

ARM[®] Cortex[®]-M
32-bit Microcontroller

NuMicro[™] Family
NUC230/240 Series
Technical Reference Manual

The information described in this document is the exclusive intellectual property of Nuvoton Technology Corporation and shall not be reproduced without permission from Nuvoton.

Nuvoton is providing this document only for reference purposes of NuMicro microcontroller based system design. Nuvoton assumes no responsibility for errors or omissions.

All data and specifications are subject to change without notice.

For additional information or questions, please contact: Nuvoton Technology Corporation.

www.nuvoton.com

TABLE OF CONTENTS

LIST OF FIGURES	8
LIST OF TABLES	13
1 GENERAL DESCRIPTION	14
2 FEATURES	15
2.1 NuMicro™ NUC230 Features – Automotive Line	15
2.2 NuMicro™ NUC240 Features – Connectivity Line	19
3 ABBREVIATIONS	23
4 PARTS INFORMATION LIST AND PIN CONFIGURATION	25
4.1 NuMicro™ NUC230/240xxxAE Selection Guide	25
4.1.1 NuMicro™ NUC230 Automotive Line Selection Guide	25
4.1.2 NuMicro™ NUC240 Connectivity Line Selection Guide	25
4.2 Pin Configuration	27
4.2.1 NuMicro™ NUC230 Pin Diagram	27
4.2.2 NuMicro™ NUC240 Pin Diagram	30
4.3 Pin Description	33
4.3.1 NuMicro™ NUC230 Pin Description	33
4.3.2 NuMicro™ NUC240 Pin Description	41
5 BLOCK DIAGRAM	49
5.1 NuMicro™ NUC230 Block Diagram	49
5.2 NuMicro™ NUC240 Block Diagram	50
6 FUNCTIONAL DESCRIPTION	51
6.1 ARM® Cortex™-M0 Core	51
6.2 System Manager	53
6.2.1 Overview	53
6.2.2 System Reset	53
6.2.3 System Power Distribution	54
6.2.4 System Memory Map	56
6.2.5 Register Map	58
6.2.6 Register Description	59
6.2.7 Register Write Protection Register (REGWRPROT)	103
6.2.8 System Timer (SysTick)	106
6.2.9 Nested Vectored Interrupt Controller (NVIC)	111
6.2.10 System Control	137

6.3	Clock Controller.....	145
6.3.1	Overview	145
6.3.2	System Clock and SysTick Clock	148
6.3.3	Power-down Mode Clock.....	149
6.3.4	Frequency Divider Output	150
6.3.5	Register Map	151
6.3.6	Register Description.....	152
6.4	Flash Memory Controller (FMC)	176
6.4.1	Overview	176
6.4.2	Features.....	176
6.4.3	Block Diagram.....	177
6.4.4	Functional Description	178
6.4.5	Register Map	188
6.4.6	Register Description.....	189
6.5	External Bus Interface (EBI)	197
6.5.1	Overview	198
6.5.2	Features.....	198
6.5.3	Block Diagram.....	199
6.5.4	Functional Description	200
6.5.5	Register Map	206
6.5.6	Register Description.....	206
6.6	General Purpose I/O (GPIO)	211
6.6.1	Overview	211
6.6.2	Features.....	211
6.6.3	Basic Configuration.....	211
6.6.4	Functional Description	212
6.6.5	Register Map	215
6.6.6	Register Description.....	218
6.7	PDMA Controller (PDMA)	230
6.7.1	Overview	230
6.7.2	Features.....	231
6.7.3	Block Diagram.....	232
6.7.4	Basic Configuration.....	234
6.7.5	Functional Description	234
6.7.6	Register Map	236
6.7.7	Register Description.....	238

6.8	Timer Controller (TIMER)	270
6.8.1	Overview	270
6.8.2	Features	270
6.8.3	Block Diagram	271
6.8.4	Basic Configuration	272
6.8.5	Functional Description	272
6.8.6	Register Map	275
6.8.7	Register Description	277
6.9	PWM Generator and Capture Timer (PWM)	286
6.9.1	Overview	286
6.9.2	Features	287
6.9.3	Block Diagram	288
6.9.4	Basic Configuration	292
6.9.5	Functional Description	293
6.9.6	Register Map	304
6.9.7	Register Description	306
6.10	Watchdog Timer (WDT)	333
6.10.1	Overview	333
6.10.2	Features	333
6.10.3	Block Diagram	334
6.10.4	Basic Configuration	335
6.10.5	Functional Description	335
6.10.6	Register Map	337
6.10.7	Register Description	338
6.11	Window Watchdog Timer (WWDT)	341
6.11.1	Overview	341
6.11.2	Features	341
6.11.3	Block Diagram	341
6.11.4	Basic Configuration	342
6.11.5	Functional Description	342
6.11.6	Register Map	344
6.11.7	Register Description	345
6.12	Real Time Clock (RTC)	350
6.12.1	Overview	350
6.12.2	Features	350
6.12.3	Block Diagram	351

6.12.4 Basic Configuration	352
6.12.5 Functional Description	352
6.12.6 Register Map	356
6.12.7 Register Description	358
6.13 UART Interface Controller (UART)	374
6.13.1 Overview	374
6.13.2 Features	374
6.13.3 Block Diagram	375
6.13.4 Basic Configuration	376
6.13.5 Functional Description	377
6.13.6 Register Map	400
6.13.7 Register Description	402
6.14 Smart Card Host Interface (SC)	429
6.14.1 Overview	429
6.14.2 Features	429
6.14.3 Block Diagram	430
6.14.4 Basic Configuration	431
6.14.5 Functional Description	431
6.14.6 Register Map	441
6.14.7 Register Description	443
6.15 PS/2 Device Controller (PS2D)	471
6.15.1 Overview	471
6.15.2 Features	471
6.15.3 Block Diagram	472
6.15.4 Basic Configuration	473
6.15.5 Functional Description	473
6.15.6 Register Map	478
6.15.7 Register Description	479
6.16 I ² C Serial Interface Controller (I ² C)	486
6.16.1 Overview	486
6.16.2 Features	486
6.16.3 Basic Configuration	486
6.16.4 Block Diagram	487
6.16.5 Functional Description	487
6.16.6 Example for Random Read on EEPROM	500
6.16.7 Register Map	503

6.16.8 Register Description	504
6.17 Serial Peripheral Interface (SPI)	514
6.17.1 Overview	514
6.17.2 Features	514
6.17.3 Block Diagram	515
6.17.4 Basic Configuration	515
6.17.5 Functional Description	517
6.17.6 Timing Diagram	526
6.17.7 Programming Examples	529
6.17.8 Register Map	531
6.17.9 Register Description	532
6.18 I ² S Controller (I ² S)	548
6.18.1 Overview	548
6.18.2 Features	548
6.18.3 Block Diagram	549
6.18.4 Basic Configuration	549
6.18.5 Functional Description	550
6.18.6 Register Map	555
6.18.7 Register Description	556
6.19 USB Device Controller (USBD)	567
6.19.1 Overview	567
6.19.2 Features	567
6.19.3 Block Diagram	568
6.19.4 Basic Configuration	568
6.19.5 Functional Description	569
6.19.6 Register Map	573
6.19.7 Register Description	575
6.20 Controller Area Network (CAN)	591
6.20.1 Overview	591
6.20.2 Features	591
6.20.3 Block Diagram	591
6.20.4 Basic Configuration	592
6.20.5 Functional Description	592
6.20.6 Test Mode	594
6.20.7 CAN Communications	596
6.20.8 CAN Interface Reset State	614

6.20.9 Register Description	618
6.20.10 Register Map	618
6.21 Analog-to-Digital Converter (ADC)	655
6.21.1 Overview	655
6.21.2 Features	655
6.21.3 Block Diagram	656
6.21.4 Basic Configuration	656
6.21.5 Functional Description	657
6.21.6 Register Map	665
6.21.7 Register Description	666
6.22 Analog Comparator (ACMP)	676
6.22.1 Overview	676
6.22.2 Features	676
6.22.3 Block Diagram	676
6.22.4 Basic Configuration	677
6.22.5 Functional Description	677
6.22.6 Register Map	678
6.22.7 Register Description	679
7 ELECTRICAL CHARACTERISTICS	681
8 PACKAGE DIMENSIONS	682
8.1 100-pin LQFP (14x14x1.4 mm footprint 2.0 mm)	682
8.2 64-pin LQFP (7x7x1.4 mm footprint 2.0 mm)	683
8.3 48-pin LQFP (7x7x1.4 mm footprint 2.0 mm)	684
9 REVISION HISTORY	685

LIST OF FIGURES

Figure 4-1 NuMicro™ NUC230/240 Series Selection Code	26
Figure 4-2 NuMicro™ NUC230VxxAE LQFP 100-pin Diagram.....	27
Figure 4-3 NuMicro™ NUC230SxxAE LQFP 64-pin Diagram.....	28
Figure 4-4 NuMicro™ NUC230LxxAE LQFP 48-pin Diagram	29
Figure 4-5 NuMicro™ NUC240VxxAE LQFP 100-pin Diagram.....	30
Figure 4-6 NuMicro™ NUC240SxxAE LQFP 64-pin Diagram.....	31
Figure 4-7 NuMicro™ NUC240LxxAE LQFP 48-pin Diagram	32
Figure 5-1 NuMicro™ NUC230 Block Diagram	49
Figure 5-2 NuMicro™ NUC240 Block Diagram	50
Figure 6-1 Functional Controller Diagram	51
Figure 6-2 NuMicro™ NUC230 Power Distribution Diagram.....	54
Figure 6-3 NuMicro™ NUC240 Power Distribution Diagram.....	55
Figure 6-4 Clock Generator Block Diagram	146
Figure 6-5 Clock Generator Global View Diagram.....	147
Figure 6-6 System Clock Block Diagram	148
Figure 6-7 SysTick Clock Control Block Diagram	148
Figure 6-8 Clock Source of Frequency Divider	150
Figure 6-9 Frequency Divider Block Diagram	150
Figure 6-33 Flash Memory Control Block Diagram.....	177
Figure 6-34 Flash Memory Organization	179
Figure 6-35 Program Executing Range for Booting from APROM and LDROM	183
Figure 6-36 Executable Range of Code with IAP Function Enabled	184
Figure 6-37 Example Flow of Boot Selection by BS Bit.....	185
Figure 6-38 ISP Flow Example	186
Figure 6-42 EBI Block Diagram.....	199
Figure 6-43 Connection of 16-bit EBI Data Width with 16-bit Device	200
Figure 6-44 Connection of 8-bit EBI Data Width with 8-bit Device	201
Figure 6-45 Timing Control Waveform for 16-bit Data Width.....	203
Figure 6-46 Timing Control Waveform for 8-bit Data Width.....	204
Figure 6-47 Timing Control Waveform for Insert Idle Cycle.....	205
Figure 6-39 Push-Pull Output.....	212
Figure 6-40 Open-Drain Output	213
Figure 6-41 Quasi-bidirectional I/O Mode	213
Figure 6-68 DMA Controller Block Diagram.....	232
Figure 6-69 CRC Generator Block Diagram	233
Figure 6-125 Timer Controller Block Diagram	271

Figure 6-126 Clock Source of Timer Controller	271
Figure 6-127 Continuous Counting Mode	273
Figure 6-76 PWM Generator 0 Clock Source Control.....	288
Figure 6-77 PWM Generator 0 Architecture Diagram.....	288
Figure 6-78 PWM Generator 2 Clock Source Control.....	289
Figure 6-79 PWM Generator 2 Architecture Diagram.....	289
Figure 6-80 PWM Generator 4 Clock Source Control.....	290
Figure 6-81 PWM Generator 4 Architecture Diagram.....	290
Figure 6-82 PWM Generator 6 Clock Source Control.....	291
Figure 6-83 PWM Generator 6 Architecture Diagram.....	291
Figure 6-84 Legend of Internal Comparator Output of PWM-Timer	293
Figure 6-85 PWM-Timer Operation Timing.....	294
Figure 6-86 PWM Edge-aligned Interrupt Generate Timing Waveform.....	294
Figure 6-87 Center-aligned Type Output Waveform.....	295
Figure 6-88 PWM Center-aligned Interrupt Generate Timing Waveform	296
Figure 6-89 PWM Double Buffering Illustration.....	297
Figure 6-90 PWM Controller Output Duty Ratio.....	298
Figure 6-91 Paired-PWM Output with Dead-zone Generation Operation	298
Figure 6-92 PWM trigger ADC to conversion in Center-aligned type Timing Waveform.....	299
Figure 6-93 Capture Operation Timing	300
Figure 6-94 PWM Group A PWM-Timer Interrupt Architecture Diagram.....	301
Figure 6-95 PWM Group B PWM-Timer Interrupt Architecture Diagram.....	301
Figure 6-152 Watchdog Timer Clock Control.....	334
Figure 6-153 Watchdog Timer Block Diagram.....	334
Figure 6-154 Watchdog Timer Time-out Interval and Reset Period Timing	336
Figure 6-155 Window Watchdog Timer Clock Control.....	341
Figure 6-156 Window Watchdog Timer Block Diagram.....	341
Figure 6-157 Window Watchdog Timer Reset and Reload Behavior	343
Figure 6-96 RTC Block Diagram	351
Figure 6-128 UART Clock Control Diagram.....	375
Figure 6-129 UART Block Diagram.....	375
Figure 6-130 Transmit Delay Time Operation.....	379
Figure 6-131 Auto Flow Control Block Diagram.....	384
Figure 6-132 UART CTS Auto Flow Control Enabled.....	384
Figure 6-133 UART RTS Auto Flow Control Enabled.....	385
Figure 6-134 UART RTS Flow with Software Control.....	385
Figure 6-135 IrDA Control Block Diagram	386

Figure 6-136 IrDA TX/RX Timing Diagram	387
Figure 6-137 Structure of LIN Frame	387
Figure 6-138 Structure of LIN Byte	388
Figure 6-139 Break Detection in LIN Mode	390
Figure 6-140 LIN Frame ID and Parity Format	391
Figure 6-141 LIN Sync Field Measurement	393
Figure 6-142 UA_BAUD Update Sequence in Automatic Resynchronization Mode when LINS_DUM_EN (UA_LIN_CTL[3]) = 1	394
Figure 6-143 UA_BAUD Update Sequence in Automatic Resynchronization Mode when LINS_DUM_EN (UA_LIN_CTL[3]) = 0	394
Figure 6-144 RS-485 RTS Driving Level in Auto Direction Mode	397
Figure 6-145 RS-485 RTS Driving Level with Software Control	398
Figure 6-146 Structure of RS-485 Frame	399
Figure 6-97 SC Clock Control Diagram (8-bit Prescale Counter in Clock Controller)	430
Figure 6-98 SC Controller Block Diagram	431
Figure 6-99 SC Data Character	432
Figure 6-100 SC Activation Sequence	433
Figure 6-101 SC Warm Reset Sequence	434
Figure 6-102 SC Deactivation Sequence	435
Figure 6-103 Initial Character TS	435
Figure 6-104 SC Error Signal	436
Figure 6-105 SC Transmitter Retry Number and Retry Over Flag	436
Figure 6-106 SC Receiver Retry Number and Retry Over Flag	437
Figure 6-107 Transmit Direction Block Guard Time Operation	439
Figure 6-108 Receive Direction Block Guard Time Operation	439
Figure 6-109 Extended Guard Time Operation	439
Figure 6-70 PS/2 Device Block Diagram	472
Figure 6-71 Data Format of Device-to-Host	474
Figure 6-72 Data Format of Host-to-Device	474
Figure 6-73 PS/2 Bit Data Format	475
Figure 6-74 PS/2 Bus Timing	475
Figure 6-75 PS/2 Data Format	477
Figure 6-42 I ² C Controller Block Diagram	487
Figure 6-43 I ² C Bus Timing	487
Figure 6-44 I ² C Protocol	488
Figure 6-45 START and STOP Conditions	489
Figure 6-46 Bit Transfer on the I ² C Bus	489
Figure 6-47 Acknowledge on the I ² C Bus	490

Figure 6-48 Master Transmits Data to Slave	490
Figure 6-49 Master Reads Data from Slave	490
Figure 6-50 Control I ² C Bus according to Current I ² C Status	491
Figure 6-51 Master Transmitter Mode Control Flow	492
Figure 6-52 Master Receiver Mode Control Flow	493
Figure 6-53 Save Mode Control Flow	494
Figure 6-54 GC Mode	496
Figure 6-55 Arbitration Lost.....	496
Figure 6-56 I ² C Data Shifting Direction	498
Figure 6-57 I ² C Time-out Count Block Diagram.....	500
Figure 6-58 EEPROM Random Read	501
Figure 6-59 Protocol of EEPROM Random Read.....	502
Figure 6-110 SPI Block Diagram.....	515
Figure 6-111 SPI Master Mode Application Block Diagram.....	517
Figure 6-112 SPI Slave Mode Application Block Diagram.....	518
Figure 6-113 32-Bit in One Transaction	518
Figure 6-114 Variable Bus Clock Frequency	520
Figure 6-115 Byte Reorder Function.....	521
Figure 6-116 Timing Waveform for Byte Suspend	521
Figure 6-117 2-bit Transfer Mode (Slave Mode)	522
Figure 6-118 Bit Sequence of Dual Output Mode	523
Figure 6-119 Bit Sequence of Dual Input Mode	523
Figure 6-120 FIFO Mode Block Diagram	524
Figure 6-121 SPI Timing in Master Mode	527
Figure 6-122 SPI Timing in Master Mode (Alternate Phase of SPI Bus Clock)	527
Figure 6-123 SPI Timing in Slave Mode	528
Figure 6-124 SPI Timing in Slave Mode (Alternate Phase of SPI Bus Clock)	528
Figure 6-60 I ² S Controller Block Diagram	549
Figure 6-61 I ² S Clock Control Diagram	550
Figure 6-62 I ² S Data Format Timing Diagram.....	551
Figure 6-63 MSB Justified Data Format Timing Diagram	551
Figure 6-64 I ² S Interrupts	552
Figure 6-65 FIFO Contents for Various I ² S Modes	553
Figure 6-66 Master Mode Interface	554
Figure 6-67 Slave Mode Interface	554
Figure 6-147 USB Device Block Diagram	568
Figure 6-148 Wake-up Interrupt Operation Flow	570

Figure 6-149 Endpoint SRAM Structure	571
Figure 6-150 Setup Transaction Followed by Data IN Transaction	572
Figure 6-151 Data Out Transfer	572
Figure 6-22 CAN Peripheral Block Diagram	592
Figure 6-23 CAN Core in Silent Mode	594
Figure 6-24 CAN Core in Loop Back Mode	595
Figure 6-25 CAN Core in Loop Back Mode Combined with Silent Mode	595
Figure 6-26 Data Transfer between IF ⁿ Registers and Message	598
Figure 6-27 Application Software Handling of a FIFO Buffer	603
Figure 6-28 Bit Timing	605
Figure 6-29 Propagation Time Segment.....	606
Figure 6-30 Synchronization on “late” and “early” Edges.....	608
Figure 6-31 Filtering of Short Dominant Spikes.....	609
Figure 6-32 Structure of the CAN Core’s CAN Protocol Controller	611
Figure 6-13 ADC Controller Block Diagram	656
Figure 6-14 ADC Clock Control.....	657
Figure 6-15 Single Mode Conversion Timing Diagram	658
Figure 6-16 Single-Cycle Scan on Enabled Channels Timing Diagram	659
Figure 6-17 Continuous Scan on Enabled Channels Timing Diagram	660
Figure 6-105 V _{BG} for Measuring AV _{DD} Application Block Diagram	661
Figure 6-18 A/D Conversion Result Monitor Logics Diagram	663
Figure 6-19 A/D Controller Interrupt.....	663
Figure 6-20 ADC Single-end Input Conversion Voltage and Conversion Result Mapping	667
Figure 6-21 ADC Differential Input Conversion Voltage and Conversion Result Mapping	667
Figure 6-10 Analog Comparator Block Diagram	676
Figure 6-11 Comparator Controller Interrupt Sources	677
Figure 6-12 Comparator Hysteresis Function	677

LIST OF TABLES

Table 1-1 NuMicro™ NUC230/240 Series Connectivity Support Table	14
Table 3-1 List of Abbreviations.....	24
Table 6-1 Address Space Assignments for On-Chip Controllers.....	57
Table 6-2 Exception Model	112
Table 6-3 System Interrupt Map.....	113
Table 6-4 Vector Table Format	114
Table 6-5 Chip Idle/Power-down Mode Control Table	155
Table 6-14 Memory Address Map.....	179
Table 6-15 ISP Command List.....	187
Table 6-29 Watchdog Timer Time-out Interval Period Selection	335
Table 6-30 Window Watchdog Timer Prescale Value Selection	342
Table 6-31 WINCMP Setting Limitation	343
Table 6-20 UART Interface Controller Pin	377
Table 6-21 UART Baud Rate Equation	377
Table 6-22 UART Controller Baud Rate Parameter Setting Table	378
Table 6-23 UART Controller Baud Rate Register (UA_BAUD) Setting Table	379
Table 6-24 UART Controller Interrupt Source and Flag List.....	381
Table 6-25 Controller Interrupt Source and Flag in DMA Mode List.....	382
Table 6-26 UART Line Control of Word and Stop Length Setting	383
Table 6-27 UART Line Control of Parity Bit Setting	383
Table 6-28 LIN Header Selection in Master Mode.....	388
Table 6-17 SC Host Controller Pin.....	431
Table 6-18 UART Pin	431
Table 6-19 Timer2/Timer1/Timer0 Operation Mode	439
Table 6-16 I ² C Status Code Description	499
Table 6-6 Initialization of a Transmit Object.....	600
Table 6-7 Initialization of a Receive Object	601
Table 6-8 CAN Bit Time Parameters.....	605
Table 6-9 CAN Register Map for Each Bit Function	617
Table 6-10 Error Codes.....	624
Table 6-11 Source of Interrupts	627
Table 6-12 IF1 and IF2 Message Interface Register	630
Table 6-13 Structure of a Message Object in the Message Memory.....	644

1 GENERAL DESCRIPTION

The NuMicro™ NUC230/240 series 32-bit microcontrollers are embedded with the ARM® Cortex™-M0 core with a cost equivalent to traditional 8-bit MCU for industrial control and applications requiring rich communication interfaces. The NuMicro™ NUC230/240 series includes NUC230 and NUC240 product lines.

The NuMicro™ NUC230 CAN Line is embedded with the Cortex™-M0 core running up to 72 MHz and features 32K/64K/128K bytes flash, 8K/16K bytes embedded SRAM, and 8 Kbytes loader ROM for the ISP. It is also equipped with plenty of peripheral devices, such as Timers, Watchdog Timer, Window Watchdog Timer, RTC, PDMA with CRC calculation unit, UART, SPI, I²C, I²S, PWM Timer, GPIO, LIN, CAN, PS/2, Smart Card Host, 12-bit ADC, Analog Comparator, Low Voltage Reset Controller and Brown-out Detector.

The NuMicro™ NUC240 Connectivity Line with USB 2.0 full-speed and CAN functions is embedded with the Cortex™-M0 core running up to 72 MHz and features 32K/64K/128K bytes flash, 8K/16K bytes embedded SRAM, and 8 Kbytes loader ROM for the ISP. It is also equipped with plenty of peripheral devices, such as Timers, Watchdog Timer, Window Watchdog Timer, RTC, PDMA with CRC calculation unit, UART, SPI, I²C, I²S, PWM Timer, GPIO, LIN, CAN, PS/2, USB 2.0 FS Device, Smart Card Host, 12-bit ADC, Analog Comparator, Low Voltage Reset Controller and Brown-out Detector.

Product Line	UART	SPI	I ² C	USB	LIN	CAN	PS/2	I ² S	SC
NUC230	●	●	●		●	●	●	●	●
NUC240	●	●	●	●	●	●	●	●	●

Table 1-1 NuMicro™ NUC230/240 Series Connectivity Support Table

2 FEATURES

The equipped features are dependent on the product line and their sub products.

2.1 NuMicro™ NUC230 Features – Automotive Line

- ARM® Cortex™-M0 core
 - Runs up to 72 MHz
 - One 24-bit system timer
 - Supports low power sleep mode
 - Single-cycle 32-bit hardware multiplier
 - NVIC for the 32 interrupt inputs, each with 4-levels of priority
 - Serial Wire Debug supports with 2 watchpoints/4 breakpoints
- Built-in LDO for wide operating voltage ranged from 2.5 V to 5.5 V
- Flash Memory
 - 32K/64K/128K bytes Flash for program code
 - 8 KB flash for ISP loader
 - Supports In-System-Program (ISP) and In-Application-Program (IAP) application code update
 - 512 byte page erase for flash
 - Configurable Data Flash address and size for 128 KB system, fixed 4 KB Data Flash for the 32 KB and 64 KB system
 - Supports 2-wired ICP update through SWD/ICE interface
 - Supports fast parallel programming mode by external programmer
- SRAM Memory
 - 8K/16K bytes embedded SRAM
 - Supports PDMA mode
- PDMA (Peripheral DMA)
 - Supports 9 channels PDMA for automatic data transfer between SRAM and peripherals
 - Supports CRC calculation with four common polynomials, CRC-CCITT, CRC-8, CRC-16 and CRC-32
- Clock Control
 - Flexible selection for different applications
 - Built-in 22.1184 MHz high speed oscillator for system operation
 - Trimmed to $\pm 1\%$ at $+25\text{ }^{\circ}\text{C}$ and $V_{DD} = 5\text{ V}$
 - Trimmed to $\pm 3\%$ at $-40\text{ }^{\circ}\text{C} \sim +105\text{ }^{\circ}\text{C}$ and $V_{DD} = 2.5\text{ V} \sim 5.5\text{ V}$
 - Built-in 10 kHz low speed oscillator for Watchdog Timer and Wake-up operation
 - Supports one PLL, up to 72 MHz, for high performance system operation
 - External 4~24 MHz high speed crystal input for precise timing operation
 - External 32.768 kHz low speed crystal input for RTC function and low power system operation
- GPIO
 - Four I/O modes:
 - Quasi-bidirectional
 - Push-pull output
 - Open-drain output
 - Input only with high impedance
 - TTL/Schmitt trigger input selectable
 - I/O pin configured as interrupt source with edge/level setting
- Timer
 - Supports 4 sets of 32-bit timers with 24-bit up-timer and one 8-bit prescale counter
 - Independent clock source for each timer
 - Provides one-shot, periodic, toggle and continuous counting operation modes
 - Supports event counting function
 - Supports input capture function
- Watchdog Timer
 - Multiple clock sources

- 8 selectable time-out period from 1.6 ms ~ 26.0 sec (depending on clock source)
- Wake-up from Power-down or Idle mode
- Interrupt or reset selectable on watchdog time-out
- Supports 4 selectable Watchdog Timer reset delay period(1026, 130, 18 or 3 WDT_CLK)
- Window Watchdog Timer
 - 6-bit down counter with 11-bit prescale for wide range window selected
- RTC
 - Supports software compensation by setting frequency compensate register (FCR)
 - Supports RTC counter (second, minute, hour) and calendar counter (day, month, year)
 - Supports Alarm registers (second, minute, hour, day, month, year)
 - Selectable 12-hour or 24-hour mode
 - Automatic leap year recognition
 - Supports periodic time tick interrupt with 8 period options 1/128, 1/64, 1/32, 1/16, 1/8, 1/4, 1/2 and 1 second
 - Supports battery power pin (VBAT)
 - Supports wake-up function
- PWM/Capture
 - Up to four built-in 16-bit PWM generators providing eight PWM outputs or four complementary paired PWM outputs
 - Each PWM generator equipped with one clock source selector, one clock divider, one 8-bit prescaler and one Dead-Zone generator for complementary paired PWM
 - Supports One-shot or Auto-reload mode
 - Up to eight 16-bit digital capture timers (shared with PWM timers) providing eight rising/falling capture inputs
 - Supports Capture interrupt
- UART
 - Up to six UART controllers (three UART controllers are shared with SC)
 - UART ports with flow control (TXD, RXD, nCTS and nRTS)
 - UART0 with 64-byte FIFO is for high speed
 - UART1/2(optional) with 16-byte FIFO for standard device
 - Supports IrDA (SIR) and LIN function
 - Supports RS-485 9-bit mode and direction control
 - Programmable baud-rate generator up to 1/16 system clock
 - Supports CTS wake-up function (UART0 and UART1 support)
 - Supports PDMA mode
- Smart Card Host (SC)
 - Supports up to three ISO-7816-3 ports
 - Compliant to ISO-7816-3 T=0, T=1
 - Separate receive / transmit 4 bytes entry FIFO for data payloads
 - Programmable transmission clock frequency
 - Programmable receiver buffer trigger level
 - Programmable guard time selection (11 ETU ~ 266 ETU)
 - One 24-bit and two 8-bit time-out counters for Answer to Request (ATR) and waiting times processing
 - Supports auto inverse convention function
 - Supports transmitter and receiver error retry and error limit function
 - Supports hardware activation sequence process
 - Supports hardware warm reset sequence process
 - Supports hardware deactivation sequence process
 - Supports hardware auto deactivation sequence when detecting the card is removal
 - Supports up to three UART ports
 - Full duplex, asynchronous communications
 - Supports receiving / transmitting 4-bytes FIFO
 - Supports programmable baud rate generator for each channel
 - Programmable even, odd or no parity bit generation and detection
 - Programmable stop bit, 1 or 2 stop bit generation

- SPI
 - Up to four sets of SPI controllers
 - The maximum SPI clock rate of Master can up to 36 MHz (chip working at 5V)
 - The maximum SPI clock rate of Slave can up to 18 MHz (chip working at 5V)
 - Supports SPI Master/Slave mode
 - Full duplex synchronous serial data transfer
 - Variable length of transfer data from 8 to 32 bits
 - MSB or LSB first data transfer
 - Rx and Tx on both rising or falling edge of serial clock independently
 - Two slave/device select lines in Master mode, and one slave/device select line in Slave mode
 - Supports Byte Suspend mode in 32-bit transmission
 - Supports PDMA mode
 - Supports three wire, no slave select signal, bi-direction interface
- I²C
 - Up to two sets of I²C devices
 - Master/Slave mode
 - Bidirectional data transfer between masters and slaves
 - Multi-master bus (no central master)
 - Arbitration between simultaneously transmitting masters without corruption of serial data on the bus
 - Serial clock synchronization allowing devices with different bit rates to communicate via one serial bus
 - Serial clock synchronization used as a handshake mechanism to suspend and resume serial transfer
 - Programmable clocks allowing for versatile rate control
 - Supports multiple address recognition (four slave address with mask option)
 - Supports wake-up function
- I²S
 - Interface with external audio CODEC
 - Operate as either Master or Slave mode
 - Capable of handling 8-, 16-, 24- and 32-bit word sizes
 - Supports mono and stereo audio data
 - Supports I²S and MSB justified data format
 - Provides two 8 word FIFO data buffers, one for transmitting and the other for receiving
 - Generates interrupt requests when buffer levels cross a programmable boundary
 - Supports two DMA requests, one for transmitting and the other for receiving
- PS/2 Device
 - Host communication inhibit and request to send detection
 - Reception frame error detection
 - Programmable 1 to 16 bytes transmit buffer to reduce CPU intervention
 - Double buffer for data reception
 - Software override bus
- CAN 2.0
 - Supports CAN protocol version 2.0 part A and B
 - Bit rates up to 1M bit/s
 - 32 Message Objects
 - Each Message Object has its own identifier mask
 - Programmable FIFO mode (concatenation of Message Object)
 - Maskable interrupt
 - Disabled Automatic Re-transmission mode for Time Triggered CAN applications
 - Support wake-up function
- ADC
 - 12-bit SAR ADC with 1 MSPS (chip working at 5V)
 - Up to 8-ch single-end input or 4-ch differential input
 - Single scan/single cycle scan/continuous scan

- Each channel with individual result register
- Scan on enabled channels
- Threshold voltage detection
- Conversion started by software programming, external input or PWM Center-aligned trigger
- Supports PDMA mode
- Analog Comparator
 - Up to two analog comparators
 - External input or internal Band-gap voltage selectable at negative node
 - Interrupt when compare result change
 - Supports Power-down wake-up
- EBI (External bus interface)
 - Accessible space: 64 KB in 8-bit mode or 128 KB in 16-bit mode
 - Supports 8-/16-bit data width
 - Supports byte write in 16-bit data width mode
- 96-bit unique ID (UID)
- 128-bit unique customer ID(UCID)
- One built-in temperature sensor with 1°C resolution
- Brown-out Detector
 - With 4 levels: 4.4 V/3.7 V/2.7 V/2.2 V
 - Supports Brown-out Interrupt and Reset option
- Low Voltage Reset
 - Threshold voltage level: 2.0 V
- Operating Temperature: -40°C ~ 105°C
- Packages:
 - All Green package (RoHS)
 - LQFP 100-pin / 64-pin / 48-pin

2.2 NuMicro™ NUC240 Features – Connectivity Line

- ARM® Cortex™-M0 core
 - Runs up to 72 MHz
 - One 24-bit system timer
 - Supports low power sleep mode
 - Single-cycle 32-bit hardware multiplier
 - NVIC for the 32 interrupt inputs, each with 4-levels of priority
 - Serial Wire Debug supports with 2 watchpoints/4 breakpoints
- Built-in LDO for wide operating voltage ranges from 2.5 V to 5.5 V
- Flash Memory
 - 32K/64K/128K bytes Flash for program code
 - 8 KB flash for ISP loader
 - Supports In-System-Program (ISP) and In-Application-Program (IAP) application code update
 - 512 byte page erase for flash
 - Configurable Data Flash address and size for 128 KB system, fixed 4 KB Data Flash for the 32 KB and 64 KB system
 - Supports 2-wired ICP update through SWD/ICE interface
- SRAM Memory
 - 8K/16K bytes embedded SRAM
 - Supports PDMA mode
- PDMA (Peripheral DMA)
 - Supports 9 channels PDMA for automatic data transfer between SRAM and peripherals
 - Supports CRC calculation with four common polynomials, CRC-CCITT, CRC-8, CRC-16 and CRC-32
- Clock Control
 - Flexible selection for different applications
 - Built-in 22.1184 MHz high speed oscillator for system operation
 - Trimmed to $\pm 1\%$ at $+25\text{ }^{\circ}\text{C}$ and $V_{DD} = 5\text{ V}$
 - Trimmed to $\pm 3\%$ at $-40\text{ }^{\circ}\text{C} \sim +105\text{ }^{\circ}\text{C}$ and $V_{DD} = 2.5\text{ V} \sim 5.5\text{ V}$
 - Built-in 10 kHz low speed oscillator for Watchdog Timer and Wake-up operation
 - Supports one PLL, up to 72 MHz, for high performance system operation
 - External 4~24 MHz high speed crystal input for USB and precise timing operation
 - External 32.768 kHz low speed crystal input for RTC function and low power system operation
- GPIO
 - Four I/O modes:
 - Quasi-bidirectional
 - Push-pull output
 - Open-drain output
 - Input only with high impedance
 - TTL/Schmitt trigger input selectable
 - I/O pin configured as interrupt source with edge/level setting
- Timer
 - Supports 4 sets of 32-bit timers with 24-bit up-timer and one 8-bit prescale counter
 - Independent clock source for each timer
 - Provides one-shot, periodic, toggle and continuous counting operation modes
 - Supports event counting function
 - Supports input capture function
- Watchdog Timer
 - Multiple clock sources
 - 8 selectable time-out period from 1.6 ms ~ 26.0 sec (depending on clock source)
 - Wake-up from Power-down or Idle mode
 - Interrupt or reset selectable on watchdog time-out
 - Supports 4 selectable Watchdog Timer reset delay period(1026, 130, 18 or 3 WDT_CLK)

- Window Watchdog Timer
 - 6-bit down counter with 11-bit prescale for wide range window selected
- RTC
 - Supports software compensation by setting frequency compensate register (FCR)
 - Supports RTC counter (second, minute, hour) and calendar counter (day, month, year)
 - Supports Alarm registers (second, minute, hour, day, month, year)
 - Selectable 12-hour or 24-hour mode
 - Automatic leap year recognition
 - Supports periodic time tick interrupt with 8 period options 1/128, 1/64, 1/32, 1/16, 1/8, 1/4, 1/2 and 1 second
 - Supports battery power pin (VBAT)
 - Supports wake-up function
- PWM/Capture
 - Up to four built-in 16-bit PWM generators providing eight PWM outputs or four complementary paired PWM outputs
 - Each PWM generator equipped with one clock source selector, one clock divider, one 8-bit prescaler and one Dead-Zone generator for complementary paired PWM
 - Supports One-shot or Auto-reload mode
 - Up to eight 16-bit digital capture timers (shared with PWM timers) providing eight rising/falling capture inputs
 - Supports Capture interrupt
- UART
 - Up to six UART controllers (three UART controllers are shared with SC)
 - UART ports with flow control (TXD, RXD, nCTS and nRTS)
 - UART0 with 64-byte FIFO is for high speed
 - UART1/2(optional) with 16-byte FIFO for standard device
 - Supports IrDA (SIR) and LIN function
 - Supports RS-485 9-bit mode and direction control
 - Programmable baud-rate generator up to 1/16 system clock
 - Supports CTS wake-up function (UART0 and UART1 support)
 - Supports PDMA mode
- Smart Card Host (SC)
 - Supports up to three ISO-7816-3 ports
 - Compliant to ISO-7816-3 T=0, T=1
 - Separate receive / transmit 4 bytes entry FIFO for data payloads
 - Programmable transmission clock frequency
 - Programmable receiver buffer trigger level
 - Programmable guard time selection (11 ETU ~ 266 ETU)
 - One 24-bit and two 8-bit time-out counters for Answer to Request (ATR) and waiting times processing
 - Supports auto inverse convention function
 - Supports transmitter and receiver error retry and error limit function
 - Supports hardware activation sequence process
 - Supports hardware warm reset sequence process
 - Supports hardware deactivation sequence process
 - Supports hardware auto deactivation sequence when detecting the card is removal
 - Supports up to three UART ports
 - Full duplex, asynchronous communications
 - Supports receiving / transmitting 4-bytes FIFO
 - Supports programmable baud rate generator for each channel
 - Programmable even, odd or no parity bit generation and detection
 - Programmable stop bit, 1 or 2 stop bit generation
- SPI
 - Up to four sets of SPI controllers
 - The maximum SPI clock rate of Master can up to 36 MHz (chip working at 5V)
 - The maximum SPI clock rate of Slave can up to 18 MHz (chip working at 5V)

- Supports SPI Master/Slave mode
- Full duplex synchronous serial data transfer
- Variable length of transfer data from 8 to 32 bits
- MSB or LSB first data transfer
- Rx and Tx on both rising or falling edge of serial clock independently
- Two slave/device select lines in Master mode, and one slave/device select line in Slave mode
- Supports Byte Suspend mode in 32-bit transmission
- Supports PDMA mode
- Supports three wire, no slave select signal, bi-direction interface
- I²C
 - Up to two sets of I²C devices
 - Master/Slave mode
 - Bidirectional data transfer between masters and slaves
 - Multi-master bus (no central master)
 - Arbitration between simultaneously transmitting masters without corruption of serial data on the bus
 - Serial clock synchronization allowing devices with different bit rates to communicate via one serial bus
 - Serial clock synchronization used as a handshake mechanism to suspend and resume serial transfer
 - Programmable clocks allowing for versatile rate control
 - Supports multiple address recognition (four slave address with mask option)
 - Supports wake-up function
- I²S
 - Interface with external audio CODEC
 - Operate as either Master or Slave mode
 - Capable of handling 8-, 16-, 24- and 32-bit word sizes
 - Supports mono and stereo audio data
 - Supports I²S and MSB justified data format
 - Provides two 8 word FIFO data buffers, one for transmitting and the other for receiving
 - Generates interrupt requests when buffer levels cross a programmable boundary
 - Supports two DMA requests, one for transmitting and the other for receiving
- PS/2 Device
 - Host communication inhibit and request to send detection
 - Reception frame error detection
 - Programmable 1 to 16 bytes transmit buffer to reduce CPU intervention
 - Double buffer for data reception
 - Software override bus
- CAN 2.0
 - Supports CAN protocol version 2.0 part A and B
 - Bit rates up to 1M bit/s
 - 32 Message Objects
 - Each Message Object has its own identifier mask
 - Programmable FIFO mode (concatenation of Message Object)
 - Maskable interrupt
 - Disabled Automatic Re-transmission mode for Time Triggered CAN applications
 - Supports Power-down wake-up function
- USB 2.0 Full-Speed Device
 - One set of USB 2.0 FS Device 12 Mbps
 - On-chip USB Transceiver
 - Provides 1 interrupt source with 4 interrupt events
 - Supports Control, Bulk In/Out, Interrupt and Isochronous transfers
 - Auto suspend function when no bus signaling for 3 ms
 - Provides 8 programmable endpoints
 - Includes 512 Bytes internal SRAM as USB buffer

- Provides remote wake-up capability
- ADC
 - 12-bit SAR ADC with 1 MSPS(chip working at 5V)
 - Up to 8-ch single-end input or 4-ch differential input
 - Single scan/single cycle scan/continuous scan
 - Each channel with individual result register
 - Scan on enabled channels
 - Threshold voltage detection
 - Conversion started by software programming, external input or PWM Center-aligned trigger
 - Supports PDMA mode
- Analog Comparator
 - Up to two analog comparators
 - External input or internal Band-gap voltage selectable at negative node
 - Interrupt when compare result change
 - Supports Power-down wake-up
- EBI (External bus interface)
 - Accessible space: 64 KB in 8-bit mode or 128 KB in 16-bit mode
 - Supports 8-/16-bit data width
 - Supports byte write in 16-bit data width mode
- 96-bit unique ID (UID)
- 128-bit unique customer ID(UCID)
- One built-in temperature sensor with 1°C resolution
- Brown-out Detector
 - With 4 levels: 4.4 V/3.7 V/2.7 V/2.2 V
 - Supports Brown-out Interrupt and Reset option
- Low Voltage Reset
 - Threshold voltage level: 2.0 V
- Operating Temperature: -40°C ~ 105°C
- Packages:
 - All Green package (RoHS)
 - LQFP 100-pin / 64-pin / 48-pin

3 ABBREVIATIONS

Acronym	Description
ACMP	Analog Comparator Controller
ADC	Analog-to-Digital Converter
AES	Advanced Encryption Standard
APB	Advanced Peripheral Bus
AHB	Advanced High-Performance Bus
BOD	Brown-out Detection
CAN	Controller Area Network
DAP	Debug Access Port
DES	Data Encryption Standard
EBI	External Bus Interface
EPWM	Enhanced Pulse Width Modulation
FIFO	First In, First Out
FMC	Flash Memory Controller
FPU	Floating-point Unit
GPIO	General-Purpose Input/Output
HCLK	The Clock of Advanced High-Performance Bus
HIRC	22.1184 MHz Internal High Speed RC Oscillator
HXT	4~24 MHz External High Speed Crystal Oscillator
IAP	In Application Programming
ICP	In Circuit Programming
ISP	In System Programming
LDO	Low Dropout Regulator
LIN	Local Interconnect Network
LIRC	10 kHz internal low speed RC oscillator (LIRC)
MPU	Memory Protection Unit
NVIC	Nested Vectored Interrupt Controller
PCLK	The Clock of Advanced Peripheral Bus
PDMA	Peripheral Direct Memory Access
PLL	Phase-Locked Loop
PWM	Pulse Width Modulation
QEI	Quadrature Encoder Interface
SDIO	Secure Digital Input/Output
SPI	Serial Peripheral Interface

SPS	Samples per Second
TDES	Triple Data Encryption Standard
TMR	Timer Controller
UART	Universal Asynchronous Receiver/Transmitter
UCID	Unique Customer ID
USB	Universal Serial Bus
WDT	Watchdog Timer
WWDT	Window Watchdog Timer

Table 3-1 List of Abbreviations

4 PARTS INFORMATION LIST AND PIN CONFIGURATION

4.1 NuMicro™ NUC230/240xxxAE Selection Guide

4.1.1 NuMicro™ NUC230 Automotive Line Selection Guide

Part Number	APROM (KB)	RAM (KB)	Data Flash (KB)	ISP ROM (KB)	I/O	Timer (32-Bit)	Connectivity						I ² S	SC	Comp.	PWM	ADC (12-Bit)	RTC	EBI	ISP/ICP/IAP	Package
							UART	SPI	I ² C	USB	LIN	CAN									
NUC230LC2AE	32	8	4	8	35	4	5	1	2	-	3	2	1	2	1	4	7	v	-	v	LQFP48
NUC230LD2AE	64	8	4	8	35	4	5	1	2	-	3	2	1	2	1	4	7	v	-	v	LQFP48
NUC230LE3AE	128	16	Config.	8	35	4	5	1	2	-	3	2	1	2	1	4	7	v	-	v	LQFP48
NUC230SC2AE	32	8	4	8	49	4	5	2	2	-	3	2	1	2	2	6	7	v	v	v	LQFP64
NUC230SD2AE	64	8	4	8	49	4	5	2	2	-	3	2	1	2	2	6	7	v	v	v	LQFP64
NUC230SE3AE	128	16	Config.	8	49	4	5	2	2	-	3	2	1	2	2	6	7	v	v	v	LQFP64
NUC230VE3AE	128	16	Config.	8	83	4	6	4	2	-	3	2	1	3	2	8	8	v	v	v	LQFP100

4.1.2 NuMicro™ NUC240 Connectivity Line Selection Guide

Part Number	APROM (KB)	RAM (KB)	Data Flash (KB)	ISP ROM (KB)	I/O	Timer (32-Bit)	Connectivity						I ² S	SC	Comp.	PWM	ADC (12-Bit)	RTC	EBI	ISP/ICP/IAP	Package
							UART	SPI	I ² C	USB	LIN	CAN									
NUC240LC2AE	32	8	4	8	31	4	4	1	2	1	2	2	1	1	1	4	7	v	-	v	LQFP48
NUC240LD2AE	64	8	4	8	31	4	4	1	2	1	2	2	1	1	1	4	7	v	-	v	LQFP48
NUC240LE3AE	128	16	Config.	8	31	4	4	1	2	1	2	2	1	1	1	4	7	v	-	v	LQFP48
NUC240SC2AE	32	8	4	8	45	4	5	2	2	1	3	2	1	2	2	4	7	v	v	v	LQFP64
NUC240SD2AE	64	8	4	8	45	4	5	2	2	1	3	2	1	2	2	4	7	v	v	v	LQFP64
NUC240SE3AE	128	16	Config.	8	45	4	5	2	2	1	3	2	1	2	2	4	7	v	v	v	LQFP64
NUC240VE3AE	128	16	Config.	8	79	4	6	4	2	1	3	2	1	3	2	8	8	v	v	v	LQFP100

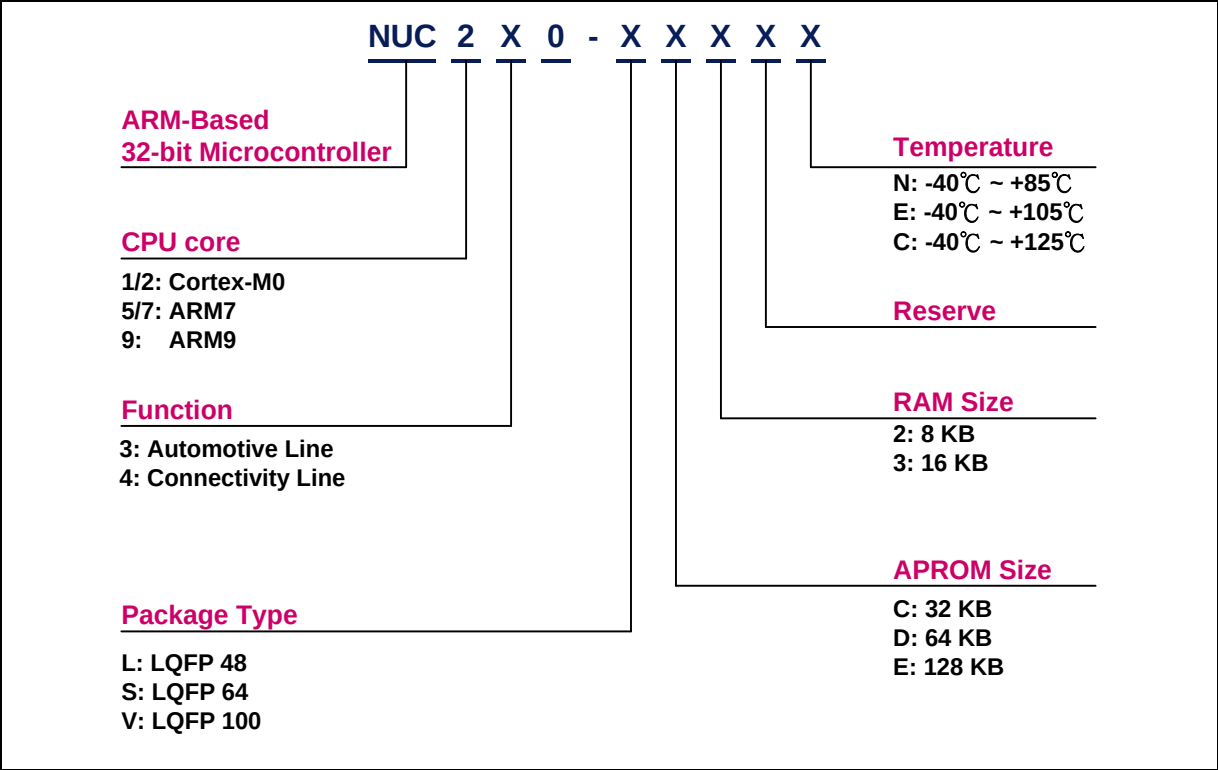


Figure 4-1 NuMicro™ NUC230/240 Series Selection Code

4.2 Pin Configuration

4.2.1 NuMicro™ NUC230 Pin Diagram

4.2.1.1 NuMicro™ NUC230VxxAE LQFP 100 pin

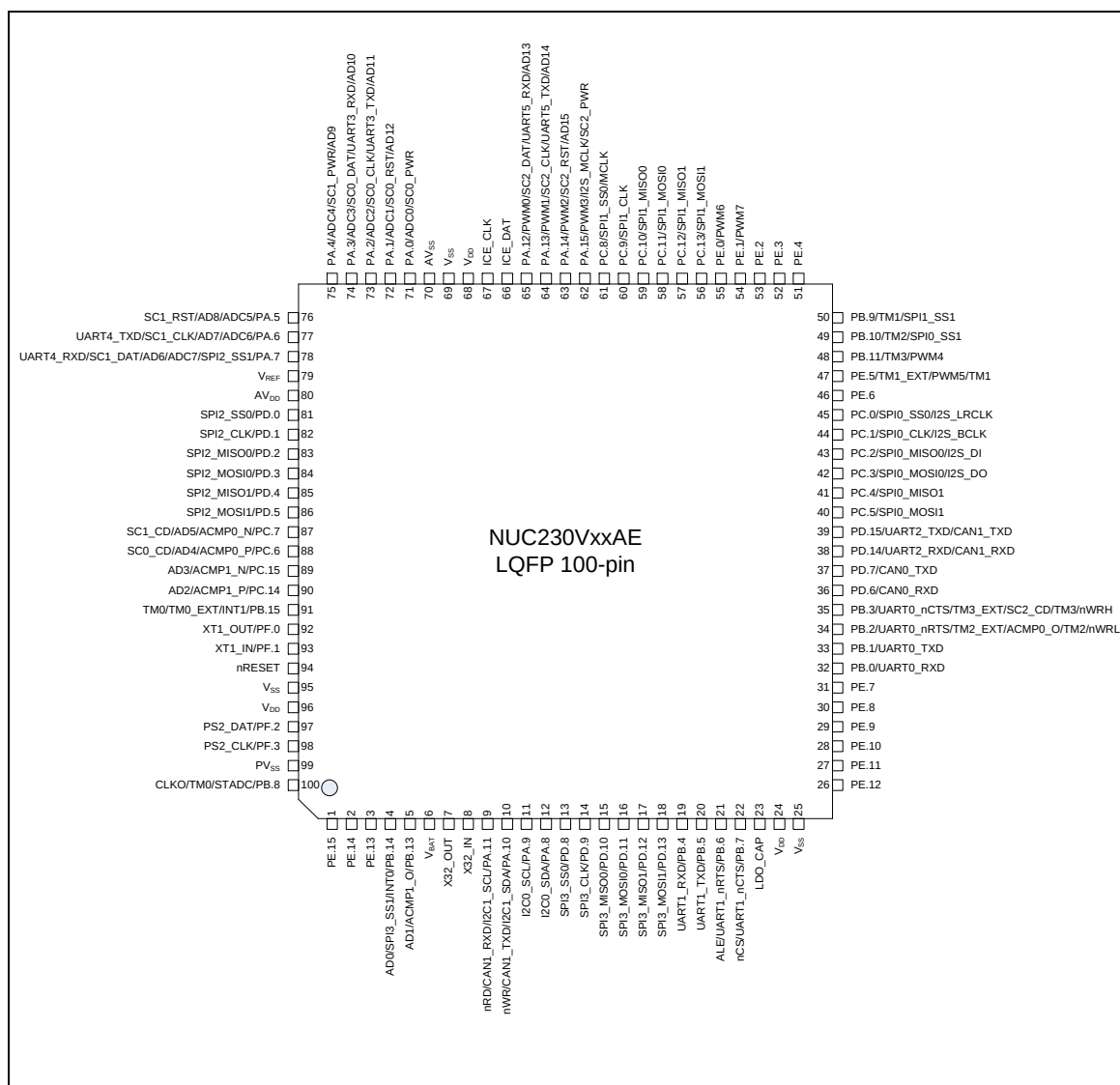


Figure 4-2 NuMicro™ NUC230VxxAE LQFP 100-pin Diagram

4.2.1.2 NuMicro™ NUC230SxxAE LQFP 64 pin

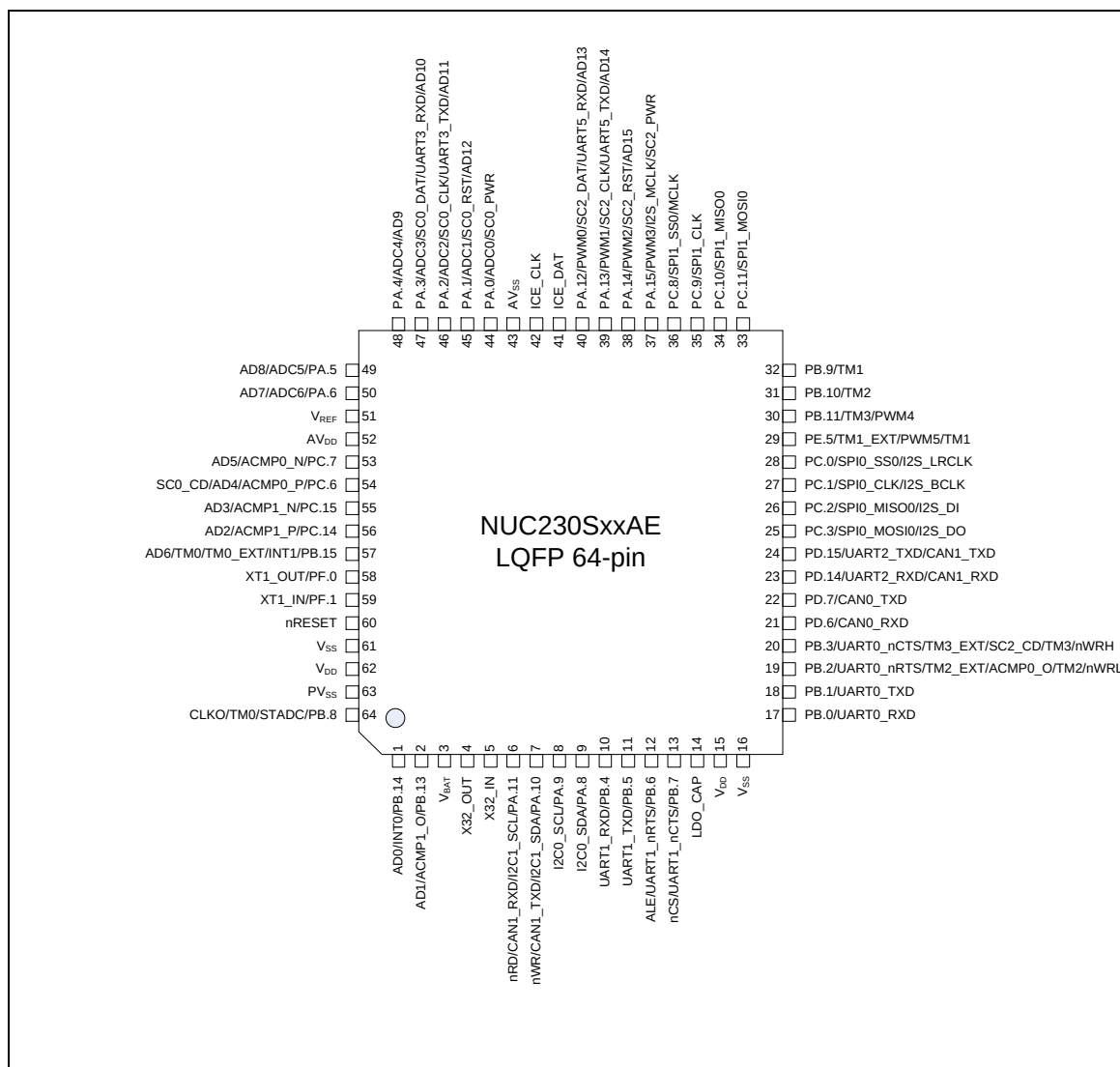


Figure 4-3 NuMicro™ NUC230SxxAE LQFP 64-pin Diagram

4.2.1.3 NuMicro™ NUC230LxxAE LQFP 48 pin

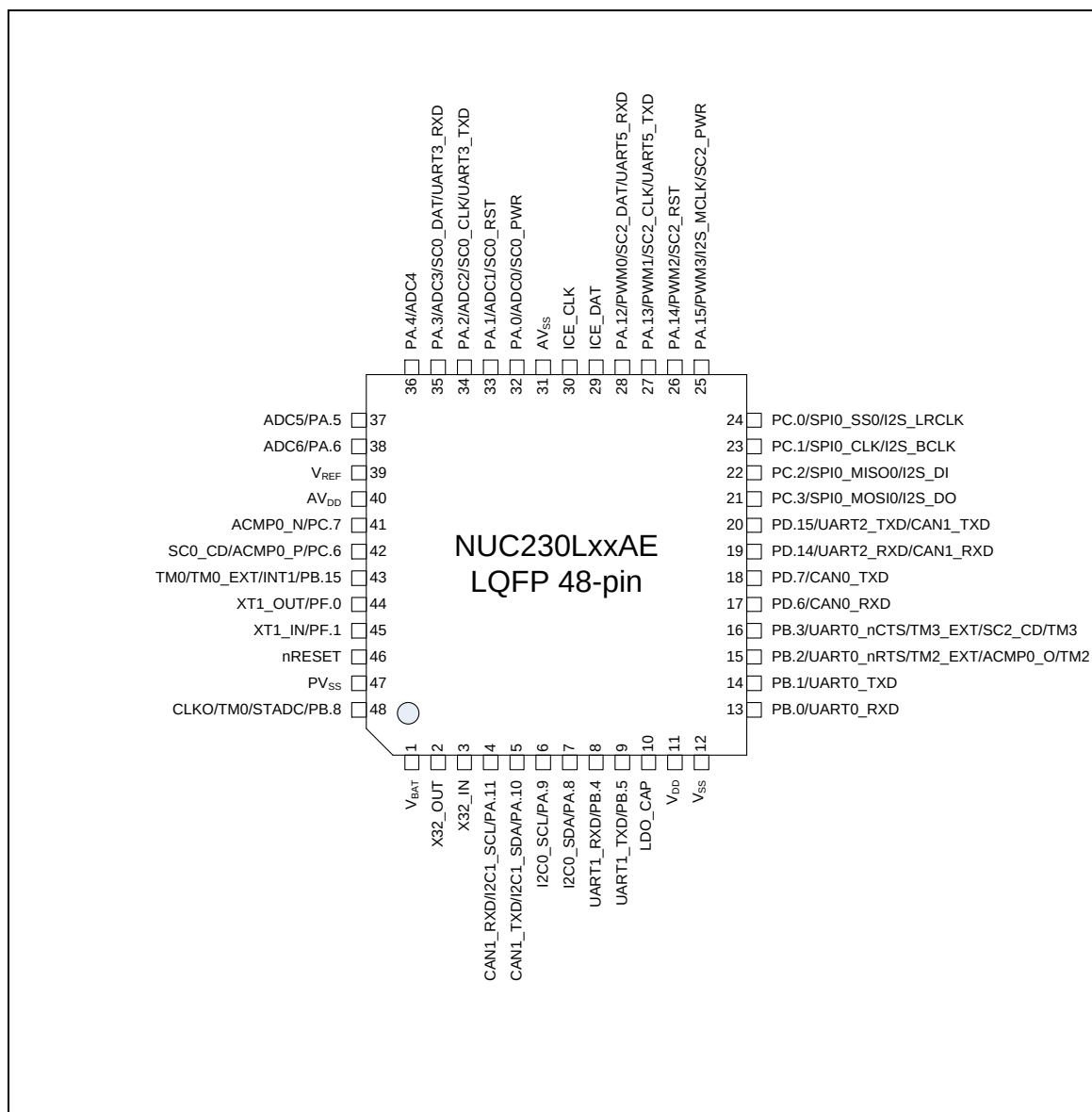


Figure 4-4 NuMicro™ NUC230LxxAE LQFP 48-pin Diagram

4.2.2 NuMicro™ NUC240 Pin Diagram

4.2.2.1 NuMicro™ NUC240VxxAE LQFP 100 pin

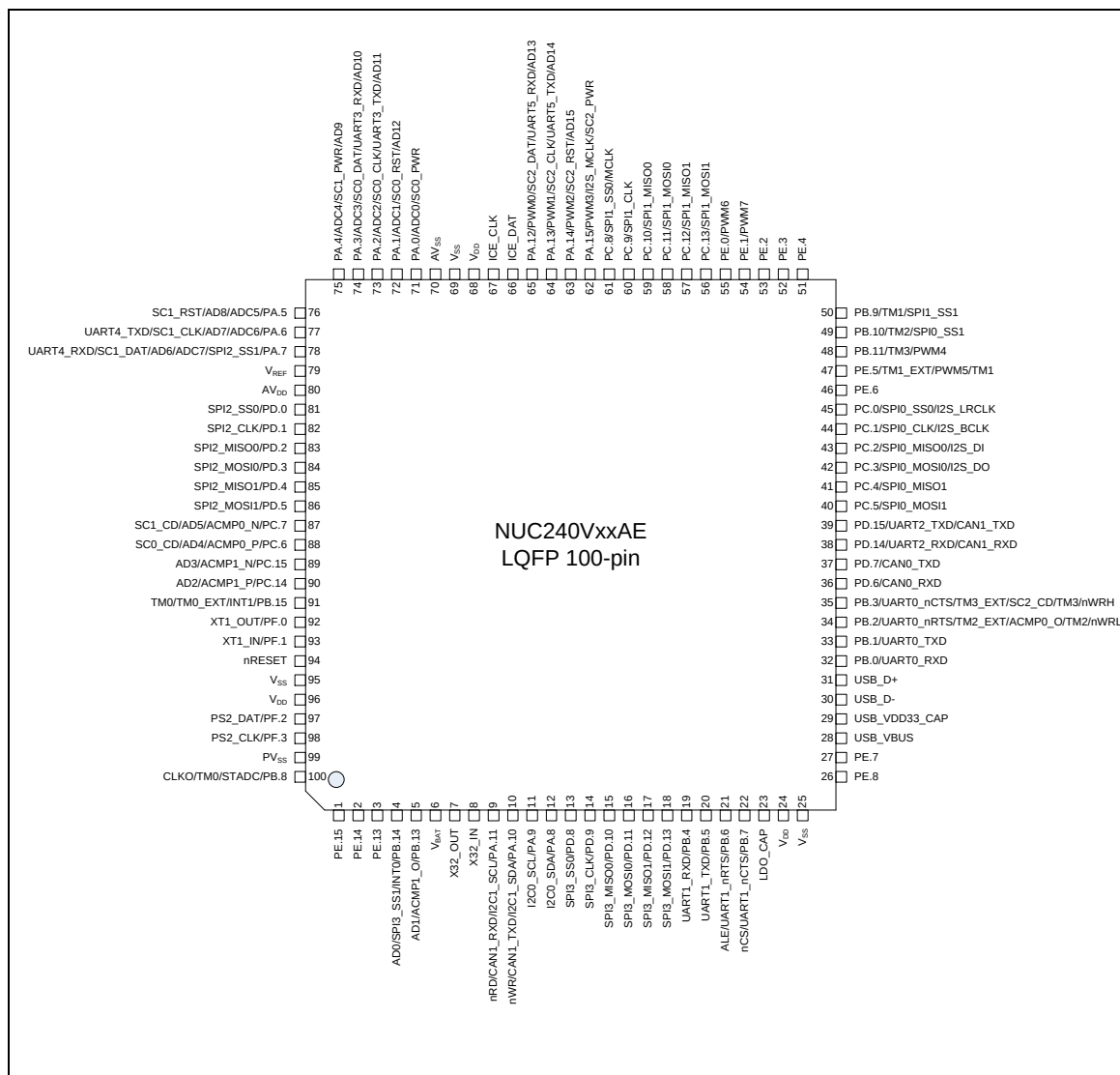


Figure 4-5 NuMicro™ NUC240VxxAE LQFP 100-pin Diagram

4.2.2.2 NuMicro™ NUC240SxxAE LQFP 64 pin

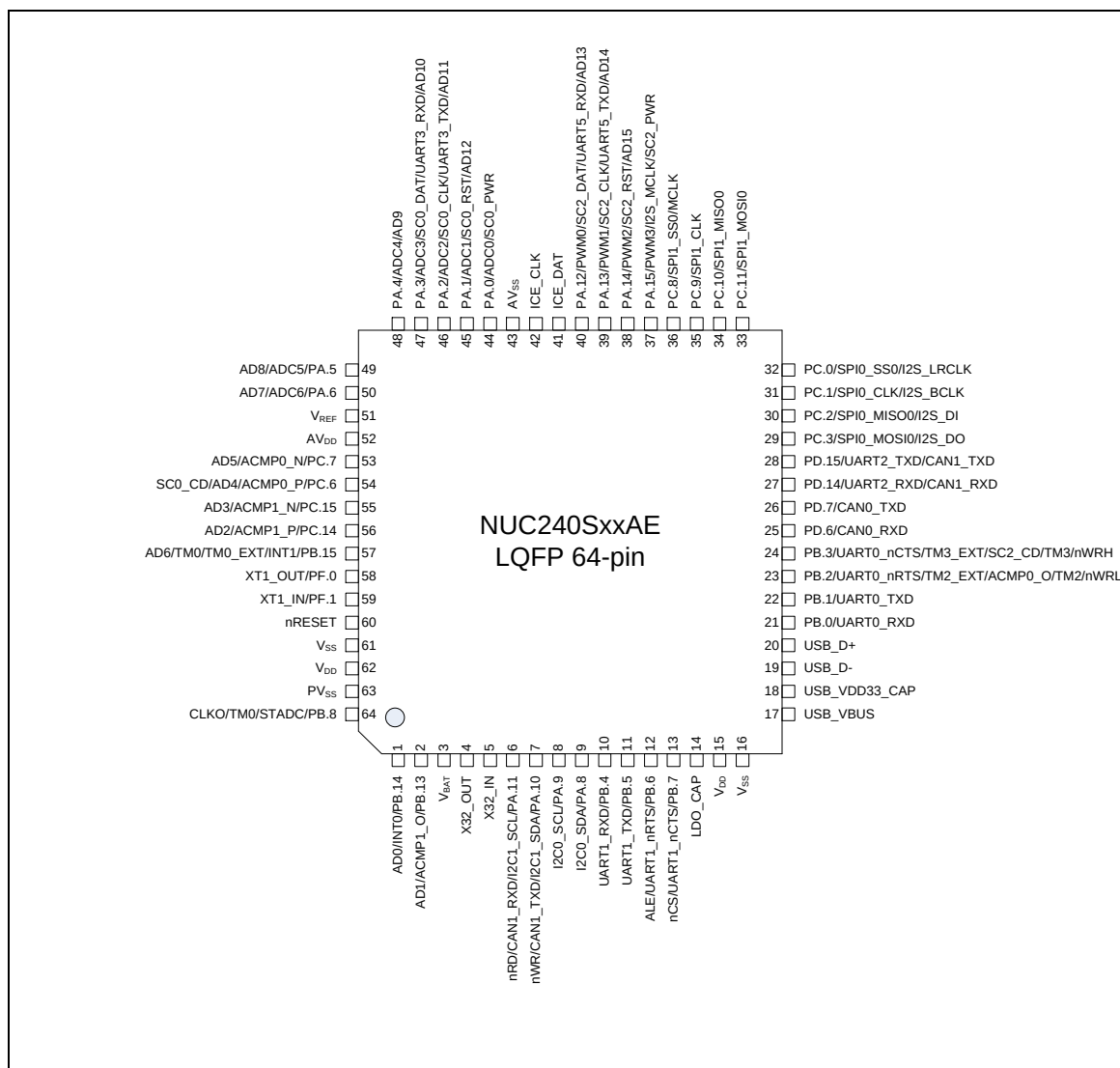


Figure 4-6 NuMicro™ NUC240SxxAE LQFP 64-pin Diagram

4.2.2.3 NuMicro™ NUC240LxxAE LQFP 48 pin

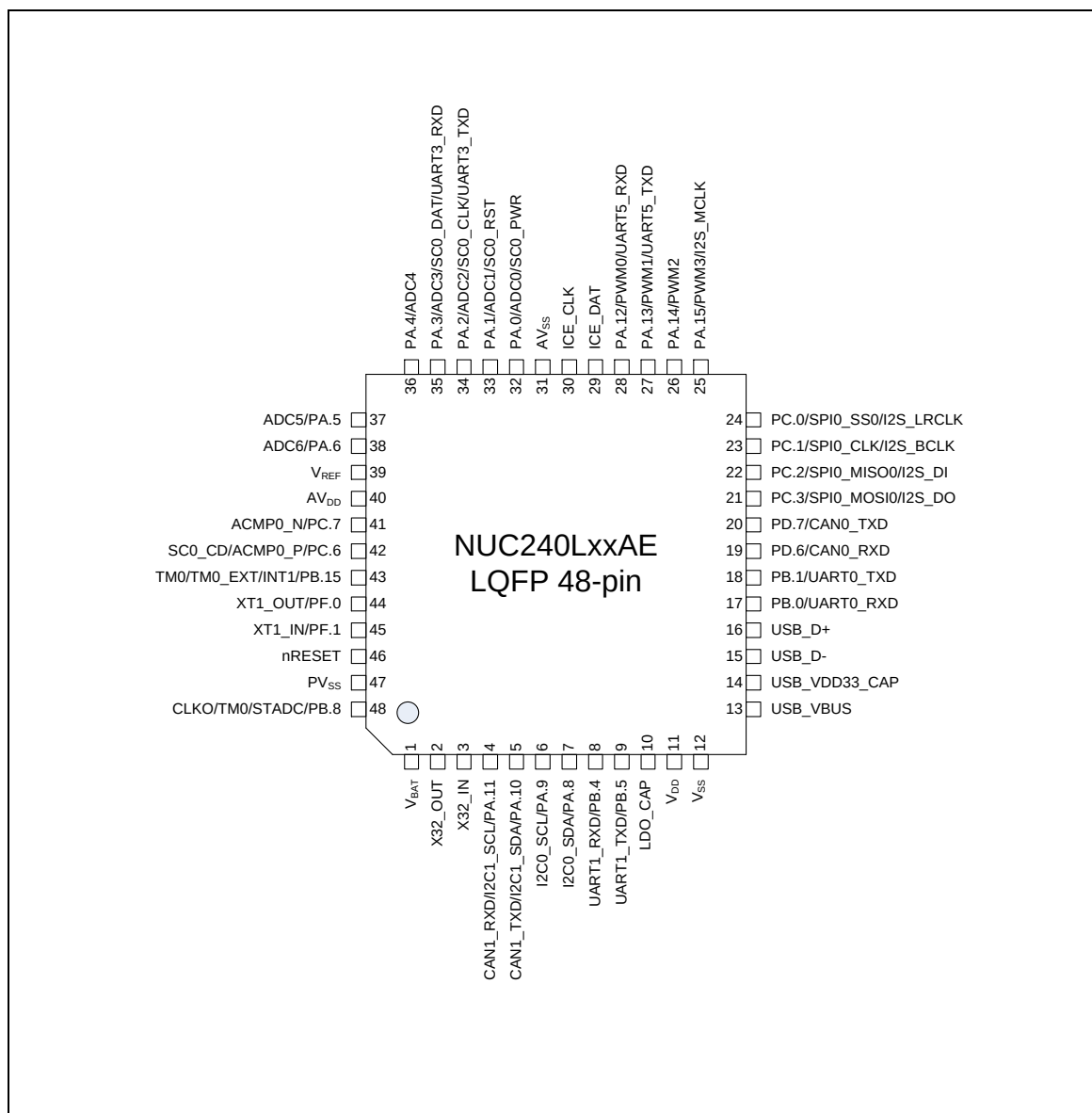


Figure 4-7 NuMicro™ NUC240LxxAE LQFP 48-pin Diagram

4.3 Pin Description

4.3.1 NuMicro™ NUC230 Pin Description

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
1			PE.15	I/O	General purpose digital I/O pin.
2			PE.14	I/O	General purpose digital I/O pin.
3			PE.13	I/O	General purpose digital I/O pin.
4	1		PB.14	I/O	General purpose digital I/O pin.
			AD0	I/O	EBI Address/Data bus bit0
			INT0	I	External interrupt0 input pin.
			SPI3_SS1	I/O	2 nd SPI3 slave select pin.
5	2		PB.13	I/O	General purpose digital I/O pin.
			AD1	I/O	EBI Address/Data bus bit1
			ACMP1_O	O	Comparator1 output pin.
6	3	1	V _{BAT}	P	Power supply by batteries for RTC.
7	4	2	X32_OUT	O	External 32.768 kHz (low speed) crystal output pin.
8	5	3	X32_IN	I	External 32.768 kHz (low speed) crystal input pin.
9	6	4	PA.11	I/O	General purpose digital I/O pin.
			I2C1_SCL	I/O	I ² C1 clock pin.
			CAN1_RXD	I	Data receiver input pin for CAN1.
			nRD	O	EBI read enable output pin
10	7	5	PA.10	I/O	General purpose digital I/O pin.
			I2C1_SDA	I/O	I ² C1 data input/output pin.
			CAN1_TXD	O	Data transmitter output pin for CAN1.
			nWR	O	EBI write enable output pin
11	8	6	PA.9	I/O	General purpose digital I/O pin.
			I2C0_SCL	I/O	I ² C0 clock pin.
12	9	7	PA.8	I/O	General purpose digital I/O pin.
			I2C0_SDA	I/O	I ² C0 data input/output pin.
13			PD.8	I/O	General purpose digital I/O pin.
			SPI3_SS0	I/O	1 st SPI3 slave select pin.
14			PD.9	I/O	General purpose digital I/O pin.
			SPI3_CLK	I/O	SPI3 serial clock pin.
15			PD.10	I/O	General purpose digital I/O pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
			SPI3_MISO0	I/O	1 st SPI3 MISO (Master In, Slave Out) pin.
16			PD.11	I/O	General purpose digital I/O pin.
			SPI3_MOSI0	I/O	1 st SPI3 MOSI (Master Out, Slave In) pin.
17			PD.12	I/O	General purpose digital I/O pin.
			SPI3_MISO1	I/O	2 nd SPI3 MISO (Master In, Slave Out) pin.
18			PD.13	I/O	General purpose digital I/O pin.
			SPI3_MOSI1	I/O	2 nd SPI3 MOSI (Master Out, Slave In) pin.
19	10	8	PB.4	I/O	General purpose digital I/O pin.
			UART1_RXD	I	Data receiver input pin for UART1.
20	11	9	PB.5	I/O	General purpose digital I/O pin.
			UART1_TXD	O	Data transmitter output pin for UART1.
21	12		PB.6	I/O	General purpose digital I/O pin.
			ALE	O	EBI address latch enable output pin
			UART1_nRTS	O	Request to Send output pin for UART1.
22	13		PB.7	I/O	General purpose digital I/O pin.
			nCS	O	EBI chip select enable output pin
			UART1_nCTS	I	Clear to Send input pin for UART1.
23	14	10	LDO_CAP	P	LDO output pin.
24	15	11	V _{DD}	P	Power supply for I/O ports and LDO source for internal PLL and digital circuit.
25	16	12	V _{SS}	P	Ground pin for digital circuit.
26			PE.12	I/O	General purpose digital I/O pin.
27			PE.11	I/O	General purpose digital I/O pin.
28			PE.10	I/O	General purpose digital I/O pin.
29			PE.9	I/O	General purpose digital I/O pin.
30			PE.8	I/O	General purpose digital I/O pin.
31			PE.7	I/O	General purpose digital I/O pin.
32	17	13	PB.0	I/O	General purpose digital I/O pin.
			UART0_RXD	I	Data receiver input pin for UART0.
33	18	14	PB.1	I/O	General purpose digital I/O pin.
			UART0_TXD	O	Data transmitter output pin for UART0.
34	19	15	PB.2	I/O	General purpose digital I/O pin.
			UART0_nRTS	O	Request to Send output pin for UART0.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
			TM2_EXT	I	Timer2 external capture input pin.
			ACMP0_O	O	Comparator0 output pin.
			nWRL	O	EBI low byte write enable output pin
35	20	16	PB.3	I/O	General purpose digital I/O pin.
			UART0_nCTS	I	Clear to Send input pin for UART0.
			TM3_EXT	I	Timer3 external capture input pin.
			SC2_CD	I	SmartCard2 card detect pin.
			nWRH	O	EBI high byte write enable output pin
36	21	17	PD.6	I/O	General purpose digital I/O pin.
			CAN0_RXD	I	Data receiver input pin for CAN0.
37	22	18	PD.7	I/O	General purpose digital I/O pin.
			CAN0_TXD	O	Data transmitter output pin for CAN0.
38	23	19	PD.14	I/O	General purpose digital I/O pin.
			UART2_RXD	I	Data receiver input pin for UART2.
			CAN1_RXD	I	Data receiver input pin for CAN1.
39	24	20	PD.15	I/O	General purpose digital I/O pin.
			UART2_TXD	O	Data transmitter output pin for UART2.
			CAN1_TXD	O	Data transmitter output pin for CAN1.
40			PC.5	I/O	General purpose digital I/O pin.
			SPI0_MOSI1	I/O	2 nd SPI0 MOSI (Master Out, Slave In) pin.
41			PC.4	I/O	General purpose digital I/O pin.
			SPI0_MISO1	I/O	2 nd SPI0 MISO (Master In, Slave Out) pin.
42	25	21	PC.3	I/O	General purpose digital I/O pin.
			SPI0_MOSI0	I/O	1 st SPI0 MOSI (Master Out, Slave In) pin.
			I2S_DO	O	I ² S data output.
43	26	22	PC.2	I/O	General purpose digital I/O pin.
			SPI0_MISO0	I/O	1 st SPI0 MISO (Master In, Slave Out) pin.
			I2S_DI	I	I ² S data input.
44	27	23	PC.1	I/O	General purpose digital I/O pin.
			SPI0_CLK	I/O	SPI0 serial clock pin.
			I2S_BCLK	I/O	I ² S bit clock pin.
45	28	24	PC.0	I/O	General purpose digital I/O pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
			SPI0_SS0	I/O	1 st SPI0 slave select pin.
			I2S_LRCLK	I/O	I ² S left right channel clock.
46			PE.6	I/O	General purpose digital I/O pin.
47	29		PE.5	I/O	General purpose digital I/O pin.
			PWM5	I/O	PWM5 output/Capture input.
			TM1_EXT	I	Timer1 external capture input pin.
			TM1	O	Timer1 toggle output pin.
48	30		PB.11	I/O	General purpose digital I/O pin.
			TM3	I/O	Timer3 event counter input / toggle output.
			PWM4	I/O	PWM4 output/Capture input.
49	31		PB.10	I/O	General purpose digital I/O pin.
			TM2	I/O	Timer2 event counter input / toggle output.
			SPI0_SS1	I/O	2 nd SPI0 slave select pin.
50	32		PB.9	I/O	General purpose digital I/O pin.
			TM1	I/O	Timer1 event counter input / toggle output.
			SPI1_SS1	I/O	2 nd SPI1 slave select pin.
51			PE.4	I/O	General purpose digital I/O pin.
52			PE.3	I/O	General purpose digital I/O pin.
53			PE.2	I/O	General purpose digital I/O pin.
54			PE.1	I/O	General purpose digital I/O pin.
			PWM7	I/O	PWM7 output/Capture input.
55			PE.0	I/O	General purpose digital I/O pin.
			PWM6	I/O	PWM6 output/Capture input.
56			PC.13	I/O	General purpose digital I/O pin.
			SPI1_MOSI1	I/O	2 nd SPI1 MOSI (Master Out, Slave In) pin.
57			PC.12	I/O	General purpose digital I/O pin.
			SPI1_MISO1	I/O	2 nd SPI1 MISO (Master In, Slave Out) pin.
58	33		PC.11	I/O	General purpose digital I/O pin.
			SPI1_MOSI0	I/O	1 st SPI1 MOSI (Master Out, Slave In) pin.
59	34		PC.10	I/O	General purpose digital I/O pin.
			SPI1_MISO0	I/O	1 st SPI1 MISO (Master In, Slave Out) pin.
60	35		PC.9	I/O	General purpose digital I/O pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
			SPI1_CLK	I/O	SPI1 serial clock pin.
61	36		PC.8	I/O	General purpose digital I/O pin.
			MCLK	O	EBI clock output
			SPI1_SS0	I/O	1 st SPI1 slave select pin.
62	37	25	PA.15	I/O	General purpose digital I/O pin.
			PWM3	I/O	PWM3 output/Capture input.
			I2S_MCLK	O	I ² S master clock output pin.
			SC2_PWR	O	SmartCard2 power pin.
63	38	26	PA.14	I/O	General purpose digital I/O pin.
			PWM2	I/O	PWM2 output/Capture input.
			SC2_RST	O	SmartCard2 reset pin.
			AD15	I/O	EBI Address/Data bus bit15
64	39	27	PA.13	I/O	General purpose digital I/O pin.
			PWM1	I/O	PWM1 output/Capture input.
			SC2_CLK	O	SmartCard2 clock pin.
			UART5_TXD	O	Data transmitter output pin for UART5.
			AD14	I/O	EBI Address/Data bus bit14
65	40	28	PA.12	I/O	General purpose digital I/O pin.
			PWM0	I/O	PWM0 output/Capture input.
			SC2_DAT	O	SmartCard2 data pin.
			UART5_RXD	I	Data receiver input pin for UART5.
			AD13	I/O	EBI Address/Data bus bit13
66	41	29	ICE_DAT	I/O	Serial wire debugger data pin.
67	42	30	ICE_CLK	I	Serial wire debugger clock pin.
68			V _{DD}	P	Power supply for I/O ports and LDO source for internal PLL and digital circuit.
69			V _{SS}	P	Ground pin for digital circuit.
70	43	31	AV _{SS}	AP	Ground pin for analog circuit.
71	44	32	PA.0	I/O	General purpose digital I/O pin.
			ADC0	AI	ADC0 analog input.
			SC0_PWR	O	SmartCard0 power pin.
72	45	33	PA.1	I/O	General purpose digital I/O pin.
			ADC1	AI	ADC1 analog input.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
			SC0_RST	O	SmartCard0 reset pin.
			AD12	I/O	EBI Address/Data bus bit12
73	46	34	PA.2	I/O	General purpose digital I/O pin.
			ADC2	AI	ADC2 analog input.
			SC0_CLK	O	SmartCard0 clock pin.
			UART3_TXD	O	Data transmitter output pin for UART3.
			AD11	I/O	EBI Address/Data bus bit11
74	47	35	PA.3	I/O	General purpose digital I/O pin.
			ADC3	AI	ADC3 analog input.
			SC0_DAT	O	SmartCard0 data pin.
			UART3_RXD	I	Data receiver input pin for UART3.
			AD10	I/O	EBI Address/Data bus bit10
75	48	36	PA.4	I/O	General purpose digital I/O pin.
			ADC4	AI	ADC4 analog input.
			AD9	I/O	EBI Address/Data bus bit9
			SC1_PWR	O	SmartCard1 power pin.
76	49	37	PA.5	I/O	General purpose digital I/O pin.
			ADC5	AI	ADC5 analog input.
			AD8	I/O	EBI Address/Data bus bit8
			SC1_RST	O	SmartCard1 reset pin.
77	50	38	PA.6	I/O	General purpose digital I/O pin.
			ADC6	AI	ADC6 analog input.
			AD7	I/O	EBI Address/Data bus bit7
			SC1_CLK	I/O	SmartCard1 clock pin.
			UART4_TXD	O	Data transmitter output pin for UART4.
78			PA.7	I/O	General purpose digital I/O pin.
			ADC7	AI	ADC7 analog input.
			AD6	I/O	EBI Address/Data bus bit6
			SC1_DAT	O	SmartCard1 data pin.
			UART4_RXD	I	Data receiver input pin for UART4.
			SPI2_SS1	I/O	2 nd SPI2 slave select pin.
79	51	39	V _{REF}	AP	Voltage reference input for ADC.
80	52	40	AV _{DD}	AP	Power supply for internal analog circuit.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
81			PD.0	I/O	General purpose digital I/O pin.
			SPI2_SS0	I/O	1 st SPI2 slave select pin.
82			PD.1	I/O	General purpose digital I/O pin.
			SPI2_CLK	I/O	SPI2 serial clock pin.
83			PD.2	I/O	General purpose digital I/O pin.
			SPI2_MISO0	I/O	1 st SPI2 MISO (Master In, Slave Out) pin.
84			PD.3	I/O	General purpose digital I/O pin.
			SPI2_MOSI0	I/O	1 st SPI2 MOSI (Master Out, Slave In) pin.
85			PD.4	I/O	General purpose digital I/O pin.
			SPI2_MISO1	I/O	2 nd SPI2 MISO (Master In, Slave Out) pin.
86			PD.5	I/O	General purpose digital I/O pin.
			SPI2_MOSI1	I/O	2 nd SPI2 MOSI (Master Out, Slave In) pin.
87	53	41	PC.7	I/O	General purpose digital I/O pin.
			CMP0_N	AI	Comparator0 negative input pin.
			AD5	I/O	EBI Address/Data bus bit5
			SC1_CD	I	SmartCard1 card detect pin.
88	54	42	PC.6	I/O	General purpose digital I/O pin.
			ACMP0_P	AI	Comparator0 positive input pin.
			SC0_CD	I	SmartCard0 card detect pin.
			AD4	I/O	EBI Address/Data bus bit4
89	55		PC.15	I/O	General purpose digital I/O pin.
			AD3	I/O	EBI Address/Data bus bit3
			ACMP1_N	AI	Comparator1 negative input pin.
90	56		PC.14	I/O	General purpose digital I/O pin.
			AD2	I/O	EBI Address/Data bus bit2
			ACMP1_P	AI	Comparator1 positive input pin.
91	57	43	PB.15	I/O	General purpose digital I/O pin.
			INT1	I	External interrupt1 input pin.
			TM0_EXT	I	Timer0 external capture input pin.
			TM0	O	Timer0 toggle output pin.
			AD6	I/O	EBI Address/Data bus bit6
92	58	44	PF.0	I/O	General purpose digital I/O pin.
			XT1_OUT	O	External 4~24 MHz (high speed) crystal output pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
93	59	45	PF.1	I/O	General purpose digital I/O pin.
			XT1_IN	I	External 4~24 MHz (high speed) crystal input pin.
94	60	46	nRESET	I	External reset input: active LOW, with an internal pull-up. Set this pin low reset chip to initial state.
95	61		V _{SS}	P	Ground pin for digital circuit.
96	62		V _{DD}	P	Power supply for I/O ports and LDO source for internal PLL and digital circuit.
97			PF.2	I/O	General purpose digital I/O pin.
			PS2_DAT	I/O	PS/2 data pin.
98			PF.3	I/O	General purpose digital I/O pin.
			PS2_CLK	I/O	PS/2 clock pin.
99	63	47	PV _{SS}	P	PLL ground.
100	64	48	PB.8	I/O	General purpose digital I/O pin.
			STADC	I	ADC external trigger input.
			TM0	I/O	Timer0 event counter input / toggle output.
			CLKO	O	Frequency divider clock output pin.

Note: Pin Type I = Digital Input, O = Digital Output; AI = Analog Input; P = Power Pin; AP = Analog Power

4.3.2 NuMicro™ NUC240 Pin Description

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
1			PE.15	I/O	General purpose digital I/O pin.
2			PE.14	I/O	General purpose digital I/O pin.
3			PE.13	I/O	General purpose digital I/O pin.
4	1		PB.14	I/O	General purpose digital I/O pin.
			AD0	I/O	EBI Address/Data bus bit0
			INT0	I	External interrupt0 input pin.
			SPI3_SS1	I/O	2 nd SPI3 slave select pin.
5	2		PB.13	I/O	General purpose digital I/O pin.
			AD1	I/O	EBI Address/Data bus bit1
			ACMP1_O	O	Comparator1 output pin.
6	3	1	V _{BAT}	P	Power supply by batteries for RTC.
7	4	2	X32_OUT	O	External 32.768 kHz (low speed) crystal output pin.
8	5	3	X32_IN	I	External 32.768 kHz (low speed) crystal input pin.
9	6	4	PA.11	I/O	General purpose digital I/O pin.
			I2C1_SCL	I/O	I ² C1 clock pin.
			CAN1_RXD	I	Data receiver input pin for CAN1.
			nRD	O	EBI read enable output pin
10	7	5	PA.10	I/O	General purpose digital I/O pin.
			I2C1_SDA	I/O	I ² C1 data input/output pin.
			CAN1_TXD	O	Data transmitter output pin for CAN1.
			nWR	O	EBI write enable output pin
11	8	6	PA.9	I/O	General purpose digital I/O pin.
			I2C0_SCL	I/O	I ² C0 clock pin.
12	9	7	PA.8	I/O	General purpose digital I/O pin.
			I2C0_SDA	I/O	I ² C0 data input/output pin.
13			PD.8	I/O	General purpose digital I/O pin.
			SPI3_SS0	I/O	1 st SPI3 slave select pin.
14			PD.9	I/O	General purpose digital I/O pin.
			SPI3_CLK	I/O	SPI3 serial clock pin.
15			PD.10	I/O	General purpose digital I/O pin.
			SPI3_MISO0	I/O	1 st SPI3 MISO (Master In, Slave Out) pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
16			PD.11	I/O	General purpose digital I/O pin.
			SPI3_MOSI0	I/O	1 st SPI3 MOSI (Master Out, Slave In) pin.
17			PD.12	I/O	General purpose digital I/O pin.
			SPI3_MISO1	I/O	2 nd SPI3 MISO (Master In, Slave Out) pin.
18			PD.13	I/O	General purpose digital I/O pin.
			SPI3_MOSI1	I/O	2 nd SPI3 MOSI (Master Out, Slave In) pin.
19	10	8	PB.4	I/O	General purpose digital I/O pin.
			UART1_RXD	I	Data receiver input pin for UART1.
20	11	9	PB.5	I/O	General purpose digital I/O pin.
			UART1_TXD	O	Data transmitter output pin for UART1.
21	12		PB.6	I/O	General purpose digital I/O pin.
			ALE	O	EBI address latch enable output pin
			UART1_nRTS	O	Request to Send output pin for UART1.
22	13		PB.7	I/O	General purpose digital I/O pin.
			nCS	O	EBI chip select enable output pin
			UART1_nCTS	I	Clear to Send input pin for UART1.
23	14	10	LDO_CAP	P	LDO output pin.
24	15	11	V _{DD}	P	Power supply for I/O ports and LDO source for internal PLL and digital circuit.
25	16	12	V _{SS}	P	Ground pin for digital circuit.
26			PE.8	I/O	General purpose digital I/O pin.
27			PE.7	I/O	General purpose digital I/O pin.
28	17	13	USB_VBUS	USB	Power supply from USB host or HUB.
29	18	14	USB_V _{DD} 33_CAP	USB	Internal power regulator output 3.3V decoupling pin.
30	19	15	USB_D-	USB	USB differential signal D-.
31	20	16	USB_D+	USB	USB differential signal D+.
32	21	17	PB.0	I/O	General purpose digital I/O pin.
			UART0_RXD	I	Data receiver input pin for UART0.
33	22	18	PB.1	I/O	General purpose digital I/O pin.
			UART0_TXD	O	Data transmitter output pin for UART0.
34	23		PB.2	I/O	General purpose digital I/O pin.
			nWRL	O	EBI low byte write enable output pin
			UART0_nRTS	O	Request to Send output pin for UART0.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
			TM2_EXT	I	Timer2 external capture input pin.
			TM2	O	Timer2 toggle output pin.
			ACMP0_O	O	Comparator0 output pin.
35	24		PB.3	I/O	General purpose digital I/O pin.
			UART0_nCTS	I	Clear to Send input pin for UART0.
			nWRH	O	EBI high byte write enable output pin
			TM3_EXT	I	Timer3 external capture input pin.
			TM3	O	Timer3 toggle output pin.
			SC2_CD	I	SmartCard2 card detect pin.
36	25	19	PD.6	I/O	General purpose digital I/O pin.
			CAN0_RXD	I	Data receiver input pin for CAN0.
37	26	20	PD.7	I/O	General purpose digital I/O pin.
			CAN0_TXD	O	Data transmitter output pin for CAN0.
38	27		PD.14	I/O	General purpose digital I/O pin.
			UART2_RXD	I	Data receiver input pin for UART2.
			CAN1_RXD	I	Data receiver input pin for CAN1.
39	28		PD.15	I/O	General purpose digital I/O pin.
			UART2_TXD	O	Data transmitter output pin for UART2.
			CAN1_TXD	O	Data transmitter output pin for CAN1.
40			PC.5	I/O	General purpose digital I/O pin.
			SPI0_MOSI1	I/O	2 nd SPI0 MOSI (Master Out, Slave In) pin.
41			PC.4	I/O	General purpose digital I/O pin.
			SPI0_MISO1	I/O	2 nd SPI0 MISO (Master In, Slave Out) pin.
42	29	21	PC.3	I/O	General purpose digital I/O pin.
			SPI0_MOSI0	I/O	1 st SPI0 MOSI (Master Out, Slave In) pin.
			I2S_DO	O	I ² S data output.
43	30	22	PC.2	I/O	General purpose digital I/O pin.
			SPI0_MISO0	I/O	1 st SPI0 MISO (Master In, Slave Out) pin.
			I2S_DI	I	I ² S data input.
44	31	23	PC.1	I/O	General purpose digital I/O pin.
			SPI0_CLK	I/O	SPI0 serial clock pin.
			I2S_BCLK	I/O	I ² S bit clock pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
45	32	24	PC.0	I/O	General purpose digital I/O pin.
			SPI0_SS0	I/O	1 st SPI0 slave select pin.
			I2S_LRCLK	I/O	I ² S left right channel clock.
46			PE.6	I/O	General purpose digital I/O pin.
47			PE.5	I/O	General purpose digital I/O pin.
			PWM5	I/O	PWM5 output/Capture input.
			TM1_EXT	I	Timer1 external capture input pin.
			TM1	O	Timer1 toggle output pin.
48			PB.11	I/O	General purpose digital I/O pin.
			TM3	I/O	Timer3 event counter input / toggle output.
			PWM4	I/O	PWM4 output/Capture input.
49			PB.10	I/O	General purpose digital I/O pin.
			TM2	I/O	Timer2 event counter input / toggle output.
			SPI0_SS1	I/O	2 nd SPI0 slave select pin.
50			PB.9	I/O	General purpose digital I/O pin.
			TM1	I/O	Timer1 event counter input / toggle output.
			SPI1_SS1	I/O	2 nd SPI1 slave select pin.
51			PE.4	I/O	General purpose digital I/O pin.
52			PE.3	I/O	General purpose digital I/O pin.
53			PE.2	I/O	General purpose digital I/O pin.
54			PE.1	I/O	General purpose digital I/O pin.
			PWM7	I/O	PWM7 output/Capture input.
55			PE.0	I/O	General purpose digital I/O pin.
			PWM6	I/O	PWM6 output/Capture input.
56			PC.13	I/O	General purpose digital I/O pin.
			SPI1_MOSI1	I/O	2 nd SPI1 MOSI (Master Out, Slave In) pin.
57			PC.12	I/O	General purpose digital I/O pin.
			SPI1_MISO1	I/O	2 nd SPI1 MISO (Master In, Slave Out) pin.
58	33		PC.11	I/O	General purpose digital I/O pin.
			SPI1_MOSI0	I/O	1 st SPI1 MOSI (Master Out, Slave In) pin.
59	34		PC.10	I/O	General purpose digital I/O pin.
			SPI1_MISO0	I/O	1 st SPI1 MISO (Master In, Slave Out) pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
60	35		PC.9	I/O	General purpose digital I/O pin.
			SPI1_CLK	I/O	SPI1 serial clock pin.
61	36		PC.8	I/O	General purpose digital I/O pin.
			MCLK	O	EBI clock output
			SPI1_SS0	I/O	1 st SPI1 slave select pin.
62	37	25	PA.15	I/O	General purpose digital I/O pin.
			PWM3	I/O	PWM3 output/Capture input.
			I2S_MCLK	O	I ² S master clock output pin.
			SC2_PWR	O	SmartCard2 power pin.
63	38	26	PA.14	I/O	General purpose digital I/O pin.
			PWM2	I/O	PWM2 output/Capture input.
			AD15	I/O	EBI Address/Data bus bit15
			SC2_RST	O	SmartCard2 reset pin.
64	39	27	PA.13	I/O	General purpose digital I/O pin.
			PWM1	I/O	PWM1 output/Capture input.
			AD14	I/O	EBI Address/Data bus bit14
			SC2_CLK	O	SmartCard2 clock pin.
		27	UART5_TXD	O	Data transmitter output pin for UART5.
65	40	28	PA.12	I/O	General purpose digital I/O pin.
			PWM0	I/O	PWM0 output/Capture input.
			AD13	I/O	EBI Address/Data bus bit13
			SC2_DAT	O	SmartCard2 data pin.
		28	UART5_RXD	I	Data receiver input pin for UART5.
66	41	29	ICE_DAT	I/O	Serial wire debugger data pin.
67	42	30	ICE_CLK	I	Serial wire debugger clock pin.
68			V _{DD}	P	Power supply for I/O ports and LDO source for internal PLL and digital circuit.
69			V _{SS}	P	Ground pin for digital circuit.
70	43	31	AV _{SS}	AP	Ground pin for analog circuit.
71	44	32	PA.0	I/O	General purpose digital I/O pin.
			ADC0	AI	ADC0 analog input.
			SC0_PWR	O	SmartCard0 power pin.
72	45	33	PA.1	I/O	General purpose digital I/O pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
			ADC1	AI	ADC1 analog input.
			SC0_RST	O	SmartCard0 reset pin.
			AD12	I/O	EBI Address/Data bus bit12
73	46	34	PA.2	I/O	General purpose digital I/O pin.
			ADC2	AI	ADC2 analog input.
			SC0_CLK	O	SmartCard0 clock pin.
			UART3_TXD	O	Data transmitter output pin for UART3.
			AD11	I/O	EBI Address/Data bus bit11
74	47	35	PA.3	I/O	General purpose digital I/O pin.
			ADC3	AI	ADC3 analog input.
			SC0_DAT	O	SmartCard0 data pin.
			UART3_RXD	I	Data receiver input pin for UART3.
			AD10	I/O	EBI Address/Data bus bit10
75	48	36	PA.4	I/O	General purpose digital I/O pin.
			ADC4	AI	ADC4 analog input.
			AD9	I/O	EBI Address/Data bus bit9
			SC1_PWR	O	SmartCard1 power pin.
76	49	37	PA.5	I/O	General purpose digital I/O pin.
			ADC5	AI	ADC5 analog input.
			AD8	I/O	EBI Address/Data bus bit8
			SC1_RST	O	SmartCard1 reset pin.
77	50	38	PA.6	I/O	General purpose digital I/O pin.
			ADC6	AI	ADC6 analog input.
			AD7	I/O	EBI Address/Data bus bit7
			SC1_CLK	I/O	SmartCard1 clock pin.
			UART4_TXD	O	Data transmitter output pin for UART4.
78			PA.7	I/O	General purpose digital I/O pin.
			ADC7	AI	ADC7 analog input.
			AD6	I/O	EBI Address/Data bus bit6
			SC1_DAT	O	SmartCard1 data pin.
			UART4_RXD	I	Data receiver input pin for UART4.
			SPI2_SS1	I/O	2 nd SPI2 slave select pin.

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
79	51	39	V _{REF}	AP	Voltage reference input for ADC.
80	52	40	AV _{DD}	AP	Power supply for internal analog circuit.
81			PD.0	I/O	General purpose digital I/O pin.
			SPI2_SS0	I/O	1 st SPI2 slave select pin.
82			PD.1	I/O	General purpose digital I/O pin.
			SPI2_CLK	I/O	SPI2 serial clock pin.
83			PD.2	I/O	General purpose digital I/O pin.
			SPI2_MISO0	I/O	1 st SPI2 MISO (Master In, Slave Out) pin.
84			PD.3	I/O	General purpose digital I/O pin.
			SPI2_MOSI0	I/O	1 st SPI2 MOSI (Master Out, Slave In) pin.
85			PD.4	I/O	General purpose digital I/O pin.
			SPI2_MISO1	I/O	2 nd SPI2 MISO (Master In, Slave Out) pin.
86			PD.5	I/O	General purpose digital I/O pin.
			SPI2_MOSI1	I/O	2 nd SPI2 MOSI (Master Out, Slave In) pin.
87	53	41	PC.7	I/O	General purpose digital I/O pin.
			ACMP0_N	AI	Comparator0 negative input pin.
			AD5	I/O	EBI Address/Data bus bit5
			SC1_CD	I	SmartCard1 card detect pin.
88	54	42	PC.6	I/O	General purpose digital I/O pin.
			ACMP0_P	AI	Comparator0 positive input pin.
			SC0_CD	I	SmartCard0 card detect pin.
			AD4	I/O	EBI Address/Data bus bit4
89	55		PC.15	I/O	General purpose digital I/O pin.
			AD3	I/O	EBI Address/Data bus bit3
			ACMP1_N	AI	Comparator1 negative input pin.
90	56		PC.14	I/O	General purpose digital I/O pin.
			AD2	I/O	EBI Address/Data bus bit2
			ACMP1_P	AI	Comparator1 positive input pin.
91	57	43	PB.15	I/O	General purpose digital I/O pin.
			INT1	I	External interrupt1 input pin.
			TM0_EXT	I	Timer 0 external capture input pin.
			TM0	O	Timer0 toggle output pin.
			AD6	I/O	EBI Address/Data bus bit6

Pin No.			Pin Name	Pin Type	Description
LQFP 100-pin	LQFP 64-pin	LQFP 48-pin			
92	58	44	PF.0	I/O	General purpose digital I/O pin.
			XT1_OUT	O	External 4~24 MHz (high speed) crystal output pin.
93	59	45	PF.1	I/O	General purpose digital I/O pin.
			XT1_IN	I	External 4~24 MHz (high speed) crystal input pin.
94	60	46	nRESET	I	External reset input: active LOW, with an internal pull-up. Set this pin low reset chip to initial state.
95	61		V _{SS}	P	Ground pin for digital circuit.
96	62		V _{DD}	P	Power supply for I/O ports and LDO source for internal PLL and digital circuit.
97			PF.2	I/O	General purpose digital I/O pin.
			PS2_DAT	I/O	PS/2 data pin.
98			PF.3	I/O	General purpose digital I/O pin.
			PS2_CLK	I/O	PS/2 clock pin.
99	63	47	PV _{SS}	P	PLL ground.
100	64	48	PB.8	I/O	General purpose digital I/O pin.
			STADC	I	ADC external trigger input.
			TM0	I/O	Timer0 event counter input / toggle output.
			CLKO	O	Frequency divider clock output pin.

Note: Pin Type I = Digital Input, O = Digital Output; AI = Analog Input; P = Power Pin; AP = Analog Power

5 BLOCK DIAGRAM

5.1 NuMicro™ NUC230 Block Diagram

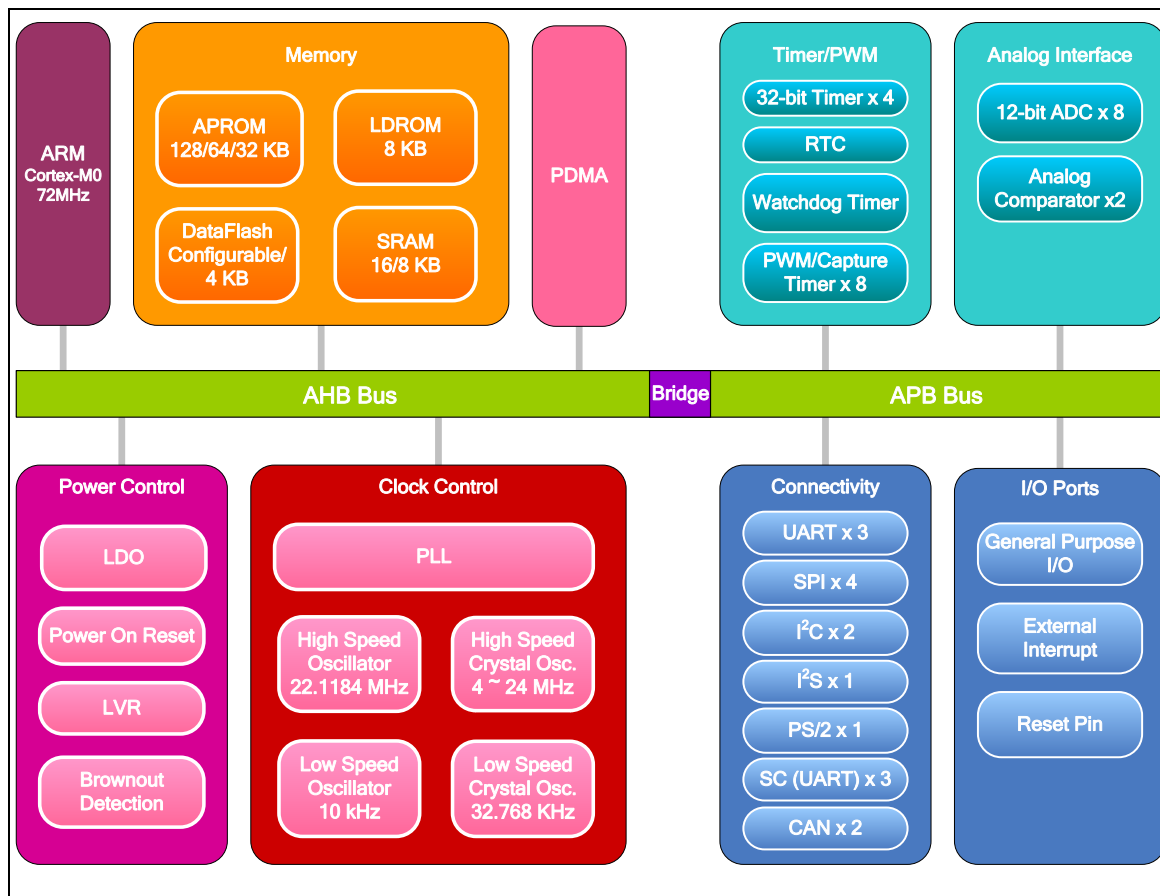


Figure 5-1 NuMicro™ NUC230 Block Diagram

5.2 NuMicro™ NUC240 Block Diagram

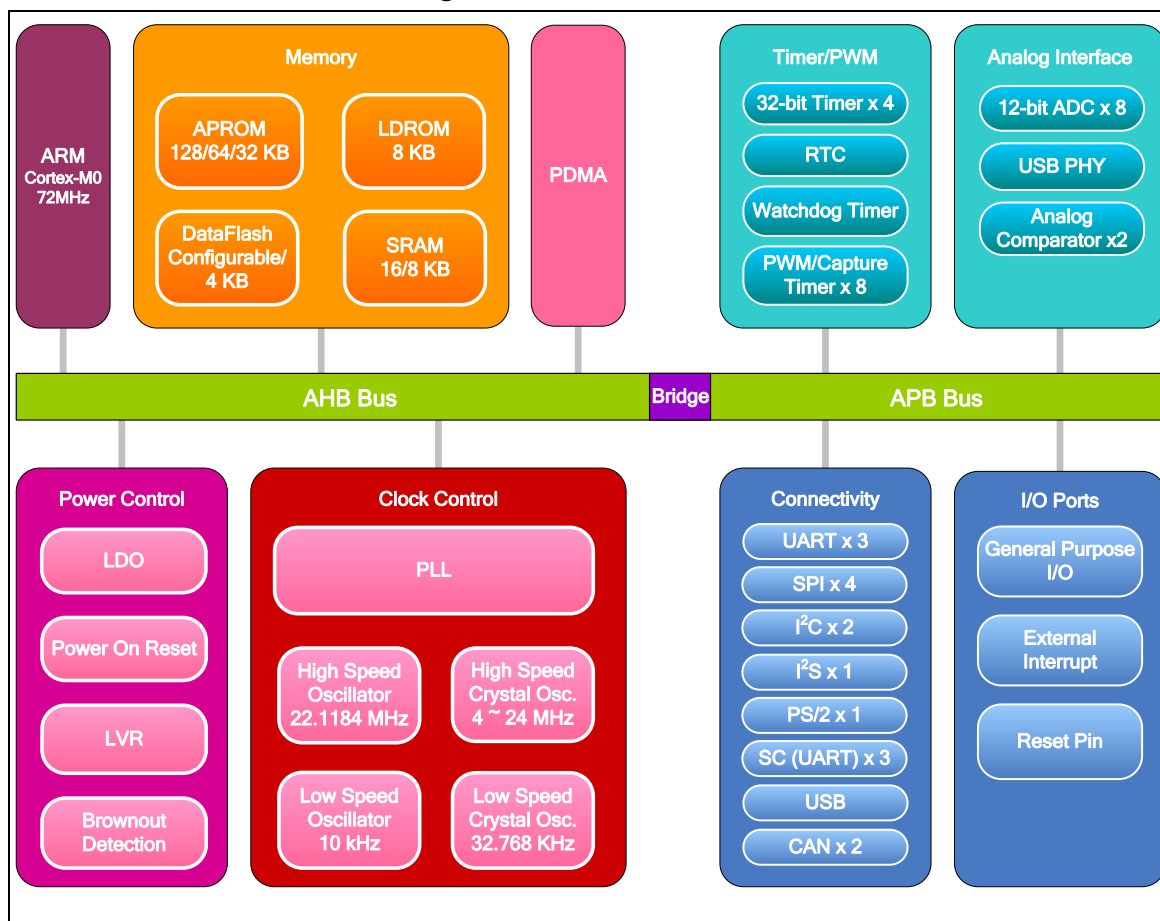


Figure 5-2 NuMicro™ NUC240 Block Diagram

6 FUNCTIONAL DESCRIPTION

6.1 ARM® Cortex™-M0 Core

The Cortex™-M0 processor is a configurable, multistage, 32-bit RISC processor, which has an AMBA AHB-Lite interface and includes an NVIC component. It also has optional hardware debug functionality. The processor can execute Thumb code and is compatible with other Cortex™-M profile processor. The profile supports two modes -Thread mode and Handler mode. Handler mode is entered as a result of an exception. An exception return can only be issued in Handler mode. Thread mode is entered on Reset, and can be entered as a result of an exception return.

Figure 6-1 shows the functional controller of processor.

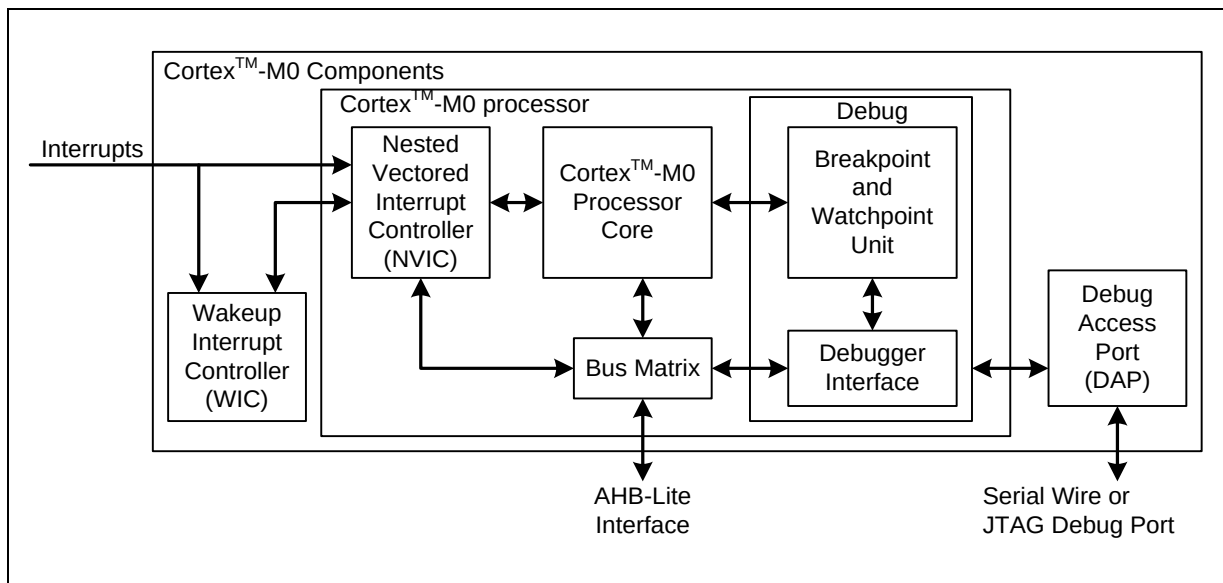


Figure 6-1 Functional Controller Diagram

The implemented device provides the following components and features:

- A low gate count processor:
 - ARMv6-M Thumb® instruction set
 - Thumb-2 technology
 - ARMv6-M compliant 24-bit SysTick timer
 - A 32-bit hardware multiplier
 - System interface supported with little-endian data accesses
 - Ability to have deterministic, fixed-latency, interrupt handling
 - Load/store-multiples and multicycle-multiplies that can be abandoned and restarted to facilitate rapid interrupt handling
 - C Application Binary Interface compliant exception model. This is the ARMv6-M, C Application Binary Interface (C-ABI) compliant exception model that enables the use of pure C functions as interrupt handlers
 - Low Power Sleep mode entry using Wait For Interrupt (WFI), Wait For Event (WFE) instructions, or the return from interrupt sleep-on-exit feature

- NVIC:
 - 32 external interrupt inputs, each with four levels of priority
 - Dedicated Non-maskable Interrupt (NMI) input
 - Supports for both level-sensitive and pulse-sensitive interrupt lines
 - Supports Wake-up Interrupt Controller (WIC) and, providing Ultra-low Power Sleep mode
- Debug support
 - Four hardware breakpoints
 - Two watchpoints
 - Program Counter Sampling Register (PCSR) for non-intrusive code profiling
 - Single step and vector catch capabilities
- Bus interfaces:
 - Single 32-bit AMBA-3 AHB-Lite system interface that provides simple integration to all system peripherals and memory
 - Single 32-bit slave port that supports the DAP (Debug Access Port)

6.2 System Manager

6.2.1 Overview

System management includes the following sections:

- System Resets
- System Memory Map
- System management registers for Part Number ID, chip reset and on-chip controllers reset , multi-functional pin control
- System Timer (SysTick)
- Nested Vectored Interrupt Controller (NVIC)
- System Control registers

6.2.2 System Reset

The system reset can be issued by one of the following listed events. For these reset event flags can be read by RSTSRC register.

- Power-on Reset
- Low level on the nRESET pin
- Watchdog Time-out Reset
- Low Voltage Reset
- Brown-out Detector Reset
- CPU Reset
- System Reset

System Reset and Power-on Reset all reset the whole chip including all peripherals. The difference between System Reset and Power-on Reset is external crystal circuit and BS(ISPCON[1]) bit. System Reset does not reset external crystal circuit and BS(ISPCON[1]) bit, but Power-on Reset does.

6.2.3 System Power Distribution

In this chip, the power distribution is divided into three segments.

- Analog power from AV_{DD} and AV_{SS} provides the power for analog components operation.
- Digital power from V_{DD} and V_{SS} supplies the power to the internal regulator which provides a fixed 1.8 V power for digital operation and I/O pins.
- USB transceiver power from V_{BUS} offers the power for operating the USB transceiver.
- Battery power from V_{BAT} supplies the RTC and external 32.768 kHz crystal.

The outputs of internal voltage regulators, LDO and V_{DD33} , require an external capacitor which should be located close to the corresponding pin. Analog power (AV_{DD}) should be the same voltage level with the digital power (V_{DD}). 錯誤! 找不到參照來源。 Figure 6-2 shows the NuMicro™ NUC230 power distribution, and Figure 6-3 shows the NuMicro™ NUC240 power distribution.

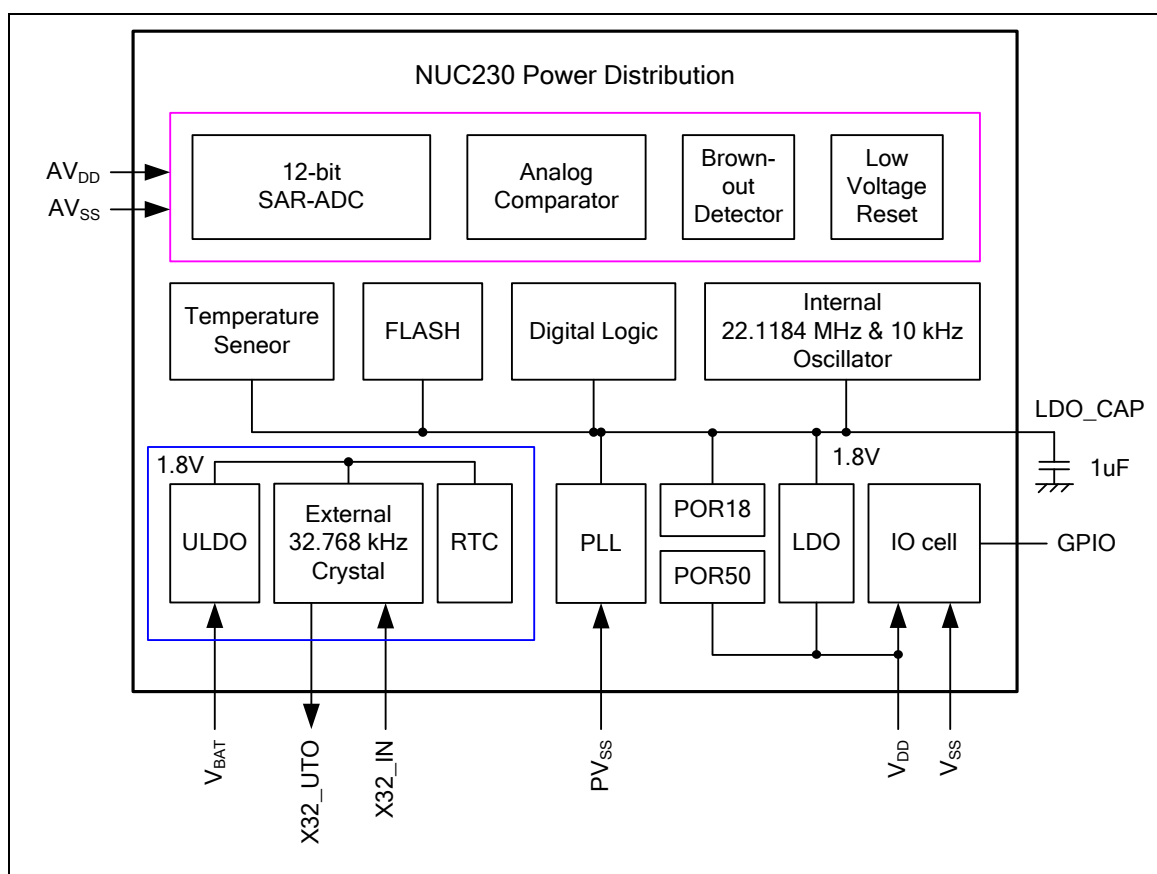


Figure 6-2 NuMicro™ NUC230 Power Distribution Diagram

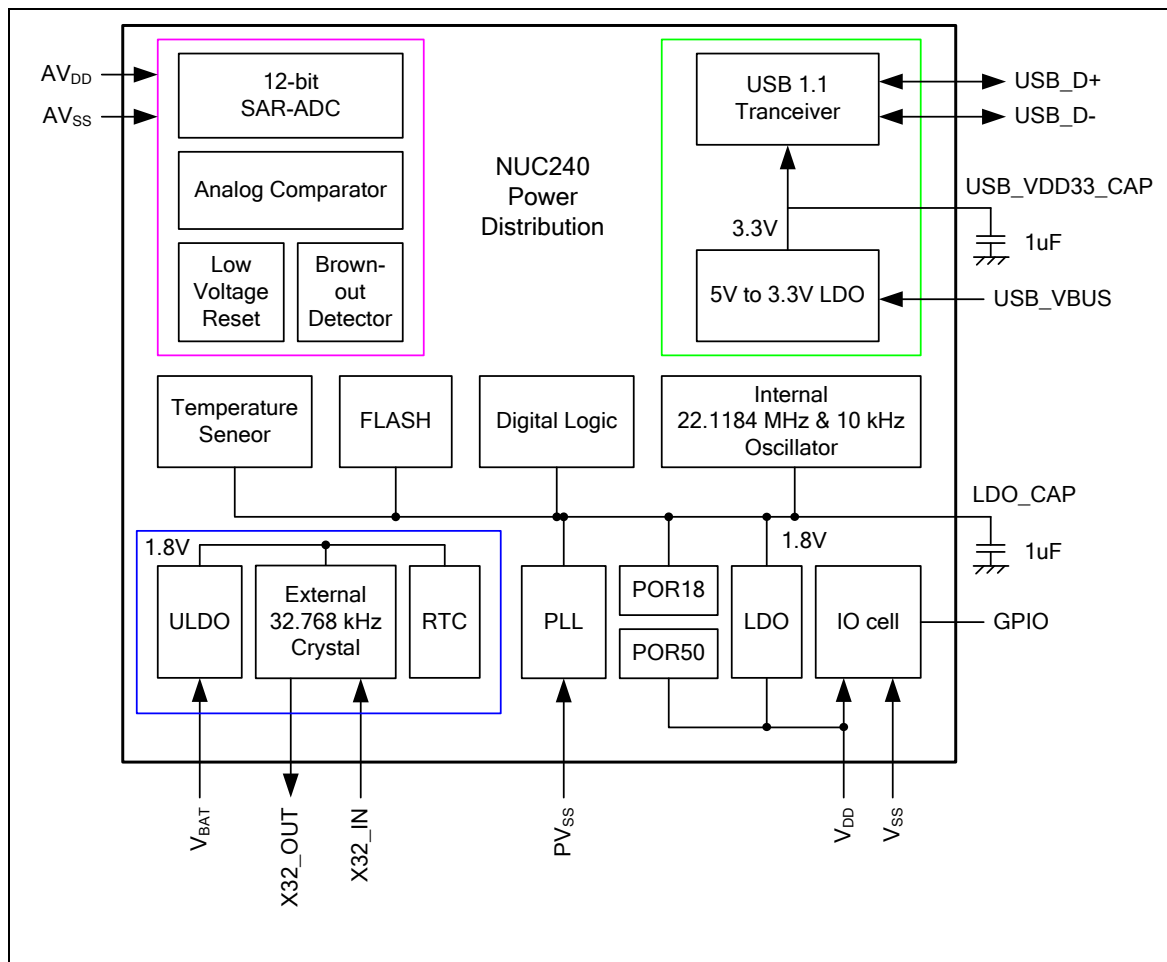


Figure 6-3 NuMicro™ NUC240 Power Distribution Diagram

6.2.4 System Memory Map

The NuMicro™ NUC230/240 series provides 4G-byte addressing space. The memory locations assigned to each on-chip controllers are shown in the following table. The detailed register definition, memory space, and programming detailed will be described in the following sections for each on-chip peripheral. The NuMicro™ NUC230/240 series only supports little-endian data format.

Address Space	Token	Controllers
Flash and SRAM Memory Space		
0x0000_0000 – 0x0001_FFFF	FLASH_BA	FLASH Memory Space (128 KB)
0x2000_0000 – 0x2000_3FFF	SRAM_BA	SRAM Memory Space (16 KB)
AHB Controllers Space (0x5000_0000 – 0x501F_FFFF)		
0x5000_0000 – 0x5000_01FF	GCR_BA	System Global Control Registers
0x5000_0200 – 0x5000_02FF	CLK_BA	Clock Control Registers
0x5000_0300 – 0x5000_03FF	INT_BA	Interrupt Multiplexer Control Registers
0x5000_4000 – 0x5000_7FFF	GPIO_BA	GPIO Control Registers
0x5000_8000 – 0x5000_BFFF	PDMA_BA	Peripheral DMA Control Registers
0x5000_C000 – 0x5000_FFFF	FMC_BA	Flash Memory Control Registers
0x5001_0000 – 0x5001_03FF	EBI_BA	External Bus Interface Control Registers
APB1 Controllers Space (0x4000_0000 ~ 0x400F_FFFF)		
0x4000_4000 – 0x4000_7FFF	WDT_BA	Watchdog Timer Control Registers
0x4000_8000 – 0x4000_BFFF	RTC_BA	Real Time Clock (RTC) Control Register
0x4001_0000 – 0x4001_3FFF	TMR01_BA	Timer0/Timer1 Control Registers
0x4002_0000 – 0x4002_3FFF	I2C0_BA	I ² C0 Interface Control Registers
0x4003_0000 – 0x4003_3FFF	SPI0_BA	SPI0 with master/slave function Control Registers
0x4003_4000 – 0x4003_7FFF	SPI1_BA	SPI1 with master/slave function Control Registers
0x4004_0000 – 0x4004_3FFF	PWMA_BA	PWM0/1/2/3 Control Registers
0x4005_0000 – 0x4005_3FFF	UART0_BA	UART0 Control Registers
0x4006_0000 – 0x4006_3FFF	USB_D_BA	USB 2.0 FS device Controller Registers
0x400D_0000 – 0x400D_3FFF	ACMP_BA	Analog Comparator Control Registers
0x400E_0000 – 0x400E_FFFF	ADC_BA	Analog-Digital-Converter (ADC) Control Registers
APB2 Controllers Space (0x4010_0000 ~ 0x401F_FFFF)		
0x4010_0000 – 0x4010_3FFF	PS2_BA	PS/2 Interface Control Registers
0x4011_0000 – 0x4011_3FFF	TMR23_BA	Timer2/Timer3 Control Registers
0x4012_0000 – 0x4012_3FFF	I2C1_BA	I ² C1 Interface Control Registers
0x4013_0000 – 0x4013_3FFF	SPI2_BA	SPI2 with master/slave function Control Registers
0x4013_4000 – 0x4013_7FFF	SPI3_BA	SPI3 with master/slave function Control Registers

0x4014_0000 – 0x4014_3FFF	PWMB_BA	PWM4/5/6/7 Control Registers
0x4015_0000 – 0x4015_3FFF	UART1_BA	UART1 Control Registers
0x4015_4000 – 0x4015_7FFF	UART2_BA	UART2 Control Registers
0x4018_0000 – 0x4018_3FFF	CAN0_BA	CAN0 Bus Control Registers
0x4018_4000 – 0x4018_7FFF	CAN1_BA	CAN1 Bus Control Registers
0x4019_0000 – 0x4019_3FFF	SC0_BA	SC0 Control Registers
0x4019_4000 – 0x4019_7FFF	SC1_BA	SC1 Control Registers
0x4019_8000 – 0x4019_BFFF	SC2_BA	SC2 Control Registers
0x401A_0000 – 0x401A_3FFF	I2S_BA	I ² S Interface Control Registers
System Controllers Space (0xE000_E000 ~ 0xE000_EFFF)		
0xE000_E010 – 0xE000_E0FF	SCS_BA	System Timer Control Registers
0xE000_E100 – 0xE000_ECFF	SCS_BA	External Interrupt Controller Control Registers
0xE000_ED00 – 0xE000_ED8F	SCS_BA	System Control Registers

Table 6-1 Address Space Assignments for On-Chip Controllers

6.2.5 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
GCR Base Address: GCR_BA = 0x5000_0000				
PDID	GCR_BA+0x00	R	Part Device Identification Number Register	0x2014_0018 ^[1]
RSTSRC	GCR_BA+0x04	R/W	System Reset Source Register	0x0000_00XX
IPRSTC1	GCR_BA+0x08	R/W	Peripheral Reset Control Register 1	0x0000_0000
IPRSTC2	GCR_BA+0x0C	R/W	Peripheral Reset Control Register 2	0x0000_0000
IPRSTC3	GCR_BA+0x10	R/W	Peripheral Reset Control Register 3	0x0000_0000
BODCR	GCR_BA+0x18	R/W	Brown-out Detector Control Register	0x0000_008X
TEMPCR	GCR_BA+0x1C	R/W	Temperature Sensor Control Register	0x0000_0000
PORCR	GCR_BA+0x24	R/W	Power-on-Reset Controller Register	0x0000_XXXX
GPA_MFP	GCR_BA+0x30	R/W	GPIOA Multiple Function and Input Type Control Register	0x0000_0000
GPB_MFP	GCR_BA+0x34	R/W	GPIOB Multiple Function and Input Type Control Register	0x0000_0000
GPC_MFP	GCR_BA+0x38	R/W	GPIOC Multiple Function and Input Type Control Register	0x0000_0000
GPD_MFP	GCR_BA+0x3C	R/W	GPIOD Multiple Function and Input Type Control Register	0x0000_0000
GPE_MFP	GCR_BA+0x40	R/W	GPIOE Multiple Function and Input Type Control Register	0x0000_0000
GPF_MFP	GCR_BA+0x44	R/W	GPIOF Multiple Function and Input Type Control Register	0x0000_000X
ALT_MFP	GCR_BA+0x50	R/W	Alternative Multiple Function Pin Control Register	0x0000_0000
ALT_MFP1	GCR_BA+0x58	R/W	Alternative Multiple Function Pin Control Register 1	0x0000_0000
ALT_MFP2	GCR_BA+0x5C	R/W	Alternative Multiple Function Pin Control Register 2	0x0000_0000
IRCTRMCTL	GCR_BA+0x80	R/W	IRC Trim Control Register	0x0000_0000
IRCTRMIEN	GCR_BA+0x84	R/W	IRC Trim Interrupt Enable Register	0x0000_0000
IRCTRIMINT	GCR_BA+0x88	R/W	IRC Trim Interrupt Status Register	0x0000_0000
REGWRPROT	GCR_BA+0x100	R/W	Register Write Protection Register	0x0000_0000

Note: [1] It depends on the part number.

6.2.6 Register Description

Part Device ID Code Register (PDID)

Register	Offset	R/W	Description	Reset Value
PDID	GCR_BA+0x00	R	Part Device Identification Number Register	0x2014_0018 ^[1]

[1] Each part number has a unique default reset value.

31	30	29	28	27	26	25	24
PDID[31:24]							
23	22	21	20	19	18	17	16
PDID[23:16]							
15	14	13	12	11	10	9	8
PDID[15:8]							
7	6	5	4	3	2	1	0
PDID[7:0]							

Bits	Description
[31:0]	PDID Part Device Identification Number This register reflects device part number code. Software can read this register to identify which device is used.

System Reset Source Register (RSTSRC)

This register provides specific information for software to identify this chip's reset source from last operation.

Register	Offset	R/W	Description	Reset Value
RSTSRC	GCR_BA+0x04	R/W	System Reset Source Register	0x0000_00XX

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
RSTS_CPU	Reserved	RSTS_SYS	RSTS_BOD	RSTS_LVR	RSTS_WDT	RSTS_RESET	RSTS_POR

Bits	Description
[31:8]	Reserved Reserved.
[7]	RSTS_CPU CPU Reset Flag The RSTS_CPU flag is set by hardware if software writes CPU_RST (IPRSTC1[1]) 1 To reset Cortex™-M0 kernel and flash memory controller (FMC). 0 = No reset from CPU. 1 = Cortex™-M0 CPU kernel and FMC are reset by software setting CPU_RST(IPRSTC1[1]) to 1. Note: Write 1 to clear this bit to 0.
[6]	Reserved Reserved.
[5]	RSTS_SYS SYS Reset Flag The RSTS_SYS flag is set by the "Reset Signal" from the Cortex™-M0 kernel to indicate the previous reset source. 0 = No reset from Cortex™-M0. 1 = The Cortex™-M0 had issued the reset signal to reset the system by writing 1 to bit SYSRESETREQ (AIRC[2], Application Interrupt and Reset Control Register, address = 0xE00ED0C) in system control registers of Cortex™-M0 kernel. Note: Write 1 to clear this bit to 0.
[4]	RSTS_BOD Brown-Out Detector Reset Flag The RSTS_BOD flag is set by the "Reset Signal" from the Brown-Out Detector to indicate the previous reset source. 0 = No reset from BOD. 1 = The BOD had issued the reset signal to reset the system. Note: Write 1 to clear this bit to 0.
[3]	RSTS_LVR Low Voltage Reset Flag The RSTS_LVR flag is set by the "Reset Signal" from the Low-Voltage-Reset controller to indicate the previous reset source.

		0 = No reset from LVR. 1 = The LVR controller had issued the reset signal to reset the system. Note: Write 1 to clear this bit to 0.
[2]	RSTS_WDT	Watchdog Timer Reset Flag The RSTS_WDT flag is set by the "Reset Signal" from the watchdog timer or window watchdog timer to indicate the previous reset source. 0 = No reset from watchdog timer or window watchdog timer. 1 = The watchdog timer or window watchdog timer had issued the reset signal to reset the system. Note1: Write 1 to clear this bit to 0. Note2: Watchdog Timer register WTRF(WTCR[2]) bit is set if the system has been reset by WDT time-out reset. Window Watchdog Timer register WWDTRF(WWDTSR) bit is set if the system has been reset by WWDT time-out reset.
[1]	RSTS_RESET	Reset Pin Reset Flag The RSTS_RESET flag is set by the "Reset Signal" from the nRESET Pin to indicate the previous reset source 0 = No reset from nRESET pin. 1 = The Pin nRESET had issued the reset signal to reset the system. Note: Write 1 to clear this bit to 0.
[0]	RSTS_POR	Power-On Reset Flag The RSTS_POR Flag is set by the "Reset Signal" from the Power-On Reset (POR) controller or bit CHIP_RST (IPRSTC1[0]) to indicate the previous reset source 0 = No reset from POR or CHIP_RST (IPRSTC1[0]). 1 = Power-on Reset (POR) or CHIP_RST (IPRSTC1[0]) had issued the reset signal to reset the system. Note: Write 1 to clear this bit to 0.

Peripheral Reset Control Register 1 (IPRSTC1)

Register	Offset	R/W	Description	Reset Value
IPRSTC1	GCR_BA+0x08	R/W	Peripheral Reset Control Register 1	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				EBI_RST	PDMA_RST	CPU_RST	CHIP_RST

Bits	Description
[31:4]	Reserved Reserved.
[3]	EBI_RST EBI Controller Reset (Write-protection Bit) Set this bit to 1 will generate a reset signal to the EBI. User need to set this bit to 0 to release from the reset state. This bit is the protected bit, It means programming this bit needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100 1 = EBI controller reset 0 = EBI controller normal operation
[2]	PDMA_RST PDMA Controller Reset (Write Protect) Setting this bit to 1 will generate a reset signal to the PDMA. User needs to set this bit to 0 to release from reset state. 0 = PDMA controller normal operation. 1 = PDMA controller reset. Note1: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100. Note2: Setting PDMA_RST bit to 1 will generate asynchronous reset signal to PDMA module. Users need to set PDMA_RST to 0 to release PDMA module from reset state.
[1]	CPU_RST CPU Kernel One-Shot Reset (Write Protect) Setting this bit will only reset the CPU kernel and Flash Memory Controller(FMC), and this bit will automatically return 0 after the two clock cycles 0 = CPU normal operation. 1 = CPU one-shot reset. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[0]	CHIP_RST CHIP One-Shot Reset (Write Protect) Setting this bit will reset the whole chip, including CPU kernel and all peripherals, and this bit will automatically return to 0 after the 2 clock cycles.

		The CHIP_RST is the same as the POR reset, all the chip controllers are reset and the chip setting from flash are also reload. For the difference between CHIP_RST and SYSRESETREQ, please refer to section 5.2.2 0 = CHIP normal operation. 1 = CHIP one-shot reset. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.

Peripheral Reset Control Register 2 (IPRSTC2)

Setting these bits to 1 will generate asynchronous reset signals to the corresponding module. User needs to set these bits to 0 to release the corresponding module from reset state.

Register	Offset	R/W	Description	Reset Value
IPRSTC2	GCR_BA+0x0C	R/W	Peripheral Reset Control Register 2	0x0000_0000

31	30	29	28	27	26	25	24
Reserved		I2S_RST	ADC_RST	USBD_RST	Reserved	CAN1_RST	CAN0_RST
23	22	21	20	19	18	17	16
PS2_RST	ACMP_RST	PWM47_RST	PWM03_RST	Reserved	UART2_RST	UART1_RST	UART0_RST
15	14	13	12	11	10	9	8
SPI3_RST	SPI2_RST	SPI1_RST	SPI0_RST	Reserved		I2C1_RST	I2C0_RST
7	6	5	4	3	2	1	0
Reserved		TMR3_RST	TMR2_RST	TMR1_RST	TMR0_RST	GPIO_RST	Reserved

Bits	Description	
[31:30]	Reserved	Reserved.
[29]	I2S_RST	I²S Controller Reset 0 = I ² S controller normal operation. 1 = I ² S controller reset.
[28]	ADC_RST	ADC Controller Reset 0 = ADC controller normal operation. 1 = ADC controller reset.
[27]	USBD_RST	USB Device Controller Reset 0 = USB device controller normal operation. 1 = USB device controller reset.
[26]	Reserved	Reserved.
[25]	CAN1_RST	CAN1 Controller Reset 0 = CAN1 controller normal operation. 1 = CAN1 controller reset.
[24]	CAN0_RST	CAN0 Controller Reset 0 = CAN0 controller normal operation. 1 = CAN0 controller reset.
[23]	PS2_RST	PS/2 Controller Reset 0 = PS/2 controller normal operation. 1 = PS/2 controller reset.
[22]	ACMP_RST	Analog Comparator Controller Reset 0 = Analog Comparator controller normal operation. 1 = Analog Comparator controller reset.

[21]	PWM47_RST	PWM47 Controller Reset 0 = PWM47 controller normal operation. 1 = PWM47 controller reset.
[20]	PWM03_RST	PWM03 Controller Reset 0 = PWM03 controller normal operation. 1 = PWM03 controller reset.
[19]	Reserved	Reserved.
[18]	UART2_RST	UART2 Controller Reset 0 = UART2 controller normal operation. 1 = UART2 controller reset.
[17]	UART1_RST	UART1 Controller Reset 0 = UART1 controller normal operation. 1 = UART1 controller reset.
[16]	UART0_RST	UART0 Controller Reset 0 = UART0 controller normal operation. 1 = UART0 controller reset.
[15]	SPI3_RST	SPI3 Controller Reset 0 = SPI3 controller normal operation. 1 = SPI3 controller reset.
[14]	SPI2_RST	SPI2 Controller Reset 0 = SPI2 controller normal operation. 1 = SPI2 controller reset.
[13]	SPI1_RST	SPI1 Controller Reset 0 = SPI1 controller normal operation. 1 = SPI1 controller reset.
[12]	SPI0_RST	SPI0 Controller Reset 0 = SPI0 controller normal operation. 1 = SPI0 controller reset.
[11:10]	Reserved	Reserved.
[9]	I2C1_RST	I²C1 Controller Reset 0 = I ² C1 controller normal operation. 1 = I ² C1 controller reset.
[8]	I2C0_RST	I²C0 Controller Reset 0 = I ² C0 controller normal operation. 1 = I ² C0 controller reset.
[7:6]	Reserved	Reserved.
[5]	TMR3_RST	Timer3 Controller Reset 0 = Timer3 controller normal operation. 1 = Timer3 controller reset.
[4]	TMR2_RST	Timer2 Controller Reset 0 = Timer2 controller normal operation. 1 = Timer2 controller reset.
[3]	TMR1_RST	Timer1 Controller Reset

		0 = Timer1 controller normal operation. 1 = Timer1 controller reset.
[2]	TMR0_RST	Timer0 Controller Reset 0 = Timer0 controller normal operation. 1 = Timer0 controller reset.
[1]	GPIO_RST	GPIO Controller Reset 0 = GPIO controller normal operation. 1 = GPIO controller reset.
[0]	Reserved	Reserved.

Peripheral Reset Control Register 3 (IPRSTC3)

Setting these bits to 1 will generate asynchronous reset signals to the corresponding module. User needs to set these bits to 0 to release corresponding module from reset state.

Register	Offset	R/W	Description	Reset Value
IPRSTC3	GCR_BA+0x10	R/W	Peripheral Reset Control Register 3	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					SC2_RST	SC1_RST	SC0_RST

Bits	Description	
[31:3]	Reserved	Reserved.
[2]	SC2_RST	SC2 Controller Reset 0 = SC2 controller normal operation. 1 = SC2 controller reset.
[1]	SC1_RST	SC1 Controller Reset 0 = SC1 controller normal operation. 1 = SC1 controller reset.
[0]	SC0_RST	SC0 Controller Reset 0 = SC0 controller normal operation. 1 = SC0 controller reset.

Brown-out Detector Control Register (BODCR)

Partial of the BODCR control registers values are initiated by the flash configuration and partial bits are write-protected bit. Programming write-protected bits needs to write “59h”, “16h”, “88h” to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.

Register	Offset	R/W	Description	Reset Value
BODCR	GCR_BA+0x18	R/W	Brown-out Detector Control Register	0x0000_008X

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
LVR_EN	BOD_OUT	BOD_LPM	BOD_INTF	BOD_RSTEN	BOD_VL		BOD_EN

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	LVR_EN	Low Voltage Reset Enable Bit (Write Protect) The LVR function reset the chip when the input power voltage is lower than LVR circuit setting. LVR function is enabled by default. 0 = Low Voltage Reset function Disabled. 1 = Low Voltage Reset function Enabled – After enabling the bit, the LVR function will be active with 100us delay for LVR output stable (default). Note: This bit is the protected bit, and programming it needs to write “59h”, “16h”, and “88h” to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[6]	BOD_OUT	Brown-Out Detector Output Status 0 = Brown-out Detector output status is 0. It means the detected voltage is higher than BOD_VL setting or BOD_EN is 0. 1 = Brown-out Detector output status is 1. It means the detected voltage is lower than BOD_VL setting. If the BOD_EN is 0, BOD function disabled, this bit always responds to 0.
[5]	BOD_LPM	Brown-Out Detector Low Power Mode (Write Protect) 0 = BOD operated in Normal mode (default). 1 = BOD Low Power mode Enabled. Note1: The BOD consumes about 100 uA in Normal mode, and the low power mode can reduce the current to about 1/10 but slow the BOD response. Note2: This bit is the protected bit, and programming it needs to write “59h”, “16h”, and “88h” to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[4]	BOD_INTF	Brown-Out Detector Interrupt Flag 0 = Brown-out Detector does not detect any voltage draft at V _{DD} down through or up through the voltage of BOD_VL setting.

		1 = When Brown-out Detector detects the V_{DD} is dropped down through the voltage of BOD_VL setting or the V_{DD} is raised up through the voltage of BOD_VL setting, this bit is set to 1 and the Brown-out interrupt is requested if Brown-out interrupt is enabled. Note: Write 1 to clear this bit to 0.
[3]	BOD_RSTEN	Brown-Out Reset Enable Bit (Write Protect) 0 = Brown-out "INTERRUPT" function Enabled. 1 = Brown-out "RESET" function Enabled. While the Brown-out Detector function is enabled (BOD_EN high) and BOD reset function is enabled (BOD_RSTEN high), BOD will assert a signal to reset chip when the detected voltage is lower than the threshold (BOD_OUT high). Note1: While the BOD function is enabled (BOD_EN high) and BOD interrupt function is enabled (BOD_RSTEN low), BOD will assert an interrupt if BOD_OUT is high. BOD interrupt will keep till to the BOD_EN set to 0. BOD interrupt can be blocked by disabling the NVIC BOD interrupt or disabling BOD function (set BOD_EN low). Note2: The default value is set by flash controller user configuration register CBORST(CONFIG0[20]) bit. Note3: This bit is the protected bit. It means programming this needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[2:1]	BOD_VL	Brown-Out Detector Threshold Voltage Selection (Write Protect) The default value is set by flash memory controller user configuration register CBOV(CONFIG0[22:21]) bit. 00 = Brown-out voltage is 2.2V. 01 = Brown-out voltage is 2.7V. 10 = Brown-out voltage is 3.7V. 11 = Brown-out voltage is 4.4V. Note: This bit is the protected bit. It means programming this needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[0]	BOD_EN	Brown-Out Detector Enable Bit (Write Protect) The default value is set by flash memory controller user configuration register CBODEN(CONFIG0[23]) bit. 0 = Brown-out Detector function Disabled. 1 = Brown-out Detector function Enabled. Note: This bit is the protected bit. It means programming this needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.

Temperature Sensor Control Register (TEMPCR)

Register	Offset	R/W	Description	Reset Value
TEMPCR	GCR_BA+0x1C	R/W	Temperature Sensor Control Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	VTEMP_EN	Temperature Sensor Enable Bit This bit is used to enable/disable temperature sensor function. 0 = Temperature sensor function Disabled (default). 1 = Temperature sensor function Enabled. Note: After this bit is set to 1, the value of temperature can be obtained from ADC conversion result by ADC channel selecting channel 7 and alternative multiplexer channel selecting temperature sensor. Please refer to the ADC function chapter for detail ADC conversion functional description.

Power-on-Reset Control Register (PORCR)

Register	Offset	R/W	Description	Reset Value
PORCR	GCR_BA+0x24	R/W	Power-on-Reset Controller Register	0x0000_XXXX

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
POR_DIS_CODE[15:8]							
7	6	5	4	3	2	1	0
POR_DIS_CODE[7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	POR_DIS_CODE	Power-On-Reset Enable Bit (Write Protect) When powered on, the POR circuit generates a reset signal to reset the whole chip function, but noise on the power may cause the POR active again. User can disable internal POR circuit to avoid unpredictable noise to cause chip reset by writing 0x5AA5 to this field. The POR function will be active again when this field is set to another value or chip is reset by other reset source, including: nRESET, Watchdog Timer reset, Window Watchdog Timer reset, LVR reset, BOD reset, ICE reset command and the software-chip reset function Note: This bit is the protected bit. It means programming this needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.

GPIOA Multiple Function Pin and Input Type Control Register (GPA_MFP)

Register	Offset	R/W	Description	Reset Value
GPA_MFP	GCR_BA+0x30	R/W	GPIOA Multiple Function and Input Type Control Register	0x0000_0000

31	30	29	28	27	26	25	24
GPA_TYPE[15:8]							
23	22	21	20	19	18	17	16
GPA_TYPE[7:0]							
15	14	13	12	11	10	9	8
GPA_MFP[15:8]							
7	6	5	4	3	2	1	0
GPA_MFP[7:0]							

Bits	Description	
[31:16]	GPA_TYPEn	Trigger Function Selection 0 = GPIOA[15:0] I/O input Schmitt Trigger function Disabled. 1 = GPIOA[15:0] I/O input Schmitt Trigger function Enabled.
[15]	GPA_MFP15	PA.15 Pin Function Selection Bits PA15_SC2PWR (ALT_MFP1[12]), PA15_I2SMCLK (ALT_MFP[9]) and GPA_MFP[15] determine the PA.15 function. (PA15_SC2PWR, PA15_I2SMCLK, GPA_MFP15) value and function mapping is as following list. (0, 0, 0) = GPIOA function is selected. (0, 0, 1) = PWM3 function is selected. (0, 1, 1) = I2S_MCLK function is selected. (1, 0, 1) = SC2_PWR function is selected.
[14]	GPA_MFP14	PA.14 Pin Function Selection Bits EBI_HB_EN[7] (ALT_MFP[23]), EBI_EN (ALT_MFP[11]), PA14_SC2RST (ALT_MFP1[13]) and GPA_MFP[14] determine the PA.14 function. (EBI_HB_EN, EBI_EN, PA14_SC2RST, GPA_MFP14) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM2 function is selected. (0, 0, 1, 1) = SC2_RST function is selected. (1, 1, 0, 1) = AD15 function is selected.

[13]	GPA_MFP13	PA.13 Pin Function Selection Bits EBI_HB_EN[6] (ALT_MFP[22]), EBI_EN (ALT_MFP[11]), PA13_SC2CLK (ALT_MFP1[10]) and GPA_MFP[13] determine the PA.13 function. (EBI_HB_EN, EBI_EN, PA13_SC2CLK, GPA_MFP13) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM1 function is selected. (0, 0, 1, 1) = SC2_CLK/UART5_TXD function is selected. (1, 1, 0, 1) = AD14 function is selected.
[12]	GPA_MFP12	PA.12 Pin Function Selection Bits EBI_HB_EN[5] (ALT_MFP[21]), EBI_EN (ALT_MFP[11]), PA12_SC2DAT (ALT_MFP1[11]) and GPA_MFP[12] determine the PA.12 function. (EBI_HB_EN, EBI_EN, PA12_SC2DAT, GPA_MFP12) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM0 function is selected. (0, 0, 1, 1) = SC2_DAT/UART5_RXD function is selected. (1, 1, 0, 1) = AD13 function is selected.
[11]	GPA_MFP11	PA.11 Pin Function Selection Bits EBI_EN (ALT_MFP[11]), PA10_11_CAN1 (ALT_MFP[28]) and GPA_MFP[11] determine the PA.11 function. (EBI_EN, PA10_11_CAN1, GPA_MFP11) value and function mapping is as following list. (0,0, 0) = GPIO function is selected. (0,0, 1) = I2C1_SCL function is selected. (0, 1, 1) = CAN1_RXD function is selected. (1, 0, 1) = nRD(EBI) function is selected.
[10]	GPA_MFP10	PA.10 Pin Function Selection Bits EBI_EN (ALT_MFP[11]), PA10_11_CAN1 (ALT_MFP[28]) and GPA_MFP[10] determine the PA.10 function. (EBI_EN, PA10_11_CAN1, GPA_MFP10) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = I2C1_SDA function is selected. (0, 1, 1) = CAN1_TXD function is selected. (1, 0, 1) = nWR(EBI) function is selected.
[9]	GPA_MFP9	PA.9 Pin Function Selection Bit GPA_MFP[9] determines the PA.9 function. 0 = GPIO function is selected. 1 = I2C0_SCL function is selected.
[8]	GPA_MFP8	PA.8 Pin Function Selection Bit GPA_MFP[8] determines the PA.9 function. 0 = GPIO function is selected to the pin PA.8. 1 = I2C0_SDA function is selected to the pin PA.8.

[7]	GPA_MFP7	PA.7 Pin Function Selection Bits EBI_EN (ALT_MFP[11]), PA7_SC1DAT (ALT_MFP[6]), PA7_S21 (ALT_MFP[2]) and GPA_MFP[7] determine the PA.7 function. (EBI_EN, PA7_SC1DAT, PA7_S21, GPA_MFP7) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC7 function is selected. (0, 0, 1, 1) = SPI2_SS1 function is selected. (0, 1, 0, 1) = SC1_DAT\UART4_RXD function is selected. (1, 0, 0, 1) = AD6 function is selected.
[6]	GPA_MFP6	PA.6 Pin Function Selection Bits EBI_EN (ALT_MFP[11]), PA6_SC1CLK (ALT_MFP[5]) and GPA_MFP[6] determine the PA.6 function. (EBI_EN, PA6_SC1CLK, GPA_MFP6) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = ADC6 function is selected. (0, 1, 1) = SC1_CLK\UART4_TXD function is selected. (1, 0, 1) = AD7 function is selected.
[5]	GPA_MFP5	PA.5 Pin Function Selection Bits EBI_HB_EN[0] (ALT_MFP[16]), EBI_EN (ALT_MFP[11]), PA5_SC1RST (ALT_MFP[8]) and GPA_MFP[5] determine the PA.5 function. (EBI_HB_EN, EBI_EN, PA5_SC1RST, GPA_MFP5) value and function mapping is as following list, (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC5 function is selected. (0, 0, 1, 1) = SC1_RST function is selected. (1, 1, 0, 1) = AD8 function is selected.
[4]	GPA_MFP4	PA.4 Pin Function Selection Bits EBI_HB_EN[1] (ALT_MFP[17]), EBI_EN (ALT_MFP[11]), PA4_SC1PWR (ALT_MFP[7]) and GPA_MFP[4] determine the PA.4 function. (EBI_HB_EN, EBI_EN, PA4_SC1PWR, GPA_MFP4) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC4 function is selected. (0, 0, 1, 1) = SC1_PWR function is selected. (1, 1, 0, 1) = AD9 function is selected.
[3]	GPA_MFP3	PA.3 Pin Function Selection Bits EBI_HB_EN[2] (ALT_MFP[18]), EBI_EN (ALT_MFP[11]), PA3_SC0DAT (ALT_MFP[1]) and GPA_MFP[3] determine the PA.3 function. (EBI_HB_EN, EBI_EN, PA3_SC0DAT, GPA_MFP3) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC3 function is selected. (0, 0, 1, 1) = SC0_DAT\UART3_RXD function is selected. (1, 1, 0, 1) = AD10 function is selected.

[2]	GPA_MFP2	PA.2 Pin Function Selection Bits EBI_HB_EN[3] (ALT_MFP[19]), EBI_EN (ALT_MFP[11]), PA2_SC0CLK (ALT_MFP1[0]) and GPA_MFP[2] determine the PA.2 function. (EBI_HB_EN, EBI_EN, PA2_SC0CLK, GPA_MFP2) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC2 function is selected. (0, 0, 1, 1) = SC0_CLK/UART3_TXD function is selected. (1, 1, 0, 1) = AD11 function is selected.
[1]	GPA_MFP1	PA.1 Pin Function Selection Bit EBI_HB_EN[4] (ALT_MFP[20]), EBI_EN (ALT_MFP[11]), PA1_SC0RST (ALT_MFP1[3]) and GPA_MFP[1] determine the PA.1 function. (EBI_HB_EN, EBI_EN, PA1_SC0RST, GPA_MFP1) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC1 function is selected. (0, 0, 1, 1) = SC0_RST function is selected. (1, 1, 0, 1) = AD12 function is selected.
[0]	GPA_MFP0	PA.0 Pin Function Selection Bit PA0_SC0PWR (ALT_MFP1[2]) and GPA_MFP[0] determine the PA.0 function. (PA0_SC0PWR, GPA_MFP0) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = ADC0 function is selected. (1, 1) = SC0_PWR function is selected.

GPIOB Multiple Function Pin and Input Type Control Register (GPB_MFP)

Register	Offset	R/W	Description	Reset Value
GPB_MFP	GCR_BA+0x34	R/W	GPIOB Multiple Function and Input Type Control Register	0x0000_0000

31	30	29	28	27	26	25	24
GPB_TYPE[15:8]							
23	22	21	20	19	18	17	16
GPB_TYPE[7:0]							
15	14	13	12	11	10	9	8
GPB_MFP[15:8]							
7	6	5	4	3	2	1	0
GPB_MFP[7:0]							

Bits	Description
[31:16]	GPB_TYPEn Trigger Function Selection 0 = GPIOB[15:0] I/O input Schmitt Trigger function Disabled. 1 = GPIOB[15:0] I/O input Schmitt Trigger function Enabled.
[15]	GPB_MFP15 PB.15 Pin Function Selection Bits PB14_15_EBI (ALT_MFP2[1]), PB15_T0EX (ALT_MFP[24]), PB15_TM0 (ALT_MFP2[2]) and GPB_MFP[15] determine the PB.15 function. (PB14_15_EBI, PB15_T0EX, PB15_TM0, GPB_MFP15) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = INT1 function is selected. (0, 0, 1, 1) = TM0 function is selected. (0, 1, 0, 1) = TM0_EXT function is selected. (1, 0, 0, 1) = AD6 function is selected.
[14]	GPB_MFP14 PB.14 Pin Function Selection Bits PB14_15_EBI (ALT_MFP2[1]), PB14_S31 (ALT_MFP[3]) and GPB_MFP[14] determine the PB.14 function. (PB14_15_EBI, PB14_S31, GPB_MFP14) value and function mapping is as following list (0, 0, 0) = GPIO function is selected. (0, 0, 1) = INT0 function is selected. (0, 1, 1) = SPI3_SS1 function is selected. (1, 0, 1) = AD0 function is selected.
[13]	GPB_MFP13 PB.13 Pin Function Selection Bit EBI_EN (ALT_MFP[11]), GPB_MFP[13] determines the PB.13 function. (EBI_EN, GPB_MFP13) value and function mapping is as following list (0, 0) = GPIO function is selected to the pin PB.13. (0, 1) = ACMP1_O function is selected to the pin PB.13. (1, 1) = AD1 function is selected.
[12]	GPB_MFP12 Reserved

[11]	GPB_MFP11	PB.11 Pin Function Selection Bits PB11_PWM4 (ALT_MFP[4]) and GPB_MFP[11] determine the PB.11 function. (PB11_PWM4, GPB_MFP11) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = TM3 function is selected. (1, 1) = PWM4 function is selected.
[10]	GPB_MFP10	PB.10 Pin Function Selection Bits PB10_S01 (ALT_MFP[0]) and GPB_MFP[10] determine the PB.10 function. (PB10_S01, GPB_MFP10) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = TM2 function is selected. (1, 1) = SPI0_SS1 function is selected.
[9]	GPB_MFP9	PB.9 Pin Function Selection Bits PB9_S11 (ALT_MFP[1]) and GPB_MFP[9] determine the PB.9 function. (PB9_S11, GPB_MFP9) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = TM1 function is selected. (1, 1) = SPI1_SS1 function is selected.
[8]	GPB_MFP8	PB.8 Pin Function Selection Bits PB8_CLKO (ALT_MFP[29]) and GPB_MFP[8] determine the PB.8 function. (PB8_CLKO, GPB_MFP8) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = TM0 function is selected to the pin PB.8. (1, 1) = CLKO function is selected to the pin PB.8.
[7]	GPB_MFP7	PB.7 Pin Function Selection Bit EBI_EN (ALT_MFP[11]), GPB_MFP[7] determines the PB.7 function. (EBI_EN, GPB_MFP7) value and function mapping is as following list. (0, 0) = GPIO function is selected to the pin PB.7. (0, 1) = UART1_nCTS function is selected to the pin PB.7. (1, 1) = nCS(EBI) function is selected to the pin PB.7.
[6]	GPB_MFP6	PB.6 Pin Function Selection Bit EBI_EN (ALT_MFP[11]), GPB_MFP[6] determines the PB.6 function. (EBI_EN, GPB_MFP6) value and function mapping is as following list. (0, 0) = GPIO function is selected to the pin PB.6. (0, 1) = UART1_nRTS function is selected to the pin PB.6. (1, 1) = ALE(EBI) function is selected to the pin PB.6.
[5]	GPB_MFP5	PB.5 Pin Function Selection Bit GPB_MFP[5] determines the PB.5 function. 0 = GPIO function is selected to the pin PB.5. 1 = UART1_TXD function is selected to the pin PB.5.
[4]	GPB_MFP4	PB.4 Pin Function Selection Bit GPB_MFP[4] determines the PB.4 function. 0 = GPIO function is selected to the pin PB.4. 1 = UART1_RXD function is selected to the pin PB.4.
[3]	GPB_MFP3	PB.3 Pin Function Selection Bits EBI_nWRH_EN (ALT_MFP[14]), EBI_EN (ALT_MFP[11]), PB3_TM3 (ALT_MFP2[5]),

		PB3_SC2CD (ALT_MFP1[14]), PB3_T3EX (ALT_MFP[27]) and GPB_MFP[3] determine the PB.3 function. (EBI_nWRH_EN, EBI_EN, PB3_TM3, PB3_SC2CD, PB3_T3EX, GPB_MFP3) value and function mapping is as following list. (0, 0, 0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 0, 0, 1) = UART0_nCTS function is selected. (0, 0, 0, 0, 1, 1) = TM3_EXT function is selected. (0, 0, 0, 1, 0, 1) = SC2_CD function is selected. (0, 0, 1, 0, 0, 1) = TM3 function is selected. (1, 1, 0, 0, 0, 1) = nWRH(EBI) function is selected.
[2]	GPB_MFP2	PB.2 Pin Function Selection Bits EBI_nWRL_EN (ALT_MFP[13]), EBI_EN (ALT_MFP[11]), PB2_TM2 (ALT_MFP2[4]), PB2_CPO0 (ALT_MFP[30]), PB2_T2EX (ALT_MFP[26]) and GPB_MFP[2] determine the PB.2 function. (EBI_nWRL_EN, EBI_EN, PB2_TM2, PB2_CPO0, PB2_T2EX, GPB_MFP2) value and function mapping is as following list. (0, 0, 0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 0, 0, 1) = UART0_nRTS function is selected. (0, 0, 0, 0, 1, 1) = TM2_EXT function is selected. (0, 0, 0, 1, 0, 1) = ACMP0_O function is selected. (0, 0, 1, 0, 0, 1) = TM2 function is selected. (1, 1, 0, 0, 0, 1) = nWRL(EBI) function is selected.
[1]	GPB_MFP1	PB.1 Pin Function Selection Bit GPB_MFP[1] determines the PB.1 function. 0 = GPIO function is selected to the pin PB.1. 1 = UART0_TXD function is selected to the pin PB.1.
[0]	GPB_MFP0	PB.0 Pin Function Selection Bit GPB_MFP[0] determines the PB.0 function. 0 = GPIO function is selected to the pin PB.0. 1 = UART0_RXD function is selected to the pin PB.0.

GPIOC Multiple Function Pin and input Type Control Register (GPC_MFP)

Register	Offset	R/W	Description	Reset Value
GPC_MFP	GCR_BA+0x38	R/W	GPIOC Multiple Function and Input Type Control Register	0x0000_0000

31	30	29	28	27	26	25	24
GPC_TYPE[15:8]							
23	22	21	20	19	18	17	16
GPC_TYPE[7:0]							
15	14	13	12	11	10	9	8
GPC_MFP[15:8]							
7	6	5	4	3	2	1	0
GPC_MFP[7:0]							

Bits	Description	
[31:16]	GPC_TYPEn	Trigger Function Selection 0 = GPIOC[15:0] I/O input Schmitt Trigger function Disabled. 1 = GPIOC[15:0] I/O input Schmitt Trigger function Enabled.
[15]	GPC_MFP15	PC.15 Pin Function Selection Bits EBI_EN (ALT_MFP[11]) and GPC_MFP[15] determine the PC.15 function. (EBI_EN, GPC_MFP15) value and function mapping is as following list (0, 0) = GPIO function is selected. (0, 1) = ACMP1_N function is selected. (1, 1) = AD3 function is selected.
[14]	GPC_MFP14	PC.14 Pin Function Selection Bits EBI_EN (ALT_MFP[11]) and GPC_MFP[14] determine the PC.14 function. (EBI_EN, GPC_MFP14) value and function mapping is as following list (0, 0) = GPIO function is selected. (0, 1) = ACMP1_P function is selected. (1, 1) = AD2 function is selected.
[13]	GPC_MFP13	PC.13 Pin Function Selection Bit GPC_MFP[13] determines the PC.13 function. 0 = GPIO function is selected to the pin PC.13. 1 = SPI1_MOSI1 function is selected to the pin PC.13.
[12]	GPC_MFP12	PC.12 Pin Function Selection Bit GPC_MFP[12] determines the PC.12 function. 0 = GPIO function is selected to the pin PC.12. 1 = SPI1_MISO1 function is selected to the pin PC.12.
[11]	GPC_MFP11	PC.11 Pin Function Selection Bit GPC_MFP[11] determines the PC.11 function. 0 = GPIO function is selected to the pin PC.11. 1 = SPI1_MOSI0 function is selected to the pin PC.11.

[10]	GPC_MFP10	PC.10 Pin Function Selection Bit GPC_MFP[10] determines the PC.10 function. 0 = GPIO function is selected to the pin PC.10. 1 = SPI1_MISO0 function is selected to the pin PC.10.
[9]	GPC_MFP9	PC.9 Pin Function Selection Bit GPC_MFP[9] determines the PC.9 function. 0 = GPIO function is selected to the pin PC.9. 1 = SPI1_CLK function is selected to the pin PC.9.
[8]	GPC_MFP8	PC.8 Pin Function Selection Bits EBI_MCLK_EN (ALT_MFP[12]), EBI_EN (ALT_MFP[11]), GPC_MFP[8] determine the PC.8 function. (EBI_MCLK_EN, EBI_EN, GPC_MFP8) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected to the pin PC.8. (0, 0, 1) = SPI1_SS0 function is selected to the pin PC.8. (1, 1, 1) = MCLK(EBI) function is selected to the pin PC.8.
[7]	GPC_MFP7	PC.7 Pin Function Selection Bits EBI_EN (ALT_MFP[11]), PC7_SC1CD (ALT_MFP1[9]) and GPC_MFP[7] determine the PC.7 function. (EBI_EN, PC7_SC1CD, GPC_MFP7) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = ACMP0_N function is selected. (0, 1, 1) = SC1_CD function is selected. (1, 0, 1) = AD5 function is selected.
[6]	GPC_MFP6	PC.6 Pin Function Selection Bits EBI_EN (ALT_MFP[11]), PC6_SC0CD (ALT_MFP1[4]) and GPC_MFP[6] determine the PC.6 function. (EBI_EN, PC6_SC0CD, GPC_MFP6) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = ACMP0_P function is selected. (0, 1, 1) = SC0_CD function is selected. (1, 0, 1) = AD4 function is selected.
[5]	GPC_MFP5	PC.5 Pin Function Selection Bit GPC_MFP[5] determines the PC.5 function. 0 = GPIO function is selected to the pin PC.5. 1 = SPI0_MOSI1 function is selected to the pin PC.5.
[4]	GPC_MFP4	PC.4 Pin Function Selection Bit GPC_MFP[4] determines the PC.4 function. 0 = GPIO function is selected to the pin PC.4. 1 = SPI0_MISO1 function is selected to the pin PC.4.
[3]	GPC_MFP3	PC.3 Pin Function Selection Bits PC3_I2SDO (ALT_MFP[8]) and GPC_MFP[3] determine the PC.3 function. (PC3_I2SDO, GPC_MFP3) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = SPI0_MOSI0 function is selected. (1, 1) = I2S_DO function is selected.

