User's Manual

16

M16C/65C Group

User’s Manual: Hardware

RENESAS MCU

M16C Family / M16C/60 Series

All information contained in these materials, including products and product specifications, represents information on the product at the time of publication and is subject to change by Renesas Electronics Corp. without notice. Please review the latest information published by Renesas Electronics Corp. through various means, including the Renesas Electronics Corp. website (http://www.renesas.com).

Renesas Electronics
www.renesas.com

Rev.1.10 Jul 2012

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

1. Handling of Unused Pins

   Handle unused pins in accord with the directions given under Handling of Unused Pins in the manual.

   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment when power is supplied.

   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.

   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.

   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.

5. Differences between Products

   Before changing from one product to another, i.e. to one with a different part number, confirm that the change will not lead to problems.

   — The characteristics of MPU/MCU in the same group but having different part numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different part numbers, implement a system-evaluation test for each of the products.

About This Manual

1. Purpose and Target User

This manual is designed to be read primarily by application developers who have an understanding of this microcomputer (MCU) including its hardware functions and electrical characteristics. The user should have a basic understanding of electric circuits, logic circuits and, MCUs.
This manual consists of six main categories: Overview, CPU, System Control, Peripherals, Electrical Characteristics, and Usage Notes.

Carefully read all notes in this document prior to use. Notes are found throughout each chapter, at the end of each chapter, and in the dedicated Usage Notes chapter.

The Revision History at the end of this manual summarizes primary modifications and additions to the previous versions. For details, please refer to the relative chapters or sections of this manual.

The M16C/65C Group includes the documents listed below. Verify this manual is the latest version by visiting the Renesas Electronics website.

Type of Document	Contents	Document Name	Document Number
Datasheet	Overview of Hardware and Electrical Characteristics	M16C/65C Group Datasheet	R01DS0015EJ0110
User’s Manual: Hardware	Specifications and detailed descriptions of: -pin layout -memory map -peripherals -electrical characteristics -timing characteristics Refer to the Application Manual for peripheral usage.	M16C/65C Group User’s Manual: Hardware	This publication
User’s Manual: Software/Software Manual	Descriptions of instruction set	M16C/60, M16C/20, M16C/Tiny Series Software Manual	REJ09B0137
Application Note	-Usages -Applications -Sample programs -Programming technics using Assembly language or C programming language	Available on the Renesas Electronics website.	
Renesas Technical Update	Bulletins on product specifications, documents, etc.		

2. Numbers and Symbols

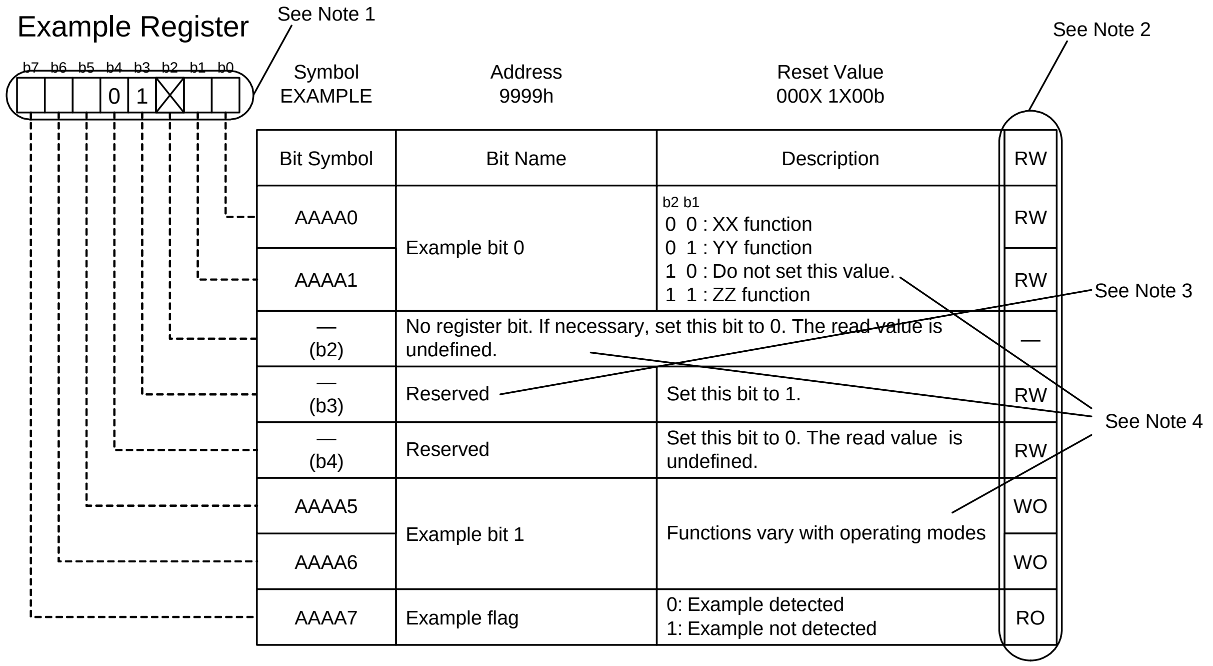
The following explains the denotations used in this manual for registers, bits, pins and various numbers.

(1) Registers, bits, and pins
Registers, bits, and pins are indicated by symbols. Each symbol has a register/bit/pin identifier after the symbol.
Example: PM03 bit in the PM0 register
P3_5 pin, VCC pin

(2) Numbers
A binary number has the suffix “b” except for a 1-bit value.
A hexadecimal number has the suffix “h”.
A decimal number has no suffix.
Example: Binary notation: 11b
Hexadecimal notation: EFA0h
Decimal notation: 1234

3. Registers

The following illustration describes registers used throughout this manual.



Symbol	Address	Reset Value
EXAMPLE	9999h	000X 1X00b

Bit Symbol	Bit Name	Description	RW
AAAA0	Example bit 0	b2 b1 0 0 : XX function 0 1 : YY function 1 0 : Do not set this value. 1 1 : ZZ function	RW
AAAA1			RW
— (b2)	No register bit. If necessary, set this bit to 0. The read value is undefined.		—
— (b3)	Reserved	Set this bit to 1.	RW
— (b4)	Reserved	Set this bit to 0. The read value is undefined.	RW
AAAA5	Example bit 1	Functions vary with operating modes	WO
AAAA6			WO
AAAA7	Example flag	0: Example detected 1: Example not detected	RO

Notes:

1. Blank box: Set this bit to 0 or 1 according to the function.
   0: Set this bit to 0.
   1: Set this bit to 1.
   X: Nothing is assigned to this bit.

2. RW: Read and write
   RO: Read only
   WO: Write only (the read value is undefined)
   —: Not applicable

3. Reserved bit: This bit field is reserved. Set this bit to a specified value. For RW bits, the written value is read unless otherwise noted.

4.
- No register bit(s): No register bit(s) is/are assigned to this field. If necessary, set to 0 for possible future implementation.
- Do not use this combination: Proper operation is not guaranteed when this value is set.
- Functions vary with operating modes: Functions vary with peripheral operating modes. Refer to register illustrations of the respective mode.

4. Abbreviations and Acronyms

The following acronyms and terms are used throughout this manual.

Abbreviation/Acronym	Meaning
ACIA	Asynchronous Communication Interface Adapter
bps	bits per second
CRC	Cyclic Redundancy Check
DMA	Direct Memory Access
DMAC	Direct Memory Access Controller
GSM	Global System for Mobile Communications
Hi-Z	High Impedance
IEBus	Inter Equipment Bus
I/O	Input/Output
IrDA	Infrared Data Association
LSB	Least Significant Bit
MSB	Most Significant Bit
NC	Non-Connection
PLL	Phase Locked Loop
PWM	Pulse Width Modulation
SIM	Subscriber Identity Module
UART	Universal Asynchronous Receiver/Transmitter
VCO	Voltage Controlled Oscillator

Table of Contents

Quick Reference

Only one page number is listed for each register. Refer to the REGISTER INDEX for more details.

Address	Register	Symbol	Page
0000h			
0001h			
0002h			
0003h			
0004h	Processor Mode Register 0	PM0	56
0005h	Processor Mode Register 1	PM1	146
0006h	System Clock Control Register 0	CM0	97
0007h	System Clock Control Register 1	CM1	99
0008h	Chip Select Control Register	CSR	152
0009h	External Area Recovery Cycle Control Register	EWR	155
000Ah	Protect Register	PRCR	50
000Bh	Data Bank Register	DBR	173
000Ch	Oscillation Stop Detection Register	CM2	101
000Dh			
000Eh			
000Fh			
0010h	Program 2 Area Control Register	PRG2C	148
0011h	External Area Wait Control Expansion Register	EWC	154
0012h	Peripheral Clock Select Register	PCLKR	103
0013h			
0014h			
0015h	Clock Prescaler Reset Flag	CPSRF	275
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	103
0017h			
0018h	Reset Source Determine Register	RSTFR	57
0019h	Voltage Detector 2 Flag Register	VCR1	73
001Ah	Voltage Detector Operation Enable Register	VCR2	74
001Bh	Chip Select Expansion Control Register	CSE	153
001Ch	PLL Control Register 0	PLC0	105
001Dh			
001Eh	Processor Mode Register 2	PM2	106
001Fh			
0020h			
0021h			
0022h	40 MHz On-Chip Oscillator Control Register 0	FRA0	107
0023h			
0024h			
0025h			
0026h	Voltage Monitor Function Select Register	VWCE	75
0027h			
0028h	Voltage Detector 1 Level Select Register	VD1LS	76
0029h			
002Ah	Voltage Monitor 0 Control Register	VW0C	77
002Bh	Voltage Monitor 1 Control Register	VW1C	78
002Ch	Voltage Monitor 2 Control Register	VW2C	80
002Dh			
002Eh			
002Fh			
0030h to 003Fh			
0040h			
0041h			
0042h	$\overline{\text{INT7}}$ Interrupt Control Register	INT7IC	215
0043h	$\overline{\text{INT6}}$ Interrupt Control Register	INT6IC	215
0044h	$\overline{\text{INT3}}$ Interrupt Control Register	INT3IC	215
0045h	Timer B5 Interrupt Control Register	TB5IC	215
0046h	Timer B4 Interrupt Control Register UART1 Bus Collision Detection Interrupt Control Register	TB4IC U1BCNIC	214
0047h	Timer B3 Interrupt Control Register UART0 Bus Collision Detection Interrupt Control Register	TB3IC U0BCNIC	214
0048h	SI/O4 Interrupt Control Register $\overline{\text{INT5}}$ Interrupt Control Register	S4IC INT5IC	215

Address	Register	Symbol	Page
0049h	SI/O3 Interrupt Control Register $\overline{\text{INT4}}$ Interrupt Control Register	S3IC INT4IC	215
004Ah	UART2 Bus Collision Detection Interrupt Control Register	BCNIC	214
004Bh	DMA0 Interrupt Control Register	DM0IC	214
004Ch	DMA1 Interrupt Control Register	DM1IC	214
004Dh	Key Input Interrupt Control Register	KUPIC	214
004Eh	A/D Conversion Interrupt Control Register	ADIC	215
004Fh	UART2 Transmit Interrupt Control Register	S2TIC	214
0050h	UART2 Receive Interrupt Control Register	S2RIC	214
0051h	UART0 Transmit Interrupt Control Register	S0TIC	214
0052h	UART0 Receive Interrupt Control Register	S0RIC	214
0053h	UART1 Transmit Interrupt Control Register	S1TIC	214
0054h	UART1 Receive Interrupt Control Register	S1RIC	214
0055h	Timer A0 Interrupt Control Register	TA0IC	214
0056h	Timer A1 Interrupt Control Register	TA1IC	214
0057h	Timer A2 Interrupt Control Register	TA2IC	214
0058h	Timer A3 Interrupt Control Register	TA3IC	214
0059h	Timer A4 Interrupt Control Register	TA4IC	214
005Ah	Timer B0 Interrupt Control Register	TB0IC	214
005Bh	Timer B1 Interrupt Control Register	TB1IC	214
005Ch	Timer B2 Interrupt Control Register	TB2IC	214
005Dh	$\overline{\text{INT0}}$ Interrupt Control Register	INT0IC	215
005Eh	$\overline{\text{INT1}}$ Interrupt Control Register	INT1IC	215
005Fh	$\overline{\text{INT2}}$ Interrupt Control Register	INT2IC	215
0060h to 0068h			
0069h	DMA2 Interrupt Control Register	DM2IC	214
006Ah	DMA3 Interrupt Control Register	DM3IC	214
006Bh	UART5 Bus Collision Detection Interrupt Control Register, CEC1 Interrupt Control Register	U5BCNIC, CEC1IC	214
006Ch	UART5 Transmit Interrupt Control Register, CEC2 Interrupt Control Register	S5TIC, CEC2IC	214
006Dh	UART5 Receive Interrupt Control Register	S5RIC	214
006Eh	UART6 Bus Collision Detection Interrupt Control Register, Real-Time Clock Periodic Interrupt Control Register	U6BCNIC RTCTIC	214
006Fh	UART6 Transmit Interrupt Control Register, Real-Time Clock Compare Interrupt Control Register	S6TIC, RTCCIC	214
0070h	UART6 Receive Interrupt Control Register	S6RIC	214
0071h	UART7 Bus Collision Detection Interrupt Control Register, Remote Control Signal Receiver 0 Interrupt Control Register	U7BCNIC, PMC0IC	214
0072h	UART7 Transmit Interrupt Control Register, Remote Control Signal Receiver 1 Interrupt Control Register	S7TIC, PMC1IC	214
0073h	UART7 Receive Interrupt Control Register	S7RIC	214
0074h			
0075h			
0076h			
0077h			
0078h			
0079h			
007Ah			
007Bh	I2C-bus Interface Interrupt Control Register	IICIC	214
007Ch	SCL/SDA Interrupt Control Register	SCLDAIC	214
007Dh			
007Eh			
007Fh			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
0080h to 017Fh			
0180h	DMA0 Source Pointer	SAR0	256
0181h			
0182h			
0183h			
0184h	DMA0 Destination Pointer	DAR0	256
0185h			
0186h			
0187h			
0188h	DMA0 Transfer Counter	TCR0	257
0189h			
018Ah			
018Bh			
018Ch	DMA0 Control Register	DM0CON	258
018Dh			
018Eh			
018Fh			
0190h	DMA1 Source Pointer	SAR1	256
0191h			
0192h			
0193h			
0194h	DMA1 Destination Pointer	DAR1	256
0195h			
0196h			
0197h			
0198h	DMA1 Transfer Counter	TCR1	257
0199h			
019Ah			
019Bh			
019Ch	DMA1 Control Register	DM1CON	258
019Dh			
019Eh			
019Fh			
01A0h	DMA2 Source Pointer	SAR2	256
01A1h			
01A2h			
01A3h			
01A4h	DMA2 Destination Pointer	DAR2	256
01A5h			
01A6h			
01A7h			
01A8h	DMA2 Transfer Counter	TCR2	257
01A9h			
01AAh			
01ABh			
01ACh	DMA2 Control Register	DM2CON	258
01ADh			
01AEh			
01AFh			
01B0h	DMA3 Source Pointer	SAR3	256
01B1h			
01B2h			
01B3h			
01B4h	DMA3 Destination Pointer	DAR3	256
01B5h			
01B6h			
01B7h			
01B8h	DMA3 Transfer Counter	TCR3	257
01B9h			
01BAh			
01BBh			
01BCh	DMA3 Control Register	DM3CON	258
01BDh			
01BEh			
01BFh			

Address	Register	Symbol	Page
01C0h	Timer B0-1 Register	TB01	328
01C1h			
01C2h	Timer B1-1 Register	TB11	328
01C3h			
01C4h	Timer B2-1 Register	TB21	328
01C5h			
01C6h	Pulse Period/Pulse Width Measurement Mode Function Select Register 1	PPWFS1	329
01C7h			
01C8h	Timer B Count Source Select Register 0	TBCS0	330
01C9h	Timer B Count Source Select Register 1	TBCS1	330
01CAh			
01CBh	Timer AB Division Control Register 0	TCKDIVC0	277
01CCh			
01CDh			
01CEh			
01CFh			
01D0h	Timer A Count Source Select Register 0	TACS0	278
01D1h	Timer A Count Source Select Register 1	TACS1	278
01D2h	Timer A Count Source Select Register 2	TACS2	278
01D3h			
01D4h	16-bit Pulse Width Modulation Mode Function Select Register	PWMFS	279
01D5h	Timer A Waveform Output Function Select Register	TAPOFS	280
01D6h			
01D7h			
01D8h	Timer A Output Waveform Change Enable Register	TAOW	281
01D9h			
01DAh	Three-Phase Protect Control Register	TPRC	363
01DBh			
01DCh			
01DDh			
01DEh			
01DFh			
01E0h	Timer B3-1 Register	TB31	328
01E1h			
01E2h	Timer B4-1 Register	TB41	328
01E3h			
01E4h	Timer B5-1 Register	TB51	328
01E5h			
01E6h	Pulse Period/Pulse Width Measurement Mode Function Select Register 2	PPWFS2	329
01E7h			
01E8h	Timer B Count Source Select Register 2	TBCS2	330
01E9h	Timer B Count Source Select Register 3	TBCS3	330
01EAh			
01EBh			
01ECh			
01EDh			
01EEh			
01EFh			
01F0h	PMC0 Function Select Register 0	PMC0CON0	428
01F1h	PMC0 Function Select Register 1	PMC0CON1	430
01F2h	PMC0 Function Select Register 2	PMC0CON2	432
01F3h	PMC0 Function Select Register 3	PMC0CON3	434
01F4h	PMC0 Status Register	PMC0STS	435
01F5h	PMC0 Interrupt Source Select Register	PMC0INT	438
01F6h	PMC0 Compare Control Register	PMC0CPC	444
01F7h	PMC0 Compare Data Register	PMC0CPD	445
01F8h	PMC1 Function Select Register 0	PMC1CON0	428
01F9h	PMC1 Function Select Register 1	PMC1CON1	430
01FAh	PMC1 Function Select Register 2	PMC1CON2	432
01FBh	PMC1 Function Select Register 3	PMC1CON3	434
01FCh	PMC1 Status Register	PMC1STS	435
01FDh	PMC1 Interrupt Source Select Register	PMC1INT	438
01FEh			
01FFh			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
0200h			
0201h			
0202h			
0203h			
0204h			
0205h	Interrupt Source Select Register 3	IFSR3A	216
0206h	Interrupt Source Select Register 2	IFSR2A	217
0207h	Interrupt Source Select Register	IFSR	218
0208h			
0209h			
020Ah			
020Bh			
020Ch			
020Dh			
020Eh	Address Match Interrupt Enable Register	AIER	219
020Fh	Address Match Interrupt Enable Register 2	AIER2	219
0210h	Address Match Interrupt Register 0	RMAD0	220
0211h			
0212h			
0213h			
0214h	Address Match Interrupt Register 1	RMAD1	220
0215h			
0216h			
0217h			
0218h	Address Match Interrupt Register 2	RMAD2	220
0219h			
021Ah			
021Bh			
021Ch	Address Match Interrupt Register 3	RMAD3	220
021Dh			
021Eh			
021Fh			
0220h	Flash Memory Control Register 0	FMR0	681
0221h	Flash Memory Control Register 1	FMR1	684
0222h	Flash Memory Control Register 2	FMR2	124
0223h	Flash Memory Control Register 3	FMR3	686
0224h			
0225h			
0226h			
0227h			
0228h			
0229h			
022Ah			
022Bh			
022Ch			
022Dh			
022Eh			
022Fh			
0230h	Flash Memory Control Register 6	FMR6	687
0231h			
0232h			
0233h			
0234h			
0235h			
0236h			
0237h			
0238h			
0239h			
023Ah			
023Bh			
023Ch			
023Dh			
023Eh			
023Fh			
0240h			
0241h			
0242h			
0243h			

Address	Register	Symbol	Page
0244h	UART0 Special Mode Register 4	U0SMR4	487
0245h	UART0 Special Mode Register 3	U0SMR3	489
0246h	UART0 Special Mode Register 2	U0SMR2	490
0247h	UART0 Special Mode Register	U0SMR	491
0248h	UART0 Transmit/Receive Mode Register	U0MR	479
0249h	UART0 Bit Rate Register	U0BRG	480
024Ah	UART0 Transmit Buffer Register	U0TB	480
024Bh			
024Ch	UART0 Transmit/Receive Control Register 0	U0C0	481
024Dh	UART0 Transmit/Receive Control Register 1	U0C1	483
024Eh	UART0 Receive Buffer Register	U0RB	484
024Fh			
0250h	UART Transmit/Receive Control Register 2	UCON	486
0251h			
0252h	UART Clock Select Register	UCLKSEL0	478
0253h			
0254h	UART1 Special Mode Register 4	U1SMR4	487
0255h	UART1 Special Mode Register 3	U1SMR3	489
0256h	UART1 Special Mode Register 2	U1SMR2	490
0257h	UART1 Special Mode Register	U1SMR	491
0258h	UART1 Transmit/Receive Mode Register	U1MR	479
0259h	UART1 Bit Rate Register	U1BRG	480
025Ah	UART1 Transmit Buffer Register	U1TB	480
025Bh			
025Ch	UART1 Transmit/Receive Control Register 0	U1C0	481
025Dh	UART1 Transmit/Receive Control Register 1	U1C1	483
025Eh	UART1 Receive Buffer Register	U1RB	484
025Fh			
0260h			
0261h			
0262h			
0263h			
0264h	UART2 Special Mode Register 4	U2SMR4	487
0265h	UART2 Special Mode Register 3	U2SMR3	489
0266h	UART2 Special Mode Register 2	U2SMR2	490
0267h	UART2 Special Mode Register	U2SMR	491
0268h	UART2 Transmit/Receive Mode Register	U2MR	479
0269h	UART2 Bit Rate Register	U2BRG	480
026Ah	UART2 Transmit Buffer Register	U2TB	480
026Bh			
026Ch	UART2 Transmit/Receive Control Register 0	U2C0	481
026Dh	UART2 Transmit/Receive Control Register 1	U2C1	483
026Eh	UART2 Receive Buffer Register	U2RB	484
026Fh			
0270h	SI/O3 Transmit/Receive Register	S3TRR	544
0271h			
0272h	SI/O3 Control Register	S3C	545
0273h	SI/O3 Bit Rate Register	S3BRG	546
0274h	SI/O4 Transmit/Receive Register	S4TRR	544
0275h			
0276h	SI/O4 Control Register	S4C	545
0277h	SI/O4 Bit Rate Register	S4BRG	546
0278h	SI/O3, 4 Control Register 2	S34C2	546
0279h			
027Ah			
027Bh			
027Ch			
027Dh			
027Eh			
027Fh			
0280h			
0281h			
0282h			
0283h			
0284h	UART5 Special Mode Register 4	U5SMR4	487
0285h	UART5 Special Mode Register 3	U5SMR3	489
0286h	UART5 Special Mode Register 2	U5SMR2	490
0287h	UART5 Special Mode Register	U5SMR	491

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
0288h	UART5 Transmit/Receive Mode Register	U5MR	479
0289h	UART5 Bit Rate Register	U5BRG	480
028Ah	UART5 Transmit Buffer Register	U5TB	480
028Bh			
028Ch	UART5 Transmit/Receive Control Register 0	U5C0	481
028Dh	UART5 Transmit/Receive Control Register 1	U5C1	483
028Eh	UART5 Receive Buffer Register	U5RB	484
028Fh			
0290h			
0291h			
0292h			
0293h			
0294h	UART6 Special Mode Register 4	U6SMR4	487
0295h	UART6 Special Mode Register 3	U6SMR3	489
0296h	UART6 Special Mode Register 2	U6SMR2	490
0297h	UART6 Special Mode Register	U6SMR	491
0298h	UART6 Transmit/Receive Mode Register	U6MR	479
0299h	UART6 Bit Rate Register	U6BRG	480
029Ah	UART6 Transmit Buffer Register	U6TB	480
029Bh			
029Ch	UART6 Transmit/Receive Control Register 0	U6C0	481
029Dh	UART6 Transmit/Receive Control Register 1	U6C1	483
029Eh	UART6 Receive Buffer Register	U6RB	484
029Fh			
02A0h			
02A1h			
02A2h			
02A3h			
02A4h	UART7 Special Mode Register 4	U7SMR4	487
02A5h	UART7 Special Mode Register 3	U7SMR3	489
02A6h	UART7 Special Mode Register 2	U7SMR2	490
02A7h	UART7 Special Mode Register	U7SMR	491
02A8h	UART7 Transmit/Receive Mode Register	U7MR	479
02A9h	UART7 Bit Rate Register	U7BRG	480
02AAh	UART7 Transmit Buffer Register	U7TB	480
02ABh			
02ACh	UART7 Transmit/Receive Control Register 0	U7C0	481
02ADh	UART7 Transmit/Receive Control Register 1	U7C1	483
02AEh	UART7 Receive Buffer Register	U7RB	484
02AFh			
02B0h	I2C0 Data Shift Register	S00	560
02B1h			
02B2h	I2C0 Address Register 0	S0D0	561
02B3h	I2C0 Control Register 0	S1D0	562
02B4h	I2C0 Clock Control Register	S20	564
02B5h	I2C0 Start/Stop Condition Control Register	S2D0	566
02B6h	I2C0 Control Register 1	S3D0	567
02B7h	I2C0 Control Register 2	S4D0	571
02B8h	I2C0 Status Register 0	S10	573
02B9h	I2C0 Status Register 1	S11	578
02BAh	I2C0 Address Register 1	S0D1	561
02BBh	I2C0 Address Register 2	S0D2	561
02BCh			
02BDh			
02BEh			
02BFh			
02C0h to 02FFh			

Address	Register	Symbol	Page
0300h	Timer B3/B4/B5 Count Start Flag	TBSR	332
0301h			
0302h	Timer A1-1 Register	TA11	283
0303h			
0304h	Timer A2-1 Register	TA21	283
0305h			
0306h	Timer A4-1 Register	TA41	283
0307h			
0308h	Three-Phase PWM Control Register 0	INVC0	355
0309h	Three-Phase PWM Control Register 1	INVC1	357
030Ah	Three-Phase Output Buffer Register 0	IDB0	359
030Bh	Three-Phase Output Buffer Register 1	IDB1	359
030Ch	Dead Time Timer	DTT	359
030Dh	Timer B2 Interrupt Generation Frequency Set Counter	ICTB2	360
030Eh	Position-Data-Retain Function Control Register	PDRF	362
030Fh			
0310h	Timer B3 Register	TB3	327
0311h			
0312h	Timer B4 Register	TB4	327
0313h			
0314h	Timer B5 Register	TB5	327
0315h			
0316h			
0317h			
0318h	Port Function Control Register	PFCR	363
0319h			
031Ah			
031Bh	Timer B3 Mode Register	TB3MR	333
031Ch	Timer B4 Mode Register	TB4MR	333
031Dh	Timer B5 Mode Register	TB5MR	333
031Eh			
031Fh			
0320h	Count Start Flag	TABSR	283
0321h			
0322h	One-Shot Start Flag	ONSF	284
0323h	Trigger Select Register	TRGSR	285
0324h	Increment/Decrement Flag	UDF	286
0325h			
0326h	Timer A0 Register	TA0	282
0327h			
0328h	Timer A1 Register	TA1	282
0329h			
032Ah	Timer A2 Register	TA2	282
032Bh			
032Ch	Timer A3 Register	TA3	282
032Dh			
032Eh	Timer A4 Register	TA4	282
032Fh			
0330h	Timer B0 Register	TB0	327
0331h			
0332h	Timer B1 Register	TB1	327
0333h			
0334h	Timer B2 Register	TB2	327
0335h			
0336h	Timer A0 Mode Register	TA0MR	287
0337h	Timer A1 Mode Register	TA1MR	287
0338h	Timer A2 Mode Register	TA2MR	287
0339h	Timer A3 Mode Register	TA3MR	287
033Ah	Timer A4 Mode Register	TA4MR	287

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
033Bh	Timer B0 Mode Register	TB0MR	333
033Ch	Timer B1 Mode Register	TB1MR	333
033Dh	Timer B2 Mode Register	TB2MR	333
033Eh	Timer B2 Special Mode Register	TB2SC	361
033Fh			
0340h	Real-Time Clock Second Data Register	RTCSEC	392
0341h	Real-Time Clock Minute Data Register	RTCMIN	393
0342h	Real-Time Clock Hour Data Register	RTCHR	394
0343h	Real-Time Clock Day Data Register	RTCWK	395
0344h	Real-Time Clock Control Register 1	RTCCR1	396
0345h	Real-Time Clock Control Register 2	RTCCR2	398
0346h	Real-Time Clock Count Source Select Register	RTCCSR	400
0347h			
0348h	Real-Time Clock Second Compare Data Register	RTCCSEC	401
0349h	Real-Time Clock Minute Compare Data Register	RTCCMIN	402
034Ah	Real-Time Clock Hour Compare Data Register	RTCCHR	403
034Bh			
034Ch			
034Dh			
034Eh			
034Fh			
0350h	CEC Function Control Register 1	CECC1	606
0351h	CEC Function Control Register 2	CECC2	607
0352h	CEC Function Control Register 3	CECC3	609
0353h	CEC Function Control Register 4	CECC4	611
0354h	CEC Flag Register	CECFLG	613
0355h	CEC Interrupt Source Select Register	CISEL	614
0356h	CEC Transmit Buffer Register 1	CCTB1	615
0357h	CEC Transmit Buffer Register 2	CCTB2	615
0358h	CEC Receive Buffer Register 1	CCRB1	616
0359h	CEC Receive Buffer Register 2	CCRB2	616
035Ah	CEC Receive Follower Address Set Register 1	CRADRI1	617
035Bh	CEC Receive Follower Address Set Register 2	CRADRI2	617
035Ch			
035Dh			
035Eh			
035Fh			
0360h	Pull-Up Control Register 0	PUR0	197
0361h	Pull-Up Control Register 1	PUR1	198
0362h	Pull-Up Control Register 2	PUR2	199
0363h	Pull-Up Control Register 3	PUR3	200
0364h			
0365h			
0366h	Port Control Register	PCR	201
0367h			
0368h			
0369h	NMI/SD Digital Filter Register	NMIDF	222
036Ah			
036Bh			
036Ch			
036Dh			
036Eh			
036Fh			
0370h	PWM Control Register 0	PWMCON0	418
0371h			
0372h	PWM0 Prescaler	PWMPRE0	419
0373h	PWM0 Register	PWMREG0	419
0374h	PWM1 Prescaler	PWMPRE1	419
0375h	PWM1 Register	PWMREG1	419
0376h	PWM Control Register 1	PWMCON1	420

Address	Register	Symbol	Page
0377h			
0378h			
0379h			
037Ah			
037Bh			
037Ch	Count Source Protection Mode Register	CSPR	245
037Dh	Watchdog Timer Refresh Register	WDTR	246
037Eh	Watchdog Timer Start Register	WDTS	246
037Fh	Watchdog Timer Control Register	WDC	247
0380h			
0381h			
0382h			
0383h			
0384h			
0385h			
0386h			
0387h			
0388h			
0389h			
038Ah			
038Bh			
038Ch			
038Dh			
038Eh			
038Fh			
0390h	DMA2 Source Select Register	DM2SL	259
0391h			
0392h	DMA3 Source Select Register	DM3SL	259
0393h			
0394h			
0395h			
0396h			
0397h			
0398h	DMA0 Source Select Register	DM0SL	259
0399h			
039Ah	DMA1 Source Select Register	DM1SL	259
039Bh			
039Ch			
039Dh			
039Eh			
039Fh			
03A0h			
03A1h			
03A2h	Open-Circuit Detection Assist Function Register	AINRST	641
03A3h			
03A4h			
03A5h			
03A6h			
03A7h			
03A8h			
03A9h			
03AAh			
03ABh			
03ACh			
03ADh			
03AEh			
03AFh			
03B0h			
03B1h			
03B2h			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
03B3h			
03B4h	SFR Snoop Address Register	CRCSAR	673
03B5h			
03B6h	CRC Mode Register	CRCMR	674
03B7h			
03B8h			
03B9h			
03BAh			
03BBh			
03BCh	CRC Data Register	CRCD	674
03BDh			
03BEh	CRC Input Register	CRCIN	674
03BFh			
03C0h	A/D Register 0	AD0	642
03C1h			
03C2h	A/D Register 1	AD1	642
03C3h			
03C4h	A/D Register 2	AD2	642
03C5h			
03C6h	A/D Register 3	AD3	642
03C7h			
03C8h	A/D Register 4	AD4	642
03C9h			
03CAh	A/D Register 5	AD5	642
03CBh			
03CCh	A/D Register 6	AD6	642
03CDh			
03CEh	A/D Register 7	AD7	642
03CFh			
03D0h			
03D1h			
03D2h			
03D3h			
03D4h	A/D Control Register 2	ADCON2	643
03D5h			
03D6h	A/D Control Register 0	ADCON0	644
03D7h	A/D Control Register 1	ADCON1	646
03D8h	D/A0 Register	DA0	669
03D9h			
03DAh	D/A1 Register	DA1	669
03DBh			
03DCh	D/A Control Register	DACON	669
03DDh			
03DEh			
03DFh			
03E0h	Port P0 Register	P0	202
03E1h	Port P1 Register	P1	202
03E2h	Port P0 Direction Register	PD0	203
03E3h	Port P1 Direction Register	PD1	203
03E4h	Port P2 Register	P2	202
03E5h	Port P3 Register	P3	202
03E6h	Port P2 Direction Register	PD2	203
03E7h	Port P3 Direction Register	PD3	203
03E8h	Port P4 Register	P4	202
03E9h	Port P5 Register	P5	202
03EAh	Port P4 Direction Register	PD4	203
03EBh	Port P5 Direction Register	PD5	203
03ECh	Port P6 Register	P6	202
03EDh	Port P7 Register	P7	202
03EEh	Port P6 Direction Register	PD6	203
03EFh	Port P7 Direction Register	PD7	203
03F0h	Port P8 Register	P8	202
03F1h	Port P9 Register	P9	202
03F2h	Port P8 Direction Register	PD8	203
03F3h	Port P9 Direction Register	PD9	203
03F4h	Port P10 Register	P10	202
03F5h	Port P11 Register	P11	202
03F6h	Port P10 Direction Register	PD10	203
03F7h	Port P11 Direction Register	PD11	203
03F8h	Port P12 Register	P12	202
03F9h	Port P13 Register	P13	202
03FAh	Port P12 Direction Register	PD12	203
03FBh	Port P13 Direction Register	PD13	203
03FCh	Port P14 Register	P14	202
03FDh			
03FEh	Port P14 Direction Register	PD14	203
03FFh			
D000h to D07Fh			

The blank areas are reserved. No access is allowed.

Address	Register	Symbol	Page
D080h	PMC0 Header Pattern Set Register (Min)	PMC0HDPMIN	439
D081h			
D082h	PMC0 Header Pattern Set Register (Max)	PMC0HDPMAX	439
D083h			
D084h	PMC0 Data 0 Pattern Set Register (Min)	PMC0D0PMIN	441
D085h	PMC0 Data 0 Pattern Set Register (Max)	PMC0D0PMAX	441
D086h	PMC0 Data 1 Pattern Set Register (Min)	PMC0D1PMIN	441
D087h	PMC0 Data 1 Pattern Set Register (Max)	PMC0D1PMAX	441
D088h	PMC0 Measurements Register	PMC0TIM	442
D089h			
D08Ah			
D08Bh			
D08Ch	PMC0 Receive Data Store Register 0	PMC0DAT0	443
D08Dh	PMC0 Receive Data Store Register 1	PMC0DAT1	443
D08Eh	PMC0 Receive Data Store Register 2	PMC0DAT2	443
D08Fh	PMC0 Receive Data Store Register 3	PMC0DAT3	443
D090h	PMC0 Receive Data Store Register 4	PMC0DAT4	443
D091h	PMC0 Receive Data Store Register 5	PMC0DAT5	443
D092h	PMC0 Receive Bit Count Register	PMC0RBIT	442
D093h			
D094h	PMC1 Header Pattern Set Register (Min)	PMC1HDPMIN	439
D095h			
D096h	PMC1 Header Pattern Set Register (Max)	PMC1HDPMAX	439
D097h			
D098h	PMC1 Data 0 Pattern Set Register (Min)	PMC1D0PMIN	441
D099h	PMC1 Data 0 Pattern Set Register (Max)	PMC1D0PMAX	441
D09Ah	PMC1 Data 1 Pattern Set Register (Min)	PMC1D1PMIN	441
D09Bh	PMC1 Data 1 Pattern Set Register (Max)	PMC1D1PMAX	441
D09Ch	PMC1 Measurements Register	PMC1TIM	442
D09Dh			
D09Eh			
D09Fh			
D0A0h to D7FFh			

The blank areas are reserved. No access is allowed.

FFFFFh	Optional Function Select Address 1	OFS1	689

OFS1 address is not an SFR.

M16C/65C Group

RENESAS MCU

R01UH0093EJ0110
Rev.1.10
Jul 31, 2012

1. Overview

1.1 Features

The M16C/65C Group microcomputer (MCU) incorporates the M16C/60 Series CPU core and flash memory, employing sophisticated instructions for a high level of efficiency. This MCU has 1 MB of address space (expandable to 4 MB), and it is capable of executing instructions at high speed. In addition, the CPU core boasts a multiplier for high-speed operation processing.

This MCU consumes low power, and supports operating modes that allow additional power control. The MCU also uses an anti-noise configuration to reduce emissions of electromagnetic noise and is designed to withstand electromagnetic interference (EMI). By integrating many of the peripheral functions, including the multifunction timer and serial interface, the number of system components has been reduced.

1.1.1 Applications

This MCU can be used in audio components, cameras, televisions, household appliances, office equipment, communication devices, mobile devices, industrial equipment, and other applications.

1.2 Specifications

The M16C/65C Group includes 128-pin and 100-pin packages. Table 1.1 to Table 1.4 list specifications.

Table 1.1 Specifications for the 128-Pin Package (1/2)

Item	Function	Description
CPU	Central processing unit	M16C/60 Series core (multiplier: 16 bit × 16 bit → 32 bit, multiply and accumulate instruction: 16 bit × 16 bit + 32 bit → 32 bit) • Number of basic instructions: 91 • Minimum instruction execution time: 31.25 ns (f(BCLK) = 32 MHz, VCC1 = VCC2 = 2.7 to 5.5 V) • Operating modes: Single-chip, memory expansion, and microprocessor
Memory	ROM, RAM, data flash	See Table 1.5 “Product List (N-Version)” to Table 1.6 “Product List (D-Version)”.
Voltage Detection	Voltage detector	• Power-on reset • 3 voltage detection points (detection level of voltage detection 0 and 1 selectable)
Clock	Clock generator	• 5 circuits: Main clock, sub clock, low-speed on-chip oscillator (125 kHz), high-speed on-chip oscillator (40 MHz ±5%), PLL frequency synthesizer • Oscillation stop detection: Main clock oscillation stop/restart detection function • Frequency divider circuit: Divide ratio selectable from 1, 2, 4, 8, and 16 • Power saving features: Wait mode, stop mode • Real-time clock
External Bus Expansion	Bus memory expansion	• Address space: 1 MB • External bus interface: 0 to 8 waits inserted, 4 chip select outputs, memory area expansion function (expandable to 4 MB), 3 V and 5 V interfaces • Bus format: Separate bus or multiplexed bus selectable, data bus width selectable (8 or 16 bits), number of address buses selectable (12, 16, or 20)
I/O Ports	Programmable I/O ports	• CMOS I/O ports: 111 (selectable pull-up resistors) • N-channel open drain ports: 3
Interrupts		• Interrupt vectors: 70 • External interrupt inputs: 13 ($\overline{\mathrm{NMI}}$, $\overline{\mathrm{INT}}$ × 8, key input × 4) • Interrupt priority levels: 7
Watchdog Timer		15-bit timer × 1 (with prescaler) Automatic reset start function selectable
DMA	DMAC	• 4 channels, cycle steal mode • Trigger sources: 43 • Transfer modes: 2 (single transfer, repeat transfer)

Table 1.2 Specifications for the 128-Pin Package (2/2)

Item	Function	Description
Timers	Timer A	16-bit timer × 5 Timer mode, event counter mode, one-shot timer mode, pulse width modulation (PWM) mode Event counter two-phase pulse signal processing (two-phase encoder input) × 3 Programmable output mode × 3
	Timer B	16-bit timer × 6 Timer mode, event counter mode, pulse period measurement mode, pulse width measurement mode
	Three-phase motor control timer functions	• Three-phase inverter control (timer A1, timer A2, timer A4, timer B2) • On-chip dead time timer
	Real-time clock	Count: seconds, minutes, hours, days of the week
	PWM function	8 bits × 2
	Remote control signal receiver	• 2 circuits • 4 wave pattern matchings (differentiate wave pattern for headers, data 0, data 1, and special data) • 6-byte receive buffer (1 circuit only) • Operating frequency of 32 kHz
Serial Interface	UART0 to UART2, UART5 to UART7	Clock synchronous/asynchronous × 6 channels I^2C-bus, IEBus, special mode 2 SIM (UART2)
	SI/O3, SI/O4	Clock synchronization only × 2 channels
Multi-master I^2C-bus Interface		1 channel
CEC Functions [2]		CEC transmit/receive, arbitration lost detection, ACK automatic output, operation frequency of 32 kHz
A/D Converter		10-bit resolution × 26 channels, including sample and hold function Conversion time: 1.72 µs
D/A Converter		8-bit resolution × 2 circuits
CRC Calculator		CRC-CCITT ($X^{16} + X^{12} + X^5 + 1$), CRC-16 ($X^{16} + X^{15} + X^2 + 1$) compliant
Flash Memory		• Program and erase power supply voltage: 2.7 to 5.5 V • Program and erase cycles: 1,000 times (program ROM 1, program ROM 2), 10,000 times (data flash) • Program security: ROM code protect, ID code check
Debug Functions		On-chip debug, on-board flash rewrite, address match interrupt × 4
Operation Frequency/Supply Voltage		32 MHz/VCC1 = 2.7 to 5.5 V, VCC2 = 2.7 V to VCC1
Current Consumption		Refer to the Electrical Characteristics chapter
Operating Temperature		-20°C to 85°C, -40°C to 85°C [1]
Package		128-pin LQFP: PLQP0128KB-A (Previous package code: 128P6Q-A)

Notes:

1. See Table 1.5 “Product List (N-Version)” to Table 1.6 “Product List (D-Version)” for the operating temperature.
2. The CEC function indicates circuitry which supports the transmission and reception of CEC signals standardized by the High-Definition Multimedia Interface (HDMI). HDMI and High-Definition Multimedia Interface are registered trademarks of HDMI Licensing, LLC.

Table 1.3 Specifications for the 100-Pin Package (1/2)

Item	Function	Description
CPU	Central processing unit	M16C/60 Series core (multiplier: 16 bit × 16 bit → 32 bit, multiply and accumulate instruction: 16 bit × 16 bit + 32 bit → 32 bit) • Number of basic instructions: 91 • Minimum instruction execution time: 31.25 ns (f(BCLK) = 32 MHz, VCC1 = VCC2 = 2.7 to 5.5 V) • Operating modes: Single-chip, memory expansion, and microprocessor
Memory	ROM, RAM, data flash	See Table 1.5 “Product List (N-Version)” to Table 1.6 “Product List (D-Version)”.
Voltage Detection	Voltage detector	• Power-on reset • 3 voltage detection points (detection level of voltage detection 0 and 1 selectable)
Clock	Clock generator	• 5 circuits: Main clock, sub clock, low-speed on-chip oscillator (125 kHz), high-speed on-chip oscillator (40 MHz ±5%), PLL frequency synthesizer • Oscillation stop detection: Main clock oscillation stop/restart detection function • Frequency divider circuit: Divide ratio selectable from 1, 2, 4, 8, and 16 • Power saving features: Wait mode, stop mode • Real-time clock
External Bus Expansion	Bus memory expansion	• Address space: 1 MB • External bus interface: 0 to 8 waits inserted, 4 chip select outputs, memory area expansion function (expandable to 4 MB), 3 V and 5 V interfaces • Bus format: Separate bus or multiplexed bus selectable, data bus width selectable (8 or 16 bits), number of address buses selectable (12, 16, or 20)
I/O Ports	Programmable I/O ports	• CMOS I/O ports: 85 (selectable pull-up resistors) • N-channel open drain ports: 3
Interrupts		• Interrupt vectors: 70 • External interrupt inputs: 13 ($\overline{\text{NMI}}$, $\overline{\text{INT}}$ × 8, key input × 4) • Interrupt priority levels: 7
Watchdog Timer		15-bit timer × 1 (with prescaler) Automatic reset start function selectable
DMA	DMAC	• 4 channels, cycle steal mode • Trigger sources: 43 • Transfer modes: 2 (single transfer, repeat transfer)

Table 1.4 Specifications for the 100-Pin Package (2/2)

Item	Function	Description
Timers	Timer A	16-bit timer × 5 Timer mode, event counter mode, one-shot timer mode, pulse width modulation (PWM) mode Event counter two-phase pulse signal processing (two-phase encoder input) × 3 Programmable output mode × 3
	Timer B	16-bit timer × 6 Timer mode, event counter mode, pulse period measurement mode, pulse width measurement mode
	Three-phase motor control timer functions	• Three-phase inverter control (timer A1, timer A2, timer A4, timer B2) • On-chip dead time timer
	Real-time clock	Count: seconds, minutes, hours, days of the week
	PWM function	8 bits × 2
	Remote control signal receiver	• 2 circuits • 4 wave pattern matchings (differentiate wave pattern for headers, data 0, data 1, and special data) • 6-byte receive buffer (1 circuit only) • Operating frequency of 32 kHz
Serial Interface	UART0 to UART2, UART5 to UART7	Clock synchronous/asynchronous × 6 channels I^{2}C-bus, IEBus, special mode 2 SIM (UART2)
	SI/O3, SI/O4	Clock synchronization only × 2 channels
Multi-master I^{2}C-bus Interface		1 channel
CEC Functions (2)		CEC transmit/receive, arbitration lost detection, ACK automatic output, operation frequency of 32 kHz
A/D Converter		10-bit resolution × 26 channels, including sample and hold function Conversion time: 1.72 µs
D/A Converter		8-bit resolution × 2 circuits
CRC Calculator		CRC-CCITT ($X^{16} + X^{12} + X^5 + 1$), CRC-16 ($X^{16} + X^{15} + X^2 + 1$) compliant
Flash Memory		• Program and erase power supply voltage: 2.7 to 5.5 V • Program and erase cycles: 1,000 times (program ROM 1, program ROM 2), 10,000 times (data flash) • Program security: ROM code protect, ID code check
Debug Functions		On-chip debug, on-board flash rewrite, address match interrupt × 4
Operation Frequency/Supply Voltage		25 MHz/VCC1 = 2.7 to 5.5 V, VCC2 = 2.7 V to VCC1 32 MHz/VCC1 = 2.7 to 5.5 V, VCC2 = 2.7 V to VCC1
Current Consumption		Refer to the Electrical Characteristics chapter
Operating Temperature		-20°C to 85°C, -40°C to 85°C (1)
Package		100-pin QFP: PRQP0100JD-B (Previous package code: 100P6F-A) 100-pin LQFP: PLQP0100KB-A (Previous package code: 100P6Q-A)

Notes:

1. See Table 1.5 “Product List (N-Version)” to Table 1.6 “Product List (D-Version)” for the operating temperature.
2. The CEC function indicates circuitry which supports the transmission and reception of CEC signals standardized by the High-Definition Multimedia Interface (HDMI). HDMI and High-Definition Multimedia Interface are registered trademarks of HDMI Licensing, LLC.

1.3 Product List

Table 1.5 and Table 1.6 list product information. Figure 1.1 shows the Part No., with Memory Size and Package, and Figure 1.2 shows the Marking Diagram (Top View).

Table 1.5 Product List (N-Version) As of July, 2012

Part No.	ROM Capacity			RAM Capacity	Package Code	Remarks
	Program ROM 1	Program ROM 2	Data flash			
R5F36506CNFA	128 KB	16 KB	4 KB × 2 blocks	12 KB	PRQP0100JD-B	Operating temperature -20°C to 85°C
R5F36506CNFB					PLQP0100KB-A	
R5F3651ECNFC	256 KB	16 KB	4 KB × 2 blocks	20 KB	PLQP0128KB-A	
R5F3650ECNFA					PRQP0100JD-B	
R5F3650ECNFB					PLQP0100KB-A	
R5F3651KCNFC	384 KB	16 KB	4 KB × 2 blocks	31 KB	PLQP0128KB-A	
R5F3650KCNFA					PRQP0100JD-B	
R5F3650KCNFB					PLQP0100KB-A	
R5F3651MCNFC	512 KB	16 KB	4 KB × 2 blocks	31 KB	PLQP0128KB-A	
R5F3650MCNFA					PRQP0100JD-B	
R5F3650MCNFB					PLQP0100KB-A	
R5F3651NCNFC	512 KB	16 KB	4 KB × 2 blocks	47 KB	PLQP0128KB-A	
R5F3650NCNFA					PRQP0100JD-B	
R5F3650NCNFB					PLQP0100KB-A	

(D): Under development
(P): Planning
Note:
1. Previous package codes are as follows:
PLQP0128KB-A: 128P6Q-A, PRQP0100JD-B: 100P6F-A, PLQP0100KB-A: 100P6Q-A

Table 1.6 Product List (D-Version) As of July, 2012

Part No.	ROM Capacity			RAM Capacity	Package Code	Remarks
	Program ROM 1	Program ROM 2	Data flash			
R5F36506CDFA	128 KB	16 KB	4 KB × 2 blocks	12 KB	PRQP0100JD-B	Operating temperature -40°C to 85°C
R5F36506CDFB					PLQP0100KB-A	
R5F3651ECDFC	256 KB	16 KB	4 KB × 2 blocks	20 KB	PLQP0128KB-A	
R5F3650ECDFA					PRQP0100JD-B	
R5F3650ECDFB					PLQP0100KB-A	
R5F3651KCDFC	384 KB	16 KB	4 KB × 2 blocks	31 KB	PLQP0128KB-A	
R5F3650KCDFA					PRQP0100JD-B	
R5F3650KCDFB					PLQP0100KB-A	
R5F3651MCDFC	512 KB	16 KB	4 KB × 2 blocks	31 KB	PLQP0128KB-A	
R5F3650MCDFA					PRQP0100JD-B	
R5F3650MCDFB					PLQP0100KB-A	
R5F3651NCDFC	512 KB	16 KB	4 KB × 2 blocks	47 KB	PLQP0128KB-A	
R5F3650NCDFA					PRQP0100JD-B	
R5F3650NCDFB					PLQP0100KB-A	

(D): Under development
(P): Planning
Note:
1. Previous package codes are as follows:
PLQP0128KB-A: 128P6Q-A, PRQP0100JD-B: 100P6F-A, PLQP0100KB-A: 100P6Q-A

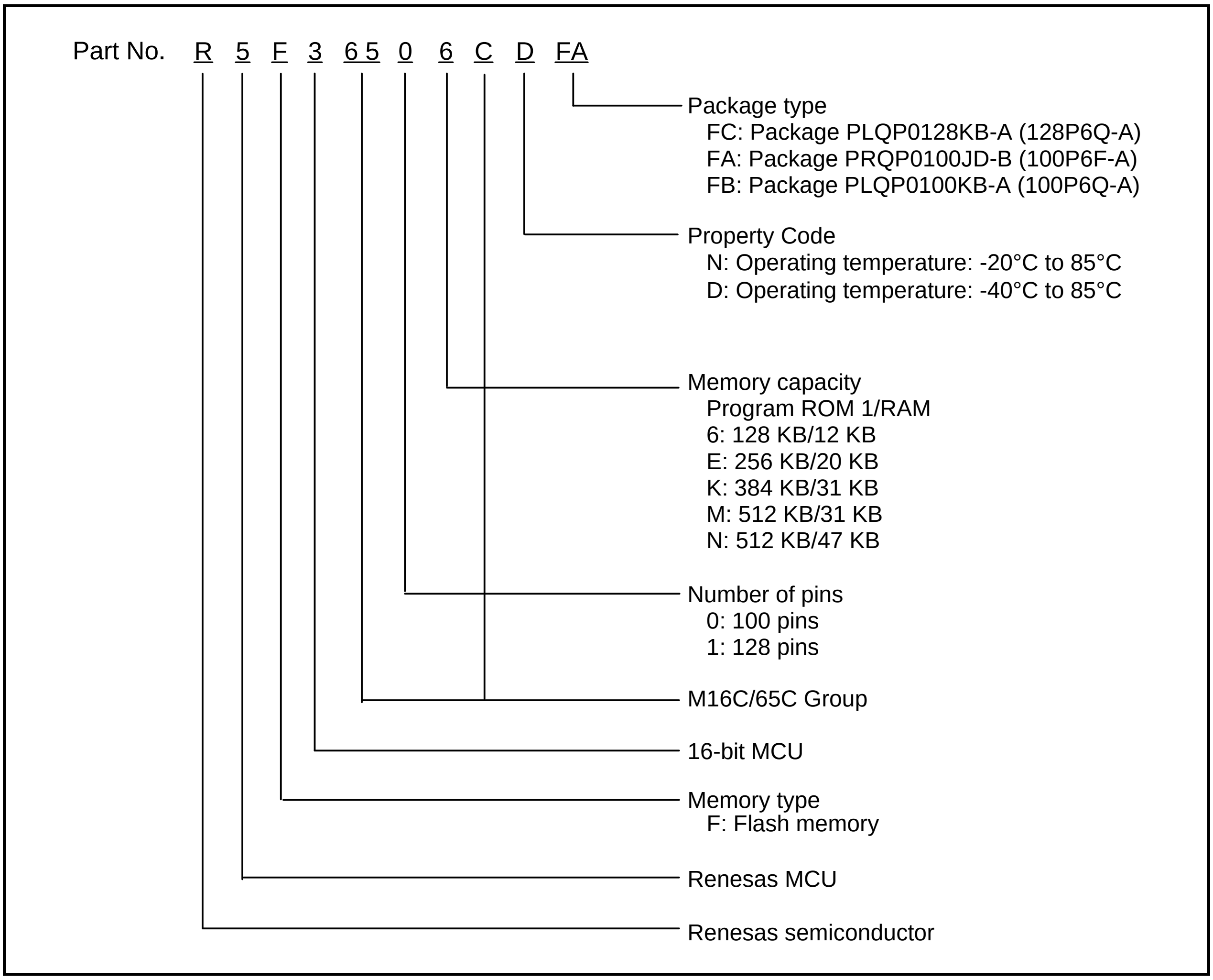


Figure 1.1 Part No., with Memory Size and Package

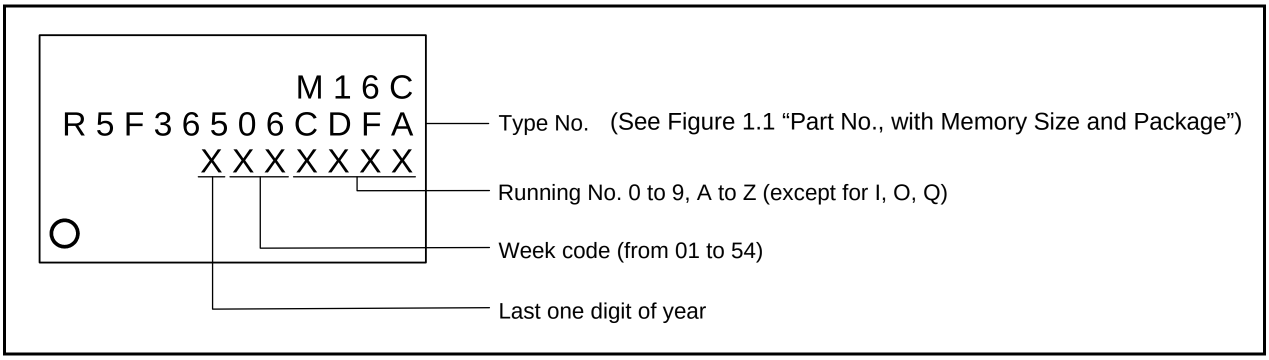
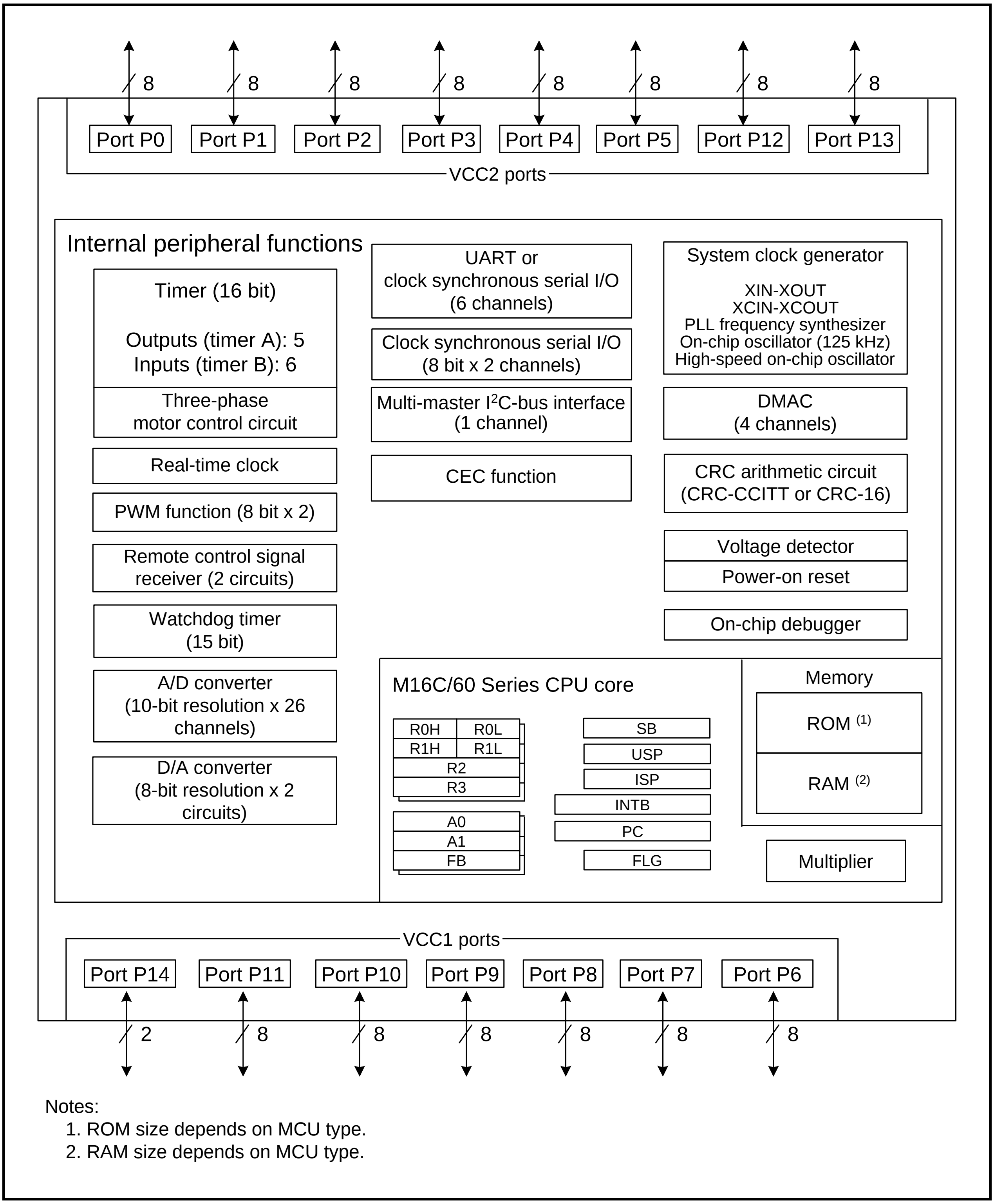

M16C
R5F36506CDFA
XXXXXXX
Type No. (See Figure 1.1 “Part No., with Memory Size and Package”)
Running No. 0 to 9, A to Z (except for I, O, Q)
Week code (from 01 to 54)
Last one digit of year

Figure 1.2 Marking Diagram (Top View)

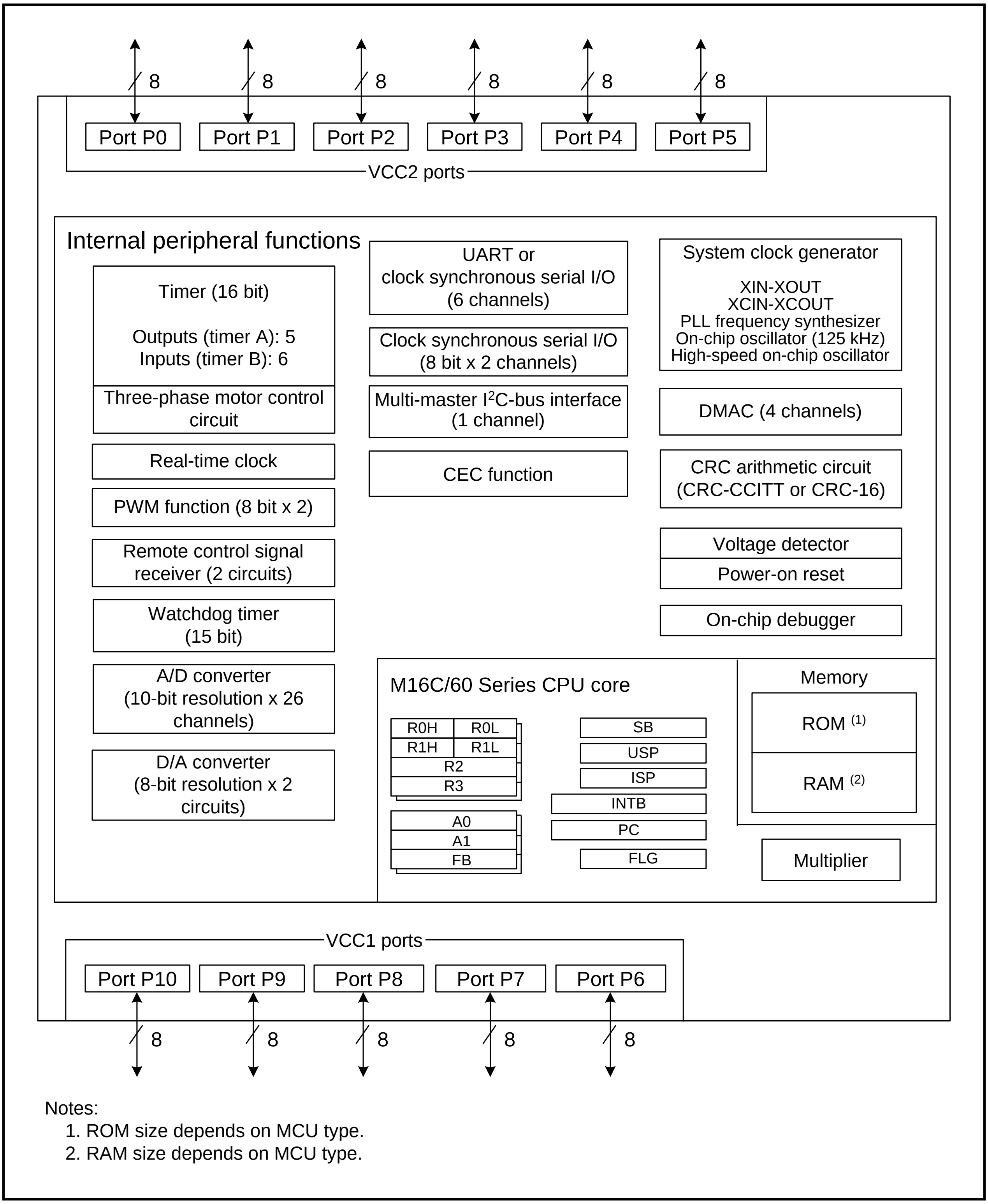
1.4 Block Diagram

Figure 1.3 to Figure 1.4 show block diagrams.


8
Port P0
Port P1
Port P2
Port P3
Port P4
Port P5
Port P12
Port P13
VCC2 ports
Internal peripheral functions
Timer (16 bit)
Outputs (timer A): 5
Inputs (timer B): 6
Three-phase motor control circuit
Real-time clock
PWM function (8 bit x 2)
Remote control signal receiver (2 circuits)
Watchdog timer (15 bit)
A/D converter (10-bit resolution x 26 channels)
D/A converter (8-bit resolution x 2 circuits)
UART or clock synchronous serial I/O (6 channels)
Clock synchronous serial I/O (8 bit x 2 channels)
Multi-master I2C-bus interface (1 channel)
CEC function
System clock generator
XIN-XOUT
XCIN-XCOUT
PLL frequency synthesizer
On-chip oscillator (125 kHz)
High-speed on-chip oscillator
DMAC (4 channels)
CRC arithmetic circuit (CRC-CCITT or CRC-16)
Voltage detector
Power-on reset
On-chip debugger
M16C/60 Series CPU core
R0H
R0L
R1H
R1L
R2
R3
A0
A1
FB
SB
USP
ISP
INTB
PC
FLG
Memory
ROM (1)
RAM (2)
Multiplier
VCC1 ports
Port P14
Port P11
Port P10
Port P9
Port P8
Port P7
Port P6
2

Notes:
1. ROM size depends on MCU type.
2. RAM size depends on MCU type.

Figure 1.3 Block Diagram for the 128-Pin Package


8
8
8
8
8
8
Port P0
Port P1
Port P2
Port P3
Port P4
Port P5
VCC2 ports
Internal peripheral functions
Timer (16 bit)
Outputs (timer A): 5
Inputs (timer B): 6
Three-phase motor control circuit
Real-time clock
PWM function (8 bit x 2)
Remote control signal receiver (2 circuits)
Watchdog timer (15 bit)
A/D converter (10-bit resolution x 26 channels)
D/A converter (8-bit resolution x 2 circuits)
UART or clock synchronous serial I/O (6 channels)
Clock synchronous serial I/O (8 bit x 2 channels)
Multi-master I²C-bus interface (1 channel)
CEC function
System clock generator
XIN-XOUT
XCIN-XCOUT
PLL frequency synthesizer
On-chip oscillator (125 kHz)
High-speed on-chip oscillator
DMAC (4 channels)
CRC arithmetic circuit (CRC-CCITT or CRC-16)
Voltage detector
Power-on reset
On-chip debugger
M16C/60 Series CPU core
R0H
R0L
R1H
R1L
R2
R3
A0
A1
FB
SB
USP
ISP
INTB
PC
FLG
Memory
ROM (1)
RAM (2)
Multiplier
VCC1 ports
Port P10
Port P9
Port P8
Port P7
Port P6
8
8
8
8
8

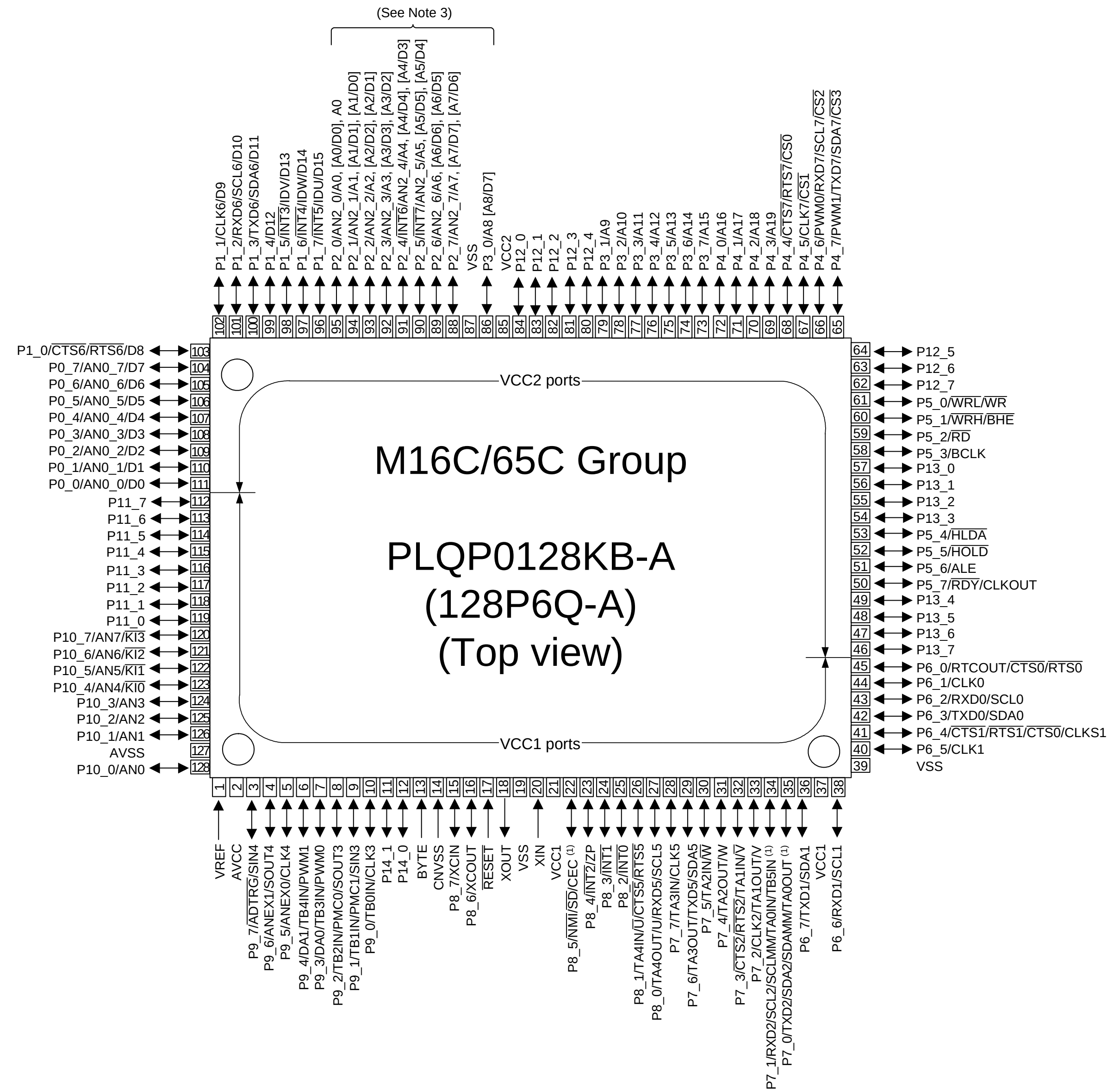
Notes:

1. ROM size depends on MCU type.
2. RAM size depends on MCU type.

Figure 1.4 Block Diagram for the 100-Pin Package

1.5 Pin Assignments

Figure 1.5 to Figure 1.7 show pin assignments. Table 1.7 to Table 1.11 list pin names.



Notes:
1. N-channel open drain output.
2. Check the position of Pin 1 by referring to appendix 1, Package Dimensions.
3. Pin names in brackets [ ] represent a single functional signal. They should not be considered as two separate functional signals.

Figure 1.5 Pin Assignment for the 128-Pin Package

Table 1.7 Pin Names for the 128-Pin Package (1/3)

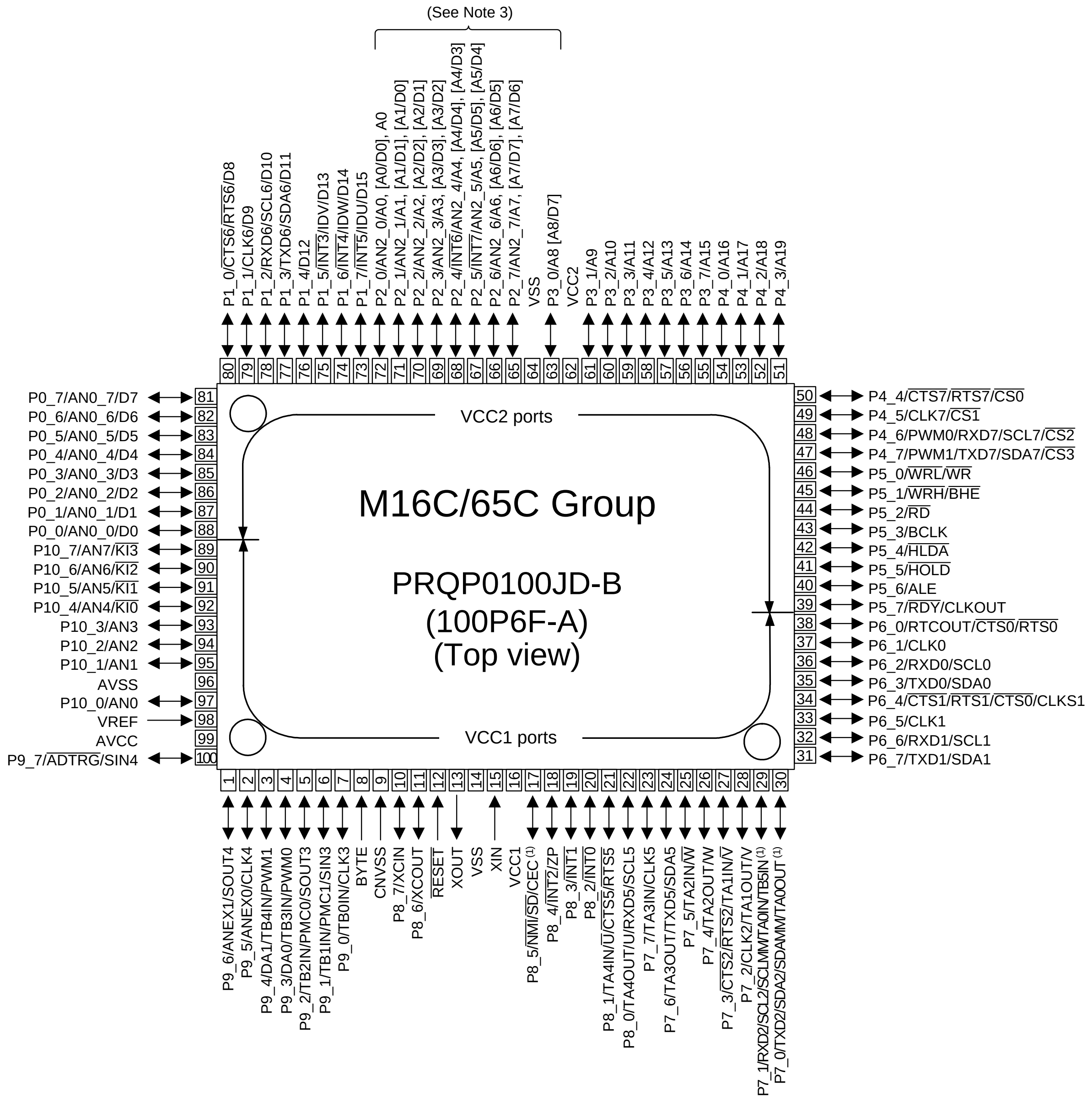
Pin No.	Control Pin	Port	I/O Pin for Peripheral Function				Bus Control Pin
			Interrupt	Timer	Serial interface	A/D converter, D/A converter	
1	VREF						
2	AVCC						
3		P9_7			SIN4	$\overline{\text{ADTRG}}$	
4		P9_6			SOUT4	ANEX1	
5		P9_5			CLK4	ANEX0	
6		P9_4		TB4IN/PWM1		DA1	
7		P9_3		TB3IN/PWM0		DA0	
8		P9_2		TB2IN/PMC0	SOUT3		
9		P9_1		TB1IN/PMC1	SIN3		
10		P9_0		TB0IN	CLK3		
11		P14_1					
12		P14_0					
13	BYTE						
14	CNVSS						
15	XCIN	P8_7					
16	XCOUT	P8_6					
17	$\overline{\text{RESET}}$						
18	XOUT						
19	VSS						
20	XIN						
21	VCC1						
22		P8_5	$\overline{\text{NMI}}$	$\overline{\text{SD}}$	CEC		
23		P8_4	$\overline{\text{INT2}}$	ZP			
24		P8_3	$\overline{\text{INT1}}$				
25		P8_2	$\overline{\text{INT0}}$				
26		P8_1		TA4IN/$\overline{\text{U}}$	$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$		
27		P8_0		TA4OUT/U	RXD5/SCL5		
28		P7_7		TA3IN	CLK5		
29		P7_6		TA3OUT	TXD5/SDA5		
30		P7_5		TA2IN/$\overline{\text{W}}$			
31		P7_4		TA2OUT/W			
32		P7_3		TA1IN/$\overline{\text{V}}$	$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$		
33		P7_2		TA1OUT/V	CLK2		
34		P7_1		TA0IN/TB5IN	RXD2/SCL2/SCLMM		
35		P7_0		TA0OUT	TXD2/SDA2/SDAMM		
36		P6_7			TXD1/SDA1		
37	VCC1						
38		P6_6			RXD1/SCL1		
39	VSS						
40		P6_5			CLK1		
41		P6_4			$\overline{\text{CTS1}}$/$\overline{\text{RTS1}}$/$\overline{\text{CTS0}}$/CLKS1		
42		P6_3			TXD0/SDA0		
43		P6_2			RXD0/SCL0		
44		P6_1			CLK0		
45		P6_0		RTCOUT	$\overline{\text{CTS0}}$/$\overline{\text{RTS0}}$		
46		P13_7					
47		P13_6					
48		P13_5					
49		P13_4					
50	CLKOUT	P5_7					$\overline{\text{RDY}}$

Table 1.8 Pin Names for the 128-Pin Package (2/3)

Pin No.	Control Pin	Port	I/O Pin for Peripheral Function				Bus Control Pin
			Interrupt	Timer	Serial interface	A/D converter, D/A converter	
51		P5_6					ALE
52		P5_5					$\overline{\mathrm{HOLD}}$
53		P5_4					$\overline{\mathrm{HLDA}}$
54		P13_3					
55		P13_2					
56		P13_1					
57		P13_0					
58		P5_3					BCLK
59		P5_2					$\overline{\mathrm{RD}}$
60		P5_1					$\overline{\mathrm{WRH}}$/$\overline{\mathrm{BHE}}$
61		P5_0					$\overline{\mathrm{WRL}}$/$\overline{\mathrm{WR}}$
62		P12_7					
63		P12_6					
64		P12_5					
65		P4_7		PWM1	TXD7/SDA7		$\overline{\mathrm{CS3}}$
66		P4_6		PWM0	RXD7/SCL7		$\overline{\mathrm{CS2}}$
67		P4_5			CLK7		$\overline{\mathrm{CS1}}$
68		P4_4			$\overline{\mathrm{CTS7}}$/$\overline{\mathrm{RTS7}}$		$\overline{\mathrm{CS0}}$
69		P4_3					A19
70		P4_2					A18
71		P4_1					A17
72		P4_0					A16
73		P3_7					A15
74		P3_6					A14
75		P3_5					A13
76		P3_4					A12
77		P3_3					A11
78		P3_2					A10
79		P3_1					A9
80		P12_4					
81		P12_3					
82		P12_2					
83		P12_1					
84		P12_0					
85	VCC2						
86		P3_0					A8, [A8/D7]
87	VSS						
88		P2_7				AN2_7	A7, [A7/D7], [A7/D6]
89		P2_6				AN2_6	A6, [A6/D6], [A6/D5]
90		P2_5	$\overline{\mathrm{INT7}}$			AN2_5	A5, [A5/D5], [A5/D4]
91		P2_4	$\overline{\mathrm{INT6}}$			AN2_4	A4[A4/D4], [A4/D3]
92		P2_3				AN2_3	A3, [A3/D3], [A3/D2]
93		P2_2				AN2_2	A2, [A2/D2], [A2/D1]
94		P2_1				AN2_1	A1, [A1/D1], [A1/D0]
95		P2_0				AN2_0	A0, [A0/D0], A0
96		P1_7	$\overline{\mathrm{INT5}}$	IDU			D15
97		P1_6	$\overline{\mathrm{INT4}}$	IDW			D14
98		P1_5	$\overline{\mathrm{INT3}}$	IDV			D13
99		P1_4					D12
100		P1_3			TXD6/SDA6		D11

Table 1.9 Pin Names for the 128-Pin Package (3/3)

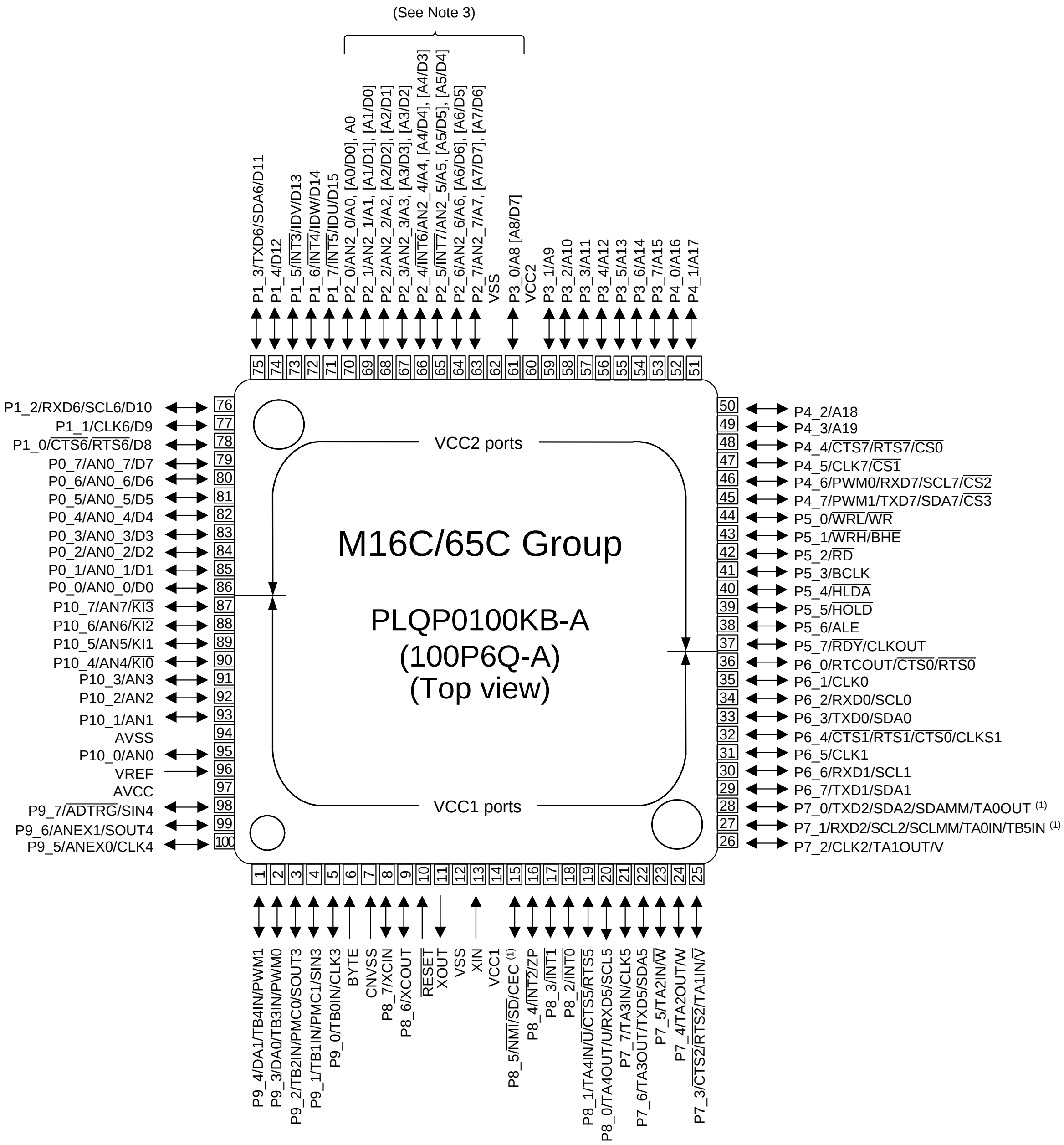
Pin No.	Control Pin	Port	I/O Pin for Peripheral Function				Bus Control Pin
			Interrupt	Timer	Serial interface	A/D converter, D/A converter	
101		P1_2			RXD6/SCL6		D10
102		P1_1			CLK6		D9
103		P1_0			$\overline{\mathrm{CTS6}}$/$\overline{\mathrm{RTS6}}$		D8
104		P0_7				AN0_7	D7
105		P0_6				AN0_6	D6
106		P0_5				AN0_5	D5
107		P0_4				AN0_4	D4
108		P0_3				AN0_3	D3
109		P0_2				AN0_2	D2
110		P0_1				AN0_1	D1
111		P0_0				AN0_0	D0
112		P11_7					
113		P11_6					
114		P11_5					
115		P11_4					
116		P11_3					
117		P11_2					
118		P11_1					
119		P11_0					
120		P10_7	$\overline{\mathrm{KI3}}$			AN7	
121		P10_6	$\overline{\mathrm{KI2}}$			AN6	
122		P10_5	$\overline{\mathrm{KI1}}$			AN5	
123		P10_4	$\overline{\mathrm{KI0}}$			AN4	
124		P10_3				AN3	
125		P10_2				AN2	
126		P10_1				AN1	
127	AVSS						
128		P10_0				AN0	



Notes:

1. N-channel open drain output.
2. Check the position of Pin 1 by referring to appendix 1, Package Dimensions.
3. Pin names in brackets [ ] represent a single functional signal. They should not be considered as two separate functional signals.

Figure 1.6 Pin Assignment for the 100-Pin Package



Notes:
1. N-channel open drain output.
2. Check the position of Pin 1 by referring to appendix 1, Package Dimensions.
3. Pin names in brackets [ ] represent a single functional signal. They should not be considered as two separate functional signals.

Figure 1.7 Pin Assignment for the 100-Pin Package

Table 1.10 Pin Names for the 100-Pin Package (1/2)

Pin No.		Control Pin	Port	I/O Pin for Peripheral Function				Bus Control Pin
FA	FB			Interrupt	Timer	Serial interface	A/D converter, D/A converter	
1	99		P9_6			SOUT4	ANEX1	
2	100		P9_5			CLK4	ANEX0	
3	1		P9_4		TB4IN/PWM1		DA1	
4	2		P9_3		TB3IN/PWM0		DA0	
5	3		P9_2		TB2IN/PMC0	SOUT3		
6	4		P9_1		TB1IN/PMC1	SIN3		
7	5		P9_0		TB0IN	CLK3		
8	6	BYTE						
9	7	CNVSS						
10	8	XCIN	P8_7					
11	9	XCOUT	P8_6					
12	10	$\overline{\mathrm{RESET}}$						
13	11	XOUT						
14	12	VSS						
15	13	XIN						
16	14	VCC1						
17	15		P8_5	$\overline{\mathrm{NMI}}$	$\overline{\mathrm{SD}}$	CEC		
18	16		P8_4	$\overline{\mathrm{INT2}}$	ZP			
19	17		P8_3	$\overline{\mathrm{INT1}}$				
20	18		P8_2	$\overline{\mathrm{INT0}}$				
21	19		P8_1		TA4IN/$\overline{\mathrm{U}}$	$\overline{\mathrm{CTS5}}$/$\overline{\mathrm{RTS5}}$		
22	20		P8_0		TA4OUT/U	RXD5/SCL5		
23	21		P7_7		TA3IN	CLK5		
24	22		P7_6		TA3OUT	TXD5/SDA5		
25	23		P7_5		TA2IN/$\overline{\mathrm{W}}$			
26	24		P7_4		TA2OUT/W			
27	25		P7_3		TA1IN/$\overline{\mathrm{V}}$	$\overline{\mathrm{CTS2}}$/$\overline{\mathrm{RTS2}}$		
28	26		P7_2		TA1OUT/V	CLK2		
29	27		P7_1		TA0IN/TB5IN	RXD2/SCL2/SCLMM		
30	28		P7_0		TA0OUT	TXD2/SDA2/SDAMM		
31	29		P6_7			TXD1/SDA1		
32	30		P6_6			RXD1/SCL1		
33	31		P6_5			CLK1		
34	32		P6_4			CTS1/RTS1/CTS0/ CLKS1		
35	33		P6_3			TXD0/SDA0		
36	34		P6_2			RXD0/SCL0		
37	35		P6_1			CLK0		
38	36		P6_0		RTCOUT	$\overline{\mathrm{CTS0}}$/$\overline{\mathrm{RTS0}}$		
39	37	CLKOUT	P5_7					$\overline{\mathrm{RDY}}$
40	38		P5_6					ALE
41	39		P5_5					$\overline{\mathrm{HOLD}}$
42	40		P5_4					$\overline{\mathrm{HLDA}}$
43	41		P5_3					BCLK
44	42		P5_2					$\overline{\mathrm{RD}}$
45	43		P5_1					$\overline{\mathrm{WRH}}$/$\overline{\mathrm{BHE}}$
46	44		P5_0					$\overline{\mathrm{WRL}}$/$\overline{\mathrm{WR}}$
47	45		P4_7		PWM1	TXD7/SDA7		$\overline{\mathrm{CS3}}$
48	46		P4_6		PWM0	RXD7/SCL7		$\overline{\mathrm{CS2}}$
49	47		P4_5			CLK7		$\overline{\mathrm{CS1}}$
50	48		P4_4			$\overline{\mathrm{CTS7}}$/$\overline{\mathrm{RTS7}}$		$\overline{\mathrm{CS0}}$

Table 1.11 Pin Names for the 100-Pin Package (2/2)

Pin No.		Control Pin	Port	I/O Pin for Peripheral Function				Bus Control Pin
FA	FB			Interrupt	Timer	Serial interface	A/D converter, D/A converter	
51	49		P4_3					A19
52	50		P4_2					A18
53	51		P4_1					A17
54	52		P4_0					A16
55	53		P3_7					A15
56	54		P3_6					A14
57	55		P3_5					A13
58	56		P3_4					A12
59	57		P3_3					A11
60	58		P3_2					A10
61	59		P3_1					A9
62	60	VCC2						
63	61		P3_0					A8, [A8/D7]
64	62	VSS						
65	63		P2_7				AN2_7	A7, [A7/D7], [A7/D6]
66	64		P2_6				AN2_6	A6, [A6/D6], [A6/D5]
67	65		P2_5	$\overline{\mathrm{INT7}}$			AN2_5	A5, [A5/D5], [A5/D4]
68	66		P2_4	$\overline{\mathrm{INT6}}$			AN2_4	A4, [A4/D4], [A4/D3]
69	67		P2_3				AN2_3	A3, [A3/D3], [A3/D2]
70	68		P2_2				AN2_2	A2, [A2/D2], [A2/D1]
71	69		P2_1				AN2_1	A1, [A1/D1], [A1/D0]
72	70		P2_0				AN2_0	A0, [A0/D0], A0
73	71		P1_7	$\overline{\mathrm{INT5}}$	IDU			D15
74	72		P1_6	$\overline{\mathrm{INT4}}$	IDW			D14
75	73		P1_5	$\overline{\mathrm{INT3}}$	IDV			D13
76	74		P1_4					D12
77	75		P1_3			TXD6/SDA6		D11
78	76		P1_2			RXD6/SCL6		D10
79	77		P1_1			CLK6		D9
80	78		P1_0			$\overline{\mathrm{CTS6}}$/$\overline{\mathrm{RTS6}}$		D8
81	79		P0_7				AN0_7	D7
82	80		P0_6				AN0_6	D6
83	81		P0_5				AN0_5	D5
84	82		P0_4				AN0_4	D4
85	83		P0_3				AN0_3	D3
86	84		P0_2				AN0_2	D2
87	85		P0_1				AN0_1	D1
88	86		P0_0				AN0_0	D0
89	87		P10_7	$\overline{\mathrm{KI3}}$			AN7	
90	88		P10_6	$\overline{\mathrm{KI2}}$			AN6	
91	89		P10_5	$\overline{\mathrm{KI1}}$			AN5	
92	90		P10_4	$\overline{\mathrm{KI0}}$			AN4	
93	91		P10_3				AN3	
94	92		P10_2				AN2	
95	93		P10_1				AN1	
96	94	AVSS						
97	95		P10_0				AN0	
98	96	VREF						
99	97	AVCC						
100	98		P9_7			SIN4	$\overline{\mathrm{ADTRG}}$	

1.6 Pin Functions

Table 1.12 Pin Functions for the 128-Pin Package (1/3)

Signal Name	Pin Name	I/O	Power Supply	Description
Power supply input	VCC1, VCC2, VSS	I	-	Apply 2.7 to 5.5 V to pins VCC1 and VCC2 (VCC1 ≥ VCC2), and 0 V to the VSS pin.
Analog power supply input	AVCC, AVSS	I	VCC1	This is the power supply for the A/D and D/A converters. Connect the AVCC pin to VCC1, and connect the AVSS pin to VSS.
Reset input	$\overline{RESET}$	I	VCC1	Driving this pin low resets the MCU.
CNVSS	CNVSS	I	VCC1	Input pin to switch processor modes. After a reset, to start operating in single-chip mode, connect the CNVSS pin to VSS via a resistor. To start operating in microprocessor mode, connect the pin to VCC1.
External data bus width select input	BYTE	I	VCC1	Input pin to select the data bus of the external area. The data bus is 16 bits when it is low and 8 bits when it is high. This pin must be fixed either high or low. Connect the BYTE pin to VSS in single-chip mode.
Bus control pins	D0 to D7	I/O	VCC2	Inputs or outputs data (D0 to D7) while accessing an external area with a separate bus.
	D8 to D15	I/O	VCC2	Inputs or outputs data (D8 to D15) while accessing an external area with a 16-bit separate bus.
	A0 to A19	O	VCC2	Outputs address bits A0 to A19.
	A0/D0 to A7/D7	I/O	VCC2	Inputs or outputs data (D0 to D7) and outputs address bits (A0 to A7) by timesharing, while accessing an external area with an 8-bit multiplexed bus.
	A1/D0 to A8/D7	I/O	VCC2	Inputs or outputs data (D0 to D7) and outputs address bits (A1 to A8) by timesharing, while accessing an external area with a 16-bit multiplexed bus.
	$\overline{CS0}$ to $\overline{CS3}$	O	VCC2	Outputs chip-select signals $\overline{CS0}$ to $\overline{CS3}$ to specify an external area.
	$\overline{WRL}/\overline{WR}$ $\overline{WRH}/\overline{BHE}$ $\overline{RD}$	O	VCC2	Outputs $\overline{WRL}$, $\overline{WRH}$, ($\overline{WR}$, $\overline{BHE}$), and $\overline{RD}$ signals. $\overline{WRL}$ and $\overline{WRH}$ can be switched with $\overline{BHE}$ and $\overline{WR}$. • $\overline{WRL}$, $\overline{WRH}$, and $\overline{RD}$ selected If the external data bus is 16 bits, data is written to an even address in an external area when $\overline{WRL}$ is driven low. Data is written to an odd address when $\overline{WRH}$ is driven low. Data is read when $\overline{RD}$ is driven low. • $\overline{WR}$, $\overline{BHE}$, and $\overline{RD}$ selected Data is written to an external area when $\overline{WR}$ is driven low. Data in an external area is read when $\overline{RD}$ is driven low. An odd address is accessed when $\overline{BHE}$ is driven low. Select $\overline{WR}$, $\overline{BHE}$, and $\overline{RD}$ when using an 8-bit external data bus.
	ALE	O	VCC2	Outputs an ALE signal to latch the address.
	$\overline{HOLD}$	I	VCC2	$\overline{HOLD}$ input is unavailable. Connect the $\overline{HOLD}$ pin to VCC2 via a resistor (pull-up).
	$\overline{HLDA}$	O	VCC2	In a hold state, $\overline{HLDA}$ outputs a low-level signal.
	$\overline{RDY}$	I	VCC2	The MCU bus is placed in wait state while the $\overline{RDY}$ pin is driven low.

Power supply: VCC2 is used to supply power to the external bus associated pins. The dual power supply configuration allows VCC2 to interface at a different voltage than VCC1.

Table 1.13 Pin Functions for the 128-Pin Package (2/3)

Signal Name	Pin Name	I/O	Power Supply	Description
Main clock input	XIN	I	VCC1	I/O for the main clock oscillator. Connect a ceramic resonator or crystal between pins XIN and XOUT. [1] Input an external clock to XIN pin and leave XOUT pin open.
Main clock output	XOUT	O	VCC1	
Sub clock input	XCIN	I	VCC1	I/O for a sub clock oscillator. Connect a crystal between pins XCIN and XCOUT. [1] Input an external clock to XCIN pin and leave XCOUT pin open.
Sub clock output	XCOUT	O	VCC1	
BCLK output	BCLK	O	VCC2	Outputs the BCLK signal.
Clock output	CLKOUT	O	VCC2	Outputs a clock with the same frequency as fC, f1, f8, or f32.
$\overline{\text{INT}}$ interrupt input	$\overline{\text{INT0}}$ to $\overline{\text{INT2}}$	I	VCC1	Input for the $\overline{\text{INT}}$ interrupt.
	$\overline{\text{INT3}}$ to $\overline{\text{INT7}}$	I	VCC2	
$\overline{\text{NMI}}$ interrupt input	$\overline{\text{NMI}}$	I	VCC1	Input for the $\overline{\text{NMI}}$ interrupt.
Key input interrupt input	$\overline{\text{KI0}}$ to $\overline{\text{KI3}}$	I	VCC1	Input for the key input interrupt.
Timer A	TA0OUT to TA4OUT	I/O	VCC1	I/O for timers A0 to A4 (TA0OUT is N-channel open drain output).
	TA0IN to TA4IN	I	VCC1	Input for timers A0 to A4.
	ZP	I	VCC1	Input for Z-phase.
Timer B	TB0IN to TB5IN	I	VCC1	Input for timers B0 to B5.
Three-phase motor control timer	U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W, $\overline{\text{W}}$	O	VCC1	Output for the three-phase motor control timer.
	$\overline{\text{SD}}$	I	VCC1	Forced cutoff input.
	IDU, IDV, IDW	I	VCC2	Input for the position data.
Real-time clock output	RTCOUT	O	VCC1	Output for the real-time clock.
PWM output	PWM0, PWM1	O	VCC1, VCC2	PWM output.
Remote control signal receiver input	PMC0, PMC1	I	VCC1	Input for the remote control signal receiver.
Serial interface UART0 to UART2, UART5 to UART7	$\overline{\text{CTS0}}$ to $\overline{\text{CTS2}}$, $\overline{\text{CTS5}}$	I	VCC1	Input pins to control data transmission.
	$\overline{\text{CTS6}}$, $\overline{\text{CTS7}}$	I	VCC2	
	$\overline{\text{RTS0}}$ to $\overline{\text{RTS2}}$, $\overline{\text{RTS5}}$	O	VCC1	Output pins to control data reception.
	$\overline{\text{RTS6}}$, $\overline{\text{RTS7}}$	O	VCC2	
	CLK0 to CLK2, CLK5	I/O	VCC1	Transmit/receive clock I/O.
	CLK6, CLK7	I/O	VCC2	
	RXD0 to RXD2, RXD5	I	VCC1	Serial data input.
	RXD6, RXD7	I	VCC2	
	TXD0 to TXD2, TXD5	O	VCC1	Serial data output. [2]
	TXD6, TXD7	O	VCC2	
	CLKS1	O	VCC1	Output for the transmit/receive clock multiple-pin output function.

Notes:

1. Contact the manufacturer of crystal/ceramic resonator regarding the oscillation characteristics.
2. TXD2, SDA2, and SCL2 are N-channel open drain output pins. TXDi (i = 0, 1, 5 to 7), SDAi, and SCLi can be selected as CMOS output pins or N-channel open drain output pins.

Table 1.14 Pin Functions for the 128-Pin Package (3/3)

Signal Name	Pin Name	I/O	Power Supply	Description
UART0 to UART2, UART5 to UART7 I^{2}C mode	SDA0 to SDA2, SDA5	I/O	VCC1	Serial data I/O.
	SDA6, SDA7	I/O	VCC2	
	SCL0 to SCL2, SCL5	I/O	VCC1	Transmit/receive clock I/O.
	SCL6, SCL7	I/O	VCC2	
Serial interface SI/O3, SI/O4	CLK3, CLK4	I/O	VCC1	Transmit/receive clock I/O.
	SIN3, SIN4	I	VCC1	Serial data input.
	SOUT3, SOUT4	O	VCC1	Serial data output.
Multi-master I^{2}C-bus interface	SDAMM	I/O	VCC1	Serial data I/O (N-channel open drain output).
	SCLMM	I/O	VCC1	Transmit/receive clock I/O (N-channel open drain output).
CEC I/O	CEC	I/O	VCC1	CEC I/O (N-channel open drain output).
Reference voltage input	VREF	I	VCC1	Reference voltage input for the A/D and D/A converters.
A/D converter	AN0 to AN7	I	VCC1	Analog input.
	AN0_0 to AN0_7 AN2_0 to AN2_7	I	VCC2	
	$\overline{\text{ADTRG}}$	I	VCC1	External trigger input.
	ANEX0, ANEX1	I	VCC1	Extended analog input.
D/A converter	DA0, DA1	O	VCC1	Output pin the D/A converter.
I/O ports	P0_0 to P0_7 P1_0 to P1_7 P2_0 to P2_7 P3_0 to P3_7 P4_0 to P4_7 P5_0 to P5_7 P12_0 to P12_7 P13_0 to P13_7	I/O	VCC2	8-bit CMOS I/O ports. A direction register determines whether each pin is used as an input port or an output port. A pull-up resistor may be enabled or disabled for input ports in 4-bit units.
	P6_0 to P6_7 P7_0 to P7_7 P8_0 to P8_7 P9_0 to P9_7 P10_0 to P10_7 P11_0 to P11_7	I/O	VCC1	8-bit I/O ports having equivalent functions to P0. However, P7_0, P7_1, and P8_5 are N-channel open drain output ports. No pull-up resistor is provided. P8_5 is an input port for verifying the $\overline{\text{NMI}}$ pin level and shares a pin with $\overline{\text{NMI}}$.
	P14_0, P14_1	I/O	VCC1	I/O ports having equivalent functions to P0.

Table 1.15 Pin Functions for the 100-Pin Package (1/3)

Signal Name	Pin Name	I/O	Power Supply	Description
Power supply input	VCC1, VCC2, VSS	I	-	Apply 2.7 to 5.5 V to pins VCC1 and VCC2 (VCC1 ≥ VCC2) and 0 V to the VSS pin.
Analog power supply input	AVCC, AVSS	I	VCC1	This is the power supply for the A/D and D/A converters. Connect the AVCC pin to VCC1, and connect the AVSS pin to VSS.
Reset input	$\overline{\text{RESET}}$	I	VCC1	Driving this pin low resets the MCU.
CNVSS	CNVSS	I	VCC1	Input pin to switch processor modes. After a reset, to start operating in single-chip mode, connect the CNVSS pin to VSS via a resistor. To start operating in microprocessor mode, connect the pin to VCC1.
External data bus width select input	BYTE	I	VCC1	Input pin to select the data bus of the external area. The data bus is 16 bits when it is low, and 8 bits when it is high. This pin must be fixed either high or low. Connect the BYTE pin to VSS in single-chip mode.
Bus control pins	D0 to D7	I/O	VCC2	Inputs or outputs data (D0 to D7) while accessing an external area with a separate bus.
	D8 to D15	I/O	VCC2	Inputs or outputs data (D8 to D15) while accessing an external area with a 16-bit separate bus.
	A0 to A19	O	VCC2	Outputs address bits A0 to A19.
	A0/D0 to A7/D7	I/O	VCC2	Inputs or outputs data (D0 to D7) and outputs address bits (A0 to A7) by timesharing, while accessing an external area with an 8-bit multiplexed bus.
	A1/D0 to A8/D7	I/O	VCC2	Inputs or outputs data (D0 to D7) and outputs address bits (A1 to A8) by timesharing, while accessing an external area with a 16-bit multiplexed bus.
	$\overline{\text{CS0}}$ to $\overline{\text{CS3}}$	O	VCC2	Outputs chip-select signals $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$ to specify an external area.
	$\overline{\text{WRL}}$/$\overline{\text{WR}}$ $\overline{\text{WRH}}$/$\overline{\text{BHE}}$ $\overline{\text{RD}}$	O	VCC2	Outputs $\overline{\text{WRL}}$, $\overline{\text{WRH}}$, ($\overline{\text{WR}}$, $\overline{\text{BHE}}$), and $\overline{\text{RD}}$ signals. $\overline{\text{WRL}}$ and $\overline{\text{WRH}}$ can be switched with $\overline{\text{BHE}}$ and $\overline{\text{WR}}$. • $\overline{\text{WRL}}$, $\overline{\text{WRH}}$, and $\overline{\text{RD}}$ selected If the external data bus is 16 bits, data is written to an even address in an external area when $\overline{\text{WRL}}$ is driven low. Data is written to an odd address when $\overline{\text{WRH}}$ is driven low. Data is read when $\overline{\text{RD}}$ is driven low. • $\overline{\text{WR}}$, $\overline{\text{BHE}}$, and $\overline{\text{RD}}$ selected Data is written to an external area when $\overline{\text{WR}}$ is driven low. Data in an external area is read when $\overline{\text{RD}}$ is driven low. An odd address is accessed when $\overline{\text{BHE}}$ is driven low. Select $\overline{\text{WR}}$, $\overline{\text{BHE}}$, and $\overline{\text{RD}}$ when using an 8-bit external data bus.
	ALE	O	VCC2	Outputs an ALE signal to latch the address.
	$\overline{\text{HOLD}}$	I	VCC2	$\overline{\text{HOLD}}$ input is unavailable. Connect the $\overline{\text{HOLD}}$ pin to VCC2 via a resistor (pull-up).
	$\overline{\text{HLDA}}$	O	VCC2	In a hold state, $\overline{\text{HLDA}}$ outputs a low-level signal.
	$\overline{\text{RDY}}$	I	VCC2	The MCU bus is placed in a wait state while the $\overline{\text{RDY}}$ pin is driven low.

Power supply: VCC2 is used to supply power to the external bus associated pins. The dual power supply configuration allows VCC2 to interface at a different voltage than VCC1.

Table 1.16 Pin Functions for the 100-Pin Package (2/3)

Signal Name	Pin Name	I/O	Power Supply	Description
Main clock input	XIN	I	VCC1	I/O for the main clock oscillator. Connect a ceramic resonator or crystal between pins XIN and XOUT. (1) Input an external clock to XIN pin and leave XOUT pin open.
Main clock output	XOUT	O	VCC1	
Sub clock input	XCIN	I	VCC1	I/O for a sub clock oscillator. Connect a crystal between XCIN pin and XCOUT pin. (1) Input an external clock to XCIN pin and leave XCOUT pin open.
Sub clock output	XCOUT	O	VCC1	
BCLK output	BCLK	O	VCC2	Outputs the BCLK signal.
Clock output	CLKOUT	O	VCC2	Outputs a clock with the same frequency as fC, f1, f8, or f32.
$\overline{\text{INT}}$ interrupt input	$\overline{\text{INT0}}$ to $\overline{\text{INT2}}$	I	VCC1	Input for the $\overline{\text{INT}}$ interrupt.
	$\overline{\text{INT3}}$ to $\overline{\text{INT7}}$	I	VCC2	
$\overline{\text{NMI}}$ interrupt input	$\overline{\text{NMI}}$	I	VCC1	Input for the $\overline{\text{NMI}}$ interrupt.
Key input interrupt input	$\overline{\text{KI0}}$ to $\overline{\text{KI3}}$	I	VCC1	Input for the key input interrupt.
Timer A	TA0OUT to TA4OUT	I/O	VCC1	I/O for timers A0 to A4 (TA0OUT is N-channel open drain output).
	TA0IN to TA4IN	I	VCC1	Input for timers A0 to A4.
	ZP	I	VCC1	Input for Z-phase.
Timer B	TB0IN to TB5IN	I	VCC1	Input for timers B0 to B5.
Three-phase motor control timer	U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W, $\overline{\text{W}}$	O	VCC1	Output for the three-phase motor control timer.
	$\overline{\text{SD}}$	I	VCC1	Forced cutoff input.
	IDU, IDV, IDW	I	VCC2	Input for the position data.
Real-time clock output	RTCOUT	O	VCC1	Output for the real-time clock.
PWM output	PWM0, PWM1	O	VCC1, VCC2	PWM output.
Remote control signal receiver input	PMC0, PMC1	I	VCC1	Input for the remote control signal receiver.
Serial interface UART0 to UART2, UART5 to UART7	$\overline{\text{CTS0}}$ to $\overline{\text{CTS2}}$, $\overline{\text{CTS5}}$	I	VCC1	Input pins to control data transmission.
	$\overline{\text{CTS6}}$, $\overline{\text{CTS7}}$	I	VCC2	
	$\overline{\text{RTS0}}$ to $\overline{\text{RTS2}}$, $\overline{\text{RTS5}}$	O	VCC1	Output pins to control data reception.
	$\overline{\text{RTS6}}$, $\overline{\text{RTS7}}$	O	VCC2	
	CLK0 to CLK2, CLK5	I/O	VCC1	Transmit/receive clock I/O.
	CLK6, CLK7	I/O	VCC2	
	RXD0 to RXD2, RXD5	I	VCC1	Serial data input.
	RXD6, RXD7	I	VCC2	
	TXD0 to TXD2, TXD5	O	VCC1	Serial data output. (2)
	TXD6, TXD7	O	VCC2	
	CLKS1	O	VCC1	Output for the transmit/receive clock multiple-pin output function.

Notes:

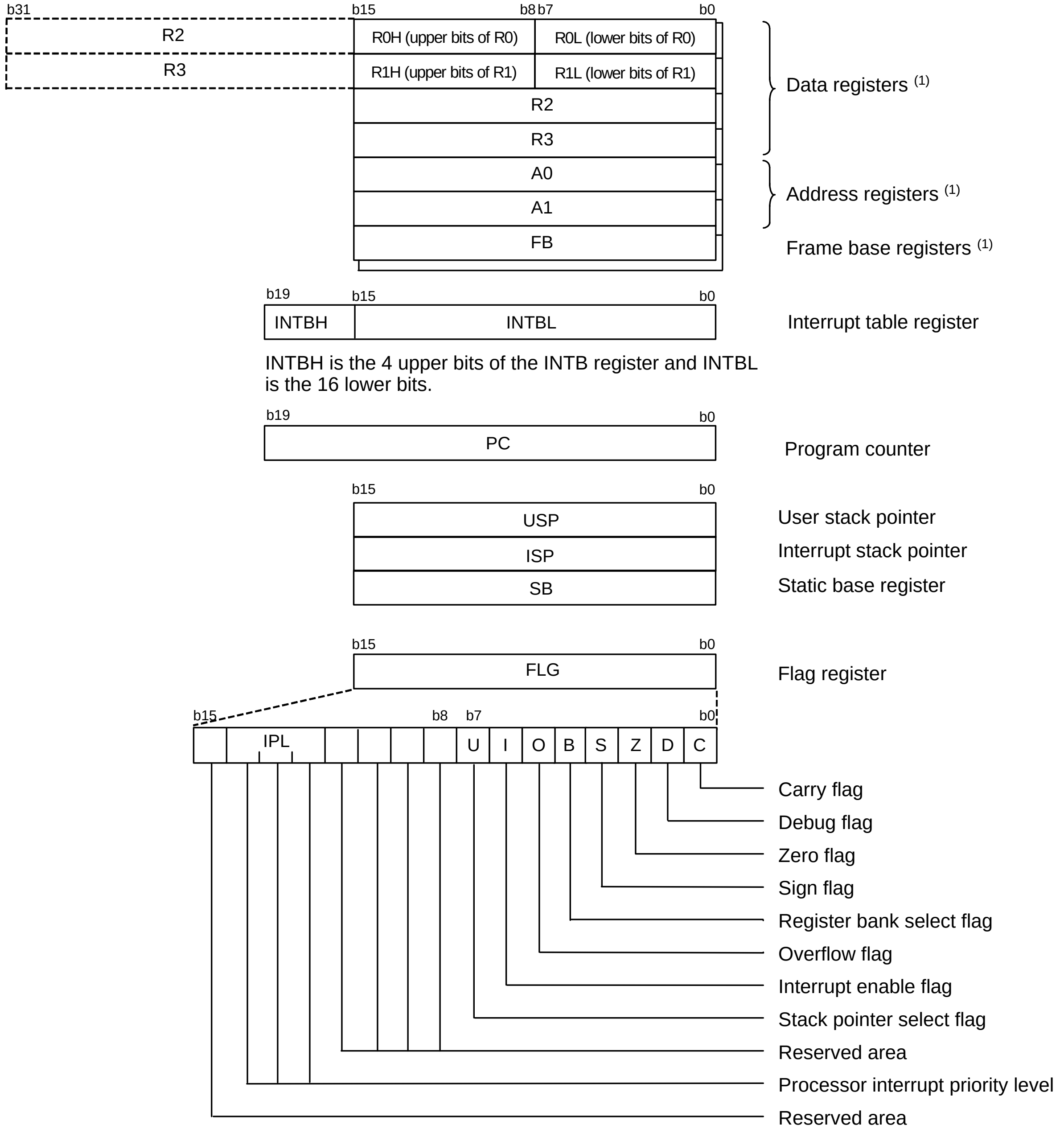
1. Contact the manufacturer of crystal/ceramic resonator regarding the oscillation characteristics.
2. TXD2, SDA2, and SCL2 are N-channel open drain output pins. TXDi (i = 0, 1, 5 to 7), SDAi, and SCLi can be selected as CMOS output pins or N-channel open drain output pins.

Table 1.17 Pin Functions for the 100-Pin Package (3/3)

Signal Name	Pin Name	I/O	Power Supply	Description
UART0 to UART2, UART5 to UART7 I^{2}C mode	SDA0 to SDA2, SDA5	I/O	VCC1	Serial data I/O.
	SDA6, SDA7	I/O	VCC2	
	SCL0 to SCL2, SCL5	I/O	VCC1	Transmit/receive clock I/O.
	SCL6, SCL7	I/O	VCC2	
Serial interface SI/O3, SI/O4	CLK3, CLK4	I/O	VCC1	Transmit/receive clock I/O.
	SIN3, SIN4	I	VCC1	Serial data input.
	SOUT3, SOUT4	O	VCC1	Serial data output.
Multi-master I^{2}C-bus interface	SDAMM	I/O	VCC1	Serial data I/O (N-channel open drain output).
	SCLMM	I/O	VCC1	Transmit/receive clock I/O (N-channel open drain output).
CEC I/O	CEC	I/O	VCC1	CEC I/O (N-channel open drain output).
Reference voltage input	VREF	I	VCC1	Reference voltage input for the A/D and D/A converters.
A/D converter	AN0 to AN7	I	VCC1	Analog input.
	AN0_0 to AN0_7 AN2_0 to AN2_7	I	VCC2	
	$\overline{\text{ADTRG}}$	I	VCC1	External trigger input.
	ANEX0, ANEX1	I	VCC1	Extended analog input.
D/A converter	DA0, DA1	O	VCC1	Output for the D/A converter.
I/O ports	P0_0 to P0_7 P1_0 to P1_7 P2_0 to P2_7 P3_0 to P3_7 P4_0 to P4_7 P5_0 to P5_7	I/O	VCC2	8-bit CMOS I/O ports. A direction register determines whether each pin is used as an input port or an output port. A pull-up resistor may be enabled or disabled for input ports in 4-bit units.
	P6_0 to P6_7 P7_0 to P7_7 P8_0 to P8_7 P9_0 to P9_7 P10_0 to P10_7	I/O	VCC1	8-bit I/O ports having equivalent functions to P0. However, P7_0, P7_1, and P8_5 are N-channel open drain output ports. No pull-up resistor is provided. P8_5 is an input port for verifying the $\overline{\text{NMI}}$ pin level and shares a pin with $\overline{\text{NMI}}$.

2. Central Processing Unit (CPU)

Figure 2.1 shows the CPU registers. Seven registers (R0, R1, R2, R3, A0, A1, and FB) out of 13 compose a register bank, and there are two register banks.



Note:

1. These registers compose a register bank. There are two register banks.

Figure 2.1 CPU Registers

2.1 Data Registers (R0, R1, R2, and R3)

R0, R1, R2, and R3 are 16-bit registers used for transfer, arithmetic, and logic operations. R0 and R1 can be split into upper (R0H/R1H) and lower (R0L/R1L) bits to be used separately as 8-bit data registers.
R0 can be combined with R2, and R3 can be combined with R1 and be used as 32-bit data registers R2R0 and R3R1, respectively.

2.2 Address Registers (A0 and A1)

A0 and A1 are 16-bit registers used for indirect addressing, relative addressing, transfer, arithmetic, and logic operations. A0 can be combined with A1 and used as a 32-bit address register (A1A0).

2.3 Frame Base Register (FB)

FB is a 16-bit register that is used for FB relative addressing.

2.4 Interrupt Table Register (INTB)

INTB is a 20-bit register that indicates the start address of a relocatable interrupt vector table.

2.5 Program Counter (PC)

The PC is 20 bits wide and indicates the address of the next instruction to be executed.

2.6 User Stack Pointer (USP) and Interrupt Stack Pointer (ISP)

The USP and ISP stack pointers (SP) are each comprised of 16 bits. The U flag is used to switch between USP and ISP.

2.7 Static Base Register (SB)

SB is a 16-bit register used for SB relative addressing.

2.8 Flag Register (FLG)

FLG is an 11-bit register that indicates the CPU state.

2.8.1 Carry Flag (C Flag)

The C flag retains a carry, borrow, or shift-out bit generated by the arithmetic/logic unit.

2.8.2 Debug Flag (D Flag)

The D flag is for debugging only. Set it to 0.

2.8.3 Zero Flag (Z Flag)

The Z flag becomes 1 when an arithmetic operation results in 0. Otherwise, it becomes 0.

2.8.4 Sign Flag (S Flag)

The S flag becomes 1 when an arithmetic operation results in a negative value. Otherwise, it becomes 0.

2.8.5 Register Bank Select Flag (B Flag)

Register bank 0 is selected when the B flag is 0. Register bank 1 is selected when this flag is 1.

2.8.6 Overflow Flag (O Flag)

The O flag becomes 1 when an arithmetic operation results in an overflow. Otherwise, it becomes 0.

2.8.7 Interrupt Enable Flag (I Flag)

The I flag enables maskable interrupts.

Maskable interrupts are disabled when the I flag is 0, and enabled when it is 1. The I flag becomes 0 when an interrupt request is accepted.

2.8.8 Stack Pointer Select Flag (U Flag)

ISP is selected when the U flag is 0. USP is selected when the U flag is 1.

The U flag becomes 0 when a hardware interrupt request is accepted, or the INT instruction of software interrupt number 0 to 31 is executed.

2.8.9 Processor Interrupt Priority Level (IPL)

IPL is 3 bits wide and assigns processor interrupt priority levels from 0 to 7.

If a requested interrupt has higher priority than IPL, the interrupt request is enabled.

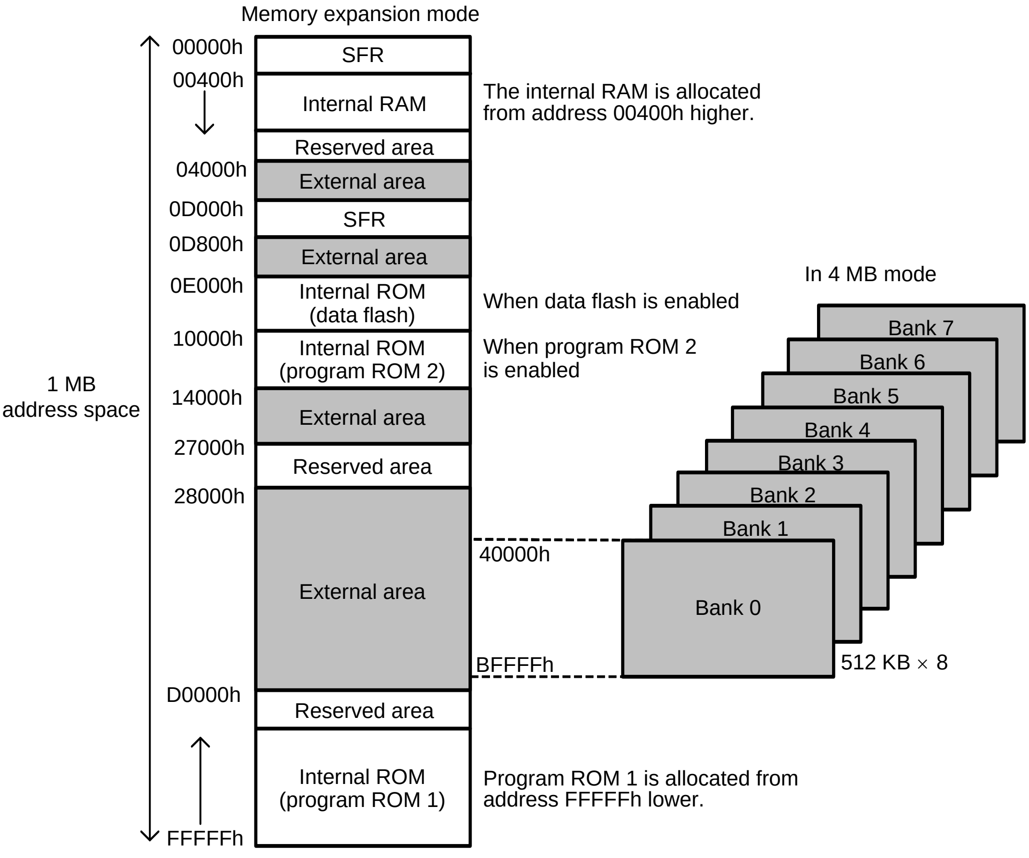
2.8.10 Reserved Areas

Only set these bits to 0. The read value is undefined.

3. Address Space

3.1 Address Space

The M16C/65C Group has a 1 MB address space from 00000h to FFFFFh. Address space is expandable to 4 MB with the memory area expansion function. Addresses 40000h to BFFFFh can be used as external areas from bank 0 to bank 7. Figure 3.1 shows the Address Space. Areas that can be accessed vary depending on processor mode and the status of each control bit.



Notes:

1. Do not access reserved areas.
2. The figure above applies under the following condition:
   - The PM13 bit in the PM1 register is 0
     (addresses 04000h to 0CFFFh and 80000h to CFFFFh are used as external areas)

Figure 3.1 Address Space

3.2 Memory Map

Special function registers (SFRs) are allocated from address 00000h to 003FFh and from 0D000h to 0D7FFh. Peripheral function control registers are located here. All blank areas within SFRs are reserved. Do not access these areas.

Internal RAM is allocated from address 00400h and higher, with 10 KB of internal RAM allocated from 00400h to 02BFFh. Internal RAM is used not only for data storage, but also for the stack area when subroutines are called or when an interrupt request is accepted.

The internal ROM is flash memory. Three internal ROM areas are available: data flash, program ROM 1, and program ROM 2.

The data flash is allocated from 0E000h to 0FFFFh. This data flash area is mostly used for data storage, but can also store programs.

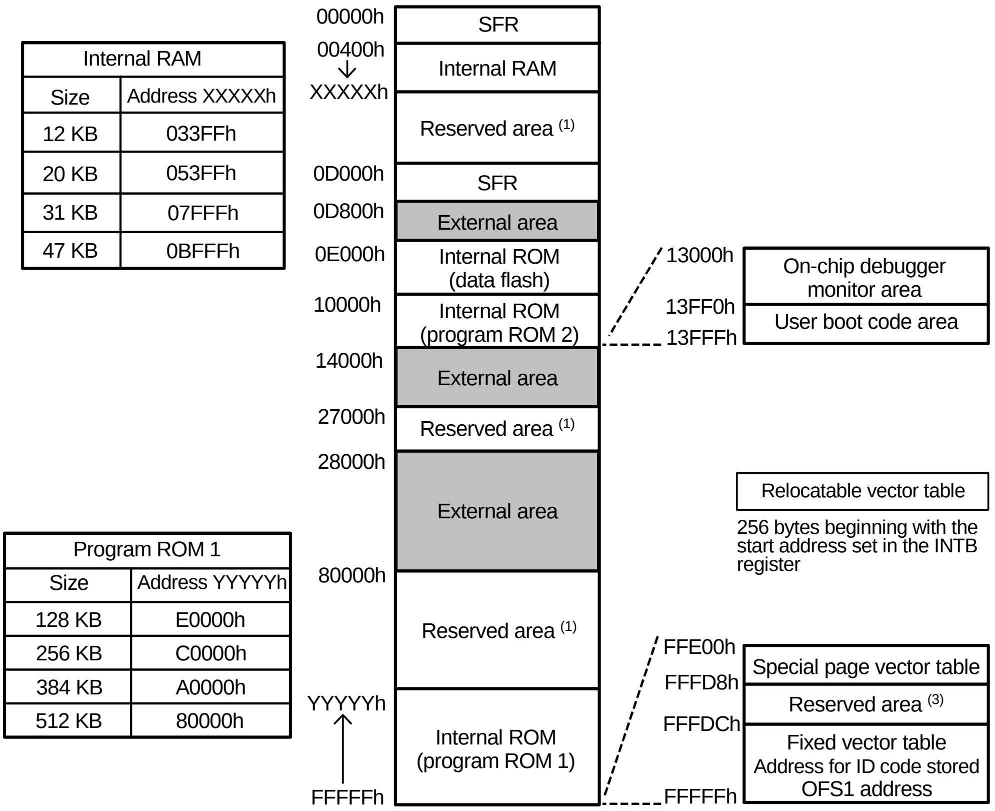
Program ROM 2 is allocated from 10000h to 13FFFh. Program ROM 1 is allocated from FFFFFh and lower, with the 64 KB program ROM 1 area allocated from address F0000h to FFFFFh.

The special page vectors are allocated from FFE00h to FFFD7h. They are used for the JMPS and JSRS instructions. Refer to the M16C/60, M16C/20, M16C/Tiny Series Software Manual for details.

The fixed vector table for interrupts is allocated from FFFDCh to FFFFFh.

The 256 bytes beginning with the start address set in the INTB register compose the relocatable vector table for interrupts.

Figure 3.2 shows the Memory Map.



Internal RAM	
Size	Address XXXXXh
12 KB	033FFh
20 KB	053FFh
31 KB	07FFFh
47 KB	0BFFFh

Program ROM 1	
Size	Address YYYYYh
128 KB	E0000h
256 KB	C0000h
384 KB	A0000h
512 KB	80000h

Notes:
1. Do not access reserved areas.
2. The figure above applies under the following conditions:
   - Memory expansion mode
   - The PM10 bit in the PM1 register is 1 (addresses 0E000h to 0FFFFh are used as data flash)
   - The PRG2C0 bit in the PRG2C register is 0 (program ROM 2 enabled)
   - The PM13 bit in the PM1 register is 1 (all areas in internal RAM, and the program ROM 1 area from 80000h are usable)
3. Do not change the data from FFh.

Figure 3.2 Memory Map

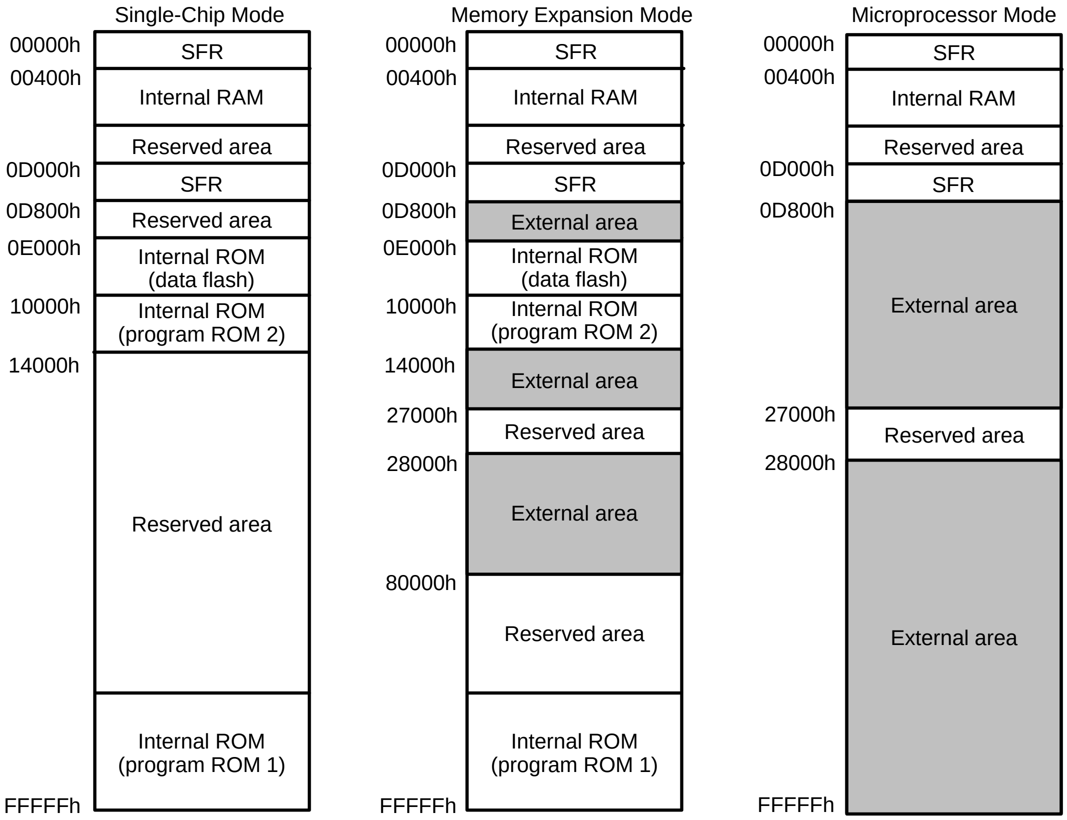
3.3 Accessible Area in Each Mode

Areas that can be accessed vary depending on processor mode and the status of each control bit. Figure 3.3 shows the Accessible Area in Each Mode.

In single-chip mode, the SFRs, internal RAM, and internal ROM can be accessed.

In memory expansion mode, the SFRs, internal RAM, internal ROM, and external areas can be accessed. Address space is expandable to 4 MB with the memory area expansion function.

In microprocessor mode, the SFRs, internal RAM, and external areas can be accessed. Address space is expandable to 4 MB with the memory area expansion function. Allocate ROM to the fixed vector table from FFFDCh to FFFFFh.



Notes:

1. Do not access reserved areas.
2. The figure above applies under the following conditions:
   Single-chip mode and memory expansion mode
   - The PM10 bit in the PM1 register is 1
     (addresses 0E000h to 0FFFFh are used as data flash)
   - The PRG2C0 bit in the PRG2C register is 0 (program ROM 2 enabled)
   - The PM13 bit in the PM1 register is 1
     (all areas in internal RAM, and the program ROM 1 area from 80000h are usable)

   Microprocessor mode
   - The PM10 bit is 0 (addresses 0E000h to 0FFFFh are used as the $\overline{\text{CS2}}$ area)
   - The PRG2C0 bit is 1 (program ROM 2 disabled)

Figure 3.3 Accessible Area in Each Mode

4. Special Function Registers (SFRs)

4.1 SFRs

An SFR is a control register for a peripheral function.

Table 4.1 SFR Information (1) [1]

Address	Register	Symbol	Reset Value
0000h			
0001h			
0002h			
0003h			
0004h	Processor Mode Register 0	PM0	0000 0000b (CNVSS pin is low) 0000 0011b (CNVSS pin is high) [2]
0005h	Processor Mode Register 1	PM1	0000 1000b
0006h	System Clock Control Register 0	CM0	0100 1000b
0007h	System Clock Control Register 1	CM1	0010 0000b
0008h	Chip Select Control Register	CSR	01h
0009h	External Area Recovery Cycle Control Register	EWR	XXXX XX00b
000Ah	Protect Register	PRCR	00h
000Bh	Data Bank Register	DBR	00h
000Ch	Oscillation Stop Detection Register	CM2	0X00 0010b [3]
000Dh			
000Eh			
000Fh			
0010h	Program 2 Area Control Register	PRG2C	XXXX XX00b
0011h	External Area Wait Control Expansion Register	EWC	00h
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
0013h			
0014h			
0015h	Clock Prescaler Reset Flag	CPSRF	0XXX XXXXb
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
0017h			
0018h	Reset Source Determine Register	RSTFR	XX00 001Xb (hardware reset) [4]
0019h	Voltage Detector 2 Flag Register	VCR1	0000 1000b [5]
001Ah	Voltage Detector Operation Enable Register	VCR2	00h [5]
001Bh	Chip Select Expansion Control Register	CSE	00h
001Ch	PLL Control Register 0	PLC0	0X01 X010b
001Dh			
001Eh	Processor Mode Register 2	PM2	XX00 0X01b
001Fh			

X: Undefined

Notes:
1. The blank areas are reserved. No access is allowed.
2. Software reset, watchdog timer reset, oscillator stop detect reset, voltage monitor 1 reset, and voltage monitor 2 reset do not affect the following bits: bits PM01 and PM00 in the PM0 register.
3. Oscillator stop detect reset does not affect bits CM20, CM21, and CM27.
4. The state of bits in the RSTFR register depends on the reset type.
5. This is the reset value after hardware reset. Refer to the explanation of each register for details.

Table 4.2 SFR Information (2) [1]

Address	Register	Symbol	Reset Value
0020h			
0021h			
0022h	40 MHz On-Chip Oscillator Control Register 0	FRA0	XXXX XX00b
0023h			
0024h			
0025h			
0026h	Voltage Monitor Function Select Register	VWCE	00h
0027h			
0028h	Voltage Detector 1 Level Select Register	VD1LS	0000 1010b[2]
0029h			
002Ah	Voltage Monitor 0 Control Register	VW0C	1000 XX10b [2]
002Bh	Voltage Monitor 1 Control Register	VW1C	1000 1010b [2]
002Ch	Voltage Monitor 2 Control Register	VW2C	1000 0X10b [2]
002Dh			
002Eh			
002Fh			
0030h			
0031h			
0032h			
0033h			
0034h			
0035h			
0036h			
0037h			
0038h			
0039h			
003Ah			
003Bh			
003Ch			
003Dh			
003Eh			
003Fh			

X: Undefined

Notes:

1. The blank areas are reserved. No access is allowed.
2. This is the reset value after hardware reset. Refer to the explanation of each register for details.

Table 4.3 SFR Information (3) (1)

Address	Register	Symbol	Reset Value
0040h			
0041h			
0042h	$\overline{\text{INT7}}$ Interrupt Control Register	INT7IC	XX00 X000b
0043h	$\overline{\text{INT6}}$ Interrupt Control Register	INT6IC	XX00 X000b
0044h	$\overline{\text{INT3}}$ Interrupt Control Register	INT3IC	XX00 X000b
0045h	Timer B5 Interrupt Control Register	TB5IC	XXXX X000b
0046h	Timer B4 Interrupt Control Register UART1 Bus Collision Detection Interrupt Control Register	TB4IC U1BCNIC	XXXX X000b
0047h	Timer B3 Interrupt Control Register UART0 Bus Collision Detection Interrupt Control Register	TB3IC U0BCNIC	XXXX X000b
0048h	SI/O4 Interrupt Control Register $\overline{\text{INT5}}$ Interrupt Control Register	S4IC INT5IC	XX00 X000b
0049h	SI/O3 Interrupt Control Register $\overline{\text{INT4}}$ Interrupt Control Register	S3IC INT4IC	XX00 X000b
004Ah	UART2 Bus Collision Detection Interrupt Control Register	BCNIC	XXXX X000b
004Bh	DMA0 Interrupt Control Register	DM0IC	XXXX X000b
004Ch	DMA1 Interrupt Control Register	DM1IC	XXXX X000b
004Dh	Key Input Interrupt Control Register	KUPIC	XXXX X000b
004Eh	A/D Conversion Interrupt Control Register	ADIC	XXXX X000b
004Fh	UART2 Transmit Interrupt Control Register	S2TIC	XXXX X000b
0050h	UART2 Receive Interrupt Control Register	S2RIC	XXXX X000b
0051h	UART0 Transmit Interrupt Control Register	S0TIC	XXXX X000b
0052h	UART0 Receive Interrupt Control Register	S0RIC	XXXX X000b
0053h	UART1 Transmit Interrupt Control Register	S1TIC	XXXX X000b
0054h	UART1 Receive Interrupt Control Register	S1RIC	XXXX X000b
0055h	Timer A0 Interrupt Control Register	TA0IC	XXXX X000b
0056h	Timer A1 Interrupt Control Register	TA1IC	XXXX X000b
0057h	Timer A2 Interrupt Control Register	TA2IC	XXXX X000b
0058h	Timer A3 Interrupt Control Register	TA3IC	XXXX X000b
0059h	Timer A4 Interrupt Control Register	TA4IC	XXXX X000b
005Ah	Timer B0 Interrupt Control Register	TB0IC	XXXX X000b
005Bh	Timer B1 Interrupt Control Register	TB1IC	XXXX X000b
005Ch	Timer B2 Interrupt Control Register	TB2IC	XXXX X000b
005Dh	$\overline{\text{INT0}}$ Interrupt Control Register	INT0IC	XX00 X000b
005Eh	$\overline{\text{INT1}}$ Interrupt Control Register	INT1IC	XX00 X000b
005Fh	$\overline{\text{INT2}}$ Interrupt Control Register	INT2IC	XX00 X000b

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.4 SFR Information (4) [1]

Address	Register	Symbol	Reset Value
0060h			
0061h			
0062h			
0063h			
0064h			
0065h			
0066h			
0067h			
0068h			
0069h	DMA2 Interrupt Control Register	DM2IC	XXXX X000b
006Ah	DMA3 Interrupt Control Register	DM3IC	XXXX X000b
006Bh	UART5 Bus Collision Detection Interrupt Control Register CEC1 Interrupt Control Register	U5BCNIC CEC1IC	XXXX X000b
006Ch	UART5 Transmit Interrupt Control Register CEC2 Interrupt Control Register	S5TIC CEC2IC	XXXX X000b
006Dh	UART5 Receive Interrupt Control Register	S5RIC	XXXX X000b
006Eh	UART6 Bus Collision Detection Interrupt Control Register Real-Time Clock Periodic Interrupt Control Register	U6BCNIC RTCTIC	XXXX X000b
006Fh	UART6 Transmit Interrupt Control Register Real-Time Clock Compare Interrupt Control Register	S6TIC RTCCIC	XXXX X000b
0070h	UART6 Receive Interrupt Control Register	S6RIC	XXXX X000b
0071h	UART7 Bus Collision Detection Interrupt Control Register Remote Control Signal Receiver 0 Interrupt Control Register	U7BCNIC PMC0IC	XXXX X000b
0072h	UART7 Transmit Interrupt Control Register Remote Control Signal Receiver 1 Interrupt Control Register	S7TIC PMC1IC	XXXX X000b
0073h	UART7 Receive Interrupt Control Register	S7RIC	XXXX X000b
0074h			
0075h			
0076h			
0077h			
0078h			
0079h			
007Ah			
007Bh	I2C-bus Interface Interrupt Control Register	IICIC	XXXX X000b
007Ch	SCL/SDA Interrupt Control Register	SCLDAIC	XXXX X000b
007Dh			
007Eh			
007Fh			
0080h to 017Fh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.5 SFR Information (5) [1]

Address	Register	Symbol	Reset Value
0180h	DMA0 Source Pointer	SAR0	XXh
0181h			XXh
0182h			0Xh
0183h			
0184h	DMA0 Destination Pointer	DAR0	XXh
0185h			XXh
0186h			0Xh
0187h			
0188h	DMA0 Transfer Counter	TCR0	XXh
0189h			XXh
018Ah			
018Bh			
018Ch	DMA0 Control Register	DM0CON	0000 0X00b
018Dh			
018Eh			
018Fh			
0190h	DMA1 Source Pointer	SAR1	XXh
0191h			XXh
0192h			0Xh
0193h			
0194h	DMA1 Destination Pointer	DAR1	XXh
0195h			XXh
0196h			0Xh
0197h			
0198h	DMA1 Transfer Counter	TCR1	XXh
0199h			XXh
019Ah			
019Bh			
019Ch	DMA1 Control Register	DM1CON	0000 0X00b
019Dh			
019Eh			
019Fh			
01A0h	DMA2 Source Pointer	SAR2	XXh
01A1h			XXh
01A2h			0Xh
01A3h			
01A4h	DMA2 Destination Pointer	DAR2	XXh
01A5h			XXh
01A6h			0Xh
01A7h			
01A8h	DMA2 Transfer Counter	TCR2	XXh
01A9h			XXh
01AAh			
01ABh			
01ACh	DMA2 Control Register	DM2CON	0000 0X00b
01ADh			
01AEh			
01AFh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.6 SFR Information (6) [1]

Address	Register	Symbol	Reset Value
01B0h	DMA3 Source Pointer	SAR3	XXh
01B1h			XXh
01B2h			0Xh
01B3h			
01B4h	DMA3 Destination Pointer	DAR3	XXh
01B5h			XXh
01B6h			0Xh
01B7h			
01B8h	DMA3 Transfer Counter	TCR3	XXh
01B9h			XXh
01BAh			
01BBh			
01BCh	DMA3 Control Register	DM3CON	0000 0X00b
01BDh			
01BEh			
01BFh			
01C0h	Timer B0-1 Register	TB01	XXh
01C1h			XXh
01C2h	Timer B1-1 Register	TB11	XXh
01C3h			XXh
01C4h	Timer B2-1 Register	TB21	XXh
01C5h			XXh
01C6h	Pulse Period/Pulse Width Measurement Mode Function Select Register 1	PPWFS1	XXXX X000b
01C7h			
01C8h	Timer B Count Source Select Register 0	TBCS0	00h
01C9h	Timer B Count Source Select Register 1	TBCS1	X0h
01CAh			
01CBh	Timer AB Division Control Register 0	TCKDIVC0	0000 X000b
01CCh			
01CDh			
01CEh			
01CFh			
01D0h	Timer A Count Source Select Register 0	TACS0	00h
01D1h	Timer A Count Source Select Register 1	TACS1	00h
01D2h	Timer A Count Source Select Register 2	TACS2	X0h
01D3h			
01D4h	16-bit Pulse Width Modulation Mode Function Select Register	PWMFS	0XX0 X00Xb
01D5h	Timer A Waveform Output Function Select Register	TAPOFS	XXX0 0000b
01D6h			
01D7h			
01D8h	Timer A Output Waveform Change Enable Register	TAOW	XXX0 X00Xb
01D9h			
01DAh	Three-Phase Protect Control Register	TPRC	00h
01DBh			
01DCh			
01DDh			
01DEh			
01DFh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.7 SFR Information (7) (1)

Address	Register	Symbol	Reset Value
01E0h	Timer B3-1 Register	TB31	XXh
01E1h			XXh
01E2h	Timer B4-1 Register	TB41	XXh
01E3h			XXh
01E4h	Timer B5-1 Register	TB51	XXh
01E5h			XXh
01E6h	Pulse Period/Pulse Width Measurement Mode Function Select Register 2	PPWFS2	XXXX X000b
01E7h			
01E8h	Timer B Count Source Select Register 2	TBCS2	00h
01E9h	Timer B Count Source Select Register 3	TBCS3	X0h
01EAh			
01EBh			
01ECh			
01EDh			
01EEh			
01EFh			
01F0h	PMC0 Function Select Register 0	PMC0CON0	00h
01F1h	PMC0 Function Select Register 1	PMC0CON1	00XX 0000b
01F2h	PMC0 Function Select Register 2	PMC0CON2	0000 00X0b
01F3h	PMC0 Function Select Register 3	PMC0CON3	00h
01F4h	PMC0 Status Register	PMC0STS	00h
01F5h	PMC0 Interrupt Source Select Register	PMC0INT	00h
01F6h	PMC0 Compare Control Register	PMC0CPC	XXX0 X000b
01F7h	PMC0 Compare Data Register	PMC0CPD	00h
01F8h	PMC1 Function Select Register 0	PMC1CON0	XXX0 X000b
01F9h	PMC1 Function Select Register 1	PMC1CON1	XXXX 0X00b
01FAh	PMC1 Function Select Register 2	PMC1CON2	0000 00X0b
01FBh	PMC1 Function Select Register 3	PMC1CON3	00h
01FCh	PMC1 Status Register	PMC1STS	X000 X00Xb
01FDh	PMC1 Interrupt Source Select Register	PMC1INT	X000 X00Xb
01FEh			
01FFh			
0200h			
0201h			
0202h			
0203h			
0204h			
0205h	Interrupt Source Select Register 3	IFSR3A	00h
0206h	Interrupt Source Select Register 2	IFSR2A	00h
0207h	Interrupt Source Select Register	IFSR	00h
0208h			
0209h			
020Ah			
020Bh			
020Ch			
020Dh			
020Eh	Address Match Interrupt Enable Register	AIER	XXXX XX00b
020Fh	Address Match Interrupt Enable Register 2	AIER2	XXXX XX00b

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.8 SFR Information (8) [1]

Address	Register	Symbol	Reset Value
0210h	Address Match Interrupt Register 0	RMAD0	00h
0211h			00h
0212h			X0h
0213h			
0214h	Address Match Interrupt Register 1	RMAD1	00h
0215h			00h
0216h			X0h
0217h			
0218h	Address Match Interrupt Register 2	RMAD2	00h
0219h			00h
021Ah			X0h
021Bh			
021Ch	Address Match Interrupt Register 3	RMAD3	00h
021Dh			00h
021Eh			X0h
021Fh			
0220h	Flash Memory Control Register 0	FMR0	0000 0001b (Other than user boot mode) 0010 0001b (User boot mode)
0221h	Flash Memory Control Register 1	FMR1	00X0 XX0Xb
0222h	Flash Memory Control Register 2	FMR2	XXXX 0000b
0223h	Flash Memory Control Register 3	FMR3	XXXX 0000b
0224h			
0225h			
0226h			
0227h			
0228h			
0229h			
022Ah			
022Bh			
022Ch			
022Dh			
022Eh			
022Fh			
0230h	Flash Memory Control Register 6	FMR6	XX0X XX00b
0231h			
0232h			
0233h			
0234h			
0235h			
0236h			
0237h			
0238h			
0239h			
023Ah			
023Bh			
023Ch			
023Dh			
023Eh			
023Fh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.9 **SFR Information (9)** [1]

Address	Register	Symbol	Reset Value
0240h			
0241h			
0242h			
0243h			
0244h	UART0 Special Mode Register 4	U0SMR4	00h
0245h	UART0 Special Mode Register 3	U0SMR3	000X 0X0Xb
0246h	UART0 Special Mode Register 2	U0SMR2	X000 0000b
0247h	UART0 Special Mode Register	U0SMR	X000 0000b
0248h	UART0 Transmit/Receive Mode Register	U0MR	00h
0249h	UART0 Bit Rate Register	U0BRG	XXh
024Ah	UART0 Transmit Buffer Register	U0TB	XXh
024Bh			XXh
024Ch	UART0 Transmit/Receive Control Register 0	U0C0	0000 1000b
024Dh	UART0 Transmit/Receive Control Register 1	U0C1	00XX 0010b
024Eh	UART0 Receive Buffer Register	U0RB	XXh
024Fh			XXh
0250h	UART Transmit/Receive Control Register 2	UCON	X000 0000b
0251h			
0252h	UART Clock Select Register	UCLKSEL0	X0h
0253h			
0254h	UART1 Special Mode Register 4	U1SMR4	00h
0255h	UART1 Special Mode Register 3	U1SMR3	000X 0X0Xb
0256h	UART1 Special Mode Register 2	U1SMR2	X000 0000b
0257h	UART1 Special Mode Register	U1SMR	X000 0000b
0258h	UART1 Transmit/Receive Mode Register	U1MR	00h
0259h	UART1 Bit Rate Register	U1BRG	XXh
025Ah	UART1 Transmit Buffer Register	U1TB	XXh
025Bh			XXh
025Ch	UART1 Transmit/Receive Control Register 0	U1C0	0000 1000b
025Dh	UART1 Transmit/Receive Control Register 1	U1C1	00XX 0010b
025Eh	UART1 Receive Buffer Register	U1RB	XXh
025Fh			XXh
0260h			
0261h			
0262h			
0263h			
0264h	UART2 Special Mode Register 4	U2SMR4	00h
0265h	UART2 Special Mode Register 3	U2SMR3	000X 0X0Xb
0266h	UART2 Special Mode Register 2	U2SMR2	X000 0000b
0267h	UART2 Special Mode Register	U2SMR	X000 0000b
0268h	UART2 Transmit/Receive Mode Register	U2MR	00h
0269h	UART2 Bit Rate Register	U2BRG	XXh
026Ah	UART2 Transmit Buffer Register	U2TB	XXh
026Bh			XXh
026Ch	UART2 Transmit/Receive Control Register 0	U2C0	0000 1000b
026Dh	UART2 Transmit/Receive Control Register 1	U2C1	0000 0010b
026Eh	UART2 Receive Buffer Register	U2RB	XXh
026Fh			XXh

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.10 SFR Information (10) (1)

Address	Register	Symbol	Reset Value
0270h	SI/O3 Transmit/Receive Register	S3TRR	XXh
0271h			
0272h	SI/O3 Control Register	S3C	0100 0000b
0273h	SI/O3 Bit Rate Register	S3BRG	XXh
0274h	SI/O4 Transmit/Receive Register	S4TRR	XXh
0275h			
0276h	SI/O4 Control Register	S4C	0100 0000b
0277h	SI/O4 Bit Rate Register	S4BRG	XXh
0278h	SI/O3, 4 Control Register 2	S34C2	00XX X0X0b
0279h			
027Ah			
027Bh			
027Ch			
027Dh			
027Eh			
027Fh			
0280h			
0281h			
0282h			
0283h			
0284h	UART5 Special Mode Register 4	U5SMR4	00h
0285h	UART5 Special Mode Register 3	U5SMR3	000X 0X0Xb
0286h	UART5 Special Mode Register 2	U5SMR2	X000 0000b
0287h	UART5 Special Mode Register	U5SMR	X000 0000b
0288h	UART5 Transmit/Receive Mode Register	U5MR	00h
0289h	UART5 Bit Rate Register	U5BRG	XXh
028Ah	UART5 Transmit Buffer Register	U5TB	XXh
028Bh			XXh
028Ch	UART5 Transmit/Receive Control Register 0	U5C0	0000 1000b
028Dh	UART5 Transmit/Receive Control Register 1	U5C1	0000 0010b
028Eh	UART5 Receive Buffer Register	U5RB	XXh
028Fh			XXh
0290h			
0291h			
0292h			
0293h			
0294h	UART6 Special Mode Register 4	U6SMR4	00h
0295h	UART6 Special Mode Register 3	U6SMR3	000X 0X0Xb
0296h	UART6 Special Mode Register 2	U6SMR2	X000 0000b
0297h	UART6 Special Mode Register	U6SMR	X000 0000b
0298h	UART6 Transmit/Receive Mode Register	U6MR	00h
0299h	UART6 Bit Rate Register	U6BRG	XXh
029Ah	UART6 Transmit Buffer Register	U6TB	XXh
029Bh			XXh
029Ch	UART6 Transmit/Receive Control Register 0	U6C0	0000 1000b
029Dh	UART6 Transmit/Receive Control Register 1	U6C1	0000 0010b
029Eh	UART6 Receive Buffer Register	U6RB	XXh
029Fh			XXh

X: Undefined

Note:
1. The blank areas are reserved. No access is allowed.

Table 4.11 SFR Information (11) (1)

Address	Register	Symbol	Reset Value
02A0h			
02A1h			
02A2h			
02A3h			
02A4h	UART7 Special Mode Register 4	U7SMR4	00h
02A5h	UART7 Special Mode Register 3	U7SMR3	000X 0X0Xb
02A6h	UART7 Special Mode Register 2	U7SMR2	X000 0000b
02A7h	UART7 Special Mode Register	U7SMR	X000 0000b
02A8h	UART7 Transmit/Receive Mode Register	U7MR	00h
02A9h	UART7 Bit Rate Register	U7BRG	XXh
02AAh	UART7 Transmit Buffer Register	U7TB	XXh
02ABh			XXh
02ACh	UART7 Transmit/Receive Control Register 0	U7C0	0000 1000b
02ADh	UART7 Transmit/Receive Control Register 1	U7C1	0000 0010b
02AEh	UART7 Receive Buffer Register	U7RB	XXh
02AFh			XXh
02B0h	I2C0 Data Shift Register	S00	XXh
02B1h			
02B2h	I2C0 Address Register 0	S0D0	0000 000Xb
02B3h	I2C0 Control Register 0	S1D0	00h
02B4h	I2C0 Clock Control Register	S20	00h
02B5h	I2C0 Start/Stop Condition Control Register	S2D0	0001 1010b
02B6h	I2C0 Control Register 1	S3D0	0011 0000b
02B7h	I2C0 Control Register 2	S4D0	00h
02B8h	I2C0 Status Register 0	S10	0001 000Xb
02B9h	I2C0 Status Register 1	S11	XXXX X000b
02BAh	I2C0 Address Register 1	S0D1	0000 000Xb
02BBh	I2C0 Address Register 2	S0D2	0000 000Xb
02BCh			
02BDh			
02BEh			
02BFh			
02C0h to 02FFh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.12 SFR Information (12) [1]

Address	Register	Symbol	Reset Value
0300h	Timer B3/B4/B5 Count Start Flag	TBSR	000X XXXXb
0301h			
0302h	Timer A1-1 Register	TA11	XXh
0303h			XXh
0304h	Timer A2-1 Register	TA21	XXh
0305h			XXh
0306h	Timer A4-1 Register	TA41	XXh
0307h			XXh
0308h	Three-Phase PWM Control Register 0	INVC0	00h
0309h	Three-Phase PWM Control Register 1	INVC1	00h
030Ah	Three-Phase Output Buffer Register 0	IDB0	XX11 1111b
030Bh	Three-Phase Output Buffer Register 1	IDB1	XX11 1111b
030Ch	Dead Time Timer	DTT	XXh
030Dh	Timer B2 Interrupt Generation Frequency Set Counter	ICTB2	XXh
030Eh	Position-Data-Retain Function Control Register	PDRF	XXXX 0000b
030Fh			
0310h	Timer B3 Register	TB3	XXh
0311h			XXh
0312h	Timer B4 Register	TB4	XXh
0313h			XXh
0314h	Timer B5 Register	TB5	XXh
0315h			XXh
0316h			
0317h			
0318h	Port Function Control Register	PFCR	0011 1111b
0319h			
031Ah			
031Bh	Timer B3 Mode Register	TB3MR	00XX 0000b
031Ch	Timer B4 Mode Register	TB4MR	00XX 0000b
031Dh	Timer B5 Mode Register	TB5MR	00XX 0000b
031Eh			
031Fh			
0320h	Count Start Flag	TABSR	00h
0321h			
0322h	One-Shot Start Flag	ONSF	00h
0323h	Trigger Select Register	TRGSR	00h
0324h	Increment/Decrement Flag	UDF	00h
0325h			
0326h	Timer A0 Register	TA0	XXh
0327h			XXh
0328h	Timer A1 Register	TA1	XXh
0329h			XXh
032Ah	Timer A2 Register	TA2	XXh
032Bh			XXh
032Ch	Timer A3 Register	TA3	XXh
032Dh			XXh
032Eh	Timer A4 Register	TA4	XXh
032Fh			XXh

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.13 SFR Information (13) (1)

Address	Register	Symbol	Reset Value
0330h	Timer B0 Register	TB0	XXh
0331h			XXh
0332h	Timer B1 Register	TB1	XXh
0333h			XXh
0334h	Timer B2 Register	TB2	XXh
0335h			XXh
0336h	Timer A0 Mode Register	TA0MR	00h
0337h	Timer A1 Mode Register	TA1MR	00h
0338h	Timer A2 Mode Register	TA2MR	00h
0339h	Timer A3 Mode Register	TA3MR	00h
033Ah	Timer A4 Mode Register	TA4MR	00h
033Bh	Timer B0 Mode Register	TB0MR	00XX 0000b
033Ch	Timer B1 Mode Register	TB1MR	00XX 0000b
033Dh	Timer B2 Mode Register	TB2MR	00XX 0000b
033Eh	Timer B2 Special Mode Register	TB2SC	X000 0000b
033Fh			
0340h	Real-Time Clock Second Data Register	RTCSEC	00h
0341h	Real-Time Clock Minute Data Register	RTCMIN	X000 0000b
0342h	Real-Time Clock Hour Data Register	RTCHR	XX00 0000b
0343h	Real-Time Clock Day Data Register	RTCWK	XXXX X000b
0344h	Real-Time Clock Control Register 1	RTCCR1	0000 X00Xb
0345h	Real-Time Clock Control Register 2	RTCCR2	X000 0000b
0346h	Real-Time Clock Count Source Select Register	RTCCSR	XXX0 0000b
0347h			
0348h	Real-Time Clock Second Compare Data Register	RTCCSEC	X000 0000b
0349h	Real-Time Clock Minute Compare Data Register	RTCCMIN	X000 0000b
034Ah	Real-Time Clock Hour Compare Data Register	RTCCHR	X000 0000b
034Bh			
034Ch			
034Dh			
034Eh			
034Fh			
0350h	CEC Function Control Register 1	CECC1	XXXX X000b
0351h	CEC Function Control Register 2	CECC2	00h
0352h	CEC Function Control Register 3	CECC3	XXXX 0000b
0353h	CEC Function Control Register 4	CECC4	00h
0354h	CEC Flag Register	CECFLG	00h
0355h	CEC Interrupt Source Select Register	CISEL	00h
0356h	CEC Transmit Buffer Register 1	CCTB1	00h
0357h	CEC Transmit Buffer Register 2	CCTB2	XXXX XX00b
0358h	CEC Receive Buffer Register 1	CCRB1	00h
0359h	CEC Receive Buffer Register 2	CCRB2	XXXX X000b
035Ah	CEC Receive Follower Address Set Register 1	CRADRI1	00h
035Bh	CEC Receive Follower Address Set Register 2	CRADRI2	00h
035Ch			
035Dh			
035Eh			
035Fh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.14 SFR Information (14) (1)

Address	Register	Symbol	Reset Value
0360h	Pull-Up Control Register 0	PUR0	00h
0361h	Pull-Up Control Register 1	PUR1	0000 0000b (2) 0000 0010b
0362h	Pull-Up Control Register 2	PUR2	00h
0363h	Pull-Up Control Register 3	PUR3	00h
0364h			
0365h			
0366h	Port Control Register	PCR	0000 0XX0b
0367h			
0368h			
0369h	NMI/SD Digital Filter Register	NMIDF	XXXX X000b
036Ah			
036Bh			
036Ch			
036Dh			
036Eh			
036Fh			
0370h	PWM Control Register 0	PWMCON0	00h
0371h			
0372h	PWM0 Prescaler	PWMPRE0	00h
0373h	PWM0 Register	PWMREG0	00h
0374h	PWM1 Prescaler	PWMPRE1	00h
0375h	PWM1 Register	PWMREG1	00h
0376h	PWM Control Register 1	PWMCON1	00h
0377h			
0378h			
0379h			
037Ah			
037Bh			
037Ch	Count Source Protection Mode Register	CSPR	00h (3)
037Dh	Watchdog Timer Refresh Register	WDTR	XXh
037Eh	Watchdog Timer Start Register	WDTS	XXh
037Fh	Watchdog Timer Control Register	WDC	00XX XXXXb
0380h to 038Fh			

X: Undefined

Notes:

1. The blank areas are reserved. No access is allowed.
2. Values after hardware reset, power-on reset, or voltage monitor 0 reset are as follows:
   - 00000000b when a low-level signal is input to the CNVSS pin
   - 00000010b when a high-level signal is input to the CNVSS pin

   Values after voltage monitor 1 reset, voltage monitor 2 reset, software reset, watchdog timer reset, or oscillation stop detect reset are as follows:
   - 00000000b when bits PM01 and PM00 in the PM0 register are 00b (single-chip mode).
   - 00000010b when bits PM01 and PM00 in the PM0 register are 01b (memory expansion mode) or 11b (microprocessor mode).
3. When the CSPROINI bit in the OFS1 address is 0, the reset value is 1000 0000b.

Table 4.15 SFR Information (15) (1)

Address	Register	Symbol	Reset Value
0390h	DMA2 Source Select Register	DM2SL	00h
0391h			
0392h	DMA3 Source Select Register	DM3SL	00h
0393h			
0394h			
0395h			
0396h			
0397h			
0398h	DMA0 Source Select Register	DM0SL	00h
0399h			
039Ah	DMA1 Source Select Register	DM1SL	00h
039Bh			
039Ch			
039Dh			
039Eh			
039Fh			
03A0h			
03A1h			
03A2h	Open-Circuit Detection Assist Function Register	AINRST	XX00 XXXXb
03A3h			
03A4h			
03A5h			
03A6h			
03A7h			
03A8h			
03A9h			
03AAh			
03ABh			
03ACh			
03ADh			
03AEh			
03AFh			
03B0h			
03B1h			
03B2h			
03B3h			
03B4h	SFR Snoop Address Register	CRCSAR	XXXX XXXXb
03B5h			00XX XXXXb
03B6h	CRC Mode Register	CRCMR	0XXX XXX0b
03B7h			
03B8h			
03B9h			
03BAh			
03BBh			
03BCh	CRC Data Register	CRCD	XXh
03BDh			XXh
03BEh	CRC Input Register	CRCIN	XXh
03BFh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.16 **SFR Information (16)** (1)

Address	Register	Symbol	Reset Value
03C0h	A/D Register 0	AD0	XXXX XXXXb
03C1h			0000 00XXb
03C2h	A/D Register 1	AD1	XXXX XXXXb
03C3h			0000 00XXb
03C4h	A/D Register 2	AD2	XXXX XXXXb
03C5h			0000 00XXb
03C6h	A/D Register 3	AD3	XXXX XXXXb
03C7h			0000 00XXb
03C8h	A/D Register 4	AD4	XXXX XXXXb
03C9h			0000 00XXb
03CAh	A/D Register 5	AD5	XXXX XXXXb
03CBh			0000 00XXb
03CCh	A/D Register 6	AD6	XXXX XXXXb
03CDh			0000 00XXb
03CEh	A/D Register 7	AD7	XXXX XXXXb
03CFh			0000 00XXb
03D0h			
03D1h			
03D2h			
03D3h			
03D4h	A/D Control Register 2	ADCON2	0000 X00Xb
03D5h			
03D6h	A/D Control Register 0	ADCON0	0000 0XXXb
03D7h	A/D Control Register 1	ADCON1	0000 X000b
03D8h	D/A0 Register	DA0	00h
03D9h			
03DAh	D/A1 Register	DA1	00h
03DBh			
03DCh	D/A Control Register	DACON	00h
03DDh			
03DEh			
03DFh			
03E0h	Port P0 Register	P0	XXh
03E1h	Port P1 Register	P1	XXh
03E2h	Port P0 Direction Register	PD0	00h
03E3h	Port P1 Direction Register	PD1	00h
03E4h	Port P2 Register	P2	XXh
03E5h	Port P3 Register	P3	XXh
03E6h	Port P2 Direction Register	PD2	00h
03E7h	Port P3 Direction Register	PD3	00h
03E8h	Port P4 Register	P4	XXh
03E9h	Port P5 Register	P5	XXh
03EAh	Port P4 Direction Register	PD4	00h
03EBh	Port P5 Direction Register	PD5	00h
03ECh	Port P6 Register	P6	XXh
03EDh	Port P7 Register	P7	XXh
03EEh	Port P6 Direction Register	PD6	00h
03EFh	Port P7 Direction Register	PD7	00h

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.17 SFR Information (17) [1]

Address	Register	Symbol	Reset Value
03F0h	Port P8 Register	P8	XXh
03F1h	Port P9 Register	P9	XXh
03F2h	Port P8 Direction Register	PD8	00h
03F3h	Port P9 Direction Register	PD9	00h
03F4h	Port P10 Register	P10	XXh
03F5h	Port P11 Register	P11	XXh
03F6h	Port P10 Direction Register	PD10	00h
03F7h	Port P11 Direction Register	PD11	00h
03F8h	Port P12 Register	P12	XXh
03F9h	Port P13 Register	P13	XXh
03FAh	Port P12 Direction Register	PD12	00h
03FBh	Port P13 Direction Register	PD13	00h
03FCh	Port P14 Register	P14	XXh
03FDh			
03FEh	Port P14 Direction Register	PD14	XXXX XX00b
03FFh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

Table 4.18 SFR Information (18) (1)

Address	Register	Symbol	Reset Value
D080h	PMC0 Header Pattern Set Register (Min)	PMC0HDPMIN	0000 0000b
D081h			XXXX X000b
D082h	PMC0 Header Pattern Set Register (Max)	PMC0HDPMAX	0000 0000b
D083h			XXXX X000b
D084h	PMC0 Data 0 Pattern Set Register (Min)	PMC0D0PMIN	00h
D085h	PMC0 Data 0 Pattern Set Register (Max)	PMC0D0PMAX	00h
D086h	PMC0 Data 1 Pattern Set Register (Min)	PMC0D1PMIN	00h
D087h	PMC0 Data 1 Pattern Set Register (Max)	PMC0D1PMAX	00h
D088h	PMC0 Measurements Register	PMC0TIM	00h
D089h			00h
D08Ah			
D08Bh			
D08Ch	PMC0 Receive Data Store Register 0	PMC0DAT0	00h
D08Dh	PMC0 Receive Data Store Register 1	PMC0DAT1	00h
D08Eh	PMC0 Receive Data Store Register 2	PMC0DAT2	00h
D08Fh	PMC0 Receive Data Store Register 3	PMC0DAT3	00h
D090h	PMC0 Receive Data Store Register 4	PMC0DAT4	00h
D091h	PMC0 Receive Data Store Register 5	PMC0DAT5	00h
D092h	PMC0 Receive Bit Count Register	PMC0RBIT	XX00 0000b
D093h			
D094h	PMC1 Header Pattern Set Register (Min)	PMC1HDPMIN	0000 0000b
D095h			XXXX X000b
D096h	PMC1 Header Pattern Set Register (Max)	PMC1HDPMAX	0000 0000b
D097h			XXXX X000b
D098h	PMC1 Data 0 Pattern Set Register (Min)	PMC1D0PMIN	00h
D099h	PMC1 Data 0 Pattern Set Register (Max)	PMC1D0PMAX	00h
D09Ah	PMC1 Data 1 Pattern Set Register (Min)	PMC1D1PMIN	00h
D09Bh	PMC1 Data 1 Pattern Set Register (Max)	PMC1D1PMAX	00h
D09Ch	PMC1 Measurements Register	PMC1TIM	00h
D09Dh			00h
D09Eh			
D09Fh			

X: Undefined

Note:

1. The blank areas are reserved. No access is allowed.

4.2 Notes on SFRs

4.2.1 Register Settings

Table 4.19 lists Registers with Write-Only Bits and registers whose function differs between reading and writing. Set these registers with immediate values. Do not use read-modify-write instructions. When establishing the next value by altering the existing value, write the existing value to the RAM as well as to the register. Transfer the next value to the register after making changes in the RAM.

Read-modify-write instructions can be used when writing to the no register bits.

Table 4.19 Registers with Write-Only Bits

Address	Register	Symbol
0249h	UART0 Bit Rate Register	U0BRG
024Bh to 024Ah	UART0 Transmit Buffer Register	U0TB
0259h	UART1 Bit Rate Register	U1BRG
025Bh to 025Ah	UART1 Transmit Buffer Register	U1TB
0269h	UART2 Bit Rate Register	U2BRG
026Bh to 026Ah	UART2 Transmit Buffer Register	U2TB
0273h	SI/O3 Bit Rate Register	S3BRG
0277h	SI/O4 Bit Rate Register	S4BRG
0289h	UART5 Bit Rate Register	U5BRG
028Bh to 028Ah	UART5 Transmit Buffer Register	U5TB
0299h	UART6 Bit Rate Register	U6BRG
029Bh to 029Ah	UART6 Transmit Buffer Register	U6TB
02A9h	UART7 Bit Rate Register	U7BRG
02ABh to 02AAh	UART7 Transmit Buffer Register	U7TB
02B6h	I2C0 Control Register 1	S3D0
02B8h	I2C0 Status Register 0	S10
0303h to 0302h	Timer A1-1 Register	TA11
0305h to 0304h	Timer A2-1 Register	TA21
0307h to 0306h	Timer A4-1 Register	TA41
030Ah	Three-Phase Output Buffer Register 0	IDB0
030Bh	Three-Phase Output Buffer Register 1	IDB1
030Ch	Dead Time Timer	DTT
030Dh	Timer B2 Interrupt Generation Frequency Set Counter	ICTB2
0327h to 0326h	Timer A0 Register	TA0
0329h to 0328h	Timer A1 Register	TA1
032Bh to 032Ah	Timer A2 Register	TA2
032Dh to 032Ch	Timer A3 Register	TA3
032Fh to 032Eh	Timer A4 Register	TA4
037Dh	Watchdog Timer Refresh Register	WDTR
037Eh	Watchdog Timer Start Register	WDTS

Table 4.20 Read-Modify-Write Instructions

Function	Mnemonic
Transfer	MOV*Dir*
Bit processing	BCLR, BM*Cnd*, BNOT, BSET, BTSTC, and BTSTS
Shifting	ROLC, RORC, ROT, SHA, and SHL
Arithmetic operation	ABS, ADC, ADCF, ADD, DEC, DIV, DIVU, DIVX, EXTS, INC, MUL, MULU, NEG, SBB, and SUB
Decimal operation	DADC, DADD, DSBB, and DSUB
Logical operation	AND, NOT, OR, and XOR
Jump	ADJNZ, SBJNZ

5. Protection

5.1 Introduction

In the event that a program runs out of control, this function protects the important registers so that they will not be rewritten easily.

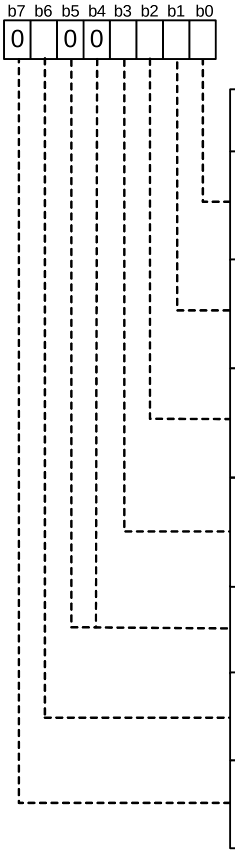
5.2 Register

Table 5.1 Registers

Address	Register	Symbol	Reset Value
000Ah	Protect Register	PRCR	00h

5.2.1 Protect Register (PRCR)

Protect Register



Symbol	Address	After Reset
PRCR	000Ah	00h

Bit Symbol	Bit Name	Function	RW
PRC0	Protect bit 0	Enable writing to registers CM0, CM1, CM2, PLC0, PCLKR, PCLKSTP1, and FRA0 0 : Write protected 1 : Write enabled	RW
PRC1	Protect bit 1	Enable writing to registers PM0, PM1, PM2, TB2SC, INVC0, and INVC1 0 : Write protected 1 : Write enabled	RW
PRC2	Protect bit 2	Enable writing to registers PD9, S3C, and S4C 0 : Write protected 1 : Write enabled	RW
PRC3	Protect bit 3	Enable writing to registers VCR2, VWCE, VD1LS, VW0C, VW1C, and VW2C 0 : Write protected 1 : Write enabled	RW
— (b5-b4)	Reserved bits	Set to 0	RW
PRC6	Protect bit 6	Enable writing to the PRG2C register 0 : Write protected 1 : Write enabled	RW
— (b7)	Reserved bit	Set to 0	RW

PRC6, PRC3, PRC1, PRC0 (Protect bits 6, 3, 1, 0) (b6, b3, b1, b0)

When setting bits PRC6, PRC3, PRC1, and PRC0 to 1 (write enabled), these bits remain 1 (write enabled). To change registers protected by these bits, follow these steps:

(1) Set the PRCi bit to 1. (i = 0, 1, 3, 6)
(2) Write to the register protected by the PRCi bit.
(3) Set the PRCi bit to 0 (write protected).

PRC2 (Protect bit 2) (b2)

After setting the PRC2 bit to 1 (write enabled), by writing to a given SFR, the PRC2 bit becomes 0. Change the registers protected by the PRC2 bit in the next instruction after setting the PRC2 bit to 1. The steps are shown below. Make sure there are no interrupts or DMA transfers between steps (1) and (2).

(1) Set the PRC2 bit to 1.
(2) Write to the register protected by the PRC2 bit.

5.3 Notes on Protection

After setting the PRC2 bit to 1 (write enabled), by writing to a given SFR, the PRC2 bit becomes 0 (write disabled). Change the registers protected by the PRC2 bit in the next instruction after setting the PRC2 bit to 1. Make sure there are no interrupts or DMA transfers between the instruction that sets the PRC2 bit to 1 and the next instruction.

6. Resets

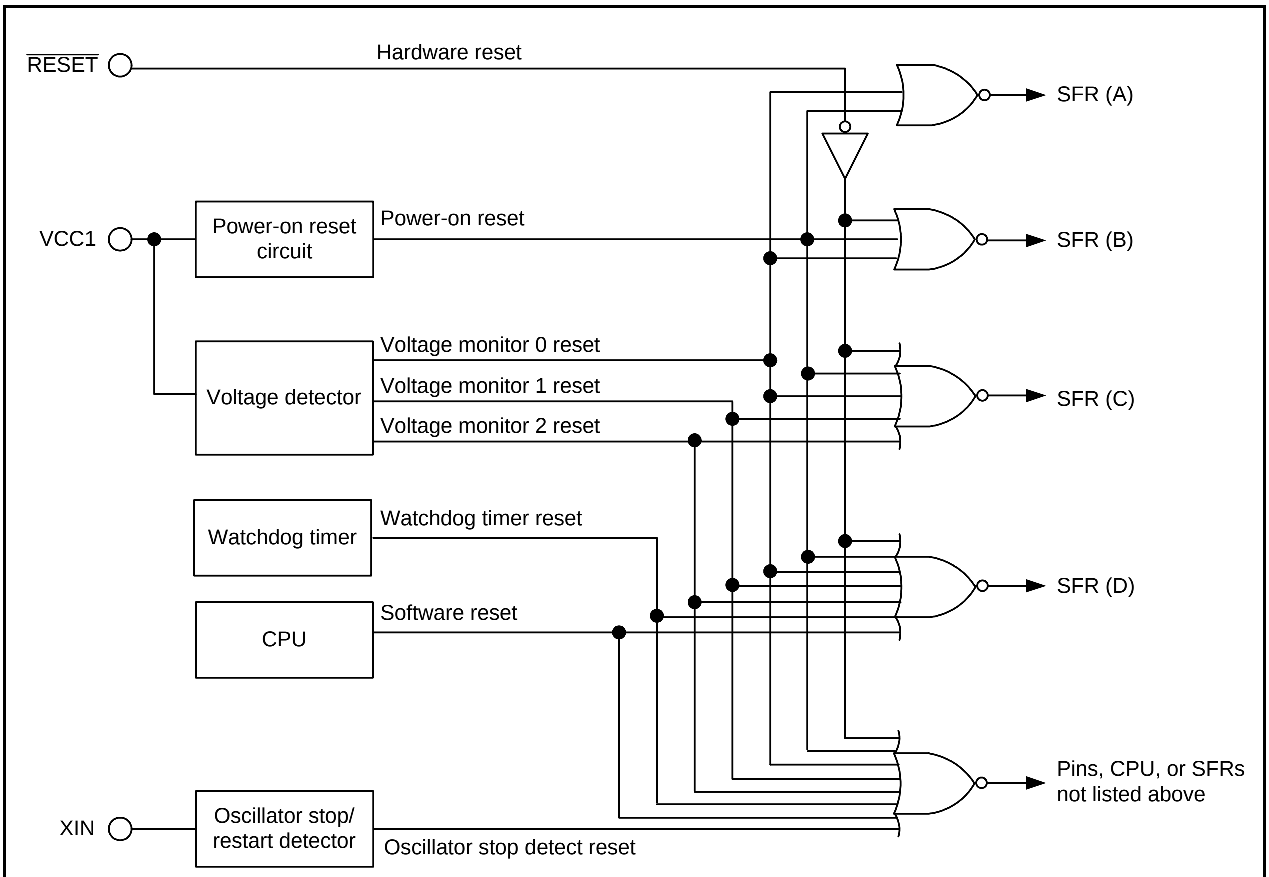
6.1 Introduction

The following resets can be used to reset the MCU: hardware reset, power-on reset, voltage monitor 0 reset, voltage monitor 1 reset, voltage monitor 2 reset, oscillator stop detect reset, watchdog timer reset, and software reset.

Table 6.1 lists the Types of Resets and Figure 6.1 shows the Reset Circuit Block Diagram. Symbols (A) to (D) in the table and figure is explained in Table 6.2. Table 6.3 lists the I/O Pins.

Table 6.1 Types of Resets

Reset Name	Trigger	Registers and Bits Not to Reset
Hardware reset	A low-level signal is applied to the $\overline{\text{RESET}}$ pin.	(A)
Power-on reset	A rise in voltage on VCC1	N/A
Voltage monitor 0 reset	A drop in voltage on VCC1 (reference voltage: Vdet0)	N/A
Voltage monitor 1 reset	A drop in voltage on VCC1 (reference voltage: Vdet1)	(B)
Voltage monitor 2 reset	A drop in voltage on VCC1 (reference voltage: Vdet2)	(B)
Oscillator stop detect reset	A stop in the main clock oscillator is detected.	(B) (C) (D)
Watchdog timer reset	The watchdog timer underflows.	(B) (C)
Software reset	Setting the PM03 bit in the PM0 register to 1.	(B) (C)



For the reset value and status, refer to 4. "Special Function Registers (SFRs)" and 6.4.1 "Status after Reset".

Figure 6.1 Reset Circuit Block Diagram

Table 6.2 **Classification of SFRs Which are Reset**

SFR	Register and Bit
SFR (A)	Bits OSDR and CWR in the RSTFR register
SFR (B)	CWR bit in the RSTFR register Registers VCR1, VCR2, and VW0C Bits VW1C2 and VW1C3 in the VW1C register Bits VW2C2 and VW2C3 in the VW2C register Bits PM00 and PM01 in the PM0 register
SFR (C)	VD1LS register
SFR (D)	Bits CM20, CM21, and CM27 in the CM2 register

Table 6.3 **I/O Pins**

Pin	I/O	Function
$\overline{\text{RESET}}$	Input	Hardware reset input
VCC1	Input	Power input. The power-on reset, voltage monitor 0 reset, voltage monitor 1 reset, and voltage monitor 2 reset are generated by monitoring VCC1.
XIN	Input	Main clock input. The oscillator stop detect reset is generated by monitoring the main clock.

6.2 Registers

Refer to 7. “Voltage Detector” for registers used with the voltage monitor 0 reset, voltage monitor 1 reset, and voltage monitor 2 reset. Refer to 15. “Watchdog Timer” for registers used with the watchdog timer reset. Refer to 8.7 “Oscillator Stop/Restart Detect Function” for registers used with the oscillator stop detect reset.

Table 6.4 Registers

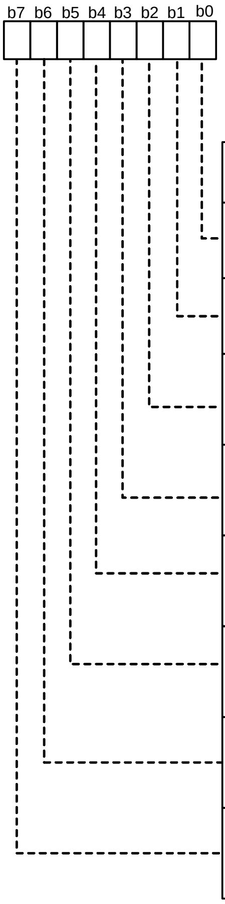
Address	Register	Symbol	Reset Value
0004h	Processor Mode Register 0	PM0	0000 0000b (CNVSS pin is low) 0000 0011b (CNVSS pin is high)
0018h	Reset Source Determine Register	RSTFR	– (1)

Note:

1. Refer to 6.2.2 “Reset Source Determine Register (RSTFR)”

6.2.1 Processor Mode Register 0 (PM0)

Processor Mode Register 0



Symbol	Address	Reset Value
PM0	0004h	0000 0000b (CNVSS pin is low) 0000 0011b (CNVSS pin is high)

Bit Symbol	Bit Name	Function	RW
PM00	Processor mode bit	b1 b0 0 0 : Single-chip mode 0 1 : Memory expansion mode 1 0 : Do not set 1 1 : Microprocessor mode	RW
PM01			RW
PM02	R/W mode select bit	0 : $\overline{RD}$, $\overline{BHE}$, $\overline{WR}$ 1 : $\overline{RD}$, $\overline{WRH}$, $\overline{WRL}$	RW
PM03	Software reset bit	Setting this bit to 1 resets the MCU. When read, the read value is 0.	RW
PM04	Multiplexed bus space select bit	b5 b4 0 0 : Multiplexed bus is not used (separate bus in the entire $\overline{CS}$ space) 0 1 : Allocated to $\overline{CS2}$ space 1 0 : Allocated to $\overline{CS1}$ space 1 1 : Allocated to the entire $\overline{CS}$ space	RW
PM05			RW
PM06	Port P4_0 to P4_3 function select bit	0 : Address output 1 : Port function (address is not output)	RW
PM07	BCLK output disable bit	0 : BCLK is output 1 : BCLK is not output (pin becomes high-impedance)	RW

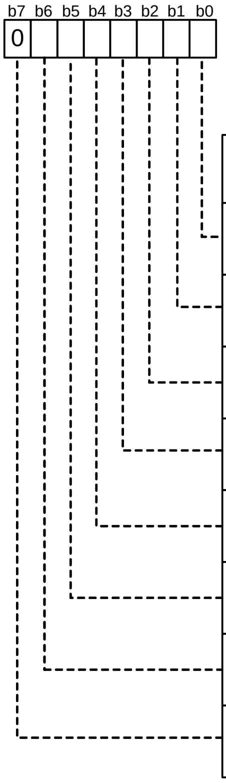
Write to this register after setting the PRC1 bit in the PRCR register to 1 (write enabled).
The software reset, watchdog timer reset, oscillator stop detect reset, voltage monitor 1 reset, and voltage monitor 2 reset have no effect on bits PM01 and PM00.
Bits PM02, PM05 to PM04, PM06, and PM07 are enabled when bits PM01 to PM00 are 01b (memory expansion mode) or 11b (microprocessor mode).

PM03 (Software reset bit) (b3)

A software reset is generated by setting the PM03 bit to 1.

6.2.2 Reset Source Determine Register (RSTFR)

Reset Source Determine Register



Symbol	Address	Reset Value
RSTFR	0018h	See Table 6.5.

Bit Symbol	Bit Name	Function	RW
CWR	Cold start/warm start discrimination flag	0 : Cold start 1 : Warm start	RW
HWR	Hardware reset detection flag	0 : Not detected 1 : Detected	RO
SWR	Software reset detection flag	0 : Not detected 1 : Detected	RO
WDR	Watchdog timer reset detect flag	0 : Not detected 1 : Detected	RO
LVD1R	Voltage monitor 1 reset detection flag	0 : Not detected 1 : Detected	RO
LVD2R	Voltage monitor 2 reset detection flag	0 : Not detected 1 : Detected	RO
OSDR	Oscillator stop detect reset detect flag	0 : Not detected 1 : Detected	RW
— (b7)	Reserved bit	If necessary, set to 0. When read, the read value is undefined.	RW

Table 6.5 RSTFR Register Reset Value

Reset	Bits in the RSTFR Register						
	OSDR	LVD2R	LVD1R	WDR	SWR	HWR	CWR
Hardware reset	No change	0	0	0	0	1	No change
Power-on reset	0	0	0	0	0	0	0
Voltage monitor 0 reset	0	0	0	0	0	0	0
Voltage monitor 1 reset	0	0	1	0	0	0	No change
Voltage monitor 2 reset	0	1	0	0	0	0	No change
Oscillator stop detect reset	1	0	0	0	0	0	No change
Watchdog timer reset	0	0	0	1	0	0	No change
Software reset	0	0	0	0	1	0	No change

CWR (Cold/warm start discrimination flag) (b0)

The CWR bit also changes when the either of following condition is met:

Condition to become 0:

- Power-on

Condition to become 1:

- Setting this bit to 1

OSDR (Oscillator stop detect reset detect flag) (b6)

The OSDR bit also changes when either of following condition is met:

Conditions to become 0:

- Power-on
- Setting this bit to 0

This bit will not become 1 even when written to 1.

6.3 Optional Function Select Area

In the optional function select area, the MCU state after reset and the function to prevent rewrite in parallel I/O mode are selected.

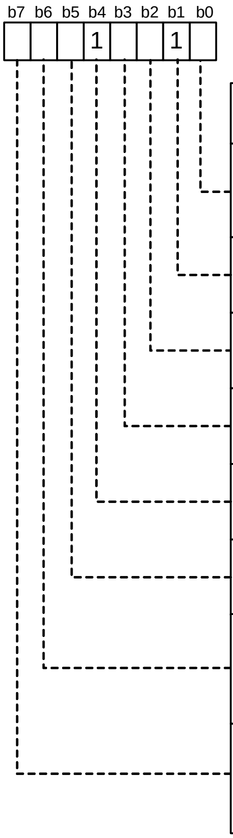
The optional function select area is not an SFR, and therefore cannot be rewritten by a program. Set an appropriate value when writing a program to flash memory. The entire optional function select area becomes FFh when the block including the optional function select area is erased.

In blank products, the OFS1 address value is FFh when shipped. After a value is written by the user, this address takes on the written value. In programmed products, the OFS1 address is the value set in the user program prior to shipping.

Selection using the optional function select area can be used in single-chip mode or memory expansion mode. The option function select area cannot be used in microprocessor mode. Clear the internal ROM before using the MCU in microprocessor mode.

6.3.1 Optional Function Select Address 1 (OFS1)

Optional Function Select Address 1



Symbol OFS1

Address FFFFFh

Bit Symbol	Bit Name	Function
WDTON	Watchdog timer start select bit	0 : Watchdog timer starts automatically after reset 1 : Watchdog timer is stopped after reset
— (b1)	Reserved bit	Set to 1.
ROMCR	ROM code protect cancel bit	0 : ROM code protection cancelled 1 : ROMCP1 bit enabled
ROMCP1	ROM code protect bit	0 : ROM code protection enabled 1 : ROM code protection disabled
— (b4)	Reserved bit	Set to 1.
VDSEL1	Vdet0 select bit 1	0 : Vdet0_2 1 : Vdet0_0
LVDAS	Voltage detector 0 start bit	0 : Voltage monitor 0 reset enabled after hardware reset 1 : Voltage monitor 0 reset disabled after hardware reset
CSPROINI	After-reset count source protection mode select bit	0 : Count source protection mode enabled after reset 1 : Count source protection mode disabled after reset

WDTON (Watchdog timer start select bit) (b0)
CSPROINI (After-reset count source protection mode select bit) (b7)

These bits select the state of the watchdog timer after reset.

Set the WDTON bit to 0 (watchdog timer starts automatically after reset) when setting the CSPROINI bit to 0 (count source protection mode enabled after reset).

Refer to 15. “Watchdog Timer” for details on the watchdog timer and count source protection mode.

ROMCR (ROM code protect cancel bit) (b2)
ROMCP1 (ROM code protect bit) (b3)

These bits prevent the flash memory from being read or changed in parallel I/O mode.

Table 6.6 ROM Code Protection

Bit Setting		ROM Code Protection
ROMCR bit	ROMCP1 bit	
0	0	Cancelled
0	1	
1	0	Enabled
1	1	Cancelled

VDSEL1 (Vdet0 select bit 1) (b5)

Set this bit to 0 (Vdet0_2) when using the power-on reset or voltage monitor 0 reset. Refer to 6.4.10 “Cold/Warm Start Discrimination”.

This bit is enabled in single-chip mode, while disabled in boot mode.

LVDAS (Voltage detector 0 start bit) (b6)

Set this bit to 0 (voltage monitor 0 reset enabled after hardware reset) when using the power-on reset.

This bit is enabled in single-chip mode, while disabled in boot mode.

6.4 Operations

6.4.1 Status after Reset

The status of SFRs after reset depends on the reset type. See the Reset Value column in 4. “Special Function Registers (SFRs)”. Table 6.7 lists Pin Status When $\overline{\mathrm{RESET}}$ Pin Level is Low, Figure 6.2 shows CPU Register Status after Reset, and Figure 6.3 shows Reset Sequence.

Table 6.7 Pin Status When $\overline{\mathrm{RESET}}$ Pin Level is Low

Pin Name	Status (1)			
	Single-chip mode (CNVSS = VSS)	Microprocessor mode (CNVSS = VCC1, P5_5 = high)		Boot mode (CNVSS = VCC1, P5_5 = low, P5_0 = high)
		BYTE = VSS	BYTE = VCC1	
P0	Input port	Data input	Data input	Input port
P1	Input port	Data input	Input port	Input port
P2, P3, P4_0 to P4_3	Input port	Address output (undefined)	Address output (undefined)	Input port
P4_4	Input port	$\overline{\mathrm{CS0}}$ output (high level is output)	$\overline{\mathrm{CS0}}$ output (high level is output)	Input port
P4_5 to P4_7	Input port	Input port (pulled high)	Input port (pulled high)	Input port
P5_0	Input port	$\overline{\mathrm{WR}}$ output (high level is output)	$\overline{\mathrm{WR}}$ output (high level is output)	$\overline{\mathrm{CE}}$ input (2)
P5_1	Input port	$\overline{\mathrm{BHE}}$ output (undefined)	$\overline{\mathrm{BHE}}$ output (undefined)	Input port
P5_2	Input port	$\overline{\mathrm{RD}}$ output (high level is output)	$\overline{\mathrm{RD}}$ output (high level is output)	Input port
P5_3	Input port	BCLK output	BCLK output	Input port
P5_4	Input port	$\overline{\mathrm{HLDA}}$ output (the output value depends on the input to the $\overline{\mathrm{HOLD}}$ pin)	$\overline{\mathrm{HLDA}}$ output (the output value depends on the input to the $\overline{\mathrm{HOLD}}$ pin)	Input port
P5_5	Input port	$\overline{\mathrm{HOLD}}$ input (2)	$\overline{\mathrm{HOLD}}$ input (2)	$\overline{\mathrm{EPM}}$ input (3)
P5_6	Input port	ALE output (low level is output)	ALE output (low level is output)	Input port
P5_7	Input port	$\overline{\mathrm{RDY}}$ input	$\overline{\mathrm{RDY}}$ input	Input port
P6 to P14	Input port	Input port	Input port	Input port

Notes:

1. The pin status shown here is when the internal power supply voltage has stabilized after power-on. The pin status is undefined until td(P-R) has elapsed after power-on.
2. Input a high-level signal.
3. Input a low-level signal.

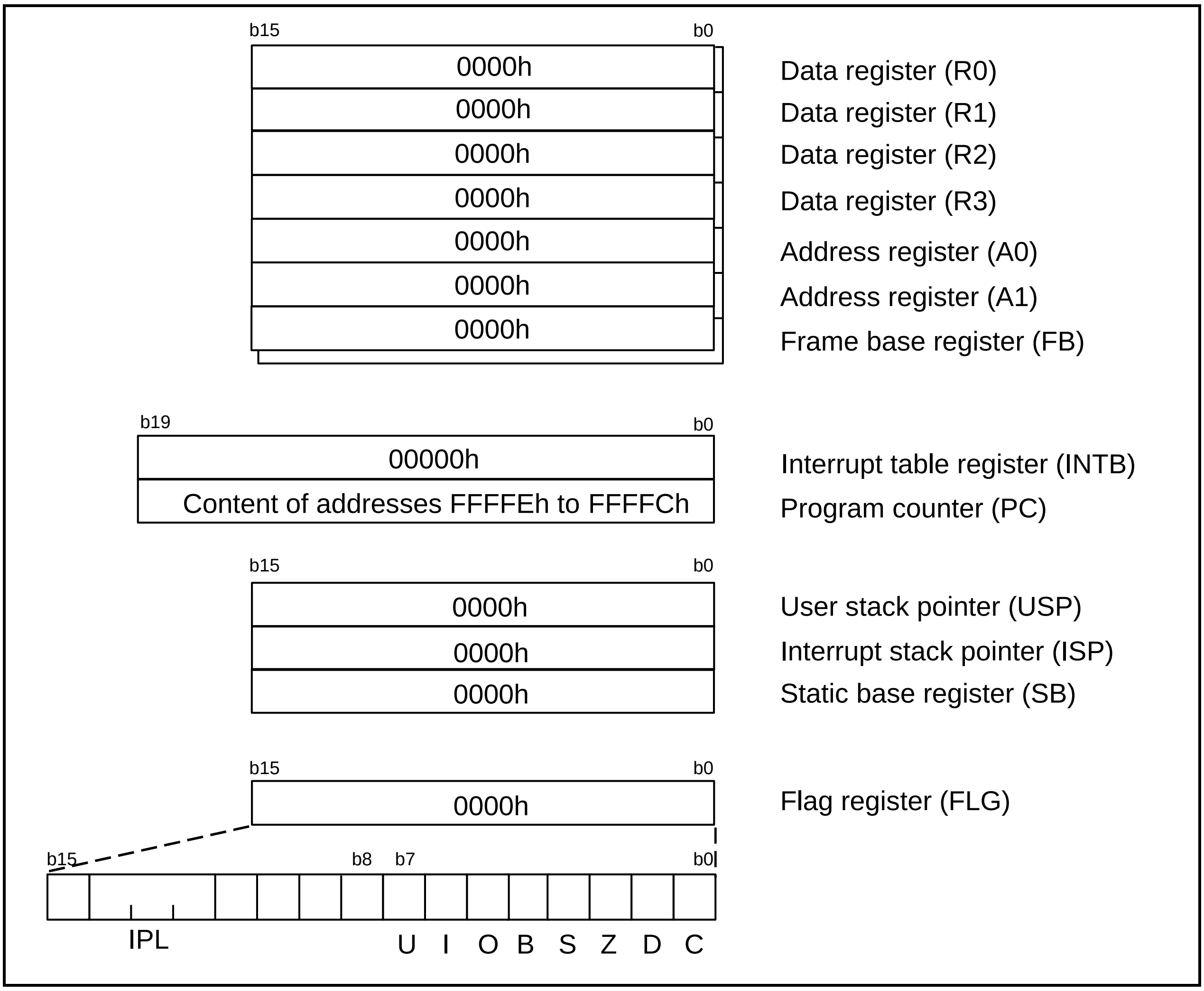


Figure 6.2 CPU Register Status after Reset

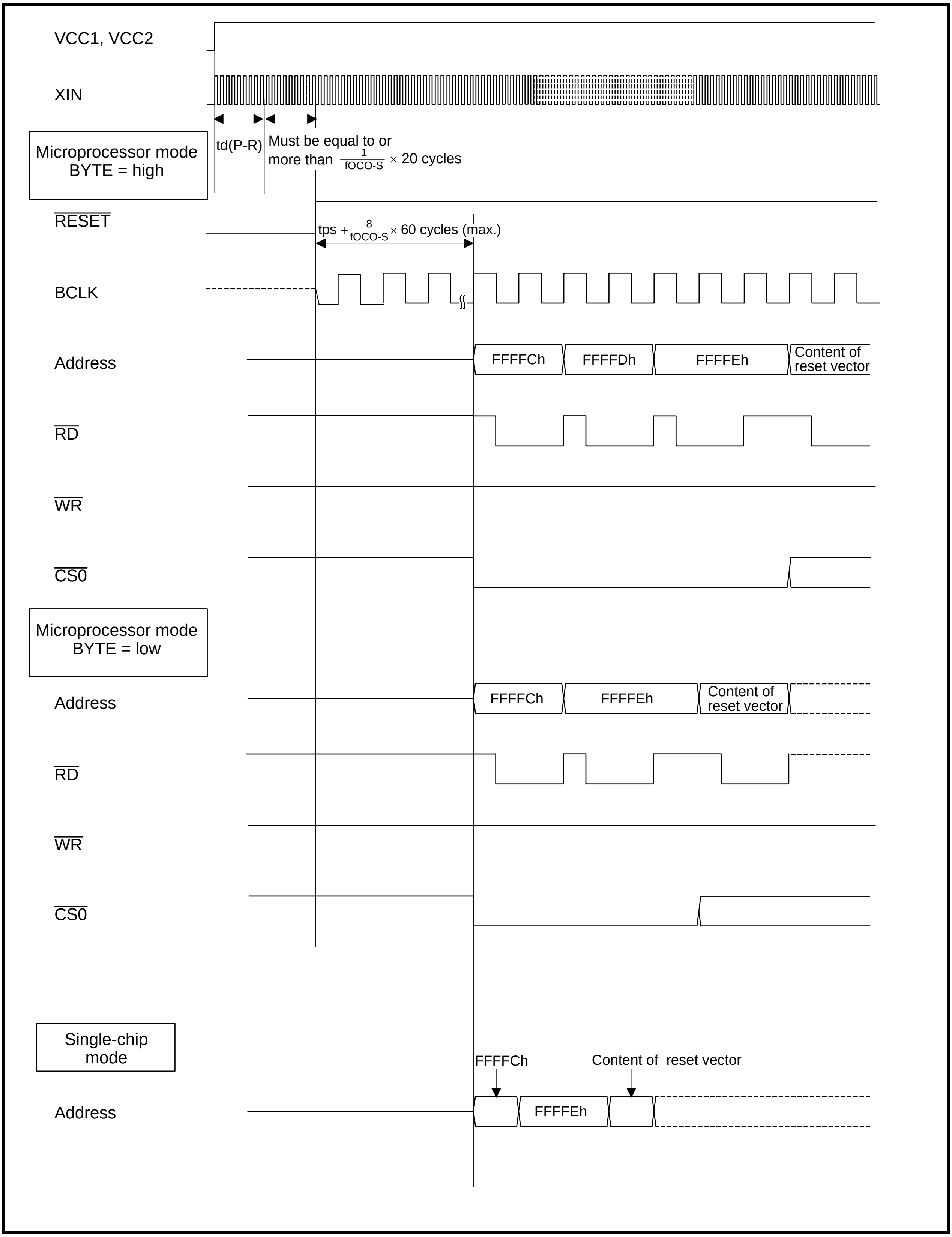


Figure 6.3 Reset Sequence

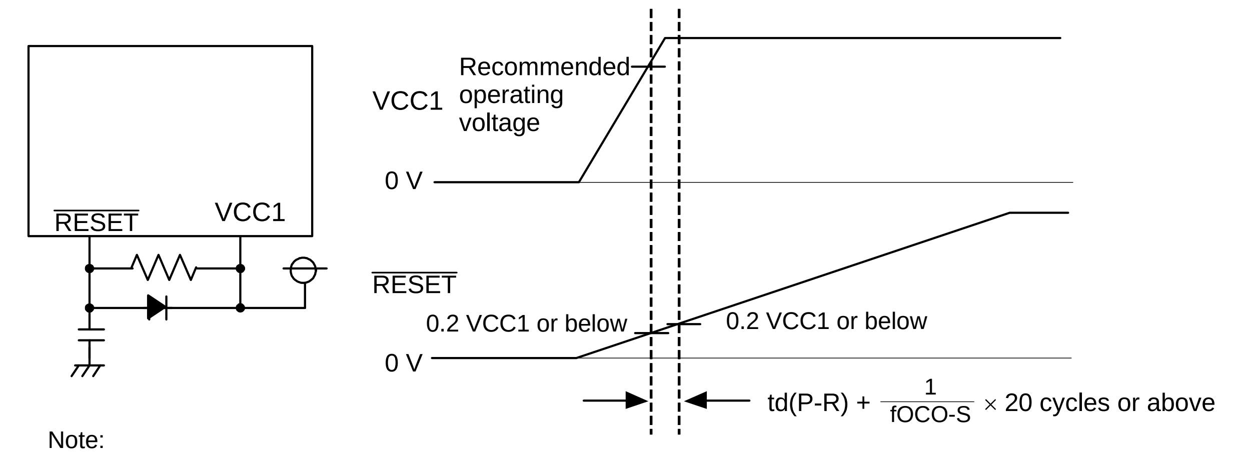
6.4.2 Hardware Reset

This reset is triggered by the $\overline{\text{RESET}}$ pin. When the power supply voltage meets the recommended operating conditions, the MCU resets the pins, CPU, and SFRs when a low-level signal is applied to the $\overline{\text{RESET}}$ pin.
When changing the signal applied to the $\overline{\text{RESET}}$ pin from low to high, the MCU executes the program at the address indicated by the reset vector. fOCO-S divided by 8 is automatically selected as the CPU clock after reset.
The HWR bit in the RSTFR register becomes 1 (hardware reset detected) after hardware reset. Refer to 4. “Special Function Registers (SFRs)” for the remaining SFR states after reset.
The internal RAM is not reset. When a low-level signal is applied to the $\overline{\text{RESET}}$ pin while writing data to the internal RAM, the internal RAM becomes undefined.
The procedures for generating a hardware reset are as follows:

When the power supply is stable
(1) Apply a low-level signal to the $\overline{\text{RESET}}$ pin.
(2) Wait for tw(RSTL).
(3) Apply a high-level signal to the $\overline{\text{RESET}}$ pin.

When the power is turned on
(1) Apply a low-level signal to the $\overline{\text{RESET}}$ pin.
(2) Raise the power supply voltage to the recommended operating level.
(3) Wait for td(P-R) until the internal voltage stabilizes.
(4) Wait for $\frac{1}{fOCO\text{–}S} \times 20$ cycles.
(5) Apply a high-level signal to the $\overline{\text{RESET}}$ pin.

Figure 6.4 shows an Reset Circuit Example.


$\overline{\text{RESET}}$
VCC1
VCC1
Recommended operating voltage
0 V
$\overline{\text{RESET}}$
0.2 VCC1 or below
0.2 VCC1 or below
0 V
$\text{td(P-R)} + \frac{1}{\text{fOCO-S}} \times 20$ cycles or above

Note:
1. When VCC1 > VCC2, make sure that the VCC2 voltage is lower than that of VCC1 when the power is turned on or off.

Figure 6.4 Reset Circuit Example

6.4.3 Power-On Reset Function

The power-on reset function can be used on the system in which VCC1 is Vdet0 or higher.

When the $\overline{\text{RESET}}$ pin is connected to VCC1 via a pull-up resistor, and the VCC1 voltage level rises while the rise gradient is trth, the power-on reset function is enabled and the MCU resets the pins, CPU, and SFRs. When the input voltage to the VCC1 pin reaches Vdet0 or above, the fOCO-S count starts. When the fOCO-S count reaches 32, the internal reset signal becomes high and the MCU executes the program at the address indicated by the reset vector. fOCO-S divided by 8 is automatically selected as the CPU clock after reset.

The CWR bit in the RSTFR register becomes 0 (cold start) after power-on reset. Refer to 4. “Special Function Registers (SFRs)” for the remaining SFR states after reset.

The internal RAM is not reset.

Use the voltage monitor 0 reset together with the power-on reset. Set the LVDAS bit in the OFS1 address to 0 (voltage monitor 0 reset enabled after hardware reset) and the VDSEL1 bit to 0 (Vdet0_2) to use the power-on reset. In this case, the voltage monitor 0 reset is enabled (the VW0C0 bit and bit 6 in the VW0C register are 1 and the VC25 bit in the VCR2 register is 1). Do not set these bits to 0 by a program.

Refer to 7. “Voltage Detector” for details of the voltage monitor 0 reset.

Figure 6.5 shows Power-On Reset Circuit and Operation Example. When a capacitor is connected to the $\overline{\text{RESET}}$ pin, always keep voltage to the $\overline{\text{RESET}}$ pin in the range of VIH.

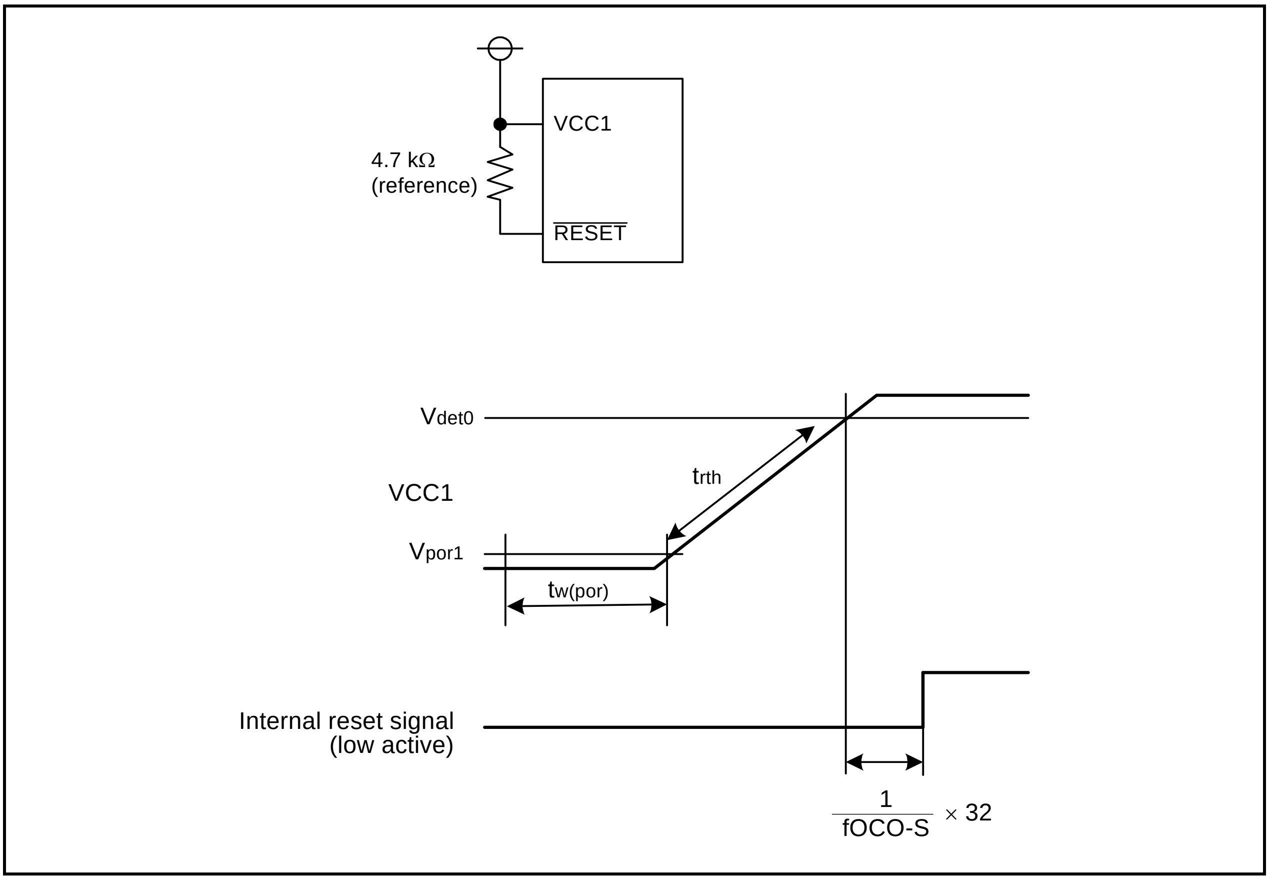


Figure 6.5 Power-On Reset Circuit and Operation Example

6.4.4 Voltage Monitor 0 Reset

This reset is triggered by the MCU's on-chip voltage detector 0. The voltage detector 0 monitors the voltage applied to the VCC1 pin (Vdet0).

The MCU resets the pins, CPU, and SFRs when the voltage applied to the VCC1 pin drops to Vdet0 or below.

Then, the fOCO-S count starts when the voltage applied to the VCC1 pin rises to Vdet0 or above. The internal reset signal becomes high after 32 cycles of fOCO-S, and then the MCU executes the program at the address indicated by the reset vector. fOCO-S divided by 8 is automatically selected as the CPU clock after reset.

The CWR bit in the RSTFR register becomes 0 (cold start) after voltage monitor 0 reset. Refer to 4. “Special Function Registers (SFRs)” for the remaining SFR states after reset.

The internal RAM is not reset. When the voltage applied to the VCC1 pin drops to Vdet0 or below while writing data to the internal RAM, the internal RAM becomes undefined.

Refer to 7. “Voltage Detector” for details of the voltage monitor 0 reset.

6.4.5 Voltage Monitor 1 Reset

This reset is triggered by the MCU's on-chip voltage detector 1. Voltage detector 1 monitors the voltage applied to the VCC1 pin (Vdet1).

When the VW1C6 bit in the VW1C register is 1 (voltage monitor 1 reset when Vdet1 passage is detected), the MCU resets the pins, CPU, and SFRs when the voltage applied to the VCC1 pin drops to Vdet1 or below. fOCO-S divided by 8 is automatically selected as the CPU clock after reset. After tps + 60 cycles of the CPU clock has elapsed, the MCU executes the program at the address indicated by the reset vector.

The LVD1R bit in the RSTFR register becomes 1 (voltage monitor 1 reset detected) after voltage monitor 1 reset. Some SFRs are not reset at voltage monitor 1 reset. Refer to 4. “Special Function Registers (SFRs)” for details. The processor mode remains unchanged since bits PM01 and PM00 in the PM0 register are not reset.

The internal RAM is not reset.

Refer to 7. “Voltage Detector” for details of the voltage monitor 1 reset.

6.4.6 Voltage Monitor 2 Reset

This reset is triggered by the MCU's on-chip voltage detector 2. Voltage detector 2 monitors the voltage applied to the VCC1 pin (Vdet2).

When the VW2C6 bit in the VW2C register is 1 (voltage monitor 2 reset when Vdet2 passage is detected), the MCU resets the pins, CPU, and SFRs when the voltage applied to the VCC1 pin drops to Vdet2 or below. fOCO-S divided by 8 is automatically selected as the CPU clock after reset. After tps + 60 cycles of the CPU clock has elapsed, the MCU executes the program at the address indicated by the reset vector.

The LVD2R bit in the RSTFR register becomes 1 (voltage monitor 2 reset detected) after voltage monitor 2 reset. Some SFRs are not reset at voltage monitor 2 reset. Refer to 4. “Special Function Registers (SFRs)” for details. The processor mode remains unchanged since bits PM01 and PM00 in the PM0 register are not reset.

The internal RAM is not reset.

Refer to 7. “Voltage Detector” for details of the voltage monitor 2 reset.

6.4.7 Oscillator Stop Detect Reset

The MCU resets and stops the pins, CPU, and SFRs when the CM27 bit in the CM2 register is 0 (reset when oscillator stop detected), if it detects that the main clock oscillator has stopped.

The OSDR bit in the RSTFR register becomes 1 (oscillator stop detect reset detected) after oscillator stop detect reset.

Some SFRs are not reset at oscillator stop detect reset. Refer to 4. “Special Function Registers (SFRs)” for details. The processor mode remains unchanged since bits PM01 and PM00 in the PM0 register are not reset.

The internal RAM is not reset. When the main clock oscillator stop is detected while writing data to the internal RAM, the internal RAM becomes undefined.

Oscillator stop detect reset is canceled by hardware reset or voltage monitor 0 reset.

Refer to 8.7 “Oscillator Stop/Restart Detect Function” for details.

6.4.8 Watchdog Timer Reset

The MCU resets the pins, CPU, and SFRs when the PM12 bit in the PM1 register is 1 (reset when watchdog timer underflows) and the watchdog timer underflows. Then the MCU executes the program at the address determined by the reset vector. fOCO-S divided by 8 is automatically selected as the CPU clock after reset.

The WDR bit in the RSTFR register becomes 1 (watchdog timer reset detected) after watchdog timer reset. Some SFRs are not reset at watchdog timer reset. Refer to 4. “Special Function Registers (SFRs)” for details. The processor mode remains unchanged since bits PM01 and PM00 in the PM0 register are not reset.

The internal RAM is not reset. When the watchdog timer underflows while writing data to the internal RAM, the internal RAM becomes undefined.

Refer to 15. “Watchdog Timer” for details.

6.4.9 Software Reset

The MCU resets the pins, CPU, and SFRs when the PM03 bit in the PM0 register is 1 (MCU reset). Then the MCU executes the program at the address determined by the reset vector. fOCO-S divided by 8 is automatically selected as the CPU clock after reset.

The SWR bit in the RSTFR register becomes 1 (software reset detected) after software reset. Some SFRs are not reset at software reset. Refer to 4. “Special Function Registers (SFRs)” for details. The processor mode remains unchanged since bits PM01 and PM00 in the PM0 register are not reset.

The internal RAM is not reset.

6.4.10 Cold/Warm Start Discrimination

The cold/warm start discrimination detects whether or not voltage applied to the VCC1 pin drops to the RAM hold voltage or below. The reference voltage is Vdet0. Therefore, the voltage monitor 0 reset is used for cold/warm start discrimination. Follow 7.4.2.1 “Voltage Monitor 0 Reset” to set the bits related to the voltage monitor 0 reset.

The CWR bit in the RSTFR register is 0 (cold start) when power is turned on. The CWR bit also becomes 0 after power-on reset or voltage monitor 0 reset. The CWR bit becomes 1 (warm start) by writing 1, and remains unchanged at hardware reset, voltage monitor 1 reset, voltage monitor 2 reset, oscillator stop detect reset, watchdog timer reset, or software reset.

In the cold/warm start discrimination, the Vdet0 level can be selected by setting the VDSEL1 bit in the OFS1 address.

- When power-on reset or voltage monitor 0 reset is used
  Set the VDSEL1 bit to 0 (Vdet0_2).
- When neither power-on reset nor voltage monitor 0 reset is used as the user system
  The VDSEL1 bit can be set to 0 or 1.
  When the VDSEL1 bit is 1 (Vdet0_0), voltage monitor 0 reset and its cancellation are based on Vdet0_0. Therefore, execute hardware reset after cancelling the voltage monitor 0 reset.

Figure 6.6 shows the Cold/Warm Start Discrimination Example.

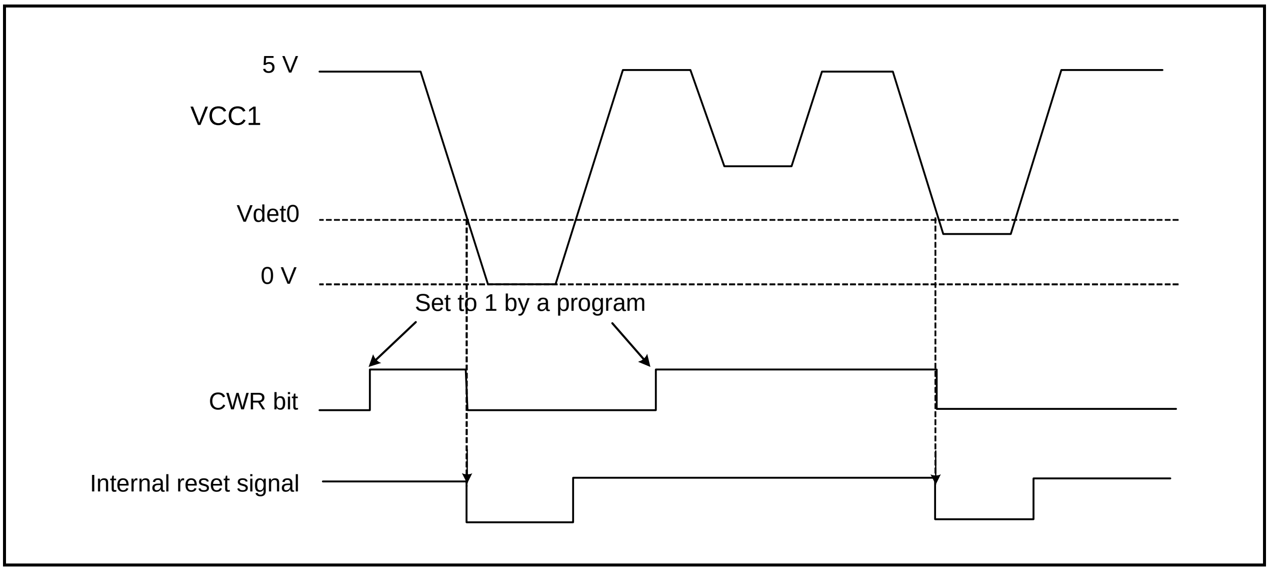


Figure 6.6 Cold/Warm Start Discrimination Example

6.5 Notes on Resets

6.5.1 Power Supply Rising Gradient

When supplying power to the MCU, make sure that the power supply voltage applied to the VCC1 pin meets the SVCC conditions.

