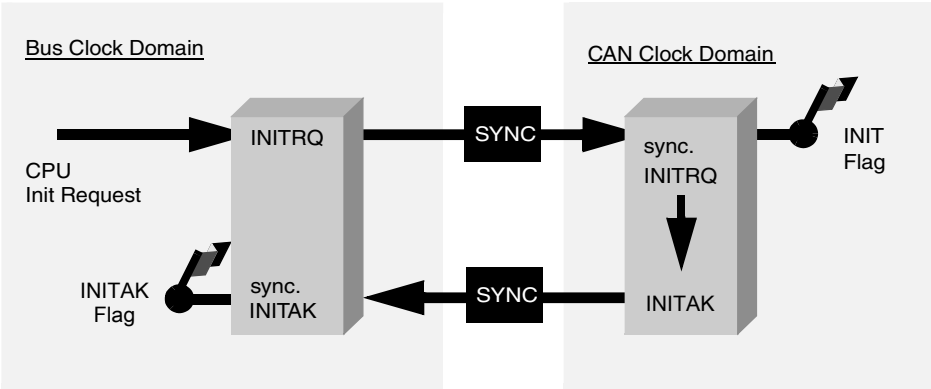


Figure 42-2. Initialization request/acknowledge cycle

Due to independent clock domains within the MSCAN, INITRQ must be synchronized to all domains by using a special handshake mechanism. This handshake causes additional synchronization delay (see Figure 42-2).

If there is no message transfer ongoing on the CAN bus, the minimum delay will be two additional bus clocks and three additional CAN clocks. When all parts of the MSCAN are in initialization mode, the INITAK flag is set. The application software must use INITAK as a handshake indication for the request (INITRQ) to go into initialization mode.

NOTE

The CPU cannot clear INITRQ before initialization mode (INITRQ = 1 and INITAK = 1) is active.

42.3 External signal description

The MSCAN uses two external pins.

NOTE

On MCUs with an integrated CAN physical interface (transceiver) the MSCAN interface is connected internally to the transceiver interface. In these cases the external availability of signals TXCAN and RXCAN is optional.

Table 42-2. MSCAN signal descriptions

Signal	Description	I/O	Function
RXCAN	CAN receiver input pin	I	-

Table continues on the next page...

Table 42-2. MSCAN signal descriptions (continued)

Signal	Description	I/O	Function
TXCAN	CAN transmitter output pin	O	The TXCAN output pin represents the logic level on the CAN bus: • 0 = Dominant state • 1 = Recessive state

42.3.1 CAN system

A typical CAN system with MSCAN is shown in the following figure. Each CAN station is connected physically to the CAN bus lines through a transceiver device. The transceiver is capable of driving the large current needed for the CAN bus and has current protection against defective CAN or defective stations.

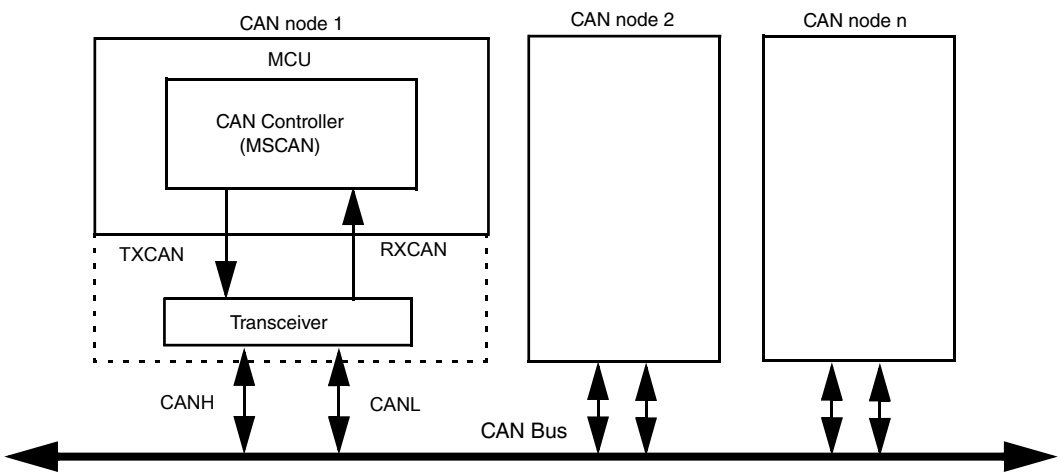


Figure 42-3. CAN system

42.4 Memory map and register definition

42.4.1 Programmer's model of message storage

Each of the receive and transmit message buffers allocates 16 bytes in the memory map containing a 13 byte data structure.

An additional transmit buffer priority register (TBPR) is defined for the transmit buffers. Within the last two bytes of this memory map, the MSCAN stores a special 16-bit time stamp, which is sampled from an internal timer after successful transmission or reception of a message. This feature is only available for transmit and receiver buffers, if the CANCTL0[TIME] is set.

The time stamp register is written by the MSCAN. The CPU can only read these registers.

The following table shows the registers that the data structure of receive and transmit buffers for extended identifiers and standard identifiers mapping to.

Table 42-3. Message buffer organization

Offset address	Extended identifiers	Standard identifiers
0x0020	REIDR0	RSIDR0
0x0021	REIDR1	RSIDR1
0x0022	REIDR2	
0x0023	REIDR3	
0x0024	REDSR0	
0x0025	REDSR1	
0x0026	REDSR2	
0x0027	REDSR3	
0x0028	REDSR4	
0x0029	REDSR5	
0x002A	REDSR6	
0x002B	REDSR7	
0x002C	RDLR	
0x0030	TEIDR0	TSIDR0
0x0031	TEIDR1	TSIDR1
0x0032	TEIDR2	
0x0033	TEIDR3	
0x0034	TEDSR0	
0x0035	TEDSR1	
0x0036	TEDSR2	
0x0037	TEDSR3	
0x0038	TEDSR4	
0x0039	TEDSR5	
0x003A	TEDSR6	
0x003B	TEDSR7	
0x003C	TDLR	

NOTE

Read:

- For transmit buffers, anytime when CANTFLG[TXE] flag is set and the corresponding transmit buffer is selected in CANTBSEL
- For receive buffers, only when CANRFLG[RXF] flag is set

Write:

- For transmit buffers, anytime when CANTFLG[TXE] flag is set and the corresponding transmit buffer is selected in CANTBSEL.
- Unimplemented for receive buffers.

Reset: Undefined because of RAM-based implementation

MSCAN memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4002_4000	MSCAN Control Register 0 (MSCAN_CANCTL0)	8	R/W	01h	42.4.2/980
4002_4001	MSCAN Control Register 1 (MSCAN_CANCTL1)	8	R/W	11h	42.4.3/982
4002_4002	MSCAN Bus Timing Register 0 (MSCAN_CANBTR0)	8	R/W	00h	42.4.4/984
4002_4003	MSCAN Bus Timing Register 1 (MSCAN_CANBTR1)	8	R/W	00h	42.4.5/985
4002_4004	MSCAN Receiver Flag Register (MSCAN_CANRFLG)	8	R/W	00h	42.4.6/986
4002_4005	MSCAN Receiver Interrupt Enable Register (MSCAN_CANRIER)	8	R/W	00h	42.4.7/988
4002_4006	MSCAN Transmitter Flag Register (MSCAN_CANTFLG)	8	R/W	07h	42.4.8/989
4002_4007	MSCAN Transmitter Interrupt Enable Register (MSCAN_CANTIER)	8	R/W	00h	42.4.9/990
4002_4008	MSCAN Transmitter Message Abort Request Register (MSCAN_CANTARQ)	8	R/W	00h	42.4.10/991
4002_4009	MSCAN Transmitter Message Abort Acknowledge Register (MSCAN_CANTAAK)	8	R	00h	42.4.11/992
4002_400A	MSCAN Transmit Buffer Selection Register (MSCAN_CANTBSEL)	8	R/W	00h	42.4.12/993
4002_400B	MSCAN Identifier Acceptance Control Register (MSCAN_CANIDAC)	8	R/W	00h	42.4.13/994
4002_400D	MSCAN Miscellaneous Register (MSCAN_CANMISC)	8	R/W	00h	42.4.14/995
4002_400E	MSCAN Receive Error Counter (MSCAN_CANRXERR)	8	R	00h	42.4.15/995
4002_400F	MSCAN Transmit Error Counter (MSCAN_CANTXERR)	8	R	00h	42.4.16/996
4002_4010	MSCAN Identifier Acceptance Register n of First Bank (MSCAN_CANIDAR0)	8	R/W	00h	42.4.17/997
4002_4011	MSCAN Identifier Acceptance Register n of First Bank (MSCAN_CANIDAR1)	8	R/W	00h	42.4.17/997
4002_4012	MSCAN Identifier Acceptance Register n of First Bank (MSCAN_CANIDAR2)	8	R/W	00h	42.4.17/997
4002_4013	MSCAN Identifier Acceptance Register n of First Bank (MSCAN_CANIDAR3)	8	R/W	00h	42.4.17/997

Table continues on the next page...

MSCAN memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4002_4014	MSCAN Identifier Mask Register n of First Bank (MSCAN_CANIDMR0)	8	R/W	00h	42.4.18/998
4002_4015	MSCAN Identifier Mask Register n of First Bank (MSCAN_CANIDMR1)	8	R/W	00h	42.4.18/998
4002_4016	MSCAN Identifier Mask Register n of First Bank (MSCAN_CANIDMR2)	8	R/W	00h	42.4.18/998
4002_4017	MSCAN Identifier Mask Register n of First Bank (MSCAN_CANIDMR3)	8	R/W	00h	42.4.18/998
4002_4018	MSCAN Identifier Acceptance Register n of Second Bank (MSCAN_CANIDAR4)	8	R/W	00h	42.4.19/998
4002_4019	MSCAN Identifier Acceptance Register n of Second Bank (MSCAN_CANIDAR5)	8	R/W	00h	42.4.19/998
4002_401A	MSCAN Identifier Acceptance Register n of Second Bank (MSCAN_CANIDAR6)	8	R/W	00h	42.4.19/998
4002_401B	MSCAN Identifier Acceptance Register n of Second Bank (MSCAN_CANIDAR7)	8	R/W	00h	42.4.19/998
4002_401C	MSCAN Identifier Mask Register n of Second Bank (MSCAN_CANIDMR4)	8	R/W	00h	42.4.20/999
4002_401D	MSCAN Identifier Mask Register n of Second Bank (MSCAN_CANIDMR5)	8	R/W	00h	42.4.20/999
4002_401E	MSCAN Identifier Mask Register n of Second Bank (MSCAN_CANIDMR6)	8	R/W	00h	42.4.20/999
4002_401F	MSCAN Identifier Mask Register n of Second Bank (MSCAN_CANIDMR7)	8	R/W	00h	42.4.20/999
4002_4020	Receive Extended Identifier Register 0 (MSCAN_REIDR0)	8	R	Undefined	42.4.21/ 1000
4002_4020	Receive Standard Identifier Register 0 (MSCAN_RSIDR0)	8	R	Undefined	42.4.22/ 1000
4002_4021	Receive Extended Identifier Register 1 (MSCAN_REIDR1)	8	R	Undefined	42.4.23/ 1001
4002_4021	Receive Standard Identifier Register 1 (MSCAN_RSIDR1)	8	R	Undefined	42.4.24/ 1002
4002_4022	Receive Extended Identifier Register 2 (MSCAN_REIDR2)	8	R	Undefined	42.4.25/ 1003
4002_4023	Receive Extended Identifier Register 3 (MSCAN_REIDR3)	8	R	Undefined	42.4.26/ 1003
4002_4024	Receive Extended Data Segment Register N (MSCAN_REDSR0)	8	R	Undefined	42.4.27/ 1004
4002_4025	Receive Extended Data Segment Register N (MSCAN_REDSR1)	8	R	Undefined	42.4.27/ 1004
4002_4026	Receive Extended Data Segment Register N (MSCAN_REDSR2)	8	R	Undefined	42.4.27/ 1004
4002_4027	Receive Extended Data Segment Register N (MSCAN_REDSR3)	8	R	Undefined	42.4.27/ 1004

Table continues on the next page...

MSCAN memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4002_4028	Receive Extended Data Segment Register N (MSCAN_REDSR4)	8	R	Undefined	42.4.27/ 1004
4002_4029	Receive Extended Data Segment Register N (MSCAN_REDSR5)	8	R	Undefined	42.4.27/ 1004
4002_402A	Receive Extended Data Segment Register N (MSCAN_REDSR6)	8	R	Undefined	42.4.27/ 1004
4002_402B	Receive Extended Data Segment Register N (MSCAN_REDSR7)	8	R	Undefined	42.4.27/ 1004
4002_402C	Receive Data Length Register (MSCAN_RDLR)	8	R	Undefined	42.4.28/ 1004
4002_402E	Receive Time Stamp Register High (MSCAN_RTSRH)	8	R	Undefined	42.4.29/ 1005
4002_402F	Receive Time Stamp Register Low (MSCAN_RTSRL)	8	R	Undefined	42.4.30/ 1006
4002_4030	Transmit Extended Identifier Register 0 (MSCAN_TEIDR0)	8	R/W	Undefined	42.4.31/ 1007
4002_4030	Transmit Standard Identifier Register 0 (MSCAN_TSIDR0)	8	R/W	Undefined	42.4.32/ 1007
4002_4031	Transmit Extended Identifier Register 1 (MSCAN_TEIDR1)	8	R/W	Undefined	42.4.33/ 1008
4002_4031	Transmit Standard Identifier Register 1 (MSCAN_TSIDR1)	8	R/W	Undefined	42.4.34/ 1009
4002_4032	Transmit Extended Identifier Register 2 (MSCAN_TEIDR2)	8	R/W	Undefined	42.4.35/ 1010
4002_4033	Transmit Extended Identifier Register 3 (MSCAN_TEIDR3)	8	R/W	Undefined	42.4.36/ 1010
4002_4034	Transmit Extended Data Segment Register N (MSCAN_TEDSR0)	8	R/W	Undefined	42.4.37/ 1011
4002_4035	Transmit Extended Data Segment Register N (MSCAN_TEDSR1)	8	R/W	Undefined	42.4.37/ 1011
4002_4036	Transmit Extended Data Segment Register N (MSCAN_TEDSR2)	8	R/W	Undefined	42.4.37/ 1011
4002_4037	Transmit Extended Data Segment Register N (MSCAN_TEDSR3)	8	R/W	Undefined	42.4.37/ 1011
4002_4038	Transmit Extended Data Segment Register N (MSCAN_TEDSR4)	8	R/W	Undefined	42.4.37/ 1011
4002_4039	Transmit Extended Data Segment Register N (MSCAN_TEDSR5)	8	R/W	Undefined	42.4.37/ 1011
4002_403A	Transmit Extended Data Segment Register N (MSCAN_TEDSR6)	8	R/W	Undefined	42.4.37/ 1011
4002_403B	Transmit Extended Data Segment Register N (MSCAN_TEDSR7)	8	R/W	Undefined	42.4.37/ 1011
4002_403C	Transmit Data Length Register (MSCAN_TDLR)	8	R/W	Undefined	42.4.38/ 1012

Table continues on the next page...

MSCAN memory map (continued)

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4002_403D	Transmit Buffer Priority Register (MSCAN_TBPR)	8	R/W	Undefined	42.4.39/ 1013
4002_403E	Transmit Time Stamp Register High (MSCAN_TTSRH)	8	R	Undefined	42.4.40/ 1013
4002_403F	Transmit Time Stamp Register Low (MSCAN_TTSRL)	8	R	Undefined	42.4.41/ 1014

42.4.2 MSCAN Control Register 0 (MSCAN_CANCTL0)

The CANCTL0 register provides various control bits of the MSCAN module.

NOTE

Write: Anytime when out of initialization mode; exceptions are read-only RXACT and SYNCH, RXFRM (which is set by the module only), and INITRQ (which is also writable in initialization mode)

The CANCTL0 register, except WUPE, INITRQ, and SLPRQ, is held in the reset state when the initialization mode is active (INITRQ = 1 and INITAK = 1). This register is writable again as soon as the initialization mode is exited (INITRQ = 0 and INITAK = 0).

Address: 4002_4000h base + 0h offset = 4002_4000h

Bit	7	6	5	4	3	2	1	0
Read	RXFRM	RXACT	CSWAI	SYNCH	TIME	WUPE	SLPRQ	INITRQ
Write								
Reset	0	0	0	0	0	0	0	1

MSCAN_CANCTL0 field descriptions

Field	Description
7 RXFRM	Received Frame Flag This bit is read and clear only. It is set when a receiver has received a valid message correctly, independently of the filter configuration. After it is set, it remains set until cleared by software or reset. Clearing is done by writing a 1. Writing a 0 is ignored. This bit is not valid in loopback mode. 0 No valid message was received since last clearing this flag. 1 A valid message was received since last clearing of this flag.
6 RXACT	Receiver Active Status

Table continues on the next page...

MSCAN_CANCTL0 field descriptions (continued)

Field	Description
	This read-only flag indicates the MSCAN is receiving a message. The flag is controlled by the receiver front end. This bit is not valid in loopback mode. **NOTE:** See the Bosch CAN 2.0A/B specification for a detailed definition of transmitter and receiver states. 0 MSCAN is transmitting or idle. 1 MSCAN is receiving a message, including when arbitration is lost.
5 CSWAI	CAN Stops in Wait Mode Enabling this bit allows for lower power consumption in wait mode by disabling all the clocks at the CPU bus interface to the MSCAN module. **NOTE:** In order to protect from accidentally violating the CAN protocol, TXCAN is immediately forced to a recessive state when the CPU enters wait (CSWAI = 1) or stop mode 0 The module is not affected during wait mode. 1 The module ceases to be clocked during wait mode.
4 SYNCH	Synchronized Status This read-only flag indicates whether the MSCAN is synchronized to the CAN bus and able to participate in the communication process. It is set and cleared by the MSCAN. 0 MSCAN is not synchronized to the CAN bus. 1 MSCAN is synchronized to the CAN bus.
3 TIME	Timer Enable This bit activates an internal 16-bit wide free running timer which is clocked by the bit clock rate. If the timer is enabled, a 16-bit time stamp will be assigned to each transmitted/received message within the active TX/RX buffer. Right after the EOF of a valid message on the CAN bus, the time stamp is written to the highest bytes (0x000E, 0x000F) in the appropriate buffer. In loopback mode no receive timestamp is generated. The internal timer is reset (all bits set to 0) when disabled. This bit is held low in initialization mode. 0 Disable internal MSCAN timer. 1 Enable internal MSCAN timer.
2 WUPE	WakeUp Enable This configuration bit allows the MSCAN to restart from sleep mode or from power down mode (entered from sleep) when traffic on CAN is detected. This bit must be configured before sleep mode entry for the selected function to take effect. **NOTE:** The CPU has to make sure that the WUPE register and the WUPIE wakeup interrupt enable register is enabled, if the recovery mechanism from stop or wait is required. 0 Wakeup disabled - The MSCAN ignores traffic on CAN. 1 Wakeup enabled - The MSCAN is able to restart.
1 SLPRQ	Sleep Mode Request This bit requests the MSCAN to enter sleep mode, which is an internal power saving mode. The sleep mode request is serviced when the CAN bus is idle, i.e., the module is not receiving a message and all transmit buffers are empty. The module indicates entry to sleep mode by setting SLPAK = 1. SLPRQ cannot be set while the WUPIF flag is set. Sleep mode will be active until SLPRQ is cleared by the CPU

Table continues on the next page...

MSCAN_CANCTL0 field descriptions (continued)

Field	Description
	or, depending on the setting of WUPE, the MSCAN detects activity on the CAN bus and clears SLPRQ itself. **NOTE:** The CPU cannot clear SLPRQ before the MSCAN has entered sleep mode (SLPRQ = 1 and SLPAK = 1). 0 Running - The MSCAN functions normally. 1 Sleep mode request - The MSCAN enters sleep mode when CAN bus idle.
0 INITRQ	Initialization Mode Request When this bit is set by the CPU, the MSCAN skips to initialization mode. Any ongoing transmission or reception is aborted and synchronization to the CAN bus is lost. The module indicates entry to initialization mode by setting INITAK = 1. The following registers enter their hard reset state and restore their default values: CANCTL0 (Not including WUPE, INITRQ, and SLPRQ), CANRFLG (TSTAT1 and TSTAT0 are not affected by initialization mode), CANRIER (RSTAT1 and RSTAT0 are not affected by initialization mode), CANTFLG, CANTIER, CANTARQ, CANTAAK, and CANTBSEL. The registers CANCTL1, CANBTR0, CANBTR1, CANIDAC, CANIDAR0-7, and CANIDMR0-7 can only be written by the CPU when the MSCAN is in initialization mode (INITRQ = 1 and INITAK = 1). The values of the error counters are not affected by initialization mode. When this bit is cleared by the CPU, the MSCAN restarts and then tries to synchronize to the CAN bus. If the MSCAN is not in bus-off state, it synchronizes after 11 consecutive recessive bits on the CAN bus; if the MSCAN is in bus-off state, it continues to wait for 128 occurrences of 11 consecutive recessive bits. Writing to other bits in CANCTL0, CANRFLG, CANRIER, CANTFLG, or CANTIER must be done only after initialization mode is exited, which is INITRQ = 0 and INITAK = 0. **NOTE:** The CPU cannot clear INITRQ before the MSCAN has entered initialization mode (INITRQ = 1 and INITAK = 1). In order to protect from accidentally violating the CAN protocol, TXCAN is immediately forced to a recessive state when the initialization mode is requested by the CPU. Thus, the recommended procedure is to bring the MSCAN into sleep mode (SLPRQ = 1 and SLPAK = 1) before requesting initialization mode. 0 Normal operation. 1 MSCAN in initialization mode.

42.4.3 MSCAN Control Register 1 (MSCAN_CANCTL1)

The CANCTL1 register provides various control bits and handshake status information of the MSCAN module.

NOTE

Write: Anytime in initialization mode (INITRQ = 1 and INITAK = 1), except CANE which is write once in normal and anytime in special system operation modes when the MSCAN is in initialization mode (INITRQ = 1 and INITAK = 1)

Address: 4002_4000h base + 1h offset = 4002_4001h

Bit	7	6	5	4	3	2	1	0
Read	CANE	CLKSRC	LOOPB	LISTEN	BORM	WUPM	SLPAK	INITAK
Write								
Reset	0	0	0	1	0	0	0	1

MSCAN_CANCTL1 field descriptions

Field	Description
7 CANE	MSCAN Enable 0 MSCAN module is disabled. 1 MSCAN module is enabled.
6 CLKSRC	MSCAN Clock Source This bit defines the clock source for the MSCAN module (only for systems with a clock generation module). 0 MSCAN clock source is the oscillator clock. 1 MSCAN clock source is the bus clock.
5 LOOPB	Loopback Self Test Mode When this bit is set, the MSCAN performs an internal loopback which can be used for self test operation. The bit stream output of the transmitter is fed back to the receiver internally. The RXCAN input is ignored and the TXCAN output goes to the recessive state (logic 1). The MSCAN behaves as it does normally when transmitting and treats its own transmitted message as a message received from a remote node. In this state, the MSCAN ignores the bit sent during the ACK slot in the CAN frame acknowledge field to ensure proper reception of its own message. Both transmit and receive interrupts are generated. 0 Loopback self test disabled. 1 Loopback self test enabled.
4 LISTEN	Listen Only Mode This bit configures the MSCAN as a CAN bus monitor. When LISTEN is set, all valid CAN messages with matching ID are received, but no acknowledgement or error frames are sent out. In addition, the error counters are frozen. Listen only mode supports applications which require "hot plugging" or throughput analysis. The MSCAN is unable to transmit any messages when listen only mode is active. 0 Normal operation. 1 Listen only mode activated.
3 BORM	Bus-Off Recovery Mode This bit configures the bus-off state recovery mode of the MSCAN. 0 Automatic bus-off recovery (see Bosch CAN 2.0A/B protocol specification). 1 Bus-off recovery upon user request.
2 WUPM	WakeUp Mode If WUPE in CANCTL0 is enabled, this bit defines whether the integrated low-pass filter is applied to protect the MSCAN from spurious wakeup. 0 MSCAN wakes on any dominant level on the CAN bus. 1 MSCAN wakes only in case of a dominant pulse on the CAN bus that has a length of T_{wup}.

Table continues on the next page...

MSCAN_CANCTL1 field descriptions (continued)

Field	Description
1 SLPAK	Sleep Mode Acknowledge This flag indicates whether the MSCAN module has entered sleep mode. It is used as a handshake flag for the SLPRQ sleep mode request. Sleep mode is active when SLPRQ = 1 and SLPAK = 1. Depending on the setting of WUPE, the MSCAN will clear the flag if it detects activity on the CAN bus while in sleep mode. 0 Running - The MSCAN operates normally. 1 Sleep mode active - The MSCAN has entered sleep mode.
0 INITAK	Initialization Mode Acknowledge This flag indicates whether the MSCAN module is in initialization mode. It is used as a handshake flag for the INITRQ initialization mode request. Initialization mode is active when INITRQ = 1 and INITAK = 1. The registers CANCTL1, CANBTR0, CANBTR1, CANIDAC, CANIDAR0-CANIDAR7, and CANIDMR0-CANIDMR7 can be written only by the CPU when the MSCAN is in initialization mode. 0 Running - The MSCAN operates normally. 1 Initialization mode active - The MSCAN has entered initialization mode.

42.4.4 MSCAN Bus Timing Register 0 (MSCAN_CANBTR0)

The CANBTR0 register configures various CAN bus timing parameters of the MSCAN module.

NOTE

Write: Anytime in initialization mode (INITRQ = 1 and INITAK = 1)

Address: 4002_4000h base + 2h offset = 4002_4002h

Bit	7	6	5	4	3	2	1	0
Read Write	SJW		BRP					
Reset	0	0	0	0	0	0	0	0

MSCAN_CANBTR0 field descriptions

Field	Description
7–6 SJW	Synchronization Jump Width The synchronization jump width defines the maximum number of time quanta (Tq) clock cycles a bit can be shortened or lengthened to achieve resynchronization to data transitions on the CAN bus. 00 1 Tq clock cycle. 01 2 Tq clock cycles. 10 3 Tq clock cycle. 11 4 Tq clock cycles.
BRP	Baud Rate Prescaler

Table continues on the next page...

MSCAN_CANBTR0 field descriptions (continued)

Field	Description
	These bits determine the time quanta (Tq) clock which is used to build up the bit timing. 000000 1 000001 2 000010 ..... 000011 ..... 111110 63 111111 64

42.4.5 MSCAN Bus Timing Register 1 (MSCAN_CANBTR1)

The CANBTR1 register configures various CAN bus timing parameters of the MSCAN module.

NOTE

Write: Anytime in initialization mode (INITRQ = 1 and INITAK = 1)

Address: 4002_4000h base + 3h offset = 4002_4003h

Bit	7	6	5	4	3	2	1	0
Read Write	SAMP	TSEG2			TSEG1			
Reset	0	0	0	0	0	0	0	0

MSCAN_CANBTR1 field descriptions

Field	Description
7 SAMP	Sampling This bit determines the number of CAN bus samples taken per bit time. If SAMP = 0, the resulting bit value is equal to the value of the single bit positioned at the sample point. If SAMP = 1, the resulting bit value is determined by using majority rule on the three total samples. For higher bit rates, it is recommended that only one sample is taken per bit time (SAMP = 0). 0 One sample per bit. 1 Three samples per bit. In this case, PHASE_SEG1 must be at least 2 time quanta (Tq).
6–4 TSEG2	Time Segment 2 Time segments within the bit time fix the number of clock cycles per bit time and the location of the sample point. 000 1 Tq clock cycle (not valid) 001 2 Tq clock cycles 010 3 Tq clock cycles 011 4 Tq clock cycles 100 5 Tq clock cycles 101 6 Tq clock cycles

Table continues on the next page...

MSCAN_CANBTR1 field descriptions (continued)

Field	Description
	110 7 Tq clock cycles 111 8 Tq clock cycles
TSEG1	Time Segment 1 Time segments within the bit time fix the number of clock cycles per bit time and the location of the sample point. The bit time is determined by the oscillator frequency, the baud rate prescaler, and the number of time quanta (Tq) clock cycles per bit. Bit time = (1 + timesegment1 + timesegment2) * (Prescaler value)/ f_{CANCLK} 0000 1 Tq clock cycle (not valid) 0001 2 Tq clock cycles (not valid) 0010 3 Tq clock cycles (not valid) 0011 4 Tq clock cycles .... 1110 15 Tq clock cycles 1111 16 Tq clock cycles

42.4.6 MSCAN Receiver Flag Register (MSCAN_CANRFLG)

A flag can be cleared only by software (writing a 1 to the corresponding bit position) when the condition which caused the setting is no longer valid. Every flag has an associated interrupt enable bit in the CANRIER register.

NOTE

Write: Anytime when not in initialization mode, except RSTAT[1:0] and TSTAT[1:0] flags which are read-only; write of 1 clears flag; write of 0 is ignored.

The CANRFLG register is held in the reset state when the initialization mode is active (INITRQ = 1 and INITAK = 1). This register is writable again as soon as the initialization mode is exited (INITRQ = 0 and INITAK = 0).