[2]	GPC_MFP2	PC.2 Pin Function Selection Bits PC2_I2SDI (ALT_MFP[7]) and GPC_MFP[2] determine the PC.2 function. (PC2_I2SDI, GPC_MFP2) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = SPI0_MISO0 function is selected. (1, 1) = I2S_DI function is selected.
[1]	GPC_MFP1	PC.1 Pin Function Selection Bits PC1_I2SBCLK (ALT_MFP[6]) and GPC_MFP[1] determine the PC.1 function. (PC1_I2SBCLK, GPC_MFP1) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = SPI0_CLK function is selected. (1, 1) = I2S_BCLK function is selected.
[0]	GPC_MFP0	PC.0 Pin Function Selection Bits PC0_I2SLRCLK (ALT_MFP[5]) and GPC_MFP[0] determine the PC.0 function. (PC0_I2SLRCLK, GPC_MFP0) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = SPI0_SS0 function is selected. (1, 1) = I2S_LRCLK function is selected.

GPIO Multiple Function Pin and Input Type Control Register (GPD_MFP)

Register	Offset	R/W	Description	Reset Value
GPD_MFP	GCR_BA+0x3C	R/W	GPIO Multiple Function and Input Type Control Register	0x0000_0000

31	30	29	28	27	26	25	24
GPD_TYPE[15:8]							
23	22	21	20	19	18	17	16
GPD_TYPE[7:0]							
15	14	13	12	11	10	9	8
GPD_MFP[15:8]							
7	6	5	4	3	2	1	0
GPD_MFP[7:0]							

Bits	Description	
[31:16]	GPD_TYPEn	Trigger Function Selection 0 = GPIOD[15:0] I/O input Schmitt Trigger function Disabled. 1 = GPIOD[15:0] I/O input Schmitt Trigger function Enabled.
[15]	GPD_MFP15	PD.15 Pin Function Selection Bits PD14_15_CAN1 (ALT_MFP2[0]) and GPD_MFP[15] determine the PD.15 function. (PD14_15_CAN1, GPD_MFP15) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = UART2_TXD function is selected. (1, 1) = CAN1_TXD function is selected.
[14]	GPD_MFP14	PD.14 Pin Function Selection Bits PD14_15_CAN1 (ALT_MFP2[0]) and GPD_MFP[14] determine the PD.14 function. (PD14_15_CAN1, GPD_MFP14) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = UART2_RXD function is selected. (1, 1) = CAN1_RXD function is selected.
[13]	GPD_MFP13	PD.13 Pin Function Selection Bit GPD_MFP[13] determines the PD.13 function. 0 = GPIO function is selected to the pin PD.13. 1 = SPI3_MOSI1 function is selected to the pin PD.13.
[12]	GPD_MFP12	PD.12 Pin Function Selection Bit GPD_MFP[12] determines the PD.12 function. 0 = GPIO function is selected to the pin PD.12. 1 = SPI3_MISO1 function is selected to the pin PD.12.
[11]	GPD_MFP11	PD.11 Pin Function Selection Bit GPD_MFP[11] determines the PD.11 function. 0 = GPIO function is selected to the pin PD.11. 1 = SPI3_MOSI0 function is selected to the pin PD.11.

[10]	GPD_MFP10	PD.10 Pin Function Selection Bit GPD_MFP[10] determines the PD.10 function. 0 = GPIO function is selected to the pin PD.10. 1 = SPI3_MISO0 function is selected to the pin PD.10.
[9]	GPD_MFP9	PD.9 Pin Function Selection Bit GPD_MFP[9] determines the PD.9 function. 0 = GPIO is function is selected to the pin PD.9. 1 = SPI3_CLK function is selected to the pin PD.9.
[8]	GPD_MFP8	PD.8 Pin Function Selection Bit GPD_MFP[8] determines the PD.8 function. 0 = GPIO function is selected to the pin PD.8. 1 = SPI3_SS0 function is selected to the pin PD.8.
[7]	GPD_MFP7	PD.7 Pin Function Selection Bit GPD_MFP[7] determines the PD.5 function. 0 = The GPIO function is selected to the pin PD.7. 1 = The CAN0_TXD function is selected to the pin PD.7.
[6]	GPD_MFP6	PD.6 Pin Function Selection Bit GPD_MFP[6] determines the PD.6 function. 0 = The GPIO function is selected to the pin PD.6. 1 = The CAN0_RXD function is selected to the pin PD.6.
[5]	GPD_MFP5	PD.5 Pin Function Selection Bit GPD_MFP[5] determines the PD.5 function. 0 = GPIO function is selected to the pin PD.5. 1 = SPI2_MOSI1 function is selected to the pin PD.5.
[4]	GPD_MFP4	PD.4 Pin Function Selection Bit GPD_MFP[4] determines the PD.4 function. 0 = GPIO function is selected to the pin PD.4. 1 = SPI2_MISO1 function is selected to the pin PD.4.
[3]	GPD_MFP3	PD.3 Pin Function Selection Bit GPD_MFP[3] determines the PD.3 function. 0 = GPIO function is selected to the pin PD.3. 1 = SPI2_MOSI0 function is selected to the pin PD.3.
[2]	GPD_MFP2	PD.2 Pin Function Selection Bit GPD_MFP[2] determines the PD.5 function. 0 = GPIO function is selected to the pin PD.2. 1 = SPI2_MISO0 function is selected to the pin PD.2.
[1]	GPD_MFP1	PD.1 Pin Function Selection Bit GPD_MFP[1] determines the PD.1 function. 0 = GPIO function is selected to the pin PD.1. 1 = SPI2_CLK function is selected to the pin PD.1.
[0]	GPD_MFP0	PD.0 Pin Function Selection Bit GPD_MFP[0] determines the PD.0 function. 0 = GPIOfunction is selected to the pin PD.0. 1 = SPI2_SS0 function is selected to the pin PD.0.

GPIO Multiple Function Pin and Input Type Control Register (GPE_MFP)

Register	Offset	R/W	Description	Reset Value
GPE_MFP	GCR_BA+0x40	R/W	GPIO Multiple Function and Input Type Control Register	0x0000_0000

31	30	29	28	27	26	25	24
GPE_TYPE[15:8]							
23	22	21	20	19	18	17	16
GPE_TYPE[7:0]							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved		GPE_MFP5	Reserved			GPE_MFP1	GPE_MFP0

Bits	Description	
[31:16]	GPE_TYPEn	Trigger Function Selection 0 = GPIOE[15:0] I/O input Schmitt Trigger function Disabled. 1 = GPIOE[15:0] I/O input Schmitt Trigger function Enabled.
[15:6]	Reserved	Reserved.
[5]	GPE_MFP5	PE.5 Pin Function Selection Bits PE5_T1EX (ALT_MFP[25]), PE5_TM1 (ALT_MFP2[3]) and GPE_MFP5 determine the PE.5 function. (PE5_T1EX, PE5_TM1, GPE_MFP5) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = PWM5 function is selected. (1, 0, 1) = TM1_EXT function is selected. (0, 1, 1) = TM1 function is selected.
[4:2]	Reserved	Reserved.
[1]	GPE_MFP1	PE.1 Pin Function Selection Bit GPE_MFP[1] determines the PE.1 function. 0 = GPIO function is selected to the pin PE.1. 1 = PWM7 function is selected to the pin PE.1.
[0]	GPE_MFP0	PE.0 Pin Function Selection Bit GPE_MFP[0] determines the PE.0 function. 0 = GPIO function is selected to the pin PE.0. 1 = PWM6 function is selected to the pin PE.0.

GPIOF Multiple Function Pin and Input Type Control Register (GPF_MFP)

Register	Offset	R/W	Description	Reset Value
GPF_MFP	GCR_BA+0x44	R/W	GPIOF Multiple Function and Input Type Control Register	0x0000_000X

Note: The default value of GPF_MFP[3]/GPF_MFP[2] is 1. The default value of GPF_MFP[1]/GPF_MFP[0] is decided by user configuration CGPFMFP(CONFIG0[27]).

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved				GPF_TYPE[3:0]			
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				GPF_MFP3	GPF_MFP2	GPF_MFP1	GPF_MFP0

Bits	Description
[31:20]	Reserved Reserved.
[19:16]	GPF_TYPEn Trigger Function Selection 0 = GPIOF[3:0] I/O input Schmitt Trigger function Disabled. 1 = GPIOF[3:0] I/O input Schmitt Trigger function Enabled.
[15:4]	Reserved Reserved.
[3]	GPF_MFP3 PF.3 Pin Function Selection Bit GPF_MFP[3] determines the PF.3 function. 0 = GPIO function is selected to the pin PF.3. 1 = PS/2_CLK function is selected to the pin PF.3.
[2]	GPF_MFP2 PF.2 Pin Function Selection Bit GPF_MFP[2] determines the PF.2 function. 0 = GPIO function is selected to the pin PF.2. 1 = PS/2_DAT function is selected to the pin PF.2.
[1]	GPF_MFP1 PF.1 Pin Function Selection Bit GPF_MFP[1] determines the PF.1 function. 0 = GPIO function is selected to the pin PF.1. 1 = XT1_IN function is selected to the pin PF.1. Note: This bit is read only and is decided by user configuration CGPFMFP (CONFIG0[27]).
[0]	GPF_MFP0 PF.0 Pin Function Selection Bit GPF_MFP[0] determines the PF.0 function. 0 = GPIO function is selected to the pin PF.0. 1 = XT1_OUT function is selected to the pin PF.0. Note: This bit is read only and is decided by user configuration CGPFMFP (CONFIG0[27]).

Alternative Multiple Function Pin Control Register (ALT_MFP)

Register	Offset	R/W	Description	Reset Value
ALT_MFP	GCR_BA+0x50	R/W	Alternative Multiple Function Pin Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved	PB2_CPO0	PB8_CLKO	PA10_11_CAN1	PB3_T3EX	PB2_T2EX	PE5_T1EX	PB15_T0EX
23	22	21	20	19	18	17	16
EBI_HB_EN							
15	14	13	12	11	10	9	8
Reserved	EBI_nWRH_EN	EBI_nWRL_EN	EBI_MCLK_EN	EBI_EN	Reserved	PA15_I2SMCLK	PC3_I2SDO
7	6	5	4	3	2	1	0
PC2_I2SDI	PC1_I2SBCLK	PC0_I2SLRCLK	PB11_PWM4	PB14_S31	PA7_S21	PB9_S11	PB10_S01

Bits	Description
[31]	Reserved
[30]	PB.2 Pin Alternative Function Selection Bits PB2_TM2 (ALT_MFP[4]), PB2_CPO0 (ALT_MFP[30]), PB2_T2EX (ALT_MFP[26]) and GPB_MFP[2] determine the PB.2 function. (PB2_TM2, PB2_CPO0, PB2_T2EX, GPB_MFP2) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = UART0_nRTS function is selected. (0, 0, 1, 1) = TM2_EXT function is selected. (0, 1, 0, 1) = ACMP0_O function is selected. (1, 0, 0, 1) = TM2 function is selected.
[29]	PB.8 Pin Alternative Function Selection Bits PB8_CLKO (ALT_MFP[29]) and GPB_MFP[8] determine the PB.8 function. (PB8_CLKO, GPB_MFP8) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = TM0 function is selected to the pin PB.8. (1, 1) = CLKO function is selected to the pin PB.8.

[28]	PA10_11_CAN1	PA.10 And PA.11 Pin Alternative Function Selection Bits PA10_11_CAN1 (ALT_MFP[28]) and GPA_MFP[11] determine the PA.11 function. (PA10_11_CAN1, GPA_MFP11) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = I2C1_SCL function is selected. (1, 1) = CAN1_RXD function is selected. Bits PA10_11_CAN1 (ALT_MFP[28]) and GPA_MFP[10] determine the PA.10 function. (PA10_11_CAN1, GPA_MFP10) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = I2C1_SDA function is selected. (1, 1) = CAN1_TXD function is selected.
[27]	PB3_T3EX	PB.3 Pin Alternative Function Selection Bits PB3_TM3 (ALT_MFP[5]), PB3_SC2CD (ALT_MFP1[14]), PB3_T3EX (ALT_MFP[27]) and GPB_MFP[3] determine the PB.3 function. (PB3_TM3, PB3_SC2CD, PB3_T3EX, GPB_MFP3) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = UART0_nCTS function is selected. (0, 0, 1, 1) = TM3_EXT function is selected. (0, 1, 0, 1) = SC2_CD function is selected. (1, 0, 0, 1) = TM3 function is selected.
[26]	PB2_T2EX	PB.2 Pin Alternative Function Selection Bits PB2_TM2 (ALT_MFP[4]), PB2_CPO0 (ALT_MFP[30]), PB2_T2EX (ALT_MFP[26]) and GPB_MFP[2] determine the PB.2 function. (PB2_TM2, PB2_CPO0, PB2_T2EX, GPB_MFP2) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = UART0_nRTS function is selected. (0, 0, 1, 1) = TM2_EXT function is selected. (0, 1, 0, 1) = ACMP0_O function is selected. (1, 0, 0, 1) = TM2 function is selected.
[25]	PE5_T1EX	PE.5 Pin Alternative Function Selection Bits PE5_T1EX (ALT_MFP[25]), PE5_TM1 (ALT_MFP2[3]) and GPE_MFP5 determine the PE.5 function. (PE5_T1EX, PE5_TM1, GPE_MFP5) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = PWM5 function is selected. (1, 0, 1) = TM1_EXT function is selected. (0, 1, 1) = TM1 function is selected.
[24]	PB15_T0EX	PB.15 Pin Alternative Function Selection Bits PB14_15_EBI (ALT_MFP2[1]), PB15_T0EX (ALT_MFP[24]), PB15_TM0 (ALT_MFP2[2]) and GPB_MFP[15] determine the PB.15 function. (PB14_15_EBI, PB15_T0EX, PB15_TM0, GPB_MFP15) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = INT1 function is selected. (0, 0, 1, 1) = TM0 function is selected. (0, 1, 0, 1) = TM0_EXT function is selected. (1, 0, 0, 1) = AD6 function is selected.

[23]	EBI_HB_EN[7]	Bits EBI_HB_EN[7] (ALT_MFP[23]), EBI_EN (ALT_MFP[11]), PA14_SC2RST (ALT_MFP1[13]) and GPA_MFP[14] determine the PA.14 function. (EBI_HB_EN, EBI_EN, PA14_SC2RST, GPA_MFP14) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM2 function is selected. (0, 0, 1, 1) = SC2_RST function is selected. (1, 1, 0, 1) = AD15 function is selected.
[22]	EBI_HB_EN[6]	Bits EBI_HB_EN[6] (ALT_MFP[22]), EBI_EN (ALT_MFP[11]), PA13_SC2CLK (ALT_MFP1[10]) and GPA_MFP[13] determine the PA.13 function. (EBI_HB_EN, EBI_EN, PA13_SC2CLK, GPA_MFP13) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM1 function is selected. (0, 0, 1, 1) = SC2_CLK/UART5_TXD function is selected. (1, 1, 0, 1) = AD14 function is selected.
[21]	EBI_HB_EN[5]	Bits EBI_HB_EN[5] (ALT_MFP[21]), EBI_EN (ALT_MFP[11]), PA12_SC2DAT (ALT_MFP1[11]) and GPA_MFP[12] determine the PA.12 function. (EBI_HB_EN, EBI_EN, PA12_SC2DAT, GPA_MFP12) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM0 function is selected. (0, 0, 1, 1) = SC2_DAT/UART5_RXD function is selected. (1, 1, 0, 1) = AD13 function is selected.
[20]	EBI_HB_EN[4]	Bit EBI_HB_EN[4] (ALT_MFP[20]), EBI_EN (ALT_MFP[11]), PA1_SC0RST (ALT_MFP1[3]) and GPA_MFP[1] determine the PA.1 function. (EBI_HB_EN, EBI_EN, PA1_SC0RST, GPA_MFP1) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC1 function is selected. (0, 0, 1, 1) = SC0_RST function is selected. (1, 1, 0, 1) = AD12 function is selected.
[19]	EBI_HB_EN[3]	Bits EBI_HB_EN[3] (ALT_MFP[19]), EBI_EN (ALT_MFP[11]), PA2_SC0CLK (ALT_MFP1[0]) and GPA_MFP[2] determine the PA.2 function. (EBI_HB_EN, EBI_EN, PA2_SC0CLK, GPA_MFP2) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC2 function is selected. (0, 0, 1, 1) = SC0_CLK/UART3_TXD function is selected. (1, 1, 0, 1) = AD11 function is selected.
[18]	EBI_HB_EN[2]	Bits EBI_HB_EN[2] (ALT_MFP[18]), EBI_EN (ALT_MFP[11]), PA3_SC0DAT (ALT_MFP1[1]) and GPA_MFP[3] determine the PA.3 function. (EBI_HB_EN, EBI_EN, PA3_SC0DAT, GPA_MFP3) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC3 function is selected. (0, 0, 1, 1) = SC0_DAT/UART3_RXD function is selected. (1, 1, 0, 1) = AD10 function is selected.

[17]	EBI_HB_EN[1]	Bits EBI_HB_EN[1] (ALT_MFP[17]), EBI_EN (ALT_MFP[11]), PA4_SC1PWR (ALT_MFP1[7]) and GPA_MFP[4] determine the PA.4 function. (EBI_HB_EN, EBI_EN, PA4_SC1PWR, GPA_MFP4) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC4 function is selected. (0, 0, 1, 1) = SC1_PWR function is selected. (1, 1, 0, 1) = AD9 function is selected.
[16]	EBI_HB_EN[0]	Bits EBI_HB_EN[0] (ALT_MFP[16]), EBI_EN (ALT_MFP[11]), PA5_SC1RST (ALT_MFP1[8]) and GPA_MFP[5] determine the PA.5 function. (EBI_HB_EN, EBI_EN, PA5_SC1RST, GPA_MFP5) value and function mapping is as following list, (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC5 function is selected. (0, 0, 1, 1) = SC1_RST function is selected. (1, 1, 0, 1) = AD8 function is selected.
[15]	Reserved	Reserved
[14]	EBI_nWRH_EN	Bits EBI_nWRH_EN (ALT_MFP[14]), EBI_EN (ALT_MFP[11]), PB3_TM3 (ALT_MFP2[5]), PB3_SC2CD (ALT_MFP1[14]), PB3_T3EX (ALT_MFP[27]) and GPB_MFP[3] determine the PB.3 function. (EBI_nWRH_EN, EBI_EN, PB3_TM3, PB3_SC2CD, PB3_T3EX, GPB_MFP3) value and function mapping is as following list. (0, 0, 0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 0, 0, 1) = UART0_nCTS function is selected. (0, 0, 0, 0, 1, 1) = TM3_EXT function is selected. (0, 0, 0, 1, 0, 1) = SC2_CD function is selected. (0, 0, 1, 0, 0, 1) = TM3 function is selected. (1, 1, 0, 0, 0, 1) = nWRH(EBI) function is selected.
[13]	EBI_nWRL_EN	Bits EBI_nWRL_EN (ALT_MFP[13]), EBI_EN (ALT_MFP[11]), PB2_TM2 (ALT_MFP2[4]), PB2_CPO0 (ALT_MFP[30]), PB2_T2EX (ALT_MFP[26]) and GPB_MFP[2] determine the PB.2 function. (EBI_nWRL_EN, EBI_EN, PB2_TM2, PB2_CPO0, PB2_T2EX, GPB_MFP2) value and function mapping is as following list. (0, 0, 0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 0, 0, 1) = UART0_nRTS function is selected. (0, 0, 0, 0, 1, 1) = TM2_EXT function is selected. (0, 0, 0, 1, 0, 1) = ACMP0_O function is selected. (0, 0, 1, 0, 0, 1) = TM2 function is selected. (1, 1, 0, 0, 0, 1) = nWRL(EBI) function is selected.
[12]	EBI_MCLK_EN	Bits EBI_MCLK_EN (ALT_MFP[12]), EBI_EN (ALT_MFP[11]), GPC_MFP[8] determine the PC.8 function. (EBI_MCLK_EN, EBI_EN, GPC_MFP8) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected to the pin PC.8. (0, 0, 1) = SPI1_SS0 function is selected to the pin PC.8. (1, 1, 1) = MCLK(EBI) function is selected to the pin PC.8.
[11]	EBI_EN	EBI_EN is use to switch GPIO function to EBI function (AD[15:0], ALE, RE, WE, CS, MCLK), it need additional registers EBI_EN[7:0] and EBI_MCLK_EN for some GPIO to switch to EBI function(AD[15:8], MCLK)
[15]	Reserved	Reserved

[9]	PA15_I2SMCLK	PA.15 Pin Alternative Function Selection Bits PA15_SC2PWR (ALT_MFP[12]), PA15_I2SMCLK (ALT_MFP[9]) and GPA_MFP[15] determine the PA.15 function. (PA15_SC2PWR, PA15_I2SMCLK, GPA_MFP15) value and function mapping is as following list. (0, 0, 0) = GPIOA function is selected. (0, 0, 1) = PWM3 function is selected. (0, 1, 1) = I2S_MCLK function is selected. (1, 0, 1) = SC2_PWR function is selected.
[8]	PC3_I2SDO	PC.3 Pin Alternative Function Selection Bits PC3_I2SDO (ALT_MFP[8]) and GPC_MFP[3] determine the PC.3 function. (PC3_I2SDO, GPC_MFP3) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = SPI0_MOSI0 function is selected. (1, 1) = I2S_DO function is selected.
[7]	PC2_I2SDI	PC.2 Pin Alternative Function Selection Bits PC2_I2SDI (ALT_MFP[7]) and GPC_MFP[2] determine the PC.2 function. (PC2_I2SDI, GPC_MFP2) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = SPI0_MISO0 function is selected. (1, 1) = I2S_DI function is selected.
[6]	PC1_I2SBCLK	PC.1 Pin Alternative Function Selection Bits PC1_I2SBCLK (ALT_MFP[6]) and GPC_MFP[1] determine the PC.1 function. (PC1_I2SBCLK, GPC_MFP1) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = SPI0_CLK function is selected. (1, 1) = I2S_BCLK function is selected.
[5]	PC0_I2SLRCLK	Bits PC0_I2SLRCLK (ALT_MFP[5]) And GPC_MFP[0] Determine The PC.0 Function Bits PC0_I2SLRCLK (ALT_MFP[5]) and GPC_MFP[0] determine the PC.0 function. (PC0_I2SLRCLK, GPC_MFP0) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = SPI0_SS0 function is selected. (1, 1) = I2S_LRCLK function is selected.
[4]	PB11_PWM4	PB.11 Pin Alternative Function Selection Bits PB11_PWM4 (ALT_MFP[4]) and GPB_MFP[11] determine the PB.11 function. (PB11_PWM4, GPB_MFP11) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = TM3 function is selected. (1, 1) = PWM4 function is selected.
[3]	PB14_S31	PB.14 Pin Alternative Function Selection Bits PB14_15_EBI (ALT_MFP2[1]), PB14_S31 (ALT_MFP[3]) and GPB_MFP[14] determine the PB.14 function. (PB14_15_EBI, PB14_S31, GPB_MFP14) value and function mapping is as following list (0, 0, 0) = GPIO function is selected. (0, 0, 1) = INT0 function is selected. (0, 1, 1) = SPI3_SS1 function is selected. (1, 0, 1) = AD0 function is selected.

[2]	PA7_S21	PA.7 Pin Alternative Function Selection Bits EBI_EN (ALT_MFP[11]), PA7_SC1DAT (ALT_MFP1[6]), PA7_S21 (ALT_MFP[2]) and GPA_MFP[7] determine the PA.7 function. (EBI_EN, PA7_SC1DAT, PA7_S21, GPA_MFP7) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC7 function is selected. (0, 0, 1, 1) = SPI2_SS1 function is selected. (0, 1, 0, 1) = SC1_DAT\UART4_RXD function is selected. (1, 0, 0, 1) = AD6 function is selected.
[1]	PB9_S11	PB.9 Pin Alternative Function Selection Bits PB9_S11 (ALT_MFP[1]) and GPB_MFP[9] determine the PB.9 function. (PB9_S11, GPB_MFP9) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = TM1 function is selected. (1, 1) = SPI1_SS1 function is selected.
[0]	PB10_S01	PB.10 Pin Alternative Function Selection Bits PB10_S01 (ALT_MFP[0]) and GPB_MFP[10] determine the PB.10 function. (PB10_S01, GPB_MFP10) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = TM2 function is selected. (1, 1) = SPI0_SS1 function is selected.

Alternative Multiple Function Pin Control Register 1 (ALT_MFP1)

Register	Offset	R/W	Description	Reset Value
ALT_MFP1	GCR_BA+0x58	R/W	Alternative Multiple Function Pin Control Register 1	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved	PB3_ SC2CD	PA14_ SC2RST	PA15_ SC2PWR	PA12_ SC2DAT	PA13_ SC2CLK	PC7_ SC1CD	PA5_ SC1RST
7	6	5	4	3	2	1	0
PA4_ SC1PWR	PA7_ SC1DAT	PA6_ SC1CLK	PC6_ SC0CD	PA1_ SC0RST	PA0_ SC0PWR	PA3_ SC0DAT	PA2_ SC0CLK

Bits	Description
[31:15]	Reserved
[14]	PB.3 Pin Alternative Function Selection Bits EBI_nWRH_EN (ALT_MFP[14]), EBI_EN (ALT_MFP[11]), PB3_TM3 (ALT_MFP2[5]), PB3_SC2CD (ALT_MFP1[14]), PB3_T3EX (ALT_MFP[27]) and GPB_MFP3 determine the PB.3 function. (EBI_nWRH_EN, EBI_EN, PB3_TM3, PB3_SC2CD, PB3_T3EX, GPB_MFP3) value and function mapping is as following list. (0, 0, 0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 0, 0, 1) = UART0_nCTS function is selected. (0, 0, 0, 0, 1, 1) = TM3_EXT function is selected. (0, 0, 0, 1, 0, 1) = SC2_CD function is selected. (0, 0, 1, 0, 0, 1) = TM3 function is selected. (1, 1, 0, 0, 0, 1) = nWRH function is selected.
[13]	PA.14 Pin Alternative Function Selection Bits EBI_HB_EN[7] (ALT_MFP[23]), EBI_EN (ALT_MFP[11]), PA14_SC2RST (ALT_MFP1[13]) and GPA_MFP[14] determine the PA.14 function. (EBI_HB_EN, EBI_EN, PA14_SC2RST, GPA_MFP[14]) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM2 function is selected. (0, 0, 1, 1) = SC2_RST function is selected. (1, 1, 0, 1) = AD15 function is selected.

[12]	PA15_SC2PWR	PA.15 Pin Alternative Function Selection Bits PA15_SC2PWR (ALT_MFP1[12]), PA15_I2SMCLK (ALT_MFP[9]) and GPA_MFP[15] determine the PA.15 function. (PA15_SC2PWR, PA15_I2SMCLK, GPA_MFP15) value and function mapping is as following list. (0, 0, 0) = GPIOA function is selected. (0, 0, 1) = PWM3 function is selected. (0, 1, 1) = I2S_MCLK function is selected. (1, 0, 1) = SC2_PWR function is selected.
[11]	PA12_SC2DAT	PA.12 Pin Alternative Function Selection Bits EBI_HB_EN[5] (ALT_MFP[21]), EBI_EN (ALT_MFP[11]), PA12_SC2DAT (ALT_MFP1[11]) and GPA_MFP[12] determine the PA.12 function. (EBI_HB_EN, EBI_EN, PA12_SC2DAT, GPA_MFP12) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM0 function is selected. (0, 0, 1, 1) = SC2_DAT/UART5_RXD function is selected. (1, 1, 0, 1) = AD13 function is selected.
[10]	PA13_SC2CLK	PA.13 Pin Alternative Function Selection Bits EBI_HB_EN[6] (ALT_MFP[22]), EBI_EN (ALT_MFP[11]), PA13_SC2CLK (ALT_MFP1[10]) and GPA_MFP[13] determine the PA.13 function. (EBI_HB_EN, EBI_EN, PA13_SC2CLK, GPA_MFP13) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = PWM1 function is selected. (0, 0, 1, 1) = SC2_CLK/UART5_TXD function is selected. (1, 1, 0, 1) = AD14 function is selected.
[9]	PC7_SC1CD	PC.7 Pin Alternative Function Selection Bits EBI_EN (ALT_MFP[11]), PC7_SC1CD (ALT_MFP1[9]) and GPC_MFP[7] determine the PC.7 function. (EBI_EN, PC7_SC1CD, GPC_MFP7) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = ACMP0_N function is selected. (0, 1, 1) = SC1_CD function is selected. (1, 0, 1) = AD5 function is selected.
[8]	PA5_SC1RST	PA.5 Pin Alternative Function Selection Bits EBI_HB_EN[1] (ALT_MFP[17]), EBI_EN (ALT_MFP[11]), PA5_SC1RST (ALT_MFP1[8]) and GPA_MFP[5] determine the PA.5 function. (EBI_HB_EN, EBI_EN, PA5_SC1RST, GPA_MFP5) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = ADC5 function is selected. (0, 1, 1) = SC1_RST function is selected. (1, 0, 1) = AD8 function is selected.

[7]	PA4_SC1PWR	PA.4 Pin Alternative Function Selection Bits EBI_HB_EN[1] (ALT_MFP[17]), EBI_EN (ALT_MFP[11]), PA5_SC1RST (ALT_MFP1[8]) and GPA_MFP[5] determine the PA.5 function. (EBI_HB_EN, EBI_EN, PA5_SC1RST, GPA_MFP5) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = ADC5 function is selected. (0, 1, 1) = SC1_RST function is selected. (1, 0, 1) = AD9 function is selected.
[6]	PA7_SC1DAT	PA.7 Pin Alternative Function Selection Bits EBI_EN (ALT_MFP[11]), PA7_SC1DAT (ALT_MFP1[6]), PA7_S21 (ALT_MFP[2]) and GPA_MFP[7] determine the PA.7 function. (EBI_EN, PA7_SC1DAT, PA7_S21, GPA_MFP7) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC7 function is selected. (0, 0, 1, 1) = SPI2_SS1 function is selected. (0, 1, 0, 1) = SC1_DAT\UART4_RXD function is selected. (1, 0, 0, 1) = AD6 function is selected.
[5]	PA6_SC1CLK	PA.6 Pin Alternative Function Selection Bits EBI_EN (ALT_MFP[11]), PA6_SC1CLK (ALT_MFP1[5]) and GPA_MFP[6] determine the PA.6 function. (EBI_EN, PA6_SC1CLK, GPA_MFP6) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = ADC6 function is selected. (0, 1, 1) = SC1_CLK\UART4_TXD function is selected. (1, 0, 1) = AD7 function is selected.
[4]	PC6_SC0CD	PC.6 Pin Alternative Function Selection Bits EBI_EN (ALT_MFP[11]), PC6_SC0CD (ALT_MFP1[4]) and GPC_MFP[6] determine the PC.6 function. (EBI_EN, PC6_SC0CD, GPB_MFP6) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = ACMP0_P function is selected. (0, 1, 1) = SC0_CD function is selected. (1, 0, 1) = AD4 function is selected.
[3]	PA1_SC0RST	PA.1 Pin Alternative Function Selection Bit EBI_HB_EN[4] (ALT_MFP[20]), EBI_EN (ALT_MFP[11]), PA1_SC0RST (ALT_MFP1[3]) and GPA_MFP[1] determine the PA.1 function. (EBI_HB_EN, EBI_EN, PA1_SC0RST, GPA_MFP1) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC1 function is selected. (0, 0, 1, 1) = SC0_RST function is selected. (1, 1, 0, 1) = AD12 function is selected.

[2]	PA0_SC0PWR	PA.0 Pin Alternative Function Selection Bit PA0_SC0PWR (ALT_MFP1[2]) and GPA_MFP[0] determine the PA.0 function. (PA0_SC0PWR, GPA_MFP0) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = ADC0 function is selected. (1, 1) = SC0_PWR function is selected.
[1]	PA3_SC0DAT	PA.3 Pin Alternative Function Selection Bits EBI_HB_EN[2] (ALT_MFP[18]), EBI_EN (ALT_MFP[11]), PA3_SC0DAT (ALT_MFP1[1]) and GPA_MFP[3] determine the PA.3 function. (EBI_HB_EN, EBI_EN PA3_SC0DAT, GPA_MFP3) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC3 function is selected. (0, 0, 1, 1) = SC0_DAT/UART3_RXD function is selected. (1, 1, 0, 1) = AD10 function is selected.
[0]	PA2_SC0CLK	PA.2 Pin Alternative Function Selection Bits EBI_HB_EN[3] (ALT_MFP[19]), EBI_EN (ALT_MFP[11]), PA2_SC0CLK (ALT_MFP1[0]) and GPA_MFP[2] determine the PA.2 function. (EBI_HB_EN, EBI_EN, PA2_SC0CLK, GPA_MFP2) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = ADC2 function is selected. (0, 0, 1, 1) = SC0_CLK/UART3_TXD function is selected. (1, 1, 0, 1) = AD11 function is selected.

Alternative Multiple Function Pin Control Register 2 (ALT_MFP2)

Register	Offset	R/W	Description	Reset Value
ALT_MFP2	GCR_BA+0x5C	R/W	Alternative Multiple Function Pin Control Register 2	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved		PB3_TM3	PB2_TM2	PE5_TM1	PB15_TM0	PB14_15_EBI	PD14_15_CANN1

Bits	Description	
[31:6]	Reserved	Reserved.
[5]	PB3_TM3	PB.3 Pin Alternative Function Selection Bits EBI_nWRH_EN (ALT_MFP[14]), EBI_EN (ALT_MFP[11]), PB3_TM3 (ALT_MFP[5]), PB3_SC2CD (ALT_MFP1[14]), PB3_T3EX (ALT_MFP[27]) and GPB_MFP[3] determine the PB.3 function. (EBI_nWRH_EN, EBI_EN, PB3_TM3, PB3_SC2CD, PB3_T3EX, GPB_MFP3) value and function mapping is as following list. (0, 0, 0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 0, 0, 1) = UART0_nCTS function is selected. (0, 0, 0, 0, 1, 1) = TM3_EXT function is selected. (0, 0, 0, 1, 0, 1) = SC2_CD function is selected. (0, 0, 1, 0, 0, 1) = TM3 function is selected. (1, 1, 0, 0, 0, 1) = nWRH(EBI) function is selected.
[4]	PB2_TM2	PB.2 Pin Alternative Function Selection Bits EBI_nWRL_EN (ALT_MFP[13]), EBI_EN (ALT_MFP[11]), PB2_TM2 (ALT_MFP[4]), PB2_CPO0 (ALT_MFP[30]), PB2_T2EX (ALT_MFP[26]) and GPB_MFP[2] determine the PB.2 function. (EBI_nWRL_EN, EBI_EN, PB2_TM2, PB2_CPO0, PB2_T2EX, GPB_MFP2) value and function mapping is as following list. (0, 0, 0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 0, 0, 1) = UART0_nRTS function is selected. (0, 0, 0, 0, 1, 1) = TM2_EXT function is selected. (0, 0, 0, 1, 0, 1) = ACMP0_O function is selected. (0, 0, 1, 0, 0, 1) = TM2 function is selected. (1, 1, 0, 0, 0, 1) = nWRL function is selected.

[3]	PE5_TM1	PE.5 Pin Alternative Function Selection Bits PE5_T1EX (ALT_MFP[25]), PE5_TM1 (ALT_MFP[23]) and GPE_MFP5 determine the PE.5 function. (PE5_T1EX, PE5_TM1, GPE_MFP5) value and function mapping is as following list. (0, 0, 0) = GPIO function is selected. (0, 0, 1) = PWM5 function is selected. (1, 0, 1) = TM1_EXT function is selected. (0, 1, 1) = TM1 function is selected.																																																							
[2]	PB15_TM0	PB.15 Pin Alternative Function Selection Bits PB14_15_EBI (ALT_MFP[21]), PB15_T0EX (ALT_MFP[24]), PB15_TM0 (ALT_MFP[22]) and GPB_MFP[15] determine the PB.15 function. (PB14_15_EBI, PB15_T0EX, PB15_TM0, GPB_MFP[15]) value and function mapping is as following list. (0, 0, 0, 0) = GPIO function is selected. (0, 0, 0, 1) = INT1 function is selected. (0, 0, 1, 1) = TM0 function is selected. (0, 1, 0, 1) = TM0_EXT function is selected. (1, 0, 0, 1) = AD6 function is selected.																																																							
[1]	PB14_15_EBI	<table><tr><td colspan="5">Bits PB15_T0EX (ALT_MFP[24]), PB14_15_EBI (ALT_MFP[21]), PB15_TM0 (ALT_MFP[22]) and GPB_MFP[15] determine the PB.15 function.</td></tr><tr><th>PB15_T0EX</th><th>PB14_15_EBI</th><th>PB15_TM0</th><th>GPB_MFP[15]</th><th>PB.15 function</th></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td><td>GPIO</td></tr><tr><td>0</td><td>0</td><td>0</td><td>1</td><td>/INT1</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>T0EX (TMR0)</td></tr><tr><td>0</td><td>1</td><td>0</td><td>1</td><td>AD6</td></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td><td>TM0</td></tr></table> Bits PB14_S31 (ALT_MFP[3]), PB14_15_EBI (ALT_MFP[21]) and GPB_MFP[14] determine the PB.14 function. <table><tr><th>PB14_S31</th><th>PB14_15_EBI</th><th>GPB_MFP[14]</th><th>PB.14 function</th></tr><tr><td>0</td><td>0</td><td>0</td><td>GPIO</td></tr><tr><td>0</td><td>0</td><td>1</td><td>/INT0</td></tr><tr><td>1</td><td>0</td><td>1</td><td>SPISS31 (SPI3)</td></tr><tr><td>0</td><td>1</td><td>1</td><td>AD0</td></tr></table>	Bits PB15_T0EX (ALT_MFP[24]), PB14_15_EBI (ALT_MFP[21]), PB15_TM0 (ALT_MFP[22]) and GPB_MFP[15] determine the PB.15 function.					PB15_T0EX	PB14_15_EBI	PB15_TM0	GPB_MFP[15]	PB.15 function	0	0	0	0	GPIO	0	0	0	1	/INT1	1	0	0	1	T0EX (TMR0)	0	1	0	1	AD6	0	0	1	1	TM0	PB14_S31	PB14_15_EBI	GPB_MFP[14]	PB.14 function	0	0	0	GPIO	0	0	1	/INT0	1	0	1	SPISS31 (SPI3)	0	1	1	AD0
Bits PB15_T0EX (ALT_MFP[24]), PB14_15_EBI (ALT_MFP[21]), PB15_TM0 (ALT_MFP[22]) and GPB_MFP[15] determine the PB.15 function.																																																									
PB15_T0EX	PB14_15_EBI	PB15_TM0	GPB_MFP[15]	PB.15 function																																																					
0	0	0	0	GPIO																																																					
0	0	0	1	/INT1																																																					
1	0	0	1	T0EX (TMR0)																																																					
0	1	0	1	AD6																																																					
0	0	1	1	TM0																																																					
PB14_S31	PB14_15_EBI	GPB_MFP[14]	PB.14 function																																																						
0	0	0	GPIO																																																						
0	0	1	/INT0																																																						
1	0	1	SPISS31 (SPI3)																																																						
0	1	1	AD0																																																						

[0]	PD14_15_CAN1	PD.14 And PD.15 Pin Alternative Function Selection Bits PD14_15_CAN1 (ALT_MFP2[0]) and GPD_MFP[15] determine the PD.15 function. (PD14_15_CAN1, GPD_MFP15) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = UART2_TXD function is selected. (1, 1) = CAN1_TXD function is selected. Bits PD14_15_CAN1 (ALT_MFP2[0]) and GPD_MFP[14] determine the PD.14 function. (PD14_15_CAN1, GPD_MFP14) value and function mapping is as following list. (0, 0) = GPIO function is selected. (0, 1) = UART2_RXD function is selected. (1, 1) = CAN1_RXD function is selected.

HIRC Trim Control Register (IRCTRIMCTL)

Register	Offset	R/W	Description	Reset Value
IRCTRIMCTL	GCR_BA+0x80	R/W	IRC Trim Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							CLKERR_STOP_EN
7	6	5	4	3	2	1	0
TRIM_RETRY_CNT		TRIM_LOOP		Reserved		TRIM_SEL	

Bits	Description
[31:9]	Reserved Reserved.
[8]	CLKERR_STOP_EN Clock Error Stop Enable Bit 0 = The trim operation is kept going if clock is inaccuracy. 1 = The trim operation is stopped if clock is inaccuracy.
[7:6]	TRIM_RETRY_CNT Trim Value Update Limitation Count The field defines that how many times of HIRC trim value is updated by auto trim circuit before the HIRC frequency locked. Once the HIRC locked, the internal trim value update counter will be reset. If the trim value update counter reached this limitation value and frequency of HIRC still doesn't lock, the auto trim operation will be disabled and TRIM_SEL will be cleared to 00. 00 = Trim retry count limitation is 64. 01 = Trim retry count limitation is 128. 10 = Trim retry count limitation is 256. 11 = Trim retry count limitation is 512.
[5:4]	TRIM_LOOP Trim Calculation Loop This field defines that trim value calculation is based on how many 32.768 kHz clocks in. For example, if TRIM_LOOP is set as 00, auto trim circuit will calculate trim value based on the average frequency difference in 4 32.768 kHz clock. 00 = Trim value calculation is based on average difference in 4 clocks. 01 = Trim value calculation is based on average difference in 8 clocks. 10 = Trim value calculation is based on average difference in 16 clocks. 11 = Trim value calculation is based on average difference in 32 clocks.
[3:2]	Reserved Reserved.
[1:0]	TRIM_SEL Trim Frequency Selection This field indicates the target frequency of internal 22.1184 MHz high speed oscillator will trim to precise 22.1184MHz or 24MHz automatically. If no any target frequency is selected (TRIM_SEL is 00), the HIRC auto trim function is

		disabled. During auto trim operation, if clock error detected because of CLKERR_STOP_EN is set to 1 or trim retry limitation counts reached, this field will be cleared to 00 automatically. 00 = HIRC auto trim function Disabled. 01 = HIRC auto trim function Enabled and HIRC trimmed to 22.1184 MHz. 10 = HIRC auto trim function Enabled and HIRC trimmed to 24 MHz. 11 = Reserved.

HIRC Trim Interrupt Enable Register (IRCTRIMIEN)

Register	Offset	R/W	Description	Reset Value
IRCTRIMIEN	GCR_BA+0x84	R/W	IRC Trim Interrupt Enable Register	0x0000_0000

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

Bits	Description
[31:3]	Reserved Reserved.
[2]	CLKERR_IEN Clock Error Interrupt Enable Bit This bit controls if CPU would get an interrupt while clock is inaccuracy during auto trim operation. If this bit is set to 1, and CLKERR_INT (IRCTRIMINT[2]) is set during auto trim operation. An interrupt will be triggered to notify the clock frequency is inaccuracy. 0 = CLKERR_INT (IRCTRIMINT[2]) status to trigger an interrupt to CPU Disabled. 1 = CLKERR_INT (IRCTRIMINT[2]) status to trigger an interrupt to CPU Enabled.
[1]	TRIM_FAIL_IEN Trim Failure Interrupt Enable Bit This bit controls if an interrupt will be triggered while HIRC trim value update limitation count reached and HIRC frequency still not locked on target frequency set by TRIM_SEL (IRCTRIMCTL[1:0]). If this bit is high and TRIM_FAIL_INT (IRCTRIMINT[1]) is set during auto trim operation. An interrupt will be triggered to notify that HIRC trim value update limitation count was reached. 0 = TRIM_FAIL_INT (IRCTRIMINT[1]) status to trigger an interrupt to CPU Disabled. 1 = TRIM_FAIL_INT (IRCTRIMINT[1]) status to trigger an interrupt to CPU Enabled.
[0]	Reserved Reserved.

HIRC Trim Interrupt Status Register (IRCTRIMINT)

Register	Offset	R/W	Description	Reset Value
IRCTRIMINT	GCR_BA+0x88	R/W	IRC Trim Interrupt Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					CLKERR_INT	TRIM_FAIL_INT	FREQ_LOCK

Bits	Description	
[31:3]	Reserved	Reserved.
[2]	CLKERR_INT	Clock Error Interrupt Status When the frequency of external 32.768 kHz low speed crystal or internal 22.1184 MHz high speed oscillator is shift larger to unreasonable value, this bit will be set and to be an indicate that clock frequency is inaccuracy Once this bit is set to 1, the auto trim operation stopped and TRIM_SEL (IRCTRIMCTL[1:0]) will be cleared to 00 by hardware automatically if CLKERR_STOP_EN (IRCTRIMCTL[8]) is set to 1. If this bit is set and CLKERR_IEN (IRCTRIMIEN [2]) is high, an interrupt will be triggered to notify the clock frequency is inaccuracy. Write 1 to clear this to 0. 0 = Clock frequency is accurate. 1 = Clock frequency is inaccurate.
[1]	TRIM_FAIL_INT	Trim Failure Interrupt Status This bit indicates that internal 22.1184 MHz high speed oscillator trim value update limitation count reached and the internal 22.1184 MHz high speed oscillator clock frequency still doesn't be locked. Once this bit is set, the auto trim operation stopped and TRIM_SEL (IRCTRIMCTL[1:0]) will be cleared to 00 by hardware automatically. If this bit is set and TRIM_FAIL_IEN (IRCTRIMIEN[1]) is high, an interrupt will be triggered to notify that HIRC trim value update limitation count was reached. Write 1 to clear this to 0. 0 = Trim value update limitation count did not reach. 1 = Trim value update limitation count reached and internal 22.1184 MHz high speed oscillator frequency was still not locked.
[0]	FREQ_LOCK	HIRC Frequency Lock Status This bit indicates the internal 22.1184 MHz high speed oscillator frequency is locked. This is a status bit and doesn't trigger any interrupt.

6.2.7 Register Write Protection Register (REGWRPROT)

Some of the system control registers need to be protected to avoid inadvertent write and disturb the chip operation. These system control registers are protected after the power on reset till user to disable register protection. For user to program these protected registers, a register protection disable sequence needs to be followed by a special programming. The register protection disable sequence is writing the data “59h”, “16h” “88h” to the register REGWRPROT address at 0x5000_0100 continuously. Any different data value, different sequence or any other write to other address during these three data writing will abort the whole sequence.

After the protection is disabled, user can check the protection disable bit at address 0x5000_0100 bit0, 1 is protection disable, and 0 is protection enable. Then user can update the target protected register value and then write any data to the address “0x5000_0100” to enable register protection.

The protected registers are listed as following table.

Register	Bit	Description
IPRSTC1	[3] EBI_RST	EBI Controller Reset (Write-protection Bit)
IPRSTC1	[2] PDMA_RST	PDMA Controller Reset (Write Protect)
IPRSTC1	[1] CPU_RST	CPU Kernel One-Shot Reset (Write Protect)
IPRSTC1	[0] CHIP_RST	CHIP One-Shot Reset (Write Protect)
BODCR	[7] LVR_EN	Low Voltage Reset Enable Bit (Write Protect)
BODCR	[5] BOD_LPM	Brown-Out Detector Low Power Mode (Write Protect)
BODCR	[3] BOD_RSTEN	Brown-Out Reset Enable Bit (Write Protect)
BODCR	[2:1] BOD_VL	Brown-Out Detector Threshold Voltage Selection (Write Protect)
BODCR	[0] BOD_EN	Brown-Out Detector Enable Bit (Write Protect)
PORCR	[15:0] POR_DIS_CODE	Power-On-Reset Enable Bit (Write Protect)
REGWRPROT	[7:0] REGWRPROT	Register Write-Protection Code (Write Only)
REGWRPROT	[0] REGPROTDIS	Register Write-Protection Disable Index (Read Only)
NMI_SEL	[8] NMI_EN	NMI Interrupt Enable Bit (Write Protect)
PWRCON	[8] PD_WAIT_CPU	Power-Down Entry Condition Control (Write Protect)
PWRCON	[7] PWR_DOWN_EN	System Power-Down Enable Bit (Write Protect)
PWRCON	[5] PD_WU_INT_EN	Power-Down Mode Wake-Up Interrupt Enable Bit (Write Protect)
PWRCON	[4] PD_WU_DLY	Wake-Up Delay Counter Enable Bit (Write Protect)
PWRCON	[3] OSC10K_EN	10 KHz Internal Low Speed RC Oscillator (LIRC) Enable Bit (Write Protect)
PWRCON	[2] OSC22M_EN	22.1184 MHz Internal High Speed RC Oscillator (HIRC) Enable Bit (Write Protect)
PWRCON	[1] XTL32K_EN	32.768 KHz External Low Speed Crystal Oscillator (LXT) Enable Bit (Write Protect)
PWRCON	[0] XTL12M_EN	4~24 MHz External High Speed Crystal Oscillator (HXT) Enable Bit (Write Protect)

APBCLK	[0] WDT_EN	Watchdog Timer Clock Enable Bit (Write Protect)
CLKSEL0	[5:3] STCLK_S	Cortex™-M0 SysTick Clock Source Select (Write Protect)
CLKSEL0	[2:0] HCLK_S	HCLK Clock Source Select (Write Protect)
CLKSEL1	[1:0] WDT_S	Watchdog Timer Clock Source Select (Write Protect)
ISPCON	[6] ISPFF	ISP Fail Flag (Write Protect)
ISPCON	[5] LDUEN	LDROM Update Enable Bit (Write Protect)
ISPCON	[4] CFGUEN	Enable Config Update By ISP (Write Protect)
ISPCON	[3] APUEN	APROM Update Enable Bit (Write Protect)
ISPCON	[1] BS	Boot Select (Write Protect)
ISPCON	[0] ISPEN	ISP Enable Bit (Write Protect)
ISPTRG	[0] ISPGO	ISP Start Trigger (Write-Protection Bit)
FATCON	[4] FOMSEL0	Chip Frequency Optimization Mode Select 0 (Write-Protection Bit)
ISPSTA	[6] ISPFF	ISP Fail Flag (Write-Protection Bit)
TCSR0	[31] DBGACK_TMR	ICE Debug Mode Acknowledge Disable Bit (Write Protect)
TCSR1	[31] DBGACK_TMR	ICE Debug Mode Acknowledge Disable Bit (Write Protect)
TCSR2	[31] DBGACK_TMR	ICE Debug Mode Acknowledge Disable Bit (Write Protect)
TCSR3	[31] DBGACK_TMR	ICE Debug Mode Acknowledge Disable Bit (Write Protect)
WTCR	[31] DBGACK_WDT	ICE Debug Mode Acknowledge Disable Bit (Write Protect)
WTCR	[10:8] WTIS	Watchdog Timer Time-Out Interval Selection (Write Protect)
WTCR	[7] WTE	Watchdog Timer Enable Bit (Write Protect)
WTCR	[6] WTIE	Watchdog Timer Time-Out Interrupt Enable Bit (Write Protect)
WTCR	[4] WTWKE	Watchdog Timer Time-Out Wake-Up Function Control (Write Protect)
WTCR	[1] WTRE	Watchdog Timer Reset Enable Bit (Write Protect)
WTCRALT	[1:0] WTRDSEL	Watchdog Timer Reset Delay Selection (Write Protect)

This register is write for disable/enable register protection and read for the REGPROTDIS status

Register	Offset	R/W	Description	Reset Value
REGWRPROT	GCR_BA+0x100	R/W	Register Write Protection Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8

Reserved							
7	6	5	4	3	2	1	0
REGWRPROT[7:1]							REGWRPROT [0] REGPROTDIS

Bits	Description	
[31:16]	Reserved	Reserved.
[7:0]	REGWRPROT	Register Write-Protection Code (Write Only) Some registers have write-protection function. Writing these registers have to disable the protected function by writing the sequence value "59h", "16h", "88h" to this field. After this sequence is completed, the REGPROTDIS bit will be set to 1 and write-protection registers can be normal write.
[0]	REGPROTDIS	Register Write-Protection Disable Index (Read Only) 0 = Write-protection is enabled for writing protected registers. Any write to the protected register is ignored. 1 = Write-protection is disabled for writing protected registers. The Protected registers are: IPRSTC1 : address 0x5000_0008 BODCR : address 0x5000_0018 PORCR : address 0x5000_0024 PWRCON : address 0x5000_0200 (bit[6] is not protected for power wake-up interrupt clear) APBCLK bit[0] : address 0x5000_0208 (bit[0] is Watchdog Timer clock enable) CLKSEL0 : address 0x5000_0210 (for HCLK and CPU STCLK clock source selection) CLKSEL1 bit[1:0] : address 0x5000_0214 (for Watchdog Timer clock source selection) NMI_SEL bit[8] : address 0x5000_0380 (for NMI_EN interrupt enable) ISPCON : address 0x5000_C000 (Flash ISP Control register) ISPTRG : address 0x5000_C010 (ISP Trigger Control register) WTCR : address 0x4000_4000 FATCON : address 0x5000_C018 Note : The bits which are write-protected will be noted as " (Write Protect) " beside the description.

6.2.8 System Timer (SysTick)

The Cortex™-M0 includes an integrated system timer, SysTick, which provides a simple, 24-bit clear-on-write, decrementing, wrap-on-zero counter with a flexible control mechanism. The counter can be used as a Real Time Operating System (RTOS) tick timer or as a simple counter.

When system timer is enabled, it will count down from the value in the SysTick Current Value Register (SYST_CVR) to 0, and reload (wrap) to the value in the SysTick Reload Value Register (SYST_RVR) on the next clock cycle, then decrement on subsequent clocks. When the counter transitions to 0, the COUNTFLAG status bit is set. The COUNTFLAG bit clears on reads.

The SYST_CVR value is UNKNOWN on reset. Software should write to the register to clear it to 0 before enabling the feature. This ensures the timer will count from the SYST_RVR value rather than an arbitrary value when it is enabled.

If the SYST_RVR is 0, the timer will be maintained with a current value of 0 after it is reloaded with this value. This mechanism can be used to disable the feature independently from the timer enable bit.

For more detailed information, please refer to the “ARM® Cortex™-M0 Technical Reference Manual” and “ARM® v6-M Architecture Reference Manual”.

6.2.8.1 System Timer Control Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
SYST Base Address: SCS_BA = 0xE000_E000				
SYST_CSR	SCS_BA+0x10	R/W	SysTick Control and Status Register	0x0000_0000
SYST_RVR	SCS_BA+0x14	R/W	SysTick Reload Value Register	0xFFFF_FFFF
SYST_CVR	SCS_BA+0x18	R/W	SysTick Current Value Register	0xFFFF_FFFF

6.2.8.2 System Timer Control Register Description

SysTick Control and Status (SYST_CSR)

Register	Offset	R/W	Description	Reset Value
SYST_CSR	SCS_BA+0x10	R/W	SysTick Control and Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							COUNTFLAG
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					CLKSRC	TICKINT	ENABLE

Bits	Description
[31:17]	Reserved Reserved.
[16]	COUNTFLAG Returns 1 If Timer Counted To 0 Since Last Time This Register Was Read COUNTFLAG is set by a count transition from 1 to 0. COUNTFLAG is cleared on read or by a write to the Current Value register.
[15:3]	Reserved Reserved.
[2]	CLKSRC System Tick Clock Source Selection If CLKSRC(SYST_CSR[2]) = 1, SysTick clock source is from HCLK. If CLKSRC(SYST_CSR[2]) = 0, SysTick clock source is defined by STCLK_S(CLKSEL0[5:3]). 0 = Clock source is (optional) external reference clock. 1 = Core clock used for SysTick.
[1]	TICKINT System Tick Interrupt Enabled 0 = Counting down to 0 does not cause the SysTick exception to be pended. Software can use COUNTFLAG to determine if a count to 0 has occurred. 1 = Counting down to 0 will cause the SysTick exception to be pended. Clearing the SysTick Current Value register by a write in software will not cause SysTick to be pended.
[0]	ENABLE System Tick Counter Enabled 0 = Counter Disabled. 1 = Counter will operate in a multi-shot manner.

SysTick Reload Value Register (SYST_RVR)

Register	Offset	R/W	Description	Reset Value
SYST_RVR	SCS_BA+0x14	R/W	SysTick Reload Value Register	0xFFFF_XXXX

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
RELOAD[23:16]							
15	14	13	12	11	10	9	8
RELOAD[15:8]							
7	6	5	4	3	2	1	0
RELOAD[7:0]							

Bits	Description	
[31:24]	Reserved	Reserved.
[23:0]	RELOAD	Value to load into the Current Value register when the counter reaches 0.

SysTick Current Value Register (SYST_CVR)

Register	Offset	R/W	Description	Reset Value
SYST_CVR	SCS_BA+0x18	R/W	SysTick Current Value Register	0xFFFF_XXXX

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
CURRENT[23:16]							
15	14	13	12	11	10	9	8
CURRENT[15:8]							
7	6	5	4	3	2	1	0
CURRENT[7:0]							

Bits	Description	
[31:24]	Reserved	Reserved.
[23:0]	CURRENT	System Tick Current Value Current counter value. This is the value of the counter at the time it is sampled. The counter does not provide read-modify-write protection. The register is write-clear. A software write of any value will clear the register to 0.

6.2.9 Nested Vectored Interrupt Controller (NVIC)

The Cortex™-M0 provides an interrupt controller as an integral part of the exception mode, named as “Nested Vectored Interrupt Controller (NVIC)”, which is closely coupled to the processor kernel and provides following features:

- Nested and Vectored interrupt support
- Automatic processor state saving and restoration
- Reduced and deterministic interrupt latency

The NVIC prioritizes and handles all supported exceptions. All exceptions are handled in “Handler Mode”. This NVIC architecture supports 32 (IRQ[31:0]) discrete interrupts with 4 levels of priority. All of the interrupts and most of the system exceptions can be configured to different priority levels. When an interrupt occurs, the NVIC will compare the priority of the new interrupt to the current running one's priority. If the priority of the new interrupt is higher than the current one, the new interrupt handler will override the current handler.

When an interrupt is accepted, the starting address of the interrupt service routine (ISR) is fetched from a vector table in memory. There is no need to determine which interrupt is accepted and branch to the starting address of the correlated ISR by software. While the starting address is fetched, NVIC will also automatically save processor state including the registers “PC, PSR, LR, R0~R3, R12” to the stack. At the end of the ISR, the NVIC will restore the mentioned registers from stack and resume the normal execution. Thus it will take less and deterministic time to process the interrupt request.

The NVIC supports “Tail Chaining” which handles back-to-back interrupts efficiently without the overhead of states saving and restoration and therefore reduces delay time in switching to pending ISR at the end of current ISR. The NVIC also supports “Late Arrival” which improves the efficiency of concurrent ISRs. When a higher priority interrupt request occurs before the current ISR starts to execute (at the stage of state saving and starting address fetching), the NVIC will give priority to the higher one without delay penalty. Thus it advances the real-time capability.

For more detailed information, please refer to the “ARM® Cortex™-M0 Technical Reference Manual” and “ARM® v6-M Architecture Reference Manual”.

6.2.9.1 Exception Model and System Interrupt Map

The following table lists the exception model supported by NuMicro™ NUC230/240 series. Software can set four levels of priority on some of these exceptions as well as on all interrupts. The highest user-configurable priority is denoted as “0” and the lowest priority is denoted as “3”. The default priority of all the user-configurable interrupts is “0”. Note that priority “0” is treated as the fourth priority on the system, after three system exceptions “Reset”, “NMI” and “Hard Fault”.

Exception Name	Vector Number	Priority
Reset	1	-3
NMI	2	-2
Hard Fault	3	-1
Reserved	4 ~ 10	Reserved
SVCall	11	Configurable
Reserved	12 ~ 13	Reserved
PendSV	14	Configurable
SysTick	15	Configurable
Interrupt (IRQ0 ~ IRQ31)	16 ~ 47	Configurable

Table 6-2 Exception Model

Vector Number	Interrupt Number (Bit In Interrupt Registers)	Interrupt Name	Source Module	Interrupt Description
1 ~ 15	-	-	-	System exceptions
16	0	BOD_INT	Brown-out	Brown-out low voltage detected interrupt
17	1	WDT_INT	WDT	Watchdog Timer interrupt
18	2	EINT0	GPIO	External signal interrupt from PB.14 pin
19	3	EINT1	GPIO	External signal interrupt from PB.15 pin
20	4	GPAB_INT	GPIO	External signal interrupt from PA[15:0]/PB[13:0]
21	5	GPCDEF_INT	GPIO	External interrupt from PC[15:0]/PD[15:0]/PE[15:0]/PF[3:0]
22	6	PWMA_INT	PWM0~3	PWM0, PWM1, PWM2 and PWM3 interrupt
23	7	PWMB_INT	PWM4~7	PWM4, PWM5, PWM6 and PWM7 interrupt
24	8	TMR0_INT	TMR0	Timer 0 interrupt
25	9	TMR1_INT	TMR1	Timer 1 interrupt
26	10	TMR2_INT	TMR2	Timer 2 interrupt
27	11	TMR3_INT	TMR3	Timer 3 interrupt
28	12	UART02_INT	UART0/2	UART0 and UART2 interrupt
29	13	UART1_INT	UART1	UART1 interrupt
30	14	SPI0_INT	SPI0	SPI0 interrupt

31	15	SPI1_INT	SPI1	SPI1 interrupt
32	16	SPI2_INT	SPI2	SPI2 interrupt
33	17	SPI3_INT	SPI3	SPI3 interrupt
34	18	I2C0_INT	I ² C0	I ² C0 interrupt
35	19	I2C1_INT	I ² C1	I ² C1 interrupt
36	20	-	-	Reserved
37	21	-	-	Reserved
38	22	SC012_INT	SC0/1/2	SC0, SC1 and SC2 interrupt
39	23	USB_INT	USBD	USB 2.0 FS Device interrupt
40	24	PS2_INT	PS/2	PS/2 interrupt
41	25	ACMP_INT	ACMP	Analog Comparator interrupt
42	26	PDMA_INT	PDMA	PDMA interrupt
43	27	I2S_INT	I ² S	I ² S interrupt
44	28	PWRWU_INT	CLKC	Clock controller interrupt for chip wake-up from Power-down state
45	29	ADC_INT	ADC	ADC interrupt
46	30	IRC_INT	IRC	IRC TRIM interrupt
47	31	RTC_INT	RTC	Real Time Clock interrupt

Table 6-3 System Interrupt Map

6.2.9.2 Vector Table

When an interrupt is accepted, the processor will automatically fetch the starting address of the interrupt service routine (ISR) from a vector table in memory. For ARMv6-M, the vector table base address is fixed at 0x00000000. The vector table contains the initialization value for the stack pointer on reset, and the entry point addresses for all exception handlers. The vector number on previous page defines the order of entries in the vector table associated with exception handler entry as illustrated in previous section.

Vector Table Word Offset	Description
0	SP_main – The Main stack pointer
Vector Number	Exception Entry Pointer using that Vector Number

Table 6-4 Vector Table Format

6.2.9.3 Operation Description

NVIC interrupts can be enabled and disabled by writing to their corresponding Interrupt Set-Enable or Interrupt Clear-Enable register bit-field. The registers use a write-1-to-enable and write-1-to-clear policy, both registers reading back the current enabled state of the corresponding interrupts. When an interrupt is disabled, interrupt assertion will cause the interrupt to become Pending, however, the interrupt will not activate. If an interrupt is Active when it is disabled, it remains in its Active state until cleared by reset or an exception return. Clearing the enable bit prevents new activations of the associated interrupt.

NVIC interrupts can be pended/un-pended using a complementary pair of registers to those used to enable/disable the interrupts, named the Set-Pending Register and Clear-Pending Register respectively. The registers use a write-1-to-enable and write-1-to-clear policy, both registers reading back the current pended state of the corresponding interrupts. The Clear-Pending Register has no effect on the execution status of an Active interrupt.

NVIC interrupts are prioritized by updating an 8-bit field within a 32-bit register (each register supporting four interrupts).

The general registers associated with the NVIC are all accessible from a block of memory in the System Control Space and will be described in next section.

6.2.9.4 NVIC Control Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
NVIC Base Address: SCS_BA = 0xE000_E000				
NVIC_ISER	SCS_BA+0x100	R/W	IRQ0 ~ IRQ31 Set-Enable Control Register	0x0000_0000
NVIC_ICER	SCS_BA+0x180	R/W	IRQ0 ~ IRQ31 Clear-Enable Control Register	0x0000_0000
NVIC_ISPR	SCS_BA+0x200	R/W	IRQ0 ~ IRQ31 Set-Pending Control Register	0x0000_0000
NVIC_ICPR	SCS_BA+0x280	R/W	IRQ0 ~ IRQ31 Clear-Pending Control Register	0x0000_0000
NVIC_IPR0	SCS_BA+0x400	R/W	IRQ0 ~ IRQ3 Priority Control Register	0x0000_0000
NVIC_IPR1	SCS_BA+0x404	R/W	IRQ4 ~ IRQ7 Priority Control Register	0x0000_0000
NVIC_IPR2	SCS_BA+0x408	R/W	IRQ8 ~ IRQ11 Priority Control Register	0x0000_0000
NVIC_IPR3	SCS_BA+0x40C	R/W	IRQ12 ~ IRQ15 Priority Control Register	0x0000_0000
NVIC_IPR4	SCS_BA+0x410	R/W	IRQ16 ~ IRQ19 Priority Control Register	0x0000_0000
NVIC_IPR5	SCS_BA+0x414	R/W	IRQ20 ~ IRQ23 Priority Control Register	0x0000_0000
NVIC_IPR6	SCS_BA+0x418	R/W	IRQ24 ~ IRQ27 Priority Control Register	0x0000_0000
NVIC_IPR7	SCS_BA+0x41C	R/W	IRQ28 ~ IRQ31 Priority Control Register	0x0000_0000

6.2.9.5 NVIC Control Register Description

IRQ0 ~ IRQ31 Set-Enable Control Register (NVIC_ISER)

Register	Offset	R/W	Description	Reset Value
NVIC_ISER	SCS_BA+0x100	R/W	IRQ0 ~ IRQ31 Set-Enable Control Register	0x0000_0000

31	30	29	28	27	26	25	24
SETENA[31:24]							
23	22	21	20	19	18	17	16
SETENA[23:16]							
15	14	13	12	11	10	9	8
SETENA[15:8]							
7	6	5	4	3	2	1	0
SETENA[7:0]							

Bits	Description
[31:0]	SETENA Interrupt Enable Register Enable one or more interrupts. Each bit represents an interrupt number from IRQ0 ~ IRQ31 (Vector number from 16 ~ 47). Write Operation: 0 = No effect. 1 = Write 1 to enable associated interrupt. Read Operation: 0 = Associated interrupt status is Disabled. 1 = Associated interrupt status is Enabled. Read value indicates the current enable status.

IRQ0 ~ IRQ31 Clear-Enable Control Register (NVIC_ICER)

Register	Offset	R/W	Description	Reset Value
NVIC_ICER	SCS_BA+0x180	R/W	IRQ0 ~ IRQ31 Clear-Enable Control Register	0x0000_0000

31	30	29	28	27	26	25	24
CLRENA[31:24]							
23	22	21	20	19	18	17	16
CLRENA[23:16]							
15	14	13	12	11	10	9	8
CLRENA[15:8]							
7	6	5	4	3	2	1	0
CLRENA[7:0]							

Bits	Description
[31:0]	CLRENA Interrupt Disable Bits Disable one or more interrupts. Each bit represents an interrupt number from IRQ0 ~ IRQ31 (Vector number from 16 ~ 47). Write Operation: 0 = No effect. 1 = Write 1 to disable associated interrupt. Read Operation: 0 = Associated interrupt status is Disabled. 1 = Associated interrupt status is Enabled. Read value indicates the current enable status.

IRQ0 ~ IRQ31 Set-Pending Control Register (NVIC_ISPR)

Register	Offset	R/W	Description	Reset Value
NVIC_ISPR	SCS_BA+0x200	R/W	IRQ0 ~ IRQ31 Set-Pending Control Register	0x0000_0000

31	30	29	28	27	26	25	24
SETPEND[31:24]							
23	22	21	20	19	18	17	16
SETPEND[23:16]							
15	14	13	12	11	10	9	8
SETPEND[15:8]							
7	6	5	4	3	2	1	0
SETPEND[7:0]							

Bits	Description
[31:0]	Set Interrupt Pending Register Write Operation: 0 = No effect. 1 = Write 1 to set pending state. Each bit represents an interrupt number from IRQ0 ~ IRQ31 (Vector number from 16 ~ 47). Read Operation: 0 = Associated interrupt in not in pending status. 1 = Associated interrupt is in pending status. Read value indicates the current pending status.

IRQ0 ~ IRQ31 Clear-Pending Control Register (NVIC_ICPR)

Register	Offset	R/W	Description	Reset Value
NVIC_ICPR	SCS_BA+0x280	R/W	IRQ0 ~ IRQ31 Clear-Pending Control Register	0x0000_0000

31	30	29	28	27	26	25	24
CLRPEND[31:24]							
23	22	21	20	19	18	17	16
CLRPEND[23:16]							
15	14	13	12	11	10	9	8
CLRPEND[15:8]							
7	6	5	4	3	2	1	0
CLRPEND[7:0]							

Bits	Description
[31:0]	Clear Interrupt Pending Register Write Operation: 0 = No effect. 1 = Write 1 to clear pending state. Each bit represents an interrupt number from IRQ0 ~ IRQ31 (Vector number from 16 ~ 47). Read Operation: 0 = Associated interrupt in not in pending status. 1 = Associated interrupt is in pending status. Read value indicates the current pending status.

IRQ0 ~ IRQ3 Priority Register (NVIC_IPR0)

Register	Offset	R/W	Description	Reset Value
NVIC_IPR0	SCS_BA+0x400	R/W	IRQ0 ~ IRQ3 Priority Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PRI_3[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_2[1:0]		Reserved					
15	14	13	12	11	10	9	8
PRI_1[1:0]		Reserved					
7	6	5	4	3	2	1	0
PRI_0[1:0]		Reserved					

Bits	Description	
[31:30]	PRI_3	Priority Of IRQ3 "0" denotes the highest priority and "3" denotes the lowest priority.
[29:24]	Reserved	Reserved.
[23:22]	PRI_2	Priority Of IRQ2 "0" denotes the highest priority and "3" denotes the lowest priority.
[21:16]	Reserved	Reserved.
[15:14]	PRI_1	Priority Of IRQ1 "0" denotes the highest priority and "3" denotes the lowest priority.
[13:8]	Reserved	Reserved.
[7:6]	PRI_0	Priority Of IRQ0 "0" denotes the highest priority and "3" denotes the lowest priority.
[5:0]	Reserved	Reserved.

IRQ4 ~ IRQ7 Priority Register (NVIC_IPR1)

Register	Offset	R/W	Description	Reset Value
NVIC_IPR1	SCS_BA+0x404	R/W	IRQ4 ~ IRQ7 Priority Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PRI_7[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_6[1:0]		Reserved					
15	14	13	12	11	10	9	8
PRI_5[1:0]		Reserved					
7	6	5	4	3	2	1	0
PRI_4[1:0]		Reserved					

Bits	Description	
[31:30]	PRI_7	Priority Of IRQ7 "0" denotes the highest priority and "3" denotes the lowest priority.
[29:24]	Reserved	Reserved.
[23:22]	PRI_6	Priority Of IRQ6 "0" denotes the highest priority and "3" denotes the lowest priority.
[21:16]	Reserved	Reserved.
[15:14]	PRI_5	Priority Of IRQ5 "0" denotes the highest priority and "3" denotes the lowest priority.
[13:8]	Reserved	Reserved.
[7:6]	PRI_4	Priority Of IRQ4 "0" denotes the highest priority and "3" denotes the lowest priority.
[5:0]	Reserved	Reserved.

IRQ8 ~ IRQ11 Priority Register (NVIC_IPR2)

Register	Offset	R/W	Description	Reset Value
NVIC_IPR2	SCS_BA+0x408	R/W	IRQ8 ~ IRQ11 Priority Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PRI_11[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_10[1:0]		Reserved					
15	14	13	12	11	10	9	8
PRI_9[1:0]		Reserved					
7	6	5	4	3	2	1	0
PRI_8[1:0]		Reserved					

Bits	Description	
[31:30]	PRI_11[1:0]	Priority Of IRQ11 "0" denotes the highest priority and "3" denotes the lowest priority.
[29:24]	Reserved	Reserved.
[23:22]	PRI_10[1:0]	Priority Of IRQ10 "0" denotes the highest priority and "3" denotes the lowest priority.
[21:16]	Reserved	Reserved.
[15:14]	PRI_9[1:0]	Priority Of IRQ9 "0" denotes the highest priority and "3" denotes the lowest priority.
[13:8]	Reserved	Reserved.
[7:6]	PRI_8[1:0]	Priority Of IRQ8 "0" denotes the highest priority and "3" denotes the lowest priority.
[5:0]	Reserved	Reserved.

IRQ12 ~ IRQ15 Priority Register (NVIC_IPR3)

Register	Offset	R/W	Description	Reset Value
NVIC_IPR3	SCS_BA+0x40C	R/W	IRQ12 ~ IRQ15 Priority Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PRI_15[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_14[1:0]		Reserved					
15	14	13	12	11	10	9	8
PRI_13[1:0]		Reserved					
7	6	5	4	3	2	1	0
PRI_12[1:0]		Reserved					

Bits	Description	
[31:30]	PRI_15	Priority Of IRQ15 "0" denotes the highest priority and "3" denotes the lowest priority.
[29:24]	Reserved	Reserved.
[23:22]	PRI_14	Priority Of IRQ14 "0" denotes the highest priority and "3" denotes the lowest priority.
[21:16]	Reserved	Reserved.
[15:14]	PRI_13	Priority Of IRQ13 "0" denotes the highest priority and "3" denotes the lowest priority
[13:8]	Reserved	Reserved.
[7:6]	PRI_12	Priority Of IRQ12 "0" denotes the highest priority and "3" denotes the lowest priority.
[5:0]	Reserved	Reserved.

IRQ16 ~ IRQ19 Priority Register (NVIC_IPR4)

Register	Offset	R/W	Description	Reset Value
NVIC_IPR4	SCS_BA+0x410	R/W	IRQ16 ~ IRQ19 Priority Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PRI_19[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_18[1:0]		Reserved					
15	14	13	12	11	10	9	8
PRI_17[1:0]		Reserved					
7	6	5	4	3	2	1	0
PRI_16[1:0]		Reserved					

Bits	Description	
[31:30]	PRI_19	Priority Of IRQ19 "0" denotes the highest priority and "3" denotes the lowest priority.
[29:24]	Reserved	Reserved.
[23:22]	PRI_18	Priority Of IRQ18 "0" denotes the highest priority and "3" denotes the lowest priority.
[21:16]	Reserved	Reserved.
[15:14]	PRI_17	Priority Of IRQ17 "0" denotes the highest priority and "3" denotes the lowest priority.
[13:8]	Reserved	Reserved.
[7:6]	PRI_16	Priority Of IRQ16 "0" denotes the highest priority and "3" denotes the lowest priority.
[5:0]	Reserved	Reserved.

IRQ20 ~ IRQ23 Priority Register (NVIC_IPR5)

Register	Offset	R/W	Description	Reset Value
NVIC_IPR5	SCS_BA+0x414	R/W	IRQ20 ~ IRQ23 Priority Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PRI_23[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_22[1:0]		Reserved					
15	14	13	12	11	10	9	8
PRI_21[1:0]		Reserved					
7	6	5	4	3	2	1	0
PRI_20[1:0]		Reserved					

Bits	Description	
[31:30]	PRI_23	Priority Of IRQ23 "0" denotes the highest priority and "3" denotes the lowest priority.
[29:24]	Reserved	Reserved.
[23:22]	PRI_22	Priority Of IRQ22 "0" denotes the highest priority and "3" denotes the lowest priority.
[21:16]	Reserved	Reserved.
[15:14]	PRI_21	Priority Of IRQ21 "0" denotes the highest priority and "3" denotes the lowest priority
[13:8]	Reserved	Reserved.
[7:6]	PRI_20	Priority Of IRQ20 "0" denotes the highest priority and "3" denotes the lowest priority.
[5:0]	Reserved	Reserved.

IRQ24 ~ IRQ27 Priority Register (NVIC_IPR6)

Register	Offset	R/W	Description	Reset Value
NVIC_IPR6	SCS_BA+0x418	R/W	IRQ24 ~ IRQ27 Priority Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PRI_27[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_26[1:0]		Reserved					
15	14	13	12	11	10	9	8
PRI_25[1:0]		Reserved					
7	6	5	4	3	2	1	0
PRI_24[1:0]		Reserved					

Bits	Description	
[31:30]	PRI_27	Priority Of IRQ27 "0" denotes the highest priority and "3" denotes the lowest priority.
[29:24]	Reserved	Reserved.
[23:22]	PRI_26	Priority Of IRQ26 "0" denotes the highest priority and "3" denotes the lowest priority.
[21:16]	Reserved	Reserved.
[15:14]	PRI_25	Priority Of IRQ25 "0" denotes the highest priority and "3" denotes the lowest priority.
[13:8]	Reserved	Reserved.
[7:6]	PRI_24	Priority Of IRQ24 "0" denotes the highest priority and "3" denotes the lowest priority.
[5:0]	Reserved	Reserved.

IRQ28 ~ IRQ31 Priority Register (NVIC_IPR7)

Register	Offset	R/W	Description	Reset Value
NVIC_IPR7	SCS_BA+0x41C	R/W	IRQ28 ~ IRQ31 Priority Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PRI_31[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_30[1:0]		Reserved					
15	14	13	12	11	10	9	8
PRI_29[1:0]		Reserved					
7	6	5	4	3	2	1	0
PRI_28[1:0]		Reserved					

Bits	Description	
[31:30]	PRI_31	Priority Of IRQ31 "0" denotes the highest priority and "3" denotes the lowest priority.
[29:24]	Reserved	Reserved.
[23:22]	PRI_30	Priority Of IRQ30 "0" denotes the highest priority and "3" denotes the lowest priority.
[21:16]	Reserved	Reserved.
[15:14]	PRI_29	Priority Of IRQ29 "0" denotes the highest priority and "3" denotes the lowest priority.
[13:8]	Reserved	Reserved.
[7:6]	PRI_28	Priority Of IRQ28 "0" denotes the highest priority and "3" denotes the lowest priority.
[5:0]	Reserved	Reserved.

6.2.9.6 Interrupt Source Register Map

Besides the interrupt control registers associated with the NVIC, the NuMicro™ NUC230/240 series also implement some specific control registers to facilitate the interrupt functions, including “interrupt source identification”, “NMI source selection” and “interrupt test mode”, which are described below.

R: read only, **W:** write only, **R/W:** both read and write

Register	Offset	R/W	Description	Reset Value
INT Base Address: INT_BA = 0x5000_0300				
IRQ0_SRC	INT_BA+0x00	R	IRQ0 (BOD) Interrupt Source Identity	0XXXXX_XXXX
IRQ1_SRC	INT_BA+0x04	R	IRQ1 (WDT) Interrupt Source Identity	0XXXXX_XXXX
IRQ2_SRC	INT_BA+0x08	R	IRQ2 (EINT0) Interrupt Source Identity	0XXXXX_XXXX
IRQ3_SRC	INT_BA+0x0C	R	IRQ3 (EINT1) Interrupt Source Identity	0XXXXX_XXXX
IRQ4_SRC	INT_BA+0x10	R	IRQ4 (GPA/B) Interrupt Source Identity	0XXXXX_XXXX
IRQ5_SRC	INT_BA+0x14	R	IRQ5 (GPC/D/E/F) Interrupt Source Identity	0XXXXX_XXXX
IRQ6_SRC	INT_BA+0x18	R	IRQ6 (PWMA) Interrupt Source Identity	0XXXXX_XXXX
IRQ7_SRC	INT_BA+0x1C	R	IRQ7 (PWMB) Interrupt Source Identity	0XXXXX_XXXX
IRQ8_SRC	INT_BA+0x20	R	IRQ8 (TMR0) Interrupt Source Identity	0XXXXX_XXXX
IRQ9_SRC	INT_BA+0x24	R	IRQ9 (TMR1) Interrupt Source Identity	0XXXXX_XXXX
IRQ10_SRC	INT_BA+0x28	R	IRQ10 (TMR2) Interrupt Source Identity	0XXXXX_XXXX
IRQ11_SRC	INT_BA+0x2C	R	IRQ11 (TMR3) Interrupt Source Identity	0XXXXX_XXXX
IRQ12_SRC	INT_BA+0x30	R	IRQ12 (UART0/2) Interrupt Source Identity	0XXXXX_XXXX
IRQ13_SRC	INT_BA+0x34	R	IRQ13 (UART1) Interrupt Source Identity	0XXXXX_XXXX
IRQ14_SRC	INT_BA+0x38	R	IRQ14 (SPI0) Interrupt Source Identity	0XXXXX_XXXX
IRQ15_SRC	INT_BA+0x3C	R	IRQ15 (SPI1) Interrupt Source Identity	0XXXXX_XXXX
IRQ16_SRC	INT_BA+0x40	R	IRQ16 (SPI2) Interrupt Source Identity	0XXXXX_XXXX
IRQ17_SRC	INT_BA+0x44	R	IRQ17 (SPI3) Interrupt Source Identity	0XXXXX_XXXX
IRQ18_SRC	INT_BA+0x48	R	IRQ18 (I ² C0) Interrupt Source Identity	0XXXXX_XXXX
IRQ19_SRC	INT_BA+0x4C	R	IRQ19 (I ² C1) Interrupt Source Identity	0XXXXX_XXXX
IRQ20_SRC	INT_BA+0x50	R	Reserved	0XXXXX_XXXX
IRQ21_SRC	INT_BA+0x54	R	Reserved	0XXXXX_XXXX
IRQ22_SRC	INT_BA+0x58	R	IRQ22 (SC0/1/2) Interrupt Source Identity	0XXXXX_XXXX

IRQ23_SRC	INT_BA+0x5C	R	IRQ23 (USBD) Interrupt Source Identity	0xFFFF_XXXX
IRQ24_SRC	INT_BA+0x60	R	IRQ24 (PS/2) Interrupt Source Identity	0xFFFF_XXXX
IRQ25_SRC	INT_BA+0x64	R	IRQ25 (ACMP) Interrupt Source Identity	0xFFFF_XXXX
IRQ26_SRC	INT_BA+0x68	R	IRQ26 (PDMA) Interrupt Source Identity	0xFFFF_XXXX
IRQ27_SRC	INT_BA+0x6C	R	IRQ27 (I ² S) Interrupt Source Identity	0xFFFF_XXXX
IRQ28_SRC	INT_BA+0x70	R	IRQ28 (PWRWU) Interrupt Source Identity	0xFFFF_XXXX
IRQ29_SRC	INT_BA+0x74	R	IRQ29 (ADC) Interrupt Source Identity	0xFFFF_XXXX
IRQ30_SRC	INT_BA+0x78	R	IRQ30 (IRC) Interrupt Source Identity	0xFFFF_XXXX
IRQ31_SRC	INT_BA+0x7C	R	IRQ31 (RTC) Interrupt Source Identity	0xFFFF_XXXX
NMI_SEL	INT_BA+0x80	R/W	NMI Source Interrupt Select Control Register	0x0000_0000
MCU_IRQ	INT_BA+0x84	R/W	MCU Interrupt Request Source Register	0x0000_0000
MCU_IRQCR	INT_BA+0x88	R/W	MCU Interrupt Request Control Register	0x0000_0000

6.2.9.7 Interrupt Source Register Description

Interrupt Source Identity Register (IRQn_SRC)

Register	Offset	R/W	Description	Reset Value
IRQ0_SRC	INT_BA+0x00	R	IRQ0 (BOD) Interrupt Source Identity	0XXXXX_XXXX
IRQ1_SRC	INT_BA+0x04	R	IRQ1 (WDT) Interrupt Source Identity	0XXXXX_XXXX
IRQ2_SRC	INT_BA+0x08	R	IRQ2 (EINT0) Interrupt Source Identity	0XXXXX_XXXX
IRQ3_SRC	INT_BA+0x0C	R	IRQ3 (EINT1) Interrupt Source Identity	0XXXXX_XXXX
IRQ4_SRC	INT_BA+0x10	R	IRQ4 (GPA/B) Interrupt Source Identity	0XXXXX_XXXX
IRQ5_SRC	INT_BA+0x14	R	IRQ5 (GPC/D/E/F) Interrupt Source Identity	0XXXXX_XXXX
IRQ6_SRC	INT_BA+0x18	R	IRQ6 (PWMA) Interrupt Source Identity	0XXXXX_XXXX
IRQ7_SRC	INT_BA+0x1C	R	IRQ7 (PWMB) Interrupt Source Identity	0XXXXX_XXXX
IRQ8_SRC	INT_BA+0x20	R	IRQ8 (TMR0) Interrupt Source Identity	0XXXXX_XXXX
IRQ9_SRC	INT_BA+0x24	R	IRQ9 (TMR1) Interrupt Source Identity	0XXXXX_XXXX
IRQ10_SRC	INT_BA+0x28	R	IRQ10 (TMR2) Interrupt Source Identity	0XXXXX_XXXX
IRQ11_SRC	INT_BA+0x2C	R	IRQ11 (TMR3) Interrupt Source Identity	0XXXXX_XXXX
IRQ12_SRC	INT_BA+0x30	R	IRQ12 (UART0/2) Interrupt Source Identity	0XXXXX_XXXX
IRQ13_SRC	INT_BA+0x34	R	IRQ13 (UART1) Interrupt Source Identity	0XXXXX_XXXX
IRQ14_SRC	INT_BA+0x38	R	IRQ14 (SPI0) Interrupt Source Identity	0XXXXX_XXXX
IRQ15_SRC	INT_BA+0x3C	R	IRQ15 (SPI1) Interrupt Source Identity	0XXXXX_XXXX
IRQ16_SRC	INT_BA+0x40	R	IRQ16 (SPI2) Interrupt Source Identity	0XXXXX_XXXX
IRQ17_SRC	INT_BA+0x44	R	IRQ17 (SPI3) Interrupt Source Identity	0XXXXX_XXXX
IRQ18_SRC	INT_BA+0x48	R	IRQ18 (I ² C0) Interrupt Source Identity	0XXXXX_XXXX
IRQ19_SRC	INT_BA+0x4C	R	IRQ19 (I ² C1) Interrupt Source Identity	0XXXXX_XXXX
IRQ20_SRC	INT_BA+0x50	R	Reserved	0XXXXX_XXXX
IRQ21_SRC	INT_BA+0x54	R	Reserved	0XXXXX_XXXX
IRQ22_SRC	INT_BA+0x58	R	IRQ22 (SC0/1/2) Interrupt Source Identity	0XXXXX_XXXX
IRQ23_SRC	INT_BA+0x5C	R	IRQ23 (USBD) Interrupt Source Identity	0XXXXX_XXXX
IRQ24_SRC	INT_BA+0x60	R	IRQ24 (PS/2) Interrupt Source Identity	0XXXXX_XXXX
IRQ25_SRC	INT_BA+0x64	R	IRQ25 (ACMP) Interrupt Source Identity	0XXXXX_XXXX
IRQ26_SRC	INT_BA+0x68	R	IRQ26 (PDMA) Interrupt Source Identity	0XXXXX_XXXX

IRQ27_SRC	INT_BA+0x6C	R	IRQ27 (I ² S) Interrupt Source Identity	0XXXXX_XXXX
IRQ28_SRC	INT_BA+0x70	R	IRQ28 (PWRWU) Interrupt Source Identity	0XXXXX_XXXX
IRQ29_SRC	INT_BA+0x74	R	IRQ29 (ADC) Interrupt Source Identity	0XXXXX_XXXX
IRQ30_SRC	INT_BA+0x78	R	IRQ30 (IRC) Interrupt Source Identity	0XXXXX_XXXX
IRQ31_SRC	INT_BA+0x7C	R	IRQ31 (RTC) Interrupt Source Identity	0XXXXX_XXXX

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				INT_SRC[3:0]			

Bits	Description	
[31:4]	Reserved	Reserved.
[3:0]	INT_SRC	Interrupt Source Define the interrupt sources for interrupt event.

Bits	Address	INT-Num	Description
[2:0]	INT_BA+0x00	0	Bit2: 0 Bit1: 0 Bit0: BOD_INT
[2:0]	INT_BA+0x04	1	Bit2: 0 Bit1: WWDT_INT Bit0: WDT_INT
[2:0]	INT_BA+0x08	2	Bit2: 0 Bit1: 0 Bit0: EINT0 – external interrupt 0 from PB.14
[2:0]	INT_BA+0x0C	3	Bit2: 0 Bit1: 0 Bit0: EINT1 – external interrupt 1 from PB.15
[2:0]	INT_BA+0x10	4	Bit2: 0 Bit1: GPB_INT Bit0: GPA_INT
[3:0]	INT_BA+0x14	5	Bit3: GPF_INT

			Bit2: GPE_INT Bit1: GPD_INT Bit0: GPC_INT
[3:0]	INT_BA+0x18	6	Bit3: PWM3_INT Bit2: PWM2_INT Bit1: PWM1_INT Bit0: PWM0_INT
[3:0]	INT_BA+0x1C	7	Bit3: PWM7_INT Bit2: PWM6_INT Bit1: PWM5_INT Bit0: PWM4_INT
[2:0]	INT_BA+0x20	8	Bit2: 0 Bit1: 0 Bit0: TMR0_INT
[2:0]	INT_BA+0x24	9	Bit2: 0 Bit1: 0 Bit0: TMR1_INT
[2:0]	INT_BA+0x28	10	Bit2: 0 Bit1: 0 Bit0: TMR2_INT
[2:0]	INT_BA+0x2C	11	Bit2: 0 Bit1: 0 Bit0: TMR3_INT
[2:0]	INT_BA+0x30	12	Bit2: 0 Bit1: UART2_INT Bit0: UART0_INT
[2:0]	INT_BA+0x34	13	Bit2: 0 Bit1: 0 Bit0: UART1_INT
[2:0]	INT_BA+0x38	14	Bit2: 0 Bit1: 0 Bit0: SPI0_INT
[2:0]	INT_BA+0x3C	15	Bit2: 0 Bit1: 0 Bit0: SPI1_INT
[2:0]	INT_BA+0x40	16	Bit2: 0 Bit1: 0 Bit0: SPI2_INT
[2:0]	INT_BA+0x44	17	Bit2: 0 Bit1: 0 Bit0: SPI3_INT
[2:0]	INT_BA+0x48	18	Bit2: 0 Bit1: 0 Bit0: I2C0_INT

[2:0]	INT_BA+0x4C	19	Bit2: 0 Bit1: 0 Bit0: I2C1_INT
[2:0]	INT_BA+0x58	22	Bit2: SC2_INT Bit1: SC1_INT Bit0: SC0_INT
[2:0]	INT_BA+0x5C	23	Bit2: 0 Bit1: 0 Bit0: USB_INT
[2:0]	INT_BA+0x60	24	Bit2: 0 Bit1: 0 Bit0: PS2_INT
[2:0]	INT_BA+0x64	25	Bit2: 0 Bit1: 0 Bit0: ACMP_INT
[2:0]	INT_BA+0x68	26	Bit2: 0 Bit1: 0 Bit0: PDMA_INT
[2:0]	INT_BA+0x6C	27	Bit2: 0 Bit1: 0 Bit0: I2S_INT
[2:0]	INT_BA+0x70	28	Bit2: 0 Bit1: 0 Bit0: PWRWU_INT
[2:0]	INT_BA+0x74	29	Bit2: 0 Bit1: 0 Bit0: ADC_INT
[2:0]	INT_BA+0x78	30	Bit2: 0 Bit1: 0 Bit0: IRC_INT
[2:0]	INT_BA+0x7C	31	Bit2: 0 Bit1: 0 Bit0: RTC_INT

NMI Source Interrupt Select Control Register (NMI_SEL)

Register	Offset	R/W	Description	Reset Value
NMI_SEL	INT_BA+0x80	R/W	NMI Source Interrupt Select Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							NMI_EN
7	6	5	4	3	2	1	0
Reserved			NMI_SEL[4:0]				

Bits	Description	
[31:8]	Reserved	Reserved.
[8]	NMI_EN	NMI Interrupt Enable Bit (Write Protect) 0 = NMI interrupt Disabled. 1 = NMI interrupt Enabled. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[7:5]	Reserved	Reserved.
[4:0]	NMI_SEL	NMI Interrupt Source Selection The NMI interrupt to Cortex™-M0 can be selected from one of the peripheral interrupt by setting NMI_SEL.

MCU Interrupt Request Source Register (MCU_IRQ)

Register	Offset	R/W	Description	Reset Value
MCU_IRQ	INT_BA+0x84	R/W	MCU Interrupt Request Source Register	0x0000_0000

31	30	29	28	27	26	25	24
MCU_IRQ[31:24]							
23	22	21	20	19	18	17	16
MCU_IRQ[23:16]							
15	14	13	12	11	10	9	8
MCU_IRQ[15:8]							
7	6	5	4	3	2	1	0
MCU_IRQ[7:0]							

Bits	Description
[31:0]	MCU IRQ Source Register The MCU_IRQ collects all the interrupts from the peripherals and generates the synchronous interrupt to Cortex™-M0. There are two modes to generate interrupt to Cortex™-M0, the normal mode and test mode. The MCU_IRQ collects all interrupts from each peripheral and synchronizes them and interrupts the Cortex™-M0. When the MCU_IRQ[n] is 0: Set MCU_IRQ[n] 1 will generate an interrupt to Cortex™-M0 NVIC[n]. When the MCU_IRQ[n] is 1 (mean an interrupt is assert), setting 1 to the MCU_IRQ[n] 1 will clear the interrupt and setting MCU_IRQ[n] 0: has no effect

MCU Interrupt Request Control Register (MCU_IRQCR)

Register	Offset	R/W	Description	Reset Value
MCU_IRQCR	INT_BA+0x88	R/W	MCU Interrupt Request Control Register	0x0000_0000

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

Bits	Description
[31:1]	Reserved Reserved.
[0]	FAST_IRQ Fast IRQ Latency Enable Bit 0 = MCU IRQ latency is fixed at 13 clock cycles of HCLK, MCU will enter IRQ handler after this fixed latency when interrupt happened. 1 = MCU IRQ latency will not fixed, MCU will enter IRQ handler as soon as possible when interrupt happened.

6.2.10 System Control

The Cortex™-M0 status and operating mode control are managed by System Control Registers. Including CPUID, Cortex™-M0 interrupt priority and Cortex™-M0 power management can be controlled through these system control registers.

For more detailed information, please refer to the “ARM® Cortex™-M0 Technical Reference Manual” and “ARM® v6-M Architecture Reference Manual”.

6.2.10.1 System Control Register Map

R: read only, **W:** write only, **R/W:** both read and write

Register	Offset	R/W	Description	Reset Value
SCS Base Address: SCS_BA = 0xE000_E000				
CPUID	SCS_BA+0xD00	R	CPUID Register	0x410C_C200
ICSR	SCS_BA+0xD04	R/W	Interrupt Control and State Register	0x0000_0000
AIRCR	SCS_BA+0xD0C	R/W	Application Interrupt and Reset Control Register	0xFA05_0000
SCR	SCS_BA+0xD10	R/W	System Control Register	0x0000_0000
SHPR2	SCS_BA+0xD1C	R/W	System Handler Priority Register 2	0x0000_0000
SHPR3	SCS_BA+0xD20	R/W	System Handler Priority Register 3	0x0000_0000

6.2.10.2 System Control Register Description

CPUID Register (CPUID)

Register	Offset	R/W	Description	Reset Value
CPUID	SCS_BA+0xD00	R	CPUID Register	0x410C_C200

31	30	29	28	27	26	25	24
IMPLEMENTER[7:0]							
23	22	21	20	19	18	17	16
Reserved				PART[3:0]			
15	14	13	12	11	10	9	8
PARTNO[11:4]							
7	6	5	4	3	2	1	0
PARTNO[3:0]				REVISION[3:0]			

Bits	Description	
[31:24]	IMPLEMENTER	Implementer Code Assigned By ARM Implementer code assigned by ARM. (ARM = 0x41).
[23:20]	Reserved	Reserved.
[19:16]	PART	Architecture Of The Processor Read as 0xC for ARMv6-M parts
[15:4]	PARTNO	Part Number Of The Processor Read as 0xC20.
[3:0]	REVISION	Revision Number Read as 0x0

Interrupt Control State Register (ICSR)

Register	Offset	R/W	Description	Reset Value
ICSR	SCS_BA+0xD04	R/W	Interrupt Control and State Register	0x0000_0000

31	30	29	28	27	26	25	24
NMIPENDSET	Reserved		PENDSVSET	PENDSVCLR	PENDSTSET	PENDSTCLR	Reserved
23	22	21	20	19	18	17	16
ISRPREEMPT	ISRPENDING	Reserved				VECTPENDING[5:4]	
15	14	13	12	11	10	9	8
VECTPENDING[3:0]				Reserved			
7	6	5	4	3	2	1	0
Reserved		VECTACTIVE[5:0]					

Bits	Description	
[31]	NMIPENDSET	NMI Set-Pending Bit Write Operation: 0 = No effect. 1 = Changes NMI exception state to pending. Read Operation: 0 = NMI exception not pending. 1 = NMI exception pending. Because NMI is the highest-priority exception, normally the processor enters the NMI exception handler as soon as it detects a write of 1 to this bit. Entering the handler then clears this bit to 0. This means a read of this bit by the NMI exception handler returns 1 only if the NMI signal is reasserted while the processor is executing that handler.
[30:29]	Reserved	Reserved.
[28]	PENDSVSET	PendSV Set-Pending Bit Write Operation: 0 = No effect. 1 = Changes PendSV exception state to pending. Read Operation: 0 = PendSV exception is not pending. 1 = PendSV exception is pending. Note: Writing 1 to this bit is the only way to set the PendSV exception state to pending.
[27]	PENDSVCLR	PendSV Clear-Pending Bit Write Operation: 0 = No effect. 1 = Removes the pending state from the PendSV exception. This is a write only bit. When you want to clear PENDSV bit, you must "write 0 to PENDSVSET and write 1 to PENDSVCLR" at the same time.
[26]	PENDSTSET	SysTick Exception Set-Pending Bit Write Operation:

		0 = No effect. 1 = Changes SysTick exception state to pending. Read Operation: 0 = SysTick exception is not pending. 1 = SysTick exception is pending.
[25]	PENDSTCLR	SysTick Exception Clear-Pending Bit Write Operation: 0 = No effect. 1 = Removes the pending state from the SysTick exception. This is a write only bit. When you want to clear PENDST bit, you must "write 0 to PENDSTSET and write 1 to PENDSTCLR" at the same time.
[24]	Reserved	Reserved.
[23]	ISRPREEMPT	If Set, A Pending Exception Will Be Serviced On Exit From The Debug Halt State This bit is read only.
[22]	ISRPENDING	Interrupt Pending Flag, Excluding NMI And Faults: 0 = Interrupt not pending. 1 = Interrupt pending. This bit is read only.
[21:18]	Reserved	Reserved.
[17:12]	VECTPENDING	Indicates The Exception Number Of The Highest Priority Pending Enabled Exception: 0 = No pending exceptions. Non-zero = Exception number of the highest priority pending enabled exception.
[11:6]	Reserved	Reserved.
[5:0]	VECTACTIVE	Contains The Active Exception Number 0 = Thread mode. Non-zero = Exception number of the currently active exception.

Application Interrupt and Reset Control Register (AIRCR)

Register	Offset	R/W	Description	Reset Value
AIRCR	SCS_BA+0xD0C	R/W	Application Interrupt and Reset Control Register	0xFA05_0000

31	30	29	28	27	26	25	24
VECTORKEY[15:8]							
23	22	21	20	19	18	17	16
VECTORKEY[7:0]							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					SYSRESETREQ	VECTCLRACTIVE	Reserved

Bits	Description	
[31:16]	VECTORKEY	Register Access Key Write Operation: When writing to this register, the VECTORKEY field need to be set to 0x05FA, otherwise the write operation would be ignored. The VECTORKEY filed is used to prevent accidental write to this register from resetting the system or clearing of the exception status. Read Operation: Read as 0xFA05.
[15:3]	Reserved	Reserved.
[2]	SYSRESETREQ	System Reset Request Writing this bit 1 will cause a reset signal to be asserted to the chip to indicate a reset is requested. The bit is a write only bit and self-clears as part of the reset sequence.
[1]	VECTCLRACTIVE	Exception Active Status Clear Bit Reserved for debug use. When writing to the register, user must write 0 to this bit, otherwise behavior is unpredictable.
[0]	Reserved	Reserved.

System Control Register (SCR)

Register	Offset	R/W	Description	Reset Value
SCR	SCS_BA+0xD10	R/W	System Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved			SEVONPEND	Reserved	SLEEPDEEP	SLEEPONEXIT	Reserved

Bits	Description	
[31:5]	Reserved	Reserved.
[4]	SEVONPEND	Send Event On Pending Bit 0 = Only enabled interrupts or events can wake-up the processor, disabled interrupts are excluded. 1 = Enabled events and all interrupts, including disabled interrupts, can wake-up the processor. When an event or interrupt enters pending state, the event signal wakes up the processor from WFE. If the processor is not waiting for an event, the event is registered and affects the next WFE. The processor also wakes up on execution of an SEV instruction or an external event.
[3]	Reserved	Reserved.
[2]	SLEEPDEEP	Processor Deep Sleep And Sleep Mode Selection Controls whether the processor uses sleep or deep sleep as its low power mode: 0 = Sleep mode. 1 = Deep Sleep mode.
[1]	SLEEPONEXIT	Sleep-On-Exit Enable Bit This bit indicates sleep-on-exit when returning from Handler mode to Thread mode. 0 = Do not sleep when returning to Thread mode. 1 = Enter Sleep or Deep Sleep when returning from ISR to Thread mode. Setting this bit to 1 enables an interrupt driven application to avoid returning to an empty main application..
[0]	Reserved	Reserved.

System Handler Priority Register 2 (SHPR2)

Register	Offset	R/W	Description	Reset Value
SHPR2	SCS_BA+0xD1C	R/W	System Handler Priority Register 2	0x0000_0000

31	30	29	28	27	26	25	24
PRI_11[1:0]		Reserved					
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved							

Bits	Description	
[31:30]	PRI_11	Priority Of System Handler 11 – SVCall “0” denotes the highest priority and “3” denotes the lowest priority
[29:0]	Reserved	Reserved.

System Handler Priority Register 3 (SHPR3)

Register	Offset	R/W	Description	Reset Value
SHPR3	SCS_BA+0xD20	R/W	System Handler Priority Register 3	0x0000_0000

31	30	29	28	27	26	25	24
PRI_15[1:0]		Reserved					
23	22	21	20	19	18	17	16
PRI_14[1:0]		Reserved					
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved							

Bits	Description	
[31:30]	PRI_15	Priority Of System Handler 15 – SysTick “0” denotes the highest priority and “3” denotes the lowest priority
[29:24]	Reserved	Reserved.
[23:22]	PRI_14	Priority Of System Handler 14 – PendSV “0” denotes the highest priority and “3” denotes the lowest priority
[21:0]	Reserved	Reserved.

6.3 Clock Controller

6.3.1 Overview

The clock controller generates the clocks for the whole chip, including system clocks and all peripheral clocks. The clock controller also implements the power control function with the individually clock ON/OFF control, clock source selection and clock divider. The chip enters Power-down mode when Cortex™-M0 core executes the WFI instruction only if the PWR_DOWN_EN (PWRCON[7]) bit and PD_WAIT_CPU (PWRCON[8]) bit are both set to 1. After that, chip enters Power-down mode and wait for wake-up interrupt source triggered to leave Power-down mode. In the Power-down mode, the clock controller turns off the 4~24 MHz external high speed crystal oscillator and 22.1184 MHz internal high speed RC oscillator to reduce the overall system power consumption. The following figures show the clock generator and the overview of the clock source control.

The clock generator consists of 5 clock sources as listed below:

- 32.768 kHz external low speed crystal oscillator (LXT)
- 4~24 MHz external high speed crystal oscillator (HXT)
- Programmable PLL output clock frequency (PLL source can be selected from external 4~24 MHz external high speed crystal oscillator (HXT) or 22.1184 MHz internal high speed RC oscillator (HIRC)) (PLL FOUT)
- 22.1184 MHz internal high speed RC oscillator (HIRC)
- 10 kHz internal low speed RC oscillator (LIRC)

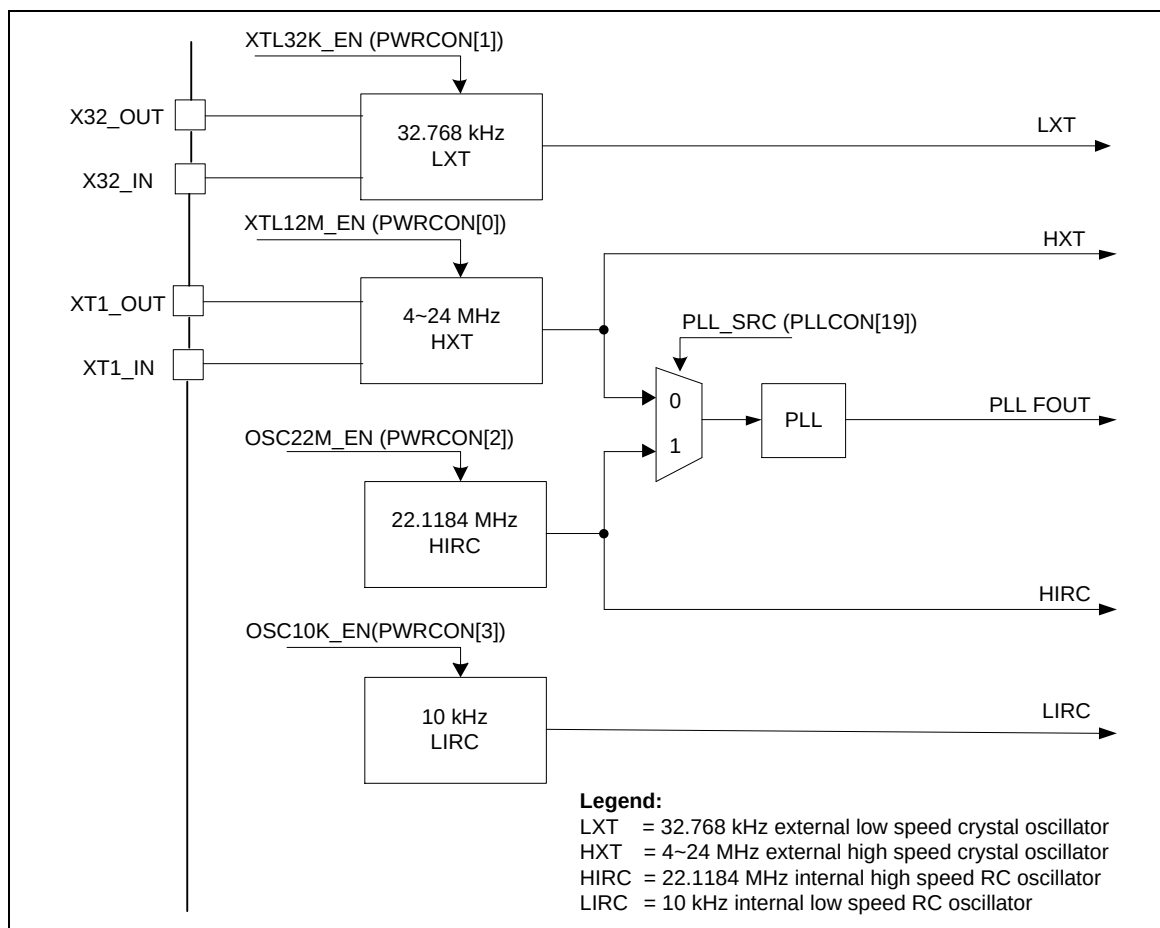


Figure 6-4 Clock Generator Block Diagram

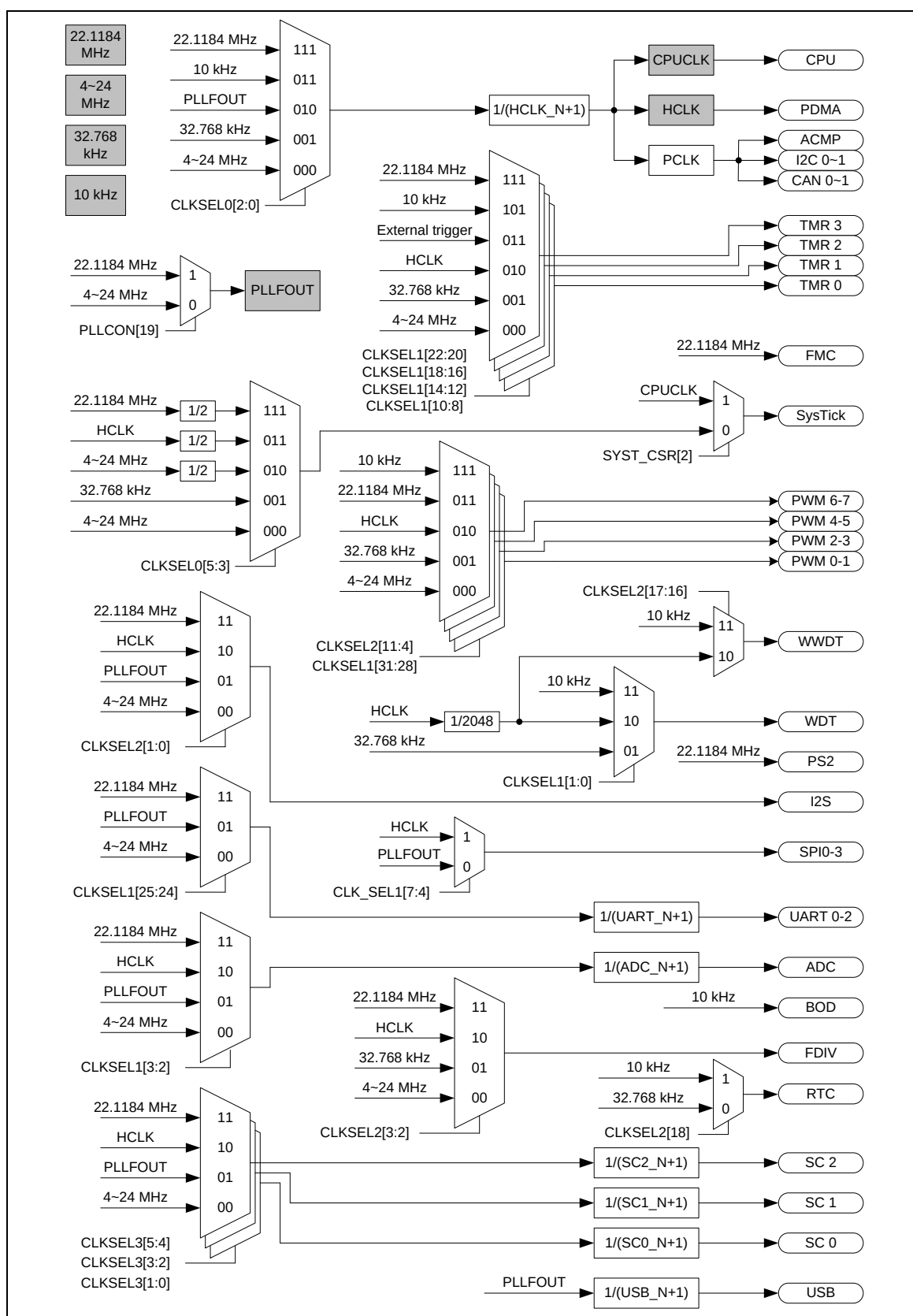


Figure 6-5 Clock Generator Global View Diagram

6.3.2 System Clock and SysTick Clock

The system clock has 5 clock sources which were generated from clock generator block. The clock source switch depends on the register HCLK_S (CLKSEL0[2:0]). The block diagram is shown in Figure 6-6.

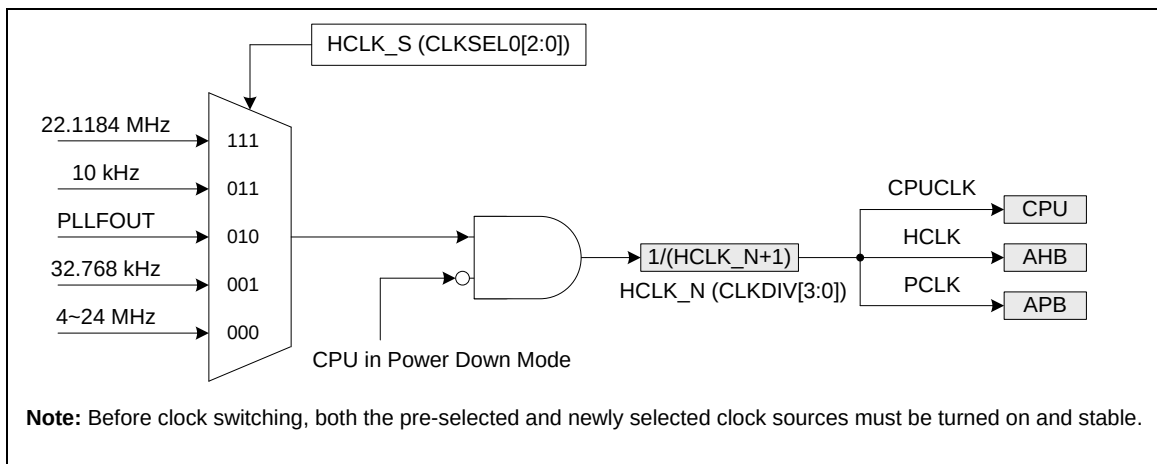


Figure 6-6 System Clock Block Diagram

The clock source of SysTick in Cortex™-M0 core can use CPU clock or external clock (SYST_CSR[2]). If using external clock, the SysTick clock (STCLK) has 5 clock sources. The clock source switch depends on the setting of the register STCLK_S (CLKSEL0[5:3]). The block diagram is shown in Figure 6-7.

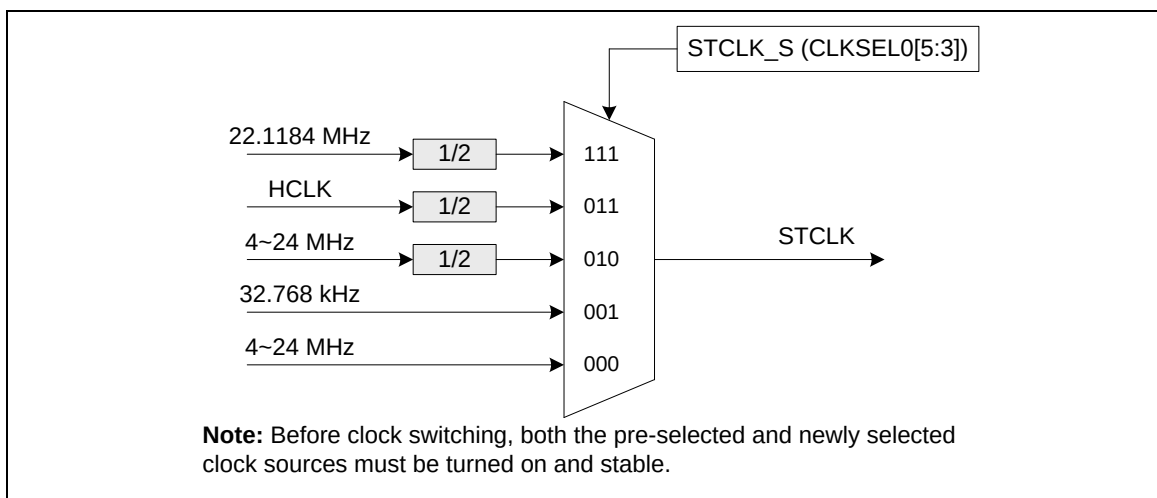


Figure 6-7 SysTick Clock Control Block Diagram

6.3.3 Power-down Mode Clock

When chip enters Power-down mode, system clocks, some clock sources, and some peripheral clocks will be disabled. Some clock sources and peripherals clocks are still active in Power-down mode.

The clocks still kept active are listed below:

- Clock Generator
 - 10 kHz internal low speed RC oscillator clock
 - 32.768 kHz external low speed crystal oscillator clock
- RTC/WDT/Timer/PWM Peripherals Clock (when 32.768 kHz external low speed crystal oscillator or 10 kHz internal low speed RC oscillator is adopted as clock source)

6.3.4 Frequency Divider Output

This device is equipped with a power-of-2 frequency divider which is composed by 16 chained divide-by-2 shift registers. One of the 16 shift register outputs selected by a sixteen to one multiplexer is reflected to CLKO function pin. Therefore there are 16 options of power-of-2 divided clocks with the frequency from $F_{in}/2^1$ to $F_{in}/2^{16}$ where F_{in} is input clock frequency to the clock divider.

The output formula is $F_{out} = F_{in}/2^{(N+1)}$, where F_{in} is the input clock frequency, F_{out} is the clock divider output frequency and N is the 4-bit value in FSEL (FRQDIV[3:0]).

When writing 1 to DIVIDER_EN (FRQDIV[4]), the chained counter starts to count. When writing 0 to DIVIDER_EN (FRQDIV[4]), the chained counter continuously runs till divided clock reaches low state and stay in low state.

If DIVIDER1 (FRQDIV[5]) is set to 1, the frequency divider clock (FRQDIV_CLK) will bypass power-of-2 frequency divider. The frequency divider clock will be output to CLKO pin directly.

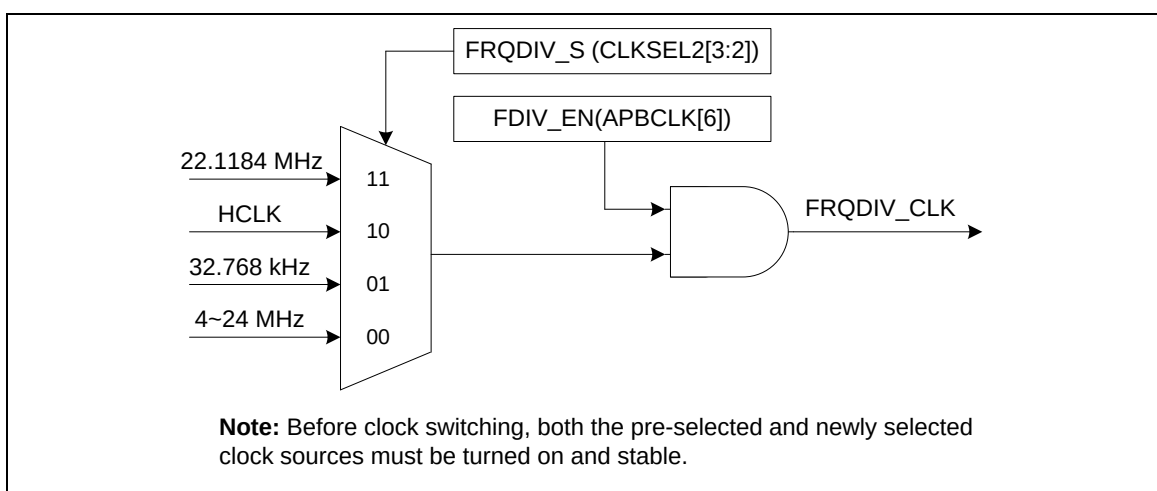


Figure 6-8 Clock Source of Frequency Divider

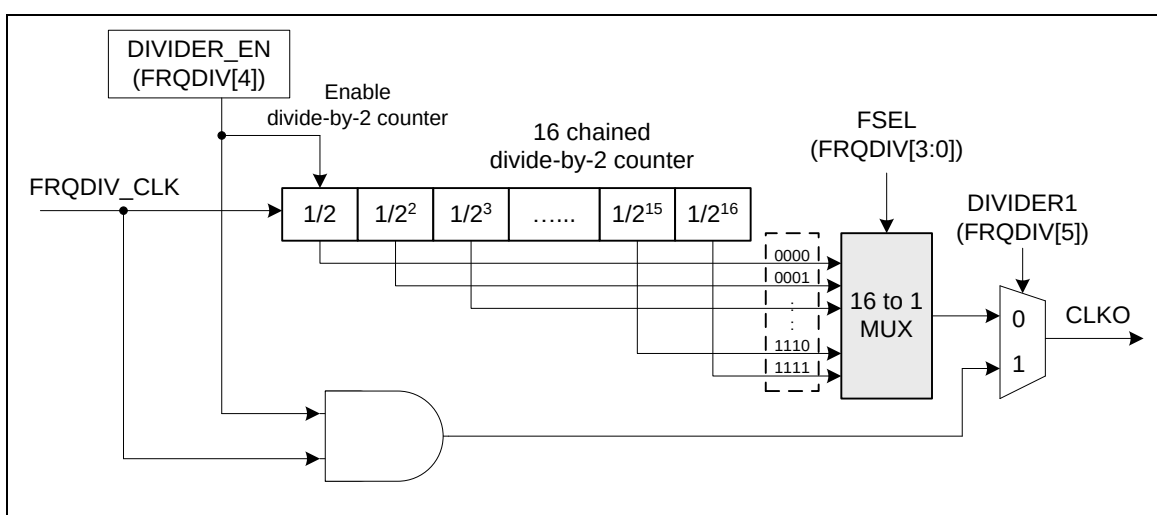


Figure 6-9 Frequency Divider Block Diagram

6.3.5 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
CLK Base Address: CLK_BA = 0x5000_0200				
PWRCON	CLK_BA+0x00	R/W	System Power-down Control Register	0x0000_001X
AHBCLK	CLK_BA+0x04	R/W	AHB Devices Clock Enable Control Register	0x0000_0005
APBCLK	CLK_BA+0x08	R/W	APB Devices Clock Enable Control Register	0x0000_000X
APBCLK1	CLK_BA+0x30	R/W	APB Devices Clock Enable Control Register 1	0x0000_0000
CLKSTATUS	CLK_BA+0x0C	R/W	Clock status monitor Register	0x0000_00XX
CLKSEL0	CLK_BA+0x10	R/W	Clock Source Select Control Register 0	0x0000_003X
CLKSEL1	CLK_BA+0x14	R/W	Clock Source Select Control Register 1	0xFFFF_FFFF
CLKSEL2	CLK_BA+0x1C	R/W	Clock Source Select Control Register 2	0x0002_00FF
CLKSEL3	CLK_BA+0x34	R/W	Clock Source Select Control Register 3	0x0000_003F
CLKDIV	CLK_BA+0x18	R/W	Clock Divider Number Register	0x0000_0000
CLKDIV1	CLK_BA+0x38	R/W	Clock Divider Number Register 1	0x0000_0000
PLLCON	CLK_BA+0x20	R/W	PLL Control Register	0x0005_C22E
FRQDIV	CLK_BA+0x24	R/W	Frequency Divider Control Register	0x0000_0000

6.3.6 Register Description

System Power-down Control Register (PWRCON)

Except the BIT[6], all the other bits are protected, programming these bits need to write “59h”, “16h”, “88h” to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100

Register	Offset	R/W	Description	Reset Value
PWRCON	CLK_BA+0x00	R/W	System Power-down Control Register	0x0000_001X

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							PD_WAIT_CPU
7	6	5	4	3	2	1	0
PWR_DOWN_EN	PD_WU_STS	PD_WU_INT_EN	PD_WU_DLY	OSC10K_EN	OSC22M_EN	XTL32K_EN	XTL12M_EN

Bits	Description
[31:9]	Reserved Reserved.
[8]	PD_WAIT_CPU Power-Down Entry Condition Control (Write Protect) 0 = Chip enters Power-down mode when the PWR_DOWN_EN bit is set to 1. 1 = Chip enters Power-down mode when the both PD_WAIT_CPU and PWR_DOWN_EN bits are set to 1 and CPU run WFI instruction. Note: This bit is the protected bit, and programming it needs to write “59h”, “16h”, and “88h” to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[7]	PWR_DOWN_EN System Power-Down Enable Bit (Write Protect) When this bit is set to 1, Power-down mode is enabled and chip Power-down behavior will depends on the PD_WAIT_CPU bit (a) If the PD_WAIT_CPU is 0, the chip enters Power-down mode immediately after the PWR_DOWN_EN bit set. (b) if the PD_WAIT_CPU is 1, the chip keeps active till the CPU sleep mode is also active and then the chip enters Power-down mode (recommend) When chip wakes up from Power-down mode, this bit is cleared by hardware. User needs to set this bit again for next Power-down. In Power-down mode, 4~24 MHz external high speed crystal oscillator and the 22.1184 MHz internal high speed RC oscillator will be disabled in this mode, but the 32.768 kHz external low speed crystal oscillator and 10 kHz internal low speed oscillator are not controlled by Power-down mode. In Power-down mode, the PLL and system clock are disabled, and ignored the clock source selection. The clocks of peripheral are not controlled by Power-down mode, if the peripheral clock source is from 32.768 kHz external low speed crystal oscillator or the internal 10 kHz low speed oscillator.

		0 = Chip operating normally or chip in Idle mode because of WFI command. 1 = Chip enters Power-down mode instantly or waits CPU sleep command WFI. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[6]	PD_WU_STS	Power-Down Mode Wake-Up Interrupt Status Set by "Power-down wake-up event", it indicates that resume from Power-down mode" The flag is set if the GPIO, USB, UART, WDT, I²C, TIMER, ACMP, BOD or RTC wake-up occurred Write 1 to clear the bit to 0. Note: This bit is working only if PD_WU_INT_EN (PWRCON[5]) set to 1.
[5]	PD_WU_INT_EN	Power-Down Mode Wake-Up Interrupt Enable Bit (Write Protect) 0 = Power-down mode wake-up interrupt Disabled. 1 = Power-down mode wake-up interrupt Enabled. Note1: The interrupt will occur when both PD_WU_STS and PD_WU_INT_EN are high. Note2: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[4]	PD_WU_DLY	Wake-Up Delay Counter Enable Bit (Write Protect) When the chip wakes up from Power-down mode, the clock control will delay certain clock cycles to wait system clock stable. The delayed clock cycle is 4096 clock cycles when chip work at external 4~24 MHz high speed crystal, and 256 clock cycles when chip work at internal 22.1184 MHz high speed oscillator. 0 = Clock cycles delay Disabled. 1 = Clock cycles delay Enabled. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[3]	OSC10K_EN	10 KHz Internal Low Speed RC Oscillator (LIRC) Enable Bit (Write Protect) 0 = 10 kHz internal low speed RC oscillator (LIRC) Disabled. 1 = 10 kHz internal low speed RC oscillator (LIRC) Enabled. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[2]	OSC22M_EN	22.1184 MHz Internal High Speed RC Oscillator (HIRC) Enable Bit (Write Protect) 0 = 22.1184 MHz internal high speed RC oscillator (HIRC) Disabled. 1 = 22.1184 MHz internal high speed RC oscillator (HIRC) Enabled. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[1]	XTL32K_EN	32.768 KHz External Low Speed Crystal Oscillator (LXT) Enable Bit (Write Protect) 0 = 32.768 kHz external low speed crystal oscillator (LXT) Disabled. 1 = 32.768 kHz external low speed crystal oscillator (LXT) Enabled (Normal operation). Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.
[0]	XTL12M_EN	4~24 MHz External High Speed Crystal Oscillator (HXT) Enable Bit (Write Protect) The bit default value is set by flash controller user configuration register CONFIG0 [26:24]. When the default clock source is from 4~24 MHz external high speed crystal oscillator, this bit is set to 1 automatically. 0 = 4 ~ 24 MHz external high speed crystal oscillators (HXT) Disabled.

		1 = 4~24 MHz external high speed crystal oscillator (HXT) Enabled. Note: This bit is the protected bit, and programming it needs to write “59h”, “16h”, and “88h” to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.

Register Or Instruction Mode	SLEEPDEEP (SCR[2])	PD_WAIT_CPU (PWRCON[8])	PWR_DOWN_EN (PWRCON[7])	CPU Run WFI Instruction	Clock Disable
Normal operation	0	0	0	NO	All clocks disabled by control register
Idle mode (CPU entering Sleep mode)	0	x	0	YES	Only CPU clock disabled
Power-down mode (CPU entering Deep Sleep mode)	1	1	1	YES	Most clocks are disabled except 10 kHz and 32.768 kHz, only RTC/WDT/Timer/PWM peripheral clock still enable if their clock source are selected as 10 kHz or 32.768 kHz.

Table 6-5 Chip Idle/Power-down Mode Control Table

When chip enters Power-down mode, user can wake-up chip using some interrupt sources. The related interrupt sources and NVIC IRQ enable bits (NVIC_ISER) should be enabled before setting the PWR_DOWN_EN bit in PWRCON[7] to ensure chip can enter Power-down and wake-up successfully.

AHB Devices Clock Enable Control Register (AHBCLK)

These bits for this register are used to enable/disable clock for system clock PDMA clock.

Register	Offset	R/W	Description	Reset Value
AHBCLK	CLK_BA+0x04	R/W	AHB Devices Clock Enable Control Register	0x0000_0005

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				EBI_EN	ISP_EN	PDMA_EN	Reserved

Bits	Description
[31:4]	Reserved
[3]	EBI_EN EBI Controller Clock Enable Control 1 = EBI engine clock Enabled. 0 = EBI engine clock Disabled.
[2]	ISP_EN Flash ISP Controller Clock Enable Bit 0 = Flash ISP peripheral clock Disabled. 1 = Flash ISP peripheral clock Enabled.
[1]	PDMA_EN PDMA Controller Clock Enable Bit 0 = PDMA peripheral clock Disabled. 1 = PDMA peripheral clock Enabled.
[0]	Reserved

APB Devices Clock Enable Register (APBCLK)

These bits of this register are used to enable/disable clock for peripheral controller clocks.

Register	Offset	R/W	Description	Reset Value
APBCLK	CLK_BA+0x08	R/W	APB Devices Clock Enable Register	0x0000_000X

31	30	29	28	27	26	25	24
PS2_EN	ACMP_EN	I2S_EN	ADC_EN	USBD_EN	Reserved	CAN1_EN	CAN0_EN
23	22	21	20	19	18	17	16
PWM67_EN	PWM45_EN	PWM23_EN	PWM01_EN	Reserved	UART2_EN	UART1_EN	UART0_EN
15	14	13	12	11	10	9	8
SPI3_EN	SPI2_EN	SPI1_EN	SPI0_EN	Reserved		I2C1_EN	I2C0_EN
7	6	5	4	3	2	1	0
Reserved	FDIV_EN	TMR3_EN	TMR2_EN	TMR1_EN	TMR0_EN	RTC_EN	WDT_EN

Bits	Description	
[31]	PS2_EN	PS/2 Clock Enable Bit 0 = PS/2 clock Disabled. 1 = PS/2 clock Enabled.
[30]	ACMP_EN	Analog Comparator Clock Enable Bit 0 = Analog Comparator clock Disabled. 1 = Analog Comparator clock Enabled.
[29]	I2S_EN	I²S Clock Enable Bit 0 = I ² S clock Disabled. 1 = I ² S clock Enabled.
[28]	ADC_EN	Analog-Digital-Converter (ADC) Clock Enable Bit 0 = ADC clock Disabled. 1 = ADC clock Enabled.
[27]	USBD_EN	USB 2.0 FS Device Controller Clock Enable Bit 0 = USB clock Disabled. 1 = USB clock Enabled.
[26]	Reserved	Reserved.
[25]	CAN1_EN	CAN Bus Controller-1 Clock Enable Bit 0 = CAN1 clock Disable. 1 = CAN1 clock Enabled.
[24]	CAN0_EN	CAN Bus Controller-0 Clock Enable Bit 0 = CAN0 clock Disabled. 1 = CAN0 clock Enable.
[23]	PWM67_EN	PWM_67 Clock Enable Bit 0 = PWM67 clock Disabled.

		1 = PWM67 clock Enabled.
[22]	PWM45_EN	PWM_45 Clock Enable Bit 0 = PWM45 clock Disabled. 1 = PWM45 clock Enabled.
[21]	PWM23_EN	PWM_23 Clock Enable Bit 0 = PWM23 clock Disabled. 1 = PWM23 clock Enabled.
[20]	PWM01_EN	PWM_01 Clock Enable Bit 0 = PWM01 clock Disabled. 1 = PWM01 clock Enabled.
[19]	Reserved	Reserved.
[18]	UART2_EN	UART2 Clock Enable Bit 0 = UART2 clock Disabled. 1 = UART2 clock Enabled.
[17]	UART1_EN	UART1 Clock Enable Bit 0 = UART1 clock Disabled. 1 = UART1 clock Enabled.
[16]	UART0_EN	UART0 Clock Enable Bit 0 = UART0 clock Disabled. 1 = UART0 clock Enabled.
[15]	SPI3_EN	SPI3 Clock Enable Bit 0 = SPI3 clock Disabled. 1 = SPI3 clock Enabled.
[14]	SPI2_EN	SPI2 Clock Enable Bit 0 = SPI2 clock Disabled. 1 = SPI2 clock Enabled.
[13]	SPI1_EN	SPI1 Clock Enable Bit 0 = SPI1 clock Disabled. 1 = SPI1 clock Enabled.
[12]	SPI0_EN	SPI0 Clock Enable Bit 0 = SPI0 clock Disabled. 1 = SPI0 clock Enabled.
[11:10]	Reserved	Reserved.
[9]	I2C1_EN	I²C1 Clock Enable Bit 0 = I ² C1 clock Disabled. 1 = I ² C1 clock Enabled.
[8]	I2C0_EN	I²C0 Clock Enable Bit 0 = I ² C0 clock Disabled. 1 = I ² C0 clock Enabled.
[7]	Reserved	Reserved.
[6]	FDIV_EN	Frequency Divider Output Clock Enable Bit 0 = FDIV clock Disabled. 1 = FDIV clock Enabled.

[5]	TMR3_EN	Timer3 Clock Enable Bit 0 = Timer3 clock Disabled. 1 = Timer3 clock Enabled.
[4]	TMR2_EN	Timer2 Clock Enable Bit 0 = Timer2 clock Disabled. 1 = Timer2 clock Enabled.
[3]	TMR1_EN	Timer1 Clock Enable Bit 0 = Timer1 clock Disabled. 1 = Timer1 clock Enabled.
[2]	TMR0_EN	Timer0 Clock Enable Bit 0 = Timer0 clock Disabled. 1 = Timer0 clock Enabled.
[1]	RTC_EN	Real-Time-Clock APB Interface Clock Enable Bit This bit is used to control the RTC APB clock only, The RTC peripheral clock source is selected from RTC_SEL_10K(CLKSEL2[18]). It can be selected to the 32.768 kHz external low speed crystal oscillator or 10 kHz internal low speed RC oscillator. 0 = RTC clock Disabled. 1 = RTC clock Enabled.
[0]	WDT_EN	Watchdog Timer Clock Enable Bit (Write Protect) 0 = Watchdog Timer clock Disabled. 1 = Watchdog Timer clock Enabled. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.

APB Devices Clock Enable Register 1 (APBCLK1)

These bits of this register are used to enable/disable clock for peripheral controller clocks.

Register	Offset	R/W	Description	Reset Value
APBCLK1	CLK_BA+0x30	R/W	APB Devices Clock Enable Register 1	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					SC2_EN	SC1_EN	SC0_EN

Bits	Description	
[31:3]	Reserved	Reserved.
[2]	SC2_EN	SC2 Clock Enable Bit 0 = SC2 clock Disabled. 1 = SC2 clock Enabled.
[1]	SC1_EN	SC1 Clock Enable Bit 0 = SC1 clock Disabled. 1 = SC1 clock Enabled.
[0]	SC0_EN	SC0 Clock Enable Bit 0 = SC0 Clock Disabled. 1 = SC0 Clock Enabled.

Clock status Register (CLKSTATUS)

These bits of this register are used to monitor if the chip clock source stable or not, and whether clock switch failed.

Register	Offset	R/W	Description	Reset Value
CLKSTATUS	CLK_BA+0x0C	R/W	Clock status monitor Register	0x0000_00XX

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
CLK_SW_FAIL	Reserved		OSC22M_STB	OSC10K_STB	PLL_STB	XTL32K_STB	XTL12M_STB

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	CLK_SW_FAIL	Clock Switching Fail Flag (Read Only) 0 = Clock switching success. 1 = Clock switching failure. This bit is an index that if current system clock source is match as user defined at HCLK_S (CLKSEL[2:0]). When user switch system clock, the system clock source will keep old clock until the new clock is stable. During the period that waiting new clock stable, this bit will be an index shows system clock source is not match as user wanted.
[6:5]	Reserved	Reserved.
[4]	OSC22M_STB	22.1184 MHz Internal High Speed RC Oscillator (HIRC) Clock Source Stable Flag (Read Only) 0 = 22.1184 MHz internal high speed RC oscillator (HIRC) clock is not stable or disabled. 1 = 22.1184 MHz internal high speed RC oscillator (HIRC) clock is stable and enabled.
[3]	OSC10K_STB	Internal 10 KHz Low Speed Oscillator (LIRC) Clock Source Stable Flag (Read Only) 0 = 10 kHz internal low speed RC oscillator (LIRC) clock is not stable or disabled. 1 = 10 kHz internal low speed RC oscillator (LIRC) clock is stable and enabled.
[2]	PLL_STB	Internal PLL Clock Source Stable Flag (Read Only) 0 = Internal PLL clock is not stable or disabled. 1 = Internal PLL clock is stable in normal mode.
[1]	XTL32K_STB	32.768 KHz External Low Speed Crystallator Oscillator (LXT) Clock Source Stable Flag (Read Only) 0 = 32.768 kHz external low speed crystal oscillator (LXT) clock is not stable or disabled. 1 = 32.768 kHz external low speed crystal oscillator (LXT) clock is stable and enabled.
[0]	XTL12M_STB	4-24 MHz External High Speed Crystal Oscillator (HXT) Clock Source Stable Flag (Read Only)

		0 = 4~24 MHz external high speed crystal oscillator (HXT) clock is not stable or disabled. 1 = 4~24 MHz external high speed crystal oscillator (HXT) clock is stable and enabled.

Clock Source Select Control Register 0 (CLKSEL0)

Register	Offset	R/W	Description	Reset Value
CLKSEL0	CLK_BA+0x10	R/W	Clock Source Select Control Register 0	0x0000_003X

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

Bits	Description	
[31:6]	Reserved	Reserved.
[5:3]	STCLK_S	Cortex™-M0 SysTick Clock Source Select (Write Protect) If CLKSRC(SYST_CSR[2]) = 1, SysTick clock source is from HCLK. If CLKSRC(SYST_CSR[2]) = 0, SysTick clock source is defined by STCLK_S(CLKSEL0[5:3]). 000 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 001 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 010 = Clock source from 4~24 MHz external high speed crystal oscillator clock/2. 011 = Clock source from HCLK/2. 111 = Clock source from 22.1184 MHz internal high speed RC oscillator clock/2. Note1: These bits are protected bit. It means programming this bit needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100. Note2: if SysTick clock source is not from HCLK (i.e. SYST_CSR[2] = 0), SysTick clock source must less than or equal to HCLK/2.
[2:0]	HCLK_S	HCLK Clock Source Select (Write Protect) - Before clock switching, the related clock sources (both pre-select and new-select) must be enabled - The 3-bit default value is reloaded from the value of CFOSC (CONFIG0[26:24]) in user configuration register of Flash controller by any reset. Therefore the default value is either 000b or 111b. - These bits are protected bit, It means programming this bit needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100. 000 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 001 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 010 = Clock source from PLL clock. 011 = Clock source from 10 kHz internal low speed RC oscillator clock. 111 = Clock source from 22.1184 MHz internalhigh speed RC oscillator clock. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register

		REGWRPROT at address GCR_BA+0x100.

Clock Source Select Control Register 1(CLKSEL1)

Before clock switching, the related clock sources (pre-select and new-select) must be turned on.

Register	Offset	R/W	Description	Reset Value
CLKSEL1	CLK_BA+0x14	R/W	Clock Source Select Control Register 1	0xFFFF_FFFF

31	30	29	28	27	26	25	24
PWM23_S		PWM01_S		Reserved		UART_S	
23	22	21	20	19	18	17	16
Reserved		TMR3_S		Reserved		TMR2_S	
15	14	13	12	11	10	9	8
Reserved		TMR1_S		Reserved		TMR0_S	
7	6	5	4	3	2	1	0
SPI3_S		SPI2_S		ADC_S		WDT_S	

Bits	Description
[31:30]	PWM2 And PWM3 Clock Source Selection PWM2 and PWM3 used the same peripheral clock source; both of them used the same prescaler. The peripheral clock source of PWM2 and PWM3 is defined by PWM23_S (CLKSEL1[31:30]) and PWM23_S_E (CLKSEL2[9]). If PWM23_S_E = 0, the peripheral clock source of PWM2 and PWM3 defined by PWM23_S list below: 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. If PWM23_S_E = 1, the peripheral clock source of PWM2 and PWM3 defined by PWM23_S list below: 00 = Reserved. 01 = Reserved. 10 = Reserved. 11 = Clock source from 10 kHz internal low speed RC oscillator clock.
[29:28]	PWM0 And PWM1 Clock Source Selection PWM0 and PWM1 used the same peripheral clock source; both of them used the same prescaler. The peripheral clock source of PWM0 and PWM1 is defined by PWM01_S (CLKSEL1[29:28]) and PWM01_S_E (CLKSEL2[8]). If PWM01_S_E = 0, the peripheral clock source of PWM0 and PWM1 defined by PWM01_S list below: 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. If PWM01_S_E = 1, the peripheral clock source of PWM0 and PWM1 defined by PWM01_S list below:

		00 = Reserved. 01 = Reserved. 10 = Reserved. 11 = Clock source from 10 kHz internal low speed RC oscillator clock.
[27:26]	Reserved	Reserved.
[25:24]	UART_S	UART Clock Source Selection 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from PLL clock. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock.
[23]	Reserved	Reserved.
[22:20]	TMR3_S	TIMER3 Clock Source Selection 000 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 001 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 010 = Clock source from HCLK. 011 = Clock source from external trigger. 101 = Clock source from 10 kHz internal low speed RC oscillator clock. 111 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. Others = reserved.
[19]	Reserved	Reserved.
[18:16]	TMR2_S	TIMER2 Clock Source Selection 000 = Clock source from external 4~24 MHz high speed crystal oscillator clock. 001 = Clock source from external 32.768 kHz low speed crystal oscillator clock. 010 = Clock source from HCLK. 011 = Clock source from external trigger. 101 = Clock source from internal 10 kHz low speed RC oscillator clock. 111 = Clock source from internal 22.1184 MHz high speed RC oscillator clock. Others = reserved.
[15]	Reserved	Reserved.
[14:12]	TMR1_S	TIMER1 Clock Source Selection 000 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 001 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 010 = Clock source from HCLK. 011 = Clock source from external trigger. 101 = Clock source from 10 kHz internal low speed RC oscillator clock. 111 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. Others = reserved.
[11]	Reserved	Reserved.
[10:8]	TMR0_S	TIMER0 Clock Source Selection 000 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 001 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 010 = Clock source from HCLK. 011 = Clock source from external trigger. 101 = Clock source from 10 kHz internal low speed RC oscillator clock. 111 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. Others = reserved.

[7]	SPI3_S	SPI3 Clock Source Selection 0 = Clock source from PLL clock. 1 = Clock source from HCLK.
[6]	SPI2_S	SPI2 Clock Source Selection 0 = Clock source from PLL clock. 1 = Clock source from HCLK.
[5]	SPI1_S	SPI1 Clock Source Selection 0 = Clock source from PLL clock. 1 = Clock source from HCLK.
[4]	SPI0_S	SPI0 Clock Source Selection 0 = Clock source from PLL clock. 1 = Clock source from HCLK.
[3:2]	ADC_S	ADC Clock Source Select 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from PLL clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock.
[1:0]	WDT_S	Watchdog Timer Clock Source Select (Write Protect) 00 = Reserved. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK/2048 clock. 11 = Clock source from 10 kHz internal low speed RC oscillator clock. Note: This bit is the protected bit, and programming it needs to write "59h", "16h", and "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100.

Clock Source Select Control Register 2 (CLKSEL2)

Before clock switching, the related clock sources (pre-select and new-select) must be turned on.

Register	Offset	R/W	Description	Reset Value
CLKSEL2	CLK_BA+0x1C	R/W	Clock Source Select Control Register 2	0x0002_00FF

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved					RTC_SEL_10K	WWDT_S	
15	14	13	12	11	10	9	8
Reserved				PWM67_S_E	PWM45_S_E	PWM23_S_E	PWM01_S_E
7	6	5	4	3	2	1	0
PWM67_S		PWM45_S		FRQDIV_S		I2S_S	

Bits	Description
[31:19]	Reserved Reserved.
[18]	RTC_SEL_10K RTC Clock Source Selection 0 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 1 = Clock source from 10 kHz internal low speed RC oscillator clock.
[17:16]	WWDT_S Window Watchdog Timer Clock Source Selection 10 = Clock source from HCLK/2048 clock. 11 = Clock source from 10 kHz internal low speed RC oscillator clock.
[15:12]	Reserved Reserved.
[11]	PWM67_S_E PWM6 And PWM7 Clock Source Selection Extend PWM6 and PWM7 used the same peripheral clock source; both of them used the same prescaler. The peripheral clock source of PWM6 and PWM7 is defined by PWM67_S (CLKSEL2[7:6]) and PWM67_S_E (CLKSEL2[11]). If PWM67_S_E = 0, the peripheral clock source of PWM6 and PWM7 defined by PWM67_S list below. 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. If PWM67_S_E = 1, the peripheral clock source of PWM6 and PWM7 defined by PWM67_S list below. 00 = Reserved. 01 = Reserved. 10 = Reserved. 11 = Clock source from 10 kHz internal low speed RC oscillator clock.
[10]	PWM45_S_E PWM4 And PWM5 Clock Source Selection Extend PWM4 and PWM5 used the same peripheral clock source; both of them used the same prescaler. The peripheral clock source of PWM4 and PWM5 is defined by PWM45_S

		(CLKSEL2[5:4]) and PWM45_S_E (CLKSEL2[10]). If PWM45_S_E = 0, the peripheral clock source of PWM4 and PWM5 defined by PWM45_S list below: 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. If PWM45_S_E = 1, the peripheral clock source of PWM4 and PWM5 defined by PWM45_S list below: 00 = Reserved. 01 = Reserved. 10 = Reserved. 11 = Clock source from internal 10 kHz low speed oscillator clock.
[9]	PWM23_S_E	PWM2 And PWM3 Clock Source Selection Extend PWM2 and PWM3 used the same peripheral clock source; both of them used the same prescaler. The peripheral clock source of PWM2 and PWM3 is defined by PWM23_S (CLKSEL1[31:30]) and PWM23_S_E (CLKSEL2[9]). If PWM23_S_E = 0, the peripheral clock source of PWM2 and PWM3 defined by PWM23_S list below: 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. If PWM23_S_E = 1, the peripheral clock source of PWM2 and PWM3 defined by PWM23_S list below: 00 = Reserved. 01 = Reserved. 10 = Reserved. 11 = Clock source from 10 kHz internal low speed RC oscillator clock.
[8]	PWM01_S_E	PWM0 And PWM1 Clock Source Selection Extend PWM0 and PWM1 used the same peripheral clock source; both of them used the same prescaler. The peripheral clock source of PWM0 and PWM1 is defined by PWM01_S (CLKSEL1[29:28]) and PWM01_S_E (CLKSEL2[8]). If PWM01_S_E = 0, the peripheral clock source of PWM0 and PWM1 defined by PWM01_S list below: 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. If PWM01_S_E = 1, the peripheral clock source of PWM0 and PWM1 defined by PWM01_S list below: 00 = Reserved. 01 = Reserved. 10 = Reserved. 11 = Clock source from 10 kHz internal low speed RC oscillator clock.
[7:6]	PWM67_S	PWM6 And PWM7 Clock Source Selection PWM6 and PWM7 used the same peripheral clock source; both of them used the same prescaler. The peripheral clock source of PWM6 and PWM7 is defined by PWM67_S (CLKSEL2[7:6]) and PWM67_S_E (CLKSEL2[11]). If PWM67_S_E = 0, the peripheral clock source of PWM6 and PWM7 defined by PWM67_S list below: 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock.

		01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. If PWM67_S_E = 1, the peripheral clock source of PWM6 and PWM7 defined by PWM67_S list below:. 00 = Reserved. 01 = Reserved. 10 = Reserved. 11 = Clock source from 10 kHz internal low speed RC oscillator clock.
[5:4]	PWM45_S	PWM4 And PWM5 Clock Source Selection PWM4 and PWM5 used the same peripheral clock source; both of them used the same prescaler. The peripheral clock source of PWM4 and PWM5 is defined by PWM45_S (CLKSEL2[5:4]) and PWM45_S_E (CLKSEL2[10]). If PWM45_S_E = 0, the peripheral clock source of PWM4 and PWM5 defined by PWM45_S list below:. 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock. If PWM45_S_E = 1, the peripheral clock source of PWM4 and PWM5 defined by PWM45_S list below:. 00 = Reserved. 01 = Reserved. 10 = Reserved. 11 = Clock source from 10 kHz internal low speed RC oscillator clock.
[3:2]	FRQDIV_S	Clock Divider Clock Source Selection 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from 32.768 kHz external low speed crystal oscillator clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock.
[1:0]	I2S_S	I²S Clock Source Selection 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from PLL clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock.

Clock Source Select Control Register 3 (CLKSEL3)

Before clock switching, the related clock sources (pre-select and new-select) must be turned on.

Register	Offset	R/W	Description	Reset Value
CLKSEL3	CLK_BA+0x34	R/W	Clock Source Select Control Register 3	0x0000_003F

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved		SC2_S		SC1_S		SC0_S	

Bits	Description	
[31:6]	Reserved	Reserved.
[5:4]	SC2_S	SC2 Clock Source Selection 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from PLL clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock.
[3:2]	SC1_S	SC1 Clock Source Selection 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from PLL clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock.
[1:0]	SC0_S	SC0 Clock Source Selection 00 = Clock source from 4~24 MHz external high speed crystal oscillator clock. 01 = Clock source from PLL clock. 10 = Clock source from HCLK. 11 = Clock source from 22.1184 MHz internal high speed RC oscillator clock.

Clock Divider Register (CLKDIV)

Register	Offset	R/W	Description	Reset Value
CLKDIV	CLK_BA+0x18	R/W	Clock Divider Number Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
ADC_N							
15	14	13	12	11	10	9	8
Reserved				UART_N			
7	6	5	4	3	2	1	0
USB_N				HCLK_N			

Bits	Description	
[15:12]	Reserved	Reserved.
[23:16]	ADC_N	ADC Clock Divide Number From ADC Clock Source ADC clock frequency = (ADC clock source frequency) / (ADC_N + 1).
[15:12]	Reserved	Reserved.
[11:8]	UART_N	UART Clock Divide Number From UART Clock Source UART clock frequency = (UART clock source frequency) / (UART_N + 1).
[7:4]	USB_N	USB Clock Divide Number From PLL Clock USB clock frequency = (PLL frequency) / (USB_N + 1).
[3:0]	HCLK_N	HCLK Clock Divide Number From HCLK Clock Source HCLK clock frequency = (HCLK clock source frequency) / (HCLK_N + 1).

Clock Divider Register 1 (CLKDIV1)

Register	Offset	R/W	Description	Reset Value
CLKDIV1	CLK_BA+0x38	R/W	Clock Divider Number Register 1	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
SC2_N							
15	14	13	12	11	10	9	8
SC1_N							
7	6	5	4	3	2	1	0
SC0_N							

Bits	Description	
[31:24]	Reserved	Reserved.
[23:16]	SC2_N	SC2 Clock Divide Number From SC2 Clock Source The SC2 clock frequency = (SC2 clock source frequency) / (SC2_N + 1).
[15:8]	SC1_N	SC1 Clock Divide Number From SC1 Clock Source The SC1 clock frequency = (SC1 clock source frequency) / (SC1_N + 1).
[7:0]	SC0_N	SC0 Clock Divide Number From SC0 Clock Source The SC0 clock frequency = (SC0 clock source frequency) / (SC0_N + 1).

PLL Control Register (PLLCON)

The PLL reference clock input is from the 4~24 MHz external high speed crystal oscillator clock input or from the 22.1184 MHz internal high speed RC oscillator. These registers are used to control the PLL output frequency and PLL operating mode.

Register	Offset	R/W	Description	Reset Value
PLLCON	CLK_BA+0x20	R/W	PLL Control Register	0x0005_C22E

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved			FCO_SEL	PLL_SRC	OE	BP	PD
15	14	13	12	11	10	9	8
OUT_DV		IN_DV					FB_DV
7	6	5	4	3	2	1	0
FB_DV							

Bits	Description
[31:20]	Reserved
[19]	PLL_SRC PLL Source Clock Selection 0 = PLL source clock from 4~24 MHz external high speed crystal oscillator. 1 = PLL source clock from 22.1184 MHz internal high speed RC oscillator.
[18]	OE PLL OE (FOUT Enable) Pin Control 0 = PLL FOUT Enabled. 1 = PLL FOUT is fixed low.
[17]	BP PLL Bypass Control 0 = PLL is in Normal mode (default). 1 = PLL clock output is same as PLL source clock input.
[16]	PD Power-Down Mode If the PWR_DOWN_EN bit is set to 1 in PWRCON register, the PLL will enter Power-down mode too. 0 = PLL is in Normal mode. 1 = PLL is in Power-down mode (default).
[15:14]	OUT_DV PLL Output Divider Control Bits Refer to the formulas below the table.
[13:9]	IN_DV PLL Input Divider Control Bits Refer to the formulas below the table.
[8:0]	FB_DV PLL Feedback Divider Control Bits Refer to the formulas below the table.

Output Clock Frequency Setting

$$F_{OUT} = F_{IN} \times \frac{NF}{NR} \times \frac{1}{NO}$$

Constraint:

1. $3.2MHz < F_{IN} < 150MHz$
2. $800KHz < \frac{F_{IN}}{2 * NR} < 7.5MHz$
3. $100MHz < F_{CO} = F_{IN} * \frac{NF}{NR} < 200MHz$
 $120MHz < F_{CO}$ is preferred

Symbol	Description
FOUT	Output Clock Frequency
FIN	Input (Reference) Clock Frequency
NR	Input Divider (IN_DV + 2)
NF	Feedback Divider (FB_DV + 2)
NO	OUT_DV = "00" : NO = 1 OUT_DV = "01" : NO = 2 OUT_DV = "10" : NO = 2 OUT_DV = "11" : NO = 4

Default Frequency Setting

The default value: 0xC22E

FIN = 12 MHz

NR = (1+2) = 3

NF = (46+2) = 48

NO = 4

FOUT = 12/4 x 48 x 1/3 = 48 MHz

Frequency Divider Control Register (FRQDIV)

Register	Offset	R/W	Description	Reset Value
FRQDIV	CLK_BA+0x24	R/W	Frequency Divider Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved	CLKO_1HZ_EN N	DIVIDER1	DIVIDER_EN	FSEL			

Bits	Description
[31:7]	Reserved
[6]	CLKO_1HZ_EN Clock Output 1Hz Enable Bit 0 = 1 Hz clock output for 32.768 kHz external low speed crystal oscillator clock frequency compensation Disabled. 1 = 1 Hz clock output for 32.768 kHz external low speed crystal oscillator clock frequency compensation Enabled.
[5]	DIVIDER1 Frequency Divider One Enable Bit 0 = Frequency divider will output clock with source frequency divided by FSEL. 1 = Frequency divider will output clock with source frequency.
[4]	DIVIDER_EN Frequency Divider Enable Bit 0 = Frequency Divider function Disabled. 1 = Frequency Divider function Enabled.
[3:0]	FSEL Divider Output Frequency Selection Bits The formula of output frequency is $F_{out} = F_{in} / 2^{(N+1)}$ F _{in} is the input clock frequency. F _{out} is the frequency of divider output clock. N is the 4-bit value of FSEL[3:0].

6.4 Flash Memory Controller (FMC)

6.4.1 Overview

The NuMicro™ NUC230/240 series has 128/64/32K bytes on-chip embedded Flash for application program memory (APROM) that can be updated through ISP procedure. The In-System-Programming (ISP) function enables user to update program memory when chip is soldered on PCB. After chip is powered on, Cortex™-M0 CPU fetches code from APROM or LDROM decided by boot select (CBS) in CONFIG0. By the way, the NuMicro™ NUC230/240 series also provides additional Data Flash for user to store some application dependent data. For 128K bytes APROM device, the Data Flash is shared with original 128K program memory and its start address is configurable in CONFIG1. For 64K/32K bytes APROM device, the Data Flash is fixed at 4KB.

6.4.2 Features

- Runs up to 50 MHz with zero wait cycle for continuous address read access and runs up to 72MHz with one wait cycle for continuous address read.
- All embedded flash memory supports 512 bytes page erase
- 128/64/32 KB application program memory (APROM)
- 8KB In-System-Programming (ISP) loader program memory (LDROM)
- 4KB Data Flash for 64/32 KB APROM device
- Configurable Data Flash size for 128KB APROM device
- Configurable or fixed 4 KB Data Flash with 512 bytes page erase unit
- Supports In-Application-Programming (IAP) to switch code between APROM and LDROM without reset
- In-System-Programming (ISP) to update on-chip Flash

6.4.3 Block Diagram

The flash memory controller consists of AHB slave interface, ISP control logic, writer interface and flash macro interface timing control logic. The block diagram of flash memory controller is shown as follows:

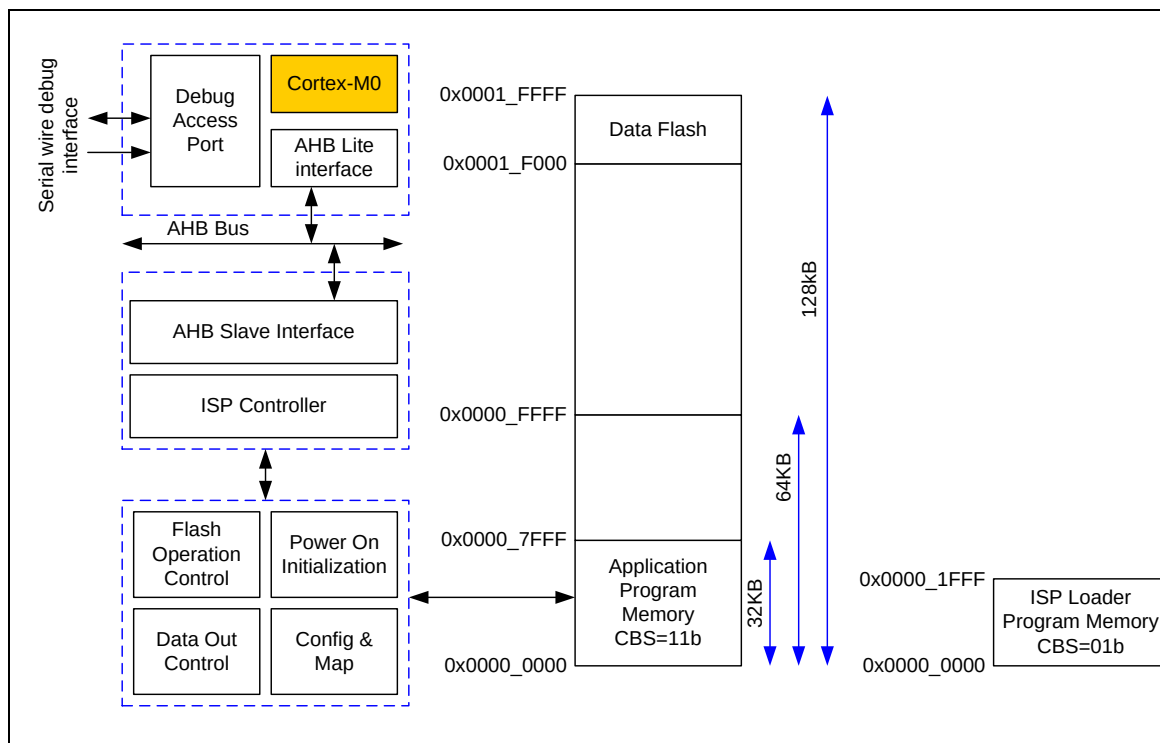


Figure 6-10 Flash Memory Control Block Diagram

6.4.4 Functional Description

6.4.4.1 Flash Memory Organization

The NuMicro™ NUC230/240 series flash memory consists of program memory (APROM), Data Flash, ISP loader program memory (LDROM), and user configuration.

Program memory is main memory for user applications and called APROM. User can write their application to APROM and set system to boot from APROM.

ISP loader program memory is designed for a loader to implement In-System-Programming function. LDROM is independent to APROM and system can also be set to boot from LDROM. Therefore, user can use LDROM to avoid system boot fail when code of APROM was corrupted.

Data Flash is used for user to store data. It can be read by ISP read or memory read and programmed through ISP procedure. The size of each erase unit is 512 bytes. For 128 KB APROM device, the Data Flash and application program share the same 128 KB memory, if DFEN (Data Flash Enable) bit in CONFIG0 is enabled, the Data Flash base address is defined by DFBADR and its size is (0x20000 - DFBADR), At the same time, the APROM size will be (128 KB – Data Flash size). For 64/32 KB APROM devices, Data Flash size is always 4 KB and start address is fixed at 0x0001_F000.

User configuration provides several bytes to control system logic, such as flash security lock, boot select, Brown-out voltage level, Data Flash base address, etc.... User configuration works like a fuse for power on setting and loaded from flash memory to its corresponding control registers during chip powered on.

In NuMicro™ Family, the flash memory organization is different to system memory map. Flash memory organization is used when user using ISP command to read, program or erase flash memory. System memory map is used when CPU access flash memory to fetch code or data. For example, When system is set to boot from LDROM by CBS = 01b, CPU will be able to fetch code of LDROM from 0x0 ~ 0x1FFF. However, if user want to read LDROM by ISP, they still need to read the address of LDROM as 0x0010_0000 ~ 0x0010_1FFF.

Table 6-6 and Figure 6-11 show the address mapping information of APROM, LDROM, Data Flash and user configuration for 32/64 and 128 KB devices.

Block Name	Device Type	Size		Start Address	End Address
APROM	32 KB	32 KB		0x0000_0000	0x0000_7FFF
	64 KB	64 KB		0x0000_0000	0x0000_FFFF
	128 KB	Data Flash Enable	128 KB - Data Flash Size	0x0000_0000	0x20000 – Data Flash Size - 1
		Data Flash Disable	128 KB	0x0000_0000	0x0001_FFFF
Data Flash	32 KB	4 KB		0x0001_F000	0x0001_FFFF
	64 KB	4 KB		0x0001_F000	
	128 KB	Data Flash Enable	0x20000-DFBADR	DFBADR	
		Data Flash Disable	0 KB	N/A	N/A
LDROM	32/64/128 KB	8 KB		0x0010_0000	0x0010_1FFF
User Configuration	32/64/128 KB	2 words		0x0030_0000	0x0030_0004

Table 6-6 Memory Address Map

The Flash memory organization is shown as Figure 6-11:

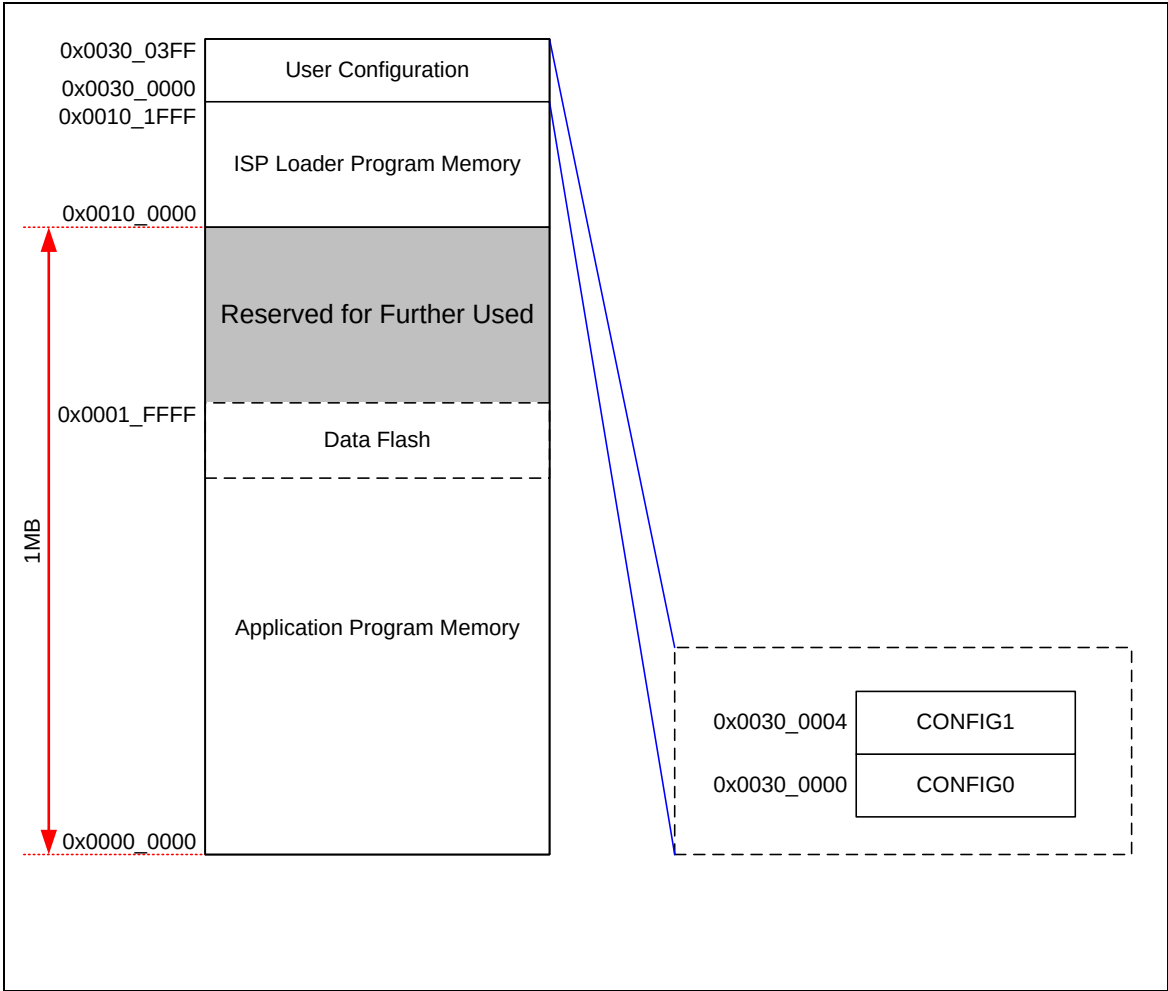


Figure 6-11 Flash Memory Organization

6.4.4.2 User Configuration

User configuration is internal programmable configuration area for boot options. The user configuration is located at 0x300000 of Flash Memory Organization and they are two 32 bits words. Any change on user configuration will take effect after system reboot.