Symbol	Parameter		Standard			Unit
			Min.	Typ.	Max.	
SVCC	Power supply VCC1 rising gradient (Voltage range: 0 to 2.0 V)		0.05			V/ms
	Power supply VCC1 rising gradient (Voltage range: 2.0 V to VCC1)	3.6 V < VCC1 ≤ 5.5 V			5.5	V/ms

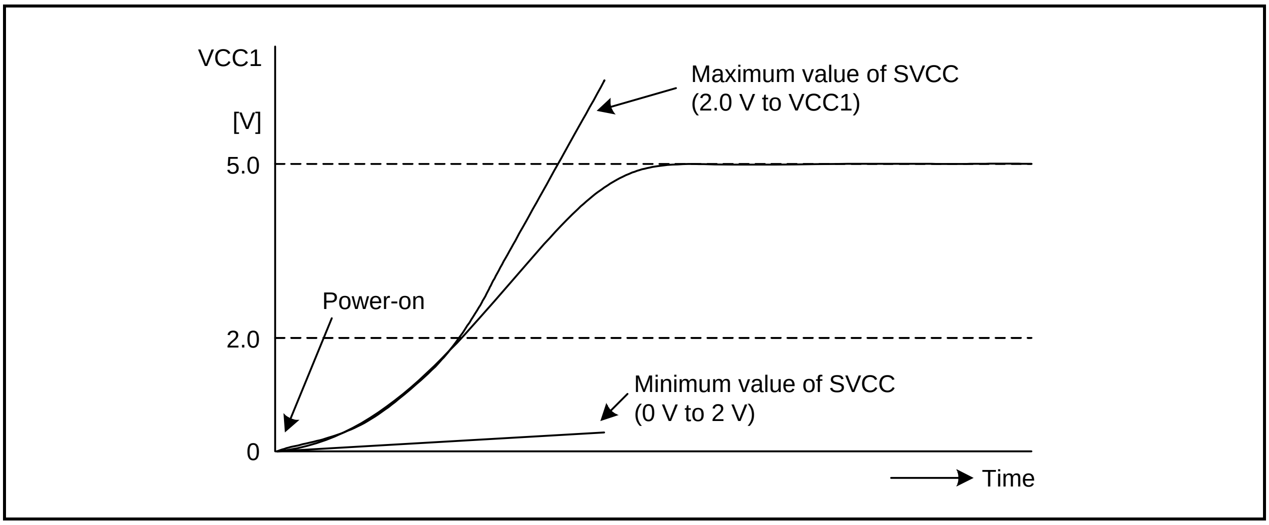


Figure 6.7 SVCC Timing (3.6 V < VCC1)

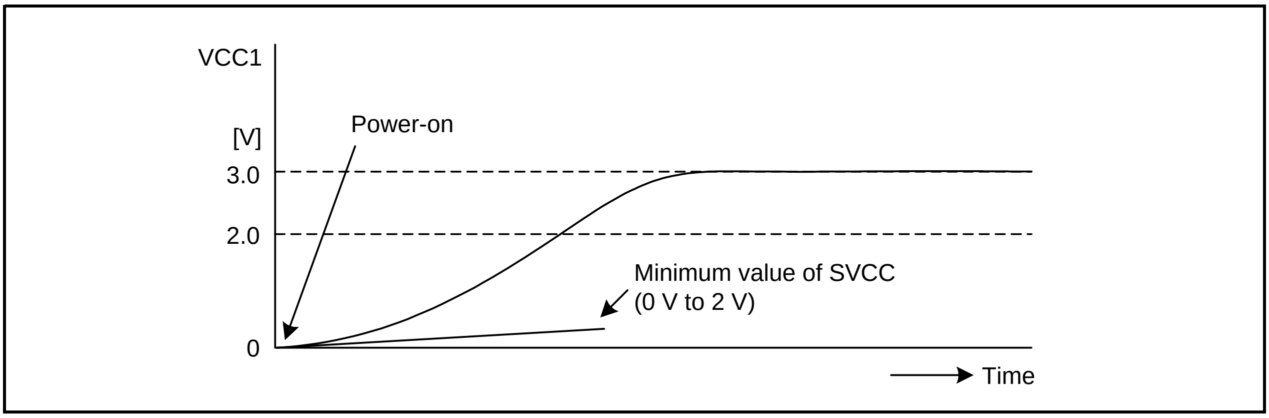


Figure 6.8 SVCC Timing (VCC1 ≤ 3.6 V)

6.5.2 Power-On Reset

Use the voltage monitor 0 reset together with the power-on reset. To use the power-on reset, set the LVDAS bit in the OFS1 address to 0 (voltage monitor 0 reset enabled after hardware reset) and the VDSEL1 bit to 0 (Vdet0_2). In this case, the voltage monitor 0 reset is enabled (the VW0C0 bit and bit 6 in the VW0C register are 1, and the VC25 bit in the VCR2 register is 1) after power-on reset. Do not disable these bits by a program.

6.5.3 OSDR Bit (Oscillation Stop Detect Reset Detect Flag)

When an oscillator stop detect reset is generated, the MCU is reset and then stopped. This state is canceled by hardware reset or voltage monitor 0 reset.

Note that the OSDR bit in the RSTFR register is not affected by a hardware reset, but becomes 0 (not detected) from a voltage monitor 0 reset.

7. Voltage Detector

7.1 Introduction

The voltage detector monitors the voltage applied to the VCC1 pin. This circuit can be programmed to monitor the VCC1 input voltage. Voltage monitor 0 reset, voltage monitor 1 interrupt, voltage monitor 1 reset, voltage monitor 2 interrupt, and voltage monitor 2 reset can also be used.

Table 7.1 lists the Voltage Detector Specifications and Figure 7.1 shows Voltage Detector Block Diagram.

Table 7.1 Voltage Detector Specifications

Item		Voltage Detector 0	Voltage Detector 1	Voltage Detector 2
VCC1 monitor	Voltage to monitor	Vdet0	Vdet1	Vdet2
	Detection target	Whether rises through or falls through Vdet0	Whether rises through or falls through Vdet1	Whether rises through or falls through Vdet2
	Voltage to detect	Selectable from two levels in the OFS1 address	Selectable from three levels in the VD1LS register	Fixed level
	Monitor	None	VW1C3 bit in the VW1C register	VC13 bit in the VCR1 register
			Whether VCC1 is higher or lower than Vdet1	Whether VCC1 is higher or lower than Vdet2
Process when voltage is detected	Reset	Voltage monitor 0 reset	Voltage monitor 1 reset	Voltage monitor 2 reset
		Reset when Vdet0 > VCC1; restart CPU operation when VCC1 > Vdet0	Reset when Vdet1 > VCC1; restart CPU operation after tps + 60 cycles of fOCO-S divided by 8	Reset when Vdet2 > VCC1; restart CPU operation after tps + 60 cycles of fOCO-S divided by 8
	Interrupt	None	Voltage monitor 1 interrupt	Voltage monitor 2 interrupt
			Interrupt request when Vdet1 > VCC1 and VCC1 > Vdet1 while digital filter is enabled; interrupt request when Vdet1 > VCC1 or VCC1 > Vdet1 while digital filter is disabled	Interrupt request when Vdet2 > VCC1 and VCC1 > Vdet2 while digital filter is enabled; interrupt request when Vdet2 > VCC1 or VCC1 > Vdet2 while digital filter is disabled
Digital filter	Switch enabled/disabled	No digital filter function	Available	Available
	Sampling time	–	(fOCO-S divided by n) × 3 n: 1, 2, 4, 8	(fOCO-S divided by n) × 3 n: 1, 2, 4, 8

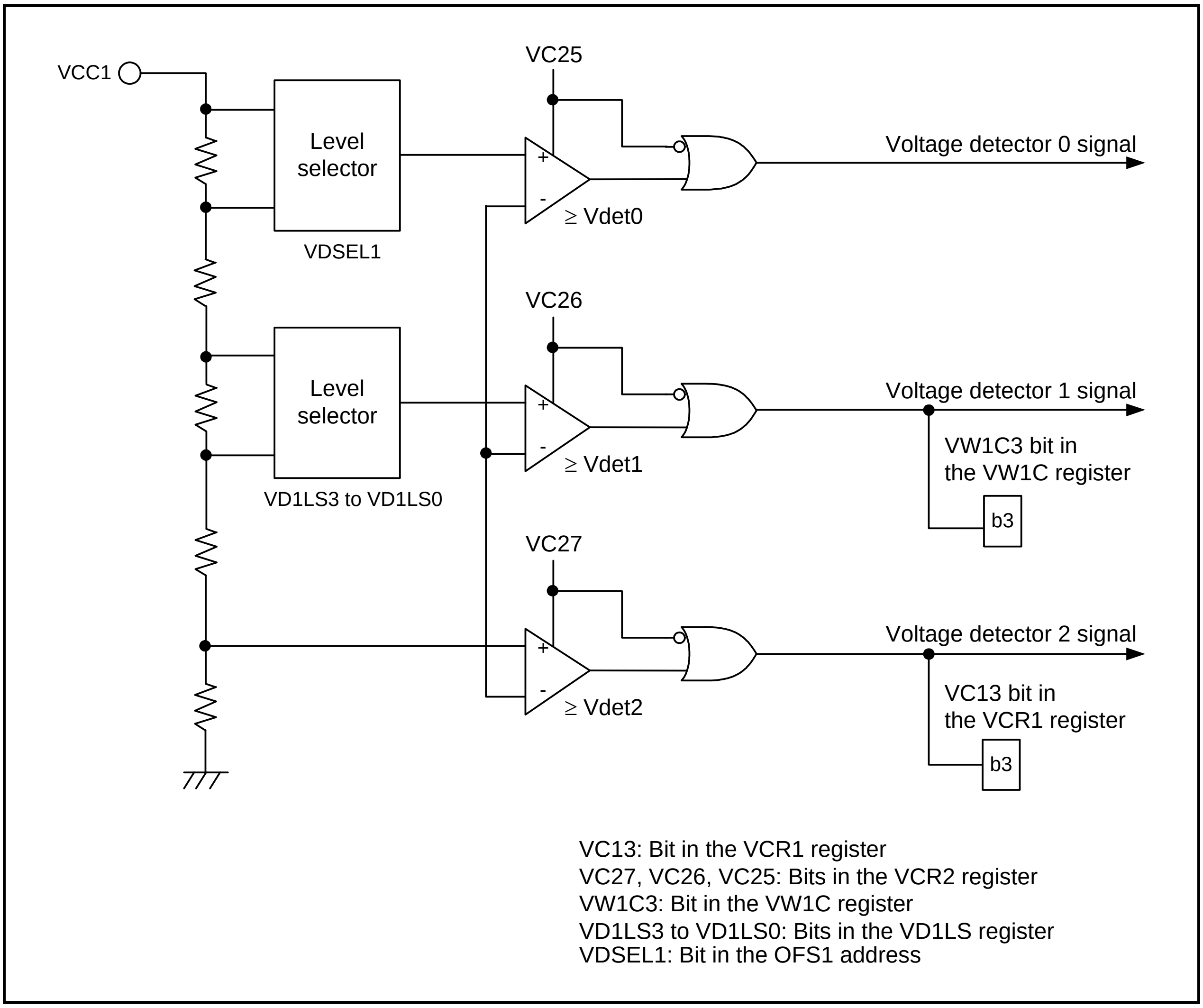

VCC1
Level selector
VDSEL1
Level selector
VD1LS3 to VD1LS0
VC25
VC26
VC27
+
-
≥ Vdet0
≥ Vdet1
≥ Vdet2
Voltage detector 0 signal
Voltage detector 1 signal
Voltage detector 2 signal
VW1C3 bit in the VW1C register
b3
VC13 bit in the VCR1 register
b3
VC13: Bit in the VCR1 register
VC27, VC26, VC25: Bits in the VCR2 register
VW1C3: Bit in the VW1C register
VD1LS3 to VD1LS0: Bits in the VD1LS register
VDSEL1: Bit in the OFS1 address

Figure 7.1 Voltage Detector Block Diagram

7.2 Registers

Table 7.2 shows the registers of the voltage detector. The reset value shows the values after hardware reset.

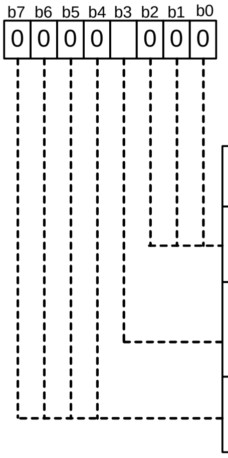
Refer to the each register explanation for details.

Table 7.2 Registers

Address	Register Name	Register Symbol	Reset Value
0019h	Voltage Detector 2 Flag Register	VCR1	0000 1000b
001Ah	Voltage Detector Operation Enable Register	VCR2	00h
0026h	Voltage Monitor Function Select Register	VWCE	00h
0028h	Voltage Detector 1 Level Select Register	VD1LS	0000 1010b
002Ah	Voltage Monitor 0 Control Register	VW0C	1000 XX10b
002Bh	Voltage Monitor 1 Control Register	VW1C	1000 1010b
002Ch	Voltage Monitor 2 Control Register	VW2C	1000 0X10b

7.2.1 Voltage Detector 2 Flag Register (VCR1)

Voltage Detector 2 Flag Register



Symbol	Address	Reset Value
VCR1	0019h	0000 1000b (hardware reset, power-on reset, voltage monitor 0 reset)

Bit Symbol	Bit Name	Function	RW
— (b2-b0)	Reserved bits	Set to 0	RW
VC13	Low-voltage monitor flag	0: VCC1 < Vdet2 1: VCC1 ≥ Vdet2 or voltage detector 2 disabled	RO
— (b7-b4)	Reserved bits	Set to 0	RW

This register does not change at voltage monitor 1 reset, voltage monitor 2 reset, oscillator stop detect reset, watchdog timer reset, or software reset.

VC13 (Low-voltage monitor flag) (b3)

The VC13 bit is enabled when the VW12E bit in the VWCE register is 1 (voltage monitors 1 and 2 enabled) and the VC27 bit in the VCR2 register is 1 (voltage detector 2 enabled).

Condition to become 0:

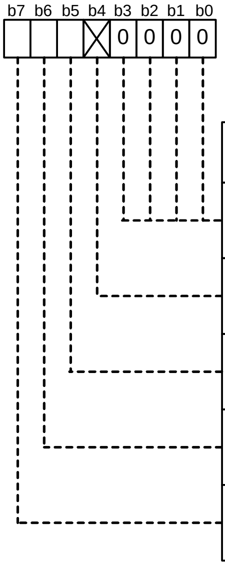
- VCC1 < Vdet2 (when the VW12E bit is 1 and the VC27 bit is 1)

Conditions to become 1:

- VCC1 ≥ Vdet2 (when the VW12E bit is 1 and the VC27 bit is 1)
- The VC27 bit is 0 (voltage detector 2 disabled).

7.2.2 Voltage Detector Operation Enable Register (VCR2)

Voltage Detector Operation Enable Register



Symbol	Address	Reset Value
VCR2	001Ah	0000 0000b [1] 0010 0000b [2]

Bit Symbol	Bit Name	Function	RW
— (b3-b0)	Reserved bits	Set to 0	RW
— (b4)	Reserved bits	Set to 0	RW
VC25	Voltage detector 0 enable bit	0 : Voltage detector 0 disabled 1 : Voltage detector 0 enabled	RW
VC26	Voltage detector 1 enable bit	0 : Voltage detector 1 disabled 1 : Voltage detector 1 enabled	RW
VC27	Voltage detector 2 enable bit	0 : Voltage detector 2 disabled 1 : Voltage detector 2 enabled	RW

Notes:

1. This is the reset value when the LVDAS bit of address OFS1 is 1 during hardware reset
2. This is the reset value after voltage monitor 0 reset, power-on reset, and when the LVDAS bit of address OFS1 is 0 during hardware reset.

Set the PRC3 bit in the PRCR register to 1 (write enabled) before rewriting this register.
This register does not change at voltage monitor 1 reset, voltage monitor 2 reset, oscillator stop detect reset, watchdog timer reset, or software reset.

VC25 (Voltage detector 0 enable bit) (b5)

To use voltage monitor 0 reset, set the VC25 bit to 1 (voltage detector 0 enabled). After changing the VC25 bit to 1, the detector starts operating when the td(E-A) elapses.

VC26 (Voltage detector 1 enable bit) (b6)

Voltage detector 1 is enabled when the VW12E bit in the VWCE register is 1 (voltage monitors 1 and 2 enabled) and the VC26 bit is 1 (voltage detector 1 enabled). Set bits VW12E and VC26 to 1 under the following conditions:

- When using voltage monitor 1 interrupt/reset
- When using bits VW1C2 and VW1C3 in the VW1C register

After changing this bit from 0 to 1, the detector will start operating after td(E-A) elapses.

VC27 (Voltage detector 2 enable bit) (b7)

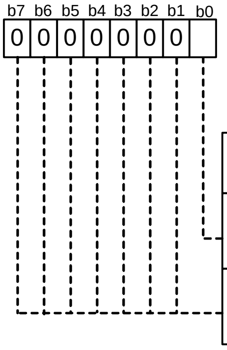
Voltage detector 2 is enabled when the VW12E bit in the VWCE register is set to 1 (voltage monitors 1 and 2 enabled) and the VC27 bit is 1 (voltage detector 2 enabled). Set bits VW12E and VC27 to 1 under the following conditions:

- When using voltage monitor 2 interrupt/reset
- When using the VC13 bit in the VCR1 register
- When using the VW2C2 bit in the VW2C register

After changing this bit from 0 to 1, the detector will start operating after td(E-A) elapses.

7.2.3 Voltage Monitor Function Select Register (VWCE)

Voltage Monitor Function Select Register



Symbol	Address	Reset Value
VWCE	0026h	00h

Bit Symbol	Bit Name	Function	RW
VW12E	Voltage monitors 1 and 2 enable bit	0: Voltage monitors 1 and 2 disabled 1: Voltage monitors 1 and 2 enabled	RW
— (b7-b1)	Reserved bits	Set to 0	RW

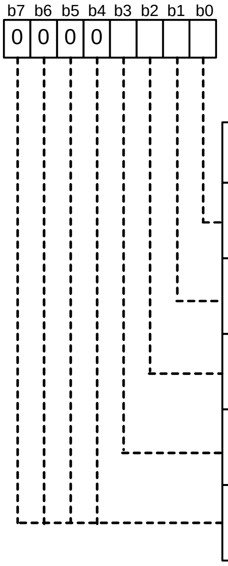
Set the PRC3 bit in the PRCR register to 1 (write enabled) before rewriting this register.

VW12E (Voltage monitors 1 and 2 enable bit) (b0)

Set this bit to 1 (enabled) to set either or both bits VC26 and VC27 in the VCR2 register to 1 (enabled).

7.2.4 Voltage Detector 1 Level Select Register (VD1LS)

Voltage Detector 1 Level Select Register



Symbol	Address	Reset Value
VD1LS	0028h	0000 1010b (Hardware reset, power-on reset, voltage monitor 0 reset, voltage monitor 1 reset, voltage monitor 2 reset)

Bit Symbol	Bit Name	Function	RW
VD1LS0	Vdet1 select bit	b3 b2 b1 b0 0 1 1 0 : Vdet1_6 1 0 1 1 : Vdet1_B 1 1 1 1 : Vdet1_F Only set the values listed above.	RW
VD1LS1			RW
VD1LS2			RW
VD1LS3			RW
— (b7-b4)	Reserved bits	Set to 0.	RW

Set the PRC3 bit in the PRCR register to 1 (write enabled) before rewriting this register. Also, rewrite this register when the VW12E bit in the VWCE register is 1.

This register does not change at watchdog timer reset, oscillation stop detect reset, or software reset.

The register value is affected by the VW12E bit in the VWCE register. Table 7.3 lists VD1LS Register Value. After setting a value to this register, by setting the VW12E bit first to 0 and then to 1, the register will revert to the previous setting.

Table 7.3 VD1LS Register Value

VW12E Bit	VD1LS Register Value
0	0000 1010b
1	Value set in the register (0000 0111b when no value is set)

VD1LS3 to VD1LS0 (Vdet1 select bit) (b3 to b0)

When using voltage detector 1, the reset value cannot be used as is. Only set the values shown in the register.

When not using detector 1, the reset values can remain as is.

7.2.5 Voltage Monitor 0 Control Register (VW0C)

Voltage Monitor 0 Control Register

b7	b6	b5	b4	b3	b2	b1	b0
1	1	0	0		0	1	

Symbol	Address	Reset Value
VW0C	002Ah	1000 XX10b [1] 1100 XX11b [2]

Bit Symbol	Bit Name	Function	RW
VW0C0	Voltage monitor 0 reset enable bit	0 : Disabled 1 : Enabled	RW
— (b1)	Reserved bit	Set to 1.	RW
— (b2)	Reserved bit	Set to 0. When read, the read value is undefined.	RW
— (b3)	Reserved bit	When read, the read value is undefined.	RO
— (b5-b4)	Reserved bits	Set to 0	RW
— (b7-b6)	Reserved bits	Set to 1	RW

Notes:

1. This is the reset value when the LVDAS bit of address OFS1 is 1 during hardware reset.
2. This is the reset value after voltage monitor 0 reset, power-on reset, and when the LVDAS bit of address OFS1 is 0 during hardware reset.

Set the PRC3 bit in the PRCR register to 1 (write enabled) before rewriting to this register.
This register does not change at voltage monitor 1 reset, voltage monitor 2 reset, oscillator stop detect reset, watchdog timer reset, or software reset.

VW0C0 (Voltage monitor 0 reset enable bit) (b0)

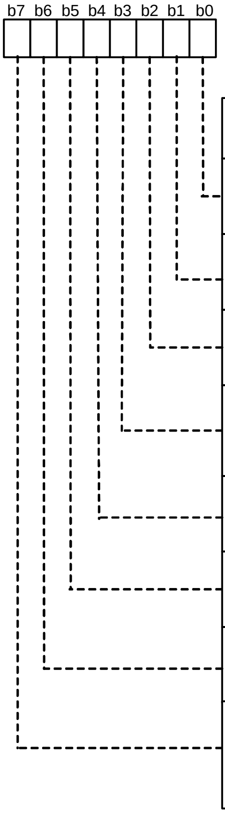
The VW0C0 bit is enabled when the VC25 bit in the VCR2 register is 1 (voltage detector 0 enabled). Set the VW0C0 bit to 0 (disabled) when the VC25 bit is 0 (voltage detector 0 disabled).

Bit 6

When the LVDAS bit in the OFS1 address is 1, this bit becomes 0 after hardware reset. When using voltage monitor 0 reset, set this bit to 1.

7.2.6 Voltage Monitor 1 Control Register (VW1C)

Voltage Monitor 1 Control Register



Symbol	Address	Reset Value
VW1C	002Bh	1000 1010b

Bit Symbol	Bit Name	Function	RW
VW1C0	Voltage monitor 1 interrupt/ reset enable bit	0 : Disabled 1 : Enabled	RW
VW1C1	Voltage monitor 1 digital filter disable mode select bit	0 : Digital filter enabled 1 : Digital filter disabled	RW
VW1C2	Voltage change detection flag	0 : Not detected 1 : Vdet1 passage detected	RW
VW1C3	Voltage detector 1 signal monitor flag	0 : VCC1 < Vdet1 1 : VCC1 ≥ Vdet1 or voltage detector 1 disabled	RO
VW1F0	Sampling clock select bit	b5 b4 0 0 : fOCO-S divided by 1 0 1 : fOCO-S divided by 2 1 0 : fOCO-S divided by 4 1 1 : fOCO-S divided by 8	RW
VW1F1			
VW1C6	Voltage monitor 1 mode select bit	0 : Voltage monitor 1 interrupt at Vdet1 passage 1 : Voltage monitor 1 reset at Vdet1 passage	RW
VW1C7	Voltage monitor 1 interrupt/ reset generation condition select bit	0 : When VCC1 reaches or goes above Vdet1 1 : When VCC1 reaches or goes below Vdet1	RW

Set the PRC3 bit in the PRCR register to 1 (write enabled) before rewriting this register.
Bits VW1C2 and VW1C3 do not change at voltage monitor 1 reset, voltage monitor 2 reset, oscillator stop detect reset, watchdog timer reset, or software reset.
The VW1C2 bit may become 1 after rewriting this register is rewritten. Therefore, set the VW1C2 bit to 0 after rewriting this register.

VW1C0 (Voltage monitor 1 interrupt/reset enable bit) (b0)

The VW1C0 bit is enabled when the VW12E bit in the VWCE register is 1 (voltage monitors 1 and 2 enabled) and the VC26 bit in the VCR2 register is 1 (voltage detector 1 enabled). Set the VW1C0 bit to 0 (disabled) when the VC26 bit is 0 (voltage detector 1 disabled).

VW1C1 (Voltage monitor 1 digital filter disable mode select bit) (b1)

After using voltage monitor 1 interrupt to exit stop mode, to use it again to exit stop mode, set the VW1C1 bit to 0 first, and then to 1.

VW1C2 (Voltage change detection flag) (b2)

The VW1C2 bit is enabled when the VC26 bit in the VCR2 register is 1 (voltage detector 1 enabled). This bit does not change even if set to 1.

Condition to become 0:

- Setting this bit to 0

Conditions to become 1:

- Refer to the following table.

Table 7.4 Conditions under Which the VW1C2 Bit Becomes 1

Bit Setting [1]			Condition
WV1C1	VW1C6	VW1C7	
0	0	0 or 1	The VW1C3 bit changes from 0 to 1 or from 1 to 0.
	1	1	The VW1C3 bit changes from 1 to 0.
1	0	0	The VW1C3 bit changes from 0 to 1.
		1	The VW1C3 bit changes from 1 to 0.
	1	1	The VW1C3 bit changes from 1 to 0.

Note:

1. Only set the values listed above.

VW1C3 (Voltage detector 1 signal monitor flag) (b3)

The VW1C3 bit is enabled when the VW12E bit in the VWCE register is 1 (voltage monitors 1 and 2 enabled) and the VC26 bit in the VCR2 register is 1 (voltage detector 1 enabled).

Condition to become 0:

- VCC1 < Vdet1 (when the VW12E bit is 1 and the VC26 bit is 1)

Conditions to become 1:

- VCC1 ≥ Vdet1 (when the VW12E bit is 1 and the VC26 bit is 1)
- The VC26 bit in the VCR2 register is 0 (voltage detector 1 disabled).

After a hardware reset, power-on reset, voltage monitor 0 reset, voltage monitor 1 reset, or voltage monitor 2 reset, the reference level of Vdet1 switches because value in the VD1LS register changes. When monitoring the voltage detector 1 signal level, set the value to the VD1LS register again, then set the VW1C3 bit.

The VW12E bit in the VWCE register becomes 0 from a reset. When monitoring the voltage detector 1 signal level, set the VW12E bit to 1 again.

VW1C6 (Voltage monitor 1 mode select bit) (b6)

The VW1C6 bit is enabled when the VW1C0 bit is 1 (voltage monitor 1 interrupt/reset enabled).

VW1C7 (Voltage monitor 1 interrupt/reset generation condition select bit) (b7)

The voltage monitor 1 interrupt/reset generation condition can be selected by the VW1C7 bit when the VW1C6 bit is 0 (voltage monitor 1 interrupt at Vdet1 passage) and the VW1C1 bit is 1 (digital filter disabled).

When the VW1C6 bit is 1 (voltage monitor 1 reset at Vdet1 passage), set the VW1C7 bit to 1 (when VCC1 reaches Vdet1 or below). (Do not set the VW1C7 bit to 0.)

When the VW1C1 bit is 0 (digital filter enabled), regardless of the VW1C7 bit's setting, the voltage monitor 1 interrupt is generated when VCC1 reaches, or goes above of below Vdet1.

7.2.7 Voltage Monitor 2 Control Register (VW2C)

Voltage Monitor 2 Control Register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
VW2C	002Ch	1000 0X10b

Bit Symbol	Bit Name	Function	RW
VW2C0	Voltage monitor 2 interrupt/ reset enable bit	0 : Disabled 1 : Enabled	RW
VW2C1	Voltage monitor 2 digital filter disable mode select bit	0 : Digital filter enabled 1 : Digital filter disabled	RW
VW2C2	Voltage change detection flag	0 : Not detected 1 : Vdet2 passage detected	RW
VW2C3	Watchdog timer detection flag	0 : Not detected 1 : Watchdog timer underflow detected	RW
VW2F0	Sampling clock select bit	b5 b4 0 0 : fOCO-S divided by 1 0 1 : fOCO-S divided by 2 1 0 : fOCO-S divided by 4 1 1 : fOCO-S divided by 8	RW
VW2F1			
VW2C6	Voltage monitor 2 mode select bit	0 : Voltage monitor 2 interrupt at Vdet2 passage 1 : Voltage monitor 2 reset at Vdet2 passage	RW
VW2C7	Voltage monitor 2 interrupt/ reset generation condition select bit	0: When VCC1 reaches or goes above Vdet2 1: When VCC1 reaches or goes below Vdet2	RW

Set the PRC3 bit in the PRCR register to 1 (write enabled) before rewriting the VW2C register.
Bits VW2C2 and VW2C3 do not change at voltage monitor 1 reset, voltage monitor 2 reset, oscillator stop detect reset, watchdog timer reset, or software reset.
When rewriting the VW2C register (excluding the VW2C3 bit), the VW2C2 bit may become 1. Set the VW2C2 bit to 0 after rewriting the VW2C register.

VW2C0 (Voltage monitor 2 interrupt/reset enable bit) (b0)

The VW2C0 bit is enabled when the VW12E bit in the VWCE register is 1 (voltage monitors 1 and 2 enabled) and the VC27 bit in the VCR2 register is 1 (voltage detector 2 enabled). Set the VW2C0 bit to 0 (disabled) when the VC27 bit is 0 (voltage detector 2 disabled).

VW2C1 (Voltage monitor 2 digital filter disable mode select bit) (b1)

After using the voltage monitor 2 interrupt to exit stop mode, to use it again to exit stop mode, set the VW2C1 bit to 0 first and then to 1.

VW2C2 (Voltage change detection flag) (b2)

The VW2C2 bit is enabled when the VC27 bit in the VCR2 register is 1 (voltage detector 2 enabled). This bit does not change even if set to 1.

Condition to become 0:

- Writing this bit to 0

Condition to become 1:

- Refer to the following table.

Table 7.5 Conditions Under Which the VW2C2 Bit Becomes 1

Bit Setting (1)			Conditions under Which the VW2C2 Bit Becomes 1
VW2C1	VW2C6	VW2C7	
0	0	0 or 1	The VC13 bit changes from 0 to 1 or from 1 to 0.
	1	1	The VC13 bit changes from 1 to 0.
1	0	0	The VC13 bit changes from 0 to 1.
		1	The VC13 bit changes from 1 to 0.
	1	1	The VC13 bit changes from 1 to 0.

VC13 bit: Bit in the VCR1 register

Note:

1. Only set the values listed above.

VW2C6 (Voltage monitor 2 mode select bit) (b6)

The VW2C6 bit is enabled when the VW2C0 bit is 1 (voltage monitor 2 interrupt/reset enabled).

VW2C7 (Voltage monitor 2 interrupt/reset generation condition select bit) (b7)

The voltage monitor 2 interrupt/reset generation condition can be selected by the VW2C7 bit when the VW2C6 bit is 0 (voltage monitor 2 interrupt at Vdet2 passage) and the VW2C1 bit is 1 (digital filter disabled).

When the VW2C6 bit is 1 (voltage monitor 2 reset at Vdet2 passage), set the VW2C7 bit to 1 (when VCC1 reaches Vdet2 or below). (Do not set the VW2C7 bit to 0.)

When the VW2C1 bit is 0 (digital filter enabled), regardless of the VW2C7 bit setting, the voltage monitor 2 interrupt is generated when VCC1 reaches Vdet2 or above, and also when VCC1 reaches Vdet2 or below.

7.3 Optional Function Select Area

In the optional function select area, the MCU state after reset and the function to prevent rewrite in parallel I/O mode are selected.

The optional function select area is not an SFR, and therefore cannot be rewritten by a program. Set an appropriate value when writing a program to flash memory. The entire optional function select area becomes FFh when the block including the optional function select area is erased.

In blank products, the OFS1 address value is FFh when shipped. After a value is written by the user, this address takes on the written value.

In programmed products, the OFS1 address value is the value set in the user program prior to shipping.

Selection using the optional function select area can be used in single-chip mode or memory expansion mode. The option function select area cannot be used in microprocessor mode. When using the MCU in microprocessor mode, clear the internal ROM.

7.3.1 Optional Function Select Address 1 (OFS1)

Optional Function Select Address 1

b7	b6	b5	b4	b3	b2	b1	b0
			1			1	

Symbol: OFS1 Address: FFFFFh

Bit Symbol	Bit Name	Function
WDTON	Watchdog timer start select bit	0 : Watchdog timer starts automatically after reset 1 : Watchdog timer is stopped after reset
— (b1)	Reserved bit	Set to 1.
ROMCR	ROM code protect cancel bit	0 : ROM code protection cancelled 1 : ROMCP1 bit enabled
ROMCP1	ROM code protect bit	0 : ROM code protection enabled 1 : ROM code protection disabled
— (b4)	Reserved bit	Set to 1.
VDSEL1	Vdet0 select bit 1	0 : Vdet0_2 1 : Vdet0_0
LVDAS	Voltage detector 0 start bit	0 : Voltage monitor 0 reset enabled after hardware reset 1 : Voltage monitor 0 reset disabled after hardware reset
CSPROINI	After-reset count source protection mode select bit	0 : Count source protection mode enabled after reset 1 : Count source protection mode disabled after reset

VDSEL1 (Vdet0 select bit 1) (b5)

The Vdet0 level used in voltage detector 0 is selectable. Voltage detector 0 operates based on Vdet0. Set the VDSEL1 bit to 0 (Vdet0_2) when using power-on reset or voltage monitor 0 reset. Refer to 6.4.10 “Cold/Warm Start Discrimination”.

This bit is enabled in single-chip mode, while disabled in boot mode.

LVDAS (Voltage detector 0 start bit) (b6)

When using power-on reset, set this bit to 0 (voltage monitor 0 reset enabled after hardware reset).

This bit is enabled in single-chip mode, while disabled in boot mode.

7.4 Operations

7.4.1 Digital Filter

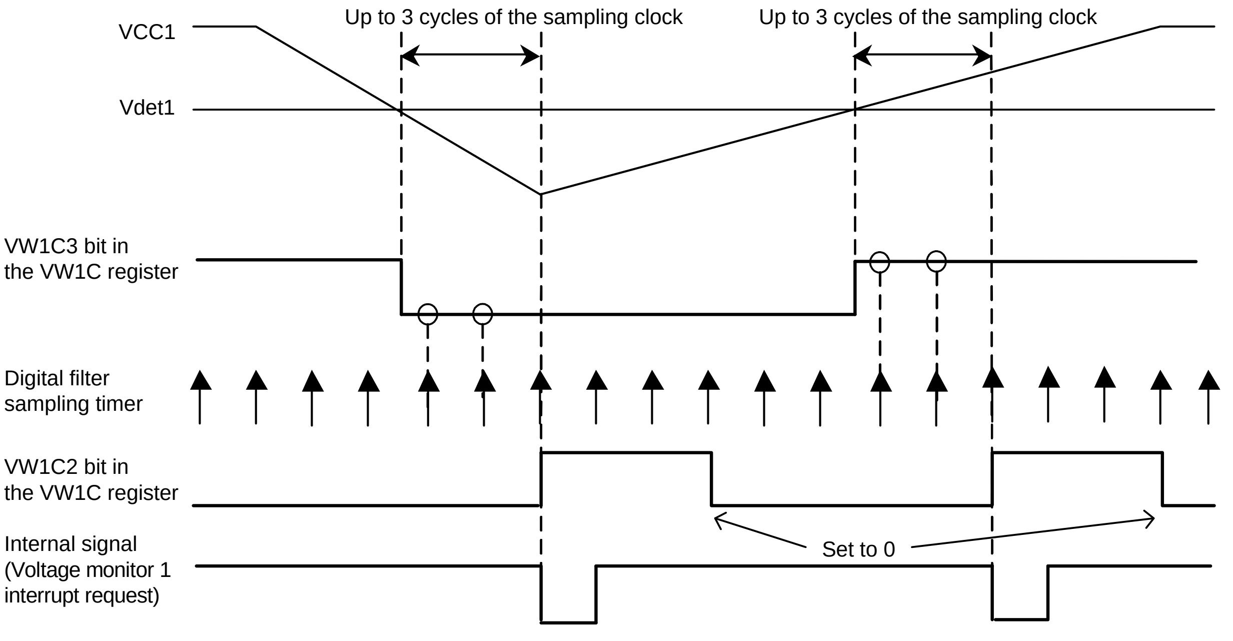
A digital filter can be used to monitor VCC1 input voltage. For the voltage detector i (i = 1 to 2), the digital filter is enabled when the VWiC1 bit in the VWiC register is set to 0 (digital filter enabled).

fOCO-S divided by 1, 2, 4, or 8 is selected as a sampling clock. When using the digital filter, set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on).

The VCC1 input level is sampled by the digital filter for every sampling clock. When the same sampled level is detected twice in a row, at the next sampling timing, the internal reset signal goes low or a voltage monitor i interrupt request is generated. Therefore, when the digital filter is used, the time from when the VCC1 input voltage level passes Vdeti until when a reset or an interrupt is generated is up to three cycles of the sampling clock.

Since fOCO-S stops in stop mode, the digital filter does not function. When using voltage detector i to exit stop mode, set the VWiC1 bit in the VWiC register to 1 (digital filter disabled).

Figure 7.2 shows Digital Filter Operation Example.


VCC1
Vdet1
Up to 3 cycles of the sampling clock
Up to 3 cycles of the sampling clock
VW1C3 bit in the VW1C register
Digital filter sampling timer
VW1C2 bit in the VW1C register
Set to 0
Internal signal (Voltage monitor 1 interrupt request)

The above diagram assumes the following:

- The VW12E bit in the VWCE register is 1 (voltage monitors 1 and 2 enabled).
- The VW1C0 bit in the VW1C register is 1 (voltage monitor 1 interrupt/reset enabled).
- The VW1C1 bit in the VW1C register is 0 (digital filter enabled).
- The VW1C6 bit in the VW1C register is 0 (voltage monitor 1 interrupt at Vdet1 passage).

Figure 7.2 Digital Filter Operation Example

7.4.2 Voltage Detector 0

When the VC25 bit in the VCR2 register is 1 (voltage detector 0 enabled), voltage detector 0 monitors the voltage applied to the VCC1 pin and detects whether the voltage rises through or falls through Vdet0. The Vdet0 level can be selected by the VDSEL1 bit in the OFS1 address.

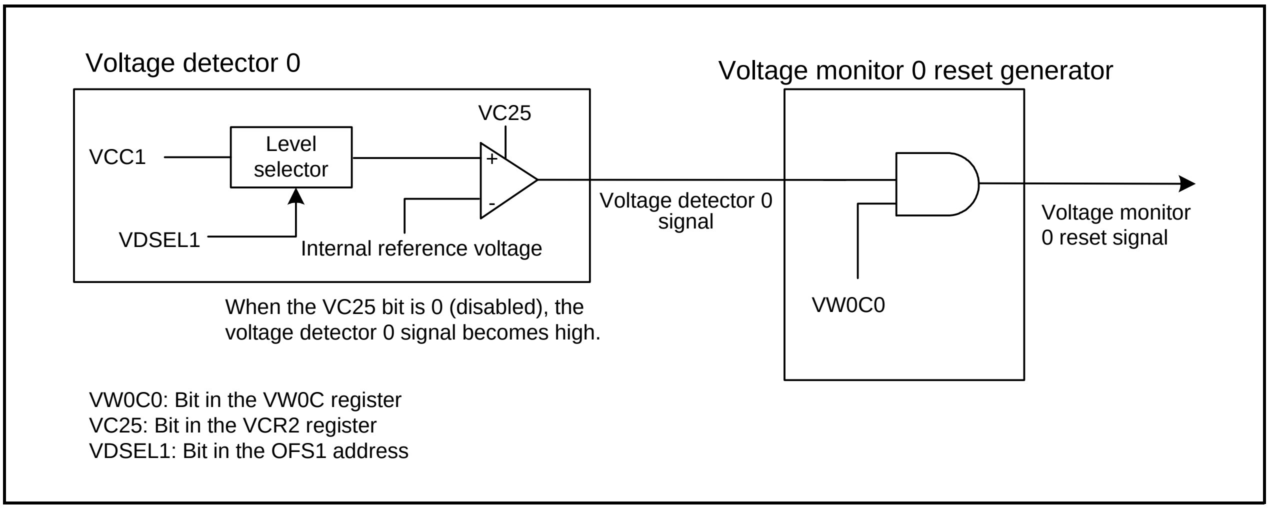

Voltage detector 0
Voltage monitor 0 reset generator
VC25
VCC1
Level selector
+
-
VDSEL1
Internal reference voltage
Voltage detector 0 signal
Voltage monitor 0 reset signal
VW0C0
When the VC25 bit is 0 (disabled), the voltage detector 0 signal becomes high.
VW0C0: Bit in the VW0C register
VC25: Bit in the VCR2 register
VDSEL1: Bit in the OFS1 address

Figure 7.3 Voltage Monitor 0 Reset Generator Block Diagram

7.4.2.1 Voltage Monitor 0 Reset

When using voltage monitor 0 reset, set the VDSEL1 bit in the OFS1 address to 0 (Vdet0_2).

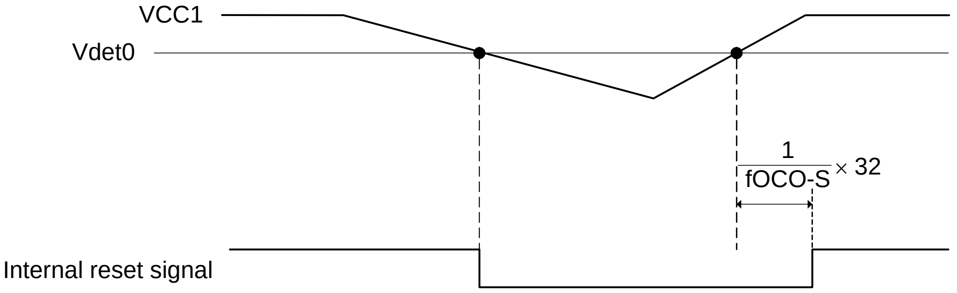
When the LVDAS bit in the OFS1 address is 1 (voltage monitor 0 reset disabled after hardware reset), set the related bits according to the procedure listed in Table 7.6. When the LVDAS bit in the OFS1 address is 0 (voltage monitor 0 reset enabled after hardware reset), the procedure listed in Table 7.6 is unnecessary.

Table 7.6 Procedure for Setting Voltage Monitor 0 Reset Related Bits

Step	Processing
1	Set the VC25 bit in the VCR2 register to 1 (voltage detector 0 enabled).
2	Wait for td(E-A).
3	Set the VW0C0 bit in the VW0C register to 1 (voltage monitor 0 reset enabled).

When voltage monitor 0 reset is generated, the CWR bit in the RSTFR register becomes 0 (cold start). Refer to 6.4.4 “Voltage Monitor 0 Reset” for status after reset.

Figure 7.4 shows Voltage Monitor 0 Reset Operation Example.



The above diagram assumes the following:

- The VC25 bit in the VCR2 register is 1 (voltage detector 0 enabled).
- The VW0C0 bit in the VW0C register is 1 (voltage monitor 0 reset enabled).

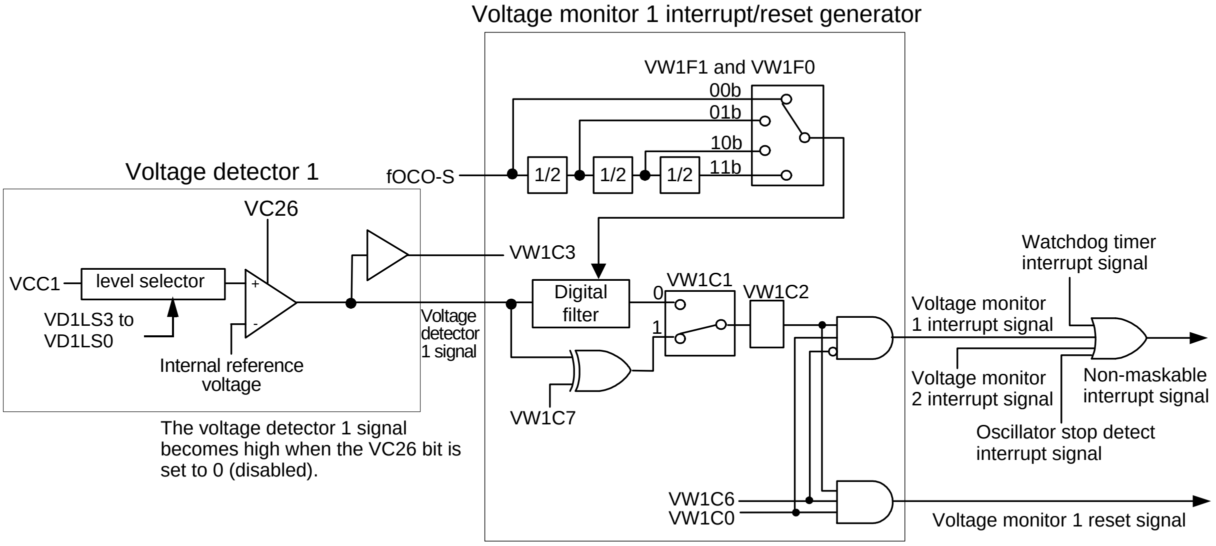
The pins, CPU, and SFRs are initialized when the internal reset signal goes low.
The MCU executes the program at the address indicated by the reset vector when the internal reset signal changes from low to high.
Refer to 4. “SFRs” for the SFR status after reset.

Note:
1. Make sure that VCC1 does not drop to recommended operating condition VCC1 during sampling time.

Figure 7.4 Voltage Monitor 0 Reset Operation Example

7.4.3 Voltage Detector 1

When the VW12E bit in the VWCE register is 1 (voltage monitors 1 and 2 enabled) and the VC26 bit in the VCR2 register is 1 (voltage detector 1 enabled), voltage detector 1 monitors the voltage applied to the VCC1 pin and detects whether the voltage rises through or falls through Vdet1.



The voltage detector 1 signal becomes high when the VC26 bit is set to 0 (disabled).

VW1C0 to VW1C3, VW1F0 to VW1F1, VW1C6 to VW1C7: Bits in the VW1C register
VC26: Bit in the VCR2 register
VD1LS3 to VD1LS0: Bit in the VD1LS register

Figure 7.5 Voltage Monitor 1 Interrupt/Reset Generator

7.4.3.1 Monitoring Vdet1

Set the VW12E bit in the VWCE register to 1 (voltage monitors 1 and 2 enabled) and the VC26 bit in the VCR2 register to 1 (voltage detector 1 enabled). Vdet1 can be monitored by using the VW1C3 bit in the VW1C register after td(E-A) elapses.

7.4.3.2 Voltage Monitor 1 Interrupt and Voltage Monitor 1 Reset

Table 7.7 lists Procedures for Setting Voltage Monitor 1 Interrupt/Reset Related Bits.

Table 7.7 Procedures for Setting Voltage Monitor 1 Interrupt/Reset Related Bits

Step	When Using the Digital Filter		When Not Using the Digital Filter	
	Voltage monitor 1 interrupt	Voltage monitor 1 reset	Voltage monitor 1 interrupt	Voltage monitor 1 reset
1	Set the VW12E bit in the VWCE register to 1 (voltage monitors 1 and 2 enabled).			
2	Set bits VD1LS3 to VD1LS0 in the VD1LS register to select Vdet1.			
3	Set the VC26 bit in the VCR2 register to 1 (voltage detector 1 enabled).			
4	Wait for td(E-A).			
5	Use bits VW1F1 and VW1F0 in the VW1C register to select the digital filter sampling clock.		Use the VW1C7 bit in the VW1C register to select the timing of the interrupt and reset request. (1)	
6 (2)	Set the VW1C1 bit in the VW1C register to 0 (digital filter enabled).		Set the VW1C1 bit in the VW1C register to 1 (digital filter disabled).	
7 (2)	Set the VW1C6 bit in the VW1C register to 0 (voltage monitor 1 interrupt).	Set the VW1C6 bit in the VW1C register to 1 (voltage monitor 1 reset).	Set the VW1C6 bit in the VW1C register to 0 (voltage monitor 1 interrupt).	Set the VW1C6 bit in the VW1C register to 1 (voltage monitor 1 reset).
8	Set the VW1C2 bit in the VW1C register to 0 (Vdet1 passage not detected).			
9	Set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on)		-	
10	Wait for digital filter sampling clock x 3 cycles.		- (no wait time)	
11	Set the VW1C0 bit in the VW1C register to 1 (voltage monitor 1 interrupt/reset enabled).			

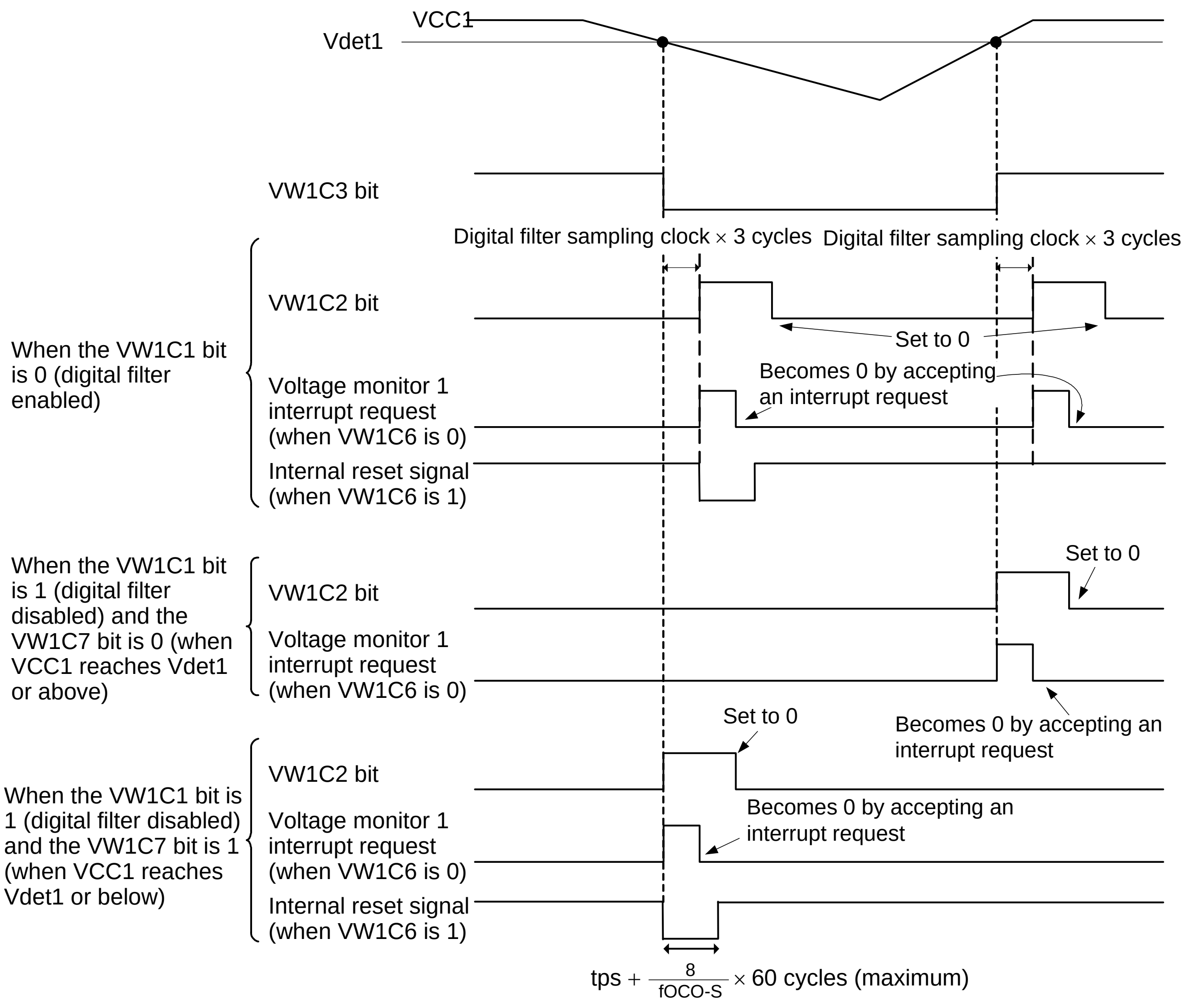
Notes:

1. Set the VW1C7 bit to 1 (when VCC1 reaches Vdet1 or below) for the voltage monitor 1 reset.
2. When the VW1C0 bit is 0, steps 5, 6, and 7 can be executed simultaneously (with one instruction).
3. If above setting is performed while voltage monitor 1 interrupt/reset is disabled (VW1C0 bit in the VW1C register is 0, VC26 bit in the VCR2 register is 0) and VCC1 < Vdet1 (or VCC1 > Vdet1) is detected before enabling voltage monitor 1 interrupt/reset (step 11), an interrupt does not occur. When VCC1 < Vdet1 (or VCC1 > Vdet1) is detected while executing steps 9 to 11, the VW1C2 bit becomes 1.
   When using this result detected between steps 9 and 11, read the VW1C2 bit after step 11. If the bit is 1, execute the process to be performed after detecting the VCC1 < Vdet1 (or VCC1 > Vdet1).
   When ignoring the result detected between steps 9 and 11, set the VW1C2 bit to 0 after step 11.

When using voltage monitor 1 interrupt or voltage monitor 1 reset to exit stop mode, set the VW1C1 bit in the VW1C register to 1 (digital filter disabled).

When voltage monitor 1 reset is generated, the LVD1R bit in the RSTFR register becomes 1 (voltage monitor 1 reset detected). Refer to 6.4.5 “Voltage Monitor 1 Reset” for status after reset.

Figure 7.6 shows Voltage Monitor 1 Interrupt/Reset Operation Example.


VCC1
Vdet1
VW1C3 bit
Digital filter sampling clock × 3 cycles
Digital filter sampling clock × 3 cycles
When the VW1C1 bit is 0 (digital filter enabled)
VW1C2 bit
Set to 0
Becomes 0 by accepting an interrupt request
Voltage monitor 1 interrupt request (when VW1C6 is 0)
Internal reset signal (when VW1C6 is 1)
When the VW1C1 bit is 1 (digital filter disabled) and the VW1C7 bit is 0 (when VCC1 reaches Vdet1 or above)
VW1C2 bit
Set to 0
Voltage monitor 1 interrupt request (when VW1C6 is 0)
Becomes 0 by accepting an interrupt request
When the VW1C1 bit is 1 (digital filter disabled) and the VW1C7 bit is 1 (when VCC1 reaches Vdet1 or below)
VW1C2 bit
Set to 0
Voltage monitor 1 interrupt request (when VW1C6 is 0)
Becomes 0 by accepting an interrupt request
Internal reset signal (when VW1C6 is 1)
tps + $\frac{8}{\text{fOCO-S}}$ × 60 cycles (maximum)

VW1C1, VW1C2, VW1C3, VW1C6, VW1C7: Bits in the VW1C register

The above diagram assumes the following:

- The VC26 bit in the VCR2 register is 1 (voltage detector 1 enabled)
- The VW1C0 bit in the VW1C register is 1 (voltage monitor 1 interrupt/reset enabled)

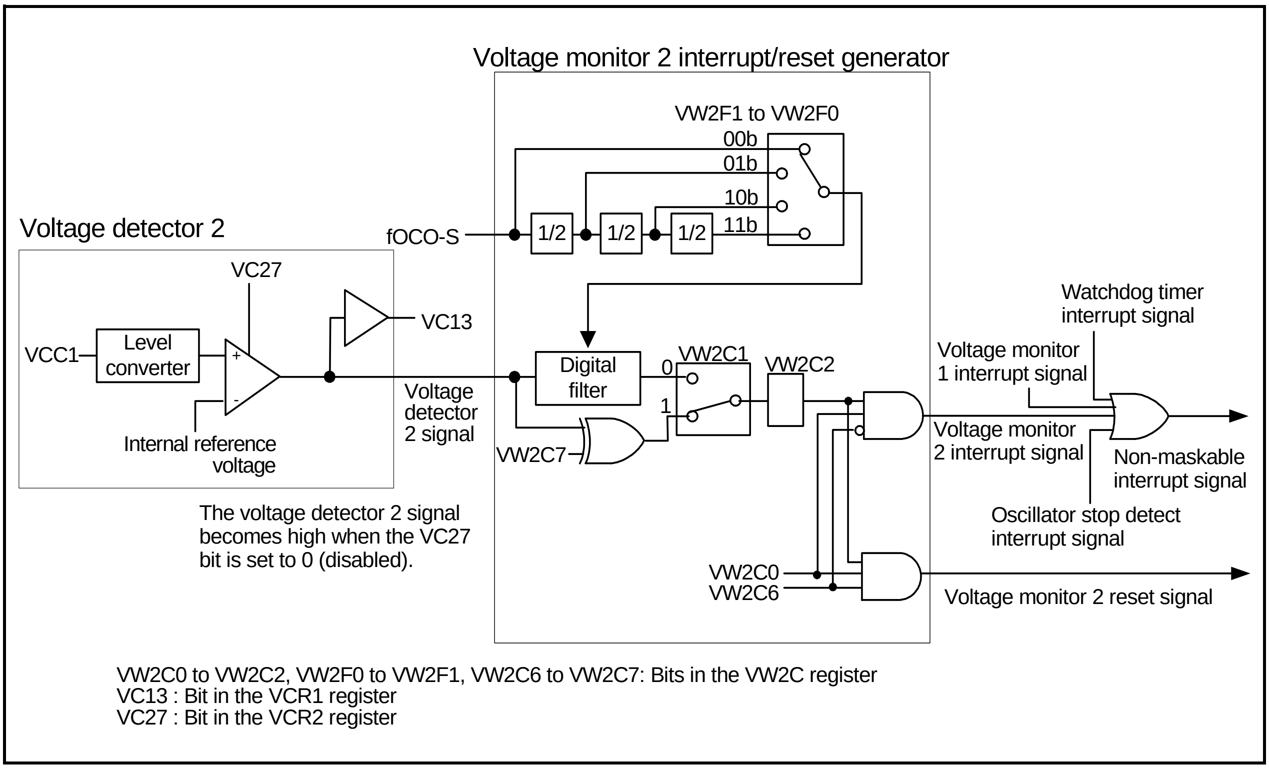
Note:

1. When not using the voltage monitor 0 reset, operate at recommended operation condition VCC1.

Figure 7.6 Voltage Monitor 1 Interrupt/Reset Operation Example

7.4.4 Voltage Detector 2

When the VW12E bit in the VWCE register is 1 (voltage monitors 1 and 2 enabled) and the VC27 bit in the VCR2 register is 1 (voltage detector 2 enabled), voltage detector 2 monitors the voltage applied to the VCC1 pin and detects whether the voltage rises through or falls through Vdet2.


Voltage monitor 2 interrupt/reset generator
VW2F1 to VW2F0
00b
01b
10b
11b
fOCO-S
1/2
1/2
1/2
Voltage detector 2
VC27
VCC1
Level converter
+
-
Internal reference voltage
VC13
Voltage detector 2 signal
Digital filter
0
1
VW2C1
VW2C2
VW2C7
Watchdog timer interrupt signal
Voltage monitor 1 interrupt signal
Voltage monitor 2 interrupt signal
Non-maskable interrupt signal
Oscillator stop detect interrupt signal
VW2C0
VW2C6
Voltage monitor 2 reset signal

The voltage detector 2 signal becomes high when the VC27 bit is set to 0 (disabled).

VW2C0 to VW2C2, VW2F0 to VW2F1, VW2C6 to VW2C7: Bits in the VW2C register
VC13 : Bit in the VCR1 register
VC27 : Bit in the VCR2 register

Figure 7.7 Voltage Monitor 2 Interrupt/Reset Generator

7.4.4.1 Monitoring Vdet2

Set the VW12E bit in the VWCE register to 1 (voltage monitors 1 and 2 enabled) and the VC27 bit in the VCR2 register to 1 (voltage detector 2 enabled). Vdet2 can be monitored using the VC13 bit in the VCR1 register after td(E-A) elapses.

7.4.4.2 Voltage Monitor 2 Interrupt and Voltage Monitor 2 Reset

Table 7.8 lists Procedure for Setting Voltage Monitor 2 Interrupt/Reset Related Bits.

Table 7.8 Procedure for Setting Voltage Monitor 2 Interrupt/Reset Related Bits

<table>
<tr><th rowspan="2">Step</th><th colspan="2">When Using the Digital Filter</th><th colspan="2">When Not Using the Digital Filter</th></tr>
<tr><th>Voltage monitor 2 interrupt</th><th>Voltage monitor 2 reset</th><th>Voltage monitor 2 interrupt</th><th>Voltage monitor 2 reset</th></tr>
<tr><td>1</td><td colspan="4">Set the VW12E bit in the VWCE register to 1 (voltage monitors 1 and 2 enabled).</td></tr>
<tr><td>2</td><td colspan="4">Set the VC27 bit in the VCR2 register to 1 (voltage detector 2 enabled).</td></tr>
<tr><td>3</td><td colspan="4">Wait for td(E-A).</td></tr>
<tr><td>4</td><td colspan="2">Set bits VW2F0 to VW2F1 in the VW2C register to select the digital filter sampling clock.</td><td colspan="2">Set the VW2C7 bit in the VW2C register to select the timing of the interrupt and reset request. [1]</td></tr>
<tr><td>5 [2]</td><td colspan="2">Set the VW2C1 bit in the VW2C register to 0 (digital filter enabled).</td><td colspan="2">Set the VW2C1 bit in the VW2C register to 1 (digital filter disabled).</td></tr>
<tr><td>6 [2]</td><td>Set the VW2C6 bit in the VW2C register to 0 (voltage monitor 2 interrupt).</td><td>Set the VW2C6 bit in the VW2C register to 1 (voltage monitor 2 reset).</td><td>Set the VW2C6 bit in the VW2C register to 0 (voltage monitor 2 interrupt).</td><td>Set the VW2C6 bit in the VW2C register to 1 (voltage monitor 2 reset).</td></tr>
<tr><td>7</td><td colspan="4">Set the VW2C2 bit in the VW2C register to 0 (Vdet2 passage not detected).</td></tr>
<tr><td>8</td><td colspan="2">Set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on)</td><td colspan="2">-</td></tr>
<tr><td>9</td><td colspan="2">Wait for digital filter sampling clock x 3 cycles.</td><td colspan="2">- (no wait time)</td></tr>
<tr><td>10</td><td colspan="4">Set the VW2C0 bit in the VW2C register to 1 (voltage monitor 2 interrupt/reset enabled).</td></tr>
</table>

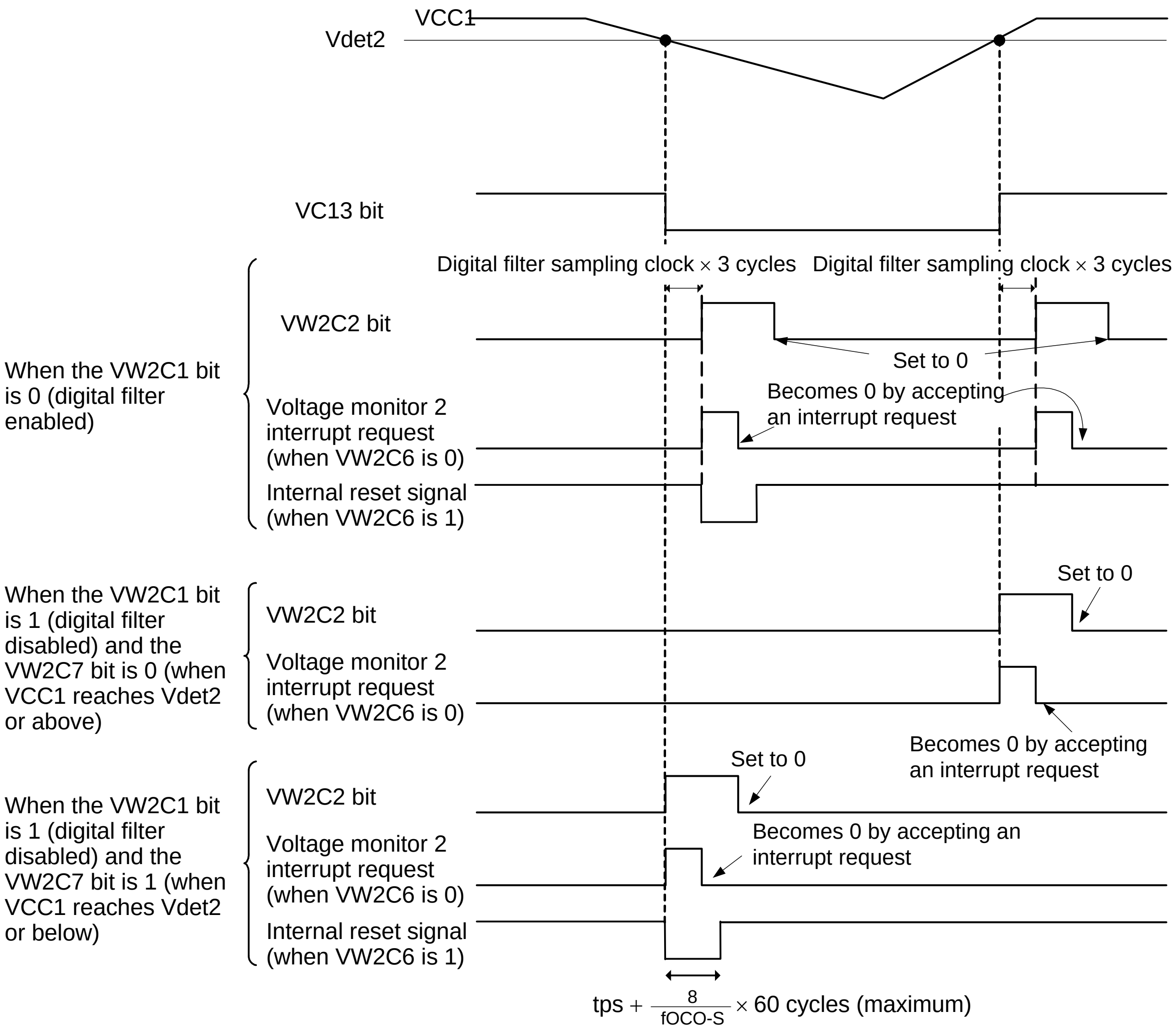
Notes:

1. Set the VW2C7 bit to 1 (when VCC1 reaches Vdet2 or below) for the voltage monitor 2 reset.
2. When the VW2C0 bit is 0, steps 4, 5, and 6 can be executed simultaneously (with one instruction).
3. If the above settings are performed while the voltage monitor 2 interrupt/reset is disabled (VW2C0 bit in the VW2C register is 0, VC27 bit in the VCR2 register is 0), and VCC1 < Vdet2 (or VCC1 > Vdet2) is detected before enabling the voltage monitor 2 interrupt/reset (step 10), an interrupt is not generated. When VCC1 < Vdet2 (or VCC1 > Vdet2) is detected while executing steps 8 to 10, the VW2C2 bit becomes 1.
   When using this result detected between steps 8 and 10, read the VW2C2 bit after step 10. If the bit is 1, execute the process to be performed after detecting the VCC1 < Vdet2 (or VCC1 > Vdet2).
   When ignoring the result detected between steps 8 and 10, set the VW2C2 bit to 0 after step 10.

When using voltage monitor 2 interrupt or voltage monitor 2 reset to exit stop mode, set the VW2C1 bit in the VW2C register to 1 (digital filter disabled).

When voltage monitor 2 reset is generated, the LVD2R bit in the RSTFR register is automatically becomes 1 (voltage monitor 2 reset detected). Refer to 6.4.6 “Voltage Monitor 2 Reset” for status after reset.

Figure 7.8 shows Voltage Monitor 2 Interrupt/Reset Operation Example.


VCC1
Vdet2
VC13 bit
Digital filter sampling clock × 3 cycles
Digital filter sampling clock × 3 cycles
When the VW2C1 bit is 0 (digital filter enabled)
VW2C2 bit
Set to 0
Voltage monitor 2 interrupt request (when VW2C6 is 0)
Becomes 0 by accepting an interrupt request
Internal reset signal (when VW2C6 is 1)
When the VW2C1 bit is 1 (digital filter disabled) and the VW2C7 bit is 0 (when VCC1 reaches Vdet2 or above)
VW2C2 bit
Set to 0
Voltage monitor 2 interrupt request (when VW2C6 is 0)
Becomes 0 by accepting an interrupt request
When the VW2C1 bit is 1 (digital filter disabled) and the VW2C7 bit is 1 (when VCC1 reaches Vdet2 or below)
VW2C2 bit
Set to 0
Voltage monitor 2 interrupt request (when VW2C6 is 0)
Becomes 0 by accepting an interrupt request
Internal reset signal (when VW2C6 is 1)
tps + $\frac{8}{fOCO\text{-}S}$ × 60 cycles (maximum)

VC13: Bit in the VCR1 register
VW2C1, VW2C2, VW2C6, VW2C7: Bits in the VW2C register

The above diagram assumes the following:

- The VC27 bit in the VCR2 register is 1 (voltage detector 2 enabled).
- The VW2C0 bit in the VW2C register is 1 (voltage monitor 2 interrupt/reset enabled).

Note:

1. When not using the voltage monitor 0 reset, operate at recommended operating condition VCC1.

Figure 7.8 Voltage Monitor 2 Interrupt/Reset Operation Example

7.5 Interrupts

The voltage monitor 1 interrupt and voltage monitor 2 interrupt is a non-maskable interrupt.

The watchdog timer interrupt, oscillator stop/restart detect interrupt, voltage monitor 1 interrupt, and voltage monitor 2 interrupt share the same vector. When using some functions together, read the detect flags of the events in an interrupt processing program, and determine the source of the interrupt.

The detect flag for voltage monitor 1 is the VW1C2 bit in the VW1C register, and the detect flag for voltage monitor 2 is the VW2C2 bit in the VW2C register. After the interrupt source is determined, set bits VW1C2 and VW2C2 to 0 (not detected).

8. Clock Generator

8.1 Introduction

The clock generator generates operating clocks for the CPU and peripheral functions. The following circuits are incorporated to generate the system clock signals.

- Main clock oscillator
- PLL frequency synthesizer
- 40 MHz on-chip oscillator
- 125 kHz on-chip oscillator
- Sub clock oscillator

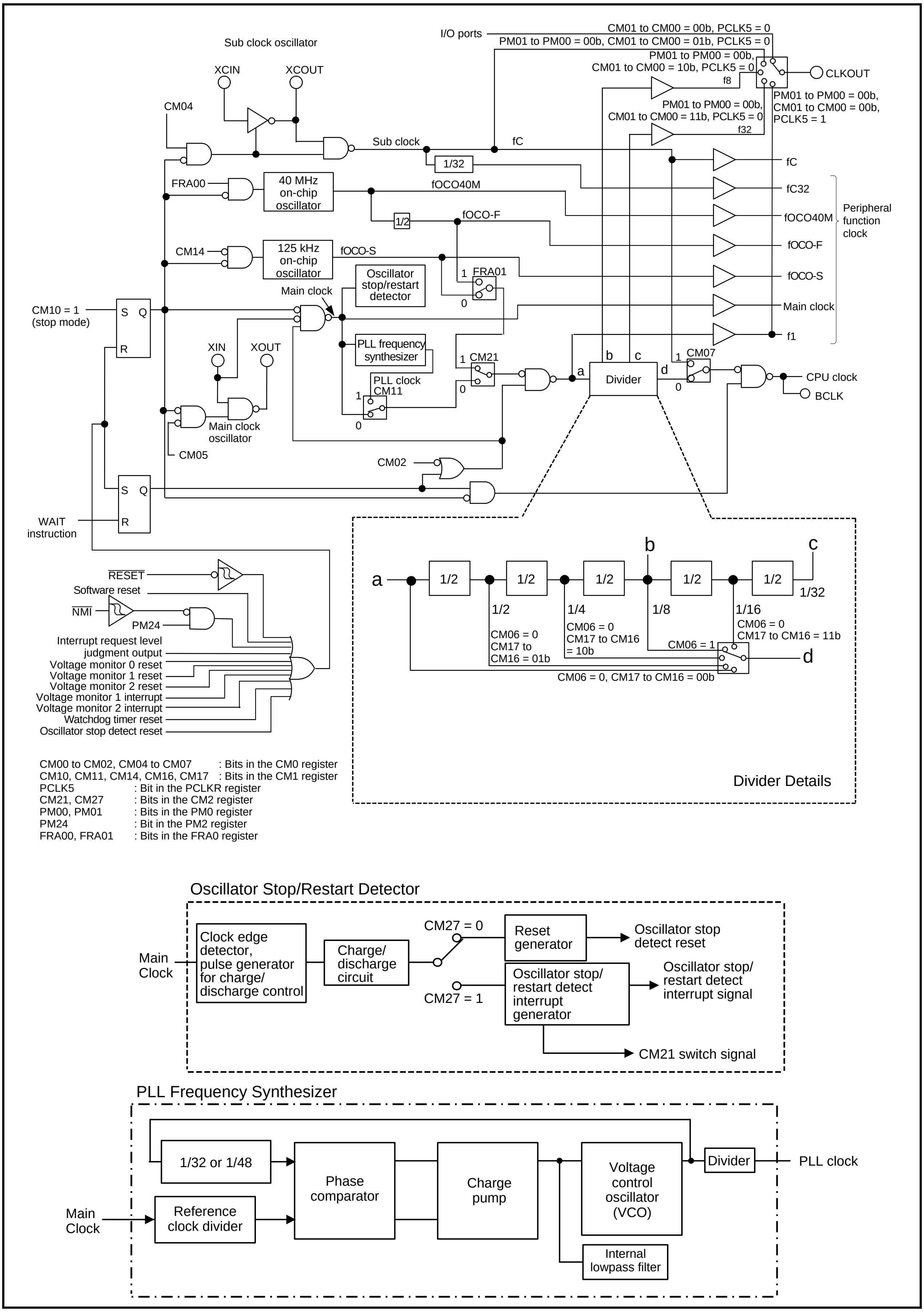
Table 8.1 lists the specifications of the clock generator, and Figure 8.1 shows the block diagram of system clock generator.

Table 8.1 Clock Generator Specifications

Item	Main Clock Oscillator	PLL Frequency Synthesizer	On-Chip Oscillator		Sub Clock Oscillator
			40 MHz on-chip oscillator	125 kHz on-chip oscillator	
Application	• CPU clock source • Peripheral function clock source	• CPU clock source • Peripheral function clock source	• CPU clock source • Peripheral function clock source • CPU and peripheral function clock sources when the main clock stops oscillating	• CPU clock source • Peripheral function clock source • CPU and peripheral function clock sources when the main clock stops oscillating • Watchdog timer count source when the CPU clock is stopped	• CPU clock source • Peripheral function clock source
Clock frequency	f(XIN)	f(PLL)	fOCO40M	fOCO-S	f(XCIN)
Connectable oscillators	• Ceramic resonator • Crystal	- (see note 1)	-	-	Crystal
Pins connecting to oscillator	XIN, XOUT	- (see note 1)	-	-	XCIN, XCOUT
Oscillator start/ stop function	Enabled	Enabled	Enabled	Enabled	Enabled
Oscillator status after reset	Oscillating	Stopped	Stopped	Oscillating	Stopped
Other	An externally generated clock can be input.	- (see note 1)	-	-	An externally generated clock can be input.

Note:

1. The PLL frequency synthesizer uses the main clock oscillator as a reference clock source. The items above are based on the main clock oscillator.



CM00 to CM02, CM04 to CM07 : Bits in the CM0 register
CM10, CM11, CM14, CM16, CM17 : Bits in the CM1 register
PCLK5 : Bit in the PCLKR register
CM21, CM27 : Bits in the CM2 register
PM00, PM01 : Bits in the PM0 register
PM24 : Bit in the PM2 register
FRA00, FRA01 : Bits in the FRA0 register

Figure 8.1 System Clock Generator

Table 8.2 I/O Pins

Pin Name	I/O	Function
XIN	Input	I/O pins for the main clock oscillator
XOUT	Output	
XCIN	Input (1)	I/O pins for a sub clock oscillator
XCOUT	Output (1)	
CLKOUT	Output	Clock output (in single-chip mode)
BCLK	Output	BCLK output (in memory expansion and microprocessor modes)

Note:

1. Set the port direction bits which share pins to 0 (input mode).

8.2 Registers

Table 8.3 Registers

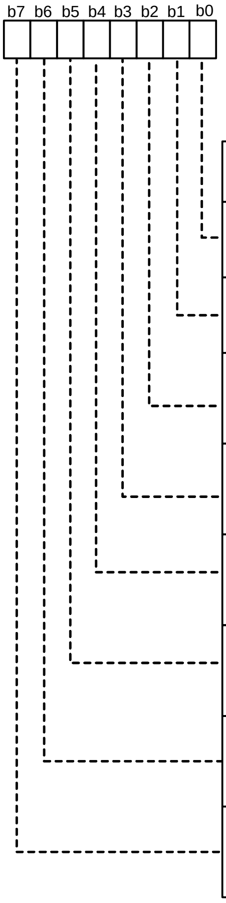
Address	Register	Symbol	Reset Value
0004h	Processor Mode Register 0	PM0	0000 0000b (CNVSS pin is low) 0000 0011b (CNVSS pin is high)
0006h	System Clock Control Register 0	CM0	0100 1000b
0007h	System Clock Control Register 1	CM1	0010 0000b
000Ch	Oscillation Stop Detection Register	CM2	0X00 0010b (1)
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
001Ch	PLL Control Register 0	PLC0	0X01 X010b
001Eh	Processor Mode Register 2	PM2	XX00 0X01b
0022h	40 MHz On-Chip Oscillator Control Register 0	FRA0	XXXX XX00b

Note:

1. Bits CM20, CM21, and CM27 remain unchanged at oscillator stop detect reset.

8.2.1 Processor Mode Register 0 (PM0)

Processor Mode Register 0



Symbol	Address	Reset Value
PM0	0004h	0000 0000b (CNVSS pin is low) 0000 0011b (CNVSS pin is high)

Bit Symbol	Bit Name	Function	RW
PM00	Processor mode bit	b1 b0 0 0 : Single-chip mode 0 1 : Memory expansion mode 1 0 : Do not set 1 1 : Microprocessor mode	RW
PM01			RW
PM02	R/W mode select bit	0 : $\overline{RD}$, $\overline{BHE}$, $\overline{WR}$ 1 : $\overline{RD}$, $\overline{WRH}$, $\overline{WRL}$	RW
PM03	Software reset bit	Setting this bit to 1 resets the MCU. When read, the read value is 0.	RW
PM04	Multiplexed bus space select bit	b5 b4 0 0 : Multiplexed bus is not used (separate bus in the entire $\overline{CS}$ space) 0 1 : Allocated to $\overline{CS2}$ space 1 0 : Allocated to $\overline{CS1}$ space 1 1 : Allocated to the entire $\overline{CS}$ space	RW
PM05			RW
PM06	Port P4_0 to P4_3 function select bit	0 : Address output 1 : Port function (address is not output)	RW
PM07	BCLK output disable bit	0 : BCLK is output 1 : BCLK is not output (pin becomes high-impedance)	RW

Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register. Bits PM01 to PM00 do not change at software reset, watchdog timer reset, oscillator stop detect reset, voltage monitor 1 reset, or voltage monitor 2 reset.

Bits PM02, PM05 to PM04, PM06, and PM07 are enabled when bits PM01 to PM00 are 01b (memory expansion mode) or 11b (microprocessor mode).

PM07 (BCLK output disable bit) (b7)

This bit is enabled in memory expansion mode and microprocessor mode. A clock with the same frequency as the CPU clock can be output as the BCLK signal from the BCLK pin.

8.2.2 System Clock Control Register 0 (CM0)

System Clock Control Register 0

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
CM0	0006h	0100 1000b

Bit Symbol	Bit Name	Function	RW
CM00	Clock output function select bit (enabled in single-chip mode only)	b1 b0 0 0 : I/O port 0 1 : Output fC 1 0 : Output f8 1 1 : Output f32	RW
CM01			
CM02	Wait mode peripheral function clock stop bit	0 : Peripheral function clock f1 does not stop in wait mode 1 : Peripheral function clock f1 stops in wait mode	RW
CM03	XCIN-XCOUT drive capacity select bit	0 : Low 1 : High	RW
CM04	Port XC select bit	0 : I/O port 1 : XCIN-XCOUT oscillation function	RW
CM05	Main clock stop bit	0 : On 1 : Off	RW
CM06	Main clock division select bit 0	0 : Bits CM16 and CM17 in the CM1 register enabled 1 : Divide-by-8 mode	RW
CM07	System clock select bit	0 : Main clock, PLL clock, or on-chip oscillator clock 1 : Sub clock	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.
See Table 9.3 “Clock-Related Bit Setting and Modes” to select a clock and mode.

CM01 and CM00 (Clock output function select bit) (b1-b0)

The CLKOUT pin outputs can be selected. These bits are enabled when the PCLK5 bit in the PCLKR register is set to 0 in single-chip mode. When the PCLK5 bit is 1, set bits CM01 and CM00 to 00b. Table 8.4 lists CLKOUT Pin Functions in Single-Chip Mode.

Table 8.4 CLKOUT Pin Functions in Single-Chip Mode

PCLKR Register	CM0 Register		CLKOUT Pin Output
PCLK5 bit	CM01 bit	CM00 bit	
0	0	0	I/O port
0	0	1	fC is output
0	1	0	f8 is output
0	1	1	f32 is output
1	0	0	f1 is output

Only set the combinations listed above.

CM02 (Wait mode peripheral function clock stop bit) (b2)

This bit is used to stop the f1 peripheral function clock in wait mode. fC, fC32, fOCO-S, fOCO-F, and fOCO40M are not affected by the CM02 bit.

When the PM21 bit in the PM2 register is 1 (clock change disabled), the CM02 bit remains unchanged even when written to.

CM03 (XCIN-XCOUT drive capacity select Bit) (b3)

Setting the driving capacity to low while sub clock oscillation is stable reduces power consumption.

The CM03 bit becomes 1 (high) while the CM04 bit is 0 (P8_6 and P8_7 are I/O ports), or when entering stop mode.

CM04 (Port XC select bit) (b4)

The CM03 bit becomes 1 (high) while the CM04 bit is 0 (P8_6 and P8_7 are I/O ports).

CM05 (Main clock stop bit) (b5)

This bit is used to stop the main clock. The main clock is allowed to stop in the following cases.

- Entering low power mode
- Entering 125 kHz on-chip oscillator low power mode
- Stopping the main clock in 40 MHz on-chip oscillator mode

This bit cannot be used to detect if the main clock is stopped or not. Refer to 8.7 “Oscillator Stop/Restart Detect Function” for details on main clock stop detection.

When the PM21 bit in the PM2 register is 1 (clock change disabled), this bit remains unchanged even when written to.

CM06 (Main clock division select bit) (b6)

The CM06 bit becomes 1 (divide-by-8 mode) under the following conditions:

- When entering stop mode
- When the CM21 bit in the CM2 register is 0 (main clock or PLL clock) and the CM05 bit is 1 (main clock off)

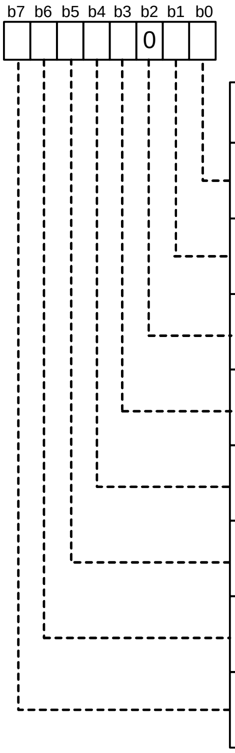
CM07 (System clock select bit) (b7)

The CPU clock source and the peripheral function clock f1 depend on combinations of the bit status of the CM07 bit, the CM11 bit in the CM1 register, and the CM21 bit in the CM2 register. When the CM07 bit is 0 (main clock, PLL clock or on-chip oscillator clock used as CPU clock), the CPU clock source and the peripheral function clock f1 can be selected by combinations of the bit status of the CM11 bit and the CM21 bit. When the CM07 bit is 1 (sub clock used as CPU clock), the CPU clock source is fC, and the peripheral function clock f1 can be selected by combinations of the bit status of bits CM11 and CM21.

When setting the PM21 bit in the PM2 register to 1 (clock change disabled), set the CM07 bit to 0 (main clock) before setting the PM21 bit to 1. When the PM21 bit is set to 1, this bit remains unchanged even when written to.

8.2.3 System Clock Control Register 1 (CM1)

System Clock Control Register 1



Symbol	Address	Reset Value
CM1	0007h	0010 0000b

Bit Symbol	Bit Name	Function	RW
CM10	All clock stop control bit	0 : Clock on 1 : All clocks off (stop mode)	RW
CM11	System clock select bit 1	0 : Main clock 1 : PLL clock	RW
— (b2)	Reserved bit	Set to 0	RW
CM13	XIN-XOUT feedback resistor select bit	0 : Internal feedback resistor connected 1 : Internal feedback resistor not connected	RW
CM14	125 kHz on-chip oscillator stop bit	0 : 125 kHz on-chip oscillator on 1 : 125 kHz on-chip oscillator off	RW
CM15	XIN-XOUT drive capacity select bit	0 : Low 1 : High	RW
CM16	Main clock division select bit 1	b7 b6 0 0 : No division mode 0 1 : Divide-by-2 mode 1 0 : Divide-by-4 mode 1 1 : Divide-by-16 mode	RW
CM17			

Rewrite the CM1 register after setting the PRC0 bit in the PRCR register to 1 (write enabled).
See Table 9.3 “Clock-Related Bit Setting and Modes” to select a clock and a mode.

CM10 (All clock stop control bit) (b0)

When the CM11 bit is 1 (PLL clock), or the CM20 bit in the CM2 register is 1 (oscillator stop/restart detect function enabled), do not set the CM10 bit to 1.

In the following cases, this bit remains unchanged even when written to (The MCU does not enter stop mode).

- The PM21 bit in the PM2 register is 1 (clock change disabled).
- The CSPRO bit in the CSPR register is 1 (watchdog timer count source protection mode enabled).
- The PLC07 bit in the PLC0 register is 1 (PLL on).
- A low is input to the $\overline{\text{NMI}}$ pin.

CM11 (System clock select bit) (b1)

The CM11 bit is valid when the CM21 bit in the CM2 register is set to 0 (main clock or PLL clock).

The CPU clock source and the peripheral function clock f1 can be selected by the CM11 bit when the CM07 bit is 0 (main clock, PLL clock, or on-chip oscillator clock used as CPU clock). The peripheral function clock f1 can be selected by the CM11 bit when the CM07 bit is 1 (sub clock used as CPU clock).

When the PM21 bit in the PM2 register is 1 (clock change disabled), the CM11 bit remains unchanged even when written to.

CM13 (XIN-XOUT feedback resistor select bit) (b3)

The CM13 bit can be used when the main clock is not used at all, or when the externally generated clock is supplied to the XIN pin. When connecting a ceramic resonator or crystal between pins XIN and XOUT, set the CM13 bit to 0 (internal feedback resistor connected). Do not set this bit to 1.
When the CM10 bit is 1 (stop mode), the feedback resistor is not connected regardless of the CM13 bit value.

CM14 (125 kHz on-chip oscillator stop bit) (b4)

The CM14 bit can be set to 1 (125 kHz on-chip oscillator off) when the CM21 bit is 0 (main clock or PLL clock). When the CM21 bit is set to 1 (on-chip oscillator clock), the CM14 bit is automatically set to 0 (125 kHz on-chip oscillator on) and remains unchanged even when 1 is written to this bit. Note that the 125 kHz on-chip oscillator does not stop.
When the CSPRO bit in the CSPR register is 1 (watchdog timer count source protection mode), the CM14 bit is automatically set to 0 (125 kHz on-chip oscillator on) and remains unchanged even when 1 is written to this bit. Note that the 125 kHz on-chip oscillator does not stop.

CM15 (XIN-XOUT drive capacity select bit) (b5)

In the following cases, the CM15 bit is fixed as 1 (drive capacity high):

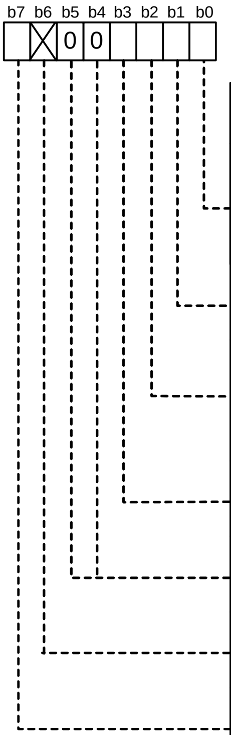
- Entering stop mode.
- The CM21 bit in the CM2 register is 0 (main clock or PLL clock) and the CM05 bit in the CM0 register is set to 1 (main clock stopped).

CM17 and CM16 (Main clock division select bit 1) (b7-b6)

Bits CM17 and CM16 are enabled when the CM06 bit is 0 (bits CM17 and CM16 enabled).

8.2.4 Oscillation Stop Detection Register (CM2)

Oscillation Stop Detection Register



Symbol	Address	Reset Value
CM2	000Ch	0X00 0010b

Bit Symbol	Bit Name	Function	RW
CM20	Oscillator stop/restart detect enable bit	0: Oscillator stop/restart detect function disabled 1: Oscillator stop/restart detect function enabled	RW
CM21	System clock select bit 2	0: Main clock or PLL clock 1: On-chip oscillator clock	RW
CM22	Oscillator stop/restart detect flag	0: Main clock stop/restart not detected 1: Main clock stop/restart detected	RW
CM23	XIN monitor flag	0: Main clock oscillating 1: Main clock stopped	RO
— (b5-b4)	Reserved bits	Set to 0	RW
— (b6)	No register bit. If necessary, set to 0. The read value is undefined.		—
CM27	Operation select bit (when an oscillator stop/restart is detected)	0: Oscillator stop detect reset 1: Oscillator stop/restart detect interrupt	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.
Bits CM20, CM21, and CM27 do not change at oscillator stop detect reset.
See Table 9.3 “Clock-Related Bit Setting and Modes” to select a clock and a mode.

CM20 (Oscillator stop/restart detect enable bit) (b0)

Set the CM20 bit to 0 (oscillator stop/restart detect function disabled) to enter stop mode. Set the CM20 bit back to 1 (enabled) after exiting stop mode.

When the PM21 bit in the PM2 register is 1 (clock change disabled), the CM20 bit remains unchanged even when being written.

CM21 (System clock select bit 2) (b1)

When the CM07 bit is 0 (main clock, PLL clock, or on-chip oscillator clock used as CPU clock source), the CPU clock source and the peripheral function clock f1 can be selected by the CM21 bit. When the CM07 bit is 1 (sub clock used as CPU clock source), the peripheral function clock f1 can be selected by the CM21 bit.

To set the CM21 bit to 1 (on-chip oscillator clock), set the FRA01 bit in the FRA0 register to select either the 125 kHz on-chip oscillator, or the 40 MHz on-chip oscillator.

When the CM20 bit is 1 (oscillator stop/restart detect function enabled) and the CM23 bit is 1 (main clock stopped), do not set the CM21 bit to 0 (main clock or PLL clock).

When the CM20 bit is 1 (oscillator stop/restart detect function enabled), the CM27 bit is 1 (oscillator stop/restart detect interrupt), and the main clock is used as a CPU clock source, the CM21 bit becomes 1 (on-chip oscillator clock) if the main clock stop is detected. Refer to 8.7 “Oscillator Stop/Restart Detect Function” for details.

CM22 (Oscillator stop/restart detect flag) (b2)

Condition to become 0:

- Set it to 0.

Conditions to become 1:

- Main clock stop is detected.
- Main clock restart is detected.

(The CM22 bit remains unchanged even if 1 is written.)

When the CM22 bit changes state from 0 to 1, an oscillator stop/restart detect interrupt is generated. Use this bit in an interrupt routine to determine the factors of interrupts between the oscillator stop/restart detect interrupt and other interrupts.

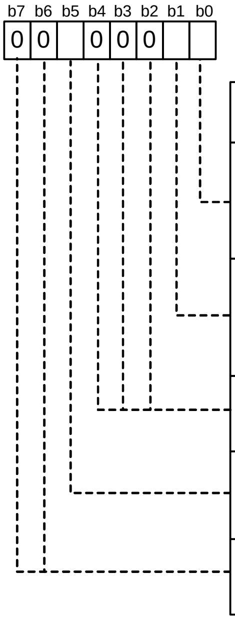
When the CM22 bit is 1 and oscillator stop or restart is detected, an oscillator stop/restart detect interrupt is not generated. The bit does not become 0 even if an oscillator stop/restart detect interrupt request is accepted.

CM23 (XIN monitor flag) (b3)

Determine the main clock status by reading the CM23 bit several times in the oscillator stop/restart detect interrupt routine.

8.2.5 Peripheral Clock Select Register (PCLKR)

Peripheral Clock Select Register



Symbol	Address	Reset Value
PCLKR	0012h	0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A and B clock select bit (clock source for timers A and B, the dead time timer, and multi-master I^{2}C-bus interface)	0: f2TIMAB/f2IIC 1: f1TIMAB/f1IIC	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART2, UART5 to UART7, SI/O3, and SI/O4)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function expansion bit (enabled in single-chip mode)	0: Selected by setting bits CM01 to CM00 in the CM0 register 1: Output f1	RW
— (b7-b6)	Reserved bits	Set to 0	RW

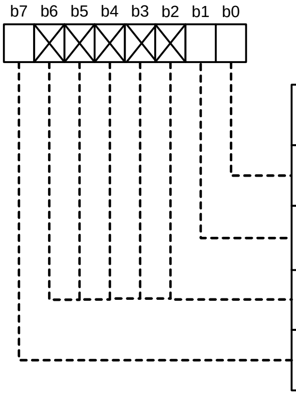
Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.

PCLK5 (Clock output function extension bit) (b5)

The PCLK5 bit is enabled in single-chip mode. Output from the CLKOUT pin is selectable. When the PCLK5 bit is 1, set bits CM01 and CM00 to 00b. See Table 8.4 “CLKOUT Pin Functions in Single-Chip Mode”.

8.2.6 Peripheral Clock Stop Register 1 (PCLKSTP1)

Peripheral Clock Stop Register 1



Symbol	Address	Reset Value
PCLKSTP1	0016h	0XXX XX00b

Bit Symbol	Bit Name	Function	RW
PCKSTP1A	Peripheral clock stop bit (other than timer A, timer B)	0: f1 provide enabled 1: f1 provide disabled	RW
PCKSTP11	Timer peripheral clock stop bit (timer A, timer B)	0: f1 provide enabled 1: f1 provide disabled	RW
— (b6-b2)	No register bit. If necessary, set to 0. The read value is undefined.		—
PCKSTP17	Timer clock source select bit (timer A, timer B)	0: f1 1: Main clock	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.

PCKSTP1A (Peripheral clock stop bit) (b0)

When using f1 for the clock source for the following peripherals, set the PCKSTP1A bit to 0 (f1 provide enabled):

Real-time clock, pulse width modulator, remote control signal receiver,
serial interface UART0 to UART2, UART5 to UART7, SI/O3, SI/O4
multi-master I^{2}C-bus interface, A/D converter

To change the PCKSTP1A bit from 1 (f1 provide disabled) to 0, use following procedure:

(1) Stop the peripherals listed above that use peripheral clock f1.
(2) Set the PCKSTP1A bit to 0.
(3) Set the registers for the peripherals again.

To change the clock source for the peripherals from fOCO-F or fOCO40M to f1, perform (1) and (2) above, and change the clock source from fOCO-F or fOCO40M to f1, then perform (3).

PCKSTP11 (Timer peripheral clock stop bit) (b1)

When using f1 or the main clock for the timer A and timer B count source, set the PCKSTP11 bit to 0 (f1 provide enabled).

To change the PCKSTP11 bit from 1 (f1 provide disabled) to 0, use following procedure:

(1) Stop timer A and timer B.
(2) Set the PCKSTP11 bit to 0.
(3) Set the registers for timer A and timer B again.

To change the timer A and timer B count source from fOCO-F to f1, perform (1) and (2) above, and set the TCDIV00 bit in the TCKDIVC0 register from 1 (fOCO-F) to 0 (f1), then perform (3).

PCKSTP17 (Timer clock source select bit) (b7)

Change the PCKSTP17 bit when all of the following conditions are met:

- Both f1 and the main clock are stably supplied.
- Both timer A and timer B are stopped.

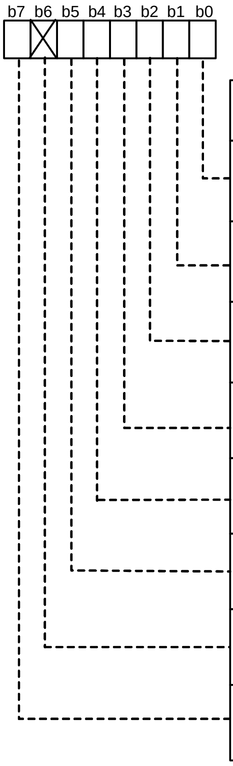
The PCKSTP17 bit is used for supplying the main clock to timer A and timer B.

When in PLL operating mode, high-speed mode, medium-speed mode, or wait mode, the main clock can be used for the timer A and timer B count source.

Do not use the main clock for the timer A and timer B count source in other normal operating modes (refer to 9.3 “Clock”).

8.2.7 PLL Control Register 0 (PLC0)

PLL Control Register 0



Symbol	Address	Reset Value
PLC0	001Ch	0X01 X010b

Bit Symbol	Bit Name	Function	RW
PLC00	PLL multiplying factor select bit	b2 b1 b0 0 0 0 : Do not set 0 0 1 : Multiply-by-2 0 1 0 : Multiply-by-4 0 1 1 : Multiply-by-6 1 0 0 : Multiply-by-8 1 0 1 : 1 1 0 : Do not set these values 1 1 1 :	RW
PLC01			RW
PLC02			RW
— (b3)	Reserved bit	The read value is undefined	RO
PLC04	Reference frequency counter set bit	b5 b4 0 0 : No division 0 1 : Divide-by-2 1 0 : Divide-by-4 1 1 : Do not set	RW
PLC05			RW
— (b6)	No register bit. If necessary, set to 0. The read value is undefined.		—
PLC07	Operation enable bit	0 : PLL off 1 : PLL on	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.

PLC02 to PLC00 (PLL multiplying factor select bit) (b2-b0)

Write to bits PLC00 to PLC02 when the PLC07 bit is 0 (PLL off).

When the PM21 bit in the PM2 register is 1 (clock change disabled), writing to bits PLC02 to PLC00 has no effect.

PLC05 and PLC04 (Reference frequency counter set bit) (b5-b4)

Write to bits PLC05 and PLC04 when the PLC07 bit is 0 (PLL off).

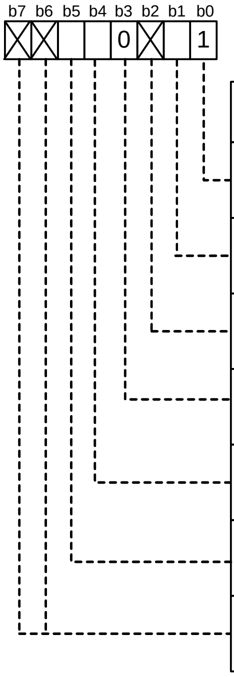
When the PM21 bit in the PM2 register is 1 (clock change disabled), writing to bits PLC05 and PLC04 has no effect.

PLC07 (Operation enable bit) (b7)

When the PM21 bit in the PM2 register is 1 (clock change disabled), writing to the PLC07 bit has no effect.

8.2.8 Processor Mode Register 2 (PM2)

Processor Mode Register 2



Symbol	Address	Reset Value
PM2	001Eh	XX00 0X01b

Bit Symbol	Bit Name	Function	RW
— (b0)	Reserved bit	Set to 1.	RW
PM21	System clock protection bit	0 : Clock is protected by PRCR register 1 : Clock change disabled	RW
— (b2)	No register bit. If necessary, set to 0. The read value is undefined.		—
— (b3)	Reserved bit	Set to 0	RW
PM24	$\overline{\text{NMI}}$ interrupt enable bit	0 : $\overline{\text{NMI}}$ interrupt disabled 1 : $\overline{\text{NMI}}$ interrupt enabled	RW
PM25	Peripheral clock fC provide bit	0 : Not provided 1 : Provided	RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is undefined.		—

Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register.

PM21 (System clock protection bit) (b1)

The PM21 bit is used to protect the CPU clock. (Refer to 8.6 “System Clock Protection Function”).
When the PM21 bit is set to 1, writing to the following bits has no effect:

- Bits CM02, CM05, and CM07 in the CM0 register
- Bits CM10 and CM11 in the CM1 register
- The CM20 bit in the CM2 register
- All bits in the PLC0 register

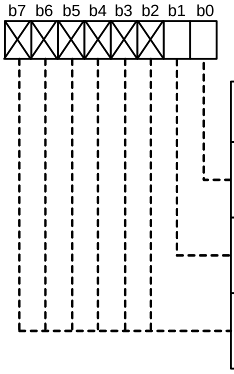
Do not execute the WAIT instruction when the PM21 bit is 1.
Once the PM21 bit is set to 1, it cannot be set to 0 by a program (writing 0 has no effect).

PM25 (Peripheral clock fC provide bit) (b5)

The PM25 bit provides fC to the real-time clock, CEC function, and remote control signal receiver. (See Figure 8.5 “Peripheral Function Clocks”.)

8.2.9 40 MHz On-Chip Oscillator Control Register 0 (FRA0)

40 MHz On-Chip Oscillator Control Register 0



Symbol	Address	Reset Value
FRA0	0022h	XXXX XX00b

Bit Symbol	Bit Name	Function	RW
FRA00	40 MHz on-chip oscillator start bit	0 : 40 MHz on-chip oscillator off 1 : 40 MHz on-chip oscillator on	RW
FRA01	On-chip oscillator select bit	0 : 125 kHz on-chip oscillator 1 : 40 MHz on-chip oscillator	RW
— (b7-b2)	No register bits. If necessary, set to 0. The read value is undefined.		—

Rewrite the FRA0 register after setting the PRC0 bit in the PRCR register to 1 (write enabled).
See Table 9.3 “Clock-Related Bit Setting and Modes” to select a clock and a mode.

FRA00 (40 MHz on-chip oscillator start bit) (b0)

When using an oscillator stop/restart detect interrupt, do not set the FRA00 bit to 0 (40 MHz on-chip oscillator off) while the FRA01 bit to 1 (40 MHz on-chip oscillator), and vice versa.

FRA01 (On-chip oscillator select bit) (b1)

Change the FRA01 bit if the both of the following conditions are met:

- When the FRA00 bit is 1 (40 MHz on-chip oscillator on) and oscillation is stable
- When the CM14 bit in the CM1 register is 0 (125 kHz on-chip oscillator on) and oscillation is stable

When setting the FRA01 bit to 0 (125 kHz on-chip oscillator), do not set the FRA00 bit to 0 (40 MHz on-chip oscillator off) at the same time. Set the FRA00 bit to 0 after setting the FRA01 bit to 0.

8.3 Clocks Generated by Clock Generators

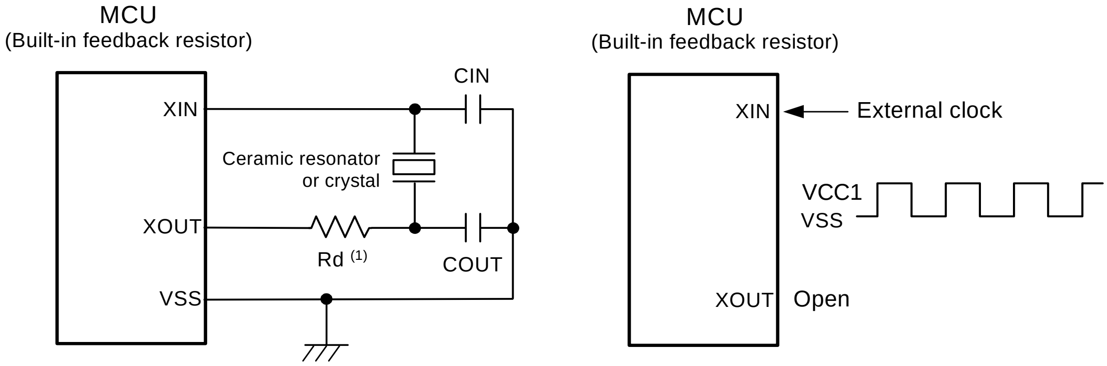
Clocks generated by the clock generators are described below.

8.3.1 Main Clock

This clock is supplied by the main clock oscillator and used as a clock source for the CPU and peripheral function clocks. After reset, the main clock is running, but is not used as a clock source for the CPU.

The main clock oscillator is configured by connecting a ceramic resonator or crystal between pins XIN and XOUT. The main clock oscillator contains a feedback resistor, which is disconnected from the oscillator in stop mode in order to reduce the amount of power consumed by the chip. The main clock oscillator may also be configured by feeding an externally generated clock to the XIN pin.

Figure 8.2 shows Main Clock Connection Example.



Note:
1. Insert a damping resistor if required. The resistance will vary depending on a crystal/ceramic resonator and the oscillation drive capacity setting. Use the value recommended by the manufacturer of crystal/ceramic resonator.
When the oscillation drive capacity is set to low, check if oscillation is stable in a low state. Also, place a feedback resistor between XIN and XOUT if the manufacturer recommends placing the resistor externally.

Figure 8.2 Main Clock Connection Example

The XOUT becomes high by setting the CM05 bit in the CM0 register to 1 (main clock oscillator turned off) after switching the clock source for the CPU clock to the sub clock (fC) or on-chip oscillator clock (fOCO-F, fOCO-S). In this case, the XIN is pulled high to the XOUT via the feedback resistor because the internal feedback resistor remains connected.

When the main clock oscillator is not used, setting the CM13 bit in the CM1 register to 1 enables to select the internal feedback resistor not connected.

Perform the following steps to start or stop the main clock. Refer to 8.2 “Registers” for details on register and bit access.

To start the main clock oscillation:

(1) Set the CM15 bit to 1 (drive capacity high) when a ceramic resonator or crystal is connected between pins XIN and XOUT.
(2) Set the CM05 bit to 0 (main clock oscillating).
(3) Wait until main clock oscillation stabilizes. (When using an external clock, input the external clock through the XIN pin.)

To stop the main clock oscillation,

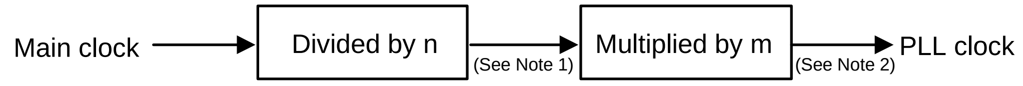
(1) Set the CM20 bit in the CM2 register to 0 (oscillator stop/restart detect function disabled).
(2) Set the CM05 bit to 1 (stop).
(3) Stop the external clock (when inputting the external clock through the XIN pin).

8.3.2 PLL Clock

PLL clock is generated by the PLL frequency synthesizer. This clock is used as the clock source for the CPU and peripheral function clocks.

After reset, the PLL frequency synthesizer is stopped.

PLL clock is a clock which divides the main clock by the selected values of bits PLC05 to PLC04 in the PLC0 register, and then multiplied by the selected values of bits PLC02 to PLC00. Set bits PLC05 and PLC04 to fit divided frequency between 2 MHz and 5 MHz. Figure 8.3 shows Relation between Main Clock and PLL Clock.



n: 1, 2, 4 (selected by setting bits PLC05 and PLC04 in the PLC0 register)
m: 2, 4, 6, 8 (selected by setting bits PLC02 to PLC00 in the PLC0 register)

Notes:
1. Set the frequency divided by n to between 2 MHz and 5 MHz.
2. Set the PLL clock frequency to be within the f(PLL) range.

Figure 8.3 Relation between Main Clock and PLL Clock

Table 8.5 Example Settings for PLL Clock Frequencies

Main Clock	Setting Value		PLL Clock
	Bits PLC05 to PLC04	Bits PLC02 to PLC00	
10 MHz	01b (divide-by-2)	010b (multiply-by-4)	20 MHz
5 MHz	00b (not divided)	010b (multiply-by-4)	
12 MHz	10b (divide-by-4)	100b (multiply-by-8)	24 MHz
6 MHz	01b (divide-by-2)	100b (multiply-by-8)	
16 MHz	10b (divide-by-4)	100b (multiply-by-8)	32 MHz
8 MHz	01b (divide-by-2)	100b (multiply-by-8)	

8.3.3 fOCO40M

fOCO40M is a 40 MHz clock (approx.) supplied by the 40 MHz on-chip oscillator. It is the clock source for ϕAD in the A/D converter.

Follow the steps below to start or stop the 40 MHz on-chip oscillator clock. Refer to 8.2 “Registers” for details on register and bit access.

40 MHz on-chip oscillator start

(1) Set the FRA00 bit in the FRA0 register to 1 (40 MHz on-chip oscillator on).

(2) Wait for tsu(fOCO40M).

40 MHz on-chip oscillator stop

(1) Set the FRA01 bit in the FRA0 register to 0 (125 MHz on-chip oscillator) (when the CM27 bit is 1 (oscillator stop/restart detect interrupt)).

(2) Set the FRA00 bit in the FRA0 register to 0 (40 MHz on-chip oscillator off).

8.3.4 fOCO-F

fOCO-F is a 40 MHz clock (approx.) supplied by the 40 MHz on-chip oscillator, and divided by 2. It is the clock source for the CPU and peripheral function clocks.

After reset, fOCO-F is stopped.

If the main clock stops oscillating and the FRA01 bit is 1 when the CM20 bit in the CM2 register is 1 (oscillator stop/restart detect function enabled), and the CM27 bit is 1 (oscillator stop/restart detect interrupt), fOCO-F is used as the clock source for the CPU.

Refer to 8.3.3 “fOCO40M” to start or stop the 40 MHz on-chip oscillator clock.

8.3.5 125 kHz On-Chip Oscillator Clock (fOCO-S)

This clock is approximately 125 kHz, and is supplied by the 125 kHz on-chip oscillator. It is used as the clock source for the CPU and peripheral function clocks. In addition, when the CSPRO bit in the CSPR register is 1 (count source protection mode enabled), this clock is used as the count source for the watchdog timer (refer to 15.4.2 “Count Source Protection Mode Enabled”).

After reset, fOCO-S divided by 8 becomes the CPU clock.

If the main clock stops oscillating and the FRA01 bit is 0, when the CM20 bit in the CM2 register is 1 (oscillator stop/restart detect function enabled) and the CM27 bit is 1 (oscillator stop/restart detect interrupt), the 125 kHz on-chip oscillator automatically starts operating and supplying the necessary clock for the MCU.

Follow the steps below to start or stop fOCO-S. Refer to 8.2 “Registers” for details on register and bit access.

To start fOCO-S:

(1) Set the CM14 bit in the CM1 register to 0 (125 kHz on-chip oscillator on).

(2) Wait for tsu(fOCO-S).

To start fOCO-S:

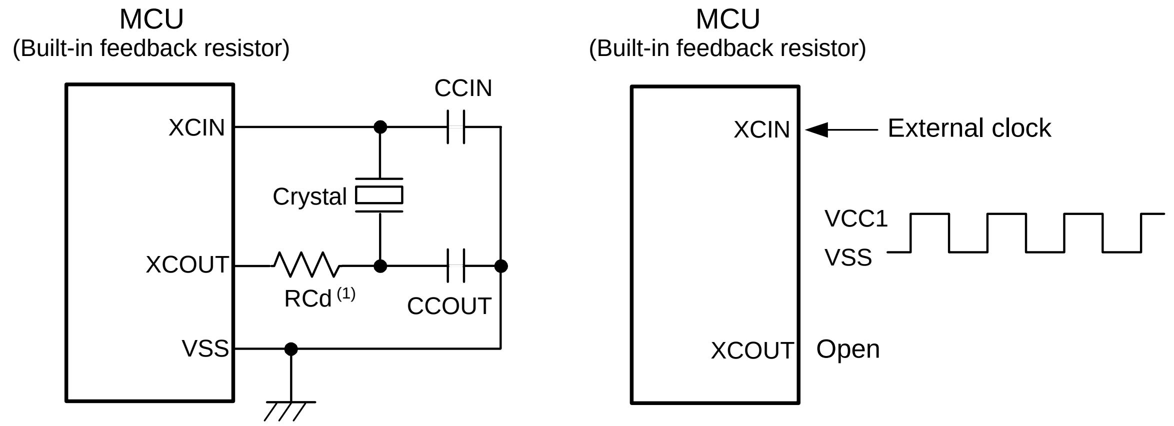
(1) Set the CM14 bit in the CM1 register to 1 (125 kHz on-chip oscillator off).

When the CM21 bit is 1 (on-chip oscillator used as the clock source for the CPU), the CM14 bit becomes 0 (125 kHz on-chip oscillator on).

8.3.6 Sub Clock (fC)

The sub clock is supplied by the sub clock oscillator. This clock is the clock source for count sources of the CPU clock, timer A, timer B, real-time clock, CEC function, and remote control signal receiver.

The sub clock oscillator is configured by connecting a crystal between pins XCIN and XCOUT. The sub clock oscillator contains a feedback resistor, which is disconnected from the oscillation circuit in stop mode in order to reduce the amount of power consumed by the chip. The sub clock oscillator circuit may also be configured by feeding an externally generated clock to the XCIN pin. Figure 8.4 shows Sub Clock Connection Example.



Note:

1. Insert a damping resistor if required. The resistance will vary depending on a crystal/ceramic resonator and the oscillation drive capacity setting. Use the value recommended by the manufacturer of crystal/ceramic resonator.
When the oscillation drive capacity is set to low, check if oscillation is stable in low status. Also, place a feedback resistor between XCIN and XCOUT if the manufacturer recommends placing the resistor externally.

Figure 8.4 Sub Clock Connection Example

After reset, the sub clock is stopped. At this time, the feedback resistor is disconnected from the oscillator.

Follow the steps below to start the sub clock. Refer to 8.2 “Registers” for details on register and bit access.

(1) Set the PU21 bit in the PUR2 register to 0 (P8_4, P8_6 and P8_7 not pulled high).
(2) Set bits PD8_6 and PD8_7 in the PD8 register to 0 (P8_6, P8_7 function as input ports).
(3) Set the CM04 bit to 1 (XCIN-XCOUT oscillation function). Set the CM03 bit to 1 (XCIN-XCOUT drive capacity high).
(4) Wait until sub clock oscillation stabilizes (enter the external clock when entering it from the XCIN pin).

8.4 CPU Clock and Peripheral Function Clocks

The CPU is run by the CPU clock, and the peripheral functions are run by the peripheral function clocks.

8.4.1 CPU Clock and BCLK

The CPU clock is an operating clock for the CPU and watchdog timer. It is also used as a sampling clock for the $\overline{\text{NMI}}/\overline{\text{SD}}$ digital filter.

The main clock, PLL clock, fOCO-F, fOCO-S, or fC can be selected as the clock source for the CPU clock. (See Table 9.2 “Clocks in Normal Operating Mode”.)

When the main clock, PLL clock, or fOCO-S is selected as the clock source for the CPU clock, the selected clock divided by 1, 2, 4, 8 or 16 becomes the CPU clock. Use the CM06 bit in the CM0 register and bits CM17 to CM16 in the CM1 register to select a frequency-divided value.

When selecting fOCO-F as the clock source for the CPU clock, fOCO-F divided by 2, 4, 8, or 16 becomes the CPU clock. Use the CM06 bit in the CM0 register and bits CM17 to CM16 in the CM1 register to select a frequency-divided value.

When fC is selected as the clock source for the CPU clock, it is not divided and is used directly as the CPU clock.

After reset, fOCO-S divided by 8 becomes the CPU clock. Note that when entering stop mode or when the CM21 bit in the CM2 register is 0 (main clock or PLL clock) and the CM05 bit is 1 (main clock off), the CM06 bit in the CM0 register becomes 1 (divide-by-8 mode).

BCLK is a bus reference clock.

In memory expansion or microprocessor mode, a BCLK signal with the same frequency as the CPU clock can be output from the BCLK pin by setting the PM07 bit in the PM0 register to 0 (output enabled).

8.4.2 Peripheral Function Clocks (f1, fOCO40M, fOCO-F, fOCO-S, fC32, fC, Main Clock)

f1, fOCO40M, fOCO-F, fOCO-S, and fC32 are operating clocks for the peripheral functions.

f1 is one of the following:

- Main clock divided by 1 (no division)
- PLL clock divided by 1 (no division)
- fOCO-S divided by 1 (no division)
- fOCO-F divided by 1 (no division)

f1 is used for timers A and B, PWM, real-time clock, remote control signal receiver, UART0 to UART2, UART5 to UART7, SI/O3, SI/O4, multi-master I^2C-bus interface, and the A/D converter.

When the WAIT instruction is executed after setting the CM02 bit in the CM0 register to 1 (peripheral function clock f1 turned off during wait mode), the f1 clock is stopped.

fOCO40M can be used for the A/D converter. fOCO40M can be used when the FRA00 bit in the FRA0 register is 1 (40 MHz on-chip oscillator on).

fOCO-F can be used for timers A and B, UART0 to UART2, UART5 to UART7, SI/O3, and SI/O4.

fOCO-F can be used when the FRA00 bit in the FRA0 register is 1 (40 MHz on-chip oscillator on).

fOCO-S is used for timers A and B. It is also used for reset, voltage detector, and watchdog timer.

fOCO-S is also used when the CM14 bit in the CM1 register is set to 0 (125 kHz on-chip oscillator on).

fC divided by 32 becomes fC32. fC32 is used for timers A and B, and can be used when the sub clock is on.

fC is used as the count source for the real-time clock, remote control signal receiver, and CEC function when the PM25 bit in the PM2 register is 1 (peripheral clock fC provided). fC can be used when the sub clock is on.

When in PLL operating mode, high-speed mode, medium-speed mode, or wait mode, main clock can be used for the timer A and timer B count source.

Figure 8.5 shows Peripheral Function Clocks.

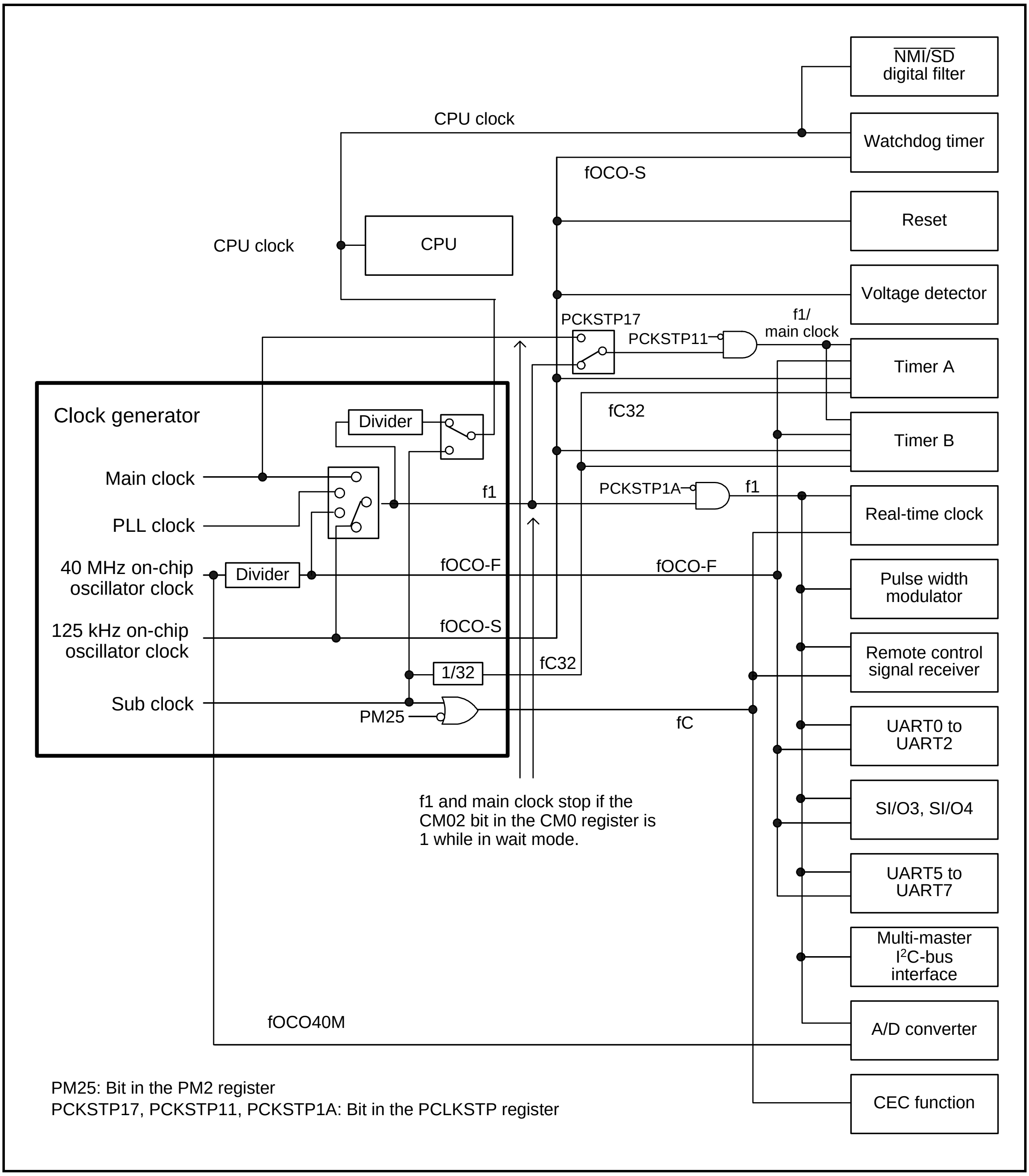


Figure 8.5 Peripheral Function Clocks

8.5 Clock Output Function

In single-chip mode, the f1, f8, f32 or fC clock can be output from the CLKOUT pin. Use bits CM01 to CM00 in the CM0 register, and the PCLK5 bit in the PCLKR register to select a clock. f8 has the same frequency as f1 divided by 8, and f32 has the same frequency as f1 divided by 32.
Set the frequency of the clock output from the CLKOUT pin to 25 MHz or below.

8.6 System Clock Protection Function

The system clock protection function prohibits the CPU clock from changing clock sources when the main clock is selected as the CPU clock source. This is to prevent the CPU clock from stopping due to an unexpected program operation.
When the PM21 bit in the PM2 register is set to 1 (clock change disabled), the following bits remain unchanged even if they are written to:

- The CM02 bit in the CM0 register (peripheral function clock f1 in wait mode)
- The CM05 bit in the CM0 register (to prevent the main clock from being stopped)
- The CM07 bit in the CM0 register (clock source of the CPU clock)
- The CM10 bit in the CM1 register (MCU does not enter stop mode)
- The CM11 bit in the CM1 register (clock source of the CPU clock)
- The CM20 bit in the CM2 register (oscillator stop/restart detect function set)
- All bits in the PLC0 register (PLL frequency synthesizer set)

To use the system clock protect function, set the CM05 bit in the CM0 register to 0 (main clock oscillation) and CM07 bit to 0 (main clock as CPU clock source), and then follow the steps below.

(1) Set the PRC1 bit in the PRCR register to 1 (write to PM2 register enabled).
(2) Set the PM21 bit in the PM2 register to 1 (clock change disabled).
(3) Set the PRC1 bit in the PRCR register to 0 (write to PM2 register disabled).

When the PM21 bit is 1, do not execute the WAIT instruction.

8.7 Oscillator Stop/Restart Detect Function

This function detects a stop/restart of the main clock oscillator. The oscillator stop/restart detect function can be enabled and disabled with the CM20 bit in the CM2 register.
A reset or oscillator stop/restart detect interrupt is generated when an oscillator stop or restart is detected. Set the CM27 bit in the CM2 register to select the reset or interrupt.
Table 8.6 lists Oscillator Stop/Restart Detect Function Specifications.

Table 8.6 Oscillator Stop/Restart Detect Function Specifications

Item	Specification
Oscillator stop detectable clock and frequency bandwidth	f(XIN) ≥ 2 MHz
Enabling condition for the oscillator stop/restart detect function	Set the CM20 bit to 1 (enabled)
Operation when oscillator stop/restart detected	When CM27 bit is 0: Oscillator stop detect reset generated When CM27 bit is 1: Oscillator stop/restart detect interrupt generated

8.7.1 Operation When CM27 Bit is 0 (Oscillator Stop Detect Reset)

When main clock stop is detected while the CM20 bit is 1 (oscillator stop/restart detect function enabled), the MCU is initialized, and then stops (oscillator stop reset). Refer to 4. “Special Function Registers (SFRs)” and 6. “Resets”.
The status can be cancelled by a hardware reset or a voltage monitor 0 reset. The MCU can also be initialized and stopped when a restart is detected, but do not use the MCU in this manner. During main clock stop, do not set the CM20 bit to 1 and the CM27 bit to 0.

8.7.2 Operation When CM27 Bit is 1 (Oscillator Stop/Restart Detect Interrupt)

When the CM20 bit is 1 (oscillator stop/restart detect function enabled), the system is placed in the state shown in Table 8.7 if the main clock detects oscillator stop or restart.

The CM21 bit becomes 1 in high-speed, medium-speed, or low-speed mode. The FRA01 bit does not change. Thus, high-speed and medium-speed mode become 125 kHz on-chip oscillator mode or 40 MHz on-chip oscillator mode. Because the CM07 bit does not change, low-speed mode remains in low-speed mode, but fOCO-S or fOCO-F becomes the clock source for the peripheral functions.

When the CM21 bit is set to 1, the CM14 bit becomes 0 (125 kHz on-chip oscillator on), but the FRA00 bit does not change (40 MHz on-chip oscillator does not oscillate automatically). Thus, when the FRA01 bit is 1 (40 MHz on-chip oscillator selected), set the FRA00 bit to 1 (40 MHz on-chip oscillator on). Do not set the FRA00 bit to 0 while the FRA01 bit is 1, and vice versa.

Since the CM21 bit does not change in PLL operating mode, change the mode to 125 kHz on-chip oscillator mode or 40 MHz on-chip oscillator mode in the interrupt routine.

Table 8.7 State after Oscillator Stop/Restart Detect When CM27 Bit is 1

Condition		After Detection
Main clock oscillator stop detected	High-speed mode Medium-speed mode	• Oscillator stop/restart detect interrupt is generated • CM14 bit is 0 (125 kHz on-chip oscillator on) • CM21 bit is 1 (fOCO-S or fOCO-F is used as the clock source for the CPU and peripheral function clocks) (1, 2) • CM22 bit is 1 (main clock stop detected) • CM23 bit is 1 (main clock stopped)
	Low-speed mode	
	40 MHz on-chip oscillator mode	
	125 kHz on-chip oscillator mode	
	PLL operating mode	• Oscillator stop/restart detect interrupt is generated • CM14 bit is 0 (125 kHz on-chip oscillator on) • CM21 bit remains unchanged • CM22 bit is 1 (main clock stop detected) • CM23 bit is 1 (main clock stopped)
Main clock oscillator restart detected	-	• Oscillator stop/restart detect interrupt is generated • CM14 bit is 0 (125 kHz on-chip oscillator on) • CM21 bit does not change • CM22 bit is 1 (main clock stop detected) • CM23 bit is 0 (main clock oscillating)

CM14 bit: Bit in the CM1 register

Bits CM21, CM22, CM23: Bits in the CM2 register

Notes:

1. fOCO-S or fOCO-F is selected depending on the FRA01 bit setting.
2. fC is used as the CPU clock in low-speed mode.

8.7.3 Using the Oscillator Stop/Restart Detect Function

After oscillator stop is detected, if the main clock reoscillates, set the main clock back to the clock source for the CPU clock and peripheral functions by a program. Figure 8.6 shows the Switching from On-Chip Oscillator Clock to Main Clock.

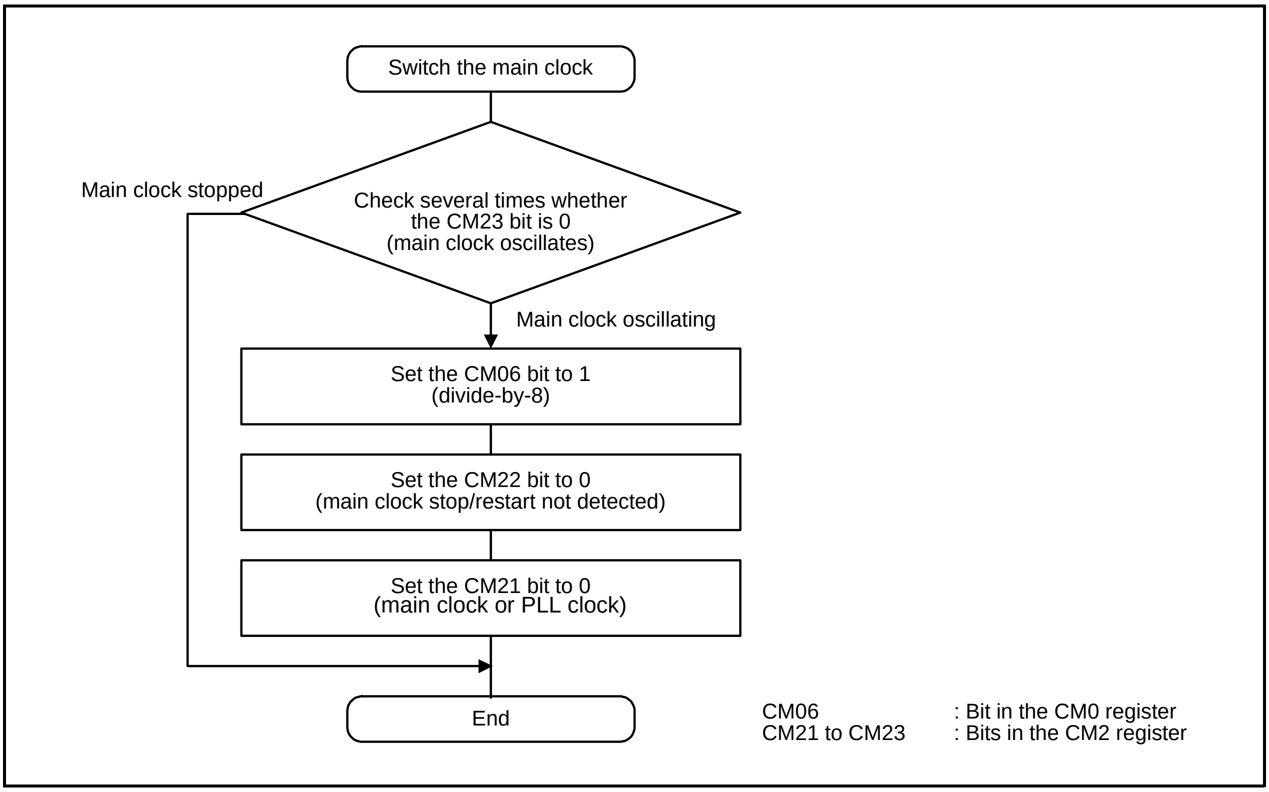

Switch the main clock
Main clock stopped
Check several times whether the CM23 bit is 0 (main clock oscillates)
Main clock oscillating
Set the CM06 bit to 1 (divide-by-8)
Set the CM22 bit to 0 (main clock stop/restart not detected)
Set the CM21 bit to 0 (main clock or PLL clock)
End
CM06 : Bit in the CM0 register
CM21 to CM23 : Bits in the CM2 register

Figure 8.6 Switching from On-Chip Oscillator Clock to Main Clock

The CM22 bit becomes 1 at the same time an oscillator stop/restart detect interrupt is generated. When the CM22 bit is 1, the oscillator stop/restart detect interrupt is disabled. When setting the CM22 bit to 0 by a program, the oscillator stop/restart detect interrupt is enabled.

8.8 Interrupt

The oscillator stop/restart detect interrupt is a non-maskable interrupt.

The watchdog timer interrupt, oscillator stop/restart detect interrupt, voltage monitor 1 interrupt, and voltage monitor 2 interrupt share the same vector. When using multiple interrupts together, read the detect flags of the events in the interrupt processing program, and determine the source of the interrupt.

The detect flag for oscillator stop/restart detect is the CM22 bit in the CM2 register. After the interrupt source is determined, set the CM22 bit to 0 (not detected).

8.9 Notes on Clock Generator

8.9.1 Oscillator Using a Crystal or a Ceramic Resonator

To connect a crystal/ceramic resonator follow the instructions below:

- The oscillation characteristics are tied closely to the user’s board design. Perform a careful evaluation of the board before connecting an oscillator.
- Oscillator structure depends on a crystal/ceramic resonator. The M16C/65C Group MCU contains a feedback resistor, but an additional external feedback resistor may be required. Contact the manufacturer of crystal/ceramic resonator regarding circuit constants, as they are dependent on the a crystal/ceramic resonator or stray capacitance of the mounted circuit.
- Check output from the CLKOUT pin to confirm that the clock generated by the oscillator is properly transmitted to the MCU.

The procedure for outputting a clock from the CLKOUT pin is listed below. Set the clock output from the CLKOUT pin to 25 MHz or lower.

Outputting the main clock

(1) Set the PRC0 bit in the PRCR register to 1 (write enabled).
(2) Set the CM11 bit in the CM1 register, the CM07 bit in the CM0 register, and the CM21 bit in the CM2 register all to 0 (main clock selected).
(3) Select the clock output from the CLKOUT pin (see the table below).
(4) Set the PRC0 bit in the PRCR register to 0 (write disabled).

Table 8.8 Output from CLKOUT Pin When Selecting Main Clock

Bit Setting		Output from the CLKOUT Pin
PCLKR register	CM0 register	
PCLK5 bit	Bits CM01 to CM00	
1	00b	Clock with the same frequency as the main clock
0	10b	Main clock divided by 8
0	11b	Main clock divided by 32

Outputting the sub clock

(1) Set the PRC0 bit in the PRCR register to 1 (write enabled).
(2) Set the CM07 bit in the CM0 register to 1 (sub clock selected).
(3) Set the PCLK5 bit in the PCLKR register to 0, and bits CM01 to CM00 in the CM0 register to 01b (fC output from CLKOUT pin).
(4) Set the PRC0 bit in the PRCR register to 0 (write disabled).

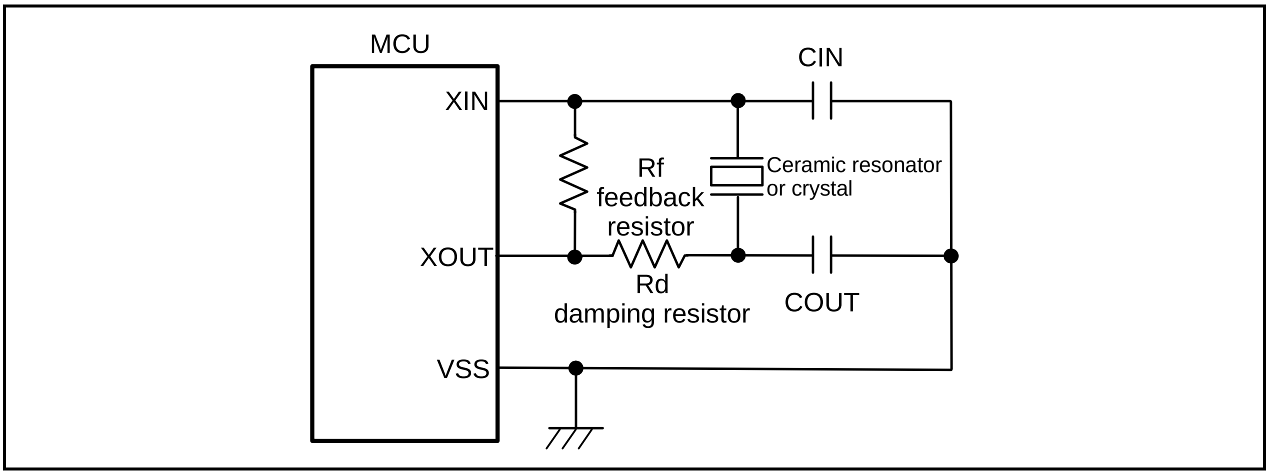


Figure 8.7 Oscillator Example

8.9.2 Noise Countermeasure

8.9.2.1 Clock I/O Pin Wiring

- Connect the shortest possible wiring to the clock I/O pin.
- Connect (a) the capacitor's ground lead connected to the crystal/ceramic resonator, and (b) the MCU's VSS pin, with the shortest possible wiring (maximum 20 mm).

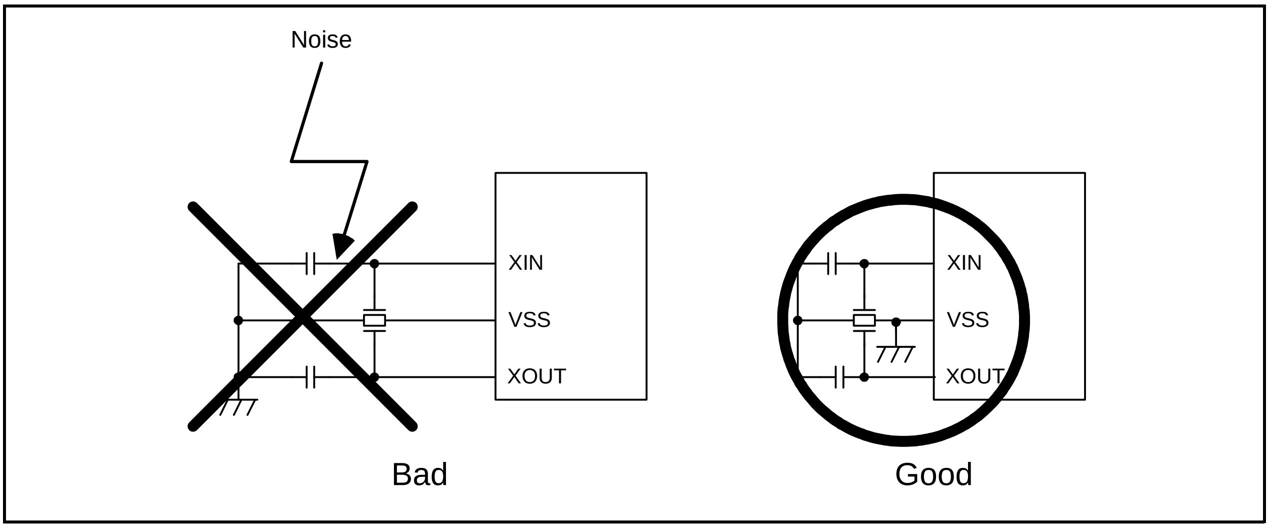


Figure 8.8 Clock I/O Pin Wiring

Reason:
When noise enters the clock I/O pin, the clock waveform becomes unstable, which causes an error in operation or a program runaway. Also, if a potential difference attributed to the noise occurs between the VSS level of the MCU and the VSS level of the crystal/ceramic resonator, an accurate clock is not input to the MCU.

8.9.2.2 Large Current Signal Line

For large currents that exceed the MCU's current range, wire the signal lines as far away from the MCU as possible (especially the crystal/ceramic resonator).

Reason:
In the system using the MCU, there are signal lines for controlling motors, LEDs, and thermal heads. When a large current flows through these signal lines, noise is generated due to mutual inductance.

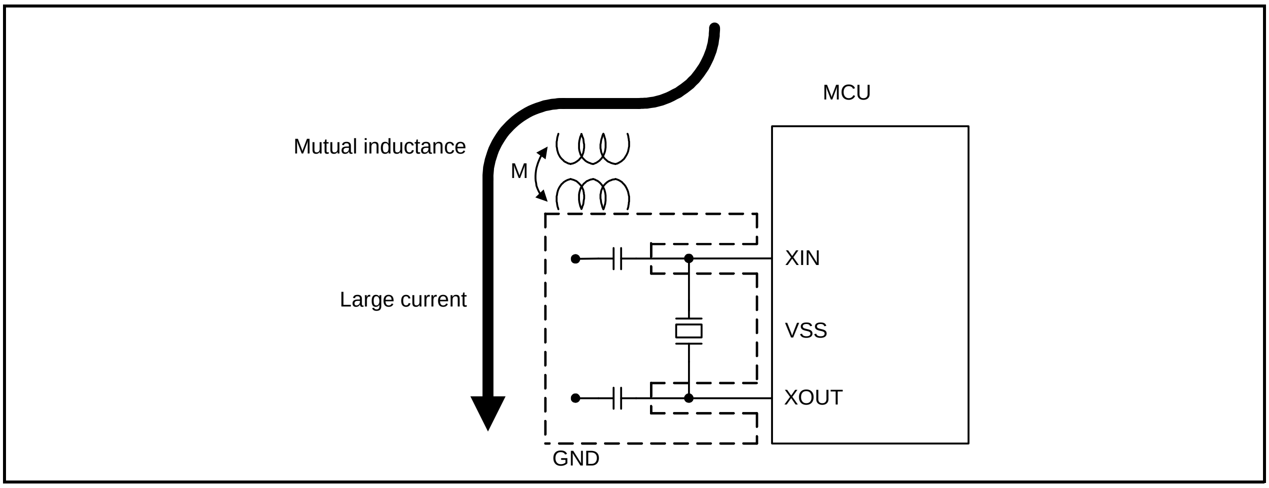


Figure 8.9 Large Current Signal Line Wiring

8.9.2.3 Signal Line Whose Level Changes at a High-Speed

For a signal line whose level changes at a high-speed, wire it as far away from the crystal/ceramic resonator and its wiring pattern as possible. Do not wire it across or extend it parallel to a clock-related signal line or other signal lines which are sensitive to noise.

Reason:
A signal whose level changes at a high-speed (such as the signal from the TAiOUT pin) affects other signal lines due to the level change at rising or falling edges. Specifically, when the signal line crosses the clock-related signal line, the clock waveform becomes unstable, which causes an error in operation or a program runaway.

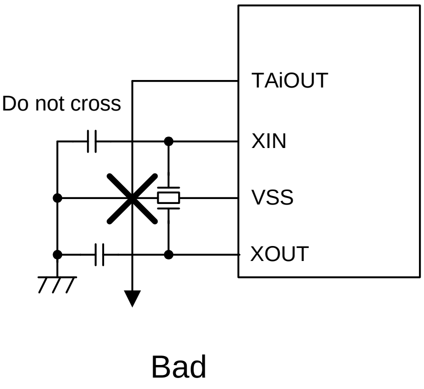


Figure 8.10 Wiring of Signal Line Whose Level Changes at High-Speed

8.9.3 CPU Clock

(Technical update number: TN-M16C-109-0309)
When an external clock is input from the XIN pin and the main clock is used as the CPU clock, do not stop the external clock.

8.9.4 Oscillator Stop/Restart Detect Function

- In the following cases, set the CM20 bit to 0 (oscillator stop/restart detect function disabled), and then change the setting of each bit.
  - When the CM05 bit is set to 1 (main clock stopped)
  - When the CM10 bit is set to 1 (stop mode)
- To enter wait mode while using the oscillator stop/restart detect function, set the CM02 bit to 0 (peripheral function clock f1 not turned off during wait mode).
- This function cannot be used if the main clock frequency is 2 MHz or lower. In that case, set the CM20 bit to 0 (oscillator stop/restart detect function disabled).
- While the CM27 bit is 1 (oscillation stop/restart detect interrupt), when the FRA01 bit is 1 (40 MHz on-chip oscillator selected), set the FRA00 bit to 1 (40 MHz on-chip oscillator on). (Do not set the FRA00 bit to 0 while FRA01 bit is 1, and vice versa.)

8.9.5 PLL Frequency Synthesizer

To use the PLL frequency synthesizer, stabilize the supply voltage within the acceptable range of power supply ripple.

Table 8.9 Acceptable Range of Power Supply Ripple

Symbol	Parameter		Standard			Unit
			Min.	Typ.	Max.	
$f_{(ripple)}$	Power supply ripple allowable frequency (VCC1)				10	kHz
$V_{P-P(ripple)}$	Power supply ripple allowable amplitude voltage	(VCC1 = 5 V)			0.5	V
		(VCC1 = 3 V)			0.3	V
$V_{CC(\lvert\Delta V/\Delta T\rvert)}$	Power supply ripple rising/falling gradient	(VCC1 = 5 V)			0.3	V/ms
		(VCC1 = 3 V)			0.3	V/ms

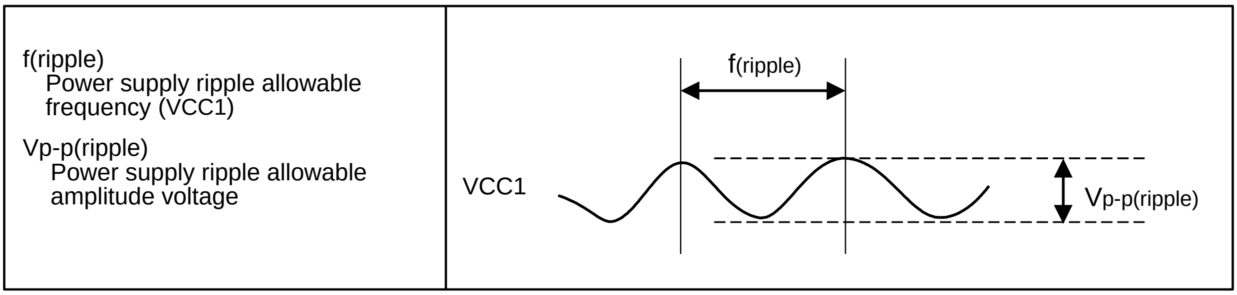

f(ripple)
Power supply ripple allowable frequency (VCC1)
Vp-p(ripple)
Power supply ripple allowable amplitude voltage
f(ripple)
VCC1
Vp-p(ripple)

Figure 8.11 Voltage Fluctuation Timing

9. Power Control

9.1 Introduction

This chapter describes how to reduce the amount of current consumption.

9.2 Registers

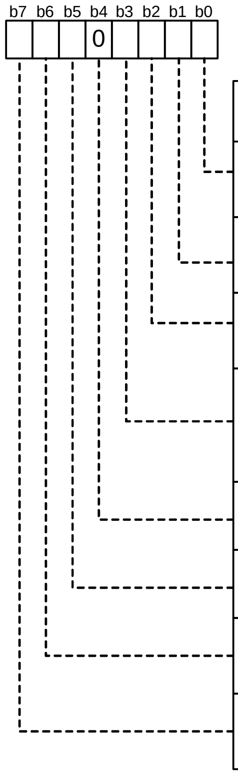
Refer to 8. “Clock Generator” for clock-related registers.

Table 9.1 Registers

Address	Register	Symbol	Reset Value
0220h	Flash Memory Control Register 0	FMR0	0000 0001b (Other than user boot mode) 0010 0001b (User boot mode)
0222h	Flash Memory Control Register 2	FMR2	XXXX 0000b

9.2.1 Flash Memory Control Register 0 (FMR0)

Flash Memory Control Register 0



Symbol	Address	Reset Value
FMR0	0220h	0000 0001b (other than user boot mode) 0010 0001b (user boot mode)

Bit Symbol	Bit Name	Function	RW
FMR00	RY/$\overline{\text{BY}}$ status flag	0 : Busy (being written or erased) 1 : Ready	RO
FMR01	CPU rewrite mode select bit	0 : CPU rewrite mode disabled 1 : CPU rewrite mode enabled	RW
FMR02	Lock bit disable select bit	0 : Lock bit enabled 1 : Lock bit disabled	RW
FMSTP	Flash memory stop bit	0 : Flash memory operation enabled 1 : Flash memory operation stopped (low power-mode, flash memory initialized)	RW
— (b4)	Reserved bit	Set to 0	RW
— (b5)	Reserved bit	Set to 0 in other than user boot mode Set to 1 in user boot mode	RW
FMR06	Program status flag	0 : Completed as expected 1 : Completed in error	RO
FMR07	Erase status flag	0 : Completed as expected 1 : Completed in error	RO

FMR01 (CPU rewrite mode select bit) (b1)

Commands can be accepted by setting the FMR01 bit to 1 (CPU rewrite mode enabled).
To set the FMR01 bit to 1, write 0 and then 1 in succession. Do not generate any interrupts or DMA transfers between setting 0 and 1.
Change the FMR01 bit when the PM24 bit in the PM2 register is 0 ($\overline{\text{NMI}}$ interrupt disabled) or high is input to the $\overline{\text{NMI}}$ pin.
While in EW0 mode, write to this bit from a program in an area other than flash memory.
Enter read array mode, and then set this bit to 0.

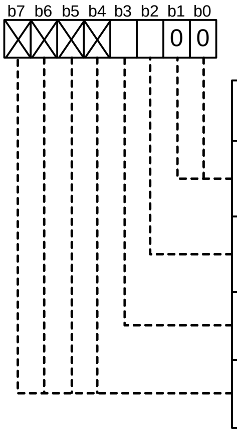
FMSTP (Flash memory stop bit) (b3)

The FMSTP bit resets the flash memory control circuits and minimizes current consumption in the flash memory. Access to the internal flash memory is disabled when the FMSTP bit is set to 1 (flash memory operation stopped). Set the FMSTP bit by a program located in an area other than the flash memory.
Set the FMSTP bit to 1 under the following condition:

- A flash memory access error occurs while erasing or programming in EW0 mode (the FMR00 bit does not revert to 1 (ready)).

9.2.2 Flash Memory Control Register 2 (FMR2)

Flash Memory Control Register 2



Symbol	Address	Reset Value
FMR2	0222h	XXXX 0000b

Bit Symbol	Bit Name	Function	RW
— (b1-b0)	Reserved bits	Set to 0	RW
FMR22	Slow read mode enable bit	0 : Disabled 1 : Enabled	RW
FMR23	Low current consumption read mode enable bit	0 : Disabled 1 : Enabled	RW
— (b7-b4)	No register bits. If necessary, set to 0. The read value is undefined.		—

FMR22 (Slow read mode enable bit) (b2)

This bit enables the mode which reduces the amount of current consumption when reading the flash memory. When rewriting the flash memory (CPU rewrite mode), set the FMR22 bit to 0 (slow read mode disabled).

To set the FMR22 bit to 1, write 0 and then 1 in succession. Make sure no interrupts or DMA transfers occur between writing 0 and 1.

Set the FMR23 bit to 1 (low current consumption read mode enabled) after the FMR22 bit is set to 1 (slow read mode enabled). Also, set the FMR22 bit to 0 (slow read mode disabled) after the FMR23 bit is set to 0 (low current consumption read mode disabled). Do not change the FMR22 bit and FMR23 bit at the same time.

FMR23 (Low current consumption read mode enable bit) (b3)

This bit enables the mode which reduces the amount of current consumption when reading the flash memory. When rewriting the flash memory (CPU rewrite mode), set the FMR23 bit to 0 (low current consumption read mode disabled).

Low current consumption read mode can be used when the CM07 bit in the CM0 register is 1 (sub clock used as CPU clock).

To set the FMR23 bit to 1, write 0 and then 1 in succession. Make sure no interrupts or DMA transfers occur between writing 0 and 1.

Set the FMR23 bit to 1 (low current consumption read mode enabled) after the FMR22 bit is set to 1 (slow read mode enabled). Also, set the FMR22 bit to 0 (slow read mode disabled) after the FMR23 bit is set to 0 (low current consumption read mode disabled). Do not change bits FMR22 and FMR23 at the same time.

Do not set the FMR23 bit to 1 (low current consumption read mode enabled) when any of the following occurs:

- When the CM07 bit is 0 (main clock, PLL clock, or on-chip oscillator clock selected as CPU clock source).
- When the FMR22 bit is 0 (slow read mode disabled)
- When the FMSTP bit is 1 (flash memory stopped)
- During the wake up operation when the FMSTP bit is changed from 1 to 0 (tps)

Do not perform the operations below when the FMR23 bit is 1. Set the FMR23 to 0 before performing them.

- Change the CPU clock
- Set to the FMSTP bit to 1 (flash memory stopped)
- Enter the wait mode or stop mode
- Execute the following commands:
  Program, block erase, lock bit program, read lock bit status, and block blank check

9.3 Clock

The amount of current consumption correlates with the number of operating clocks and frequency. When there are fewer operating clocks and a lower frequency, current consumption will be low.

Normal operating mode, wait mode, and stop mode can be used to control power consumption. All mode states, except wait mode and stop mode, are referred to as normal operating mode in this document.

9.3.1 Normal Operating Mode

In normal operating mode, because both the CPU clock and the peripheral function clocks are supplied, the CPU and the peripheral functions are operating. Power control is exercised by controlling the CPU clock frequency. The higher the CPU clock frequency, the higher the processing capability. The lower the CPU clock frequency, the lower the power consumption in the chip. If unnecessary oscillator are stopped, power consumption is further reduced.

9.3.1.1 High-Speed Mode and Medium-Speed Mode

In high-speed mode, the main clock divided by 1 (no division) is used as the CPU clock.

In medium-speed mode, the main clock divided by 2, 4, 8 or 16 is used as the CPU clock.

f1 with the same frequency of the main clock divided by 1 is used as the peripheral function clocks in both high-speed and medium-speed modes. When fC is supplied, fC and fC32 can be used as the peripheral function clocks. When fOCO-S is supplied, it can be used as the peripheral function clocks. When fOCO40M and fOCO-F are supplied, they can be used as the peripheral function clocks.

9.3.1.2 PLL Operating Mode

The PLL clock divided by 1 (no division), 2, 4, 8 or 16 is used as the CPU clock. f1 with the same frequency of the PLL clock divided by 1 (no division) is used as the peripheral function clocks.

When fC is supplied, fC and fC32 can be used as the peripheral function clocks. When fOCO-S is supplied, it can be used as the peripheral function clocks. When fOCO40M and fOCO-F are supplied, they can be used as the peripheral function clocks.

PLL operating mode can be entered and exited from medium-speed mode. To enter other modes including wait mode and stop mode, enter medium-speed mode first, and then enter the intended mode. Refer to Figure 9.1 “Clock Mode Transition” for details.

9.3.1.3 40 MHz On-Chip Oscillator Mode

The fOCO-F clock divided by 2, 4, 8 or 16 is used as the CPU clock. f1 with the same frequency of the fOCO-F clock divided by 1 is used as the peripheral function clocks.

When fC is supplied, fC and fC32 can be used as the peripheral function clocks. When fOCO-S is supplied, it can be used as the peripheral function clocks. fOCO40M and fOCO-F can be used as the peripheral function clocks.

9.3.1.4 125 kHz On-Chip Oscillator Mode

The fOCO-S clock divided by 1 (no division), 2, 4, 8 or 16 is used as the CPU clock. f1 with the same frequency of the fOCO-S clock divided by 1 is used as the peripheral function clocks.

When fC is supplied, fC and fC32 can be used as the peripheral function clocks. fOCO-S can be used as the peripheral function clocks. When fOCO40M and fOCO-F are supplied, they can be used as the peripheral function clocks.

9.3.1.5 125 kHz On-Chip Oscillator Low Power Mode

The main clock and fOCO-F are turned off after the MCU enters 125 kHz on-chip oscillator mode. The fOCO-S clock divided by 1 (no division), 2, 4, 8 or 16 is used as the CPU clock. f1 with the same frequency of the fOCO-S clock divided by 1 is used as the peripheral function clocks.

When fC is supplied, fC and fC32 can be used as the peripheral function clocks. fOCO-S can be used as the peripheral function clocks.

9.3.1.6 Low-Speed Mode

fC is used as the CPU clock.

When the CM21 bit is 0 and the CM11 bit is 0 (main clock), f1 with the same frequency of the main clock divided by 1 is used as the peripheral function clocks. When the CM21 bit is 0 and the CM11 bit is 1 (PLL clock), f1 with the same frequency of the PLL clock divided by 1 is used as the peripheral function clocks. When the CM21 bit is 1 (on-chip oscillator clock) and the FRA01 bit is 0 (125 kHz on-chip oscillator), f1 with the same frequency as the fOCO-S clock divided by 1 is used as the peripheral function clocks. When the CM21 bit is 1 (on-chip oscillator clock) and the FRA01 bit is 1 (40 MHz on-chip oscillator), f1 with the same frequency as the fOCO-F clock divided by 1 is used as the peripheral function clocks.

fC and fC32 can be used as the peripheral function clocks. When fOCO-S is supplied, it can be used as the peripheral function clocks. When fOCO40M and fOCO-F are supplied, they can be used as the peripheral function clocks.

9.3.1.7 Low Power Mode

The main clock and fOCO-F are stopped after the MCU enters low-speed mode. fC is used as the CPU clock. When the CM21 bit is 1 (on-chip oscillator clock) and the FRA01 bit is 0 (125 kHz on-chip oscillator clock), f1 with the same frequency as the fOCO-S clock divided by 1 is used as the peripheral function clocks.

fC and fC32 can be used as the peripheral function clocks. When fOCO-S is supplied, it can be used as the peripheral function clocks.

Table 9.2 Clocks in Normal Operating Mode

Mode	CPU Clock	Peripheral Clocks [2]			
		f1	fC, fC32	fOCO-S	fOCO-F fOCO40M
High-speed mode	Main clock divided by 1 [1]	Main clock divided by 1	Enabled	Enabled	Enabled
Medium-speed mode	Main clock divided by n [1]				
PLL operating mode	PLL clock divided by n [1]	PLL clock divided by 1			
40 MHz on-chip oscillator mode	fOCO-F divided by n [1]	fOCO-F divided by 1	Enabled	Enabled	Enabled
125 kHz on-chip oscillator mode	fOCO-S divided by n [1]	fOCO-S divided by 1	Enabled	Enabled	Enabled
125 kHz on-chip oscillator low power mode	fOCO-S divided by n [1]	fOCO-S divided by 1	Enabled	Enabled	Disabled
Low-speed mode	fC	Any of the following: Main clock divided by 1 (when the CM21 is 0 and the CM11 is 0) PLL clock divided by 1 (when the CM21 is 0 and the CM11 is 1) fOCO-F divided by 1 (when the CM21 is 1 and the FRA01 is 1) fOCO-S divided by 1 (when the CM21 is 1 and the FRA01 is 0)	Enabled	Enabled	Enabled
Low power mode	fC	fOCO-S divided by 1 (when the CM21 is 1 and the FRA01 is 0)	Enabled	Enabled	Disabled

CM11 : Bit in the CM1 register
CM21 : Bit in the CM2 register
FRA01 : Bit in the FRA0 register

Notes:

1. Select by setting the CM06 bit in the CM0 register and bits CM17 to CM16 in the CM1 register.
2. The peripheral clock is enabled when each clock is supplied. Refer to 8. “Clock Generator” for the clock supply method.

Table 9.3 Clock-Related Bit Setting and Modes

Mode	CM2 Register	CM1 Register		CM0 Register			FRA0 Register	
	CM21	CM14	CM11	CM07	CM05	CM04	FRA01	FRA00
High-speed mode, medium-speed mode	0	–	0	0	0	–	–	–
PLL operating mode	0	–	1	0	0	–	–	–
40 MHz on-chip oscillator mode	1	–	0	0	–	–	1	1
125 kHz on-chip oscillator mode	1	0	0	0	0 [1]	–	0	1 [1]
125 kHz on-chip oscillator low power mode	1	0	0	0	1	–	0	0
Low-speed mode	–	–	0	1	0 [1]	1	–	1 [1]
Low power mode	–	–	0	1	1	1	–	0

–: 0 or 1

Note:

1. Both or either the main clock and fOCO-F are oscillated.

Table 9.4 Selecting Clock Division Related Bits [1]

Division	CM1 Register	CM0 Register
	Bits CM17 to CM16	CM06 bit
No division [2]	00b	0
Divide-by-2	01b	0
Divide-by-4	10b	0
Divide-by-8	–	1
Divide-by-16	11b	0

–: Any value from 00b to 11b

Notes:

1. While in high-speed mode, medium-speed mode, PLL operating mode, 125 kHz on-chip oscillator mode, or 125 kHz on-chip oscillator low power mode.
2. Select divide-by-1 (no division) in high-speed mode.

Table 9.5 Example Settings for 40 MHz On-Chip Oscillator Mode Division Related Bits

Division	CPU Clock Frequency	CM1 Register	CM0 Register
		Bits CM17 and CM16	CM06 bit
Divide-by-4 (fOCO divided by 2)	Approx. 10 MHz	01b (divide-by-2)	0
Divide-by-8 (fOCO divided by 4)	Approx. 5 MHz	10b (divide-by-4)	0
Divide-by-16 (fOCO divided by 8)	Approx. 2.5 MHz	-	1 (divide-by-8)
Divide-by-32 (fOCO divided by 16)	Approx. 1.25 MHz	11b (divide-by-16)	0

–: Any value from 00b to 11b

9.3.2 Clock Mode Transition Procedure

Figure 9.1 shows Clock Mode Transition. Arrows indicate possible mode transitions.

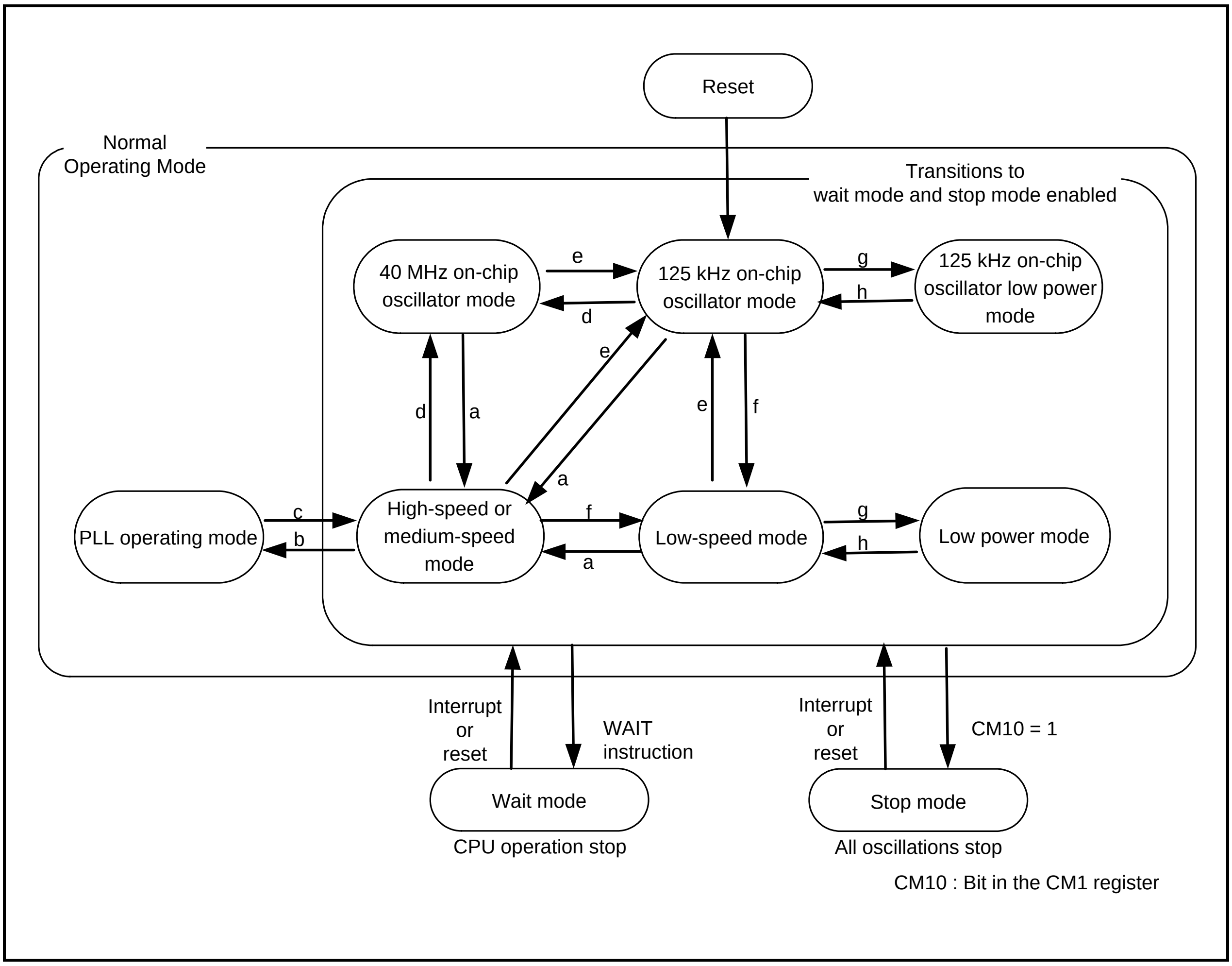

Reset
Normal Operating Mode
Transitions to wait mode and stop mode enabled
40 MHz on-chip oscillator mode
125 kHz on-chip oscillator mode
125 kHz on-chip oscillator low power mode
PLL operating mode
High-speed or medium-speed mode
Low-speed mode
Low power mode
a
b
c
d
e
f
g
h
Interrupt or reset
WAIT instruction
Interrupt or reset
CM10 = 1
Wait mode
Stop mode
CPU operation stop
All oscillations stop
CM10 : Bit in the CM1 register

Figure 9.1 Clock Mode Transition

To start or stop clock oscillations, or to change modes in normal operating mode, follow the instructions below.

- Enter a different mode after the clock for that mode stabilizes completely.
- When stopping a clock, do it after mode transition is completed. Do not stop the clock at the same time as mode transition.
- When entering a new mode from PLL operating mode, high-speed or medium-speed mode, 40 MHz on-chip oscillator mode, or 125 kHz on-chip oscillator mode, or entering one of these modes from another mode, select divide by 8 or divide by 16.
- When the clock division ratio is switched in PLL operating mode, high-speed or medium-speed mode, or 40 MHz on-chip oscillator mode, the ratio changes in the order shown in Figure 9.2.
- To change the mode, follow procedures a to h listed below. For details on register and bit access, refer to 9.2 “Registers”. Letters a to h correspond to those in Figure 9.1 “Clock Mode Transition” and Figure 9.2 “Clock Divide Transition”.
- For details on oscillator start and stop, refer to 8.3.1 “Main Clock” to 8.3.6 “Sub Clock (fC)”.

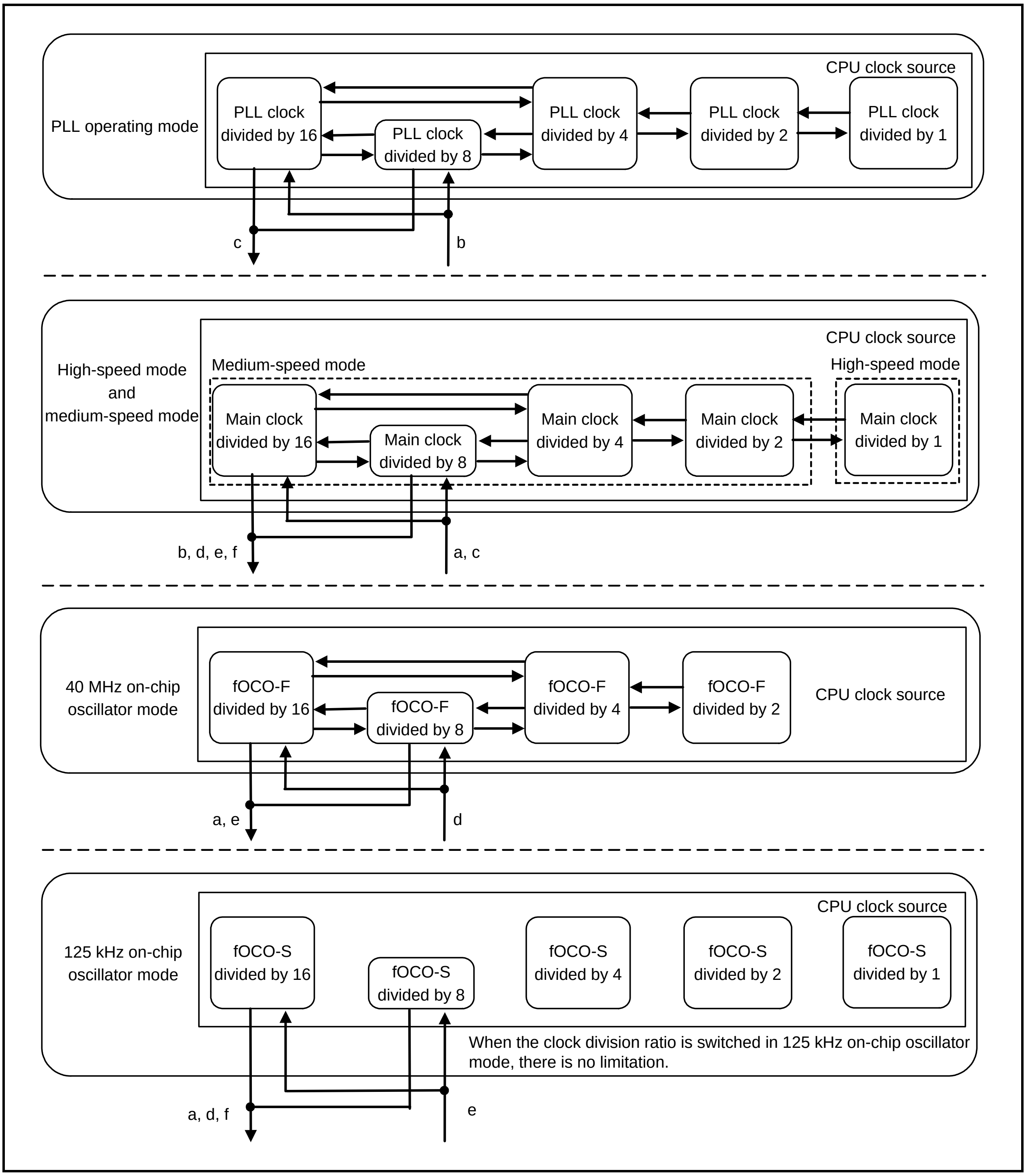


Figure 9.2 Clock Divide Transition

a. Entering high-speed mode or medium-speed mode from 40 MHz on-chip oscillator mode, 125 kHz on-chip oscillator mode, or low-speed mode

(1) Start the main clock and wait until the oscillation stabilizes. Refer to 8.3.1 “Main Clock” for details.
(2) Select divide-by-8 or divide-by-16 mode by setting the CM06 bit and bits CM17 to CM16.
(3) Set the CM11 bit to 0, the CM21 bit to 0, and the CM07 bit to 0 (main clock selected as CPU clock source).

b. Entering PLL operating mode from high-speed mode or medium-speed mode

(1) Select the division of reference frequency counter by setting bits PLC05 and PLC04 in the PLC0 register, and the multiplication rate by setting bits PLC02 to PLC00 in the PLC0 register.
(2) Set the PLC07 bit to 1 (PLL on).
(3) Wait for tsu(PLL) until the PLL clock stabilizes.
(4) Select divide-by-8 or divide-by-16 mode by setting the CM06 bit and bits CM17 to CM16.
(5) Set the CM11 bit to 1, the CM21 bit to 0, and the CM07 bit to 0 (PLL clock selected as CPU clock source).

c. Entering high-speed mode or medium-speed mode from PLL operating mode

(1) Select divide-by-8 or divide-by-16 mode by setting the CM06 bit and bits CM17 to CM16.
(2) Set the CM11 bit to 0, the CM21 bit to 0, and the CM07 bit to 0 (main clock selected as CPU clock source).
(3) Set the PLC07 bit to 0 (PLL off).

d. Entering 40 MHz on-chip oscillator mode from high-speed mode, medium-speed mode, or 125 kHz on-chip oscillator mode

(1) Start the 40 MHz on-chip oscillator and wait until the oscillation stabilizes.
Refer to 8.3.4 “fOCO-F” for details.
(2) Select divide-by-8 or divide-by-16 mode by setting the CM06 bit and bits CM17 to CM16.
(3) Set the FRA01 bit to 1 (40 MHz on-chip oscillator).
(4) Set the CM21 bit to 1 (on-chip oscillator clock selected as CPU clock source).
(5) Set the CM07 bit to 0 (main clock, PLL clock, or on-chip oscillator clock selected as CPU clock source).

e. Entering 125 kHz on-chip oscillator mode from 40 MHz on-chip oscillator mode, high-speed mode, medium-speed mode, or low-speed mode

(1) Start the 125 kHz on-chip oscillator and wait until the oscillation stabilizes. Refer to 8.3.5 “125 kHz On-Chip Oscillator Clock (fOCO-S)” for details.
(2) Select divide-by-8 or divide-by-16 mode by setting the CM06 bit and bits CM17 to CM16.
(3) Set the FRA01 bit to 0 (125 kHz on-chip oscillator).
(4) Set the CM21 bit to 1 (on-chip oscillator clock selected as CPU clock source).
(5) Set the CM07 bit to 0 (main clock, PLL clock, or on-chip oscillator clock selected as CPU clock source).

f. Entering low-speed mode from high-speed mode, medium-speed mode, or 125 kHz on-chip oscillator mode

(1) Start the sub clock and wait until the oscillation stabilizes. Refer to 8.3.6 “Sub Clock (fC)” for details.
(2) Select divide-by-8 or divide-by-16 mode by setting the CM06 bit and bits CM17 to CM16.
(3) Set the CM07 bit to 1 (sub clock selected as CPU clock source).

g. Entering 125 kHz on-chip oscillator low power mode from 125 kHz on-chip oscillator mode
Entering low power mode from low-speed mode

Follow both or either of the procedures below (in no particular order).

(1) Stop the main clock. Refer to 8.3.1 “Main Clock” for details.
(2) Stop the 40 MHz on-chip oscillator. Refer to 8.3.4 “fOCO-F” for details for details.

h. Entering 125 kHz on-chip oscillator mode from 125 kHz on-chip oscillator low power mode
Entering low-speed mode from low power mode

Follow both or either of the procedures below (in no particular order).

(1) Start the main clock and wait until the oscillation stabilizes. Refer to 8.3.1 “Main Clock” for details.
(2) Start the 40 MHz on-chip oscillator and wait until the oscillation stabilizes. Refer to 8.3.4 “fOCO-F” for details.

9.3.3 Wait Mode

The CPU clock stops in wait mode, therefore, the CPU, the watchdog timer, and $\overline{\mathrm{NMI}}$/$\overline{\mathrm{SD}}$ digital filter clocked by the CPU clock stops running. However, if the CSPRO bit in the CSPR register is 1 (count source protection mode enabled), the watchdog timer remains active. Because the clock generator does not stop, peripheral functions supplied by a peripheral clock keep operating.

9.3.3.1 Peripheral Function Clock Stop Function

When the CM02 bit is 1 (peripheral function clock f1 stops in wait mode), the f1 clock is turned off while in wait mode, and power consumption is reduced. However, all the peripheral clocks except f1 (i.e. fOCO40M, fOCO-F, fOCO-S, fC, and fC32) do not stop.

9.3.3.2 Entering Wait Mode

The MCU enters wait mode by executing a WAIT instruction.
When the CM11 bit is 1 (PLL clock selected as CPU clock source), set the CM11 bit to 0 (main clock selected as CPU clock source) before entering wait mode. Chip power consumption can be reduced by setting the PLC07 bit to 0 (PLL off).
When using wait mode, set the following:

(1) Set the I flag to 0.
(2) Set the interrupt priority level of bits ILVL2 to ILVL0 in the interrupt control register for the peripheral function interrupt which is used to exit wait mode. Start the peripheral function which is used to exit wait mode if it is stopped.
(3) Set 000b (interrupt disabled) to bits ILVL2 to ILVL0 in the interrupt control registers for the peripheral function interrupts not used to exit wait mode.
(When using any of the following resets or interrupts to exit wait mode, set 000b to bits ILVL2 to ILVL0 in all interrupt control registers for peripheral function interrupts: hardware reset, voltage monitor 0 reset, voltage monitor 1 reset, voltage monitor 2 reset, watchdog timer reset, $\overline{\mathrm{NMI}}$ interrupt, voltage monitor 1 interrupt, or voltage monitor 2 interrupt).
(4) Set the I flag to 1.
(5) Execute the WAIT instruction.

9.3.3.3 Pin Status in Wait Mode

Table 9.6 lists Pin Status in Wait Mode.

Table 9.6 Pin Status in Wait Mode

Pin		Memory Expansion Mode Microprocessor Mode	Single-Chip Mode
A0 to A19, D0 to D15, $\overline{\mathrm{CS0}}$ to $\overline{\mathrm{CS3}}$, $\overline{\mathrm{BHE}}$		Retains the status just prior to entering wait mode	Cannot be used as a bus control pin
$\overline{\mathrm{RD}}$, $\overline{\mathrm{WR}}$, $\overline{\mathrm{WRL}}$, $\overline{\mathrm{WRH}}$		High	
$\overline{\mathrm{HLDA}}$, BCLK		High	
ALE		Low	
I/O ports		Retains the status just prior to entering wait mode	Retains the status just prior to entering wait mode
CLKOUT	fC selected	Cannot be used as a CLKOUT pin	Does not stop
	f1, f8, f32 selected		Does not stop when the CM02 bit is 0. When the CM02 bit is 1, the status immediately prior to entering wait mode is retained.

9.3.3.4 Exiting Wait Mode

The MCU exits wait mode by a reset or interrupt. Table 9.7 lists Resets and Interrupts to Exit Wait Mode and Conditions for Use.

The peripheral function interrupts are affected by the CM02 bit in the CM0 register. When the CM02 bit is 0 (peripheral function clock f1 does not stop in wait mode), peripheral function interrupts can be used to exit wait mode. When the CM02 bit is 1 (peripheral function clock f1 stops in wait mode), the peripheral functions using the peripheral function clock f1 stop operating, so the peripheral functions activated by external signals and the peripheral function clocks except f1 (fOCO40M, fOCO-F, fOCO-S, fC, fC32) can be used to exit wait mode.

fOCO-S is also used for the digital filter in the voltage detector, so the MCU exits wait mode when the digital filter is disabled or when fOCO-S is supplied.

Table 9.7 Resets and Interrupts to Exit Wait Mode and Conditions for Use

Interrupt, Reset			Conditions for Use	
			CM02 = 0	CM02 = 1
Interrupt	Peripheral function interrupt	$\overline{\text{INT}}$	Usable	Usable
		Key input	Usable	Usable
		Timer A, timer B	Usable in all modes	Usable when fOCO-F, fOCO-S or fC32 is supplied and is used as count source. Usable when counting external signals in event counter mode.
		Remote control signal receiver	Usable	Usable when fC is supplied and is used as count source. Usable when fOCO-F, fOCO-S, or fC32 is supplied and is used as count source for timer B1 or B2, and timer B1 or B2 underflow is used as count source for remote control signal receiver.
		Serial interface	Usable in internal clock or external clock	Usable in external clock The internal clock can be used when fOCO-F is supplied and the internal clock is operated by fOCO-F.
		Multi-master I^{2}C-bus interface	Both I^{2}C-bus interface interrupt and SCL/SDA interrupt are usable	SCL/SDA interrupt is usable
		CEC function	Usable	Usable when fC is supplied and is used as count source.
		A/D converter	Usable in one-shot mode or single sweep mode.	Usable when fOCO40M is supplied and is used as fAD in one-shot mode or single sweep mode.
		Real-time clock	Usable when fC is supplied and is used as count source	
	Voltage monitor 1, Voltage monitor 2		Usable when the digital filter is disabled (VW1C1 bit in the VW1C register or the VW2C1 bit in the VW2C register is 1). Usable when the digital filter is enabled (VW1C1 bit in the VW1C register or the VW2C1 bit in the VW2C register is 0) and fOCO-S is supplied (CM14 bit in the CM1 register is 0).	
	$\overline{\text{NMI}}$		Usable when the digital filter is disabled (bits NMIDF2 to NMIDF0 in the NMIDF register are 000b)	
Reset	Hardware reset		Usable	
	Voltage monitor 0 reset		Usable	
	Voltage monitor 1 reset, Voltage monitor 2 reset		Usable when the digital filter is disabled (VW1C1 bit in the VW1C register or the VW2C1 bit in the VW2C register is 1). Usable when the digital filter is enabled (VW1C1 bit in the VW1C register or the VW2C1 bit in the VW2C register is 0) and fOCO-S is supplied (CM14 bit in the CM1 register is 0).	
	Watchdog timer		Usable when count source protection mode is enabled (the CSPRO bit in the CSPR register is 1).	

When the MCU exits wait mode by using an interrupt, an interrupt request is generated, the CPU clock starts running, and interrupt routine is performed.

When the MCU exits wait mode by an interrupt, the CPU clock is the same CPU clock used while executing the WAIT instruction.

9.3.4 Stop Mode

In stop mode, all oscillator are stopped, so the CPU clock and peripheral function clocks are also stopped. Therefore, the CPU and the peripheral functions using these clocks stop operating. The least amount of power is consumed in this mode. If the voltage applied to pins VCC1 and VCC2 is VRAM or greater, the contents of internal RAM are retained. When applying 2.7 V or less to pins VCC1 and VCC2, make sure VCC1 ≥ VCC2 ≥ VRAM.
However, the peripheral functions activated by external signals keep operating.

9.3.4.1 Entering Stop Mode

The MCU enters stop mode by setting the CM10 bit in the CM1 register to 1 (all clocks turned off). At the same time, the CM06 bit in the CM0 register becomes 1 (divide-by-8 mode), and the CM15 bit in the CM1 register becomes 1 (main clock oscillator drive capability high).
Before entering stop mode, set the CM20 bit to 0 (oscillator stop/restart detect function disabled).
When the CM11 bit is 1 (PLL clock used as the CPU clock source), set the CM11 bit to 0 (main clock used as the CPU clock source), and then the PLC07 bit to 0 (PLL turned off) before entering stop mode.
When using stop mode, set the following:

(1) Set the I flag to 0.
(2) Set the interrupt priority level of bits ILVL2 to ILVL0 in the interrupt control register for the peripheral function interrupt which is used to exit stop mode. Start the peripheral function which is used to stop mode if it is stopped.
(3) Set 000b (interrupt disabled) to bits ILVL2 to ILVL0 in the interrupt control registers for the peripheral function interrupts not used to exit stop mode.
(When using any of the following resets or interrupts to exit stop mode, set 000b to bits ILVL2 to ILVL0 in all interrupt control registers for peripheral function interrupts: hardware reset, voltage monitor 0 reset, $\overline{\mathrm{NMI}}$ interrupt, voltage monitor 1 interrupt, or voltage monitor 2 interrupt)
(4) Set the I flag to 1.
(5) Set the CM10 bit in the CM1 register to 1.

9.3.4.2 Pin Status in Stop Mode

Table 9.8 lists Pin Status in Stop Mode.

Table 9.8 Pin Status in Stop Mode

Pin		Memory Expansion Mode Microprocessor Mode	Single-Chip Mode
A0 to A19, D0 to D15, $\overline{\mathrm{CS0}}$ to $\overline{\mathrm{CS3}}$, $\overline{\mathrm{BHE}}$		Retains status just prior to stop mode	Cannot be used as bus control pin
$\overline{\mathrm{RD}}$, $\overline{\mathrm{WR}}$, $\overline{\mathrm{WRL}}$, $\overline{\mathrm{WRH}}$		High	
$\overline{\mathrm{HLDA}}$, BCLK		High	
ALE		Undefined	
I/O ports		Retains status just prior to stop mode	Retains status just prior to stop mode
CLKOUT	f1, f8, f32, fC selected	Cannot be used as CLKOUT pin	Retains status just prior to stop mode
XOUT		High	
XCIN, XCOUT		High-impedance	

9.3.4.3 Exiting Stop Mode

Use a reset or an interrupt to exit stop mode. Table 9.9 lists Resets and Interrupts to Exit Stop Mode and Conditions for Use.

Table 9.9 Resets and Interrupts to Exit Stop Mode and Conditions for Use

Interrupt, Reset			Conditions for Use
Interrupt	Peripheral function interrupt	$\overline{\text{INT}}$	Usable
		Key input	Usable
		Timer A, timer B	Usable when counting external signals in event counter mode
		Serial interface	Usable when an external clock is selected
		Multi-master I^{2}C-bus interface	SCL/SDA interrupt is usable
	Voltage monitor 1 interrupt		Usable when the digital filter is disabled (VW1C1 bit in the VW1C register is 1)
	Voltage monitor 2 interrupt		Usable when the digital filter is disabled (VW2C1 bit in the VW2C register is 1)
	$\overline{\text{NMI}}$		Usable when the digital filter is disabled (bits NMIDF2 to NMIDF0 in the NMIDF register are 000b)
Reset	Hardware reset		Usable
	Voltage monitor 0 reset		Usable

To exit stop mode by using hardware reset, voltage monitor 0 reset, $\overline{\text{NMI}}$ interrupt, voltage monitor 1 interrupt, or voltage monitor 2 interrupt, set bits ILVL2 to ILVL0 in the interrupt control registers for the peripheral function interrupt to 000b (interrupt disabled) before setting the CM10 bit to 1.

When the MCU exits stop mode by using an interrupt, an interrupt request is generated, the CPU clock starts running, and interrupt routine is performed.
When exiting stop mode by means of an interrupt, the CPU clock source varies depending on the CPU clock source setting before the MCU had entered stop mode. Table 9.10 lists CPU Clock After Exiting Stop Mode.

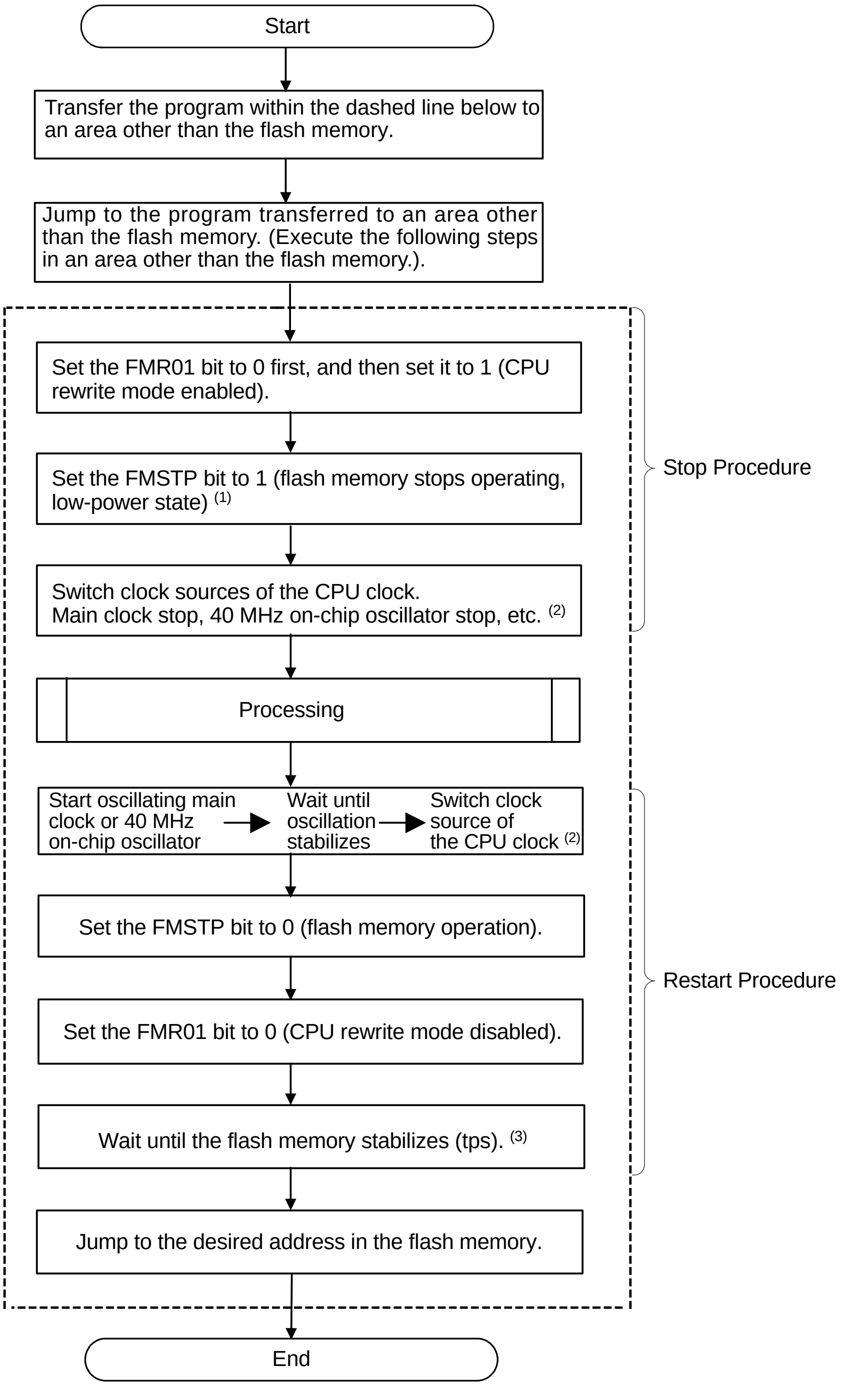
Table 9.10 CPU Clock After Exiting Stop Mode

CPU Clock Before Entering Stop Mode	CPU Clock After Exiting Stop Mode
Main clock divided by 1 (no division), 2, 4, 8 or 16	Main clock divided by 8
fOCO-S divided by 1 (no division), 2, 4, 8 or 16	fOCO-S divided by 8
fOCO-F divided by 2, 4, 8 or 16	fOCO-F divided by 8
fC	fC

9.4 Power Control in Flash Memory

9.4.1 Stopping Flash Memory

When the flash memory is stopped, current consumption is reduced. Execute a program in any area other than the flash memory. Figure 9.3 shows the setting procedure to stop and restart the flash memory. Follow the flowchart of Figure 9.3.


Start
Transfer the program within the dashed line below to an area other than the flash memory.
Jump to the program transferred to an area other than the flash memory. (Execute the following steps in an area other than the flash memory.).
Set the FMR01 bit to 0 first, and then set it to 1 (CPU rewrite mode enabled).
Set the FMSTP bit to 1 (flash memory stops operating, low-power state) (1)
Switch clock sources of the CPU clock.
Main clock stop, 40 MHz on-chip oscillator stop, etc. (2)
Stop Procedure
Processing
Start oscillating main clock or 40 MHz on-chip oscillator
Wait until oscillation stabilizes
Switch clock source of the CPU clock (2)
Set the FMSTP bit to 0 (flash memory operation).
Set the FMR01 bit to 0 (CPU rewrite mode disabled).
Wait until the flash memory stabilizes (tps). (3)
Restart Procedure
Jump to the desired address in the flash memory.
End

Notes:

1. Set the FMSTP bit to 1 after the FMR01 bit is set to 1 (CPU rewrite mode enabled).
2. Wait until the clock stabilizes before switching the clock source of the CPU clock.
3. Add tps wait time by a program. Do not access the flash memory during this wait time.

Figure 9.3 Stop and Restart of the Flash Memory

9.4.2 Reading Flash Memory

Current consumption while reading the flash memory can be reduced by using bits FMR22 and FMR23 in the FMR2 register.

9.4.2.1 Slow Read Mode

Slow read mode can be used when f(BCLK) is less than or equal to f(SLOW_R) and the PM17 bit in the PM1 register is 1 (one wait). Figure 9.4 shows Setting and Canceling Slow Read Mode.
When using 125 kHz on-chip oscillator clock or sub clock as the CPU clock source, a wait is unnecessary (technical update number: TN-16C-A179A/E).

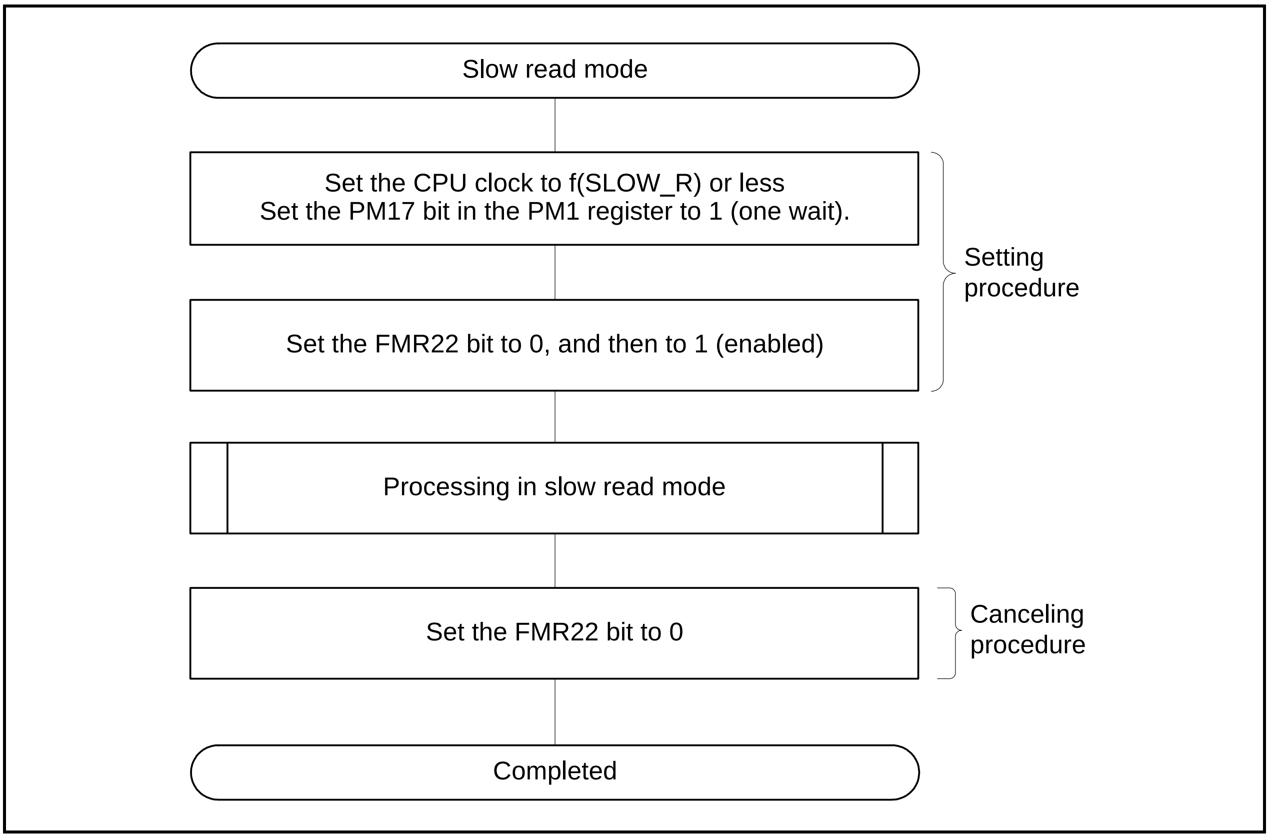
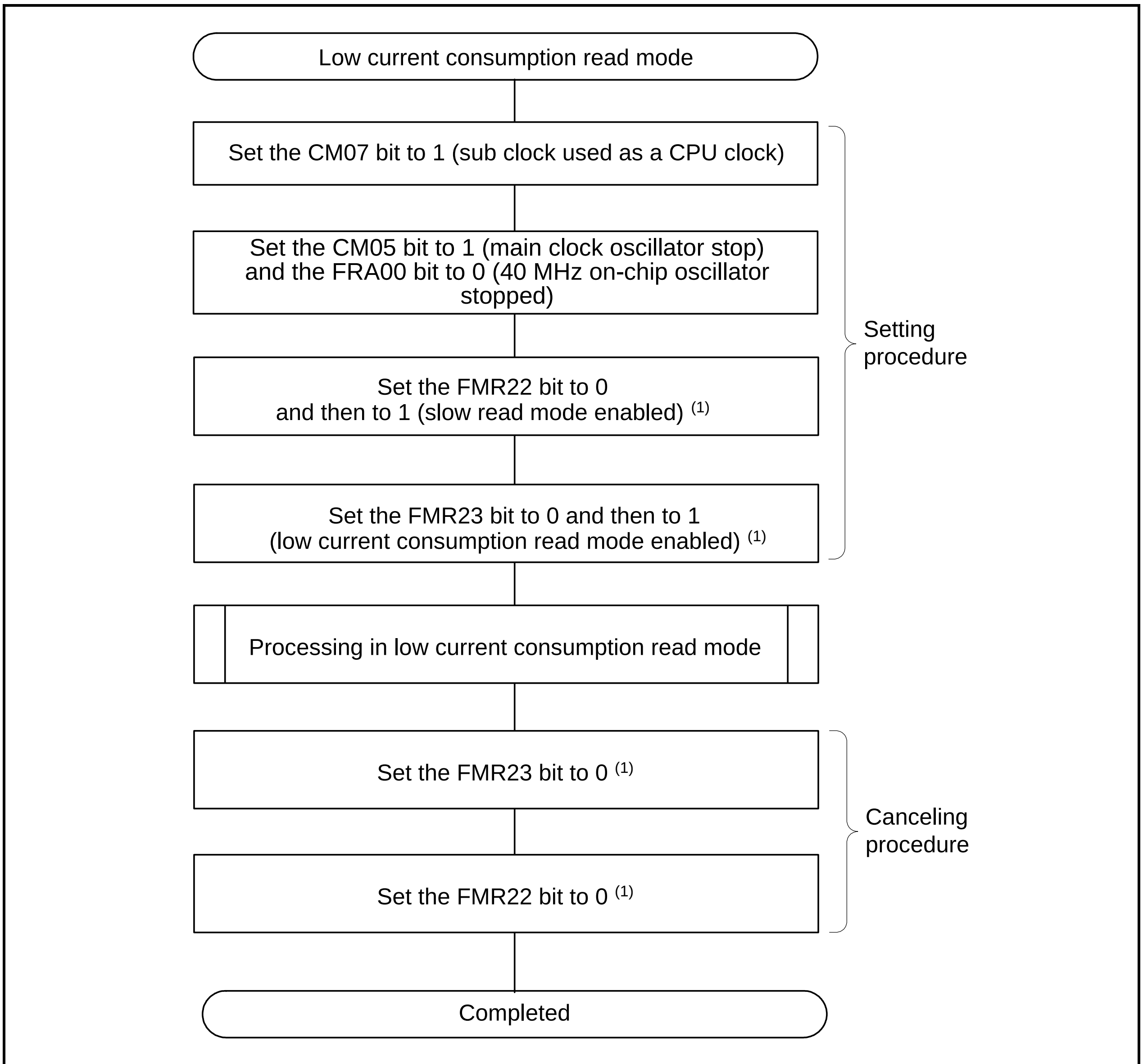

Slow read mode
Set the CPU clock to f(SLOW_R) or less
Set the PM17 bit in the PM1 register to 1 (one wait).
Set the FMR22 bit to 0, and then to 1 (enabled)
Setting procedure
Processing in slow read mode
Set the FMR22 bit to 0
Canceling procedure
Completed

Figure 9.4 Setting and Canceling Slow Read Mode

9.4.2.2 Low Current Consumption Read Mode

Low current consumption read mode can be used when the CM07 bit in the CM0 register is 1 (sub clock used as CPU clock).Figure 9.5 shows Setting and Canceling Low Current Consumption Read Mode.


Low current consumption read mode
Set the CM07 bit to 1 (sub clock used as a CPU clock)
Set the CM05 bit to 1 (main clock oscillator stop) and the FRA00 bit to 0 (40 MHz on-chip oscillator stopped)
Set the FMR22 bit to 0 and then to 1 (slow read mode enabled) (1)
Set the FMR23 bit to 0 and then to 1 (low current consumption read mode enabled) (1)
Setting procedure
Processing in low current consumption read mode
Set the FMR23 bit to 0 (1)
Set the FMR22 bit to 0 (1)
Canceling procedure
Completed

Note:
1. Do not rewrite bits FMR22 and FMR23 simultaneously.

Figure 9.5 Setting and Canceling Low Current Consumption Read Mode

9.5 Reducing Power Consumption

To reduce power consumption, refer to the following descriptions when designing a system or writing a program.

9.5.1 Ports

The MCU retains the state of each I/O port even when it enters wait mode or stop mode. A current flows in the active output ports. A shoot-through current flows to the input ports in the high-impedance state. Set the unassigned pins to input state, wait until the potential stabilizes, and then enter wait mode or stop mode.

9.5.2 A/D Converter

When not performing A/D conversion, set the ADSTBY bit in the ADCON1 register to 0 (A/D operation stopped).

9.5.3 D/A Converter

When not performing D/A conversion, set the DAiE bit (i = 0, 1) in the DACON register to 0 (Output disabled) and the DAi register to 00h.

9.5.4 Stopping Peripheral Functions

Use the PCLKSTP1 register to stop providing f1 to the peripheral functions not using f1.
Use the CM02 bit in the CM0 register to stop the unnecessary peripheral functions while in wait mode.

9.5.5 Switching the Oscillation-Driving Capacity

Set the driving capacity to low when oscillation is stable.

9.6 Notes on Power Control

9.6.1 CPU Clock

When switching the CPU clock source, wait until oscillation of the switched clock source is stable. After exiting stop mode, wait until oscillation stabilizes before changing the division.

9.6.2 Wait Mode

- Insert four or more NOP instructions following the WAIT instruction. When entering wait mode, because the instruction queue prefetches instructions that follow the WAIT instruction, prefetched instructions are sometimes executed prior to the interrupt routine used to exit wait mode. As shown below, when the instruction to set the I flag to 1 is allocated just before the WAIT instruction, interrupt requests are not accepted before the WAIT instruction is executed.

  The following is an example program for entering wait mode:

```
Program Example:  FSET    I        ;
                  WAIT             ; Enter wait mode
                  NOP              ; Insert at least four NOP instructions
                  NOP
                  NOP
                  NOP
```

- Do not enter wait mode from PLL operating mode. To enter wait mode from PLL operating mode, first enter medium-speed mode, then set the PLC07 bit to 0 (PLL off).
- Do not enter wait mode from low current consumption read mode. To enter wait mode from low current consumption read mode, set the FMR23 bit in the FMR2 register to 0 (low current consumption read mode disabled).
- Do not enter wait mode from CPU rewrite mode. To enter wait mode from CPU rewrite mode, first set the FMR01 bit in the FMR0 register to 0 (CPU rewrite mode disabled), then disable the DMA transfer.
- Set the PLC07 bit in the PLC0 register to 0 (PLL off). When the PLC07 bit is 1 (PLL on), current consumption cannot be reduced even in wait mode.

9.6.3 Stop Mode

- When exiting stop mode by a hardware reset, drive the $\overline{\text{RESET}}$ pin low for 20 fOCO-S cycles or more.
- Set the MR0 bit in the TAiMR register (i = 0 to 4) to 0 (pulse not output) when using timer A to exit stop mode.
- When entering stop mode, insert a JMP.B instruction immediately after executing an instruction that sets the CM10 bit in the CM1 register to 1 (stop mode), and then insert at least four NOP instructions. When entering stop mode, the instruction queue reads ahead the instructions following the instruction which sets the CM10 bit to 1. Thus, some of the instructions may be executed before the MCU enters stop mode or before the interrupt routine for returning from stop mode. As shown below, when the instruction to set the I flag to 1 is allocated just before the instruction to set the CM10 bit to 1, interrupt requests are not accepted before entering stop mode.

The following is an example program for entering stop mode:

```
Program Example:   FSET     I
                   BSET     0, CM1    ;  Enter stop mode
                   JMP.B    L2        ;  Insert a JMP.B instruction
         L2:
                   NOP                ;  At least four NOP instructions
                   NOP
                   NOP
                   NOP
```

- Do not enter stop mode from PLL operating mode. To enter stop mode from PLL operating mode, first enter medium-speed mode, then set the PLC07 bit to 0 (PLL off).
- Do not enter stop mode from low current consumption read mode. To enter stop mode from low current consumption read mode, set the FMR23 bit in the FMR2 register to 0 (low current consumption read mode disabled).
- Do not enter stop mode from CPU rewrite mode. To enter stop mode from CPU rewrite mode, first set the FMR01 bit in the FMR0 register to 0 (CPU rewrite mode disabled), then disable the DMA transfer.
- Do not enter stop mode when the oscillator stop/restart detect function is enabled. To enter stop mode, set the CM20 bit in the CM2 register to 0 (oscillator stop/restart detect function disabled).
- Do not enter stop mode when the FMR01 bit is 1 (CPU rewrite mode enabled), and do not enter stop mode when the flash memory is stopped (bits FMR01 and FMSTP are 1).

9.6.4 Low Current Consumption Read Mode

- Enter low current consumption read mode through slow read mode (see Figure 9.5 “Setting and Canceling Low Current Consumption Read Mode” for details).
- When the FMR23 bit in the FMR2 register is 1 (low current consumption read mode enabled), do not set the FMSTP bit to 1 (flash memory stopped). Also, when the FMSTP bit is 1, do not set the FMR23 bit to 1.
- When the FMR01 bit in the FMR0 register to 1 (CPU rewrite mode enabled), do not set the FMR23 bit in the FMR2 register to 1 (low current consumption read mode enable).

9.6.5 Slow Read Mode

- When the FMR01 bit in the FMR0 register to 1 (CPU rewrite mode enabled), do not set the FMR22 bit in the FMR2 register to 1 (slow read mode enabled).

10. Processor Mode

10.1 Introduction

Single-chip mode, memory expansion mode, or microprocessor mode can be selected for the processor mode. Table 10.1 lists the Processor Mode Features.

Table 10.1 Processor Mode Features

Processor Mode	Access Space	Pins Assigned as I/O Ports
Single-chip mode	SFR, internal RAM, internal ROM	All pins are I/O ports or peripheral function I/O pins
Memory expansion mode	SFR, internal RAM, internal ROM, external area (1)	Some pins serve as bus control pins (1)
Microprocessor mode	SFR, internal RAM, external area (1)	Some pins serve as bus control pins (1)

Note:

1. Refer to 11. “Bus” for details.

Table 10.2 I/O Pins

Pin Name	I/O	Function
CNVSS	Input	Selects a processor mode

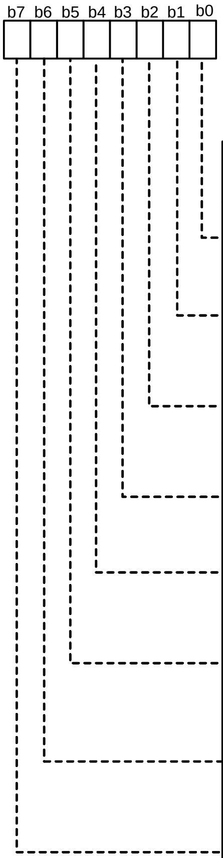
10.2 Registers

Table 10.3 Registers

Address	Register	Symbol	Reset Value
0004h	Processor Mode Register 0	PM0	0000 0000b (CNVSS pin is low) 0000 0011b (CNVSS pin is high)
0005h	Processor Mode Register 1	PM1	0000 1000b
0010h	Program 2 Area Control Register	PRG2C	XXXX XX00b

10.2.1 Processor Mode Register 0 (PM0)

Processor Mode Register 0



Symbol	Address	Reset Value
PM0	0004h	0000 0000b (CNVSS pin is low) 0000 0011b (CNVSS pin is high)

Bit Symbol	Bit Name	Function	RW
PM00	Processor mode bit	b1 b0 0 0 : Single-chip mode 0 1 : Memory expansion mode 1 0 : Do not set 1 1 : Microprocessor mode	RW
PM01			RW
PM02	R/W mode select bit	0 : $\overline{RD}$, $\overline{BHE}$, $\overline{WR}$ 1 : $\overline{RD}$, $\overline{WRH}$, $\overline{WRL}$	RW
PM03	Software reset bit	Setting this bit to 1 resets the MCU. When read, the read value is 0.	RW
PM04	Multiplexed bus space select bit	b5 b4 0 0 : Multiplexed bus is not used (separate bus in the entire $\overline{CS}$ space) 0 1 : Allocated to $\overline{CS2}$ space 1 0 : Allocated to $\overline{CS1}$ space 1 1 : Allocated to the entire $\overline{CS}$ space	RW
PM05			RW
PM06	Port P4_0 to P4_3 function select bit	0 : Address output 1 : Port function (address is not output)	RW
PM07	BCLK output disable bit	0 : BCLK is output 1 : BCLK is not output (pin becomes high-impedance)	RW

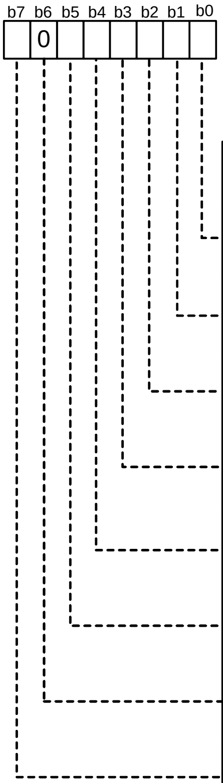
Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register.
Bits PM01 to PM00 do not change at software reset, watchdog timer reset, oscillator stop detect reset, voltage monitor 1 reset, or voltage monitor 2 reset.
Bits PM02, PM05 to PM04, PM06, and PM07 are enabled when bits PM01 to PM00 are 01b (memory expansion mode) or 11b (microprocessor mode).

PM01 to PM00 (Processor mode bit) (b1 to b0)

Do not rewrite bits PM01 to PM00 and PM07 to PM02 at the same time.
(Technical update number: TN-M16C-71-0105)

10.2.2 Processor Mode Register 1 (PM1)

Processor Mode Register 1



Symbol	Address	Reset Value
PM1	0005h	0000 1000b

Bit Symbol	Bit Name	Function	RW
PM10	$\overline{\text{CS2}}$ area switch bit (data flash enable bit)	0 : $\overline{\text{CS2}}$ (0E000h to 0FFFFh) 1 : Data flash (0E000h to 0FFFFh)	RW
PM11	Port P3_7 to P3_4 function select bit	0 : Address output 1 : Port function	RW
PM12	Watchdog timer function select bit	0 : Watchdog timer interrupt 1 : Watchdog timer reset	RW
PM13	Internal area expansion bit 0	Refer to the bit explanation below “PM13 (Internal Area Expansion Bit 0) (b3)”	RW
PM14	Memory area expansion bit	b5 b4 0 0 : 1-MB mode (no expansion) 0 1 : Do not set 1 0 : Do not set 1 1 : 4-MB mode	RW
PM15			RW
— (b6)	Reserved bit	Set to 0	RW
PM17	Wait bit	0 : No wait state 1 : Wait state (1 wait)	RW

Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register.
The PM12 bit becomes 1 by a program. Setting it to 0 has no effect.
Bits PM11, PM15 to PM14 are enabled when bits PM01 to PM00 are 01b (memory expansion mode) or 11b (microprocessor mode).

PM10 ($\overline{\text{CS2}}$ area switch bit (data flash enable bit)) (b0)

This bit is used to select the function of addresses 0E000h to 0FFFFh. Table 10.4 lists Data Flash (Addresses 0E000h to 0FFFFh).

Table 10.4 Data Flash (Addresses 0E000h to 0FFFFh)

PM10 Bit in PM1 Register		0	1
Processor Mode	Single-chip mode	Reserved area	Data flash
	Memory expansion mode	External area	Data flash
	Microprocessor mode	External area	Reserved area

Data flash includes block A (addresses 0E000h to 0EFFFh) and block B (addresses 0F000h to 0FFFFh). When data flash is selected by the setting of the PM10 bit, both block A and block B can be used.
The PM10 bit automatically becomes 1 while the FMR01 bit in the FMR0 register is 1 (CPU rewrite mode).

PM13 (Internal area expansion bit 0) (b3)

This bit is used to select the range of the RAM, program ROM 1, and external area.
When the PM13 bit is 0, the size of the RAM and program ROM 1 is limited, but a wide range can be selected for the external area.
When the PM13 bit is 1, the entire RAM and addresses 80000h to CFFFFh in program ROM 1 are available. Table 10.5 lists the Functions of PM13 Bit and Table 10.6 lists Functions of Addresses 80000h to CFFFFh.

Table 10.5 Functions of PM13 Bit

Access Area			Bit Setting	
			PM13 = 0	PM13 = 1
Internal	RAM		Addresses 00400h up to 03FFFh (15 KB) are available (addresses 04000h to 0CFFFh cannot be used).	The entire area is usable.
	Program ROM 1		Addresses D0000h up to FFFFFh (192 KB) are available (addresses 40000h to CFFFFh cannot be used).	Addresses 80000h up to FFFFFh are available (addresses 40000h to 7FFFFh cannot be used).
External	Memory expansion mode	04000h to 0CFFFh	Usable	Reserved
		40000h to 7FFFFh	Usable	Usable
		80000 to CFFFFh	Usable	Reserved
	Micro-processor mode	04000h to 0CFFFh	Usable	Reserved
		40000h to 7FFFFh	Usable	Usable
		80000 to CFFFFh	Usable	Usable

PM13: Bit in the PM1 register

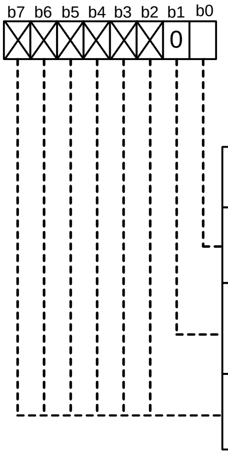
Table 10.6 Functions of Addresses 80000h to CFFFFh

PM13 Bit in PM1 Register		0	1
Processor Mode	Single-chip mode	Reserved area	When program ROM 1 is available, then program ROM 1. When program ROM 1 is not available, then reserved area.
	Memory expansion mode	External area	
	Microprocessor mode	External area	External area

The PM13 bit becomes 1 while the FMR01 bit in the FMR0 register is set to 1 (CPU rewrite mode).

10.2.3 Program 2 Area Control Register (PRG2C)

Program 2 Area Control Register



Symbol	Address	Reset Value
PRG2C	0010h	XXXX XX00b

Bit Symbol	Bit Name	Function	RW
PRG2C0	Program ROM 2 disable bit	0 : Enable program ROM 2 1 : Disable program ROM 2	RW
(b1)	Reserved bit	Set to 0.	RW
— (b7-b2)	No register bits. If necessary, set to 0. The read value is undefined.		—

Set the PRC6 bit in the PRCR register to 1 (write enabled) before rewriting this register.

PRG2C0 (Program ROM 2 disable bit) (b0)

This bit is used to select the function of addresses 10000h to 13FFFh. Table 10.7 lists Program ROM 2 (Addresses 10000h to 13FFFh).

Table 10.7 Program ROM 2 (Addresses 10000h to 13FFFh)

PRG2C0 Bit in PRG2C Register		0	1
Processor Mode	Single-chip mode	Program ROM 2	Reserved area
	Memory expansion mode	Program ROM 2	External area
	Microprocessor mode	Reserved area	External area

Program ROM 2 includes the on-chip debugger monitor area and user boot code area. Refer to 30.7.1 “User Boot Function” for details.

10.3 Operations

10.3.1 Processor Mode Settings

Set the processor mode using the CNVSS pin and bits PM01 to PM00 in the PM0 register.

In hardware reset, power-on reset, or voltage monitor 0 reset, the processor mode is selected by the CNVSS pin input level. Table 10.8 lists Processor Mode after Hardware Reset, Power-On Reset, or Voltage Monitor 0 Reset.

Table 10.8 Processor Mode after Hardware Reset, Power-On Reset, or Voltage Monitor 0 Reset

CNVSS Pin Input Level	Processor Mode	Bits PM01 to PM00 in the PM0 Register
VSS	Single-chip mode	00b (single-chip mode)
VCC1	Microprocessor mode	11b (microprocessor mode)

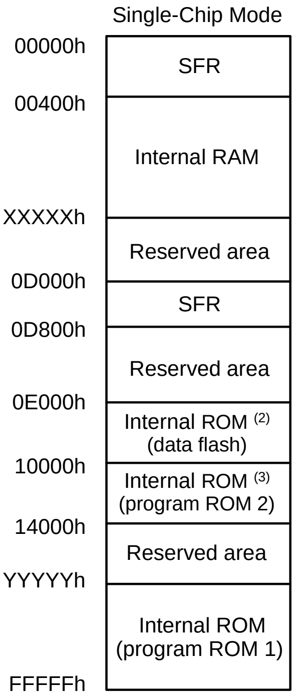
Rewriting bits PM01 to PM00 places the MCU in the mode corresponding to bits PM01 to PM00 regardless of whether the input level of the CNVSS pin is high or low. When VCC1 is applied to the CNVSS pin and then the MCU is reset by hardware reset, power-on reset, or voltage monitor 0 reset, the internal ROM cannot be accessed regardless of the value of bits PM01 to PM00. Table 10.9 lists Bits PM01 to PM00 Set Values and Processor Modes.

Do not rewrite these bits to enter microprocessor mode in the internal ROM, or to exit microprocessor mode in areas overlapping the internal ROM.

Table 10.9 Bits PM01 to PM00 Set Values and Processor Modes

Bits PM01 to PM00	Processor Mode
00b	Single-chip mode
01b	Memory expansion mode
10b	Do not set this value.
11b	Microprocessor mode

Figure 10.1 shows Memory Map in Single-Chip Mode.