Address: 4002_4000h base + 4h offset = 4002_4004h

Bit	7	6	5	4	3	2	1	0
Read	WUPIF	CSCIF	RSTAT		TSTAT		OVRIF	RXF
Write								
Reset	0	0	0	0	0	0	0	0

MSCAN_CANRFLG field descriptions

Field	Description
7 WUPIF	Wake-Up Interrupt Flag If the MSCAN detects CAN bus activity while in sleep mode and CANTCTL0[WUPE] = 1, the module will set WUPIF. If not masked, a wake-up interrupt is pending while this flag is set. 0 No wakeup activity observed while in sleep mode. 1 MSCAN detected activity on the CAN bus and requested wakeup.
6 CSCIF	CAN Status Change Interrupt Flag This flag is set when the MSCAN changes its current CAN bus status due to the actual value of the transmit error counter (TEC) and the receive error counter (REC). An additional 4-bit (RSTAT[1:0], TSTAT[1:0]) status register, which is split into separate sections for TEC/REC, informs the system on the actual CAN bus status. If not masked, an error interrupt is pending while this flag is set. CSCIF provides a blocking interrupt. That guarantees that the receiver/transmitter status bits (RSTAT/TSTAT) are only updated when no CAN status change interrupt is pending. If the TECs/RECs change their current value after the CSCIF is asserted, which would cause an additional state change in the RSTAT/TSTAT bits, these bits keep their status until the current CSCIF interrupt is cleared again. 0 No change in CAN bus status occurred since last interrupt. 1 MSCAN changed current CAN bus status.
5–4 RSTAT	Receiver Status The values of the error counters control the actual CAN bus status of the MSCAN. As soon as the status change interrupt flag (CSCIF) is set, these bits indicate the appropriate receiver related CAN bus status of the MSCAN. **NOTE:** This field is not affected by initialization mode. 00 RxOK: 0≤receive error counter<96 01 RxWRN: 96≤receive error counter<128 10 RxERR: 128≤receive error counter 11 Bus-off: 256≤transmit error counter (Redundant Information for the most critical CAN bus status which is "bus-off". This only occurs if the Tx error counter exceeds a number of 255 errors. Bus-off affects the receiver state. As soon as the transmitter leaves its bus-off state the receiver state skips to RxOK too. Refer also to TSTAT[1:0] coding in this register.)
3–2 TSTAT	Transmitter Status The values of the error counters control the actual CAN bus status of the MSCAN. As soon as the status change interrupt flag (CSCIF) is set, these bits indicate the appropriate transmitter related CAN bus status of the MSCAN. **NOTE:** This field is not affected by initialization mode. 00 TxOK: 0≤transmit error counter<96 01 TxWRN: 96≤transmit error counter<128 10 TxERR: 128≤transmit error counter<256 11 Bus-off: 256≤transmit error counter
1 OVRIF	Overrun Interrupt Flag This flag is set when a data overrun condition occurs. If not masked, an error interrupt is pending while this flag is set.

Table continues on the next page...

MSCAN_CANRFLG field descriptions (continued)

Field	Description
	0 No data overrun condition. 1 A data overrun detected.
0 RXF	Receive Buffer Full Flag RXF is set by the MSCAN when a new message is shifted in the receiver FIFO. This flag indicates whether the shifted buffer is loaded with a correctly received message (matching identifier, matching cyclic redundancy code (CRC) and no other errors detected). After the CPU has read that message from the RxFG buffer in the receiver FIFO, the RXF flag must be cleared to release the buffer. A set RXF flag prohibits the shifting of the next FIFO entry into the foreground buffer (RxFG). If not masked, a receive interrupt is pending while this flag is set. **NOTE:** To ensure data integrity, do not read the receive buffer registers while the RXF flag is cleared. For MCUs with dual CPUs, reading the receive buffer registers while the RXF flag is cleared may result in a CPU fault condition. 0 No new message available within the RxFG. 1 The receiver FIFO is not empty. A new message is available in the RxFG.

42.4.7 MSCAN Receiver Interrupt Enable Register (MSCAN_CANRIER)

This register contains the interrupt enable bits for the interrupt flags described in the CANRFLG register.

NOTE

The CANRIER register is held in the reset state when the initialization mode is active (INITRQ=1 and INITAK=1). This register is writable when not in initialization mode (INITRQ=0 and INITAK=0).

The RSTATE[1:0], TSTATE[1:0] bits are not affected by initialization mode.

Address: 4002_4000h base + 5h offset = 4002_4005h

Bit	7	6	5	4	3	2	1	0
Read Write	WUPIE	CSCIE	RSTATE		TSTATE		OVRIE	RXFIE
Reset	0	0	0	0	0	0	0	0

MSCAN_CANRIER field descriptions

Field	Description
7 WUPIE	WakeUp Interrupt Enable WUPIE and WUPE must both be enabled if the recovery mechanism from stop or wait is required.

Table continues on the next page...

MSCAN_CANRIER field descriptions (continued)

Field	Description
	0 No interrupt request is generated from this event. 1 A wake-up event causes a Wake-Up interrupt request.
6 CSCIE	CAN Status Change Interrupt Enable 0 No interrupt request is generated from this event. 1 A CAN Status Change event causes an error interrupt request.
5–4 RSTATE	Receiver Status Change Enable These RSTAT enable bits control the sensitivity level in which receiver state changes are causing CSCIF interrupts. Independent of the chosen sensitivity level the RSTAT flags continue to indicate the actual receiver state and are only updated if no CSCIF interrupt is pending. 00 Do not generate any CSCIF interrupt caused by receiver state changes. 01 Generate CSCIF interrupt only if the receiver enters or leaves "bus-off" state. Discard other receiver state changes for generating CSCIF interrupt. 10 Generate CSCIF interrupt only if the receiver enters or leaves "RxErr" or "bus-off"[1] state. Discard other receiver state changes for generating CSCIF interrupt. 11 Generate CSCIF interrupt on all state changes.
3–2 TSTATE	Transmitter Status Change Enable These TSTAT enable bits control the sensitivity level in which transmitter state changes are causing CSCIF interrupts. Independent of the chosen sensitivity level, the TSTAT flags continue to indicate the actual transmitter state and are only updated if no CSCIF interrupt is pending. 00 Do not generate any CSCIF interrupt caused by transmitter state changes. 01 Generate CSCIF interrupt only if the transmitter enters or leaves "bus-off" state. Discard other transmitter state changes for generating CSCIF interrupt. 10 Generate CSCIF interrupt only if the transmitter enters or leaves "TxErr" or "bus-off" state. Discard other transmitter state changes for generating CSCIF interrupt. 11 Generate CSCIF interrupt on all state changes.
1 OVRIE	Overrun Interrupt Enable 0 No interrupt request is generated from this event. 1 An overrun event causes an error interrupt request.
0 RXFIE	Receiver Full Interrupt Enable 0 No interrupt request is generated from this event. 1 A receive buffer full (successful message reception) event causes a receiver interrupt request.

1. Bus-off state is only defined for transmitters by the CAN standard (see Bosch CAN 2.0A/B protocol specification). Because the only possible state change for the transmitter from bus-off to TxOK also forces the receiver to skip its current state to RxOK, the coding of the RXSTAT[1:0] flags define an additional bus-off state for the receiver

42.4.8 MSCAN Transmitter Flag Register (MSCAN_CANTFLG)

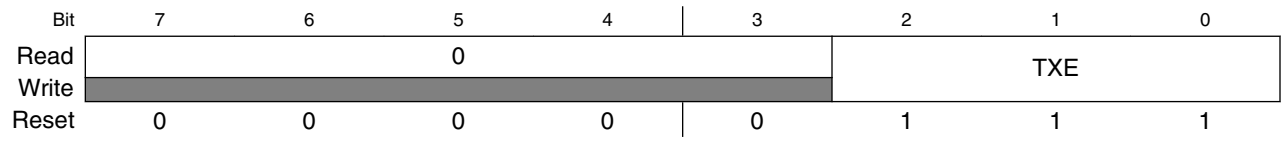
The transmit buffer empty flags each have an associated interrupt enable bit in the CANTIER register.

NOTE

Write: Anytime when not in initialization mode; write of 1 clears flag, write of 0 is ignored.

The CANTFLG register is held in the reset state when the initialization mode is active (INITRQ = 1 and INITAK = 1). This register is writable when not in initialization mode (INITRQ = 0 and INITAK = 0).

Address: 4002_4000h base + 6h offset = 4002_4006h



MSCAN_CANTFLG field descriptions

Field	Description
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TXE	Transmitter Buffer Empty This flag indicates that the associated transmit message buffer is empty, and thus not scheduled for transmission. The CPU must clear the flag after a message is set up in the transmit buffer and is due for transmission. The MSCAN sets the flag after the message is sent successfully. The flag is also set by the MSCAN when the transmission request is successfully aborted due to a pending abort request. If not masked, a transmit interrupt is pending while this flag is set. Clearing a TXEx flag also clears the corresponding ABTAKx. When a TXEx flag is set, the corresponding ABTRQx bit is cleared. When listen-mode is active, the TXEx flags cannot be cleared and no transmission is started. Read and write accesses to the transmit buffer will be blocked, if the corresponding TXEx bit is cleared (TXEx = 0) and the buffer is scheduled for transmission. 0 The associated message buffer is full (loaded with a message due for transmission). 1 The associated message buffer is empty (not scheduled).

42.4.9 MSCAN Transmitter Interrupt Enable Register (MSCAN_CANTIER)

This register contains the interrupt enable bits for the transmit buffer empty interrupt flags.

NOTE

The CANTIER register is held in the reset state when the initialization mode is active (INITRQ = 1 and INITAK = 1). This register is writable when not in initialization mode (INITRQ = 0 and INITAK = 0).

Write at anytime when not in initialization mode.

Address: 4002_4000h base + 7h offset = 4002_4007h

Bit	7	6	5	4	3	2	1	0
Read	0						TXEIE	
Write								
Reset	0	0	0	0	0	0	0	0

MSCAN_CANTIER field descriptions

Field	Description
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TXEIE	Transmitter Empty Interrupt Enable 0 No interrupt request is generated from this event. 1 A transmitter empty (transmit buffer available for transmission) event causes a transmitter empty interrupt request.

42.4.10 MSCAN Transmitter Message Abort Request Register (MSCAN_CANTARQ)

The CANTARQ register allows abort request of queued messages.

NOTE

Write: Anytime when not in initialization mode

The CANTARQ register is held in the reset state when the initialization mode is active (INITRQ = 1 and INITAK = 1). This register is writable when not in initialization mode (INITRQ = 0 and INITAK = 0).

Address: 4002_4000h base + 8h offset = 4002_4008h

Bit	7	6	5	4	3	2	1	0
Read	0						ABTRQ	
Write								
Reset	0	0	0	0	0	0	0	0

MSCAN_CANTARQ field descriptions

Field	Description
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
ABTRQ	Abort Request The CPU sets the ABTRQx bit to request that a scheduled message buffer (TXEx = 0) be aborted. The MSCAN grants the request if the message has not already started transmission, or if the transmission is not successful (lost arbitration or error). When a message is aborted, the associated TXE and abort acknowledge flags ABTAK, are set and a transmit interrupt occurs if enabled. The CPU cannot reset ABTRQx. ABTRQx is reset whenever the associated TXE flag is set. 0 No abort request. 1 Abort request pending.

42.4.11 MSCAN Transmitter Message Abort Acknowledge Register (MSCAN_CANTAAK)

The CANTAAK register indicates the successful abort of a queued message, if requested by the appropriate bits in the CANTARQ register.

NOTE

The CANTAAK register is held in the reset state when the initialization mode is active (INITRQ = 1 and INITAK = 1).

Address: 4002_4000h base + 9h offset = 4002_4009h

Bit	7	6	5	4	3	2	1	0
Read	0						ABTAK	
Write								
Reset	0	0	0	0	0	0	0	0

MSCAN_CANTAAK field descriptions

Field	Description
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
ABTAK	Abort Acknowledge This flag acknowledges that a message was aborted due to a pending abort request from the CPU. After a particular message buffer is flagged empty, this flag can be used by the application software to identify whether the message was aborted successfully or was sent anyway. The ABTAKx flag is cleared whenever the corresponding TXE flag is cleared. 0 The message was not aborted. 1 The message was aborted.

42.4.12 MSCAN Transmit Buffer Selection Register (MSCAN_CANTBSEL)

The CANTBSEL register allows the selection of the actual transmit message buffer, which then will be accessible in the CANTFLG register space.

NOTE

Read: Find the lowest ordered bit set to 1, all other bits will be read as 0.

Write: Anytime when not in initialization mode

The CANTBSEL register is held in the reset state when the initialization mode is active (INITRQ = 1 and INITAK=1). This register is writable when not in initialization mode (INITRQ = 0 and INITAK = 0).

The following gives a short programming example of the usage of the CANTBSEL register:

To get the next available transmit buffer, application software must read the CANTFLG register and write this value back into the CANTBSEL register. In this example Tx buffers TX1 and TX2 are available. The value read from CANTFLG is therefore 0b0000_0110. When writing this value back to CANTBSEL, the Tx buffer TX1 is selected in the CANTFLG because the lowest numbered bit set to 1 is at bit position 1. Reading back this value out of CANTBSEL results in 0b0000_0010, because only the lowest numbered bit position set to 1 is presented. This mechanism eases the application software's selection of the next available Tx buffer.

- LDAA CANTFLG; value read is 0b0000_0110
- STAA CANTBSEL; value written is 0b0000_0110
- LDAA CANTBSEL; value read is 0b0000_0010

If all transmit message buffers are deselected, no accesses are allowed to the CANTFLG registers.

Address: 4002_4000h base + Ah offset = 4002_400Ah

Bit	7	6	5	4	3	2	1	0
Read	0						TX	
Write								
Reset	0	0	0	0	0	0	0	0

MSCAN_CANTBSEL field descriptions

Field	Description
7–3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TX	Transmit Buffer Select The lowest numbered bit places the respective transmit buffer in the CANTFLG register space (e.g., TX1 = 1 and TX0 = 1 selects transmit buffer TX0; TX1 = 1 and TX0 = 0 selects transmit buffer TX1). Read and write accesses to the selected transmit buffer will be blocked, if the corresponding TXEx bit is cleared and the buffer is scheduled for transmission. 0 The associated message buffer is deselected. 1 The associated message buffer is selected, if lowest numbered bit.

42.4.13 MSCAN Identifier Acceptance Control Register (MSCAN_CANIDAC)

The CANIDAC register is used for identifier acceptance control as described below.

NOTE

Write: Anytime in initialization mode (INITRQ = 1 and INITAK = 1), except bits IDHITx, which are read-only

Address: 4002_4000h base + Bh offset = 4002_400Bh

Bit	7	6	5	4	3	2	1	0
Read	0		IDAM		0	IDHIT		
Write								
Reset	0	0	0	0	0	0	0	0

MSCAN_CANIDAC field descriptions

Field	Description
7–6 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
5–4 IDAM	Identifier Acceptance Mode The CPU sets these flags to define the identifier acceptance filter organization. In filter closed mode, no message is accepted such that the foreground buffer is never reloaded. 00 Two 32-bit acceptance filters. 01 Four 16-bit acceptance filters. 10 Eight 8-bit acceptance filters. 11 Filter closed.
3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
IDHIT	Identifier Acceptance Hit Indicator

Table continues on the next page...

MSCAN_CANIDAC field descriptions (continued)

Field	Description
	The MSCAN sets these flags to indicate an identifier acceptance hit. The IDHIT indicators are always related to the message in the foreground buffer (RxFG). When a message gets shifted into the foreground buffer of the receiver FIFO the indicators are updated as well. 000 Filter 0 hit. 001 Filter 1 hit. 010 Filter 2 hit. 011 Filter 3 hit. 100 Filter 4 hit. 101 Filter 5 hit. 110 Filter 6 hit. 111 Filter 7 hit.

42.4.14 MSCAN Miscellaneous Register (MSCAN_CANMISC)

This register provides additional features.

NOTE

Write: Anytime; write of ‘1’ clears flag; write of ‘0’ ignored.

Address: 4002_4000h base + Dh offset = 4002_400Dh

Bit	7	6	5	4	3	2	1	0
Read	0							BOHOLD
Write								
Reset	0	0	0	0	0	0	0	0

MSCAN_CANMISC field descriptions

Field	Description
7–1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 BOHOLD	Bus-off State Hold Until User Request If BORM is set in MSCAN Control Register 1 (CANCTL1), this bit indicates whether the module has entered the bus-off state. Clearing this bit requests the recovery from bus-off. 0 Module is not bus-off or recovery has been requested by user in bus-off state. 1 Module is bus-off and holds this state until user request.

42.4.15 MSCAN Receive Error Counter (MSCAN_CANRXERR)

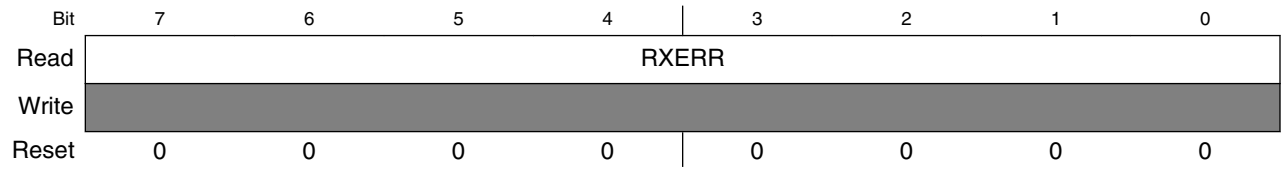
This register reflects the status of the MSCAN receive error counter.

NOTE

Read: Only when in sleep mode (SLPRQ = 1 and SLPAK = 1) or initialization mode (INITRQ = 1 and INITAK = 1).

Reading this register when in any other mode other than sleep or initialization mode may return an incorrect value. For MCUs with dual CPUs, this may result in a CPU fault condition.

Address: 4002_4000h base + Eh offset = 4002_400Eh



MSCAN_CANRXERR field descriptions

Field	Description
RXERR	Receive Error Counter This field is read only in sleep mode (SLPRQ = 1 and SLPAK = 1) or initialization mode (INITRQ = 1 and INITAK = 1)

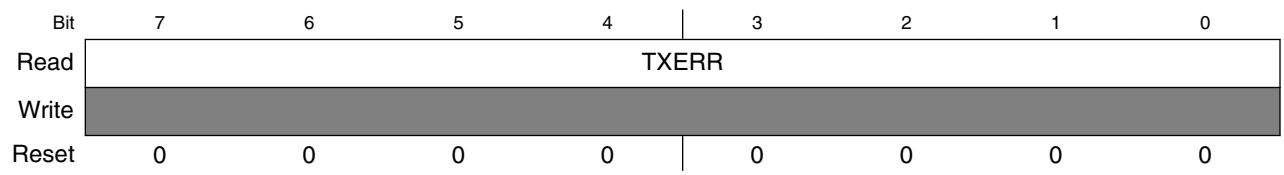
42.4.16 MSCAN Transmit Error Counter (MSCAN_CANTXERR)

This register reflects the status of the MSCAN transmit error counter.

NOTE

Reading this register when in any other mode other than sleep or initialization mode may return an incorrect value. For MCUs with dual CPUs, this may result in a CPU fault condition.

Address: 4002_4000h base + Fh offset = 4002_400Fh



MSCAN_CANTXERR field descriptions

Field	Description
TXERR	Transmit Error Counter This field is read only in sleep mode (SLPRQ = 1 and SLPAK = 1) or initialization mode (INITRQ = 1 and INITAK = 1)

42.4.17 MSCAN Identifier Acceptance Register n of First Bank (MSCAN_CANIDAR*n*)

On reception, each message is written into the background receive buffer. The CPU is only signalled to read the message if it passes the criteria in the identifier acceptance and identifier mask registers (accepted); otherwise, the message is overwritten by the next message (dropped).

The acceptance registers of the MSCAN are applied on the REIDR0-REIDR3 registers for the extended identifiers and RSIDR0-RSIDR1 registers for the standard identifiers of incoming messages in a bit by bit manner.

For extended identifiers, all four acceptance and mask registers are applied. For standard identifiers, only the first two (CANIDAR0/1, CANIDMR0/1) are applied.

Address: 4002_4000h base + 10h offset + (1d × i), where i=0d to 3d

Bit	7	6	5	4	3	2	1	0
Read Write	AC							
Reset	0	0	0	0	0	0	0	0

MSCAN_CANIDAR*n* field descriptions

Field	Description
AC	Acceptance Code Bits AC[7:0] comprise a user-defined sequence of bits with which the corresponding bits of the related identifier register (RSIDRn or REIDRn) of the receive message buffer are compared. The result of this comparison is then masked with the corresponding identifier mask register.

42.4.18 MSCAN Identifier Mask Register n of First Bank (MSCAN_CANIDMR*n*)

The identifier mask register specifies which of the corresponding bits in the identifier acceptance register are relevant for acceptance filtering. To receive standard identifiers in 32-bit filter mode, it is required to program the last three bits (AM[2:0]) in the mask registers CANIDMR1 and CANIDMR5 to "don't care." To receive standard identifiers in 16 bit filter mode, it is required to program the last three bits (AM[2:0]) in the mask registers CANIDMR1, CANIDMR3, CANIDMR5, and CANIDMR7 to "don't care."

Address: 4002_4000h base + 14h offset + (1d × i), where i=0d to 3d

Bit	7	6	5	4	3	2	1	0
Read Write	AM							
Reset	0	0	0	0	0	0	0	0

MSCAN_CANIDMR*n* field descriptions

Field	Description
AM	Acceptance Mask Bits If a particular bit in this register is cleared, this indicates that the corresponding bit in the identifier acceptance register must be the same as its identifier bit before a match is detected. The message is accepted if all such bits match. If a bit is set, it indicates that the state of the corresponding bit in the identifier acceptance register does not affect whether or not the message is accepted. 0 Match corresponding acceptance code register and identifier bits. 1 Ignore corresponding acceptance code register bit.

42.4.19 MSCAN Identifier Acceptance Register n of Second Bank (MSCAN_CANIDAR*n*)

On reception, each message is written into the background receive buffer. The CPU is only signalled to read the message if it passes the criteria in the identifier acceptance and identifier mask registers (accepted); otherwise, the message is overwritten by the next message (dropped).

The acceptance registers of the MSCAN are applied on the REIDR0-REIDR3 registers for the extended identifiers and RSIDR0-RSIDR1 registers for the standard identifiers of incoming messages in a bit by bit manner.

For extended identifiers, all four acceptance and mask registers are applied. For standard identifiers, only the first two (CANIDAR4/5, CANIDMR4/5) are applied.

Address: 4002_4000h base + 18h offset + (1d × i), where i=0d to 3d

Bit	7	6	5	4	3	2	1	0
Read Write	AC							
Reset	0	0	0	0	0	0	0	0

MSCAN_CANIDAR*n* field descriptions

Field	Description
AC	Acceptance Code Bits AC[7:0] comprise a user-defined sequence of bits with which the corresponding bits of the related identifier register (RSIDRn or REIDRn) of the receive message buffer are compared. The result of this comparison is then masked with the corresponding identifier mask register.

42.4.20 MSCAN Identifier Mask Register n of Second Bank (MSCAN_CANIDMR*n*)

The identifier mask register specifies which of the corresponding bits in the identifier acceptance register are relevant for acceptance filtering. To receive standard identifiers in 32 bit filter mode, it is required to program the last three bits (AM[2:0]) in the mask registers CANIDMR1 and CANIDMR5 to "don't care." To receive standard identifiers in 16 bit filter mode, it is required to program the last three bits (AM[2:0]) in the mask registers CANIDMR1, CANIDMR3, CANIDMR5, and CANIDMR7 to "don't care."

Address: 4002_4000h base + 1Ch offset + (1d × i), where i=0d to 3d

Bit	7	6	5	4	3	2	1	0
Read Write	AM							
Reset	0	0	0	0	0	0	0	0

MSCAN_CANIDMR*n* field descriptions

Field	Description
AM	Acceptance Mask Bits If a particular bit in this register is cleared, this indicates that the corresponding bit in the identifier acceptance register must be the same as its identifier bit before a match is detected. The message is accepted if all such bits match. If a bit is set, it indicates that the state of the corresponding bit in the identifier acceptance register does not affect whether or not the message is accepted. 0 Match corresponding acceptance code register and identifier bits. 1 Ignore corresponding acceptance code register bit.

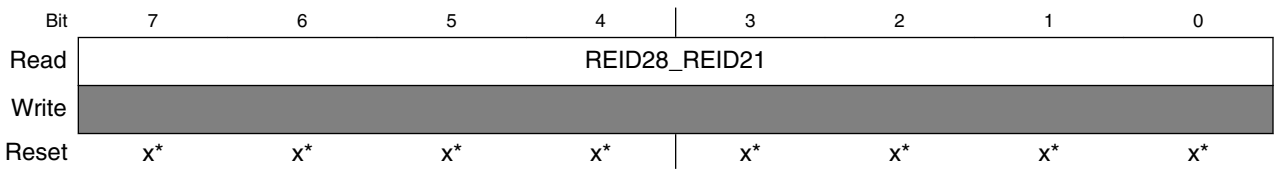
42.4.21 Receive Extended Identifier Register 0 (MSCAN_REIDR0)

The identifier registers for an extended format identifier consist of a total of 32 bits: REID[28:0], RSRR, RIDE, and RRTR.

NOTE

This register can be read only when RXF flag is set.

Address: 4002_4000h base + 20h offset = 4002_4020h



* Notes:
- x = Undefined at reset.

MSCAN_REIDR0 field descriptions

Field	Description
REID28_REID21	Extended Format Identifier The extended identifiers consist of 29 bits (REID[28:0]) for the extended format. REID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.

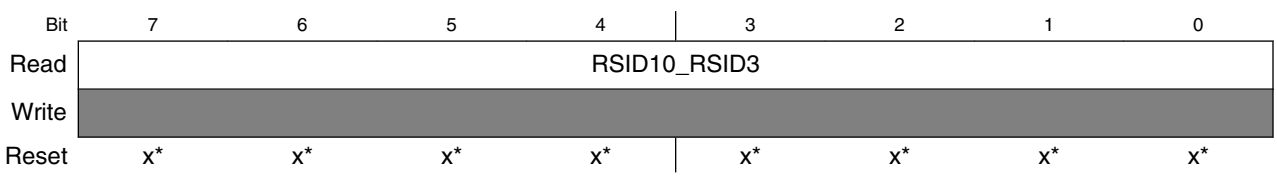
42.4.22 Receive Standard Identifier Register 0 (MSCAN_RSIDR0)

The identifier registers for a standard format identifier consist of a total of 13 bits: RID[10:0], RRTR, and RSIDE.

NOTE

This register can be read only when RXF flag is set.

Address: 4002_4000h base + 20h offset = 4002_4020h



* Notes:
- x = Undefined at reset.

MSCAN_RSIDR0 field descriptions

Field	Description
RSID10_RSID3	Standard Format Identifier The identifiers consist of 11 bits (RSID[10:0]) for the standard format. RSID10 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.

42.4.23 Receive Extended Identifier Register 1 (MSCAN_REIDR1)

The identifier registers for an extended format identifier consist of a total of 32 bits: REID[28:0], RSRR, REIDE, and RRTR.

NOTE

This register can be read only when RXF flag is set.

Address: 4002_4000h base + 21h offset = 4002_4021h

Bit	7	6	5	4	3	2	1	0
Read	REID20_REID18			RSRR	REIDE	REID17_REID15		
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_REIDR1 field descriptions

Field	Description
7–5 REID20_REID18	Extended Format Identifier 20-18 The identifiers consist of 29 bits (REID[28:0]) for the extended format. EID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.
4 RSRR	Substitute Remote Request This fixed recessive bit is used only in extended format. It must be set to 1 by the user for transmission buffers and is stored as received on the CAN bus for receive buffers.
3 REIDE	ID Extended This flag indicates whether the extended or standard identifier format is applied in this buffer. In the case of a receive buffer, the flag is set as received and indicates to the CPU how to process the buffer identifier registers. In the case of a transmit buffer, the flag indicates to the MSCAN what type of identifier to send. 0 Standard format (11 bit). 1 Extended format (29 bit).
REID17_REID15	Extended Format Identifier 17-15

Table continues on the next page...

MSCAN_REIDR1 field descriptions (continued)

Field	Description
	The identifiers consist of 29 bits (REID[28:0]) for the extended format. RID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.

42.4.24 Receive Standard Identifier Register 1 (MSCAN_RSIDR1)

The identifier registers for a standard format identifier consist of a total of 13 bits: RSID[10:0], RRTR, and REIDE.

NOTE

This register can be read only when RXF flag is set.

Address: 4002_4000h base + 21h offset = 4002_4021h

Bit	7	6	5	4	3	2	1	0
Read	RSID2_RSID0			RSRTR	RSIDE	Reserved		
Write						Reserved		
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_RSIDR1 field descriptions

Field	Description
7–5 RSID2_RSID0	Standard Format Identifier 2-0 The identifiers consist of 11 bits (RID[10:0]) for the standard format. RID10 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.
4 RSRTR	Remote Transmission Request This flag reflects the status of the Remote Transmission Request bit in the CAN frame. In the case of a receive buffer, it indicates the status of the received frame and supports the transmission of an answering frame in software. In the case of a transmit buffer, this flag defines the setting of the RRTR bit to be sent. 0 Data frame. 1 Remote frame.
3 RSIDE	ID Extended This flag indicates whether the extended or standard identifier format is applied in this buffer. In the case of a receive buffer, the flag is set as received and indicates to the CPU how to process the buffer identifier registers. In the case of a transmit buffer, the flag indicates to the MSCAN what type of identifier to send. 0 Standard format (11 bit). 1 Extended format (29 bit).
Reserved	This field is reserved.

42.4.25 Receive Extended Identifier Register 2 (MSCAN_REIDR2)

The identifier registers for an extended format identifier consist of a total of 32 bits: REID[28:0], RSRR, REIDE, and RRTR.

NOTE

This register can be read only when RXF flag is set.

Address: 4002_4000h base + 22h offset = 4002_4022h

Bit	7	6	5	4	3	2	1	0
Read	REID14_REID7							
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_REIDR2 field descriptions

Field	Description
REID14_REID7	Extended Format Identifier 14-7 The identifiers consist of 29 bits (REID[28:0]) for the extended format. REID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.