CONFIG0 (Address = 0x0030_0000)

31	30	29	28	27	26	25	24
CWDTEN	CWDTPDEN	Reserved		CGPFMFP	CFOSC		
23	22	21	20	19	18	17	16
CBODEN	CBOV		CBORST	Reserved			
15	14	13	12	11	10	9	8
Reserved					CIOINI	Reserved	
7	6	5	4	3	2	1	0
CBS		Reserved				LOCK	DFEN

CONFIG0	Address = 0x0030_0000	
Bits	Description	
[31]	CWDTEN	Watchdog Enable Bit 0 = Watchdog Timer Enabled and force Watchdog Timer clock source as OSC10K after chip powered on. 1 = Watchdog Timer Disabled after chip powered on.
[30]	CWDTPDEN	Watchdog Clock Power-down Enable Bit 0 = OSC10K Watchdog Timer clock source is forced to be always enabled. 1 = OSC10K Watchdog Timer clock source is controlled by OSC10K_EN (PWRCON[3]) when chip enters Power-down. Note: This bit only works at CWDTEN is set to 0
[29:28]	Reserved	Reserved
[27]	CGPFMFP	GPF Multi-function Selection 0 = XT1_IN and XT1_OUT pin is configured as GPIO function. 1 = XT1_IN and XT1_OUT pin is used as external 4~24MHz crystal oscillator pin. Note: XT1_IN, XT1_OUT multi-function can only be changed by CGPFMFP.
[26:24]	CFOSC	CPU Clock Source Selection after Reset 000 = External 4~24 MHz high speed crystal oscillator clock. 111 = Internal RC 22.1184 MHz high speed oscillator clock. Others = Reserved. The value of CFOSC will be load to HCLK_S (CLKSEL0[2:0]) in system register after any reset occurs.
[23]	CBODEN	Brown-out Detector Enable Bit 0= Brown-out detect Enabled after powered on. 1= Brown-out detect Disabled after powered on.

[22:21]	CBOV	Brown-out Voltage Selection 00 = 2.2 V 01 = 2.7 V 10 = 3.7 V 11 = 4.4 V
[20]	CBORST	Brown-out Reset Enable Bit 0 = Brown-out reset Enabled after powered on. 1 = Brown-out reset Disabled after powered on.
[19:11]	Reserved	Reserved
[10]	CIOINI	I/O Initial State Select 0 = All GPIO default to be input tri-state mode after powered on 1 = All GPIO default to be Quasi-bidirectional mode after chip is powered on
[9:8]	Reserved	Reserved
[7:6]	CBS	Chip Boot Selection 00 = Boot from LDROM with IAP function 01 = Boot from LDROM without IAP function 10 = Boot from APROM with IAP function 11 = Boot from APROM without IAP function IAP function means APROM and LDROM can be executed and access by CPU without reset. When IAP function enabled, APROM base address is 0x0 and LDROM base address is 0x100000.
[5:2]	Reserved	Reserved
[1]	LOCK	Security Lock 0 = Flash data is locked 1 = Flash data is not locked When flash data is locked, only device ID, CONFIG0 and CONFIG1 can be read by writer and ICP through serial debug interface. Others data is locked as 0xFFFFFFFF. ISP can read data anywhere regardless of LOCK bit value. User need to erase whole chip by ICP/Writer tool or erase user configuration by ISP to unlock.
[0]	DFEN	Data Flash Enable Bit 0 = Data Flash Enabled. 1 = Data Flash Disabled. Note: This bit only for 128 KB APROM Device

Brown-out detection function is for monitoring the voltage on V_{DD} pin. If V_{DD} voltage falls below level setting of CBOV, the BOD event will be triggered when BOD enabled. User can decide to use BOD reset by enable CBORST or just enable BOD interrupt by NVIC when BOD detected. Because BOD reset is issued whenever V_{DD} voltage falls below the level setting of CBOV, user must make sure the CBOV setting to avoid BOD reset right after BOD reset enabled. For example, if the V_{DD} is 3.3V, CBOV could only be 00'b or 01'b. Otherwise, the system will be halted in BOD reset state when BOD reset is enabled and CBOV is 10'b or 11'b.

CONFIG1 (Address = 0x0030_0004)

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

Config	Address = 0x0030_0004	
Bits	Description	
[31:20]	Reserved	Reserved (It is mandatory to program 0x00 to these Reserved bits)
[19:0]	DFBADR	Data Flash Base Address (Only for 128 KB APROM Device) For 128 KB APROM device, its Data Flash base address is defined by user. Since on-chip flash erase unit is 512 bytes, it is mandatory to keep bit 8-0 as 0. This configuration is only valid for 128 KB flash device.

6.4.4.3 Boot Selection

The NuMicro™ NUC230/240 series provides In-System-Programming (ISP) feature to enable user to update program memory by a stand-alone ISP firmware. A dedicated 8 KB program memory (LDROM) is used to store ISP firmware. User can select to start program fetch from APROM or LDROM by CBS[1] in CONFIG0.

In addition to setting boot from APROM or LDROM, CBS in CONFIG0 is also used to control system memory map after booting. When CBS[0] = 1 and set CBS[1] = 1 to boot from APROM, the application in APROM will not be able to access LDROM by memory read. In other words, when CBS[0] = 1 and CBS[1] = 0 are set to boot from LDROM, the software executed in LDROM will not be able to access APROM by memory read. Figure 6-12 shows the memory map when booting from APROM and LDROM.

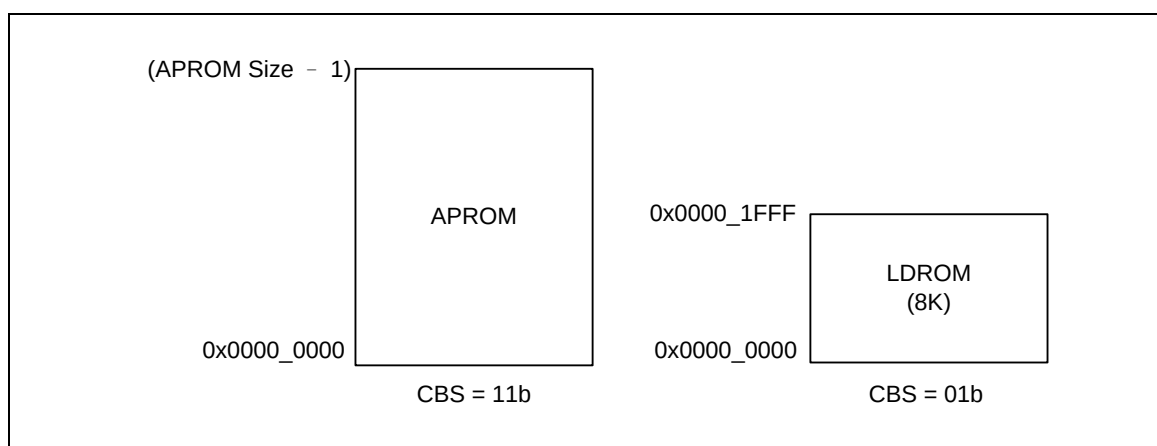


Figure 6-12 Program Executing Range for Booting from APROM and LDROM

For the application that software needs to execute code in APROM and call the functions in LDROM or to execute code in LDROM and call the APROM function without changing boot mode, CBS[0] needs to be set as 0 and this is called In-Application-Programming(IAP).

6.4.4.4 In-Application-Programming (IAP)

The NuMicro™ NUC230/240 series provides In-application-programming (IAP) function for user to switch the code executing between APROM and LDROM without a reset. User can enable the IAP function by re-booting chip and setting the chip boot selection bits in CONFIG0 (CBS[1:0]) as 10b or 00b.

In the case that the chip boots from APROM with the IAP function enabled (CBS[1:0] = 10b), the executable range of code includes all of APROM and LDROM. The address space of APROM is kept as the original size but the address space of the 8 KB LDROM is mapped to 0x0010_0000~0x0010_1FFF.

In the case that the chip boots from LDROM with the IAP function enabled (CBS[1:0] = 00b), the executable range of code includes all of LDROM and almost all of APROM except for its first page. User cannot access the first page of APROM by CPU because the first page of executable code range becomes the mirror of the first page of LDROM as set by default. Meanwhile, the address space of 8 KB LDROM is mapped to 0x0010_0000~0x0010_1FFF.

Please refer to Figure 6-13 for the address map while IAP is activating.

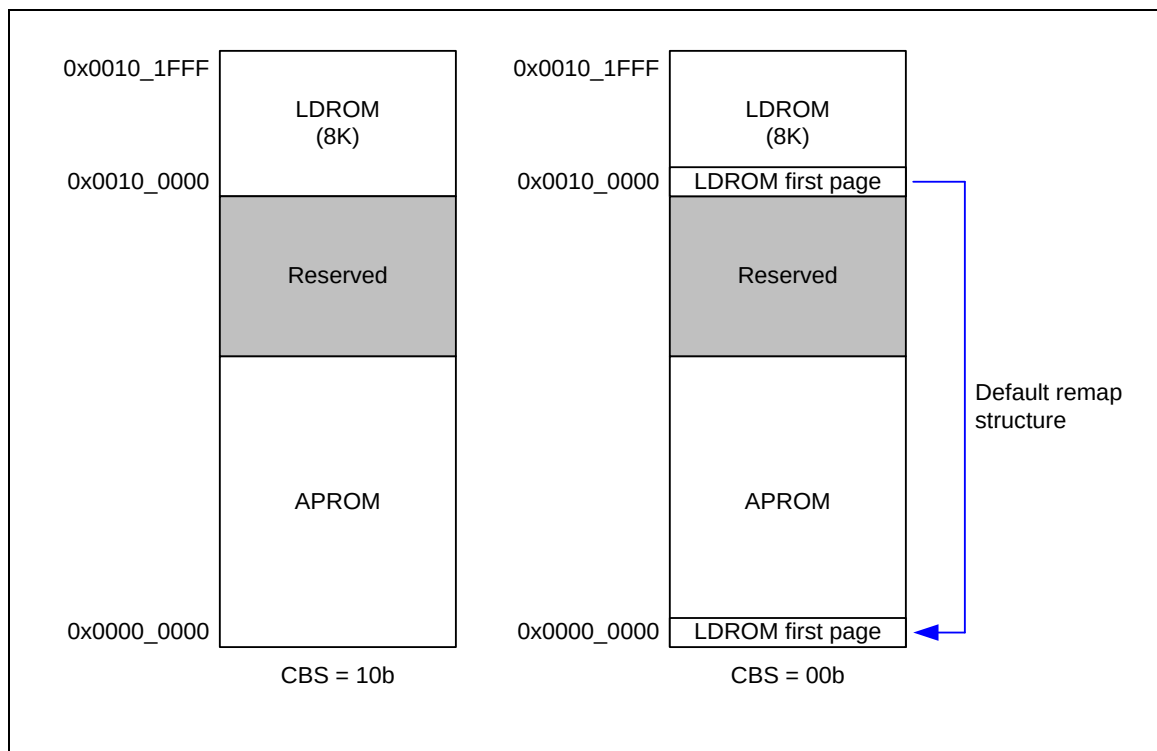


Figure 6-13 Executable Range of Code with IAP Function Enabled

When chip boots with the IAP function enabled, any other page within the executable range of code can be mirrored to the first page of executable code (0x0000_0000~0x0000_01FF) any time. User can change the remap address of the first executing page by filling the target remap address to ISPADR and then go through ISP procedure with the Vector Page Re-map command. After changing the remap address, user can check if the change is successful by reading the VECMAP field in the ISPSTA register.

6.4.4.5 In-System-Programming (ISP)

The NuMicro™ NUC230/240 series supports ISP mode which allows a device to be reprogrammed under software control and avoids system fail risk when download or programming fail. Furthermore, the capability to update the application firmware makes a wide range of applications possible.

ISP provides the ability to update system firmware on board. Various peripheral interfaces let ISP loader in LDROM to update application program code easily. The most common method to perform ISP is via UART along with the ISP loader in LDROM. General speaking, PC transfers the new APROM code through serial port. Then ISP loader receives it and re-programs into APROM through ISP commands.

6.4.4.6 ISP Procedure

The NuMicro™ NUC230/240 series supports booting from APROM or LDROM initially defined by user configuration. The change of user configuration needs to reboot system to make it take effect. If user wants to switch between APROM or LDROM mode without changing user configuration, he needs to control BS bit of ISPCON control register, then reset CPU by IPRSTC1 control register. The boot switching flow by BS bit is shown in the following figure.

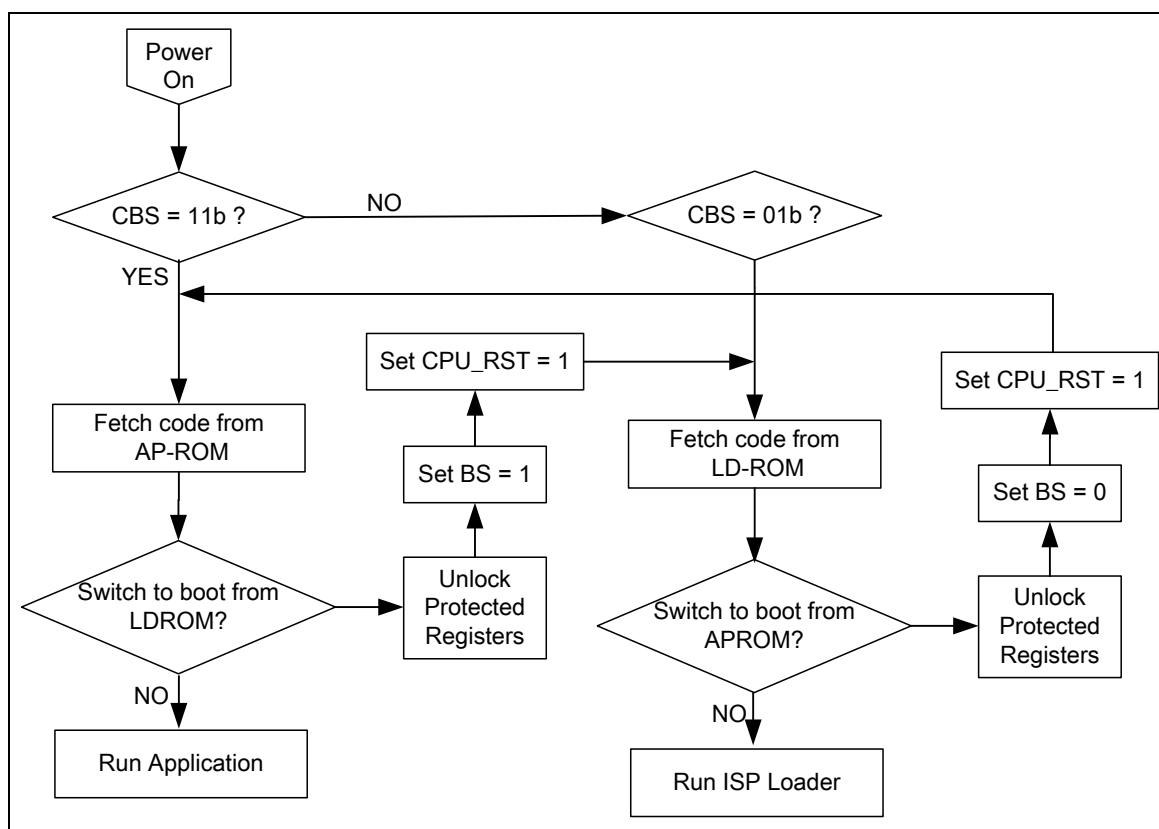


Figure 6-14 Example Flow of Boot Selection by BS Bit

Updating APROM by software in LDROM or updating LDROM by software in APROM can avoid a system failure when update fails.

The ISP controller supports to read, erase and program embedded flash memory. Several control bits of ISP controller are write-protected, thus it is necessary to unlock before we can set them. To unlock the protected register bits, software needs to write 0x59, 0x16 and 0x88 sequentially to

REGWRPROT. If register is unlocked successfully, the value of REGWRPROT will be 1. The unlock sequence must not be interrupted by other access; otherwise it may fail to unlock.

After unlocking the protected register bits, user needs to set the ISPCON control register to decide to update LDROM, User Configuration, APROM and enable ISP controller.

Once the ISPCON register is set properly, user can set ISPCMD for erase, read or programming. Set ISPADR for target flash memory based on flash memory origination. ISPDAT can be used to set the data to program or used to return the read data according to ISPCMD.

Finally, set ISPGO bit of ISPTRG control register to perform the relative ISP function. The ISPGO bit is self-cleared when ISP function has been done. To make sure ISP function has been finished before CPU goes ahead, ISB instruction is used right after ISPGO setting.

Several error conditions are checked after ISP is completed. If an error condition occurs, ISP operation is not started and the ISP fail flag will be set instead. ISPFF flag can only be cleared by software. The next ISP procedure can be started even ISPFF bit is kept as 1. Therefore, it is recommended to check the ISPFF bit and clear it after each ISP operation if it is set to 1.

When the ISPGO bit is set, CPU will wait for ISP operation to finish during this period; the peripheral still keeps working as usual. If any interrupt request occurs, CPU will not service it till ISP operation is finished. When ISP operation is finished, the ISPGO bit will be cleared by hardware automatically. User can check whether ISP operation is finished or not by the ISPGO bit. User should add ISB instruction next to the instruction in which ISPGO bit is set 1 to ensure correct execution of the instructions following ISP operation.

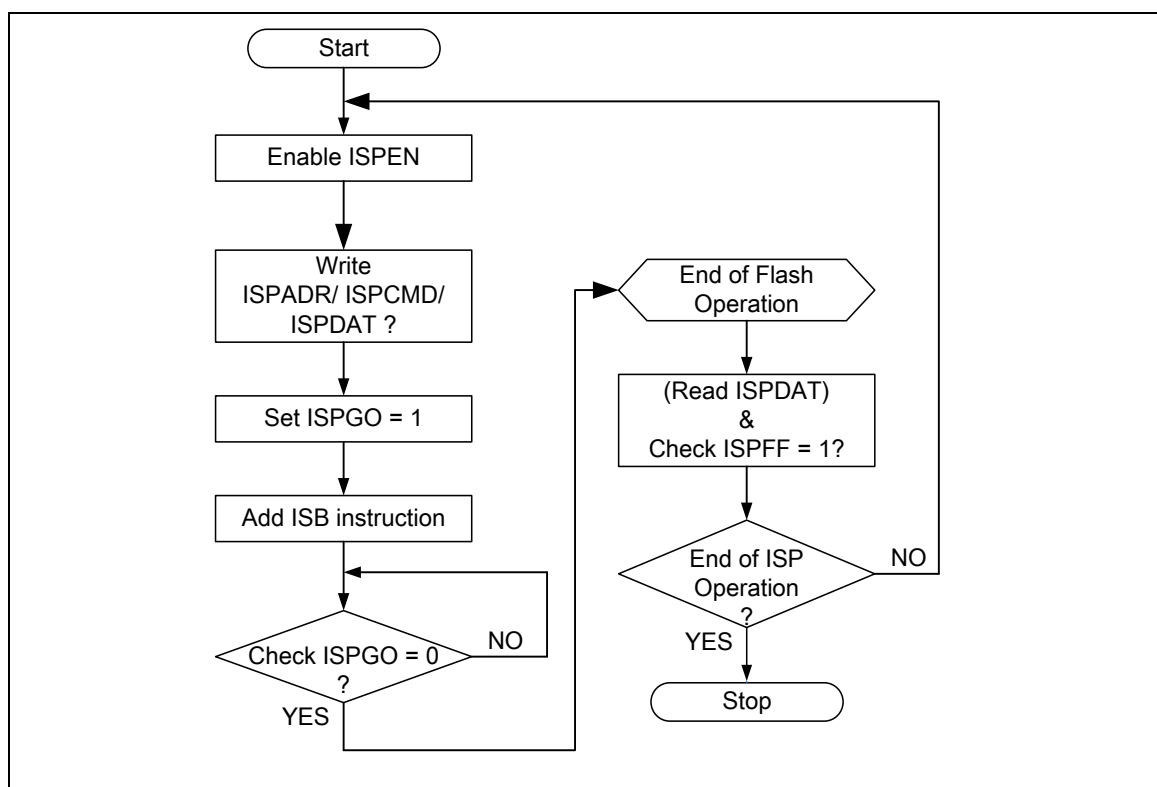


Figure 6-15 ISP Flow Example

ISP Command	ISPCMD	ISPADR	ISPDAT
FLASH Page Erase	0x22	Valid address of flash memory origination. It must be 512 bytes page alignment.	N/A

FLASH Program	0x21	Valid address of flash memory origination	Programming Data
FLASH Read	0x00	Valid address of flash memory origination	Return Data
Read Unique ID	0x04	0x0000_0000	Unique ID Word 0
		0x0000_0004	Unique ID Word 1
		0x0000_0008	Unique ID Word 2
Vector Page Re-Map	0x2E	Page in APROM or LDROM It must be 512 bytes page alignment	N/A

Table 6-7 ISP Command List

6.4.5 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
FMC Base Address: FMC_BA = 0x5000_C000				
ISPCON	FMC_BA+0x00	R/W	ISP Control Register	0x0000_0000
ISPADR	FMC_BA+0x04	R/W	ISP Address Register	0x0000_0000
ISPDAT	FMC_BA+0x08	R/W	ISP Data Register	0x0000_0000
ISPCMD	FMC_BA+0x0C	R/W	ISP Command Register	0x0000_0000
ISPTRG	FMC_BA+0x10	R/W	ISP Trigger Control Register	0x0000_0000
DFBADR	FMC_BA+0x14	R	Data Flash Base Address	0x000X_XXXX
FATCON	FMC_BA+0x18	R/W	Flash Access Time Control Register	0x0000_0000
ISPSTA	FMC_BA+0x40	R/W	ISP Status Register	0x0000_0000

6.4.6 Register Description

ISP Control Register (ISPCON)

Register	Offset	R/W	Description	Reset Value
ISPCON	FMC_BA+0x00	R/W	ISP Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved	ISPPF	LDUEN	CFGUEN	APUEN	Reserved	BS	ISPEN

Bits	Description	
[31:7]	Reserved	Reserved.
[6]	ISPPF	ISP Fail Flag (Write Protect) This bit is set by hardware when a triggered ISP meets any of the following conditions: (1) APROM writes to itself if APUEN is set to 0 (2) LDROM writes to itself if LDUEN is set to 0 (3) CONFIG is erased/programmed if CFGUEN is set to 0 (4) Destination address is illegal, such as over an available range Write 1 to clear to this bit to 0.
[5]	LDUEN	LDROM Update Enable Bit (Write Protect) 0 = LDROM cannot be updated. 1 = LDROM can be updated when chip runs in APROM.
[4]	CFGUEN	Enable Config Update By ISP (Write Protect) 0 = ISP update config-bit Disabled. 1 = ISP update config-bit Enabled.
[3]	APUEN	APROM Update Enable Bit (Write Protect) 0 = APROM cannot be updated when chip runs in APROM. 1 = APROM can be updated when chip runs in APROM.
[2]	Reserved	Reserved.
[1]	BS	Boot Select (Write Protect) Set/clear this bit to select next booting from LDROM/APROM, respectively. This bit also functions as chip booting status flag, which can be used to check where chip booted from. This bit is initiated with the inversed value of CBS in CONFIG0 after any reset is happened except CPU reset (RSTS_CPU is 1) or system reset (RSTS_SYS) is happened 0 = Boot from APROM. 1 = Boot from LDROM.

[0]	ISPEN	ISP Enable Bit (Write Protect) ISP function enable bit. Set this bit to enable ISP function. 0 = ISP function Disabled. 1 = ISP function Enabled.

ISP Address Register (ISPADR)

Register	Offset	R/W	Description	Reset Value
ISPADR	FMC_BA+0x04	R/W	ISP Address Register	0x0000_0000

31	30	29	28	27	26	25	24
ISPADR[31:24]							
23	22	21	20	19	18	17	16
ISPADR[23:16]							
15	14	13	12	11	10	9	8
ISPADR[15:8]							
7	6	5	4	3	2	1	0
ISPADR[7:0]							

Bits	Description	
[31:0]	ISPADR	ISP Address The NuMicro™ NUC230/240 series has a maximum of 32Kx32 (128 KB) embedded Flash, which supports word program only. ISPADR[1:0] must be kept 00b for ISP operation.

ISP Data Register (ISPDAT)

Register	Offset	R/W	Description	Reset Value
ISPDAT	FMC_BA+0x08	R/W	ISP Data Register	0x0000_0000

31	30	29	28	27	26	25	24
ISPDAT[31:24]							
23	22	21	20	19	18	17	16
ISPDAT [23:16]							
15	14	13	12	11	10	9	8
ISPDAT [15:8]							
7	6	5	4	3	2	1	0
ISPDAT [7:0]							

Bits	Description	
[31:0]	ISPDAT	ISP Data Write data to this register before ISP program operation Read data from this register after ISP read operation

ISP Command Register (ISPCMD)

Register	Offset	R/W	Description	Reset Value
ISPCMD	FMC_BA+0x0C	R/W	ISP Command Register	0x0000_0000

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

Bits	Description	
[31:6]	Reserved	Reserved.
[5:0]	ISPCMD	ISP Command ISP command table is shown below: 0x00 = Read. 0x04 = Read Unique ID. 0x0B = Read Company ID (0xDA). 0x21 = Program. 0x22 = Page Erase. 0x2E = Set Vector Page Re-Map.

ISP Trigger Control Register (ISPTRG)

Register	Offset	R/W	Description	Reset Value
ISPTRG	FMC_BA+0x10	R/W	ISP Trigger Control Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	ISPGO	ISP Start Trigger (Write-Protection Bit) Write 1 to start ISP operation and this bit will be cleared to 0 by hardware automatically when ISP operation is finished. 0 = ISP operation finished. 1 = ISP progressed. This bit is the protected bit, It means programming this bit needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Refer to the register REGWRPROT at address GCR_BA+0x100

Data Flash Base Address Register (DFBADR)

Register	Offset	R/W	Description	Reset Value
DFBADR	FMC_BA+0x14	R	Data Flash Base Address	0x000X_XXXX

31	30	29	28	27	26	25	24
DFBADR[31:23]							
23	22	21	20	19	18	17	16
DFBADR[23:16]							
15	14	13	12	11	10	9	8
DFBADR[15:8]							
7	6	5	4	3	2	1	0
DFBADR[7:0]							

Bits	Description
[31:0]	Data Flash Base Address This register indicates Data Flash start address. It is read only. For 128 KB flash memory device, the Data Flash size is defined by user configuration, register content is loaded from CONFIG1 when chip is powered on but for 64/32 KB device, it is fixed at 0x0001_F000.

Flash Access Time Control Register (FATCON)

Register	Offset	R/W	Description	Reset Value
FATCON	FMC_BA+0x18	R/W	Flash Access Time Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved	FOMSEL1	Reserved	FOMSEL0	Reserved			

Bits	Description	
[31:7]	Reserved	Reserved.
[6]	FOMSEL1	Chip Frequency Optimization Mode Select1 (Write-protection Bit)
[5]	Reserved	Reserved.
[4]	FOMSEL0	Chip Frequency Optimization Mode Select 0 (Write-Protection Bit) When CPU frequency is lower than 72 MHz, user can modify flash access delay cycle by FOMSEL1 and FOMSEL0 to improve system performance. 00 = CPU runs at 50MHz with zero wait cycle for continuous address read access. 01 = CPU runs at 25MHz with zero wait cycle for random address read access. 10 = CPU runs at 50MHz with zero wait cycle for continuous address read access. 11 = CPU runs at 72MHz with one wait cycle for continuous address read access. Where 00 means FOMSEL1 = 0, FOMSEL0 = 0; 01 means FOMSEL1 = 0, FOMSEL0 = 1 and etc.
[3:0]	Reserved	Reserved.

ISP Status Register (ISPSTA)

Register	Offset	R/W	Description	Reset Value
ISPSTA	FMC_BA+0x40	R/W	ISP Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved				VECMAP[11:7]			
15	14	13	12	11	10	9	8
VECMAP[6:0]							Reserved
7	6	5	4	3	2	1	0
Reserved	ISPFF	Reserved			CBS		ISPGO

Bits	Description	
[31:21]	Reserved	Reserved.
[20:9]	VECMAP	Vector Page Mapping Address (Read Only) The current flash address space 0x0000_0000~0x0000_01FF is mapping to address {VECMAP[11:0], 9'h000} ~ {VECMAP[11:0], 9'h1FF}
[8:7]	Reserved	Reserved.
[6]	ISPFF	ISP Fail Flag (Write-Protection Bit) This bit is set by hardware when a triggered ISP meets any of the following conditions: (1) APROM writes to itself (2) LDROM writes to itself (3) CONFIG is erased/programmed if CFGUEN is set to 0 (4) Destination address is illegal, such as over an available range Write 1 to clear this bit. Note: The function of this bit is the same as ISPCON bit6
[5:3]	Reserved	Reserved.
[2:1]	CBS	Chip Boot Selection (Read Only) This is a mirror of CBS in CONFIG0.
[0]	ISPGO	ISP Start Trigger (Read Only) Write 1 to start ISP operation and this bit will be cleared to 0 by hardware automatically when ISP operation is finished. 0 = ISP operation finished. 1 = ISP operation progressed. Note: This bit is the same as ISPTRG bit0

6.5 External Bus Interface (EBI)

6.5.1 Overview

The NuMicro™ NUC100 series LQFP-64 and LQFP-100 package equips an external bus interface (EBI) for access external device.

To save the connections between external device and this chip, EBI supports address bus and data bus multiplex mode. And, address latch enable (ALE) signal is used to differentiate the address and data cycle.

6.5.2 Features

External Bus Interface has the following functions:

- Supports external devices with max. 64 KB size (8-bit data width)/128 KB (16-bit data width)
- Supports variable external bus base clock (MCLK) which based on HCLK
- Supports 8-bit or 16-bit data width
- Supports variable data access time (tACC), address latch enable time (tALE) and address hold time (tAHD)
- Supports address bus and data bus multiplex mode to save the address pins
- Supports configurable idle cycle for different access condition: Write command finish (W2X), Read-to-Read (R2R)

6.5.3 Block Diagram

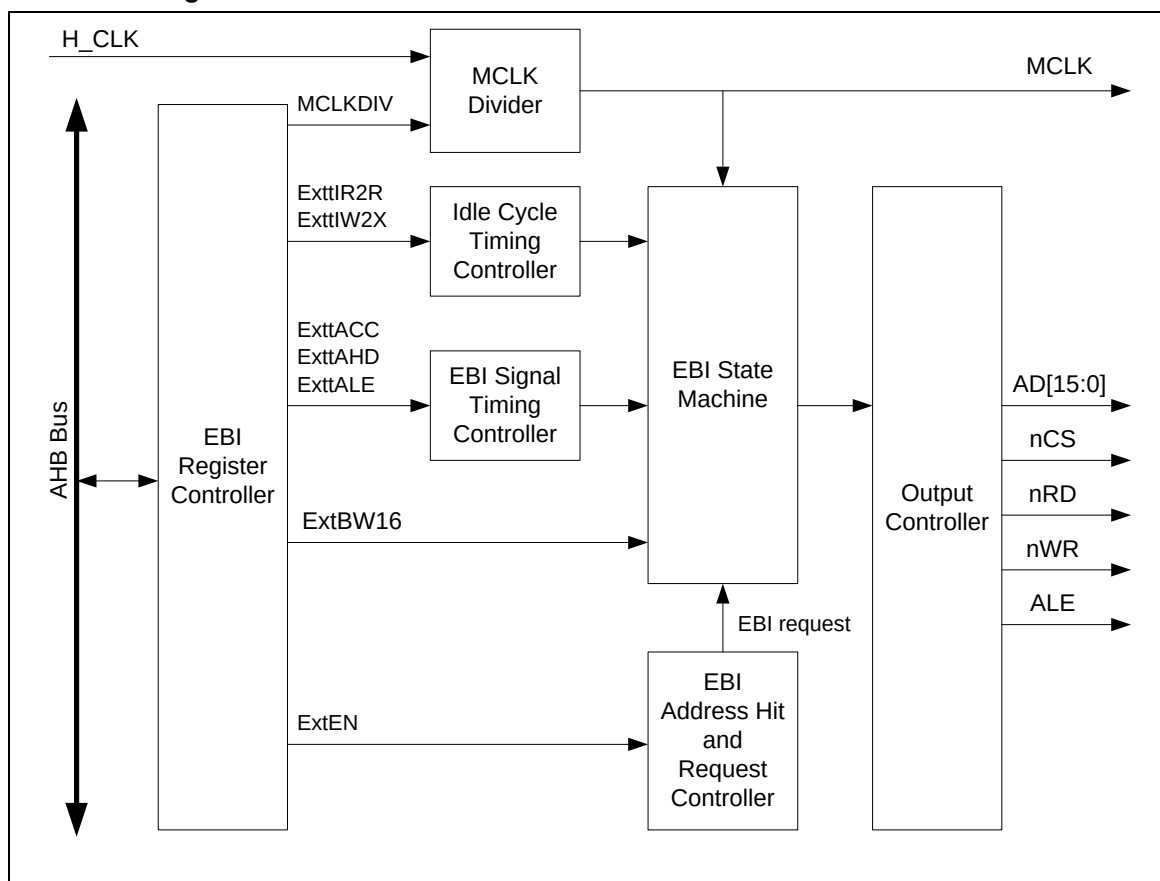


Figure 6-16 EBI Block Diagram

6.5.4 Functional Description

6.5.4.1 EBI Area and Address Hit

The EBI mapping address is located at 0x6000_0000 ~ 0x6001_FFFF and the maximum available memory space is 128 Kbytes. When the system request address hits EBI's memory space, the corresponding EBI chip select signal (nCS) is assert and EBI state machine operates.

For an 8-bit device (64 Kbytes), EBI mapped this 64 Kbytes device to 0x6000_0000 ~ 0x6000_FFFF and 0x6001_0000 ~ 0x6001_FFFF simultaneously.

For a 16-bit device (128 Kbytes), EBI mapped this 128 Kbytes device to 0x6000_0000 ~ 0x6001_FFFF.

6.5.4.2 EBI Data Width Connection

The EBI controller supports to connect the external device whose address bus and data bus are multiplexed. For the external device with separated address and data bus, the connection to device needs additional logic (latch device) to latch the address. In this case, pin ALE is connected to the latch device to latch the address value. Pins AD0~AD15 for 16-bit data width / Pins AD0~AD7 for 8-bit data width are the input pins of the latch device, and the output pins of the latch device are connected to the Addr[15:0] of external device.

For 16-bit device, the AD [15:0] shared by address (Addr [15:0]) and 16-bit data (Data [15:0]). For 8-bit device, only AD [7:0] shared by address (Addr [7:0]) and 8-bit data (Data [7:0]), AD [15:8] is dedicated for address (Addr [15:8]) and could be connected to 8-bit device directly.

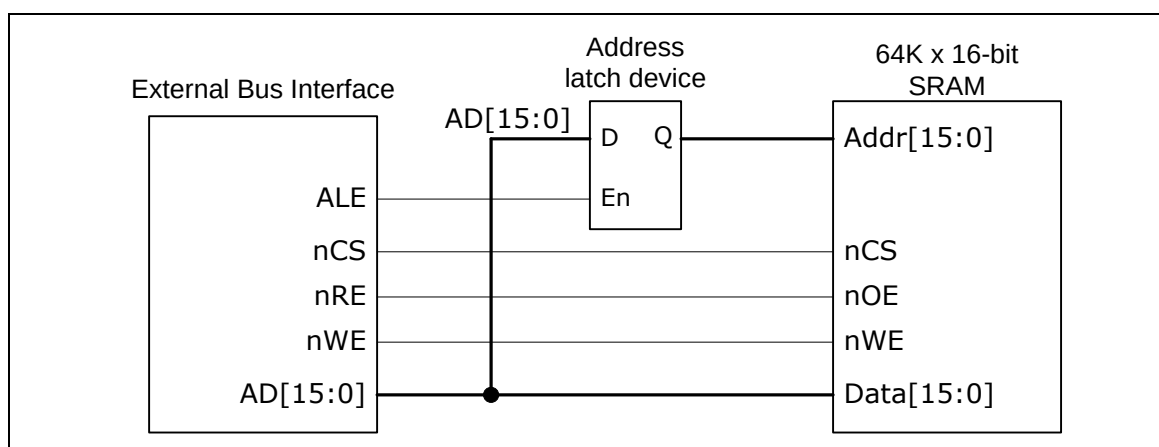


Figure 6-17 Connection of 16-bit EBI Data Width with 16-bit Device

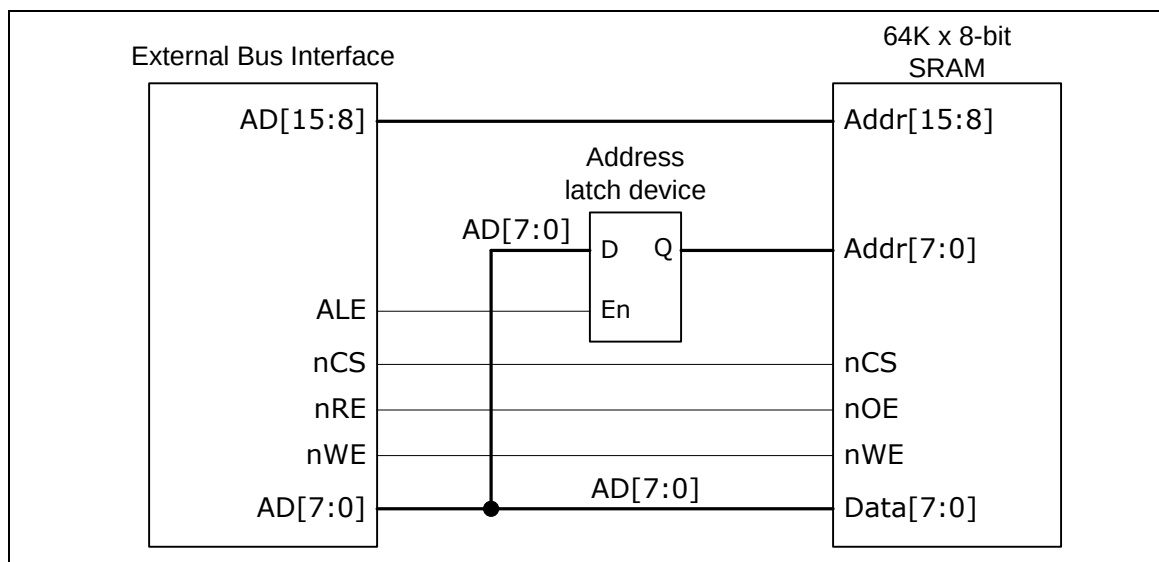


Figure 6-18 Connection of 8-bit EBI Data Width with 8-bit Device

When the system access data width is larger than EBI data width (8-bit / 16 bit data width), the EBI controller will finish a system access command by operating EBI access more than once. For example, if system requests a 32-bit data through EBI device, the EBI controller will operate accessing four times when setting EBI data width with 8-bit data width.

6.5.4.3 EBI Operating Control

MCLK Control

In the chip, all EBI signals will be synchronized by MCLK when EBI is operating. When the chip connects to the external device with slower operating frequency, the MCLK can divide most to 32 from HCLK by setting MCLKDIV[2:0] (EBICON [10:8] External Output Clock Divider). Therefore, the EBI controller is suitable for a wide frequency range of EBI device. If MCLK frequency is setting as HCLK/1, EBI signals are synchronized by positive edge of MCLK, else by negative edge of MCLK.

Operation and Access Timing Control

In the start of EBI access, chip select signal (nCS) asserts to low and waits one MCLK for address setup time (tASU) for address stable. Then ALE signal asserts to high after address is stable and keeps for a period of time (tALE) for latch address. After latch address, ALE signal asserts to low and wait one MCLK for address latch hold time (tLHD) and another one MCLK cycle (tA2D) that is inserted behind address latch hold time (tLHD) to be the bus turn-around time for address change to data. Then nRD signal asserts to low when read access or nWR signal asserts to low when write access. Then nRD or nWR signal asserts to high after keeps access time (tACC) for reading output stable or writing finish. After that, EBI signals keep for data access hold time (tAHD) and chip select signal (nCS) asserts to high then address is released by current access control.

The EBI controller provides a flexible timing control for different external devices. In EBI timing control, tASU, tLHD and tA2D are all fixed to 1 MCLK cycle, tAHD can modulate to 1~8 MCLK cycles by setting ExttAHD[2:0] (EXTIME [10:8] EBI Data Access Hold Time), tACC can modulate to 1~32 MCLK cycles by setting ExttACC[4:0] (EXTIME [7:3] EBI Data Access Time), and tALE can modulate to 1~8 MCLK cycles by setting ExttALE [2:0] (EBICON [18:16] Expand Time of ALE).

Parameter	Value	Unit	Description
tASU	1	MCLK	Address Latch Setup Time.
tALE	1 ~ 8	MCLK	ALE High Period. Controlled by ExttALE[2:0] of EBICON[18:16].
tLHD	1	MCLK	Address Latch Hold Time.
tA2D	1	MCLK	Address To Data Delay (Bus Turn-Around Time).
tACC	1 ~ 32	MCLK	Data Access Time. Controlled by ExttACC[4:0] of EXTIME[7:3].
tAHD	1 ~ 8	MCLK	Data Access Hold Time. Controlled by ExttAHD[2:0] of EXTIME[10:8].
IDLE	0 ~ 15	MCLK	Idle Cycle. Controlled by ExttR2R[3:0] of EXTIME[27:24] and ExttW2X[3:0] of EXTIME[15:12].

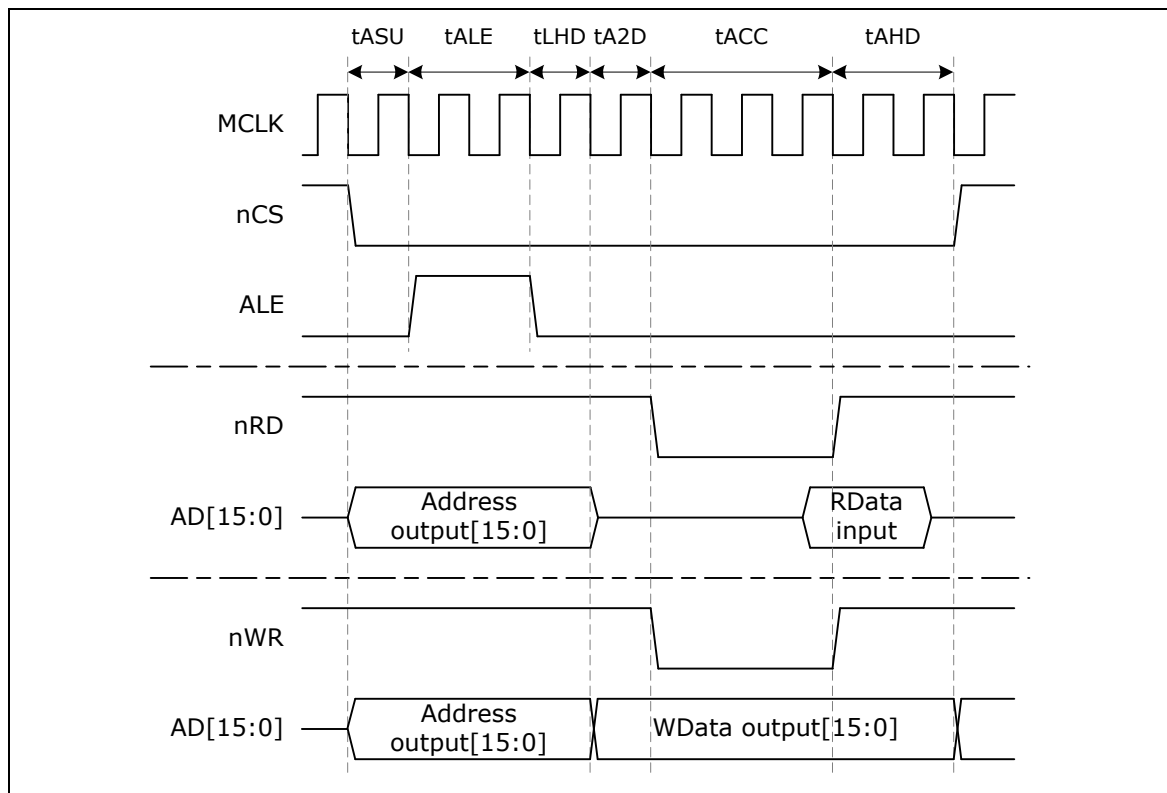


Figure 6-19 Timing Control Waveform for 16-bit Data Width

The figure above shows an example of setting 16-bit data width for EBI application. In this example, AD0~AD15 are used to be address[15:0] and data[15:0]. When ALE signal asserts to high, AD0~AD15 are the address output. After address is latched (tLHD), ALE signal asserts to low and the AD bus changes to high impedance to wait device output data in read access operation, or it is used to be write data output.

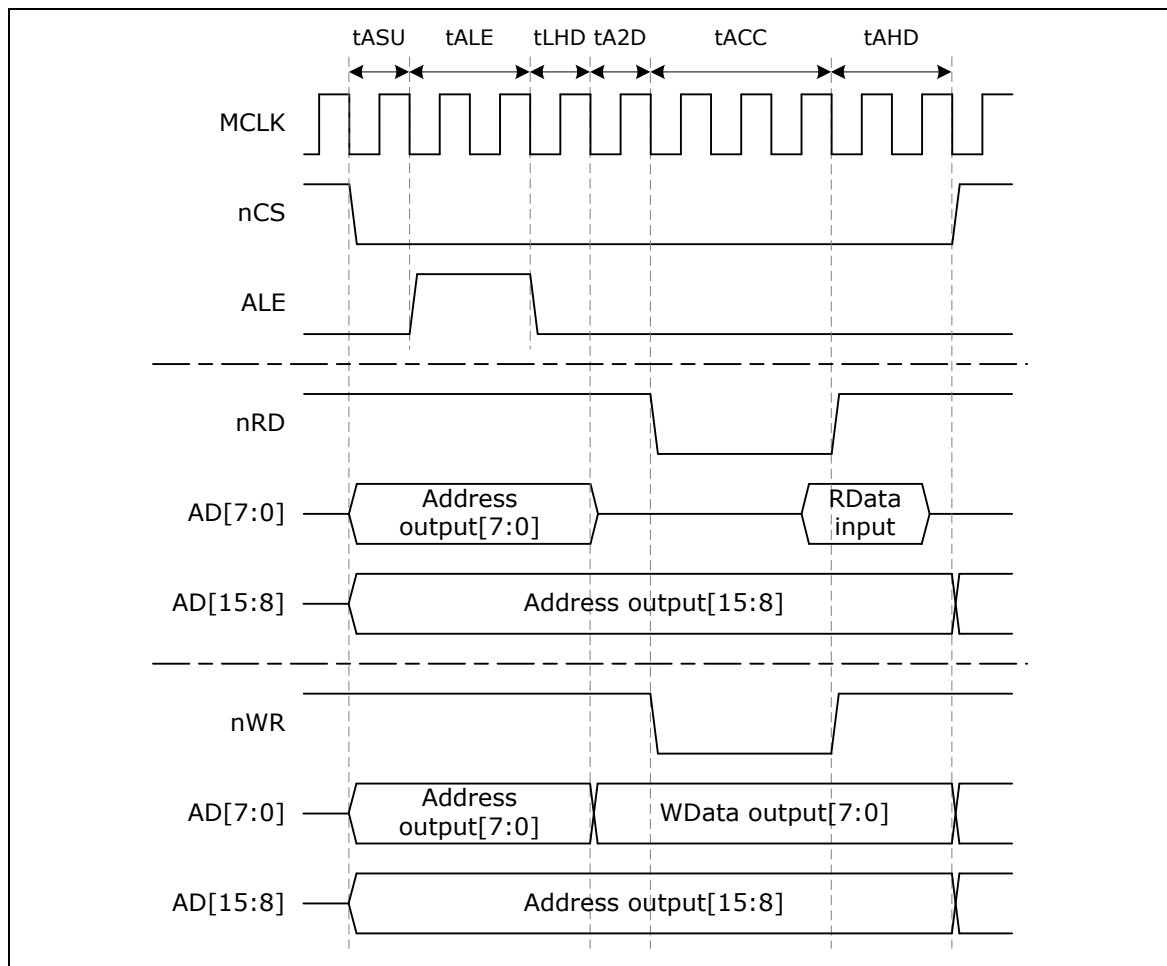


Figure 6-20 Timing Control Waveform for 8-bit Data Width

The figure above shows an example of setting 8-bit data width for EBI application. The difference between 8-bit and 16-bit data width is AD8~AD15. In 8-bit data width setting, and AD8~AD15 are always the Address[15:8] output so that the external latch needs only 8-bit width.

Insert Idle Cycle

When EBI is accessing continuously, bus conflict may occur if the device access time is much longer compared with system clock frequency. The EBI controller supplies additional idle cycle to solve this problem. During idle cycle period, all control signals of EBI bus are inactive. The following figure shows idle cycle.

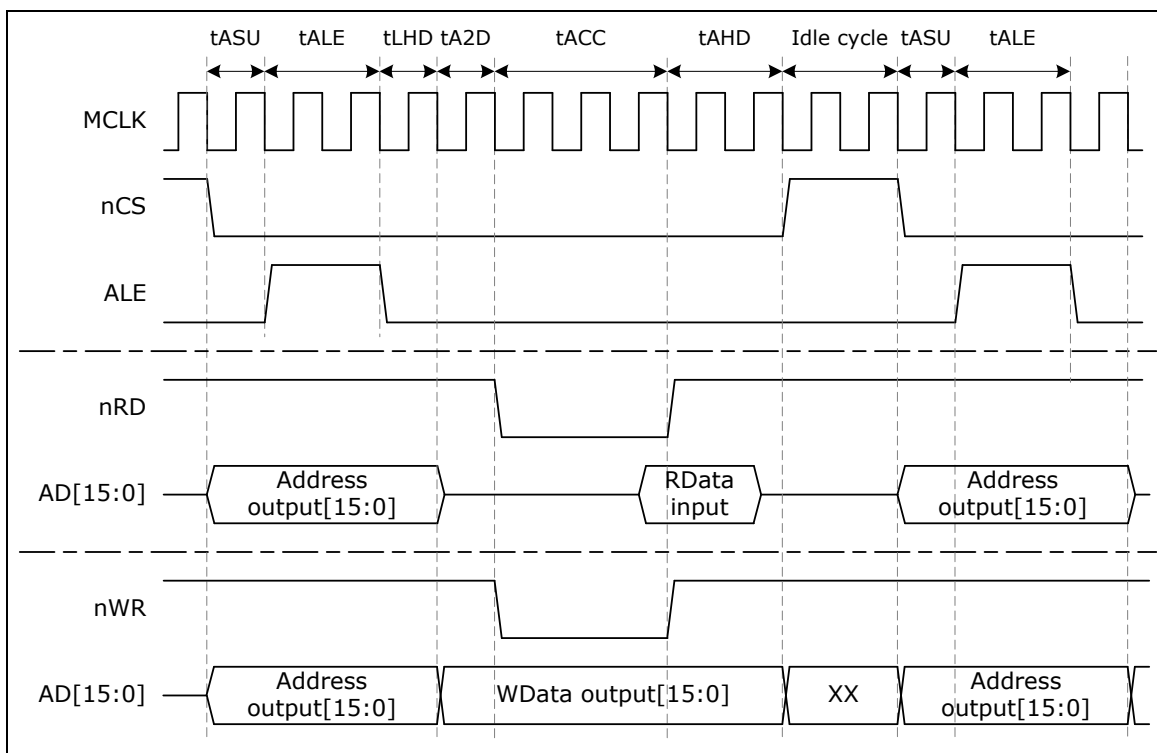


Figure 6-21 Timing Control Waveform for Insert Idle Cycle

There are two conditions that EBI can insert idle cycle by timing control:

1. After write access
2. After read access and before the next read access

By setting ExtIW2X[3:0] of EXTTIME [15:12] and ExtIR2R[3:0] of the register EXTTIME[27:24], the time of idle cycle can be specified from 0~15 MCLK.

6.5.5 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
EBI Base Address: EBI_BA = 0x5001_0000				
EBICON	EBI_BA+0x00	R/W	External Bus Interface General Control Register	0x0000_0000
EXTIME	EBI_BA+0x04	R/W	External Bus Interface Timing Control Register	0x0000_0000
EBICON2	EBI_BA+0x08	R/W	External Bus Interface General Control Register 2	0x0000_0000

6.5.6 Register Description

6.5.6.1.1

External Bus Interface General Control Register (EBICON)

Register	Offset	R/W	Description	Reset Value
EBICON	EBI_BA+0x00	R/W	External Bus Interface General Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved				ExttALE			
15	14	13	12	11	10	9	8
Reserved				MCLKDIV			
7	6	5	4	3	2	1	0
Reserved						ExtBW16	ExtEN

Bits	Description																	
[31:19]	Reserved	Reserved																
[18:16]	ExttALE	Expand Time of ALE This field is used for control the ALE pulse width (tALE) for latch the address $tALE = (ExttALE+1)*MCLK$																
[15:11]	Reserved	Reserved																
[10:8]	MCLKDIV	External Output Clock Divider The frequency of EBI output clock (MCLK) is controlled by MCLKDIV as follows table: <table><tr><th>MCLKDIV</th><th>Output Clock (MCLK)</th></tr><tr><td>000</td><td>HCLK/1</td></tr><tr><td>001</td><td>HCLK/2</td></tr><tr><td>010</td><td>HCLK/4</td></tr><tr><td>011</td><td>HCLK/8</td></tr><tr><td>100</td><td>HCLK/16</td></tr><tr><td>101</td><td>HCLK/32</td></tr><tr><td>Others</td><td>default</td></tr></table>	MCLKDIV	Output Clock (MCLK)	000	HCLK/1	001	HCLK/2	010	HCLK/4	011	HCLK/8	100	HCLK/16	101	HCLK/32	Others	default
		MCLKDIV	Output Clock (MCLK)															
		000	HCLK/1															
		001	HCLK/2															
		010	HCLK/4															
		011	HCLK/8															
		100	HCLK/16															
		101	HCLK/32															
		Others	default															
Note: Default value of output clock is HCLK/1																		
[7:2]	Reserved	Reserved																
[1]	ExtBW16	EBI Data Width 16-bit/8-bit This bit defines if the data bus is 8-bit or 16-bit. 1 = EBI data width is 16-bit 0 = EBI data width is 8-bit																

[0]	ExtEN	EBI Enable This bit is the functional enable bit for EBI. 1 = EBI function Enabled 0 = EBI function Disabled

6.5.6.1.2

External Bus Interface Timing Control Register (EXTIME)

Register	Offset	R/W	Description	Reset Value
EXTIME	EBI_BA+0x04	R/W	External Bus Interface Timing Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved				ExtIR2R			
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
ExtIW2X				Reserved	ExttAHD		
7	6	5	4	3	2	1	0
ExttACC					Reserved		

Bits	Description	
[31:28]	Reserved	Reserved
[27:24]	ExtIR2R	Idle State Cycle Between Read-Read When read action is finished and the next action is going to read, idle state is inserted and nCS signal return to high if ExtIR2R is not zero. Idle state cycle = (ExtIR2R*MCLK)
[23:16]	Reserved	Reserved
[15:12]	ExtIW2X	Idle State Cycle After Write When write action is finished, idle state is inserted and nCS signal return to high if ExtIW2X is not zero. Idle state cycle = (ExtIW2X*MCLK)
[11]	Reserved	Reserved
[10:8]	ExttAHD	EBI Data Access Hold Time ExttAHD defines data access hold time (tAHD). $tAHD = (ExttAHD + 1) * MCLK$
[7:3]	ExttACC	EBI Data Access Time ExttACC defines data access time (tACC). $tACC = (ExttACC + 1) * MCLK$
[2:0]	Reserved	Reserved

6.5.6.1.3

External Bus Interface Control Register 2 (EBICON2)

Register	Offset	R/W	Description	Reset Value
EBICON2	EBI_CTL_BA+0x08	R/W	External Bus Interface General Control Register 2	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					WAHD_OFF	RAHD_OFF	WBUF_EN

Bits	Description	
[31:3]	Reserved	Reserved
[2]	WAHD_OFF	Access Hold Time Disable Control When Write 0 = tAHD is controlled by ExttAHD when write through EBI 1 = No tAHD when write through EBI
[1]	RAHD_OFF	Access Hold Time Disable Control When Read 0 = tAHD is controlled by ExttAHD when read through EBI 1 = No tAHD when read through EBI
[0]	WBUF_EN	EBI Write Buffer Enable 0 = EBI write buffer disable 1 = EBI write buffer enable

6.6 General Purpose I/O (GPIO)

6.6.1 Overview

The NuMicro™ NUC230/240 series has up to 84 General Purpose I/O pins to be shared with other function pins depending on the chip configuration. These 84 pins are arranged in 6 ports named as GPIOA, GPIOB, GPIOC, GPIOD, GPIOE and GPIOF. The GPIOA/B/C/D/E port has the maximum of 16 pins and GPIOF port has the maximum of 4 pins. Each of the 84 pins is independent and has the corresponding register bits to control the pin mode function and data.

The I/O type of each of I/O pins can be configured by software individually as input, output, open-drain or Quasi-bidirectional mode. After reset, the I/O mode of all pins are depending on Config0[10] setting. In Quasi-bidirectional mode, I/O pin has a very weak individual pull-up resistor which is about 110~300 K Ω for V_{DD} is from 5.0 V to 2.5 V.

6.6.2 Features

- Four I/O modes:
 - Quasi-bidirectional
 - Push-Pull output
 - Open-Drain output
 - Input only with high impedance
- TTL/Schmitt trigger input selectable by GPx_TYPE[15:0] in GPx_MFP[31:16]
- I/O pin configured as interrupt source with edge/level setting
- Configurable default I/O mode of all pins after reset by Config0[10] setting
 - If Config[10] is 0, all GPIO pins in input tri-state mode after chip reset
 - If Config[10] is 1, all GPIO pins in Quasi-bidirectional mode after chip reset
- I/O pin internal pull-up resistor enabled only in Quasi-bidirectional I/O mode
- Enabling the pin interrupt function will also enable the pin wake-up function.

6.6.3 Basic Configuration

The GPIO pin functions are configured in GPA_MFP, GPB_MFP, GPC_MFP, GPD_MFP, GPE_MFP, ALT_MFP, ALT_MFP1 and ALT_MFP2 registers.

6.6.4 Functional Description

6.6.4.1 Input Mode Explanation

Set GPIOx_PMD (PMDn[1:0]) to 00b as the GPIOx port [n] pin is in Input mode and the I/O pin is in tri-state (high impedance) without output drive capability. The GPIOx_PIN value reflects the status of the corresponding port pins.

6.6.4.2 Push-pull Output Mode Explanation

Set GPIOx_PMD (PMDn[1:0]) to 01b as the GPIOx port [n] pin is in Push-pull Output mode and the I/O pin supports digital output function with source/sink current capability. The bit value in the corresponding bit [n] of GPIOx_DOUT is driven on the pin.

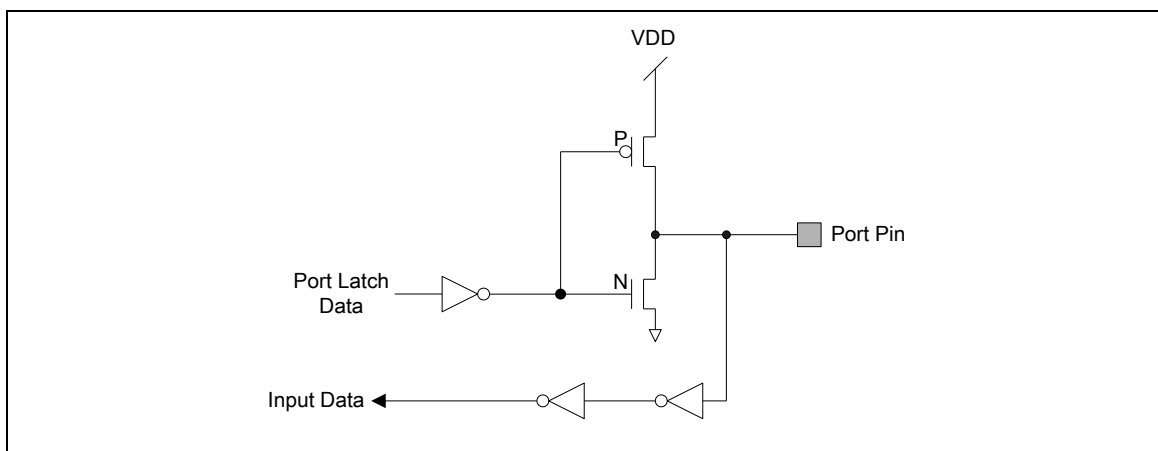


Figure 6-22 Push-Pull Output

6.6.4.3 Open-drain Output Mode Explanation

Set GPIOx_PMD (PMDn[1:0]) to 10b as the GPIOx port [n] pin is in Open-drain mode and the digital output function of I/O pin supports only sink current capability, an additional pull-up resistor is needed for driving high state. If the bit value in the corresponding bit [n] of GPIOx_DOUT is 0, the pin drive a “low” output on the pin. If the bit value in the corresponding bit [n] of GPIOx_DOUT is 1, the pin output drives high that is controlled by external pull-up resistor.

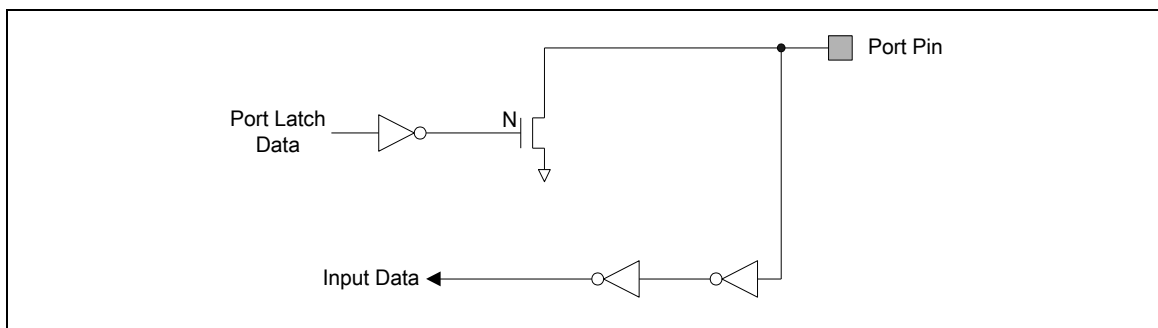


Figure 6-23 Open-Drain Output

6.6.4.4 Quasi-bidirectional Mode Explanation

Set GPIOx_PMD (PMDn[1:0]) to 11b as the GPIOx port [n] pin is in Quasi-bidirectional mode and the I/O pin supports digital output and input function at the same time but the source current is only up to hundreds of μA . Before the digital input function is performed the corresponding bit in GPIOx_DOUT must be set to 1. The Quasi-bidirectional output is common on the 80C51 and most of its derivatives. If the bit value in the corresponding bit [n] of GPIOx_DOUT is 0, the pin drive a “low” output on the pin. If the bit value in the corresponding bit [n] of GPIOx_DOUT is 1, the pin will check the pin value. If pin value is high, no action takes. If pin state is low, then pin will drive strong high with 2 clock cycles on the pin and then disable the strong output drive and then the pin status is control by internal pull-up resistor. Note that the source current capability in Quasi-bidirectional mode is only about 200 μA to 30 μA for V_{DD} is form 5.0 V to 2.5 V.

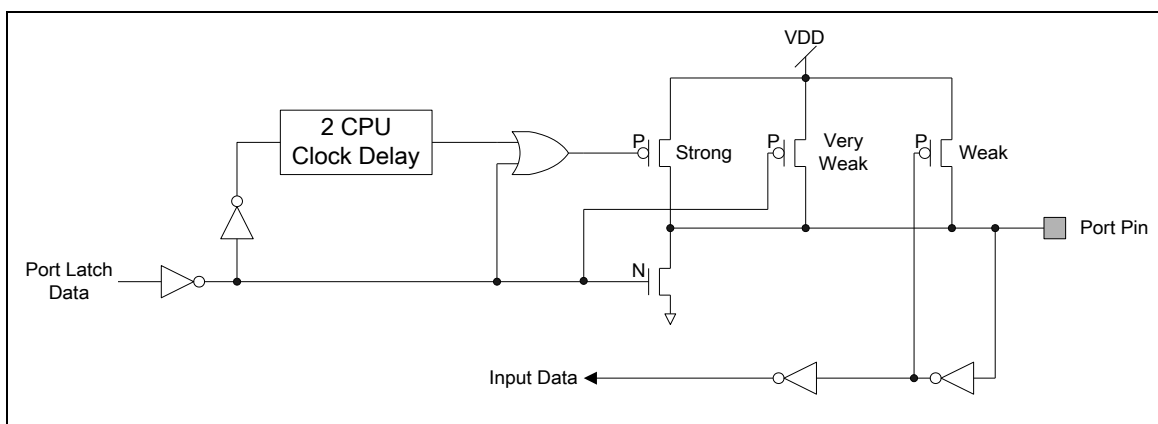


Figure 6-24 Quasi-bidirectional I/O Mode

6.6.4.5 GPIO Interrupt and Wake-up Function

Each GPIO pin can be set as chip interrupt source by setting correlative GPIOx_IEN bit and GPIOx_IMD. There are four types of interrupt condition can be selected: low level trigger, high level trigger, falling edge trigger and rising edge trigger. For edge trigger condition, user can enable input signal de-bounce function to prevent unexpected interrupt happened which caused by noise. The de-bounce clock source and sampling cycle can be set through DEBOUNCE register.

The GPIO can also be the chip wake-up source when chip enters Idle mode or Power-down mode. The setting of wake-up trigger condition is the same as GPIO interrupt trigger, but there is one thing need to be noticed if using GPIO as chip wake-up source

- **To ensure the I/O status before enter into Power-down mode**

When using toggle GPIO to wake-up system, user must make sure the I/O status before entering Idle mode or Power-down mode according to the relative wake-up settings.

For example, if configuring the wake-up event occurred by I/O rising edge/high level trigger, user must make sure the I/O status of specified pin is at low level before entering to Idle/Power-down mode; and if configure I/O falling edge/low level trigger to trigger a wake-up event, user must make sure the I/O status of specified pin is at high level before entering to Power-down mode.

6.6.5 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
GPIO Base Address: GPIO_BA = 0x5000_4000				
GPIOA_PMD	GPIO_BA+0x000	R/W	GPIO Port A Pin I/O Mode Control	0xFFFF_XXXX
GPIOA_OFFD	GPIO_BA+0x004	R/W	GPIO Port A Pin Digital Input Path Disable Control	0x0000_0000
GPIOA_DOUT	GPIO_BA+0x008	R/W	GPIO Port A Data Output Value	0x0000_FFFF
GPIOA_DMASK	GPIO_BA+0x00C	R/W	GPIO Port A Data Output Write Mask	0x0000_0000
GPIOA_PIN	GPIO_BA+0x010	R	GPIO Port A Pin Value	0x0000_XXXX
GPIOA_DBEN	GPIO_BA+0x014	R/W	GPIO Port A De-bounce Enable	0x0000_0000
GPIOA_IMD	GPIO_BA+0x018	R/W	GPIO Port A Interrupt Mode Control	0x0000_0000
GPIOA_IEN	GPIO_BA+0x01C	R/W	GPIO Port A Interrupt Enable	0x0000_0000
GPIOA_ISRC	GPIO_BA+0x020	R/W	GPIO Port A Interrupt Source Flag	0x0000_0000
GPIOB_PMD	GPIO_BA+0x040	R/W	GPIO Port B Pin I/O Mode Control	0xFFFF_XXXX
GPIOB_OFFD	GPIO_BA+0x044	R/W	GPIO Port B Pin Digital Input Path Disable Control	0x0000_0000
GPIOB_DOUT	GPIO_BA+0x048	R/W	GPIO Port B Data Output Value	0x0000_FFFF
GPIOB_DMASK	GPIO_BA+0x04C	R/W	GPIO Port B Data Output Write Mask	0x0000_0000
GPIOB_PIN	GPIO_BA+0x050	R	GPIO Port B Pin Value	0x0000_XXXX
GPIOB_DBEN	GPIO_BA+0x054	R/W	GPIO Port B De-bounce Enable	0x0000_0000
GPIOB_IMD	GPIO_BA+0x058	R/W	GPIO Port B Interrupt Mode Control	0x0000_0000
GPIOB_IEN	GPIO_BA+0x05C	R/W	GPIO Port B Interrupt Enable	0x0000_0000
GPIOB_ISRC	GPIO_BA+0x060	R/W	GPIO Port B Interrupt Source Flag	0x0000_0000
GPIOC_PMD	GPIO_BA+0x080	R/W	GPIO Port C Pin I/O Mode Control	0xFFFF_XXXX
GPIOC_OFFD	GPIO_BA+0x084	R/W	GPIO Port C Pin Digital Input Path Disable Control	0x0000_0000
GPIOC_DOUT	GPIO_BA+0x088	R/W	GPIO Port C Data Output Value	0x0000_FFFF
GPIOC_DMASK	GPIO_BA+0x08C	R/W	GPIO Port C Data Output Write Mask	0x0000_0000
GPIOC_PIN	GPIO_BA+0x090	R	GPIO Port C Pin Value	0x0000_XXXX
GPIOC_DBEN	GPIO_BA+0x094	R/W	GPIO Port C De-bounce Enable	0x0000_0000
GPIOC_IMD	GPIO_BA+0x098	R/W	GPIO Port C Interrupt Mode Control	0x0000_0000
GPIOC_IEN	GPIO_BA+0x09C	R/W	GPIO Port C Interrupt Enable	0x0000_0000

Register	Offset	R/W	Description	Reset Value
GPIOC_ISRC	GPIO_BA+0x0A0	R/W	GPIO Port C Interrupt Source Flag	0x0000_0000
GPIOD_PMD	GPIO_BA+0x0C0	R/W	GPIO Port D Pin I/O Mode Control	0xFFFF_XXXX
GPIOD_OFFD	GPIO_BA+0x0C4	R/W	GPIO Port D Pin Digital Input Path Disable Control	0x0000_0000
GPIOD_DOUT	GPIO_BA+0x0C8	R/W	GPIO Port D Data Output Value	0x0000_FFFF
GPIOD_DMASK	GPIO_BA+0x0CC	R/W	GPIO Port D Data Output Write Mask	0x0000_0000
GPIOD_PIN	GPIO_BA+0x0D0	R	GPIO Port D Pin Value	0x0000_XXXX
GPIOD_DBEN	GPIO_BA+0x0D4	R/W	GPIO Port D De-bounce Enable	0x0000_0000
GPIOD_IMD	GPIO_BA+0x0D8	R/W	GPIO Port D Interrupt Mode Control	0x0000_0000
GPIOD_IEN	GPIO_BA+0x0DC	R/W	GPIO Port D Interrupt Enable	0x0000_0000
GPIOE_ISRC	GPIO_BA+0x0E0	R/W	GPIO Port E Interrupt Source Flag	0x0000_0000
GPIOE_PMD	GPIO_BA+0x100	R/W	GPIO Port E Pin I/O Mode Control	0xFFFF_XXXX
GPIOE_OFFD	GPIO_BA+0x104	R/W	GPIO Port E Pin Digital Input Path Disable Control	0x0000_0000
GPIOE_DOUT	GPIO_BA+0x108	R/W	GPIO Port E Data Output Value	0x0000_FFFF
GPIOE_DMASK	GPIO_BA+0x10C	R/W	GPIO Port E Data Output Write Mask	0x0000_0000
GPIOE_PIN	GPIO_BA+0x110	R	GPIO Port E Pin Value	0x0000_XXXX
GPIOE_DBEN	GPIO_BA+0x114	R/W	GPIO Port E De-bounce Enable	0x0000_0000
GPIOE_IMD	GPIO_BA+0x118	R/W	GPIO Port E Interrupt Mode Control	0x0000_0000
GPIOE_IEN	GPIO_BA+0x11C	R/W	GPIO Port E Interrupt Enable	0x0000_0000
GPIOE_ISRC	GPIO_BA+0x120	R/W	GPIO Port E Interrupt Source Flag	0x0000_0000
GPIOF_PMD	GPIO_BA+0x140	R/W	GPIO Port F Pin I/O Mode Control	0x0000_00XX
GPIOF_OFFD	GPIO_BA+0x144	R/W	GPIO Port F Pin Digital Input Path Disable Control	0x0000_0000
GPIOF_DOUT	GPIO_BA+0x148	R/W	GPIO Port F Data Output Value	0x0000_000F
GPIOF_DMASK	GPIO_BA+0x14C	R/W	GPIO Port F Data Output Write Mask	0x0000_0000
GPIOF_PIN	GPIO_BA+0x150	R	GPIO Port F Pin Value	0x0000_000X
GPIOF_DBEN	GPIO_BA+0x154	R/W	GPIO Port F De-bounce Enable	0x0000_0000
GPIOF_IMD	GPIO_BA+0x158	R/W	GPIO Port F Interrupt Mode Control	0x0000_0000
GPIOF_IEN	GPIO_BA+0x15C	R/W	GPIO Port F Interrupt Enable	0x0000_0000
GPIOF_ISRC	GPIO_BA+0x160	R/W	GPIO Port F Interrupt Source Flag	0x0000_0000
DBNCECON	GPIO_BA+0x180	R/W	External Interrupt De-bounce Control	0x0000_0020
PAn_PDIO	GPIO_BA+0x200	R/W	GPIO PA.n Pin Data Input/Output	0x0000_000X

Register	Offset	R/W	Description	Reset Value
n=0,1..15	+ 0x04 * n			
PBn_PDIO n=0,1..15	GPIO_BA+0x240 + 0x04 * n	R/W	GPIO PB.n Pin Data Input/Output	0x0000_000X
PCn_PDIO n=0,1..15	GPIO_BA+0x280 + 0x04 * n	R/W	GPIO PC.n Pin Data Input/Output	0x0000_000X
PDn_PDIO n=0,1..15	GPIO_BA+0x2C0 + 0x04 * n	R/W	GPIO PD.n Pin Data Input/Output	0x0000_000X
PEn_PDIO n=0,1..15	GPIO_BA+0x300 + 0x04 * n	R/W	GPIO PE.n Pin Data Input/Output	0x0000_000X
PFn_PDIO n=0,1..3	GPIO_BA+0x340 + 0x04 * n	R/W	GPIO PF.n Pin Data Input/Output	0x0000_000X

6.6.6 Register Description

GPIO Port [A/B/C/D/E/F] Pin I/O Mode Control (GPIOx_PMD)

Register	Offset	R/W	Description	Reset Value
GPIOA_PMD	GPIO_BA+0x000	R/W	GPIO Port A Pin I/O Mode Control	0xFFFF_XXXX
GPIOB_PMD	GPIO_BA+0x040	R/W	GPIO Port B Pin I/O Mode Control	0xFFFF_XXXX
GPIOC_PMD	GPIO_BA+0x080	R/W	GPIO Port C Pin I/O Mode Control	0xFFFF_XXXX
GIOD_PMD	GPIO_BA+0x0C0	R/W	GPIO Port D Pin I/O Mode Control	0xFFFF_XXXX
GPIOE_PMD	GPIO_BA+0x100	R/W	GPIO Port E Pin I/O Mode Control	0xFFFF_XXXX
GPIOF_PMD	GPIO_BA+0x140	R/W	GPIO Port F Pin I/O Mode Control	0x0000_00XX

31	30	29	28	27	26	25	24
PMD15		PMD14		PMD13		PMD12	
23	22	21	20	19	18	17	16
PMD11		PMD10		PMD9		PMD8	
15	14	13	12	11	10	9	8
PMD7		PMD6		PMD5		PMD4	
7	6	5	4	3	2	1	0
PMD3		PMD2		PMD1		PMD0	

Bits	Description
[2n+1:2n] n=0,1...15	PMDn GPIOx I/O Pin[N] Mode Control Determine each I/O mode of GPIOx pins. 00 = GPIO port [n] pin is in Input mode. 01 = GPIO port [n] pin is in Push-pull Output mode. 10 = GPIO port [n] pin is in Open-drain Output mode. 11 = GPIO port [n] pin is in Quasi-bidirectional mode. Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE. The initial value of this field is defined by CIOINI (CONFIG0[10]). If CIOINI is set to 1, the default value is 0xFFFF_FFFF and all pins will be Quasi-bidirectional mode after chip is powered on. If CIOINI is cleared to 0, the default value is 0x0000_0000 and all pins will be input only mode after chip is powered on.

GPIO Port [A/B/C/D/E/F] Pin Digital Input Path Disable Register (GPIOx_OFFD)

Register	Offset	R/W	Description	Reset Value
GPIOA_OFFD	GPIO_BA+0x004	R/W	GPIO Port A Pin Digital Input Path Disable Register	0x0000_0000
GPIOB_OFFD	GPIO_BA+0x044	R/W	GPIO Port B Pin Digital Input Path Disable Register	0x0000_0000
GPIOC_OFFD	GPIO_BA+0x084	R/W	GPIO Port C Pin Digital Input Path Disable Register	0x0000_0000
GIOD_OFFD	GPIO_BA+0x0C4	R/W	GPIO Port D Pin Digital Input Path Disable Register	0x0000_0000
GPIOE_OFFD	GPIO_BA+0x104	R/W	GPIO Port E Pin Digital Input Path Disable Register	0x0000_0000
GPIOF_OFFD	GPIO_BA+0x144	R/W	GPIO Port F Pin Digital Input Path Disable Register	0x0000_0000

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

Bits	Description
[31:16]	OFFD GPIOx Pin[N] Digital Input Path Disable Bit Each of these bits is used to control if the digital input path of corresponding GPIO pin is disabled. If input is analog signal, users can disable GPIO digital input path to avoid current leakage. 0 = I/O digital input path Enabled. 1 = I/O digital input path Disabled (digital input tied to low). Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE.
[15:0]	Reserved Reserved.

GPIO Port [A/B/C/D/E/F] Data Output Value (GPIOx_DOUT)

Register	Offset	R/W	Description	Reset Value
GPIOA_DOUT	GPIO_BA+0x008	R/W	GPIO Port A Data Output Value	0x0000_FFFF
GPIOB_DOUT	GPIO_BA+0x048	R/W	GPIO Port B Data Output Value	0x0000_FFFF
GPIOC_DOUT	GPIO_BA+0x088	R/W	GPIO Port C Data Output Value	0x0000_FFFF
GIOD_DOUT	GPIO_BA+0x0C8	R/W	GPIO Port D Data Output Value	0x0000_FFFF
GPIOE_DOUT	GPIO_BA+0x108	R/W	GPIO Port E Data Output Value	0x0000_FFFF
GPIOF_DOUT	GPIO_BA+0x148	R/W	GPIO Port F Data Output Value	0x0000_000F

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
DOUT[15:8]							
7	6	5	4	3	2	1	0
DOUT[7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[n] n = 0,1..15	DOUT[n]	GPIOx Pin[N] Output Value Each of these bits controls the status of a GPIO pin when the GPIO pin is configured as Push-pull output, open-drain output or quasi-bidirectional mode. 0 = GPIO port [A/B/C/D/E/F] Pin[n] will drive Low if the GPIO pin is configured as Push-pull output, Open-drain output or Quasi-bidirectional mode. 1 = GPIO port [A/B/C/D/E/F] Pin[n] will drive High if the GPIO pin is configured as Push-pull output or Quasi-bidirectional mode. Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE.

GPIO Port [A/B/C/D/E/F] Data Output Write Mask (GPIOx_DMASK)

Register	Offset	R/W	Description	Reset Value
GPIOA_DMASK	GPIO_BA+0x00C	R/W	GPIO Port A Data Output Write Mask	0x0000_0000
GPIOB_DMASK	GPIO_BA+0x04C	R/W	GPIO Port B Data Output Write Mask	0x0000_0000
GPIOC_DMASK	GPIO_BA+0x08C	R/W	GPIO Port C Data Output Write Mask	0x0000_0000
GIOD_DMASK	GPIO_BA+0x0CC	R/W	GPIO Port D Data Output Write Mask	0x0000_0000
GPIOE_DMASK	GPIO_BA+0x10C	R/W	GPIO Port E Data Output Write Mask	0x0000_0000
GPIOF_DMASK	GPIO_BA+0x14C	R/W	GPIO Port F Data Output Write Mask	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
DMASK[15:8]							
7	6	5	4	3	2	1	0
DMASK[7:0]							

Bits	Description
[31:16]	Reserved Reserved.
[n] n = 0,1..15	Port [A/B/C/D/E/F] Data Output Write Mask These bits are used to protect the corresponding register of GPIOx_DOUT[n] bit. When the DMASK[n] bit is set to 1, the corresponding GPIOx_DOUT[n] bit is protected. If the write signal is masked, write data to the protect bit is ignored 0 = Corresponding GPIOx_DOUT[n] bit can be updated. 1 = Corresponding GPIOx_DOUT[n] bit protected. Note: This function only protects the corresponding GPIOx_DOUT[n] bit, and will not protect the corresponding bit control register (PAn_PDIO, PBn_PDIO, PCn_PDIO, PDn_PDIO, PEn_PDIO and PFn_PDIO). Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE.

GPIO Port [A/B/C/D/E/F] Pin Value (GPIOx_PIN)

Register	Offset	R/W	Description	Reset Value
GPIOA_PIN	GPIO_BA+0x010	R	GPIO Port A Pin Value	0x0000_XXXX
GPIOB_PIN	GPIO_BA+0x050	R	GPIO Port B Pin Value	0x0000_XXXX
GPIOC_PIN	GPIO_BA+0x090	R	GPIO Port C Pin Value	0x0000_XXXX
GIOD_PIN	GPIO_BA+0x0D0	R	GPIO Port D Pin Value	0x0000_XXXX
GPIOE_PIN	GPIO_BA+0x110	R	GPIO Port E Pin Value	0x0000_XXXX
GPIOF_PIN	GPIO_BA+0x150	R	GPIO Port F Pin Value	0x0000_000X

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
PIN[15:8]							
7	6	5	4	3	2	1	0
PIN[7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[n] n = 0,1..15	PIN[n]	Port [A/B/C/D/E/F] Pin Values Each bit of the register reflects the actual status of the respective GPIO pin. If the bit is 1, it indicates the corresponding pin status is high, else the pin status is low Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE.

GPIO Port [A/B/C/D/E/F] De-bounce Enable Register (GPIOx_DBEN)

Register	Offset	R/W	Description	Reset Value
GPIOA_DBEN	GPIO_BA+0x014	R/W	GPIO Port A De-bounce Enable Register	0x0000_0000
GPIOB_DBEN	GPIO_BA+0x054	R/W	GPIO Port B De-bounce Enable Register	0x0000_0000
GPIOC_DBEN	GPIO_BA+0x094	R/W	GPIO Port C De-bounce Enable Register	0x0000_0000
GIOD_DBEN	GPIO_BA+0x0D4	R/W	GPIO Port D De-bounce Enable Register	0x0000_0000
GPIOE_DBEN	GPIO_BA+0x114	R/W	GPIO Port E De-bounce Enable Register	0x0000_0000
GPIOF_DBEN	GPIO_BA+0x154	R/W	GPIO Port F De-bounce Enable Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
DBEN[15:8]							
7	6	5	4	3	2	1	0
DBEN[7:0]							

Bits	Description
[31:16]	Reserved Reserved.
[n] n = 0,1..15	Port [A/B/C/D/E/F] Input Signal De-Bounce Enable Bit DBEN[n] is used to enable the de-bounce function for each corresponding bit. If the input signal pulse width cannot be sampled by continuous two de-bounce sample cycle, the input signal transition is seen as the signal bounce and will not trigger the interrupt. The de-bounce clock source is controlled by DBNCECON[4], one de-bounce sample cycle period is controlled by DBNCECON[3:0] 0 = Bit[n] de-bounce function Disabled. 1 = Bit[n] de-bounce function Enabled. The de-bounce function is valid only for edge triggered interrupt. If the interrupt mode is level triggered, the de-bounce enable bit is ignored. Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE..

GPIO Port [A/B/C/D/E/F] Interrupt Mode Control (GPIOx_IMD)

Register	Offset	R/W	Description	Reset Value
GPIOA_IMD	GPIO_BA+0x018	R/W	GPIO Port A Interrupt Mode Control	0x0000_0000
GPIOB_IMD	GPIO_BA+0x058	R/W	GPIO Port B Interrupt Mode Control	0x0000_0000
GPIOC_IMD	GPIO_BA+0x098	R/W	GPIO Port C Interrupt Mode Control	0x0000_0000
GPIOD_IMD	GPIO_BA+0x0D8	R/W	GPIO Port D Interrupt Mode Control	0x0000_0000
GPIOE_IMD	GPIO_BA+0x118	R/W	GPIO Port E Interrupt Mode Control	0x0000_0000
GPIOF_IMD	GPIO_BA+0x158	R/W	GPIO Port F Interrupt Mode Control	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
IMD[15:8]							
7	6	5	4	3	2	1	0
IMD[7:0]							

Bits	Description
[31:16]	Reserved Reserved.
[n] n = 0,1..15	IMD[n] Port [A/B/C/D/E/F] Edge Or Level Detection Interrupt Control IMD[n] is used to control the interrupt is by level trigger or by edge trigger. If the interrupt is by edge trigger, the trigger source can be controlled by de-bounce. If the interrupt is by level trigger, the input source is sampled by one HCLK clock and generates the interrupt. 0 = Edge trigger interrupt. 1 = Level trigger interrupt. If the pin is set as the level trigger interrupt, only one level can be set on the registers GPIOx_IEN. If both levels to trigger interrupt are set, the setting is ignored and no interrupt will occur The de-bounce function is valid only for edge triggered interrupt. If the interrupt mode is level triggered, the de-bounce enable bit is ignored. Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE.

GPIO Port [A/B/C/D/E/F] Interrupt Enable Register (GPIOx_IEN)

Register	Offset	R/W	Description	Reset Value
GPIOA_IEN	GPIO_BA+0x01C	R/W	GPIO Port A Interrupt Enable Register	0x0000_0000
GPIOB_IEN	GPIO_BA+0x05C	R/W	GPIO Port B Interrupt Enable Register	0x0000_0000
GPIOC_IEN	GPIO_BA+0x09C	R/W	GPIO Port C Interrupt Enable Register	0x0000_0000
GIOD_IEN	GPIO_BA+0x0DC	R/W	GPIO Port D Interrupt Enable Register	0x0000_0000
GPIOE_IEN	GPIO_BA+0x11C	R/W	GPIO Port E Interrupt Enable Register	0x0000_0000
GPIOF_IEN	GPIO_BA+0x15C	R/W	GPIO Port F Interrupt Enable Register	0x0000_0000

31	30	29	28	27	26	25	24
IR_EN[15:8]							
23	22	21	20	19	18	17	16
IR_EN[7:0]							
15	14	13	12	11	10	9	8
IF_EN[15:8]							
7	6	5	4	3	2	1	0
IF_EN[7:0]							

Bits	Description
[n+16] n = 0,1..15	Port [A/B/C/D/E/F] Interrupt Enabled By Input Rising Edge Or Input Level High IR_EN[n] used to enable the interrupt for each of the corresponding input GPIO_PIN[n]. Set bit to 1 also enable the pin wake-up function When setting the IR_EN[n] bit to 1: If the interrupt is level trigger, the input PIN[n] state at level "high" will generate the interrupt. If the interrupt is edge trigger, the input PIN[n] state change from "low-to-high" will generate the interrupt. 0 = PIN[n] level-high or low-to-high interrupt Disabled. 1 = PIN[n] level-high or low-to-high interrupt Enabled. Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE.
[n] n = 0,1..15	Port [A/B/C/D/E/F] Interrupt Enabled By Input Falling Edge Or Input Level Low IF_EN[n] is used to enable the interrupt for each of the corresponding input GPIO_PIN[n]. Set bit to 1 also enable the pin wake-up function When setting the IF_EN[n] bit to 1: If the interrupt is level trigger, the input PIN[n] state at level "low" will generate the interrupt. If the interrupt is edge trigger, the input PIN[n] state change from "high-to-low" will generate the interrupt. 0 = PIN[n] state low-level or high-to-low change interrupt Disabled. 1 = PIN[n] state low-level or high-to-low change interrupt Enabled. Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE.

GPIO Port [A/B/C/D/E/F] Interrupt Source Flag (GPIOx_ISRC)

Register	Offset	R/W	Description	Reset Value
GPIOA_ISRC	GPIO_BA+0x020	R/W	GPIO Port A Interrupt Source Flag	0x0000_0000
GPIOB_ISRC	GPIO_BA+0x060	R/W	GPIO Port B Interrupt Source Flag	0x0000_0000
GPIOC_ISRC	GPIO_BA+0x0A0	R/W	GPIO Port C Interrupt Source Flag	0x0000_0000
GIOD_ISRC	GPIO_BA+0x0E0	R/W	GPIO Port D Interrupt Source Flag	0x0000_0000
GPIOE_ISRC	GPIO_BA+0x120	R/W	GPIO Port E Interrupt Source Flag	0x0000_0000
GPIOF_ISRC	GPIO_BA+0x160	R/W	GPIO Port F Interrupt Source Flag	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
ISRC[15:8]							
7	6	5	4	3	2	1	0
ISRC[7:0]							

Bits	Description
[31:16]	Reserved Reserved.
[n] n = 0,1..15	ISRC[n] Port [A/B/C/D/E/F] Interrupt Source Flag Read : 0 = No interrupt at GPIOx[n]. 1 = GPIOx[n] generates an interrupt. Write : 0= No action. 1= Clear the corresponding pending interrupt. Note: Max. n = 3 for GPIOF; Max. n = 15 for GPIOA/GPIOB/GPIOC/GPIOD/GPIOE.

Interrupt De-bounce Cycle Control (DBNCECON)

Register	Offset	R/W	Description	Reset Value
DBNCECON	GPIO_BA+0x180	R/W	External Interrupt De-bounce Control	0x0000_0020

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved		ICLK_ON	DBCLKSRC	DBCLKSEL			

Bits	Description																													
[5]	ICLK_ON	Interrupt Clock On Mode 0 = Edge detection circuit is active only if I/O pin corresponding GPIOx_IEN bit is set to 1. 1 = All I/O pins edge detection circuit is always active after reset. It is recommended to disable this bit to save system power if no special application concern.																												
[4]	DBCLKSRC	De-Bounce Counter Clock Source Selection 0 = De-bounce counter clock source is the HCLK. 1 = De-bounce counter clock source is the internal 10 kHz low speed oscillator.																												
[3:0]	DBCLKSEL	De-Bounce Sampling Cycle Selection <table><tr><th>DBCLKSEL</th><th>Description</th></tr><tr><td>0</td><td>Sample interrupt input once per 1 clocks</td></tr><tr><td>1</td><td>Sample interrupt input once per 2 clocks</td></tr><tr><td>2</td><td>Sample interrupt input once per 4 clocks</td></tr><tr><td>3</td><td>Sample interrupt input once per 8 clocks</td></tr><tr><td>4</td><td>Sample interrupt input once per 16 clocks</td></tr><tr><td>5</td><td>Sample interrupt input once per 32 clocks</td></tr><tr><td>6</td><td>Sample interrupt input once per 64 clocks</td></tr><tr><td>7</td><td>Sample interrupt input once per 128 clocks</td></tr><tr><td>8</td><td>Sample interrupt input once per 256 clocks</td></tr><tr><td>9</td><td>Sample interrupt input once per 2*256 clocks</td></tr><tr><td>10</td><td>Sample interrupt input once per 4*256clocks</td></tr><tr><td>11</td><td>Sample interrupt input once per 8*256 clocks</td></tr><tr><td>12</td><td>Sample interrupt input once per 16*256 clocks</td></tr></table>	DBCLKSEL	Description	0	Sample interrupt input once per 1 clocks	1	Sample interrupt input once per 2 clocks	2	Sample interrupt input once per 4 clocks	3	Sample interrupt input once per 8 clocks	4	Sample interrupt input once per 16 clocks	5	Sample interrupt input once per 32 clocks	6	Sample interrupt input once per 64 clocks	7	Sample interrupt input once per 128 clocks	8	Sample interrupt input once per 256 clocks	9	Sample interrupt input once per 2*256 clocks	10	Sample interrupt input once per 4*256clocks	11	Sample interrupt input once per 8*256 clocks	12	Sample interrupt input once per 16*256 clocks
DBCLKSEL	Description																													
0	Sample interrupt input once per 1 clocks																													
1	Sample interrupt input once per 2 clocks																													
2	Sample interrupt input once per 4 clocks																													
3	Sample interrupt input once per 8 clocks																													
4	Sample interrupt input once per 16 clocks																													
5	Sample interrupt input once per 32 clocks																													
6	Sample interrupt input once per 64 clocks																													
7	Sample interrupt input once per 128 clocks																													
8	Sample interrupt input once per 256 clocks																													
9	Sample interrupt input once per 2*256 clocks																													
10	Sample interrupt input once per 4*256clocks																													
11	Sample interrupt input once per 8*256 clocks																													
12	Sample interrupt input once per 16*256 clocks																													

		13	Sample interrupt input once per 32*256 clocks	
		14	Sample interrupt input once per 64*256 clocks	
		15	Sample interrupt input once per 128*256 clocks	

GPIO Px.n Pin Data Input/Output (Pxn_PDIO)

Register	Offset	R/W	Description	Reset Value
PAn_PDIO n=0,1..15	GPIO_BA+0x200 + 0x04 * n	R/W	GPIO PA.n Pin Data Input/Output	0x0000_000X
PBn_PDIO n=0,1..15	GPIO_BA+0x240 + 0x04 * n	R/W	GPIO PB.n Pin Data Input/Output	0x0000_000X
PCn_PDIO n=0,1..15	GPIO_BA+0x280 + 0x04 * n	R/W	GPIO PC.n Pin Data Input/Output	0x0000_000X
PDn_PDIO n=0,1..15	GPIO_BA+0x2C0 + 0x04 * n	R/W	GPIO PD.n Pin Data Input/Output	0x0000_000X
PEn_PDIO n=0,1..15	GPIO_BA+0x300 + 0x04 * n	R/W	GPIO PE.n Pin Data Input/Output	0x0000_000X
PFn_PDIO n=0,1..3	GPIO_BA+0x340 + 0x04 * n	R/W	GPIO PF.n Pin Data Input/Output	0x0000_000X

Note: x = A/B/C/D/E/F and n = 0~15

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

Bits	Description
[0]	Pxn_PDIO GPIO Px.N Pin Data Input/Output Write this bit can control one GPIO pin output value 0 = Corresponding GPIO pin set to low. 1 = Corresponding GPIO pin set to high. Read this register to get GPIO pin status. For example: writing PA0_PDIO will reflect the written value to bit GPIOA_DOUT[0], read PA0_PDIO will return the value of GPIOA_PIN[0] Note: The write operation will not be affected by register GPIOx_DMASK

6.7 PDMA Controller (PDMA)

6.7.1 Overview

The NuMicro™ NUC230/240 series DMA contains nine-channel peripheral direct memory access (PDMA) controller and a cyclic redundancy check (CRC) generator.

The PDMA that transfers data to and from memory or transfer data to and from APB devices. For PDMA channel (PDMA CH0~CH8), there is one-word buffer as transfer buffer between the Peripherals APB devices and Memory. Software can stop the PDMA operation by disable PDMA PDMACEN (PDMA_CSRx[0]). The CPU can recognize the completion of a PDMA operation by software polling or when it receives an internal PDMA interrupt. The PDMA controller can increase source or destination address or fixed them as well.

The DMA controller contains a cyclic redundancy check (CRC) generator that can perform CRC calculation with programmable polynomial settings. The CRC engine supports CPU PIO mode and DMA transfer mode.

6.7.2 Features

- Supports nine PDMA channels and one CRC channel. Each PDMA channel can support a unidirectional transfer
- AMBA AHB master/slave interface compatible, for data transfer and register read/write
- Hardware round robin priority scheme. DMA channel 0 has the highest priority and channel 8 has the lowest priority
- PDMA operation
 - Peripheral-to-memory, memory-to-peripheral, and memory-to-memory transfer
 - Supports word/half-word/byte transfer data width from/to peripheral
 - Supports address direction: increment, fixed.
- Cyclic Redundancy Check (CRC)
 - Supports four common polynomials CRC-CCITT, CRC-8, CRC-16, and CRC-32
 - CRC-CCITT: $X^{16} + X^{12} + X^5 + 1$
 - CRC-8: $X^8 + X^2 + X + 1$
 - CRC-16: $X^{16} + X^{15} + X^2 + 1$
 - CRC-32: $X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + X + 1$
 - Supports programmable CRC seed value.
 - Supports programmable order reverse setting for input data and CRC checksum.
 - Supports programmable 1's complement setting for input data and CRC checksum.
 - Supports CPU PIO mode or DMA transfer mode.
 - Supports the follows write data length in CPU PIO mode
 - 8-bit write mode (byte): 1-AHB clock cycle operation.
 - 16-bit write mode (half-word): 2-AHB clock cycle operation.
 - 32-bit write mode (word): 4-AHB clock cycle operation.
 - Supports byte alignment transfer data length and word alignment transfer source address in CRC DMA mode.

6.7.3 Block Diagram

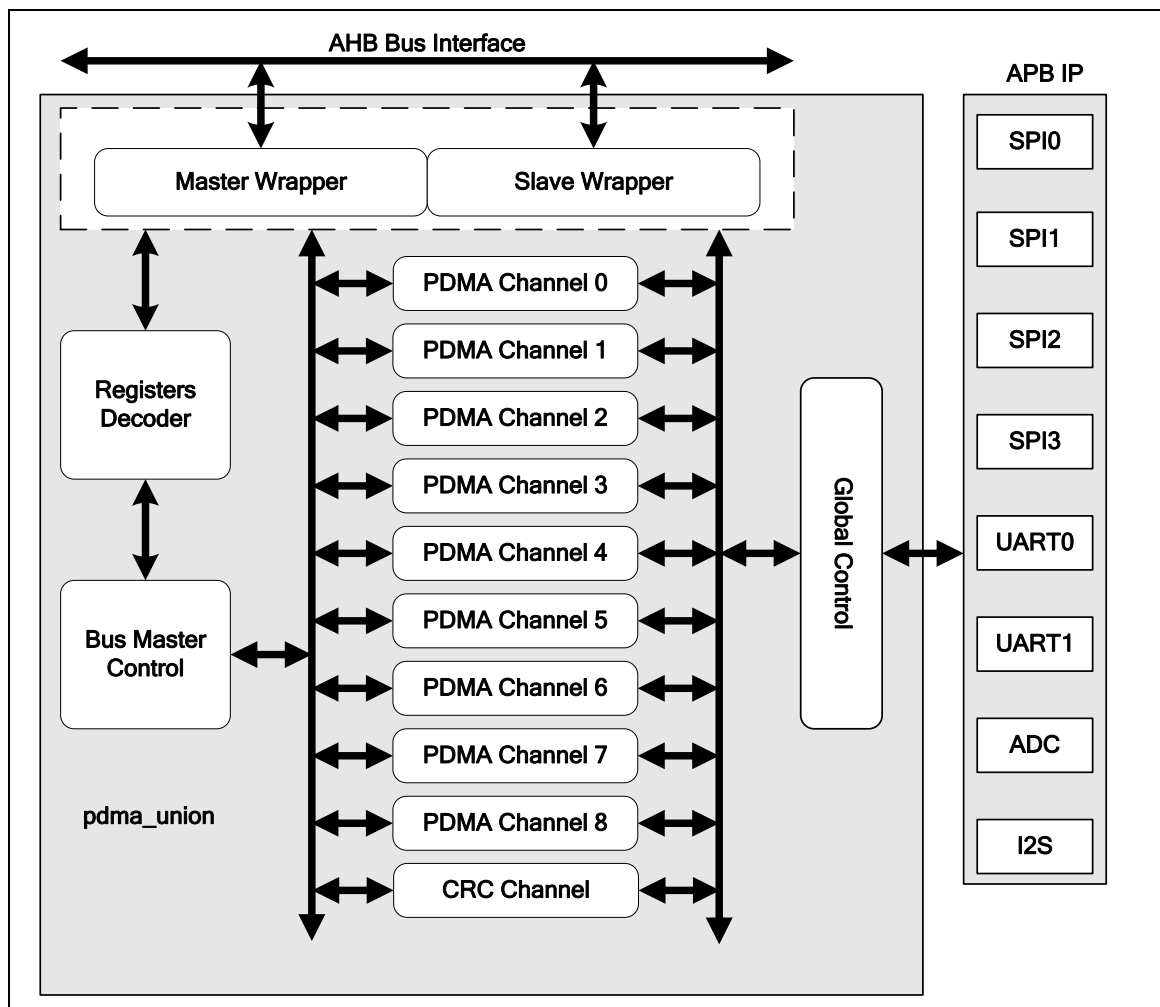


Figure 6-25 DMA Controller Block Diagram

6.7.4 Basic Configuration

The PDMA controller peripheral clock can be enabled in PDMA_EN (AHBCLK[1]).

6.7.5 Functional Description

The direct memory access (DMA) controller module transfers data from one address to another address, without CPU intervention. The DMA controller contains nine PDMA (Peripheral-to-Memory or Memory-to-Peripheral or Memory-to-Memory) channels and one CRC generator channel.

The CPU can recognize the completion of a DMA operation by software polling or when it receives an internal DMA interrupt.

6.7.5.1 PDMA

The DMA controller has nine channels PDMA (Peripheral-to-Memory or Memory-to-Peripheral or Memory-to-Memory). As to the source and destination address, the PDMA controller has two modes: increased and fixed.

Every PDMA channel behavior is not pre-defined, users must configure the channel service settings of PDMA_PDSSR0, PDMA_PDSSR1 and PDMA_PDSSR2 registers before starting the related PDMA channel.

Software must enable PDMA channel by setting PDMACEN (PDMA_CSRx[0]) bit and then write a valid source address to the PDMA_SARx register, a destination address to the PDMA_DARx register, and a transfer count to the PDMA_BCRx register. Next, trigger the TRIG_EN (PDMA_CSRx[23]). PDMA will continue the transfer until PDMA_CBCRx counts down to 0. The following sequence is a program sequence example.

- Enable PDMA peripheral clock by setting PDMA_EN (AHBCLK[1]) bit.
- Configure the channel service setting by setting PDMA_PDSSR0/ PDMA_PDSSR1/ PDMA_PDSSR2 register.
- Configure PDMA_CSRx register:
 - Enable PDMA channel(PDMACEN (PDMA_CSRx[0]))
 - Set source/destination address direction(SAD_SEL (PDMA_CSRx[5:4]) / DAD_SEL (PDMA_CSRx[7:6]))
 - Configure PDMA mode selection(MODE_SEL (PDMA_CSRx[3:2]))
 - Configure peripheral transfer width selection (APB_TWS (PDMA_CSRx[20:19])).
- Configure source/destination address by setting PDMA_SARx/PDMA_DARx registers.
- Configure PDMA_transfer byte count by setting PDMA_BCRx register.
- Enable PDMA block transfer done interrupt by setting BLKD_IE(PDMA_IERx [1]). (optional)
- Enable PDMA NVIC by setting NVIC_IUSER register bit 26 to “1”. (optional)
- Enable PDMA read/write transfer by setting TRIG_EN (PDMA_CSRx[23]) bit.
- If PDMA block transfer done interrupt is generated, write “1” to BLKD_IF (PDMA_ISRx[1])by software to clear interrupt flag.
- Enable PDMA read/write transfer by setting the TRIG_EN (PDMA_CSRx[23])bit for the next block transfer.

If an error occurs during the PDMA operation, the channel stops unless software clears the error condition and sets the SW_RST (PDMA_CSRx[1]) to reset the PDMA channel and set PDMACEN (PDMA_CSRx[0]) and TRIG_EN (PDMA_CSRx[23]) bits field to start again.

In PDMA (Peripheral-to-Memory or Memory-to-Peripheral) mode, DMA can transfer data between the Peripherals (e.g. UART, SPI, ADC) and Memory.

6.7.5.2 CRC

The DMA controller contains a cyclic redundancy check (CRC) generator that can perform CRC calculation with programmable polynomial settings. The operation polynomial includes CRC-CCITT, CRC-8, CRC-16 and CRC-32; Software can choose the CRC operation polynomial mode by setting CRC polynomial mode (CRC_MODE (CRC_CTL[31:30])).

The CRC engine supports CPU PIO mode if CRC channel enable bit CRCCEN (CRC_CLT[0]) is 1, CRC DMA trigger enable bit TRIG_EN (CRC_CTL[23]) is 0 and DMA transfer mode if CRC channel enable bit CRCCEN (CRC_CLT[0]) is 1, CRC DMA trigger enable bit TRIG_EN (CRC_CTL[23]) is 1. The following sequence is a program sequence example.

Procedure when operating in CPU PIO mode:

- Enable CRC engine by setting CRC channel enable bit CRCCEN (CRC_CLT[0]) to 1.
- Set the transfer data format to enable write data order reverse (WDATA_RVS (CRC_CTL[24])), checksum reverse (CHECKSUM_RVS (CRC_CTL[25])), write data 1's complement (WDATA_COM (CRC_CTL[26])), checksum 1's complement (CHECKSUM_COM (CRC_CTL[27])), initial seed value in CRC seed register (CRC_SEED (CRC_SEED[31:0])) and select write data length by setting CPU write data length (CPU_WDLEN (CRC_CTL[29:28])).
- Set the CRC engine reset bit CRC_RST (CRC_CTL[1]) to 1 to load the initial seed value to CRC circuit but others contents of CRT_CTL register will not be cleared. This bit will be cleared automatically.
- Write data to CRC write data register (CRC_WDATA (CRC_WDATA[31:0])) to perform CRC calculation.
- Then, get the CRC checksum results by reading the CRC checksum register (CRC_CHECKSUM (CRC_CHECKSUM[31:0])).

Procedure when operating in CRC DMA mode:

- Enable CRC engine by setting CRC Channel Enable bit CRCCEN (CRC_CLT[0]) to 1.
- Set the transfer data format to enable write data order reverse (WDATA_RVS (CRC_CTL[24])), checksum reverse (CHECKSUM_RVS (CRC_CTL[25])), write data 1's complement (WDATA_COM (CRC_CTL[26])), checksum 1's complement (CHECKSUM_COM (CRC_CTL[27])) and initial seed value in CRC seed register (CRC_SEED (CRC_SEED[31:0])).
- Specify a valid source address (word alignment) and transfer counts by setting CRC DMA transfer source address register (CRC_DMASAR (CRC_DMASAR[31:0])) and CRC DMA transfer byte count register (CRC_DMABCR (CRC_DMABCR[15:0])).
- Set CRC DMA trigger enable bit TRIG_EN (CRC_CTL[23]) to 1 to perform CRC calculation.
- Wait CRC DMA transfer and check if CRC DMA transfer is done by the CRC DMA block transfer done interrupt flag (CRC_BLKD_IF (CRC_DMAISR[1])), and then get the CRC checksum results by reading the CRC checksum register (CRC_CHECKSUM (CRC_CHECKSUM[31:0])).

6.7.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
PDMA Base Address: PDMA_CHx_BA = 0x5000_8000 + 0x100 * x x=0,1 .. 8 CRC_BA = 0x5000_8E00 PDMA_GCR_BA = 0x5000_8F00				
PDMA_CSRx x=0,1 .. 8	PDMA_CHx_BA+0x00	R/W	PDMA Channel x Control Register	0x0000_0000
PDMA_SARx x=0,1 .. 8	PDMA_CHx_BA+0x04	R/W	PDMA Channel x Source Address Register	0x0000_0000
PDMA_DARx x=0,1 .. 8	PDMA_CHx_BA+0x08	R/W	PDMA Channel x Destination Address Register	0x0000_0000
PDMA_BCRx x=0,1 .. 8	PDMA_CHx_BA+0x0C	R/W	PDMA Channel x Transfer Byte Count Register	0x0000_0000
PDMA_POINTx x=0,1 .. 8	PDMA_CHx_BA+0x10	R	PDMA Channel x Internal buffer pointer Register	0xFFFF_0000
PDMA_CSARx x=0,1 .. 8	PDMA_CHx_BA+0x14	R	PDMA Channel x Current Source Address Register	0x0000_0000
PDMA_CDARx x=0,1 .. 8	PDMA_CHx_BA+0x18	R	PDMA Channel x Current Destination Address Register	0x0000_0000
PDMA_CBCRx x=0,1 .. 8	PDMA_CHx_BA+0x1C	R	PDMA Channel x Current Transfer Byte Count Register	0x0000_0000
PDMA_IERx x=0,1 .. 8	PDMA_CHx_BA+0x20	R/W	PDMA Channel x Interrupt Enable Register	0x0000_0001
PDMA_ISRx x=0,1 .. 8	PDMA_CHx_BA+0x24	R/W	PDMA Channel x Interrupt Status Register	0x0000_0000
PDMA_SBUF0_Cx x=0,1 .. 8	PDMA_CHx_BA+0x80	R	PDMA Channel x Shared Buffer FIFO 0 Register	0x0000_0000
CRC_CTL	CRC_BA+0x00	R/W	CRC Control Register	0x2000_0000
CRC_DMASAR	CRC_BA+0x04	R/W	CRC DMA Source Address Register	0x0000_0000
CRC_DMABCR	CRC_BA+0x0C	R/W	CRC DMA Transfer Byte Count Register	0x0000_0000
CRC_DMACSAR	CRC_BA+0x14	R	CRC DMA Current Source Address Register	0x0000_0000
CRC_DMACBCR	CRC_BA+0x1C	R	CRC DMA Current Transfer Byte Count Register	0x0000_0000
CRC_DMAIER	CRC_BA+0x20	R/W	CRC DMA Interrupt Enable Register	0x0000_0001
CRC_DMAISR	CRC_BA+0x24	R/W	CRC DMA Interrupt Status Register	0x0000_0000
CRC_WDATA	CRC_BA+0x80	R/W	CRC Write Data Register	0x0000_0000

CRC_SEED	CRC_BA+0x84	R/W	CRC Seed Register	0xFFFF_FFFF
CRC_CHECKSUM	CRC_BA+0x88	R	CRC Checksum Register	0xFFFF_FFFF
PDMA_GCRCR	PDMA_GCR_BA+0x00	R/W	PDMA Global Control Register	0x0000_0000
PDMA_PDSSR0	PDMA_GCR_BA+0x04	R/W	PDMA Service Selection Control Register 0	0xFFFF_FFFF
PDMA_PDSSR1	PDMA_GCR_BA+0x08	R/W	PDMA Service Selection Control Register 1	0xFFFF_FFFF
PDMA_GCRISR	PDMA_GCR_BA+0x0C	R	PDMA Global Interrupt Status Register	0x0000_0000
PDMA_PDSSR2	PDMA_GCR_BA+0x10	R/W	PDMA Service Selection Control Register 2	0x0000_00FF

6.7.7 Register Description

PDMA Channel x Control Register (PDMA_CSRx)

Register	Offset	R/W	Description	Reset Value
PDMA_CSRx x=0,1 .. 8	PDMA_CHx_BA+0x00	R/W	PDMA Channel x Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
TRIG_EN	Reserved		APB_TWS		Reserved		
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
DAD_SEL		SAD_SEL		MODE_SEL		SW_RST	PDMACEN

Bits	Description
[31:24]	Reserved Reserved.
[23]	TRIG_EN Trigger Enable Bit 0 = No effect. 1 = PDMA data read or write transfer Enabled. Note: When PDMA transfer completed, this bit will be cleared automatically. If the bus error occurs, all PDMA transfer will be stopped. Software must reset all PDMA channel, and then trigger again.
[22:21]	Reserved Reserved.
[20:19]	APB_TWS Peripheral Transfer Width Selection 00 = One word (32-bit) is transferred for every PDMA operation. 01 = One byte (8-bit) is transferred for every PDMA operation. 10 = One half-word (16-bit) is transferred for every PDMA operation. 11 = Reserved. Note: This field is meaningful only when MODE_SEL (PDMA_CSRx[3:2]) is Peripheral to Memory mode (Peripheral-to-Memory) or Memory to Peripheral mode (Memory-to-Peripheral).
[18:8]	Reserved Reserved.
[7:6]	DAD_SEL Transfer Destination Address Direction Selection 00 = Transfer destination address is increasing successively. 01 = Reserved. 10 = Transfer destination address is fixed. (This feature can be used when data where transferred from multiple sources to a single destination). 11 = Reserved.

[5:4]	SAD_SEL	Transfer Source Address Direction Selection 00 = Transfer source address is increasing successively. 01 = Reserved. 10 = Transfer source address is fixed (This feature can be used when data where transferred from a single source to multiple destinations). 11 = Reserved.
[3:2]	MODE_SEL	PDMA Mode Selection 00 = Memory to Memory mode (Memory-to-Memory). 01 = Peripheral to Memory mode (Peripheral-to-Memory). 10 = Memory to Peripheral mode (Memory-to-Peripheral).
[1]	SW_RST	Software Engine Reset 0 = No effect. 1 = Reset the internal state machine, pointers and internal buffer. The contents of control register will not be cleared. This bit will be automatically cleared after few clock cycles.
[0]	PDMACEN	PDMA Channel Enable Bit Setting this bit to 1 enables PDMA operation. If this bit is cleared, PDMA will ignore all PDMA request and force Bus Master into IDLE state. Note: SW_RST(PDMA_CSRx[1], x= 0~8) will clear this bit.

PDMA Channel x Source Address Register (PDMA_SARx)

Register	Offset	R/W	Description	Reset Value
PDMA_SARx x=0,1 .. 8	PDMA_CHx_BA+0x04	R/W	PDMA Channel x Source Address Register	0x0000_0000

31	30	29	28	27	26	25	24
PDMA_SAR [31:24]							
23	22	21	20	19	18	17	16
PDMA_SAR [23:16]							
15	14	13	12	11	10	9	8
PDMA_SAR [15:8]							
7	6	5	4	3	2	1	0
PDMA_SAR [7:0]							

Bits	Description
[31:0]	PDMA_SAR PDMA Transfer Source Address Register This field indicates a 32-bit source address of PDMA. Note: The source address must be word alignment.

PDMA Channel x Destination Address Register (PDMA_DARx)

Register	Offset	R/W	Description	Reset Value
PDMA_DARx x=0,1 .. 8	PDMA_CHx_BA+0x08	R/W	PDMA Channel x Destination Address Register	0x0000_0000

31	30	29	28	27	26	25	24
PDMA_DAR [31:24]							
23	22	21	20	19	18	17	16
PDMA_DAR [23:16]							
15	14	13	12	11	10	9	8
PDMA_DAR [15:8]							
7	6	5	4	3	2	1	0
PDMA_DAR [7:0]							

Bits	Description
[31:0]	PDMA_DAR PDMA Transfer Destination Address Register This field indicates a 32-bit destination address of PDMA. Note: The destination address must be word alignment

PDMA Channel x Transfer Byte Count Register (PDMA_BCRx)

Register	Offset	R/W	Description	Reset Value
PDMA_BCRx x=0,1 .. 8	PDMA_CHx_BA+0x0C	R/W	PDMA Channel x Transfer Byte Count Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
PDMA_BCR [15:8]							
7	6	5	4	3	2	1	0
PDMA_BCR [7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	PDMA_BCR	PDMA Transfer Byte Count Register This field indicates a 16-bit transfer byte count number of PDMA; it must be word alignment.

PDMA Channel x Internal Buffer Pointer Register (PDMA_POINTx)

Register	Offset	R/W	Description	Reset Value
PDMA_POINTx x=0,1 .. 8	PDMA_CHx_BA+0x10	R	PDMA Channel x Internal buffer pointer Register	0xFFFF_0000

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

Bits	Description	
[31:4]	Reserved	Reserved.
[3:0]	PDMA_POINT	PDMA Internal Buffer Pointer Register (Read Only) This field indicates the internal buffer pointer.

PDMA Channel x Current Source Address Register (PDMA_CSARx)

Register	Offset	R/W	Description	Reset Value
PDMA_CSARx x=0,1 .. 8	PDMA_CHx_BA+0x14	R	PDMA Channel x Current Source Address Register	0x0000_0000

31	30	29	28	27	26	25	24
PDMA_CSAR [31:24]							
23	22	21	20	19	18	17	16
PDMA_CSAR [23:16]							
15	14	13	12	11	10	9	8
PDMA_CSAR [15:8]							
7	6	5	4	3	2	1	0
PDMA_CSAR [7:0]							

Bits	Description
[31:0]	PDMA_CSAR PDMA Current Source Address Register (Read Only) This field indicates the source address where the PDMA transfer just occurred.

PDMA Channel x Current Destination Address Register (PDMA_CDARx)

Register	Offset	R/W	Description	Reset Value
PDMA_CDARx x=0,1 .. 8	PDMA_CHx_BA+0x18	R	PDMA Channel x Current Destination Address Register	0x0000_0000

31	30	29	28	27	26	25	24
PDMA_CDAR [31:24]							
23	22	21	20	19	18	17	16
PDMA_CDAR [23:16]							
15	14	13	12	11	10	9	8
PDMA_CDAR [15:8]							
7	6	5	4	3	2	1	0
PDMA_CDAR [7:0]							

Bits	Description	
[31:0]	PDMA_CDAR	PDMA Current Destination Address Register (Read Only) This field indicates the destination address where the PDMA transfer just occurred.

PDMA Channel x Current Byte Count Register (PDMA_CBCRx)

Register	Offset	R/W	Description	Reset Value
PDMA_CBCRx x=0,1 .. 8	PDMA_CHx_BA+0x1C	R	PDMA Channel x Current Transfer Byte Count Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
PDMA_CBCR [15:8]							
7	6	5	4	3	2	1	0
PDMA_CBCR [7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	PDMA_CBCR	PDMA Current Byte Count Register (Read Only) This field indicates the current remained byte count of PDMA. Note: This field value will be cleared to 0, when software set SW_RST (PDMA_CSRx[1]) to "1".

PDMA Channel x Interrupt Enable Register (PDMA_IERx)

Register	Offset	R/W	Description	Reset Value
PDMA_IERx x=0,1 .. 8	PDMA_CHx_BA+0x20	R/W	PDMA Channel x Interrupt Enable Register	0x0000_0001

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

Bits	Description	
[31:2]	Reserved	Reserved.
[1]	BLKD_IE	PDMA Block Transfer Done Interrupt Enable Bit 0 = Interrupt generator Disabled when PDMA transfer is done. 1 = Interrupt generator Enabled when PDMA transfer is done.
[0]	TABORT_IE	PDMA Read/Write Target Abort Interrupt Enable Bit 0 = Target abort interrupt generation Disabled during PDMA transfer. 1 = Target abort interrupt generation Enabled during PDMA transfer.

PDMA Channel x Interrupt Status Register (PDMA_ISRx)

Register	Offset	R/W	Description	Reset Value
PDMA_ISRx x=0,1 .. 8	PDMA_CHx_BA+0x24	R/W	PDMA Channel x Interrupt Status Register	0x0000_0000

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

Bits	Description	
[31:2]	Reserved	Reserved.
[1]	BLKD_IF	PDMA Block Transfer Done Interrupt Flag This bit indicates that PDMA has finished all transfers. 0 = Not finished. 1 = Done. Write 1 to clear this bit to 0.
[0]	TABORT_IF	PDMA Read/Write Target Abort Interrupt Flag Write 1 to clear this bit to 0. 0 = No bus ERROR response received. 1 = Bus ERROR response received. Note: This bit filed indicates bus master received ERROR response or not. If bus master received ERROR response, it means that target abort is happened. PDMA controller will stop transfer and respond this event to software then goes to IDLE state. When target abort occurred, software must reset PDMA, and then transfer those data again.

PDMA Shared Buffer FIFO 0 Register (PDMA_SBUF0_Cx)

Register	Offset	R/W	Description	Reset Value
PDMA_SBUF0_Cx x=0,1 .. 8	PDMA_CHx_BA+0x80	R	PDMA Channel x Shared Buffer FIFO 0 Register	0x0000_0000

31	30	29	28	27	26	25	24
PDMA_SBUF0 [31:24]							
23	22	21	20	19	18	17	16
PDMA_SBUF0 [23:16]							
15	14	13	12	11	10	9	8
PDMA_SBUF0 [15:8]							
7	6	5	4	3	2	1	0
PDMA_SBUF0 [7:0]							

Bits	Description	
[31:0]	PDMA_SBUF0	PDMA Shared Buffer FIFO 0 (Read Only) Each channel has its own 1 word internal buffer.

CRC Control Register (CRC_CTL)

Register	Offset	R/W	Description	Reset Value
CRC_CTL	CRC_BA+0x00	R/W	CRC Control Register	0x2000_0000

31	30	29	28	27	26	25	24
CRC_MODE		CPU_WDLEN		CHECKSUM_COM	WDATA_COM	CHECKSUM_RVS	WDATA_RVS
23	22	21	20	19	18	17	16
TRIG_EN	Reserved						
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved						CRC_RST	CRCCEN

Bits	Description	
[31:30]	CRC_MODE	CRC Polynomial Mode This field indicates the CRC operation polynomial mode. 00 = CRC-CCITT Polynomial Mode. 01 = CRC-8 Polynomial Mode. 10 = CRC-16 Polynomial Mode. 11 = CRC-32 Polynomial Mode.
[29:28]	CPU_WDLEN	CPU Write Data Length This field indicates the CPU write data length only when operating in CPU PIO mode. 00 = The write data length is 8-bit mode. 01 = The write data length is 16-bit mode. 10 = The write data length is 32-bit mode. 11 = Reserved. Note1: This field is only valid when operating in CPU PIO mode. Note2: When the write data length is 8-bit mode, the valid data in CRC_WDATA register is only CRC_WDATA [7:0] bits; if the write data length is 16-bit mode, the valid data in CRC_WDATA register is only CRC_WDATA [15:0].
[27]	CHECKSUM_COM	Checksum 1's Complement This bit is used to enable the 1's complement function for checksum result in CRC_CHECKSUM register. 0 = 1's complement for CRC checksum Disabled. 1 = 1's complement for CRC checksum Enabled.
[26]	WDATA_COM	Write Data 1's Complement This bit is used to enable the 1's complement function for write data value in CRC_WDATA register. 0 = 1's complement for CRC write data in Disabled. 1 = 1's complement for CRC write data in Enabled.

[25]	CHECKSUM_RVS	Checksum Reverse This bit is used to enable the bit order reverse function for write data value in CRC_CHECKSUM register. 0 = Bit order reverse for CRC checksum Disabled. 1 = Bit order reverse for CRC checksum Enabled. Note: If the checksum result is 0XDD7B0F2E, the bit order reverse for CRC checksum is 0x74F0DEBB
[24]	WDATA_RVS	Write Data Order Reverse This bit is used to enable the bit order reverse function for write data value in CRC_WDATA register. 0 = Bit order reverse for CRC write data in Disabled. 1 = Bit order reverse for CRC write data in Enabled (per byte). Note: If the write data is 0xAABBCCDD, the bit order reverse for CRC write data in is 0x55DD33BB
[23]	TRIG_EN	Trigger Enable Bit This bit is used to trigger the CRC DMA transfer. 0 = No effect. 1 = CRC DMA data read or write transfer Enabled. Note1: If this bit asserts which indicates the CRC engine operation in CRC DMA mode, do not fill in any data in CRC_WDATA register. Note2: When CRC DMA transfer completed, this bit will be cleared automatically. Note3: If the bus error occurs when CRC DMA transfer data, all CRC DMA transfer will be stopped. Software must reset all DMA channel before trigger DMA again.
[22:2]	Reserved	Reserved.
[1]	CRC_RST	CRC Engine Reset 0 = No effect. 1 = Reset the internal CRC state machine and internal buffer. The others contents of CRC_CTL register will not be cleared. This bit will be cleared automatically. Note: When operated in CPU PIO mode, setting this bit will reload the initial seed value (CRC_SEED register).
[0]	CRCCEN	CRC Channel Enable Bit 0 = No effect. 1 = CRC operation Enabled. Note1: When operating in CRC DMA mode (TRIG_EN (CRC_CTL[23]) = 1), if user clears this bit, the DMA operation will be continuous until all CRC DMA operation is done, and the TRIG_EN (CRC_CTL[23]) bit will keep 1 until all CRC DMA operation done. But in this case, the CRC_BLKD_IF (CRC_DMAISR[1]) flag will inactive, user can read CRC checksum result only if TRIG_EN (CRC_CTL[23]) clears to 0 Note2: When operating in CRC DMA mode (TRIG_EN (CRC_CTL[23]) = 1), if user wants to stop the transfer immediately, user can write 1 to CRC_RST (CRC_CTL [1]) bit to stop the transmission.

CRC DMA Source Address Register (CRC_DMASAR)

Register	Offset	R/W	Description	Reset Value
CRC_DMASAR	CRC_BA+0x04	R/W	CRC DMA Source Address Register	0x0000_0000

31	30	29	28	27	26	25	24
CRC_DMASAR [31:24]							
23	22	21	20	19	18	17	16
CRC_DMASAR [23:16]							
15	14	13	12	11	10	9	8
CRC_DMASAR [15:8]							
7	6	5	4	3	2	1	0
CRC_DMASAR [7:0]							

Bits	Description
[31:0]	CRC DMA Transfer Source Address Register This field indicates a 32-bit source address of CRC DMA. $(CRC\_DMASAR + CRC\_DMABCR) = (CRC\_DMACSAR + CRC\_DMACBCR)$. Note: The source address must be word alignment

CRC DMA Transfer Byte Count Register (CRC_DMABCR)

Register	Offset	R/W	Description	Reset Value
CRC_DMABCR	CRC_BA+0x0C	R/W	CRC DMA Transfer Byte Count Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
CRC_DMABCR [15:8]							
7	6	5	4	3	2	1	0
CRC_DMABCR [7:0]							

Bits	Description
[31:16]	Reserved
[15:0]	CRC DMA Transfer Byte Count Register This field indicates a 16-bit total transfer byte count number of CRC DMA $(CRC\_DMASAR + CRC\_DMABCR) = (CRC\_DMACSAR + CRC\_DMACBCR)$.

CRC DMA Current Source Address Register (CRC_DMACSAR)

Register	Offset	R/W	Description	Reset Value
CRC_DMACSAR	CRC_BA+0x14	R	CRC DMA Current Source Address Register	0x0000_0000

31	30	29	28	27	26	25	24
CRC_DMACSAR [31:24]							
23	22	21	20	19	18	17	16
CRC_DMACSAR [23:16]							
15	14	13	12	11	10	9	8
CRC_DMACSAR [15:8]							
7	6	5	4	3	2	1	0
CRC_DMACSAR [7:0]							

Bits	Description
[31:0]	CRC_DMACSAR CRC DMA Current Source Address Register (Read Only) This field indicates the current source address where the CRC DMA transfer just occurs. $(CRC\_DMASAR + CRC\_DMABCR) = (CRC\_DMACSAR + CRC\_DMACBCR)$.

CRC DMA Current Transfer Byte Count Register (CRC_DMABCR)

Register	Offset	R/W	Description	Reset Value
CRC_DMABCR	CRC_BA+0x1C	R	CRC DMA Current Transfer Byte Count Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
CRC_DMABCR [15:8]							
7	6	5	4	3	2	1	0
CRC_DMABCR [7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	CRC_DMABCR	CRC DMA Current Remained Byte Count Register (Read Only) This field indicates the current remained byte count of CRC DMA. $(CRC\_DMASAR + CRC\_DMABCR) = (CRC\_DMACSAR + CRC\_DMABCR)$. Note: Setting CRC_RST (CRC_CTL[1]) bit to 1 will clear this register value.

CRC DMA Interrupt Enable Register (CRC_DMAIER)

Register	Offset	R/W	Description	Reset Value
CRC_DMAIER	CRC_BA+0x20	R/W	CRC DMA Interrupt Enable Register	0x0000_0001

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved						CRC_BLKD_ IE	CRC_TABOR T_IE

Bits	Description	
[31:2]	Reserved	Reserved.
[1]	CRC_BLKD_IE	CRC DMA Block Transfer Done Interrupt Enable Bit Enable this bit will generate the CRC DMA Transfer Done interrupt signal while CRC_BLKD_IF (CRC_DMAISR[1]) bit is set to 1. 0 = Interrupt generator Disabled when CRC DMA transfer done. 1 = Interrupt generator Enabled when CRC DMA transfer done.
[0]	CRC_TABORT_IE	CRC DMA Read/Write Target Abort Interrupt Enable Bit Enable this bit will generate the CRC DMA Target Abort interrupt signal while CRC_TARBOT_IF (CRC_DMAISR[0]) bit is set to 1. 0 = Target abort interrupt generation Disabled during CRC DMA transfer. 1 = Target abort interrupt generation Enabled during CRC DMA transfer.

CRC DMA Interrupt Status Register (CRC_DMAISR)

Register	Offset	R/W	Description	Reset Value
CRC_DMAISR	CRC_BA+0x24	R/W	CRC DMA Interrupt Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved						CRC_BLKD_I F	CRC_TABOR T_IF

Bits	Description
[31:2]	Reserved
[1]	CRC_BLKD_IF CRC DMA Block Transfer Done Interrupt Flag This bit indicates that CRC DMA transfer has finished or not. 0 = Not finished if TRIG_EN (CRC_CTL[23]) bit has enabled. 1 = CRC transfer done if TRIG_EN (CRC_CTL[23]) bit has enabled. It is cleared by writing 1 to it through software.. (When CRC DMA transfer done, TRIG_EN (CRC_CTL[23]) bit will be cleared automatically)
[0]	CRC_TABORT_IF CRC DMA Read/Write Target Abort Interrupt Flag This bit indicates that CRC bus has error or not during CRC DMA transfer. 0 = No bus error response received during CRC DMA transfer. 1 = Bus error response received during CRC DMA transfer. It is cleared by writing 1 to it through software. Note: The bit filed indicate bus master received error response or not. If bus master received error response, it means that CRC transfer target abort is happened. DMA will stop transfer and respond this event to software then CRC state machine goes to IDLE state. When target abort occurred, software must reset DMA before transfer those data again.

CRC Write Data Register (CRC_WDATA)

Register	Offset	R/W	Description	Reset Value
CRC_WDATA	CRC_BA+0x80	R/W	CRC Write Data Register	0x0000_0000

31	30	29	28	27	26	25	24
CRC_WDATA [31:24]							
23	22	21	20	19	18	17	16
CRC_WDATA [23:16]							
15	14	13	12	11	10	9	8
CRC_WDATA [15:8]							
7	6	5	4	3	2	1	0
CRC_WDATA [7:0]							

Bits	Description
[31:0]	CRC Write Data Register When operating in CPU PIO mode, software can write data to this field to perform CRC operation. When operating in DMA mode, this field indicates the DMA read data from memory and cannot be written. Note: When the write data length is 8-bit mode, the valid data in CRC_WDATA register is only CRC_WDATA [7:0] bits; if the write data length is 16-bit mode, the valid data in CRC_WDATA register is only CRC_WDATA [15:0].

CRC Seed Register (CRC_SEED)

Register	Offset	R/W	Description	Reset Value
CRC_SEED	CRC_BA+0x84	R/W	CRC Seed Register	0xFFFF_FFFF

31	30	29	28	27	26	25	24
CRC_SEED [31:24]							
23	22	21	20	19	18	17	16
CRC_SEED [23:16]							
15	14	13	12	11	10	9	8
CRC_SEED [15:8]							
7	6	5	4	3	2	1	0
CRC_SEED [7:0]							

Bits	Description	
[31:0]	CRC_SEED	CRC Seed Register This field indicates the CRC seed value.

CRC Checksum Register (CRC_CHECKSUM)

Register	Offset	R/W	Description	Reset Value
CRC_CHECKSUM	CRC_BA+0x88	R	CRC Checksum Register	0xFFFF_FFFF

31	30	29	28	27	26	25	24
CRC_CHECKSUM [31:24]							
23	22	21	20	19	18	17	16
CRC_CHECKSUM [23:16]							
15	14	13	12	11	10	9	8
CRC_CHECKSUM [15:8]							
7	6	5	4	3	2	1	0
CRC_CHECKSUM [7:0]							

Bits	Description
[31:0]	CRC_CHECKSUM CRC Checksum Register This fields indicates the CRC checksum result

PDMA Global Control Register (PDMA_GCRCSR)

Register	Offset	R/W	Description	Reset Value
PDMA_GCRCSR	PDMA_GCR_BA+0x00	R/W	PDMA Global Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							CRC_CLK_EN
23	22	21	20	19	18	17	16
Reserved							CLK8_EN
15	14	13	12	11	10	9	8
CLK7_EN	CLK6_EN	CLK5_EN	CLK4_EN	CLK3_EN	CLK2_EN	CLK1_EN	CLK0_EN
7	6	5	4	3	2	1	0
Reserved							

Bits	Description	
[31:25]	Reserved	Reserved.
[24]	CRC_CLK_EN	CRC Controller Clock Enable Bit 0 = Disabled. 1 = Enabled.
[23:17]	Reserved	Reserved.
[16]	CLK8_EN	PDMA Controller Channel 8 Clock Enable Bit 0 = Disabled. 1 = Enabled.
[15]	CLK7_EN	PDMA Controller Channel 7 Clock Enable Bit 0 = Disabled. 1 = Enabled.
[14]	CLK6_EN	PDMA Controller Channel 6 Clock Enable Bit 0 = Disabled. 1 = Enabled.
[13]	CLK5_EN	PDMA Controller Channel 5 Clock Enable Bit 0 = Disabled. 1 = Enabled.
[12]	CLK4_EN	PDMA Controller Channel 4 Clock Enable Bit 0 = Disabled. 1 = Enabled.
[11]	CLK3_EN	PDMA Controller Channel 3 Clock Enable Bit 0 = Disabled. 1 = Enabled.

[10]	CLK2_EN	PDMA Controller Channel 2 Clock Enable Bit 0 = Disabled. 1 = Enabled.
[9]	CLK1_EN	PDMA Controller Channel 1 Clock Enable Bit 0 = Disabled. 1 = Enabled.
[8]	CLK0_EN	PDMA Controller Channel 0 Clock Enable Bit 0 = Disabled. 1 = Enabled.
[7:0]	Reserved	Reserved.

PDMA Service Selection Control Register 0 (PDMA_PDSSR0)

Register	Offset	R/W	Description	Reset Value
PDMA_PDSSR0	PDMA_GCR_BA+0x04	R/W	PDMA Service Selection Control Register 0	0xFFFF_FFFF

31	30	29	28	27	26	25	24
SPI3_TXSEL				SPI3_RXSEL			
23	22	21	20	19	18	17	16
SPI2_TXSEL				SPI2_RXSEL			
15	14	13	12	11	10	9	8
SPI1_TXSEL				SPI1_RXSEL			
7	6	5	4	3	2	1	0
SPI0_TXSEL				SPI0_RXSEL			

Bits	Description	
[31:28]	SPI3_TXSEL	PDMA SPI3 TX Selection This field defines which PDMA channel is connected to the on-chip peripheral SPI3 TX. Software can configure the TX channel setting by this field. The channel configuration is the same as SPI0_RXSEL (PDMA_PDSSR0[3:0]) field. Please refer to the explanation of SPI0_RXSEL (PDMA_PDSSR0[3:0]).
[27:24]	SPI3_RXSEL	PDMA SPI3 RX Selection This field defines which PDMA channel is connected to the on-chip peripheral SPI3 RX. Software can configure the RX channel setting by this field. The channel configuration is the same as SPI0_RXSEL (PDMA_PDSSR0[3:0]) field. Please refer to the explanation of SPI0_RXSEL (PDMA_PDSSR0[3:0]).
[23:20]	SPI2_TXSEL	PDMA SPI2 TX Selection This field defines which PDMA channel is connected to the on-chip peripheral SPI2 TX. Software can configure the TX channel setting by this field. The channel configuration is the same as SPI0_RXSEL (PDMA_PDSSR0[3:0]) field. Please refer to the explanation of SPI0_RXSEL (PDMA_PDSSR0[3:0]).
[19:16]	SPI2_RXSEL	PDMA SPI2 RX Selection This field defines which PDMA channel is connected to the on-chip peripheral SPI2 RX. Software can configure the RX channel setting by this field. The channel configuration is the same as SPI0_RXSEL (PDMA_PDSSR0[3:0]) field. Please refer to the explanation of SPI0_RXSEL (PDMA_PDSSR0[3:0]).
[15:12]	SPI1_TXSEL	PDMA SPI1 TX Selection This field defines which PDMA channel is connected to the on-chip peripheral SPI1 TX. Software can configure the TX channel setting by this field. The channel configuration is the same as SPI0_RXSEL (PDMA_PDSSR0[3:0]) field. Please refer to the explanation of SPI0_RXSEL (PDMA_PDSSR0[3:0]).
[11:8]	SPI1_RXSEL	PDMA SPI1 RX Selection This field defines which PDMA channel is connected to the on-chip peripheral SPI1 RX. Software can configure the RX channel setting by this field. The channel configuration is the same as SPI0_RXSEL (PDMA_PDSSR0[3:0]) field. Please refer to the explanation of SPI0_RXSEL (PDMA_PDSSR0[3:0]).

[7:4]	SPI0_TXSEL	PDMA SPI0 TX Selection This field defines which PDMA channel is connected to the on-chip peripheral SPI0 TX. Software can configure the TX channel setting by this field. The channel configuration is the same as SPI0_RXSEL (PDMA_PDSSR0[3:0]) field. Please refer to the explanation of SPI0_RXSEL (PDMA_PDSSR0[3:0]).
[3:0]	SPI0_RXSEL	PDMA SPI0 RX Selection This field defines which PDMA channel is connected to the on-chip peripheral SPI0 RX. Software can change the channel RX setting by this field. For example, SPI0_RXSEL (PDMA_PDSSR0[3:0]) = 0110, that means SPI0_RX is connected to PDMA_CH6. 0000: CH0 0001: CH1 0010: CH2 0011: CH3 0100: CH4 0101: CH5 0110: CH6 0111: CH7 1000: CH8 Others : Reserved

PDMA Service Selection Control Register 1 (PDMA_PDSSR1)

Register	Offset	R/W	Description	Reset Value
PDMA_PDSSR1	PDMA_GCR_BA+0x08	R/W	PDMA Service Selection Control Register 1	0xFFFF_FFFF

31	30	29	28	27	26	25	24
Reserved				ADC_RXSEL			
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
UART1_TXSEL				UART1_RXSEL			
7	6	5	4	3	2	1	0
UART0_TXSEL				UART0_RXSEL			

Bits	Description	
[31:28]	Reserved	Reserved.
[27:24]	ADC_RXSEL	PDMA ADC RX Selection This field defines which PDMA channel is connected to the on-chip peripheral ADC RX. Software can configure the RX channel setting by this field. The channel configuration is the same as UART0_RXSEL (PDMA_PDSSR1[3:0]) field. Please refer to the explanation of UART0_RXSEL (PDMA_PDSSR1[3:0]).
[23:16]	Reserved	Reserved.
[15:12]	UART1_TXSEL	PDMA UART1 TX Selection This field defines which PDMA channel is connected to the on-chip peripheral UART1 TX. Software can configure the TX channel setting by this field. The channel configuration is the same as UART0_RXSEL (PDMA_PDSSR1[3:0]) field. Please refer to the explanation of UART0_RXSEL (PDMA_PDSSR1[3:0]).
[11:8]	UART1_RXSEL	PDMA UART1 RX Selection This field defines which PDMA channel is connected to the on-chip peripheral UART1 RX. Software can configure the RX channel setting by this field. The channel configuration is the same as UART0_RXSEL (PDMA_PDSSR1[3:0]) field. Please refer to the explanation of UART0_RXSEL (PDMA_PDSSR1[3:0]).
[7:4]	UART0_TXSEL	PDMA UART0 TX Selection This field defines which PDMA channel is connected to the on-chip peripheral UART0 TX. Software can configure the TX channel setting by this field. The channel configuration is the same as UART0_RXSEL (PDMA_PDSSR1[3:0]) field. Please refer to the explanation of UART0_RXSEL (PDMA_PDSSR1[3:0]).

[3:0]	UART0_RXSEL	PDMA UART0 RX Selection This field defines which PDMA channel is connected to the on-chip peripheral UART0 RX. Software can change the channel RX setting by this field. For example, UART0_RXSEL (PDMA_PDSSR1[3:0]) = 0110, which means UART0_RX is connected to PDMA_CH6. 0000: CH0 0001: CH1 0010: CH2 0011: CH3 0100: CH4 0101: CH5 0110: CH6 0111: CH7 1000: CH8 Others : Reserved

PDMA Global Interrupt Status Register (PDMA_GCRISR)

Register	Offset	R/W	Description	Reset Value
PDMA_GCRISR	PDMA_GCR_BA+0x0C	R	PDMA Global Interrupt Status Register	0x0000_0000

31	30	29	28	27	26	25	24
INTR	Reserved						
23	22	21	20	19	18	17	16
Reserved							INTRCRC
15	14	13	12	11	10	9	8
Reserved							INTR8
7	6	5	4	3	2	1	0
INTR7	INTR6	INTR5	INTR4	INTR3	INTR2	INTR1	INTR0

Bits	Description	
[31]	INTR	Interrupt Status This bit is the interrupt status of PDMA controller. Note: This bit is read only.
[30:17]	Reserved	Reserved.
[16]	INTRCRC	Interrupt Status Of CRC Controller This bit is the interrupt status of CRC controller Note: This bit is read only
[15:9]	Reserved	Reserved.
[8]	INTR8	Interrupt Status Of Channel 8 This bit is the interrupt status of PDMA channel8. Note: This bit is read only.
[7]	INTR7	Interrupt Status Of Channel 7 This bit is the interrupt status of PDMA channel7. Note: This bit is read only.
[6]	INTR6	Interrupt Status Of Channel 6 This bit is the interrupt status of PDMA channel6. Note: This bit is read only.
[5]	INTR5	Interrupt Status Of Channel 5 This bit is the interrupt status of PDMA channel5. Note: This bit is read only.
[4]	INTR4	Interrupt Status Of Channel 4 This bit is the interrupt status of PDMA channel4. Note: This bit is read only.

[3]	INTR3	Interrupt Status Of Channel 3 This bit is the interrupt status of PDMA channel3. Note: This bit is read only.
[2]	INTR2	Interrupt Status Of Channel 2 This bit is the interrupt status of PDMA channel2. Note: This bit is read only.
[1]	INTR1	Interrupt Status Of Channel 1 This bit is the interrupt status of PDMA channel1. Note: This bit is read only.
[0]	INTR0	Interrupt Status Of Channel 0 This bit is the interrupt status of PDMA channel0. Note: This bit is read only.

PDMA Service Selection Control Register 2 (PDMA_PDSSR2)

Register	Offset	R/W	Description	Reset Value
PDMA_PDSSR2	PDMA_GCR_BA+0x10	R/W	PDMA Service Selection Control Register 2	0x0000_00FF

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
I2S_TXSEL				I2S_RXSEL			

Bits	Description	
[31:8]	Reserved	Reserved.
[7:4]	I2S_TXSEL	PDMA I²S TX Selection This field defines which PDMA channel is connected to the on-chip peripheral I ² S TX. Software can configure the TX channel setting by this field. The channel configuration is the same as I2S_RXSEL (PDMA_PDSSR2[3:0]) field. Please refer to the explanation of I2S_RXSEL (PDMA_PDSSR2[3:0]).
[3:0]	I2S_RXSEL	PDMA I²S RX Selection This field defines which PDMA channel is connected to the on-chip peripheral I ² S RX. Software can change the channel RX setting by this field. For example: I2S_RXSEL (PDMA_PDSSR2[3:0]) = 0110, that means I2S_RX is connected to PDMA_CH6. 0000: CH0 0001: CH1 0010: CH2 0011: CH3 0100: CH4 0101: CH5 0110: CH6 0111: CH7 1000: CH8 Others : Reserved

6.8 Timer Controller (TIMER)

6.8.1 Overview

The timer controller includes four 32-bit timers, TIMER0 ~ TIMER3, allowing user to easily implement a timer control for applications. The timer can perform functions, such as frequency measurement, delay timing, clock generation, and event counting by external input pins, and interval measurement by external capture pins.

6.8.2 Features

- Four sets of 32-bit timers with 24-bit up counter and one 8-bit prescale counter
- Independent clock source for each timer
- Provides four timer counting modes: one-shot, periodic, toggle and continuous counting
- Time-out period = (Period of timer clock input) * (8-bit prescale counter + 1) * (24-bit TCMP)
- Maximum counting cycle time = $(1 / T \text{ MHz}) * (2^8) * (2^{24})$, T is the period of timer clock
- 24-bit up counter value is readable through TDR (Timer Data Register)
- Supports event counting function to count the event from external counter pin (TM0~TM3)
- Supports external pin capture (TM0_EXT~TM3_EXT) for interval measurement
- Supports external pin capture (TM0_EXT~TM3_EXT) for reset 24-bit up counter
- Supports chip wake-up from Idle/Power-down mode if a timer interrupt signal is generated

6.8.3 Block Diagram

The Timer Controller block diagram and clock control are shown as follows.

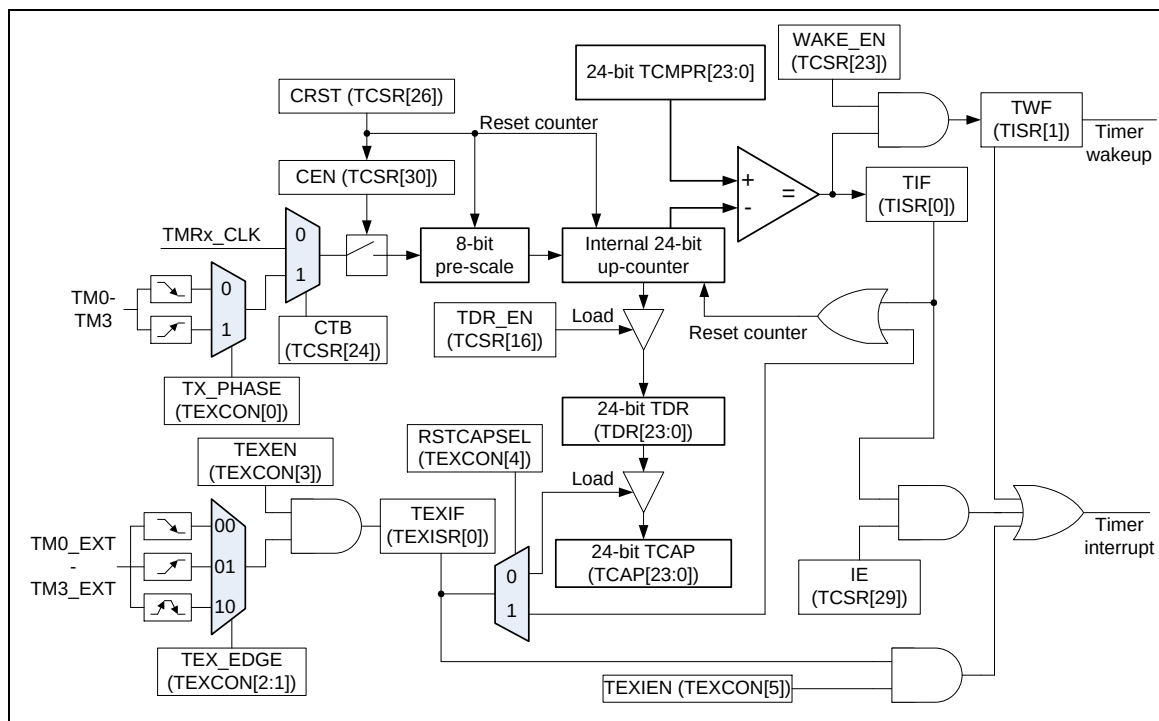


Figure 6-27 Timer Controller Block Diagram

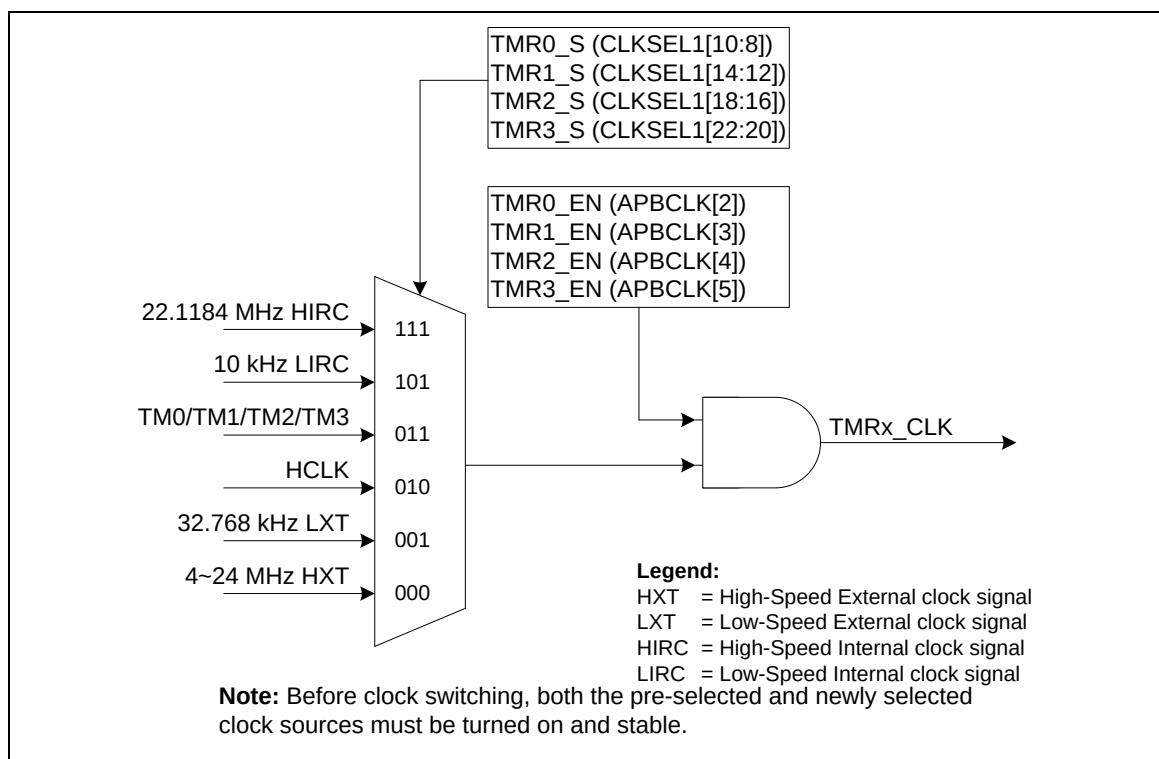


Figure 6-28 Clock Source of Timer Controller

6.8.4 Basic Configuration

The peripheral clock source of Timer0 ~ Timer3 can be enabled in APBCLK[5:2] and selected as different frequency in CLKSEL1[10:8] for Timer0, CLKSEL1[14:12] for Timer1, CLKSEL1[18:16] for Timer2 and CLKSEL1[22:20] for Timer3.

6.8.5 Functional Description

6.8.5.1 Timer Interrupt Flag

Timer controller supports two interrupt flags; one is TIF flag and its set while timer counter value (TDR) matches the timer compared value (TCMP), the other is TEXIF flag and its set when the transition on the TMx_EXT pin associated TEX_EDGE setting.

6.8.5.2 One-shot Mode

If timer controller is configured at one-shot mode (TCSR[28:27] is 00) and CEN (TCSR[30]) bit is set, the timer counter starts up counting. Once the TDR value reaches TCMP value, the TIF flag will be set to 1, TDR value and CEN bit is cleared by timer controller then timer counting operation stops. In the meantime, if the IE (TCSR[29]) bit is enabled, the timer interrupt signal is generated and sent to NVIC to inform CPU also.

6.8.5.3 Periodic Mode

If timer controller is configured at periodic mode (TCSR[28:27] is 01) and CEN bit is set, the timer counter starts up counting. Once the TDR value reaches TCMP value, the TIF flag will be set to 1, TDR value will be cleared by timer controller and timer counter operates counting again. In the meantime, if the IE bit is enabled, the timer interrupt signal is generated and sent to NVIC to inform CPU also. In this mode, timer controller operates counting and compares with TCMP value periodically until the CEN bit is cleared by software.

6.8.5.4 Toggle-output Mode

If timer controller is configured at toggle-out mode (TCSR[28:27] is 10) and CEN bit is set, the timer counter starts up counting. The counting operation of toggle-out mode is almost the same as periodic mode, except toggle-out mode has associated TM0~MT3 pin to output signal while specify TIF bit is set. Thus, the toggle-output signal on TM0~TM3 pin is changing back and forth with 50% duty cycle.

6.8.5.5 Continuous Counting Mode

If timer controller is configured at continuous counting mode (TCSR[28:27] is 11) and CEN bit is set, the timer counter starts up counting. Once the TDR value reaches TCMP value, the TIF flag will be set to 1 and TDR value keeps up counting. In the meantime, if the IE bit is enabled, the timer interrupt signal is generated and sent to NVIC to inform CPU also. User can change different TCMP value immediately without disabling timer counting and restarting timer counting in this mode.

For example, TCMP value is set as 80, first. The TIF flag will set to 1 when TDR value is equal to 80, timer counter is kept counting and TDR value will not goes back to 0, it continues to count 81, 82, 83, ... to $2^{24}-1$, 0, 1, 2, 3, ... to $2^{24}-1$ again and again. Next, if software programs TCMP value as 200 and clears TIF flag, the TIF flag will set to 1 again when TDR value reaches to 200. At last, software programs TCMP as 500 and clears TIF flag, the TIF flag will set to 1 again when TDR value reaches to 500.

In this mode, the timer counting is continuous. So, this operation mode is called as continuous counting mode.

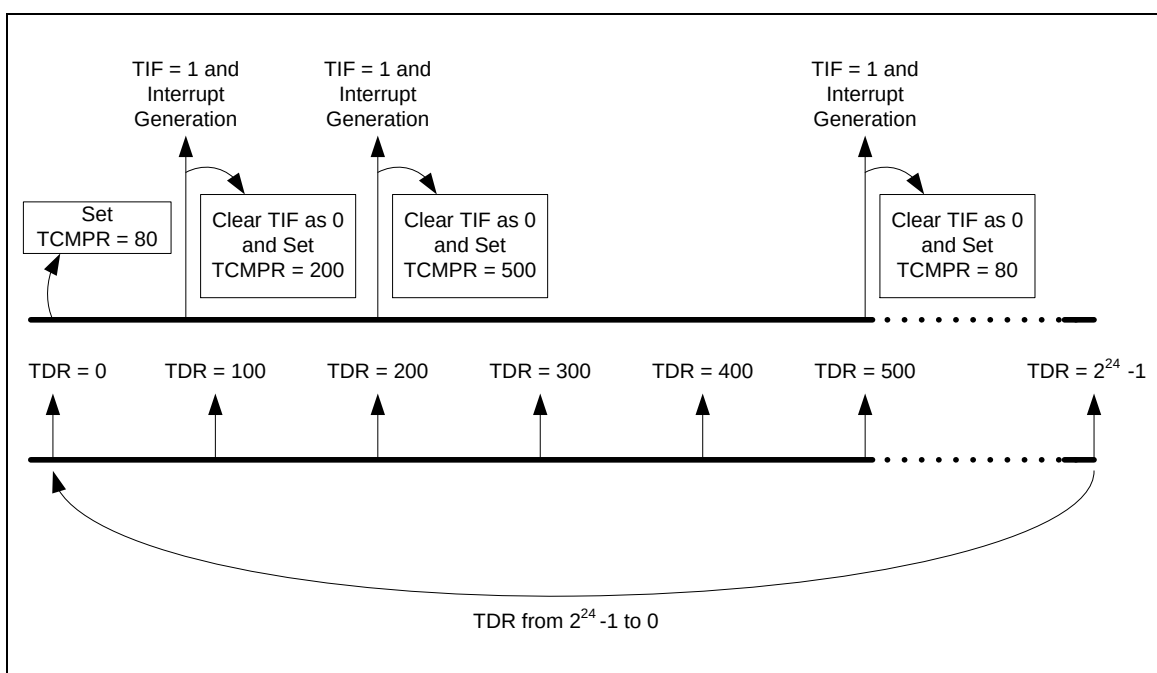


Figure 6-29 Continuous Counting Mode

6.8.5.6 Event Counting Mode

Timer controller also provides an application which can count the input event from TMx pin (x= 0~3) and the number of event will reflect to TDR value. It is also called as event counting function. In this function, CTB (TCSR[24]) bit should be set and the timer peripheral clock source should be set as HCLK.

Software can enable or disable TMx pin de-bounce circuit by TCDB (TEXCON[7]) bit. The input event frequency should be less than 1/3 HCLK if TMx pin de-bounce disabled or less than 1/8 HCLK if TMx pin de-bounce enabled to assure the returned TDR value is incorrect, and software can also select edge detection phase of TMx pin by TX_PHASE (TEXCON[0]) bit.

In event counting mode, the timer counting operation mode can be selected as one-shot, periodic and continuous counting mode to counts the TDR value by input event from TMx pin.

6.8.5.7 External Capture Mode

The event capture function is used to capture Timer Capture Data Register (TDR) value to TCAP value while edge transition detected on TMx_EXT pin (x= 0~3). In this mode, RSTCAPSEL (TEXCON[4]) bit should be as 0 for select TMx_EXT transition is using as the event capture function and the timer peripheral clock source should be set as HCLK.

Software can enable or disable TxEX pin de-bounce circuit by TEXDB (TEXCON[6]) bit. The transition frequency of TMx_EXT pin should be less than 1/3 HCLK if TMx_EXT pin de-bounce disabled or less than 1/8 HCLK if TMx_EXT pin de-bounce enabled to assure the capture function can be work normally, and software can also select edge transition detection of TMx_EXT pin by TEX_EDGE (TEXCON[2:1]) bits.

In event capture mode, software does not consider what timer counting operation mode is selected, the capture event occurred only if edge transition on TMx_EXT pin is detected.

6.8.5.8 Event Reset Counter Mode

It also provides event reset counter function to reset TDR value while edge transition detected on TMx_EXT pin (x= 0~3). In this mode, most the settings are the same as event capture function except RSTCAPSEL (TEXCON[4]) bit should be as 1 for select TMx_EXT transition is using as the event reset counter.

6.8.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
TIMER Base Address: TMR01_BA = 0x4001_0000 TMR23_BA = 0x4011_0000				
TCSR0	TMR01_BA+0x00	R/W	Timer0 Control and Status Register	0x0000_0005
TCMPR0	TMR01_BA+0x04	R/W	Timer0 Compare Register	0x0000_0000
TISR0	TMR01_BA+0x08	R/W	Timer0 Interrupt Status Register	0x0000_0000
TDR0	TMR01_BA+0x0C	R	Timer0 Data Register	0x0000_0000
TCAP0	TMR01_BA+0x10	R	Timer0 Capture Data Register	0x0000_0000
TEXCON0	TMR01_BA+0x14	R/W	Timer0 External Control Register	0x0000_0000
TEXISR0	TMR01_BA+0x18	R/W	Timer0 External Interrupt Status Register	0x0000_0000
TCSR1	TMR01_BA+0x20	R/W	Timer1 Control and Status Register	0x0000_0005
TCMPR1	TMR01_BA+0x24	R/W	Timer1 Compare Register	0x0000_0000
TISR1	TMR01_BA+0x28	R/W	Timer1 Interrupt Status Register	0x0000_0000
TDR1	TMR01_BA+0x2C	R	Timer1 Data Register	0x0000_0000
TCAP1	TMR01_BA+0x30	R	Timer1 Capture Data Register	0x0000_0000
TEXCON1	TMR01_BA+0x34	R/W	Timer1 External Control Register	0x0000_0000
TEXISR1	TMR01_BA+0x38	R/W	Timer1 External Interrupt Status Register	0x0000_0000
TCSR2	TMR23_BA+0x00	R/W	Timer2 Control and Status Register	0x0000_0005
TCMPR2	TMR23_BA+0x04	R/W	Timer2 Compare Register	0x0000_0000
TISR2	TMR23_BA+0x08	R/W	Timer2 Interrupt Status Register	0x0000_0000
TDR2	TMR23_BA+0x0C	R	Timer2 Data Register	0x0000_0000
TCAP2	TMR23_BA+0x10	R	Timer2 Capture Data Register	0x0000_0000
TEXCON2	TMR23_BA+0x14	R/W	Timer2 External Control Register	0x0000_0000
TEXISR2	TMR23_BA+0x18	R/W	Timer2 External Interrupt Status Register	0x0000_0000
TCSR3	TMR23_BA+0x20	R/W	Timer3 Control and Status Register	0x0000_0005
TCMPR3	TMR23_BA+0x24	R/W	Timer3 Compare Register	0x0000_0000
TISR3	TMR23_BA+0x28	R/W	Timer3 Interrupt Status Register	0x0000_0000
TDR3	TMR23_BA+0x2C	R	Timer3 Data Register	0x0000_0000
TCAP3	TMR23_BA+0x30	R	Timer3 Capture Data Register	0x0000_0000

TEXCON3	TMR23_BA+0x34	R/W	Timer3 External Control Register	0x0000_0000
TEXISR3	TMR23_BA+0x38	R/W	Timer3 External Interrupt Status Register	0x0000_0000

6.8.7 Register Description

Timer Control Register (TCSR)

Register	Offset	R/W	Description	Reset Value
TCSR0	TMR01_BA+0x00	R/W	Timer0 Control and Status Register	0x0000_0005
TCSR1	TMR01_BA+0x20	R/W	Timer1 Control and Status Register	0x0000_0005
TCSR2	TMR23_BA+0x00	R/W	Timer2 Control and Status Register	0x0000_0005
TCSR3	TMR23_BA+0x20	R/W	Timer3 Control and Status Register	0x0000_0005

31	30	29	28	27	26	25	24
DBGACK_TMR	CEN	IE	MODE[1:0]		CRST	CACT	CTB
23	22	21	20	19	18	17	16
WAKE_EN	Reserved						TDR_EN
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
PRESCALE[7:0]							

Bits	Description	
[31]	DBGACK_TMR	ICE Debug Mode Acknowledge Disable Bit (Write Protect) 0 = ICE debug mode acknowledgement effects TIMER counting. TIMER counter will be held while CPU is held by ICE. 1 = ICE debug mode acknowledgement Disabled. TIMER counter will keep going no matter CPU is held by ICE or not.
[30]	CEN	Timer Enable Bit 0 = Stops/Suspends counting. 1 = Starts counting. Note1: In stop status, and then set CEN to 1 will enable the 24-bit up counter to keep counting from the last stop counting value. Note2: This bit is auto-cleared by hardware in one-shot mode (TCSR [28:27] = 00) when the timer interrupt flag TIF (TISR[0]) is generated.
[29]	IE	Interrupt Enable Bit 0 = Timer Interrupt function Disabled. 1 = Timer Interrupt function Enabled. If this bit is enabled, when the timer interrupt flag TIF (TISR[0]) is set to 1, the timer interrupt signal is generated and inform to CPU.

[28:27]	MODE	Timer Operating Mode 00 = The Timer controller is operated in One-shot mode. 01 = The Timer controller is operated in Periodic mode. 10 = The Timer controller is operated in Toggle-output mode. 11 = The Timer controller is operated in Continuous Counting mode.
[26]	CRST	Timer Reset 0 = No effect. 1 = Reset 8-bit prescale counter, 24-bit up counter value and CEN bit if CACT is 1.
[25]	CACT	Timer Active Status (Read Only) This bit indicates the 24-bit up counter status. 0 = 24-bit up counter is not active. 1 = 24-bit up counter is active.
[24]	CTB	Counter Mode Enable Bit This bit is for external counting pin function enabled. When timer is used as an event counter, this bit should be set to 1 and select HCLK as timer clock source. Please refer to 6.8.5.6 for detail description. 0 = External counter mode Disabled. 1 = External counter mode Enabled.
[23]	WAKE_EN	Wake Up Function Enable Bit 0 = Wake-up trigger event Disabled. 1 = Wake-up trigger event Enabled.
[22:17]	Reserved	Reserved.
[16]	TDR_EN	Data Load Enable Bit When TDR_EN is set, TDR (Timer Data Register) will be updated continuously with the 24-bit up-timer value as the timer is counting. 0 = Timer Data Register update Disabled. 1 = Timer Data Register update Enabled while Timer counter is active.
[15:8]	Reserved	Reserved.
[7:0]	PRESCALE	Prescale Counter Timer input clock source is divided by (PRESCALE+1) before it is fed to the Timer up counter. If this field is 0 (PRESCALE = 0), then there is no scaling.

Timer Compare Register (TCMPR)

Register	Offset	R/W	Description	Reset Value
TCMPR0	TMR01_BA+0x04	R/W	Timer0 Compare Register	0x0000_0000
TCMPR1	TMR01_BA+0x24	R/W	Timer1 Compare Register	0x0000_0000
TCMPR2	TMR23_BA+0x04	R/W	Timer2 Compare Register	0x0000_0000
TCMPR3	TMR23_BA+0x24	R/W	Timer3 Compare Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
TCMP [23:16]							
15	14	13	12	11	10	9	8
TCMP [15:8]							
7	6	5	4	3	2	1	0
TCMP [7:0]							

Bits	Description	
[31:24]	Reserved	Reserved.
[23:0]	TCMP	Timer Compared Value TCMP is a 24-bit compared value register. When the internal 24-bit up counter value is equal to TCMP value, the TIF flag will set to 1. Time-out period = (Period of Timer clock input) * (8-bit PRESCALE + 1) * (24-bit TCMP). Note1: Never write 0x0 or 0x1 in TCMP field, or the core will run into unknown state. Note2: When timer is operating at continuous counting mode, the 24-bit up counter will keep counting continuously even if user writes a new value into TCMP field. But if timer is operating at other modes, the 24-bit up counter will restart counting and using newest TCMP value to be the timer compared value if user writes a new value into TCMP field.