Address XXXXXh

PM13 bit in PM1 register		0	1
RAM size	12 KB	033FFh	033FFh
	20 KB	03FFFh	053FFh
	31 KB	03FFFh	07FFFh
	47 KB	03FFFh	0BFFFh

Address YYYYYh

PM13 bit in PM1 register		0	1
Program ROM 1 size	128 KB	E0000h	E0000h
	256 KB	D0000h	C0000h
	384 KB	D0000h	A0000h
	512 KB	D0000h	80000h

Notes:

1. When the PM13 bit is 0, 15 KB of internal RAM and 192 KB of internal ROM can be used.
2. Data flash can be used when the PM10 bit in the PM1 register is 1 (0E000h to 0FFFFh are used as data flash).
3. Program ROM 2 can be used when the PRG2C0 bit in the PRG2C register is 0 (program ROM 2 enabled).

Figure 10.1 Memory Map in Single-Chip Mode

11. Bus

11.1 Introduction

Two types of buses are available:

- Internal bus in the MCU
- External bus which is used to access to external devices in memory expansion mode or microprocessor mode

Table 11.1 Bus Specifications

Item	Specification
Internal bus	• Used in all processor modes • Separate bus • 16-bit data bus width • 0 or 1 software waits can be inserted
External bus	• Used in memory expansion mode or microprocessor mode • Separate bus or multiplexed bus selectable • Data bus width selectable (8 or 16 bits) • Number of address buses selectable (12, 16, or 20 buses) • 4 chip select outputs $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$ • Combinations of read and write signals selectable ($\overline{\text{RD}}$, $\overline{\text{BHE}}$, $\overline{\text{WR}}$ or $\overline{\text{RD}}$, $\overline{\text{WRL}}$, $\overline{\text{WRH}}$) • $\overline{\text{RDY}}$ available • 0 to 8 software waits can be inserted • Memory area expansion function (up to 4 MB) (refer to 12. “Memory Space Expansion Function”) • 3 V or 5 V interface

11.2 Registers

Table 11.2 lists bus related registers. Refer to 10. “Processor Mode” for registers PM0 and PM1. Refer to 30. “Flash Memory” for the FMR1 register.

Table 11.2 Registers

Address	Register	Symbol	Reset Value
0004h	Processor Mode Register 0	PM0	0000 0000b (CNVSS pin is low) 0000 0011b (CNVSS pin is high)
0005h	Processor Mode Register 1	PM1	0000 1000b
0008h	Chip Select Control Register	CSR	01h
0009h	External Area Recovery Cycle Control Register	EWR	XXXX XX00b
0011h	External Area Wait Control Expansion Register	EWC	00h
001Bh	Chip Select Expansion Control Register	CSE	00h
0221h	Flash Memory Control Register 1	FMR1	00X0 XX0Xb

11.2.1 Chip Select Control Register (CSR)

Chip Select Control Register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
CSR	0008h	01h

Bit Symbol	Bit Name	Function	RW
CS0	$\overline{\text{CS0}}$ output enable bit	0 : Chip select output disabled (functions as an I/O port) 1 : Chip select output enabled	RW
CS1	$\overline{\text{CS1}}$ output enable bit		RW
CS2	$\overline{\text{CS2}}$ output enable bit		RW
CS3	$\overline{\text{CS3}}$ output enable bit		RW
CS0W	$\overline{\text{CS0}}$ wait bit	0 : Wait state 1 : No wait state	RW
CS1W	$\overline{\text{CS1}}$ wait bit		RW
CS2W	$\overline{\text{CS2}}$ wait bit		RW
CS3W	$\overline{\text{CS3}}$ wait bit		RW

CSiW ($\overline{\text{CSi}}$ wait bit) (i = 0 to 3) (b7-b4)

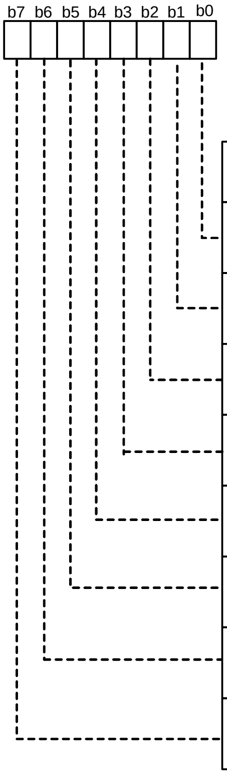
Set the CSiW bit to 0 (wait state) under the following conditions:

- The $\overline{\text{RDY}}$ signal is used in the area indicated by $\overline{\text{CSi}}$.
- The multiplexed bus is used in the area indicated by $\overline{\text{CSi}}$.
- The PM17 bit in the PM1 register is 1 (wait state) in memory expansion mode or microprocessor mode.

When the CSiW bit is 0 (wait state), the number of wait states can be selected using bits CSEi1W to CSEi0W in the CSE register.

11.2.2 Chip Select Expansion Control Register (CSE)

Chip Select Expansion Control Register



Symbol	Address	Reset Value
CSE	001Bh	00h

Bit Symbol	Bit Name	Function	RW
CSE00W	$\overline{\text{CS0}}$ wait expansion bit	b1 b0 0 0 : 1 wait (1ϕ + 1ϕ) 0 1 : 2 waits (1ϕ + 2ϕ) 1 0 : 3 waits (1ϕ + 3ϕ) 1 1 : Select wait states by bits EWC01 and EWC00 in the EWC register	RW
CSE01W			RW
CSE10W	$\overline{\text{CS1}}$ wait expansion bit	b3 b2 0 0 : 1 wait (1ϕ + 1ϕ) 0 1 : 2 waits (1ϕ + 2ϕ) 1 0 : 3 waits (1ϕ + 3ϕ) 1 1 : Select wait states by bits EWC11 and EWC10 in the EWC register	RW
CSE11W			RW
CSE20W	$\overline{\text{CS2}}$ wait expansion bit	b5 b4 0 0 : 1 wait (1ϕ + 1ϕ) 0 1 : 2 waits (1ϕ + 2ϕ) 1 0 : 3 waits (1ϕ + 3ϕ) 1 1 : Select wait states by bits EWC21 and EWC20 in the EWC register	RW
CSE21W			RW
CSE30W	$\overline{\text{CS3}}$ wait expansion bit	b7 b6 0 0 : 1 wait (1ϕ + 1ϕ) 0 1 : 2 waits (1ϕ + 2ϕ) 1 0 : 3 waits (1ϕ + 3ϕ) 1 1 : Select wait states by bits EWC31 and EWC30 in the EWC register	RW
CSE31W			RW

Set the CSiW bit (i = 0 to 3) in the CSR register to 0 (wait state) before writing to bits CSEi1W to CSEi0W. To set the CSiW bit to 1 (no wait state), set bits CSEi1W to CSEi0W to 00b first, and then set the CSiW bit to 1.

Do not set bits CSEi1W to CSEi0W to 11b for a multiplexed bus area.

11.2.3 External Area Wait Control Expansion Register (EWC)

External Area Wait Control Expansion Register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
EWC	0011h	00h

Bit Symbol	Bit Name	Function	RW
EWC00	$\overline{\text{CS0}}$ area wait expansion bit	b1 b0 0 0 : 2ϕ + 3ϕ 0 1 : 2ϕ + 4ϕ 1 0 : 3ϕ + 4ϕ 1 1 : 4ϕ + 5ϕ	RW
EWC01			RW
EWC10	$\overline{\text{CS1}}$ area wait expansion bit	b3 b2 0 0 : 2ϕ + 3ϕ 0 1 : 2ϕ + 4ϕ 1 0 : 3ϕ + 4ϕ 1 1 : 4ϕ + 5ϕ	RW
EWC11			RW
EWC20	$\overline{\text{CS2}}$ area wait expansion bit	b5 b4 0 0 : 2ϕ + 3ϕ 0 1 : 2ϕ + 4ϕ 1 0 : 3ϕ + 4ϕ 1 1 : 4ϕ + 5ϕ	RW
EWC21			RW
EWC30	$\overline{\text{CS3}}$ area wait expansion bit	b7 b6 0 0 : 2ϕ + 3ϕ 0 1 : 2ϕ + 4ϕ 1 0 : 3ϕ + 4ϕ 1 1 : 4ϕ + 5ϕ	RW
EWC31			RW

This register can be used as a separate bus area. When bits CSEi1W to CSEi0W in the CSE register are 11b (select wait states by bits EWCi1 to EWCi0), bits EWCi1 to EWCi0 are enabled (i = 0 to 3).

The following is an example of the number of cycles:

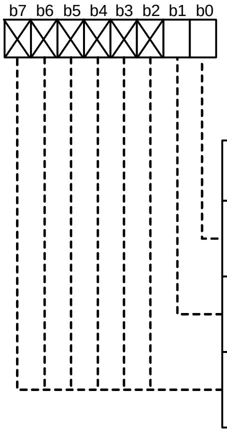
Example: 2ϕ + 3ϕ

└The number of cycles between the falling edge and the rising edge of the $\overline{\text{RD}}$ or $\overline{\text{WR}}$ signal.

└The number of cycles between bus access start and the falling edge of the $\overline{\text{RD}}$ or $\overline{\text{WR}}$ signal.

11.2.4 External Area Recovery Cycle Control Register (EWR)

External Area Recovery Cycle Control Register



Symbol	Address	Reset Value
EWR	0009h	XXXX XX00b

Bit Symbol	Bit Name	Function	RW
EWR0	Recovery cycle insert bit	b1 b0 0 0 : No recovery cycle 0 1 : 1 recovery cycle inserted 1 0 : 2 recovery cycles inserted 1 1 : 3 recovery cycles inserted	RW
EWR1			RW
— (b7-b2)	No register bits. If necessary, set to 0. When read, the read value is undefined.		—

The EWR register is enabled when bits CSEi1W to CSEi0W in the CSE register are 11b.

11.3 Operations

11.3.1 Common Specifications between the Internal Bus and External Bus

11.3.1.1 Reference Clock

Both the internal and external buses operate based on the BCLK. However, the area accessed and wait states affect bus operation. Refer to 11.3.2.1 “Software Wait States of the Internal Bus” and 11.3.5.9 “Software Wait States” for details.

11.3.1.2 Bus Hold

Both the internal and external buses are in a hold state under the following condition:

- Rewriting the flash memory in EW1 mode while auto-programming or auto-erasing

When the bus is in hold state, the following occur:

- CPU stops
- DMAC stops
- The watchdog timer stops when the CSPRO bit in the CSPR register is 0 (count source protection mode disabled)
- State of I/O ports is retained.

Bus use priority is given to bus hold, DMAC, and CPU in descending order. However, if the CPU is accessing an odd address in word units, DMAC cannot gain control of the bus between two separate accesses.

Bus Hold > DMAC > CPU

Figure 11.1 Bus Use Priority

11.3.2 Internal Bus

The internal bus is used to access the internal area in the MCU.

11.3.2.1 Software Wait States of the Internal Bus

The PM17 bit in the PM1 register, which is a software-wait-related bit, affects both the internal memory and the external area. Table 11.3 lists Bits and Bus Cycles Related to Software Wait States (SFR and Internal Memory).

The data flash of the internal ROM is affected by both the PM17 bit in the PM1 register and the FMR17 bit in the FMR1 register.

Table 11.3 Bits and Bus Cycles Related to Software Wait States (SFR and Internal Memory)

Area		Setting of Software-Wait-Related Bits		Software Wait States	Bus Cycle
		FMR1 register FMR17 bit	PM1 register PM17 bit		
SFR		0 or 1	0 or 1	1	2 BCLK cycles [1]
Internal RAM		0 or 1	0	None	1 BCLK cycle [1]
			1	1	2 BCLK cycles
Internal ROM	Program ROM 1 Program ROM 2	0 or 1	0	None	1 BCLK cycle [1]
			1	1	2 BCLK cycles
	Data flash	0	0 or 1	1	2 BCLK cycles [1]
		1	0	None	1 BCLK cycle
			1	1	2 BCLK cycle

Note:

1. Status after reset.

11.3.3 External Bus

The external bus is used to access external devices in memory expansion mode or microprocessor mode.

In memory expansion or microprocessor mode, some pins serve as the bus control pins to perform data input to and output from external devices. The bus control pins are as follows: A0 to A19, D0 to D15, $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$, $\overline{\text{RD}}$, $\overline{\text{WRL}}/\overline{\text{WR}}$, $\overline{\text{WRH}}/\overline{\text{BHE}}$, ALE, $\overline{\text{RDY}}$, $\overline{\text{HOLD}}$, $\overline{\text{HLDA}}$, and BCLK.

11.3.4 External Bus Mode

Multiplexed bus mode or separate bus mode can be selected using bits PM05 to PM04 in the PM0 register. Table 11.4 lists the Difference between Separate Bus and Multiplexed Bus Modes.

11.3.4.1 Separate Bus

In external bus mode, data and address are separate.

11.3.4.2 Multiplexed Bus

In external bus mode, data and address are multiplexed.

- When the input level to the BYTE pin is high (8-bit data bus)
  D0 to D7 and A0 to A7 are multiplexed.
- When the input level to the BYTE pin is low (16-bit data bus)
  D0 to D7 and A1 to A8 are multiplexed. D8 to D15 are not multiplexed (do not use these pins).
  External devices connected to a multiplexed bus are assigned only even addresses of the MCU.

Table 11.4 Difference between Separate Bus and Multiplexed Bus Modes

Pin Name [1]	Separate Bus	Multiplexed Bus	
		BYTE = high	BYTE = low
P0_0 to P0_7/D0 to D7	D0 to D7	(Note 2)	(Note 2)
P1_0 to P1_7/D8 to D15	D8 to D15	I/O port P1_0 to P1_7	(Note 2)
P2_0/A0 (/D0)	A0	A0 D0	A0
P2_1 to P2_7/A1 to A7 (/D1 to D7/D0 to D6)	A1 to A7	A1 to A7 D1 to D7	A1 to A7 D0 to D6
P3_0/A8 (/D7)	A8	A8	A8 D7

Notes:

1. See Table 11.8 “Pin Functions for Each Processor Mode” for bus control signals not listed above.
2. Depends on the setting of bits PM05 to PM04 in the PM0 register, and area being accessed.
   See Table 11.8 “Pin Functions for Each Processor Mode” for details.

11.3.5 External Bus Control

The following describes the signals needed for accessing external devices and the functionality of software wait states.

11.3.5.1 Address Bus

The address bus consists of 20 lines: A0 to A19. The address bus width can be set to 12, 16, or 20 bits using the PM06 bit in the PM0 register, and the PM11 bit in the PM1 register. Table 11.5 lists the Set Value of Bits PM06 and PM11 and the Corresponding Address Bus Widths.

Table 11.5 Set Value of Bits PM06 and PM11 and the Corresponding Address Bus Widths

Bit Set Value (1)	Pin Function	Address Bus Width
PM11 = 1	P3_4 to P3_7	12 bits
PM06 = 1	P4_0 to P4_3	
PM11 = 0	A12 to A15	16 bits
PM06 = 1	P4_0 to P4_3	
PM11 = 0	A12 to A15	20 bits
PM06 = 0	A16 to A19	

Note:

1. Only set the values listed above.

When the processor mode is changed from single-chip mode to memory expansion mode, the address bus is undefined until an external area is accessed.

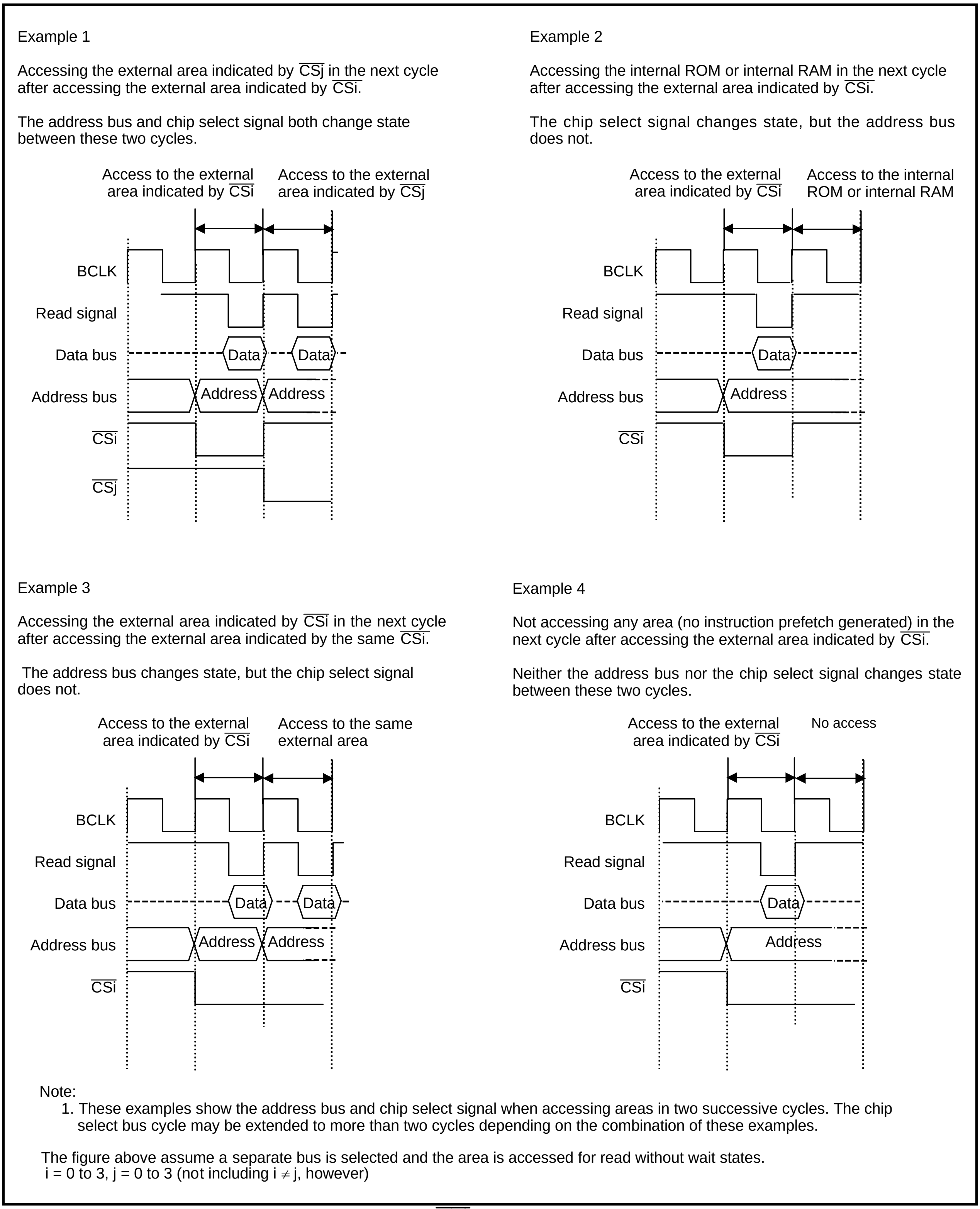
11.3.5.2 Data Bus

When input to the BYTE pin is high (8-bit width), the data bus is comprised of eight lines (D0 to D7). When input to the BYTE pin is low (16-bit width), the data bus is comprised of 16 lines (D0 to D15). Do not change the input level to the BYTE pin.

11.3.5.3 Chip Select Signal

The chip select signals (hereafter referred to as $\overline{\mathrm{CS}}$) are output from the $\overline{\mathrm{CSi}}$ pin (i = 0 to 3). These pins can be set to function as I/O ports or as $\overline{\mathrm{CS}}$ using the CSi bit in the CSR register.

In 1-MB mode, the external area can be separated into a maximum of four spaces by the $\overline{\mathrm{CSi}}$ signal. In 4-MB mode, the $\overline{\mathrm{CSi}}$ signal or bank number is output from the $\overline{\mathrm{CSi}}$ pin. Refer to 12. “Memory Space Expansion Function”. Figure 11.2 shows Examples of Address Bus and $\overline{\mathrm{CSi}}$ Signal Output in 1-MB Mode.



Example 1

Accessing the external area indicated by $\overline{\text{CSj}}$ in the next cycle after accessing the external area indicated by $\overline{\text{CSi}}$.

The address bus and chip select signal both change state between these two cycles.

Access to the external area indicated by CSi
Access to the external area indicated by CSj
BCLK
Read signal
Data bus
Data
Data
Address bus
Address
Address
CSi
CSj

Example 2

Accessing the internal ROM or internal RAM in the next cycle after accessing the external area indicated by $\overline{\text{CSi}}$.

The chip select signal changes state, but the address bus does not.

Access to the external area indicated by CSi
Access to the internal ROM or internal RAM
BCLK
Read signal
Data bus
Data
Address bus
Address
CSi

Example 3

Accessing the external area indicated by $\overline{\text{CSi}}$ in the next cycle after accessing the external area indicated by the same $\overline{\text{CSi}}$.

The address bus changes state, but the chip select signal does not.

Access to the external area indicated by CSi
Access to the same external area
BCLK
Read signal
Data bus
Data
Data
Address bus
Address
Address
CSi

Example 4

Not accessing any area (no instruction prefetch generated) in the next cycle after accessing the external area indicated by $\overline{\text{CSi}}$.

Neither the address bus nor the chip select signal changes state between these two cycles.

Note:

1. These examples show the address bus and chip select signal when accessing areas in two successive cycles. The chip select bus cycle may be extended to more than two cycles depending on the combination of these examples.

The figure above assume a separate bus is selected and the area is accessed for read without wait states.
i = 0 to 3, j = 0 to 3 (not including i ≠ j, however)

Figure 11.2 Examples of Address Bus and $\overline{\text{CSi}}$ Signal Output in 1-MB Mode

11.3.5.4 Read and Write Signals

When the data bus is 16 bits wide, the read and write signals can be selected based on combinations of $\overline{\mathrm{RD}}$, $\overline{\mathrm{BHE}}$, and $\overline{\mathrm{WR}}$, or combinations of $\overline{\mathrm{RD}}$, $\overline{\mathrm{WRL}}$, and $\overline{\mathrm{WRH}}$ using the PM02 bit in the PM0 register. When the data bus is 8 bits wide, use combinations of $\overline{\mathrm{RD}}$, $\overline{\mathrm{WR}}$, and $\overline{\mathrm{BHE}}$.

Table 11.6 lists Operation of the $\overline{\mathrm{RD}}$, $\overline{\mathrm{WRL}}$ and $\overline{\mathrm{WRH}}$ Signals. Table 11.7 lists Operation of the $\overline{\mathrm{RD}}$, $\overline{\mathrm{WR}}$ and $\overline{\mathrm{BHE}}$ Signals.

Table 11.6 Operation of the $\overline{\mathrm{RD}}$, $\overline{\mathrm{WRL}}$ and $\overline{\mathrm{WRH}}$ Signals

Data Bus Width	$\overline{\mathrm{RD}}$	$\overline{\mathrm{WRL}}$	$\overline{\mathrm{WRH}}$	Status of External Data Bus
16-bit (BYTE pin input = low)	L	H	H	Read data
	H	L	H	Write 1 byte of data to an even address
	H	H	L	Write 1 byte of data to an odd address
	H	L	L	Write data to both even and odd addresses

Table 11.7 Operation of the $\overline{\mathrm{RD}}$, $\overline{\mathrm{WR}}$ and $\overline{\mathrm{BHE}}$ Signals

Data Bus Width	$\overline{\mathrm{RD}}$	$\overline{\mathrm{WR}}$	$\overline{\mathrm{BHE}}$	A0	Status of External Data Bus
16-bit (BYTE pin input = low)	H	L	L	H	Write 1 byte of data to an odd address.
	L	H	L	H	Read 1 byte of data from an odd address.
	H	L	H	L	Write 1 byte of data to an even address.
	L	H	H	L	Read 1 byte of data from an even address.
	H	L	L	L	Write data to both even and odd addresses.
	L	H	L	L	Read data from both even and odd addresses.
8-bit (BYTE pin input = high)	H	L	– [1]	H or L	Write 1 byte of data.
	L	H	– [1]	H or L	Read 1 byte of data.

Note:

1. Do not use.

11.3.5.5 ALE Signal

The ALE signal is used to latch the address when a multiplexed bus space is accessed. Latch the address at the falling edge of the ALE signal.

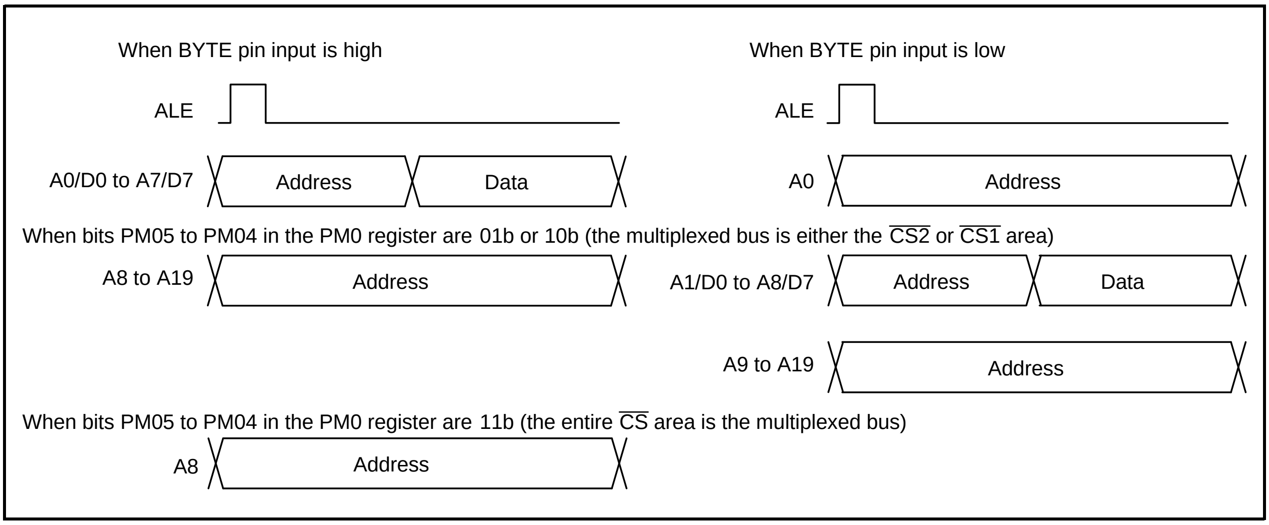
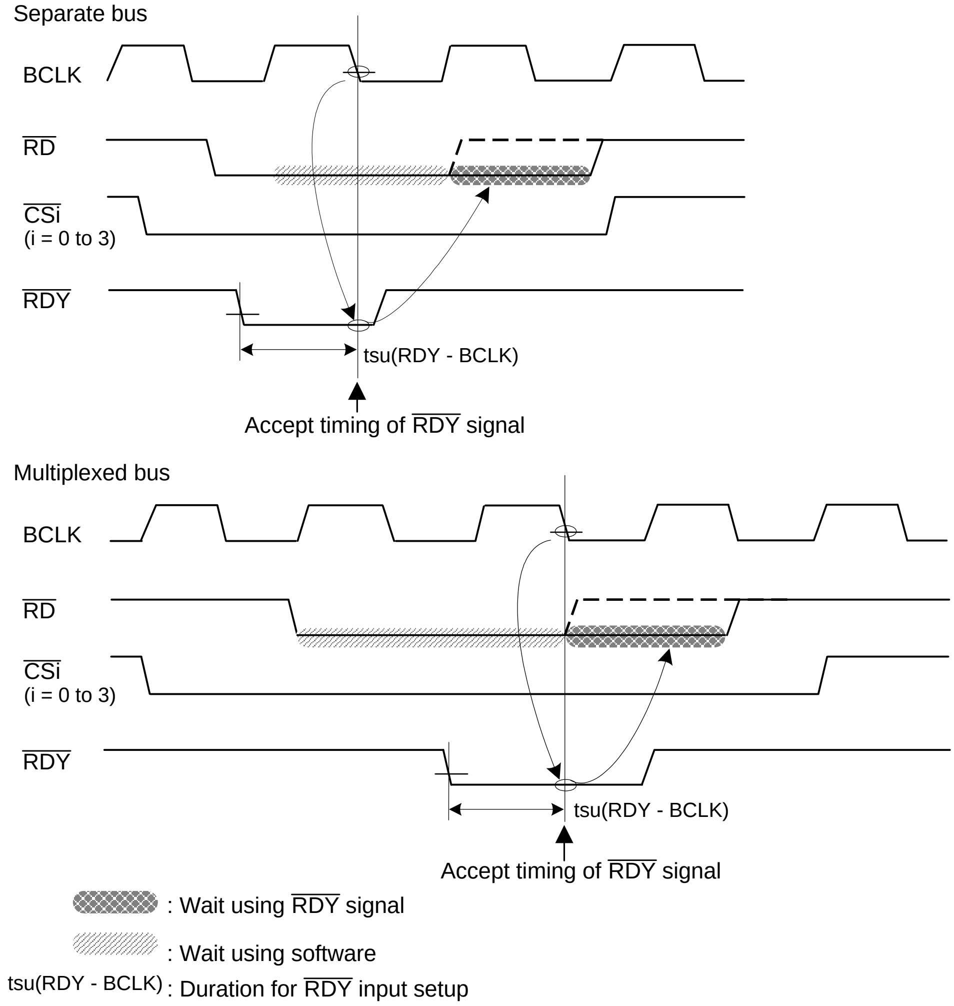

When BYTE pin input is high
When BYTE pin input is low
ALE
ALE
A0/D0 to A7/D7
Address
Data
A0
Address
When bits PM05 to PM04 in the PM0 register are 01b or 10b (the multiplexed bus is either the $\overline{\mathrm{CS2}}$ or $\overline{\mathrm{CS1}}$ area)
A8 to A19
Address
A1/D0 to A8/D7
Address
Data
A9 to A19
Address
When bits PM05 to PM04 in the PM0 register are 11b (the entire $\overline{\mathrm{CS}}$ area is the multiplexed bus)
A8
Address

Figure 11.3 ALE Signal, Address Bus, and Data Bus

11.3.5.6 $\overline{\text{RDY}}$ Signal

This signal is provided for accessing external devices which need to be accessed at low speed. If input to the $\overline{\text{RDY}}$ pin is low at the last falling edge of BCLK in the bus cycle, one wait state is inserted in the bus cycle. While in wait state, the following signals retain the state in which they were when the $\overline{\text{RDY}}$ signal was acknowledged:
A0 to A19, D0 to D15, $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$, $\overline{\text{RD}}$, $\overline{\text{WRL}}$, $\overline{\text{WRH}}$, $\overline{\text{WR}}$, $\overline{\text{BHE}}$, ALE, $\overline{\text{HLDA}}$

Then, when input to the $\overline{\text{RDY}}$ pin is detected high at the falling edge of BCLK, the remaining bus cycle is executed. Figure 11.4 shows Examples in Which Wait State Was Inserted into Read Cycle by $\overline{\text{RDY}}$ Signal. To use the $\overline{\text{RDY}}$ signal, set the corresponding bit (among bits CS3W to CS0W) in the CSR register to 0 (with wait state). When not using the $\overline{\text{RDY}}$ signal, pull-up the $\overline{\text{RDY}}$ pin.



The above diagrams assume bits CSEi1W to CSEi0W (i = 0 to 3) in the CSE register are 00b (one wait).

Figure 11.4 Examples in Which Wait State Was Inserted into Read Cycle by $\overline{\text{RDY}}$ Signal

11.3.5.7 BCLK Output

When the PM07 bit in the PM0 register is set to 0 (output enabled), a clock with the same frequency as the CPU clock is output as BCLK from the BCLK pin. Refer to 8.4 “CPU Clock and Peripheral Function Clocks”.

Table 11.8 Pin Functions for Each Processor Mode

Processor Mode		Memory Expansion Mode or Microprocessor Mode				Memory Expansion Mode
Bits PM05 to PM04		00b (separate bus)		01b ($\overline{\text{CS2}}$ is for multiplexed bus and the others are for separate bus) 10b ($\overline{\text{CS1}}$ is for multiplexed bus and the others are for separate bus)		11b (the entire $\overline{\text{CS}}$ space is for multiplexed bus) (1, 2, 3)
Data bus width BYTE Pin		8 bits High	16 bits Low	8 bits High	16 bits Low	8 bits High
P0_0 to P0_7		D0 to D7	D0 to D7	D0 to D7 (6)	D0 to D7 (6)	I/O ports
P1_0 to P1_7		I/O ports	D8 to D15	I/O ports	D8 to D15(6, 7)	I/O ports
P2_0		A0	A0	A0/D0 (4)	A0	A0/D0
P2_1 to P2_7		A1 to A7	A1 to A7	A1 to A7 /D1 to D7 (4)	A1 to A7 /D0 to D6 (4)	A1 to A7 /D1 to D7
P3_0		A8	A8	A8	A8/D7 (4)	Undefined value is output
P3_1 to P3_3		A9 to A11				I/O ports
P3_4 to P3_7	PM11 = 0	A12 to A15				I/O ports
	PM11 = 1	I/O ports				
P4_0 to P4_3	PM06 = 0	A16 to A19				I/O ports
	PM06 = 1	I/O ports				
P4_4	CS0 = 0	I/O ports				
	CS0 = 1	$\overline{\text{CS0}}$				
P4_5	CS1 = 0	I/O ports				
	CS1 = 1	$\overline{\text{CS1}}$				
P4_6	CS2 = 0	I/O ports				
	CS2 = 1	$\overline{\text{CS2}}$				
P4_7	CS3 = 0	I/O ports				
	CS3 = 1	$\overline{\text{CS3}}$				
P5_0	PM02 = 0	$\overline{\text{WR}}$				
	PM02 = 1	– (5)	$\overline{\text{WRL}}$	– (5)	$\overline{\text{WRL}}$	– (5)
P5_1	PM02 = 0	$\overline{\text{BHE}}$				
	PM02 = 1	– (5)	$\overline{\text{WRH}}$	– (5)	$\overline{\text{WRH}}$	– (5)
P5_2		$\overline{\text{RD}}$				
P5_3		BCLK				
P5_4		$\overline{\text{HLDA}}$				
P5_5		$\overline{\text{HOLD}}$				
P5_6		ALE				
P5_7		$\overline{\text{RDY}}$				

I/O port: Functions as I/O ports or peripheral function I/O pins.
PM11: Bit in the PM1 register
PM06, PM05 to PM04, PM02: Bits in the PM0 register
CS3 to CS0: Bits in the CSR register

Notes:

1. When setting bits PM05 and PM04 to 11b (multiplexed bus assigned to the entire $\overline{\text{CS}}$ space) while bits PM01 and PM00 are 01b (memory expansion mode), apply a high to the BYTE pin (external data bus 8 bits wide).
2. While the CNVSS pin is driven high (= VCC1), do not set bits PM05 to PM04 to 11b.
3. When bits PM05 to PM04 are set to 11b in memory expansion mode, P3_1 to P3_7 and P4_0 to P4_3 become I/O ports, in which case the accessible area for each $\overline{\text{CS}}$ is 256 bytes.
4. In separate bus mode, these pins serve as the address bus.
5. When the data bus is 8 bits wide, set the PM02 bit to 0 ($\overline{\text{RD}}$, $\overline{\text{BHE}}$, $\overline{\text{WR}}$).
6. When accessing an area using a multiplexed bus, these pins output an undefined value while writing.
7. Do not use D8 to D15 with multiplexed bus.

11.3.5.8 External Bus Status When Internal Area is Accessed

Table 11.9 lists the External Bus Status When an Internal Area is Accessed. Figure 11.5 shows the Typical Bus Timings When Accessing SFRs.

Table 11.9 External Bus Status When an Internal Area is Accessed

Item		SFR Accessed	Internal ROM or RAM Accessed
A0 to A19		Address output	Retain the last accessed address of external area or SFR
D0 to D15	Read	High-impedance	High-impedance
	Write	Data output	Undefined
$\overline{RD}$, $\overline{WR}$, $\overline{WRL}$, $\overline{WRH}$		$\overline{RD}$, $\overline{WR}$, $\overline{WRL}$, $\overline{WRH}$ output	High-level output
$\overline{BHE}$		$\overline{BHE}$ output	Retain the last accessed status of external area or SFRs
$\overline{CS0}$ to $\overline{CS3}$		High-level output	High-level output
ALE		Low-level output	Low-level output

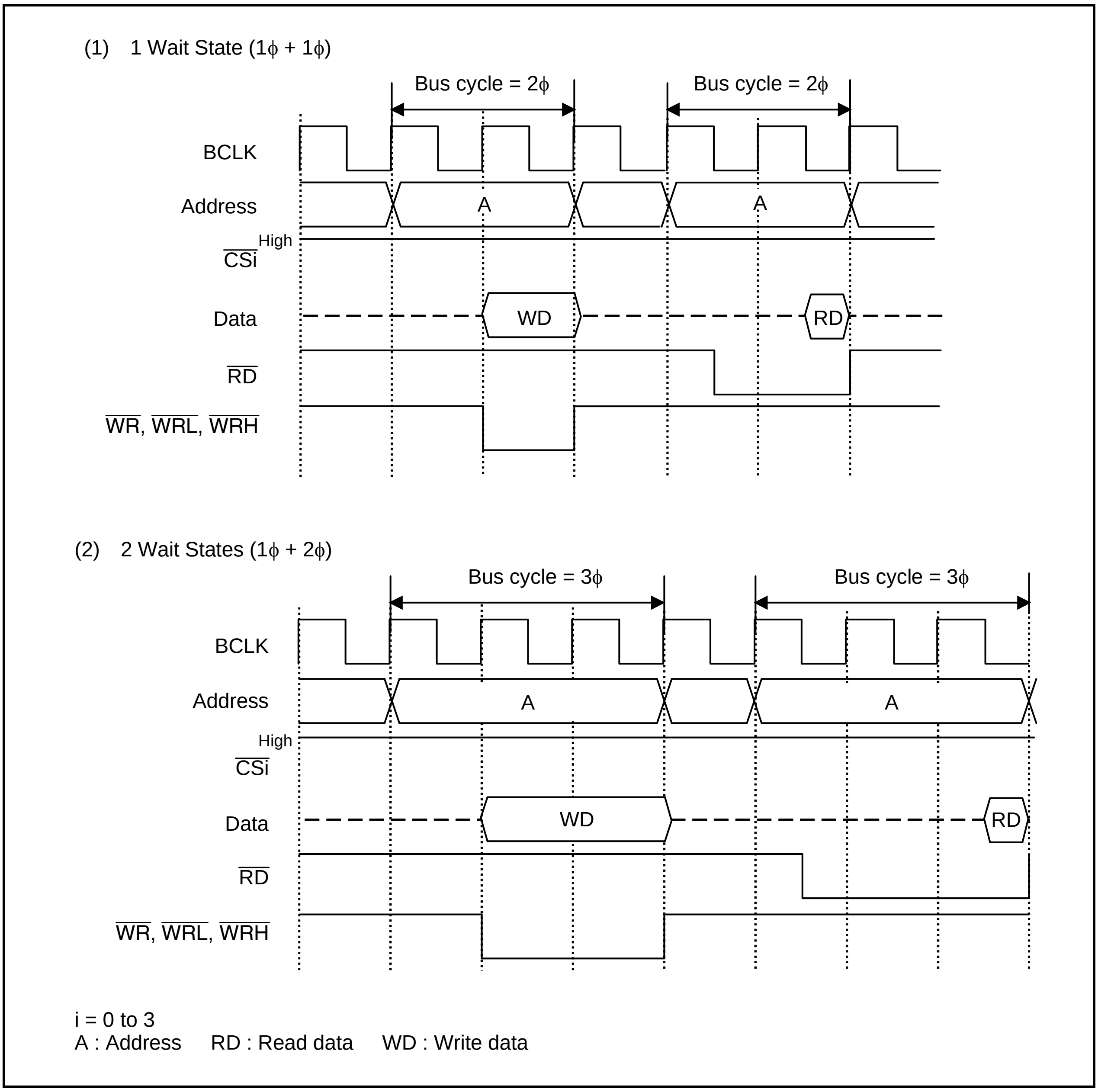


Figure 11.5 Typical Bus Timings When Accessing SFRs

11.3.5.9 Software Wait States

The PM17 bit in the PM1 register, which is a software-wait-related bit, affects both the internal memory and the external area.

Software wait states can be inserted to the external area by setting the PM17 bit, setting the CSiW bit in the CSR register, and bits CSEi1W to CSEi0W in the CSE register for each $\overline{\text{CSi}}$ (i = 0 to 3). To use the $\overline{\text{RDY}}$ signal, set the corresponding CSiW bit to 0 (wait state). See Table 11.10 “Bits and Bus Cycles Related to Software Wait States (External Area)” for details.

Table 11.10 Bits and Bus Cycles Related to Software Wait States (External Area)

Area	Bus Mode	Setting of Software-Wait-Related Bits				Software Wait Cycles	Bus Cycles
		PM17	CSiW	CSEi1W to CSEi0W	EWCi1 to EWCi0		
External area	Separate bus	0	1	00b	-	None	1 BCLK cycle (read) 2 BCLK cycles (write)
		-	0	00b	-	1 (1ϕ + 1ϕ)	2 BCLK cycles (4)
		-	0	01b	-	2 (1ϕ + 2ϕ)	3 BCLK cycles
		-	0	10b	-	3 (1ϕ + 3ϕ)	4 BCLK cycles
		-	0	11b	00b	(2ϕ + 3ϕ)	5 BCLK cycles
					01b	(2ϕ + 4ϕ)	6 BCLK cycles
					10b	(3ϕ + 4ϕ)	7 BCLK cycles
					11b	(4ϕ + 5ϕ)	9 BCLK cycles
		1	0 (3)	00b	-	1 (1ϕ + 1ϕ)	2 BCLK cycles
	Multiplexed bus	-	0 (2)	00b	-	1 (5)	3 BCLK cycles
		-	0 (2)	01b	-	2	3 BCLK cycles
		-	0 (2)	10b	-	3	4 BCLK cycles
		1	0 (2, 3)	00b	-	1 (5)	3 BCLK cycles

i = 0 to 3

– indicates that either 0 or 1 can be set.

PM17: Bit in the PM1 register

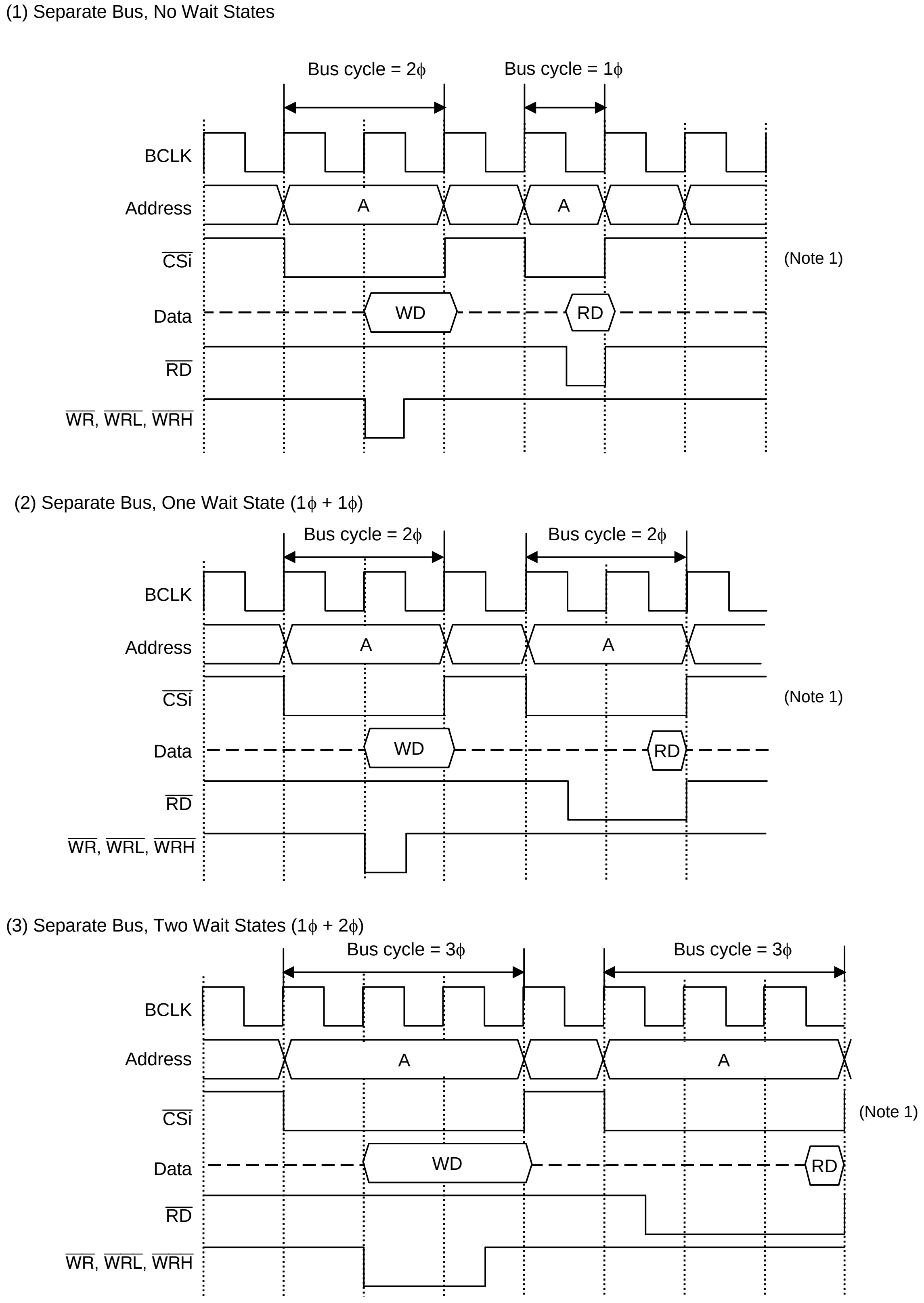
CSiW: Bits in the CSR register (1)

CSEi1W, CSEi0W: Bits in the CSE register

EWCi1, EWCi0: Bits in the EWC register

Notes:

1. To use the $\overline{\text{RDY}}$ signal, set the CSiW bit to 0 (wait state).
2. When accessing with a multiplexed bus, set the CSiW bit to 0 (wait state).
3. To access an external area when the PM17 bit is 1, set the CSiW bit to 0 (wait state).
4. After reset, the PM17 bit is set to 0 (no wait state), bits CS0W to CS3W are set to 0 (wait state), and the CSE register is set to 00h (one wait state for $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$). Therefore, all external areas are accessed with one wait state.
5. When setting one wait in the multiplexed bus, the bus cycle is the same as two waits.


(1) Separate Bus, No Wait States

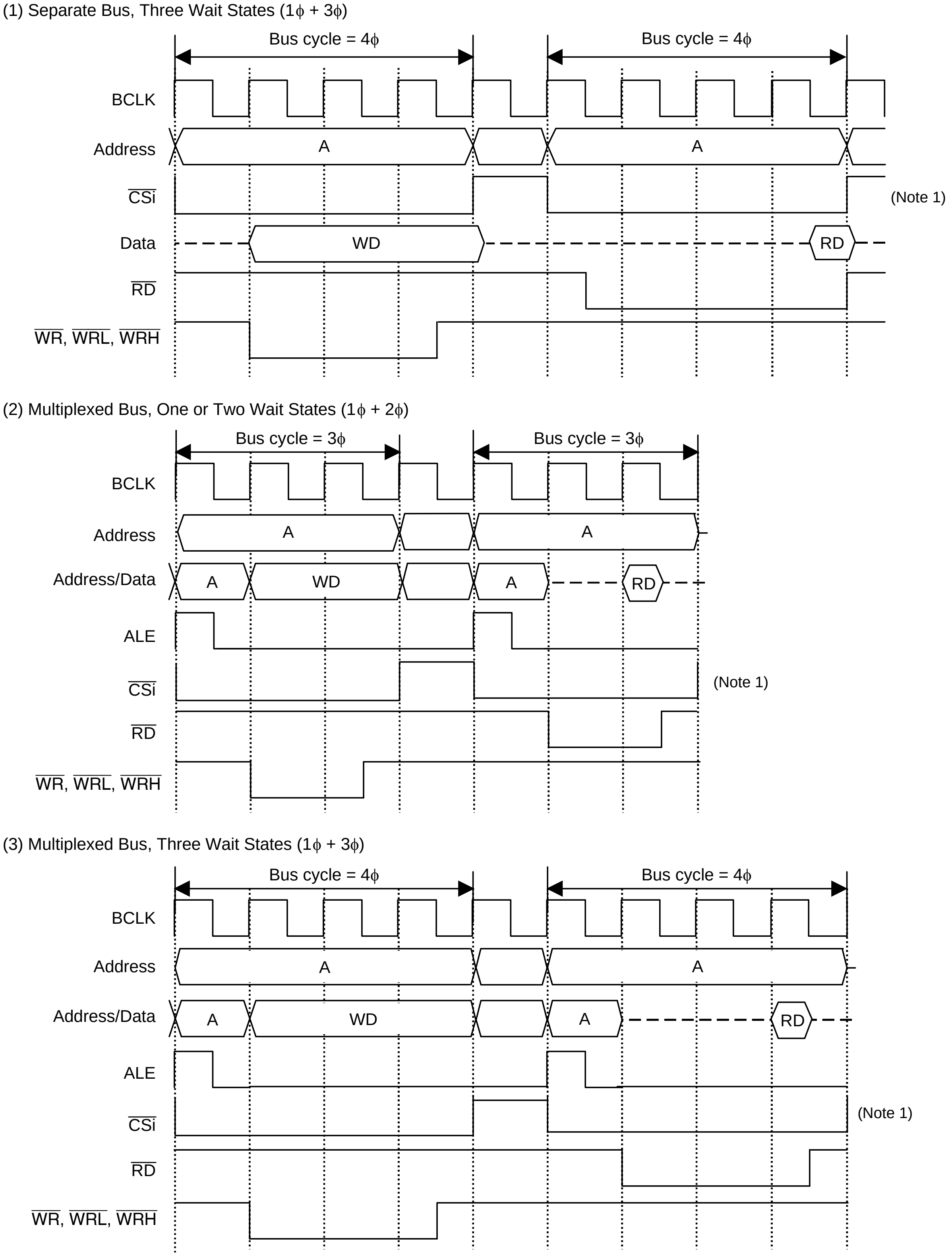
(2) Separate Bus, One Wait State (1ϕ + 1ϕ)

(3) Separate Bus, Two Wait States (1ϕ + 2ϕ)

i = 0 to 3
A: Address RD: Read data (input) WD: Write data (output)

Note:
1. When consecutively accessing the same chip-select area, $\overline{\text{CSi}}$ continues outputting a low level.

Figure 11.6 Typical Bus Timings Using Software Wait States (1/4)



(1) Separate Bus, Three Wait States (1ϕ + 3ϕ)

(2) Multiplexed Bus, One or Two Wait States (1ϕ + 2ϕ)

(3) Multiplexed Bus, Three Wait States (1ϕ + 3ϕ)

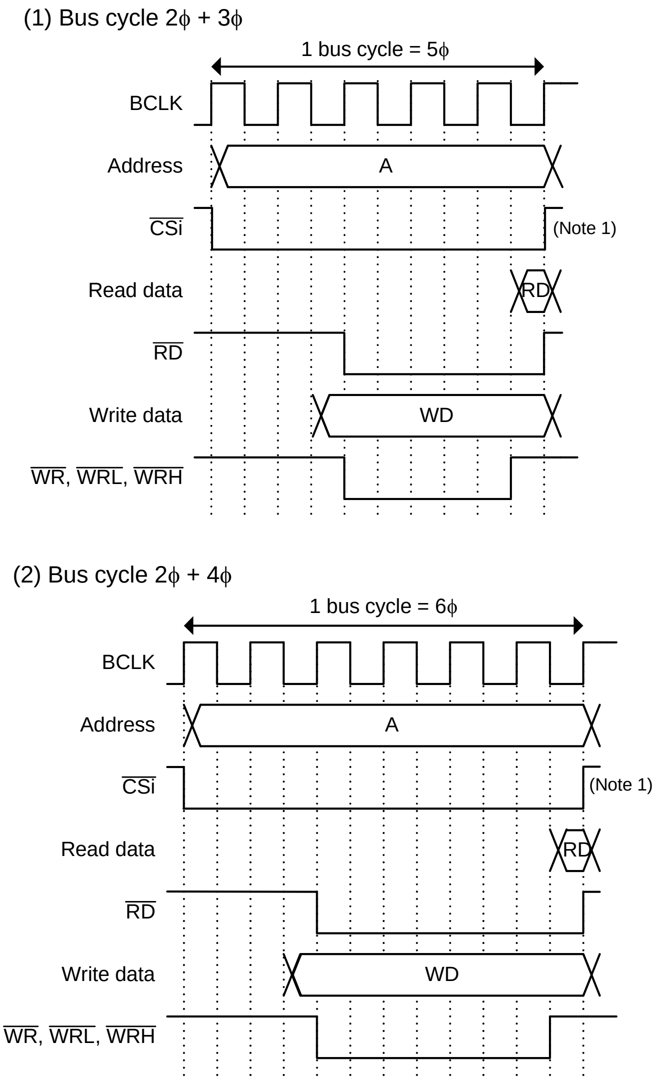
i = 0 to 3

A: Address RD: Read data (input) WD: Write data (output)

Note:

1. When consecutively accessing the same chip-select area, $\overline{\text{CSi}}$ continues outputting a low level.

Figure 11.7 Typical Bus Timings Using Software Wait States (2/4)

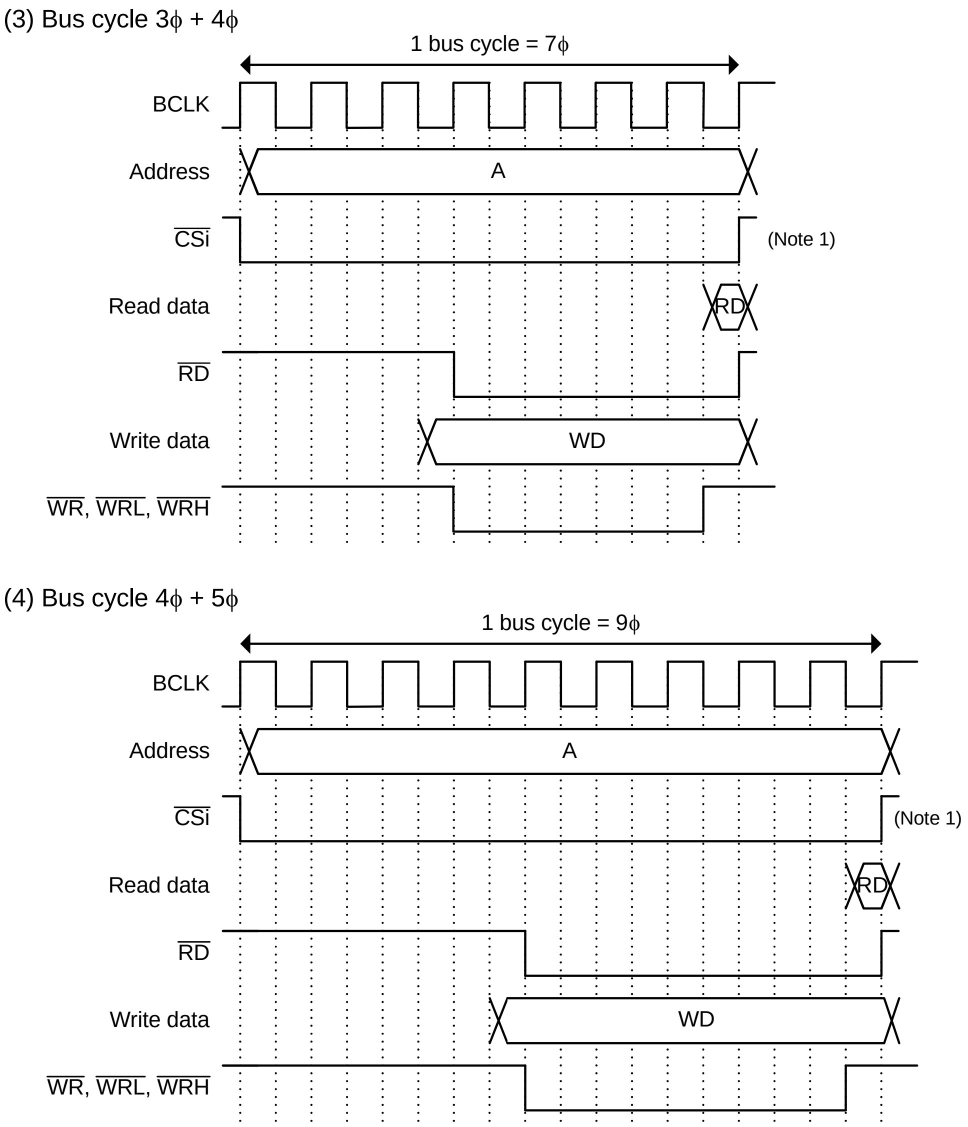


i = 0 to 3
A: Address RD: Read data (input) WD: Write data (output)

Note:

1. When consecutively accessing the same chip-select area, $\overline{\text{CSi}}$ continues outputting a low level.

Figure 11.8 Typical Bus Timings Using Software Wait States (3/4)

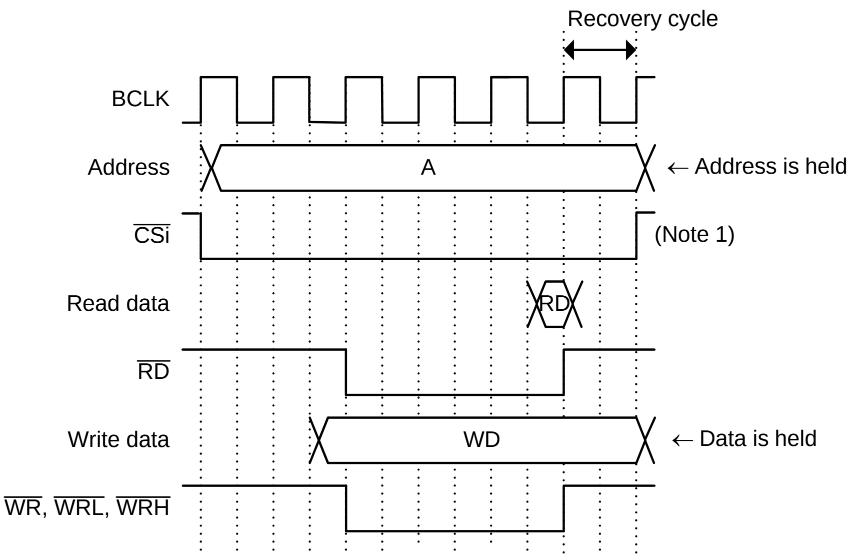


i = 0 to 3
A: Address RD: Read data (input) WD: Write data (output)

Note:

1. When consecutively accessing the same chip-select area, CSi continues outputting a low level.

Figure 11.9 Typical Bus Timings Using Software Wait States (4/4)



i = 0 to 3

A: Address RD: Read data (input) WD: Write data (output)

Note:

1. When consecutively accessing the same chip-select area, CSi continues outputting a low level.

The above diagram assumes the following:

- Bits EWR1 to EWR0 in the EWR register are 01b (1 recovery cycle inserted).
- The CSiW bit in the CSR register is 0 (wait state).
- Bits CSEi1W to CSEi0W in the CSE register are 11b (select a bus cycle pattern by the EWC register).
- Bits EWCi1 to EWCi0 in the EWC register are 00b (2ϕ + 3ϕ).

Figure 11.10 Recovery Cycle

11.4 Notes on Bus

11.4.1 Reading Data Flash

When 2.7 V ≤ VCC1 ≤ 3.0 V and f(BCLK) ≥ 16 MHz, or when 3.0 V < VCC1 ≤ 5.5 V and f(BCLK) ≥ 20 MHz, one wait must be inserted to read the data flash. Use the PM17 bit or the FMR17 bit to insert one wait.

11.4.2 External Bus

When a hardware reset, power-on reset, or voltage monitor 0 reset is performed with a high-level input on the CNVSS pin, the internal ROM cannot be read.

11.4.3 External Access Immediately after Writing to the SFRs

When accessing an external device after writing to the SFRs, the write signal and $\overline{\mathrm{CSi}}$ signal switch simultaneously. Thus, adjust the capacity of each signal so as not to delay the write signal.

11.4.4 Wait and $\overline{\mathrm{RDY}}$

Do not use the $\overline{\mathrm{RDY}}$ function when bits CSEi1W to CSEi0W in the CSE register are 11b.

11.4.5 $\overline{\mathrm{HOLD}}$

$\overline{\mathrm{HOLD}}$ input is unavailable. Connect the $\overline{\mathrm{HOLD}}$ pin to VCC2 via a resistor (pull-up).

12. Memory Space Expansion Function

12.1 Introduction

The following describes the memory space expansion function. In memory expansion or microprocessor mode, the memory space expansion function allows the access space to be expanded. Table 12.1 lists Memory Space Expansion Function Specifications. In this chapter, the external area accessed by the $\overline{\text{CSi}}$ (i = 0 to 3) signal is referred to as the $\overline{\text{CSi}}$ area.

Table 12.1 Memory Space Expansion Function Specifications

Item	Specification
1-MB mode	• Memory space 1 MB (no expansion) • Specify the external area ($\overline{\text{CSi}}$ area) accessed by the $\overline{\text{CSi}}$ signal.
4-MB mode	• Memory space 4 MB • Select bank numbers to access to data. • Allows the accessed address to be offset by 40000h • The $\overline{\text{CSi}}$ pin function differs depending on the area to be accessed.

i = 0 to 3

12.2 Registers

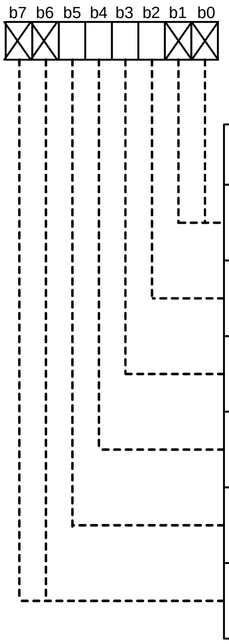
Table 12.2 lists registers related to the memory expansion function. Refer to 10. “Processor Mode” for the PM1 register.

Table 12.2 Registers

Address	Register	Symbol	Reset Value
0005h	Processor Mode Register 1	PM1	0000 1000b
000Bh	Data Bank Register	DBR	00h

12.2.1 Data Bank Register (DBR)

Data Bank Register



Symbol	Address	Reset Value
DBR	000Bh	00h

Bit Symbol	Bit Name	Function	RW
— (b1-b0)	No register bits. If necessary, set to 0. The read value is 0.		—
OFS	Offset bit	0 : No offset 1 : Offset	RW
BSR0	Bank select bit	b5 b4 b3 0 0 0 : Bank 0 0 0 1 : Bank 1 0 1 0 : Bank 2 0 1 1 : Bank 3 b5 b4 b3 1 0 0 : Bank 4 1 0 1 : Bank 5 1 1 0 : Bank 6 1 1 1 : Bank 7	RW
BSR1			RW
BSR2			RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is 0.		—

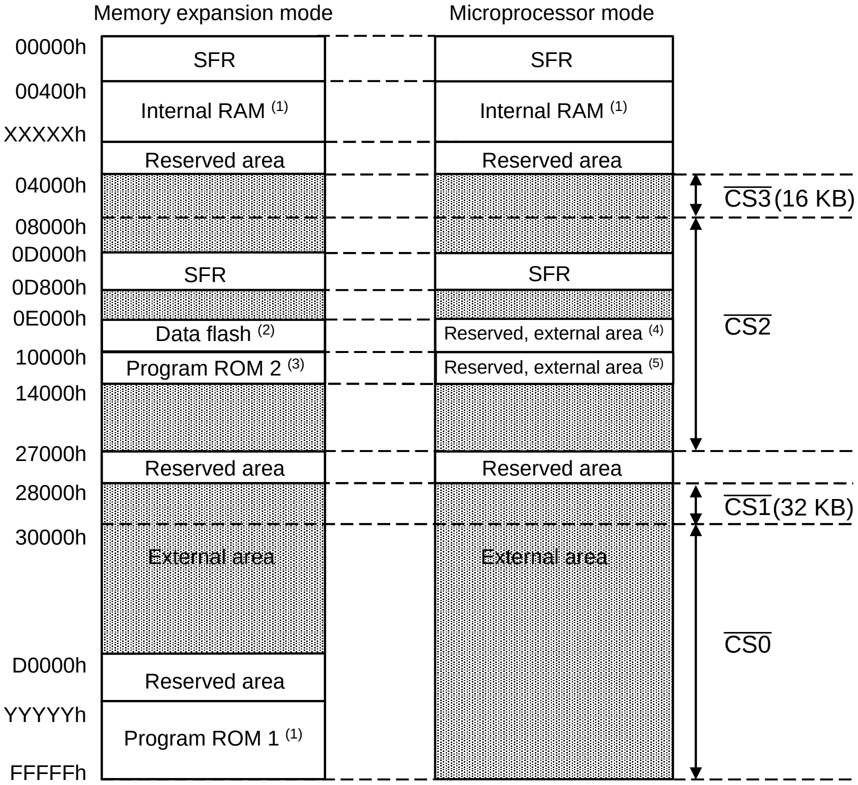
The DBR register is enabled when bits PM01 to PM00 in the PM0 register are 01b (memory expansion mode) or 11b (microprocessor mode).

This register becomes write enabled when bits PM15 to PM14 in the PM1 register are 11b (4-MB mode).

12.3 Operations

12.3.1 1-MB Mode

In 1-MB mode, the memory space is 1 MB. The external area to be accessed is specified using the $\overline{CSi}$ signals.



Notes:

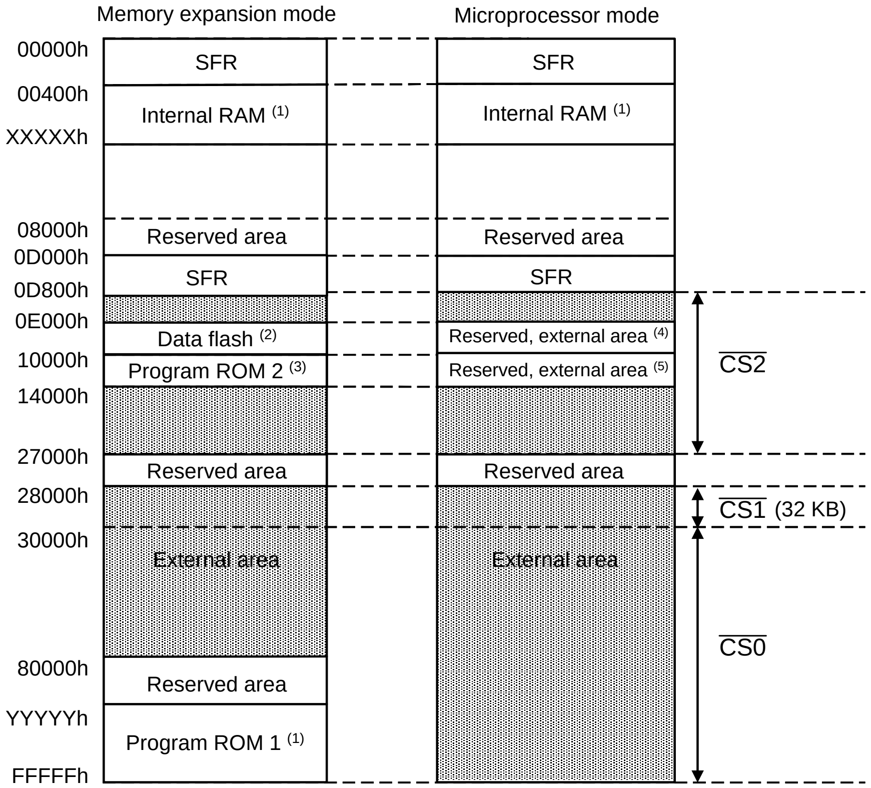
1. When the PM13 bit in the PM1 register is 0, 15 KB of the internal RAM and 192 KB of the internal ROM can be used. See the table below for addresses XXXXXh and YYYYYh.

Internal RAM	
Capacity	Address XXXXXh
12 KB	033FFh
20 KB	03FFFh
31 KB	03FFFh
47 KB	03FFFh

Program ROM 1	
Capacity	Address YYYYYh
128 KB	E0000h
256 KB	D0000h
384 KB	D0000h
512 KB	D0000h

2. When the PM10 bit is 0, this area is used as an external area; when the bit is 1, this area is used as internal ROM (data flash).
3. When the PRG2C0 bit in the PRG2C register is 1, this area is used as an external area; when the bit is 0, this area is used as internal ROM (program ROM 2).
4. When the PM10 bit is 0, this area is used as an external area; when the bit is 1, this area is used as a reserved area.
5. When the PRG2C0 bit in the PRG2C register is 1, this area is used as an external area; when the bit is 0, this area is used as a reserved area.

Figure 12.1 Memory Mapping and $\overline{CS}$ Areas in 1-MB Mode (PM13 = 0)



Notes:

1. See the table below for addresses XXXXXh and YYYYYh.

Internal RAM	
Capacity	Address XXXXXh
12 KB	033FFh
20 KB	053FFh
31 KB	07FFFh
47 KB	0BFFFh

Program ROM 1	
Capacity	Address YYYYYh
128 KB	E0000h
256 KB	C0000h
384 KB	A0000h
512 KB	80000h

2. When the PM10 bit is 0, this area is used as an external area; when the bit is 1, this area is used as internal ROM (data flash).
3. When the PRG2C0 bit in the PRG2C register is 1, this area is used as an external area; when the bit is 0, this area is used as internal ROM (program ROM 2).
4. When the PM10 bit is 0, this area is used as an external area; when the bit is 1, this area is used as a reserved area.
5. When the PRG2C0 bit in the PRG2C register is 1, this area is used as an external area; when the bit is 0, this area is used as a reserved area.

Figure 12.2 Memory Mapping and $\overline{\text{CS}}$ Areas in 1-MB Mode (PM13 = 1)

12.3.2 4-MB Mode

In 4-MB mode, the memory space is 4 MB. Bits BSR2 to BSR0 in the DBR register select the bank number to be accessed to read or write data. Setting the OFS bit to 1 (offset) allows the accessed address to be offset by 40000h.

In 4-MB mode, the $\overline{\text{CSi}}$ pin function differs depending on the area to be accessed.

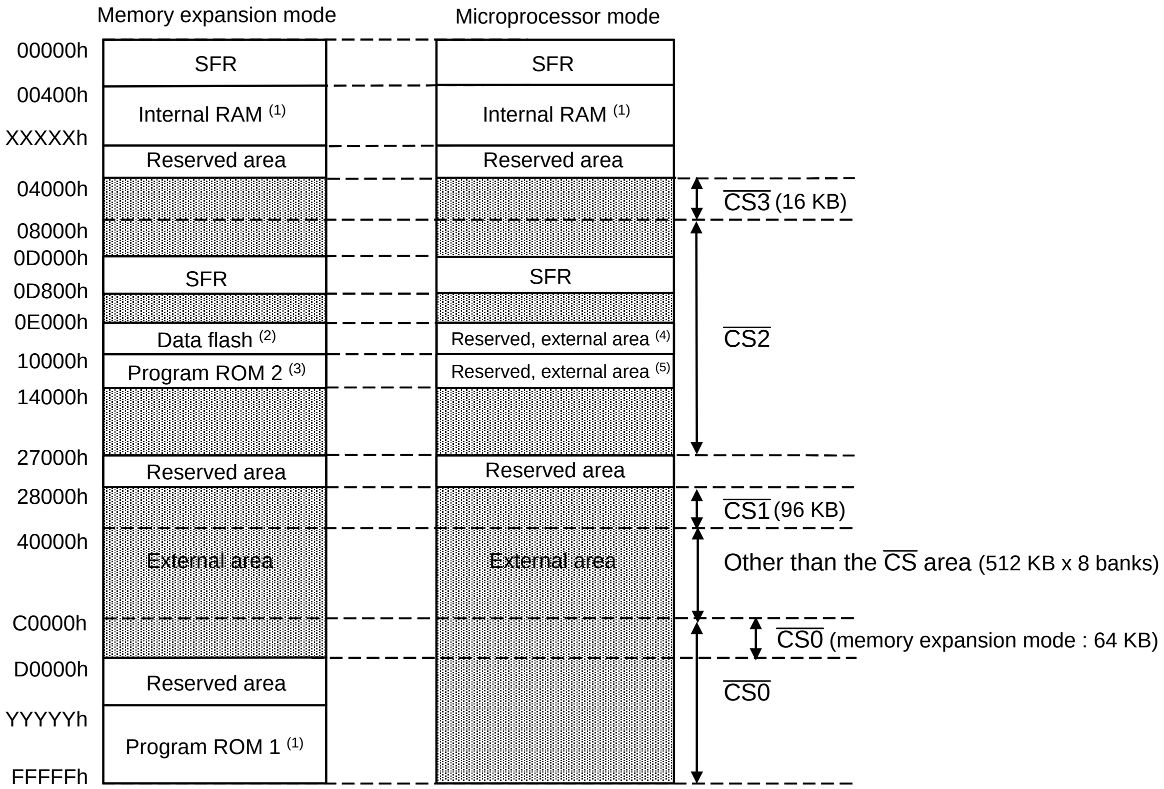
12.3.2.1 Addresses 04000h to 3FFFFh, C0000h to FFFFFh

- The $\overline{\text{CSi}}$ signal is output from the $\overline{\text{CSi}}$ pin (same operation as 1-MB mode, except the last address of the $\overline{\text{CS1}}$ area is up to 3FFFFh).

12.3.2.2 Addresses 40000h to BFFFFh

- The $\overline{\text{CS0}}$ pin outputs a low-level signal.
- Pins $\overline{\text{CS3}}$ to $\overline{\text{CS1}}$ output the setting values of bits BSR2 to BSR0 (bank number).

Figure 12.3 and Figure 12.4 show the memory mapping and $\overline{\text{CS}}$ areas in 4-MB mode.
Note that banks 0 to 6 are data-only areas. Place programs in bank 7 or the $\overline{\text{CSi}}$ area.



Notes:

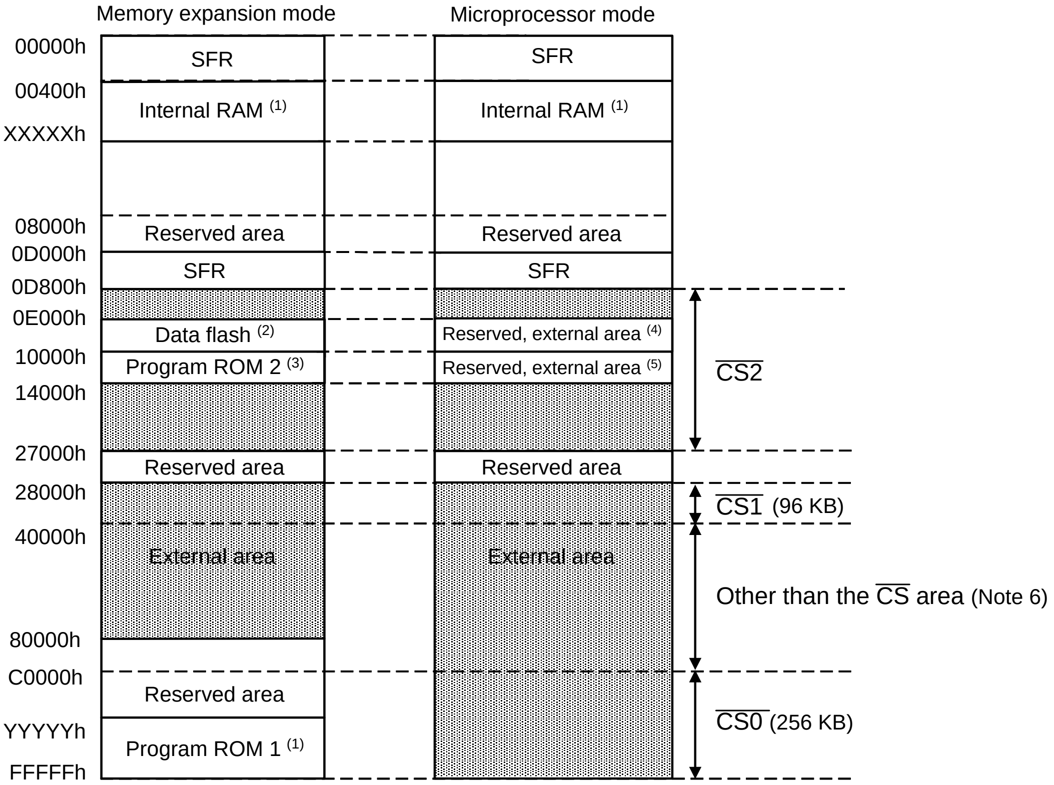
1. When the PM13 bit in the PM1 register is 0, 15 KB of the internal RAM and 192 KB of the internal ROM can be used. See the table below for addresses XXXXXh and YYYYYh.

Internal RAM	
Capacity	Address XXXXXh
12 KB	033FFh
20 KB	03FFFh
31 KB	03FFFh
47 KB	03FFFh

Program ROM 1	
Capacity	Address YYYYYh
128 KB	E0000h
256 KB	D0000h
384 KB	D0000h
512 KB	D0000h

2. When the PM10 bit is 0, this area is used as an external area; when the bit is 1, this area is used as internal ROM (data flash).
3. When the PRG2C0 bit in the PRG2C register is 1, this area is used as an external area; when the bit is 0, this area is used as internal ROM (program ROM 2).
4. When the PM10 bit is 0, this area is used as an external area; when the bit is 1, this area is used as a reserved area.
5. When the PRG2C0 bit in the PRG2C register is 1, this area is used as an external area; when the bit is 0, this area is used as a reserved area.
6. The CS0 pin outputs a low signal, and pins CS3 to CS1 output a bank number.

Figure 12.3 Memory Mapping and $\overline{\text{CS}}$ Areas in 4-MB Mode (PM13 = 0)



Notes:

1. See the table below for addresses XXXXXh and YYYYYh.

Internal RAM	
Capacity	Address XXXXXh
12 KB	033FFh
20 KB	053FFh
31 KB	07FFFh
47 KB	0BFFFh

Program ROM 1	
Capacity	Address YYYYYh
128 KB	E0000h
256 KB	C0000h
384 KB	A0000h
512 KB	80000h

2. When the PM10 bit is 0, this area is used as an external area; when the bit is 1, this area is used as internal ROM (data flash).
3. When the PRG2C0 bit in the PRG2C register is 1, this area is used as an external area; when the bit is 0, this area is used as internal ROM (program ROM 2).
4. When the PM10 bit is 0, this area is used as an external area; when the bit is 1, this area is used as a reserved area.
5. When the PRG2C0 bit in the PRG2C register is 1, this area is used as an external area; when the bit is 0, this area is used as a reserved area.
6. The CS0 pin outputs a low signal, and pins CS3 to CS1 output a bank number.

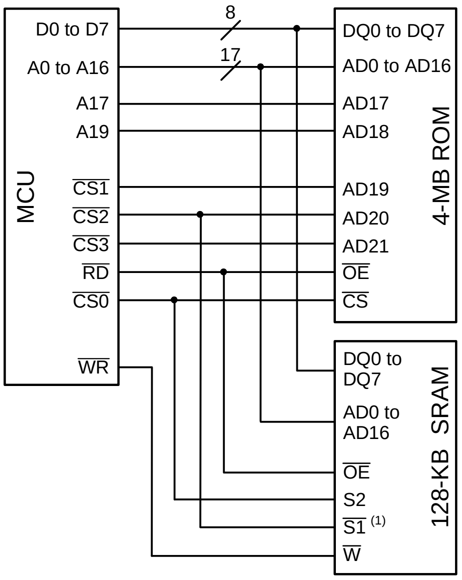
Figure 12.4 Memory Mapping and $\overline{\text{CS}}$ Areas in 4-MB Mode (PM13 = 1)

In the example below, the $\overline{\text{CS}}$ pin of a 4-MB ROM is connected to the MCU's $\overline{\text{CS0}}$ pin. The 4-MB ROM address input pins AD21, AD20, and AD19 are connected to the MCU's $\overline{\text{CS3}}$, $\overline{\text{CS2}}$, and $\overline{\text{CS1}}$ pins, respectively. The address input AD18 pin is connected to the MCU's A19 pin. Figure 12.6 to Figure 12.8 show the relationship of addresses between the 4-MB ROM and the MCU in the connection example of Figure 12.5.

In microprocessor mode or memory expansion mode, where the PM13 bit in the PM1 register is 0, banks are located every 512 KB. Setting the OFS bit in the DBR register to 1 (offset) allows the accessed address to be offset by 40000h, allowing even data overlapping at a bank boundary to be accessed in succession.

In memory expansion mode, where the PM13 bit is 1, each 512-KB bank can be accessed in 256 KB units by switching them with the OFS bit.

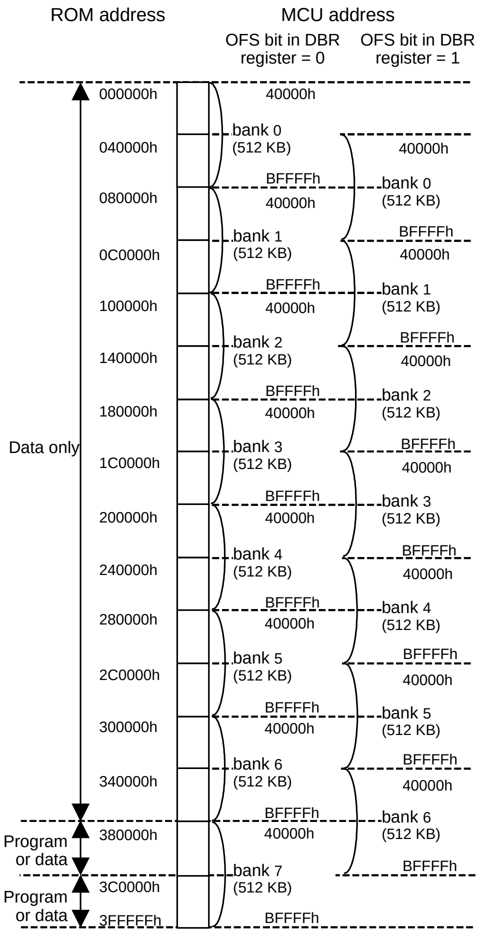
Because the SRAM can be accessed when the chip select signals S2 is high and $\overline{\text{S1}}$ is low, $\overline{\text{CS0}}$ and $\overline{\text{CS2}}$ can be connected to S2 and $\overline{\text{S1}}$, respectively. If SRAM does not have the input pins that accept high active and low active chip select signals ($\overline{\text{S1}}$, S2), $\overline{\text{CS0}}$ and $\overline{\text{CS2}}$ should be decoded externally to the chip.



Note:
1. If only one chip select pin ($\overline{\text{S1}}$ or S2) is present, use an external circuit for decoding.

Figure 12.5 External Memory Connection Example in 4-MB Mode

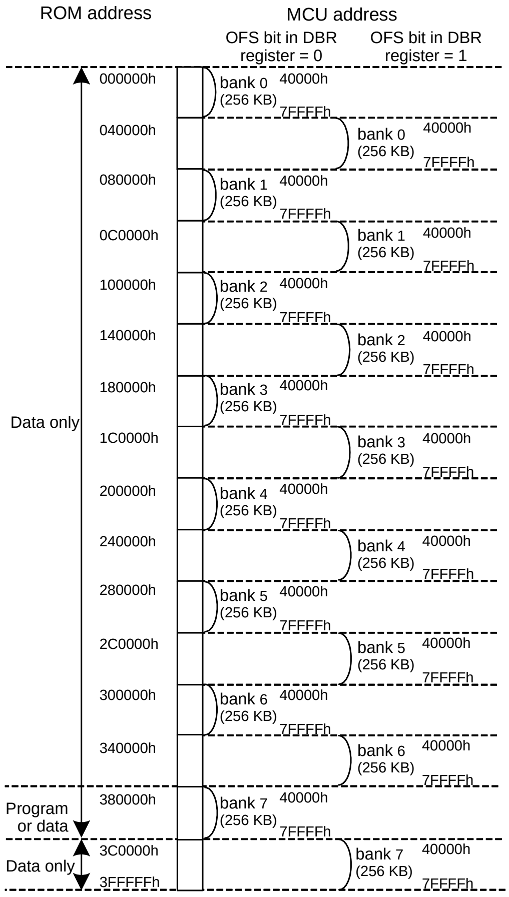
Memory expansion mode where the PM13 bit is 0



Bank Number	OFS	Access Area	Output from the MCU Pins								
			$\overline{CS}$ Output			Address Output					
			$\overline{CS3}$	$\overline{CS2}$	$\overline{CS1}$	A19	A18	A17	A16	A15 to A0	
0	0	40000h	0	0	0	0	1	0	0	0000h	000000h
		BFFFFh	0	0	0	1	0	1	1	FFFFh	07FFFFh
	1	40000h	0	0	0	1	0	0	0	0000h	040000h
		BFFFFh	0	0	1	0	1	1	1	FFFFh	0BFFFFh
1	0	40000h	0	0	1	0	1	0	0	0000h	080000h
		BFFFFh	0	0	1	1	0	1	1	FFFFh	0FFFFFh
	1	40000h	0	0	1	1	0	0	0	0000h	0C0000h
		BFFFFh	0	1	0	0	1	1	1	FFFFh	13FFFFh
2	0	40000h	0	1	0	0	1	0	0	0000h	100000h
		BFFFFh	0	1	0	1	0	1	1	FFFFh	17FFFFh
	1	40000h	0	1	0	1	0	0	0	0000h	140000h
		BFFFFh	0	1	1	0	1	1	1	FFFFh	1BFFFFh
3	0	40000h	0	1	1	0	1	0	0	0000h	180000h
		BFFFFh	0	1	1	1	0	1	1	FFFFh	1FFFFFh
	1	40000h	0	1	1	1	0	0	0	0000h	1C0000h
		BFFFFh	1	0	0	0	1	1	1	FFFFh	23FFFFh
4	0	40000h	1	0	0	0	1	0	0	0000h	200000h
		BFFFFh	1	0	0	1	0	1	1	FFFFh	27FFFFh
	1	40000h	1	0	0	1	0	0	0	0000h	240000h
		BFFFFh	1	0	1	0	1	1	1	FFFFh	2BFFFFh
5	0	40000h	1	0	1	0	1	0	0	0000h	280000h
		BFFFFh	1	0	1	1	0	1	1	FFFFh	2FFFFFh
	1	40000h	1	0	1	1	0	0	0	0000h	2C0000h
		BFFFFh	1	1	0	0	1	1	1	FFFFh	33FFFFh
6	0	40000h	1	1	0	0	1	0	0	0000h	300000h
		BFFFFh	1	1	0	1	0	1	1	FFFFh	37FFFFh
	1	40000h	1	1	0	1	0	0	0	0000h	340000h
		BFFFFh	1	1	1	0	1	1	1	FFFFh	3BFFFFh
7	0	40000h	1	1	1	0	1	0	0	0000h	380000h
		7FFFFh	1	1	1	0	1	1	1	FFFFh	3BFFFFh
		80000h	1	1	1	1	0	0	0	0000h	3C0000h
		BFFFFh	1	1	1	1	0	1	1	FFFFh	3FFFFFh
		C0000h	1	1	1	1	1	0	0	0000h	3C0000h
		CFFFFh	1	1	1	1	1	0	0	FFFFh	3CFFFFh
		D0000h									Internal ROM access
		DFFFFh									Internal ROM access
		D0000h									Internal ROM access
		DFFFFh									Internal ROM access
			A21	A20	A19	A18	N.C.	A17	A16	A15 to A0	4-MB ROM access area
			Address input for 4-MB ROM								

Figure 12.6 Relationship between Addresses in 4-MB ROM and Those in MCU (1/3)

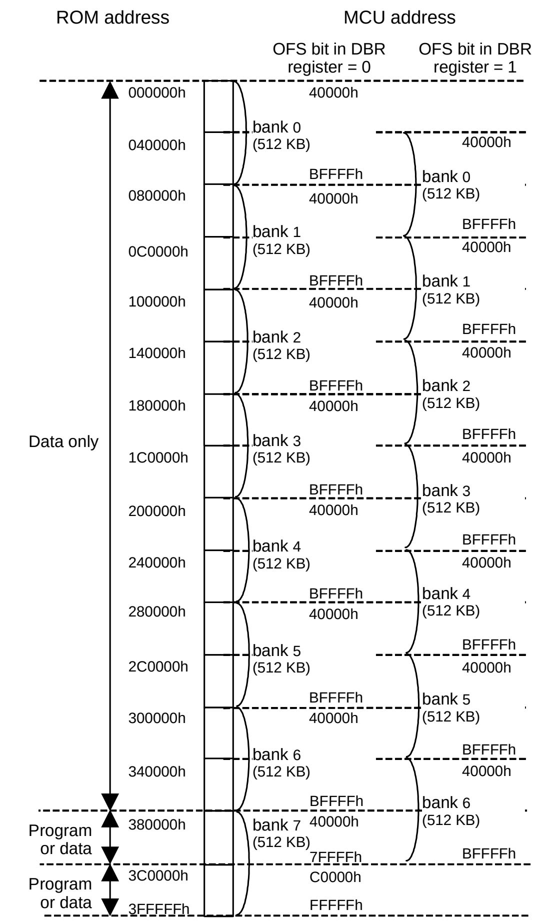
Memory expansion mode where the PM13 bit is 1


ROM address
MCU address
OFS bit in DBR register = 0
OFS bit in DBR register = 1
000000h
040000h
080000h
0C0000h
100000h
140000h
180000h
1C0000h
200000h
240000h
280000h
2C0000h
300000h
340000h
380000h
3C0000h
3FFFFFh
Data only
Program or data
Data only
bank 0 (256 KB) 40000h 7FFFFh
bank 1 (256 KB) 40000h 7FFFFh
bank 2 (256 KB) 40000h 7FFFFh
bank 3 (256 KB) 40000h 7FFFFh
bank 4 (256 KB) 40000h 7FFFFh
bank 5 (256 KB) 40000h 7FFFFh
bank 6 (256 KB) 40000h 7FFFFh
bank 7 (256 KB) 40000h 7FFFFh

Bank Number	OFS	Access Area	Output from the MCU Pins								
			$\overline{CS}$ Output			Address Output					
			$\overline{CS3}$	$\overline{CS2}$	$\overline{CS1}$	A19	A18	A17	A16	A15 to A0	
0	0	40000h	0	0	0	0	1	0	0	0000h	000000h
		7FFFFh	0	0	0	0	1	1	1	FFFFh	03FFFFh
	1	40000h	0	0	0	1	0	0	0	0000h	040000h
		7FFFFh	0	0	0	1	0	1	1	FFFFh	07FFFFh
1	0	40000h	0	0	1	0	1	0	0	0000h	080000h
		7FFFFh	0	0	1	0	1	1	1	FFFFh	0BFFFFh
	1	40000h	0	0	1	1	0	0	0	0000h	0C0000h
		7FFFFh	0	0	1	1	0	1	1	FFFFh	0FFFFFh
2	0	40000h	0	1	0	0	1	0	0	0000h	100000h
		7FFFFh	0	1	0	0	1	1	1	FFFFh	13FFFFh
	1	40000h	0	1	0	1	0	0	0	0000h	140000h
		7FFFFh	0	1	0	1	0	1	1	FFFFh	17FFFFh
3	0	40000h	0	1	1	0	1	0	0	0000h	180000h
		7FFFFh	0	1	1	0	1	1	1	FFFFh	1BFFFFh
	1	40000h	0	1	1	1	0	0	0	0000h	1C0000h
		7FFFFh	0	1	1	1	0	1	1	FFFFh	1FFFFFh
4	0	40000h	1	0	0	0	1	0	0	0000h	200000h
		7FFFFh	1	0	0	0	1	1	1	FFFFh	23FFFFh
	1	40000h	1	0	0	1	0	0	0	0000h	240000h
		7FFFFh	1	0	0	1	0	1	1	FFFFh	27FFFFh
5	0	40000h	1	0	1	0	1	0	0	0000h	280000h
		7FFFFh	1	0	1	0	1	1	1	FFFFh	2BFFFFh
	1	40000h	1	0	1	1	0	0	0	0000h	2C0000h
		7FFFFh	1	0	1	1	0	1	1	FFFFh	2FFFFFh
6	0	40000h	1	1	0	0	1	0	0	0000h	300000h
		7FFFFh	1	1	0	0	1	1	1	FFFFh	33FFFFh
	1	40000h	1	1	0	1	0	0	0	0000h	340000h
		7FFFFh	1	1	0	1	0	1	1	FFFFh	37FFFFh
7	0	40000h	1	1	1	0	1	0	0	0000h	380000h
		7FFFFh	1	1	1	0	1	1	1	FFFFh	3BFFFFh
		80000h									Internal ROM access
		FFFFFh									Internal ROM access
7	1	40000h	1	1	1	1	0	0	0	0000h	3C0000h
		7FFFFh	1	1	1	1	0	1	1	FFFFh	3FFFFFh
		80000h									Internal ROM access
		FFFFFh									Internal ROM access
			A21	A20	A19	A18	N.C.	A17	A16	A15 to A0	4-MB ROM access area
			Address input for 4-MB ROM								

Figure 12.7 Relationship between Addresses in 4-MB ROM and Those in MCU (2/3)

Microprocessor mode



Bank Number	OFS	Access Area	Output from the MCU Pins								
			$\overline{CS}$ Output			Address Output					
			$\overline{CS3}$	$\overline{CS2}$	$\overline{CS1}$	A19	A18	A17	A16	A15 to A0	
0	0	40000h	0	0	0	0	1	0	0	0000h	000000h
		BFFFFh	0	0	0	1	0	1	1	FFFFh	07FFFFh
	1	40000h	0	0	0	1	0	0	0	0000h	040000h
		BFFFFh	0	0	1	0	1	1	1	FFFFh	0BFFFFh
1	0	40000h	0	0	1	0	1	0	0	0000h	080000h
		BFFFFh	0	0	1	1	0	1	1	FFFFh	0FFFFFh
	1	40000h	0	0	1	1	0	0	0	0000h	0C0000h
		BFFFFh	0	1	0	0	1	1	1	FFFFh	13FFFFh
2	0	40000h	0	1	0	0	1	0	0	0000h	100000h
		BFFFFh	0	1	0	1	0	1	1	FFFFh	17FFFFh
	1	40000h	0	1	0	1	0	0	0	0000h	140000h
		BFFFFh	0	1	1	0	1	1	1	FFFFh	1BFFFFh
3	0	40000h	0	1	1	0	1	0	0	0000h	180000h
		BFFFFh	0	1	1	1	0	1	1	FFFFh	1FFFFFh
	1	40000h	0	1	1	1	0	0	0	0000h	1C0000h
		BFFFFh	1	0	0	0	1	1	1	FFFFh	23FFFFh
4	0	40000h	1	0	0	0	1	0	0	0000h	200000h
		BFFFFh	1	0	0	1	0	1	1	FFFFh	27FFFFh
	1	40000h	1	0	0	1	0	0	0	0000h	240000h
		BFFFFh	1	0	1	0	1	1	1	FFFFh	2BFFFFh
5	0	40000h	1	0	1	0	1	0	0	0000h	280000h
		BFFFFh	1	0	1	1	0	1	1	FFFFh	2FFFFFh
	1	40000h	1	0	1	1	0	0	0	0000h	2C0000h
		BFFFFh	1	1	0	0	1	1	1	FFFFh	33FFFFh
6	0	40000h	1	1	0	0	1	0	0	0000h	300000h
		BFFFFh	1	1	0	1	0	1	1	FFFFh	37FFFFh
	1	40000h	1	1	0	1	0	0	0	0000h	340000h
		BFFFFh	1	1	1	0	1	1	1	FFFFh	3BFFFFh
7	0	40000h	1	1	1	0	1	0	0	0000h	380000h
		7FFFFh	1	1	1	0	1	1	1	FFFFh	3BFFFFh
		80000h	1	1	1	1	0	0	0	0000h	3C0000h
		BFFFFh	1	1	1	1	0	1	1	FFFFh	3FFFFFh
		C0000h	1	1	1	1	1	0	0	0000h	3C0000h
		FFFFFh	1	1	1	1	1	1	1	FFFFh	3FFFFFh
			A21	A20	A19	A18	N.C.	A17	A16	A15 to A0	4-MB ROM access area
			Address input for 4-MB ROM								

Figure 12.8 Relationship between Addresses in 4-MB ROM and Those in MCU (3/3)

13. Programmable I/O Ports

Note

For the 100-pin package, do not access the addresses of registers P11 to P14, PD11 to PD14, or PUR3.

13.1 Introduction

Table 13.1 lists Programmable I/O Ports Specifications (hereafter referred to as I/O ports).

Each pin functions as an I/O port, a peripheral function input/output, or a bus control pin.

To set peripheral functions, refer to the description for the individual function. To use ports as peripheral function input/output pins, refer to 13.4 “Peripheral Function I/O”.

To use ports as bus control pins, refer to 11.3.5 “External Bus Control”.

Table 13.1 Programmable I/O Ports Specifications

Item		Specification	
		128-pin package	100-pin package
Number of ports	Total	114	88
	CMOS output	111	85
	N-channel open drain output	3	3
Input/output	VCC2 level	P0 to P5, P12, P13 (1)	P0 to P5
	VCC1 level	P6 to P11, P14 (1)	P6 to P10
Input/output level		Select input or output for each individual port by a program.	
Select function		Select a pull-up resistor in 4-bit units.	

Note:

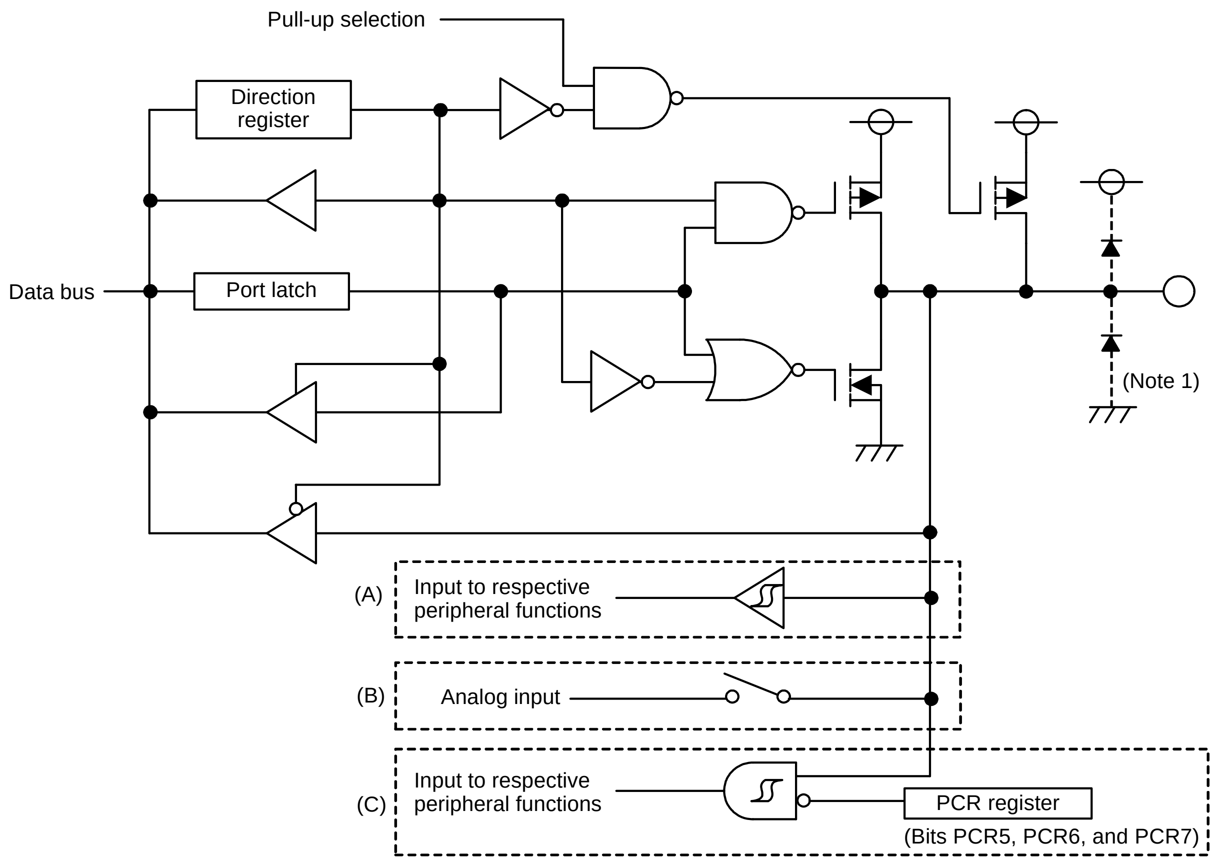
1. P11 to P14 can be used when the PU37 bit in the PUR3 register is 1 (P11 to P14 enabled).

Table 13.2 I/O Pins

Pin Name	I/O	Function
P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7	I/O	Input/output port CMOS output, pull-up resistor selectable
P7_0 to P7_7	I/O	Input/output port P7_0 to P7_1: N-channel open drain output, no pull-up resistor P7_2 to P7_7: CMOS output, pull-up resistor selectable
P8_0 to P8_7	I/O	Input/output port P8_0 to P8_4, P8_6, P8_7: CMOS output, pull-up resistor selectable P8_5: N-channel open drain output, no pull-up resistor
P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0 to P14_1	I/O	Input/output port CMOS output, pull-up resistor selectable

13.2 I/O Ports and Pins

Figure 13.1 to Figure 13.11 and Table 13.3 to Table 13.11 show the I/O port configuration, and Figure 13.12 shows the I/O pin configuration.


Pull-up selection
Direction register
Data bus
Port latch
(Note 1)
(A)
Input to respective peripheral functions
(B)
Analog input
(C)
Input to respective peripheral functions
PCR register
(Bits PCR5, PCR6, and PCR7)

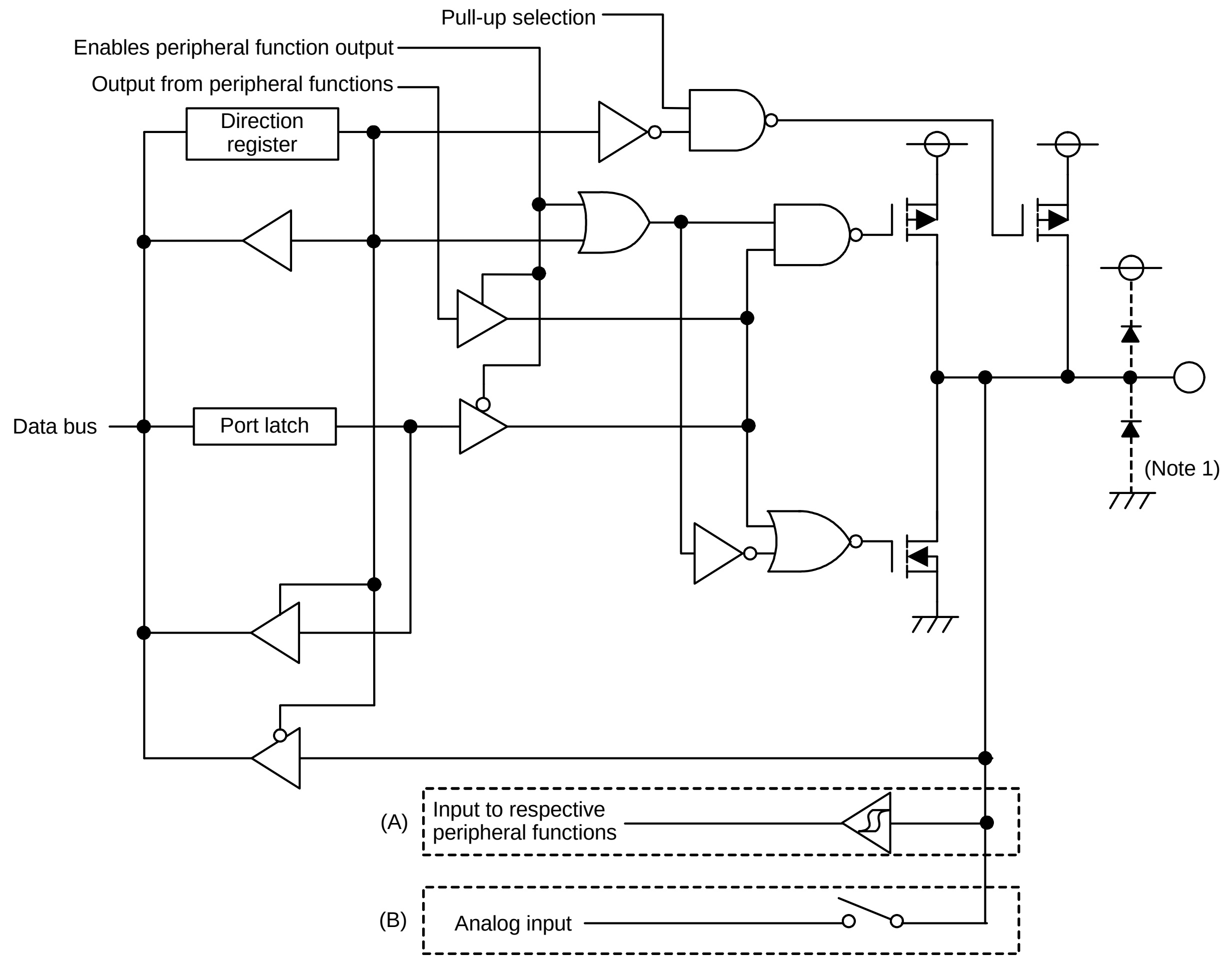
Note:

1. - - -|◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.1 I/O Ports (Basic)

Table 13.3 I/O Ports (Basic)

Port	Peripheral Function I/O		
	Peripheral function input (A) in Figure 13.1	Analog input (B) in Figure 13.1	Peripheral function input (A) in Figure 13.1
P3_0 to P3_7, P4_0 to P4_3, P5_0 to P5_4, P5_6, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1	N/A	N/A	N/A
P0_0 to P0_7, P2_0 to P2_3, P2_6, P2_7, P10_0 to P10_3	N/A	Available	N/A
P5_5	Available ($\overline{\text{HOLD}}$)	N/A	N/A
P8_2 to P8_4, P9_1, P9_7	Available	N/A	N/A
P2_4, P2_5, P10_4 to P10_7	N/A	Available	Available


Pull-up selection
Enables peripheral function output
Output from peripheral functions
Direction register
Data bus
Port latch
(Note 1)
(A)
Input to respective peripheral functions
(B)
Analog input

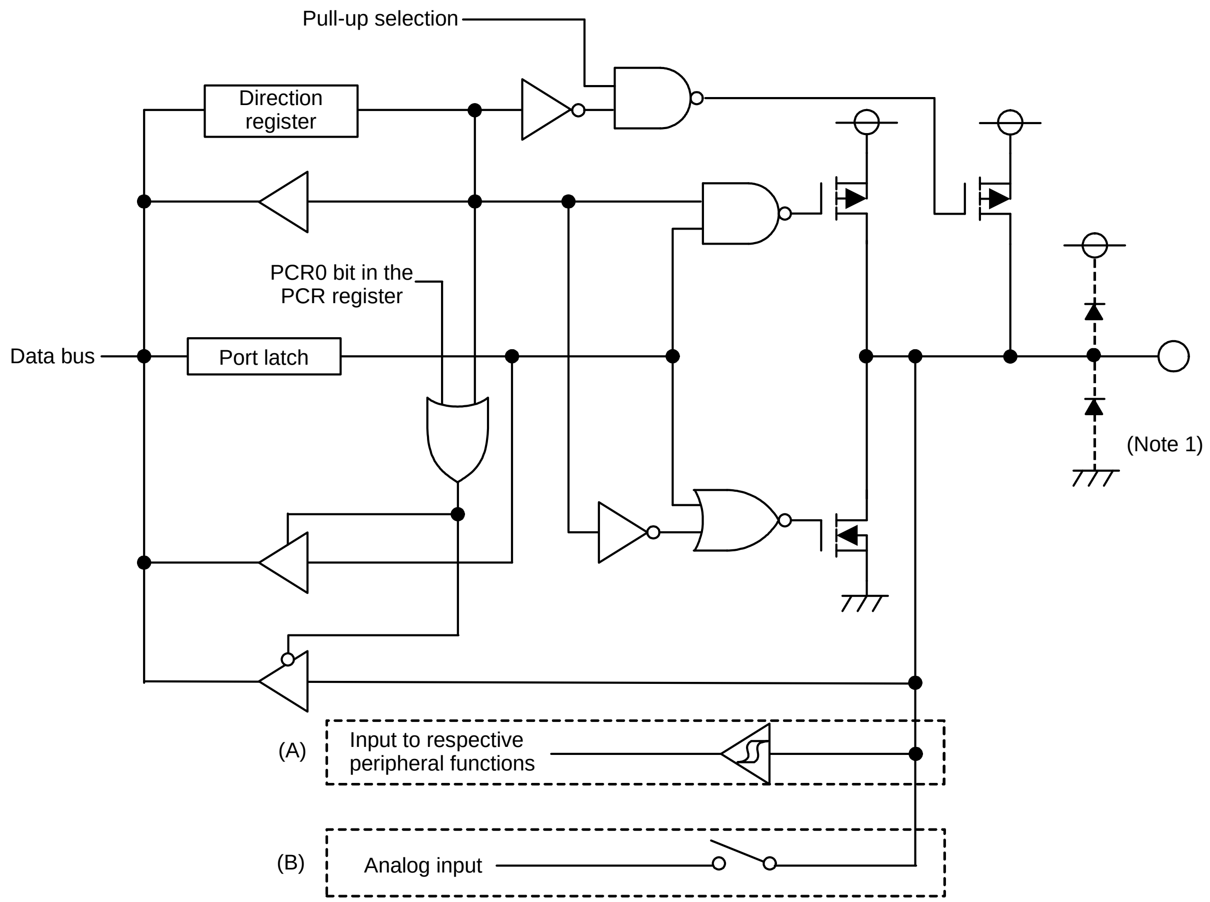
Note:

1. - - -⏴- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.2 I/O Ports (Basic + Output from Peripheral Functions)

Table 13.4 I/O Ports (Basic + Output from Peripheral Functions)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.2	Analog input (B) in Figure 13.2
P9_6	N/A	Available
P4_4, P6_0, P6_4, P7_3 to P7_5, P8_1, P9_0, P9_2	Available	N/A
P5_7	Available ($\overline{\text{RDY}}$)	N/A
P9_5	Available	Available



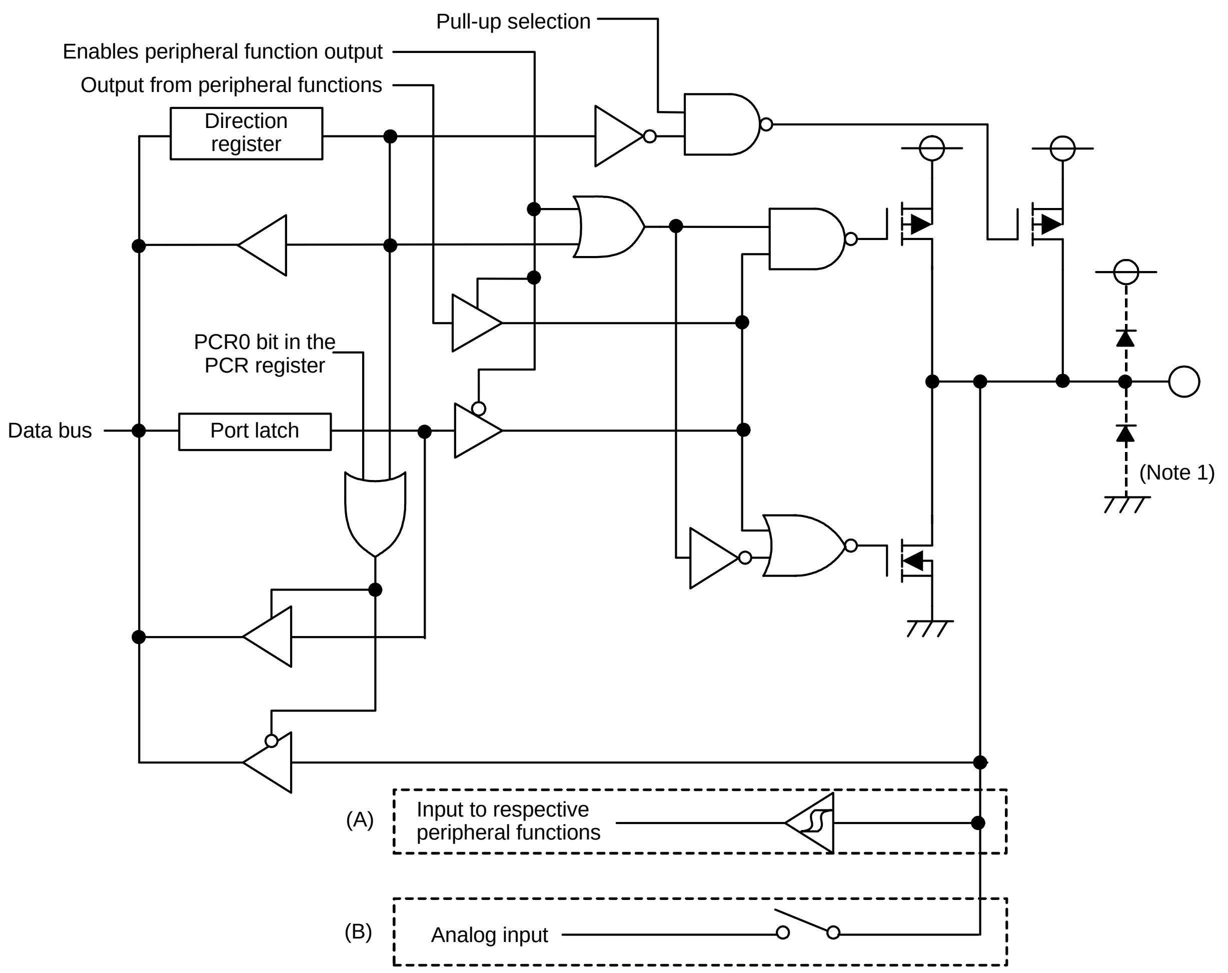
Note:

1. - - -|◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.3 I/O Ports (Port P1)

Table 13.5 I/O Ports (Port P1)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.3	Analog input (B) in Figure 13.3
P1_4	N/A	N/A
P1_5 to P1_7	Available	N/A


Pull-up selection
Enables peripheral function output
Output from peripheral functions
Direction register
PCR0 bit in the PCR register
Data bus
Port latch
(Note 1)
(A)
Input to respective peripheral functions
(B)
Analog input

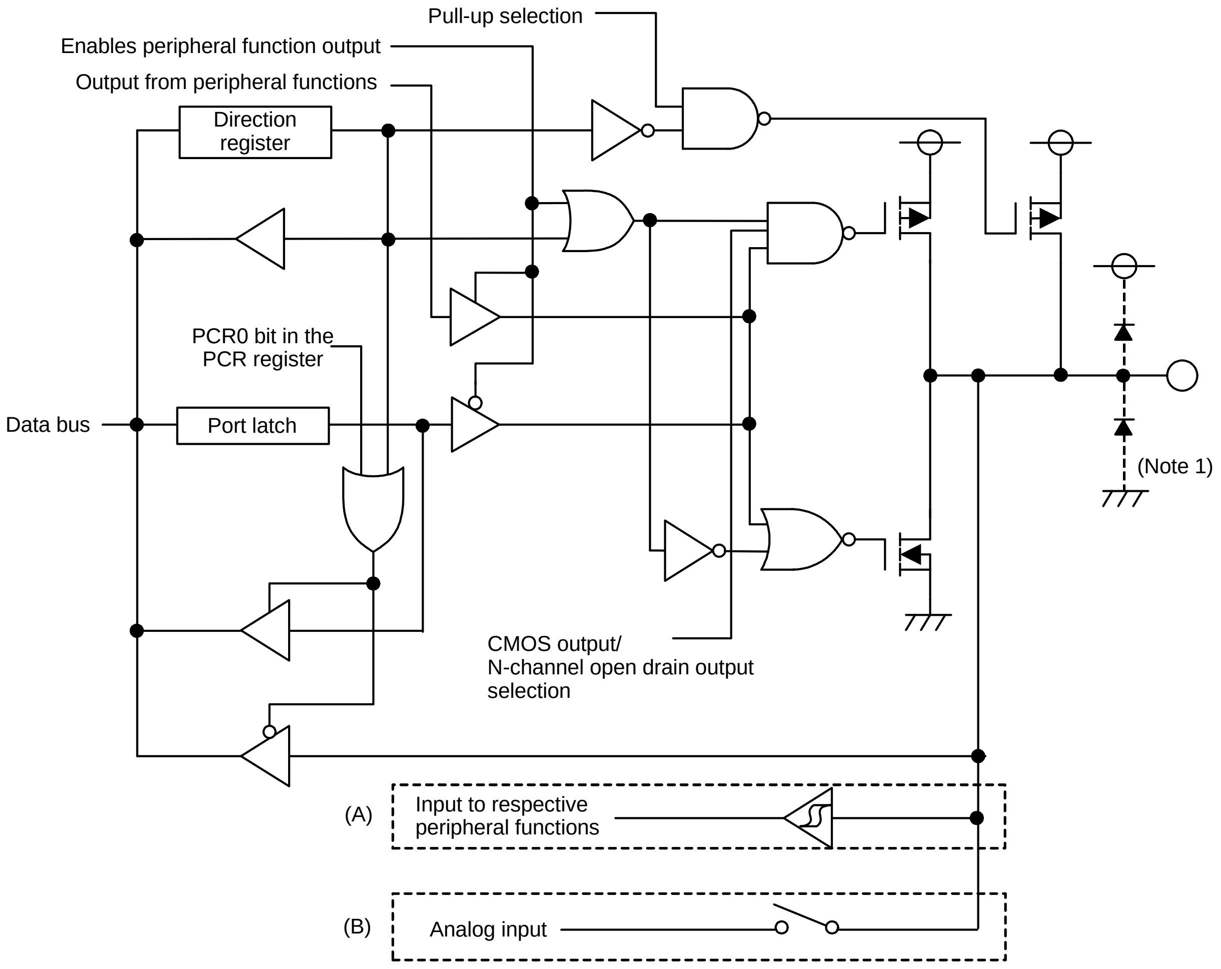
Note:

1. - - -|◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.4 I/O Ports (Port P1 + Output from Peripheral Functions)

Table 13.6 I/O Ports (Port P1 + Output from Peripheral Functions)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.4	Analog input (B) in Figure 13.4
P1_0	Available	N/A


Pull-up selection
Enables peripheral function output
Output from peripheral functions
Direction register
PCR0 bit in the PCR register
Data bus
Port latch
CMOS output/ N-channel open drain output selection
(Note 1)
(A)
Input to respective peripheral functions
(B)
Analog input

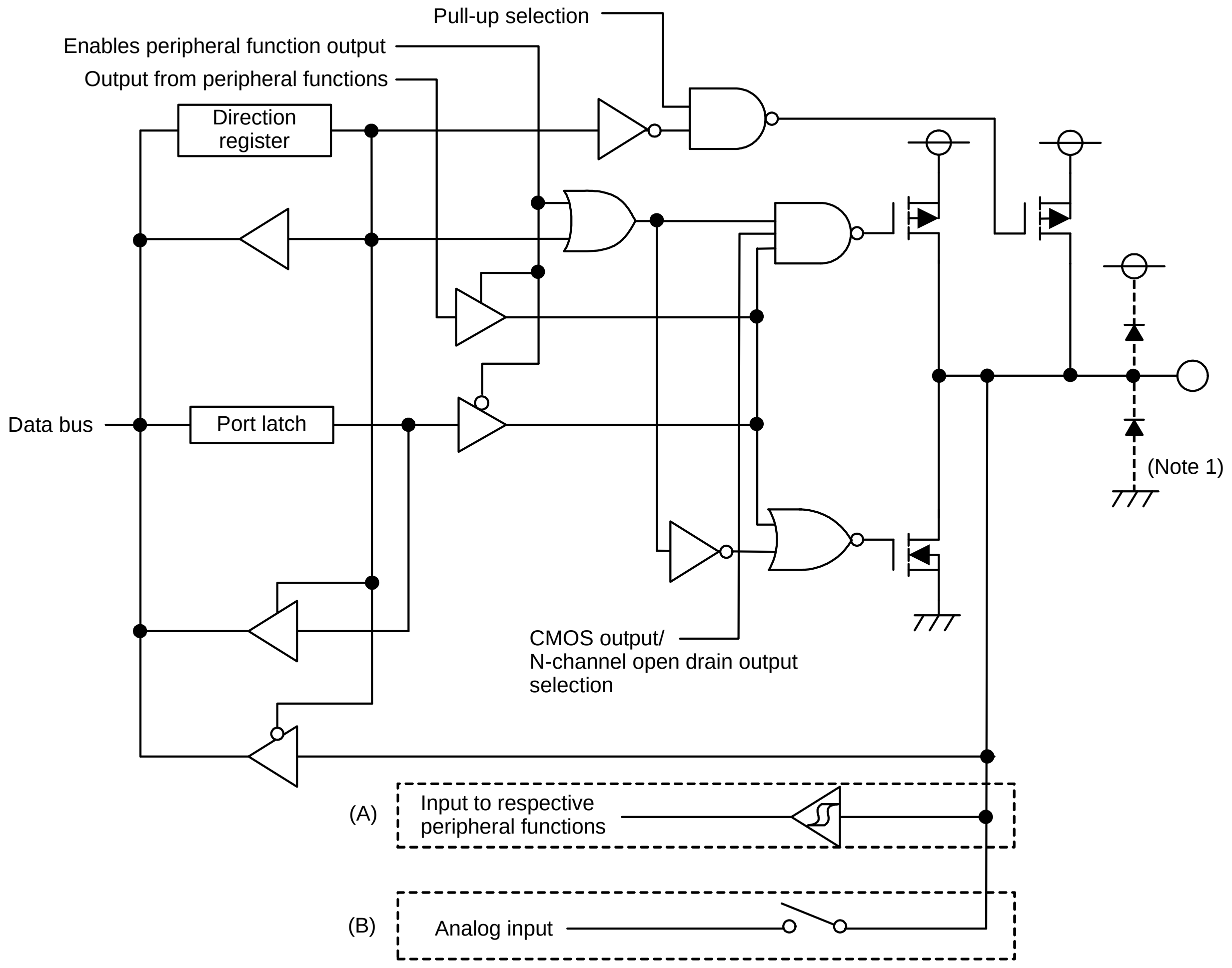
Note:

1. - - -◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.5 I/O Ports (Port P1, CMOS Output/N-channel Open Drain Output Selection)

Table 13.7 I/O Ports (Port P1, CMOS Output/N-channel Open Drain Output Selection)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.5	Analog input (B) in Figure 13.5
P1_1 to P1_3	Available	N/A



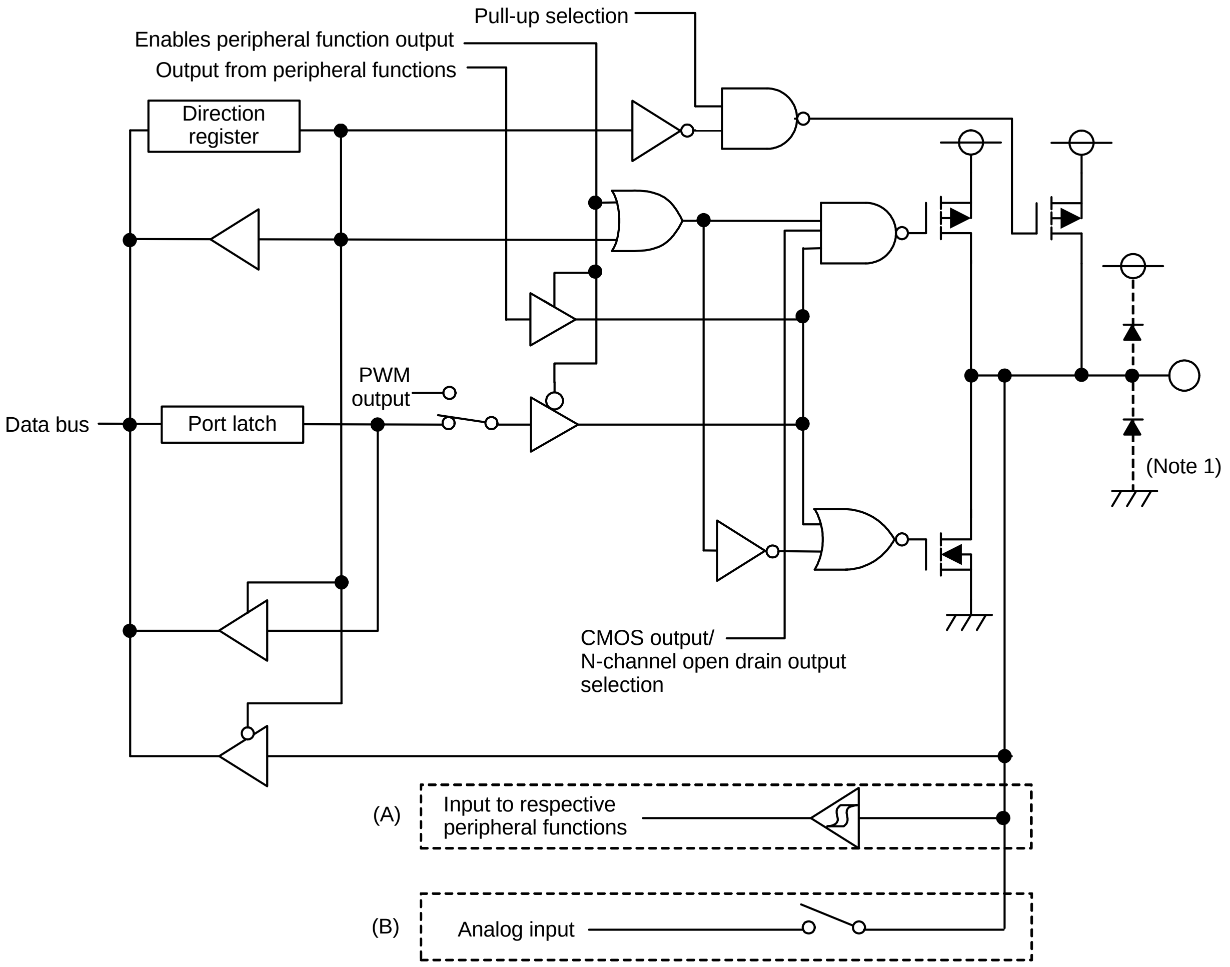
Note:

1. - - -|◀- - - symbolizes a parasitic diode.
Make sure the input voltage to each port does not exceed VCC.
VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.6 I/O Ports (CMOS Output/N-channel Open Drain Output Selection)

Table 13.8 I/O Ports (CMOS Output/N-channel Open Drain Output Selection)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.6	Analog input (B) in Figure 13.6
P4_5, P6_1 to P6_3, P6_5 to P6_7, P7_2, P7_6, P7_7, P8_0	Available	N/A


Pull-up selection
Enables peripheral function output
Output from peripheral functions
Direction register
PWM output
Data bus
Port latch
(Note 1)
CMOS output/ N-channel open drain output selection
(A)
Input to respective peripheral functions
(B)
Analog input

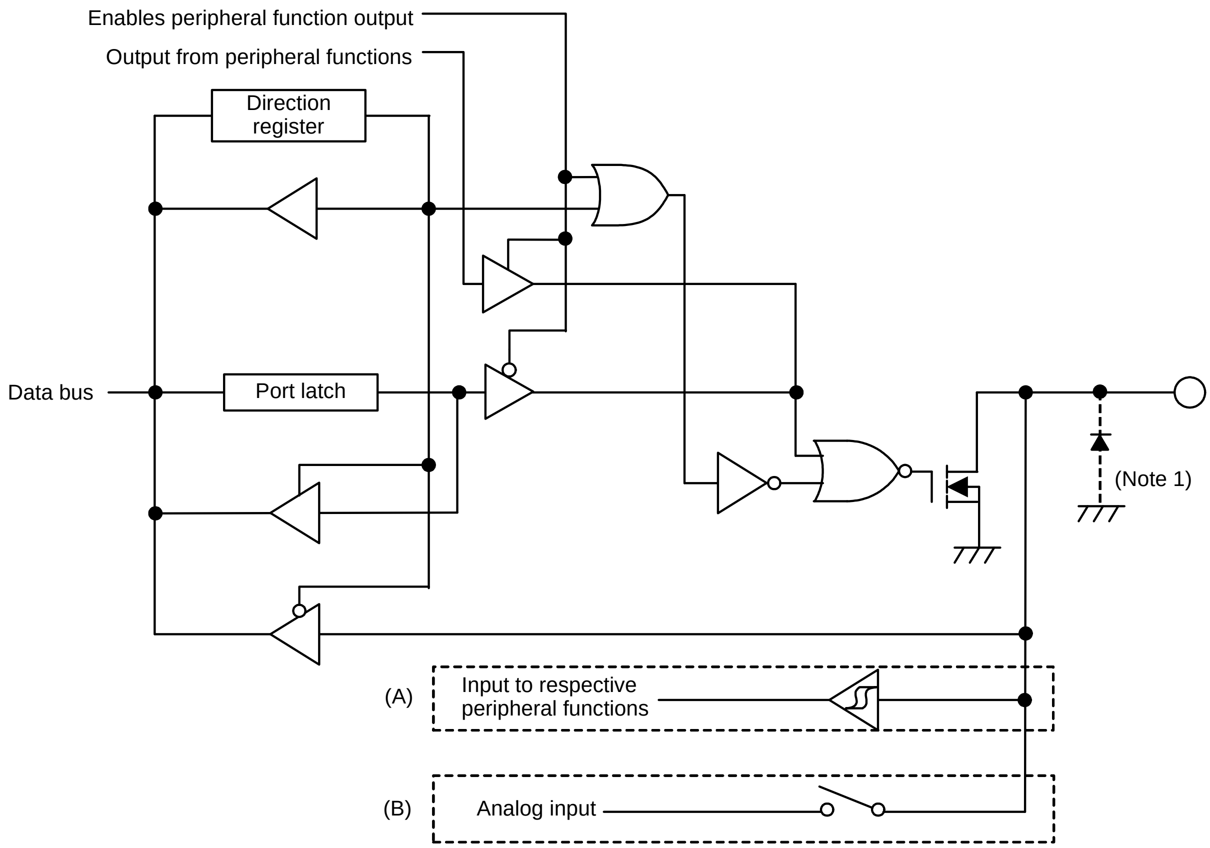
Note:

1. - - -|◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.7 I/O Ports (CMOS Output/N-channel Open Drain Output Selection, PWM)

Table 13.9 I/O Ports (CMOS Output/N-channel Open Drain Output Selection, PWM)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.7	Analog input (B) in Figure 13.7
P4_6, P4_7	Available	N/A


Enables peripheral function output
Output from peripheral functions
Direction register
Data bus
Port latch
(Note 1)
(A)
Input to respective peripheral functions
(B)
Analog input

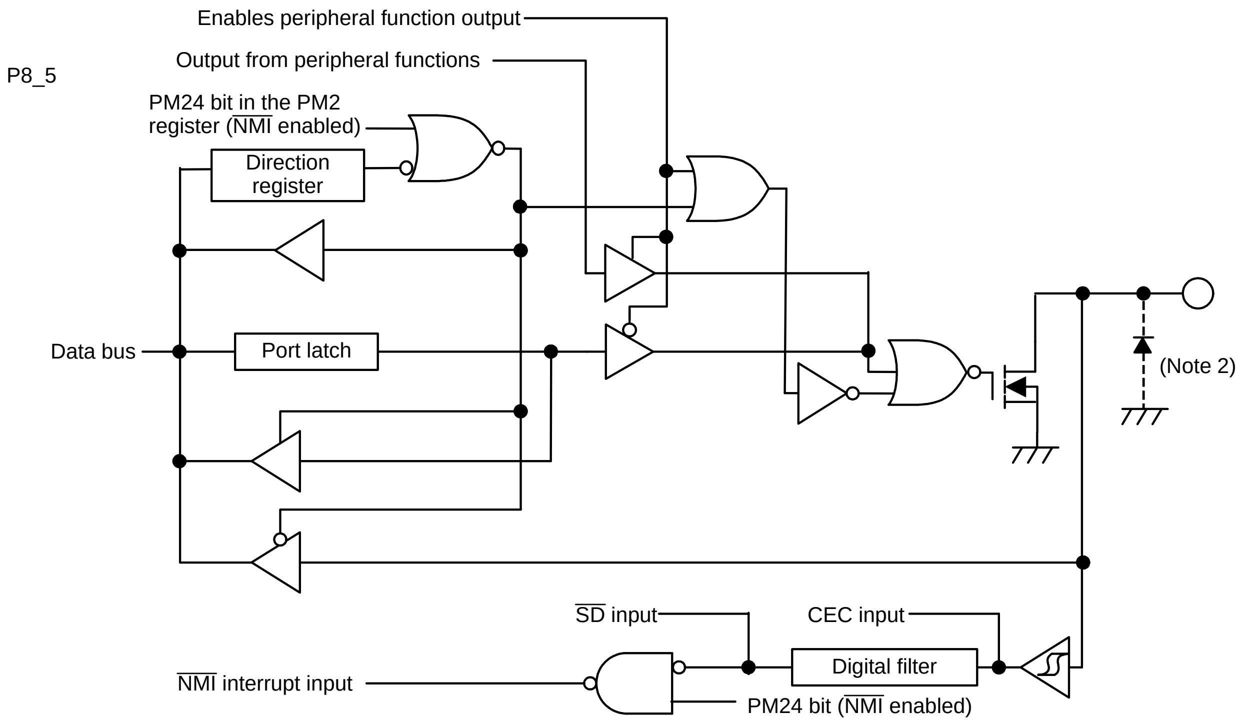
Note:

1. - - -|◀- - - symbolizes a parasitic diode.

Figure 13.8 I/O Ports (N-channel Open Drain Output)

Table 13.10 I/O Ports (N-channel Open Drain Output)

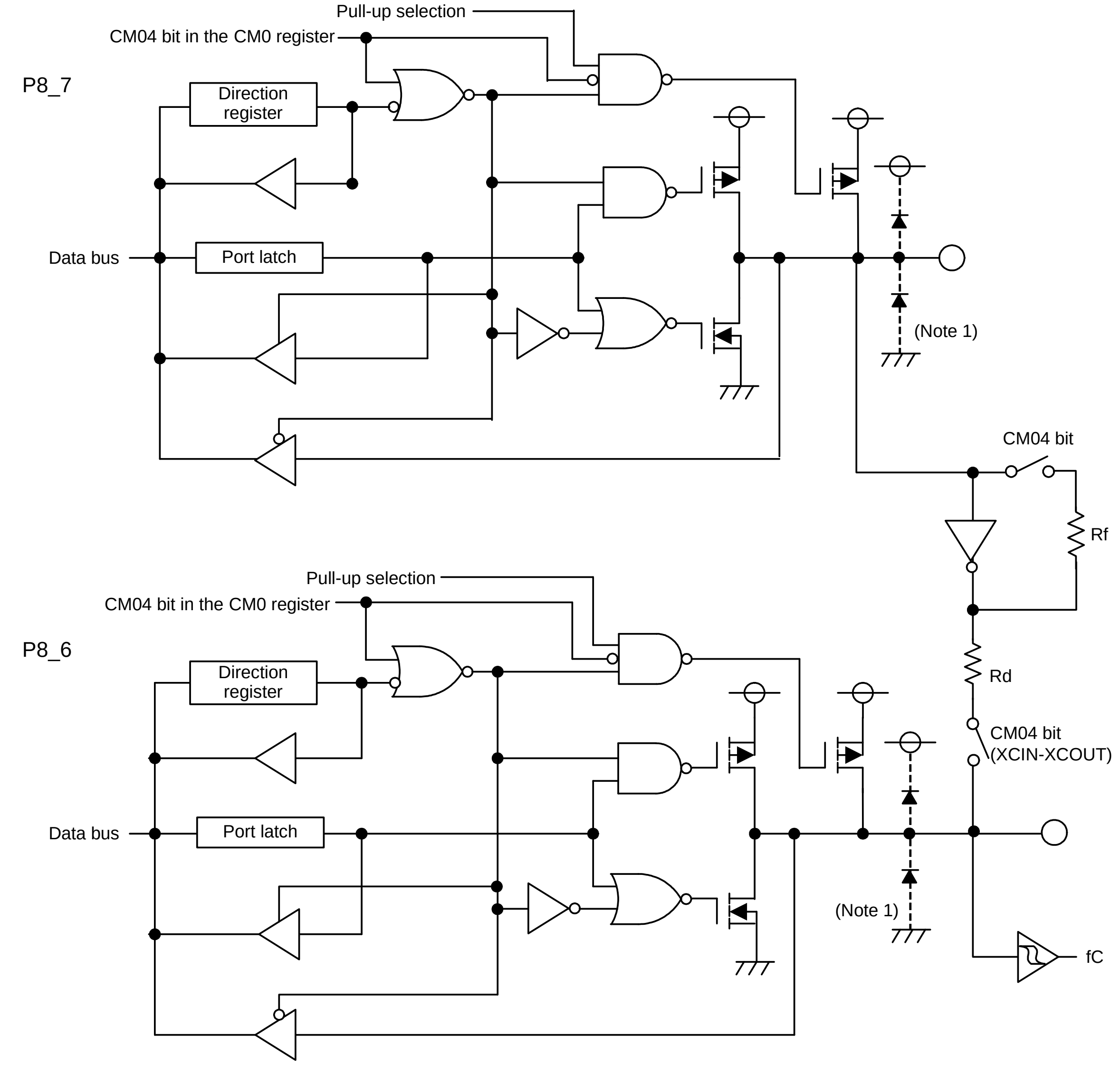
Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.8	Analog input (B) in Figure 13.8
P7_0, P7_1	Available	N/A


Enables peripheral function output
Output from peripheral functions
P8_5
PM24 bit in the PM2
register ($\overline{\text{NMI}}$ enabled)
Direction
register
Data bus
Port latch
(Note 2)
$\overline{\text{SD}}$ input
CEC input
Digital filter
$\overline{\text{NMI}}$ interrupt input
PM24 bit ($\overline{\text{NMI}}$ enabled)

Note:

1. - - -|◀- - - symbolizes a parasitic diode.

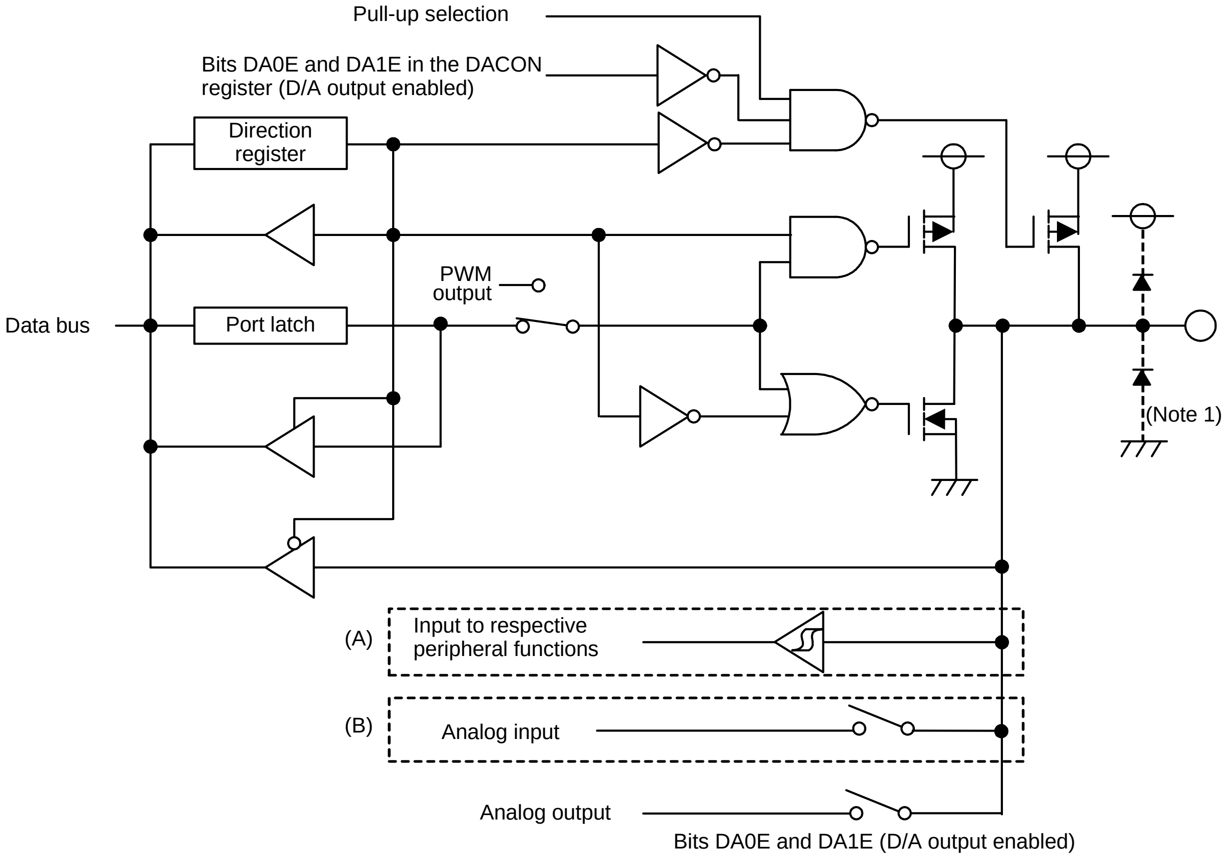
Figure 13.9 I/O Ports ($\overline{\text{NMI}}$)



Note:

1. - - -▶|- - - symbolizes a parasitic diode.
Make sure the input voltage to each port does not exceed VCC.
VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.10 I/O Ports (XC)


Pull-up selection
Bits DA0E and DA1E in the DACON register (D/A output enabled)
Direction register
Data bus
Port latch
PWM output
(Note 1)
(A)
Input to respective peripheral functions
(B)
Analog input
Analog output
Bits DA0E and DA1E (D/A output enabled)

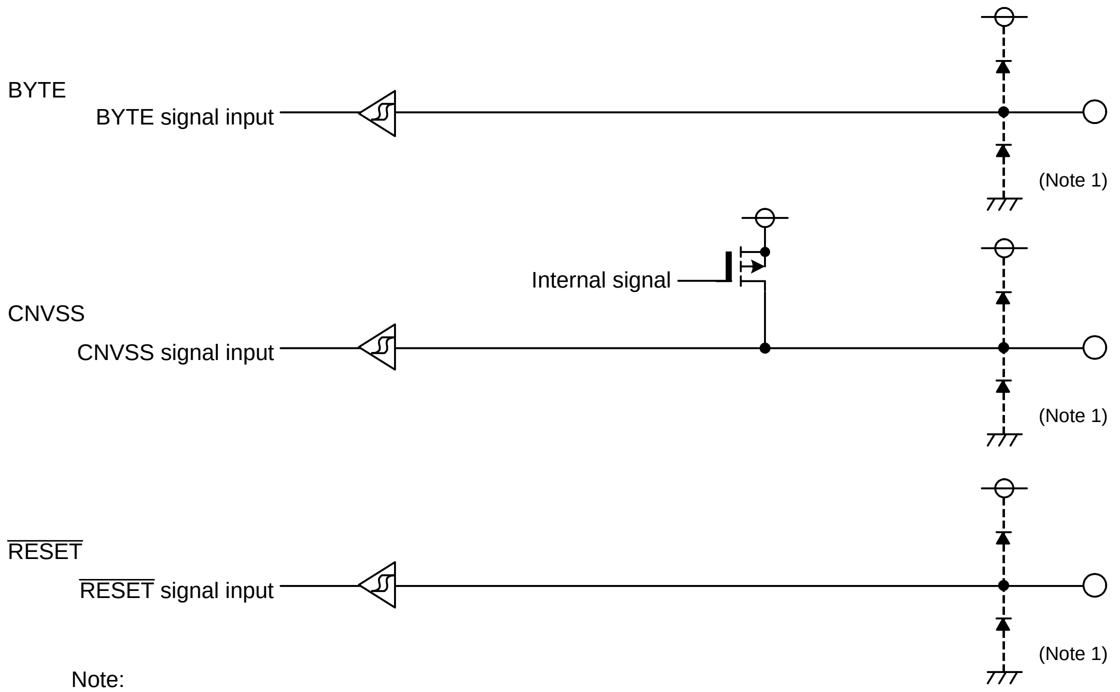
Note:

1. - - -|◀- - - symbolizes a parasitic diode.
   Make sure the input voltage to each port does not exceed VCC.
   VCC: VCC1 for ports P6 to P11 and P14, and VCC2 for ports P0 to P5, P12, and P13.

Figure 13.11 I/O Ports (D/A)

Table 13.11 I/O Ports (D/A)

Port	Peripheral Function I/O	
	Peripheral function input (A) in Figure 13.11	Analog input (B) in Figure 13.11
P9_3, P9_4	Available	N/A



Note:
1. ---|◀---- symbolizes a parasitic diode.
Make sure the input voltage to each port does not exceed VCC1.

Figure 13.12 I/O Pins

13.3 Registers

Table 13.12 Registers

Address	Register	Symbol	Reset Value
0360h	Pull-Up Control Register 0	PUR0	00h
0361h	Pull-Up Control Register 1	PUR1	0000 0000b [(1)] 0000 0010b
0362h	Pull-Up Control Register 2	PUR2	00h
0363h	Pull-Up Control Register 3	PUR3	00h
0366h	Port Control Register	PCR	0000 0XX0b
0369h	NMI/SD Digital Filter Register	NMIDF	XXXX X000b
03E0h	Port P0 Register	P0	XXh
03E1h	Port P1 Register	P1	XXh
03E2h	Port P0 Direction Register	PD0	00h
03E3h	Port P1 Direction Register	PD1	00h
03E4h	Port P2 Register	P2	XXh
03E5h	Port P3 Register	P3	XXh
03E6h	Port P2 Direction Register	PD2	00h
03E7h	Port P3 Direction Register	PD3	00h
03E8h	Port P4 Register	P4	XXh
03E9h	Port P5 Register	P5	XXh
03EAh	Port P4 Direction Register	PD4	00h
03EBh	Port P5 Direction Register	PD5	00h
03ECh	Port P6 Register	P6	XXh
03EDh	Port P7 Register	P7	XXh
03EEh	Port P6 Direction Register	PD6	00h
03EFh	Port P7 Direction Register	PD7	00h
03F0h	Port P8 Register	P8	XXh
03F1h	Port P9 Register	P9	XXh
03F2h	Port P8 Direction Register	PD8	00h
03F3h	Port P9 Direction Register	PD9	00h
03F4h	Port P10 Register	P10	XXh
03F5h	Port P11 Register	P11	XXh
03F6h	Port P10 Direction Register	PD10	00h
03F7h	Port P11 Direction Register	PD11	00h
03F8h	Port P12 Register	P12	XXh
03F9h	Port P13 Register	P13	XXh
03FAh	Port P12 Direction Register	PD12	00h
03FBh	Port P13 Direction Register	PD13	00h
03FCh	Port P14 Register	P14	XXh
03FEh	Port P14 Direction Register	PD14	XXXX XX00b

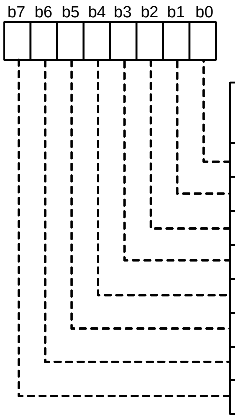
Note:

1. Values after hardware reset, power-on reset, or voltage monitor 0 reset are as follows:
   - 00000000b when input to the CNVSS pin is low.
   - 00000010b when input to the CNVSS pin is high.

   Values after voltage monitor 1 reset, voltage monitor 2 reset, software reset, watchdog timer reset, or oscillation stop detection reset are as follows:
   - 00000000b when bits PM01 to PM00 in the PM0 register are 00b (single-chip mode).
   - 00000010b when bits PM01 to PM00 in the PM0 register are 01b (memory expansion mode) or 11b (microprocessor mode).

13.3.1 Pull-Up Control Register 0 (PUR0)

Pull-Up Control Register 0



Symbol	Address	Reset Value
PUR0	0360h	00h

Bit Symbol	Bit Name	Function	RW
PU00	P0_0 to P0_3 pull-up	0 : Not pulled high 1 : Pulled high	RW
PU01	P0_4 to P0_7 pull-up		RW
PU02	P1_0 to P1_3 pull-up		RW
PU03	P1_4 to P1_7 pull-up		RW
PU04	P2_0 to P2_3 pull-up		RW
PU05	P2_4 to P2_7 pull-up		RW
PU06	P3_0 to P3_3 pull-up		RW
PU07	P3_4 to P3_7 pull-up		RW

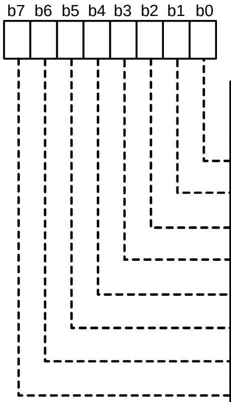
In memory expansion or microprocessor mode, the register value can be modified, but the pins are not pulled high.

PU0i (b7-b0) (i = 0 to 7)

When the PU0i bit is 1 (pulled high) and the direction bit is 0 (input mode), the corresponding pin is pulled high.

13.3.2 Pull-Up Control Register 1 (PUR1)

Pull-Up Control Register 1



Symbol	Address	Reset Value
PUR1	0361h	0000 0000b 0000 0010b

Bit Symbol	Bit Name	Function	RW
PU10	P4_0 to P4_3 pull-up	0 : Not pulled high 1 : Pulled high	RW
PU11	P4_4 to P4_7 pull-up		RW
PU12	P5_0 to P5_3 pull-up		RW
PU13	P5_4 to P5_7 pull-up		RW
PU14	P6_0 to P6_3 pull-up		RW
PU15	P6_4 to P6_7 pull-up		RW
PU16	P7_2 to P7_3 pull-up		RW
PU17	P7_4 to P7_7 pull-up		RW

Values after hardware reset, power-on reset, or voltage monitor 0 reset are as follows:

- 00000000b when input to the CNVSS pin is low
- 00000010b when input to the CNVSS pin is high

Values after voltage monitor 1 reset, voltage monitor 2 reset, software reset, watchdog timer reset, or oscillation stop detection reset are as follows:

- 00000000b when bits PM01 to PM00 are 00b (single-chip mode).
- 00000010b when bits PM01 to PM00 are 01b (memory expansion mode) or 11b (microprocessor mode).

PU10 (P4_0 to P4_3 pull-up) (b0)
PU11 (P4_4 to P4_7 pull-up) (b1)
PU12 (P5_0 to P5_3 pull-up) (b2)
PU13 (P5_4 to P5_7 pull-up) (b3)

When the PU1i bit (i = 0 to 3) is 1 (pulled high) and the direction bit is 0 (input mode), the corresponding pin is pulled high.

In memory expansion and microprocessor modes, pins are not pulled high although the bit values can be modified.

PU14 (P6_0 to P6_3 pull-up) (b4)
PU15 (P6_4 to P6_7 pull-up) (b5)
PU17 (P7_4 to P7_7 pull-up) (b7)

When the PU1i (i = 4, 5, 7) bit is 1 (pulled high) and the direction bit is 0 (input mode), the corresponding pin is pulled high.

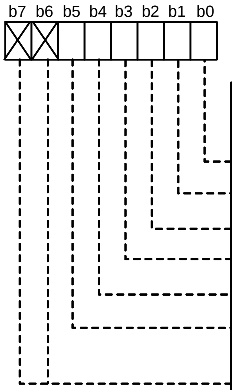
PU16 (P7_2 to P7_3 pull-up) (b6)

When the PU16 bit is 1 (pulled high) and the direction bit is 0 (input mode), the corresponding pin is pulled high.

Pins P7_0 and P7_1 are not pulled high.

13.3.3 Pull-Up Control Register 2 (PUR2)

Pull-Up Control Register 2



Symbol	Address	Reset Value
PUR2	0362h	00h

Bit Symbol	Bit Name	Function	RW
PU20	P8_0 to P8_3 pull-up	0 : Not pulled high 1 : Pulled high	RW
PU21	P8_4, P8_6, P8_7 pull-up		RW
PU22	P9_0 to P9_3 pull-up		RW
PU23	P9_4 to P9_7 pull-up		RW
PU24	P10_0 to P10_3 pull-up		RW
PU25	P10_4 to P10_7 pull-up		RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is 0.		—

PU20 (P8_0 to P8_3 pull-up) (b0)
PU22 (P9_0 to P9_3 pull-up) (b2)
PU23 (P9_4 to P9_7 pull-up) (b3)
PU24 (P10_0 to P10_3 pull-up) (b4)
PU25 (P10_4 to P10_7 pull-up) (b5)

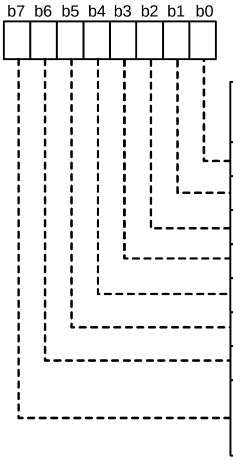
When the PU2i (i = 0, 2 to 5) bit is 1 (pulled high) and the direction bit is 0 (input mode), the corresponding pin is pulled high.

PU21 (P8_4, P8_6, P8_7 pull-up) (b1)

When the PU21 bit is 1 (pulled high) and the direction bit is 0 (input mode), the corresponding pin is pulled high.
The P8_5 pin is not pulled high.

13.3.4 Pull-Up Control Register 3 (PUR3)

Pull-Up Control Register 3



Symbol	Address	After Reset
PUR3	0363h	00h

Bit Symbol	Bit Name	Function	RW
PU30	P11_0 to P11_3 pull-up	0 : Not pulled high 1 : Pulled high	RW
PU31	P11_4 to P11_7 pull-up		RW
PU32	P12_0 to P12_3 pull-up		RW
PU33	P12_4 to P12_7 pull-up		RW
PU34	P13_0 to P13_3 pull-up		RW
PU35	P13_4 to P13_7 pull-up		RW
PU36	P14_0, P14_1 pull-up		RW
PU37	P11 to P14 enable bit	0 : Disabled 1 : Enabled	RW

PU3i (b6-b0) (i = 0 to 6)

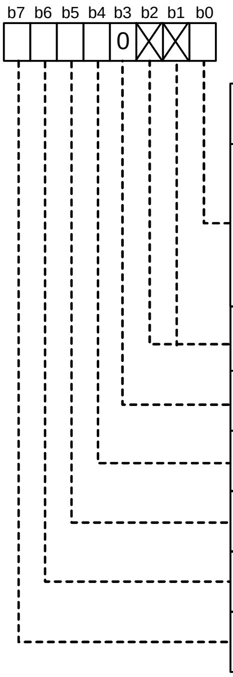
The pin for which the PU3i bit is 1 (pulled high) and the direction bit is 0 (input mode) is pulled high.

PU37 (P11 to P14 enable bit) (b7)

When the PU37 bit is 1 (P11 to P14 enabled), registers P11 to P14 and registers PD0 to PD14 are enabled.

13.3.5 Port Control Register (PCR)

Port Control Register



Symbol	Address	Reset Value
PCR	0366h	0000 0XX0b

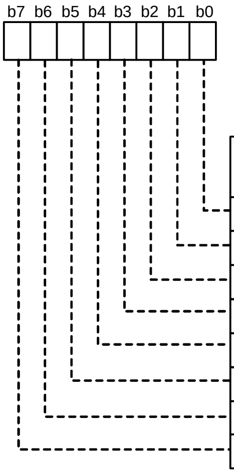
Bit Symbol	Bit Name	Function	RW
PCR0	Port P1 control bit	Operation performed when the P1 register is read 0 : When the port is set to input, the input levels of pins P1_0 to P1_7 are read. When set to output, the port latch is read. 1 : The port latch is read regardless of whether the port is set to input or output.	RW
— (b2-b1)	No register bits. If necessary, set to 0. The read value is undefined.		—
— (b3)	Reserved bit	Set to 0.	RW
PCR4	CEC output enable bit	0 : CEC output disabled 1 : CEC output enabled	RW
PCR5	$\overline{\text{INT6}}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR6	$\overline{\text{INT7}}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR7	Key input enable bit	0 : Enabled 1 : Disabled	RW

PCR0 (Port P1 control bit) (b0)

When the P1 register is read after the PCR0 bit is set to 1, the corresponding port latch is read regardless of the PD1 register setting.

13.3.6 Port Pi Register (Pi) (i = 0 to 14)

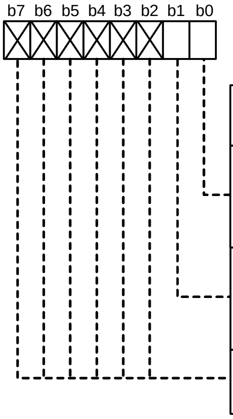
Port Pi Register (i = 0 to 14)



Symbol	Address	Reset Value
P0 to P3	03E0h, 03E1h, 03E4h, 03E5h	XXh
P4 to P7	03E8h, 03E9h, 03ECh, 03EDh	XXh
P8 to P11	03F0h, 03F1h, 03F4h, 03F5h	XXh
P12 to P13	03F8h, 03F9h	XXh

Bit Symbol	Bit Name	Function	RW
Pi_0	Port Pi_0 bit	The pin level of any I/O port which is set to input mode can be read by reading the corresponding bit in this register. The pin level of any I/O port which is set to output mode can be controlled by writing to the corresponding bit in this register. 0 : Low level 1 : High level	RW
Pi_1	Port Pi_1 bit		RW
Pi_2	Port Pi_2 bit		RW
Pi_3	Port Pi_3 bit		RW
Pi_4	Port Pi_4 bit		RW
Pi_5	Port Pi_5 bit		RW
Pi_6	Port Pi_6 bit		RW
Pi_7	Port Pi_7 bit		RW

Port P14 Register



Symbol	Address	After Reset
P14	03FCh	Undefined

Bit Symbol	Bit Name	Function	RW
P14_0	Port P14_0 bit	The pin level of any I/O port which is set to input mode can be read by reading the corresponding bit in this register. The pin level of any I/O port which is set to output mode can be controlled by writing to the corresponding bit in this register. 0 : Low level 1 : High level	RW
P14_1	Port P14_1 bit		RW
— (b7-b2)	No register bit. If necessary, set to 0. The read value is undefined.		—

Data input/output to and from external devices is accomplished by reading and writing to the Pi register. Each bit in the Pi register consists of a port latch to hold the output data and a circuit to read the pin status.

For ports set to input mode, the input level of the pin can be read by reading the corresponding Pi register, and data can be written to the port latch by writing to the Pi register.

For ports set to output mode, the port latch can be read by reading the corresponding Pi register, and data can be written to the port latch by writing to the Pi register. The data written to the port latch is output from the pin. Each bit in the Pi register corresponds to one port.

In memory expansion and microprocessor modes, the Pi register for the pins functioning as bus control pins (A0 to A19, D0 to D15, $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$, $\overline{\text{RD}}$, $\overline{\text{WRL}}/\overline{\text{WR}}$, $\overline{\text{WRH}}/\overline{\text{BHE}}$, ALE, $\overline{\text{RDY}}$, $\overline{\text{HOLD}}$, $\overline{\text{HLDA}}$, and BCLK) cannot be modified (writing a value has no effect).

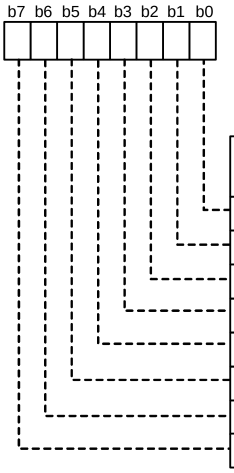
Since P7_0, P7_1, and P8_5 are N-channel open drain ports, when set to 1, the pin status becomes high-impedance.

When the CM04 bit in the CM0 register is 1 (XCIN-XCOUT oscillation function) and bits PD8_6 and PD8_7 in the PD8 register are 0 (input mode), values of bits P8_6 and P8_7 in the P8 register are undefined.

Registers P11 to P14 are enabled when the PU37 bit in the PUR3 register is 1 (P11 to P14 enabled). Access registers P11 to P14 after setting the PU37 bit to 1. When the PU37 bit is 0 (P11 to P14 disabled), the values of registers P11 to P14 are retained. In this case, the read value is undefined.

13.3.7 Port Pi Direction Register (PDi) (i = 0 to 14)

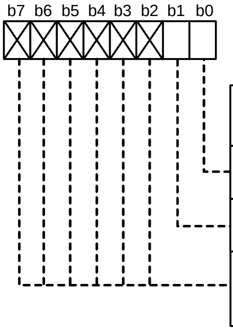
Port Pi Direction Register (i = 0 to 13)



Symbol	Address	Reset Value
PD0 to PD3	03E2h, 03E3h, 03E6h, 03E7h	00h
PD4 to PD7	03EAh, 03EBh, 03EEh, 03EFh	00h
PD8 to PD11	03F2h, 03F3h, 03F6h, 03F7h	00h
PD12 to PD13	03FAh, 03FBh	00h

Bit Symbol	Bit Name	Function	RW
PDi_0	Port Pi_0 direction bit	0 : Input mode (functions as an input port) 1 : Output mode (functions as an output port)	RW
PDi_1	Port Pi_1 direction bit		RW
PDi_2	Port Pi_2 direction bit		RW
PDi_3	Port Pi_3 direction bit		RW
PDi_4	Port Pi_4 direction bit		RW
PDi_5	Port Pi_5 direction bit		RW
PDi_6	Port Pi_6 direction bit		RW
PDi_7	Port Pi_7 direction bit		RW

Port P14 Direction Register



Symbol	Address	After Reset
PD14	03FEh	XXXX XX00b

Bit Symbol	Bit Name	Function	RW
PD14_0	Port P14_0 direction bit	0 : Input mode (functions as an input port) 1 : Output mode (functions as an output port)	RW
PD14_1	Port P14_1 direction bit		RW
— (b7-b2)	No register bit. If necessary, set to 0. The read value is undefined.		—

Write to the PD9 register in the next instruction after setting the PRC2 bit in the PRCR register to 1 (write enabled).

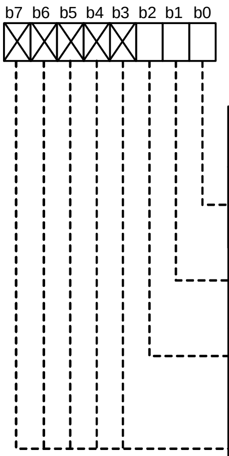
Select whether I/O ports are to be used for input or output by the PDi register. Each bit in the PDi register has a corresponding port.

In memory expansion mode or microprocessor mode, the PDi register for the pins functioning as bus control pins (A0 to A19, D0 to D15, $\overline{\text{CS0}}$ to $\overline{\text{CS3}}$, $\overline{\text{RD}}$, $\overline{\text{WRL}}$/$\overline{\text{WR}}$, $\overline{\text{WRH}}$/$\overline{\text{BHE}}$, ALE, $\overline{\text{RDY}}$, $\overline{\text{HOLD}}$, $\overline{\text{HLDA}}$, and BCLK) cannot be modified (writing a value has no effect).

Registers PD11 to PD14 are enabled when the PU37 bit in the PUR3 register is 1 (P11 to P14 enabled). Access registers PD11 to PD14 after setting the PU37 bit to 1. When the PU37 bit is 0 (P11 to P14 disabled), the values of registers PD11 to PD14 are retained. In this case, the read value is undefined.

13.3.8 $\overline{\text{NMI}}$/$\overline{\text{SD}}$ Digital Filter Register (NMIDF)

$\overline{\text{NMI}}$/$\overline{\text{SD}}$ Digital Filter Register



Symbol	Address	Reset Value
NMIDF	0369h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
NMIDF0	$\overline{\text{NMI}}$/$\overline{\text{SD}}$ filter sampling clock select bit	b2 b1 b0 0 0 0 : No filter 0 0 1 : CPU clock divided by 2 0 1 0 : CPU clock divided by 4 0 1 1 : CPU clock divided by 8 1 0 0 : CPU clock divided by 16 1 0 1 : CPU clock divided by 32 1 1 0 : CPU clock divided by 64 1 1 1 : CPU clock divided by 128	RW
NMIDF1			RW
NMIDF2			RW
— (b7-b3)	No register bits. If necessary, set to 0. The read value is undefined.		—

Change the NMIDF register under the following conditions:

- The PM24 bit in the PM2 register is 0 ($\overline{\text{NMI}}$ interrupt disabled)
- Bits INV02 and INV03 in the INVC0 register are 0 (three-phase motor control timer function not used, three-phase motor control timer output disabled).

Once the PM24 bit is set to 1 ($\overline{\text{NMI}}$ interrupt enabled), it cannot be set to 0 by a program. Change the NMIDF register before setting the PM24 bit to 1.

13.4 Peripheral Function I/O

13.4.1 Peripheral Function I/O and Port Direction Bits

Programmable I/O ports can share pins with peripheral function I/O (see Table 1.7 to Table 1.11 “Pin Names, Pin Package”). Some peripheral function I/O are affected by a port direction bit which shares the same pin. Table 13.13 lists Setting of Direction Bits Functioning as Peripheral Function I/O. For peripheral function settings, see descriptions of each function.

Table 13.13 Setting of Direction Bits Functioning as Peripheral Function I/O

Peripheral Function I/O		Setting of the Port Direction Bit Sharing the Same Pin
Input		Set to 0 (input mode).
Output	PWM	Set to 1 (output mode).
	D/A converter	Set to 0 (input mode).
	Others	Set to either 0 or 1 (outputs regardless of the direction bit setting).

13.4.2 Priority Level of Peripheral Function I/O

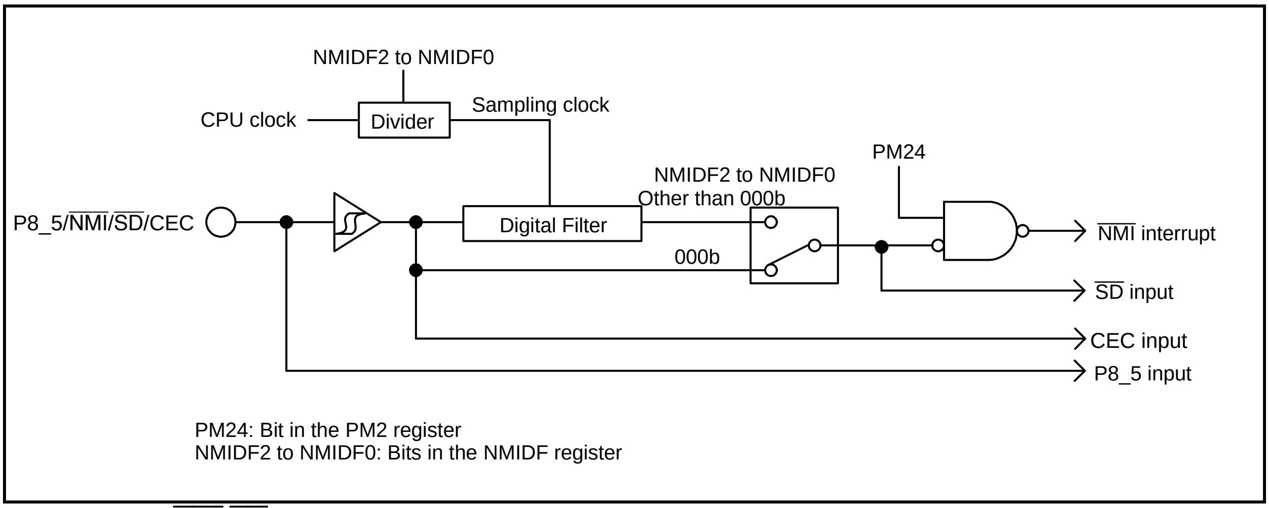
Multiple peripheral functions can share the same pin.

For example, when peripheral function A and peripheral function B share a pin, input and output are as follows:

- When the pin functions as input for peripheral functions A and B
  The same signal is input as an input signal for each function. However, the timing of accepting the signal differs depending on conditions (e.g. internal delay) of peripheral functions A and B.
- When the pin functions as output for peripheral function A and as input for peripheral function B
  Peripheral function A outputs a signal from the pin, and peripheral function B inputs the signal.

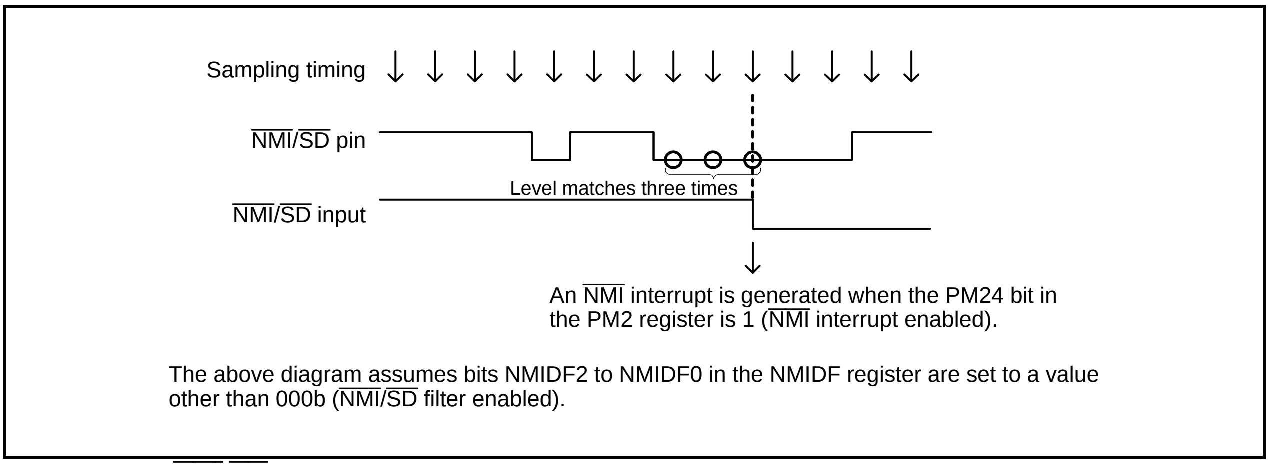
13.4.3 NMI/SD Digital Filter

The NMI/SD input function includes a digital filter. A sampling clock can be selected by bits NMIDF2 to NMIDF0 in the NMIDF register. The NMI level is sampled for every sampling clock. When the same sampled level is detected three times in a row, the level is transferred to the internal circuit.
When using the NMI/SD digital filter, do not enter wait mode or stop mode.
Port P8_5 is not affected by the digital filter.
Figure 13.13 shows NMI/SD Digital Filter, and Figure 13.14 shows NMI/SD Digital Filter Operation Example.



PM24: Bit in the PM2 register
NMIDF2 to NMIDF0: Bits in the NMIDF register

Figure 13.13 NMI/SD Digital Filter



An NMI interrupt is generated when the PM24 bit in the PM2 register is 1 (NMI interrupt enabled).

The above diagram assumes bits NMIDF2 to NMIDF0 in the NMIDF register are set to a value other than 000b (NMI/SD filter enabled).

Figure 13.14 NMI/SD Digital Filter Operation Example

13.4.4 CNVSS Pin

The built-in pull-up resistor of the CNVSS pin is activated after watchdog timer reset, hardware reset, power-on reset, or voltage monitor 0 reset. Thus, the CNVSS pin outputs a high-level signal up to two cycles of fOCO-S. Connect the CNVSS pin to VSS via a resistor to use it in single-chip mode.

13.5 Unassigned Pin Handling

Table 13.14 Unassigned Pin Handling in Single-Chip Mode

Pin Name	Connection [2]
Ports P0 to P5, P12, P13	One of the following: • Set to input mode and connect a pin to VSS via a resistor (pull-down) • Set to input mode and connect a pin to VCC2 via a resistor (pull-up) • Set to output mode and leave the pins open [1]
Ports P6 to P11, P14	One of the following: • Set to input mode and connect a pin to VSS via a resistor (pull-down) • Set to input mode and connect a pin to VCC1 via a resistor (pull-up) • Set to output mode and leave the pins open [1, 3]
XOUT [4]	Open
XIN	Connect to VCC1 via a resistor (pull-up)
AVCC	Connect to VCC1
AVSS, VREF, BYTE	Connect to VSS

Notes:

1. When setting a port to output mode and leaving it open, be aware that the port remains in input mode until it is switched to output mode by a program after reset. For this reason, the voltage level on the pin becomes undefined, causing the power supply current to increase while the port remains in input mode. Furthermore, since the values of the direction registers can be changed by noise or noise-induced loss of control, it is recommended that the values of the direction registers be regularly reset in software to improve the reliability of the program.
2. Make sure unassigned pins are connected with the shortest possible wiring from the MCU pins (maximum 2 cm).
3. Ports P7_0, P7_1, and P8_5 are N-channel open drain outputs. When ports P7_0, P7_1, and P8_5 are set to output mode, make sure a low is output from the pins.
4. This applies when an external clock is input to the XIN pin or when VCC1 is connected via a resistor.

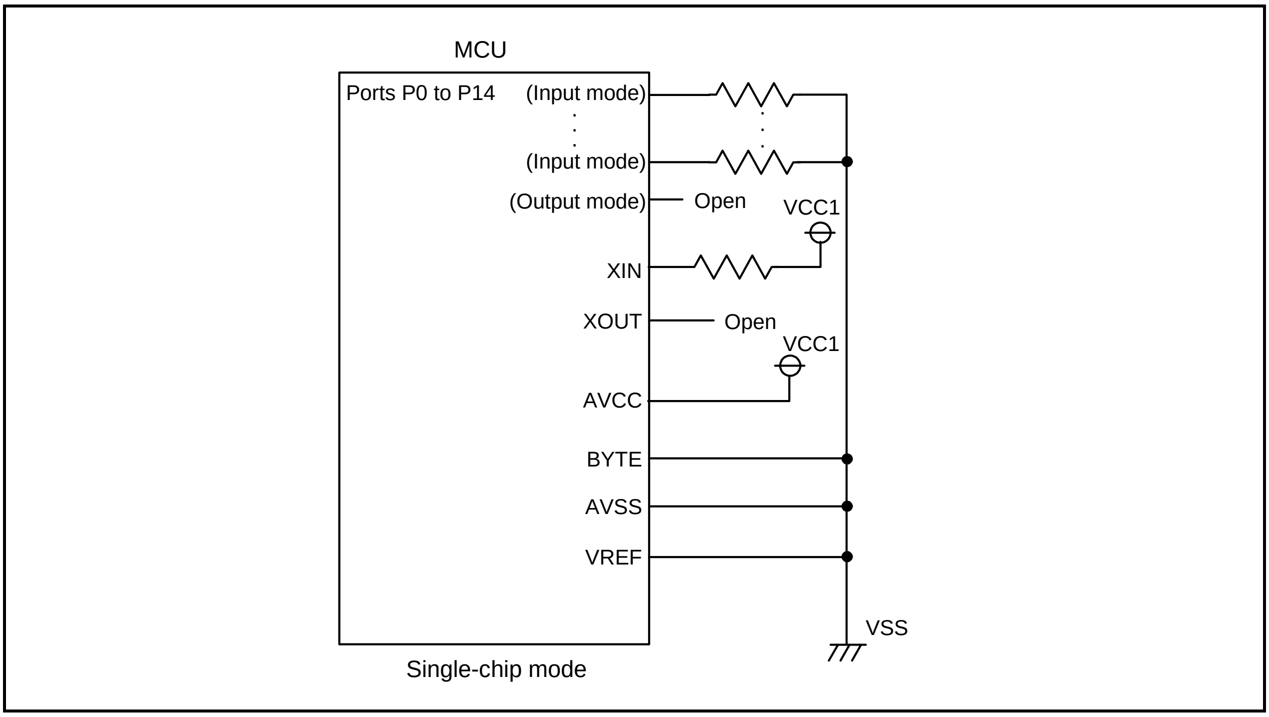


Figure 13.15 Unassigned Pin Handling in Single-Chip Mode

Table 13.15 Unassigned Pin Handling in Memory Expansion Mode and Microprocessor Mode

Pin Name	Connection [2]
Ports P0 to P5, P12, P13	One of the following: • Set to input mode and connect a pin to VSS via a resistor (pull-down) • Set to input mode and connect a pin to VCC2 via a resistor (pull-up) • Set to output mode and leave the pins open [1, 3]
Ports P6 to P11, P14	One of the following: • Set to input mode and connect a pin to VSS via a resistor (pull-down) • Set to input mode and connect a pin to VCC1 via a resistor (pull-up) • Set to output mode and leave the pins open [1, 4]
$\overline{\text{BHE}}$, ALE, $\overline{\text{HLDA}}$, XOUT [5], BCLK [6]	Open
$\overline{\text{HOLD}}$, $\overline{\text{RDY}}$	Connect to VCC2 via a resistor (pull-up)
XIN	Connect to VCC1 via a resistor (pull-up)
AVCC	Connect to VCC1
AVSS, VREF	Connect to VSS

Notes:

1. When setting a port to output mode and leaving it open, be aware that the port remains in input mode until it is switched to output mode by a program after reset. For this reason, the voltage level on the pin becomes undefined, causing the power supply current to increase while the port remains in input mode. Furthermore, since the values of the direction registers can be changed by noise or noise-induced loss of control, it is recommended that the values of the direction registers be regularly reset in software to improve the reliability of the program.
2. Connect unassigned pins with shortest possible wiring from the MCU pins (maximum 2 cm).
3. When the CNVSS pin has the VSS level applied to it, these pins are set as input ports until the processor mode is switched by a program after reset. For this reason, the voltage levels on these pins become undefined, causing the power supply current to increase while they remain set as input ports.
4. Ports P7_0, P7_1, and P8_5 are N-channel open drain outputs. When ports P7_0, P7_1, and P8_5 are set to output mode, make sure a low is output from the pins.
5. This applies when an external clock is input to the XIN pin or when VCC1 is connected via a resistor.
6. When the PM07 bit in the PM0 register is 1 (BCLK not output), connect it to VCC2 via a resistor (pull-up).

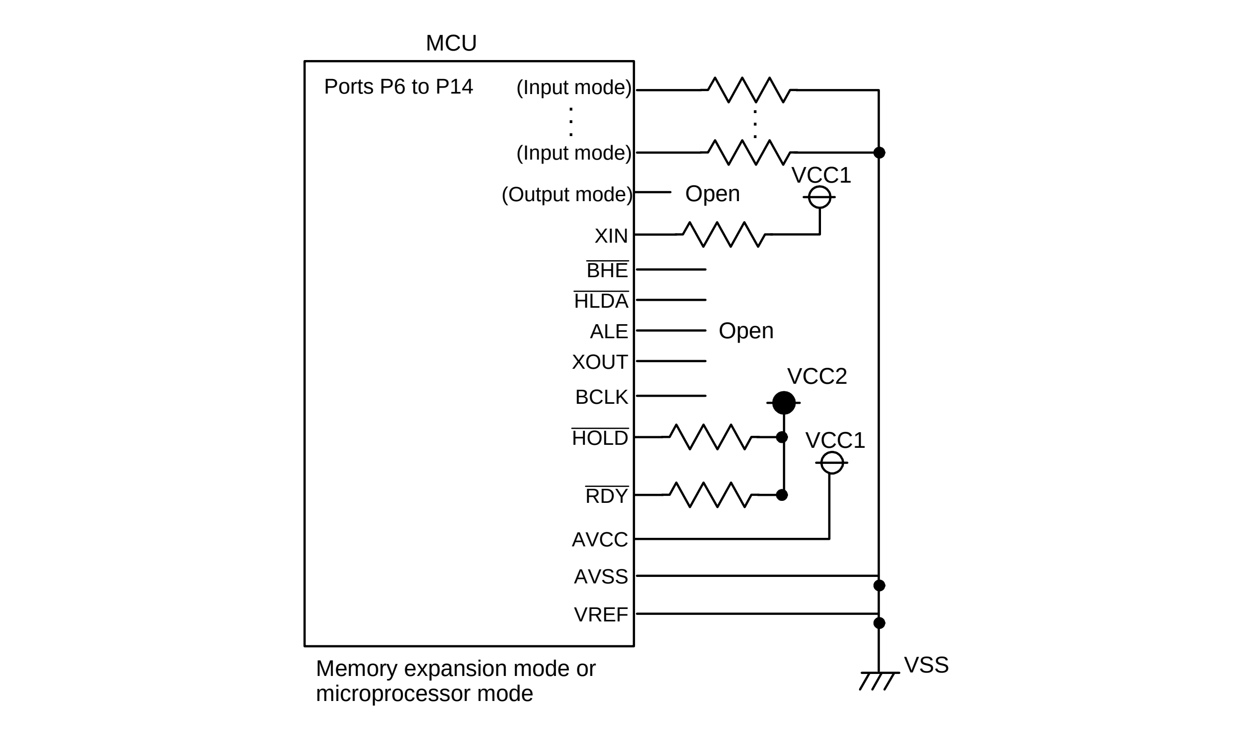


Figure 13.16 Unassigned Pin Handling in Memory Expansion Mode and Microprocessor Mode

13.6 Notes on Programmable I/O Ports

13.6.1 Influence of $\overline{\text{SD}}$

When a low-level signal is applied to the $\overline{\text{SD}}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{\text{SD}}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$/TA1IN/$\overline{\text{V}}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{\text{W}}$, P8_0/TA4OUT/RXD5/SCL5/U, P8_1/TA4IN/$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$/$\overline{\text{U}}$

13.6.2 Influence of SI/O3 and SI/O4

When the SMi2 bit in the SiC register is set to 1 (SOUTi output disabled), the target pin becomes high-impedance regardless of which pin function being used.

13.6.3 100-Pin Package

Do not access the addresses assigned to registers P11 to P14, PD11 to PD14, and the PUR3 register.

14. Interrupts

14.1 Introduction

Table 14.1 lists Types of Interrupts, and Table 14.2 lists I/O Pins. The pins shown in Table 14.2 are external interrupt input pins. Refer to the peripheral functions for the pins related to the peripheral functions.

Table 14.1 Types of Interrupts

Type		Interrupt	Function
Software		Undefined instruction (UND instruction) Overflow (INTO instruction) BRK instruction INT instruction	An interrupt is generated by executing an instruction. Non-maskable interrupt [2]
Hardware	Specific	$\overline{\text{NMI}}$ Watchdog timer Oscillator stop/restart detect Voltage monitor 1 Voltage monitor 2 Address match Single step [1] $\overline{\text{DBC}}$ [1]	Interrupt by the MCU hardware Non-maskable interrupt [2]
	Peripheral function	$\overline{\text{INT}}$, timers, etc. (Refer to 14.6.2 “Relocatable Vector Tables”.)	Interrupt by the peripheral functions in the MCU Maskable interrupt (interrupt priority level: 7 levels) [2]

Notes:

1. This interrupt is provided exclusively for developers and should not be used.
2. Maskable interrupt: Interrupt status (enabled or disabled) can be selected by the interrupt enable flag (I flag).
   Interrupt priority can be changed by the interrupt priority level.
   Non-maskable interrupt: Interrupt status (enabled or disabled) cannot be selected by the interrupt enable flag (I flag).
   Interrupt priority cannot be changed by the interrupt priority level.

Table 14.2 I/O Pins

Pin Name	I/O	Function
$\overline{\text{NMI}}$	Input [1]	$\overline{\text{NMI}}$ interrupt input
$\overline{\text{INTi}}$	Input [1]	$\overline{\text{INTi}}$ interrupt input
$\overline{\text{KI0}}$ to $\overline{\text{KI3}}$	Input [1]	Key input

i = 0 to 7

Note:

1. Set the port direction bits which share pins to 0 (input mode).

14.2 Registers

Table 14.3 Registers (1/2)

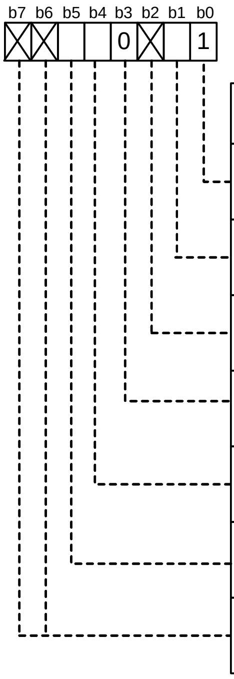
Address	Register	Symbol	Reset Value
001Eh	Processor Mode Register 2	PM2	XX00 0X01b
0042h	$\overline{\text{INT7}}$ Interrupt Control Register	INT7IC	XX00 X000b
0043h	$\overline{\text{INT6}}$ Interrupt Control Register	INT6IC	XX00 X000b
0044h	$\overline{\text{INT3}}$ Interrupt Control Register	INT3IC	XX00 X000b
0045h	Timer B5 Interrupt Control Register	TB5IC	XXXX X000b
0046h	Timer B4 Interrupt Control Register, UART1 Bus Collision Detection Interrupt Control Register	TB4IC, U1BCNIC	XXXX X000b
0047h	Timer B3 Interrupt Control Register, UART0 Bus Collision Detection Interrupt Control Register	TB3IC, U0BCNIC	XXXX X000b
0048h	SI/O4 Interrupt Control Register, $\overline{\text{INT5}}$ Interrupt Control Register	S4IC, INT5IC	XX00 X000b
0049h	SI/O3 Interrupt Control Register, $\overline{\text{INT4}}$ Interrupt Control Register	S3IC, INT4IC	XX00 X000b
004Ah	UART2 Bus Collision Detection Interrupt Control Register	BCNIC	XXXX X000b
004Bh	DMA0 Interrupt Control Register	DM0IC	XXXX X000b
004Ch	DMA1 Interrupt Control Register	DM1IC	XXXX X000b
004Dh	Key Input Interrupt Control Register	KUPIC	XXXX X000b
004Eh	A/D Conversion Interrupt Control Register	ADIC	XXXX X000b
004Fh	UART2 Transmit Interrupt Control Register	S2TIC	XXXX X000b
0050h	UART2 Receive Interrupt Control Register	S2RIC	XXXX X000b
0051h	UART0 Transmit Interrupt Control Register	S0TIC	XXXX X000b
0052h	UART0 Receive Interrupt Control Register	S0RIC	XXXX X000b
0053h	UART1 Transmit Interrupt Control Register	S1TIC	XXXX X000b
0054h	UART1 Receive Interrupt Control Register	S1RIC	XXXX X000b
0055h	Timer A0 Interrupt Control Register	TA0IC	XXXX X000b
0056h	Timer A1 Interrupt Control Register	TA1IC	XXXX X000b
0057h	Timer A2 Interrupt Control Register	TA2IC	XXXX X000b
0058h	Timer A3 Interrupt Control Register	TA3IC	XXXX X000b
0059h	Timer A4 Interrupt Control Register	TA4IC	XXXX X000b
005Ah	Timer B0 Interrupt Control Register	TB0IC	XXXX X000b
005Bh	Timer B1 Interrupt Control Register	TB1IC	XXXX X000b
005Ch	Timer B2 Interrupt Control Register	TB2IC	XXXX X000b
005Dh	$\overline{\text{INT0}}$ Interrupt Control Register	INT0IC	XX00 X000b
005Eh	$\overline{\text{INT1}}$ Interrupt Control Register	INT1IC	XX00 X000b
005Fh	$\overline{\text{INT2}}$ Interrupt Control Register	INT2IC	XX00 X000b
0069h	DMA2 Interrupt Control Register	DM2IC	XXXX X000b
006Ah	DMA3 Interrupt Control Register	DM3IC	XXXX X000b
006Bh	UART5 Bus Collision Detection Interrupt Control Register, CEC1 Interrupt Control Register	U5BCNIC, CEC1IC	XXXX X000b
006Ch	UART5 Transmit Interrupt Control Register, CEC2 Interrupt Control Register	S5TIC, CEC2IC	XXXX X000b
006Dh	UART5 Receive Interrupt Control Register	S5RIC	XXXX X000b
006Eh	UART6 Bus Collision Detection Interrupt Control Register, Real-Time Clock Periodic Interrupt Control Register	U6BCNIC, RTCTIC	XXXX X000b

Table 14.4 Registers (2/2)

Address	Register	Symbol	Reset Value
006Fh	UART6 Transmit Interrupt Control Register, Real-Time Clock Compare Interrupt Control Register	S6TIC, RTCCIC	XXXX X000b
0070h	UART6 Receive Interrupt Control Register	S6RIC	XXXX X000b
0071h	UART7 Bus Collision Detection Interrupt Control Register, Remote Control Signal Receiver 0 Interrupt Control Register	U7BCNIC, PMC0IC	XXXX X000b
0072h	UART7 Transmit Interrupt Control Register, Remote Control Signal Receiver 1 Interrupt Control Register	S7TIC, PMC1IC	XXXX X000b
0073h	UART7 Receive Interrupt Control Register	S7RIC	XXXX X000b
007Bh	I2C-bus Interface Interrupt Control Register	IICIC	XXXX X000b
007Ch	SCL/SDA Interrupt Control Register	SCLDAIC	XXXX X000b
0205h	Interrupt Source Select Register 3	IFSR3A	00h
0206h	Interrupt Source Select Register 2	IFSR2A	00h
0207h	Interrupt Source Select Register	IFSR	00h
020Eh	Address Match Interrupt Enable Register	AIER	XXXX XX00b
020Fh	Address Match Interrupt Enable Register 2	AIER2	XXXX XX00b
0210h	Address Match Interrupt Register 0	RMAD0	00h
0211h			00h
0212h			X0h
0214h	Address Match Interrupt Register 1	RMAD1	00h
0215h			00h
0216h			X0h
0218h	Address Match Interrupt Register 2	RMAD2	00h
0219h			00h
021Ah			X0h
021Ch	Address Match Interrupt Register 3	RMAD3	00h
021Dh			00h
021Eh			X0h
0366h	Port Control Register	PCR	0000 0XX0b
0369h	NMI/SD Digital Filter Register	NMIDF	XXXX X000b

14.2.1 Processor Mode Register 2 (PM2)

Processor Mode Register 2



Symbol	Address	Reset Value
PM2	001Eh	XX00 0X01b

Bit Symbol	Bit Name	Function	RW
— (b0)	Reserved bit	Set to 1.	RW
PM21	System clock protection bit	0 : Clock is protected by PRCR register 1 : Clock change disabled	RW
— (b2)	No register bit. If necessary, set to 0. The read value is undefined.		—
— (b3)	Reserved bit	Set to 0	RW
PM24	$\overline{\text{NMI}}$ interrupt enable bit	0 : $\overline{\text{NMI}}$ interrupt disabled 1 : $\overline{\text{NMI}}$ interrupt enabled	RW
PM25	Peripheral clock fC provide bit	0 : Not provided 1 : Provided	RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is undefined.		—

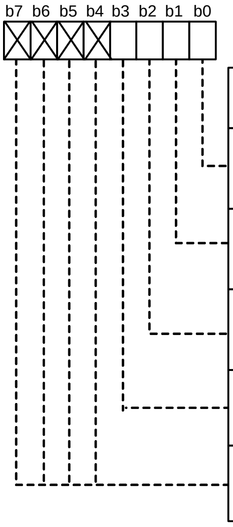
Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register.

PM24 ($\overline{\text{NMI}}$ interrupt enable bit) (b4)

Once this bit is set to 1, it cannot be set to 0 by a program (writing 0 has no effect).

14.2.2 Interrupt Control Register 1 (TB5IC, TB4IC/U1BCNIC, TB3IC/U0BCNIC, BCNIC, DM0IC to DM3IC, KUPIC, ADIC, S0TIC to S2TIC, S0RIC to S2RIC, TA0IC to TA4IC, TB0IC to TB2IC, U5BCNIC/CEC1IC, S5TIC/CEC2IC, S5RIC to S7RIC, U6BCNIC/RTCTIC, S6TIC/RTCCIC, U7BCNIC/PMC0IC, S7TIC/PMC1IC, IICIC, SCLDAIC)

Interrupt Control Register 1



Symbol	Address	Reset Value
Refer to the table below for symbols and addresses.		XXXX X000b

Bit Symbol	Bit Name	Function	RW
ILVL0	Interrupt priority level select bit	b2 b1 b0 0 0 0 : Level 0 (interrupt disabled) 0 0 1 : Level 1 0 1 0 : Level 2 0 1 1 : Level 3 1 0 0 : Level 4 1 0 1 : Level 5 1 1 0 : Level 6 1 1 1 : Level 7	RW
ILVL1			RW
ILVL2			RW
IR	Interrupt request bit	0: Interrupt not requested 1: Interrupt requested	RW
— (b7-b4)	No register bits. If necessary, set to 0. The read value is undefined.		—

Symbol	Address
TB5IC	0045h
TB4IC/U1BCNIC	0046h
TB3IC/U0BCNIC	0047h
BCNIC	004Ah
DM0IC	004Bh
DM1IC	004Ch
DM2IC	0069h
DM3IC	006Ah
KUPIC	004Dh
ADIC	004Eh
S0TIC	0051h
S1TIC	0053h
S2TIC	004Fh
S0RIC	0052h
S1RIC	0054h
S2RIC	0050h
TA0IC	0055h
TA1IC	0056h

Symbol	Address
TA2IC	0057h
TA3IC	0058h
TA4IC	0059h
TB0IC	005Ah
TB1IC	005Bh
TB2IC	005Ch
U5BCNIC/CEC1IC	006Bh
S5TIC/CEC2IC	006Ch
S5RIC	006Dh
S6RIC	0070h
S7RIC	0073h
U6BCNIC/RTCTIC	006Eh
S6TIC/RTCCIC	006Fh
U7BCNIC/PMC0IC	0071h
S7TIC/PMC1IC	0072h
IICIC	007Bh
SCLDAIC	007Ch

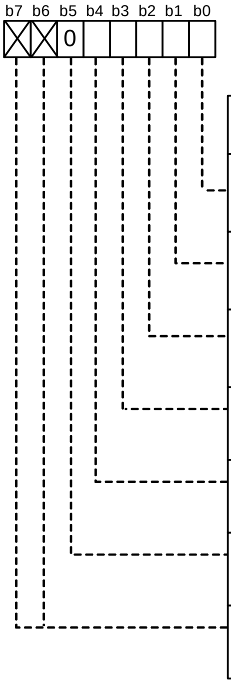
Rewrite these registers at a point where an interrupt request for the corresponding register is not generated.
When multiple interrupt sources share the register, select an interrupt source in registers IFSR2A and IFSR3A.

IR (Interrupt request bit) (b3)

Do not set the IR bit to 1 when it is 0.

14.2.3 Interrupt Control Register 2 (INT7IC, INT6IC, INT3IC, S4IC/INT5IC, S3IC/INT4IC, INT0IC to INT2IC)

Interrupt Control Register 2



Symbol Address Reset Value

Refer to the table below for symbols and addresses. XX00 X000b

Bit Symbol	Bit Name	Function	RW
ILVL0	Interrupt priority level select bit	b2 b1 b0 0 0 0 : Level 0 (interrupt disabled) 0 0 1 : Level 1 0 1 0 : Level 2 0 1 1 : Level 3 1 0 0 : Level 4 1 0 1 : Level 5 1 1 0 : Level 6 1 1 1 : Level 7	RW
ILVL1			RW
ILVL2			RW
IR	Interrupt request bit	0: Interrupt not requested 1: Interrupt requested	RW
POL	Polarity select bit	0 : Select falling edge 1 : Select rising edge	RW
— (b5)	Reserved bit	Set to 0	RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is undefined.		—

Symbol	Address
INT7IC	0042h
INT6IC	0043h
INT3IC	0044h
S4IC/INT5IC	0048h
S3IC/INT4IC	0049h

Symbol	Address
INT0IC	005Dh
INT1IC	005Eh
INT2IC	005Fh

Rewrite these registers at a point where an interrupt request for the corresponding register is not generated.
When multiple interrupt sources share the register, select an interrupt source in the IFSR register.

ILVL2-ILVL0 (Interrupt priority level select bit) (b2-b0)

In memory expansion or microprocessor mode, set bits ILVL2 to ILVL0 in registers INT6IC and INT7IC to 000b (interrupts disabled).
When the BYTE pin is low in memory expansion or microprocessor mode, set bits ILVL2 to ILVL0 in registers INT3IC, INT4IC, and INT5IC to 000b (interrupts disabled).

IR (Interrupt request bit) (b3)

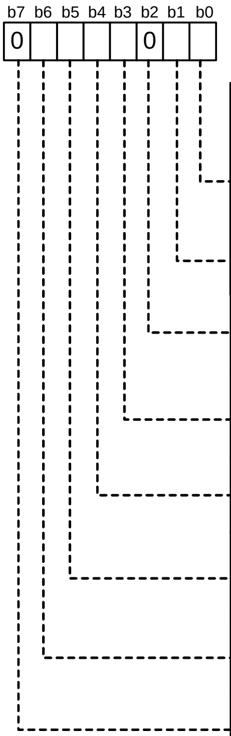
Do not set the IR bit to 1 when it is 0.

POL (Polarity select bit) (b4)

When the IFSRi bit in the IFSR register is 1 (both edges), set the POL bit in the INTiIC register to 0 (falling edge) (i = 0 to 5). When bits IFSR30 and IFSR31 in the IFSR3A register are 1 (both edges), set the POL bit in registers INT6IC and INT7IC to 0 (falling edge).
Set the POL bit in the S3IC or S4IC register to 0 (falling edge) when the IFSR6 bit in the IFSR register is 0 (SI/O3 selected) or IFSR7 bit is 0 (SI/O4 selected), respectively.

14.2.4 Interrupt Source Select Register 3 (IFSR3A)

Interrupt Source Select Register 3



Symbol	Address	Reset Value
IFSR3A	0205h	00h

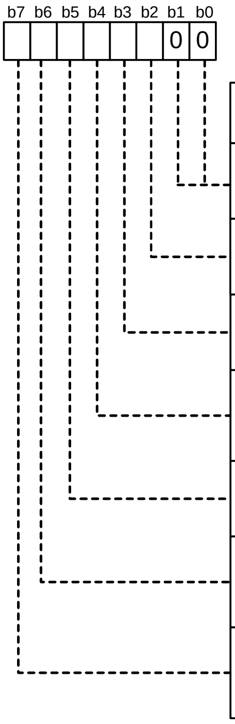
Bit Symbol	Bit Name	Function	RW
IFSR30	$\overline{\text{INT6}}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR31	$\overline{\text{INT7}}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
— (b2)	Reserved bit	Set to 0	RW
IFSR33	Interrupt request source select bit	0 : UART5 start/stop condition detection, bus collision detection 1 : CEC1	RW
IFSR34	Interrupt request source select bit	0 : UART5 transmission, NACK 1 : CEC2	RW
IFSR35	Interrupt request source select bit	0 : UART6 start/stop condition detection, bus collision detection 1 : Real-time clock cycle	RW
IFSR36	Interrupt request source select bit	0 : UART6 transmission, NACK 1 : Real-time clock compare	RW
— (b7)	Reserved bit	Set to 0	RW

IFSR31 and IFSR30 ($\overline{\text{INT7}}$ and $\overline{\text{INT6}}$ interrupt polarity select bit) (b1-b0)

When setting this bit to 1 (both edges), make sure the corresponding POL bit in registers INT6IC and INT7IC is set to 0 (falling edge).

14.2.5 Interrupt Source Select Register 2 (IFSR2A)

Interrupt Source Select Register 2

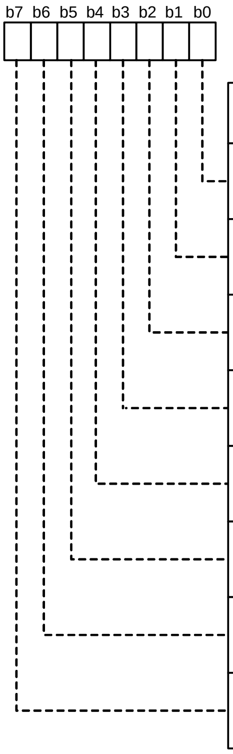


Symbol	Address	Reset Value
IFSR2A	0206h	00h

Bit Symbol	Bit Name	Function	RW
— (b1-b0)	Reserved bits	Set to 0	RW
IFSR22	Interrupt request source select bit	0 : Not used 1 : I^{2}C-bus interface	RW
IFSR23	Interrupt request source select bit	0 : Not used 1 : SCL/SDA	RW
IFSR24	Interrupt request source select bit	0 : UART7 start/stop condition detection, bus collision detection 1 : Remote control 0	RW
IFSR25	Interrupt request source select bit	0 : UART7 transmission, NACK 1 : Remote control 1	RW
IFSR26	Interrupt request source select bit	0 : Timer B3 1 : UART0 start/stop condition detection, bus collision detection	RW
IFSR27	Interrupt request source select bit	0 : Timer B4 1 : UART1 start/stop condition detection, bus collision detection	RW

14.2.6 Interrupt Source Select Register (IFSR)

Interrupt Source Select Register



Symbol	Address	Reset Value
IFSR	0207h	00h

Bit Symbol	Bit Name	Function	RW
IFSR0	$\overline{\text{INT0}}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR1	$\overline{\text{INT1}}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR2	$\overline{\text{INT2}}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR3	$\overline{\text{INT3}}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR4	$\overline{\text{INT4}}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR5	$\overline{\text{INT5}}$ interrupt polarity select bit	0 : One edge 1 : Both edges	RW
IFSR6	Interrupt request source select bit	0 : $\overline{\text{SI/O3}}$ 1 : $\overline{\text{INT4}}$	RW
IFSR7	Interrupt request source select bit	0 : $\overline{\text{SI/O3}}$ 1 : $\overline{\text{INT5}}$	RW

IFSR5-IFSR0 ($\overline{\text{INT5}}$-$\overline{\text{INT0}}$ interrupt polarity select bit) (b5-b0)

When setting these bits to 1 (both edges), make sure the corresponding POL bit in registers INT0IC to INT5IC is set to 0 (falling edge).

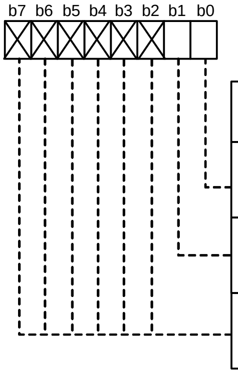
IFSR7, IFSR6 (Interrupt request source select bit) (b7, b6)

In memory expansion or microprocessor mode, when the data bus is 16 bits wide (BYTE pin is low), set these bits to 0 (SI/O3, SI/O4).

When setting these bits to 0 (SI/O3, SI/O4), make sure the corresponding POL bit in registers S3IC and S4IC is set to 0 (falling edge).

14.2.7 Address Match Interrupt Enable Register (AIER)

Address Match Interrupt Enable Register

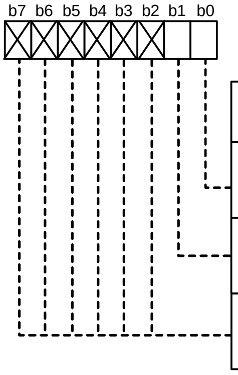


Symbol	Address	Reset Value
AIER	020Eh	XXXX XX00b

Bit Symbol	Bit Name	Function	RW
AIER0	Address match interrupt 0 enable bit	0 : Interrupt disabled 1 : Interrupt enabled	RW
AIER1	Address match interrupt 1 enable bit	0 : Interrupt disabled 1 : Interrupt enabled	RW
— (b7-b2)	No register bits. If necessary, set to 0. The read value is undefined.		—

14.2.8 Address Match Interrupt Enable Register 2 (AIER2)

Address Match Interrupt Enable Register 2

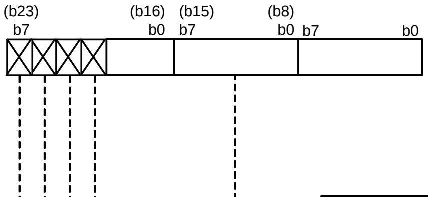


Symbol	Address	Reset Value
AIER2	020Fh	XXXX XX00b

Bit Symbol	Bit Name	Function	RW
AIER20	Address match interrupt 2 enable bit	0 : Interrupt disabled 1 : Interrupt enabled	RW
AIER21	Address match interrupt 3 enable bit	0 : Interrupt disabled 1 : Interrupt enabled	RW
— (b7-b2)	No register bits. If necessary, set to 0. The read value is undefined.		—

14.2.9 Address Match Interrupt Register i (RMADi) (i = 0 to 3)

Address Match Interrupt Register i (i = 0 to 3)

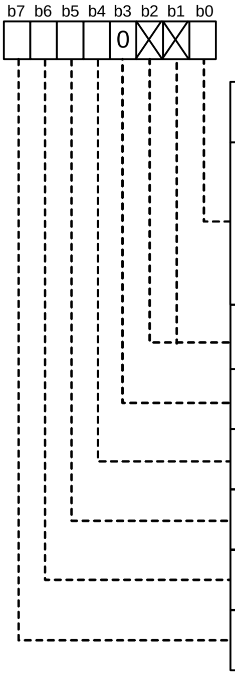


Symbol	Address	Reset Value
RMAD0	0212h to 0210h	X0 0000h
RMAD1	0216h to 0214h	X0 0000h
RMAD2	021Ah to 0218h	X0 0000h
RMAD3	021Eh to 021Ch	X0 0000h

Function	Setting Range	RW
Address setting register for address match interrupt (b19 to b0)	00000h to FFFFFh	RW
No register bits. If necessary, set to 0. The read value is undefined.		—

14.2.10 Port Control Register (PCR)

Port Control Register



Symbol	Address	Reset Value
PCR	0366h	0000 0XX0b

Bit Symbol	Bit Name	Function	RW
PCR0	Port P1 control bit	Operation performed when the P1 register is read 0 : When the port is set to input, the input levels of pins P1_0 to P1_7 are read. When set to output, the port latch is read. 1 : The port latch is read regardless of whether the port is set to input or output.	RW
— (b2-b1)	No register bits. If necessary, set to 0. The read value is undefined.		—
— (b3)	Reserved bit	Set to 0.	RW
PCR4	CEC output enable bit	0 : CEC output disabled 1 : CEC output enabled	RW
PCR5	$\overline{\text{INT6}}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR6	$\overline{\text{INT7}}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR7	Key input enable bit	0 : Enabled 1 : Disabled	RW

PCR5 ($\overline{\text{INT6}}$ input enable bit) (b5)

To use the AN2_4 pin as an analog input pin, set the PCR5 bit to 1 ($\overline{\text{INT6}}$ input disabled).

PCR6 ($\overline{\text{INT7}}$ input enable bit) (b6)

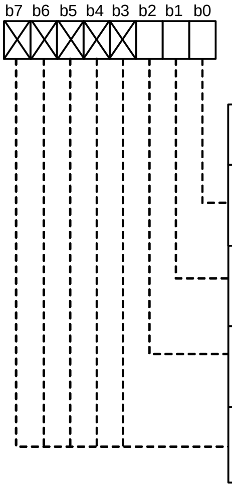
To use the AN2_5 pin as an analog input pin, set the PCR6 bit to 1 ($\overline{\text{INT7}}$ input disabled).

PCR7 (Key input enable bit) (b7)

To use pins AN4 to AN7 as analog input pins, set the PCR7 bit to 1 (key input disabled).

14.2.11 $\overline{\text{NMI}}$/$\overline{\text{SD}}$ Digital Filter Register (NMIDF)

$\overline{\text{NMI}}$/$\overline{\text{SD}}$ Digital Filter Register



Symbol	Address	Reset Value
NMIDF	0369h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
NMIDF0	$\overline{\text{NMI}}$/$\overline{\text{SD}}$ filter sampling clock select bit	b2 b1 b0 0 0 0 : No filter 0 0 1 : CPU clock divided by 2 0 1 0 : CPU clock divided by 4 0 1 1 : CPU clock divided by 8 1 0 0 : CPU clock divided by 16 1 0 1 : CPU clock divided by 32 1 1 0 : CPU clock divided by 64 1 1 1 : CPU clock divided by 128	RW
NMIDF1			RW
NMIDF2			RW
— (b7-b3)	No register bits. If necessary, set to 0. The read value is undefined.		—

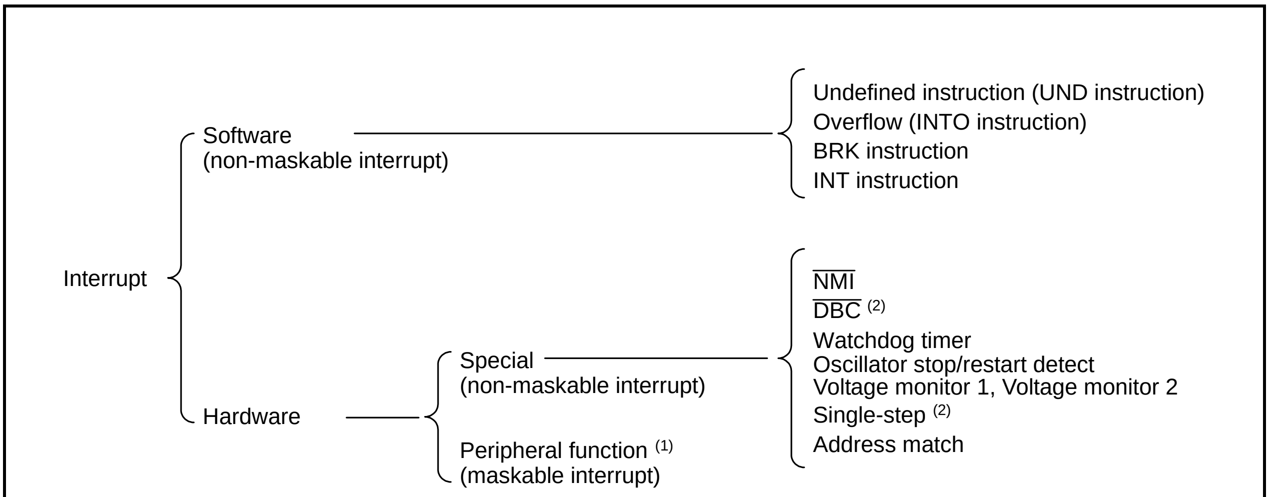
Change the NMIDF register under the following conditions:

- The PM24 bit in the PM2 register is 0 ($\overline{\text{NMI}}$ interrupt disabled)
- Bits INV02 and INV03 in the INVC0 register are 0 (three-phase motor control timer function not used, three-phase motor control timer output disabled).

Once the PM24 bit is set to 1 ($\overline{\text{NMI}}$ interrupt enabled), it cannot be set to 0 by a program. Change the NMIDF register before setting the PM24 bit to 1.

14.3 Types of Interrupts

Figure 14.1 shows Types of Interrupts.



Notes:

1. The peripheral functions in the MCU are used to generate peripheral interrupts.
2. Do not use this interrupt because it is provided exclusively for use by development tools.

Figure 14.1 Types of Interrupts

- Maskable interrupt : The I flag (interrupt enable flag) **can** enable/disable these interrupts. The interrupt priority order **can be changed** by using the interrupt priority level.
- Non-maskable interrupt : The I flag (interrupt enable flag) **cannot** enable/disable these interrupts. The interrupt priority order **cannot be changed** by using the interrupt priority level.

14.4 Software Interrupts

A software interrupt occurs when executing instructions. Software interrupts are non-maskable interrupts.

14.4.1 Undefined Instruction Interrupt

An undefined instruction interrupt occurs when executing the UND instruction.

14.4.2 Overflow Interrupt

An overflow interrupt occurs when executing the INTO instruction with the O flag in the FLG register set to 1 (the operation resulted in an overflow). The following are instructions whose O flag changes by an arithmetic operation:
ABS, ADC, ADCF, ADD, CMP, DIV, DIVU, DIVX, NEG, RMPA, SBB, SHA, and SUB

14.4.3 BRK Interrupt

A BRK interrupt occurs when the BRK instruction is executed.

14.4.4 INT Instruction Interrupt

An INT instruction interrupt occurs when the INT instruction is executed. Software interrupt numbers 0 to 63 can be specified for the INT instruction. Because software interrupt numbers 2 to 31, 41 to 51, 59, and 60 are assigned to peripheral function interrupts, the same interrupt routine used for peripheral function interrupts can be executed by executing the INT instruction.
For software interrupt numbers 0 to 31, the U flag is saved on the stack during instruction execution and is cleared to 0 (ISP selected) before executing an interrupt sequence. The U flag is restored from the stack when returning from the interrupt routine. For software interrupt numbers 32 to 63, the U flag does not change state during instruction execution, and the SP selected at the time is used.

14.5 Hardware Interrupts

Hardware interrupts are classified into two types: special interrupts and peripheral function interrupts.

14.5.1 Special Interrupts

Special interrupts are non-maskable interrupts.

14.5.1.1 $\overline{\text{NMI}}$ Interrupt

An $\overline{\text{NMI}}$ interrupt is generated when input on the $\overline{\text{NMI}}$ pin changes state from high to low. For details on the $\overline{\text{NMI}}$ interrupt, refer to 14.9 “$\overline{\text{NMI}}$ Interrupt”.

14.5.1.2 $\overline{\text{DBC}}$ Interrupt

Do not use this interrupt because it is provided exclusively for use by development tools.

14.5.1.3 Watchdog Timer Interrupt

This interrupt is generated by the watchdog timer. Once a watchdog timer interrupt is generated, be sure to refresh the watchdog timer. For details on the watchdog timer, refer to 15. “Watchdog Timer”.

14.5.1.4 Oscillator Stop/Restart Detect Interrupt

The interrupt is generated by the oscillator stop/restart detect function. For details on this function, refer to 8. “Clock Generator”.

14.5.1.5 Voltage Monitor 1, Voltage Monitor 2 Interrupt

The interrupt is generated by the voltage detector. For details on the voltage detector, refer to 7. “Voltage Detector”.

14.5.1.6 Single-Step Interrupt

Do not use this interrupt because it is provided exclusively for use by development tools.

14.5.1.7 Address Match Interrupt

When the AIER0 or AIER1 bit in the AIER register, or the AIER20 or AIER21 bit in the AIER2 register is 1 (address match interrupt enabled), an address match interrupt is generated immediately before executing an instruction at the address indicated by the corresponding registers RMAD0 to RMAD3. For details on the address match interrupt, refer to 14.11 “Address Match Interrupt”.

14.5.2 Peripheral Function Interrupts

A peripheral function interrupt occurs when a request from a peripheral function in the MCU is acknowledged. Peripheral function interrupts are maskable interrupts. See Table 14.6 and Table 14.7 “Relocatable Vector Tables”. Refer to the descriptions of each function for details on how the corresponding peripheral function interrupt is generated.

14.6 Interrupts and Interrupt Vectors

One interrupt vector consists of 4 bytes. Set the start address of each interrupt routine in the respective interrupt vectors. When an interrupt request is accepted, the CPU branches to the address set in the corresponding interrupt vector. Figure 14.2 shows an Interrupt Vector.

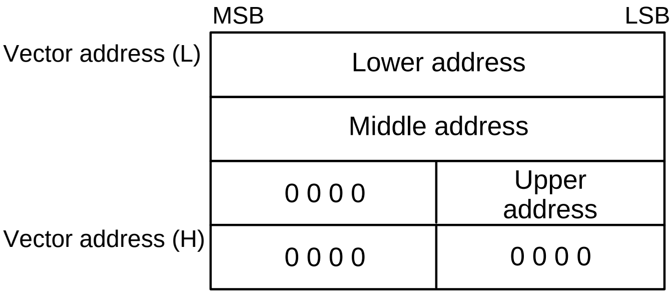


Figure 14.2 Interrupt Vector

14.6.1 Fixed Vector Tables

The fixed vector tables are allocated to addresses from FFFDCh to FFFFFh. Table 14.5 lists the Fixed Vector Tables. In the flash memory MCU version, the vector addresses (H) of fixed vectors are used for the ID code check function and OFS1 address. For details, refer to 30. “Flash Memory”.

Table 14.5 Fixed Vector Tables

Interrupt Source	Vector Table Addresses Address (L) to Address (H)	Reference
Undefined instruction (UND instruction)	FFFDCh to FFFDFh	M16C/60, M16C/20, M16C/Tiny Series Software Manual
Overflow (INTO instruction)	FFFE0h to FFFE3h	
BRK instruction [2]	FFFE4h to FFFE7h	
Address match	FFFE8h to FFFEBh	14.11 “Address Match Interrupt”
Single-step [1]	FFFECh to FFFEFh	-
Watchdog timer, oscillator stop/restart detect, voltage monitor 1, voltage monitor 2	FFFF0h to FFFF3h	15. “Watchdog Timer” 8. “Clock Generator” 7. “Voltage Detector”
$\overline{\text{DBC}}$ [1]	FFFF4h to FFFF7h	-
$\overline{\text{NMI}}$	FFFF8h to FFFFBh	14.9 “$\overline{\text{NMI}}$ Interrupt”
Reset	FFFFCh to FFFFFh	6. “Resets”

Notes:

1. Do not use this interrupt because it is provided exclusively for use by development tools.
2. If the value of address FFFE6h is FFh, program execution starts from the address shown by the vector in the relocatable vector table.