42.4.26 Receive Extended Identifier Register 3 (MSCAN_REIDR3)

The identifier registers for an extended format identifier consist of a total of 32 bits: REID[28:0], RSRR, REIDE, and RRTR.

NOTE

This register can be read only when RXF flag is set.

Address: 4002_4000h base + 23h offset = 4002_4023h

Bit	7	6	5	4	3	2	1	0
Read	REID6_REID0							RERTR
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_REIDR3 field descriptions

Field	Description
7–1 REID6_REID0	Extended Format Identifier 6-0 The identifiers consist of 29 bits (REID[28:0]) for the extended format. REID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.
0 RERTR	Remote Transmission Request This flag reflects the status of the remote transmission request bit in the CAN frame. In the case of a receive buffer, it indicates the status of the received frame and supports the transmission of an answering frame in software. In the case of a transmit buffer, this flag defines the setting of the RTR bit to be sent. 0 Data frame. 1 Remote frame.

42.4.27 Receive Extended Data Segment Register N (MSCAN_REDSR*n*)

The eight data segment registers, each with bits RDB[7:0], contain the data to be received. The number of bytes to be received is determined by the data length code in the corresponding RDLR register.

NOTE

This register can be read only when RXF flag is set.

Address: 4002_4000h base + 24h offset + (1d × i), where i=0d to 7d

Bit	7	6	5	4	3	2	1	0
Read	RDB							
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_REDSR*n* field descriptions

Field	Description
RDB	Data Bits Data to be received

42.4.28 Receive Data Length Register (MSCAN_RDLR)

This register keeps the data length field of the CAN frame.

NOTE

This register can be read only when RXF flag is set.

Address: 4002_4000h base + 2Ch offset = 4002_402Ch

Bit	7	6	5	4	3	2	1	0
Read	Reserved				RDLC			
Write	Reserved							
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_RDLR field descriptions

Field	Description
7–4 Reserved	This field is reserved.
RDLC	Data Length Code Bits The data length code contains the number of bytes (data byte count) of the respective message. During the transmission of a remote frame, the data length code is transmitted as programmed while the number of transmitted data bytes is always 0. The data byte count ranges from 0 to 8 for a data frame. 0000 0 0001 1 0010 2 0011 3 0100 4 0101 5 0110 6 0111 7 1000 8 others Reserved

42.4.29 Receive Time Stamp Register High (MSCAN_RTSRH)

If the TIME bit is enabled, the MSCAN will write a time stamp to the respective registers in the active receive buffer right after the EOF of a valid message on the CAN bus.

The timer value, which is used for stamping, is taken from a free running internal CAN bit clock. A timer overrun is not indicated by the MSCAN. The timer is reset (all bits set to 0) during initialization mode. The CPU can only read the time stamp registers.

NOTE

This register can be read only when RXF is set.

Address: 4002_4000h base + 2Eh offset = 4002_402Eh

Bit	7	6	5	4	3	2	1	0
Read	RTS							
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_RTSRH field descriptions

Field	Description
RTS	Time Stamp Time stamp 7 to 0.

42.4.30 Receive Time Stamp Register Low (MSCAN_RTSRL)

If the TIME bit is enabled, the MSCAN will write a time stamp to the respective registers in the active receive buffer right after the EOF of a valid message on the CAN bus.

The timer value, which is used for stamping, is taken from a free running internal CAN bit clock. A timer overrun is not indicated by the MSCAN. The timer is reset (all bits set to 0) during initialization mode. The CPU can only read the time stamp registers.

NOTE

This register can be read only when RXF is set.

Address: 4002_4000h base + 2Fh offset = 4002_402Fh

Bit	7	6	5	4	3	2	1	0
Read	RTS							
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_RTSRL field descriptions

Field	Description
RTS	Time Stamp Time stamp 15 to 8.

42.4.31 Transmit Extended Identifier Register 0 (MSCAN_TEIDR0)

The identifier registers for an extended format identifier consist of a total of 32 bits: TEID[28:0], TSRR, TIDE, and TRTR.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 30h offset = 4002_4030h

Bit	7	6	5	4	3	2	1	0
Read Write	TEID28_TEID21							
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TEIDR0 field descriptions

Field	Description
TEID28_TEID21	Extended Format Identifier The extended identifiers consist of 29 bits (TEID[28:0]) for the extended format. TEID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.

42.4.32 Transmit Standard Identifier Register 0 (MSCAN_TSIDR0)

The identifier registers for a standard format identifier consist of a total of 13 bits: TID[10:0], TRTR, and TSIDE.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 30h offset = 4002_4030h

Bit	7	6	5	4	3	2	1	0
Read Write	TSID10_TSID3							
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TSIDR0 field descriptions

Field	Description
TSID10_TSID3	Standard Format Identifier The identifiers consist of 11 bits (TSID[10:0]) for the standard format. TSID10 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.

42.4.33 Transmit Extended Identifier Register 1 (MSCAN_TEIDR1)

The identifier registers for an extended format identifier consist of a total of 32 bits: TEID[28:0], TSRR, TEIDE, and TRTR.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 31h offset = 4002_4031h

Bit	7	6	5	4	3	2	1	0
Read Write	TEID20_TEID18			TSRR	TEIDE	TEID17_TEID15		
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TEIDR1 field descriptions

Field	Description
7–5 TEID20_TEID18	Extended Format Identifier 20-18 The identifiers consist of 29 bits (TEID[28:0]) for the extended format. TEID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.
4 TSRR	Substitute Remote Request This fixed recessive bit is used only in extended format. It must be set to 1 by the user for transmission buffers and is stored as received on the CAN bus for receive buffers.
3 TEIDE	ID Extended This flag indicates whether the extended or standard identifier format is applied in this buffer. In the case of a receive buffer, the flag is set as received and indicates to the CPU how to process the buffer identifier registers. In the case of a transmit buffer, the flag indicates to the MSCAN what type of identifier to send. 0 Standard format (11 bit). 1 Extended format (29 bit).
TEID17_TEID15	Extended Format Identifier 17-15

Table continues on the next page...

MSCAN_TEIDR1 field descriptions (continued)

Field	Description
	The identifiers consist of 29 bits (TEID[28:0]) for the extended format. TID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.

42.4.34 Transmit Standard Identifier Register 1 (MSCAN_TSIDR1)

The identifier registers for a standard format identifier consist of a total of 13 bits: TEID[10:0], TRTR, and TEIDE.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 31h offset = 4002_4031h

Bit	7	6	5	4	3	2	1	0
Read	TSID2_TSID0			TSRTR	TSIDE	Reserved		
Write						Reserved		
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TSIDR1 field descriptions

Field	Description
7–5 TSID2_TSID0	Standard Format Identifier 2-0 The identifiers consist of 11 bits (TID[10:0]) for the standard format. ID10 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.
4 TSRTR	Remote Transmission Request This flag reflects the status of the Remote Transmission Request bit in the CAN frame. In the case of a receive buffer, it indicates the status of the received frame and supports the transmission of an answering frame in software. In the case of a transmit buffer, this flag defines the setting of the TRTR bit to be sent. 0 Data frame. 1 Remote frame.
3 TSIDE	ID Extended This flag indicates whether the extended or standard identifier format is applied in this buffer. In the case of a receive buffer, the flag is set as received and indicates to the CPU how to process the buffer identifier registers. In the case of a transmit buffer, the flag indicates to the MSCAN what type of identifier to send.

Table continues on the next page...

MSCAN_TSIDR1 field descriptions (continued)

Field	Description
	0 Standard format (11 bit). 1 Extended format (29 bit).
Reserved	This field is reserved.

42.4.35 Transmit Extended Identifier Register 2 (MSCAN_TEIDR2)

The identifier registers for an extended format identifier consist of a total of 32 bits: TEID[28:0], TSRR, TEIDE, and TRTR.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 32h offset = 4002_4032h

Bit	7	6	5	4	3	2	1	0
Read Write	TEID14_TEID7							
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TEIDR2 field descriptions

Field	Description
TEID14_TEID7	Extended Format Identifier 14-7 The identifiers consist of 29 bits (TEID[28:0]) for the extended format. TEID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.

42.4.36 Transmit Extended Identifier Register 3 (MSCAN_TEIDR3)

The identifier registers for an extended format identifier consist of a total of 32 bits: TEID[28:0], TSRR, TEIDE, and TRTR.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 33h offset = 4002_4033h

Bit	7	6	5	4	3	2	1	0
Read Write	TEID6_TEID0							TERTR
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TEIDR3 field descriptions

Field	Description
7–1 TEID6_TEID0	Extended Format Identifier 6-0 The identifiers consist of 29 bits (TEID[28:0]) for the extended format. TEID28 is the most significant bit and is transmitted first on the CAN bus during the arbitration procedure. The priority of an identifier is defined to be highest for the smallest binary number.
0 TERTR	Remote Transmission Request This flag reflects the status of the remote transmission request bit in the CAN frame. In the case of a receive buffer, it indicates the status of the received frame and supports the transmission of an answering frame in software. In the case of a transmit buffer, this flag defines the setting of the TRTR bit to be sent. 0 Data frame. 1 Remote frame.

42.4.37 Transmit Extended Data Segment Register N (MSCAN_TEDSR*n*)

The eight data segment registers, each with bits TDB[7:0], contain the data to be transmitted. The number of bytes to be transmitted is determined by the data length code in the corresponding TDLR register.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 34h offset + (1d × i), where i=0d to 7d

Bit	7	6	5	4	3	2	1	0
Read Write	TDB							
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TEDSR*n* field descriptions

Field	Description
TDB	Data Bits Data to be received

42.4.38 Transmit Data Length Register (MSCAN_TDLR)

This register keeps the data length field of the CAN frame.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 3Ch offset = 4002_403Ch

Bit	7	6	5	4	3	2	1	0
Read	Reserved				TDLC			
Write	Reserved							
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TDLR field descriptions

Field	Description
7–4 Reserved	This field is reserved.
TDLC	Data Length Code Bits The data length code contains the number of bytes (data byte count) of the respective message. During the transmission of a remote frame, the data length code is transmitted as programmed while the number of transmitted data bytes is always 0. The data byte count ranges from 0 to 8 for a data frame. 0000 0 0001 1 0010 2 0011 3 0100 4 0101 5 0110 6 0111 7 1000 8 others Reserved

42.4.39 Transmit Buffer Priority Register (MSCAN_TBPR)

This register defines the local priority of the associated message buffer. The local priority is used for the internal prioritization process of the MSCAN and is defined to be highest for the smallest binary number. The MSCAN implements the following internal prioritization mechanisms:

- All transmission buffers with a cleared TXEx flag participate in the prioritization immediately before the SOF (start of frame) is sent.
- The transmission buffer with the lowest local priority field wins the prioritization.

In cases of more than one buffer having the same lowest priority, the message buffer with the lower index number wins.

NOTE

This register can be read or write at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL.

Address: 4002_4000h base + 3Dh offset = 4002_403Dh

Bit	7	6	5	4	3	2	1	0
Read Write	PRIO							
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TBPR field descriptions

Field	Description
PRIO	Priority Local priority of the associated message buffer.

42.4.40 Transmit Time Stamp Register High (MSCAN_TTSRH)

If the TIME bit is enabled, the MSCAN will write a time stamp to the respective registers in the active transmit buffer right after the EOF of a valid message on the CAN bus. In case of a transmission, the CPU can only read the time stamp after the respective transmit buffer has been flagged empty.

The timer value, which is used for stamping, is taken from a free running internal CAN bit clock. A timer overrun is not indicated by the MSCAN. The timer is reset (all bits set to 0) during initialization mode. The CPU can only read the time stamp registers.

NOTE

This register can be read at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL

Address: 4002_4000h base + 3Eh offset = 4002_403Eh

Bit	7	6	5	4	3	2	1	0
Read	TTS							
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TTSRH field descriptions

Field	Description
TTS	Time Stamp Time stamp 7 to 0.

42.4.41 Transmit Time Stamp Register Low (MSCAN_TTSRL)

If the TIME bit is enabled, the MSCAN will write a time stamp to the respective registers in the active transmit buffer right after the EOF of a valid message on the CAN bus. In case of a transmission, the CPU can only read the time stamp after the respective transmit buffer has been flagged empty.

The timer value, which is used for stamping, is taken from a free running internal CAN bit clock. A timer overrun is not indicated by the MSCAN. The timer is reset (all bits set to 0) during initialization mode. The CPU can only read the time stamp registers.

NOTE

This register can be read at anytime when TXEx flag is set and the corresponding transmit buffer is selected in CANTBSEL

Address: 4002_4000h base + 3Fh offset = 4002_403Fh

Bit	7	6	5	4	3	2	1	0
Read	TTS							
Write								
Reset	x*	x*	x*	x*	x*	x*	x*	x*

* Notes:
- x = Undefined at reset.

MSCAN_TTSRL field descriptions

Field	Description
TTS	Time Stamp Time stamp 15 to 8.

42.5 Functional description

42.5.1 Message storage

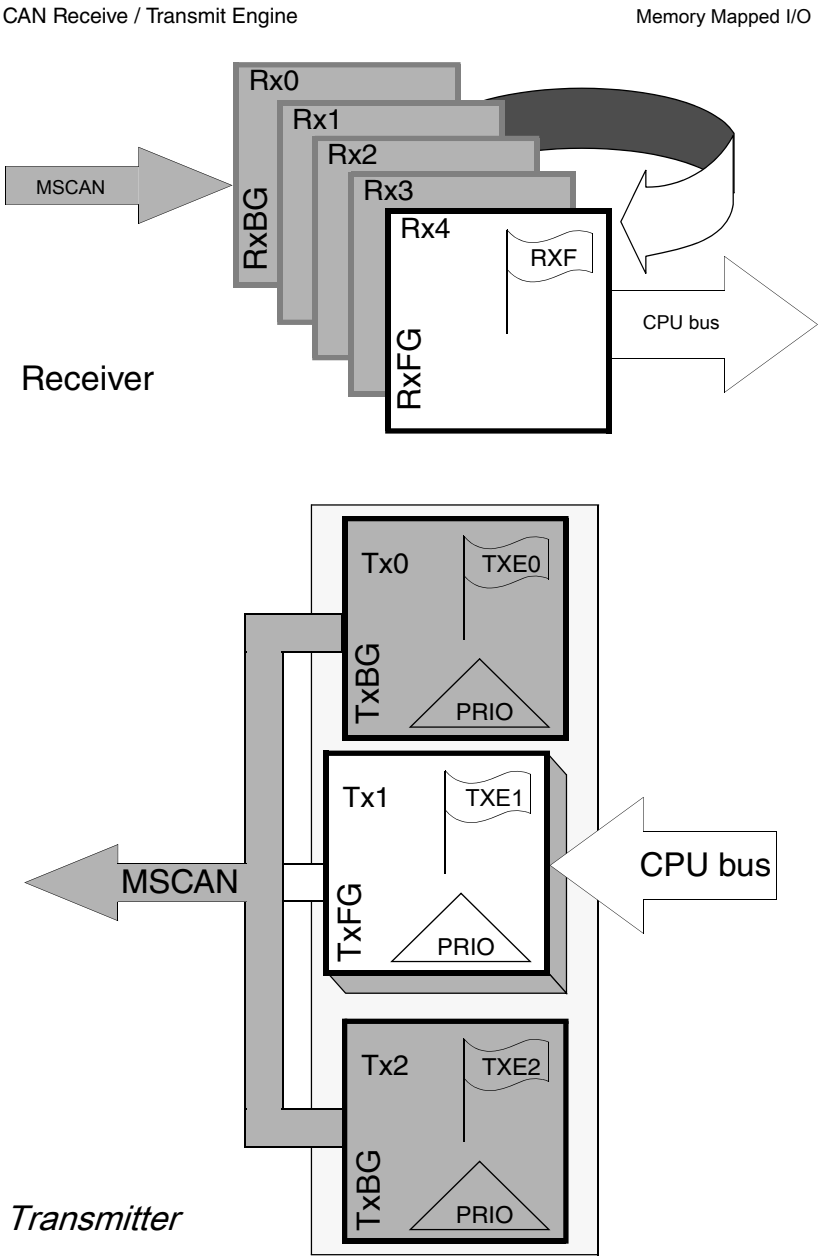


Figure 42-4. User model for message buffer organization

The MSCAN facilitates a sophisticated message storage system which addresses the requirements of a broad range of network applications.

42.5.2 Message transmit background

Modern application layer software is built upon two fundamental assumptions:

- Any CAN node is able to send out a stream of scheduled messages without releasing the CAN bus between the two messages. Such nodes arbitrate for the CAN bus immediately after sending the previous message and only release the CAN bus in case of lost arbitration.
- The internal message queue within any CAN node is organized such that the highest priority message is sent out first, if more than one message is ready to be sent.

The behavior described in the bullets above cannot be achieved with a single transmit buffer. That buffer must be reloaded immediately after the previous message is sent. This loading process lasts a finite amount of time and must be completed within the inter-frame sequence (IFS) to be able to send an uninterrupted stream of messages. Even if this is feasible for limited CAN bus speeds, it requires that the CPU reacts with short latencies to the transmit interrupt.

A double buffer scheme de-couples the reloading of the transmit buffer from the actual message sending and, therefore, reduces the reactiveness requirements of the CPU. Problems can arise if the sending of a message is finished while the CPU re-loads the second buffer. No buffer would then be ready for transmission, and the CAN bus would be released.

At least three transmit buffers are required to meet the first of the above requirements under all circumstances. The MSCAN has three transmit buffers.

The second requirement calls for some sort of internal prioritization which the MSCAN implements with the "local priority" concept described in .

42.5.3 Transmit structures

The MSCAN triple transmit buffer scheme optimizes real-time performance by allowing multiple messages to be set up in advance. The three buffers are arranged as shown in Figure 42-4.

All three buffers have a 13-byte data structure similar to the outline of the receive buffers. An additional Transmit Buffer Priority Register (TBPR) contains an 8-bit local priority field (PRIO). The remaining two bytes are used for time stamping of a message, if required.

To transmit a message, the CPU must identify an available transmit buffer, which is indicated by a set transmitter buffer empty (TXEx) flag. If a transmit buffer is available, the CPU must set a pointer to this buffer by writing to the CANTBSEL register. This makes the respective buffer accessible within the CANTFLG address space. The algorithmic feature associated with the CANTBSEL register simplifies the transmit buffer selection. In addition, this scheme makes the handler software simpler because only one address area is applicable for the transmit process, and the required address space is minimized.

The CPU then stores the identifier, the control bits, and the data content into one of the transmit buffers. Finally, the buffer is flagged as ready for transmission by clearing the associated TXE flag.

The MSCAN then schedules the message for transmission and signals the successful transmission of the buffer by setting the associated TXE flag. A transmit interrupt is generated[3] when TXEx is set and can be used to drive the application software to re-load the buffer.

If more than one buffer is scheduled for transmission when the CAN bus becomes available for arbitration, the MSCAN uses the local priority setting of the three buffers to determine the prioritization. For this purpose, every transmit buffer has an 8-bit local priority field (PRIO). The application software programs this field when the message is set up. The local priority reflects the priority of this particular message relative to the set of messages being transmitted from this node. The lowest binary value of the PRIO field is defined to be the highest priority. The internal scheduling process takes place whenever the MSCAN arbitrates for the CAN bus. This is also the case after the occurrence of a transmission error.

When a high priority message is scheduled by the application software, it may become necessary to abort a lower priority message in one of the three transmit buffers. Because messages that are already in transmission cannot be aborted, the user must request the abort by setting the corresponding abort request bit (ABTRQ). The MSCAN then grants the request, if possible, by:

1. Setting the corresponding abort acknowledge flag (ABTAK) in the CANTAAK register.
2. Setting the associated TXE flag to release the buffer.
3. Generating a transmit interrupt. The transmit interrupt handler software can determine from the setting of the ABTAK flag whether the message was aborted (ABTAK = 1) or sent (ABTAK = 0).

3. The transmit interrupt occurs only if not masked. A polling scheme can be applied on TXEx also.

42.5.4 Receive structures

The received messages are stored in a five stage input FIFO. The five message buffers are alternately mapped into a single memory area. The background receive buffer (RxBG) is exclusively associated with the MSCAN, but the foreground receive buffer (RxFG) is addressable by the CPU. This scheme simplifies the handler software because only one address area is applicable for the receive process.

All receive buffers have a size of 15 bytes to store the CAN control bits, the identifier (standard or extended), the data contents, and a time stamp, if enabled.

The receiver full flag (RXF) signals the status of the foreground receive buffer. When the buffer contains a correctly received message with a matching identifier, this flag is set.

On reception, each message is checked to see whether it passes the filter and simultaneously is written into the active RxBG. After successful reception of a valid message, the MSCAN shifts the content of RxBG into the receiver FIFO, sets the RXF flag, and generates a receive interrupt[4] to the CPU. The user's receive handler must read the received message from the RxFG and then reset the RXF flag to acknowledge the interrupt and to release the foreground buffer. A new message, which can follow immediately after the IFS field of the CAN frame, is received into the next available RxBG. If the MSCAN receives an invalid message in its RxBG (wrong identifier, transmission errors, etc.) the actual contents of the buffer will be over-written by the next message. The buffer will then not be shifted into the FIFO.

When the MSCAN module is transmitting, the MSCAN receives its own transmitted messages into the background receive buffer, RxBG, but does not shift it into the receiver FIFO, generate a receive interrupt, or acknowledge its own messages on the CAN bus. The exception to this rule is in loopback mode where the MSCAN treats its own messages exactly like all other incoming messages. The MSCAN receives its own transmitted messages in the event that it loses arbitration. If arbitration is lost, the MSCAN must be prepared to become a receiver.

An overrun condition occurs when all receive message buffers in the FIFO are filled with correctly received messages with accepted identifiers and another message is correctly received from the CAN bus with an accepted identifier. The latter message is discarded and an error interrupt with overrun indication is generated if enabled. The MSCAN remains able to transmit messages while the receiver FIFO is being filled, but all incoming messages are discarded. As soon as a receive buffer in the FIFO is available again, new valid messages will be accepted.

4. The receive interrupt occurs only if not masked. A polling scheme can be applied on RXF also.

42.5.5 Identifier acceptance filter

The MSCAN identifier acceptance registers define the acceptable patterns of the standard or extended identifier (ID[10:0] or ID[28:0]). Any of these bits can be marked `don't care' in the MSCAN identifier mask registers.

A filter hit is indicated to the application software by a set receive buffer full flag (RXF = 1) and three bits in the CANIDAC register. These identifier hit flags (IDHIT[2:0]) clearly identify the filter section that caused the acceptance. They simplify the application software's task to identify the cause of the receiver interrupt. If more than one hit occurs (two or more filters match), the lower hit has priority.

A very flexible programmable generic identifier acceptance filter has been introduced to reduce the CPU interrupt loading. The filter is programmable to operate in four different modes:

- Two identifier acceptance filters, each to be applied to:
  - The full 29 bits of the extended identifier and to the following bits of the CAN 2.0B frame:
    - Remote transmission request (RTR)
    - Identifier extension (IDE)
    - Substitute remote request (SRR)
  - The 11 bits of the standard identifier plus the RTR and IDE bits of the CAN 2.0A/B messages. This mode implements two filters for a full length CAN 2.0B compliant extended identifier. Although this mode can be used for standard identifiers, it is recommended to use the four or eight identifier acceptance filters.

    Figure 42-5 shows how the first 32-bit filter bank (CANIDAR0-CANIDAR3, CANIDMR0-CANIDMR3) produces a filter 0 hit. Similarly, the second filter bank (CANIDAR4-CANIDAR7, CANIDMR4-CANIDMR7) produces a filter 1 hit.

- Four identifier acceptance filters, each to be applied to:
  - The 14 most significant bits of the extended identifier plus the SRR and IDE bits of CAN 2.0B messages.
  - The 11 bits of the standard identifier, the RTR and IDE bits of CAN 2.0A/B messages. Figure 42-6 shows how the first 32-bit filter bank (CANIDAR0-CANIDAR3, CANIDMR0-CANIDMR3) produces filter 0 and 1 hits. Similarly, the second filter bank (CANIDAR4-CANIDAR7, CANIDMR4-CANIDMR7) produces filter 2 and 3 hits.

- Eight identifier acceptance filters, each to be applied to the first 8 bits of the identifier. This mode implements eight independent filters for the first 8 bits of a CAN 2.0A/B compliant standard identifier or a CAN 2.0B compliant extended identifier. Figure 42-7 shows how the first 32-bit filter bank (CANIDAR0-CANIDAR3, CANIDMR0-CANIDMR3) produces filter 0 to 3 hits. Similarly, the second filter bank (CANIDAR4-CANIDAR7, CANIDMR4-CANIDMR7) produces filter 4 to 7 hits.
- Closed filter. No CAN message is copied into the foreground buffer RxFG, and the RXF flag is never set.

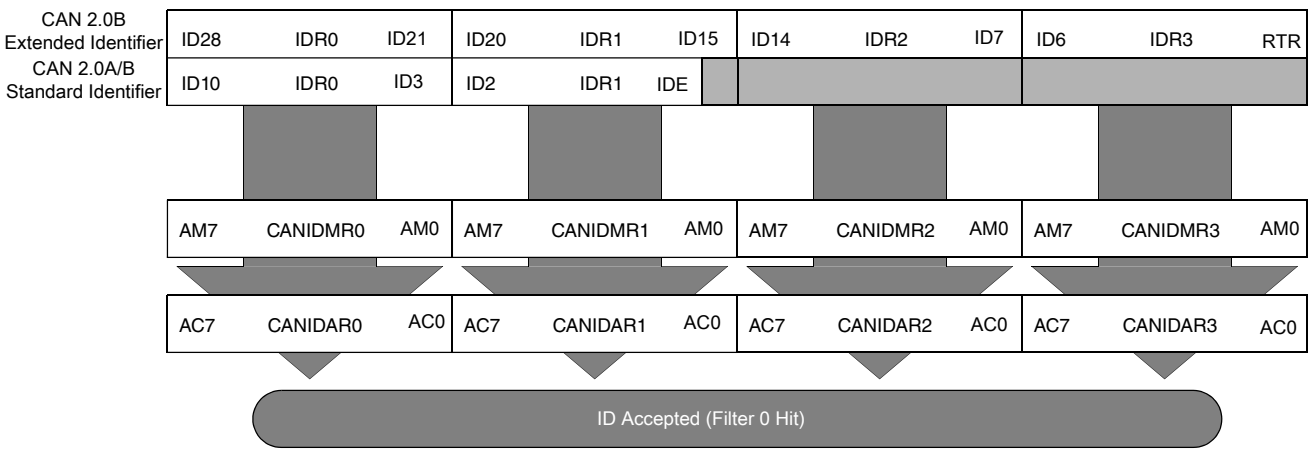


Figure 42-5. 32-bit maskable identifier acceptance filter

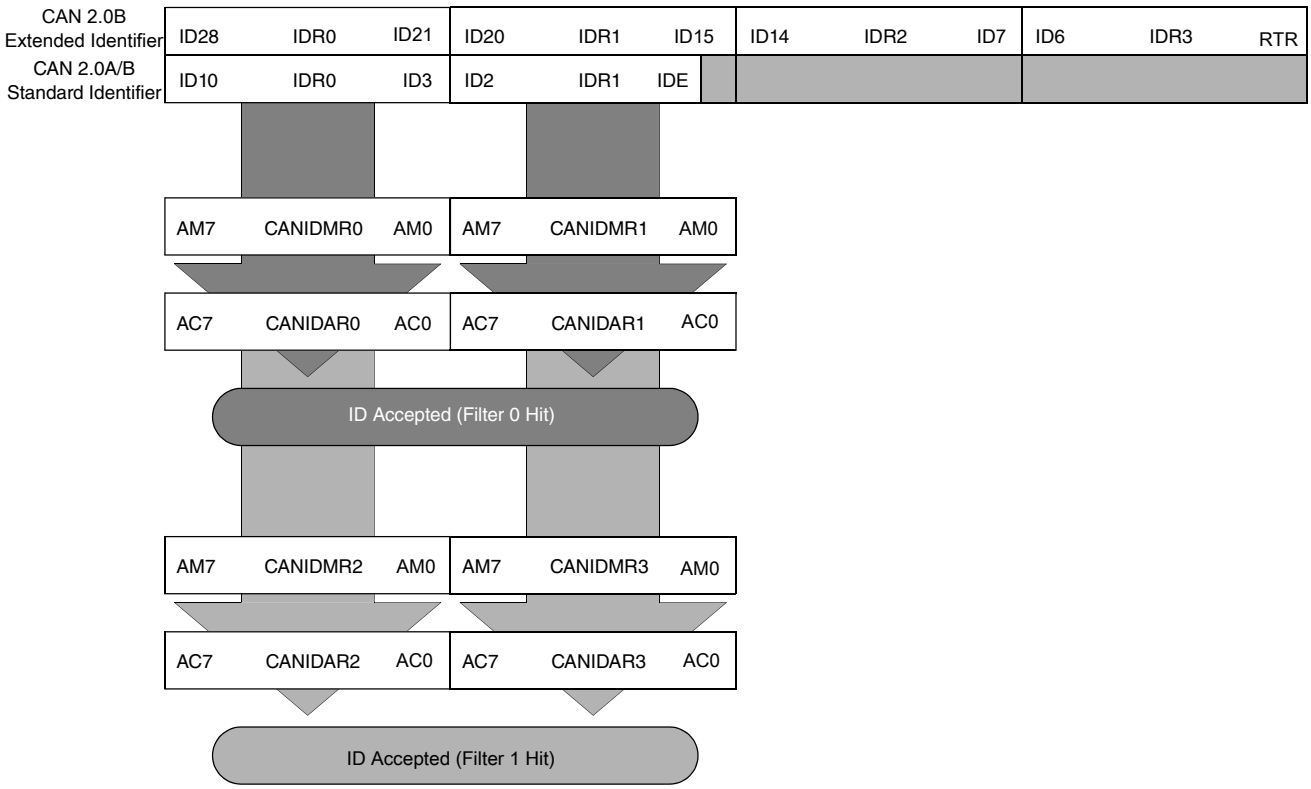


Figure 42-6. 16-bit maskable identifier acceptance filter

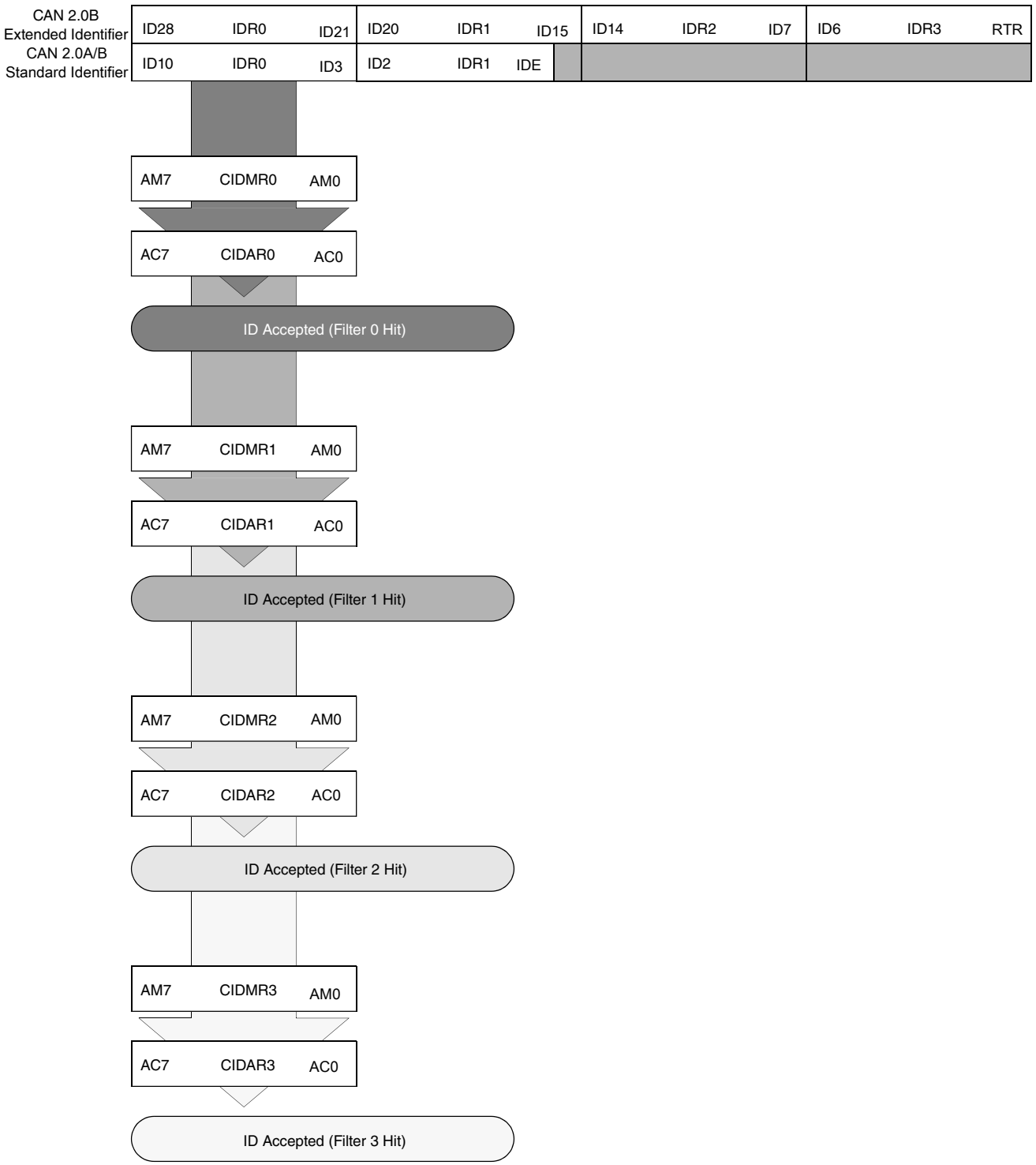


Figure 42-7. 8-bit maskable identifier acceptance filter

42.5.5.1 Protocol violation protection

The MSCAN protects the user from accidentally violating the CAN protocol through programming errors. The protection logic implements the following features:

- The receive and transmit error counters cannot be written or otherwise manipulated.
- All registers which control the configuration of the MSCAN cannot be modified while the MSCAN is on-line. The MSCAN has to be in Initialization Mode. The corresponding INITRQ/INITAK handshake bits in the CANCTL0/CANCTL1 registers serve as a lock to protect the following registers:
  - MSCAN control 1 register (CANCTL1)
  - MSCAN bus timing registers 0 and 1 (CANBTR0, CANBTR1)
  - MSCAN identifier acceptance control register (CANIDAC)
  - MSCAN identifier acceptance registers (CANIDAR0-CANIDAR7)
  - MSCAN identifier mask registers (CANIDMR0-CANIDMR7)
- The TXCAN is immediately forced to a recessive state when the MSCAN goes into the power down mode or initialization mode.
- The MSCAN enable bit (CANE) is writable only once in normal system operation modes, which provides further protection against inadvertently disabling the MSCAN.

42.5.5.2 Clock system

shows the structure of the MSCAN clock generation circuitry.

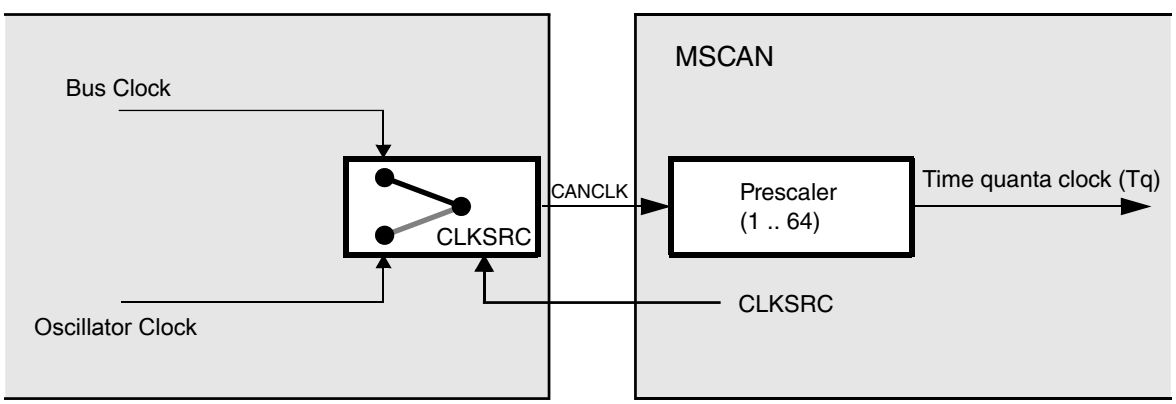


Figure 42-8. MSCAN clocking scheme

The clock source bit (CLKSRC) in the CANCTL1 register defines whether the internal CANCLK is connected to the output of a crystal oscillator (oscillator clock) or to the bus clock.

The clock source has to be chosen such that the tight oscillator tolerance requirements (up to 0.4%) of the CAN protocol are met. Additionally, for high CAN bus rates (1 Mbps), a 45% to 55% duty cycle of the clock is required.

If the bus clock is generated from a PLL, it is recommended to select the oscillator clock rather than the bus clock due to jitter considerations, especially at the faster CAN bus rates.

For microcontrollers without a clock and reset generator (CRG), CANCLK is driven from the crystal oscillator (oscillator clock).

A programmable prescaler generates the time quanta (Tq) clock from CANCLK. A time quantum is the atomic unit of time handled by the MSCAN.

$\Gamma_q = f_{CANCLK}$ / (Prescaler value)

A bit time is subdivided into three segments as described in the Bosch CAN 2.0A/B specification. (see Figure 42-9):

- SYNC_SEG: This segment has a fixed length of one time quantum. Signal edges are expected to happen within this section.
- Time Segment 1: This segment includes the PROP_SEG and the PHASE_SEG1 of the CAN standard. It can be programmed by setting the parameter TSEG1 to consist of 4 to 16 time quanta.
- Time Segment 2: This segment represents the PHASE_SEG2 of the CAN standard. It can be programmed by setting the TSEG2 parameter to be 2 to 8 time quanta long.

Bit rate = f_{Γ_q} / (Number of time quanta)

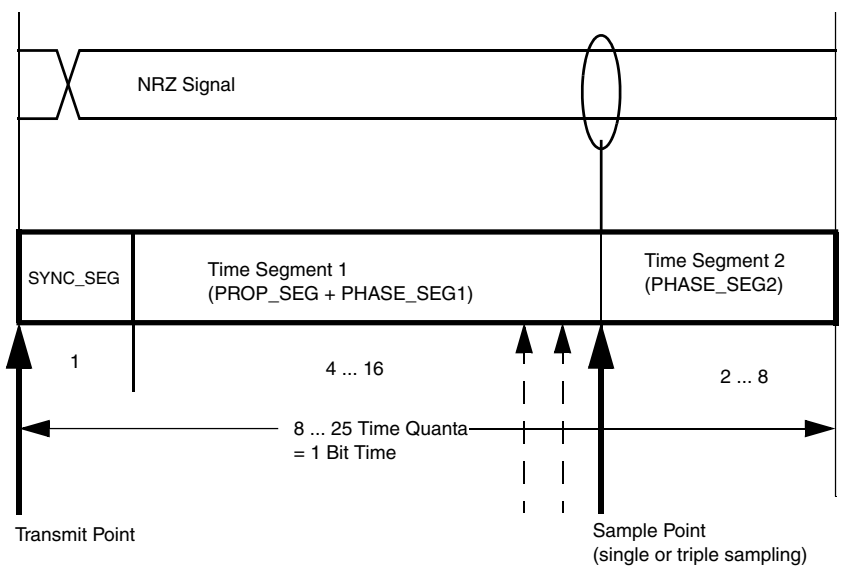


Figure 42-9. Segments within the bit time

Table 42-4. Time segment syntax

Syntax	Description
SYNC_SEG	System expects transitions to occur on the CAN bus during this period.

Table continues on the next page...

Table 42-4. Time segment syntax (continued)

Syntax	Description
Transmit Point	A node in transmit mode transfers a new value to the CAN bus at this point.
Sample Point	A node in receive mode samples the CAN bus at this point. If the three samples per bit option is selected, then this point marks the position of the third sample.

The synchronization jump width (see the Bosch CAN 2.0A/B specification for details) can be programmed in a range of 1 to 4 time quanta by setting the SJW parameter.

The SYNC_SEG, TSEG1, TSEG2, and SJW parameters are set by programming the MSCAN bus timing registers (CANBTR0, CANBTR1).

Table 42-5 gives an overview of the Bosch CAN 2.0A/B specification compliant segment settings and the related parameter values.

Table 42-5. Bosch CAN 2.0A/B compliant bit time segment settings

Time Segment 1	TSEG1	Time Segment 2	TSEG2	Synchronization Jump Width	SJW
5 .. 10	4 .. 9	2	1	1 .. 2	0 .. 1
4 .. 11	3 .. 10	3	2	1 .. 3	0 .. 2
5 .. 12	4 .. 11	4	3	1 .. 4	0 .. 3
6 .. 13	5 .. 12	5	4	1 .. 4	0 .. 3
7 .. 14	6 .. 13	6	5	1 .. 4	0 .. 3
8 .. 15	7 .. 14	7	6	1 .. 4	0 .. 3
9 .. 16	8 .. 15	8	7	1 .. 4	0 .. 3

42.5.6 Low-power options

If the MSCAN is disabled (CANE = 0), the MSCAN clocks are stopped for power saving.

If the MSCAN is enabled (CANE = 1), the MSCAN has two additional modes with reduced power consumption, compared to normal mode: sleep and power down mode. In sleep mode, power consumption is reduced by stopping all clocks except those to access the registers from the CPU side. In power down mode, all clocks are stopped and no power is consumed.

Table 42-6 summarizes the combinations of MSCAN and CPU modes. A particular combination of modes is entered by the given settings on the CSWAI and SLPRQ/SLPAK bits.

Table 42-6. CPU vs. MSCAN operating modes

CPU Mode	MSCAN Mode			
	Normal	Reduced power consumption		
		Sleep	Power down	Disabled (CANE=0)
RUN	• CSWAI = X[1] • SLPRQ = 0 • SLPAK = 0	• CSWAI = X • SLPRQ = 1 • SLPAK = 1		• CSWAI = X • SLPRQ = X • SLPAK = X
WAIT	• CSWAI = 0 • SLPRQ = 0 • SLPAK = 0	• CSWAI = 0 • SLPRQ = 1 • SLPAK = 1	• CSWAI = 1 • SLPRQ = X • SLPAK = X	• CSWAI = X • SLPRQ = X • SLPAK = X
STOP			• CSWAI = X • SLPRQ = X • SLPAK = X	• CSWAI = X • SLPRQ = X • SLPAK = X

1. X means don't care.

42.5.6.1 Operation in run mode

As shown in Table 42-6, only MSCAN sleep mode is available as low power option when the CPU is in run mode.

42.5.6.2 Operation in wait mode

The WAI instruction puts the MCU in a low power consumption stand-by mode. If the CSWAI bit is set, additional power can be saved in power down mode because the CPU clocks are stopped. After leaving this power down mode, the MSCAN restarts and enters normal mode again.

While the CPU is in wait mode, the MSCAN can be operated in normal mode and generate interrupts (registers can be accessed via background debug mode).

42.5.6.3 Operation in stop mode

The STOP instruction puts the MCU in a low power consumption stand-by mode. In stop mode, the MSCAN is set in power down mode regardless of the value of the SLPRQ/ SLPAK and CSWAI bits (Table 42-6).

42.5.6.4 MSCAN normal mode

This is a non-power-saving mode. Enabling the MSCAN puts the module from disabled mode into normal mode. In this mode the module can either be in initialization mode or out of initialization mode. See MSCAN initialization mode.

42.5.6.5 MSCAN sleep mode

The CPU can request the MSCAN to enter this low power mode by asserting the SLPRQ bit in the CANCTL0 register. The time when the MSCAN enters sleep mode depends on a fixed synchronization delay and its current activity:

- If there are one or more message buffers scheduled for transmission (TXEx = 0), the MSCAN will continue to transmit until all transmit message buffers are empty (TXEx = 1, transmitted successfully or aborted) and then goes into sleep mode.
- If the MSCAN is receiving, it continues to receive and goes into sleep mode as soon as the CAN bus next becomes idle.
- If the MSCAN is neither transmitting nor receiving, it immediately goes into sleep mode.

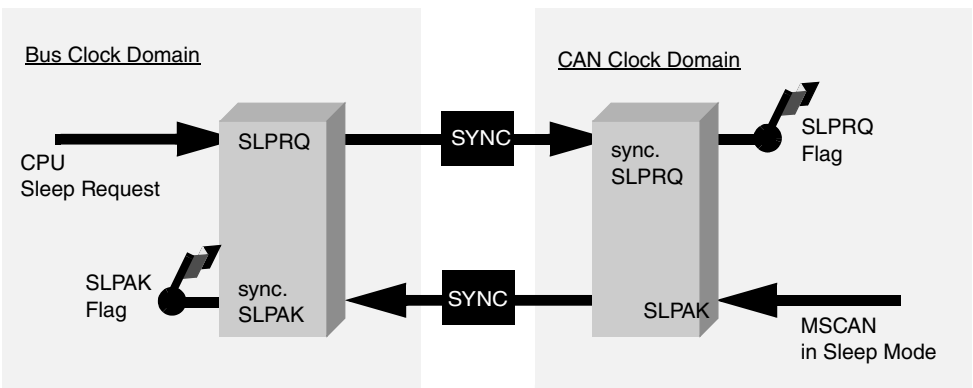


Figure 42-10. Sleep request / acknowledge cycle

NOTE

The application software must avoid setting up a transmission (by clearing one or more TXEx flag(s)) and immediately request sleep mode (by setting SLPRQ). Whether the MSCAN starts transmitting or goes into sleep mode directly depends on the exact sequence of operations.

If sleep mode is active, the SLPRQ and SLPAK bits are set (Figure 42-10). The application software must use SLPAK as a handshake indication for the request (SLPRQ) to go into sleep mode.

When in sleep mode (SLPRQ = 1 and SLPAK = 1), the MSCAN stops its internal clocks. However, clocks that allow register accesses from the CPU side continue to run.

If the MSCAN is in bus-off state, it stops counting the 128 occurrences of 11 consecutive recessive bits due to the stopped clocks. TXCAN remains in a recessive state. If RXF = 1, the message can be read and RXF can be cleared. Shifting a new message into the foreground buffer of the receiver FIFO (RxFG) does not take place while in sleep mode.

It is possible to access the transmit buffers and to clear the associated TXE flags. No message abort takes place while in sleep mode.

If the WUPE bit in CANCTL0 is not asserted, the MSCAN will mask any activity it detects on CAN. RXCAN is therefore held internally in a recessive state. This locks the MSCAN in sleep mode. WUPE must be set before entering sleep mode to take effect.

The MSCAN is able to leave sleep mode (wake up) only when:
- CAN bus activity occurs and WUPE = 1 or
- the CPU clears the SLPRQ bit

NOTE

The CPU cannot clear the SLPRQ bit before sleep mode (SLPRQ = 1 and SLPAK = 1) is active.

After wake-up, the MSCAN waits for 11 consecutive recessive bits to synchronize to the CAN bus. As a consequence, if the MSCAN is woken-up by a CAN frame, this frame is not received.

The receive message buffers (RxFG and RxBG) contain messages if they were received before sleep mode was entered. All pending actions will be executed upon wake-up; copying of RxBG into RxFG, message aborts and message transmissions. If the MSCAN remains in bus-off state after sleep mode was exited, it continues counting the 128 occurrences of 11 consecutive recessive bits.

42.5.6.6 MSCAN power down mode

The MSCAN is in power down mode (Table 42-6) when
- CPU is in stop mode or
- CPU is in wait mode and the CSWAI bit is set

When entering the power down mode, the MSCAN immediately stops all ongoing transmissions and receptions, potentially causing CAN protocol violations. To protect the CAN bus system from fatal consequences of violations to the above rule, the MSCAN immediately drives TXCAN into a recessive state.

NOTE

The user is responsible for ensuring that the MSCAN is not active when power down mode is entered. The recommended procedure is to bring the MSCAN into Sleep mode before the STOP or WAI instruction (if CSWAI is set) is executed. Otherwise, the abort of an ongoing message can cause an error condition and impact other CAN bus devices.

In power down mode, all clocks are stopped and no registers can be accessed. If the MSCAN was not in sleep mode before power down mode became active, the module performs an internal recovery cycle after powering up. This causes some fixed delay before the module enters normal mode again.

42.5.6.7 Disabled mode

The MSCAN is in disabled mode out of reset (CANE=0). All module clocks are stopped for power saving, however the register map can still be accessed as specified.

42.5.6.8 Programmable wake-Up function

The MSCAN can be programmed to wake up from sleep or power down mode as soon as CAN bus activity is detected (see control bit WUPE in MSCAN Control Register 0 (CANCTL0). The sensitivity to existing CAN bus action can be modified by applying a low-pass filter function to the RXCAN input line.

This feature can be used to protect the MSCAN from wake-up due to short glitches on the CAN bus lines. Such glitches can result from-for example-electromagnetic interference within noisy environments

42.5.7 Reset initialization

The reset state of each individual bit is listed in Memory map and register definition which details all the registers and their bit-fields.

42.5.8 Interrupts

This section describes all interrupts originated by the MSCAN. It documents the enable bits and generated flags. Each interrupt is listed and described separately.

42.5.8.1 Description of interrupt operation

The MSCAN supports four interrupt vectors (see Table 42-7), any of which can be individually masked.

Refer to the device overview section to determine the dedicated interrupt vector addresses.

Table 42-7. Interrupt vectors

Interrupt source	CCR mask	Local enable
Wake-up interrupt (WUPIF)	I bit	CANRIER (WUPIE)
Error Interrupts interrupt (CSCIF, OVRIF)	I bit	CANRIER (CSCIE, OVRIE)
Receive interrupt (RXF)	I bit	CANRIER (RXFIE)
Transmit interrupts (TXE[2:0])	I bit	CANTIER (TXEIE[2:0])

42.5.8.2 Transmit interrupt

At least one of the three transmit buffers is empty (not scheduled) and can be loaded to schedule a message for transmission. The TXEx flag of the empty message buffer is set.

42.5.8.3 Receive interrupt

A message is successfully received and shifted into the foreground buffer (RxFG) of the receiver FIFO. This interrupt is generated immediately after receiving the EOF symbol. The RXF flag is set. If there are multiple messages in the receiver FIFO, the RXF flag is set as soon as the next message is shifted to the foreground buffer.

42.5.8.4 Wake-up interrupt

A wake-up interrupt is generated if activity on the CAN bus occurs during MSCAN sleep or power-down mode.

NOTE

This interrupt can only occur if the MSCAN was in sleep mode (SLPRQ = 1 and SLPAK = 1) before entering power down mode, the wake-up option is enabled (WUPE = 1), and the wake-up interrupt is enabled (WUPIE = 1).

42.5.8.5 Error interrupt

An error interrupt is generated if an overrun of the receiver FIFO, error, warning, or bus-off condition occurs. MSCAN Receiver Flag Register (CANRFLG) indicates one of the following conditions:

- Overrun - An overrun condition of the receiver FIFO as described in Receive structures occurred.
- CAN Status Change - The actual value of the transmit and receive error counters control the CAN bus state of the MSCAN. As soon as the error counters skip into a critical range (Tx/Rx-warning, Tx/Rx-error, bus-off) the MSCAN flags an error condition. The status change, which caused the error condition, is indicated by the TSTAT and RSTAT flags.

42.5.8.6 Interrupt acknowledge

Interrupts are directly associated with one or more status flags in either the MSCAN Receiver Flag Register (CANRFLG) or the MSCAN Transmitter Flag Register (CANTFLG). Interrupts are pending as long as one of the corresponding flags is set. The flags in CANRFLG and CANTFLG must be reset within the interrupt handler to handshake the interrupt. The flags are reset by writing a 1 to the corresponding bit position. A flag cannot be cleared if the respective condition prevails.

NOTE

It must be guaranteed that the CPU clears only the bit causing the current interrupt. For this reason, bit manipulation instructions (BSET) must not be used to clear interrupt flags. These instructions may cause accidental clearing of interrupt flags which are set after entering the current interrupt service routine.

42.5.9 Initialization/Application information

42.5.9.1 MSCAN initialization

The procedure to initially start up the MSCAN module out of reset is as follows:

1. Assert CANE
2. Write to the configuration registers in initialization mode
3. Clear INITRQ to leave initialization mode

If the configuration of registers which are only writable in initialization mode shall be changed:

1. Bring the module into sleep mode by setting SLPRQ and awaiting SLPAK to assert after the CAN bus becomes idle.
2. Enter initialization mode: assert INITRQ and await INITAK
3. Write to the configuration registers in initialization mode
4. Clear INITRQ to leave initialization mode and continue

42.5.9.2 Bus-off recovery

The bus-off recovery is user configurable. The bus-off state can either be left automatically or on user request.

For reasons of backwards compatibility, the MSCAN defaults to automatic recovery after reset. In this case, the MSCAN will become error active again after counting 128 occurrences of 11 consecutive recessive bits on the CAN bus (see the Bosch CAN 2.0 A/B specification for details).

If the MSCAN is configured for user request (BORM set in MSCAN Control Register 1 (CANCTL1)), the recovery from bus-off starts after both independent events have become true:

- 128 occurrences of 11 consecutive recessive bits on the CAN bus have been monitored
- BOHOLD in MSCAN Miscellaneous Register (CANMISC) has been cleared by the user

These two events may occur in any order.

Chapter 43
Touch Sensing Input (TSI)

43.1 Chip-specific information for this module

43.1.1 Instantiation Information

Number of TSI module	1
Number of input channels	6 Tx and 6 Rx mutual-cap channels
	up to 25 touch channels for self-cap mode
Support for low-power mode	one selectable pin is active

NOTE

DMA is not supported in this device.

43.1.1.1 TSI module functionality in MCU operation modes

In Stop, VLPS modes, only one TSI channel can be enabled to be the wakeup source. TS I hardware trigger is from the TRGMUX.

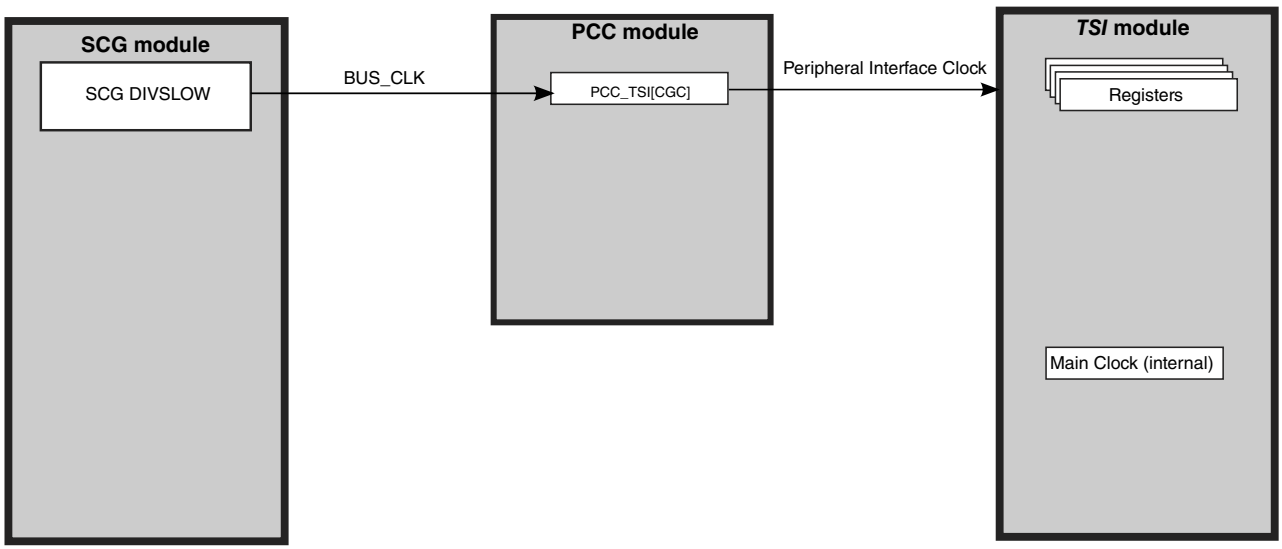
Table 43-1. TSI module functionality in MCU operation modes

MCU operation mode	TSI clock sources	TSI operation mode when GENCS[TSIEN] is 1	Functional electrode pins	Required GENCS[STPE] state
Run	BUS_CLK	Active mode	All	Don’t care
Wait	BUS_CLK	Active mode	All	Don’t care
Stop	Asynch operation	Stop mode	only 1	1
VLPR	BUS_CLK	Active mode	All	Don’t care
VLPW	BUS_CLK	Active mode	All	Don’t care
VLPS	Asynch operation	Stop mode	only 1	1

43.1.2 TSI Clocking Information

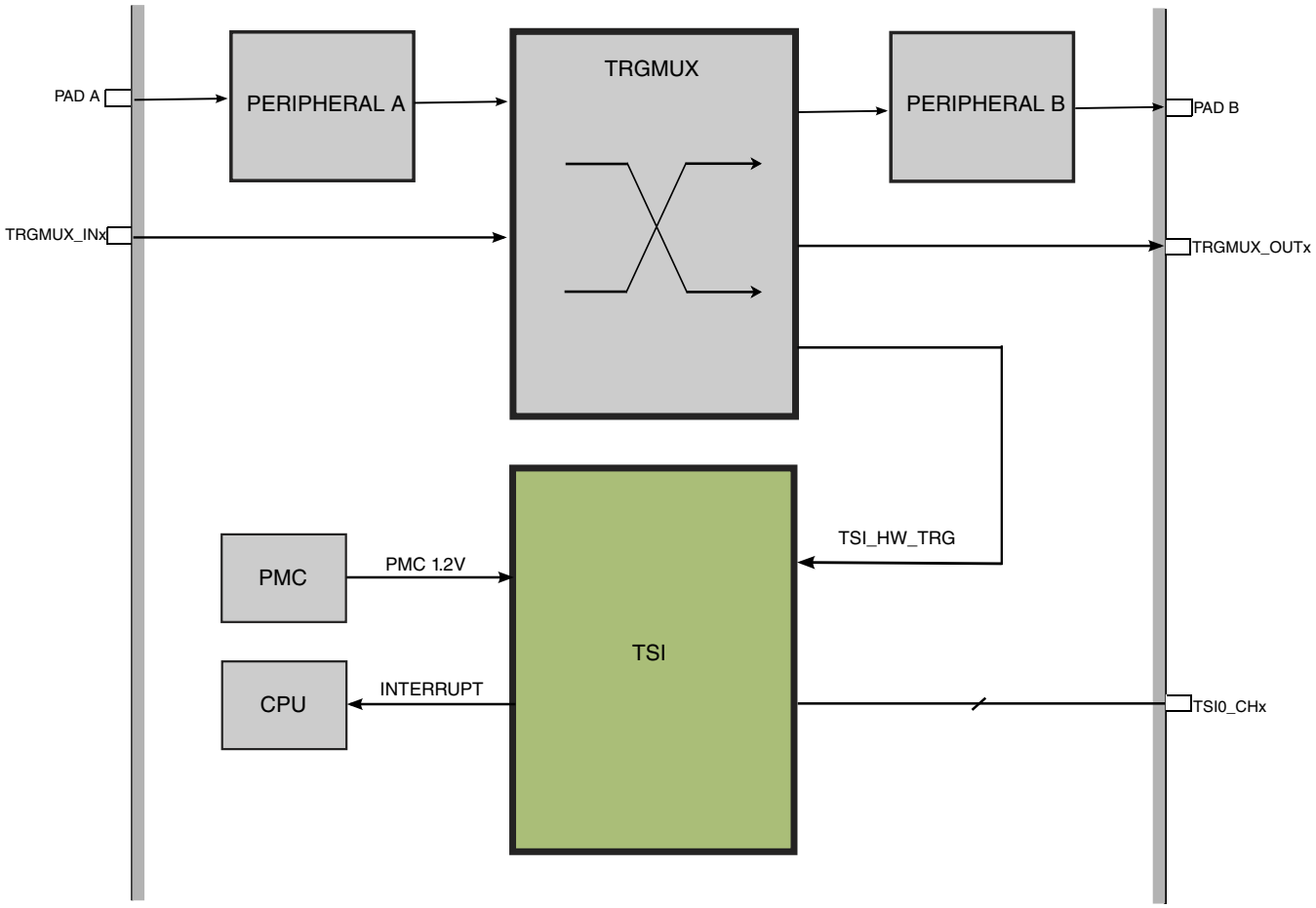
This following figure shows the TSI clocks.