Timer Interrupt Status Register (TISR)

Register	Offset	R/W	Description	Reset Value
TISR0	TMR01_BA+0x08	R/W	Timer0 Interrupt Status Register	0x0000_0000
TISR1	TMR01_BA+0x28	R/W	Timer1 Interrupt Status Register	0x0000_0000
TISR2	TMR23_BA+0x08	R/W	Timer2 Interrupt Status Register	0x0000_0000
TISR3	TMR23_BA+0x28	R/W	Timer3 Interrupt Status Register	0x0000_0000

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

Bits	Description	
[31:2]	Reserved	Reserved.
[1]	TWF	Timer Wake-Up Flag This bit indicates the interrupt wake-up flag status of Timer. 0 = Timer does not cause CPU wake-up. 1 = CPU wake-up from Idle or Power-down mode if Timer time-out interrupt signal generated. Note: This bit is cleared by writing 1 to it.
[0]	TIF	Timer Interrupt Flag This bit indicates the interrupt flag status of Timer while TDR value reaches to TCMP value. 0 = No effect. 1 = TDR value matches the TCMP value. Note: This bit is cleared by writing 1 to it.

Timer Data Register (TDR)

Register	Offset	R/W	Description	Reset Value
TDR0	TMR01_BA+0x0C	R	Timer0 Data Register	0x0000_0000
TDR1	TMR01_BA+0x2C	R	Timer1 Data Register	0x0000_0000
TDR2	TMR23_BA+0x0C	R	Timer2 Data Register	0x0000_0000
TDR3	TMR23_BA+0x2C	R	Timer3 Data Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
TDR[23:16]							
15	14	13	12	11	10	9	8
TDR[15:8]							
7	6	5	4	3	2	1	0
TDR[7:0]							

Bits	Description	
[31:24]	Reserved	Reserved.
[23:0]	TDR	Timer Data Register If TDR_EN (TCSR[16]) is set to 1, TDR register will be updated continuously to monitor 24-bit up counter value.

Timer Capture Data Register (TCAP)

Register	Offset	R/W	Description	Reset Value
TCAP0	TMR01_BA+0x10	R	Timer0 Capture Data Register	0x0000_0000
TCAP1	TMR01_BA+0x30	R	Timer1 Capture Data Register	0x0000_0000
TCAP2	TMR23_BA+0x10	R	Timer2 Capture Data Register	0x0000_0000
TCAP3	TMR23_BA+0x30	R	Timer3 Capture Data Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
TCAP[23:16]							
15	14	13	12	11	10	9	8
TCAP[15:8]							
7	6	5	4	3	2	1	0
TCAP[7:0]							

Bits	Description	
[31:24]	Reserved	Reserved.
[23:0]	TCAP	Timer Capture Data Register When TEXIF (TEXISR[0]) flag and RSTCAPSEL (TEXCON[4]) is set to 1, the current TDR value will be auto-loaded into this TCAP filed immediately.

Timer External Control Register (TEXCON)

Register	Offset	R/W	Description	Reset Value
TEXCON0	TMR01_BA+0x14	R/W	Timer0 External Control Register	0x0000_0000
TEXCON1	TMR01_BA+0x34	R/W	Timer1 External Control Register	0x0000_0000
TEXCON2	TMR23_BA+0x14	R/W	Timer2 External Control Register	0x0000_0000
TEXCON3	TMR23_BA+0x34	R/W	Timer3 External Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
TCDB	TEXDB	TEXIEN	RSTCAPSEL	TEXEN	TEX_EDGE		TX_PHASE

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	TCDB	Timer External Counter Input Pin De-Bounce Enable Bit 0 = TMx pin de-bounce Disabled. 1 = TMx pin de-bounce Enabled. If this bit is enabled, the edge detection of TMx pin is detected with de-bounce circuit.
[6]	TEXDB	Timer External Capture Input Pin De-Bounce Enable Bit 0 = TMx_EXT pin de-bounce Disabled. 1 = TMx_EXT pin de-bounce Enabled. If this bit is enabled, the edge detection of TMx_EXT pin is detected with de-bounce circuit.
[5]	TEXIEN	Timer External Capture Interrupt Enable Bit 0 = TMx_EXT pin detection Interrupt Disabled. 1 = TMx_EXT pin detection Interrupt Enabled. If TEXIEN enabled, Timer will raise an external capture interrupt signal and inform to CPU while TEXIF flag is set to 1.
[4]	RSTCAPSEL	Timer External Reset Counter / Timer External Capture Mode Selection 0 = Transition on TMx_EXT pin is using to save the TDR value into TCAP.(event capture function) 1 = Transition on TMx_EXT pin is using to reset the 24-bit up counter.(event reset counter function)
[3]	TEXEN	Timer External Pin Function Enable Bit This bit enables the RSTCAPSEL function on the TMx_EXT pin. 0 = RSTCAPSEL function of TMx_EXT pin will be ignored.

		1 = RSTCAPSEL function of TMx_EXT pin is active.
[2:1]	TEX_EDGE	Timer External Capture Pin Edge Detect Selection 00 = A 1 to 0 transition on TMx_EXT pin will be detected. 01 = A 0 to 1 transition on TMx_EXT pin will be detected. 10 = Either 1 to 0 or 0 to 1 transition on TMx_EXT pin will be detected. 11 = Reserved.
[0]	TX_PHASE	Timer External Count Pin Phase Detect Selection This bit indicates the detection phase of TMx_EXT pin. 0 = A falling edge of TMx_EXT pin will be counted. 1 = A rising edge of TMx_EXT pin will be counted.

Timer External Interrupt Status Register (TEXISR)

Register	Offset	R/W	Description	Reset Value
TEXISR0	TMR01_BA+0x18	R/W	Timer0 External Interrupt Status Register	0x0000_0000
TEXISR1	TMR01_BA+0x38	R/W	Timer1 External Interrupt Status Register	0x0000_0000
TEXISR2	TMR23_BA+0x18	R/W	Timer2 External Interrupt Status Register	0x0000_0000
TEXISR3	TMR23_BA+0x38	R/W	Timer3 External Interrupt Status Register	0x0000_0000

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

Bits	Description
[31:1]	Reserved
[0]	Timer External Capture Interrupt Flag This bit indicates the external capture interrupt flag status. When TEXEN (TEXCON[3]) enabled, TMx_EXT pin selected as external capture function, and a transition on TMx_EXT pin matched the TEX_EDGE (TEXCON[2:1]) setting, this flag will set to 1 by hardware. 0 = TMx_EXT pin interrupt did not occur. 1 = TMx_EXT pin interrupt occurred. Note: This bit is cleared by writing 1 to it.

6.9 PWM Generator and Capture Timer (PWM)

6.9.1 Overview

The NuMicro™ NUC230/240 series has 2 sets of PWM group supporting a total of 4 sets of PWM generators that can be configured as 8 independent PWM outputs, PWM0~PWM7, or as 4 complementary PWM pairs, (PWM0, PWM1), (PWM2, PWM3), (PWM4, PWM5) and (PWM6, PWM7) with 4 programmable Dead-zone generators.

Each PWM generator has one 8-bit prescaler, one clock divider with 5 divided frequencies (1, 1/2, 1/4, 1/8, 1/16), two PWM Timers including two clock selectors, two 16-bit PWM counters for PWM period control, two 16-bit comparators for PWM duty control and one Dead-zone generator. The 4 sets of PWM generators provide eight independent PWM interrupt flags set by hardware when the corresponding PWM period down counter reaches 0. Each PWM interrupt source with its corresponding enable bit can cause CPU to request PWM interrupt. The PWM generators can be configured as one-shot mode to produce only one PWM cycle signal or auto-reload mode to output PWM waveform continuously.

When DZEN01 (PCR[4]) is set, PWM0 and PWM1 perform complementary PWM paired function; the paired PWM period, duty and Dead-time are determined by PWM0 timer and Dead-zone generator 0. Similarly, the complementary PWM pairs of (PWM2, PWM3), (PWM4, PWM5) and (PWM6, PWM7) are controlled by PWM2, PWM4 and PWM6 timers and Dead-zone generator 2, 4 and 6, respectively. Refer to Figure 6-30 and Figure 6-37 for the architecture of PWM Timers.

To prevent PWM driving output pin with unsteady waveform, the 16-bit period down counter and 16-bit comparator are implemented with double buffer. When user writes data to counter/comparator buffer registers the updated value will be load into the 16-bit down counter/comparator at the time down counter reaching 0. The double buffering feature avoids glitch at PWM outputs.

When the 16-bit period down counter reaches 0, the interrupt request is generated. If PWM-timer is set as auto-reload mode, when the down counter reaches 0, it is reloaded with PWM Counter Register (CNRx) automatically then start decreasing, repeatedly. If the PWM-timer is set as one-shot mode, the down counter will stop and generate one interrupt request when it reaches 0.

The value of PWM counter comparator is used for pulse high width modulation. The counter control logic changes the output to high level when down-counter value matches the value of compare register.

The alternate feature of the PWM-timer is digital input Capture function. If Capture function is enabled the PWM output pin is switched as capture input mode. The Capture0 and PWM0 share one timer which is included in PWM0 and the Capture1 and PWM1 share PWM1 timer, and etc. Therefore user must setup the PWM-timer before enable Capture feature. After capture feature is enabled, the capture always latched PWM-counter to Capture Rising Latch Register (CRLR) when input channel has a rising transition and latched PWM-counter to Capture Falling Latch Register (CFLR) when input channel has a falling transition. Capture channel 0 interrupt is programmable by setting CRL_IE0 (CCR0[1]) (Rising latch Interrupt enable) and CFL_IE0 (CCR0[2]) (Falling latch Interrupt enable) to decide the condition of interrupt occur. Capture channel 1 has the same feature by setting CRL_IE1 (CCR0[17]) and CFL_IE1 (CCR0[18]). And capture channel 2 to channel 3 on each group have the same feature by setting the corresponding control bits in CCR2. For each group, whenever Capture issues Interrupt 0/1/2/3, the PWM counter 0/1/2/3 will be reload at this moment.

The maximum captured frequency that PWM can capture is confined by the capture interrupt latency. When capture interrupt occurred, software will do at least three steps, including: Read PIIR to get interrupt source and Read CRLRx/CFLRx(x=0~3) to get capture value and finally write 1 to clear PIIR to 0. If interrupt latency will take time T0 to finish, the capture signal mustn't transition during this interval (T0). In this case, the maximum capture frequency will be 1/T0. For example:

HCLK = 50 MHz, PWM_CLK = 25 MHz, Interrupt latency is 900 ns

So the maximum capture frequency will be $1/900\text{ns} \approx 1000\text{ kHz}$

6.9.2 Features

6.9.2.1 PWM Function:

- Up to 2 PWM groups (PWMA/PWMB) to support 8 PWM channels or 4 complementary PWM paired channels
- Each PWM group has two PWM generators with each PWM generator supporting one 8-bit prescaler, two clock divider, two PWM-timers, one Dead-zone generator and two PWM outputs.
- Up to 16-bit resolution
- PWM Interrupt request synchronized with PWM period
- One-shot or Auto-reload mode
- Edge-aligned type or Center-aligned type option
- PWM trigger ADC start-to-conversion

6.9.2.2 Capture Function:

- Timing control logic shared with PWM Generators
- Supports 8 Capture input channels shared with 8 PWM output channels
- Each channel supports one rising latch register (CRLR), one falling latch register (CFLR) and Capture interrupt flag (CAPIFx)

6.9.3 Block Diagram

Figure 6-30 to Figure 6-37 illustrate the architecture of PWM in pair (e.g. PWM-Timer 0/1 are in one pair and PWM-Timer 2/3 are in another one).

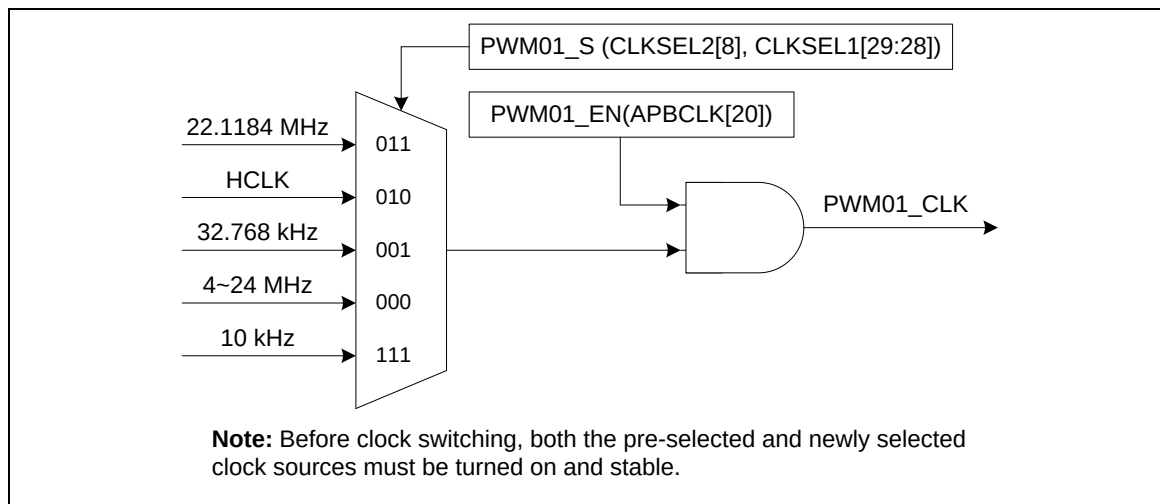


Figure 6-30 PWM Generator 0 Clock Source Control

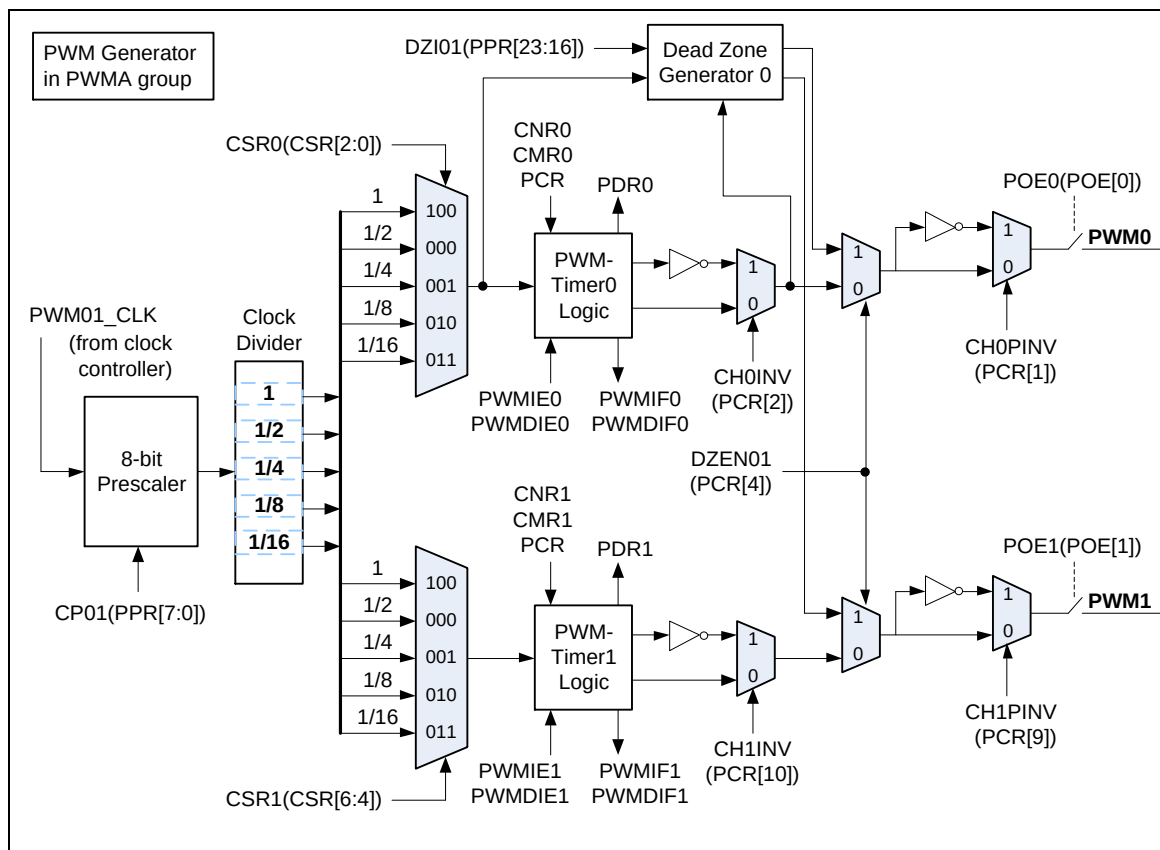


Figure 6-31 PWM Generator 0 Architecture Diagram

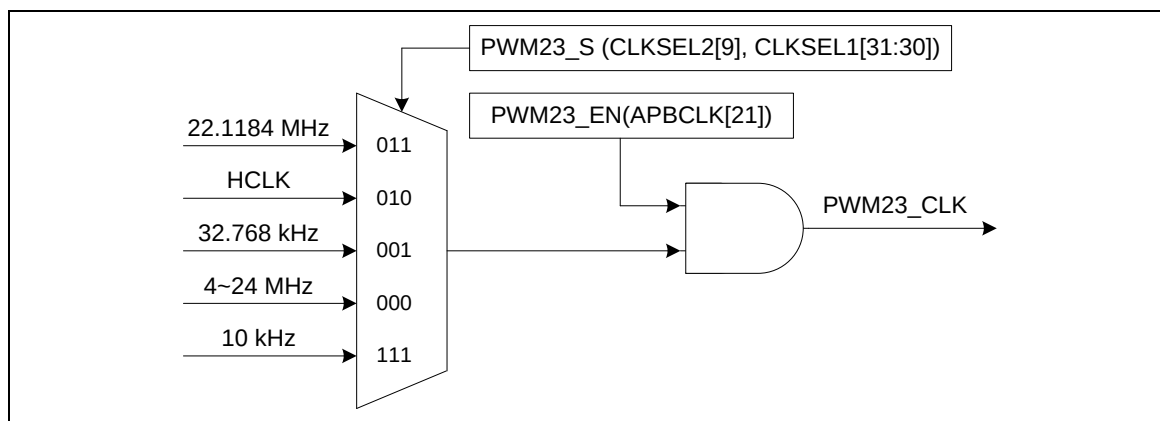


Figure 6-32 PWM Generator 2 Clock Source Control

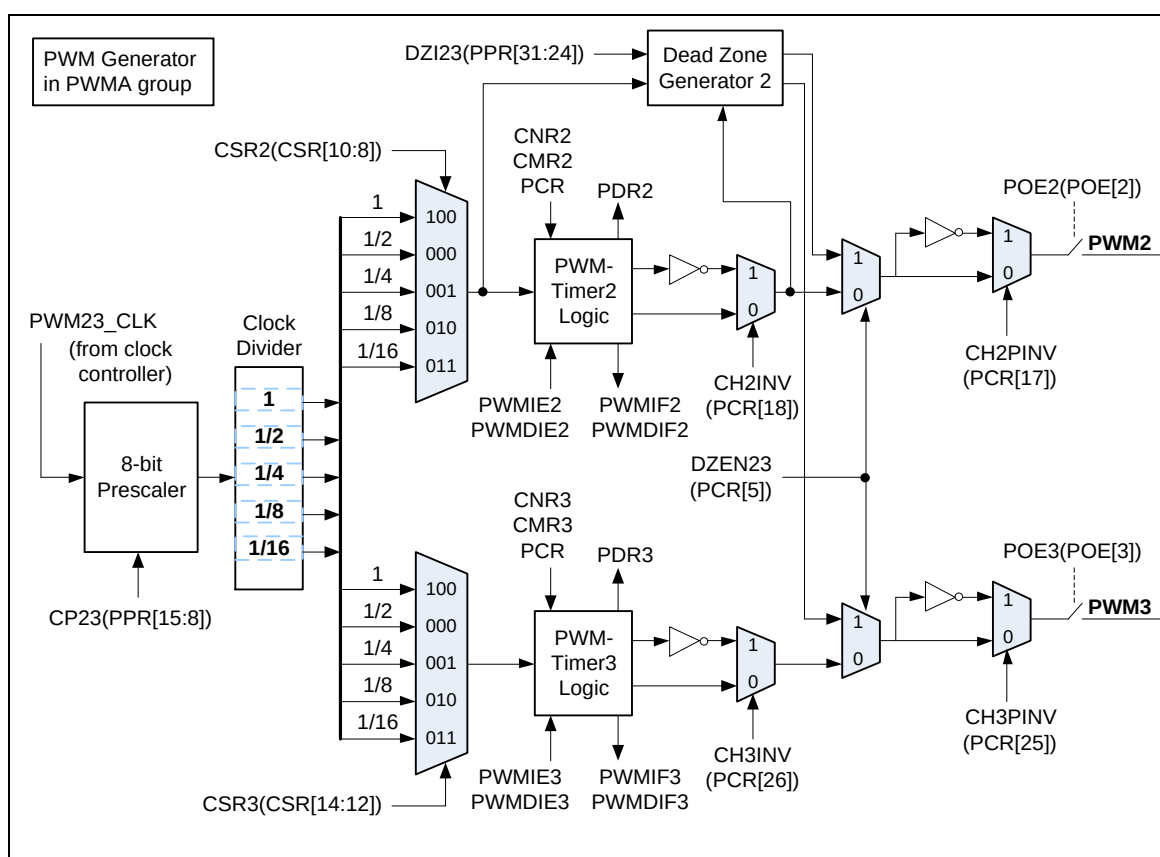


Figure 6-33 PWM Generator 2 Architecture Diagram

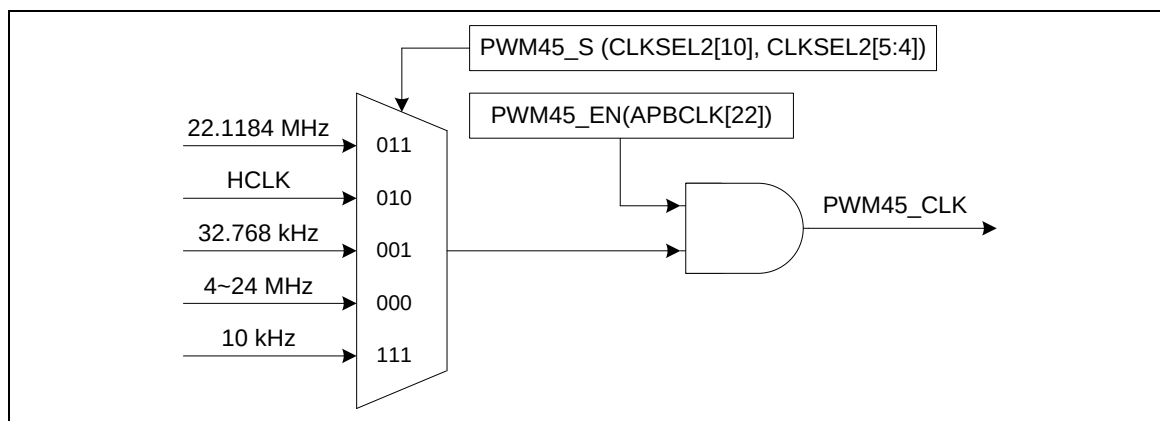


Figure 6-34 PWM Generator 4 Clock Source Control

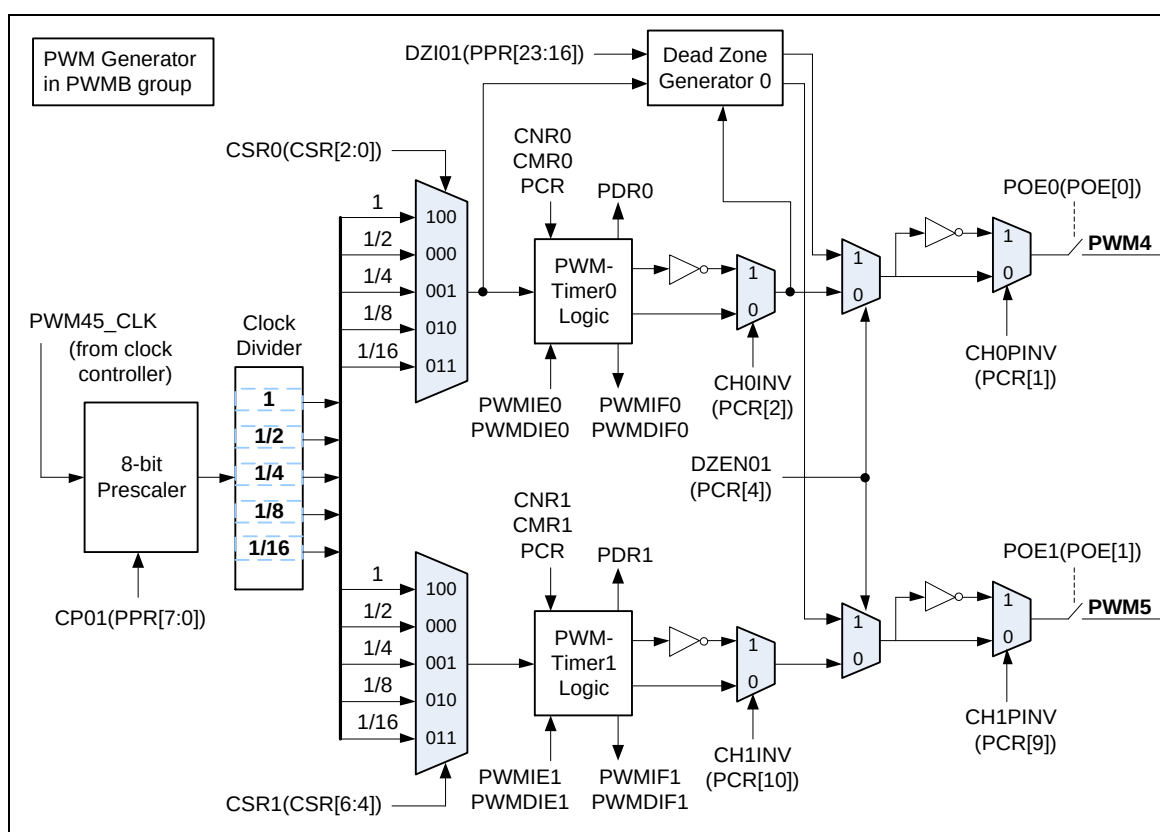


Figure 6-35 PWM Generator 4 Architecture Diagram

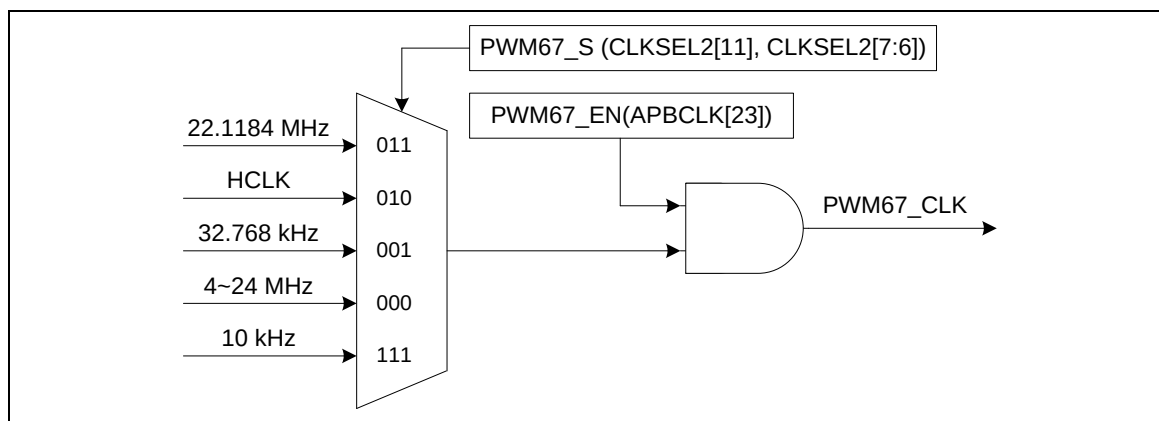


Figure 6-36 PWM Generator 6 Clock Source Control

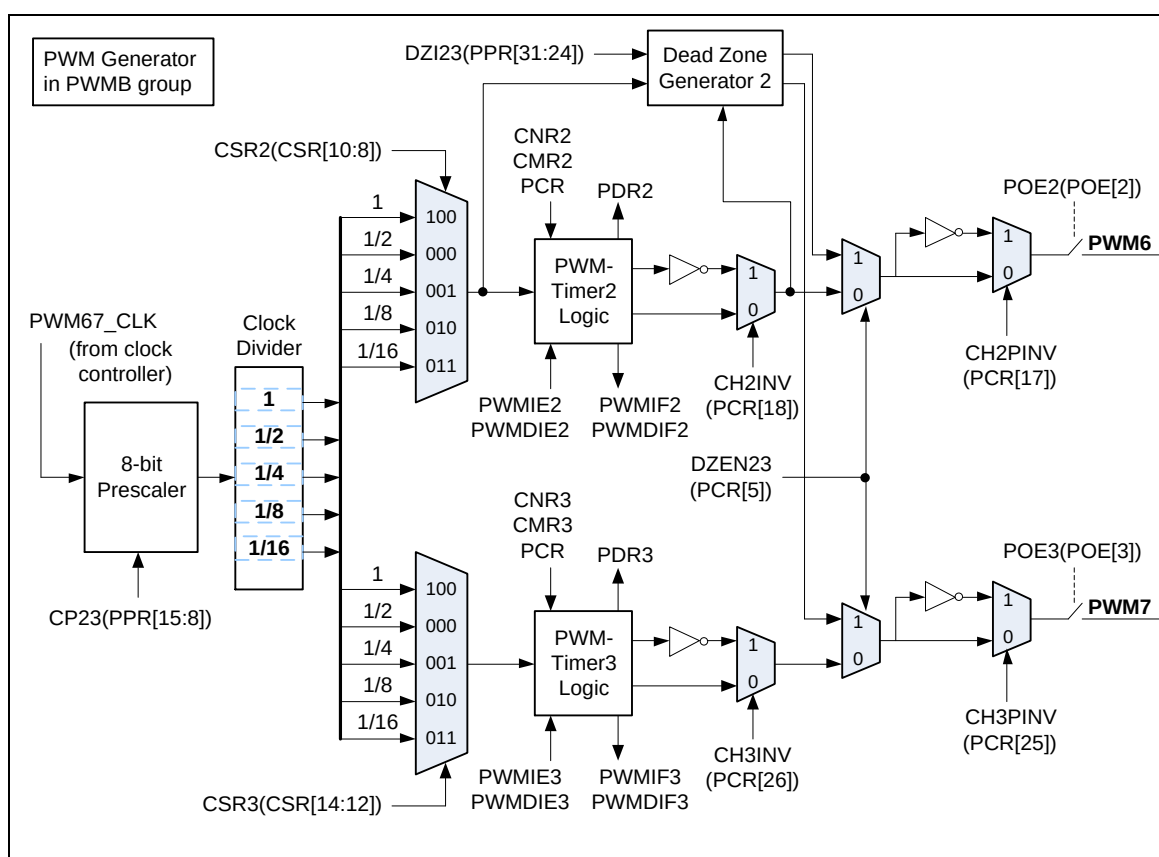


Figure 6-37 PWM Generator 6 Architecture Diagram

6.9.4 Basic Configuration

The PWM pin functions are configured in GPA_MFP, GPB_MFP and GPE_MFP registers.

The PWM clock can be enabled in APBCLK[23:20]. The PWM clock source is selected by CLKSEL1[31:28], CLKSEL2[7:4] and CLKSEL2[11:8].

6.9.5 Functional Description

6.9.5.1 PWM-Timer Operation

The PWM controller supports 2 operation types: Edge-aligned and Center-aligned type.

6.9.5.2 Edge-aligned PWM (down-counter)

In Edge-aligned PWM Output mode, the 16 bits PWM counter will starts down-counting from CNRn to match with the value of the duty cycle CMRn (old), when this happen it will toggle the PWMn generator output to low. The counter will continue down-counting to 0, at this moment, it toggles the PWMn generator output to high and CMRn(new) and CNRn(new) are updated with CHnMODE=1 and request the PWM interrupt if PWM interrupt is enabled(PWMIEn (PIER[3:0]) = 1).

The PWM period and duty control are configured by PWM down-counter register (CNR) and PWM comparator register (CMR). The PWM-timer timing operation is shown in Figure 6-39. The pulse width modulation follows the formula below and the legend of PWM-Timer Comparator is shown as Figure 6-38. Note that the corresponding GPIO pins must be configured as PWM function (enable POE and disable CAPENR) for the corresponding PWM channel.

- PWM frequency = $\text{PWMxy\_CLK} / [(\text{prescale}+1) * (\text{clock divider}) * (\text{CNR}+1)]$; where xy, could be 01, 23, 45 or 67, depends on selected PWM channel.
- Duty ratio = $(\text{CMR}+1) / (\text{CNR}+1)$
- $\text{CMR} \geq \text{CNR}$: PWM output is always high
- $\text{CMR} < \text{CNR}$: PWM low width = $(\text{CNR}-\text{CMR})$ unit^[1]; PWM high width = $(\text{CMR}+1)$ unit
- $\text{CMR} = 0$: PWM low width = (CNR) unit; PWM high width = 1 unit

Note [1]: unit = one PWM clock cycle.

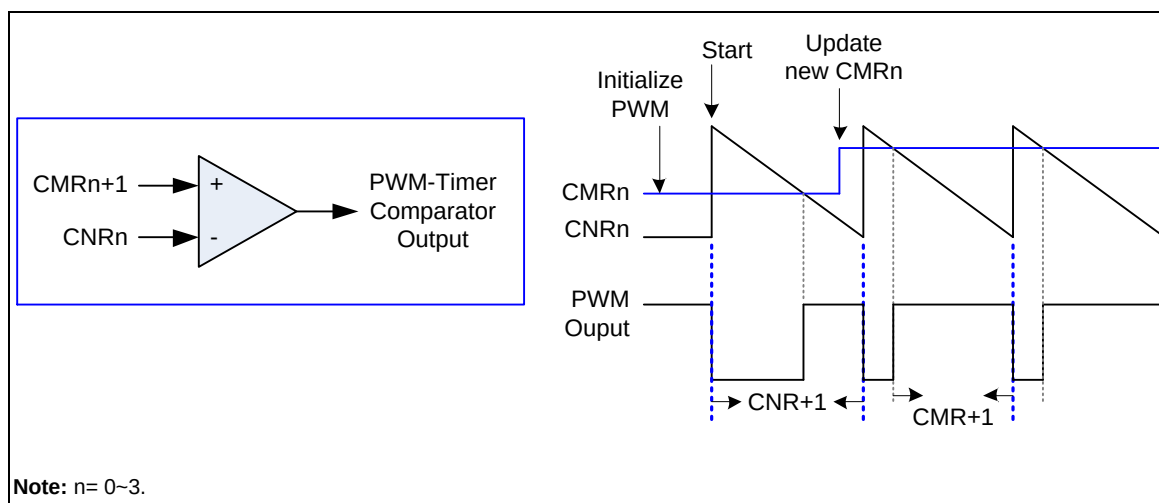


Figure 6-38 Legend of Internal Comparator Output of PWM-Timer

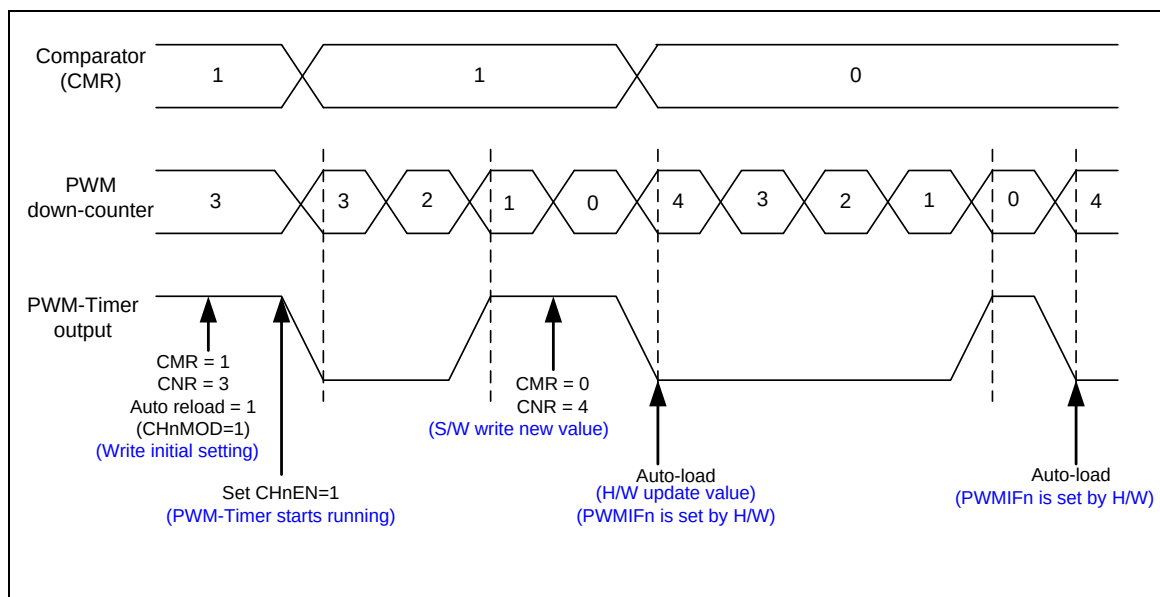


Figure 6-39 PWM-Timer Operation Timing

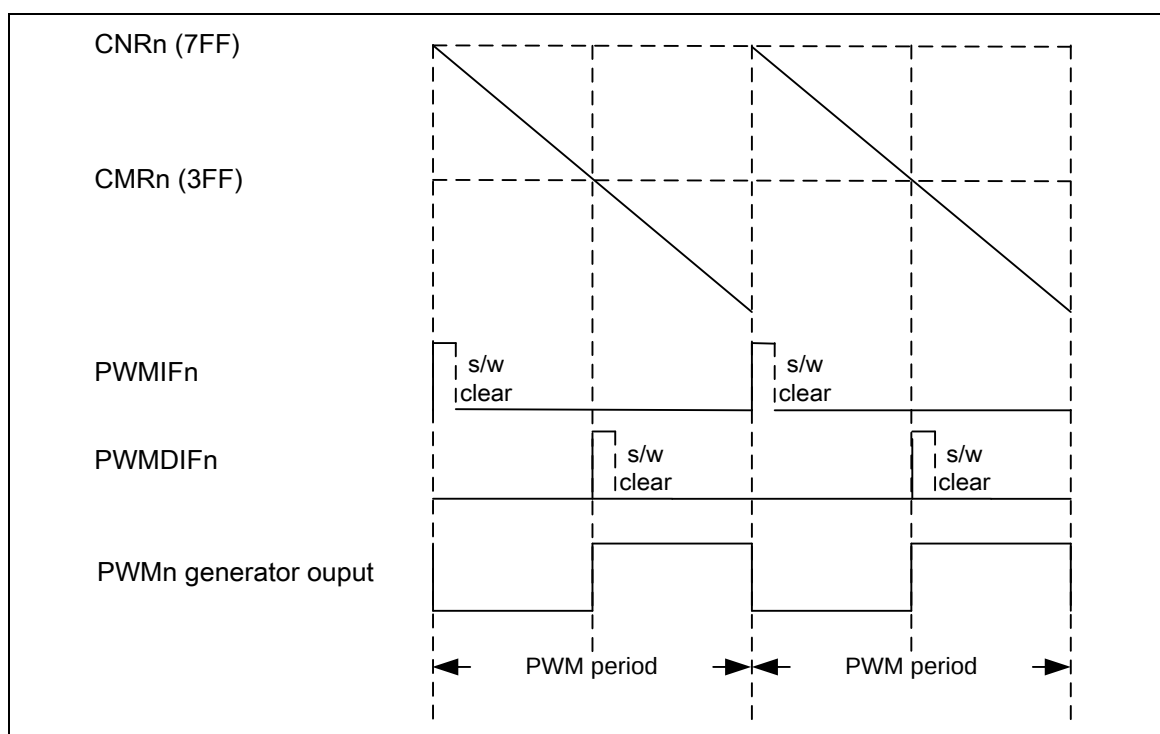


Figure 6-40 PWM Edge-aligned Interrupt Generate Timing Waveform

6.9.5.3 Center-aligned PWM (up/down-counter)

The Center-aligned PWM signals are produced by the module when the PWM time base is configured in an Up/Down Counting mode. The PWM counter will start counting-up from 0 to match the value of CMRn (old); this will cause the toggling of the PWMn generator output to low. The counter will continue counting to match with the CNRn (old). Upon reaching this states counter is configured automatically to down counting, when PWM counter matches the CMRn (old) value again the PWMn generator output toggles to high. Once the PWM counter underflows it will update the PWM period register CNRn(new) and duty cycle register CMRn(new) with CHnMODE = 1.

In Center-aligned type, the PWM period interrupt is requested at down-counter underflow if INTxxTYPE (PIER[17:16]) = 0, i.e. at start (end) of each PWM cycle or at up-counter matching with CNRn if INTxxTYPE (PIER[17:16]) = 1, i.e. at center point of PWM cycle.

- PWM frequency = $\text{PWMxy\_CLK} / [(\text{prescale} + 1) * (\text{clock divider}) * (\text{CNR} + 1)]$; where xy, could be 01, 23, 45 or 67, depends on selected PWM channel.
- Duty ratio = $[(2 \times \text{CMR}) + 1] / [2 \times (\text{CNR} + 1)]$
- $\text{CMR} > \text{CNR}$: PWM output is always high
- $\text{CMR} \leq \text{CNR}$: PWM low width = $2 \times (\text{CNR} - \text{CMR}) + 1$ unit^[1]; PWM high width = $(2 \times \text{CMR}) + 1$ unit
- $\text{CMR} = 0$: PWM low width = $2 \times \text{CNR} + 1$ unit; PWM high width = 1 unit

Note [1]: unit = one PWM clock cycle.

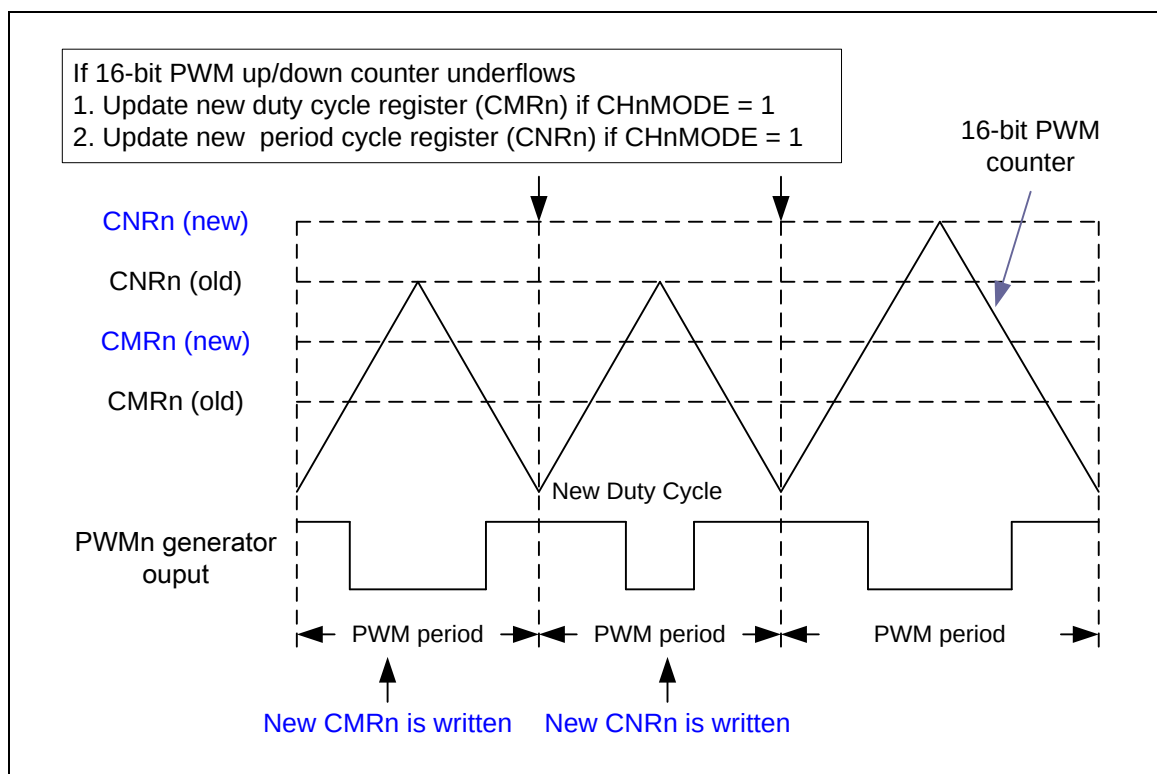


Figure 6-41 Center-aligned Type Output Waveform

In Center-aligned type, system can generate period interrupt, at two specified timings. PWM period interrupt is generated at counter equals zero on down-count if INTxxTYPE (PIER[17:16]) = 0 or at counter equals CNRn on up-count if INTxxTYPE (PIER[17:16]) = 1, i.e. at center point of

PWM cycle.

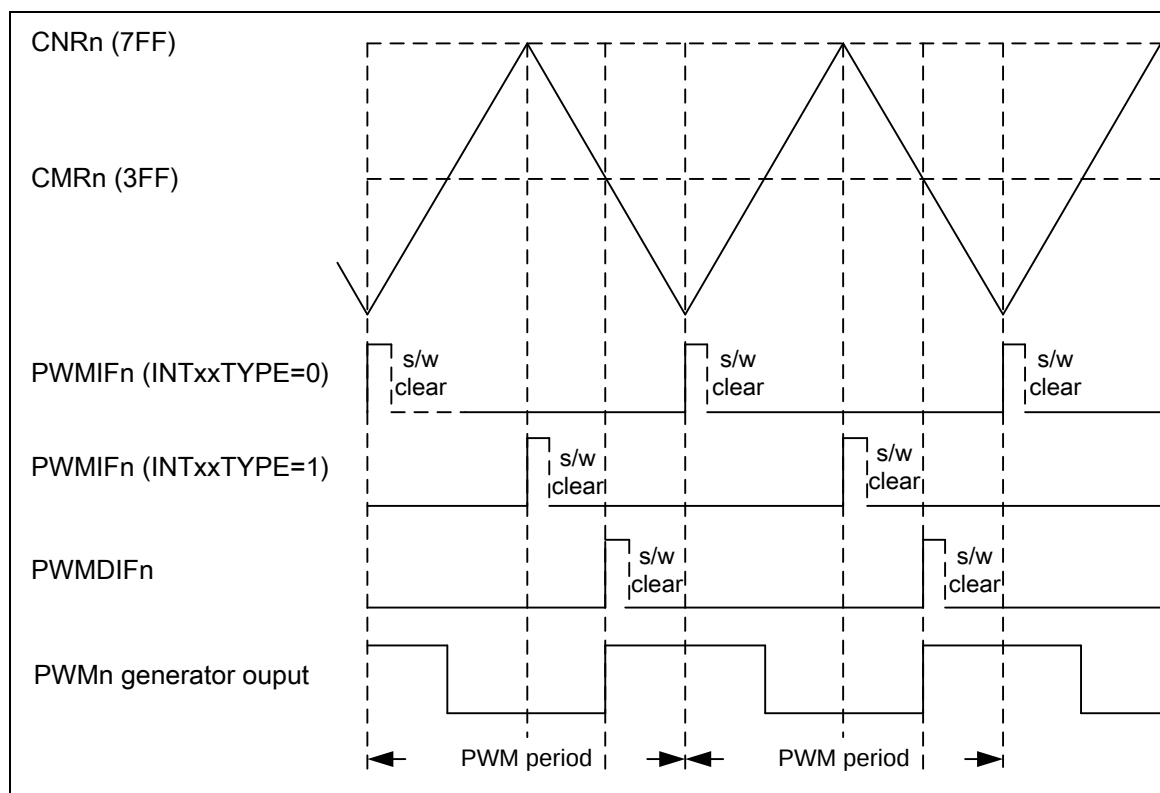


Figure 6-42 PWM Center-aligned Interrupt Generate Timing Waveform

6.9.5.4 PWM Double Buffering, Auto-reload and One-shot Operation

PWM Timers have double buffering function and the reload value is updated at the start of next period without affecting current timer operation. The PWM counter value can be written into CNRx and current PWM counter value can be read from PDRx.

PWM0 will operate at One-shot mode if CH0MOD (PCR[3]) bit is set to 0, and operate at Auto-reload mode if CH0MOD (PCR[3]) bit is set to 1. It is recommend that switch PWM0 operating mode before set CH0EN (PCR[0]) bit to 1 to enable PWM0 counter start running because the content of CNR0 and CMR0 will be cleared to 0 to reset the PWM0 period and duty setting when PWM0 operating mode is changed. As PWM0 operate at One-shot mode, CMR0 and CNR0 should be written first and then set CH0EN (PCR[0]) bit to 1 to enable PWM0 counter start running. After PWM0 counter down count from CNR0 value to 0, CNR0 and CMR0 will be cleared to 0 by hardware and PWM counter will be held. Software need to write new CMR0 and CNR0 value to set next one-shot period and duty. When re-start next one-shot operation, the CMR0 should be written first because PWM0 counter will auto re-start counting when CNR0 is written a non-zero value. As PWM0 operates at auto-reload mode, CMR0 and CNR0 should be written first and then set CH0EN (PCR[0]) bit to 1 to enable PWM0 counter start running. The value of CNR0 will reload to PWM0 counter when it down count reaches 0. If CNR0 is set to 0, PWM0 counter will be held. PWM1~PWM7 performs the same function as PWM0.

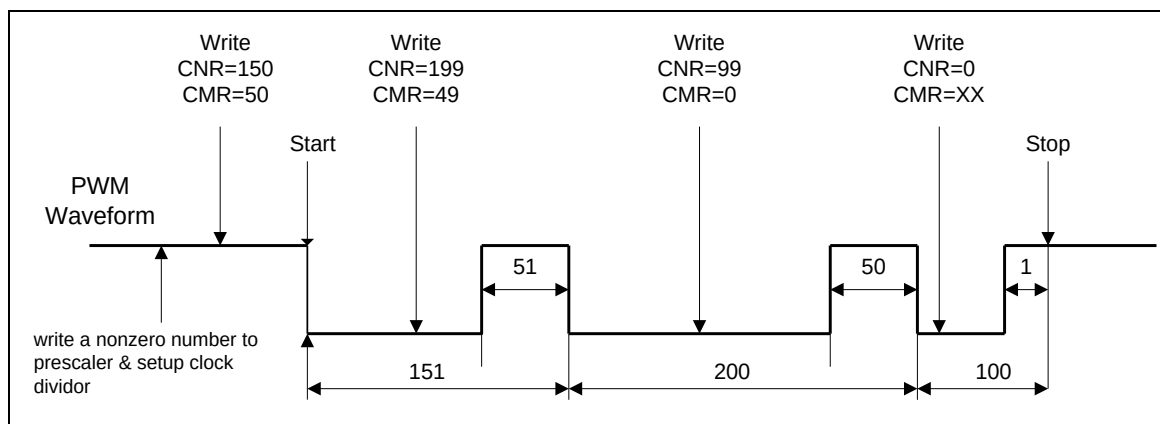


Figure 6-43 PWM Double Buffering Illustration

6.9.5.5 Modulate Duty Ratio

The double buffering function allows CMRn written at any point in current cycle. The loaded value will take effect from next cycle.

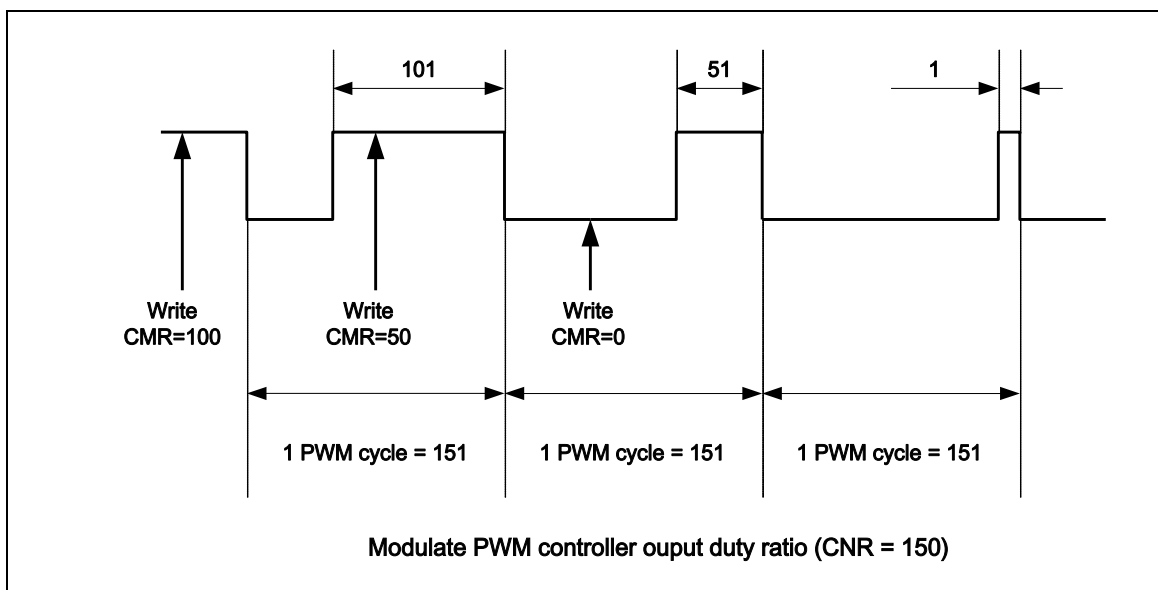


Figure 6-44 PWM Controller Output Duty Ratio

6.9.5.6 Dead-Zone Generator

The PWM controller is implemented with Dead-zone generator. They are built for power device protection. This function generates a programmable time gap to delay PWM rising output. User can program DZlxx (PPR[31:16]) to determine the Dead-zone interval.

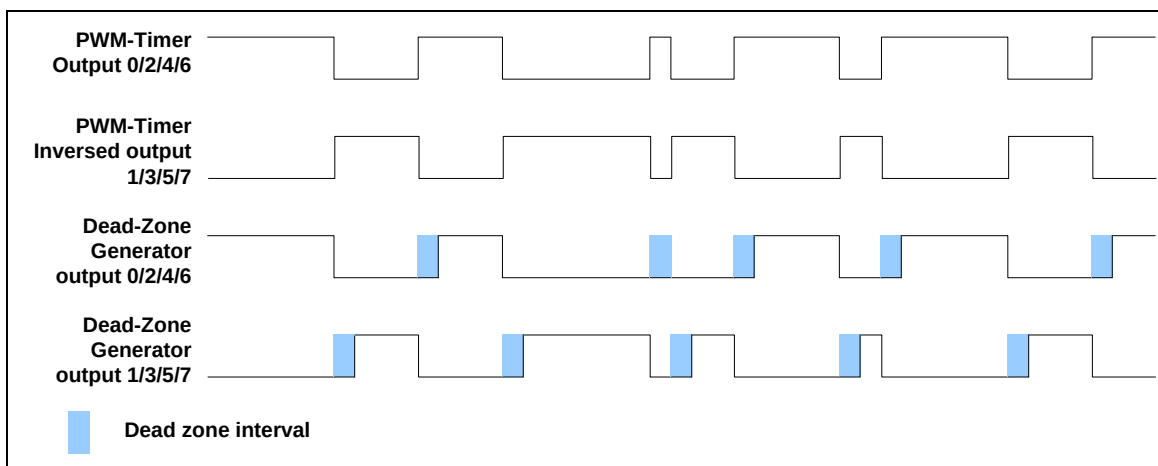


Figure 6-45 Paired-PWM Output with Dead-zone Generation Operation

6.9.5.7 PWM Center-aligned Trigger ADC Function

PWM can trigger ADC to start conversion when PWM counter up count to CNR in Center-aligned type by setting PWMnTEN (TCON[3:0]) to "1".

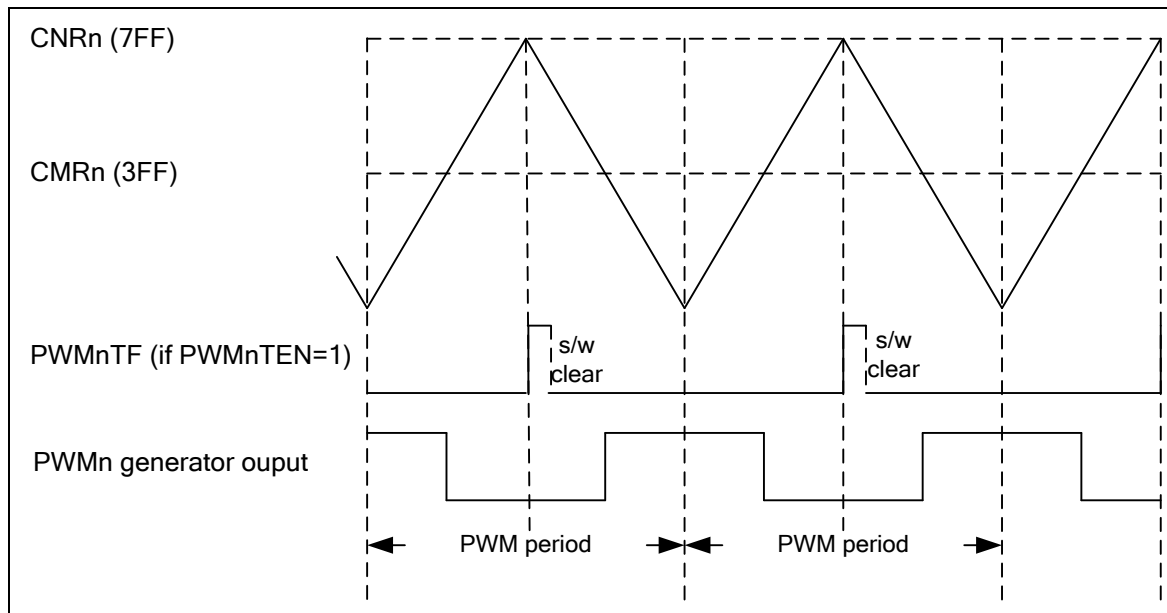


Figure 6-46 PWM trigger ADC to conversion in Center-aligned type Timing Waveform

6.9.5.8 Capture Operation

The Capture 0 and PWM 0 share one timer that included in PWM 0; and the Capture 1 and PWM 1 share another timer, and etc. The capture always latches PWM-counter to CRLRn when input channel has a rising transition and latches PWM-counter to CFLRn when input channel has a falling transition. Capture channel 0 interrupt is programmable by setting CRL_IE0 (CCR0[1]) (Rising latch Interrupt enable) and CFL_IE0 (CCR0[2]) (Falling latch Interrupt enable) to decide the condition of interrupt occur. Capture channel 1 has the same feature by setting CRL_IE1 (CCR0[17]) and CFL_IE1 (CCR0[18]), and etc. Whenever the Capture controller issues a capture interrupt, the corresponding PWM counter will be reloaded with CNRn at this moment. Note that the corresponding GPIO pins must be configured as capture function (POE disabled and CAPENR enabled) for the corresponding capture channel.

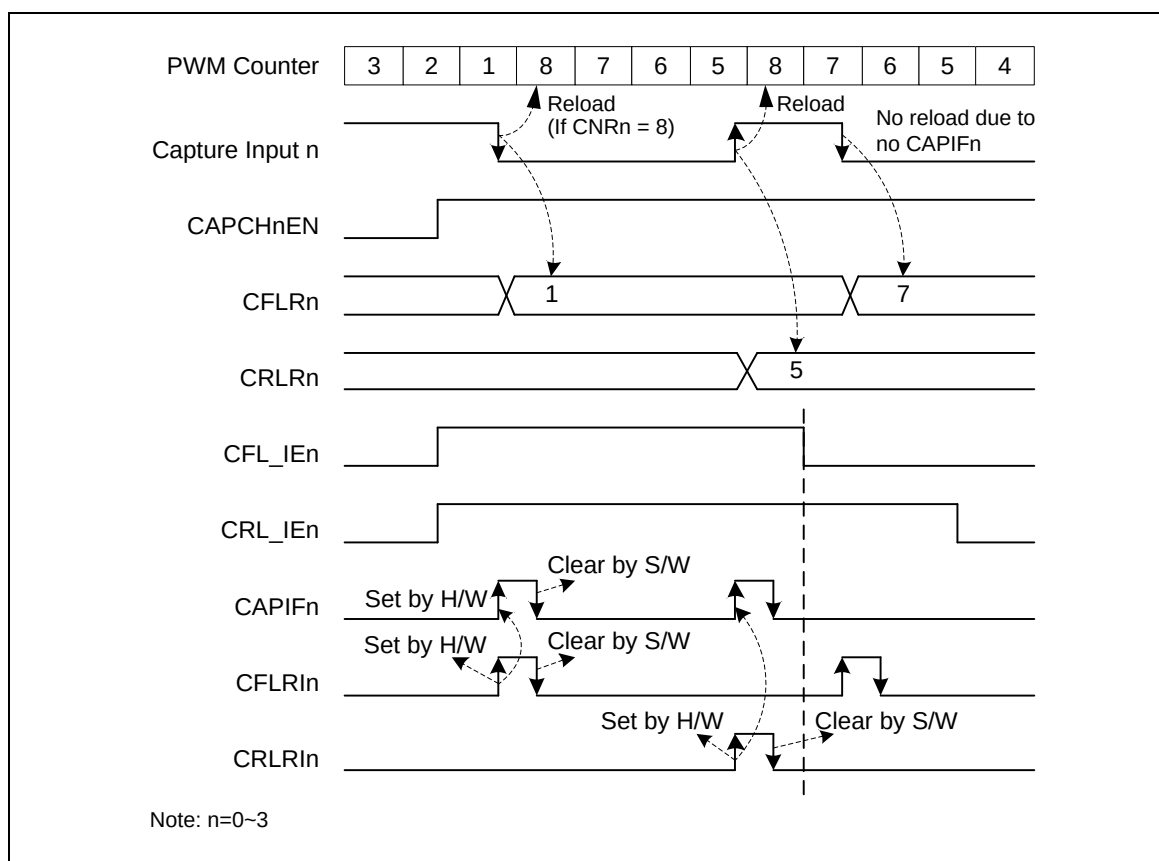


Figure 6-47 Capture Operation Timing

In this case, the CNR is 8:

- The PWM counter will be reloaded with CNRn when a capture interrupt flag (CAPIFn) is set.
- The channel low pulse width is $(CNR + 1 - CRLR)$.
- The channel high pulse width is $(CNR + 1 - CFLR)$.

6.9.5.9 PWM-Timer Interrupt Architecture

There are eight PWM interrupts, PWM0_INT~PWM7_INT, which are divided into PWMA_INT and PWMB_INT for Advanced Interrupt Controller (AIC). PWM 0 and Capture 0 share one interrupt, PWM1 and Capture 1 share the same interrupt and so on. Therefore, PWM function and Capture

function in the same channel cannot be used at the same time. Figure 6-48 and Figure 5-48 demonstrates the architecture of PWM-Timer interrupts.

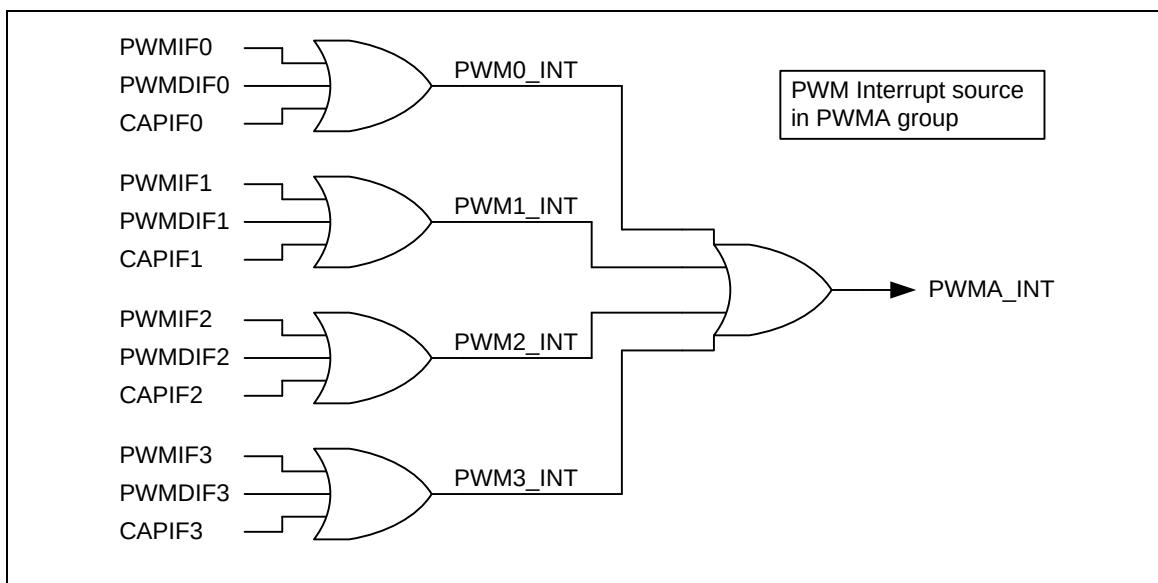


Figure 6-48 PWM Group A PWM-Timer Interrupt Architecture Diagram

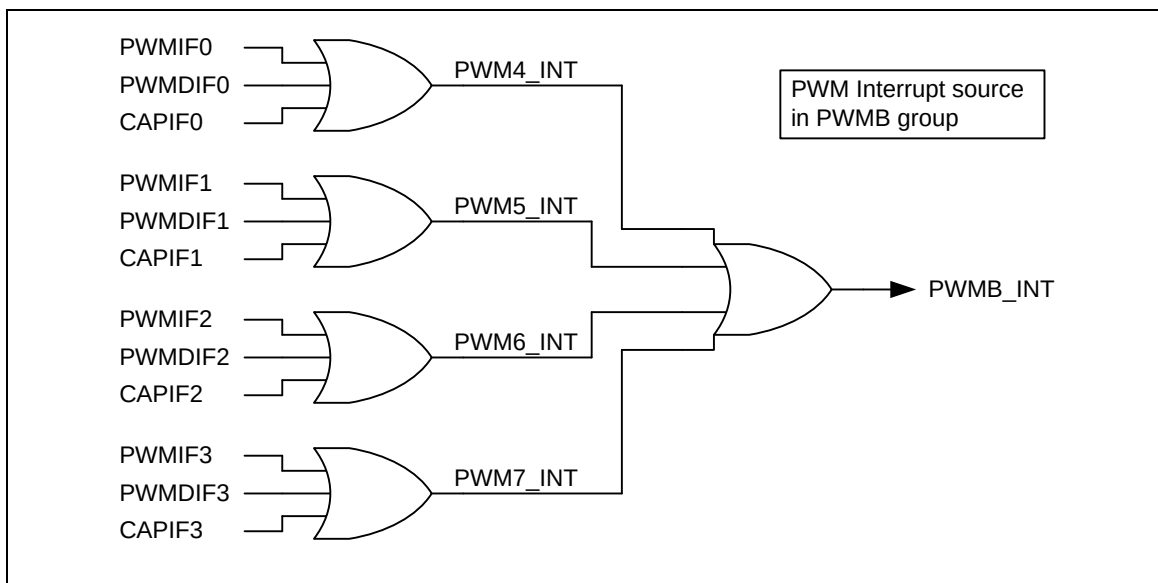


Figure 6-49 PWM Group B PWM-Timer Interrupt Architecture Diagram

6.9.5.10 PWM-Timer Start Procedure

The following procedure is recommended for starting a PWM drive.

1. Setup clock source divider select register (CSR)
2. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
3. Setup prescaler (PPR)
4. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
5. Setup inverter on/off, Dead-zone generator on/off, Auto-reload/One-shot mode and Stop PWM-timer (PCR)
6. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
7. Setup comparator register (CMR) for setting PWM duty.
8. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
9. Setup PWM down-counter register (CNR) for setting PWM period.
10. Setup interrupt enable register (PIER) (optional)
11. Setup corresponding GPIO pins as PWM function (enable POE and disable CAPENR) for the corresponding PWM channel.
12. Enable PWM timer start running (Set CHnEN = 1 in PCR)

6.9.5.11 Modify PWM counter register (CNR), comparator register (CMR), Clock prescaler(CP01/CP23) and PWM operation mode(CHnMOD in PCR register bit3) Procedure

The following procedure is recommended for modifying CNR/CMR/Clock prescaler/PWM operation mode.

1. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
2. Modify CMRn/CNRn/CHnMOD/CP01/CP23

6.9.5.12 PWM-Timer Re-Start Procedure in Single-shot mode

After PWM waveform is generated once in PWM One-shot mode, PWM-Timer will be stopped automatically and both of CNR and CMR will be cleared by hardware. Software must fill CMR and CNR value again to re-start another PWM one-shot waveform. The following procedure is recommended for re-starting PWM one-shot waveform.

1. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
2. Setup comparator register (CMR) for setting PWM duty.
3. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
4. Setup PWM down-counter register (CNR) for setting PWM period. After setup CNR, PWM wave will be generated.

6.9.5.13 PWM-Timer Stop Procedure

Method 1:

Set 16-bit counter (CNR) as 0, and monitor PDR (current value of 16-bit down-counter). When PDR reaches to 0, disable PWM-Timer (CHnEN in PCR). **(Recommended)**

Method 2:

Set 16-bit counter (CNR) as 0. When interrupt request happened, disable PWM-Timer (CHnEN in PCR). **(Recommended)**

Method 3:

Disable PWM-Timer directly ((CHnEN in PCR). **(Not recommended)**

The reason why method 3 is not recommended is that disable CHnEN will immediately stop PWM output signal and lead to change the duty of the PWM output, this may cause damage to the control circuit of motor

6.9.5.14 Capture Start Procedure

1. Setup clock source divider select register (CSR)
2. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
3. Setup prescaler (PPR)
4. Setup channel enabled, rising/falling interrupt enable and input signal inverter on/off (CCR0, CCR2)
5. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
6. Setup Auto-reload mode, Edge-aligned type and Stop PWM-timer (PCR)
7. Wait until SYNCBUSYn be set to 0 by hardware (if PWM clock source is not from HCLK)
8. Setup PWM down-counter (CNR)
9. Enable PWM timer start running (Set CHnEN = 1 in PCR)
10. Setup corresponding GPIO pins as capture function (disable POE and enable CAPENR) for the corresponding PWM channel.

6.9.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
PWM Base Address: • PWM group A PWMA_BA = 0x4004_0000 • PWM group B PWMB_BA = 0x4014_0000				
PPR	PWMA_BA+0x00 PWMB_BA+0x00	R/W	PWM Prescaler Register	0x0000_0000
CSR	PWMA_BA+0x04 PWMB_BA+0x04	R/W	PWM Clock Source Divider Select Register	0x0000_0000
PCR	PWMA_BA+0x08 PWMB_BA+0x08	R/W	PWM Control Register	0x0000_0000
CNR0	PWMA_BA+0x0C PWMB_BA+0x0C	R/W	PWM Counter Register 0	0x0000_0000
CMR0	PWMA_BA+0x10 PWMB_BA+0x10	R/W	PWM Comparator Register 0	0x0000_0000
PDR0	PWMA_BA+0x14 PWMB_BA+0x14	R	PWM Data Register 0	0x0000_0000
CNR1	PWMA_BA+0x18 PWMB_BA+0x18	R/W	PWM Counter Register 1	0x0000_0000
CMR1	PWMA_BA+0x1C PWMB_BA+0x1C	R/W	PWM Comparator Register 1	0x0000_0000
PDR1	PWMA_BA+0x20 PWMB_BA+0x20	R	PWM Data Register 1	0x0000_0000
CNR2	PWMA_BA+0x24 PWMB_BA+0x24	R/W	PWM Counter Register 2	0x0000_0000
CMR2	PWMA_BA+0x28 PWMB_BA+0x28	R/W	PWM Comparator Register 2	0x0000_0000
PDR2	PWMA_BA+0x2C PWMB_BA+0x2C	R	PWM Data Register 2	0x0000_0000
CNR3	PWMA_BA+0x30 PWMB_BA+0x30	R/W	PWM Counter Register 3	0x0000_0000
CMR3	PWMA_BA+0x34 PWMB_BA+0x34	R/W	PWM Comparator Register 3	0x0000_0000
PDR3	PWMA_BA+0x38 PWMB_BA+0x38	R	PWM Data Register 3	0x0000_0000
PBCR	PWMA_BA+0x3C PWMB_BA+0x3C	R/W	PWM Backward Compatible Register	0x0000_0000

PIER	PWMA_BA+0x40 PWMB_BA+0x40	R/W	PWM Interrupt Enable Register	0x0000_0000
PIIR	PWMA_BA+0x44 PWMB_BA+0x44	R/W	PWM Interrupt Indication Register	0x0000_0000
CCR0	PWMA_BA+0x50 PWMB_BA+0x50	R/W	PWM Capture Control Register 0	0x0000_0000
CCR2	PWMA_BA+0x54 PWMB_BA+0x54	R/W	PWM Capture Control Register 2	0x0000_0000
CRLR0	PWMA_BA+0x58 PWMB_BA+0x58	R	PWM Capture Rising Latch Register (Channel 0)	0x0000_0000
CFLR0	PWMA_BA+0x5C PWMB_BA+0x5C	R	PWM Capture Falling Latch Register (Channel 0)	0x0000_0000
CRLR1	PWMA_BA+0x60 PWMB_BA+0x60	R	PWM Capture Rising Latch Register (Channel 1)	0x0000_0000
CFLR1	PWMA_BA+0x64 PWMB_BA+0x64	R	PWM Capture Falling Latch Register (Channel 1)	0x0000_0000
CRLR2	PWMA_BA+0x68 PWMB_BA+0x68	R	PWM Capture Rising Latch Register (Channel 2)	0x0000_0000
CFLR2	PWMA_BA+0x6C PWMB_BA+0x6C	R	PWM Capture Falling Latch Register (Channel 2)	0x0000_0000
CRLR3	PWMA_BA+0x70 PWMB_BA+0x70	R	PWM Capture Rising Latch Register (Channel 3)	0x0000_0000
CFLR3	PWMA_BA+0x74 PWMB_BA+0x74	R	PWM Capture Falling Latch Register (Channel 3)	0x0000_0000
CAPENR	PWMA_BA+0x78 PWMB_BA+0x78	R/W	PWM Capture Input 0~3 Enable Register	0x0000_0000
POE	PWMA_BA+0x7C PWMB_BA+0x7C	R/W	PWM Output Enable for Channel 0~3	0x0000_0000
TCON	PWMA_BA+0x80 PWMB_BA+0x80	R/W	PWM Trigger Control for Channel 0~3	0x0000_0000
TSTATUS	PWMA_BA+0x84 PWMB_BA+0x84	R/W	PWM Trigger Status Register	0x0000_0000
SYNCBUSY0	PWMA_BA+0x88 PWMB_BA+0x88	R	PWM0 Synchronous Busy Status Register	0x0000_0000
SYNCBUSY1	PWMA_BA+0x8C PWMB_BA+0x8C	R	PWM1 Synchronous Busy Status Register	0x0000_0000
SYNCBUSY2	PWMA_BA+0x90 PWMB_BA+0x90	R	PWM2 Synchronous Busy Status Register	0x0000_0000
SYNCBUSY3	PWMA_BA+0x94 PWMB_BA+0x94	R	PWM3 Synchronous Busy Status Register	0x0000_0000

6.9.7 Register Description

PWM Prescale Register (PPR)

Register	Offset	R/W	Description	Reset Value
PPR	PWMA_BA+0x00 PWMB_BA+0x00	R/W	PWM Prescaler Register	0x0000_0000

31	30	29	28	27	26	25	24
DZI23							
23	22	21	20	19	18	17	16
DZI01							
15	14	13	12	11	10	9	8
CP23							
7	6	5	4	3	2	1	0
CP01							

Bits	Description
[31:24]	DZI23 Dead-Zone Interval For Pair Of Channel2 And Channel3 (PWM2 And PWM3 Pair For PWM Group A, PWM6 And PWM7 Pair For PWM Group B) These 8-bit determine the Dead-zone length. The unit time of Dead-zone length = $[(\text{prescale}+1) \times (\text{clock source divider})] / \text{PWMxy\_CLK}$ (where xy could be 23 or 67, depends on selected PWM channel.).
[23:16]	DZI01 Dead-Zone Interval For Pair Of Channel 0 And Channel 1 (PWM0 And PWM1 Pair For PWM Group A, PWM4 And PWM5 Pair For PWM Group B) These 8-bit determine the Dead-zone length. The unit time of Dead-zone length = $[(\text{prescale}+1) \times (\text{clock source divider})] / \text{PWMxy\_CLK}$ (where xy could be 01 or 45, depends on selected PWM channel.).
[15:8]	CP23 Clock Prescaler 2 (PWM-Timer2 / 3 For Group A And PWM-Timer 6 / 7 For Group B) Clock input is divided by (CP23 + 1) before it is fed to the corresponding PWM-timer If CP23=0, then the clock prescaler 2 output clock will be stopped. So corresponding PWM-timer will also be stopped.
[7:0]	CP01 Clock Prescaler 0 (PWM-Timer 0 / 1 For Group A And PWM-Timer 4 / 5 For Group B) Clock input is divided by (CP01 + 1) before it is fed to the corresponding PWM-timer If CP01=0, then the clock prescaler 0 output clock will be stopped. So corresponding PWM-timer will also be stopped.

PWM Clock Source Divider Select Register (CSR)

Register	Offset	R/W	Description	Reset Value
CSR	PWMA_BA+0x04 PWMB_BA+0x04	R/W	PWM Clock Source Divider Select Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved	CSR3			Reserved	CSR2		
7	6	5	4	3	2	1	0
Reserved	CSR1			Reserved	CSR0		

Bits	Description	
[31:15]	Reserved	Reserved.
[14:12]	CSR3	PWM Timer 3 Clock Source Divider Selection (PWM Timer 3 For Group A And PWM Timer 7 For Group B) Select clock source divider for PWM timer 3. 000 = 2. 001 = 4. 010 = 8. 011 = 16. 100 = 1.
[11]	Reserved	Reserved.
[10:8]	CSR2	PWM Timer 2 Clock Source Divider Selection (PWM Timer 2 For Group A And PWM Timer 6 For Group B) Select clock source divider for PWM timer 2. (Table is the same as CSR3)
[7]	Reserved	Reserved.
[6:4]	CSR1	PWM Timer 1 Clock Source Divider Selection (PWM Timer 1 For Group A And PWM Timer 5 For Group B) Select clock source divider for PWM timer 1. (Table is the same as CSR3)
[3]	Reserved	Reserved.
[2:0]	CSR0	PWM Timer 0 Clock Source Divider Selection (PWM Timer 0 For Group A And PWM Timer 4 For Group B) Select clock source divider for PWM timer 0. (Table is the same as CSR3)

PWM Control Register (PCR)

Register	Offset	R/W	Description	Reset Value
PCR	PWMA_BA+0x08 PWMB_BA+0x08	R/W	PWM Control Register	0x0000_0000

31	30	29	28	27	26	25	24
PWM23TYPE	PWM01TYPE	Reserved		CH3MOD	CH3INV	CH3PINV	CH3EN
23	22	21	20	19	18	17	16
Reserved				CH2MOD	CH2INV	CH2PINV	CH2EN
15	14	13	12	11	10	9	8
Reserved				CH1MOD	CH1INV	CH1PINV	CH1EN
7	6	5	4	3	2	1	0
Reserved		DZEN23	DZEN01	CH0MOD	CH0INV	CH0PINV	CH0EN

Bits	Description	
[31]	PWM23TYPE	PWM23 Aligned Type Selection (PWM2 And PWM3 Pair For PWM Group A, PWM6 And PWM7 Pair For PWM Group B) 0 = Edge-aligned type. 1 = Center-aligned type.
[30]	PWM01TYPE	PWM01 Aligned Type Selection (PWM0 And PWM1 Pair For PWM Group A, PWM4 And PWM5 Pair For PWM Group B) 0 = Edge-aligned type. 1 = Center-aligned type.
[30:28]	Reserved	Reserved.
[27]	CH3MOD	PWM-Timer 3 Auto-Reload/One-Shot Mode (PWM Timer 3 For Group A And PWM Timer 7 For Group B) 0 = One-shot mode. 1 = Auto-reload mode. Note: If there is a transition at this bit, it will cause CNR3 and CMR3 be cleared.
[26]	CH3INV	PWM-Timer 3 Output Inverter Enable (PWM Timer 3 For Group A And PWM Timer 7 For Group B) 0 = Inverter Disabled. 1 = Inverter Enabled.
[25]	CH3PINV	PWM-Timer 3 Output Polar Inverse Enable (PWM Timer 3 For Group A And PWM Timer 7 For Group B) 0 = PWM3 output polar inverse Disable. 1 = PWM3 output polar inverse Enable.
[24]	CH3EN	PWM-Timer 3 Enable (PWM Timer 3 For Group A And PWM Timer 7 For Group B) 0 = Corresponding PWM-Timer Stopped. 1 = Corresponding PWM-Timer Start Running.
[23:20]	Reserved	Reserved.

[19]	CH2MOD	PWM-Timer 2 Auto-Reload/One-Shot Mode (PWM Timer 2 For Group A And PWM Timer 6 For Group B) 0 = One-shot mode. 1 = Auto-reload mode. Note: If there is a transition at this bit, it will cause CNR2 and CMR2 be cleared.
[18]	CH2INV	PWM-Timer 2 Output Inverter Enable (PWM Timer 2 For Group A And PWM Timer 6 For Group B) 0 = Inverter Disabled. 1 = Inverter Enabled.
[17]	CH2PINV	PWM-Timer 2 Output Polar Inverse Enable (PWM Timer 2 For Group A And PWM Timer 6 For Group B) 0 = PWM2 output polar inverse Disabled. 1 = PWM2 output polar inverse Enabled.
[16]	CH2EN	PWM-Timer 2 Enable (PWM Timer 2 For Group A And PWM Timer 6 For Group B) 0 = Corresponding PWM-Timer Stopped. 1 = Corresponding PWM-Timer Start Running.
[15:12]	Reserved	Reserved.
[11]	CH1MOD	PWM-Timer 1 Auto-Reload/One-Shot Mode (PWM Timer 1 For Group A And PWM Timer 5 For Group B) 0 = One-shot mode. 1 = Auto-reload mode. Note: If there is a transition at this bit, it will cause CNR1 and CMR1 be cleared.
[10]	CH1INV	PWM-Timer 1 Output Inverter Enable (PWM Timer 1 For Group A And PWM Timer 5 For Group B) 0 = Inverter Disable. 1 = Inverter Enable.
[9]	CH1PINV	PWM-Timer 1 Output Polar Inverse Enable (PWM Timer 1 For Group A And PWM Timer 5 For Group B) 0 = PWM1 output polar inverse Disabled. 1 = PWM1 output polar inverse Enabled.
[8]	CH1EN	PWM-Timer 1 Enable (PWM Timer 1 For Group A And PWM Timer 5 For Group B) 0 = Corresponding PWM-Timer Stopped. 1 = Corresponding PWM-Timer Start Running.
[7:6]	Reserved	Reserved.
[5]	DZEN23	Dead-Zone 2 Generator Enable (PWM2 And PWM3 Pair For PWM Group A, PWM6 And PWM7 Pair For PWM Group B) 0 = Disabled. 1 = Enabled. Note: When Dead-zone generator is enabled, the pair of PWM2 and PWM3 becomes a complementary pair for PWM group A and the pair of PWM6 and PWM7 becomes a complementary pair for PWM group B.
[4]	DZEN01	Dead-Zone 0 Generator Enable (PWM0 And PWM1 Pair For PWM Group A, PWM4 And PWM5 Pair For PWM Group B) 0 = Disabled. 1 = Enabled. Note: When Dead-zone generator is enabled, the pair of PWM0 and PWM1 becomes a complementary pair for PWM group A and the pair of PWM4 and PWM5 becomes a complementary pair for PWM group B.

[3]	CH0MOD	PWM-Timer 0 Auto-Reload/One-Shot Mode (PWM Timer 0 For Group A And PWM Timer 4 For Group B) 0 = One-shot mode. 1 = Auto-reload mode. Note: If there is a transition at this bit, it will cause CNR0 and CMR0 be cleared.
[2]	CH0INV	PWM-Timer 0 Output Inverter Enable (PWM Timer 0 For Group A And PWM Timer 4 For Group B) 0 = Inverter Disabled. 1 = Inverter Enabled.
[1]	CH0PINV	PWM-Timer 0 Output Polar Inverse Enable (PWM Timer 0 For Group A And PWM Timer 4 For Group B) 0 = PWM0 output polar inverse Disabled. 1 = PWM0 output polar inverse Enabled.
[0]	CH0EN	PWM-Timer 0 Enable (PWM Timer 0 For Group A And PWM Timer 4 For Group B) 0 = The corresponding PWM-Timer stops running. 1 = The corresponding PWM-Timer starts running.

PWM Counter Register 3-0 (CNR3-0)

Register	Offset	R/W	Description	Reset Value
CNR0	PWMA_BA+0x0C PWMB_BA+0x0C	R/W	PWM Counter Register 0	0x0000_0000
CNR1	PWMA_BA+0x18 PWMB_BA+0x18	R/W	PWM Counter Register 1	0x0000_0000
CNR2	PWMA_BA+0x24 PWMB_BA+0x24	R/W	PWM Counter Register 2	0x0000_0000
CNR3	PWMA_BA+0x30 PWMB_BA+0x30	R/W	PWM Counter Register 3	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
CNRx [15:8]							
7	6	5	4	3	2	1	0
CNRx [7:0]							

Bits	Description
[31:16]	Reserved
[15:0]	CNRx PWM Timer Loaded Value CNR determines the PWM period. PWM frequency = $\text{PWM}_{xy\_CLK} / [(\text{prescale} + 1) * (\text{clock divider}) * (\text{CNR} + 1)]$; where xy, could be 01, 23, 45 or 67, depends on selected PWM channel. For Edge-aligned type: • Duty ratio = $(\text{CMR} + 1) / (\text{CNR} + 1)$. • $\text{CMR} \geq \text{CNR}$: PWM output is always high. • $\text{CMR} < \text{CNR}$: PWM low width = $(\text{CNR} - \text{CMR})$ unit; PWM high width = $(\text{CMR} + 1)$ unit. • $\text{CMR} = 0$: PWM low width = (CNR) unit; PWM high width = 1 unit. For Center-aligned type: • Duty ratio = $[(2 \times \text{CMR}) + 1] / [2 \times (\text{CNR} + 1)]$. • $\text{CMR} > \text{CNR}$: PWM output is always high. • $\text{CMR} \leq \text{CNR}$: PWM low width = $2 \times (\text{CNR} - \text{CMR}) + 1$ unit; PWM high width = $(2 \times \text{CMR}) + 1$ unit. • $\text{CMR} = 0$: PWM low width = $2 \times \text{CNR} + 1$ unit; PWM high width = 1 unit. (Unit = one PWM clock cycle). Note: Any write to CNR will take effect in next PWM cycle. Note: When PWM operating at Center-aligned type, CNR value should be set between 0x0000 to 0xFFFE. If CNR equal to 0xFFFF, the PWM will work unpredictable. Note: When CNR value is set to 0, PWM output is always high.

PWM Comparator Register 3-0 (CMR3-0)

Register	Offset	R/W	Description	Reset Value
CMR0	PWMA_BA+0x10 PWMB_BA+0x10	R/W	PWM Comparator Register 0	0x0000_0000
CMR1	PWMA_BA+0x1C PWMB_BA+0x1C	R/W	PWM Comparator Register 1	0x0000_0000
CMR2	PWMA_BA+0x28 PWMB_BA+0x28	R/W	PWM Comparator Register 2	0x0000_0000
CMR3	PWMA_BA+0x34 PWMB_BA+0x34	R/W	PWM Comparator Register 3	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
CMRx [15:8]							
7	6	5	4	3	2	1	0
CMRx [7:0]							

Bits	Description
[31:16]	Reserved
[15:0]	CMRx PWM Comparator Register CMR determines the PWM duty. PWM frequency = $PWM_{xy\_CLK} / [(prescale+1) * (clock\ divider) * (CNR+1)]$; where xy, could be 01, 23, 45 or 67, depends on selected PWM channel. For Edge-aligned type: - Duty ratio = $(CMR+1)/(CNR+1)$. - CMR $\geq$ CNR: PWM output is always high. - CMR < CNR: PWM low width = (CNR-CMR) unit; PWM high width = (CMR+1) unit. - CMR = 0: PWM low width = (CNR) unit; PWM high width = 1 unit. For Center-aligned type: - Duty ratio = $[(2 \times CMR) + 1] / [2 \times (CNR+1)]$. - CMR > CNR: PWM output is always high. - CMR $\leq$ CNR: PWM low width = $2 \times (CNR-CMR) + 1$ unit; PWM high width = $(2 \times CMR) + 1$ unit. - CMR = 0: PWM low width = $2 \times CNR + 1$ unit; PWM high width = 1 unit. (Unit = one PWM clock cycle). Note: Any write to CNR will take effect in next PWM cycle.

PWM Data Register 3-0 (PDR 3-0)

Register	Offset	R/W	Description	Reset Value
PDR0	PWMA_BA+0x14 PWMB_BA+0x14	R	PWM Data Register 0	0x0000_0000
PDR1	PWMA_BA+0x20 PWMB_BA+0x20	R	PWM Data Register 1	0x0000_0000
PDR2	PWMA_BA+0x2C PWMB_BA+0x2C	R	PWM Data Register 2	0x0000_0000
PDR3	PWMA_BA+0x38 PWMB_BA+0x38	R	PWM Data Register 3	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
PDR[15:8]							
7	6	5	4	3	2	1	0
PDR[7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	PDRx	PWM Data Register User can monitor PDR to know the current value in 16-bit counter.

PWM Backward Compatible Register (PBCR)

Register	Offset	R/W	Description	Reset Value
PBCR	PWMA_BA+0x3C PWMB_BA+0x3C	R/W	PWM Backward Compatible Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	BCn	PWM Backward Compatible Register 0 = Configure write 0 to clear CFLRI0~3 and CRLRI0~3. 1 = Configure write 1 to clear CFLRI0~3 and CRLRI0~3. Refer to the CCR0/CCR2 register bit 6, 7, 22, 23 description Note: It is recommended that this bit be set to 1 to prevent CFLRIx and CRLRIx from being cleared when writing CCR0/CCR2.

PWM Interrupt Enable Register (PIER)

Register	Offset	R/W	Description	Reset Value
PIER	PWMA_BA+0x40 PWMB_BA+0x40	R/W	PWM Interrupt Enable Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved						INT23TYPE	INT01TYPE
15	14	13	12	11	10	9	8
Reserved				PWMDIE3	PWMDIE2	PWMDIE1	PWMDIE0
7	6	5	4	3	2	1	0
Reserved				PWMIE3	PWMIE2	PWMIE1	PWMIE0

Bits	Description	
[31:18]	Reserved	Reserved.
[17]	INT23TYPE	PWM23 Interrupt Period Type Selection Bit (PWM2 And PWM3 Pair For PWM Group A, PWM6 And PWM7 Pair For PWM Group B) 0 = PWMIFn will be set if PWM counter underflow. 1 = PWMIFn will be set if PWM counter matches CNRn register. Note: This bit is effective when PWM in Center-aligned type only.
[16]	INT01TYPE	PWM01 Interrupt Period Type Selection Bit (PWM0 And PWM1 Pair For PWM Group A, PWM4 And PWM5 Pair For PWM Group B) 0 = PWMIFn will be set if PWM counter underflow. 1 = PWMIFn will be set if PWM counter matches CNRn register. Note: This bit is effective when PWM in Center-aligned type only.
[11]	PWMDIE3	PWM Channel 3 Duty Interrupt Enable Bit 0 = Disabled. 1 = Enabled.
[10]	PWMDIE2	PWM Channel 2 Duty Interrupt Enable Bit 0 = Disabled. 1 = Enabled.
[9]	PWMDIE1	PWM Channel 1 Duty Interrupt Enable Bit 0 = Disabled. 1 = Enabled.
[8]	PWMDIE0	PWM Channel 0 Duty Interrupt Enable Bit 0 = Disabled. 1 = Enabled.
[7:4]	Reserved	Reserved.
[3]	PWMIE3	PWM Channel 3 Period Interrupt Enable Bit

		0 = Disabled. 1 = Enabled.
[2]	PWMIE2	PWM Channel 2 Period Interrupt Enable Bit 0 = Disabled. 1 = Enabled.
[1]	PWMIE1	PWM Channel 1 Period Interrupt Enable Bit 0 = Disabled. 1 = Enabled.
[0]	PWMIE0	PWM Channel 0 Period Interrupt Enable Bit 0 = Disabled. 1 = Enabled.

PWM Interrupt Indication Register (PIIR)

Register	Offset	R/W	Description	Reset Value
PIIR	PWMA_BA+0x44 PWMB_BA+0x44	R/W	PWM Interrupt Indication Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved				PWMDIF3	PWMDIF2	PWMDIF1	PWMDIF0
7	6	5	4	3	2	1	0
Reserved				PWMIF3	PWMIF2	PWMIF1	PWMIF0

Bits	Description
[31:12]	Reserved Reserved.
[11]	PWMDIF3 PWM Channel 3 Duty Interrupt Flag Flag is set by hardware when channel 3 PWM counter down count and reaches CMR3, software can clear this bit by writing a one to it. Note: If CMR equal to CNR, this flag is not working in Edge-aligned type selection
[10]	PWMDIF2 PWM Channel 2 Duty Interrupt Flag Flag is set by hardware when channel 2 PWM counter down count and reaches CMR2, software can clear this bit by writing a one to it. Note: If CMR equal to CNR, this flag is not working in Edge-aligned type selection
[9]	PWMDIF1 PWM Channel 1 Duty Interrupt Flag Flag is set by hardware when channel 1 PWM counter down count and reaches CMR1, software can clear this bit by writing a one to it. Note: If CMR equal to CNR, this flag is not working in Edge-aligned type selection
[8]	PWMDIF0 PWM Channel 0 Duty Interrupt Flag Flag is set by hardware when channel 0 PWM counter down count and reaches CMR0, software can clear this bit by writing a one to it. Note: If CMR equal to CNR, this flag is not working in Edge-aligned type selection
[7:4]	Reserved Reserved.
[3]	PWMIF3 PWM Channel 3 Period Interrupt Status This bit is set by hardware when PWM3 counter reaches the requirement of interrupt (depend on INT23TYPE bit of PIER register), software can write 1 to clear this bit to 0.
[2]	PWMIF2 PWM Channel 2 Period Interrupt Status This bit is set by hardware when PWM2 counter reaches the requirement of interrupt (depend on INT23TYPE bit of PIER register), software can write 1 to clear this bit to 0.
[1]	PWMIF1 PWM Channel 1 Period Interrupt Status This bit is set by hardware when PWM1 counter reaches the requirement of interrupt (depend on INT01TYPE bit of PIER register), software can write 1 to clear this bit to 0.

[0]	PWMIF0	PWM Channel 0 Period Interrupt Status This bit is set by hardware when PWM0 counter reaches the requirement of interrupt (depend on INT01TYPE bit of PIER register), software can write 1 to clear this bit to 0.

Note: User can clear each interrupt flag by writing 1 to corresponding bit in PIIR.

Capture Control Register (CCR0)

Register	Offset	R/W	Description	Reset Value
CCR0	PWMA_BA+0x50 PWMB_BA+0x50	R/W	PWM Capture Control Register 0	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
CFLRI1	CRLRI1	Reserved	CAPIF1	CAPCH1EN	CFL_IE1	CRL_IE1	INV1
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
CFLRI0	CRLRI0	Reserved	CAPIF0	CAPCH0EN	CFL_IE0	CRL_IE0	INV0

Bits	Description
[31:24]	Reserved Reserved.
[23]	CFLRI1 CFLR1 Latched Indicator Bit When PWM group input channel 1 has a falling transition, CFLR1 was latched with the value of PWM down-counter and this bit is set by hardware. Software can write 0 to clear this bit to 0 if BCn bit is 0, and can write 1 to clear this bit to 0 if BCn bit is 1.
[22]	CRLRI1 CRLR1 Latched Indicator Bit When PWM group input channel 1 has a rising transition, CRLR1 was latched with the value of PWM down-counter and this bit is set by hardware. Software can write 0 to clear this bit to 0 if BCn bit is 0, and can write 1 to clear this bit to 0 if BCn bit is 1.
[5]	Reserved Reserved.
[20]	CAPIF1 Channel 1 Capture Interrupt Indication Flag If PWM group channel 1 rising latch interrupt is enabled (CRL_IE1 = 1), a rising transition occurs at PWM group channel 1 will result in CAPIF1 to high; Similarly, a falling transition will cause CAPIF1 to be set high if PWM group channel 1 falling latch interrupt is enabled (CFL_IE1 = 1). Write 1 to clear this bit to 0.
[19]	CAPCH1EN Channel 1 Capture Function Enable Bit 0 = Capture function on PWM group channel 1 Disabled. 1 = Capture function on PWM group channel 1 Enabled. When Enabled, Capture latched the PWM-counter and saved to CRLR (Rising latch) and CFLR (Falling latch). When Disabled, Capture does not update CRLR and CFLR, and disable PWM group channel 1 Interrupt.
[18]	CFL_IE1 Channel 1 Falling Latch Interrupt Enable Bit 0 = Falling latch interrupt Disabled. 1 = Falling latch interrupt Enabled. When Enabled, if Capture detects PWM group channel 1 has falling transition, Capture will

		issue an Interrupt.
[17]	CRL_IE1	Channel 1 Rising Latch Interrupt Enable Bit 0 = Rising latch interrupt Disabled. 1 = Rising latch interrupt Enabled. When Enabled, if Capture detects PWM group channel 1 has rising transition, Capture will issue an Interrupt.
[16]	INV1	Channel 1 Inverter Enable Bit 0 = Inverter Disabled. 1 = Inverter Enabled. Reverse the input signal from GPIO before fed to Capture timer
[15:8]	Reserved	Reserved.
[7]	CFLRI0	CFLR0 Latched Indicator When PWM group input channel 0 has a falling transition, CFLR0 was latched with the value of PWM down-counter and this bit is set by hardware. Software can write 0 to clear this bit to 0 if the BCn bit is 0, and can write 1 to clear this bit to 0 if BCn bit is 1.
[6]	CRLRI0	CRLR0 Latched Indicator When PWM group input channel 0 has a rising transition, CRLR0 was latched with the value of PWM down-counter and this bit is set by hardware. Software can write 0 to clear this bit to 0 if the BCn bit is 0, and can write 1 to clear this bit to 0 if the BCn bit is 1.
[5]	Reserved	Reserved.
[4]	CAPIF0	Channel 0 Capture Interrupt Indication Flag If PWM group channel 0 rising latch interrupt is enabled (CRL_IE0 = 1), a rising transition occurs at PWM group channel 0 will result in CAPIF0 to high; Similarly, a falling transition will cause CAPIF0 to be set high if PWM group channel 0 falling latch interrupt is enabled (CFL_IE0 = 1). Write 1 to clear this bit to 0.
[3]	CAPCH0EN	Channel 0 Capture Function Enable 0 = Capture function on PWM group channel 0 Disabled. 1 = Capture function on PWM group channel 0 Enabled. When Enabled, Capture latched the PWM-counter value and saved to CRLR (Rising latch) and CFLR (Falling latch). When Disabled, Capture does not update CRLR and CFLR, and disable PWM group channel 0 Interrupt.
[2]	CFL_IE0	Channel 0 Falling Latch Interrupt Enable Bit 0 = Falling latch interrupt Disabled. 1 = Falling latch interrupt Enabled. When Enabled, if Capture detects PWM group channel 0 has falling transition, Capture will issue an Interrupt.
[1]	CRL_IE0	Channel 0 Rising Latch Interrupt Enable Bit 0 = Rising latch interrupt Disabled. 1 = Rising latch interrupt Enabled. When Enabled, if Capture detects PWM group channel 0 has rising transition, Capture will issue an Interrupt.
[0]	INV0	Channel 0 Inverter Enable Bit 0 = Inverter Disabled. 1 = Inverter Enabled. Reverse the input signal from GPIO before fed to Capture timer

Capture Control Register (CCR2)

Register	Offset	R/W	Description	Reset Value
CCR2	PWMA_BA+0x54 PWMB_BA+0x54	R/W	PWM Capture Control Register 2	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
CFLRI3	CRLRI3	Reserved	CAPIF3	CAPCH3EN	CFL_IE3	CRL_IE3	INV3
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
CFLRI2	CRLRI2	Reserved	CAPIF2	CAPCH2EN	CFL_IE2	CRL_IE2	INV2

Bits	Description	
[31:24]	Reserved	Reserved.
[23]	CFLRI3	CFLR3 Latched Indicator When PWM group input channel 3 has a falling transition, CFLR3 was latched with the value of PWM down-counter and this bit is set by hardware. Software can write 0 to clear this bit to 0 if the BCn bit is 0, and can write 1 to clear this bit to 0 if the BCn bit is 1.
[22]	CRLRI3	CRLR3 Latched Indicator When PWM group input channel 3 has a rising transition, CRLR3 was latched with the value of PWM down-counter and this bit is set by hardware. Software can write 0 to clear this bit to 0 if the BCn bit is 0, and can write 1 to clear this bit to 0 if the BCn bit is 1.
[21]	Reserved	Reserved.
[20]	CAPIF3	Channel 3 Capture Interrupt Indication Flag If PWM group channel 3 rising latch interrupt is enabled (CRL_IE3=1), a rising transition occurs at PWM group channel 3 will result in CAPIF3 to high; Similarly, a falling transition will cause CAPIF3 to be set high if PWM group channel 3 falling latch interrupt is enabled (CFL_IE3=1). Write 1 to clear this bit to 0
[19]	CAPCH3EN	Channel 3 Capture Function Enable Bit 0 = Capture function on PWM group channel 3 Disabled. 1 = Capture function on PWM group channel 3 Enabled. When Enabled, Capture latched the PWM-counter and saved to CRLR (Rising latch) and CFLR (Falling latch). When Disabled, Capture does not update CRLR and CFLR, and disable PWM group channel 3 Interrupt.
[18]	CFL_IE3	Channel 3 Falling Latch Interrupt Enable Bit 0 = Falling latch interrupt Disabled. 1 = Falling latch interrupt Enabled. When Enabled, if Capture detects PWM group channel 3 has falling transition, Capture will

		issue an Interrupt.
[17]	CRL_IE3	Channel 3 Rising Latch Interrupt Enable Bit 0 = Rising latch interrupt Disabled. 1 = Rising latch interrupt Enabled. When Enabled, if Capture detects PWM group channel 3 has rising transition, Capture will issue an Interrupt.
[16]	INV3	Channel 3 Inverter Enable Bit 0 = Inverter Disabled. 1 = Inverter Enabled. Reverse the input signal from GPIO before fed to Capture timer
[15:8]	Reserved	Reserved.
[7]	CFLRI2	CFLR2 Latched Indicator When PWM group input channel 2 has a falling transition, CFLR2 was latched with the value of PWM down-counter and this bit is set by hardware. Software can write 0 to clear this bit to 0 if BCn bit is 0, and can write 1 to clear this bit to 0 if the BCn bit is 1.
[6]	CRLRI2	CRLR2 Latched Indicator When PWM group input channel 2 has a rising transition, CRLR2 was latched with the value of PWM down-counter and this bit is set by hardware. Software can write 0 to clear this bit to 0 if the BCn bit is 0, and can write 1 to clear this bit to 0 if the BCn bit is 1.
[5]	Reserved	Reserved.
[4]	CAPIF2	Channel 2 Capture Interrupt Indication Flag If PWM group channel 2 rising latch interrupt is enabled (CRL_IE2=1), a rising transition occurs at PWM group channel 2 will result in CAPIF2 to high; Similarly, a falling transition will cause CAPIF2 to be set high if PWM group channel 2 falling latch interrupt is enabled (CFL_IE2=1). Write 1 to clear this bit to 0
[3]	CAPCH2EN	Channel 2 Capture Function Enable Bit 0 = Capture function on PWM group channel 2 Disabled. 1 = Capture function on PWM group channel 2 Enabled. When Enabled, Capture latched the PWM-counter value and saved to CRLR (Rising latch) and CFLR (Falling latch). When Disabled, Capture does not update CRLR and CFLR, and disable PWM group channel 2 Interrupt.
[2]	CFL_IE2	Channel 2 Falling Latch Interrupt Enable Bit 0 = Falling latch interrupt Disabled. 1 = Falling latch interrupt Enabled. When Enabled, if Capture detects PWM group channel 2 has falling transition, Capture will issue an Interrupt.
[1]	CRL_IE2	Channel 2 Rising Latch Interrupt Enable Bit 0 = Rising latch interrupt Disabled. 1 = Rising latch interrupt Enabled. When Enabled, if Capture detects PWM group channel 2 has rising transition, Capture will issue an Interrupt.
[0]	INV2	Channel 2 Inverter Enable Bit 0 = Inverter Disabled. 1 = Inverter Enabled. Reverse the input signal from GPIO before fed to Capture timer

Capture Rising Latch Register3-0 (CRLR3-0)

Register	Offset	R/W	Description	Reset Value
CRLR0	PWMA_BA+0x58 PWMB_BA+0x58	R	PWM Capture Rising Latch Register (Channel 0)	0x0000_0000
CRLR1	PWMA_BA+0x60 PWMB_BA+0x60	R	PWM Capture Rising Latch Register (Channel 1)	0x0000_0000
CRLR2	PWMA_BA+0x68 PWMB_BA+0x68	R	PWM Capture Rising Latch Register (Channel 2)	0x0000_0000
CRLR3	PWMA_BA+0x70 PWMB_BA+0x70	R	PWM Capture Rising Latch Register (Channel 3)	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
CRLRx [15:8]							
7	6	5	4	3	2	1	0
CRLRx [7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	CRLRx	Capture Rising Latch Register Latch the PWM counter when Channel 0/1/2/3 has rising transition.

Capture Falling Latch Register3-0 (CFLR3-0)

Register	Offset	R/W	Description	Reset Value
CFLR0	PWMA_BA+0x5C PWMB_BA+0x5C	R	PWM Capture Falling Latch Register (Channel 0)	0x0000_0000
CFLR1	PWMA_BA+0x64 PWMB_BA+0x64	R	PWM Capture Falling Latch Register (Channel 1)	0x0000_0000
CFLR2	PWMA_BA+0x6C PWMB_BA+0x6C	R	PWM Capture Falling Latch Register (Channel 2)	0x0000_0000
CFLR3	PWMA_BA+0x74 PWMB_BA+0x74	R	PWM Capture Falling Latch Register (Channel 3)	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
CFLRx [15:8]							
7	6	5	4	3	2	1	0
CFLRx [7:0]							

Bits	Description
[31:16]	Reserved Reserved.
[15:0]	CFLRx Capture Falling Latch Register Latch the PWM counter when Channel 0/1/2/3 has Falling transition.

Capture Input Enable Register (CAPENR)

Register	Offset	R/W	Description	Reset Value
CAPENR	PWMA_BA+0x78 PWMB_BA+0x78	R/W	PWM Capture Input 0~3 Enable Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				CINEN3	CINEN2	CINEN1	CINEN0

Bits	Description	
[31:4]	Reserved	Reserved.
[3]	CINEN3	Channel 3 Capture Input Enable Bit 0 = PWM Channel 3 capture input path Disabled. The input of PWM channel 3 capture function is always regarded as 0. 1 = PWM Channel 3 capture input path Enabled. The input of PWM channel 3 capture function comes from correlative multifunction pin if GPIO multi-function is set as PWM3.
[2]	CINEN2	Channel 2 Capture Input Enable Bit 0 = PWM Channel 2 capture input path Disabled. The input of PWM channel 2 capture function is always regarded as 0. 1 = PWM Channel 2 capture input path Enabled. The input of PWM channel 2 capture function comes from correlative multifunction pin if GPIO multi-function is set as PWM2.
[1]	CINEN1	Channel 1 Capture Input Enable Bit 0 = PWM Channel 1 capture input path Disabled. The input of PWM channel 1 capture function is always regarded as 0. 1 = PWM Channel 1 capture input path Enabled. The input of PWM channel 1 capture function comes from correlative multifunction pin if GPIO multi-function is set as PWM1.
[0]	CINEN0	Channel 0 Capture Input Enable Bit 0 = PWM Channel 0 capture input path Disabled. The input of PWM channel 0 capture function is always regarded as 0. 1 = PWM Channel 0 capture input path Enabled. The input of PWM channel 0 capture function comes from correlative multifunction pin if GPIO multi-function is set as PWM0.

PWM Output Enable Register (POE)

Register	Offset	R/W	Description	Reset Value
POE	PWMA_BA+0x7C PWMB_BA+0x7C	R/W	PWM Output Enable for Channel 0~3	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				POE3	POE2	POE1	POE0

Bits	Description	
[31:4]	Reserved	Reserved.
[3]	POE3	Channel 3 Output Enable Bit 0 = PWM channel 3 output to pin Disabled. 1 = PWM channel 3 output to pin Enabled. Note: The corresponding GPIO pin must also be switched to PWM function
[2]	POE2	Channel 2 Output Enable Bit 0 = PWM channel 2 output to pin Disabled. 1 = PWM channel 2 output to pin Enabled. Note: The corresponding GPIO pin must also be switched to PWM function
[1]	POE1	Channel 1 Output Enable Bit 0 = PWM channel 1 output to pin Disabled. 1 = PWM channel 1 output to pin Enabled. Note: The corresponding GPIO pin must also be switched to PWM function
[0]	POE0	Channel 0 Output Enable Bit 0 = PWM channel 0 output to pin Disabled. 1 = PWM channel 0 output to pin Enabled. Note: The corresponding GPIO pin must also be switched to PWM function

PWM Trigger Control Register (TCON)

Register	Offset	R/W	Description	Reset Value
TCON	PWMA_BA+0x80 PWMB_BA+0x80	R/W	PWM Trigger Control for Channel 0~3	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				PWM3TEN	PWM2TEN	PWM1TEN	PWM0TEN

Bits	Description	
[31:4]	Reserved	Reserved.
[3]	PWM3TEN	Channel 3 Center-Aligned Trigger Enable Bit 0 = PWM channel 3 trigger ADC function Disabled. 1 = PWM channel 3 trigger ADC function Enabled. PWM can trigger ADC to start conversion when PWM counter up count to CNR if this bit is set to 1. Note: This function is only supported when PWM operating at Center-aligned type.
[2]	PWM2TEN	Channel 2 Center-Aligned Trigger Enable Bit 0 = PWM channel 2 trigger ADC function Disabled. 1 = PWM channel 2 trigger ADC function Enabled. PWM can trigger ADC to start conversion when PWM counter up count to CNR if this bit is set to 1. Note: This function is only supported when PWM operating at Center-aligned type.
[1]	PWM1TEN	Channel 1 Center-Aligned Trigger Enable Bit 0 = PWM channel 1 trigger ADC function Disabled. 1 = PWM channel 1 trigger ADC function Enabled. PWM can trigger ADC to start conversion when PWM counter up count to CNR if this bit is set to 1. Note: This function is only supported when PWM operating at Center-aligned type.
[0]	PWM0TEN	Channel 0 Center-Aligned Trigger Enable Bit 0 = PWM channel 0 trigger ADC function Disabled. 1 = PWM channel 0 trigger ADC function Enabled. PWM can trigger ADC to start conversion when PWM counter up count to CNR if this bit is set to 1. Note: This function is only supported when PWM operating at Center-aligned type.

PWM Trigger Status Register (TSTATUS)

Register	Offset	R/W	Description	Reset Value
TSTATUS	PWMA_BA+0x84 PWMB_BA+0x84	R/W	PWM Trigger Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				PWM3TF	PWM2TF	PWM1TF	PWM0TF

Bits	Description	
[3]	PWM3TF	Channel 3 Center-Aligned Trigger Flag For Center-aligned Operating mode, this bit is set to 1 by hardware when PWM counter up count to CNR if PWM3TEN bit is set to 1. After this bit is set to 1, ADC will start conversion if ADC triggered source is selected by PWM. Software can write 1 to clear this bit.
[2]	PWM2TF	Channel 2 Center-Aligned Trigger Flag For Center-aligned Operating mode, this bit is set to 1 by hardware when PWM counter up count to CNR if PWM2TEN bit is set to 1. After this bit is set to 1, ADC will start conversion if ADC triggered source is selected by PWM. Software can write 1 to clear this bit.
[1]	PWM1TF	Channel 1 Center-Aligned Trigger Flag For Center-aligned Operating mode, this bit is set to 1 by hardware when PWM counter up count to CNR if PWM1TEN bit is set to 1. After this bit is set to 1, ADC will start conversion if ADC triggered source is selected by PWM. Software can write 1 to clear this bit.
[0]	PWM0TF	Channel 0 Center-Aligned Trigger Flag For Center-aligned Operating mode, this bit is set to 1 by hardware when PWM counter up counts to CNR if PWM0TEN bit is set to 1. After this bit is set to 1, ADC will start conversion if ADC triggered source is selected by PWM. Software can write 1 to clear this bit.

PWM0 Synchronous Busy Status Register (SYNCBUSY0)

Register	Offset	R/W	Description	Reset Value
SYNCBUSY0	PWMA_BA+0x88 PWMB_BA+0x88	R	PWM0 Synchronous Busy Status Register	0x0000_0000

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

Bits	Description
[31:1]	Reserved
[0]	PWM Synchronous Busy When software writes CNR0/CMR0/PPR or switches PWM0 operation mode (PCR[3]), PWM will have a busy time to update these values completely because PWM clock may be different from system clock domain. Software needs to check this busy status before writing CNR0/CMR0/PPR or switching PWM0 operation mode (PCR[3]) to make sure previous setting has been updated completely. This bit will be set when software writes CNR0/CMR0/PPR or switches PWM0 operation mode (PCR[3]) and will be cleared by hardware automatically when PWM update these value completely.

PWM1 Synchronous Busy Status Register (SYNCBUSY1)

Register	Offset	R/W	Description	Reset Value
SYNCBUSY1	PWMA_BA+0x8C PWMB_BA+0x8C	R	PWM1 Synchronous Busy Status Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	S_BUSY	PWM Synchronous Busy When Software writes CNR1/CMR1/PPR or switches PWM1 operation mode (PCR[11]), PWM will have a busy time to update these values completely because PWM clock may be different from system clock domain. Software needs to check this busy status before writing CNR1/CMR1/PPR or switching PWM1 operation mode (PCR[11]) to make sure previous setting has been updated completely. This bit will be set when software writes CNR1/CMR1/PPR or switches PWM1 operation mode (PCR[11]) and will be cleared by hardware automatically when PWM update these value completely.

PWM2 Synchronous Busy Status Register (SYNCBUSY2)

Register	Offset	R/W	Description	Reset Value
SYNCBUSY2	PWMA_BA+0x90 PWMB_BA+0x90	R	PWM2 Synchronous Busy Status Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	S_BUSY	PWM Synchronous Busy When Software writes CNR2/CMR2/PPR or switch PWM2 operation mode (PCR[19]), PWM will have a busy time to update these values completely because PWM clock may be different from system clock domain. Software needs to check this busy status before writing CNR2/CMR2/PPR or switching PWM2 operation mode (PCR[19]) to make sure previous setting has been updated completely. This bit will be set when software writes CNR2/CMR2/PPR or switch PWM2 operation mode (PCR[19]) and will be cleared by hardware automatically when PWM update these value completely.

PWM3 Synchronous Busy Status Register (SYNCBUSY3)

Register	Offset	R/W	Description	Reset Value
SYNCBUSY3	PWMA_BA+0x94 PWMB_BA+0x94	R	PWM3 Synchronous Busy Status Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	S_BUSY	PWM Synchronous Busy When Software writes CNR3/CMR3/PPR or switch PWM3 operation mode (PCR[27]), PWM will have a busy time to update these values completely because PWM clock may be different from system clock domain. Software need to check this busy status before writing CNR3/CMR3/PPR or switching PWM3 operation mode (PCR[27]) to make sure previous setting has been updated completely. This bit will be set when Software writes CNR3/CMR3/PPR or switch PWM3 operation mode (PCR[27]) and will be cleared by hardware automatically when PWM update these value completely.

6.10 Watchdog Timer (WDT)

6.10.1 Overview

The purpose of Watchdog Timer is to perform a system reset when system runs into an unknown state. This prevents system from hanging for an infinite period of time. Besides, this Watchdog Timer supports the function to wake-up system from Idle/Power-down mode.

6.10.2 Features

- 18-bit free running up counter for Watchdog Timer time-out interval.
- Selectable time-out interval ($2^4 \sim 2^{18}$) WDT_CLK cycle and the time-out interval period is 104 ms ~ 26.3168 s if WDT_CLK = 10 kHz.
- System kept in reset state for a period of $(1 / \text{WDT\_CLK}) * 63$
- Supports Watchdog Timer reset delay period
 - Selectable it includes (1026、130、18 or 3) * WDT_CLK reset delay period.
- Supports to force Watchdog Timer enabled after chip powered on or reset while CWDTEN (CONFIG0[31] Watchdog Enable) bit is set to 0.
- Supports Watchdog Timer time-out wake-up function only if WDT clock source is selected as 10 kHz

6.10.3 Block Diagram

The Watchdog Timer clock control and block diagram are shown as follows.

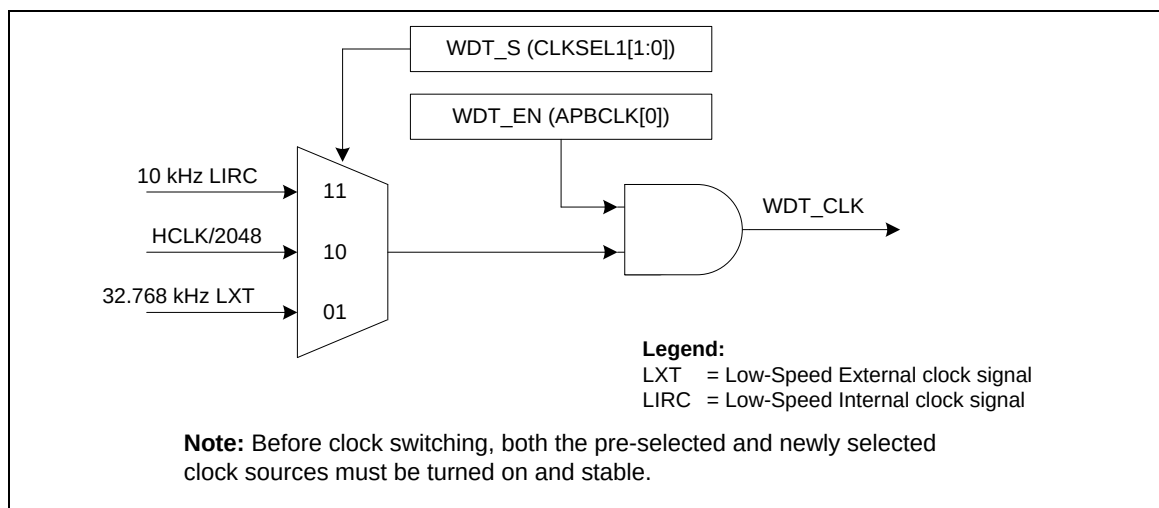


Figure 6-50 Watchdog Timer Clock Control

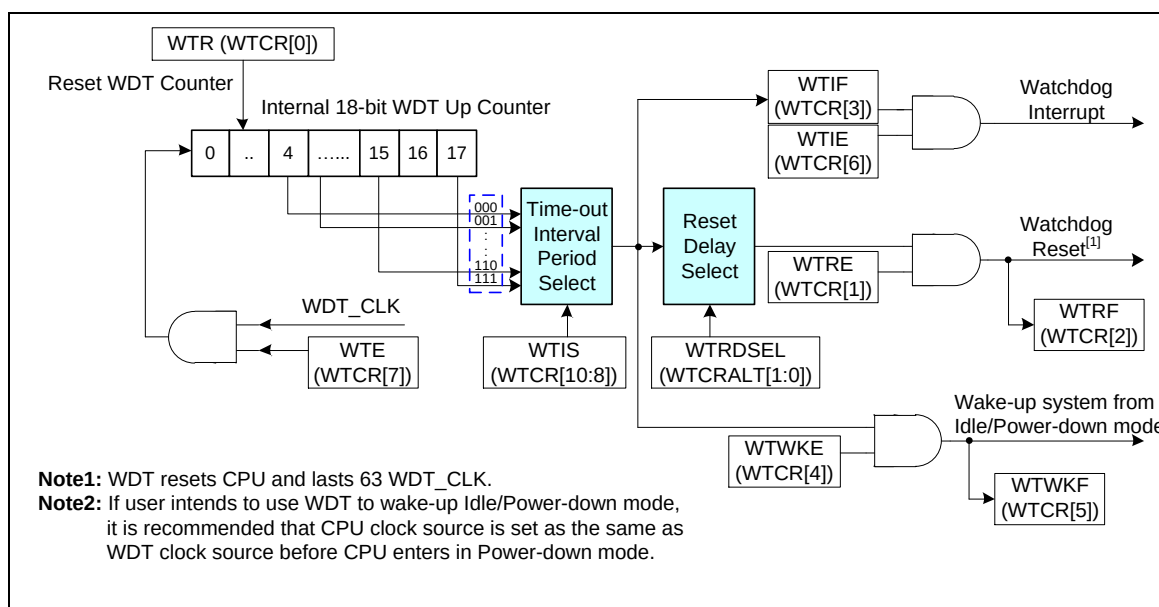


Figure 6-51 Watchdog Timer Block Diagram

6.10.4 Basic Configuration

The WDT peripheral clock is enabled in APBCLK[0] and clock source can be selected in CLKSEL1[1:0].
Or user can setting CONFIG0[31] is 0 to force Watchdog Timer enabled and active in 10 kHz after chip powered on or reset.

6.10.5 Functional Description

The Watchdog Timer (WDT) includes an 18-bit free running up counter with programmable time-out intervals. Table 5-29 shows the WDT time-out interval period selection and Figure 6-52 Watchdog Timer Time-out Interval and Reset Period Timing shows the WDT time-out interval and reset period timing.

- WDT Time-out Interrupt

Setting WTE bit to 1 will enable the WDT function and the WDT counter to start counting up. There are eight time-out interval period can be selected by setting WTIS. When the WDT up counter reaches the WTIS settings, WDT time-out interrupt will occur then WTIF flag will be set to 1 immediately.

- WDT Reset Delay Period and Reset System

There is a specified T_{RSTD} delay period follows the WTIF flag is setting to 1. User should set WTR bit to reset the 18-bit WDT up counter value to avoid generate WDT time-out reset signal before the T_{RSTD} delay period expires. If the WDT up counter value has not been cleared after the specific T_{RSTD} delay period expires, the WDT control will set WTRF flag to 1 if WTRE bit is enabled, then chip enters to reset state immediately. Refer to Figure 6-52 Watchdog Timer Time-out Interval and Reset Period Timing, the T_{RST} reset period will keep last 63 WDT clocks then chip restart executing program from reset vector (0x0000_0000). The WTRF flag will keep 1 after WDT time-out reset the chip, user can check WTRF flag by software to recognize the system has been reset by WDT time-out reset or not.

- WDT Wake-up

If WDT clock source is selected to 10 kHz, system can be waken-up from Power-down mode while WDT time-out interrupt signal is generated and WTWKE bit enabled. In the meanwhile, the WTWKF flag will set to 1 automatically, user can check WTWKF flag by software to recognize the system has been waken-up by WDT time-out interrupt or not.

WTIS	Time-Out Interval Period T_{TIS}	Reset Delay Period T_{RSTD}
000	$2^4 * T_{WDT}$	$(3/18/130/1026) * T_{WDT}$
001	$2^6 * T_{WDT}$	$(3/18/130/1026) * T_{WDT}$
010	$2^8 * T_{WDT}$	$(3/18/130/1026) * T_{WDT}$
011	$2^{10} * T_{WDT}$	$(3/18/130/1026) * T_{WDT}$
100	$2^{12} * T_{WDT}$	$(3/18/130/1026) * T_{WDT}$
101	$2^{14} * T_{WDT}$	$(3/18/130/1026) * T_{WDT}$
110	$2^{16} * T_{WDT}$	$(3/18/130/1026) * T_{WDT}$
111	$2^{18} * T_{WDT}$	$(3/18/130/1026) * T_{WDT}$

Table 6-8 Watchdog Timer Time-out Interval Period Selection

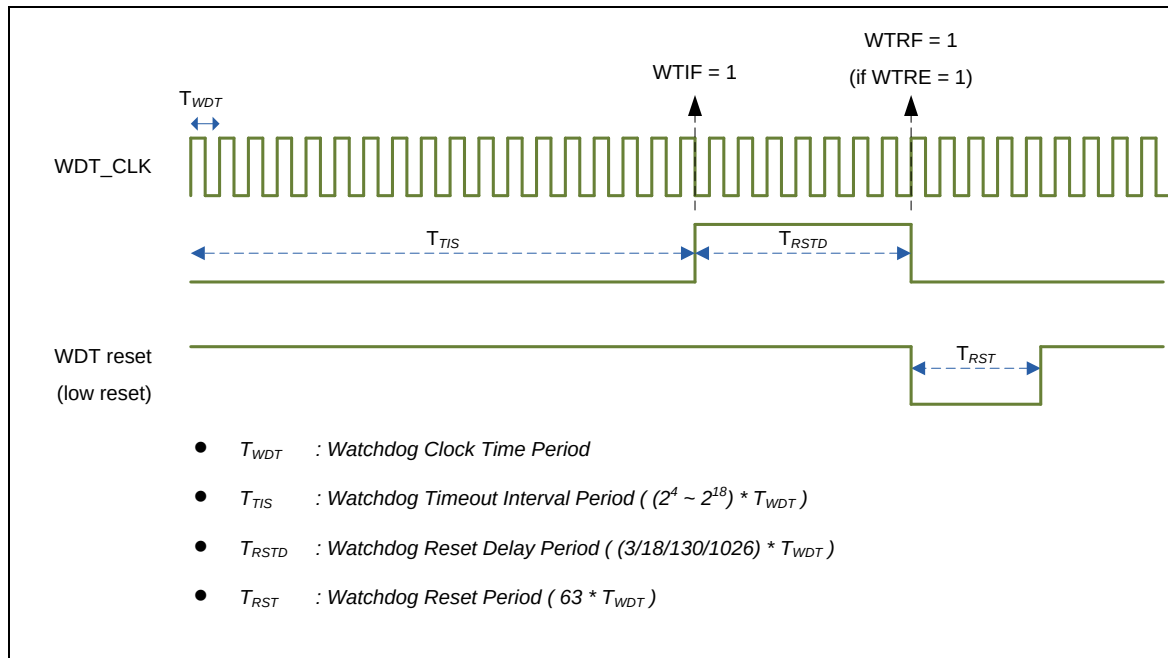


Figure 6-52 Watchdog Timer Time-out Interval and Reset Period Timing

6.10.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
WDT Base Address: WDT_BA = 0x4000_4000				
WTCR	WDT_BA+0x00	R/W	Watchdog Timer Control Register	0x0000_0700
WTCRALT	WDT_BA+0x04	R/W	Watchdog Timer Alternative Control Register	0x0000_0000

6.10.7 Register Description

Watchdog Timer Control Register (WTCR)

Register	Offset	R/W	Description	Reset Value
WTCR	WDT_BA+0x00	R/W	Watchdog Timer Control Register	0x0000_0700

31	30	29	28	27	26	25	24
DBGACK_WDT	Reserved						
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved					WTIS		
7	6	5	4	3	2	1	0
WTE	WTIE	WTWKF	WTWKE	WTIF	WTRF	WTRE	WTR

Bits	Description	
[31]	DBGACK_WDT	ICE Debug Mode Acknowledge Disable Bit (Write Protect) 0 = ICE debug mode acknowledgement effects WDT counting. WDT up counter will be held while CPU is held by ICE. 1 = ICE debug mode acknowledgement Disabled. WDT up counter will keep going no matter CPU is held by ICE or not.
[30:11]	Reserved	Reserved.
[10:8]	WTIS	Watchdog Timer Time-Out Interval Selection (Write Protect) These three bits select the time-out interval period for the WDT. $000 = 2^4 * T_{WDT}$ $001 = 2^6 * T_{WDT}$ $010 = 2^8 * T_{WDT}$ $011 = 2^{10} * T_{WDT}$ $100 = 2^{12} * T_{WDT}$ $101 = 2^{14} * T_{WDT}$ $110 = 2^{16} * T_{WDT}$ $111 = 2^{18} * T_{WDT}$
[7]	WTE	Watchdog Timer Enable Bit (Write Protect) 0 = WDT Disabled. (This action will reset the internal up counter value.) 1 = WDT Enabled. Note: If CWDTEN (CONFIG0[31] Watchdog Enable) bit is set to 0, this bit is forced as 1 and user cannot change this bit to 0.
[6]	WTIE	Watchdog Timer Time-Out Interrupt Enable Bit (Write Protect) If this bit is enabled, the WDT time-out interrupt signal is generated and inform to CPU.

		0 = WDT time-out interrupt Disabled. 1 = WDT time-out interrupt Enabled.
[5]	WTWKF	Watchdog Timer Time-Out Wake-Up Flag This bit indicates the interrupt wake-up flag status of WDT. 0 = WDT does not cause chip wake-up. 1 = Chip wake-up from Idle or Power-down mode if WDT time-out interrupt signal generated. Note: This bit is cleared by writing 1 to it.
[4]	WTWKE	Watchdog Timer Time-Out Wake-Up Function Control (Write Protect) If this bit is set to 1, while WTIF is generated to 1 and WTIE enabled, the WDT time-out interrupt signal will generate a wake-up trigger event to chip. 0 = Wake-up trigger event Disabled if WDT time-out interrupt signal generated. 1 = Wake-up trigger event Enabled if WDT time-out interrupt signal generated. Note: Chip can be woken-up by WDT time-out interrupt signal generated only if WDT clock source is selected to 10 kHz oscillator.
[3]	WTIF	Watchdog Timer Time-Out Interrupt Flag This bit will set to 1 while WDT up counter value reaches the selected WDT time-out interval. 0 = WDT time-out interrupt did not occur. 1 = WDT time-out interrupt occurred. Note: This bit is cleared by writing 1 to it.
[2]	WTRF	Watchdog Timer Time-Out Reset Flag This bit indicates the system has been reset by WDT time-out reset or not. 0 = WDT time-out reset did not occur. 1 = WDT time-out reset occurred. Note: This bit is cleared by writing 1 to it.
[1]	WTRE	Watchdog Timer Reset Enable Bit (Write Protect) Setting this bit will enable the WDT time-out reset function if the WDT up counter value has not been cleared after the specific WDT reset delay period expires. 0 = WDT time-out reset function Disabled. 1 = WDT time-out reset function Enabled.
[0]	WTR	Reset Watchdog Timer Up Counter (Write Protect) 0 = No effect. 1 = Reset the internal 18-bit WDT up counter value. Note: This bit will be automatically cleared by hardware.

Watchdog Timer Alternative Control Register (WTCRALT)

Register	Offset	R/W	Description	Reset Value
WTCRALT	WDT_BA+0x04	R/W	Watchdog Timer Alternative Control Register	0x0000_0000

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

Bits	Description	
[31:2]	Reserved	Reserved.
[1:0]	WTRDSEL	Watchdog Timer Reset Delay Selection (Write Protect) When WDT time-out happened, user has a time named WDT Reset Delay Period to clear WDT counter to prevent WDT time-out reset happened. User can select a suitable value of WDT Reset Delay Period for different WDT time-out period. These bits are protected bit. It means programming this bit needs to write "59h", "16h", "88h" to address 0x5000_0100 to disable register protection. Reference the register REGWRPROT at address GCR_BA+0x100. 00 = Watchdog Timer Reset Delay Period is 1026 * WDT_CLK. 01 = Watchdog Timer Reset Delay Period is 130 * WDT_CLK. 10 = Watchdog Timer Reset Delay Period is 18 * WDT_CLK. 11 = Watchdog Timer Reset Delay Period is 3 * WDT_CLK. Note: This register will be reset to 0 if WDT time-out reset happened.

6.11 Window Watchdog Timer (WWDT)

6.11.1 Overview

The Window Watchdog Timer is used to perform a system reset within a specified window period to prevent software run to uncontrollable status by any unpredictable condition.

6.11.2 Features

- 6-bit down counter value (WWDTVAL[5:0]) and 6-bit compare window value (WWDCR[21:16]) to make the WWDT time-out window period flexible
- Supports 4-bit value to programmable maximum 11-bit prescale counter period of WWDT counter

6.11.3 Block Diagram

The Window Watchdog Timer clock control and block diagram are shown as follows.

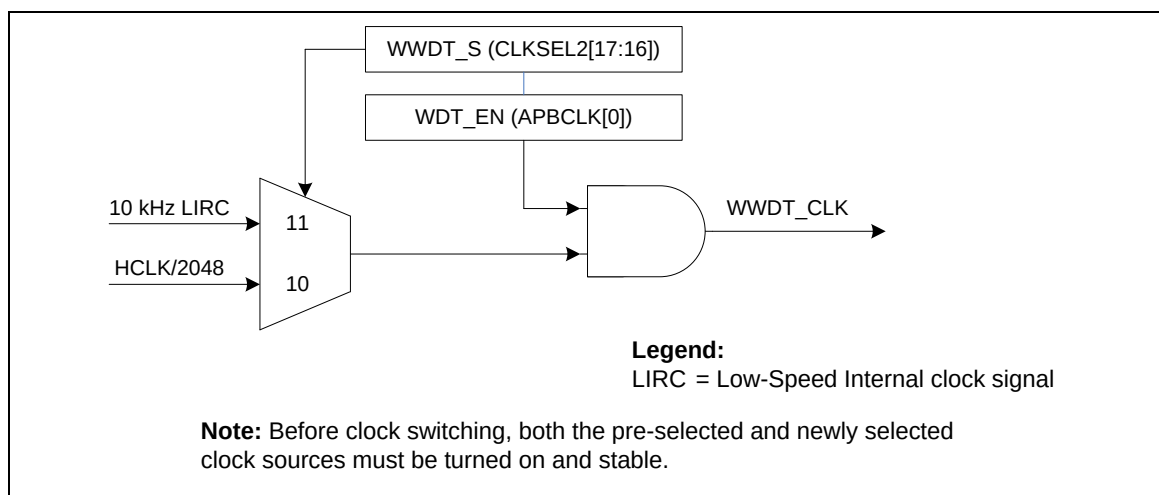


Figure 6-53 Window Watchdog Timer Clock Control

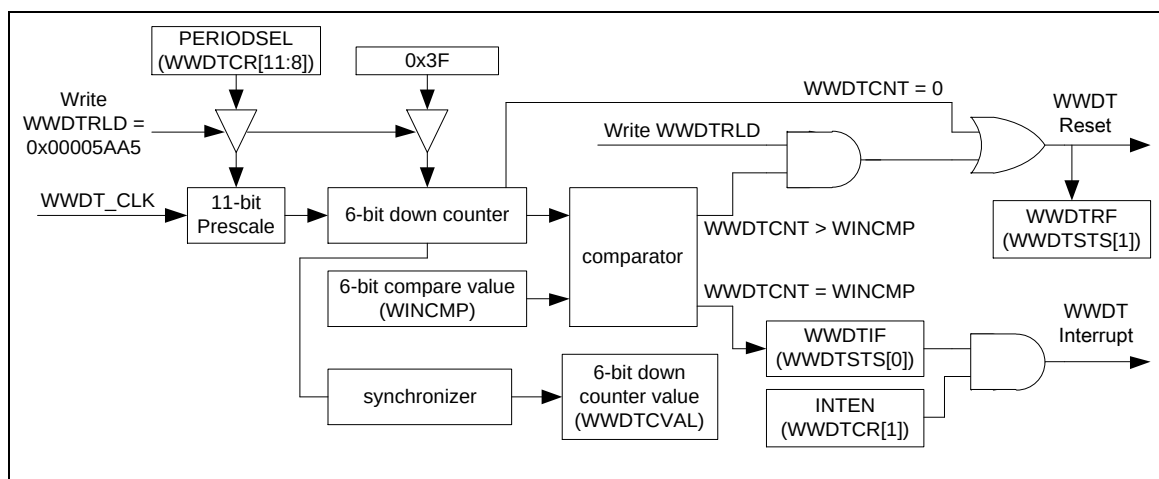


Figure 6-54 Window Watchdog Timer Block Diagram

6.11.4 Basic Configuration

The WWDT peripheral clock is enabled in APBCLK[0] and clock source can be selected in CLKSEL2[17:16].

6.11.5 Functional Description

The Window Watchdog Timer (WWDT) includes a 6-bit down counter with programmable prescale value to define different WWDT time-out intervals.

The clock source of 6-bit WWDT is based on system clock divide 2048 (HCLK/2048) or internal 10 kHz oscillator with a programmable 11-bit prescale counter value which controlled by PERIODSEL (WWDTCTRL[11:8]) setting. Also, the correlate of PERIODSEL and prescale value are listed in the following table.

PERIODSEL	Prescaler Value	Max. Time-Out Period	Max. Time-Out Interval (WWDT_CLK=10 KHz)
0000	1	$1 * 64 * T_{WWDT}$	6.4 ms
0001	2	$2 * 64 * T_{WWDT}$	12.8 ms
0010	4	$4 * 64 * T_{WWDT}$	25.6 ms
0011	8	$8 * 64 * T_{WWDT}$	51.2 ms
0100	16	$16 * 64 * T_{WWDT}$	102.4 ms
0101	32	$32 * 64 * T_{WWDT}$	204.8 ms
0110	64	$64 * 64 * T_{WWDT}$	409.6 ms
0111	128	$128 * 64 * T_{WWDT}$	819.2 ms
1000	192	$192 * 64 * T_{WWDT}$	1.2288 s
1001	256	$256 * 64 * T_{WWDT}$	1.6384 s
1010	384	$384 * 64 * T_{WWDT}$	2.4576 s
1011	512	$512 * 64 * T_{WWDT}$	3.2768 s
1100	768	$768 * 64 * T_{WWDT}$	4.9152 s
1101	1024	$1024 * 64 * T_{WWDT}$	6.5536 s
1110	1536	$1536 * 64 * T_{WWDT}$	9.8304 s
1111	2048	$2048 * 64 * T_{WWDT}$	13.1072 s

Table 6-9 Window Watchdog Timer Prescale Value Selection

- WWDT Counting

When the WWDTEN bit is set, WWDT down counter will start counting from 0x3F to 0. To prevent program runs to disable WWDT counter counting unexpected, the WWDT control register WWDTCTRL can only be written once after chip is powered on or reset. User cannot disable WWDT counter counting (WWDTEN), change counter prescale period (PERIODSEL) or change window compare value (WINCMP) while WWDTEN (WWDTCTRL[0]) bit has been enabled by software unless chip is reset.

- WWDT Compare Match Interrupt

During down counting by the WWDT counter, the WWDTIF is set to 1 while the WWDT counter

value (WWDTCVAL) is equal to WINCMP value and WWDTIF can be cleared by software; if WWDTIE is also set to 1 by software, the WWDT compare match interrupt signal is generated also while WWDTIF is set to 1 by hardware.

● WWDT Reset System

When WWDTIF is generated, user must reload WWDT internal counter value to 0x3F by writing 0x00005AA5 to WWDTRLD, and also to prevent WWDT counter value reached to 0 and generate WWDT reset system signal to info system reset.

If current WWDTCVAL value is larger than WINCMP value and user writes 0x00005AA5 to the WWDTRLD register, the WWDT reset system signal will be generated immediately to cause chip reset also.

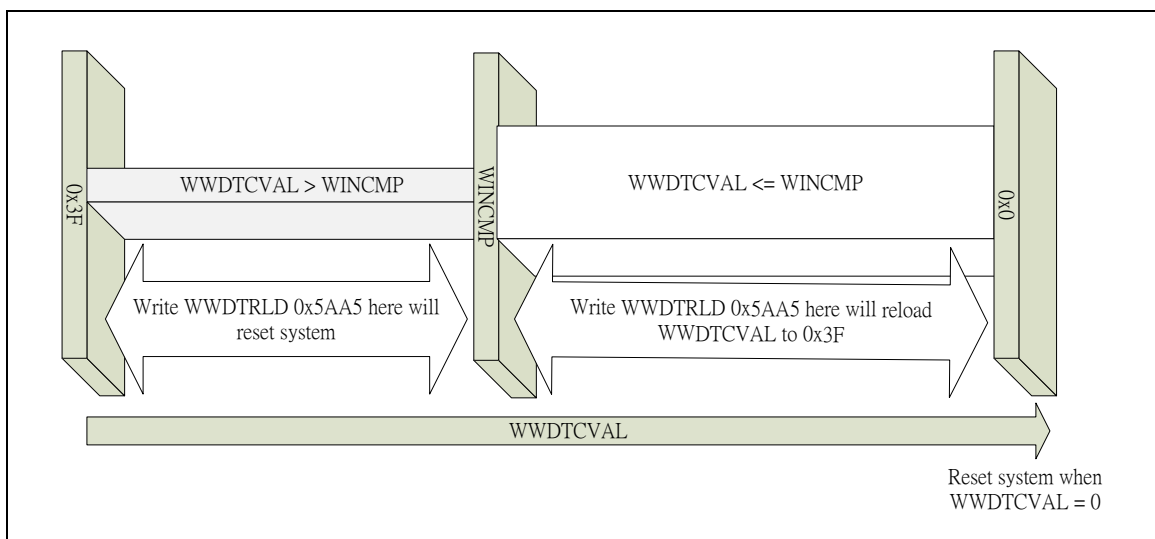


Figure 6-55 Window Watchdog Timer Reset and Reload Behavior

● WWDT Window Setting Limitation

When user writes 0x00005AA5 to WWDTRLD register to reload WWDT counter value to 0x3F, it needs 3 WWDT clocks to sync the reload command to actually perform reload action.

This means if user set PERIODSEL to 0000, the counter prescale value should be as 1, and the WINCMP value must be larger than 2; otherwise, writing WWDTRLD to reload WWDT counter value to 0x3F is unavailable while WWDTIF is generated and WWDT reset system event always happened.

PERIODSEL	Prescale Value	Valid WINCMP Value
0000	1	0x3 ~ 0x3F
0001	2	0x2 ~ 0x3F
Others	Others	0x0 ~ 0x3F

Table 6-10 WINCMP Setting Limitation

6.11.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
WWDT Base Address: WWDT_BA = 0x4000_4100				
WWDTRLD	WWDT_BA+0x00	W	Window Watchdog Timer Reload Counter Register	0x0000_0000
WWDTCR	WWDT_BA+0x04	R/W	Window Watchdog Timer Control Register	0x003F_0800
WWDTSR	WWDT_BA+0x08	R/W	Window Watchdog Timer Status Register	0x0000_0000
WWDTCVR	WWDT_BA+0x0C	R	Window Watchdog Timer Counter Value Register	0x0000_003F

6.11.7 Register Description

Window Watchdog Timer Reload Counter Register (WWDTRLD)

Register	Offset	R/W	Description	Reset Value
WWDTRLD	WWDT_BA+0x00	W	Window Watchdog Timer Reload Counter Register	0x0000_0000

31	30	29	28	27	26	25	24
WWDTRLD[31:24]							
23	22	21	20	19	18	17	16
WWDTRLD[23:16]							
15	14	13	12	11	10	9	8
WWDTRLD[15:8]							
7	6	5	4	3	2	1	0
WWDTRLD[7:0]							

Bits	Description
[31:0]	WWDTRLD WWDTRLD Reload Counter Register Writing 0x00005AA5 to this register will reload the WWDTRLD counter value to 0x3F. Note: User can only write WWDTRLD to reload WWDTRLD counter value when current WWDTRLD counter value between 0 and WINCMP. If user writes WWDTRLD when current WWDTRLD counter value is larger than WINCMP, WWDTRLD reset signal will generate immediately.

Window Watchdog Timer Control Register (WWDTCR)

Register	Offset	R/W	Description	Reset Value
WWDTCR	WWDT_BA+0x04	R/W	Window Watchdog Timer Control Register	0x003F_0800

Note: This register can be written only one time after chip is powered on or reset.

31	30	29	28	27	26	25	24
DBGACK_WWDT	Reserved						
23	22	21	20	19	18	17	16
Reserved		WINCMP					
15	14	13	12	11	10	9	8
Reserved				PERIODSEL			
7	6	5	4	3	2	1	0
Reserved						WWDTIE	WWDTEN

Bits	Description
[31]	DBGACK_WWDT ICE Debug Mode Acknowledge Disable Bit 0 = ICE debug mode acknowledgement effects WWDT counting. WWDT down counter will be held while CPU is held by ICE. 1 = ICE debug mode acknowledgement Disabled. WWDT down counter will keep going no matter CPU is held by ICE or not.
[30:22]	Reserved Reserved.
[21:16]	WINCMP WWDT Window Compare Register Set this register to adjust the valid reload window. Note: User can only write WWDTRLD to reload WWDT counter value when current WWDT counter value between 0 and WINCMP. If user writes WWDTRLD when current WWDT counter value larger than WINCMP, WWDT reset signal will generate immediately.
[15:12]	Reserved Reserved.
[11:8]	PERIODSEL WWDT Counter Prescale Period Selection 0000 = Pre-scale is 1; Max time-out period is $1 * 64 * T_{WWDT}$. 0001 = Pre-scale is 2; Max time-out period is $2 * 64 * T_{WWDT}$. 0010 = Pre-scale is 4; Max time-out period is $4 * 64 * T_{WWDT}$. 0011 = Pre-scale is 8; Max time-out period is $8 * 64 * T_{WWDT}$. 0100 = Pre-scale is 16; Max time-out period is $16 * 64 * T_{WWDT}$. 0101 = Pre-scale is 32; Max time-out period is $32 * 64 * T_{WWDT}$. 0110 = Pre-scale is 64; Max time-out period is $64 * 64 * T_{WWDT}$. 0111 = Pre-scale is 128; Max time-out period is $128 * 64 * T_{WWDT}$. 1000 = Pre-scale is 192; Max time-out period is $192 * 64 * T_{WWDT}$. 1001 = Pre-scale is 256; Max time-out period is $256 * 64 * T_{WWDT}$. 1010 = Pre-scale is 384; Max time-out period is $384 * 64 * T_{WWDT}$. 1011 = Pre-scale is 512; Max time-out period is $512 * 64 * T_{WWDT}$. 1100 = Pre-scale is 768; Max time-out period is $768 * 64 * T_{WWDT}$.

		1101 = Pre-scale is 1024; Max time-out period is $1024 * 64 * T_{WWDT}$. 1110 = Pre-scale is 1536; Max time-out period is $1536 * 64 * T_{WWDT}$. 1111 = Pre-scale is 2048; Max time-out period is $2048 * 64 * T_{WWDT}$.
[7:2]	Reserved	Reserved.
[1]	WWDTIE	WWDT Interrupt Enable Bit If this bit is enabled, the WWDT counter compare match interrupt signal is generated and inform to CPU. 0 = WWDT counter compare match interrupt Disabled. 1 = WWDT counter compare match interrupt Enabled.
[0]	WWDTEN	WWDT Enable Bit Set this bit to enable WWDT counter counting 0 = WWDT counter is stopped. 1 = WWDT counter is starting counting.

Window Watchdog Timer Status Register (WWDTSR)

Register	Offset	R/W	Description	Reset Value
WWDTSR	WWDTSR_BA+0x08	R/W	Window Watchdog Timer Status Register	0x0000_0000

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

Bits	Description
[31:2]	Reserved Reserved.
[1]	WWDTRF WWDT Time-Out Reset Flag This bit indicates the system has been reset by WWDT time-out reset or not. 0 = WWDT time-out reset did not occur. 1 = WWDT time-out reset occurred. Note: This bit is cleared by writing 1 to it.
[0]	WWDTIF WWDT Compare Match Interrupt Flag This bit indicates the interrupt flag status of WWDT while WWDT counter value matches WINCMP value. 0 = No effect. 1 = WWDT counter value matches WINCMP value. Note: This bit is cleared by writing 1 to it.

Window Watchdog Timer Counter Value Register (WWDTCSR)

Register	Offset	R/W	Description	Reset Value
WWDTCSR	WWDT_BA+0x0C	R	Window Watchdog Timer Counter Value Register	0x0000_003F

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

Bits	Description
[31:6]	Reserved
[5:0]	WWDTCSR

Reserved.

WWDT Counter Value
WWDTCSR will be updated continuously to monitor 6-bit down counter value.

6.12 Real Time Clock (RTC)

6.12.1 Overview

The Real Time Clock (RTC) controller provides the real time and calendar message. The RTC offers programmable time tick and alarm match interrupts. The data format of time and calendar messages are expressed in BCD format. A digital frequency compensation feature is available to compensate external crystal oscillator frequency accuracy.

The RTC controller also offers 80 bytes spare registers to store user's important information.

6.12.2 Features

- Supports real time counter in Time Loading Register (TLR) (hour, minute, second) and calendar counter in Calendar Loading Register (CLR) (year, month, day) for RTC time and calendar check
- Supports alarm time (hour, minute, second) and calendar (year, month, day) settings in Time Alarm Register (TAR) and Calendar Alarm Register (CAR) register
- Selectable 12-hour or 24-hour time scale in Time Scale Selection Register (TSSR) register
- Supports Leap Year indication in Leap Year Indicator Register (LIR) register
- Supports Day of the Week counter in Day of the Week Register (DWR) register
- Frequency of RTC clock source compensate by RTC Frequency Compensation Register (FCR) register
- All time and calendar message expressed in BCD format
- Supports periodic RTC Time Tick interrupt with 8 period interval options 1/128, 1/64, 1/32, 1/16, 1/8, 1/4, 1/2 and 1 second
- Supports RTC Time Tick and Alarm Match interrupt
- Supports chip wake-up from Idle or Power-down mode while a RTC interrupt signal is generated
- Supports 80 bytes spare registers

6.12.3 Block Diagram

The block diagram of Real Time Clock is depicted as follows:

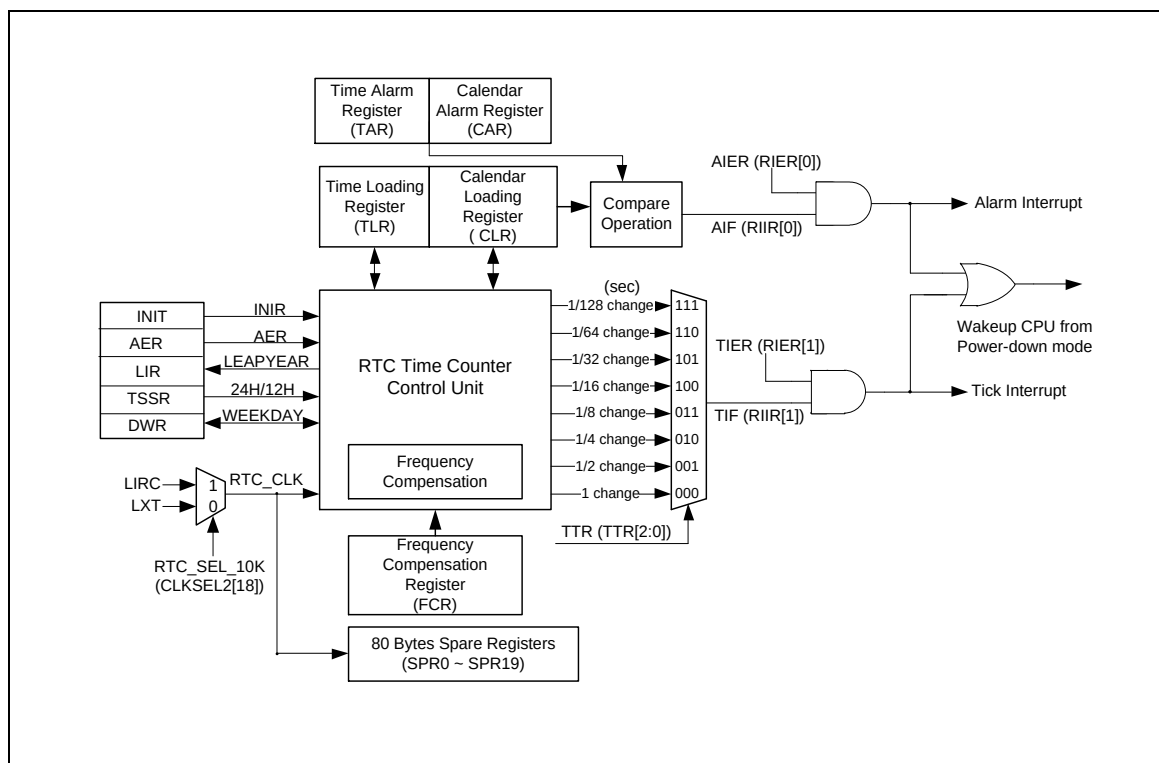


Figure 6-56 RTC Block Diagram

6.12.4 Basic Configuration

RTC controller clock enable is in RTC_EN (APBCLK[1]) and low speed 32 kHz oscillator is enabled by XTL32K_EN (PWRCON[1]).

6.12.5 Functional Description

6.12.5.1 RTC Initiation

When a RTC block is powered on, RTC is at reset state. User has to write a number 0xa5eb1357 to INIR (INIR [31:0] RTC Initiation) register to make RTC leaving reset state. Once the INIR is written as 0xa5eb1357, the RTC will be in normal active state permanently. User can read Active bit (INIR[0] RTC Active Status) to check the RTC is at normal active state or reset state.

6.12.5.2 Access to RTC register

Due to clock frequency difference between RTC clock and system clock, when user write new data to any one of the RTC registers, the data will not be updated until 2 RTC clocks later (about 60us).

In addition, user must be aware that RTC controller does not check whether loaded data is out of bounds or not in TLR, CLR, TAR and CAR registers. RTC does not check rationality between DWR and CLR either.

6.12.5.3 RTC Read/Write Enable

AER (AER[15:0] RTC Register Access Enable Password) is served as read/write access of RTC registers to unlock register read/write protection function. If AER[15:0] is written to 0xA965, user can read ENF (AER[16] RTC Register Access Enable Flag) bit status to check the RTC registers are read/write accessible or locked. Once ENF bit enabled, RTC access enable function will keep effect at least 1024 RTC clocks (about 30ms) and ENF bit will be cleared automatically after 1024 RTC clocks.

The RTC control registers access attribute when ENF is 1 and 0 are shown in below table.

Register	ENF=1	ENF=0
INIR	R/W	R/W
AER	R/W	R/W
FCR	R/W	Not available
TLR	R/W	R
CLR	R/W	R
TSSR	R/W	R/W
DWR	R/W	R
TAR	R/W	Not available
CAR	R/W	Not available
LIR	R	R
RIER	R/W	R/W
RIIR	R/W	R/W
TTR	R/W	Not available
SPRCTL	R/W	Not available

SPR0-SPR19	R/W	Not available

6.12.5.4 Frequency Compensation

The RTC source clock may not precise to exactly 32768 Hz and the FCR register (Frequency Compensation Register) allows user to make digital compensation to the RTC source clock only if the frequency of RTC source clock is in the range from 32761 Hz to 32776 Hz.

Integer Part Of Detected Value	INTEGER (FCR[11:8])	Integer Part Of Detected Value	INTEGER (FCR[11:8])
32776	1111	32768	0111
32775	1110	32767	0110
32774	1101	32766	0101
32773	1100	32765	0100
32772	1011	32764	0011
32771	1010	32763	0010
32770	1001	32762	0001
32769	1000	32761	0000

Following are the compensation examples for the real RTC source clock is higher or lower than 32768 Hz.

Example 1: (RTC Source Clock > 32768 Hz)
RTC Source Clock Measured: 32773.65 Hz (> 32768 Hz)
Integer Part: 32773 => 0x8005
INTEGER (FCR [11:8] Integer Part) = 0x05 – 0x01 + 0x08 = 0x0c
Fraction Part: 0.65
FRACTION (FCR [5:0] Fraction Part) = 0.65 X 60 = 39 = 0x27
RTC FCR Register Should Be As 0xC27.

Example 2: (RTC source clock ≤ 32768 Hz)
RTC source clock measured: 32765.27 Hz (≤ 32768 Hz)
Integer part: 32765 => 0x7FFD
INTEGER (FCR [11:8] Integer Part) = 0x0D – 0x01 – 0x08 = 0x04
Fraction part: 0.27
FRACTION (FCR [5:0] Fraction Part) = 0.27 x 60 = 16.2 = 0x10
RTC FCR register should be as 0x410.

6.12.5.5 Time and Calendar counter

TLR and CLR register are used to load the real time and calendar. TAR and CAR register are used for setup alarm time and calendar.

6.12.5.6 12/24 hour Time Scale Selection

The 12/24 hour time scale selection depends on 24H_12H bit (TSSR[0] 24-Hour / 12-Hour Time Scale Selection).

24-Hour Time Scale (24H_12H = 1)	12-Hour Time Scale (24H_12H = 0)	24-Hour Time Scale (24H_12H = 1)	12-Hour Time Scale (PM Time + 20) (24H_12H = 0)
00	12 (AM12)	12	32 (PM12)
01	01 (AM01)	13	21 (PM01)
02	02 (AM02)	14	22 (PM02)
03	03 (AM03)	15	23 (PM03)
04	04 (AM04)	16	24 (PM04)
05	05 (AM05)	17	25 (PM05)
06	06 (AM06)	18	26 (PM06)
07	07 (AM07)	19	27 (PM07)
08	08 (AM08)	20	28 (PM08)
09	09 (AM09)	21	29 (PM09)
10	10 (AM10)	22	30 (PM10)
11	11 (AM11)	23	31 (PM11)

6.12.5.7 Day of the Week counter

The RTC controller provides day of week in DWR (DWR[2:0] Day of the Week Register). The value is defined from 0 to 6 to represent Sunday to Saturday respectively.

6.12.5.8 Periodic Time Tick Interrupt

The Periodic Time Tick interrupt has 8 period interval options 1/128, 1/64, 1/32, 1/16, 1/8, 1/4, 1/2 and 1 second that are selected by TTR (TTR[2:0] Time Tick Register). When Periodic Time Tick interrupt is enabled by setting TIER (RIER[1] Time Tick Interrupt Enable) to 1, the Periodic Time Tick interrupt is requested periodically in the period selected by TTR[2:0] settings.

6.12.5.9 Alarm Interrupt

When the real time and calendar message in TLR and CLR registers are equal to alarm time and calendar values in RTC TAR and CAR registers, the AIF (RIIR[0] RTC Alarm Interrupt Flag) is set to 1 and the RTC alarm interrupt signal asserted if the AIER (RIER[0] Alarm Interrupt Enable) is enabled.

6.12.5.10 Application Note

1. All data in TAR, CAR, TLR and CLR registers are all expressed in BCD format.
2. User has to make sure that the loaded values are reasonable. For example, load CLR as 201a (year), 13 (month), 00 (day), or CLR does not match with DWR, etc.
3. Registers value after powered on or reset:

Register	Reset State
AER	0
CLR	05/1/1 (year/month/day)
TLR	00:00:00 (hour : minute : second)
CAR	00/00/00 (year/month/day)

TAR	00:00:00 (hour : minute : second)
TSSR	1 (24-hour mode)
DWR	6 (Saturday)
RIER	0
RIIR	0
LIR	0
TTR	0

4. In CLR and CAR, only 2 BCD digits are used to express "year". The 2 BCD digits of xy means 20xy, rather than 19xy or 21xy.

6.12.5.11 Spare registers

The RTC module is equipped 80 bytes spare registers to store user's important information. These spare registers are located in RTC clock domain, user needs to enable SPREN (SPRCTL[2] SPR Register Enable) before writing one of 20 spare registers (SPR0 ~ SPR19). User could read SPRRDY (SPRCTL[7] SPR Register Ready) to check if data has been written into registers or not. User could only access the spare registers again once SPRRDY is 1. Any access to spare registers is available if SPRRDY is 0.

If external 32 kHz clock (LXT) is not available in system design, user can choose RTC_SEL_10K (CLKSEL2[18]) to 1 to use on chip 10 kHz clock (LIRC) instead of for spare registers read and write operations.

6.12.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
RTC Base Address: RTC_BA = 0x4000_8000				
INIR	RTC_BA+0x00	R/W	RTC Initiation Register	0x0000_0000
AER	RTC_BA+0x04	R/W	RTC Access Enable Register	0x0000_0000
FCR	RTC_BA+0x08	R/W	RTC Frequency Compensation Register	0x0000_0700
TLR	RTC_BA+0x0C	R/W	Time Loading Register	0x0000_0000
CLR	RTC_BA+0x10	R/W	Calendar Loading Register	0x0005_0101
TSSR	RTC_BA+0x14	R/W	Time Scale Selection Register	0x0000_0001
DWR	RTC_BA+0x18	R/W	Day of the Week Register	0x0000_0006
TAR	RTC_BA+0x1C	R/W	Time Alarm Register	0x0000_0000
CAR	RTC_BA+0x20	R/W	Calendar Alarm Register	0x0000_0000
LIR	RTC_BA+0x24	R	Leap Year Indicator Register	0x0000_0000
RIER	RTC_BA+0x28	R/W	RTC Interrupt Enable Register	0x0000_0000
RIIR	RTC_BA+0x2C	R/W	RTC Interrupt Indicator Register	0x0000_0000
TTR	RTC_BA+0x30	R/W	RTC Time Tick Register	0x0000_0000
SPRCTL	RTC_BA+0x3C	R/W	RTC Spare Functional Control Register	0x0000_0080
SPR0	RTC_BA+0x40	R/W	RTC Spare Register 0	0x0000_0000
SPR1	RTC_BA+0x44	R/W	RTC Spare Register 1	0x0000_0000
SPR2	RTC_BA+0x48	R/W	RTC Spare Register 2	0x0000_0000
SPR3	RTC_BA+0x4C	R/W	RTC Spare Register 3	0x0000_0000
SPR4	RTC_BA+0x50	R/W	RTC Spare Register 4	0x0000_0000
SPR5	RTC_BA+0x54	R/W	RTC Spare Register 5	0x0000_0000
SPR6	RTC_BA+0x58	R/W	RTC Spare Register 6	0x0000_0000
SPR7	RTC_BA+0x5C	R/W	RTC Spare Register 7	0x0000_0000
SPR8	RTC_BA+0x60	R/W	RTC Spare Register 8	0x0000_0000
SPR9	RTC_BA+0x64	R/W	RTC Spare Register 9	0x0000_0000
SPR10	RTC_BA+0x68	R/W	RTC Spare Register 10	0x0000_0000
SPR11	RTC_BA+0x6C	R/W	RTC Spare Register 11	0x0000_0000

SPR12	RTC_BA+0x70	R/W	RTC Spare Register 12	0x0000_0000
SPR13	RTC_BA+0x74	R/W	RTC Spare Register 13	0x0000_0000
SPR14	RTC_BA+0x78	R/W	RTC Spare Register 14	0x0000_0000
SPR15	RTC_BA+0x7C	R/W	RTC Spare Register 15	0x0000_0000
SPR16	RTC_BA+0x80	R/W	RTC Spare Register 16	0x0000_0000
SPR17	RTC_BA+0x84	R/W	RTC Spare Register 17	0x0000_0000
SPR18	RTC_BA+0x88	R/W	RTC Spare Register 18	0x0000_0000
SPR19	RTC_BA+0x8C	R/W	RTC Spare Register 19	0x0000_0000

6.12.7 Register Description

RTC Initiation Register (INIR)

Register	Offset	R/W	Description	Reset Value
INIR	RTC_BA+0x00	R/W	RTC Initiation Register	0x0000_0000

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

Bits	Description
[31:1]	RTC Initiation When RTC block is powered on, RTC is at reset state. User has to write a number (0xa5eb1357) to INIR to make RTC leaving reset state. Once the INIR is written as 0xa5eb1357, the RTC will be in un-reset state permanently. The INIR is a write-only field and read value will be always 0.
[0]	RTC Active Status (Read Only) 0 = RTC is at reset state. 1 = RTC is at normal active state.

RTC Access Enable Register (AER)

Register	Offset	R/W	Description	Reset Value
AER	RTC_BA+0x04	R/W	RTC Access Enable Register	0x0000_0000

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

Bits	Description	
[31:17]	Reserved	Reserved.
[16]	ENF	RTC Register Access Enable Flag (Read Only) 0 = RTC register read/write access Disabled. 1 = RTC register read/write access Enabled. Note: This bit will be set after AER[15:0] is load a 0xA965, and will be cleared automatically after 1024 RTC clocks.
[15:0]	AER	RTC Register Access Enable Password (Write Only) Writing 0xA965 to this register will enable RTC access and keep 1024 RTC clocks.

RTC Frequency Compensation Register (FCR)

Register	Offset	R/W	Description	Reset Value
FCR	RTC_BA+0x08	R/W	RTC Frequency Compensation Register	0x0000_0700

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

Bits	Description	
[31:12]	Reserved	Reserved.
[11:8]	INTEGER	Integer Part Please refer to 5.14.5.4 .
[5:0]	FRACTION	Fraction Part Formula = (fraction part of detected value) x 60. Note: Digit in FCR must be expressed as hexadecimal number..

Note: This register can be read back after the ENF (AER[16] RTC Register Access Enable Flag) is active.

RTC Time Loading Register (TLR)

Register	Offset	R/W	Description	Reset Value
TLR	RTC_BA+0x0C	R/W	Time Loading Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved		10HR		1HR			
15	14	13	12	11	10	9	8
Reserved	10MIN			1MIN			
7	6	5	4	3	2	1	0
Reserved	10SEC			1SEC			

Bits	Description
[31:22]	Reserved Reserved.
[21:20]	10HR 10-Hour Time Digit (0~2)
[19:16]	1HR 1-Hour Time Digit (0~9)
[15]	Reserved Reserved.
[14:12]	10MIN 10-Min Time Digit (0~5)
[11:8]	1MIN 1-Min Time Digit (0~9)
[7]	Reserved Reserved.
[6:4]	10SEC 10-Sec Time Digit (0~5)
[3:0]	1SEC 1-Sec Time Digit (0~9)

Note:

1. TLR is a BCD digit counter and RTC controller will not check the loaded data is reasonable or not.
2. The reasonable value range is listed in the parenthesis.
3. When RTC runs as 12-hour time scale mode, the high bit of 10HR field means AM/PM.