14.6.2 Relocatable Vector Tables

The 256 bytes beginning with the start address set in the INTB register compose a relocatable vector table area. Setting an even address in the INTB register results in the interrupt sequence being executed faster than setting an odd address.

Table 14.6 Relocatable Vector Tables (1/2)

Interrupt Source	Vector Address (1) Address (L) to Address (H)	Software Interrupt Number	Reference
INT instruction interrupt (5)	+0 to +3 (0000h to 0003h) to +252 to +255 (00FCh to 00FFh)	0 to 63	M16C/60, M16C/20, M16C/Tiny Series Software Manual
BRK instruction (5)	+0 to +3 (0000h to 0003h)	0	
$\overline{\text{INT7}}$	+8 to +11 (0008h to 000Bh)	2	14.8 “$\overline{\text{INT}}$ Interrupt”
$\overline{\text{INT6}}$	+12 to +15 (000Ch to 000Fh)	3	
$\overline{\text{INT3}}$	+16 to +19 (0010h to 0013h)	4	
Timer B5	+20 to +23 (0014h to 0017h)	5	18. “Timer B”
Timer B4, UART1 start/stop condition detection, bus collision detection (4)	+24 to +27 (0018h to 001Bh)	6	18. “Timer B”
Timer B3, UART0 start/stop condition detection, bus collision detection (4)	+28 to +31 (001Ch to 001Fh)	7	23. “Serial Interface UARTi (i = 0 to 2, 5 to 7)”
SI/O4, $\overline{\text{INT5}}$ (2)	+32 to +35 (0020h to 0023h)	8	14.8 “$\overline{\text{INT}}$ Interrupt” 24. “Serial Interface SI/O3 and SI/O4”
SI/O3, $\overline{\text{INT4}}$ (2)	+36 to +39 (0024h to 0027h)	9	
UART2 start/stop condition detection, bus collision detection (4)	+40 to +43 (0028h to 002Bh)	10	23. “Serial Interface UARTi (i = 0 to 2, 5 to 7)”
DMA0	+44 to +47 (002Ch to 002Fh)	11	16. “DMAC”
DMA1	+48 to +51 (0030h to 0033h)	12	
Key input interrupt	+52 to +55 (0034h to 0037h)	13	14.10 “Key Input Interrupt”
A/D converter	+56 to +59 (0038h to 003Bh)	14	27. “A/D Converter”
UART2 transmit, NACK2 (3)	+60 to +63 (003Ch to 003Fh)	15	23. “Serial Interface UARTi (i = 0 to 2, 5 to 7)”
UART2 receive, ACK2 (3)	+64 to +67 (0040h to 0043h)	16	
UART0 transmit, NACK0 (3)	+68 to +71 (0044h to 0047h)	17	
UART0 receive, ACK0 (3)	+72 to +75 (0048h to 004Bh)	18	
UART1 transmit, NACK1 (3)	+76 to +79 (004Ch to 004Fh)	19	
UART1 receive, ACK1 (3)	+80 to +83 (0050h to 0053h)	20	
Timer A0	+84 to +87 (0054h to 0057h)	21	17. “Timer A”
Timer A1	+88 to +91 (0058h to 005Bh)	22	
Timer A2	+92 to +95 (005Ch to 005Fh)	23	
Timer A3	+96 to +99 (0060h to 0063h)	24	
Timer A4	+100 to +103 (0064h to 0067h)	25	
Timer B0	+104 to +107 (0068h to 006Bh)	26	18. “Timer B”
Timer B1	+108 to +111 (006Ch to 006Fh)	27	
Timer B2	+112 to +115 (0070h to 0073h)	28	

Notes:

1. Address relative to address in INTB.
2. Use bits IFSR6 and IFSR7 in the IFSR register to select a source.
3. In I^2C mode, NACK and ACK are interrupt sources.
4. Use bits IFSR26 and IFSR27 in the IFSR2A register to select a source.
5. These interrupts cannot be disabled using the I flag.

Table 14.7 Relocatable Vector Tables (2/2)

Interrupt Source	Vector Address (1) Address (L) to Address (H)	Software Interrupt Number	Reference
$\overline{\text{INT0}}$	+116 to +119 (0074h to 0077h)	29	14.8 “$\overline{\text{INT}}$ Interrupt”
$\overline{\text{INT1}}$	+120 to +123 (0078h to 007Bh)	30	
$\overline{\text{INT2}}$	+124 to +127 (007Ch to 007Fh)	31	
DMA2	+164 to +167 (00A4h to 00A7h)	41	16. “DMAC”
DMA3	+168 to +171 (00A8h to 00ABh)	42	
UART5 start/stop condition detection, bus collision detection, CEC1 (3)	+172 to +175 (00ACh to 00AFh)	43	23. “Serial Interface UARTi (i = 0 to 2, 5 to 7)” 26. “Consumer Electronics Control (CEC) Function”
UART5 transmit, NACK5, CEC2 (2, 3)	+176 to +179 (00B0h to 00B3h)	44	
UART5 receive, ACK5 (2)	+180 to +183 (00B4h to 00B7h)	45	
UART6 start/stop condition detection, bus collision detection, real-time clock period (4)	+184 to +187 (00B8h to 00BBh)	46	20. “Real-Time Clock” 23. “Serial Interface UARTi (i = 0 to 2, 5 to 7)”
UART6 transmit, NACK6, real-time clock compare (2, 4)	+188 to +191 (00BCh to 00BFh)	47	
UART6 receive, ACK6 (2)	+192 to +195 (00C0h to 00C3h)	48	
UART7 start/stop condition detection, bus collision detection, remote control 0 (5)	+196 to +199 (00C4h to 00C7h)	49	22. “Remote Control Signal Receiver” 23. “Serial Interface UARTi (i = 0 to 2, 5 to 7)”
UART7 transmit, NACK7, remote control 1 (2, 5)	+200 to +203 (00C8h to 00CBh)	50	
UART7 receive, ACK7 (2)	+204 to +207 (00CCh to 00CFh)	51	
I^{2}C-bus interface interrupt (6)	+236 to +239 (00ECh to 00EFh)	59	25. “Multi-master I^{2}C-bus Interface”
SCL/SDA interrupt (6)	+240 to +243 (00F0h to 00F3h)	60	

Notes:

1. Address relative to address in INTB.
2. In I^{2}C mode, NACK and ACK are the interrupt sources.
3. Use bits IFSR33 and IFSR34 in the IFSR3A register to select a source.
4. Use bits IFSR35 and IFSR36 in the IFSR3A register to select a source.
5. Use bits IFSR24 and IFSR25 in the IFSR2A register to select a source.
6. Use bits IFSR22 and IFSR23 in the IFSR2A register to select a source.

14.7 Interrupt Control

14.7.1 Maskable Interrupt Control

The settings for enabling/disabling the maskable interrupts and of the acceptance priority are explained below. Note that these explanations do not apply to non-maskable interrupts.

Use the I flag in the FLG register, IPL, and bits ILVL2 to ILVL0 in the corresponding interrupt control register to enable or disable a maskable interrupt. Whether an interrupt is requested or not is indicated by the IR bit in the corresponding interrupt control register.

14.7.1.1 I Flag

The I flag enables or disables maskable interrupts. Setting the I flag to 1 (enabled) enables maskable interrupts. Setting the I flag to 0 (disabled) disables all maskable interrupts.

14.7.1.2 IR Bit

The IR bit becomes 1 (interrupt requested) when an interrupt request is generated. Then, when the interrupt request is accepted, the IR bit becomes 0 (interrupt not requested).

The IR bit can be set to 0 by a program. Do not write 1 to this bit.

14.7.1.3 Bits ILVL2 to ILVL0 and IPL

Interrupt priority levels can be selected by setting bits ILVL2 to ILVL0.

Table 14.8 lists the Settings of Interrupt Priority Levels and Table 14.9 lists the Interrupt Priority Levels Enabled by IPL.

An interrupt request is accepted under the following conditions.

- I flag = 1
- IR bit = 1
- Interrupt priority level > IPL

The I flag, IR bit, bits ILVL2 to ILVL0, and IPL are independent of each other. They do not affect one another.

Table 14.8 Settings of Interrupt Priority Levels

Bits ILVL2 to ILVL0	Interrupt Priority Level	Priority
000b	Level 0 (interrupt disabled)	-
001b	Level 1	Low
010b	Level 2	
011b	Level 3	
100b	Level 4	
101b	Level 5	
110b	Level 6	
111b	Level 7	High

Table 14.9 Interrupt Priority Levels Enabled by IPL

IPL	Enabled Interrupt Priority Levels
000b	Level 1 and above are enabled
001b	Level 2 and above are enabled
010b	Level 3 and above are enabled
011b	Level 4 and above are enabled
100b	Level 5 and above are enabled
101b	Level 6 and above are enabled
110b	Level 7 and above are enabled
111b	All maskable interrupts are disabled

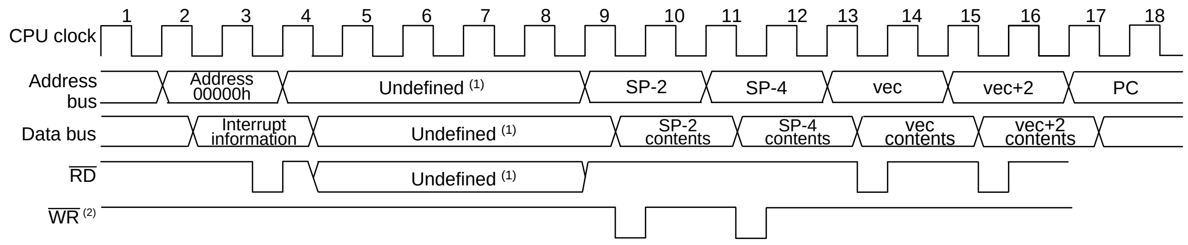
14.7.2 Interrupt Sequence

The interrupt sequence is explained here. The sequence starts when an interrupt request is accepted and ends when the interrupt routine is executed.
When an interrupt request occurs during execution of an instruction, the processor determines its priority after the execution of the instruction is completed, and transfers control to the interrupt sequence from the next cycle. However, if an interrupt occurs during execution of either the SMOVB, SMOVF, SSTR, or RMPA instruction, the processor temporarily suspends the instruction being executed, and transfers control to the interrupt sequence.
The CPU behavior during the interrupt sequence is described below. Figure 14.3 shows Time Required for Executing Interrupt Sequence.

(1) The CPU obtains interrupt information (interrupt number and interrupt request level) by reading address 00000h. Then, the IR bit applicable to the interrupt information is set to 0 (interrupt not requested).
(2) The FLG register, prior to the interrupt sequence, is saved to a temporary register [1] within the CPU.
(3) Flags I, D, and U in the FLG register are set as follows:
The I flag is set to 0 (interrupt disabled)
The D flag is set to 0 (single-step interrupt disabled).
The U flag is set to 0 (ISP selected).
Note that the U flag does not change states when an INT instruction for software interrupt numbers 32 to 63 is executed.
(4) The temporary register [1] within the CPU is saved on the stack.
(5) The PC is saved on the stack.
(6) The interrupt priority level of the acknowledged interrupt is set in the IPL.
(7) The start address of the relevant interrupt routine set in the interrupt vector is stored in the PC.

After the interrupt sequence is completed, an instruction is executed from the starting address of the interrupt routine.

Note:
1. Temporary registers cannot be modified by the user.

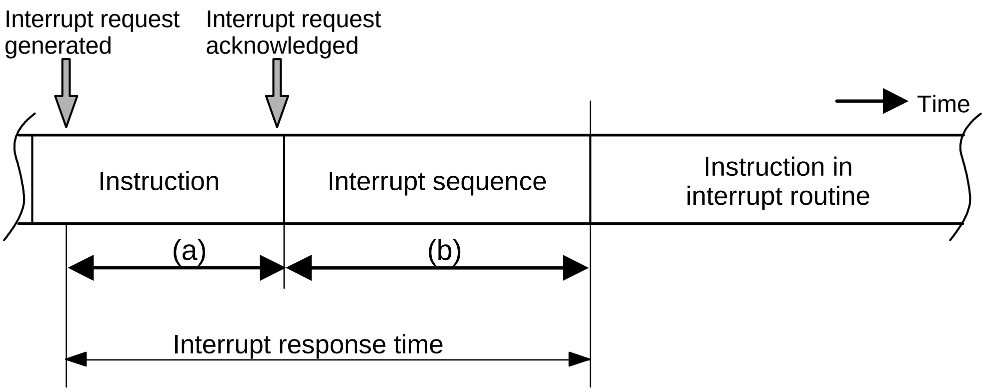


Notes:
1. The undefined state depends on the instruction queue buffer. A read cycle is generated when the instruction queue buffer is ready to prefetch.
2. The WR signal timing shown here applies when the stack is located in the internal RAM.

Figure 14.3 Time Required for Executing Interrupt Sequence

14.7.3 Interrupt Response Time

Figure 14.4 shows the Interrupt Response Time. The interrupt response or interrupt acknowledge time denotes the time from when an interrupt request is generated until the first instruction in the interrupt routine is executed. Specifically, it consists of the time from when an interrupt request is generated until the executing instruction is completed ((a) in Figure 14.4) and the time during which the interrupt sequence is executed ((b) in Figure 14.4).


Interrupt request generated
Interrupt request acknowledged
Time
Instruction
Interrupt sequence
Instruction in interrupt routine
(a)
(b)
Interrupt response time

(a) The time from when an interrupt request is generated until the instruction being executed is completed. The length of this time varies with the instruction being executed. The DIVX instruction requires the longest time, which is equal to 30 cycles (no wait state, and when the divisor is a register).

(b) The time during which the interrupt sequence is executed. For details, see the table below. Note, however, that the values in this table must be increased by two cycles for the $\overline{\mathrm{DBC}}$ interrupt and by one cycle for the address match and single-step interrupts.

Interrupt Vector Address	SP Value	16-bit Bus, No Wait States	8-bit Bus, No Wait States
Even	Even	18 cycles	20 cycles
Even	Odd	19 cycles	20 cycles
Odd	Even	19 cycles	20 cycles
Odd	Odd	20 cycles	20 cycles

Figure 14.4 Interrupt Response Time

14.7.4 Variation of IPL When Interrupt Request is Accepted

When a maskable interrupt request is accepted, the interrupt priority level of the accepted interrupt is set in the IPL.

When a software interrupt or special interrupt request is accepted, one of the interrupt priority levels listed in Table 14.10 is set in the IPL. Table 14.10 lists the IPL Level Set in IPL When Software or Special Interrupt is Accepted.

Table 14.10 IPL Level Set in IPL When Software or Special Interrupt is Accepted

Interrupt Source	Level Set in IPL
Watchdog timer, $\overline{\mathrm{NMI}}$, oscillator stop/restart detect, voltage monitor 1, voltage monitor 2	7
Software, address match, $\overline{\mathrm{DBC}}$, single-step	Not changed

14.7.5 Saving Registers

In the interrupt sequence, the FLG register and PC are saved on the stack.

At this time, the 4 upper bits of the PC and the 4 upper (IPL) and 8 lower bits in the FLG register, 16 bits in total, are saved on the stack first. Next, the 16 lower bits of the PC are saved. Figure 14.5 shows the Stack Status Before and After Acceptance of Interrupt Request.

The other necessary registers must be saved by a program at the beginning of the interrupt routine. Use the PUSHM instruction, and all registers except SP can be saved with a single instruction.

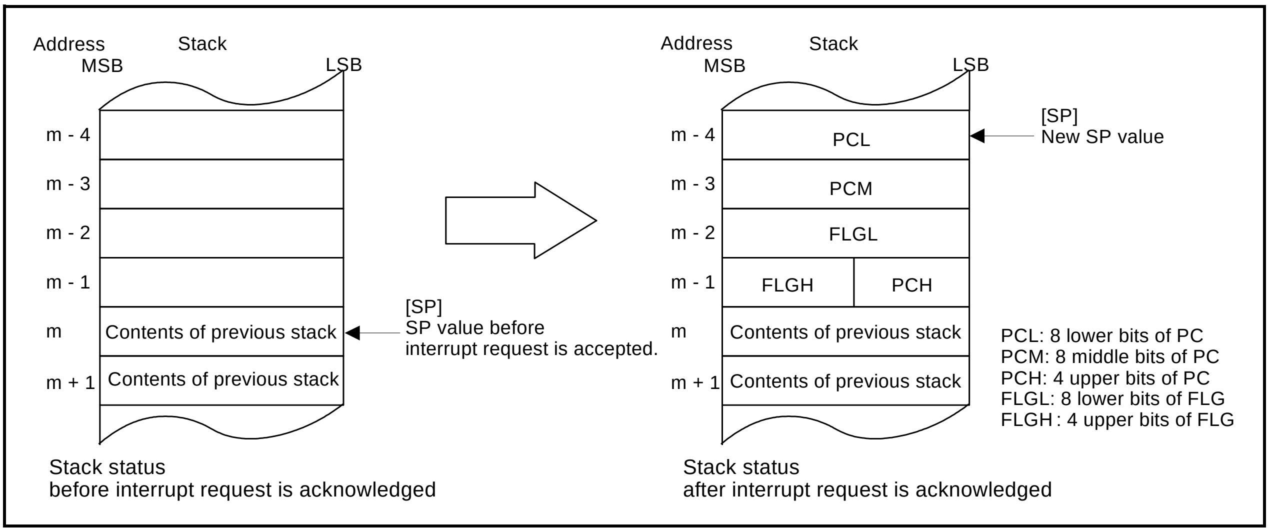
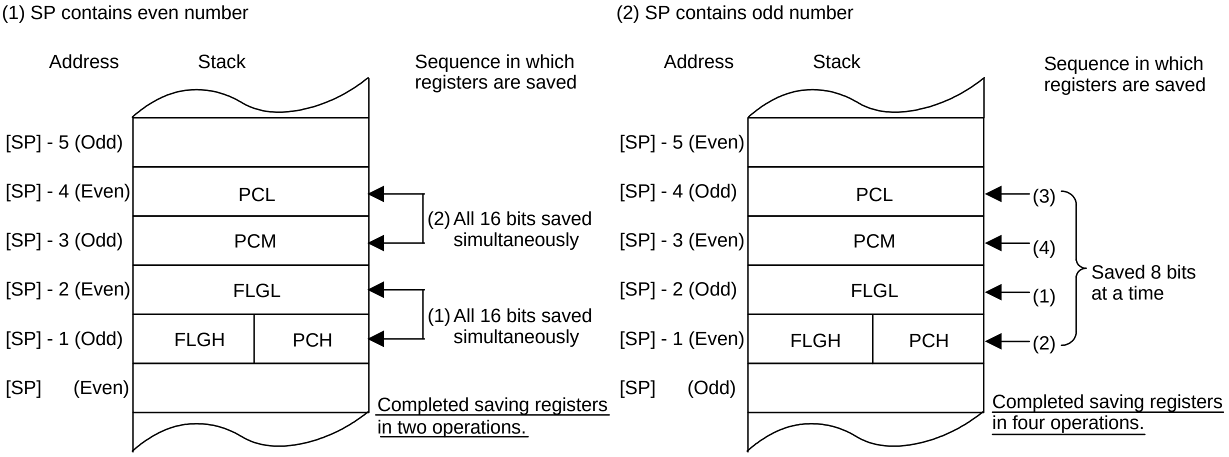

Address
Stack
MSB
LSB
m - 4
m - 3
m - 2
m - 1
m
m + 1
Contents of previous stack
Contents of previous stack
[SP]
SP value before
interrupt request is accepted.
Stack status
before interrupt request is acknowledged
Address
Stack
MSB
LSB
m - 4
m - 3
m - 2
m - 1
m
m + 1
PCL
PCM
FLGL
FLGH
PCH
Contents of previous stack
Contents of previous stack
[SP]
New SP value
PCL: 8 lower bits of PC
PCM: 8 middle bits of PC
PCH: 4 upper bits of PC
FLGL: 8 lower bits of FLG
FLGH : 4 upper bits of FLG
Stack status
after interrupt request is acknowledged

Figure 14.5 Stack Status Before and After Acceptance of Interrupt Request

The register save operation carried out in the interrupt sequence is dependent on whether the SP (1), at the time of acceptance of an interrupt request, is even or odd. If the SP (1) is even, the FLG register and the PC are saved 16 bits at a time. If odd, they are saved in two steps, 8 bits at a time. Figure 14.6 shows the Register Save Operation.

Note:

1. When an INT instruction with software numbers 32 to 63 has been executed, it is the SP indicated by the U flag. Otherwise, it is the ISP.



PCL: 8 lower bits of PC
PCM: 8 middle bits of PC
PCH: 4 upper bits of PC
FLGL : 8 lower bits of FLG
FLGH: 4 upper bits of FLG

Note:

1. [SP] denotes the initial value of the SP when an interrupt request is acknowledged. After registers are saved, the SP content is [SP] minus 4.

Figure 14.6 Register Save Operation

14.7.6 Returning from an Interrupt Routine

The FLG register and PC saved in the stack immediately before entering the interrupt sequence are restored from the stack by executing the REIT instruction at the end of the interrupt routine. Then, the CPU returns to the program which was being executed before the interrupt request was accepted.

Restore the other registers saved by a program within the interrupt routine using the POPM or a similar instruction before executing the REIT instruction.

The register bank is switched back to the bank used prior to the interrupt sequence by the REIT instruction.

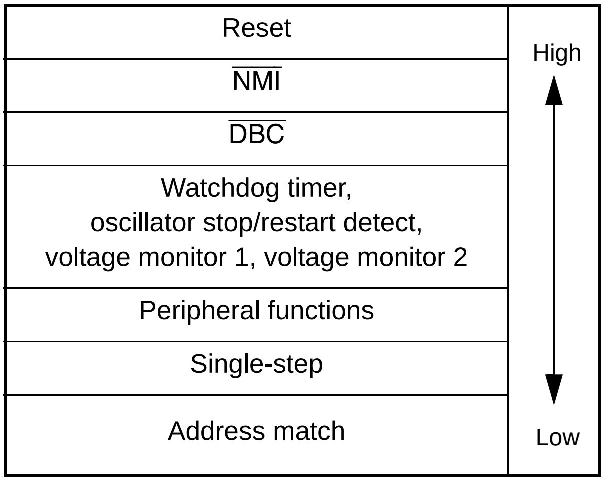
14.7.7 Interrupt Priority

If two or more interrupt requests occur at the same sampling points (the point in time at which interrupt requests are detected), the interrupt with the highest priority is acknowledged.

For maskable interrupts (peripheral function interrupts), any priority level can be selected using bits ILVL2 to ILVL0. However, if two or more maskable interrupts have the same priority level, their interrupt priority is selected by hardware, with the highest priority interrupt accepted.

The watchdog timer interrupt and other special interrupts have their priority levels set in hardware. Figure 14.7 shows the Hardware Interrupt Priority.

Software interrupts are not affected by the interrupt priority. When an instruction is executed, control always branches to the interrupt routine.



Reset

$\overline{\text{NMI}}$

$\overline{\text{DBC}}$

Watchdog timer,
oscillator stop/restart detect,
voltage monitor 1, voltage monitor 2

Peripheral functions

Single-step

Address match

Figure 14.7 Hardware Interrupt Priority

14.7.8 Interrupt Priority Level Select Circuit

The interrupt priority level select circuit selects the highest priority interrupt among sampled interrupt requests at the same sampling point.

Figure 14.8 shows the Interrupt Priority Select Circuit 1, and Figure 14.9 shows the Interrupt Priority Select Circuit 2.

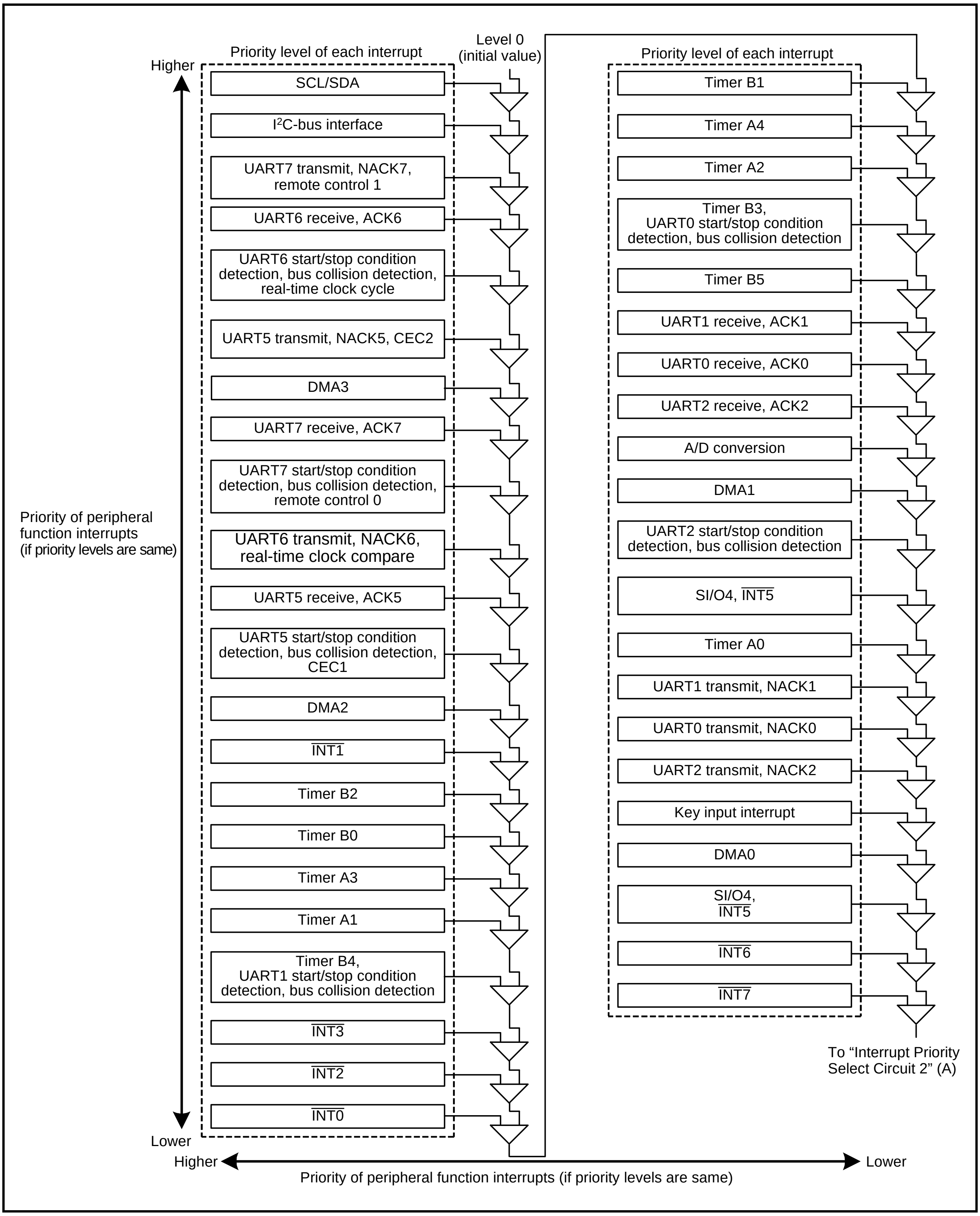


Figure 14.8 Interrupt Priority Select Circuit 1

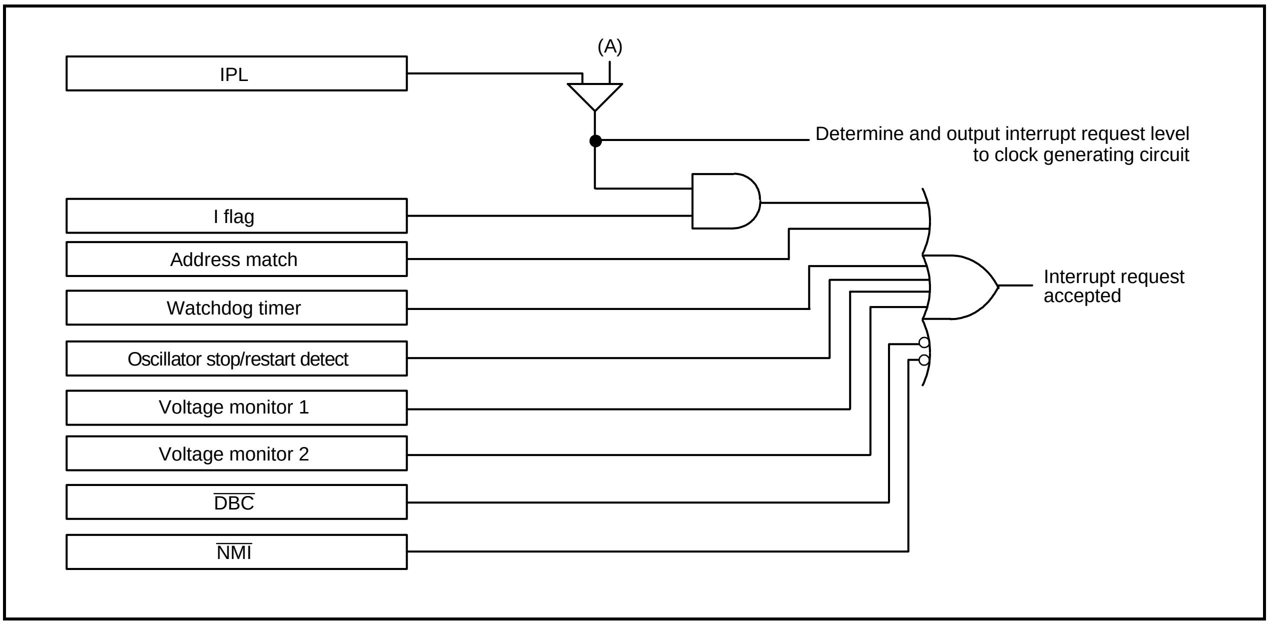


Figure 14.9 Interrupt Priority Select Circuit 2

14.7.9 Multiple Interrupts

The following shows the internal bit states when control has branched to an interrupt routine.

- I flag = 0 (interrupt disabled)
- IR bit = 0 (interrupt not requested)
- Interrupt priority level = IPL

By setting the I flag to 1 (interrupt enabled) in the interrupt routine, an interrupt request with higher priority than the IPL can be acknowledged.

The interrupt requests not acknowledged because of their low interrupt priority level are kept pending. When the IPL is restored by the REIT instruction and interrupt priority is resolved against it, the pending interrupt request is acknowledged if the following condition is met:

Interrupt priority level of pending interrupt request > Restored IPL

14.8 $\overline{\text{INT}}$ Interrupt

The $\overline{\text{INTi}}$ interrupt (i = 0 to 7) is triggered by the edges of external inputs. The edge polarity is selected using the IFSRi bit in the IFSR register, or the IFSR30 or IFSR31 bit in the IFSR3A register.

$\overline{\text{INT4}}$ and $\overline{\text{INT5}}$ each share an interrupt vector and interrupt control register with SI/O3 and SI/O4, respectively. To use the $\overline{\text{INT4}}$ interrupt, set the IFSR6 bit in the IFSR register to 1 ($\overline{\text{INT4}}$). To use the $\overline{\text{INT5}}$ interrupt, set the IFSR7 bit in the IFSR register to 1 ($\overline{\text{INT5}}$).

After modifying the IFSR6 or IFSR7 bit, set the corresponding IR bit to 0 (interrupt not requested) before enabling the interrupt.

To use the $\overline{\text{INT6}}$ interrupt, set the PCR5 bit in the PCR register to 0 ($\overline{\text{INT6}}$ input enabled). To use the $\overline{\text{INT7}}$ interrupt, set the PCR6 bit in the PCR register to 0 ($\overline{\text{INT7}}$ input enabled).

14.9 $\overline{\text{NMI}}$ Interrupt

An $\overline{\text{NMI}}$ interrupt is generated when input to the $\overline{\text{NMI}}$ pin changes state from high to low. The $\overline{\text{NMI}}$ interrupt is a non-maskable interrupt. To use the $\overline{\text{NMI}}$ interrupt, set the PM24 bit in the PM2 register to 1 ($\overline{\text{NMI}}$ interrupt enabled). The $\overline{\text{NMI}}$ input uses the digital filter. Refer to 13. "Programmable I/O Ports" for the digital filter. Figure 14.10 shows $\overline{\text{NMI}}$ Interrupt Block Diagram.

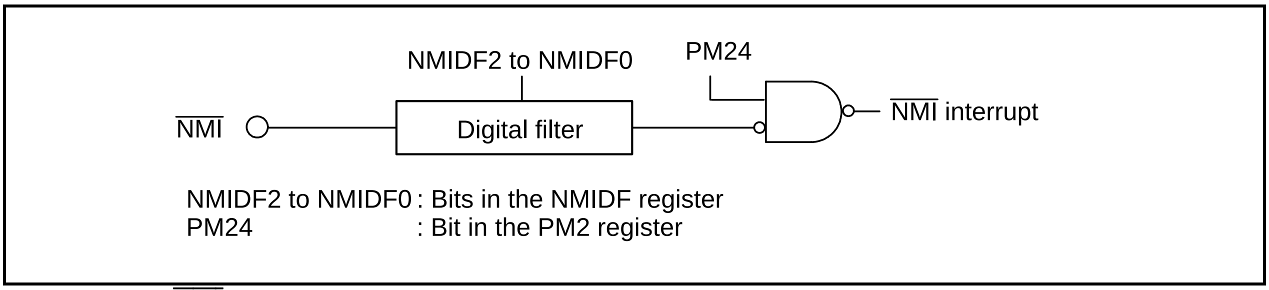

NMIDF2 to NMIDF0
PM24
$\overline{\text{NMI}}$
Digital filter
$\overline{\text{NMI}}$ interrupt
NMIDF2 to NMIDF0 : Bits in the NMIDF register
PM24 : Bit in the PM2 register

Figure 14.10 $\overline{\text{NMI}}$ Interrupt Block Diagram

14.10 Key Input Interrupt

If the PCR7 bit in the PCR register is 0 ($\overline{\text{KI0}}$ to $\overline{\text{KI3}}$ key input enabled), when input to any pin from P10_4 to P10_7 becomes low where the corresponding PD10_4 to PD10_7 bit in the PD10 register is 0 (input), the IR bit in the KUPIC register becomes 1 (key input interrupt request). When using any pin from $\overline{\text{KI0}}$ to $\overline{\text{KI3}}$ for the key input interrupt, do not use all four pins AN4 to AN7 as analog input pins. While input to any pin from P10_4 to P10_7 is low, inputs to all other pins of the port are not detected as interrupts.

Key input interrupts can be used as a key-on wake up function for getting the MCU out of wait or stop mode.

Figure 14.11 shows Block Diagram of Key Input Interrupt.

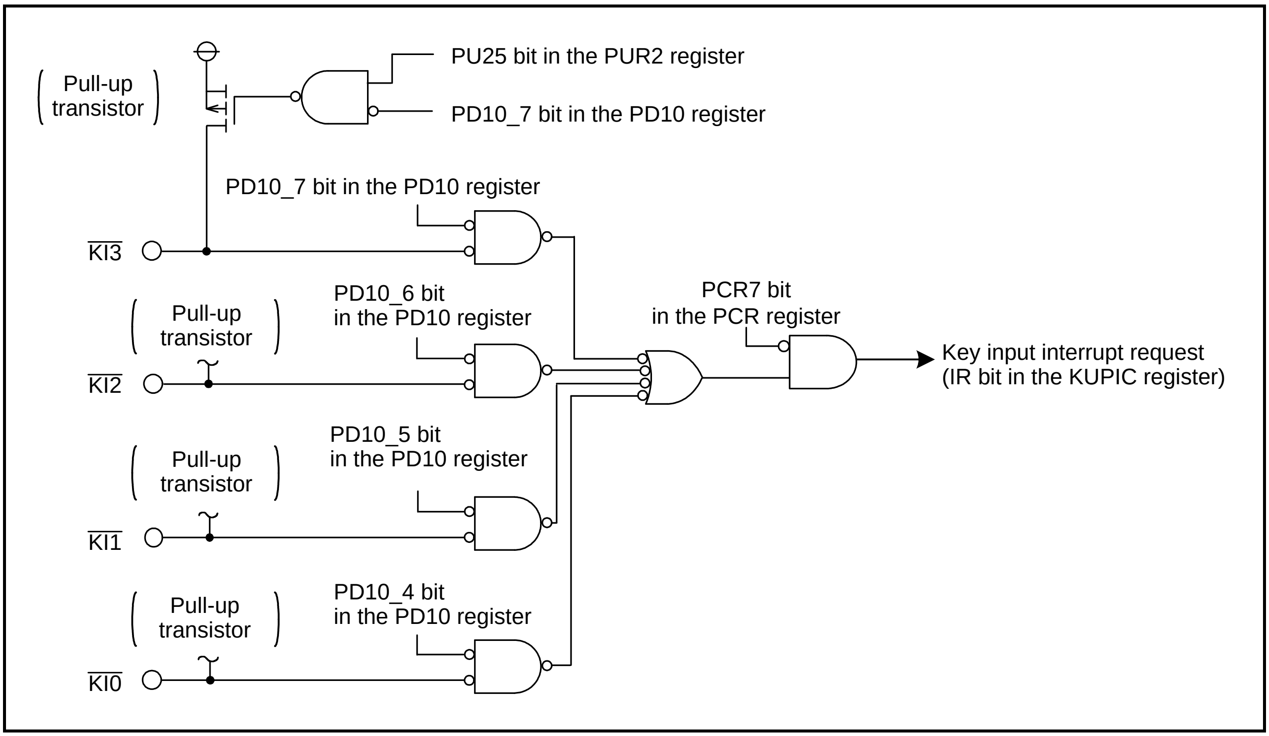

Pull-up transistor
PU25 bit in the PUR2 register
PD10_7 bit in the PD10 register
PD10_7 bit in the PD10 register
$\overline{\text{KI3}}$
Pull-up transistor
PD10_6 bit in the PD10 register
PCR7 bit in the PCR register
Key input interrupt request (IR bit in the KUPIC register)
$\overline{\text{KI2}}$
Pull-up transistor
PD10_5 bit in the PD10 register
$\overline{\text{KI1}}$
Pull-up transistor
PD10_4 bit in the PD10 register
$\overline{\text{KI0}}$

Figure 14.11 Block Diagram of Key Input Interrupt

14.11 Address Match Interrupt

An address match interrupt is generated immediately before executing the instruction at the address indicated by the RMADi register (i = 0 to 3). Set the start address of any instruction in the RMADi register. Use bits AIER0 and AIER1 in the AIER register, and bits AIER20 and AIER21 in the AIER2 register to enable or disable the interrupt. Note that the address match interrupt is unaffected by the I flag and IPL. When an address match interrupt request is acknowledged, the value of the PC that is saved to the stack area (refer to 14.7.5 “Saving Registers”) varies depending on the instruction at the address indicated by the RMADi register. (The value of the PC that is saved to the stack area is not the correct return address.) Therefore, use one of the following methods to return from the address match interrupt:

- Rewrite the values of the stack and then use the REIT instruction to return.
- Restore the stack to its previous state by using the POP or similar instructions before the interrupt request was accepted and then use a jump instruction to return.

Table 14.11 Value of PC Saved on Stack Area When Address Match Interrupt Request Accepted

Instruction at the Address Indicated by the RMADi Register	Value of the PC That Is Saved to the Stack Area
• 16-bit operation code instructions • Instruction shown below among 8-bit operation code instructions ADD.B:S #IMM8, dest SUB.B:S #IMM8, dest AND.B:S #IMM8, dest OR.B:S #IMM8, dest MOV.B:S #IMM8, dest STZ #IMM8, dest STNZ #IMM8, dest STZX #IMM81, #IMM82,dest CMP.B:S #IMM8, dest PUSHM src POPM dest JMPS #IMM8 JSRS #IMM8 MOV.B:S #IMM, dest (however, dest = A0 or A1)	The address indicated by the RMADi register +2
Instructions not listed above	The address indicated by the RMADi register +1

Refer to 14.7.5 “Saving Registers” for PC values saved to the stack area.

Table 14.12 Relationship between Address Match Interrupt Sources and Associated Registers

Address Match Interrupt Sources	Address Match Interrupt Enable Bit	Address Match Interrupt Register
Address match interrupt 0	AIER0	RMAD0
Address match interrupt 1	AIER1	RMAD1
Address match interrupt 2	AIER20	RMAD2
Address match interrupt 3	AIER21	RMAD3

14.12 Non-Maskable Interrupt Source Discrimination

The watchdog timer interrupt, oscillator stop/restart detect interrupt, voltage monitor 1 interrupt, and voltage monitor 2 interrupt share the same interrupt vector. When using some functions together, read the detect flags of the events in an interrupt processing program, and determine the source of the interrupt. Table 14.13 lists Bits Used for Non-Maskable Interrupt Source Discrimination.

Table 14.13 Bits Used for Non-Maskable Interrupt Source Discrimination

Interrupt	Detect Flag	
	Bit Position	Function
Watchdog timer	VW2C3 bit in the VW2C register (watchdog timer underflow detected)	0: Not detected 1: Detected
Oscillator stop/restart detect	CM22 bit in the CM2 register (oscillator stop/restart detected)	
Voltage monitor 1	VW1C2 bit in the VW1C register (Vdet1 passage detected)	
Voltage monitor 2	VW2C2 bit in the VW2C register (Vdet2 passage detected)	

14.13 Notes on Interrupts

14.13.1 Reading Address 00000h

Do not read address 00000h by a program. When a maskable interrupt request is accepted, the CPU reads interrupt information (interrupt number and interrupt request priority level) from address 00000h during the interrupt sequence. At this time, the IR bit of the accepted interrupt is cleared to 0 (interrupt not requested).

If address 00000h is read by a program, the IR bit for the interrupt which has the highest priority among the enabled interrupts becomes 0. This may cause problems such as interrupts being canceled or an unexpected interrupt request being generated.

14.13.2 SP Setting

Set a value in the SP (USP, ISP) before accepting an interrupt. The SP (USP, ISP) is set to 0000h after reset. Therefore, if an interrupt is accepted before setting a value in the SP (USP, ISP), the program may go out of control.

Set a value in the ISP at the beginning of the program. For the first instruction after reset only, all interrupts are disabled.

14.13.3 $\overline{\text{NMI}}$ Interrupt

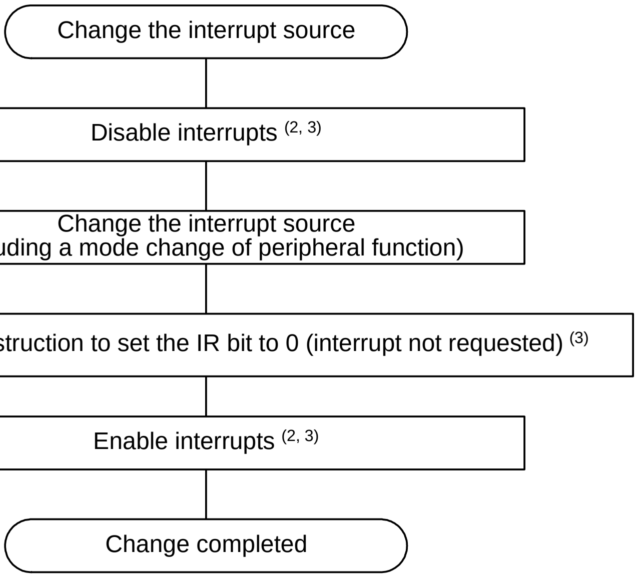
- When not using the $\overline{\text{NMI}}$ interrupt, set the PM24 bit in the PM2 register to 0 ($\overline{\text{NMI}}$ interrupt disabled).
- The $\overline{\text{NMI}}$ interrupt is disabled after reset. The $\overline{\text{NMI}}$ interrupt is enabled by setting the PM24 bit in the PM2 register to 1. Set the PM24 bit to 1 when a high-level signal is applied to the $\overline{\text{NMI}}$ pin. When the PM24 bit is set to 1 while a low-level signal is applied, an $\overline{\text{NMI}}$ interrupt is generated. Once the $\overline{\text{NMI}}$ interrupt is enabled, it cannot be disabled until the MCU is reset.
- The MCU cannot enter stop mode while the PM24 bit is 1 ($\overline{\text{NMI}}$ interrupt enabled) and input on the $\overline{\text{NMI}}$ pin is low. When input on the $\overline{\text{NMI}}$ pin is low, the CM10 bit in the CM1 register is fixed to 0.
- Do not enter wait mode while the PM24 bit is 1 ($\overline{\text{NMI}}$ interrupt enabled) and a low signal is input to the $\overline{\text{NMI}}$ pin. When the $\overline{\text{NMI}}$ pin is driven low, the CPU clock remains active even though the CPU stops, and therefore, the current consumption of the chip does not drop. In this case, the normal condition is restored by the next interrupt generation.
- Set the low- and high-level durations of the input signal to the $\overline{\text{NMI}}$ pin to 2 CPU clock cycles + 300 ns or more.

14.13.4 Changing an Interrupt Source

When the interrupt source is changed, the IR bit in the interrupt control register may become 1 (interrupt requested). To use an interrupt, change the interrupt source, and then set the IR bit to 0 (interrupt not requested).

In this section, the changing of an interrupt source refers to all elements used in changing the interrupt source, polarity, and timing assigned to each software interrupt number. Therefore, if a mode change of any peripheral function involves changing the source, polarity or timing of an interrupt, be sure to clear the IR bit for that interrupt to 0 (interrupt not requested) after making such changes. Refer to the descriptions of the individual peripheral functions for details of the interrupts.

Figure 14.12 shows the Procedure for Changing the Interrupt Generate Source.


Change the interrupt source
Disable interrupts (2, 3)
Change the interrupt source
(including a mode change of peripheral function)
Use the MOV instruction to set the IR bit to 0 (interrupt not requested) (3)
Enable interrupts (2, 3)
Change completed

IR bit: A bit in the interrupt control register

Notes:

1. Execute the above settings individually. Do not use one instruction to execute two or more settings simultaneously.
2. Use the I flag for the $\overline{\text{INTi}}$ interrupt (i = 0 to 7).
   For the interrupts from peripheral functions other than the $\overline{\text{INTi}}$ interrupt, disable the peripheral function that is the source of the interrupt so as not to generate an interrupt request before changing the interrupt source. In this case, if the maskable interrupts can all be disabled without causing a problem, use the I flag. Otherwise, use corresponding bits ILVL2 to ILVL0 in the interrupt control register whose interrupt source is to be changed.
3. Refer to 14.13.5 “Rewriting the Interrupt Control Register” for details about the instructions to be used and the notes to be taken for instruction execution.

Figure 14.12 Procedure for Changing the Interrupt Generate Source

14.13.5 Rewriting the Interrupt Control Register

To modify the interrupt control register, follow either of the procedures below:

- Modify in places where no interrupt requests corresponding to the interrupt control register may occur.
- If an interrupt request can be generated, disable that interrupt and then rewrite the interrupt control register.

When using the I flag to disable an interrupt, set the I flag as shown in the sample program code below. (Refer to 14.13.6 “Instruction to Rewrite the Interrupt Control Register” for rewriting the interrupt control registers using the sample program code.)

Examples 1 through 3 show how to prevent the I flag from becoming 1 (interrupt enabled) before the contents of the interrupt control register is rewritten, owing to the effects of the internal bus and the instruction queue buffer.

Example 1: Using the NOP instruction to pause the program until the interrupt control register is modified

```
INT_SWITCH1:
    FCLR      I                   ; Disable interrupts.
    AND.B     #00H, 0055H         ; Set the TA0IC register to 00h.
    NOP                           ;
    NOP
    FSET      I                   ; Enable interrupts.
```

Example 2: Using a dummy read to delay the FSET instruction

```
INT_SWITCH2:
    FCLR      I                   ; Disable interrupts.
    AND.B     #00H, 0055H         ; Set the TA0IC register to 00h.
    MOV.W     MEM, R0             ; Dummy read.
    FSET      I                   ; Enable interrupts.
```

Example 3: Using the POPC instruction to change the I flag

```
INT_SWITCH3:
    PUSHC     FLG
    FCLR      I                   ; Disable interrupts.
    AND.B     #00H, 0055H         ; Set the TA0IC register to 00h.
    POPC      FLG                 ; Enable interrupts.
```

14.13.6 Instruction to Rewrite the Interrupt Control Register

- Do not use the BTSTC and BTSTS instructions to rewrite the interrupt control registers.
- Use the AND, OR, BCLR, BSET, or MOV instruction to rewrite interrupt control registers.
  When an interrupt request is generated for the register being rewritten while executing an AND, OR, BCLR, or BSET instruction, the IR bit becomes 1 (interrupt requested) and remains 1.

14.13.7 $\overline{\text{INT}}$ Interrupt

- Either a low level of at least tw(INL) width or a high level of at least tw(INH) width is necessary for the signal input to pins $\overline{\text{INT0}}$ through $\overline{\text{INT7}}$, regardless of the CPU operation clock.
- If the POL bit in registers INT0IC to INT7IC, bits IFSR7 to IFSR0 in the IFSR register, or bits IFSR31 to IFSR30 in the IFSR3A register are changed, the IR bit may inadvertently become 1 (interrupt requested). Be sure to set the IR bit to 0 (interrupt not requested) after changing any of these register bits.

15. Watchdog Timer

15.1 Introduction

The watchdog timer contains a 15-bit counter, and the count source protection mode (enabled/disabled) can be set.

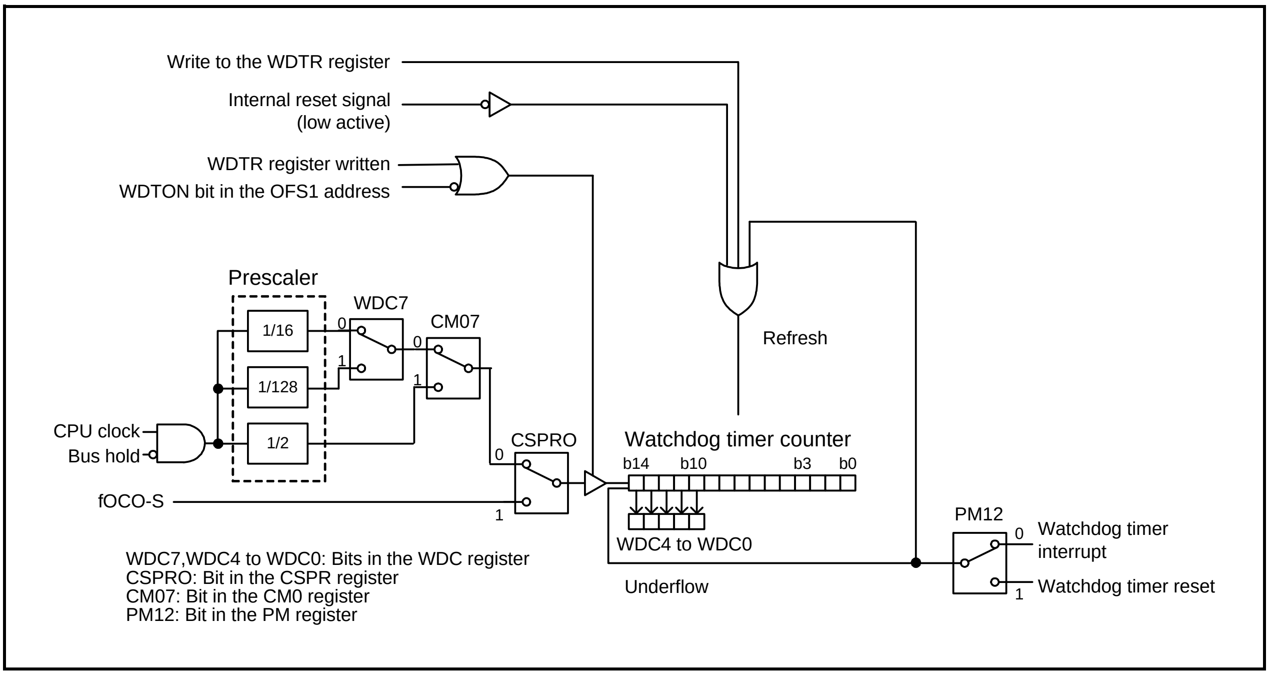
Table 15.1 lists Watchdog Timer Specifications.

Refer to 6.4.8 “Watchdog Timer Reset” for details of watchdog timer reset.

Figure 15.1 shows Watchdog Timer Block Diagram.

Table 15.1 Watchdog Timer Specifications

Item	Count Source Protection Mode Disabled	Count Source Protection Mode Enabled
Count source	CPU clock	fOCO-S
Count operation	Decrement	
Count start conditions	Either of the following can be selected (selected by the WDTON bit in the OFS1 address) • Count automatically starts after reset. • Count starts by writing to the WDTS register.	
Count stop condition	Stop mode, wait mode, bus hold	None
Watchdog timer counter refresh timing	• Reset (refer to 6. “Resets”) • Write 00h, and then FFh to the WDTR register. • Underflow	
Operation when the timer underflows	Watchdog timer interrupt or watchdog timer reset	Watchdog timer reset
Selectable functions	• Prescaler divide ratio Divide-by-16 or divide-by-128 (selected by the WDC7 bit in the WDC register) However, divide-by-2 is selected when the CM07 bit in the CM0 register is 1 (sub clock). • Count source protection mode Enabled or disabled (selected by the CSPROINI bit in the OFS1 address and the CSPRO bit in the CSPR register)	



WDC7,WDC4 to WDC0: Bits in the WDC register
CSPRO: Bit in the CSPR register
CM07: Bit in the CM0 register
PM12: Bit in the PM register

Figure 15.1 Watchdog Timer Block Diagram

15.2 Registers

Table 15.2 Registers

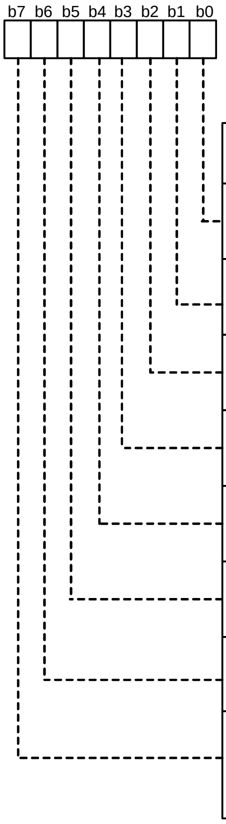
Address	Register	Symbol	Reset Value
002Ch	Voltage Monitor 2 Control Register	VW2C	1000 0X10b
037Ch	Count Source Protection Mode Register	CSPR	00h [1]
037Dh	Watchdog Timer Refresh Register	WDTR	XXh
037Eh	Watchdog Timer Start Register	WDTS	XXh
037Fh	Watchdog Timer Control Register	WDC	00XX XXXXb

Note:

1. When the CSPROINI bit in the OFS1 address is 0, the reset value becomes 1000 0000b.

15.2.1 Voltage Monitor 2 Control Register (VW2C)

Voltage Monitor 2 Control Register



Symbol VW2C Address 002Ch Reset Value 1000 0X10b

Bit Symbol	Bit Name	Function	RW
VW2C0	Voltage monitor 2 interrupt/ reset enable bit	0 : Disabled 1 : Enabled	RW
VW2C1	Voltage monitor 2 digital filter disable mode select bit	0 : Digital filter enabled 1 : Digital filter disabled	RW
VW2C2	Voltage change detection flag	0 : Not detected 1 : Vdet2 passage detected	RW
VW2C3	Watchdog timer detection flag	0 : Not detected 1 : Watchdog timer underflow detected	RW
VW2F0	Sampling clock select bit	b5 b4 0 0 : fOCO-S divided by 1 0 1 : fOCO-S divided by 2 1 0 : fOCO-S divided by 4 1 1 : fOCO-S divided by 8	RW
VW2F1			
VW2C6	Voltage monitor 2 mode select bit	0 : Voltage monitor 2 interrupt at Vdet2 passage 1 : Voltage monitor 2 reset at Vdet2 passage	RW
VW2C7	Voltage monitor 2 interrupt/ reset generation condition select bit	0: When VCC1 reaches or goes above Vdet2 1: When VCC1 reaches or goes below Vdet2	RW

Set the PRC3 bit in the PRCR register to 1 (write enabled) before rewriting the VW2C register.

Bits VW2C2 and VW2C3 do not change at voltage monitor 1 reset, voltage monitor 2 reset, oscillator stop detect reset, watchdog timer reset, or software reset.
When rewriting the VW2C register (excluding the VW2C3 bit), the VW2C2 bit may become 1. Set the VW2C2 bit to 0 after rewriting the VW2C register.

VW2C3 (WDT detection flag) (b3)

Use this bit in an interrupt routine to determine the source of the interrupts from the watchdog timer, the oscillator stop/restart detect, the voltage monitor 1, and the voltage monitor 2.

Condition to become 0:

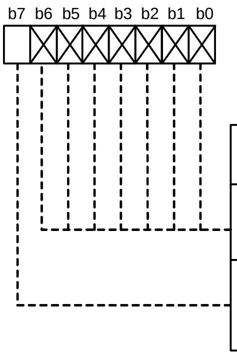
- Writing 0 by a program

Condition to become 1:

- Watchdog timer underflow detected
  (This flag remains unchanged even if 1 is written by a program.)

15.2.2 Count Source Protection Mode Register (CSPR)

Count Source Protection Mode Register



Symbol	Address	Reset Value
CSPR	037Ch	0000 0000b (when the CSPROINI bit in the OFS1 address is 1) 1000 0000b (when the CSPROINI bit in the OFS1 address is 0)

Bit Symbol	Bit Name	Function	RW
— (b6-b0)	No register bits. If necessary, set to 0. The read value is 0.		—
CSPRO	Count source protection mode select bit	0 : Count source protection mode disabled 1 : Count source protection mode enabled	RW

CSPRO (Count source protection mode select bit) (b7)

Select the CSPRO bit before the watchdog timer starts counting. Once counting starts, do not change the CSPRO bit.

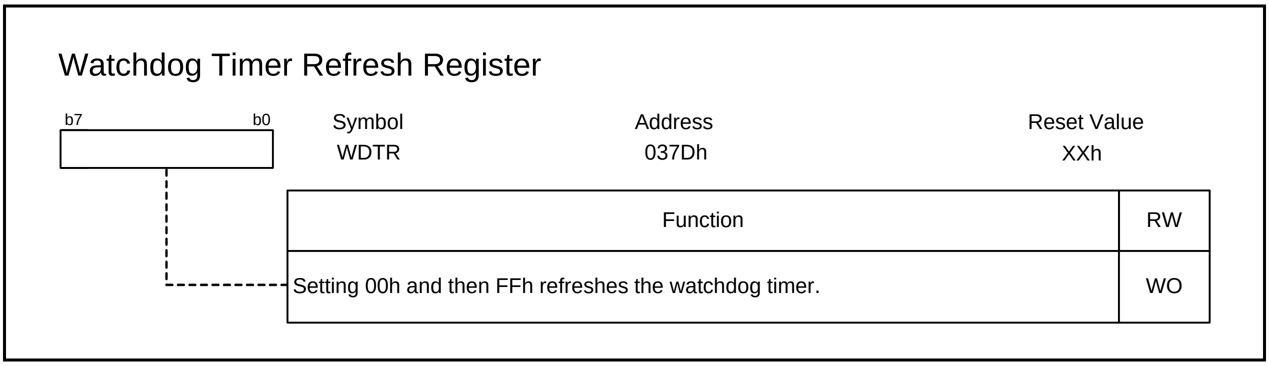
Condition to become 0:

- Reset when the CSPROINI bit in the OFS1 address is 1.
  (This flag remains unchanged even if 0 is written by a program.)

Conditions to become 1:

- When the CSPROINI bit in the OFS1 address is 0
- Write 0, and then write 1.
  Make sure no interrupts or DMA transfers occur between setting the bit to 0 and setting it to 1.

15.2.3 Watchdog Timer Refresh Register (WDTR)



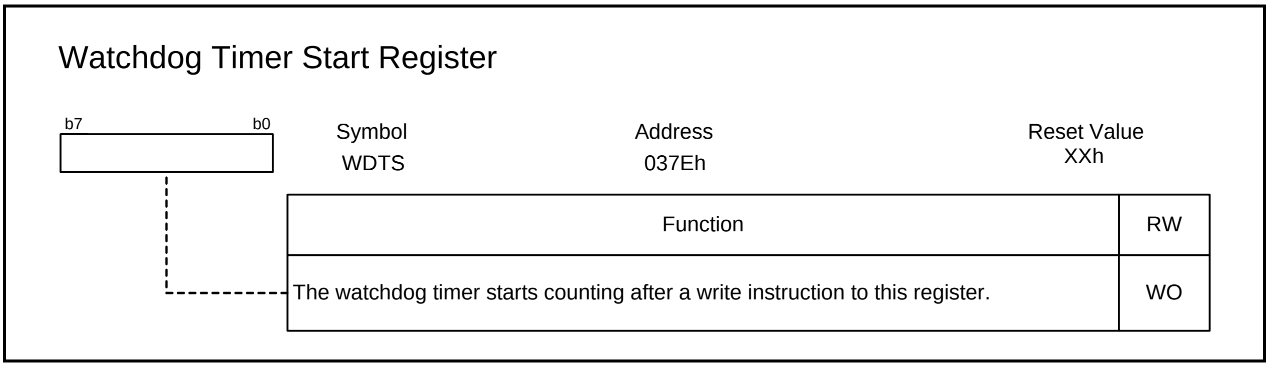
Watchdog Timer Refresh Register

Symbol	Address	Reset Value
WDTR	037Dh	XXh

Function	RW
Setting 00h and then FFh refreshes the watchdog timer.	WO

After the watchdog timer interrupt occurs, refresh the watchdog timer by setting the WDTR register.

15.2.4 Watchdog Timer Start Register (WDTS)



Watchdog Timer Start Register

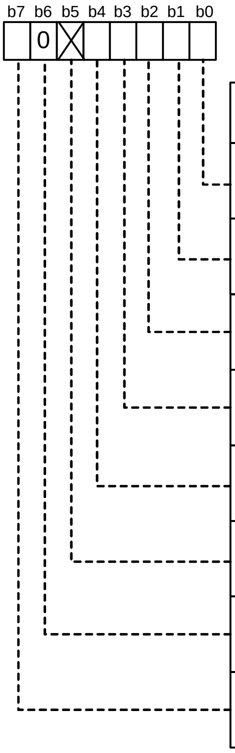
Symbol	Address	Reset Value
WDTS	037Eh	XXh

Function	RW
The watchdog timer starts counting after a write instruction to this register.	WO

The WDTS register is enabled when the WDTON bit in the OFS1 address is 1 (watchdog timer is in a stopped state after reset).

15.2.5 Watchdog Timer Control Register (WDC)

Watchdog Timer Control Register



Symbol	Address	Reset Value
WDC	037Fh	00XX XXXXb

Bit Symbol	Bit Name	Function	RW
WDC0	Higher-order bits (b14 to b10) of the watchdog timer can be read		RO
WDC1			RO
WDC2			RO
WDC3			RO
WDC4			RO
— (b5)	No register bit. If necessary, set to 0. The read value is undefined.		—
— (b6)	Reserved bit	Set to 0	RW
WDC7	Prescaler select bit	0 : Divide-by-16 1 : Divide-by-128	RW

WDC4-WDC0 (b4-b0)

When reading the watchdog timer value while the CSPRO bit in the CSPR register is 1 (count source protection mode enabled), read bits WDC4 to WDC0 more than three times to determine the values.

15.3 Optional Function Select Area

In the optional function select area, the MCU state after reset and the function to prevent rewrite in parallel I/O mode are selected.

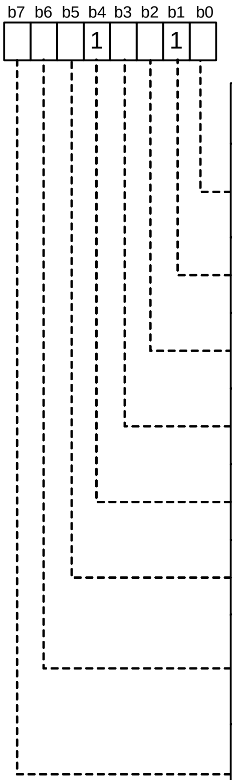
The optional function select area is not an SFR, and therefore cannot be rewritten by a program. Set an appropriate value when writing a program to flash memory. The entire optional function select area becomes FFh when the block including the optional function select area is erased.

In blank products, the OFS1 address value is FFh when shipped. After a value is written by the user, this register takes on the written value. In programmed products, the OFS1 address is the value set in the user program prior to shipping.

Selection using the optional function select area can be used in single-chip mode or memory expansion mode. The option function select area cannot be used in microprocessor mode. When using the MCU in microprocessor mode, clear the internal ROM.

15.3.1 Optional Function Select Address 1 (OFS1)

Optional Function Select Address 1



Symbol OFS1

Address FFFFFh

Bit Symbol	Bit Name	Function
WDTON	Watchdog timer start select bit	0 : Watchdog timer starts automatically after reset 1 : Watchdog timer is stopped after reset
— (b1)	Reserved bit	Set to 1.
ROMCR	ROM code protect cancel bit	0 : ROM code protection cancelled 1 : ROMCP1 bit enabled
ROMCP1	ROM code protect bit	0 : ROM code protection enabled 1 : ROM code protection disabled
— (b4)	Reserved bit	Set to 1.
VDSEL1	Vdet0 select bit 1	0 : Vdet0_2 1 : Vdet0_0
LVDAS	Voltage detector 0 start bit	0 : Voltage monitor 0 reset enabled after hardware reset 1 : Voltage monitor 0 reset disabled after hardware reset
CSPROINI	After-reset count source protection mode select bit	0 : Count source protection mode enabled after reset 1 : Count source protection mode disabled after reset

WDTON (Watchdog timer start select bit) (b0)

CSPROINI (After-reset count source protection mode select bit) (b7)

Set the WDTON bit to 0 (watchdog timer starts automatically after reset) when setting the CSPROINI bit to 0 (count source protection mode enabled after reset).

15.4 Operations

15.4.1 Count Source Protection Mode Disabled

The CPU clock is used as the watchdog timer count source when count source protection mode is disabled.

Table 15.3 lists Watchdog Timer Specifications (Count Source Protection Mode Disabled).

Table 15.3 Watchdog Timer Specifications (Count Source Protection Mode Disabled)

Item	Specification
Count source	CPU clock
Count operation	Decrement
Cycles	When the CM07 bit in the CM0 register is 0 (main clock, PLL clock, fOCO-F, fOCO-S): $\frac{\text{Prescaler divide value (n)} \times \text{watchdog timer count value (32768)}}{\text{CPU clock}}$ (1) n: 16 or 128 (selected by the WDC7 bit in the WDC register) Example: When CPU clock frequency is 16 MHz and the prescaler division rate is 16, the watchdog timer cycle is approximately 32.8 ms. When the CM07 bit is 1 (sub clock): $\frac{\text{Prescaler divide value (2)} \times \text{watchdog timer count value (32768)}}{\text{CPU clock}}$ (1)
Watchdog timer counter refresh timing	• Reset (refer to 6. “Resets”) • Write 00h, and then FFh to the WDTR register. • Underflow
Count start conditions	Set the WDTON bit in the OFS1 address to select the watchdog timer operation after reset. • WDTON bit is 1 (watchdog timer is in stop state after reset) The watchdog timer counter and prescaler stop after reset and count starts by writing to the WDTS register. • WDTON bit is 0 (watchdog timer starts automatically after reset) The watchdog timer counter and prescaler start counting automatically after reset.
Count stop conditions	• Stop mode • Wait mode • Bus hold (Count resumes from the hold value after exiting.)
Operation when timer underflows	• PM12 bit in the PM1 register is 0 Watchdog timer interrupt • PM12 bit in the PM1 register is 1 Watchdog timer reset (Refer to 6.4.8 “Watchdog Timer Reset”.)

Note:

1. When writing 00h and then FFh to the WDTR register, the watchdog timer is refreshed, but the prescaler is not initialized. Thus, some errors in the watchdog timer period may be caused by the prescaler. The prescaler is initialized after reset.

15.4.2 Count Source Protection Mode Enabled

fOCO-S is used as the watchdog timer count source when the count source protection mode is enabled.

Table 15.4 lists the Watchdog Timer Specifications (Count Source Protection Mode Enabled).

Table 15.4 Watchdog Timer Specifications (Count Source Protection Mode Enabled)

Item	Specification
Count source	fOCO-S (The 125 kHz on-chip oscillator clock automatically starts oscillating.)
Count operation	Decrement
Cycle	$\frac{\text{Watchdog timer count value (4096)}}{\text{fOCO-S}}$ (The watchdog timer cycle is approximately 32.8 ms.)
Watchdog timer counter refresh timing	• Reset (refer to 6. “Resets”) • Write 00h, then FFh to the WDTR register. • Underflow
Count start conditions	Set the WDTON bit in the OFS1 address to select the watchdog timer operation after reset. • WDTON bit is 1 (watchdog timer is stopped after reset) The watchdog timer counter and prescaler stop after reset and count starts by writing to the WDTS register. • WDTON bit is 0 (watchdog timer starts automatically after reset) The watchdog timer counter and prescaler start counting automatically after reset.
Count stop condition	None (The count does not stop in wait mode or by bus hold once started. The MCU does not enter stop mode.)
Operation when timer underflows	Watchdog timer reset (refer to 6.4.8 “Watchdog Timer Reset”).

When the CSPRO bit in the CSPR register is 1 (count source protection mode enabled), the watchdog timer counter underflows every 4096 cycles because the 3 low-order bits are not used.

Also when the CSPRO bit is set to 1 (count source protection mode enabled), the following bits change:

- The CM14 bit in the CM1 register becomes 0 (125 kHz on-chip oscillator on). It remains unchanged even if 1 is written, and the 125 kHz on-chip oscillator does not stop.
- The PM12 bit in the PM1 register becomes 1 (watchdog timer reset when watchdog timer counter underflows).
- The CM10 bit in the CM1 register remains unchanged even if 1 is written, and the MCU does not enter stop mode.

15.5 Interrupts

Watchdog timer interrupts are non-maskable interrupts.

The watchdog timer interrupt, oscillator stop/restart detect interrupt, voltage monitor 1 interrupt, and voltage monitor 2 interrupt share an vector. When using multiple functions, read the detect flag in an interrupt process program to determine the source of the interrupt.

The VW2C3 bit in the VW2C register is the detect flag for the watchdog timer. After the interrupt factor is determined, set the VW2C3 bit to 0 (not detected) by a program.

15.6 Notes on the Watchdog Timer

After the watchdog timer interrupt is generated, use the WDTR register to refresh the watchdog timer counter.

16. DMAC

16.1 Introduction

The direct memory access controller (DMAC) allows data to be transferred without CPU intervention. There are four DMAC channels. Each time a DMA request occurs, the DMAC transfers one (8- or 16-bit) unit of data from the source address to the destination address. The DMAC uses the same data bus used by the CPU. Because the DMAC has higher priority for bus control than the CPU, and because it makes use of a cycle steal method, it can transfer 1 word (16 bits) or 1 byte (8 bits) of data within a very short time after a DMA request is generated. Table 16.1 lists DMAC Specifications, and Figure 16.1 shows the DMAC Block Diagram.

Table 16.1 DMAC Specifications

Item		Specification
Number of channels		4 (cycle steal method)
Transfer memory spaces		• From a given address in a 1 MB space to a fixed address • From a fixed address to a given address in a 1 MB space • From a fixed address to a fixed address
Maximum number of bytes transferred		128 KB (with 16-bit transfers) or 64 KB (with 8-bit transfers)
DMA request sources [(1)]		43 sources Falling edge of $\overline{\text{INT0}}$ to $\overline{\text{INT7}}$ (8) Both edge of $\overline{\text{INT0}}$ to $\overline{\text{INT7}}$ (8) Timer A0 to timer A4 interrupt request (5) Timer B0 to timer B5 interrupt request (6) UART0 to UART2, UART5 to 7 transmission interrupt request (6) UART0 to UART2, UART5 to 7 reception/ACK interrupt request (6) SI/O3, SI/O4 interrupt request (2) A/D conversion interrupt request (1) Software trigger (1)
Channel priority		DMA0 > DMA1 > DMA2 > DMA3 (DMA0 takes precedence)
Transfers		8 bits or 16 bits
Transfer address direction		Forward or fixed (The source and destination addresses cannot both be in the forward direction.)
Transfer mode	Single transfer	Transfer is completed when the DMAi transfer counter underflows.
	Repeat transfer	When the DMAi transfer counter underflows, it is reloaded with the value of the DMAi transfer counter reload register, and DMA transfer continues.
DMA interrupt request generation timing		When the DMAi transfer counter underflows
DMA transfer start		Data transfer is initiated each time a DMA request is generated when the DMAE bit in the DMiCON register is 1 (enabled).
DMA transfer stop	Single transfer	• When the DMAE bit is set to 0 (disabled) • After the DMAi transfer counter underflows
	Repeat transfer	When the DMAE bit is set to 0 (disabled)
Reload timing for forward address pointer and DMAi transfer counter		When a data transfer is started after setting the DMAE bit to 1 (enabled), the forward address pointer is reloaded with the value of the SARi or DARi register (whichever is specified to be in the forward direction), and the DMAi transfer counter is reloaded with the value of the DMAi transfer counter reload register.
DMA transfer cycles		Minimum 3 cycles between SFR and internal RAM

i = 0 to 3

Note:

1. The selectable sources of DMA requests differ for each channel.

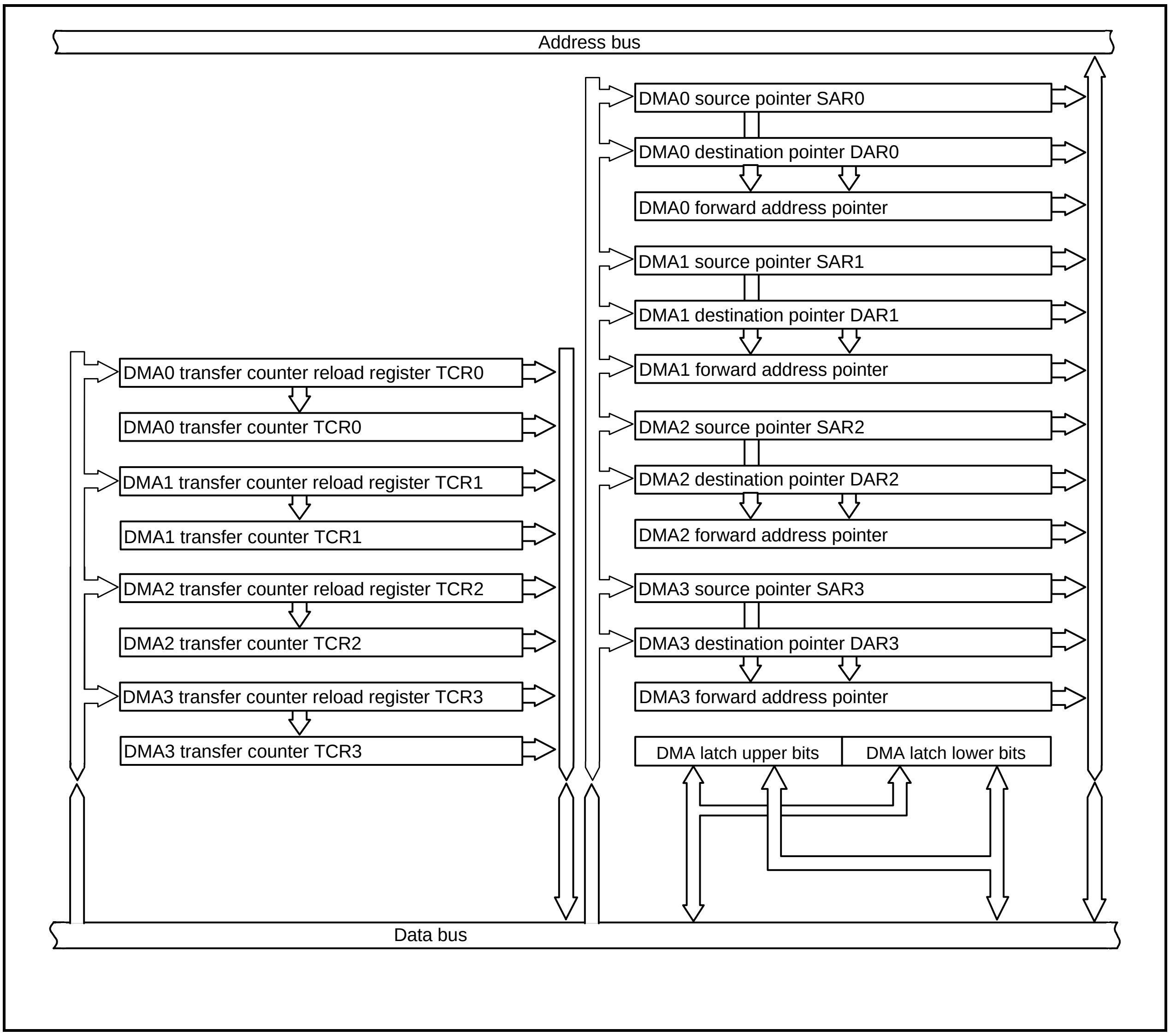

Address bus
DMA0 source pointer SAR0
DMA0 destination pointer DAR0
DMA0 forward address pointer
DMA1 source pointer SAR1
DMA1 destination pointer DAR1
DMA1 forward address pointer
DMA2 source pointer SAR2
DMA2 destination pointer DAR2
DMA2 forward address pointer
DMA3 source pointer SAR3
DMA3 destination pointer DAR3
DMA3 forward address pointer
DMA0 transfer counter reload register TCR0
DMA0 transfer counter TCR0
DMA1 transfer counter reload register TCR1
DMA1 transfer counter TCR1
DMA2 transfer counter reload register TCR2
DMA2 transfer counter TCR2
DMA3 transfer counter reload register TCR3
DMA3 transfer counter TCR3
DMA latch upper bits
DMA latch lower bits
Data bus

Figure 16.1 DMAC Block Diagram

16.2 Registers

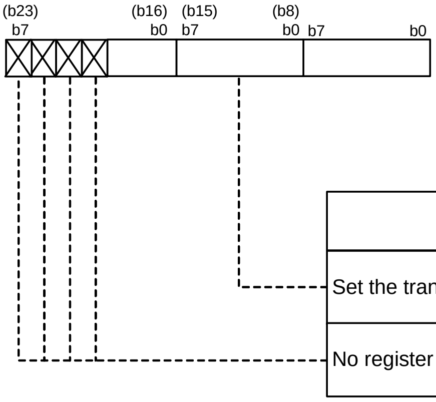
Table 16.2 lists Registers. Do not access these registers using the DMAC.

Table 16.2 Registers

Address	Register	Symbol	Reset Value
0180h	DMA0 Source Pointer	SAR0	XXh
0181h			XXh
0182h			0Xh
0184h	DMA0 Destination Pointer	DAR0	XXh
0185h			XXh
0186h			0Xh
0188h	DMA0 Transfer Counter	TCR0	XXh
0189h			XXh
018Ch	DMA0 Control Register	DM0CON	0000 0X00b
0190h	DMA1 Source Pointer	SAR1	XXh
0191h			XXh
0192h			0Xh
0194h	DMA1 Destination Pointer	DAR1	XXh
0195h			XXh
0196h			0Xh
0198h	DMA1 Transfer Counter	TCR1	XXh
0199h			XXh
019Ch	DMA1 Control Register	DM1CON	0000 0X00b
01A0h	DMA2 Source Pointer	SAR2	XXh
01A1h			XXh
01A2h			0Xh
01A4h	DMA2 Destination Pointer	DAR2	XXh
01A5h			XXh
01A6h			0Xh
01A8h	DMA2 Transfer Counter	TCR2	XXh
01A9h			XXh
01ACh	DMA2 Control Register	DM2CON	0000 0X00b
01B0h	DMA3 Source Pointer	SAR3	XXh
01B1h			XXh
01B2h			0Xh
01B4h	DMA3 Destination Pointer	DAR3	XXh
01B5h			XXh
01B6h			0Xh
01B8h	DMA3 Transfer Counter	TCR3	XXh
01B9h			XXh
01BCh	DMA3 Control Register	DM3CON	0000 0X00b
0390h	DMA2 Source Select Register	DM2SL	00h
0392h	DMA3 Source Select Register	DM3SL	00h
0398h	DMA0 Source Select Register	DM0SL	00h
039Ah	DMA1 Source Select Register	DM1SL	00h

16.2.1 DMAi Source Pointer (SARi) (i = 0 to 3)

DMAi Source Pointer (i = 0 to 3)



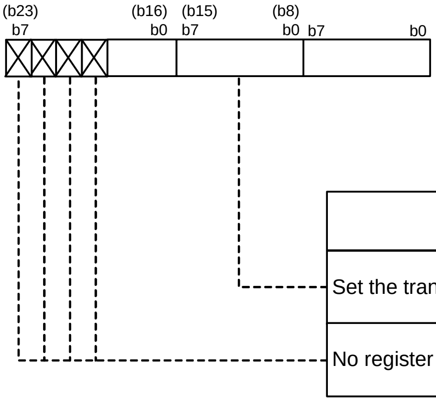
Symbol	Address	Reset Value
SAR0	0182h to 0180h	0X XXXXh
SAR1	0192h to 0190h	0X XXXXh
SAR2	01A2h to 01A0h	0X XXXXh
SAR3	01B2h to 01B0h	0X XXXXh

Function	Setting Range	RW
Set the transfer source	00000h to FFFFFh	RW
No register bits. If necessary, set to 0. The read value is 0		—

If the DSD bit in the DMiCON register is 0 (fixed), write to SARi register when the DMAE bit in the DMiCON register is 0 (DMA disabled).
If the DSD bit is 1 (forward direction), this register can be written to at any time.
If the DSD bit is 1 and the DMAE bit is 1 (DMA enabled), the DMAi forward address pointer can be read from this register. Otherwise, the value written to it can be read.
The forward address pointer increments when a DMA request is accepted.

16.2.2 DMAi Destination Pointer (DARi) (i = 0 to 3)

DMAi Destination Pointer (i = 0 to 3)



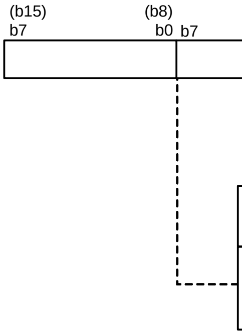
Symbol	Address	Reset Value
DAR0	0186h to 0184h	0X XXXXh
DAR1	0196h to 0194h	0X XXXXh
DAR2	01A6h to 01A4h	0X XXXXh
DAR3	01B6h to 01B4h	0X XXXXh

Function	Setting Range	RW
Set the transfer destination address	00000h to FFFFFh	RW
No register bits. If necessary, set to 0. The read value is 0		—

If the DAD bit in the DMiCON register is 0 (fixed), write to the DARi register when the DMAE bit in the DMiCON register is 0 (DMA disabled).
If the DAD bit is 1 (forward direction), this register can be written to at any time.
If the DAD bit is 1 and the DMAE bit is 1 (DMA enabled), the DMAi forward address pointer can be read from this register. Otherwise, the value written to it can be read.
The forward address pointer increments when a DMA request is accepted.

16.2.3 DMAi Transfer Counter (TCRi) (i = 0 to 3)

DMAi Transfer Counter (i = 0 to 3)



Symbol	Address	Reset Value
TCR0	0189h to 0188h	Undefined
TCR1	0199h to 0198h	Undefined
TCR2	01A9h to 01A8h	Undefined
TCR3	01B9h to 01B8h	Undefined

Function	Setting Range	RW
Set the number of transfers minus 1.	0000h to FFFFh	RW

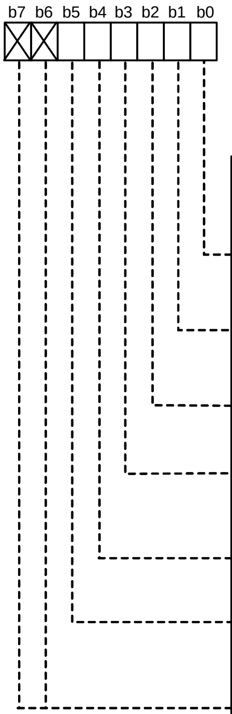
The value written in the TCRi register is stored in the DMAi transfer counter reload register.

The DMAi transfer counter reload register value is transferred to the DMAi transfer counter in either of the following cases:

- The DMAE bit in the DMiCON register is set to 1 (DMA enabled) (single transfer mode, repeat transfer mode).
- The DMAi transfer counter underflows (repeat transfer mode).

16.2.4 DMAi Control Register (DMiCON) (i = 0 to 3)

DMAi Control Register (i = 0 to 3)



Symbol	Address	Reset Value
DM0CON	018Ch	0000 0X00b
DM1CON	019Ch	0000 0X00b
DM2CON	01ACh	0000 0X00b
DM3CON	01BCh	0000 0X00b

Bit Symbol	Bit Name	Function	RW
DMBIT	Transfer unit bit select bit	0 : 16 bits 1 : 8 bits	RW
DMASL	Repeat transfer mode select bit	0 : Single transfer 1 : Repeat transfer	RW
DMAS	DMA request bit	0 : DMA not requested 1 : DMA requested	RW
DMAE	DMA enable bit	0 : DMA disabled 1 : DMA enabled	RW
DSD	Source address direction select bit	0 : Fixed 1 : Forward	RW
DAD	Destination address direction select bit	0 : Fixed 1 : Forward	RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is 0		—

DMAS (DMA request bit) (b2)

Conditions to become 0:

- Set the bit to 0.
- Start data transfer

Condition to become 1:

- Set the bit to 1.

DMAE (DMA enable bit) (b3)

Conditions to become 0:

- Set the bit to 0.
- The DMA transfer counter underflows (single transfer mode).

Condition to become 1:

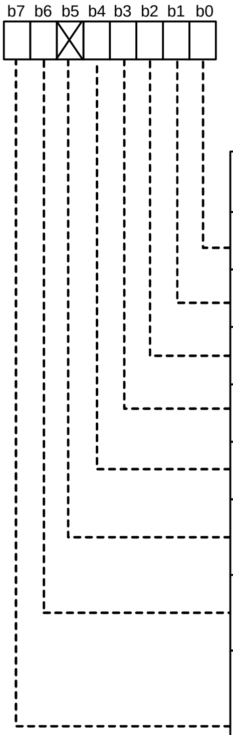
- Set the bit to 1.

DSD (Source address direction select bit) (b4)
DAD (Destination address direction select bit) (b5)

Set the DAD bit and/or DSD bit to 0 (address direction fixed).

16.2.5 DMAi Source Select Register (DMiSL) (i = 0 to 3)

DMAi Source Select Register (i = 0 to 3)



Symbol	Address	Reset Value
DM0SL	0398h	00h
DM1SL	039Ah	00h
DM2SL	0390h	00h
DM3SL	0392h	00h

Bit Symbol	Bit Name	Function	RW
DSEL0	DMA request source select bit	See the bit explanation below.	RW
DSEL1			RW
DSEL2			RW
DSEL3			RW
DSEL4			RW
— (b5)	No register bit. If necessary, set to 0. The read value is undefined.		—
DMS	DMA request source expansion select bit	0: Basic request source 1: Extended request source	RW
DSR	Software DMA request bit	A DMA request is generated by setting this bit to 1 when the DMS bit is 0 (basic source) and bits DSEL4 to DSEL0 are 00001b (software trigger). The read value is 0.	RW

DSEL4-DSEL0 (DMA request source select bit) (b4-b0)

The DMAi request sources can be selected by a combination of the DMS bit and bits DSEL4 to DSEL0 in the manner shown in Table 16.3 to Table 16.6. These tables list the DMAi request sources.

Table 16.3 Sources of DMA Request (DMA0)

DSEL4 to DSEL0	DMS is 0 (Basic Source of Request)	DMS is 1 (Expanded Source of Request)
0 0 0 0 0 b	Falling edge of the INT0 pin	–
0 0 0 0 1 b	Software trigger	–
0 0 0 1 0 b	Timer A0	–
0 0 0 1 1 b	Timer A1	–
0 0 1 0 0 b	Timer A2	–
0 0 1 0 1 b	Timer A3	–
0 0 1 1 0 b	Timer A4	Both edges of the $\overline{\text{INT0}}$ pin
0 0 1 1 1 b	Timer B0	Timer B3
0 1 0 0 0 b	Timer B1	Timer B4
0 1 0 0 1 b	Timer B2	Timer B5
0 1 0 1 0 b	UART0 transmission	–
0 1 0 1 1 b	UART0 reception	–
0 1 1 0 0 b	UART2 transmission	–
0 1 1 0 1 b	UART2 reception	–
0 1 1 1 0 b	A/D converter	–
0 1 1 1 1 b	UART1 transmission	–
1 0 0 0 0 b	UART1 reception	Falling edge of the $\overline{\text{INT4}}$ pin
1 0 0 0 1 b	UART5 transmission	Both edges of the $\overline{\text{INT4}}$ pin
1 0 0 1 0 b	UART5 reception	–
1 0 0 1 1 b	UART6 transmission	–
1 0 1 0 0 b	UART6 reception	–
1 0 1 0 1 b	UART7 transmission	–
1 0 1 1 0 b	UART7 reception	–
1 0 1 1 1 b	–	–
1 1 X X X b	–	–

X: 0 or 1 –: Do not set.

Table 16.4 Source of DMA Request (DMA1)

DSEL4 to DSEL0	DMS = 0 (Basic Source of Request)	DMS = 1 (Expanded Source of Request)
0 0 0 0 0 b	Falling edge of the $\overline{\text{INT1}}$ pin	–
0 0 0 0 1 b	Software trigger	–
0 0 0 1 0 b	Timer A0	–
0 0 0 1 1 b	Timer A1	–
0 0 1 0 0 b	Timer A2	–
0 0 1 0 1 b	Timer A3	SI/O3
0 0 1 1 0 b	Timer A4	SI/O4
0 0 1 1 1 b	Timer B0	Both edges of the $\overline{\text{INT1}}$ pin
0 1 0 0 0 b	Timer B1	–
0 1 0 0 1 b	Timer B2	–
0 1 0 1 0 b	UART0 transmission	–
0 1 0 1 1 b	UART0 reception/ACK0	–
0 1 1 0 0 b	UART2 transmission	–
0 1 1 0 1 b	UART2 reception/ACK2	–
0 1 1 1 0 b	A/D converter	–
0 1 1 1 1 b	UART1 reception/ACK1	–
1 0 0 0 0 b	UART1 transmission	Falling edge of the $\overline{\text{INT5}}$ pin
1 0 0 0 1 b	UART5 transmission	Both edges of the $\overline{\text{INT5}}$ pin
1 0 0 1 0 b	UART5 reception/ACK5	–
1 0 0 1 1 b	UART6 transmission	–
1 0 1 0 0 b	UART6 reception/ACK6	–
1 0 1 0 1 b	UART7 transmission	–
1 0 1 1 0 b	UART7 reception/ACK7	–
1 0 1 1 1 b	–	–
1 1 X X X b	–	–

X: 0 or 1 – Do not set.

Table 16.5 Sources of DMA Request (DMA2)

DSEL4 to DSEL0	DMS is 0 (Basic Source of Request)	DMS is 1 (Expanded Source of Request)
0 0 0 0 0 b	Falling edge of the $\overline{\text{INT2}}$ pin	–
0 0 0 0 1 b	Software trigger	–
0 0 0 1 0 b	Timer A0	–
0 0 0 1 1 b	Timer A1	–
0 0 1 0 0 b	Timer A2	–
0 0 1 0 1 b	Timer A3	–
0 0 1 1 0 b	Timer A4	Both edges of the $\overline{\text{INT2}}$ pin
0 0 1 1 1 b	Timer B0	Timer B3
0 1 0 0 0 b	Timer B1	Timer B4
0 1 0 0 1 b	Timer B2	Timer B5
0 1 0 1 0 b	UART0 transmission	–
0 1 0 1 1 b	UART0 reception	–
0 1 1 0 0 b	UART2 transmission	–
0 1 1 0 1 b	UART2 reception	–
0 1 1 1 0 b	A/D converter	–
0 1 1 1 1 b	UART1 transmission	–
1 0 0 0 0 b	UART1 reception	Falling edge of the $\overline{\text{INT6}}$ pin
1 0 0 0 1 b	UART5 transmission	Both edges of the $\overline{\text{INT6}}$ pin
1 0 0 1 0 b	UART5 reception	–
1 0 0 1 1 b	UART6 transmission	–
1 0 1 0 0 b	UART6 reception	–
1 0 1 0 1 b	UART7 transmission	–
1 0 1 1 0 b	UART7 reception	–
1 0 1 1 1 b	–	–
1 1 X X X b	–	–

X: 0 or 1 – Do not set.

Table 16.6 Source of DMA Request (DMA3)

DSEL4 to DSEL0	DMS is 0 (Basic Source of Request)	DMS is 1 (Expanded Source of Request)
0 0 0 0 0 b	Falling edge of the $\overline{\text{INT3}}$ pin	–
0 0 0 0 1 b	Software trigger	–
0 0 0 1 0 b	Timer A0	–
0 0 0 1 1 b	Timer A1	–
0 0 1 0 0 b	Timer A2	–
0 0 1 0 1 b	Timer A3	SI/O3
0 0 1 1 0 b	Timer A4	SI/O4
0 0 1 1 1 b	Timer B0	Both edges of the $\overline{\text{INT3}}$ pin
0 1 0 0 0 b	Timer B1	–
0 1 0 0 1 b	Timer B2	–
0 1 0 1 0 b	UART0 transmission	–
0 1 0 1 1 b	UART0 reception/ACK0	–
0 1 1 0 0 b	UART2 transmission	–
0 1 1 0 1 b	UART2 reception/ACK2	–
0 1 1 1 0 b	A/D converter	–
0 1 1 1 1 b	UART1 reception/ACK1	–
1 0 0 0 0 b	UART1 transmission	Falling edge of the $\overline{\text{INT7}}$ pin
1 0 0 0 1 b	UART5 transmission	Both edges of the $\overline{\text{INT7}}$ pin
1 0 0 1 0 b	UART5 reception/ACK5	–
1 0 0 1 1 b	UART6 transmission	–
1 0 1 0 0 b	UART6 reception/ACK6	–
1 0 1 0 1 b	UART7 transmission	–
1 0 1 1 0 b	UART7 reception/ACK7	–
1 0 1 1 1 b	–	–
1 1 X X X b	–	–

X: 0 or 1 – Do not set.

16.3 Operations

16.3.1 DMA Enabled

When data transfer starts after setting the DMAE bit in the DMiCON register to 1 (enabled), the DMAC operates as listed below (i = 0 to 3). If 1 is written to the DMAE bit when it is already set to 1, the DMAC also performs the following operations.

- The forward address pointer is reloaded with the SARi register value when the DSD bit in the DMiCON register is 1 (forward), or the DARi register value when the DAD bit in the DMiCON register is 1 (forward).
- The DMAi transfer counter is reloaded with the DMAi transfer counter reload register value.

16.3.2 DMA Request

The DMAC can generate a DMA request as triggered by the request source that is selected with the DMS bit and bits DSEL4 to DSEL0 in the DMiSL register (i = 0 to 3) on each channel. Table 16.7 lists the Timing at Which the DMAS Bit Value Changes.

When a DMA request is generated, the DMAS bit becomes 1 (DMA requested) regardless of the DMAE bit status. If the DMAE bit is 1 (enabled) when this occurs, the DMAS bit becomes 0 (DMA not requested) immediately before a data transfer starts. This bit cannot be set to 1 by a program (writing 1 has no effect).

If the DMAE bit is 1, data transfers start immediately after a DMA request is generated, so the DMAS bit in almost all cases is 0 when read in a program. Read the DMAE bit to determine whether the DMAC is enabled. When a DMA request transfer cycle is shorter than the DMA transfer cycle, the number of transfer requests and the number of transfers do not match.

When a peripheral function is selected as the DMA source, relations with the interrupt control registers are as follows:

- DMA transfers are not affected by the I flag or interrupt control registers. DMA requests are always accepted even when interrupt requests are not accepted.
- The IR bit in the interrupt control register retains its value when a DMA transfer is accepted.

Table 16.7 Timing at Which the DMAS Bit Value Changes

DMA Source	DMAS Bit in the DMiCON Register	
	Timing at which the bit becomes 1	Timing at which the bit becomes 0
Software trigger	When the DSR bit in the DMiSL register is set to 1.	• Immediately before a data transfer starts • When set to 0 by a program
External source	When an input edge of pins $\overline{\text{INT0}}$ to $\overline{\text{INT7}}$ matches with what is selected by setting bits DSEL4 to DSEL0 and DMS in the DMiSL register.	
Peripheral function	When an interrupt request is generated by the peripheral function selected by setting the DMS bit and bits DSEL4 to DSEL0 in the DMiSL register.(If the IR bit in an interrupt control register is 0, the timing is when the IR bit becomes 1.)	

i = 0 to 3

16.3.3 Transfer Cycles

A transfer cycle is composed of a bus cycle to read data from a source address (source read), and a bus cycle to write data to a destination address (destination write). The number of read and write bus cycles varies with the source and destination addresses.

Figure 16.2 shows Source Read Cycle Example. For convenience, the destination write cycle is shown as one bus cycle and the source read cycles for the different conditions are shown. In reality, the destination write cycle is subject to the same conditions as the source read cycle, with the transfer cycle changing accordingly. When calculating transfer cycles, take into consideration each condition for the source read and the destination write cycle. For example, when data is transferred in 16-bit units, and the source and destination addresses are both odd addresses ((2) in Figure 16.2), two source read bus cycles and two destination write bus cycles are required.

16.3.3.1 Effect of Source and Destination Addresses

When a 16-bit unit of data is transferred with a 16-bit data bus and the source address starts with an odd address, the source read cycle increments by one bus cycle, compared to a source address starting with an even address.

When a 16-bit unit of data is transferred with a 16-bit data bus and the destination address starts with an odd address, the destination write cycle increments by one bus cycle, compared to a destination address starting with an even address.

16.3.3.2 Effect of Software Wait

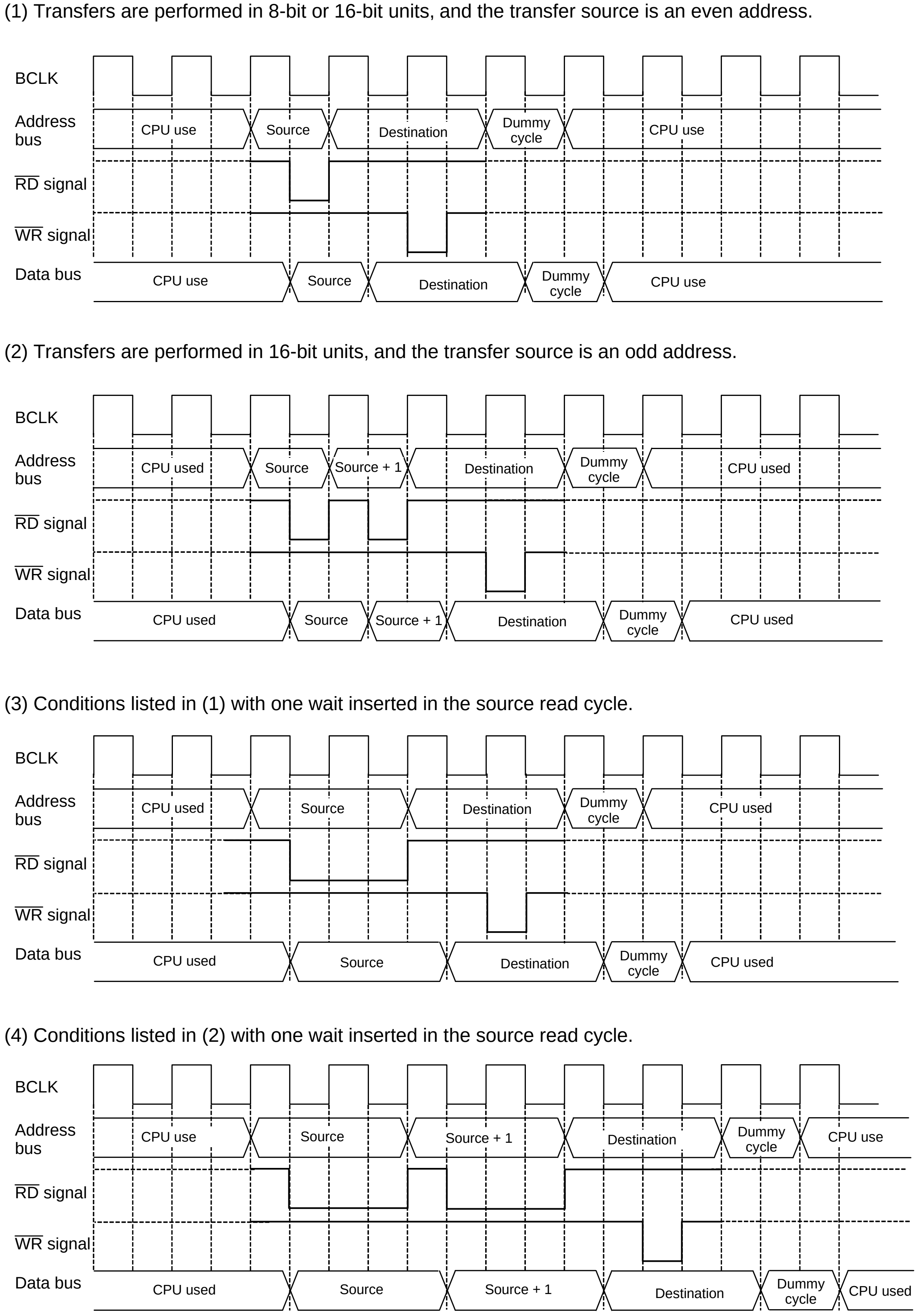
For memory or SFR accesses in which one or more software wait states are inserted, the number of bus cycles required increases by an amount equal to the number of software wait states.

16.3.3.3 Memory Expansion Mode and Microprocessor Mode

In memory expansion or microprocessor mode, the transfer cycle is also affected by the BYTE pin level. Furthermore, the bus cycle itself is extended by a software wait or $\overline{\text{RDY}}$ signal.

If 16 bits of data are transferred on an 8-bit data bus (input to the BYTE pin is high), the operation is accomplished by transferring 8 bits of data twice. Therefore, this operation requires two bus cycles to read data and two bus cycles to write data. Furthermore, if the DMAC accesses an internal area (internal ROM, internal RAM, or SFR), unlike in the case of the CPU, the DMAC uses the data bus width selected by the BYTE pin.

DMA transfers to and from an external area are affected by the $\overline{\text{RDY}}$ signal. Refer to 11.3.5.6 “$\overline{\text{RDY}}$ Signal” for more information.



(1) Transfers are performed in 8-bit or 16-bit units, and the transfer source is an even address.

(2) Transfers are performed in 16-bit units, and the transfer source is an odd address.

(3) Conditions listed in (1) with one wait inserted in the source read cycle.

(4) Conditions listed in (2) with one wait inserted in the source read cycle.

Note:

1. The same timing changes occur with the respective conditions at the destination as at the source.

Figure 16.2 Source Read Cycle Example

16.3.4 DMAC Transfer Cycles

The formula for calculating the number of DMAC transfer cycles is shown below.

Number of transfer cycles per transfer unit = Number of read cycles × j + Number of write cycles × k

Table 16.8 DMAC Transfer Cycles

Transfer Unit	Bus Width	Access Address	Single-Chip Mode		Memory Expansion Mode Microprocessor Mode	
			Number of read cycles	Number of write cycles	Number of read cycles	Number of write cycles
8-bit transfers (DMBIT = 1)	16-bit (BYTE = low)	Even	1	1	1	1
		Odd	1	1	1	1
	8-bit (BYTE = high)	Even	N/A	N/A	1	1
		Odd	N/A	N/A	1	1
16-bit transfers (DMBIT = 0)	16-bit (BYTE = low)	Even	1	1	1	1
		Odd	2	2	2	2
	8-bit (BYTE = high)	Even	N/A	N/A	2	2
		Odd	N/A	N/A	2	2

DMBIT: Bit in the DMiCON register (i = 0 to 3)

Table 16.9 Coefficients j and k (1/2)

	Internal Area			External Area		
	Internal ROM, RAM		SFR	Multiplex bus		
	No waits inserted	Wait inserted	one wait inserted	Wait inserted (1)		
				one wait	two wait	three wait
j	1	2	2	3	3	4
k	1	2	2	3	3	4

Note:

1. Depends on the set value of the CSE register.

Table 16.10 Coefficients j and k (2/2)

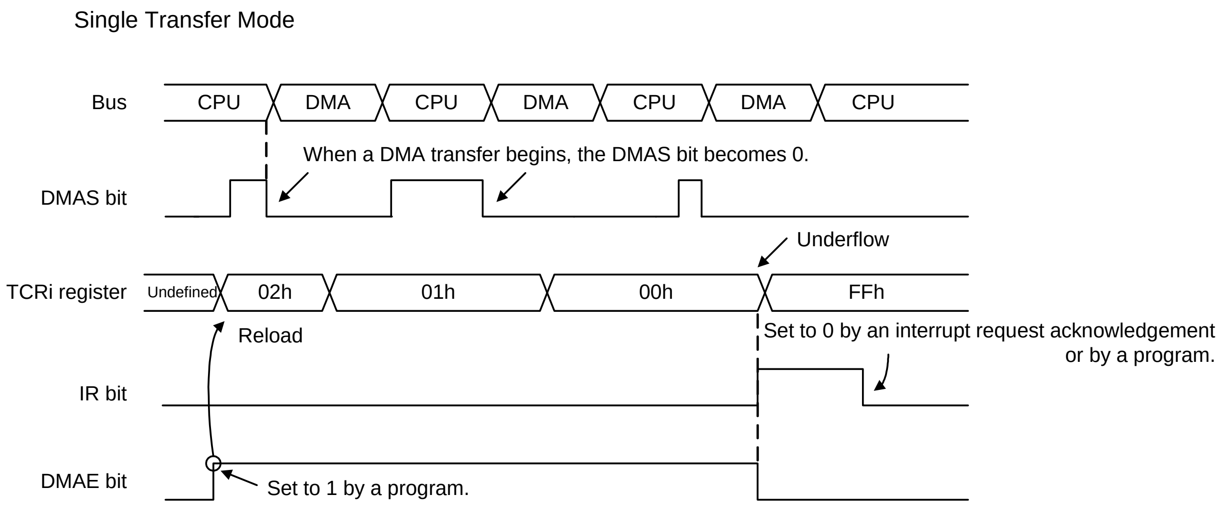
	External Area							
	Separate bus (1)							
	No waits inserted	Wait inserted (2)						
		one wait (1φ + 1φ)	two wait (1φ + 2φ)	three wait (1φ + 3φ)	2φ + 3φ	2φ + 4φ	3φ + 4φ	4φ + 5φ
j	1	2	3	4	5	6	7	9
k	2	2	3	4	5	6	7	9

Notes:

1. When recovery cycle inserted is selected by setting bits EWR1 and EWR0 in the EWR register, add the recovery cycle.
2. Depends on the set values of registers CSE and EWC.

16.3.5 Single Transfer Mode

In single transfer mode, the transfer stops when the DMAi transfer counter underflows. Figure 16.3 shows an Operation Example in Single Transfer Mode.



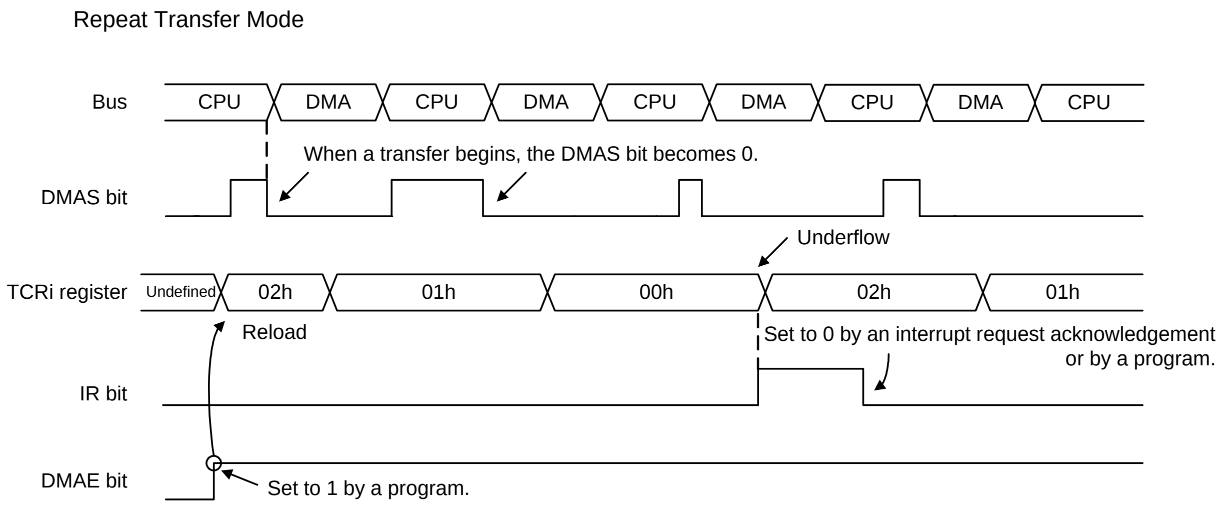
i = 0 to 3
DMAS, DMAE: Bits in the DMiCON register
IR: Bit in the DMiIC register

The above assumes the following:
The TCRi register value is 02h (there are three transfers).

Figure 16.3 Operation Example in Single Transfer Mode

16.3.6 Repeat Transfer Mode

In repeat transfer mode, when the DMAi transfer counter underflows, it is reloaded with the value of the DMAi transfer counter reload register and DMA transfer continues. Figure 16.4 shows an Operation Example in Repeat Transfer Mode.



i = 0 to 3
DMAS, DMAE: Bits in the DMiCON register
IR: Bit in the DMiIC register

The above assumes the following:
The TCRi register value is 02h (there are three transfers).

Figure 16.4 Operation Example in Repeat Transfer Mode

16.3.7 Channel Priority and DMA Transfer Timing

If multiple channels among DMA0 to DMA3 are enabled and DMA transfer request signals are detected as active in the same sampling period (one period from a falling edge to the next falling edge of BCLK), the DMAS bit on each channel becomes 1 (DMA requested) at the same time. In this case, the DMA requests are arbitrated according to the following channel priority: DMA0 > DMA1 > DMA2 > DMA3. DMAC operation when DMA0 and DMA1 requests are detected as active in the same sampling period is described below. Figure 16.5 shows an example of DMA Transfer Initiated by External Sources.

In Figure 14.5, as DMA0 and DMA1 requests are generated simultaneously, the higher channel prioritized DMA0 is received first, and data transfer starts. After one DMA0 transfer is completed, the bus access privilege is returned to the CPU. When the CPU has completed one bus access, a DMA1 transfer starts. After one DMA1 transfer is completed, the bus access privilege is again returned to the CPU.

In addition, DMA requests cannot increment since each channel has one DMAS bit. Therefore, when DMA requests, such as DMA1 in Figure 16.5, occur more than once, the DMAS bit is set to 0 after receiving the bus access privilege. The bus access privilege is returned to the CPU when one transfer is completed.

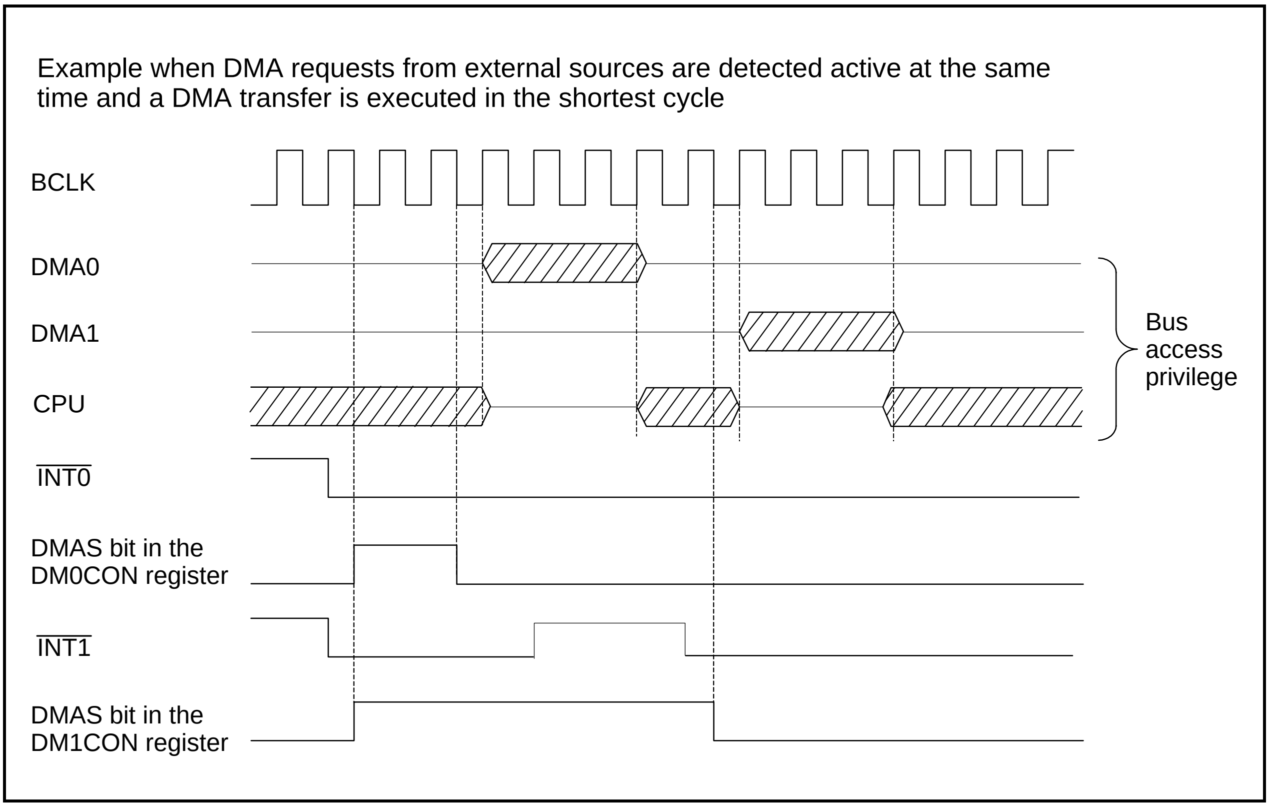

Example when DMA requests from external sources are detected active at the same time and a DMA transfer is executed in the shortest cycle
BCLK
DMA0
DMA1
CPU
$\overline{\text{INT0}}$
DMAS bit in the DM0CON register
$\overline{\text{INT1}}$
DMAS bit in the DM1CON register
Bus access privilege

Figure 16.5 DMA Transfer Initiated by External Sources

16.4 Interrupts

Refer to operation examples for interrupt request generation timing.
For details on interrupt control, refer to 14.7 “Interrupt Control”.

Table 16.11 DMAC Interrupt Related Registers

Address	Register	Symbol	Reset Value
004Bh	DMA0 Interrupt Control Register	DM0IC	XXXX X000b
004Ch	DMA1 Interrupt Control Register	DM1IC	XXXX X000b
0069h	DMA2 Interrupt Control Register	DM2IC	XXXX X000b
006Ah	DMA3 Interrupt Control Register	DM3IC	XXXX X000b

When the DMS bit or bits DSEL4 to DSEL0 in the DMiSL register are changed, the DMAS bit in the DMiCON sometimes becomes 1 (DMA requested) (i = 0 to 3). Therefore, set the DMAS bit to 0 (DMA not requested) after the DMS bit or bits DSEL4 to DSEL0 in the DMiSL register are changed. Refer to 14.13 “Notes on Interrupts” for more details.

16.5 Notes on DMAC

16.5.1 Write to the DMAE Bit in the DMiCON Register (i = 0 to 3)

(Technical update number: TN-M16C-92-0306)
When both of the following conditions are met, follow steps (1) and (2) below.

Conditions

- Write 1 (DMAi is in active state) to the DMAE bit when it is 1.
- A DMA request may be generated simultaneously when writing to the DMAE bit.

Steps

(1) Set bits DMAE and DMAS in the DMiCON register to 1 simultaneously. [1]

(2) Make sure the DMAi circuit is in an initialized state [2] by a program.
If DMAi is not in an initialized state, repeat these two steps.

Notes:

1. The DMAS bit does not change even if set to 1. However, it becomes 0 when set to 0 (DMA not requested). Therefore, when writing to the DMiCON register to set the DMAE bit to 1, set the value to be written to the DMAS bit to 1 to retain its state immediately before writing.
Similarly, when writing to the DMAE bit with a read-modify-write instruction, set the DMAS bit to 1 to retain the DMA request that was generated while executing the instruction.
2. Read the TCRi register to verify whether DMAi is in an initialized state.
If the read value is equal to the value that was written to the TCRi register before the DMA transfer started, DMAi is in an initialized state. When a DMA request is generated after writing to the DMAE bit, the read value is a value written to the TCRi register minus 1. If the read value is a value in the middle of a transfer, DMAi is not in an initialized state.

16.5.2 Changing the DMA Request Source

When the DMS bit or any of bits from DSEL4 to DSEL0 in the DMiSL register is changed, the DMAS bit in the DMiCON sometimes becomes 1 (DMA requested). Set the DMAS bit to 0 (DMA not requested) after changing the DMS bit or bits DSEL4 to DSEL0 in the DMiSL register.

17. Timer A

17.1 Introduction

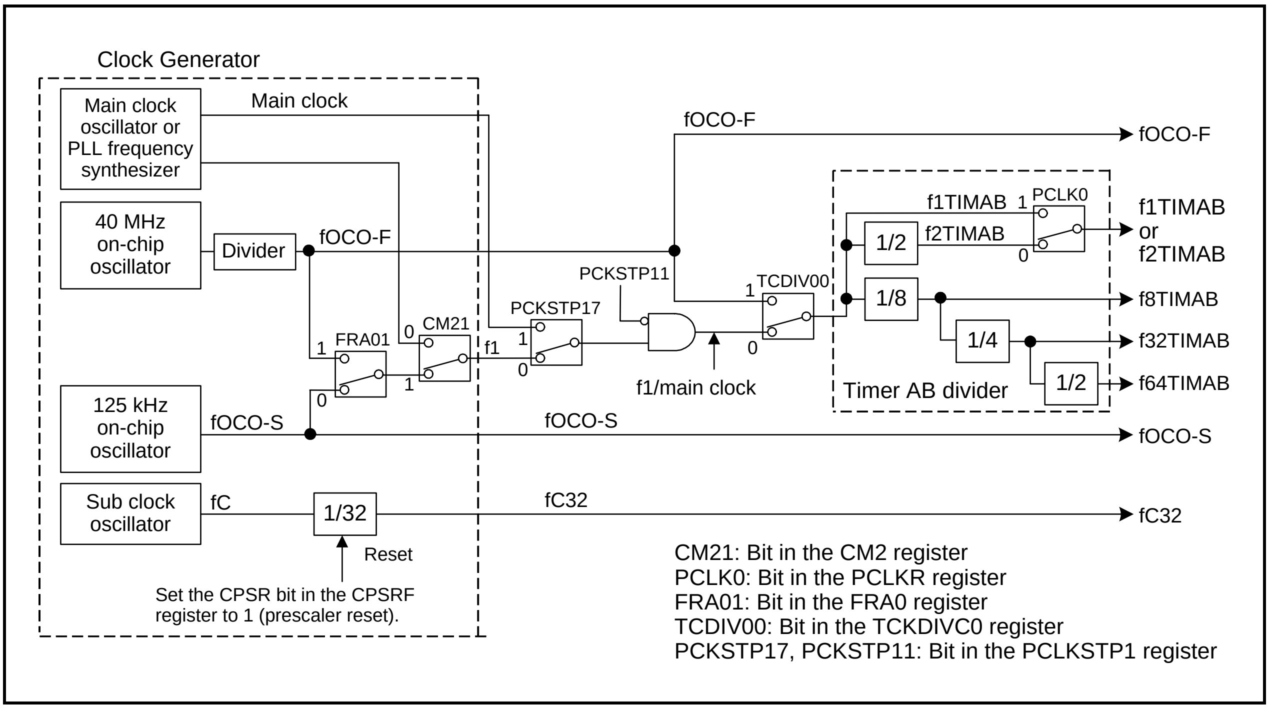
Timers A consists of timers A0 to A4. Each timer operates independently of the others. Table 17.1 lists Timer A Specifications, Table 17.2 lists Differences in Timer A Mode, Figure 17.1 shows Timer A and B Count Sources, Figure 17.2 shows Timer A Configuration, Figure 17.3 shows Timer A Block Diagram, and Table 17.3 lists I/O Ports.

Table 17.1 Timer A Specifications

Item	Specification
Configuration	16-bit timer × 5
Operating modes	• Timer mode The timer counts an internal count source. • Event counter mode The timer counts pulses from an external device, or overflows and underflows of other timers. • One-shot timer mode The timer outputs a single pulse before it reaches the count 0000h. • Pulse width modulation mode (PWM mode) The timer outputs pulses of given width and cycle successively. • Programmable output mode The timer outputs a given pulse width of a high/low level signal (timers A1, A2, and A4).
Interrupt sources	Overflow/underflow × 5

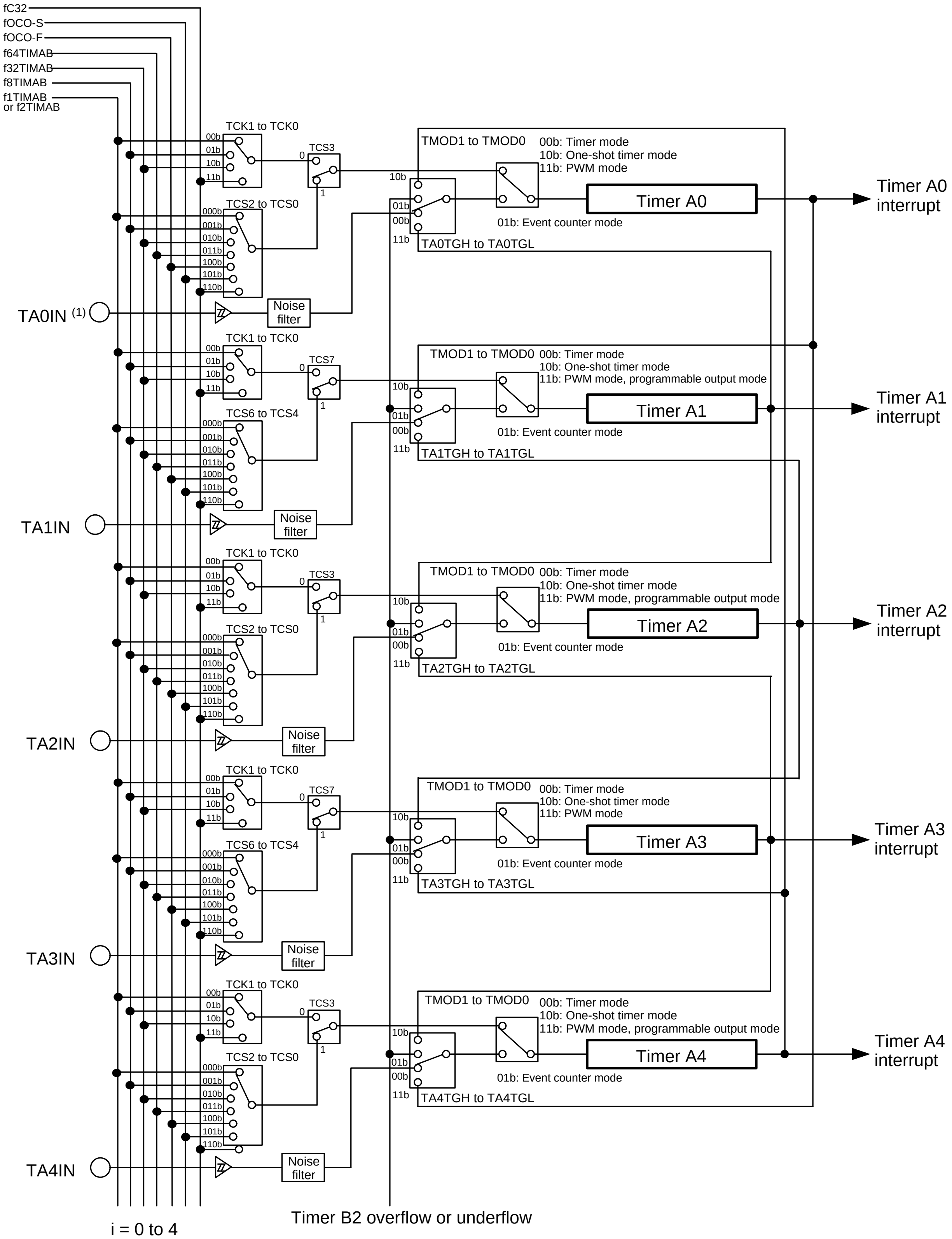
Table 17.2 Differences in Timer A Mode

Item	Timer				
	A0	A1	A2	A3	A4
Event counter mode (two-phase pulse signal processing)	No	No	Yes	Yes	Yes
Programmable output mode	No	Yes	Yes	No	Yes



CM21: Bit in the CM2 register
PCLK0: Bit in the PCLKR register
FRA01: Bit in the FRA0 register
TCDIV00: Bit in the TCKDIVC0 register
PCKSTP17, PCKSTP11: Bit in the PCLKSTP1 register

Figure 17.1 Timer A and B Count Sources



i = 0 to 4

TCK1 to TCK0, TMOD1 to TMOD0 : Bits in the TAiMR register

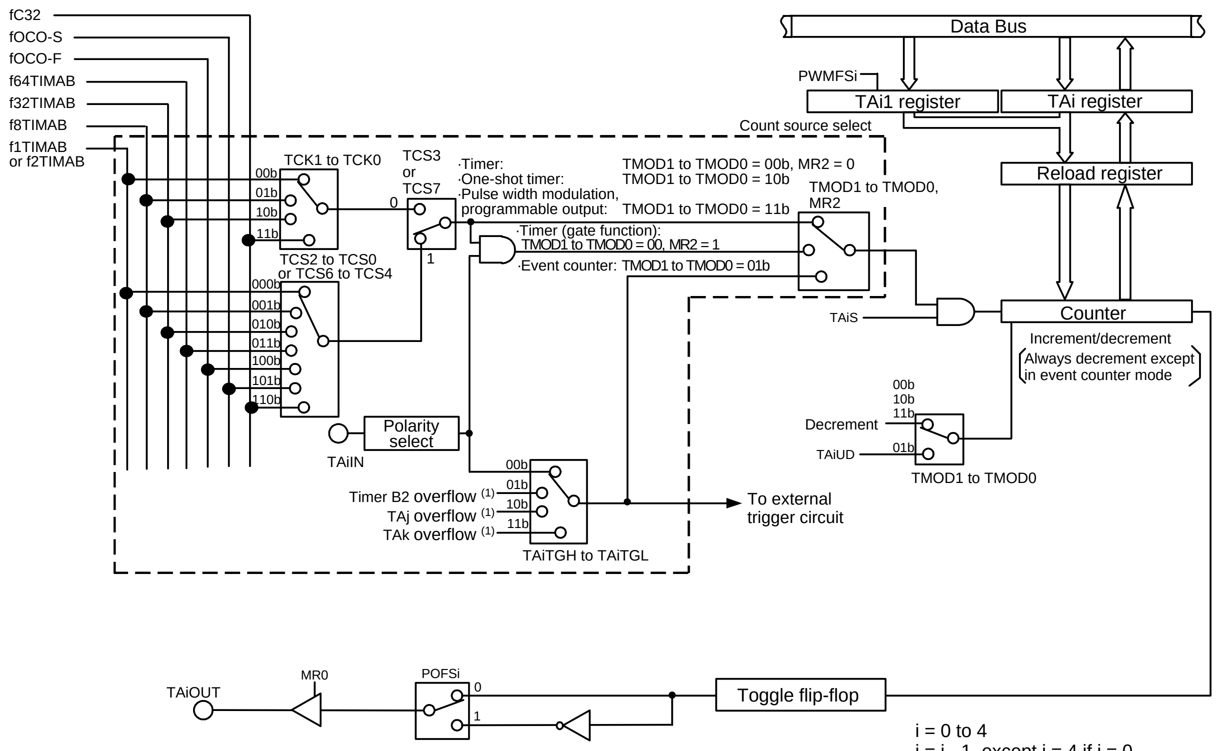
TAiTGH to TAiTGL : Bits in the ONSF register or TRGSR register

TCS7 to TCS0 : Bits in registers TACS0 to TACS2

Note:

1. TA0IN shares a pin with TB5IN.

Figure 17.2 Timer A Configuration



i = 0 to 4
j = i - 1, except j = 4 if i = 0
k = i + 1, except k = 0 if i = 4

TAi	TAj	TAk
Timer A0	Timer A4	Timer A1
Timer A1	Timer A0	Timer A2
Timer A2	Timer A1	Timer A3
Timer A3	Timer A2	Timer A4
Timer A4	Timer A3	Timer A0

Note:
1. Overflow or underflow

TCK1 to TCK0, TMOD1 to TMOD0, MR2 to MR0: Bits in the TAiMR register
TAiTGH to TAiTGL: Bits in the ONSF register when i = 0, bits in the TRGSR register when i = 1 to 4
TAiS: Bit in the TABSR register
TAiUD: Bit in the UDF register
TCS7 to TCS0: Bits in the registers TACS0 to TACS2
POFSi: Bit in the TAPOFS register
PWMFSi: Bit in the PWMFS register

Figure 17.3 Timer A Block Diagram

Table 17.3 I/O Ports

Pin Name	I/O	Function
TAiIN	Input (1)	Gate input (timer mode) Count source input (event counter mode) Two-phase signal input (event counter mode (two-phase pulse signal processing)) Trigger input (one-shot timer mode, PWM mode, programmable output mode)
TAiOUT	Output (2)	Pulse output (timer mode, event counter mode, one-shot timer mode, PWM mode, and programmable output mode)
	Input (1)	Two-phase pulse input (event counter mode (two-phase pulse signal processing))
ZP	Input (1)	Z-phase (counter initialization) input (event counter mode (two-phase pulse signal processing))

i = 0 to 4; however, i = 2, 3, 4 for two-phase pulse input, and i = 1, 2, 4 in programmable output mode

Notes:
1. When using pins TAiIN, TAiOUT, and ZP for input, set the port direction bits sharing pins to 0 (input mode).
2. The TA0OUT pin is N-channel open drain output.

17.2 Registers

Table 17.4 lists registers associated with timer A.

Set the TCDIV00 bit in the TCKDIVC0 register before setting other registers associated with timer A. After changing the TCDIV00 bit, set other registers associated with timer A again.

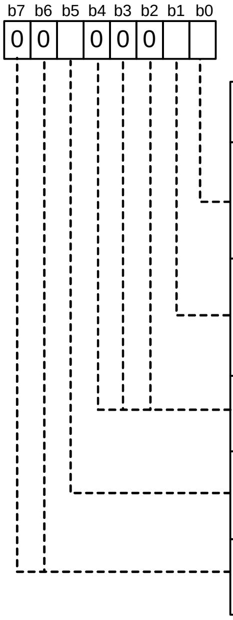
Refer to “registers and the setting” in each mode for registers and bit settings.

Table 17.4 Registers

Address	Register	Symbol	Reset Value
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
0015h	Clock Prescaler Reset Flag	CPSRF	0XXX XXXXb
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
01CBh	Timer AB Division Control Register 0	TCKDIVC0	0000 X000b
01D0h	Timer A Count Source Select Register 0	TACS0	00h
01D1h	Timer A Count Source Select Register 1	TACS1	00h
01D2h	Timer A Count Source Select Register 2	TACS2	X0h
01D4h	16-bit Pulse Width Modulation Mode Function Select Register	PWMFS	0XX0 X00Xb
01D5h	Timer A Waveform Output Function Select Register	TAPOFS	XXX0 0000b
01D8h	Timer A Output Waveform Change Enable Register	TAOW	XXX0 X00Xb
0302h	Timer A1-1 Register	TA11	XXh
0303h			XXh
0304h	Timer A2-1 Register	TA21	XXh
0305h			XXh
0306h	Timer A4-1 Register	TA41	XXh
0307h			XXh
0320h	Count Start Flag	TABSR	00h
0322h	One-Shot Start Flag	ONSF	00h
0323h	Trigger Select Register	TRGSR	00h
0324h	Increment/Decrement Flag	UDF	00h
0326h	Timer A0 Register	TA0	XXh
0327h			XXh
0328h	Timer A1 Register	TA1	XXh
0329h			XXh
032Ah	Timer A2 Register	TA2	XXh
032Bh			XXh
032Ch	Timer A3 Register	TA3	XXh
032Dh			XXh
032Eh	Timer A4 Register	TA4	XXh
032Fh			XXh
0336h	Timer A0 Mode Register	TA0MR	00h
0337h	Timer A1 Mode Register	TA1MR	00h
0338h	Timer A2 Mode Register	TA2MR	00h
0339h	Timer A3 Mode Register	TA3MR	00h
033Ah	Timer A4 Mode Register	TA4MR	00h

17.2.1 Peripheral Clock Select Register (PCLKR)

Peripheral Clock Select Register



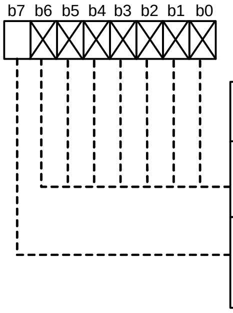
Symbol	Address	Reset Value
PCLKR	0012h	0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A and B clock select bit (clock source for timers A and B, the dead time timer, and multi-master I^2C-bus interface)	0: f2TIMAB/f2IIC 1: f1TIMAB/f1IIC	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART2, UART5 to UART7, SI/O3, and SI/O4)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function expansion bit (enabled in single-chip mode)	0: Selected by setting bits CM01 to CM00 in the CM0 register 1: Output f1	RW
— (b7-b6)	Reserved bits	Set to 0	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.

17.2.2 Clock Prescaler Reset Flag (CPSRF)

Clock Prescaler Reset Flag

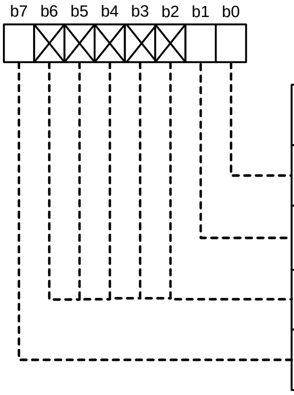


Symbol	Address	Reset Value
CPSRF	0015h	0XXX XXXXb

Bit Symbol	Bit Name	Function	RW
— (b6-b0)	No register bits. If necessary, set to 0. The read values are undefined.		—
CPSR	Clock prescaler reset flag	Setting this bit to 1 initializes the prescaler for the timekeeping clock. (The read value is 0.)	RW

17.2.3 Peripheral Clock Stop Register 1 (PCLKSTP1)

Peripheral Clock Stop Register 1



Symbol	Address	Reset Value
PCLKSTP1	0016h	0XXX XX00b

Bit Symbol	Bit Name	Function	RW
PCKSTP1A	Peripheral clock stop bit (other than timer A, timer B)	0: f1 provide enabled 1: f1 provide disabled	RW
PCKSTP11	Timer peripheral clock stop bit (timer A, timer B)	0: f1 provide enabled 1: f1 provide disabled	RW
— (b6-b2)	No register bit. If necessary, set to 0. The read value is undefined.		—
PCKSTP17	Timer clock source select bit (timer A, timer B)	0: f1 1: Main clock	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register

PCKSTP11 (Timer peripheral clock stop bit) (b1)

When using f1 or the main clock for the timer A and timer B count source, set the PCKSTP11 bit to 0 (f1 provide enabled).

To change the PCKSTP11 bit from 1 (f1 provide disabled) to 0, use following procedure:

(1) Stop timer A and timer B.
(2) Set the PCKSTP11 bit to 0.
(3) Set the registers for timer A and timer B again.

To change the timer A and timer B count source from fOCO-F to f1, perform (1) and (2) above, and set the TCDIV00 bit in the TCKDIVC0 register from 1 (fOCO-F) to 0 (f1), then perform (3).

PCKSTP17 (Timer clock source select bit) (b7)

Change the PCKSTP17 bit when all of the following conditions are met:

- Both f1 and the main clock are stably supplied.
- Both timer A and timer B are stopped.

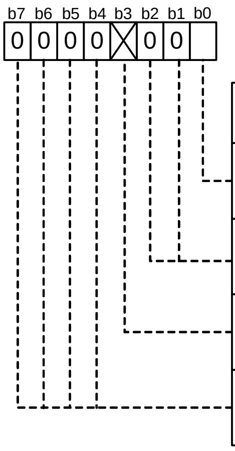
The PCKSTP17 bit is used for supplying the main clock to timer A and timer B.

When in PLL operating mode, high-speed mode, medium-speed mode, or wait mode, the main clock can be used for the timer A and timer B count source.

Do not use the main clock for the timer A and timer B count source in other normal operating modes (refer to 9.3 “Clock”).

17.2.4 Timer AB Division Control Register 0 (TCKDIVC0)

Timer AB Division Control Register 0



Symbol	Address	Reset Value
TCKDIVC0	01CBh	0000 X000b

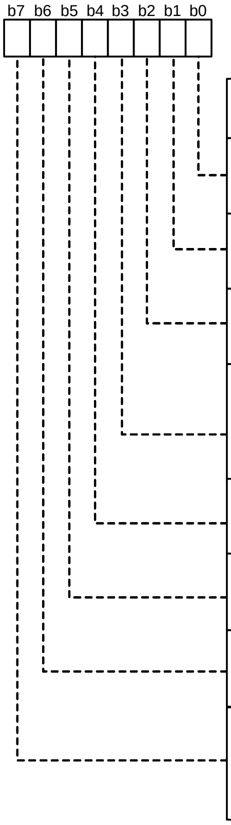
Bit Symbol	Bit Name	Function	RW
TCDIV00	Clock select prior to timer AB division bit	0 : f1 1 : fOCO-F	RW
— (b2-b1)	Reserved bits	Set to 0	RW
— (b3)	No register bit. If necessary, set to 0. The read value is undefined.		—
— (b7-b4)	Reserved bits	Set to 0	RW

TCDIV00 (Clock select prior to timer AB division bit) (b0)

Set the TCDIV00 bit while timers A and B are stopped.
Set the TCDIV00 bit before setting other registers associated with timer A.
After changing the TCDIV00 bit, set other registers associated with timer A again.

17.2.5 Timer A Count Source Select Register i (TACSi) (i = 0 to 2)

Timer A Count Source Select Register 0, Timer A Count Source Select Register 1

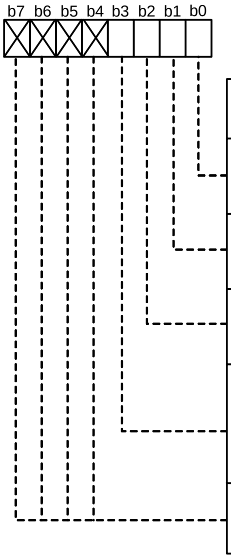


Symbol	Address	Reset Value
TACS0 to TACS1	01D0h to 01D1h	00h

Bit Symbol	Bit Name	Function	RW
TCS0	TAi count source select bit	b2 b1 b0 0 0 0 : f1TIMAB or f2TIMAB 0 0 1 : f8TIMAB 0 1 0 : f32TIMAB 0 1 1 : f64TIMAB 1 0 0 : fOCO-F 1 0 1 : fOCO-S 1 1 0 : fC32 1 1 1 : Do not set	RW
TCS1			RW
TCS2			RW
TCS3	TAi count source option specified bit	0 : TCK0, TCK1 enabled, TCS0 to TCS2 disabled 1 : TCK0, TCK1 disabled, TCS0 to TCS2 enabled	RW
TCS4	TAj count source select bit	b6 b5 b4 0 0 0 : f1TIMAB or f2TIMAB 0 0 1 : f8TIMAB 0 1 0 : f32TIMAB 0 1 1 : f64TIMAB 1 0 0 : fOCO-F 1 0 1 : fOCO-S 1 1 0 : fC32 1 1 1 : Do not set	RW
TCS5			RW
TCS6			RW
TCS7	TAj count source option specified bit	0 : TCK0, TCK1 enabled, TCS4 to TCS6 disabled 1 : TCK0, TCK1 disabled, TCS4 to TCS6 enabled	RW

TACS0 register: i = 0, j = 1 TACS1 register: i = 2, j = 3

Timer A Count Source Select Register 2



Symbol	Address	Reset Value
TACS2	01D2h	X0h

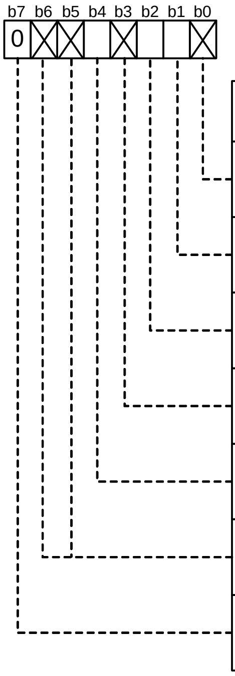
Bit Symbol	Bit Name	Function	RW
TCS0	TA4 count source select bit	b2 b1 b0 0 0 0 : f1TIMAB or f2TIMAB 0 0 1 : f8TIMAB 0 1 0 : f32TIMAB 0 1 1 : f64TIMAB 1 0 0 : fOCO-F 1 0 1 : fOCO-S 1 1 0 : fC32 1 1 1 : Do not set	RW
TCS1			RW
TCS2			RW
TCS3	TA4 count source option specified bit	0 : TCK0 to TCK1 enabled, TCS0 to TCS2 disabled 1 : TCK0 to TCK1 disabled, TCS0 to TCS2 enabled	RW
— (b7-b4)	No register bits. If necessary, set to 0. The read values are undefined.		—

TCS2 to TCS0 (TAi count source select bit) (b2-b0) (i = 0, 2, 4)
TCS6 to TCS4 (TAj count source select bit) (b6-b4) (i = 1, 3)

Select f1TIMAB or f2TIMAB by the PCLK0 bit in the PCLKR register.

17.2.6 16-bit Pulse Width Modulation Mode Function Select Register (PWMFS)

16-bit Pulse Width Modulation Mode Function Select Register



Symbol	Address	Reset Value
PWMFS	01D4h	0XX0 X00Xb

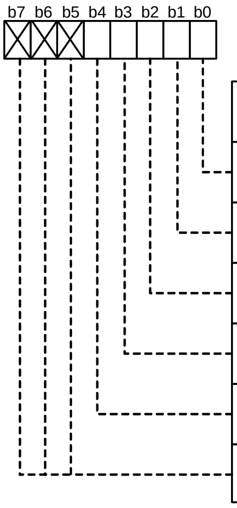
Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. The read value is undefined.		—
PWMFS1	Timer A1 programmable output mode select bit	0 : PWM mode 16-bit PWM 1 : Programmable output mode	RW
PWMFS2	Timer A2 programmable output mode select bit	0 : PWM mode 16-bit PWM 1 : Programmable output mode	RW
— (b3)	No register bit. If necessary, set to 0. The read value is undefined.		—
PWMFS4	Timer A4 programmable output mode select bit	0 : PWM mode 16-bit PWM 1 : Programmable output mode	RW
— (b6-b5)	No register bits. If necessary, set to 0. The read value is undefined.		—
— (b7)	Reserved bit	Set to 0	RW

PWMFS1 (Timer A1 programmable output mode select bit) (b1)
PWMFS2 (Timer A2 programmable output mode select bit) (b2)
PWMFS4 (Timer A4 programmable output mode select bit) (b4)

These bits are enabled when bits TMOD1 to TMOD0 in the TAiMR register are 11b (PWM mode or programmable output mode), and the MR3 bit in the TAiMR register is 0 (16-bit PWM mode).

17.2.7 Timer A Waveform Output Function Select Register (TAPOFS)

Timer A Waveform Output Function Select Register

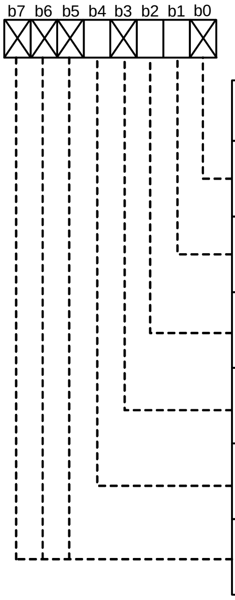


Symbol	Address	Reset Value
TAPOFS	01D5h	XXX0 0000b

Bit Symbol	Bit Name	Function	RW
POFS0	TA0OUT output polar control bit	0 : Output waveform high-level active 1 : Output waveform high-level active (output inverted)	RW
POFS1	TA1OUT output polar control bit		RW
POFS2	TA2OUT output polar control bit		RW
POFS3	TA3OUT output polar control bit		RW
POFS4	TA4OUT output polar control bit		RW
— (b7-b5)	No register bits. If necessary, set to 0. The read value is undefined.		—

17.2.8 Timer A Output Waveform Change Enable Register (TAOW)

Timer A Output Waveform Change Enable Register



Symbol	Address	Reset Value
TAOW	01D8h	XXX0 X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. The read value is undefined.		—
TA1OW	Timer A1 output waveform change enable bit	0 : Change disabled 1 : Change enabled	RW
TA2OW	Timer A2 output waveform change enable bit	0 : Change disabled 1 : Change enabled	RW
— (b3)	No register bit. If necessary, set to 0. The read value is undefined.		—
TA4OW	Timer A4 output waveform change enable bit	0 : Change disabled 1 : Change enabled	RW
— (b7-b5)	No register bits. If necessary, set to 0. The read value is undefined.		—

The TAOW register is enabled in programmable output mode.

To change cycles or width of the output waveform, follow the instructions below.

(1)Set the TAiOW bit to 0 (output waveform change disabled). (i = 1, 2, 4)

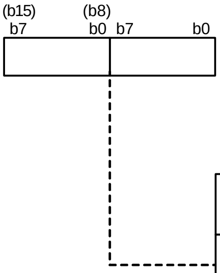
(2)Write to the TAi register and/or the TAi1 register.

(3)Set the TAiOW bit to 1 (output waveform change enabled).

The updated value is reloaded when the TAiOW bit is 1 (output waveform change enabled) at one cycle before the rising edge of the TAiOUT output (the falling edge when the POFSi bit is 1). The value before the update is reloaded when the TAiOW bit is 0 (output waveform change disabled).

17.2.9 Timer Ai Register (TAi) (i = 0 to 4)

Timer Ai Register (i = 0 to 4)



Symbol	Address	Reset Value
TA0	0327h to 0326h	XXXXh
TA1	0329h to 0328h	XXXXh
TA2	032Bh to 032Ah	XXXXh
TA3	032Dh to 032Ch	XXXXh
TA4	032Fh to 032Eh	XXXXh

Mode	Function	Setting Range	RW
Timer mode	When n is a setting value, counter cycle: $\frac{(n + 1)}{fj}$	0000h to FFFFh	RW
Event counter mode	When n is a set value, FFFFh - n + 1 count (at increment) n + 1 count (at decrement)	0000h to FFFFh	RW
One-shot timer mode	When n is a set value, pulse width: $\frac{n}{fj}$	0000h to FFFFh	WO
Pulse width modulation mode (16-bit PWM mode)	When n is a set value, PWM period: $\frac{(2^{16} – 1)}{fj}$ PWM pulse width: $\frac{n}{fj}$	0000h to FFFEh	WO
Pulse width modulation mode (8-bit PWM mode)	When n is an upper address setting value, and m is a lower address setting value, PWM period: $\frac{(2^{8} – 1) \times (m + 1)}{fj}$ PWM pulse width: $\frac{(m + 1)n}{fj}$	00h to FEh (upper address) 00h to FFh (lower address)	WO
Programmable output mode	When n is a setting value of TAi1 register, and m is a setting value of TAi register, high-level duration: $\frac{m}{fj}$ low-level duration: $\frac{n}{fj}$	0000h to FFFFh	WO

fj : Count source frequency

Access the register in 16-bit units. Use the MOV instruction to write to the TAi register.

Event Counter Mode

The timer counts pulses from an external device, or the overflows/underflows of other timers.

One-Shot Timer Mode

If the TAi register is set to 0000h, the counter does not work and timer Ai interrupt requests are not generated. Furthermore, if pulse output is selected, no pulses are output from the TAiOUT pin.

Pulse Width Modulation Mode (16-bit PWM mode)

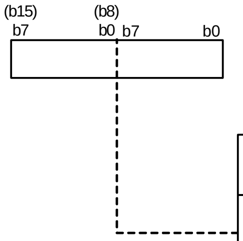
When the TAi register is set to 0000h, the counter does not work, the output level on the TAiOUT pin remains low, and timer Ai interrupt requests are not generated.

Pulse Width Modulation Mode (8-bit PWM mode)

This mode operates as an 8-bit prescaler (lower 8 bits) and an 8-bit pulse width modulator (upper 8 bits). When the upper 8 bits of the TAi register are set to 00h, the counter does not work, the output level on the TAiOUT pin remains low, and a timer Ai interrupt request is not generated.

17.2.10 Timer Ai-1 Register (TAi1) (i = 1, 2, 4)

Timer Ai-1 Register (i = 1, 2, 4)



Symbol	Address	Reset Value
TA11	0303h to 0302h	XXXXh
TA21	0305h to 0304h	XXXXh
TA41	0307h to 0306h	XXXXh

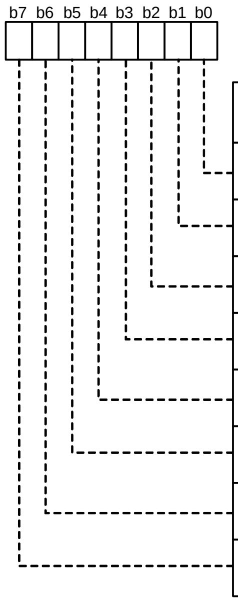
Mode	Function	Setting Range	RW
Programmable output mode	When n is a setting value of TAi1 register, and m is a setting value of TAi register, high-level duration: $\frac{m}{fj}$ low-level duration: $\frac{n}{fj}$	0001h to FFFFh	WO

fj: Count source frequency

Access the register in 16-bit units. Use the MOV instruction to write to the TAi1 register.

17.2.11 Count Start Flag (TABSR)

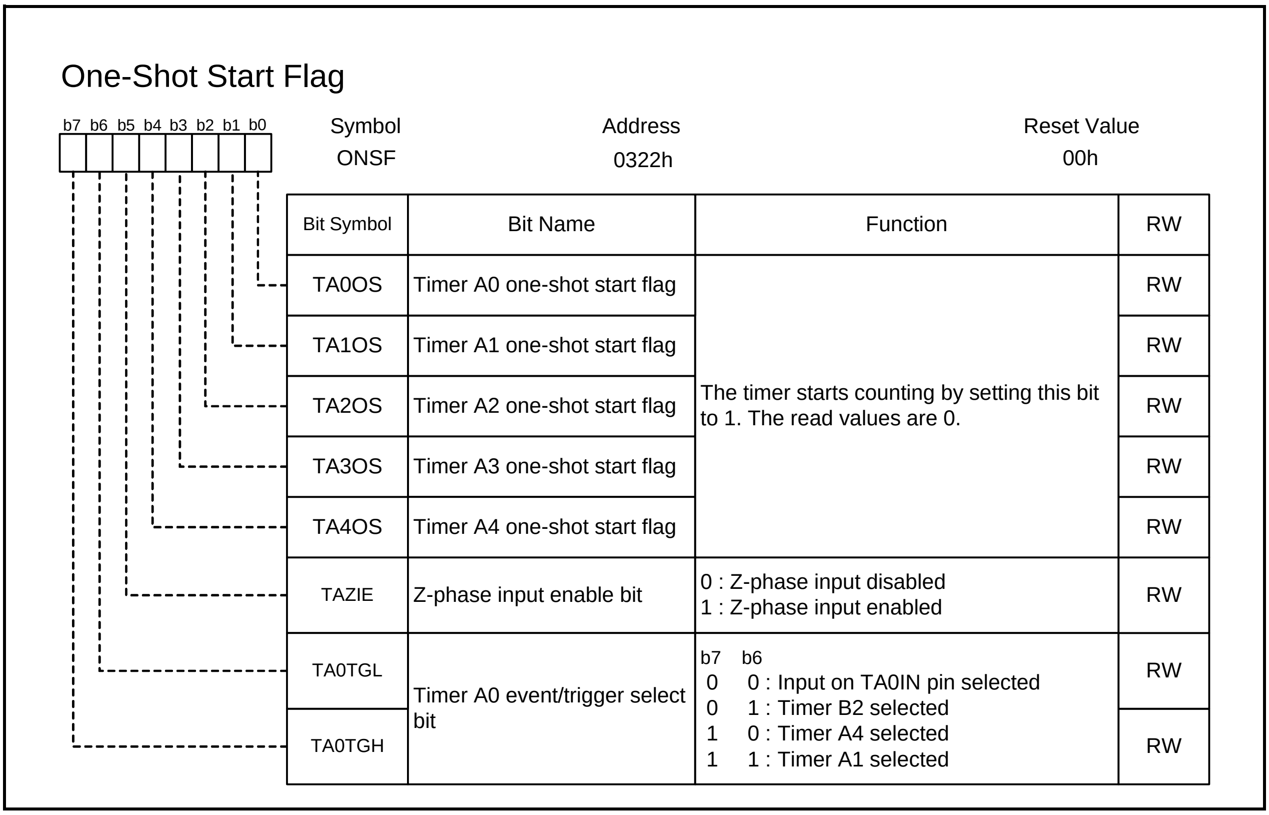
Count Start Flag



Symbol	Address	Reset Value
TABSR	0320h	00h

Bit Symbol	Bit Name	Function	RW
TA0S	Timer A0 count start flag	0 : Count stopped 1 : Count started	RW
TA1S	Timer A1 count start flag		RW
TA2S	Timer A2 count start flag		RW
TA3S	Timer A3 count start flag		RW
TA4S	Timer A4 count start flag		RW
TB0S	Timer B0 count start flag		RW
TB1S	Timer B1 count start flag		RW
TB2S	Timer B2 count start flag		RW

17.2.12 One-Shot Start Flag (ONSF)



Bit Symbol	Bit Name	Function	RW
TA0OS	Timer A0 one-shot start flag	The timer starts counting by setting this bit to 1. The read values are 0.	RW
TA1OS	Timer A1 one-shot start flag		RW
TA2OS	Timer A2 one-shot start flag		RW
TA3OS	Timer A3 one-shot start flag		RW
TA4OS	Timer A4 one-shot start flag		RW
TAZIE	Z-phase input enable bit	0 : Z-phase input disabled 1 : Z-phase input enabled	RW
TA0TGL	Timer A0 event/trigger select bit	b7 b6 0 0 : Input on TA0IN pin selected 0 1 : Timer B2 selected 1 0 : Timer A4 selected 1 1 : Timer A1 selected	RW
TA0TGH			RW

TAiOS (Timer Ai one-shot start flag) (b4-b0) (i = 0 to 4)

This bit is enabled in one-shot timer mode. When the MR2 bit in the TAi register is 0 (TAiOS bit enabled), the timer Ai count starts by setting the TAiOS bit to 1 after setting the TAiS bit in the TABSR register to 1 (start counting).

TAZIE (Z-phase input enable bit) (b5)

This bit is used in event counter mode (two-phase pulse signal processing) of timer A3. Refer to 17.3.4.3 “Counter Initialization Using Two-Phase Pulse Signal Processing” for details.

TA0TGH-TA0TGL (Timer A0 event/trigger select bit) (b7-b6)

These bits are used to select an event or a trigger in the following modes:

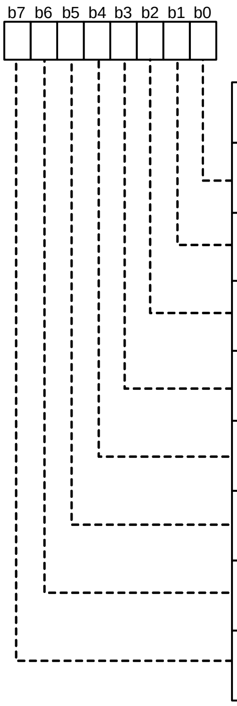
- An event in event counter mode (when not using two-phase pulse signal processing)
- A trigger in one-shot timer mode or PWM mode
  The above applies when the MR2 bit in the TA0MR register is 1 (trigger selected by setting bits TA0TGH to TA0TGL).

When bits TA0TGH to TA0TGL are 00b, the active edge of input signals can be selected by setting the MR1 bit in the TA0MR register.

When bits TA0TGH to TA0TGL are set to 01b, 10b, or 11b, an event or a trigger occurs when an interrupt request for the selected timer is generated. An event or trigger can occur while interrupts are disabled because an interrupt request signal is generated regardless of the I flag, IPL, or interrupt control registers.

17.2.13 Trigger Select Register (TRGSR)

Trigger Select Register



Symbol	Address	Reset Value
TRGSR	0323h	00h

Bit Symbol	Bit Name	Function	RW
TA1TGL	Timer A1 event/trigger select bit	b1 b0 0 0 : Input on TA1IN selected 0 1 : TB2 selected 1 0 : TA0 selected 1 1 : TA2 selected	RW
TA1TGH			RW
TA2TGL	Timer A2 event/trigger select bit	b3 b2 0 0 : Input on TA2IN selected 0 1 : TB2 selected 1 0 : TA1 selected 1 1 : TA3 selected	RW
TA2TGH			RW
TA3TGL	Timer A3 event/trigger select bit	b5 b4 0 0 : Input on TA3IN selected 0 1 : TB2 selected 1 0 : TA2 selected 1 1 : TA4 selected	RW
TA3TGH			RW
TA4TGL	Timer A4 event/trigger select bit	b7 b6 0 0 : Input on TA4IN selected 0 1 : TB2 selected 1 0 : TA3 selected 1 1 : TA0 selected	RW
TA4TGH			RW

TA1TGH-TA1TGL (Timer A1 event/trigger select bit) (b1-b0)
TA2TGH-TA2TGL (Timer A2 event/trigger select bit) (b3-b2)
TA3TGH-TA3TGL (Timer A3 event/trigger select bit) (b5-b4)
TA4TGH-TA4TGL (Timer A4 event/trigger select bit) (b7-b6)

These bits are used to select an event or a trigger of the following modes:

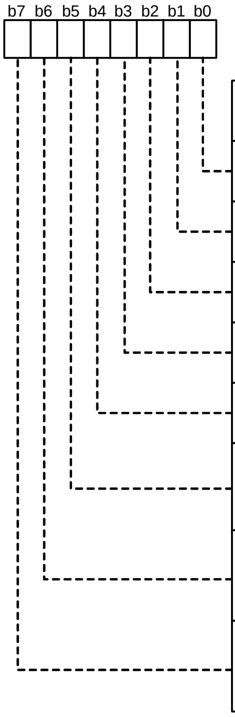
- An event in event counter mode (when not using two-phase pulse signal processing)
- A trigger in one-shot timer mode, PWM mode, or programmable output mode
  The above applies when the MR2 bit in the TAiMR register is 1 (trigger selected by setting bits TAiTGH to TAiTGL).

When bits TAiTGH to TAiTGL are 00b, the active edge of input signals can be selected by setting the MR1 bit in the TAiMR register.

When bits TAiTGH to TAiTGL are set to 01b, 10b, or 11b, an event or a trigger occurs when an interrupt request of the selected timer is generated. An event or trigger can occur while interrupts are disabled because an interrupt request signal is generated regardless of the I flag, IPL, or interrupt control registers.

17.2.14 Increment/Decrement Flag (UDF)

Increment/Decrement Flag



Symbol	Address	Reset Value
UDF	0324h	00h

Bit Symbol	Bit Name	Function	RW
TA0UD	Timer A0 increment/ decrement flag	0 : Decrement 1 : Increment	RW
TA1UD	Timer A1 increment/ decrement flag		RW
TA2UD	Timer A2 increment/ decrement flag		RW
TA3UD	Timer A3 increment/ decrement flag		RW
TA4UD	Timer A4 increment/ decrement flag		RW
TA2P	Timer A2 two-phase pulse signal processing select bit	0 : Two-phase pulse signal processing disabled 1 : Two-phase pulse signal processing enabled	RW
TA3P	Timer A3 two-phase pulse signal processing select bit		RW
TA4P	Timer A4 two-phase pulse signal processing select bit		RW

TAiUD (Timer Ai increment/decrement flag) (b4 to b0) (i = 0 to 4)

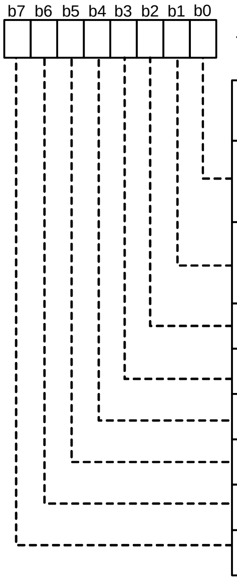
Enabled in event counter mode (when not using two-phase pulse signal processing).

TA2P (Timer A2 two-phase pulse signal processing select bit) (b5)
TA3P (Timer A3 two-phase pulse signal processing select bit) (b6)
TA4P (Timer A4 two-phase pulse signal processing select bit) (b7)

Set these bits to 0 when not using two-phase pulse signal processing.

17.2.15 Timer Ai Mode Register (TAiMR) (i = 0 to 4)

Timer Ai Mode Register (i = 0 to 4)



Symbol	Address	Reset Value
TA0MR to TA4MR	0336h to 033Ah	00h

Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 0 0 : Timer mode 0 1 : Event counter mode 1 0 : One-shot timer mode 1 1 : Pulse width modulation (PWM) mode or programmable output mode	RW
TMOD1			RW
MR0	Function varies with the operation mode		RW
MR1			RW
MR2			RW
MR3			RW
TCK0	Function varies with operation mode		RW
TCK1			RW

17.3 Operations

17.3.1 Common Operations

17.3.1.1 Operating Clock

The count source for each timer acts as a clock, controlling such timer operations as counting and reloading.

If the conditions to start counting are met, the stopped counter starts counting at the count timing of the first count source. For this reason, a delay exists between when the count start conditions are met and the counter starts counting. Figure 17.4 shows Output Example of One-Shot Timer Mode.

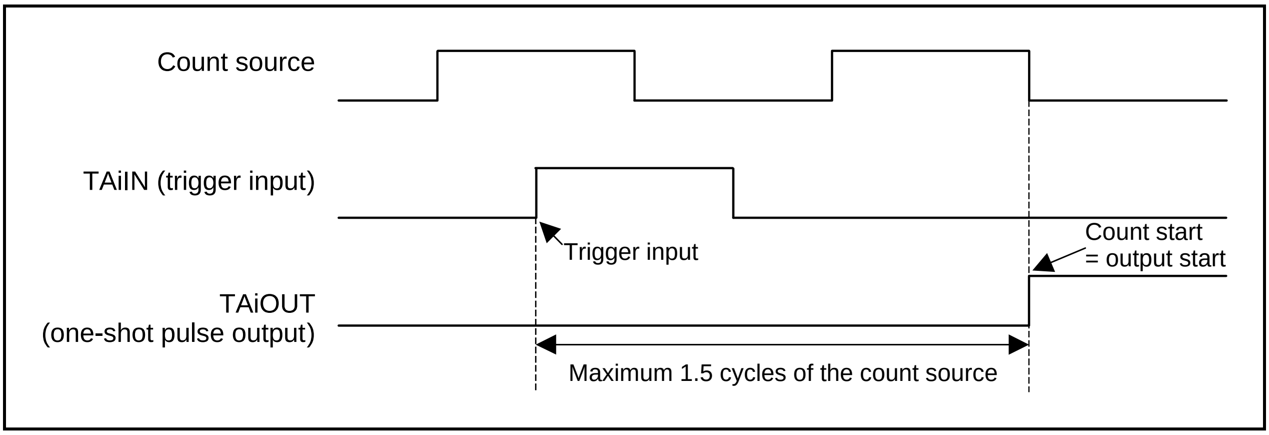


Figure 17.4 Output Example of One-Shot Timer Mode

17.3.1.2 Counter Reload Timing

Timer Ai starts counting from the value set (n) in the TAi register. The TAi register consists of a counter and a reload register. The counter starts decrementing the count source from n, reloads a value in the reload register at the next count source after the value becomes 0000h, and continues decrementing. When incrementing, the counter reloads a value in the reload register at the next count source after the value becomes FFFFh.

The value written in the TAi register is reflected in the counter and the reload register at the following timings:

- When the count is stopped
- Between when the count starts and when the first count source is input
  A value written to the TAi register is immediately written to the counter and the reload register.

- After the count starts and the first count source is input
  A value written to the TAi register is immediately written to the reload register. The counter continues counting and reloads the value in the reload register at the next count source after the value becomes 0000h (or FFFFh).

17.3.1.3 Count Source

Internal clocks are counted in timer mode, one-shot timer mode, PWM mode, and programmable output mode. Refer to Figure 17.1 “Timer A and B Count Sources” for details. Table 17.5 lists the Timer A Count Sources.

f1 is any of the clocks listed below (refer to 8. “Clock Generator” for details).

- Main clock divided by 1 (no division)
- PLL clock divided by 1 (no division)
- fOCO-S divided by 1 (no division)
- fOCO-F divided by 1 (no division)

When f1 or the main clock is used for the timer A and timer B count source, set the PCKSTP11 bit in the PCLKSTP1 register to 0 (f1 supply enabled).

When the clock mode is PLL operating mode, high-speed mode, medium-speed mode, or wait mode, the main clock can be used for the timer A and timer B count source instead of f1. Use the PCKSTP17 bit in the PCLKSTP1 register to select the clock (refer to 17.2.3 “Peripheral Clock Stop Register 1 (PCLKSTP1)”).

When using wait mode, if the CM02 bit in the CM0 register is set to 1 (peripheral function clock f1 stops in wait mode) before entering wait mode, the main clock is also stopped. Therefore, when the PCKSTP17 bit is 1 and timer A or timer B is used while in wait mode, do not set the CM02 bit to 1.

Table 17.5 Timer A Count Sources

Count Source	Bit Setting Value				Remarks
	PCLK0	TCS3	TCS2 to TCS0	TCK1 to TCK0	
		TCS7	TCS6 to TCS4		
f1TIMAB	1	0	-	00b	f1 or fOCO-F (1)
		1	000b	-	
f2TIMAB	0	0	-	00b	f1 divided by 2 or fOCO-F divided by 2 (1)
		1	000b	-	
f8TIMAB	-	0	-	01b	f1 divided by 8 or fOCO-F divided by 8 (1)
		1	001b	-	
f32TIMAB	-	0	-	10b	f1 divided by 32 or fOCO-F divided by 32 (1)
		1	010b	-	
f64TIMAB	-	1	011b	-	f1 divided by 64 or fOCO-F divided by 64 (1)
fOCO-F	-	1	100b	-	fOCO-F
fOCO-S	-	1	101b	-	fOCO-S
fC32	-	0	-	11b	fC32
		1	110b	-	

PCLK0: Bit in the PCLKR register
TCS7 to TCS0: Bits in registers TACS0 to TACS2
TCK1 to TCK0: Bits in the TAiMR register (i = 0 to 4)

Note:

1. Set the TCDIV00 bit in the TCKDIVC0 register to select f1 or fOCO-F.

When in PLL operating mode, high-speed mode, medium-speed mode, or wait mode, the main clock can be used for the timer A and timer B count source instead of f1. Use the PCKSTP17 bit in the PCLKSTP1 register to select the clock (refer to 17.2.3 “Peripheral Clock Stop Register 1 (PCLKSTP1)”).

17.3.2 Timer Mode

In timer mode, the timer counts an internally generated count source. Table 17.6 lists Timer Mode Specifications, Table 17.7 lists Registers and the Setting in Timer Mode, and Figure 17.5 shows an Operation Example in Timer Mode.

Table 17.6 Timer Mode Specifications

Item	Specification
Count source	f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32
Count operation	• Decrement • When the timer underflows, it reloads the reload register value and continues counting.
Counter cycles	$\frac{(n + 1)}{fj}$ n: set value of TAi register, 0000h to FFFFh fj: frequency of count source
Count start condition	Set the TAiS bit in the TABSR register to 1 (start counting).
Count stop condition	Set the TAiS bit to 0 (stop counting).
Interrupt request generation timing	Timer underflow
TAiIN pin function	I/O port or gate input
TAiOUT pin function	I/O port or pulse output
Read from timer	The count value can be read by reading the TAi register.
Write to timer	• When not counting Value written to the TAi register is written to both the reload register and counter. • When counting Value written to the TAi register is only written to reload register (transferred to counter when reloaded next).
Selectable functions	• Gate function Counting can be started and stopped by an input signal to the TAiIN pin. • Pulse output function Whenever the timer underflows, the output polarity of the TAiOUT pin is inverted. When the TAiS bit is set to 0 (stop counting), the pin outputs a low-level signal. • Output polarity control The output polarity of the TAiOUT pin is inverted. (While the TAiS bit is set to 0 (stop counting), a high-level signal is output.)

i = 0 to 4

Table 17.7 Registers and Settings in Timer Mode [1]

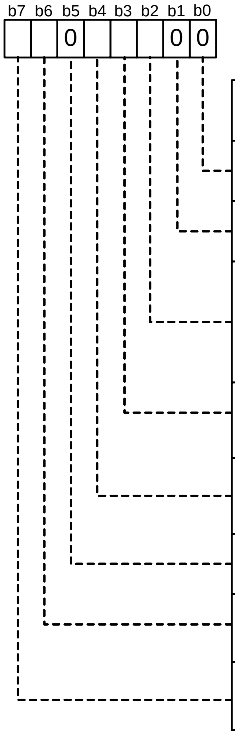
Register	Bit	Function and Setting
PCLKR	PCLK0	Select the count source.
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TCKDIVC0	TCDIV00	Select the clock used prior to timer AB frequency dividing.
PWMFS	PWMFSi	Set to 0.
TACS0 to TACS2	7 to 0	Select the count source.
TAPOFS	POFSi	Select the output polarity when the MR0 bit in the TAiMR register is 1 (pulse output).
TAOW	TAiOW	Set to 0.
TAi1	15 to 0	- (does not need to be set)
TABSR	TAiS	Set to 1 when starting counting. Set to 0 when stopping counting.
ONSF	TAiOS	Set to 0.
	TAZIE	Set to 0.
	TA0TGH to TA0TGL	Set to 00b.
TRGSR	TAiTGH to TAiTGL	Set to 00b.
UDF	TAiUD	Set to 0.
	TAiP	Set to 0.
TAi	15 to 0	Set the counter value.
TAiMR	7 to 0	Refer to the TAiMR register below

i = 0 to 4

Note:

1. This table does not describe a procedure.

Timer Mode
Timer Ai Mode Register (i = 0 to 4)



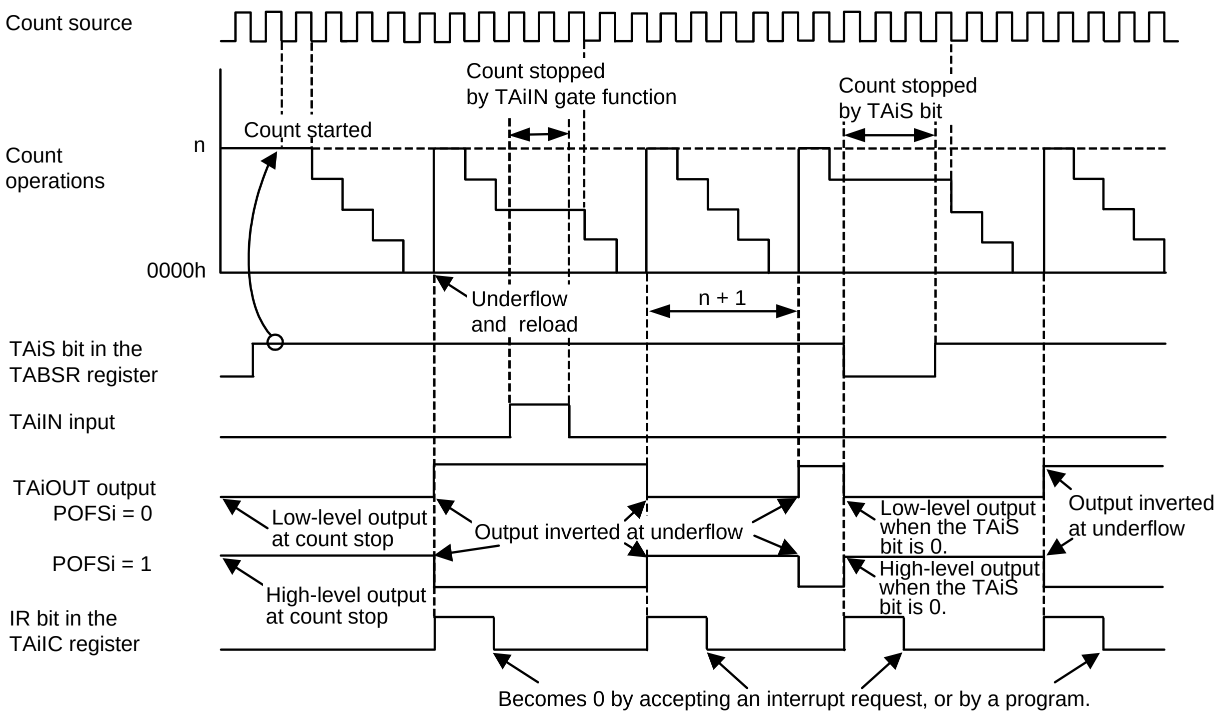
Symbol	Address	Reset Value
TA0MR to TA4MR	0336h to 033Ah	00h

Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 0 0 : Timer mode	RW
TMOD1			RW
MR0	Pulse output function select bit	0 : No pulse output (TAiOUT pin functions as I/O port) 1 : Pulse output (TAiOUT pin functions as a pulse output pin)	RW
MR1	Gate function select bit	b4 b3 0 0 : } Gate function not available 0 1 : } (TAiIN pin functions as I/O port) 1 0 : Counts while input on the TAiIN pin is low 1 1 : Counts while input on the TAiIN pin is high	RW
MR2			RW
MR3	Set to 0 in timer mode		RW
TCK0	Count source select bit	b7 b6 0 0 : f1TIMAB or f2TIMAB 0 1 : f8TIMAB 1 0 : f32TIMAB 1 1 : fC32	RW
TCK1			

TCK1-TCK0 (Count source select bit) (b7-b6)

These bits are enabled when the TCS3 bit or TCS7 bit in registers TACS0 to TACS2 is set to 0 (TCK0 to TCK1 enabled).

Set the PCLK0 bit in the PCLKR register to select f1TIMAB or f2TIMAB.


Count source
Count stopped by TAiIN gate function
Count stopped by TAiS bit
Count started
n
Count operations
0000h
Underflow and reload
n + 1
TAiS bit in the TABSR register
TAiIN input
TAiOUT output
POFSi = 0
Low-level output at count stop
Output inverted at underflow
Low-level output when the TAiS bit is 0.
Output inverted at underflow
POFSi = 1
High-level output at count stop
High-level output when the TAiS bit is 0.
IR bit in the TAiIC register
Becomes 0 by accepting an interrupt request, or by a program.

i = 0 to 4
POFSi : Bit in the TAPOFS register

The above timing diagram assumes the following:
- The MR0 bit in the TAiMR register = 1 (pulse output)
- Bits MR2 to MR1 in the TAiMR register = 10b (counts while a low-level signal is applied to the TAiIN pin)
- The TAi register (n) value = 0004h

Figure 17.5 Operation Example in Timer Mode

17.3.3 Event Counter Mode (When Not Using Two-Phase Pulse Signal Processing)

In event counter mode, the timer counts pulses from an external device, or overflows/underflows of other timers. Timers A2, A3, and A4 can count two-phase external signals. Refer to 17.3.4 “Event Counter Mode (When Processing Two-Phase Pulse Signal)” for details. Table 17.8 lists Event Counter Mode Specifications (When Not Using Two-Phase Pulse Signal Processing). Table 17.9 lists Registers and the Setting in Event Counter Mode (When Not Processing Two-Phase Pulse Signal). Figure 17.6 shows Operation Example in Event Counter Mode.

Table 17.8 Event Counter Mode Specifications (When Not Using Two-Phase Pulse Signal Processing)

Item	Specification
Count source	• External signals input to the TAiIN pin (active edge can be selected) • Timer B2 overflows or underflows • Timer Aj overflows or underflows (j = i - 1, except j = 4 if i = 0) • Timer Ak overflows or underflows (k = i + 1, except k = 0 if i = 4)
Count operations	• Increment or decrement can be selected by a program. • When the timer overflows or underflows, it reloads the reload register value and continues counting. When selecting free-run type, the timer continues counting without reloading.
Number of counts	When selecting reload type: • FFFFh - n + 1 for increment • n + 1 for decrement n: setting value of the TAi register, 0000h to FFFFh
Count start condition	Set the TAiS bit in the TABSR register to 1 (start counting).
Count stop condition	Set the TAiS bit to 0 (stop counting).
Interrupt request generation timing	Timer overflow or underflow
TAiIN pin function	I/O port or count source input
TAiOUT pin function	I/O port or pulse output
Read from timer	Count value can be read by reading the TAi register.
Write to timer	• When not counting Value written to the TAi register is written to both the reload register and counter. • When counting Value written to the TAi register is written to only reload register (transferred to counter when reloaded next).
Selectable functions	• Free-run count function Even when the timer overflows or underflows, the reload register content is not reloaded. • Pulse output function Whenever the timer underflows or underflows, the output polarity of the TAiOUT pin is inverted. When the TAiS bit is set to 0 (stop counting), the pin outputs a low-level signal. • Output polarity control The output polarity of the TAiOUT pin is inverted. (While the TAiS bit is set to 0 (stop counting), a high-level signal is output.)

i = 0 to 4

Table 17.9 Registers and Settings in Event Counter Mode (When Not Using Two-Phase Pulse Signal Processing) (1)

Register	Bit	Function and Setting
PCLKR	PCLK0	- (setting unnecessary)
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	- (setting unnecessary)
	PCKSTP17	- (setting unnecessary)
TCKDIVC0	TCDIV00	- (setting unnecessary)
PWMFS	PWMFSi	Set to 0.
TACS0 to TACS2	7 to 0	- (setting unnecessary)
TAPOFS	POFSi	Select the output polarity when the MR0 bit in the TAiMR register is 1 (pulse output).
TAOW	TAiOW	Set to 0.
TAi1	15 to 0	- (setting unnecessary)
TABSR	TAiS	Set to 1 when starting counting. Set to 0 when stopping counting.
ONSF	TAiOS	Set to 0.
	TAZIE	Set to 0.
	TA0TGH to TA0TGL	Select a count source.
TRGSR	TAiTGH to TAiTGL	Select a count source.
UDF	TAiUD	Select a count operation.
	TAiP	Set to 0.
TAi	15 to 0	Set the counter value.
TAiMR	7 to 0	Refer to the TAiMR register below.

i = 0 to 4

Note:

1. This table does not describe a procedure.

Event Counter Mode (When Not Using Two-Phase Pulse Signal Processing)
Timer Ai Mode Register (i = 0 to 4)

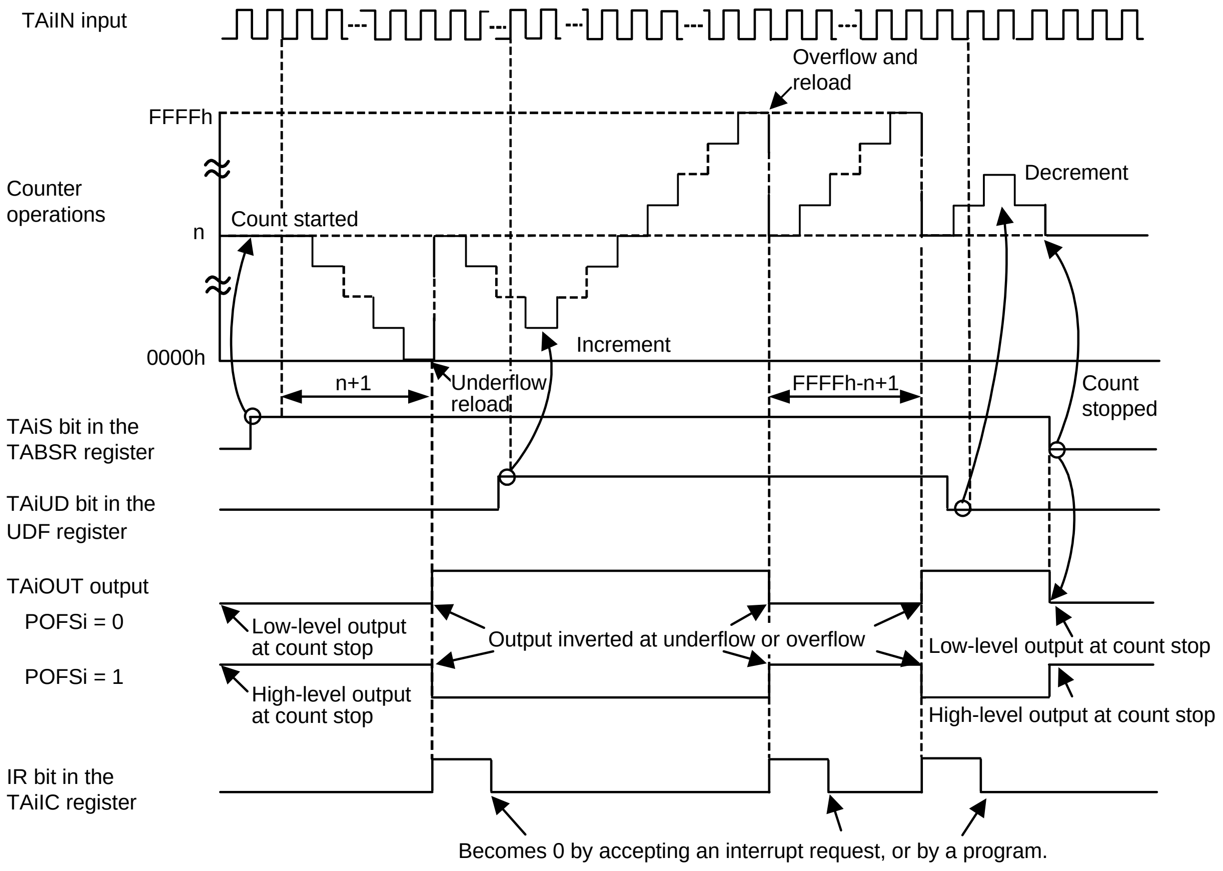
b7	b6	b5	b4	b3	b2	b1	b0
		0	0			0	1

Symbol	Address	Reset Value
TA0MR to TA4MR	0336h to 033Ah	00h

Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 0 1 : Event counter mode	RW
TMOD1			RW
MR0	Pulse output function select bit	0 : Pulse is not output (TAiOUT pin functions as I/O port) 1 : Pulse is output (TAiOUT pin functions as pulse output pin)	RW
MR1	Count polarity select bit	0 : Counts falling edge of an external signal 1 : Counts rising edge of an external signal	RW
MR2	Set to 0 in event counter mode		RW
MR3	Set to 0 in event counter mode		RW
TCK0	Count operation type select bit	0 : Reload type 1 : Free-run type	RW
TCK1	Can be 0 or 1 when not using two-phase pulse signal processing		RW

MR1 (Count polarity select bit) (b3)

This bit is enabled when bits TAiTGH to TAiTGL in the ONSF or TRGSR register are 00b (TAiIN pin input).


TAiIN input
Overflow and reload
FFFFh
Counter operations
n
Count started
Decrement
0000h
Increment
n+1
Underflow reload
FFFFh-n+1
Count stopped
TAiS bit in the TABSR register
TAiUD bit in the UDF register
TAiOUT output
POFSi = 0
POFSi = 1
Low-level output at count stop
Output inverted at underflow or overflow
Low-level output at count stop
High-level output at count stop
High-level output at count stop
IR bit in the TAiIC register
Becomes 0 by accepting an interrupt request, or by a program.

i = 0 to 4
n: TAi register setting
POFSi: Bits in the TAPOFS register

The above timing diagram assumes the following:

- Bits TAiTGH to TAiTGL in the ONSF or TRGSR register	= 00b	} (The falling edges of the TAiIN pin input is counted.)
- The MR1 bit in the TAiMR register	= 0	
- The MR0 bit in the TAiMR register	= 1 (pulse output)	
- The TCK0 bit in the TAiMR register	= 0 (reload type)	

Figure 17.6 Operation Example in Event Counter Mode

17.3.4 Event Counter Mode (When Processing Two-Phase Pulse Signal)

Timers A2, A3, and A4 can be used to count two-phase pulse signals. Table 17.10 lists Event Counter Mode Specifications (When Processing Two-Phase Pulse Signal with Timers A2, A3, and A4). Table 17.11 lists Registers and the Setting in Event Counter Mode (When Processing Two-Phase Pulse Signal).

Table 17.10 Event Counter Mode Specifications (When Processing Two-Phase Pulse Signal with Timers A2, A3, and A4)

Item	Specification
Count source	Two-phase pulse signals input to the TAiIN or TAiOUT pin
Count operations	• Increment or decrement can be selected by a two-phase pulse signal. • When the timer overflows or underflows, it reloads the reload register value and continues counting. When selecting free-run type, the timer continues counting without reloading.
Number of counts	When selecting reload type: • FFFFh - n + 1 when incrementing • n + 1 when decrementing n: setting value of the TAi register, 0000h to FFFFh
Count start condition	Set the TAiS bit in the TABSR register to 1 (start counting).
Count stop condition	Set the TAiS bit to 0 (stop counting).
Interrupt request generation timing	Timer overflow or underflow
TAiIN pin function	Two-phase pulse input
TAiOUT pin function	Two-phase pulse input
Read from timer	Count value can be read by reading timer A2, A3, or A4 register.
Write to timer	• When not counting Value written to the TAi register is written to both the reload register and counter. • When counting Value written to the TAi register is written to only reload register (transferred to counter when reloaded next).
Selectable functions	• Select normal or multiply-by-4 processing operation (timer A3). • Counter initialization by Z-phase input (timer A3) The timer count value is initialized to 0 by Z-phase input.

i = 2 to 4

Table 17.11 **Registers and Settings in Event Counter Mode (When Processing Two-Phase Pulse Signal) (1)**

Register	Bit	Function and Setting
PCLKR	PCLK0	- (setting unnecessary)
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	- (setting unnecessary)
	PCKSTP17	- (setting unnecessary)
TCKDIVC0	TCDIV00	- (setting unnecessary)
PWMFS	PWMFSi	Set to 0.
TACS0 to TACS2	7 to 0	- (setting unnecessary)
TAPOFS	POFSi	Set to 0.
TAOW	TAiOW	Set to 0.
TAi1	15 to 0	- (setting unnecessary)
TABSR	TAiS	Set to 1 when starting counting. Set to 0 when stopping counting.
ONSF	TAiOS	Set to 0.
	TAZIE	Set to 1 when using Z-phase input with timer A3.
	TA0TGH to TA0TGL	- (setting unnecessary)
TRGSR	TAiTGH to TAiTGL	Set to 00b.
UDF	TAiUD	Set to 0.
	TAiP	Set to 1.
TAi	15 to 0	Set the counter value.
TAiMR	7 to 0	Refer to the TAiMR register below.

i = 2 to 4

Note:

1. This table does not describe a procedure.

Event Counter Mode (When Using Two-Phase Pulse Signal Processing)
Timer Ai Mode Register (i = 2 to 4)

b7	b6	b5	b4	b3	b2	b1	b0
		0	1	0	0	0	1

Symbol	Address	Reset Value
TA2MR to TA4MR	0338h to 033Ah	00h

Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 0 1 : Event counter mode	RW
TMOD1			RW
MR0	Set to 0 to use two-phase signal processing		RW
MR1	Set to 0 to use two-phase signal processing		RW
MR2	Set to 1 to use two-phase signal processing		RW
MR3	Set to 0 to use two-phase signal processing		RW
TCK0	Count operation type select bit	0 : Reload type 1 : Free-run type	RW
TCK1	Two-phase pulse signal processing operation type select bit	0 : Normal processing operation 1 : Multiply-by-4 processing operation	RW

TCK1 (Two-phase pulse signal processing operation type select bit) (b7)

The TCK1 bit can be set only for timer A3. No matter how this bit is set, timers A2 and A4 always operate in normal processing mode and multiply-by-4 processing mode, respectively.

17.3.4.1 Normal Processing

The timer increments at rising edges or decrements at falling edges on the TAjIN pin when input signals to the TAjOUT (j = 2, 3) pin is high level.

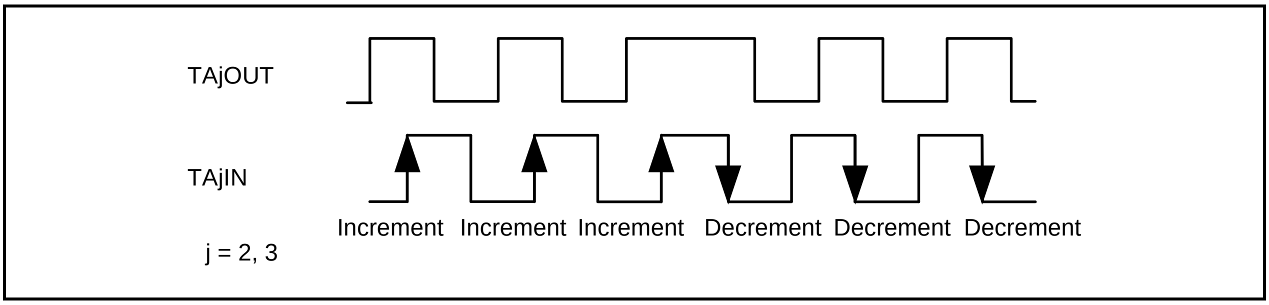


Figure 17.7 Normal Processing

17.3.4.2 Multiply-by-4 Processing

If the phase relationship is such that the input signal to the TAkIN pin goes high while the input signal to the TAkOUT pin (k = 3, 4) is high, the timer increments at both rising and falling edges of the input signal to pins TAkOUT and TAkIN. If the phase relationship is such that the input signal to the TAkIN pin goes low while the input signal to the TAkOUT pin is high, the timer decrements at both rising and falling edges of the input signal to pins TAkOUT and TAkIN.

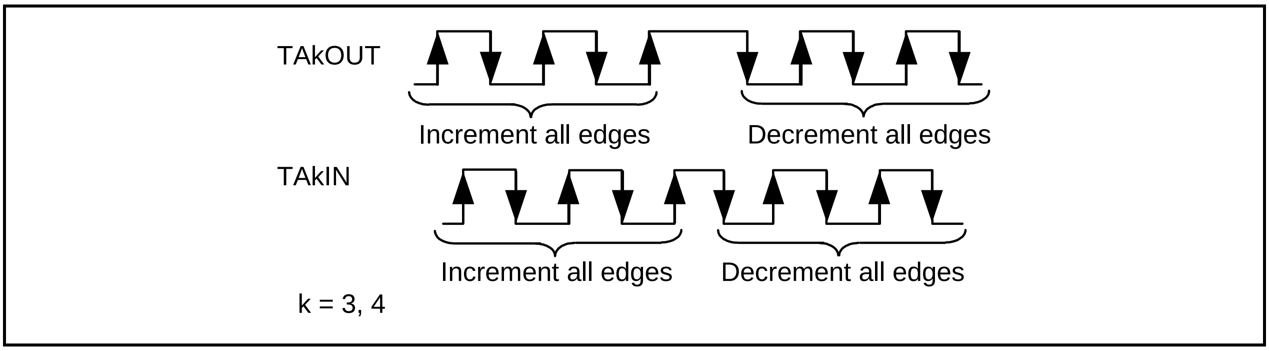


Figure 17.8 Multiply-by-4 Processing

17.3.4.3 Counter Initialization Using Two-Phase Pulse Signal Processing

This function initializes the timer count value to 0000h using Z-phase (counter initialization) input during two-phase pulse signal processing.

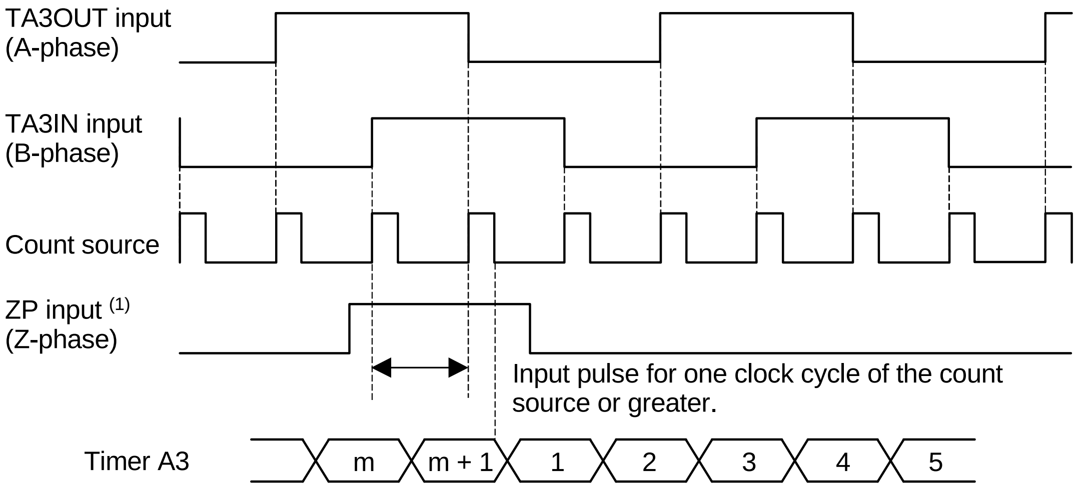
This function can only be used in timer A3 event counter mode during two-phase pulse signal processing, free-running type, multiply-by-4 processing, with Z-phase entered from the ZP pin.

Counter initialization by Z-phase input is enabled by writing 0000h to the TA3 register and setting the TAZIE bit in the ONSF register to 1 (Z-phase input enabled).

Counter initialization is accomplished by Z-phase input edge detection. The rising or falling edge can be selected as the active edge by setting the POL bit in the INT2IC register. The Z-phase pulse width must be equal to or greater than one clock cycle of the timer A3 count source.

The counter is initialized at the next count timing after accepting Z-phase input. Figure 17.9 shows the Relationship between the Two-Phase Pulse (A-Phase and B-Phase) and the Z-Phase.

When timer A3 overflow or underflow coincides with counter initialization by Z-phase input, a timer A3 interrupt request is generated twice in succession. Do not use the timer A3 interrupt when using this function.



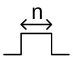
Note:
1. This timing diagram assumes when the POL bit in the INT2IC register is 1 (rising edge).

Figure 17.9 Relationship between the Two-Phase Pulse (A-Phase and B-Phase) and the Z-Phase

17.3.5 One-Shot Timer Mode

In one-shot timer mode, the timer is activated only once per trigger. When the trigger occurs, the timer starts and continues operating for a given period. Table 17.12 lists One-Shot Timer Mode Specifications. Table 17.13 lists Registers and the Setting in One-Shot Timer Mode. Figure 17.10 shows Operation Example in One-Shot Timer Mode.

Table 17.12 One-Shot Timer Mode Specifications

Item	Specification
Count source	f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32
Count operations	• Decrement • When the timer counter reaches 0000h, it stops running after the reload register value is reloaded • When a trigger occurs while counting, the reload register value is reloaded into the counter to continue counting
Pulse width	$\frac{n}{fj}$  n: Set value of the TAi register, 0000h to FFFFh However, the counter does not run if 0000h is set. fj: Count source frequency
Count start condition	The TAiS bit in the TABSR register is 1 (start counting) and one of the following triggers occurs: • External trigger input from the TAiIN pin • Timer B2 overflow or underflow • Timer Aj overflow or underflow (j = i - 1, except j = 4 if i = 0) • Timer Ak overflow or underflow (k = i + 1, except k = 0 if i = 4) • The TAiOS bit in the ONSF register is set to 1 (one-shot timer start).
Count stop condition	• When the counter is reloaded after reaching 0000h • The TAiS bit is set to 0 (stop counting)
Interrupt request generation timing	When the counter reaches 0000h
TAiIN pin function	I/O port or trigger input
TAiOUT pin function	I/O port or pulse output
Read from timer	An undefined value is read when reading the TAi register.
Write to timer	• When not counting and until the first count source is input after counting starts, the value written to the TAi register is written to both the reload register and counter. • When counting (after the first count source input), the value written to the TAi register is written to only the reload register (transferred to the counter when reloaded next time).
Selectable functions	• Pulse output function The timer outputs a low-level signal when not counting and a high-level signal when counting. • Output polarity control The output polarity of the TAiOUT pin is inverted. (While the TAiS bit is set to 0 (stop counting), a high-level signal is output.)

i = 0 to 4

Table 17.13 Registers and Settings in One-Shot Timer Mode [1]

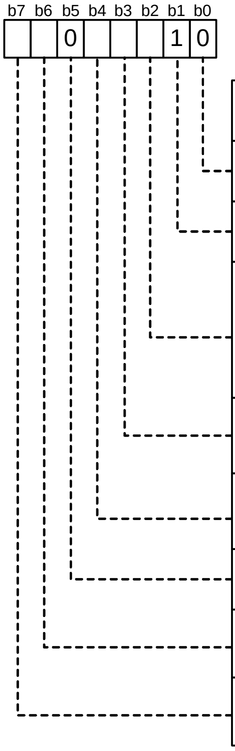
Register	Bit	Setting
PCLKR	PCLK0	Select the count source.
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TCKDIVC0	TCDIV00	Select a clock used prior to dividing timer AB frequency.
PWMFS	PWMFSi	Set to 0.
TACS0 to TACS2	7 to 0	Select the count source.
TAPOFS	POFSi	Select the output polarity when the MR0 bit in the TAiMR register is 1 (pulse output).
TAOW	TAiOW	Set to 0.
TAi1	15 to 0	- (setting unnecessary)
TABSR	TAiS	Set to 1 when starting counting. Set to 0 when stopping counting.
ONSF	TAiOS	Set to 1 when starting counting while the MR2 bit is 0.
	TAZIE	Set to 0.
	TA0TGH to TA0TGL	Select a count trigger.
TRGSR	TAiTGH to TAiTGL	Select a count trigger.
UDF	TAiUD	Set to 0.
	TAiP	Set to 0.
TAi	15 to 0	Set a high-level pulse width. [2]
TAiMR	7 to 0	Refer to the TAiMR register below.

i = 0 to 4

Notes:

1. This table does not describe a procedure.
2. This applies when the POFSi bit in the TAPOFS register is 0.

One-Shot Timer Mode
Timer Ai Mode Register (i = 0 to 4)



Symbol	Address	Reset Value
TA0MR to TA4MR	0336h to 033Ah	00h

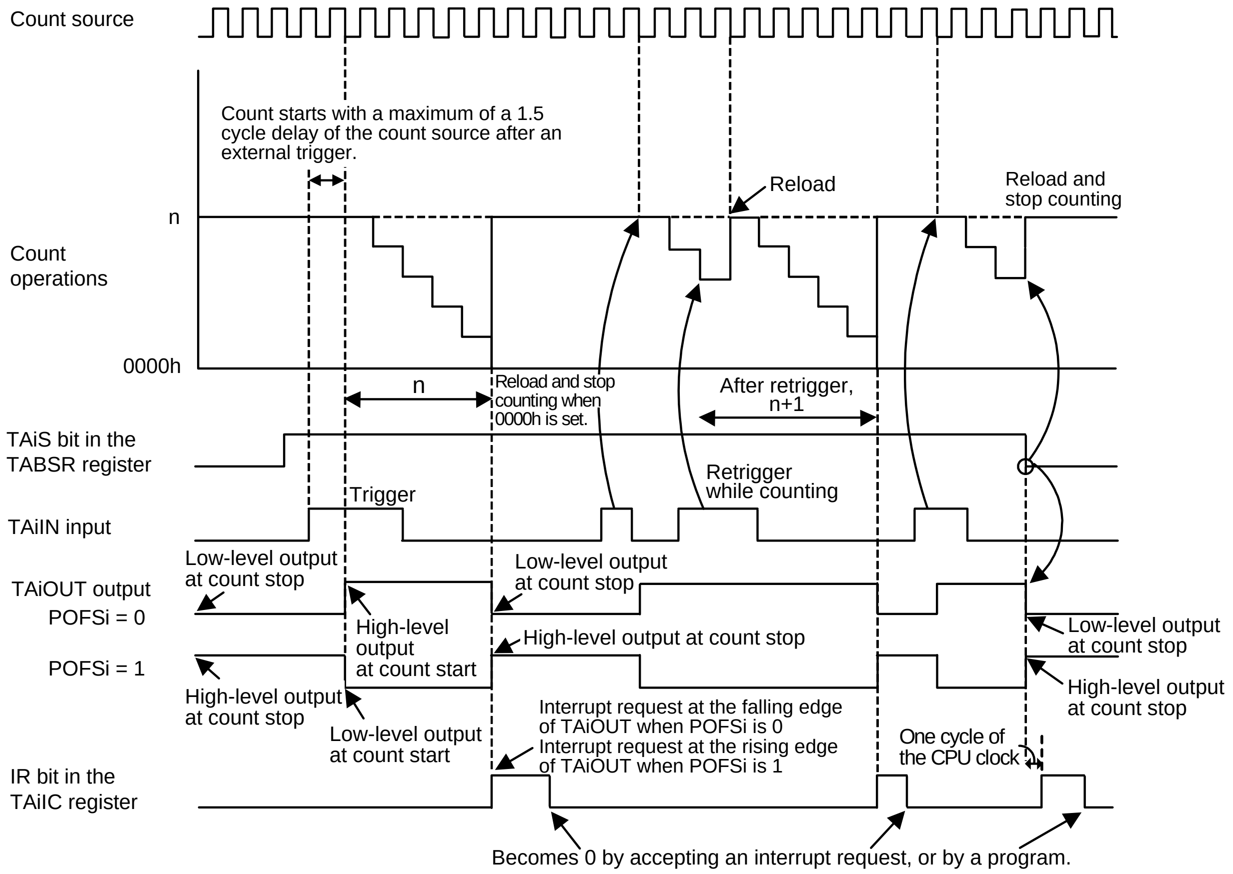
Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 1 0 : One-shot timer mode	RW
TMOD1			RW
MR0	Pulse output function select bit	0 : No pulse output (TAiOUT pin functions as an I/O port) 1 : Pulse output (TAiOUT pin functions as a pulse output pin)	RW
MR1	External trigger select bit	0 : Falling edge of input signal to TAiIN pin 1 : Rising edge of input signal to TAiIN pin	RW
MR2	Trigger select bit	0 : TAiOS bit enabled 1 : Selected by bits TAiTGH and TAiTGL	RW
MR3	Set to 0 in one-shot timer mode		RW
TCK0	Count source select bit	b7 b6 0 0 : f1TIMAB or f2TIMAB 0 1 : f8TIMAB 1 0 : f32TIMAB 1 1 : fC32	RW
TCK1			

MR1 (External trigger select bit) (b3)

This bit is enabled when the MR2 bit is 1 and bits TAiTGH to TAiTGL in the ONSF register or TRGSR register are set to 00b (TAiIN pin input).

TCK1 and TCK0 (Count source select bit) (b7-b6)

These bits are enabled when the TCS3 bit or TCS7 bit in registers TACS0 to TACS2 is set to 0 (TCK0 to TCK1 enabled).
Set the PCLK0 bit in the PCLKR register to select f1TIMAB or f2TIMAB.


Count source
Count starts with a maximum of a 1.5 cycle delay of the count source after an external trigger.
Reload
Reload and stop counting
n
Count operations
0000h
n
Reload and stop counting when 0000h is set.
After retrigger, n+1
TAiS bit in the TABSR register
Retrigger while counting
Trigger
TAiIN input
Low-level output at count stop
Low-level output at count stop
TAiOUT output
POFSi = 0
High-level output at count start
High-level output at count stop
Low-level output at count stop
POFSi = 1
High-level output at count stop
High-level output at count stop
Low-level output at count start
Interrupt request at the falling edge of TAiOUT when POFSi is 0
Interrupt request at the rising edge of TAiOUT when POFSi is 1
One cycle of the CPU clock
IR bit in the TAiIC register
Becomes 0 by accepting an interrupt request, or by a program.

i = 0 to 4
POFSi : Bits in the TAPOFS register

The above timing diagram assumes the following:

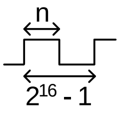
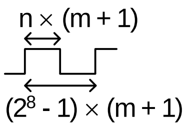
- The MR0 bit in the TAiMR register	= 1 (pulse output)	
- The MR1 bit in the TAiMR register	= 1	(The rising edge of the TAiIN pin input is the trigger.)
- The MR2 bit in the TAiMR register	= 1	
- Bits TAiTGH to TAiTGL in the ONSF or TRGSR register	= 00b	
- The TAi register (n) value	= 0005h	

Figure 17.10 Operation Example in One-Shot Timer Mode

17.3.6 Pulse Width Modulation (PWM) Mode

In PWM mode, the timer outputs pulses of a given width in succession. The counter functions as either a 16-bit pulse width modulator or 8-bit pulse width modulator. Table 17.14 lists PWM Mode Specifications. Table 17.15 lists Registers and the Setting in PWM Mode. Figure 17.11 and Figure 17.12 show Operation Example in 16-Bit Pulse Width Modulation Mode and Operation Example in 8-Bit Pulse Width Modulation Mode, respectively.

Table 17.14 PWM Mode Specifications

Item	Specification
Count sources	f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32
Count operations	• Decrement (operating as an 8-bit or a 16-bit pulse width modulator) • The timer reloads the reload register value at a rising edge of PWM pulse and continues counting. • The timer is not affected by a trigger that occurs during counting.
16-bit PWM	• Pulse width $\frac{n}{fj}$  • Cycle time $\frac{(2^{16}-1)}{fj}$ n: set value of the TAi register fj: count source frequency
8-bit PWM	• Pulse width $\frac{n \times (m+1)}{fj}$  • Cycle time $\frac{(2^8-1) \times (m+1)}{fj}$ m: set value of the TAi register lower address n: set value of the TAi register upper address fj: count source frequency
Count start condition	• The TAiS bit of the TABSR register is set to 1 (start counting). • The TAiS bit is 1 and external trigger input from the TAiIN pin • The TAiS bit is 1 and one of the following triggers occurs Timer B2 overflow or underflow Timer Aj overflow or underflow (j = i - 1, except j = 4 if i = 0) Timer Ak overflow or underflow (k = i + 1, except k = 0 if i = 4)
Count stop condition	The TAiS bit is set to 0 (stop counting).
Interrupt request generation timing	On the falling edge of the PWM pulse
TAiIN pin function	I/O port or trigger input
TAiOUT pin function	Pulse output
Read from timer	An undefined value is read when reading the TAi register.
Write to timer	• When not counting Value written to the TAi register is written to both the reload register and counter. • When counting Value written to the TAi register is written to only the reload register (transferred to counter when reloaded next time).
Selectable functions	• Output polarity control The output polarity of the TAiOUT pin is inverted. (While the TAiS bit is set to 0 (stop counting), a high-level signal is output).

i = 0 to 4

Table 17.15 Registers and Settings in PWM Mode [1]

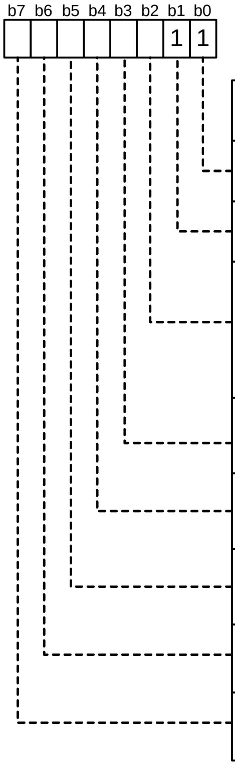
Register	Bit	Setting
PCLKR	PCLK0	Select the count source.
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TCKDIVC0	TCDIV00	Select the clock used prior to dividing timer AB frequency.
PWMFS	PWMFSi	Set to 0.
TACS0 to TACS2	7 to 0	Select the count source.
TAPOFS	POFSi	Select the output polarity.
TAOW	TAiOW	Set to 0.
TAi1	15 to 0	- (setting unnecessary)
TABSR	TAiS	Set to 1 when starting counting. Set to 0 when stopping counting.
ONSF	TAiOS	Set to 0.
	TAZIE	Set to 0.
	TA0TGH to TA0GL	Select a count trigger.
TRGSR	TAiTGH to TAiTGL	Select a count trigger.
UDF	TAiUD	Set to 0.
	TAiP	Set to 0.
TAi	15 to 0	Select the PWM pulse width and cycles.
TAiMR	7 to 0	Refer to the TAiMR register below.

i = 0 to 4

Note:

1. This table does not describe a procedure.

Pulse Width Modulation (PWM) Mode
Timer Ai Mode Register (i = 0 to 4)



Symbol	Address	Reset Value
TA0MR to TA4MR	0336h to 033Ah	00h

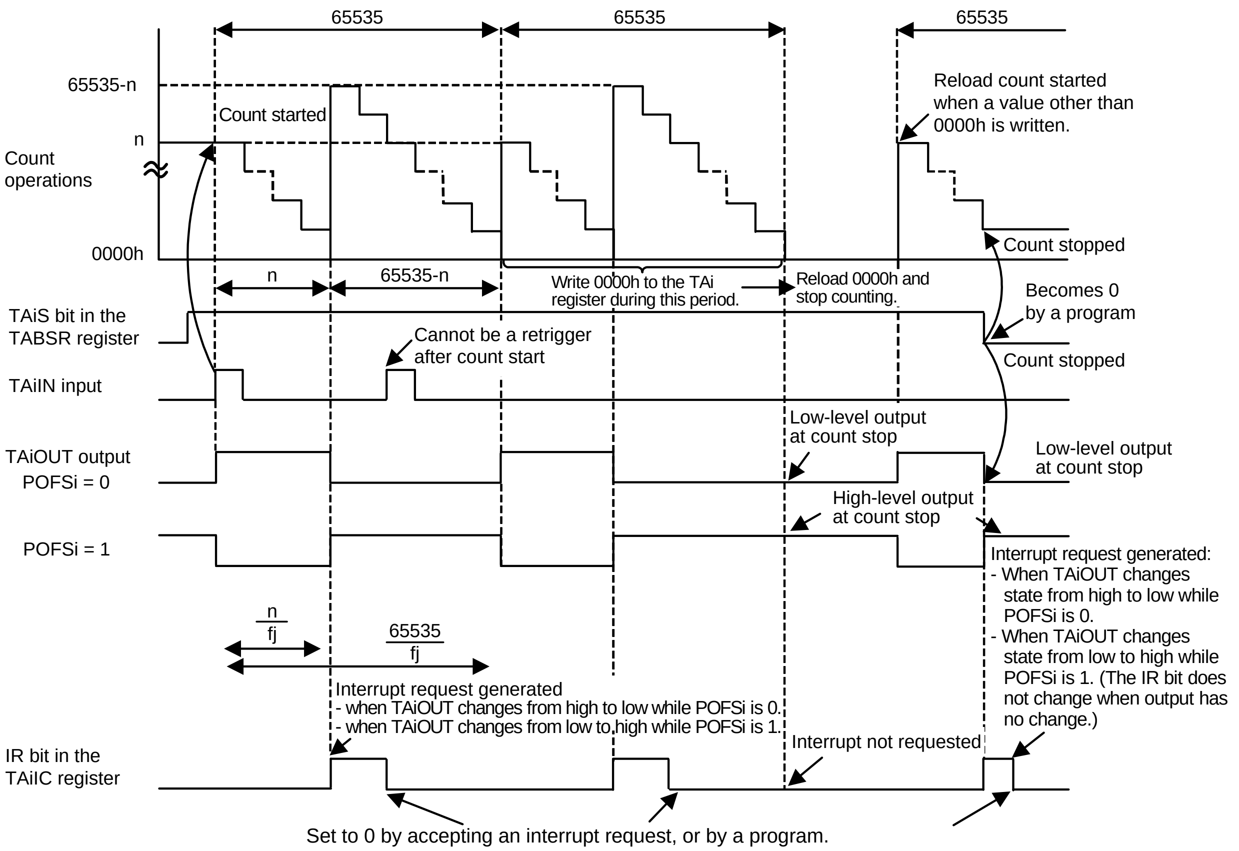
Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 1 1 : PWM mode or programmable output mode	RW
TMOD1			RW
MR0	Pulse output function select bit	0 : No pulse output (TAiOUT pin functions as I/O port) 1 : Pulse output (TAiOUT pin functions as a pulse output pin)	RW
MR1	External trigger select bit	0 : Falling edge of input signal to TAiIN pin 1 : Rising edge of input signal to TAiIN pin	RW
MR2	Trigger select bit	0 : Write 1 to the TAiS bit in the TABSR register 1 : Selected by bits TAiTGH to TAiTGL	RW
MR3	16-/8-bit PWM mode select bit	0 : 16-bit PWM mode 1 : 8-bit PWM mode	RW
TCK0	Count source select bit	b7 b6 0 0 : f1TIMAB or f2TIMAB 0 1 : f8TIMAB 1 0 : f32TIMAB 1 1 : fC32	RW
TCK1			

MR1 (External trigger select bit) (b3)

This bit is enabled when the MR2 bit is 1, and bits TAiTGH to TAiTGL in the ONSF register or TRGSR register are set to 00b (TAiIN pin input).

TCK1 and TCK0 (Count source select bit) (b7-b6)

These bits are enabled when the TCS3 bit or TCS7 bit in registers TACS0 to TACS2 is set to 0 (TCK0 to TCK1 enabled).
Set the PCLK0 bit in the PCLKR register to select f1TIMAB or f2TIMAB.


65535
65535
65535
65535-n
Count started
n
Count operations
0000h
Reload count started when a value other than 0000h is written.
Count stopped
n
65535-n
Write 0000h to the TAi register during this period.
Reload 0000h and stop counting.
Becomes 0 by a program
TAiS bit in the TABSR register
Cannot be a retrigger after count start
Count stopped
TAiIN input
Low-level output at count stop
TAiOUT output
POFSi = 0
Low-level output at count stop
High-level output at count stop
POFSi = 1
Interrupt request generated:
- When TAiOUT changes state from high to low while POFSi is 0.
- When TAiOUT changes state from low to high while POFSi is 1. (The IR bit does not change when output has no change.)
n/fj
65535/fj
Interrupt request generated
- when TAiOUT changes from high to low while POFSi is 0.
- when TAiOUT changes from low to high while POFSi is 1.
Interrupt not requested
IR bit in the TAiIC register
Set to 0 by accepting an interrupt request, or by a program.

i = 0 to 4
POFSi: Bit in the TAPOFS register
fj: Count source frequency

The above timing diagram assumes the following:
- The MR0 bit in the TAiMR register = 1 (pulse output)
- The MR3 bit in the TAiMR register = 0 (16-bit PWM mode)
- The MR1 bit in the TAiMR register = 1
- The MR2 bit in the TAiMR register = 1
- Bits TAiTGH to TAiTGL in the ONSF or TRGSR register = 00b

} The rising edge of the TAiIN pin input is the trigger.