Peripheral Clocking - TSI



43.1.3 Inter-connectivity Information

The TSI inter-connectivity is shown in the following diagram.



43.2 Introduction

Touch sensing interface (TSI) provides touch sensing detection on capacitive touch sensors. The external capacitive touch sensor is typically formed on PCB and the sensor electrodes are connected to TSI input channels through the I/O pins in the device.

The TSI operates in switching integration mode to achieve low-power, high-sensitivity and advanced EMC robustness. It supports both of self-cap and mutual-cap sensors. In self-cap mode, the TSI requires only one pin for each touch sensor. In mutual-cap mode, sensing is done using capacitive touch matrix in various Tx-Rx configurations. The TSI requires one pin per Tx line and one pin per Rx line.

It fully supports NXP touch sensing software (TSS) library which provides a solid capacitive measurement module to the implementation of touch keyboard, rotaries and sliders.

43.2.1 Features

TSI features are as follows:

- Advanced EMC robustness
- Support both of Self-cap sensor and Mutual-cap sensor
- One pin per electrode – no external components
- Adjustable touch sensing resolution and sensitivity for sensing a variety of overlay materials and thicknesses
- Low-power consumption
- Capability to wake up MCU from low power modes for low power application
- Support DMA data transfer
- Fully support NXP touch sensing software (TSS) library, see http://www.nxp.com/touchsensing

For electrode design recommendations, refer to AN3863: Designing Touch Sensing Electrodes

43.2.2 Modes of operation

This module supports the following operation modes.

Table 43-2. Operating modes

Mode	Description
Stop and low power stop	TSI module is fully functional in all of the stop modes as long as TSI_GENCS[STPE] is set. The channel specified by TSI_DATA[TSICH] will be scanned upon the trigger. After scan finishes, either end-of-scan or out-of-range interrupt can be selected to bring MCU out of low power modes.
Wait	TSI module is fully functional in this mode. When a scan completes, TSI submits an interrupt request to CPU if the interrupt is enabled.
Run	TSI module is fully functional in this mode. When a scan completes, TSI submits an interrupt request to CPU if the interrupt is enabled.

43.2.3 Block diagram

The following figure is a block diagram of the TSI module.

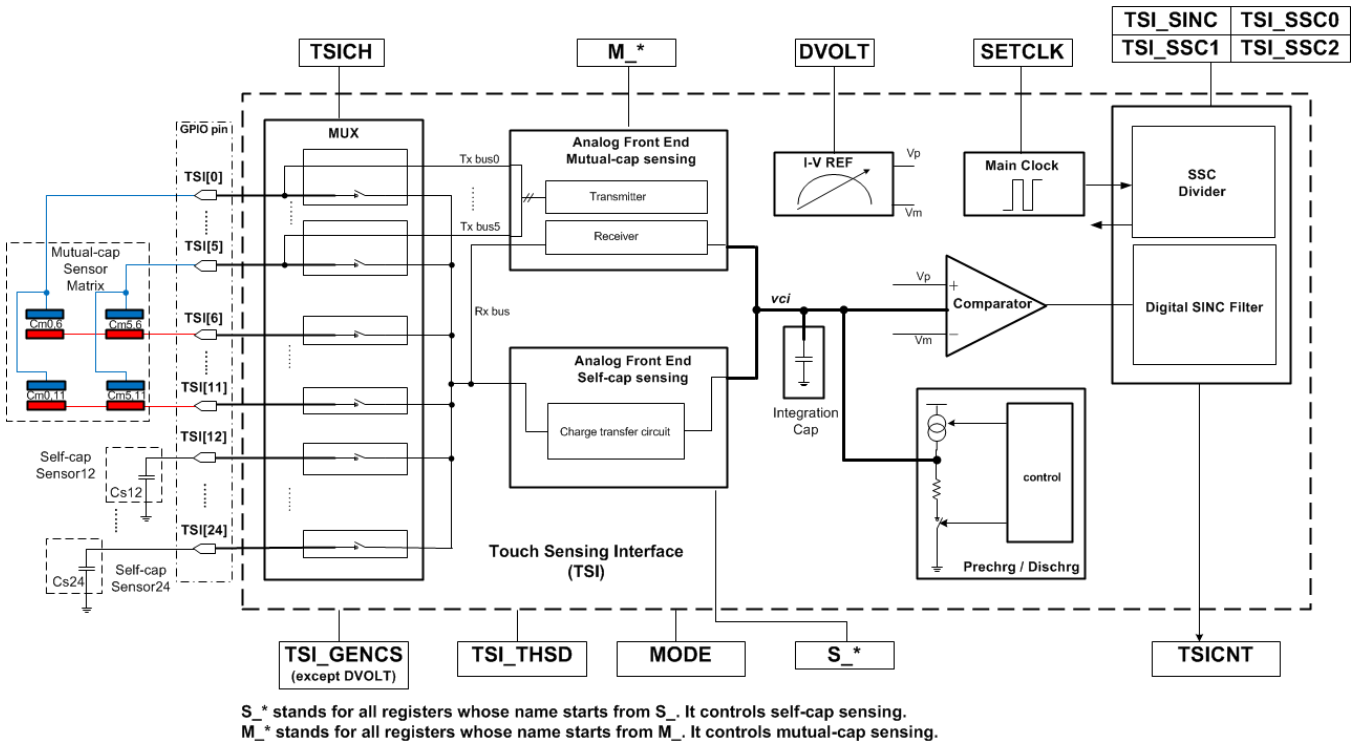


Figure 43-1. TSI module block diagram

43.3 External signal description

The TSI module contains up to 25 external pins for touch sensing. The table found here describes each of the TSI external pins.

Table 43-3. TSI signal description (self-cap sensing)

Name	Port	Direction	Function	Reset state
TSI[24:0]	TSI	I/O	TSI sensing pins or GPIO pins.	I/O

Table 43-4. TSI signal description (mutual-cap sensing)

Name	Port	Direction	Function	Reset state
TSI[5:0]	TSI	I/O	TSI Tx pins or GPIO pins.	I/O
TSI[11:6]	TSI	I/O	TSI Rx pins or GPIO pins.	I/O
TSI[24:12]	TSI	I/O	GPIO pins.	I/O

43.3.1 TSI[24:0]

When TSI functionality is enabled, the TSI analog portion uses the corresponding channel to connect external on-board touch capacitors. The PCB connection between the pin and the touch pad must be kept as short as possible to reduce parasitic capacity on board.

43.4 Register definition

This section describes the memory map and control/status registers for the TSI module.

TSI memory map

Absolute address (hex)	Register name	Width (in bits)	Access	Reset value	Section/ page
4004_5000	TSI General Control and Status Register (TSI_GENCS)	32	R/W	0000_0000h	43.4.1/1040
4004_5004	TSI DATA Register (TSI_DATA)	32	R/W	0000_0000h	43.4.2/1043
4004_5008	TSI Threshold Register (TSI_TSHD)	32	R/W	0000_0000h	43.4.3/1045
4004_500C	TSI MODE Register (TSI_MODE)	32	R/W	003C_0060h	43.4.4/1045
4004_5010	TSI MUTUAL-CAP Register 0 (TSI_MUL0)	32	R/W	603F_6300h	43.4.5/1048
4004_5014	TSI MUTUAL-CAP Register 1 (TSI_MUL1)	32	R/W	0005_007Eh	43.4.6/1050
4004_5018	TSI SINC filter Register (TSI_SINC)	32	R/W	0007_0001h	43.4.7/1053
4004_501C	TSI SSC Register 0 (TSI_SSC0)	32	R/W	6032_0000h	43.4.8/1057
4004_5020	TSI SSC Register 1 (TSI_SSC1)	32	R/W	0060_0040h	43.4.9/1059
4004_5024	TSI SSC Register 2 (TSI_SSC2)	32	R/W	1008_0101h	43.4.10/ 1060

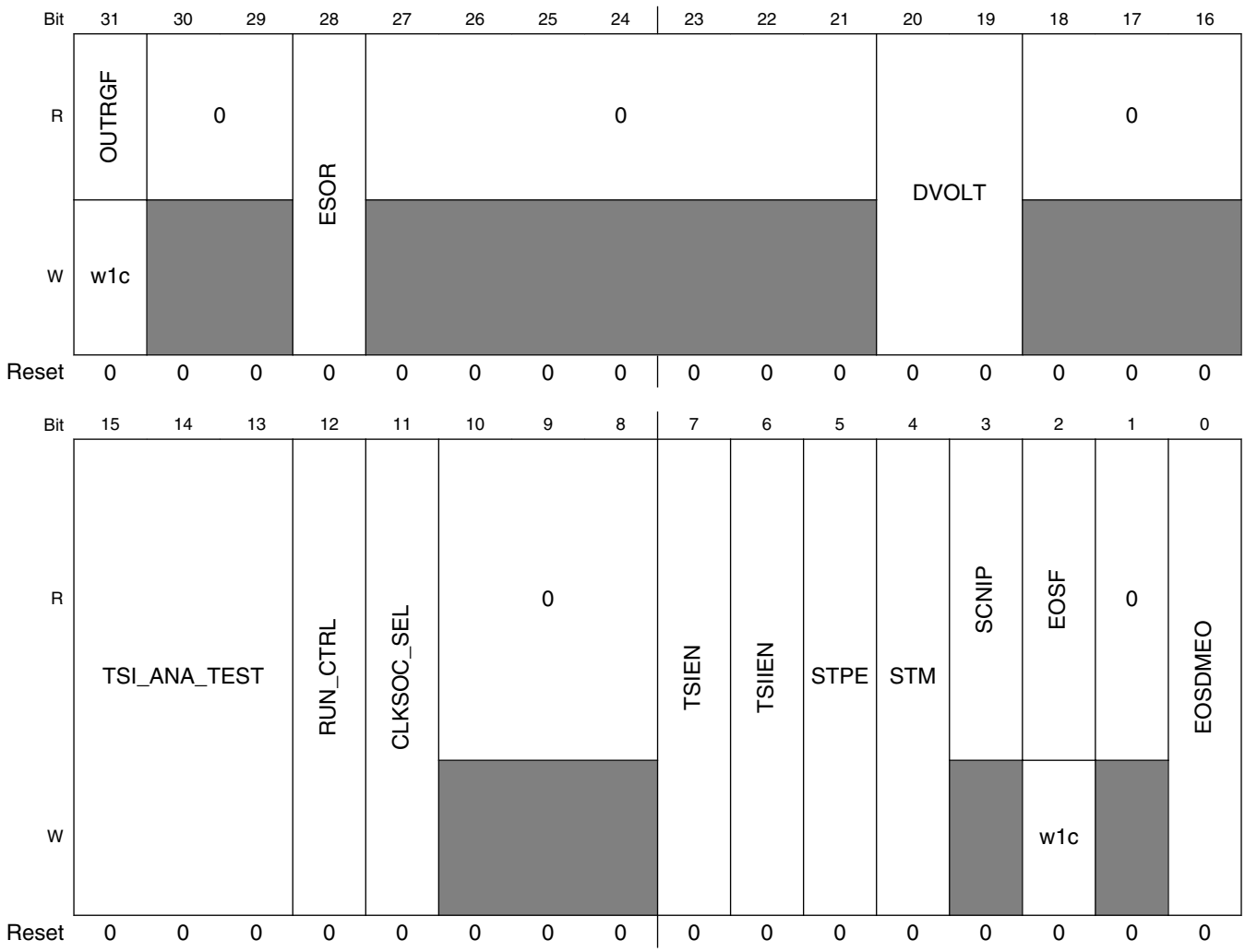
43.4.1 TSI General Control and Status Register (TSI_GENCS)

This control register provides various control and configuration information for the TSI module.

NOTE

When TSI is working, the configuration bits (GENCS[TSIEN], GENCS[TSIIEN], and GENCS[STM]) must not be changed.
The EOSF flag is kept until the software acknowledge it.

Address: 4004_5000h base + 0h offset = 4004_5000h



TSI_GENCS field descriptions

Field	Description
31 OUTRGF	Out of Range Flag. This flag is set if the result register of the enabled electrode is out of the range defined by the TSI_THRESHOLD register. It can be read once the CPU wakes. Write "1" , when this flag is set, to clear it.
30–29 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
28 ESOR	End-of-scan or Out-of-Range Interrupt Selection This bit is used to select out-of-range or end-of-scan event to generate an interrupt. 0 Out-of-range interrupt is allowed. 1 End-of-scan interrupt is allowed.
27–21 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

TSI_GENCS field descriptions (continued)

Field	Description
20–19 DVOLT	DVOLT select comparator Vm, Vp. From DIP. 00 Vm=0.3V; Vp=1.3V; dvolt=1.0V. 01 Vm=0.3V; Vp=1.6V; dvolt=1.3V. 10 Vm=0.3V; Vp=1.9V; dvolt=1.6V. 11 Vm=0.3V; Vp=2.3V; dvolt=2.0V.
18–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
15–13 TSI_ANA_TEST	TSI_ANA_TEST These bits can only be accessed when in test mode .
12 RUN_CTRL	RUN_CTRL This bit can only be accessed when in test mode .
11 CLKSOC_SEL	CLKSOC_SEL This bit can only be accessed when in test mode .
10–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
7 TSIEN	Touch Sensing Input Module Enable This bit enables TSI module. 0 TSI module disabled. 1 TSI module enabled.
6 TSIIEN	Touch Sensing Input Interrupt Enable This bit enables TSI module interrupt request to CPU when the scan completes. The interrupt will wake MCU from low power mode if this interrupt is enabled. 0 TSI interrupt is disabled. 1 TSI interrupt is enabled.
5 STPE	TSI STOP Enable This bit enables TSI module function in low power modes (stop, VLPS etc). 0 TSI is disabled when MCU goes into low power mode. 1 Allows TSI to continue running in all low power modes.
4 STM	Scan Trigger Mode This bit specifies the trigger mode. User is allowed to change this bit when TSI is not working in progress. 0 Software trigger scan. 1 Hardware trigger scan.
3 SCNIP	Scan In Progress Status This read-only bit indicates if scan is in progress. This bit will get asserted after the analog bias circuit is stable after a trigger and it changes automatically by the TSI.

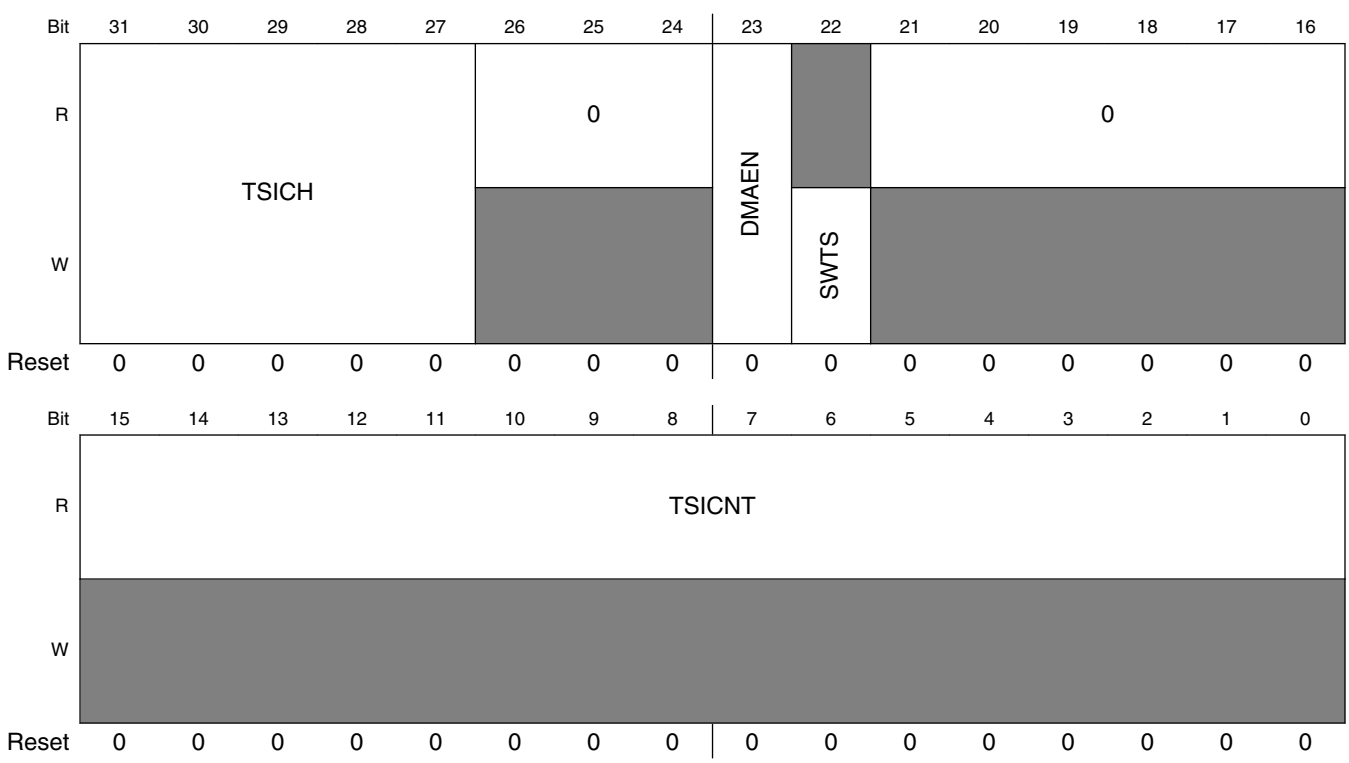
Table continues on the next page...

TSI_GENCS field descriptions (continued)

Field	Description
	0 No scan in progress. 1 Scan in progress.
2 EOSF	End of Scan Flag This flag is set when all active electrodes are finished scanning after a scan trigger. Write "1" , when this flag is set, to clear it. 0 Scan not complete. 1 Scan complete.
1 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
0 EOSDMEO	End-of-Scan DMA Transfer Request Enable Only This bit makes simultaneous DMA request at End-of-Scan and Interrupt at Out-of-Range possible. EOSDMEO has precedence to ESOR when trying to set this bit and ESOR bit. When EOSDMEO = 1, End-of-Scan will generate DMA request and Out-of-Range will generate interrupt. 0 Do not enable the End-of-Scan DMA transfer request only. Depending on ESOR state, either Out-of-Range or End-of-Scan can trigger a DMA transfer request and interrupt. 1 Only the End-of-Scan event can trigger a DMA transfer request. The Out-of-Range event only and always triggers an interrupt if TSIIE is set.

43.4.2 TSI DATA Register (TSI_DATA)

Address: 4004_5000h base + 4h offset = 4004_5004h



TSI_DATA field descriptions

Field	Description
31–27 TSICH	TSICH These bits specify current channel to be measured for self-cap mode. In hardware trigger mode (TSI_GENCS[STM] = 1), the scan will not start until the hardware trigger occurs. In software trigger mode (TSI_GENCS[STM] = 0), the scan starts immediately when TSI_DATA[SWTS] bit is written by 1. 00000 For self-cap mode: Channel 0. 00001 For self-cap mode: Channel 1. 00010 For self-cap mode: Channel 2. 00011 For self-cap mode: Channel 3. 00100 For self-cap mode: Channel 4. 00101 For self-cap mode: Channel 5. 00110 For self-cap mode: Channel 6. 00111 For self-cap mode: Channel 7. 01000 For self-cap mode: Channel 8. 01001 For self-cap mode: Channel 9. 01010 For self-cap mode: Channel 10. 01011 For self-cap mode: Channel 11. 01100 For self-cap mode: Channel 12. 01101 For self-cap mode: Channel 13. 01110 For self-cap mode: Channel 14. 01111 For self-cap mode: Channel 15. 10000 For self-cap mode: Channel 16. 10001 For self-cap mode: Channel 17. 10010 For self-cap mode: Channel 18. 10011 For self-cap mode: Channel 19. 10100 For self-cap mode: Channel 20. 10101 For self-cap mode: Channel 21. 10110 For self-cap mode: Channel 22. 10111 For self-cap mode: Channel 23. 11000 For self-cap mode: Channel 24.
26–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23 DMAEN	DMA Transfer Enabled This bit is used together with the TSI interrupt enable bits(TSIIE, ESOR) to generate a DMA transfer request instead of an interrupt. 0 Interrupt is selected when the interrupt enable bit is set and the corresponding TSI events assert. 1 DMA transfer request is selected when the interrupt enable bit is set and the corresponding TSI events assert.
22 SWTS	Software Trigger Start This write-only bit is a software trigger start control. When the STM bit is cleared, write "1" to this bit will start a scan. Read value is always 0. 0 No effect. 1 Start a scan.

Table continues on the next page...

TSI_DATA field descriptions (continued)

Field	Description
21–16 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
TSICNT	TSI Conversion Counter Value These read-only bits record the accumulated scan counter value ticked by the reference oscillator.

43.4.3 TSI Threshold Register (TSI_TSHD)

Address: 4004_5000h base + 8h offset = 4004_5008h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	THRESH																THRESL															
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TSI_TSHD field descriptions

Field	Description
31–16 THRESH	TSI Wakeup Channel High-threshold This half-word specifies the high threshold of the wakeup channel.
THRESL	TSI Wakeup Channel Low-threshold This half-word specifies the low threshold of the wakeup channel.

43.4.4 TSI MODE Register (TSI_MODE)

Address: 4004_5000h base + Ch offset = 4004_500Ch

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
R	0	S_XDN			0				S_W_SHIELD	S_SEN	S_CTRIM			S_XIN	0	
W																
Reset	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	0	S_XCH			0				SETCLK			0			MODE	S_NOISE
W																
Reset	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0

TSI_MODE field descriptions

Field	Description
31 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
30–28 S_XDN	S_XDN When TSI_MODE[S_SEN]=1, adjust sensitivity. 000 1/16. 001 1/8. 010 1/4. 011 1/2. 100 NA. 101 NA. 110 NA. 111 NA.
27–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23 S_W_SHIELD	S_W_SHIELD Shield switch control when TSI_MODE[MODE] = '0'. 0 shield switch off. 1 shield switch on.
22 S_SEN	S_SEN Sensitivity boost mode of self-cap. 0 Sensitivity boost off. 1 Sensitivity boost on.
21–19 S_CTRIM	Capacitor trim setting When TSI_MODE[S_SEN]=1, adjust sensitivity. 000 Ctrim=2.5p. 001 Ctrim=5.0p. 010 Ctrim=7.5p. 011 Ctrim=10p. 100 Ctrim=12.5p. 101 Ctrim=15p. 110 Ctrim=17.5p. 111 Ctrim=20p.
18 S_XIN	S_XIN Input current multiple. 0 1/8. 1 1/4.
17–15 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
14–12 S_XCH	S_XCH

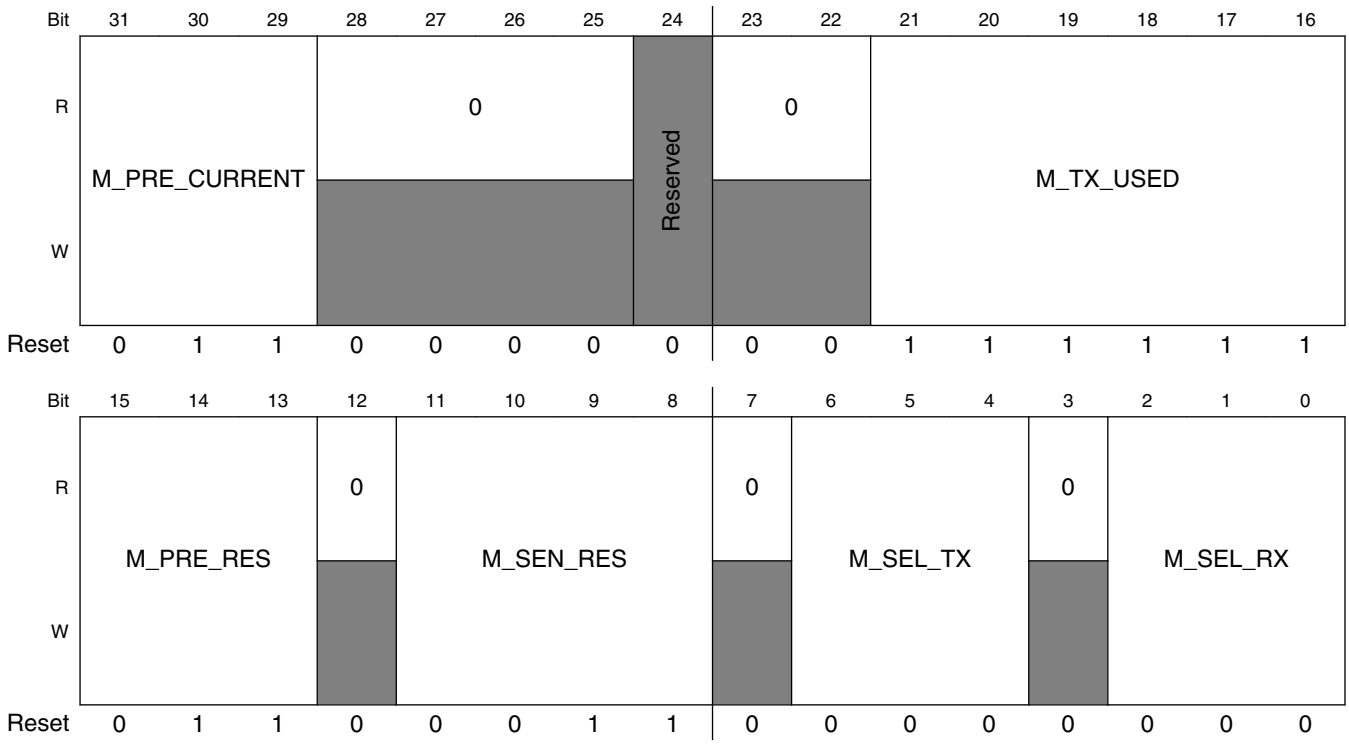
Table continues on the next page...

TSI_MODE field descriptions (continued)

Field	Description
	Charge/Discharge current multiple. 000 1/16. 001 1/8. 010 1/4. 011 1/2. 100 NA. 101 NA. 110 NA. 111 NA.
11–7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
6–5 SETCLK	SETCLK Set main clock frequency. 00 20.72MHz. 01 16.65MHz. 10 13.87MHz. 11 11.91MHz.
4–2 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
1 MODE	MODE Select sensing mod. 0 self-cap mode. 1 mutual-cap mode.
0 S_NOISE	S_NOISE Noise cancellation mode of self-cap. 0 noise cancellation off. 1 noise cancellation on.

43.4.5 TSI MUTUAL-CAP Register 0 (TSI_MUL0)

Address: 4004_5000h base + 10h offset = 4004_5010h



TSI_MUL0 field descriptions

Field	Description
31–29 M_PRE_ CURRENT	M_PRE_CURRENT Choose the current used in Vref generator, default 4uA. 000 1uA. 001 2uA. 010 3uA. 011 4uA. 100 5uA. 101 6uA. 110 7uA. 111 8uA.
28–25 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
24 Reserved	This field is reserved.
23–22 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
21–16 M_TX_USED	M_TX_USED

Table continues on the next page...

TSI_MUL0 field descriptions (continued)

Field	Description
	Indicates which channel used for mutual cap TX. Value 1 means used for mutual cap; value 0 means used for GPIO.
15–13 M_PRE_RES	M_PRE_RES choose the resistor used in pre-charge, default 4k. 000 1k. 001 2k. 010 3k. 011 4k. 100 5k. 101 6k. 110 7k. 111 8k.
12 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
11–8 M_SEN_RES	M_SEN_RES Choose the resistor used in the I_sense generator, default 10k. 0000 2.5k. 0001 5k. 0010 7.5k. 0011 10k. 0100 12.5k. 0101 15k. 0110 17.5k. 0111 20k. 1000 22.5k. 1001 25k. 1010 27.5k. 1011 30k. 1100 32.5k. 1101 35k. 1110 37.5k. 1111 40k.
7 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
6–4 M_SEL_TX	M_SEL_TX TX channel selection when TSI_MODE[MODE] = '1'. 000 select channel 0 as tx0. 001 select channel 1 as tx1. 010 select channel 2 as tx2. 011 select channel 3 as tx3. 100 select channel 4 as tx4. 101 select channel 5 as tx5.