RTC Calendar Loading Register (CLR)

Register	Offset	R/W	Description	Reset Value
CLR	RTC_BA+0x10	R/W	Calendar Loading Register	0x0005_0101

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
10YEAR				1YEAR			
15	14	13	12	11	10	9	8
Reserved			10MON	1MON			
7	6	5	4	3	2	1	0
Reserved		10DAY		1DAY			

Bits	Description	
[31:24]	Reserved	Reserved.
[23:20]	10YEAR	10-Year Calendar Digit (0~9)
[19:16]	1YEAR	1-Year Calendar Digit (0~9)
[15:13]	Reserved	Reserved.
[12]	10MON	10-Month Calendar Digit (0~1)
[11:8]	1MON	1-Month Calendar Digit (0~9)
[7:6]	Reserved	Reserved.
[5:4]	10DAY	10-Day Calendar Digit (0~3)
[3:0]	1DAY	1-Day Calendar Digit (0~9)

Note:

- CLR is a BCD digit counter and RTC will not check the loaded data is reasonable or not.
- The reasonable value range is listed in the parenthesis.

RTC Time Scale Selection Register (TSSR)

Register	Offset	R/W	Description	Reset Value
TSSR	RTC_BA+0x14	R/W	Time Scale Selection Register	0x0000_0001

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved							24H_12H

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	24H_12H	24-Hour / 12-Hour Time Scale Selection It indicates that RTC TLR and TAR counter are in 24-hour time scale or 12-hour time scale. Please refer to 5.14.5.6 . 0 = 24-hour time scale selected. 1 = 24-hour time scale selected.

RTC Day of the Week Register (DWR)

Register	Offset	R/W	Description	Reset Value
DWR	RTC_BA+0x18	R/W	Day of the Week Register	0x0000_0006

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

Bits	Description	
[31:3]	Reserved	Reserved.
[2:0]	DWR	Day Of The Week Register 000 = Sunday. 001 = Monday. 010 = Tuesday. 011 = Wednesday. 100 = Thursday. 101 = Friday. 110 = Saturday. 111 = Reserved.

RTC Time Alarm Register (TAR)

Register	Offset	R/W	Description	Reset Value
TAR	RTC_BA+0x1C	R/W	Time Alarm Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved		10HR		1HR			
15	14	13	12	11	10	9	8
Reserved	10MIN			1MIN			
7	6	5	4	3	2	1	0
Reserved	10SEC			1SEC			

Bits	Description	
[31:22]	Reserved	Reserved.
[21:20]	10HR	10-Hour Time Digit of Alarm Setting (0~2)
[19:16]	1HR	1-Hour Time Digit of Alarm Setting (0~9)
[15]	Reserved	Reserved.
[14:12]	10MIN	10-Min Time Digit of Alarm Setting (0~5)
[11:8]	1MIN	1-Min Time Digit of Alarm Setting (0~9)
[7]	Reserved	Reserved.
[6:4]	10SEC	10-Sec Time Digit of Alarm Setting (0~5)
[3:0]	1SEC	1-Sec Time Digit of Alarm Setting (0~9)

Note:

1. This register can be read back after the ENF (AER[16] RTC Register Access Enable Flag) is active.
2. TAR is a BCD digit counter and RTC controller will not check the loaded data is reasonable or not.
3. The reasonable value range is listed in the parenthesis.
4. When RTC runs as 12-hour time scale mode, the high bit of 10HR field means AM/PM.

RTC Calendar Alarm Register (CAR)

Register	Offset	R/W	Description	Reset Value
CAR	RTC_BA+0x20	R/W	Calendar Alarm Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
10YEAR				1YEAR			
15	14	13	12	11	10	9	8
Reserved			10MON	1MON			
7	6	5	4	3	2	1	0
Reserved		10DAY		1DAY			

Bits	Description
[31:24]	Reserved Reserved.
[23:20]	10YEAR 10-Year Calendar Digit of Alarm Setting (0~9)
[19:16]	1YEAR 1-Year Calendar Digit of Alarm Setting (0~9)
[15:13]	Reserved Reserved.
[12]	10MON 10-Month Calendar Digit of Alarm Setting (0~1)
[11:8]	1MON 1-Month Calendar Digit of Alarm Setting (0~9)
[7:6]	Reserved Reserved.
[5:4]	10DAY 10-Day Calendar Digit of Alarm Setting (0~3)
[3:0]	1DAY 1-Day Calendar Digit of Alarm Setting (0~9)

Note:

1. This register can be read back after the ENF (AER [16] RTC Register Access Enable Flag) is active.
2. CAR is a BCD digit counter and RTC will not check the loaded data is reasonable or not.
3. The reasonable value range is listed in the parenthesis.

RTC Leap Year Indication Register (LIR)

Register	Offset	R/W	Description	Reset Value
LIR	RTC_BA+0x24	R	Leap Year Indicator Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	LIR	Leap Year Indication Register (Read Only) 0 = This year is not a leap year. 1 = This year is a leap year.

RTC Interrupt Enable Register (RIER)

Register	Offset	R/W	Description	Reset Value
RIER	RTC_BA+0x28	R/W	RTC Interrupt Enable Register	0x0000_0000

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

Bits	Description	
[31:2]	Reserved	Reserved.
[1]	TIER	Time Tick Interrupt Enable Bit This bit is used to enable/disable RTC Time Tick Interrupt, and generate an interrupt signal if TIF (RIIR[1] RTC Time Tick Interrupt Flag) is set to 1. 0 = RTC Time Tick Interrupt Disabled. 1 = RTC Time Tick Interrupt Enabled. Note: This bit will also trigger a wake-up event while system runs in Idle/Power-down mode and RTC Time Tick Interrupt signal generated.
[0]	AIER	Alarm Interrupt Enable Bit This bit is used to enable/disable RTC Alarm Interrupt, and generate an interrupt signal if AIF (RIIR[0] RTC Alarm Interrupt Flag) is set to 1. 0 = RTC Alarm Interrupt Disabled. 1 = RTC Alarm Interrupt Enabled. Note: This bit will also trigger a wake-up event while system runs in Idle/Power-down mode and RTC Alarm Interrupt signal generated.

RTC Interrupt Indication Register (RIIR)

Register	Offset	R/W	Description	Reset Value
RIIR	RTC_BA+0x2C	R/W	RTC Interrupt Indicator Register	0x0000_0000

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

Bits	Description	
[31:2]	Reserved	Reserved.
[1]	TIF	RTC Time Tick Interrupt Flag When RTC time tick happened, this bit will be set to 1 and an interrupt will be generated if RTC Tick Interrupt enabled TIER (RIER[1]) is set to 1. Chip will also be wake-up if RTC Tick Interrupt is enabled and this bit is set to 1 when chip is running at Power-down mode. 0 = Tick condition does not occur. 1 = Tick condition occur. Note: Write 1 to clear this bit.
[0]	AIF	RTC Alarm Interrupt Flag When RTC time counters TLR and CLR match the alarm setting time registers TAR and CAR, this bit will be set to 1 and an interrupt will be generated if RTC Alarm Interrupt enabled AIER (RIER[0]) is set to 1. Chip will be wake-up if RTC Alarm Interrupt is enabled when chip is at Power-down mode. 0 = Alarm condition is not matched. 1 = Alarm condition is matched. Note: Write 1 to clear this bit.

RTC Time Tick Register (TTR)

Register	Offset	R/W	Description	Reset Value
TTR	RTC_BA+0x30	R/W	RTC Time Tick Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					TTR[2:0]		

Bits	Description	
[31:3]	Reserved	Reserved.
[2:0]	TTR	Time Tick Register These bits are used to select RTC time tick period for Periodic Time Tick Interrupt request. 000 = Time tick is 1 second. 001 = Time tick is 1/2 second. 010 = Time tick is 1/4 second. 011 = Time tick is 1/8 second. 100 = Time tick is 1/16 second. 101 = Time tick is 1/32 second. 110 = Time tick is 1/64 second. 111 = Time tick is 1/28 second. Note: This register can be read back after the RTC register access enable bit ENF (AER[16]) is active.

RTC Spare Functional Control Register (SPRCTL)

Register	Offset	R/W	Description	Reset Value
SPRCTL	RTC_BA+0x3C	R/W	RTC Spare Functional Control Register	0x0000_0080

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

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	SPRRDY	SPR Register Ready This bit indicates if the registers SPRCTL, SPR0 ~ SPR19 are ready to be accessed. After user writing registers SPRCTL, SPR0 ~ SPR19, read this bit to check if these registers are updated done is necessary. 0 = SPRCTL, SPR0 ~ SPR19 updating is in progress. 1 = SPRCTL, SPR0 ~ SPR19 are updated done and ready to be accessed. Note: This bit is read only and any write to it won't take any effect.
[6:3]	Reserved	Reserved.
[2]	SPREN	SPR Register Enable Bit 0 = Spare register is Disabled. 1 = Spare register is Enabled. Note: When spare register is disabled, RTC SPR0 ~ SPR19 cannot be accessed.
[1:0]	Reserved	Reserved.

RTC Spare Register (SPRx)

Register	Offset	R/W	Description	Reset Value
SPR0	RTC_BA+0x40	R/W	RTC Spare Register 0	0x0000_0000
SPR1	RTC_BA+0x44	R/W	RTC Spare Register 1	0x0000_0000
SPR2	RTC_BA+0x48	R/W	RTC Spare Register 2	0x0000_0000
SPR3	RTC_BA+0x4C	R/W	RTC Spare Register 3	0x0000_0000
SPR4	RTC_BA+0x50	R/W	RTC Spare Register 4	0x0000_0000
SPR5	RTC_BA+0x54	R/W	RTC Spare Register 5	0x0000_0000
SPR6	RTC_BA+0x58	R/W	RTC Spare Register 6	0x0000_0000
SPR7	RTC_BA+0x5C	R/W	RTC Spare Register 7	0x0000_0000
SPR8	RTC_BA+0x60	R/W	RTC Spare Register 8	0x0000_0000
SPR9	RTC_BA+0x64	R/W	RTC Spare Register 9	0x0000_0000
SPR10	RTC_BA+0x68	R/W	RTC Spare Register 10	0x0000_0000
SPR11	RTC_BA+0x6C	R/W	RTC Spare Register 11	0x0000_0000
SPR12	RTC_BA+0x70	R/W	RTC Spare Register 12	0x0000_0000
SPR13	RTC_BA+0x74	R/W	RTC Spare Register 13	0x0000_0000
SPR14	RTC_BA+0x78	R/W	RTC Spare Register 14	0x0000_0000
SPR15	RTC_BA+0x7C	R/W	RTC Spare Register 15	0x0000_0000
SPR16	RTC_BA+0x80	R/W	RTC Spare Register 16	0x0000_0000
SPR17	RTC_BA+0x84	R/W	RTC Spare Register 17	0x0000_0000
SPR18	RTC_BA+0x88	R/W	RTC Spare Register 18	0x0000_0000
SPR19	RTC_BA+0x8C	R/W	RTC Spare Register 19	0x0000_0000

31	30	29	28	27	26	25	24
SPARE[31:24]							
23	22	21	20	19	18	17	16
SPARE[23:16]							
15	14	13	12	11	10	9	8
SPARE[15:8]							
7	6	5	4	3	2	1	0
SPARE[7:0]							

Bits	Descriptions	
[31:0]	SPARE	Spare Register This field is used to store back-up information defined by user.. Before storing back-up information in to SPARE register, user should write 0xA965 to AER[15:0] to make sure register read/write enable bit ENF (AER[16]) is active.

6.13 UART Interface Controller (UART)

6.13.1 Overview

The NuMicro NUC230/240 series provides up to three channels of Universal Asynchronous Receiver/Transmitters (UART). UART0 supports High Speed UART and UART1~2 perform Normal Speed UART. Besides, only UART0 and UART1 support the flow control function. The UART Controller performs a serial-to-parallel conversion on data received from the peripheral, and a parallel-to-serial conversion on data transmitted from the CPU. The UART controller also supports IrDA SIR Function, LIN master/slave function and RS-485 function mode. Each UART Controller channel supports seven types of interrupts.

6.13.2 Features

- Full duplex, asynchronous communications
- Separates receive / transmit 64/16/16 bytes (UART0/UART1/UART2) entry FIFO for data payloads
- Supports hardware auto flow control/flow control function (CTS, RTS) and programmable RTS flow control trigger level (UART0 and UART1 support)
- Programmable receiver buffer trigger level
- Supports programmable baud-rate generator for each channel individually
- Supports CTS wake-up function (UART0 and UART1 support)
- Supports 7-bit receiver buffer time-out detection function
- UART0/UART1 can through DMA channels to receive/transmit data
- Programmable transmitting data delay time between the last stop and the next start bit by setting UA_TOR [DLY] register
- Supports break error, frame error, parity error and receive / transmit buffer overflow detect function
- Fully programmable serial-interface characteristics
 - Programmable data bit length, 5-, 6-, 7-, 8-bit character
 - Programmable parity bit, even, odd, no parity or stick parity bit generation and detection
 - Programmable stop bit length, 1, 1.5, or 2 stop bit generation
- IrDA SIR function mode
 - Supports 3-/16-bit duration for normal mode
- LIN function mode
 - Supports LIN master/slave mode
 - Supports programmable break generation function for transmitter
 - Supports break detect function for receiver
- RS-485 function mode.
 - Supports RS-485 9-bit mode
 - Supports hardware or software direct enable control provided by RTS pin (UART0 and UART1 support)

6.13.3 Block Diagram

The UART clock control and block diagram are shown in Figure 5-67 and Figure 5-68 respectively.

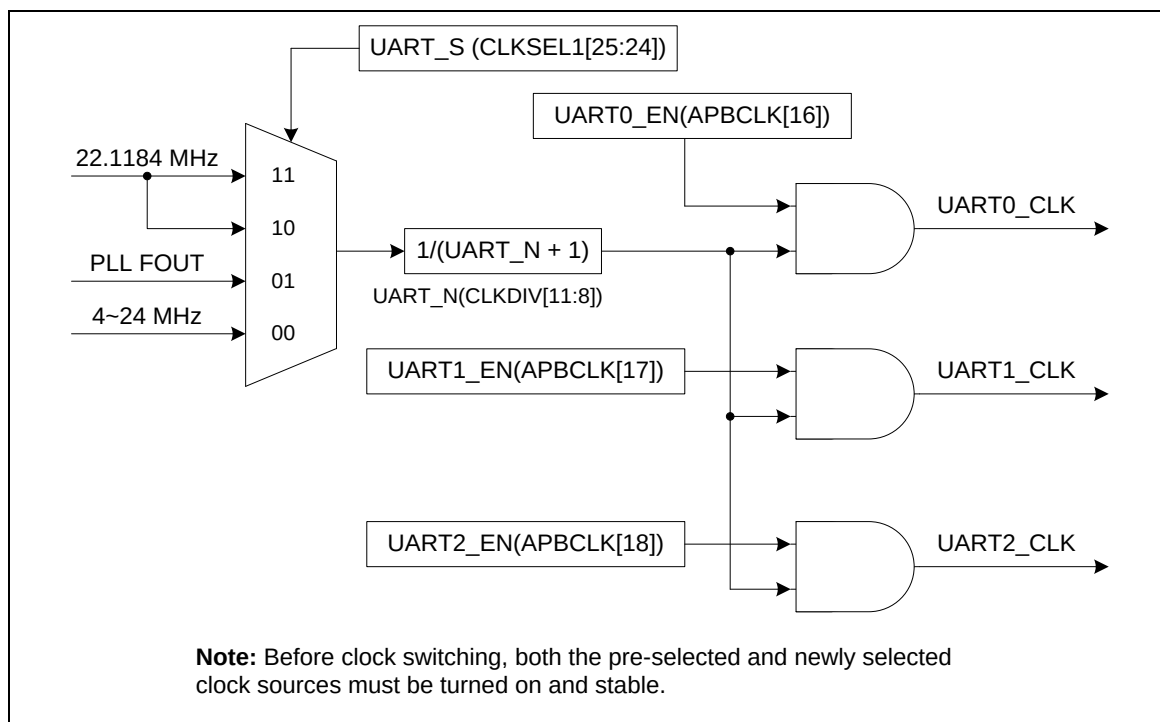


Figure 6-57 UART Clock Control Diagram

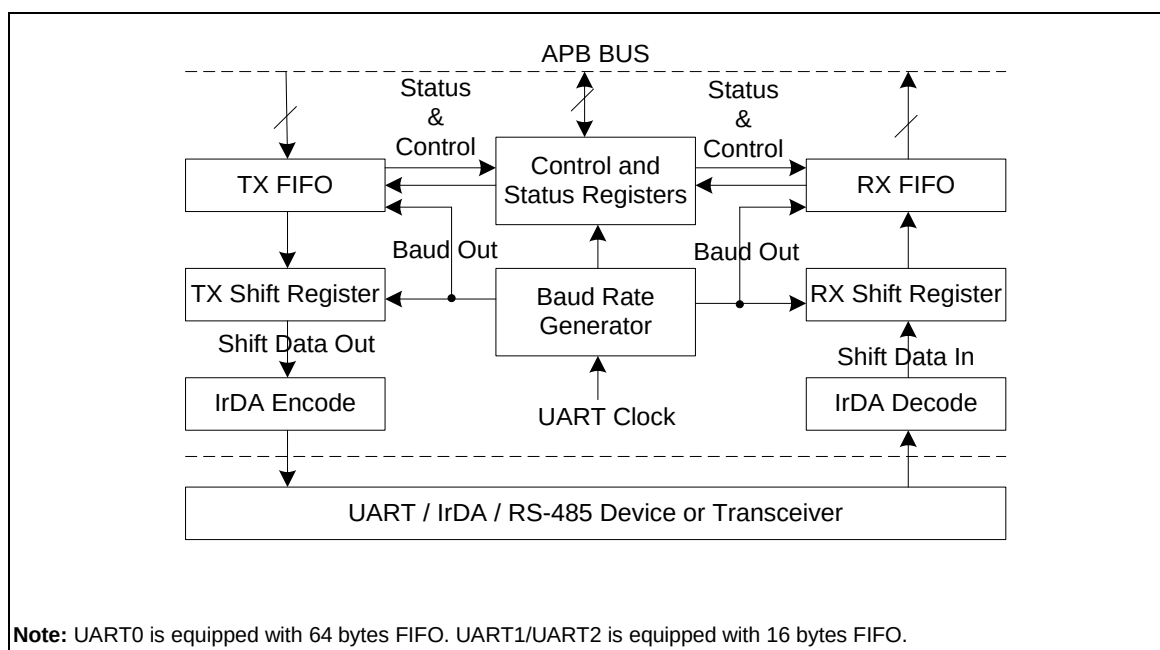


Figure 6-58 UART Block Diagram

Each block is described in detail as follows:

TX_FIFO

The transmitter is buffered with a 64/16 byte FIFO to reduce the number of interrupts presented to the CPU.

RX_FIFO

The receiver is buffered with a 64/16 byte FIFO (plus three error bits per byte) to reduce the number of interrupts presented to the CPU.

TX shift Register

This block is the shifting the transmitting data out of serially control.

RX shift Register

This block is the shifting the receiving data in of serially control.

Modem Control Register

This register controls the interface to the MODEM or data set (or a peripheral device emulating a MODEM).

Baud Rate Generator

Divide the external clock by the divisor to get the desired baud rate. Refer to baud rate equation.

IrDA Encode

This block is IrDA encode control block.

IrDA Decode

This block is IrDA decode control block.

Control and Status Register

This field is register set that including the FIFO control registers (UA_FCR), FIFO status registers (UA_FSR), and line control register (UA_LCR) for transmitter and receiver. The time-out control register (UA_TOR) identifies the condition of time-out interrupt. This register set also includes the interrupt enable register (UA_IER) and interrupt status register (UA_ISR) to enable or disable the responding interrupt and to identify the occurrence of the responding interrupt. There are seven types of interrupts, transmitter FIFO empty interrupt (THRE_INT), receiver threshold level reaching interrupt (RDA_INT), line status interrupt (parity error or framing error or break interrupt) (RLS_INT), time-out interrupt (TOUT_INT), MODEM/Wake-up status interrupt (MODEM_INT), Buffer error interrupt (BUF_ERR_INT) and LIN receiver break field detected interrupt (LIN_INT).

6.13.4 Basic Configuration

The UART Controller function pins are configured in PB_MFP, PD_MFP, ALT_MFP, ALT_MFP1 and ALT_MFP2 registers.

The UART Controller clock are enabled in UART0_EN (APBCLK[16]) for UART0 and UART1_EN (APBCLK[17]) for UART1.

The UART Controller clock source is selected by UART_S (CLKSEL[25:24]).

The UART Controller clock prescaler is determined by UART_N (CLKDIV[11:8]).

UART Interface Controller Pin description is shown as following:

Pin	Type	Description
UART_TXD	Output	UART transmit
UART_RXD	Input	UART receive

UART_nCTS	Input	UART modem clear to send
UART_nRTS	Output	UART modem request to send

Table 6-11 UART Interface Controller Pin

6.13.5 Functional Description

The UART Controller supports four function modes including UART, IrDA, LIN and RS-485 mode. User can select a function by setting the UA_FUN_SEL register. The four function modes will be described in following section.

6.13.5.1 UART Controller Baud Rate Generator

The UART Controller includes a programmable baud rate generator capable of dividing clock input by divisors to produce the serial clock that transmitter and receiver need. The baud rate equation is $\text{Baud Rate} = \text{UART\_CLK} / M * [\text{BRD} + 2]$, where M and BRD are defined in Baud Rate Divider Register (UA_BAUD). The following tables list the UART baud rate equations in the various conditions and UART baud rate parameter settings. There is no error for the baud rate results calculated through the baud rate parameter and register setting below. In IrDA function mode, the baud rate generator must be set in Mode 0.

Mode	DIV_X_EN	DIV_X_ONE	Divider X	BRD	Baud Rate Equation
0	0	0	Don't care	A	$\text{UART\_CLK} / [16 * (A+2)]$.
1	1	0	B	A	$\text{UART\_CLK} / [(B+1) * (A+2)]$, B must ≥ 8 .
2	1	1	Don't care	A	$\text{UART\_CLK} / (A+2)$, If UART peripheral clock $\leq$ HCLK, A must ≥ 9 . If $\text{HCLK} < \text{UART peripheral clock} \leq 2 * \text{HCLK}$, A must ≥ 15 . If $2 * \text{HCLK} < \text{UART peripheral clock} \leq 3 * \text{HCLK}$, A must ≥ 21 . If UART peripheral clock $> 3 * \text{HCLK}$, it is unsupported. $\text{UART peripheral clock} = \text{UART clock source} / (\text{UART clock divider number} + 1)$.

Table 6-12 UART Baud Rate Equation

UART Peripheral Clock = 22.1184 MHz			
Baud Rate	Mode 0	Mode 1	Mode 2
921600	Not support	A=0, B=11	A=22
460800	A=1	A=1, B=15 A=2, B=11	A=46
230400	A=4	A=4, B=15 A=6, B=11	A=94
115200	A=10	A=10, B=15 A=14, B=11	A=190

57600	A=22	A=22, B=15 A=30, B=11	A=382
38400	A=34	A=62, B=8 A=46, B=11 A=34, B=15	A=574
19200	A=70	A=126, B=8 A=94, B=11 A=70, B=15	A=1150
9600	A=142	A=254, B=8 A=190, B=11 A=142, B=15	A=2302
4800	A=286	A=510, B=8 A=382, B=11 A=286, B=15	A=4606

Table 6-13 UART Controller Baud Rate Parameter Setting Table

UART Peripheral Clock = 22.1184 MHz			
Baud Rate	Mode 0	Mode 1	Mode 2
921600	Not support	0x2B00_0000	0x3000_0016
460800	0x0000_0001	0x2F00_0001 0x2B00_0002	0x3000_002E
230400	0x0000_0004	0x2F00_0004 0x2B00_0006	0x3000_005E
115200	0x0000_000A	0x2F00_000A 0x2B00_000E	0x3000_00BE
57600	0x0000_0016	0x2F00_0016 0x2B00_001E	0x3000_017E
38400	0x0000_0022	0x2800_003E 0x2B00_002E 0x2F00_0022	0x3000_023E
19200	0x0000_0046	0x2800_007E 0x2B00_005E 0x2F00_0046	0x3000_047E
9600	0x0000_008E	0x2800_00FE 0x2B00_00BE 0x2F00_008E	0x3000_08FE
4800	0x0000_011E	0x2800_01FE 0x2B00_017E 0x2F00_011E	0x3000_11FE

Table 6-14 UART Controller Baud Rate Register (UA_BAUD) Setting Table

6.13.5.2 UART Controller Transmit Delay Time Value

The UART Controller programs DLY (UA_TOR [15:8]) to control the transfer delay time between the last stop bit and next start bit in transmission. The unit is baud. The operation is shown in Figure

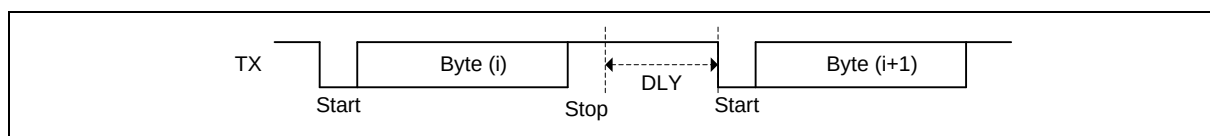


Figure 6-59 Transmit Delay Time Operation

6.13.5.3 UART Controller FIFO Control and Status

The UART0 is built-in with a 64-byte transmitter FIFO (TX_FIFO) and a 64-byte receiver FIFO (RX_FIFO) that reduces the number of interrupts presented to the CPU. The UART1~2 are equipped with 16-byte transmitter FIFO (TX_FIFO) and 16-byte receiver FIFO (RX_FIFO). The

CPU can read the status of the UART at any time during operation. The reported status information includes the type and condition of the transfer operations being performed by the UART, as well as 3 error conditions (parity error, framing error, break interrupt) probably occur while receiving data. This FIFO control and status also support all of UART, IrDA, LIN and RS-485 function mode.

6.13.5.4 UART Controller Wake-up Function

When the chip is in Power-down mode, an external CTS change will wake up chip from Power-down mode. This wake-up function is available in every function mode and it is supported for UART0 and UART1. User must enable the MODEN_INT interrupt to use the wake-up function.

6.13.5.5 UART Controller Interrupt and Status

Each UART Controller supports seven types of interrupts including:

- Receiver threshold level reached interrupt (RDA_INT)
- Transmitter FIFO empty interrupt (THRE_INT)
- Line status interrupt (parity error, frame error or break interrupt) (RLS_INT)
- MODEM/Wake-up status interrupt (MODEM_INT)
- Receiver buffer time-out interrupt (TOUT_INT)
- Buffer error interrupt (BUF_ERR_INT)
- LIN bus interrupt (LIN_INT)

The following tables describe the interrupt sources and flags. The interrupt is generated when the interrupt flag is generated and the interrupt enable bit is set. User must clear the interrupt flag after the interrupt is generated.

Interrupt Source	Interrupt Indicator	Interrupt Enable Bit	Interrupt Flag	Flag Cleared By
Receive Data Available Interrupt	RDA_INT	RDA_IEN	RDA_IF	Read UA_RBR
Transmit Holding Register Empty Interrupt	THRE_INT	THRE_IEN	THRE_IF	Write UA_THR
Receive Line Status Interrupt	RLS_INT	RLS_IEN	RLS_IF = BIF	Writing "1" to BIF
			RLS_IF = FEF	Writing "1" to FEF
			RLS_IF = PEF	Writing "1" to PEF
			RLS_IF = RS485_ADD_DETF	Writing '1' to RS485_ADD_DETF
Modem Status Interrupt	MODEM_INT	MODEM_IEN	MODEM_IF = DCTSF	Write "1" to DCTSF
RX Time-out Interrupt	TOUT_INT	RTO_IEN	TOUT_IF	Read UA_RBR
Buffer Error Interrupt	BUF_ERR_INT	BUF_ERR_IEN	BUF_ERR_IF = TX_OVER_IF	Write "1" to TX_OVER_IF
			BUF_ERR_IF = RX_OVER_IF	Write "1" to RX_OVER_IF
LIN Bus Interrupt	LIN_INT	LIN_IEN	LIN_IF = LIN_BKDET_F	Write "1" to LIN_IF and Write "1" to LIN_BKDET_F
			LIN_IF = BIT_ERR_F	Write "1" to BIT_ERR_F
			LIN_IF = LIN_IDPERR_F	Write "1" to LIN_IDPERR_F
			LIN_IF = LINS_HERR_F	Write "1" to LINS_HERR_F
			LIN_IF = LINS_HDET_F	Write "1" to LINS_HDET_F

Table 6-15 UART Controller Interrupt Source and Flag List

UART Interrupt Source	Interrupt Enable Bit	Interrupt Indicator To Interrupt Controller	Interrupt Flag	Flag Cleared By
Receive Data Available Interrupt	RDA_INT	RDA_IEN	HW_RDA_IF	Read UA_RBR
Transmit Holding Register Empty Interrupt	THRE_INT	THRE_IEN	HW_THRE_IF	Write UA_THR
Receive Line Status Interrupt	RLS_INT	RLS_IEN	HW_RLS_IF = BIF	Write '1' to RFR
			HW_RLS_IF = FEF	
			HW_RLS_IF = PEF	
			HW_RLS_IF=RS485_ADD_DET	
Modem Status Interrupt	MODEM_INT	MODEM_IEN	MODEM_IF = DCTSF	Write "1" to DCTSF
RX Time-out Interrupt	TOUT_INT	RTO_IEN	HW_TOUT_IF	Read UA_RBR
Buffer Error Interrupt	BUF_ERR_INT	BUF_ERR_IEN	HW_BUF_ERR_IF = TX_OVER_IF	Write "1" to RFR
			HW_BUF_ERR_IF = RX_OVER_IF	

Table 6-16 Controller Interrupt Source and Flag in DMA Mode List

6.13.5.6 UART Function Mode

The UART Controller provides UART function (user must set UA_FUN_SEL [1:0] to "00" to enable UART function mode). The UART baud rate is up to 1 Mbps.

The UART provides full-duplex and asynchronous communications. The transmitter and receiver contain 16 bytes FIFO for payloads. User can program receiver buffer trigger level and receiver buffer time-out detection for receiver. The transmitting data delay time between the last stop and the next start bit can be programed by setting DLY (UA_TOR [15:8]) register. The UART supports hardware auto-flow control and flow control function (CTS, RTS), programmable RTS flow control trigger level and fully programmable serial-interface characteristics.

UART Line Control Function

The UART Controller supports fully programmable serial-interface characteristics by setting the UA_LCR register. Software can use the UA_LCR register to program the word length, stop bit and parity bit. The following tables list the UART word and stop bit length settings and the UART parity bit settings.

NSB (UA_LCR[2])	WLS (UA_LCR[1:0])	Word Length (Bit)	Stop Length (Bit)
0	00	5	1
0	01	6	1
0	10	7	1
0	11	8	1
1	00	5	1.5

1	01	6	2
1	10	7	2
1	11	8	2

Table 6-17 UART Line Control of Word and Stop Length Setting

Parity Type	SPE (UA_LCR[5])	EPE (UA_LCR[4])	PBE (UA_LCR[3])	Description
No Parity	x	x	0	No parity bit output.
Odd Parity	0	0	1	Odd Parity is calculated by adding all the "1's" in a data stream and adding a parity bit to the total bits, to make the total count an odd number.
Even Parity	0	1	1	Even Parity is calculated by adding all the "1's" in a data stream and adding a parity bit to the total bits, to make the count an even number.
Forced Mask Parity	1	0	1	Parity bit always logic 1. Parity bit on the serial byte is set to "1" regardless of total number of "1's" (even or odd counts).
Forced Space Parity	1	1	1	Parity bit always logic 0. Parity bit on the serial byte is set to "0" regardless of total number of "1's" (even or odd counts).

Table 6-18 UART Line Control of Parity Bit Setting

UART Auto-Flow Control Function

The UART supports auto-flow control function that uses two signals, CTS (clear-to-send) and RTS (request-to-send), to control the flow of data transfer between the UART and external devices (e.g. Modem). When auto flow is enabled, the UART is not allowed to receive data until the UART asserts RTS to external device. When the number of bytes in the RX FIFO equals the value of RTS_TRI_LEV (UA_FCR [19:16]), the RTS is de-asserted. The UART sends data out when UART detects CTS is asserted from external device. If the valid asserted CTS is not detected, the UART will not send data out.

The following diagram demonstrates the auto-flow control block.

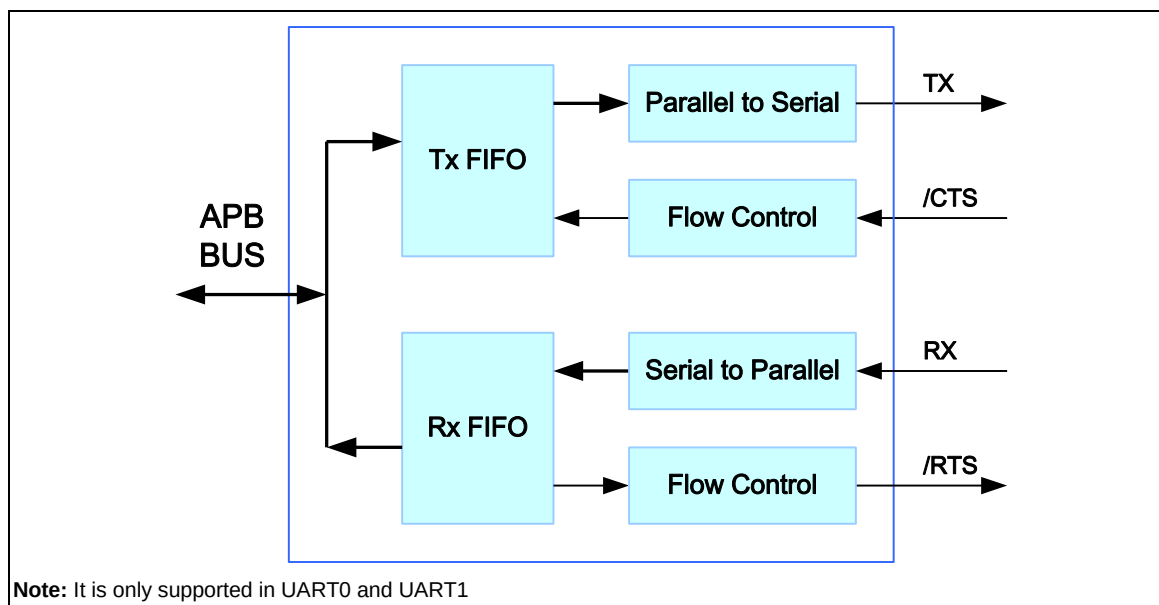


Figure 6-60 Auto Flow Control Block Diagram

The following diagram demonstrates the CTS auto flow control of UART function mode. User must set `AUTO_CTS_EN` (`UA_IER` [13]) to enable CTS auto flow control function. The `LEV_CTS` (`UA_MCR` [8]) can set CTS pin input active state. The `DCTSF` (`UA_MSR` [0]) is set when any state change of CTS pin input has occurred, and then TX data will be automatically transmitted from TX FIFO.

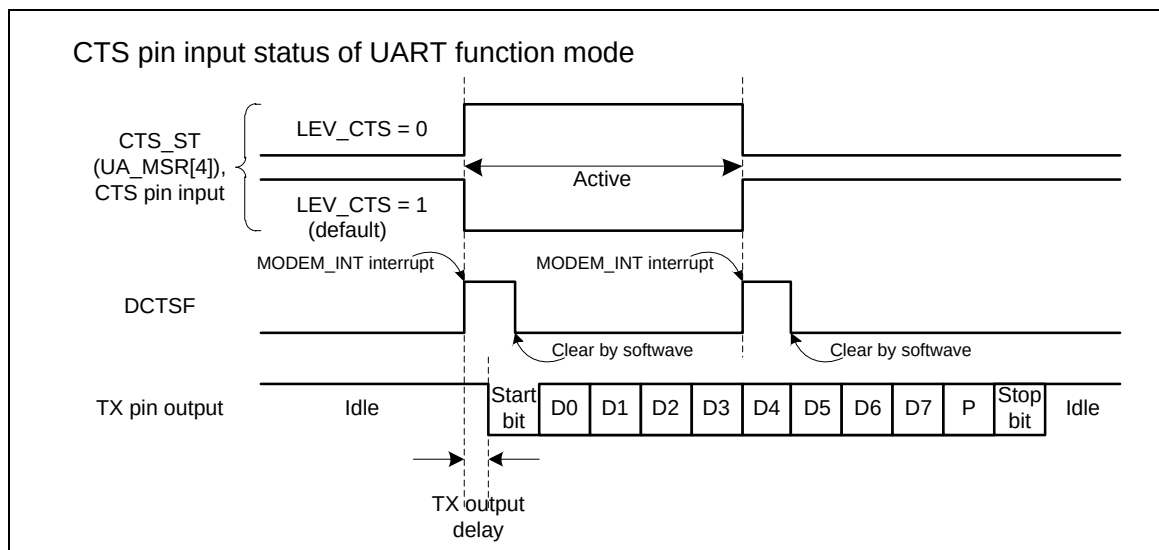


Figure 6-61 UART CTS Auto Flow Control Enabled

As shown in the following figure, in UART RTS Auto Flow control mode (AUTO_RTS_EN (UA_IER[12])=1), the RTS internal signal is controlled by UART FIFO controller with RTS_RTI_LEV(UA_FCR[19:16]) trigger level.

Setting LEV_RTS(UA_MCR[9]) can control the RTS pin output is inverse or non-inverse from RTS signal. User can read the RTS_ST(UA_MCR[13]) bit to get real RTS pin output voltage logic status.

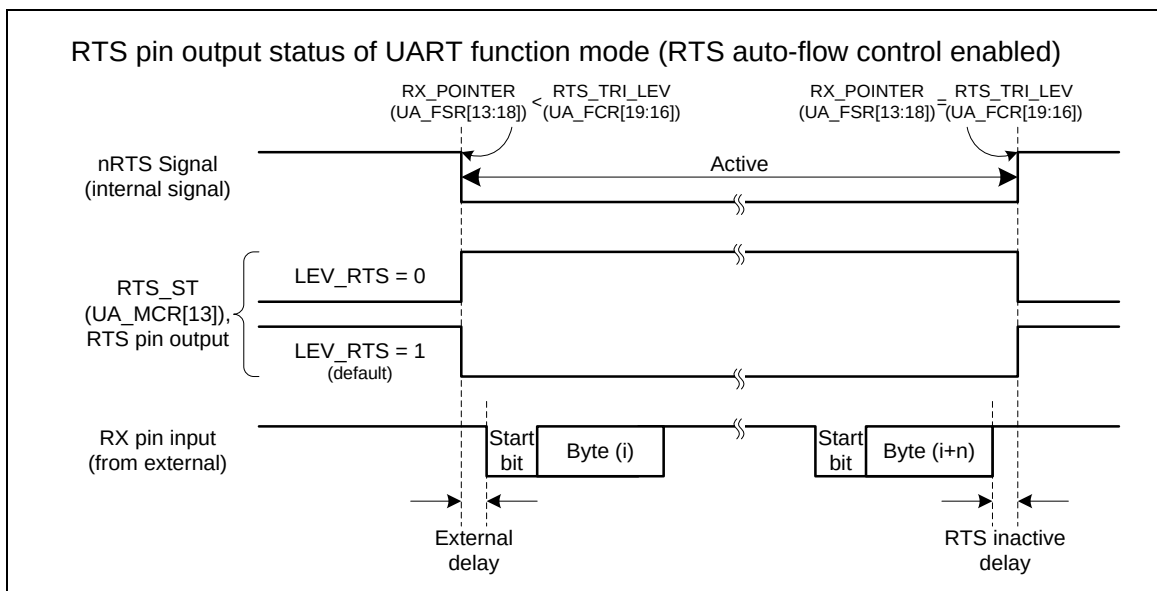


Figure 6-62 UART RTS Auto Flow Control Enabled

As shown in the following figure, in software mode (AUTO_RTS_EN(UA_IER[12])=0) the RTS flow is directly controlled by software programming of RTS(UA_MCR[1]) control bit.

Setting LEV_RTS(UA_MCR[9]) can control the RTS pin output is inverse or non-inverse from RTS(UA_MCR[1]) control bit. User can read the RTS_ST(UA_MCR[13]) bit to get real RTS pin output voltage logic status.

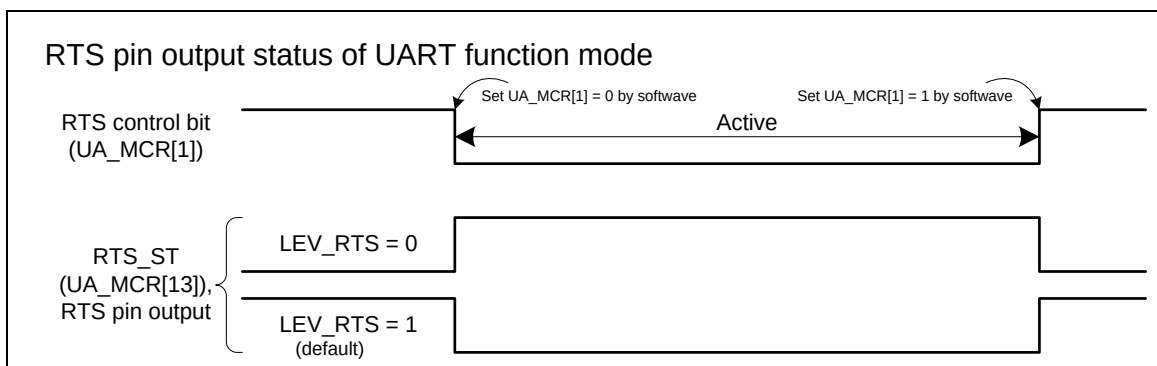


Figure 6-63 UART RTS Flow with Software Control

6.13.5.7 IrDA Function Mode

The UART Controller also provides Serial IrDA (SIR, Serial Infrared) function (user must set UA_FUN_SEL [1:0] to '10' to enable the IrDA function). The SIR specification defines a short-

range infrared asynchronous serial transmission mode with one start bit, 8 data bits, and 1 stop bit. The maximum data rate is 115.2 kbps. The IrDA SIR block contains an IrDA SIR protocol encoder/decoder. The IrDA SIR protocol is half-duplex only. So it cannot transmit and receive data at the same time. The IrDA SIR physical layer specifies a minimum 10 ms transfer delay between transmission and reception, and this delay feature must be implemented by software.

In IrDA mode, the DIV_X_EN (UA_BAUD [29]) register must be disabled.

Baud Rate = Clock / (16 * BRD), where BRD is Baud Rate Divider in UA_BAUD register.

The following diagram demonstrates the IrDA control block diagram.

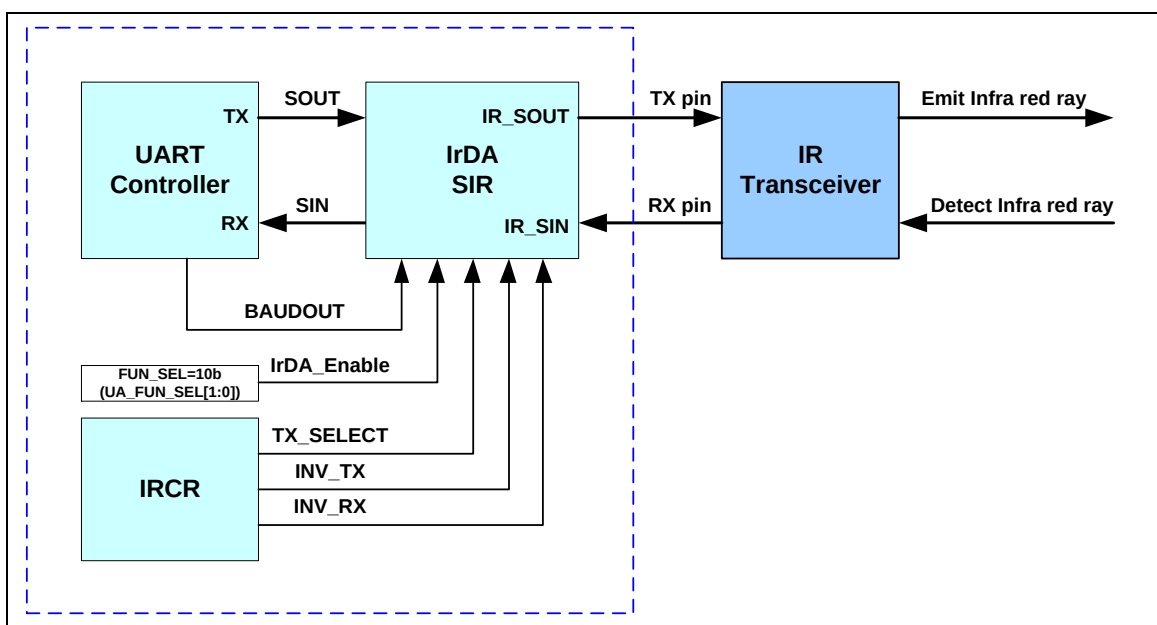


Figure 6-64 IrDA Control Block Diagram

IrDA SIR Transmit Encoder

The IrDA SIR Transmit Encoder modulates Non-Return-to Zero (NRZ) transmit bit stream output from UART. The IrDA SIR physical layer specifies the use of Return-to-Zero, Inverted (RZI) modulation scheme which represents logic 0 as an infra light pulse. The modulated output pulse stream is transmitted to an external output driver and infrared light emitting diode.

In Normal mode, the transmitted pulse width is specified as 3/16 period of baud rate.

IrDA SIR Receive Decoder

The IrDA SIR Receive Decoder demodulates the Return-to-Zero bit stream from the input detector and outputs the NRZ serial bits stream to the UART received data input. The decoder input is normally high in idle state. (Because of this, IRCR (INV_RX [6]) should be set as 1 by default).

A start bit is detected when the decoder input is LOW.

IrDA SIR Operation

The IrDA SIR encoder/decoder provides functionality which converts between UART data stream

and half-duplex serial SIR interface. The following diagram is IrDA encoder/decoder waveform.

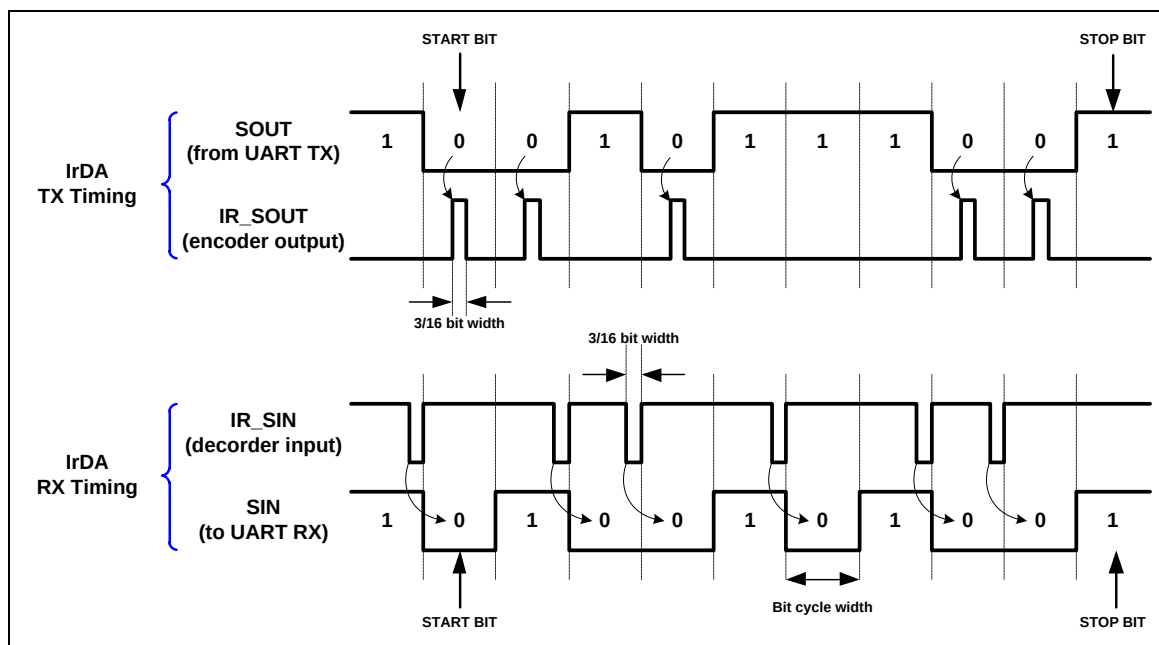


Figure 6-65 IrDA TX/RX Timing Diagram

6.13.5.8 LIN (Local Interconnection Network) Mode

The UART0~UART2 supports LIN function. Setting FUN_SEL (UA_FUN_SEL[1:0]) to '01' to select LIN mode operation. The UART0~UART2 supports LIN break/delimiter generation and break/delimiter detection in LIN master mode, and supports header detection and automatic resynchronization in LIN Slave mode.

6.13.5.8.1 Structure of LIN Frame

According to the LIN protocol, all information transmitted is packed as frames; a frame consists of a header (provided by the master task) and a response (provided by a slave task), followed by a response (provided by a slave task). The header (provided by the master task) consists of a break field and a synch field followed by a frame identifier (frame ID). The frame identifier uniquely defines the purpose of the frame. The slave task is appointed for providing the response associated with the frame ID. The response consists of a data field and a checksum field. The following diagram is the structure of LIN Frame.

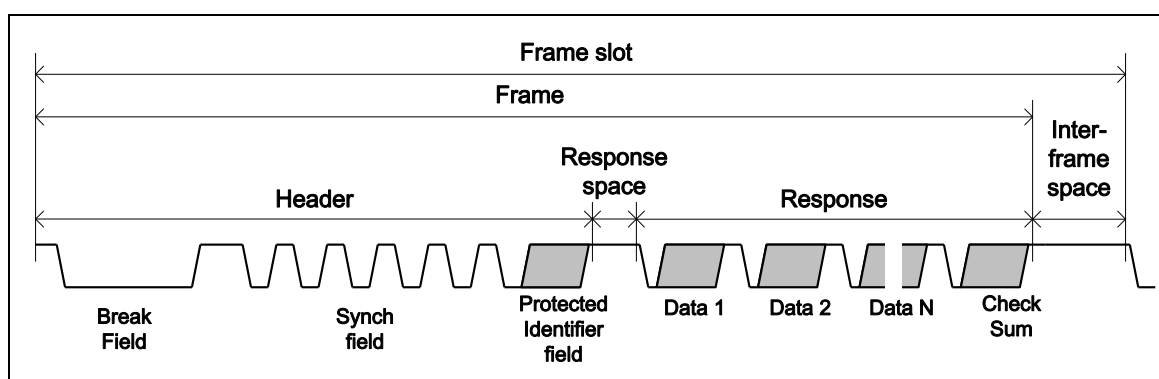


Figure 6-66 Structure of LIN Frame

6.13.5.8.2 Structure of LIN Byte

In LIN mode, each byte field is initiated by a START bit with value 0 (dominant), followed by 8 data bits and no parity bit, LSB is first and ended by 1 stop bit with value 1 (recessive) in accordance with the LIN standard. The structure of Byte is shown as follows.

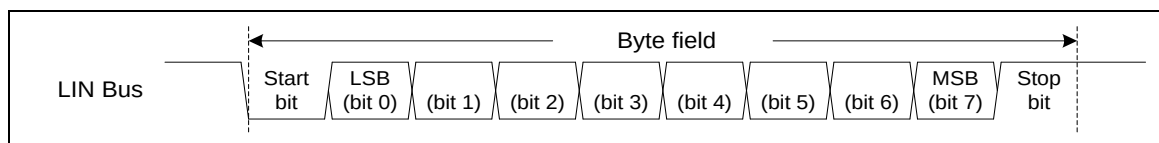


Figure 6-67 Structure of LIN Byte

6.13.5.8.3 LIN Master Mode

The UART0~UART2 controller supports LIN Master mode. To enable and initialize the LIN Master mode, the following steps are necessary:

1. Setting the UA_BAUD register to select the desired baud rate.
2. Setting WLS (UA_LCR[1:0]) to "11" to configure the data length with 8 bits, clearing PBE (UA_LCR[3]) bit to disable parity check and clearing NSB (UA_LCR[2]) bit to configure with one stop bit.
3. Setting FUN_SEL (UA_FUN_SEL[1:0]) to "01" to select LIN function mode operation.

A complete header consists of a break field and sync field followed by a frame identifier (frame ID). The UART0/UART1 controller can be selected header sending by three header selected modes. The header selected mode can be "break field" or "break field and sync field" or "break field, sync field and frame ID field" by setting LIN_HEAD_SEL (UA_LIN_CTL[23:22]). If the selected header is "break field", software must handle the following sequence to send a complete header to bus by filling sync data (0x55) and frame ID data to the UA_THR register. If the selected header is "break field and sync field", software must handle the sequence to send a complete header to bus by filling the frame ID data to UA_THR register, and if the selected header is "break field, sync field and frame ID field", hardware will control the header sending sequence automatically but software must filled frame ID data to LIN_PID (UA_LIN_CTL [31:24]). When operating in header selected mode in which the selected header is "break field, sync field and frame ID field", the frame ID parity bit can be calculated by software or hardware depending whether the LIN_IDPEN (UA_LIN_CTL[9]) bit is set or not.

LIN_HEAD_SEL	Break Field	Sync Field	ID Field
0	Generated by Hardware	Handled by Software	Handled by Software
1	Generated by Hardware	Generated by Hardware	Handled by Software
2	Generated by Hardware	Generated by Hardware	Generated by Hardware (But Software needs to fill ID to LIN_PID (UA_LIN_CTL[31:24]) first

Table 6-19 LIN Header Selection in Master Mode

When UART is operated in LIN data transmission, LIN bus transfer state can be monitored by hardware or software. User can enable hardware monitoring by setting BIT_ERR_EN (UA_LIN_CTL [12]) to "1", if the input pin (UART_RX) state is not equal to the output pin

(UART_TX) state in LIN transmitter state that hardware will generate an interrupt to CPU. Software can also monitor the LIN bus transfer state by checking the read back data in UA_RBR register. The following sequence is a program sequence example.

The procedure without software error monitoring in Master mode:

1. Fill Protected Identifier to LIN_PID (UA_LIN_CTL[31:24]).
2. Select the hardware transmission header field including “break field + sync field + protected identifier field” by setting LIN_HEAD_SEL (UA_LIN_CTL [23:22]) to 10
3. Setting LIN_SHD (UA_LIN_CTL[8]) bit to 1 for requesting header transmission.
4. Wait until LIN_SHD (UA_LIN_CTL[8]) bit cleared by hardware.
5. Wait until TE_FLAG (UA_FSR[28]) set to 1 by hardware.

Note1: The default setting of break field is 12 dominant bits (break field) and 1 recessive bit break/sync delimiter. Setting LIN_BKFL (UA_LIN_CTL [19:16]) and LIN_BS_LEN (UA_LIN_CTL[21:20]) to change the LIN break field length and break/sync delimiter length.

Note2: The default setting of break/sync delimiter length is 1-bit time and the inter-byte spaces default setting is also 1-bit time. Setting LIN_BS_LEN (UA_LIN_CTL[21:20]) and DLY(UA_TOR[7:0]) can change break/sync delimiter length and inter-byte spaces.

Note3: If the header includes the “break field, sync field and frame ID field”, software must fill frame ID to LIN_PID (UA_LIN_CTL[31:24]) before trigger header transmission (setting the LIN_SHD (UA_LIN_CTL[8])). The frame ID parity can be generated by software or hardware depending on LIN_IDPEN (UA_LIN_CTL[9]) setting. If the parity generated by software with LIN_IDPEN (UA_LIN_CTL[9]) is set to ‘0’, software must fill 8 bit data (include 2 bit parity) in this field. If the parity generated by hardware with LIN_IDPEN (UA_LIN_CTL[9]) is set to ‘1’, software fill ID0~ID5 and hardware calculates P0 and P1.

Procedure with software error monitoring in Master mode:

1. Choose the hardware transmission header field only including “break field” by setting LIN_HEAD_SEL (UA_LIN_CTL [23:22]) to ‘00’.
2. Enable break detection function by setting LIN_BKDET_EN (UA_LIN_CTL[10]).
3. Request break + break/sync delimiter transmission by setting the LIN_SHD (UA_LIN_CTL[8])
4. Wait until the LIN_BKDET_F (UA_LIN_SR[8]) flag is set to “1” by hardware..
5. Request sync field transmission by writing 0x55 into UA_THR register.
6. Wait until the RDA_IF (UA_ISR[0]) is set to “1” by hardware and then read back the UA_RBR register.
7. Request header frame ID transmission by writing the protected identifier value to UA_THR register.
8. Wait until the RDA_IF (UA_ISR[0]) is set to “1” by hardware and then read back the UA_RBR register.

LIN break and delimiter detection

When software enables the break detection function by setting LIN_BKDET_EN (UA_LIN_CTL[10]), the break detection circuit is activated. The break detection circuit is totally independent from the UART0/UART1 receiver.

When the break detection function is enabled, the circuit looks at the input UART_RX pin for a start signal. If UART LIN controller detects consecutive dominant is greater than 11 bits dominant followed by a recessive bit (delimiter), the LIN_BKDET_F (UA_LIN_SR[8]) flag is set at the end of break field. If the LIN_IEN (UA_IER[8]) bit is set to 1, an interrupt LIN_INT (UA_ISR[15]) will be generated. The behavior of the break detection and break flag are shown in the following figure.

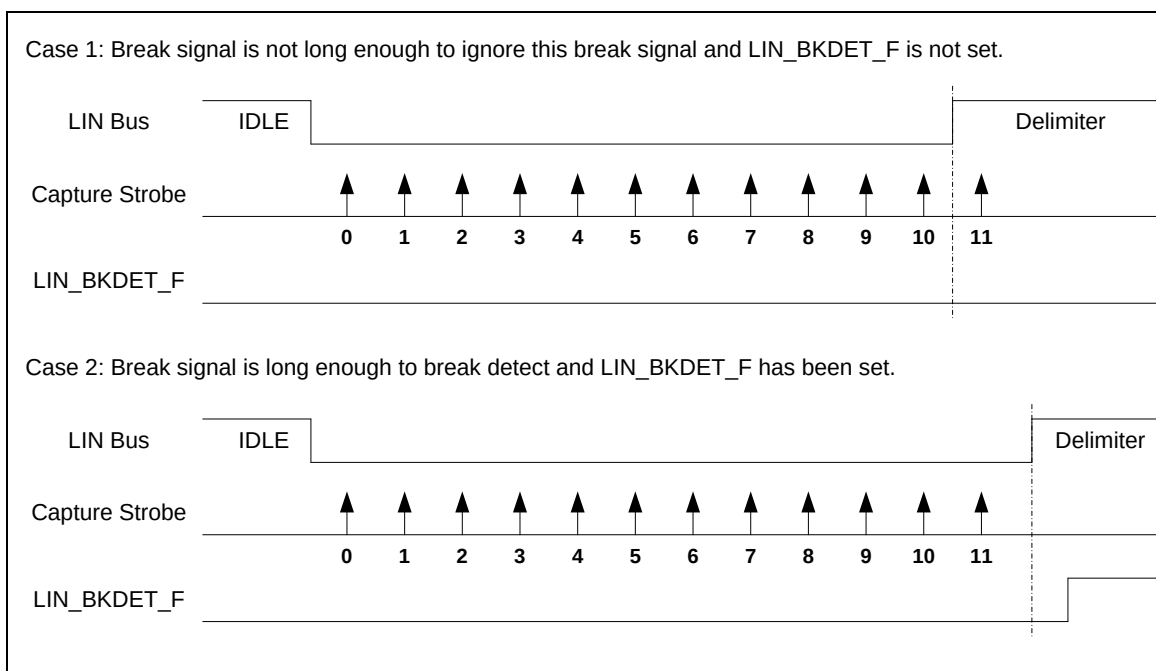


Figure 6-68 Break Detection in LIN Mode

LIN break and delimiter detection

The LIN master can transmit response (master is the publisher of the response) and receive response (master is the subscriber of the response). When the master is the publisher of the response, the master sends response by writing the UA_THR register. If the master is the subscriber of the response, the master will receive response from other slave node.

LIN Frame ID and Parity Format

The LIN frame ID value in LIN function mode is shown, the frame ID parity can be generated by software or hardware depends on IDPEN (UART_LINCTL[9]) = 1.

If the parity generated by hardware, user fill ID0~ID5, (UART_LINCTL [29:24])hardware will calculate P0 (UART_LINCTL[30]) and P1 (UART_LINCTL[31]), otherwise user must filled frame ID and parity in this field.

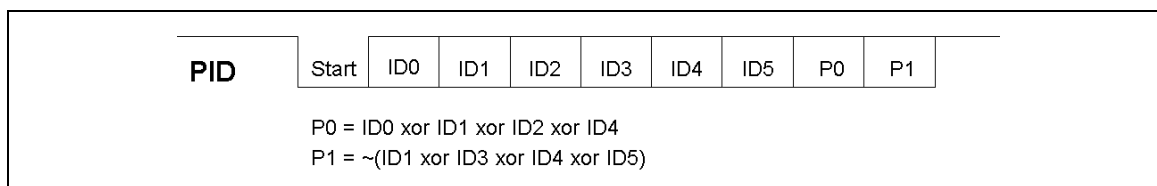


Figure 6-69 LIN Frame ID and Parity Format

6.13.5.8.4 LIN Slave Mode

The UART0/UART1 controller supports LIN Slave mode. To enable and initialize the LIN Slave mode, the following steps are necessary:

1. Setting the UA_BAUD register to select the desired baud rate.
2. Configure the data length to 8 bits by setting WLS (UA_LCR[1:0]) to '11' and disable parity check by clearing PBE (UA_LCR[3]) bit and configure with one stop bit by clearing NSB (UA_LCR[2]) bit.
3. Select LIN function mode by setting FUN_SEL (UA_FUN_SEL[1:0]) to "01".
4. Enable LIN slave mode by setting the LINS_EN (UA_LIN_CTL[0]) to 1.

LIN header reception

According to the LIN protocol, a slave node must wait for a valid header which comes from the master node. Next the slave task will take one of following actions (depend on the master header frame ID value).

- Receive the response.
- Transmit the response.
- Ignore the response and wait for next header.

In LIN Slave mode, user can enable the slave header detection function by setting the LINS_HDET_EN (UA_LIN_CTL[10]) to detect complete frame header (receive "break field", "sync field" and "frame ID field"). When a LIN header is received, the LINS_HDET_F (UA_LIN_SR[0]) flag will be set. If the LIN_IEN (UA_IER[8]) bit is set to 1, an interrupt will be generated. User can enable the frame ID parity check function by setting LIN_IDPEN (UA_LIN_CTL[9]). If only received frame ID parity is not correct (break and sync filed are correct), the LIN_IDPERR_F (UA_LIN_SR[2]) flag is set to '1'. If the LIN_IEN(UA_IER[8]) is set to 1, an interrupt will be generated and LINS_HDET_F (UA_LIN_SR[0]) is set to '1'. User can also put LIN in mute mode by setting LIN_MUTE_EN (UA_LIN_CTL[4]) to '1'. This mode allows detection of headers only (break + sync + frame ID) and prevents the reception of any other characters. In order to avoid bit rate tolerance, the controller supports automatic resynchronization function to avoid clock deviation error, user can enable this feature by setting LINS_ARS_EN (UA_LIN_CTL[2]).

LIN response transmission

The LIN slave node can transmit response and receive response. When slave node is the publisher of the response, the slave node sends response by filling data to the UA_THR register. If the slave node is the subscriber of the response, the slave node receives data from LIN bus.

LIN header time-out error

The LIN slave controller contains a header time-out counter. If the entire header is not received within the maximum time limit of 57 bit times, the header error flag LINS_HERR_F (UA_LIN_SR[1]) will be set. The time-out counter is enabled at each break detect edge and stopped in the following conditions.

- A LIN frame ID field has been received.
- The header error flag asserts.
- Writing 1 to the LINS_SYNC_F (UA_LIN_SR[3]) to re-search a new frame header.

Mute mode and LIN exit from mute mode condition

In Mute mode, a LIN slave node will not receive any data until specified condition occurred. It allows header detection only and prevents the reception of any other characters. User can enable Mute mode by setting the LIN_MUTE_EN (UA_LIN_CTL[4]) and exiting from Mute mode condition can be selected by LIN_HEAD_SEL (UA_LIN_CTL[23:22]).

Note: It is recommended to set LIN slave node to Mute mode after checksum transmission.

The LIN slave controller exiting from Mute mode is described as follows: If LIN_HEAD_SEL (UA_LIN_CTL[23:22]) is set to “break field”, when LIN slave controller detects a valid LIN break + delimiter, the controller will enable the receiver (exit from Mute mode) and subsequent data (sync data, frame ID data, response data) are received in RX-FIFO.

If LIN_HEAD_SEL (UA_LIN_CTL[23:22]) is set to “break field and sync field”, when the LIN slave controller detects a valid LIN break + delimiter followed by a valid sync field without frame error, the controller will enable the receiver (exit from mute mode) and subsequent data (ID data, response data) are received in RX-FIFO. If LIN_HEAD_SEL (UA_LIN_CTL[23:22]) is set to “break field, sync field and ID field”, when the LIN slave controller detects a valid LIN break + delimiter and valid sync field without frame error followed by ID data without frame error and received ID data matched LIN_PID (UA_LIN_CTL[31:24]) value. The controller will enable the receiver (exit from mute mode) and subsequent data (response data) are received in RX-FIFO.

Slave mode non-automatic resynchronization

User can disable the automatic resynchronization function to fix the communication baud rate. When operating in Non-Automatic Resynchronization mode, software needs some initial process, and the initialization process flow of Non-Automatic Resynchronization mode is shown as follows:

1. Select the desired baud rate by setting the UA_BAUD register.
2. Select LIN function mode by setting UA_FUN_SEL (UA_FUN_SEL[1:0]) to ‘01’.
3. Disable automatic resynchronization function by setting LINS_ARS_EN (UA_LIN_CTL[2]) is set to 0.
4. Enable LIN slave mode by setting the LINS_EN (UA_LIN_CTL[0]) is set to 1.

Slave mode with automatic resynchronization

In Automatic Resynchronization mode, the controller will adjust the baud rate generator after each sync field reception. The initialization process flow of Automatic Resynchronization mode is shown as follows:

1. Select the desired baud rate by setting the UA_BAUD register.
2. Select LIN function mode by setting UA_FUN_SEL (UA_FUN_SEL[1:0]) to "01".
3. Enable automatic resynchronization function by setting LINS_ARS_EN (UA_LIN_CTL[2]) to 1.
4. Enable LIN slave mode by setting the LINS_EN (UA_LIN_CTL[0]) is set to 1.

When the automatic resynchronization function is enabled, after each LIN break field, the time duration between five falling edges is sampled on UART peripheral clock and the result of this measurement is stored in an internal 13-bit register and the UA_BAUD register value will be automatically updated at the end of the fifth falling edge. If the measure timer (13-bit) overflows before five falling edges, then the header error flag LIN_HERR_F (UA_LIN_SR [1]) will be set.

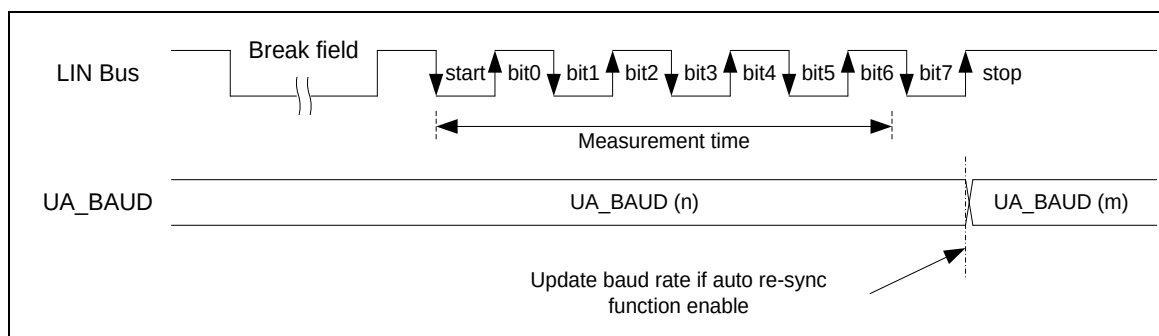


Figure 6-70 LIN Sync Field Measurement

When operating in Automatic Resynchronization mode, software must select the desired baud rate by setting the UA_BAUD register and hardware will store it at internal TEMP_REG register, after each LIN break field, the time duration between five falling edges is sampled on UART peripheral clock and the result of this measurement is stored in an internal 13-bit register BAUD_LIN and the result will be updated to UA_BAUD register automatically.

In order to guarantee the transmission baud rate, the baud rate generator must reload the initial value before each new break reception. The initial value is programmed by the application during initialization (TEMP_REG). User can set LINS_DUM_EN (UA_LIN_CTL [3]) to enable auto reload initial baud rate value function. If the LINS_DUM_EN (UA_LIN_CTL [3]) is set, when received the next character, hardware will auto reload the initial value to UA_BAUD, and when the UA_BAUD be updated, the LINS_DUM_EN (UA_LIN_CTL [3]) will be cleared automatically. The behavior of LIN updated method as shown in the following figure.

Note1: It is recommended to set the LINS_DUM_EN bit before every checksum reception.

Note2: When a header error is detected, user must write 1 to LINS_SYNC_F (UA_LIN_SR[3]) to re-search new frame header. When writing 1 to it, hardware will reload the initial baud rate TEMP_REG and re-search new frame header.

Note3: When operating in Automatic Resynchronization mode, the baud rate setting must be operated at mode2 (DIV_X_EN (UA_BAUD [29]) and DIV_X_ONE (UA_BAUD[28]) must be 1).

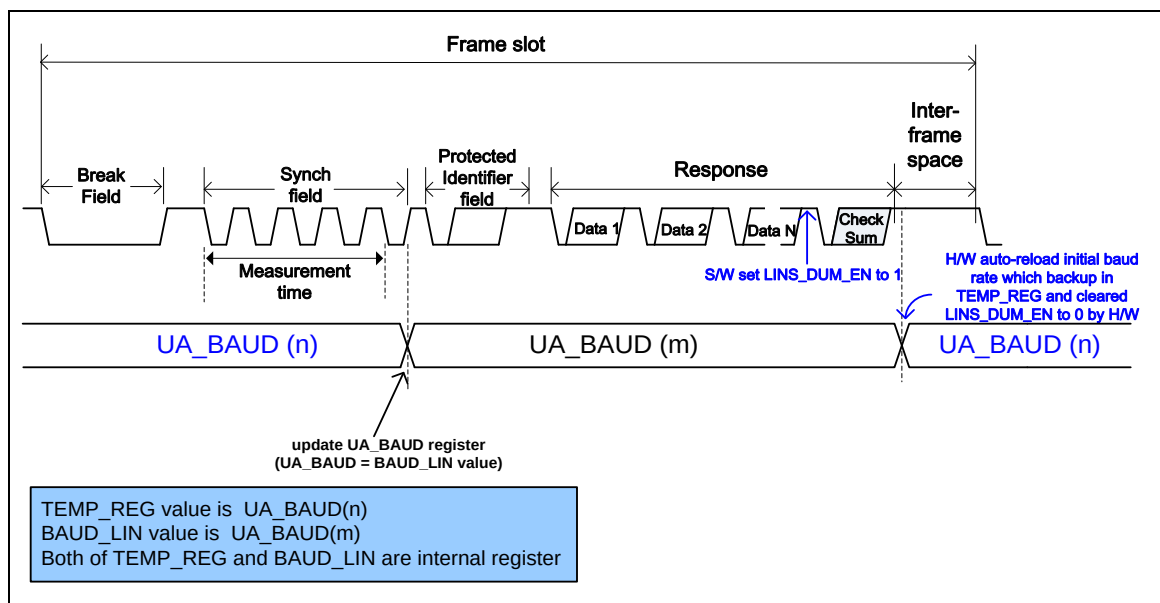


Figure 6-71 UA_BAUD Update Sequence in Automatic Resynchronization Mode when LINS_DUM_EN (UA_LIN_CTL[3]) = 1

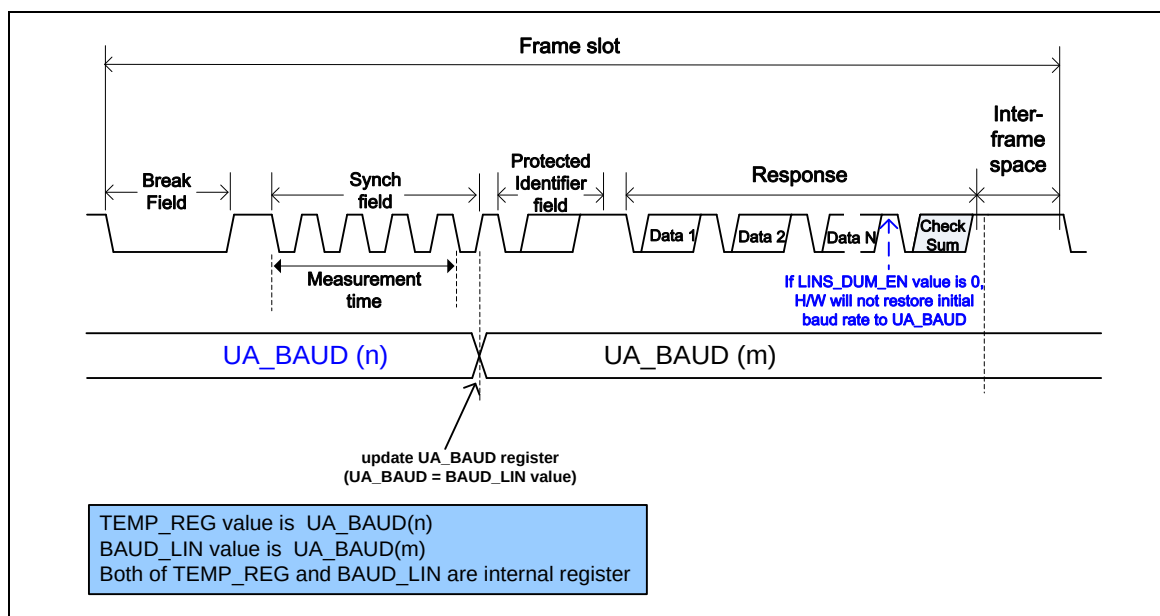


Figure 6-72 UA_BAUD Update Sequence in Automatic Resynchronization Mode when LINS_DUM_EN (UA_LIN_CTL[3]) = 0

Deviation error on the sync field

When operating in Automatic Resynchronization mode, the controller will check the deviation error on the sync field. The deviation error is checked by comparing the current baud rate with the received sync field. Two checks are performed in parallel.

Check1: Based on measurement between the first falling edge and the last falling edge of the sync field.

- If the difference is more than 14.84%, the header error flag LINS_HERR_F (UA_LIN_SR[1]) will be set.
- If the difference is less than 14.06%, the header error flag LINS_HERR_F (UA_LIN_SR[1]) will not be set.
- If the difference is between 14.84% and 14.06%, the header error flag LINS_HERR_F (UA_LIN_SR[1]) may either set or not.

Check2: Based on measurement of time between each falling edge of the sync field.

- If the difference is more than 18.75%, the header error flag LINS_HERR_F (UA_LIN_SR[1]) will be set.
- If the difference is less than 15.62%, the header error flag LINS_HERR_F (UA_LIN_SR[1]) will not be set.
- If the difference is between 18.75% and 15.62%, the header error flag LINS_HERR_F (UA_LIN_SR[1]) may either set or not.

Note: The deviation check is based on the current baud rate clock. Therefore, in order to guarantee correct deviation checking, the baud rate must reload the nominal value before each new break reception by setting LINS_DUM_EN (UA_LIN_CTL[3]) register (It is recommend setting the LINS_DUM_EN (UA_LIN_CTL[3]) bit before every checksum reception)

LIN header error detection

In LIN Slave function mode, when user enables the header detection function by setting the LINS_HDET_EN (UA_LIN_CTL[1]), hardware will handle the header detect flow. If the header has an error, the LIN header error flag LIN_HERR_F (UA_LIN_SR[1]) will be set and an interrupt is generated if the LIN_IEN (UA_IER[8]) bit is set. When header error is detected, user must reset the detect circuit to re-search a new frame header by writing 1 to LINS_SYNC_F (UA_LIN_SR[3]) to re-search a new frame header.

The LIN header error flag LIN_HERR_F (UA_LIN_SR[1]) is set if one of the following conditions occurs:

- Break Delimiter is too short (less than 0.5-bit time).
- Frame error in sync field or Identifier field.
- The sync field data is not 0x55 (Non-Automatic Resynchronization mode).
- The sync field deviation error (With Automatic Resynchronization mode).
- The sync field measure time-out (With Automatic Resynchronization mode).
- LIN header reception time-out.

6.13.5.9 RS-485 Function Mode

Another alternate function of UART Controller is RS-485 function (user must set UA_FUN_SEL [1:0] to "11" to enable RS-485 function), and direction control provided by RTS pin from an asynchronous serial port. The RS-485 transceiver control is implemented by using the RTS control signal to enable the RS-485 driver. Many characteristics of the RX and TX are same as UART in RS-485 mode.

The UART controller can be configured as an RS-485 addressable slave and the RS-485 master transmitter will identify an address character by setting the parity (9-th bit) to 1. For data characters, the parity is set to 0. Software can use UA_LCR register to control the 9-th bit (When the PBE(UA_LCR[3]), EPE(UA_LCR[4]) and SPE(UA_LCR[5]) are set, the 9-th bit is transmitted 0 and when PBE and SPE are set and EPE is cleared, the 9-th bit is transmitted 1).

The controller supports three operation modes: RS-485 Normal Multidrop Operation Mode (NMM), RS-485 Auto Address Detection Operation Mode (AAD) and RS-485 Auto Direction Control Operation Mode (AUD). Software can choose any operation mode by programming the UA_ALT_CSR register, and drive the transfer delay time between the last stop bit leaving the TX FIFO and the de-assertion of by setting DLY (UA_TOR [15:8]) register.

6.13.5.9.1 RS-485 Normal Multidrop Operation Mode (NMM)

In RS-485 Normal Multidrop Operation Mode (RS485_NMM(UA_ALT_CSR[8]) = 1), in first, software must decide the data which before the address byte be detected will be stored in RX FIFO or not. If software wants to ignore any data before address byte detected, the flow is set RX_DIS (UA_FCR [8]) then enable RS485_NMM (UA_ALT_CSR [8]) and the receiver will ignore any data until an address byte is detected (bit 9 = 1) and the address byte data will be stored in the RX FIFO. If software wants to receive any data before address byte detected, the flow is disables RX_DIS (UA_FCR [8]) then enable RS485_NMM (UA_ALT_CSR [8]) and the receiver will received any data.

If an address byte is detected (bit 9 = 1), it will generate an interrupt to CPU and RX_DIS (UA_FCR [8]) can decide whether accepting the following data bytes are stored in the RX FIFO. If software disables receiver by setting RX_DIS (UA_FCR [8]) register, when a next address byte is detected, the controller will clear the RX_DIS (UA_FCR [8]) bit and the address byte data will be stored in the RX FIFO.

6.13.5.9.2 RS-485 Auto Address Detection Operation Mode (AAD)

In RS-485 Auto Address Detection Operation Mode (RS485_AAD(UA_ALT_CSR[9]) = 1), the receiver will ignore any data until an address byte is detected (bit 9 = 1) and the address byte data matches the ADDR_MATCH (UA_ALT_CSR[31:24]) value. The address byte data will be stored in the RX FIFO. The all received byte data will be accepted and stored in the RX FIFO until an address byte data not match the ADDR_MATCH (UA_ALT_CSR[31:24]) value.

6.13.5.9.3 RS-485 Auto Direction Mode (AUD)

Another option function of RS-485 controllers is RS-485 auto direction control function (RS485_AUD(UA_ALT_CSR[10]) = 1). The RS-485 transceiver control is implemented by using the RTS control signal from an asynchronous serial port. The RTS line is connected to the RS-485 transceiver enable pin such that setting the RTS line to high (logic 1) enables the RS-485 transceiver. Setting the RTS line to low (logic 0) puts the transceiver into the tri-state condition to disabled. User can set LEV_RTS in UA_MCR register to change the RTS driving level.

The following diagram demonstrates the RS-485 RTS driving level in AUD mode. The RTS pin will be automatically driven during TX data transmission.

Setting LEV_RTS(UA_MCR[9]) can control RTS pin output driving level. User can read the RTS_ST(UA_MCR[13]) bit to get real RTS pin output voltage logic status.

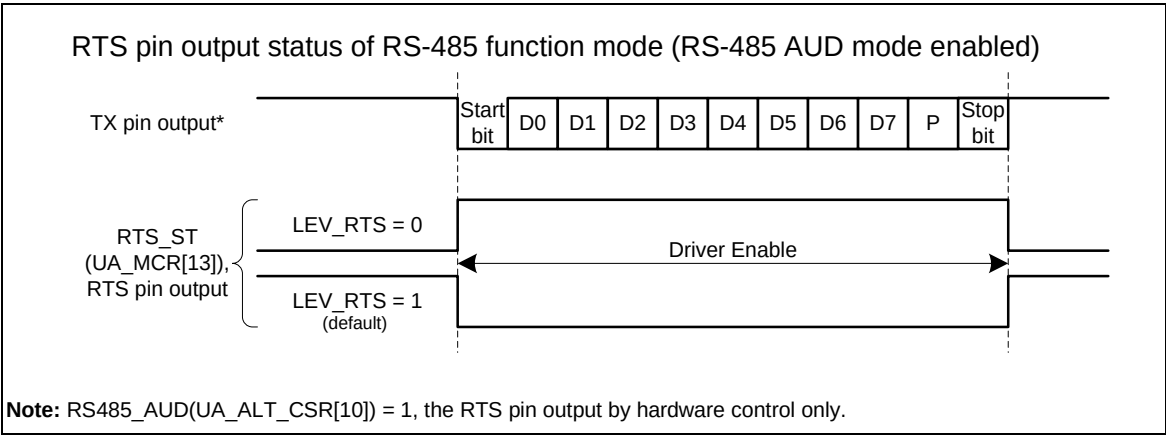


Figure 6-73 RS-485 RTS Driving Level in Auto Direction Mode

The following diagram demonstrates the RS-485 RTS driving level in software control (RS485_AUD(UA_ALT_CSR[10])=0). The RTS driving level is controlled by programming the RTS(UA_MCR[1]) control bit.

Setting LEV_RTS(UA_MCR[9]) can control the RTS pin output is inverse or non-inverse from RTS(UA_MCR[1]) control bit. User can read the RTS_ST(UA_MCR[13]) bit to get real RTS pin output voltage logic status.

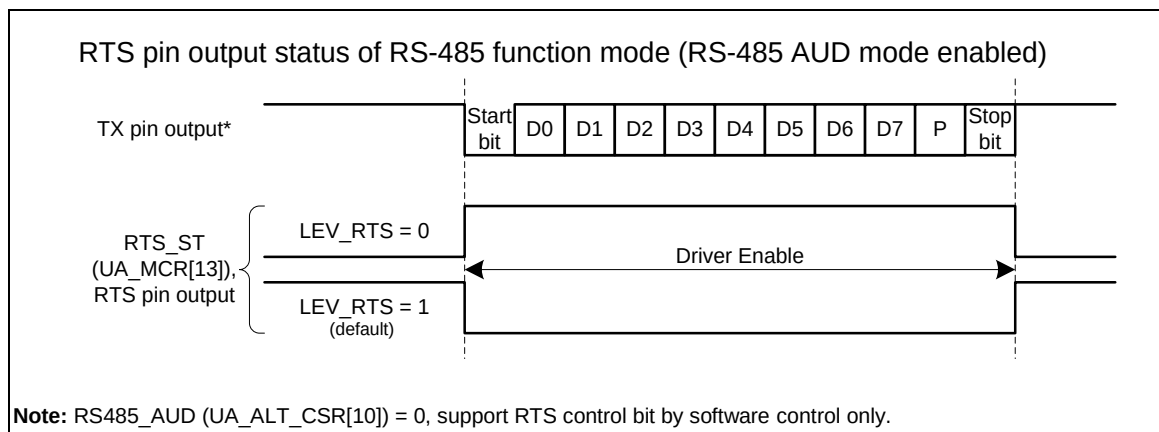


Figure 6-74 RS-485 RTS Driving Level with Software Control

Program Sequence Example:

1. Program FUN_SEL in UA_FUN_SEL to select RS-485 function.
2. Program the RX_DIS (UA_FCR[8]) to determine enable or disable the receiver RS-485 receiver
3. Program the RS485_NMM (UA_ALT_CSR[8]) or RS485_AAD (UA_ALT_CSR[9]) mode.
4. If the RS485_AAD (UA_ALT_CSR[9]) mode is selected, the ADDR_MATCH (UA_ALT_CSR[31:24]) is programmed for auto address match value.
5. Determine auto direction control by programming RS485_AUD (UA_ALT_CSR[10]).

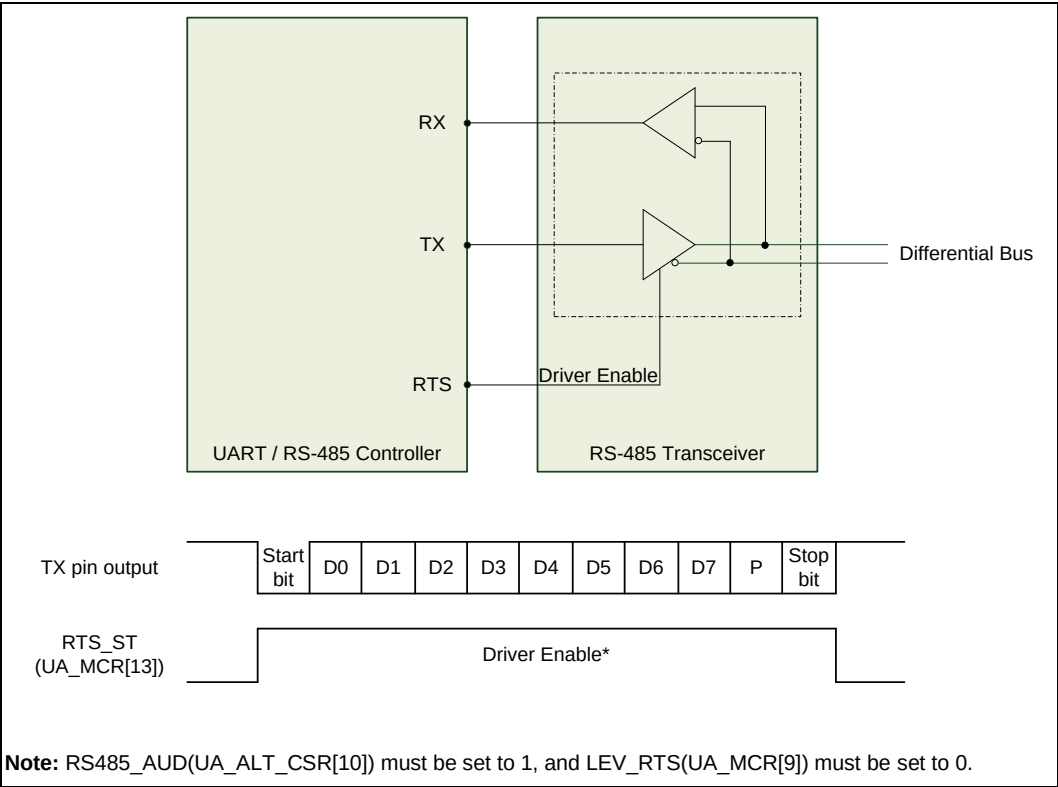


Figure 6-75 Structure of RS-485 Frame

6.13.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
UART Base Address: UART0_BA = 0x4005_0000 UART1_BA = 0x4015_0000 UART2_BA = 0x4015_4000				
UA_RBR x=0,1,2	UARTx_BA+0x00	R	UART Receive Buffer Register	Undefined
UA_THR x=0,1,2	UARTx_BA+0x00	W	UART Transmit Holding Register	Undefined
UA_IER x=0,1,2	UARTx_BA+0x04	R/W	UART Interrupt Enable Register	0x0000_0000
UA_FCR x=0,1,2	UARTx_BA+0x08	R/W	UART FIFO Control Register	0x0000_0101
UA_LCR x=0,1,2	UARTx_BA+0x0C	R/W	UART Line Control Register	0x0000_0000
UA_MCR x=0,1	UARTx_BA+0x10	R/W	UART Modem Control Register	0x0000_0200
UA_MSR x=0,1	UARTx_BA+0x14	R/W	UART Modem Status Register	0x0000_0110
UA_FSR x=0,1,2	UARTx_BA+0x18	R/W	UART FIFO Status Register	0x1040_4000
UA_ISR x=0,1,2	UARTx_BA+0x1C	R/W	UART Interrupt Status Register	0x0000_0002
UA_TOR x=0,1,2	UARTx_BA+0x20	R/W	UART Time-out Register	0x0000_0000
UA_BAUD x=0,1,2	UARTx_BA+0x24	R/W	UART Baud Rate Divisor Register	0x0F00_0000
UA_IRCR x=0,1,2	UARTx_BA+0x28	R/W	UART IrDA Control Register	0x0000_0040
UA_ALT_CSR x=0,1,2	UARTx_BA+0x2C	R/W	UART Alternate Control/Status Register	0x0000_000C
UA_FUN_SEL x=0,1,2	UARTx_BA+0x30	R/W	UART Function Select Register	0x0000_0000
UA_LIN_CTL x=0,1,2	UARTx_BA+0x34	R/W	UART LIN Control Register	0x000C_0000

UA_LIN_SR x=0,1,2	UARTx_BA+0x38	R/W	UART LIN Status Register	0x0000_0000

6.13.7 Register Description

UART Receive Buffer Register (UA_RBR)

Register	Offset	R/W	Description	Reset Value
UA_RBR x=0,1,2	UARTx_BA+0x00	R	UART Receive Buffer Register	Undefined

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

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	RBR	Receive Buffer Register (Read Only) By reading this register, the UART will return the 8-bit data received from RX pin (LSB first).

UART Transmit Holding Register (UA_THR)

Register	Offset	R/W	Description	Reset Value
UA_THR x=0,1,2	UARTx_BA+0x00	W	UART Transmit Holding Register	Undefined

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

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	THR	Transmit Holding Register By writing one byte to this register, the data byte will be stored in transmitter FIFO. The UART Controller will send out the data stored in transmitter FIFO top location through the TX pin.

UART Interrupt Enable Register (UA_IER)

Register	Offset	R/W	Description	Reset Value
UA_IER x=0,1,2	UARTx_BA+0x04	R/W	UART Interrupt Enable Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
DMA_RX_EN	DMA_TX_EN	AUTO_CTS_EN	AUTO_RTS_EN	TIME_OUT_EN	Reserved		LIN_IEN
7	6	5	4	3	2	1	0
Reserved	WAKE_EN	BUF_ERR_IEN	TOUT_IEN	MODEM_IEN	RLS_IEN	THRE_IEN	RDA_IEN

Bits	Description
[31:16]	Reserved
[15]	DMA_RX_EN RX DMA Enable Bit (Not Available In UART2 Channel) This bit can enable or disable RX DMA service. 0 = RX DMA Disabled. 1 = RX DMA Enabled.
[14]	DMA_TX_EN TX DMA Enable Bit (Not Available In UART2 Channel) This bit can enable or disable TX DMA service. 0 = TX DMA Disabled. 1 = TX DMA Enabled.
[13]	AUTO_CTS_EN CTS Auto Flow Control Enable Bit (Not Available In UART2 Channel) 0 = CTS auto flow control Disabled. 1 = CTS auto flow control Enabled. When CTS auto-flow is enabled, the UART will send data to external device when CTS input assert (UART will not send data to device until CTS is asserted).
[12]	AUTO_RTS_EN RTS Auto Flow Control Enable Bit (Not Available In UART2 Channel) 0 = RTS auto flow control Disabled. 1 = RTS auto flow control Enabled. When RTS auto-flow is enabled, if the number of bytes in the RX FIFO equals the RTS_TRI_LEV (UA_FCR [19:16]), the UART will de-assert RTS signal.
[11]	TIME_OUT_EN Time-Out Counter Enable Bit 0 = Time-out counter Disabled. 1 = Time-out counter Enabled.
[10:9]	Reserved
[8]	LIN_IEN LIN Bus Interrupt Enable Bit

		0 = Lin bus interrupt Disabled. 1 = Lin bus interrupt Enabled. Note: This field is used for LIN function mode.
[7]	Reserved	Reserved.
[6]	WAKE_EN	UART Wake-Up Function Enable Bit (Not Available In UART2 Channel) 0 = UART wake-up function Disabled. 1 = UART wake-up function Enabled, when the chip is in Power-down mode, an external CTS change will wake-up chip from Power-down mode.
[5]	BUF_ERR_IEN	Buffer Error Interrupt Enable Bit 0 = BUF_ERR_INT Masked off. 1 = BUF_ERR_INT Enabled.
[4]	TOUT_IEN	RX Time-Out Interrupt Enable Bit 0 = TOUT_INT Masked off. 1 = TOUT_INT Enabled.
[3]	MODEM_IEN	Modem Status Interrupt Enable Bit (Not Available In UART2 Channel) 0 = MODEM_INT Masked off. 1 = MODEM_INT Enabled..
[2]	RLS_IEN	Receive Line Status Interrupt Enable Bit 0 = RLS_INT Masked off. 1 = RLS_INT Enabled.
[1]	THRE_IEN	Transmit Holding Register Empty Interrupt Enable Bit 0 = THRE_INT Masked off. 1 = THRE_INT Enabled.
[0]	RDA_IEN	Receive Data Available Interrupt Enable Bit 0 = RDA_INT Masked off. 1 = RDA_INT Enabled.

UART FIFO Control Register (UA_FCR)

Register	Offset	R/W	Description	Reset Value
UA_FCR x=0,1,2	UARTx_BA+0x08	R/W	UART FIFO Control Register	0x0000_0101

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved				RTS_TRI_LEV			
15	14	13	12	11	10	9	8
Reserved							RX_DIS
7	6	5	4	3	2	1	0
RFITL				Reserved	TFR	RFR	Reserved

Bits	Description	
[31:20]	Reserved	Reserved.
[19:16]	RTS_TRI_LEV	RTS Trigger Level For Auto-Flow Control Use (Not Available In UART2 Channel) 0000 = RTS Trigger Level is 1 byte. 0001 = RTS Trigger Level is 4 bytes. 0010 = RTS Trigger Level is 8 bytes. 0011 = RTS Trigger Level is 14 bytes. 0100 = RTS Trigger Level is 30/14 bytes (High Speed/Normal Speed). 0101 = RTS Trigger Level is 46/14 bytes (High Speed/Normal Speed). 0110 = RTS Trigger Level is 62/14 bytes (High Speed/Normal Speed). Other = Reserved. Note: This field is used for RTS auto-flow control.
[15:9]	Reserved	Reserved.
[8]	RX_DIS	Receiver Disable Bit The receiver is disabled or not (set 1 to disable receiver) 0 = Receiver Enabled. 1 = Receiver Disabled. Note: This field is used for RS-485 Normal Multi-drop mode. It should be programmed before UA_ALT_CSR [RS-485_NMM] is programmed.
[7:4]	RFITL	RX FIFO Interrupt (INT_RDA) Trigger Level When the number of bytes in the receive FIFO equals the RFITL, the RDA_IF will be set (if UA_IER [RDA_IEN] enabled, and an interrupt will be generated). 0000 = RX FIFO Interrupt Trigger Level is 1 byte. 0001 = RX FIFO Interrupt Trigger Level is 4 bytes. 0010 = RX FIFO Interrupt Trigger Level is 8 bytes. 0011 = RX FIFO Interrupt Trigger Level is 14 bytes. 0100 = RX FIFO Interrupt Trigger Level is 30/14 bytes (High Speed/Normal Speed). 0101 = RX FIFO Interrupt Trigger Level is 46/14 bytes (High Speed/Normal Speed).

		0110 = RX FIFO Interrupt Trigger Level is 62/14 bytes (High Speed/Normal Speed). Other = Reserved.
[3]	Reserved	Reserved.
[2]	TFR	TX Field Software Reset When TFR is set, all the byte in the transmit FIFO and TX internal state machine are cleared. 0 = No effect. 1 = Reset the TX internal state machine and pointers. Note: This bit will automatically clear at least 3 UART peripheral clock cycles.
[1]	RFR	RX Field Software Reset When RFR is set, all the byte in the receiver FIFO and RX internal state machine are cleared. 0 = No effect. 1 = Reset the RX internal state machine and pointers. Note: This bit will automatically clear at least 3 UART peripheral clock cycles.
[0]	Reserved	Reserved.

UART Line Control Register (UA_LCR)

Register	Offset	R/W	Description	Reset Value
UA_LCR x=0,1,2	UARTx_BA+0x0C	R/W	UART Line Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved	BCB	SPE	EPE	PBE	NSB	WLS	

Bits	Description	
[31:7]	Reserved	Reserved.
[6]	BCB	Break Control Bit When this bit is set to logic 1, the serial data output (TX) is forced to the Spacing State (logic 0). This bit acts only on TX and has no effect on the transmitter logic.
[5]	SPE	Stick Parity Enable Bit 0 = Stick parity Disabled. 1 = If PBE (UA_LCR[3]) and EBE (UA_LCR[4]) are logic 1, the parity bit is transmitted and checked as logic 0. If PBE (UA_LCR[3]) is 1 and EBE (UA_LCR[4]) is 0 then the parity bit is transmitted and checked as 1.
[4]	EPE	Even Parity Enable Bit 0 = Odd number of logic 1's is transmitted and checked in each word. 1 = Even number of logic 1's is transmitted and checked in each word. This bit has effect only when PBE (UA_LCR[3]) is set.
[3]	PBE	Parity Bit Enable Bit 0 = No parity bit. 1 = Parity bit is generated on each outgoing character and is checked on each incoming data.
[2]	NSB	Number Of "STOP Bit" 0 = One "STOP bit" is generated in the transmitted data. 1 = When select 5-bit word length, 1.5 "STOP bit" is generated in the transmitted data. When select 6-, 7- and 8-bit word length, 2 "STOP bit" is generated in the transmitted data.
[1:0]	WLS	Word Length Selection 00 = Word length is 5-bit. 01 = Word length is 6-bit. 10 = Word length is 7-bit. 11 = Word length is 8-bit.

UART MODEM Control Register (UA_MCR) (Not Available in UART2 Channel)

Register	Offset	R/W	Description	Reset Value
UA_MCR x=0,1	UARTx_BA+0x10	R/W	UART Modem Control Register	0x0000_0200

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved		RTS_ST	Reserved			LEV_RTS	Reserved
7	6	5	4	3	2	1	0
Reserved						RTS	Reserved

Bits	Description	
[31:14]	Reserved	Reserved.
[13]	RTS_ST	RTS Pin State (Read Only) (Not Available In UART2 Channel) This bit mirror from RTS pin output of voltage logic status. 0 = RTS pin output is low level voltage logic state. 1 = RTS pin output is high level voltage logic state.
[12:10]	Reserved	Reserved.
[9]	LEV_RTS	RTS Pin Active Level (Not Available In UART2 Channel) This bit defines the active level state of RTS pin output. 0 = RTS pin output is high level active. 1 = RTS pin output is low level active. Note1: Refer to Figure 6-62 and Figure 6-63 for UART function mode. Note2: Refer to Figure 6-73 And Figure 6-74for RS-485 function mode.
[8:2]	Reserved	Reserved.
[1]	RTS	RTS (Request-To-Send) Signal Control (Not Available In UART2 Channel) This bit is direct control internal RTS signal active or not, and then drive the RTS pin output with LEV_RTS bit configuration. 0 = RTS signal is active. 1 = RTS signal is inactive. Note1: This RTS signal control bit is not effective when RTS auto-flow control is enabled in UART function mode. Note2: This RTS signal control bit is not effective when RS-485 auto direction mode (AUD) is enabled in RS-485 function mode.
[0]	Reserved	Reserved.

UART Modem Status Register (UA_MSR) (Not Available in UART2 Channel)

Register	Offset	R/W	Description	Reset Value
UA_MSR x=0,1	UARTx_BA+0x14	R/W	UART Modem Status Register	0x0000_0110

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							LEV_CTS
7	6	5	4	3	2	1	0
Reserved			CTS_ST	Reserved			DCTS_F

Bits	Description
[31:9]	Reserved Reserved.
[8]	LEV_CTS CTS Pin Active Level This bit defines the active level state of CTS pin input. 0 = CTS pin input is high level active. 1 = CTS pin input is low level active. Note: Refer to Figure 6-61 for more information
[7:5]	Reserved Reserved.
[4]	CTS_ST CTS Pin Status (Read Only) (Not Available In UART2 Channel) This bit mirror from CTS pin input of voltage logic status. 0 = CTS pin input is low level voltage logic state. 1 = CTS pin input is high level voltage logic state. Note: This bit echoes when UART Controller peripheral clock is enabled, and CTS multi-function port is selected
[3:1]	Reserved Reserved.
[0]	DCTS_F Detect CTS State Change Flag (Read Only) (Not Available In UART2 Channel) This bit is set whenever CTS input has change state, and it will generate Modem interrupt to CPU when MODEM_IEN (UA_IER [3]) is set to 1. 0 = CTS input has not change state. 1 = CTS input has change state. Note: This bit is read only, but can be cleared by writing "1" to it.

UART FIFO Status Register (UA_FSR)

Register	Offset	R/W	Description	Reset Value
UA_FSR x=0,1,2	UARTx_BA+0x18	R/W	UART FIFO Status Register	0x1040_4000

31	30	29	28	27	26	25	24
Reserved			TE_FLAG	Reserved			TX_OVER_IF
23	22	21	20	19	18	17	16
TX_FULL	TX_EMPTY	TX_POINTER					
15	14	13	12	11	10	9	8
RX_FULL	RX_EMPTY	RX_POINTER					
7	6	5	4	3	2	1	0
Reserved	BIF	FEF	PEF	RS485_ADD_DETF	Reserved		RX_OVER_IF

Bits	Description
[31:29]	Reserved Reserved.
[28]	TE_FLAG Transmitter Empty Flag (Read Only) This bit is set by hardware when TX FIFO (UA_THR) is empty and the STOP bit of the last byte has been transmitted. 0 = TX FIFO is not empty. 1 = TX FIFO is empty. Note: This bit is cleared automatically when TX FIFO is not empty or the last byte transmission has not completed.
[27:25]	Reserved Reserved.
[24]	TX_OVER_IF TX Overflow Error Interrupt Flag (Read Only) If TX FIFO (UA_THR) is full, an additional write to UA_THR will cause this bit to logic 1. 0 = TX FIFO is not overflow. 1 = TX FIFO is overflow. Note: This bit is read only, but can be cleared by writing "1" to it.
[23]	TX_FULL Transmitter FIFO Full (Read Only) This bit indicates TX FIFO full or not. 0 = TX FIFO is not full. 1 = TX FIFO is full. This bit is set when the number of usage in TX FIFO Buffer is equal to 64/16/16(UART0/UART1/UART2), otherwise is cleared by hardware.
[22]	TX_EMPTY Transmitter FIFO Empty (Read Only) This bit indicates TX FIFO empty or not. 0 = TX FIFO is not empty. 1 = TX FIFO is empty. Note: When the last byte of TX FIFO has been transferred to Transmitter Shift Register, hardware sets this bit high. It will be cleared when writing data into THR (TX FIFO not

		empty).
[21:16]	TX_POINTER	TX FIFO Pointer (Read Only) This field indicates the TX FIFO Buffer Pointer. When CPU writes one byte into UA_THR, then TX_POINTER increases one. When one byte of TX FIFO is transferred to Transmitter Shift Register, then TX_POINTER decreases one. The Maximum value shown in TX_POINTER is 63/15/15 (UART0/UART1/UART2). When the using level of TX FIFO Buffer equal to 64/16/16, the TX_FULL bit is set to 1 and TX_POINTER will show 0. As one byte of TX FIFO is transferred to Transmitter Shift Register, the TX_FULL bit is cleared to 0 and TX_POINTER will show 63/15/15 (UART0/UART1/UART2).
[15]	RX_FULL	Receiver FIFO Full (Read Only) This bit initiates RX FIFO is full or not. 0 = RX FIFO is not full. 1 = RX FIFO is full. Note: This bit is set when the number of usage in RX FIFO Buffer is equal to 64/16/16(UART0/UART1/UART2), otherwise is cleared by hardware.
[14]	RX_EMPTY	Receiver FIFO Empty (Read Only) This bit initiate RX FIFO empty or not. 0 = RX FIFO is not empty. 1 = RX FIFO is empty. Note: When the last byte of RX FIFO has been read by CPU, hardware sets this bit high. It will be cleared when UART receives any new data.
[13:8]	RX_POINTER	RX FIFO Pointer (Read Only) This field indicates the RX FIFO Buffer Pointer. When UART receives one byte from external device, then RX_POINTER increases one. When one byte of RX FIFO is read by CPU, then RX_POINTER decreases one. The Maximum value shown in RX_POINTER is 63/15/15 (UART0/UART1/UART2). When the using level of RX FIFO Buffer equal to 64/16/16, the RX_FULL bit is set to 1 and RX_POINTER will show 0. As one byte of RX FIFO is read by CPU, the RX_FULL bit is cleared to 0 and RX_POINTER will show 63/15/15 (UART0/UART1/UART2).
[7]	Reserved	Reserved.
[6]	BIF	Break Interrupt Flag (Read Only) This bit is set to logic 1 whenever the received data input(RX) is held in the “spacing state” (logic 0) for longer than a full word transmission time (that is, the total time of “start bit” + data bits + parity + stop bits) and is reset whenever the CPU writes 1 to this bit. 0 = No Break interrupt is generated. 1 = Break interrupt is generated. Note: This bit is read only, but can be cleared by writing “1” to it.
[5]	FEF	Framing Error Flag (Read Only) This bit is set to logic 1 whenever the received character does not have a valid “stop bit” (that is, the stop bit following the last data bit or parity bit is detected as logic 0), and is reset whenever the CPU writes 1 to this bit. 0 = No framing error is generated. 1 = Framing error is generated. Note: This bit is read only, but can be cleared by writing “1” to it.
[4]	PEF	Parity Error Flag (Read Only) This bit is set to logic 1 whenever the received character does not have a valid “parity bit”, and is reset whenever the CPU writes 1 to this bit. 0 = No parity error is generated. 1 = Parity error is generated. Note: This bit is read only, but can be cleared by writing “1” to it.

[3]	RS485_ADD_DETF	RS-485 Address Byte Detection Flag (Read Only) 0 = Receiver detects a data that is not an address bit (bit 9 = '1'). 1 = Receiver detects a data that is an address bit (bit 9 = '1'). Note1: This field is used for RS-485 function mode and RS485_ADD_EN (UA_ALT_CSR[15]) is set to 1 to enable Address detection mode. Note2: This bit is read only, but can be cleared by writing '1' to it.
[2:1]	Reserved	Reserved.
[0]	RX_OVER_IF	RX Overflow Error IF (Read Only) This bit is set when RX FIFO overflow. If the number of bytes of received data is greater than RX_FIFO (UA_RBR) size, 64/16/16 bytes of UART0/UART1/UART2, this bit will be set. 0 = RX FIFO is not overflow. 1 = RX FIFO is overflow. Note: This bit is read only, but can be cleared by writing "1" to it.

UART Interrupt Status Control Register (UA_ISR)

Register	Offset	R/W	Description	Reset Value
UA_ISR x=0,1,2	UARTx_BA+0x1C	R/W	UART Interrupt Status Register	0x0000_0002

31	30	29	28	27	26	25	24
Reserved		HW_BUF_ERR_INT	HW_TOUT_INT	HW_MODEM_INT	HW_RLS_INT	Reserved	
23	22	21	20	19	18	17	16
Reserved		HW_BUF_ERR_IF	HW_TOUT_IF	HW_MODEM_IF	HW_RLS_IF	Reserved	
15	14	13	12	11	10	9	8
LIN_INT	Reserved	BUF_ERR_INT	TOUT_INT	MODEM_INT	RLS_INT	THRE_INT	RDA_INT
7	6	5	4	3	2	1	0
LIN_IF	Reserved	BUF_ERR_IF	TOUT_IF	MODEM_IF	RLS_IF	THRE_IF	RDA_IF

Bits	Description	
[31:30]	Reserved	Reserved.
[29]	HW_BUF_ERR_INT	In DMA Mode, Buffer Error Interrupt Indicator (Read Only) This bit is set if BUF_ERR_IEN (UA_IER[5]) and HW_BUF_ERR_IF (UA_ISR[5]) are both set to 1. 0 = No buffer error interrupt is generated in DMA mode. 1 = Buffer error interrupt is generated in DMA mode.
[28]	HW_TOUT_INT	In DMA Mode, Time-Out Interrupt Indicator (Read Only) This bit is set if TOUT_IEN (UA_IER[4]) and HW_TOUT_IF (UA_ISR[20]) are both set to 1. 0 = No Tout interrupt is generated in DMA mode. 1 = Tout interrupt is generated in DMA mode.
[27]	HW_MODEM_INT	In DMA Mode, MODEM Status Interrupt Indicator (Read Only) (Not Available In UART2 Channel) This bit is set if MODEM_IEN (UA_IER[3]) and HW_MODEM_IF (UA_ISR[3]) are both set to 1. 0 = No Modem interrupt is generated in DMA mode. 1 = Modem interrupt is generated in DMA mode.
[26]	HW_RLS_INT	In DMA Mode, Receive Line Status Interrupt Indicator (Read Only) This bit is set if RLS_IEN (UA_IER[2]) and HW_RLS_IF (UA_ISR[18]) are both set to 1. 0 = No RLS interrupt is generated in DMA mode. 1 = RLS interrupt is generated in DMA mode.
[25:22]	Reserved	Reserved.
[21]	HW_BUF_ERR_IF	In DMA Mode, Buffer Error Interrupt Flag (Read Only) This bit is set when the TX or RX FIFO overflows (TX_OVER_IF (UA_FSR[24]) or RX_OVER_IF (UA_FSR[0]) is set). When BUF_ERR_IF (UA_ISR[5]) is set, the transfer maybe is not correct. If BUF_ERR_IEN (UA_IER[5]) is enabled, the buffer error interrupt

		will be generated. 0 = No buffer error interrupt flag is generated. 1 = Buffer error interrupt flag is generated. Note: This bit is cleared when both TX_OVER_IF (UA_FSR[24]) and RX_OVER_IF (UA_FSR[0]) are cleared.
[20]	HW_TOUT_IF	In DMA Mode, Time-Out Interrupt Flag (Read Only) This bit is set when the RX FIFO is not empty and no activities occurred in the RX FIFO and the time-out counter equal to TOIC (UA_TOR[7:0]). If TOUT_IEN (UA_IER [4]) is enabled, the Tout interrupt will be generated. 0 = No Time-out interrupt flag is generated. 1 = Time-out interrupt flag is generated. Note: This bit is read only and user can read UA_RBR (RX is in active) to clear it.
[19]	HW_MODEM_IF	In DMA Mode, MODEM Interrupt Flag (Read Only) (Not Available In UART2 Channel) This bit is set when the CTS pin has state change (DCTS (US_MSR[0] =1)). If MODEM_IEN (UA_IER [3]) is enabled, the Modem interrupt will be generated. 0 = No Modem interrupt flag is generated. 1 = Modem interrupt flag is generated. Note: This bit is read only and reset to 0 when the bit DCTS(US_MSR[0]) is cleared by writing 1 on DCTS (US_MSR[0]).
[18]	HW_RLS_IF	In DMA Mode, Receive Line Status Flag (Read Only) This bit is set when the RX receive data have parity error, frame error or break error (at least one of 3 bits, BIF (UA_FSR[6]), FEF (UA_FSR[5]) and PEF (UA_FSR[4]) is set). If RLS_IEN (UA_IER [2]) is enabled, the RLS interrupt will be generated. 0 = No RLS interrupt flag is generated. 1 = RLS interrupt flag is generated. Note1: In RS-485 function mode, this field include "receiver detect any address byte received address byte character (bit9 = '1') bit". Note2: In UART function mode, this bit is read only and reset to 0 when all bits of BIF(UA_FSR[6]) , FEF(UA_FSR[5]) and PEF(UA_FSR[4]) are cleared. Note3: In RS-485 function mode, this bit is read only and reset to 0 when all bits of BIF(UA_FSR[6]) , FEF(UA_FSR[5]) and PEF(UA_FSR[4]) and RS485_ADD_DET (UA_FSR[3]) are cleared.
[17:16]	Reserved	Reserved.
[15]	LIN_INT	LIN Bus Interrupt Indicator (Read Only) This bit is set if LIN_IEN (UA_IER[8]) and LIN_IF(UA_ISR[7]) are both set to 1. 0 = No LIN Bus interrupt is generated. 1 = The LIN Bus interrupt is generated.
[14]	Reserved	Reserved.
[13]	BUF_ERR_INT	Buffer Error Interrupt Indicator (Read Only) This bit is set if BUF_ERR_IEN(UA_IER[5]) and BUF_ERR_IF(UA_ISR[5]) are both set to 1. 0 = No buffer error interrupt is generated. 1 = Buffer error interrupt is generated.
[12]	TOUT_INT	Time-Out Interrupt Indicator (Read Only) This bit is set if TOUT_IEN(UA_IER[4]) and TOUT_IF(UA_ISR[4]) are both set to 1. 0 = No Tout interrupt is generated. 1 = Tout interrupt is generated.
[11]	MODEM_INT	MODEM Status Interrupt Indicator (Read Only) (Not Available In UART2 Channel)

		This bit is set if MODEM_IEN(UA_IER[3] and MODEM_IF(UA_ISR[4]) are both set to 1 0 = No Modem interrupt is generated. 1 = Modem interrupt is generated.
[10]	RLS_INT	Receive Line Status Interrupt Indicator (Read Only) This bit is set if RLS_IEN (UA_IER[2]) and RLS_IF(UA_ISR[2]) are both set to 1. 0 = No RLS interrupt is generated. 1 = RLS interrupt is generated.
[9]	THRE_INT	Transmit Holding Register Empty Interrupt Indicator (Read Only) This bit is set if THRE_IEN (UA_IER[1])and THRE_IF(UA_SR[1]) are both set to 1. 0 = No THRE interrupt is generated. 1 = THRE interrupt is generated.
[8]	RDA_INT	Receive Data Available Interrupt Indicator (Read Only) This bit is set if RDA_IEN (UA_IER[0]) and RDA_IF (UA_ISR[0]) are both set to 1. 0 = No RDA interrupt is generated. 1 = RDA interrupt is generated.
[7]	LIN_IF	LIN Bus Flag (Read Only) This bit is set when LIN slave header detect (LINS_HDET_F (UA_LIN_SR[0] =1)), LIN break detect (LIN_BKDET_F(UA_LIN_SR[9]=1)), bit error detect (BIT_ERR_F(UA_LIN_SR[9]=1), LIN slave ID parity error (LINS_IDPERR_F(UA_LIN_SR[2] = 1) or LIN slave header error detect (LINS_HERR_F (UA_LIN_SR[1])). If LIN_IEN (UA_IER [8]) is enabled the LIN interrupt will be generated. 0 = None of LINS_HDET_F, LIN_BKDET_F, BIT_ERR_F, LINS_IDPERR_F and LINS_HERR_F is generated. 1 = At least one of LINS_HDET_F, LIN_BKDET_F, BIT_ERR_F, LINS_IDPERR_F and LINS_HERR_F is generated. Note: This bit is read only. This bit is cleared when LINS_HDET_F(UA_LIN_SR[0]), LIN_BKDET_F(UA_LIN_SR[9]), BIT_ERR_F(UA_LIN_SR[9]), LINS_IDPENR_F (UA_LIN_SR[2]) and LINS_HERR_F(UA_LIN_SR[1]) all are cleared.
[6]	Reserved	Reserved.
[5]	BUF_ERR_IF	Buffer Error Interrupt Flag (Read Only) This bit is set when the TX FIFO or RX FIFO overflows (TX_OVER_IF (UA_FSR[24]) or RX_OVER_IF (UA_FSR[0]) is set). When BUF_ERR_IF (UA_ISR[5])is set, the transfer is not correct. If BUF_ERR_IEN (UA_IER [8]) is enabled, the buffer error interrupt will be generated. 0 = No buffer error interrupt flag is generated. 1 = Buffer error interrupt flag is generated. 0 = No buffer error interrupt flag is generated. 1 = Buffer error interrupt flag is generated. Note: This bit is read only and reset to 0 when all bits of TX_OVER_IF(UA_FSR[24]) and RX_OVER_IF(UA_FSR[0]) are cleared.
[4]	TOUT_IF	Time-Out Interrupt Flag (Read Only) This bit is set when the RX FIFO is not empty and no activities occurred in the RX FIFO and the time-out counter equal to TOIC. If TOUT_IEN (UA_IER [4]) is enabled, the Tout interrupt will be generated. 0 = No Time-out interrupt flag is generated. 1 = Time-out interrupt flag is generated. Note: This bit is read only and user can read UA_RBR (RX is in active) to clear it
[3]	MODEM_IF	MODEM Interrupt Flag (Read Only) (Not Available In UART2 Channel) This bit is set when the CTS pin has state change (DCTSF (UA_MSR[0]) = 1). If MODEM_IEN (UA_IER [3]) is enabled, the Modem interrupt will be generated. 0 = No Modem interrupt flag is generated.

		1 = Modem interrupt flag is generated. Note: This bit is read only and reset to 0 when bit DCTSF is cleared by a write 1 on DCTSF(UA_MSR[0]).
[2]	RLS_IF	Receive Line Interrupt Flag (Read Only) This bit is set when the RX receive data have parity error, frame error or break error (at least one of 3 bits, BIF(UA_FSR[6]), FEF(UA_FSR[5]) and PEF(UA_FSR[4]), is set). If RLS_IEN (UA_IER [2]) is enabled, the RLS interrupt will be generated. 0 = No RLS interrupt flag is generated. 1 = RLS interrupt flag is generated. Note1: In RS-485 function mode, this field is set include "receiver detect and received address byte character (bit9 = '1') bit". At the same time, the bit of UA_FSR[RS485_ADD_DETF] is also set. Note2: This bit is read only and reset to 0 when all bits of BIF(UA_FSR[6]), FEF(UA_FSR[5]) and PEF(UA_FSR[4]) are cleared. Note3: In RS-485 function mode, this bit is read only and reset to 0 when all bits of BIF(UA_FSR[6]), FEF(UA_FSR[5]) and PEF(UA_FSR[4]) and RS485_ADD_DETF (UA_FSR[3]) are cleared.
[1]	THRE_IF	Transmit Holding Register Empty Interrupt Flag (Read Only) This bit is set when the last data of TX FIFO is transferred to Transmitter Shift Register. If THRE_IEN (UA_IER[1]) is enabled, the THRE interrupt will be generated. 0 = No THRE interrupt flag is generated. 1 = THRE interrupt flag is generated. Note: This bit is read only and it will be cleared when writing data into THR (TX FIFO not empty).
[0]	RDA_IF	Receive Data Available Interrupt Flag (Read Only) When the number of bytes in the RX FIFO equals the RFITL then the RDA_IF(UA_ISR[0]) will be set. If RDA_IEN (UA_IER [0]) is enabled, the RDA interrupt will be generated. 0 = No RDA interrupt flag is generated. 1 = RDA interrupt flag is generated. Note: This bit is read only and it will be cleared when the number of unread bytes of RX FIFO drops below the threshold level (RFITL(UA_FCR[7:4])).

UART Time-out Register (UA_TOR)

Register	Offset	R/W	Description	Reset Value
UA_TOR x=0,1,2	UARTx_BA+0x20	R/W	UART Time-out Register	0x0000_0000

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

Bits	Description	
[31:16]	Reserved	Reserved.
[15:8]	DLY	TX Delay Time Value This field is used to programming the transfer delay time between the last stop bit and next start bit.
[7:0]	TOIC	Time-Out Interrupt Comparator The time-out counter resets and starts counting (the counting clock = baud rate) whenever the RX FIFO receives a new data word. Once the content of time-out counter is equal to that of time-out interrupt comparator (TOIC (UA_TOR[7:0])), a receiver time-out interrupt (INT_TOUT) is generated if TOUT_IEN (UA_IER [4]) enabled. A new incoming data word or RX FIFO empty will clear TOUT_INT(UA_IER[9]). In order to avoid receiver time-out interrupt generation immediately during one character is being received, TOIC (UA_TOR[7:0]) value should be set between 40 and 255. So, for example, if TOIC (UA_TOR[7:0]) is set with 40, the time-out interrupt is generated after four characters are not received when 1 stop bit and no parity check is set for UART transfer.

UART Baud Rate Divider Register (UA_BAUD)

Register	Offset	R/W	Description	Reset Value
UA_BAUD x=0,1,2	UARTx_BA+0x24	R/W	UART Baud Rate Divisor Register	0x0F00_0000

31	30	29	28	27	26	25	24
Reserved		DIV_X_EN	DIV_X_ONE	DIVIDER_X			
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
BRD							
7	6	5	4	3	2	1	0
BRD							

Bits	Description	
[31:30]	Reserved	Reserved.
[29]	DIV_X_EN	Divider X Enable Bit The BRD = Baud Rate Divider, and the baud rate equation is $\text{Baud Rate} = \text{Clock} / [M * (\text{BRD} + 2)]$; The default value of M is 16. 0 = Divider X Disabled (the equation of $M = 16$). 1 = Divider X Enabled (the equation of $M = X+1$, but DIVIDER_X [27:24] must ≥ 8). Refer to Table 6-12 for more information. Note: In IrDA mode, this bit must disable.
[28]	DIV_X_ONE	Divider X Equal To 1 0 = Divider $M = X$ (the equation of $M = X+1$, but DIVIDER_X [27:24] must ≥ 8). 1 = Divider $M = 1$ (the equation of $M = 1$, but BRD [15:0] must ≥ 3). Refer to Table 6-12 for more information.
[27:24]	DIVIDER_X	Divider X The baud rate divider $M = X+1$.
[23:16]	Reserved	Reserved.
[15:0]	BRD	Baud Rate Divider The field indicates the baud rate divider

UART IrDA Control Register (IRCR)

Register	Offset	R/W	Description	Reset Value
UA_IRCR x=0,1,2	UARTx_BA+0x28	R/W	UART IrDA Control Register	0x0000_0040

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved	INV_RX	INV_TX	Reserved			TX_SELECT	Reserved

Bits	Description	
[31:7]	Reserved	Reserved.
[6]	INV_RX	IrDA Inverse Receive Input Signal Control 0 = None inverse receiving input signal. 1 = Inverse receiving input signal.
[5]	INV_TX	IrDA Inverse Transmitting Output Signal Control 0 = None inverse transmitting signal.. 1 = Inverse transmitting output signal.
[4:2]	Reserved	Reserved.
[1]	TX_SELECT	TX_SELECT 0 = IrDA Transmitter Disabled and Receiver Enabled. 1 = IrDA Transmitter Enabled and Receiver Disabled.
[0]	Reserved	Reserved.

Note: In IrDA mode, the UA_BAUD (UA_BAUD [29]) register must be disabled (the baud equation must be Clock / 16 * (BRD))

UART Alternate Control/Status Register (UA_ALT_CSR)

Register	Offset	R/W	Description	Reset Value
UA_ALT_CSR x=0,1,2	UARTx_BA+0x2C	R/W	UART Alternate Control/Status Register	0x0000_000C

31	30	29	28	27	26	25	24
ADDR_MATCH							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
RS485_ADD_EN	Reserved				RS485_AUD	RS485_AAD	RS485_NMM
7	6	5	4	3	2	1	0
LIN_TX_EN	LIN_RX_EN	Reserved		LIN_BKFL			

Bits	Description	
[31:24]	ADDR_MATCH	Address Match Value Register This field contains the RS-485 address match values. Note: This field is used for RS-485 auto address detection mode.
[23:16]	Reserved	Reserved.
[15]	RS485_ADD_EN	RS-485 Address Detection Enable Bit This bit is used to enable RS-485 Address Detection mode. 0 = Address detection mode Disabled. 1 = Address detection mode Enabled. Note: This bit is used for RS-485 any operation mode.
[14:11]	Reserved	Reserved.
[10]	RS485_AUD	RS-485 Auto Direction Mode (AUD) 0 = RS-485 Auto Direction Operation mode (AUO) Disabled. 1 = RS-485 Auto Direction Operation mode (AUO) Enabled. Note: It can be active with RS-485_AAD or RS-485_NMM operation mode.
[9]	RS485_AAD	RS-485 Auto Address Detection Operation Mode (AAD) 0 = RS-485 Auto Address Detection Operation mode (AAD) Disabled. 1 = RS-485 Auto Address Detection Operation mode (AAD) Enabled. Note: It cannot be active with RS-485_NMM operation mode.
[8]	RS485_NMM	RS-485 Normal Multi-Drop Operation Mode (NMM) 0 = RS-485 Normal Multi-drop Operation mode (NMM) Disabled. 1 = RS-485 Normal Multi-drop Operation mode (NMM) Enabled. Note: It cannot be active with RS-485_AAD operation mode.
[7]	LIN_TX_EN	LIN TX Break Mode Enable Bit 0 = LIN TX Break mode Disabled.

		1 = LIN TX Break mode Enabled. Note: When TX break field transfer operation finished, this bit will be cleared automatically.
[6]	LIN_RX_EN	LIN RX Enable Bit 0 = LIN RX mode Disabled. 1 = LIN RX mode Enabled.
[5:4]	Reserved	Reserved.
[3:0]	LIN_BKFL	UART LIN Break Field Length This field indicates a 4-bit LIN TX break field count. Note1: This break field length is UA_LIN_BKFL + 1 Note2: According to LIN spec, the reset value is 0xC (break field length = 13).

UART Function Select Register (UA_FUN_SEL)

Register	Offset	R/W	Description	Reset Value
UA_FUN_SEL x=0,1,2	UARTx_BA+0x30	R/W	UART Function Select Register	0x0000_0000

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

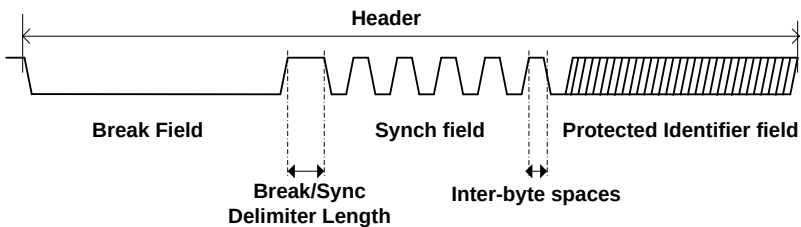
Bits	Description	
[31:2]	Reserved	Reserved.
[1:0]	FUN_SEL	Function Select Enable Bit 00 = UART function Enabled. 01 = LIN function Enabled. 10 = IrDA function Enabled. 11 = RS-485 function Enabled.

UART LIN Control Register (UA_LIN_CTL)

Register	Offset	R/W	Description	Reset Value
UA_LIN_CTL x=0,1,2	UARTx_BA+0x34	R/W	UART LIN Control Register	0x000C_0000

31	30	29	28	27	26	25	24
LIN_PID							
23	22	21	20	19	18	17	16
LIN_HEAD_SEL		LIN_BS_LEN		LIN_BKFL			
15	14	13	12	11	10	9	8
Reserved			BIT_ERR_EN	LIN_RX_DIS	LIN_BKDET_EN	LIN_IDPEN	LIN_SHD
7	6	5	4	3	2	1	0
Reserved			LIN_MUTE_EN	LINS_DUM_EN	LINS_ARS_EN	LINS_HDET_EN	LINS_EN

Bits	Description											
[31:24]	LIN_PID	LIN PID Register This field contains the LIN frame ID value when in LIN function mode, the frame ID parity can be generated by software or hardware depends on LIN_IDPEN (UA_LIN_CTL[9]) = 1. If the parity generated by hardware, user fill ID0~ID5, (LIN_PID [29:24]) hardware will calculate P0 (LIN_PID[30]) and P1 (LIN_PID[31]), otherwise user must filled frame ID and parity in this field. <table><tr><td>PID</td><td>Start</td><td>ID0</td><td>ID1</td><td>ID2</td><td>ID3</td><td>ID4</td><td>ID5</td><td>P0</td><td>P1</td></tr></table> P0 = ID0 xor ID1 xor ID2 xor ID4 P1 = ~(ID1 xor ID3 xor ID4 xor ID5) Note1: User can fill any 8-bit value to this field and the bit 24 indicates ID0 (LSB first). Note2: This field can be used for LIN master mode or slave mode.	PID	Start	ID0	ID1	ID2	ID3	ID4	ID5	P0	P1
PID	Start	ID0	ID1	ID2	ID3	ID4	ID5	P0	P1			
[23:22]	LIN_HEAD_SEL	LIN Header Select 00 = The LIN header includes “break field”. 01 = The LIN header includes “break field” and “sync field”. 10 = The LIN header includes “break field”, “sync field” and “frame ID field”. 11 = Reserved. Note: This bit is used to master mode for LIN to send header field (LIN_SHD (UA_LIN_CTL [8]) = 1) or used to slave to indicates exit from mute mode condition (LIN_MUTE_EN (UA_LIN_CTL[4] = 1).										
[21:20]	LIN_BS_LEN	LIN Break/Sync Delimiter Length 00 = The LIN break/sync delimiter length is 1 bit time. 10 = The LIN break/sync delimiter length is 2 bit time. 10 = The LIN break/sync delimiter length is 3 bit time. 11 = The LIN break/sync delimiter length is 4 bit time.										

		 Note: This bit used for LIN master to sending header field.
[19:16]	LIN_BKFL	LIN Break Field Length This field indicates a 4-bit LIN TX break field count. Note1: These registers are shadow registers of LIN_BKFL, User can read/write it by setting LIN_BKFL (UA_ALT_CSR[3:0]) or LIN_BKFL (UA_LIN_CTL[19:16]). Note2: This break field length is LIN_BKFL + 1. Note3: According to LIN spec, the reset value is 12 (break field length = 13).
[15:13]	Reserved	Reserved.
[12]	BIT_ERR_EN	Bit Error Detect Enable Bit 0 = Bit error detection function Disabled. 1 = Bit error detection Enabled. Note: In LIN function mode, when occur bit error, the BIT_ERR_F (UA_LIN_SR[9]) flag will be asserted. If the LIN_IEN (UA_IER[8]) = 1, an interrupt will be generated.
[11]	LIN_RX_DIS	LIN Receiver Disable Bit If the receiver is enabled (LIN_RX_DIS (UA_LIN_CTL[11]) = 0), all received byte data will be accepted and stored in the RX-FIFO, and if the receiver is disabled (LIN_RX_DIS (UA_LIN_CTL[11]) = 1), all received byte data will be ignore. 0 = LIN receiver Enabled. 1 = LIN receiver Disabled. Note: This bit is only valid when operating in LIN function mode (FUN_SEL (UA_FUN_SEL[1:0]) = 01).
[10]	LIN_BKDET_EN	LIN Break Detection Enable Bit When detect consecutive dominant greater than 11 bits, and are followed by a delimiter character, the LIN_BKDET_F (UA_LIN_SR[8]) flag is set in UA_LIN_SR register at the end of break field. If the LIN_IEN (UA_IER[8])=1, an interrupt will be generated. 0 = LIN break detection Disabled. 1 = LIN break detection Enabled.
[9]	LIN_IDPEN	LIN ID Parity Enable Bit 0 = LIN frame ID parity Disabled. 1 = LIN frame ID parity Enabled. Note1: This bit can be used for LIN master to sending header field (LIN_SHD (UA_LIN_CTL[8])) = 1 and LIN_HEAD_SEL (UA_LIN_CTL[23:22]) = 10) or be used for enable LIN slave received frame ID parity checked. Note2: This bit is only use when the operation header transmitter is in LIN_HEAD_SEL (UA_LIN_CTL[23:22]) = 10.
[8]	LIN_SHD	LIN TX Send Header Enable Bit The LIN TX header can be "break field" or "break and sync field" or "break, sync and frame ID field", it is depend on setting LIN_HEAD_SEL (UA_LIN_CTL[23:22]). 0 = Send LIN TX header Disabled. 1 = Send LIN TX header Enabled. Note1: These registers are shadow registers of LIN_SHD (UA_ALT_CSR [7]); user can read/write it by setting LIN_SHD (UA_ALT_CSR [7]) or LIN_SHD (UA_LIN_CTL [8]). Note2: When transmitter header field (it may be "break" or "break + sync" or "break + sync + frame ID" selected by LIN_HEAD_SEL (UA_LIN_CTL[23:22]) field) transfer operation

		finished, this bit will be cleared automatically.
[7:5]	Reserved	Reserved.
[4]	LIN_MUTE_EN	LIN Mute Mode Enable Bit 0 = LIN mute mode Disabled. 1 = LIN mute mode Enabled. Note: The exit from mute mode condition and each control and interactions of this field are explained in (LIN slave mode).
[3]	LINS_DUM_EN	LIN Slave Divider Update Method Enable Bit 0 = UA_BAUD updated is written by software (if no automatic resynchronization update occurs at the same time). 1 = UA_BAUD is updated at the next received character. User must set the bit before checksum reception. Note1: This bit only valid when in LIN slave mode (LINS_EN (UA_LIN_CTL[0]) = 1). Note2: This bit used for LIN Slave Automatic Resynchronization mode. (for Non-Automatic Resynchronization mode, this bit should be kept cleared) Note3: The control and interactions of this field are explained in 6.13.5.8.4. (Slave mode with automatic resynchronization).
[2]	LINS_ARS_EN	LIN Slave Automatic Resynchronization Mode Enable Bit 0 = LIN automatic resynchronization Disabled. 1 = LIN automatic resynchronization Enabled. Note1: This bit only valid when in LIN slave mode (LINS_EN (UA_LIN_CTL[0]) = 1). Note2: When operation in Automatic Resynchronization mode, the baud rate setting must be mode2 (BAUD_M1 (UA_BAUD [29]) and BAUD_M0 (UA_BAUD [28]) must be 1). Note3: The control and interactions of this field are explained in 6.13.5.8.4. (Slave mode with automatic resynchronization).
[1]	LINS_HDET_EN	LIN Slave Header Detection Enable Bit 0 = LIN slave header detection Disabled. 1 = LIN slave header detection Enabled. Note1: This bit only valid when in LIN slave mode (LINS_EN (UA_LIN_CTL[0]) = 1). Note2: In LIN function mode, when detect header field (break + sync + frame ID), LINS_HDET_F (UA_LIN_SR [0]) flag will be asserted. If the LIN_IEN (UA_IER[8]) = 1, an interrupt will be generated.
[0]	LINS_EN	LIN Slave Mode Enable Bit 0 = LIN slave mode Disabled. 1 = LIN slave mode Enabled.

UART LIN Status Register (UA_LIN_SR)

Register	Offset	R/W	Description	Reset Value
UA_LIN_SR x=0,1,2	UARTx_BA+0x38	R/W	UART LIN Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved						BIT_ERR_F	LIN_BKDET_F
7	6	5	4	3	2	1	0
Reserved				LINS_SYNC_F	LINS_IDPERR_F	LINS_HERR_F	LINS_HDET_F

Bits	Description
[31:10]	Reserved.
[9]	Bit Error Detect Status Flag (Read Only) At TX transfer state, hardware will monitoring the bus state, if the input pin (SIN) state not equals to the output pin (SOUT) state, BIT_ERR_F (UA_LIN_SR[9]) will be set. When occur bit error, if the LIN_IEN (UA_IER[8]) = 1, an interrupt will be generated. Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: This bit is only valid when enable bit error detection function (BIT_ERR_EN (UA_LIN_CTL [12]) = 1).
[8]	LIN Break Detection Flag (Read Only) This bit is set by hardware when a break is detected and be cleared by writing 1 to it through software. 0 = LIN break not detected. 1 = LIN break detected. Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: This bit is only valid when LIN break detection function is enabled (LIN_BKDET_EN (UA_LIN_CTL[10]) = 1).
[7:4]	Reserved.
[3]	LIN Slave Sync Field This bit indicates that the LIN sync field is being analyzed in Automatic Resynchronization mode. When the receiver header have some error been detect, user must reset the internal circuit to re-search new frame header by writing 1 to this bit. 0 = The current character is not at LIN sync state. 1 = The current character is at LIN sync state. Note1: This bit is only valid when in LIN Slave mode (LINS_EN(UA_LIN_CTL[0]) = 1). Note2: This bit is read only, but it can be cleared by writing 1 to it. Note3: When writing 1 to it, hardware will reload the initial baud rate and re-search a new frame header.

[2]	LINS_IDPERR_F	LIN Slave ID Parity Error Flag (Read Only) This bit is set by hardware when receipted frame ID parity is not correct. 0 = No active. 1 = Receipted frame ID parity is not correct. Note1: This bit is read only, but it can be cleared by writing "1" to it. Note2: This bit is only valid when in LIN slave mode (LINS_EN (UA_LIN_CTL [0])= 1) and enable LIN frame ID parity check function LIN_IDPEN (UA_LIN_CTL [9]).
[1]	LINS_HERR_F	LIN Slave Header Error Flag (Read Only) This bit is set by hardware when a LIN header error is detected in LIN slave mode and be cleared by writing 1 to it. The header errors include "break delimiter is too short (less than 0.5 bit time)", "frame error in sync field or Identifier field", "sync field data is not 0x55 in Non-Automatic Resynchronization mode", "sync field deviation error with Automatic Resynchronization mode", "sync field measure time-out with Automatic Resynchronization mode" and "LIN header reception time-out". 0 = LIN header error not detected. 1 = LIN header error detected. Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: This bit is only valid when UART is operated in LIN slave mode (LINS_EN (UA_LIN_CTL [0]) = 1) and enables LIN slave header detection function (LINS_HDET_EN (UA_LIN_CTL [1])).
[0]	LINS_HDET_F	LIN Slave Header Detection Flag (Read Only) This bit is set by hardware when a LIN header is detected in LIN slave mode and be cleared by writing 1 to it. 0 = LIN header not detected. 1 = LIN header detected (break + sync + frame ID). Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: This bit is only valid when in LIN slave mode (LINS_EN (UA_LIN_CTL [0]) = 1) and enable LIN slave header detection function (LINS_HDET_EN (UA_LIN_CTL [1])). Note3: When enable ID parity check LIN_IDPEN (UA_LIN_CTL [9]), if hardware detect complete header ("break + sync + frame ID"), the LINS_HDET_F will be set whether the frame ID correct or not.

6.14 Smart Card Host Interface (SC)

6.14.1 Overview

The Smart Card Interface controller (SC controller) is based on ISO/IEC 7816-3 standard and fully compliant with PC/SC Specifications. It also provides status of card insertion/removal. It also support UART mode for full duplex asynchronous communications.

6.14.2 Features

- Supports up to three ISO7816-3 ports (SC0, SC1 and SC2)
 - ISO7816-3 T=0, T=1 compliant
 - EMV2000 compliant
 - Separates receive/ transmit 4 byte entry FIFO for data payloads.
 - Programmable transmission clock frequency.
 - Programmable receiver buffer trigger level.
 - Programmable guard time selection (11 ETU ~ 267 ETU).
 - A 24-bit and two 8-bit times for Answer to Request (ATR) and waiting times processing.
 - Supports auto inverse convention function.
 - Supports transmitter and receiver error retry and error number limiting function.
 - Supports hardware activation sequence, hardware warm reset sequence and hardware deactivation sequence process.
 - Supports hardware auto deactivation sequence when detecting the card removal.
- Supports up to three UART ports (UART3, UART4, UART5)
 - Full duplex, asynchronous communications.
 - Programmable data bit length, 5-, 6-, 7-, 8-bit character.
 - Separates receiving / transmitting 4 bytes entry FIFO for data payloads.
 - Supports programmable baud rate generator for each channel.
 - Supports programmable receiver buffer trigger level.
 - Programmable transmitting data delay time between the last stop bit leaving the TX-FIFO and the de-assertion by setting SCx_EGTR [EGT] register.
 - Programmable even, odd or no parity bit generation and detection.
 - Programmable stop bit, 1 or 2 stop bit generation.

6.14.3 Block Diagram

The SC clock control and block diagram are shown as follows. The SC controller is completely asynchronous design with two clock domains, PCLK and peripheral clock (SC_CLK). Note that PCLK frequency should be higher than the frequency of peripheral clock.

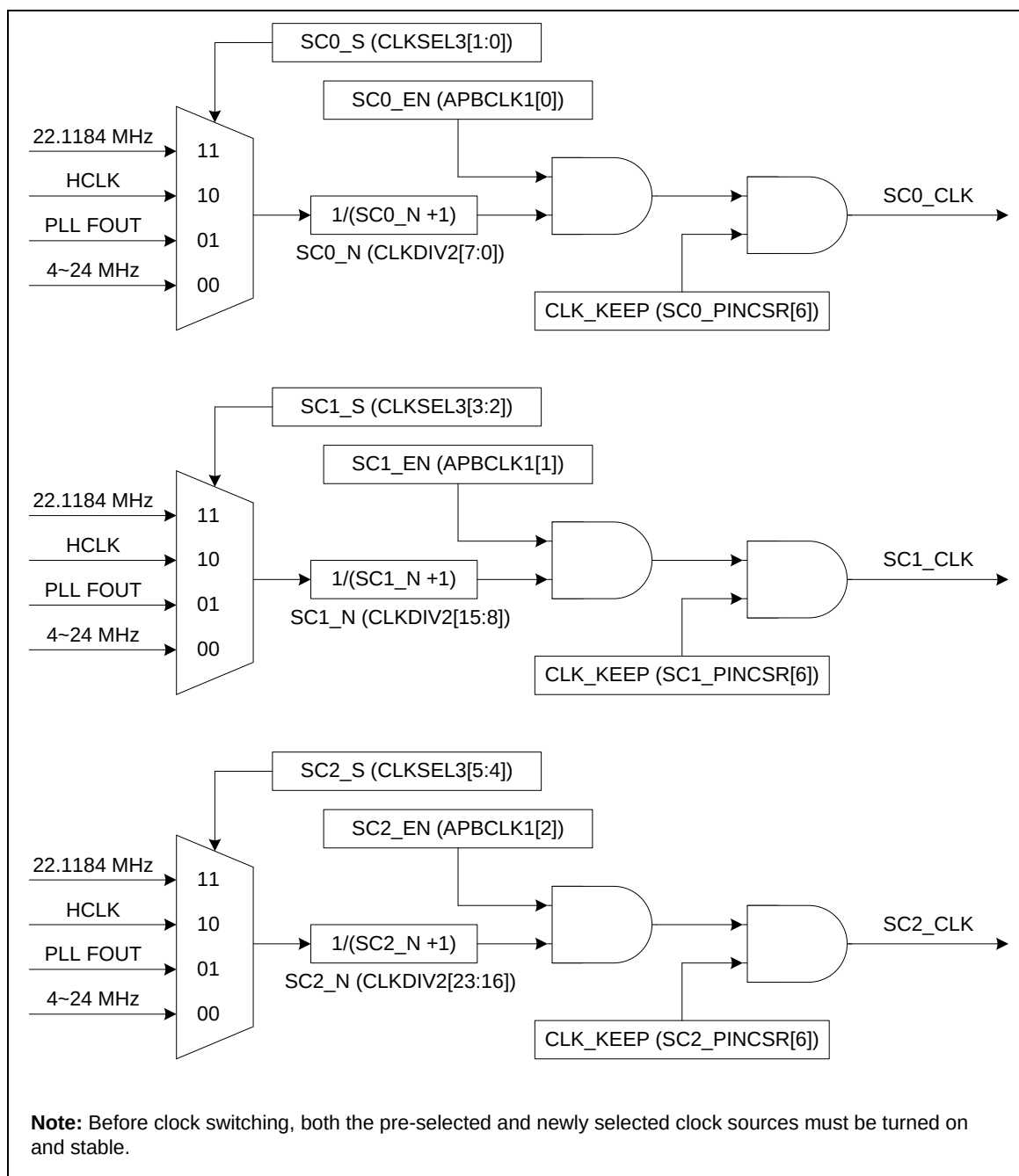


Figure 6-76 SC Clock Control Diagram (8-bit Prescale Counter in Clock Controller)

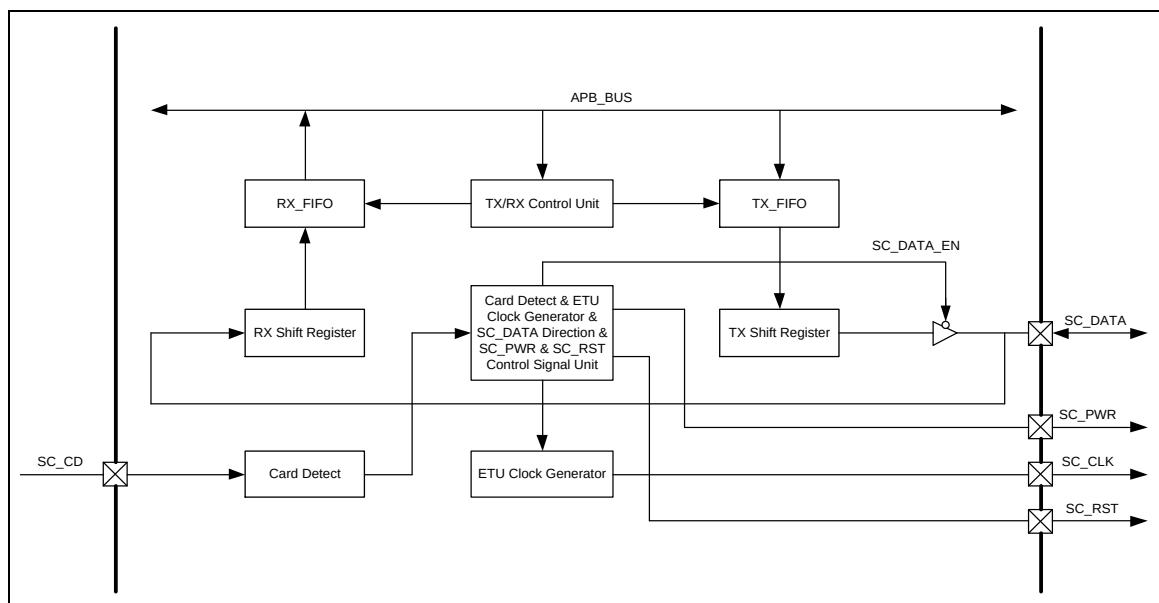


Figure 6-77 SC Controller Block Diagram

6.14.4 Basic Configuration

The SC function pins are configured in GPA_MFP, GPB_MFP, GPC_MFP Multiple Function Pin Registers.

SC Host Controller Pin description is shown as following:

Pin	Type	Description
SC_DATA	Bi-direction	SC Host Controller DATA
SC_CD	Input	SC Host Controller Card Detect
SC_PWR	Output	SC Host Controller Power ON/OFF Switch for CARD
SC_CLK	Output	SC Host Controller Clock
SC_RST	Output	SC Host Controller Reset

Table 6-20 SC Host Controller Pin

UART Pin description is shown as following:

Pin	Type	Description
SC_DATA	Input	UART Receive Data
SC_CLK	Output	UART Transmit Data

Table 6-21 UART Pin

6.14.5 Functional Description

Basically, the smart card interface acts as a half-duplex asynchronous communication port and its data format is composed of ten consecutive bits, which is shown as follows.

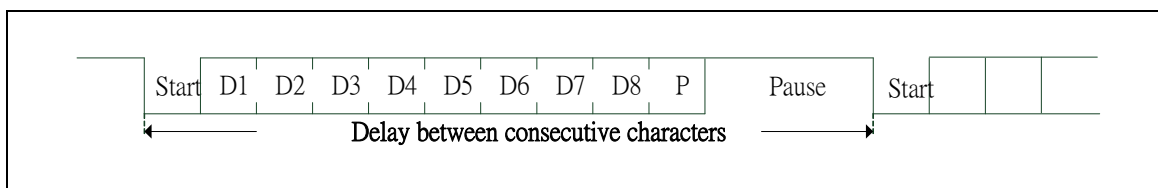


Figure 6-78 SC Data Character

6.14.5.1 Activation, Warm Reset and Deactivation Sequence

The Smart Card Interface controller supports hardware activation, warm reset and deactivation sequence. The activation, Warm Reset and Deactivation and sequence are shown as following.

Activation

- Set SC_RST to low
- Set SC_PWR at high level and SC_DAT at high level (reception mode).
- Enable SC_CLK clock
- De-assert SC_RST to high

The activation sequence can be controlled by two ways. The procedure is shown as following:

Software Timing Control:

Software sets SC_PINCSR and SC_TMRx (x = 0, 1, 2) to process the activation sequence. SC_PWR, SC_CLK, SC_RST and SC_DATA pin state can be programmed by SC_PINCSR. The activation sequence timing can be controlled by setting SC_TMRx (x = 0, 1, 2). This programming procedure provides user has a flexible timing setting for activation sequence.

Hardware Timing Control:

Software sets ACT_EN (SC_ALTCTL[3]) to '1' and the interface will perform the activation sequence by hardware. The SC_PWR to SC_CLK start (T1) and SC_CLK_start to SC_RST assert (T2) can be selected by programming INIT_SEL (SC_ALTCTL[9:8]). This programming procedure provides user has a simple setting for activation sequence.

Following is activation control sequence generation by hardware:

- Set activation timing by setting INIT_SEL (SC_ALTCTL[9:8]).
- TMR0 can be selected by setting TMR_SEL (SC_CTL[14:13]) to '01', '10' or '11'.
- Set operation mode MODE (SC_TMR0[27:24]) to '0011' and give an Answer to Request (ATR) value by setting CNT (SC_TMR0 [23:0]) register.
- When hardware de-asserts SC_RST to high, hardware will generator an interrupt INIT_IS (SC_ISR[8]) to CPU at the same time INIT_IE(SC_IER[8]) = "1".
- If the TMR0 decreases the counter to '0' (start from SC_RST de-assert) and the card does not response ATR before that time, hardware will generate interrupt TMR0_IS (SC_ISR[3]) to CPU.

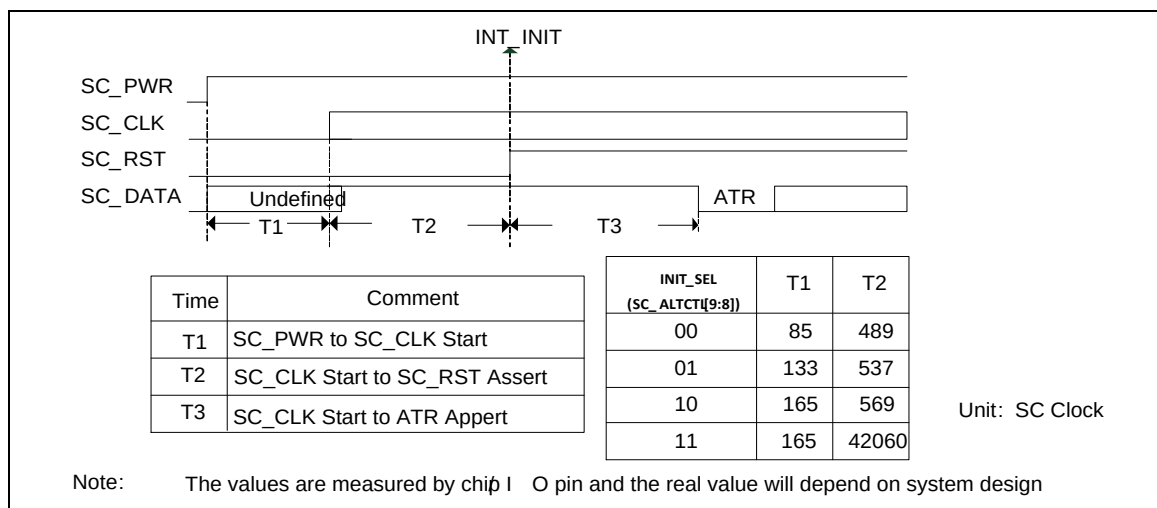


Figure 6-79 SC Activation Sequence

Warm Reset

The warm reset sequence is showed as follows.

- Set SC_RST to low and set SC_DAT to high.
- Set SC_RST to high.

The warm reset sequence can be controlled by two ways. The procedure is shown as following.

Software Timing Control:

Software sets SC_PINCSR and SC_TMRx (x = 0, 1, 2) to process the warm reset sequence. SC_RST and SC_DATA pin state can be programmed by SC_PINCSR. The warm reset sequence timing cab be controlled by setting SC_TMRx (x = 0, 1, 2). This programming procedure provides user has a flexible timing setting for warm reset sequence.

Hardware Timing Control:

Software sets WARST_EN (SC_ALTCTL[4]) to '1' and the interface will perform the warm reset sequence by hardware. The SC_RST to SC_DATA reception mode (T4) and SC_DATA reception mode to SC_RST assert (T5) can be selected by programming INIT_SEL (SC_ALTCTL[9:8]). This programming procedure provides user has a simple setting for warm reset sequence.

Following is warm reset control sequence by hardware:

- Set warm reset timing by setting INIT_SEL (SC_ALTCTL[9:8]).
- Select TMR0 by setting TMR_SEL (SC_CTL[14:13]) register (TMR_SEL can be set to '01', '10', or '11').
- Set operation mode MODE (SC_TMR0[27:24]) to '0011' and give an Answer to Request value by setting CNT (SC_TMR0[23:0]) register.
- Set TM0_SEN (SC_ALTCTL[5]) and WARST_EN (SC_ALTCTL[4]) to start counting.
- When hardware de-asserts SC_RST to high, hardware will generate an interrupt INIT_IS (SC_ISR[8]) to CPU at the same time (INIT_IE(SC_IER[8] = '1')).
- If the TMR0 decrease the counter to '0' (start from SC_RST) and the card does not response ATR before that time, hardware will generate interrupt TMR0_IS (SC_ISR[3]) to CPU.

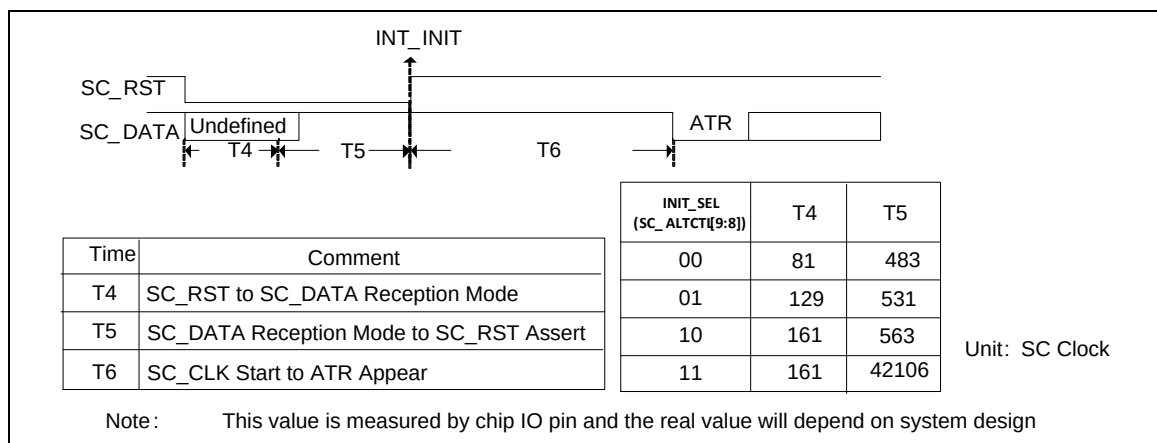


Figure 6-80 SC Warm Reset Sequence

Deactivation

The deactivation sequence is showed as follows:

- Set SC_RST to low.
- Stop SC_CLK.
- Set SC_DATA to state low.
- Deactivated SC_PWR.

The deactivation sequence can be controlled by two ways. The procedure is shown as following.

Software Timing Control:

Software sets SC_PINCSR and SC_TMR0 to process the deactivation sequence. SC_PWR, SC_CLK, SC_RST and SC_DATA pin state can be programmed by SC_PINCSR. The deactivation sequence timing can be controlled by setting SC_TMR0. This programming procedure provides user has a flexible timing setting for deactivation sequence.

Hardware Timing Control:

Software sets DACT_EN (SC_ALTCTL[2]) to '1' and the interface will perform the deactivation sequence by hardware. The Deactivation Trigger to SC_RST low (T7), SMC_RST low to SC_CLK (T8) and stop SC_CLK to stop SC_PWR (T9) time can be selected by programming INIT_SEL (SC_ALTCTL[9:8]). This programming procedure provides user has a simple setting for deactivation sequence.

The SC controller also supports auto deactivation sequence when the card removal detection is enabled by setting ADAC_CDEN (SC_ALTCTL[11]).

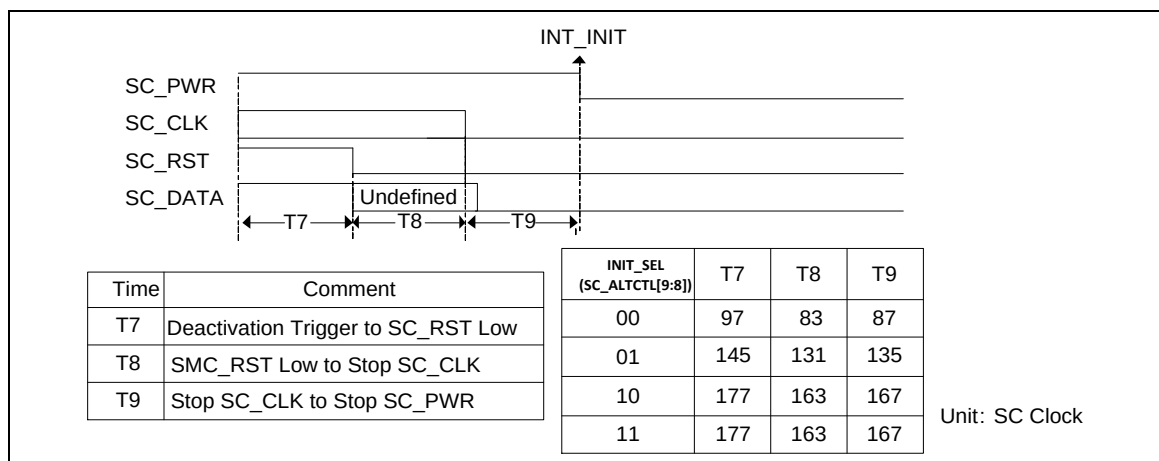


Figure 6-81 SC Deactivation Sequence

6.14.5.2 Initial Character TS

According to 7816-3, the initial character TS has two possible patterns (as shown in the following figure). If the TS pattern is 1100_0000, it is inverse convention. When decoded by inverse convention, the conveyed byte is equal to 0x3F. If the TS pattern is 1101_1100, it is direct convention. When decoded by direct convention, the conveyed byte is equal to 0x3B. Software can set AUTO_CON_EN (SC_CTL[3]) and then the operating convention will be decided by hardware. Software can also set the CON_SEL (SC_CTL[5:4]) register (set to '00' or '11') to change the operating convention after SC received TS of answer to request (ATR).

If software enables auto convention function by setting AUTO_CON_EN (SC_CTL[3]) register, the setting step must be done before Answer to Request state and the first data must be 0x3B or 0x3F. After hardware received first data and stored it at buffer, the hardware will decide the convention and change the CON_SEL (SC_CTL[5:4]) register automatically. If the first data is neither 0x3B nor 0x3F, the hardware will generate an interrupt INT_ACON_ERR (if ACON_ERR_IE (SC_IER [10]) = '1') to CPU.

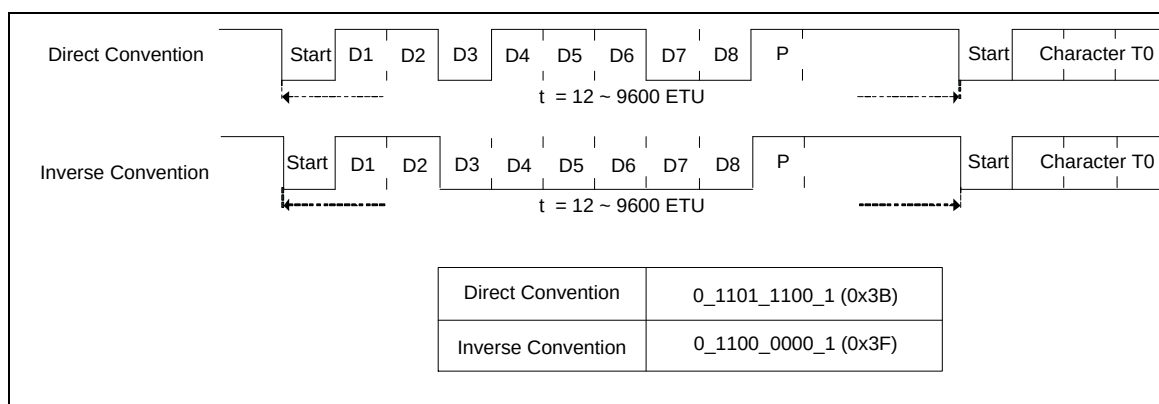


Figure 6-82 Initial Character TS

6.14.5.3 Error signal and character repetition

According to ISO7816-3 T=0 mode description, as shown in following, if the receiver receives a wrong parity bit, it will pull the SC_DAT to low by 1.5 bit period to inform the transmitter parity error. Then the transmitter will retransmit the character. The SC interface controller supports hardware error detection function in receiver and supports hardware re-transmit function in transmitter. Software can enable re-transmit function by setting TX_ERETRY_EN(SC_CTL[23]). Software can also define the retry (re-transmit) number limitation in TX_ERETRY(SC_CTL[22:20]). The re-transmit number is up to TX_ERETRY +1 and if the re-transmit number is equal to TX_ERETRY +1, TX_OVER_REERR flag will be set by hardware and if TERR_IE (SC_IER [2]), SC controller will generate a transfer error interrupt to CPU. Software can also define the received retry number limitation in RX_ERETRY(SC_CTL[18:16]) register. The receiver retry number is up to RX_ERETRY +1, if the number of received errors by receiver is equal to RX_ERETRY +1, receiver will receive this error data to buffer and RX_OVER_REERR flag will be set by hardware and if TERR_IE(SC_IER[2]), SC controller will generate a transfer error interrupt to CPU.

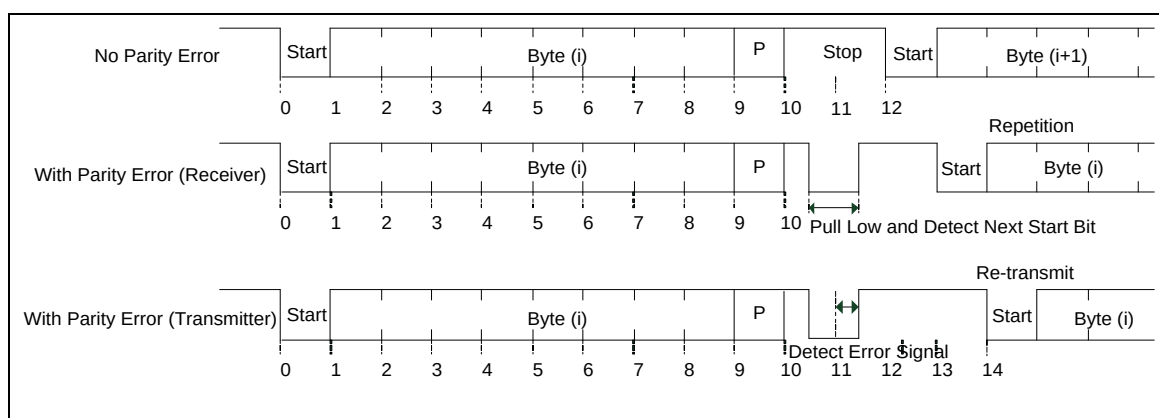


Figure 6-83 SC Error Signal

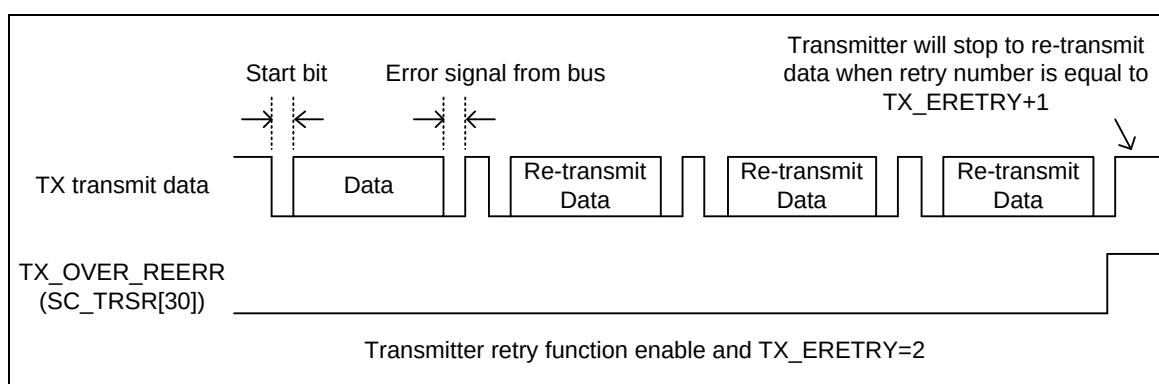


Figure 6-84 SC Transmitter Retry Number and Retry Over Flag

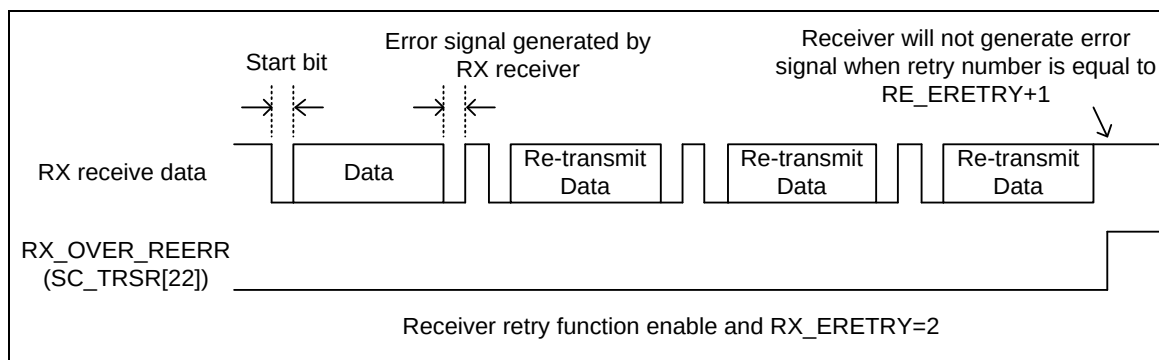


Figure 6-85 SC Receiver Retry Number and Retry Over Flag

6.14.5.4 Internal time-out counter

The smart card interface includes a 24-bit time-out counter and two 8 bit time-out counters. These counters help the controller in processing different real-time interval. Each counter can be set to start counting once the trigger enable bit has been written or a START bit has been detected.