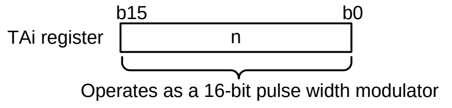
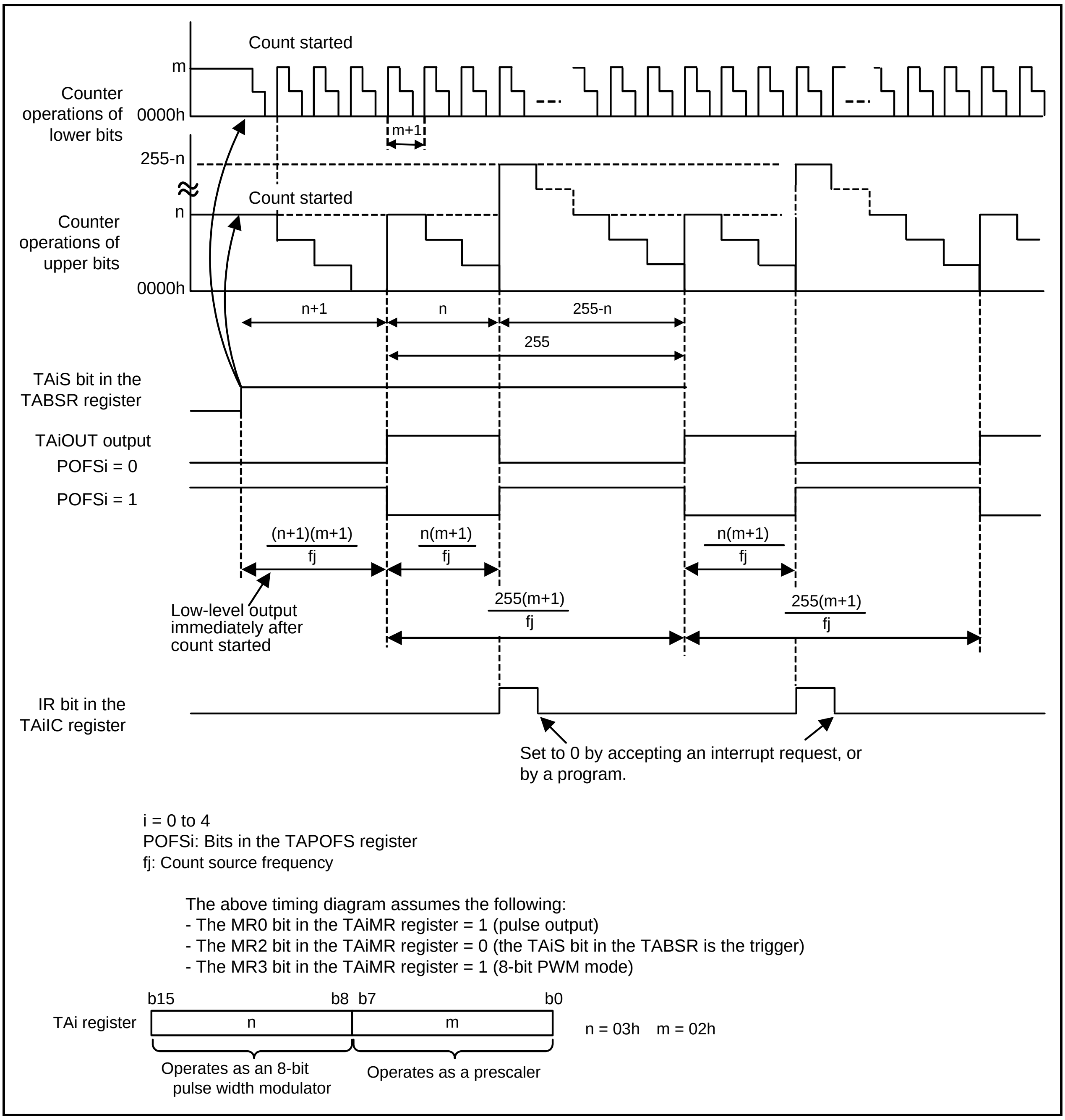


Figure 17.11 Operation Example in 16-Bit Pulse Width Modulation Mode


Count started
m
Counter operations of lower bits
0000h
m+1
255-n
Count started
n
Counter operations of upper bits
0000h
n+1
n
255-n
255
TAiS bit in the TABSR register
TAiOUT output
POFSi = 0
POFSi = 1
(n+1)(m+1) / fj
n(m+1) / fj
n(m+1) / fj
Low-level output immediately after count started
255(m+1) / fj
255(m+1) / fj
IR bit in the TAiIC register
Set to 0 by accepting an interrupt request, or by a program.
TAi register
b15
b8
b7
b0
n
m
n = 03h m = 02h
Operates as an 8-bit pulse width modulator
Operates as a prescaler

i = 0 to 4
POFSi: Bits in the TAPOFS register
fj: Count source frequency

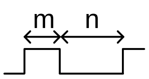
The above timing diagram assumes the following:
- The MR0 bit in the TAiMR register = 1 (pulse output)
- The MR2 bit in the TAiMR register = 0 (the TAiS bit in the TABSR is the trigger)
- The MR3 bit in the TAiMR register = 1 (8-bit PWM mode)

Figure 17.12 Operation Example in 8-Bit Pulse Width Modulation Mode

17.3.7 Programmable Output Mode (Timers A1, A2, and A4)

In programmable output mode, the timer outputs low- and high-levels of pulse width successively. Table 17.16 lists Programmable Output Mode Specifications. Table 17.17 lists Registers and the Setting in Programmable Output Mode. Figure 17.13 shows Operation Example in Programmable Output Mode.

Table 17.16 Programmable Output Mode Specifications

Item	Specification
Count sources	f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32
Count operations	• Decrement • The timer reloads the reload register value at the rising edge of pulse and continues counting • When a trigger occurs while counting, the timer is not affected.
Pulse width	• High-level pulse width $\frac{m}{fj}$  • Low-level pulse width $\frac{n}{fj}$ m: set value of the TAi register n: set value of the TAi1 register fj: count source frequency
Count start conditions	• The TAiS bit of the TABSR register is set to 1 (start counting). • The TAiS bit is 1 and external trigger input from the TAiIN pin • The TAiS bit is 1 and one of the following external triggers occurs: Timer B2 overflow or underflow Timer Aj overflow or underflow (j = i - 1) Timer Ak overflow or underflow (k = i + 1, except k = 0 if i = 4)
Count stop condition	The TAiS bit is set to 0 (stop counting).
Interrupt request generation timing	At the rising edge of pulse
TAiIN pin function	I/O port or trigger input
TAiOUT pin function	Pulse output
Read from timer	An undefined value is read when reading registers TAi and TAi1.
Write to timer	• When writing to registers TAi and TAi1 while not counting, the value is written to both reload register and counter. • When writing to registers TAi and TAi1 while counting, the value is written to the reload register. (transferred to the counter when reloaded next time).
Selectable functions	Output polarity control The output polarity of the TAiOUT pin is inverted. (While the TAiS bit is set to 0 (stop counting), a high-level signal is output.)

i = 1, 2, and 4

Table 17.17 Registers and Settings in Programmable Output Mode [1]

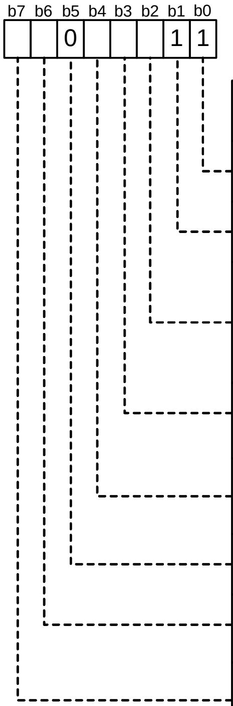
Register	Bit	Function and Setting
PCLKR	PCLK0	Select the count source.
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TCKDIVC0	TCDIV00	Select a clock used prior to dividing timer AB frequency.
PWMFS	PWMFSi	Set to 1.
TACS0 to TACS2	7 to 0	Select the count source.
TAPOFS	POFSi	Select the output polarity.
TAOW	TAiOW	Set to 0 to disable output waveform change, and set to 1 to enable output waveform change.
TAi1	15 to 0	Set a low-level pulse width. [2]
TABSR	TAiS	Set to 1 when starting counting. Set to 0 when stopping counting.
ONSF	TAiOS	Set to 0.
	TAZIE	Set to 0.
	TA0TGH to TA0TGL	Select a count trigger.
TRGSR	TAiTGH to TAiTGL	Select a count trigger.
UDF	TAiUD	Set to 0.
	TAiP	Set to 0.
TAi	15 to 0	Set a high-level pulse width. [2]
TAiMR	7 to 0	Refer to the TAiMR register below.

i = 1, 2, and 4

Notes:

1. This table does not describe a procedure.
2. This applies when the POFSi bit in the TAPOFS register is 0.

Programmable Output Mode
Timer Ai Mode Register (i = 1, 2, 4)



Symbol	Address	Reset Value
TA0MR to TA4MR	0336h to 033Ah	00h

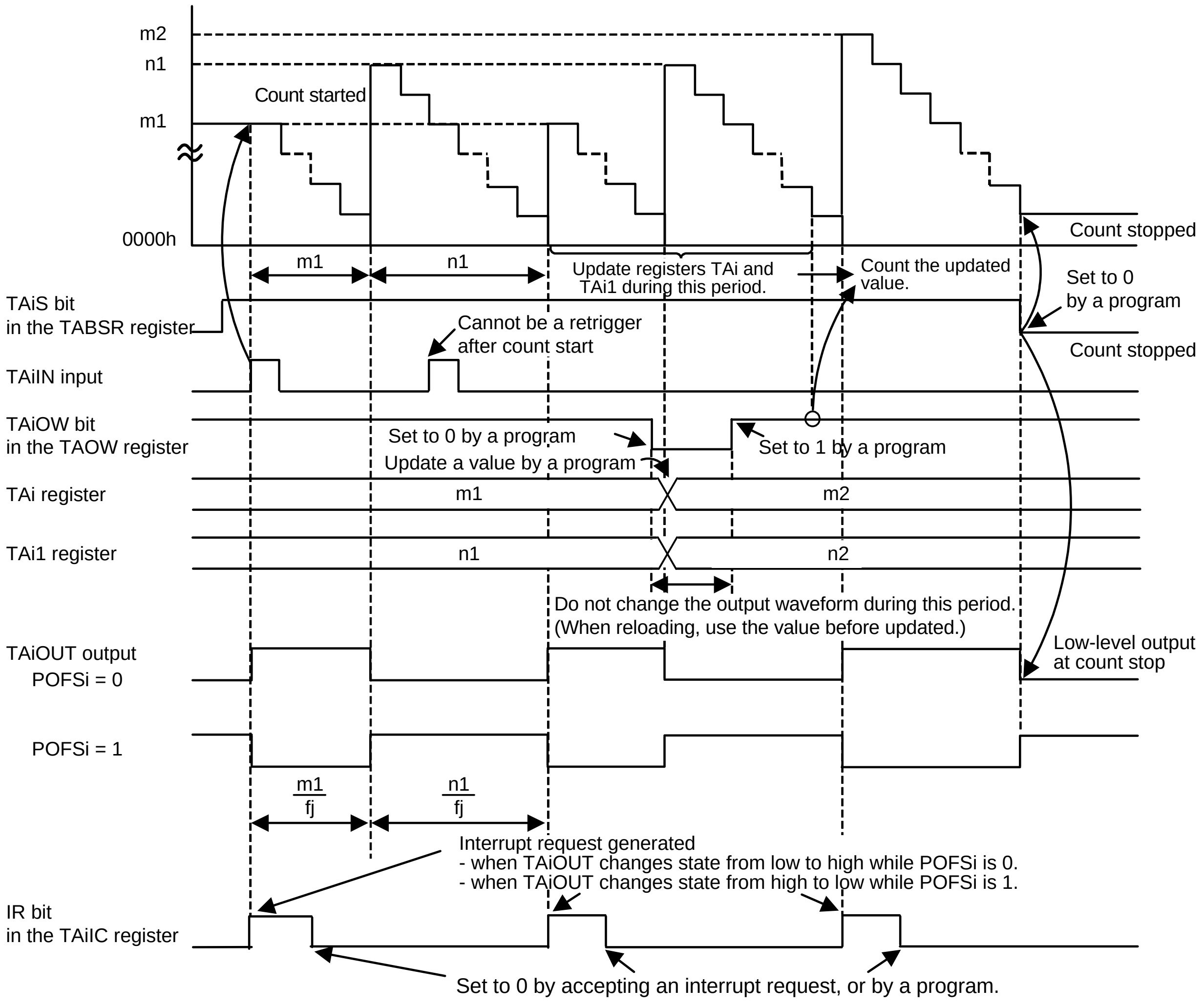
Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 1 1 : PWM mode or programmable output mode	RW
TMOD1			RW
MR0	Pulse output function select bit	0 : No pulse output (TAiOUT pin functions as an I/O port) 1 : Pulse output (TAiOUT pin functions as a pulse output pin)	RW
MR1	External trigger select bit	0 : Falling edge of input signal to TAiIN pin 1 : Rising edge of input signal to TAiIN pin	RW
MR2	Trigger select bit	0 : Write 1 to the TAiS bit in the TABSR register 1 : Selected by bits TAiTGH to TAiTGL	RW
MR3	Set to 0 in programmable output mode		RW
TCK0	Count source select bit	b7 b6 0 0 : f1TIMAB or f2TIMAB 0 1 : f8TIMAB 1 0 : f32TIMAB 1 1 : fC32	RW
TCK1			

MR1 (External trigger select bit) (b3)

This bit is enabled when the MR2 bit is 1, and bits TAiTGH to TAiTGL in the ONSF register or TRGSR register are set to 00b (TAiIN pin input).

TCK1 and TCK0 (Count source select bit) (b7-b6)

These bits are enabled when the TCS3 bit or TCS7 bit in registers TACS0 to TACS2 is set to 0 (TCK0 to TCK1 enabled).
Set the PCLK0 bit in the PCLKR register to select f1TIMAB or f2TIMAB.


m2
n1
m1
0000h
Count started
m1
n1
Update registers TAi and TAi1 during this period.
Count the updated value.
Count stopped
Set to 0 by a program
Count stopped
TAiS bit in the TABSR register
Cannot be a retrigger after count start
TAiIN input
TAiOW bit in the TAOW register
Set to 0 by a program
Update a value by a program
Set to 1 by a program
TAi register
m1
m2
TAi1 register
n1
n2
Do not change the output waveform during this period.
(When reloading, use the value before updated.)
TAiOUT output
POFSi = 0
Low-level output at count stop
POFSi = 1
m1/fj
n1/fj
Interrupt request generated
- when TAiOUT changes state from low to high while POFSi is 0.
- when TAiOUT changes state from high to low while POFSi is 1.
IR bit in the TAiIC register
Set to 0 by accepting an interrupt request, or by a program.

i = 1, 2, 4

The above timing diagram assumes the following:
- The MR0 bit in the TAiMR register = 1 (pulse output)
- The MR1 bit in the TAiMR register = 1
- The MR2 bit in the TAiMR register = 1
- Bits TAiTGH to TAiTGL in the ONSF or TRGSR register = 00b

} The rising edge of the TAiIN pin input is the trigger.

fj: Count source frequency
POFSi: Bits in the TAPOFS register

Figure 17.13 Operation Example in Programmable Output Mode

17.4 Interrupts

Refer to individual operation examples for interrupt request generating timing.

Refer to 14.7 “Interrupt Control” for details of interrupt control. Table 17.18 lists Timer A Interrupt Related Registers.

Table 17.18 Timer A Interrupt Related Registers

Address	Register	Symbol	Reset Value
0055h	Timer A0 Interrupt Control Register	TA0IC	XXXX X000b
0056h	Timer A1 Interrupt Control Register	TA1IC	XXXX X000b
0057h	Timer A2 Interrupt Control Register	TA2IC	XXXX X000b
0058h	Timer A3 Interrupt Control Register	TA3IC	XXXX X000b
0059h	Timer A4 Interrupt Control Register	TA4IC	XXXX X000b

The IR bit in the TAiIC register may become 1 (interrupt requested) when the TMOD1 bit in the TAiMR register is changed from 0 to 1 (change from timer mode or event counter mode to one-shot timer mode, PWM mode, or programmable output mode). Make sure to follow the procedure below when setting the TMOD1 bit to 1. Refer to 14.13 “Notes on Interrupts” for details.

(1)Set bits ILVL2 to ILVL0 in the TAiIC register to 000b (interrupt disabled).

(2)Set the TAiMR register.

(3)Set the IR bit in the TAiIC register to 0 (interrupt not requested).

17.5 Notes on Timer A

17.5.1 Common Notes on Multiple Modes

17.5.1.1 Register Setting

The timer stops after reset. Set the mode, count source, counter value, etc., using registers TAiMR, TAi, TAi1, UDF, TRGSR, PWMFS, TACS0 to TACS2, TAPOFS, TCKDIVC0, PCLKR, and bits TAZIE, TA0TGL, and TA0TGH in the ONSF register before setting the TAiS bit in the TABSR register to 1 (count started) (i = 0 to 4).
Set the TCDIV00 bit in the TCKDIVC0 register before setting other registers associated with timer A. After changing the TCDIV00 bit, set other registers associated with timer A again.
Always make sure registers TAiMR, UDF, TRGSR, PWMFS, TACS0 to TACS2, TAPOFS, TCKDIVC0, PCLKR, and bits TAZIE, TA0TGL, TA0TGH in the ONSF register are modified while the TAiS bit is 0 (count stopped), regardless of whether after reset or not.

17.5.1.2 Event or Trigger

When bits TAiTGH to TAiTGL in the registers ONSF or TRGSR are 01b, 10b, or 11b, an event or a trigger occurs when an interrupt request of the selected timer is generated. An event or trigger occurs while an interrupt is disabled because an interrupt request signal is generated regardless of the I flag, IPL, or interrupt control registers.
For some modes of the timers selected using bits TAiTGH to TAiTGL, an interrupt request is generated by a source other than overflow or underflow.
For example, when using pulse-period measurement mode or pulse-width measurement mode in timer B2, an interrupt request is generated at an active edge of the measurement pulse. For details, refer to the “Interrupt request generation timing” in each mode’s specification table.

17.5.1.3 Influence of $\overline{\text{SD}}$

When a low-level signal is applied to the $\overline{\text{SD}}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{\text{SD}}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$/TA1IN/$\overline{\text{V}}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{\text{W}}$, P8_0/TA4OUT/RXD5/SCL5/U, P8_1/TA4IN/$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$/$\overline{\text{U}}$

17.5.1.4 Main Clock

When using the main clock for the timer A and timer B count source (PCKSTP17 bit in the PCLKSTP1 register is 1), adhere the following:

- Set the PCKSTP11 bit in the PCLKSTP1 register to 0 (f1 supply enabled).
- The main clock can be used in PLL operating mode, high-speed mode, medium-speed mode, or wait mode. Do not use the main clock for the timer A and timer B count source in other modes.
- When the PCKSTP17 bit is set to 1 and timer A or timer B operates in wait mode, set the CM02 bit to 0 (peripheral function clock f1 does not stop in wait mode).

17.5.2 Timer A (Timer Mode)

17.5.2.1 Reading the Timer

The counter value can be read from the TAi register at any time while counting. However, if the counter is read at the same time as it is reloaded, the read value is FFFFh. Also, if the counter is read before it starts counting, or after a value is set in the TAi register while not counting, the set value is read.

17.5.3 Timer A (Event Counter Mode)

17.5.3.1 Reading the Timer

While counting, the counter value can be read at any time by reading the TAi register. However, while reloading, FFFFh can be read in underflow, and 0000h in overflow. When the counter is read before it starts counting and after a value is set in the TAi register while not counting, the set value is read.

17.5.4 Timer A (One-Shot Timer Mode)

17.5.4.1 Stop While Counting

When setting the TAiS bit to 0 (count stopped), the following occurs:

- The counter stops counting and reload register values are reloaded.
- The TAiOUT pin outputs a low-level signal when the POFSi bit in the TAPOFS register is 0, and outputs a high-level signal when it is 1.
- After one cycle of the CPU clock, the IR bit in the TAiIC register becomes 1 (interrupt requested).

17.5.4.2 Delay between the Trigger Input and Timer Output

As the one-shot timer output is synchronized with an internally generated count source, when an external trigger is selected, a maximum 1.5 cycle delay of the count source occurs between the trigger input to the TAiIN pin and timer output.

17.5.4.3 Changing Operating Modes

The IR bit becomes 1 when the timer operating mode is set by any of the following:

- Selecting one-shot timer mode after reset
- Changing the operating mode from timer mode to one-shot timer mode
- Changing the operating mode from event counter mode to one-shot timer mode

To use the timer Ai interrupt (IR bit), set the IR bit to 0 after the changes listed above are made.

17.5.4.4 Retrigger

When a trigger occurs while counting, the counter reloads the reload register to continue counting after generating a retrigger and decrementing once. To generate a trigger while counting, generate a retrigger after at least one cycle of the timer count source has elapsed following the previous trigger.

When an external trigger is generated, do not generate a retrigger for 300 ns before the count value becomes 0000h. The one-shot timer may stop counting.

17.5.5 Timer A (Pulse Width Modulation Mode)

17.5.5.1 Changing Operating Modes

The IR bit becomes 1 when setting a timer operating mode with any of the following:

- Selecting PWM mode or programmable output mode after reset
- Changing the operating mode from timer mode to PWM mode or programmable output mode
- Changing the operating mode from event counter mode to PWM mode or programmable output mode

To use the timer Ai interrupt (IR bit), set the IR bit to 0 by a program after the changes listed above are made.

17.5.5.2 Stop While Counting

When setting the TAiS bit to 0 (count stopped) during PWM pulse output, the following occur:
When the POFSi bit in the TAPOFS register is 0:

- Counting stops
- When the TAiOUT pin is high, the output level goes low and the IR bit becomes 1.
- When the TAiOUT pin is low, both the output level and the IR bit remain unchanged.

When the POFSi bit in the TAPOFS register is 1:

- Counting stops.
- When the TAiOUT pin output is low, the output level goes high and the IR bit is set to 1.
- When the TAiOUT pin output is high, both the output level and the IR bit remain unchanged.

17.5.6 Timer A (Programmable Output Mode)

17.5.6.1 Changing the Operating Mode

The IR bit becomes 1 when setting a timer operating mode with any of the following:

- Selecting PWM mode or programmable output mode after reset
- Changing the operating mode from timer mode to PWM mode or programmable output mode
- Changing the operating mode from event counter mode to PWM mode or programmable output mode

To use the timer Ai interrupt (IR bit), set the IR bit to 0 by a program after the changes listed above are made.

17.5.6.2 Stop While Counting

When setting the TAiS bit to 0 (count stopped) during pulse output, the following occur:
When the POFSi bit in the TAPOFS register is 0:

- Counting stops.
- When the TAiOUT pin is high, the output level goes low.
- When the TAiOUT pin is low, the output level remains unchanged.
- The IR bit remains unchanged.

When the POFSi bit in the TAPOFS register is 1:

- Counting stops
- When the TAiOUT pin output is low, the output level goes high.
- When the TAiOUT pin output is high, the output level remains unchanged.
- The IR bit remains unchanged.

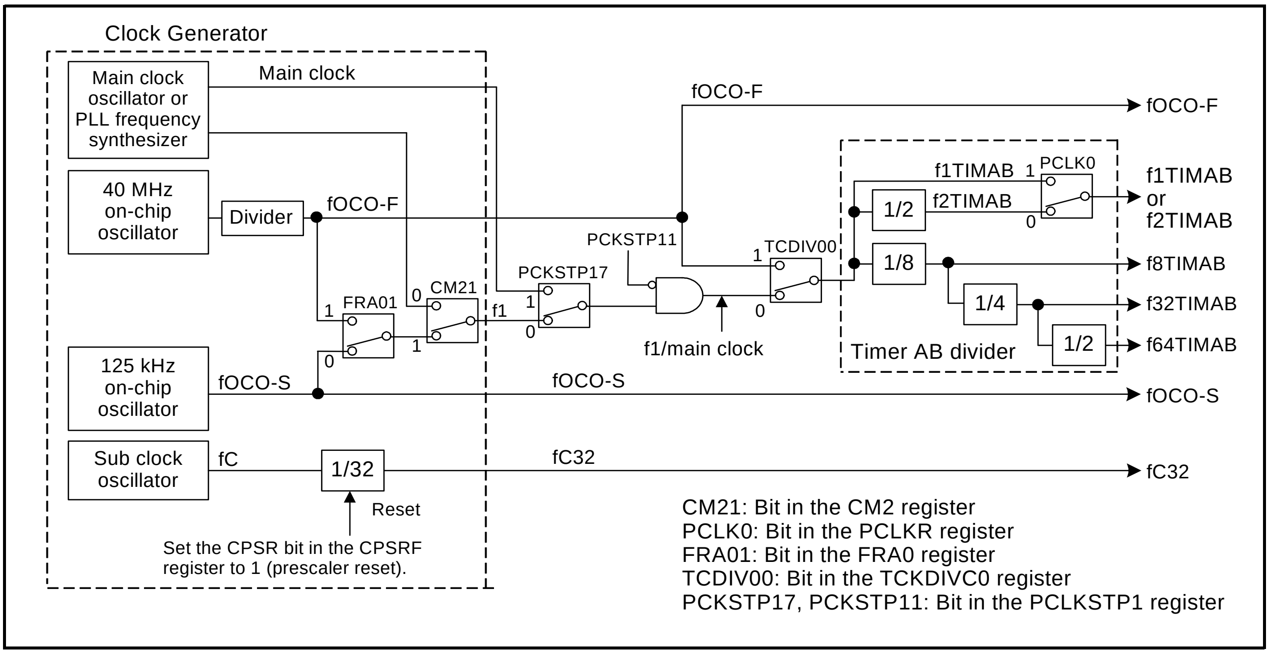
18. Timer B

18.1 Introduction

Timer B consists of timers B0 to B5. Each timer operates independently of the others. Table 18.1 lists Timer B Specifications, Figure 18.1 shows Timer A and B Count Sources, Figure 18.2 shows the Timer B Configuration, Figure 18.3 shows the Timer B Block Diagram, and Table 18.2 lists the I/O Ports.

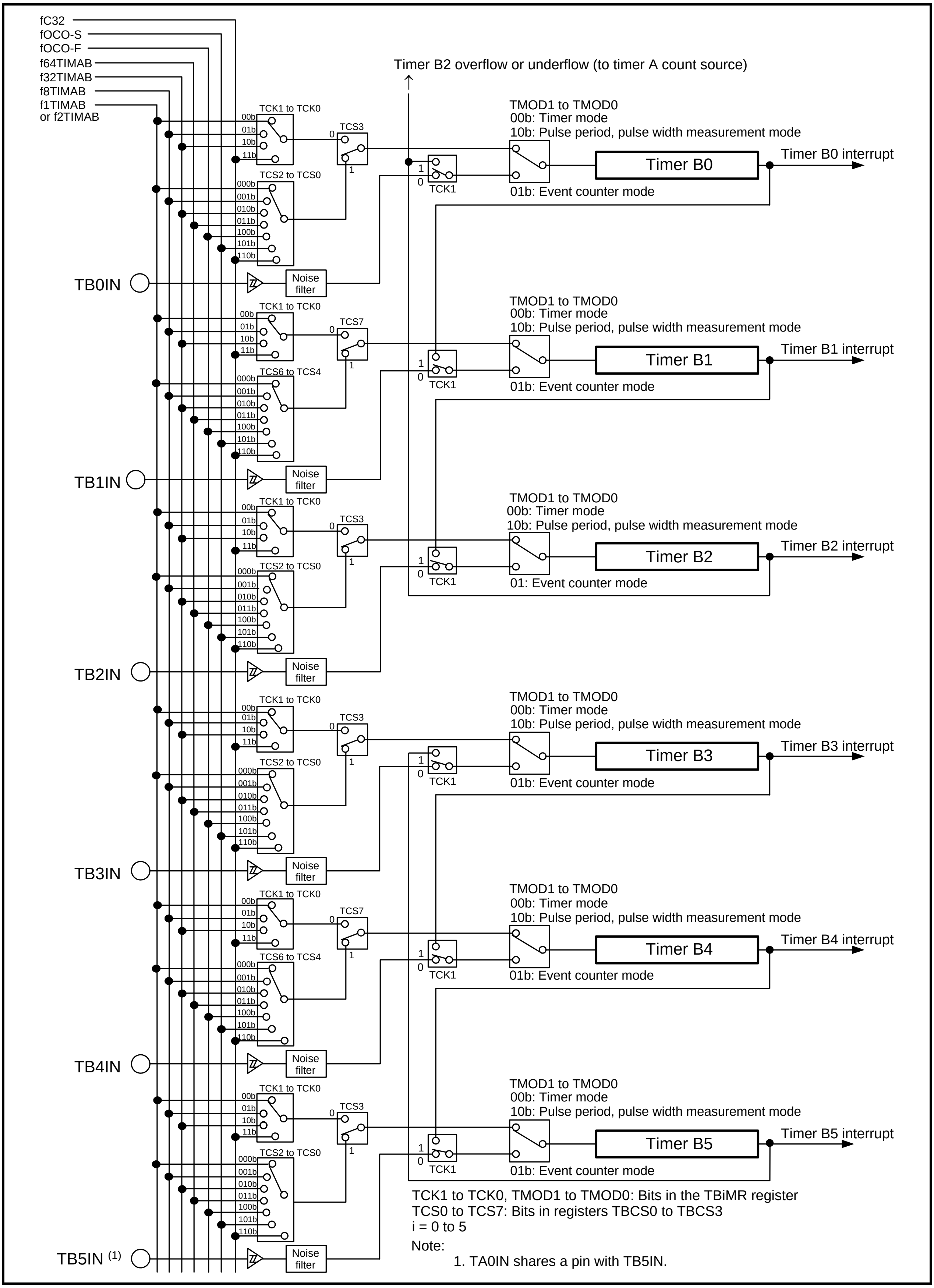
Table 18.1 Timer B Specifications

Item	Specification
Configuration	16-bit timer × 6
Operating modes	• Timer mode The timer counts an internal count source. • Event counter mode The timer counts pulses from an external device, or overflows and underflows of other timers. • Pulse period/pulse width measurement modes The timer measures pulse periods or pulse widths of an external signal.
Interrupt source	Overflow/underflow/active edge of measurement pulse × 6



CM21: Bit in the CM2 register
PCLK0: Bit in the PCLKR register
FRA01: Bit in the FRA0 register
TCDIV00: Bit in the TCKDIVC0 register
PCKSTP17, PCKSTP11: Bit in the PCLKSTP1 register

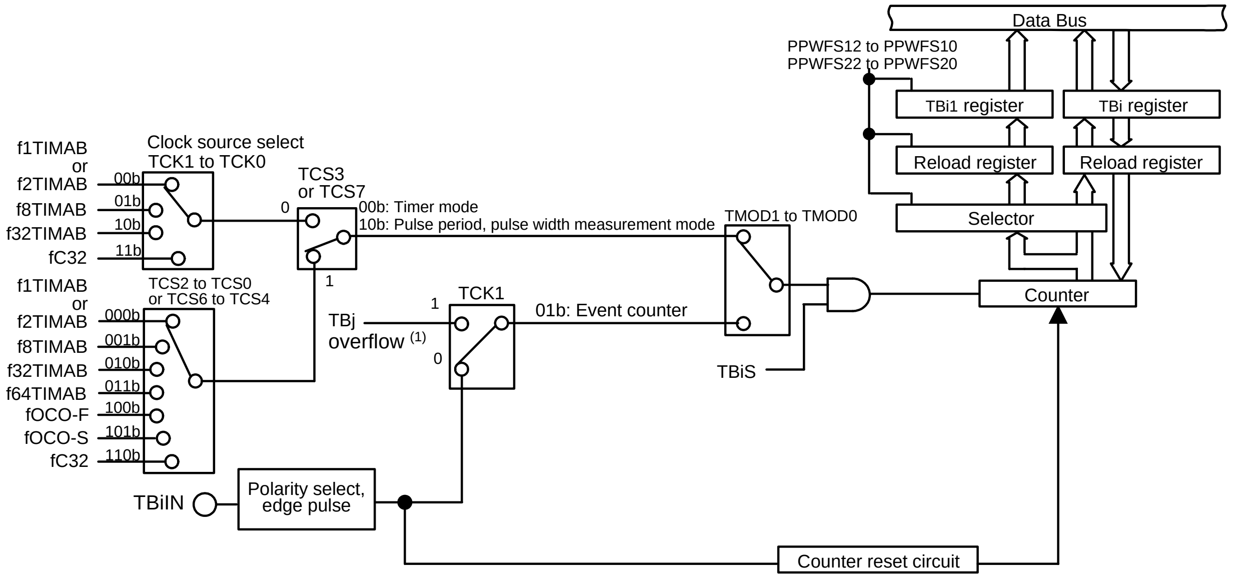
Figure 18.1 Timer A and B Count Sources



TCK1 to TCK0, TMOD1 to TMOD0: Bits in the TBiMR register
TCS0 to TCS7: Bits in registers TBCS0 to TBCS3
i = 0 to 5

Note:
1. TA0IN shares a pin with TB5IN.

Figure 18.2 Timer B Configuration



Note:
1. Overflow or underflow

TCK1 to TCK0, TMOD1 to TMOD0: Bits in the TBiMR register
TBiS: Bits in the TABSR register or TBSR register
TCS0 to TCS7: Bits in the registers TBCS0 to TBCS3
PPWFS12 to PPWFS10: Bits in the PPWFS1 register
PPWFS22 to PPWFS20: Bits in the PPWFS2 register

i = 0 to 5
j = i - 1, except j = 2 if i = 0, and j = 5 if i = 3

TBi	TBj
Timer B0	Timer B2
Timer B1	Timer B0
Timer B2	Timer B1
Timer B3	Timer B5
Timer B4	Timer B3
Timer B5	Timer B4

Figure 18.3 Timer B Block Diagram

Table 18.2 I/O Ports

Pin Name	I/O	Function
TBiIN	Input (1)	Count source input (event counter mode) Measurement pulse input (pulse period measurement mode, pulse width measurement mode)

i = 0 to 5

Note:

1. When using the TBiIN pin for input, set the port direction bit sharing the same pin to 0 (input mode).

18.2 Registers

Table 18.3 lists registers associated with timer B.

Set the TCDIV00 bit in the TCKDIVC0 register before setting other registers associated with timer B. After changing the TCDIV00 bit, set other registers associated with timer B again.

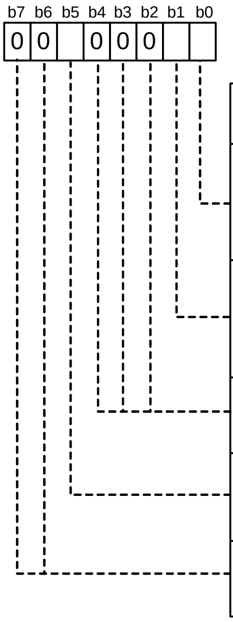
Refer to “registers and the setting” in each mode for registers and bit settings.

Table 18.3 Registers

Address	Register	Symbol	Reset Value
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
0015h	Clock Prescaler Reset Flag	CPSRF	0XXX XXXXb
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
01C0h	Timer B0-1 Register	TB01	XXh
01C1h			XXh
01C2h	Timer B1-1 Register	TB11	XXh
01C3h			XXh
01C4h	Timer B2-1 Register	TB21	XXh
01C5h			XXh
01C6h	Pulse Period/Pulse Width Measurement Mode Function Select Register 1	PPWFS1	XXXX X000b
01C8h	Timer B Count Source Select Register 0	TBCS0	00h
01C9h	Timer B Count Source Select Register 1	TBCS1	X0h
01CBh	Timer AB Division Control Register 0	TCKDIVC0	0000 X000b
01E0h	Timer B3-1 Register	TB31	XXh
01E1h			XXh
01E2h	Timer B4-1 Register	TB41	XXh
01E3h			XXh
01E4h	Timer B5-1 Register	TB51	XXh
01E5h			XXh
01E6h	Pulse Period/Pulse Width Measurement Mode Function Select Register 2	PPWFS2	XXXX X000b
01E8h	Timer B Count Source Select Register 2	TBCS2	00h
01E9h	Timer B Count Source Select Register 3	TBCS3	X0h
0300h	Timer B3/B4/B5 Count Start Flag	TBSR	000X XXXXb
0310h	Timer B3 Register	TB3	XXh
0311h			XXh
0312h	Timer B4 Register	TB4	XXh
0313h			XXh
0314h	Timer B5 Register	TB5	XXh
0315h			XXh
031Bh	Timer B3 Mode Register	TB3MR	00XX 0000b
031Ch	Timer B4 Mode Register	TB4MR	00XX 0000b
031Dh	Timer B5 Mode Register	TB5MR	00XX 0000b
0320h	Count Start Flag	TABSR	00h
0330h	Timer B0 Register	TB0	XXh
0331h			XXh
0332h	Timer B1 Register	TB1	XXh
0333h			XXh
0334h	Timer B2 Register	TB2	XXh
0335h			XXh
033Bh	Timer B0 Mode Register	TB0MR	00XX 0000b
033Ch	Timer B1 Mode Register	TB1MR	00XX 0000b
033Dh	Timer B2 Mode Register	TB2MR	00XX 0000b

18.2.1 Peripheral Clock Select Register (PCLKR)

Peripheral Clock Select Register



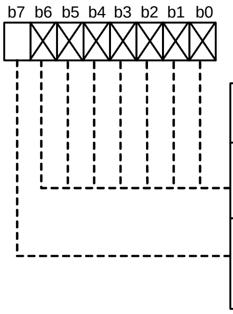
Symbol	Address	Reset Value
PCLKR	0012h	0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A and B clock select bit (clock source for timers A and B, the dead time timer, and multi-master I^{2}C-bus interface)	0: f2TIMAB/f2IIC 1: f1TIMAB/f1IIC	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART2, UART5 to UART7, SI/O3, and SI/O4)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function expansion bit (enabled in single-chip mode)	0: Selected by setting bits CM01 to CM00 in the CM0 register 1: Output f1	RW
— (b7-b6)	Reserved bits	Set to 0	RW

Write to the PCLKR register after setting the PRC0 bit in the PRCR register to 1 (write enabled).

18.2.2 Clock Prescaler Reset Flag (CPSRF)

Clock Prescaler Reset Flag

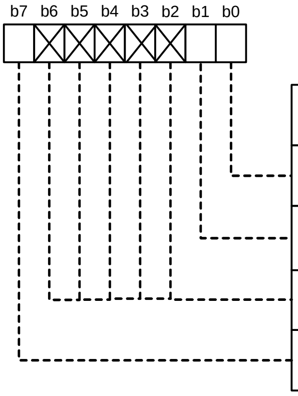


Symbol	Address	Reset Value
CPSRF	0015h	0XXX XXXXb

Bit Symbol	Bit Name	Function	RW
— (b6-b0)	No register bits. If necessary, set to 0. The read values are undefined.		—
CPSR	Clock prescaler reset flag	Setting this bit to 1 initializes the prescaler for the timekeeping clock. (The read value is 0.)	RW

18.2.3 Peripheral Clock Stop Register 1 (PCLKSTP1)

Peripheral Clock Stop Register 1



Symbol	Address	Reset Value
PCLKSTP1	0016h	0XXX XX00b

Bit Symbol	Bit Name	Function	RW
PCKSTP1A	Peripheral clock stop bit (other than timer A, timer B)	0: f1 provide enabled 1: f1 provide disabled	RW
PCKSTP11	Timer peripheral clock stop bit (timer A, timer B)	0: f1 provide enabled 1: f1 provide disabled	RW
— (b6-b2)	No register bit. If necessary, set to 0. The read value is undefined.		—
PCKSTP17	Timer clock source select bit (timer A, timer B)	0: f1 1: Main clock	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register

PCKSTP11 (Timer peripheral clock stop bit) (b1)

When using f1 or the main clock for the timer A and timer B count source, set the PCKSTP11 bit to 0 (f1 provide enabled).

To change the PCKSTP11 bit from 1 (f1 provide disabled) to 0, use following procedure:

(1) Stop timer A and timer B.
(2) Set the PCKSTP11 bit to 0.
(3) Set the registers for timer A and timer B again.

To change the timer A and timer B count source from fOCO-F to f1, perform (1) and (2) above, and set the TCDIV00 bit in the TCKDIVC0 register from 1 (fOCO-F) to 0 (f1), then perform (3).

PCKSTP17 (Timer clock source select bit) (b7)

Change the PCKSTP17 bit when all of the following conditions are met:

- Both f1 and the main clock are stably supplied.
- Both timer A and timer B are stopped.

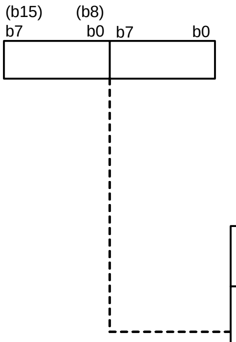
The PCKSTP17 bit is used for supplying the main clock to timer A and timer B.

When in PLL operating mode, high-speed mode, medium-speed mode, or wait mode, the main clock can be used for the timer A and timer B count source.

Do not use the main clock for the timer A and timer B count source in other normal operating modes (refer to 9.3 “Clock”).

18.2.4 Timer Bi Register (TBi) (i = 0 to 5)

Timer Bi Register (i = 0 to 5)



Symbol	Address	Reset Value
TB0	0331h to 0330h	XXXXh
TB1	0333h to 0332h	XXXXh
TB2	0335h to 0334h	XXXXh
TB3	0311h to 0310h	XXXXh
TB4	0313h to 0312h	XXXXh
TB5	0315h to 0314h	XXXXh

Mode	Function	Setting Range	RW
Timer mode	When n = setting value, counter cycle: $\frac{(n + 1)}{fj}$	0000h to FFFFh	RW
Event counter mode	When n = setting value, n + 1 count	0000h to FFFFh	RW
Pulse period measurement mode, Pulse width measurement mode	Set an initial value. Measures a pulse period or width. Read the counter value while counting.	0000h to FFFFh	RW

fj : Count source frequency

Access this register in 16-bit units.

Event Counter Mode

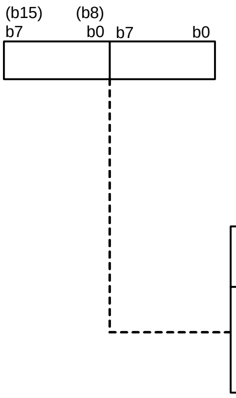
The timer counts pulses from an external device, or overflows or underflows of other timers.

Pulse Period Measurement Mode, Pulse Width Measurement Mode

Set these modes when the TBiS bit in the TABSR or TBSR register is 0 (count stopped).
These modes become read only (RO) when the TBiS bit in the TABSR or TBSR register is 1 (count started).
The counter starts counting the count source at an active edge of the measurement pulse, transfers the count value to a register at the next active edge, and continues counting.
The measurement result can be read by reading the TBi register when bits PPWFS12 to PPWFS10 in the PPWFS1 register and bits PPWFS22 to PPWFS20 in the PPWFS2 register are 0.
While counting, the counter value can be read by reading the TBi register when bits PPWFS12 to PPWFS10 and bits PPWFS22 to PPWFS20 are 1.

18.2.5 Timer Bi-1 Register (TBi1) (i = 0 to 5)

Timer Bi-1 Register (i = 0 to 5)



Symbol	Address	Reset Value
TB01	01C1h to 01C0h	XXXXh
TB11	01C3h to 01C2h	XXXXh
TB21	01C5h to 01C4h	XXXXh
TB31	01E1h to 01E0h	XXXXh
TB41	01E3h to 01E2h	XXXXh
TB51	01E5h to 01E4h	XXXXh

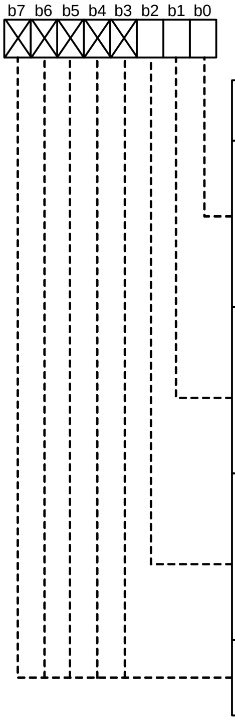
Mode	Function	Setting Range	RW
Pulse period measurement mode Pulse width measurement mode	Measures a pulse period or width	0000h to FFFFh	RO

Access this register in 16-bit units.

When bits PPWFS12 to PPWFS10 in the PPWFS1 register and bits PPWFS22 to PPWFS20 in the PPWFS2 register are 1, the measurement result can be read by reading the TBi-1 register. When these bits are 0, the value in this register is undefined.

18.2.6 Pulse Period/Pulse Width Measurement Mode Function Select Register i (PPWFSi) (i = 1, 2)

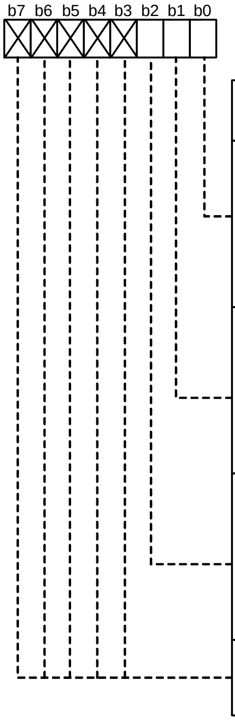
Pulse Period/Pulse Width Measurement Mode Function Select Register 1



Symbol	Address	Reset Value
PPWFS1	01C6h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
PPWFS10	Timer B0 pulse period/pulse width measurement mode function select bit	0 : Measurement result is stored in the TB0 register. The TB01 register is not used 1 : The counter value is read from the TB0 register. Measurement result is stored in the TB01 register	RW
PPWFS11	Timer B1 pulse period/pulse width measurement mode function select bit	0 : Measurement result is stored in the TB1 register. The TB11 register is not used 1 : The counter value is read from the TB1 register. Measurement result is stored in the TB11 register	RW
PPWFS12	Timer B2 pulse period/pulse width measurement mode function select bit	0 : Measurement result is stored in the TB2 register. The TB21 register is not used 1 : The counter value is read from the TB2 register. Measurement result is stored in the TB21 register	RW
— (b7-b3)	No register bits. If necessary, set to 0. The read value is undefined.		—

Pulse Period/Pulse Width Measurement Mode Function Select Register 2



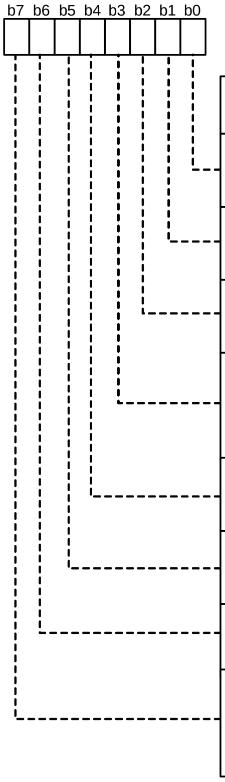
Symbol	Address	Reset Value
PPWFS2	01E6h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
PPWFS20	Timer B3 pulse period/pulse width measurement mode function select bit	0 : Measurement result is stored in the TB3 register. The TB31 register is not used 1 : The counter value is read from the TB3 register. Measurement result is stored in the TB31 register	RW
PPWFS21	Timer B4 pulse period/pulse width measurement mode function select bit	0 : Measurement result is stored in the TB4 register. The TB41 register is not used 1 : The counter value is read from the TB4 register. Measurement result is stored in the TB41 register	RW
PPWFS22	Timer B5 pulse period/pulse width measurement mode function select bit	0 : Measurement result is stored in the TB5 register. The TB51 register is not used 1 : The counter value is read from the TB5 register. Measurement result is stored in the TB51 register	RW
— (b7-b3)	No register bits. If necessary, set to 0. The read value is undefined.		—

Enabled in pulse period measurement mode or pulse width measurement mode.

18.2.7 Timer B Count Source Select Register i (TBCSi) (i = 0 to 3)

Timer B Count Source Select Register 0, Timer B Count Source Select Register 2

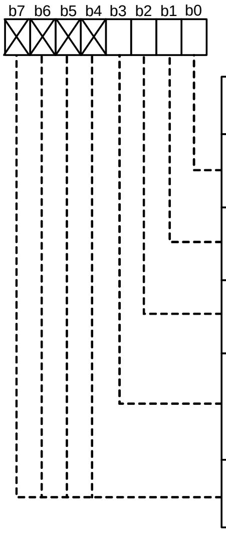


Symbol	Address	Reset Value
TBCS0	01C8h	00h
TBCS2	01E8h	00h

Bit Symbol	Bit Name	Function	RW
TCS0	TBi count source select bit	b2 b1 b0 0 0 0 : f1TIMAB or f2TIMAB 0 0 1 : f8TIMAB 0 1 0 : f32TIMAB 0 1 1 : f64TIMAB 1 0 0 : fOCO-F 1 0 1 : fOCO-S 1 1 0 : fC32 1 1 1 : Do not set	RW
TCS1			RW
TCS2			RW
TCS3	TBi count source option specified bit	0 : TCK0 to TCK1 enabled, TCS0 to TCS2 disabled 1 : TCK0 to TCK1 disabled, TCS0 to TCS2 enabled	RW
TCS4	TBj count source select bit	b6 b5 b4 0 0 0 : f1TIMAB or f2TIMAB 0 0 1 : f8TIMAB 0 1 0 : f32TIMAB 0 1 1 : f64TIMAB 1 0 0 : fOCO-F 1 0 1 : fOCO-S 1 1 0 : fC32 1 1 1 : Do not set	RW
TCS5			RW
TCS6			RW
TCS7	TBj count source option specified bit	0 : TCK0 to TCK1 enabled, TCS4 to TCS6 disabled 1 : TCK0 to TCK1 disabled, TCS4 to TCS6 enabled	RW

TBCS0 register: i = 0, j = 1; TBCS2 register: i = 3, j = 4

Timer B Count Source Select Register 1, Timer B Count Source Select Register 3



Symbol	Address	Reset Value
TBCS1	01C9h	X0h
TBCS3	01E9h	X0h

Bit Symbol	Bit Name	Function	RW
TCS0	TBi count source select bit	b2 b1 b0 0 0 0: f1TIMAB or f2TIMAB 0 0 1: f8TIMAB 0 1 0: f32TIMAB 0 1 1: f64TIMAB 1 0 0: fOCO-F 1 0 1: fOCO-S 1 1 0: fC32 1 1 1: Do not set	RW
TCS1			RW
TCS2			RW
TCS3	TBi count source option specified bit	0: TCK0 to TCK1 enabled, TCS0 to TCS2 disabled 1: TCK0 to TCK1 disabled, TCS0 to TCS2 enabled	RW
— (b7-b4)	No register bits. If necessary, set to 0. The read value is undefined.		—

TBCS1 register: i = 2; TBCS3 register: i = 5

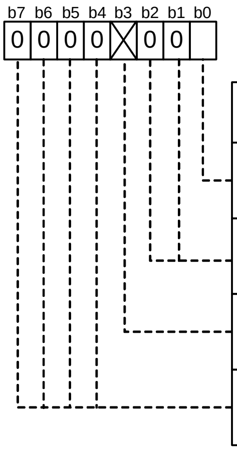
TCS2-TCS0 (TBi count source select bit) (b2-b0)
TCS6-TCS4 (TBj count source select bit) (b6-b4)

Select f1TIMAB or f2TIMAB by setting the PCLK0 bit in the PCLKR register.

18.2.8 Timer AB Division Control Register 0 (TCKDIVC0)

Timer AB Division Control Register 0

Symbol	Address	Reset Value
TCKDIVC0	01CBh	0000 X000b



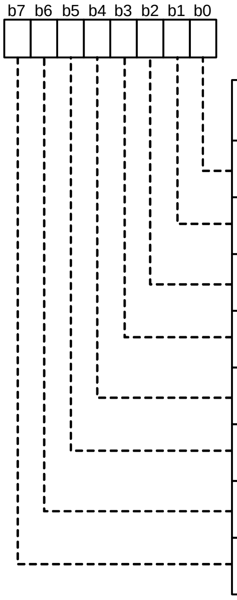
Bit Symbol	Bit Name	Function	RW
TCDIV00	Clock select prior to timer AB division bit	0 : f1 1 : fOCO-F	RW
— (b2-b1)	Reserved bits	Set to 0	RW
— (b3)	No register bit. If necessary, set to 0. The read value is undefined.		—
— (b7-b4)	Reserved bits	Set to 0	RW

TCDIV00 (Clock select prior to timer AB division bit) (b0)

Set the TCDIV00 bit while timers A and B are stopped.
Set the TCDIV00 bit before setting other registers associated with timer B.
After changing the TCDIV00 bit, set other registers associated with timer B again.

18.2.9 Count Start Flag (TABSR)
Timer B3/B4/B5 Count Start Flag (TBSR)

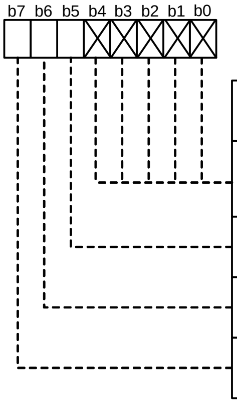
Count Start Flag



Symbol	Address	Reset Value
TABSR	0320h	00h

Bit Symbol	Bit Name	Function	RW
TA0S	Timer A0 count start flag	0 : Count stopped 1 : Count started	RW
TA1S	Timer A1 count start flag		RW
TA2S	Timer A2 count start flag		RW
TA3S	Timer A3 count start flag		RW
TA4S	Timer A4 count start flag		RW
TB0S	Timer B0 count start flag		RW
TB1S	Timer B1 count start flag		RW
TB2S	Timer B2 count start flag		RW

Timer B3/B4/B5 Count Start Flag

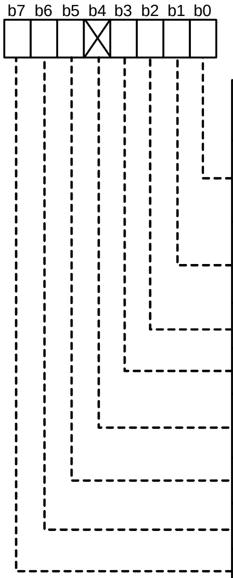


Symbol	Address	Reset Value
TBSR	0300h	000X XXXXb

Bit Symbol	Bit Name	Function	RW
— (b4-b0)	No register bits. If necessary, set to 0. The read value is undefined.		—
TB3S	Timer B3 count start flag	0 : Stop counting 1 : Start counting	RW
TB4S	Timer B4 count start flag		RW
TB5S	Timer B5 count start flag		RW

18.2.10 Timer Bi Mode Register (TBiMR) (i = 0 to 5)

Timer Bi Mode Register (i = 0 to 5)



Symbol	Address	Reset Value
TB0MR to TB2MR	033Bh to 033Dh	00XX 0000b
TB3MR to TB5MR	031Bh to 031Dh	00XX 0000b

Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 0 0 : Timer mode 0 1 : Event counter mode 1 0 : Pulse period measurement mode Pulse width measurement mode 1 1 : Do not set	RW
TMOD1			RW
MR0	Function varies with the operation mode		RW
MR1			RW
— (b4)	No register bit. If necessary, set to 0. The read value is undefined.		—
MR3	Function varies with the operation mode		RO
TCK0	Count source select bit (function varies with the operation mode)		RW
TCK1			RW

18.3 Operations

18.3.1 Common Operations

18.3.1.1 Operating Clock

The count source for each timer acts as a clock, controlling such timer operations as counting and reloading.

18.3.1.2 Counter Reload Timing

Timer Bi starts counting from the value (n) set in the TBi register. The TBi register consists of a counter and a reload register. The counter starts decrementing the count source from n, reloads a value in the reload register at the next count source after the value becomes 0000h, and continues decrementing.
The value written in the TBi register is reflected in the counter and the reload register at the following timings.

- When the count is stopped
- Between when the count starts and the first count source is input
  The value written to the TBi register is immediately written to the counter and the reload register.

- After the count starts and the first count source is input
  The value written to the TBi register is immediately written to the reload register.
  The counter continues counting and reloads the value in the reload register at the next count source after the value becomes 0000h.

18.3.1.3 Count Source

Internal clocks are counted in timer mode, pulse period measurement mode, and pulse width measurement mode. Refer to Figure 18.1 “Timer A and B Count Sources” for details. Table 18.4 lists Timer B Count Sources.

f1 is any of the clocks listed below. Refer to 8. “Clock Generator” for details.

- Main clock divided by 1 (no division)
- PLL clock divided by 1 (no division)
- fOCO-S divided by 1 (no division)
- fOCO-F divided by 1 (no division)

When f1 or the main clock is used for the timer A and timer B count source, set the PCKSTP11 bit in the PCLKSTP1 register to 0 (f1 supply enabled).

When the clock mode is PLL operating mode, high-speed mode, medium-speed mode, or wait mode, the main clock can be used for the timer A and timer B count source instead of f1. Use the PCKSTP17 bit in the PCLKSTP1 register to select the clock (refer to 18.2.3 “Peripheral Clock Stop Register 1 (PCLKSTP1)”).

When using wait mode, if the CM02 bit in the CM0 register is set to 1 (peripheral function clock f1 stops in wait mode) before entering wait mode, the main clock is also stopped. Therefore, when the PCKSTP17 bit is 1 and timer A or timer B is used while in wait mode, do not set the CM02 bit to 1.

Table 18.4 Timer B Count Sources

Count Source	Bit Setting Value				Remarks
	PCLK0	TCS3 TCS7	TCS2 to TCS0 TCS6 to TCS4	TCK1 to TCK0	
f1TIMAB	1	0	-	00b	f1 or fOCO-F (1)
		1	000b	-	
f2TIMAB	0	0	-	00b	f1 divided by 2 or fOCO-F divided by 2 (1)
		1	000b	-	
f8TIMAB	-	0	-	01b	f1 divided by 8 or fOCO-F divided by 8 (1)
		1	001b	-	
f32TIMAB	-	0	-	10b	f1 divided by 32 or fOCO-F divided by 32 (1)
		1	010b	-	
f64TIMAB	-	1	011b	-	f1 divided by 64 or fOCO-F divided by 64 (1)
fOCO-F	-	1	100b	-	fOCO-F
fOCO-S	-	1	101b	-	fOCO-S
fC32	-	0	-	11b	fC32
		1	110b	-	

PCLK0: Bit in the PCLKR register

TCS7 to TCS0: Bits in registers TBCS0 to TBCS3

TCK1 to TCK0: Bits in the TBiMR register (i = 0 to 5)

Note:

1. Select f1 or fOCO-F by setting the TCDIV00 bit in the TCKDIVC0 register.

When in PLL operating mode, high-speed mode, medium-speed mode, or wait mode, the main clock can be used for the timer A and timer B count source instead of f1. Use the PCKSTP17 bit in the PCLKSTP1 register to select the clock (refer to 18.2.3 “Peripheral Clock Stop Register 1 (PCLKSTP1)”).

18.3.2 Timer Mode

In timer mode, the timer counts an internally generated count source. Table 18.5 lists Timer Mode Specifications, Table 18.6 lists Registers and Setting in Timer Mode, and Figure 18.4 shows an Operation Example in Timer Mode.

Table 18.5 Timer Mode Specifications

Item	Specification
Count sources	f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32
Count operations	• Decrement • When the timer underflows, it reloads the reload register value and continues counting.
Counter cycles	$\frac{1}{(n+1)}$ n: setting value of the TBi register 0000h to FFFFh
Count start condition	Set the TBiS bit to 1 (start counting).
Count stop condition	Set the TBiS bit to 0 (stop counting).
Interrupt request generation timing	Timer underflow
TBiIN pin function	I/O port
Read from timer	Count value can be read by reading the TBi register.
Write to timer	• When not counting The value written to the TBi register is written to both the reload register and the counter. • When counting The value written to the TBi register is only written to the reload register (transferred to the counter when reloaded next).

i = 0 to 5

TBiS: Bit in the TABSR or TBSR register

Table 18.6 Registers and Settings in Timer Mode [(1)]

Register	Bit	Function and Setting
PCLKR	PCLK0	Select the count source.
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TBi1	15 to 0	- (setting unnecessary)
PPWFS1 to PPWFS2	PPWFS12 to PPWFS10 PPWFS22 to PPWFS20	Set to 0.
TCKDIVC0	TCDIV00	Select the clock used prior to timer AB frequency dividing.
TBCS0 to TBCS3	7 to 0	Select the count source.
TABSR TBSR	TBiS	Set to 1 when starting counting. Set to 0 when stopping counting.
TBi	15 to 0	Set the count value.
TBiMR	7 to 0	Refer to the TBiMR register below.

i = 0 to 5

Note:

1. This table does not describe a procedure.

Timer Mode

Timer Bi Mode Register (i = 0 to 5)

b7	b6	b5	b4	b3	b2	b1	b0
			☒	0	0	0	0

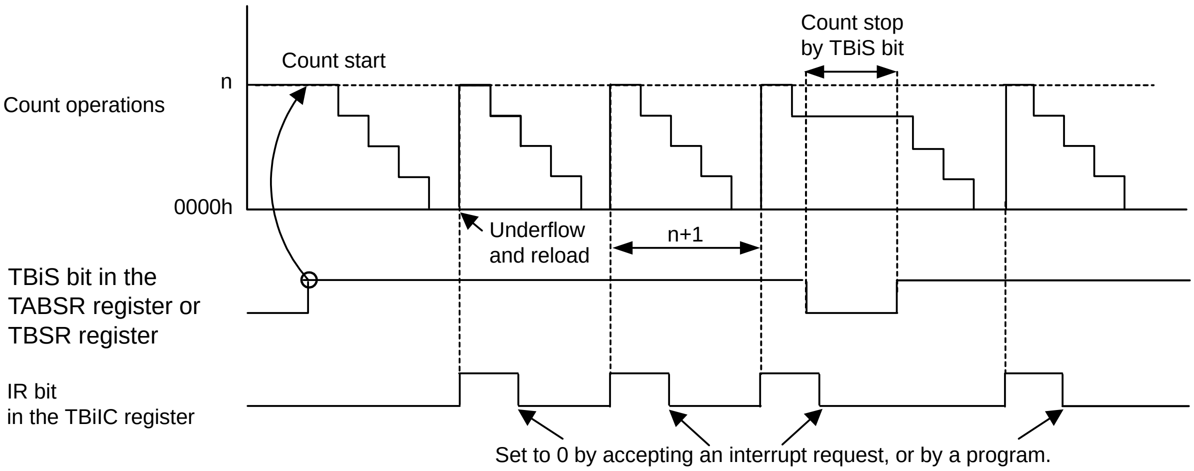
Symbol	Address	Reset Value
TB0MR to TB2MR	033Bh to 033Dh	00XX 0000b
TB3MR to TB5MR	031Bh to 031Dh	00XX 0000b

Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 0 0 : Timer mode	RW
TMOD1			RW
MR0	Set to 0 in timer mode.		RW
MR1			RW
— (b4)	No register bit. If necessary, set to 0. The read value is undefined.		—
MR3	Write 0 in timer mode. The read value is undefined in timer mode.		RO
TCK0	Count source select bit	b7 b6 0 0 : f1TIMAB or f2TIMAB 0 1 : f8TIMAB 1 0 : f32TIMAB 1 1 : fC32	RW
TCK1			RW

TCK1 and TCK0 (Count source select bit) (b7-b6)

These bits are enabled when the TCS3 or TCS7 bit in registers TBCS0 to TBCS3 is set to 0 (bits TCK0 to TCK1 enabled).

Select f1TIMAB or f2TIMAB by the PCLK0 bit in the PCLKR register.



i = 0 to 5

The above assumes the following:

- The value in the TBi register (n) = 0004h

Figure 18.4 Operation Example in Timer Mode

18.3.3 Event Counter Mode

In event counter mode, the timer counts pulses from an external device, or overflows and underflows of other timers. Table 18.7 lists Event Counter Mode Specifications, Table 18.8 lists Registers and Settings in Event Counter Mode, and Figure 18.5 shows an Operation Example in Event Counter Mode.

Table 18.7 Event Counter Mode Specifications

Item	Specification
Count sources	• External signals input to TBiIN pin (active edge can be selected by a program: rising edge, falling edge, or both rising and falling edges) • Timer Bj overflow or underflow
Count operations	• Decrement • When the timer underflows, it reloads the reload register value and continues counting.
Number of counts	$\frac{1}{(n+1)}$ n: setting value of the TBi register 0000h to FFFFh
Count start condition	Set the TBiS bit to 1 (start counting).
Count stop condition	Set the TBiS bit to 0 (stop counting).
Interrupt request generation timing	Timer underflow
TBiIN pin function	Count source input
Read from timer	Count value can be read by reading the TBi register.
Write to timer	• When not counting The value written to the TBi register is written to both the reload register and the counter. • When counting The value written to the TBi register is written to only reload register (transferred to counter when reloaded next).

i = 0 to 5 j = i - 1, except j = 2 if i = 0; j = 5 if i = 3
TBiS: Bit in the TABSR or TBSR register

Table 18.8 Registers and Settings in Event Counter Mode (1)

Register	Bit	Function and Setting
PCLKR	PCLK0	- (setting unnecessary)
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	- (setting unnecessary)
	PCKSTP17	- (setting unnecessary)
TBi1	15 to 0	- (setting unnecessary)
PPWFS1 to PPWFS2	PPWFS12 to PPWFS10 PPWFS22 to PPWFS20	Set to 0.
TCKDIVC0	TCDIV00	- (setting unnecessary)
TBCS0 to TBCS3	7 to 0	- (setting unnecessary)
TABSR TBSR	TBiS	Set to 1 when starting counting. Set to 0 when stopping counting.
TBi	15 to 0	Set the count value.
TBiMR	7 to 0	Refer to the TBiMR register below.

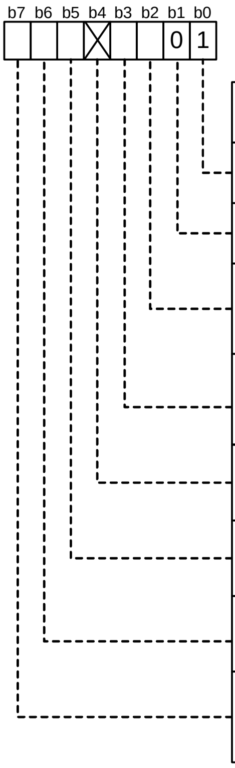
i = 0 to 5

Note:

1. This table does not describe a procedure.

Event Counter Mode
Timer Bi Mode Register (i = 0 to 5)

Symbol	Address	Reset Value
TB0MR to TB2MR	033Bh to 033Dh	00XX 0000b
TB3MR to TB5MR	031Bh to 031Dh	00XX 0000b



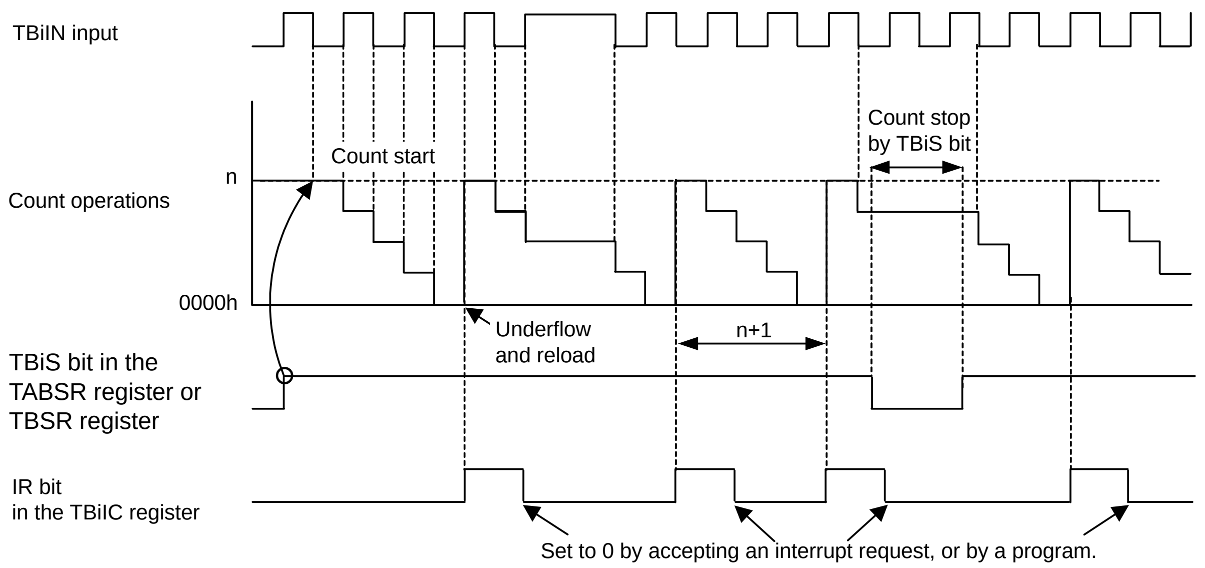
Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 0 1 : Event counter mode	RW
TMOD1			RW
MR0	Count polarity select bit	b3 b2 0 0 : Counts falling edges of an external signal 0 1 : Counts rising edges of an external signal 1 0 : Counts falling and rising edges of an external signal 1 1 : Do not set	RW
MR1			RW
— (b4)	No register bit. If necessary, set to 0. The read value is undefined.		—
MR3	Write 0 in event counter mode. The read value is undefined in event counter mode		RO
TCK0	Disabled in event counter mode. Set 0 or 1.		RW
TCK1	Event clock select bit	0 : Input from TBiIN pin 1 : Timer Bj (j = i - 1; however, j = 2 if i = 0, j = 5 if i = 3)	RW

MR1 and MR0 (Count polarity select bit) (b3-b2)

These bits are enabled when the TCK1 bit is 0 (input from TBiIN pin). When the TCK1 bit is 1 (timer Bj), these bits can be set to 0 or 1.

TCK1 (Event clock select bit) (b7)

When the TCK1 bit is 1, an event occurs when an interrupt request of timer Bj (j = i - 1; however, j = 2 if i = 0, j = 5 if i = 3) is generated. An event occurs while an interrupt is disabled because an interrupt request signal is generated regardless of the I flag, IPL, or interrupt control registers



i = 0 to 5

The above assumes the following:

- Bits MR1 to MR0 in the TBiMR register = 10b (the falling edge and rising edge of an external signal).
- The TCK1 bit in the TBiMR register = 0 (input signals from the TBiIN pin counted).
- The value in the TBi register (n) = 0004h.

Figure 18.5 Operation Example in Event Counter Mode

18.3.4 Pulse Period/Pulse Width Measurement Modes

In pulse period and pulse width measurement modes, the timer measures the pulse period or pulse width of an external signal. Table 18.9 lists Specifications of Pulse Period/Pulse Width Measurement Modes, Table 18.10 lists Registers and Settings in Pulse Period/Pulse Width Measurement Modes, Figure 18.6 shows Operation Example in Pulse Period Measurement Mode, and Figure 18.7 shows an Operation Example in Pulse Width Measurement Mode.

Table 18.9 Specifications of Pulse Period/Pulse Width Measurement Modes

Item	Specification
Count sources	f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32
Count operations	• Increment • The counter value is transferred to the reload register at an active edge of the measurement pulse. The counter value becomes 0000h and count continues.
Count start condition	Set the TBiS bit to 1 (start counting).
Count stop condition	Set the TBiS bit to 0 (stop counting).
Interrupt request generation timing [3]	• When an active edge of measurement pulse is input [1] • Timer overflow. The MR3 bit in the TBiMR register becomes 1 (overflowed) at the same time an overflow occurs.
TBiIN pin function	Measurement pulse input
Read from timer	When bits PPWFS12 to PPWFS10 and PPWFS22 to PPWFS20 in registers PPWFS1 and PPWFS2 are 0 • Value of the reload register (measurement result) can be read by reading the TBi register. [2] When bits PPWFS12 to PPWFS10 and PPWFS22 to PPWFS20 in registers PPWFS1 and PPWFS2 register are 1 • Value of the counter (counter value) can be read by reading the TBi register. • Value of the reload register (measurement result) can be read by reading the TBi1 register.
Write to timer	When not counting, the value written to the TBi register is written to both the reload register and counter.

i = 0 to 5

TBiS: Bit in the TABSR or TBSR register

Notes:

1. No interrupt request is generated when the first active edge is input after the timer starts counting.
2. The value read from the TBi register is undefined until the second active edge is input after the timer starts counting.
3. When timer Bi in pulse-period measurement mode or pulse-width measurement mode is used as an event or trigger for timer A or timer B other than timer Bi, an event or trigger occurs at both the overflow and active edge of the measurement pulse.

Table 18.10 Registers and Settings in Pulse Period/Pulse Width Measurement Modes [1]

Register	Bit	Function and Setting
PCLKR	PCLK0	Select the count source.
CPSRF	CPSR	Write 1 to reset the clock prescaler.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TBi1	15 to 0	Measurement result can be read when the bits in the PPWFS1 or PPWFS2 register corresponding to timer Bi are 1.
PPWFS1 to PPWFS2	PPWFS12 to PPWFS10 PPWFS22 to PPWFS20	Set to 1 to read the counter value while counting.
TCKDIVC0	TCDIV00	Select the clock used prior to timer AB frequency dividing.
TBCS0 to TBCS3	7 to 0	Select the count source.
TABSR TBSR	TBiS	Set to 1 when starting counting. Set to 0 when stopping counting.
TBi	15 to 0	Set the initial value. The measurement result can be read when the bits in the PPWFS1 or PPWFS2 register corresponding to timer Bi are 0. The counter value can be read when the bits in the PPWFS1 or PPWFS2 register corresponding to timer Bi are 1.
TBiMR	7 to 0	Refer to the TBiMR register below.

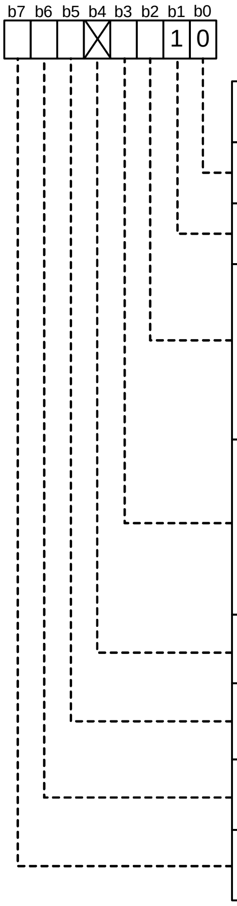
i = 0 to 5

Note:

1. This table does not describe a procedure.

Pulse Period/Pulse Width Measurement Modes Timer Bi Mode Register (i = 0 to 5)

Symbol	Address	Reset Value
TB0MR to TB2MR	033Bh to 033Dh	00XX 0000b
TB3MR to TB5MR	031Bh to 031Dh	00XX 0000b



Bit Symbol	Bit Name	Function	RW
TMOD0	Operation mode select bit	b1 b0 1 0 : Pulse period/pulse width measurement modes	RW
TMOD1			RW
MR0	Measurement mode select bit	b3 b2 0 0 : Pulse period measurement (measurement between a falling edge and the next falling edge of measured pulse) 0 1 : Pulse period measurement (measurement between a rising edge and the next rising edge of measured pulse) 1 0 : Pulse width measurement (measurement between a falling edge and the next rising edge of measured pulse and between a rising edge and the next falling edge) 1 1 : Do not set	RW
MR1			RW
— (b4)	No register bit. If necessary, set to 0. The read value is undefined.		—
MR3	Timer Bi overflow flag	0 : No overflow 1 : Overflow	RO
TCK0	Count source select bit	b7 b6 0 0 : f1TIMAB or f2TIMAB 0 1 : f8TIMAB 1 0 : f32TIMAB 1 1 : fC32	RW
TCK1			RW

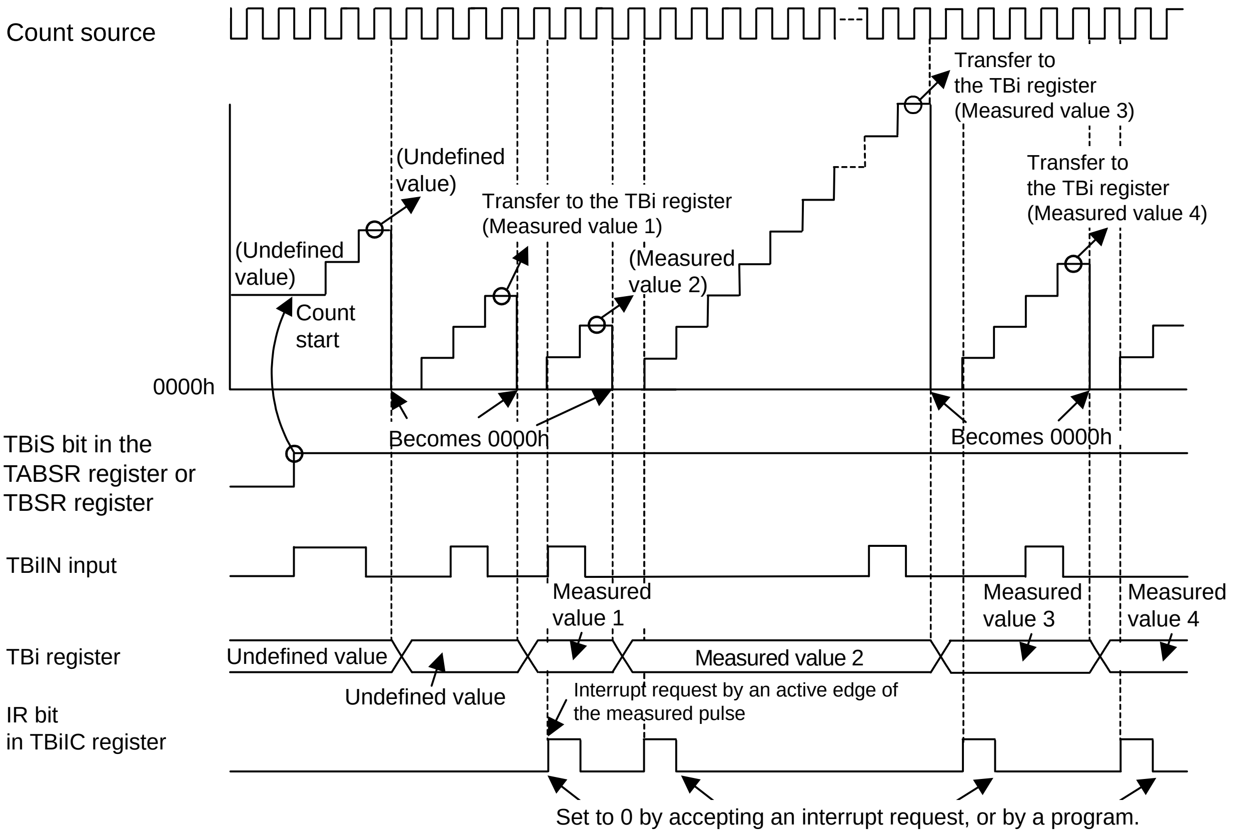
MR3 (Timer Bi overflow flag) (b5)

This bit is undefined after reset. The MR3 bit becomes 0 (no overflow) by writing to the TBiMR register. The MR3 bit cannot be set to 1 by a program.

TCK1 and TCK0 (Count source select bit) (b7-b6)

These bits are enabled when the TCS3 bit or TCS7 bit in registers TBCS0 to TBCS3 is set to 0 (TCK0, TCK1 enabled).

Set the PCLK0 bit in the PCLKR register to select f1TIMAB or f2TIMAB.

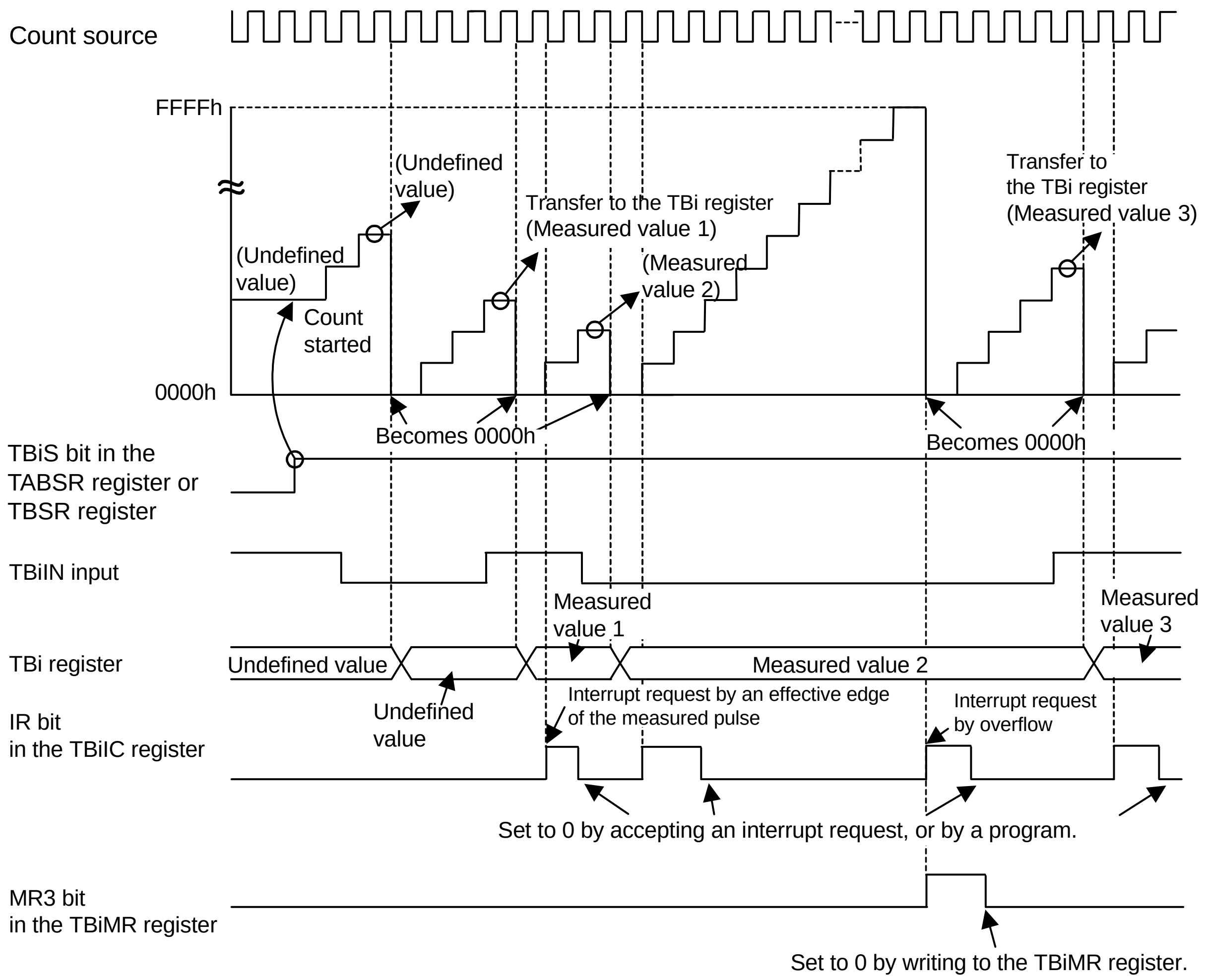


i = 0 to 5

The above assumes the following:

- Bits MR1 to MR0 in the TBiMR register = 00b (measurement between a falling edge and the next falling edge of measured pulse).
- Bits PPWFS12 to PPWFS10 and PPWFS22 to PPWFS20 in the PPWFS1 and PPWFS2 registers = 0 (measurement result stored in the TBi register).
- No initial value is set while timer Bi is stopped.

Figure 18.6 Operation Example in Pulse Period Measurement Mode


Count source
FFFFh
0000h
(Undefined value)
(Undefined value)
Count started
Transfer to the TBi register (Measured value 1)
(Measured value 2)
Transfer to the TBi register (Measured value 3)
Becomes 0000h
Becomes 0000h
TBiS bit in the TABSR register or TBSR register
TBiIN input
Measured value 1
Measured value 3
TBi register
Undefined value
Measured value 2
Undefined value
IR bit in the TBiIC register
Interrupt request by an effective edge of the measured pulse
Interrupt request by overflow
Set to 0 by accepting an interrupt request, or by a program.
MR3 bit in the TBiMR register
Set to 0 by writing to the TBiMR register.

i = 0 to 5

The above assumes the following:

- Bits MR1 to MR0 in the TBiMR register = 10b (measure pulse width).
- Bits PPWFS12 to PPWFS10 and PPWFS22 to PPWFS20 in the PPWFS1 and PPWFS2 registers = 0 (measurement result stored in the TBi register).
- No initial value is set while timer Bi is stopped.

Figure 18.7 Operation Example in Pulse Width Measurement Mode

18.4 Interrupts

Refer to individual operation examples for interrupt request generating timing.

Refer to 14.7 “Interrupt Control” for details of interrupt control. Table 18.11 lists Timer B Interrupt Related Registers.

Table 18.11 Timer B Interrupt Related Registers

Address	Register	Symbol	Reset Value
0045h	Timer B5 Interrupt Control Register	TB5IC	XXXX X000b
0046h	Timer B4 Interrupt Control Register	TB4IC	XXXX X000b
0047h	Timer B3 Interrupt Control Register	TB3IC	XXXX X000b
005Ah	Timer B0 Interrupt Control Register	TB0IC	XXXX X000b
005Bh	Timer B1 Interrupt Control Register	TB1IC	XXXX X000b
005Ch	Timer B2 Interrupt Control Register	TB2IC	XXXX X000b
0206h	Interrupt Source Select Register 2	IFSR2A	00h

Timers B3 and B4 share interrupt vectors and interrupt control registers with other peripheral functions. When using the timer B3 interrupt, set the IFSR26 bit in the IFSR2A register to 0 (timer B3). When using the timer B4 interrupt, set the IFSR27 bit in the IFSR2A register to 0 (timer B4).

18.5 Notes on Timer B

18.5.1 Common Notes on Multiple Modes

18.5.1.1 Register Setting

The timer is stopped after reset. Set the mode, count source, etc., using registers TBiMR, TBCS0 to TBCS3, TBi, TCKDIVC0, PCLKR, PPWFS1, and PPWFS2 before setting the TBiS bit in the TABSR or TBSR register to 1 (count started) (i = 0 to 5).
Rewrite registers TBiMR, TBCS0 to TBCS3, TCKDIVC0, PCLKR, PPWFS1, and PPWFS2 while the TBiS bit is 0 (count stopped), regardless of whether after reset or not.

18.5.1.2 Main Clock

When using the main clock for the timer A and timer B count source (PCKSTP17 bit in the PCLKSTP1 register is 1), adhere the following:

- Set the PCKSTP11 bit in the PCLKSTP1 register to 0 (f1 supply enabled).
- The main clock can be used in PLL operating mode, high-speed mode, medium-speed mode, or wait mode. Do not use the main clock for the timer A and timer B count source in other modes.
- When the PCKSTP17 bit is set to 1 and timer A or timer B operates in wait mode, set the CM02 bit to 0 (peripheral function clock f1 does not stop in wait mode).

18.5.2 Timer B (Timer Mode)

18.5.2.1 Reading the Timer

While counting, the counter value can be read at any time by reading the TBi register. However, FFFFh is read while reloading. When the counter is read before it starts counting and after a value is set in the TBi register while not counting, the set value is read.

18.5.3 Timer B (Event Counter Mode)

18.5.3.1 Reading the Timer

While counting, the counter value can be read at any time by reading the TBi register. However, FFFFh is read while reloading. When the counter is read before it starts counting and after a value is set in the TBi register while not counting, the set value is read.

18.5.3.2 Event

When the TCK1 bit in the TBiMR register is 1, an event occurs when an interrupt request of the selected timer is generated. An event or trigger occurs while an interrupt is disabled because an interrupt request signal is generated regardless of the I flag, IPL, or interrupt control registers.
When the timer selected by the TCK1 bit uses pulse-period measurement mode or pulse-width measurement mode, an interrupt request is generated at an active edge of the measurement pulse.

18.5.4 Timer B (Pulse Period/Pulse Width Measurement Modes)

18.5.4.1 MR3 Bit in the TBiMR Register

To clear the MR3 bit to 0 by writing to the TBiMR register while the TBiS bit is 1 (count started), be sure to set the same value as previously set to bits TMOD0, TMOD1, MR0, MR1, TCK0, and TCK1, and set bit 4 to 0.

18.5.4.2 Interrupts

The IR bit in the TBiIC register becomes 1 (interrupt requested) when an active edge of a measurement pulse is input, or timer Bi overflows (i = 0 to 5). The source of an interrupt request can be determined by setting the MR3 bit in the TBiMR register within the interrupt routine.
Use the IR bit in the TBiIC register to detect overflows only. Use the MR3 bit only to determine the interrupt source.

18.5.4.3 Event or Trigger

When timer Bi in pulse-period measurement mode or pulse-width measurement mode is used as an event or trigger for timer A or timer B other than timer Bi, an event or trigger occurs at both the overflow and active edge of the measurement pulse.

18.5.4.4 Operations between Count Start and the First Measurement

When a count is started and the first active edge is input, an undefined value is transferred to the reload register. At this time, a timer Bi interrupt request is not generated.

The value of the counter is undefined after reset. If the count is started in this state, the MR3 bit may become 1 and a timer Bi interrupt request may be generated after the count starts before an active edge is input. When a value is set in the TBi register while the TBiS bit is 0 (count stopped), the same value is written to the counter.

18.5.4.5 Pulse Period Measurement Mode

When an active edge and overflow are generated simultaneously, input is not recognized at the active edge because an interrupt request is generated only once. Use this mode so an overflow is not generated, or use pulse width measurement mode.

18.5.4.6 Pulse Width Measurement Mode

In pulse width measurement, pulse widths are measured successively. Check whether the measurement result is a high-level width or a low-level width in the user program.
When an interrupt request is generated, read the TBiIN pin level in the interrupt routine, and check whether it is the edge of an input pulse or overflow. The TBiIN pin level can be read from bits in the register of ports sharing a pin.

19. Three-Phase Motor Control Timer Function

19.1 Introduction

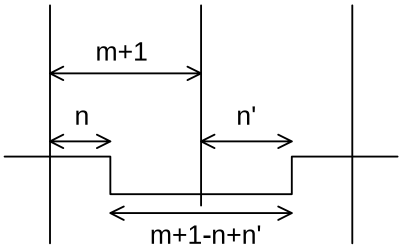
Timers A1, A2, A4, and B2 can be used to output three-phase motor drive waveforms.

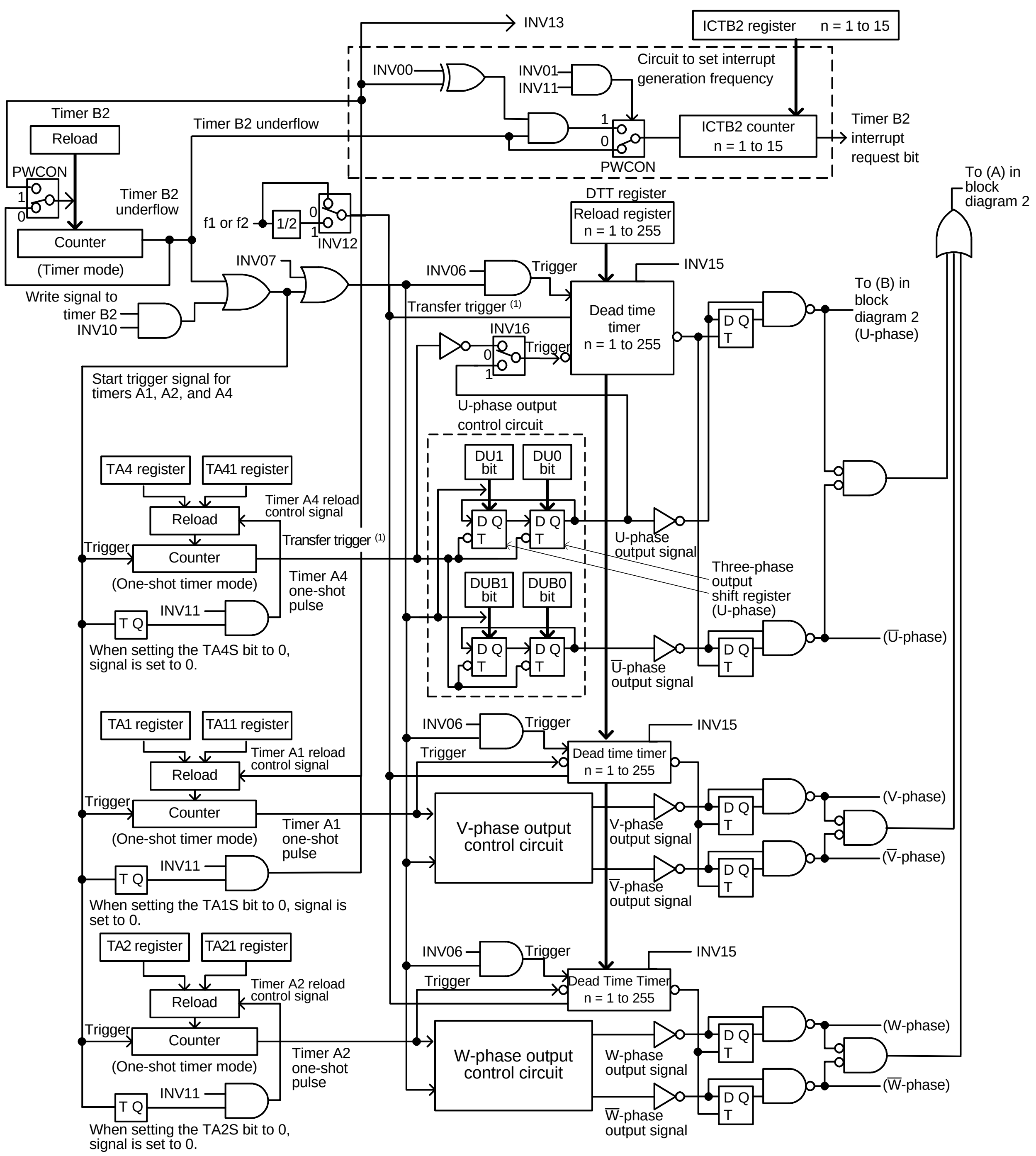
Table 19.1 and Table 19.2 list Three-Phase Motor Control Timer Function Specifications. Three-Phase Motor Control Timer Function Block Diagrams are shown in Figure 19.1 and Figure 19.2. Table 19.3 lists I/O Ports.

Table 19.1 Three-Phase Motor Control Timer Function Specifications (1/2)

Item	Specification
Operation modes	• Triangular wave modulation three-phase mode 0 Three-phase PWM waveform of triangular wave modulation is output. Output data is updated every half cycle of the carrier wave, and an output waveform is generated. • Triangular wave modulation three-phase mode 1 Three-phase PWM waveform of triangular wave modulation is output. Output data is updated every cycle of the carrier wave, and an output waveform is generated. • Sawtooth wave modulation mode Three-phase PWM waveform of sawtooth wave modulation is output.
Three-phase PWM waveform output pins	6 (U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W, $\overline{\text{W}}$)
Forced cutoff input	Input a low-level signal to the $\overline{\text{SD}}$ pin
Used timers	Timers A4, A1, A2 (used in one-shot timer mode) Timer A4: U-/$\overline{\text{U}}$-phase waveform control Timer A1: V-/$\overline{\text{V}}$-phase waveform control Timer A2: W-/$\overline{\text{W}}$-phase waveform control Timer B2 (used in timer mode) Carrier wave cycle control Dead time timer (three 8-bit timers and shared reload register) Dead time control
Output waveform	Triangular wave modulation, sawtooth wave modulation • All high or low outputs for one cycle supported • Output logic of high- and low-side turn-on signals can be set separately.
Carrier wave cycle	Triangular wave modulation : $\frac{(m+1) \times 2}{fi}$ Sawtooth wave modulation : $\frac{m+1}{fi}$ m: Setting value of the TB2 register, 0000h to FFFFh fi: Count source frequency (f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32)

Table 19.2 Three-Phase Motor Control Timer Function Specifications (2/2)

Item	Specification
Three-phase PWM output width	Triangular wave modulation : $\frac{m+1-n+n'}{fi}$  Sawtooth wave modulation : $\frac{n}{fi}$ n, n’: Setting value of registers TA4, TA1, and TA2 (of registers TA4, TA41, TA1, TA11, TA2, and TA21 when setting the INV11 bit to 1), 0001h to FFFFh fi: Count source frequency (f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32)
Dead time (width)	$\frac{p}{fi}$ or no dead time p: Setting value of the DTT register, 01h to FFh fi: Count source frequency (f1TIMAB, f2TIMAB, f1TIMAB divided by 2, f2TIMAB divided by 2)
Active level	Selectable either active high or active low
Simultaneous conduction prevention function	Simultaneous conduction prevention Simultaneous conduction detection
Interrupt frequency	A timer B2 interrupt is generated every carrier wave cycle to every 15 carrier wave cycles.

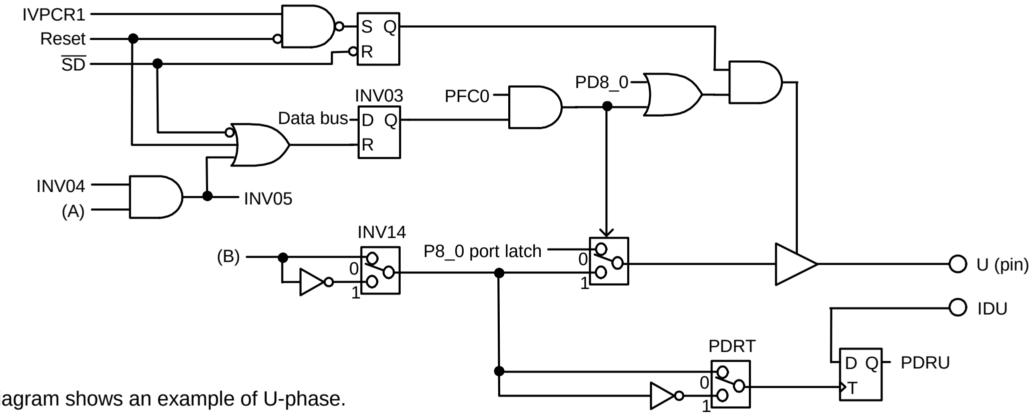


Note:

1. When the INV06 bit is 0 (triangular wave modulation mode), a transfer trigger is generated only at the first timer B2 underflow after writing to registers IDB0 and IDB1.

INV07, INV06, INV01, INV00: Bits in the INVC0 register
INV16, INV15, INV13 to INV10: Bits in the INVC1 register
DUB0, DU0: Bits in the IDB0 register
DUB1, DU1: Bits in the IDB1 register
PWCON: Bit in the TB2SC register
TA4S, TA2S, TA1S: Bits in the TABSR register

Figure 19.1 Three-Phase Motor Control Timer Function Block Diagram 1



The above diagram shows an example of U-phase.

IVPCR1 : Bit in the TB2SC register
INV03 to INV05 : Bits in the INVC0 register
PD8_0 : Bit in the PD8 register
PFC0 : Bit in the PFCR register
PDRT, PDRU : Bits in the PDRF register

Figure 19.2 Three-Phase Motor Control Timer Function Block Diagram 2

Table 19.3 I/O Ports

Pin Name	I/O	Function
U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W, $\overline{\text{W}}$	Output	Three-phase PWM waveform output
$\overline{\text{SD}}$	Input (1)	Forced cutoff input
IDU, IDV, IDW	Input (2)	Position-data-retain function input

Notes:

1. Set the port direction bits which share pins to 0 (input mode). When not using the three-phase output forced cutoff function, input a high-level signal to the $\overline{\text{SD}}$ pin.
2. Set the port direction bits which share pins to 0 (input mode).

19.2 Registers

Refer to “registers and settings” in each mode for register and bit settings.

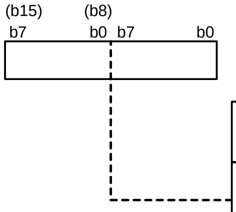
Three-phase motor control timer function uses timers A1, A2, A4, and B2. For other registers related to timers A1, A2, A4, and B2, refer to 17. “Timer A” and 18. “Timer B”.

Table 19.4 Registers

Address	Register	Symbol	Reset Value
01DAh	Three-Phase Protect Control Register	TPRC	00h
0302h 0303h	Timer A1-1 Register	TA11	XXh XXh
0304h 0305h	Timer A2-1 Register	TA21	XXh XXh
0306h 0307h	Timer A4-1 Register	TA41	XXh XXh
0308h	Three-Phase PWM Control Register 0	INVC0	00h
0309h	Three-Phase PWM Control Register 1	INVC1	00h
030Ah	Three-Phase Output Buffer Register 0	IDB0	XX11 1111b
030Bh	Three-Phase Output Buffer Register 1	IDB1	XX11 1111b
030Ch	Dead Time Timer	DTT	XXh
030Dh	Timer B2 Interrupt Generation Frequency Set Counter	ICTB2	XXh
030Eh	Position-Data-Retain Function Control Register	PDRF	XXXX 0000b
0318h	Port Function Control Register	PFCR	0011 1111b
0328h 0329h	Timer A1 Register	TA1	XXh XXh
032Ah 032Bh	Timer A2 Register	TA2	XXh XXh
032Eh 032Fh	Timer A4 Register	TA4	XXh XXh
0334h 0335h	Timer B2 Register	TB2	XXh XXh
033Eh	Timer B2 Special Mode Register	TB2SC	X000 0000b

19.2.1 Timer B2 Register (TB2)

Timer B2 Register



Symbol	Address	Reset Value
TB2	0335h to 0334h	Undefined

Function	Setting Range	RW
If the setting value is n, the counter frequency is $\frac{n + 1}{fj}$ Timers A1, A2, and A4 start each time an underflow occurs.	0000h to FFFFh	RW

fj : Count source frequency

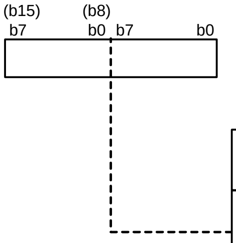
Read and write in 16-bit units.

The carrier wave cycle is determined by this counter. Timer B2 underflow is a one-shot trigger of timers A1, A2, and A4.

In three-phase mode 1, the reload timing of the TB2 register can be selected by setting the PWCON bit in the TB2SC register.

19.2.2 Timer Ai, Ai-1 Register (TAi, TAi1) (i = 1, 2, 4)

Timer Ai, Ai-1 Register (i = 1, 2, 4)



Symbol	Address	Reset Value
TA1, TA2, TA4	0329h to 0328h, 032Bh to 032Ah, 032Fh to 032Eh	Undefined
TA11, TA21, TA41	0303h to 0302h, 0305h to 0304h, 0307h to 0306h	Undefined

Function	Setting Range	RW
If the setting value is n, the timer stops when the nth count source is counted after a start trigger is generated. Output signals of each phase change when timers A1, A2, and A4 stop.	0000h to FFFFh	WO

Write to these registers in 16-bit units. Use the MOV instruction to set registers TAi and TAi1. If the TAi or TAi1 register is set to 0000h, no counters start and no timer Ai interrupt is generated.

The TAi or TAi1 register is used to determine waveforms of U-, V-, and W-phases. It is triggered by timer B2 underflow, and operates in one-shot timer mode.

Registers TA1, TA2, and TA4 are used in sawtooth wave modulation mode and three-phase mode 0 of triangular wave modulation mode.

Registers TA1, TA2, TA4, TA11, TA21, and TA41 are used in three-phase mode 1 of triangular wave modulation mode.

When the INV15 bit in the INVC1 register is set to 0 (dead time enabled), some high- and low-side turn-on signals, whose output level changes from inactive to active, switch the output level when the dead time timer stops.

In three-phase mode 1, the value of the TAi1 register is counted first. Then, the values of registers TAi and TAi1 are counted alternately.

19.2.3 Three-Phase PWM Control Register 0 (INVC0)

Three-Phase PWM Control Register 0

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
INVC0	0308h	00h

Bit Symbol	Bit Name	Function	RW
INV00	ICTB2 count condition select bit	b1 b0 0 0 : } Timer B2 underflow 0 1 : } 1 0 : Timer B2 underflow when timer A1 reload control signal is 0 1 1 : Timer B2 underflow when timer A1 reload control signal is 1	RW
INV01			RW
INV02	Three-phase motor control timer function enable bit	0 : Three-phase motor control timer function not used 1 : Three-phase motor control timer function used	RW
INV03	Three-phase motor control timer output control bit	0 : Three-phase motor control timer output disabled 1 : Three-phase motor control timer output enabled	RW
INV04	High- and low-side simultaneous turn-on disable bit	0 : Simultaneous turn-on enabled 1 : Simultaneous turn-on disabled	RW
INV05	High- and low-side simultaneous turn-on detect flag	0 : Not detected 1 : Detected	RW
INV06	Modulation mode select bit	0 : Triangular wave modulation mode 1 : Sawtooth wave modulation mode	RW
INV07	Software trigger select bit	A transfer trigger is generated when the INV07 bit is set to 1. A trigger to the dead time timer is also generated when setting the INV06 bit to 1. The read value is 0.	RW

Set the INVC0 register after the PRC1 bit in the PRCR register is set to 1 (write enabled). Rewrite bits INV00 to INV02, INV04, and INV06 when timers A1, A2, A4, and B2 are stopped.

INV01 and INV00 (ICTB2 count condition select bit) (b1-b0)

Bits INV00 and INV01 are enabled only when the INV11 bit in the INVC1 register is 1 (three-phase mode 1).

To set the INV01 bit to 1, set the ICTB2 register first, and then set the INV01 bit to 1. Set the TA1S bit in the TABSR register (timer A1 count start flag) to 1 prior to the first timer B2 underflow.

When the INV11 bit is 0 (three-phase mode 0), the timer B2 underflow is counted regardless of the values of bits INV01 to INV00.

INV02 (Three-phase motor control timer function enable bit) (b2)

Set the INV02 bit to 1 to operate the dead time timer, U-, V- and, W-phase output control circuits, and the ICTB2 counter.

INV03 (Three-phase motor control timer output control bit) (b3)

Conditions to become 0:

- The INV04 bit is 1 (simultaneous turn-on disabled) and the INV05 bit is 1 (simultaneous turn-on detected).
- The INV03 bit is set to 0 by a program.
- The signal applied to the $\overline{\text{SD}}$ pin is low.

INV05 (High- and low-side simultaneous turn-on detect flag) (b5)

The INV05 bit cannot be set to 1 by a program. Set the INV04 bit to 0 when setting the INV05 bit to 0.

INV06 (Modulation mode select bit) (b6)

The following table lists items influenced by the INV06 bit.

Table 19.5 Influence of the INV06 Bit

Item	INV06 is 0	INV06 is 1
Mode	Triangular wave modulation mode	Sawtooth wave modulation mode
Transfer timing from registers IDB0 and IDB1 to three-phase output shift register	Transferred once by generating a transfer trigger after setting registers IDB0 and IDB1	Transferred every time a transfer trigger is generated
Trigger timing of the dead time timer when the INV16 bit is 0	Falling edge of a one-shot pulse of the timers A1, A2, or A4	• Falling edge of a one-shot pulse of the timer A1, A2, or A4 • Transfer trigger
INV13 bit	Enabled when the INV11 bit is 1 and the INV06 bit is 0	Disabled

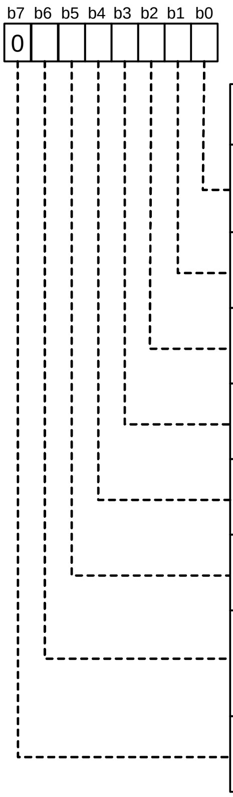
One of the following conditions must be met to trigger a transfer:

- Timer B2 underflows.
- A value is written to the INV07 bit.
- A value is written to the TB2 register during timer B2 stop when the INV10 bit is 1.

INV16, INV13, INV11: Bits in the INVC1 register

19.2.4 Three-Phase PWM Control Register 1 (INVC1)

Three-Phase PWM Control Register 1



Symbol	Address	Reset Value
INVC1	0309h	00h

Bit Symbol	Bit Name	Function	RW
INV10	Timer A1, A2 and A4 start trigger select bit	0 : Timer B2 underflow 1 : Timer B2 underflow and write to the TB2 register when timer B2 stops	RW
INV11	Timer A1-1, A2-1 and A4-1 control bit	0 : Three-phase mode 0 1 : Three-phase mode 1	RW
INV12	Dead time timer count source select bit	0 : f1TIMAB or f2TIMAB 1 : f1TIMAB divided by 2 or f2TIMAB divided by 2	RW
INV13	Carrier wave rise/fall detect flag	0 : Timer A1 reload control signal is 0 1 : Timer A1 reload control signal is 1	RO
INV14	Active level control bit	0 : Active low 1 : Active high	RW
INV15	Dead time disable bit	0 : Dead time enabled 1 : Dead time disabled	RW
INV16	Dead time timer trigger select bit	0 : Falling edge of one-shot pulse of timer (A4, A1, and A2) 1 : Rising edge of the three-phase output shift register (U-, V-, W-phase) output	RW
— (b7)	Reserved bit	Set to 0	RW

Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register.
Rewrite the INVC1 register while timers A1, A2, A4, and B2 are stopped.

INV11 (Timer A1, A2, and A4 start trigger select bit) (b1)

The following table lists items influenced by the INV11 bit.

Table 19.6 INV11 Bit

Item	INV11 = 0	INV11 = 1
Mode	Three-phase mode 0	Three-phase mode 1
Registers TA11, TA21 and TA41	Not used	Used
Bits INV00 to INV01 in the INVC0 register	Disabled The ICTB2 counter decrements whenever timer B2 underflows.	Enabled
INV13 bit	Disabled	Enabled when INV11 is 1 and INV06 is 0

When the INV06 bit is 1 (sawtooth wave modulation mode), set the INV11 bit to 0 (three-phase mode 0). Also, when the INV11 bit is 0, set the PWCON bit in the TB2SC register to 0 (timer B2 is reloaded when timer B2 underflows).

INV13 (Carrier wave rise/fall detect flag) (b3)

The INV13 bit is enabled only when the INV06 bit is set to 0 (triangular wave modulation mode) and the INV11 bit to 1 (three-phase mode 1).

INV16 (Dead time timer trigger select bit) (b6)

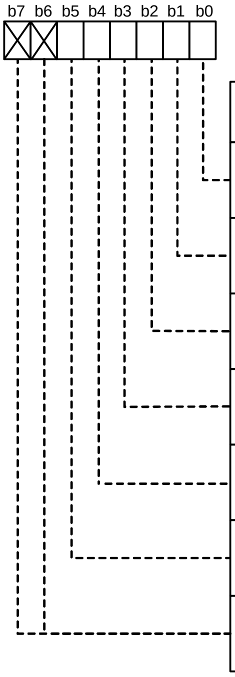
If both of the following conditions are met, set the INV16 bit to 1 (rising edge of the three-phase output shift register output).

- The INV15 bit is 0 (dead time timer enabled)
- Bits Dij and DiBj always have different values when the INV03 bit is set to 1 (three-phase control timer output enabled). The high- and low-side signals always output opposite level signals at any time except dead time. (i = U, V, or W; j = 0, 1).

If either of the above conditions is not met, set the INV16 bit to 0 (dead time timer is triggered on the falling edge of a one-shot pulse of timers).

19.2.5 Three-Phase Output Buffer Register i (IDBi) (i = 0, 1)

Three-Phase Output Buffer Register i (i = 0, 1)



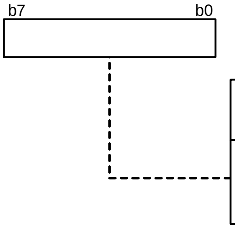
Symbol	Address	Reset Value
IDB0	030Ah	XX11 1111b
IDB1	030Bh	XX11 1111b

Bit Symbol	Bit Name	Function	RW
DUi	U-phase output buffer i	Set the output logical value of the three-phase output shift registers. The set value is reflected in each turn-on signal as follows: 0 : Active (on) 1 : Inactive (off) When read, the values of the three-phase output shift registers are read.	RW
DUBi	$\overline{U}$-phase output buffer i		RW
DVi	V-phase output buffer i		RW
DVBi	$\overline{V}$-phase output buffer i		RW
DWi	W-phase output buffer i		RW
DWBi	$\overline{W}$-phase output buffer i		RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is undefined.		—

Values of registers IDB0 and IDB1 are transferred to the three-phase output shift registers in response to a transfer trigger. After the transfer trigger occurs, the IDB0 register value determines each phase output signal (internal signal) first. Then, the IDB1 register value on the falling edge of timers A1, A2, and A4 one-shot pulse determines each phase output signal (internal signal).

19.2.6 Dead Time Timer (DTT)

Dead Time Timer



Symbol	Address	Reset Value
DTT	030Ch	Undefined

Function	Setting Range	RW
If a setting value is n, the count source is counted n times after the start trigger occurs, and then the timer stops.	1 to 255	WO

Use the MOV instruction to set the DTT register.

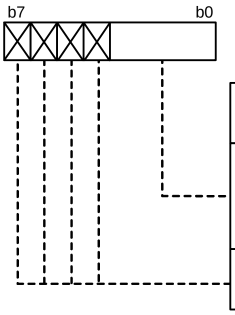
The DTT register acts as a one-shot timer which delays the timing for a turn-on signal to be switched to its active level in order to prevent the upper and lower transistors from being turned on simultaneously.

The DTT register is enabled when the INV15 bit in the INVC1 register is set to 0 (dead time enabled). No dead time can be set when the INV15 bit is set to 1 (dead time disabled).

Select a trigger by the INV16 bit in the INVC1 register, and a count source by the INV12 bit in the INVC1 register.

19.2.7 Timer B2 Interrupt Generation Frequency Set Counter (ICTB2)

Timer B2 Interrupt Generation Frequency Set Counter



Symbol	Address	Reset Value
ICTB2	030Dh	Undefined

Function	Setting Range	RW
When a setting value is n, timer B2 interrupt is generated every nth count timer B2 underflow meets the condition selected by bits INV01 to INV00 in the INVC0 register.	1 to 15	WO
No register bits. If necessary, set to 0		—

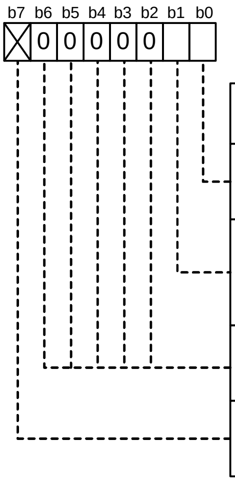
Use the MOV instruction to set the ICTB2 register.

If the INV01 bit in the INVC0 register is 1, set the ICTB2 register when the TB2S bit in the TABSR register is set to 0 (timer B2 counter stopped). If the INV01 bit is 0 and the TB2S bit to 1 (timer B2 counter start), do not set the ICTB2 register when timer B2 underflows.

When bits INV01 to INV00 are 11b, the first interrupt is generated when timer B2 underflows n-1 times if a setting value in the ICTB2 counter is n. Subsequent interrupts are generated every n times timer B2 underflows.

19.2.8 Timer B2 Special Mode Register (TB2SC)

Timer B2 Special Mode Register



Symbol	Address	Reset Value
TB2SC	033Eh	X000 0000b

Bit Symbol	Bit Name	Function	RW
PWCON	Timer B2 reload timing switch bit	0 : Timer B2 underflow 1 : Timer A output at odd-numbered occurrences	RW
IVPCR1	Three-phase output port $\overline{SD}$ control bit 1	0 : Three-phase output forced cutoff by $\overline{SD}$ input (high-impedance) disabled 1 : Three-phase output forced cutoff by $\overline{SD}$ input (high-impedance) enabled	RW
— (b6-b2)	Reserved bits	Set to 0	RW
— (b7)	No register bit. If necessary, set to 0. The read value is undefined.		—

Set the PRC1 bit in the PRCR register to 1 (write enabled) before rewriting this register.

PWCON (Timer B2 reload timing switch bit) (b0)

If the INV11 bit in the INVC1 register is 0 (three-phase mode 0) or the INV06 bit in the INVC0 register is 1 (sawtooth wave modulation mode), set the PWCON bit to 0 (timer B2 underflow).

IVPCR1 (Three-phase output port $\overline{SD}$ control bit 1) (b1)

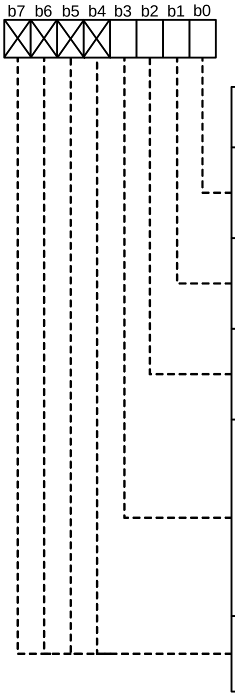
Related pins are U, $\overline{U}$, V, $\overline{V}$, W, and $\overline{W}$.

If a low-level signal is applied to the $\overline{SD}$ pin when the IVPCR1 bit is 1, three-phase motor control timer output is disabled (INV03 bit in the INVC0 register becomes 0). Then, the target pins become high-impedance regardless of the functions those pins are using.

After a forced cutoff, input a high-level signal to the $\overline{SD}$ pin and set the IVPCR1 bit to 0 to cancel the forced cutoff.

19.2.9 Position-Data-Retain Function Control Register (PDRF)

Position-Data-Retain Function Control Register



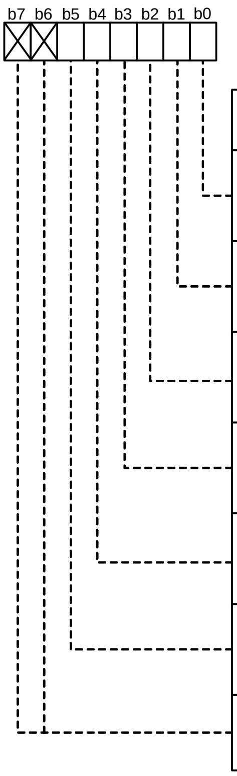
Symbol	Address	Reset Value
PDRF	030Eh	XXXX 0000b

Bit Symbol	Bit Name	Function	RW
PDRW	W-phase position data retain bit	Input level at IDW pin is retained. 0: Low level 1: High level	RO
PDRV	V-phase position data retain bit	Input level at IDV pin is retained. 0: Low level 1: High level	RO
PDRU	U-phase position data retain bit	Input level at IDU pin is retained. 0: Low level 1: High level	RO
PDRT	Retain-trigger polarity select bit	Select polarity of a retain-trigger When the INV14 bit is 0 (active low): 0: Falling edge of high-side output signal 1: Rising edge of high-side output signal When the INV14 bit is 1 (active high): 0: Rising edge of high-side output signal 1. Falling edge of high-side output signal	RW
— (b7-b4)	No register bits. If necessary, set to 0. The read value is undefined.		—

This register is only enabled in three-phase mode.

19.2.10 Port Function Control Register (PFCR)

Port Function Control Register



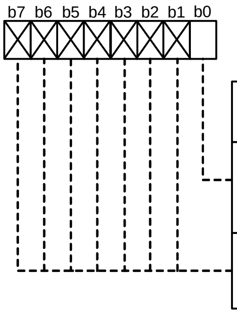
Symbol	Address	Reset Value
PFCR	0318h	0011 1111b

Bit Symbol	Bit Name	Function	RW
PFC0	Port P8_0 output function select bit	0: I/O port P8_0 1: Three-phase PWM output (U-phase output)	RW
PFC1	Port P8_1 output function select bit	0: I/O port P8_1 1: Three-phase PWM output ($\overline{U}$-phase output)	RW
PFC2	Port P7_2 output function select bit	0: I/O port P7_2 1: Three-phase PWM output (V-phase output)	RW
PFC3	Port P7_3 output function select bit	0: I/O port P7_3 1: Three-phase PWM output ($\overline{V}$-phase output)	RW
PFC4	Port P7_4 output function select bit	0: I/O port P7_4 1: Three-phase PWM output (W-phase output)	RW
PFC5	Port P7_5 output function select bit	0: I/O port P7_5 1: Three-phase PWM output ($\overline{W}$-phase output)	RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is 0.		—

This register is enabled only when the INV03 bit in the INVC0 register is set to 1 (three-phase motor control timer output enabled). Set the TPRC0 bit in the TPRC register to 1 (write enabled) before rewriting this register.

19.2.11 Three-Phase Protect Control Register (TPRC)

Three-Phase Protect Control Register



Symbol	Address	Reset Value
TPRC	01DAh	00h

Bit Symbol	Bit Name	Function	RW
TPRC0	Three-phase protect control bit	Enable write to the PFCR register 0: Write disabled 1: Write enabled	RW
— (b7-b1)	No register bits. If necessary, set to 0. The read value is 0.		—

Once the TPRC0 bit is set to 1 (write enabled) by a program, the set value 1 is retained. To change the register protected by this bit, follow these steps:

(1) Set the TPRC0 bit to 1.
(2) Set a value to the PFCR register.
(3) Set the TPRC0 bit to 0 (write disabled).

19.3 Operations

19.3.1 Common Operations in Multiple Modes

19.3.1.1 Carrier Wave Cycle Control

Timer B2 controls the cycle of the carrier wave. In triangular wave modulation mode, the cycle of the carrier wave is double the cycle of timer B2 underflow. In sawtooth wave modulation mode, the cycle of the carrier wave is equal to the cycle of timer B2 underflow. Figure 19.3 shows the Relationship between the Carrier Wave Cycle and Timer B2.

Timer B2 underflow is a start trigger for timers A1, A2, and A4, which control the three-phase PWM waveform. However, when the INV10 bit in the INVC1 register is 1, writing to the TB2 register while timer B2 is stopped also generates a trigger for timers A1, A2, and A4.

The frequency of timer B2 interrupt requests can be selected for three-phase motor control timers.

In triangular wave modulation three-phase mode 0 and sawtooth wave modulation mode, when the setting value in the ICTB2 register is n, a timer B2 interrupt request is generated every nth count of timer B2 underflow.

In triangular wave modulation three-phase mode 1, when the setting value in the ICTB2 register is n, a timer B2 interrupt request is generated every nth time of the timing selected by bits INV01 to INV00 in the INVC0 register. However, when bits INV01 to INV00 are 11b, the first interrupt is generated at the n-1 time of timer B2 underflow.

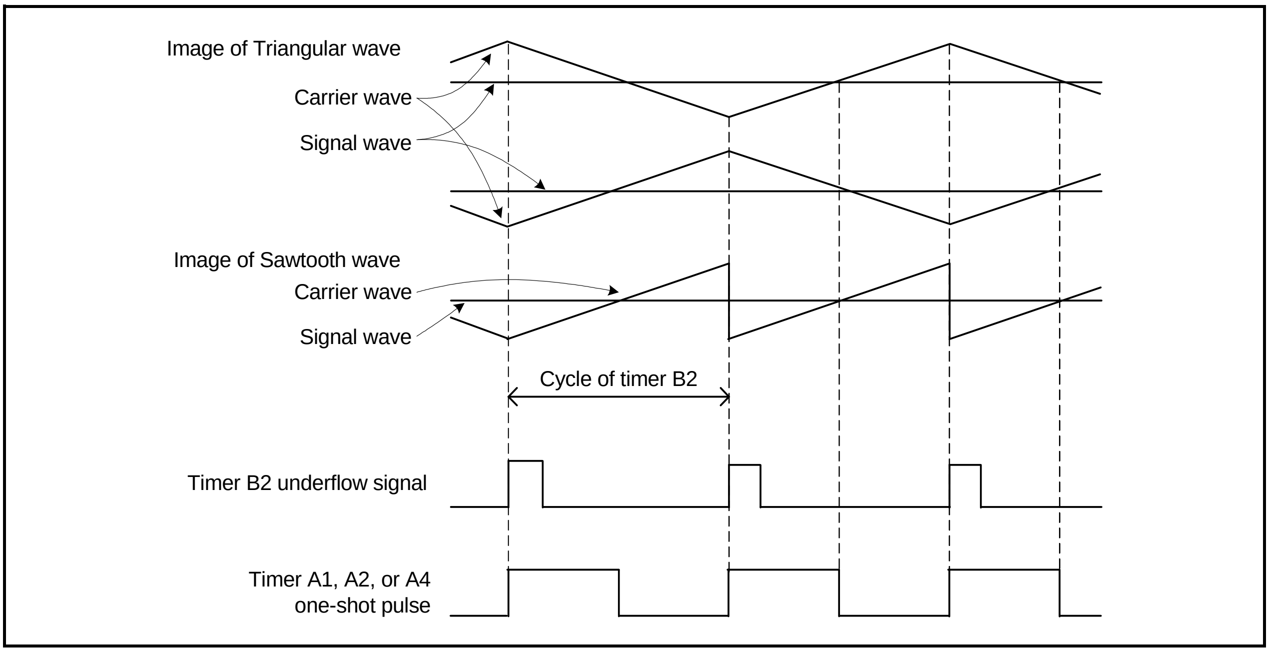


Figure 19.3 Relationship between the Carrier Wave Cycle and Timer B2

19.3.1.2 Three-Phase PWM Wave Control

Timer A4 controls U- and $\overline{U}$-phase waveforms, timer A1 controls V- and $\overline{V}$-phase waveforms, and timer A2 controls W- and $\overline{W}$-phase waveforms. Timer Ai (i = 1, 2, 4) starts counting by a trigger selected by the INV10 bit in the INVC1 register, and generates a one-shot pulse (internal signal). The output signal of each phase changes at the falling edge of the one-shot pulse.

Triangular wave modulation three-phase mode 1 counts values in the TAi1 register and TAi register alternately, and generates a one-shot pulse.

19.3.1.3 Dead Time Control

Due to delays in the transistors turning off, the upper and lower transistors are turned on simultaneously. To prevent this, there are three 8-bit dead time timers, one in each phase. The reload resistor is shared. When the INV15 bit in the INVC1 register is 0 (dead time enabled), the dead time set in the DTT register is enabled. When the INV15 bit is 1 (dead time disabled), no dead time is set. Select a count source for the dead time timer by setting the INV12 bit in the INVC1 register.

A trigger for the dead time timer can be selected by setting the INV16 bit in the INVC1 register.

When both of the following conditions are met, set the INV16 bit to 1 (the rising edge of the three-phase output shift register is a trigger for the dead time timer):

- The INV15 bit is 0 (dead time enabled).
- Bits Dij and DiBj in the IDBj register have different values when the INV03 bit in the INVC0 register is 1 (three-phase motor control timer output enabled) (i = U, V or W; j = 0, 1). (During the period other than dead time, the high- and low-side output signals always output opposite level signals.)

If either of the conditions above is not met, set the INV16 bit to 0 (a trigger for the dead time timer is the falling edge of one-shot pulse of the timer).

In sawtooth wave modulation mode, the generation of a transfer trigger causes a trigger for the dead time timer.

19.3.1.4 Output Level of Three-Phase PWM Output Pins

Set values to registers IDB0 and IDB1 to select the state of each high- or low-side output signal (either active (on) or not active (off)). The values of registers IDB0 and IDB1 are transferred to the three-phase output shift registers by a transfer trigger. After a transfer trigger is generated, the value set in the IDB0 register becomes the first output signal of each phase (internal signal), and then at the falling edge of a timer A1, A2, or A4 (internal signal) one-shot pulse, the value set in the IDB1 register becomes the output signal of each phase.

A transfer trigger is generated under any of the following conditions:

- At the first timer B2 underflow after registers IDB0 and IDB1 are written (in triangular wave modulation mode)
- Each time timer B2 underflows (in sawtooth wave modulation mode)
- Writing to the TB2 register while timer B2 is stopped (when the INV10 bit in the INVC1 register is 1)
- Setting the INV07 bit in the INVC0 register to 1 (software trigger)

The active level can be selected by the INV14 bit in the INVC1 register.

Table 19.7 Output Level of Three-Phase PWM Output Pins

Value Set in Registers IDB0 and IDB1	Output Signal of Each Phase (Internal Signal)	Value Set to the INV14 Bit in the INVC1 Register	
		0 (active, low level)	1 (active, high level)
0 (active (on))	0	Low	High
1 (not active (off))	1	High	Low

19.3.1.5 Simultaneous Conduction Prevention

This function prevents the upper and lower output signals from being active simultaneously due to program errors or unexpected program operation. When the high- and low-side output signals become active at the same time while the simultaneous conduction is disabled by the INV04 bit in the INVC0 register, the following occur:

- The INV03 bit in the INVC0 register becomes 0 (three-phase motor control timer output disabled).
- The INV05 bit in the INVC0 register becomes 1 (simultaneous conduction detected).
- Pins U, $\overline{U}$, V, $\overline{V}$, W, and $\overline{W}$ become high-impedance.

19.3.1.6 Three-Phase PWM Waveform Output Pins

Pins U, $\overline{U}$, V, $\overline{V}$, W, and $\overline{W}$ output a PWM waveform under the following conditions:

- The INVC02 bit in the INVC0 register is 1 (three-phase motor control timer function).
- The INVC03 bit in the INVC0 register is 1 (three-phase motor control timer output enabled).
- Bits PFC5 to PFC0 in the PFCR register are 1 (three-phase PWM output (selected independently for each pin)).

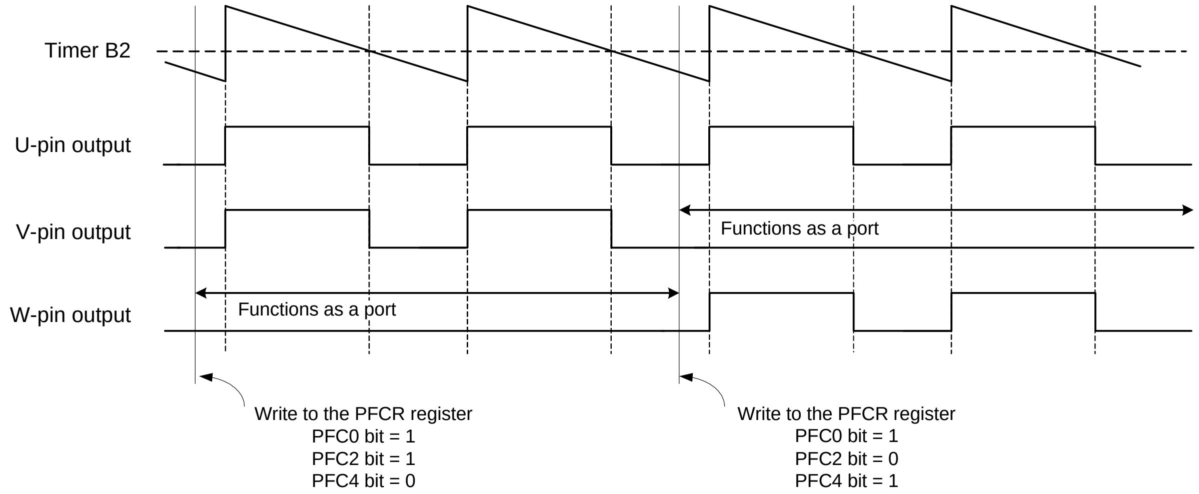
The three-phase output forced cutoff by the $\overline{SD}$ pin is available.

19.3.1.7 Three-Phase PWM Output Pin Select

Pins U, $\overline{U}$, V, $\overline{V}$, W, and $\overline{W}$ output a three-phase PWM waveform when the PFCi bit (i = 0 to 5) in the PFCR register is 1 (three-phase PWM output). When the PFCi bit is 0 (I/O port), these pins are used as I/O ports (or other peripheral function I/O ports). Therefore, while some of the six pins output a three-phase PWM waveform, the other pins can be used as I/O ports (or other peripheral function I/O ports).

The PFCR register can be rewritten when the TPRC0 bit in the TPRC register is 1 (write to the PFCR register enabled). The functions of the three-phase PWM waveform output pins can be protected from being rewritten due to an unexpected program operation. To prevent rewrite, follow these steps:
(1) Set the TPRC0 bit to 1.
(2) Rewrite the PFCR register.
(3) Set the TPRC0 bit to 0 (write to the PFCR register disabled).

Figure 19.4 shows Three-Phase Output and I/O Port Switch Function Operation.



The above assumes the following:

- The output data of the ports which share a pin with pins V and W are both 0 (low-level).
- The direction bits of the ports which share a pin with pins V and W are both 1 (output mode).

Figure 19.4 Three-Phase Output and I/O Port Switch Function Operation

19.3.1.8 Three-Phase Output Forced Cutoff Function

While the INV02 bit in the INVC0 register is 1 (three-phase motor control timer function) and the INV03 bit is 1 (three-phase motor control timer output enabled), when a low-level signal is applied to the $\overline{\text{SD}}$ pin, the INV03 bit in the INVC0 register becomes 0 (three-phase motor control timer output disabled), and pins corresponding to U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W and $\overline{\text{W}}$ outputs change concurrently as follows:

- When the IVPCR1 bit in the TB2SC register is 1 (three-phase output forced cutoff enabled)
  High-impedance
- When the IVPCR1 bit in the TB2SC register is 0 (three-phase output forced cutoff disabled)
  I/O ports or other peripheral function I/O ports

However, applying a low-level signal to the $\overline{\text{SD}}$ pin while the IVPCR1 bit is 1 places the pins in a high-impedance state even when the pins are used as functions other than U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W and $\overline{\text{W}}$ outputs. Table 19.8 lists State of Pins U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W, and $\overline{\text{W}}$.

Table 19.8 State of Pins U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W, and $\overline{\text{W}}$ (1)

State of Bit and Pin		Function or State of Pins U, $\overline{\text{U}}$, V, $\overline{\text{V}}$, W and $\overline{\text{W}}$
IVPCR1 bit in the TB2SC register	$\overline{\text{SD}}$ pin input	
1	High	Three-phase PWM output
	Low	High-impedance
0	High	Three-phase PWM output
	Low	I/O port or other peripheral functions

Note:

1. The above assumes bits INVC02, INVC03, and PFCi are all 1.

The digital filter is available for the $\overline{\text{SD}}$ pin. When the value of bits NMIDF2 to NMIDF0 in the NMIDF register is not 000b (digital filter enabled), $\overline{\text{SD}}$ pin input is sampled for every sampling clock. When the same sampled level is detected three times in a row, the level is transferred to the internal circuit. Refer to 13.4.3 “$\overline{\text{NMI}}$/$\overline{\text{SD}}$ Digital Filter”.

To return the pin function to three-phase PWM output after a forced cutoff, follow these steps:

(1) Apply a high-level signal to the $\overline{\text{SD}}$ pin.
(2) Wait for more than three cycles of the digital filter sampling clock.
(3) Set the INV03 bit in the INVC0 register to 1 (three-phase motor control timer output enabled).
(4) Confirm that the INV03 bit is 1. If the bit is 0, return to step (3).
(5) Set the IVPCR1 bit to 0 (three-phase output forced cutoff disabled).
(6) Set the IVPCR1 bit to 1 (when enabling three-phase output forced cutoff again).

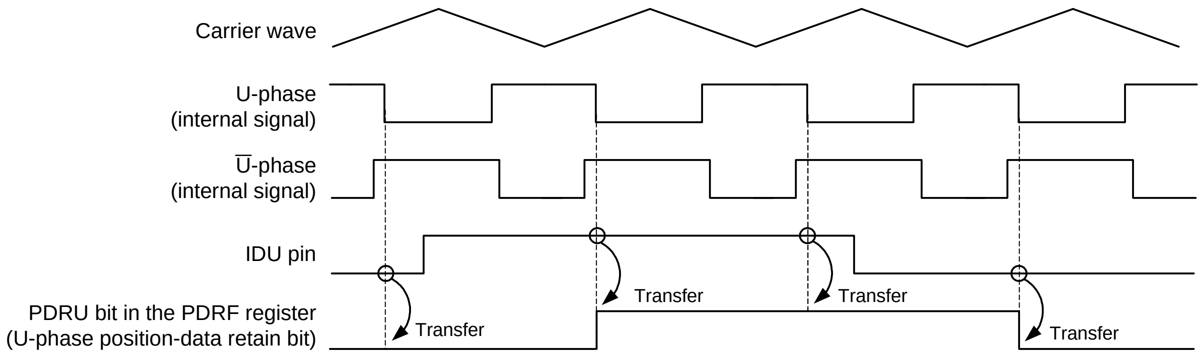
When not using the three-phase output forced cutoff function, set a port direction bit which shares the pin with $\overline{\text{SD}}$ input to 0 (input port), and apply a high-level signal to the $\overline{\text{SD}}$ pin.
The same pin is used for both $\overline{\text{SD}}$ input and $\overline{\text{NMI}}$ input. To disable the $\overline{\text{NMI}}$ interrupt, set the PM24 bit in the PM2 register to 0 ($\overline{\text{NMI}}$ interrupt disabled).

19.3.1.9 Position-Data-Retain Function

The position-data-retain function employs three position-data input pins: U-, V-, and W-phase. Input levels of IDU, IDV, and IDW inputs are retained. The falling edge or rising edge of the high-side output signal of each phase can be selected by setting the PDRT bit in the PDRF register as a position-data-retain trigger.

For example, in the case of U-phase, when the U-phase trigger is generated, the state of the IDU pin is transferred to the PDRU bit in the PDRF register. The value is retained until the next trigger of the U-phase waveform output.

Figure 19.5 shows Position-Data-Retain Function (U-Phase) Operation.



The above assumes the following:

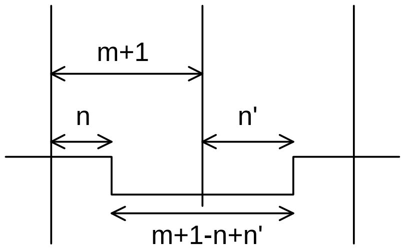
- The INV06 bit in the INVC0 register is 0 (triangular wave modulation mode).
- The INV14 bit in the INVC1 register is 0 (active low).
- The PDRT bit in the PDRF register is 0 (the falling edge of the high-side output signal is a trigger).

Figure 19.5 Position-Data-Retain Function (U-Phase) Operation

19.3.2 Triangular Wave Modulation Three-Phase Mode 0

Triangular wave modulation uses the timer B2 cycle as a reference cycle. Table 19.9 lists Three-Phase Mode 0 Specifications, and Figure 19.6 shows Example of Three-Phase Mode 0 Operation.

Table 19.9 Three-Phase Mode 0 Specifications

Item		Specification
Carrier wave cycle		$\frac{(m+1)\times 2}{fi}$ m: Setting value of the TB2 register, 0000h to FFFFh fi: Count source frequency (f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32)
Three-phase PWM output width		$\frac{m+1-n+n'}{fi}$  n, n’: Setting value of the TAi register, 0001h to FFFFh fi: Count source frequency (f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32)
Differences from three-phase mode 1	Reference cycle	Timer B2 cycle (one-half cycle of the carrier wave)
	Timer B2 reload timing	Timer B2 underflow
	Three-phase PWM waveform control	Counts the value of the TAi register every time a timer Ai start trigger is generated (the TAi1 register is not used).
	Timer B2 interrupt	When the setting value in the ICTB2 register is n, a timer B2 interrupt request is generated every nth time of timer B2 underflow (not influenced by bits INV00 and INV01 in the INVC0 register).
	Detection of a carrier wave cycle (first half or last half)	Not detected (the INV13 bit in the INVC1 register is disabled).

i = 1, 2, 4

Table 19.10 Registers and Settings in Three-Phase Mode 0 (1/2) [1]

Register	Bit	Function and Setting
INVC0	INV00	Disabled (Despite the setting, the ICTB2 register counts timer B2 underflow.)
	INV01	
	INV02	Set to 1 (three-phase motor control timer function used).
	INV03	Set to 1 (three-phase motor control timer output enabled).
	INV04	Select simultaneous conduction enabled or disabled.
	INV05	Simultaneous conduction detect flag
	INV06	Set to 0 (triangular wave modulation mode).
	INV07	Software trigger bit
INVC1	INV10	Select a start trigger for timers A1, A2, and A4.
	INV11	Set to 0 (three-phase mode 0).
	INV12	Select a count source for the dead time timer.
	INV13	Disabled
	INV14	Select the active level (either active high or active high).
	INV15	Select dead time enabled or disabled.
	INV16	Select a trigger for the dead time timer.
	7	Set to 0.
IDB0, IDB1	5 to 0	Set the output logic of the three-phase output shift registers.
DTT	7 to 0	Set the dead time.
ICTB2	3 to 0	Set the frequency of the timer B2 interrupt request.
TB2SC	PWCON	Set to 0 (timer B2 underflow).
	IVPCR1	Select three-phase output forced cutoff enabled or disabled.
	b7 to b2	Set to 0.
PDRF	PDRU, PDRV, PDRW	Position-data-retain bit
	PDRT	Select a position-data-retain trigger.
PFCR	PFC5 to PFC0	Select I/O port or three-phase PWM output.
TPRC	TPRC0	Set to 1 when writing to the PFCR register, or to 0 when not writing to it.
TA1, TA2, TA4	15 to 0	Set the one-shot pulse width.
TA11, TA21, TA41	15 to 0	Not used.
TB2	15 to 0	Set one-half cycle of the carrier wave.
TRGSR	TA1TGH to TA1TGL	Set to 01b (when using V-phase output control circuit).
	TA2TGH to TA2TGL	Set to 01b (when using W-phase output control circuit).
	TA3TGH to TA3TGL	Not used for three-phase motor control timer.
	TA4TGH to TA4TGL	Set to 01b (when using U-phase output control circuit).

Note:

1. This table does not describe a procedure.

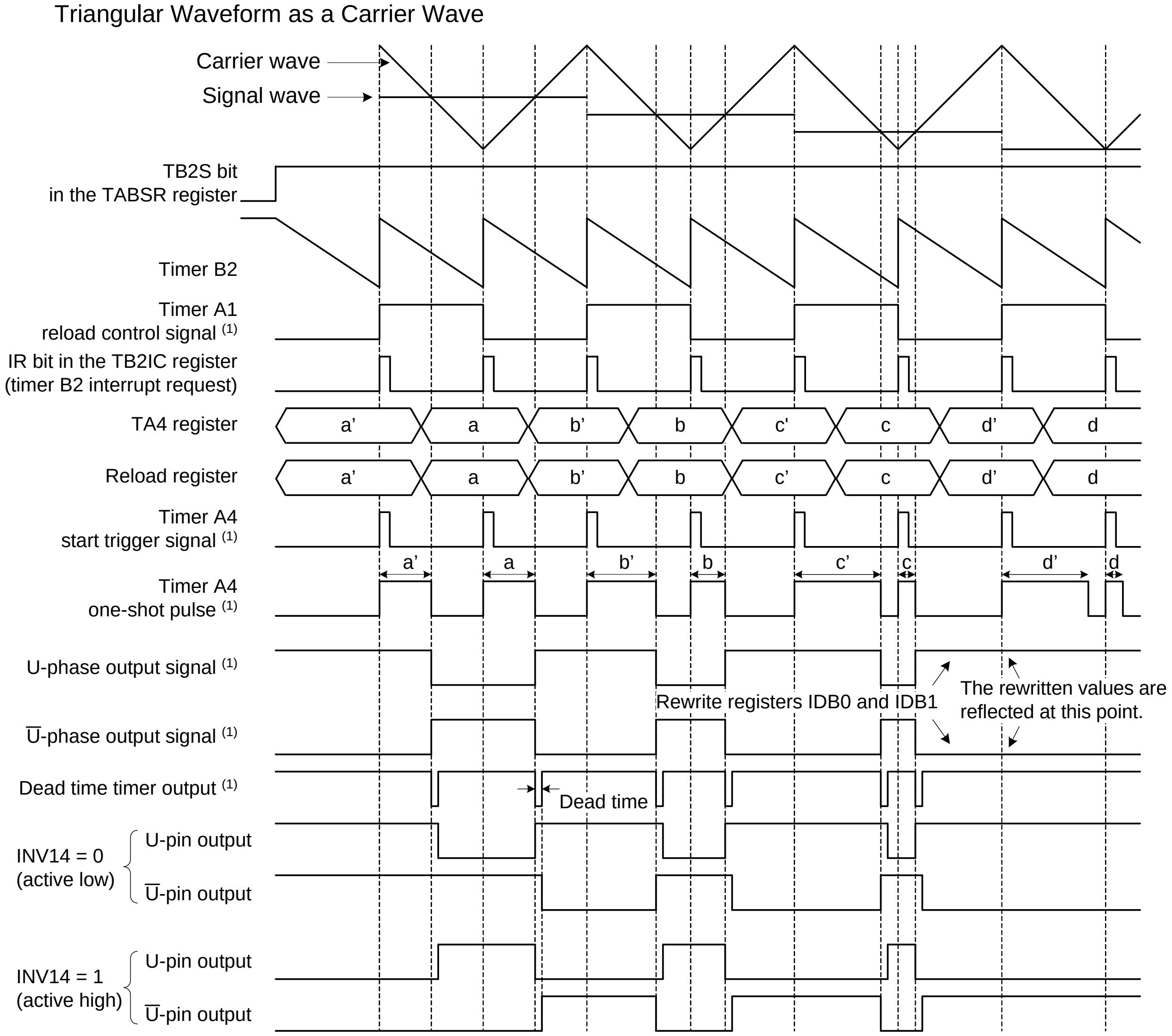
Table 19.11 Registers and Settings in Three-Phase Mode 0 (2/2) (1)

Register	Bit	Function and Setting
TABSR	TA0S	Not used for three-phase motor control timer.
	TA1S	Set to 1 when starting counting, and to 0 when stopping counting.
	TA2S	Set to 1 when starting counting, and to 0 when stopping counting.
	TA3S	Not used for three-phase motor control timer.
	TA4S	Set to 1 when starting counting, and to 0 when stopping counting.
	TB0S	Not used for three-phase motor control timer.
	TB1S	Not used for three-phase motor control timer.
	TB2S	Set to 1 when starting counting, and to 0 when stopping counting.
TA1MR, TA2MR, TA4MR	TMOD1 to TMOD0	Set to 10b (one-shot timer mode).
	MR0	Set to 0.
	MR1	Set to 0.
	MR2	Set to 1 (select a trigger by setting bits TAiTGH and TAiTGL).
	MR3	Set to 0.
	TCK1 to TCK0	Select a count source.
TB2MR	TMOD1 to TMOD0	Set to 00b (timer mode).
	MR1 to MR0	Set to 00b.
	4	Set to 0.
	MR3	Set to 0.
	TCK1 to TCK0	Select a count source.
PCLKR	PCLK0	Select a count source.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TCKDIVC0	TCDIV00	Select the clock prior to timer AB division.
TACS0 to TACS2	7 to 0	Select a count source.
TBCS1	TCS3 to TCS0	Select a count source.
TAPOFS	POFSi	Set to 0.
UDF	TAiP	Set to 0.

i = 1, 2, 4

Note:

1. This table does not describe a procedure.


Triangular Waveform as a Carrier Wave
Carrier wave
Signal wave
TB2S bit in the TABSR register
Timer B2
Timer A1 reload control signal (1)
IR bit in the TB2IC register (timer B2 interrupt request)
TA4 register
a' a b' b c' c d' d
Reload register
a' a b' b c' c d' d
Timer A4 start trigger signal (1)
Timer A4 one-shot pulse (1)
a' a b' b c' c d' d
U-phase output signal (1)
U̅-phase output signal (1)
Rewrite registers IDB0 and IDB1
The rewritten values are reflected at this point.
Dead time timer output (1)
Dead time
INV14 = 0 (active low)
U-pin output
U̅-pin output
INV14 = 1 (active high)
U-pin output
U̅-pin output

The above assumes the following:
In the INVC1 register
- The INV16 bit is 1 (the dead time timer is triggered on the rising edge of the three-phase output shift register).
- The INV15 bit is 0 (dead time timer enabled).
- The INV10 bit is 0 (timer B2 underflow is a start trigger for timers A1, A2, and A4).

The ICTB2 register is 1h (timer B2 interrupt request is generated at every timer B2 underflow).
Bits PFC1 to PFC0 in the PFCR register are 11b (U-, U̅-phase outputs).
In the TA4 register
- Initial value : a'
- Changes at every timer B2 interrupt
  1st : a; 2nd : b'; 3rd : b; 4th: c'; 5th : c; 6th : d'; 7th : d

Registers IDB0 and IDB1
- Initial values: DU0 = 1; DUB0 = 0; DU1 = 0; DUB1 = 1
- At the sixth timer B2 interrupt, the values are changed to: DU0 = 1; DUB0 = 0; DU1 = 1; DUB1 = 0.

Note:
1. Internal signal. Refer to Figure 19.1.

Figure 19.6 Example of Three-Phase Mode 0 Operation

19.3.2.1 Three-Phase PWM Wave Output Timing Control

In three-phase mode 0, when a start trigger for timers A1, A2, and A4 is generated, the counter starts counting the value of the TAi register (i = 1, 2, 4).

19.3.2.2 Three-Phase PWM Waveform Output Level Control

In triangular wave modulation mode, the output levels set in registers IDB0 and IDB1 are transferred to the three-phase output shift registers by a transfer trigger. After a transfer trigger is generated, first the value set in the IDB0 register becomes the output signal for each phase (internal signal), then at the falling edge of one-shot pulse for timers A1, A2, and A4, followed by the values set in the IDB1 register. Consequently, the three-phase PWM output changes. Afterward, the values in registers IDB0 and IDB1 alternately become output signals for each phase at every falling edge of the one-shot pulse for timers A1, A2, and A4.
When the INV15 bit in the INVC1 register is 0 (dead time enabled), a phase changing from active to nonactive changes simultaneously with output signals for each phase (internal signal), while a phase changing from nonactive to active changes when the dead time timer stops.

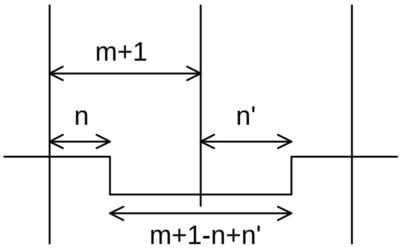
A transfer trigger is generated under the following conditions:

- The first timer B2 underflow after registers IDB0 and IDB1 are written.
- Writing to the TB2 register when timer B2 is stopped (when the INV10 bit in the INVC1 register is 1).
- Setting the INV07 bit in the INVC0 register to 1 (software trigger).

19.3.3 Triangular Wave Modulation Three-Phase Mode 1

Triangular wave modulation uses twice the cycles of timer B2 as a reference cycle. Table 19.12 lists Three-Phase Mode 1 Specifications, and Figure 19.7 shows Example of Three-Phase Mode 1 Operation.

Table 19.12 Three-Phase Mode 1 Specifications

Item		Specification
Carrier wave cycle		$\frac{(m+1)\times 2}{fi}$ m: Setting value of the TB2 register, 0000h to FFFFh fi: Count source frequency (f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32)
Three-phase PWM output width		$\frac{m+1-n+n'}{fi}$  n, n’: Setting value of the TAi register, 0001h to FFFFh fi: Count source frequency (f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32)
Differences from three-phase mode 0	Reference cycle	Twice the cycle of timer B2 (cycle of the carrier wave)
	Timer B2 reload timing	Select either of the following: • Timer B2 underflow • Timer A output at an odd number of times
	Three-phase PWM waveform control	Counts the values of registers TAi and TAi1 alternately every time a timer Ai start trigger is generated
	Timer B2 interrupt	Select a count timing for the ICTB2 register by bits INV01 to INV00 in the INVC0 register: • Timer B2 underflow (each time) • Timer B2 underflow when the INV13 bit in the INVC1 register is 0 • Timer B2 underflow when the INV13 bit is 1 When the setting value in the ICTB2 register is n, a timer B2 interrupt request is generated every nth time of the timing selected by setting bits INV01 to INV00.
	Detection of a carrier wave cycle (first half or last half)	Detected (The INV13 bit in the INVC1 register is enabled.)

i = 1, 2, 4

Table 19.13 Registers and Settings in Three-Phase Mode 1 (1/2) [1]

Register	Bit	Functions and Setting
INVC0	INV00	Select the timing that the ICTB2 register starts counting.
	INV01	
	INV02	Set to 1 (three-phase motor control timer function used).
	INV03	Set to 1 (three-phase motor control timer output enabled).
	INV04	Select simultaneous conduction enabled or disabled.
	INV05	Simultaneous conduction detect flag
	INV06	Set to 0 (triangular wave modulation mode).
	INV07	Software trigger bit
INVC1	INV10	Select a start trigger for timers A1, A2, and A4.
	INV11	Set to 1 (three-phase mode 1).
	INV12	Select a count source for the dead time timer.
	INV13	Carrier wave state detect flag
	INV14	Select the active level (either active high or active high).
	INV15	Select dead time enabled or disabled.
	INV16	Select a trigger for the dead time timer.
	7	Set to 0.
IDB0, IDB1	5 to 0	Set an output logic of the three-phase output shift registers.
DTT	7 to 0	Set the dead time.
ICTB2	3 to 0	Set the frequency of the timer B2 interrupt request.
TB2SC	PWCON	Select timer B2 reload timing.
	IVPCR1	Select three-phase output forced cutoff enabled or disabled.
	b7 to b2	Set to 0.
PDRF	PDRU, PDRV, PDRW	Position-data-retain bit
	PDRT	Select a position-data-retain trigger.
PFCR	PFC5 to PFC0	Select I/O port or three-phase PWM output.
TPRC	TPRC0	Set to 1 when writing to the PFCR register, or to 0 when not writing to it.
TA1, TA2, TA4	15 to 0	Set the one-shot pulse width.
TA11, TA21, TA41	15 to 0	Set the one-shot pulse width.
TB2	15 to 0	Set one-half cycle of the carrier wave.

i = 1, 2, 4

Note:

1. This table does not describe a procedure.

Table 19.14 Registers and Settings in Three-Phase Mode 1 (2/2) [1]

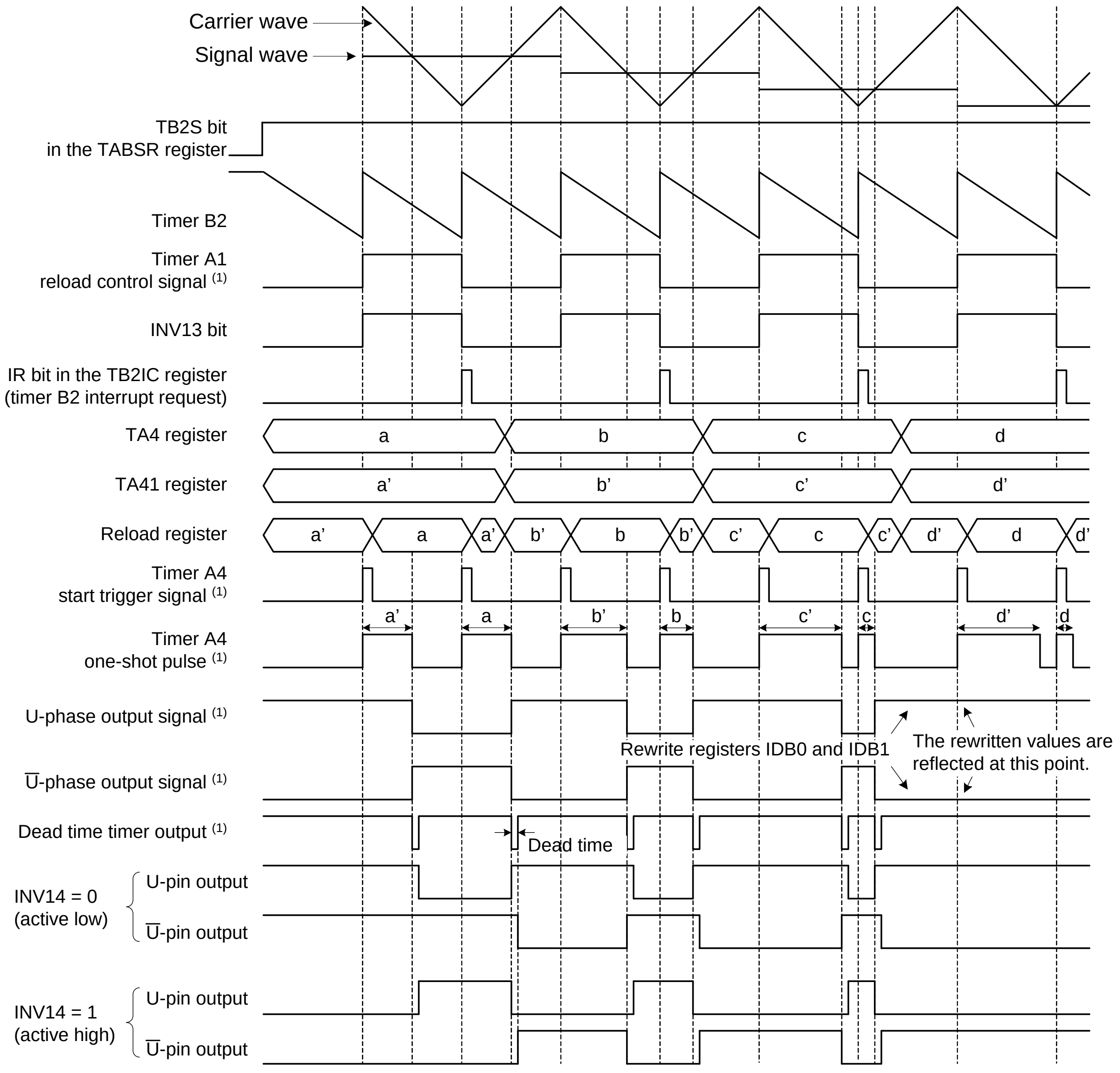
Register	Bit	Function and Setting
TRGSR	TA1TGH to TA1TGL	Se to 01b (when using V-phase output control circuit).
	TA2TGH to TA2TGL	Set to 01b (when using W-phase output control circuit).
	TA3TGH to TA3TGL	(Not used for three-phase motor control timer.)
	TA4TGH to TA4TGL	Set to 01b (when using U-phase output control circuit).
TABSR	TA0S	Not used for three-phase motor control timer.
	TA1S	Set to 1 when starting counting, and to 0 when stopping counting.
	TA2S	Set to 1 when starting counting, and to 0 when stopping counting.
	TA3S	Not used for three-phase motor control timer.
	TA4S	Set to 1 when starting counting, and to 0 when stopping counting.
	TB0S	Not used for three-phase motor control timer.
	TB1S	Not used for three-phase motor control timer.
	TB2S	Set to 1 when starting counting, and to 0 when stopping counting.
TA1MR, TA2MR, TA4MR	TMOD1 to TMOD0	Set to 10b (one-shot timer mode).
	MR0	Set to 0.
	MR1	Set to 0.
	MR2	Set to 1 (select a trigger by setting bits TAiTGH and TAiTGL.).
	MR3	Set to 0.
	TCK1 to TCK0	Select a count source.
TB2MR	TMOD1 to TMOD0	Set to 00b (timer mode).
	MR1 to MR0	Set to 00b.
	4	Set to 0.
	MR3	Set to 0.
	TCK1 to TCK0	Select a count source.
PCLKR	PCLK0	Select a count source.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TCKDIVC0	TCDIV00	Select the clock prior to timer AB division.
TACS0 to TACS2	7 to 0	Select a count source.
TBCS1	TCS3 to TCS0	Select a count source.
TAPOFS	POFSi	Set to 0.
UDF	TAiP	Set to 0.

i = 1, 2, 4

Note:

1. This table does not describe a procedure.

Triangular Waveform as a Carrier Wave


Carrier wave
Signal wave
TB2S bit in the TABSR register
Timer B2
Timer A1 reload control signal (1)
INV13 bit
IR bit in the TB2IC register (timer B2 interrupt request)
TA4 register
a
b
c
d
TA41 register
a’
b’
c’
d’
Reload register
a’ a a’ b’ b b’ c’ c c’ d’ d d’
Timer A4 start trigger signal (1)
a’ a b’ b c’ c d’ d
Timer A4 one-shot pulse (1)
U-phase output signal (1)
Rewrite registers IDB0 and IDB1
The rewritten values are reflected at this point.
$\overline{U}$-phase output signal (1)
Dead time timer output (1)
Dead time
INV14 = 0 (active low)
U-pin output
$\overline{U}$-pin output
INV14 = 1 (active high)
U-pin output
$\overline{U}$-pin output

The above assumes the following:
In the INVC0 register
- The INV01 bit is 0 and the ICTB2 register is 2h (timer B2 interrupt at every second timer B2 underflow) or bits INV01 to INV00 are 11b and the ICTB2 register is 1h (timer B2 interrupt at timer B2 underflow while the timer A1 reload control signal is 1).

In the INVC1 register
- The INV16 bit is 1 (the dead time timer is triggered on the rising edge of the three-phase output shift register).
- The INV15 bit is 0 (dead time timer enabled).
- The INV10 bit is 0 (timer B2 underflow is a start trigger for timers A1, A2 and A4).

The PWCON bit in the TB2SC register is 0 (timer B2 reload at the timing of timer B2 underflow).
Bits PFC1 to PFC0 in the PFCR register are 11b (U-, $\overline{U}$-phase outputs).
In registers TA4 and TA41
- Initial value: TA41 = a’, TA4 = a
- Registers TA4 and TA41 change at every timer B2 interrupt
  1st : TA41 = b’; TA4 = b; 2nd : TA41 = c’; TA4 = c; 3rd: TA41 = d’; TA4 = d

In registers IDB0 and IDB1
- Initial values: DU0 = 1; DUB0 = 0; DU1 = 0; DUB1 = 1
- At the third timer B2 interrupt, the values are changed to: DU0 = 1; DUB0 = 0; DU1 = 1; DUB1 = 0 .

Note:
1. Internal signal. Refer to Figure 19.1.

Figure 19.7 Example of Three-Phase Mode 1 Operation

19.3.3.1 INV13 Bit in the INVC1 Register

In three-phase mode 1, the INV13 bit can be used to detect whether the cycle of the carrier wave is the first half or the last half. The INV13 bit is a flag which checks the state of timer A1 reload control signals. The timer A1 reload control signal becomes 0 while timer A1 is stopped, and the value is inverted at every start trigger signal for timers A1, A2, and A4. Thus, if the cycle of the carrier wave starts at the first timer B2 underflow, the first half comes when the INV13 bit is 1, and the last half comes when it is 0. Table 19.15 lists Relations of the INV13 Bit with Other Factors.

Table 19.15 Relations of the INV13 Bit with Other Factors

INV13 bit	1	0
Timer A1 reload control signal		
One-shot pulse count value	TAi1 register value	TAi register value
Timer B2 underflow	At an odd number of times	At an even number of times
Carrier wave	First half	Last half

i = 1, 2, 4

19.3.3.2 Three-Phase PWM Waveform Output Timing Control

In three-phase mode 1, when a start trigger for timers A1, A2, and A4 is generated, the value set in the TAi1 register is counted first. Afterward, the values in registers TAi1 and TAi are alternately counted every time a start trigger for timers A1, A2, and A4 is generated.

When the values in registers TAi1 and TAi are rewritten during processing, the updated value is output from the next carrier wave cycle. Figure 19.8 shows Update Timing of Registers TAi and TAi1 in Three-Phase Mode 1.

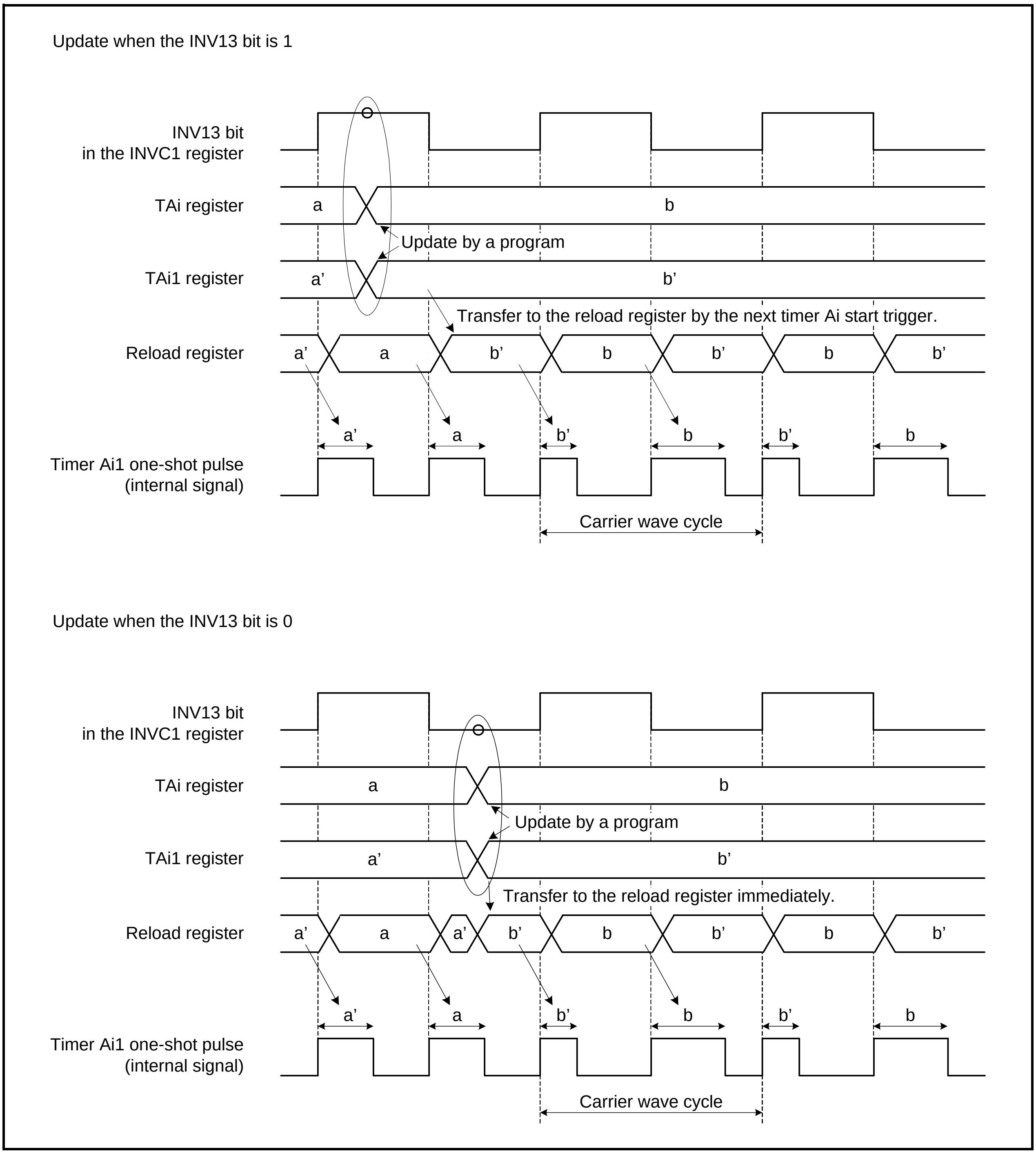

Update when the INV13 bit is 1
INV13 bit in the INVC1 register
TAi register
a
b
Update by a program
TAi1 register
a’
b’
Transfer to the reload register by the next timer Ai start trigger.
Reload register
a’ a b’ b b’ b b’
a’ a b’ b b’ b
Timer Ai1 one-shot pulse (internal signal)
Carrier wave cycle
Update when the INV13 bit is 0
INV13 bit in the INVC1 register
TAi register
a
b
Update by a program
TAi1 register
a’
b’
Transfer to the reload register immediately.
Reload register
a’ a a’ b’ b b’ b b’
a’ a b’ b b’ b
Timer Ai1 one-shot pulse (internal signal)
Carrier wave cycle

Figure 19.8 Update Timing of Registers TAi and TAi1 in Three-Phase Mode 1

19.3.3.3 Carrier Wave Control

In three-phase mode 1, the reload timing of the TB2 register can be selected by setting the PWCON bit in the TB2SC register.

19.3.3.4 Three-Phase PWM Waveform Output Level Control

In triangular wave modulation mode, the output levels set in registers IDB0 and IDB1 are transferred to the three-phase output shift registers by a transfer trigger. After a transfer trigger is generated, first the value set in the IDB0 register, and then, at the falling edge of one-shot pulse for timers A1, A2, and A4, the values set in the IDB1 register become output signals for each phase (internal signal) and consequently the three-phase PWM output changes. Afterward, the values in registers IDB0 and IDB1 alternately become an output signal for each phase at every falling edge of one-shot pulse for timers A1, A2, and A4.
When the INV15 bit in the INVC1 register is 0 (dead time enabled), a phase changing from active to nonactive changes simultaneously with output signals for each phase (internal signal), while a phase changing from nonactive to active changes when the dead time timer stops.

A transfer trigger is generated under the following conditions:

- The first timer B2 underflow after registers IDB0 and IDB1 are written.
- Writing to the TB2 register when timer B2 is stopped (when the INV10 bit in the INVC1 register is 1).
- Setting the INV07 bit in the INVC0 register to 1 (software trigger).

19.3.4 Sawtooth Wave Modulation Mode

In this mode, the sawtooth wave is modulated. Table 19.16 lists Sawtooth Wave Modulation Mode Specifications, and Figure 19.9 shows Example of Sawtooth Wave Modulation Mode Operation.

Table 19.16 Sawtooth Wave Modulation Mode Specifications

Item		Specification
Carrier wave cycle		$\frac{m + 1}{fi}$ m: Setting value of the TB2 register, 0000h to FFFFh fi: Count source frequency (f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32)
Three-phase PWM output width		$\frac{n}{fi}$ n: Setting value of the TAi register, 0001h to FFFFh fi: Count source frequency (f1TIMAB, f2TIMAB, f8TIMAB, f32TIMAB, f64TIMAB, fOCO-F, fOCO-S, fC32)
Differences from triangular wave modulation mode	Reference cycle	Timer B2 cycle (cycle of the carrier wave)
	Timer B2 reload timing	Timer B2 underflow
	Three-phase PWM waveform control	Counts the value of the TAi register every time a timer Ai start trigger is generated (the TAi1 register is not used).
		The output levels set in registers IDB0 and IDB1 are transferred to the three-phase output shift register at every timer B2 underflow.
	Timer B2 interrupt	When the setting value in the ICTB2 register is n, a timer B2 interrupt request is generated every nth time of timer B2 underflow (not influenced by bits INV00 and INV01 in the INVC0 register).
	Dead time timer trigger	Both of the following: • Transfer trigger (generated at every timer B2 underflow) • Falling edge of timer Ai one-shot pulse
	Detection of a carrier wave cycle (first half or last half)	-

i = 1, 2, 4

Table 19.17 Registers and Settings in Sawtooth Wave Modulation Mode (1/2) (1)

Register	Bit	Function and Setting
INVC0	INV00	Disabled (Despite the settings, the ICTB2 register counts timer B2 underflow.)
	INV01	
	INV02	Set to 1 (three-phase motor control timer function used).
	INV03	Set to 1 (three-phase motor control timer output enabled).
	INV04	Select simultaneous conduction enabled or disabled.
	INV05	Simultaneous conduction detect flag
	INV06	Set to 1 (sawtooth wave modulation mode).
	INV07	Software trigger bit
INVC1	INV10	Select a start trigger for timers A1, A2, and A4.
	INV11	Set to 0.
	INV12	Select a count source for the dead time timer.
	INV13	Disabled
	INV14	Select the active level (either active high or active high).
	INV15	Select dead time enabled or disabled.
	INV16	Select a trigger for the dead time timer.
	7	Set to 0.
IDB0, IDB1	5 to 0	Set an output logic of the three-phase output shift register.
DTT	7 to 0	Set the dead time.
ICTB2	3 to 0	Set the frequency of timer B2 interrupt request.
TB2SC	PWCON	Set to 0 (timer B2 underflow).
	IVPCR1	Select three-phase output forced cutoff enabled or disabled.
	b7 to b2	Set to 0.
PDRF	PDRU, PDRV, PDRW	Position-data-retain bit
	PDRT	Select a position-data-retain trigger.
PFCR	PFC5 to PFC0	Select I/O port or three-phase PWM output.
TPRC	TPRC0	Set to 1 when writing to the PFCR register, or to 0 when not writing to it.
TA1, TA2, TA4	15 to 0	Set the one-shot pulse width.
TA11, TA21, TA41	15 to 0	Not used
TB2	15 to 0	Set the cycle of the carrier wave.

i = 1, 2, 4

Note:

1. This table does not describe a procedure.

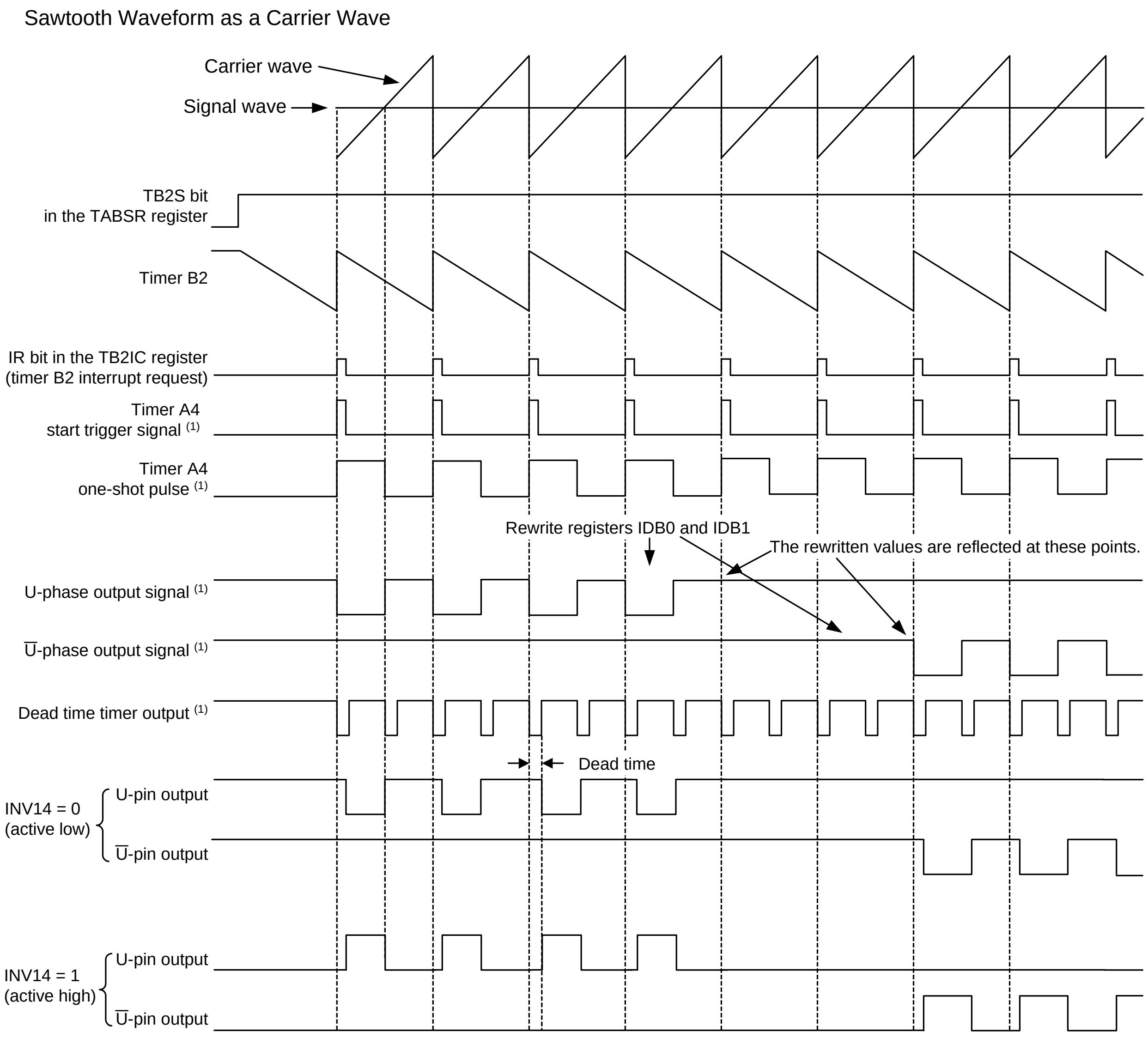
Table 19.18 Registers and Settings in Sawtooth Wave Modulation Mode (2/2) (1)

Register	Bit	Function and Setting
TRGSR	TA1TGH to TA1TGL	Set to 01b (when using V-phase output control circuit).
	TA2TGH to TA2TGL	Set to 01b (when using W-phase output control circuit).
	TA3TGH to TA3TGL	(Not used for three-phase motor control timer.)
	TA4TGH to TA4TGL	Set to 01b (when using U-phase output control circuit).
TABSR	TA0S	Not used for three-phase motor control timer.
	TA1S	Set to 1 when starting counting, and to 0 when stopping counting.
	TA2S	Set to 1 when starting counting, and to 0 when stopping counting.
	TA3S	Not used for three-phase motor control timer.
	TA4S	Set to 1 when starting counting, and to 0 when stopping counting.
	TB0S	Not used for three-phase motor control timer.
	TB1S	Not used for three-phase motor control timer.
	TB2S	Set to 1 when starting counting, and to 0 when stopping counting.
TA1MR, TA2MR, TA4MR	TMOD1 to TMOD0	Set to 10b (one-shot timer mode).
	MR0	Set to 0.
	MR1	Set to 0.
	MR2	Set to 1 (select a trigger by setting bits TAiTGH and TAiTGL).
	MR3	Set to 0.
	TCK1 to TCK0	Select a count source.
TB2MR	TMOD1 to TMOD0	Set to 00b (timer mode).
	MR1 to MR0	Set to 00b.
	4	Set to 0.
	MR3	Set to 0.
	TCK1 to TCK0	Select a count source.
PCLKR	PCLK0	Select a count source.
PCLKSTP1	PCKSTP11	Set to 0 when using f1 or main clock.
	PCKSTP17	Select the count source.
TCKDIVC0	TCDIV00	Select the clock prior to timer AB division.
TACS0 to TACS2	7 to 0	Select a count source.
TBCS1	TCS3 to TCS0	Select a count source.
TAPOFS	POFSi	Set to 0.
UDF	TAiP	Set to 0.

i = 1, 2, 4

Note:

1. This table does not describe a procedure.


Sawtooth Waveform as a Carrier Wave
Carrier wave
Signal wave
TB2S bit in the TABSR register
Timer B2
IR bit in the TB2IC register (timer B2 interrupt request)
Timer A4 start trigger signal (1)
Timer A4 one-shot pulse (1)
Rewrite registers IDB0 and IDB1
The rewritten values are reflected at these points.
U-phase output signal (1)
Ū-phase output signal (1)
Dead time timer output (1)
Dead time
INV14 = 0 (active low)
U-pin output
Ū-pin output
INV14 = 1 (active high)
U-pin output
Ū-pin output

The above diagram assumes the following:
In the INVC1 register
- The INV10 bit is 0 (Timer B2 underflow is a start trigger for timers A1, A2 and A4.).
- The INV15 bit is 0 (dead time timer enabled).
- The INV16 bit is 0 (the dead time timer is triggered on the falling edge of timers A4, A1 and A2 one-shot pulse).

The ICTB2 register is 1h (timer B2 interrupt request is generated at every timer B2 underflow).
Bits PFC1 to PFC0 in the PFCR register are 11b (U-, Ū-phase outputs).
In registers IDB0 and IDB1
- Initial values: DU0 = 0; DUB0 = 1; DU1 = 1; DUB1 = 1
- At the fourth timer B2 interrupt, the values are changed to DU0 = 1; DUB0 = 1; DU1 = 1; DUB1 = 1.
- At the sixth timer B2 interrupt, the values are changed to: DU0 = 1; DUB0 = 0; DU1 = 1; DUB1 = 1.

Note:
1. Internal signal. See Figure 19.1.

Figure 19.9 Example of Sawtooth Wave Modulation Mode Operation

19.3.4.1 Three-Phase PWM Waveform Output Timing Control

In sawtooth wave modulation mode, when a start trigger for timers A1, A2, and A4 is generated, the counter starts counting the value in the TAi register (i = 1, 2, 4).

19.3.4.2 Three-Phase PWM Waveform Output Level Control

In sawtooth wave modulation mode, the output levels set in registers IDB0 and IDB1 are transferred to the three-phase output shift register by a transfer trigger. After a transfer trigger is generated, first the value set in the IDB0 register, and then at the falling edge of one-shot pulse for timers A1, A2, and A4, the value set in the IDB1 register become output signals for each phase (internal signal) and consequently the three-phase PWM output changes. Then, the following two actions are repeated:
(1) The setting levels are transferred to the three-phase output shift register by a transfer trigger generated at timer B2 underflow, and therefore, the value in the IDB0 register becomes output signals for each phase. (2) The values set in the IDB1 register become output signals for each phase at the falling edge of one-shot pulse for timers A1, A2, and A4.
When the INV15 bit in the INVC1 register is 0 (dead time enabled), a phase changing from active to nonactive changes simultaneously with output signals for each phase (internal signal), while a phase changing from nonactive to active changes when the dead time timer stops.

A transfer trigger is generated under the following conditions:

- Timer B2 underflow (each time).
- Writing to the TB2 register when timer B2 is stopped (when the INV10 bit in the INVC1 register is 1).
- Setting the INV07 bit in the INVC0 register to 1 (software trigger).

19.4 Interrupts

The timer B2 interrupt and timer A1, A2, and A4 interrupts can be used with the three-phase motor control timer.

19.4.1 Timer B2 Interrupt

When the setting value in the ICTB2 register is n, a timer B2 interrupt request is generated at the timings below. For details, refer to the specifications and usage examples of each mode.
In triangular wave modulation three-phase mode 0 and sawtooth wave modulation mode, an interrupt request is generated at the nth count of timer B2 underflow.
In triangular wave modulation three-phase mode 1, an interrupt request is generated at the nth count of timing selected by setting bits INV01 to INV00 in the INVC0 register.

Refer to 14.7 “Interrupt Control” for details of interrupt control. Table 19.19 lists the Timer B2 Interrupt Related Register.

Table 19.19 Timer B2 Interrupt Related Register

Address	Register	Symbol	Reset Value
005Ch	Timer B2 Interrupt Control Register	TB2IC	XXXX X000b

19.4.2 Timer A1, A2, and A4 Interrupts

A timer Ai interrupt request is generated at the falling edge of timer Ai one-shot pulse (internal signal) (i = 1, 2, 4). Refer to 14.7 “Interrupt Control” for details of interrupt control. Table 19.20 lists Timer A1, A2, and A4 Interrupt Related Registers.

Table 19.20 Timer A1, A2, and A4 Interrupt Related Registers

Address	Register	Symbol	Reset Value
0056h	Timer A1 Interrupt Control Register	TA1IC	XXXX X000b
0057h	Timer A2 Interrupt Control Register	TA2IC	XXXX X000b
0059h	Timer A4 Interrupt Control Register	TA4IC	XXXX X000b

In the timer Ai interrupt, when the TMOD1 bit in the TAiMR register is changed from 0 to 1 (from timer mode or event counter mode to one-shot timer mode, PWM mode, or programmable output mode), the IR bit in the TAiIC register is occasionally becomes 1 (interrupt requested). Thus, when changing the TMOD1 bit, follow the steps below. Also refer to 14.13 “Notes on Interrupts”.

(1) Set bits ILVL2 to ILVL0 in the TAiIC register to 000b (interrupt disabled).
(2) Set the TAiMR register.
(3) Set the IR bit in the TAiIC register to 0 (interrupt not requested).

19.5 Notes on Three-Phase Motor Control Timer Function

19.5.1 Timer A and Timer B

Refer to 17.5 “Notes on Timer A” and 18.5 “Notes on Timer B”.

19.5.2 Influence of $\overline{\text{SD}}$

When a low-level signal is applied to the $\overline{\text{SD}}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{\text{SD}}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$/TA1IN/$\overline{\text{V}}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{\text{W}}$, P8_0/TA4OUT/RXD5/SCL5/U, P8_1/TA4IN/$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$/$\overline{\text{U}}$

20. Real-Time Clock

20.1 Introduction

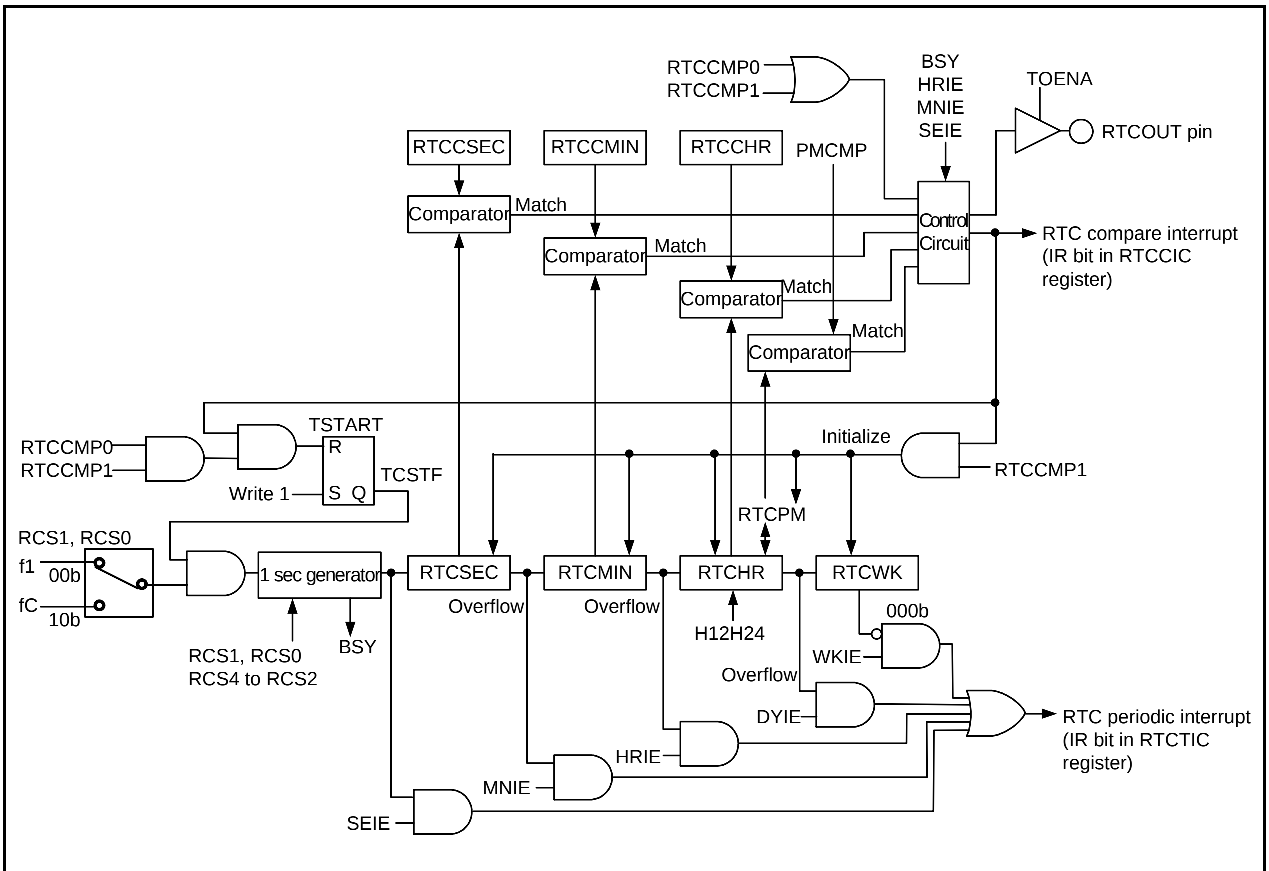
The real-time clock generates a 1-second signal from a count source and counts seconds, minutes, hours, a.m./p.m., a day, and a week. It also detects matches with specified seconds, minutes, and hours. Table 20.1 lists Real-Time Clock Specifications, Figure 20.1 shows a Real-Time Clock Block Diagram, and Table 20.2 lists the I/O Port.

Table 20.1 Real-Time Clock Specifications

Item	Specification
Count source	f1, fC
Count operation	• Increment • Compare mode 1 or not using compare mode The count value is continuously used, and the count continues. • Compare mode 2 When a compare match is detected, the count value is set to 0 and the count continues. • Compare mode 3 When a compare match is detected, the count value is set to 0 and the count stops.
Count start condition	1 (count started) is written to the TSTART bit in the RTCCR1 register.
Count stop condition	0 (count stopped) is written to the TSTART bit in the RTCCR1 register.
Interrupt request generation timing	Select one of the following: • Update second data • Update minute data • Update hour data • Update day data • When day data is set to 000b • When time data and compare data match
RTCOUT pin function	Programmable I/O port or compare output
Read from timer	When the RTCSEC, RTCMIN, RTCHR, or RTCWK register is read, the count value can be read. The values read from registers RTCSEC, RTCMIN, and RTCHR are represented by the BCD code.
Write to timer	When bits TSTART and TCSTF in the RTCCR1 register are 0 (count stopped), the RTCSEC, RTCMIN, RTCHR, and RTCWK registers are write enabled. Values written to registers RTCSEC, RTCMIN, and RTCHR are represented by the BCD code.
Selectable functions	• 12-/24-hour mode switch function • Compare output

Note:

1. In this manual, day refers to one day of the week. Refer to 20.2.4 “Real-Time Clock Day Data Register (RTCWK)” for details.



TCSTF, TOENA, RTCPM, H12H24, TSTART: Bits in the RTCCR1 register
SEIE, MNIE, HRIE, DYIE, WKIE, RTCCMP0, RTCCMP1: Bits in the RTCCR2 register
RCS4 to RCS0: Bits in the RTCCSR register
BSY: Bit in the RTCSEC register
PMCMP: Bit in the RTCCHR register
RTCWK: Bits WK2 to WK0 in the RTCWK register
RTCHR: Bits HR11 to HR10 and HR03 to HR00 in the RTCHR register
RTCMIN: Bits MN12 to MN10 and MN03 to MN00 in the RTCMIN register
RTCSEC: Bits SC12 to SC10 and SC03 to SC00 in the RTCSEC register
RTCCHR: Bits HCMP11 to HCMP10 and HCMP03 to HCMP00 in the RTCCHR register
RTCCMIN: Bits MCMP12 to MCMP10 and MCMP03 to MCMP00 in the RTCCMIN register
RTCCSEC: Bits SCMP12 to SCMP10 and SCMP03 to SCMP00 in the RTCCSEC register

Figure 20.1 Real-Time Clock Block Diagram

Table 20.2 I/O Port

Pin Name	I/O	Function
RTCOUT	Output	Compare output

20.2 Registers

Refer to 8.2.6 “Peripheral Clock Stop Register 1 (PCLKSTP1)” for the explanation of the PCLKSTP1 register.

Table 20.3 Registers

Address	Register	Symbol	Reset Value
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
0340h	Real-Time Clock Second Data Register	RTCSEC	00h
0341h	Real-Time Clock Minute Data Register	RTCMIN	X000 0000b
0342h	Real-Time Clock Hour Data Register	RTCHR	XX00 0000b
0343h	Real-Time Clock Day Data Register	RTCWK	XXXX X000b
0344h	Real-Time Clock Control Register 1	RTCCR1	0000 X00Xb
0345h	Real-Time Clock Control Register 2	RTCCR2	X000 0000b
0346h	Real-Time Clock Count Source Select Register	RTCCSR	XXX0 0000b
0348h	Real-Time Clock Second Compare Data Register	RTCCSEC	X000 0000b
0349h	Real-Time Clock Minute Compare Data Register	RTCCMIN	X000 0000b
034Ah	Real-Time Clock Hour Compare Data Register	RTCCHR	X000 0000b

20.2.1 Real-Time Clock Second Data Register (RTCSEC)

Real-Time Clock Second Data Register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
RTCSEC	0340h	00h

Bit Symbol	Bit Name	Function	Setting Range	RW
SC00	First digit of second count bit	Count 0 to 9 every second. When the digit increments, 1 is added to the 2nd digit of second.	0 to 9	RW
SC01				RW
SC02				RW
SC03				RW
SC10	Second digit of second count bit	When counting 0 to 5, 60 seconds are counted.	0 to 5	RW
SC11				RW
SC12				RW
BSY	Real-time clock busy flag	This bit is 1 while registers RTCSEC, RTCMIN, RTCHR or RTCWK are updated.		RO

SC03 to SC00 (First digit of second count bit) (b3-b0)
SC12 to SC10 (Second digit of second count bit) (b6-b4)

Set a value between 00 and 59 by the BCD code.
These bits become 00 at compare match in compare mode 2 and compare mode 3.
Write to bits SC12 to SC10 and SC03 to SC00 in the RTCSEC register when bits TSTART and TCSTF in the RTCCR1 register are both 0 (count stopped). Read these bits when the BSY bit is 0 (not while data is updated).

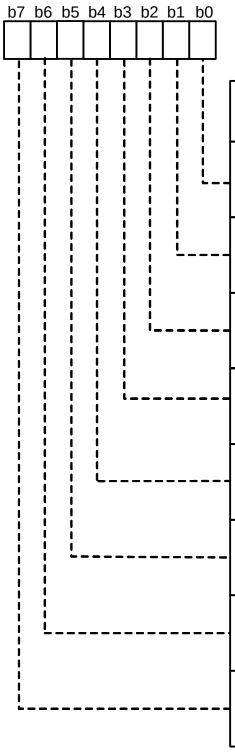
BSY (Real-time clock busy flag) (b7)

This bit is 1 while data is updated. Read the following bits when the BSY bit is 0 (not while data is updated):

- Bits SC12 to SC10 and SC03 to SC00 in the RTCSEC register
- Bits MN12 to MN10 and MN03 to MN00 in the RTCMIN register
- Bits HR11 to HR10 and HR03 to HR00 in the RTCHR register
- Bits WK2 to WK0 in the RTCWK register
- The RTCPM bit in the RTCCR1 register

20.2.2 Real-Time Clock Minute Data Register (RTCMIN)

Real-Time Clock Minute Data Register



Symbol	Address	Reset Value
RTCMIN	0341h	X000 0000b

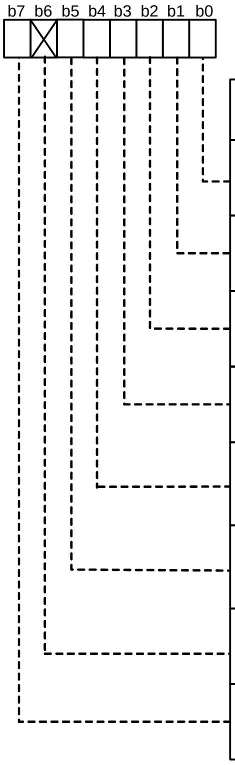
Bit Symbol	Bit Name	Function	Setting Range	RW
MN00	First digit of minute count bit	Count 0 to 9 every minute. When the digit increments, 1 is added to the 2nd digit of minute.	0 to 9	RW
MN01				RW
MN02				RW
MN03				RW
MN10	Second digit of minute count bit	When counting 0 to 5, 60 minutes are counted.	0 to 5	RW
MN11				RW
MN12				RW
— (b7)	Reserved bit	The read value is undefined.		RO

MN03 to MN00 (First digit of minute count bit) (b3-b0)
MN12 to MN10 (Second digit of minute count bit) (b6-b4)

Set a value between 00 and 59 by the BCD code.
When the digit increments from the RTCSEC register, 1 is added.
These bits become 00 at compare match in compare mode 2 and compare mode 3.
Write to bits MN12 to MN10 and MN03 to MN00 in the RTCMIN register when bits TSTART and TCSTF in the RTCCR1 register are both 0 (count stopped). Read these bits when the BSY bit in the RTCSEC is 0 (not while data is updated).

20.2.3 Real-Time Clock Hour Data Register (RTCHR)

Real-Time Clock Hour Data Register



Symbol	Address	Reset Value
RTCHR	0342h	XX00 0000b

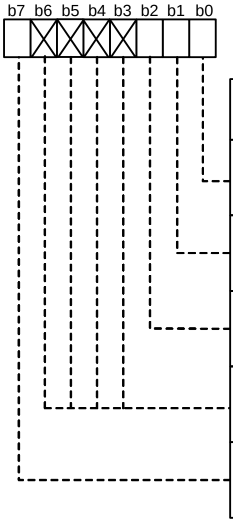
Bit Symbol	Bit Name	Function	Setting Range	RW
HR00	First digit of hour count bit	Count 0 to 9 every hour. When the digit increments, 1 is added to the 2nd digit of hour.	0 to 9	RW
HR01				RW
HR02				RW
HR03				RW
HR10	Second digit of hour count bit	Count 0 to 1 when the H12H24 bit is set to 0 (12-hour mode). Count 0 to 2 when the H12H24 bit is set to 1 (24-hour mode).	0 to 2	RW
HR11				RW
— (b6)	No register bit. If necessary, set to 0. The read value is undefined.			—
— (b7)	Reserved bit	The read value is undefined.		RO

HR03 to HR00 (First digit of hour count bit) (b3-b0)
HR11 and HR10 (Second digit of hour count bit) (b5-b4)

When the H12H24 bit in the RTCCR1 register is 0 (12-hour mode), set a value between 00 and 11 by BCD code. When the H12H24 bit in the RTCCR1 register is 1 (24-hour mode), set a value between 00 and 23 by the BCD code.
When the digit increments from the RTCMIN register, 1 is added.
These bits become 00 at compare match in compare mode 2 and compare mode 3.
Write to bits HR11 to HR10 and HR03 to HR00 in the RTCHR register when bits TSTART and TCSTF in the RTCCR1 register are both 0 (count stopped). Read these bits when the BSY bit in the RTCSEC register is 0 (not while data is updated).

20.2.4 Real-Time Clock Day Data Register (RTCWK)

Real-Time Clock Day Data Register



Symbol	Address	Reset Value
RTCWK	0343h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
WK0	Day count bit	b2 b1 b0 0 0 0 : Day 1 0 0 1 : Day 2 0 1 0 : Day 3 0 1 1 : Day 4 1 0 0 : Day 5 1 0 1 : Day 6 1 1 0 : Day 7 1 1 1 : Do not set	RW
WK1			RW
WK2			RW
— (b6-b3)	No register bits. If necessary, set to 0. The read value is undefined.		—
— (b7)	Reserved bit	The read value is undefined.	RO

WK2 to WK0 (Day count bit) (b2-b0)

A week is counted by counting from 000b (Day 1) to 110b (Day 7) repeatedly. Do not set these bits to 111b.

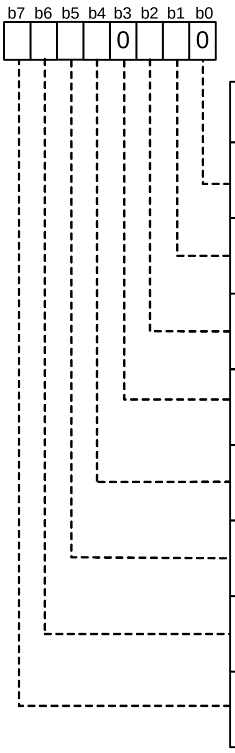
When the digit increments from the RTCHR register, 1 is added.

These bits become 000b at compare match in compare mode 2 and compare mode 3.

Write to bits WK2 to WK0 in the RTCWK register when bits TSTART and TCSTF in the RTCCR1 register are both 0 (count stopped). Read these bits when the BSY bit in the RTCSEC register is 0 (not while data is updated).

20.2.5 Real-Time Clock Control Register 1 (RTCCR1)

Real-Time Clock Control Register 1



Symbol	Address	Reset Value
RTCCR1	0344h	0000 X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	Reserved bit	Set to 0	RW
TCSTF	Real-time clock count status flag	0 : Count stopped 1 : Counting	RO
TOENA	RTCOUT pin output bit	0 : Compare output disabled 1 : Compare output enabled	RW
— (b3)	Reserved bit	Set to 0	RW
RTCRST	Real-time clock reset bit	Setting this bit to 0 after setting it to 1 resets the real-time clock.	RW
RTCPM	a.m./p.m. bit	0 : a.m. 1 : p.m.	RW
H12H24	Operating mode select bit	0 : 12-hour mode 1 : 24-hour mode	RW
TSTART	Real-time clock count start bit	0 : Count stopped 1 : Count started	RW

TCSTF (Real-time clock count status flag) (b1)
TSTART (Real-time clock count start bit) (b7)

The real-time clock uses the TSTART bit to instruct the count to start or stop, and use the TCSTF bit to indicate count start or stop.

The real-time clock starts counting and the TCSTF bit becomes 1 (count started) when the TSTART bit is set to 1 (count started). It takes up to two cycles of the count source until the TCSTF bit becomes 1 after setting the TSTART bit to 1. During this time, do not access registers associated with the real-time clock [1] other than the TCSTF bit.

Also, when setting the TSTART bit to 0 (count stopped), the real-time clock stops counting and the TCSTF bit becomes 0 (count stopped). It takes the time for up to three cycles of the count source until the TCSTF bit becomes 0 after setting the TSTART bit to 0. During this time, do not access registers associated with the real-time clock [1] other than the TCSTF bit.

Note:
1. Registers associated with the real-time clock: RTCSEC, RTCMIN, RTCHR, RTCWK, RTCCR1, RTCCR2, RTCCSR, RTCCSEC, RTCCMIN, and RTCCHR.

RTCRST (Real-Time clock reset bit) (b4)

When setting this bit to 0 after setting it to 1, the following are set automatically:

- The values are reset in registers RTCSEC, RTCMIN, RTCHR, RTCWK, RTCCR2, RTCCSR, RTCCSEC, RTCCMIN, and RTCCHR.
- Bits TCSTF, RTCPM, H12H24, and TSTART in the RTCCR1 register become 0.

RTCPM (a.m./p.m. bit) (b5)

Write to the RTCPM bit when bits TSTART and TCSTF in the RTCCR1 register are both 0 (count stopped). Read this bit when the BSY bit in the RTCSEC register is 0 (not while data is updated).
The RTCPM bit is enabled when the H12H24 bit is 0 (12-hour mode) or 1 (24-hour mode). Set the RTCPM bit as shown below to set the time while the H12H24 bit is 1:

- Set the RTCPM bit to 0 when bits HR11 to HR10 and HR03 to HR00 in the RTCHR register are 00 to 11.
- Set the RTCPM bit to 1 when bits HR11 to HR10 and HR03 to HR00 in the RTCHR register are 12 to 23.

The RTCPM bit changes as follows while counting:

- Becomes 0 when the RTCPM bit is 1 (p.m.) while the clock increments from 11:59:59 (23:59:59 for 24-hour mode) to 00:00:00.
- Becomes 1 when the RTCPM bit is 0 (a.m.) while the clock increments from 11:59:59 to 00:00:00 (12:00:00 for 24-hour mode).

Figure 20.2 shows Time Representation.

Noon

Contents of RTCHR Register	H12H24 bit = 1 (24-hour mode)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	H12H24 bit = 0 (12-hour mode)	0	1	2	3	4	5	6	7	8	9	10	11	0	1	2	3	4	5
Contents of RTCPM bit		0 (a.m.)												1 (p.m.)					
Contents in RTCWK register		000 (Day 1)																	

Date changes

Contents of RTCHR Register	H12H24 bit = 1 (24-hour mode)	18	19	20	21	22	23	0	1	2	3	...
	H12H24 bit = 0 (12-hour mode)	6	7	8	9	10	11	0	1	2	3	...
Contents of RTCPM bit		1 (p.m.)						0 (a.m.)				...
Contents in RTCWK register		000 (Day 1)						001 (Day 2)				...

Bits RTCPM and H12H24 : Bits in the RTCCR1 register.
The above assumes the count starts from 00:00 (12 a.m.) of day 1.

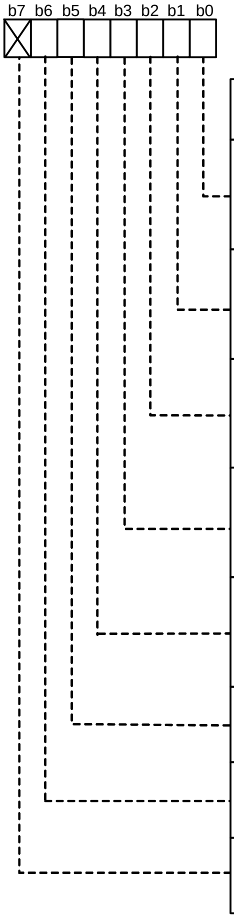
Figure 20.2 Time Representation

H12H24 (Operating mode select bit) (b6)

Write to the H12H24 bit when bits TSTART and TCSTF in the RTCCR1 register are both 0 (count stopped).

20.2.6 Real-Time Clock Control Register 2 (RTCCR2)

Real-Time Clock Control Register 2



Symbol	Address	Reset Value
RTCCR2	0345h	X000 0000b

Bit Symbol	Bit Name	Function	RW
SEIE	Periodic interrupt triggered every second enable bit	0 : Disable periodic interrupt triggered every second 1 : Enable periodic interrupt triggered every second	RW
MNIE	Periodic interrupt triggered every minute enable bit	0 : Disable periodic interrupt triggered every minute 1 : Enable periodic interrupt triggered every minute	RW
HRIE	Periodic interrupt triggered every hour enable bit	0 : Disable periodic interrupt triggered every hour 1 : Enable periodic interrupt triggered every hour	RW
DYIE	Periodic interrupt triggered every day enable bit	0 : Disable periodic interrupt triggered every day 1 : Enable periodic interrupt triggered every day	RW
WKIE	Periodic interrupt triggered every week enable bit	0 : Disable periodic interrupt triggered every week 1 : Enable periodic interrupt triggered every week	RW
RTCCMP0	Compare mode select bit	b6 b5 0 0 : No compare mode 0 1 : Compare mode 1 1 0 : Compare mode 2 1 1 : Compare mode 3	RW
RTCCMP1			RW
— (b7)	No register bit. If necessary, set to 0. The read value is undefined.		—

Write to the RTCCR2 register when bits TSTART and TCSTF in the RTCCR1 register are both 0 (count stopped).

While bits RTCCMP1 to RTCCMP0 are 00b (no compare mode), an interrupt request can be generated every second, minute, hour, day, or week. To generate an interrupt request, set one of the following bits to 1 (interrupt enabled): SEIE, MNIE, HRIE, DAYIE, or WKIE. (Do not set more than one bit to 1.) Table 20.4 lists Periodic Interrupt Sources.

Table 20.4 **Periodic Interrupt Sources**

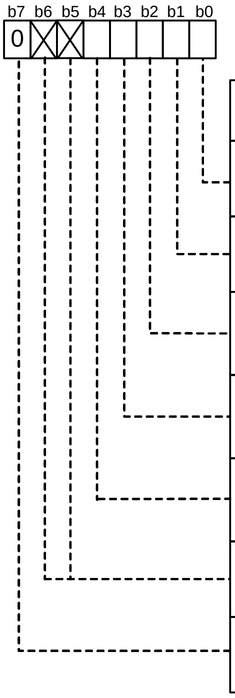
Factor	Interrupt Source	Interrupt Enable Bit
Periodic interrupt triggered every week	Value in RTCWK register is set to 000b (1-week period)	WKIE
Periodic interrupt triggered every day	RTCWK register is updated (1-day period)	DYIE
Periodic interrupt triggered every hour	RTCHR register is updated (1-hour period)	HRIE
Periodic interrupt triggered every minute	RTCMIN register is updated (1-minute period)	MNIE
Periodic interrupt triggered every second	RTCSEC register is updated (1-second period)	SEIE

When bits RTCCMP1 to RTCCMP0 are 01b, 10b, or 11b (any compare mode), set the following according to which registers are compared:

- When comparing to the RTCCSEC register, set the SEIE bit to 1 (interrupt enabled).
- When comparing to the RTCCMIN register, set bits SEIE and MNIE to 1.
- When comparing to the RTCCHR register, set bits SEIE, MNIE, and HRIE to 1.

20.2.7 Real-Time Clock Count Source Select Register (RTCCSR)

Real-Time Clock Count Source Select Register



Symbol	Address	Reset Value
RTCCSR	0346h	XXX0 0000b

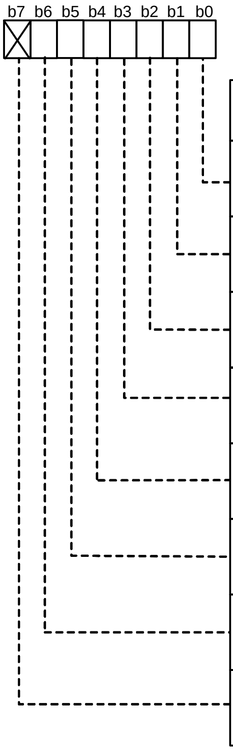
Bit Symbol	Bit Name	Function	RW
RCS0	Count source select bit	b1 b0 0 0 : f1 0 1 : Do not set 1 0 : fC 1 1 : Do not set	RW
RCS1			RW
RCS2	Count source frequency select bit	b4 b3 b2 0 0 0 : f1 = fC or 4 MHz 0 0 1 : f1 = 6 MHz 0 1 0 : f1 = 8 MHz 0 1 1 : f1 = 16 MHz 1 0 0 : f1 = 20 MHz 1 0 1 : f1 = 24 MHz 1 1 0 : f1 = 32 MHz 1 1 1 : Do not set	RW
RCS3			RW
RCS4			RW
— (b6-b5)	No register bits. If necessary, set to 0. The read value is undefined.		—
— (b7)	Reserved bit	Set to 0	RW

When bits RCS1 to RCS0 are 10b (fC), set bits RCS4 to RCS2 to 000b.
When bits RCS1 to RCS0 are 00b (f1), select a frequency matched to f1 by bits RCS4 to RCS2.
Write to the RTCCSR register when both bits TSTART and TCSTF in the RTCCR1 register are 0 (count stopped).

When using fC, set the PM25 bit in the PM2 register to 1 (peripheral clock fC provided). Refer to 8. “Clock Generator” for details on fC.

20.2.8 Real-Time Clock Second Compare Data Register (RTCCSEC)

Real-Time Clock Second Compare Data Register



Symbol	Address	Reset Value
RTCCSEC	0348h	X000 0000b

Bit Symbol	Bit Name	Function	Setting Range	RW
SCMP00	First digit of second compare data bit	Store compare data	0 to 9	RW
SCMP01				RW
SCMP02				RW
SCMP03				RW
SCMP10	Second digit of second compare data bit	Store compare data	0 to 5	RW
SCMP11				RW
SCMP12				RW
— (b7)	No register bit. If necessary, set to 0. The read value is undefined value.			—

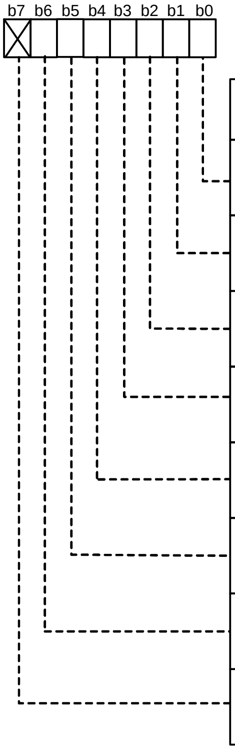
The RTCCSEC register is enabled when bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 01b, 10b, or 11b (any compare mode).

SCMP03 to SCMP00 (First digit of second compare data bit) (b3-b0)
SCMP12 to SCMP10 (Second digit of second compare data bit) (b6-b4)

Set a value between 00 and 59 by the BCD code.
Write to these bits when the BSY bit in the RTCSEC register is 0 (not while data is updated).

20.2.9 Real-Time Clock Minute Compare Data Register (RTCCMIN)

Real-Time Clock Minute Compare Data Register



Symbol	Address	Reset Value
RTCCMIN	0349h	X000 0000b

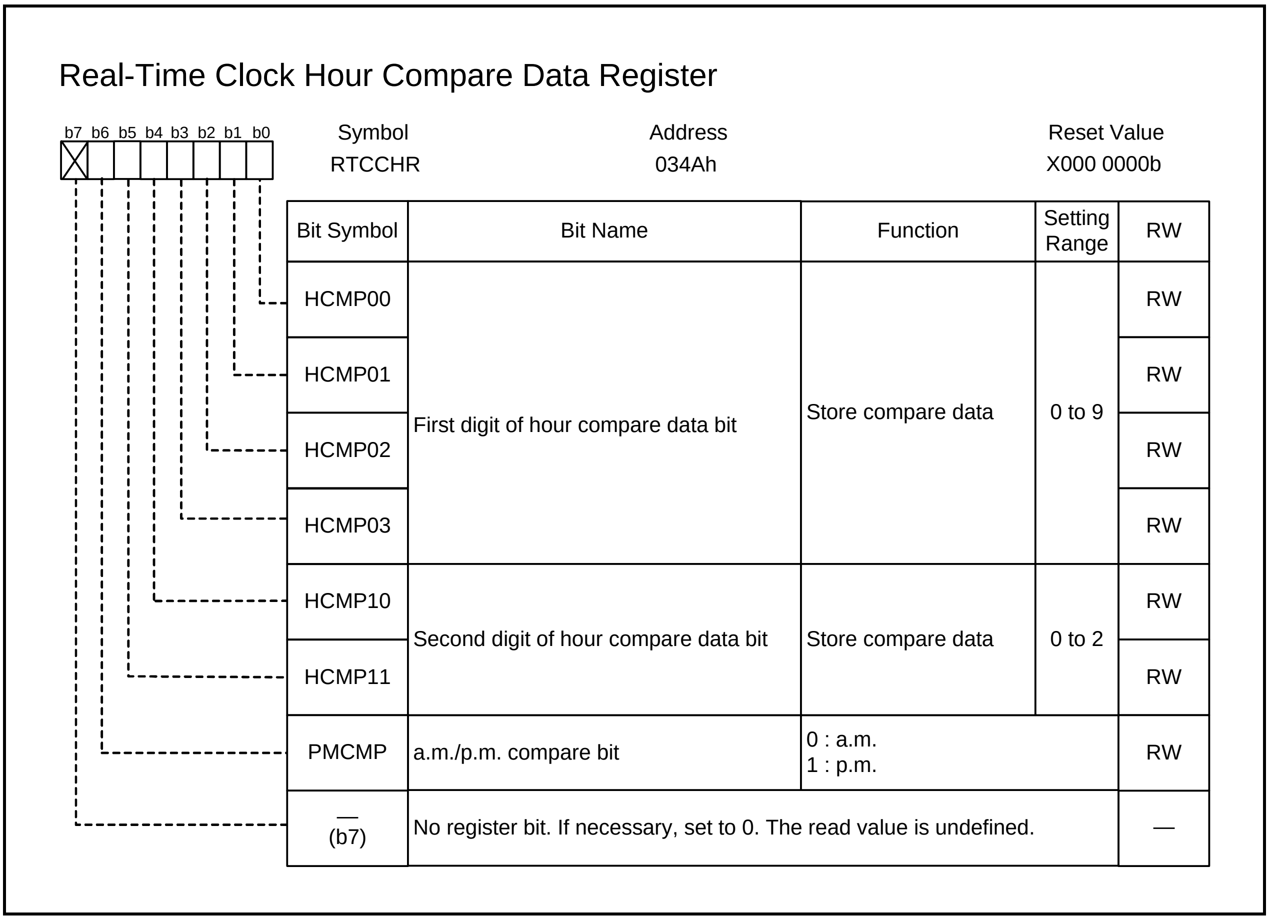
Bit Symbol	Bit Name	Function	Setting Range	RW
MCMP00	First digit of minute compare data bit	Store compare data	0 to 9	RW
MCMP01				RW
MCMP02				RW
MCMP03				RW
MCMP10	Second digit of minute compare data bit	Store compare data	0 to 5	RW
MCMP11				RW
MCMP12				RW
— (b7)	No register bit. If necessary, set to 0. The read value is undefined.			—

The RTCCMIN register is enabled when bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 01b, 10b, or 11b (any compare mode).

MCMP03 to MCMP00 (First digit of minute compare data bit) (b3-b0)
MCMP12 to MCMP10 (Second digit of minute compare data bit) (b6-b4)

Set a value between 00 and 59 by the BCD code.
Write to these bits when the BSY bit in the RTCSEC register is 0 (not while data is updated).

20.2.10 Real-Time Clock Hour Compare Data Register (RTCCHR)



Real-Time Clock Hour Compare Data Register

Symbol	Address	Reset Value
RTCCHR	034Ah	X000 0000b

Bit Symbol	Bit Name	Function	Setting Range	RW
HCMP00	First digit of hour compare data bit	Store compare data	0 to 9	RW
HCMP01				RW
HCMP02				RW
HCMP03				RW
HCMP10	Second digit of hour compare data bit	Store compare data	0 to 2	RW
HCMP11				RW
PMCMP	a.m./p.m. compare bit	0 : a.m. 1 : p.m.		RW
— (b7)	No register bit. If necessary, set to 0. The read value is undefined.			—

The RTCCHR register is enabled when bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 01b, 10b, or 11b (any compare mode).

HCMP03-HCMP00 (First digit of hour compare data bit) (b3-b0)
HCMP11-HCMP10 (Second digit of hour compare data bit) (b5-b4)

When the H12H24 bit in the RTCCR1 register is 0 (12-hour mode), set a value between 00 and 11 by the BCD codes. When the H12H24 bit in the RTCCR1 register is 1 (24-hour mode), set a value between 00 and 23 by the BCD codes.
Write to these bits when the BSY bit in the RTCSEC register is 0 (not while data is updated).

PMCMP (a.m./p.m compare bit) (b6)

This bit is enabled when the H12H24 bit in the RTCCR1 register is either 0 (12-hour mode) or 1 (24-hour mode). When the H12H24 bit is 1, set the following:

- When bits HCMP11 to HCMP10 and HCMP03 to HCMP00 are 00 to 11, set the PMCMP bit to 0.
- When bits HCMP11 to HCMP10 and HCMP03 to HCMP00 are 12 to 23, set the PMCMP bit to 1.

Write to this bit when the BSY bit in the RTCSEC register is 0 (not while data is updated).