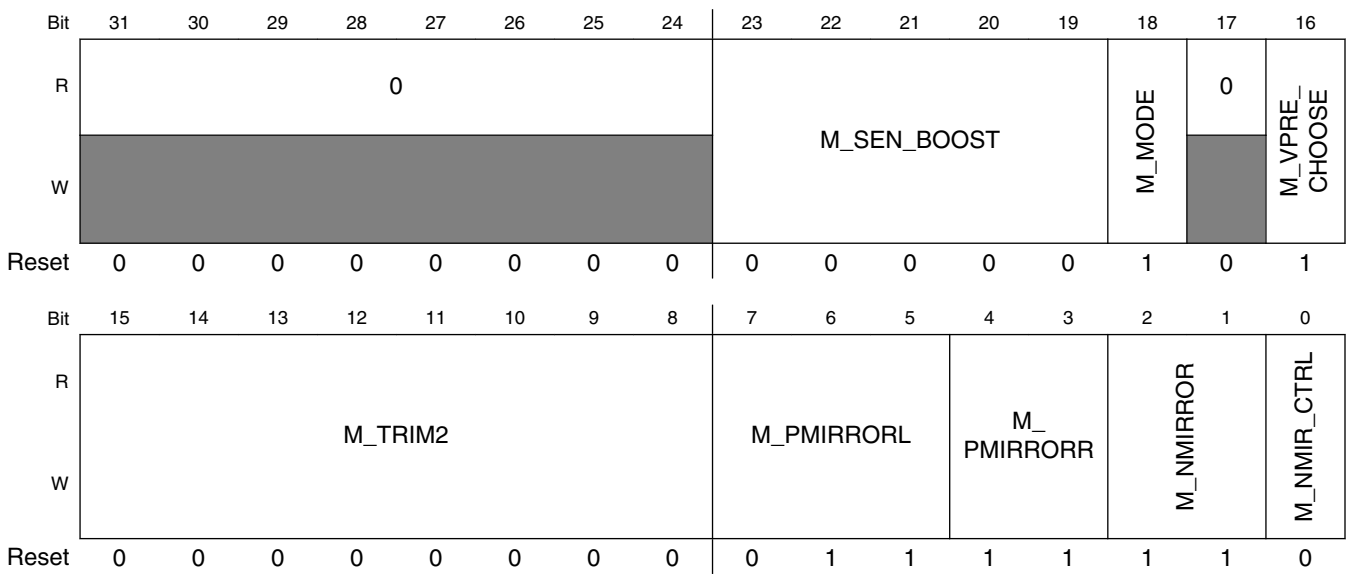
Table continues on the next page...

TSI_MUL0 field descriptions (continued)

Field	Description
	110 NA. 111 NA.
3 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
M_SEL_RX	M_SEL_RX RX channel selection when TSI_MODE[MODE] = '1'. 000 select channel 6 as rx6. 001 select channel 7 as rx7. 010 select channel 8 as rx8. 011 select channel 9 as rx9. 100 select channel 10 as rx10. 101 select channel 11 as rx11. 110 NA. 111 NA.

43.4.6 TSI MUTUAL-CAP Register 1 (TSI_MUL1)

Address: 4004_5000h base + 14h offset = 4004_5014h



TSI_MUL1 field descriptions

Field	Description
31–24 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
23–19 M_SEN_BOOST	M_SEN_BOOST

Table continues on the next page...

TSI_MUL1 field descriptions (continued)

Field	Description
	Choose the sensitivity boost current, default 0. 00000 0u. 00001 2u. 00010 4u. 00011 6u. 00100 8u. 00101 10u. 00110 12u. 00111 14u 01000 16u. 01001 18u. 01010 20u. 01011 22u. 01100 24u. 01101 26u. 01110 28u. 01111 30u. 10000 32u. 10001 34u. 10010 36u. 10011 38u. 10100 40u. 10101 42u. 10110 44u. 10111 46u. 11000 48u. 11001 50u. 11010 52u. 11011 54u. 11100 56u. 11101 58u. 11110 60u. 11111 62u.
18 M_MODE	M_MODE TX drive mode control, default 0V~5V. 0 -5V~+5V. 1 0V~+5V.
17 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
16 M_VPRE_ CHOOSE	M_VPRE_CHOOSE Digital control signal for pre-voltage choose. 0 Internal 1.2V voltage. 1 1.2V PMC output.

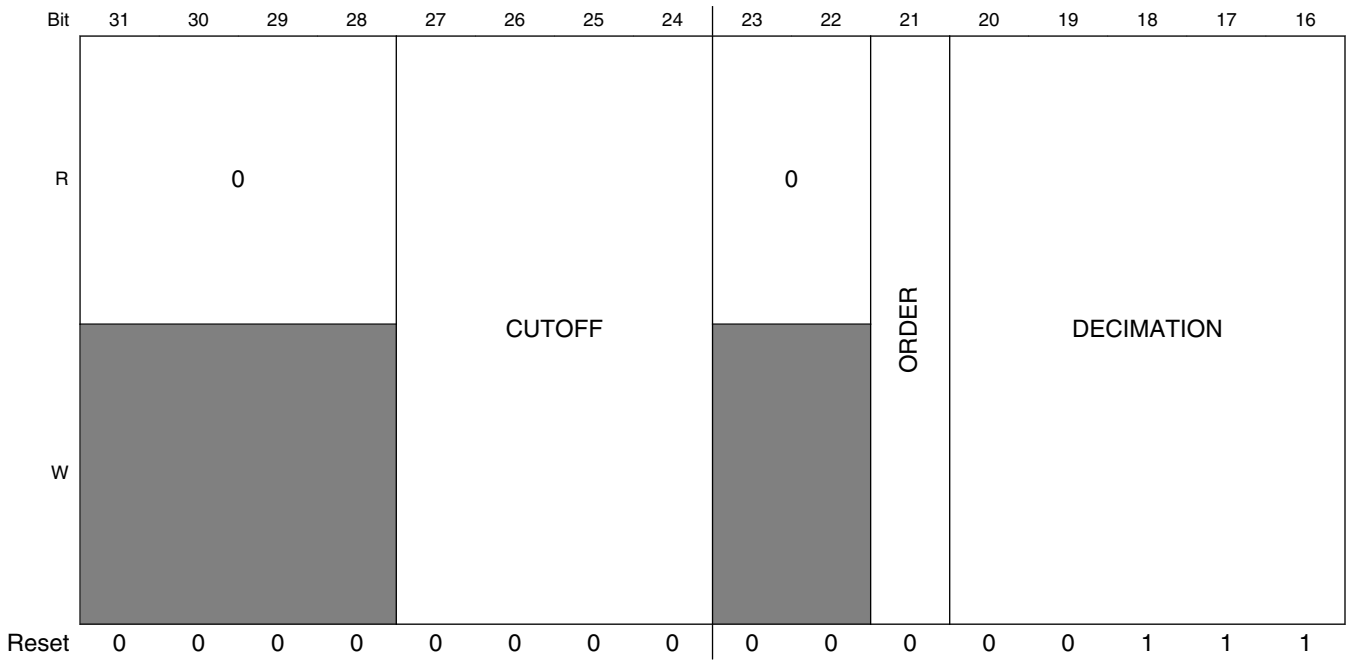
Table continues on the next page...

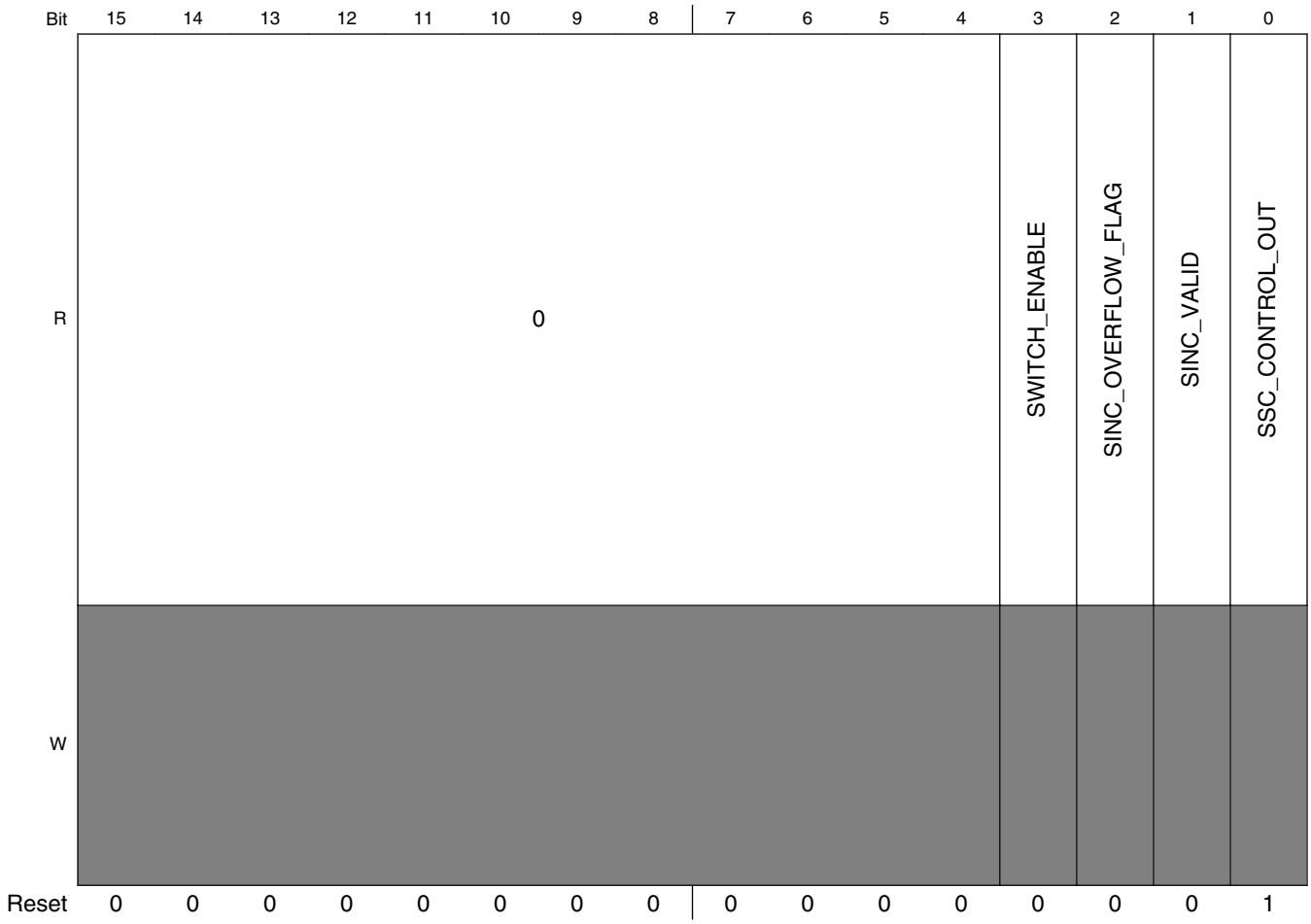
TSI_MUL1 field descriptions (continued)

Field	Description
15–8 M_TRIM2	M_TRIM2 M_TRIM2[7:0] is for trim use. For M_TRIM2[0], • value 0: choose Vref as source of Vp/Vm/Vmid; • value 1: choose Vpre in mutual AFE as source of Vp/Vm/Vmid. When this bit is set to 1, it will choose Vp/Vm/Vmid from a resistor divider from VDD5V to ground. Then it could help reduce variation on the power VDD5V. For M_TRIM2[6], • value 0: choose Vp-0.1V as Vmid; • value 1: choose Vp-0.4V as Vmid.
7–5 M_PMIRRORL	M_PMIRRORL PMOS current mirror on the left side, default m=16. 000 m=4. 001 m=8. 010 m=12. 011 m=16. 100 m=20. 101 m=24. 110 m=28. 111 m=32.
4–3 M_PMIRRORR	M_PMIRRORR PMOS current mirror on the right side, default m=4. 00 m=1. 01 m=2. 10 m=3. 11 m=4.
2–1 M_NMIRROR	M_NMIRROR NMOS current mirror, default m=4. 00 m=1. 01 m=2. 10 m=3. 11 m=4.
0 M_NMIR_CTRL	M_NMIR_CTRL NMOS mirror control signal, default enable. 0 Enable NMOS mirror. 1 Disable NMOS mirror.

43.4.7 TSI SINC filter Register (TSI_SINC)

Address: 4004_5000h base + 18h offset = 4004_5018h





TSI_SINC field descriptions

Field	Description
31–28 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
27–24 CUTOFF	CUTOFF The value of shifting out lower bits of counter, equal to divide the result by div, default div=0. 0000 div=1. 0001 div=2. 0010 div=4. 0011 div=8. 0100 div=16. 0101 div=32. 0110 div=64. 0111 div=128. 1000 NC. 1001 NC. 1010 NC. 1011 NC. 1100 NC.

Table continues on the next page...

TSI_SINC field descriptions (continued)

Field	Description
	1101 NC 1110 NC. 1111 NC.
23–22 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
21 ORDER	ORDER Select the order of SINC filter, the SINC filter is a digital decimation filter for filtering out the low frequency noise from EMC (Electro Magnetic Compatibility). 0 Using 1 order SINC filter. 1 Using 2 order SINC filter.
20–16 DECIMATION	DECIMATION Choose the decimation value of the SINC filter. 00000 The TSI_DATA[TSICNT] bits is the counter value of 1 scan period. 00001 The TSI_DATA[TSICNT] bits is the counter value of 2 scan periods. 00010 The TSI_DATA[TSICNT] bits is the counter value of 3 scan periods. 00011 The TSI_DATA[TSICNT] bits is the counter value of 4 scan periods. 00100 The TSI_DATA[TSICNT] bits is the counter value of 5 scan periods. 00101 The TSI_DATA[TSICNT] bits is the counter value of 6 scan periods. 00110 The TSI_DATA[TSICNT] bits is the counter value of 7 scan periods. 00111 The TSI_DATA[TSICNT] bits is the counter value of 8 scan periods. 01000 The TSI_DATA[TSICNT] bits is the counter value of 9 scan periods. 01001 The TSI_DATA[TSICNT] bits is the counter value of 10 scan periods. 01010 The TSI_DATA[TSICNT] bits is the counter value of 11 scan periods. 01011 The TSI_DATA[TSICNT] bits is the counter value of 12 scan periods. 01100 The TSI_DATA[TSICNT] bits is the counter value of 13 scan periods. 01101 The TSI_DATA[TSICNT] bits is the counter value of 14 scan periods. 01110 The TSI_DATA[TSICNT] bits is the counter value of 15 scan periods. 01111 The TSI_DATA[TSICNT] bits is the counter value of 16 scan periods. 10000 The TSI_DATA[TSICNT] bits is the counter value of 17 scan periods. 10001 The TSI_DATA[TSICNT] bits is the counter value of 18 scan periods. 10010 The TSI_DATA[TSICNT] bits is the counter value of 19 scan periods. 10011 The TSI_DATA[TSICNT] bits is the counter value of 20 scan periods. 10100 The TSI_DATA[TSICNT] bits is the counter value of 21 scan periods. 10101 The TSI_DATA[TSICNT] bits is the counter value of 22 scan periods. 10110 The TSI_DATA[TSICNT] bits is the counter value of 23 scan periods. 10111 The TSI_DATA[TSICNT] bits is the counter value of 24 scan periods. 11000 The TSI_DATA[TSICNT] bits is the counter value of 25 scan periods. 11001 The TSI_DATA[TSICNT] bits is the counter value of 26 scan periods. 11010 The TSI_DATA[TSICNT] bits is the counter value of 27 scan periods. 11011 The TSI_DATA[TSICNT] bits is the counter value of 28 scan periods. 11100 The TSI_DATA[TSICNT] bits is the counter value of 29 scan periods. 11101 The TSI_DATA[TSICNT] bits is the counter value of 30 scan periods. 11110 The TSI_DATA[TSICNT] bits is the counter value of 31 scan periods. 11111 The TSI_DATA[TSICNT] bits is the counter value of 32 scan periods.

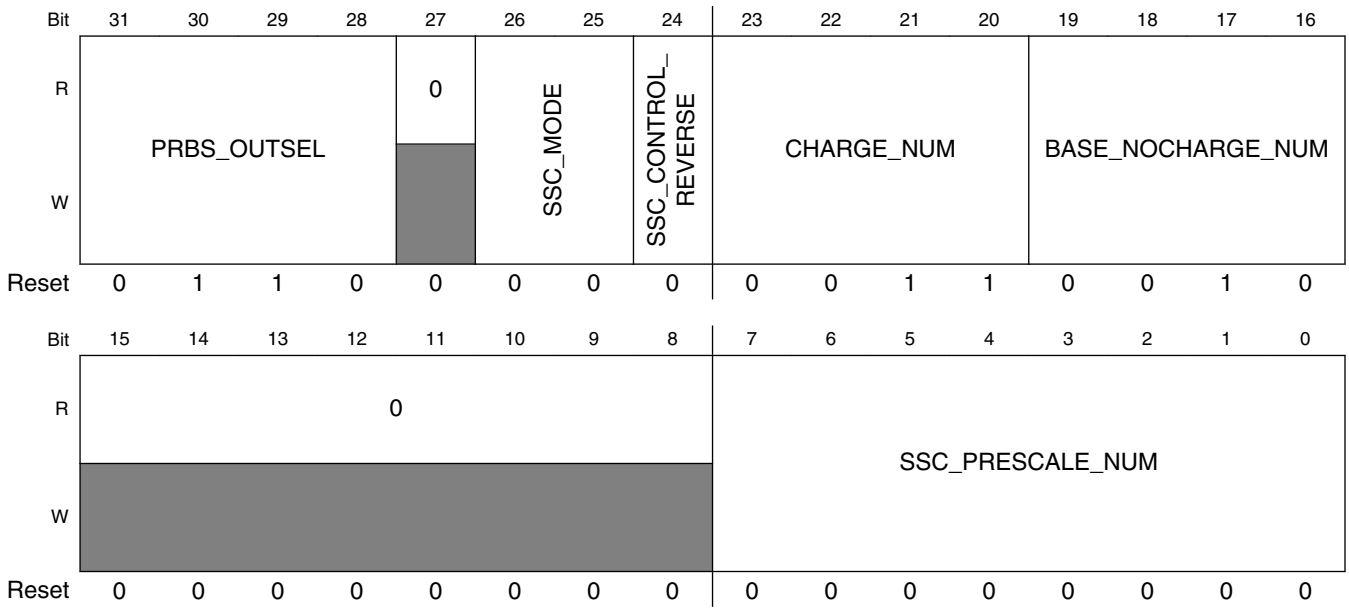
Table continues on the next page...

TSI_SINC field descriptions (continued)

Field	Description
15–4 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
3 SWITCH_ ENABLE	SWITCH_ENABLE Indicating the state of SSC (spread spectrum clocking), for digital testing. SSC function is used for spreading frequency of sampling clock, reducing EMC (Electro Magnetic Compatibility). 0 SSC function is disabled. 1 SSC function is enabled.
2 SINC_ OVERFLOW_ FLAG	SINC_OVERFLOW_FLAG Indicating whether the counter result in TSI_DATA[TSICNT] has an overflow occurrence in the last scan process. Note: this bit has no default value, please force it to 0 or deposit it if necessary. 0 The counter result has no overflow occurrence in the last scan process. 1 The counter result has an overflow occurrence in the last scan process.
1 SINC_VALID	SINC_VALID Indicating the state of SINC filter, for digital testing. 0 SINC filter is disabled. 1 SINC filter is enabled.
0 SSC_ CONTROL_OUT	SSC_CONTROL_OUT Indicating the state of SSC output value, for digital testing. 0 SSC output value is 0. 1 SSC output value is 1.

43.4.8 TSI SSC Register 0 (TSI_SSC0)

Address: 4004_5000h base + 1Ch offset = 4004_501Ch



TSI_SSC0 field descriptions

Field	Description
31–28 PRBS_OUTSEL	PRBS_OUTSEL When SSC0[SSC_MODE] = 2'b00, choosing the length of the PRBS (Pseudo-RandomBinarySequence) method. 0000 NC. 0001 NC. 0010 The length of the PRBS is 2. 0011 The length of the PRBS is 3. 0100 The length of the PRBS is 4. 0101 The length of the PRBS is 5. 0110 The length of the PRBS is 6. 0111 The length of the PRBS is 7. 1000 The length of the PRBS is 8. 1001 The length of the PRBS is 9. 1010 The length of the PRBS is 10. 1011 The length of the PRBS is 11. 1100 The length of the PRBS is 12. 1101 The length of the PRBS is 13. 1110 The length of the PRBS is 14. 1111 The length of the PRBS is 15.
27 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.

Table continues on the next page...

TSI_SSC0 field descriptions (continued)

Field	Description
26–25 SSC_MODE	SSC_MODE Choosing the SSC mode. 00 Using PRBS method generating SSC output bit. 01 Using up-down counter generating SSC output bit. 10 SSC function is disabled. 11 NC.
24 SSC_ CONTROL_ REVERSE	SSC_CONTROL_REVERSE Reversing the SSC output bit's polarity or not. 0 Keep the polarity of the SSC output bit. 1 Reverse the polarity of the SSC output bit.
23–20 CHARGE_NUM	CHARGE_NUM Choosing the period of the SSC output bit 0's period, when using up-down counter mode. 0000 The SSC output bit 0's period will be 1 clock cycle of system clock. 0001 The SSC output bit 0's period will be 2 clock cycles of system clock. 0010 The SSC output bit 0's period will be 3 clock cycles of system clock. 0011 The SSC output bit 0's period will be 4 clock cycles of system clock. 0100 The SSC output bit 0's period will be 5 clock cycles of system clock. 0101 The SSC output bit 0's period will be 6 clock cycles of system clock. 0110 The SSC output bit 0's period will be 7 clock cycles of system clock. 0111 The SSC output bit 0's period will be 8 clock cycles of system clock. 1000 The SSC output bit 0's period will be 9 clock cycles of system clock. 1001 The SSC output bit 0's period will be 10 clock cycles of system clock. 1010 The SSC output bit 0's period will be 11 clock cycles of system clock. 1011 The SSC output bit 0's period will be 12 clock cycles of system clock. 1100 The SSC output bit 0's period will be 13 clock cycles of system clock. 1101 The SSC output bit 0's period will be 14 clock cycles of system clock. 1110 The SSC output bit 0's period will be 15 clock cycles of system clock. 1111 The SSC output bit 0's period will be 16 clock cycles of system clock.
19–16 BASE_ NOCHARGE_ NUM	BASE_NOCHARGE_NUM Choosing the basic period of the SSC output bit 1's period, when using up-down counter mode. Together with the TSI_SSC2[MOVE_ NOCHARGE_MAX] and TSI_SSC2[MOVE_ NOCHARGE_MIN], they are determining the SSC output 1's period. 0000 The SSC output bit 1's basic period will be 1 clock cycle of system clock. 0001 The SSC output bit 1's basic period will be 2 clock cycles of system clock. 0010 The SSC output bit 1's basic period will be 3 clock cycles of system clock. 0011 The SSC output bit 1's basic period will be 4 clock cycles of system clock. 0100 The SSC output bit 1's basic period will be 5 clock cycles of system clock. 0101 The SSC output bit 1's basic period will be 6 clock cycles of system clock. 0110 The SSC output bit 1's basic period will be 7 clock cycles of system clock. 0111 The SSC output bit 1's basic period will be 8 clock cycles of system clock. 1000 The SSC output bit 1's basic period will be 9 clock cycles of system clock. 1001 The SSC output bit 1's basic period will be 10 clock cycles of system clock.

Table continues on the next page...

TSI_SSC0 field descriptions (continued)

Field	Description
	1010 The SSC output bit 1's basic period will be 11 clock cycles of system clock. 1011 The SSC output bit 1's basic period will be 12 clock cycles of system clock. 1100 The SSC output bit 1's basic period will be 13 clock cycles of system clock. 1101 The SSC output bit 1's basic period will be 14 clock cycles of system clock. 1110 The SSC output bit 1's basic period will be 15 clock cycles of system clock. 1111 The SSC output bit 1's basic period will be 16 clock cycles of system clock.
15–8 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
SSC_ PRESCALE_ NUM	SSC_PRESCALE_NUM Selecting the divider ratio for the clock used for generating the SSC output bit. The clock frequency is main_clock/(SSC_PRESCALE_NUM + 1) before going into SSC logic. The average SSC output frequency is determined by SSC_PRESCALE_NUM and detailed SSC configuration. 00000000 div1 00000001 div2 00000011 div4 00000111 div8 00001111 div16 00011111 div32 00111111 div64 01111111 div128 11111111 div256

43.4.9 TSI SSC Register 1 (TSI_SSC1)

Address: 4004_5000h base + 20h offset = 4004_5020h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R W	PRBS_WEIGHT_HI								PRBS_WEIGHT_LO								PRBS_SEED_HI								PRBS_SEED_LO							
Reset	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

TSI_SSC1 field descriptions

Field	Description
31–24 PRBS_WEIGHT_ HI	PRBS_WEIGHT_HI Together with the TSI_SSC1[PRBS_WEIGHT_LO], choosing the PRBS's feeding back nodes, when using PRBS method generating SSC output bit. The nodes whose value corresponding with "1" will be feed back and connected to the input of the XOR.
23–16 PRBS_WEIGHT_ LO	PRBS_WEIGHT_LO Together with the TSI_SSC1[PRBS_WEIGHT_HI], choosing the PRBS's feeding back nodes, when using PRBS method generating SSC output bit. The nodes whose value corresponding with "1" will be feed back and connected to the input of the XOR.

Table continues on the next page...

TSI_SSC1 field descriptions (continued)

Field	Description
15–8 PRBS_SEED_HI	PRBS_SEED_HI Together with the TSI_SSC1[PRBS_SEED_LO], choosing the initial value of the PRBS method, when using PRBS method generating SSC output bit.
PRBS_SEED_LO	PRBS_SEED_LO Together with the TSI_SSC1[PRBS_SEED_HI], choosing the initial value of the PRBS method, when using PRBS method generating SSC output bit.

43.4.10 TSI SSC Register 2 (TSI_SSC2)

Address: 4004_5000h base + 24h offset = 4004_5024h

Bit	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
R	MOVE_NOCHARGE_MIN				0						MOVE_NOCHARGE_MAX						0					MOVE_STEPS_NUM			0			MOVE_REPEAT_NUM				
W																																
Reset	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1

TSI_SSC2 field descriptions

Field	Description
31–28 MOVE_NOCHARGE_MIN	MOVE_NOCHARGE_MIN Choosing the min period of the SSC output bit 1's period, when using up-down counter mode. Together with the TSI_SSC0[BASE_ NOCHARGE_NUM] and TSI_SSC2[MOVE_ NOCHARGE_MAX], they are determining the SSC output 1's period. 0000 The SSC output bit 1's min period will be (1 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycle of divided system clock. 0001 The SSC output bit 1's min period will be (2 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 0010 The SSC output bit 1's min period will be (3 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 0011 The SSC output bit 1's min period will be (4 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 0100 The SSC output bit 1's min period will be (5 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 0101 The SSC output bit 1's min period will be (6 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 0110 The SSC output bit 1's min period will be (7 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 0111 The SSC output bit 1's min period will be (8 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 1000 The SSC output bit 1's min period will be (9 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 1001 The SSC output bit 1's min period will be (10 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 1010 The SSC output bit 1's min period will be (11 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock.

Table continues on the next page...

TSI_SSC2 field descriptions (continued)

Field	Description
	1011 The SSC output bit 1's min period will be (12 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 1100 The SSC output bit 1's min period will be (13 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 1101 The SSC output bit 1's min period will be (14 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 1110 The SSC output bit 1's min period will be (15 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock. 1111 The SSC output bit 1's min period will be (16 + TSI_SSC0[BASE_ NOCHARGE_NUM]) clock cycles of divided system clock.
27–22 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
21–16 MOVE_ NOCHARGE_ MAX	MOVE_NOCHARGE_MAX Similar with TSI_SSC2[MOVE_NOCHARGE_MAX], it is choosing the max period of the SSC output bit 1's period, when using up-down counter mode. Together with the TSI_SSC0[BASE_ NOCHARGE_NUM] and TSI_SSC2[MOVE_ NOCHARGE_MIN], they are determining the SSC output 1's period.
15–11 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
10–8 MOVE_STEPS_ NUM	MOVE_STEPS_NUM Choosing the steps for the counters of TSI_SSC0[BASE_NOCHARGE_NUM]/ TSI_SSC2[MOVE_NOCHARGE_MAX]/ TSI_SSC2[MOVE_CHARGE_MIN], when using up-down counter mode. 000 The added value for up-down counter is 0. 001 The added value for up-down counter is 1. 010 The added value for up-down counter is 2. 011 The added value for up-down counter is 3. 100 The added value for up-down counter is 4. 101 The added value for up-down counter is 5. 110 The added value for up-down counter is 6. 111 The added value for up-down counter is 7.
7–5 Reserved	This field is reserved. This read-only field is reserved and always has the value 0.
MOVE_ REPEAT_NUM	MOVE_REPEAT_NUM Choosing the repeat times for the same setting of TSI_SSC0[BASE_NOCHARGE_NUM]/ TSI_SSC2[MOVE_NOCHARGE_MAX]/ TSI_SSC2[MOVE_CHARGE_MIN], when using up-down counter mode. Only when this repeat times is reached, these settings can be changed to the next values. 00000 The up_down counter will be updated for every sample-charge cycle. 00001 The up_down counter will be updated for every 2 sample-charge cycles. 00010 The up_down counter will be updated for every 3 sample-charge cycles. 00011 The up_down counter will be updated for every 4 sample-charge cycles. 00100 The up_down counter will be updated for every 5 sample-charge cycles. 00101 The up_down counter will be updated for every 6 sample-charge cycles. 00110 The up_down counter will be updated for every 7 sample-charge cycles. others NC.