The following is the programming flow:

Enable counter by setting TMR_SEL (SC_CTL[14:13]). Select operation mode MODE (SC_TMRx[27:24]) and give a count value CNT(SC_TMRx[23:0]) by setting SC_TMRx register. Set TMR0_SEN (SC_ALTCTL [5]), TMR1_SEN (SC_ALTCTL [6]) or TMR2_SEN (SC_ALTCTL [7]) is to start counting.

The SC_TMR0, SC_TMR1 and SC_TMR2 timer operation mode are listed below table

Note: Only SC_TMR0 supports mode 0011.

TMRx_SEL (X=0 ~2)	Operation Description	
0000	The down counter started when TMRx_SEN (SC_ALTCTL[7:5]) enabled and ended when counter time-out. The time-out value will be CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0])+1	
	Start	Start counting when TMRx_SEN (SC_ALTCTL[7:5]) enabled
	End	When the down counter equals to 0, hardware will set TMRx_IS(SC_ISR[5:3]) and clear TMRx_SEN (SC_ALTCTL[7:5]) automatically.
0001	The down counter started when the first START bit (reception or transmission) detected and ended when counter time-out. The time-out value will be CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0])+1.	
	Start	Start counting when the first START bit (reception or transmission) detected after TMRx_SEN (SC_ALTCTL[7:5]) set to 1.
	End	When the down counter equals to 0, hardware will set TMRx_IS(SC_ISR[5:3]) and clear TMRx_SEN (SC_ALTCTL[7:5]) automatically.
0010	The down counter started when the first START bit (reception) detected and ended when counter time-out . The time-out value will be CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0])+1.	
	Start	Start counting when the first START bit (reception) detected bit after TMRx_SEN (SC_ALTCTL[7:5]) set to 1.
	End	When the down counter equals to 0, hardware will set TMRx_IS(SC_ISR[5:3]) and clear TMRx_SEN (SC_ALTCTL[7:5]) automatically.
0011	The down counter is only used for hardware activation, warm reset sequence to measure ATR timing.	

	The timing starts when SC_RST de-assertion and ends when ATR response received or time-out. If the counter decreases to 0 before ATR response received, hardware will generate an interrupt to CPU. The time-out value will be CNT (SC_TMR0[23:0])+1.	
	Start	Start counting when SC_RST de-assertion after TMR0_SEN (SC_ALTCTL[5]) set to 1. It is used for hardware activation, warm reset mode.
	End	When the down counter equals to 0 before ATR response received, hardware will set TMR0_IS and clear TMR0_SEN (SC_ALTCTL[5]) automatically. When ATR received and down counter does not equal to 0, hardware will clear TMR0_SEN (SC_ALTCTL[5]) automatically.
0100	Same as 0000, but when the down counter equals to 0, hardware will set TMRx_IS(SC_ISR[5:3]) and counter will re-load the CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) value and re-count until software clears TMRx_SEN (SC_ALTCTL[7:5]). When TMRx_ATV (SC_ALTCTL[15:13]) =1, software can change CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) value at any time. When the down counter equals to 0, counter will reload the new value of CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) and re-count. The time-out value will be CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0])+1.	
0101	Same as 0001, but when the down counter equals to 0, hardware will set TMRx_IS(SC_ISR[5:3]) and counter will re-load the CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) value. When the next START bit is detected, counter will re-count until software clears TMRx_ATV (SC_ALTCTL[15:13]). When TMRx_ATV (SC_ALTCTL[15:13]) =1 software can change CNT (SC_TMR0[23:0], SC_TMR0[7:0], SC_TMR0[7:0]) value at any time. When the down counter equal to 0, it will reload the new value of CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) and re-counting. The time-out value will be CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0])+1.	
0110	Same as 0010, but when the down counter equals to 0, it will set TMRx_IS(SC_ISR[5:3]) and counter will re-load the CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) value. When the next START bit is detected, counter will re-count until software clears TMRx_SEN (SC_ALTCTL[7:5]). When TMRx_ATV (SC_ALTCTL[15:13]) =1, software can change CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) value at any time. When the down counter equals to 0, counter will reload the new value of CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) and re-count. The time-out value will be CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0])+1.	
0111	The down counter started when the first START bit (reception or transmission) detected and ended when software clears TMRx_SEN (SC_ALTCTL[7:5]) bit. If next START bit detected, counter will reload the new value of CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) and re-counting. If the counter decreases to 0 before the next START bit detected, hardware will generate an interrupt to CPU. The time-out value will be CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0])+1.	
	Start	Start counting when the first START bit detected after TMRx_SEN (SC_ALTCTL[7:5]) set to 1.
	End	Stop counting after TMRx_SEN (SC_ALTCTL[7:5]) set to 0.
1000	The up counter starts when TMRx_SEN (SC_ALTCTL[7:5]) enabled and ends when TMRx_SEN (SC_ALTCTL[7:5]) disabled. This count value will be stored in TDRx(SC_TDRA [23:0], SC_TDRB[7:0], SC_TDRB[15:8]). In this mode, hardware cannot generate any interrupt to CPU. The real count value will be TDRx(SC_TDRA [23:0], SC_TDRB[7:0], SC_TDRB[15:8]) +1.	
	Start	Start counting after TMRx_SEN (SC_ALTCTL[7:5]) set to 1, and the start count value is 0 (hardware will ignore CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) value).
	End	Stop counting after TMRx_SEN (SC_ALTCTL[7:5]) set to 0 and the value stored to TDRx(SC_TDRA [23:0], SC_TDRB[7:0], SC_TDRB[15:8]) register.
1111	Down counter starts when software set TMRx_SEN (SC_ALTCTL[7:5]) bit or any START bit been detected and ends when software clears TMRx_SEN (SC_ALTCTL[7:5]) bit. If next START bit detected, counter will reload the new value of CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0]) and re-counting. If the counter decreases to "0" before the next START bit be detected, hardware will generate an interrupt to CPU. The time-out value will be CNT (SC_TMR0[23:0], SC_TMR1[7:0], SC_TMR2[7:0])+1.	
	Start	Start count when the TMRx_SEN (SC_ALTCTL[7:5]) set to "1" or any START bit (TMRx_SEN (SC_ALTCTL[7:5]) must be set) be detected

	End	Stop count after TMRx_SEN (SC_ALTCTL[7:5]) set to "0".

Table 6-22 Timer2/Timer1/Timer0 Operation Mode

6.14.5.5Block Guard Time and Extended Guarg Time

Block guard time means the minimum bit length between the leading edges of two consecutive characters between different transfer directions. This field indicates the counter for the bit length of block guard time. According to ISO7816-3, in T = 0 mode, software must fill 15 (real block guard time = 16.5) to this field; in T = 1 mode, software must fill 21 (real block guard time = 22.5) to it.

In transmit direction, the smart card sends data to smart card host controller, first. After the period is greater than BGT (SC_CTL[12:8]), the smart card host controller begin to send the data.

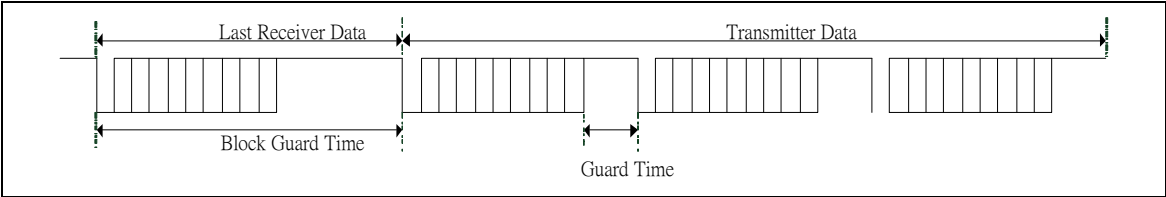


Figure 6-86 Transmit Direction Block Guard Time Operation

In receive direction, the smart card host controller sends data to smart card, first. If the smart card sends data to smart card host controller at the time which is less than BGT (SC_CTL[12:8]),the block guard time interrupt BGT_IS (SC_ISR[6]) is generated when RX_BGT_EN (SC_ALTCTL[12]) is enabled.

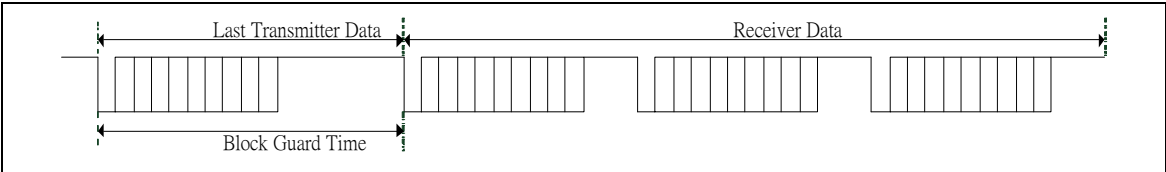


Figure 6-87 Receive Direction Block Guard Time Operation

Extended Guard Time is two ETU plus EGT (SC_EGTR[7:0]), the format is shown as following:

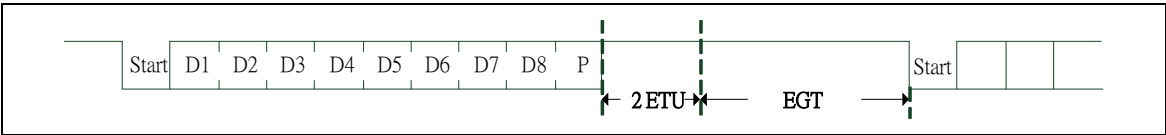


Figure 6-88 Extended Guard Time Operation

6.14.5.6 UART Mode

When the UA_MODE_EN (SC_UACTL[0]) bit set, the Smart Card Interface controller can also be used as base UART function. The following is the program example for UART mode.

Program example:

1. Software can entry UART mode by setting UA_MODE_EN (SC_UACTL[0]) bit.
2. Do software reset by setting RX_RST (SC_ALTCTL[1]) and TX_RST(SC_ALTCTL[0]) bit to ensure that all state machine return idle state.
3. Filled "0" to CON_SEL (SC_CTL[5:4]) and AUTO_CON_EN (SC_CTL[3]) field. (In UART mode, those fields must be "0")
4. Select the UART baud rate by setting ETU_RDIV (SC_ETUCR[11:0]) fields. For example, if smartcard module clock is 12 MHZ and target baud rate is 115200bps, ETU_RDIV should fill with $(12000000 / 115200 - 1)$.
5. Select the data format include data length (by setting DATA_LEN (SC_UACTL [5:4]), parity format (by setting OPE(SC_UACTL[7]) and PBDIS(SC_UACTL[6])) and stop bit length (by setting SLEN(SC_CTL[15] or EGT(SC_EGTR[7:0])).
6. Select the receiver buffer trigger level by setting RX_FTRI_LEV (SC_CTL[7:6]) field and select the receiver buffer time-out value by setting RFTMR (SC_RFTMR[8:0]) field.

Write SC_THR (SC_THR[7:0]) (TX) register or read SC_RBR (SC_RBR[7:0]) (RX) register can perform UART function.

6.14.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
SC Base Address: SC0_BA = 0x4019_0000 SC1_BA = 0x4019_4000 SC2_BA = 0x4019_8000				
SC_RBR x=0,1,2	SCx_BA+0x00	R	SC Receiving Buffer Register.	Undefined
SC_THR x=0,1,2	SCx_BA+0x00	W	SC Transmit Holding Register	Undefined
SC_CTL x=0,1,2	SCx_BA+0x04	R/W	SC Control Register	0x0000_0000
SC_ALTCTL x=0,1,2	SCx_BA+0x08	R/W	SC Alternate Control Register	0x0000_0000
SC_EGTR x=0,1,2	SCx_BA+0x0C	R/W	SC Extend Guard Time Register	0x0000_0000
SC_RFTMR x=0,1,2	SCx_BA+0x10	R/W	SC Receive buffer Time-out Register	0x0000_0000
SC_ETUCR x=0,1,2	SCx_BA+0x14	R/W	SC ETU Control Register	0x0000_0173
SC_IER x=0,1,2	SCx_BA+0x18	R/W	SC Interrupt Enable Control Register	0x0000_0000
SC_ISR x=0,1,2	SCx_BA+0x1C	R/W	SC Interrupt Status Register	0x0000_0002
SC_TRSR x=0,1,2	SCx_BA+0x20	R/W	SC Status Register	0x0000_0202
SC_PINCSR x=0,1,2	SCx_BA+0x24	R/W	SC Pin Control State Register	0x0000_00x0
SC_TMR0 x=0,1,2	SCx_BA+0x28	R/W	SC Internal Timer Control Register 0	0x0000_0000
SC_TMR1 x=0,1,2	SCx_BA+0x2C	R/W	SC Internal Timer Control Register 1	0x0000_0000
SC_TMR2 x=0,1,2	SCx_BA+0x30	R/W	SC Internal Timer Control Register 2	0x0000_0000
SC_UACTL x=0,1,2	SCx_BA + 0x34	R/W	SC UART Mode Control Register.	0x0000_0000
SC_TDRA x=0,1,2	SCx_BA+0x38	R	SC Timer Current Data Register A	0x0000_07FF
SC_TDRB x=0,1,2	SCx_BA+0x3C	R	SC Timer Current Data Register B	0x0000_7F7F

Note: The post-fix “x” of SCx represents the SC channel.

6.14.7 Register Description

SC Receiving Buffer Register (SC_RBR)

Register	Offset	R/W	Description	Reset Value
SC_RBR	SCx_BA+0x00	R	SC Receiving Buffer Register.	Undefined

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

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	RBR	Receiving Buffer By reading RBR, the SC will return an 8-bit received data.

SC Transmit Holding Register (SC_THR)

Register	Offset	R/W	Description	Reset Value
SC_THR	SCx_BA+0x00	W	SC Transmit Holding Register	Undefined

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

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	THR	Transmit Holding Buffer By writing data to THR, the SC will send out an 8-bit data. Note: If SC_CEN(SC_CTL[0]) is not enabled, THR cannot be programmed.

SC Control Register (SC_CTL)

Register	Offset	R/W	Description	Reset Value
SC_CTL	SCx_BA+0x04	R/W	SC Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved	SYNC	Reserved				CD_DEB_SEL	
23	22	21	20	19	18	17	16
TX_ERETRY_EN	TX_ERETRY			RX_ERETRY_EN	RX_ERETRY		
15	14	13	12	11	10	9	8
SLEN	TMR_SEL		BGT				
7	6	5	4	3	2	1	0
RX_FTRI_LEV		CON_SEL		AUTO_CON_EN	DIS_TX	DIS_RX	SC_CEN

Bits	Description
[31]	Reserved Reserved.
[30]	SYNC SYNC Flag Indicator Due to synchronization, software should check this bit before writing a new value to RX_ERETRY and TX_ERETRY. 0 = synchronizing is completion, user can write new data to RX_ERETRY and TX_ERETRY. 1 = Last value is synchronizing. Note: This bit is read only.
[30:26]	Reserved Reserved.
[25:24]	CD_DEB_SEL Card Detect De-Bounce Selection This field indicates the card detect de-bounce selection. 00 = De-bounce sample card insert once per 384 (128 * 3) SC peripheral clocks and de-bounce sample card removal once per 128 SC peripheral clocks. 01 = De-bounce sample card insert once per 192 (64 * 3) SC peripheral clocks and de-bounce sample card removal once per 64 SC peripheral clocks. 10 = De-bounce sample card insert once per 96 (32 * 3) SC peripheral clocks and de-bounce sample card removal once per 32 SC peripheral clocks. 11 = De-bounce sample card insert once per 48 (16 * 3) SC peripheral clocks and de-bounce sample card removal once per 16 SC peripheral clocks.
[23]	TX_ERETRY_EN TX Error Retry Enable Bit This bit enables transmitter retry function when parity error has occurred. 0 = TX error retry function Disabled. 1 = TX error retry function Enabled.
[22:20]	TX_ERETRY TX Error Retry Count Number This field indicates the maximum number of transmitter retries that are allowed when parity error has occurred. Note1: The real retry number is TX_ERETRY + 1, so 8 is the maximum retry number. Note2: This field cannot be changed when TX_ERETRY_EN enabled. The change flow is

		to disable TX_ETRTRY_EN first and then fill in new retry value.
[19]	RX_ERETRY_EN	RX Error Retry Enable Bit This bit enables receiver retry function when parity error has occurred. 0 = RX error retry function Disabled. 1 = RX error retry function Enabled. Note: Software must fill in the RX_ERETRY value before enabling this bit.
[18:16]	RX_ERETRY	RX Error Retry Count Number This field indicates the maximum number of receiver retries that are allowed when parity error has occurred Note1: The real retry number is RX_ERETRY + 1, so 8 is the maximum retry number. Note2: This field cannot be changed when RX_ERETRY_EN enabled. The change flow is to disable RX_ETRTRY_EN first and then fill in new retry value.
[15]	SLEN	Stop Bit Length This field indicates the length of stop bit. 0 = The stop bit length is 2 ETU. 1 = The stop bit length is 1 ETU. Note: The default stop bit length is 2. SMC and UART adopts SLEN to program the stop bit length
[14:13]	TMR_SEL	Timer Selection 00 = All internal timer function Disabled. 01 = Internal 24 bit timer Enabled. Software can configure it by setting SC_TMR0 [23:0]. SC_TMR1 and SC_TMR2 will be ignored in this mode. 10 = internal 24 bit timer and 8 bit internal timer Enabled. Software can configure the 24 bit timer by setting SC_TMR0 [23:0] and configure the 8 bit timer by setting SC_TMR1[7:0]. SC_TMR2 will be ignored in this mode. 11 = Internal 24 bit timer and two 8 bit timers Enabled. Software can configure them by setting SC_TMR0 [23:0], SC_TMR1 [7:0] and SC_TMR2 [7:0].
[12:8]	BGT	Block Guard Time (BGT) Block guard time means the minimum bit length between the leading edges of two consecutive characters between different transfer directions. This field indicates the counter for the bit length of block guard time. According to ISO7816-3, in T = 0 mode, software must fill 15 (real block guard time = 16.5) to this field; in T = 1 mode, software must fill 21 (real block guard time = 22.5) to it. Note: The real block guard time is BGT + 1.
[7:6]	RX_FTRI_LEV	Rx Buffer Trigger Level When the number of bytes in the receiving buffer equals the RX_FTRI_LEV, the RDA_IF will be set (if IER [RDA_IEN] is enabled, an interrupt will be generated). 00 = INTR_RDA Trigger Level with 01 Bytes. 01 = INTR_RDA Trigger Level with 02 Bytes. 10 = INTR_RDA Trigger Level with 03 Bytes. 11 = Reserved.
[5:4]	CON_SEL	Convention Selection 00 = Direct convention. 01 = Reserved. 10 = Reserved. 11 = Inverse convention. Note: If AUTO_CON_EN(SC_CTL[3]) enabled, this fields are ignored.
[3]	AUTO_CON_EN	Auto Convention Enable Bit 0 = Auto-convention Disabled. 1 = Auto-convention Enabled. When hardware receives TS in answer to reset state and

		the TS is direct convention, CON_SEL(SC_CTL[5:4]) will be set to 00 automatically, otherwise if the TS is inverse convention, and CON_SEL (SC_CTL[5:4]) will be set to 11. If software enables auto convention function, the setting step must be done before Answer to Reset state and the first data must be 0x3B or 0x3F. After hardware received first data and stored it at buffer, hardware will decided the convention and change the CON_SEL (SC_CTL[5:4]) bits automatically. If the first data is not 0x3B or 0x3F, hardware will generate an interrupt INT_ACON_ERR (if ACON_ERR IE (SC_IER[10]) = 1 to CPU.
[2]	DIS_TX	TX Transition Disable Bit 0 = The transceiver Enabled. 1 = The transceiver Disabled.
[1]	DIS_RX	RX Transition Disable Bit 0 = The receiver Enabled. 1 = The receiver Disabled. Note: If AUTO_CON_EN (SC_CTL[3]) is enabled, these fields must be ignored.
[0]	SC_CEN	SC Engine Enable Bit Set this bit to 1 to enable SC operation. If this bit is cleared, SC will force all transition to IDLE state.

SC Alternate Control Register (SC_ALTCTL)

Register	Offset	R/W	Description	Reset Value
SC_ALTCTL	SCx_BA+0x08	R/W	SC Alternate Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							OUTSEL
15	14	13	12	11	10	9	8
TMR2_ATV	TMR1_ATV	TMR0_ATV	RX_BGT_EN	Reserved		INIT_SEL	
7	6	5	4	3	2	1	0
TMR2_SEN	TMR1_SEN	TMR0_SEN	WARST_EN	ACT_EN	DACT_EN	RX_RST	TX_RST

Bits	Description	
[31:17]	Reserved	Reserved.
[16]	OUTSEL	Smartcard Data Pin Output Mode Selection Use this bit to select smartcard data pin (SC_DATA) output mode 0 = Quasi mode. 1 = Open-drain mode.
[15]	TMR2_ATV	Internal Timer2 Active State (Read Only) This bit indicates the timer counter status of timer2. 0 = Timer2 is not active. 1 = Timer2 is active.
[14]	TMR1_ATV	Internal Timer1 Active State (Read Only) This bit indicates the timer counter status of timer1. 0 = Timer1 is not active. 1 = Timer1 is active.
[13]	TMR0_ATV	Internal Timer0 Active State (Read Only) This bit indicates the timer counter status of timer0. 0 = Timer0 is not active. 1 = Timer0 is active.
[12]	RX_BGT_EN	Receiver Block Guard Time Function Enable Bit 0 = Receiver block guard time function Disabled. 1 = Receiver block guard time function Enabled.
[11:10]	Reserved	Reserved.
[9:8]	INIT_SEL	Initial Timing Selection This fields indicates the timing of hardware initial state (activation or warm-reset or deactivation). Unit: SC clock Activation: refer to SC Activation Sequence in Figure 6-79.

		Warm-reset: refer to Warm-Reset Sequence in Figure 6-80. Deactivation: refer to Deactivation Sequence in Figure 6-81.
[7]	TMR2_SEN	Internal Timer2 Start Enable Bit This bit enables Timer 2 to start counting. Software can fill 0 to stop it and set 1 to reload and count. 0 = Stops counting. 1 = Start counting. Note1: This field is used for internal 8 bit timer when TMR_SEL(SC_CTL[14:13]) = 11. Don't filled TMR2_SEN when TMR_SEL(SC_CTL[14:13]) = 00 or TMR_SEL(SC_CTL[14:13]) = 01 or TMR_SEL(SC_CTL[14:13]) = 10. Note2: If the operation mode is not in auto-reload mode (SC_TMR2[26] = 0), this bit will be auto-cleared by hardware. Note3: This field will be cleared by TX_RST(SC_ALTCTL[0]) and RX_RST(SC_ALTCTL[1]). So don't fill this bit, TX_RST(SC_ALTCTL[0]), and RX_RST(SC_ALTCTL[1]) at the same time. Note4: If SC_CEN(SC_CTL[0]) is not enabled, this filed cannot be programmed.
[6]	TMR1_SEN	Internal Timer1 Start Enable Bit This bit enables Timer 1 to start counting. Software can fill 0 to stop it and set 1 to reload and count. 0 = Stops counting. 1 = Start counting. Note1: This field is used for internal 8 bit timer when TMR_SEL(SC_CTL[14:13]) = 10 or TMR_SEL(SC_CTL[14:13]) = 11. Don't filled TMR1_SEN when TMR_SEL(SC_CTL[14:13]) = 00 or TMR_SEL(SC_CTL[14:13]) = 01. Note2: If the operation mode is not in auto-reload mode (SC_TMR1[26] = 0), this bit will be auto-cleared by hardware. Note3: This field will be cleared by TX_RST(SC_ALTCTL[0]) and RX_RST(SC_ALTCTL[1]), so don't fill this bit, TX_RST(SC_ALTCTL[0]), and RX_RST(SC_ALTCTL[1]) at the same time. Note4: If SC_CEN(SC_CTL[0]) is not enabled, this filed cannot be programmed.
[5]	TMR0_SEN	Internal Timer0 Start Enable Bit This bit enables Timer 0 to start counting. Software can fill 0 to stop it and set 1 to reload and count. 0 = Stops counting. 1 = Start counting. Note1: This field is used for internal 24 bit timer when TMR_SEL (SC_CTL[14:13]) = 01. Note2: If the operation mode is not in auto-reload mode (SC_TMR0[26] = 0), this bit will be auto-cleared by hardware. Note3: This field will be cleared by TX_RST(SC_ALTCTL[0]) and RX_RST(SC_ALTCTL[1]). So don't fill this bit, TX_RST and RX_RST at the same time. Note4: If SC_CEN(SC_CTL[0]) is not enabled, this filed cannot be programmed.
[4]	WARST_EN	Warm Reset Sequence Generator Enable Bit This bit enables SC controller to initiate the card by warm reset sequence 0 = No effect. 1 = Warm reset sequence generator Enabled. Note1: When the warm reset sequence completed, this bit will be cleared automatically and the INIT_IS(SC_ISR[8]) will be set to 1. Note2: This field will be cleared by TX_RST(SC_ALTCTL[0]) and RX_RST(SC_ALTCTL[1]), so don't fill this bit, TX_RST, and RX_RST at the same time. Note3: If SC_CEN(SC_CTL[0]) is not enabled, this filed cannot be programmed.
[3]	ACT_EN	Activation Sequence Generator Enable Bit This bit enables SC controller to initiate the card by activation sequence

		0 = No effect. 1 = Activation sequence generator Enabled. Note1: When the activation sequence completed, this bit will be cleared automatically and the INIT_IS(SC_ISR[8]) will be set to 1. Note2: This field will be cleared by TX_RST(SC_ALTCTL[0]) and RX_RST(SC_ALTCTL[1]), so don't fill this bit, TX_RST(SC_ALTCTL[0]), and RX_RST(SC_ALTCTL[1]) at the same time. Note3: If SC_CEN(SC_CTL[0]) is not enabled, this filed cannot be programmed.
[2]	DACT_EN	Deactivation Sequence Generator Enable Bit This bit enables SC controller to initiate the card by deactivation sequence 0 = No effect. 1 = Deactivation sequence generator Enabled. Note1: When the deactivation sequence completed, this bit will be cleared automatically and the INIT_IS(SC_ISR[8]) will be set to 1. Note2: This field will be cleared by TX_RST (SC_ALTCTL[0]) and RX_RST(SC_ALTCTL[1]). So don't fill this bit, TX_RST, and RX_RST at the same time. Note3: If SC_CEN (SC_CTL[0]) is not enabled, this filed cannot be programmed.
[1]	RX_RST	Rx Software Reset When RX_RST is set, all the bytes in the receiver buffer and Rx internal state machine will be cleared. 0 = No effect. 1 = Reset the Rx internal state machine and pointers. Note: This bit will be auto cleared after reset is complete.
[0]	TX_RST	TX Software Reset When TX_RST is set, all the bytes in the transmit buffer and TX internal state machine will be cleared. 0 = No effect. 1 = Reset the TX internal state machine and pointers. Note: This bit will be auto cleared after reset is complete.

SC Extend Guard Time Register (SC_EGTR)

Register	Offset	R/W	Description	Reset Value
SC_EGTR	SCx_BA+0x0C	R/W	SC Extend Guard Time Register	0x0000_0000

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

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	EGT	Extended Guard Time This field indicates the extended guard timer value. Note: The counter is ETU base and the real extended guard time is EGT.

SC Receiver buffer Time-out Register (SC_RFTMR)

Register	Offset	R/W	Description	Reset Value
SC_RFTMR	SCx_BA+0x10	R/W	SC Receive buffer Time-out Register	0x0000_0000

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

Bits	Description	
[31:9]	Reserved	Reserved.
[8:0]	RFTM	SC Receiver Buffer Time-Out (ETU Base) The time-out counter resets and starts counting whenever the RX buffer received a new data word. Once the counter decrease to 1 and no new data is received or CPU does not read data by reading SC_RBR buffer, a receiver time-out interrupt INT_RTMR will be generated(if RTMR_IE(SC_IER[9]) = 1). Note1: The counter unit is ETU based and the interval of time-out is RFTM + 0.5 Note2: Fill all 0 to this field indicates to disable this function.

SC Clock Divider Control Register (SC_ETUCR)

Register	Offset	R/W	Description	Reset Value
SC_ETUCR	SCx_BA+0x14	R/W	SC ETU Control Register	0x0000_0173

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

Bits	Description	
[31:16]	Reserved	Reserved.
[15]	COMPEN_EN	Compensation Mode Enable Bit This bit enables clock compensation function. When this bit enabled, hardware will alternate between n clock cycles and n-1 clock cycles, where n is the value to be written into the ETU_RDIV . 0 = Compensation function Disabled. 1 = Compensation function Enabled.
[14:12]	Reserved	Reserved.
[11:0]	ETU_RDIV	ETU Rate Divider The field indicates the clock rate divider. The real ETU is ETU_RDIV + 1. Note: Software can configure this field, but this field must be greater than 0x004.

SC Interrupt Control Register (SC_IER)

Register	Offset	R/W	Description	Reset Value
SC_IER	SCx_BA+0x18	R/W	SC Interrupt Enable Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved					ACON_ERR_IE	RTMR_IE	INIT_IE
7	6	5	4	3	2	1	0
CD_IE	BGT_IE	TMR2_IE	TMR1_IE	TMR0_IE	TERR_IE	TXBE_IE	RDA_IE

Bits	Description
[31:11]	Reserved Reserved.
[10]	ACON_ERR_IE Auto Convention Error Interrupt Enable Bit This field is used for auto-convention error interrupt enable. 0 = Auto-convention error interrupt Disabled. 1 = Auto-convention error interrupt Enabled.
[9]	RTMR_IE Receiver Buffer Time-Out Interrupt Enable Bit This field is used for receiver buffer time-out interrupt enable. 0 = Receiver buffer time-out interrupt Disabled. 1 = Receiver buffer time-out interrupt Enabled.
[8]	INIT_IE Initial End Interrupt Enable Bit This field is used for activation (ACT_EN(SC_ALTCTL[3] = 1)), deactivation ((DACT_EN SC_ALTCTL[2]) = 1) and warm reset (WARST_EN (SC_ALTCTL [4])) sequence interrupt enable. 0 = Initial end interrupt Disabled. 1 = Initial end interrupt Enabled.
[7]	CD_IE Card Detect Interrupt Enable Bit This field is used for card detect interrupt enable. The card detect status is CD_INS_F(SC_SR[12]) 0 = Card detect interrupt Disabled. 1 = Card detect interrupt Enabled.
[6]	BGT_IE Block Guard Time Interrupt Enable Bit This field is used for block guard time interrupt enable. 0 = Block guard time Disabled. 1 = Block guard time Enabled.
[5]	TMR2_IE Timer2 Interrupt Enable Bit This field is used for TMR2 interrupt enable.

		0 = Timer2 interrupt Disabled. 1 = Timer2 interrupt Enabled.
[4]	TMR1_IE	Timer1 Interrupt Enable Bit This field is used to enable the TMR1 interrupt. 0 = Timer1 interrupt Disabled. 1 = Timer1 interrupt Enabled.
[3]	TMR0_IE	Timer0 Interrupt Enable Bit This field is used to enable TMR0 interrupt enable. 0 = Timer0 interrupt Disabled. 1 = Timer0 interrupt Enabled.
[2]	TERR_IE	Transfer Error Interrupt Enable Bit This field is used for transfer error interrupt enable. The transfer error states is at SC_SR register which includes receiver break error RX_EBR_F(SC_SR[6]), frame error RX_EFR_F(SC_SR[5]), parity error RX_EPA_F(SC_SR[4]), receiver buffer overflow error RX_OVER_F(SC_SR[0]), transmit buffer overflow error TX_OVER_F(SC_SR[8]), receiver retry over limit error RX_OVER_REERR(SC_SR[22]) and transmitter retry over limit error TX_OVER_REERR(SC_SR[30]). 0 = Transfer error interrupt Disabled. 1 = Transfer error interrupt Enabled.
[1]	TXBE_IE	Transmit Buffer Empty Interrupt Enable Bit This field is used for transmit buffer empty interrupt enable. 0 = Transmit buffer empty interrupt Disabled. 1 = Transmit buffer empty interrupt Enabled.
[0]	RDA_IE	Receive Data Reach Interrupt Enable Bit This field is used for received data reaching trigger level RX_FTRI_LEV (SC_CTL[7:6]) interrupt enable. 0 = Receive data reach trigger level interrupt Disabled. 1 = Receive data reach trigger level interrupt Enabled.

SC Interrupt Status Register (SC_ISR)

Register	Offset	R/W	Description	Reset Value
SC_ISR	SCx_BA+0x1C	R/W	SC Interrupt Status Register	0x0000_0002

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved					ACON_ERR_IS	RTMR_IS	INIT_IS
7	6	5	4	3	2	1	0
CD_IS	BGT_IS	TMR2_IS	TMR1_IS	TMR0_IS	TERR_IS	TBE_IS	RDA_IS

Bits	Description	
[31:11]	Reserved	Reserved.
[10]	ACON_ERR_IS	Auto Convention Error Interrupt Status Flag (Read Only) This field indicates auto convention sequence error. If the received TS at ATR state is neither 0x3B nor 0x3F, this bit will be set. Note: This bit is read only, but it can be cleared by writing 1 to it.
[9]	RTMR_IS	Receiver Buffer Time-Out Interrupt Status Flag (Read Only) This field is used for receiver buffer time-out interrupt status flag. Note: This field is the status flag of receiver buffer time-out state. If software wants to clear this bit, software must read all receiver buffer remaining data by reading SC_RBR buffer,
[8]	INIT_IS	Initial End Interrupt Status Flag (Read Only) This field is used for activation (ACT_EN(SC_ALTCTL[3])), deactivation (DACT_EN(SC_ALTCTL[2])) and warm reset (WARST_EN(SC_ALTCTL[4])) sequence interrupt status flag. Note: This bit is read only, but it can be cleared by writing 1 to it.
[7]	CD_IS	Card Detect Interrupt Status Flag (Read Only) This field is used for card detect interrupt status flag. The card detect status is CD_INS_F(SC_SR[12]) and CD_REM_F(SC_SR[11]). Note: This field is the status flag of CD_INS_F(SC_SR[12]) or CD_REM_F(SC_TRSR[11]). So if software wants to clear this bit, software must write 1 to this field.
[6]	BGT_IS	Block Guard Time Interrupt Status Flag (Read Only) This field is used for block guard time interrupt status flag. Note1: This bit is valid when RX_BGT_EN(SC_ALTCTL[12]) is enabled. Note2: This bit is read only, but it can be cleared by writing "1" to it.
[5]	TMR2_IS	Timer2 Interrupt Status Flag (Read Only) This field is used for TMR2 interrupt status flag. Note: This bit is read only, but it can be cleared by writing 1 to it.

[4]	TMR1_IS	Timer1 Interrupt Status Flag (Read Only) This field is used for TMR1 interrupt status flag. Note: This bit is read only, but it can be cleared by writing 1 to it.
[3]	TMR0_IS	Timer0 Interrupt Status Flag (Read Only) This field is used for TMR0 interrupt status flag. Note: This bit is read only, but it can be cleared by writing 1 to it.
[2]	TERR_IS	Transfer Error Interrupt Status Flag (Read Only) This field is used for transfer error interrupt status flag. The transfer error states is at SC_SR register which includes receiver break error RX_EBR_F(SC_SR[6]), frame error RX_EFR_F(SC_TRSR[5]), parity error RX_EPA_F(SC_TRSR[4]) and receiver buffer overflow error RX_OVER_F(SC_TRSR[0]), transmit buffer overflow error TX_OVER_F(SC_TRSR[8]), receiver retry over limit error RX_OVER_REERR(SC_TRSR[22]) and transmitter retry over limit error TX_OVER_REERR(SC_TRSR[30]). Note: This field is the status flag of RX_EBR_F(SC_TRSR[6]), RX_EFR_F(SC_TRSR[5]), RX_EPA_F(SC_TRSR[4]), RX_OVER_F(SC_TRSR[0]), TX_OVER_F(SC_TRSR[8]), RX_OVER_REERR(SC_TRSR[22]) or TX_OVER_REERR(SC_TRSR[30]). So, if software wants to clear this bit, software must write 1 to each field.
[1]	TBE_IS	Transmit Buffer Empty Interrupt Status Flag (Read Only) This field is used for transmit buffer empty interrupt status flag. Note: This field is the status flag of transmit buffer empty state. If software wants to clear this bit, software must write data to THR(SC_THR[7:0]) buffer and then this bit will be cleared automatically.
[0]	RDA_IS	Receive Data Reach Interrupt Status Flag (Read Only) This field is used for received data reaching trigger level RX_FTRI_LEV (SC_CTL[7:6]) interrupt status flag. Note: This field is the status flag of received data reaching RX_FTRI_LEV (SC_CTL[7:6]). If software reads data from SC_RBR and receiver buffer data byte number is less than RX_FTRI_LEV (SC_CTL[7:6]), this bit will be cleared automatically.

SC Transfer Status Register (SC_TRSR)

Register	Offset	R/W	Description	Reset Value
SC_TRSR	SCx_BA+0x20	R/W	SC Status Register	0x0000_0202

31	30	29	28	27	26	25	24
TX_ATV	TX_OVER_REERR	TX_REERR	Reserved		TX_POINT_F		
23	22	21	20	19	18	17	16
RX_ATV	RX_OVER_REERR	RX_REERR	Reserved		RX_POINT_F		
15	14	13	12	11	10	9	8
Reserved					TX_FULL_F	TX_EMPTY_F	TX_OVER_F
7	6	5	4	3	2	1	0
Reserved	RX_EBR_F	RX_EFR_F	RX_EPA_F	Reserved	RX_FULL_F	RX_EMPTY_F	RX_OVER_F

Bits	Description
[31]	TX_ATV Transmit In Active Status Flag (Read Only) 0 = This bit is cleared automatically when TX transfer is finished or the last byte transmission has completed. 1 = This bit is set by hardware when TX transfer is in active and the STOP bit of the last byte has been transmitted.
[30]	TX_OVER_REERR Transmitter Over Retry Error (Read Only) This bit is set by hardware when transmitter re-transmits over retry number limitation. Note: This bit is read only, but it can be cleared by writing 1 to it.
[29]	TX_REERR Transmitter Retry Error (Read Only) This bit is set by hardware when transmitter re-transmits. Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: This bit is a flag and cannot generate any interrupt to CPU.
[28:26]	Reserved Reserved.
[25:24]	TX_POINT_F Transmit Buffer Pointer Status Flag (Read Only) This field indicates the TX buffer pointer status flag. When CPU writes data into SC_THR, TX_POINT_F increases one. When one byte of TX Buffer is transferred to transmitter shift register, TX_POINT_F decreases one.
[23]	RX_ATV Receiver In Active Status Flag (Read Only) This bit is set by hardware when RX transfer is in active. This bit is cleared automatically when RX transfer is finished.
[22]	RX_OVER_REERR Receiver Over Retry Error (Read Only) This bit is set by hardware when RX transfer error retry over retry number limit. Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: If CPU enables receiver retries function by setting RX_ERETRY_EN (SC_CTL[19]), the RX_EPA_F(SC_TRSR[4]) flag will be ignored (hardware will not set RX_EPA_F(SC_TRSR[4])).

[21]	RX_REERR	Receiver Retry Error (Read Only) This bit is set by hardware when RX has any error and retries transfer. Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: This bit is a flag and cannot generate any interrupt to CPU. Note3: If CPU enables receiver retry function by setting RX_ERETRY_EN (SC_CTL[19]) , the RX_EPA_F(SC_TRSR[4]) flag will be ignored (hardware will not set RX_EPA_F(SC_TRSR[4])).
[20:18]	Reserved	Reserved.
[17:16]	RX_POINT_F	Receiver Buffer Pointer Status Flag (Read Only) This field indicates the RX buffer pointer status flag. When SC receives one byte from external device, RX_POINT_F(SC_SR[17:16]) increases one. When one byte of RX buffer is read by CPU, RX_POINT_F(SC_SR[17:16]) decreases one.
[15:11]	Reserved	Reserved.
[10]	TX_FULL_F	Transmit Buffer Full Status Flag (Read Only) This bit indicates TX buffer full or not. This bit is set when TX pointer is equal to 4, otherwise is cleared by hardware.
[9]	TX_EMPTY_F	Transmit Buffer Empty Status Flag (Read Only) This bit indicates TX buffer empty or not. When the last byte of TX buffer has been transferred to Transmitter Shift Register, hardware sets this bit high. It will be cleared when writing data into THR(SC_THR[7:0]) (TX buffer not empty).
[8]	TX_OVER_F	TX Overflow Error Interrupt Status Flag (Read Only) If TX buffer is full, an additional write to THR(SC_THR[7:0]) will cause this bit be set to "1" by hardware. Note: This bit is read only, but it can be cleared by writing 1 to it.
[7]	Reserved	Reserved.
[6]	RX_EBR_F	Receiver Break Error Status Flag (Read Only) This bit is set to logic 1 whenever the received data input (RX) held in the "spacing state" (logic 0) is longer than a full word transmission time (that is, the total time of "start bit" + data bits + parity + stop bits). Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: If CPU sets receiver retries function by setting RX_ERETRY_EN(SC_CTL[19]) , hardware will not set this flag.
[5]	RX_EFR_F	Receiver Frame Error Status Flag (Read Only) This bit is set to logic 1 whenever the received character does not have a valid "stop bit" (that is, the stop bit following the last data bit or parity bit is detected as logic 0). Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: If CPU sets receiver retries function by setting RX_ERETRY_EN(SC_CTL[19]) , hardware will not set this flag.
[4]	RX_EPA_F	Receiver Parity Error Status Flag (Read Only) This bit is set to logic 1 whenever the received character does not have a valid "parity bit". Note1: This bit is read only, but it can be cleared by writing 1 to it. Note2: If CPU sets receiver retries function by setting RX_ERETRY_EN(SC_CTL[19]) , hardware will not set this flag.
[3]	Reserved	Reserved.
[2]	RX_FULL_F	Receiver Buffer Full Status Flag (Read Only) This bit indicates RX buffer full or not. This bit is set when RX pointer is equal to 4, otherwise it is cleared by hardware.

[1]	RX_EMPTY_F	Receiver Buffer Empty Status Flag(Read Only) This bit indicates RX buffer empty or not. When the last byte of Rx buffer has been read by CPU, hardware sets this bit high. It will be cleared when SC receives any new data.
[0]	RX_OVER_F	RX Overflow Error Status Flag (Read Only) This bit is set when RX buffer overflow. If the number of received bytes is greater than Rx Buffer size (4 bytes), this bit will be set. Note: This bit is read only, but it can be cleared by writing 1 to it.

SC PIN Control State Register (SC_PINCSR)

Register	Offset	R/W	Description	Reset Value
SC_PINCSR	SCx_BA+0x24	R/W	SC Pin Control State Register	0x0000_00x0

31	30	29	28	27	26	25	24
Reserved	SYNC	Reserved					
23	22	21	20	19	18	17	16
Reserved							SC_DATA_I_ST
15	14	13	12	11	10	9	8
Reserved				POW_INV	CD_LEV	SC_DATA_O	SC_OEN_ST
7	6	5	4	3	2	1	0
ADAC_CD_EN	CLK_KEEP	Reserved	CD_PIN_ST	CD_INS_F	CD_REM_F	SC_RST	POW_EN

Bits	Description	
[31]	Reserved	Reserved.
[30]	SYNC	SYNC Flag Indicator Due to synchronization, software should check this bit when writing a new value to SC_PINCSR register. 0 = Synchronizing is completion, user can write new data to SC_PINCSR register. 1 = Last value is synchronizing. Note: This bit is read only.
[29:17]	Reserved	Reserved.
[16]	SC_DATA_I_ST	SC Data Pin Status (Read Only) This bit is the pin status of SC_DATA 0 = The SC_DATA pin is low. 1 = The SC_DATA pin is high.
[15:12]	Reserved	Reserved.
[11]	POW_INV	SC_POW Pin Inverse This bit is used for inverse the SC_POW pin. There are four kinds of combination for SC_POW pin setting by POW_INV(SC_PINCSR[11]) and POW_EN(SC_PINCSR[0]). POW_INV (SC_PINCSR[11]) is bit 1 and POW_EN(SC_PINCSR[0]) is bit 0 for SC_POW_Pin as high or low voltage selection. 00 = SC_POW_Pin is 0. 01 = SC_POW_Pin is 1. 10 = SC_POW_Pin is 1. 11 = SC_POW_Pin is 0. Note: Software must select POW_INV (SC_PINCSR[11]) before Smart Card is enabled by SC_CEN (SC_CTL[0]).
[10]	CD_LEV	Card Detect Level 0 = When hardware detects the card detect pin from high to low, it indicates a card is

		detected. 1 = When hardware detects the card detect pin from low to high, it indicates a card is detected.  Note: Software must select card detect level before Smart Card engine is enabled
[9]	SC_DATA_O	SC Data Output Pin This bit is the pin status of SC_DATA_O but user can drive SC_DATA_O pin to high or low by setting this bit. 0 = Drive SC_DATA_O pin to low. 1 = Drive SC_DATA_O pin to high. Note: When SC is at activation, warm reset or deactivation mode, this bit will be changed automatically. So don't fill this field when SC is in these modes.
[8]	SC_OEN_ST	SC Data Output Enable Pin Status (Read Only) This bit is the pin status of SC_DATA_OEN 0 = The SC_DATA_OEN pin state at low. 1 = The SC_DATA_OEN pin state at high.
[7]	ADAC_CD_EN	Auto Deactivation When Card Removal 0 = Auto deactivation Disabled when hardware detected the card removal. 1 = Auto deactivation Enabled when hardware detected the card removal. Note: When the card is removed, hardware will stop any process and then do deactivation sequence (if this bit be setting). If this process completes. Hardware will generate an initial end interrupt to CPU.
[6]	CLK_KEEP	SC Clock Enable Bit 0 = SC clock generation Disabled. 1 = SC clock always keeps free running. Note: When operating in activation, warm reset or deactivation mode, this bit will be changed automatically. So don't fill this field when operating in these modes.
[5]	Reserved	Reserved.
[4]	CD_PIN_ST	Card Detect Status Of SC_CD Pin Status (Read Only) This bit is the pin status flag of SC_CD 0 = The SC_CD pin state at low. 1 = The SC_CD pin state at high.
[3]	CD_INS_F	Card Detect Insert Status Of SC_CD Pin (Read Only) This bit is set whenever card has been inserted. 0 = No effect. 1 = Card insert. Note1: This bit is read only, but it can be cleared by writing "1" to it. Note2: The card detect engine will start after SC_CEN (SC_CTL[0])set.
[2]	CD_REM_F	Card Detect Removal Status Of SC_CD Pin (Read Only) This bit is set whenever a card has been removed. 0 = No effect. 1 = Card removed. Note1: This bit is read only, but it can be cleared by writing "1" to it. Note2: Card detect engine will start after SC_CEN (SC_CTL[0])set.

[1]	SC_RST	SC_RST Pin Signal This bit is the pin status of SC_RST but user can drive SC_RST pin to high or low by setting this bit. Write this field to drive SC_RST pin. 0 = Drive SC_RST pin to low. 1 = Drive SC_RST pin to high. Read this field to get SC_RST pin status. 0 = SC_RST pin status is low. 1 = SC_RST pin status is high. Note: When operating at activation, warm reset or deactivation mode, this bit will be changed automatically. So don't fill this field when operating in these modes.
[0]	POW_EN	SC_POW_EN Pin Signal Software can set POW_EN (SC_PINCSR[0]) and POW_INV (SC_PINCSR[1]) to decide SC_PWR pin is in high or low level. Write this field to drive SC_PWR pin Refer POW_INV (SC_PINCSR[1]) description for programming SC_PWR pin voltage level. Read this field to get SC_PWR pin status. 0 = SC_PWR pin status is low. 1 = SC_PWR pin status is high. Note: When operating at activation, warm reset or deactivation mode, this bit will be changed automatically. So don't fill this field when operating in these modes.

SC Timer Control Register 0 (SC_TMR0)

Register	Offset	R/W	Description	Reset Value
SC_TMR0	SCx_BA+0x28	R/W	SC Internal Timer Control Register 0	0x0000_0000

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

Bits	Description	
[31:28]	Reserved	Reserved.
[27:24]	MODE	Timer 0 Operation Mode Selection This field indicates the internal 24-bit timer operation selection. Refer to 6.14.5.4 for programming Timer0
[23:0]	CNT0	Timer 0 Counter Value (ETU Base) This field indicates the internal timer operation values.

SC Timer Control Register 1 (SC_TMR1)

Register	Offset	R/W	Description	Reset Value
SC_TMR1	SCx_BA+0x2C	R/W	SC Internal Timer Control Register 1	0x0000_0000

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

Bits	Description	
[31:28]	Reserved	Reserved.
[27:24]	MODE	Timer 1 Operation Mode Selection This field indicates the internal 8-bit timer operation selection. Refer to 6.14.5.4 for programming Timer1
[7:0]	CNT1	Timer 1 Counter Value (ETU Base) This field indicates the internal timer operation values.

SC Timer Control Register 2 (SC_TMR2)

Register	Offset	R/W	Description	Reset Value
SC_TMR2	SCx_BA+0x30	R/W	SC Internal Timer Control Register 2	0x0000_0000

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

Bits	Description	
[31:28]	Reserved	Reserved.
[27:24]	MODE	Timer 2 Operation Mode Selection This field indicates the internal 8-bit timer operation selection Refer to 6.14.5.4 for programming Timer2
[7:0]	CNT2	Timer 2 Counter Value (ETU Base) This field indicates the internal timer operation values.

SC UART Mode Control Register (SCx_UACTL)

Register	Offset	R/W	Description	Reset Value
SC_UACTL	SCx_BA + 0x34	R/W	SC UART Mode Control Register.	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
OPE	PBDIS	DATA_LEN		Reserved			UA_MODE_EN

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	OPE	Odd Parity Enable Bit 0 = Even number of logic 1's are transmitted or check the data word and parity bits in receiving mode. 1 = Odd number of logic 1's are transmitted or check the data word and parity bits in receiving mode. Note: This bit has effect only when PBDIS bit is '0'.
[6]	PBDIS	Parity Bit Disable Bit 0 = Parity bit is generated or checked between the "last data word bit" and "stop bit" of the serial data. 1 = Parity bit is not generated (transmitting data) or checked (receiving data) during transfer. Note: In smart card mode, this field must be '0' (default setting is with parity bit)
[5:4]	DATA_LEN [1:0]	Data Length 00 = Character Data Length is 8 bits. 01 = Character Data Length is 7 bits. 10 = Character Data length is 6 bits. 11 = Character Data Length is 5 bits. Note: In smart card mode, this DATA_LEN must be '00'
[3:1]	Reserved	Reserved.
[0]	UA_MODE_EN	UART Mode Enable Bit 0 = Smart Card mode. 1 = UART mode. Note1: When operating in UART mode, user must set CON_SEL (SC_CTL[5:4]) = 00 and AUTO_CON_EN(SC_CTL[3]) = 0. Note2: When operating in Smart Card mode, user must set UA_MODE_EN(SC_UACTL[0]) = 00. Note3: When UART is enabled, hardware will generate a reset to reset FIFO and internal

Bits	Description	
		state machine.

SC Timer Current Data Register A (SC_TDRA)

Register	Offset	R/W	Description	Reset Value
SC_TDRA	SCx_BA+0x38	R	SC Timer Current Data Register A	0x0000_07FF

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
TDR0							
15	14	13	12	11	10	9	8
TDR0							
7	6	5	4	3	2	1	0
TDR0							

Bits	Description	
[31:24]	Reserved	Reserved.
[23:0]	TDR0	Timer0 Current Data Value(Read Only) This field indicates the current count values of timer0.

SC Timer Current Data Register B (SC_TDRB)

Register	Offset	R/W	Description	Reset Value
SC_TDRB	SCx_BA+0x3C	R	SC Timer Current Data Register B	0x0000_7F7F

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
TDR2							
7	6	5	4	3	2	1	0
TDR1							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:8]	TDR2	Timer2 Current Data Value (Read Only) This field indicates the current count values of timer2.
[7:0]	TDR1	Timer1 Current Data Value(Read Only) This field indicates the current count values of timer1.

6.15 PS/2 Device Controller (PS2D)

6.15.1 Overview

PS/2 device controller provides a basic timing control for PS/2 communication. All communication between the device and the host is managed through the PS2_CLK and PS2_DATA pins. Unlike PS/2 keyboard or mouse device controller, the receive/transmit code needs to be translated as meaningful code by firmware. The device controller generates the PS2_CLK signal after receiving a "Request to Send" state, but host has ultimate control over communication. Data of PS2_DATA line sent from the host to the device is read on the rising edge and sent from the device to the host is change after rising edge. A 16 bytes FIFO is used to reduce CPU intervention. Software can select 1 to 16 bytes for a continuous transmission.

6.15.2 Features

- Host communication inhibit and "Request-to-Send" state detection
- Reception frame error detection
- Programmable 1 to 16 bytes transmit buffer to reduce CPU intervention
- Double buffer for data reception
- Software override bus

6.15.3 Block Diagram

The PS/2 device controller consists of APB bus interface and timing control logic for PS2_DATA and PS2_CLK lines.

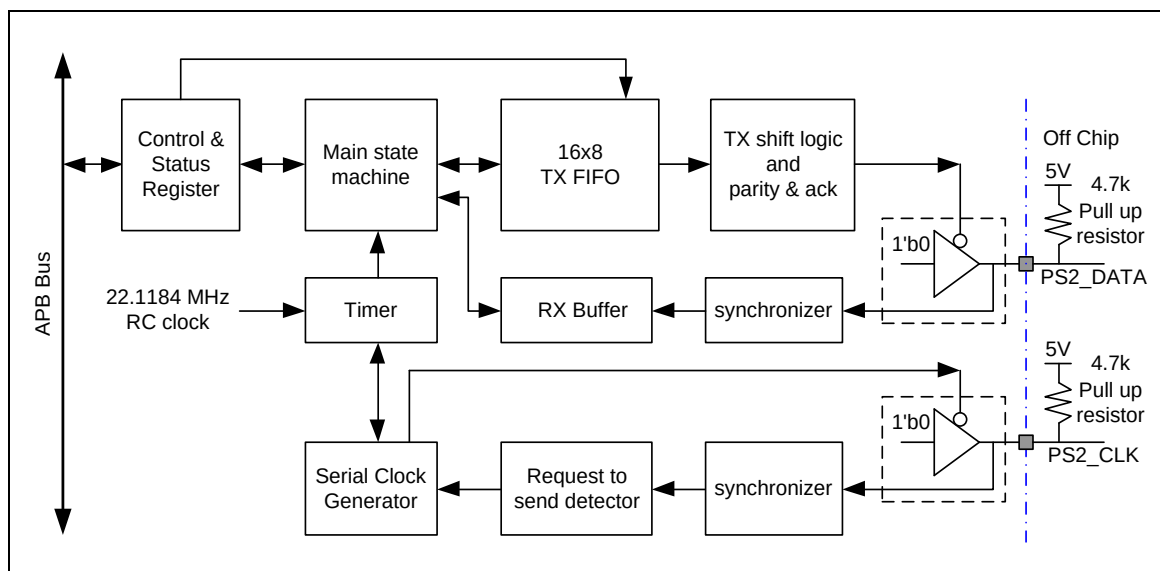


Figure 6-89 PS/2 Device Block Diagram

6.15.4 Basic Configuration

The basic configurations of PS/2 device controller are as follows:

- PS2_CLK and PS2_DATA pins are configured on GPF_MFP[3:2] register.
- Enable PS/2 device bus clock PS2_EN on APBCLK[31] register.
- Reset PS/2 Device PS2_RST on IPRSTC2[23] register.

6.15.5 Functional Description

6.15.5.1 Communication

The PS/2 device implements a bidirectional synchronous serial protocol. The bus is "Idle" when both lines are high (open-collector). This is the only state where the device is allowed start to transmit PS/2 data. The host has ultimate control over the bus and may inhibit communication at any time by pulling the PS2_CLK line low.

The PS2_CLK signal is generated by PS/2 device. If the host wants to send PS/2 data, it must first inhibit communication from the device by pulling PS2_CLK low. The host then pulls PS2_DATA low and releases PS2_CLK. This is the "Request-to-Send" state and signals the device to start generating PS2_CLK pulses.

PS2_DATA	PS2_CLK	Bus State
High	High	Idle
High	Low	Communication Inhibit
Low	High	Host Request to Send

All data is transmitted one byte at a time and each byte is sent in a frame consisting of 11 or 12 bits. These bits are:

- 1 start bit, which is always 0
- 8 data bits, least significant bit first
- 1 parity bit (odd parity)
- 1 stop bit, which is always 1
- 1 acknowledge bit (host-to-device communication only)

The parity bit is set if there is an even number of 1's in the data bits and cleared to 0 if there is an odd number of 1's in the data bits. This is used for parity error detection that is the number of 1's in the data bits plus the parity bit should always add up to an odd number. The device must check this bit and if incorrect it should respond as if it had received an invalid command.

The host may inhibit communication at any time by pulling the PS2_CLK line low for at least 100 us. If a transmission is inhibited before the 11th clock pulse, the device must abort the current transmission and prepare to resend the current data when host releases PS2_CLK. In order to reserve enough time for software to decode host command, the transmit logic is blocked by RXINT(PS2INTID[0]) bit, software must clear the RXINT bit to start resend. Software can write CLR_FIFO(PS2CON[8]) to 1 to reset FIFO pointer if needed.

Device-to-Host

The device uses a serial protocol with 11-bit frames. These bits are:

- 1 start bit, which is always 0

- 8 data bits, least significant bit first
- 1 parity bit (odd parity)
- 1 stop bit, which is always 1

The device writes a bit on the PS2_DATA line when PS2_CLK is high, and it is read by the host when PS2_CLK is low, which is illustrated in Figure 6-90.

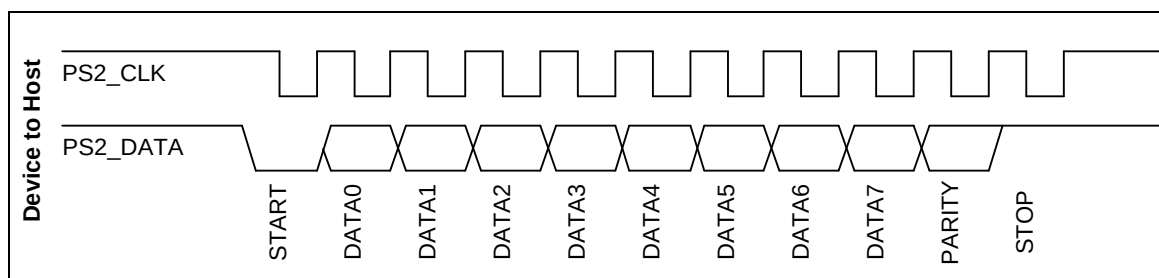


Figure 6-90 Data Format of Device-to-Host

Host-to-Device:

First, the PS/2 device always generates the PS2_CLK signal. If the host wants to send PS/2 data, it must first put the PS2_CLK and PS2_DATA lines in a "Request-to-send" state as follows:

- Inhibit communication by pulling PS2_CLK low for at least 100 us
- Apply "Request-to-send" by pulling PS2_DATA low, then release PS2_CLK

The device should check for this state at intervals not to exceed 10 ms. When the device detects this state, it will begin generating PS2_CLK signals and PS2_CLK in eight PS2_DATA bits, one parity bit and one stop bit. The host changes the PS2_DATA line status only when the PS2_CLK line status is low, and PS2_DATA is read by the device when PS2_CLK is high.

After the stop bit is received, the device will acknowledge the received byte by bringing the PS2_DATA line low and generating one last PS2_CLK pulse. If the host does not release the PS2_DATA line after the 11th CLK pulse, the device will continue to generate PS2_CLK pulses until the PS2_DATA line is released.

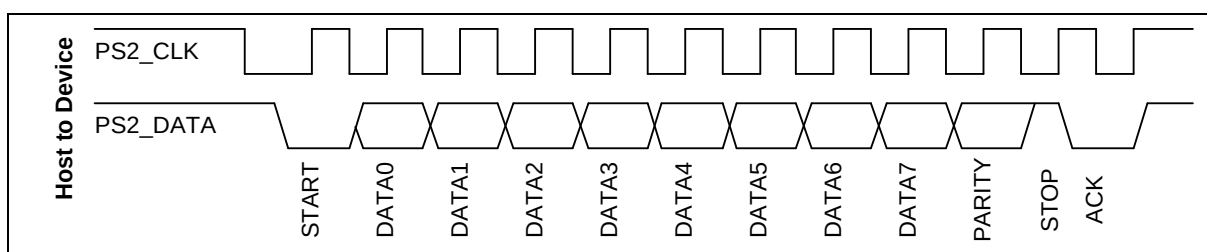


Figure 6-91 Data Format of Host-to-Device

The host and the detailed timing of the PS2_DATA and PS2_CLK for communication are shown below:

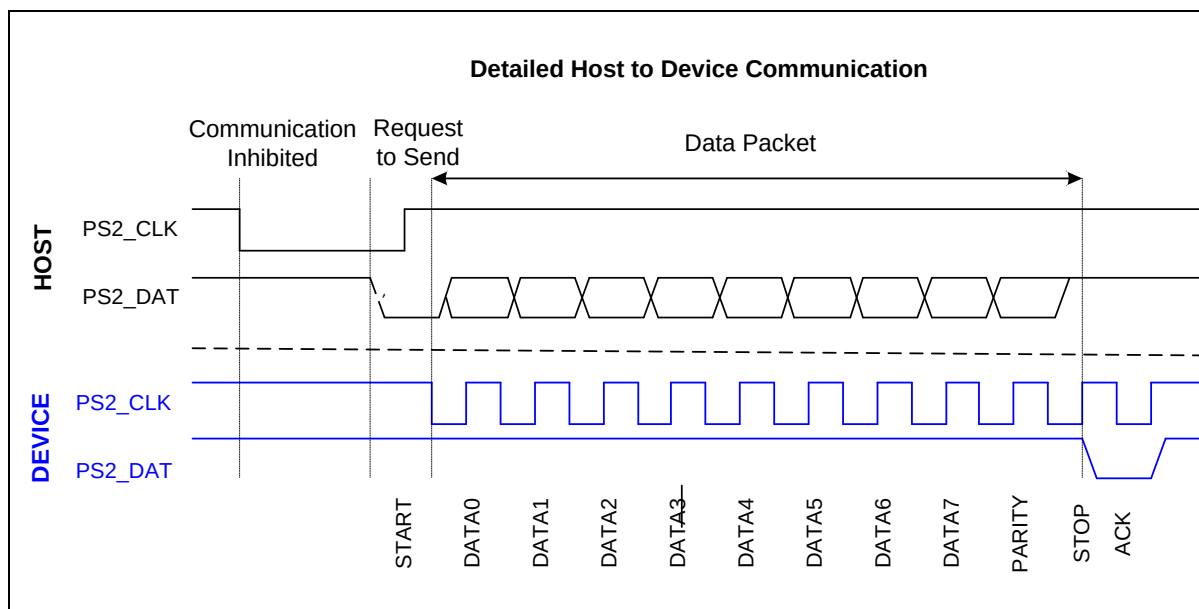


Figure 6-92 PS/2 Bit Data Format

6.15.5.2 PS/2 Bus Timing Specification

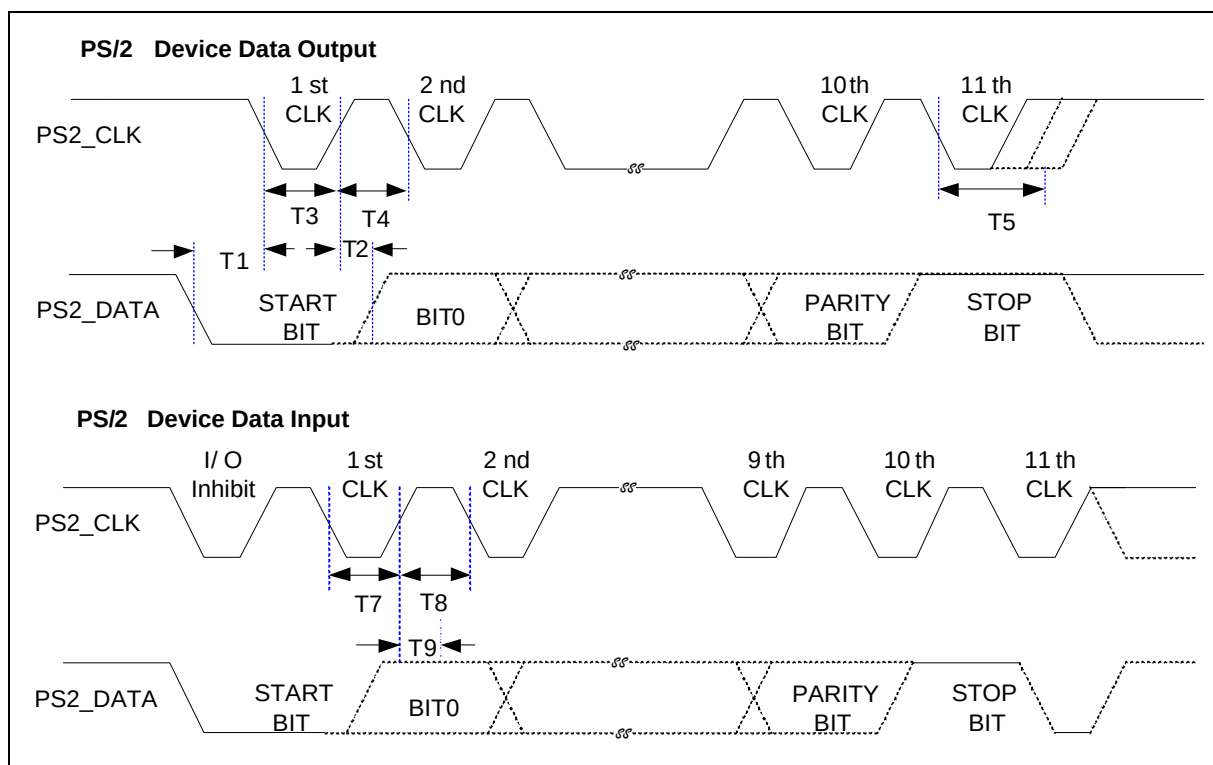


Figure 6-93 PS/2 Bus Timing

Symbol	Timing Parameter	Min.	Max.
T1	PS2_DATA transition to the falling edge of PS2_CLK	5us	25us
T2	Rising edge of PS2_CLK to PS2_DATA transition	5us	T4-5us
T3	Duration of PS2_CLK inactive	30us	50us
T4	Duration of PS2_CLK active	30us	50us
T5	Time to auxiliary device inhibit after 11 th clock to ensure auxiliary device does not start another transmission	>0	50us
T7	Duration of PS2_CLK inactive	30us	50us
T8	Duration of PS2_CLK active	30us	50us
T9	Time from inactive to active PS2_CLK transition, use to time auxiliary device sample PS2_DATA	5us	25us

6.15.5.3 TX FIFO Operation

Writing data to PS2TXDATA0 register starts device to host communication. Software is required to define the TXFIFO depth before writing transmission data to TX FIFO. The first START bit is sent to PS/2 bus when software writes TX FIFO and delays 100us. If there are more than 4 bytes data need to send, software can write residual data to PS2TXDATA1-3 before 4th byte transmit complete. A time delay 100us is added between two consecutive bytes.

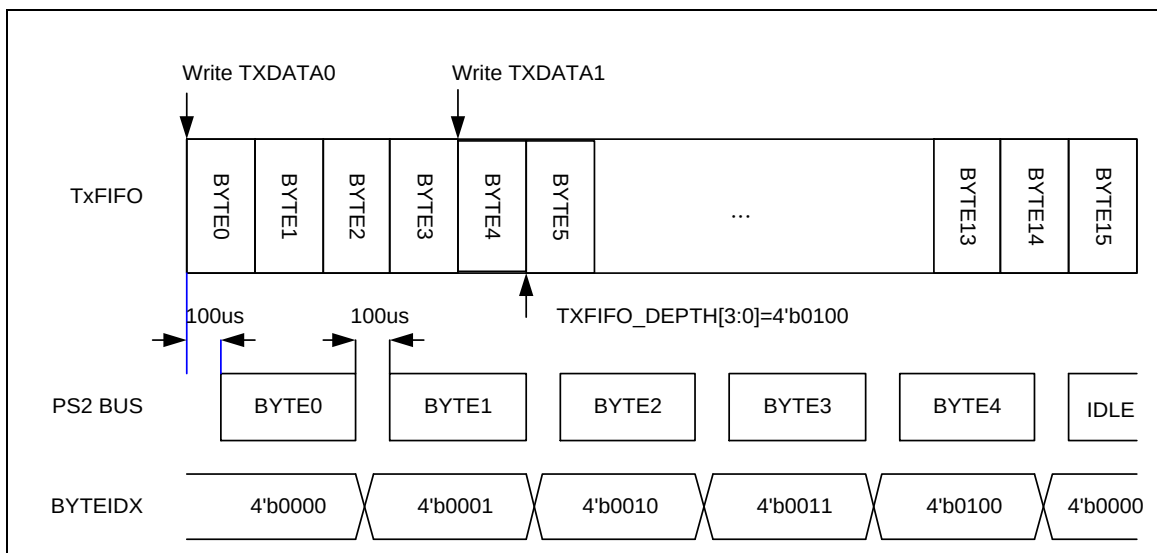


Figure 6-94 PS/2 Data Format

6.15.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
PS/2 Base Address: PS2_BA = 0x4010_0000				
PS2CON	PS2_BA+0x00	R/W	PS/2 Control Register	0x0000_0000
PS2TXDATA0	PS2_BA+0x04	R/W	PS/2 Transmit Data Register 0	0x0000_0000
PS2TXDATA1	PS2_BA+0x08	R/W	PS/2 Transmit Data Register 1	0x0000_0000
PS2TXDATA2	PS2_BA+0x0C	R/W	PS/2 Transmit Data Register 2	0x0000_0000
PS2TXDATA3	PS2_BA+0x10	R/W	PS/2 Transmit Data Register 3	0x0000_0000
PS2RXDATA	PS2_BA+0x14	R	PS/2 Receive Data Register	0x0000_0000
PS2STATUS	PS2_BA+0x18	R/W	PS/2 Status Register	0x0000_0083
PS2INTID	PS2_BA+0x1C	R/W	PS/2 Interrupt Identification Register	0x0000_0000

6.15.7 Register Description

PS/2 Control Register (PS2CON)

Register	Offset	R/W	Description	Reset Value
PS2CON	PS2_BA+0x00	R/W	PS/2 Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved				FPS2DAT	FPS2CLK	OVERRIDE	CLR_FIFO
7	6	5	4	3	2	1	0
ACK	TX_FIFO_DEPTH				RXINTEN	TXINTEN	PS2EN

Bits	Description	
[31:12]	Reserved	Reserved.
[11]	FPS2DAT	Force PS2DATA Line It forces PS2_DATA high or low regardless of the internal state of the device controller if OVERRIDE (PS2CON[9]) is set to 1. 0 = Force PS2_DATA low. 1 = Force PS2_DATA high.
[10]	FPS2CLK	Force PS2CLK Line It forces PS2_CLK line high or low regardless of the internal state of the device controller if OVERRIDE(PS2CON[9]) is set to 1. 0 = Force PS2_CLK line low. 1 = Force PS2_CLK line high.
[9]	OVERRIDE	Software Override PS/2 CLK/DATA Pin State 0 = PS2_CLK and PS2_DATA pins are controlled by internal state machine. 1 = PS2_CLK and PS2_DATA pins are controlled by software.
[8]	CLR_FIFO	Clear TX FIFO Write 1 to this bit to terminate device to host transmission. The TXEMPTY(PS2STATUS[7]) bit will be set to 1 and pointer BYTEIDX (PS2STATUS[11:8]) is reset to 0 regardless there is residue data in buffer or not. The buffer content is not been cleared. 0 = Not active. 1 = Clear FIFO.
[7]	ACK	Acknowledge Enable Bit 0 = Always send acknowledge to host at 12th clock for host to device communication. 1 = If parity bit error or stop bit is not received correctly, acknowledge bit will not be sent to host at 12th clock.
[6:3]	TX_FIFO_DEPTH	Transmit Data FIFO Depth There is a 16 bytes buffer for data transmit. Software can define the FIFO depth from 1 to

		16 bytes depends on application. 0 = 1 byte. 1 = 2 bytes. ... 14 = 15 bytes. 15 = 16 bytes.
[2]	RXINTEN	Receive Interrupt Enable Bit 0 = Data receive complete interrupt Disabled. 1 = Data receive complete interrupt Enabled.
[1]	TXINTEN	Transmit Interrupt Enable Bit 0 = Data transmit complete interrupt Disabled. 1 = Data transmit complete interrupt Enabled.
[0]	PS2EN	PS/2 Device Enable Bit 0 = Disabled. 1 = Enabled.

PS/2 TX DATA Register 0-3 (PS2TXDATA0-3)

Register	Offset	R/W	Description	Reset Value
PS2TXDATA0	PS2_BA+0x04	R/W	PS/2 Transmit Data Register 0	0x0000_0000
PS2TXDATA1	PS2_BA+0x08	R/W	PS/2 Transmit Data Register 1	0x0000_0000
PS2TXDATA2	PS2_BA+0x0C	R/W	PS/2 Transmit Data Register 2	0x0000_0000
PS2TXDATA3	PS2_BA+0x10	R/W	PS/2 Transmit Data Register 3	0x0000_0000

31	30	29	28	27	26	25	24
PS2TXDATAx[31:24]							
23	22	21	20	19	18	17	16
PS2TXDATAx[23:16]							
15	14	13	12	11	10	9	8
PS2TXDATAx[15:8]							
7	6	5	4	3	2	1	0
PS2TXDATAx[7:0]							

Bits	Description	
[31:0]	PS2TXDATAx	Transmit Data Writing data to this register starts in device to host communication if bus is in IDLE state. Software must enable PS2EN(PS2CON[0]) before writing data to TX buffer.

PS/2 Receiver DATA Register (PS2RXDATA)

Register	Offset	R/W	Description	Reset Value
PS2RXDATA	PS2_BA+0x14	R	PS/2 Receive Data Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
RXDATA[7:0]							

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	RXDATA	Received Data For host to device communication, after acknowledge bit is sent, the received data is copied from receive shift register to PS2RXDATA register. CPU must read this register before next byte reception complete, otherwise the data will be overwritten and RXOVF(PS2STATUS[6]) bit will be set to 1.

PS/2 Status Register (PS2STATUS)

Register	Offset	R/W	Description	Reset Value
PS2STATUS	PS2_BA+0x18	R/W	PS/2 Status Register	0x0000_0083

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved				BYTEIDX[3:0]			
7	6	5	4	3	2	1	0
TXEMPTY	RXOVF	TXBUSY	RXBUSY	RXPARITY	FRAMERR	PS2DATA	PS2CLK

Bits	Description
[31:12]	Reserved Reserved.
[11:8]	BYTEIDX Byte Index It indicates which data byte in transmit data shift register. When all data in FIFO is transmitted and it will be cleared to 0. This bit is read only. 0000 = PS2TXDATA0[7:0]. 0001 = PS2TXDATA0[15:8]. 0010 = PS2TXDATA0[23:16]. 0011 = PS2TXDATA0[31:24]. 0100 = PS2TXDATA1[7:0]. 0101 = PS2TXDATA1[15:8]. 0110 = PS2TXDATA1[23:16]. 0111 = PS2TXDATA1[31:24]. 1000 = PS2TXDATA2[7:0]. 1001 = PS2TXDATA2[15:8]. 1010 = PS2TXDATA2[23:16]. 1011 = PS2TXDATA2[31:24]. 1100 = PS2TXDATA3[7:0]. 1101 = PS2TXDATA3[15:8]. 1110 = PS2TXDATA3[23:16]. 1111 = PS2TXDATA3[31:24].
[7]	TXEMPTY TX FIFO Empty When software writes data to PS2TXDATA0-3, the TXEMPTY bit is cleared to 0 immediately if PS2EN(PS2CON[0]) is enabled. When transmitted data byte number is equal to TXFIFO_DEPTH (PS2CON[6:3]) then TXEMPTY bit is set to 1. 0 = There is data to be transmitted. 1 = FIFO is empty. This bit is read only.

[6]	RXOVF	RX Buffer Overwrite 0 = No overwrite. 1 = Data in PS2RXDATA register is overwritten by new received data. Write 1 to clear this bit.
[5]	TXBUSY	Transmit Busy This bit indicates that the PS/2 device is currently sending data. 0 = Idle. 1 = Currently sending data. This bit is read only.
[4]	RXBUSY	Receive Busy This bit indicates that the PS/2 device is currently receiving data. 0 = Idle. 1 = Currently receiving data. This bit is read only.
[3]	RXPARTY	Received Parity This bit reflects the parity bit for the last received data byte (odd parity). This bit is read only.
[2]	FRAMERR	Frame Error For host to device communication, this bit sets to 1 if STOP bit (logic 1) is not received. If frame error occurs, the PS/2_DATA line may keep at low state after 12th clock. At this moment, software overrides PS2_CLK to send clock till PS2_DATA release to high state. After that, device sends a "Resend" command to host. 0 = No frame error. 1 = Frame error occur. Write 1 to clear this bit.
[1]	PS2DATA	DATA Pin State This bit reflects the status of the PS2_DATA line after synchronizing and sampling.
[0]	PS2CLK	CLK Pin State This bit reflects the status of the PS2_CLK line after synchronizing.

PS/2 Interrupt Identification Register (PS2INTID)

Register	Offset	R/W	Description	Reset Value
PS2INTID	PS2_BA+0x1C	R/W	PS/2 Interrupt Identification Register	0x0000_0000

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

Bits	Description	
[31:3]	Reserved	Reserved.
[1]	TXINT	Transmit Interrupt This bit is set to 1 after STOP bit is transmitted. Interrupt occur if TXINTEN(PS2CON[1]) bit is set to 1. 0 = No interrupt. 1 = Transmit interrupt occurs. Write 1 to clear this bit to 0.
[0]	RXINT	Receive Interrupt This bit is set to 1 when acknowledge bit is sent for Host to device communication. Interrupt occurs if RXINTEN(PS2CON[2]) bit is set to 1. 0 = No interrupt. 1 = Receive interrupt occurs. Write 1 to clear this bit to 0.

6.16 I²C Serial Interface Controller (I²C)

6.16.1 Overview

I²C is a two-wire, bi-directional serial bus that provides a simple and efficient method of data exchange between devices. The I²C standard is a true multi-master bus including collision detection and arbitration that prevents data corruption if two or more masters attempt to control the bus simultaneously.

6.16.2 Features

The I²C bus uses two wires (I2Cn_SDA and I2Cn_SCL) to transfer information between devices connected to the bus. The main features of the I²C bus include:

- Supports up to two I²C serial interface controller
- Master/Slave mode
- Bidirectional data transfer between masters and slaves
- Multi-master bus (no central master)
- Arbitration between simultaneously transmitting masters without corruption of serial data on the bus
- Serial clock synchronization allow devices with different bit rates to communicate via one serial bus
- Built-in a 14-bit time-out counter requesting the I²C interrupt if the I²C bus hangs up and timer-out counter overflows.
- Programmable clocks allow for versatile rate control
- Supports 7-bit addressing mode
- Supports multiple address recognition (four slave address with mask option)
- Supports Power-down wake-up function

6.16.3 Basic Configuration

The basic configurations of I²C0 are as follows:

- I²C0 pins are configured on GPA_MFP [9:8] register
- Enable I²C0 clock by setting I2C0_EN (APBCLK [8])
- Reset I²C0 controller by setting I2C0_RST(IPRSTC2 [8])

The basic configurations of I²C1 are as follows:

- I²C1 pins are configured on GPE_MFP [11:10] register
- Enable I²C1 clock by setting I2C1_EN(APBCLK [9])
- Reset I²C1 controller by setting I2C1_RST (IPRSTC2 [9])

6.16.4 Block Diagram

The basic configurations of I²C are as follows:

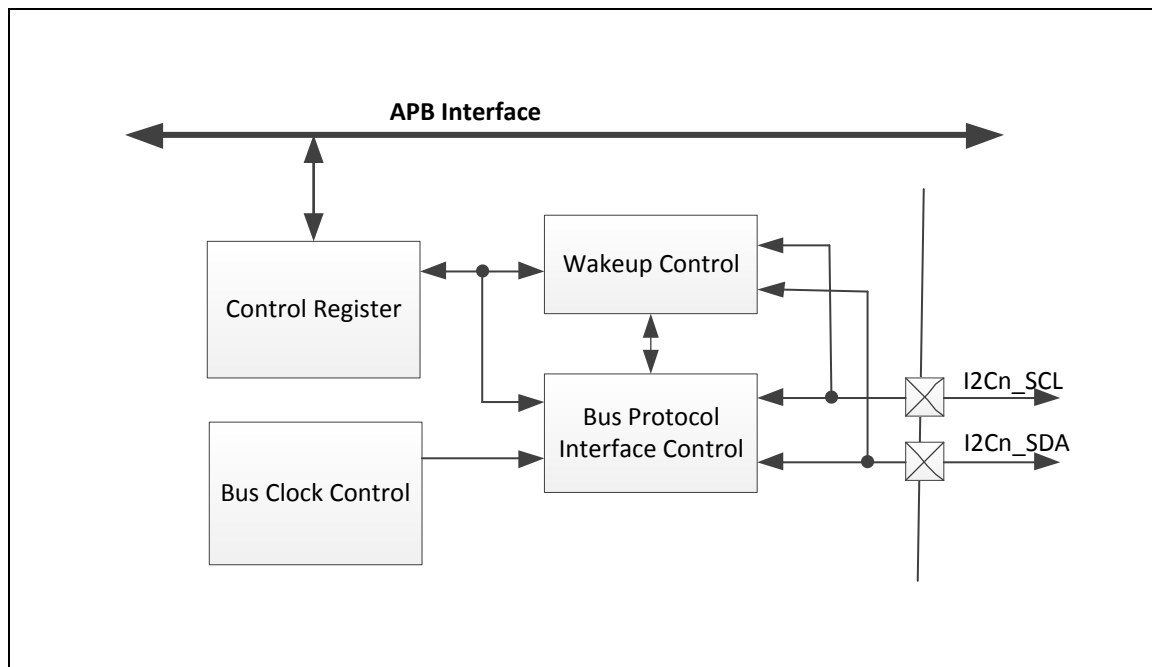


Figure 6-95 I²C Controller Block Diagram

6.16.5 Functional Description

On I²C bus, data is transferred between a Master and a Slave. Data bits transfer on the I2Cn_SCL and I2Cn_SDA lines are synchronously on a byte-by-byte basis. Each data byte is 8-bit long. There is one I2Cn_SCL clock pulse for each data bit with the MSB being transmitted first, and an acknowledge bit follows each transferred byte. Each bit is sampled during the high period of I2Cn_SCL; therefore, the I2Cn_SDA line may be changed only during the low period of I2Cn_SCL and must be held stable during the high period of I2Cn_SCL. A transition on the I2Cn_SDA line while I2Cn_SCL is high is interpreted as a command (START or STOP). Please refer to the following figure for more detailed I²C bus timing.

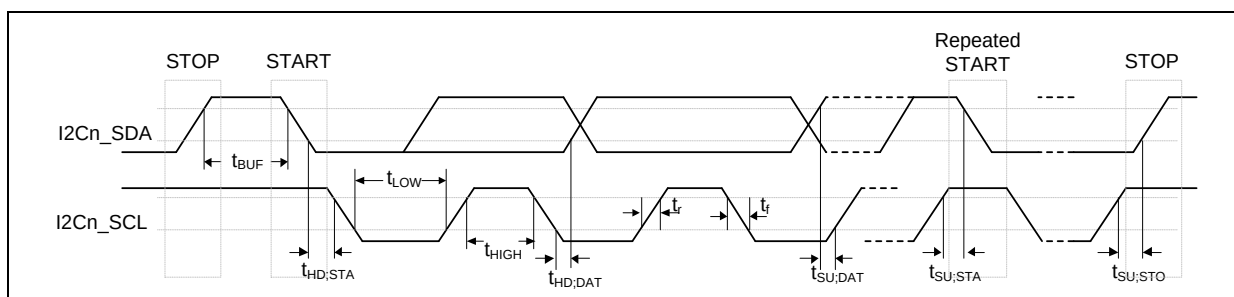


Figure 6-96 I²C Bus Timing

The device's on-chip I²C provides the serial interface that meets the I²C bus standard mode specification. The I²C port handles byte transfers autonomously. To enable this port, ENS1 (I2CON[6]) should be set to '1'. The I²C hardware interfaces to the I²C bus via two pins: I2Cn_SDA and I2Cn_SCL. When I/O pins are used as I²C ports, user must set the pins function to

I²C in advance.

Note: Pull-up resistor is needed for I²C operation as the I2Cn_SDA and I2Cn_SCL are open-drain pins.

6.16.5.1 I²C Protocol

The following figure shows the typical I²C protocol. Normally, a standard communication consists of four parts:

- START or Repeated START signal generation
- Slave address and R/W bit transfer
- Data transfer
- STOP signal generation

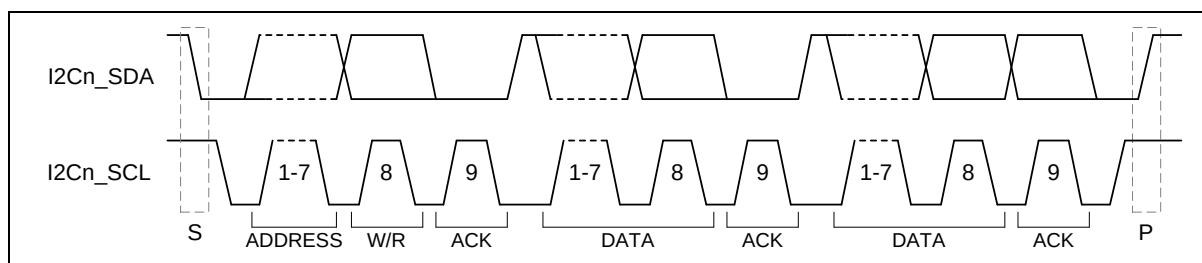


Figure 6-97 I²C Protocol

6.16.5.1.1 START or Repeated START signal

When the bus is free or idle, meaning no master device is engaging the bus (both I2Cn_SCL and I2Cn_SDA lines are high), a master can initiate a transfer by sending a START signal. A START signal, usually referred to as the “S” bit, is defined as a HIGH to LOW transition on the I2Cn_SDA line while I2Cn_SCL is HIGH. The START signal denotes the beginning of a new data transmission.

After having sent the address byte (address and read/write bit) the master may send any number of bytes followed by a stop condition. Instead of sending the stop condition it is also allowed to send another start condition again followed by an address (and of course including a read/write bit) and more data. The start condition is called as Repeat START (Sr). This is defined recursively allowing any number of start conditions to be sent. The purpose of this is to allow combined write/read operations to one or more devices without releasing the bus and thus with the guarantee that the operation is not interrupted. The controller uses this method to communicate with another slave or the same slave in a different transfer direction (e.g. from writing to a device to reading from a device) without releasing the bus.

6.16.5.1.2 STOP signal

The master can terminate the communication by generating a STOP signal. A STOP signal, usually referred to as the “P” bit, is defined as a LOW to HIGH transition on the I2Cn_SDA line while I2Cn_SCL is HIGH.

The following figure shows the waveform of START, Repeat START and STOP.

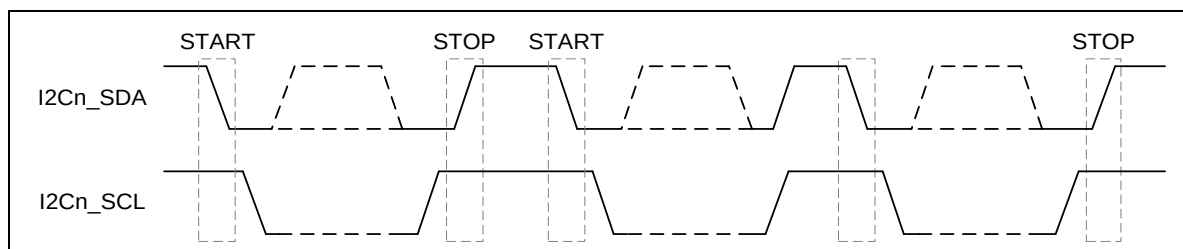


Figure 6-98 START and STOP Conditions

6.16.5.1.3 Slave Address Transfer

The first byte of data transferred by the master immediately after the START signal is the Slave address (SLA). This is a 7-bit calling address followed by a Read/Write (R/W) bit. The R/W bit signals of the slave indicate the data transfer direction. No two slaves in the system can have the same address. Only the slave with an address that matches the one transmitted by the master will respond by returning an acknowledge bit by pulling the I2Cn_SDA low at the 9th I2Cn_SCL clock cycle.

6.16.5.1.4 Data Transfer

When a slave receives a correct address with an R/W bit, the data will follow R/W bit specified to transfer. Each transferred byte is followed by an acknowledge bit on the 9th I2Cn_SCL clock cycle. If the slave signals a Not Acknowledge (NACK), the master can generate a STOP signal to abort the data transfer or generate a Repeated START signal and start a new transfer cycle.

If the master, as a receiving device, does Not Acknowledge (NACK) the slave, the slave releases the I2Cn_SDA line for the master to generate a STOP or Repeated START signal.

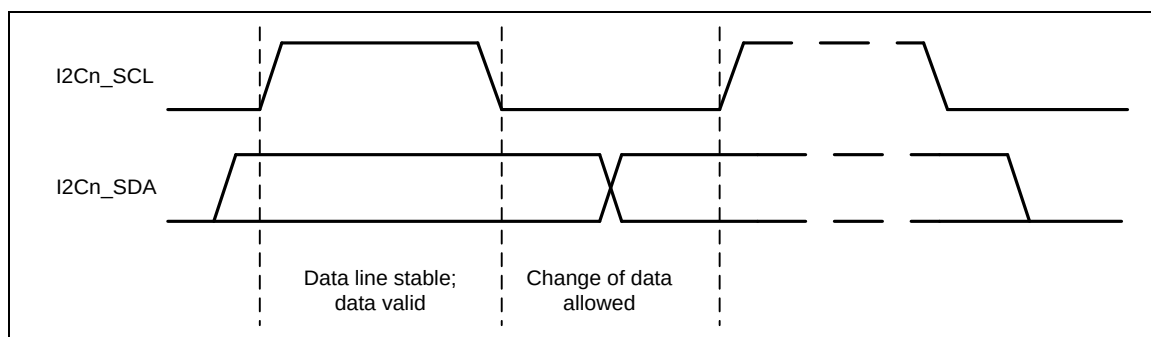


Figure 6-99 Bit Transfer on the I²C Bus

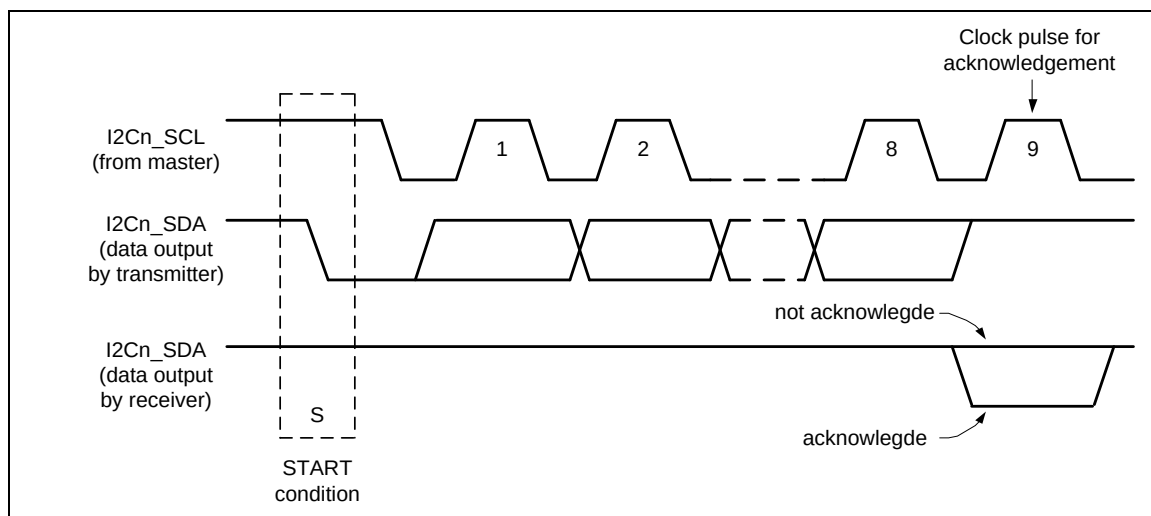


Figure 6-100 Acknowledge on the I²C Bus

6.16.5.1.5 Data transfer on the I²C bus

The following figure shows a master transmits data to slave. A master addresses a slave with a 7-bit address and 1-bit write index to denote that the master wants to transmit data to the slave. The master keeps transmitting data after the slave returns acknowledge to the master.

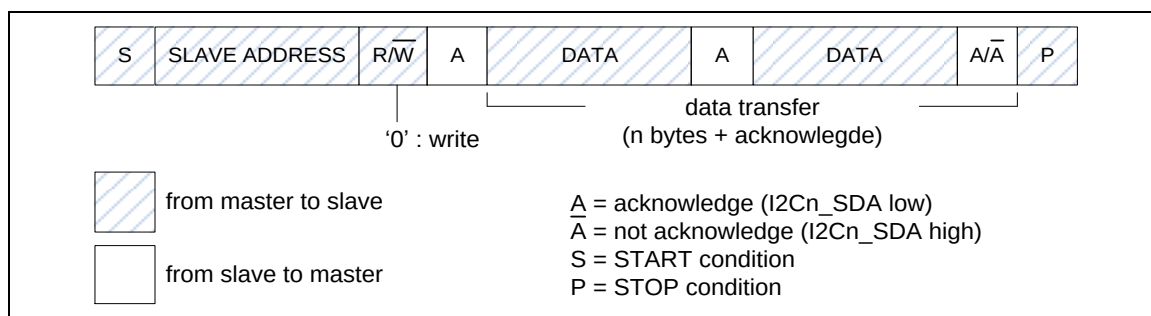


Figure 6-101 Master Transmits Data to Slave

The following figure shows a master read data from slave. A master addresses a slave with a 7-bit address and 1-bit read index to denote that the master wants to read data from the slave. The slave will start transmitting data after the slave returns acknowledge to the master.

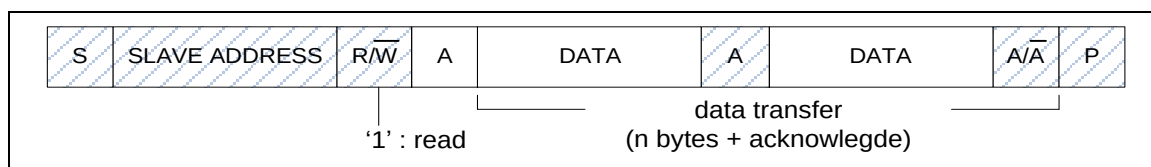


Figure 6-102 Master Reads Data from Slave

6.16.5.2 Operation Modes

The on-chip I²C ports support three operation modes, Master, Slave, and General Call Mode.

In a given application, I²C port may operate as a master or as a slave. In Slave mode, the I²C port

hardware looks for its own slave address and the general call address. If one of these addresses is detected, and if the slave is willing to receive or transmit data from/to master (by setting the AA bit), acknowledge pulse will be transmitted out on the 9th clock, hence an interrupt is requested on both master and slave devices if interrupt is enabled. When the microcontroller wishes to become the bus master, hardware waits until the bus is free before entering Master mode so that a possible slave action is not be interrupted. If bus arbitration is lost in Master mode, I²C port switches to Slave mode immediately and can detect its own slave address in the same serial transfer.

To control the I²C bus transfer in each mode, user needs to set I2CON, I2CDAT registers according to current status code of I2CSTATUS register. In other words, for each I²C bus action, user needs to check current status by I2CSTATUS register, and then set I2CON, I2CDAT registers to take bus action. Finally, check the response status by I2CSTATUS.

The bits, STA(I2CON[5]), STO(I2CON[4]) and AA(I2CON[2]) are used to control the next state of the I²C hardware after SI (I2CON[3]) flag is cleared. Upon completion of the new action, a new status code will be updated in I2CSTATUS register and the SI flag will be set. If the I²C interrupt control bit EI (I2CON [7]) is set, appropriate action or software branch of the new status code can be performed in the Interrupt service routine.

The following figure shows the current I²C status code is 0x08, and then set I2CDATA=SLA+W and (STA,STO,SI,AA) = (0,0,1,x) to send the address to I²C bus. If a slave on the bus matches the address and response ACK, the I2CSTATUS will be updated by status code 0x18.

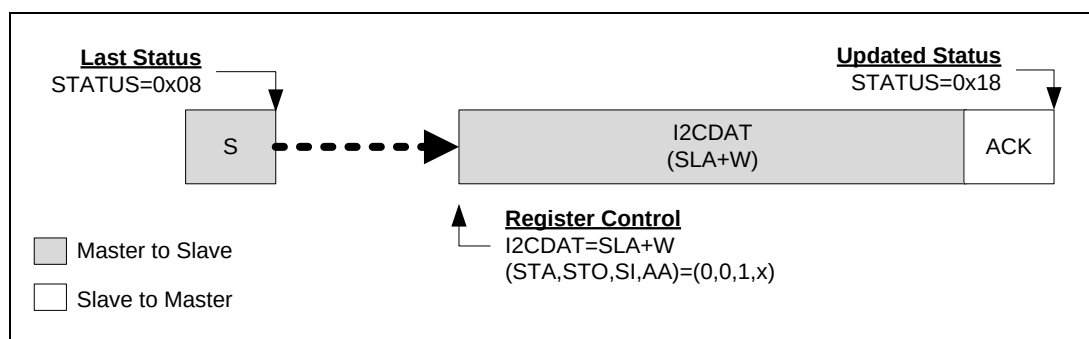


Figure 6-103 Control I²C Bus according to Current I²C Status

6.16.5.2.1 Master Mode

In below figures, all possible protocols for I²C master are shown. User needs to follow proper path of the flow to implement required I²C protocol.

In other words, user can send a START signal to bus and I²C will be in Master Transmitter mode (Figure 6-104) or Master receiver mode (Figure 6-106) after START signal has been sent successfully and new status code would be 0x08. Followed by START signal, user can send slave address, read/write bit, data and Repeat START, STOP to perform I²C protocol.

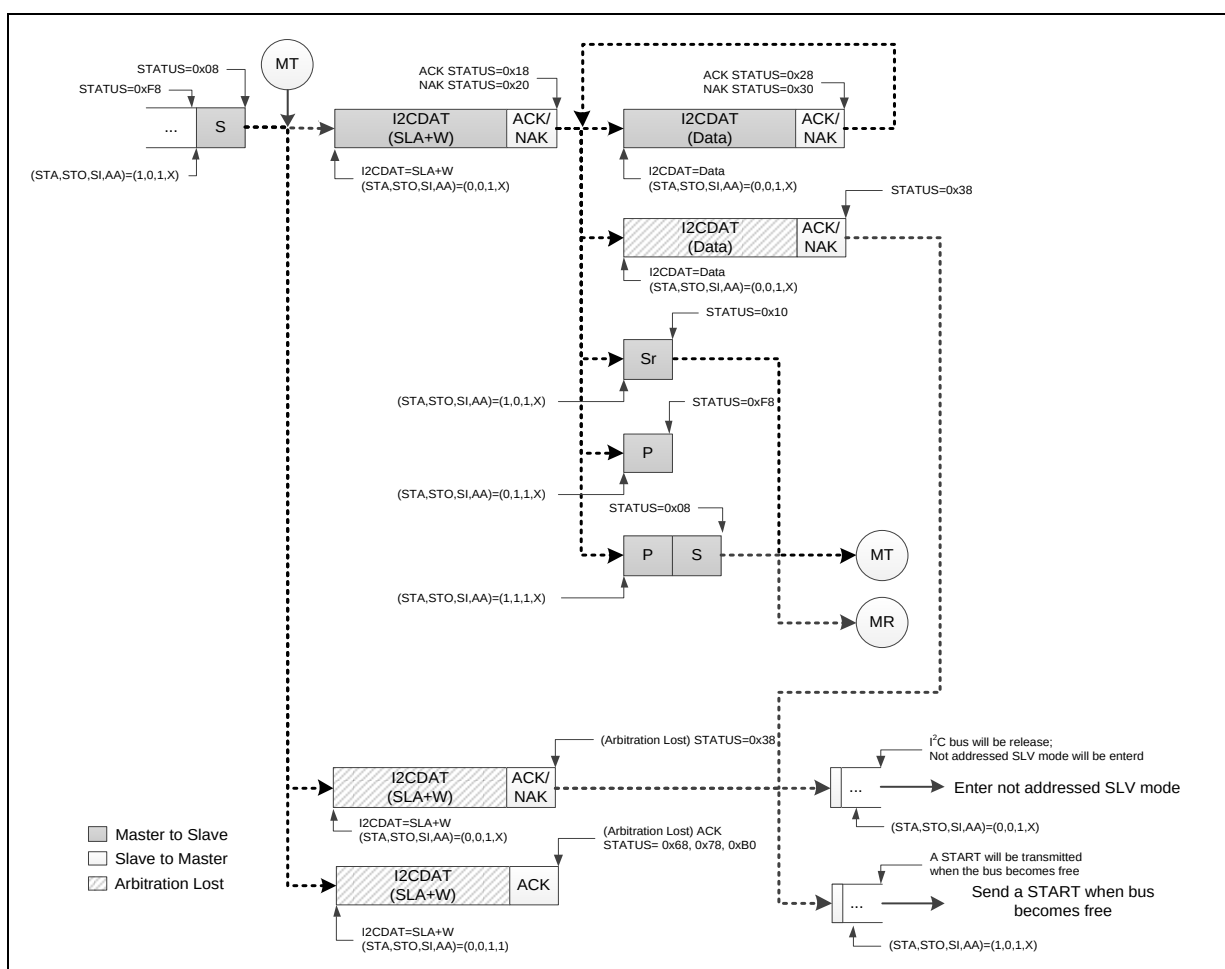


Figure 6-104 Master Transmitter Mode Control Flow

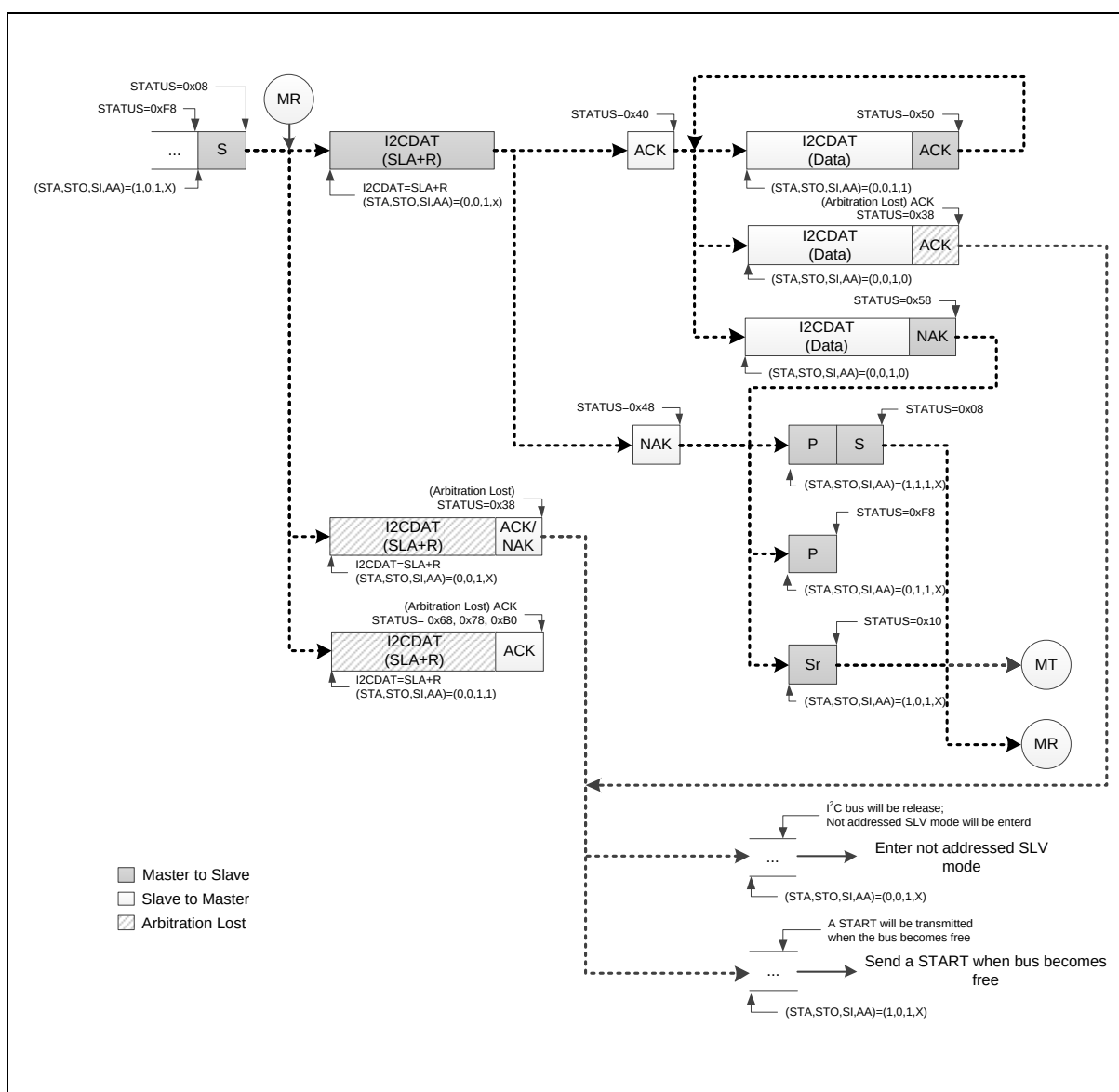


Figure 6-105 Master Receiver Mode Control Flow

If the I²C is in Master mode and gets arbitration lost, the status code will be 0x38. In status 0x38, user may set (STA, STO, SI, AA) = (1, 0, 1, X) to send START to re-start Master operation when bus become free. Otherwise, user may set (STA, STO, SI, AA) = (0, 0, 1, X) to release I²C bus and enter not addressed Slave mode.

6.16.5.2.2 *Slave Mode*

When reset default, I²C is not addressed and will not recognize the address on I²C bus. User can set slave address by I2CADDRx and set (STA, STO, SI, AA) = (0, 0, 1, 1) to let I²C recognize the address sent by master. Figure 6-106 shows all the possible flow for I²C in Slave mode. Users need to follow a proper flow (as shown in Figure 6-106) to implement their own I²C protocol.

If bus arbitration is lost in Master mode, I²C port switches to Slave mode immediately and can

detect its own slave address in the same serial transfer. If the detected address is SLA+W (Master want to write data to Slave) after arbitration lost, the status code is 0x68. If the detected address is SLA+R (Master want to read data from Slave) after arbitration lost, the status code is 0xB0.

Note: During I²C communication, the I2Cn_SCL clock will be released when writing '1' to clear SI flag in Slave mode.

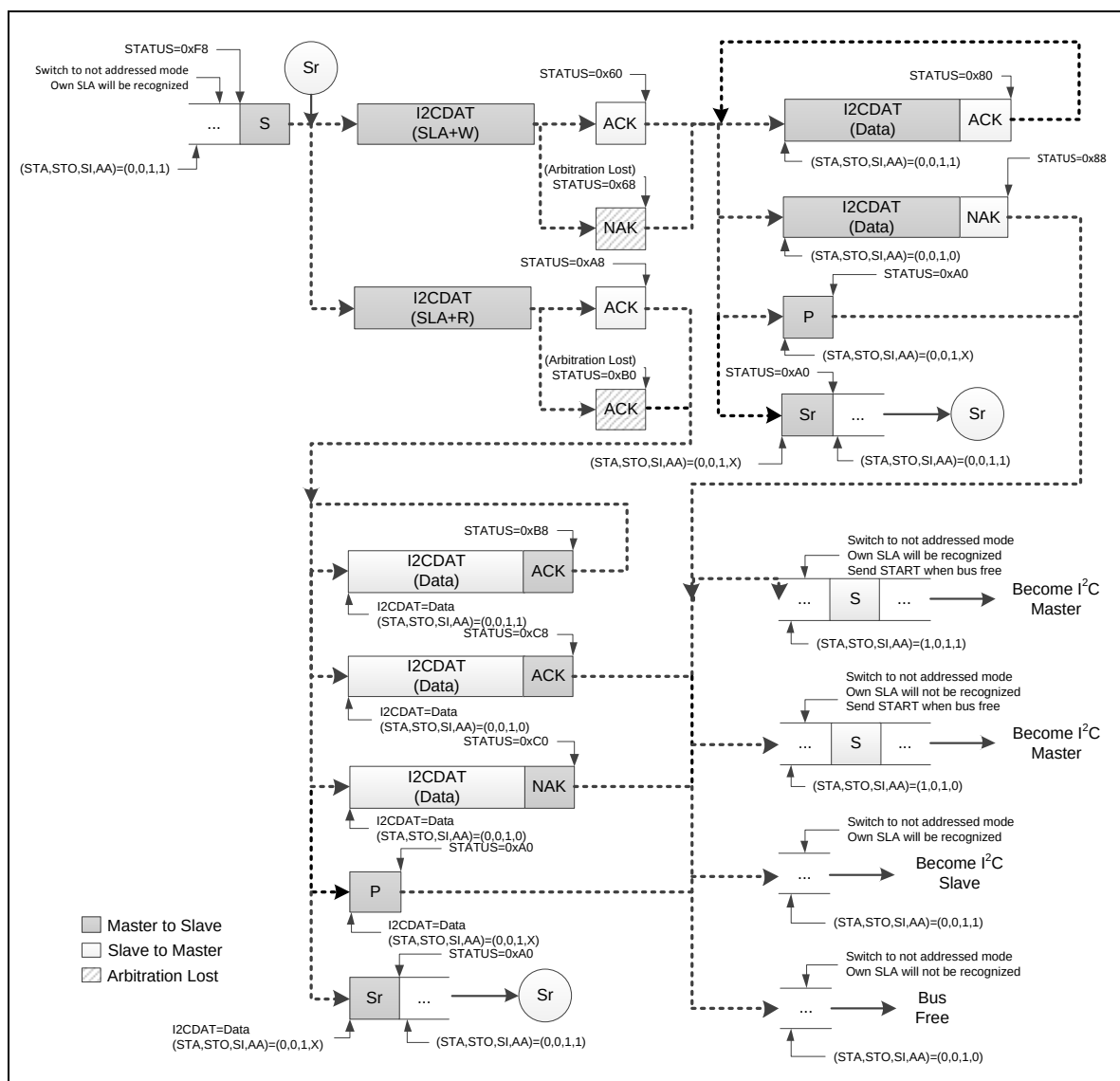


Figure 6-106 Save Mode Control Flow

If I²C is still receiving data in addressed Slave mode but got a STOP or Repeat START, the status code will be 0xA0. User could follow the action for status code 0x88 as shown in the above figure when getting 0xA0 status.

If I²C is still transmitting data in addressed Slave mode but got a STOP or Repeat START, the status code will be 0xA0. User could follow the action for status code 0xC8 as shown in the above figure when getting 0xA0 status.

Note: After slave gets status of 0x88, 0xC8, 0xC0 and 0xA0, slave can switch to not address mode and own SLA will not be recognized. If entering this status, slave will not receive any I²C signal or address from master. At this status, I²C should be reset to leave this status.

6.16.5.2.3 General Call (GC) Mode

If the GC(I2CADDRn [0]) bit is set, the I²C port hardware will respond to General Call address (0x00). User can clear GC bit to disable general call function. When the GC bit is set and the I²C in Slave mode, it can receive the general call address by 0x00 after master send general call address to I²C bus, then it will follow status of GC mode.

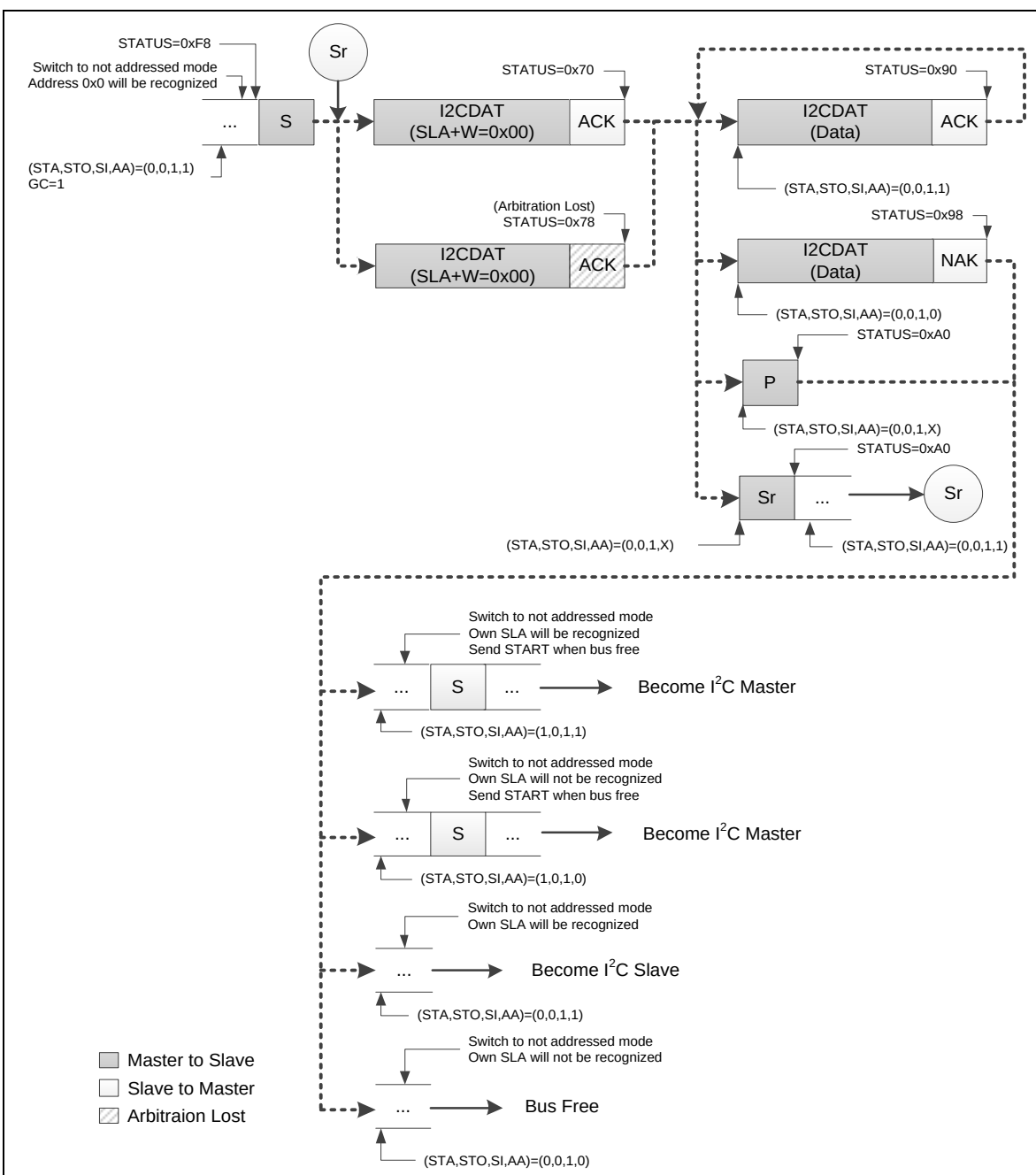


Figure 6-107 GC Mode

If I²C is still receiving data in GC mode but got a STOP or Repeat START, the status code will be 0xA0. User could follow the action for status code 0x98 in above figure when getting 0xA0 status.

Note: After slave gets status of 0x98 and 0xA0, slave can switch to not address mode and own SLA will not be recognized. If entering this status, slave will not receive any I²C signal or address from master. At this time, I²C controller should be reset to leave this status.

6.16.5.2.4 Multi-Master

In some applications, there are two or more masters on the same I²C bus to access slaves, and the masters may transmit data simultaneously. The I²C supports multi-master by including collision detection and arbitration to prevent data corruption.

If for some reason two masters initiate command at the same time, the arbitration procedure determines which master wins and can continue with the command. Arbitration is performed on the I2Cn_SDA signal while the I2Cn_SCL signal is high. Each master checks if the I2Cn_SDA signal on the bus corresponds to the generated I2Cn_SDA signal. If the I2Cn_SDA signal on the bus is low but it should be high, then this master has lost arbitration. The device that has lost arbitration can generate I2Cn_SCL pulses until the byte ends. The arbitration procedure can continue until all the data is transferred. This means that in multi-master system each master must monitor the bus for collisions and act accordingly.

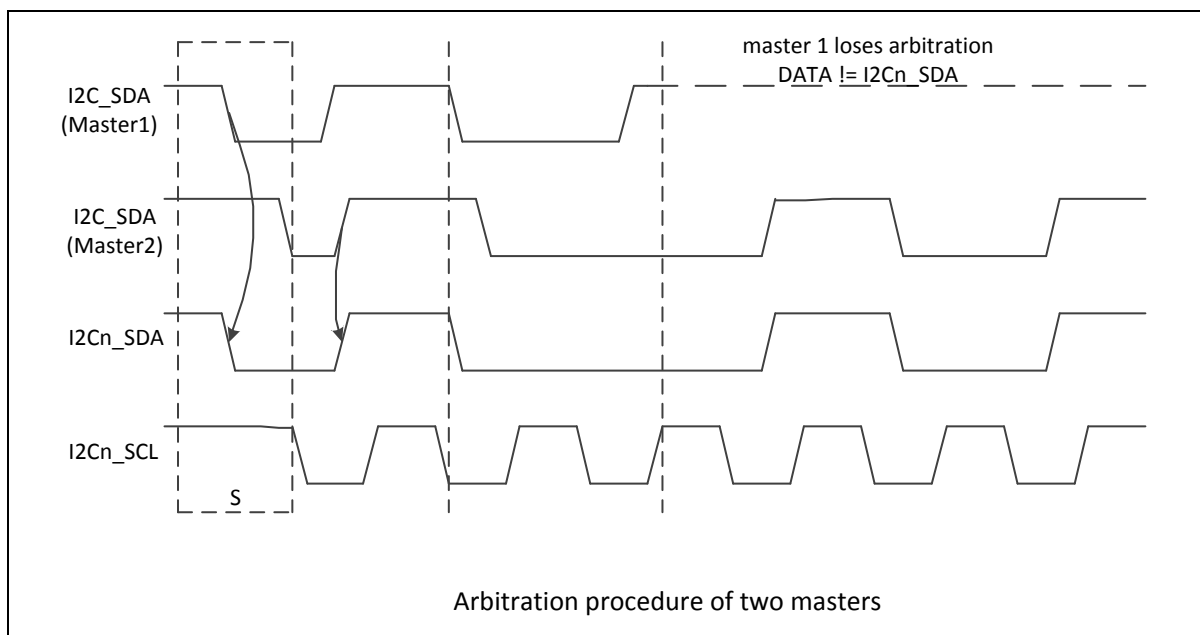


Figure 6-108 Arbitration Lost

- When I2CSTATUS = 0x38, an “Arbitration Lost” is received. Arbitration lost event maybe occur during the send START bit, data bits or STOP bit. User could set (STA, STO, SI, AA) = (1, 0, 1, X) to send START again when bus free, or set (STA, STO, SI, AA) = (0, 0, 1, X) back to not addressed Slave mode.
- When I2CSTATUS = 0x00, a “Bus Error” is received. To recover I²C bus from a bus error, STO(I2CON[4]) should be set and SI(I2CON[3]) should be cleared, and then STO(I2CON[4]) is cleared to release bus.
 - Set (STA, STO, SI, AA) = (0, 1, 1, X) to stop current transfer

- Set (STA, STO, SI, AA) = (0, 0, 1, X) to release bus

6.16.5.3 I²C Protocol Registers

To control I²C port through the following fifteen special function registers: I2CON (Control register), I2CSTATUS (Status register), I2CDAT (Data register), I2CADDRn (Address registers, n=0~3), I2CADMn (Address mask registers, n=0~3), I2CLK (Clock rate register), I2CTOC (Time-out counter register), I2CWKCON (Wake up control register), I2CWKSTS (Wake up status register).

6.16.5.3.1 Address Registers (I2CADDR)

The I²C port is equipped with four slave address registers, I2CADDRn (n=0~3). The contents of the register are irrelevant when I²C is in Master mode. In Slave mode, the bit field I2CADDRn[7:1] must be loaded with the chip's own slave address. The I²C hardware will react if the contents of I2CADDRn are matched with the received slave address.

The I²C ports support the "General Call" function. If the GC (I2CADDRn [0]) bit is set the I²C port hardware will respond to General Call address (0x00). Clear GC bit to disable general call function.

When the GC bit is set and the I²C is in Slave mode, it can receive the general call address by 0x00 after Master send general call address to I²C bus, then it will follow status of GC mode.

6.16.5.3.2 Slave Address Mask Registers (I2CADM)

The I²C bus controller supports multiple address recognition with four address mask registers I2CADMn (n=0~3). When the bit in the address mask register is set to 1, it means the received corresponding address bit is "Don't care". If the bit is set to 0, it means the received corresponding register bit should be exactly the same as address register.

6.16.5.3.3 Data Register (I2CDAT)

This register contains a byte of serial data to be transmitted or a byte which just has been received. The CPU can be read from or written to the 8-bit (I2CDAT [7:0]) directly while it is not in the process of shifting a byte. When I²C is in a defined state and the SI (I2CON[3]) is set, data in I2CDAT [7:0] remains stable. While data is being shifted out, data on the bus is simultaneously being shifted in; I2CDAT [7:0] always contains the last data byte presented on the bus.

The acknowledge bit is controlled by the I²C hardware and cannot be accessed by the CPU. Serial data is shifted into I2CDAT [7:0] on the rising edges of serial clock pulses on the I2Cn_SCL line. When a byte has been shifted into I2CDAT [7:0], the serial data is available in I2CDAT [7:0], and the acknowledge bit (ACK or NACK) is returned by the control logic during the ninth clock pulse. In order to monitor bus status while sending data, the bus data will be shifted to I2CDAT[7:0] when sending I2CDAT[7:0] to bus. In the case of sending data, serial data bits are shifted out from I2CDAT [7:0] on the falling edge of I2Cn_SCL clocks, and is shifted to I2CDAT [7:0] on the rising edge of I2Cn_SCL clocks.

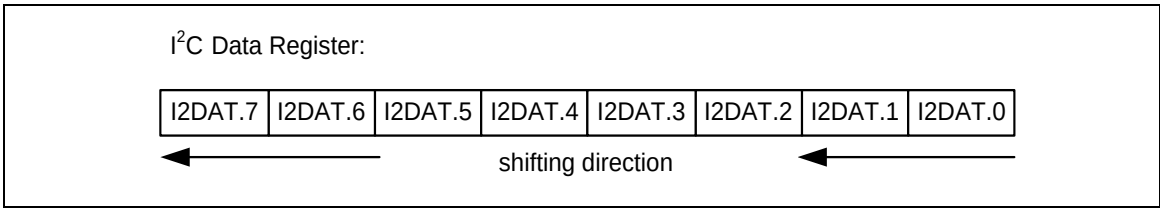


Figure 6-109 I²C Data Shifting Direction

6.16.5.3.4 Control Register (I2CON)

The CPU can be read from and written to I2CON register directly. When the I²C port is enabled by setting ENS1 (I2CON [6]) to high, the internal states will be controlled by I2CON and I²C logic hardware.

There are two bits are affected by hardware: the SI(I2CON[3]) bit is set when the I²C hardware requests a serial interrupt, and the STO bit is cleared when a STOP condition is present on the bus. The STO(I2CON[4]) bit is also cleared when ENS1(I2CON[6]) = 0.

Once a new status code is generated and stored in I2CSTATUS, the I²C Interrupt Flag bit SI will be set automatically. If the Enable Interrupt bit EI (I2CON [7]) is set at this time, the I²C interrupt will be generated. These bit fields I2CSTATUS[7:0] stores the internal state code, the content keeps stable until SI(I2CON[3]) is cleared by software.

6.16.5.3.5 Status Register (I2CSTATUS)

I2CSTATUS [7:0] is an 8-bit read-only register. The bit fields I2CSTATUS [7:0] contains the status code and there are 26 possible status codes. All states are listed in 0 when I2CSTATUS [7:0] is 0xF8, no serial interrupt is requested. All other I2CSTATUS [7:0] values correspond to the defined I²C states. When each of these states is entered, a status interrupt is requested (SI (I2CON[3]) = 1). A valid status code is present in I2CSTATUS[7:0] one cycle after SI set by hardware and is still present one cycle after SI reset by software.

In addition, the state 0x00 stands for a Bus Error, which occurs when a START or STOP condition is present at an incorrect position in the I²C format frame. A Bus Error may occur during the serial transfer of an address byte, a data byte or an acknowledge bit. To recover I²C from bus error, STO (I2CON[4]) should be set and SI(I2CON[3]) should be cleared to enter Not Addressed Slave mode. Then STO(I2CON[4]) is cleared to release bus and to wait for a new communication. The I²C bus cannot recognize stop condition during this action when a bus error occurs.

Master Mode		Slave Mode	
STATUS	Description	STATUS	Description
0x08	Start	0xA0	Slave Transmit Repeat Start or Stop
0x10	Master Repeat Start	0xA8	Slave Transmit Address ACK
0x18	Master Transmit Address ACK	0xB0	Slave Transmit Arbitration Lost
0x20	Master Transmit Address NACK	0xB8	Slave Transmit Data ACK
0x28	Master Transmit Data ACK	0xC0	Slave Transmit Data NACK
0x30	Master Transmit Data NACK	0xC8	Slave Transmit Last Data ACK

0x38	Master Arbitration Lost	0x60	Slave Receive Address ACK
0x40	Master Receive Address ACK	0x68	Slave Receive Arbitration Lost
0x48	Master Receive Address NACK	0x80	Slave Receive Data ACK
0x50	Master Receive Data ACK	0x88	Slave Receive Data NACK
0x58	Master Receive Data NACK	0x70	GC mode Address ACK
0x00	Bus error	0x78	GC mode Arbitration Lost
		0x90	GC mode Data ACK
		0x98	GC mode Data NACK
0xF8	Bus Released Note: Status "0xF8" exists in both master/slave modes, and it won't raise interrupt.		

Table 6-23 I²C Status Code Description

6.16.5.3.6 Clock Baud Rate Bits (I2CLK)

The data baud rate of I²C is determined by I2CLK (I2CLK[7:0]) when I²C is in Master Mode, and it is not necessary in a Slave mode. In the Slave mode, I²C will automatically synchronize it with any clock frequency from master I²C device.

The data baud rate of I²C setting is Data Baud Rate of I²C = (system clock) / (4x (I2CLK [7:0] + 1)). If system clock = 16 MHz, the I2CLK [7:0] = 40 (0x28), the data baud rate of I²C = 16 MHz / (4x (40 + 1)) = 97.5 Kbits/sec.

6.16.5.3.7 Time-out Counter Register (I2CTOC)

There is a 14-bit time-out counter which can be used to deal with the I²C bus hang-up. If the time-out counter is enabled, the counter starts up counting until it overflows (TIF (I2CTOC[0]) = 1) and generates I²C interrupt to CPU or stops counting by clearing ENTI(I2CTOC[2]) to 0. When time-out counter is enabled, writing 1 to the SI (I2CON[3]) flag will reset counter and re-start up counting after SI is cleared. If I²C bus hangs up, it causes the I2CSTATUS and flag SI (I2CON[3]) are not updated for a period, the 14-bit time-out counter may overflow and acknowledge CPU the I²C interrupt. Refer to the following figure for the 14-bit time-out counter. User may write 1 to clear TIF(I2C_TOC[0]) to 0.

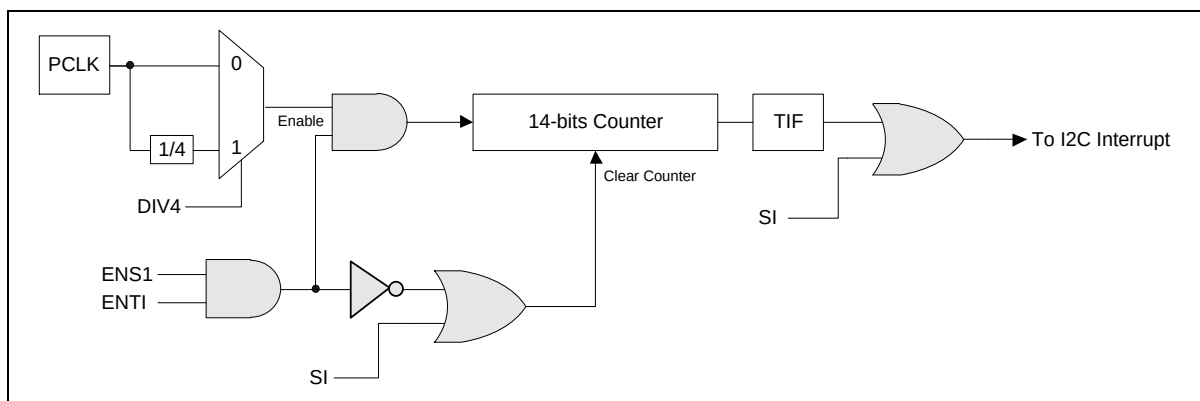


Figure 6-110 I²C Time-out Count Block Diagram

6.16.5.3.8 Wake-up Control Register (I2CWKUPCON)

When chip enters Power-down mode, other I²C master can wake up our chip by addressing our I²C device, user must configure the related setting before entering Sleep mode. When the chip is woken-up by address match with one of the four address register, the following data will be abandoned at this time.

6.16.5.3.9 Wake-up Status Register (I2CWKUPSTS)

When system is woken up by other I²C master device, WKUPIF(I2CWKUPSTS[0]) is set to indicate this event. User needs write "1" to clear this bit.

6.16.6 Example for Random Read on EEPROM

The following steps are used to configure the I²C0 related registers when using I²C to read data from EEPROM.

1. Set the multi-function pin in the "GPA_MFP" registers as I2C0_SCL and I2C0_SDA pins.

2. Enable I²C APB clock by setting I2C0_EN(APBCLK[8]).
3. Set I2C0_RST (IPRSTC2 [8]) = 1 to reset I²C controller then set I²C controller to normal operation by setting I2C0_RST(IPRSTC2 [8]) = 0;
4. Set ENS1(I2CON[6])=1 to enable I²C0 controller.
5. Write a divided value by setting I2CLK register for I²C clock rate.
6. Set SETENA(NVIC_IUSER[31:0])=0x00040000 in the "NVIC_IUSER" register to set I²C0 IRQ.
7. Set EI(I2CON[7])=1 to enable I²C0 Interrupt.
8. Set I²C0 address registers which are "I2CADDR0~I2CADDR3".

Random read operation is one of the methods of access EEPROM. The method allows the master to access any address of EEPROM space. The following figure shows the EEPROM random read operation.

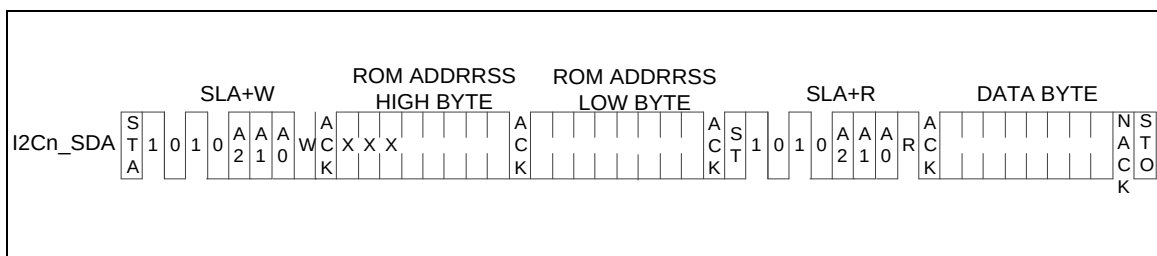


Figure 6-111 EEPROM Random Read

The following figure shows how to use I²C controller to implement the protocol of EEPROM random read.

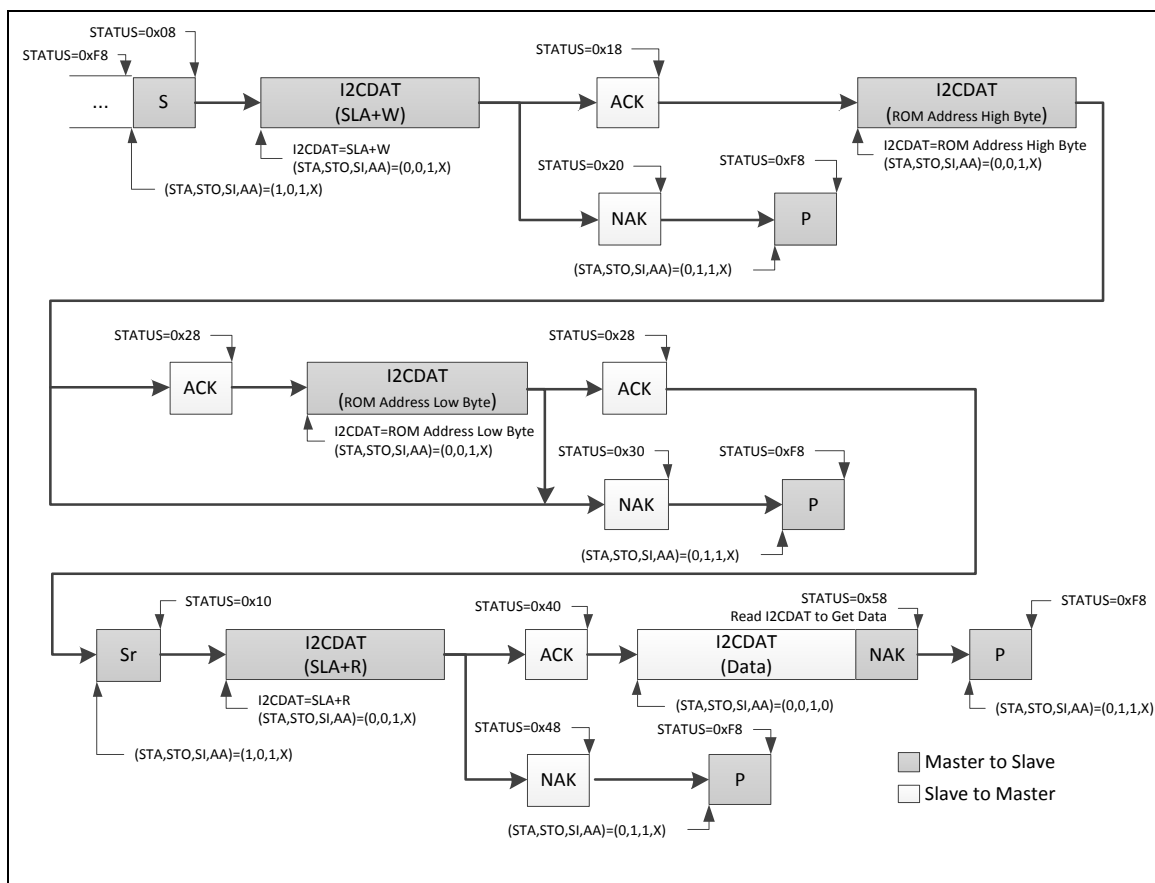


Figure 6-112 Protocol of EEPROM Random Read

The I²C controller sends START to bus to be a master. Then it sends a SLA+W (Slave address + Write bit) to EEPROM followed by two bytes data address to set the EEPROM address to read. Finally, a Repeat START followed by SLA+R is sent to read the data from EEPROM.

6.16.7 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
I²C Base Address: I2C0_BA = 0x4002_0000 I2C1_BA = 0x4001_2000				
I2CON n=0,1	I2Cn_BA+0x00	R/W	I ² C Control Register	0x0000_0000
I2CADDR0 n=0,1	I2Cn_BA+0x04	R/W	I ² C Slave Address Register0	0x0000_0000
I2CDAT n=0,1	I2Cn_BA+0x08	R/W	I ² C Data Register	0x0000_0000
I2CSTATUS n=0,1	I2Cn_BA+0x0C	R	I ² C Status Register	0x0000_00F8
I2CLK n=0,1	I2Cn_BA+0x10	R/W	I ² C Clock Divided Register	0x0000_0000
I2CTOC n=0,1	I2Cn_BA+0x14	R/W	I ² C Time-out Counter Register	0x0000_0000
I2CADDR1 n=0,1	I2Cn_BA+0x18	R/W	I ² C Slave Address Register1	0x0000_0000
I2CADDR2 n=0,1	I2Cn_BA+0x1C	R/W	I ² C Slave Address Register2	0x0000_0000
I2CADDR3 n=0,1	I2Cn_BA+0x20	R/W	I ² C Slave Address Register3	0x0000_0000
I2CADM0 n=0,1	I2Cn_BA+0x24	R/W	I ² C Slave Address Mask Register0	0x0000_0000
I2CADM1 n=0,1	I2Cn_BA+0x28	R/W	I ² C Slave Address Mask Register1	0x0000_0000
I2CADM2 n=0,1	I2Cn_BA+0x2C	R/W	I ² C Slave Address Mask Register2	0x0000_0000
I2CADM3 n=0,1	I2Cn_BA+0x30	R/W	I ² C Slave Address Mask Register3	0x0000_0000
I2CWKUPCON n=0,1	I2Cn_BA+0x3C	R/W	I ² C Wake-up Control Register	0x0000_0000
I2CWKUPSTS n=0,1	I2Cn_BA+0x40	R/W	I ² C Wake-up Status Register	0x0000_0000

6.16.8 Register Description

I²C Control Register (I2CON)

Register	Offset	R/W	Description	Reset Value
I2CON n=0,1	I2Cn_BA+0x00	R/W	I ² C Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
EI	ENS1	STA	STO	SI	AA	Reserved	

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	EI	Interrupt Enable Bit 0 = I ² C interrupt Disabled. 1 = I ² C interrupt Enabled.
[6]	ENS1	I²C Controller Enable Bit 0 = Disabled. 1 = Enabled. Set to enable I ² C serial function controller. When ENS1=1 the I ² C serial function enables. The multi-function pin function of I2Cn_SDA and I2Cn_SCL must set to I ² C function first.
[5]	STA	I²C START Control Setting STA to logic 1 to enter Master mode, the I ² C hardware sends a START or repeat START condition to bus when the bus is free.
[4]	STO	I²C STOP Control In Master mode, setting STO to transmit a STOP condition to bus then I ² C hardware will check the bus condition if a STOP condition is detected this bit will be cleared by hardware automatically. In a slave mode, setting STO resets I ² C hardware to the defined "not addressed" slave mode. This means it is NO LONGER in the slave receiver mode to receive data from the master transmit device.
[3]	SI	I²C Interrupt Flag When a new I ² C state is present in the I2CSTATUS register, the SI flag is set by hardware, and if bit EI (I2CON [7]) is set, the I ² C interrupt is requested. SI must be cleared by software. Clear SI by writing 1 to this bit.
[2]	AA	Assert Acknowledge Control When AA =1 prior to address or data received, an acknowledged (low level to I2Cn_SDA) will be returned during the acknowledge clock pulse on the I2Cn_SCL line when 1.) A slave is acknowledging the address sent from master, 2.) The receiver devices are acknowledging the data sent by transmitter. When AA=0 prior to address or data received,

		a Not acknowledged (high level to I2Cn_SDA) will be returned during the acknowledge clock pulse on the I2Cn_SCL line.
[1:0]	Reserved	Reserved.

I²C Data Register (I2CDAT)

Register	Offset	R/W	Description	Reset Value
I2CDAT n=0,1	I2Cn_BA+0x08	R/W	I ² C Data Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
I2CDAT[7:0]							

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	I2CDAT	I ² C Data Register This field is located with the 8-bit transferred data of I ² C serial port.

I²C Status Register (I2CSTATUS)

Register	Offset	R/W	Description	Reset Value
I2CSTATUS n=0,1	I2Cn_BA+0x0C	R	I ² C Status Register	0x0000_00F8

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
I2CSTATUS[7:0]							

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	I2CSTATUS	I²C Status Register There are 26 possible status codes. When I2CSTATUS contains 0xF8, no serial interrupt is requested. All other I2CSTATUS values correspond to defined I²C states. When each of these states is entered, a status interrupt is requested (SI (I2CON[3])= 1). A valid status code is present in I2CSTATUS one cycle after SI is set by hardware and is still present one cycle after SI has been reset by software. In addition, states 0x00 stands for a Bus Error. A Bus Error occurs when a START or STOP condition is present at an illegal position in the formation frame. Example of illegal position are during the serial transfer of an address byte, a data byte or an acknowledge bit.

I²C Clock Divided Register (I2CLK)

Register	Offset	R/W	Description	Reset Value
I2CLK n=0,1	I2Cn_BA+0x10	R/W	I ² C Clock Divided Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
I2CLK[7:0]							

Bits	Description	
[31:8]	Reserved	Reserved.
[7:0]	I2CLK	I²C Clock Divided Register The I ² C clock rate bits: Data Baud Rate of I ² C = (system clock) / (4x (I2CLK+1)). Note: The minimum value of I2CLK is 4.

I²C Time-out Counter Register (I2CTOC)

Register	Offset	R/W	Description	Reset Value
I2CTOC n=0,1	I2Cn_BA+0x14	R/W	I ² C Time-out Counter Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					ENTI	DIV4	TIF

Bits	Description	
[31:3]	Reserved	Reserved.
[2]	ENTI	Time-Out Counter Enable Bit 0 = Disabled. 1 = Enabled. When Enabled, the 14-bit time-out counter will start counting when SI(I2CON[3]) is clear. Setting flag SI SI(I2CON[3]) to high will reset counter and re-start up counting after SI SI(I2CON[3]) is cleared.
[1]	DIV4	Time-Out Counter Input Clock Divided By 4 0 = Disabled. 1 = Enabled. When Enabled, The time-out period is extend 4 times.
[0]	TIF	Time-Out Flag This bit is set by hardware when I ² C time-out happened and it can interrupt CPU if I ² C interrupt enable bit EI(I2CON[7]) is set to 1. Note: Write 1 to clear this bit.

I²C Slave Address Register (I2CADDRx)

Register	Offset	R/W	Description	Reset Value
I2CADDR0 n=0,1	I2Cn_BA+0x04	R/W	I ² C Slave Address Register0	0x0000_0000
I2CADDR1 n=0,1	I2Cn_BA+0x18	R/W	I ² C Slave Address Register1	0x0000_0000
I2CADDR2 n=0,1	I2Cn_BA+0x1C	R/W	I ² C Slave Address Register2	0x0000_0000
I2CADDR3 n=0,1	I2Cn_BA+0x20	R/W	I ² C Slave Address Register3	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
I2CADDR[7:1]							GC

Bits	Description	
[31:8]	Reserved	Reserved.
[7:1]	I2CADDR	I²C Address Register The content of this register is irrelevant when I ² C is in Master mode. In the slave mode, the seven most significant bits must be loaded with the chip's own address. The I ² C hardware will react if either of the address is matched.
[0]	GC	General Call Function 0 = General Call Function Disabled. 1 = General Call Function Enabled.

I²C Slave Address Mask Register (I2CADMx)

Register	Offset	R/W	Description	Reset Value
I2CADM0 n=0,1	I2Cn_BA+0x24	R/W	I ² C Slave Address Mask Register0	0x0000_0000
I2CADM1 n=0,1	I2Cn_BA+0x28	R/W	I ² C Slave Address Mask Register1	0x0000_0000
I2CADM2 n=0,1	I2Cn_BA+0x2C	R/W	I ² C Slave Address Mask Register2	0x0000_0000
I2CADM3 n=0,1	I2Cn_BA+0x30	R/W	I ² C Slave Address Mask Register3	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
I2CADM[7:1]							Reserved

Bits	Description
[31:8]	Reserved
[7:1]	I²C Address Mask Register 0 = Mask Disabled (the received corresponding register bit should be exact the same as address register.). 1 = Mask Enabled (the received corresponding address bit is don't care.). I ² C bus controllers support multiple address recognition with four address mask register. When the bit in the address mask register is set to one, it means the received corresponding address bit is don't-care. If the bit is set to zero, that means the received corresponding register bit should be exact the same as address register.
[0]	Reserved

I²C Wake-up Control Register (I2CWKUPCON)

Register	Offset	R/W	Description	Reset Value
I2CWKUPCON n=0,1	I2Cn_BA+0x3C	R/W	I ² C Wake-up Control Register	0x0000_0000

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

Bits	Description
[31:1]	Reserved
[0]	I²C Wake-Up Enable Bit 0 = I ² C wake-up function Disabled. 1 = I ² C wake-up function Enabled.

I²C Wake-up Status Register (I2C WKUPSTS)

Register	Offset	R/W	Description	Reset Value
I2C WKUPSTS n=0,1	I2Cn_BA+0x40	R/W	I ² C Wake-up Status Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	WKUPIF	I²C Wake-Up Flag 0 = Chip is not woken-up from Power-down mode by I ² C. 1 = Chip is woken-up from Power-down mode by I ² C. Note: Software can write 1 to clear this bit.

6.17 Serial Peripheral Interface (SPI)

6.17.1 Overview

The Serial Peripheral Interface (SPI) is a synchronous serial data communication protocol that operates in full duplex mode. Devices communicate in Master/Slave mode with the 4-wire bi-direction interface. The NuMicro™ NUC230/240 series contains up to four sets of SPI controllers performing a serial-to-parallel conversion on data received from a peripheral device, and a parallel-to-serial conversion on data transmitted to a peripheral device. Each set of SPI controller can be configured as a master or a slave device.

The SPI controller supports the variable bus clock function for special applications and 2-bit Transfer mode to connect 2 off-chip slave devices at the same time. This controller also supports the PDMA function to access the data buffer and also supports Dual I/O Transfer mode.

6.17.2 Features

- Up to four sets of SPI controllers
- Supports Master or Slave mode operation
- Supports 2-bit Transfer mode
- Supports Dual I/O Transfer mode
- Configurable bit length of a transaction word from 8 to 32 bits
- Provides separate 8-layer depth transmit and receive FIFO buffers
- Supports MSB first or LSB first transfer sequence
- Two slave select lines in Master mode
- Supports the Byte Reorder function
- Supports Byte or Word Suspend mode
- Variable output bus clock frequency in Master mode
- Supports PDMA transfer
- Supports 3-wire, no slave select signal, bi-direction interface

6.17.3 Block Diagram

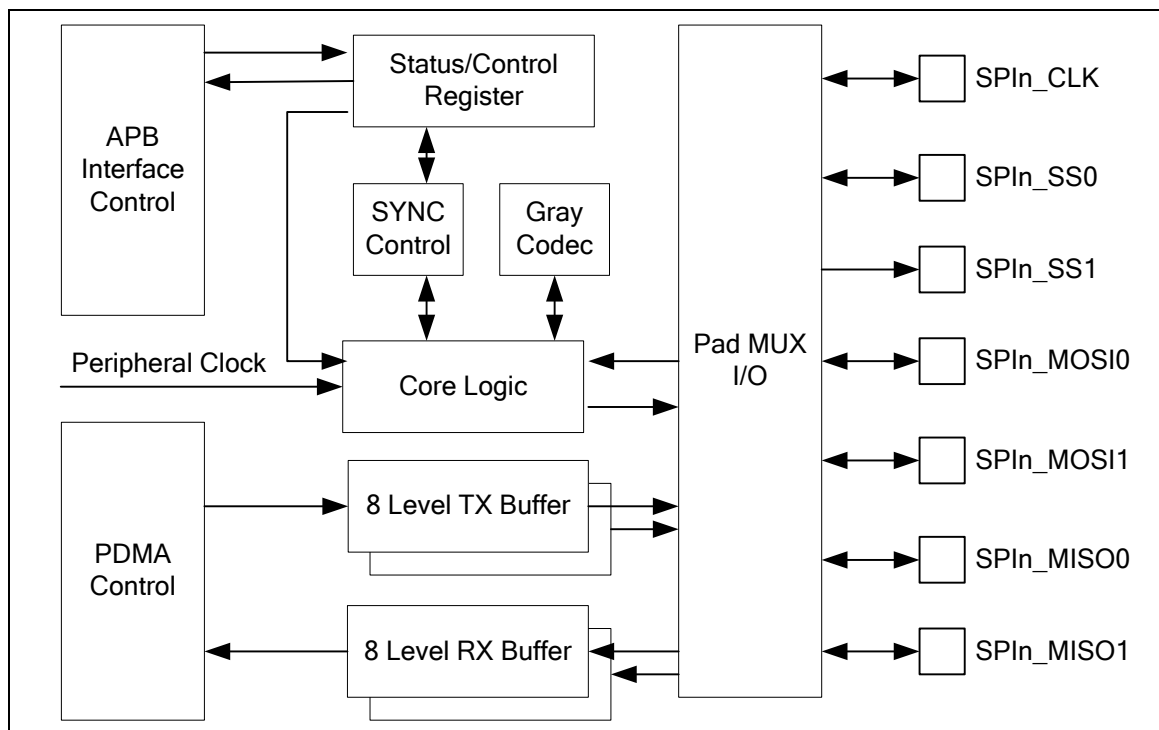


Figure 6-113 SPI Block Diagram

6.17.4 Basic Configuration

The basic configurations of SPI0 are as follows:

- SPI0 pin functions are configured in ALT_MFP, GPB_MFP and GPC_MFP registers.
- Select the source of SPI0 peripheral clock on SPI0_S (CLKSEL1[4]).
- Enable SPI0 peripheral clock on SPI0_EN (APBCLK[12]).
- Reset SPI0 controller on SPI0_RST (IPRSC2[12]).

The basic configurations of SPI1 are as follows:

- SPI1 pin functions are configured in ALT_MFP, GPB_MFP and GPC_MFP registers.
- Select the source of SPI1 peripheral clock on SPI1_S (CLKSEL1[5]).
- Enable SPI1 peripheral clock on SPI1_EN (APBCLK[13]).
- Reset SPI1 controller on SPI1_RST (IPRSC2[13]).

The basic configurations of SPI2 are as follows:

- SPI2 pin functions are configured in ALT_MFP, ALT_MFP1, GPA_MFP and GPD_MFP registers.
- Select the source of SPI2 peripheral clock on SPI2_S (CLKSEL1[6]).
- Enable SPI2 peripheral clock on SPI2_EN (APBCLK[14]).
- Reset SPI2 controller on SPI2_RST (IPRSC2[14]).

The basic configurations of SPI3 are as follows:

- SPI3 pin functions are configured in ALT_MFP, GPB_MFP and GPD_MFP registers.
- Select the source of SPI3 peripheral clock on SPI3_S (CLKSEL1[7]).
- Enable SPI3 peripheral clock on SPI3_EN (APBCLK[15]).
- Reset SPI3 controller on SPI3_RST (IPRSC2[15]).

6.17.5 Functional Description

6.17.5.1 Terminology

SPI Peripheral Clock and SPI Bus Clock

The SPI controller needs the SPI peripheral clock to drive the SPI logic unit to perform the data transfer. The SPI bus clock is the clock presented on SPIn_CLK pin.

The SPI peripheral clock rate is determined by the settings of clock source, BCn option and clock divisor. The SPIn_S bit of CLKSEL1 register determines the clock source of the SPI peripheral clock. The clock source can be HCLK or PLL output clock. Set the BCn bit of SPI_CNTRL2 register to 0 for the compatible SPI clock rate calculation of previous products. DIVIDER (SPI_DIVIDER[7:0]) setting determines the divisor of the clock rate calculation.

In Master mode, if the variable clock function is disabled, the output frequency of the SPI bus clock output pin is equal to the SPI peripheral clock rate. In general, the SPI bus clock is denoted as SPI clock. In Slave mode, the SPI bus clock is provided by an off-chip master device. The SPI peripheral clock rate of slave device must be faster than the SPI bus clock rate of the master device connected together. The frequency of SPI peripheral clock cannot be faster than the APB clock rate regardless of Master or Slave mode.

Master/Slave Mode

The SPI controller can be set as Master or Slave mode by setting SLAVE (SPI_CNTRL[18]) to communicate with the off-chip SPI Slave or Master device. The application block diagrams in Master and Slave mode are shown below.

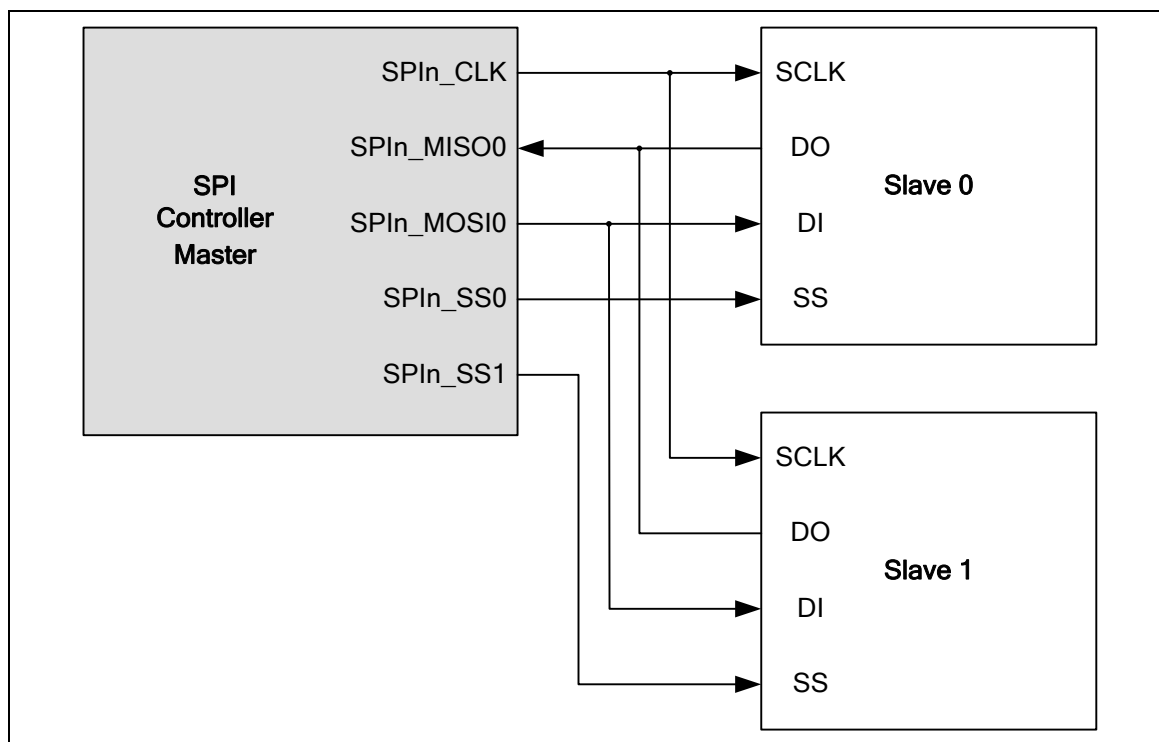


Figure 6-114 SPI Master Mode Application Block Diagram

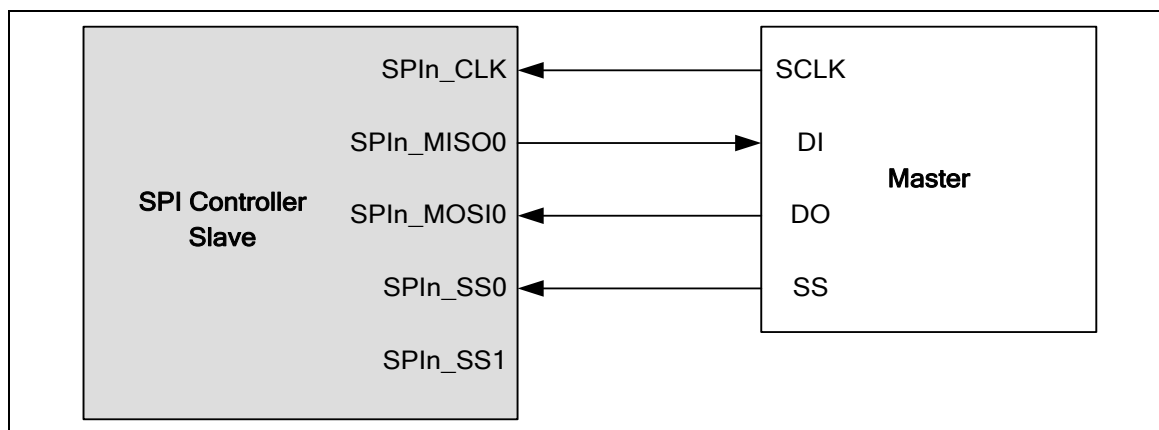


Figure 6-115 SPI Slave Mode Application Block Diagram

Clock Polarity

The CLKP (SPI_CTL[11]) defines the bus clock idle state. If CLKP = 1, the SPIn_CLK output is idle at high state, otherwise it is at low state if CLKP = 0.

Transmit/Receive Bit Length

The bit length of a transaction word is defined in TX_BIT_LEN bit field (SPI_CNTRL[7:3]). It can be configured up to 32-bit length in a transaction word for transmitting and receiving.

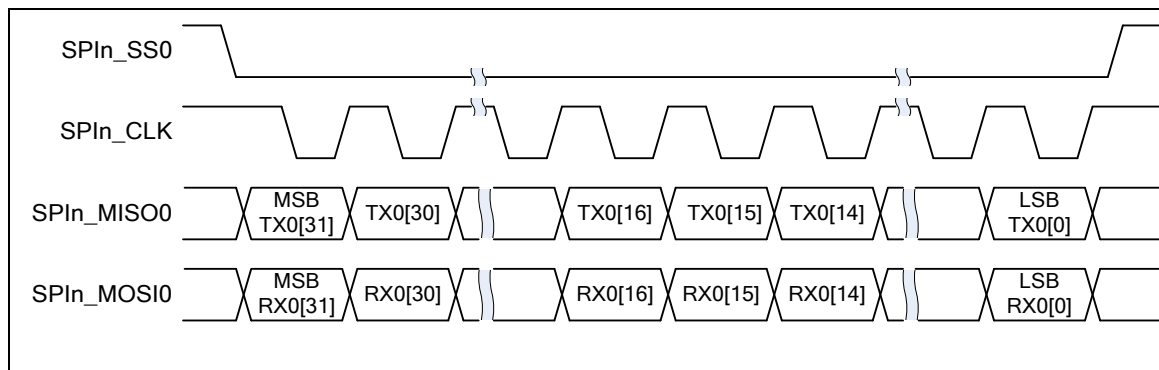


Figure 6-116 32-Bit in One Transaction

LSB/MSB First

LSB (SPI_CNTRL[10]) defines the bit transfer sequence in a transaction. If the LSB bit is set to 1, the transfer sequence is LSB first. The bit 0 will be transferred firstly. If the LSB bit is cleared to 0, the transfer sequence is MSB first.

Transmit Edge

TX_NEG (SPI_CNTRL[2]) defines the data transmitted out either on negative edge or on positive edge of SPI bus clock.

Receive Edge

RX_NEG (SPI_CNTRL[1]) defines the data received either on negative edge or on positive edge

of SPI clock.

Note: The settings of TX_NEG and RX_NEG are mutual exclusive. In other words, do not transmit and receive data on the same clock edge.

Word Suspend

SP_CYCLE (SPI_CNTRL[15:12]) provide a configurable suspend interval, 0.5 ~ 15.5 SPI clock periods, between two successive transaction words in Master mode. The definition of the suspend interval is the duration between the last clock edge of the preceding transaction word and the first clock edge of the following transaction word. The default value of SP_CYCLE is 0x3 (3.5 SPI bus clock cycles). This SP_CYCLE setting will not take effect to the word suspend interval if FIFO mode is disabled by software.

If both VARCLK_EN (SPI_CNTRL[23]) and FIFO (SPI_CNTRL[21]) bits are set to 1, the minimum word suspend period is $(6.5 + SP\_CYCLE) \times \text{SPI clock period}$.

Slave Selection

In Master mode, this SPI controller can drive up to two off-chip slave devices through the slave select output pins SPIn_SS0 and SPIn_SS1. In Slave mode, the off-chip master device drives the slave select signal from the SPIn_SS0 input pin to this SPI controller. In Master and Slave mode, the active state of slave select signal can be programmed to low or high active in SS_LVL (SPI_SSR[2]), and SS_LTRIG (SPI_SSR[4]) defines the slave select signal SPIn_SS0/1 is level-triggered or edge-triggered. The selection of trigger conditions depends on what type of peripheral slave/master device is connected.

In Slave mode, if the SS_LTRIG bit is configured as level trigger, the LTRIG_FLAG (SPI_SSR[5]) is used to indicate if the received bits among one transaction meets the requirement defined in TX_BIT_LEN (SPI_CNTRL[7:3]).

Level-trigger/Edge-trigger

In Slave mode, the slave select signal can be configured as level-trigger or edge-trigger. In edge-trigger, the data transfer starts from an active edge and ends on an inactive edge of the slave select signal. The unit-transfer interrupt flag (SPI_CNTRL[16]) will be set to 1 as an inactive edge is detected. If the master does not send an inactive edge to slave, the transfer procedure will not be completed and the unit transfer interrupt flag of slave will not be set. In level-trigger, the unit-transfer interrupt flag of slave will be set when one of the following two conditions occurs. The first condition is that if the number of transferred bits matches the settings of TX_BIT_LEN, the unit transfer interrupt flag of slave will be set. As to the second condition, if the master set the slave select pin to inactive level during the transfer is in progress, it will force slave device to terminate the current transfer no matter how many bits have been transferred and the unit transfer interrupt flag will be set. User can read the status of LTRIG_FLAG bit to check if the data has been completely transferred.

6.17.5.2 Automatic Slave Selection

In Master mode, if AUTOSS (SPI_SSR[3]) is set to 1, the slave select signals will be generated automatically and output to the SPIn_SS0 and SPIn_SS1 pins according to whether SSR[0] (SPI_SSR[0]) and SSR[1] (SPI_SSR[1]) are enabled or not. This means that the slave select signals, which are selected in SSR[1:0], will be asserted by the SPI controller when the SPI data transfer is started by setting the GO_BUSY bit (SPI_CNTRL[0]) and will be de-asserted after the data transfer is finished. If the AUTOSS bit is cleared, the slave select output signals will be asserted/de-asserted by setting/clearing the related bits of SPI_SSR[1:0]. The active state of the slave select output signals is specified in SS_LVL (SPI_SSR[2]).

In Master mode, if the value of SP_CYCLE[3:0] is less than 3 and the AUTOSS is set as 1, the slave select signal will be kept in active state between two successive transactions.

In Slave mode, to recognize the inactive state of the slave select signal, the inactive period of the slave select signal must be larger than or equal to 6 peripheral clock periods between two successive transactions.

6.17.5.3Variable Bus Clock Frequency

In Master mode, if VARCLK_EN (SPI_CNTRL[23]) is set to 1, the output of SPI clock can be programmed as variable frequency pattern. The SPI clock period of each cycle depends on the setting of the SPI_VARCLK register. When the variable clock function is enabled, the TX_BIT_LEN setting must be set as 0x10 to configure the data transfer as 16-bit transfer mode. The VARCLK[31] determines the clock period of the first clock cycle. If VARCLK[31] is 0, the first clock cycle depends on the DIVIDER setting; if it is 1, the first clock cycle depends on the DIVIDER2 setting. Two successive bits in VARCLK[30:1] defines one clock cycle. If the two successive bits are 00, the clock cycle depends on the DIVIDER setting; if they are 11, the clock cycle depends on the DIVIDER2 setting. The bit field VARCLK[30:29] defines the second clock cycle of SPI clock of a transaction, and the bit field VARCLK[28:27] defines the third clock cycle, and so on. The VARCLK[0] has no meaning. The following figure shows the timing relationship among the SPI bus clock, the VARCLK setting, the DIVIDER setting and the DIVIDER2 setting.

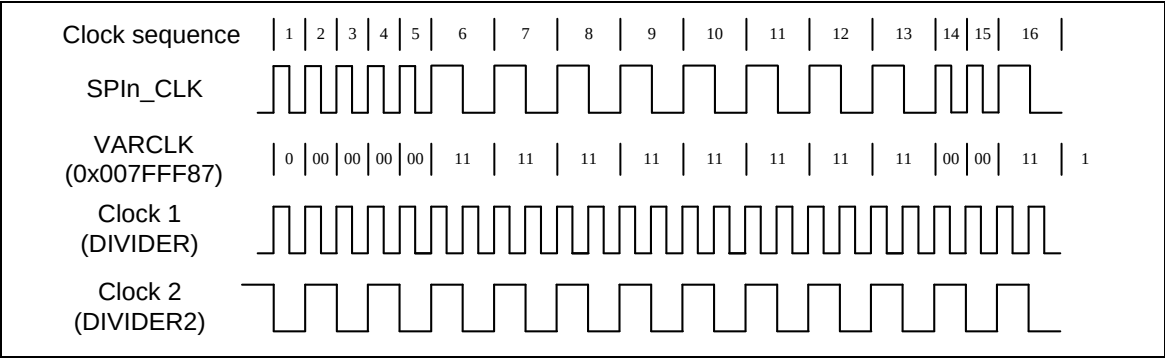


Figure 6-117 Variable Bus Clock Frequency

6.17.5.4Byte Reorder Function

When the transfer is set as MSB first (LSB = 0) and the REORDER bit is set to 1, the data stored in the TX buffer and RX buffer will be rearranged in the order as [Byte0, Byte1, Byte2, Byte3] in 32-bit Transfer mode (TX_BIT_LEN = 0). The sequence of transmitted/received data will be Byte0, Byte1, Byte2, and then Byte3. If the TX_BIT_LEN is set as 24-bit transfer mode, the data in TX buffer and RX buffer will be rearranged as [unknown byte, Byte0, Byte1, Byte2]. The SPI controller will transmit/receive data with the sequence of Byte0, Byte1 and then Byte2. Each byte will be transmitted/received with MSB first. The rule of 16-bit mode is the same as above. Byte Reorder function is only available when TX_BIT_LEN is configured as 16, 24, and 32 bits.