20.3 Operations

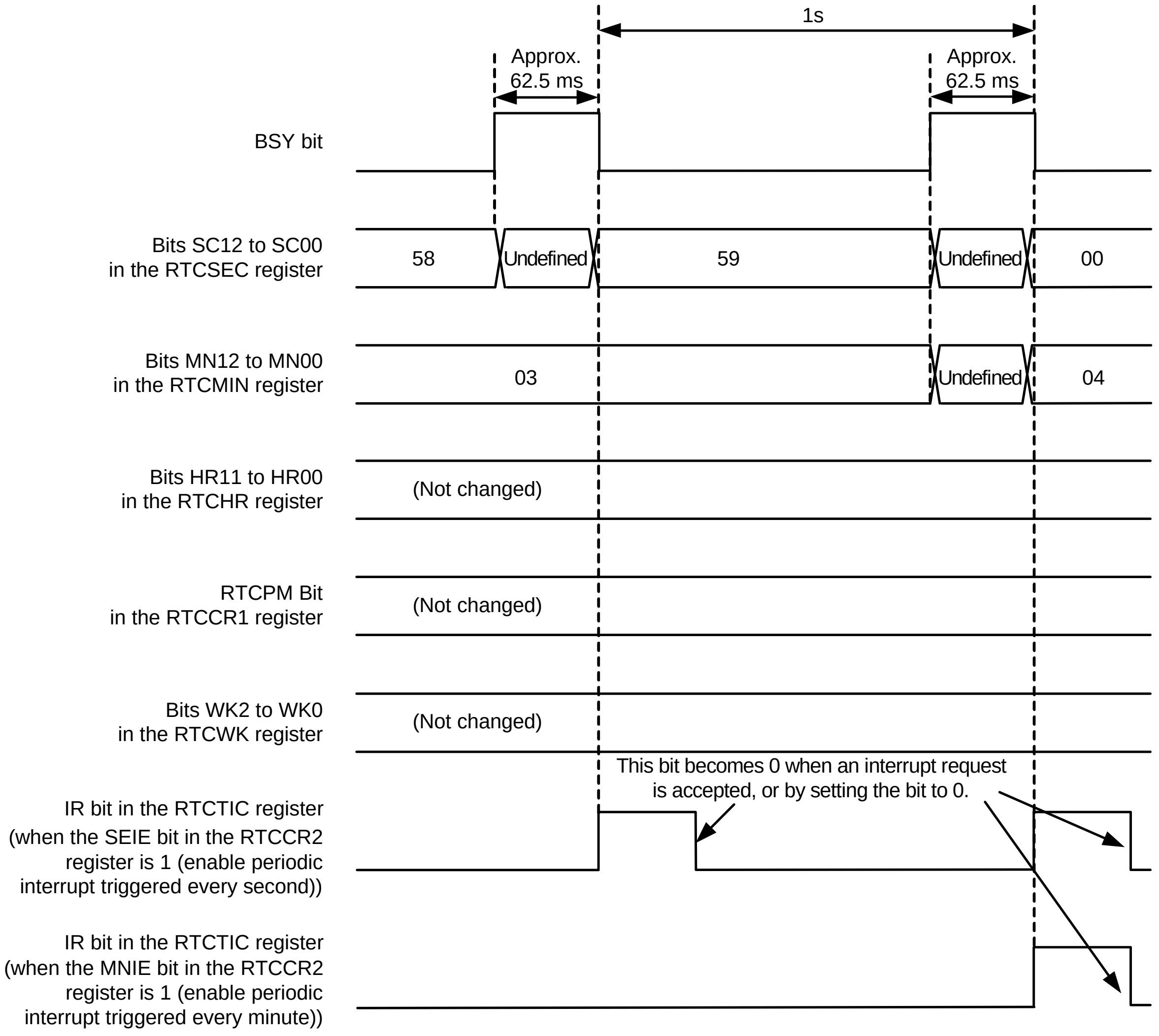
20.3.1 Basic Operation

The real-time clock generates a 1-second signal from the count source selected in the RTCCSR register and counts seconds, minutes, hours, a.m./p.m., a day, and a week.

The day and time to start the count can be set using registers RTCSEC, RTCMIN, RTCHR, RTCWK, and the RTCPM bit in the RTCCR1 register. Current time and day are read from registers RTCSEC, RTCMIN, RTCHR, RTCWK, and the RTCPM bit in the RTCCR1 register. However, do not read these registers when the BSY bit in the RTCSEC register is 1 (while data is updated).

An interrupt request can be generated every second, minute, hour, day, or week. While bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 00b (no compare mode), use the RTCCR2 register to enable one of the periodic interrupts triggered every second, minute, hour, day and week. When a periodic interrupt is generated, the IR bit in the RTCTIC register becomes 1 (interrupt request).

Figure 20.3 shows Real-Time Clock Basic Operating Example, Figure 20.4 shows Time and Day Change Procedure (No Compare Mode or Compare Mode 1), and Figure 20.5 shows Time and Day Change Procedure (Compare Mode 2 or Compare Mode 3).


1s
Approx. 62.5 ms
Approx. 62.5 ms
BSY bit
Bits SC12 to SC00 in the RTCSEC register
58
Undefined
59
Undefined
00
Bits MN12 to MN00 in the RTCMIN register
03
Undefined
04
Bits HR11 to HR00 in the RTCHR register
(Not changed)
RTCPM Bit in the RTCCR1 register
(Not changed)
Bits WK2 to WK0 in the RTCWK register
(Not changed)
This bit becomes 0 when an interrupt request is accepted, or by setting the bit to 0.
IR bit in the RTCTIC register (when the SEIE bit in the RTCCR2 register is 1 (enable periodic interrupt triggered every second))
IR bit in the RTCTIC register (when the MNIE bit in the RTCCR2 register is 1 (enable periodic interrupt triggered every minute))

BSY : Bit in RTCSEC register

Figure 20.3 Real-Time Clock Basic Operating Example

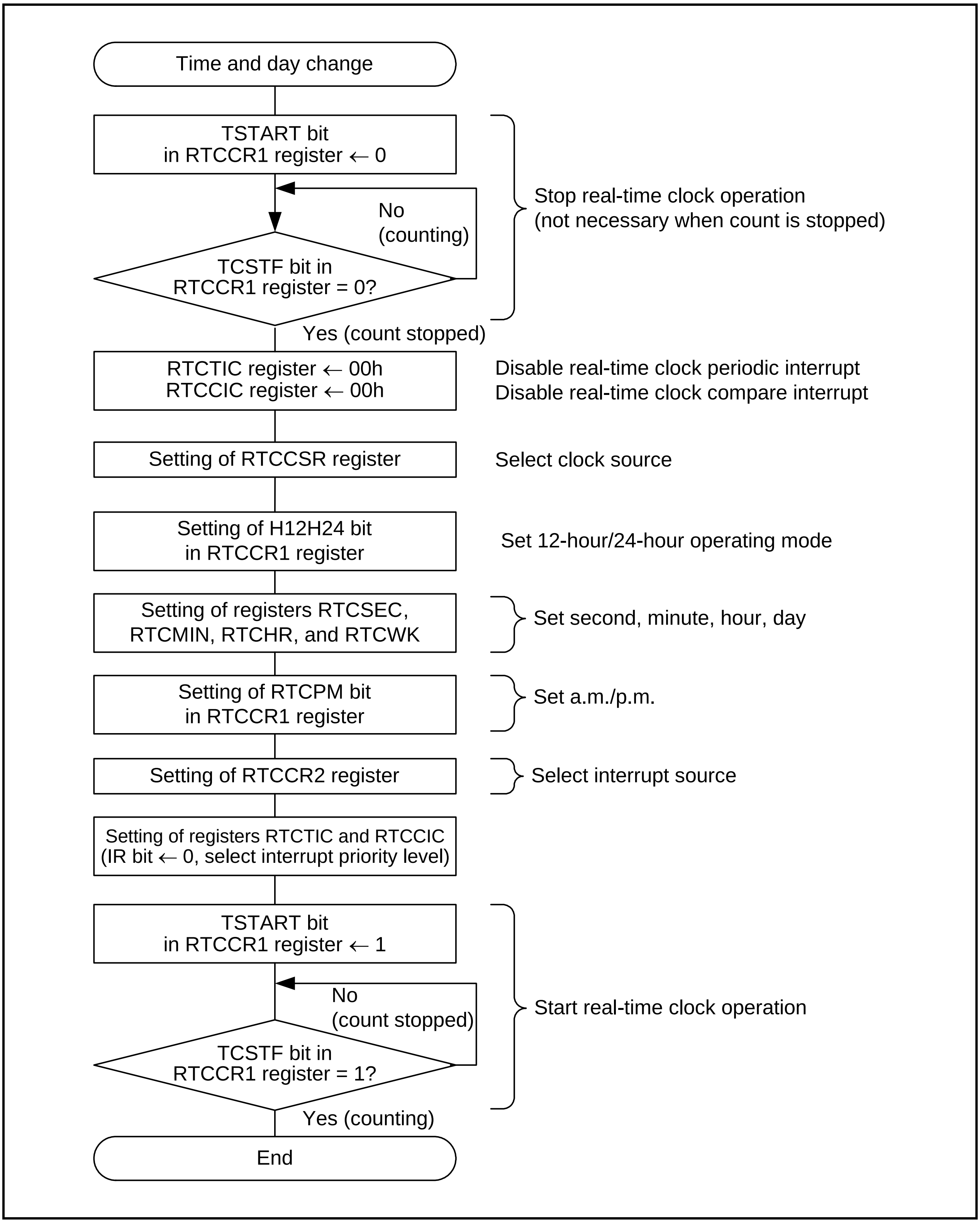
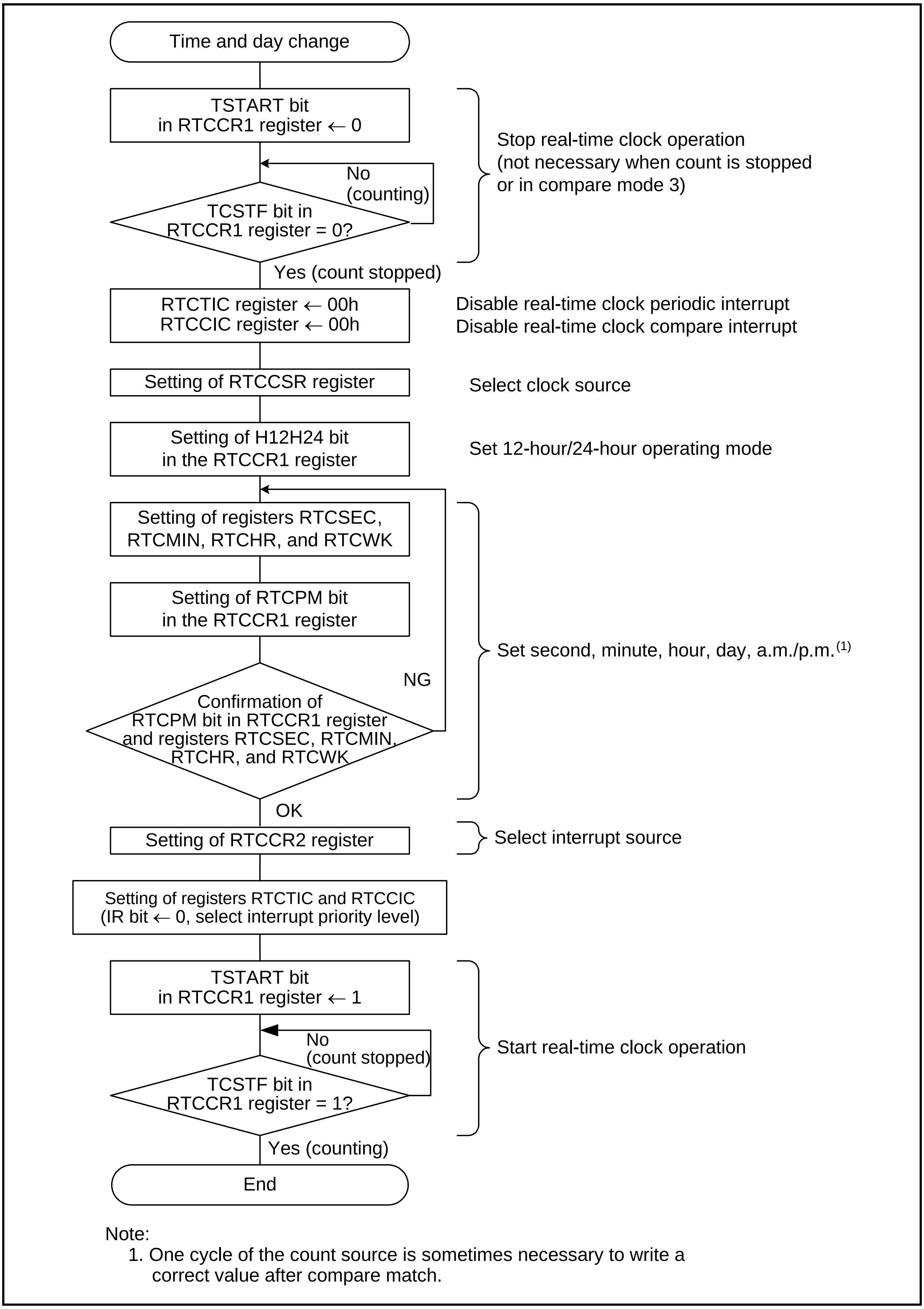

Time and day change
TSTART bit in RTCCR1 register ← 0
No (counting)
TCSTF bit in RTCCR1 register = 0?
Yes (count stopped)
Stop real-time clock operation (not necessary when count is stopped)
RTCTIC register ← 00h
RTCCIC register ← 00h
Disable real-time clock periodic interrupt
Disable real-time clock compare interrupt
Setting of RTCCSR register
Select clock source
Setting of H12H24 bit in RTCCR1 register
Set 12-hour/24-hour operating mode
Setting of registers RTCSEC, RTCMIN, RTCHR, and RTCWK
Set second, minute, hour, day
Setting of RTCPM bit in RTCCR1 register
Set a.m./p.m.
Setting of RTCCR2 register
Select interrupt source
Setting of registers RTCTIC and RTCCIC (IR bit ← 0, select interrupt priority level)
TSTART bit in RTCCR1 register ← 1
No (count stopped)
TCSTF bit in RTCCR1 register = 1?
Yes (counting)
Start real-time clock operation
End

Figure 20.4 Time and Day Change Procedure (No Compare Mode or Compare Mode 1)


Time and day change
TSTART bit in RTCCR1 register ← 0
No (counting)
TCSTF bit in RTCCR1 register = 0?
Yes (count stopped)
Stop real-time clock operation (not necessary when count is stopped or in compare mode 3)
RTCTIC register ← 00h
RTCCIC register ← 00h
Disable real-time clock periodic interrupt
Disable real-time clock compare interrupt
Setting of RTCCSR register
Select clock source
Setting of H12H24 bit in the RTCCR1 register
Set 12-hour/24-hour operating mode
Setting of registers RTCSEC, RTCMIN, RTCHR, and RTCWK
Setting of RTCPM bit in the RTCCR1 register
NG
Confirmation of RTCPM bit in RTCCR1 register and registers RTCSEC, RTCMIN, RTCHR, and RTCWK
OK
Set second, minute, hour, day, a.m./p.m.(1)
Setting of RTCCR2 register
Select interrupt source
Setting of registers RTCTIC and RTCCIC (IR bit ← 0, select interrupt priority level)
TSTART bit in RTCCR1 register ← 1
No (count stopped)
TCSTF bit in RTCCR1 register = 1?
Yes (counting)
Start real-time clock operation
End

Note:

1. One cycle of the count source is sometimes necessary to write a correct value after compare match.

Figure 20.5 Time and Day Change Procedure (Compare Mode 2 or Compare Mode 3)

20.3.2 Compare Mode

In compare mode, time data [1] and compare data [2] are compared, and a compare match is detected. When a match is detected, the following occur:

- Compare interrupt request
  Refer to 20.4 “Interrupts” for details.
- RTCOUT pin output level inversion
  When the TOENA bit in the RTCCR1 register is 1 (compare output enabled), if a compare match is detected, the RTCOUT pin output level is inverted.

Notes:

1. Bits for time data are as follows:
   Bits SC12 to SC10 and SC03 to SC00 in the RTCSEC register
   Bits MN12 to MN10 and MN03 to MN00 in the RTCMIN register
   Bits HR11 to HR10 and HR03 to HR00 in the RTCHR register
   The RTCPM bit in the RTCCR1 register

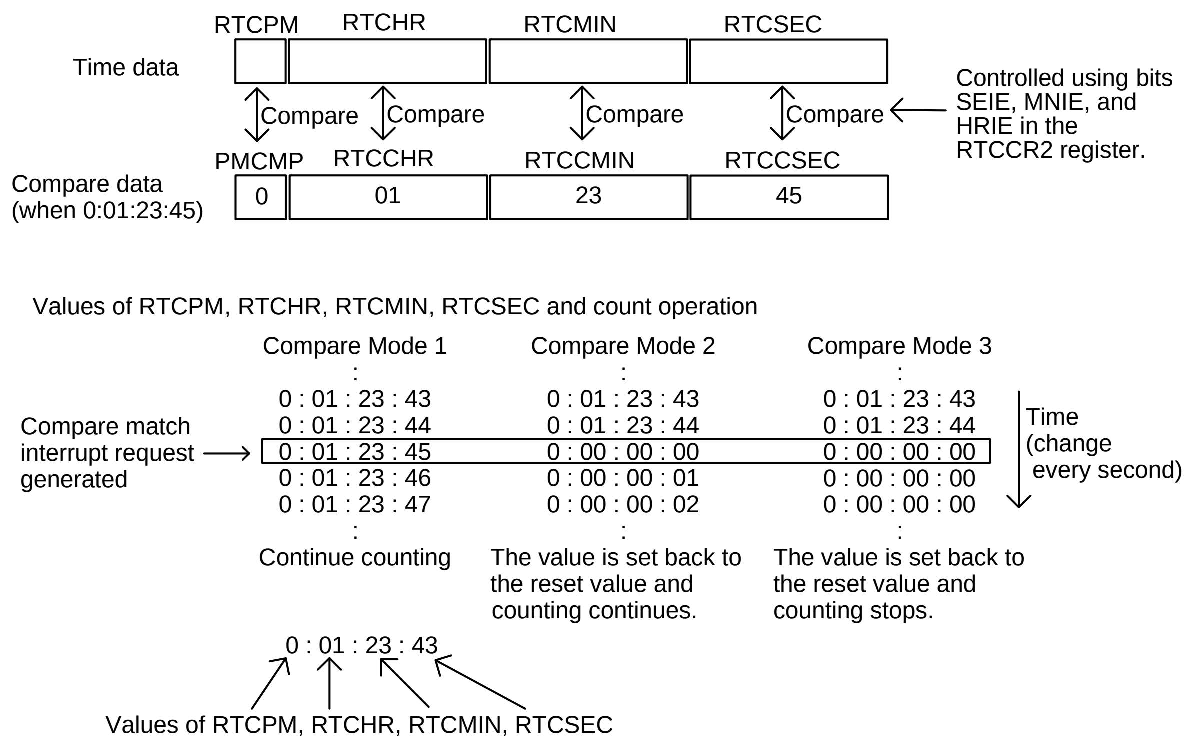
2. Bits for compare data are as follows:
   Bits SCMP12 to SCMP10 and SCMP03 to SCMP00 in the RTCCSEC register
   Bits MCMP12 to MCMP10 and MCMP03 to MCMP00 in the RTCCMIN register
   Bits HCMP11 to HCMP10 and HCMP03 to HCMP00 in the RTCCHR register
   The PMCMP bit in the RTCCHR register

In compare mode, set the SEIE, MNIE, or HRIE bit in the RTCCR2 register to 1 (interrupt enabled) according to compare data (second, minute, or hour). Refer to 20.2.6 “Real-Time Clock Control Register 2 (RTCCR2)” for details.

Compare mode has three modes: compare mode 1, compare mode 2, and compare mode 3. Operation after a compare match differs depending on the compare mode.

- Compare mode 1
  The time data is used continuously and counting continues.
- Compare mode 2
  The reset value is used as the time data and counting continues.
- Compare mode 3
  The reset value is used as the time data and counting stops.

Figure 20.6 shows Difference between Compare Modes, Figure 20.7 shows Count Start/Stop Operating Example, Figure 20.8 shows Compare Mode 1 Operating Example, Figure 20.9 shows Compare Mode 2 Operating Example, and Figure 20.10 shows Compare Mode 3 Operating Example.

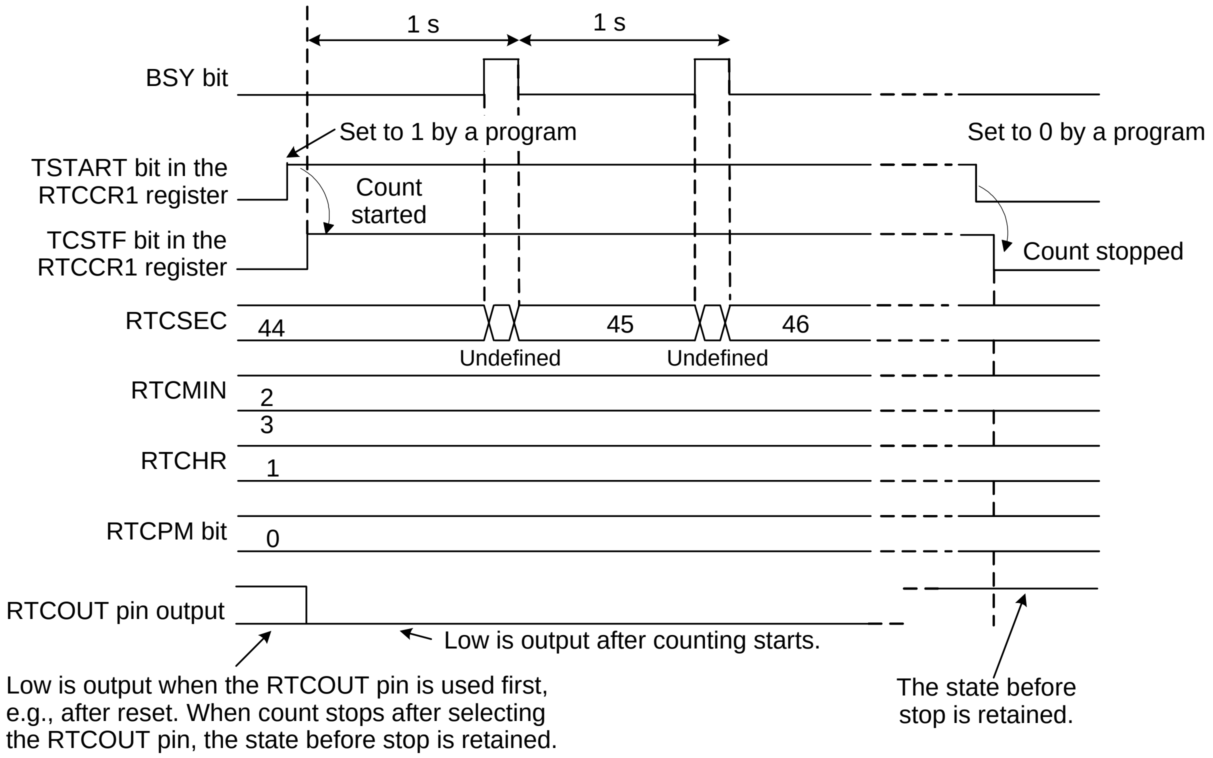


The above assumes the following:

- The H12H24 bit in the RTCCR1 register is 0 (12-hour mode).
- Bits SEIE, MNIE, and HRIE in the RTCCR2 register are 1.

RTCPM	: RTCPM bit in RTCCR1 register
RTCHR	: Bits HR11 to HR10 and HR03 to HR00 in RTCHR register
RTCMIN	: Bits MN12 to MN10 and MN03 to MN00 in RTCMIN register
RTCSEC	: Bits SC12 to SC10 and SC03 to SC00 in RTCSEC register
PMCMP	: PMCMP bit in RTCCHR register
RTCCHR	: Bits HCMP11 to HCMP10 and HCMP03 to HCMP00 in RTCCHR register
RTCCMIN	: Bits MCMP12 to MCMP10 and MCMP03 to MCMP00 in RTCCMIN register
RTCCSEC	: Bits SCMP12 to SCMP10 and SCMP03 to SCMP00 in RTCCSEC register

Figure 20.6 Difference between Compare Modes



Low is output after counting starts.

Low is output when the RTCOUT pin is used first, e.g., after reset. When count stops after selecting the RTCOUT pin, the state before stop is retained.

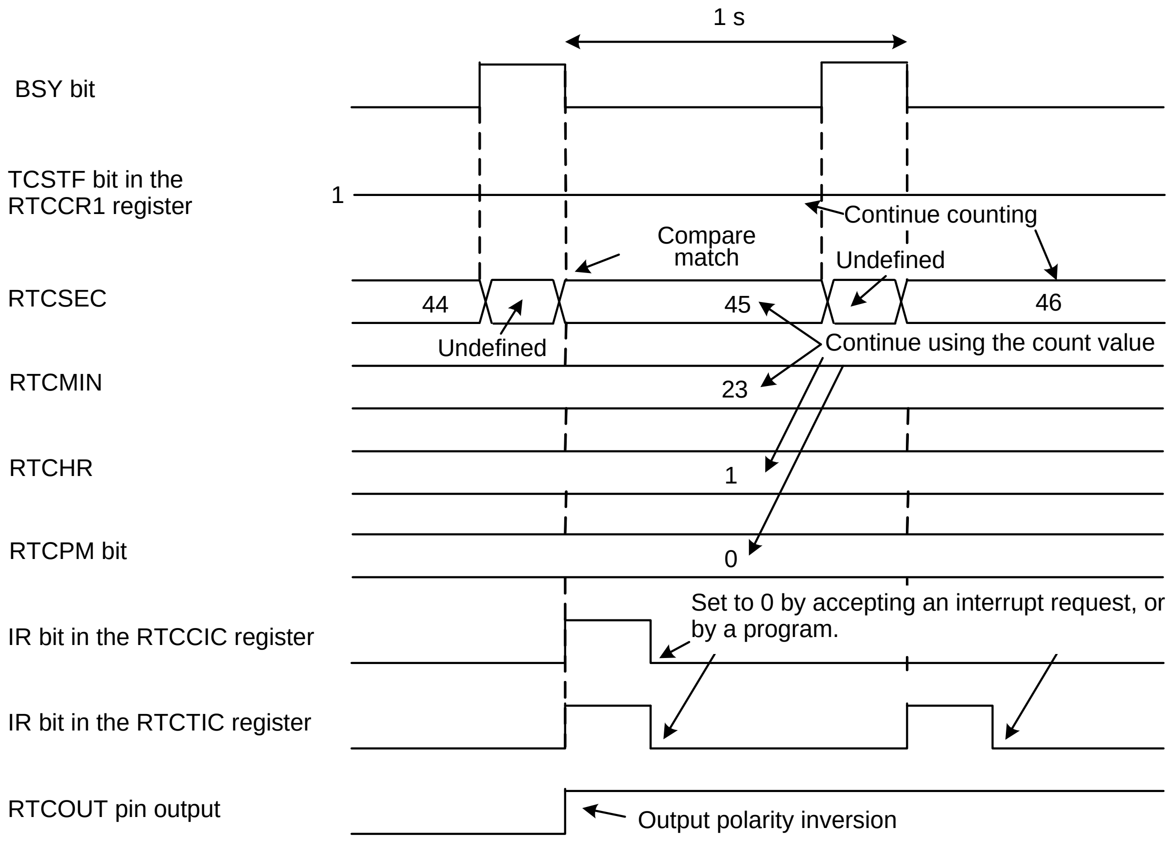
The state before stop is retained.

The above assumes the following:

- The TOENA bit in the RTCCR1 register is 1 (compare output enabled).
- Bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 01b (compare mode 1).

BSY bit: Bit in RTCSEC register
RTCSEC: Bits SC12 to SC10 and SC03 to SC00 in RTCSEC register
RTCMIN: Bits MN12 to MN10 and MN03 to MN00 in RTCMIN register
RTCHR: Bits HR11 to HR10 and HR03 to HR00 in RTCHR register
RTCPM bit: Bit in RTCCR1 register

Figure 20.7 Count Start/Stop Operating Example

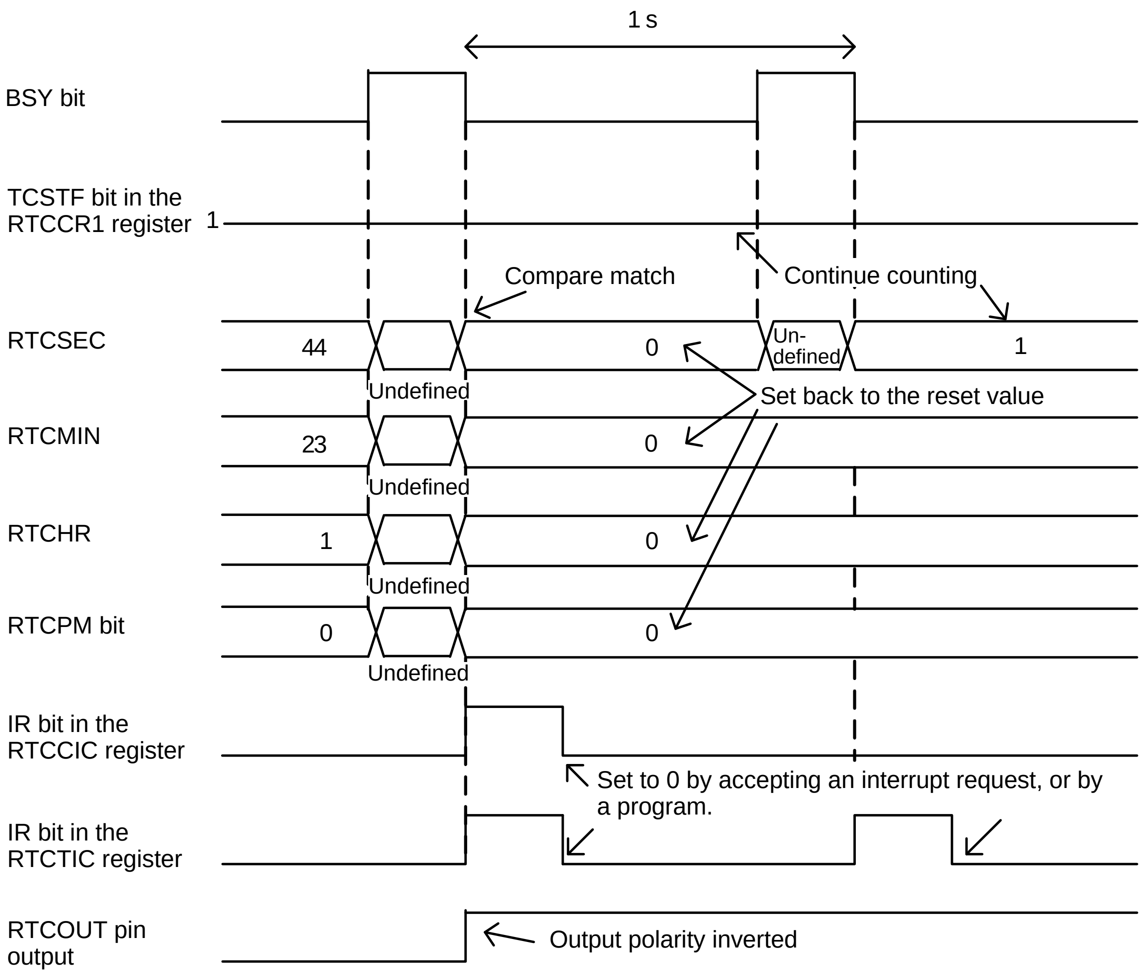

1 s
BSY bit
TCSTF bit in the RTCCR1 register
1
Continue counting
Compare match
Undefined
RTCSEC
44
45
46
Undefined
Continue using the count value
RTCMIN
23
RTCHR
1
RTCPM bit
0
Set to 0 by accepting an interrupt request, or by a program.
IR bit in the RTCCIC register
IR bit in the RTCTIC register
RTCOUT pin output
Output polarity inversion

The above assumes the following:

- The TOENA bit in the RTCCR1 register is 1 (compare output enabled).
- Bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 01b (compare mode 1).
- Bits SEIE, MNIE, and HRIE in the RTCCR2 are 1 (compare by seconds, minutes, and hours. Interrupt enabled).
- Bits SCMP12 to SCMP10 and SCMP03 to SCMP00 in the RTCCSEC register are 4 and 5, respectively (second setting: 45).
  Bits MCMP12 to MCMP10 and MCMP03 to MCMP00 in the RTCCMIN register are 2 and 3, respectively (minute setting: 23).
  Bits HCMP11 to HCMP10 and HCMP03 to HCMP00 in the RTCCHR register are 0 and 1, respectively (hour setting: 1).
  The PMCMP bit in the RTCCHR register is 0 (a.m.).

BSY bit: Bit in RTCSEC register
RTCSEC: Bits SC12 to SC10 and SC03 to SC00 in RTCSEC register
RTCMIN: Bits MN12 to MN10 and MN03 to MN00 in RTCMIN register
RTCHR: Bits HR11 to HR10 and HR03 to HR00 in RTCHR register
RTCPM bit: Bit in RTCCR1 register

Figure 20.8 Compare Mode 1 Operating Example

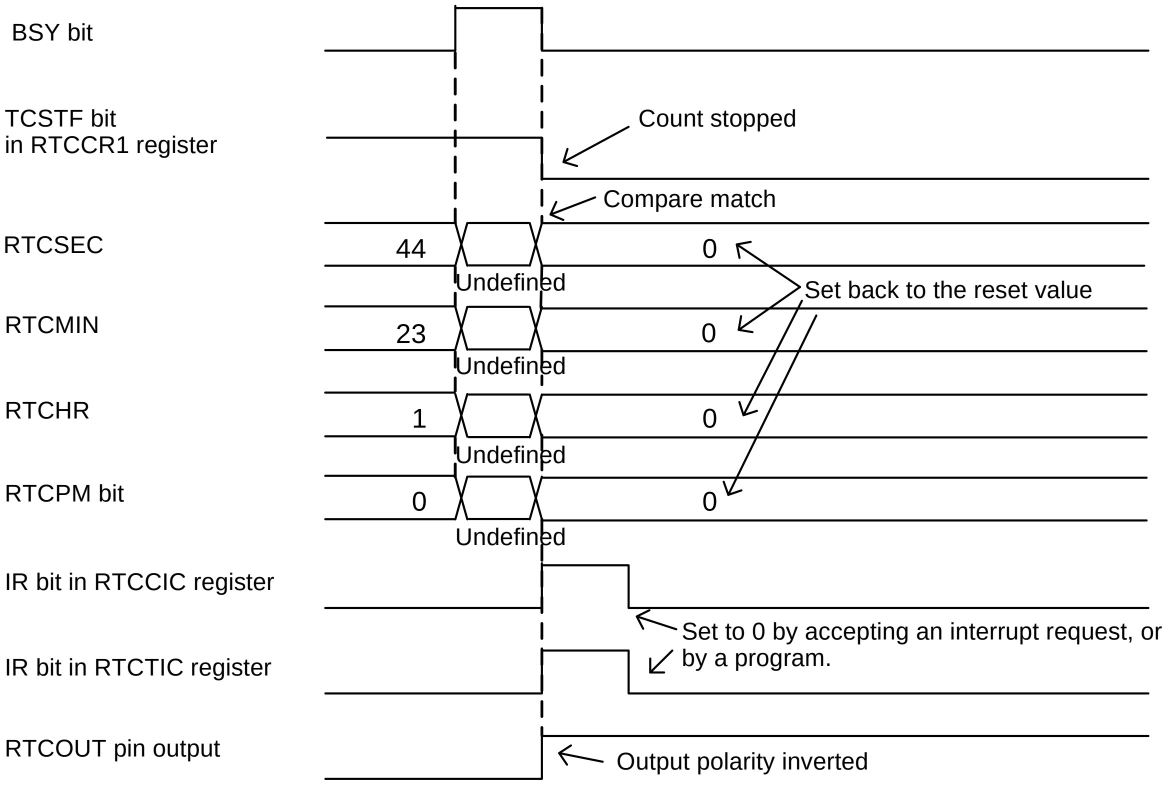

1 s
BSY bit
TCSTF bit in the RTCCR1 register
1
Compare match
Continue counting
RTCSEC
44
0
Un-defined
1
Undefined
Set back to the reset value
RTCMIN
23
0
Undefined
RTCHR
1
0
Undefined
RTCPM bit
0
0
Undefined
IR bit in the RTCCIC register
Set to 0 by accepting an interrupt request, or by a program.
IR bit in the RTCTIC register
RTCOUT pin output
Output polarity inverted

The above assumes the following:

- The TOENA bit in the RTCCR1 register is 1 (compare output enabled).
- Bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 10b (compare mode 2).
- Bits SEIE, MNIE, and HRIE in the RTCCR2 register are 1 (compare by seconds, minutes, and hours. Interrupt enabled).
- Bits SCMP12 to SCMP10 and SCMP03 to SCMP00 in the RTCCSEC register are 4 and 5, respectively (second setting: 45).
  Bits MCMP12 to MCMP10 and MCMP03 to MCMP00 in the RTCCMIN register are 2 and 3, respectively (minute setting: 23).
  Bits HCMP11 to HCMP10 and HCMP03 to HCMP00 in the RTCCHR register are 0 and 1, respectively (hour setting: 1).
  The PMCMP bit in the RTCCHR register is 0 (a.m.).

BSY bit	: Bit in RTCSEC register
RTCSEC	: Bits SC12 to SC10 and SC03 to SC00 in RTCSEC register
RTCMIN	: Bits MN12 to MN10 and MN03 to MN00 in RTCMIN register
RTCHR	: Bits HR11 to HR10 and HR03 to HR00 in RTCHR register
RTCPM bit	: Bit in RTCCR1 register

Figure 20.9 Compare Mode 2 Operating Example



The above assumes the following:

- The TOENA bit in the RTCCR1 register is 1 (compare output enabled).
- Bits RTCCMP1 to RTCCMP0 in the RTCCR2 register are 11b (compare mode 3).
- Bits SEIE, MNIE, and HRIE in the RTCCR2 register are 1 (compare by seconds, minutes, and hours. Interrupt enabled).
- Bits SCMP12 to SCMP10 and SCMP03 to SCMP00 in the RTCCSEC register are 4 and 5, respectively (second setting: 45).
  Bits MCMP12 to MCMP10 and MCMP03 to MCMP00 in the RTCCMIN register are 2 and 3, respectively (minute setting: 23).
  Bits HCMP11 to HCMP10 and HCMP03 to HCMP00 in the RTCCHR register are 0 and 1, respectively (hour setting: 1).
  The PMCMP bit in the RTCCHR register is 0 (a.m.).

BSY bit: Bit in RTCSEC register
RTCSEC: Bits SC12 to SC10 and SC03 to SC00 in RTCSEC register
RTCMIN: Bits MN12 to MN10 and MN03 to MN00 in RTCMIN register
RTCHR: Bits HR11 to HR10 and HR03 to HR00 in RTCHR register
RTCPM bit: Bit in RTCCR1 register

Figure 20.10 Compare Mode 3 Operating Example

20.4 Interrupts

The real-time clock generates two types of interrupt:

- Periodic interrupts triggered every second, minute, hour, day, and week
- Compare match interrupt

See Table 20.4 Periodic Interrupt Sources for details on periodic interrupt sources, individual mode specifications and an operating example for the interrupt request generating timing. Refer to 14.7 “Interrupt Control” for details of interrupt control. Table 20.5 lists Real-Time Clock Interrupt-Associated Registers.

Table 20.5 Real-Time Clock Interrupt-Associated Registers

Address	Register	Symbol	Reset Value
006Eh	Real-Time Clock Periodic Interrupt Control Register	RTCTIC	XXXX X000b
006Fh	Real-Time Clock Compare Interrupt Control Register	RTCCIC	XXXX X000b
0205h	Interrupt Source Select Register 3	IFSR3A	00h

The real-time clock shares interrupt vectors and interrupt control registers with other peripheral functions. To use period interrupts, set the IFSR35 bit in the IFSR3A register to 1 (real-time clock cycle). To use compare interrupts, set the IFSR36 bit in the IFSR3A register to 1 (real-time clock compare).

20.5 Notes on Real-Time Clock

20.5.1 Starting and Stopping the Count

The real-time clock uses the TSTART bit for instructing the count to start or stop, and the TCSTF bit which indicates count started or stopped. Bits TSTART and TCSTF are in the RTCCR1 register.

The real-time clock starts counting and the TCSTF bit becomes 1 (count started) when the TSTART bit is set to 1 (count started). It takes up to two cycles of the count source until the TCSTF bit becomes 1 after setting the TSTART bit to 1. During this time, do not access registers associated with the real-time clock [1] other than the TCSTF bit.

Similarly, when setting the TSTART bit to 0 (count stopped), the real-time clock stops counting and the TCSTF bit becomes 0 (count stopped). It takes up to three cycles of the count source until the TCSTF bit becomes 0 after setting the TSTART bit to 0. During this time, do not access registers associated with the real-time clock other than the TCSTF bit.

Note:

1. Registers associated with the real-time clock: RTCSEC, RTCMIN, RTCHR, RTCWK, RTCCR1, RTCCR2, RTCCSR, RTCCSEC, RTCCMIN, and RTCCHR.

20.5.2 Register Settings (Time Data, etc.)

Write to the following registers/bits when the real-time clock is stopped:

- Registers RTCSEC, RTCMIN, RTCHR, RTCWK, and RTCCR2
- Bits H12H24 and RTCPM in the RTCCR1 register
- Bits RCS0 to RCS4 in the RTCCSR register

The real-time clock is stopped when bits TSTART and TCSTF in the RTCCR1 register are 0 (real-time clock stopped).

Set the RTCCR2 register after setting the registers and bits mentioned above (immediately before the real-time clock count starts).

Figure 20.4 shows Time and Day Change Procedure (No Compare Mode or Compare Mode 1), and Figure 20.5 shows Time and Day Change Procedure (Compare Mode 2 or Compare Mode 3).

20.5.3 Register Settings (Compare Data)

Write to the following registers when the BSY bit in the RTCSEC register is 0 (not while data is updated).

- Registers RTCCSEC, RTCCMIN, and RTCCHR

20.5.4 Time Reading Procedure in Real-Time Clock Mode

In real-time clock mode, read time data bits [1] when the BSY bit in the RTCSEC register is 0 (not while data is updated).

When reading multiple registers, if data is rewritten between reading registers, an errant time will be read. To prevent this, use one of the following steps when reading:

- Using an interrupt
  In the real-time clock periodic interrupt routine, read the values necessary from the appropriate time data bits.
- Monitoring by a program 1
  Monitor the IR bit in the RTCTIC register by a program and read necessary values of time data bits after the IR bit becomes 1 (periodic interrupt requested).
- Monitoring by a program 2
  Read the time data according to Figure 20.11 “Time Data Reading”.

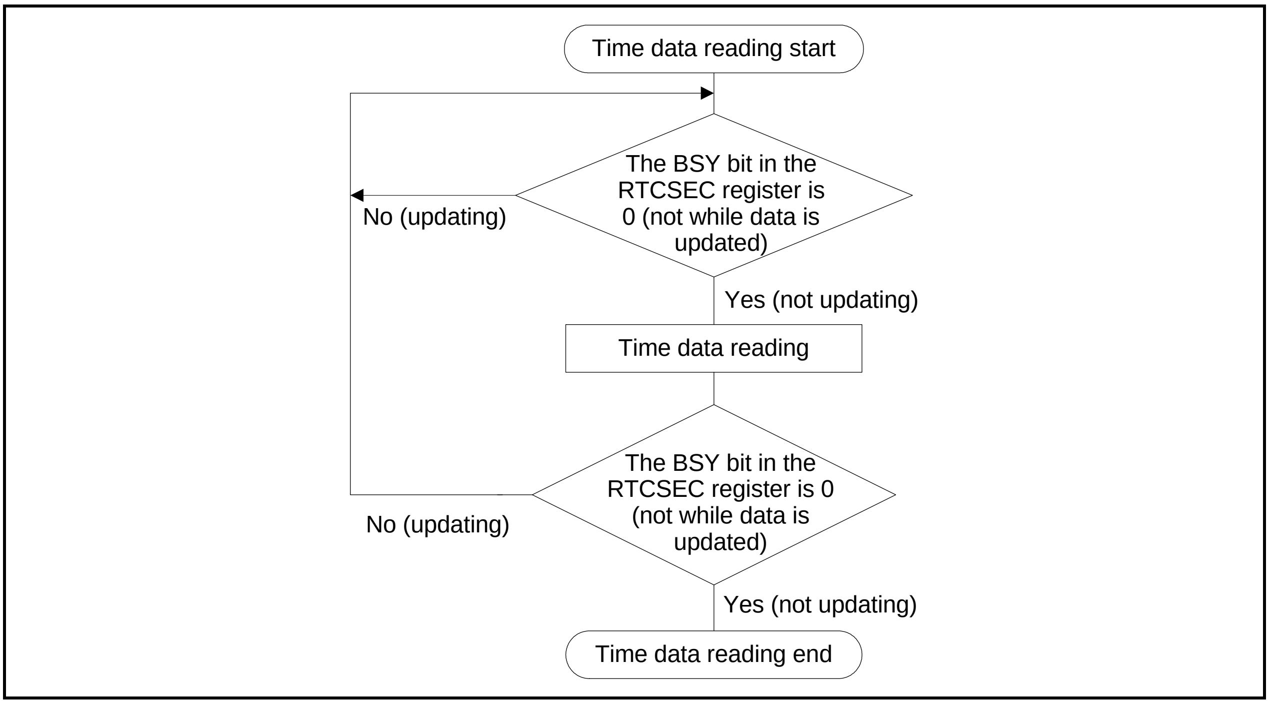

Time data reading start
The BSY bit in the RTCSEC register is 0 (not while data is updated)
No (updating)
Yes (not updating)
Time data reading
The BSY bit in the RTCSEC register is 0 (not while data is updated)
No (updating)
Yes (not updating)
Time data reading end

Figure 20.11 Time Data Reading

- Using read results if they are the same value twice
  (1) Read the values necessary from time data bits.
  (2) Read the same bit as (1) and compare the contents.
  (3) If the contents match, adopt that value as the correct value. If the contents do not match, repeat until the read contents match with the previous contents.

Also, when reading multiple registers, read them as continuously as possible.

Note:

1. Time data bits are as follows:
   Bits SC12 to SC10 and SC03 to SC00 in the RTCSEC register
   Bits MN12 to MN10 and MN03 to MN00 in the RTCMIN register
   Bits HR11 to HR10 and HR03 to HR00 in the RTCHR register
   Bits WK2 to WK0 in the RTCWK register
   The RTCPM bit in the RTCCR1 register

21. Pulse Width Modulator

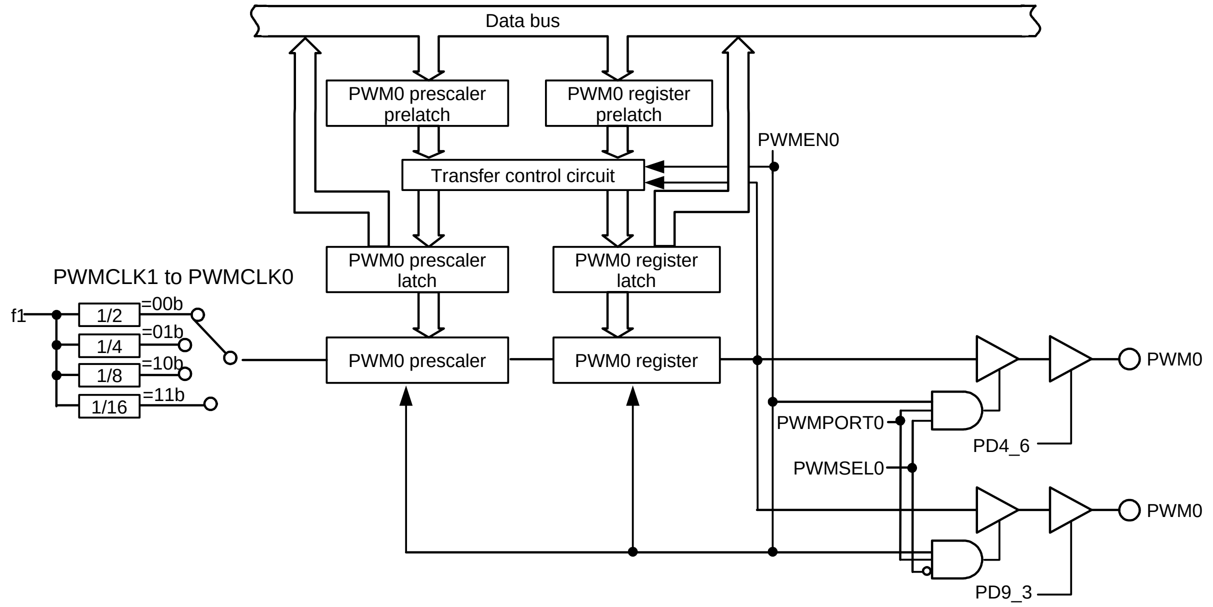
21.1 Introduction

The pulse width modulator (PWM) consists of two independent PWM circuits. Table 21.1 lists PWM Specifications, Figure 21.1 shows Block Diagram of PWM, and Table 21.2 lists I/O Ports.

Table 21.1 PWM Specifications

Item	Specification
Resolution	8 bits
Count source	f1 divided by 2, 4, 8, or 16
PWM Cycle	$\frac{(2^8 - 1) \times (m + 1)}{fj}$ (Unit: s) m: PWMPREi register setting value fj: Count source frequency (Unit : Hz)
High-level pulse width	$\frac{(m + 1) \times n}{fj}$ (Unit: s) m: PWMPREi register setting value n: PWMREGi register setting value fj: Count source frequency (Unit: Hz)
Selectable function	Select output pin: P4 or P9

i = 0, 1



The above shows an example block diagram of PWM0.

PWMSEL0, PWMCLK1, PWMCLK0 : Bits in the PWMCON0 register
PWMEN0, PWMPORT0 : Bits in the PWMCON1 register
PD4_6 : Bit in the PD4 register
PD9_3 : Bit in the PD9 register

Figure 21.1 Block Diagram of PWM

Table 21.2 I/O Ports

Port	I/O	Function
PWM0	Output (1)	PWM output
PWM1		

Note:

1. Set the direction bit corresponding to selected pin to 1 (output mode)

21.2 Registers

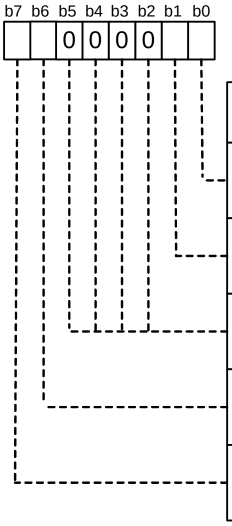
Refer to 8.2.6 “Peripheral Clock Stop Register 1 (PCLKSTP1)” for the explanation of the PCLKSTP1 register.

Table 21.3 Registers

Address	Register	Symbol	Reset Value
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
0370h	PWM Control Register 0	PWMCON0	00h
0372h	PWM0 Prescaler	PWMPRE0	00h
0373h	PWM0 Register	PWMREG0	00h
0374h	PWM1 Prescaler	PWMPRE1	00h
0375h	PWM1 Register	PWMREG1	00h
0376h	PWM Control Register 1	PWMCON1	00h

21.2.1 PWM Control Register 0 (PWMCON0)

PWM Control Register 0



Symbol	Address	Reset Value
PWMCON0	0370h	00h

Bit Symbol	Bit Name	Function	RW
PWMSEL0	PWM0 output pin select bit	0: Output PWM0 signal from P9_3 1: Output PWM0 signal from P4_6	RW
PWMSEL1	PWM1 output pin select bit	0: Output PWM1 signal from P9_4 1: Output PWM1 signal from P4_7	RW
— (b5-b2)	Reserved bits	Set to 0	RW
PWMCLK0	PWM count source select bit	b7 b6 0 0: f1 divided by 2 0 1: f1 divided by 4 1 0: f1 divided by 8 1 1: f1 divided by 16	RW
PWMCLK1			RW

Set bits PWMSELi and PWMCLKi (i = 0, 1) in the PWMCON0 register when the PWMENi bit in the PWMCON1 register is 0 (PWMi output disabled).

PWMSEL0 (PWM0 output pin select bit) (b0)
PWMSEL1 (PWM1 output pin select bit) (b1)

Set these bits to select PWM output pins. See Table 21.4 “PWM Pin and Bit Setting”.

PWMCLK1-PWMCLK0 (PWM count source select bit) (b7-b6)

Set these bits to select a count source for the PWMi prescaler. Prescalers PWM0 and PWM1 share the same count source.

21.2.2 PWMi Prescaler (PWMPREi) (i = 0, 1)

PWMi Prescaler (i = 0, 1)

b7 b0

Symbol	Address	Reset Value
PWMPRE0	0372h	00h
PWMPRE1	0374h	00h

Function	Setting Range	RW
PWM cycle	00h to FFh	RW

21.2.3 PWMi Register (PWMREGi) (i = 0, 1)

PWMi Register (i = 0, 1)

b7 b0

Symbol	Address	Reset Value
PWMREG0	0373h	00h
PWMREG1	0375h	00h

Function	Setting Range	RW
Output high-level pulse width	00h to FFh	RW

The PWMi register (i = 0, 1) sets the PWMi cycle (i = 0, 1) and high-level pulse width. The PWM cycle and high-level pulse width are given by:

$$\text{PWM cycle} = \frac{(2^8 - 1) \times (m + 1)}{fj} \quad \text{(Units: s)}$$

$$\text{High level pulse width} = \frac{(m + 1) \times n}{fj} \quad \text{(Units: s)}$$

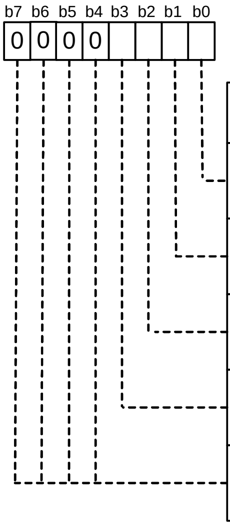
fj: PWM count source frequency (Unit: Hz)
m: PWMPREi register setting
n: PWMREGi register setting

The value written in the PWMPREi register is written to the PWMi prescaler prelatch. At the beginning of the next PWM cycle, the PWMi prescalser prelatch value is transferred to the PWMi prescaler latch and the PWMi prescaler, and then the associated PWMi waveform is output.
The value written in the PWMREGi register is written to the PWMi register prelatch. At the beginning of the next PWM cycle, the PWMi register prelatch value is transferred to the PWMi register latch and the PWMi register, and then the associated PWMi waveform is output.
When rewriting the PWMPREi and PWMREGi register values while the PWMENi bit in the PWMCON1 register is 0 (PWMi output disabled), after the PWMENi bit is set to 1 (PWMi output enabled), the values prior to being rewritten are reflected in the first cycle of PWM output.
Refer 21.3.2 “Operation Example” for output waveforms and transfer timings.

When reading the PWMPREi register while the PWMENi bit is 0 (PWMi output disabled), the PWMi prescaler prelatch value is read. Also, when reading the PWMREGi register, the PWMi register latch value is read (See Figure 21.1 “Block Diagram of PWM”). When reading registers PWMPREi and PWMREGi while the PWMENi bit is 1 (PWMi output enabled), an undefined value is read.

21.2.4 PWM Control Register 1 (PWMCON1)

PWM Control Register 1



Symbol	Address	Reset Value
PWMCON1	0376h	00h

Bit Symbol	Bit Name	Function	RW
PWMEN0	PWM0 output enable bit	0: Output disabled 1: Output enabled	RW
PWMEN1	PWM1 output enable bit	0: Output disabled 1: Output enabled	RW
PWMPORT0	PWM0 port switch bit	0: I/O port 1: PWM0 output	RW
PWMPORT1	PWM1 port switch bit	0: I/O port 1: PWM1 output	RW
— (b7-b4)	Reserved bits	Set to 0	RW

PWMEN0 (PWM0 output enable bit) (b0)
PWMEN1 (PWM1 output enable bit) (b1)

Set these bits to start PWM output. See Table 21.4 “PWM Pin and Bit Setting” for details.

PWMPORT0 (PWM0 port switch bit) (b2)
PWMPORT1 (PWM1 port switch bit) (b3)

Set these bits to select a PWM output pin. See Table 21.4 “PWM Pin and Bit Setting” for details.

Table 21.4 PWM Pin and Bit Setting

Bit Setting			Pin Function or State			
PWMCON0 register	PWMCON1 register					
PWMSELi bit	PWMPORTi bit	PWMENi bit	P9_3	P9_4	P4_6	P4_7
0	0	0 or 1	I/O port or pin for other peripheral function		I/O port or pin for other peripheral function	
	1 (1)	0	PWMi output level maintained (2)			
		1	PWMi pulse output			
1	0	0 or 1	I/O port or pin for other peripheral function		I/O port or pin for other peripheral function	
	1 (1)	0			PWMi output level maintained (2)	
		1			PWMi pulse output	

i = 0, 1

Notes:

1. Set the direction bit corresponding to the selected pin to 1 (output mode).
2. Even if the PWMENi bit is set from 1 to 0 during PWMi output, the PWMi output remains unchanged. The PWM output signal is low immediately after the MCU is reset.

21.3 Operations

21.3.1 Setting Procedure

Follow the procedure below to set individual registers in order to start PWMi (i = 0, 1) output. (All SFRs are assumed to be reset. Refer the register descriptions to access registers or bits.)

(1) Write output data of the port corresponding to the pin for PWMi output to the P9 or P4 register. Then, set the direction bit for the corresponding port to 1 (output mode).

(2) Set the PWMSELi bit in the PWMCON0 register to select a pin for PWMi output. Set the PWMCLKi bit to select the count source.

(3) Set registers PWMPREi and PWMREGi to set the PWM cycle and high-level pulse width.

(4) Set the PWMPORTi bit in the PWMCON1 register to 1 (PWMi function) and the PWMENi bit to 1 (PWM output enabled).

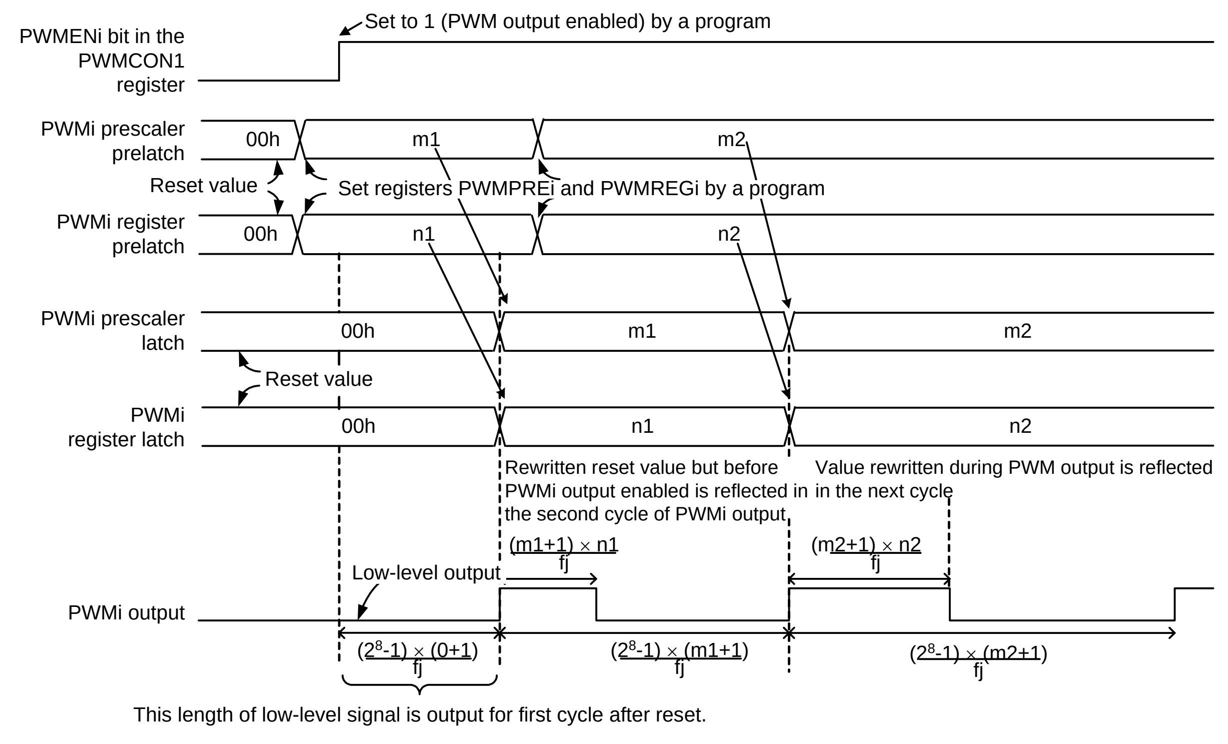
21.3.2 Operation Example

The values written to registers PWMPREi and PWMREGi during PWMi (i = 0, 1) output are not reflected until the next cycle of PWMi output begins.

The PWM output signal is low immediately after the MCU is reset. Then, the associated waveform output starts.

The PWMi output level remains unchanged even if the PWMENi bit in the PWMCON1 register is changed from 1 (PWMi output enabled) to 0 (PWMi output disabled) during PWMi output. Registers PWMPREi and PWMREGi retain the value before the PWMi output is disabled. When setting the PWMENi bit to 1 after registers PWMPREi and PWMREGi are rewritten while PWMi output is disabled, the values of registers PWMPREi and PWMREGi prior to the change are reflected for the first cycle of PWM output. The rewritten register values are reflected in the following PWMi cycle.

Figure 21.2 to Figure 21.4 shows PWMi output examples.


PWMENi bit in the PWMCON1 register
Set to 1 (PWM output enabled) by a program
PWMi prescaler prelatch
00h
m1
m2
Reset value
Set registers PWMPREi and PWMREGi by a program
PWMi register prelatch
00h
n1
n2
PWMi prescaler latch
00h
m1
m2
Reset value
PWMi register latch
00h
n1
n2
Rewritten reset value but before PWMi output enabled is reflected in the second cycle of PWMi output
Value rewritten during PWM output is reflected in the next cycle
(m1+1) × n1 / fj
(m2+1) × n2 / fj
Low-level output
PWMi output
(2⁸-1) × (0+1) / fj
(2⁸-1) × (m1+1) / fj
(2⁸-1) × (m2+1) / fj
This length of low-level signal is output for first cycle after reset.

i: 0, 1
fj: PWM count source frequency
The above diagram assumes the PWMPORTi bit in the PWMCON1 register is 1 (PWMi output).

Figure 21.2 PWMi Output Example (After Reset and During PWM Output)

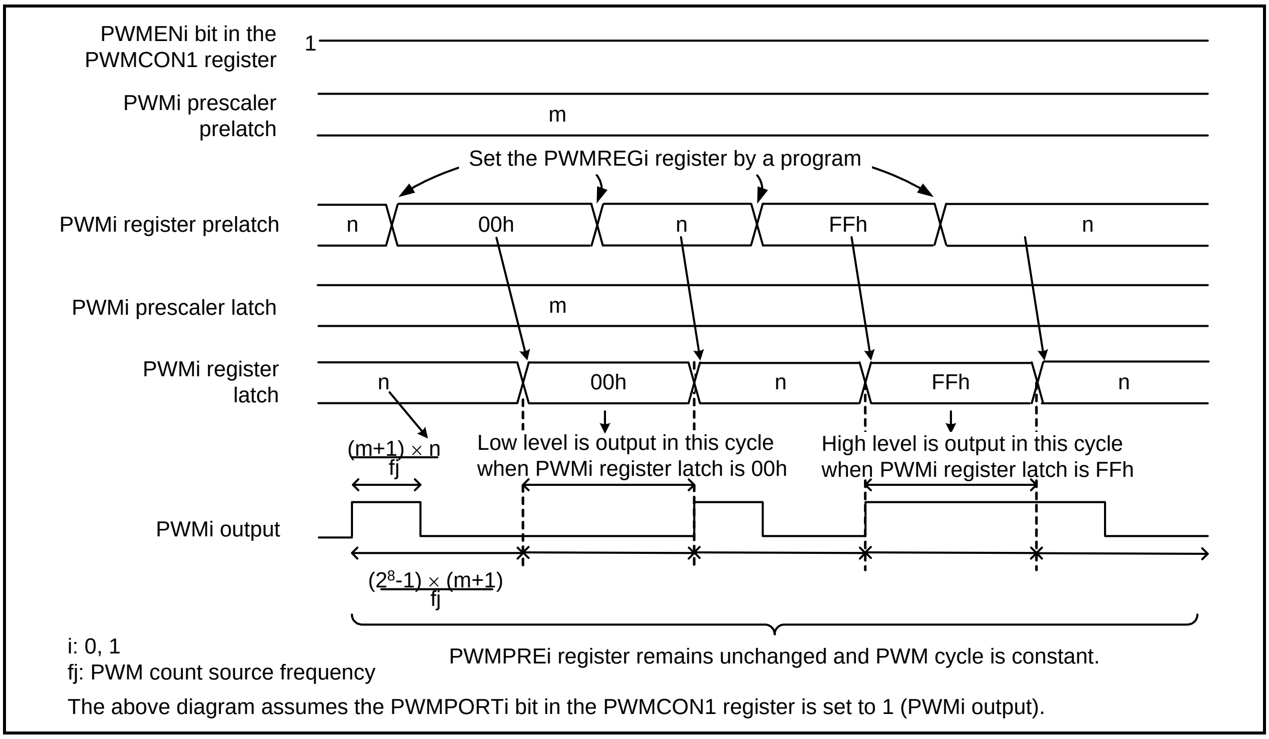

PWMENi bit in the PWMCON1 register
1
PWMi prescaler prelatch
m
Set the PWMREGi register by a program
PWMi register prelatch
n
00h
n
FFh
n
PWMi prescaler latch
m
PWMi register latch
n
00h
n
FFh
n
(m+1) × n / fj
Low level is output in this cycle when PWMi register latch is 00h
High level is output in this cycle when PWMi register latch is FFh
PWMi output
(2⁸-1) × (m+1) / fj
PWMPREi register remains unchanged and PWM cycle is constant.
i: 0, 1
fj: PWM count source frequency
The above diagram assumes the PWMPORTi bit in the PWMCON1 register is set to 1 (PWMi output).

Figure 21.3 PWMi Output Example (Duty 0%, Duty 100%)

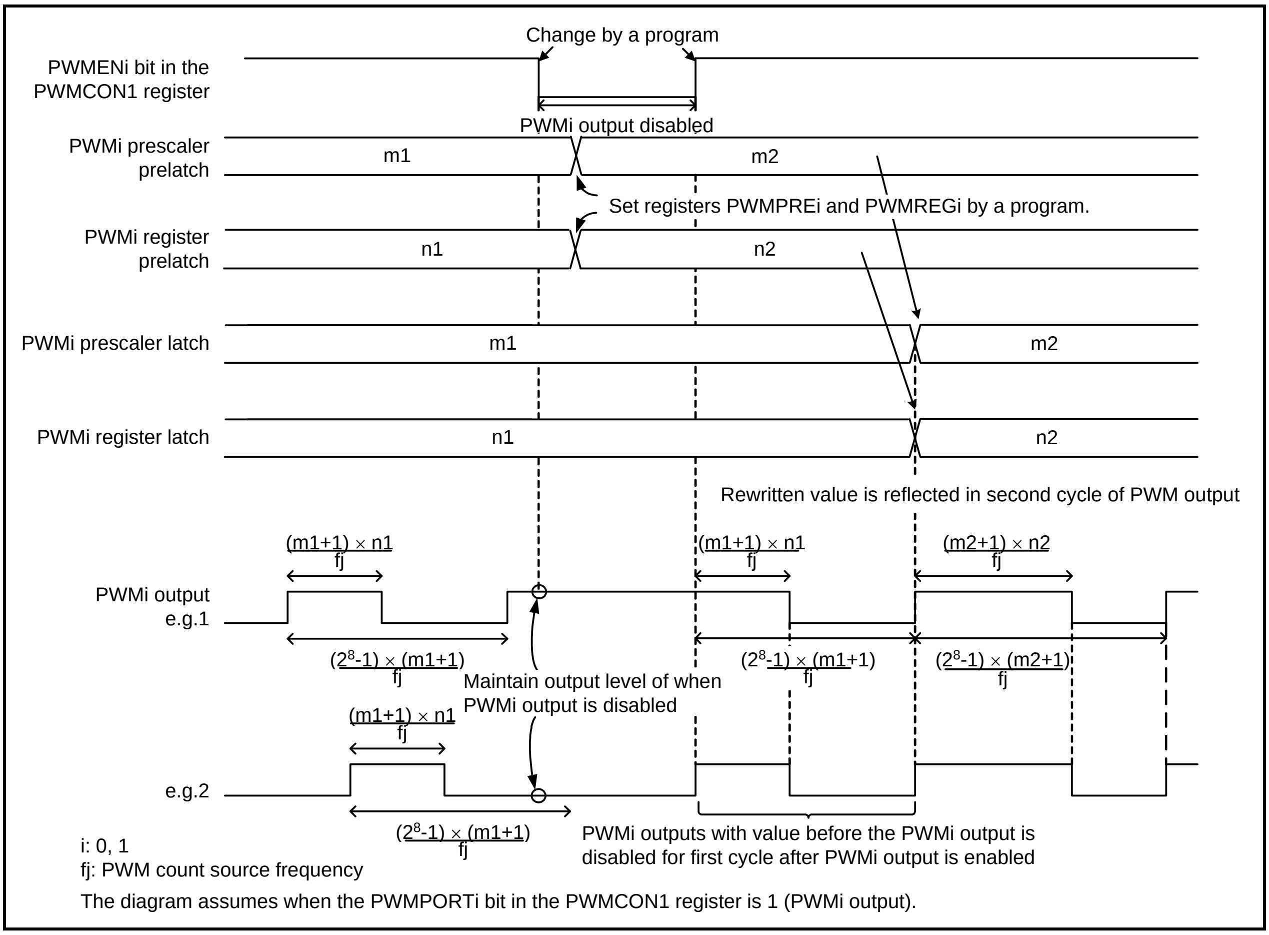

Change by a program
PWMENi bit in the PWMCON1 register
PWMi output disabled
PWMi prescaler prelatch
m1
m2
Set registers PWMPREi and PWMREGi by a program.
PWMi register prelatch
n1
n2
PWMi prescaler latch
m1
m2
PWMi register latch
n1
n2
Rewritten value is reflected in second cycle of PWM output
(m1+1) × n1 / fj
(m1+1) × n1 / fj
(m2+1) × n2 / fj
PWMi output e.g.1
(2⁸-1) × (m1+1) / fj
(2⁸-1) × (m1+1) / fj
(2⁸-1) × (m2+1) / fj
Maintain output level of when PWMi output is disabled
(m1+1) × n1 / fj
e.g.2
(2⁸-1) × (m1+1) / fj
PWMi outputs with value before the PWMi output is disabled for first cycle after PWMi output is enabled
i: 0, 1
fj: PWM count source frequency
The diagram assumes when the PWMPORTi bit in the PWMCON1 register is 1 (PWMi output).

Figure 21.4 PWMi Output Example (PWM Output Disabled and PWM Output Resumed)

22. Remote Control Signal Receiver

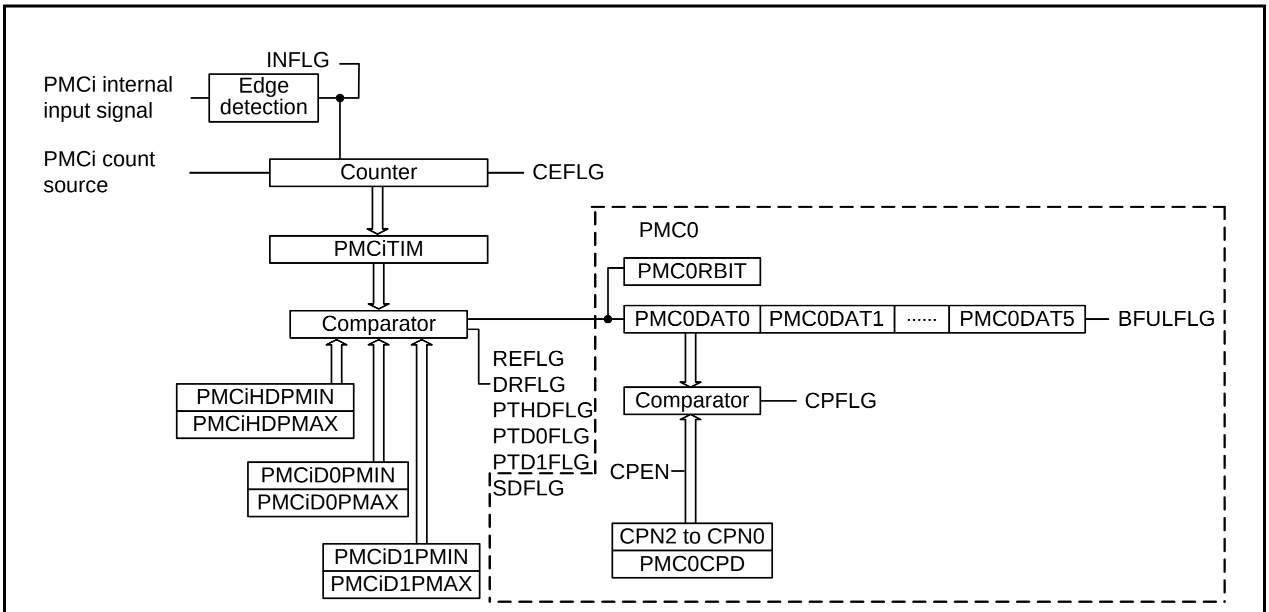
22.1 Introduction

The remote control signal receiver has two circuits for checking the width and period of an of external pulse.

Table 22.1 lists Remote Control Receiver Specifications, Figure 22.1 to Figure 22.3 show remote control signal receiver block diagrams, and Table 22.2 lists the I/O Ports.

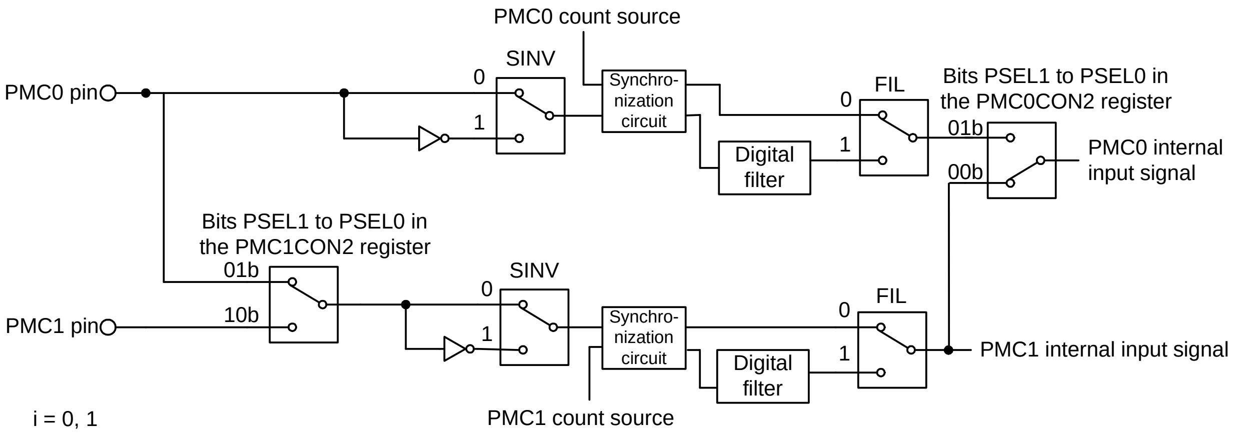
Table 22.1 Remote Control Receiver Specifications

Item		Content	
		PMC0 circuit	PMC1 circuit
Count sources	Clock sources	One of the following: • fC • f1 • Timer B2 underflow • Count source of PMC1	One of the following: • fC • f1 • Timer B1 underflow • Timer B2 underflow
	Division	No division, divided-by-8, divided-by-32, or divided-by-64	
Count operation		Increment	
Operation modes		• Pattern match mode Determines that external pulse matches specified pattern • Input capture mode Measures width and period of external pulse	
Pattern match mode	Detect patterns	• Header • Data 0 • Data 1 • Special data	
	Receive buffer	6 bytes (48 bits)	None
	Interrupt request generation timing	• Receive error • Completion of data reception • Header match • Data 0/1 match • Special data match • Receive buffer full • Compare match	• Receive error • Completion of data reception • Header match • Data 0/1 match
	Selectable functions	• Input signal inversion • Digital filter	
Input capture mode	Measurement items	• Pulse period (between rising edge and rising edge) • Pulse period (between falling edge and falling edge) • Pulse width	
	Interrupt request generation timing	• Timer measurement • Counter overflow	
	Selectable functions	• Input signal inversion • Digital filter • Individual count of PMC0 and PMC1 inputs or simultaneous count of PMC0 and PMC1 inputs	



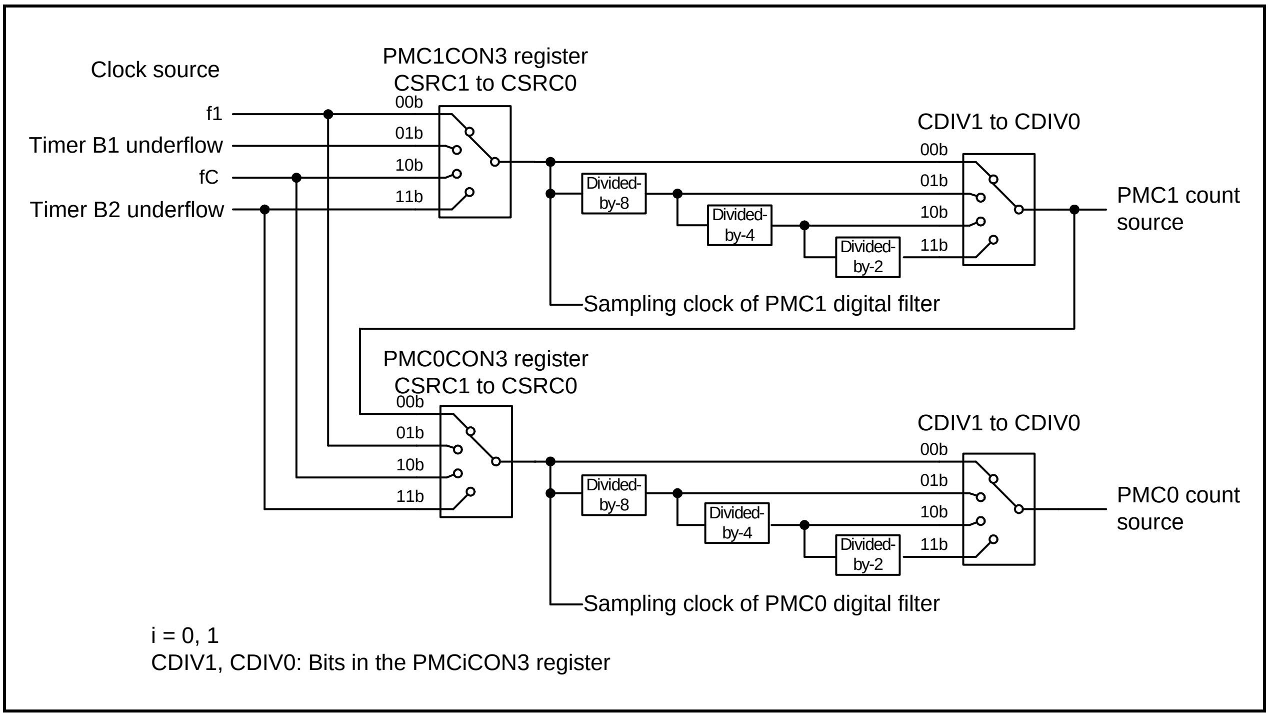
i = 0, 1
INFLG, CEFLG: Bits in registers PMC1CON2 and PMC0CON2
REFLG, DRFLG, PTHDFLG, PTD0FLG, PTD1FLG: Bits in registers PMC0STS and PMC1STS
SDFLG, CPFLG, BFULFLG: Bits in the PMC0STS register
CPEN, CPN2 to CPN0: Bits in the PM0CPC register

Figure 22.1 Remote Control Signal Receiver Block Diagram (1/3)



i = 0, 1
FIL, SINV: Bits in the PMCiCON0 register

Figure 22.2 Remote Control Signal Receiver Block Diagram (2/3) (PMCi Input)



i = 0, 1
CDIV1, CDIV0: Bits in the PMCiCON3 register

Figure 22.3 Remote Control Signal Receiver Block Diagram (3/3) (PMCi Count Source)

Table 22.2 I/O Ports

Pin Name	I/O	Function
PMC0	Input (1)	External pulse input
PMC1		

Note:

1. Set the port direction bits sharing pins to 0 (input mode).

22.2 Registers

Refer to 8.2.6 “Peripheral Clock Stop Register 1 (PCLKSTP1)” for the explanation of the PCLKSTP1 register.

Table 22.3 Registers (PMC0 and PMC1 Circuits)

Address	Register	Symbol	Reset Value
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b

Table 22.4 Registers (PMC0 Circuit)

Address	Register	Symbol	Reset Value
01F0h	PMC0 Function Select Register 0	PMC0CON0	00h
01F1h	PMC0 Function Select Register 1	PMC0CON1	00XX 0000b
01F2h	PMC0 Function Select Register 2	PMC0CON2	0000 00X0b
01F3h	PMC0 Function Select Register 3	PMC0CON3	00h
01F4h	PMC0 Status Register	PMC0STS	00h
01F5h	PMC0 Interrupt Source Select Register	PMC0INT	00h
01F6h	PMC0 Compare Control Register	PMC0CPC	XXX0 X000b
01F7h	PMC0 Compare Data Register	PMC0CPD	00h
D080h	PMC0 Header Pattern Set Register (Min)	PMC0HDPMIN	0000 0000b
D081h			XXXX X000b
D082h	PMC0 Header Pattern Set Register (Max)	PMC0HDPMAX	0000 0000b
D083h			XXXX X000b
D084h	PMC0 Data 0 Pattern Set Register (Min)	PMC0D0PMIN	00h
D085h	PMC0 Data 0 Pattern Set Register (Max)	PMC0D0PMAX	00h
D086h	PMC0 Data 1 Pattern Set Register (Min)	PMC0D1PMIN	00h
D087h	PMC0 Data 1 Pattern Set Register (Max)	PMC0D1PMAX	00h
D088h	PMC0 Measurements Register	PMC0TIM	00h
D089h			00h
D08Ch	PMC0 Receive Data Store Register 0	PMC0DAT0	00h
D08Dh	PMC0 Receive Data Store Register 1	PMC0DAT1	00h
D08Eh	PMC0 Receive Data Store Register 2	PMC0DAT2	00h
D08Fh	PMC0 Receive Data Store Register 3	PMC0DAT3	00h
D090h	PMC0 Receive Data Store Register 4	PMC0DAT4	00h
D091h	PMC0 Receive Data Store Register 5	PMC0DAT5	00h
D092h	PMC0 Receive Bit Count Register	PMC0RBIT	XX00 0000b

Table 22.5 **Registers (PMC1 Circuit)**

Address	Register	Symbol	Reset Value
01F8h	PMC1 Function Select Register 0	PMC1CON0	XXX0 X000b
01F9h	PMC1 Function Select Register 1	PMC1CON1	XXXX 0X00b
01FAh	PMC1 Function Select Register 2	PMC1CON2	0000 00X0b
01FBh	PMC1 Function Select Register 3	PMC1CON3	00h
01FCh	PMC1 Status Register	PMC1STS	X000 X00Xb
01FDh	PMC1 Interrupt Source Select Register	PMC1INT	X000 X00Xb
D094h	PMC1 Header Pattern Set Register (Min)	PMC1HDPMIN	0000 0000b
D095h			XXXX X000b
D096h	PMC1 Header Pattern Set Register (Max)	PMC1HDPMAX	0000 0000b
D097h			XXXX X000b
D098h	PMC1 Data 0 Pattern Set Register (Min)	PMC1D0PMIN	00h
D099h	PMC1 Data 0 Pattern Set Register (Max)	PMC1D0PMAX	00h
D09Ah	PMC1 Data 1 Pattern Set Register (Min)	PMC1D1PMIN	00h
D09Bh	PMC1 Data 1 Pattern Set Register (Max)	PMC1D1PMAX	00h
D09Ch	PMC1 Measurements Register	PMC1TIM	00h
D09Dh			00h

22.2.1 PMCi Function Select Register 0 (PMCiCON0) (i = 0, 1)

PMC0 Function Select Register 0

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
PMC0CON0	01F0h	00h

Bit Symbol	Bit Name	Function	RW
EN	PMC0 operation enable bit	0: Operation disabled 1: Operation enabled	RW
SINV	Input signal polarity invert bit	0: Not inverted 1: Inverted	RW
FIL	Filter enable bit	0: Filter disabled 1: Filter enabled	RW
EHOLD	Error flag hold bit	State of the REFLG bit in the PMC0STS register: 0: Held until next data received 1: Held even after next data received	RW
HDEN	Header pattern enable bit	0: Header disabled 1: Header enabled	RW
SDEN	Special data pattern enable bit	0: Special data pattern disabled 1: Special data pattern enabled	RW
DRINT0	Receive interrupt control bit	Interrupt request is generated under the following conditions: b7 b6 0 0: When reception completed 0 1: When compare match occurs and reception completed 1 0: When no receive error occurs and reception completed 1 1: When compare match and no receive error occurs, and reception completed	RW
DRINT1			

PMC1 Function Select Register 0

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
PMC1CON0	01F8h	XXX0 X000b

Bit Symbol	Bit Name	Function	RW
EN	PMC1 operation enable bit	0: Operation disabled 1: Operation enabled	RW
SINV	Input signal polarity invert bit	0: Not inverted 1: Inverted	RW
FIL	Filter enable bit	0: Filter disabled 1: Filter enabled	RW
— (b3)	No register bit. If necessary, set to 0. Read as undefined value.		—
HDEN	Header pattern enable bit	0: Header disabled 1: Header enabled	RW
— (b7-b5)	No register bits. If necessary, set to 0. Read as undefined value.		—

EN (PMCi operation enable bit) (b0)

The EN bit is used to control start/stop of PMCi operation. Confirm that the operation has started or stopped by the ENFLG bit in the PMCiCON2 register.

EHOLD (Error flag hold bit) (b3)

When a receive error occurs, the period when the REFLG bit in the PMC0STS register retains 1 (receive error) can be selected. Refer to “REFLG (Receive error flag) (b1)” in 22.2.5 “PMCi Status Register (PMCiSTS) (i = 0, 1)” for details.

HDEN (Header pattern enable bit) (b4)

While the HDEN bit is 1 (header enabled), after data reception starts (DRFLG flag is 1), if data 0, data 1, or special data is detected before the header is detected, the following occur:

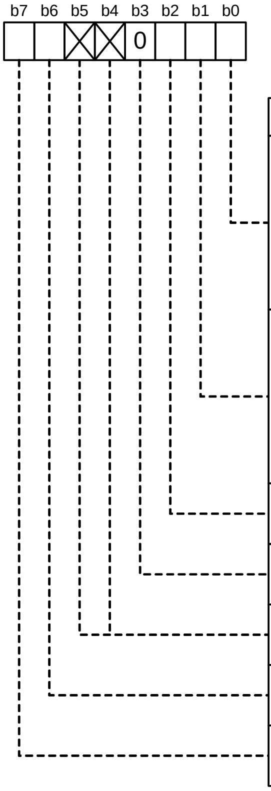
- The REFLG bit in the PMCiSTS register becomes 1 (error occurs)
- Bits PTD0FLG, PTD1FLG, and SDFLG in the PMCiSTS register remain unchanged.
- Registers PMC0DAT0 to PMC0DAT5 are not rewritten.

DRINT1-DRINT0 (Receive interrupt control bit) (b7-b6)

Set these bits to select a condition for generating a data reception complete interrupt request.
Set the DRINT bit in the PMC0INT register to 1 (reception complete interrupt enabled) after setting these bits.
When setting the DRINT1 bit to 1, set the EHOLD bit in the PMC0CON0 register to 1 (hold the REFLG bit state after next data received).

22.2.2 PMCi Function Select Register 1 (PMCiCON1) (i = 0, 1)

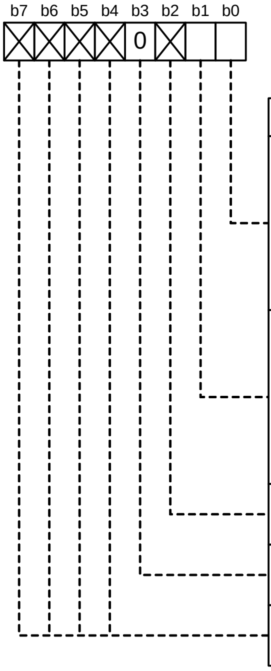
PMC0 Function Select Register 1



Symbol	Address	Reset Value
PMC0CON1	01F1h	00XX 0000b

Bit Symbol	Bit Name	Function	RW
TYP0	Receive mode select bit	b1 b0 0 0 : Period measurement (between rising edge and rising edge) 0 1 : In pattern match mode, high level width measurement (between rising edge and falling edge) In input capture mode, period measurement (between falling edge and falling edge) 1 0 : Pulse width measurement (between rising edge and falling edge, and falling edge and rising edge) 1 1 : Do not set.	RW
TYP1			
CSS	Counter start control bit	0: Counters operate individually 1: Counters operate simultaneously	RW
— (b3)	Reserved bit	Set to 0.	RW
— (b5-b4)	No register bits. If necessary, set to 0. Read as undefined value.		—
EXSDEN	Special pattern detect block select bit	0: PMC0 1: PMC1	RW
EXHDEN	Header pattern detect block select bit	0: PMC0 1: PMC1	RW

PMC1 Function Select Register 1



Symbol	Address	Reset Value
PMC1CON1	01F9h	XXXX 0X00b

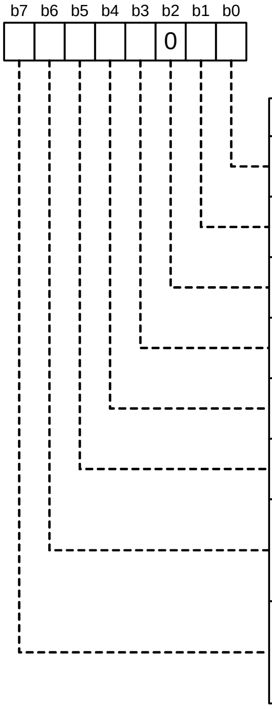
Bit Symbol	Bit Name	Function	RW
TYP0	Receive mode select bit	b1 b0 0 0 : Period measurement (between rising edge and rising edge) 0 1 : In pattern match mode, high level width measurement (between rising edge and falling edge) In input capture mode, period measurement (between falling edge and falling edge) 1 0 : Pulse width measurement (between rising edge and falling edge, and falling edge and rising edge) 1 1 : Do not set.	RW
TYP1			
— (b2)	No register bit. If necessary, set to 0. Read as undefined value.		—
— (b3)	Reserved bit	Set to 0.	RW
— (b7-b4)	No register bits. If necessary, set to 0. Read as undefined value.		—

EXSDEN (Special pattern detect block select bit) (b6)
EXHDEN (Header pattern detect block select bit) (b7)

Use these bits when PMC0 and PMC1 are linked and operated in pattern match mode. Otherwise, set them to 0.
Set bits EXHDEN to EXSDEN to 01b or 10b when setting the HDEN bit in the PMC0CON0 register to 1 (header enabled) and SDEN bit to 1 (special data pattern enabled). Refer to 22.3.3.2 “Header and Special Data Detection”.

22.2.3 PMCi Function Select Register 2 (PMCiCON2) (i = 0, 1)

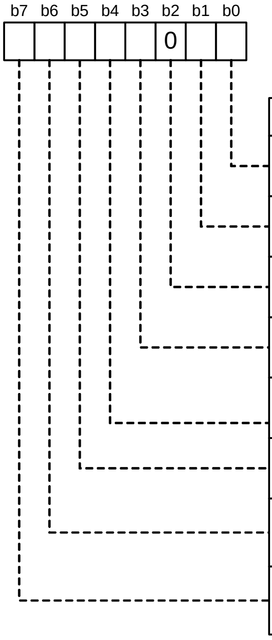
PMC0 Function Select Register 2



Symbol	Address	Reset Value
PMC0CON2	01F2h	0000 00X0b

Bit Symbol	Bit Name	Function	RW
ENFLG	PMC0 status flag	0: Stops 1: Operating	RO
— (b1)	Reserved bit	Read as undefined value	RO
— (b2)	Reserved bit	Set to 0	RW
INFLG	Input signal flag	0: PMC0 internal input signal level is low 1: PMC0 internal input signal level is high	RO
CEFLG	Counter overflow flag	0: No overflow 1: Overflows	RO
CEINT	Counter overflow interrupt enable bit	0: Disabled 1: Enabled	RW
PSEL0	Input pin select bit	b7 b6 0 0 : Same as PMC1 (Set bits PSEL1 to PSEL0 in the PMC1CON2 register to select) 0 1 : PMC0 pin 1 0 : Do not set 1 1 : Do not set	RW
PSEL1			

PMC1 Function Select Register 2



Symbol	Address	Reset Value
PMC1CON2	01FAh	0000 00X0b

Bit Symbol	Bit Name	Function	RW
ENFLG	PMC1 status flag	0: Stops 1: Operating	RO
— (b1)	Reserved bit	Read as undefined value	RO
— (b2)	Reserved bit	Set to 0	RW
INFLG	Input signal flag	0: PMC1 internal input signal level is low 1: PMC1 internal input signal level is high	RO
CEFLG	Counter overflow flag	0: No overflow 1: Overflows	RO
CEINT	Counter overflow interrupt enable bit	0: Disabled 1: Enabled	RW
PSEL0	Input pin select bit	b7 b6 0 0 : In an idle state 0 1 : PMC0 pin 1 0 : PMC1 pin 1 1 : Do not set	RW
PSEL1			

CEFLG (Counter overflow flag) (b4)

Conditions to become 0:

- The EN bit in the PMCiCON0 register is 0 (PMCi operation stops)
- Measurement timing selected by bits TYP1 to TYP0 in the PMCiCON1 register

Condition to become 1:

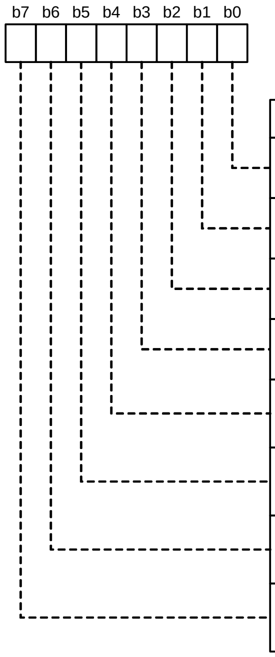
- Counter overflow (the counter becomes 0000h from FFFFh)

PSEL1-PSEL0 (Input pin select bit) (b7-b6)

Change these bits when the EN bit in the PMCiCON0 register and the ENFLG bit in the PMCiCON2 register are both 0 (PMCi stops).
Refer to Figure 22.2 “Remote Control Signal Receiver Block Diagram (2/3) (PMCi Input)” and 22.3.1.2 “PMCi Input”.

22.2.4 PMCi Function Select Register 3 (PMCiCON3) (i = 0, 1)

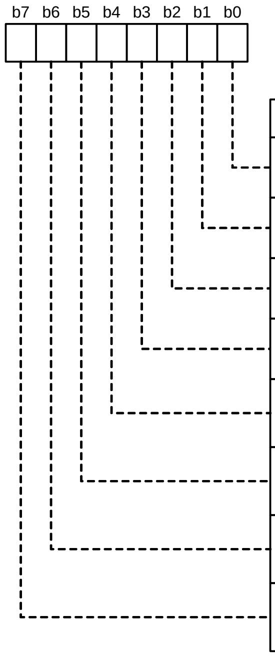
PMC0 Function Select Register 3



Symbol	Address	Reset Value
PMC0CON3	01F3h	00h

Bit Symbol	Bit Name	Function	RW
CRE	Mode select bit	b3 b2 b1 b0 0 0 0 0 : Pattern match mode 1 1 1 1 : Input capture mode Only set the values listed above.	RW
CFR			
CST			
PD			
CSRC0	Clock source select bit	b5 b4 0 0 : Same as PMC1 0 1 : f1 1 0 : fC 1 1 : Timer B2 underflow	RW
CSRC1			
CDIV0	Count source divisor select bit	b7 b6 0 0 : No division 0 1 : Divided-by-8 1 0 : Divided-by-32 1 1 : Divided-by-64	RW
CDIV1			

PMC1 Function Select Register 3



Symbol	Address	Reset Value
PMC1CON3	01FBh	00h

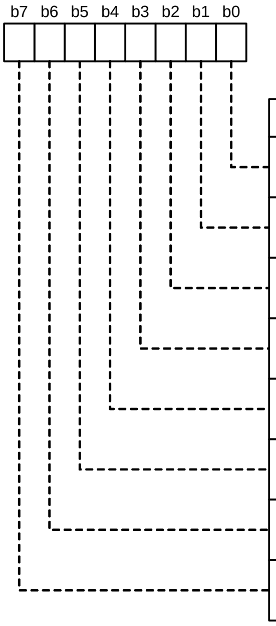
Bit Symbol	Bit Name	Function	RW
CRE	Mode select bit	b3 b2 b1 b0 0 0 0 0 : Pattern match mode 1 1 1 1 : Input capture mode Only set the values listed above.	RW
CFR			
CST			
PD			
CSRC0	Clock source select bit	b5 b4 0 0 : f1 0 1 : Timer B1 underflow 1 0 : fC 1 1 : Timer B2 underflow	RW
CSRC1			
CDIV0	Count source divisor select bit	b7 b6 0 0 : No division 0 1 : Divided-by-8 1 0 : Divided-by-32 1 1 : Divided-by-64	RW
CDIV1			

CDIV1-CDIV0 (Clock source divisor select bit) (b7-b6)

When bits CSRC1 to CSRC0 in the PMC0CON3 register are set to 00b (same as PMC1), set bits CDIV1 to CDIV0 in the PMC0CON3 register to 00b (no division).

22.2.5 PMCi Status Register (PMCiSTS) (i = 0, 1)

PMC0 Status Register



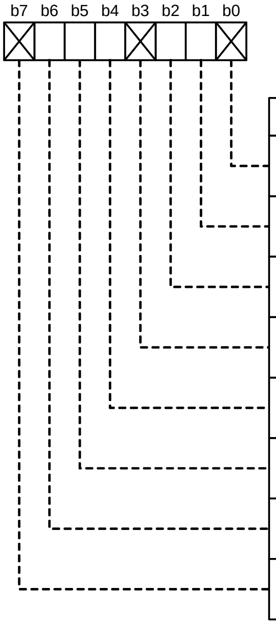
Symbol PMC0STS

Address 01F4h

Reset Value 00h

Bit Symbol	Bit Name	Function	RW
CPFLG	Compare match flag	0: Not match 1: Match	RO
REFLG	Receive error flag	0: No error occurs 1: Error occurs	RO
DRFLG	Data receiving flag	0: Waiting for data reception 1: Data receiving	RO
BFULFLG	Receive buffer full flag	0: Receive buffer empty 1: Receive buffer full (48 bits received)	RO
PTHDFLG	Header pattern match flag	0: Not match 1: Match	RO
PTD0FLG	Data 0 pattern match flag	0: Not match 1: Match	RO
PTD1FLG	Data 1 pattern match flag	0: Not match 1: Match	RO
SDFLG	Special pattern match flag	0: Not match 1: Match	RO

PMC1 Status Register



Symbol PMC1STS

Address 01FCh

Reset Value X000 X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. Read as undefined value.		—
REFLG	Receive error flag	0: No error occurs 1: Error occurs	RO
DRFLG	Data receiving flag	0: Waiting for data reception 1: Data receiving	RO
— (b3)	No register bit. If necessary, set to 0. Read as undefined value.		—
PTHDFLG	Header pattern match flag	0: Not match 1: Match	RO
PTD0FLG	Data 0 pattern match flag	0: Not match 1: Match	RO
PTD1FLG	Data 1 pattern match flag	0: Not match 1: Match	RO
— (b7)	No register bit. If necessary, set to 0. Read as undefined value.		—

Each bit in the PMCiSTS register changes at a measurement edge of the PMCi internal input signal. However, the DRFLG bit also changes according to the counter value judgement.

CPFLG (Compare match flag) (b0)

This bit is enabled when the CPEN bit in the PMC0CPC register is set to 1 (compare enabled).
Conditions to become 0:

- When the EN bit in the PMCiCON0 register is 0 (PMCi operation disabled).
- When the DRFLG bit in the PMC0STS register changes from 0 to 1 (next frame reception starts).
- When the 48th bit is received after the CPFLG bit becomes 1, and then (the DRFLG bit remains 1 (receiving)) no compare match occurs after receiving bit n (n = value set by bits CPN2 to CPN0 in the PMC0CPC register).

Condition to become 1:

- The PMC0CPD register matches the PMC0DAT0 register (when the setting value of bits CPN2 to CPN0 in the PMC0CPC register is n, bits n to 0 in the PMC0CPD register match bits n to 0 in the PMC0DAT0 register).

REFLG (Receive error flag) (b1)

The REFLG bit is a flag indicating a receive error. Conditions for changing the REFLG bit are affected by the HDEN bit in the PMCiCON0 register and bits EHOLD and SDEN in the PMC0CON0 register. Table 22.6 lists Conditions for Changing the REFLG Bit.

Table 22.6 Conditions for Changing the REFLG Bit

Bit Setting [1]		Conditions for Changing the REFLG Bit to 1 [2]	Conditions for Changing the REFLG bit to 0 [2, 3]
EHOLD	HDEN		
0	0	Input signal width is not data 0 or data 1 (or special data)	Receive data 0 or data 1 (or special data)
0	1	• Input signal width is not the header, data 0, or data 1 (or special data) • Detect data 0 or data 1 (or special data) prior to header	• Receive header • Receive header prior to data 0 or data 1 (or special data)
1	0	Input signal width is not data 0 or data 1 (or special data)	-
1	1	• Input signal width is not the header, data 0, or data 1 (or special data) • Detect data 0 or data 1 (or special data) prior to header	• Receive header

EHOLD: Bit in the PMC0CON0 register
HDEN: Bit in the PMCiCON0 register (i = 0, 1)
Notes:

1. For the REFLG bit of PMC1, refer to settings where the EHOLD bit is 0.
2. Special data is added to the conditions when the SDEN bit in the PMC0CON0 register is 1 (special data pattern enabled).
3. The REFLG bit becomes 0 regardless of bits HDEN and EHOLD under the following conditions:
   - The EN bit in the PMCiCON0 register is 0 (PMCi stops).
   - The DRFLG bit in the PMCiSTS register changes from 0 to 1.

DRFLG (Data receiving flag) (b2)

The DRFLG bit indicates the receiving state of the remote control signal. The bit is 1 while receiving one frame. When data reception ends, the bit becomes 0.

Conditions to become 0:

- The EN bit in the PMCiCON0 register is 0 (PMCi operation disabled).
- The counter value is larger than values of registers PMCiHDPMAX, PMCiD0PMAX, and PMCiD1PMAX (if the counter value is larger than these register values, this bit becomes 0 after waiting one to two cycles of the count source).

Conditions to become 1:

The condition to become 1 is dependent on bits TYP1 to TYP0 in the PMCiCON1 register (receive mode select).

- When bits TYP1 to TYP0 are 00b (pulse period measurement) or 01b (high level width measurement):
  rising edge of the PMCi internal input signal
- When bits TYP1 to TYP0 are 10b (pulse width measurement):
  rising edge and falling edge of the PMCi internal input signal

BFULFLG (Receive buffer full flag) (b3)

Conditions to become 0:

- The EN bit in the PMCiCON0 register is 0 (PMCi operation disabled).
- The DRFLG bit in the PMCiSTS register changes from 0 to 1.
- The value of the PMC0RBIT register changes from 48 to 1.

Condition to become 1:

- The value of the PMC0RBIT register changes from 47 to 48.

PTHDFLG (Header pattern match flag) (b4), PTD0FLG (Data 0 pattern match flag) (b5), PTD1FLG (Data 1 pattern match flag) (b6), SDFLG (Special pattern match flag) (b7)

Conditions to become 0:

- The EN in the PMCiCON0 register bit is 0 (PMCi stops).
- The DRFLG bit in the PMCiSTS register changes from 0 to 1.
- See Table 22.7 “Measurements and Flags”.
- The REFLG bit changes from 0 to 1.

Condition to become 1:

- See Table 22.7 “Measurements and Flags”.

Table 22.7 Measurements and Flags

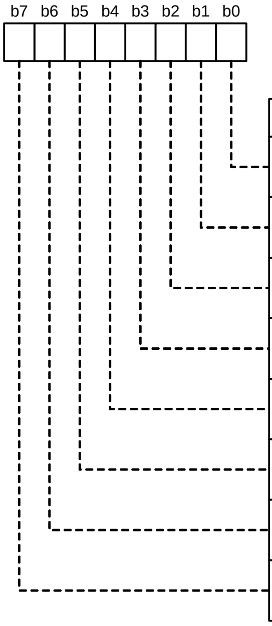
Value (Measurements) of the PMCiTIM Register	Flag			
	PTHDFLG	PTD0FLG	PTD1FLG	SDFLG
Between PMCiHDPMIN and PMCiHDPMAX (header measurement in PMCi)	1	0	0	0
Between PMCiD0PMIN and PMCiD0PMAX	0	1 (1)	0	0
Between PMCiD1PMIN and PMCiD1PMAX	0	0	1 (1)	0
Between PMCiHDPMIN and PMCiHDPMAX (special data measurement in PMCi)	0	0	0	1 (1)
Values not listed above	0	0	0	0

Note:

1. When the HDEN bit in the PMCiCON0 register is 1 (header enabled), PTD0FLG, PTD1FLG, and SDFLG remain unchanged until header is detected.

22.2.6 PMCi Interrupt Source Register (PMCiINT) (i = 0, 1)

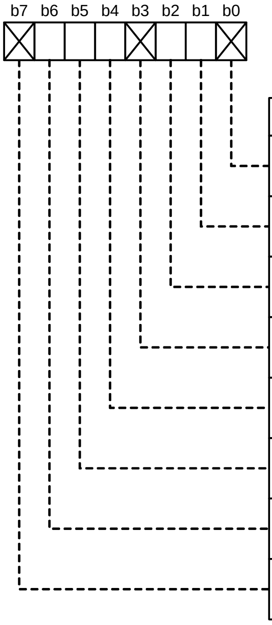
PMC0 Interrupt Source Register



Symbol PMC0INT
Address 01F5h
Reset Value 00h

Bit Symbol	Bit Name	Function	RW
CPINT	Compare match flag interrupt enable bit	0: Disabled 1: Enabled	RW
REINT	Receive error flag interrupt enable bit	0: Disabled 1: Enabled	RW
DRINT	Data reception complete interrupt enable bit	0: Disabled 1: Enabled	RW
BFULINT	Receive buffer full flag interrupt enable bit	0: Disabled 1: Enabled	RW
PTHDINT	Header match flag interrupt enable bit	0: Disabled 1: Enabled	RW
PTDINT	Data 0/1 match flag interrupt enable bit	0: Disabled 1: Enabled	RW
TIMINT	Timer measure interrupt enable bit	0: Disabled 1: Enabled	RW
SDINT	Special data match flag interrupt enable bit	0: Disabled 1: Enabled	RW

PMC1 Interrupt Source Register

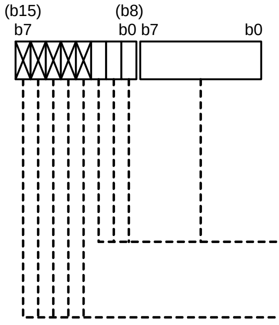


Symbol PMC1INT
Address 01FDh
Reset Value X000 X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. Read as undefined value.		—
REINT	Receive error flag interrupt enable bit	0: Disabled 1: Enabled	RW
DRINT	Data reception complete interrupt enable bit	0: Disabled 1: Enabled	RW
— (b3)	No register bit. If necessary, set to 0. Read as undefined value.		—
PTHDINT	Header match flag interrupt enable bit	0: Disabled 1: Enabled	RW
PTDINT	Data 0/1 match flag interrupt enable bit	0: Disabled 1: Enabled	RW
TIMINT	Timer measure interrupt enable bit	0: Disabled 1: Enabled	RW
— (b7)	No register bit. If necessary, set to 0. Read as undefined value.		—

22.2.7 PMCi Header Pattern Set Register (MIN) (PMCiHDPMIN) (i = 0, 1) PMCi Header Pattern Set Register (MAX) (PMCiHDPMAX) (i = 0, 1)

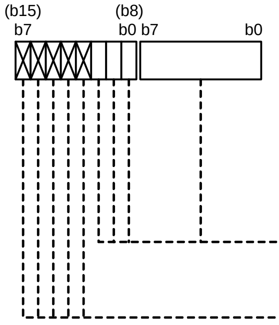
PMCi Header Pattern Set Register (MIN) (i = 0, 1)



Symbol	Address	Reset Value
PMC0HDPMIN	D081h to D080h	XXXX X000 0000 0000b
PMC1HDPMIN	D095h to D094h	XXXX X000 0000 0000b

Function	Setting Range	RW
Set the minimum width of header pattern or special data pattern.	0000h to 07FFh	RW
No register bits. If necessary, set to 0. Read as undefined value.		—

PMCi Header Pattern Set Register (MAX) (i = 0, 1)



Symbol	Address	Reset Value
PMC0HDPMAX	D083h to D082h	XXXX X000 0000 0000b
PMC1HDPMAX	D097h to D096h	XXXX X000 0000 0000b

Function	Setting Range	RW
Set the maximum width of header pattern or special data pattern.	0000h to 07FFh	RW
No register bits. If necessary, set to 0. Read as undefined value.		—

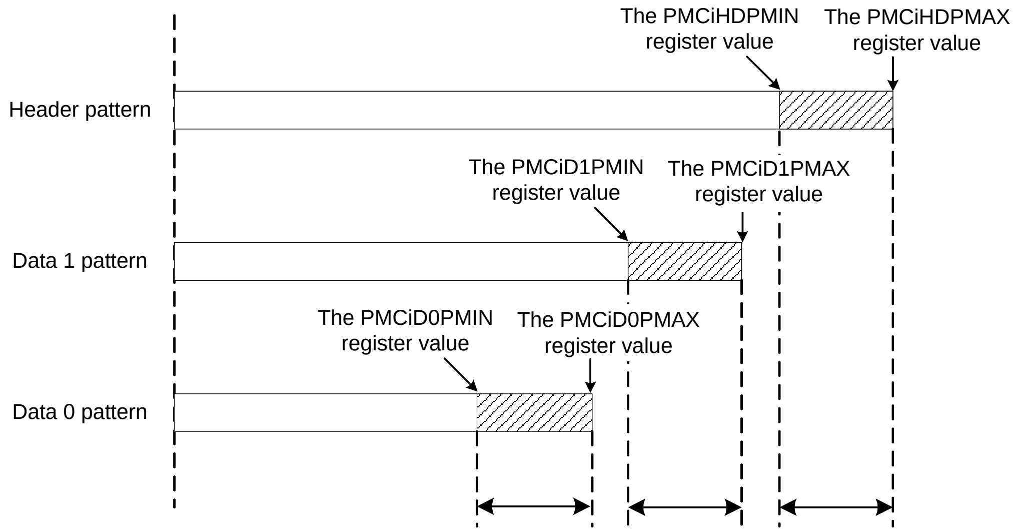
When using a header or special data detection, set the minimum width of header or special data pattern to the PMCiHDPMIN register and the maximum width to the PMCiHDPMAX register.

$$\text{Setting value n} = \frac{\text{Minimum width (maximum width) of header or special data pattern}}{\text{Count source}}$$

Set different values from data 0 or data 1 to these registers.
Each value must meet following:

- PMCiHDPMIN register value < PMCiHDPMAX register value
- The value other than 0000h

See Figure 22.4 “Setting Values of the Header Pattern and Data Patterns”.
When not using a header or special data detection, set registers PMCiHDPMIN and PMCiHDPMAX to 0000h.


The PMCiHDPMIN register value
The PMCiHDPMAX register value
Header pattern
The PMCiD1PMIN register value
The PMCiD1PMAX register value
Data 1 pattern
The PMCiD0PMIN register value
The PMCiD0PMAX register value
Data 0 pattern

The above shows the case for independent operation.

For independent operation, the ranges between minimum and maximum values of header, data 0, and data 1 patterns should not overlap each other.
For combined operation, the ranges between minimum and maximum values of header, data 0, data 1, and special patterns should not overlap each other.

Figure 22.4 Setting Values of the Header Pattern and Data Patterns

22.2.8 PMCi Data 0 Pattern Set Register (MIN) (PMCiD0PMIN) (i = 0, 1)
PMCi Data 0 Pattern Set Register (MAX) (PMCiD0PMAX) (i = 0, 1)
PMCi Data 1 Pattern Set Register (MIN) (PMCiD1PMIN) (i = 0, 1)
PMCi Data 1 Pattern Set Register (MAX) (PMCiD1PMAX) (i = 0, 1)

PMCi Data 0 Pattern Set Register (MIN) (i = 0, 1)

b7 b0

Symbol	Address	Reset Value
PMC0D0PMIN	D084h	00h
PMC1D0PMIN	D098h	00h

Function	Setting Range	RW
Set the minimum width of data 0 pattern.	00h to FFh	RW

PMCi Data 0 Pattern Set Register (MAX) (i = 0, 1)

b7 b0

Symbol	Address	Reset Value
PMC0D0PMAX	D085h	00h
PMC1D0PMAX	D099h	00h

Function	Setting Range	RW
Set the maximum width of data 0 pattern.	00h to FFh	RW

PMCi Data 1 Pattern Set Register (MIN) (i = 0, 1)

b7 b0

Symbol	Address	Reset Value
PMC0D1PMIN	D086h	00h
PMC1D1PMIN	D09Ah	00h

Function	Setting Range	RW
Set the minimum width of data 1 pattern.	00h to FFh	RW

PMCi Data 1 Pattern Set Register (MAX) (i = 0, 1)

b7 b0

Symbol	Address	Reset Value
PMC0D1PMAX	D087h	00h
PMC1D1PMAX	D09Bh	00h

Function	Setting Range	RW
Set the maximum width of data 1 pattern.	00h to FFh	RW

When detecting data 0, set the minimum width of the data 0 pattern to the PMCiD0PMIN register and the maximum width to the PMCiD0PMAX register. Also when detecting data 1, set the minimum width of the data 1 pattern to the PMCiD1PMIN register and the maximum width to the PMCiD1PMAX register.

$$\text{Setting value n} = \frac{\text{minimum width (maximum width) of data 0/1 pattern}}{\text{count source}}$$

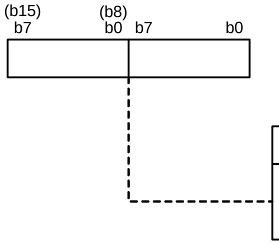
Data 0, data 1, and header or special data pattern must be different values. Also, each value must meet following:

- PMCiD0PMIN register value < PMCiD0PMAX register value
- PMCiD1PMIN register value < PMCiD1PMAX register value
- Value other than 0000h

See Figure 22.4 “Setting Values of the Header Pattern and Data Patterns”.
When not detecting data 0, set registers PMCiD0PMIN and PMCiD0PMAX to 00h. When not detecting data 1, set registers PMCiD1PMIN and PMCiD1PMAX to 00h.
When in combined operation, set registers PMC1D0PMIN, PMC1D0PMAX, PMC1D1PMIN, and PMC1D1PMAX to 00h.

22.2.9 PMCi Measurements Register (PMCiTIM) (i = 0, 1)

PMCi Measurements Register (i = 0, 1)



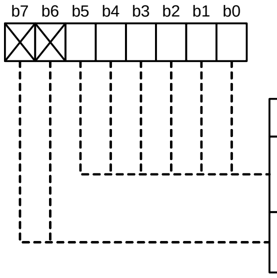
Symbol	Address	Reset Value
PMC0TIM	D089h to D088h	0000h
PMC1TIM	D09Dh to D09Ch	0000h

Function	RW
Measurements of pulse period and pulse width can be read.	RO

When the EN bit in the PMCiCON0 register is 0 (PMCi operation disabled), the PMCiTIM register becomes 0000h.

22.2.10 PMC0 Receive Bit Count Register (PMC0RBIT)

PMC0 Receive Bit Count Register



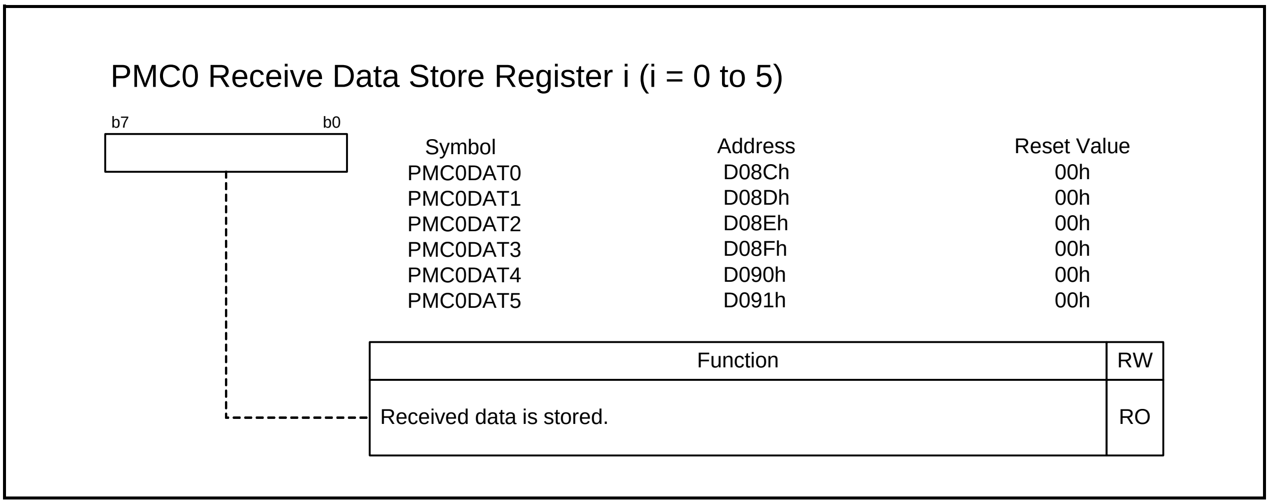
Symbol	Address	Reset Value
PMC0RBIT	D092h	XX00 0000b

Function	RW
Receive bit count can be read.	RO
No register bit. If necessary, set to 0. Read as undefined value.	—

The bit position of the storing buffer is specified by counting detected data 0 or data 1.
When the receive bit count exceeds 48, it returns to 1. The header and special data are not counted.
The PMC0RBIT register becomes 0 when:

- The EN bit in the PMC0CON0 register is 0 (PMCi operation disabled).
- The DRFLG bit in the PMC0STS register changes from 0 to 1.

22.2.11 PMC0 Receive Data Store Register i (PMC0DATi) (i = 0 to 5)



PMC0 Receive Data Store Register i (i = 0 to 5)

Symbol	Address	Reset Value
PMC0DAT0	D08Ch	00h
PMC0DAT1	D08Dh	00h
PMC0DAT2	D08Eh	00h
PMC0DAT3	D08Fh	00h
PMC0DAT4	D090h	00h
PMC0DAT5	D091h	00h

Function	RW
Received data is stored.	RO

When detecting data 0 or data 1, the result is stored bit by bit according to the PMC0RBIT register setting. The data is stored to the PMC0DATi register starting from bit 0 in the PMC0DAT0 register. Table 22.8 lists Order of Storing Data.

When the data exceeds 48 bits, the PMC0DATi register is sequentially overwritten from the first bit in the PMC0DAT0 register. Also, after the DRFLG bit in the PMCiSTS register changes from 0 to 1 (next frame reception starts), the PMC0DATi register is sequentially overwritten from the first bit in the PMC0DAT0 register.

The header and special data are not stored.

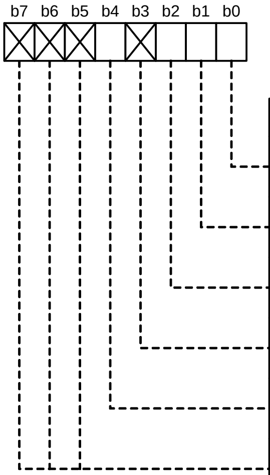
When the EN bit in the PMCiCON0 register is 0 (PMCi operation disabled), the PMC0DATi register becomes 00h.

Table 22.8 Order of Storing Data

Register	b7	b6	b5	b4	b3	b2	b1	b0
PMC0DAT0	8	7	6	5	4	3	2	1
PMC0DAT1	16	15	14	13	12	11	10	9
PMC0DAT2	24	23	22	21	20	19	18	17
PMC0DAT3	32	31	30	29	28	27	26	25
PMC0DAT4	40	39	38	37	36	35	34	33
PMC0DAT5	48	47	46	45	44	43	42	41

22.2.12 PMC0 Compare Control Register (PMC0CPC)

PMC0 Compare Control Register



Symbol	Address	Reset Value
PMC0CPC	01F6h	XXX0 X000b

Bit Symbol	Bit Name	Function	RW
CPN0	Compare bit specify bit	When the setting value is n, bits n to 0 are compared.	RW
CPN1			RW
CPN2			RW
— (b3)	No register bit. If necessary, set to 0. Read as undefined value.		—
CPEN	Compare enable bit	0: Compare disabled 1: Compare enabled	RW
— (b7-b5)	No register bits. If necessary, set to 0. Read as undefined value.		—

CPN2-CPN0 (Compare bit specify bit) (b2-b0)

These bits are enabled when the CPEN bit is 1 (compare enabled).

When the setting value of bits CPN2 to CPN0 is n, bits n to 0 are compared.

e.g.1 Setting value = 0

Bit 0 in the PMC0CPD register and bit 0 in the PMC0DAT0 register are compared.

e.g.2 Setting value = 7

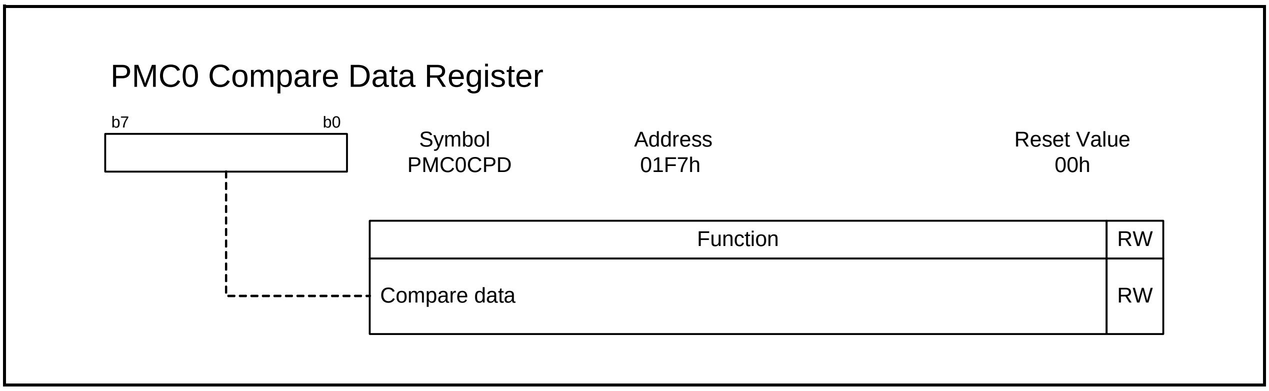
Bits 7 to 0 in the PMC0CPD register and bits 7 to 0 in the PMC0DAT0 register are compared.

CPEN (Compare enable bit) (b4)

When the CPEN bit is 1 (compare enabled), values from registers PMC0CPD and PMC0DAT0 are compared.

When storing received data, if the compared results match, the CPFLG bit in the PMC0STS register becomes 1 (compare match).

22.2.13 PMC0 Compare Data Register (PMC0CPD)



PMC0 Compare Data Register

Symbol	Address	Reset Value
PMC0CPD	01F7h	00h

Function	RW
Compare data	RW

This register is enabled when the CPEN bit in the PMC0CPC register is 1 (compare enabled). Bits to be compared are selected by bits CPN2 to CPN0 in the PMC0CPC register.

22.3 Operations

22.3.1 Common Operations in Multiple Modes

22.3.1.1 Count Source

The clock source and divisor of the count source can be selected by bits CSRC1 to CSRC0 and bits CDIV1 to CDIV0 in the PMCiCON3 register (see Figure 22.3 “Remote Control Signal Receiver Block Diagram (3/3) (PMCi Count Source)”).
When using fC, set the PM25 bit in the PM2 register to 1 (peripheral clock fC provided). Refer to 8. “Clock Generator” for details of fC.
When using timer B1 or B2 underflow, one cycle of the count source consists of one timer B1 or B2 underflow cycle. Use timer B1 or B2 in timer mode. Refer to 18. “Timer B” for details.

To use the same count source in PMC0 and PMC1, set bits CSRC1 to CSRC0 in the PMC0CON3 register to 00b (same count source as PMC1), and bits CDIV1 to CDIV0 in the PMC0CON3 register to 00b (no division).

22.3.1.2 PMCi Input

The options below can be selected in PMCi input (see Figure 22.2 “Remote Control Signal Receiver Block Diagram (2/3) (PMCi Input)”).

- Input pin
- Input polarity
- Digital filter

A pin to which the PMCi signal is input is selected by setting bits PSEL1 to PSEL0 in the PMCiCON2 register.

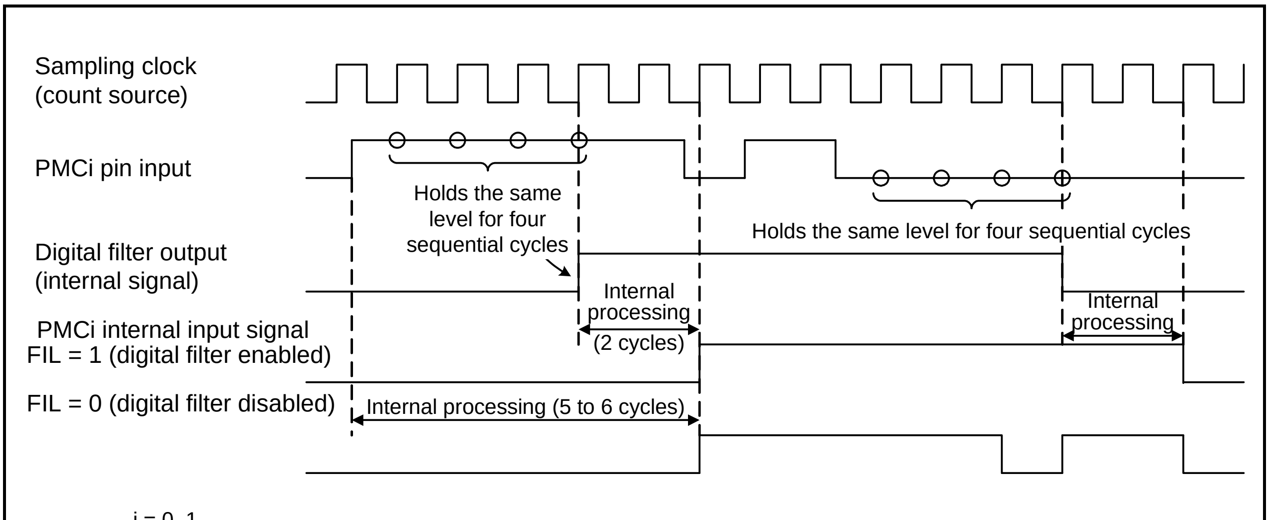
To process the signal input to the PMC0 pin in the PMC1 circuit, or to process the signal input to the PMC1 pin in the PMC0 circuit, use the same count source in PMC0 and PMC1.

(refer to 22.3.1.1 “Count Source”).

Input polarity of the PMCi pin can be inverted. Whether to invert or not can be selected by setting the SINV bit in the PMCiCON0 register.

If the signal input to the PMCi pin holds the same level for four sequential cycles when the FIL bit in the PMCiCON0 register is 1 (digital filter enabled), that level is transferred to the internal circuit. The sampling clock of the digital filter is the count source.

Select bits CSRC1 to CSRC0 (count source) in the PMC0CON3 register and bits CDIV1 to CDIV0 (count source divisor) before selecting bits PSEL1 to PSEL0 (input pin), the FIL bit (digital filter), and the SINV bit (input signal polarity invert). Input to the PMCi pin is transferred to the internal circuit in synchronization with the count source. Internal processing causes a delay. Figure 22.5 shows PMCi Input Delay.


Sampling clock
(count source)
PMCi pin input
Holds the same
level for four
sequential cycles
Holds the same level for four sequential cycles
Digital filter output
(internal signal)
Internal
processing
(2 cycles)
Internal
processing
PMCi internal input signal
FIL = 1 (digital filter enabled)
FIL = 0 (digital filter disabled)
Internal processing (5 to 6 cycles)

i = 0, 1
FIL: Bit in the PMCiCON0 register

Figure 22.5 PMCi Input Delay

22.3.2 Pattern Match Mode (PMC0 and PMC1 Operate Independently)

Pattern match mode determines whether an external pulse matches a specified pattern. The header, data 0, and data 1 patterns can be measured in PMC0 and PMC1 separately.

Table 22.9 Pattern Match Mode Specifications (Independent Operation)

Item		Contents	
		PMC0 Circuit	PMC1 Circuit
Count sources	Clock sources	One of the following: • fC • f1 • Timer B2 underflow • Count source of PMC1	One of the following: • fC • f1 • Timer B1 underflow • Timer B2 underflow
	Division	No division, divided-by-8, divided-by-32, or divided-by-64	
Count operation		Increment	
Detect patterns		• Header or special data • Data 0 • Data 1	• Header • Data 0 • Data 1
Receive buffer		6 bytes (48 bits)	None
Interrupt request generation timing		• Receive error • Completion of data reception • Header match • Data 0/1 match • Special data match • Receive buffer full • Compare match	• Receive error • Completion of data reception • Header match • Data 0/1 match
Selectable functions		• Input signal inversion • Digital filter	

Table 22.10 Registers and Setting Values in Pattern Match Mode (Independent Operation) (1/2) (1)

Register	Bit	Function	
		PMC0	PMC1
PMCiCON0	EN	Set to 1.	Set to 1.
	SINV	Select input signal polarity.	Select input signal polarity.
	FIL	Select filter enabled or disabled.	Select filter enabled or disabled.
	EHOLD	Select receive error holding period.	-
	HDEN	Select header enabled or disabled.	Select header enabled or disabled.
	SDEN	Select special data enabled or disabled.	-
	DRINT0	Select receive interrupt generating condition.	-
	DRINT1		
PMCiCON1	TYP0	Select measuring object.	Select measuring object.
	TYP1		
	CSS	Set to 0.	-
	EXSDEN	Set to 0.	-
	EXHDEN	Set to 0.	-
PMCiCON2	ENFLG	Flag indicating PMC0 operated/stopped.	Flag indicating PMC1 operated/stopped.
	INFLG	Input signal flag	Input signal flag
	CEFLG	Not used.	Not used.
	CEINT	Set to 0.	Set to 0.
	PSEL0	Set to 01b.	Select input pin.
	PSEL1		
PMCiCON3	CRE	Set to 0.	Set to 0.
	CFR	Set to 0.	Set to 0.
	CST	Set to 0.	Set to 0.
	PD	Set to 0.	Set to 0.
	CSRC0	Select clock source	Select clock source
	CSRC1		
	CDIV0	Select count source divisor.	Select count source divisor.
	CDIV1		
PMCiSTS	CPFLG	Compare match flag	-
	REFLG	Receive error flag	Receive error flag
	DRFLG	Data receiving flag	Data receiving flag
	BFULFLG	Receive buffer full flag	-
	PTHDFLG	Header pattern match flag	Header pattern match flag
	PTD0FLG	Data 0 pattern match flag	Data 0 pattern match flag
	PTD1FLG	Data 1 pattern match flag	Data 1 pattern match flag
	SDFLG	Special pattern match flag	-

i = 0, 1

-: Unimplemented bits in PMC1

Note:

1. This table does not describe a procedure.

Table 22.11 Registers and Setting Values in Pattern Match Mode (Independent Operation) (2/2) (1)

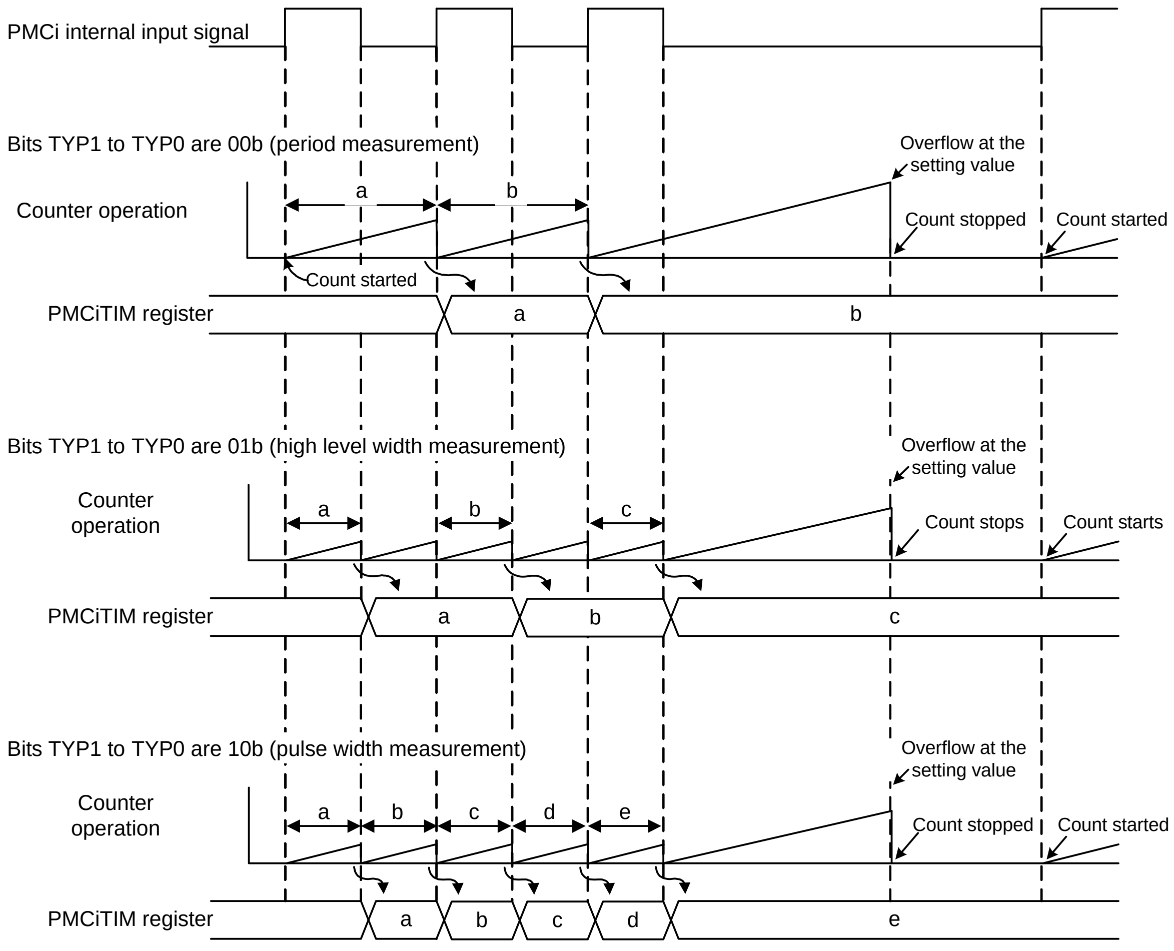
Register	Bit	Function	
		PMC0	PMC1
PMCiINT	CPINT	Set to 1 when using compare match flag interrupt.	-
	REINT	Set to 1 when using receive error flag interrupt.	Set to 1 when using receive error flag interrupt.
	DRINT	Set to 1 when using data reception complete interrupt.	Set to 1 when using data reception complete interrupt.
	BFULINT	Set to 1 when using receive buffer full flag interrupt.	-
	PTHDINT	Set to 1 when using header match flag interrupt.	Set to 1 when using header match flag interrupt.
	PTDINT	Set to 1 when using data 0/1 match flag interrupt.	Set to 1 when using data 0/1 match flag interrupt.
	TIMINT	Set to 0.	Set to 0.
	SDINT	Set to 1 when using special data match flag interrupt.	-
PMC0CPC	CPN0	Select bits to be compared when using compare function.	-
	CPN1		
	CPN2		
	CPEN	Set to 1 when using compare function.	-
PMC0CPD	0 to 7	Set compare value when using compare function.	-
PMCiHDPMIN	0 to 10	Set minimum value of header pattern.	Set minimum value of header pattern.
PMCiHDPMAX	0 to 10	Set maximum value of header pattern.	Set maximum value of header pattern.
PMCiD0PMIN	0 to 7	Set minimum value of data 0 pattern.	Set minimum value of data 0 pattern.
PMCiD0PMAX	0 to 7	Set maximum value of data 0 pattern.	Set maximum value of data 0 pattern.
PMCiD1PMIN	0 to 7	Set minimum value of data 1 pattern.	Set minimum value of data 1 pattern.
PMCiD1PMAX	0 to 7	Set maximum value of data 1 pattern.	Set maximum value of data 1 pattern.
PMCiTIM	0 to 15	Measured value of pulse period or width can be read.	Measured value of pulse period or width can be read.
PMC0DAT0 to PMC0DAT5	0 to 7	Received data can be read.	-
PMC0RBIT	0 to 5	Received bit count can be read.	-

i = 0, 1

-: Unimplemented bits in PMC1

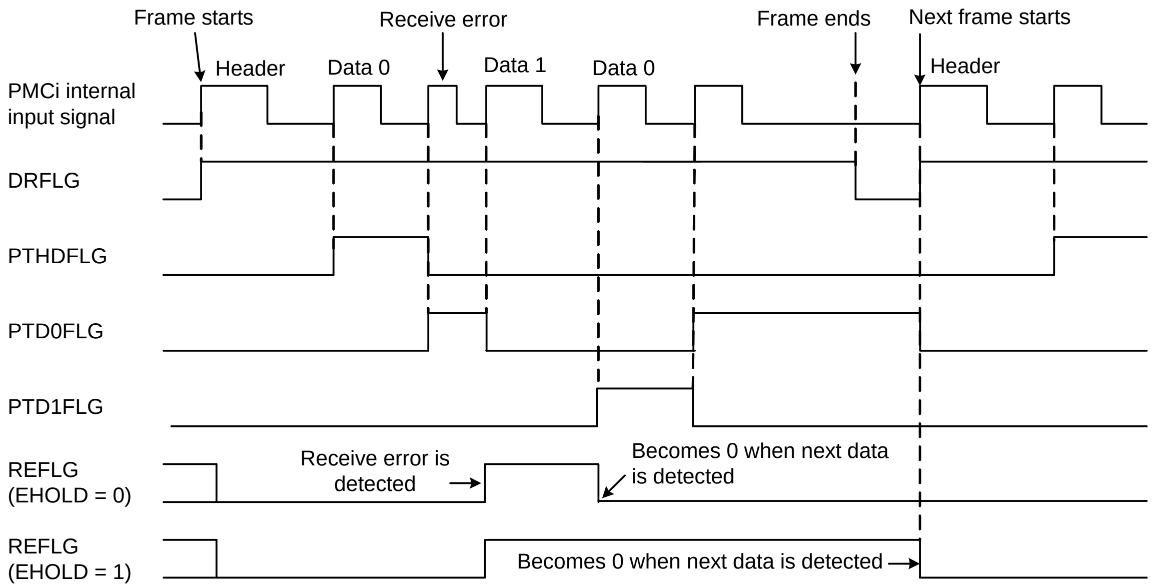
Note:

1. This table does not describe a procedure.


PMCi internal input signal
Bits TYP1 to TYP0 are 00b (period measurement)
Overflow at the setting value
Counter operation
a
b
Count stopped
Count started
Count started
PMCiTIM register
a
b
Bits TYP1 to TYP0 are 01b (high level width measurement)
Overflow at the setting value
Counter operation
a
b
c
Count stops
Count starts
PMCiTIM register
a
b
c
Bits TYP1 to TYP0 are 10b (pulse width measurement)
Overflow at the setting value
Counter operation
a
b
c
d
e
Count stopped
Count started
PMCiTIM register
a
b
c
d
e

i = 0, 1
TYP1 to TYP0: Bits in the PMCiCON1 register
Overflow at the setting value: Counter value is larger than values of registers PMCiHDPMAX, PMCiD0PMAX, and PMCiD1MAX.

Figure 22.6 Operations in Pattern Match Mode



The above assumes the following:

- The HDEN bit in the PMCiCON0 register is 1 (header enabled)

i = 0, 1
REFLG, DRFLG, PTHDFLG, PTD0FLG, PTD1FLG: Bits in the PMCiSTS register
EHOLD: Bit in the PMC0CON0 register
Refer to EHOLD = 0 for PMC1.

Figure 22.7 Flag Operation Example

22.3.2.1 Header Detection (PMC0, PMC1)

While the HDEN bit in the PMCiCON0 register is 1 (header enabled), after data reception starts (DRFLG flag is 1), when signal other than the header pattern is detected before the header is detected, the following occur:

- The REFLG bit in the PMCiSTS register becomes 1 (error occurs).
- Bits PTD0FLG, PTD1FLG, and SDFLG in the PMCiSTS register remain unchanged even if the detected signal is data 0, data 1, or special data.
- Registers PMC0DAT0 to PMC0DAT5 remain unchanged.

When detecting the header in PMC0, set the SDEN bit in the PMC0CON0 register to 0 (special data disabled).

22.3.2.2 Special Data Detection (PMC0)

When the SDEN bit in the PMC0CON0 register is 1 (special data enabled), special data can be detected. When detecting special data, set the HDEN bit in the PMC0CON0 register to 0 (header disabled).

22.3.2.3 Receive Data Buffer (PMC0)

There is a 6-byte (48-bit) buffer for storing received data. When the data exceeds 48 bits, the buffer is sequentially overwritten from the first bit. Refer to 22.2.11 “PMC0 Receive Data Store Register i (PMC0DATi) (i = 0 to 5)” and 22.2.10 “PMC0 Receive Bit Count Register (PMC0RBIT)”.

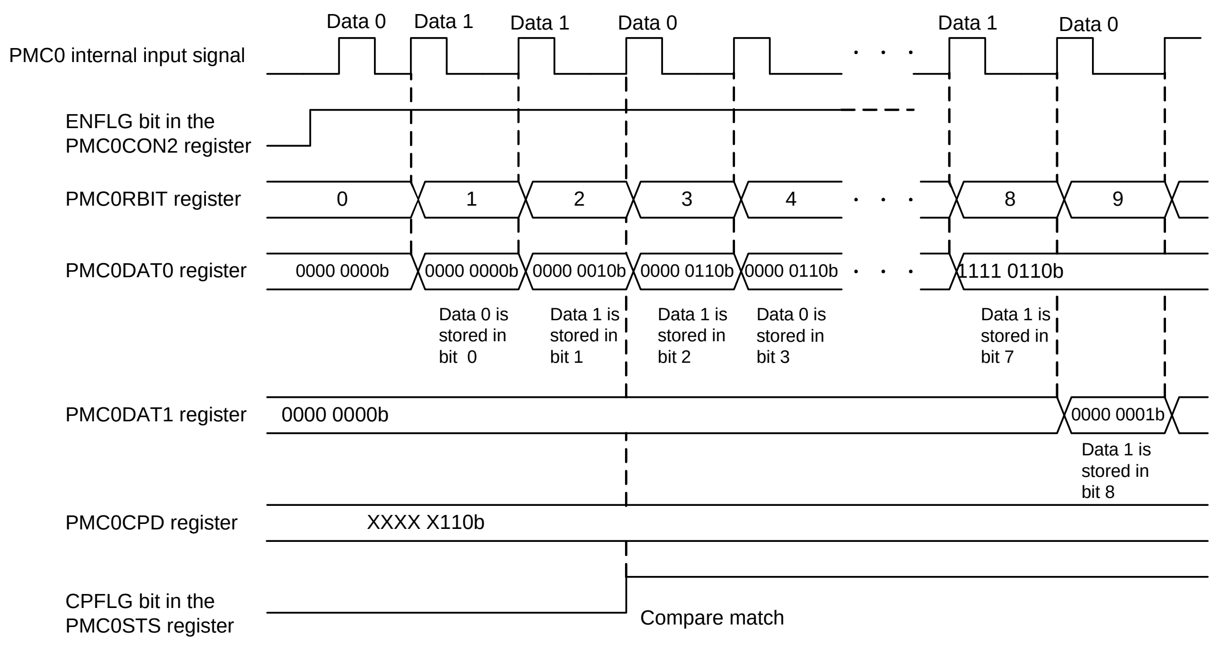
22.3.2.4 Compare Function (PMC0)

Values for registers PMC0CPD and PMC0DAT0 are compared. As a result, it can be detected that the first 1 to 8 bits of the remote control signal are the specific values.

When using the compare function, set the following:

- Set the CPEN bit in the PMC0CPC register to 1 (compare enabled).
- Select bits to be compared by setting bits CPN2 to CPN0 in the PMC0CPC register (when the setting value is n, bits n to 0 are compared. n: 0 to 7).
- Set the compare data in the PMC0CPD register.

When storing received data, if the compared results match, the CPFLG bit in the PMC0STS register becomes 1 (compare match).


PMC0 internal input signal
Data 0
Data 1
Data 1
Data 0
Data 1
Data 0
ENFLG bit in the PMC0CON2 register
PMC0RBIT register
0
1
2
3
4
8
9
PMC0DAT0 register
0000 0000b
0000 0000b
0000 0010b
0000 0110b
0000 0110b
1111 0110b
Data 0 is stored in bit 0
Data 1 is stored in bit 1
Data 1 is stored in bit 2
Data 0 is stored in bit 3
Data 1 is stored in bit 7
PMC0DAT1 register
0000 0000b
0000 0001b
Data 1 is stored in bit 8
PMC0CPD register
XXXX X110b
CPFLG bit in the PMC0STS register
Compare match

The above diagram shows an instance in which the following conditions are met:

- The CPEN bit in the PMC0CPC register is 1 (compare enabled)
- Bits CPN2 to CPN0 in the PMC0CPC register equal 2 (bits 2 to 0 are compared)

Figure 22.8 Receive Buffer and Compare Function

22.3.3 Pattern Match Mode (Combined Operation of PMC0 and PMC1)

PMC0 and PMC1 are combined and one remote control signal can be received. In a combined operation, data 0 and data 1 are detected in PMC0. Whether to detect the header and special data in PMC0 or PMC1 can be selected. Select count source and remote control signal input pins in PMC1.

Table 22.12 Pattern Match Mode Specifications (Combined Operation)

Item		Content	
		PMC0 Circuit	PMC1 Circuit
Count sources	Clock sources	Count source of PMC1	One of the following: • fC • f1 • Timer B1 underflow • Timer B2 underflow
	Division	No division	No division, divided-by-8, divided-by-32, or divided-by-64
Count operation		Increment	
Detect patterns		• Header • Data 0 • Data 1 • Special data	• Header • Special data
Receive buffer		6 bytes (48 bits)	None
Interrupt request generation timing		• Receive error • Completion of data reception • Header match • Data 0/1 match • Special data match • Receive buffer full • Compare match	Not used
Selectable functions		• Input signal inversion • Digital filter	

Table 22.13 Registers and Setting Values in Pattern Match Mode (Combined Operation) (1/2) (1)

Register	Bit	Function	
		PMC0	PMC1
PMCiCON0	EN	Set to 1. Refer to 22.3.3.1 “Setting Procedure”.	Set to 1. Refer to 22.3.3.1 “Setting Procedure”.
	SINV	Set to 0.	Select input signal polarity.
	FIL	Set to 0.	Select filter enabled/disabled.
	EHOLD	Select receive error holding period.	-
	HDEN	Select header enabled/disabled.	Set to 1.
	SDEN	Select special data enabled/disabled.	-
	DRINT0	Select receive interrupt generating condition.	-
	DRINT1		
PMCiCON1	TYP0	Select measuring object.	Select measuring object. Set the same value as PMC0.
	TYP1		
	CSS	Set to 0.	-
	EXSDEN	Select block in which header and special pattern is detected.	-
	EXHDEN		
PMCiCON2	ENFLG	Flag indicating PMCi operated/stopped.	Not used.
	INFLG	Input signal flag	Not used.
	CEFLG	Not used.	Not used.
	CEINT	Set to 0.	Set to 0.
	PSEL0	Set to 00b.	Select input pin.
	PSEL1		
PMCiCON3	CRE	Set to 0.	Set to 0.
	CFR	Set to 0.	Set to 0.
	CST	Set to 0.	Set to 0.
	PD	Set to 0.	Set to 0.
	CSRC0	Set to 00b.	Select clock source.
	CSRC1		
	CDIV0	Set to 00b.	Select count source divisor.
	CDIV1		
PMCiSTS	CPFLG	Compare match flag	-
	REFLG	Receive error flag	Not used
	DRFLG	Data receiving flag	Not used
	BFULFLG	Receive buffer full flag	-
	PTHDFLG	Header pattern match flag	Not used
	PTD0FLG	Data 0 pattern match flag	Not used
	PTD1FLG	Data 1 pattern match flag	Not used
	SDFLG	Special pattern match flag	-

i = 0, 1

-: Unimplemented bit in PMC1

Note:

1. This table does not describe a procedure.

Table 22.14 Registers and Setting Values in Pattern Match Mode (Combined Operation) (2/2) (1)

Register	Bit	Function	
		PMC0	PMC1
PMCiINT	CPINT	Set to 1 when using compare match flag interrupt.	-
	REINT	Set to 1 when using receive error flag interrupt.	Set to 0.
	DRINT	Set to 1 when using data reception complete interrupt.	Set to 0.
	BFULINT	Set to 1 when using receive buffer full flag interrupt.	-
	PTHDINT	Set to 1 when using header match flag interrupt.	Set to 0.
	PTDINT	Set to 1 when using data 0/1 match flag interrupt.	Set to 0.
	TIMINT	Set to 0.	Set to 0.
	SDINT	Set to 1 when using special data match flag interrupt.	-
PMC0CPC	CPN0	Select bits to be compared when using compare function.	-
	CPN1		
	CPN2		
	CPEN	Set to 1 when using compare function.	-
PMC0CPD	0 to 7	Set compare value when using compare function.	-
PMCiHDPMIN	0 to 10	Set minimum value of header pattern or special data pattern.	Set minimum value of header pattern or special data pattern.
PMCiHDPMAX	0 to 10	Set maximum value of header pattern or special data pattern.	Set maximum value of header pattern or special data pattern.
PMCiD0PMIN	0 to 7	Set minimum value of data 0 pattern.	Set to 00h.
PMCiD0PMAX	0 to 7	Set maximum value of data 0 pattern.	Set to 00h.
PMCiD1PMIN	0 to 7	Set minimum value of data 1 pattern.	Set to 00h.
PMCiD1PMAX	0 to 7	Set maximum value of data 1 pattern.	Set to 00h.
PMCiTIM	0 to 15	Measured value of pulse period or width can be read.	Not used.
PMC0DAT0 to PMC0DAT5	0 to 7	Received data can be read.	-
PMC0RBIT	0 to 5	Received bit count can be read.	-

i = 0, 1

-: Unimplemented bit in PMC1

Note:

1. This table does not describe a procedure.

22.3.3.1 Setting Procedure

To start or stop counting, follow these steps:

(1) Set bits CSRC1 to CSRC0 and bits CDIV1 to CDIV0 in the PMCiCON3 register.
(2) Set bits PSEL1 to PSEL0 in the PMCiCON2 register and bits FIL and SINV in the PMCiCON0 register.
(3) Wait for four cycles of count source.
(4) Set the EN bit in the PMC1CON0 register to 1 (0 to stop).
(5) Set the EN bit in the PMC0CON0 register to 1 (0 to stop).
(6) Wait for two cycles of count source.
(7) Confirm that the ENFLG bit in the PMC0CON2 register is 1 (0 to stop). (The ENFLG bit in the PMC1CON2 register is disabled)

22.3.3.2 Header and Special Data Detection

The header and special data can be detected. Table 22.15 lists Selection of Header and Special Data Detecting Block.

Table 22.15 Selection of Header and Special Data Detecting Block

Detected Item		Bit Setting (1)			
PMC0	PMC1	PMC0CON0 register		PMC0CON1 register	
		HDEN bit	SDEN bit	EXHDEN bit	EXSDEN bit
-	Header	1	0	1	0
-	Special data	0	1	0	1
Header	Special data	1	1	0	1
Special data	Header	1	1	1	0

-: Neither header nor special data is detected

Note:

1. Only set the values listed in this table.

When the header is enabled, after data reception starts (DRFLG flag is 1), if data 0, data 1, or special data is detected before the header is detected, the following occur:

- The REFLG bit in the PMC0STS register becomes 1 (error occurs).
- Bits PTD0FLG, PTD1FLG, and SDFLG in the PMC0STS register remain unchanged.
- Registers PMC0DAT0 to PMC0DAT5 remain unchanged.

22.3.3.3 Status Flag and Interrupt

When connecting PMC0 and PMC1, use flags and the interrupt control in PMC0. The corresponding bits are as follows:

Each bit in the PMC0STS register
Each bit in the PMC0INT register
The INFLG bit in the PMC0CON2 register
Even when detecting the header or special data in PMC1, the result including that data can be detected in the above registers.

22.3.3.4 Receive Data Buffer (PMC0)

There is a 6-byte (48-bit) buffer for storing received data. When the data exceeds 48 bits, the buffer is sequentially overwritten from the first bit. Refer to 22.2.11 “PMC0 Receive Data Store Register i (PMC0DATi) (i = 0 to 5)” and 22.2.10 “PMC0 Receive Bit Count Register (PMC0RBIT)”.

22.3.3.5 Compare Function (PMC0)

Values from registers PMC0CPD and PMC0DAT0 are compared. From the result, reception of the specified value which is selected from the first 1 to 8 bits of the remote control signal can be detected.

When using the compare function, set the following:

- Set the CPEN bit in the PMC0CPC register to 1 (compare enabled).
- Select bits to be compared by setting bits CPN2 to CPN0 in the PMC0CPC register (when setting value is n, bits n to 0 are compared; n: 0 to 7).
- Set the compare data in the PMC0CPD register.

When storing received data, if the compared results match, the CPFLG bit in the PMC0STS register becomes 1 (compare match).

22.3.4 Input Capture Mode (Operating PMC0 and PMC1 Independently)

The input capture mode measures width or period of external pulse. PMC0 and PMC1 can be measured independently.

Table 22.16 Input Capture Mode Specifications (Independent Operation)

Item		Content	
		PMC0 Circuit	PMC1 Circuit
Count sources	Clock sources	One of the following: • fC • f1 • Timer B2 underflow • Count source of PMC1	One of the following: • fC • f1 • Timer B1 underflow • Timer B2 underflow
	Division	No division, divided-by-8, divided-by-32, or divided-by-64	
Count operation		Increment	
Measured items		One of the following: Pulse period (between rising edge and rising edge) Pulse period (between falling edge and falling edge) Pulse width (both high level and low level)	
Interrupt request generation timing		• Timer measurement • Counter overflow	
Selectable functions		• Input signal inversion • Digital filter	

Table 22.17 Registers and Setting Values in Input Capture Mode (Independent Operation) (1/2) (1)

Register	Bit	Function	
		PMC0	PMC1
PMCiCON0	EN	Set to 1.	Set to 1.
	SINV	Select input signal polarity.	Select input signal polarity.
	FIL	Select filter enabled or disabled.	Select filter enabled or disabled.
	EHOLD	Set to 0.	-
	HDEN	Set to 0.	Set to 0.
	SDEN	Set to 0.	-
	DRINT0	Set to 00b.	-
	DRINT1		
PMCiCON1	TYP0	Select measuring object.	Select measuring object.
	TYP1		
	CSS	Set to 0.	-
	EXSDEN	Set to 0.	-
	EXHDEN	Set to 0.	-
PMCiCON2	ENFLG	Flag indicating PMC0 operated/stopped.	Flag indicating PMC1 operated/stopped.
	INFLG	Input signal flag.	Input signal flag.
	CEFLG	Counter overflow flag.	Counter overflow flag.
	CEINT	Set to 1 when using counter overflow interrupt.	Set to 1 when using counter overflow interrupt.
	PSEL0	Set to 01b.	Set to 10b.
	PSEL1		
PMCiCON3	CRE	Set to 1.	Set to 1.
	CFR	Set to 1.	Set to 1.
	CST	Set to 1.	Set to 1.
	PD	Set to 1.	Set to 1.
	CSRC0	Select clock source.	Select clock source.
	CSRC1		
	CDIV0	Select count source divisor.	Select count source divisor.
	CDIV1		
PMCiSTS	CPFLG	Not used (read as undefined value)	-
	REFLG	Not used (read as undefined value)	Not used (read as undefined value)
	DRFLG	Not used (read as undefined value)	Not used (read as undefined value)
	BFULFLG	Not used (read as undefined value)	-
	PTHDFLG	Not used (read as undefined value)	Not used (read as undefined value)
	PTD0FLG	Not used (read as undefined value)	Not used (read as undefined value)
	PTD1FLG	Not used (read as undefined value)	Not used (read as undefined value)
	SDFLG	Not used (read as undefined value)	-

i = 0, 1

-: Unimplemented bits in PMC1

Note:

1. This table does not describe a procedure.

Table 22.18 Registers and Setting Values in Input Capture Mode (Independent Operation) (2/2) [1]

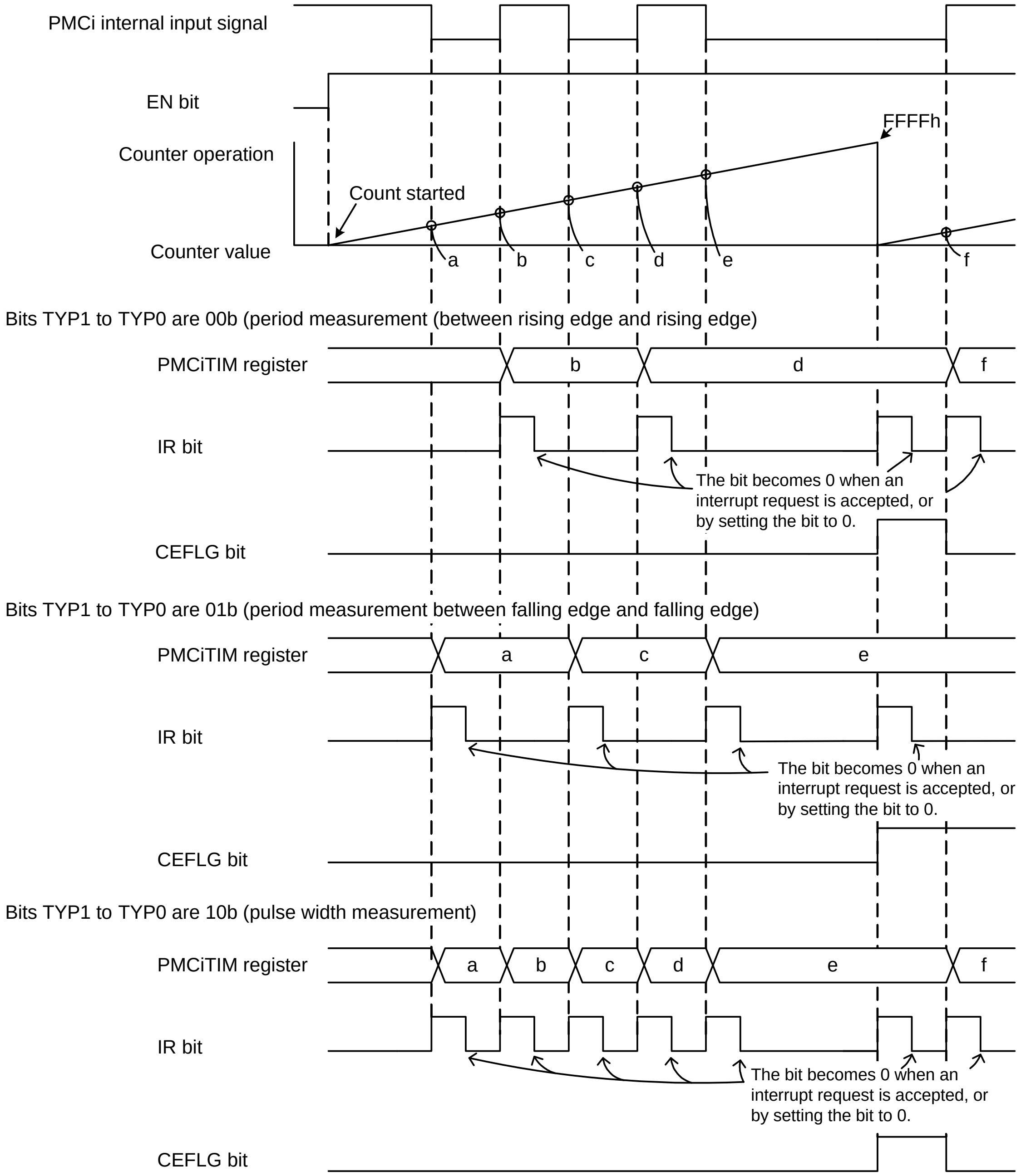
Register	Bit	Function	
		PMC0	PMC1
PMCiINT	CPINT	Set to 0.	-
	REINT	Set to 0.	Set to 0.
	DRINT	Set to 0.	Set to 0.
	BFULINT	Set to 0.	-
	PTHDINT	Set to 0.	Set to 0.
	PTDINT	Set to 0.	Set to 0.
	TIMINT	Set to 1 when using timer measure interrupt.	Set to 1 when using timer measure interrupt.
	SDINT	Set to 0.	-
PMC0CPC	CPN0	Set to 000b.	-
	CPN1		
	CPN2		
	CPEN	Set to 0.	-
PMC0CPD	0 to 7	Set to 00h.	-
PMCiHDPMIN	0 to 10	Set to 0000h.	Set to 0000h.
PMCiHDPMAX	0 to 10	Set to 0000h.	Set to 0000h.
PMCiD0PMIN	0 to 7	Set to 00h.	Set to 00h.
PMCiD0PMAX	0 to 7	Set to 00h.	Set to 00h.
PMCiD1PMIN	0 to 7	Set to 00h.	Set to 00h.
PMCiD1PMAX	0 to 7	Set to 00h.	Set to 00h.
PMCiTIM	0 to 15	Measured value of pulse period or width can be read.	Measured value of pulse period or width can be read.
PMC0DAT0 to PMC0DAT5	0 to 7	Not used.	Not used.
PMC0RBIT	0 to 5	Not used.	Not used.

i = 0, 1

-: Unimplemented bits in PMC1

Note:

1. This table does not describe a procedure.


PMCi internal input signal
EN bit
Counter operation
FFFFh
Count started
Counter value
a
b
c
d
e
f
Bits TYP1 to TYP0 are 00b (period measurement (between rising edge and rising edge)
PMCiTIM register
b
d
f
IR bit
The bit becomes 0 when an interrupt request is accepted, or by setting the bit to 0.
CEFLG bit
Bits TYP1 to TYP0 are 01b (period measurement between falling edge and falling edge)
PMCiTIM register
a
c
e
IR bit
The bit becomes 0 when an interrupt request is accepted, or by setting the bit to 0.
CEFLG bit
Bits TYP1 to TYP0 are 10b (pulse width measurement)
PMCiTIM register
a
b
c
d
e
f
IR bit
The bit becomes 0 when an interrupt request is accepted, or by setting the bit to 0.
CEFLG bit

i = 0, 1
EN: Bit in the PMCiCON0 register
TYP1 to TYP0: Bits in the PMCiCON1 register
CEFLG: Bit in the PMCiCON2 register
IR: Bit in the PMCiIC register

The above diagram shows an instance in which the following condition is met:

- The TIMINT bit in the PMCiINT register is 1 (timer measure interrupt enabled)
- The CEINT bit in the PMCiCON2 register is 0 (counter overflow interrupt enabled)

Figure 22.9 Operations in Input Capture Mode

22.3.4.1 Count Operation

In input capture mode, the counter counts from 0000h to FFFFh, and then returns to 0000h to continue counting.

When the counter becomes 0000h after FFFFh, the CEFLG bit in the PMCiCON2 register becomes 1 (counter overflow) and stays 1 until the next measurement timing.

22.3.5 Input Capture Mode (Simultaneous Count Operation of PMC0 and PMC1)

PMC0 and PMC1 inputs can be measured simultaneously in input capture mode.

Table 22.19 Input Capture Mode Specifications (Simultaneous Count Operation)

Item		Content	
		PMC0 Circuit	PMC1 Circuit
Count sources	Clock sources	Count source of PMC1	One of the following: • fC • f1 • Timer B1 underflow • Timer B2 underflow
	Division	No division	No division, divided-by-8, divided-by-32, or divided-by-64
Count operation		Increment	
Measured items		One of the following: Pulse period (between rising edge and rising edge) Pulse period (between falling edge and falling edge) Pulse width (both high level and low level)	
Interrupt request generation timing		• Timer measurement • Counter overflow	
Selectable functions		• Input signal inversion • Digital filter	

Table 22.20 Registers and Setting Values in Input Capture Mode (Simultaneous Count Operation) (1/2) (1)

Register	Bit	Function	
		PMC0	PMC1
PMCiCON0	EN	Set to 1. (Refer to 22.3.5.1 “Setting Procedure”).	Set to 1. (Refer to 22.3.5.1 “Setting Procedure”).
	SINV	Select input signal polarity.	Select input signal polarity.
	FIL	Select filter enabled/disabled.	Select filter enabled/disabled.
	EHOLD	Set to 0.	-
	HDEN	Set to 0.	Set to 0.
	SDEN	Set to 0.	-
	DRINT0	Set to 00b.	-
	DRINT1		
PMCiCON1	TYP0	Select measuring object.	Select measuring object.
	TYP1		
	CSS	Set to 1.	-
	EXSDEN	Set to 0.	-
	EXHDEN	Set to 0.	-
PMCiCON2	ENFLG	Flag indicating PMCi operated/stopped.	Not used.
	INFLG	Input signal flag	Input signal flag
	CEFLG	Counter overflow flag	Counter overflow flag
	CEINT	Set to 1 when using counter overflow interrupt.	Set to 1 when using counter overflow interrupt.
	PSEL0	Set to 01b.	Set to 10b.
	PSEL1		
PMCiCON3	CRE	Set to 1.	Set to 1.
	CFR	Set to 1.	Set to 1.
	CST	Set to 1.	Set to 1.
	PD	Set to 1.	Set to 1.
	CSRC0	Set to 00b	Select clock source.
	CSRC1		
	CDIV0	Set to 00b.	Select count source divisor.
	CDIV1		
PMCiSTS	CPFLG	Not used (read as undefined value)	-
	REFLG	Not used (read as undefined value)	Not used (read as undefined value)
	DRFLG	Not used (read as undefined value)	Not used (read as undefined value)
	BFULFLG	Not used (read as undefined value)	-
	PTHDFLG	Not used (read as undefined value)	Not used (read as undefined value)
	PTD0FLG	Not used (read as undefined value)	Not used (read as undefined value)
	PTD1FLG	Not used (read as undefined value)	Not used (read as undefined value)
	SDFLG	Not used (read as undefined value)	-

i = 0, 1

-: Unimplemented bits in PMC1

Note:

1. This table does not describe a procedure.

Table 22.21 Registers and Setting Values in Input Capture Mode (Simultaneous Count Operation) (2/2) [(1)]

Register	Bit	Function	
		PMC0	PMC1
PMCiINT	CPINT	Set to 0.	-
	REINT	Set to 0.	Set to 0.
	DRINT	Set to 0.	Set to 0.
	BFULINT	Set to 0.	-
	PTHDINT	Set to 0.	Set to 0.
	PTDINT	Set to 0.	Set to 0.
	TIMINT	Set to 1 when using timer measure interrupt.	Set to 1 when using timer measure interrupt.
	SDINT	Set to 0.	-
PMC0CPC	CPN0	Set to 000b.	-
	CPN1		
	CPN2		
	CPEN	Set to 0.	-
PMC0CPD	0 to 7	Set to 00h.	-
PMCiHDPMIN	0 to 10	Set to 0000h.	Set to 0000h.
PMCiHDPMAX	0 to 10	Set to 0000h.	Set to 0000h.
PMCiD0PMIN	0 to 7	Set to 00h.	Set to 00h.
PMCiD0PMAX	0 to 7	Set to 00h.	Set to 00h.
PMCiD1PMIN	0 to 7	Set to 00h.	Set to 00h.
PMCiD1PMAX	0 to 7	Set to 00h.	Set to 00h.
PMCiTIM	0 to 15	Measured value of pulse period or width can be read.	Measured value of pulse period or width can be read.
PMC0DAT0 to PMC0DAT5	0 to 7	Not used.	Not used.
PMC0RBIT	0 to 5	Not used.	Not used.

i = 0, 1

-: Unimplemented bits in PMC1

Note:

1. This table does not describe a procedure.

22.3.5.1 Setting Procedure

To start or stop counting, follow these steps:

(1) Set bits CSRC1 to CSRC0 and bits CDIV1 to CDIV0 in the PMCiCON3 register.
(2) Set bits PSEL1 to PSEL0 in the PMCiCON2 register and bits FIL and SINV in the PMCiCON0 register.
(3) Wait for four cycles of the count source.
(4) Set the EN bit in the PMC1CON0 register to 1 (0 to stop).
(5) Set the EN bit in the PMC0CON0 register to 1 (0 to stop).
(6) Wait for two cycles of the count source.
(7) Confirm that the ENFLG bit in the PMC0CON2 register is 1 (0 to stop). (The ENFLG bit in the PMC1CON2 register is disabled)

22.3.5.2 Count Operation

In input capture mode, the counter counts from 0000h to FFFFh, and then returns to 0000h to continue counting.

When the counter becomes 0000h after FFFFh, the CEFLG bit in the PMCiCON2 register becomes 1 (counter overflow) and stays 1 until the next measurement.

22.4 Interrupts

The remote control signal receiver has remote control signal receiver 0 interrupt and remote control signal receiver 1 interrupt. The remote control signal receiver 0 interrupt and remote control signal receiver 1 interrupt are interrupts in PMC0 and PMC1, respectively.

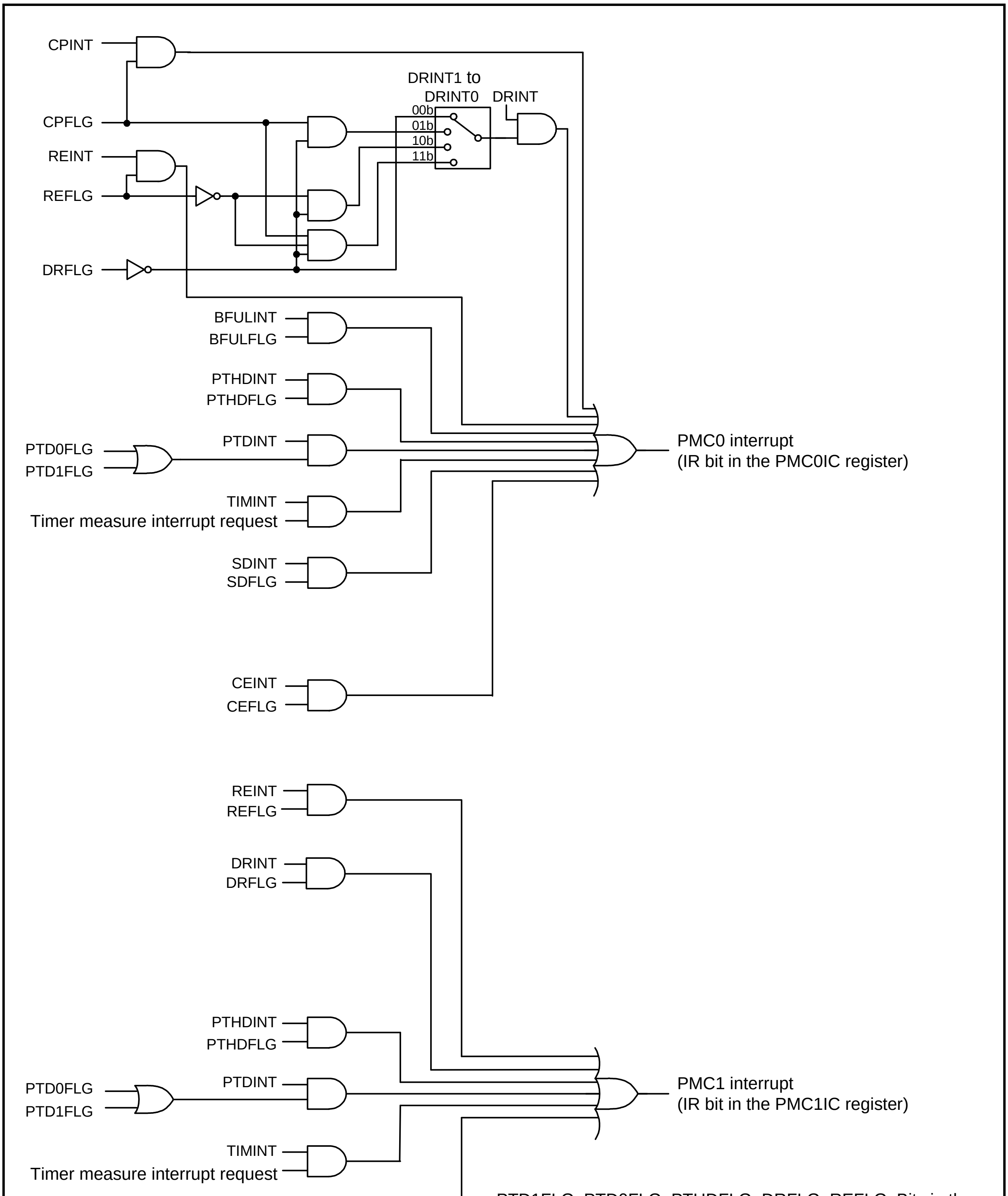
A remote control signal receiver i interrupt request signal is generated every time the conditions are met. If the interrupt enable bit in the PMCiCON2 or PMCiINT register is 1, the IR bit in the PMCiIC register becomes 1 (interrupt request) when the corresponding interrupt request signal is generated. Table 22.22 lists Interrupt Source of Remote Control Signal Receiver i Interrupt (i = 0, 1).

Table 22.22 Interrupt Source of Remote Control Signal Receiver i Interrupt (i = 0, 1)

Mode	Interrupt Source	Interrupt Request Generating Condition	Interrupt Request Bit		Interrupt Enable Bit	
			Register	Bit	Register	Bit
Pattern match mode	Completion of data reception	Counter value is larger than values of registers PMCiHDPMAX, PMCiD0PMAX, and PMCiD1PMAX	PMCiSTS	DRFLG (Changes from 1 to 0)	PMCiINT	DRINT
	Header match	The measured result is within the range set by registers PMCiHDPMIN and PMCiHDPMAX (when header is enabled)	PMCiSTS	PTHDFLG	PMCiINT	PTHDINT
	Data 0/1 match	The measured result is within the range set by registers PMCiD0PMIN and PMCiD0PMAX or registers PMCiD1PMIN and PMCiD1PMAX	PMCiSTS PMCiSTS	PTD0FLG PTD1FLG	PMCiINT	PTDINT
	Special data match	The measured result is within the range set by registers PMCiHDPMIN and PMCiHDPMAX (when special data is enabled)	PMC0STS	SDFLG	PMC0INT	SDINT
	Receive error	Input signal width is not the header, data 0, data 1, or special data. Data 0 or data 1 is detected before detecting the header when the HDEN bit is 1	PMCiSTS	REFLG	PMCiINT	REINT
	Receive buffer full	The value of the PMC0RBIT register is 48	PMC0STS	BFULFLG	PMC0INT	BFULINT
	Compare match	The values of registers PMC0CPD and PMC0DAT0 are matched (only bits selected by bits CPN2 to CPN0 in the PMC0CPC register are compared)	PMC0STS	CPFLG	PMC0INT	CPINT
	Timer measurement	Measurement end edge of PMCi internal input signal	-	-	PMCiINT	TIMINT
Input capture mode	Timer measurement	Measurement end edge of PMCi internal input signal	-	-	PMCiINT	TIMINT
	Counter overflow	Counter overflow (counter value exceeds FFFFh and becomes 0000h)	PMCiCON2	CEFLG	PMCiCON2	CEINT

Measured result: Content of the PMCiTIM register

Figure 22.10 shows Remote Control Signal Receiver Interrupts.



PTD1FLG, PTD0FLG, PTHDFLG, DRFLG, REFLG: Bits in the PMCiSTS register
SDFLG, BFULFLG, CPFLG: Bits in the PMC0STS register
SDINT, TIMINT, PTDINT, PTHDINT, BFULINT, DRINT, REINT, CPINT: Bits in the PMCiINT register
CEINT, CEFLG: Bits in the PMCiCON2 register
DRINT1 to DRINT0: Bits in the PMC0CON0 register

Figure 22.10 Remote Control Signal Receiver Interrupts

Refer to 14.7 “Interrupt Control” for details on interrupt control. Table 22.23 lists Registers Associated with Remote Control Signal Receiver Interrupts.

Table 22.23 Registers Associated with Remote Control Signal Receiver Interrupts

Address	Register	Symbol	Reset Value
0071h	UART7 Bus Collision Detection Interrupt Control Register, Remote Control Signal Receiver 0 Interrupt Control Register	U7BCNIC/ PMC0IC	XXXX X000b
0072h	UART7 Transmit Interrupt Control Register, Remote Control Signal Receiver 1 Interrupt Control Register	S7TIC/PMC1IC	XXXX X000b
0206h	Interrupt Source Select Register 2	IFSR2A	00h

The remote control signal receiver shares interrupt vectors or interrupt control registers with other peripheral functions. To use the remote control signal receiver 0 interrupt, set the IFSR24 bit in the IFSR2A register to 1 (remote control signal receiver 0). To use the remote control signal receiver 1 interrupt, set the IFSR25 bit in the IFSR2A register to 1 (remote control signal receiver 1).

22.5 Notes on Remote Control Signal Receiver

22.5.1 Starting/Stopping PMCi

The EN bit in the PMCiCON0 register controls the start/stop of PMCi. The ENFLG bit in the PMCiCON2 register indicates that operation started/stopped.

The PMCi circuit starts operating by setting the EN bit to 1 (operation enabled) and the ENFLG bit becomes 1 (operating). After setting the EN bit to 1, it takes up to two cycles of the count source before the ENFLG bit becomes 1.

When the EN bit is set to 0 (operation disabled), the PMCi circuit stops operating and the ENFLG bit becomes 0 (operation stopped). After setting the EN bit to 0, it takes up to one cycle of the count source before the ENFLG bit becomes 0.

Between setting the EN bit to 1 and the ENFLG bit becoming 1, and while the ENFLG bit is 1, do not access bits in the PMCi associated registers (registers listed in Table 22.4 and Table 22.5 "Registers”) except for the ENFLG bit.

22.5.2 Reading the Register

When the following registers are read while data changes, an undefined value may be read.

Flags in registers PMCiCON2 and PMCiSTS

Registers PMCiTIM, PMC0DAT0 to PMC0DAT5, and PMC0RBIT

Follow the procedures below to avoid reading an undefined value.

In pattern match mode

- Using an interrupt

  Set the DRINT bit in the PMCiINT register to 1 (data reception complete interrupt enabled) and read the registers within the PMCi interrupt routine.

- Monitoring by a program 1

  Set the DRINT bit in the PMCiINT register to 1 (data reception complete interrupt enabled) and monitor the IR bit in the PMCiIC register by a program. Read the registers when the IR bit becomes 1 (interrupt request is generated).

- Monitoring by a program 2

  (1) Monitor the DRFLG bit in the PMCiSTS register.

  (2) When the DRFLG bit becomes 1, monitor the DRFLG bit until it becomes 0.

  (3) Read the necessary content of the registers when the DRFLG bit becomes 0.

In input capture mode

- Using an interrupt

  Set the TIMINT bit in the PMCiINT register to 1 (timer measure interrupt enabled) and read the registers within the PMCi interrupt routine.

- Monitoring by a program 1

  Set the TIMINT bit in the PMCiINT register to 1 (timer measure interrupt enabled) and monitor the IR bit in the PMCiIC register by a program. Read the registers when the IR bit becomes 1 (interrupt request is generated).

If the register data may change at the same time as the register is read even with above countermeasures, read the register more than once to determine whether the read value is correct.

22.5.3 Rewriting the Register

Rewrite the registers and bits related to PMC excluding the EN bit in the PMCiCON0 register when both of the EN bit in the PMCiCON0 register and the ENFLG bit in the PMCiCON2 register are 0 (PMCi stops).

22.5.4 Combined Operation

When using combined operation, set same value to bits TYP1 to TYP0 in the PMC0CON1 register and bits TYP1 to TYP0 in the PMC1CON1 register.

23. Serial Interface UARTi (i = 0 to 2, 5 to 7)

23.1 Introduction

Each UART has a dedicated timer to generate a transmit/receive clock, and operates independently of the others.

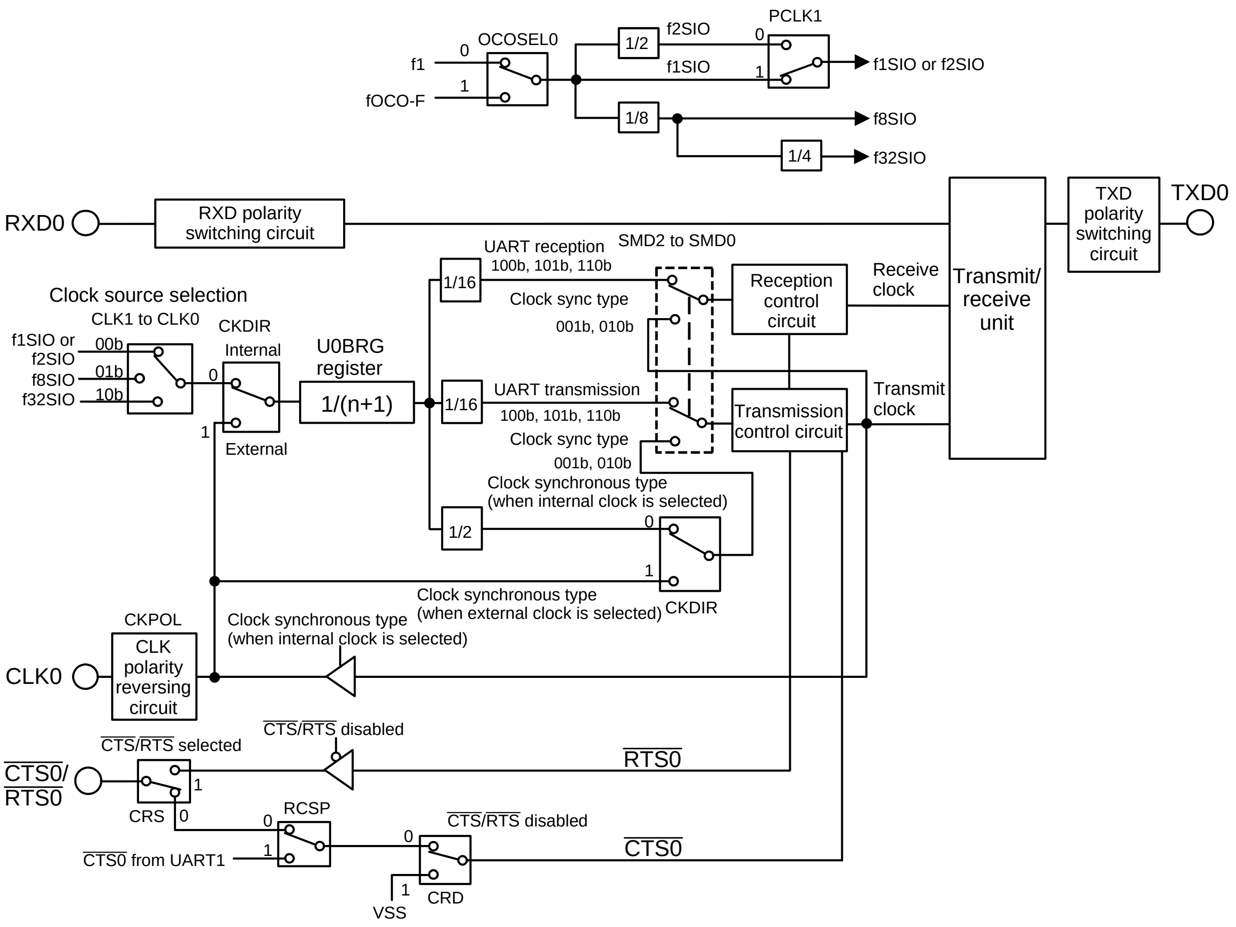
Table 23.1 lists UARTi Specifications (i = 0 to 2, 5 to 7). Table 23.2 lists Specification Differences between UART0 to UART2 and UART5 to UART7. Figure 23.1 to Figure 23.3 show the block diagrams of UARTi. Figure 23.4 shows UARTi Transmit/Receive Unit Block Diagram.

Table 23.1 UARTi Specifications (i = 0 to 2, 5 to 7)

Item	Specification
Operational mode	• Clock synchronous serial I/O mode • Clock asynchronous serial I/O mode (UART mode) • Special mode 1 (I^2C mode) The simplified I^2C-bus interface is supported. • Special mode 2 The transmit/receive clock polarity and phase are selectable. • Special mode 3 (bus collision detection function, IE mode) A 1-byte wave of the UART mode approximates 1-bit of the IEBus. • Special mode 4 (SIM mode) Can be used with UART2. The SIM interface is supported.

Table 23.2 Specification Differences between UART0 to UART2 and UART5 to UART7

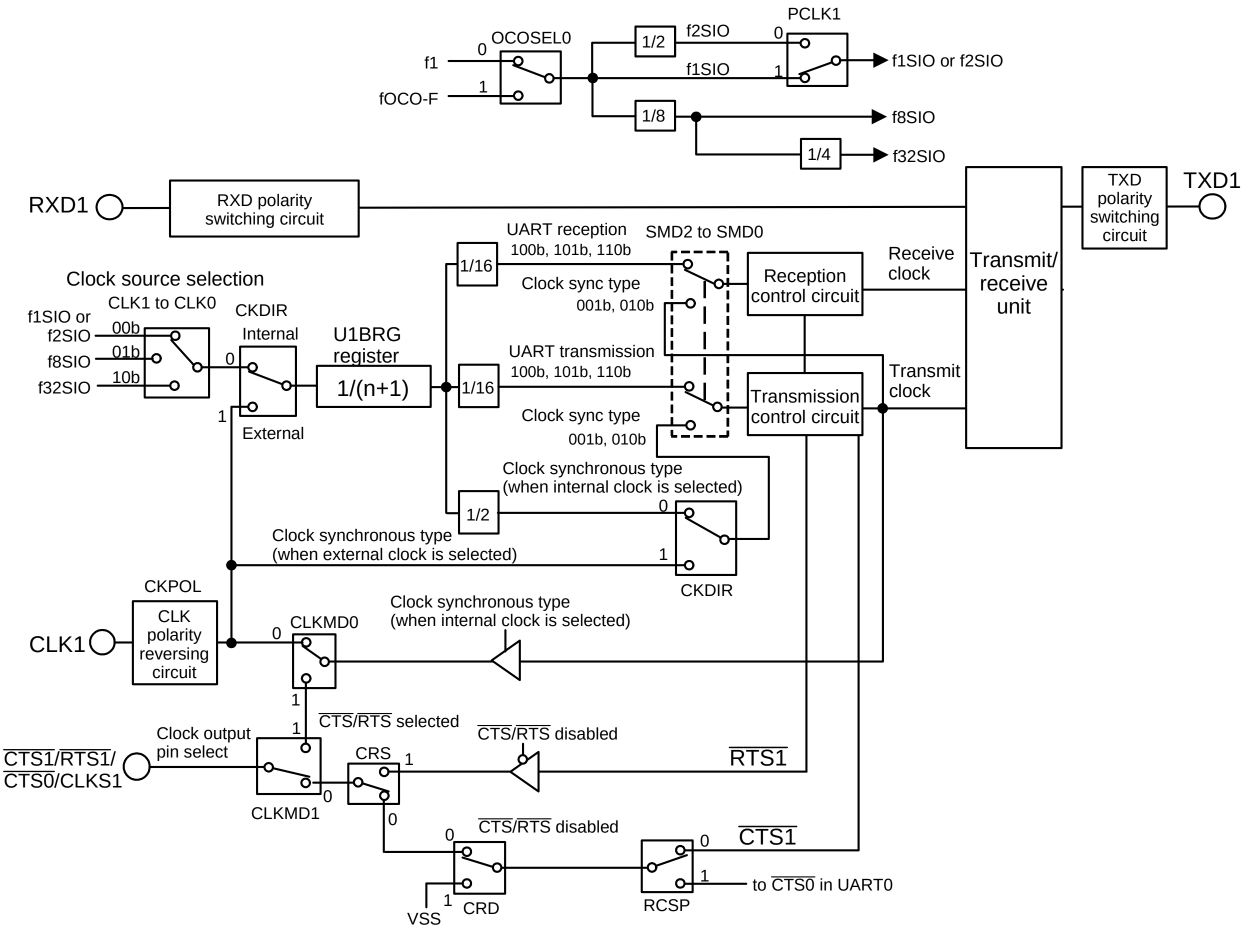
Mode	UART0	UART1	UART2	UART5	UART6	UART7
Clock synchronous serial I/O mode	Available		Available	Available	Available	
Clock asynchronous serial I/O mode (UART mode)	Available		Available	Available	Available	
Special mode 1 (I^2C mode)	Available		Available	Available	Available	
Special mode 2	Available		Available	Available	Available	
Special mode 3 (IE mode)	Available		Available	Available	Available	
Special mode 4 (SIM mode)	Not available		Available	Not available	Not available	
Memory expansion mode or microprocessor mode	Can be used				Do not use.	



n: Value set to the U0BRG register

PCLK1	: Bit in the PCLKR register
SMD2 to SMD0, CKDIR	: Bits in the U0MR register
CLK1 to CLK0, CKPOL, CRD, CRS	: Bits in the U0C0 register
RCSP	: Bit in the UCON register
OCOSEL0	: Bit in the UCLKSEL0 register

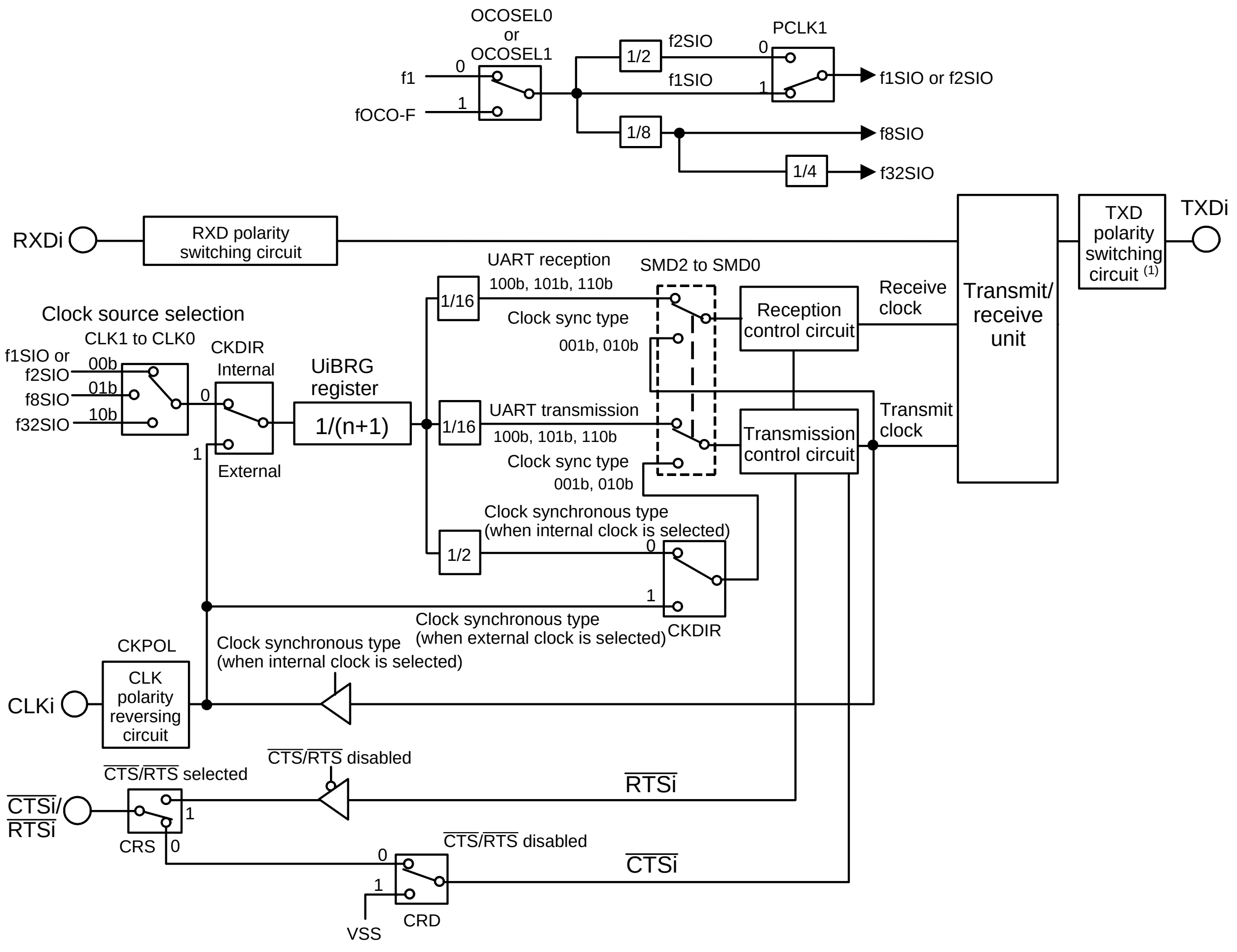
Figure 23.1 UART0 Block Diagram



n: Value set to the U1BRG register

PCLK1	: Bit in the PCLKR register
SMD2 to SMD0, CKDIR	: Bits in the U1MR register
CLK1 to CLK0, CKPOL, CRD, CRS	: Bits in the U1C0 register
CLKMD0, CLKMD1, RCSP	: Bits in the UCON register
OCOSEL0	: Bit in the UCLKSEL0 register

Figure 23.2 UART1 Block Diagram

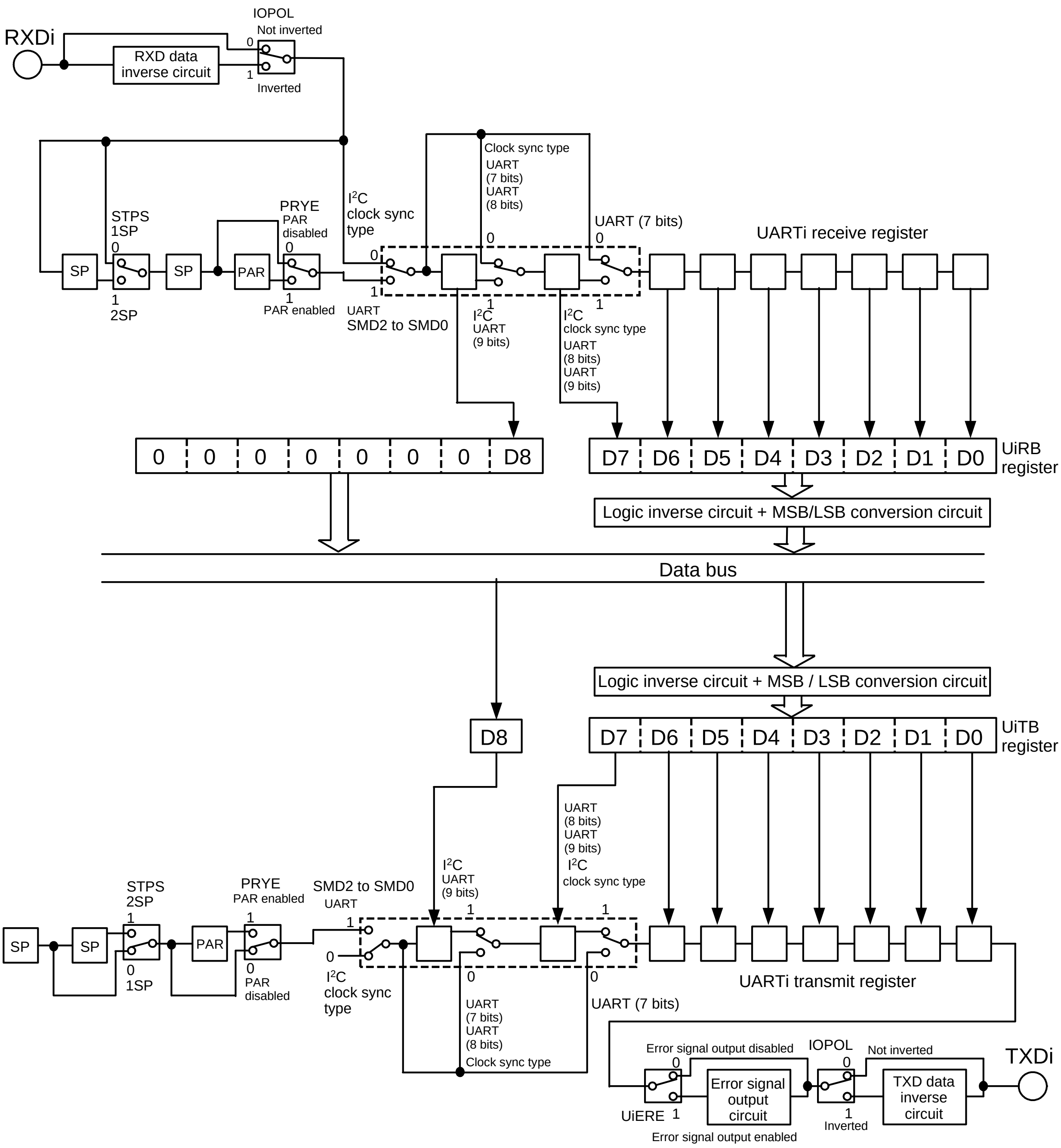


n: Value set to the UiBRG register
i = 2, 5 to 7

PCLK1	: Bit in the PCLKR register
SMD2 to SMD0, CKDIR	: Bits in the UiMR register
CLK1 to CLK0, CKPOL, CRD, CRS	: Bits in the UiC0 register
OCOSEL1, OCOSEL0	: Bits in the UCLKSEL0 register

Note:
1. UART2 is N-channel open drain output. CMOS output cannot be selected.

Figure 23.3 Block Diagram of UART2 and UART5 to UART7



SP: Stop bit
PAR: Parity bit

i = 0 to 2, 5 to 7

SMD2 to SMD0, STPS, PRYE, IOPOL: Bits in the UiMR register
UiERE: Bit in the UiC1 register

Figure 23.4 UARTi Transmit/Receive Unit Block Diagram

23.2 Registers

Table 23.3 and Table 23.4 list registers associated with UART0 to UART2 and UART5 to UART7. Refer to 8.2.6 “Peripheral Clock Stop Register 1 (PCLKSTP1)” for the explanation of the PCLKSTP1 register.
Set the OCOSEL0 or OCOSEL1 bit in the UCLKSEL0 register before setting other registers associated with UART0 to UART2 and UART5 to UART7. After changing the OCOSEL0 or OCOSEL1 bit, set other registers associated with UART0 to UART2 and UART5 to UART7 again.
Refer to “Registers Used and Settings” in each mode for the settings of registers and bits.

Table 23.3 Registers (1/2)

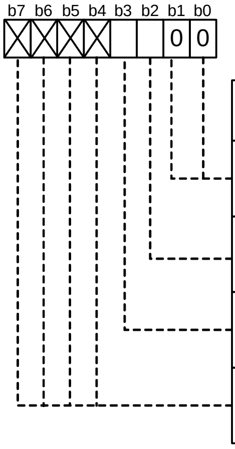
Address	Register	Symbol	Reset Value
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
0244h	UART0 Special Mode Register 4	U0SMR4	00h
0245h	UART0 Special Mode Register 3	U0SMR3	000X 0X0Xb
0246h	UART0 Special Mode Register 2	U0SMR2	X000 0000b
0247h	UART0 Special Mode Register	U0SMR	X000 0000b
0248h	UART0 Transmit/Receive Mode Register	U0MR	00h
0249h	UART0 Bit Rate Register	U0BRG	XXh
024Ah	UART0 Transmit Buffer Register	U0TB	XXh
024Bh			XXh
024Ch	UART0 Transmit/Receive Control Register 0	U0C0	0000 1000b
024Dh	UART0 Transmit/Receive Control Register 1	U0C1	00XX 0010b
024Eh	UART0 Receive Buffer Register	U0RB	XXh
024Fh			XXh
0250h	UART Transmit/Receive Control Register 2	UCON	X000 0000b
0252h	UART Clock Select Register	UCLKSEL0	X0h
0254h	UART1 Special Mode Register 4	U1SMR4	00h
0255h	UART1 Special Mode Register 3	U1SMR3	000X 0X0Xb
0256h	UART1 Special Mode Register 2	U1SMR2	X000 0000b
0257h	UART1 Special Mode Register	U1SMR	X000 0000b
0258h	UART1 Transmit/Receive Mode Register	U1MR	00h
0259h	UART1 Bit Rate Register	U1BRG	XXh
025Ah	UART1 Transmit Buffer Register	U1TB	XXh
025Bh			XXh
025Ch	UART1 Transmit/Receive Control Register 0	U1C0	0000 1000b
025Dh	UART1 Transmit/Receive Control Register 1	U1C1	00XX 0010b
025Eh	UART1 Receive Buffer Register	U1RB	XXh
025Fh			XXh
0264h	UART2 Special Mode Register 4	U2SMR4	00h
0265h	UART2 Special Mode Register 3	U2SMR3	000X 0X0Xb
0266h	UART2 Special Mode Register 2	U2SMR2	X000 0000b
0267h	UART2 Special Mode Register	U2SMR	X000 0000b
0268h	UART2 Transmit/Receive Mode Register	U2MR	00h
0269h	UART2 Bit Rate Register	U2BRG	XXh
026Ah	UART2 Transmit Buffer Register	U2TB	XXh
026Bh			XXh
026Ch	UART2 Transmit/Receive Control Register 0	U2C0	0000 1000b

Table 23.4 Registers (2/2)

Address	Register	Symbol	Reset Value
026Dh	UART2 Transmit/Receive Control Register 1	U2C1	0000 0010b
026Eh	UART2 Receive Buffer Register	U2RB	XXh
026Fh			XXh
0284h	UART5 Special Mode Register 4	U5SMR4	00h
0285h	UART5 Special Mode Register 3	U5SMR3	000X 0X0Xb
0286h	UART5 Special Mode Register 2	U5SMR2	X000 0000b
0287h	UART5 Special Mode Register	U5SMR	X000 0000b
0288h	UART5 Transmit/Receive Mode Register	U5MR	00h
0289h	UART5 Bit Rate Register	U5BRG	XXh
028Ah	UART5 Transmit Buffer Register	U5TB	XXh
028Bh			XXh
028Ch	UART5 Transmit/Receive Control Register 0	U5C0	0000 1000b
028Dh	UART5 Transmit/Receive Control Register 1	U5C1	0000 0010b
028Eh	UART5 Receive Buffer Register	U5RB	XXh
028Fh			XXh
0294h	UART6 Special Mode Register 4	U6SMR4	00h
0295h	UART6 Special Mode Register 3	U6SMR3	000X 0X0Xb
0296h	UART6 Special Mode Register 2	U6SMR2	X000 0000b
0297h	UART6 Special Mode Register	U6SMR	X000 0000b
0298h	UART6 Transmit/Receive Mode Register	U6MR	00h
0299h	UART6 Bit Rate Register	U6BRG	XXh
029Ah	UART6 Transmit Buffer Register	U6TB	XXh
029Bh			XXh
029Ch	UART6 Transmit/Receive Control Register 0	U6C0	0000 1000b
029Dh	UART6 Transmit/Receive Control Register 1	U6C1	0000 0010b
029Eh	UART6 Receive Buffer Register	U6RB	XXh
029Fh			XXh
02A4h	UART7 Special Mode Register 4	U7SMR4	00h
02A5h	UART7 Special Mode Register 3	U7SMR3	000X 0X0Xb
02A6h	UART7 Special Mode Register 2	U7SMR2	X000 0000b
02A7h	UART7 Special Mode Register	U7SMR	X000 0000b
02A8h	UART7 Transmit/Receive Mode Register	U7MR	00h
02A9h	UART7 Bit Rate Register	U7BRG	XXh
02AAh	UART7 Transmit Buffer Register	U7TB	XXh
02ABh			XXh
02ACh	UART7 Transmit/Receive Control Register 0	U7C0	0000 1000b
02ADh	UART7 Transmit/Receive Control Register 1	U7C1	0000 0010b
02AEh	UART7 Receive Buffer Register	U7RB	XXh
02AFh			XXh

23.2.1 UART Clock Select Register (UCLKSEL0)

UART Clock Select Register



Symbol	Address	Reset Value
UCLKSEL0	0252h	X0h

Bit Symbol	Bit Name	Function	RW
— (b1-b0)	Reserved bits	Set to 0	RW
OCOSEL0	UART0 to UART2 clock prior to division select bit	0 : f1 1 : fOCO-F	RW
OCOSEL1	UART5 to UART7 clock prior to division select bit	0 : f1 1 : fOCO-F	RW
— (b7-b4)	No register bits. If necessary, set to 0. The read value is undefined.		—

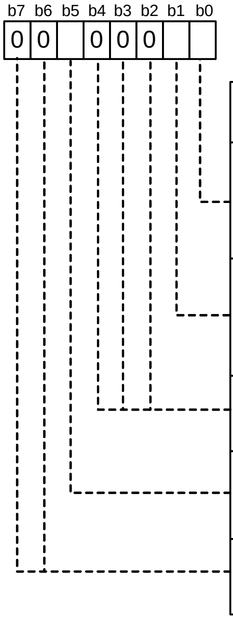
OCOSEL0 (UART0 to UART2 clock prior to division select bit) (b2)
OCOSEL1 (UART5 to UART7 clock prior to division select bit) (b3)

Set bits OCOSEL0 and OCOSEL1 while transmission/reception of UART0 to UART2 and UART5 to UART7 stops.

Set the OCOSEL0 or OCOSEL1 bit before setting other registers associated with UART0 to UART2 and UART5 to UART7. After changing the OCOSEL0 or OCOSEL1 bit, set other registers associated with UART0 to UART2 and UART5 to UART7 again.

23.2.2 Peripheral Clock Select Register (PCLKR)

Peripheral Clock Select Register



Symbol	Address	Reset Value
PCLKR	0012h	0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A and B clock select bit (clock source for timers A and B, the dead time timer, and multi-master I^{2}C-bus interface)	0: f2TIMAB/f2IIC 1: f1TIMAB/f1IIC	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART2, UART5 to UART7, SI/O3, and SI/O4)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function expansion bit (enabled in single-chip mode)	0: Selected by setting bits CM01 to CM00 in the CM0 register 1: Output f1	RW
— (b7-b6)	Reserved bits	Set to 0	RW

Set the PRC0 bit in the PRCR register to 1 (write enabled) before rewriting this register.

23.2.3 UARTi Transmit/Receive Mode Register (UiMR) (i = 0 to 2, 5 to 7)

UARTi Transmit/Receive Mode Register (i = 0 to 2, 5 to 7)

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
U0MR, U1MR, U2MR	0248h, 0258h, 0268h	00h
U5MR, U6MR, U7MR	0288h, 0298h, 02A8h	00h

Bit Symbol	Bit Name	Function	RW
SMD0	Serial I/O mode select bit	b2 b1 b0 0 0 0 : Serial interface disabled 0 0 1 : Clock synchronous serial I/O mode 0 1 0 : I^{2}C mode 1 0 0 : UART mode character bit length is 7 bits 1 0 1 : UART mode character bit length is 8 bits 1 1 0 : UART mode character bit length is 9 bits Only set the values listed above.	RW
SMD1			RW
SMD2			RW
CKDIR	Internal/external clock select bit	0 : Internal clock 1 : External clock	RW
STPS	Stop bit length select bit	0 : 1 stop bit 1 : 2 stop bit	RW
PRY	Odd/even parity select bit	Enabled when PRYE is 1 0 : Odd parity 1 : Even parity	RW
PRYE	Parity enable bit	0 : Parity disabled 1 : Parity enabled	RW
IOPOL	TXD, RXD I/O polarity inverse bit	0 : Not inverted 1 : Inverted	RW

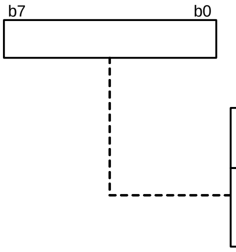
SMD2 to SMD0 (Serial I/O mode select bit) (b2 to b0)

When setting bits SMD2 to SMD0 to 000b (serial interface disabled), set the TE bit in the UiC1 register to 0 (transmission disabled) and the RE bit to 0 (reception disabled).

When using I^{2}C mode, set the IICM bit in the UiSMR register to 1 (I^{2}C mode), then set bits SMD2 to SMD0 to 010b (I^{2}C mode).

23.2.4 UARTi Bit Rate Register (UiBRG) (i = 0 to 2, 5 to 7)

UARTi Bit Rate Register (i = 0 to 2, 5 to 7)



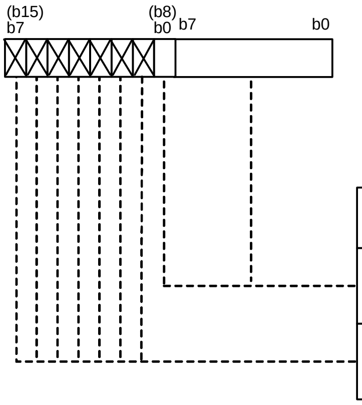
Symbol	Address	Reset Value
U0BRG, U1BRG, U2BRG	0249h, 0259h, 0269h	XXh
U5BRG, U6BRG, U7BRG	0289h, 0299h, 02A9h	XXh

Function	Setting Range	RW
If set value is n, UiBRG divides the count source by n + 1.	00h to FFh (other than I^2C mode) 03h to FFh (I^2C mode)	WO

Write to the UiBRG register while the serial interface is neither transmitting nor receiving.
Use the MOV instruction to write to the UiBRG register.
Write to the UiBRG register after setting bits CLK1 to CLK0 in the UiC0 register.

23.2.5 UARTi Transmit Buffer Register (UiTB) (i = 0 to 2, 5 to 7)

UARTi Transmit Buffer Register (i = 0 to 2, 5 to 7)



Symbol	Address	Reset Value
U0TB	024Bh to 024Ah	XXXXh
U1TB	025Bh to 025Ah	XXXXh
U2TB	026Bh to 026Ah	XXXXh
U5TB	028Bh to 028Ah	XXXXh
U6TB	029Bh to 029Ah	XXXXh
U7TB	02ABh to 02AAh	XXXXh

Function	RW
Transmit data	WO
No register bits. If necessary, set to 0. The read value is undefined.	—

Use the MOV instruction to write to this register.
When character length is 9 bits long or I^2C mode, write to this register in 16-bit units, or in 8-bit units from upper byte to lower byte.

23.2.6 UARTi Transmit/Receive Control Register 0 (UiC0) (i = 0 to 2, 5 to 7)

UARTi Transmit/Receive Control Register 0 (i = 0 to 2, 5 to 7)

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
U0C0, U1C0, U2C0	024Ch, 025Ch, 026Ch	0000 1000b
U5C0, U6C0, U7C0	028Ch, 029Ch, 02ACh	0000 1000b

Bit Symbol	Bit Name	Function	RW
CLK0	UiBRG count source select bit	b1 b0 0 0 : f1SIO or f2SIO selected 0 1 : f8SIO selected 1 0 : f32SIO selected 1 1 : Do not set	RW
CLK1			RW
CRS	$\overline{\text{CTS}}$/$\overline{\text{RTS}}$ function select bit	Enabled when CRD is 0 0 : $\overline{\text{CTS}}$ function selected 1 : $\overline{\text{RTS}}$ function selected	RW
TXEPT	Transmit register empty flag	0 : Data present in transmit register (transmission in progress) 1 : No data present in transmit register (transmission completed)	RO
CRD	$\overline{\text{CTS}}$/$\overline{\text{RTS}}$ disable bit	0 : $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ function enabled 1 : $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ function disabled	RW
NCH	Data output select bit	0 : Pins TXDi/SDAi and SCLi are CMOS output 1 : Pins TXDi/SDAi and SCLi are N-channel open drain output	RW
CKPOL	CLK polarity select bit	0 : Transmit data is output at the falling edge of transmit/receive clock and receive data is input at the rising edge 1 : Transmit data is output at the rising edge of transmit/receive clock and receive data is input at the falling edge	RW
UFORM	Bit order select bit	0 : LSB first 1 : MSB first	RW

CLK1 to CLK0 (UiBRG count source select bit) (b1-b0)

When bits CLK1 to CLK0 are 00b (f1SIO or f2SIO selected), select f1SIO or f2SIO by the PCLK1 bit in the PCLKR register.
Set bits CLK1 to CLK0 after setting registers UCLKSEL0 and PCLKR.
If bits CLK1 to CLK0 are changed, set the UiBRG register.

CRS ($\overline{\text{CTS}}$/$\overline{\text{RTS}}$ function select bit) (b2)

$\overline{\text{CTS1}}$/$\overline{\text{RTS1}}$ can be used when the CLKMD1 bit in the UCON register is 0 (CLK output is only from CLK1) and the RCSP bit in the UCON register is 0 ($\overline{\text{CTS0}}$/$\overline{\text{RTS0}}$ not separated).

CRD ($\overline{\text{CTS}}$/$\overline{\text{RTS}}$ disable bit) (b4)

When the CRD bit is 1 ($\overline{\text{CTS}}$/$\overline{\text{RTS}}$ function disabled), the $\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$ pin can be used as an I/O port.

NCH (Data output select bit) (b5)

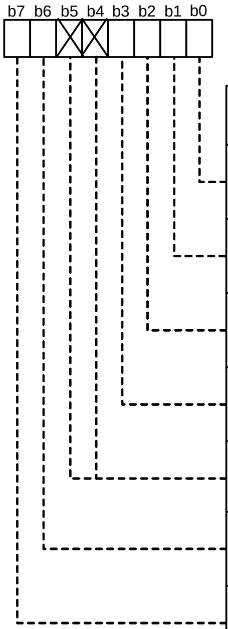
TXD2/SDA2 and SCL2 are N-channel open drain outputs. They cannot be set as CMOS outputs. Nothing is assigned to the NCH bit in the U2C0 register. If necessary, set this bit to 0.
This function is used to set the P-channel transistor of the CMOS output buffer always off, but not to change pins TXDi/SDAi and SCLi to open drain output completely.
Refer to the electrical characteristics for the input voltage range.

UFORM (Bit order select bit) (b7)

The UFORM bit is enabled when bits SMD2 to SMD0 in the UiMR register are 001b (clock synchronous serial I/O mode), or 101b (UART mode, 8-bit character data).
Set the UFORM bit to 1 when bits SMD2 to SMD0 are 010b (I^2C mode), and to 0 when bits SMD2 to SMD0 are 100b (UART mode, 7-bit character data) or 110b (UART mode, 9-bit character data).