43.5 Functional description

43.5.1 Touch Sensor

Self-cap touch sensor

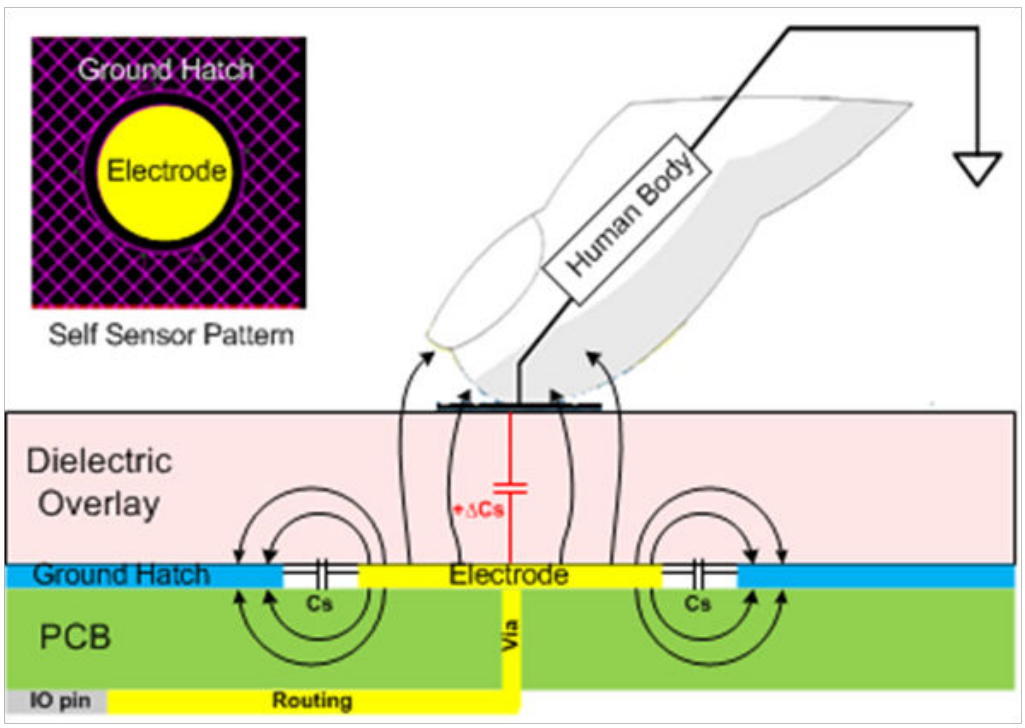


Figure 43-2. Self-cap Touch Sensor structure and Electric field

Sensor structure:

- Cs: Intrinsic self capacitance. 10pF ~ 50pF as usual.
- ΔCs: Touch generated self capacitance. 0.3pF ~ 2pF as usual.
- Sensitivity of sensor: ΔCs/Cs. 1% ~ 10% as usual.

Intrinsic performance depends on: electrode pattern design, thickness/dielectric of overlay and PCB routing.

Mutual-cap touch sensor

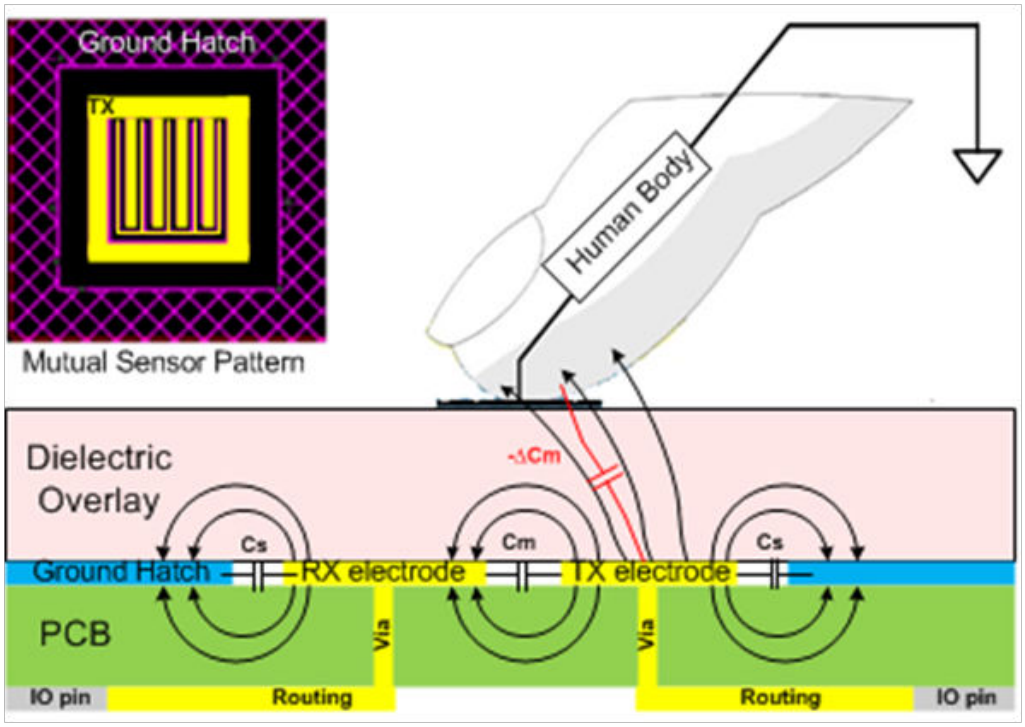


Figure 43-3. Mutual-cap Touch Sensor structure and Electric field

Sensor structure:

- Cm: Intrinsic mutual cap. 2pF ~ 10pF as usual.
- ΔCm: Touch reduced mutual cap. 0.3pF ~ 2pF as usual.
- Cs: Parasitic self cap. 10pF ~ 50pF as usual.
- Sensitivity of sensor: ΔCm/Cm. 1% ~ 20% as usual.

Intrinsic performance depends on: electrode pattern design, thickness/dielectric of overlay and PCB routing.

43.5.2 Brief timing and Operation of TSI

TSI works by switching integration, no matter under self-cap mode or mutual-cap mode. The difference of sensing modes is on analog processing.

Brief timing

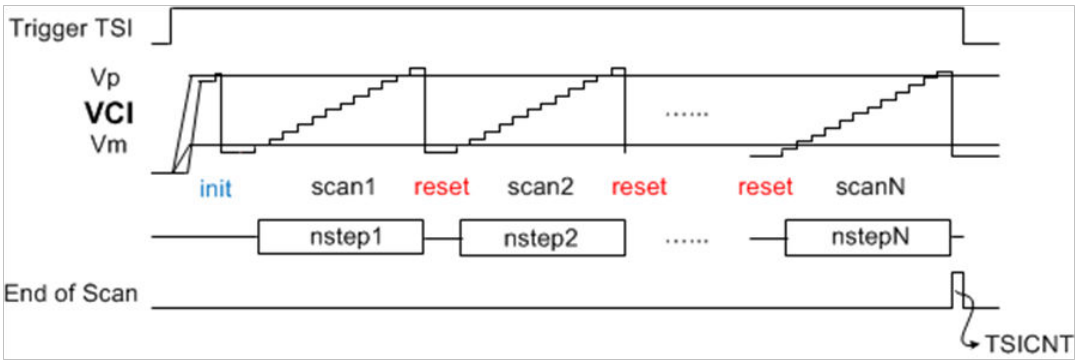


Figure 43-4. Brief timing of TSI operation

Formula

TSICNT = NSTEP x DECIMATION x ORDER

SCANTIME = TNSTEP x DECIMATION x ORDER

where:

DECIMATION: the times of scan, defined by IP configuration DECIMATION<4:0>.

ORDER: the order of sum up, defined by IP configuration ORDER.

NSTEP: the analog integration steps, decided by IP configurations and sensor.

TNSTEP: the scan time of getting each NSTEP.

SCANTIME: the total scan time of getting each TSICNT.

Operation

- TSI needs very short initialization time for each trigger, then starts to scan touch sensor.
- During scanning, analog front end senses self-cap/mutual-cap value and generates voltage steps on integration capacitor. The step voltage depends on touch sensor and IP configuration.
- Once the step voltage (VCI) reach threshold Vp of comparator, the integration cap and analog front end will be reset. The voltage VCI is discharged to Vm for next scanning.
- For each TSI trigger, there are many scan times which is set by registers. The step numbers of each scan are summed up together as final counts for software to use.
- The counts relate with touch sensor capacitance (self-cap/mutual-cap) through formulas and it can be used to sense touch event.

43.5.3 Self-cap sensing mode

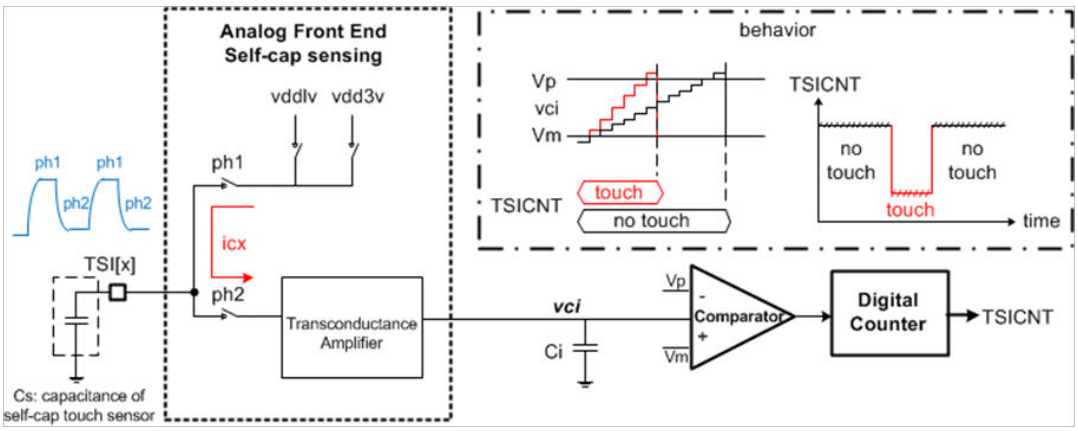


Figure 43-5. Self-cap sensing mode

Charge transfer operates through non-overlapping clock ph1/ph2 and trans-conductance amplifier. Charge accumulates in integration capacitor Ci which creates step voltage Vci.

The basic formula is given by

$$NSTEP = \frac{Ci \times (vp - vm)}{vdd3v \times Cs \times S_XIN \times S_XCH}$$

$$TNSTEP = \frac{Ci \times (vp - vm)}{vdd3v \times Cs \times S_XIN \times S_XCH} \times \frac{1}{F_{SW}}$$

where

Ci: is integration capacitance. Typical 90pF.

Vp, Vm: dual reference voltage which can be configured by TSI_GENCS[DVOLT].

Vdd3v: is analog power supply voltage. Typical 3.3V.

S_XIN, S_XCH: is parameter of analog front end which can be configured by TSI_MODE[S_XIN], TSI_MODE[S_XCH].

Fsw: is the switching frequency which is controlled by SSC (Spread Spectrum Clocking) block.

Cs: is the self-capacitance of touch sensor.

DVOLT, S_XIN, S_XCH can be used to adjust the sensing resolution.

If the touch sensor intrinsic sensitivity is limited due to parasitic, sensitivity boost feature can be activated by setting S_SEN. The formula is given by

$$NSTEP = \frac{Ci \times (vp - vm)}{vdd3v \times (Cs - S_CTRIM * (S_XDN/S_XCH)) \times S_XIN \times S_XCH}$$

Where

S_CTRIM: is internal trim capacitance which can be configured by TSI_MODE[S_CTRIM].

S_XDN: is parameter of analog front end which can be configured by TSI_MODE[S_XDN].

S_CTRIM, S_XDN, S_XCH can be used to adjust the sensitivity. The intrinsic sensitivity of sensor is given by ΔCs/Cs. With this option, sensitivity can be improved to ΔCs/(Cs-S_CTRIM*(S_XDN/S_XCH)).

If touch sensor encounters strong low frequency noise, noise cancellation can be activated by setting S_NOISE. The formula is given by

$$NSTEP = \frac{2 \times Ci \times (vp - vm)}{(vdd3v - vddlv) \times Cx \times S_XIN \times S_XCH}$$

Where

Vddlv: is internal power supply voltage. Typical 1.2V.

During noise cancellation mode, vdd3v and vddlv are dual sample voltages. Analog front end samples twice which includes charging phase (sampling vdd3v) and discharging phase (sampling vddlv). At the end of each second phase, low frequency noise will be subtracted. In a long integration period, the noise induced error can be cancelled.

Example

In one typical case, Ci=90 pF, Cx=25 pF, vdd3v=3.3 V, DVOLT=1 V, S_XIN=1/8, S_XCH=1/8; Dec=8, Order=2.

Then,

NSTEP=69; TSICNT=4416; SCANTIME = 1.117 ms.

NOTE

Do not set S_SEN and S_NOISE at the same time.

43.5.4 Mutual-cap sensing mode

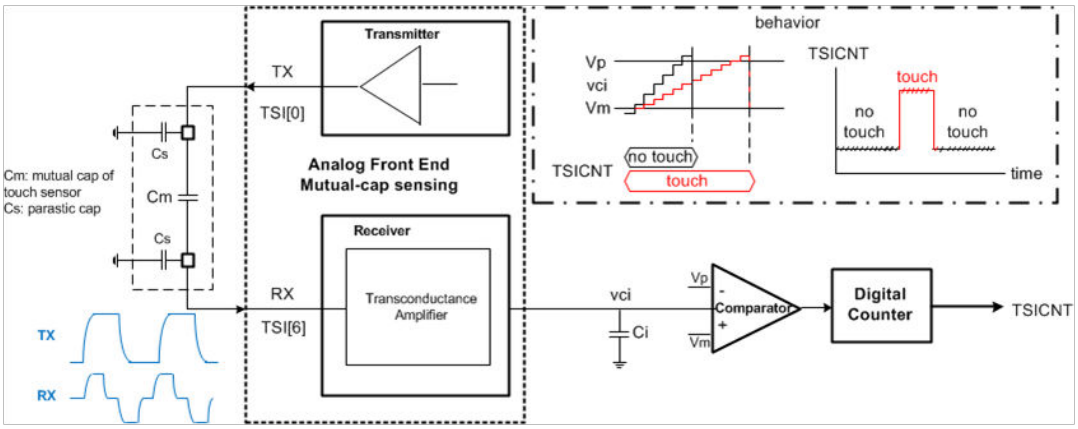


Figure 43-6. Mutual-cap sensing mode

Mutual-cap sensing includes transmitter and receiver. Under clocking, transmitter outputs pulses which couple through mutual cap then reach receiver. Receiver amplifies the signal and converts to charge current on integration cap Ci which creates step voltage Vci.

The formula is given by:

$$NSTEP = \frac{Ci \times (Vp - Vm) \times Rs}{\Delta V} \times \frac{M_PMIRRORL}{M_PMIRRORR} \times \frac{1}{t3},$$

$$TNSTEP = \frac{Ci \times (Vp - Vm) \times Rs}{\Delta V} \times \frac{M_PMIRRORL}{M_PMIRRORR} \times \frac{Tsw}{t3},$$

where

Ci: is integration capacitance. Typical 90pF.

Vp, Vm: dual reference voltage which can be configured by TSI_GENCS[DVOLT].

Fsw: is the switching frequency which is controlled by SSC (Spread Spectrum Clocking) block.

Tsw: is the switching period, and Tsw =1/Fsw.

t3: is the SSC output low period.

Rs: is parameter of analog front end which can be configured by TSI_MUL0[M_SEN_RES].

M: is a parameter decided by TSI_MUL1[M_PMIRRORR] and TSI_MUL1[M_PMIRRORL].

ΔV: is signal voltage received. It is decided by

$$\Delta V = VDD5V \times \frac{Cm}{Cm + Cs}$$

which can be tens to hundreds of volts.

Cm, Cs: are the mutual capacitance and parasitic capacitance of sensor.

If the touch sensor intrinsic sensitivity is limited due to parasitic, sensitivity boost feature can be activated by setting TSI_MUL1[M_SEN_BOOST]. The basis average charge current will be subtracted by boost current which enlarge the signal current.

Example

In one typical case, ΔV=100 mV, Rs=10k, Vp-Vm=1 V, Ci=90 pF, M_PMIRRORL=8, M_PMIRRORR= M_NMIRROR= 2, Tsw=1 μs, t3=0.25 μs.

NSTEP=144, TNSTEP=144 μs.

Dec=8, Order=2, TSICNT=144 × 64 = 9216, SCANTIME=144 μs × 8 × 2 = 2304 μs.

NOTE

Keep M_PMIRRORR and M_NMIRROR the same.

43.5.5 Water shield

Shield electrode can reduce mis-trigger risk induced by water drop. A parasitic mutual cap is created between shield electrode (channel 12) and sensing electrode. In PH1, Cx is charged and Cm,shield is cleared. In PH2, Cm,shield shares some charge in Cx during transfer. So it induces TSI count increasing, which is an opposite trend comparing with normal touch – count decreasing.

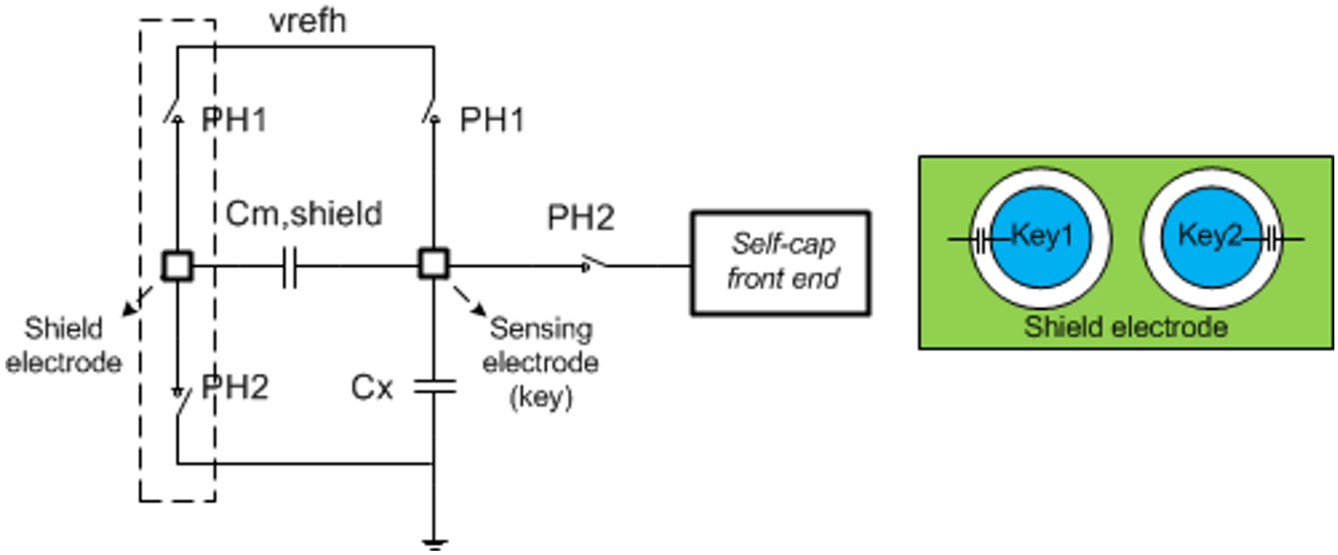


Figure 43-7. Self-cap touch key with water shield function

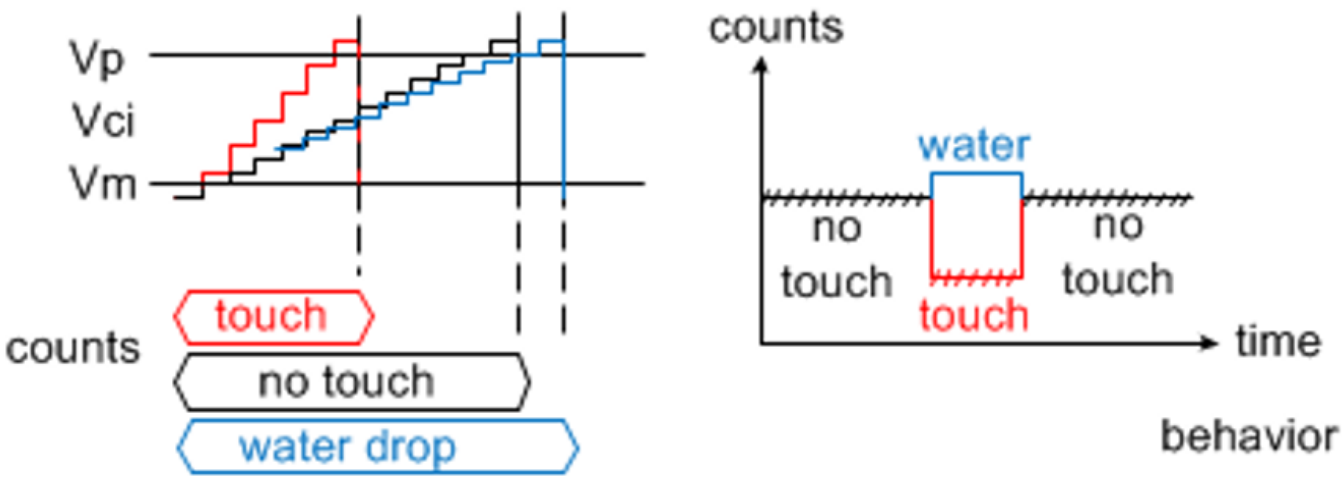


Figure 43-8. Self-cap mode count values of touch, no touch and water drop

Mutual-cap mode does not need the shield electrode. When there is a water drop between RX and TX, a parasitic cap is made between drive electrode and receive electrode. This enlarges the collected charge and reduces the count number. While the panel is touched, there is less coupling between drive electrode and receive electrode. This increases the count number. Therefore, water drops do not send out a mis-trigger in mutual-cap mode.

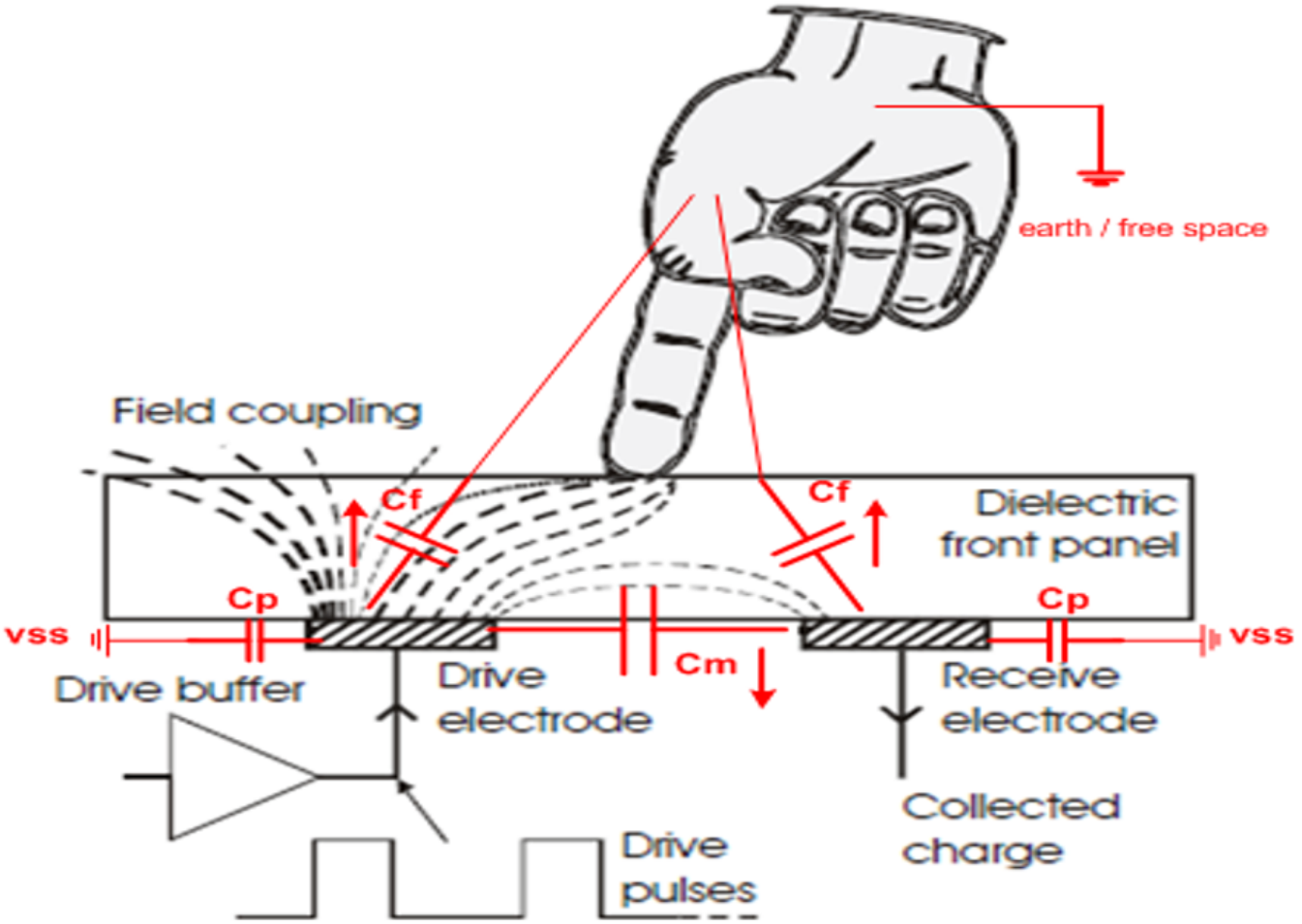


Figure 43-9. Mutual-cap touch key structure

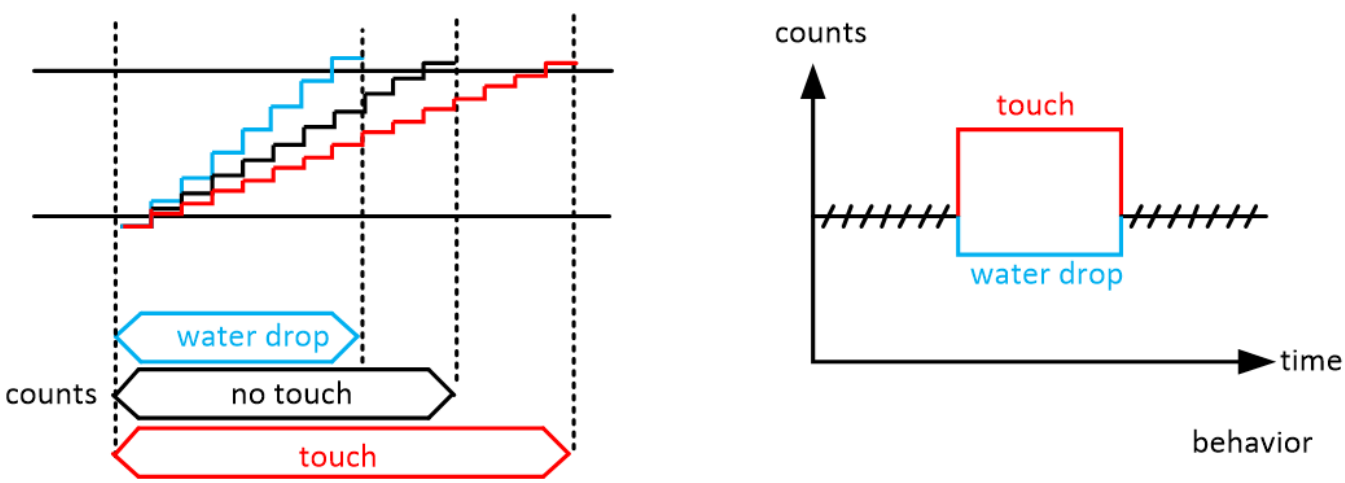


Figure 43-10. Mutual-cap mode count values of touch, no touch and water drop

43.5.6 Enable TSI module

The TSI module can be fully functional in run, wait and low power modes. The TSI_GENCS[TSIEN] bit must be set to enable the TSI module in run and wait mode. When TSI_GENCS[STPE] bit is set, it allows the TSI module to work in low power mode.

43.5.7 Software and hardware trigger

The TSI module allows a software or hardware trigger to start a scan. When a software trigger is applied (i.e. TSI_GENCS[STM] bit cleared), the TSI_DATA[SWTS] bit must be written "1" to start the scan electrode channel that is identified by TSI_CONFIG. When a hardware trigger is applied (i.e. TSI_GENCS[STM] bit set), the TSI will not start scanning until the hardware trigger arrives. The hardware trigger is different depending on the MCU configuration. Generally, it could be an event that RTC overflows. See chip configuration section for details.

43.5.8 Scan times

The TSI provides multi-scan function. The number of scans is indicated by TSI_SINC[DECIMATION] that allow the scan number from 1 to 32. When TSI_SINC[DECIMATION] is set to 0 (only once), the single scan is engaged. The 16-bit counter accumulates all scan results until the scan times reaches TSI_SINC[DECIMATION], and users can read TSI_DATA[TSICNT] to get this accumulation. When DMA transfer is enabled, the counter values can also be read out by DMA engine.

43.5.9 Clock setting

Both of self-cap front end and mutual-cap front end are driven by switching clock with frequency Fsw. It comes from SSC clock with flatten emission energy. In addition, the frequency of switching clock can be configured by TSI_SSC0, TSI_SSC1 and TSI_SSC2 (Refer to chapter Spread spectrum clocking for details). The clock source of SSC is from Main Clock block in TSI. The frequency of main clock can be configured by SETCLK<1:0>.