Note: The Byte Reorder function is not supported when the variable bus clock function is enabled.

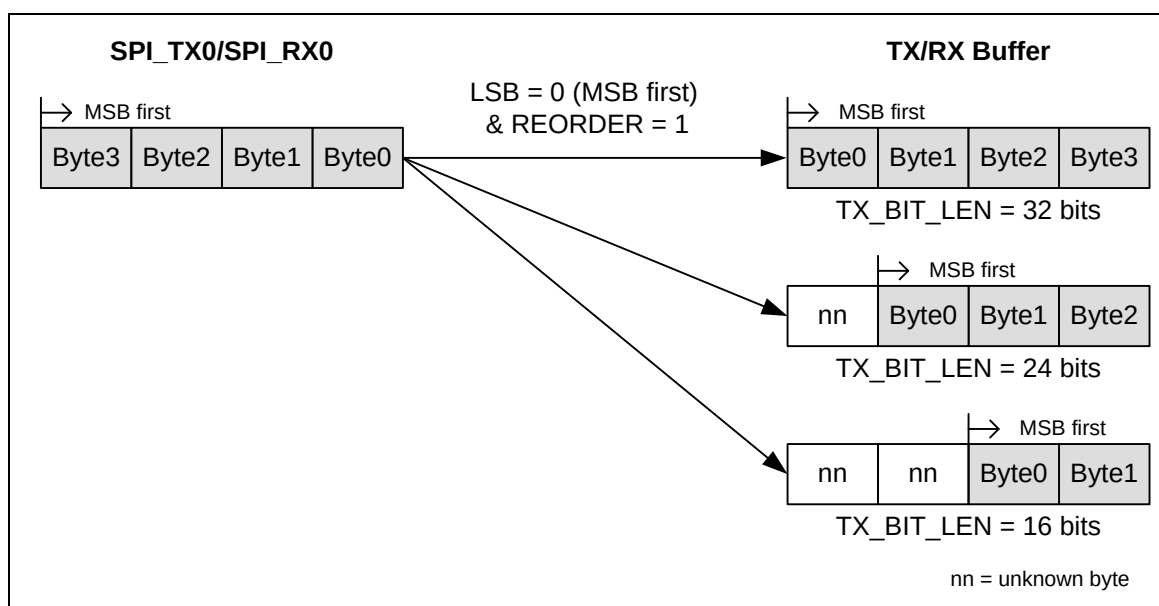


Figure 6-118 Byte Reorder Function

6.17.5.5 Byte Suspend Function

In Master mode, if REORDER (SPI_CNTRL[19]) is set to 1, a suspend interval of 0.5 ~ 15.5 SPI clock periods will be inserted by hardware between two successive bytes in a transaction word. Both settings of byte suspend interval and word suspend interval are configured in SP_CYCLE (SPI_CNTRL[15:12]).

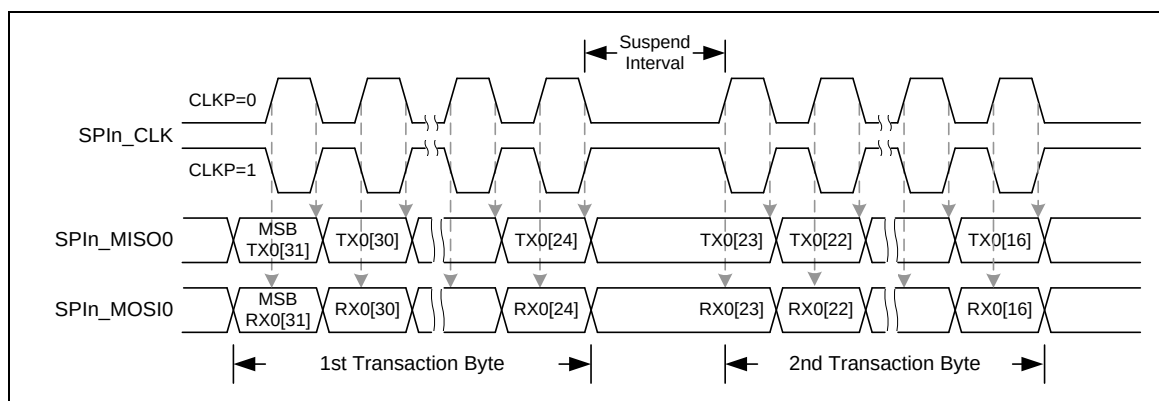


Figure 6-119 Timing Waveform for Byte Suspend

6.17.5.6 Slave 3-wire Mode

When NOSLVSEL (SPI_CNTRL2[8]) is set by software to enable the Slave 3-wire mode, the SPI controller can work with no slave select signal in Slave mode. The NOSLVSEL bit only takes effect in Slave mode. Only three pins, SPIn_CLK, SPIn_MISO0, and SPIn_MOSI0, are required to communicate with a SPI master. The SPIn_SS pin can be configured as a GPIO. When the NOSLVSEL bit is set to 1, the SPI slave will be ready to transmit/receive data after the GO_BUSY bit is set to 1. As the number of received bits meets the requirement which defined in TX_BIT_LEN (SPI_CNTRL[7:3]), the unit-transfer interrupt flag, IF (SPI_CNTRL[16]), will be set to 1.

Note: In Slave 3-wire mode, the SS_LTRIG (SPI_SSR[4]) should be set as 1.

6.17.5.72-bit Transfer Mode

The SPI controller also supports 2-bit Transfer mode when setting TWOB (SPI_CNTRL[22]) to 1. In 2-bit Transfer mode, the SPI controller performs full duplex data transfer. In other words, the 2-bit serial data can be transmitted and received simultaneously.

For example, in Master mode, the data stored in the SPI_TX0 and SPI_TX1 register will be transmitted through the SPIn_MOSI0 and SPIn_MOSI1 pin respectively. In the meanwhile, the SPI_RX0 and SPI_RX1 will store the data received from SPIn_MISO0 pin and SPIn_MISO1 pin respectively.

In Slave mode, the data stored in the SPI_TX0 and SPI_TX1 register will be transmitted through the SPIn_MISO0 and SPIn_MISO1 pin respectively. In the meanwhile, the SPI_RX0 and SPI_RX1 will store the data received from the SPIn_MOSI0 and SPIn_MOSI1 pin respectively.

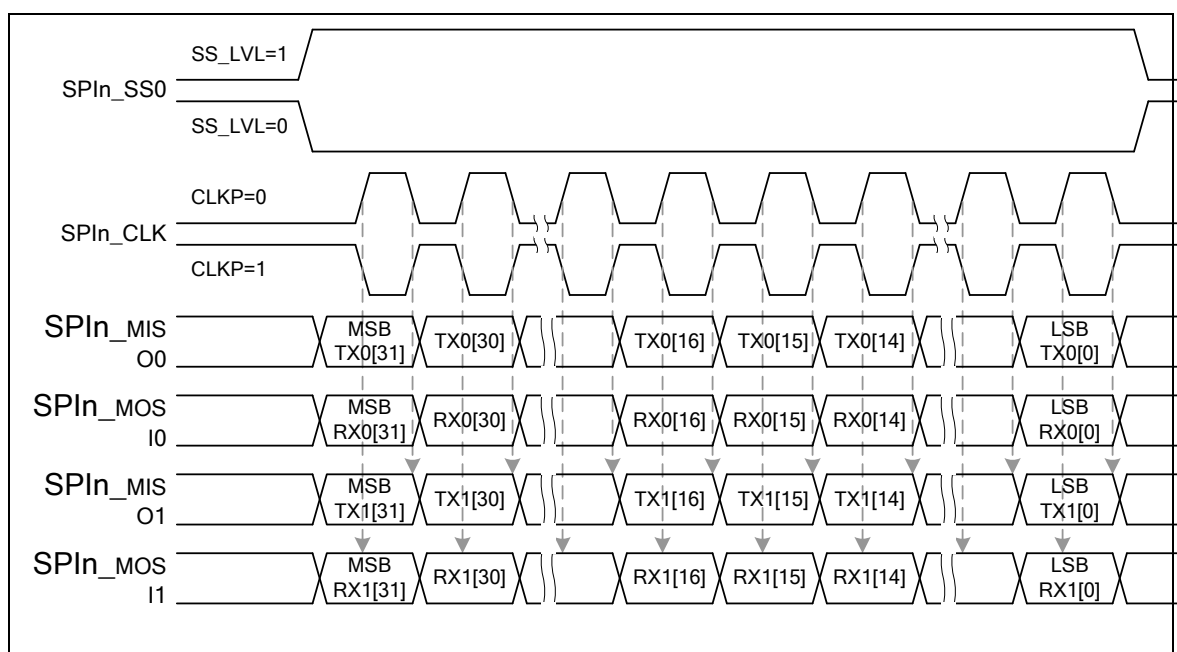


Figure 6-120 2-bit Transfer Mode (Slave Mode)

6.17.5.8Dual I/O Mode

The SPI controller also supports Dual I/O transfer when setting the DUAL_IO_EN (SPI_CNTRL2[13]) to 1. Many general SPI flashes support Dual I/O transfer. The DUAL_IO_DIR (SPI_CNTRL2[12]) is used to define the direction of the transfer data. When the DUAL_IO_DIR bit is set to 1, the controller will send the data to external device. When the DUAL_IO_DIR bit is set to 0, the controller will read the data from the external device. This function supports 8, 16, 24, and 32-bit data transfer.

The Dual I/O mode is not supported when the Slave 3-wire mode or the Byte Reorder function is enabled.

If both the DUAL_IO_EN and DUAL_IO_DIR bits are set as 1, the SPIn_MOSI0 is the even bit data output and the SPIn_MISO0 will be set as the odd bit data output. If the DUAL_IO_EN is set as 1 and DUAL_IO_DIR is set as 0, both the SPIn_MISO0 and SPIn_MOSI0 will be set as data input ports.

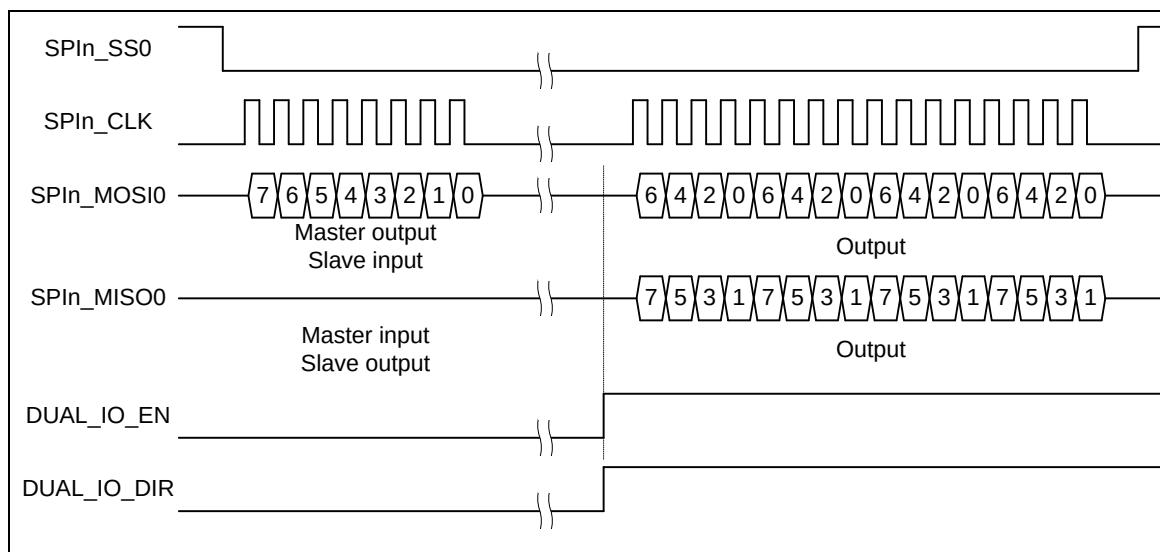


Figure 6-121 Bit Sequence of Dual Output Mode

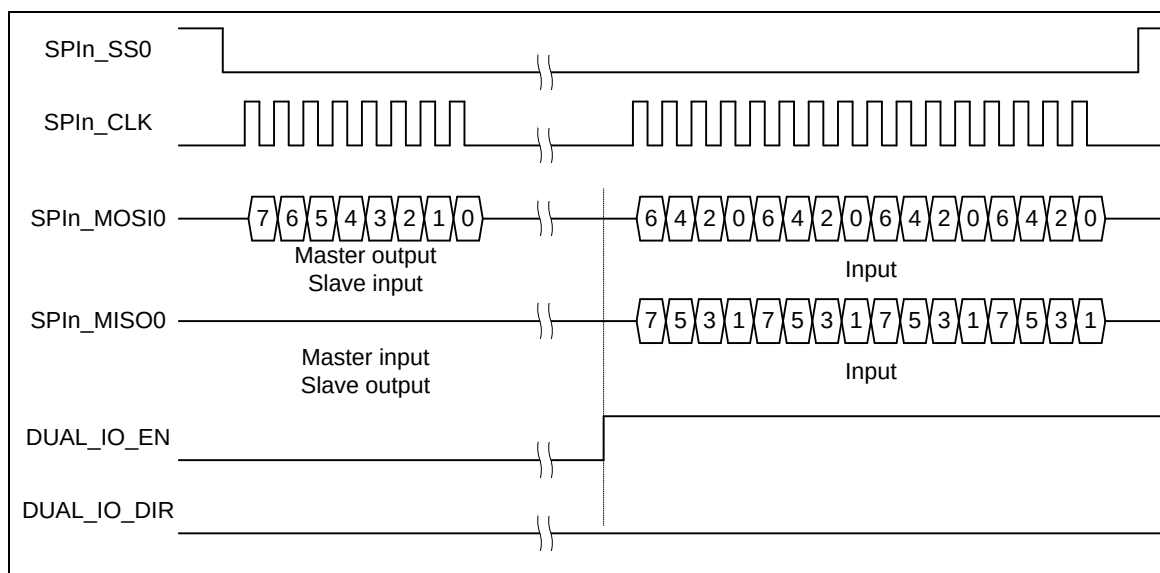


Figure 6-122 Bit Sequence of Dual Input Mode

6.17.5.9 FIFO Mode

The SPI controller supports FIFO mode when the FIFO bit in SPI_CNTRL[21] is set as 1. The SPI controllers equip with eight 32-bit wide transmit and receive FIFO buffers.

The transmit FIFO buffer is an 8-layer depth, 32-bit wide, first-in, first-out register buffer. Data can be written to the transmit FIFO buffer through software by writing the SPI_TX0 register. The data stored in the transmit FIFO buffer will be read and sent out by the transmission control logic. If the 8-layer transmit FIFO buffer is full, the TX_FULL bit will be set to 1. When the SPI transmission logic unit draws out the last datum of the transmit FIFO buffer, so that the 8-layer transmit FIFO buffer is empty, the TX_EMPTY bit will be set to 1. Notice that the TX_EMPTY bit is set to 1 while the last transaction is still in progress. In Master mode, both the GO_BUSY bit and TX_EMPTY bit should be checked by software to make sure whether the SPI is in idle or not.

The received FIFO buffer is also an 8-layer depth, 32-bit wide, first-in, first-out register buffer. The

receive control logic will store the received data to this buffer. The FIFO buffer data can be read from SPI_RX0 register by software. There are FIFO related status bits, like RX_EMPTY and RX_FULL, to indicate the current status of FIFO buffer.

In FIFO mode, the transmitting and receiving threshold can be set through software by setting the TX_THRESHOLD and RX_THRESHOLD settings. When the count of valid data stored in transmit FIFO buffer is less than or equal to TX_THRESHOLD setting, the TX_INTSTS bit will be set to 1. When the count of valid data stored in receive FIFO buffer is larger than RX_THRESHOLD setting, the RX_INTSTS bit will be set to 1.

In FIFO mode, 8 data can be written to the SPI transmit FIFO buffer by software in advance. When the SPI controller operates with FIFO mode, the GO_BUSY bit of SPI_CNTRL register will be controlled by hardware, and the content of SPI_CNTRL register should not be modified by software unless the FIFO bit is cleared to disable FIFO mode.

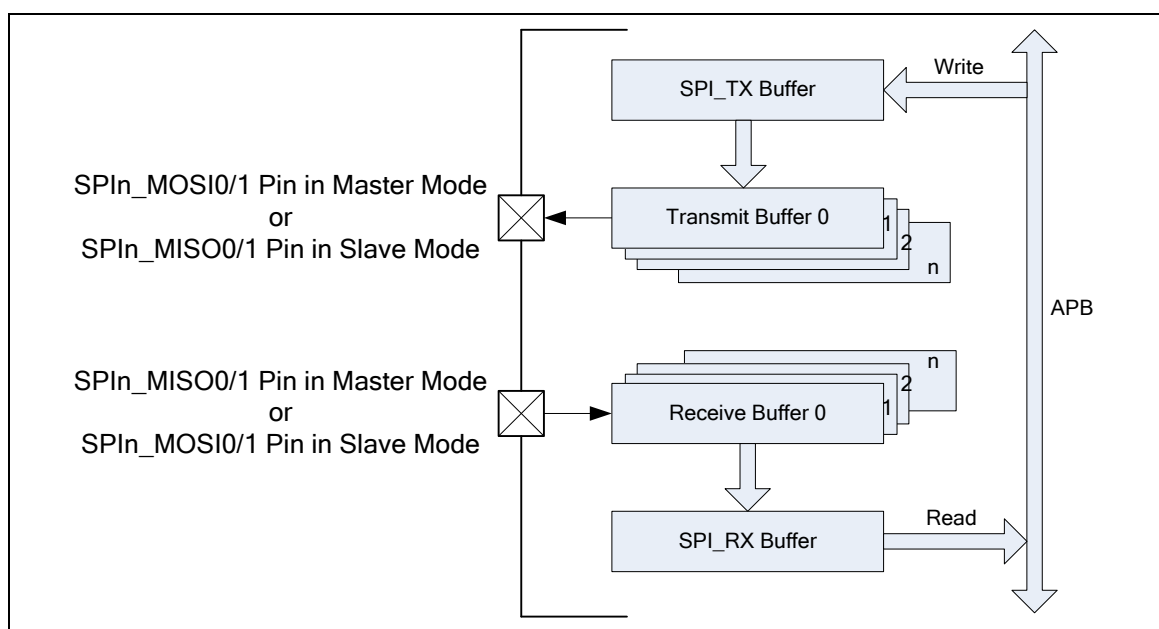


Figure 6-123 FIFO Mode Block Diagram

In Master mode, when the FIFO bit is set to 1 and the first datum is written to the SPI_TX0 register, the TX_EMPTY flag will be cleared to 0. The transmission immediately starts as long as the transmit FIFO buffer is not empty. User can write the next data into SPI_TX0 register immediately. The SPI controller will insert a suspend interval between two successive transactions in FIFO mode and the period of suspend interval is decided by the setting of SP_CYCLE (SPI_CNTRL [15:12]). User can write data into SPI_TX0 register as long as the TX_FULL flag is 0.

The subsequent transactions will be triggered automatically if the transmitted data are updated in time. If the SPI_TX0 register does not be updated after all data transfer are done, the transfer will stop.

In Master mode, during receiving operation, the serial data are received from SPIn_MISO0/1 pin and stored to receive FIFO buffer. The RX_EMPTY flag will be cleared to 0 while the receive FIFO buffer contains unread data. The received data can be read by software from SPI_RX0 register as long as the RX_EMPTY flag is 0. If the receive FIFO buffer contains 8 unread data, the RX_FULL flag will be set to 1. The SPI controller will stop receiving data until the SPI_RX0

register is read by software.

In Slave mode, when the FIFO bit is set as 1, the GO_BUSY bit will be set as 1 by hardware automatically.

In Slave mode, during transmission operation, when data is written to the SPI_TX0 register by software, the data will be loaded into transmit FIFO buffer and the TX_EMPTY flag will be set to 0. The transmission will start when the slave device receives clock signal from master. Data can be written to SPI_TX0 register as long as the TX_FULL flag is 0. After all data have been drawn out by the SPI transmission logic unit and the SPI_TX0 register is not updated by software, the TX_EMPTY flag will be set to 1.

In Slave mode, during receiving operation, the serial data is received from SPIn_MOSI0/1 pin and stored to SPI_RX0 register. The reception mechanism is similar to Master mode reception operation.

6.17.5.10 Interrupt

- SPI unit transfer interrupt

As the SPI controller finishes a unit transfer, the unit transfer interrupt flag IF (SPI_CNTRL[16]) will be set to 1. The unit transfer interrupt event will generate an interrupt to CPU if the unit transfer interrupt enable bit IE (SPI_CNTRL[17]) is set. The unit transfer interrupt flag can be cleared only by writing 1 to it.

- SPI Slave 3-wire mode start interrupt

In 3-wire mode, the slave 3-wire mode start interrupt flag, SLV_START_INTSTS, will be set to 1 when the slave senses the SPI clock signal. The SPI controller will issue an interrupt if the SSTA_INTEN is set to 1. If the count of the received bits is less than the setting of TX_BIT_LEN and there is no more SPI clock input over the expected time period which is defined by the user, the user can set the SLV_ABORT bit to abort the current transfer. The unit transfer interrupt flag, IF, will be set to 1 if the software set the SLV_ABORT bit.

- Receive FIFO time-out interrupt

In FIFO mode, there is a time-out function to inform user. If there is a received data in the FIFO and it is not read by software over 64 SPI peripheral clock periods in Master mode or over 576 SPI peripheral clock periods in Slave mode, it will send a time-out interrupt to the system if the time-out interrupt enable bit, FIFO_CTL[21], is set to 1.

- Transmit FIFO interrupt

In FIFO mode, if the valid data count of the transmit FIFO buffer is less than or equal to the setting value of TX_THRESHOLD, the transmit FIFO interrupt flag will be set to 1. The SPI controller will generate a transmit FIFO interrupt to the system if the transmit FIFO interrupt enable bit, SPI_FIFO_CTL[3], is set to 1.

- Receive FIFO interrupt

In FIFO mode, if the valid data count of the receive FIFO buffer is larger than the setting value of RX_THRESHOLD, the receive FIFO interrupt flag will be set to 1. The SPI controller will generate a receive FIFO interrupt to the system if the receive FIFO interrupt enable bit, SPI_FIFO_CTL[2], is set to 1.

6.17.6 Timing Diagram

The active state of slave select signal can be defined by setting the SS_LVL (SPI_SSR[2]) and SS_LTRIG (SPI_SSR[4]). The SPI clock which is in idle state can be configured as high or low state by setting the CLKP (SPI_CNTRL[11]). It also provides the bit length of a transaction word in TX_BIT_LEN (SPI_CNTRL[7:3]), and transmitting/receiving data from MSB or LSB first in LSB (SPI_CNTRL[10]). User can also select which edge of SPI clock to transmit/receive data in TX_NEG/RX_NEG (SPI_CNTRL[2:1]). Four SPI timing diagrams for master/slave operations and the related settings are shown below.

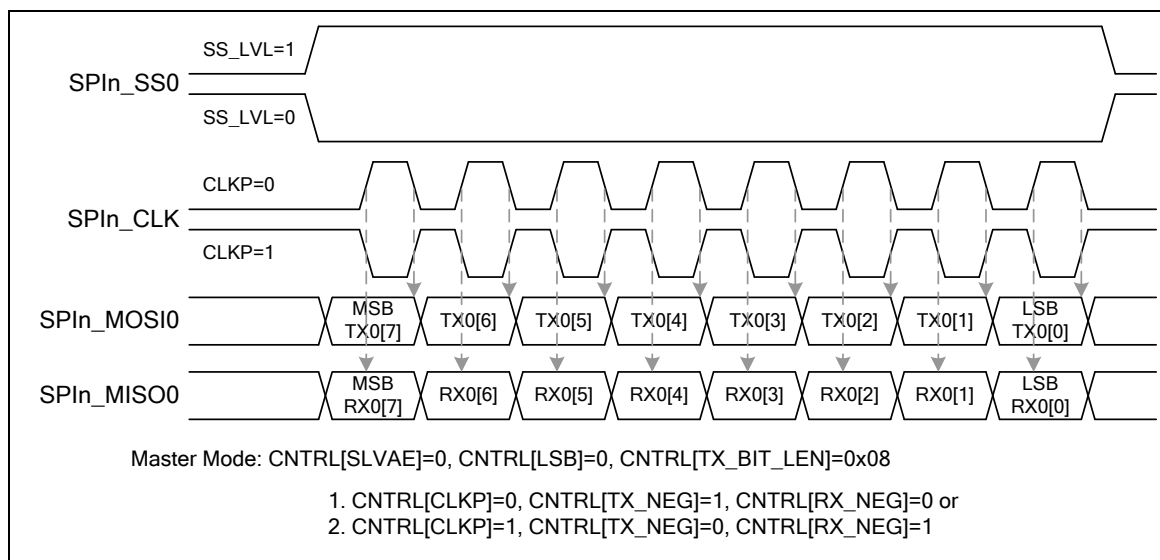


Figure 6-124 SPI Timing in Master Mode

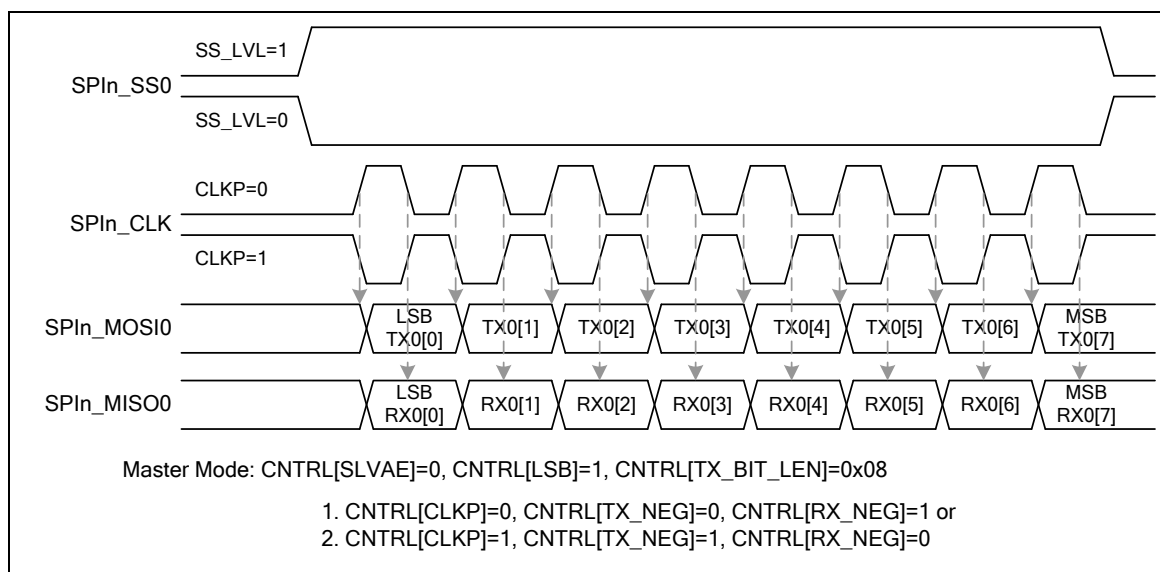


Figure 6-125 SPI Timing in Master Mode (Alternate Phase of SPI Bus Clock)

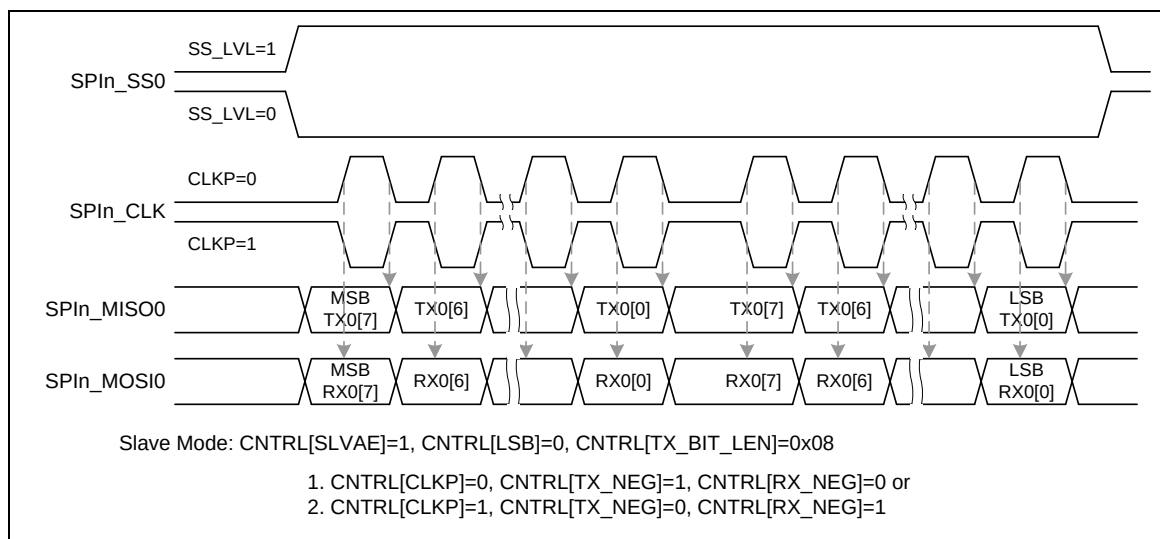


Figure 6-126 SPI Timing in Slave Mode

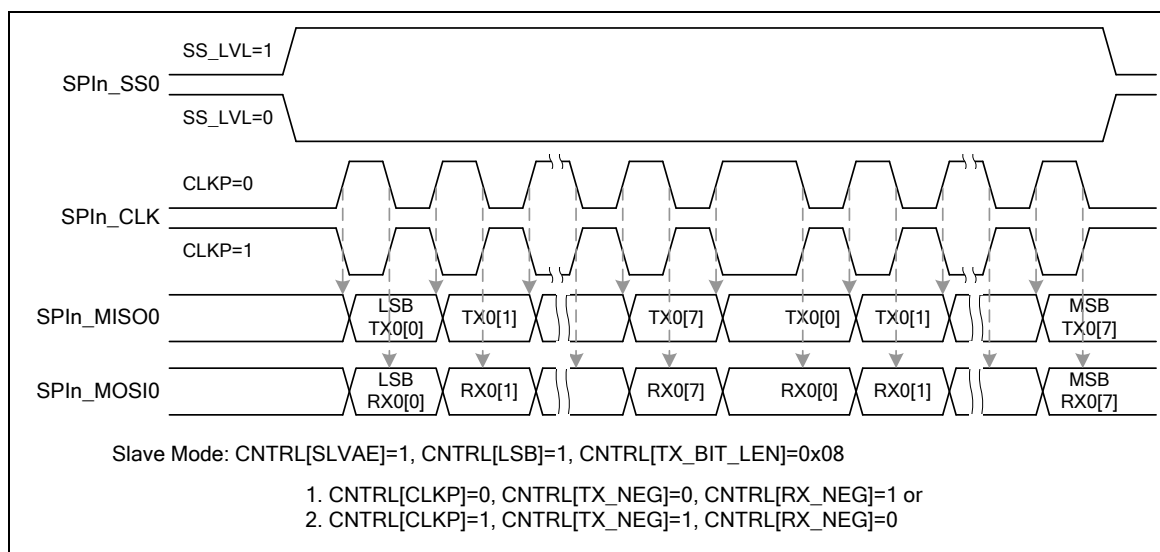


Figure 6-127 SPI Timing in Slave Mode (Alternate Phase of SPI Bus Clock)

6.17.7 Programming Examples

Example 1: The SPI controller is set as a master to access an off-chip slave device with the following specifications:

- Data bit is latched on positive edge of SPI clock.
- Data bit is driven on negative edge of SPI clock.
- Data is transferred from MSB first.
- SPI bus clock is idle at low state.
- Only one byte of data to be transmitted/received in a transaction.
- Uses the first SPI slave select pin to connect with an off-chip slave device. The slave select signal is active low.

The operation flow is as follows.

- 1) Set the DIVIDER (SPI_DIVIDER [7:0]) register to determine the output frequency of SPI clock.
- 2) Write the SPI_SSR register a proper value for the related settings of Master mode:
 1. Clear the Automatic Slave Selection bit, AUTOSS (SPI_SSR[3]), to 0.
 2. Select low level trigger output of slave select signal in the Slave Select Active Level bit, SS_LVL (SPI_SSR[2]), and Slave Select Level Trigger bit, SS_LTRIG (SPI_SSR[4]).
 3. Select slave select signal to be output active at the I/O pin by setting the Slave Select Register bit SSR[0] (SPI_SSR[0]) to active the off-chip slave device.
- 3) Write the related settings into the SPI_CNTRL register to control the SPI master actions
 1. Set this SPI controller as master device in SLAVE bit (SPI_CNTRL[18] = 0).
 2. Force the SPI clock idle state at low in CLKP bit (SPI_CNTRL[11] = 0).
 3. Select data transmitted at negative edge of SPI clock in TX_NEG bit (SPI_CNTRL[2] = 1).
 4. Select data latched at positive edge of SPI clock in RX_NEG bit (SPI_CNTRL[1] = 0).
 5. Set the bit length of word transfer as 8-bit in TX_BIT_LEN bit field. (SPI_CNTRL[7:3] = 0x08).
 6. Set MSB transfer first in MSB bit (SPI_CNTRL[10] = 0).
- 4) If this SPI master attempts to transmit (write) one byte data to the off-chip slave device, write the byte data that will be transmitted into the SPI_TX0 register.
- 5) If this SPI master just only attempts to receive (read) one byte data from the off-chip slave device and does not care what data will be transmitted, the SPI_TX0 register does not need to be updated by software.
- 6) Enable the GO_BUSY bit (SPI_CNTRL [0] = 1) to start the data transfer with the SPI interface.
- 7) Waiting for SPI interrupt (if the Interrupt Enable IE bit is set) or just polling the GO_BUSY bit till it is cleared to 0 by hardware automatically.
- 8) Read out the received one byte data from SPI_RX0[7:0].

- 9) Go to 4) to continue another data transfer or set SSR [0] to 0 to inactivate the off-chip slave device.

Example 2: The SPI controller is set as a slave device and connects with an off-chip master device. The off-chip master device communicates with the on-chip SPI slave controller through the SPI interface with the following specifications:

- Data bit is latched on positive edge of SPI clock.
- Data bit is driven on negative edge of SPI clock.
- Data is transferred from LSB first.
- SPI bus clock is idle at high state.
- Only one byte of data to be transmitted/received in a transaction.
- Slave select signal is high level trigger.

The operation flow is as follows.

- 1) Write the SPI_SSR register a proper value for the related settings of Slave mode:
Select high level and level trigger for the input of slave select signal by setting the Slave Select Active Level bit SS_LVL (SPI_SSR[2] = 1) and the Slave Select Level Trigger bit SS_LTRIG (SPI_SSR[4] = 1).
- 2) Write the related settings into the SPI_CNTRL register to control this SPI slave actions
 1. Set the SPI controller as slave device in SLAVE bit (SPI_CNTRL[18] = 1).
 2. Select the SPI clock idle state at high in CLKP bit (SPI_CNTRL[11] = 1).
 3. Select data transmitted at negative edge of SPI clock in TX_NEG bit (SPI_CNTRL[2] = 1).
 4. Select data latched at positive edge of SPI clock in RX_NEG bit (SPI_CNTRL[1] = 0).
 5. Set the bit length of word transfer as 8-bit in TX_BIT_LEN bit field (SPI_CNTRL[7:3] = 0x08).
 6. Set LSB transfer first in LSB bit (SPI_CNTRL[10] = 1).
- 3) If this SPI slave attempts to transmit (be read) one byte data to the off-chip master device, write the byte data that will be transmitted into the SPI_TX0 register.
- 4) If this SPI slave just only attempts to receive (be written) one byte data from the off-chip master device and does not care what data will be transmitted, the SPI_TX0 register does not need to be updated by software.
- 5) Enable the GO_BUSY bit (SPI_CNTRL[0] = 1) to wait for the slave select trigger input and SPI clock input from the off-chip master device to start the data transfer at the SPI interface.
- 6) Waiting for SPI interrupt (if the Interrupt Enable IE bit is set), or just polling the GO_BUSY bit till it is cleared to 0 by hardware automatically.
- 7) Read out the received one byte data from SPI_RX0[7:0].
- 8) Go to 3) to continue another data transfer or stop data transfer.

6.17.8 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
SPI Base Address: SPI0_BA = 0x4003_0000 SPI1_BA = 0x4003_4000 SPI2_BA = 0x4013_0000 SPI3_BA = 0x4013_4000				
SPI_CNTRL n=0,1,2,3	SPIn_BA+0x00	R/W	Control and Status Register	0x0500_3004
SPI_DIVIDER n=0,1,2,3	SPIn_BA+0x04	R/W	Clock Divider Register	0x0000_0000
SPI_SSR n=0,1,2,3	SPIn_BA+0x08	R/W	Slave Select Register	0x0000_0000
SPI_RX0 n=0,1,2,3	SPIn_BA+0x10	R	Data Receive Register 0	0x0000_0000
SPI_RX1 n=0,1,2,3	SPIn_BA+0x14	R	Data Receive Register 1	0x0000_0000
SPI_TX0 n=0,1,2,3	SPIn_BA+0x20	W	Data Transmit Register 0	0x0000_0000
SPI_TX1 n=0,1,2,3	SPIn_BA+0x24	W	Data Transmit Register 1	0x0000_0000
SPI_VARCLK n=0,1,2,3	SPIn_BA+0x34	R/W	Variable Clock Pattern Register	0x007F_FF87
SPI_DMA n=0,1,2,3	SPIn_BA+0x38	R/W	SPI DMA Control Register	0x0000_0000
SPI_CNTRL2 n=0,1,2,3	SPIn_BA+0x3C	R/W	Control and Status Register 2	0x0000_1000
SPI_FIFO_CTL n=0,1,2,3	SPIn_BA+0x40	R/W	SPI FIFO Control Register	0x4400_0000
SPI_STATUS n=0,1,2,3	SPIn_BA+0x44	R/W	SPI Status Register	0x0500_0000

6.17.9 Register Description

SPI Control and Status Register (SPI_CNTRL)

Register	Offset	R/W	Description	Reset Value
SPI_CNTRL	SPIn_BA+0x00	R/W	Control and Status Register	0x0500_3004

31	30	29	28	27	26	25	24
Reserved				TX_FULL	TX_EMPTY	RX_FULL	RX_EMPTY
23	22	21	20	19	18	17	16
VARCLK_EN	TWOB	FIFO	Reserved	REORDER	SLAVE	IE	IF
15	14	13	12	11	10	9	8
SP_CYCLE				CLKP	LSB	Reserved	
7	6	5	4	3	2	1	0
TX_BIT_LEN					TX_NEG	RX_NEG	GO_BUSY

Bits	Description
[31:28]	Reserved Reserved.
[27]	TX_FULL Transmit FIFO Buffer Full Indicator (Read Only) It is a mutual mirror bit of SPI_STATUS[27]. 0 = Transmit FIFO buffer is not full. 1 = Transmit FIFO buffer is full.
[26]	TX_EMPTY Transmit FIFO Buffer Empty Indicator (Read Only) It is a mutual mirror bit of SPI_STATUS[26]. 0 = Transmit FIFO buffer is not empty. 1 = Transmit FIFO buffer is empty.
[25]	RX_FULL Receive FIFO Buffer Full Indicator (Read Only) It is a mutual mirror bit of SPI_STATUS[25]. 0 = Receive FIFO buffer is not full. 1 = Receive FIFO buffer is full.
[24]	RX_EMPTY Receive FIFO Buffer Empty Indicator (Read Only) It is a mutual mirror bit of SPI_CNTRL[24]. 0 = Receive FIFO buffer is not empty. 1 = Receive FIFO buffer is empty.
[23]	VARCLK_EN Variable Clock Enable Bit (Master Only) 0 = SPI clock output frequency is fixed and decided only by the value of DIVIDER. 1 = SPI clock output frequency is variable. The output frequency is decided by the value of VARCLK, DIVIDER, and DIVIDER2. Note: When this VARCLK_EN bit is set to 1, the setting of TX_BIT_LEN must be programmed as 0x10 (16-bit mode).
[22]	TWOB 2-Bit Transfer Mode EnableBit 0 = 2-bit Transfer mode Disabled.

		1 = 2-bit Transfer mode Enabled. Note: When 2-bit Transfer mode is enabled, the serial transmitted 2-bit data are from SPI_TX1/0, and the received 2-bit data input are put in SPI_RX1/0.
[21]	FIFO	FIFO Mode EnableBit 0 = FIFO mode Disabled. 1 = FIFO mode Enabled. Note: - Before enabling FIFO mode, the other related settings should be set in advance. - In Master mode, if the FIFO mode is enabled, the GO_BUSY bit will be set to 1 automatically after writing data to the transmit FIFO buffer; the GO_BUSY bit will be cleared to 0 automatically when the SPI controller is in idle. If all data stored at transmit FIFO buffer are sent out, the TX_EMPTY bit will be set to 1 and the GO_BUSY bit will be cleared to 0. - After clearing this bit to 0, user must wait for at least 2 peripheral clock periods before setting this bit to 1 again.
[20]	Reserved	Reserved.
[19]	REORDER	Byte Reorder Function EnableBit 0 = Byte Reorder function Disabled. 1 = Byte Reorder function Enabled. A byte suspend interval will be inserted among each byte. The period of the byte suspend interval depends on the setting of SP_CYCLE. Note: - Byte Reorder function is only available if TX_BIT_LEN is defined as 16, 24, and 32 bits. - In Slave mode with level-trigger configuration, the slave select pin must be kept at active state during the byte suspend interval. - The Byte Reorder function is not supported when the variable bus clock function or Dual I/O mode is enabled.
[18]	SLAVE	Slave Mode EnableBit 0 = Master mode. 1 = Slave mode.
[17]	IE	Unit Transfer Interrupt EnableBit 0 = SPI unit transfer interrupt Disabled. 1 = SPI unit transfer interrupt Enabled.
[16]	IF	Unit Transfer Interrupt Flag 0 = No transaction has been finished since this bit was cleared to 0. 1 = SPI controller has finished one unit transfer. Note: This bit will be cleared by writing 1 to itself.
[15:12]	SP_CYCLE	Suspend Interval (Master Only) The four bits provide configurable suspend interval between two successive transmit/receive transaction in a transfer. The definition of the suspend interval is the interval between the last clock edge of the preceding transaction word and the first clock edge of the following transaction word. The default value is 0x3. The period of the suspend interval is obtained according to the following equation. $(SP\_CYCLE[3:0] + 0.5) * \text{period of SPI bus clock cycle}$ Example: SP_CYCLE = 0x0 0.5 SPI bus clock cycle. SP_CYCLE = 0x1 1.5 SPI bus clock cycles. SP_CYCLE = 0xE 14.5 SPI bus clock cycles. SP_CYCLE = 0xF 15.5 SPI bus clock cycles. If the variable clock function is enabled and the transmit FIFO buffer is not empty, the

		minimum period of suspend interval between the successive transactions is (6.5 + SP_CYCLE) * SPI bus clock cycle.
[11]	CLKP	Clock Polarity 0 = SPI bus clock is idle low. 1 = SPI bus clock is idle high.
[10]	LSB	Send LSB First 0 = The MSB, which bit of transmit/receive register depends on the setting of TX_BIT_LEN, is transmitted/received first. 1 = The LSB, bit 0 of the SPI TX0/1 register, is sent first to the SPI data output pin, and the first bit received from the SPI data input pin will be put in the LSB position of the RX register (bit 0 of SPI_RX0/1).
[9:8]	Reserved	Reserved.
[7:3]	TX_BIT_LEN	Transmit Bit Length This field specifies how many bits can be transmitted / received in one transaction. The minimum bit length is 8 bits and can up to 32 bits. TX_BIT_LEN = 0x08 8 bits. TX_BIT_LEN = 0x09 9 bits. TX_BIT_LEN = 0x1F 31 bits. TX_BIT_LEN = 0x00 32 bits.
[2]	TX_NEG	Transmit On Negative Edge 0 = Transmitted data output signal is changed on the rising edge of SPI bus clock. 1 = Transmitted data output signal is changed on the falling edge of SPI bus clock.
[1]	RX_NEG	Receive On Negative Edge 0 = Received data input signal is latched on the rising edge of SPI bus clock. 1 = Received data input signal is latched on the falling edge of SPI bus clock.
[0]	GO_BUSY	SPI Transfer Control Bit And Busy Status 0 = Data transfer stopped. 1 = In Master mode, writing 1 to this bit to start the SPI data transfer; in Slave mode, writing 1 to this bit indicates that the slave is ready to communicate with a master. If FIFO mode is disabled, during the data transfer, this bit keeps the value of 1. As the transfer is finished, this bit will be cleared automatically. Software can read this bit to check if the SPI is in busy status. In FIFO mode, this bit will be controlled by hardware. Software should not modify this bit. In Slave mode, this bit always returns 1 when this register is read by software. In Master mode, this bit reflects the busy or idle status of SPI. Note: 1. When FIFO mode is disabled, all configurations should be set before writing 1 to this GO_BUSY bit. 2. When FIFO mode is disabled and the software uses TX or RX PDMA function to transfer data, this bit will be cleared after the PDMA finishes the data transfer.

SPI Divider Register (SPI_DIVIDER)

Register	Offset	R/W	Description	Reset Value
SPI_DIVIDER	SPIn_BA+0x04	R/W	Clock Divider Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
DIVIDER2[7:0]							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
DIVIDER[7:0]							

Bits	Description
[31:24]	Reserved Reserved.
[23:16]	DIVIDER2 Clock Divider 2 Register (Master Only) The value in this field is the 2 nd frequency divider for generating the second clock of the variable clock function. The frequency is obtained according to the following equation: $f_{clock2} = \frac{f_{spi\_clk}}{(DIVIDER2 + 1) * 2}$ If the VARCLK_EN bit is cleared to 0, this setting is unmeaning.
[15:8]	Reserved Reserved.
[7:0]	DIVIDER Clock Divider 1 Register The value in this field is the frequency divider for generating the SPI peripheral clock, f_{spi_clk} , and the SPI bus clock of SPI master. The frequency is obtained according to the following equation. If the bit of BCn, SPI_CNTRL2[31], is set to 0, $f_{spi\_clk} = \frac{f_{system\_clock}}{(DIVIDER + 1) * 2}$ else if BCn is set to 1, $f_{spi\_clk} = \frac{f_{spi\_clock\_src}}{(DIVIDER + 1)}$ where $f_{spi\_clock\_src}$ is the SPI peripheral clock source, which is defined in the CLKSEL1 register.

SPI Slave Select Register (SPI_SSR)

Register	Offset	R/W	Description	Reset Value
SPI_SSR	SPIn_BA+0x08	R/W	Slave Select Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved		LTRIG_FLAG	SS_LTRIG	AUTOSS	SS_LVL	SSR	

Bits	Description	
[31:6]	Reserved	Reserved.
[5]	LTRIG_FLAG	Level Trigger Accomplish Flag In Slave mode, this bit indicates whether the received bit number meets the requirement or not after the current transaction done. 0 = Transferred bit length of one transaction does not meet the specified requirement. 1 = Transferred bit length meets the specified requirement which defined in TX_BIT_LEN. Note: This bit is READ only. As the GO_BUSY bit is set to 1 by software, the LTRIG_FLAG will be cleared to 0 after 4 SPI peripheral clock periods plus 1 system clock period. In FIFO mode, this bit has no meaning.
[4]	SS_LTRIG	Slave Select Level Trigger Enable Bit (Slave Only) 0 = Slave select signal is edge-trigger. This is the default value. The SS_LVL bit decides the signal is active after a falling-edge or rising-edge. 1 = Slave select signal is level-trigger. The SS_LVL bit decides the signal is active low or active high.
[3]	AUTOSS	Automatic Slave Select Function Enable Bit (Master Only) 0 = If this bit is cleared, slave select signals will be asserted/de-asserted by setting /clearing the corresponding bits of SPI_SSR[1:0]. 1 = If this bit is set, SPIn_SPISS0/1 signals will be generated automatically. It means that device/slave select signal, which is set in SPI_SSR[1:0], will be asserted by the SPI controller when transmit/receive is started, and will be de-asserted after each transmit/receive is finished.
[2]	SS_LVL	Slave Select Active Level This bit defines the active status of slave select signal (SPIn_SPISS0/1). 0 = The slave select signal SPIn_SPISS0/1 is active on low-level/falling-edge. 1 = The slave select signal SPIn_SPISS0/1 is active on high-level/rising-edge.
[1:0]	SSR	Slave Select Control Bits (Master Only) If AUTOSS bit is cleared, writing 1 to any bit of this field sets the proper SPIn_SPISS0/1 line to an active state and writing 0 sets the line back to inactive state. If the AUTOSS bit is set, writing 0 to any bit location of this field will keep the corresponding SPIn_SPISS0/1 line at inactive state; writing 1 to any bit location of this field will select appropriate SPIn_SPISS0/1 line to be automatically driven to active state for the

		duration of the transmit/receive, and will be driven to inactive state for the rest of the time. The active state of SPIn_SPISS0/1 is specified in SS_LVL. Note: SPIn_SPISS0 is defined as the slave select input in Slave mode.

SPI Data Receive Register (SPI_RX)

Register	Offset	R/W	Description	Reset Value
SPI_RX0	SPIn_BA+0x10	R	Data Receive Register 0	0x0000_0000
SPI_RX1	SPIn_BA+0x14	R	Data Receive Register 1	0x0000_0000

31	30	29	28	27	26	25	24
RX[31:24]							
23	22	21	20	19	18	17	16
RX[23:16]							
15	14	13	12	11	10	9	8
RX[15:8]							
7	6	5	4	3	2	1	0
RX[7:0]							

Bits	Description
[31:0]	Data Receive Register The data receive register holds the datum received from SPI data input pin. If FIFO mode is disabled, the last received data can be accessed through software by reading this register. If the FIFO bit is set as 1 and the RX_EMPTY bit, SPI_CNTRL[24] or SPI_STATUS[24], is not set to 1, the receive FIFO buffer can be accessed through software by reading this register. This is a read-only register.

SPI Data Transmit Register (SPI_TX)

Register	Offset	R/W	Description	Reset Value
SPI_TX0	SPIn_BA+0x20	W	Data Transmit Register 0	0x0000_0000
SPI_TX1	SPIn_BA+0x24	W	Data Transmit Register 1	0x0000_0000

31	30	29	28	27	26	25	24
TX[31:24]							
23	22	21	20	19	18	17	16
TX[23:16]							
15	14	13	12	11	10	9	8
TX[15:8]							
7	6	5	4	3	2	1	0
TX[7:0]							

Bits	Description
[31:0]	Data Transmit Register The data transmit registers hold the data to be transmitted in the next transfer. The number of valid bits depends on the setting of transmit bit length field of the SPI_CNTRL register. For example, if TX_BIT_LEN is set to 0x08, the bits TX[7:0] will be transmitted in next transfer. If TX_BIT_LEN is set to 0x00, the SPI controller will perform a 32-bit transfer. Note 1: When the SPI controller is configured as a slave device and FIFO mode is disabled, if the SPI controller attempts to transmit data to a master, the transmit data register should be updated by software before setting the GO_BUSY bit to 1. Note 2: In Master mode, SPI controller will start to transfer after 5 peripheral clock cycles since user wrote to this register.

SPI Variable Clock Pattern Register (SPI_VARCLK)

Register	Offset	R/W	Description	Reset Value
SPI_VARCLK	SPIn_BA+0x34	R/W	Variable Clock Pattern Register	0x007F_FF87

31	30	29	28	27	26	25	24
VARCLK[31:24]							
23	22	21	20	19	18	17	16
VARCLK[23:16]							
15	14	13	12	11	10	9	8
VARCLK[15:8]							
7	6	5	4	3	2	1	0
VARCLK[7:0]							

Bits	Description	
[31:0]	VARCLK	Variable Clock Pattern This register defines the clock pattern of the SPI transfer. If the variable clock function is disabled, this setting is unmeaning. Refer to the "Variable Clock Function" paragraph for more detail description.

SPI DMA Control Register (SPI_DMA)

Register	Offset	R/W	Description	Reset Value
SPI_DMA	SPIn_BA+0x38	R/W	SPI DMA Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved					PDMA_RST	RX_DMA_GO	TX_DMA_GO

Bits	Description	
[31:2]	Reserved	Reserved.
[2]	PDMA_RST	PDMA Reset 0 = No effect. 1 = Reset the PDMA control logic of the SPI controller. This bit will be cleared to 0 automatically.
[1]	RX_DMA_GO	Receive DMA Start Setting this bit to 1 will start the receive PDMA process. The SPI controller will issue request to PDMA controller automatically when the SPI receive buffer is not empty. This bit will be cleared to 0 by hardware automatically after PDMA transfer is done. If the software uses the receive PDMA function to access the received data of SPI and does not use the transmit PDMA function, the GO_BUSY bit should be set by software. Enabling FIFO mode is recommended if the software uses more than one PDMA channel to transfer data. In Slave mode and when FIFO mode is disabled, if the software only uses one PDMA channel for SPI receive PDMA function and the other PDMA channels are not in use, the minimal suspend interval between two successive transactions must be larger than (9 SPI slave peripheral clock periods + 4 APB clock periods) for Edge-trigger mode or (9.5 SPI slave peripheral clock periods + 4 APB clock periods) for Level-trigger mode.
[0]	TX_DMA_GO	Transmit DMA Start Setting this bit to 1 will start the transmit PDMA process. SPI controller will issue request to PDMA controller automatically. Hardware will clear this bit to 0 automatically after PDMA transfer done. If the SPI transmit PDMA function is used to transfer data, the GO_BUSY bit should not be set to 1 by software. The PDMA control logic of SPI controller will set it automatically whenever necessary. In Slave mode and when FIFO mode is disabled, the minimal suspend interval between two successive transactions must be larger than (8 SPI clock periods + 14 APB clock periods) for edge-trigger mode or (9.5 SPI clock periods + 14 APB clock periods) for level-trigger mode. If the 2-bit Transfer mode is enabled, additional 18 APB clock periods for the above conditions is required.

SPI Control and Status Register 2 (SPI_CNTRL2)

Register	Offset	R/W	Description	Reset Value
SPI_CNTRL2	SPIn_BA+0x3C	R/W	Control and Status Register 2	0x0000_1000

31	30	29	28	27	26	25	24
BCn	Reserved						
23	22	21	20	19	18	17	16
Reserved							SS_INT_OPT
15	14	13	12	11	10	9	8
Reserved		DUAL_IO_EN	DUAL_IO_DIR	SLV_START_INTSTS	SSTA_INTEN	SLV_ABORT	NOSLVSEL
7	6	5	4	3	2	1	0
Reserved							

Bits	Description
[31]	BCn SPI Peripheral Clock Backward Compatible Option 0 = Backward compatible clock configuration. 1 = Clock configuration is not backward compatible. Refer to the description of SPI_DIVIDER register for details.
[30:17]	Reserved Reserved.
[16]	SS_INT_OPT Slave Select Inactive Interrupt Option This setting is only available if the SPI controller is configured as level trigger slave device. 0 = As the slave select signal goes to inactive level, the IF bit will NOT be set to 1. 1 = As the slave select signal goes to inactive level, the IF bit will be set to 1.
[15:14]	Reserved Reserved.
[13]	DUAL_IO_EN Dual I/O Mode EnableBit 0 = Dual I/O mode Disabled. 1 = Dual I/O mode Enabled.
[12]	DUAL_IO_DIR Dual I/O Mode Direction Control 0 = Dual Input mode. 1 = Dual Output mode.
[11]	SLV_START_INTSTS Slave 3-Wire Mode Start Interrupt Status This bit indicates if a transaction has started in Slave 3-wire mode. It is a mutual mirror bit of SPI_STATUS[11]. 0 = Slave has not detected any SPI clock transition since the SSTA_INTEN bit was set to 1. 1 = A transaction has started in Slave 3-wire mode. It will be cleared automatically when a transaction is done or by writing 1 to this bit.
[10]	SSTA_INTEN Slave 3-Wire Mode Start Interrupt EnableBit Used to enable interrupt when the transfer has started in Slave 3-wire mode. If there is no transfer done interrupt over the time period which is defined by user

		after the transfer start, the user can set the SLV_ABORT bit to force the transfer done. 0 = Transaction start interrupt Disabled. 1 = Transaction start interrupt Enabled. It will be cleared to 0 as the current transfer is done or the SLV_START_INTSTS bit is cleared.
[9]	SLV_ABORT	Slave 3-Wire Mode Abort Control In normal operation, there is an interrupt event when the received data meet the required bits which defined in TX_BIT_LEN. If the received bits are less than the requirement and there is no more SPI clock input over the one transfer time in Slave 3-wire mode, the user can set this bit to force the current transfer done and then the user can get a transfer done interrupt event. Note: This bit will be cleared to 0 automatically by hardware after it is set to 1 by software.
[8]	NOSLVSEL	Slave 3-Wire Mode Enable Bit This is used to ignore the slave select signal in Slave mode. The SPI controller can work with 3-wire interface including SPIn_CLK, SPIn_MISO, and SPIn_MOSI. 0 = 4-wire bi-direction interface. 1 = 3-wire bi-direction interface. Note: In Slave 3-wire mode, the SS_LTRIG, SPI_SSR[4] will be set as 1 automatically.
[7:0]	Reserved	Reserved.

SPI FIFO Control Register (SPI_FIFO_CTL)

Register	Offset	R/W	Description	Reset Value
SPI_FIFO_CTL	SPIn_BA+0x40	R/W	SPI FIFO Control Register	0x4400_0000

31	30	29	28	27	26	25	24
Reserved	TX_THRESHOLD			Reserved	RX_THRESHOLD		
23	22	21	20	19	18	17	16
Reserved		TIMEOUT_INTEN	Reserved				
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved	RXOV_INTEN	Reserved		TX_INTEN	RX_INTEN	TX_CLR	RX_CLR

Bits	Description
[31]	Reserved
[30:28]	TX_THRESHOLD Transmit FIFO Threshold If the valid data count of the transmit FIFO buffer is less than or equal to the TX_THRESHOLD setting, the TX_INTSTS bit will be set to 1, else the TX_INTSTS bit will be cleared to 0.
[27]	Reserved
[26:24]	RX_THRESHOLD Receive FIFO Threshold If the valid data count of the receive FIFO buffer is larger than the RX_THRESHOLD setting, the RX_INTSTS bit will be set to 1, else the RX_INTSTS bit will be cleared to 0.
[23:22]	Reserved
[21]	TIMEOUT_INTEN Receive FIFO Time-Out Interrupt Enable Bit 0 = Time-out interrupt Disabled. 1 = Time-out interrupt Enabled.
[20:7]	Reserved
[6]	RXOV_INTEN Receive FIFO Overrun Interrupt Enable Bit 0 = Receive FIFO overrun interrupt Disabled. 1 = Receive FIFO overrun interrupt Enabled.
[5:4]	Reserved
[3]	TX_INTEN Transmit Threshold Interrupt Enable Bit 0 = TX threshold interrupt Disabled. 1 = TX threshold interrupt Enabled.
[2]	RX_INTEN Receive Threshold Interrupt Enable Bit 0 = RX threshold interrupt Disabled. 1 = RX threshold interrupt Enabled.

[1]	TX_CLR	Clear Transmit FIFO Buffer 0 = No effect. 1 = Clear transmit FIFO buffer. The TX_FULL flag will be cleared to 0 and the TX_EMPTY flag will be set to 1. This bit will be cleared to 0 by hardware after it is set to 1 by software.
[0]	RX_CLR	Clear Receive FIFO Buffer 0 = No effect. 1 = Clear receive FIFO buffer. The RX_FULL flag will be cleared to 0 and the RX_EMPTY flag will be set to 1. This bit will be cleared to 0 by hardware after it is set to 1 by software.

SPI Status Register (SPI_STATUS)

Register	Offset	R/W	Description	Reset Value
SPI_STATUS	SPIn_BA+0x44	R/W	SPI Status Register	0x0500_0000

31	30	29	28	27	26	25	24
TX_FIFO_COUNT				TX_FULL	TX_EMPTY	RX_FULL	RX_EMPTY
23	22	21	20	19	18	17	16
Reserved			TIMEOUT	Reserved			IF
15	14	13	12	11	10	9	8
RX_FIFO_COUNT				SLV_START_INTSTS	Reserved		
7	6	5	4	3	2	1	0
Reserved			TX_INTSTS	Reserved	RX_OVERRUN	Reserved	RX_INTSTS

Bits	Description
[31:28]	TX_FIFO_COUNT Transmit FIFO Data Count (Read Only) This bit field indicates the valid data count of transmit FIFO buffer.
[27]	TX_FULL Transmit FIFO Buffer Full Indicator (Read Only) It is a mutual mirror bit of SPI_CNTRL[27]. 0 = Transmit FIFO buffer is not full. 1 = Transmit FIFO buffer is full.
[26]	TX_EMPTY Transmit FIFO Buffer Empty Indicator (Read Only) It is a mutual mirror bit of SPI_CNTRL[26]. 0 = Transmit FIFO buffer is not empty. 1 = Transmit FIFO buffer is empty.
[25]	RX_FULL Receive FIFO Buffer Empty Indicator (Read Only) It is a mutual mirror bit of SPI_CNTRL[24]. 0 = Receive FIFO buffer is not empty. 1 = Receive FIFO buffer is empty.
[24]	RX_EMPTY Receive FIFO Buffer Empty Indicator (Read Only) It is a mutual mirror bit of SPI_CNTRL[24]. 0 = Receive FIFO buffer is not empty. 1 = Receive FIFO buffer is empty.
[23:21]	Reserved Reserved.
[20]	TIMEOUT Time-Out Interrupt Flag 0 = No receive FIFO time-out event. 1 = Receive FIFO buffer is not empty and no read operation on receive FIFO buffer over 64 SPI clock period in Master mode or over 576 SPI peripheral clock period in Slave mode. When the received FIFO buffer is read by software, the time-out status will be cleared automatically. Note: This bit will be cleared by writing 1 to itself.

[19:17]	Reserved	Reserved.
[16]	IF	SPI Unit Transfer Interrupt Flag It is a mutual mirror bit of SPI_CNTRL[16]. 0 = No transaction has been finished since this bit was cleared to 0. 1 = SPI controller has finished one unit transfer. Note: This bit will be cleared by writing 1 to itself.
[15:12]	RX_FIFO_COUNT	Receive FIFO Data Count (Read Only) This bit field indicates the valid data count of receive FIFO buffer.
[11]	SLV_START_INTSTS	Slave Start Interrupt Status It is used to dedicate if a transaction has started in Slave 3-wire mode. It is a mutual mirror bit of SPI_CNTRL2[11]. 0 = Slave has not detected any SPI clock transition since the SSTA_INTEN bit was set to 1. 1 = A transaction has started in Slave 3-wire mode. It will be cleared as a transaction is done or by writing 1 to this bit.
[10:5]	Reserved	Reserved.
[4]	TX_INTSTS	Transmit FIFO Threshold Interrupt Status (Read Only) 0 = The valid data count within the transmit FIFO buffer is larger than the setting value of TX_THRESHOLD. 1 = The valid data count within the transmit FIFO buffer is less than or equal to the setting value of TX_THRESHOLD. Note: If TX_INTEN = 1 and TX_INTSTS = 1, the SPI controller will generate a SPI interrupt request.
[3]	Reserved	Reserved.
[2]	RX_OVERRUN	Receive FIFO Overrun Status When the receive FIFO buffer is full, the follow-up data will be dropped and this bit will be set to 1. Note: This bit will be cleared by writing 1 to itself.
[1]	Reserved	Reserved.
[0]	RX_INTSTS	Receive FIFO Threshold Interrupt Status (Read Only) 0 = The valid data count within the Rx FIFO buffer is smaller than or equal to the setting value of RX_THRESHOLD. 1 = The valid data count within the receive FIFO buffer is larger than the setting value of RX_THRESHOLD. Note: If RX_INTEN = 1 and RX_INTSTS = 1, the SPI controller will generate a SPI interrupt request.

6.18 I²S Controller (I²S)

6.18.1 Overview

The I²S controller consists of I²S protocol to interface with external audio CODEC. Two 8-word depth FIFO for reading path and writing path respectively and is capable of handling 8-, 16-, 24- and 32-bit word sizes. PDMA controller handles the data movement between FIFO and memory.

6.18.2 Features

- Supports Master mode and Slave mode
- Capable of handling 8-, 16-, 24- and 32-bit word sizes
- Supports monaural and stereo audio data
- Supports I²S and MSB justified data format
- Provides two 8-word FIFO data buffers, one for transmitting and the other for receiving
- Supports PDMA transfer

6.18.3 Block Diagram

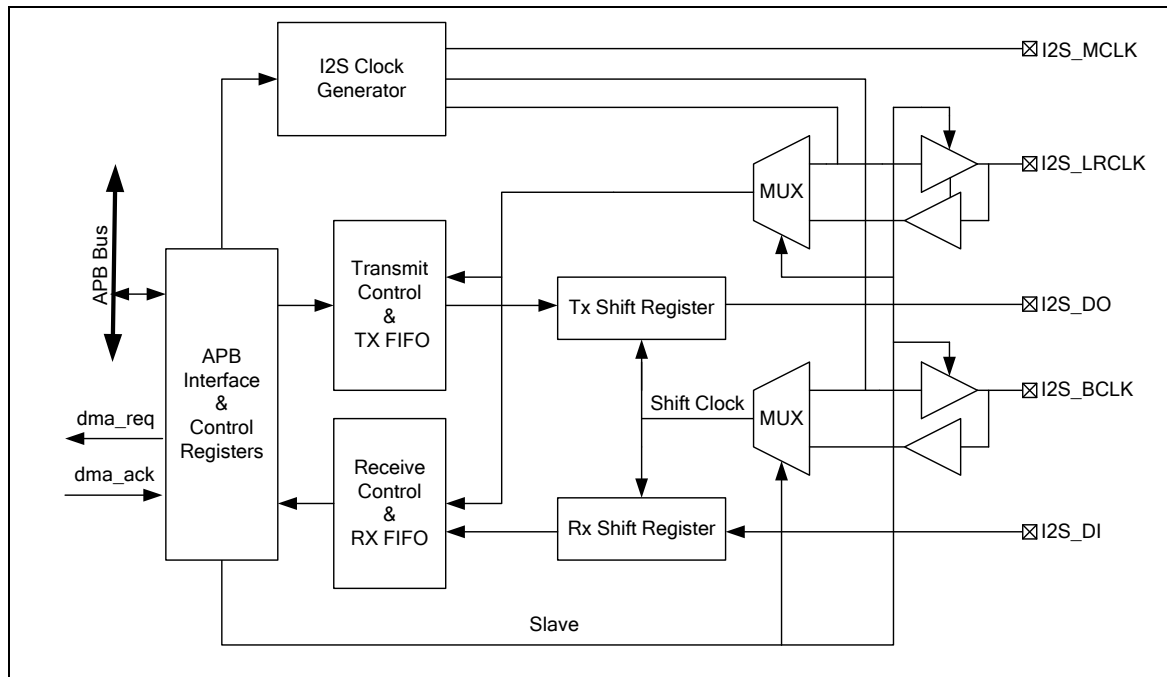


Figure 6-128 I²S Controller Block Diagram

6.18.4 Basic Configuration

The I²S pin functions are configured in GPA_MFP, GPC_MFP, ALT_MFP and ALT_MFP1 registers. The I²S peripheral clock can be enabled in I2S_EN (APBCLK[29]). The clock source is determined in I2S_S (CLKSEL2[1:0]).

6.18.5 Functional Description

6.18.5.1 I²S Clock

The I²S controller has four clock sources selected by I2S_S (CLKSEL2[1:0]). The I²S clock rate must be slower than or equal to system clock rate.

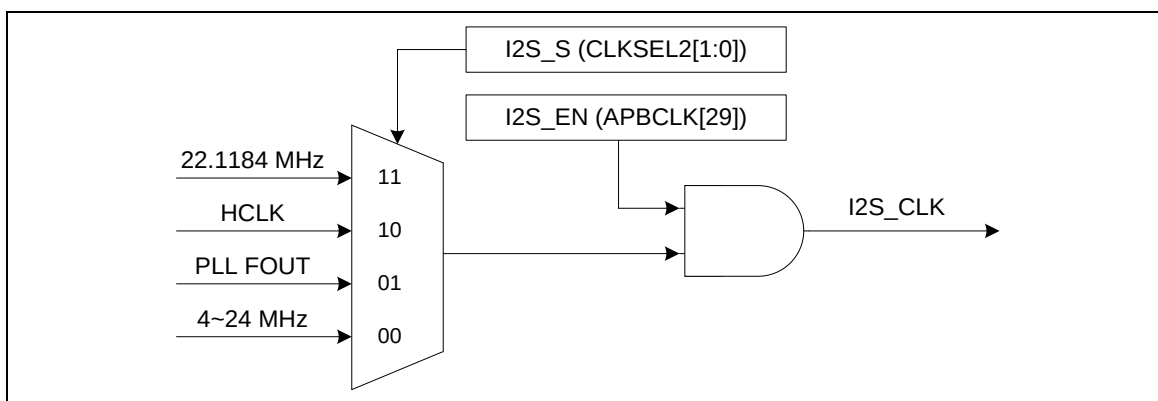


Figure 6-129 I²S Clock Control Diagram

6.18.5.2 I²S Operation

The I²S controller supports MSB justified and I²S data format. The I2SLRCLK signal indicates which audio channel is in transferring. The bit count of an audio channel is determined by WORDWIDTH (I2SCON[5:4]). The transfer sequence is always first from the most significance bit, MSB. Data are read on rising clock edge and are driven on falling clock edge.

In I²S data format, the MSB is sent and latched on the second clock of an audio channel.

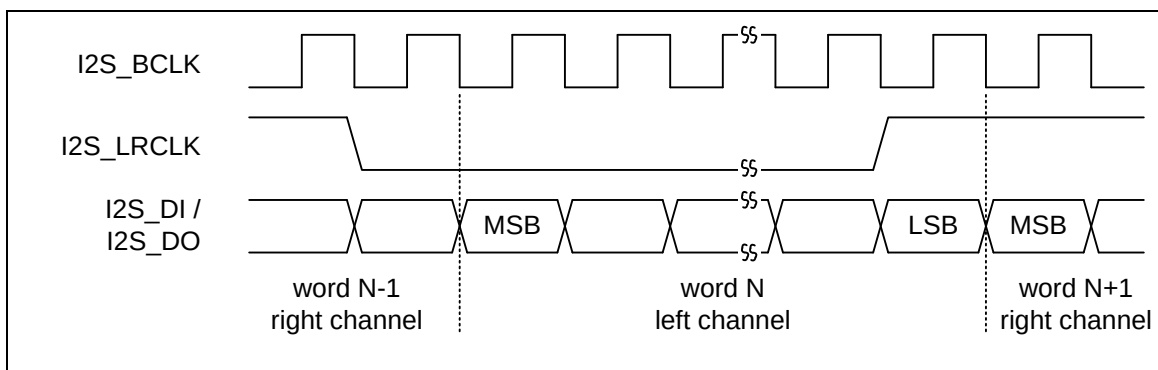


Figure 6-130 I²S Data Format Timing Diagram

In MSB justified data format, the MSB is sent and latched on the first clock of an audio channel.

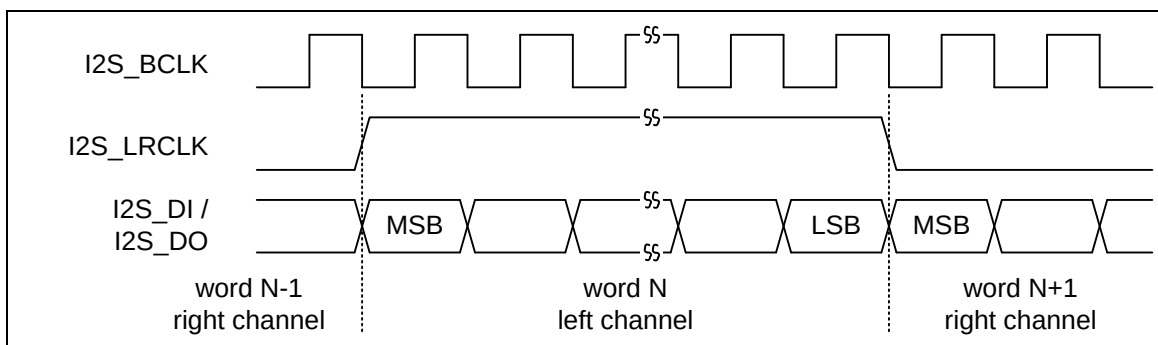


Figure 6-131 MSB Justified Data Format Timing Diagram

6.18.5.3 I²S Interrupt Sources

The I²S controller supports left channel zero-cross interrupt, right channel zero-cross interrupt, transmit FIFO threshold level interrupt, transmit FIFO overflow interrupt and transmit FIFO underflow interrupt in transmit operation. In receive operation, it supports receive FIFO threshold level interrupt, receive FIFO overflow interrupt and receive FIFO underflow interrupt. When I²S interrupt occurs, user can check I2STXINT (I2SSTATUS[2]) and I2SRXINT (I2SSTATUS[1]) flags to recognize the interrupt sources.

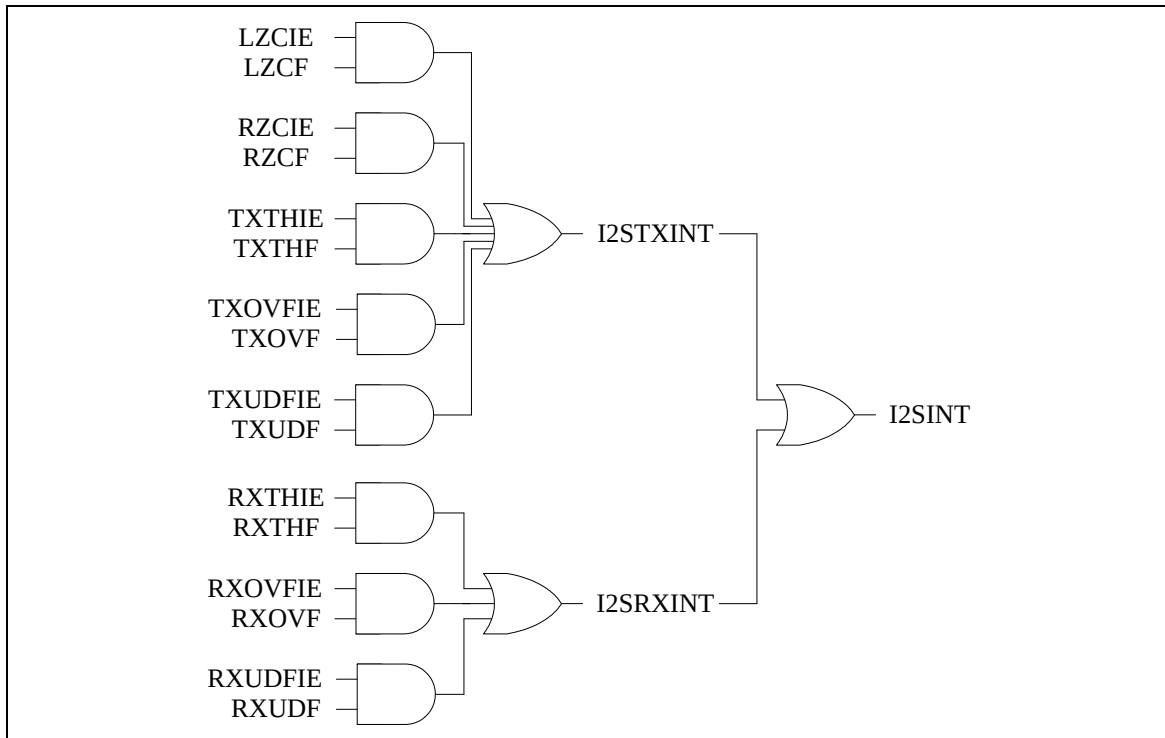


Figure 6-132 I²S Interrupts

6.18.5.4FIFO Operation

The word width of an audio channel can be 8, 16, 24 or 32 bits. The memory arrangements for various settings are shown below.

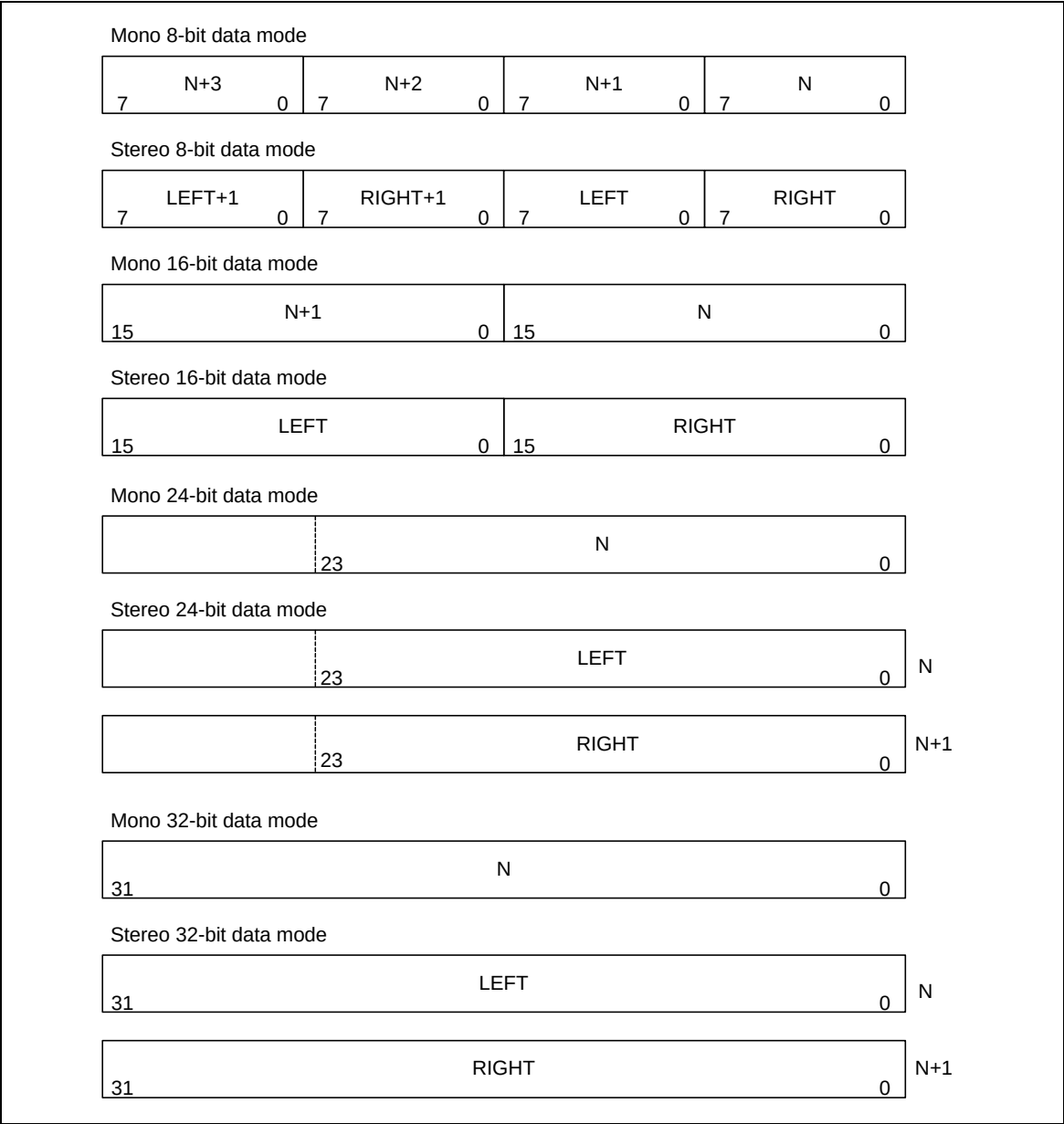


Figure 6-133 FIFO Contents for Various I²S Modes

6.18.5.5 Zero Cross Detection

When playing audio by I²S function, the output data comes from the memory by PDMA or by CPU. However, it may result some pop noise if the playing gain level is changed by user at any time. Because, the output data is not zero, and the output data cross the gain change will generate a sharp pop noise. Therefore, the zero-cross flag will help to reduce this situation. If enable the zero cross detection function, hardware will detect the next transfer data is zero or sign change. If the next data is zero or sign change, zero-cross flag will be set to high, and the output data will be mute automatically, until the flag is cleared by software.

6.18.5.6 PDMA Mode

The I²S function can use PDMA function to access the data. In transmit mode, when PDMA function is enabled, if TX FIFO is not full, the I²S will generate the request signal and get a data from memory by PDMA automatically, until the TX FIFO is full. However, in receive mode, when PDMA function is enabled, if the RX FIFO is not empty, the I²S will generate the request signal and move a receive data to memory by PDMA automatically, until the RX FIFO is empty. User can enable PDMA function to ease CPU's' loading.

6.18.5.7 Master/Slave Interface

If I²S controller is configured as Master mode, it drives I2S_MCLK, I2S_BCLK and I2S_LRCLK for a device slave, such as an audio CODEC.

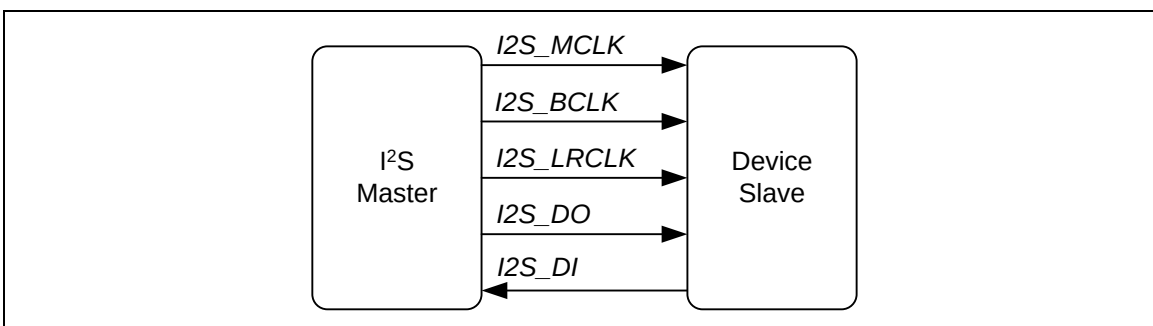


Figure 6-134 Master Mode Interface

If I²S controller is configured as Slave mode, I2S_MCLK, I2S_BCLK and I2S_LRCLK are driven by a device master, such as an audio CODEC.

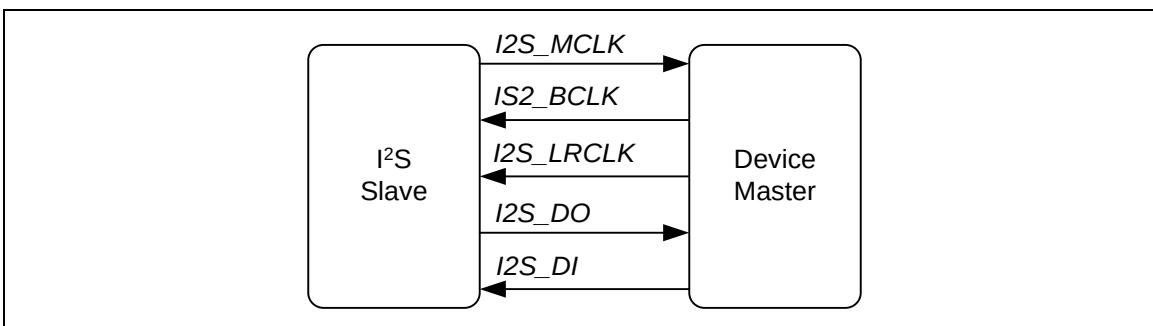


Figure 6-135 Slave Mode Interface

6.18.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
I ² S Base Address: I2S_BA = 0x401A_0000				
I2SCON	I2S_BA+0x00	R/W	I ² S Control Register	0x0000_0000
I2SCLKDIV	I2S_BA+0x04	R/W	I ² S Clock Divider Control Register	0x0000_0000
I2SIE	I2S_BA+0x08	R/W	I ² S Interrupt Enable Register	0x0000_0000
I2SSTATUS	I2S_BA+0x0C	R/W	I ² S Status Register	0x0014_1000
I2STXFIFO	I2S_BA+0x10	W	I ² S Transmit FIFO Register	0x0000_0000
I2SRXFIFO	I2S_BA+0x14	R	I ² S Receive FIFO Register	0x0000_0000

6.18.7 Register Description

I²S Control Register (I2SCON)

Register	Offset	R/W	Description	Reset Value
I2SCON	I2S_BA+0x00	R/W	I ² S Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
RXLCH	Reserved	RXDMA	TXDMA	CLR_RXFIFO	CLR_TXFIFO	LCHZCEN	RCHZCEN
15	14	13	12	11	10	9	8
MCLKEN	RXTH			TXTH			SLAVE
7	6	5	4	3	2	1	0
FORMAT	MONO	WORDWIDTH		MUTE	RXEN	TXEN	I2SEN

Bits	Description	
[31:22]	Reserved	Reserved.
[23]	RXLCH	Receive Left Channel Enable Bit When monaural format is selected (MONO = 1), I ² S controller will receive right channel data if RXLCH is set to 0, and receive left channel data if RXLCH is set to 1. 0 = Receive right channel data in Mono mode. 1 = Receive left channel data in Mono mode.
[22]	Reserved	Reserved.
[21]	RXDMA	Receive DMA Enable Bit When RX DMA is enabled, I ² S requests DMA to transfer data from receive FIFO to SRAM if FIFO is not empty. 0 = RX DMA Disabled. 1 = RX DMA Enabled.
[20]	TXDMA	Transmit DMA Enable Bit When TX DMA is enabled, I ² S request DMA to transfer data from SRAM to transmit FIFO if FIFO is not full. 0 = TX DMA Disabled. 1 = TX DMA Enabled.
[19]	CLR_RXFIFO	Clear Receive FIFO Write 1 to clear receive FIFO, internal pointer is reset to FIFO start point, and RX_LEVEL[3:0] returns 0 and receive FIFO becomes empty. This bit is cleared by hardware automatically. Returns 0 on read.
[18]	CLR_TXFIFO	Clear Transmit FIFO Write 1 to clear transmit FIFO, internal pointer is reset to FIFO start point, and TX_LEVEL[3:0] returns to 0 and transmit FIFO becomes empty but data in transmit FIFO is not changed. This bit is cleared by hardware automatically. Returns 0 on read.

[17]	LCHZCEN	Left Channel Zero Cross Detection Enable Bit If this bit is set to 1, when left channel data sign bit changes or next shift data bits are all 0 then LZCF flag in I2SSTATUS register is set to 1. This function is only available in transmit operation. 0 = Left channel zero cross detection Disabled. 1 = Left channel zero cross detection Enabled.
[16]	RCHZCEN	Right Channel Zero Cross Detection Enable Bit If this bit is set to 1, when right channel data sign bit change or next shift data bits are all 0 then RZCF flag in I2SSTATUS register is set to 1. This function is only available in transmit operation. 0 = Right channel zero cross detection Disabled. 1 = Right channel zero cross detection Enabled.
[15]	MCLKEN	Master Clock Enable Bit If MCLKEN is set to 1, I ² S controller will generate master clock on I2S_MCLK pin for external audio devices. 0 = Master clock Disabled. 1 = Master clock Enabled.
[14:12]	RXTH	Receive FIFO Threshold Level When the count of received data word(s) in buffer is equal to or higher than threshold level, RXTHF (I2SSTATUS[10]) will be set. 000 = 1 word data in receive FIFO. 001 = 2 word data in receive FIFO. 010 = 3 word data in receive FIFO. 011 = 4 word data in receive FIFO. 100 = 5 word data in receive FIFO. 101 = 6 word data in receive FIFO. 110 = 7 word data in receive FIFO. 111 = 8 word data in receive FIFO.
[11:9]	TXTH	Transmit FIFO Threshold Level If the count of remaining data word (32 bits) in transmit FIFO is equal to or less than threshold level then TXTHF (I2SSTATUS[18]) is set. 000 = 0 word data in transmit FIFO. 001 = 1 word data in transmit FIFO. 010 = 2 words data in transmit FIFO. 011 = 3 words data in transmit FIFO. 100 = 4 words data in transmit FIFO. 101 = 5 words data in transmit FIFO. 110 = 6 words data in transmit FIFO. 111 = 7 words data in transmit FIFO.
[8]	SLAVE	Slave Mode I ² S can operate as master or slave. For Master mode, I2S_BCLK and I2S_LRCLK pins are output mode and send bit clock from NuMicro™ NUC230/240 series to Audio CODEC chip. In Slave mode, I2S_BCLK and I2S_LRCLK pins are input mode and I2S_BCLK and I2S_LRCLK signals are received from outer Audio CODEC chip. 0 = Master mode. 1 = Slave mode.
[7]	FORMAT	Data Format 0 = I ² S data format. 1 = MSB justified data format.

[6]	MONO	Monaural Data 0 = Data is stereo format. 1 = Data is monaural format.
[5:4]	WORDWIDTH	Word Width 00 = data is 8-bit word. 01 = data is 16-bit word. 10 = data is 24-bit word. 11 = data is 32-bit word.
[3]	MUTE	Transmit Mute Enable Bit 0 = Transmit data is shifted from buffer. 1 = Send zero on transmit channel.
[2]	RXEN	Receive Enable Bit 0 = Data receiving Disabled. 1 = Data receiving Enabled.
[1]	TXEN	Transmit Enable Bit 0 = Data transmit Disabled. 1 = Data transmit Enabled.
[0]	I2SEN	I²S Controller Enable Bit 0 = Disabled. 1 = Enabled.

I²S Clock Divider Register (I2SCLKDIV)

Register	Offset	R/W	Description	Reset Value
I2SCLKDIV	I2S_BA+0x04	R/W	I ² S Clock Divider Control Register	0x0000_0000

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

Bits	Description	
[31:16]	Reserved	Reserved.
[15:8]	BCLK_DIV	Bit Clock Divider The I ² S controller will generate bit clock in Master mode. The bit clock rate, F_BCLK, is determined by the following expression. $F\_BCLK = F\_I2SCLK / (2 \times (BCLK\_DIV + 1))$, where F_I2SCLK is the frequency of I ² S peripheral clock.
[7:3]	Reserved	Reserved.
[2:0]	MCLK_DIV	Master Clock Divider If MCLKEN is set to 1, I ² S controller will generate master clock for external audio devices. The master clock rate, F_MCLK, is determined by the following expressions. If MCLK_DIV >= 1, $F\_MCLK = F\_I2SCLK / (2 \times (MCLK\_DIV))$. If MCLK_DIV = 0, $F\_MCLK = F\_I2SCLK$. F_I2SCLK is the frequency of I ² S peripheral clock. In general, the master clock rate is 256 times sampling clock rate.

I²S Interrupt Enable Register (I2SIE)

Register	Offset	R/W	Description	Reset Value
I2SIE	I2S_BA+0x08	R/W	I ² S Interrupt Enable Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved			LZCIE	RZCIE	TXTHIE	TXOVFIE	TXUDFIE
7	6	5	4	3	2	1	0
Reserved					RXTHIE	RXOVFIE	RXUDFIE

Bits	Description	
[31:13]	Reserved	Reserved.
[12]	LZCIE	Left Channel Zero-Cross Interrupt Enable Bit Interrupt occurs if this bit is set to 1 and left channel zero-cross event is detected. 0 = Interrupt Disabled. 1 = Interrupt Enabled.
[11]	RZCIE	Right Channel Zero-Cross Interrupt Enable Bit Interrupt occurs if this bit is set to 1 and right channel zero-cross event is detected. 0 = Interrupt Disabled. 1 = Interrupt Enabled.
[10]	TXTHIE	Transmit FIFO Threshold Level Interrupt Enable Bit Interrupt occurs if this bit is set to 1 and the count of data words in transmit FIFO is less than TXTH (I2SCON[11:9]). 0 = Interrupt Disabled. 1 = Interrupt Enabled.
[9]	TXOVFIE	Transmit FIFO Overflow Interrupt Enable Bit Interrupt occurs if this bit is set to 1 and the transmit FIFO overflow flag is set to 1. 0 = Interrupt Disabled. 1 = Interrupt Enabled.
[8]	TXUDFIE	Transmit FIFO Underflow Interrupt Enable Bit Interrupt occurs if this bit is set to 1 and the transmit FIFO underflow flag is set to 1. 0 = Interrupt Disabled. 1 = Interrupt Enabled.
[7:3]	Reserved	Reserved.

[2]	RXTHIE	Receive FIFO Threshold Level Interrupt Enable Bit When the count of data words in receive FIFO is equal to or higher than RXTH (I2SCON[14:12]) and this bit is set to 1, receive FIFO threshold level interrupt will be asserted. 0 = Interrupt Disabled. 1 = Interrupt Enabled.
[1]	RXOVFIE	Receive FIFO Overflow Interrupt Enable Bit 0 = Interrupt Disabled. 1 = Interrupt Enabled.
[0]	RXUDFIE	Receive FIFO Underflow Interrupt Enable Bit 0 = Interrupt Disabled. 1 = Interrupt Enabled.

I²S Status Register (I2SSTATUS)

Register	Offset	R/W	Description	Reset Value
I2SSTATUS	I2S_BA+0x0C	R/W	I ² S Status Register	0x0014_1000

31	30	29	28	27	26	25	24
TX_LEVEL				RX_LEVEL			
23	22	21	20	19	18	17	16
LZCF	RZCF	TXBUSY	TXEMPTY	TXFULL	TXTHF	TXOVF	TXUDF
15	14	13	12	11	10	9	8
Reserved			RXEMPTY	RXFULL	RXTHF	RXOVF	RXUDF
7	6	5	4	3	2	1	0
Reserved				RIGHT	I2STXINT	I2SRXINT	I2SINT

Bits	Description	
[31:28]	TX_LEVEL	Transmit FIFO Level These bits indicate word number in transmit FIFO 0000 = No data. 0001 = 1 word in transmit FIFO. 1000 = 8 words in transmit FIFO.
[27:24]	RX_LEVEL	Receive FIFO Level These bits indicate word number in receive FIFO 0000 = No data. 0001 = 1 word in receive FIFO. 1000 = 8 words in receive FIFO.
[23]	LZCF	Left Channel Zero-Cross Flag It indicates the sign bit of left channel sample data is changed or all data bits are 0. 0 = No zero-cross. 1 = Left channel zero-cross event is detected. Note: Write 1 to clear this bit to 0.
[22]	RZCF	Right Channel Zero-Cross Flag It indicates the sign bit of right channel sample data is changed or all data bits are 0. 0 = No zero-cross. 1 = Right channel zero-cross event is detected. Note: Write 1 to clear this bit to 0.

[21]	TXBUSY	Transmit Busy This bit is cleared to 0 when all data in transmit FIFO and shift buffer is shifted out. And set to 1 when 1st data is load to shift buffer. 0 = Transmit shift buffer is empty. 1 = Transmit shift buffer is not empty. Note: This bit is read only.
[20]	TXEMPTY	Transmit FIFO Empty This bit reflects data word number in transmit FIFO is 0 0 = Not empty. 1 = Empty. Note: This bit is read only.
[19]	TXFULL	Transmit FIFO Full This bit reflects data word number in transmit FIFO is 8 0 = Not full. 1 = Full. Note: This bit is read only.
[18]	TXTHF	Transmit FIFO Threshold Flag When the count of data stored in transmit-FIFO is equal to or less than threshold value set in TXTH (I2SCON[11:9]). The TXTHF bit becomes to 1. It keeps at 1 till TX_LEVEL (I2SSTATUS[31:28]) is larger than TXTH. 0 = Data word(s) in FIFO is larger than threshold level. 1 = Data word(s) in FIFO is equal to or less than threshold level. Note: This bit is read only.
[17]	TXOVF	Transmit FIFO Overflow Flag This bit will be set to 1 if writes data to transmit FIFO when transmit FIFO is full. 0 = No overflow. 1 = Overflow. Note: Write 1 to clear this bit to 0.
[16]	TXUDF	Transmit FIFO Underflow Flag If transmit FIFO is empty and hardware reads data from transmit FIFO. This bit will be set to 1. 0 = No underflow. 1 = Underflow. Note: Software can write 1 to clear this bit to 0.
[15:13]	Reserved	Reserved.
[12]	RXEMPTY	Receive FIFO Empty This bit reflects the count of data in receive FIFO is 0 0 = Not empty. 1 = Empty. Note: This bit is read only.
[11]	RXFULL	Receive FIFO Full This bit reflects the count of data in receive FIFO is 8 0 = Not full. 1 = Full. Note: This bit is read only.

[10]	RXTHF	Receive FIFO Threshold Flag When data word(s) in receive FIFO is equal to or larger than threshold value set in RXTH (I2SCON[14:12]). The RXTHF bit becomes to 1. It keeps at 1 till RX_LEVEL (I2SSTATUS[27:24]) is less than RXTH. 0 = Data word(s) in FIFO is less than threshold level. 1 = Data word(s) in FIFO is equal to or larger than threshold level. Note: This bit is read only.
[9]	RXOVF	Receive FIFO Overflow Flag When receive FIFO is full and hardware attempt to write data to receive FIFO, this bit will be set to 1, data in 1st buffer will be overwrote. 0 = No overflow. 1 = Overflow. Note: Write 1 to clear this bit to 0.
[8]	RXUDF	Receive FIFO Underflow Flag Underflow event will occur if read the empty receive FIFO. 0 = No underflow event occurred. 1 = Underflow. Note: Write 1 to clear this bit to 0.
[7:4]	Reserved	Reserved.
[3]	RIGHT	Right Channel This bit indicates current transmit data is belong to which channel 0 = Left channel. 1 = Right channel. Note: This bit is read only.
[2]	I2STXINT	I²S Transmit Interrupt 0 = No transmit interrupt. 1 = Transmit interrupt. Note: This bit is read only.
[1]	I2SRXINT	I²S Receive Interrupt 0 = No receive interrupt. 1 = Receive interrupt. Note: This bit is read only.
[0]	I2SINT	I²S Interrupt Flag This bit is wire-OR of I2STXINT and I2SRXINT bits. 0 = No I ² S interrupt. 1 = I ² S interrupt. Note: This bit is read only.

I²S Transmit FIFO Register (I2STXFIFO)

Register	Offset	R/W	Description	Reset Value
I2STXFIFO	I2S_BA+0x10	W	I ² S Transmit FIFO Register	0x0000_0000

31	30	29	28	27	26	25	24
TXFIFO[31:24]							
23	22	21	20	19	18	17	16
TXFIFO[23:16]							
15	14	13	12	11	10	9	8
TXFIFO[15:8]							
7	6	5	4	3	2	1	0
TXFIFO[7:0]							

Bits	Description	
[31:0]	TXFIFO	Transmit FIFO Register I ² S contains 8 words (8x32 bits) data buffer for data transmit. Write data to this register to prepare data for transmission. The remaining word number is indicated by TX_LEVEL (I2SSTATUS[31:28])

I²S Receive FIFO Register (I2SRXFIFO)

Register	Offset	R/W	Description	Reset Value
I2SRXFIFO	I2S_BA+0x14	R	I ² S Receive FIFO Register	0x0000_0000

31	30	29	28	27	26	25	24
RXFIFO[31:24]							
23	22	21	20	19	18	17	16
RXFIFO[23:16]							
15	14	13	12	11	10	9	8
RXFIFO[15:8]							
7	6	5	4	3	2	1	0
RXFIFO[7:0]							

Bits	Description	
[31:0]	RXFIFO	Receive FIFO Register I ² S contains 8 words (8x32 bits) data buffer for data receive. Read this register to get data of receive FIFO. The remaining data word number is indicated by RX_LEVEL (I2SSTATUS[27:24]).

6.19 USB Device Controller (USB_D)

6.19.1 Overview

There is one set of USB 2.0 full-speed device controller and transceiver in this device. It is compliant with USB 2.0 full-speed device specification and supports control/bulk/interrupt/isochronous transfer types.

In this device controller, there are two main interfaces: the APB bus and USB bus which comes from the USB PHY transceiver. For the APB bus, the CPU can program control registers through it. There are 512 bytes internal SRAM as data buffer in this controller. For IN or OUT transfer, it is necessary to write data to SRAM or read data from SRAM through the APB interface or SIE. User needs to set the effective starting address of SRAM for each endpoint buffer through "buffer segmentation register (USB_BUFSEGx)".

There are 8 endpoints in this controller. Each of the endpoint can be configured as IN or OUT endpoint. All the operations including Control, Bulk, Interrupt and Isochronous transfer are implemented in this block. The block of "Endpoint Control" is also used to manage the data sequential synchronization, endpoint states, current start address, transaction status, and data buffer status for each endpoint.

There are four different interrupt events in this controller. They are the wake-up function, device plug-in or plug-out event, USB events, and BUS events. Any event will cause an interrupt, and users just need to check the related event flags in interrupt event status register (USB_INTSTS) to acknowledge what kind of interrupt occurring, and then check the related USB Endpoint Status Register (USB_EPSTS) to acknowledge what kind of event occurring in this endpoint.

A software-disconnect function is also supported for this USB controller. It is used to simulate the disconnection of this device from the host. If DRVSE0 (USB_DRVSE0[0]) is set to 1, the USB controller will force the output of USB_D+ and USB_D- to level low. After DRVSE0 bit is cleared to 0, host will enumerate the USB device again.

Please refer to *Universal Serial Bus Specification Revision 1.1* for details.

6.19.2 Features

- Compliant with USB 2.0 Full-Speed specification
- Provides 1 interrupt vector with 4 different interrupt events (WAKEUP, FLDET, USB and BUS)
- Supports Control/Bulk/Interrupt/Isochronous transfer type
- Supports suspend function when no bus activity existing for 3 ms
- Provides 8 endpoints for configurable Control/Bulk/Interrupt/Isochronous transfer types and maximum 512 bytes buffer size
- Provides remote wake-up capability

6.19.3 Block Diagram

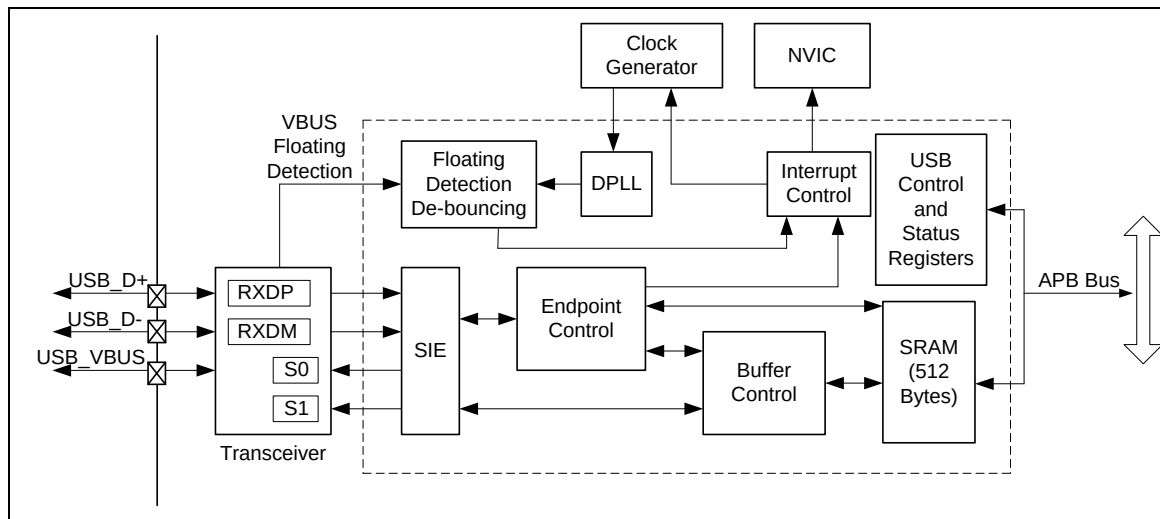


Figure 6-136 USB Device Block Diagram

6.19.4 Basic Configuration

USBD clock source is derived from PLL. User has to set the PLL related configurations before USB device controller is enabled. Set the USBD_EN (APBCLK[27]) bit to enable USBD clock and 4-bit pre-scaler USB_N (CLKDIV[7:4]) to generate the proper USBD clock rate.

6.19.5 Functional Description

6.19.5.1 SIE (Serial Interface Engine)

The SIE is the front-end of the device controller and handles most of the USB packet protocol. The SIE typically comprehends signaling up to the transaction level. The functions that it handles could include:

- Packet recognition, transaction sequencing
- SOF, EOP, RESET, RESUME signal detection/generation
- Clock/Data separation
- NRZI Data encoding/decoding and bit-stuffing
- CRC generation and checking (for Token and Data)
- Packet ID (PID) generation and checking/ decoding
- Serial-Parallel/ Parallel-Serial conversion

6.19.5.2 Endpoint Control

There are 8 endpoints in this controller. Each of the endpoint can be configured as Control, Bulk, Interrupt, or Isochronous transfer type. All the operations including Control, Bulk, Interrupt and Isochronous transfer are implemented in this block. It is also used to manage the data sequential synchronization, endpoint state control, current endpoint start address, current transaction status, and data buffer status in each endpoint.

6.19.5.3 Digital Phase Lock Loop (DPLL)

The bit rate of USB data is 12 MHz. The DPLL uses the 48 MHz which comes from the clock controller to lock the input data RXDP and RXDM. The 12 MHz bit rate clock is also converted from DPLL.

6.19.5.4 Floating Detection De-bouncing

A USB device may be plugged-in or plugged-out from the USB host. To monitor the state of a USB device when it is detached from the USB host, the device controller provides hardware de-bouncing for USB floating detection interrupt to avoid bounce problems on USB plug-in or unplug. Floating detection interrupt appears about 10 ms later than USB plug-in or plug-out. User can acknowledge USB plug-in/plug-out by reading USB_FLDET register. The FLDET flag represents the current state of USB_VBUS without de-bouncing. If the FLDET flag is 1, it means the USB cable is plugged-in. If user polls the flag to check USB state, software de-bouncing must be added if needed.

6.19.5.5 Interrupt

This USB provides 1 interrupt vector with 4 interrupt events (WAKE-UP, FLDET, USB and BUS). The WAKE-UP event is used to wake-up the system clock when Power-down mode is enabled. (The power mode function is defined in system Power-down control register, PWRCON). The FLDET event is used for USB plug-in or unplug. The USB event notifies users of some USB requests, such as IN ACK, OUT ACK., and the BUS event notifies users of some bus events, such as suspend and, resume. The related bits must be set in the interrupt enable register (USB_INTEN) of USB Device Controller to enable USB interrupts.

Wake-up interrupt is only present when the chip enters Power-down mode and then wake-up event had happened. After the chip enters Power-down mode, any change on USB_VBUS, USB_D+ and USB_D- can wake up this chip if the USB wake-up function is enabled. If this change is not intentionally, no interrupt but wake-up interrupt will occur. After USB wake-up, this interrupt will occur when no other USB interrupt events are presented for more than 20ms. The following figure is the control flow of wake-up interrupt.

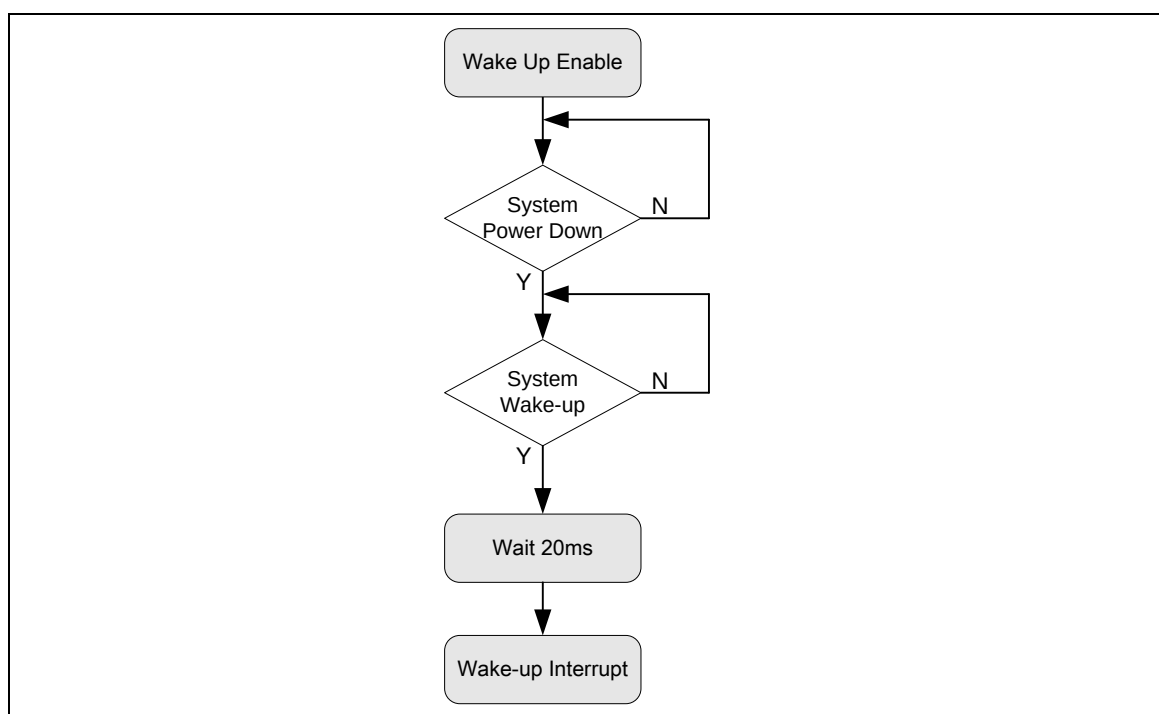


Figure 6-137 Wake-up Interrupt Operation Flow

USB interrupt is used to notify users of any USB event on the bus, and user can read EPSTS (USB_EPSTS[31:8]) and EPEVT7~0 (USB_INTSTS[23:16]) to take necessary responses.

Same as USB interrupt, BUS interrupt notifies users of some bus events, like USB reset, suspend, time-out, and resume. A user can read USB_ATTR to acknowledge bus events.

6.19.5.6 Power Saving

The USB turns off PHY transceiver automatically to save power while this chip enters Power-down mode. User can write 0 into USB_ATTR[4] to disable PHY under special circumstances like suspend to save power.

6.19.5.7 Buffer Control

There is 512 bytes SRAM in the controller and the 8 endpoints share this buffer. User shall configure each endpoint's effective starting address in the buffer segmentation register before the USB function active. The "Buffer Control" block is used to control each endpoint's effective starting address and its SRAM size is defined in the USB_MXPLDx register.

Figure 6-138 depicts the starting address for each endpoint according the content of USB_BUFSEGx and USB_MXPLDx registers. If the USB_BUFSEG0 is programmed as 0x08h and USB_MXPLD0 is set as 0x40h, the SRAM size of endpoint 0 is start from USBD_BA+0x108h and end in USBD_BA+0x148h. (**Note:** The USB SRAM base is USBD_BA+0x100h).

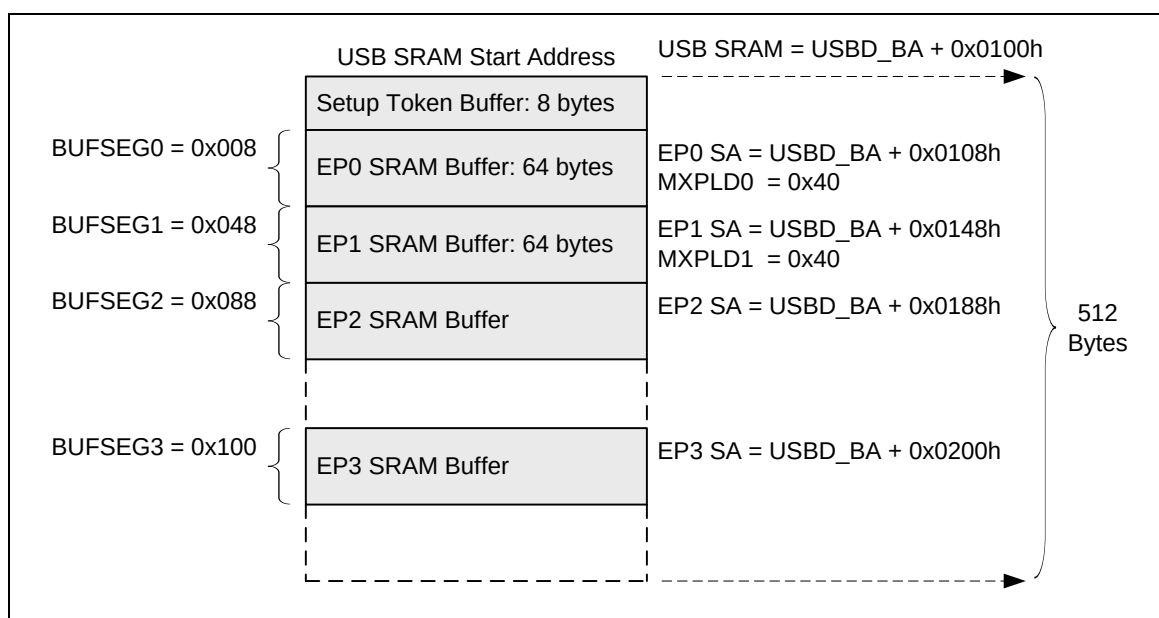


Figure 6-138 Endpoint SRAM Structure

6.19.5.8 Handling Transactions with USB Device Peripheral

User can use interrupt or poll USB_INTSTS to monitor the USB transactions. When transactions occur, USB_INTSTS will be set by hardware and send an interrupt request to CPU (if related interrupt enabled), or user can poll USB_INTSTS to get these events without interrupt. The following is the control flow with interrupt enabled.

When USB host has requested data from a device controller, user needs to prepare related data in the specified endpoint buffer in advance. After buffering the required data, user needs to write the actual data length in the specified USB_MXPLDx register. Once this register is written, the internal signal "In_Rdy" will be asserted and the buffering data will be transmitted immediately after receiving associated IN token from Host. Note that after transferring the specified data, the signal "In_Rdy" will be de-asserted automatically by hardware.

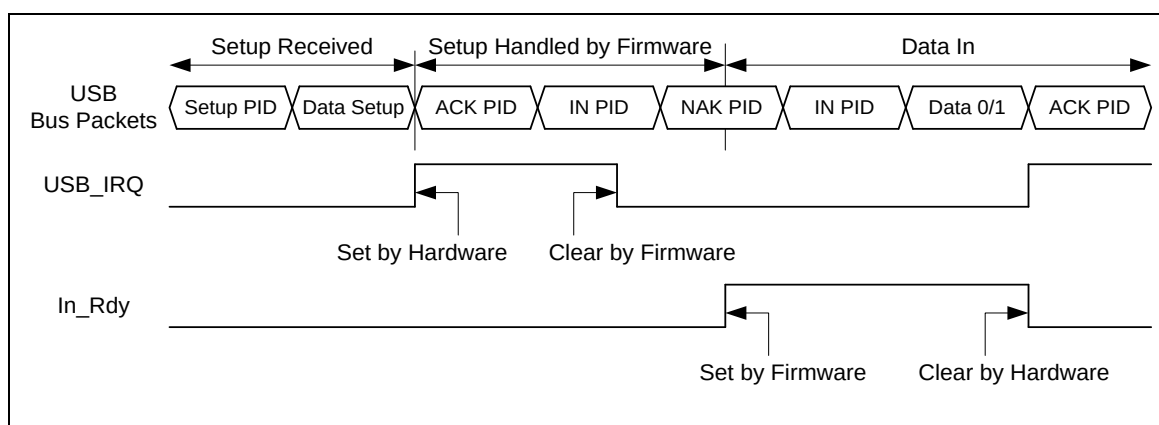


Figure 6-139 Setup Transaction Followed by Data IN Transaction

Alternatively, when USB host wants to transmit data to the OUT endpoint in the device controller, hardware will buffer these data to the specified endpoint buffer. After this transaction is completed, hardware will record the data length in specified USB_MXPLDx register and de-assert the internal signal "Out_Rdy". This will avoid hardware accepting next transaction until user moves out the current data in the related endpoint buffer. Once users have processed this transaction, the specified USB_MXPLDx register needs to be written by firmware to assert the signal "Out_Rdy" again to accept the next transaction.

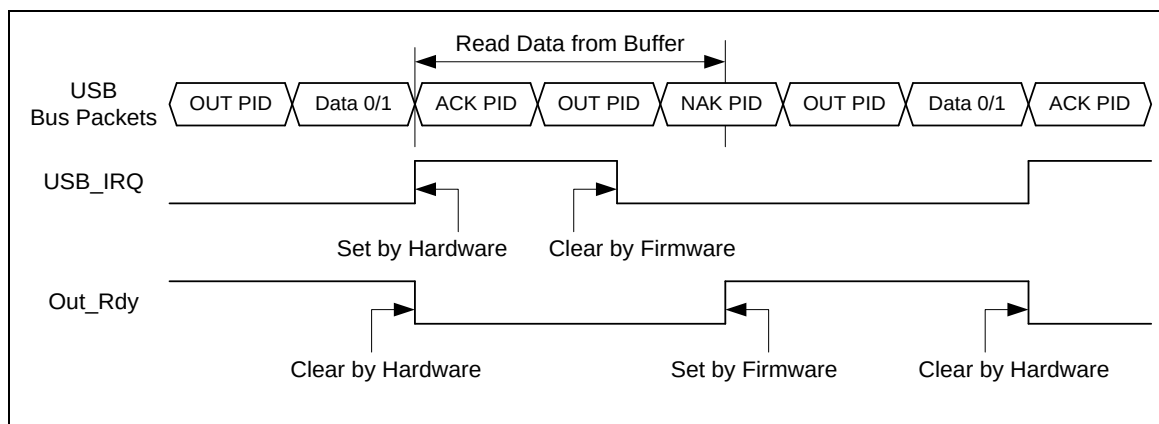


Figure 6-140 Data Out Transfer

6.19.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
USB Base Address: USBD_BA = 0x4006_0000				
USB_INTEN	USBD_BA+0x000	R/W	USB Interrupt Enable Register	0x0000_0000
USB_INTSTS	USBD_BA+0x004	R/W	USB Interrupt Event Status Register	0x0000_0000
USB_FADDR	USBD_BA+0x008	R/W	USB Device Function Address Register	0x0000_0000
USB_EPSTS	USBD_BA+0x00C	R	USB Endpoint Status Register	0x0000_0000
USB_ATTR	USBD_BA+0x010	R/W	USB Bus Status and Attribution Register	0x0000_0040
USB_FLDET	USBD_BA+0x014	R	USB Floating Detection Register	0x0000_0000
USB_STBUFSEG	USBD_BA+0x018	R/W	Setup Token Buffer Segmentation Register	0x0000_0000
USB_DRVSE0	USBD_BA+0x090	R/W	USB Drive SE0 Control Register	0x0000_0001
USB_BUFSEG0	USBD_BA+0x500	R/W	Endpoint 0 Buffer Segmentation Register	0x0000_0000
USB_MXPLD0	USBD_BA+0x504	R/W	Endpoint 0 Maximal Payload Register	0x0000_0000
USB_CFG0	USBD_BA+0x508	R/W	Endpoint 0 Configuration Register	0x0000_0000
USB_CFGP0	USBD_BA+0x50C	R/W	Endpoint 0 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_BUFSEG1	USBD_BA+0x510	R/W	Endpoint 1 Buffer Segmentation Register	0x0000_0000
USB_MXPLD1	USBD_BA+0x514	R/W	Endpoint 1 Maximal Payload Register	0x0000_0000
USB_CFG1	USBD_BA+0x518	R/W	Endpoint 1 Configuration Register	0x0000_0000
USB_CFGP1	USBD_BA+0x51C	R/W	Endpoint 1 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_BUFSEG2	USBD_BA+0x520	R/W	Endpoint 2 Buffer Segmentation Register	0x0000_0000
USB_MXPLD2	USBD_BA+0x524	R/W	Endpoint 2 Maximal Payload Register	0x0000_0000
USB_CFG2	USBD_BA+0x528	R/W	Endpoint 2 Configuration Register	0x0000_0000
USB_CFGP2	USBD_BA+0x52C	R/W	Endpoint 2 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_BUFSEG3	USBD_BA+0x530	R/W	Endpoint 3 Buffer Segmentation Register	0x0000_0000
USB_MXPLD3	USBD_BA+0x534	R/W	Endpoint 3 Maximal Payload Register	0x0000_0000
USB_CFG3	USBD_BA+0x538	R/W	Endpoint 3 Configuration Register	0x0000_0000
USB_CFGP3	USBD_BA+0x53C	R/W	Endpoint 3 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_BUFSEG4	USBD_BA+0x540	R/W	Endpoint 4 Buffer Segmentation Register	0x0000_0000
USB_MXPLD4	USBD_BA+0x544	R/W	Endpoint 4 Maximal Payload Register	0x0000_0000

USB_CFG4	USBD_BA+0x548	R/W	Endpoint 4 Configuration Register	0x0000_0000
USB_CFGP4	USBD_BA+0x54C	R/W	Endpoint 4 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_BUFSEG5	USBD_BA+0x550	R/W	Endpoint 5 Buffer Segmentation Register	0x0000_0000
USB_MXPLD5	USBD_BA+0x554	R/W	Endpoint 5 Maximal Payload Register	0x0000_0000
USB_CFG5	USBD_BA+0x558	R/W	Endpoint 5 Configuration Register	0x0000_0000
USB_CFGP5	USBD_BA+0x55C	R/W	Endpoint 5 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_BUFSEG6	USBD_BA+0x560	R/W	Endpoint 6 Buffer Segmentation Register	0x0000_0000
USB_MXPLD6	USBD_BA+0x564	R/W	Endpoint 6 Maximal Payload Register	0x0000_0000
USB_CFG6	USBD_BA+0x568	R/W	Endpoint 6 Configuration Register	0x0000_0000
USB_CFGP6	USBD_BA+0x56C	R/W	Endpoint 6 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_BUFSEG7	USBD_BA+0x570	R/W	Endpoint 7 Buffer Segmentation Register	0x0000_0000
USB_MXPLD7	USBD_BA+0x574	R/W	Endpoint 7 Maximal Payload Register	0x0000_0000
USB_CFG7	USBD_BA+0x578	R/W	Endpoint 7 Configuration Register	0x0000_0000
USB_CFGP7	USBD_BA+0x57C	R/W	Endpoint 7 Set Stall and Clear In/Out Ready Control Register	0x0000_0000

Memory Type	Address	Size	Description
USBD_BA = 0x4006_0000			
SRAM	USBD_BA+0x100 ~ USBD_BA+0x2FF	512 Bytes	The SRAM is used for the entire endpoint buffers. Refer to section 5.4.4.7 for the endpoint SRAM structure and its description.

6.19.7 Register Description

USB Interrupt Enable Register (USB_INTEN)

Register	Offset	R/W	Description	Reset Value
USB_INTEN	USBD_BA+0x000	R/W	USB Interrupt Enable Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
INNAK_EN	Reserved						WAKEUP_EN
7	6	5	4	3	2	1	0
Reserved				WAKEUP_IE	FLDET_IE	USB_IE	BUS_IE

Bits	Description
[31:16]	Reserved Reserved.
[15]	INNAK_EN Active NAK Function And Its Status In IN Token 0 = When device responds NAK after receiving IN token, IN NAK status will not be updated to USBD_EPSTS register, so that the USB interrupt event will not be asserted. 1 = IN NAK status will be updated to USBD_EPSTS register and the USB interrupt event will be asserted, when the device responds NAK after receiving IN token.
[14:9]	Reserved Reserved.
[8]	WAKEUP_EN Wake-Up Function Enable Bit 0 = USB wake-up function Disabled. 1 = USB wake-up function Enabled.
[7:4]	Reserved Reserved.
[3]	WAKEUP_IE USB Wake-Up Interrupt Enable Bit 0 = Wake-up Interrupt Disabled. 1 = Wake-up Interrupt Enabled.
[2]	FLDET_IE Floating Detection Interrupt Enable Bit 0 = Floating detection Interrupt Disabled. 1 = Floating detection Interrupt Enabled.
[1]	USB_IE USB Event Interrupt Enable Bit 0 = USB event interrupt Disabled. 1 = USB event interrupt Enabled.
[0]	BUS_IE Bus Event Interrupt Enable Bit 0 = BUS event interrupt Disabled. 1 = BUS event interrupt Enabled.

USB Interrupt Event Status Register (USB_INTSTS)

Register	Offset	R/W	Description	Reset Value
USB_INTSTS	USBD_BA+0x004	R/W	USB Interrupt Event Status Register	0x0000_0000

31	30	29	28	27	26	25	24
SETUP	Reserved						
23	22	21	20	19	18	17	16
EPEVT7	EPEVT6	EPEVT5	EPEVT4	EPEVT3	EPEVT2	EPEVT1	EPEVT0
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				WAKEUP_ST	FLDET_STS	USB_STS	BUS_STS

Bits	Description
[31]	SETUP Setup Event Status 0 = No Setup event. 1 = SETUP event occurred, cleared by write 1 to USB_INTSTS[31].
[30:24]	Reserved.
[23]	EPEVT7 Endpoint 7's USB Event Status 0 = No event occurred on endpoint 7. 1 = USB event occurred on Endpoint 7, check USB_EPSTS[31:29] to know which kind of USB event was occurred, cleared by write 1 to USB_INTSTS[23] or USB_INTSTS[1].
[22]	EPEVT6 Endpoint 6's USB Event Status 0 = No event occurred on endpoint 6. 1 = USB event occurred on Endpoint 6, check USB_EPSTS[28:26] to know which kind of USB event was occurred, cleared by write 1 to USB_INTSTS[22] or USB_INTSTS[1].
[21]	EPEVT5 Endpoint 5's USB Event Status 0 = No event occurred on endpoint 5. 1 = USB event occurred on Endpoint 5, check USB_EPSTS[25:23] to know which kind of USB event was occurred, cleared by write 1 to USB_INTSTS[21] or USB_INTSTS[1].
[20]	EPEVT4 Endpoint 4's USB Event Status 0 = No event occurred on endpoint 4. 1 = USB event occurred on Endpoint 4, check USB_EPSTS[22:20] to know which kind of USB event was occurred, cleared by write 1 to USB_INTSTS[20] or USB_INTSTS[1].
[19]	EPEVT3 Endpoint 3's USB Event Status 0 = No event occurred on endpoint 3. 1 = USB event occurred on Endpoint 3, check USB_EPSTS[19:17] to know which kind of USB event was occurred, cleared by write 1 to USB_INTSTS[19] or USB_INTSTS[1].
[18]	EPEVT2 Endpoint 2's USB Event Status 0 = No event occurred on endpoint 2. 1 = USB event occurred on Endpoint 2, check USB_EPSTS[16:14] to know which kind of

		USB event was occurred, cleared by write 1 to USB_INTSTS[18] or USB_INTSTS[1].
[17]	EPEVT1	Endpoint 1's USB Event Status 0 = No event occurred on endpoint 1. 1 = USB event occurred on Endpoint 1, check USB_EPSTS[13:11] to know which kind of USB event was occurred, cleared by write 1 to USB_INTSTS[17] or USB_INTSTS[1].
[16]	EPEVT0	Endpoint 0's USB Event Status 0 = No event occurred on endpoint 0. 1 = USB event occurred on Endpoint 0, check USB_EPSTS[10:8] to know which kind of USB event was occurred, cleared by write 1 to USB_INTSTS[16] or USB_INTSTS[1].
[15:4]	Reserved	Reserved.
[3]	WAKEUP_STS	Wake-Up Interrupt Status 0 = No Wake-up event occurred. 1 = Wake-up event occurred, cleared by write 1 to USB_INTSTS[3].
[2]	FLDET_STS	Floating Detection Interrupt Status 0 = There is not attached/detached event in the USB. 1 = There is attached/detached event in the USB bus and it is cleared by write 1 to USB_INTSTS[2].
[1]	USB_STS	USB Event Interrupt Status The USB event includes the SETUP Token, IN Token, OUT ACK, ISO IN, or ISO OUT events in the bus. 0 = No USB event occurred. 1 = USB event occurred, check EPSTS0~7 to know which kind of USB event occurred. Cleared by write 1 to USB_INTSTS[1] or EPEVT0~7 and SETUP (USB_INTSTS[31]).
[0]	BUS_STS	BUS Interrupt Status The BUS event means that there is one of the suspense or the resume function in the bus. 0 = No BUS event occurred. 1 = Bus event occurred; check USB_ATTR[3:0] to know which kind of bus event was occurred, cleared by write 1 to USB_INTSTS[0].

USB Device Function Address Register (USB_FADDR)

A 7-bit value is used as the address of a device on the USB BUS.

Register	Offset	R/W	Description	Reset Value
USB_FADDR	USBD_BA+0x008	R/W	USB Device Function Address Register	0x0000_0000

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

Bits	Description	
[31:7]	Reserved	Reserved.
[6:0]	FADDR	USB Device Function Address

USB Endpoint Status Register (USB_EPSTS)

Register	Offset	R/W	Description	Reset Value
USB_EPSTS	USBD_BA+0x00C	R	USB Endpoint Status Register	0x0000_0000

31	30	29	28	27	26	25	24
EPSTS7			EPSTS6			EPSTS5[2:1]	
23	22	21	20	19	18	17	16
EPSTS5[0]	EPSTS4			EPSTS3			EPSTS2[2]
15	14	13	12	11	10	9	8
EPSTS2[1:0]		EPSTS1			EPSTS0		
7	6	5	4	3	2	1	0
OVERRUN		Reserved					

Bits	Description	
[31:29]	EPSTS7	Endpoint 7 Bus Status These bits are used to indicate the current status of this endpoint 000 = In ACK. 001 = In NAK. 010 = Out Packet Data0 ACK. 110 = Out Packet Data1 ACK. 011 = Setup ACK. 111 = Isochronous transfer end.
[28:26]	EPSTS6	Endpoint 6 Bus Status These bits are used to indicate the current status of this endpoint 000 = In ACK. 001 = In NAK. 010 = Out Packet Data0 ACK. 110 = Out Packet Data1 ACK. 011 = Setup ACK. 111 = Isochronous transfer end.
[25:23]	EPSTS5	Endpoint 5 Bus Status These bits are used to indicate the current status of this endpoint 000 = In ACK. 001 = In NAK. 010 = Out Packet Data0 ACK. 110 = Out Packet Data1 ACK. 011 = Setup ACK. 111 = Isochronous transfer end.
[22:20]	EPSTS4	Endpoint 4 Bus Status These bits are used to indicate the current status of this endpoint 000 = In ACK.

		001 = In NAK. 010 = Out Packet Data0 ACK. 110 = Out Packet Data1 ACK. 011 = Setup ACK. 111 = Isochronous transfer end.
[19:17]	EPSTS3	Endpoint 3 Bus Status These bits are used to indicate the current status of this endpoint 000 = In ACK. 001 = In NAK. 010 = Out Packet Data0 ACK. 110 = Out Packet Data1 ACK. 011 = Setup ACK. 111 = Isochronous transfer end.
[16:14]	EPSTS2	Endpoint 2 Bus Status These bits are used to indicate the current status of this endpoint 000 = In ACK. 001 = In NAK. 010 = Out Packet Data0 ACK. 110 = Out Packet Data1 ACK. 011 = Setup ACK. 111 = Isochronous transfer end.
[13:11]	EPSTS1	Endpoint 1 Bus Status These bits are used to indicate the current status of this endpoint 000 = In ACK. 001 = In NAK. 010 = Out Packet Data0 ACK. 110 = Out Packet Data1 ACK. 011 = Setup ACK. 111 = Isochronous transfer end.
[10:8]	EPSTS0	Endpoint 0 Bus Status These bits are used to indicate the current status of this endpoint 000 = In ACK. 001 = In NAK. 010 = Out Packet Data0 ACK. 110 = Out Packet Data1 ACK. 011 = Setup ACK. 111 = Isochronous transfer end.
[7]	OVERRUN	Overrun It indicates that the received data is over the maximum payload number or not. 0 = No overrun. 1 = Out Data is more than the Max Payload in MXPLD register or the Setup Data is more than 8 Bytes.
[6:0]	Reserved	Reserved.

USB Bus Status and Attribution Register (USB_ATTR)

Register	Offset	R/W	Description	Reset Value
USB_ATTR	USBD_BA+0x010	R/W	USB Bus Status and Attribution Register	0x0000_0040

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved					BYTEM	PWRDN	DPPU_EN
7	6	5	4	3	2	1	0
USB_EN	Reserved	RWAKEUP	PHY_EN	TIMEOUT	RESUME	SUSPEND	USBRS

Bits	Description	
[31:11]	Reserved	Reserved.
[10]	BYTEM	CPU Access USB SRAM Size Mode Selection 0 = Word mode: The size of the transfer from CPU to USB SRAM can be Word only. 1 = Byte mode: The size of the transfer from CPU to USB SRAM can be Byte only.
[9]	PWRDN	Power-Down PHY Transceiver, Low Active 0 = Power-down related circuit of PHY transceiver. 1 = Turn-on related circuit of PHY transceiver.
[8]	DPPU_EN	Pull-Up Resistor On USB_D+ Enable Bit 0 = Pull-up resistor in USB_D+ pin Disabled. 1 = Pull-up resistor in USB_D+ pin Enabled.
[7]	USB_EN	USB Controller Enable Bit 0 = USB Controller Disabled. 1 = USB Controller Enabled.
[6]	Reserved	Reserved.
[5]	RWAKEUP	Remote Wake-Up 0 = Release the USB bus from K state. 1 = Force USB bus to K (USB_D+ low, USB_D- high) state, used for remote wake-up.
[4]	PHY_EN	PHY Transceiver Function Enable Bit 0 = PHY transceiver function Disabled. 1 = PHY transceiver function Enabled.
[3]	TIMEOUT	Time-Out Status 0 = No time-out. 1 = No Bus response more than 18 bits time. Note: This bit is read only.
[2]	RESUME	Resume Status

		0 = No bus resume. 1 = Resume from suspend. Note: This bit is read only.
[1]	SUSPEND	Suspend Status 0 = Bus no suspend. 1 = Bus idle more than 3ms, either cable is plugged off or host is sleeping. Note: This bit is read only.
[0]	USBRST	USB Reset Status 0 = Bus no reset. 1 = Bus reset when SE0 (single-ended 0) is presented more than 2.5us. Note: This bit is read only.

Floating detection Register (USB_FLDET)

Register	Offset	R/W	Description	Reset Value
USB_FLDET	USBD_BA+0x014	R	USB Floating Detection Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	FLDET	Device Floating Detected 0 = Controller is not attached into the USB host. 1 = Controller is attached into the BUS.

Buffer Segmentation Register (USB_STBUFSEG)

For Setup token only.

Register	Offset	R/W	Description	Reset Value
USB_STBUFSEG	USBD_BA+0x018	R/W	Setup Token Buffer Segmentation Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							STBUFSEG[8]
7	6	5	4	3	2	1	0
STBUFSEG[7:3]					Reserved		

Bits	Description	
[31:9]	Reserved	Reserved.
[8:3]	STBUFSEG	Setup Token Buffer Segmentation It is used to indicate the offset address for the SETUP token with the USB Device SRAM starting address. The effective starting address is USB_SRAM address + {STBUFSEG[8:3], 3'b000} Where the USB_SRAM address = USBD_BA+0x100h. Note: It is used for SETUP token only.
[2:0]	Reserved	Reserved.

Buffer Segmentation Register (USB_BUFSEGx)

Register	Offset	R/W	Description	Reset Value
USB_BUFSEG0	USBD_BA+0x500	R/W	Endpoint 0 Buffer Segmentation Register	0x0000_0000
USB_BUFSEG1	USBD_BA+0x510	R/W	Endpoint 1 Buffer Segmentation Register	0x0000_0000
USB_BUFSEG2	USBD_BA+0x520	R/W	Endpoint 2 Buffer Segmentation Register	0x0000_0000
USB_BUFSEG3	USBD_BA+0x530	R/W	Endpoint 3 Buffer Segmentation Register	0x0000_0000
USB_BUFSEG4	USBD_BA+0x540	R/W	Endpoint 4 Buffer Segmentation Register	0x0000_0000
USB_BUFSEG5	USBD_BA+0x550	R/W	Endpoint 5 Buffer Segmentation Register	0x0000_0000
USB_BUFSEG6	USBD_BA+0x560	R/W	Endpoint 6 Buffer Segmentation Register	0x0000_0000
USB_BUFSEG7	USBD_BA+0x570	R/W	Endpoint 7 Buffer Segmentation Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							BUFSEG[8]
7	6	5	4	3	2	1	0
BUFSEG[7:3]					Reserved		

Bits	Description	
[31:9]	Reserved	Reserved.
[8:3]	BUFSEG	Endpoint Buffer Segmentation It is used to indicate the offset address for each endpoint with the USB SRAM starting address. The effective starting address of the endpoint is USB_SRAM address + { BUFSEG[8:3], 3'b000} Where the USB_SRAM address = USBD_BA+0x100h. Refer to the section 5.4.4.7 for the endpoint SRAM structure and its description.
[2:0]	Reserved	Reserved.

Maximal Payload Register (USB MXPLDx)

Register	Offset	R/W	Description	Reset Value
USB_MXPLD0	USBD_BA+0x504	R/W	Endpoint 0 Maximal Payload Register	0x0000_0000
USB_MXPLD1	USBD_BA+0x514	R/W	Endpoint 1 Maximal Payload Register	0x0000_0000
USB_MXPLD2	USBD_BA+0x524	R/W	Endpoint 2 Maximal Payload Register	0x0000_0000
USB_MXPLD3	USBD_BA+0x534	R/W	Endpoint 3 Maximal Payload Register	0x0000_0000
USB_MXPLD4	USBD_BA+0x544	R/W	Endpoint 4 Maximal Payload Register	0x0000_0000
USB_MXPLD5	USBD_BA+0x554	R/W	Endpoint 5 Maximal Payload Register	0x0000_0000
USB_MXPLD6	USBD_BA+0x564	R/W	Endpoint 6 Maximal Payload Register	0x0000_0000
USB_MXPLD7	USBD_BA+0x574	R/W	Endpoint 7 Maximal Payload Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							MXPLD[8]
7	6	5	4	3	2	1	0
MXPLD[7:0]							

Bits	Description
[31:9]	Reserved Reserved.
[8:0]	MXPLD Maximal Payload Define the data length which is transmitted to host (IN token) or the actual data length which is received from the host (OUT token). It also used to indicate that the endpoint is ready to be transmitted in IN token or received in OUT token. (1) When the register is written by CPU, For IN token, the value of MXPLD is used to define the data length to be transmitted and indicate the data buffer is ready. For OUT token, it means that the controller is ready to receive data from the host and the value of MXPLD is the maximal data length comes from host. (2) When the register is read by CPU, For IN token, the value of MXPLD is indicated by the data length be transmitted to host For OUT token, the value of MXPLD is indicated the actual data length receiving from host. Note: Once MXPLD is written, the data packets will be transmitted/received immediately after IN/OUT token arrived.

Configuration Register (USB_CFGx)

Register	Offset	R/W	Description	Reset Value
USB_CFG0	USBD_BA+0x508	R/W	Endpoint 0 Configuration Register	0x0000_0000
USB_CFG1	USBD_BA+0x518	R/W	Endpoint 1 Configuration Register	0x0000_0000
USB_CFG2	USBD_BA+0x528	R/W	Endpoint 2 Configuration Register	0x0000_0000
USB_CFG3	USBD_BA+0x538	R/W	Endpoint 3 Configuration Register	0x0000_0000
USB_CFG4	USBD_BA+0x548	R/W	Endpoint 4 Configuration Register	0x0000_0000
USB_CFG5	USBD_BA+0x558	R/W	Endpoint 5 Configuration Register	0x0000_0000
USB_CFG6	USBD_BA+0x568	R/W	Endpoint 6 Configuration Register	0x0000_0000
USB_CFG7	USBD_BA+0x578	R/W	Endpoint 7 Configuration Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved						CSTALL	Reserved
7	6	5	4	3	2	1	0
DSQ_SYNC	STATE		ISOCH	EP_NUM			

Bits	Description
[31:10]	Reserved Reserved.
[9]	CSTALL Clear STALL Response 0 = Disable the device to clear the STALL handshake in setup stage. 1 = Clear the device to response STALL handshake in setup stage.
[8]	Reserved Reserved.
[7]	DSQ_SYNC Data Sequence Synchronization 0 = DATA0 PID. 1 = DATA1 PID. Note: It is used to specify the DATA0 or DATA1 PID in the following IN token transaction. Hardware will toggle automatically in IN token base on the bit.
[6:5]	STATE Endpoint STATE 00 = Endpoint is Disabled. 01 = Out endpoint. 10 = IN endpoint. 11 = Undefined.
[4]	ISOCH Isochronous Endpoint

		This bit is used to set the endpoint as Isochronous endpoint, no handshake. 0 = No Isochronous endpoint. 1 = Isochronous endpoint.
[3:0]	EP_NUM	Endpoint Number These bits are used to define the endpoint number of the current endpoint.

Extra Configuration Register (USB_CFGPx)

Register	Offset	R/W	Description	Reset Value
USB_CFGP0	USBD_BA+0x50 C	R/W	Endpoint 0 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_CFGP1	USBD_BA+0x51 C	R/W	Endpoint 1 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_CFGP2	USBD_BA+0x52 C	R/W	Endpoint 2 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_CFGP3	USBD_BA+0x53 C	R/W	Endpoint 3 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_CFGP4	USBD_BA+0x54 C	R/W	Endpoint 4 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_CFGP5	USBD_BA+0x55 C	R/W	Endpoint 5 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_CFGP6	USBD_BA+0x56 C	R/W	Endpoint 6 Set Stall and Clear In/Out Ready Control Register	0x0000_0000
USB_CFGP7	USBD_BA+0x57 C	R/W	Endpoint 7 Set Stall and Clear In/Out Ready Control Register	0x0000_0000

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

Bits	Description
[31:2]	Reserved Reserved.
[1]	SSTALL Set STALL 0 = Disable the device to response STALL. 1 = Set the device to respond STALL automatically.
[0]	CLRRDY Clear Ready When the USB_MXPLD register is set by user, it means that the endpoint is ready to transmit or receive data. If the user wants to disable this transaction before the transaction start, users can set this bit to 1 to turn it off and it will be cleared to 0 automatically. For IN token, write '1' to clear the IN token had ready to transmit the data to USB. For OUT token, write '1' to clear the OUT token had ready to receive the data from USB. This bit is write 1 only and is always 0 when it is read back.

USB Drive SE0 Register (USB_DRVSE0)

Register	Offset	R/W	Description	Reset Value
USB_DRVSE0	USBD_BA+0x090	R/W	USB Drive SE0 Control Register	0x0000_0001

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved							DRVSE0

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	DRVSE0	Drive Single Ended Zero In USB Bus The Single Ended Zero (SE0) is when both lines (USB_D+ and USB_D-) are being pulled low. 0 = None. 1 = Force USB PHY transceiver to drive SE0.

6.20 Controller Area Network (CAN)

6.20.1 Overview

The C_CAN consists of the CAN Core, Message RAM, Message Handler, Control Registers and Module Interface (Refer Figure 6-141). The CAN Core performs communication according to the CAN protocol version 2.0 part A and B. The bit rate can be programmed to values up to 1MBit/s. For the connection to the physical layer, additional transceiver hardware is required.

For communication on a CAN network, individual Message Objects are configured. The Message Objects and Identifier Masks for acceptance filtering of received messages are stored in the Message RAM. All functions concerning the handling of messages are implemented in the Message Handler. These functions include acceptance filtering, the transfer of messages between the CAN Core and the Message RAM, and the handling of transmission requests as well as the generation of the module interrupt.

The register set of the C_CAN can be accessed directly by the software through the module interface. These registers are used to control/configure the CAN Core and the Message Handler and to access the Message RAM.

6.20.2 Features

- Supports CAN protocol version 2.0 part A and B.
- Bit rates up to 1 MBit/s.
- 32 Message Objects.
- Each Message Object has its own identifier mask.
- Programmable FIFO mode (concatenation of Message Objects).
- Maskable interrupt.
- Disabled Automatic Re-transmission mode for Time Triggered CAN applications.
- Programmable loop-back mode for self-test operation.
- 16-bit module interfaces to the AMBA APB bus.
- Supports wake-up function

6.20.3 Block Diagram

The C_CAN interfaces with the AMBA APB bus. The following figure shows the block diagram of the C_CAN.

CAN Core

CAN Protocol Controller and Rx/Tx Shift Register for serial/parallel conversion of messages.

Message RAM

Stores Message Objects and Identifier Masks

Registers

All registers used to control and to configure the C_CAN.

Message Handler

State Machine that controls the data transfer between the Rx/Tx Shift Register of the CAN Core

and the Message RAM as well as the generation of interrupts as programmed in the Control and Configuration Registers.

Module Interface

C_CAN interfaces to the AMBA APB 16-bit bus from ARM.

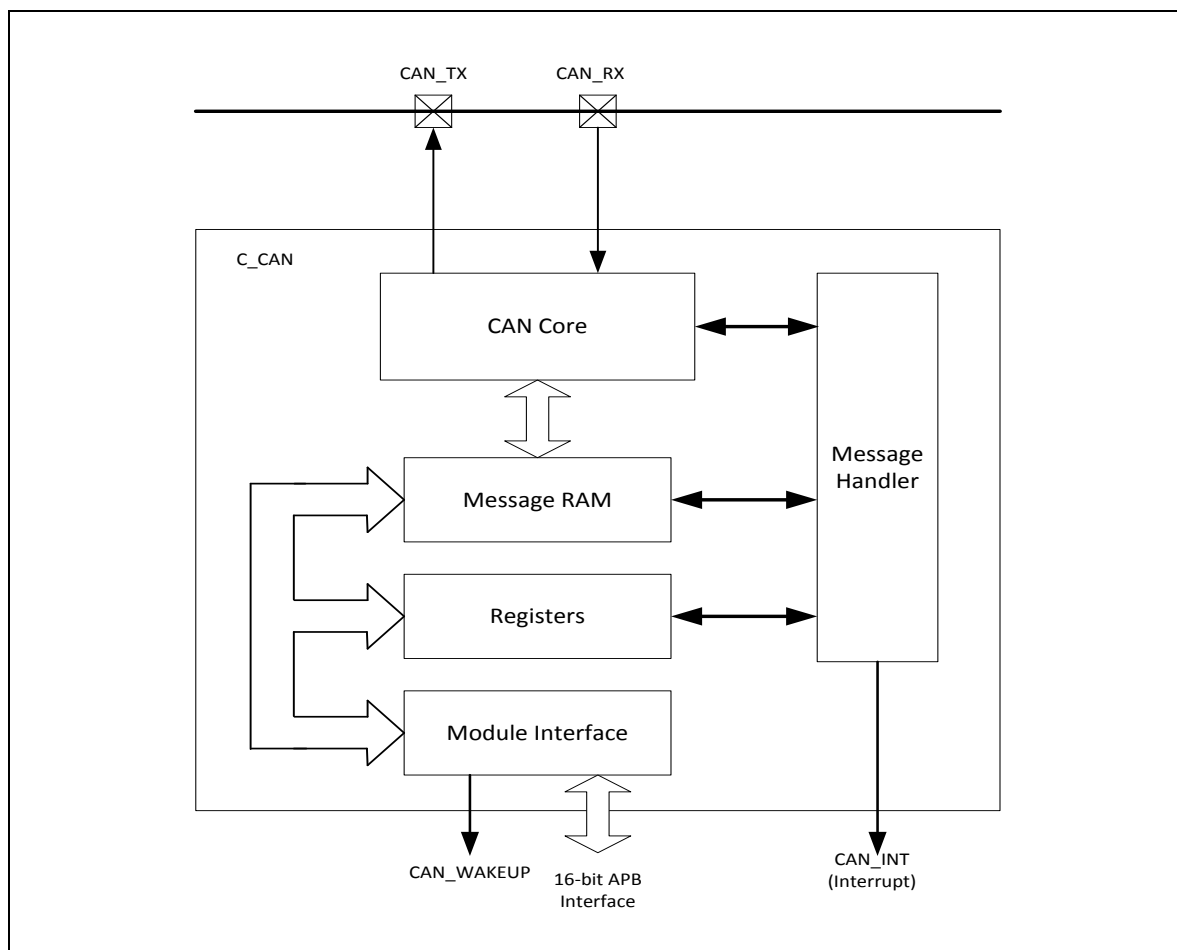


Figure 6-141 CAN Peripheral Block Diagram

6.20.4 Basic Configuration

The basic configurations of CAN are as follows.

- CAN pins are configured on GPA_MFP and GPC_MFP registers.
- Enable CAN clock (CAN0_EN (APBCLK[24]) and CAN1_EN (APBCLK[25])).
- Reset CAN controller (CAN0_RST (IPRSTC2[24]) and CAN1_RST (IPRSTC2[25])).

6.20.5 Functional Description

6.20.5.1 Software Initialization

The software initialization is started by setting the Init bit (CAN_CON[0]), either by a software or a

hardware reset, or by going to bus-off state.

While the Init bit is set, all messages transfer to and from the CAN bus are stopped and the status of the CAN_TX output pin is recessive (HIGH). The Error Management Logic (EML) counters are unchanged. Setting the Init bit does not change any configuration register.

To initialize the CAN Controller, software has to set up the Bit Timing Register and each Message Object. If a Message Object is not required, the corresponding MsgVal bit (CAN_IFn_ARB2[15]) should be cleared. Otherwise, the entire Message Object has to be initialized.

Access to the Bit Timing Register and to the Baud Rate Prescaler Extension Register for configuring bit timing is enabled when both the Init and CCE (CAN_CON[6]) bits are set.

Resetting the Init bit (by software only) finishes the software initialization. Later, the Bit Stream Processor (BSP) (see Section 5.13.6.10: Configuring the Bit Timing) synchronizes itself to the data transfer on the CAN bus by waiting for the occurrence of a sequence of 11 consecutive recessive bits ($\equiv$ Bus Idle) before it can take part in bus activities and start the message transfer.

The initialization of the Message Objects is independent of Init and can be done on the fly, but the Message Objects should all be configured to particular identifiers or set to not valid before the BSP starts the message transfer.

To change the configuration of a Message Object during normal operation, the software has to start by resetting the corresponding MsgVal bit. When the configuration is completed, MsgVal bit is set again.

6.20.5.2 CAN Message Transfer

Once the C_CAN is initialized and Init bit (CAN_CON[0]) is reset to zero, the C_CAN Core synchronizes itself to the CAN bus and starts the message transfer.

Received messages are stored in their appropriate Message Objects if they pass the Message Handler's acceptance filtering. The whole message including all arbitration bits, DLC (CAN_IFn_MCON[3:0]) and eight data bytes (CAN_IFn_DAT_A1/2; CAN_IFn_DAT_B1/2) are stored in the Message Object. If the Identifier Mask is used, the arbitration bits which are masked to "don't care" may be overwritten in the Message Object.

Software can read or write each message any time through the Interface Registers and the Message Handler guarantees data consistency in case of concurrent accesses.

Messages to be transmitted are updated by the application software. If a permanent Message Object (arbitration and control bits are set during configuration) exists for the message, only the data bytes are updated and the TxRqst bit (CAN_IFn_MCON[8]) with NewDat bit (CAN_IFn_MCON[15]) are set to start the transmission. If several transmit messages are assigned to the same Message Object (when the number of Message Objects is not sufficient), the whole Message Object has to be configured before the transmission of this message is requested.

The transmission of any number of Message Objects may be requested at the same time. Message objects are transmitted subsequently according to their internal priority. Messages may be updated or set to not valid any time, even when their requested transmission is still pending. The old data will be discarded when a message is updated before its pending transmission has started.

Depending on the configuration of the Message Object, the transmission of a message may be requested autonomously by the reception of a remote frame with a matching identifier.

6.20.5.3 Disabled Automatic Retransmission

In accordance with the CAN Specification (see ISO11898, 6.3.3 Recovery Management), the C_CAN provides means for automatic retransmission of frames that have lost arbitration or have

been disturbed by errors during transmission. The frame transmission service will not be confirmed to the user before the transmission is successfully completed. This means that, by default, automatic retransmission is enabled. It can be disabled to enable the C_CAN to work within a Time Triggered CAN (TTCAN, see ISO11898-1) environment.

The Disabled Automatic Retransmission mode is enabled by setting the Disable Automatic Retransmission (DAR bit (CAN_CON[5])) to one. In this operation mode, the programmer has to consider the different behavior of bits TxRqst (CAN_IFn_MCON[8]) and NewDat (CAN_IFn_MCON[15]) of the Message Buffers:

- When a transmission starts, bit TxRqst of the respective Message Buffer is cleared, while bit NewDat remains set.
- When the transmission completed successfully, bit NewDat is cleared.
- When a transmission fails (lost arbitration or error), bit NewDat remains set.
- To restart the transmission, the software should set the bit TxRqst again.

6.20.6 Test Mode

Test Mode is entered by setting the Test bit (CAN_CON[7]). In Test Mode, bits Tx1 (CAN_TEST[6]), Tx0 (CAN_TEST[5]), LBack (CAN_TEST[4]), Silent (CAN_TEST[3]) and Basic (CAN_TEST[2]) are writeable. Bit Rx monitors the state of the CAN_RX pin and therefore is only readable. All Test Register functions are disabled when the Test bit is cleared.

6.20.6.1 Silent Mode

The CAN Core can be set in Silent Mode by programming the Silent bit (CAN_TEST[3]) to one. In Silent Mode, the C_CAN is able to receive valid data frames and valid remote frames, but it sends only recessive bits on the CAN bus and it cannot start a transmission. If the CAN Core is required to send a dominant bit (ACK bit, Error Frames), the bit is rerouted internally so that the CAN Core monitors this dominant bit, although the CAN bus may remain in recessive state. The Silent Mode can be used to analysis the traffic on a CAN bus without affecting it by the transmission of dominant bits. The following figure shows the connection of signals CAN_TX and CAN_RX to the CAN Core in Silent Mode.

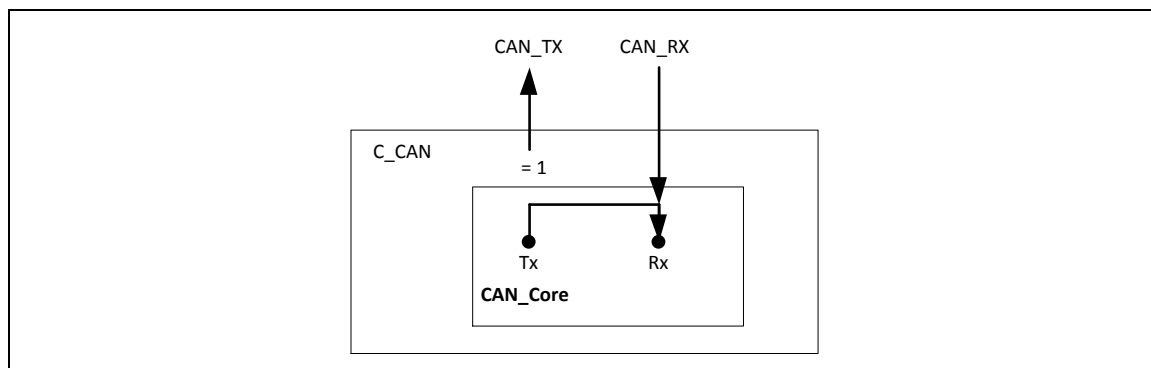


Figure 6-142 CAN Core in Silent Mode

6.20.6.2 Loop Back Mode

The CAN Core can be set in Loop Back Mode by programming the Test Register bit LBack (CAN_TEST[4]) to one. In Loop Back Mode, the CAN Core treats its own transmitted messages

as received messages and stores them in a Receive Buffer (if they pass acceptance filtering). The following figure shows the connection of signals, CAN_TX and CAN_RX, to the CAN Core in Loop Back Mode.

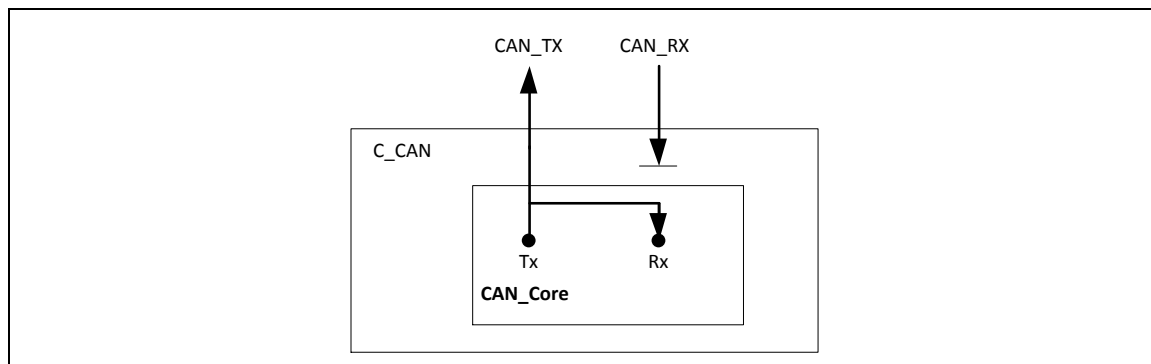


Figure 6-143 CAN Core in Loop Back Mode

This mode is provided for self-test functions. To be independent from external stimulation, the CAN Core ignores acknowledge errors (recessive bit sampled in the acknowledge slot of a data/remote frame) in Loop Back Mode. In this mode, the CAN Core performs an internal feedback from its Tx output to its Rx input. The actual value of the CAN_RX input pin is disregarded by the CAN Core. The transmitted messages can be monitored on the CAN_TX pin.

6.20.6.3 Loop Back Combined with Silent Mode

It is also possible to combine Loop Back Mode and Silent Mode by programming bits LBack (CAN_TEST[4]) and Silent (CAN_TEST[3]) to one at the same time. This mode can be used for a “Hot Selftest”, which means that C_CAN can be tested without affecting a running CAN system connected to the CAN_TX and CAN_RX pins. In this mode, the CAN_RX pin is disconnected from the CAN Core and the CAN_TX pin is held recessive. The following figure shows the connection of signals CAN_TX and CAN_RX to the CAN Core in case of the combination of Loop Back Mode with Silent Mode.

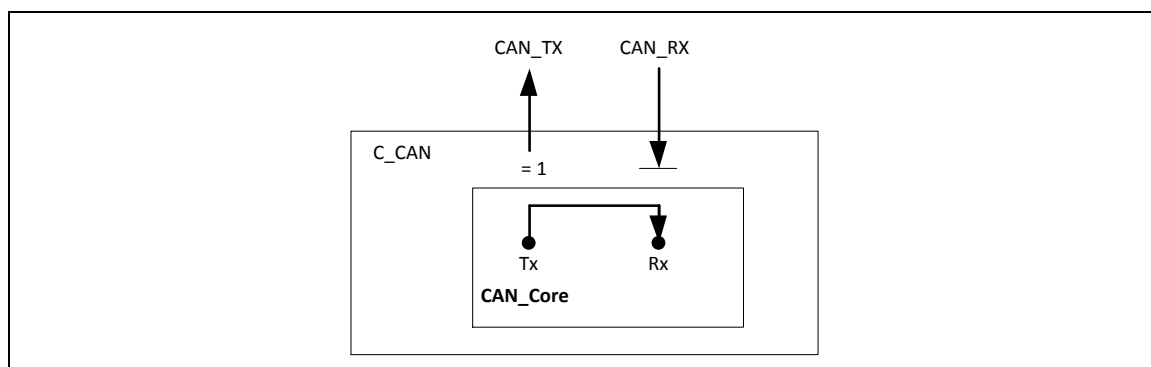


Figure 6-144 CAN Core in Loop Back Mode Combined with Silent Mode

6.20.6.4 Basic Mode

The CAN Core can be set in Basic Mode by programming the Basic bit (CAN_TEST[2]) to one. In this mode, the C_CAN runs without the Message RAM.

The IF1 Registers are used as Transmit Buffer. The transmission of the contents of the IF1 Registers is requested by writing the Busy bit (CAN_IFn_CREQ[15]) of the IF1 Command Request Register to one. The IF1 Registers are locked while the Busy bit is set. The Busy bit indicates that the transmission is pending.

As soon the CAN bus is idle, the IF1 Registers are loaded into the shift register of the CAN Core and the transmission is started. When the transmission has been completed, the Busy bit is reset and the locked IF1 Registers are released.

A pending transmission can be aborted at any time by resetting the Busy bit in the IF1 Command Request Register while the IF1 Registers are locked. If the software has reset the Busy bit, a possible retransmission in case of lost arbitration or in case of an error is disabled.

The IF2 Registers are used as a Receive Buffer. After the reception of a message the contents of the shift register is stored into the IF2 Registers, without any acceptance filtering.

Additionally, the actual contents of the shift register can be monitored during the message transfer. Each time a read Message Object is initiated by writing the Busy bit of the IF2 Command Request Register to one, the contents of the shift register are stored into the IF2 Registers.

In Basic Mode, the evaluation of all Message Object related control and status bits and the control bits of the IFn Command Mask Registers are turned off. The message number of the Command request registers is not evaluated. The NewDat (CAN_IFn_MCON[15]) and MsgLst (CAN_IFn_MCON[14]) bits retain their function, DLC3-0 indicates the received DLC (CAN_IFn_MCON[[3:0]]), and the other control bits are read as '0'.

6.20.6.5 Software Control of CAN_TX Pin

Four output functions are available for the CAN transmit pin, CAN_TX. In addition to its default function (serial data output), the CAN transmit pin can drive the CAN Sample Point signal to monitor CAN_Core's bit timing and it can drive constant dominant or recessive values. The latter two functions, combined with the readable CAN receive pin CAN_RX, can be used to check the physical layer of the CAN bus.

The output mode for the CAN_TX pin is selected by programming the Tx1 (CAN_TEST[6]) and Tx0 (CAN_TEST[5]) bits.

The three test functions of the CAN_TX pin interfere with all CAN protocol functions. CAN_TX must be left in its default function when CAN message transfer or any of the test modes (Loop Back Mode, Silent Mode, or Basic Mode) are selected.

6.20.7 CAN Communications

6.20.7.1 Managing Message Objects

The configuration of the Message Objects in the Message RAM (with the exception of the bits MsgVal, NewDat, IntPnd, and TxRqst) will not be affected by resetting the chip. All the Message Objects must be initialized by the application software or they must be "not valid" (MsgVal bit = '0') and the bit timing must be configured before the application software clears the Init bit (CAN_CON[0]).

The configuration of a Message Object is done by programming Mask, Arbitration, Control and Data fields of one of the two interface registers to the desired values. By writing to the corresponding IFn Command Request Register, the IFn Message Buffer Registers are loaded into the addressed Message Object in the Message RAM.

When the Init bit is cleared, the CAN Protocol Controller state machine of the CAN_Core and the state machine of the Message Handler control the internal data flow of the C_CAN. Received messages that pass the acceptance filtering are stored into the Message RAM, messages with

pending transmission request are loaded into the CAN_Core's Shift Register and are transmitted through the CAN bus.

The application software reads received messages and updates messages to be transmitted through the IFn Interface Registers. Depending on the configuration, the application software is interrupted on certain CAN message and CAN error events.

6.20.7.2 Message Handler State Machine

The Message Handler controls the data transfer between the Rx/Tx Shift Register of the CAN Core, the Message RAM and the IFn Registers.

The Message Handler FSM controls the following functions:

- Data Transfer from IFn Registers to the Message RAM
- Data Transfer from Message RAM to the IFn Registers
- Data Transfer from Shift Register to the Message RAM
- Data Transfer from Message RAM to Shift Register
- Data Transfer from Shift Register to the Acceptance Filtering unit
- Scanning of Message RAM for a matching Message Object
- Handling of TxRqst flags
- Handling of interrupts.

6.20.7.3 Data Transfer from/to Message RAM

When the application software initiates a data transfer between the IFn Registers and Message RAM, the Message Handler sets the Busy bit (CAN_IFn_CREQ[15]) to '1'. After the transfer has completed, the Busy bit is again cleared (see the following figure).

The respective Command Mask Register specifies whether a complete Message Object or only parts of it will be transferred. Due to the structure of the Message RAM, it is not possible to write single bits/bytes of one Message Object. It is always necessary to write a complete Message Object into the Message RAM. Therefore, the data transfer from the IFn Registers to the Message RAM requires a read-modify-write cycle. First, those parts of the Message Object that are not to be changed are read from the Message RAM and then the complete contents of the Message Buffer Registers are written into the Message Object.