23.2.7 UARTi Transmit/Receive Control Register 1 (UiC1) (i = 0 to 2, 5 to 7)

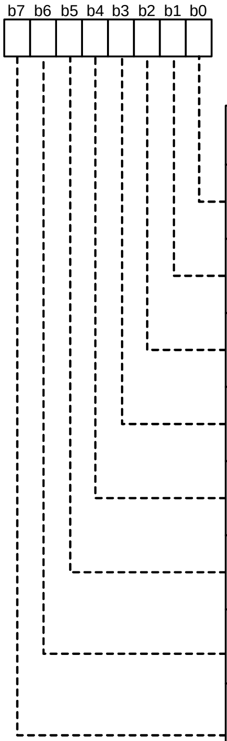
UARTi Transmit/Receive Control Register 1 (i = 0, 1)



Symbol	Address	After Reset
U0C1, U1C1	024Dh, 025Dh	00XX 0010b

Bit Symbol	Bit Name	Function	RW
TE	Transmit enable bit	0 : Transmission disabled 1 : Transmission enabled	RW
TI	Transmit buffer empty flag	0 : Data present in UiTB register 1 : No data present in UiTB register	RO
RE	Receive enable bit	0 : Reception disabled 1 : Reception enabled	RW
RI	Receive complete flag	0 : No data present in UiRB register 1 : Data present in UiRB register	RO
— (b5-b4)	No register bits. If necessary, set to 0. Read as undefined value		—
UiLCH	Data logic select bit	0 : No reverse 1 : Reverse	RW
UiERE	Error signal output enable bit	0 : Output disabled 1 : Output enabled	RW

UARTi Transmit/Receive Control Register 1 (i = 2, 5 to 7)



Symbol	Address	Reset Value
U2C1	026Dh	0000 0010b
U5C1, U6C1, U7C1,	028Dh, 029Dh, 02ADh	0000 0010b

Bit symbol	Bit Name	Function	RW
TE	Transmit enable bit	0 : Transmission disabled 1 : Transmission enabled	RW
TI	Transmit buffer empty flag	0 : Data present in UiTB register 1 : No data present in UiTB register	RO
RE	Receive enable bit	0 : Reception disabled 1 : Reception enabled	RW
RI	Receive complete flag	0 : No data present in UiRB register 1 : Data present in UiRB register	RO
UiIRS	UARTi transmit interrupt source select bit	0 : UiTB register empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	RW
UiRRM	UARTi continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enabled	RW
UiLCH	Data logic select bit	0 : Not inverted 1 : Inverted	RW
UiERE	Error signal output enable bit	0 : Output disabled 1 : Output enabled	RW

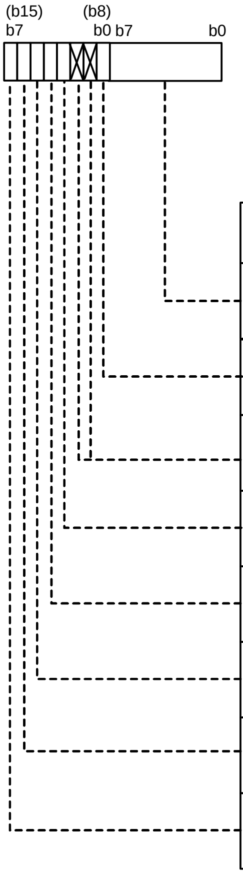
Bits UiIRS and UiRRM of UART0 and UART1 are bits in the UCON register.

UiLCH (Data logic select bit) (b6)

The UiLCH bit is enabled when bits SMD2 to SMD0 in the UiMR register are 001b (clock synchronous serial I/O mode), 100b (UART mode, 7-bit character), or 101b (UART mode, 8-bit character). Set this bit to 0 when bits SMD2 to SMD0 are set to 010b (I^{2}C mode) or 110b (UART mode, 9-bit character).

23.2.8 UARTi Receive Buffer Register (UiRB) (i = 0 to 2, 5 to 7)

UARTi Receive Buffer Register (i = 0 to 2, 5 to 7)



Symbol	Address	Reset Value
U0RB	024Fh to 024Eh	XXXXh
U1RB	025Fh to 025Eh	XXXXh
U2RB	026Fh to 026Eh	XXXXh
U5RB	028Fh to 028Eh	XXXXh
U6RB	029Fh to 029Eh	XXXXh
U7RB	02AFh to 02AEh	XXXXh

Bit Symbol	Bit Name	Function	RW
— (b7-b0)	——	Receive data (D7 to D0)	RO
— (b8)	——	Receive data (D8)	RO
— (b10-b9)	No register bits. If necessary, set to 0. The read value is undefined.		—
ABT	Arbitration lost detect flag	0 : Not detected 1 : Detected	RW
OER	Overrun error flag	0 : No overrun error 1 : Overrun error found	RO
FER	Framing error flag	0 : No framing error 1 : Framing error found	RO
PER	Parity error flag	0 : No parity error 1 : Parity error found	RO
SUM	Error sum flag	0 : No error 1 : Error found	RO

When bits SMD2 to SMD0 in the UiMR register are 100b, 101b, or 110b, read this register in 16-bit units, or in 8-bit units from upper byte to lower byte.

Bits FER and PER in the upper byte become 0 when the lower byte of the UiRB register is read.

If an overrun error occurs, the receive data of the UiRB register is undefined.

ABT (Arbitration lost detect flag) (b11)

The ABT bit is set to 0 by a program. (It remains unchanged even if 1 is written.)

OER (Overrun error flag) (b12)

Conditions to become 0:

- Bits SMD2 to SMD0 in the UiMR register are 000b (serial interface disabled).
- The RE bit in the UiC1 register is 0 (reception disabled).

Condition to become 1:

- The RI bit in the UiC1 register is 1 (data present in UiRB register), and the last bit of the next data is received.

FER (Framing error flag) (b13)

The FER bit is disabled when bits SMD2 to SMD0 are set to 001b (clock synchronous serial I/O mode) or to 010b (I^2C mode). The read value is undefined.

Conditions to become 0:

- Bits SMD2 to SMD0 in the UiMR register are 000b (serial interface disabled).
- The RE bit in the UiC1 register is 0 (reception disabled).
- The lower bytes of the UiRB register are read.

Condition to become 1:

- The set number of stop bits is not detected.
  (detected when the received data is transferred from the UARTi receive register to the UiRB register.)

PER (Parity error flag) (b14)

The PER bit is disabled when bits SMD2 to SMD0 are set to 001b (clock synchronous serial I/O mode) or to 010b (I^2C mode). The read value is undefined.

Conditions to become 0:

- Bits SMD2 to SMD0 in the UiMR register are 000b (serial interface disabled).
- The RE bit in the UiC1 register is 0 (reception disabled).
- The lower bytes of the UiRB register are read.

Condition to become 1:

- The number of 1’s of the parity bit and character bits do not match the set value of the PRY bit in the UiMR register.
  (detected when the received data is transferred from the UARTi receive register to the UiRB register.)

SUM (Error sum flag) (b15)

The SUM bit is disabled when bits SMD2 to SMD0 are set to 001b (clock synchronous serial I/O mode) or to 010b (I^2C mode). The read value is undefined.

Conditions to become 0:

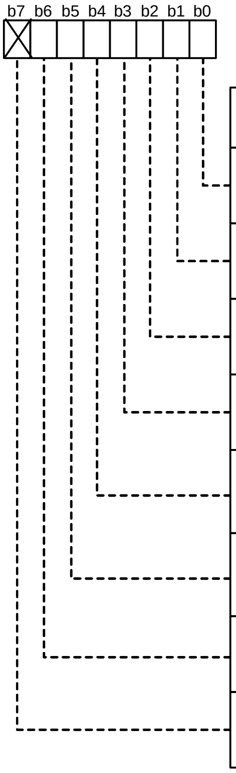
- Bits SMD2 to SMD0 in the UiMR register are 000b (serial interface disabled).
- The RE bit in the UiC1 register is 0 (reception disabled).
- Bits PER, FER and OER are all 0 (no error).

Condition to become 1:

- At least two bits out of PER, FER, or OER are 1 (error found).

23.2.9 UART Transmit/Receive Control Register 2 (UCON)

UART Transmit/Receive Control Register 2



Symbol	Address	After Reset
UCON	0250h	X000 0000b

Bit symbol	Bit Name	Function	RW
U0IRS	UART0 transmit interrupt source select bit	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	RW
U1IRS	UART1 transmit interrupt source select bit	0 : Transmit buffer empty (TI = 1) 1 : Transmission completed (TXEPT = 1)	RW
U0RRM	UART0 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enabled	RW
U1RRM	UART1 continuous receive mode enable bit	0 : Continuous receive mode disabled 1 : Continuous receive mode enabled	RW
CLKMD0	UART1CLK, CLKS select bit 0	Enabled when CLKMD1 is 1 0 : Clock output from CLK1 1 : Clock output from CLKS1	RW
CLKMD1	UART1CLK, CLKS select bit 1	0 : CLK output is only from CLK1 1 : Transmit/receive clock output from multiple-pin output function selected	RW
RCSP	Separate UART0 $\overline{\text{CTS}}/\overline{\text{RTS}}$ bit	0 : $\overline{\text{CTS}}/\overline{\text{RTS}}$ shared pin 1 : $\overline{\text{CTS}}/\overline{\text{RTS}}$ separated	RW
— (b7)	No register bit. If necessary, set to 0. Read as undefined value		—

Bits UiIRS and UiRRM of UART2 and UART5 to UART7 are bits in the UiC1 register.

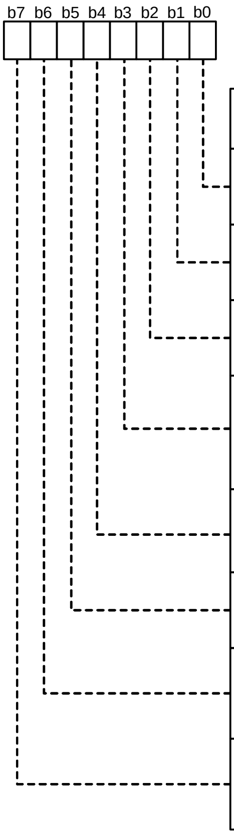
CLKMD1 (UART1CLK, CLKS select bit 1) (b5)

When using multiple transmit/receive clock output pins, make sure that the CKDIR bit in the U1MR register is 0 (internal clock).

23.2.10 UARTi Special Mode Register 4 (UiSMR4) (i = 0 to 2, 5 to 7)

UARTi Special Mode Register 4 (i = 0 to 2, 5 to 7)

Symbol	Address	Reset Value
U0SMR4, U1SMR4, U2SMR4	0244h, 0254h, 0264h	00h
U5SMR4, U6SMR4, U7SMR4	0284h, 0294h, 02A4h	00h



Bit Symbol	Bit Name	Function	RW
STAREQ	Start condition generate bit	0 : Clear 1 : Start	RW
RSTAREQ	Restart condition generate bit	0 : Clear 1 : Start	RW
STPREQ	Stop condition generate bit	0 : Clear 1 : Start	RW
STSPSEL	SCL, SDA output select bit	0 : Select serial I/O circuit 1 : Select start condition/stop condition generate circuit	RW
ACKD	ACK data bit	0 : ACK 1 : NACK	RW
ACKC	ACK data output enable bit	0 : Serial data output 1 : ACK data output	RW
SCLHI	SCL output stop bit	If stop condition is detected, 0 : Do not stop SCLi output 1 : Stop SCLi output	RW
SWC9	SCL wait auto insert bit 3	0 : No wait-state/wait-state cleared 1 : Hold the SCLi pin low after the ninth bit of the SCLi is received	RW

STAREQ (Start condition generate bit) (b0)

The STAREQ bit becomes 0 when a start condition is generated.

This bit is used in master mode of I^2C mode. To set this bit to 1, preset the IICM bit in the UiSMR register to 1 (I^2C mode). Do not set this bit to 1 when the IICM bit is 0.

RSTAREQ (Restart condition generate bit) (b1)

The RSTAREQ bit becomes 0 when a restart condition is generated.

This bit is used in master mode of I^2C mode. To set this bit to 1, preset the IICM bit in the UiSMR register to 1 (I^2C mode). Do not set this bit to 1 when the IICM bit is 0.

STPREQ (Stop condition generate bit) (b2)

The STPREQ bit becomes 0 when a stop condition is generated.

This bit is used in master mode of I^2C mode. To set this bit to 1, preset the IICM bit in the UiSMR register to 1 (I^2C mode). Do not set this bit to 1 when the IICM bit is 0.

STSPSEL (SCL, SDA output select bit) (b3)

This bit is used in master mode of I^2C mode. To set this bit to 1, preset the IICM bit in the UiSMR register to 1 (I^2C mode). Do not set this bit to 1 when the IICM bit is 0.

Set the STSPSEL bit to 1 (select start condition/stop condition generate circuit) after setting the STARREQ, RSTAREQ, or STPREQ bit to 1 (start).

ACKD (ACK data bit) (b4)
ACKC (ACK data output enable bit) (b5)
SWC9 (SCL wait auto insert bit 3) (b7)

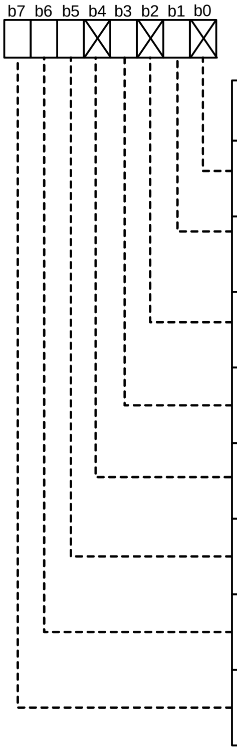
This bit is used in slave mode of I^2C mode. To set this bit to 1, preset the IICM bit in the UiSMR register to 1 (I^2C mode). Do not set this bit to 1 when the IICM bit is 0.

SCLHI (SCL output stop bit) (b6)

This bit is used in master mode of I^2C mode. To set this bit to 1, preset the IICM bit in the UiSMR register to 1 (I^2C mode). Do not set this bit to 1 when the IICM bit is 0.

23.2.11 UARTi Special Mode Register 3 (UiSMR3) (i = 0 to 2, 5 to 7)

UARTi Special Mode Register 3 (i = 0 to 2, 5 to 7)



Symbol	Address	Reset Value
U0SMR3, U1SMR3, U2SMR3	0245h, 0255h, 0265h	000X 0X0Xb
U5SMR3, U6SMR3, U7SMR3	0285h, 0295h, 02A5h	000X 0X0Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. Read as undefined value		—
CKPH	Clock phase set bit	0 : No clock delay 1 : With clock delay	RW
— (b2)	No register bit. If necessary, set to 0. Read as undefined value		—
NODC	Clock output select bit	0 : CLKi is CMOS output 1 : CLKi is N-channel open drain output	RW
— (b4)	No register bit. If necessary, set to 0. Read as undefined value		—
DL0	SDAi digital delay setup bit	b7 b6 b5 0 0 0 : No delay 0 0 1 : 1 to 2 cycles of UiBRG count source 0 1 0 : 2 to 3 cycles of UiBRG count source 0 1 1 : 3 to 4 cycles of UiBRG count source 1 0 0 : 4 to 5 cycles of UiBRG count source 1 0 1 : 5 to 6 cycles of UiBRG count source 1 1 0 : 6 to 7 cycles of UiBRG count source 1 1 1 : 7 to 8 cycles of UiBRG count source	RW
DL1			RW
DL2			RW

NODC (Clock output select bit) (b3)

This function is used to set P-channel transistor of the CMOS output buffer always off, but not to change the CLKi pin to open drain output completely.

Refer to the electrical characteristics for the input voltage range.

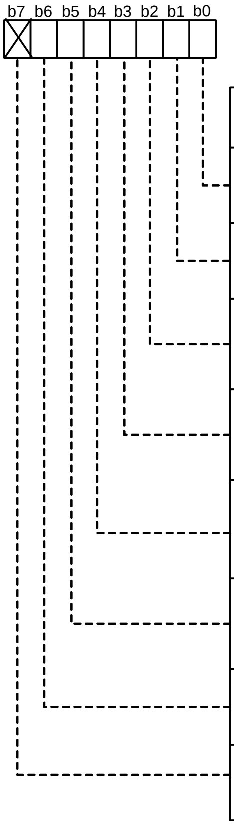
DL2-DL0 (SDAi digital delay setup bit) (b7-b5)

Bits DL2 to DL0 are used to generate a digital delay in SDAi output in I^{2}C mode. Except in I^{2}C mode, set these bits to 000b (no delay).

The delay length varies with the load on pins SCLi and SDAi. Also, when using an external clock, the delay length increases by about 100 ns.

23.2.12 UARTi Special Mode Register 2 (UiSMR2) (i = 0 to 2, 5 to 7)

UARTi Special Mode Register 2 (i = 0 to 2, 5 to 7)



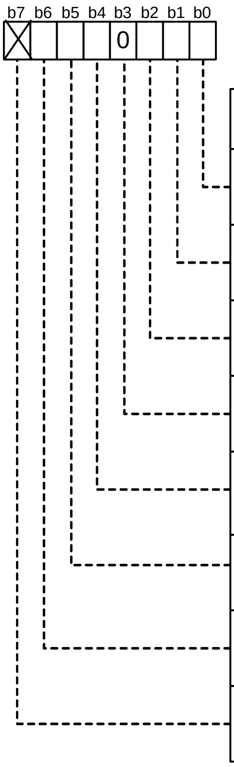
Symbol	Address	Reset Value
U0SMR2, U1SMR2, U2SMR2	0246h, 0256h, 0266h	X000 0000b
U5SMR2, U6SMR2, U7SMR2	0286h, 0296h, 02A6h	X000 0000b

Bit Symbol	Bit Name	Function	RW
IICM2	I^{2}C mode select bit 2	0 : Use NACK/ACK interrupt 1 : Use transmit/receive interrupt	RW
CSC	Clock synchronization bit	0 : Clock synchronization disabled 1 : Clock synchronization enabled	RW
SWC	SCL wait auto insert bit	0 : No wait-state/wait-state cleared 1 : Hold the SCLi pin low after the eighth bit is received	RW
ALS	SDA output auto stop bit	When arbitration lost is detected, 0 : Do not stop the SDAi output 1 : Stop the SDAi output	RW
STAC	UARTi auto initialize bit	When the start condition is detected, 0 : Do not initialize the circuit 1 : Initialize the circuit	RW
SWC2	SCL wait output bit 2	0: Output the transmit/receive clock at the SCLi pin 1: Hold the SCLi pin low	RW
SDHI	SDA output disable bit	0: Output data 1: Stop the output (high-impedance)	RW
— (b7)	No register bit. If necessary, set to 0. The read value is undefined.		—

23.2.13 UARTi Special Mode Register (UiSMR) (i = 0 to 2, 5 to 7)

UARTi Special Mode Register (i = 0 to 2, 5 to 7)

Symbol	Address	Reset Value
U0SMR, U1SMR, U2SMR	0247h, 0257h, 0267h	X000 0000b
U5SMR, U6SMR, U7SMR	0287h, 0297h, 02A7h	X000 0000b



Bit Symbol	Bit Name	Function	RW
IICM	I^2C mode select bit	0 : Other than I^2C mode 1 : I^2C mode	RW
ABC	Arbitration lost detect flag control bit	0 : Update every bit 1 : Update every byte	RW
BBS	Bus busy flag	0 : Stop-condition detected 1 : Start-condition detected (busy)	RW
— (b3)	Reserved bit	Set to 0	RW
ABSCS	Bus collision detect sampling clock select bit	0 : Rising edge of transmit/receive clock 1 : Underflow signal of timer Aj	RW
ACSE	Auto clear function select bit of transmit enable bit	0 : No auto clear function 1 : Auto clear at bus collision	RW
SSS	Transmit start condition select bit	0 : Not synchronized to RXDi 1 : Synchronized to RXDi	RW
— (b7)	No register bit. If necessary, set to 0. The read value is undefined.		—

BBS (Bus busy flag) (b2)

The BBS bit is set to 0 by a program. (It remains unchanged even if 1 is written.)

ABSCS (Bus collision detect sampling clock select bit) (b4)

When the ABSCS bit is 1, the combinations of UARTi and timer Aj are as follows:

UART0, UART6: Underflow signal of timer A3
UART1, UART7: Underflow signal of timer A4
UART2, UART5: Underflow signal of timer A0

SSS (Transmit start condition select bit) (b6)

When a transmission starts, the SSS bit becomes 0 (not synchronized to RXDi).

23.3 Operations

23.3.1 Clock Synchronous Serial I/O Mode

The clock synchronous serial I/O mode uses a transmit/receive clock to transmit/receive data. Table 23.5 lists the Clock Synchronous Serial I/O Mode Specifications.

Table 23.5 Clock Synchronous Serial I/O Mode Specifications

Item	Specification
Data format	Character length: 8 bits

Transmit/receive clock	• CKDIR bit in the UiMR register = 0 (internal clock): $\frac{fj}{2(n+1)}$
	fj = f1SIO, f2SIO, f8SIO, f32SIO
	n = setting value of UiBRG register (00h to FFh)
	• CKDIR bit = 1 (external clock): input from CLKi pin

Transmit/receive control	Selectable from $\overline{\text{CTS}}$, $\overline{\text{RTS}}$, or $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ function disabled
Transmission start conditions	To start transmission, satisfy the following requirements (1) • The TE bit in the UiC1 register is 1 (transmission enabled) • The TI bit in the UiC1 register is 0 (data presents in UiTB register) • When $\overline{\text{CTS}}$ function is selected, input on the $\overline{\text{CTSi}}$ pin is low
Reception start conditions	To start reception, satisfy the following requirements (1) • The RE bit in the UiC1 register is 1 (reception enabled) • The TE bit in the UiC1 register is 1 (transmission enabled) • The TI bit in the UiC1 register is 0 (data presents in the UiTB register)
Interrupt request generation timing	For transmission, one of the following conditions can be selected • The UiIRS bit in the UiC1 or UCON register is 0 (transmit buffer empty): When transferring data from the UiTB register to the UARTi transmit register (at start of transmission) • The UiIRS bit is 1 (transfer completed): When the serial interface completes sending data from the UARTi transmit register For reception • When transferring data from the UARTi receive register to the UiRB register (at completion of reception)
Error detection	Overrun error (2) This error occurs if the serial interface starts receiving the next unit of data before reading the UiRB register and receiving the seventh bit of the next unit of data
Selectable functions	• CLK polarity selection Data input/output can be selected to occur synchronously with the rising or falling edge of the transmit/receive clock • LSB first, MSB first selection Whether to start transmitting/receiving the data from bit 0 or from bit 7 can be selected • Continuous receive mode selection Reception is enabled immediately by reading the UiRB register • Switching serial data logic This function inverts the logic value of the transmit/receive data • Transmit/receive clock output from multiple pins selection (UART1) Two pins are set as UART1 transmit/receive clock pins. Output pin can be selected from them by a program. • Separate $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ pins (UART0) $\overline{\text{CTS0}}$ and $\overline{\text{RTS0}}$ are input/output from separate pins.

i = 0 to 2, 5 to 7

Notes:

1. These requirements do not have to be set in any particular order. If transmission/reception is started while an external clock is selected and the TXEPT bit in the UiC0 register is 1 (no data present in transmit register), meet the last requirement at either of the following timings:
   - The CKPOL bit in the UiC0 register is 0 (transmit data is output at the falling edge of transmit/receive clock and receive data is input at the rising edge) and the external clock is high.
   - The CKPOL bit is 1 (transmit data is output at the rising edge of transmit/receive clock and receive data is input at the falling edge) and the external clock is low.
2. If an overrun error occurs, the receive data of the UiRB register will be undefined. The IR bit in the SiRIC register remains unchanged.

Table 23.6 lists Pin Functions in Clock Synchronous Serial I/O Mode (Multiple Transmit/Receive Clock Output Pin Function Not Selected). Table 23.7 lists P6_4 Pin Functions in Clock Synchronous Serial I/O Mode.

Note that for a period from when UARTi operating mode is selected to when transmission starts, the TXDi pin outputs a high-level signal. (If N-channel open drain output is selected, this pin is high-impedance.)

Table 23.6 Pin Functions in Clock Synchronous Serial I/O Mode (Multiple Transmit/Receive Clock Output Pin Function Not Selected)

Pin Name	I/O	Function	Method of Selection
TXDi	Output	Serial data output	(Outputs dummy data only when receiving)
RXDi	Input	Serial data input	Set the port direction bit sharing pin to 0.
	Input	Input port	Set the port direction bit sharing pin to 0. (can be used as an input port only when transmitting)
CLKi	Output	Transmit/receive clock output	The CKDIR bit in the UiMR register = 0
	Input	Transmit/receive clock input	The CKDIR bit in the UiMR register = 1 Set the port direction bit sharing pin to 0.
$\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$	Input	$\overline{\text{CTS}}$ input	The CRD bit in the UiC0 register = 0 The CRS bit in the UiC0 register = 0 Set the port direction bit sharing pin to 0.
	Output	$\overline{\text{RTS}}$ output	The CRD bit in the UiC0 register = 0 The CRS bit in the UiC0 register = 1
	I/O	I/O port	The CRD bit in the UiC0 register = 1

i = 0 to 2, 5 to 7

Table 23.7 P6_4 Pin Functions in Clock Synchronous Serial I/O Mode

Pin Function	Bit Set Value					
	U1C0 register		UCON register			PD6 register
	CRD	CRS	RCSP	CLKMD1	CLKMD0	PD6_4
P6_4	1	-	0	0	-	Input: 0, Output: 1
$\overline{\text{CTS1}}$	0	0	0	0	-	0
$\overline{\text{RTS1}}$	0	1	0	0	-	-
$\overline{\text{CTS0}}$ (1)	0	0	1	0	-	0
CLKS1	-	-	-	1 (2)	1	-

- indicates either 0 or 1

Notes:

1. In addition to these settings, set the CRD bit in the U0C0 register to 0 ($\overline{\text{CTS0}}$/$\overline{\text{RTS0}}$ enabled) and the CRS bit in the U0C0 register to 1 ($\overline{\text{RTS0}}$ selected).
2. When the CLKMD1 bit is 1 and the CLKMD0 bit is 0, the following logic levels are output:
   - High if the CLKPOL bit in the U1C0 register is 0
   - Low if the CLKPOL bit in the U1C0 register is 1

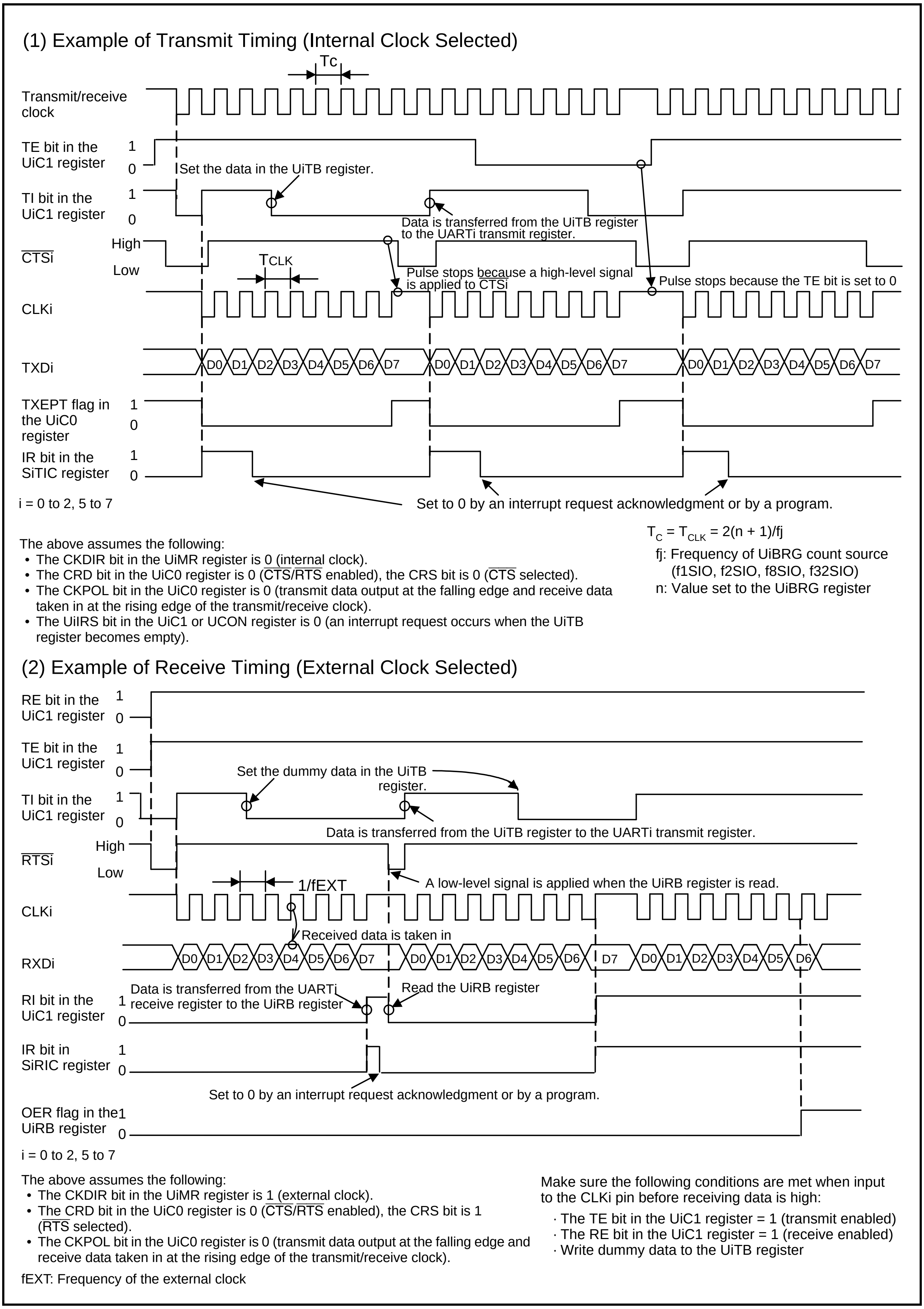
Table 23.8 Registers Used and Settings in Clock Synchronous Serial I/O Mode [1]

Register	Bits	Function
UCLKSEL0	OCOSEL0	Select clock prior to division for UART0 to UART2.
	OCOSEL1	Select clock prior to division for UART5 to UART7.
PCLKR	PCLK1	Select the count source for the UiBRG register.
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.
UiTB	0 to 7	Set transmission data.
	8	- (does not need to be set) If necessary, set to 0.
UiRB	0 to 7	Reception data can be read.
	8, 11, 13 to 15	When read, the read value is undefined.
	OER	Overrun error flag
UiBRG	0 to 7	Set bit rate.
UiMR	SMD2 to SMD0	Set to 001b.
	CKDIR	Select internal clock or external clock.
	4 to 6	Set to 0.
	IOPOL	Set to 0.
UiC0	CLK1 to CLK0	Select the count source for the UiBRG register.
	CRS	If $\overline{\text{CTS}}$ or $\overline{\text{RTS}}$ is used, select which function to use.
	TXEPT	Transmit register empty flag
	CRD	Enable or disable the $\overline{\text{CTS}}$ or $\overline{\text{RTS}}$ function.
	NCH	Select TXDi pin output mode. [2]
	CKPOL	Select the transmit/receive clock polarity.
	UFORM	Select LSB first or MSB first.
UiC1	TE	Set to 1 to enable transmission/reception.
	TI	Transmit buffer empty flag
	RE	Set to 1 to enable reception.
	RI	Reception complete flag
	UjIRS	Select source of UARTj transmit interrupt.
	UjRRM	Set to 1 to use continuous receive mode.
	UiLCH	Set to 1 to use inverted data logic.
	UiERE	Set to 0.
UiSMR	0 to 7	Set to 0.
UiSMR2	0 to 7	Set to 0.
UiSMR3	0 to 2	Set to 0.
	NODC	Select clock output mode.
	4 to 7	Set to 0.
UiSMR4	0 to 7	Set to 0.
UCON	U0IRS	Select source of UART0 transmit interrupt.
	U1IRS	Select source of UART1 transmit interrupt.
	U0RRM	Set to 1 to use continuous receive mode.
	U1RRM	Set to 1 to use continuous receive mode.
	CLKMD0	Select the transmit/receive clock output pin when CLKMD1 is 1.
	CLKMD1	Set to 1 to output UART1 transmit/receive clock from two pins.
	RCSP	Set to 1 to separate the $\overline{\text{CTS0}}$/$\overline{\text{RTS}}$ signal of UART0.
	7	Set to 0.

i = 0 to 2, 5 to 7; j = 2, 5 to 7

Notes:

1. This table does not describe a procedure.
2. The TXD2 pin is N-channel open drain output. Nothing is assigned to the NCH bit in the U2C0 register. If necessary, set it to 0.



(1) Example of Transmit Timing (Internal Clock Selected)

Tc
Transmit/receive clock
TE bit in the UiC1 register
1
0
Set the data in the UiTB register.
TI bit in the UiC1 register
1
0
Data is transferred from the UiTB register to the UARTi transmit register.
CTSi
High
Low
TCLK
Pulse stops because a high-level signal is applied to CTSi
Pulse stops because the TE bit is set to 0
CLKi
TXDi
D0 D1 D2 D3 D4 D5 D6 D7
TXEPT flag in the UiC0 register
1
0
IR bit in the SiTIC register
1
0
Set to 0 by an interrupt request acknowledgment or by a program.

i = 0 to 2, 5 to 7

$T_C = T_{CLK} = 2(n + 1)/fj$

fj: Frequency of UiBRG count source (f1SIO, f2SIO, f8SIO, f32SIO)
n: Value set to the UiBRG register

The above assumes the following:

- The CKDIR bit in the UiMR register is 0 (internal clock).
- The CRD bit in the UiC0 register is 0 (CTS/RTS enabled), the CRS bit is 0 (CTS selected).
- The CKPOL bit in the UiC0 register is 0 (transmit data output at the falling edge and receive data taken in at the rising edge of the transmit/receive clock).
- The UiIRS bit in the UiC1 or UCON register is 0 (an interrupt request occurs when the UiTB register becomes empty).

(2) Example of Receive Timing (External Clock Selected)

RE bit in the UiC1 register
1
0
TE bit in the UiC1 register
1
0
Set the dummy data in the UiTB register.
TI bit in the UiC1 register
1
0
Data is transferred from the UiTB register to the UARTi transmit register.
RTSi
High
Low
1/fEXT
A low-level signal is applied when the UiRB register is read.
CLKi
Received data is taken in
RXDi
D0 D1 D2 D3 D4 D5 D6 D7
Data is transferred from the UARTi receive register to the UiRB register
Read the UiRB register
RI bit in the UiC1 register
1
0
IR bit in SiRIC register
1
0
Set to 0 by an interrupt request acknowledgment or by a program.
OER flag in the UiRB register
1
0

i = 0 to 2, 5 to 7

The above assumes the following:

- The CKDIR bit in the UiMR register is 1 (external clock).
- The CRD bit in the UiC0 register is 0 (CTS/RTS enabled), the CRS bit is 1 (RTS selected).
- The CKPOL bit in the UiC0 register is 0 (transmit data output at the falling edge and receive data taken in at the rising edge of the transmit/receive clock).

fEXT: Frequency of the external clock

Make sure the following conditions are met when input to the CLKi pin before receiving data is high:

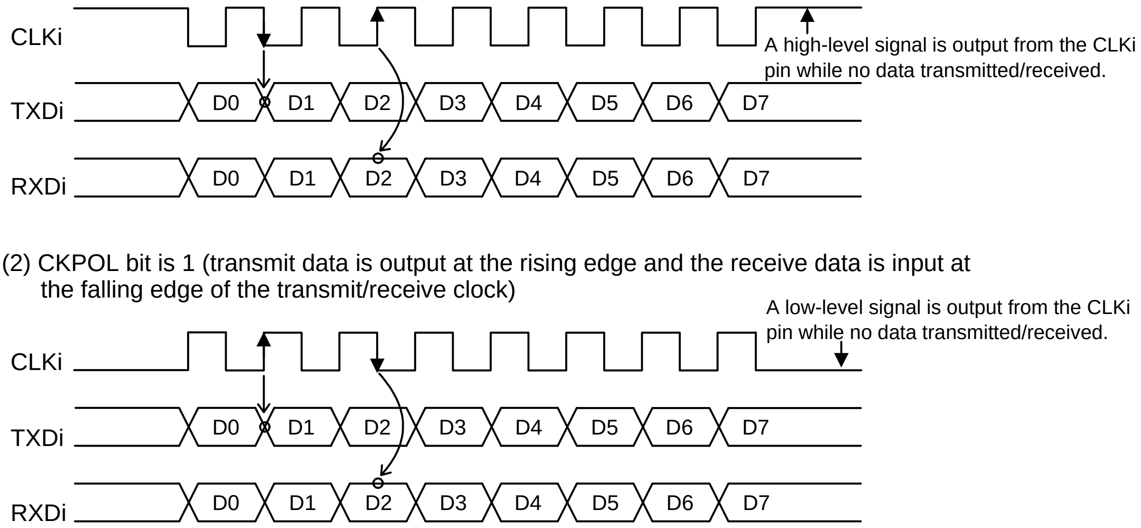
· The TE bit in the UiC1 register = 1 (transmit enabled)
· The RE bit in the UiC1 register = 1 (receive enabled)
· Write dummy data to the UiTB register

Figure 23.5 Transmit and Receive Operation during Clock Synchronous Serial I/O Mode

23.3.1.1 CLK Polarity Select Function

Use the CKPOL bit in the UiC0 register (i = 0 to 2, 5 to 7) to select the transmit/receive clock polarity. Figure 23.6 shows the Transmit/Receive Clock Polarity.

(1) CKPOL bit in the UiC0 register is 0 (transmit data is output at the falling edge and the receive data is input at the rising edge of the transmit/receive clock)


CLKi
TXDi
RXDi
D0
D1
D2
D3
D4
D5
D6
D7
A high-level signal is output from the CLKi pin while no data transmitted/received.
A low-level signal is output from the CLKi pin while no data transmitted/received.

(2) CKPOL bit is 1 (transmit data is output at the rising edge and the receive data is input at the falling edge of the transmit/receive clock)

i = 0 to 2, 5 to 7

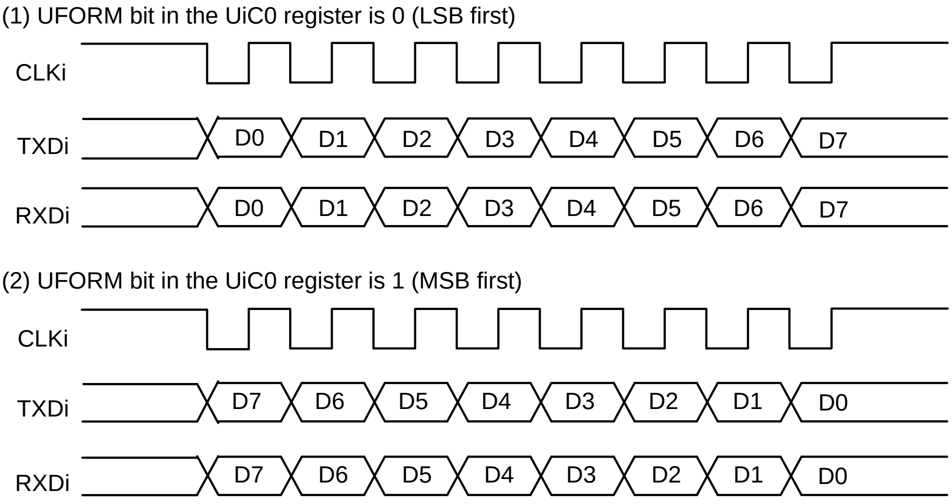
The above assumes the following:

- The CKDIR bit in the UiMR register is 0 (internal clock).
- The UFORM bit in the UiC0 register is 0 (LSB first).
- The UiLCH bit in the UiC1 register is 0 (not inverted).

Figure 23.6 Transmit/Receive Clock Polarity

23.3.1.2 LSB First/MSB First Select Function

Use the UFORM bit in the UiC0 register (i = 0 to 2, 5 to 7) to select the bit order. Figure 23.7 shows the Bit Order.



i = 0 to 2, 5 to 7

The above assumes the following:
- The CKPOL bit in the UiC0 register is 0 (transmit data is output at the falling edge and the receive data is input at the rising edge of the transmit/receive clock).
- The UiLCH bit in the UiC1 register is 0 (not inverted).

Figure 23.7 Bit Order

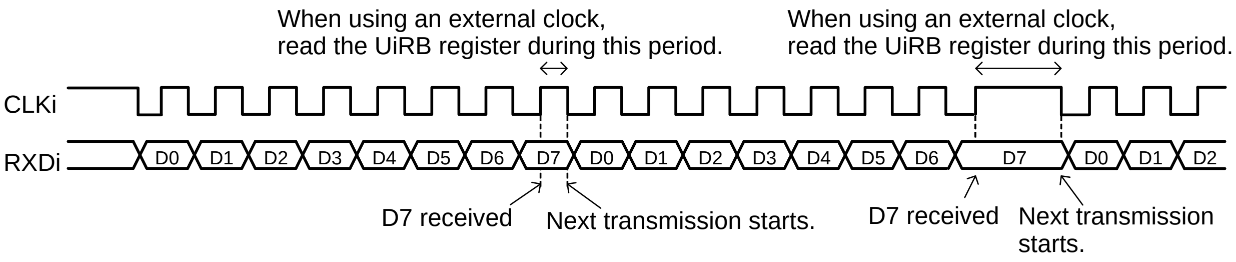
23.3.1.3 Continuous Receive Mode

In continuous receive mode, the receive operation is enabled when the receive buffer register is read. Thus, a dummy write to the transmit buffer register to enable the receive operation is unnecessary in this mode. However, a dummy read of the receive buffer register is required when start receiving.

When setting the UiRRM bit in the UiC1 or UCON register (i = 0 to 2, 5 to 7) to 1 (continuous receive mode), the TI bit in the UiC1 register is set to 0 (data present in the UiTB register) by reading the UiRB register. When the UiRRM bit is 1, do not write dummy data to the UiTB register by a program.

When using an external clock, read the UiRB register between receiving the eighth bit of data and starting the next transmission.

Figure 23.8 shows Operation Example in Continuous Receive Mode.


When using an external clock,
read the UiRB register during this period.
When using an external clock,
read the UiRB register during this period.
CLKi
RXDi
D0 D1 D2 D3 D4 D5 D6 D7 D0 D1 D2 D3 D4 D5 D6 D7 D0 D1 D2
D7 received
Next transmission starts.
D7 received
Next transmission starts.

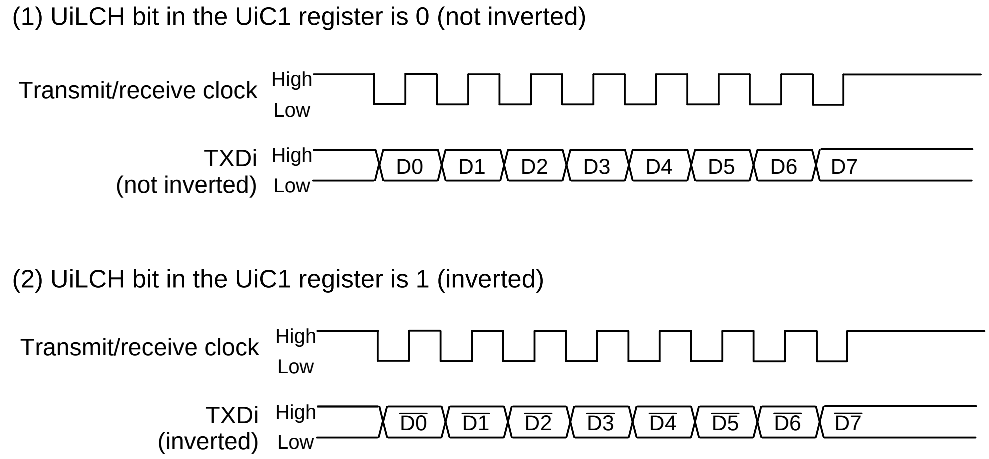
i = 0 to 2, 5 to 7

The above diagram assumes the following:
- The CKPOL bit in the UiC0 register is 0 (receive data input at the rising edge of the transmit/receive clock).
- The UFORM bit in the UiC0 register is 0 (LSB first).
- The CKDIR bit in the UiMR register is 1 (external clock).

Figure 23.8 Operation Example in Continuous Receive Mode

23.3.1.4 Serial Data Logic Switching Function

When the UiLCH bit in the UiC1 register (i = 0 to 2, 5 to 7) is 1 (inverted), the data written to the UiTB register has its logic inverted before being transmitted. Similarly, the inverted data has its logic inverted when read from the UiRB register. Figure 23.9 shows Serial Data Logic.



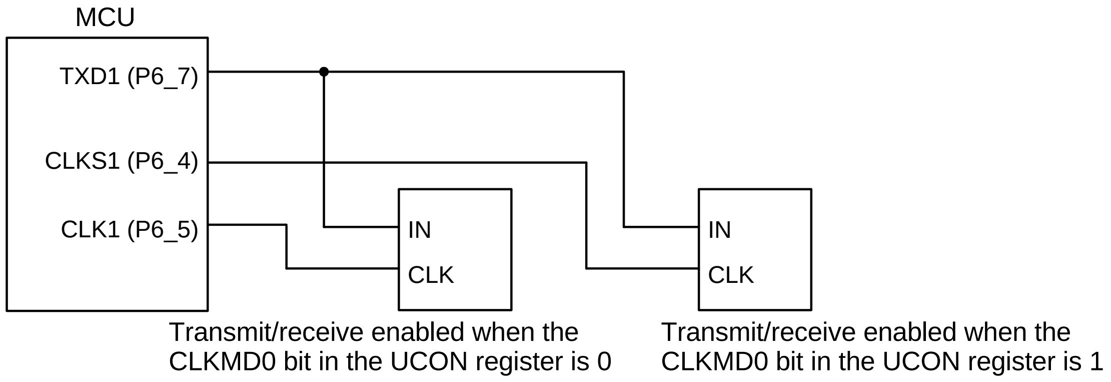
i = 0 to 2, 5 to 7

The above assumes the following:
- The CKPOL bit in the UiC0 register is 0 (transmit data output at the falling edge of the transmit/receive clock).
- The UFORM bit in the UiC0 register is 0 (LSB first).

Figure 23.9 Serial Data Logic

23.3.1.5 Transmit/Receive Clock Output from Multiple Pins (UART1)

Use bits CLKMD1 to CLKMD0 in the UCON register to select one of the two transmit/receive clock output pins (see Figure 23.10). This function can be used when the selected transmit/receive clock for UART1 is an internal clock.



MCU
TXD1 (P6_7)
CLKS1 (P6_4)
CLK1 (P6_5)
IN
CLK
IN
CLK
Transmit/receive enabled when the CLKMD0 bit in the UCON register is 0
Transmit/receive enabled when the CLKMD0 bit in the UCON register is 1

The above diagram assumes the following:
- The CKDIR bit in the U1MR register is 0 (internal clock).
- The CLKMD1 bit in the UCON register is 1 (transmit/receive clock output from multiple pins).

Figure 23.10 Transmit/Receive Clock Output from Multiple Pins

23.3.1.6 CTS/RTS Function

The CTS function is used to start transmit/receive operation when a low signal is applied to the CTSi/RTSi (i = 0 to 2, 5 to 7) pin. Transmit/receive operation begins when input to the CTSi/RTSi pin becomes low. If the low signal is switched to high during a transmit or receive operation, the operation stops before the next data.

For the RTS function, the CTSi/RTSi pin outputs a low signal when the MCU is ready to receive. The output level becomes high at the detection of the start bit.

See Table 23.6 "Pin Functions in Clock Synchronous Serial I/O Mode (Multiple Transmit/Receive Clock Output Pin Function Not Selected)".

23.3.1.7 CTS/RTS Separate Function (UART0)

This function separates CTS0/RTS0, outputs RTS0 from the P6_0 pin, and inputs CTS0 from the P6_4 pin. To use this function, set the register bits as follows:

- The CRD bit in the U0C0 register is 0 (enable CTS/RTS of UART0)
- The CRS bit in the U0C0 register is 1 (output RTS of UART0)
- The CRD bit in the U1C0 register is 0 (enable CTS/RTS of UART1)
- The CRS bit in the U1C0 register is 0 (input CTS of UART1)
- The RCSP bit in the UCON register is 1 (inputs CTS0 from the P6_4 pin)
- The CLKMD1 bit in the UCON register is 0 (CLKS1 not used)

Note that when using the CTS/RTS separate function, CTS/RTS of UART1 function cannot be used.

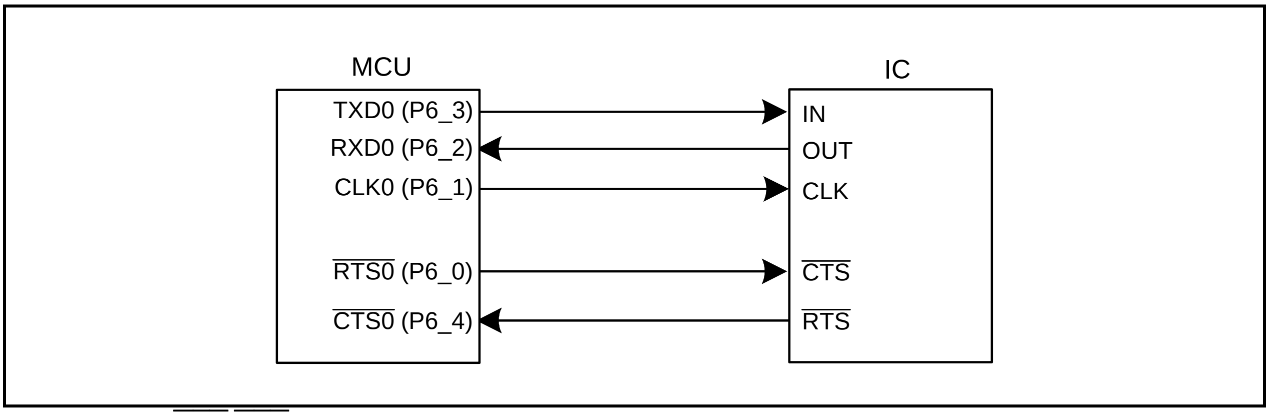


Figure 23.11 CTS/RTS Separate Function

23.3.1.8 Processing When Terminating Communication or When an Error Occurs

When communication is terminated in clock synchronous serial I/O mode, or when a communication error occurs, use the following procedure to reset communication:

(1) Set the TE bit in the UiC1 (i = 0 to 2, 5 to 7) register to 0 (transmission disabled) and the RE bit to 0 (reception disabled).
(2) Set bits SMD2 to SMD0 in the UiMR register to 000b (serial interface disabled).
(3) Set bits SMD2 to SMD0 in the UiMR register to 001b (clock synchronous serial I/O mode).
(4) Set the TE bit in the UiC1 register to 1 (transmission enabled) and the RE bit to 1 (reception enabled).

23.3.2 Clock Asynchronous Serial I/O (UART) Mode

The UART mode allows data to be transmitted/received after setting the desired bit rate and bit order. Table 23.9 lists the UART Mode Specifications.

Table 23.9 UART Mode Specifications

Item	Specification
Data format	• Character bit: selectable from 7, 8, or 9 bits • Start bit: 1 bit • Parity bit: selectable from odd, even, or none • Stop bit: selectable from 1 bit or 2 bits
Transmit/receive clock	• The CKDIR bit in the UiMR register = 0 (internal clock): $\frac{fj}{16(n+1)}$ fj = f1SIO, f2SIO, f8SIO, f32SIO n: Setting value of UiBRG register 00h to FFh • CKDIR bit = 1 (external clock): $\frac{fEXT}{16(n+1)}$ fEXT: Input from CLKi pin n: Setting value of UiBRG register 00h to FFh
Transmit/receive control	Selectable from $\overline{\text{CTS}}$, $\overline{\text{RTS}}$, or $\overline{\text{CTS}}/\overline{\text{RTS}}$ function disabled
Transmission start conditions	To start transmission, satisfy the following requirements: • The TE bit in the UiC1 register is 1 (transmission enabled) • The TI bit in the UiC1 register is 0 (data present in the UiTB register) • If $\overline{\text{CTS}}$ function is selected, input on the $\overline{\text{CTSi}}$ pin = low
Reception start conditions	To start reception, satisfy the following requirements: • The RE bit in the UiC1 register is 1 (reception enabled) • Start bit detection
Interrupt request generation timing	For transmission, one of the following conditions can be selected: • The UiIRS bit in the UiC1 or UCON register is 0 (transmit buffer empty): When transferring data from the UiTB register to the UARTi transmit register (at start of transmission) • The UiIRS bit is 1 (transmission completed): When the serial interface completes sending data from the UARTi transmit register For reception: • When transferring data from the UARTi receive register to the UiRB register (at completion of reception)
Error detection	• Overrun error (1) This error occurs if the serial interface starts receiving the next unit of data before reading the UiRB register and receives the bit before the last stop bit of the next unit of data. • Framing error This error occurs when the number of stop bits set is not detected. • Parity error This error occurs when the number of 1's of the parity bit and character bit does not match the set value of the PRY bit in the UiMR register. • Error sum flag This flag becomes 1 when any of the overrun, framing, or parity errors occur.
Selectable functions	• LSB first, MSB first selection Whether to start transmitting/receiving the data from bit 0 or from bit 7 can be selected. • Serial data logic switch This function inverts the logic of the transmit/receive data. The start and stop bits are not inverted. • TXD, RXD I/O polarity switch This function inverts the polarities of the TXD pin output and RXD pin input. The logic levels of all I/O data are inverted. • Separate $\overline{\text{CTS}}/\overline{\text{RTS}}$ pins (UART0) $\overline{\text{CTS0}}$ and $\overline{\text{RTS0}}$ are input/output from separate pins.

i = 0 to 2, 5 to 7

Note:

1. If an overrun error occurs, the receive data of the UiRB register will be undefined. The IR bit in the SiRIC register remains unchanged.

Table 23.10 lists I/O Pin Functions in UART Mode. Table 23.11 lists the P6_4 Pin Functions in UART Mode. Note that for a period from when the UARTi operating mode is selected to when transmission starts, the TXDi pin outputs a high-level signal. (If N-channel open drain output is selected, this pin becomes high-impedance.)

Table 23.10 I/O Pin Functions in UART Mode

Pin Name	I/O	Function	Method of Selection
TXDi	Output	Serial data output	(High-level output only when receiving.)
RXDi	Input	Serial data input	Set the port direction bit sharing pin to 0.
	Input	Input port	Set the port direction bit sharing pin to 0. (can be used as an input port only when transmitting.)
CLKi	I/O	Input/output port	The CKDIR bit in the UiMR register = 0
	Input	Transmit/receive clock input	The CKDIR bit in the UiMR register = 1 Set the port direction bit sharing pin to 0.
$\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$	Input	$\overline{\text{CTS}}$ input	The CRD bit in the UiC0 register = 0 The CRS bit in the UiC0 register = 0 Set the port direction bit sharing pin to 0.
	Output	$\overline{\text{RTS}}$ output	The CRD bit in the UiC0 register = 0 The CRS bit in the UiC0 register = 1
	I/O	I/O port	The CRD bit in the UiC0 register = 1

i = 0 to 2, 5 to 7

Table 23.11 P6_4 Pin Functions in UART Mode

Pin Function	Bit Set Value				
	U1C0 register		UCON register		PD6 register
	CRD	CRS	RCSP	CLKMD1	PD6_4
P6_4	1	-	0	0	Input: 0, Output: 1
$\overline{\text{CTS1}}$	0	0	0	0	0
$\overline{\text{RTS1}}$	0	1	0	0	-
$\overline{\text{CTS0}}$ (1)	0	0	1	0	0

– indicates either 0 or 1.

Note:

1. In addition to these settings, set the CRD bit in the U0C0 register to 0 ($\overline{\text{CTS0}}$/$\overline{\text{RTS0}}$ enabled) and the CRS bit in the U0C0 register to 1 ($\overline{\text{RTS0}}$ selected).

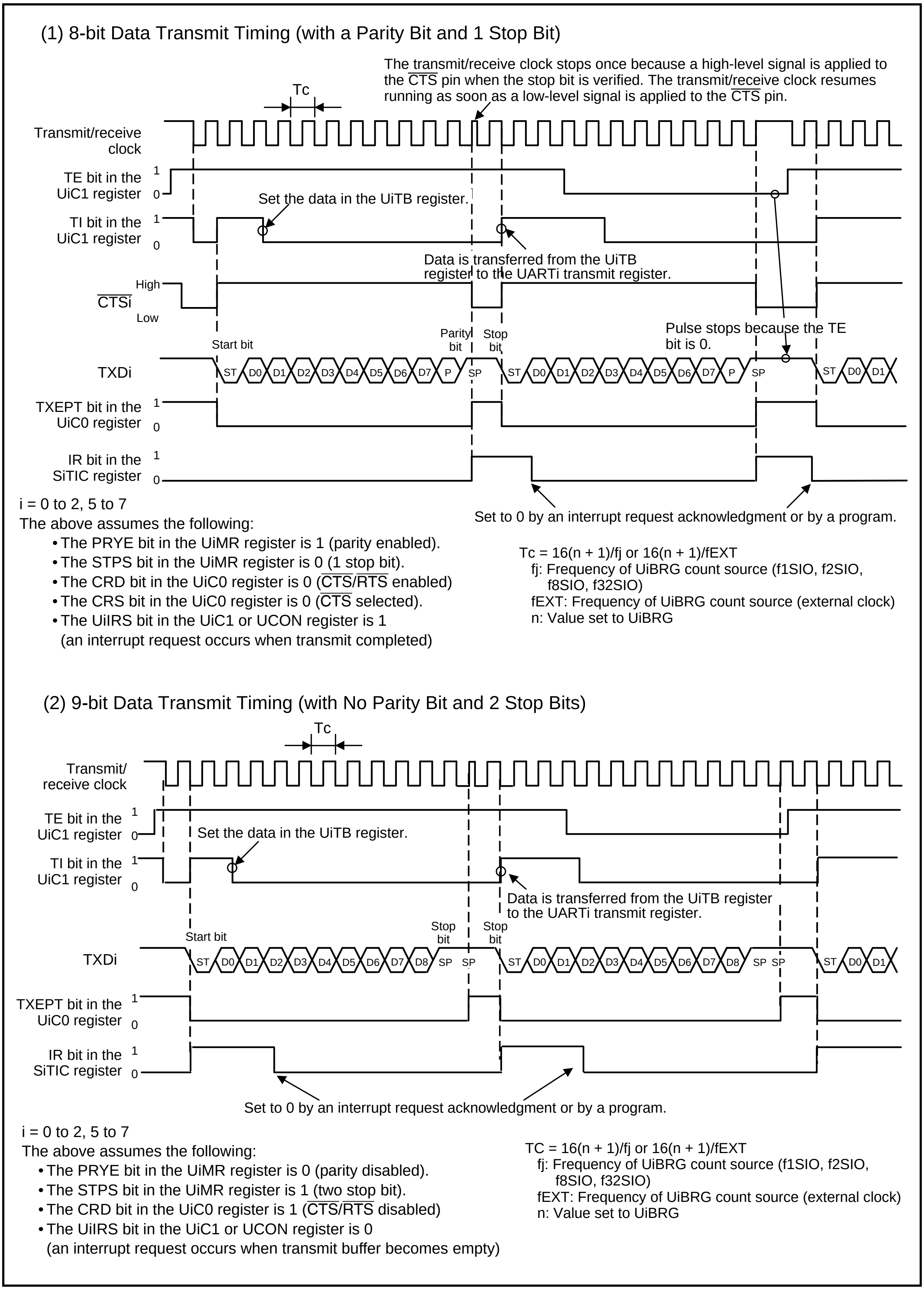
Table 23.12 Registers Used and Settings in UART Mode (1)

Register	Bits	Function
UCLKSEL0	OCOSEL0	Select clock prior to division for UART0 to UART2.
	OCOSEL1	Select clock prior to division for UART5 to UART7.
PCLKR	PCLK1	Select the count source for the UiBRG register.
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.
UiTB	0 to 8	Set transmission data. (2)
UiRB	0 to 8	Reception data can be read. (2, 4)
	OER, FER, PER, SUM	Error flag
	11	When read, the read value is undefined.
UiBRG	0 to 7	Set bit rate.
UiMR	SMD2 to SMD0	Set to 100b when character bit length is 7 bits.
		Set to 101b when character bit length is 8 bits.
		Set to 110b when character bit length is 9 bits.
	CKDIR	Select the internal clock or external clock.
	STPS	Select number of stop bits.
	PRY, PRYE	Select whether parity is included and whether odd or even.
	IOPOL	Select the TXD/RXD input/output polarity.
UiC0	CLK0, CLK1	Select the count source for the UiBRG register.
	CRS	If $\overline{\mathrm{CTS}}$ or $\overline{\mathrm{RTS}}$ is used, select which function to use.
	TXEPT	Transmit register empty flag
	CRD	Enable or disable the $\overline{\mathrm{CTS}}$ or $\overline{\mathrm{RTS}}$ function.
	NCH	Select TXDi pin output mode. (3)
	CKPOL	Set to 0.
	UFORM	LSB first or MSB first can be selected when character bit length is 8 bits. Set to 0 when character bit length is 7 or 9 bits.
UiC1	TE	Set to 1 to enable transmission.
	TI	Transmit buffer empty flag
	RE	Set to 1 to enable reception.
	RI	Reception complete flag
	UjIRS	Select source of UARTj transmit interrupt.
	UjRRM	Set to 0.
	UiLCH	Set to 1 to use reversed data logic.
	UiERE	Set to 0.
UiSMR	0 to 7	Set to 0.
UiSMR2	0 to 7	Set to 0.
UiSMR3	0 to 7	Set to 0.
UiSMR4	0 to 7	Set to 0.
UCON	U0IRS	Select source of UART0 transmit interrupt.
	U1IRS	Select source of UART1 transmit interrupt.
	U0RRM	Set to 0.
	U1RRM	Set to 0.
	CLKMD0	Disabled because CLKMD1 is 0
	CLKMD1	Set to 0.
	RCSP	Set to 1 to input $\overline{\mathrm{CTS0}}$ signal of UART0 from the P6_4 pin.
	7	Set to 0.

i = 0 to 2, 5 to 7; j = 2, 5 to 7

Notes:

1. This table does not describe a procedure.
2. The bits used for transmit/receive data are as follows: Bits 0 to 6 when character bit length is 7 bits; bits 0 to 7 when character bit length is 8 bits; bits 0 to 8 when character bit length is 9 bits.
3. The TXD2 pin is N-channel open drain output. Nothing is assigned to the NCH bit in the U2C0 register. If necessary, set it to 0.
4. The values of bits 7 and 8 are undefined when character bit length is 7 bits.
   The values of bit 8 is undefined when character bit length is 8 bits.


(1) 8-bit Data Transmit Timing (with a Parity Bit and 1 Stop Bit)

Tc
The transmit/receive clock stops once because a high-level signal is applied to the CTS pin when the stop bit is verified. The transmit/receive clock resumes running as soon as a low-level signal is applied to the CTS pin.
Transmit/receive clock
TE bit in the UiC1 register
1
0
Set the data in the UiTB register.
TI bit in the UiC1 register
1
0
Data is transferred from the UiTB register to the UARTi transmit register.
CTSi
High
Low
Start bit
Parity bit
Stop bit
Pulse stops because the TE bit is 0.
TXDi
ST D0 D1 D2 D3 D4 D5 D6 D7 P SP ST D0 D1 D2 D3 D4 D5 D6 D7 P SP ST D0 D1
TXEPT bit in the UiC0 register
1
0
IR bit in the SiTIC register
1
0
Set to 0 by an interrupt request acknowledgment or by a program.

i = 0 to 2, 5 to 7

The above assumes the following:

- The PRYE bit in the UiMR register is 1 (parity enabled).
- The STPS bit in the UiMR register is 0 (1 stop bit).
- The CRD bit in the UiC0 register is 0 (CTS/RTS enabled)
- The CRS bit in the UiC0 register is 0 (CTS selected).
- The UiIRS bit in the UiC1 or UCON register is 1 (an interrupt request occurs when transmit completed)

Tc = 16(n + 1)/fj or 16(n + 1)/fEXT
fj: Frequency of UiBRG count source (f1SIO, f2SIO, f8SIO, f32SIO)
fEXT: Frequency of UiBRG count source (external clock)
n: Value set to UiBRG

(2) 9-bit Data Transmit Timing (with No Parity Bit and 2 Stop Bits)

Tc
Transmit/receive clock
TE bit in the UiC1 register
1
0
Set the data in the UiTB register.
TI bit in the UiC1 register
1
0
Data is transferred from the UiTB register to the UARTi transmit register.
Start bit
Stop bit
Stop bit
TXDi
ST D0 D1 D2 D3 D4 D5 D6 D7 D8 SP SP ST D0 D1 D2 D3 D4 D5 D6 D7 D8 SP SP ST D0 D1
TXEPT bit in the UiC0 register
1
0
IR bit in the SiTIC register
1
0
Set to 0 by an interrupt request acknowledgment or by a program.

i = 0 to 2, 5 to 7

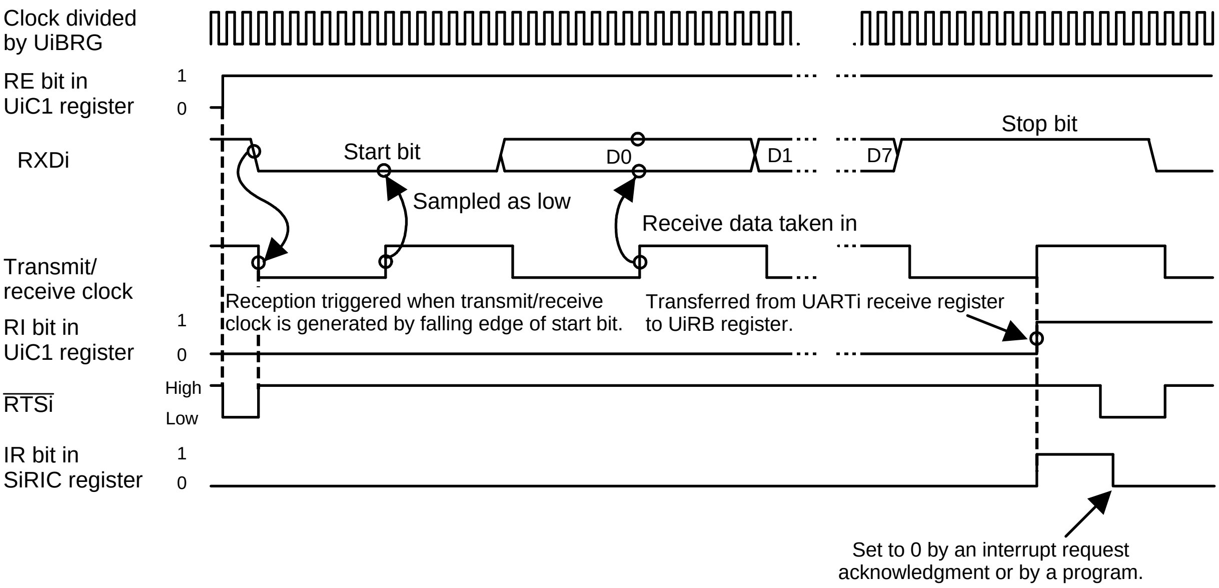
The above assumes the following:

- The PRYE bit in the UiMR register is 0 (parity disabled).
- The STPS bit in the UiMR register is 1 (two stop bit).
- The CRD bit in the UiC0 register is 1 (CTS/RTS disabled)
- The UiIRS bit in the UiC1 or UCON register is 0 (an interrupt request occurs when transmit buffer becomes empty)

TC = 16(n + 1)/fj or 16(n + 1)/fEXT
fj: Frequency of UiBRG count source (f1SIO, f2SIO, f8SIO, f32SIO)
fEXT: Frequency of UiBRG count source (external clock)
n: Value set to UiBRG

Figure 23.12 Transmit Timing in UART Mode

Example of Receive Timing When Character Bit Length is 8 Bits
(Parity Disabled, 1 Stop Bit)


Clock divided by UiBRG
RE bit in UiC1 register
1
0
RXDi
Start bit
D0
D1
D7
Stop bit
Sampled as low
Receive data taken in
Transmit/ receive clock
Reception triggered when transmit/receive clock is generated by falling edge of start bit.
Transferred from UARTi receive register to UiRB register.
RI bit in UiC1 register
1
0
RTSi
High
Low
IR bit in SiRIC register
1
0
Set to 0 by an interrupt request acknowledgment or by a program.

i = 0 to 2, 5 to 7

The above assumes the following:

- The PRYE bit in the UiMR register is 0 (parity disabled).
- The STPS bit in the UiMR register is 0 (1 stop bit).
- The CRD bit in the UiC0 register is 0 ($\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$ enabled)
- The CRS bit in the UiC0 register is 1 ($\overline{\text{RTSi}}$ selected)

Figure 23.13 Receive Timing in UART Mode

23.3.2.1 Bit Rate

In UART mode, the frequency set by the UiBRG register (i = 0 to 2, 5 to 7) divided by 16 becomes a bit rate.

The setting value (n) of the UiBRG register is calculated by the following formula:

$$n = \frac{fj}{\mathrm{bitrate(bps)} \times 16} - 1$$

fj = f1SIO, f2SIO, f8SIO, f32SIO

n = 00h to FFh

Table 23.13 lists Example Bit Rates and Settings.

Table 23.13 Example of Bit Rates and Settings [1]

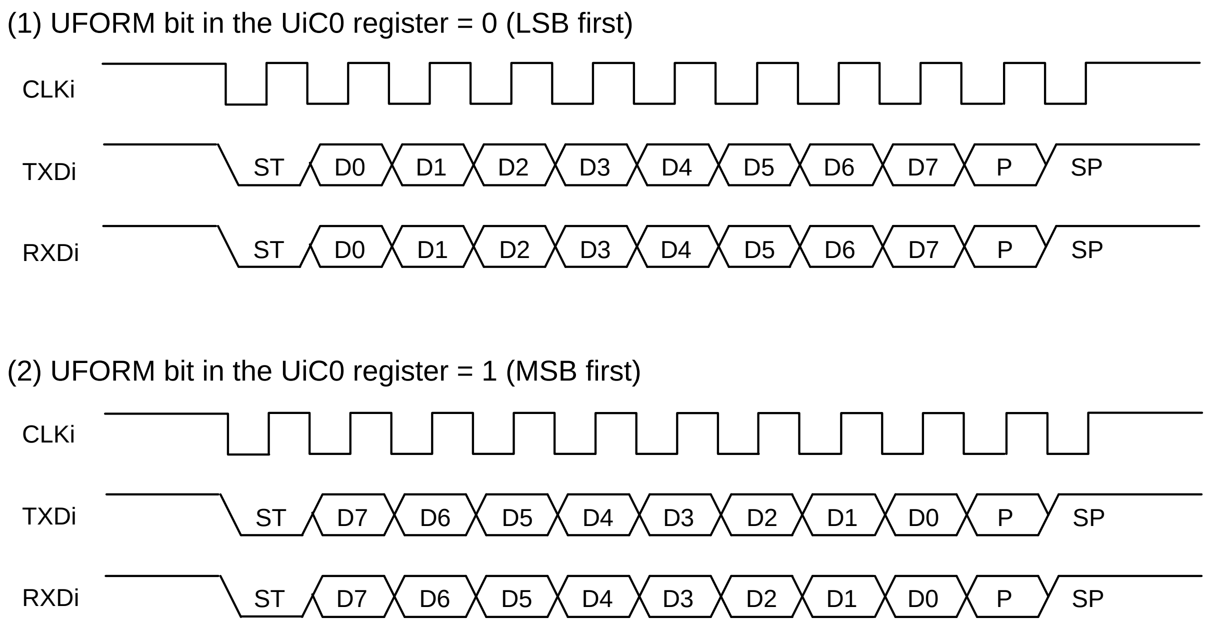
Bit Rate (bps)	Count Source of UiBRG	Peripheral Function Clock f1: 16 MHz		Peripheral Function Clock f1: 24 MHz	
		Set Value of UiBRG: n	Bit Rate (bps)	Set value of UiBRG: n	Bit Rate (bps)
1200	f8SIO	103 (67h)	1202	155 (9Bh)	1202
2400	f8SIO	51 (33h)	2404	77 (4Dh)	2404
4800	f8SIO	25 (19h)	4808	38 (26h)	4808
9600	f1SIO	103 (67h)	9615	155 (9Bh)	9615
14400	f1SIO	68 (44h)	14493	103 (67h)	14423
19200	f1SIO	51 (33h)	19231	77 (4Dh)	19231
28800	f1SIO	34 (22h)	28571	51 (33h)	28846
31250	f1SIO	31 (1Fh)	31250	47 (2Fh)	31250
38400	f1SIO	25 (19h)	38462	38 (26h)	38462
51200	f1SIO	19 (13h)	50000	28 (1Ch)	51724

Note:

1. Assumed that either the OCOSEL0 bit or OCOSEL1 bit in the UCLKSEL0 register is 0 (f1).

23.3.2.2 LSB First/MSB First Select Function

As shown in Figure 23.14, the bit order can be selected by setting the UFORM bit in the UiC0 register. This function is enabled when the character bit length is 8 bits.



(1) UFORM bit in the UiC0 register = 0 (LSB first)

(2) UFORM bit in the UiC0 register = 1 (MSB first)

CLKi
TXDi
ST D0 D1 D2 D3 D4 D5 D6 D7 P SP
RXDi
ST D0 D1 D2 D3 D4 D5 D6 D7 P SP
CLKi
TXDi
ST D7 D6 D5 D4 D3 D2 D1 D0 P SP
RXDi
ST D7 D6 D5 D4 D3 D2 D1 D0 P SP

i = 0 to 2, 5 to 7

The above assumes the following:

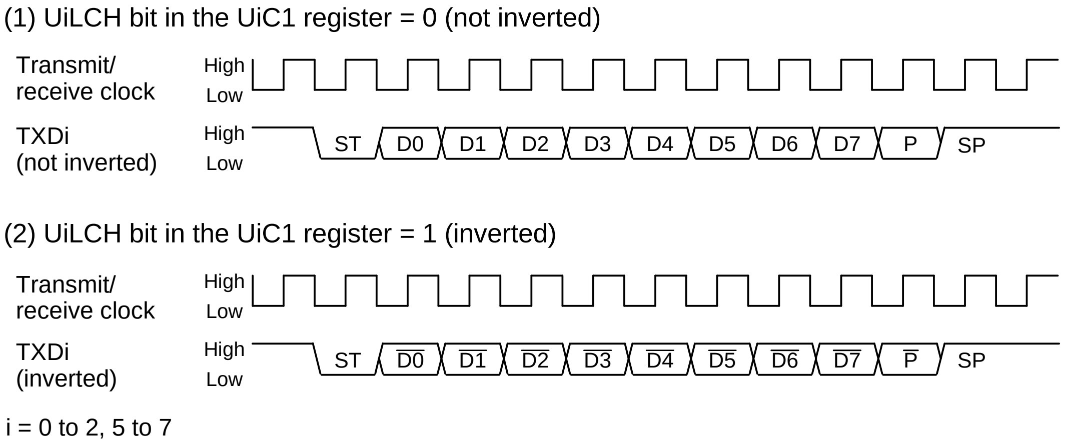
- The CKPOL bit in the UiC0 register is 0 (transmit data output at the falling edge and the receive data taken in at the rising edge of the transmit/receive clock).
- The UiLCH bit in the UiC1 register is 0 (not inverted).
- The STPS bit in the UiMR register is 0 (1 stop bit).
- The PRYE bit in the UiMR register is 1 (parity enabled).

ST: Start bit
P: Parity bit
SP: Stop bit

Figure 23.14 Bit Order

23.3.2.3 Serial Data Logic Switching Function

The logic of the data written to the UiTB register is inverted and then transmitted. Similarly, the inverted logic of the received data is read when the UiRB register is read.



The above assumes the following:

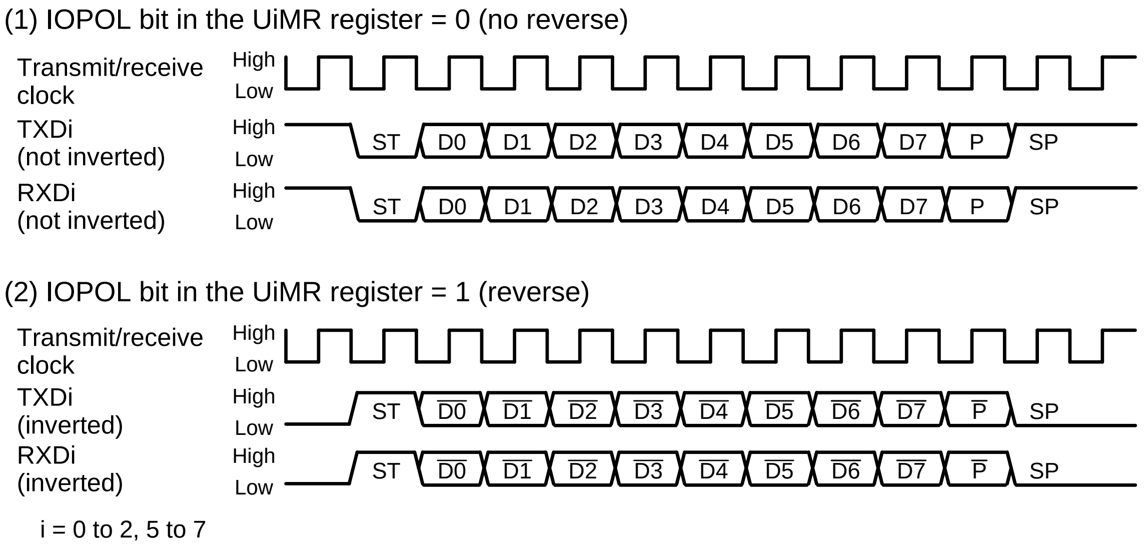
- The CKPOL bit in the UiC0 register is 0 (transmit data output at the falling edge of the transmit/receive clock).
- The UFORM bit in the UiC0 register is 0 (LSB first).
- The STPS bit in the UiMR register is 0 (1 stop bit).
- The PRYE bit in the UiMR register is 1 (parity enabled).
- The IOPOL bit in the UiMR register is 0 (TXD, RXD I/O not reversed).

ST: Start bit
P: Parity bit
SP: Stop bit

Figure 23.15 Serial Data Logic Switching

23.3.2.4 TXD and RXD I/O Polarity Reverse Function

This function reverses the polarities of the TXDi pin output and RXDi pin input. The logic levels of all I/O data (including bits for start, stop, and parity) are inverted.



The above assumes the following:

- The UFORM bit in the UiC0 register is 0 (LSB first).
- The STPS bit in the UiMR register is 0 (1 stop bit).
- The PRYE bit in the UiMR register is 1 (parity enabled).
- The UiLCH bit in the UiC1 register is 0 (serial data logic not inverted).

ST: Start bit
P: Parity bit
SP: Stop bit

Figure 23.16 TXD and RXD I/O Polarity Inversion

23.3.2.5 $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ Function

The $\overline{\text{CTS}}$ function is used to start transmit operation when a low signal is applied to the $\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$ (i = 0 to 2, 5 to 7) pin. Transmit operation begins when input to the $\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$ pin becomes low. If the input level is switched from low to high during transmit operation, the operation stops after the ongoing transmit/receive operation is completed.
When the $\overline{\text{RTS}}$ function is selected, the $\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$ pin outputs a low signal when the MCU is ready to receive. The output level becomes high when a start bit is detected.
See Table 23.10 “I/O Pin Functions in UART Mode”.

23.3.2.6 $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ Separate Function (UART0)

This function separates $\overline{\text{CTS0}}$ and $\overline{\text{RTS0}}$, outputs $\overline{\text{RTS0}}$ from the P6_0 pin, and inputs $\overline{\text{CTS0}}$ from the P6_4 pin. To use this function, set the register bits as follows:

- The CRD bit in the U0C0 register is 0 (enable $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ of UART0)
- The CRS bit in the U0C0 register is 1 (output $\overline{\text{RTS}}$ of UART0)
- The CRD bit in the U1C0 register is 0 (enable $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ of UART1)
- The CRS bit in the U1C0 register is 0 (input $\overline{\text{CTS}}$ of UART1)
- The RCSP bit in the UCON register is 1 (inputs $\overline{\text{CTS0}}$ from the P6_4 pin)
- The CLKMD1 bit in the UCON register is 0 (CLKS1 not used)

Note that when using the $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ separate function, $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ function of UART1 cannot be used.

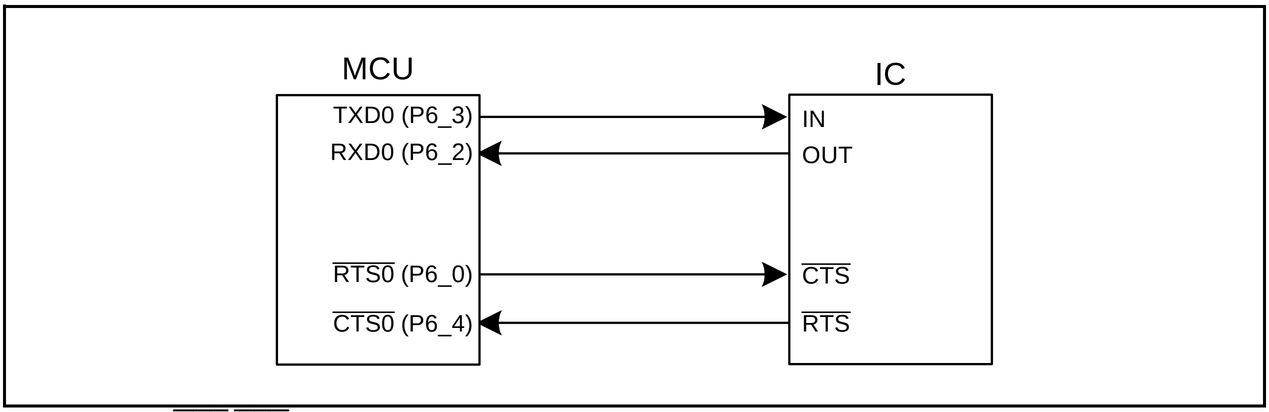


Figure 23.17 $\overline{\text{CTS}}$/$\overline{\text{RTS}}$ Separate Function

23.3.2.7 Processing When Terminating Communication or When an Error Occurs

If communication is terminated in UART mode, or a communication error occurs, use following procedure reset communication:

(1) Set the TE bit in the UiC1 (i = 0 to 2, 5 to 7) register to 0 (transmission disabled) and the RE bit to 0 (reception disabled).
(2) Set bits SMD2 to SMD0 in the UiMR register to 000b (serial interface disabled).
(3) Set bits SMD2 to SMD0 in the UiMR register to 100b (UART mode character bit length is 7 bits), 101b (UART mode character bit length is 8 bits), and 110b (UART mode character bit length is 9 bits).
(4) Set the TE bit in the UiC1 register to 1 (transmission enabled) and the RE bit to 1 (reception enabled).

23.3.3 Special Mode 1 (I^2C Mode)

I^2C mode is compatible with the simplified I^2C interface. Table 23.14 lists the I^2C Mode Specifications. Table 23.16 and Table 23.17 list the Registers Used and Settings in I^2C Mode. Table 23.18 lists the I^2C Mode Functions. Figure 23.18 shows the I^2C Mode Block Diagram.

As shown in Table 23.18, the MCU is placed in I^2C mode by setting the IICM bit in the UiSMR register to 1 and bits SMD2 to SMD0 in the UiMR register to 010b. Because SDAi transmit output has a delay circuit attached, SDAi output does not change state until SCLi goes low and remains stably low.

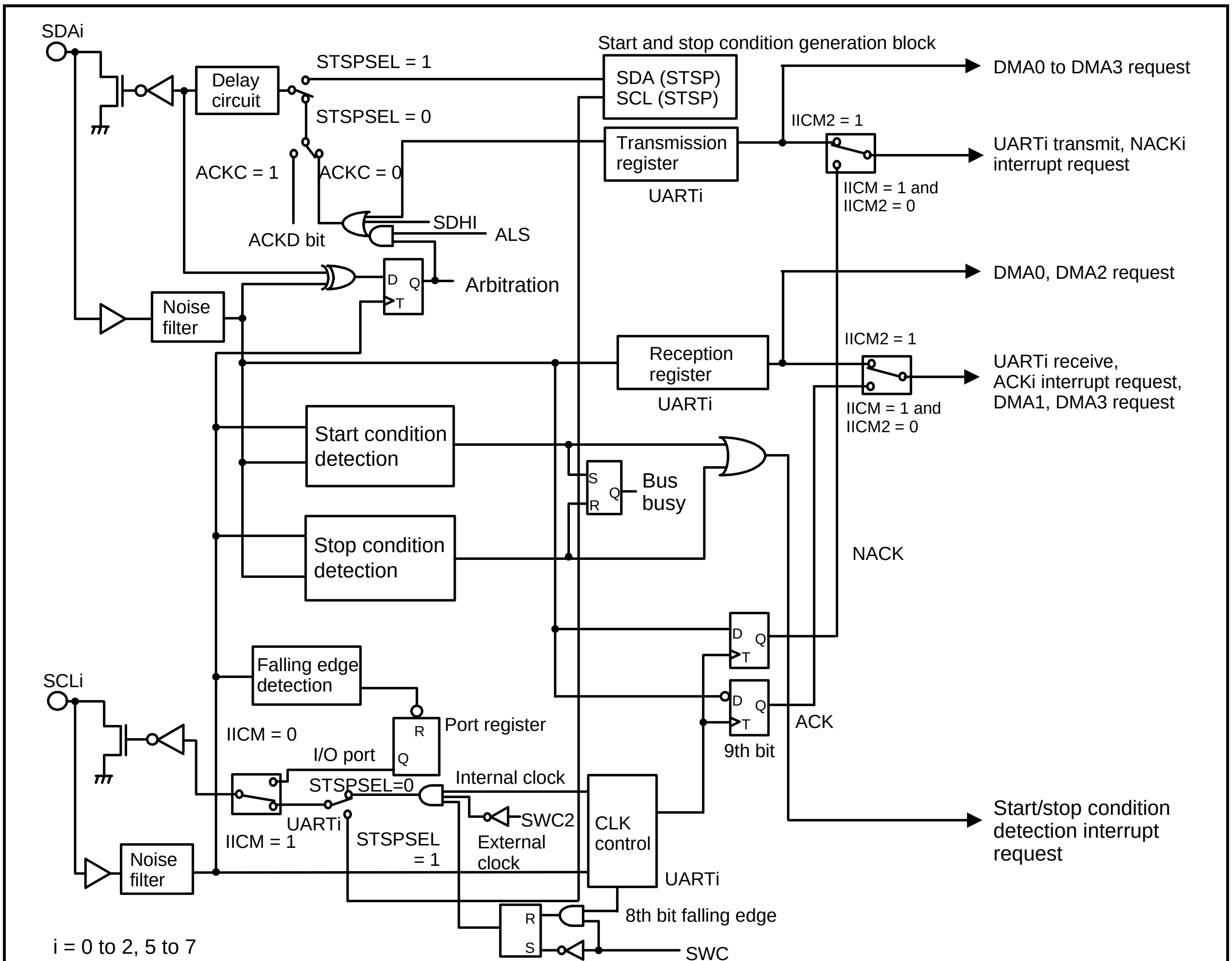
Table 23.14 I^2C Mode Specifications

Item	Specification
Data format	Character bit length: 8 bits
Transfer clock	• Master mode The CKDIR bit in the UiMR register is 0 (internal clock): fj / (2(n+1)) fj = f1SIO, f2SIO, f8SIO, f32SIO n = setting value of the UiBRG register (03h to FFh) • Slave mode The CKDIR bit is 1 (external clock): input from the SCLi pin
Transmit/receive clock	To start transmission, satisfy the following requirements (1) • The TE bit in the UiC1 register is 1 (transmission enabled) • The TI bit in the UiC1 register is 0 (data present in UiTB register)
Reception start conditions	To start reception, satisfy the following requirements (1) • The RE bit in the UiC1 register is 1 (reception enabled) • The TE bit in the UiC1 register is 1 (transmission enabled) • The TI bit in the UiC1 register is 0 (data present in the UiTB register)
Interrupt request generation timing	When a start condition, stop condition, ACK (acknowledge), or NACK (not-acknowledge) is detected.
Error detection	Overrun error (2) This error occurs if the serial interface starts receiving the next unit of data before reading the UiRB register and receives the eighth bit of the unit of next data.
Selectable functions	• Arbitration lost Timing at which the ABT bit in the UiRB register is updated can be selected. • SDAi digital delay No digital delay or a delay of 2 to 8 UiBRG count source clock cycles can be selected. • Clock phase setting With or without clock delay can be selected.

i = 0 to 2, 5 to 7

Notes:

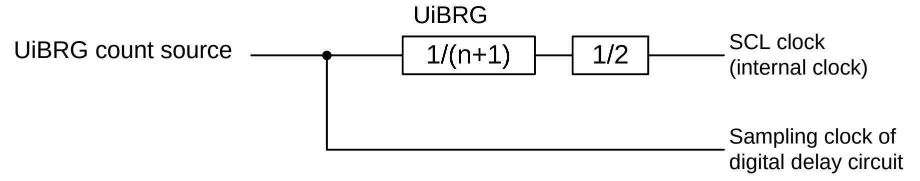
1. These requirements do not have to be set in any particular order. When transmission/reception is started as a slave and the TXEPT bit in the UiC0 register is 1 (no data present in transmit register), meet the last requirement when the external clock is high.
2. If an overrun error occurs, the received data of the UiRB register will be undefined.



This diagram applies when bits SMD2 to SMD0 in the UiMR register are 010b and the IICM bit in the UiSMR register is 1.

IICM: Bit in the UiSMR register
IICM2, SWC, ALS, SWC2, SDHI: Bits in the UiSMR2 register
STSPSEL, ACKD, ACKC: Bits in the UiSMR4 register

Figure 23.18 I^{2}C Mode Block Diagram


UiBRG
UiBRG count source
1/(n+1)
1/2
SCL clock (internal clock)
Sampling clock of digital delay circuit

n: UiBRG register setting value

Figure 23.19 Internal Clock Configuration

Table 23.15 I/O Pin Functions in I^{2}C Mode

Pin Name	I/O	Function
SCLi (1, 2)	I/O	Clock input or output
SDAi (1, 2)	I/O	Data input or output

Note:
1. Set the port direction bit sharing pin to 0.
2. Pins CLKi and $\overline{\text{CTSi}}$/RTSi are not used (they can be used as I/O ports).

Table 23.16 Registers Used and Settings in I^2C Mode (1/2) [1]

Register	Bits	Function	
		Master	Slave
UCLKSEL0	OCOSEL0	Select clock prior to division for UART0 to UART2.	Select clock prior to division for UART0 to UART2.
	OCOSEL1	Select clock prior to division for UART5 to UART7.	Select clock prior to division for UART5 to UART7.
PCLKR	PCLK1	Select the count source for the UiBRG register.	Select the count source for the UiBRG register.
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.	Set to 0 when using f1.
UiTB	0 to 7	When transmitting, set the transmission data. When receiving, set FFh.	When transmitting, set the transmission data. When receiving, set FFh.
	8	When transmitting, set to 1. When receiving, set the value in the ACK bit.	When transmitting, set to 1. When receiving, set the value in the ACK bit.
UiRB	0 to 7	Reception data can be read.	Reception data can be read.
	8	ACK or NACK is set in this bit.	ACK or NACK is set in this bit.
	ABT	Arbitration lost detection flag	Disabled
	OER	Overrun error flag	Overrun error flag
	13 to 15	When read, the read value is undefined.	When read, the read value is undefined.
UiBRG	0 to 7	Set a bit rate.	Disabled
UiMR	SMD2 to SMD0	Set to 010b.	Set to 010b.
	CKDIR	Set to 0.	Set to 1.
	4 to 6	Set to 0.	Set to 0.
	IOPOL	Set to 0.	Set to 0.
UiC0	CLK1, CLK0	Select the count source for the UiBRG register.	Disabled
	CRS	Disabled because CRD is 1	Disabled because CRD is 1
	TXEPT	Transmit register empty flag	Transmit register empty flag
	CRD [3]	Set to 1.	Set to 1.
	NCH	Set to 1. [2]	Set to 1. [2]
	CKPOL	Set to 0.	Set to 0.
	UFORM	Set to 1.	Set to 1.
UiC1	TE	Set to 1 to enable transmission.	Set to 1 to enable transmission.
	TI	Transmit buffer empty flag	Transmit buffer empty flag
	RE	Set to 1 to enable reception.	Set to 1 to enable reception.
	RI	Reception complete flag	Reception complete flag
	UjIRS	Set to 1.	Set to 1.
	UjRRM, UiLCH, UiERE	Set to 0.	Set to 0.
UiSMR	IICM	Set to 1.	Set to 1.
	ABC	Select the timing that arbitration lost is detected.	Disabled
	BBS	Bus busy flag	Bus busy flag
	3 to 7	Set to 0.	Set to 0.

i = 0 to 2, 5 to 7; j = 2, 5 to 7

Notes:

1. This table does not describe a procedure.
2. The TXD2 pin is N-channel open drain output. Nothing is assigned to the NCH bit in the U2C0 register. If necessary, set it to 0.
3. When using UART1 in I^2C mode, to enable the $\overline{\text{CTS}}/\overline{\text{RTS}}$ separate function of UART0, set the CRD bit in the U1C0 register to 0 ($\overline{\text{CTS}}/\overline{\text{RTS}}$ enabled) and the CRS bit to 0 ($\overline{\text{CTS}}$ input).

Table 23.17 Registers Used and Settings in I^{2}C Mode (2/2) (1)

Register	Bits	Function	
		Master	Slave
UiSMR2	IICM2	See Table 23.18 "I^{2}C Mode Functions".	See Table 23.18 "I^{2}C Mode Functions".
	CSC	Set to 1 to enable clock synchronization.	Set to 0.
	SWC	Set to 1 to fix SCLi output to low after receiving the eighth bit of the clock.	Set to 1 to fix SCLi output to low after receiving the eighth bit of the clock.
	ALS	Set to 1 to stop SDAi output when arbitration lost is detected.	Set to 0.
	STAC	Set to 0.	Set to 1 to initialize UARTi at start condition detection.
	SWC2	Set to 1 to forcibly pull SCLi output low.	Set to 1 to forcibly pull SCLi output low.
	SDHI	Set to 1 to disable SDAi output.	Set to 1 to disable SDAi output.
	7	Set to 0.	Set to 0.
UiSMR3	0, 2, 4 NODC	Set to 0.	Set to 0.
	CKPH	Set to 1.	Set to 1.
	DL2 to DL0	Set the amount of SDAi digital delay.	Set the amount of SDAi digital delay.
UiSMR4	STAREQ	Set to 1 to generate start condition.	Set to 0.
	RSTAREQ	Set to 1 to generate restart condition.	Set to 0.
	STPREQ	Set to 1 to generate stop condition.	Set to 0.
	STSPSEL	Set to 1 to output each condition.	Set to 0.
	ACKD	Select ACK or NACK.	Select ACK or NACK.
	ACKC	Set to 1 to output ACK data.	Set to 1 to output ACK data.
	SCLHI	Set to 1 to stop SCLi output when stop condition is detected.	Set to 0.
	SWC9	Set to 0.	Set to 1 to set SCLi to remain low at the falling edge of the ninth bit of clock.
UCON	U0IRS	Set to 1.	Set to 1.
	U1IRS	Set to 1.	Set to 1.
	U0RRM	Set to 0.	Set to 0.
	U1RRM	Set to 0.	Set to 0.
	CLKMD0	Set to 0.	Set to 0.
	CLKMD1	Set to 0.	Set to 0.
	RCSP	Set to 0.	Set to 0.
	7	Set to 0.	Set to 0.

i = 0 to 2, 5 to 7

Note:

1. This table does not describe a procedure.

In I^{2}C mode, functions and timings vary depending on the IICM2 bit setting in the UiSMR2 register. Figure 23.20 shows Transfer to UiRB Register and Interrupt Timing. See Figure 23.20 for the timing of transferring data to the UiRB register, the bit position of the data stored in the UiRB register, types of interrupts, interrupt requests, and DMA request generation timing.

Table 23.18 lists a comparison of other functions in clock synchronous serial I/O mode with I^{2}C mode.

Table 23.18 I^{2}C Mode Functions

Function	Clock Synchronous Serial I/O Mode (SMD2 to SMD0 = 001b, IICM = 0)	I^{2}C Mode (SMD2 to SMD0 = 010b, IICM = 1)	
		IICM2 = 0 (NACK/ACK interrupt)	IICM2 = 1 (UART transmit/receive interrupt)
		CKPH = 1 (Clock delay)	CKPH = 1 (Clock delay)
Start and stop condition detect interrupts [3]	-	Start condition or stop condition detection (See Figure 23.22 “STSPSEL Bit Functions”)	
Transmission, NACK interrupt [2, 3]	UARTi transmission Transmission started or completed (selected by UiIRS)	No acknowledgment detection (NACK) Rising edge of the 9th bit of SCLi	UARTi transmission Falling edge of the 9th bit of SCLi

Reception, ACK interrupt [2, 3]	UARTi reception
	When 8th bit received
	CKPOL = 0 (rising edge)
	CKPOL = 1 (falling edge)
		Acknowledgment detection (ACK)
		Rising edge of the 9th bit of SCLi
			UARTi reception
			Falling edge of the 9th bit of SCLi

Timing for transferring data from UART reception shift register to UiRB register	CKPOL = 0 (rising edge)
	CKPOL = 1 (falling edge)
		Rising edge of the 9th bit of SCLi	Falling edges of the 8th bit of SCLi and rising edges of the 9th bit of SCLi

UARTi transmission output delay	Not delayed	Delayed	Delayed
Read RXDi and SCLi pin levels	Possible when the corresponding port direction bit = 0	Always possible no matter how the corresponding port direction bit is set	Always possible no matter how the corresponding port direction bit is set

Initial value of TXDi and SDAi outputs	CKPOL = 0 (high)
	CKPOL = 1 (low)
		The value set in the port register before setting I^{2}C mode [1]	The value set in the port register before setting I^{2}C mode [1]

Initial and end values of SCLi	-	Low	Low
DMA1, DMA3 factor [2]	UARTi reception	Acknowledgment detection (ACK)	UARTi reception Falling edge of the 9th bit of SCLi
Read received data	1st to 8th bits of the received data are stored in bits 0 to 7 in the UiRB register.	1st to 8th bits of the received data are stored in bits 7 to 0 in the UiRB register.	Refer to Figure 23.20 “Transfer to UiRB Register and Interrupt Timing”.

i = 0 to 2, 5 to 7
SMD2 to SMD0: Bits in the UiMR register
CKPOL: Bit in the UiC0 register
IICM: Bit in the UiSMR register
IICM2: Bit in the UiSMR2 register
CKPH: Bit in the UiSMR3 register
UiIRS: Bit in the UCON or UiC1 register

Notes:

1. Set the initial value of SDAi output while bits SMD2 to SMD0 in the UiMR register are 000b (serial interface disabled).
2. See Figure 23.20 “Transfer to UiRB Register and Interrupt Timing”.
3. The procedure to change interrupt sources is as follows:
   (1) Disable the interrupt to be changed the source.
   (2) Change the source of interrupt.
   (3) Set the IR bit in the interrupt control register of that interrupt to 0 (no interrupt requested).
   (4) Set bits ILVL2 to ILVL0 in the interrupt control register of that interrupt.

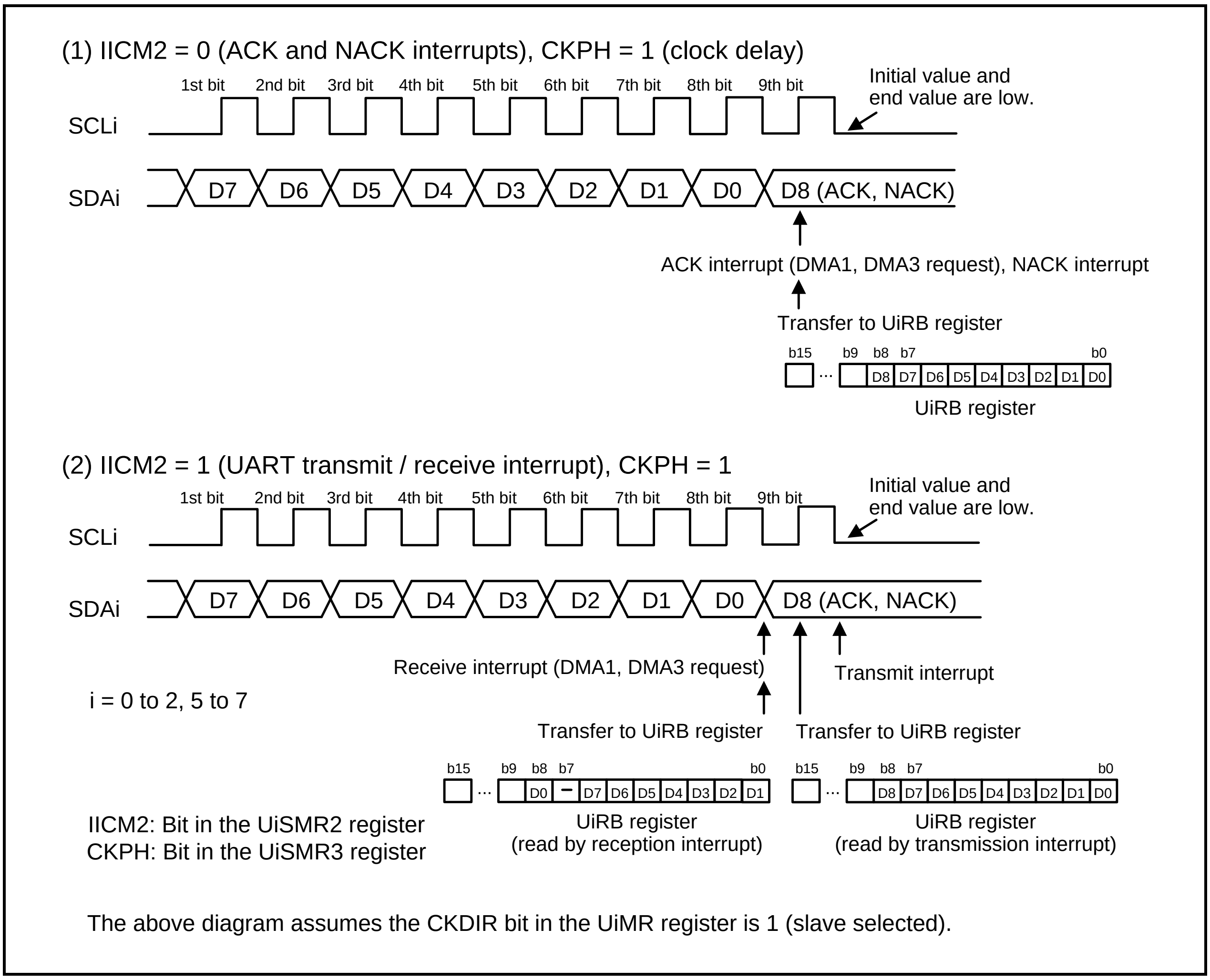

(1) IICM2 = 0 (ACK and NACK interrupts), CKPH = 1 (clock delay)
1st bit
2nd bit
3rd bit
4th bit
5th bit
6th bit
7th bit
8th bit
9th bit
Initial value and end value are low.
SCLi
SDAi
D7
D6
D5
D4
D3
D2
D1
D0
D8 (ACK, NACK)
ACK interrupt (DMA1, DMA3 request), NACK interrupt
Transfer to UiRB register
b15
b9
b8
b7
b0
D8 D7 D6 D5 D4 D3 D2 D1 D0
UiRB register
(2) IICM2 = 1 (UART transmit / receive interrupt), CKPH = 1
1st bit
2nd bit
3rd bit
4th bit
5th bit
6th bit
7th bit
8th bit
9th bit
Initial value and end value are low.
SCLi
SDAi
D7
D6
D5
D4
D3
D2
D1
D0
D8 (ACK, NACK)
Receive interrupt (DMA1, DMA3 request)
Transmit interrupt
i = 0 to 2, 5 to 7
Transfer to UiRB register
Transfer to UiRB register
b15
b9
b8
b7
b0
D0 – D7 D6 D5 D4 D3 D2 D1
b15
b9
b8
b7
b0
D8 D7 D6 D5 D4 D3 D2 D1 D0
IICM2: Bit in the UiSMR2 register
CKPH: Bit in the UiSMR3 register
UiRB register (read by reception interrupt)
UiRB register (read by transmission interrupt)
The above diagram assumes the CKDIR bit in the UiMR register is 1 (slave selected).

Figure 23.20 Transfer to UiRB Register and Interrupt Timing

23.3.3.1 Detecting Start and Stop Conditions

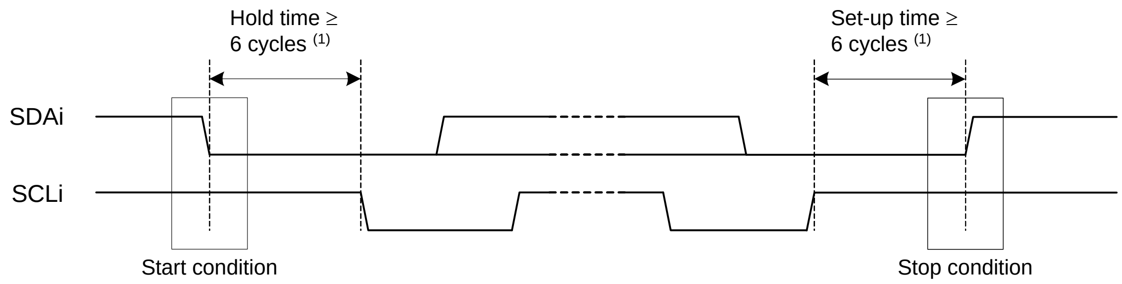
Start and stop conditions are detected by their respective detectors.

Whether a start or a stop condition has been detected is determined.

A start condition detect interrupt request is generated when the SDAi pin changes state from high to low while the SCLi pin is in the high state. A stop condition detect interrupt request is generated when the SDAi pin changes state from low to high while the SCLi pin is in the high state.

Because the start and stop condition detect interrupts share the interrupt control register and vector, check the BBS bit in the UiSMR register to determine which interrupt source is requesting the interrupt.

To detect a start or stop condition, both the set-up and hold times require at least six cycles of the BRGi count source as shown in Figure 23.21. To meet the condition for the Fast-mode specification, the BRGi count source must be at least 10 MHz.



i = 0 to 2, 5 to 7

Note:

1. The number of cycles are the BRGi count source cycles.

Figure 23.21 Detecting Start and Stop Conditions

23.3.3.2 Generating Start and Stop Conditions

A start condition is generated by setting the STAREQ bit in the UiSMR4 register (i = 0 to 2, 5 to 7) to 1 (start).

A restart condition is generated by setting the RSTAREQ bit in the UiSMR4 register to 1 (start).

A stop condition is generated by setting the STPREQ bit in the UiSMR4 register to 1 (start).

The output procedure is described below.

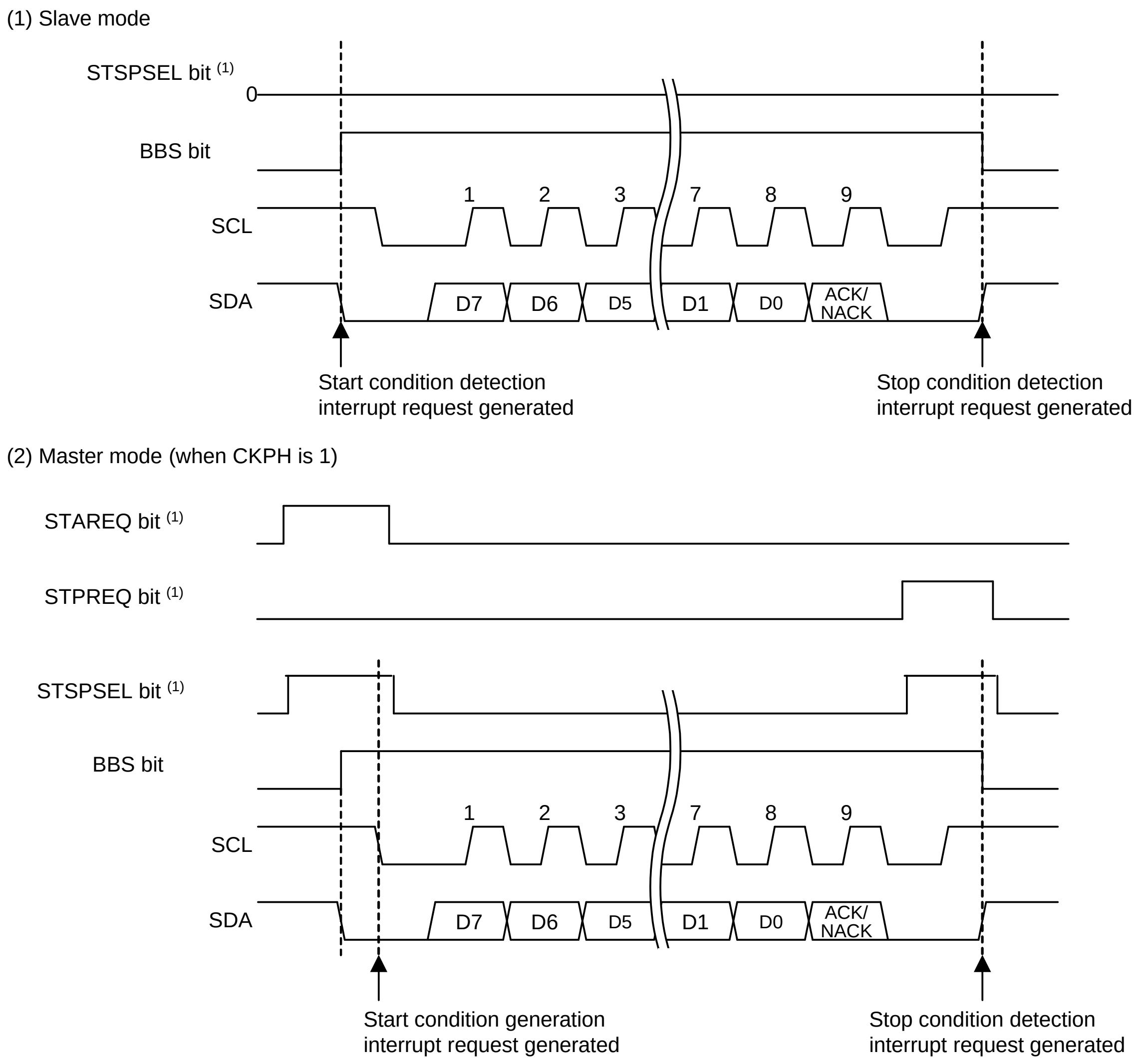
(1) Set the STAREQ bit, RSTAREQ bit or STPREQ bit to 1 (start).

(2) Set the STSPSEL bit in the UiSMR4 register to 1 (output).

The functions of the STSPSEL bit are shown in Table 23.19 and Figure 23.22.

Table 23.19 STSPSEL Bit Functions

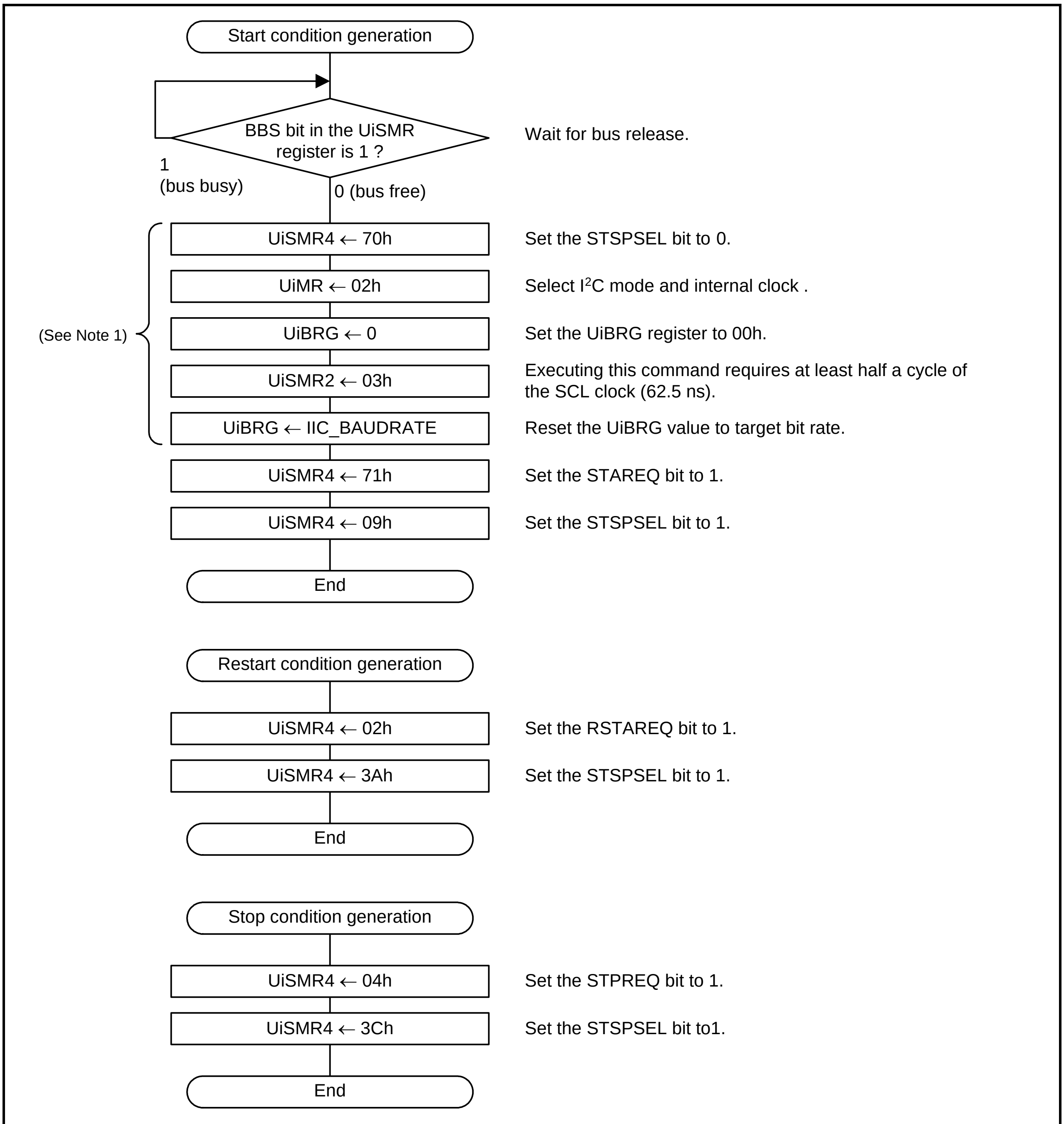
Function	STSPSEL = 0	STSPSEL = 1
Output of pins SCLi and SDAi	Output of transmit/receive clock and data Output of start/stop condition is accomplished by a program using ports (not automatically generated in hardware)	Output of a start/stop condition according to bits STAREQ, RSTAREQ, and STPREQ
Start/stop condition Interrupt request generation timing	Detection of start/stop condition	Completion of generating start/stop condition


(1) Slave mode
STSPSEL bit (1)
0
BBS bit
SCL
SDA
1
2
3
7
8
9
D7
D6
D5
D1
D0
ACK/ NACK
Start condition detection interrupt request generated
Stop condition detection interrupt request generated
(2) Master mode (when CKPH is 1)
STAREQ bit (1)
STPREQ bit (1)
STSPSEL bit (1)
BBS bit
SCL
SDA
1
2
3
7
8
9
D7
D6
D5
D1
D0
ACK/ NACK
Start condition generation interrupt request generated
Stop condition detection interrupt request generated

STAREQ, STPREQ, STSPSEL: Bits in the UiSMR4 register (i = 0 to 2, 5 to 7)
BBS: Bit in the UiSMR register

Note:
1. Set to 0 or 1 by a program.

Figure 23.22 STSPSEL Bit Functions


Start condition generation
BBS bit in the UiSMR register is 1 ?
1 (bus busy)
0 (bus free)
Wait for bus release.
(See Note 1)
UiSMR4 ← 70h
Set the STSPSEL bit to 0.
UiMR ← 02h
Select I²C mode and internal clock .
UiBRG ← 0
Set the UiBRG register to 00h.
UiSMR2 ← 03h
Executing this command requires at least half a cycle of the SCL clock (62.5 ns).
UiBRG ← IIC_BAUDRATE
Reset the UiBRG value to target bit rate.
UiSMR4 ← 71h
Set the STAREQ bit to 1.
UiSMR4 ← 09h
Set the STSPSEL bit to 1.
End
Restart condition generation
UiSMR4 ← 02h
Set the RSTAREQ bit to 1.
UiSMR4 ← 3Ah
Set the STSPSEL bit to 1.
End
Stop condition generation
UiSMR4 ← 04h
Set the STPREQ bit to 1.
UiSMR4 ← 3Ch
Set the STSPSEL bit to1.
End

The above assumes the following:
XIN = 16 MHz, main clock divided by 1 (no division), UiBRG count source = f1

Note:

1. After a stop condition is generated, when generating the next start condition, after setting the STSPSEL bit in the UiSMR4 register to 0 and waiting at least half a cycle of the SCL clock, then set the STAREQ bit to 1.

Technical update number: TN-16C-130A/EA

Figure 23.23 Register Setting Procedures for Condition Generation

23.3.3.3 Arbitration

The MCU determines whether the transmit data matches data input to the SDAi pin on the rising edge of SCLi. If it does not match the input data, arbitration takes place at the SDAi pin by stopping data output.

The ABC bit in the UiSMR register (i = 0 to 2, 5 to 7) determines the update timing for the ABT bit in the UiRB register.

When the ABC bit is 0 (update per bit), the ABT bit becomes 1 as soon as a data discrepancy is detected. If not detected, the ABT bit becomes 0. When the ABC bit is 1 (update per byte), the ABT bit becomes 1 on the falling edge of the eighth bit of SCLi if any discrepancy is detected. In this ABC bit setting, the ABT bit should be set to 0 after ACK detection of 1-byte is completed to start the next 1-byte transmission/reception.

When the ALS bit in the UiSMR2 register is set to 1 (SDA output stop enabled), an arbitration lost occurs. As soon as the ABT bit becomes 1, the SDAi pin becomes high-impedance.

23.3.3.4 SCL Control and Clock Synchronization

Data transmission/reception in I^{2}C mode uses the transmit/receive clock as shown in Figure 23.20 “Transfer to UiRB Register and Interrupt Timing”. The clock speed increase makes it difficult to secure the required time for ACK generation and data transmit procedure. The I^{2}C mode supports a function of wait-state insertion to secure this required time and a function of clock synchronization with a wait-state inserted by other devices.

The SWC bit in the UiSMR2 register (i = 0 to 2, 5 to 7) is used to insert a wait-state for ACK generation. When the SWC bit is set to 1 (the SCLi pin is held low after the eighth bit of SCLi is received), the SCLi pin is held low on the falling edge of the eighth bit of SCLi. When the SWC bit is set to 0 (no wait-state/wait-state cleared), the SCLi line is released.

When the SWC2 bit in the UiSMR2 register is set to 1 (the SCLi pin is held low), the SCLi pin is forced low even during transmission or reception. When the SWC2 bit is set to 0 (transmit/receive clock is output at the SCLi pin), the SCLi line is released to output the transmit/receive clock.

The SWC9 bit in the UiSMR4 register is used to insert a wait-state for checking received acknowledge bits. While the CKPH bit in the UiSMR3 register is 1 (clock delayed), when the SWC9 bit is set to 1 (the SCLi pin is held low after the ninth bit of the SCLi is received), the SCLi pin is held low on the falling edge of the ninth bit of SCLi. When the SWC9 bit is set to 0 (no wait-state/wait-state cleared), the SCLi line is released.

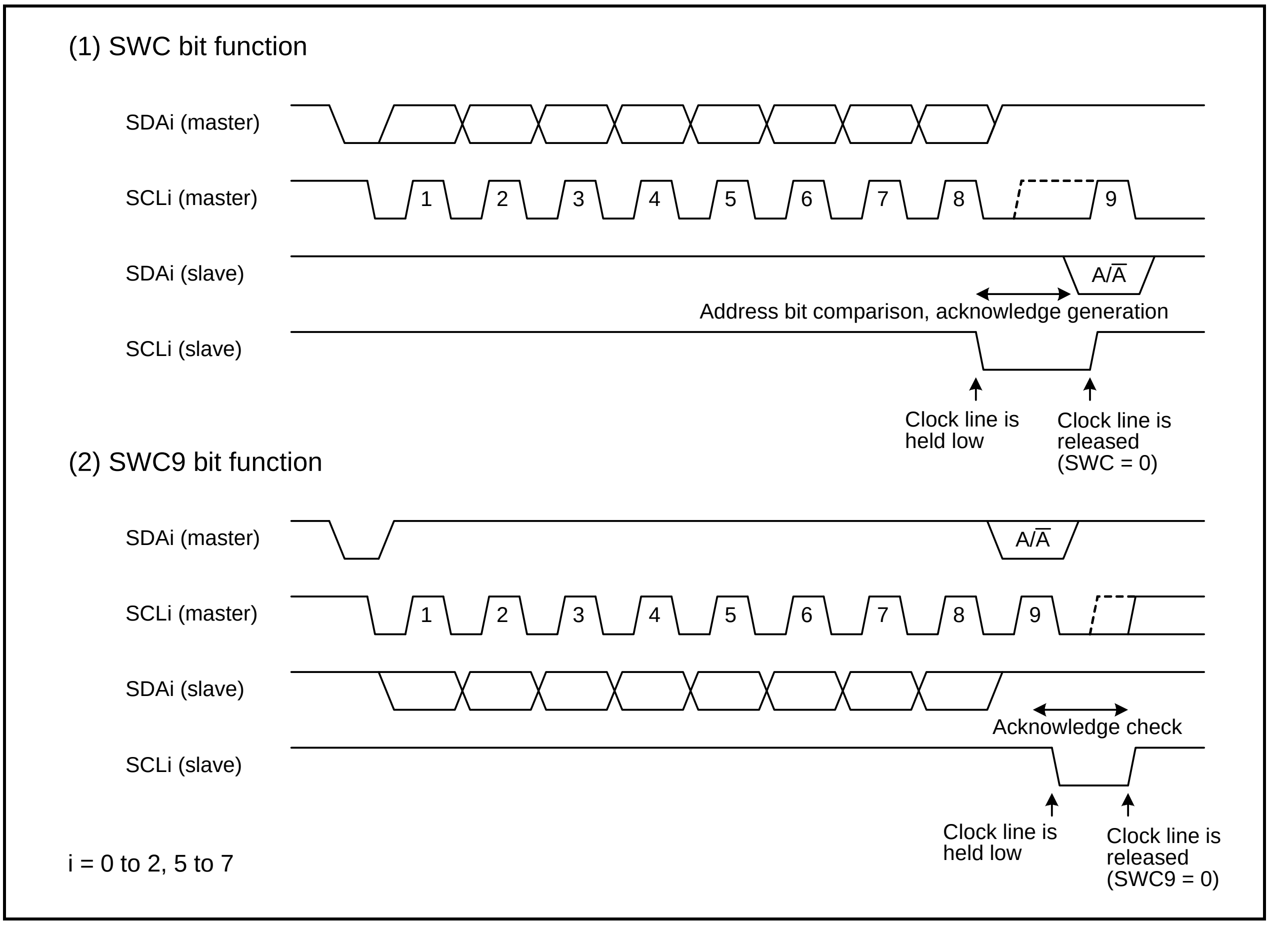


Figure 23.24 Inserting Wait-States Using Bits SWC and SWC9

The CSC bit in the UiSMR2 register synchronizes an internally generated clock with the clock applied to the SCLi pin. For example, if a wait-state is inserted from other devices, the two clocks are not synchronized. While the CSC bit is 1 (clock synchronization enabled) and the internal clock is held high, when a high at the SCLi pin changes to low, the internal clock becomes low in order to reload the UiBRG register value and resume counting. While the SCLi pin is held low, when the internal clock changes from low to high, the count is stopped until the SCLi pin becomes high. That is, the UARTi transmit/receive clock is the logical AND of the internal clock and SCLi. The synchronized period starts from one clock prior to an internally generated clock and ends when the ninth clock is completed. The CSC bit can be set to 1 only when the CKDIR bit in the UiMR register is set to 0 (internal clock selected).

The SCLHI bit in the UiSMR4 register is used to leave the SCLi pin open when another master generates a stop condition while the master is performing a transmit/receive operation. While the SCLHI bit is set to 1 (output stopped), the SCLi pin is open (the pin is high-impedance) when a stop condition is detected and the clock output is stopped.

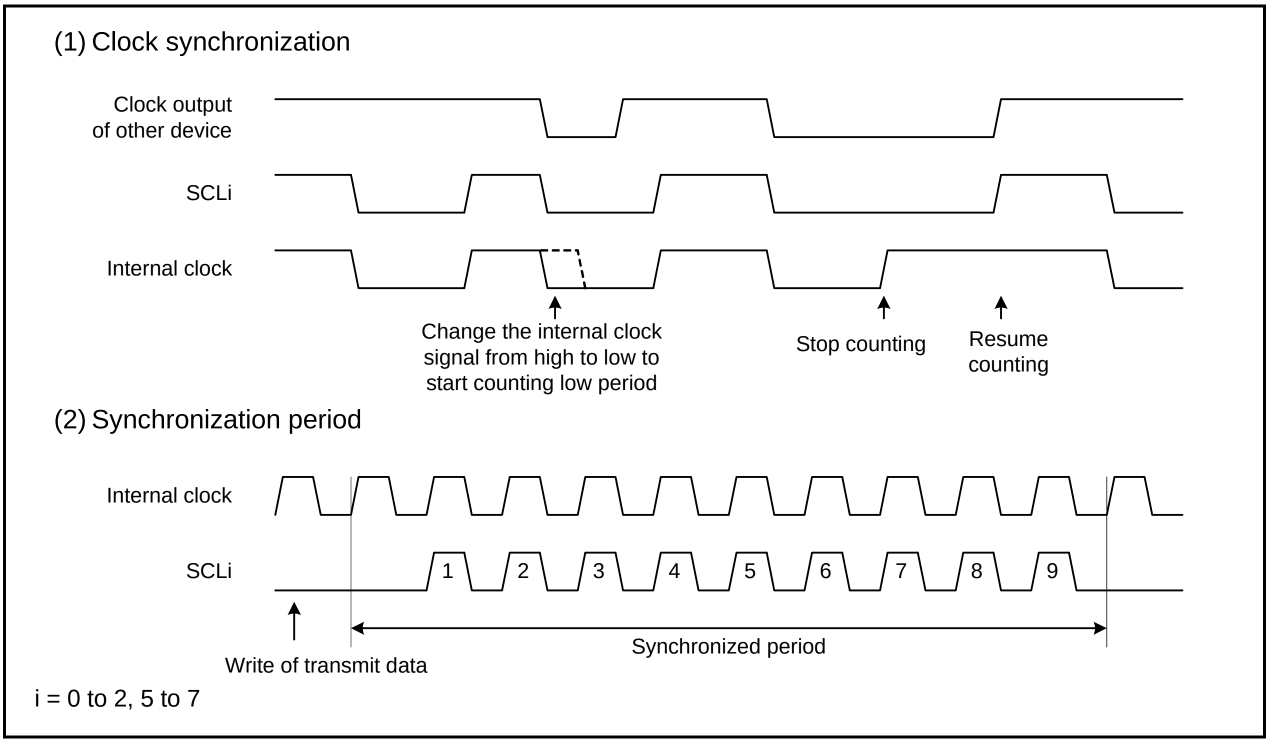

(1) Clock synchronization
Clock output of other device
SCLi
Internal clock
Change the internal clock signal from high to low to start counting low period
Stop counting
Resume counting
(2) Synchronization period
Internal clock
SCLi
1
2
3
4
5
6
7
8
9
Write of transmit data
Synchronized period
i = 0 to 2, 5 to 7

Figure 23.25 Clock Synchronization

23.3.3.5 SCL Clock Frequency

The SCL clock duty generated in I^2C mode is 50%. The low-level width of the SCL clock is 1.25 μs when the I^2C-bus setting is Fast-mode maximum SCL clock (400 kbps). This value does not satisfy the Fast-mode I^2C-bus specification (f_{LOW} = minimum 1.3 μs). Set the SCL clock to 384.6 kbps or less to satisfy the SCL clock low-level width of 1.3 μs or more.

When the clock synchronous function (Figure 23.25 “Clock Synchronization”) is enabled, there is a sampling delay of the noise filter plus 1 to 1.5 cycles of UiBRG count source.

There is also a delay of the SCL clock when high is determined and the SCL clock high width is extended. Therefore, the actual SCL clock becomes slower than SCL clock bit rate setting.

To calculate the effective value of SCL clock, take the SCL clock rise time (t_R) into consideration.

The following is an example of an SCL clock calculation.

Example of an effective value of SCL clock calculation at 384.6 kbps

- UiBRG count source: f1 = 20 MHz
- UiBRG register setting value: n = 26 - 1
- SCL clock rise time: t_R = 100 ns
- SCL clock fall time: t_F = 0 ns
- Noise filter width: t_{NF} = 100 ns (1)
- Sampling delay: t_{SD} = 1 cycle

f_{SCL} (theoretical value) = f1 / (2(n + 1)) = 20 MHz / (2(25 + 1)) = 384.6 kbps

t_{LOW} = 1 / (2f_{SCL} (theoretical value)) = 1 / (2 × 384.6 kbps) = 1.3 μs

t_{HIGH} = 1 / (2f_{SCL} (theoretical value)) + t_{NF} + (t_{SD} × 1 / f1)
= 1 / (2 × 384.6 kbps) + 100 ns + (1 × 1 / 20 MHz)
= 1.45 μs

f_{SCL} (actual value) = 1 / (t_F + t_{LOW} + t_R + t_{HIGH}) = 1 / (0 ns + 1.3 μs + 100 ns + 1.45 μs) ≈ 350.8 kbps

Note:
1. Maximum 200 ns.

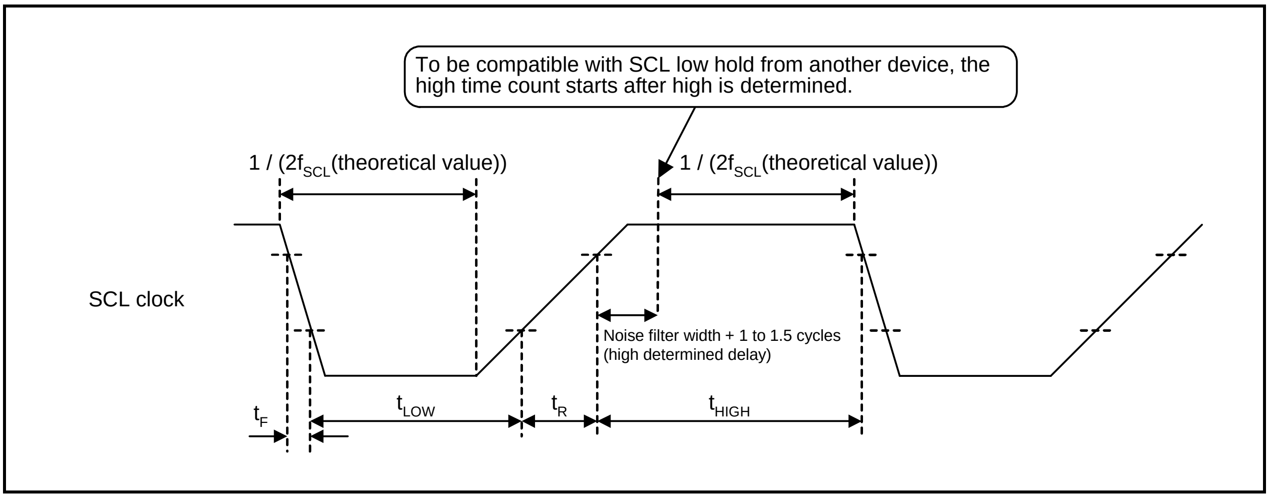

To be compatible with SCL low hold from another device, the high time count starts after high is determined.
1 / ($2f_{SCL}$(theoretical value))
1 / ($2f_{SCL}$(theoretical value))
SCL clock
Noise filter width + 1 to 1.5 cycles (high determined delay)
t_F
t_{LOW}
t_R
t_{HIGH}

Figure 23.26 SCL Clock

23.3.3.6 SDA Output Control

When transmitting byte data, the SDAi pin outputs transmit data for the first to eighth bits, and it is released to receive an acknowledgment for the ninth bit.

In I^{2}C mode, set 9-bit data to the UiTB register. In 9-bit data, set the transmit data to bits b7 to b0 and set b8 to 1. By setting the UFORM bit in the UiC0 register to 1 (MSB first) and 9-bit data to the UiTB register, transmit data is output from the SDAi pin in the following order: b7, b6, b5, b4, b3, b2, b1, b0 and b8. As b8 is 1, the SDAi pin becomes high-impedance at the ninth bit and an acknowledgment can be received.

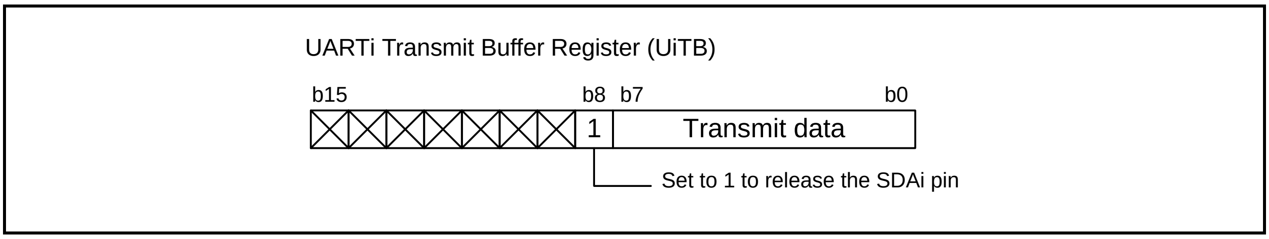

UARTi Transmit Buffer Register (UiTB)
b15
b8
b7
b0
1
Transmit data
Set to 1 to release the SDAi pin

Figure 23.27 UiTB Register Setting (SDA Output)

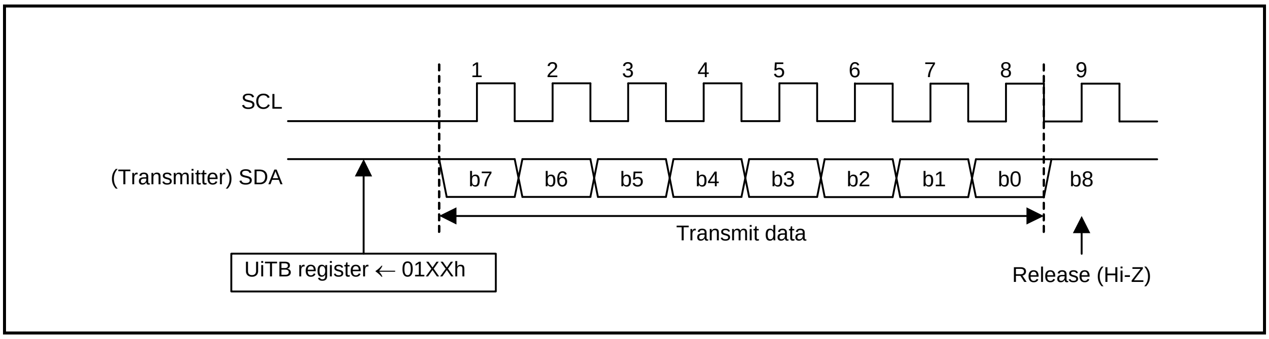


Figure 23.28 Byte Data Transmission

Set bits DL2 to DL0 in the UiSMR3 register to add no delays or a delay of one to eight UiBRG count source clock cycles to SDAi output.

Setting the SDHI bit in the UiSMR2 register to 1 (SDA output disabled) forcibly places the SDAi pin in a high-impedance state. Do not write to the SDHI bit at the rising edge of the UARTi transmit/receive clock as the ABT bit in the UiRB register may inadvertently become 1 (detected).

23.3.3.7 SDA Digital Delay

When transferring data with the I^{2}C-bus, change the data while the SCL clock is low. When SDA is changed while the SCL clock is a high, the change is recognized as one of the corresponding conditions (see 23.5.3.4 “Setup and Hold Times When Generating a Start/Stop Condition”).
This function delays output from the SDAi pin. By delaying the change of the SDA, the data can be changed while the SCL clock is low. This function is enabled by setting bits DL2 to DL0 in the UiSMR3 register to 001b to 111b, and disabled by setting them to 000b.

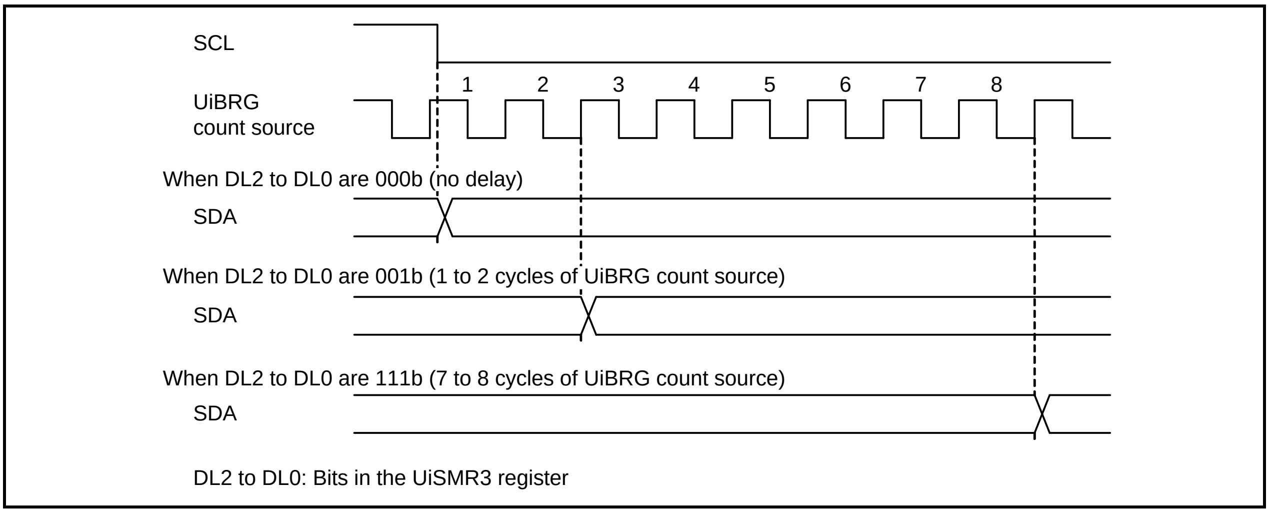

SCL
UiBRG
count source
1
2
3
4
5
6
7
8
When DL2 to DL0 are 000b (no delay)
SDA
When DL2 to DL0 are 001b (1 to 2 cycles of UiBRG count source)
SDA
When DL2 to DL0 are 111b (7 to 8 cycles of UiBRG count source)
SDA
DL2 to DL0: Bits in the UiSMR3 register

Figure 23.29 SDA Output Selection by Setting Bits DL2 to DL0

23.3.3.8 SDA Input

When the IICM2 bit in the UiSMR2 register (i = 0 to 2, 5 to 7) is set to 0, the first 8 bits of received data (D7 to D0) are stored in bits 7 to 0 in the UiRB register and the ninth bit (ACK/NACK) is stored in bit 8.
When the IICM2 bit is 1, the first to seventh bits (D7 to D1) of the received data are stored in bits 6 to 0 in the UiRB register and the eighth bit (D0) is stored in bit 8 in the UiRB register. Even when the IICM2 bit is 1, if the CKPH bit in the UiSMR3 register is 1, the same data as when the IICM2 bit is 0 can be read. To read the data, read the UiRB register after the rising edge of ninth bit of the corresponding clock pulse.

When receiving byte data, the SDAi pin is released for the first to eighth bits to receive data, and an acknowledgment is generated for the ninth bit. NACK is generated when the last byte data is received in master mode, or when the slave address does not match in slave mode. In all other cases, ACK is generated.
In I^{2}C mode, set 9-bit data to the UiTB register. In 9-bit data, set FFh to b7 to b0 to release the SDAi pin and set b8 to 0 to generate ACK or 1 to generate NACK.
By setting 00FFh or 01FFh as 9-bit data to the UiTB register, the SDAi pin becomes high-impedance for the first to eighth bits, and data can be received. ACK or NACK is generated at the ninth bit.
Read the received data from the UiRB register. When the clock delay function is used, data transfer to the UiRB register occurs twice and each UiRB register value is different. Refer to Figure 23.20 “Transfer to UiRB Register and Interrupt Timing” for details.

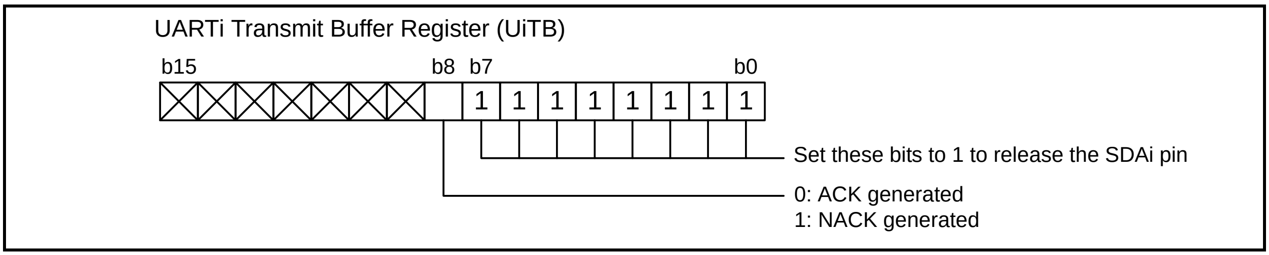

UARTi Transmit Buffer Register (UiTB)
b15
b8
b7
b0
1 1 1 1 1 1 1 1
Set these bits to 1 to release the SDAi pin
0: ACK generated
1: NACK generated

Figure 23.30 UiTB Register Setting (SDA Input)

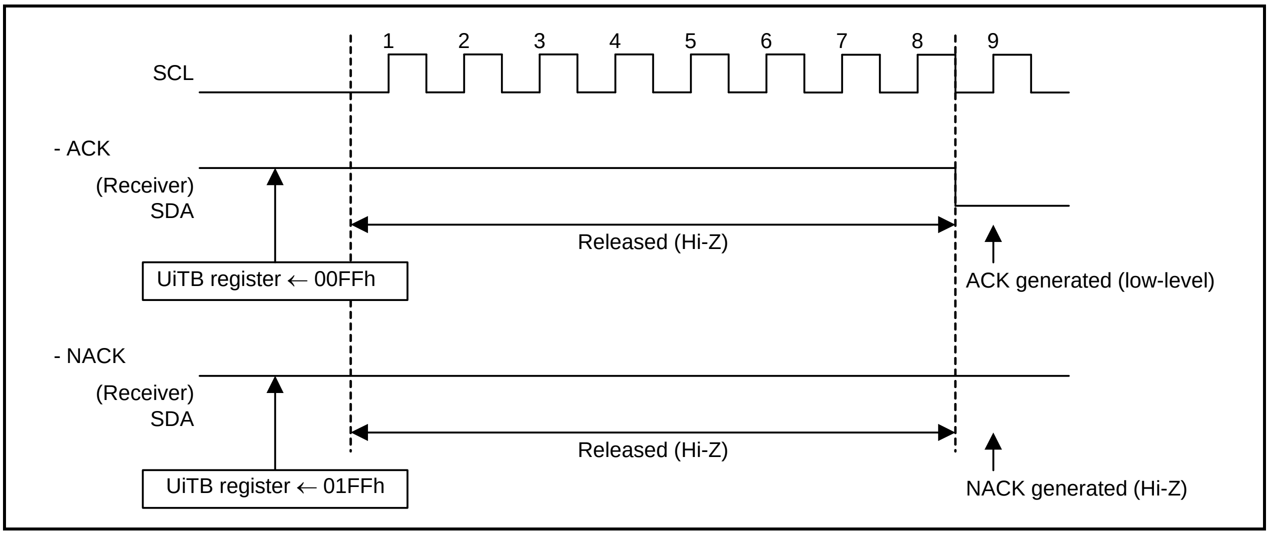


Figure 23.31 Byte Data Reception

23.3.3.9 ACK and NACK

When data is to be received, ACK is output after 8 bits are received by setting the UiTB register to 00FFh as dummy data. When the STSPSEL bit in the UiSMR4 register (i = 0 to 2, 5 to 7) is set to 0 (serial I/O circuit selected) and the ACKC bit is set to 1 (ACK data output), the value of the ACKD bit is output at the SDAi pin.

If the IICM2 bit is 0, a NACK interrupt request is generated when the SDAi pin is held high at the rising edge of the ninth bit of SCLi. An ACK interrupt request is generated when the SDAi pin is held low.

If the DMA request source is “UARTi receive interrupt request or ACK interrupt request”, the DMA transfer is activated when ACK is detected.

23.3.3.10 Initialization of Transmission/Reception

Select the external clock as the transmit/receive clock when using this function.

If a start condition is detected while the STAC bit in the UiSMR2 register is 1 (initialize the circuit if the start condition is detected), the serial interface operates as follows:

- The transmit shift register is initialized, and the UiTB register value is transferred to the transmit shift register. Doing so starts the data transmission when the next clock pulse is applied. However, the UARTi output value does not change until the first bit of data is output synchronously with the input clock. It remains the same as when a start condition was detected.
- The receive shift register is initialized, and the serial interface starts receiving data when the next clock pulse is applied.
- The SWC bit becomes 1 (hold the SCLi pin low after the eighth bit of SCLi is received). Consequently, the SCLi pin is pulled low at the falling edge of the ninth clock pulse.

When UARTi transmission/reception is started using this function, the TI bit does not change.

When the UARTi initializing function is used in slave mode, UARTi is initialized automatically when a start condition is detected. Therefore, an interrupt is unnecessary for detecting a start condition.

23.3.4 Special Mode 2

In special mode 2, the serial interface module allows serial communication between one master and multiple slaves. The transmit/receive clock polarity and phase are selectable. Table 23.20 lists Special Mode 2 Specifications.

Table 23.20 Special Mode 2 Specifications

Item	Specification
Data format	Character data length: 8 bits
Transmit/receive clock	• Master mode The CKDIR bit in the UiMR register = 0 (internal clock): $\frac{fj}{2(n+1)}$ fj = f1SIO, f2SIO, f8SIO, f32SIO n: Setting value of UiBRG register 00h to FFh
Transmit/receive control	Controlled by I/O ports
Transmission start conditions	To start transmission, satisfy the following requirements: • The TE bit in the UiC1 register is 1 (transmission enabled) • The TI bit in the UiC1 register is 0 (data present in UiTB register)
Reception start conditions	To start reception, satisfy the following requirements: • The RE bit in the UiC1 register is 1 (reception enabled) • The TE bit is 1 (transmission enabled) • The TI bit is 0 (data present in the UiTB register)
Interrupt request generation timing	For transmit interrupt, one of the following conditions can be selected • The UiIRS bit in the UiC1 or UCON register is 0 (transmit buffer empty): When transferring data from the UiTB register to the UARTi transmit register (at start of transmission) • The UiIRS bit is 1 (transfer completed): When the serial interface completed sending data from the UARTi transmit register For receive interrupt • When transferring data from the UARTi receive register to the UiRB register (at completion of reception)
Error detection	Overrun error [1] This error occurs if the serial interface starts receiving the next data before reading the UiRB register and receives the 7th bit of the next data
Selectable functions	• CLK polarity selection Whether transfer data is output/input at the rising or falling edge of the transfer clock can be selected. • LBS first, MSB first selection Whether to start sending/receiving data beginning with bit 0 or beginning with bit 7. • Continuous receive mode selection Reception is enabled by reading the UiRB register • Serial data logic switching Function to invert the logic value of the transmit/receive data. • Clock phase setting Selectable from four combinations of transmit/receive clock polarities and phases.

i = 0 to 2, 5 to 7

Note:

1. If an overrun error occurs, the received data of the UiRB register will be undefined. The IR bit in the SiRIC register does not change.

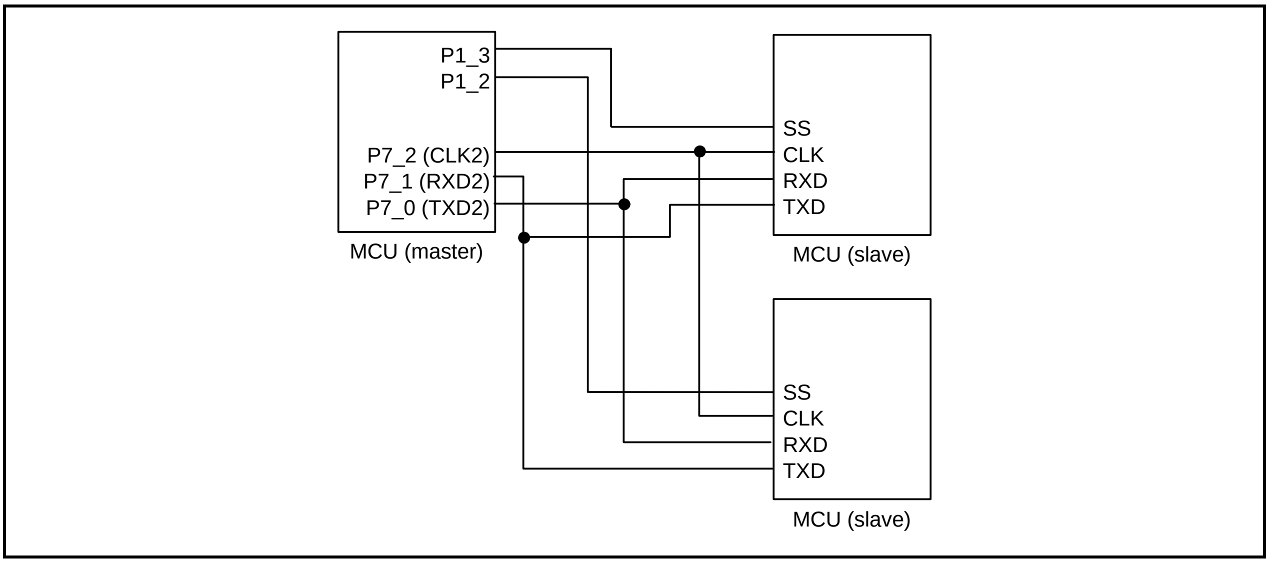


Figure 23.32 Serial Bus Communication Control Example in Special Mode 2 (UART2)

Table 23.21 I/O Pin Functions in Special Mode 2

Pin Name	I/O	Function	Method of Selection
CLKi	Output	Clock output	The CKDIR bit in the UiMR register = 0
TXDi	Output	Serial data output	(Dummy data is output when performing reception only.)
RXDi	Input	Serial data input	Set the port direction bits sharing pins to 0.
	Input	Input port	Set the port direction bits sharing pins to 0. (can be used as an input port only when transmitting)

i = 0 to 2, 5 to 7

Pins $\overline{\text{CTSi}}$/$\overline{\text{RTSi}}$ are not used. (They can be used as I/O ports.)

Table 23.22 Registers Used and Settings in Special Mode 2 (1)

Register	Bits	Function
UCLKSEL0	OCOSEL0	Select clock prior to division for UART0 to UART2.
	OCOSEL1	Select clock prior to division for UART5 to UART7.
PCLKR	PCLK1	Select the count source for the UiBRG register.
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.
UiTB	0 to 7	Set transmission data.
	8	- (does not need to be set) If necessary, set to 0.
UiRB	0 to 7	Reception data can be read.
	OER	Overrun error flag
	8, 11, 13 to 15	When read, the read value is undefined.
UiBRG	0 to 7	Set bit rate.
UiMR	SMD2 to SMD0	Set to 001b.
	CKDIR	Set to 0.
	4 to 6	Set to 0.
	IOPOL	Set to 0.
UiC0	CLK0, CLK1	Select the count source for the UiBRG register.
	CRS	Disabled because CRD is 1
	TXEPT	Transmit register empty flag
	CRD	Set to 1.
	NCH	Select TXDi pin output format. (2)
	CKPOL	Clock phases can be set in combination with the CKPH bit in the UiSMR3 register.
	UFORM	Select the LSB first or MSB first.
UiC1	TE	Set to 1 to enable transmission/reception.
	TI	Transmit buffer empty flag
	RE	Set to 1 to enable reception.
	RI	Reception complete flag
	UjIRS	Select UARTj transmit interrupt source.
	UjRRM	Set to 1 to use continuous receive mode.
	UiLCH	Set to 1 to use inverted data logic.
	UiERE	Set to 0.
UiSMR	0 to 7	Set to 0.
UiSMR2	0 to 7	Set to 0.
UiSMR3	CKPH	Clock phases can be set in combination with the CKPOL bit in the UiC0 register.
	NODC	Set to 0.
	0, 2, 4 to 7	Set to 0.
UiSMR4	0 to 7	Set to 0.
UCON	U0IRS	Select UART0 transmit interrupt source.
	U1IRS	Select UART1 transmit interrupt source.
	U0RRM	Set to 1 to use continuous receive mode.
	U1RRM	Set to 1 to use continuous receive mode.
	CLKMD0	Disabled because CLKMD1 is 0
	CLKMD1, RCSP, 7	Set to 0.

i = 0 to 2, 5 to 7; j = 2, 5 to 7

Notes:

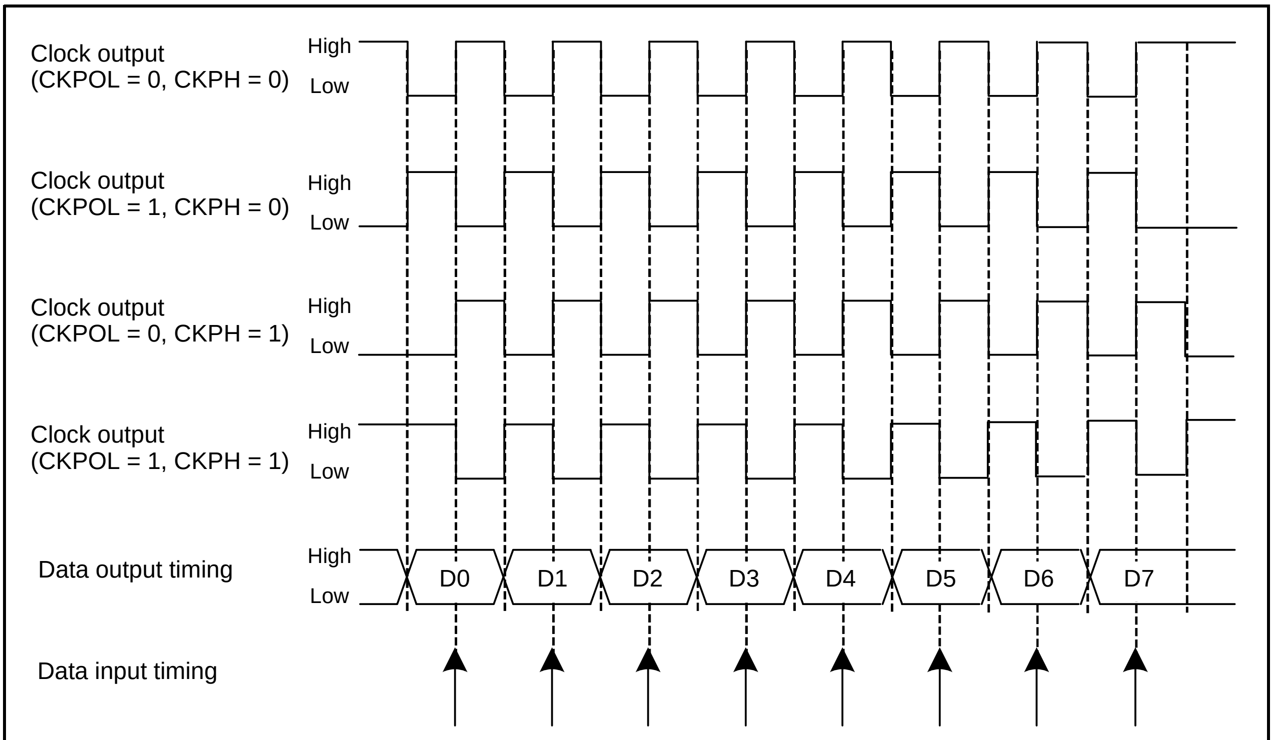
1. This table does not describe a procedure.
2. The TXD2 pin is N-channel open drain output. Nothing is assigned to the NCH bit in the U2C0 register. Only write 0 to this bit.

23.3.4.1 Clock Phase Setting Function

One of four combinations of transmit/receive clock phases and polarities can be selected using the CKPH bit in the UiSMR3 register and the CKPOL bit in the UiC0 register.

Make sure the transmit/receive clock polarity and phase are the same for the master and slaves to be used for communication.

Figure 23.33 shows the Transmit and Receive Timing in Master Mode (Internal Clock).



CKPOL: Bit in the UiC0 register
CKPH: Bit in the UiSMR3 register

Figure 23.33 Transmit and Receive Timing in Master Mode (Internal Clock)

23.3.5 Special Mode 3 (IE Mode)

In this mode, 1 bit of IEBus is approximated by 1 byte of UART mode waveform.

Table 23.23 lists the Registers Used and Settings in IE Mode. Figure 23.34 shows the Bus Collision Detect Function-Related Bits.

If the TXDi pin (i = 0 to 2, 5 to 7) output level and RXDi pin input level do not match, a UARTi bus collision detect interrupt request is generated.

Use bits IFSR26 and IFSR27 in the IFSR2A register to enable the UART0/UART1 bus collision detect function.

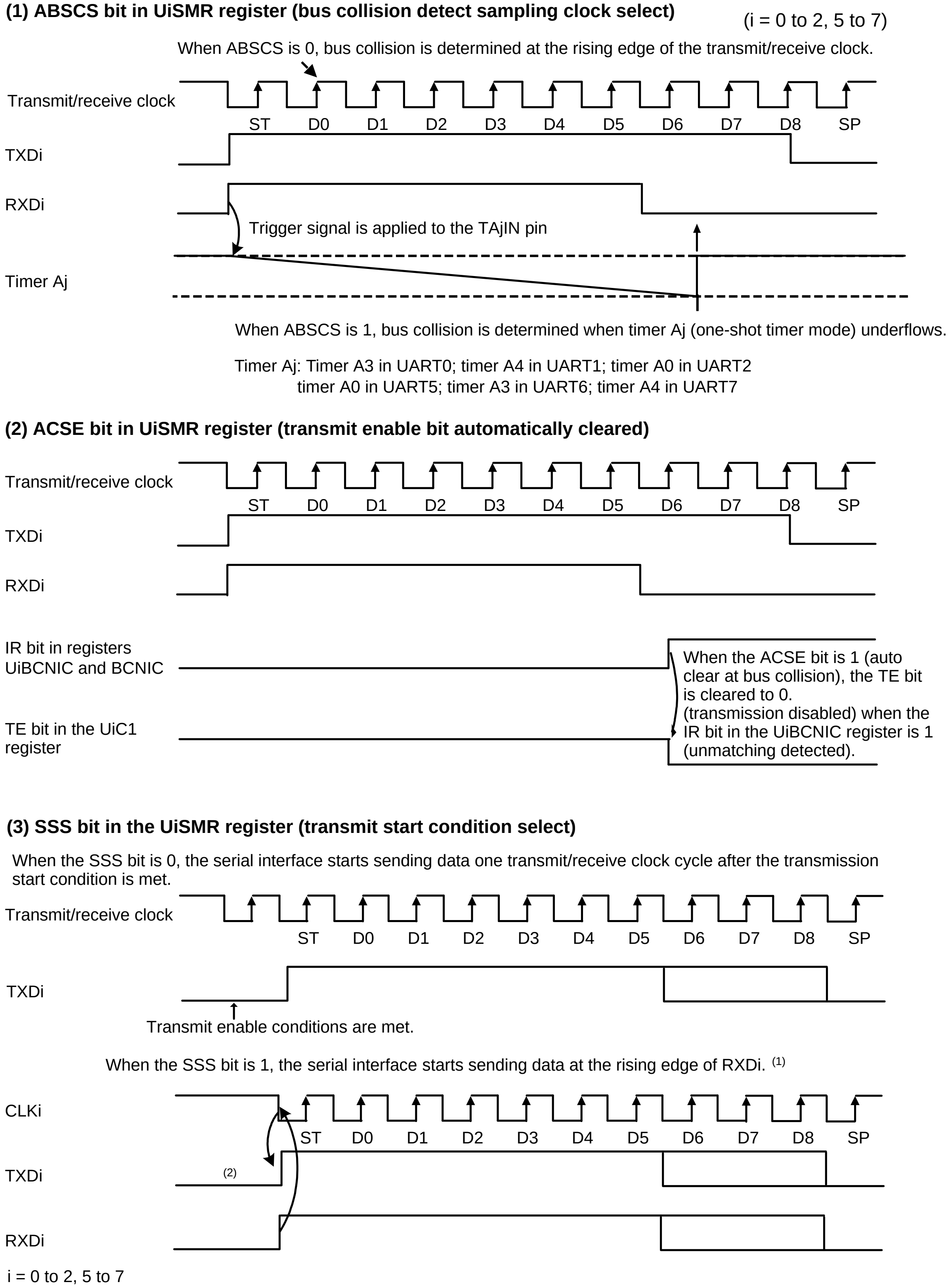
Table 23.23 Registers Used and Settings in IE Mode [1]

Register	Bits	Function
UiTB	0 to 8	Set transmission data.
UiRB [4]	0 to 8	Reception data can be read.
	OER, FER, PER, SUM	Error flag
UiBRG	0 to 7	Set bit rate.
UiMR	SMD2 to SMD0	Set to 110b.
	CKDIR	Select internal clock or external clock.
	STPS	Set to 0.
	PRY	Disabled because PRYE is 0
	PRYE	Set to 0.
	IOPOL	Select the TXD and RXD input/output polarity.
UiC0	CLK1, CLK0	Select the count source for the UiBRG register.
	CRS	Disabled because CRD is 1
	TXEPT	Transmit register empty flag
	CRD	Set to 1.
	NCH	Select TXDi pin output format. [3]
	CKPOL	Set to 0.
	UFORM	Set to 0.
UiC1	TE	Set to 1 to enable transmission.
	TI	Transmit buffer empty flag
	RE	Set to 1 to enable reception.
	RI	Reception complete flag
	UjIRS [2]	Select the source of UARTj transmit interrupt.
	UjRRM [2], UiLCH, UiERE	Set to 0.
UiSMR	0 to 3, 7	Set to 0.
	ABSCS	Select the sampling timing to detect a bus collision.
	ACSE	Set to 1 to use the auto clear function of the transmit enable bit.
	SSS	Select the transmit start condition.
UiSMR2	0 to 7	Set to 0.
UiSMR3	0 to 7	Set to 0.
UiSMR4	0 to 7	Set to 0.
UCON	U0IRS, U1IRS	Select the source of UART0/UART1 transmit interrupt.
	U0RRM, U1RRM	Set to 0.
	CLKMD0	Disabled because CLKMD1 is 0
	CLKMD1, RCSP, 7	Set to 0.

i = 0 to 2, 5 to 7; j = 2, 5 to 7

Notes:

1. This table does not describe a procedure.
2. Set bits 4 and 5 in registers U0C1 and U1C1 to 0. Bits U0IRS, U1IRS, U0RRM, and U1RRM are in the UCON register.
3. The TXD2 pin is N-channel open drain output. Nothing is assigned to the NCH bit in the U2C0 register. If necessary, set it to 0.
4. Set the bits not listed above to 0 when writing to registers in IE mode.



(1) ABSCS bit in UiSMR register (bus collision detect sampling clock select) (i = 0 to 2, 5 to 7)

When ABSCS is 0, bus collision is determined at the rising edge of the transmit/receive clock.

Trigger signal is applied to the TAjIN pin

When ABSCS is 1, bus collision is determined when timer Aj (one-shot timer mode) underflows.

Timer Aj: Timer A3 in UART0; timer A4 in UART1; timer A0 in UART2
timer A0 in UART5; timer A3 in UART6; timer A4 in UART7

(2) ACSE bit in UiSMR register (transmit enable bit automatically cleared)

When the ACSE bit is 1 (auto clear at bus collision), the TE bit is cleared to 0. (transmission disabled) when the IR bit in the UiBCNIC register is 1 (unmatching detected).

(3) SSS bit in the UiSMR register (transmit start condition select)

When the SSS bit is 0, the serial interface starts sending data one transmit/receive clock cycle after the transmission start condition is met.

Transmit enable conditions are met.

When the SSS bit is 1, the serial interface starts sending data at the rising edge of RXDi. (1)

i = 0 to 2, 5 to 7

The above diagram applies when IOPOL is 1 (reversed).

Notes:

1. The falling edge of RXDi when the IOPOL bit in the UiMR register is 0; the rising edge of RXDi when the IOPOL bit is 1.
2. The transmit conditions must be met before the falling edge of RXD.

Figure 23.34 Bus Collision Detect Function-Related Bits

23.3.6 Special Mode 4 (SIM Mode) (UART2)

In this mode, the serial interface module allows SIM interface devices to communicate in UART mode. Both direct and inverted formats are available. The TXD2 pin outputs a low-level signal when a parity error is detected.

Table 23.24 lists the specifications of SIM mode. Table 23.25 lists the related registers and their settings.

Table 23.24 SIM Mode Specifications

Item	Specification
Data formats	• Direct format • Inverted format
Transmit/receive clock	• The CKDIR bit in the U2MR register is 0 (internal clock): fi/(16(n + 1)) fi = f1SIO, f2SIO, f8SIO, f32SIO n = setting value of the U2BRG register 00h to FFh • The CKDIR bit is 1 (external clock): fEXT/(16(n + 1)) fEXT = input from the CLK2 pin n = setting value of the U2BRG register 00h to FFh
Transmission start conditions	To start transmission, satisfy the following requirements: • The TE bit in the U2C1 register is 1 (transmission enabled) • The TI bit in the U2C1 register is 0 (data present in the U2TB register)
Reception start conditions	To start reception, satisfy the following requirements: • The RE bit in the U2C1 register is 1 (reception enabled) • Start bit detection
Interrupt request generation timing (2)	• While transmitting When the serial interface completes transmitting data from the UART2 transmit register (the U2IRS bit is 1) • While receiving When transferring data from the UART2 receive register to the U2RB register (at completion of reception)
Error detection	• Overrun error (1) This error occurs if the serial interface starts receiving the next data before reading the U2RB register and receives the bit before the last stop bit of the next data. • Framing error (3) This error occurs when the number of stop bits set is not detected. • Parity error (3) During reception, if a parity error is detected, a parity error signal is output from the TXD2 pin. During transmission, a parity error is detected by the level of input to the RXD2 pin when a transmission interrupt occurs. • Error sum flag This flag becomes 1 when an overrun, framing, or parity errors occurs.

Notes:

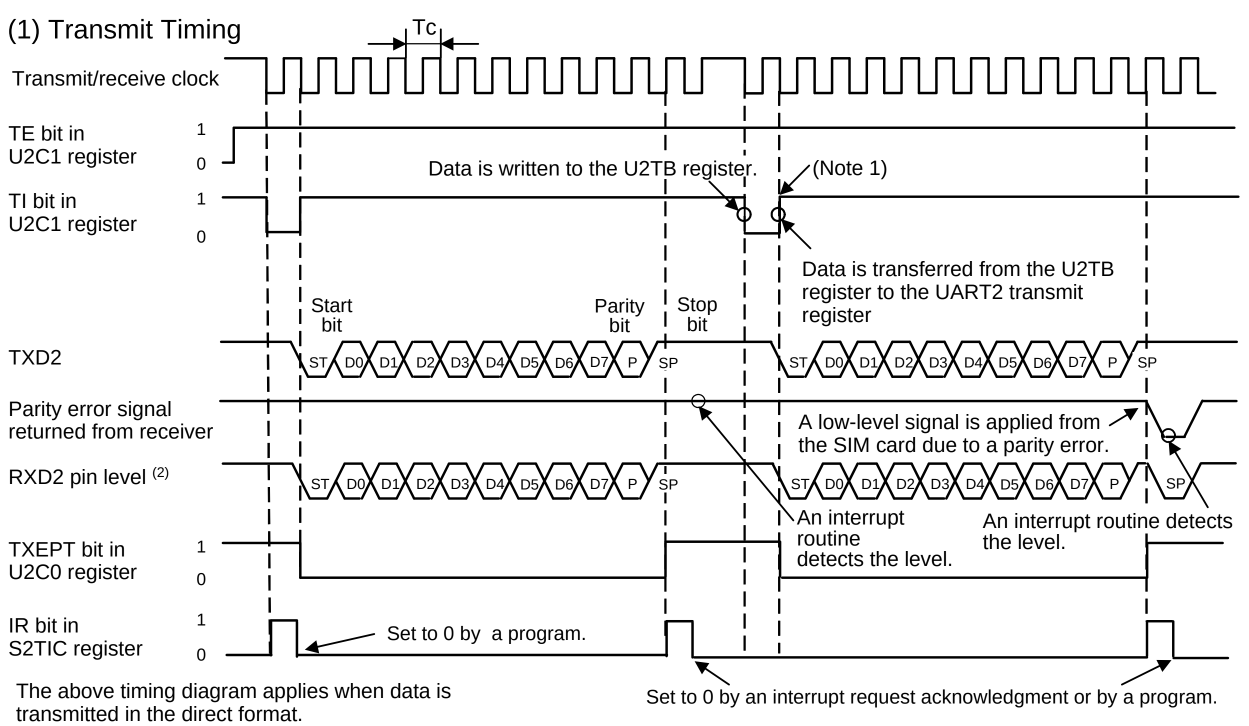
1. If an overrun error occurs, the received data of the U2RB register will be undefined. The IR bit in the S2RIC register does not change.
2. After reset, a transmit interrupt request is generated by setting bits U2IRS and U2ERE in the U2C1 register to 1 (transmission completed, error signal output), then setting the TE bit to 1 (transmission enabled) and the transmission data to the U2TB register. Therefore, when using SIM mode, make sure to set the IR bit to 0 (interrupt not requested) after setting these bits.
3. The timing at which the framing error flag and the parity error flag are set is detected when data is transferred from the UART2 receive register to the U2RB register.

Table 23.25 Registers Used and Settings in SIM Mode [1]

Register	Bit	Function
U2TB [2]	0 to 7	Set transmit data.
U2RB [2]	0 to 7	Received data can be read.
	OER, FER, PER, SUM	Error flag
U2BRG	0 to 7	Set a bit rate.
U2MR	SMD2 to SMD0	Set to 101b.
	CKDIR	Select the internal clock or external clock.
	STPS	Set to 0.
	PRY	Set to 1 in direct format or 0 in inverted format.
	PRYE	Set to 1.
	IOPOL	Set to 0.
U2C0	CLK0, CLK1	Select the count source for the U2BRG register.
	CRS	Disabled because CRD is 1.
	TXEPT	Transmit register empty flag
	CRD	Set to 1.
	NCH	Set to 0.
	CKPOL	Set to 0.
	UFORM	Set to 0 in direct format or 1 in inverted format.
U2C1	TE	Set to 1 to enable transmission.
	TI	Transmit buffer empty flag
	RE	Set to 1 to enable reception.
	RI	Reception complete flag
	U2IRS	Set to 1.
	U2RRM	Set to 0.
	U2LCH	Set to 0 in direct format or 1 in inverted format.
	U2ERE	Set to 1.
U2SMR [2]	0 to 3	Set to 0.
U2SMR2	0 to 7	Set to 0.
U2SMR3	0 to 7	Set to 0.
U2SMR4	0 to 7	Set to 0.

Notes:

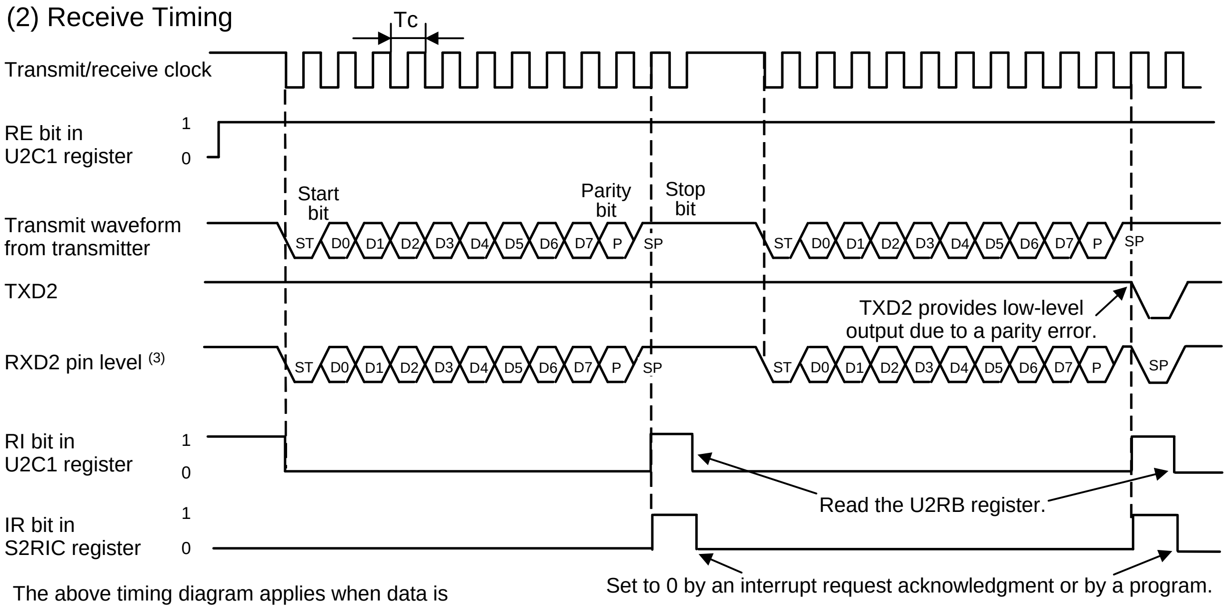
1. This table does not describe a procedure.
2. Set bits not listed above to 0 when writing to the registers in SIM mode.


(1) Transmit Timing
Tc
Transmit/receive clock
TE bit in U2C1 register
1
0
Data is written to the U2TB register.
(Note 1)
TI bit in U2C1 register
1
0
Data is transferred from the U2TB register to the UART2 transmit register
Start bit
Parity bit
Stop bit
TXD2
ST D0 D1 D2 D3 D4 D5 D6 D7 P SP
Parity error signal returned from receiver
A low-level signal is applied from the SIM card due to a parity error.
RXD2 pin level (2)
An interrupt routine detects the level.
An interrupt routine detects the level.
TXEPT bit in U2C0 register
IR bit in S2TIC register
Set to 0 by a program.
Set to 0 by an interrupt request acknowledgment or by a program.

The above timing diagram applies when data is transmitted in the direct format.

- The STPS bit in the U2MR register = 0 (1 stop bit)
- The PRY bit in the U2MR register = 1 (even parity)
- The UFORM bit in the U2C0 register = 0 (LSB first)
- The U2LCH bit in the U2C1 register = 0 (not inverted)
- The U2IRS bit in the U2C1 register = 1 (transmit completed)

TC = 16 (n + 1) / fi or 16 (n + 1) / fEXT
fi : Frequency of U2BRG count source (f1SIO, f2SIO, f8SIO, f32SIO)
fEXT : Frequency of U2BRG count source (external clock)
n : Value set to U2BRG



The above timing diagram applies when data is received in the direct format.

- The STPS bit in the U2MR register = 0 (1 stop bit)
- The PRY bit in the U2MR register = 1 (even parity)
- The UFORM bit in the U2C0 register = 0 (LSB first)
- The U2LCH bit in the U2C1 register = 0 (not inverted)
- The U2IRS bit in the U2C1 register= 1 (transmit completed)

TC = 16 (n + 1) / fi or 16 (n + 1) / fEXT
fi : Frequency of U2BRG count source (f1SIO, f2SIO, f8SIO, f32SIO)
fEXT: Frequency of U2BRG count source (external clock)
n : Value set to U2BRG

Notes:
1. Data transmission starts when BRG overflows after a value is set in the U2TB register on the rising edge of the TI bit.
2. Because pins TXD2 and RXD2 are connected, a composite waveform, consisting of the transmit waveform from the TXD2 pin and parity error signal from the receiver, is generated.
3. Because pins TXD2 and RXD2 are connected, a composite waveform, consisting of the transmit waveform from the transmitter and parity error signal from the TXD2 pin, is generated.

Figure 23.35 Transmit/Receive Timing in SIM Mode

Figure 23.36 shows the Example of SIM Interface Connection. Connect pins TXD2 and RXD2, and then place a pull-up resistance.

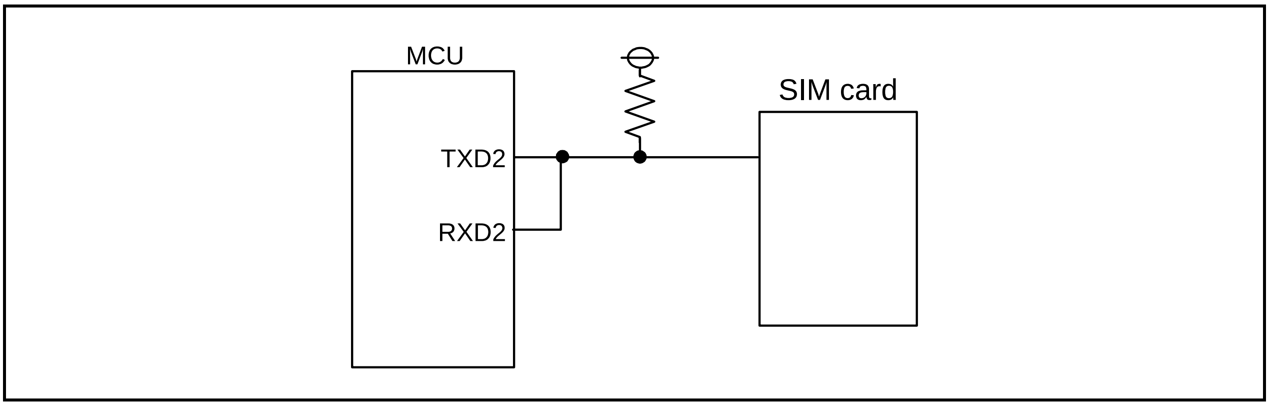


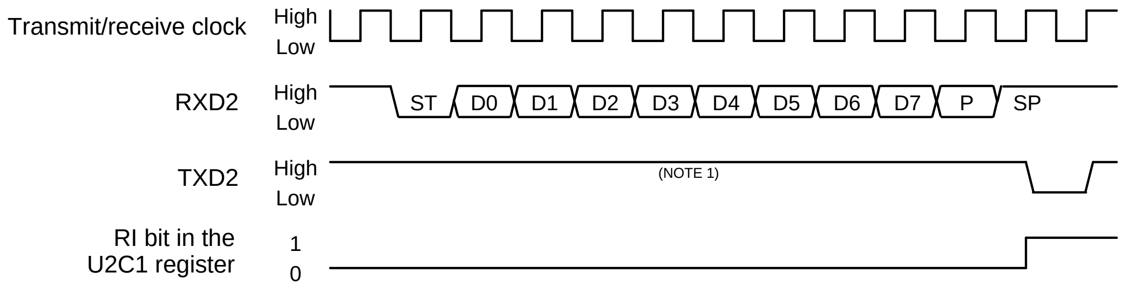
Figure 23.36 Example of SIM Interface Connection

23.3.6.1 Parity Error Signal Output

The parity error signal is enabled by setting the U2ERE bit in the U2C1 register to 1 (error signal output).

The parity error signal is output when a parity error is detected while receiving data. A low-level signal is output from the TXD2 pin in the timing shown in Figure 23.37. If the U2RB register is read while outputting a parity error signal, the PER bit is cleared to 0 (no parity error) and at the same time the TXD2 output again goes high.

When transmitting, a transmission complete interrupt request is generated at the falling edge of the transmit/receive clock pulse that immediately follows the stop bit. Therefore, whether a parity error signal has been returned can be determined by reading the port that shares the RXD2 pin in a transmission complete interrupt routine.



The timing diagram assumes the direct format is implemented.

Note:
1. MCU output is high-impedance (pulled up externally).

ST : Start bit
P : Even parity
SP : Stop bit

Figure 23.37 Parity Error Signal Output Timing

23.3.6.2 Formats

Two formats are available: direct format and inverse format.

For direct format, set the PRYE bit in the U2MR register to 1 (parity enabled), the PRY bit to 1 (even parity), the UFORM bit in the U2C0 register to 0 (LSB first), and the U2LCH bit in the U2C1 register to 0 (not inverted). When data is transmitted, data set in the U2TB register are transmitted with the even-numbered parity, starting from D0. When data is received, the received data is stored in the U2RB register, starting from D0. The even-numbered parity is used to determine whether a parity error occurs.

For inverted format, set the PRYE bit to 1, the PRY bit to 0 (odd parity), the UFORM bit to 1 (MSB first), and the U2LCH bit to 1 (inverted). When data is transmitted, values set in the U2TB register are logically inverted and are transmitted with the odd-numbered parity, starting from D7. When data is received, the received data is logically inverted to be stored in the U2RB register, starting from D7. The odd-numbered parity is used to determine whether a parity error occurs.

Figure 23.38 shows the SIM Interface Format.

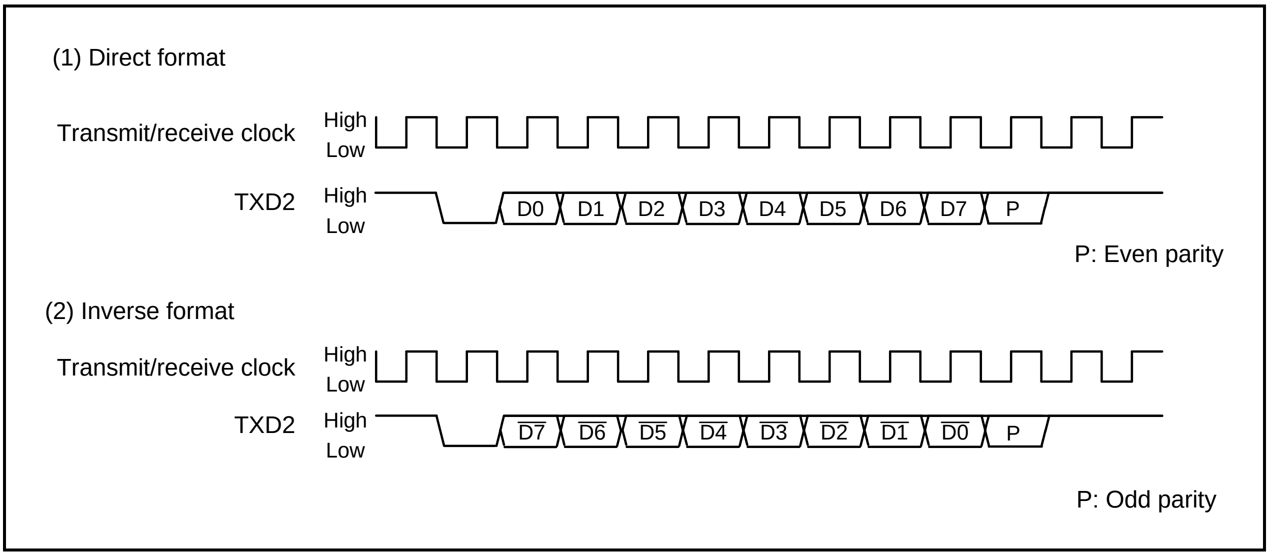


Figure 23.38 SIM Interface Format

23.4 Interrupts

UART0 to UART2, UART5 to UART7 include interrupts by transmission, reception, ACK, NACK, start/stop condition detection, and bus collision detection.

23.4.1 Interrupt Related Registers

Refer to operation examples in each mode for interrupt sources and interrupt request generation timing. For details of interrupt control, refer to 14.7 “Interrupt Control”. Table 23.26 lists UART0 to UART2, UART5 to UART7 Interrupt Related Registers.

Table 23.26 UART0 to UART2, UART5 to UART7 Interrupt Related Registers

Address	Register	Symbol	Reset Value
0046h	UART1 Bus Collision Detection Interrupt Control Register	U1BCNIC	XXXX X000b
0047h	UART0 Bus Collision Detection Interrupt Control Register	U0BCNIC	XXXX X000b
004Ah	UART2 Bus Collision Detection Interrupt Control Register	BCNIC	XXXX X000b
004Fh	UART2 Transmit Interrupt Control Register	S2TIC	XXXX X000b
0050h	UART2 Receive Interrupt Control Register	S2RIC	XXXX X000b
0051h	UART0 Transmit Interrupt Control Register	S0TIC	XXXX X000b
0052h	UART0 Receive Interrupt Control Register	S0RIC	XXXX X000b
0053h	UART1 Transmit Interrupt Control Register	S1TIC	XXXX X000b
0054h	UART1 Receive Interrupt Control Register	S1RIC	XXXX X000b
006Bh	UART5 Bus Collision Detection Interrupt Control Register	U5BCNIC	XXXX X000b
006Ch	UART5 Transmit Interrupt Control Register	S5TIC	XXXX X000b
006Dh	UART5 Receive Interrupt Control Register	S5RIC	XXXX X000b
006Eh	UART6 Bus Collision Detection Interrupt Control Register	U6BCNIC	XXXX X000b
006Fh	UART6 Transmit Interrupt Control Register	S6TIC	XXXX X000b
0070h	UART6 Receive Interrupt Control Register	S6RIC	XXXX X000b
0071h	UART7 Bus Collision Detection Interrupt Control Register	U7BCNIC	XXXX X000b
0072h	UART7 Transmit Interrupt Control Register	S7TIC	XXXX X000b
0073h	UART7 Receive Interrupt Control Register	S7RIC	XXXX X000b
0205h	Interrupt Source Select Register 3	IFSR3A	00h
0206h	Interrupt Source Select Register 2	IFSR2A	00h

Some interrupts of UART0 to UART2 and UART5 to UART7 share interrupt vectors and interrupt control registers with other peripheral functions. When using these interrupts, select them by interrupt source select registers. Table 23.27 lists Interrupt Selection in UART0 to UART2 and UART5 to UART7.

Table 23.27 Interrupt Selection in UART0 to UART2 and UART5 to UART7

Interrupt Source	Interrupt Source Select Register Settings		
	Register	Bit	Setting Value
UART0 start/stop condition detection, bus collision detection	IFSR2A	IFSR26	1
UART1 start/stop condition detection, bus collision detection	IFSR2A	IFSR27	1
UART5 start/stop condition detection, bus collision detection	IFSR3A	IFSR33	0
UART5 transmission, NACK	IFSR3A	IFSR34	0
UART6 start/stop condition detection, bus collision detection	IFSR3A	IFSR35	0
UART6 transmission, NACK	IFSR3A	IFSR36	0
UART7 start/stop condition detection, bus collision detection	IFSR2A	IFSR24	0
UART7 transmission, NACK	IFSR2A	IFSR25	0

In the following modes, an interrupt request can be generated by rewriting bit values.

- Special mode 1 (I^2C mode)
  Set the IR bit in the interrupt control register of UARTi to 0 (interrupt not requested), when the following bits are changed:
  Bits SMD2 to SMD0 in the UiMR register, the IICM bit in the UiSMR register, the IICM2 bit in the UiSMR2 register, the CKPH bit in the UiSMR3 register
- Special mode 4 (SIM mode)
  After reset, a transmit interrupt request is generated by setting bits U2IRS and U2ERE in the U2C1 register to 1 (transmission completed, error signal output), then setting the TE bit to 1 (transmission enabled) and the transmission data to the U2TB register. Therefore, when using SIM mode, make sure to set the IR bit to 0 (interrupt not requested) after setting these bits.

23.4.2 Reception Interrupt

- The case that bits SMD2 to SMD0 in the UiMR register are not set to 010b (I^2C mode)
  When the RI bit in the UiC1 register is changed from 0 (no data in the UiRB register) to 1 (data present in the UiRB register), the IR bit in the SiRIC register is automatically set to 1 (interrupt requested).
  If an overrun error occurs (when the RI bit is 1, the next data is received), the RI bit remains 1, and therefore, the IR bit in the SiRIC register remains unchanged.
- The case that bits SMD2 to SMD0 in the UiMR register are set to 010b (I^2C mode)
  When the RI bit in the UiC1 register is changed from 0 (no data in the UiRB register) to 1 (data present in the UiRB register), the IR bit in the SiRIC register is automatically set to 1 (interrupt requested).
  When an overrun error occurs, the IR bit in the SiRIC register also becomes 1.

23.5 Notes on Serial Interface UARTi (i = 0 to 2, 5 to 7)

23.5.1 Common Notes on Multiple Modes

23.5.1.1 Influence of $\overline{\text{SD}}$

When a low-level signal is applied to the $\overline{\text{SD}}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{\text{SD}}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$/TA1IN/$\overline{\text{V}}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{\text{W}}$, P8_0/TA4OUT/RXD5/SCL5/U, P8_1/TA4IN/$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$/$\overline{\text{U}}$

23.5.1.2 Register Setting

Set the OCOSEL0 or OCOSEL1 bit in the UCLKSEL0 register before setting other registers associated with UART0 to UART2 or UART5 to UART7. After changing the OCOSEL0 or OCOSEL1 bit, set other registers associated with UART0 to UART2 or UART5 to UART7 again.

23.5.1.3 CLKi Output

(Technical update number: TN-16C-A178A/E)

When using the N-channel open drain output as an output mode of the CLKi pin, use following procedure to change the pin function:

When changing the pin function from the port to CLKi.
(1) Set bits SMD2 to SMD0 in the UiMR register to a value other than 000b to select serial interface mode.
(2) Set the NODC bit in the UiSMR3 register to 1.
When changing the pin function from CLKi to the port.
(1) Set the NODC bit to 0.
(2) Set bits SMD2 to SMD0 to 000b to disable the serial interface.

23.5.2 Clock Synchronous Serial I/O Mode

23.5.2.1 Transmission/Reception

When the $\overline{\text{RTS}}$ function is used with an external clock, the $\overline{\text{RTSi}}$ pin (i = 0 to 2, 5 to 7) outputs a low-level signal, which informs the transmitting side that the MCU is ready for a receive operation. The $\overline{\text{RTSi}}$ pin outputs a high-level signal when a receive operation starts. Therefore, transmit timing and receive timing can be synchronized by connecting the $\overline{\text{RTSi}}$ pin to the $\overline{\text{CTSi}}$ pin on the transmitting side. The $\overline{\text{RTS}}$ function is disabled when an internal clock is selected.

23.5.2.2 Transmission

If the transmission is started while an external clock is selected and the TXEPT bit in the UiC0 register (i = 0 to 2, 5 to 7) is 1 (no data present in transmit register), meet the last requirement at either of the following timings:

External clock level:

- The CKPOL bit in the UiC0 register is 0 (transmit data is output at the falling edge of transmit/receive clock and receive data is input at the rising edge) and the external clock is high.
- The CKPOL bit is 1 (transmit data is output at the rising edge of transmit/receive clock and receive data is input at the falling edge) and the external clock is low.

Requirements to start transmission (in no particular order):

- The TE bit in the UiC1 register is 1 (transmission enabled).
- The TI bit in the UiC1 register is 0 (data present in the UiTB register).
- When the $\overline{\text{CTS}}$ function is selected, input on the $\overline{\text{CTSi}}$ pin is low.

23.5.2.3 Reception

In clock synchronous serial I/O mode, a shift clock is generated by activating a transmitter. Set the UARTi-associated registers for a transmit operation even if the MCU is used for a receive operations only. Dummy data is output from the TXDi pin (i = 0 to 2, 5 to 7) while receiving.

When an internal clock is selected, a shift clock is generated by setting the TE bit in the UiC1 register to 1 (transmission enabled) and placing dummy data in the UiTB register. When an external clock is selected, set the TE bit to 1 (transmission enabled), set dummy data in the UiTB register, and input an external clock to the CLKi pin to generate a shift clock.

If data is received consecutively, an overrun error occurs when the RI bit in the UiC1 register is 1 (data present in the UiRB register) and the next receive data is received in the UARTi receive register. Then, the OER bit in the UiRB register becomes 1 (overrun error occurred). At this time, the UiRB register is undefined. When an overrun error occurs, program the transmitting and receiving sides to retransmit the previous data. If an overrun error occurs again, the IR bit in the SiRIC register remains unchanged.

To receive data consecutively, set dummy data in the low-order byte in the UiTB register for each receive operation.

If the reception is started while an external clock is selected and the TXEPT bit in the UiC0 register is 1 (no data present in transmit register), meet the last requirement at either of the timings below.

External clock level:

- The CKPOL bit in the UiC0 register is 0 (transmit data is output at the falling edge of transmit/receive clock and receive data is input at the rising edge) and the external clock is high.
- The CKPOL bit is 1 (transmit data is output at the rising edge of transmit/receive clock and receive data is input at the falling edge) and the external clock is low.

Requirements to start reception (in no particular order):

- The RE bit in the UiC1 register is 1 (reception enabled).
- The TE bit in the UiC1 register is 1 (transmission enabled).
- The TI bit in the UiC1 register is 0 (data present in the UiTB register).

23.5.3 Special Mode 1 (I^{2}C Mode)

23.5.3.1 Generating Start and Stop Conditions

(Technical update number: TN-16C-130A/EA)
When generating start, stop, and restart conditions, set the STSPSEL bit in the UiSMR4 register (i = 0 to 2, 5 to 7) to 0 and wait for more than a half cycle of the transmit/receive clock. Then set each condition generation bit (STAREQ, RSTAREQ, and STPREQ) from 0 to 1.

23.5.3.2 IR Bit

Set the following bits first, and then set the IR bit in each UARTi interrupt control register to 0 (interrupt not requested).

Bits SMD2 to SMD0 in the UiMR register, the IICM bit in the UiSMR register,
the IICM2 bit in the UiSMR2 register, the CKPH bit in the UiSMR3 register

23.5.3.3 Low/High-level Input Voltage and Low-level Output Voltage

The low-level input voltage, high-level input voltage, and low-level output voltage differ from the I^{2}C-bus specification.

Refer to the recommended operating conditions for I/O ports which share the pins with SCL and SDA.

I^{2}C-bus specification

High level input voltage (V_{IH}) = min. 0.7 V_{CC}

Low level input voltage (V_{IL}) = max. 0.3 V_{CC}

23.5.3.4 Setup and Hold Times When Generating a Start/Stop Condition

When generating a start condition, the hold time (t_{HD}:STA) is a half cycle of the SCL clock. When generating a stop condition, the setup time (t_{SU}:STO) is a half cycle of the SCL clock.

When the SDA digital delay function is enabled, take delay time into consideration (see 23.3.3.7 “SDA Digital Delay”).

The following shows a calculation example of hold and setup times when generating a start/stop condition.

Calculation example when setting 100 kbps

- UiBRG count source: f1 = 20 MHz
- UiBRG register setting value: n = 100 - 1
- SDA digital delay setting value: DL2 to DL0 are 101b (5 or 6 cycles of UiBRG count source)

f_{SCL} (theoretical value) = f1 / (2(n+1)) = 20 MHz / (2 × (99 + 1)) = 100 kbps

t_{DL} = delay cycle count / f1 = 6 / 20 MHz = 0.3 μs

$t_{HD:STA}$ (theoretical value) = 1 / (2f_{SCL} (theoretical value)) = 1 / (2 × 100 kbps) = 5 μs

$t_{SU:STO}$ (theoretical value) = 1 / (2f_{SCL} (theoretical value)) = 1 / (2 × 100 kbps) = 5 μs

$f_{HD:STA}$ (actual value) = $t_{HD:STA}$ (theoretical value) - t_{DL} = 5 μs - 0.3 μs = 4.7 μs

$f_{SU:STO}$ (actual value) = $t_{SU:STO}$ (theoretical value) + t_{DL} = 5 μs + 0.3 μs = 5.3 μs

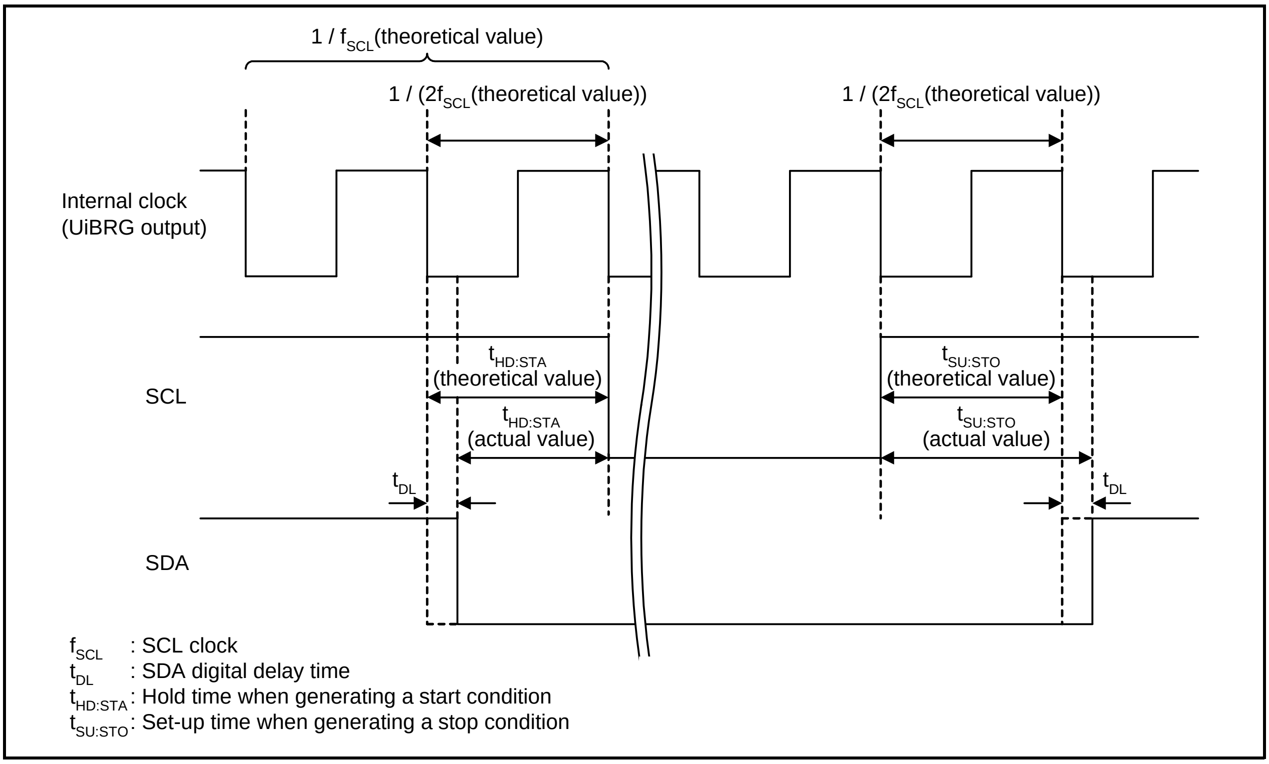

1 / f_{SCL}(theoretical value)
1 / (2f_{SCL}(theoretical value))
1 / (2f_{SCL}(theoretical value))
Internal clock (UiBRG output)
SCL
SDA
$t_{HD:STA}$ (theoretical value)
$t_{HD:STA}$ (actual value)
$t_{SU:STO}$ (theoretical value)
$t_{SU:STO}$ (actual value)
t_{DL}
t_{DL}
f_{SCL} : SCL clock
t_{DL} : SDA digital delay time
$t_{HD:STA}$: Hold time when generating a start condition
$t_{SU:STO}$: Set-up time when generating a stop condition

Figure 23.39 Setup and Hold Times When Generating Start and Stop Conditions

23.5.3.5 Restrictions on the Bit Rate When Using the UiBRG Count Source

In I^2C mode, set the UiBRG register to a value of 03h or greater.

A maximum of three UiBRG count source cycles are necessary until the internal circuit acknowledges the SCL clock level. The connectable I^2C-bus bit rate is one-third or less than the UiBRG count source speed. If a value between 00h to 02h is set to the UiBRG register, bit slippage may occur.

23.5.3.6 Restart Condition in Slave Mode

When a restart condition is detected in slave mode, the successive processes may not be executed correctly. In slave mode, do not use a restart condition.

23.5.3.7 Requirements to Start Transmission/Reception in Slave Mode

When transmission/reception is started in slave mode and the TXEPT bit in the UiC0 register is 1 (no data present in transmit register), meet the last requirement when the external clock is high.

Requirements to start transmission (in no particular order):

- The TE bit in the UiC1 register is 1 (transmission enabled).
- The TI bit in the UiC1 register is 0 (data present in the UiTB register).

Requirements to start reception (in no particular order):

- The RE bit in the UiC1 register is 1 (reception enabled).
- The TE bit in the UiC1 register is 1 (transmission enabled).
- The TI bit in the UiC1 register is 0 (data present in the UiTB register).

23.5.4 Special Mode 4 (SIM Mode)

(Technical update number: TN-M16C-101-0309)

After reset, a transmit interrupt request is generated by setting bits U2IRS and U2ERE in the U2C1 register to 1 (transmission completed, error signal output), then setting the TE bit to 1 (transmission enabled) and the transmission data to the U2TB register. Therefore, when using SIM mode, make sure to set the IR bit to 0 (interrupt not requested) after setting these bits.

24. Serial Interface SI/O3 and SI/O4

24.1 Introduction

SI/O3 and SI/O4 are dedicated clock-synchronous serial I/O ports.
Table 24.1 lists SI/O3 and SI/O4 Specifications.
Figure 24.1 shows SI/O3 and SI/O4 Block Diagram, and Table 24.2 lists the I/O Ports.

Table 24.1 SI/O3 and SI/O4 Specifications

Item	Specification
Data format	Character length: 8 bits
Transmit/receive clocks	• The SMi6 bit in the SiC register = 1 (internal clock): $\frac{fj}{2(n+1)}$ fj = f1SIO, f2SIO, f8SIO, f32SIO n = setting value of the SiBRG register 00h to FFh The SMi6 bit = 0 (external clock): Input from the CLKi pin [1]
Transmission/reception start condition	Before transmission/reception starts, write transmit data to the SiTRR register. [2]
Interrupt request generation timing	• The SMi4 bit in the SiC register = 0 The rising edge of the last transmit/receive clock • The SMi4 bit = 1 The falling edge of the last transmit/receive clock
Selectable functions	• CLK polarity selection Whether data is input/output at the rising or falling edge of the transmit/receive clock can be selected. • LSB first or MSB first selection Whether to start transmitting/receiving data from bit 0 or from bit 7 can be selected. • SOUTi initial value setting function When the SMi6 bit in the SiC register = 0 (external clock), the SOUTi pin output level while not transmitting can be selected. • SOUTi state selection after transmission Whether to set to high-impedance or retain the last bit level can be selected when the SMi6 bit in the SiC register is 1 (internal clock).

i = 3, 4

Notes:

1. The data is shifted every time the external clock is input. When completing data transmission/reception of the eighth bit, read or write to the SiTRR register before inputting the clock for the next data transmission/reception.
2. When the SMi6 bit in the SiC register is 0 (external clock), follow the steps below.
   - When the SMi4 bit in the SiC register is 0, write transmit data to the SiTRR register while input to the CLKi pin is high.
   - When the SMi4 bit is 1, write transmit data to the SiTRR register while input to the CLKi pin is low.

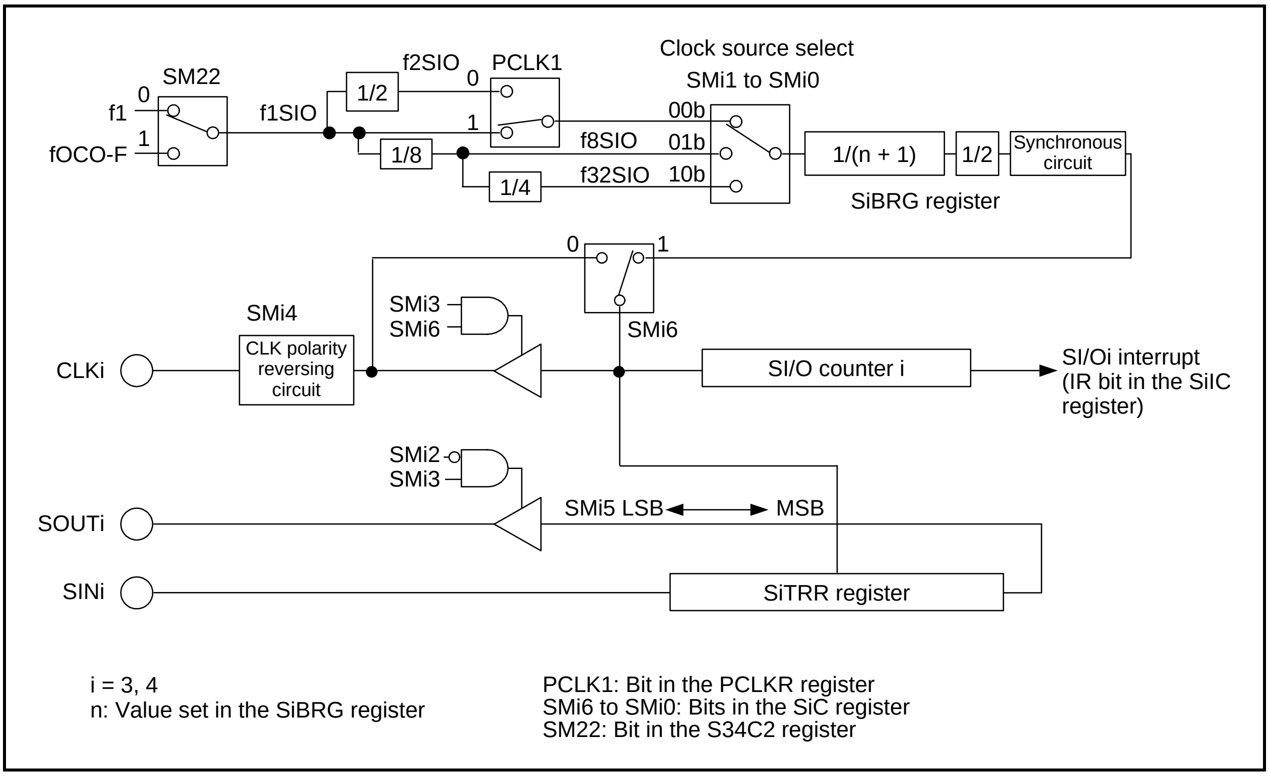


Figure 24.1 SI/O3 and SI/O4 Block Diagram

Table 24.2 I/O Ports

Pin Name	I/O	Function	Selecting Method
CLKi	Output	Transmit/receive clock output	SMi3 bit in the SiC register = 1 SMi6 bit in the SiC register = 1
	Input	Transmit/receive clock input	SMi3 bit in the SiC register = 1 SMi6 bit in the SiC register = 0 Port direction bits sharing pins = 0
SOUTi	Output	Serial data output	SMi3 bit in the SiC register = 1 SMi2 bit in the SiC register = 0
SINi	Input	Serial data input	SMi3 bit in the SiC register = 1 Port direction bits sharing pins = 0 (Dummy data is input only when transmitting.)

24.2 Registers

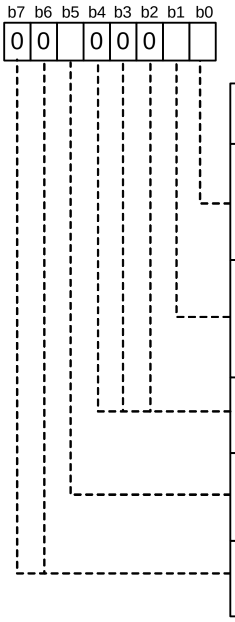
Table 24.3 lists registers associated with SI/O3 and SI/O4. Refer to 8.2.6 “Peripheral Clock Stop Register 1 (PCLKSTP1)” for the explanation of the PCLKSTP1 register.
Set the SM22 bit in the S34C2 register before setting other registers associated with SI/O3 and SI/O4. After changing the SM22 bit, set other registers associated with SI/O3 and SI/O4 again.

Table 24.3 Registers

Address	Register	Symbol	Reset Value
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
0270h	SI/O3 Transmit/Receive Register	S3TRR	XXh
0272h	SI/O3 Control Register	S3C	0100 0000b
0273h	SI/O3 Bit Rate Register	S3BRG	XXh
0274h	SI/O4 Transmit/Receive Register	S4TRR	XXh
0276h	SI/O4 Control Register	S4C	0100 0000b
0277h	SI/O4 Bit Rate Register	S4BRG	XXh
0278h	SI/O3, 4 Control Register 2	S34C2	00XX X0X0b

24.2.1 Peripheral Clock Select Register (PCLKR)

Peripheral Clock Select Register



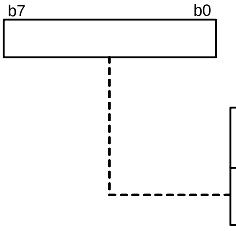
Symbol	Address	Reset Value
PCLKR	0012h	0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A and B clock select bit (clock source for timers A and B, the dead time timer, and multi-master I²C-bus interface)	0: f2TIMAB/f2IIC 1: f1TIMAB/f1IIC	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART2, UART5 to UART7, SI/O3, and SI/O4)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function expansion bit (enabled in single-chip mode)	0: Selected by setting bits CM01 to CM00 in the CM0 register 1: Output f1	RW
— (b7-b6)	Reserved bits	Set to 0	RW

Rewrite the PCLKR register after setting the PRC0 bit in the PRCR register to 1 (write enabled).

24.2.2 SI/Oi Transmit/Receive Register (SiTRR) (i = 3, 4)

SI/Oi Transmit/Receive Register (i = 3, 4)



Symbol	Address	Reset Value
S3TRR	0270h	Undefined
S4TRR	0274h	Undefined

Function	RW
Transmission/reception starts by writing transmit data to this register. After transmission/reception completes, receive data can be read.	RW

Write to the SiTRR register while the serial interface is neither transmitting nor receiving.

Write a value to the SiTRR register each time 1-byte data is received, even when data is only received.

24.2.3 SI/Oi Control Register (SiC) (i = 3, 4)

SI/Oi Control Register (i = 3, 4)

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
S3C	0272h	0100 0000b
S4C	0276h	0100 0000b

Bit symbol	Bit Name	Function	RW
SMi0	Internal synchronous clock select bit	b1 b0 0 0 : f1SIO or f2SIO selected 0 1 : f8SIO selected 1 0 : f32SIO selected 1 1 : Do not set this value.	RW
SMi1			
SMi2	SOUTi output disable bit	0 : SOUTi output enabled 1 : SOUTi output disabled (high-impedance)	RW
SMi3	SI/Oi port select bit	0 : I/O port serial interface disabled 1 : SOUTi output, CLKi function serial interface enabled	RW
SMi4	CLK polarity select bit	0 : Transmit data is output at falling edge of transmit/receive clock and receive data is input at rising edge 1 : Transmit data is output at rising edge of transmit/receive clock and receive data is input at falling edge	RW
SMi5	Bit order select bit	0 : LSB first 1 : MSB first	RW
SMi6	Synchronous clock select bit	0 : External clock 1 : Internal clock	RW
SMi7	SOUTi initial output set bit	Enabled when SMi6 is 0 0 : Low output 1 : High output	RW

After setting the PRC2 bit in the PRCR register to 1 (write enabled), use the next instruction to write to this register.

SMi1-SMi0 (Internal synchronous clock select bit) (b1-b0)

Select f1SIO or f2SIO by the PCLK1 bit in the PCLKR register.
Set the SiBRG register when changing bits SMi1 to SMi0.

SMi2 (SOUTi output disable bit) (b2)

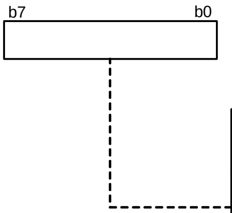
When the SMi2 bit is set to 1 (SOUTi output disabled), the target pin becomes high-impedance regardless of which function of the pin is being used.

SMi7 (SOUTi initial value set bit) (b7)

Set the SMi7 bit when the SMi3 bit is 0 (I/O port, serial interface disabled). The level selected by the SMi7 bit is output from the SOUTi pin by setting the SMi3 bit to 1 and the SMi2 bit to 0 (SOUTi output).

24.2.4 SI/Oi Bit Rate Register (SiBRG) (i = 3, 4)

SI/Oi Bit Rate Register (i = 3, 4)



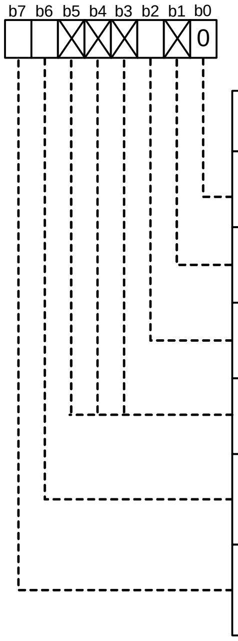
Symbol	Address	Reset Value
S3BRG	0273h	Undefined
S4BRG	0277h	Undefined

Function	Setting Range	RW
SiBRG divides the count source by n + 1 where n = set value	00h to FFh	WO

Use the MOV instruction to write to the SiBRG register.
Write to the SiBRG register after setting bits SMi1 to SMi0 in the SiC register, and while the serial interface is neither transmitting nor receiving.

24.2.5 SI/O3, 4 Control Register 2 (S34C2)

SI/O3, 4 Control Register 2



Symbol	Address	Reset Value
S34C2	0278h	00XX X0X0b

Bit Symbol	Bit Name	Function	RW
— (b0)	Reserved bit	Set to 0	RW
— (b1)	No register bit. If necessary, set to 0. Read as undefined value		—
SM22	SI/O3, SI/O4 pre-division clock select bit	0: f1 1: fOCO-F	RW
— (b5-b3)	No register bits. If necessary, set to 0. Read as undefined value		—
SM26	SOUT3 output control bit	SOUT3 state after transmission 0 : High-impedance 1 : Last bit level retained	RW
SM27	SOUT4 output control bit	SOUT4 state after transmission 0 : High-impedance 1 : Last bit level retained	RW

SM22 (SI/O3, SI/O4 pre-division clock select bit) (b2)

Set the SM22 bit while transmission/reception of SI/O3 and SI/O4 is stopped.
Set the SM22 bit before setting other registers associated with SI/O3 and SI/O4. After changing the SM22 bit, set other registers associated with SI/O3 and SI/O4 again.

SM26 (SOUT3 output control bit) (b6)
SM27 (SOUT4 output control bit) (b7)

Bits SM26 and SM27 are enabled when the SMi6 bit in the SiC register is 1 (internal clock). Set the SMi3 bit in the SiC register to 1 (serial interface enabled) after setting bits SM26 and SM27.

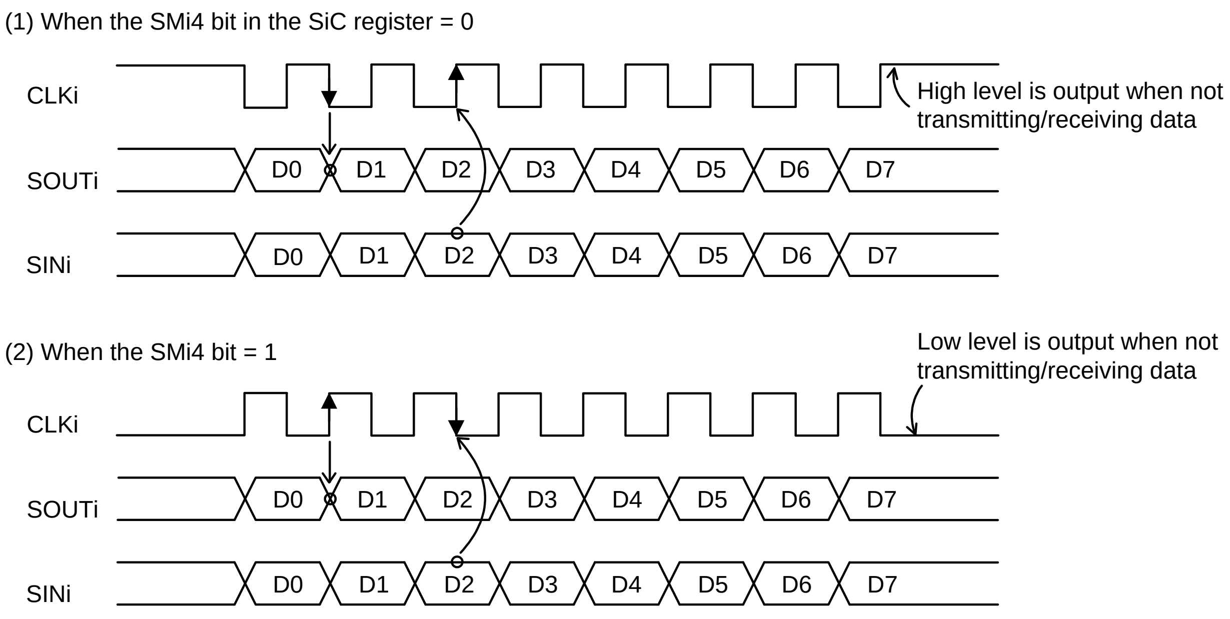
24.3 Operations

24.3.1 Basic Operations

SI/Oi transmits and receives data simultaneously. The SiTRR register is not divided into a register for transmission/reception and buffer. Write transmit data to the SiTRR register while transmission/reception is stopped. Read receive data from the SiTRR register while transmission/reception is stopped.