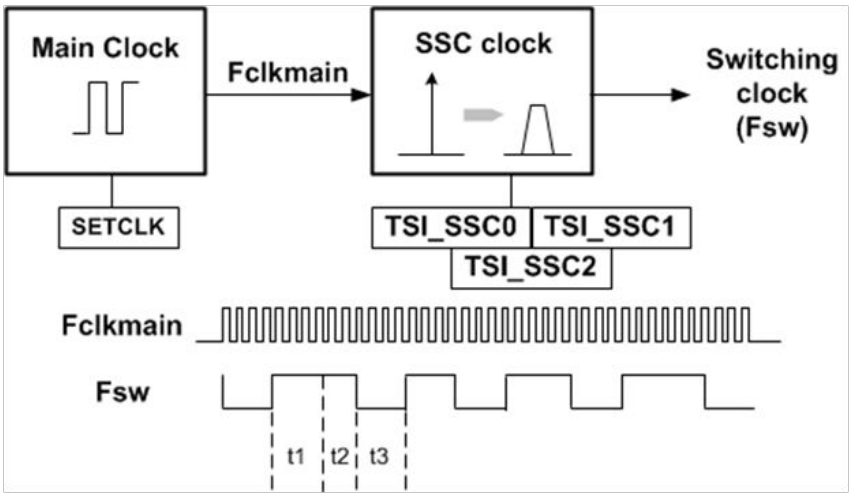


Figure 43-11. TSI clock

Example

- To use no SSC switching clock with frequency of 1MHz.
  - Set SETCLK<1:0> to '01' to get Fclkmain = 16.65MHz.
  - Set SSC_MODE<1:0> to '10' to disable SSC function.
  - Set SSC_PRESCALE_NUM<7:0> to '0000-0111' to get division 16. When SSC mode is disabled, the frequency formula is Fclkmain/[(SSC_PRESCALE_NUM +1) × 2].
  - Keep other registers in TSI_SSC0, TSI_SSC1 and TSI_SSC2 as default value.
  - Then, Fsw = 16.65MHz/16 = 1.04MHz. Fsw is square wave pulse.
- To use PRBS mode SSC switching clock with central frequency of 1MHz.
  - Set SETCLK<1:0> to '01' to get Fclkmain = 16.65MHz. Then the period of mainclock is Tclkmain.
  - Set SSC_MODE<1:0> to '00' to enable PRBS SSC mode.
  - Set BASE_NOCHARGE_NUM<3:0> to '0100' to set t1 = 5*Tclkmain*(SSC_PRESCALE_NUM + 1).
  - Set CHARGE_NUM<3:0> to '0110' to set t3 = 7*Tclkmain*(SSC_PRESCALE_NUM + 1).
  - Set PRBS_OUTSEL<3:0> to '0110' to set t2 range from 1* Tclkmain to 6* Tclkmain. The average t2 is 3.5* Tclkmain*(SSC_PRESCALE_NUM + 1).
  - Keep other registers in TSI_SSC0, TSI_SSC1 and TSI_SSC2 as default value.
  - Then, Fsw = 16.65MHz/[(5+3.5+7)*(0 + 1)] = 1.074MHz. Fsw is spectrum spread pulse.

43.5.10 Reference voltage

Reference voltage is used to setup ramp up threshold. It decides TSICNT and SCANTIME. The TSI module offers dual reference voltages for both comparators. The internal reference voltage can work in low power modes even when the MCU regulator is partially powered down, which is ideally for low-power touch detection.

The reference voltages are configurable upon the setting of TSI_GENCS[DVOLT]. The following table shows the all the delta voltage configurations.

Table 43-5. Delta voltage configuration

DVOLT	V_p (V)	V_m (V)	ΔV (V)
00	0.3	1.3	1.0
01	0.3	1.6	1.3
10	0.3	1.9	1.6
11	0.3	2.3	2.0

43.5.11 End of scan

As a scan starts, TSI_GENCS[SCNIP] bit is set to indicate scan is in progress. When the scan completes, the TSI_GENCS[EOSF] bit is set. Before clearing the TSI_GENCS[EOSF] bit, the value in TSI_DATA[TSICNT] must be read. If TSI_GENCS[TSIIEN] and TSI_GENCS[ESOR] are set, and TSI_DATA[DMAEN] is not set, an interrupt is submitted to CPU for post-processing immediately. The interrupt is also optional to wake MCU to execute ISR if it is in low power mode. When DMA function is enabled by setting TSI_GENCS[TSIIEN] and TSI_GENCS[ESOR], as soon as scan completes, a DMA transfer request is asserted to DMA controller for data movement, generally, DMA engine will fetch TSI conversion result from TSI_DATA register,store it to other memory space and then refresh the TSI scan channel index(TSI_DATA[TSICH]) for next loop. When DMA transfer is done, TSI_GENCS[EOSF] is cleared automatically.

43.5.12 Out-of-range interrupt

If enabled, TSI will scan the electrode specified by TSI_DATA[TSICH] as soon as the trigger arrives. The TSI_GENCS[OUTRGF] flag generates a TSI interrupt request if the TSI_GENCS[TSIIE] bit is set and GENCS[ESOR] bit is cleared. With this configuration, after the end-of-electrode scan, the electrode capacitance will be converted and stored to the result register TSI_DATA[TSICNT], the out-of-range interrupt is only requested if there is a considerable capacitance change defined by the TSI_TSHD. For instance, if in

low power mode the electrode capacitance does not vary, the out-of-range interrupt does not interrupt the CPU. This interrupt will not happen in noise detection mode. It is worthy to note that when the counter value reaches 0xFFFF is treated as an extreme case the out-of-range will not happen. Also in noise detection mode, the out-of-range will not assert either.

43.5.13 Wake up MCU from low power modes

In low power modes, once enabled by TSI_GENCS[STPE] and TSI_GENCS[TSIIE], TSI can bring MCU out of its low power modes (STOP, VLPS, etc) by either end of scan or out of range interrupt, that is, if TSI_GENCS[ESOR] is set, end of scan interrupt is selected and otherwise, out of range is selected.

43.5.14 DMA function support

Transmit by DMA is supported only when TSI_DATA[DMAEN] is set. A DMA transfer request is asserted when all the flags based on TSI_GENCS[ESOR] settings and TSI_GENCS[TSIIE] are set. Then the on-chip DMA controller detects this request and transfers data between memory space and TSI register space. After the data tranfer, DMA DONE is asserted to clear TSI_GENCS[EOSF] automatically. This function is normally used by DMA controller to get the conversion result from TSI_DATA[TSICNT] upon a end-of-scan event and then refresh the channel index(TSI_DATA[TSICH]) for next trigger.

43.5.15 Spread spectrum clocking

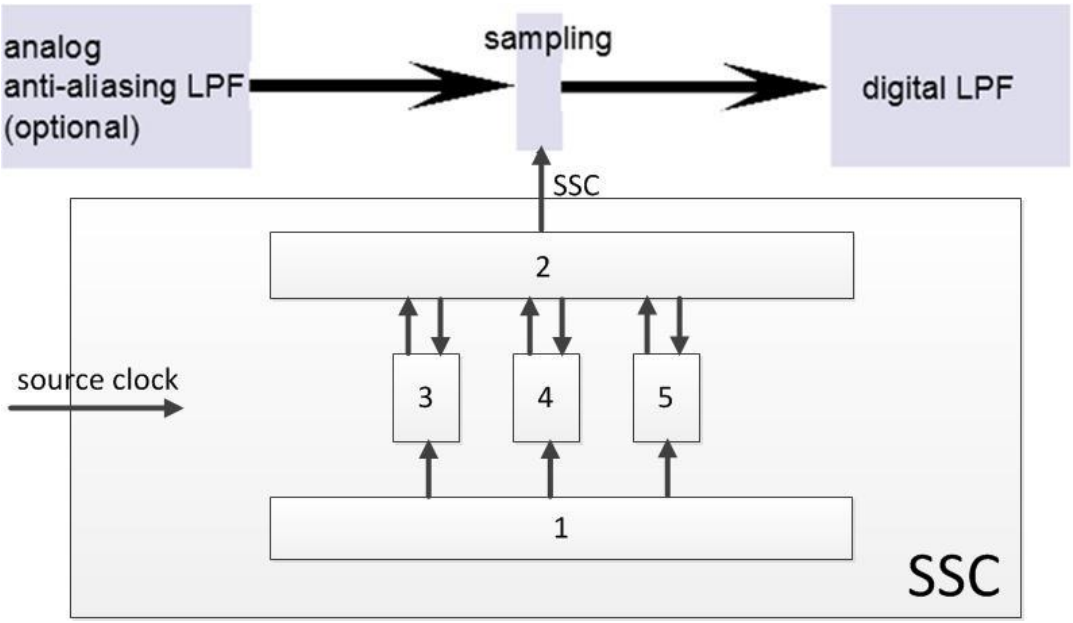


Figure 43-12. Spread spectrum clocking

In Capacitance touch sense systems, the baseband signal is narrow band and it is nearing the DC, while the noise is a wideband noise. For lower cost, the cut-off frequency of the anti-aliasing low pass filter at analog front end is not low enough comparing with the sampling frequency, so when sampling, the noises that frequency is nearing sampling frequency will be overlapped to baseband. For solving this problem in Capacitance touch sense systems, a low cost SSC can be involved. The SSC's center frequency and frequency span range should be flexible enough for handling various frequency noises.

With this SSC, the noises that frequency is nearing sampling frequency can be spanned to a wider frequency range instead of a single peak frequency noise, and only parts of the noise is overlapped into baseband (because baseband is a narrow band), so SNR can be promoted.

This SSC is composed of 5 components, they work together and generate the configurable center frequency and configurable span frequency range, they are:

1. Configurable registers, generating all configurable settings for component 3/4/5 using TSI_SSC0/ TSI_SSC1/ TSI_SSC2 registers;

2. State machine engine, controlling and monitoring the component 3/4/5;

3. A configurable counter for generating "1", the max value of the counter is controlled by TSI_SSC0[BASE_NOCHARGE_NUM];

4. A configurable up-down counter or a PRBS method for generating "1"; If using up-down counter, the counter value is limited by TSI_SSC2[MOVE_NOCHARGE_MIN] and TSI_SSC2[MOVE_NOCHARGE_MAX]; If using PRBS method, the length of the "1" is controlled by the output of the PRBS method;

5. A configurable up-down counter for “0”, the max value of the counter is controlled by TSI_SSC0[CHARGE_NUM].

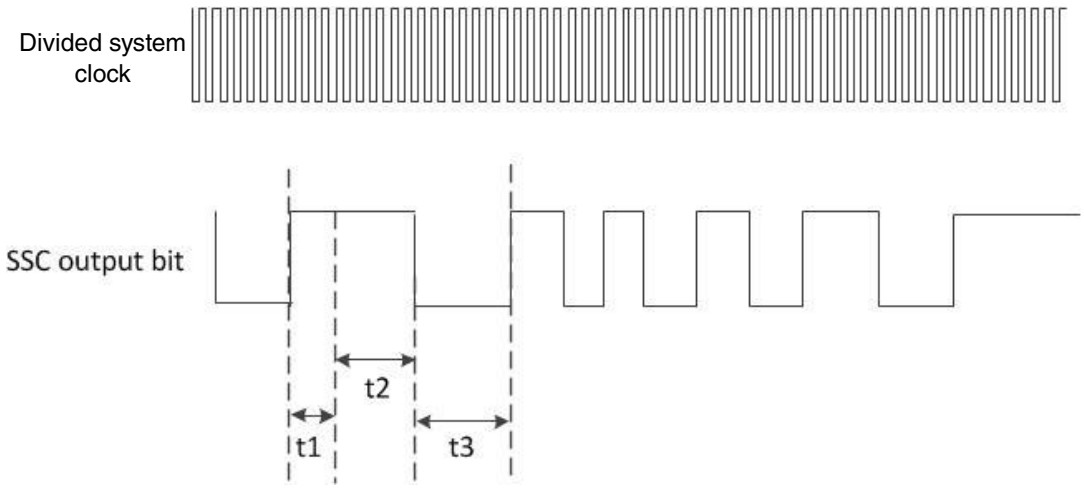


Figure 43-13. Spread spectrum clocking timing

The upper figure is presenting the timing of input system clock and the SSC output bit.

t1: controlled by component 3 and TSI_SSC0[BASE_NOCHARGE_NUM];

t2: controlled by component 4, and TSI_SSC2[MOVE_NOCHARGE_MIN] / TSI_SSC2[MOVE_NOCHARGE_MAX] if using up-down counter, or by PRBS output if using PRBS method;

t3: controlled by component 5 and TSI_SSC0[CHARGE_NUM];

So the average frequency of the SSC output bit will be:

$$frequency_{SSC} = \frac{frequency_{system}}{(t_1+t_2+t_3)*(\text{SSC_PRESCALE_NUM}+1)}$$

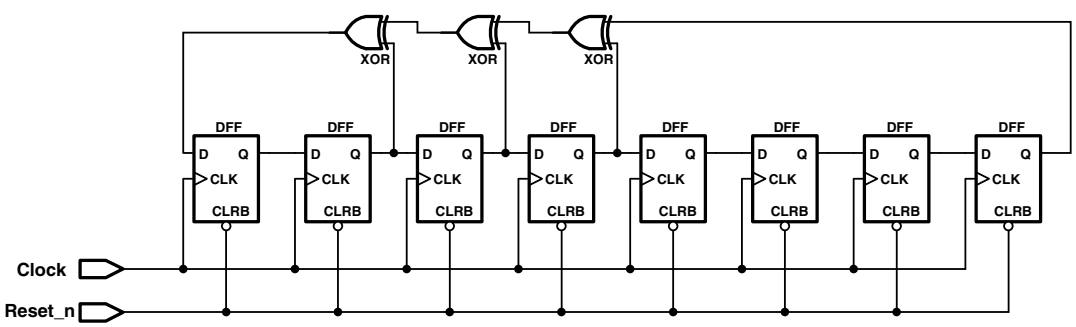


Figure 43-14. LFSR (Linear Feedback Shift Registers)

For using PRBS method generating the SSC output bit, LFSR circuit is involved for this implementation.

For the example in the figure, its eigenpolynomial is:
$f(x) = 1 + x^2 + x^3 + x^4 + x^8$

43.6 Usage Guide

43.6.1 TSI Interrupts

The TSI has multiple sources of interrupt requests. However, these sources are OR'd together to generate a single interrupt request. When a TSI interrupt occurs, read the TSI status register to determine the exact interrupt source.

43.6.2 How to use the TSI module

There are several steps as below.

- Initiate the TSI module by configuring registers
- Start TSI scan by hardware or software trigger
- Read the TSI result once TSI scan done (end-of-scan)
- Process the TSI result raw data to determine whether a touch event occurs

43.6.2.1 Initialization sequence

The following figure shows the flowchart of TSI initialization.

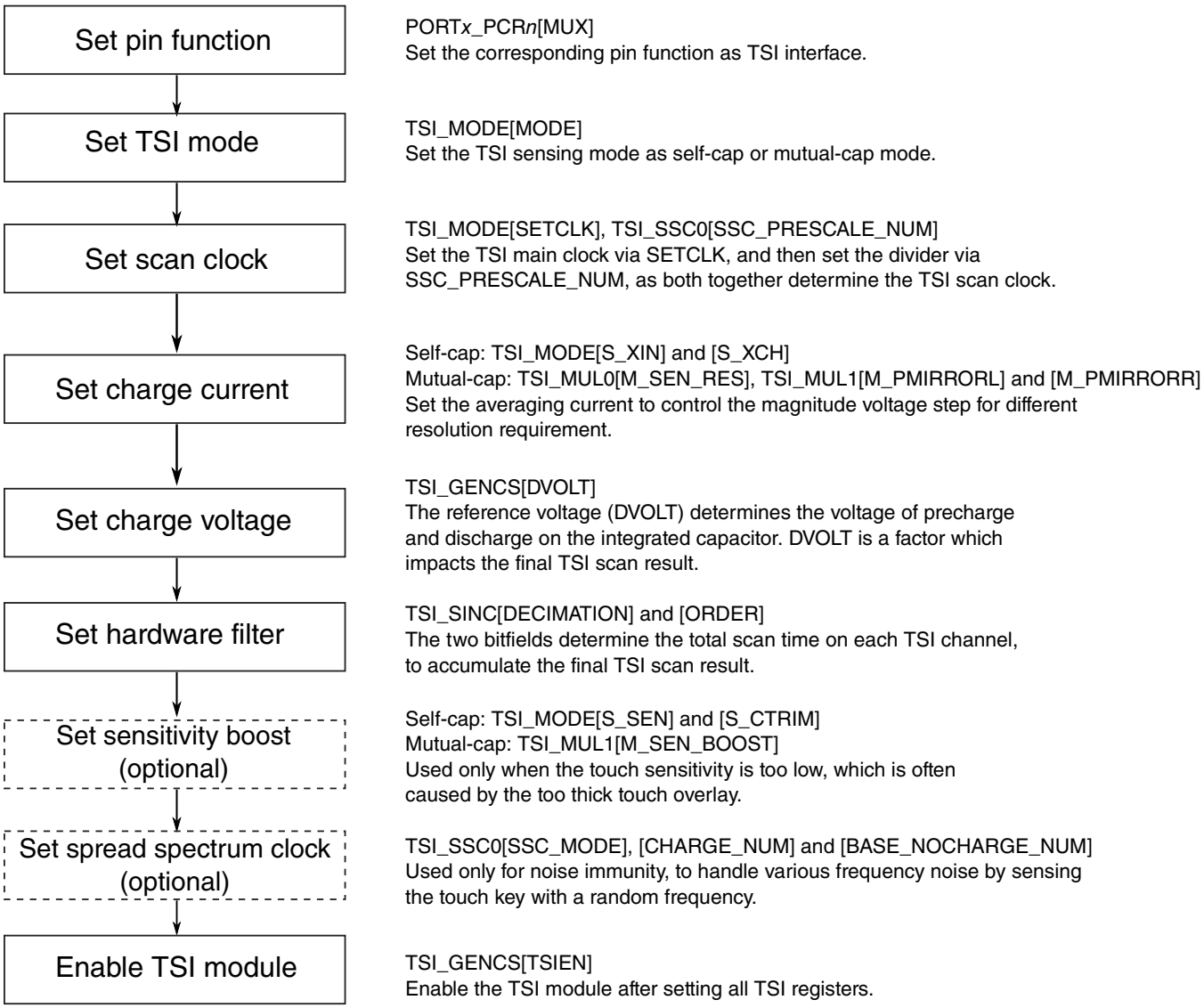


Figure 43-15. TSI initialization sequence

43.6.2.2 TSI scan example

In the self-cap mode, one touch key is connected to one TSI channel, which is measured at each TSI scan round. The following figure shows the software flowchart of TSI scan example, in self-cap mode.

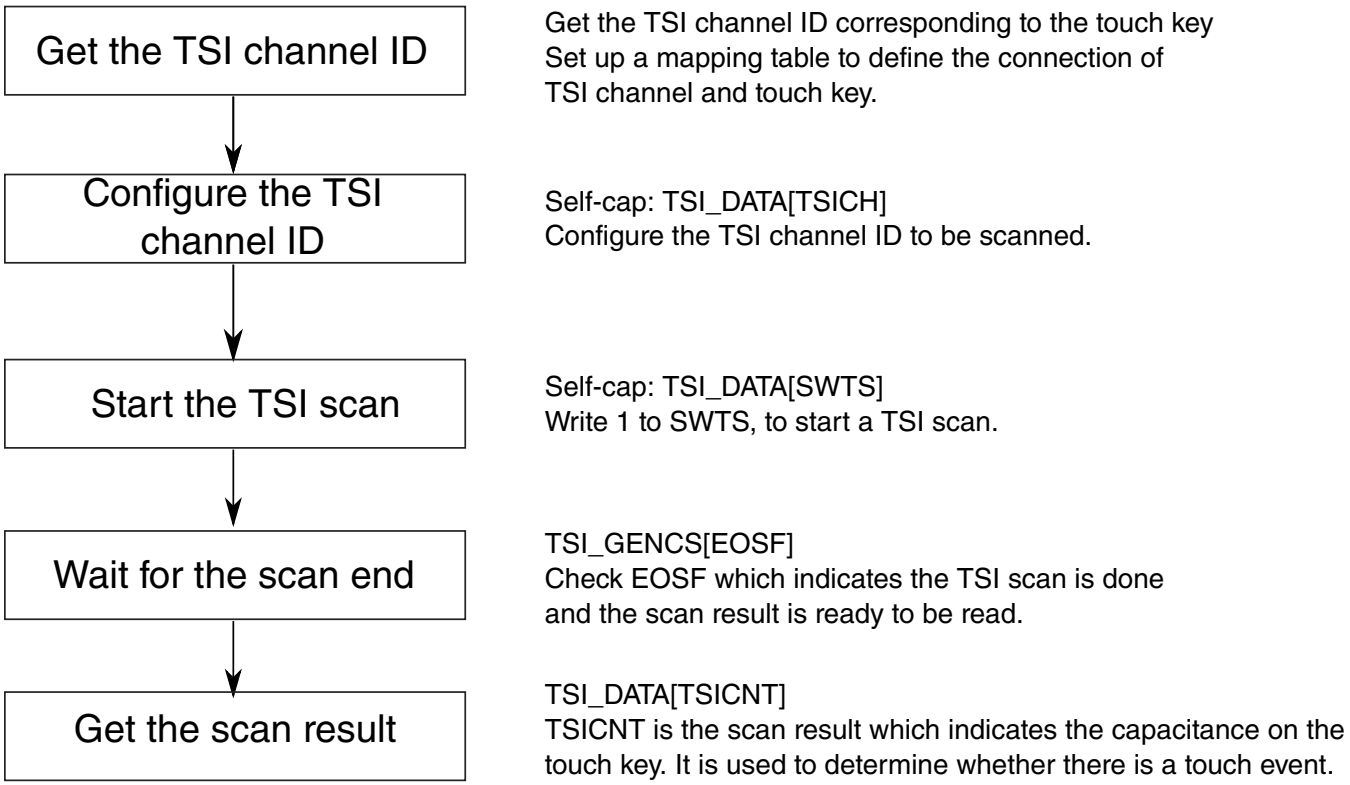


Figure 43-16. TSI scan example for self-cap mode

In mutual-cap mode, one touch key is connected to two TSI channels, i.e. the transmitter and the receiver channel respectively. The figure below shows the software flowchart of TSI scan example, in mutual-cap mode.

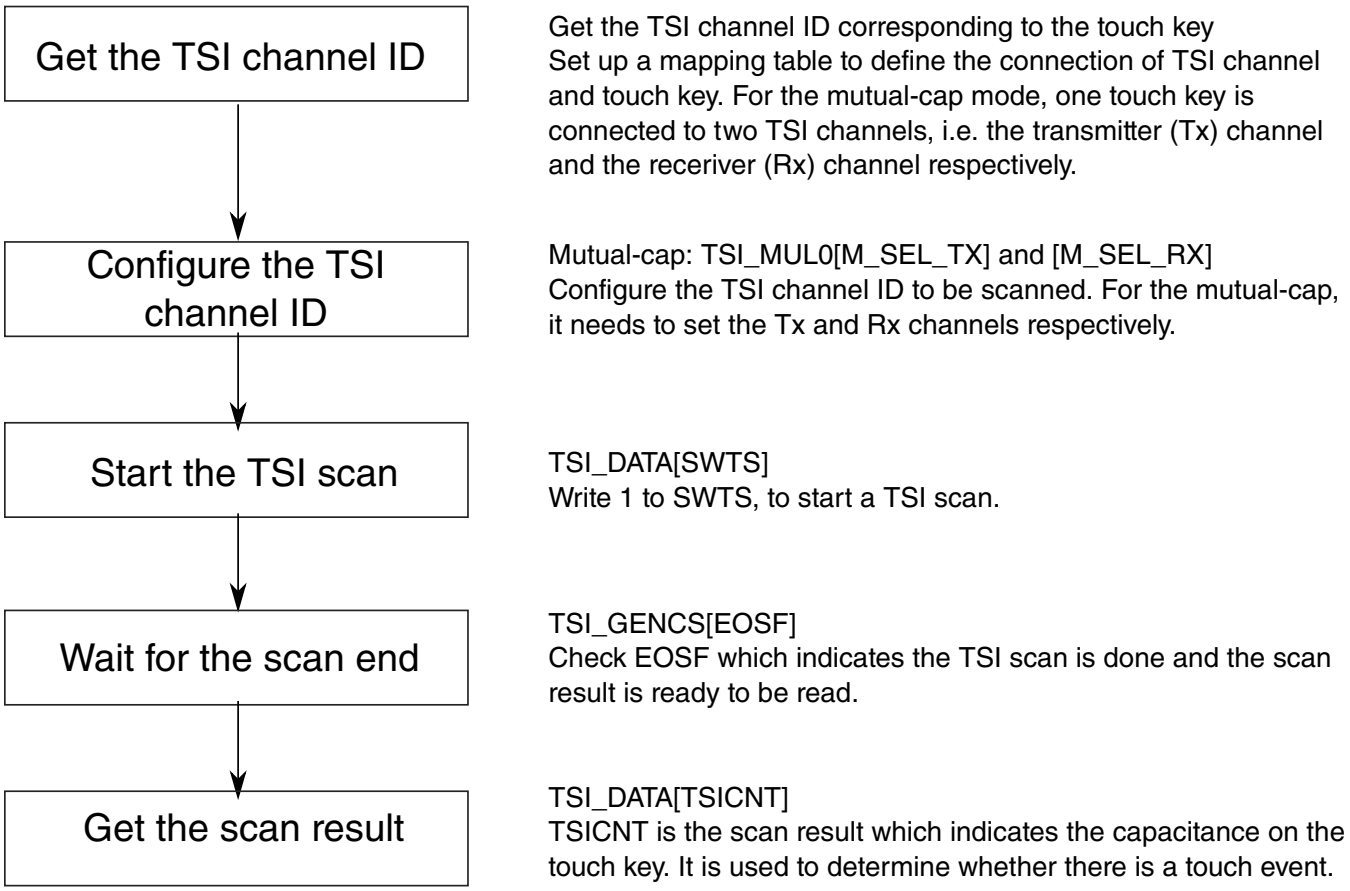


Figure 43-17. TSI scan example for mutual-cap mode

43.6.2.3 Process TSI scan result to detect a touch event

When the touch key is touched by finger, the TSI scan result (TSI_DATA[TSICNT]) changes a lot. By comparing the changed value, the touch event can be determined. The following figure shows an example of detecting a touch event by TSI scan result.

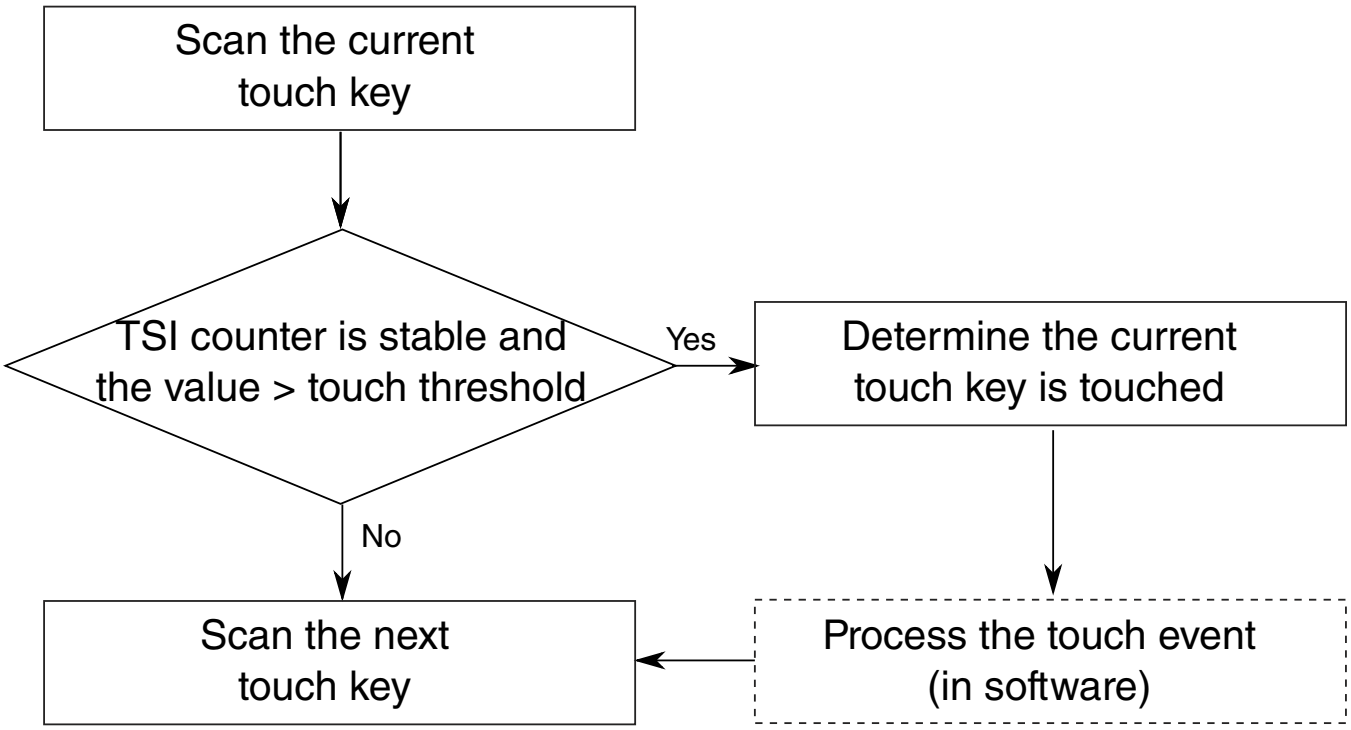


Figure 43-18. TSI scan result process

NOTE

For touch electrode hardware design guideline, see AN3863: Designing Touch Sensing Electrodes.

Appendix A
Revision History

The following table provides a revision history for this document.

Table A-1. Revision History

Rev. No.	Date	Substantial Changes
2	01/2019	Initial public release.
3	06/2020	40-QFN new package is added. Related sections (Pinout, Package, etc.) are updated.

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