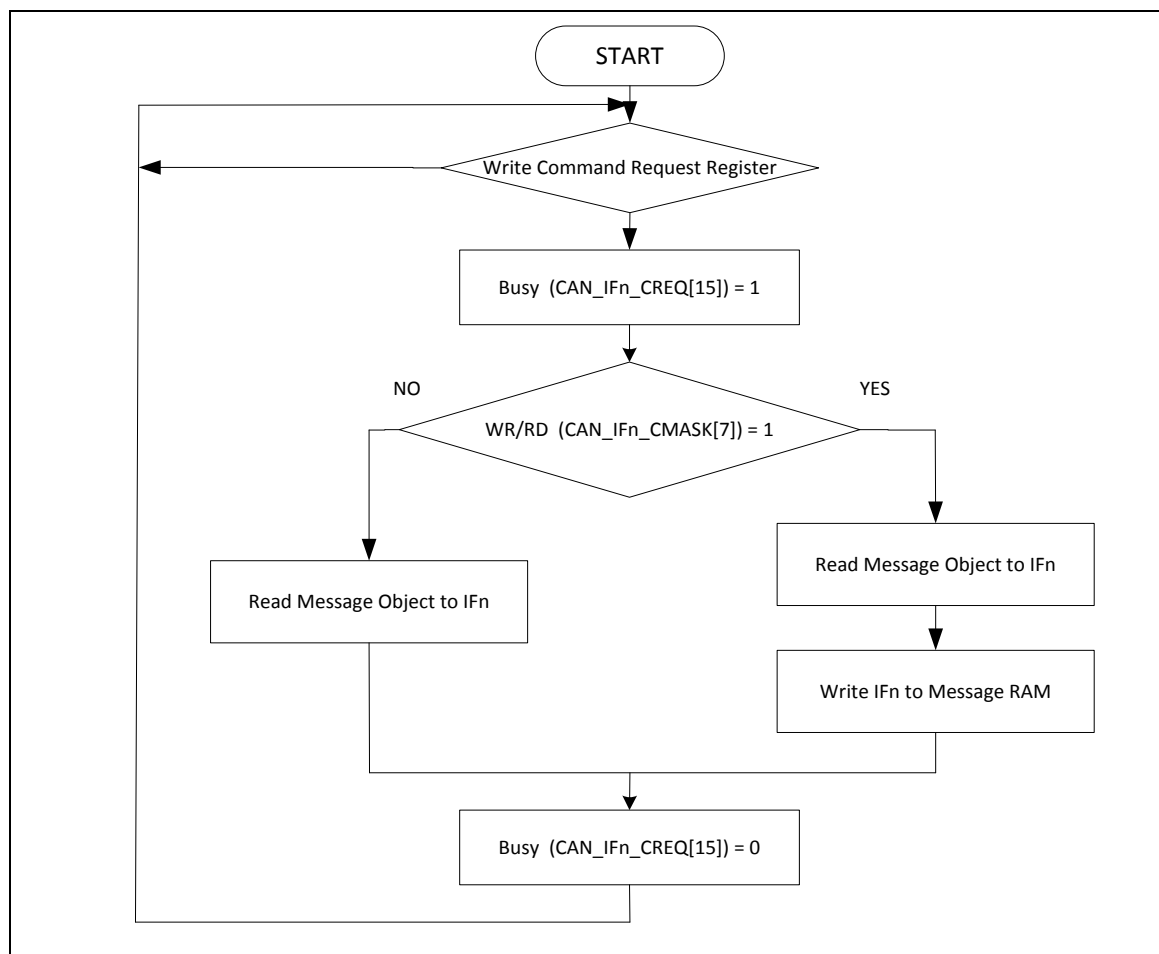


Figure 6-145 Data Transfer between IFn Registers and Message

After a partial write of a Message Object, the Message Buffer Registers that are not selected in the Command Mask Register will set the actual contents of the selected Message Object.

After a partial read of a Message Object, the Message Buffer Registers that are not selected in the Command Mask Register will be left unchanged.

6.20.7.4 Message Transmission

If the shift register of the CAN Core cell is ready for loading and if there is no data transfer between the IFn Registers and Message RAM, the MsgVal bit (CAN_IFn_ARB2[15]) bits and TxRqst bits (CAN_TXREQ1/2) are evaluated. The valid Message Object with the highest priority pending transmission request is loaded into the shift register by the Message Handler and the transmission is started. The NewDat (CAN_IFn_MCON[15]) bit of the Message Object is reset.

After a successful transmission and also if no new data was written to the Message Object (NewDat = '0') since the start of the transmission, the TxRqst bit of the Message Control register (CAN_IFn_MCON[8]) will be reset. If TxIE bit (CAN_IFn_MCON[11]) is set, IntPnd bit (CAN_IFn_MCON[13]) of the Interrupt Identifier register will be set after a successful transmission. If the C_CAN has lost the arbitration or if an error occurred during the transmission, the message will be retransmitted as soon as the CAN bus is free again. Meanwhile, if the transmission of a message with higher priority has been requested, the messages will be transmitted in the order of their priority.

6.20.7.5 Acceptance Filtering of Received Messages

When the arbitration and control field (Identifier + IDE + RTR + DLC) of an incoming message is completely shifted into the Rx/Tx Shift Register of the CAN Core, the Message Handler FSM starts the scanning of the Message RAM for a matching valid Message Object.

To scan the Message RAM for a matching Message Object, the Acceptance Filtering unit is loaded with the arbitration bits from the CAN Core shift register. The arbitration and mask fields (including MsgVal (CAN_IFn_ARB2[15]), UMask (CAN_IFn_MCON[12]), NewDat (CAN_IFn_MCON[15]), and EoB (CAN_IFn_MCON[7])) of Message Object 1 are then loaded into the Acceptance Filtering unit and compared with the arbitration field from the shift register. This is repeated with each following Message Object until a matching Message Object is found or until the end of the Message RAM is reached.

If a match occurs, the scan is stopped and the Message Handler FSM proceeds depending on the type of frame (Data Frame or Remote Frame) received.

Reception of Data Frame

The Message Handler FSM stores the message from the CAN Core shift register into the respective Message Object in the Message RAM. Not only the data bytes, but all arbitration bits and the Data Length Code are stored into the corresponding Message Object. This is done to keep the data bytes connected with the identifier even if arbitration mask registers are used.

The NewDat bit (CAN_IFn_MCON[15]) is set to indicate that new data (not yet seen by the software) has been received. The application software should reset NewDat bit when the Message Object has been read. If at the time of reception, the NewDat bit was already set, MsgLst (CAN_IFn_MCON[14]) is set to indicate that the previous data (supposedly not seen by the software) is lost. If the RxIE bit (CAN_IFn_MCON[10]) is set, the IntPnd bit (CAN_IFn_MCON[13]) is set, causing the Interrupt Register to point to this Message Object.

The TxRqst bit (CAN_IFn_MCON[8]) of this Message Object is reset to prevent the transmission of a Remote Frame, while the requested Data Frame has just been received.

Reception of Remote Frame

When a Remote Frame is received, three different configurations of the matching Message Object have to be considered:

1) Dir (CAN_IFn_ARB2[13]) = '1' (direction = transmit), RmtEn (CAN_IFn_MCON[9]) = '1', UMask (CAN_IFn_MCON[12]) = '1' or '0'

At the reception of a matching Remote Frame, the TxRqst bit of this Message Object is set. The rest of the Message Object remains unchanged.

2) Dir = '1' (direction = transmit), RmtEn = '0', UMask = '0'

At the reception of a matching Remote Frame, the TxRqst bit of this Message Object remains unchanged; the Remote Frame is ignored.

3) Dir = '1' (direction = transmit), RmtEn = '0', UMask = '1'

At the reception of a matching Remote Frame, the TxRqst bit of this Message Object is reset. The arbitration and control field (Identifier + IDE + RTR + DLC) from the shift register is stored in the Message Object of the Message RAM and the NewDat bit (CAN_IFn_MCON[15]) of this Message Object is set. The data field of the Message Object remains unchanged; the Remote Frame is treated similar to a received Data Frame.

6.20.7.6 Receive/Transmit Priority

The receive/transmit priority for the Message Objects is attached to the message number. Message Object 1 has the highest priority, while Message Object 32 has the lowest priority. If more than one transmission request is pending, they are serviced due to the priority of the corresponding Message Object

6.20.7.7 Configuring a Transmit Object

The following table shows how a Transmit Object should be initialized.

Ms	Arb	Data	Mask	EoB	Dir	NewDat	MsgLst	RxIE	TxIE	IntPnd	RmtEn	TxRqst
1	appl.	appl.	appl.	1	1	0	0	0	appl.	0	appl.	0

Table 6-24 Initialization of a Transmit Object

Note: appl. = application software.

The Arbitration Register values (ID28-0 (CAN_IFn_ARB1/2) and Xtd bit (CAN_IFn_ARB2[14])) are provided by the application. They define the identifier and type of the outgoing message. If an 11-bit Identifier ("Standard Frame") is used, it is programmed to ID28 - ID18. The ID17 - ID0 can then be disregarded.

If the TxIE bit (CAN_IFn_MCON[11]) is set, the IntPnd bit (CAN_IFn_MCON[13]) will be set after a successful transmission of the Message Object.

If the RmtEn bit (CAN_IFn_MCON[9]) is set, a matching received Remote Frame will cause the TxRqst bit (CAN_IFn_MCON[8]) to be set; the Remote Frame will autonomously be answered by a Data Frame.

The Data Register values (DLC3-0 (CAN_IFn_MCON[3:0]) , Data0-7) are provided by the application, TxRqst and RmtEn may not be set before the data is valid.

The Mask Registers (Msk28-0, UMask, MXtd, and MDir bits) may be used (UMask (CAN_IFn_MCON[12]) = '1') to allow groups of Remote Frames with similar identifiers to set the TxRqst bit. The Dir bit (CAN_IFn_ARB2[13]) should not be masked.

6.20.7.8 Updating a Transmit Object

The software may update the data bytes of a Transmit Object any time through the IFn Interface registers, neither MsgVal bit (CAN_IFn_ARB2[15]) nor TxRqst (CAN_IFn_MCON[8]) have to be reset before the update.

Even if only a part of the data bytes are to be updated, all four bytes of the corresponding IFn Data A Register or IFn Data B Register have to be valid before the contents of that register are transferred to the Message Object. Either the application software has to write all four bytes into the IFn Data Register or the Message Object is transferred to the IFn Data Register before the software writes the new data bytes.

When only the (eight) data bytes are updated, first 0x0087 is written to the Command Mask Register and then the number of the Message Object is written to the Command Request Register, concurrently updating the data bytes and setting TxRqst.

To prevent the reset of TxRqst at the end of a transmission that may already be in progress while the data is updated, NewDat (CAN_IFn_MCON[15]) has to be set together with TxRqst.

When NewDat is set together with TxRqst, NewDat will be reset as soon as the new transmission has started.

6.20.7.9 Configuring a Receive Object

The following table shows how a Receive Object should be initialized.

MsgVal	Arb	Data	Mask	EoB	Dir	NewDat	MsgLst	RxIE	TxE	IntPnd	RmtEn	TxRqst
1	appl.	appl.	appl.	1	0	0	0	appl.	0	0	0	0

Table 6-25 Initialization of a Receive Object

The Arbitration Registers values (ID28-0 (CAN_IFn_ARB1/2) and Xtd bit (CAN_IFn_ARB2[14])) are provided by the application. They define the identifier and type of accepted received messages. If an 11-bit Identifier ("Standard Frame") is used, it is programmed to ID28 - ID18. Then ID17 - ID0 can be disregarded. When a Data Frame with an 11-bit Identifier is received, ID17 - ID0 will be set to '0'.

If the RxIE bit (CAN_IFn_MCON[10]) is set, the IntPnd bit (CAN_IFn_MCON[13]) will be set when a received Data Frame is accepted and stored in the Message Object.

The Data Length Code (DLC3-0 (CAN_IFn_MCON[3:0])) is provided by the application. When the Message Handler stores a Data Frame in the Message Object, it will store the received Data Length Code and eight data bytes. If the Data Length Code is less than 8, the remaining bytes of the Message Object will be overwritten by unspecified values.

The Mask Registers (Msk28-0, UMask, MXtd, and MDir bits) may be used (UMask (CAN_IFn_MCON[12]) = '1') to allow groups of Data Frames with similar identifiers to be accepted. The Dir bit (CAN_IFn_ARB2[13]) should not be masked in typical applications.

6.20.7.10 Handling Received Messages

The application software may read a received message any time through the IFn Interface registers. The data consistency is guaranteed by the Message Handler state machine.

Typically, the software will write first 0x007F to the Command Mask Register and then the number of the Message Object to the Command Request Register. This combination will transfer the whole received message from the Message RAM into the Message Buffer Register. Additionally, the bits NewDat (CAN_IFn_MCON[15]) and IntPnd (CAN_IFn_MCON[13]) are cleared in the Message RAM (not in the Message Buffer).

If the Message Object uses masks for acceptance filtering, the arbitration bits shows which of the matching messages have been received.

The actual value of NewDat shows whether a new message has been received since the last time this Message Object was read. The actual value of MsgLst (CAN_IFn_MCON[14]) shows whether more than one message has been received since the last time this Message Object was read. MsgLst will not be automatically reset.

By means of a Remote Frame, the software may request another CAN node to provide new data for a receive object. Setting the TxRqst bit (CAN_IFn_MCON[8]) of a receive object will cause the transmission of a Remote Frame with the receive object's identifier. This Remote Frame triggers the other CAN node to start the transmission of the matching Data Frame. If the matching Data

Frame is received before the Remote Frame could be transmitted, the TxRqst bit is automatically reset.

6.20.7.11 *Configuring a FIFO Buffer*

With the exception of the EoB bit (CAN_IFn_MCON[7]), the configuration of Receive Objects belonging to a FIFO Buffer is the same as the configuration of a (single) Receive Object, see Section 5.13.6.5: Configuring a Receive Object.

To concatenate two or more Message Objects into a FIFO Buffer, the identifiers and masks (if used) of these Message Objects have to be programmed to matching values. Due to the implicit priority of the Message Objects, the Message Object with the lowest number will be the first Message Object of the FIFO Buffer. The EoB bit of all Message Objects of a FIFO Buffer except the last have to be programmed to zero. The EoB bits of the last Message Object of a FIFO Buffer is set to one, configuring it as the End of the Block.

6.20.7.12 *Receiving Messages with FIFO Buffers*

Received messages with identifiers matching to a FIFO Buffer are stored into a Message Object of this FIFO Buffer starting with the Message Object with the lowest message number.

When a message is stored into a Message Object of a FIFO Buffer, the NewDat bit (CAN_IFn_MCON[15]) of this Message Object is set. By setting NewDat while EoB (CAN_IFn_MCON[7]) is zero, the Message Object is locked for further write access by the Message Handler until the application software has written the NewDat bit back to zero.

Messages are stored into a FIFO Buffer until the last Message Object of this FIFO Buffer is reached. If none of the preceding Message Objects is released by writing NewDat to zero, all further messages for this FIFO Buffer will be written into the last Message Object of the FIFO Buffer and therefore overwrite previous messages.

6.20.7.13 *Reading from a FIFO Buffer*

When the application software transfers the contents of a Message Object to the IFn Message Buffer register by writing its number to the IFn Command Request Register, the corresponding Command Mask Register should be programmed in such a way that bits NewDat (CAN_IFn_MCON[15]) and IntPnd (CAN_IFn_MCON[13]) are reset to zero (TxRqst/NewDat (CAN_IFn_CMASK[2]) = '1' and CIntPnd (CAN_IFn_CMASK[3]) = '1'). The values of these bits in the Message Control Register always reflect the status before resetting the bits.

To assure the correct function of a FIFO Buffer, the application software should read the Message Objects starting at the FIFO Object with the lowest message number.

The following figure shows how a set of Message Objects which are concatenated to a FIFO Buffer can be handled by the application software.

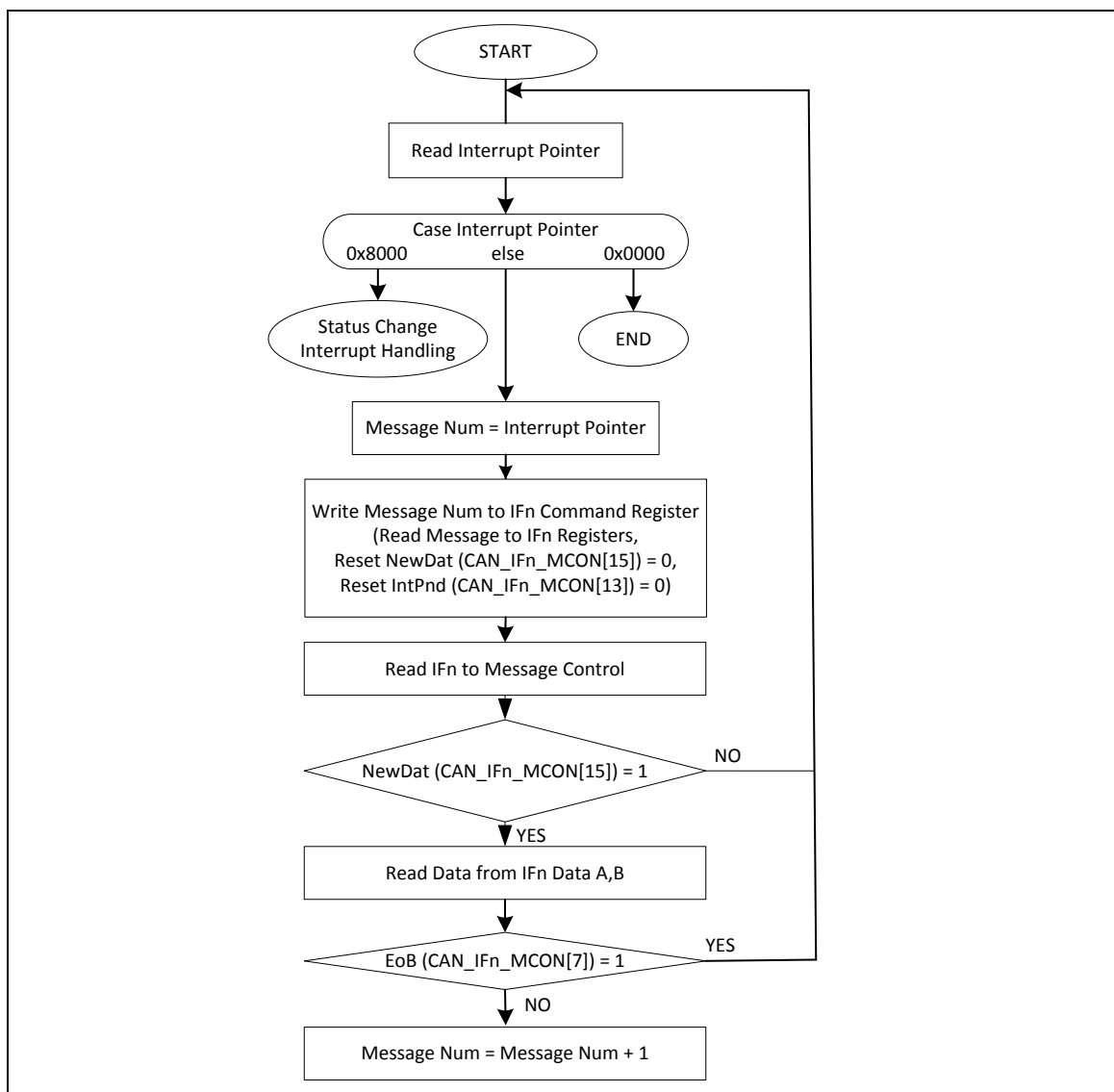


Figure 6-146 Application Software Handling of a FIFO Buffer

6.20.7.14 Handling Interrupts

If several interrupts are pending, the CAN Interrupt Register will point to the pending interrupt with the highest priority, disregarding their chronological order. An interrupt remains pending until the application software has cleared it.

The Status Interrupt has the highest priority. Among the message interrupts, interrupt priority of the Message Object decreases with increasing message number.

A message interrupt is cleared by clearing the IntPnd bit (CAN_IFn_MCON[13]) of the Message Object. The Status Interrupt is cleared by reading the Status Register.

The interrupt identifier, IntId, in the Interrupt Register, indicates the cause of the interrupt. When no interrupt is pending, the register will hold the value zero. If the value of the Interrupt Register is different from zero, then there is an interrupt pending and, if IE (CAN_IFn_CON[1]) is set, the CAN_INT interrupt signal is active. The interrupt remains active until the Interrupt Register is back to value zero (the cause of the interrupt is reset) or until IE is reset.

The value 0x8000 indicates that an interrupt is pending because the CAN Core has updated (not necessarily changed) the Status Register (Error Interrupt or Status Interrupt). This interrupt has the highest priority. The application software can update (reset) the status bits RxOk (CAN_STATUS[4]), TxOk (CAN_STATUS[3]) and LEC (CAN_STATUS[2:0]), but a write access of the software to the Status Register can never generate or reset an interrupt.

All other values indicate that the source of the interrupt is one of the Message Objects. IntId points to the pending message interrupt with the highest interrupt priority.

The application software controls whether a change of the Status Register may cause an interrupt (bits EIE (CAN_IFn_MCON[3]) and SIE (CAN_IFn_MCON[2])) and whether the interrupt line becomes active when the Interrupt Register is different from zero (bit IE in the CAN Control Register). The Interrupt Register will be updated even when IE is reset.

The application software has two possibilities to follow the source of a message interrupt. First, it can follow the IntId in the Interrupt Register and second it can poll the Interrupt Pending Register.

An interrupt service routine that is reading the message that is the source of the interrupt may read the message and reset the Message Object's IntPnd at the same time (bit ClrIntPnd (CAN_IFn_CMASK[3])). When IntPnd is cleared, the Interrupt Register will point to the next Message Object with a pending interrupt.

6.20.7.15 Configuring the Bit Timing

Even if minor errors in the configuration of the CAN bit timing do not result in immediate failure, the performance of a CAN network can be reduced significantly.

In many cases, the CAN bit synchronization will amend a faulty configuration of the CAN bit timing to such a degree that only occasionally an error frame is generated. However, in the case of arbitration, when two or more CAN nodes simultaneously try to transmit a frame, a misplaced sample point may cause one of the transmitters to become error passive.

The analysis of such sporadic errors requires a detailed knowledge of the CAN bit synchronization inside a CAN node and interaction of the CAN nodes on the CAN bus.

6.20.7.16 Bit Time and Bit Rate

CAN supports bit rates in the range of lower than 1 Kbit/s up to 1000 Kbit/s. Each member of the CAN network has its own clock generator, usually a quartz oscillator. The timing parameter of the bit time (i.e. the reciprocal of the bit rate) can be configured individually for each CAN node, creating a common bit rate even though the oscillator periods of the CAN nodes (f_{osc}) may be different.

The frequencies of these oscillators are not absolutely stable, small variations are caused by changes in temperature or voltage and by deteriorating components. As long as the variations remain inside a specific oscillator tolerance range (d_f), the CAN nodes are able to compensate for the different bit rates by re-synchronizing to the bit stream.

According to the CAN specification, the bit time is divided into four segments (see the following figure). The Synchronization Segment, the Propagation Time Segment, the Phase Buffer Segment 1 and the Phase Buffer Segment 2. Each segment consists of a specific, programmable number of time quanta (see the following table). The length of the time quantum (t_q), which is the basic time unit of the bit time, is defined by the CAN controller's APB clock f_{APB} and the BRP bit (CAN_BT[5:0]) : $t_q = BRP / f_{APB}$.

The Synchronization Segment, Sync_Seg, is that part of the bit time where edges of the CAN bus level are expected to occur. The distance between an edge that occurs outside of Sync_Seg, and the Sync_Seg is called the phase error of that edge. The Propagation Time Segment, Prop_Seg, is intended to compensate for the physical delay times within the CAN network. The Phase Buffer Segments Phase_Seg1 and Phase_Seg2 surround the Sample Point. The (Re-)Synchronization Jump Width (SJW) defines how far a re-synchronization may move the Sample Point inside the limits defined by the Phase Buffer Segments to compensate for edge phase errors.

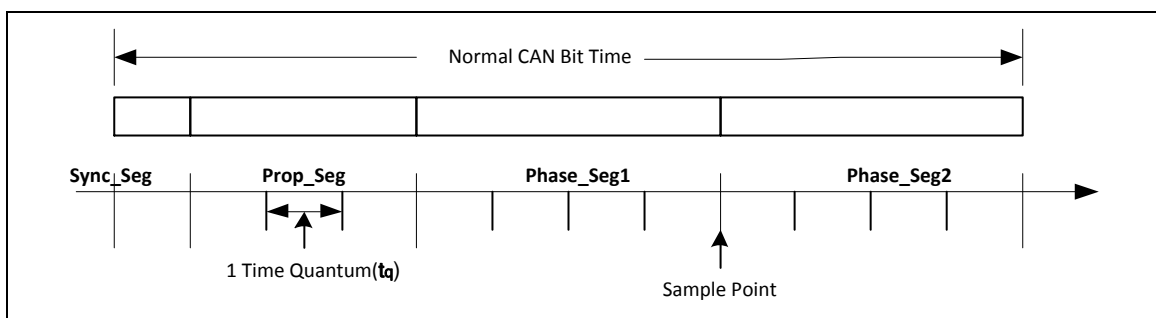


Figure 6-147 Bit Timing

Parameter	Range	Remark
BRP	[1 .. 32]	Defines the length of the time quantum t_q
Sync_Seg	1 t_q	Fixed length, synchronization of bus input to APB clock
Prop_Seg	[1.. 8] t_q	Compensates for the physical delay times
Phase_Seg1	[1..8] t_q	Which may be lengthened temporarily by synchronization
Phase_Seg2	[1.. 8] t_q	Which may be shortened temporarily by synchronization
SJW	[1 .. 4] t_q	Which may not be longer than either Phase Buffer Segment
This table describes the minimum programmable ranges required by the CAN protocol		

Table 6-26 CAN Bit Time Parameters

A given bit rate may be met by different bit time configurations, but for the proper function of the CAN network the physical delay times and the oscillator's tolerance range have to be

considered.

6.20.7.17 Propagation Time Segment

This part of the bit time is used to compensate physical delay times within the network. These delay times consist of the signal propagation time on the bus and the internal delay time of the CAN nodes.

Any CAN node synchronized to the bit stream on the CAN bus will be out of phase with the transmitter of that bit stream, caused by the signal propagation time between the two nodes. The CAN protocol's non-destructive bitwise arbitration and the dominant acknowledge bit provided by receivers of CAN messages requires that a CAN node transmitting a bit stream must also be able to receive dominant bits transmitted by other CAN nodes that are synchronized to that bit stream. The example in the following figure shows the phase shift and propagation times between two CAN nodes.

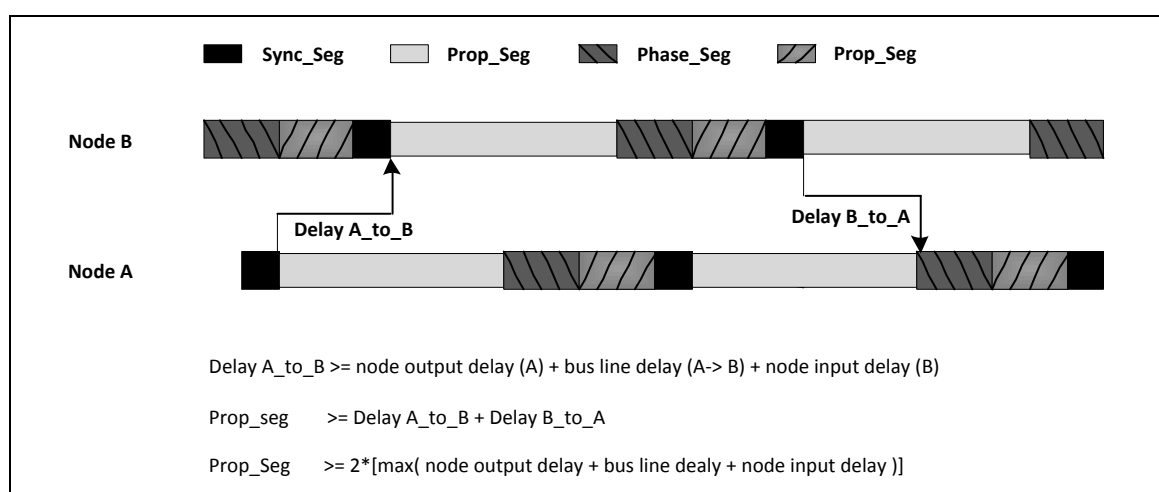


Figure 6-148 Propagation Time Segment

In this example, both nodes A and B are transmitters, performing an arbitration for the CAN bus. Node A has sent its Start of Frame bit less than one bit time earlier than node B, therefore node B has synchronized itself to the received edge from recessive to dominant. Since node B has received this edge delay (A_to_B) after it has been transmitted, B's bit timing segments are shifted with respect to A. Node B sends an identifier with higher priority and so it will win the arbitration at a specific identifier bit when it transmits a dominant bit while node A transmits a recessive bit. The dominant bit transmitted by node B will arrive at node A after the delay (B_to_A).

Due to oscillator tolerances, the actual position of node A's Sample Point can be anywhere inside the nominal range of node A's Phase Buffer Segments, so the bit transmitted by node B must arrive at node A before the start of Phase_Seg1. This condition defines the length of Prop_Seg.

If the edge from recessive to dominant transmitted by node B arrives at node A after the start of Phase_Seg1, it can happen that node A samples a recessive bit instead of a dominant bit, resulting in a bit error and the destruction of the current frame by an error flag.

The error occurs only when two nodes arbitrate for the CAN bus that have oscillators of opposite ends of the tolerance range and that are separated by a long bus line. This is an example of a minor error in the bit timing configuration (Prop_Seg too short) that causes sporadic bus errors.

Some CAN implementations provide an optional 3 Sample Mode but the C_CAN does not. In this mode, the CAN bus input signal passes a digital low-pass filter, using three samples and a majority logic to determine the valid bit value. This results in an additional input delay of $1 t_q$, requiring a longer Prop_Seg.

6.20.7.18 Phase Buffer Segments and Synchronization

The Phase Buffer Segments (Phase_Seg1 and Phase_Seg2) and the Synchronization Jump Width (SJW) are used to compensate for the oscillator tolerance. The Phase Buffer Segments may be lengthened or shortened by synchronization.

Synchronizations occur on edges from recessive to dominant, their purpose is to control the distance between edges and Sample Points.

Edges are detected by sampling the actual bus level in each time quantum and comparing it with the bus level at the previous Sample Point. A synchronization may be done only if a recessive bit was sampled at the previous Sample Point and if the bus level at the actual time quantum is dominant.

An edge is synchronous if it occurs inside of Sync_Seg, otherwise the distance between edge and the end of Sync_Seg is the edge phase error, measured in time quanta. If the edge occurs before Sync_Seg, the phase error is negative, else it is positive.

Two types of synchronization exist, Hard Synchronization and Re-synchronization.

A Hard Synchronization is done once at the start of a frame and inside a frame only when Re-synchronizations occur.

- **Hard Synchronization**

After a hard synchronization, the bit time is restarted with the end of Sync_Seg, regardless of the edge phase error. Thus hard synchronization forces the edge, which has caused the hard synchronization to lie within the synchronization segment of the restarted bit time.

- **Bit Re-synchronization**

Re-synchronization leads to a shortening or lengthening of the bit time such that the position of the sample point is shifted with regard to the edge.

When the phase error of the edge which causes Re-synchronization is positive, Phase_Seg1 is lengthened. If the magnitude of the phase error is less than SJW, Phase_Seg1 is lengthened by the magnitude of the phase error, else it is lengthened by SJW.

When the phase error of the edge, which causes Re-synchronization is negative, Phase_Seg2 is shortened. If the magnitude of the phase error is less than SJW, Phase_Seg2 is shortened by the magnitude of the phase error, else it is shortened by SJW.

When the magnitude of the phase error of the edge is less than or equal to the programmed value of SJW, the results of Hard Synchronization and Re-synchronization are the same. If the magnitude of the phase error is larger than SJW, the Re-synchronization cannot compensate the phase error completely, an error (phase error - SJW) remains.

Only one synchronization may be done between two Sample Points. The Synchronizations maintain a minimum distance between edges and Sample Points, giving the bus level time to stabilize and filtering out spikes that are shorter than (Prop_Seg + Phase_Seg1).

Apart from noise spikes, most synchronizations are caused by arbitration. All nodes synchronize

“hard” on the edge transmitted by the “leading” transceiver that started transmitting first, but due to propagation delay times, they cannot become ideally synchronized. The “leading” transmitter does not necessarily win the arbitration, therefore the receivers have to synchronize themselves to different transmitters that subsequently “take the lead” and that are differently synchronized to the previously “leading” transmitter. The same happens at the acknowledge field, where the transmitter and some of the receivers will have to synchronize to that receiver that “takes the lead” in the transmission of the dominant acknowledge bit.

Synchronizations after the end of the arbitration will be caused by oscillator tolerance, when the differences in the oscillator’s clock periods of transmitter and receivers sum up during the time between synchronizations (at most ten bits). These summarized differences may not be longer than the SJW, limiting the oscillator’s tolerance range.

The examples in the following figure show how the Phase Buffer Segments are used to compensate for phase errors. There are three drawings of each two consecutive bit timings. The upper drawing shows the synchronization on a “late” edge, the lower drawing shows the synchronization on an “early” edge, and the middle drawing is the reference without synchronization.

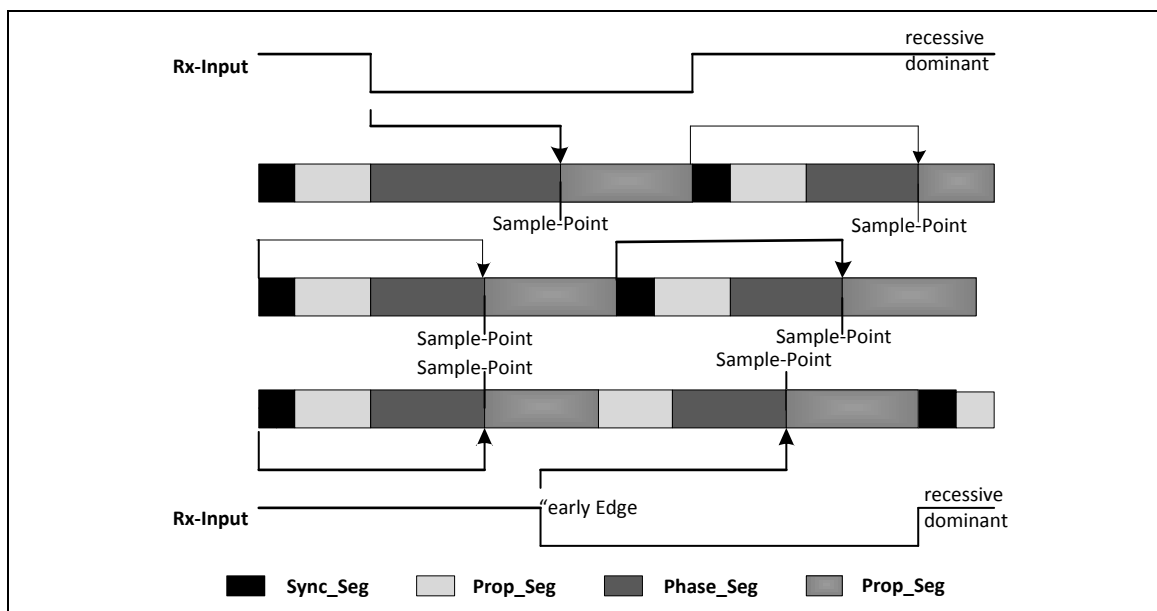


Figure 6-149 Synchronization on “late” and “early” Edges

In the first example an edge from recessive to dominant occurs at the end of Prop_Seg. The edge is “late” since it occurs after the Sync_Seg. Reacting to the “late” edge, Phase_Seg1 is lengthened so that the distance from the edge to the Sample Point is the same as it would have been from the Sync_Seg to the Sample Point if no edge had occurred. The phase error of this “late” edge is less than SJW, so it is fully compensated and the edge from dominant to recessive at the end of the bit, which is one nominal bit time long, occurs in the Sync_Seg.

In the second example an edge from recessive to dominant occurs during Phase_Seg2. The edge is “early” since it occurs before a Sync_Seg. Reacting to the “early” edge, Phase_Seg2 is shortened and Sync_Seg is omitted, so that the distance from the edge to the Sample Point is the same as it would have been from an Sync_Seg to the Sample Point if no edge had occurred. As in the previous example, the magnitude of this “early” edge’s phase error is less than SJW, so it is fully compensated.

The Phase Buffer Segments are lengthened or shortened temporarily only; at the next bit time,

the segments return to their nominal programmed values.

In these examples, the bit timing is seen from the point of view of the CAN implementation's state machine, where the bit time starts and ends at the Sample Points. The state machine omits Sync_Seg when synchronising on an "early" edge because it cannot subsequently redefine that time quantum of Phase_Seg2 where the edge occurs to be the Sync_Seg.

The examples in the following figure show how short dominant noise spikes are filtered by synchronisations. In both examples the spike starts at the end of Prop_Seg and has the length of (Prop_Seg + Phase_Seg1).

In the first example, the Synchronization Jump Width is greater than or equal to the phase error of the spike's edge from recessive to dominant. Therefore the Sample Point is shifted after the end of the spike; a recessive bus level is sampled.

In the second example, SJW is shorter than the phase error, so the Sample Point cannot be shifted far enough; the dominant spike is sampled as actual bus level.

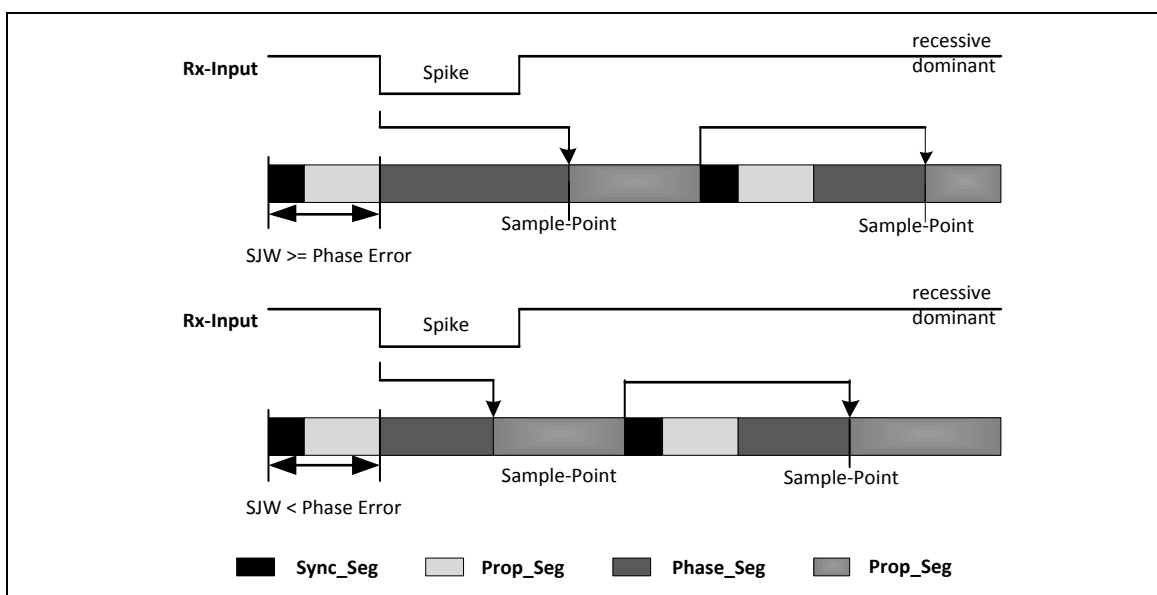


Figure 6-150 Filtering of Short Dominant Spikes

6.20.7.19 Oscillator Tolerance Range

The oscillator tolerance range was increased when the CAN protocol was developed from version 1.1 to version 1.2 (version 1.0 was never implemented in silicon). The option to synchronize on edges from dominant to recessive became obsolete, only edges from recessive to dominant are considered for synchronization. The protocol update to version 2.0 (A and B) had no influence on the oscillator tolerance.

The tolerance range df for an oscillator frequency f_{osc} around the nominal frequency f_{nom} is:

$$(1 - df) \cdot f_{nom} \leq f_{osc} \leq (1 + df) \cdot f_{nom}$$

It depends on the proportions of Phase_Seg1, Phase_Seg2, SJW, and the bit time. The maximum tolerance df is defined by two conditions (both shall be met):

$$I: d_f \leq \frac{\min(\text{Phase\_Seg1}, \text{Phase\_Seg2})}{2 * (13 * \text{bit\_time} - \text{Phase\_Seg2})}$$

$$II: d_f \leq \frac{\text{SJW}}{20 * \text{bit\_time}}$$

Note: These conditions base on the APB clock = f_{osc} .

It has to be considered that SJW may not be larger than the smaller of the Phase Buffer Segments and that the Propagation Time Segment limits that part of the bit time that may be used for the Phase Buffer Segments.

The combination Prop_Seg = 1 and Phase_Seg1 = Phase_Seg2 = SJW = 4 allows the largest possible oscillator tolerance of 1.58%. This combination with a Propagation Time Segment of only 10% of the bit time is not suitable for short bit times; it can be used for bit rates of up to 125 Kbit/s (bit time = 8us) with a bus length of 40 m.

6.20.7.20 *Configuring the CAN Protocol Controller*

In most CAN implementations and also in the C_CAN, the bit timing configuration is programmed in two register bytes. The sum of Prop_Seg and Phase_Seg1 (as TSEG1 (CAN_BT[11:8])) is combined with Phase_Seg2 (as TSEG2 (CAN_BT[14:12])) in one byte, SJW (CAN_BT[7:6]) and BRP (CAN_BT[5:0]) are combined in the other byte.

In these bit timing registers, the four components TSEG1, TSEG2, SJW, and BRP have to be programmed to a numerical value that is one less than its functional value. Therefore, instead of values in the range of [1..n], values in the range of [0..n-1] are programmed. That way, e.g. SJW (functional range of [1..4]) is represented by only two bits.

Therefore the length of the bit time is (programmed values) $[TSEG1 + TSEG2 + 3] t_q$ or (functional values) $[\text{Sync\_Seg} + \text{Prop\_Seg} + \text{Phase\_Seg1} + \text{Phase\_Seg2}] t_q$.

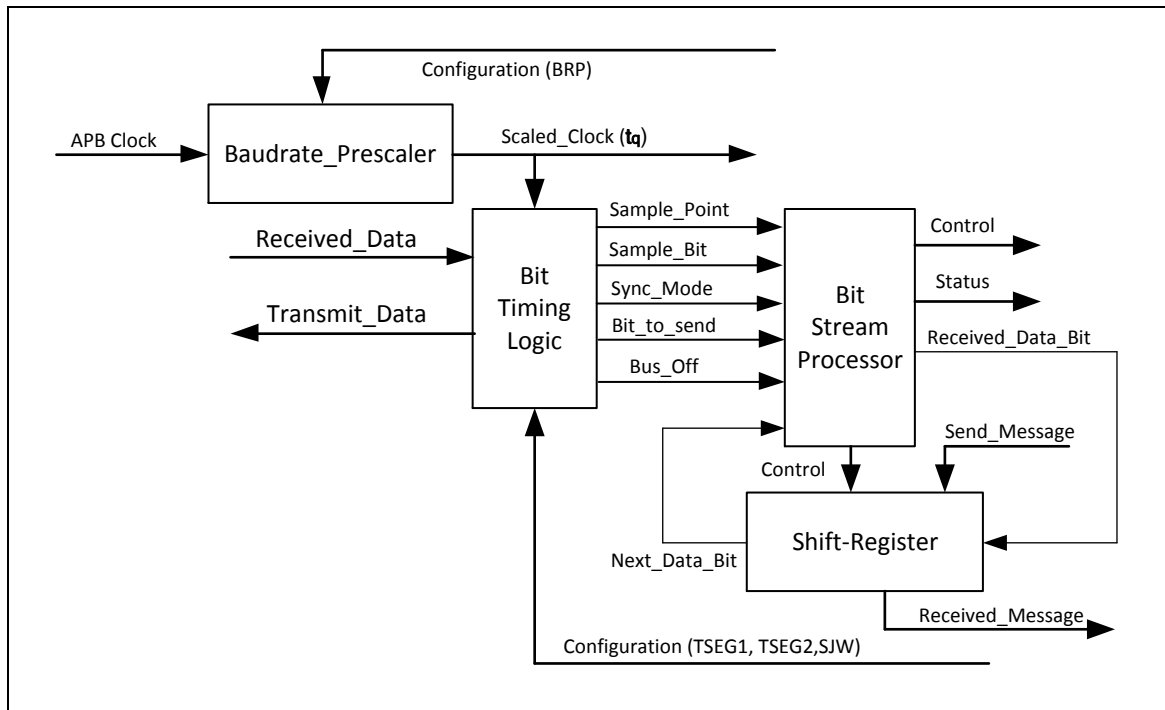


Figure 6-151 Structure of the CAN Core's CAN Protocol Controller

The data in the bit timing registers is the configuration input of the CAN protocol controller. The Baud Rate Prescaler (configured by BRP) defines the length of the time quantum, the basic time unit of the bit time; the Bit Timing Logic (configured by TSEG1, TSEG2, and SJW) defines the number of time quanta in the bit time.

The processing of the bit time, the calculation of the position of the Sample Point, and occasional synchronizations are controlled by the BTL (Bit Timing Logic) state machine, which is evaluated once each time quantum. The rest of the CAN protocol controller, the BSP (Bit Stream Processor) state machine is evaluated once each bit time, at the Sample Point.

The Shift Register sends the messages serially and parallelizes received messages. Its loading and shifting is controlled by the BSP.

The BSP translates messages into frames and vice versa. It generates and discards the enclosing fixed format bits, inserts and extracts stuff bits, calculates and checks the CRC code, performs the error management, and decides which type of synchronization is to be used. It is evaluated at the Sample Point and processes the sampled bus input bit. The time that is needed to calculate the next bit to be sent after the Sample point (e.g. data bit, CRC (Cyclic Redundancy Check) bit, stuff bit, error flag, or idle) is called the Information Processing Time (IPT).

The IPT is application specific but may not be longer than $2 t_q$; the IPT for the C_CAN is $0 t_q$. Its length is the lower limit of the programmed length of Phase_Seg2. In case of a synchronization, Phase_Seg2 may be shortened to a value less than IPT, which does not affect bus timing.

6.20.7.21 Calculating Bit Timing Parameters

Usually, the calculation of the bit timing configuration starts with a desired bit rate or bit time. The resulting bit time ($1/\text{bit rate}$) must be an integer multiple of the APB clock period.

The bit time may consist of 4 to 25 time quanta, the length of the time quantum t_q is defined by the Baud Rate Prescaler with $t_q = (\text{Baud Rate Prescaler})/f_{\text{apb\_clk}}$. Several combinations may lead to the desired bit time, allowing iterations of the following steps.

First part of the bit time to be defined is the Prop_Seg. Its length depends on the delay times measured in the APB clock. A maximum bus length as well as a maximum node delay has to be defined for expandible CAN bus systems. The resulting time for Prop_Seg is converted into time quanta (rounded up to the nearest integer multiple of t_q).

The Sync_Seg is 1 t_q long (fixed), leaving $(\text{bit time} - \text{Prop\_Seg} - 1) t_q$ for the two Phase Buffer Segments. If the number of remaining t_q is even, the Phase Buffer Segments have the same length, $\text{Phase\_Seg2} = \text{Phase\_Seg1}$, else $\text{Phase\_Seg2} = \text{Phase\_Seg1} + 1$.

The minimum nominal length of Phase_Seg2 has to be regarded as well. Phase_Seg2 may not be shorter than the IPT of the CAN controller, which, depending on the actual implementation, is in the range of $[0..2] t_q$.

The length of the Synchronization Jump Width is set to its maximum value, which is the minimum of 4 and Phase_Seg1.

The oscillator tolerance range necessary for the resulting configuration is calculated by the formulas given in Section "Oscillator Tolerance Range"

If more than one configuration is possible, that configuration allowing the highest oscillator tolerance range should be chosen.

CAN nodes with different system clocks require different configurations to come to the same bit rate. The calculation of the propagation time in the CAN network, based on the nodes with the longest delay times, is done once for the whole network.

The oscillator tolerance range of the CAN systems is limited by that node with the lowest tolerance range.

The calculation may show that bus length or bit rate have to be decreased or that the stability of the oscillator frequency has to be increased in order to find a protocol compliant configuration of the CAN bit timing. The resulting configuration is written into the Bit Timing Register: $(\text{Phase\_Seg2}-1)$ & $(\text{Phase\_Seg1}+\text{Prop\_Seg}-1)$ & $(\text{SynchronisationJumpWidth}-1)$ & $(\text{Prescaler}-1)$

Example for Bit Timing at High Baud rate

In this example, the frequency of APB_CLK is 10 MHz, BRP is 0, the bit rate is 1 MBit/s.

T_q	100	ns	$= t_{APB\_CLK}$
delay of bus driver	50	ns	
delay of receiver circuit	30	ns	
delay of bus line (40m)	220	ns	
t_{Prop}	600	ns	$= 6 \cdot t_q$
t_{SJW}	100	ns	$= 1 \cdot t_q$
t_{TSeg1}	700	ns	$= t_{Prop} + t_{SJW}$
t_{TSeg2}	200	ns	$= \text{Information Processing Time} + 1 \cdot t_q$
$t_{Sync-Seg}$	100	ns	$= 1 \cdot t_q$
bit time	1000	ns	$= t_{Sync-Seg} + t_{TSeg1} + t_{TSeg2}$
tolerance for APB_CLK	0.39	%	$= \frac{Min(PB1, PB2)}{2 \times 13 \times (bit\ time - PB2))}$ $= \frac{0.1us}{2 \times 13 \times (1us - 0.2us))}$

In this example, the CAN_BTME register is programmed to= 0x1600.

Example for Bit Timing at Low Baudrate

In this example, the frequency of APB_CLK is 2 MHz, BRP is 1, the bit rate is 100 KBit/s.

t_q	1us	$= 2 \cdot t_{APB\_CLK}$
delay of bus driver	200ns	
delay of receiver circuit	80ns	
delay of bus line (40m)	220ns	
t_{Prop}	1us	$= 1 \cdot t_q$
t_{SJW}	4us	$= 4 \cdot t_q$
t_{TSeg1}	5us	$= t_{Prop} + t_{SJW}$
t_{TSeg2}	4us	$= \text{Information Processing Time} + 3 \cdot t_q$
$t_{Sync-Seg}$	1us	$= 1 \cdot t_q$
bit time	10us	$= t_{Sync-Seg} + t_{TSeg1} + t_{TSeg2}$
tolerance for APB_CLK	1.58 %	$= \frac{\text{Min}(PB1, PB2)}{2 \times 13 \times (\text{bit time} - PB2)}$
		$= \frac{4us}{2 \times 13 \times (10us - 4us)}$

In this example, the CAN_BTME register is programmed to= 0x34C1.

6.20.8 CAN Interface Reset State

After the hardware reset, the C_CAN registers hold the reset values which are given in the register description in *CAN register map*.

Additionally the bus-off state is reset and the output CAN_TX is set to recessive (HIGH). The value 0x0001 (Init = '1') in the CAN Control Register enables the software initialization. The C_CAN does not influence the CAN bus until the application software resets the Init bit (CAN_CON[0]) to '0'.

The data stored in the Message RAM is not affected by a hardware reset. After powered on, the contents of the Message RAM are undefined.

CAN Register Map for Each Bit Function

Addr Offset	Register Name	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
00h	CAN_CON	Reserved								Test	CCE	DAR	Res	EIE	SIE	IE	Init
04h	CAN_STATUS	Reserved								BOff	EWarn	EPass	RxOk	TxOk	LEC		
08h	CAN_ERR	RP	REC6-0							TEC7-0							
0Ch	CAN_BTIME	Res	TSeg2			TSeg1				SJW		BRP					
10h	CAN_IIDR	IntId15-8								IntId7-0							
14h	CAN_TEST	Reserved								Rx	Tx1	Tx0	LBack	Silent	Basic	Reserved	
18h	CAN_BRPE	Reserved												BRPE			
20h	CAN_IF1_CRE Q	Busy	Reserved									Message Number					
24h	CAN_IF1_CMA SK	Reserved								WR/RD	Mask	Arb	Control	ClrIntPnd	TxRqst/	Data A	Data B
28h	CAN_IF1_MAS K1	Msk15-0															
2Ch	CAN_IF1_MAS K2	MXtd	MDir	Res	Msk28-16												
30h	CAN_IF1_ARB 1	ID15-0															
34h	CAN_IF1_ARB 2	MsgVal	Xtd	Dir	ID28-16												

Addr Offset	Register Name	1 5	1 4	1 3	1 2	1 1	1 0	9	8	7	6	5	4	3	2	1	0
38h	CAN_IF1_MCO N	NewDat	MsgLst	IntPnd	UMask	TxIE	RxIE	RmtEn	TxRqst	EoB	Reserved			DLC3-0			
3Ch	CAN_IF1_DAT _A1	Data(1)								Data(0)							
40h	CAN_IF1_DAT _A2	Data(3)								Data(2)							
44h	CAN_IF1_DAT _B1	Data(5)								Data(4)							
48h	CAN_IF1_DAT _B2	Data(7)								Data(6)							
80h	CAN_IF2_CRE Q	Busy	Reserved								Message Number						
84h	CAN_IF2_CMA SK	Reserved								WR/RD	Mask	Arb	Control	CirIntPnd	TxRqst/	Data A	Data B
88h	CAN_IF2_MAS K1	Msk15-0															
8Ch	CAN_IF2_MAS K2	MXtd	MDir	Res.	Msk28-16												
90h	CAN_IF2_ARB 1	ID15-0															
94h	CAN_IF2_ARB 2	MsgVal	Xtd	Dir	ID28-16												
98h	CAN_IF2_MCO N	NewDat	MsgLst	IntPnd	UMask	TxIE	RxIE	RmtEn	TxRqst	EoB	Reserved			DLC3-0			
9Ch	CAN_IF2_DAT _A1	Data(1)								Data(0)							

Addr Offset	Register Name	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
A0h	CAN_IF2_DAT_A2	Data(3)								Data(2)							
A4h	CAN_IF2_DAT_B1	Data(5)								Data(4)							
A8h	CAN_IF2_DAT_B2	Data(7)								Data(6)							
100h	CAN_TXREQ1	TxRqst16-1															
104h	CAN_TXREQ2	TxRqst32-17															
120h	CAN_NDAT1	NewDat16-1															
124h	CAN_NDAT2	NewDat32-17															
140h	CAN_IPND1	IntPnd16-1															
144h	CAN_IPND2	IntPnd32-17															
160h	CAN_MVLD1	MsgVal16-1															
164h	CAN_MVLD2	MsgVal32-17															
168h	CAN_WU_EN	Reserved															WAKU P_EN
16Ch	CAN_WU_STA TUS	Reserved															WAKU P_STS
170h	CAN_RAM_CE N	Reserved															RAM_ CEN
Others	Reserved	Reserved															

Table 6-27 CAN Register Map for Each Bit Function

Note: Reserved bits are read as 0' except for IFn Mask 2 Register where they are read as '1'.

Res. = Reserved

6.20.9 Register Description

The C_CAN allocates an address space of 256 bytes. The registers are organized as 16-bit registers.

The two sets of interface registers (IF1 and IF2) control the software access to the Message RAM. They buffer the data to be transferred to and from the RAM, avoiding conflicts between software accesses and message reception/transmission.

6.20.10 Register Map

R: read only, **W**: write only, **R/W**: both read and write

Register	Offset	R/W	Description	Reset Value
CAN Base Address: CAN0_BA = 0x4018_0000 CAN1_BA = 0x4018_4000				
CAN_CON x=0,1	CANx_BA+0x00	R/W	Control Register	0x0000_0001
CAN_STATUS x=0,1	CANx_BA+0x04	R/W	Status Register	0x0000_0000
CAN_ERR x=0,1	CANx_BA+0x08	R	Error Counter Register	0x0000_0000
CAN_BTIME x=0,1	CANx_BA+0x0C	R/W	Bit Timing Register	0x0000_2301
CAN_IIDR x=0,1	CANx_BA+0x10	R	Interrupt Identifier Register	0x0000_0000
CAN_TEST x=0,1	CANx_BA+0x14	R/W	Test Register (Register Map Note 1)	0x0000_0080
CAN_BRPE x=0,1	CANx_BA+0x18	R/W	Baud Rate Prescaler Extension Register	0x0000_0000
CAN_IF1_CREQ x=0,1	CANx_BA+0x20	R/W	IFn (Register Map Note 2) Command Request Registers	0x0000_0001
CAN_IF2_CREQ x=0,1	CANx_BA+0x80	R/W	IFn (Register Map Note 2) Command Request Registers	0x0000_0001
CAN_IF1_CMASK x=0,1	CANx_BA+0x24	R/W	IFn Command Mask Register	0x0000_0000
CAN_IF2_CMASK x=0,1	CANx_BA+0x84	R/W	IFn Command Mask Register	0x0000_0000
CAN_IF1_MASK1 x=0,1	CANx_BA+0x28	R/W	IFn Mask 1 Register	0x0000_FFFF
CAN_IF2_MASK1 x=0,1	CANx_BA+0x88	R/W	IFn Mask 1 Register	0x0000_FFFF

CAN_IF1_MASK2 x=0,1	CANx_BA+0x2C	R/W	IFn Mask 2 Register	0x0000_FFFF
CAN_IF2_MASK2 x=0,1	CANx_BA+0x8C	R/W	IFn Mask 2 Register	0x0000_FFFF
CAN_IF1_ARB1 x=0,1	CANx_BA+0x30	R/W	IFn Arbitration 1 Register	0x0000_0000
CAN_IF2_ARB1 x=0,1	CANx_BA+0x90	R/W	IFn Arbitration 1 Register	0x0000_0000
CAN_IF1_ARB2 x=0,1	CANx_BA+0x34	R/W	IFn Arbitration 2 Register	0x0000_0000
CAN_IF2_ARB2 x=0,1	CANx_BA+0x94	R/W	IFn Arbitration 2 Register	0x0000_0000
CAN_IF1_MCON x=0,1	CANx_BA+0x38	R/W	IFn Message Control Register	0x0000_0000
CAN_IF2_MCON x=0,1	CANx_BA+0x98	R/W	IFn Message Control Register	0x0000_0000
CAN_IF1_DAT_A1 x=0,1	CANx_BA+0x3C	R/W	IFn Data A1 Register (Register Map Note 3)	0x0000_0000
CAN_IF1_DAT_A2 x=0,1	CANx_BA+0x40	R/W	IFn Data A2 Register (Register Map Note 3)	0x0000_0000
CAN_IF1_DAT_B1 x=0,1	CANx_BA+0x44	R/W	IFn Data B1 Register (Register Map Note 3)	0x0000_0000
CAN_IF1_DAT_B2 x=0,1	CANx_BA+0x48	R/W	IFn Data B2 Register (Register Map Note 3)	0x0000_0000
CAN_IF2_DAT_A1 x=0,1	CANx_BA+0x9C	R/W	IFn Data A1 Register (Register Map Note 3)	0x0000_0000
CAN_IF2_DAT_A2 x=0,1	CANx_BA+0xA0	R/W	IFn Data A2 Register (Register Map Note 3)	0x0000_0000
CAN_IF2_DAT_B1 x=0,1	CANx_BA+0xA4	R/W	IFn Data B1 Register (Register Map Note 3)	0x0000_0000
CAN_IF2_DAT_B2 x=0,1	CANx_BA+0xA8	R/W	IFn Data B2 Register (Register Map Note 3)	0x0000_0000
CAN_TXREQ1 x=0,1	CANx_BA+0x100	R	Transmission Request Register 1	0x0000_0000
CAN_TXREQ2 x=0,1	CANx_BA+0x104	R	Transmission Request Register 2	0x0000_0000
CAN_NDAT1 x=0,1	CANx_BA+0x120	R	New Data Register 1	0x0000_0000
CAN_NDAT2 x=0,1	CANx_BA+0x124	R	New Data Register 2	0x0000_0000

CAN_IPND1 x=0,1	CANx_BA+0x140	R	Interrupt Pending Register 1	0x0000_0000
CAN_IPND2 x=0,1	CANx_BA+0x144	R	Interrupt Pending Register 2	0x0000_0000
CAN_MVLD1 x=0,1	CANx_BA+0x160	R	Message Valid Register 1	0x0000_0000
CAN_MVLD2 x=0,1	CANx_BA+0x164	R	Message Valid Register 2	0x0000_0000
CAN_WU_EN x=0,1	CANx_BA+0x168	R/W	Wake-up Enable Register	0x0000_0000
CAN_WU_STATUS x=0,1	CANx_BA+0x16C	R/W	Wake-up Status Register	0x0000_0000

- Note:** 1. 0x00 & 0br0000000, where r signifies the actual value of the CAN_RX
2. IFn: The two sets of Message Interface Registers – IF1 and IF2, have identical function
3. An/Bn: The two sets of data registers – A1, A2 and B1, B2.
4. CAN_BA, where x = 0 or 1.

CAN Control Register (CAN_CON)

Register	Offset	R/W	Description	Reset Value
CAN_CON x=0, 1	CANx_BA+0x00	R/W	Control Register	0x0000_0001

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Test	CCE	DAR	Reserved	EIE	SIE	IE	Init

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	Test	Test Mode Enable Bit 0 = Normal Operation. 1 = Test Mode.
[6]	CCE	Configuration Change Enable Bit 0 = No write access to the Bit Timing Register. 1 = Write access to the Bit Timing Register (CAN_BTMR) allowed. (while Init bit (CAN_CON[0]) = 1).
[5]	DAR	Automatic Re-Transmission Disable Bit 0 = Automatic Retransmission of disturbed messages enabled. 1 = Automatic Retransmission disabled.
[4]	Reserved	Reserved.
[3]	EIE	Error Interrupt Enable Bit 0 = Disabled - No Error Status Interrupt will be generated. 1 = Enabled - A change in the bits BOff (CAN_STATUS[7]) or EWarn (CAN_STATUS[6]) in the Status Register will generate an interrupt.
[2]	SIE	Status Change Interrupt Enable Bit 0 = Disabled - No Status Change Interrupt will be generated. 1 = Enabled - An interrupt will be generated when a message transfer is successfully completed or a CAN bus error is detected.
[1]	IE	Module Interrupt Enable Bit 0 = Disabled. 1 = Enabled.
[0]	Init	Init Initialization 0 = Normal Operation. 1 = Initialization is started.

Note: The bus-off recovery sequence (see CAN Specification Rev. 2.0) cannot be shortened by setting or resetting the Init bit (CAN_CON[0]). If the device goes in the bus-off state, it will set Init of its own accord, stopping all bus activities. Once Init has been cleared by the CPU, the device will then wait for 129 occurrences of Bus Idle (129 * 11 consecutive recessive bits) before resuming normal operations. At the end of the bus-off recovery sequence, the Error Management Counters will be reset.

During the waiting time after resetting Init, each time a sequence of 11 recessive bits has been monitored, a Bit0Error code is written to the Status Register, enabling the CPU to readily check up whether the CAN bus is stuck at dominant or continuously disturbed and to monitor the proceeding of the bus-off recovery sequence.

CAN Status Register (CAN STATUS)

Register	Offset	R/W	Description	Reset Value
CAN_STATUS x=0, 1	CANx_BA+0x04	R/W	Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
BOFF	EWarn	EPass	RxOK	TxOK	LEC		

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	BOff	Bus-Off Status (Read Only) 0 = The CAN module is not in bus-off state. 1 = The CAN module is in bus-off state.
[6]	EWarn	Error Warning Status (Read Only) 0 = Both error counters are below the error warning limit of 96. 1 = At least one of the error counters in the EML has reached the error warning limit of 96.
[5]	EPass	Error Passive (Read Only) 0 = The CAN Core is error active. 1 = The CAN Core is in the error passive state as defined in the CAN Specification.
[4]	RxOK	Received A Message Successfully 0 = No message has been successfully received since this bit was last reset by the CPU. This bit is never reset by the CAN Core. 1 = A message has been successfully received since this bit was last reset by the CPU (independent of the result of acceptance filtering).
[3]	TxOK	Transmitted A Message Successfully 0 = Since this bit was reset by the CPU, no message has been successfully transmitted. This bit is never reset by the CAN Core. 1 = Since this bit was last reset by the CPU, a message has been successfully (error free and acknowledged by at least one other node) transmitted.
[2:0]	LEC	Last Error Code (Type Of The Last Error To Occur On The CAN Bus) The LEC field holds a code, which indicates the type of the last error to occur on the CAN bus. This field will be cleared to '0' when a message has been transferred (reception or transmission) without error. The unused code '7' may be written by the CPU to check for updates. The following table describes the error code.

Error Code	Meanings
0	No Error
1	Stuff Error: More than 5 equal bits in a sequence have occurred in a part of a received message where this is not allowed.
2	Form Error: A fixed format part of a received frame has the wrong format.
3	AckError: The message this CAN Core transmitted was not acknowledged by another node.
4	Bit1Error: During the transmission of a message (with the exception of the arbitration field), the device wanted to send a recessive level (bit of logical value '1'), but the monitored bus value was dominant.
5	Bit0Error: During the transmission of a message (or acknowledge bit, or active error flag, or overload flag), though the device wanted to send a dominant level (data or identifier bit logical value '0'), but the monitored Bus value was recessive. During bus-off recovery, this status is set each time a sequence of 11 recessive bits has been monitored. This enables the CPU to monitor the proceedings of the bus-off recovery sequence (indicating the bus is not stuck at dominant or continuously disturbed).
6	CRCErrror: The CRC check sum was incorrect in the message received, the CRC received for an incoming message does not match with the calculated CRC for the received data.
7	Unused: When the LEC shows the value '7', no CAN bus event was detected since the CPU wrote this value to the LEC.

Table 6-28 Error Codes

Status Interrupts

A Status Interrupt is generated by bits BOff (CAN_STATUS[7]) and EWarn (CAN_STATUS[6]) (Error Interrupt) or by RxOk (CAN_STATUS[4]), TxOk (CAN_STATUS[3]), and LEC (CAN_STATUS[2:0]) (Status Change Interrupt) assumed that the corresponding enable bits in the CAN Control Register are set. A change of bit EPass (CAN_STATUS[5]) or a write to RxOk, TxOk, or LEC will never generate a Status Interrupt.

Reading the Status Register will clear the Status Interrupt value (8000h) in the Interrupt Register, if it is pending.

CAN Error Counter Register (CAN_ERR)

Register	Offset	R/W	Description	Reset Value
CAN_ERR x=0, 1	CANx_BA+0x08	R	Error Counter Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
RP	REC[6:0]						
7	6	5	4	3	2	1	0
TEC[7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15]	RP	Receive Error Passive 0 = The Receive Error Counter is below the error passive level. 1 = The Receive Error Counter has reached the error passive level as defined in the CAN Specification.
[14:8]	REC	Receive Error Counter Actual state of the Receive Error Counter. Values between 0 and 127.
[7:0]	TEC	Transmit Error Counter Actual state of the Transmit Error Counter. Values between 0 and 255.

Bit Timing Register (CAN_BTME)

Register	Offset	R/W	Description	Reset Value
CAN_BTME x=0, 1	CANx_BA+0x0C	R/W	Bit Timing Register	0x0000_2301

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved	TSeg2			TSeg1			
7	6	5	4	3	2	1	0
SJW		BRP					

Bits	Description
[31:15]	Reserved Reserved.
[14:12]	TSeg2 Time Segment After Sample Point 0x0-0x7: Valid values for TSeg2 are [0 ... 7]. The actual interpretation by the hardware of this value is such that one more than the value programmed here is used.
[11:8]	TSeg1 Time Segment Before The Sample Point Minus Sync_Seg 0x01-0x0F: valid values for TSeg1 are [1 ... 15]. The actual interpretation by the hardware of this value is such that one more than the value programmed is used.
[7:6]	SJW (Re)Synchronization Jump Width 0x0-0x3: Valid programmed values are [0 ... 3]. The actual interpretation by the hardware of this value is such that one more than the value programmed here is used.
[5:0]	BRP Baud Rate Prescaler 0x01-0x3F: The value by which the oscillator frequency is divided for generating the bit time quanta. The bit time is built up from a multiple of this quanta. Valid values for the Baud Rate Prescaler are [0 ... 63]. The actual interpretation by the hardware of this value is such that one more than the value programmed here is used.

Note: With a module clock APB_CLK of 8 MHz, the reset value of 0x2301 configures the C_CAN for a bit rate of 500 Kbit/s. The registers are only writable if bits CCE (CAN_CON[6]) and Init (CAN_CON[0]) are set.

Interrupt Identify Register (CAN_IIDR)

Register	Offset	R/W	Description	Reset Value
CAN_IIDR x=0, 1	CANx_BA+0x10	R	Interrupt Identifier Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
IntId[15:8]							
7	6	5	4	3	2	1	0
IntId[7:0]							

Bits	Description
[15:0]	IntId Interrupt Identifier (Indicates The Source Of The Interrupt) If several interrupts are pending, the CAN Interrupt Register will point to the pending interrupt with the highest priority, disregarding their chronological order. An interrupt remains pending until the application software has cleared it. If IntId is different from 0x0000 and IE (CAN_IFn_MCON[1]) is set, the IRQ interrupt signal to the EIC is active. The interrupt remains active until IntId is back to value 0x0000 (the cause of the interrupt is reset) or until IE is reset. The Status Interrupt has the highest priority. Among the message interrupts, the Message Object's interrupt priority decreases with increasing message number. A message interrupt is cleared by clearing the Message Object's IntPnd bit (CAN_IFn_MCON[13]). The Status Interrupt is cleared by reading the Status Register.

IntId Value	Meanings
0x0000	No Interrupt is Pending
0x0001-0x0020	Number of Message Object which caused the interrupt.
0x0021-0x7FFF	Unused
0x8000	Status Interrupt
0x8001-0xFFFF	Unused

Table 6-29 Source of Interrupts

Test Register (CAN_TEST)

Register	Offset	R/W	Description	Reset Value
CAN_TEST x=0, 1	CANx_BA+0x14	R/W	Test Register (Register Map Note 1)	0x0000_0080

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Rx	Tx[1:0]		LBack	Silent	Basic	Res	

Bits	Description	
[31:8]	Reserved	Reserved.
[7]	Rx	Monitors The Actual Value Of CAN_RX Pin (Read Only) 0 = The CAN bus is dominant (CAN_RX = '0'). 1 = The CAN bus is recessive (CAN_RX = '1').
[6:5]	Tx[1:0]	Tx[1:0]: Control Of CAN_TX Pin 00 = Reset value, CAN_TX pin is controlled by the CAN Core. 01 = Sample Point can be monitored at CAN_TX pin. 10 = CAN_TX pin drives a dominant ('0') value. 11 = CAN_TX pin drives a recessive ('1') value.
[4]	LBack	Loop Back Mode Enable Bit 0 = Loop Back Mode is disabled. 1 = Loop Back Mode is enabled.
[3]	Silent	Silent Mode 0 = Normal operation. 1 = The module is in Silent Mode.
[2]	Basic	Basic Mode 0 = Basic Mode disabled. 1 = IF1 Registers used as Tx Buffer, IF2 Registers used as Rx Buffer.
[1:0]	Res	Reserved There are reserved bits. These bits are always read as '0' and must always be written with '0'.

Reset value: 0000 0000 R000 0000 b (R:current value of RX pin)

Note: Write access to the Test Register is enabled by setting the Test bit (CAN_CON[7]). The different test functions may be combined, but Tx[1-0] "00" (CAN_TEST[6:5]) disturbs message transfer.

Baud Rate Prescaler Extension REGISTER (CAN_BRPE)

Register	Offset	R/W	Description	Reset Value
CAN_BRPE x=0, 1	CANx_BA+0x18	R/W	Baud Rate Prescaler Extension Register	0x0000_0000

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

Bits	Description	
[31:4]	Reserved	Reserved.
[3:0]	BRPE	BRPE: Baud Rate Prescaler Extension 0x00-0x0F: By programming BRPE, the Baud Rate Prescaler can be extended to values up to 1023. The actual interpretation by the hardware is that one more than the value programmed by BRPE (MSBs) and BTIME (LSBs) is used.

Message Interface Register Sets

There are two sets of Interface Registers, which are used to control the CPU access to the Message RAM. The Interface Registers avoid conflict between the CPU accesses to the Message RAM and CAN message reception and transmission by buffering the data to be transferred. A complete Message Object or parts of the Message Object may be transferred between the Message RAM and the IFn Message Buffer registers in one single transfer.

The function of the two interface register sets is identical except for the Basic test mode. They can be used the way one set of registers is used for data transfer to the Message RAM while the other set of registers is used for the data transfer from the Message RAM, allowing both processes to be interrupted by each other. The following table provides an overview of the two Interface Register sets.

Each set of Interface Registers consists of Message Buffer Registers controlled by their own Command Registers. The Command Mask Register specifies the direction of the data transfer and which parts of a Message Object will be transferred. The Command Request Register is used to select a Message Object in the Message RAM as target or source for the transfer and to start the action specified in the Command Mask Register.

Address	IF1 Register Set	Address	IF2 Register Set
CANx_BA+0x20; x=0,1	IF1 Command Request	CANx_BA+0x80; x=0,1	IF2 Command Request
CANx_BA+0x24; x=0,1	IF1 Command Mask	CANx_BA+0x84; x=0,1	IF2 Command Mask
CANx_BA+0x28; x=0,1	IF1 Mask 1	CANx_BA+0x88; x=0,1	IF2 Mask 1
CANx_BA+0x2C; x=0,1	IF1 Mask 2	CANx_BA+0x8C; x=0,1	IF2 Mask 2
CANx_BA+0x30; x=0,1	IF1 Arbitration 1	CANx_BA+0x90; x=0,1	IF2 Arbitration 1
CANx_BA+0x34; x=0,1	IF1 Arbitration 2	CANx_BA+0x94; x=0,1	IF2 Arbitration 2
CANx_BA+0x38; x=0,1	IF1 Message Control	CANx_BA+0x98; x=0,1	IF2 Message Control
CANx_BA+0x3C; x=0,1	IF1 Data A 1	CANx_BA+0x9C; x=0,1	IF2 Data A 1
CANx_BA+0x40; x=0,1	IF1 Data A 2	CANx_BA+0xA0; x=0,1	IF2 Data A 2
CANx_BA+0x44; x=0,1	IF1 Data B 1	CANx_BA+0xA4; x=0,1	IF2 Data B 1
CANx_BA+0x48; x=0,1	IF1 Data B 2	CANx_BA+0xA8; x=0,1	IF2 Data B 2

Table 6-30 IF1 and IF2 Message Interface Register

IFn Command Request Register (CAN IFn CREQ)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_CREQ x=0,1	CANx_BA+0x20	R/W	IFn (Register Map Note 2) Command Request Registers	0x0000_0001
CAN_IF2_CREQ x=0,1	CANx_BA+0x80	R/W	IFn (Register Map Note 2) Command Request Registers	0x0000_0001

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Busy	Res						
7	6	5	4	3	2	1	0
Res		Message Number					

Bits	Description	
[31:16]	Reserved	Reserved.
[15]	Busy	Busy Flag 0 = Read/write action has finished. 1 = Writing to the IFn Command Request Register is in progress. This bit can only be read by the software.
[14:6]	Reserved	Reserved.
[5:0]	Message Number	Message Number 0x01-0x20: Valid Message Number, the Message Object in the Message RAM is selected for data transfer. 0x00: Not a valid Message Number, interpreted as 0x20. 0x21-0x3F: Not a valid Message Number, interpreted as 0x01-0x1F.

A message transfer is started as soon as the application software has written the message number to the Command Request Register. With this write operation, the Busy bit (CAN_IFn_CREQ[15]) is automatically set to notify the CPU that a transfer is in progress. After a waiting time of 3 to 6 APB_CLK periods, the transfer between the Interface Register and the Message RAM is completed. The Busy bit is cleared.

Note: When a Message Number that is not valid is written into the Command Request Register, the Message Number will be transformed into a valid value and that Message Object will be transferred.

IFn Command Mask Register (CAN_IFn_CMASK)

The control bits of the IFn Command Mask Register specify the transfer direction and select which of the IFn Message Buffer Registers are source or target of the data transfer.

Register	Offset	R/W	Description	Reset Value
CAN_IF1_CMASK x=0,1	CANx_BA+0x24	R/W	IFn Command Mask Register	0x0000_0000
CAN_IF2_CMASK x=0,1	CANx_BA+0x84	R/W	IFn Command Mask Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
WR/RD	Mask	Arb	Control	ClrIntPnd	TxRqst/ NewDat	DAT_A	DAT_B

Bits	Description
[31:8]	Reserved Reserved.
[7]	WR/RD Write / Read Mode 0 = Read: Transfer data from the Message Object addressed by the Command Request Register into the selected Message Buffer Registers. 1 = Write: Transfer data from the selected Message Buffer Registers to the Message Object addressed by the Command Request Register.
[6]	Mask Access Mask Bits Write Operation: 0 = Mask bits unchanged. 1 = Transfer Identifier Mask + MDir + MXtd to Message Object. Read Operation: 0 = Mask bits unchanged. 1 = Transfer Identifier Mask + MDir + MXtd to IFn Message Buffer Register.
[5]	Arb Access Arbitration Bits Write Operation: 0 = Arbitration bits unchanged. 1 = Transfer Identifier + Dir (CAN_IFn_ARB2[13]) + Xtd (CAN_IFn_ARB2[14]) + MsgVal (CAN_IFn_ARB2[15]) to Message Object. Read Operation: 0 = Arbitration bits unchanged. 1 = Transfer Identifier + Dir + Xtd + MsgVal to IFn Message Buffer Register.
[4]	Control Control Access Control Bits

		Write Operation: 0 = Control Bits unchanged. 1 = Transfer Control Bits to Message Object. Read Operation: 0 = Control Bits unchanged. 1 = Transfer Control Bits to IFn Message Buffer Register.
[3]	ClrIntPnd	Clear Interrupt Pending Bit Write Operation: When writing to a Message Object, this bit is ignored. Read Operation: 0 = IntPnd bit (CAN_IFn_MCON[13]) remains unchanged. 1 = Clear IntPnd bit in the Message Object.
[2]	TxRqst/NewDat	Access Transmission Request Bit When Write Operation 0 = TxRqst bit unchanged. 1 = Set TxRqst bit. Note: If a transmission is requested by programming bit TxRqst/NewDat in the IFn Command Mask Register, bit TxRqst in the IFn Message Control Register will be ignored. Access New Data Bit when Read Operation. 0 = NewDat bit remains unchanged. 1 = Clear NewDat bit in the Message Object. Note: A read access to a Message Object can be combined with the reset of the control bits IntPnd and NewDat. The values of these bits transferred to the IFn Message Control Register always reflect the status before resetting these bits.
[1]	DAT_A	Access Data Bytes [3:0] Write Operation: 0 = Data Bytes [3:0] unchanged. 1 = Transfer Data Bytes [3:0] to Message Object. Read Operation: 0 = Data Bytes [3:0] unchanged. 1 = Transfer Data Bytes [3:0] to IFn Message Buffer Register.
[0]	DAT_B	Access Data Bytes [7:4] Write Operation: 0 = Data Bytes [7:4] unchanged. 1 = Transfer Data Bytes [7:4] to Message Object. Read Operation: 0 = Data Bytes [7:4] unchanged. 1 = Transfer Data Bytes [7:4] to IFn Message Buffer Register.

IFn Mask 1 Register (CAN_IFn_MASK1)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_MASK1 x=0,1	CANx_BA+0x28	R/W	IFn Mask 1 Register	0x0000_FFFF
CAN_IF2_MASK1 x=0,1	CANx_BA+0x88	R/W	IFn Mask 1 Register	0x0000_FFFF

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Msk[15:8]							
7	6	5	4	3	2	1	0
Msk[7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	Msk[15:0]	Identifier Mask 15-0 0 = The corresponding bit in the identifier of the message object cannot inhibit the match in the acceptance filtering. 1 = The corresponding identifier bit is used for acceptance filtering.

IFn Mask 2 Register (CAN_IFn_MASK2)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_MASK2 x=0,1	CANx_BA+0x2C	R/W	IFn Mask 2 Register	0x0000_FFFF
CAN_IF2_MASK2 x=0,1	CANx_BA+0x8C	R/W	IFn Mask 2 Register	0x0000_FFFF

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
MXtd	MDir	Reserved	Msk[28:24]				
7	6	5	4	3	2	1	0
Msk[23:16]							

Bits	Description
[31:16]	Reserved Reserved.
[15]	MXtd Mask Extended Identifier 0 = The extended identifier bit (IDE) has no effect on the acceptance filtering. 1 = The extended identifier bit (IDE) is used for acceptance filtering. Note: When 11-bit ("standard") Identifiers are used for a Message Object, the identifiers of received Data Frames are written into bits ID28 to ID18 (CAN_IFn_ARB2[12:2]). For acceptance filtering, only these bits together with mask bits Msk28 to Msk18 (CAN_IFn_MASK2[12:2]) are considered.
[14]	MDir Mask Message Direction 0 = The message direction bit (Dir (CAN_IFn_ARB2[13])) has no effect on the acceptance filtering. 1 = The message direction bit (Dir) is used for acceptance filtering.
[13]	Reserved Reserved.
[12:0]	Msk[28:16] Identifier Mask 28-16 0 = The corresponding bit in the identifier of the message object cannot inhibit the match in the acceptance filtering. 1 = The corresponding identifier bit is used for acceptance filtering.

IFn Arbitration 1 Register (CAN IFn ARB1)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_ARB1 x=0,1	CANx_BA+0x30	R/W	IFn Arbitration 1 Register	0x0000_0000
CAN_IF2_ARB1 x=0,1	CANx_BA+0x90	R/W	IFn Arbitration 1 Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
ID[15:8]							
7	6	5	4	3	2	1	0
ID[7:0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	ID[15:0]	Message Identifier 15-0 ID28 - ID0, 29-bit Identifier ("Extended Frame"). ID28 - ID18, 11-bit Identifier ("Standard Frame")

IFn Arbitration 2 Register (CAN_IFn_ARB2)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_ARB2 x=0,1	CANx_BA+0x34	R/W	IFn Arbitration 2 Register	0x0000_0000
CAN_IF2_ARB2 x=0,1	CANx_BA+0x94	R/W	IFn Arbitration 2 Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
MsgVal	Xtd	Dir	ID[28:24]				
7	6	5	4	3	2	1	0
ID[23:16]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15]	MsgVal	Message Valid 0 = The Message Object is ignored by the Message Handler. 1 = The Message Object is configured and should be considered by the Message Handler. Note: The application software must reset the MsgVal bit of all unused Messages Objects during the initialization before it resets bit Init (CAN_CON[0]). This bit must also be reset before the identifier Id28-0 (CAN_IFn_ARB1[2]), the control bits Xtd (CAN_IFn_ARB2[14]), Dir (CAN_IFn_ARB2[13]), or the Data Length Code DLC3-0 (CAN_IFn_MCON[3:0]) are modified, or if the Messages Object is no longer required.
[14]	Xtd	Extended Identifier 0 = The 11-bit ("standard") Identifier will be used for this Message Object. 1 = The 29-bit ("extended") Identifier will be used for this Message Object.
[13]	Dir	Message Direction 0 = Direction is receive. On TxRqst, a Remote Frame with the identifier of this Message Object is transmitted. On reception of a Data Frame with matching identifier, that message is stored in this Message Object. 1 = Direction is transmit. On TxRqst, the respective Message Object is transmitted as a Data Frame. On reception of a Remote Frame with matching identifier, the TxRqst bit (CAN_IFn_CMASK[2]) of this Message Object is set (if RmtEn (CAN_IFn_MCON[9]) = one).
[12:0]	ID[28:16]	Message Identifier 28-16 ID28 - ID0, 29-bit Identifier ("Extended Frame"). ID28 - ID18, 11-bit Identifier ("Standard Frame")

IFn Message Control Register (CAN_IFn_MCON)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_MCON x=0,1	CANx_BA+0x38	R/W	IFn Message Control Register	0x0000_0000
CAN_IF2_MCON x=0,1	CANx_BA+0x98	R/W	IFn Message Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
NewDat	MsgLst	IntPnd	UMask	TxIE	RxIE	RmtEn	TxRqst
7	6	5	4	3	2	1	0
EoB	Reserved			DLC[3:0]			

Bits	Description	
[31:16]	Reserved	Reserved.
[15]	NewDat	New Data 0 = No new data has been written into the data portion of this Message Object by the Message Handler since last time this flag was cleared by the application software. 1 = The Message Handler or the application software has written new data into the data portion of this Message Object.
[14]	MsgLst	Message Lost (only valid for Message Objects with direction = receive). 0 = No message lost since last time this bit was reset by the CPU. 1 = The Message Handler stored a new message into this object when NewDat was still set, the CPU has lost a message.
[13]	IntPnd	Interrupt Pending 0 = This message object is not the source of an interrupt. 1 = This message object is the source of an interrupt. The Interrupt Identifier in the Interrupt Register will point to this message object if there is no other interrupt source with higher priority.
[12]	UMask	Use Acceptance Mask 0 = Mask ignored. 1 = Use Mask (Msk28-0, MXtd, and MDir) for acceptance filtering. Note: If the UMask bit is set to one, the Message Object's mask bits have to be programmed during initialization of the Message Object before MsgVal bit (CAN_IFn_ARB2[15]) is set to one.
[11]	TxIE	Transmit Interrupt Enable Bit 0 = IntPnd (CAN_IFn_MCON[13]) will be left unchanged after the successful transmission of a frame. 1 = IntPnd will be set after a successful transmission of a frame.
[10]	RxIE	Receive Interrupt Enable Bit

		0 = IntPnd (CAN_IFn_MCON[13]) will be left unchanged after a successful reception of a frame. 1 = IntPnd will be set after a successful reception of a frame.
[9]	RmtEn	Remote Enable Bit 0 = At the reception of a Remote Frame, TxRqst (CAN_IFn_MCON[8]) is left unchanged. 1 = At the reception of a Remote Frame, TxRqst is set.
[8]	TxRqst	Transmit Request 0 = This Message Object is not waiting for transmission. 1 = The transmission of this Message Object is requested and is not yet done.
[7]	EoB	End Of Buffer 0 = Message Object belongs to a FIFO Buffer and is not the last Message Object of that FIFO Buffer. 1 = Single Message Object or last Message Object of a FIFO Buffer. Note: This bit is used to concatenate two or more Message Objects (up to 32) to build a FIFO Buffer. For single Message Objects (not belonging to a FIFO Buffer), this bit must always be set to one.
[6:4]	Reserved	Reserved.
[3:0]	DLC	Data Length Code 0-8: Data Frame has 0-8 data bytes. 9-15: Data Frame has 8 data bytes Note: The Data Length Code of a Message Object must be defined the same as in all the corresponding objects with the same identifier at other nodes. When the Message Handler stores a data frame, it will write the DLC to the value given by the received message. Data 0: 1st data byte of a CAN Data Frame Data 1: 2nd data byte of a CAN Data Frame Data 2: 3rd data byte of a CAN Data Frame Data 3: 4th data byte of a CAN Data Frame Data 4: 5th data byte of a CAN Data Frame Data 5: 6th data byte of a CAN Data Frame Data 6: 7th data byte of a CAN Data Frame Data 7 : 8th data byte of a CAN Data Frame Note: The Data 0 Byte is the first data byte shifted into the shift register of the CAN Core during a reception while the Data 7 byte is the last. When the Message Handler stores a Data Frame, it will write all the eight data bytes into a Message Object. If the Data Length Code is less than 8, the remaining bytes of the Message Object will be overwritten by unspecified values.

IFn Data A1 Register (CAN IFn DAT_A1)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_DAT_A1 x=0,1	CANx_BA+0x3C	R/W	IFn Data A1 Register (Register Map Note 3)	0x0000_0000
CAN_IF2_DAT_A1 x=0,1	CANx_BA+0x9C	R/W	IFn Data A1 Register (Register Map Note 3)	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Data[1]							
7	6	5	4	3	2	1	0
Data[0]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:8]	Data [1]	Data Byte 1 2nd data byte of a CAN Data Frame
[7:0]	Data [0]	Data Byte 0 1st data byte of a CAN Data Frame

IFn Data A2 Register (CAN IFn DAT_A2)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_DAT_A2 x=0,1	CANx_BA+0x40	R/W	IFn Data A2 Register (Register Map Note 3)	0x0000_0000
CAN_IF2_DAT_A2 x=0,1	CANx_BA+0xA0	R/W	IFn Data A2 Register (Register Map Note 3)	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Data[3]							
7	6	5	4	3	2	1	0
Data[2]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:8]	Data [3]	Data Byte 3 4th data byte of CAN Data Frame
[7:0]	Data [2]	Data Byte 2 3rd data byte of CAN Data Frame

IFn Data B1 Register (CAN IFn DAT B1)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_DAT_B1 x=0,1	CANx_BA+0x44	R/W	IFn Data B1 Register (Register Map Note 3)	0x0000_0000
CAN_IF2_DAT_B1 x=0,1	CANx_BA+0xA4	R/W	IFn Data B1 Register (Register Map Note 3)	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Data[5]							
7	6	5	4	3	2	1	0
Data[4]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:8]	Data [5]	Data Byte 5 6th data byte of CAN Data Frame
[7:0]	Data [4]	Data Byte 4 5th data byte of CAN Data Frame

IFn Data B2 Register (CAN IFn DAT B2)

Register	Offset	R/W	Description	Reset Value
CAN_IF1_DAT_B2 x=0,1	CANx_BA+0x48	R/W	IFn Data B2 Register (Register Map Note 3)	0x0000_0000
CAN_IF2_DAT_B2 x=0,1	CANx_BA+0xA8	R/W	IFn Data B2 Register (Register Map Note 3)	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Data[7]							
7	6	5	4	3	2	1	0
Data[6]							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:8]	Data [7]	Data Byte 7 8th data byte of CAN Data Frame.
[7:0]	Data [6]	Data Byte 6 7th data byte of CAN Data Frame.

In a CAN Data Frame, Data [0] is the first, Data [7] is the last byte to be transmitted or received. In CAN's serial bit stream, the MSB of each byte will be transmitted first.

Message Object in the Message Memory

There are 32 Message Objects in the Message RAM. To avoid conflicts between application software access to the Message RAM and CAN message reception and transmission, the CPU cannot directly access the Message Objects, these accesses are handled through the IFn Interface Registers. The following table provides an overview of the structures of a Message Object.

Message Object												
UMask	Msk [28:0]	MXtd	MDir	EoB	NewDat		MsgLst	RxIE	TxIE	IntPnd	RmtEn	TxRqst
MsgVal	ID [28:0]	Xtd	Dir	DLC [3:0]	Data0	Data1	Data2	Data3	Data4	Data5	Data6	Data7

Table 6-31 Structure of a Message Object in the Message Memory

The Arbitration Registers ID28-0 (CAN_IFn_ARB1/2), Xtd (CAN_IFn_ARB2[14]), and Dir (CAN_IFn_ARB2[13]) are used to define the identifier and type of outgoing messages and are used (together with the mask registers Msk28-0 (CAN_IFn_MASK1/2), MXtd (CAN_IFn_MASK2[15]), and MDir (CAN_IFn_MASK2[14])) for acceptance filtering of incoming messages. A received message is stored in the valid Message Object with matching identifier and Direction = receive (Data Frame) or Direction = transmit (Remote Frame). Extended frames can be stored only in Message Objects with Xtd = one, standard frames in Message Objects with Xtd = zero. If a received message (Data Frame or Remote Frame) matches with more than one valid Message Object, it is stored into that with the lowest message number.

Message Handler Registers

All Message Handler registers are read only. Their contents (TxRqst(CAN_IFn_MCON[8]), NewDat (CAN_IFn_MCON[15]), IntPnd(CAN_IFn_MCON[13]), and MsgVal (CAN_IFn_ARB2[15]) bits of each Message Object and the Interrupt Identifier) are status information provided by the Message Handler FSM.

Transmission Request Register 1 (CAN_TXREQ1)

These registers hold the TxRqst bits of the 32 Message Objects. By reading the TxRqst bits, the software can check which Message Object in a Transmission Request is pending. The TxRqst bit of a specific Message Object can be set/reset by the application software through the IFn Message Interface Registers or by the Message Handler after reception of a Remote Frame or after a successful transmission.

Register	Offset	R/W	Description	Reset Value
CAN_TXREQ1 x=0, 1	CANx_BA+0x100	R	Transmission Request Register 1	0x0000_0000

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

Bits	Description
[31:16]	Reserved
[15:0]	Transmission Request Bits 16-1 (Of All Message Objects) 0 = This Message Object is not waiting for transmission. 1 = The transmission of this Message Object is requested and is not yet done. These bits are read only.

Transmission Request Register 2 (CAN_TXREQ2)

Register	Offset	R/W	Description	Reset Value
CAN_TXREQ2 x=0, 1	CANx_BA+0x104	R	Transmission Request Register 2	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
TxRqst32-25							
7	6	5	4	3	2	1	0
TxRqst24-17							

Bits	Description
[31:16]	Reserved
[15:0]	TxRqst 32-17 Transmission Request Bits 32-17 (Of All Message Objects) 0 = This Message Object is not waiting for transmission. 1 = The transmission of this Message Object is requested and is not yet done. These bits are read only.

New Data Register 1 (CAN_NDAT1)

These registers hold the NewDat bits of the 32 Message Objects. By reading out the NewDat bits, the software can check for which Message Object the data portion was updated. The NewDat bit of a specific Message Object can be set/reset by the software through the IFn Message Interface Registers or by the Message Handler after reception of a Data Frame or after a successful transmission.

Register	Offset	R/W	Description	Reset Value
CAN_NDAT1 x=0, 1	CANx_BA+0x120	R	New Data Register 1	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
NewData16-9							
7	6	5	4	3	2	1	0
NewData 8-1							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	NewData16-1	New Data Bits 16-1 (Of All Message Objects) 0 = No new data has been written into the data portion of this Message Object by the Message Handler since the last time this flag was cleared by the application software. 1 = The Message Handler or the application software has written new data into the data portion of this Message Object.

New Data Register 2 (CAN_NDAT2)

Register	Offset	R/W	Description	Reset Value
CAN_NDAT2 x=0, 1	CANx_BA+0x124	R	New Data Register 2	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
NewData 32-25							
7	6	5	4	3	2	1	0
NewData 24-17							

Bits	Description
[31:16]	Reserved Reserved.
[15:0]	NewData 32-17 New Data Bits 32-17 (Of All Message Objects) 0 = No new data has been written into the data portion of this Message Object by the Message Handler since the last time this flag was cleared by the application software. 1 = The Message Handler or the application software has written new data into the data portion of this Message Object.

Interrupt Pending Register 1 (CAN_IPND1)

These registers contain the IntPnd bits of the 32 Message Objects. By reading the IntPnd bits, the software can check for which Message Object an interrupt is pending. The IntPnd bit of a specific Message Object can be set/reset by the application software through the IFn Message Interface Registers or by the Message Handler after reception or after a successful transmission of a frame. This will also affect the value of IntId in the Interrupt Register.

Register	Offset	R/W	Description	Reset Value
CAN_IPND1 x=0, 1	CANx_BA+0x140	R	Interrupt Pending Register 1	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
IntPnd16-9							
7	6	5	4	3	2	1	0
IntPnd 8-1							

Bits	Description
[31:16]	Reserved
[15:0]	IntPnd16-1 Interrupt Pending Bits 16-1 (Of All Message Objects) 0 = This message object is not the source of an interrupt. 1 = This message object is the source of an interrupt.

Interrupt Pending Register 2 (CAN IPND2)

Register	Offset	R/W	Description	Reset Value
CAN_IPND2 x=0, 1	CANx_BA+0x144	R	Interrupt Pending Register 2	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
IntPnd 32-25							
7	6	5	4	3	2	1	0
IntPnd 24-17							

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	IntPnd 32-17	Interrupt Pending Bits 32-17(Of All Message Objects) 0 = This message object is not the source of an interrupt. 1 = This message object is the source of an interrupt.

Message Valid Register 1 (CAN_MVLD1)

These registers hold the MsgVal bits of the 32 Message Objects. By reading the MsgVal bits, the application software can check which Message Object is valid. The MsgVal bit of a specific Message Object can be set/reset by the application software via the IFn Message Interface Registers.

Register	Offset	R/W	Description	Reset Value
CAN_MVLD1 x=0, 1	CANx_BA+0x160	R	Message Valid Register 1	0x0000_0000

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

Bits	Description	
[31:16]	Reserved	Reserved.
[15:0]	MsgVal 16-1	Message Valid Bits 16-1 (Of All Message Objects) (Read Only) 0 = This Message Object is ignored by the Message Handler. 1 = This Message Object is configured and should be considered by the Message Handler. Ex. CAN_MVLD1[0] means Message object No.1 is valid or not. If CAN_MVLD1[0] is set, message object No.1 is configured.

Message Valid Register 2 (CAN_MVLD2)

Register	Offset	R/W	Description	Reset Value
CAN_MVLD2 x=0, 1	CANx_BA+0x164	R	Message Valid Register 2	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
MsgVal 32-25							
7	6	5	4	3	2	1	0
MsgVal 24-17							

Bits	Description
[31:16]	Reserved Reserved.
[15:0]	MsgVal 32-17 Message Valid Bits 32-17 (Of All Message Objects) (Read Only) 0 = This Message Object is ignored by the Message Handler. 1 = This Message Object is configured and should be considered by the Message Handler. Ex.CAN_MVLD2[15] means Message object No.32 is valid or not. If CAN_MVLD2[15] is set, message object No.32 is configured.

Wake Up Enable Register (CAN_WU_EN)

Register	Offset	R/W	Description	Reset Value
CAN_WU_EN x=0, 1	CANx_BA+0x168	R/W	Wake-up Enable Register	0x0000_0000

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

Bits	Description	
[31:1]	Reserved	Reserved.
[0]	WAKUP_EN	Wake-Up Enable Bit 0 = The wake-up function Disabled. 1 = The wake-up function Enabled. Note: User can wake-up system when there is a falling edge in the CAN_Rx pin..

Wake Up Status Register (CAN_WU_STATUS)

Register	Offset	R/W	Description	Reset Value
CAN_WU_STATUS x=0, 1	CANx_BA+0x16C	R/W	Wake-up Status Register	0x0000_0000

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

Bits	Description
[31:1]	Reserved
[0]	Wake-Up Status 0 = No wake-up event occurred. 1 = Wake-up event occurred. Note: This bit can be cleared by writing '0'.

6.21 Analog-to-Digital Converter (ADC)

6.21.1 Overview

The NuMicro™ NUC230/240 series contains one 12-bit successive approximation analog-to-digital converters (SAR A/D converter) with 8 input channels. The A/D converter supports three operation modes: single, single-cycle scan and continuous scan mode. The A/D converter can be started by software, PWM Center-aligned trigger and external STADC pin.

6.21.2 Features

- Analog input voltage range: 0~VREF
- 12-bit resolution and 10-bit accuracy is guaranteed
- Up to 8 single-end analog input channels or 4 differential analog input channels
- Up to 1 MSPS conversion rate (chip working at 5V)
- Three operating modes
 - Single mode: A/D conversion is performed one time on a specified channel
 - Single-cycle scan mode: A/D conversion is performed one cycle on all specified channels with the sequence from the smallest numbered channel to the largest numbered channel
 - Continuous scan mode: A/D converter continuously performs Single-cycle scan mode until software stops A/D conversion
- An A/D conversion can be started by:
 - Writing 1 to ADST bit (ADCR[11]) through software
 - PWM Center-aligned trigger
 - External pin STADC
- Conversion results are held in data registers for each channel with valid and overrun indicators
- Supports two set digital comparators. The conversion result can be compared with specify value and user can select whether to generate an interrupt when conversion result matches the compare register setting
- Channel 7 supports 3 input sources: external analog voltage, internal Band-gap voltage, and internal temperature sensor output

6.21.3 Block Diagram

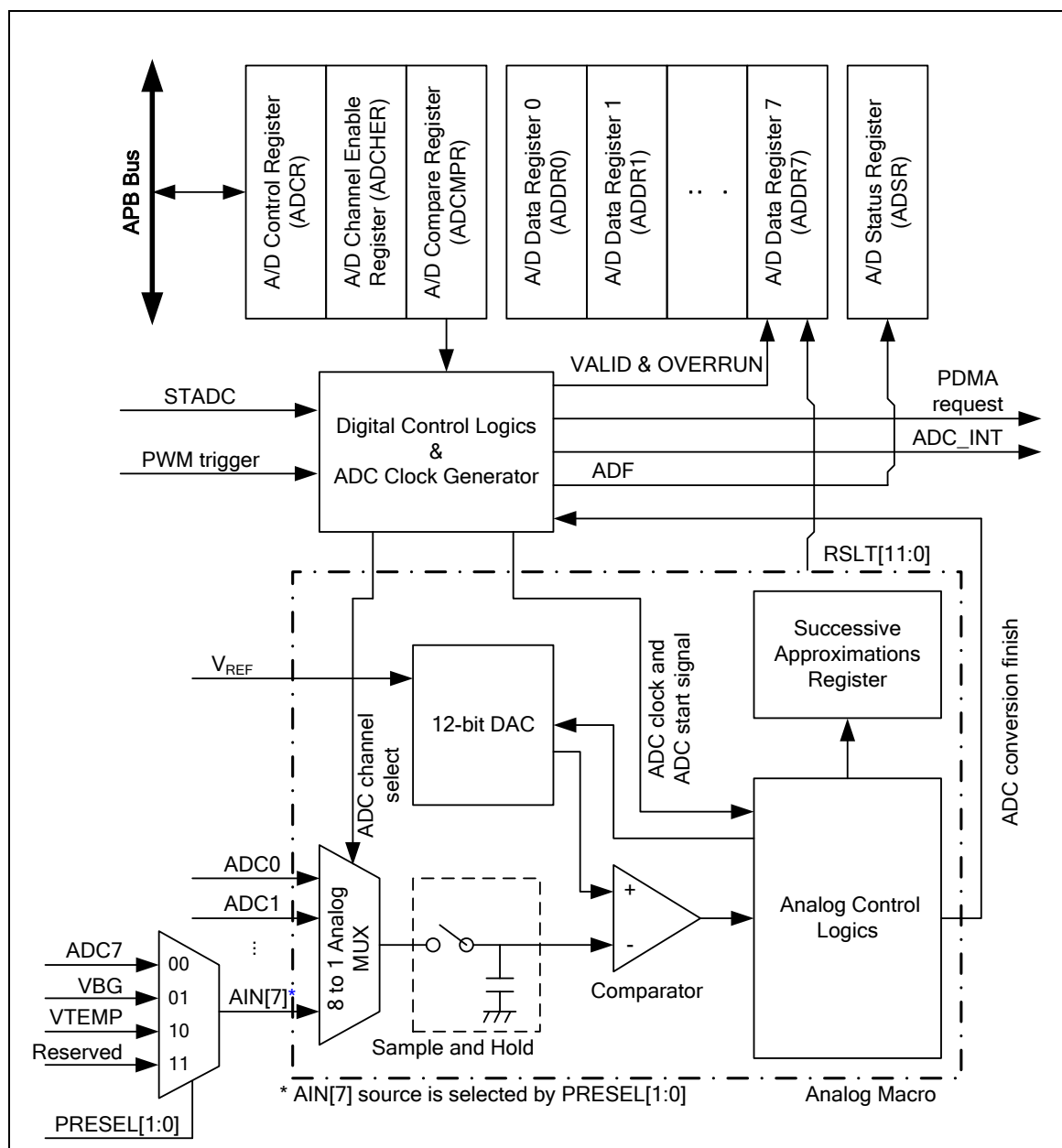


Figure 6-152 ADC Controller Block Diagram

6.21.4 Basic Configuration

The ADC Controller clock source is enabled by ADC_EN bit (CLK_APBCLK[28]). After user change the GPA_MFP register to ADC analog input, user need set OFFD (GPIOA_OFFD [23:16]) = 1 to disable digital input path.

6.21.5 Functional Description

The A/D converter operates by successive approximation with 12-bit resolution. The ADC has three operation modes: Single mode, Single-cycle Scan mode and Continuous Scan mode. When changing the operating mode or analog input channel, to prevent incorrect operation, software must clear ADST bit (ADCR[11]) to 0.

6.21.5.1 ADC Clock Generator

The maximum sampling rate is up to 1 MSPS. The ADC engine has four clock sources selected by 2-bit ADC_S (CLKSEL1[3:2]), the ADC clock frequency is divided by an 8-bit prescaler with the formula:

The ADC clock frequency = (ADC clock source frequency) / (ADC_N (CLKDIV[23:16])+1);

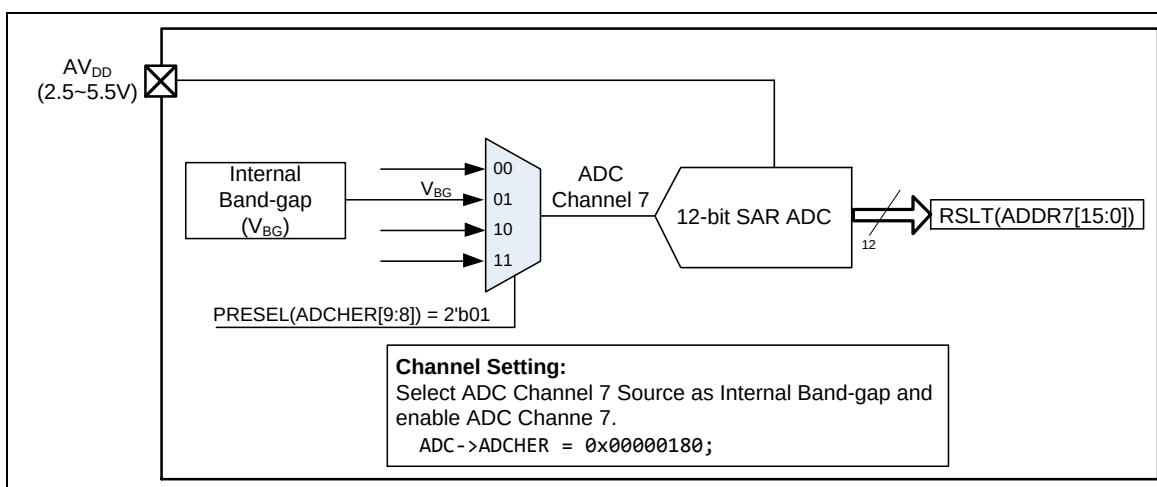


Figure 6-153 ADC Clock Control

6.21.5.2 Single Mode

In single mode, A/D conversion is performed only once on the specified single channel. The operations are as follows:

1. A/D conversion will be started when the ADST bit (ADCR[11]) is set to 1 by software.
2. When A/D conversion is finished, the result is stored in the A/D data register corresponding to the channel.
3. The ADF bit (ADSR[0]) will be set to 1. If the ADIE bit (ADCR[1]) is set to 1, the ADC interrupt will be asserted.
4. The ADST bit remains 1 during A/D conversion. When A/D conversion ends, the ADST bit is automatically cleared to 0 and the A/D converter enters idle state.

Note: If software enables more than one channel in single mode, the channel with the smallest number will be selected and the other enabled channels will be ignored.

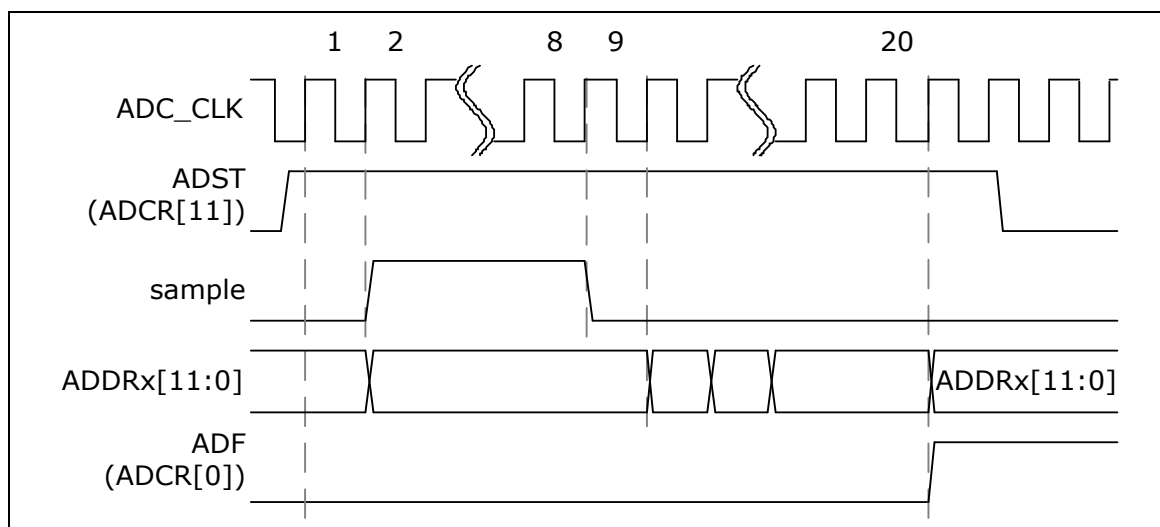


Figure 6-154 Single Mode Conversion Timing Diagram

6.21.5.3 Single-Cycle Scan Mode

In single-cycle scan mode, A/D conversion will sample and convert the specified channels once in the sequence from the smallest number enabled channel to the largest number enabled channel.

1. When the ADST bit (ADCR[11]) is set to 1 by software or external trigger input, A/D conversion starts on the channel with the smallest number.
2. When A/D conversion for each enabled channel is completed, the result is sequentially transferred to the A/D data register corresponding to each channel.
3. When the conversions of all the enabled channels are completed, the ADF bit (ADSR[0]) is set to 1. If the ADC interrupt function is enabled, the ADC interrupt occurs.
4. After A/D conversion ends, the ADST bit is automatically cleared to 0 and the A/D converter enters idle state. If ADST is cleared to 0 before all enabled ADC channels conversion done, ADC controller will finish current conversion and save the result to the ADDR_x of the current conversion channel.

An example timing diagram for single-cycle scan on enabled channels (0, 2, 3 and 7) is shown below:

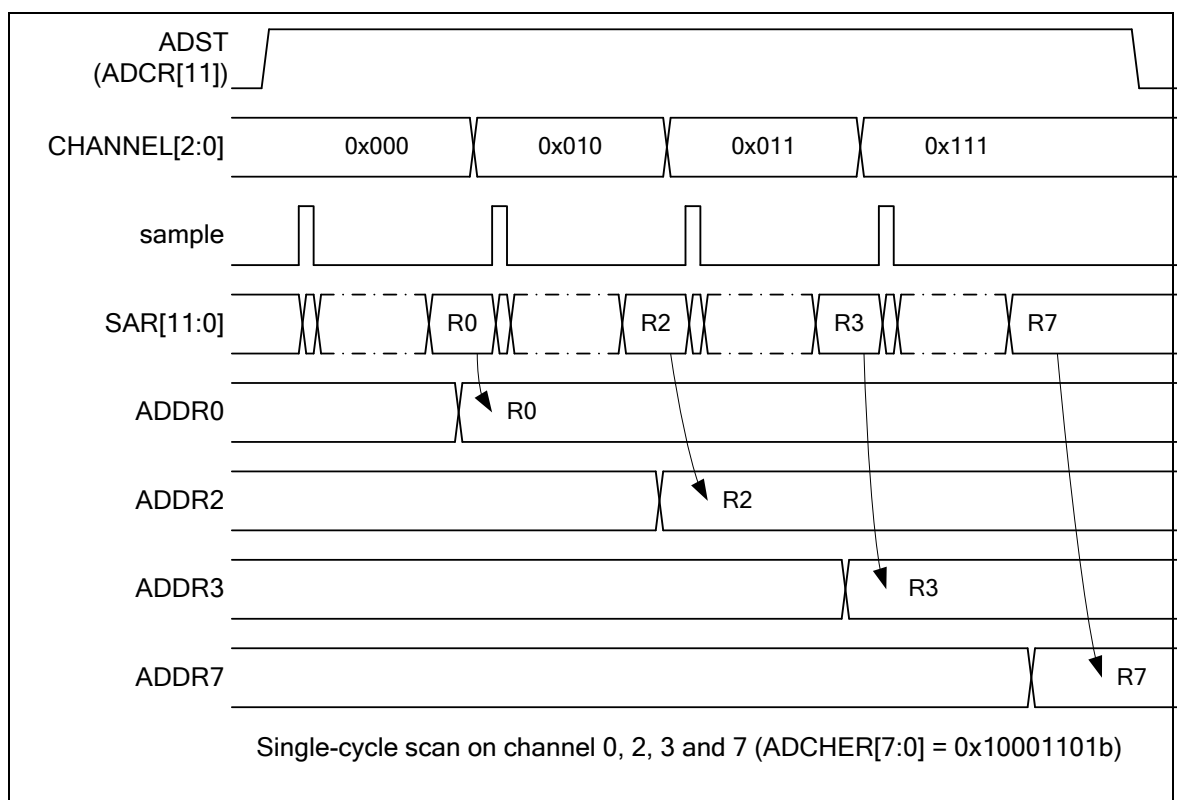


Figure 6-155 Single-Cycle Scan on Enabled Channels Timing Diagram

6.21.5.4 Continuous Scan Mode

In continuous scan mode, A/D conversion is performed sequentially on the specified channels that enabled by CHEN bits (ADCHER[7:0]). The operations are as follows:

1. When the ADST bit (ADCR[11]) is set to 1 by software, A/D conversion starts on the channel with the smallest number.
2. When A/D conversion for each enabled channel is completed, the result of each enabled

- channel is stored in the A/D data register corresponding to each enabled channel.
- 3. When A/D converter completes the conversions of all enabled channels sequentially, the ADF bit (ADSR[0]) will be set to 1. If the ADC interrupt function is enabled, the ADC interrupt occurs. The conversion of the enabled channel with the smallest number will start again if software has not cleared the ADST bit.
 - 4. As long as the ADST bit remains at 1, the step 2 ~ 3 will be repeated. When ADST is cleared to 0, ADC controller will stop conversion.

An example timing diagram for continuous scan on enabled channels (0, 2, 3 and 7) is shown below:

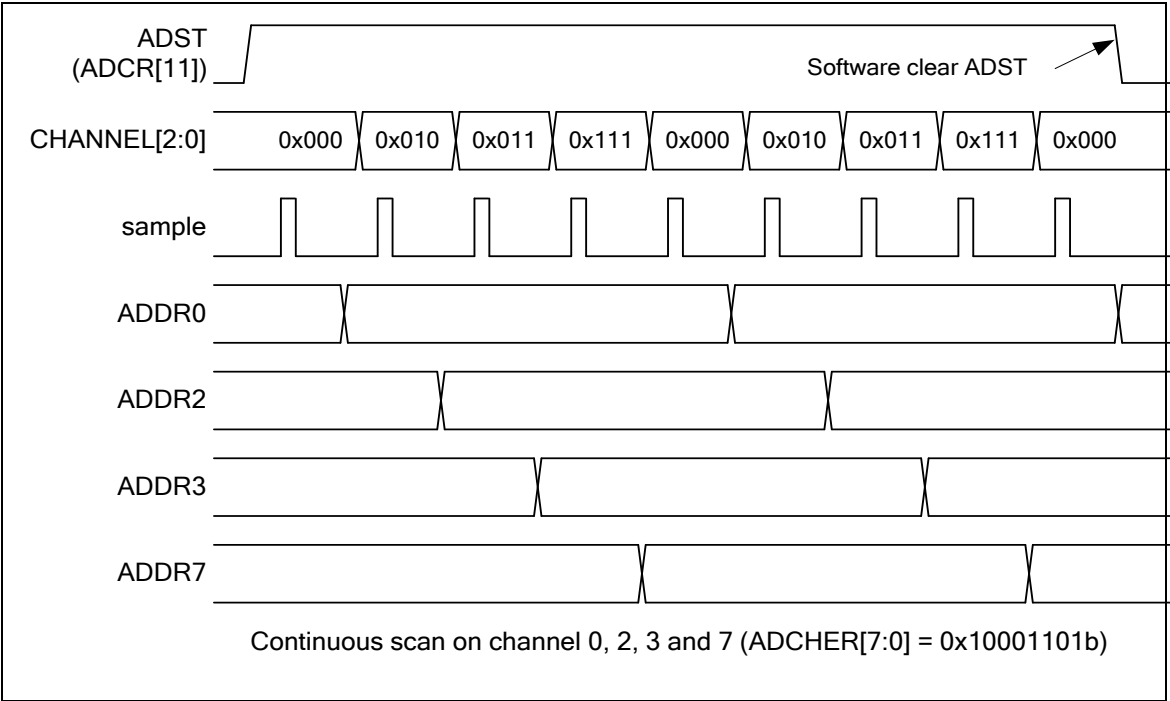


Figure 6-156 Continuous Scan on Enabled Channels Timing Diagram

6.21.5.5 Internal Reference Voltage

The band-gap voltage reference (V_{BG}) is an internal fixed reference voltage regardless of power supply variations. The V_{BG} output is internally connected to ADC channel 7 source multiplexer and Analog Comparators's (ACMP) negative input side.

For battery power detection application, user can use the V_{BG} as ADC input channel such that user can convert the A/D conversion result to calculate AV_{DD} with following formula.

$$AV_{DD} = ((2^N) / R) * V_{BG}$$

N: ADC resolution

R: A/D conversion result

V_{BG} : Band-gap voltage

The block diagram is shown as Figure 6-157.

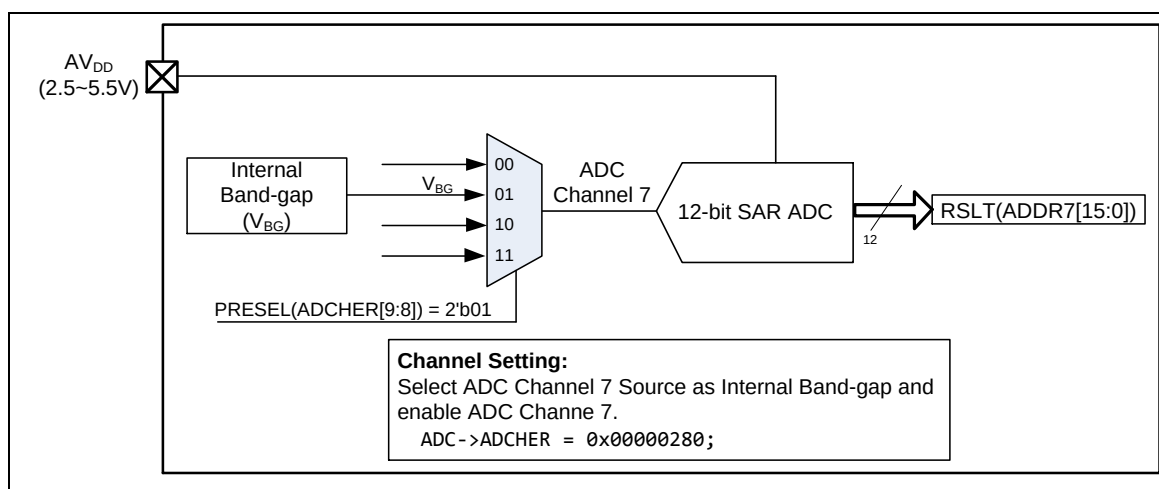


Figure 6-157 V_{BG} for Measuring AV_{DD} Application Block Diagram

For example, the V_{BG} typical value is 1.25 V, the ADC is 12-bit resolution, select V_{BG} as ADC channel 7 input source, and enable ADC channel 7. Then trigger ADC to converse.

If the A/D conversion result is 1707:

$$N = 12$$

$$R = 1707$$

$$V_{BG} = 1.25 \text{ V}$$

$$AV_{DD} = ((2^{12}) / 1707) * 1.25 = (4096 / 1707) * 1.25 = 3 \text{ V}$$

If the A/D conversion result is 2048:

$$AV_{DD} = ((2^{12}) / 2048) * 1.25 = (4096 / 2048) * 1.25 = 2.5 \text{ V}$$

6.21.5.6 External trigger Input Sampling and A/D Conversion Time

In single-cycle scan mode, A/D conversion can be triggered by external pin request. When the TRGEN (ADCR[8]) is set to high to enable ADC external trigger function, setting the TRGS bits (ADCR[5:4]) to 00b is to select external trigger input from the STADC pin. Software can set TRGCOND (ADCR[7:6]) to select trigger condition is falling/rising edge or low/high level. If level trigger condition is selected, the STADC pin must be kept at defined state at least 8 PCLKs. The ADST bit will be set to 1 at the 9th PCLK and start to conversion. Conversion is continuous if external trigger input is kept at active state in level trigger mode. It is stopped only when external condition trigger condition disappears. If edge trigger condition is selected, the high and low state must be kept at least 4 PCLKs. Pulse that is shorter than this specification will be ignored.

6.21.5.7 PWM Center-aligned trigger

In single-cycle scan mode, the PWM can be the trigger source of ADC by setting the TRGEN (ADCR[8]) to 1 and the TRGS (ADCR[5:4]) to 11b.

When PWM enables trigger ADC function, the PWM will generate a trigger signal to ADC when PWM counter is running to PWM center point.

6.21.5.8 Conversion Result Monitor by Compare Function

The ADC controller provide two sets of compare register ADCMPR0 and ADCMPR1, to monitor maximum two specified channels conversion result from A/D conversion controller, refer to Figure 6-158. Software can select which channel to be monitored by set CMPCH (ADCMPR0/1[5:3]) and CMPCOND bit (ADCMPR0/1[2]) is used to check conversion result is less than specify value or greater than (equal to) value specified in CMPD (ADCMPR0/1 [27:16]). When the conversion of the channel specified by CMPCH is completed, the comparing action will be triggered one time automatically. When the compare result meets the setting, compare match counter will increase 1, otherwise, the compare match counter will be cleared to 0. It means the comparing data must be successively matched with the compare condition. Once any comparing data does not match during the comparing, the compare match counter will clear to 0. When counter value reach the setting of (CMPMATCNT (ADCMPR0/1 [11:8])+1) then CMPF0/1 bit (ADSR[1]/[2]) will be set to 1, if CMPIE bit (ADCMPR0/1 [1]) is set then an ADC_INT interrupt request is generated. Software can use it to monitor the external analog input pin voltage transition in scan mode without imposing a load on software. Detailed logics diagram is shown below:

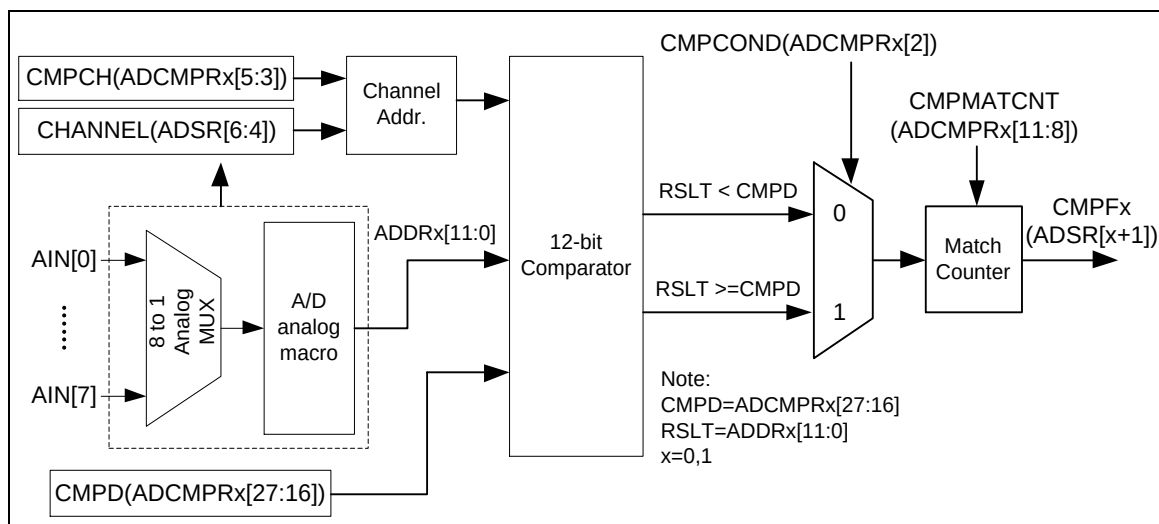


Figure 6-158 A/D Conversion Result Monitor Logics Diagram

6.21.5.9 Interrupt Sources

There are three interrupt sources of ADC interrupt. When an ADC operation mode finishes its conversion, the A/D conversion end flag, ADF, will be set to 1. The CMPF0 (ADSR[1]) and CMPF1 (ADSR[2]) are the compare flags of compare function. When the conversion result meets the settings of ADCMPR0/1, the corresponding flag will be set to 1. When one of the flags, ADF (ADSR[0]), CMPF0 and CMPF1, is set to 1 and the corresponding interrupt enable bit, ADIE (ADCR[1]) and CMPIE (ADCMPR0/1[1]), is set to 1, the ADC interrupt will be asserted. Software can clear the flag to revoke the interrupt request.

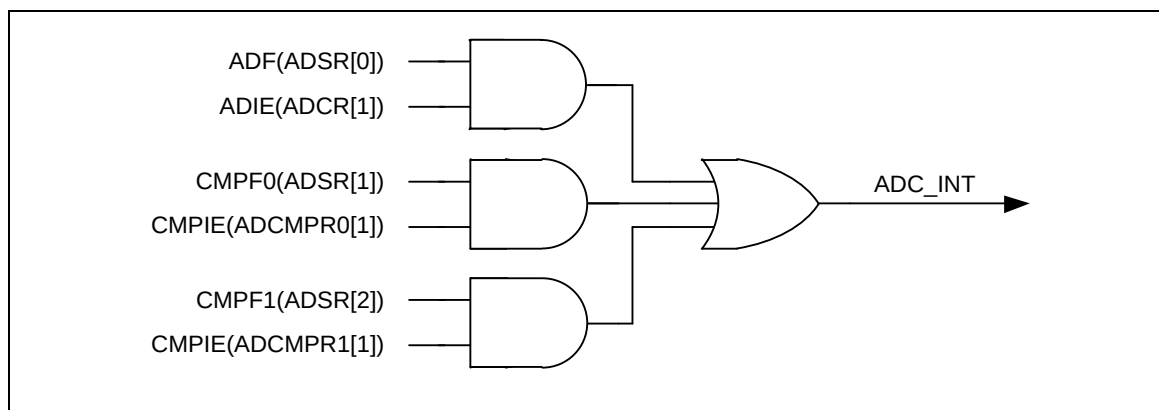


Figure 6-159 A/D Controller Interrupt

6.21.5.10 Peripheral DMA Request

When A/D conversion is finished, the conversion result will be loaded into ADDR register and VALID bit will be set to 1. If the PTEN bit (ADCR[9]) is set, ADC controller will generate a request to PDMA. User can use PDMA to transfer the conversion results to a user-specified memory space without CPU's intervention. The source address of PDMA operation is fixed at ADPDMA, no matter what channels was selected. When PDMA is transferring the conversion result, ADC will continue converting the next selected channel if the operation mode of ADC is single scan mode or continuous scan mode. User can monitor current PDMA transfer data through reading ADPDMA register. If ADC completes the conversion of a selected channel and the last conversion

result of the same channel has not been transferred by PDMA, OVERRUN bit (ADC_ADDRx[16], x=0~7) of the corresponding channel will be set and the last ADC conversion result will be overwritten by the new ADC conversion result. PDMA will transfer the latest data of selected channels to the user-specified destination address.

6.21.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
ADC Base Address: ADC_BA = 0x400E_0000				
ADDR0	ADC_BA+0x00	R	ADC Data Register 0	0x0000_0000
ADDR1	ADC_BA+0x04	R	ADC Data Register 1	0x0000_0000
ADDR2	ADC_BA+0x08	R	ADC Data Register 2	0x0000_0000
ADDR3	ADC_BA+0x0C	R	ADC Data Register 3	0x0000_0000
ADDR4	ADC_BA+0x10	R	ADC Data Register 4	0x0000_0000
ADDR5	ADC_BA+0x14	R	ADC Data Register 5	0x0000_0000
ADDR6	ADC_BA+0x18	R	ADC Data Register 6	0x0000_0000
ADDR7	ADC_BA+0x1C	R	ADC Data Register 7	0x0000_0000
ADCR	ADC_BA+0x20	R/W	ADC Control Register	0x0000_0000
ADCHER	ADC_BA+0x24	R/W	ADC Channel Enable Register	0x0000_0000
ADCMPR0	ADC_BA+0x28	R/W	ADC Compare Register 0	0x0000_0000
ADCMPR1	ADC_BA+0x2C	R/W	ADC Compare Register 1	0x0000_0000
ADSR	ADC_BA+0x30	R/W	ADC Status Register	0x0000_0000
ADPDMA	ADC_BA+0x40	R	ADC PDMA Current Transfer Data Register	0x0000_0000

6.21.7 Register Description

ADC Data Registers (ADDR0 ~ ADDR7)

Register	Offset	R/W	Description	Reset Value
ADDR0	ADC_BA+0x00	R	ADC Data Register 0	0x0000_0000
ADDR1	ADC_BA+0x04	R	ADC Data Register 1	0x0000_0000
ADDR2	ADC_BA+0x08	R	ADC Data Register 2	0x0000_0000
ADDR3	ADC_BA+0x0C	R	ADC Data Register 3	0x0000_0000
ADDR4	ADC_BA+0x10	R	ADC Data Register 4	0x0000_0000
ADDR5	ADC_BA+0x14	R	ADC Data Register 5	0x0000_0000
ADDR6	ADC_BA+0x18	R	ADC Data Register 6	0x0000_0000
ADDR7	ADC_BA+0x1C	R	ADC Data Register 7	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved						VALID	OVERRUN
15	14	13	12	11	10	9	8
RSLT [15:8]							
7	6	5	4	3	2	1	0
RSLT[7:0]							

Bits	Description
[31:18]	Reserved Reserved.
[17]	VALID Valid Flag 0 = Data in RSLT bits (ADDRx[15:0], x=0~7) is not valid. 1 = Data in RSLT bits (ADDRx[15:0], x=0~7) is valid. This bit is set to 1 when corresponding channel analog input conversion is completed and cleared by hardware after ADDR register is read. This is a read only bit
[16]	OVERRUN Overrun Flag 0 = Data in RSLT (ADDRx[15:0], x=0~7) is recent conversion result. 1 = Data in RSLT (ADDRx[15:0], x=0~7) is overwritten. If converted data in RSLT has not been read before new conversion result is loaded to this register, OVERRUN is set to 1 and previous conversion result is gone. It is cleared by hardware after ADDR register is read. This is a read only bit.

[15:0]	RSLT	A/D Conversion Result This field contains conversion result of ADC. When DMOF bit (ADCR[31]) set to 0, 12-bit ADC conversion result with unsigned format will be filled in RSLT (ADDRx[11:0], x=0~7) and zero will be filled in RSLT (ADDRx[15:12], x=0~7). When DMOF bit (ADCR[31]) set to 1, 12-bit ADC conversion result with 2's complement format will be filled in RSLT (ADDRx[11:0], x=0~7) and signed bits will be filled in RSLT (ADDRx[15:12], x=0~7).

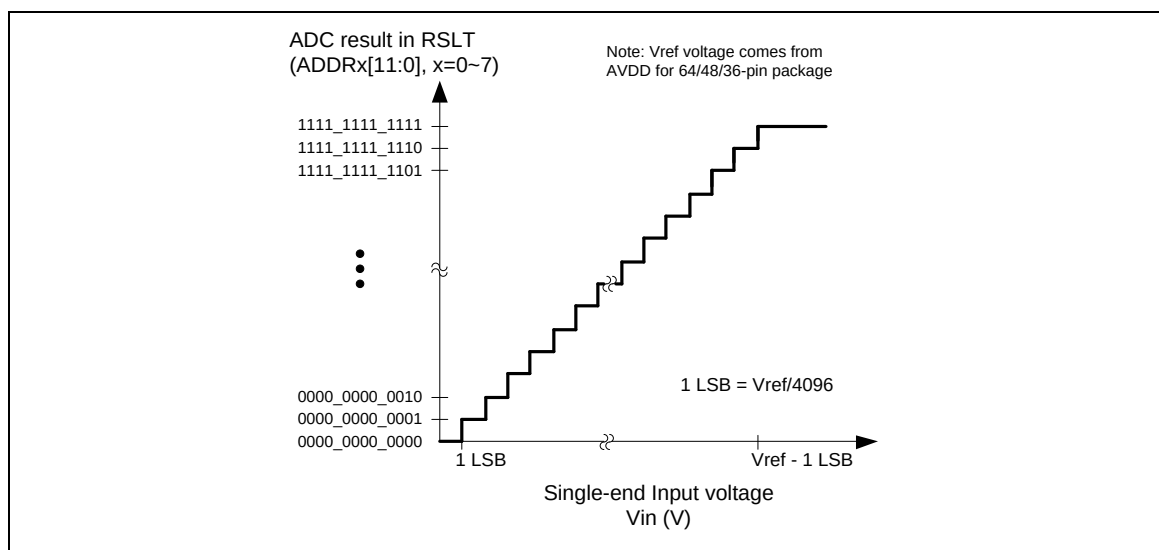


Figure 6-160 ADC Single-end Input Conversion Voltage and Conversion Result Mapping

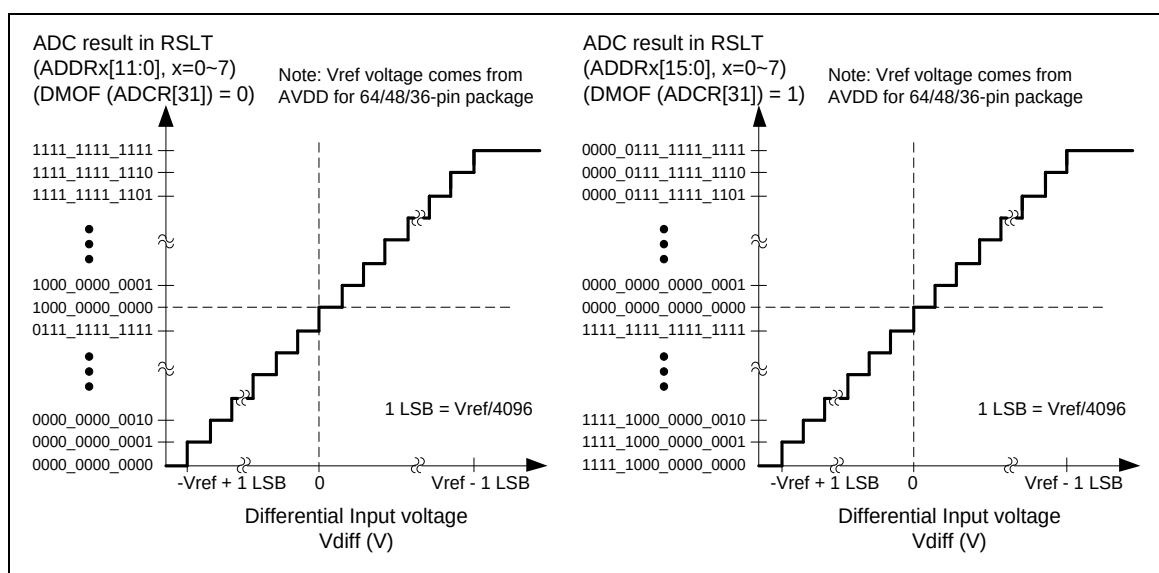


Figure 6-161 ADC Differential Input Conversion Voltage and Conversion Result Mapping

ADC Control Register (ADCR)

Register	Offset	R/W	Description	Reset Value
ADCR	ADC_BA+0x20	R/W	ADC Control Register	0x0000_0000

31	30	29	28	27	26	25	24
DMOF	Reserved						
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved				ADST	DIFFEN	PTEN	TRGEN
7	6	5	4	3	2	1	0
TRGCOND		TRGS		ADMD		ADIE	ADEN

Bits	Description																		
[31]	DMOF	A/D Differential Input Mode Output Format 0 = A/D Conversion result will be filled in RSLT at ADDR _x registers with unsigned format. 1 = A/D Conversion result will be filled in RSLT at ADDR _x registers with 2's complement format.																	
[30:12]	Reserved	Reserved.																	
[11]	ADST	A/D Conversion Start 0 = Conversion stops and A/D converter enter idle state. 1 = Conversion starts. ADST bit can be set to 1 from three sources: software, PWM Center-aligned trigger and external pin STADC. ADST will be cleared to 0 by hardware automatically at the ends of single mode and single-cycle scan mode. In continuous scan mode, A/D conversion is continuously performed until software writes 0 to this bit or chip reset.																	
[10]	DIFFEN	Differential Input Mode Control 0 = Single-end analog input mode. 1 = Differential analog input mode. <table border="1"> <thead> <tr> <th rowspan="2">Differential input Paired Channel</th><th colspan="2">ADC Analog Input</th></tr> <tr> <th>V_{plus}</th><th>V_{minus}</th></tr> </thead> <tbody> <tr> <td>0</td><td>ADC0</td><td>ADC1</td></tr> <tr> <td>1</td><td>ADC2</td><td>ADC3</td></tr> <tr> <td>2</td><td>ADC4</td><td>ADC5</td></tr> <tr> <td>3</td><td>ADC6</td><td>ADC7</td></tr> </tbody> </table> Differential input voltage (V_{diff}) = $V_{plus} - V_{minus}$, where V_{plus} is the analog input; V_{minus} is the inverted analog input. In differential input mode, only the even number of the two corresponding channels needs to be enabled in ADCHER. The conversion result will be placed to the corresponding data register of the enabled channel.	Differential input Paired Channel	ADC Analog Input		V _{plus}	V _{minus}	0	ADC0	ADC1	1	ADC2	ADC3	2	ADC4	ADC5	3	ADC6	ADC7
Differential input Paired Channel	ADC Analog Input																		
	V _{plus}	V _{minus}																	
0	ADC0	ADC1																	
1	ADC2	ADC3																	
2	ADC4	ADC5																	
3	ADC6	ADC7																	

[9]	PTEN	PDMA Transfer Enable Bit 0 = PDMA data transfer Disabled. 1 = PDMA data transfer in ADDR 0~7 Enabled. When A/D conversion is completed, the converted data is loaded into ADDR 0~7, software can enable this bit to generate a PDMA data transfer request. When PTEN=1, software must set ADIE=0 (ADCR[1]) to disable interrupt.
[8]	TRGEN	Hardware Trigger Enable Bit Enable or disable triggering of A/D conversion by hardware (external STADC pin or PWM Center-aligned trigger). 0 = Disabled. 1 = Enabled. ADC hardware trigger function is only supported in single-cycle scan mode. If hardware trigger mode, the ADST bit (ADCR[11]) can be set to 1 by the selected hardware trigger source.
[7:6]	TRGCOND	External Trigger Condition These two bits decide external pin STADC trigger event is level or edge. The signal must be kept at stable state at least 8 PCLKs for level trigger and 4 PCLKs at high and low state for edge trigger. 00 = Low level. 01 = High level. 10 = Falling edge. 11 = Rising edge.
[5:4]	TRGS	Hardware Trigger Source 00 = A/D conversion is started by external STADC pin. 11 = A/D conversion is started by PWM Center-aligned trigger. Others = Reserved. Software should disable TRGEN (ADCR[8]) and ADST (ADCR[11]) before change TRGS.
[3:2]	ADMD	A/D Converter Operation Mode 00 = Single conversion. 01 = Reserved. 10 = Single-cycle scan. 11 = Continuous scan. When changing the operation mode, software should disable ADST bit (ADCR[11]) firstly.
[1]	ADIE	A/D Interrupt Enable Bit 0 = A/D interrupt function Disabled. 1 = A/D interrupt function Enabled. A/D conversion end interrupt request is generated if ADIE bit (ADCR[1]) is set to 1.
[0]	ADEN	A/D Converter Enable Bit 0 = Disabled. 1 = Enabled. Before starting A/D conversion function, this bit should be set to 1. Clear it to 0 to disable A/D converter analog circuit for saving power consumption.

ADC Channel Enable Register (ADCHER)

Register	Offset	R/W	Description	Reset Value
ADCHER	ADC_BA+0x24	R/W	ADC Channel Enable Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved						PRESEL[1:0]	
7	6	5	4	3	2	1	0
CHEN							

Bits	Description	
[31:10]	Reserved	Reserved.
[9:8]	PRESEL	Analog Input Channel 7 Selection 00 = External analog input. 01 = Internal band-gap voltage. 10 = Internal temperature sensor. 11 = Reserved.
[7:0]	CHEN	Analog Input Channel Enable Bit Set CHEN[7:0] to enable the corresponding analog input channel 7 ~ 0. If DIFFEN bit (ADCR[10]) is set to 1, only the even number channels need to be enabled. 0 = ADC input channel Disabled. 1 = ADC input channel Enabled.

ADC Compare Register 0/1 (ADCMPR0/1)

Register	Offset	R/W	Description	Reset Value
ADCMPR0	ADC_BA+0x28	R/W	ADC Compare Register 0	0x0000_0000
ADCMPR1	ADC_BA+0x2C	R/W	ADC Compare Register 1	0x0000_0000

31	30	29	28	27	26	25	24
Reserved				CMPD[11:8]			
23	22	21	20	19	18	17	16
CMPD[7:0]							
15	14	13	12	11	10	9	8
Reserved				CMPMATCNT			
7	6	5	4	3	2	1	0
Reserved		CMPCH			CMPCOND	CMPIE	CMPEN

Bits	Description
[31:28]	Reserved Reserved.
[27:16]	CMPD Comparison Data The 12-bit data is used to compare with conversion result of specified channel. When DMOF bit (ADCR[31]) is set to 0, ADC comparator compares CMPD with conversion result with unsigned format. CMPD should be filled in unsigned format. When DMOF bit (ADCR[31]) is set to 1, ADC comparator compares CMPD with conversion result with 2's complement format. CMPD should be filled in 2's complement format.
[15:12]	Reserved Reserved.
[11:8]	CMPMATCNT Compare Match Count When the specified A/D channel analog conversion result matches the compare condition defined by CMPCOND (ADCMPR0/1[2]), the internal match counter will increase 1. The comparing data must successively matched with the compare condition. Once any comparing data does not match during the comparing, the internal counter will clear to 0. When the internal counter reaches the value to (CMPMATCNT (ADCMPR0/1[11:8]) + 1), the CMPF0/1 bit (ADSR[1]/[2]) will be set.
[7:6]	Reserved Reserved.
[5:3]	CMPCH Compare Channel Selection 000 = Channel 0 conversion result is selected to be compared. 001 = Channel 1 conversion result is selected to be compared. 010 = Channel 2 conversion result is selected to be compared. 011 = Channel 3 conversion result is selected to be compared. 100 = Channel 4 conversion result is selected to be compared. 101 = Channel 5 conversion result is selected to be compared. 110 = Channel 6 conversion result is selected to be compared. 111 = Channel 7 conversion result is selected to be compared.

[2]	CMPCOND	Compare Condition 0 = Set the compare condition as that when a 12-bit A/D conversion result is less than the 12-bit CMPD (ADCMPR0/1[27:16]), the internal match counter will increase one. 1 = Set the compare condition as that when a 12-bit A/D conversion result is greater or equal to the 12-bit CMPD (ADCMPR0/1[27:16]), the internal match counter will increase one. Note: When the internal counter reaches the value to (CMPMATCNT (ADCMPR0/1[11:8])+1), the CMPF0/1 bit (ADSR[1]/[2]) will be set.
[1]	CMPIE	Compare Interrupt Enable Bit 0 = Compare function interrupt Disabled. 1 = Compare function interrupt Enabled. If the compare function is enabled and the compare condition matches the setting of CMPCOND (ADCMPR0/1[2]) and CMPMATCNT (ADCMPR0/1[11:8]), CMPF0/1 bit (ADSR[1]/[2]) will be asserted, in the meanwhile, if CMPIE (ADCMPR0/1[1]) is set to 1, a compare interrupt request is generated.
[0]	CMPEN	Compare Enable Bit 0 = Compare function Disabled. 1 = Compare function Enabled. Set this bit to 1 to enable ADC controller to compare CMPD (ADCMPR0/1[27:16]) with specified channel conversion result when converted data is loaded into ADDR register.

ADC Status Register (ADSR)

Register	Offset	R/W	Description	Reset Value
ADSR	ADC_BA+0x30	R/W	ADC Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
OVERRUN							
15	14	13	12	11	10	9	8
VALID							
7	6	5	4	3	2	1	0
Reserved	CHANNEL			BUSY	CMPF1	CMPF0	ADF

Bits	Description	
[31:24]	Reserved	Reserved.
[23:16]	OVERRUN	Overrun Flag It is a mirror to OVERRUN bit (ADDR0~7[16]). It is read only.
[15:8]	VALID	Data Valid Flag It is a mirror of VALID bit (ADDR0~7[17]). It is read only.
[7]	Reserved	Reserved.
[6:4]	CHANNEL	Current Conversion Channel This field reflects the current conversion channel when BUSY = 1 (ADSR[3]). When BUSY = 0, it shows the number of the next converted channel. It is read only.
[3]	BUSY	BUSY/IDLE 0 = A/D converter is in idle state. 1 = A/D converter is busy at conversion. This bit is mirror of as ADST bit (ADCR[11]). It is read only.
[2]	CMPF1	Compare Flag When the selected channel A/D conversion result meets setting condition in ADCMPR1 then this bit is set to 1. And it is cleared by writing 1 to self. 0 = Conversion result in ADDR does not meet ADCMPR1 setting. 1 = Conversion result in ADDR meets ADCMPR1 setting.
[1]	CMPF0	Compare Flag When the selected channel A/D conversion result meets setting condition in ADCMPR0 then this bit is set to 1. And it is cleared by writing 1 to self. 0 = Conversion result in ADDR does not meet ADCMPR0 setting. 1 = Conversion result in ADDR meets ADCMPR0 setting.

[0]	ADF	A/D Conversion End Flag A status flag that indicates the end of A/D conversion. ADF is set to 1 at these two conditions: 1. When A/D conversion ends in Single mode. 2. When A/D conversion ends on all specified channels in Scan mode. This flag can be cleared by writing 1 to itself.

ADC PDMA Current Transfer Data Register (ADPDMA)

Register	Offset	R/W	Description	Reset Value
ADPDMA	ADC_BA+0x40	R	ADC PDMA Current Transfer Data Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved						AD_PDMA[17:16]	
15	14	13	12	11	10	9	8
AD_PDMA[15:8]							
7	6	5	4	3	2	1	0
AD_PDMA[7:0]							

Bits	Description	
[31:18]	Reserved	Reserved.
[17:0]	AD_PDMA	ADC PDMA Current Transfer Data Register When PDMA transferring, read this register can monitor current PDMA transfer data. Current PDMA transfer data is the content of ADDR0 ~ ADDR7. This is a read only register.

6.22 Analog Comparator (ACMP)

6.22.1 Overview

The NuMicro™ NUC230/240 series contains two comparators which can be used in a number of different configurations. The comparator output is logic 1 when positive input voltage is greater than negative input voltage; otherwise the output is logic 0. Each comparator can be configured to generate interrupt request when the comparator output value changes. The block diagram is shown in Figure 6-162.

6.22.2 Features

- Analog input voltage range: 0~ V_{DDA} (Voltage of AV_{DD} pin)
- Supports Hysteresis function
- Optional internal reference voltage source for each comparator negative input

6.22.3 Block Diagram

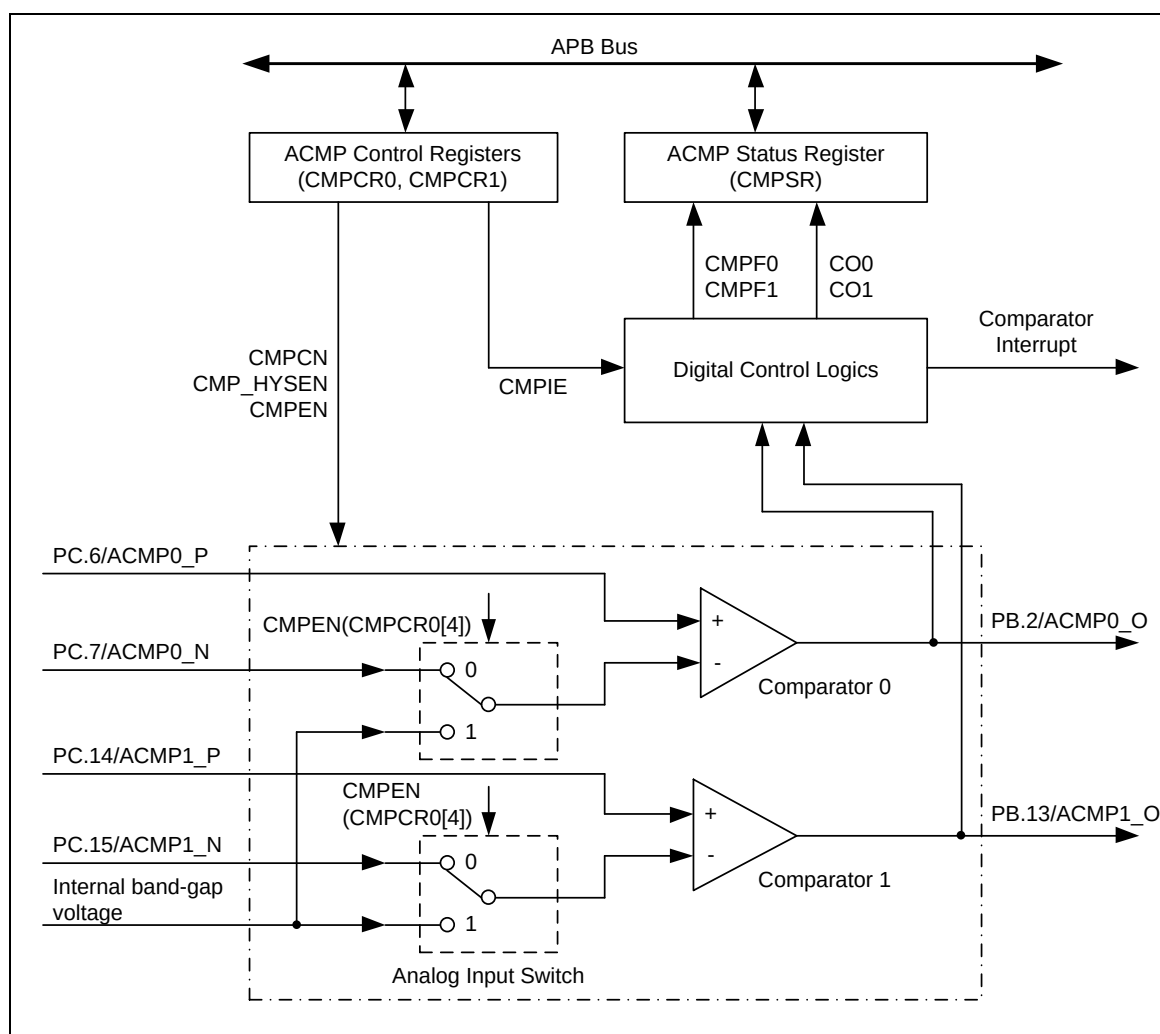


Figure 6-162 Analog Comparator Block Diagram

6.22.4 Basic Configuration

The ACMP pin functions are configured in GPB_MFP, GPC_MFP, ALT_MFP, ALT_MFP1 and ALT_MFP2 registers. It is recommended to disable the digital input path of the analog input pins to avoid the leakage current. The digital input path can be disabled by configuring GPIOC_OFFD register.

The ACMP peripheral clock can be enabled in APBCLK[30].

6.22.5 Functional Description

6.22.5.1 Interrupt Sources

The output of comparators are sampled by PCLK and reflected at CO1 and CO2 of CMPSR register. If CMPIE of CMPCRn register is set to 1, the comparator interrupt will be enabled. As the output state of comparator is changed, the comparator interrupt will be asserted and the corresponding flag, CMPF0 or CMPF1, will be set. Software can clear the flag to 0 by writing 1 to it.

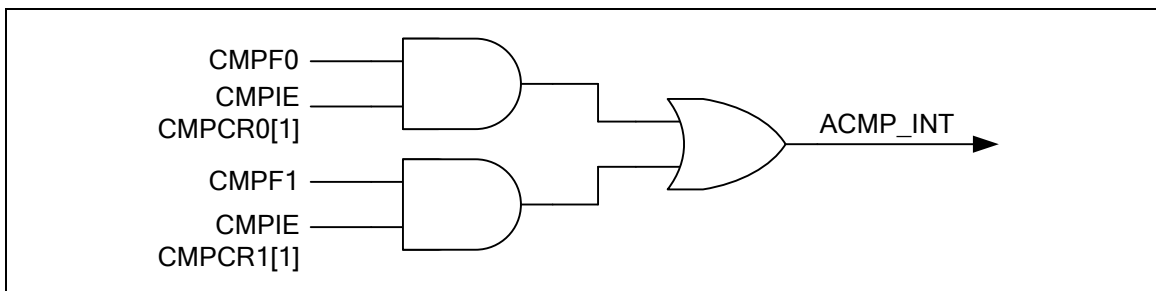


Figure 6-163 Comparator Controller Interrupt Sources

6.22.5.2 Hysteresis Function

The analog comparator provides hysteresis function to make the comparator output transition more stable. If comparator output is 0, it will not change to 1 until the positive input voltage exceeds the negative input voltage by a positive hysteresis voltage. Similarly, if comparator output is 1, it will not change to 0 until the positive input voltage drops below the negative input voltage by a negative hysteresis voltage.

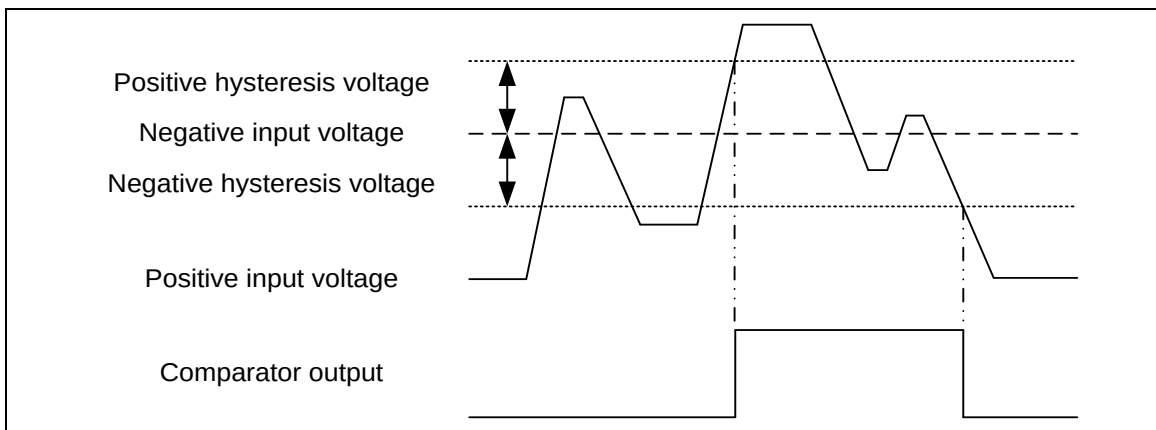


Figure 6-164 Comparator Hysteresis Function

6.22.6 Register Map

R: read only, W: write only, R/W: both read and write

Register	Offset	R/W	Description	Reset Value
ACMP Base Address: ACMP_BA = 0x400D_0000				
CMPCR0	ACMP_BA+0x00	R/W	Analog Comparator 0 Control Register	0x0000_0000
CMPCR1	ACMP_BA+0x04	R/W	Analog Comparator 1 Control Register	0x0000_0000
CMPSR	ACMP_BA+0x08	R/W	Analog Comparator Status Register	0x0000_0000

6.22.7 Register Description

CMP Control Register 0/1 (CMPCR0/1)

Register	Offset	R/W	Description	Reset Value
CMPCR0	ACMP_BA+0x00	R/W	Analog Comparator 0 Control Register	0x0000_0000
CMPCR1	ACMP_BA+0x04	R/W	Analog Comparator 1 Control Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved	CMPINV	Reserved	CMPCN	Reserved	CMP_HYSEN	CMPIE	CMPEN

Bits	Description
[31:5]	Reserved
[6]	CMPINV Comparator Output Inverse Enable Bit 0 = Comparator analog output inverse is Disabled. 1 = Comparator analog output inverse is Enabled.
[5]	Reserved
[4]	CMPCN Comparator Negative Input Selection 0 = The source of the negative comparator input is from ACMPn_N pin (n = 0, 1). 1 = Internal band-gap reference voltage is selected as the source of negative comparator input.
[3]	Reserved
[2]	CMP_HYSEN Comparator Hysteresis Enable Bit 0 = Hysteresis function Disabled (Default). 1 = Hysteresis function Enabled.
[1]	CMPIE Comparator Interrupt Enable Bit 0 = Interrupt function Disabled. 1 = Interrupt function Enabled.
[0]	CMPEN Comparator Enable Bit 0 = Comparator Disabled. 1 = Comparator Enabled.

CMP Status Register (CMPSR)

Register	Offset	R/W	Description	Reset Value
CMPSR	ACMP_BA+0x08	R/W	Analog Comparator Status Register	0x0000_0000

31	30	29	28	27	26	25	24
Reserved							
23	22	21	20	19	18	17	16
Reserved							
15	14	13	12	11	10	9	8
Reserved							
7	6	5	4	3	2	1	0
Reserved				CO1	CO0	CMPF1	CMPF0

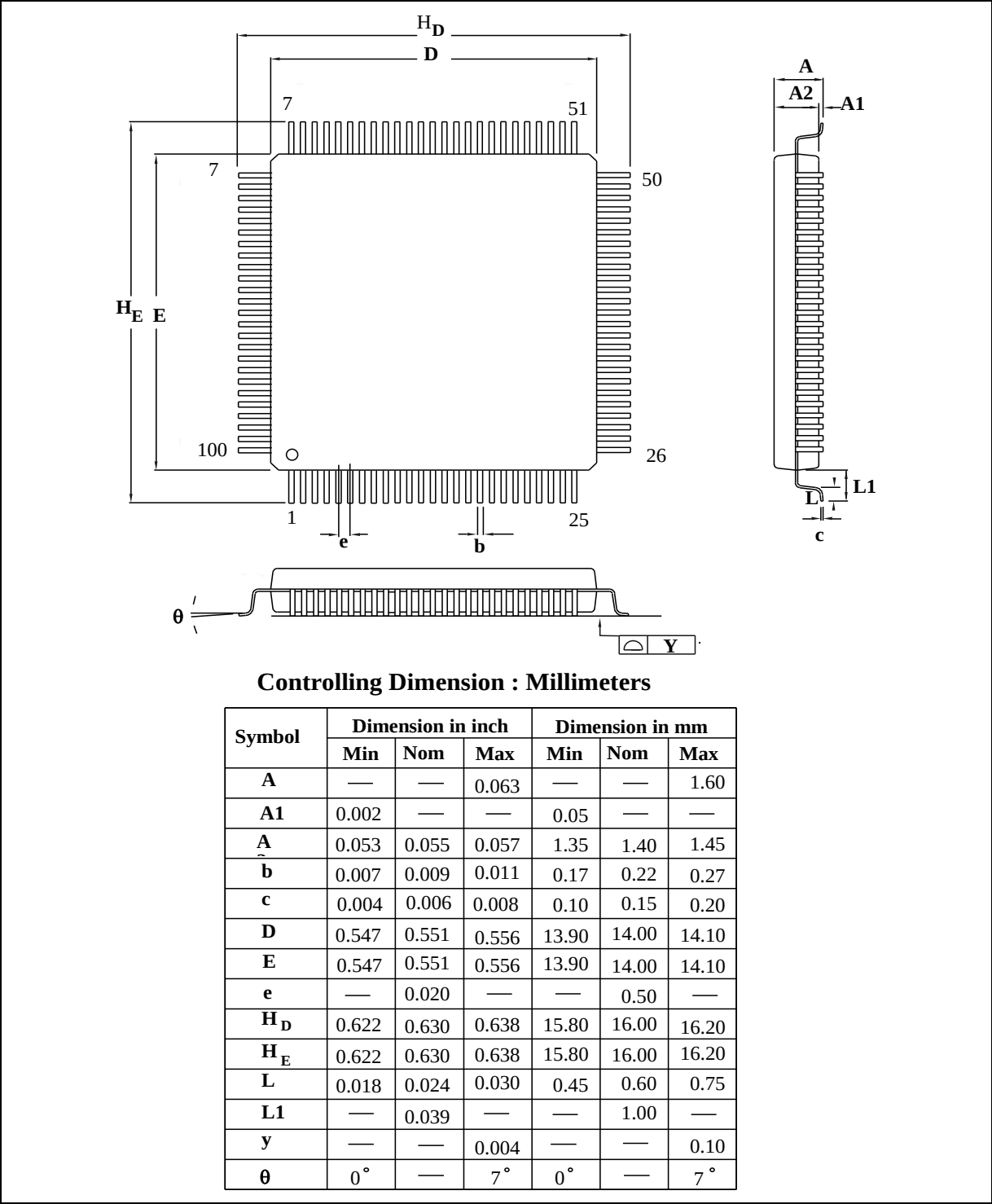
Bits	Description	
[31:4]	Reserved	Reserved.
[3]	CO1	Comparator 1 Output Synchronized to the APB clock to allow reading by software. Cleared when the comparator 1 is disabled (CMPCR1[0] = 0).
[2]	CO0	Comparator 0 Output Synchronized to the APB clock to allow reading by software. Cleared when the comparator 0 is disabled (CMPCR0[0] = 0).
[1]	CMPF1	Comparator 1 Interrupt Flag This bit is set by hardware whenever the comparator 1 output changes state. This will cause an interrupt if CMPCR1[1] is set to 1. Write 1 to clear this bit to 0.
[0]	CMPF0	Comparator 0 Interrupt Flag This bit is set by hardware whenever the comparator 0 output changes state. This will cause an interrupt if CMPCR0[1] is set to 1. Write 1 to clear this bit to 0.

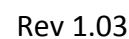
7 ELECTRICAL CHARACTERISTICS

For information on NuMicro™ NUC230/240 series electrical characteristics, please refer to NuMicro™ NUC230/240 Series Datasheet.

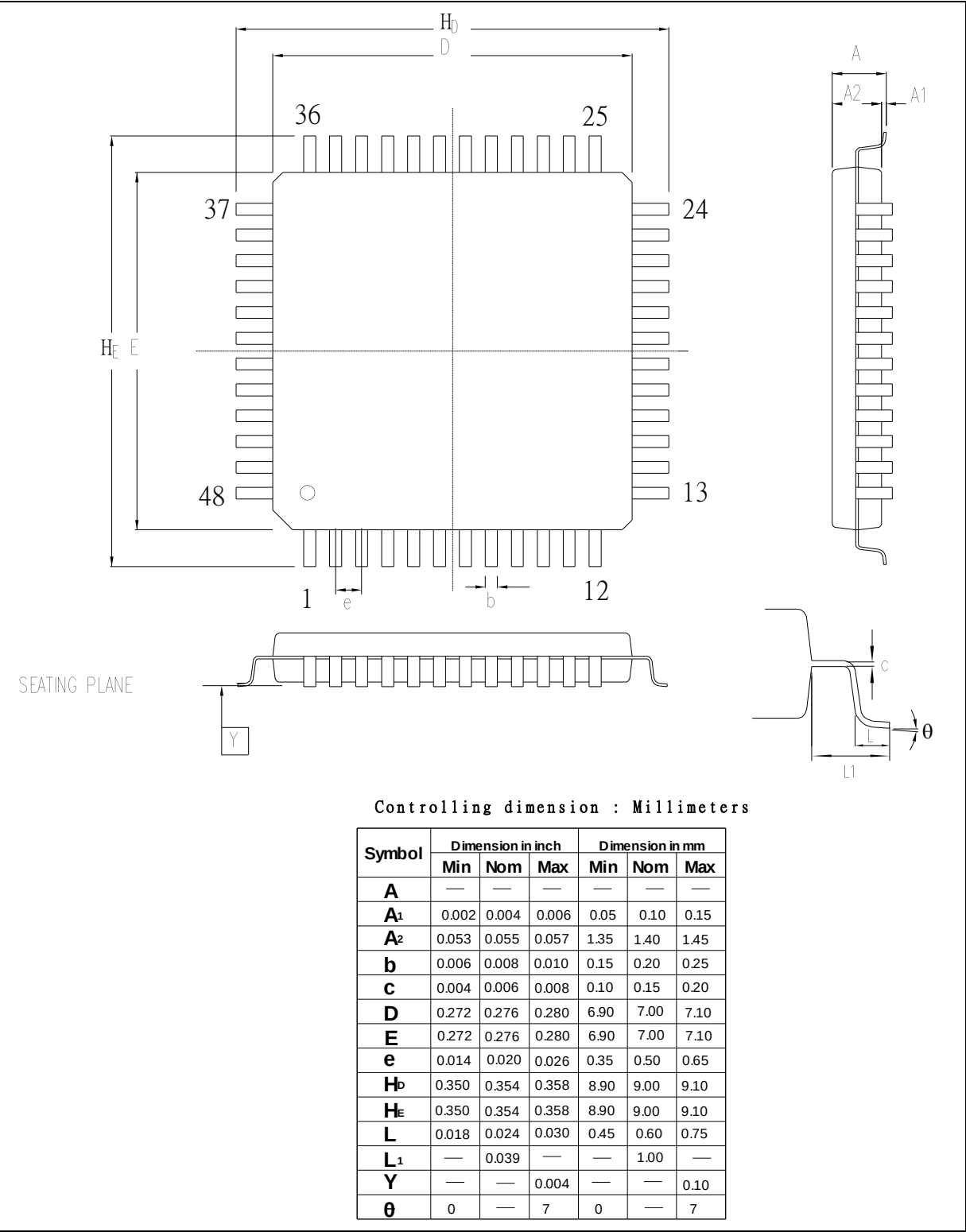
8 PACKAGE DIMENSIONS

8.1 100-pin LQFP (14x14x1.4 mm footprint 2.0 mm)





8.3 48-pin LQFP (7x7x1.4 mm footprint 2.0 mm)



9 REVISION HISTORY

Date	Revision	Description
2014.05.12	1.00	1. Preliminary version
2014.12.30	1.01	1. Added EBI function 2. Reorganized the chapter sequence
2015.05.08	1.02	1. Modified I ² C basic address, I ² C0, I ² C1 base address should be 0x40020000, 0x40120000 in section 6.16.7 2. Updated note for each IP clock source select condition
2016.04.26	1.03	1. Added Section Register Protection 2. Added Section Internal Reference Voltage

Important Notice

Nuvoton Products are neither intended nor warranted for usage in systems or equipment, any malfunction or failure of which may cause loss of human life, bodily injury or severe property damage. Such applications are deemed, "Insecure Usage".

Insecure usage includes, but is not limited to: equipment for surgical implementation, atomic energy control instruments, airplane or spaceship instruments, the control or operation of dynamic, brake or safety systems designed for vehicular use, traffic signal instruments, all types of safety devices, and other applications intended to support or sustain life.

All Insecure Usage shall be made at customer's risk, and in the event that third parties lay claims to Nuvoton as a result of customer's Insecure Usage, customer shall indemnify the damages and liabilities thus incurred by Nuvoton.

*Please note that all data and specifications are subject to change without notice.
All the trademarks of products and companies mentioned in this datasheet belong to their respective owners.*