24.3.2 CLK Polarity Selection

Use the SMi4 bit in the SiC register to select the transmit/receive clock polarity. Figure 24.2 shows Polarity of Transmit/Receive Clock.


(1) When the SMi4 bit in the SiC register = 0
CLKi
SOUTi
SINi
D0
D1
D2
D3
D4
D5
D6
D7
High level is output when not transmitting/receiving data
(2) When the SMi4 bit = 1
Low level is output when not transmitting/receiving data
CLKi
SOUTi
SINi
D0
D1
D2
D3
D4
D5
D6
D7

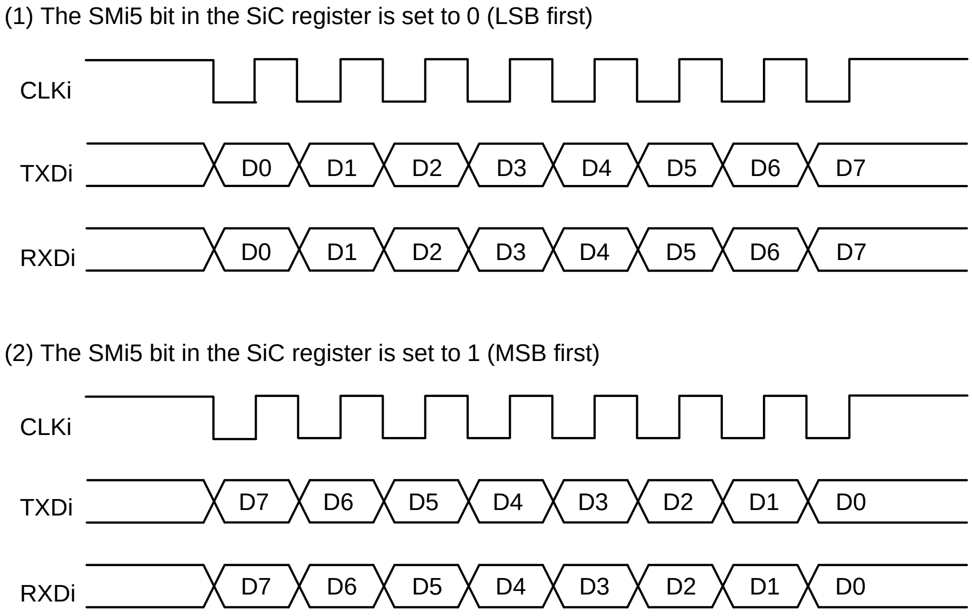
i = 3, 4

Notes:
The above diagram assumes the following:
1. The SMi5 bit in the SiC register is 0 (LSB first).
2. The SMi6 bit in the SiC register is 1 (internal clock).
3. The SM26 bit or SM27 bit in the S34C2 register is 1 (SOUTi output retains last bit level)

Figure 24.2 Polarity of Transmit/Receive Clock

24.3.3 LSB First or MSB First Selection

Bit order is selected by setting the SMi5 bit in the SiC register (i = 3, 4). Figure 24.3 shows Bit Order.


(1) The SMi5 bit in the SiC register is set to 0 (LSB first)
CLKi
TXDi
D0 D1 D2 D3 D4 D5 D6 D7
RXDi
D0 D1 D2 D3 D4 D5 D6 D7
(2) The SMi5 bit in the SiC register is set to 1 (MSB first)
CLKi
TXDi
D7 D6 D5 D4 D3 D2 D1 D0
RXDi
D7 D6 D5 D4 D3 D2 D1 D0

The above diagram assumes the following:

- The SMi4 bit in the SiC register is set to 0 (transmit data is output at falling edge of transmit/receive clock and receive data is input at rising edge)

i = 3, 4

Figure 24.3 Bit Order

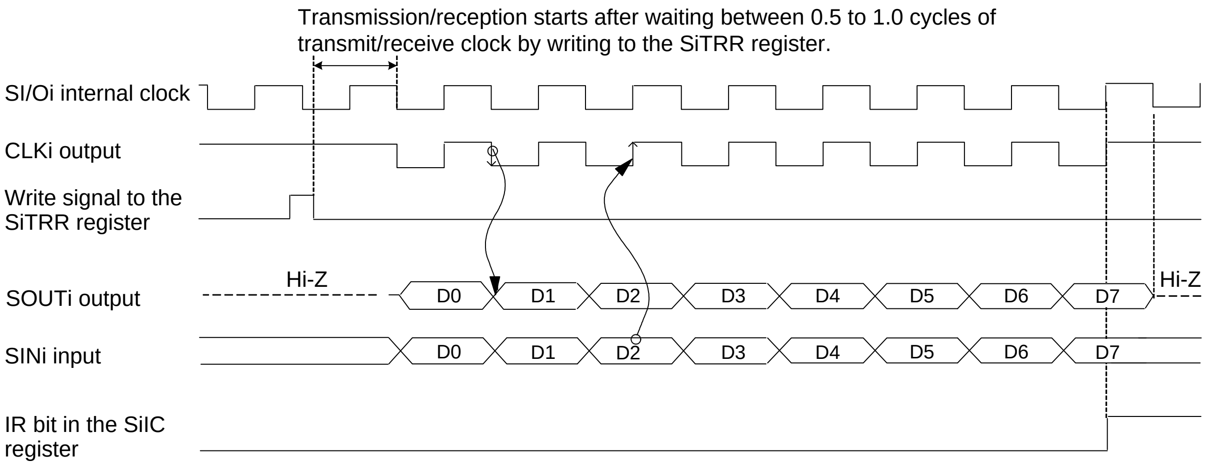
24.3.4 Internal Clock

When the SMi6 bit in the SiC register is 1, data is transmitted/received using the internal clock. The internal clock is selected by setting the SM22 bit in the S34C2 register, the PCLK1 bit in the PCLKR register, and bits SMi1 to SMi0 in the SiC register. When using f1 as the clock source of the internal clock, set the PCKSTP1A bit in the PCLKSTP1 register to 0 (f1 provide enabled).

When the internal clock is used as the transmit/receive clock, the SOUTi pin becomes high-impedance from when the SMi3 bit in the SiC register is set to 1 (SI/Oi enabled) and the SMi2 bit is set to 0 (SOUTi output enabled) to when the first data is output.

When writing transmit data to the SiTRR register, data transmission/reception starts by outputting the transmit/receive clock from the CLKi pin after waiting between 0.5 to 1.0 cycles of the transmit/receive clock. After 8 bits of data have been transmitted/received, the transmit/receive clock from the CLKi pin stops.

Figure 24.4 shows SI/Oi Operation Timing (Internal Clock).


Transmission/reception starts after waiting between 0.5 to 1.0 cycles of transmit/receive clock by writing to the SiTRR register.
SI/Oi internal clock
CLKi output
Write signal to the SiTRR register
SOUTi output
Hi-Z
D0
D1
D2
D3
D4
D5
D6
D7
Hi-Z
SINi input
D0
D1
D2
D3
D4
D5
D6
D7
IR bit in the SiIC register

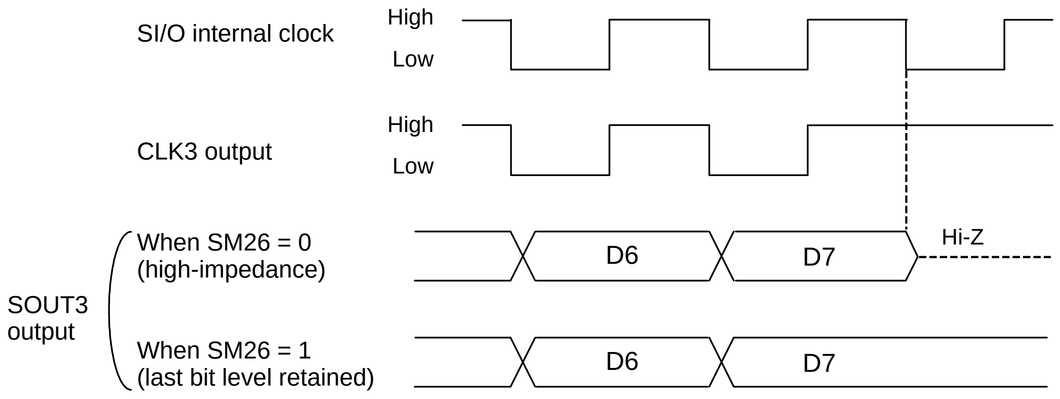
i = 3, 4

The above diagram assumes the following:
In the SiC register, SMi2 = 0 (SOUTi output), SMi3 = 1 (SOUTi output, CLKi function), SMi4 = 0 (transmit data is output at a falling edge of the transmit/receive clock, and receive data is input at a rising edge), SMi5 = 0 (LSB first), SMi6 = 1 (internal clock).
In the S34C2 register, the SM26 bit (SOUT3) or SM27 bit (SOUT4) = 0 (high-impedance after transmission).

Figure 24.4 SI/Oi Operation Timing (Internal Clock)

24.3.5 Function for Selecting SOUTi State after Transmission

The SOUTi pin state after transmission can be selected when the SMi6 bit in the SiC register is set to 1 (internal clock). If bits SM26 and SM27 in the S34C2 register are both set to 1 (last bit level retained), output from the SOUTi pin retains the last bit level after transmission. Figure 24.5 shows SOUT3 Pin Level after Transmission.



The above SOUT3 example assumes the following:
The SM32 bit in the S3C register is 0 (SOUT3 output),
The SM33 bit in the S3C register is 1 (SOUT3 output, CLK3 selected),
The SM34 bit in the S3C register is 0 (transmit data output at the falling edge of the transmit/receive clock and the receive data is input at the rising edge),
The SM35 bit in the S3C register is 0 (LSB first),
The SM36 bit in the S3C register is 1 (internal clock)

Figure 24.5 SOUT3 Pin Level after Transmission

24.3.6 External Clock

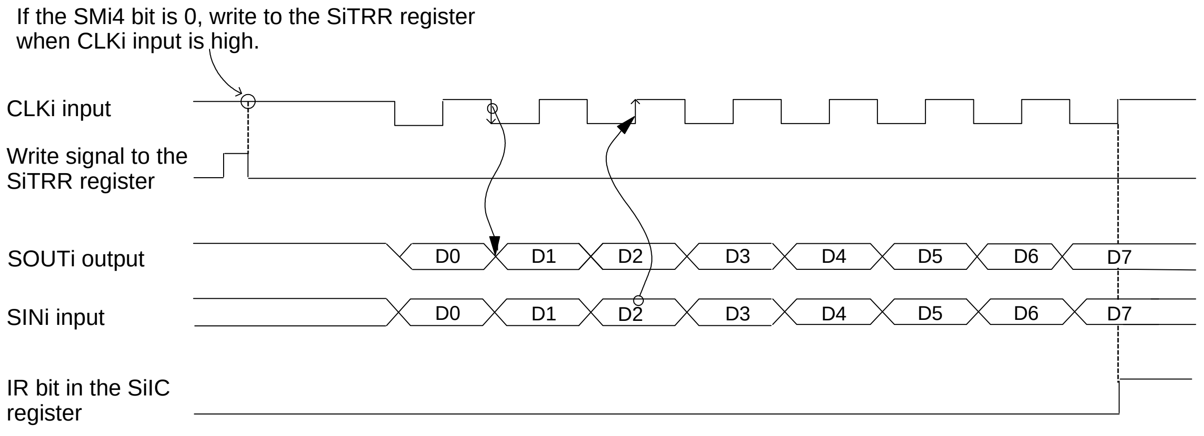
When the SMi6 bit in the SiC register is 0, data is transmitted/received using the external clock.

The external clock is used as a transmit/receive clock, the SOUTi output level from when the SMi3 bit in the SiC register is set to 1 (SI/Oi enabled) and SMi2 bit is set to 0 (SOUTi output enabled) to when the first data is output can be selected by the SMi7 bit in the SiC register. Refer to 24.3.8 “Function for Setting SOUTi Initial Value”.

Transmission/reception starts with the external clock after writing the transmit data to the SiTRR register.

Data written to the SiTRR register shifts each time the external clock is input. When completing data transmission/reception of the eighth bit, read or write to the SiTRR register before inputting the clock for the next data transmission/reception.

Figure 24.6 shows SI/Oi Operation Timing (External Clock).


If the SMi4 bit is 0, write to the SiTRR register when CLKi input is high.
CLKi input
Write signal to the SiTRR register
SOUTi output
D0
D1
D2
D3
D4
D5
D6
D7
SINi input
D0
D1
D2
D3
D4
D5
D6
D7
IR bit in the SiIC register

i = 3, 4

The above diagram assumes the following:
In the SiC register, SMi2 = 0 (SOUTi output), SMi3 = 1 (SOUTi output, CLKi function), SMi4 = 0 (transmit data is output at falling edge of transmit/receive clock and receive data is input at rising edge), SMi5 = 0 (LSB first), SMi6 = 0 (external clock)

Figure 24.6 SI/Oi Operation Timing (External Clock)

When the SMi6 bit in the SiC register is 0 (external clock), write to the SiTRR register and SMi7 bit in the SiC register under the following conditions:

- When the SMi4 bit in the SiC register is 0 (transmit data is output at falling edge of transmit/receive clock and receive data is input at rising edge): CLKi input is high.
- When the SMi4 bit is 1 (transmit data is output at rising edge of transmit/receive clock and receive data is input at falling edge): CLKi input is low.

24.3.7 SOUTi Pin

The SOUTi pin state can be selected by setting bits SMi2 and SMi3 in the SiC register.

Table 24.4 lists SOUTi Pin State.

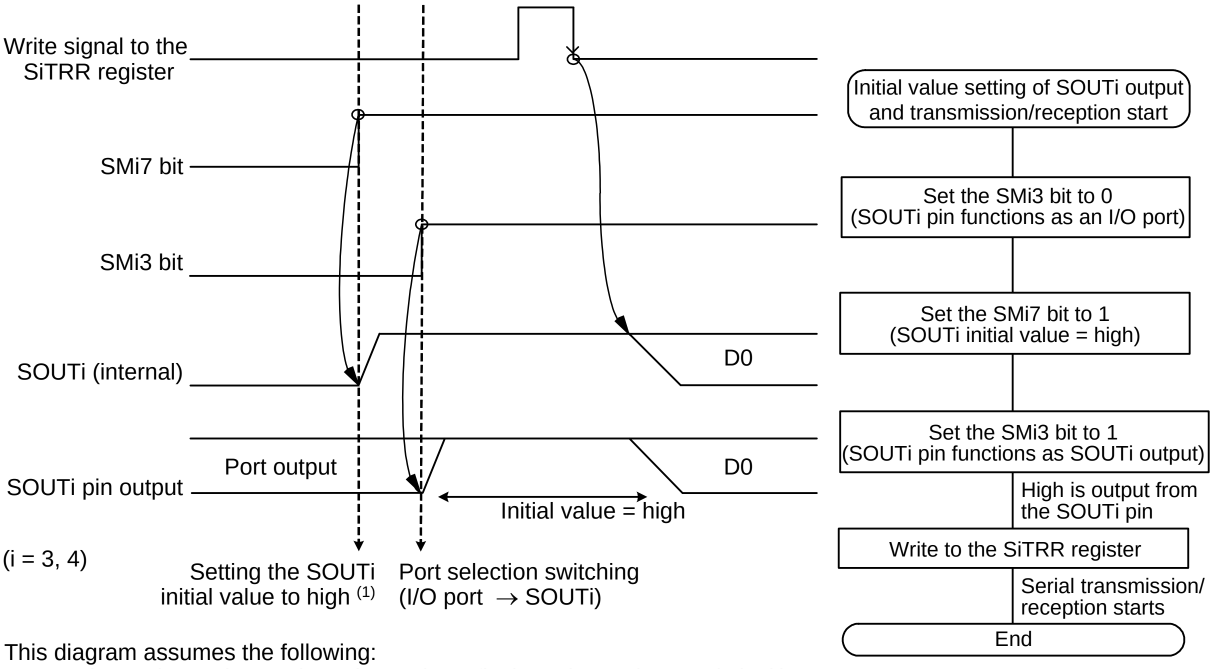
Table 24.4 SOUTi Pin State

Bit Setting		SOUTi Pin State
SiC register		
SMi2	SMi3	
0	0	I/O port or other peripheral function
	1	SOUTi output
1	0/1	High-impedance

24.3.8 Function for Setting SOUTi Initial Value

When the SMi6 bit in the SiC register is 0 (external clock), the SOUTi pin output can be fixed high or low when not transmitting/receiving data. High or low can be selected by setting the SMi7 bit in the SiC register. However, the last bit value of the previous unit of data is retained between adjacent units of data when using the external clock. Figure 24.7 shows Timing Chart for Setting SOUTi Initial Value and How to Set It.

(Example) When High Is Selected for the SOUTi Initial Value


Write signal to the SiTRR register
SMi7 bit
SMi3 bit
SOUTi (internal)
D0
Port output
SOUTi pin output
D0
Initial value = high
(i = 3, 4)
Setting the SOUTi initial value to high (1)
Port selection switching (I/O port → SOUTi)
Initial value setting of SOUTi output and transmission/reception start
Set the SMi3 bit to 0 (SOUTi pin functions as an I/O port)
Set the SMi7 bit to 1 (SOUTi initial value = high)
Set the SMi3 bit to 1 (SOUTi pin functions as SOUTi output)
High is output from the SOUTi pin
Write to the SiTRR register
Serial transmission/ reception starts
End

This diagram assumes the following:
SMi2 = 0 (SOUTi output), SMi5 = 0 (LSB first), SMi6 = 0 (external clock)

Note:
1. SOUTi can only be initialized when input on the CLKi pin is in the high state if the SMi4 bit in the SiC register = 0 (transmit data is output at the falling edge of the transmit receive clock) or in the low state if the SMi4 bit = 1 (transmit data is output at the rising edge of the transmit/receive clock).

Figure 24.7 Timing Chart for Setting SOUTi Initial Value and How to Set It

24.4 Interrupt

Refer to the operation example for interrupt source or interrupt request generation timing. Refer to 14.7 “Interrupt Control” for interrupt control. Table 24.5 lists Registers Associated with SI/O3 and SI/O4.

Table 24.5 Registers Associated with SI/O3 and SI/O4

Address	Register	Symbol	Reset Value
0048h	SI/O4 Interrupt Control Register	S4IC	XX00 X000b
0049h	SI/O3 Interrupt Control Register	S3IC	XX00 X000b
0207h	Interrupt Source Select Register	IFSR	00h

The interrupts below share the interrupt vector and interrupt control register with other peripheral functions. To use the following interrupts, set the bits as follows:

- SI/O3: Set the IFSR6 bit in the IFSR register to 0 (SI/O3).
- SI/O4: Set the IFSR7 bit in the IFSR register to 0 (SI/O4).

Set the POL bit in the SiIC register to 0 (falling edge).

24.5 Notes on Serial Interface SI/O3 and SI/O4

24.5.1 SOUTi Pin Level When SOUTi Output Is Disabled

When the SMi2 bit in the SiC register is set to 1 (SOUTi output disabled), the target pin becomes high-impedance regardless of which pin function being used.

24.5.2 External Clock Control

The data written to the SiTRR register shifts each time the external clock is input. When completing data transmission/reception of the eighth bit, read or write to the SiTRR register before inputting the clock for the next data transmission/reception.

24.5.3 Register Access

Set the SM22 bit in the S34C2 register before setting other registers associated with SI/O3 and SI/O4. After changing the SM22 bit, set other registers associated with SI/O3 and SI/O4 again.

24.5.4 Register Access When Using the External Clock

When the SMi6 bit in the SiC register is 0 (external clock), write to the SMi7 bit in the SiC register and SiTRR register under the following conditions:

- When the SMi4 bit in the SiC register is 0 (transmit data is output at the falling edge of transmit/receive clock and receive data is input at the rising edge): CLKi input is high.
- When the SMi4 bit in the SiC register is 1 (transmit data is output at the rising edge of transmit/receive clock and receive data is input at the falling edge): CLKi input is low.

24.5.5 SiTRR Register Access

Write transmit data to the SiTRR register while transmission/reception is stopped. Read receive data from the SiTRR register while transmission/reception is stopped.
The IR bit in the SiIC register becomes 1 (interrupt requested) during output of the eighth bit.
When the SM26 bit (SOUT3) or SM27 bit (SOUT4) in the S34C2 register is 0 (high-impedance after transmission), the SOUTi pin becomes high-impedance when the transmit data is written to the SiTRR register immediately after an interrupt request is generated, and the hold time of the transmit data becomes shorter.

24.5.6 Pin Function Switch When Using the Internal Clock

(Technical update number: TN-16C-121A/EA)
If the SMi3 bit in the SiC register (i = 3, 4) changes from 0 (I/O port) to 1 (SOUTi output, CLKi function) when setting the SMi2 bit to 0 (SOUTi output) and the SMi6 bit to 1 (internal clock), the SOUTi initial value set to the SOUTi pin by the SMi7 bit may be output for about 10 ns. Then, the SOUTi pin becomes high-impedance.
If the output level from the SOUTi pin when the SMi3 bit changes from 0 to 1 becomes a problem, set the SOUTi initial value by the SMi7 bit.

24.5.7 Operation after Reset When Selecting the External Clock

When the SMi6 bit in the SiC register is 0 (external clock) after reset, the IR bit in the SiIC register becomes 1 (interrupt requested) by inputting an external clock for 8 bits to the CLKi pin. This will also occur even when the SMi3 bit in the SiC register is 0 (serial interface disabled) or before a value is written to the SiTRR register.

25. Multi-master I^{2}C-bus Interface

25.1 Introduction

The multi-master I^{2}C-bus interface (I^{2}C interface) is a serial communication circuit based on the I^{2}C-bus data transmit/receive format, and is equipped with arbitration lost detect and clock synchronous functions.

Table 25.1 lists the Multi-master I^{2}C-bus Interface Specifications, Table 25.2 lists the I^{2}C Interface Detection Function, Figure 25.1 shows the Multi-master I^{2}C-bus Interface Block Diagram, and Table 25.3 lists the I/O Ports.

Table 25.1 Multi-master I^{2}C-bus Interface Specifications

Item	Function
Formats	Based on I^{2}C-bus standard: 7-bit addressing format Fast-mode Standard clock mode
Communication modes	Based on I^{2}C-bus standard: Master transmission Master reception Slave transmission Slave reception
Bit rate	16.1 kbps to 400 kbps (fVIIC = 4 MHz)
I/O pins	Serial data line SDAMM (SDA) Serial clock line SCLMM (SCL)
Interrupt request generating sources	• I^{2}C-bus interrupt Completion of transmission Completion of reception Slave address match detection General call detection Stop condition detection Timeout detection • SDA/SCL interrupt Rising or falling edge of the signal of the SDAMM or SCLMM pin
Selectable functions	• I^{2}C-bus interface pin input level select Selectable input level with I^{2}C-bus input level or SMBus input level • SDA/port, SCL/port selection A function to change the SDAMM and SCLMM pins to output ports. • Timeout detection A function that detects when the SCLMM pin is driven high over a certain period of time when the bus is busy. • Free data format select A function that generates an interrupt request when receiving the first byte of data, regardless of the slave address value.

fVIIC: I^{2}C-bus system clock

Table 25.2 I^{2}C Interface Detection Function

Item	Function
Slave address match detection	A function to detect a slave address match when in slave transmission/reception. If slave address match is detected, an ACK is returned. If the slave address match is not detected, a NACK is returned, and no further data is transmitted/received. Up to three slave addresses can be set.
General call detection	A function to detect a general call in slave reception.
Arbitration lost detection	A function to detect arbitration lost and stop the output from pins SDAMM and SCLMM.
Bus busy detection	A function to detect a bus busy state and set/reset the BB bit.

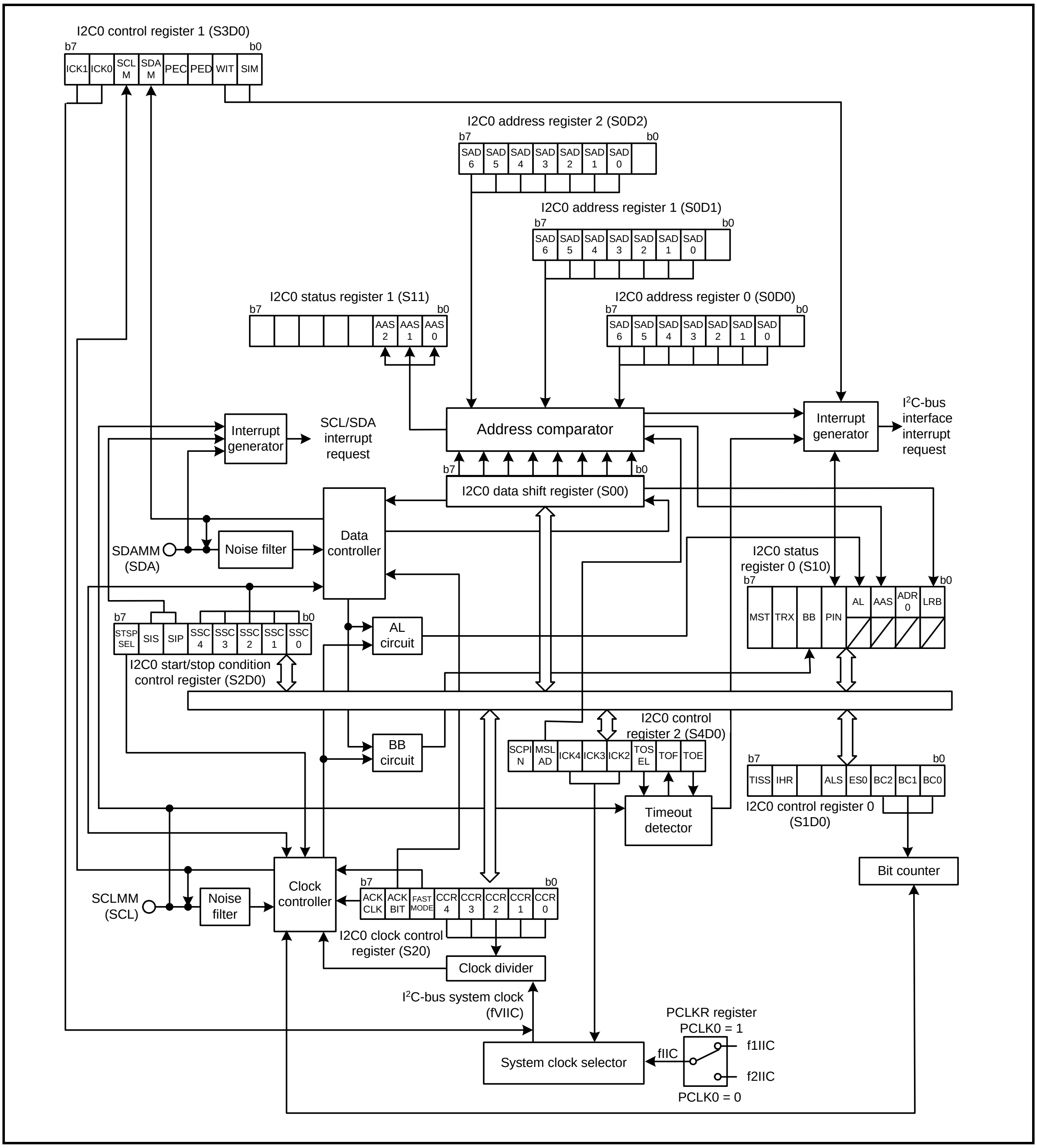


Figure 25.1 Multi-master I2C-bus Interface Block Diagram

Table 25.3 I/O Ports

Pin Name	I/O	Function
SDAMM	I/O	I/O pin for SDA (N-channel open drain output)
SCLMM	I/O	I/O pin for SCL (N-channel open drain output)

25.2 Registers Descriptions

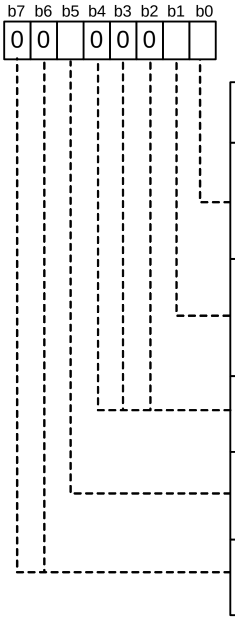
Table 25.4 lists registers associated with multi-master I2C-bus interface. Refer to 8.2.6 “Peripheral Clock Stop Register 1 (PCLKSTP1)” for the explanation of the PCLKSTP1 register. When the CM07 bit in the CM0 register is set to 1 (sub clock is CPU clock), registers listed in Table 25.4 should not be accessed. Set them after the CM07 bit is set to 0 (main clock, PLL clock, or on-chip oscillator clock).

Table 25.4 Registers

Address	Register	Symbol	Reset Value
0012h	Peripheral Clock Select Register	PCLKR	0000 0011b
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
02B0h	I2C0 Data Shift Register	S00	XXh
02B2h	I2C0 Address Register 0	S0D0	0000 000Xb
02B3h	I2C0 Control Register 0	S1D0	00h
02B4h	I2C0 Clock Control Register	S20	00h
02B5h	I2C0 Start/Stop Condition Control Register	S2D0	0001 1010b
02B6h	I2C0 Control Register 1	S3D0	0011 0000b
02B7h	I2C0 Control Register 2	S4D0	00h
02B8h	I2C0 Status Register 0	S10	0001 000Xb
02B9h	I2C0 Status Register 1	S11	XXXX X000b
02BAh	I2C0 Address Register 1	S0D1	0000 000Xb
02BBh	I2C0 Address Register 2	S0D2	0000 000Xb

25.2.1 Peripheral Clock Select Register (PCLKR)

Peripheral Clock Select Register

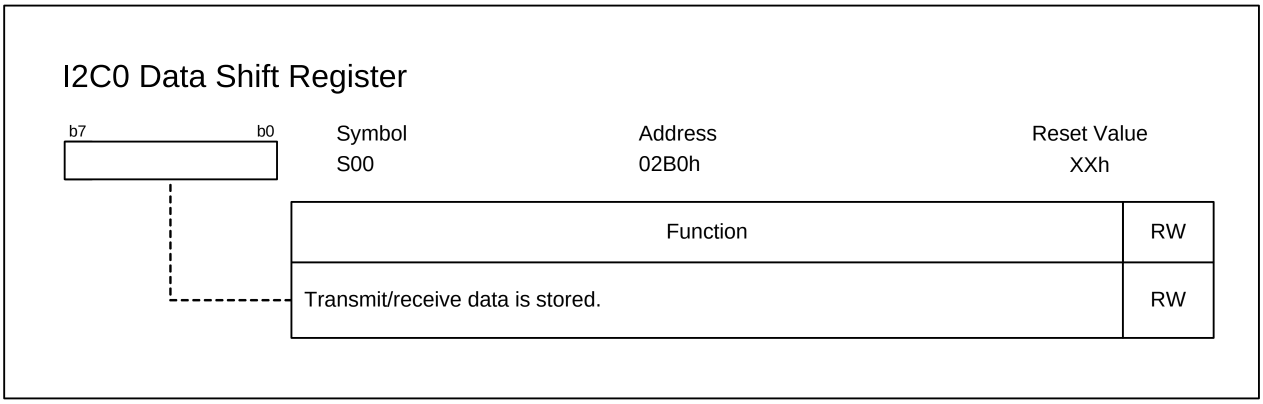


Symbol	Address	Reset Value
PCLKR	0012h	0000 0011b

Bit Symbol	Bit Name	Function	RW
PCLK0	Timers A and B clock select bit (clock source for timers A and B, the dead time timer, and multi-master I^2C-bus interface)	0: f2TIMAB/f2IIC 1: f1TIMAB/f1IIC	RW
PCLK1	SI/O clock select bit (clock source for UART0 to UART2, UART5 to UART7, SI/O3, and SI/O4)	0: f2SIO 1: f1SIO	RW
— (b4-b2)	Reserved bits	Set to 0	RW
PCLK5	Clock output function expansion bit (enabled in single-chip mode)	0: Selected by setting bits CM01 to CM00 in the CM0 register 1: Output f1	RW
— (b7-b6)	Reserved bits	Set to 0	RW

Write to the PCLKR register after setting the PRC0 bit in the PRCR register to 1 (write enabled).

25.2.2 I2C0 Data Shift Register (S00)



Symbol	Address	Reset Value
S00	02B0h	XXh

Function	RW
Transmit/receive data is stored.	RW

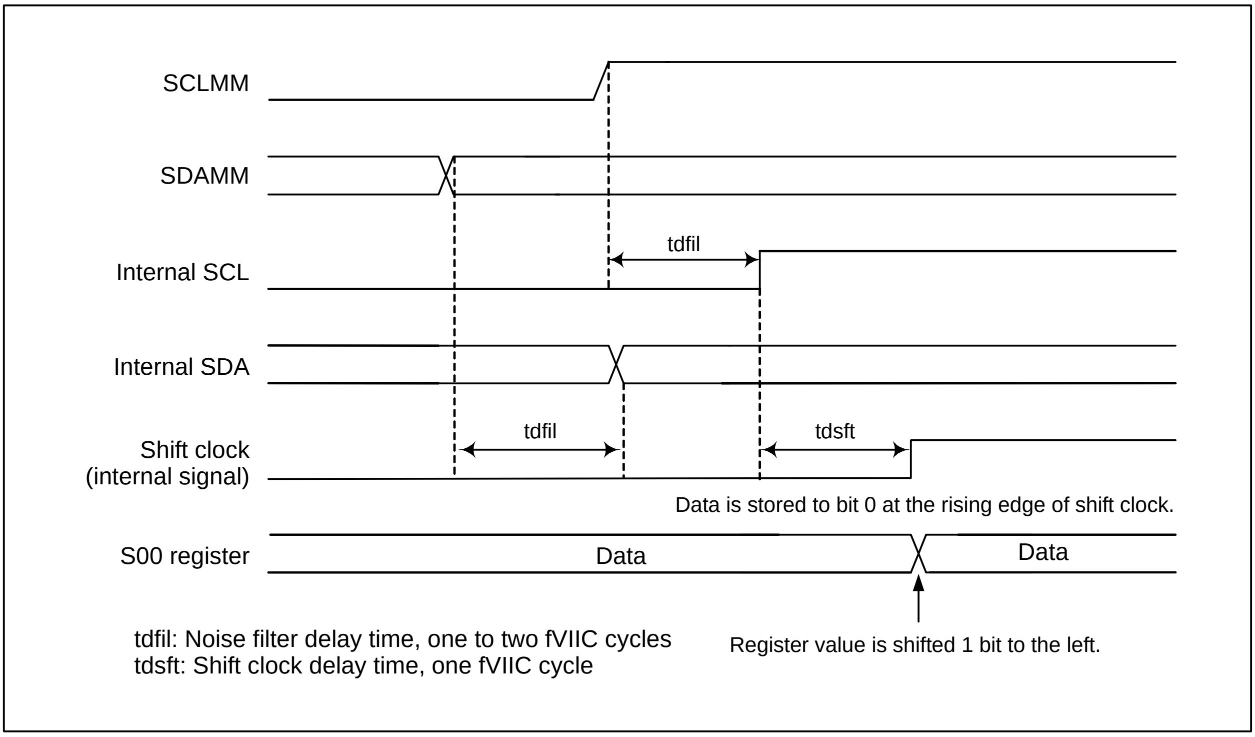
When the I^{2}C interface is a transmitter, write transmit data to the S00 register. When the I^{2}C interface is a receiver, received data can be read from the S00 register. In master mode, this register is also used to generate a start condition or stop condition on a bus. (Refer to 25.3.2 “Generating a Start Condition” and 25.3.3 “Generating a Stop Condition”.)

Write to the S00 register when the ES0 bit in the S1D0 register is 1 (I^{2}C interface enabled).

Do not write to the S00 register when transmitting/receiving data.

When the I^{2}C interface is a transmitter, the data in the S00 register is transmitted to other devices. The MSB (bit 7) is transmitted first, synchronizing with the SCLMM clock. Every time 1-bit data is output, the S00 register value is shifted 1 bit to the left.

When the I^{2}C interface is a receiver, data is transferred to the S00 register from other devices. The LSB (bit 0) is input first, synchronizing with the SCLMM clock. Every time 1-bit data is output, the S00 register value is shifted 1 bit to the left. Figure 25.2 shows Timing to Store Received Data to the S00 Register.



Data is stored to bit 0 at the rising edge of shift clock.

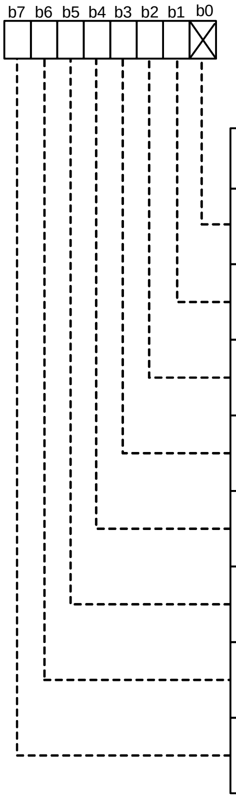
Register value is shifted 1 bit to the left.

tdfil: Noise filter delay time, one to two fVIIC cycles
tdsft: Shift clock delay time, one fVIIC cycle

Figure 25.2 Timing to Store Received Data to the S00 Register

25.2.3 I2C0 Address Register i (S0Di) (i = 0 to 2)

I2C0 Address Register i (i = 0 to 2)



Symbol	Address	Reset Value
S0D0	02B2h	0000 000Xb
S0D1	02BAh	0000 000Xb
S0D2	02BBh	0000 000Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. The read value is undefined.		—
SAD0	Slave address	Set a slave address	RW
SAD1			RW
SAD2			RW
SAD3			RW
SAD4			RW
SAD5			RW
SAD6			RW

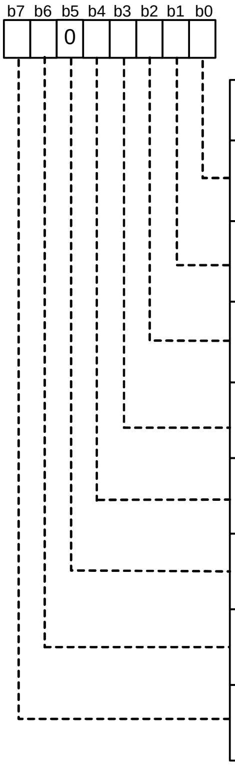
SAD6 to SAD0 (Slave address) (b7-b1)

Bits SAD6 to SAD0 indicate a slave address to be compared for a slave address match detection in slave mode. Up to three slave addresses can be set. Set the S0Di register to 00h when not setting the slave address.

However, when the MSLAD bit in the S4D0 register is 0, registers S0D1 and S0D2 are disabled. Only the slave address set to the S0D0 register is compared with address the data received.

25.2.4 I2C0 Control Register 0 (S1D0)

I2C0 Control Register 0



Symbol	Address	Reset Value
S1D0	02B3h	00h

Bit Symbol	Bit Name	Function	RW
BC0	Bit counter (number of transmitted/received bits)	b2 b1 b0 0 0 0: 8 0 0 1: 7 0 1 0: 6 0 1 1: 5 1 0 0: 4 1 0 1: 3 1 1 0: 2 1 1 1: 1	RW
BC1			RW
BC2			RW
ES0	I2C-bus interface enable bit	0: Disabled 1: Enabled	RW
ALS	Data format select bit	0: Addressing format 1: Free data format	RW
— (b5)	Reserved bit	Set to 0.	RW
IHR	I2C-bus interface reset bit	0: Reset is released (automatically) 1: Reset	RW
TISS	I2C-bus interface pin input level select bit	0: I2C-bus input 1: SMBus input	RW

BC2 to BC0 (Bit counter) (b2-b0)

Bits BC2 to BC0 become 000b (8 bits) when a start condition is detected.

When the ACKCLK bit in the S20 register is 0 (no ACK clock), and data for the number of bits selected by bits BC2 to BC0 is transmitted or received, bits BC2 to BC0 become 000b again.

When the ACKCLK bit in the S20 register is 1 (ACK clock), and data for the number of bits selected and an ACK is transmitted or received, bits BC2 to BC0 become 000b again.

ES0 (I2C-bus interface enable bit) (b3)

The ES0 bit enables the I2C interface.

When the ES0 bit is set to 0, the I2C interface becomes as follows:

- Pins SDAMM and SCLMM: I/O ports or other peripheral pins
- The S00 register is write disabled.
- The I2C-bus system clock (hereinafter called fVIIC) stops.
- S10 register

  ADR0 bit: 0 (general call not detected)
  AAS bit: 0 (slave address not matched)
  AL bit: 0 (arbitration lost not detected)
  PIN bit: 1 (no I2C-bus interrupt request)
  BB bit: 0 (bus free)
  TRX bit: 0 (receive mode)
  MST bit: 0 (slave mode)

- Bits AAS2 to AAS0 in the S11 register: 0 (slave address not matches)
- The TOF bit in the S4D0 register: 0 (timeout not detected)

ALS (Data format select bit) (b4)

The ALS bit is enabled in slave mode. When the ALS bit is 0 (addressing format), the slave address match detection is performed.
When a slave address stored to bits SAD6 to SAD0 in the S0Di register (i = 0 to 2) is compared and matched with the calling address by a master, or when a general call address is received, the IR bit in the IICIC register becomes 1 (interrupt requested).
When the ALS bit is 1 (free data format), the slave address match detection is not performed. Therefore, the IR bit in the IICIC register becomes 1 (interrupt requested), regardless of the calling address by a master.

IHR (I2C-bus interface reset bit) (b6)

The IHR bit resets the I2C interface if there is an anomaly during transmission/reception. When the ES0 bit in the S1D0 register is 1 (I2C interface enabled) and then the IHR bit is set to 1 (reset), the I2C interface becomes as follows:

- S10 register
  ADR0 bit: 0 (general call not detected)
  AAS bit: 0 (slave address not matched)
  AL bit: 0 (arbitration lost not detected)
  PIN bit: 1 (No I2C-bus interrupt request)
  BB bit: 0 (bus free)
  TRX bit: 0 (receive mode)
  MST bit: 0 (slave mode)
- Bits AAS2 to AAS0 in the S11 register: 0 (slave address not matches)
- TOF bit in the S4D0 register: 0 (timeout not detected)

When the IHR bit is set to 1, the I2C interface is reset and the IHR bit becomes 0 automatically. It takes a maximum of 2.5 fVIIC cycles to complete the reset sequence.
Figure 25.3 shows the I2C Interface Reset Timing.

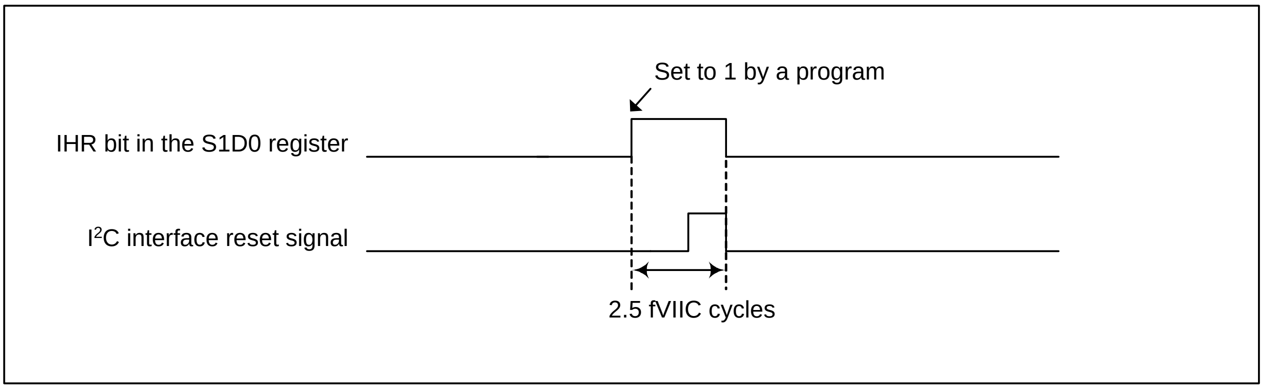


Figure 25.3 I2C Interface Reset Timing

TISS (I2C-bus interface pin input level select bit) (b7)

Set the TISS bit to select the input level of the SCLMM pin and SDAMM pin for the I2C interface.

25.2.5 I2C0 Clock Control Register (S20)

I2C0 Clock Control Register

b7 b6 b5 b4 b3 b2 b1 b0

Symbol	Address	Reset Value
S20	02B4h	00h

Bit Symbol	Bit Name	Function	RW
CCR0	Bit rate control bit	Refer to bits CCR4 to CCR0 (Bit Rate Control Bit) (b4 to b0) in the next page.	RW
CCR1			RW
CCR2			RW
CCR3			RW
CCR4			RW
FASTMODE	SCL mode select bit	0: Standard-speed clock mode 1: Fast-mode	RW
ACKBIT	ACK bit	0: ACK is returned 1: ACK is not returned	RW
ACKCLK	ACK clock bit	0: No ACK clock present 1: ACK clock present	RW

CCR4 to CCR0 (Bit rate control bit) (b4-b0)

Assuming the CCR value (3 to 31) is the value set to bits CCR4 to CCR0, the bit rate can be calculated using the following equation:
Refer to 25.3.1.2 “Bit Rate and Duty Cycle” for more details.

In standard-speed clock mode,

$$\text{Bit rate} = \frac{\text{fVIIC}}{8 \times \text{CCR value}} \leq 100 \text{ kbps}$$

When the CCR value is other than 5 in fast-mode,

$$\text{Bit rate} = \frac{\text{fVIIC}}{4 \times \text{CCR value}} \leq 400 \text{ kbps}$$

When the CCR value is 5 in fast-mode, the bit rate is assumed to reach 400 kbps, the maximum bit rate in fast-mode.

$$\text{Bit rate} = \frac{\text{fVIIC}}{2 \times \text{CCR value}} = \frac{\text{fVIIC}}{10} \leq 400 \text{ kbps}$$

Do not set the CCR value from 0 to 2 regardless of the fVIIC frequency.
Rewrite bits CCR4 to CCR0 when the ES0 bit in the S1D0 register is 0 (disabled).

FASTMODE (SCL mode select bit) (b5)

When using the fast-mode I^{2}C-bus standard (maximum 400 kbps), set the FASTMODE bit to 1 (fast-mode) and set fVIIC to 4 MHz or more.
Rewrite the FASTMODE bit when the ES0 bit in the S1D0 register is 0 (disabled).

ACKBIT (ACK bit) (b6)

The ACK bit is enabled in master reception, slave reception, or slave address reception. When receiving a slave address, the SDAMM pin level during the ACK clock pulse is determined by a combination of bits ALS and ACKBIT in the S1D0 register and the received slave address.
When receiving data, the SDAMM pin level during the ACK clock pulse is determined by the ACKBIT bit. Table 25.5 lists the SDAMM Pin Level during the ACK Clock Pulse.

Table 25.5 SDAMM Pin Level during the ACK Clock Pulse

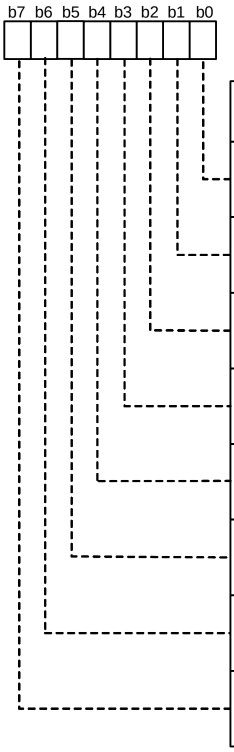
Received Content	ALS Bit in the S1D0 Register	ACKBIT Bit in the S20 Register	Slave Address Content	SDAMM Pin Level at ACK Clock
Slave Address	0	0	When the MSLAD bit in the S4D0 register is 0: Matched with bits SAD6 to SAD0 in the S0D0 register. When the MSLAD bit is 1: Matched with bits SAD6 to SAD0 in any of registers S0D0 to S0D2.	Low (ACK)
			0000000b	Low (ACK)
			Others	High (NACK)
		1	—	High (NACK)
	1	0	—	Low (ACK)
		1	—	High (NACK)
Data	—	0	—	Low (ACK)
		1	—	High (NACK)

ACKCLK (ACK clock bit) (b7)

When the ACKCLK bit is 1 (ACK clock present), an ACK clock is generated immediately after 1-byte data is transmitted or received (8 clocks).
When the ACKCLK bit is 0 (no ACK clock), no ACK clock is generated after 1-byte data is transmitted or received (8 clocks). At the falling edge of data transmission/reception (the falling edge of the eighth clock), the IR bit in the IICIC register becomes 1 (interrupt requested).
Do not write to this bit when transmitting/receiving data.

25.2.6 I2C0 Start/Stop Condition Control Register (S2D0)

I2C0 Start/Stop Condition Control Register



Symbol	Address	Reset Value
S2D0	02B5h	0001 1010b

Bit Symbol	Bit Name	Function	RW
SSC0	Start/stop condition setting bit	Refer to SSC4 to SSC0 (Start/Stop Condition Setting Bit) (b4 to b0) in the same page	RW
SSC1			RW
SSC2			RW
SSC3			RW
SSC4			RW
SIP	SCL/SDA interrupt pin polarity select bit	0: Falling edge 1: Rising edge	RW
SIS	SCL/SDA interrupt pin select bit	0: SDAMM 1: SCLMM	RW
STSPSEL	Start/stop condition generation select bit	0: Short setup/hold time mode 1: Long setup/hold time mode	RW

SSC4 to SSC0 (Start/stop condition setting bit) (b4-b0)

Set bits SSC4 to SSC0 to select the start/stop condition detect parameter (SCL open time, setup time, hold time) in standard-speed clock mode. Refer to 25.3.7 “Detecting Start/Stop Conditions”.
Do not set an odd value or 00000b to these bits.

SIP (SCL/SDA interrupt pin polarity select bit) (b5)
SIS (SCL/SDA interrupt pin select bit) (b6)

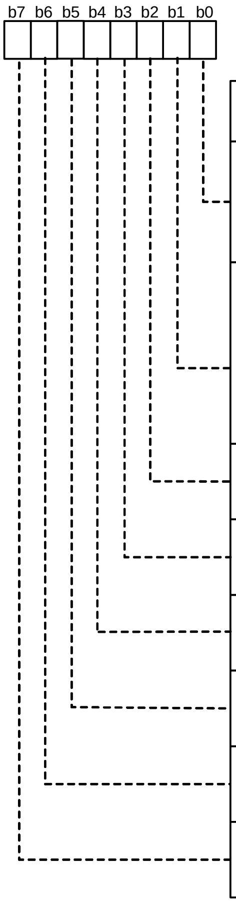
The IR bit in the SCLDAIC register becomes 1 (interrupt requested) when the I^2C interface detects the edge selected by the SIP bit for the pin signal selected by the SIS bit. Refer to 25.4 “Interrupts”.

STSPSEL (Start/stop condition generation select bit) (b7)

See Table 25.13 “Setup/Hold Time for Generating a Start/Stop Condition”.
If the fVIIC frequency is more than 4 MHz, set the STSPSEL bit to 1 (long mode).

25.2.7 I2C0 Control Register 1 (S3D0)

I2C0 Control Register 1



Symbol S3D0

Address 02B6h

After Reset 0011 0000b

Bit Symbol	Bit Name	Function	RW
SIM	Stop condition detect interrupt enable bit	0: I^{2}C-bus interrupt by stop condition detection is disabled 1: I^{2}C-bus interrupt by stop condition detection is enabled	RW
WIT	Data receive interrupt enable bit	When write, 0: I^{2}C-bus interrupt at 8th clock is disabled 1: I^{2}C-bus interrupt is enabled at 8th clock When read, internal WAIT bit monitor 0: I^{2}C-bus interrupt by falling edge of ACK clock 1: I^{2}C-bus interrupt at 8th clock	RW
PED	SDAMM/port function select bit	0: SDAMM I/O pin 1: Port output pin	RW
PEC	SCLMM/port function select bit	0: SCLMM I/O pin 1: Port output pin	RW
SDAM	Internal SDA output monitor bit	0: Logic 0 output 1: Logic 1 output	RO
SCLM	Internal SCL output monitor bit	0: Logic 0 output 1: Logic 1 output	RO
ICK0	I^{2}C-bus system clock select bit (enabled when bits ICK4 to ICK2 in the S4D0 register are 000b)	b7 b6 0 0: fIIC divided by 2 0 1: fIIC divided by 4 1 0: fIIC divided by 8 1 1: Do not set this value.	RW
ICK1			RW

Do not use the bit managing instruction (read-modify-write instruction) to access the S3D0 register. Use the MOV instruction to write to the S3D0 register.

SIM (Stop condition detect interrupt enable bit) (b0)

When the SIM bit is 1 (I^{2}C-bus interrupt by stop condition detection enabled) and a stop condition is detected, the SCPIN bit in the S4D0 register becomes 1 (stop condition detect interrupt requested) and the IR bit in the IICIC register becomes 1 (interrupt requested).

WIT (Data receive interrupt enable bit) (b1)

The WIT bit is enabled in master reception or slave reception.
The WIT bit has two functions:

- Selects the I2C-bus interrupt timing when data is received. (write)
- Monitors the state of the internal WAIT flag. (read)

The WIT bit can select whether to generate an I2C-bus interrupt request at eighth clock (before ACK clock) during the data reception.
When the ACKCLK bit in the S20 register is 1 (ACK clock presents) and the WIT bit is set to 1 (enable I2C-bus interrupt at 8th clock), an I2C-bus interrupt request is generated at the eighth clock (before the ACK clock). Then, the PIN bit in the S10 register becomes 0 (interrupt requested).
When the ACKCLK bit in the S20 register is 0 (no ACK clock presents), write 0 to the WIT bit to disable the I2C-bus interrupt by data reception.
When transmitting data and receiving a slave address, no interrupt requests are generated at the eighth clock (before the ACK clock) regardless of the value written to the WIT bit.
Reading the WIT bit returns the internal WAIT flag status.
An I2C-bus interrupt request is generated at the falling edge of the ninth clock (ACK clock) regardless of the value written to the WIT bit. Then, the PIN bit in the S10 register becomes 0 (interrupt requested).
Therefore, read the internal WAIT flag status to determine whether the I2C-bus interrupt request is generated at the eighth clock (before the ACK clock) or at the falling edge of the ACK clock.
When the WIT bit is set to 1 (I2C-bus interrupt enabled by receiving data), the internal WAIT flag changes under the following conditions:
Condition to become 0:

- The S20 register (ACKBIT bit) is written.

Condition to become 1:

- The S00 register is written during data reception.

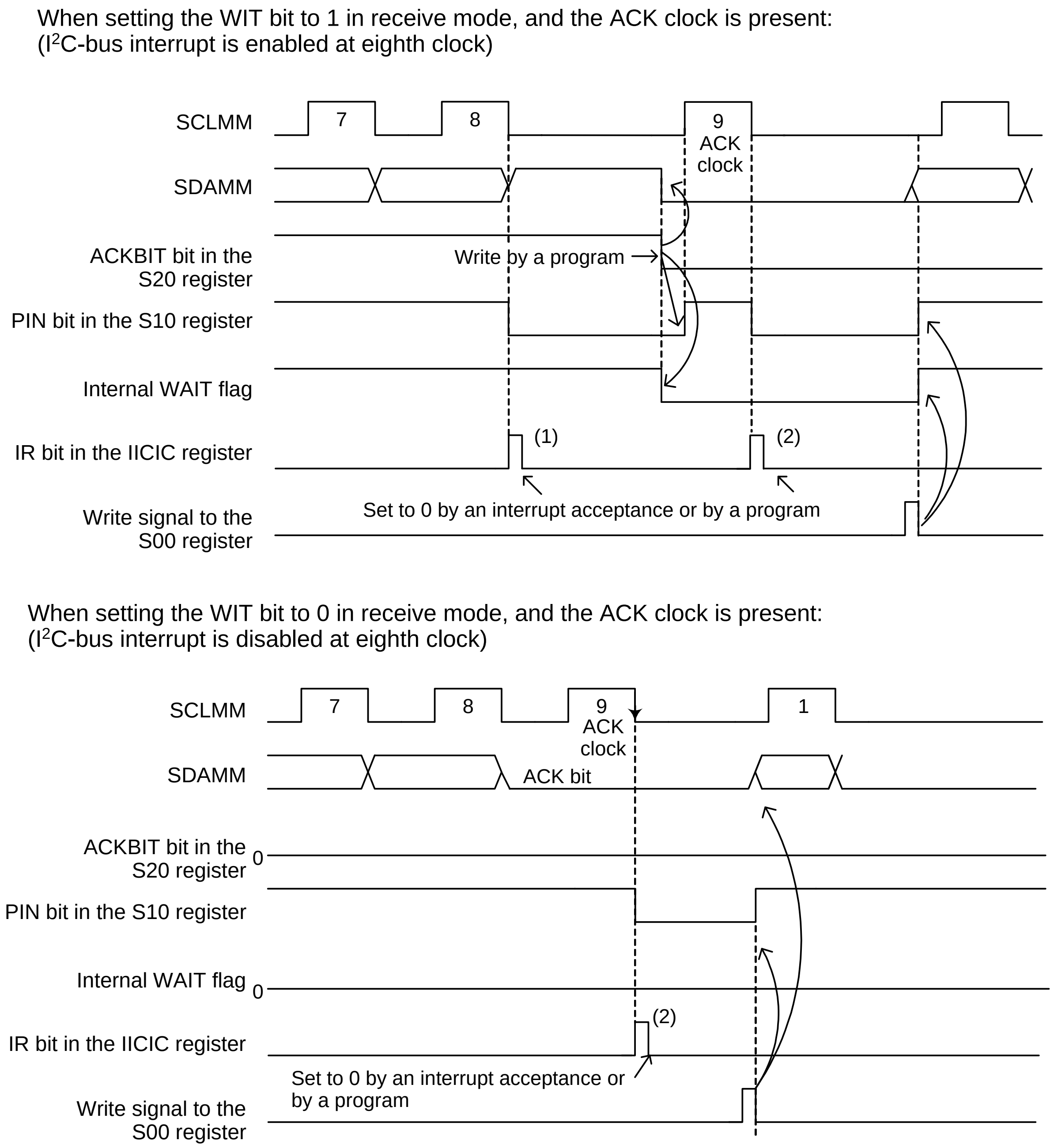
When transmitting data and receiving a slave address, the internal WAIT flag is 0 and the I2C-bus interrupt request will be generated only at the falling edge of the ninth clock (ACK clock), regardless of the value written to the WIT bit.
Table 25.6 lists interrupt request generation timing and the conditions to restart transmission/reception when receiving data. Figure 25.4 shows Interrupt Request Generation Timing in Receive Mode.

Table 25.6 Generating an Interrupt Request and Restarting Transmission/Reception When Receiving Data

I2C-bus Interrupt Request Generation Timing	Internal WAIT Flag Status	Conditions to Restart Transmission/Reception
At the falling edge of the eighth clock (before the ACK clock) (1)	1	Write to the ACKBIT bit in the S20 register (3)
At the falling edge of the ninth clock (ACK clock) (2)	0	Write to the S00 register

Notes:

1. See the timing of (1) on the IR bit in the IICIC register in Figure 25.4.
2. See the timing of (2) on the IR bit in the IICIC register in Figure 25.4.
3. When setting the ACKBIT bit, do not rewrite any other bits and do not set the S00 register.



When setting the WIT bit to 1 in receive mode, and the ACK clock is present:
(I^2C-bus interrupt is enabled at eighth clock)

When setting the WIT bit to 0 in receive mode, and the ACK clock is present:
(I^2C-bus interrupt is disabled at eighth clock)

Figure 25.4 Interrupt Request Generation Timing in Receive Mode

PED (SDAMM/port function switch bit) (b2)
PEC (SCLMM/port function switch bit) (b3)

Bits PEC and PED are enabled when the ES0 bit in the S1D0 register is 1 (I2C interface enabled).
When the PEC bit is set to 1 (output port), the P7_1 bit value is output from the SCLMM pin regardless of the internal SCL output signal and PD7_1 bit value. When the PED bit is set to 1 (output port), the P7_0 bit value is output from the SDAMM pin regardless of the internal SDA output signal and PD7_0 bit value.
The signal level on the bus is input to the internal SDA and internal SCL.
When bits P7_1 to P7_0 in the P7 register are read after setting bits PD7_1 and PD7_0 in the PD7 register to 0 (input mode), the level on the bus can be read regardless of the values set to bits PED and PEC. Table 25.7 lists SCLMM and SDAMM Pin Functions.

Table 25.7 SCLMM and SDAMM Pin Functions

Pin	S1D0 Register	S3D0 Register		Pin Function
	ES0 bit	PED bit	PEC bit	
P7_1/SCLMM	0	-	-	I/O port or other peripheral pins
	1	-	0	SCLMM (SCL input/output)
		-	1	Output port (output P7_1 bit value)
P7_0/SDAMM	0	-	-	I/O port or other peripheral pins
	1	0	-	SDAMM (SDA input/output)
		1	-	Output port (output P7_0 bit value)

–: 0 or 1

SDAM (Internal SDA output monitor bit) (b4)
SCLM (Internal SCL output monitor bit) (b5)

The internal SDA and SCL output signal levels are the same as the output level of the I2C interface before it has any effect from the external device output. Bits SDAM and SCLM are read only bits. If necessary, set these bits to 0.

ICK1 and ICK0 (I2C-bus system clock select bit) (b7-b6)

Rewrite these bits when the ES0 bit in the S1D0 register is 0 (I2C interface disabled). fVIIC is selected by setting all the bits ICK1 to ICK0, bits ICK4 to ICK2 in the S4D0 register, and the PCLK0 bit in the PCLKR register. Refer to 25.3.1.2 “Bit Rate and Duty Cycle”.

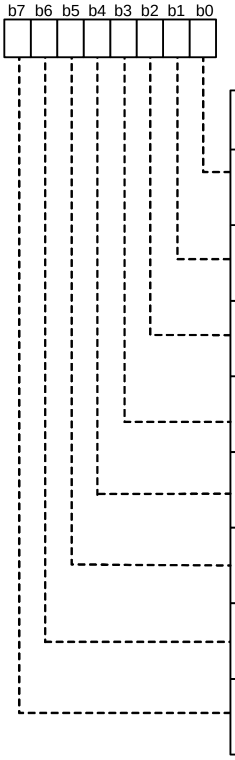
Table 25.8 I2C-bus System Clock Select Bits

S4D0 Register			S3D0 Register		fVIIC
ICK4 Bit	ICK3 Bit	ICK2 Bit	ICK1 Bit	ICK0 Bit	
0	0	0	0	0	fIIC divided-by-2
0	0	0	0	1	fIIC divided-by-4
0	0	0	1	0	fIIC divided-by-8
0	0	1	–	–	fIIC divided-by-2.5
0	1	0	–	–	fIIC divided-by-3
0	1	1	–	–	fIIC divided-by-5
1	0	0	–	–	fIIC divided-by-6

–: 0 or 1
Only set the values listed above.

25.2.8 I2C0 Control Register 2 (S4D0)

I2C0 Control Register 2



Symbol	Address	Reset Value
S4D0	02B7h	00b

Bit Symbol	Bit Name	Function	RW
TOE	Timeout detect function enable bit	0: Disabled 1: Enabled	RW
TOF	Timeout detect flag	0: Not detected 1: Detected	RO
TOSEL	Timeout detect time select bit	0: Long time 1: Short time	RW
ICK2	I²C-bus system clock select bit	b5 b4 b3 0 0 0: Bits ICK1 and ICK0 in the S3D0 register are enabled 0 0 1: fIIC divided by 2.5 0 1 0: fIIC divided by 3 0 1 1: fIIC divided by 5 1 0 0: fIIC divided by 6 Only set the values listed above.	RW
ICK3			RW
ICK4			RW
MSLAD	Slave address control bit	0: S0D0 register only 1: Registers S0D0 to S0D2	RW
SCPIN	Stop condition detect interrupt request bit	0: I²C-bus interrupt not requested 1: I²C-bus interrupt requested	RW

TOE (Timeout detect function enable bit) (b0)

The TOE bit enables the timeout detect function. Refer to 25.3.9 “Timeout Detection” for details.

TOF (Timeout detect flag) (b1)

The TOF bit is enabled when the TOE bit is set to 1. When the TOF bit becomes 1 (detected), the IR bit in the IICIC register becomes 1 (interrupt requested) at the same time.

Conditions to become 0:

- The ES0 bit in the S1D0 register is set to 0 (I²C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I²C interface reset).

Condition to become 1:

- The BB bit in the S10 register is set to 1 (bus busy) and the SCLMM high period is greater than the timeout detect period.

TOSEL (Timeout detect time select bit) (b2)

Set the TOSEL bit to select a timeout detection period. The TOSEL bit is enabled when the TOE bit is 1 (timeout detect function enabled).
When long time is selected, the internal counter increments fVIIC as a 16-bit counter. When short time is selected, the internal counter increments fVIIC as a 14-bit counter. Therefore, the timeout detect time is as follows:
When the TOSEL bit is set to 0 (long time)

$$65536 \times \frac{1}{\mathrm{fVIIC}}$$

When the TOSEL bit is set to 1 (short time)

$$16384 \times \frac{1}{\mathrm{fVIIC}}$$

Table 25.9 lists Timeout Detect Time.

Table 25.9 Timeout Detect Time

fVIIC	Timeout Detect	
	TOSEL bit: 0 (Long time)	TOSEL bit: 1 (Short time)
4 MHz	16.4 ms	4.1 ms
2 MHz	32.8 ms	8.2 ms
1 MHz	65.6 ms	16.4 ms

Rewrite this bit when the TOE bit is 0.

ICK4-ICK2 (I2C-bus system clock select bit) (b5-b3)

Rewrite bits ICK4 to ICK2 when the ES0 bit in the S1D0 register is 0 (I2C interface disabled).
fVIIC is selected by setting all the bits ICK4 to ICK2, bits ICK1 to ICK0 in the S3D0 register, and the PCLK0 bit in the PCLKR register. Refer to Table 25.8 “I2C-bus System Clock Select Bits” and 25.3.1.2 “Bit Rate and Duty Cycle”.

MSLAD (Slave address control bit) (b6)

The MSLAD bit is enabled when the ALS bit in the S1D0 register is set to 0 (addressing format). The MSLAD bit is used to select the S0Di register (i = 0 to 2) used for slave address match detection.

SCPIN (Stop condition detect interrupt request bit) (b7)

The SCPIN bit is enabled when the SIM bit in the S3D0 register is set to 1 (enable I2C-bus interrupt by stop condition detection).
Condition to become 0:

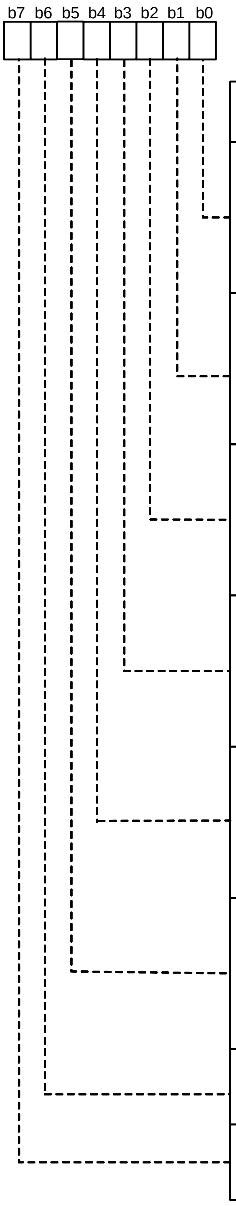
- Writing 0 by a program.

Condition to become 1:

- Stop condition is detected
(This bit cannot be set to 1 by a program.)

25.2.9 I2C0 Status Register 0 (S10)

I2C0 Status Register 0



Symbol	Address	Reset Value
S10	02B8h	0001 000Xb

Bit Symbol	Bit Name	Function	RW
LRB	Last receive bit	When read, 0: Last bit = 0 1: Last bit = 1 When write, see Table 25.10 “Functions Enabled by Writing to the S10 Register”	RW
ADR0	General call detect flag	When read, 0: Not detected 1: Detected When write, see Table 25.10 “Functions Enabled by Writing to the S10 Register”	RW
AAS	Slave address compare flag	When read, 0: Address not matched 1: Address matched When write, see Table 25.10 “Functions Enabled by Writing to the S10 Register”	RW
AL	Arbitration lost detect flag	When read, 0: Not detected 1: Detected When write, see Table 25.10 “Functions Enabled by Writing to the S10 Register”	RW
PIN	I^2C-bus interface interrupt request bit	When read, 0: Interrupt requested 1: Interrupt not requested When write, see Table 25.10 “Functions Enabled by Writing to the S10 Register”	RW
BB	Bus busy flag	When read, 0: Bus free 1: Bus busy When write, see Table 25.10 “Functions Enabled by Writing to the S10 Register”	RW
TRX	Communication mode select bit 0	0: Receive mode 1: Transmit mode	RW
MST	Communication mode select bit 1	0: Slave mode 1: Master mode	RW

Do not use the bit managing instruction (read-modify-write instruction) to access the S10 register. Use the MOV instruction to write to the S10 register.

Bit 5 to bit 0 in the S10 register (6 lower bits) monitor the state of the I^2C interface. The bit values cannot be changed by a program. However, writing to the S10 register, including the 6 lower bits, generates a start/stop condition.

Bits MST and TRX are read and write bits. To change bits MST or TRX without generating a start/stop condition, set 1111b to the 4 lower bits in the S10 register.

Table 25.10 lists Functions Enabled by Writing to the S10 Register. Only set the values listed in Table 25.10. If the values listed in Table 25.10 are written to the S10 register, the 6 lower bits in the S10 register will not be changed.

Table 25.10 Functions Enabled by Writing to the S10 Register

Bit Setting of the S10 Register								Function
MST	TRX	BB	PIN	AL	AAS	ADR0	LRB	
1	1	1	0	0	0	0	0	Sets the I2C interface to start condition standby state in master transmit/receive mode
1	1	0	0	0	0	0	0	Sets the I2C interface to stop condition standby state in master transmit/receive mode
0	0	–	0	1	1	1	1	Slave receive mode
0	1	–	0	1	1	1	1	Slave transmit mode
1	0	–	0	1	1	1	1	Master receive mode
1	1	–	0	1	1	1	1	Master transmit mode

–: 0 or 1

Refer to 25.3.2 “Generating a Start Condition” and 25.3.3 “Generating a Stop Condition” for start/stop conditions.

LRB (Last receive bit) (b0)

When read, the LRB bit functions as described below. See Table 25.10 “Functions Enabled by Writing to the S10 Register” for the bit function in write access.
The LRB bit stores the value of the last bit of the received data. It is used to check if ACK is received. The bit becomes 0 after writing to the S00 register.

ADR0 (General call detect flag) (b1)

The ADR0 bit function in read access is described below. See Table 25.10 “Functions Enabled by Writing to the S10 Register” for the bit function in write access.
Conditions to become 0:

- Stop condition is detected.
- Start condition is detected.
- The ES0 bit in the S1D0 register is set to 0 (I2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I2C interface reset).

Condition to become 1:

- The ALS bit in the S1D0 register is set to 0 (addressing format) and the received slave address is 0000000b (general call) in slave mode.

AAS (Slave address compare flag) (b2)

The AAS bit function in read access is described below. See Table 25.10 “Functions Enabled by Writing to the S10 Register” for the bit function in write access.

Conditions to become 0:

- The S00 register is written.
- The ES0 bit in the S1D0 register is set to 0 (I2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I2C interface reset).

Conditions to become 1:

- In slave receive mode, the MSLAD bit in the S4D0 register is 1 (registers S0D0 to S0D2), the ALS bit in the S1D0 register is 0 (addressing format), and the received slave address is matched with bits SAD6 to SAD0 in any registers from S0D0 to S0D2.
- In slave receive mode, the MSLAD bit is 0, the ALS bit in the S1D0 register is 0 (addressing format), and the received slave address is matched with bits SAD6 to SAD0 in the S0D0 register.
- In slave receive mode, the ALS bit in the S1D0 register is 0 (addressing format) and the received slave address is 0000000b (general call).

AL (Arbitration lost detect flag) (b3)

The AL bit function in read access is described below. See Table 25.10 “Functions Enabled by Writing to the S10 Register” for the bit function in write access.

Conditions to become 0:

- The S00 register is written.
- The ES0 bit in the S1D0 register is set to 0 (I2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I2C interface reset).

Conditions to become 1:

- In master transmit mode or master receive mode, the SDAMM pin level changes to low by an external device, not by the ACK clock, when slave address is transmitted.
- The SDAMM pin level changes to low by an external device for other than the ACK clock when data is transmitted in master transmit mode.
- In master transmit mode or master receive mode, the SDAMM pin level changes to low by an external device when start condition is transmitted.
- In master transmit mode or master receive mode, the SDAMM pin level changes to low by an external device when stop condition is transmitted.
- The function to prevent start condition overlaps is activated.

PIN (I^2C-bus interface interrupt request bit) (b4)

The PIN bit function in read access is described below. See Table 25.10 “Functions Enabled by Writing to the S10 Register” for the bit function in write access.
Conditions to become 0:

- Slave address transmission is completed in master mode (including a case of detecting arbitration lost).
- 1-byte data transmission is completed (including a case of detecting arbitration lost).
- 1-byte data reception is completed (the falling edge of eighth clock is detected when the ACKCLK bit in the S20 register is 0, or the falling edge of ACK clock when the ACKCLK bit is 1).
- The WIT bit in the S3D0 register is 1 (I^2C-bus interrupt enabled at 8th clock) and 1-byte data reception is completed (before ACK clock).
- In slave receive mode, the MSLAD bit in the S4D0 register is 1, the ALS bit in the S1D0 register is 0 (addressing format), and any of the slave address stored in bits SAD6 to SAD0 in the S0Di register (i = 0 to 2) is matched with the received slave address (slave address match).
- In slave receive mode, the MSLAD bit is 0, the ALS bit is 0 (addressing format), and the slave address stored in bits SAD6 to SAD0 in the S0D0 register is matched with the received slave address (slave address match).
- In slave receive mode, the ALS bit in the S1D0 register is 0 (addressing format) and the received slaved address is 0000000b (general call).
- In slave receive mode, the ALS bit in the S1D0 register is 1 (free data format) and the slave address reception is completed.

Conditions to become 1:

- The S00 register is written.
- The S20 register is written (when the WIT bit is 1 and the internal WAIT flag is 1).
- The ES0 bit in the S1D0 register is set to 0 (I^2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I^2C interface reset).

The IR bit in the IICIC register becomes 1 (interrupt requested) as soon as the PIN bit becomes 0 (I^2C-bus interrupt requested). When the PIN bit is 0, the SCLMM pin output level is low.
However, when all of the following conditions are met, the SCLMM pin does not output a low level signal:

- In master mode, arbitration lost is detected by a slave address or data
- The ALS bit in the S1D0 register is 0 (addressing format)
- The slave address is not 0000000b (general call) and does not match any of the bits from SAD6 to SAD0 in registers S0D0 to S0D2.

BB (Bus busy flag) (b5)

The BB bit function in read access is described below. See Table 25.10 “Functions Enabled by Writing to the S10 Register” for the bit function in write access.
The BB bit indicates the state of the bus system, whether the bus is free or not. The BB bit changes depending on the SCLMM and SDAMM input signals, regardless of master mode or slave mode.
Conditions to become 0:

- Stop condition is detected.
- The ES0 bit in the S1D0 register is set to 0 (I^2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I^2C interface reset).

Condition to become 1:

- Start condition is detected.

TRX (Communication mode select bit 0) (b6)

Set the TRX bit to select transmit mode or receive mode.

Conditions to become 0:

- The TRX bit is set to 0 by a program.
- Arbitration lost is detected.
- Stop condition is detected.
- Start condition overlap protect function is enabled.
- Start condition is detected when the MST bit in the S10 register is 0 (slave mode).
- No ACK is detected from a receiver when the MST bit in the S10 register is 0 (slave mode).
- The ES0 bit in the S1D0 register is set to 0 (I2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I2C interface reset).

Conditions to become 1:

- The TRX bit is set to 1 by a program.
- In slave mode, the ALS bit in the S1D0 register is 0 (addressing format), the AAS bit in the S10 register becomes 1 (address matched) after receiving the slave address, and the received R/W bit is 1.

MST (Communication mode select bit 1) (b7)

Set the MST bit to select master mode or slave mode.

Conditions to become 0:

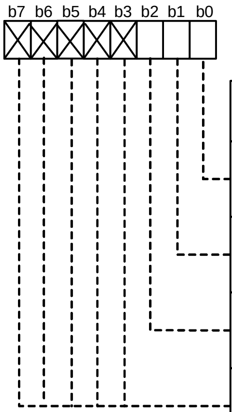
- The MST bit is set to 0 by a program.
- The 1-byte data that lost arbitration is completed transmitting/receiving when arbitration lost is detected.
- Stop condition is detected.
- Start condition overlap protect function is enabled.
- The ES0 bit in the S1D0 register is 0 (I2C interface disabled).
- The IHR bit in the S1D0 register is 1 (I2C interface reset).

Conditions to become 1:

- The MST bit is set to 1 by a program.

25.2.10 I2C0 Status Register 1 (S11)

I2C0 Status Register 1



Symbol	Address	Reset Value
S11	02B9h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
AAS0	Slave address 0 compare flag	0: No address matched 1: Address matched	RO
AAS1	Slave address 1 compare flag	0: No address matched 1: Address matched	RO
AAS2	Slave address 2 compare flag	0: No address matched 1: Address matched	RO
— (b7-b3)	No register bits. If necessary, set to 0. The read value is undefined.		—

AAS0 (Slave address 0 compare flag) (b0)
AAS1 (Slave address 1 compare flag) (b1)
AAS2 (Slave address 2 compare flag) (b2)

When the ALS bit in the S1D0 register is 0 (addressing format), any slave address stored in bits SAD6 to SAD0 in the S0Di register (i = 0 to 2) is compared with the received slave address. The compare result is shown in the AASi bit. The AASi bit becomes 1 when there is an address match or when a general call address is received.

The AAS0 bit is enabled when the MSLAD bit in the S4D0 register is 0 (S0D0 register only). Bits AAS2 to AAS0 are enabled when the MSLAD bit is 1 (registers S0D0 to S0D2).

Conditions to become 0:

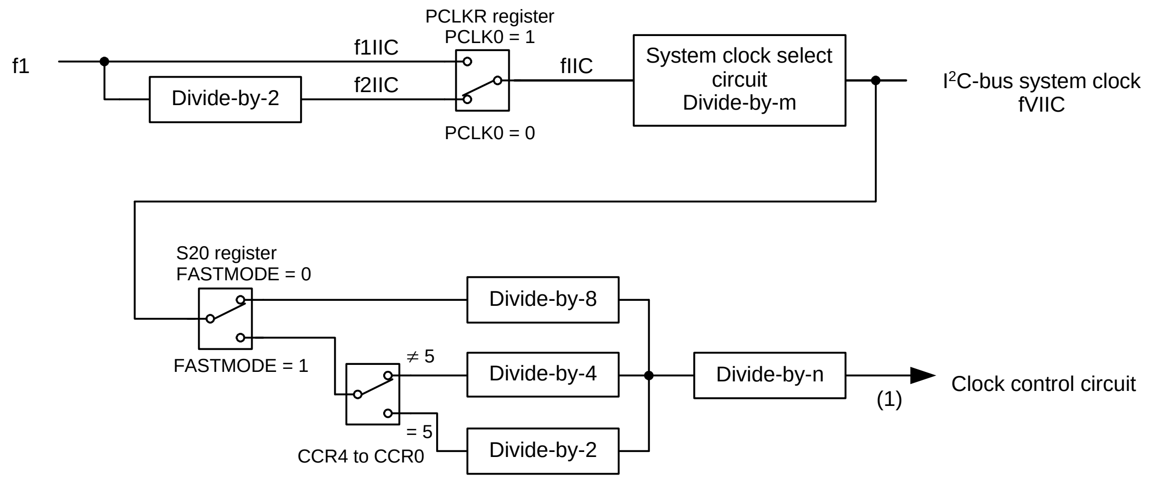
- The ES0 bit in the S1D0 register is set to 0 (I2C interface disabled).
- The IHR bit in the S1D0 register is set to 1 (I2C interface reset).
- The S00 register is written.

25.3 Operations

25.3.1 Clock

Set the PCKSTP1A bit in the PCLKSTP1 register to 0 (f1 provide enabled).

Figure 25.5 shows the I2C-bus Interface Clock.



m: 2, 4, 8, 2.5, 3, 5, 6
(selectable by bits ICK1 to ICK0 in the S3D0 register and bits ICK4 to ICK2 in the S4D0 register)
n: 3 to 31 (value set to bits CCR4 to CCR0 in the S20 register)

Note:
1. Set the CPU clock to 100 kHz or lower in standard clock mode, and 400 kHz or lower in fast-mode.

Figure 25.5 I2C-bus Interface Clock

25.3.1.1 fVIIC

fVIIC is determined by setting a combination of the following:

- The frequency of peripheral clock f1
- The PCLK0 bit in the PCLKR register
- Bits ICK1 to ICK0 in the S3D0 register
- Bits ICK4 to ICK2 in the S4D0 register

fVIIC stops when the ES0 bit in the S1D0 register is 0 (I2C interface disabled).

See Table 25.8 “I2C-bus System Clock Select Bits” for details.

25.3.1.2 Bit Rate and Duty Cycle

Bit rate is determined by a combination of fVIIC, the FASTMODE bit in the S20 register, and bits CCR4 to CCR0 in the S20 register.

Table 25.11 lists the Bit Rate of Internal SCL Output and Duty Cycle. When the change in the internal SCL output high level is a negative value, although the low period increases the amount that the high periods decreases, the bit rate does not increase. The values described is the following table are the values of the internal SCL output before being effected by the SCL output of an external device.

Table 25.11 Bit Rate of Internal SCL Output and Duty Cycle

Item	Standard Clock Mode (FASTMODE = 0)	Fast-mode (FASTMODE = 1) (CCR value = other than 5)	Fast-mode (FASTMODE = 1) (CCR value = 5)
Bit rate (bps)	$\frac{\text{fVIIC}}{8 \times \text{CCR value}}$	$\frac{\text{fVIIC}}{4 \times \text{CCR value}}$	$\frac{\text{fVIIC}}{2 \times \text{CCRvalue}} = \frac{\text{fVIIC}}{10}$
Duty cycle	50% Fluctuation of high level: -4 to +2 fVIIC cycles	50% Fluctuation of high level: -2 to +2 fVIIC cycles	35 to 45%

CCR value: Value set to bits CCR4 to CCR0

When the CCR value (setting value of bits CCR4 to CCR0) is 5 (00101b) in fast-mode, the bit rate is assumed to reach 400 kbps, the maximum bit rate in fast-mode.

The bit rate and duty cycle are as follows.

- Bit rate:

$$\frac{\text{fVIIC}}{2 \times \text{CCR value}} = \frac{\text{fVIIC}}{10}$$

When fVIIC is 4 MHz, the bit rate is 400 kbps.

- Duty cycle is 35 to 45%

Even if the bit rate is 400 kbps, the 1.3 μs minimum low period of the SCLMM clock (I2C-bus standard) is allocated. Table 25.12 lists the Bit Setting for Bits CCR4 to CCR0 and Bit Rate (fVIIC = 4 MHz).

Table 25.12 Bit Setting for Bits CCR4 to CCR0 and Bit Rate (fVIIC = 4 MHz)

Bits CCR4 to CCR0 in the S20 Register					Bit Rate (kbps)	
CCR4	CCR3	CCR2	CCR1	CCR0	Standard Clock Mode	Fast-mode
0	0	0	0	0	Do not set (1)	Do not set (1)
0	0	0	0	1	Do not set (1)	Do not set (1)
0	0	0	1	0	Do not set (1)	Do not set (1)
0	0	0	1	1	Do not set (2)	333
0	0	1	0	0	Do not set (2)	250
0	0	1	0	1	100	400
0	0	1	1	0	83.3	166
:	:	:	:	:	:	:
1	1	1	0	1	17.2	34.5
1	1	1	1	0	16.6	33.3
1	1	1	1	1	16.1	32.3

Notes:

1. Do not set bits CCR4 to CCR0 to 0 to 2 regardless of the fVIIC frequency.
2. Do not exceed the maximum bit rates of 100 kbps in standard clock mode and 400 kbps in fast-mode.

25.3.1.3 Receiving a Slave Address in Wait Mode and Stop Mode

When the CM02 bit in the CM0 register is set to 0 (peripheral clock f1 does not stop in wait mode) and transition is made to wait mode, the I2C interface can receive the slave address even in wait mode.

When the CM02 bit in the CM0 register is set to 1 (peripheral clock f1 stops in wait mode) and transition is made to wait mode, the I2C interface stops operating because fVIIC supply is stopped in stop mode and low-power consumption mode.

The SCL/SDA interrupt can be used in either wait mode or stop mode.

25.3.2 Generating a Start Condition

Follow the procedure below when the ES0 bit in the S1D0 register is 1 (I2C interface enabled) and the BB bit in the S10 register is set to 0 (bus free). Figure 25.6 shows the Procedure to Generate a Start Condition.

(1) Write E0h to the S10 register.
The I2C interface enters the start condition standby state and the SDAMM pin is released.

(2) Write a slave address to the S00 register.
A start condition is generated. Then, the bit counter becomes 000b, the SCL clock signal is output for 1 byte, and the slave address is transmitted.

After a stop condition is generated and the BB bit becomes 0 (bus free), a write to the S10 register is disabled for 1.5 fVIIC cycles. Therefore, even if the S00 register is subsequently written to, a start condition is not generated. When generating a start condition shortly after changing the BB bit from 1 to 0, confirm that both bits TRX and MST are 1 after executing step (1), then execute step (2).

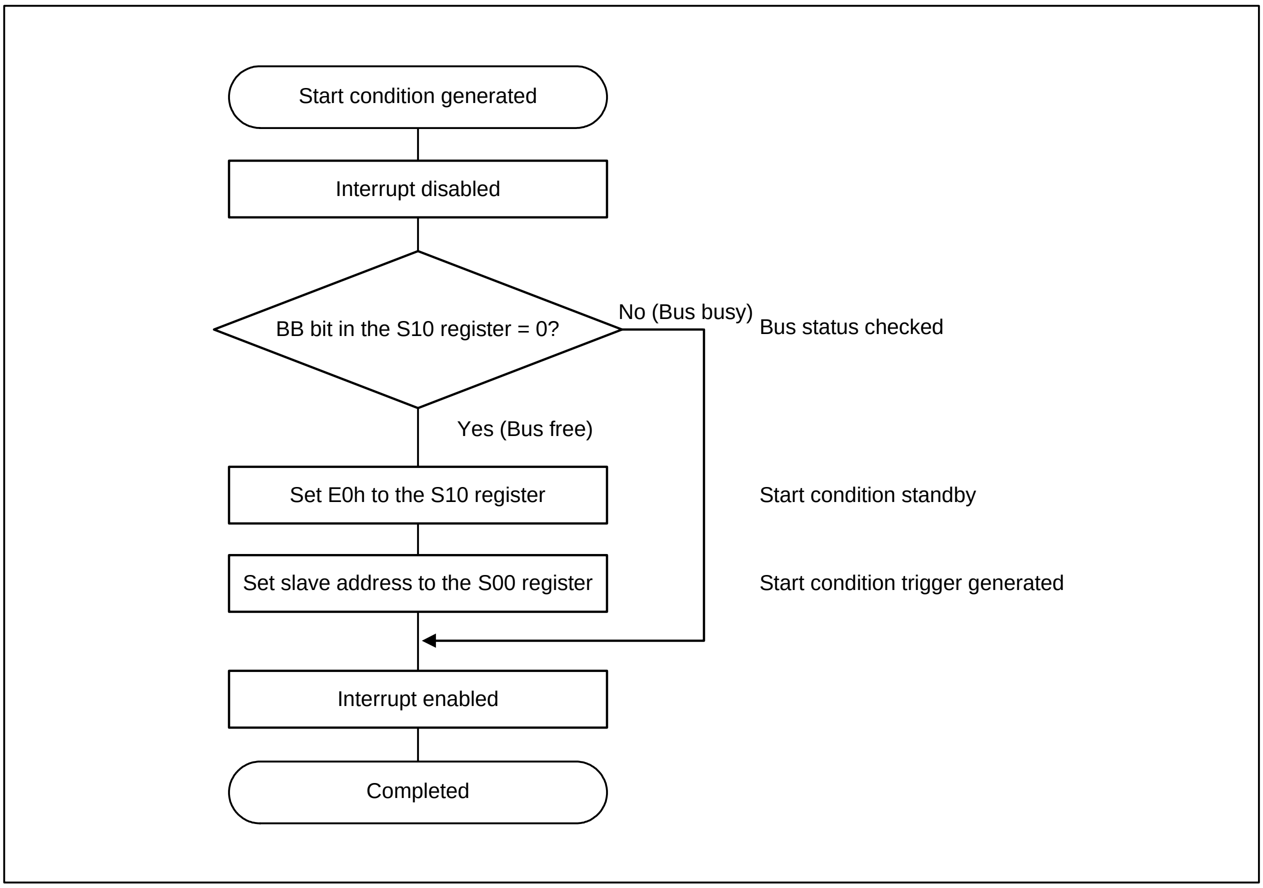

Start condition generated
Interrupt disabled
BB bit in the S10 register = 0?
No (Bus busy)
Bus status checked
Yes (Bus free)
Set E0h to the S10 register
Start condition standby
Set slave address to the S00 register
Start condition trigger generated
Interrupt enabled
Completed

Figure 25.6 Procedure to Generate a Start Condition

The start condition generation timing depends on the modes - standard clock mode or fast-mode.
Figure 25.7 shows the Start Condition Generation Timing.
Table 25.13 lists the Setup/Hold Time for Generating a Start/Stop Condition.

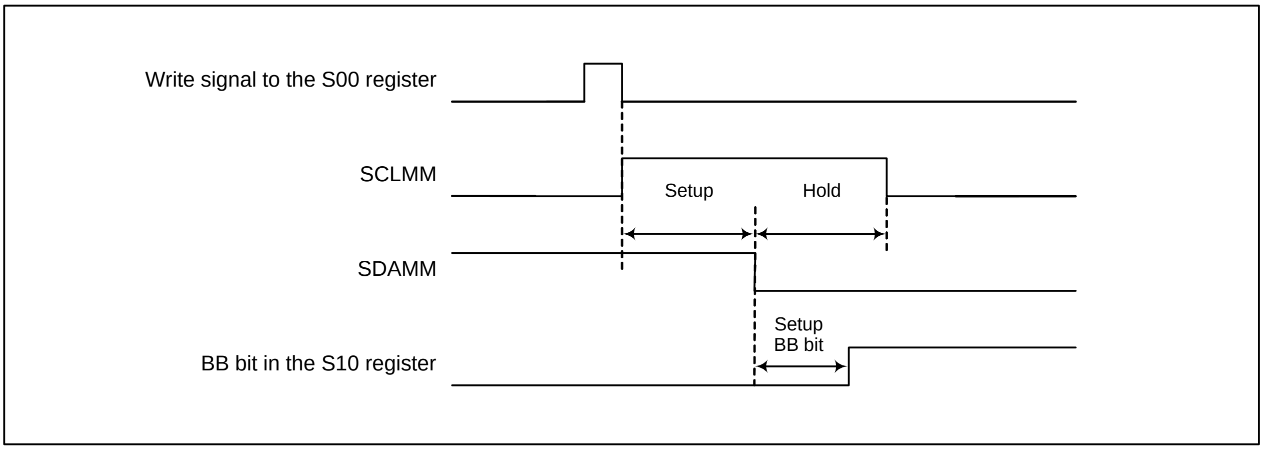


Figure 25.7 Start Condition Generation Timing

Table 25.13 Setup/Hold Time for Generating a Start/Stop Condition

Item	STSPSEL Bit	Standard Clock Mode		Fast-mode	
		fVIIC cycles	fVIIC = 4 MHz	fVIIC cycles	fVIIC = 4 MHz
Setup time	0 (short mode)	20	5.0 μs	10	2.5 μs
	1 (long mode)	52	13.0 μs	26	6.5 μs
Hold time	0 (short mode)	20	5.0 μs	10	2.5 μs
	1 (long mode)	52	13.0 μs	26	6.5 μs
BB bit set/reset time	-	$\frac{\text{SSC value} - 1}{2} + 2$	3.375 μs (1)	3.5	0.875 μs

-: 0 or 1
STSPSEL: Bit in the S2D0 register
SSC value: Value of bits SSC4 to SSC0 in the S2D0 register
Note:

1. Example value when bits SSC4 to SSC0 are 11000b.

25.3.3 Generating a Stop Condition

Use the following procedure when the ES0 bit in the S1D0 register is 1 (I2C interface enabled).

(1) Write C0h to the S10 register.

The I2C interface enters the stop condition standby state and the SDAMM pin is driven low.

(2) Write dummy data to the S00 register.

A stop condition is generated.

The stop condition generation timing depends on the modes - standard clock mode or fast-mode. Figure 25.8 shows the Stop Condition Generation Timing. See Table 25.13 “Setup/Hold Time for Generating a Start/Stop Condition” for setup/hold time.

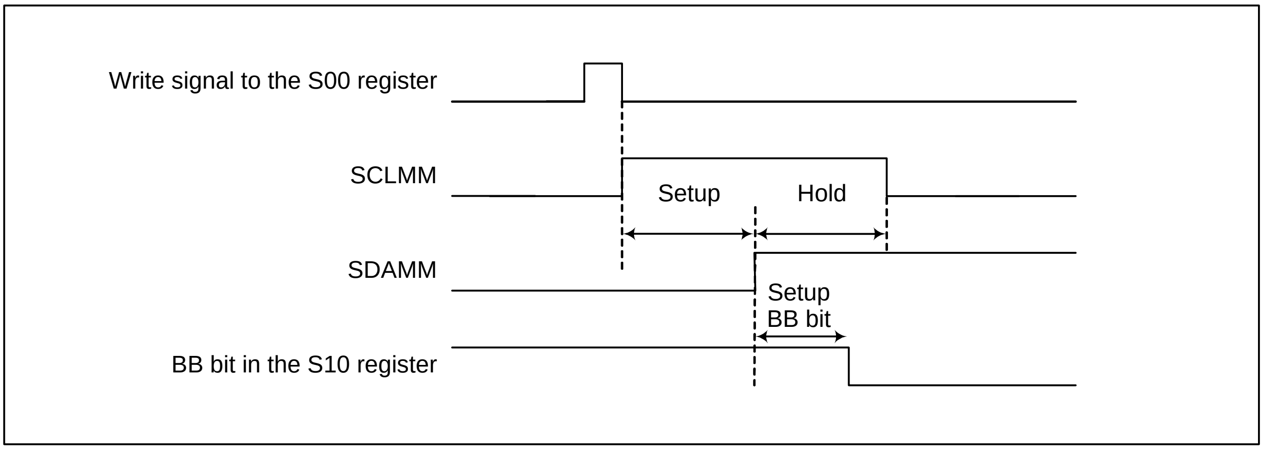


Figure 25.8 Stop Condition Generation Timing

Do not write to the S10 register or S00 register until the BB bit in the S10 register becomes 0 (bus free) after the instructions to generate a stop condition (refer to above (2)) are executed.

If the SCLMM pin input signal becomes low until the BB bit in the S10 register becomes 0 (bus free) from the instruction to generate a stop condition is executed and the SCLMM pin becomes high-level, the internal SCL output becomes low. In this case, perform one of the steps below to stop the low signal output from the SCLMM pin (release the SCLMM pin).

- Generate a stop condition (perform steps (1) and (2) above).
- Set the ES0 bit in the S1D0 register to 0 (I2C interface disabled).
- Write 1 to the IHR bit (I2C interface reset).

25.3.4 Generating a Restart Condition

Use the following procedure to generate a restart condition when 1-byte data is transmitted/received.

(1) Write E0h to the S10 register. (Start condition standby state. The SDAMM pin released.)

(2) Wait until the SDAMM pin level becomes high.

(3) Write a slave address to the S00 register (a start condition trigger is generated)

Figure 25.9 shows the Restart Condition Generation Timing.

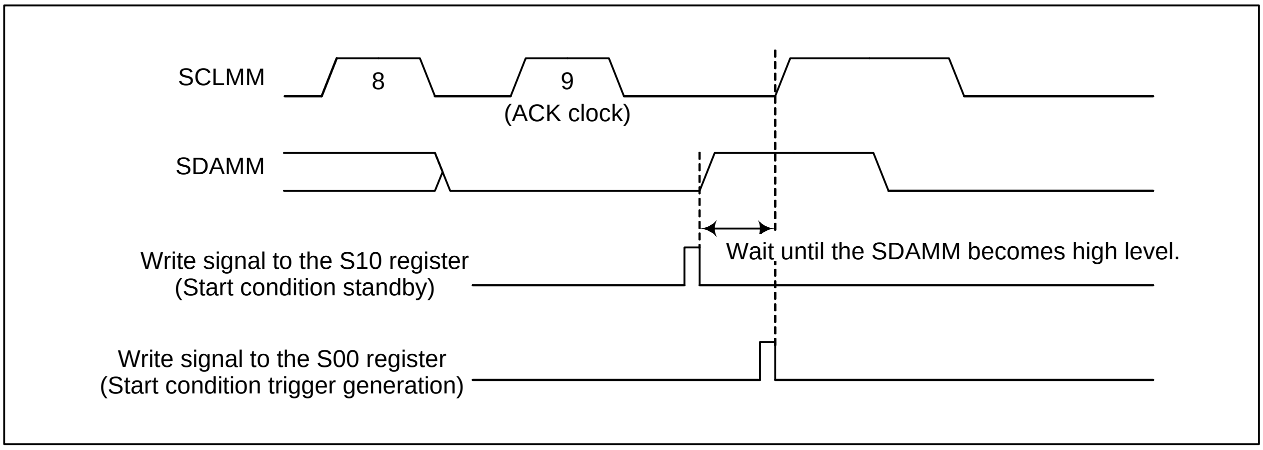

SCLMM
8
9
(ACK clock)
SDAMM
Write signal to the S10 register
(Start condition standby)
Wait until the SDAMM becomes high level.
Write signal to the S00 register
(Start condition trigger generation)

Figure 25.9 Restart Condition Generation Timing

25.3.5 Start Condition Overlap Protect

The I2C interface generates a start condition by setting registers S10 and S00 by a program. The bus system must be free before setting these registers. Check whether the bus is free with the BB bit in the S10 register by a program before setting the registers.

However, even after confirming that the bus is free, other master devices may generate a start condition before setting registers S10 and S00. In this case, when the I2C interface detects a start condition, the BB bit becomes 1 (bus busy) and the start condition overlap protect function is activated.

The start condition overlap protect function operates as follows:

- The multi-master I2C-bus interface does not enter start condition standby state even if the S10 register is set to E0h.
- If the I2C interface is in a start condition standby state, exit the state.
- A start condition trigger is not generated even if a data is written to the S00 register by program.
- Bits MST and TRX in the S10 register become 0 (slave receive mode).
- The AL bit in the S10 register becomes 1 (arbitration lost detected).

Figure 25.10 shows the Start Condition Overlap Protect Operation.

The following is an example of the start condition overlap protect operation if a start condition is generated by an external device in the start condition standby state.

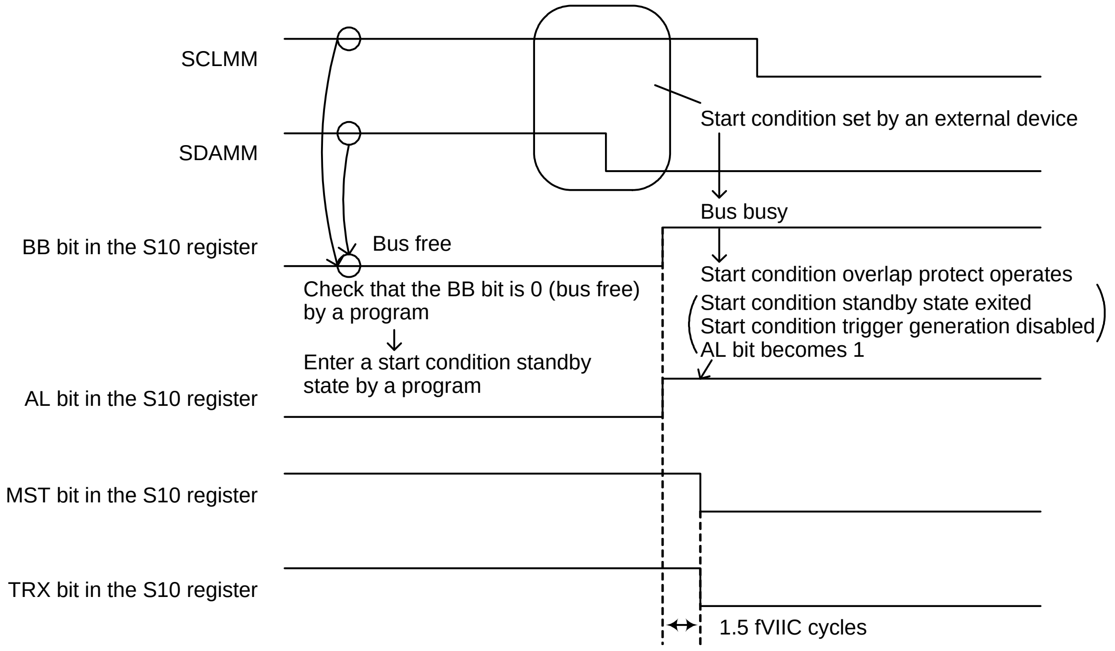

SCLMM
SDAMM
BB bit in the S10 register
AL bit in the S10 register
MST bit in the S10 register
TRX bit in the S10 register
Start condition set by an external device
Bus busy
Bus free
Check that the BB bit is 0 (bus free) by a program
Enter a start condition standby state by a program
Start condition overlap protect operates
Start condition standby state exited
Start condition trigger generation disabled
AL bit becomes 1
1.5 fVIIC cycles

Figure 25.10 Start Condition Overlap Protect Operation

The start condition overlap protect is enabled from the falling edge of SDAMM (start condition) to the completion of the slave address receive. If data is written to registers S10 and S00 during that period, the above operation is performed. Figure 25.11 shows the Start Condition Overlap Protect Function Enable Period.

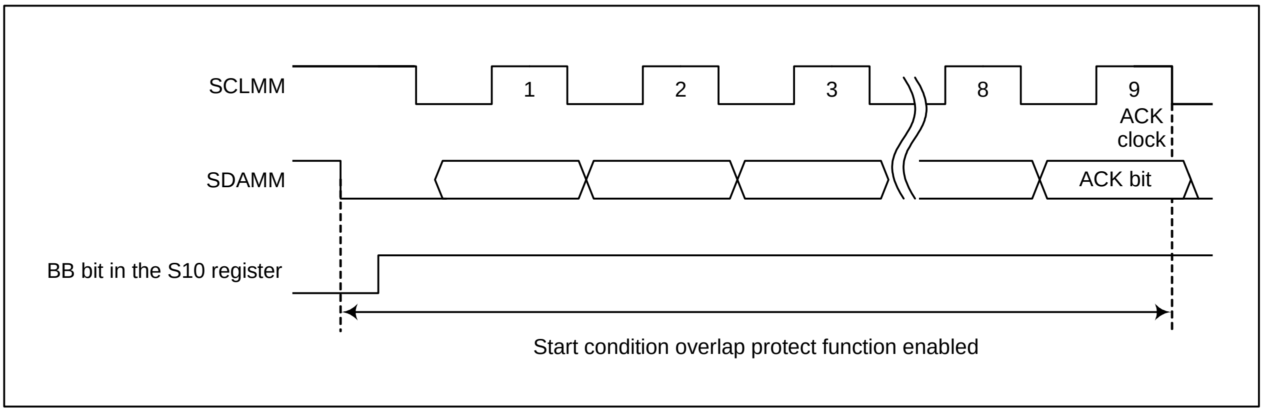

SCLMM
1
2
3
8
9
ACK
clock
SDAMM
ACK bit
BB bit in the S10 register
Start condition overlap protect function enabled

Figure 25.11 Start Condition Overlap Protect Function Enable Period

25.3.6 Arbitration Lost

When all of the conditions below are met, the SDAMM pin signal level becomes low by an external device and the I2C interface determines that it has lost arbitration.

(a) Transmit/receive (one of the following)

- Slave address transmit (not an ACK clock) in master transmit mode or master receive mode
- Data transmit (not an ACK clock) in master transmit mode
- Start condition generated in master transmit mode or master receive mode
- Stop condition generated in master transmit mode or master receive mode

(b) Internal SDA output: High

(c) SDAMM pin level: Low (sampling at the rising edge of the clock of SCLMM pin.)

Figure 25.12 shows Operation Example When Arbitration Lost is Detected.

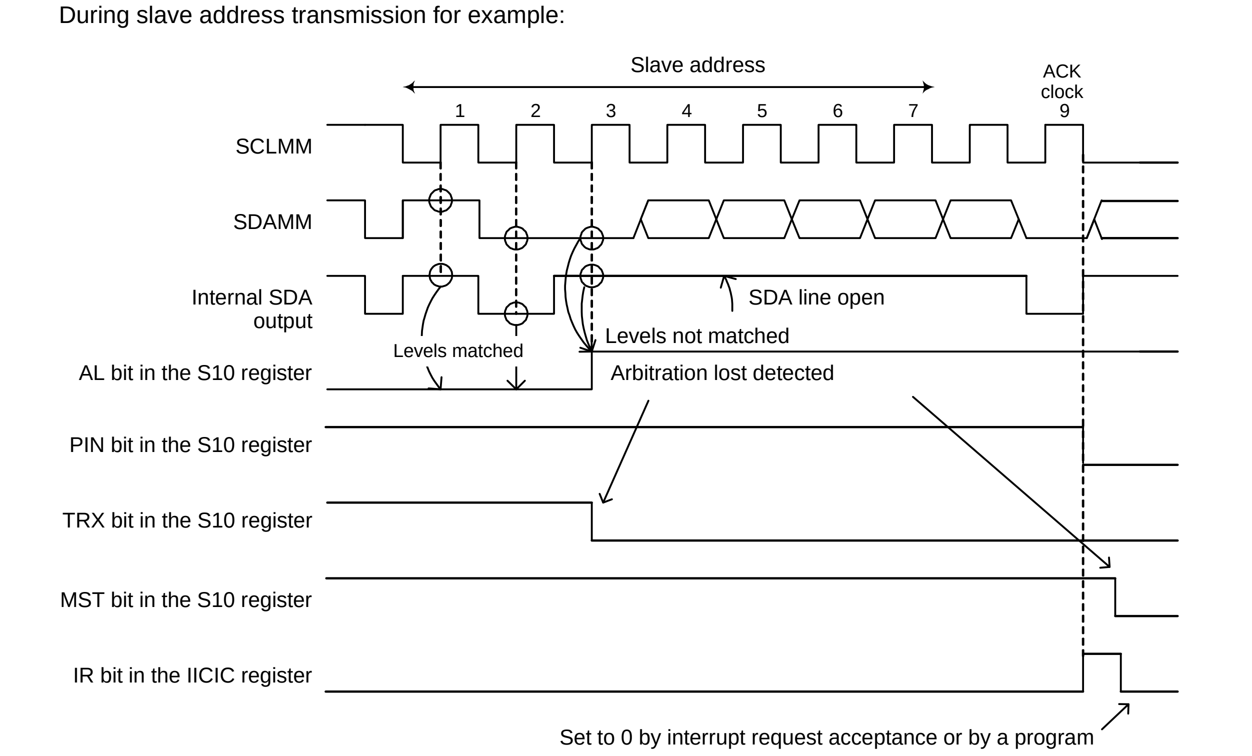

During slave address transmission for example:
Slave address
ACK clock
1
2
3
4
5
6
7
9
SCLMM
SDAMM
Internal SDA output
SDA line open
Levels matched
Levels not matched
AL bit in the S10 register
Arbitration lost detected
PIN bit in the S10 register
TRX bit in the S10 register
MST bit in the S10 register
IR bit in the IICIC register
Set to 0 by interrupt request acceptance or by a program

Figure 25.12 Operation Example When Arbitration Lost is Detected

When arbitration lost is detected:

- The AL bit in the S10 register becomes 1 (arbitration lost detected)
- Internal SDA output becomes high. (SDAMM released)
- The I2C interface enters the slave receive mode
  The TRX bit in the S10 register is 0 (receive mode).
  The MST bit in the S10 register is 0 (slave mode).

In order to set the AL bit to 0 again after arbitration lost is detected, set a value to the S00 register.

When arbitration lost is detected during slave address transmission, the I2C interface automatically enters slave receive mode and receives the slave address sent from another master. When the ALS bit in the S1D0 register is 0 (addressing format), the slave address comparison result is determined by reading bits ADR0 and AAS in the S10 register.

When arbitration lost is detected during data transmission, the I2C interface automatically enters slave receive mode.

Also, when arbitration lost is detected, the TRX bit becomes 0 (receive mode) even when the bit after the slave address is 1 (read). Therefore, read the S00 register after arbitration lost is detected. When bit 0 in the S00 register is 1, write 4Fh (slave transmit mode) to the S10 register and execute slave transmission.

25.3.7 Detecting Start/Stop Conditions

Figure 25.13 shows Start Condition Detection, Figure 25.14 shows Stop Condition Detection, and Table 25.14 lists Conditions to Detect Start/Stop Condition.

A start/stop condition can be detected only when the start/stop condition detect parameters are selected by setting bits SSC4 to SSC0 in the S2D0 register, and the signals input to pins SCLMM and SDAMM meet all three conditions (SCLMM release time, setup time, and hold time) listed in Table 25.14.

The BB bit in the S10 register becomes 1 when a start condition is detected, and becomes 0 when a stop condition is detected. The set timing and reset timing of the BB bit depends on whether the mode is standard mode or fast-mode. Refer to the BB bit set/reset times in Table 25.15.

Table 25.15 lists the Recommended Values of Bits SSC4 to SSC0 in Standard Clock Mode.

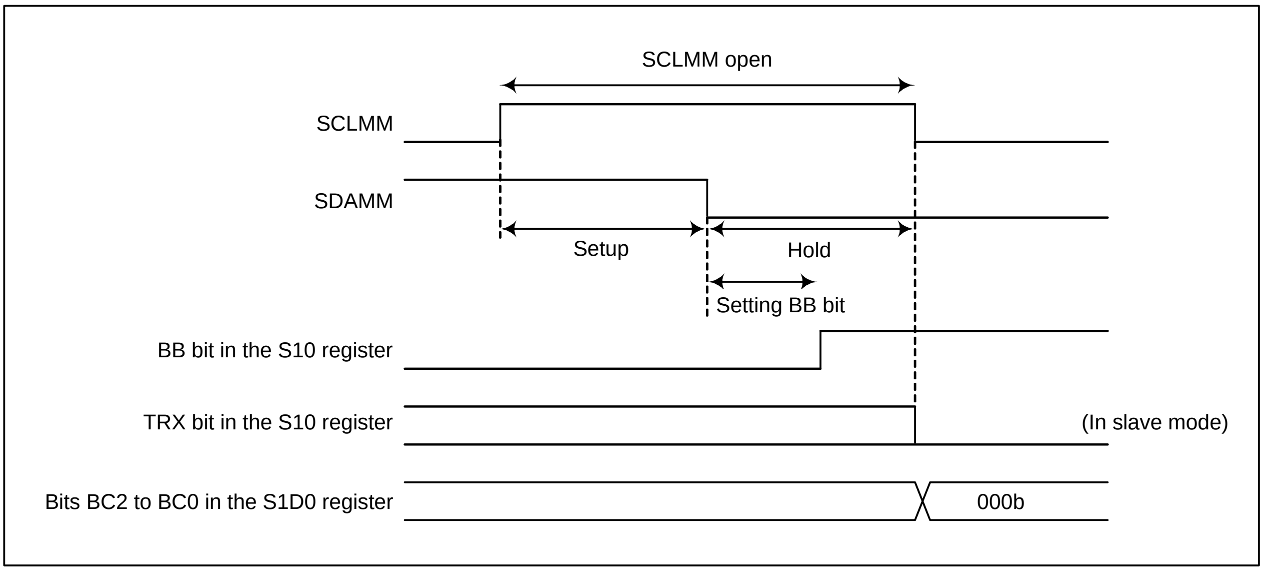

SCLMM open
SCLMM
SDAMM
Setup
Hold
Setting BB bit
BB bit in the S10 register
TRX bit in the S10 register
(In slave mode)
Bits BC2 to BC0 in the S1D0 register
000b

Figure 25.13 Start Condition Detection

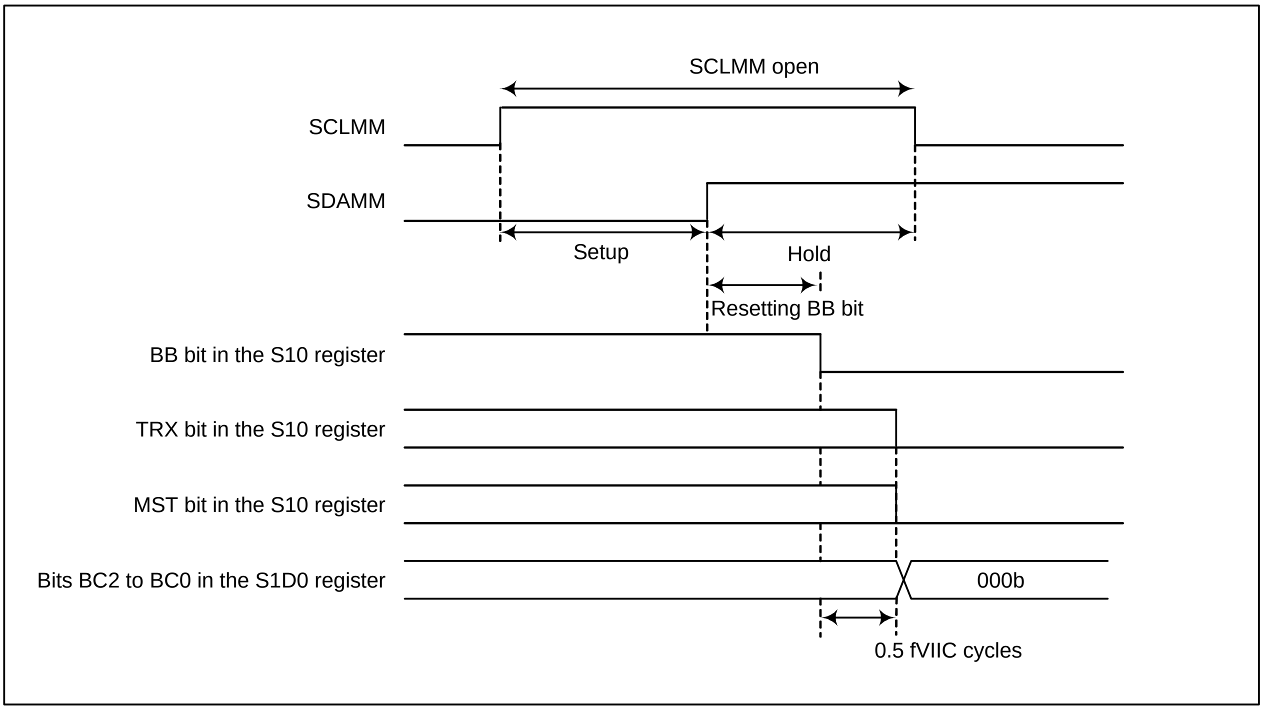

SCLMM open
SCLMM
SDAMM
Setup
Hold
Resetting BB bit
BB bit in the S10 register
TRX bit in the S10 register
MST bit in the S10 register
Bits BC2 to BC0 in the S1D0 register
000b
0.5 fVIIC cycles

Figure 25.14 Stop Condition Detection

Table 25.14 Conditions to Detect Start/Stop Condition

	Standard Clock Mode	Fast-Mode
SCLMM open time	SSC value + 1 cycle	4 cycles
Setup time	$\frac{\text{SSC value}}{2} + 1$ cycle	2 cycles
Hold time	$\frac{\text{SSC value}}{2}$ cycles	2 cycles
BB bit setting/resetting time	$\frac{\text{SSC value} - 1}{2} + 2$ cycles	3.5 cycles

Unit: Number of fVIIC cycles
SSC value: Value of bits SSC4 to SSC0 in the S2D0 register

Table 25.15 Recommended Values of Bits SSC4 to SSC0 in Standard Clock Mode

fVIIC	SSC Value (recommended)	Start/Stop Condition Detect Parameter			BB Bit Setting/Resetting Time
		SCLMM open time	Setup time	Hold time	
5 MHz	11110b	6.2 µs (31)	3.2 µs (16)	3.0 µs (15)	3.3 µs (16.5)
4 MHz	11010b	6.75 µs (27)	3.5 µs (14)	3.25 µs (13)	3.625 µs (14.5)
	11000b	6.25 µs (25)	3.25 µs (13)	3.0 µs (12)	3.375 µs (13.5)
2 MHz	01100b	6.5 µs (13)	3.5 µs (7)	3.0 µs (6)	3.75 µs (7.5)
	01010b	5.5 µs (11)	3.0 µs (6)	2.5 µs (5)	3.25 µs (6.5)
1 MHz	00100b	5.0 µs (5)	3.0 µs (3)	2.0 µs (2)	3.5 µs (3.5)

SSC value: Value of bits SSC4 to SSC0 in the S2D0 register
( ): Number of fVIIC cycles

25.3.8 Operation after Transmitting/Receiving a Slave Address or Data

After a slave address or 1-byte data has been transmitted/received, the PIN bit in the S10 register becomes 0 (interrupt requested) at the falling edge of the ACK clock. The IR bit in the IICIC register becomes 1 (interrupt requested) at the same time. The value in the S10 register or other register changes depending on the state of the transmit/receive data, and the level of pins SCLMM and SDAMM. Figure 25.15 shows Operation When Transmitted/Received a Slave Address or Data.

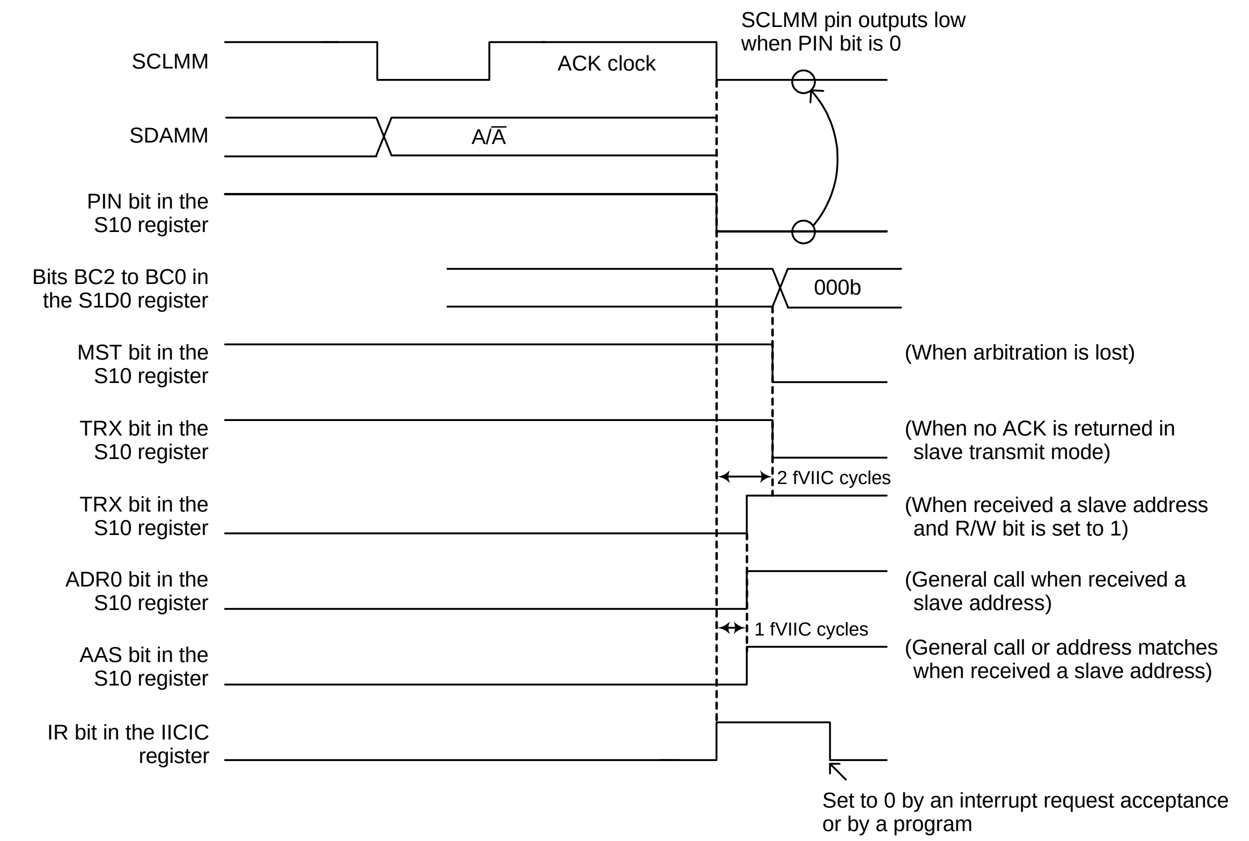
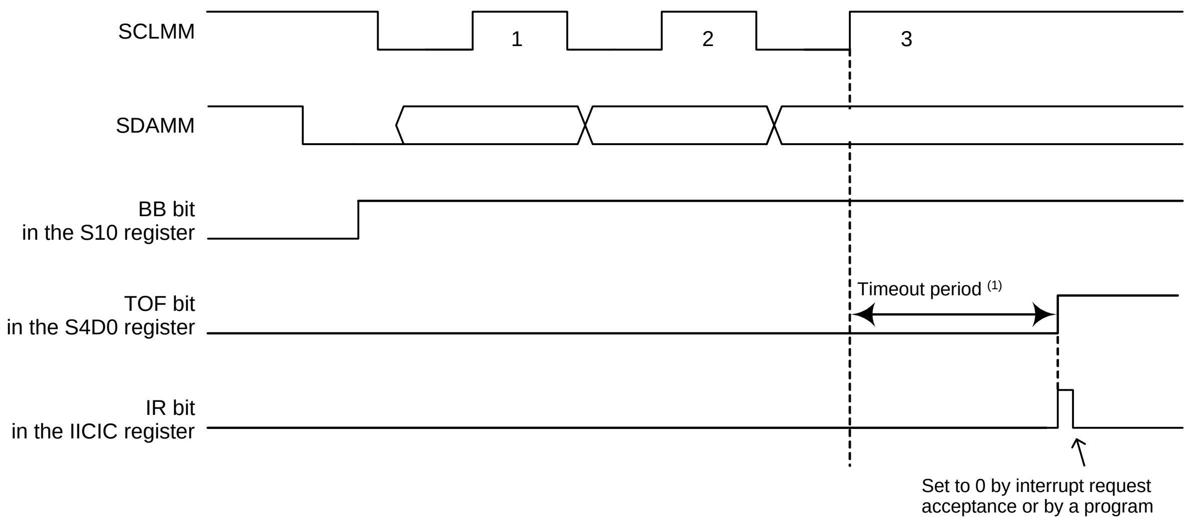


Figure 25.15 Operation When Transmitted/Received a Slave Address or Data

25.3.9 Timeout Detection

When the SCL clock is stopped during transmission/reception, each device stops operating, keeping the communication state. To avoid this, the I2C interface incorporates a function to detect timeouts and generate an I2C-bus interrupt request when the SCLMM pin is driven high for more than the selected timeout detection period during transmission/reception. Figure 25.16 shows the Timeout Detection Timing. Refer to “TOSEL (Timeout Detection Period Select Bit) (b2)” in 25.2.8 “I2C0 Control Register 2 (S4D0)” for the timeout detection period.

When the TOE bit in the S4D0 register is 1 (timeout detection enabled):


SCLMM
1
2
3
SDAMM
BB bit in the S10 register
Timeout period (1)
TOF bit in the S4D0 register
IR bit in the IICIC register
Set to 0 by interrupt request acceptance or by a program

Note:
1. Select by the TOSEL bit in the S4D0 register.

Figure 25.16 Timeout Detection Timing

A timeout is detected when all of the following conditions are met:

- The TOE bit in the S4D0 register is 1 (timeout detection enabled)
- The BB bit in the S10 register is 1 (bus busy)
- The SCLMM pin is driven high for more than the timeout detect period

When a timeout is detected:

- The TOF bit in the S4D0 register becomes 1 (timeout detected)
- The IR bit in the IICIC register becomes 1 (I2C-bus interrupt requested)

When the timeout is detected, perform one of the following:

- Set the ES0 bit in the S1D0 register to 0 (disabled).
- Set the IHR bit in the S1D0 register to 1 (I2C interface reset).

25.3.10 Data Transmit/Receive Examples

The data transmit/receive examples are described in this section. The conditions for the examples are as follows:

- Slave address: 7 bits
- Data: 8 bits
- ACK clock
- Standard clock mode, bit rate: 100 kbps (fIIC: 20 MHz; fVIIC: 4 MHz)
  20 MHz (fIIC) divided-by-5 = 4 MHz (fVIIC),
  4 MHz (fVIIC) divided-by-8 and further divided-by-5 = 100 kbps (bit rate)
- In receive mode, an ACK is returned for received data other than the last data. NACK is returned after the last data is received.
- When receiving data, I^{2}C-bus interrupt at the eighth clock (just before ACK clock): disabled
- Stop condition interrupt: enabled
- Timeout detect interrupt: disabled
- Set an own slave address to the S0D0 register (registers S0D1 or S0D2 should not be used)

When enabling an I^{2}C-bus interrupt at the eighth clock (just before ACK clock) during data reception, a receiver can determine whether to generate ACK or NACK after checking the received data each byte.

25.3.10.1 Initial Settings

Follow the initial setting procedures below for 25.3.10.2 to 25.3.10.5.

(1) Write an own slave address to bits SAD6 to SAD0 in the S0D0 register.
(2) Write 85h to the S20 register (CCR value: 5, standard clock mode, ACK clock presents).
(3) Write 18h to the S4D0 register (fVIIC: fIIC divided-by-5, timeout interrupt disabled).
(4) Write 01h to the S3D0 register (stop condition detect interrupt enabled and I^{2}C-bus interrupt at eighth clock is disabled when receiving data).
(5) Write 0Fh to the S10 register (slave receive mode).
(6) Write 98h to the S2D0 register (SSC value: 18h; start/stop condition generation timing: long mode).
(7) Write 08h to the S1D0 register (bit counter: 8, I^{2}C interface enabled, addressing format, input level: I^{2}C-bus input).

If the MCU uses a single-master system and it is a master, start the initial setting procedures from step (2).

25.3.10.2 Master Transmission

Master transmission is described in this section. The initial settings described in 25.3.10.1 “Initial Settings” are assumed to be completed. Figure 21.17 shows master transmission operation.
The following programs (A) to (C) are executed at (A) to (C) in Figure 25.17, respectively.

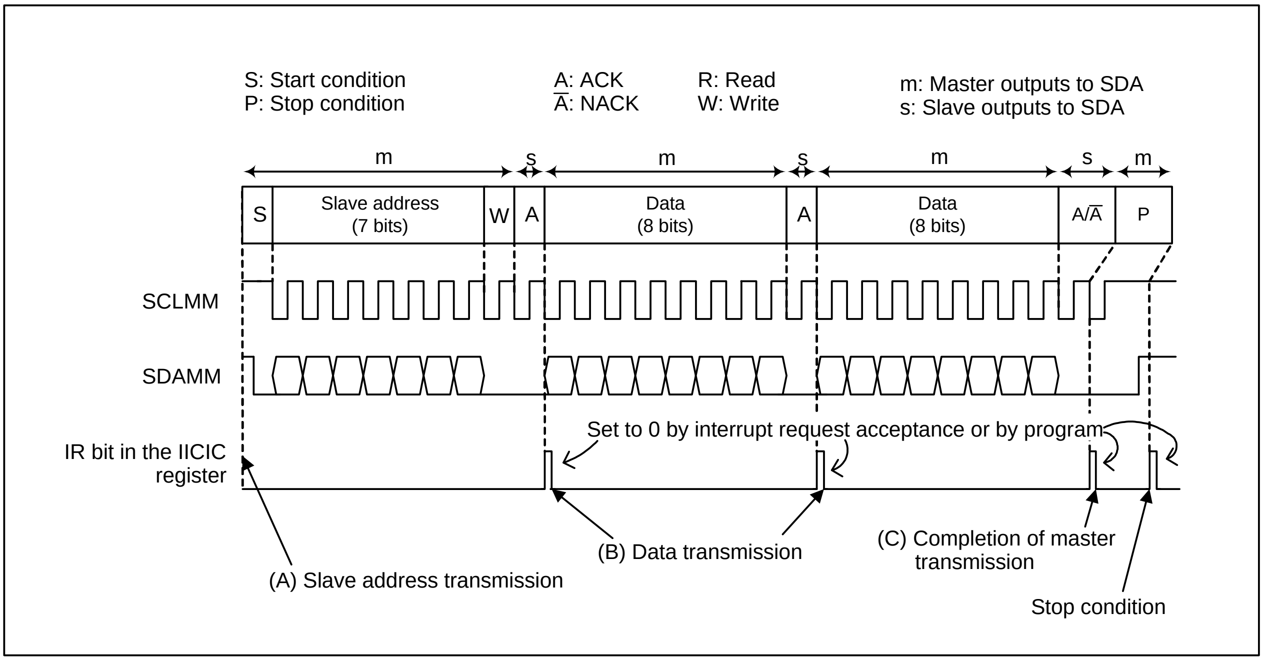


Figure 25.17 Example of Master Transmission

(A) Slave address transmission
(1) The BB bit in the S10 register must be 0 (bus free).
(2) Write E0h to the S10 register (start condition standby).
(3) Write a slave address to the upper 7 bits and set the least significant bit (LSB) to 0 (start condition generated, then slave address transmitted).

(B) Data transmission
(in I2C-bus interrupt routine)
(1) Write transmit data to the S00 register (data transmission).

(C) Completion of Master transmission
(in I2C-bus interrupt routine)
(1) Write C0h to the S10 register (stop condition standby state)
(2) Write dummy data to the S00 register (stop condition generated).

When transmission is completed or ACK is not returned from a slave device (NACK returned), master transmission should be completed as shown in the example above.

25.3.10.3 Master Reception

Master reception is described in this section. The initial settings described in 25.3.10.1 “Initial Settings” are assumed to be completed. Figure 25.18 shows the operation example of master reception. The following programs (A) to (D) are executed at (A) to (D) in Figure 25.18, respectively.

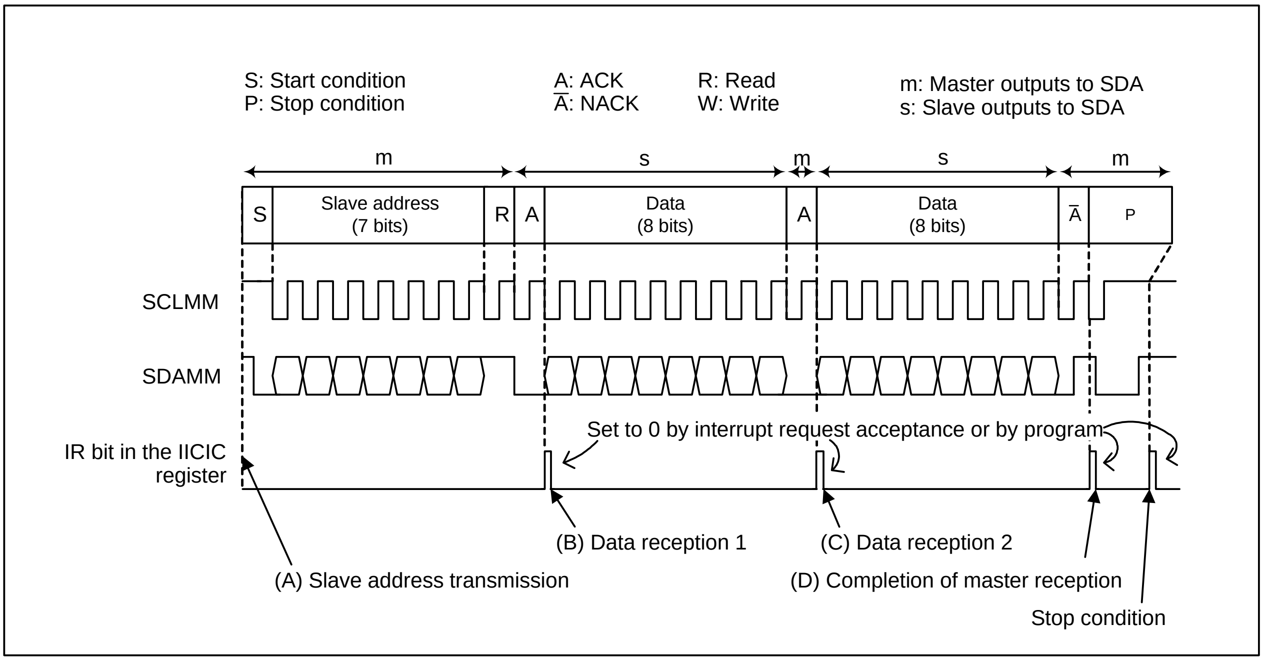


Figure 25.18 Example of Master Reception

(A) Slave address transmission
(1) The BB bit in the S10 register must be 0 (bus free).
(2) Write E0h to the S10 register (start condition standby).
(3) Write a slave address to the upper 7 bits and a set the least significant bit (LSB) to 1. (Start condition generated, then slave address transmitted)

(B) Data reception 1 (after slave address transmission)
(In I2C-bus interrupt routine)
(1) Write AFh to the S10 register (master receive mode).
(2) Set the ACKBIT bit in the S20 register to 0 (ACK presents) because the data is not the last one.
(3) Write dummy data to the S00 register

(C) Data reception 2 (data reception)
(In I2C-bus interrupt routine)
(1) Read the received data from the S00 register.
(2) Set the ACKBIT bit in the S20 register to 1 (no ACK) because the data is the last one.
(3) Write dummy data to the S00 register.

(D) Completion of master reception
(In I2C-bus interrupt routine)
(1) Read the received data from the S00 register.
(2) Write C0h to the S10 register (stop condition standby state).
(3) Write dummy data to the S00 register (stop condition generated).

25.3.10.4 Slave Reception

The slave reception is described in this section. The initial settings described in 225.3.10.1 “Initial Settings” are assumed to be completed. Figure 25.19 shows the example of slave reception. The following programs (A) to (C) are executed at (A) to (C) in Figure 25.19, respectively.

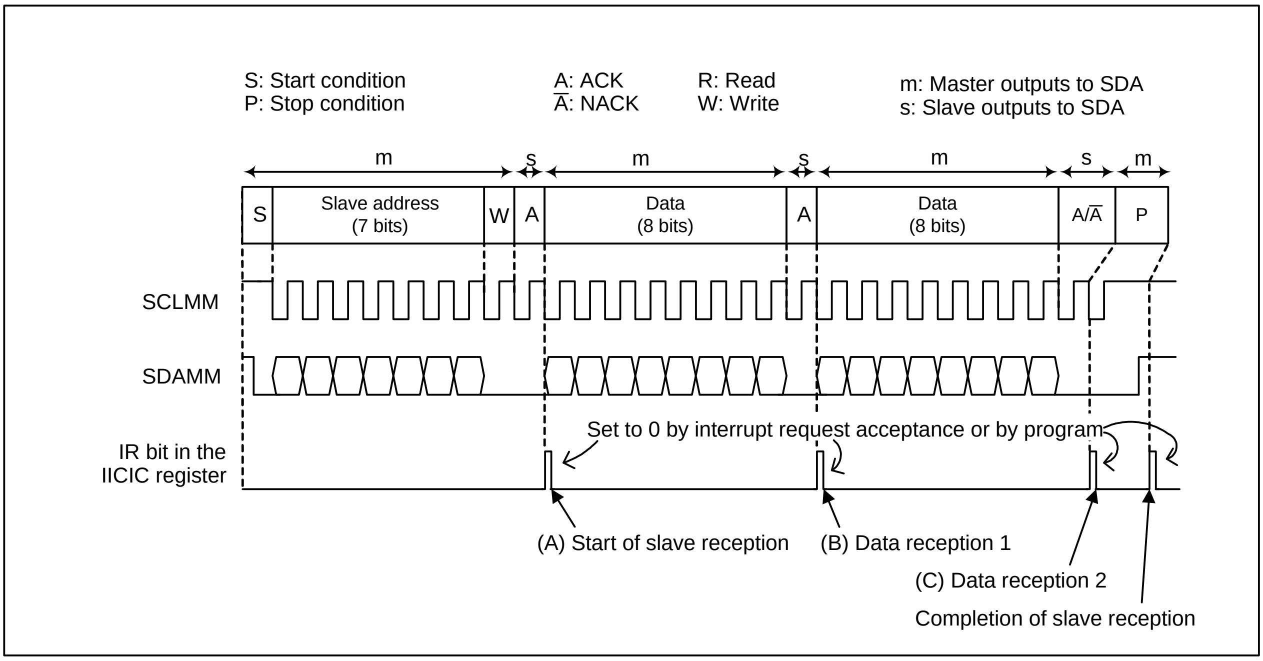


Figure 25.19 Example of Slave Reception

(A) Slave receive is started.
(In I2C-bus interrupt routine)
(1) Check the value of the S10 register. When the TRX bit is 0, the I2C interface is in slave receive mode.
(2) Write dummy data to the S00 register.

(B) Data reception 1
(In I2C-bus interrupt routine)
(1) Read the received data from the S00 register.
(2) Set the ACKBIT bit in the S20 register to 0 (ACK presents) because the data is not the last one.
(3) Write dummy data to the S00 register.

(C) Data reception 2
(In I2C-bus interrupt routine)
(1) Read the received data from the S00 register.
(2) Set the ACKBIT bit in the S20 register to 1 (no ACK presents) because the data is the last one.
(3) Write dummy data to the S00 register.

25.3.10.5 Slave Transmission

Slave transmission is described in this section. The initial settings described in 25.3.10.1 “Initial Settings” are assumed to be completed. Figure 25.20 shows the example of slave transmission. The following programs (A) to (B) are executed at (A) and (B) in Figure 25.20, respectively.

When arbitration lost is detected, the TRX bit becomes 0 (receive mode) even when the bit after the slave address is 1 (read). Therefore, after arbitration lost is detected, read the S00 register. When the bit 0 in the S00 register is 1, write 4Fh (slave transmit mode) to the S10 register and execute slave transmission.

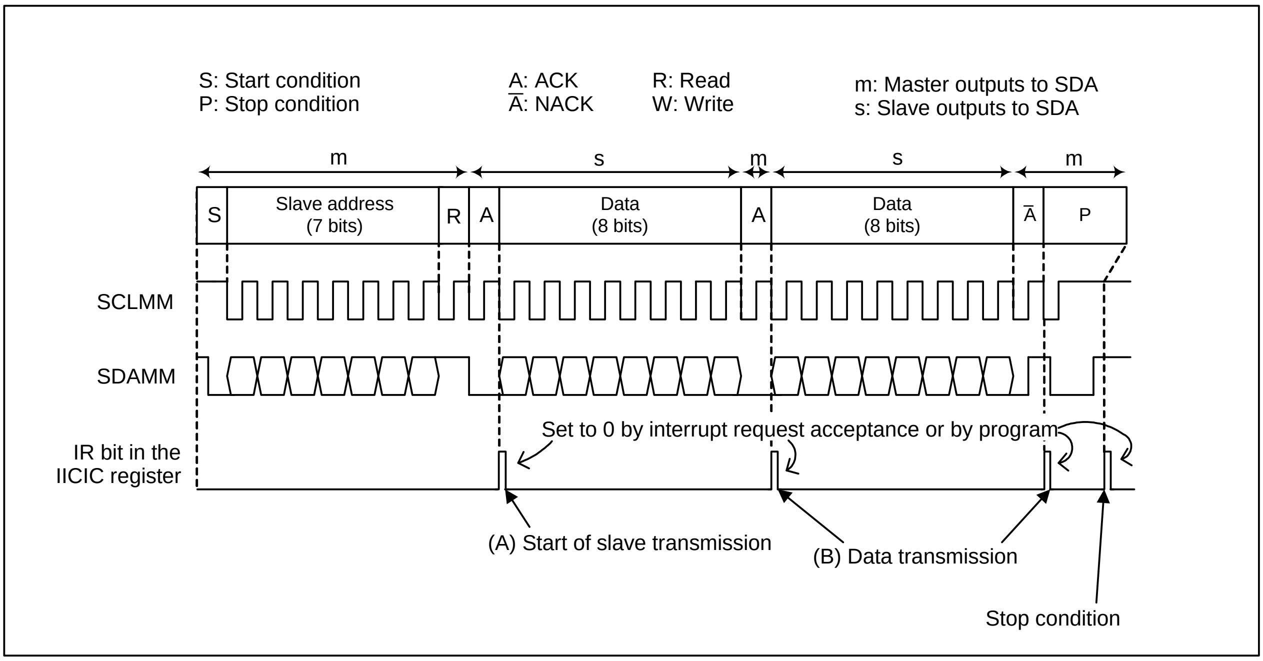


Figure 25.20 Example of Slave Transmission

(A) Start of slave transmission

(In I2C-bus interrupt routine)

(1) Check the value of the S10 register. When the TRX bit is 1, the I2C interface is in slave transmit mode.

(2) Write transmit data to the S00 register.

(B) Data transmission

(In I2C-bus interrupt routine)

(1) Write transmit data to the S00 register.

Write dummy data to the S00 register even if an interrupt occurs at an ACK clock of the last transmit data. After writing to the S00 register, the SCLMM pin is released.

25.4 Interrupts

The I2C interface generates interrupt requests. Figure 25.21 shows I2C Interface Interrupts, and Table 25.16 lists I2C-bus Interrupts.

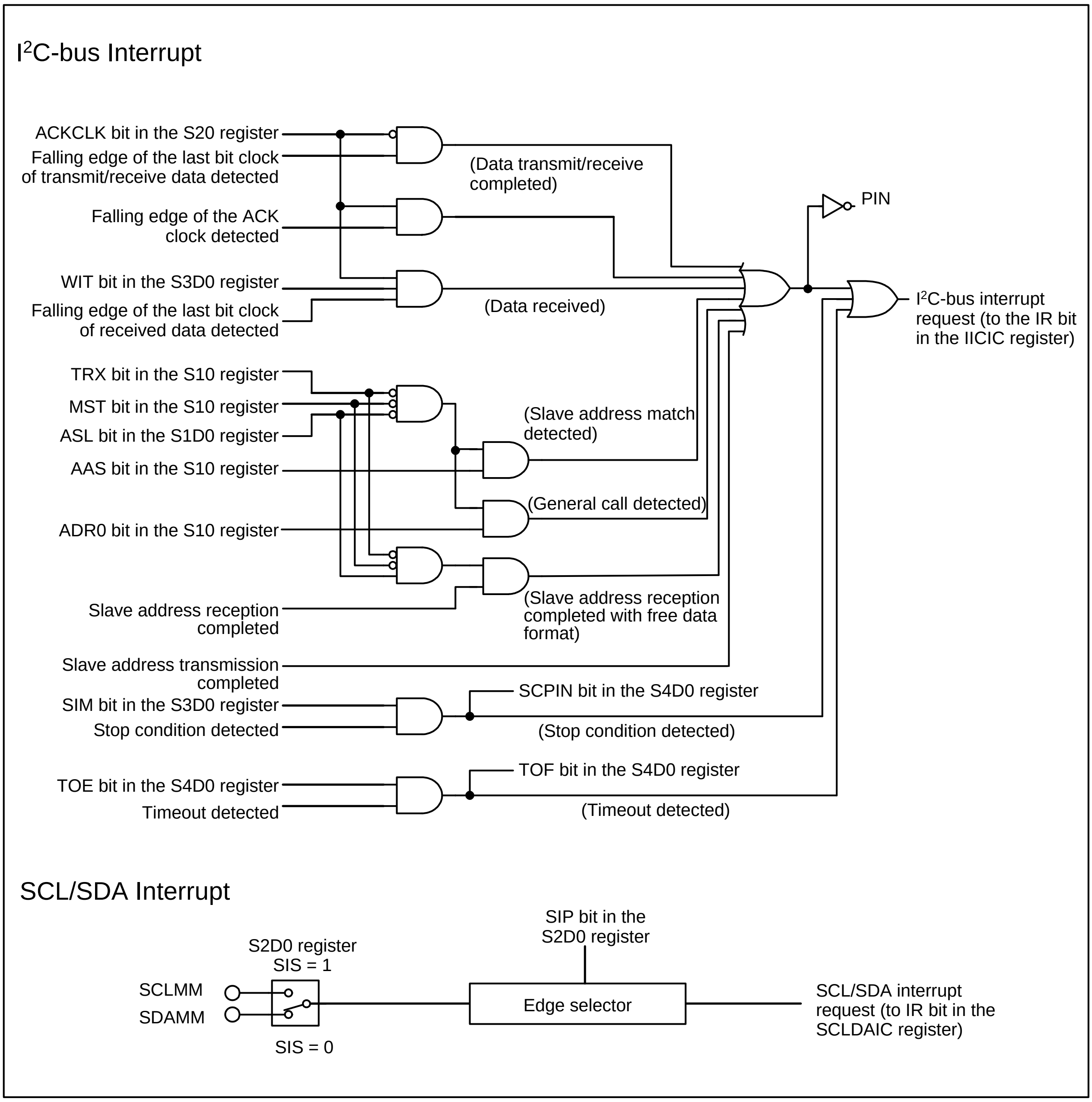

I2C-bus Interrupt
ACKCLK bit in the S20 register
Falling edge of the last bit clock of transmit/receive data detected
Falling edge of the ACK clock detected
WIT bit in the S3D0 register
Falling edge of the last bit clock of received data detected
TRX bit in the S10 register
MST bit in the S10 register
ASL bit in the S1D0 register
AAS bit in the S10 register
ADR0 bit in the S10 register
Slave address reception completed
Slave address transmission completed
SIM bit in the S3D0 register
Stop condition detected
TOE bit in the S4D0 register
Timeout detected
(Data transmit/receive completed)
(Data received)
(Slave address match detected)
(General call detected)
(Slave address reception completed with free data format)
SCPIN bit in the S4D0 register
(Stop condition detected)
TOF bit in the S4D0 register
(Timeout detected)
PIN
I2C-bus interrupt request (to the IR bit in the IICIC register)
SCL/SDA Interrupt
S2D0 register
SIS = 1
SIS = 0
SCLMM
SDAMM
SIP bit in the S2D0 register
Edge selector
SCL/SDA interrupt request (to IR bit in the SCLDAIC register)

Figure 25.21 I2C Interface Interrupts

Table 25.16 I^{2}C-bus Interrupts

Interrupt	Interrupt Source	Associated Bits (Register)		Interrupt Control Register
		Interrupt enabled	Interrupt request	
I^{2}C-bus Interrupt	Completion of data transmit/receive When the ACKCLK bit in the S20 register is 0: Detection of the falling edge of the last clock of transmit/receive data through the SCLMM pin When the ACKCLK bit is 1: Detection of the falling edge of ACK clock through the SCLMM pin	—	PIN (S10)	IICIC
	Data reception (before ACK clock) Detection of the falling edge of the last clock of transmit/receive data through the SCLMM pin	WIT (S3D0)		
	Detection of slave address match Received slave address matches bits SAD6 to SAD0 in registers S0D0 to S0D2 in slave receive mode with addressing format (AAS bit in the S10 register = 1)	—		
	Detection of general call General call in slave receive mode with addressing format (ADR0 bit in the S10 register = 1)			
	Completion of receiving slave address in slave receive mode with free data format			
	Stop condition detected	SIM (S3D0)	SCPIN (S4D0)	
	Timeout detected	TOE (S4D0)	TOF (S4D0)	
SCL/SDA interrupt	Detection of the falling edge or rising edge of input/output signal for the SCLMM or SDAMM pin	—	—	SCLDAIC

Refer to 14.7 “Interrupt Control”. Table 25.17 lists Registers Associated with I^{2}C Interface Interrupts.

Table 25.17 Registers Associated with I2C Interface Interrupts

Address	Register	Symbol	Reset Value
007Bh	I2C-bus Interface Interrupt Control Register	IICIC	XXXX X000b
007Ch	SCL/SDA Interrupt Control Register	SCLDAIC	XXXX X000b
0206h	Interrupt Source Select Register 2	IFSR2A	00h

When using the I2C-bus interface interrupt, set the IFSR22 bit in the IFSR2A register to 1 (I2C-bus interrupt). When using the SCL/SDA interrupt, set the IFSR23 bit in the IFSR2A register to 1 (SCL/SDA interrupt).

The SCL/SDA interrupt is enabled even in wait mode and stop mode.

The IR bit in the SCLDAIC register may become 1 (interrupt requested) when the ES0 bit in the S1D0 register, the SIP bit in the S2D0 register, or the SIS bit in the S2D0 register is changed. Therefore, follow the procedure below to change these bits. Refer to 14.13 “Notes on Interrupts”.

(1) Set bits ILVL2 to ILVL0 in the SCLDAIC register to 000b (interrupt disabled).
(2) Set the ES0 bit in the S1D0 register and bits SIP and SIS in the S2D0 register.
(3) Set the IR bit in the SCLDAIC register to 0 (no interrupt request).

25.5 Notes on Multi-master I^2C-bus Interface

25.5.1 Limitation on CPU Clock

When the CM07 bit in the CM0 register is 1 (CPU clock is a sub clock), do not access the registers listed in Table 25.4 “Registers”. Set the CM07 bit to 0 (main clock, PLL clock, or on-chip oscillator clock) to access these registers.

25.5.2 Register Access

Refer to the notes below when accessing the I^2C interface control registers. The period from the rising edge of the first clock of the slave address or 1-byte data transmission/reception to the falling edge of an ACK clock is considered to be the transmission/reception period. When the ACKCLK bit is 0 (no ACK clock), the transmission/reception period is from the rising edge of the first clock of the slave address or 1-byte data transmission/reception to the falling edge of the eighth clock.

25.5.2.1 S00 Register

Do not write to the S00 register during transmission/reception.

25.5.2.2 S1D0 Register

Do not change bits other than the IHR bit in the S1D0 register during transmission/reception.

25.5.2.3 S20 Register

Do not change bits other than the ACKBIT bit in the S20 register during transmission/reception.

25.5.2.4 S3D0 Register

- Do not use the bit managing instruction (read-modify-write instruction) to access the S3D0 register. Use the MOV instruction to write to this register.
- Rewrite bits ICK1 and ICK0 when the ES0 bit in the S1D0 register is 0 (I^2C interface disabled).

25.5.2.5 S4D0 Register

Rewrite bits ICK4 to ICK2 when the ES0 bit in the S1D0 register is 0 (I^2C interface disabled).

25.5.2.6 S10 Register

- Do not use the bit managing instruction (read-modify-write instruction) to access the S10 register. Use the MOV instruction to write to this register.
- Do not write to the S10 register when bits MST and TRX change their values.

Refer to operation examples in 25.3 “Operations” for bits MST and TRX change.

25.5.3 Low/High-level Input Voltage and Low-level Output Voltage

The low-level input voltage, high-level input voltage, and low-level output voltage differ from the I^2C-bus specification.
Refer to the recommended operating conditions for I/O ports which share the pins with SCL and SDA.

I^2C-bus specification

High level input voltage (V_{IH}) = min. 0.7 V_{CC}

Low level input voltage (V_{IL}) = max. 0.3 V_{CC}

26. Consumer Electronics Control (CEC) Function

26.1 Introduction

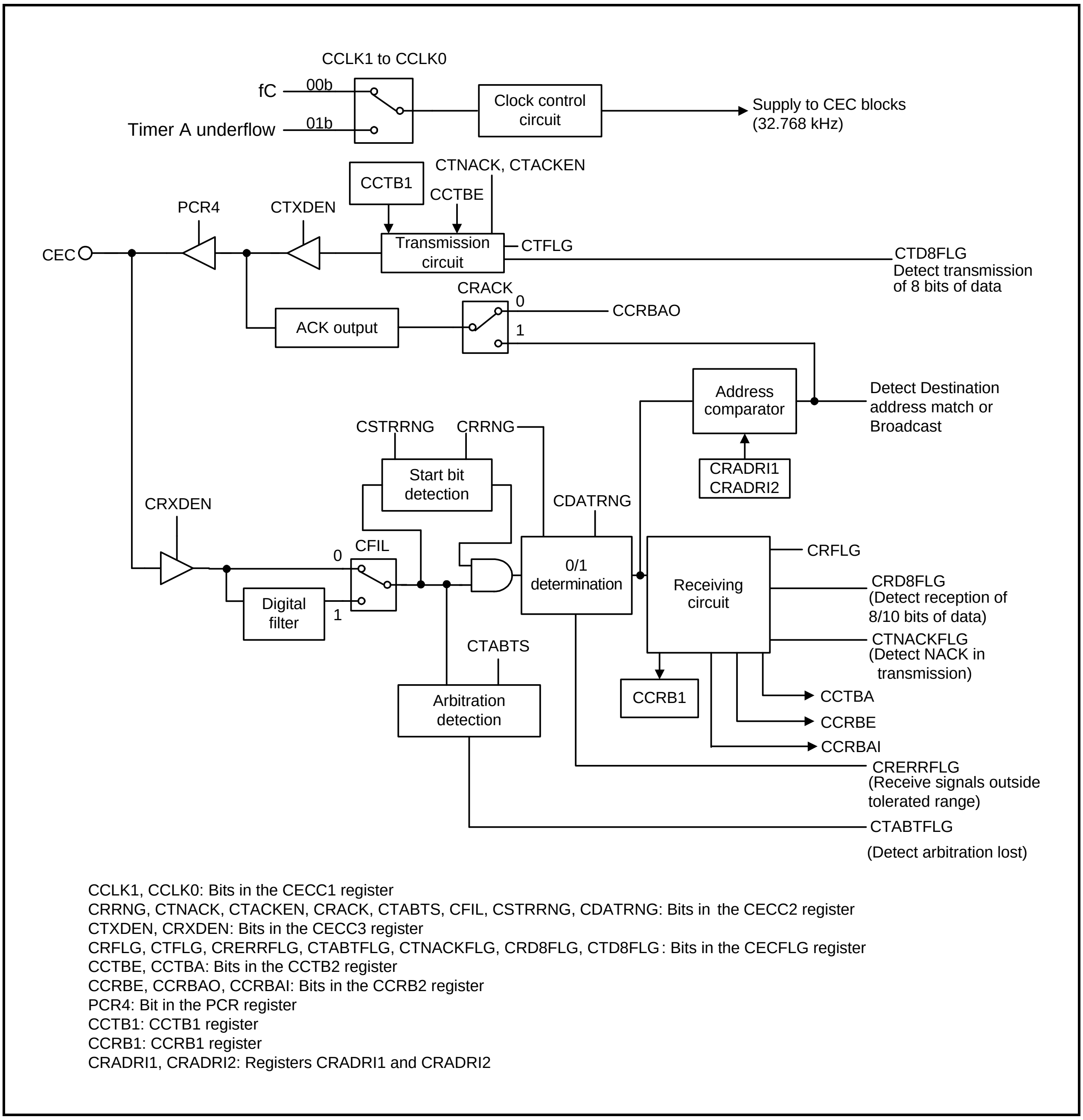
The CEC function indicates circuitry which supports the transmission and reception of CEC signals standardized by the High-Definition Multimedia Interface (HDMI).
Table 26.1 and Table 26.2 list the CEC Function Specifications, Figure 26.1 shows the CEC Function Block Diagram and Table 26.3 lists the I/O Pin.

Table 26.1 CEC Function Specifications (1/2)

Item	Specification
Count sources	fC, timer A0 underflow In either case, set the frequency to 32.768 kHz and the oscillation allowable error to within ±1%.
Data formats	Start bit: 1 bit Data bit: 8 bits EOM bit: 1 bit ACK bit: 1 bit
Transmission start condition	Before transmission starts, satisfy the following requirement: • The CTXDEN bit in the CECC3 register = 1 (transmission enabled)
Reception start condition	Before reception starts, satisfy the following requirements: • The CRXDEN bit in the CECC3 register = 1 (reception enabled) • Start bit detected
Interrupt request generation timing	A transmit interrupt is generated when: • 8 bits of data have been transmitted. • 10 bits of data have been transmitted. A transmit error interrupt is generated when: • Transmit arbitration lost occurs. • NACK is received during transmission (ACK received during broadcast transmission). A receive interrupt is generated when: • 8 bits of data have been received. • 10 bits of data have been received. • The above receive interrupts can be confined to when matching Destination address or during broadcast. • The start bit has been received. A receive error interrupt is generated when: • A signal outside the tolerated range is received.
Error detection	Arbitration lost If one of the following conditions occurs during transmission, arbitration lost is detected: • The CEC pin level is low while the pin outputs Hi-Z. • When changing the CEC pin from low output to Hi-Z, the pin level remains low even though it is outside the tolerated range. Transmission error The value of the CCTBA bit in the CCTB2 register matches the value of the CTNACK bit in the CECC2 register. Acceptable range error Low or high period of the data bit is outside the tolerated range.

Table 26.2 CEC Function Specifications (2/2)

Item	Specification
Selectable functions	Digital filter enabled/disabled
	Transmission stop selected Transmission stop by receiving ACK or NACK can be selected.
	Arbitration lost detection conditions One of the following conditions can be selected: • When transmitting the start bit and the data bit of Initiator address • When transmitting the start bit and all data bits
	Transmit rising timing selected • Selected from 8 levels, standard value -180 μs to standard value +30 μs
	Transmit falling timing selected • Start bit: standard value -160 μs to standard value • Data bit: selectable from 4 levels, standard value -310 μs to standard value
	Receive edge detection selected One of the following conditions can be selected. • Only a falling edge is detected • Both falling and rising edges are detected
	ACK output in receiving process One of the following conditions can be selected. • Inserted by program Set by the CCRBAO bit of CCRB2 register. • Inserted by hardware ACK is output when matching Destination address. NACK is output when not matching or in Broadcast.
	Start bit acceptable range • Select ±200μs or ±300μs
	Data bit acceptable range One of the following conditions can be selected: • Period between a falling edge and a rising edge ±200 μs, Period between a falling edge and a falling edge ±350 μs • Period between a falling edge and a rising edge ±300 μs, Period between a falling edge and a falling edge ±500 μs
	Low pulse output when receive error occurs • Whether error low pulse is output or not can be selected when the receive error occurs.
	Low pulse output wait control when receive error occurs. One of the following conditions can be selected: • Error low pulse is output in synchronization with the rising edge of the CEC input signal if the CEC input signal is low level when the receive error occurs. • Error low pulse is output immediately after the error occurs regardless of the CEC input signal state.



CCLK1, CCLK0: Bits in the CECC1 register
CRRNG, CTNACK, CTACKEN, CRACK, CTABTS, CFIL, CSTRRNG, CDATRNG: Bits in the CECC2 register
CTXDEN, CRXDEN: Bits in the CECC3 register
CRFLG, CTFLG, CRERRFLG, CTABTFLG, CTNACKFLG, CRD8FLG, CTD8FLG: Bits in the CECFLG register
CCTBE, CCTBA: Bits in the CCTB2 register
CCRBE, CCRBAO, CCRBAI: Bits in the CCRB2 register
PCR4: Bit in the PCR register
CCTB1: CCTB1 register
CCRB1: CCRB1 register
CRADRI1, CRADRI2: Registers CRADRI1 and CRADRI2

Figure 26.1 CEC Function Block Diagram

Table 26.3 I/O Pin

Pin Name	I/O	Description
CEC	Input/Output	CEC input and output (N-channel open drain output)

Note:

1. Set the direction bit of the ports sharing a pin to 0 (input mode).

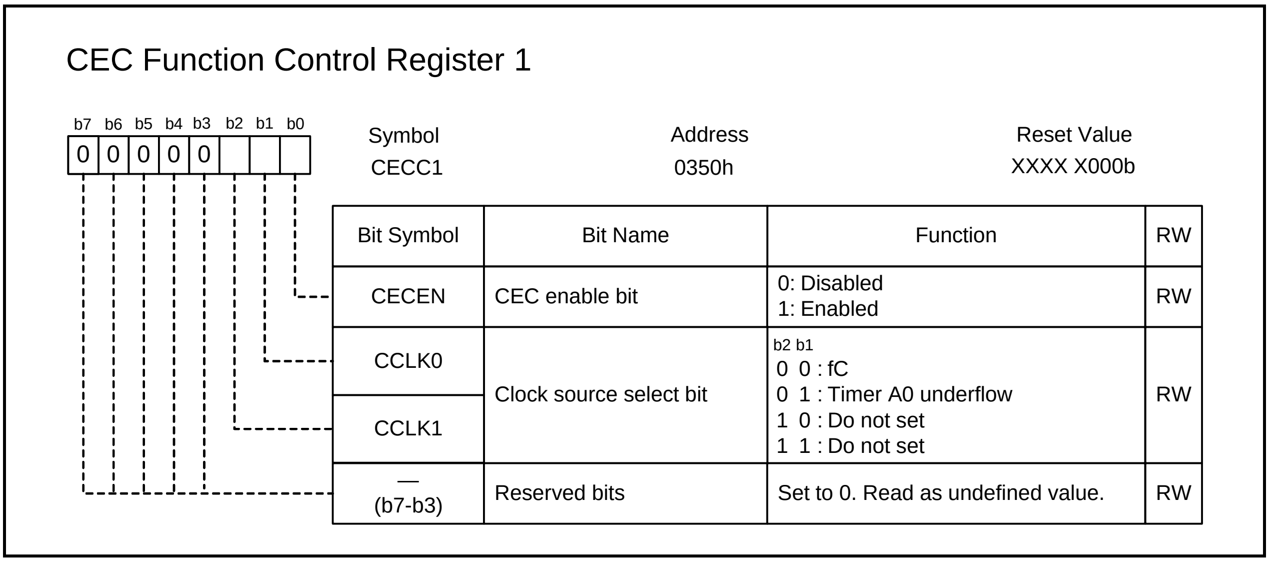
26.2 Registers

The CEC function's bits and registers are synchronized with the count source. Register values change immediately after being rewritten by a program, while the internal circuit starts operating from the next count source timing.

Table 26.4 Registers

Address	Register	Symbol	Reset Value
0350h	CEC Function Control Register 1	CECC1	XXXX X000b
0351h	CEC Function Control Register 2	CECC2	00h
0352h	CEC Function Control Register 3	CECC3	XXXX 0000b
0353h	CEC Function Control Register 4	CECC4	00h
0354h	CEC Flag Register	CECFLG	00h
0355h	CEC Interrupt Source Select Register	CISEL	00h
0356h	CEC Transmit Buffer Register 1	CCTB1	00h
0357h	CEC Transmit Buffer Register 2	CCTB2	XXXX XX00b
0358h	CEC Receive Buffer Register 1	CCRB1	00h
0359h	CEC Receive Buffer Register 2	CCRB2	XXXX X000b
035Ah	CEC Receive Follower Address Set Register 1	CRADRI1	00h
035Bh	CEC Receive Follower Address Set Register 2	CRADRI2	00h
0366h	Port Control Register	PCR	0000 0XX0b

26.2.1 CEC Function Control Register 1 (CECC1)



CEC Function Control Register 1

Symbol CECC1 Address 0350h Reset Value XXXX X000b

Bit Symbol	Bit Name	Function	RW
CECEN	CEC enable bit	0: Disabled 1: Enabled	RW
CCLK0	Clock source select bit	b2 b1 0 0 : fC 0 1 : Timer A0 underflow 1 0 : Do not set 1 1 : Do not set	RW
CCLK1			
— (b7-b3)	Reserved bits	Set to 0. Read as undefined value.	RW

CECEN (CEC enable bit) (b0)

Set the CECEN bit to 1 (enabled) when the count source is selected by using bits CCLK1 to CCLK0 and the count source is stable.

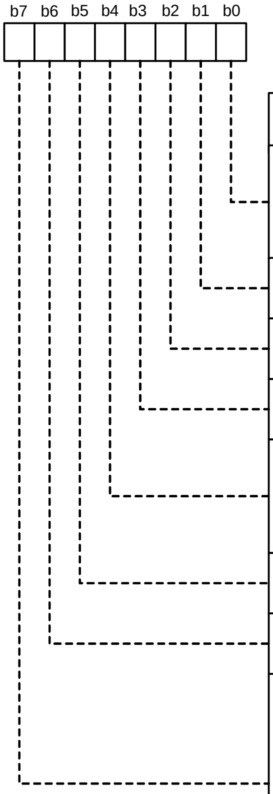
When the CECEN bit is set to 0 (disabled), the circuit of the CEC function is reset.

CCLK1 to CCLK0 (Clock source select bit) (b2-b1)

Change the clock source when the CECEN bit is set 0 (CEC disabled).

26.2.2 CEC Function Control Register 2 (CECC2)

CEC Function Control Register 2



Symbol	Address	Reset Value
CECC2	0351h	00h

Bit Symbol	Bit Name	Function	RW
CRRNG	Receive edge detection select bit	0: Detects falling edge acceptable range 1: Detects both edges acceptable range	RW
CTNACK	Transmit NACK (ACK) end select bit	0: End with ACK 1: End with NACK	RW
CTACKEN	Transmit NACK (ACK) end control bit	0: Continue transmitting 1: End with NACK/ACK	RW
CRACK	ACK output control bit	0: Inserted by program 1: Inserted by hardware	RW
CTABTS	Arbitration lost detect condition select bit	0: When transmitting start bit and Initiator address 1: When transmitting start bit and all data bits	RW
CFIL	Digital filter enable bit	0: Filter disabled 1: Filter enabled	RW
CSTRRNG	Start bit acceptable range select bit	0: ±200 µs 1: ±300 µs	RW
CDATRNG	Data bit acceptable range select bit	0: Period between falling edge and rising edge ± 200 µs Period between falling edge and falling edge ± 350 µs 1: Period between falling edge and rising edge ± 300 µs Period between falling edge and falling edge ± 500 µs	RW

Do not write to the CECC2 register while transmitting/receiving.

CTNACK (Transmit NACK (ACK) end select bit) (b1)

This bit is enabled when the CTACKEN bit is set to 1 (end with NACK/ACK).

CTACKEN (Transmit NACK (ACK) end control bit) (b2)

Select the end condition by using the CTNACK bit when the CTACKEN bit is 1 (end with NACK/ACK).

CRACK (ACK output control bit) (b3)

When the CRACK bit is set 0 (inserted by program), the value of the CCRBAO bit in the CCRB2 register is output as ACK data.

When the CRACK bit is set to 1 (inserted by hardware), ACK is output if the received Destination address matches the address selected by the CRADRI1 or CRADRI2 register. Table 26.5 lists ACK Output When Inserted by Hardware.

Table 26.5 ACK Output When Inserted by Hardware

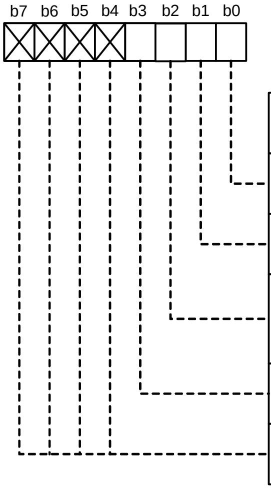
Destination Address		ACK Output
Received Destination address	Address selected by the CRADRI1 or CRADRI2 register (own address)	
Direct (0000b to 1110b)	Matches the received Destination address	ACK
	Does not match the received Destination address	NACK
Broadcast (1111b)	1111b (matches the received Destination address)	ACK
	0000b to 1110b	NACK

CTABTS (Arbitration lost detect condition select bit) (b4)

Refer to 26.3.6.2 “Arbitration Lost Detection”.

26.2.3 CEC Function Control Register 3 (CECC3)

CEC Function Control Register 3



Symbol	Address	Reset Value
CECC3	0352h	XXXX 0000b

Bit Symbol	Bit Name	Function	RW
CTXDEN	Transmit enable bit	0: Disabled 1: Enabled	RW
CRXDEN	Receive enable bit	0: Disabled 1: Enabled	RW
CREGCLR	Receive edge detect flag clear bit	The CREGFLG bit in the CECC4 register becomes 0 by setting 1 to this bit	RW
CEOMI	EOM disable bit	0: EOM enabled 1: EOM disabled (EOM ignored)	RW
— (b7-b4)	No register bits. If necessary, set to 0. Read as undefined value		—

CTXDEN (Transmit enable bit) (b0)
CRXDEN (Receive enable bit) (b1)

When changing the values of these bits, transmission/reception is enabled or disabled after one or more cycles of the clock source elapses.

When setting the CTXDEN bit to 0 while transmitting/receiving, transmitting is disabled after ACK completion. In the same way, when setting the CRXDEN bit to 0 while transmitting/receiving, reception is disabled after ACK completion.

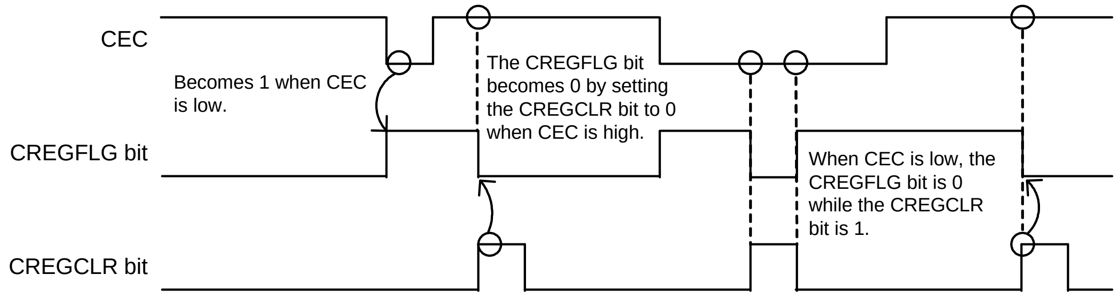
CREGCLR (Receive edge detect flag clear bit) (b2)

The CREGFLG bit in the CECC4 register becomes 0 by setting the CREGCLR bit to 1 when CEC input is Hi-Z.

The CREGCLR bit retains the value written to it. In order set the CREGFLG bit to 0 again by setting the CREGCLR bit to 1, first set the CREGCLR bit to 0, then set it to 1.

When setting the CREGCLR bit to 1 while CEC input is low, the CREGFLG bit becomes 0. If the CREGCLR bit is set to 0 after that, the CREGFLG bit becomes 1.

Figure 26.2 shows the Operation of Bits CREGFLG and CREGCLR.


CEC
Becomes 1 when CEC is low.
The CREGFLG bit becomes 0 by setting the CREGCLR bit to 0 when CEC is high.
CREGFLG bit
When CEC is low, the CREGFLG bit is 0 while the CREGCLR bit is 1.
CREGCLR bit

CREGCLR: Bit in the CECC3 register
CREGFLG: Bit in the CECC4 register

Figure 26.2 Operation of Bits CREGFLG and CREGCLR

CEOMI (EOM disable bit) (b3)

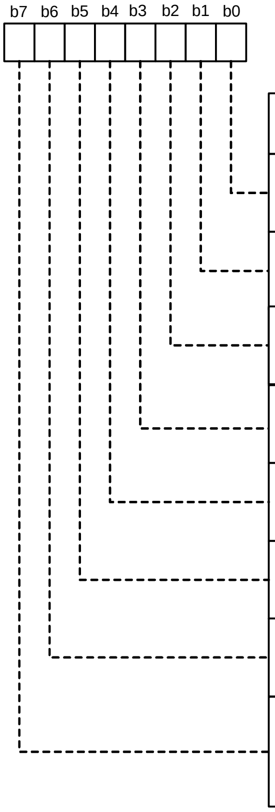
Set the CEOMI bit to select whether to continue or stop the operation when the EOM bit is 1. Table 26.6 lists Operation When the EOM Bit is 1. Do not write to the CEOMI bit while transmitting/receiving. When the CEOMI bit is 1 (EOM disabled), data transmission continues even after the EOM bit is set to 1 and transmitted. To stop transmitting, set the CTXDEN bit in the CECC3 register to 0 (transmission disabled).

Table 26.6 Operation When the EOM Bit is 1

CEOMI Bit	Reception	Transmission
0	When the EOM bit is 1 and is received, subsequent data reception is ignored. (wait for start bit)	When the EOM bit is 1 and is transmitted, subsequent data is not transmitted.
1	When the EOM bit is 1 and is received, ACK/NACK is returned for subsequent data reception.	When the EOM bit is 1 and is transmitted, data transmission continues.

26.2.4 CEC Function Control Register 4 (CECC4)

CEC Function Control Register 4



Symbol	Address	Reset Value
CECC4	0353h	00h

Bit Symbol	Bit Name	Function	RW
CRISE0	Rising timing select bit	b2 b1 b0 0 0 0: Standard value 0 0 1: Standard value - 30 µs 0 1 0: Standard value - 60 µs 0 1 1: Standard value - 90 µs 1 0 0: Standard value - 120 µs 1 0 1: Standard value - 150 µs 1 1 0: Standard value - 180 µs 1 1 1: Standard value + 30 µs	RW
CRISE1			RW
CRISE2			RW
CABTEN	Error low pulse output enabled bit	0: Disabled 1: Enabled	RW
CFALL0	Falling timing select bit	Refer to the following.	RW
CFALL1			RW
CREGFLG	Receive edge detect flag	0: Not detected 1: Detected	RO
CABTWEN	Error low pulse output wait control bit	0: Low pulse output regardless of CEC signal state 1: Low pulse output at the rising edge of the CEC signal	RW

CRISE2-CRISE0 (Rising timing select bit) (b2-b0)

The rising timing of the signal in transmission is selected. The rising timing is common to the start bit and data bit. Do not write to bits CRISE2 to CRISE0 while transmitting/receiving.

CABTEN (Error low pulse output enable bit) (b3)

When the CRXDEN bit is 0 (receive disabled), if the CABTEN bit is set to 1 (low pulse output enabled in receive error) and then the CRXDEN bit is set to 1 (receive enabled), a 3.6 ms low-level pulse is output if the data bit during reception exceeds the tolerated range. Output timing is selected by setting the CABTWEN bit.

After setting the CRXDEN bit to 1 (receive enabled) and then setting the CABTEN bit to 1 while not receiving, a low pulse is output when writing to the CABTEN bit.

After setting the CRXDEN bit to 1 (receive enabled) and then setting the CABTEN bit to 1 if the receiving data bit exceeds the tolerated range, a low pulse is output.

CFALL1-CFALL0 (Falling timing select bit) (b5-b4)

The falling timing of the signal in transmission is specified. Do not write to bits CFALL1 to CFALL0 while transmitting/receiving.

Table 26.7 Falling Timing of Signal in Transmission

Bits CFALL1 to CFALL0	Falling Timing	
	Start bit	Data bit
00b	Standard value	Standard value
01b	Standard value - 40 μs	Standard value - 190 μs
10b	Standard value - 100 μs	Standard value - 250 μs
11b	Standard value - 160 μs	Standard value - 310 μs

CREGFLG (Receive edge detect flag) (b6)

See Figure 26.2 “Operation of Bits CREGFLG and CREGCLR”.
Condition to become 0:

- Set the CREGCLR bit in the CECC3 register to 1.

Condition to become 1:

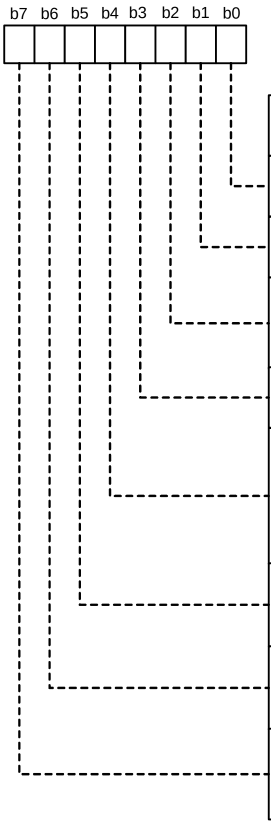
- Detect a low level input to CEC while the CREGCLR bit is 0.

CABTWEN (Error low pulse output wait control bit) (b7)

This bit is enabled when the CABTEN bit is 1 (low pulse output enabled in reception error).
If a receive error occurs when the CABTWEN bit is set to 1 (low pulse output at rising edge of the CEC signal) and the CEC input is low, a 3.6 ms low-level pulse is output from the rising edge of the CEC signal after the error. If there is no rising edge of the CEC signal within 3.6 ms from the reception error, a low-level pulse is not output because it is assumed that another device output an error low-level pulse.
Do not write to the CABTWEN bit while transmitting/receiving.

26.2.5 CEC Flag Register (CECFLG)

CEC Flag Register



Symbol	Address	Reset Value
CECFLG	0354h	00h

Bit Symbol	Bit Name	Function	RW
CRFLG	Receive status flag	0: Waiting 1: Receiving	RO
CTFLG	Transmit status flag	0: Waiting 1: Receiving	RO
CRERRFLG	Receive error detect flag	0: Not detected 1: Error detected (out of the determinable range)	RO
CTABTFLG	Arbitration lost detect flag	0: Not detected 1: Detected	RO
CTNACKFLG	Transmit NACK detect flag	0: Not detected 1: NACK detected (when transmitting a directly addressed message) ACK detected (when broadcasting)	RO
CRD8FLG	8th bit of data receive flag	0: 8th bit not received or 10th bit received 1: 8th bit received	RO
CTD8FLG	8th bit of data transmit flag	0: 8th bit not transmitted or 10th bit transmitted 1: The 8th bit transmitted	RO
CRSTFLG	Start bit detection	0: Start bit not detected or 8th bit received. 1: Start bit detected	RO

CRFLG (Receive status flag) (b0)

Condition to become 0.

- Waiting

Condition to become 1.

- Receiving
- Error low pulse is being output when the CABTEN bit in the CECC4 register is set to 1 (error low pulse output enabled).

CRERRFLG (Receive error detect flag) (b2)

Condition to become 0.

- Set the CRXDEN bit in the CECC3 to 0 (receive disabled).

Condition to become 1.

- Low or high period of the data bit is out of the acceptable range

CTABTFLG (Arbitration lost detect flag) (b3)

Condition to become 0.

- Set the CTXDEN bit in the CECC3 register to 0 (transmit disabled).

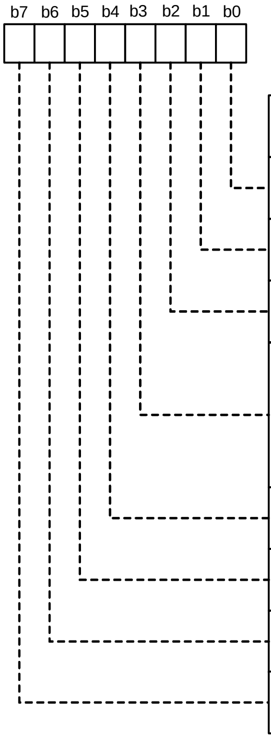
CTNACKFLG (Transmit NACK detect flag) (b4)

Condition to become 0.

- Set the CTXDEN bit in the CECC3 register to 0 (transmit disabled).

26.2.6 CEC Interrupt Source Select Register (CISEL)

CEC Interrupt Source Select Register

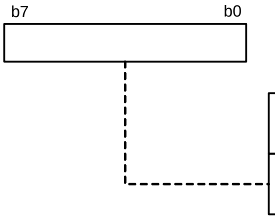


Symbol	Address	Reset Value
CISEL	0355h	00h

Bit Symbol	Bit Name	Function	RW
CRISEL0	8th bit receive interrupt enable bit	0: Disabled 1: Enabled	RW
CRISEL1	10th bit receive interrupt enable bit	0: Disabled 1: Enabled	RW
CRISEL2	Receive error interrupt enable bit	0: Disabled 1: Enabled	RW
CRISELM	Receive interrupt mode select bit	0: No limitation of 8th/10th bit receive interrupt 1: 8th/10th bit receive interrupt occurs only when matching Destination address or in Broadcast	RW
CTISEL0	8th bit transmit interrupt enable bit	0: Disabled 1: Enabled	RW
CTISEL1	10th bit transmit interrupt enable bit	0: Disabled 1: Enabled	RW
CTISEL2	Transmit error interrupt enable bit	0: Disabled 1: Enabled	RW
CRISELS	Reception start bit interrupt enable bit	0: Disabled 1: Enabled	RW

26.2.7 CEC Transmit Buffer Register 1 (CCTB1)

CEC Transmit Buffer Register 1



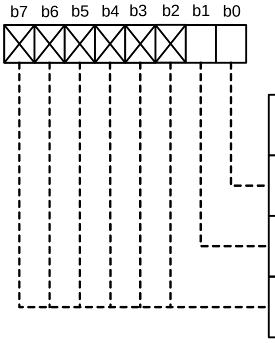
Symbol	Address	Reset Value
CCTB1	0356h	00h

Function	RW
Sets the transmit data	RW

Rewrite the CCTB1 register when the CTXDEN bit in the CECC3 register is 0 (transmit disabled), or the CTXDEN bit is 1 and the CTD8FLG in the CECFLG register is 1 (while bits EOM and ACK are being transmitted after the eighth bit has been transmitted). Do not rewrite the CCTB1 register when the CTXDEN bit is 1 and the CTD8FLG bit is 0 (while the first bit to eighth bit are being transmitted).

26.2.8 CEC Transmit Buffer Register 2 (CCTB2)

CEC Transmit Buffer Register 2



Symbol	Address	Reset Value
CCTB2	0357h	XXXX XX00b

Bit Symbol	Bit Name	Function	RW
CCTBE	Transmit data EOM bit	0: Data block continues 1: Data block ends	RW
CCTBA	Transmit data ACK input bit	0: ACK input 1: NACK input	RW
— (b7-b2)	No register bits. If necessary, set to 0. Read as undefined value		—

CCTBE (Transmit data EOM bit) (b0)

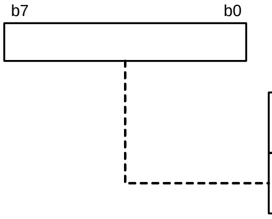
Rewrite the CCTBE bit when the CTXDEN bit in the CECC3 register is 0 (transmit disabled), or the CTXDEN bit is 1 and the CTD8FLG in the CECFLG register is 1 (while bits EOM and ACK are being transmitted after the eighth bit has been transmitted). The information written to this bit is output after the next data transmission. Do not rewrite the CCTBE bit when the CTXDEN bit is 1 and the CTD8FLG bit is 0 (while the first bit to eighth bit are being transmitted).

CCTBA (Transmit data ACK input bit) (b1)

Read the CCTBA bit after transmitting the tenth bit (ACK bit) (the CTD8FLG bit in the CECFLG register changes from 1 to 0).

26.2.9 CEC Receive Buffer Register 1 (CCRB1)

CEC Receive Buffer Register 1



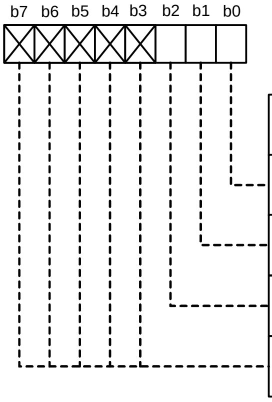
Symbol	Address	Reset Value
CCRB1	0358h	00h

Function	RW
Reads the receive data.	RO

Read the CCRB1 register after receiving the eighth bit (the CRD8FLG bit in the CECFLG register changes from 0 to 1).

26.2.10 CEC Receive Buffer Register 2 (CCRB2)

CEC Receive Buffer Register 2



Symbol	Address	Reset Value
CCRB2	0359h	XXXX X000b

Bit Symbol	Bit Name	Function	RW
CCRBE	Receive data EOM bit	0: Data block continues 1: Data block ends	RO
CCRBAO	Receive data ACK output bit	0: ACK output 1: NACK output	RW
CCRBAI	Receive data ACK input bit	0: ACK input 1: NACK input	RO
— (b7-b3)	No register bits. If necessary, set to 0. Read as undefined value		—

CCRBE (Receive data EOM bit) (b0)

Read the CCRBE bit after receiving the tenth bit (ACK bit) (the CRD8FLG bit in the CECFL register changes from 1 to 0).

CCRBAO (Receive data ACK output bit) (b1)

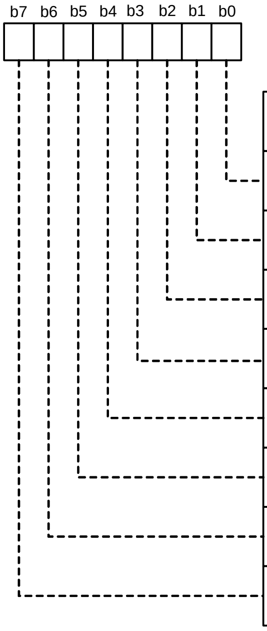
The CCRBAO bit is enabled when the CRACK bit in the CECC2 register is 0 (inserted by program). Rewrite the CCRBAO bit when the CRXDEN bit in the CECC3 register is 0 (receive disabled), or the CRXDEN bit is 1 and the start bit to EOM bit are being received. Do not rewrite the CCRBAO bit when the ACK bit is being transmitted.

CCRBAI (Receive data ACK input bit) (b2)

Read the CCRBAI bit after the tenth bit (ACK bit) is received (the CRD8FLG bit in the CECFL register changes from 1 to 0).

26.2.11 CEC Receive Follower Address Set Register 1 (CRADRI1), CEC Receive Follower Address Set Register 2 (CRADRI2)

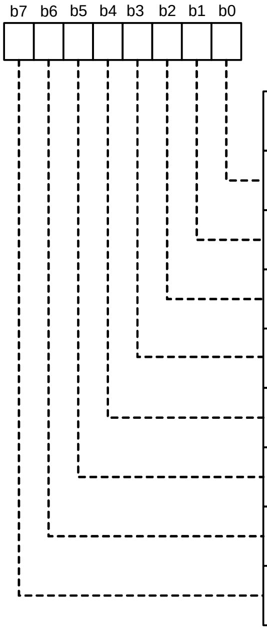
CEC Receive Follower Address Set Register 1



Symbol	Address	Reset Value
CRADRI1	035Ah	00h

Bit Symbol	Bit Name	Function	RW
CRADRI10	0000b select bit	0: Not selected 1: Selected	RW
CRADRI11	0001b select bit		RW
CRADRI12	0010b select bit		RW
CRADRI13	0011b select bit		RW
CRADRI14	0100b select bit		RW
CRADRI15	0101b select bit		RW
CRADRI16	0110b select bit		RW
CRADRI17	0111b select bit		RW

CEC Receive Follower Address Set Register 2



Symbol	Address	Reset Value
CRADRI2	035Bh	00h

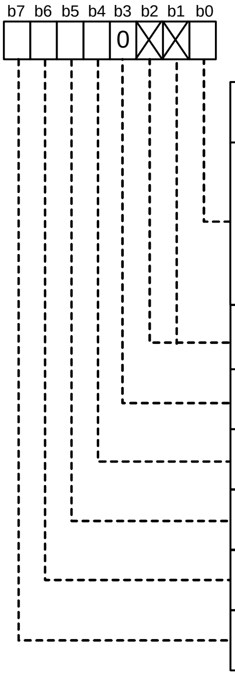
Bit Symbol	Bit Name	Function	RW
CRADRI20	1000b select bit	0: Not selected 1: Selected	RW
CRADRI21	1001b select bit		RW
CRADRI22	1010b select bit		RW
CRADRI23	1011b select bit		RW
CRADRI24	1100b select bit		RW
CRADRI25	1101b select bit		RW
CRADRI26	1110b select bit		RW
CRADRI27	1111b select bit		RW

Select the receive follower address (own address).

ACK is returned by setting the CRADRI27 bit to 1 (selects 1111b) when the Follower address is 1111b (Broadcast) and the CRACK bit in the CECC2 register is 1 (ACK output in reception is inserted by hardware).
When the received Destination address matches the address selected by the CRADRI1 or CRADRI2 register, it may be described as Destination address match in this chapter.

26.2.12 Port Control Register (PCR)

Port Control Register



Symbol	Address	Reset Value
PCR	0366h	0000 0XX0b

Bit Symbol	Bit Name	Function	RW
PCR0	Port P1 control bit	Operation performed when the P1 register is read 0 : When the port is set to input, the input levels of pins P1_0 to P1_7 are read. When set to output, the port latch is read. 1 : The port latch is read regardless of whether the port is set to input or output.	RW
— (b2-b1)	No register bits. If necessary, set to 0. The read value is undefined.		—
— (b3)	Reserved bit	Set to 0.	RW
PCR4	CEC output enable bit	0 : CEC output disabled 1 : CEC output enabled	RW
PCR5	$\overline{\text{INT6}}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR6	$\overline{\text{INT7}}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR7	Key input enable bit	0 : Enabled 1 : Disabled	RW

PCR4 (CEC output enable bit) (b4)

To use the CEC function, set the PCR4 bit to 1 (CEC output enabled).

26.3 Operations

26.3.1 Standard Value and I/O Timing

CEC transmission/reception is based on the count source cycle.

When outputting, an output waveform is based on the count source cycle which is closest to the CEC standard value. When inputting, an input waveform is sampled in the count source cycle.

Also, the input/output is practically performed based on the count source cycle closest to the acceptable range or output timing.

26.3.2 Count Source

Select fC or timer A0 underflow by bits CCLK1 to CCLK0 in the CECC1 register. In either case, the clock frequency should be 32.768 kHz and oscillation allowable error should be within ±1%. Set the CECEN bit in the CECC1 register to 1 (CEC enabled), after the count source is selected by bits CCLK1 and CCLK0 and when the count source is stable.

To use fC, set the PM25 bit in the PM2 register to 1 (peripheral clock fC provided). Refer to 8. “Clock Generator” for details.

When the timer A0 underflow is used as the count source, each time timer A0 underflows the internal signal of the timer A0 is inverted. Since this internal signal is the count source, two cycles of timer A0 underflows are one cycle of the count source. Figure 26.3 shows the Count Source When Timer A0 Underflow Selected. Use timer A0 without timer mode and gate function. Refer to 17. “Timer A” for details.

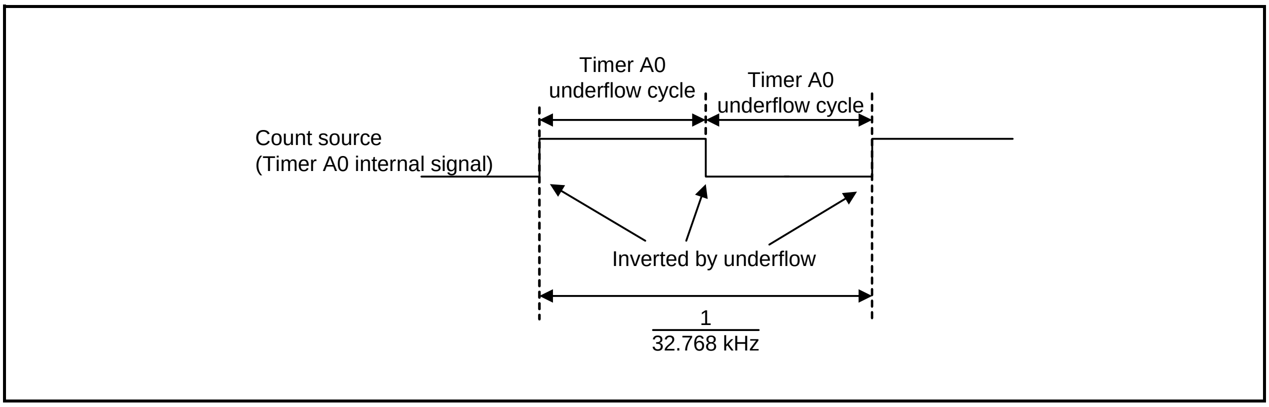


Figure 26.3 Count Source When Timer A0 Underflow Selected

26.3.3 CEC Input/Output

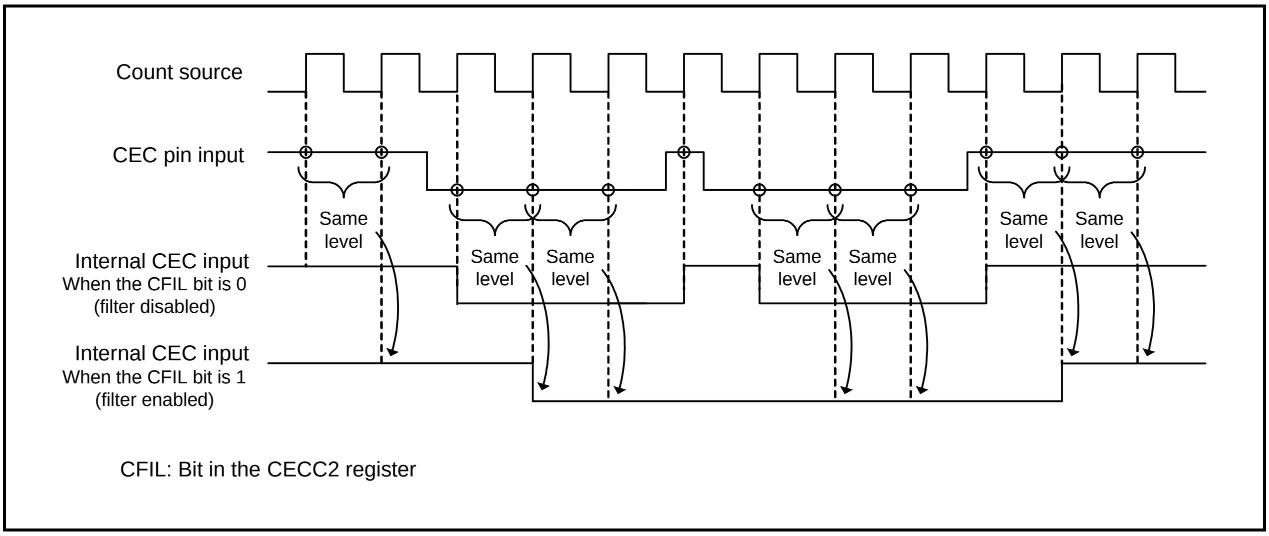
The CEC input and output share pins with the I/O port and $\overline{\text{NMI}}$ input. To use CEC input and output, set bits as follows:

- Set the PM24 bit in the PM2 register to 0 ($\overline{\text{NMI}}$ interrupt disabled)
- Set the PCR4 bit in the PCR register to 1 (CEC output enabled)
- Set the PD8_5 bit in the PD8 register to 0 (input mode)

Also, the CEC input has a digital filter. (refer to 26.3.4 “Digital Filter”).

26.3.4 Digital Filter

Input to the CEC pin goes into the internal circuit in synchronization with the count source. If the same level signal is input to the CEC pin twice in a row that level is transferred to the internal circuit, when the CFIL bit in the CECC2 register is 1 (digital filter enable). Figure 26.4 shows Digital Filter.



CFIL: Bit in the CECC2 register

Figure 26.4 Digital Filter

26.3.5 Reception

26.3.5.1 Start Bit Detection

The detect timing of the start bit and data bit is selected by setting the CRRNG bit in the CEC2 register. Select the start bit acceptable range by setting the CSTRRNG bit in the CECC2 register. Figure 26.5 shows Start Bit Acceptable Range.

When the start bit within the acceptable range is detected, the CRSTFLG bit in the CECFLG register becomes 1 (start bit detected).

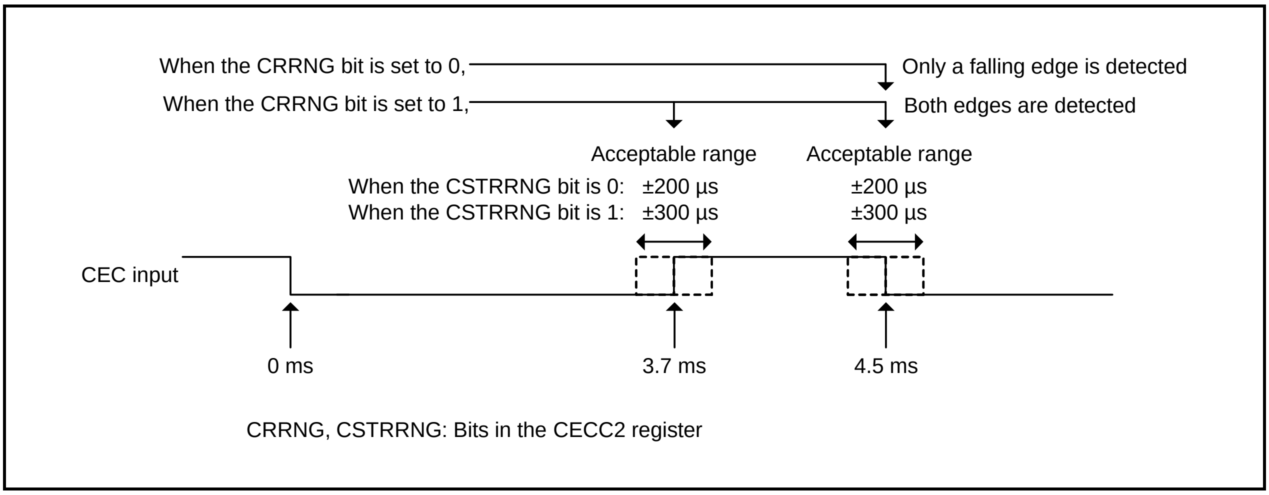
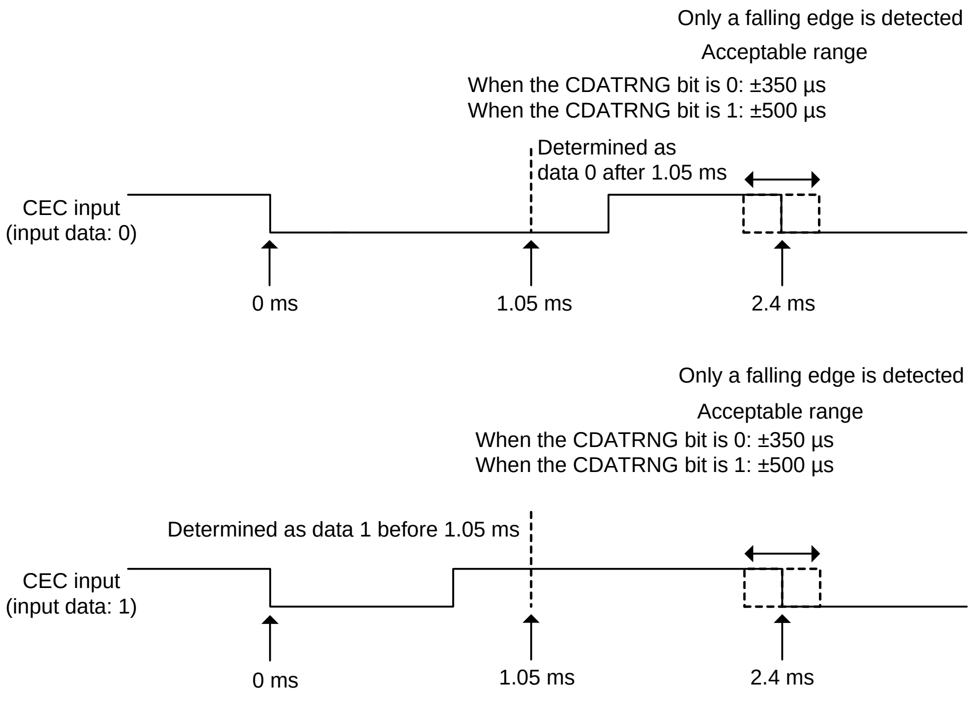

When the CRRNG bit is set to 0,
Only a falling edge is detected
When the CRRNG bit is set to 1,
Both edges are detected
Acceptable range
Acceptable range
When the CSTRRNG bit is 0: ±200 µs
±200 µs
When the CSTRRNG bit is 1: ±300 µs
±300 µs
CEC input
0 ms
3.7 ms
4.5 ms
CRRNG, CSTRRNG: Bits in the CECC2 register

Figure 26.5 Start Bit Acceptable Range

26.3.5.2 Data Bit Detection

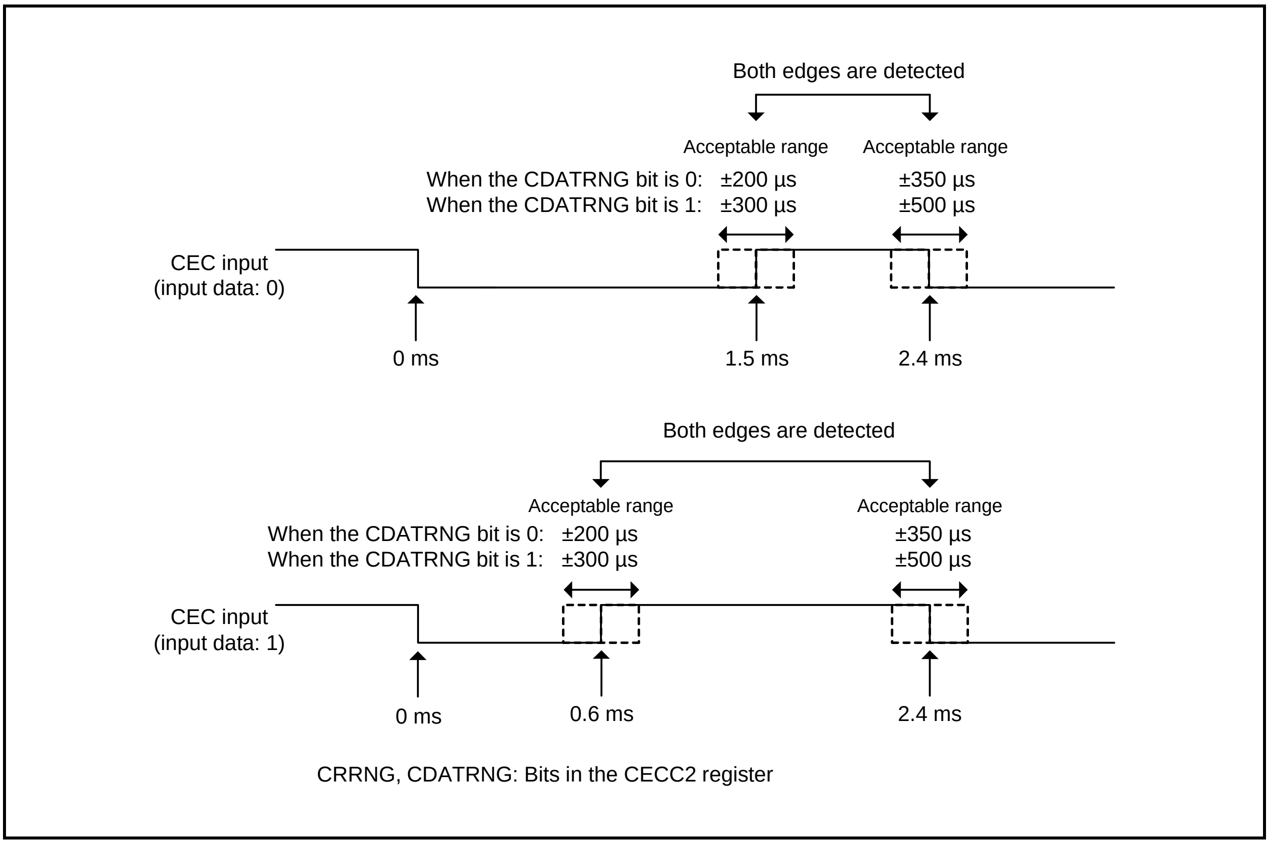
The detect timing of the start bit and data bit (other than the start bit) is selected by setting the CRRNG bit in the CECC2 register. Select the data bit acceptable range by setting the CDATRNG bit in the CECC2 register. Figure 26.6 shows Data Bit Acceptable Range (CRRNG Bit = 0).

When the CRRNG bit is 0 (detects falling edge acceptable range), the input data is determined as data 1 if the rising edge is detected before 1.05 ms and the input data is determined as data 0 if the rising edge is detected after 1.05 ms.


Only a falling edge is detected
Acceptable range
When the CDATRNG bit is 0: ±350 µs
When the CDATRNG bit is 1: ±500 µs
Determined as
data 0 after 1.05 ms
CEC input
(input data: 0)
0 ms
1.05 ms
2.4 ms
Only a falling edge is detected
Acceptable range
When the CDATRNG bit is 0: ±350 µs
When the CDATRNG bit is 1: ±500 µs
Determined as data 1 before 1.05 ms
CEC input
(input data: 1)
0 ms
1.05 ms
2.4 ms

CRRNG and CDATRNG: Bits in the CECC2 register.

Figure 26.6 Data Bit Acceptable Range (CRRNG Bit = 0)



CRRNG, CDATRNG: Bits in the CECC2 register

Figure 26.7 Data Bit Acceptable Range (CRRNG Bit = 1)

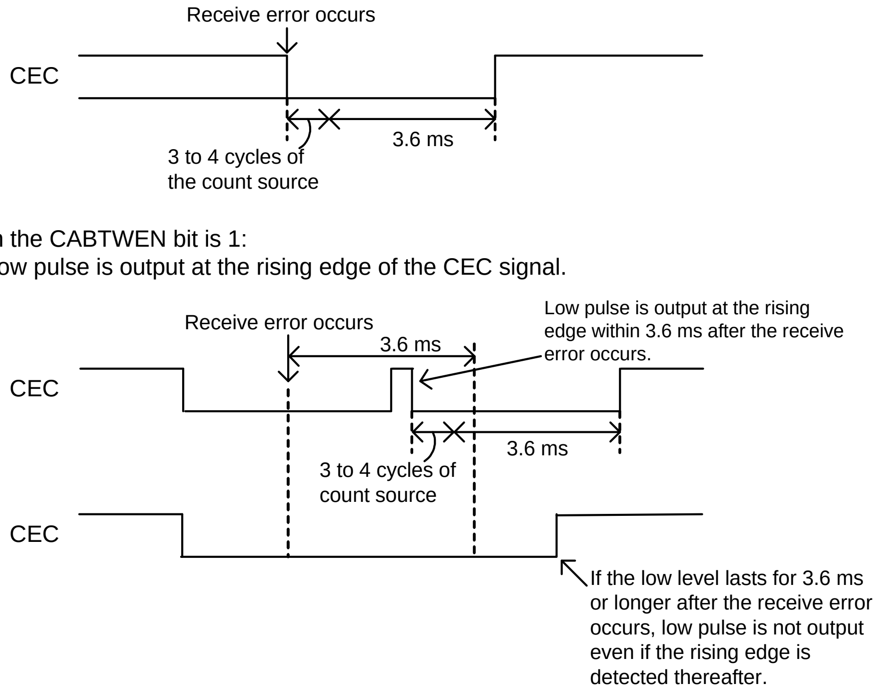
26.3.5.3 Error Determination

If the data bit is out of the acceptable range, a receive error occurs. The operations when the receive error occurs are as follows:

- The CRERRFLG bit in the CECFLG register becomes 1 (receive error)
- A 3.6 ms low-level pulse is output when the CABTEN bit in the CECC4 register is 1 (low pulse output enabled in receive error). However, this pulse is not output if an error occurs in the start bit.

Low pulse output timing can be selected by setting the CABTWEN bit in the CECC4 register when the CABTEN bit is 1 (low pulse output enabled in receive error).

When the CABTWEN bit is 0:
Low pulse is immediately output regardless of the CEC signal state.



Receive error occurs
CEC
3.6 ms
3 to 4 cycles of
the count source

When the CABTWEN bit is 1:
Low pulse is output at the rising edge of the CEC signal.

Receive error occurs
3.6 ms
Low pulse is output at the rising edge within 3.6 ms after the receive error occurs.
CEC
3.6 ms
3 to 4 cycles of count source
CEC
If the low level lasts for 3.6 ms or longer after the receive error occurs, low pulse is not output even if the rising edge is detected thereafter.

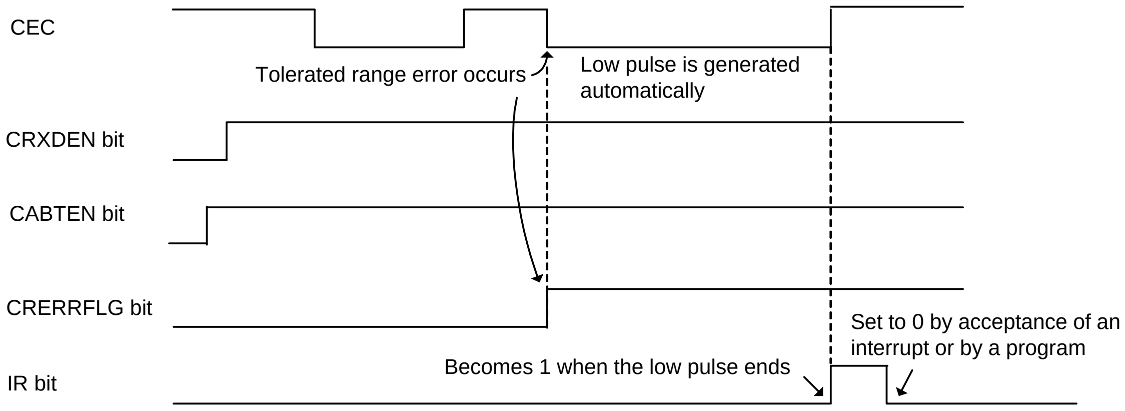
The above diagram applies under the following condition.
- The CABTEN bit in the CECC4 register is 1 (low pulse output enabled in receive error).

CABTWEN: Bit in the CECC4 register

Figure 26.8 Low Pulse Output in Receive Error

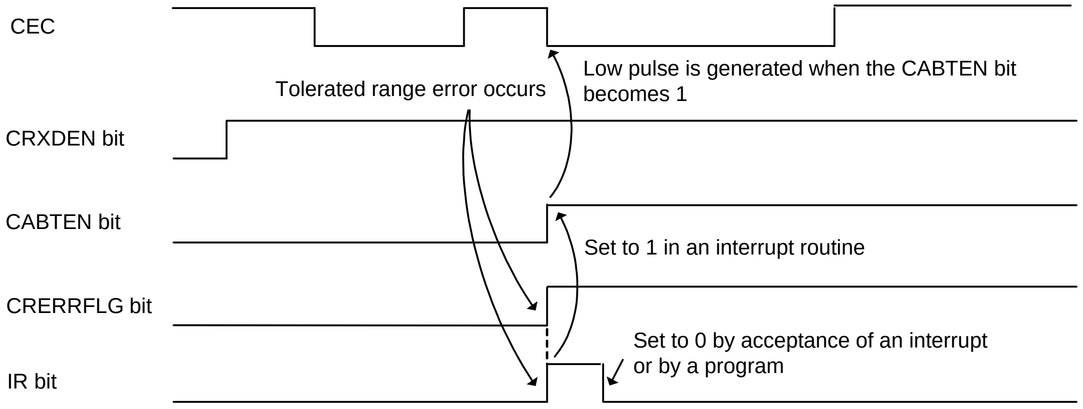
(1) Low pulse is output automatically when a reception error occurs

While the CRXDEN bit is 0 (receive disabled), by setting the CABTEN bit to 1 (error low pulse output enabled) followed by CRXDEN bit to 1 (receive enabled), an error low pulse is output for a receive error automatically.


CEC
Tolerated range error occurs
Low pulse is generated automatically
CRXDEN bit
CABTEN bit
CRERRFLG bit
Set to 0 by acceptance of an interrupt or by a program
Becomes 1 when the low pulse ends
IR bit

(2) Low pulse is output by a program when a reception error occurs

After setting the CRXDEN bit to 1 (receive enabled) and then setting the CABTEN bit to 1 if the receiving data bit exceeds the tolerated range, a low pulse is output.


CEC
Tolerated range error occurs
Low pulse is generated when the CABTEN bit becomes 1
CRXDEN bit
CABTEN bit
Set to 1 in an interrupt routine
CRERRFLG bit
Set to 0 by acceptance of an interrupt or by a program
IR bit

CRXDEN: Bit in the CECC3 register
CABTEN: Bit in the CECC4 register
CRERRFLG: Bit in the CECFLG register
IR: Bit in the CEC2IC register

The above assumes the following:

- The CFIL bit in the CECC2 register is 0 (filter disabled).
- The CRISEL2 bit in the CISEL register is 1 (receive error interrupt disabled).
- The CRISELS bit in the CISEL register is 0 (reception start bit interrupt disabled).

Figure 26.9 Low Pulse Output Timing in Receive Error

26.3.5.4 ACK Bit Output

The output value of the tenth bit (ACK bit) can be selected.

When the CRACK bit in the CECC2 register is 0 (inserted by program), the value of the CCRBAO bit in the CCRB2 register is output as ACK data.

When the CRACK bit is 1 (inserted by hardware), ACK is output when the received Destination address matches the address selected by the CRADRI1 or CRADRI2 register (own address). Table 26.8 lists ACK Output.

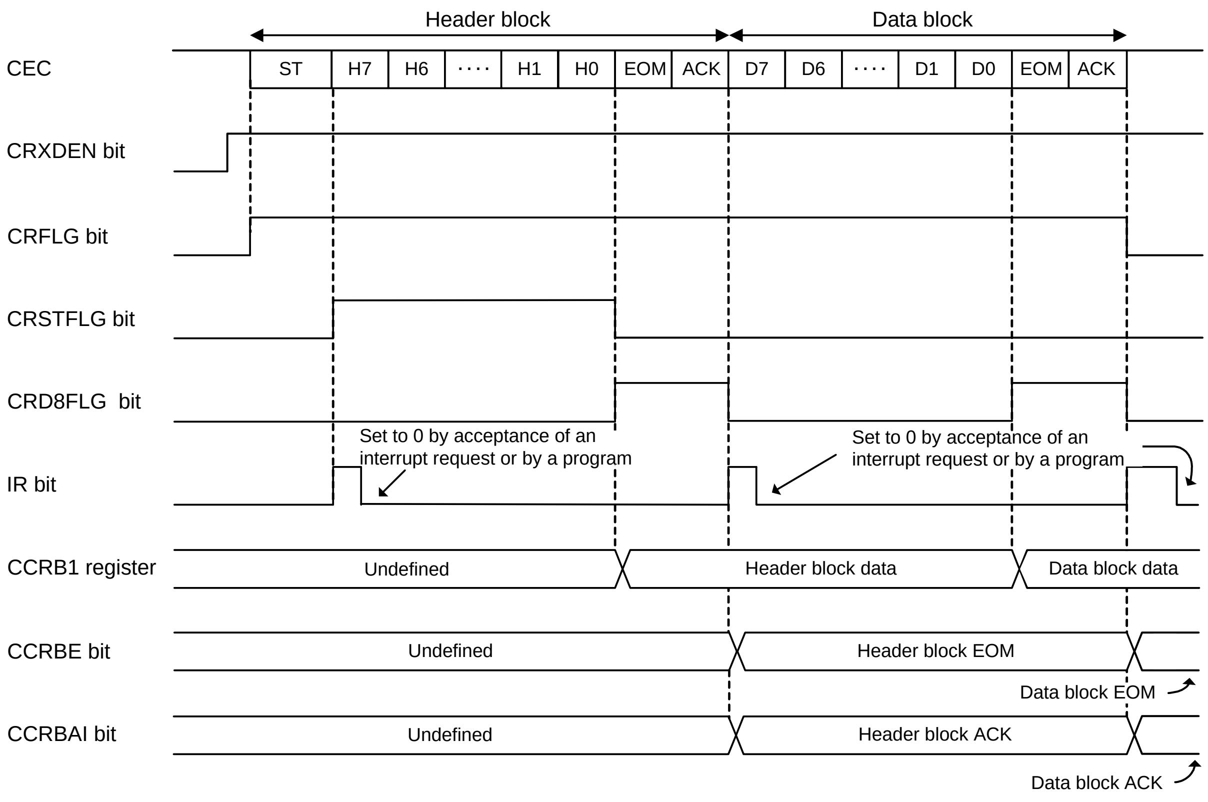
Table 26.8 ACK Output

CRACK Bit	CCRBAO Bit	Destination Address		ACK Output
		Received destination address	Address selected by the CRADRI1 or CRADRI2 register (own address)	
0	0	-	-	ACK
	1	-	-	NACK
1	-	Direct (0000b to 1110b)	Matches received Destination address	ACK
			Not match received Destination address	NACK
		Broadcast (1111b)	1111b (matches received Destination address)	ACK
			0000b to 1110b	NACK

26.3.5.5 Reception Examples

Figure 26.10 shows a Reception Example and Figure 26.11 shows a Reception Example (Change from Error Low Pulse Output Disabled to Enabled When an Error Occurs).

When a receive error occurs, the CRERRFLG bit in the CECFLG register becomes 1 (receive error). If a reception ends due to the error during reception, set the CRXDEN bit in the CECC3 register to 0 (receive disabled). When the CRXDEN bit is set to 0, the CRERRFLG bit becomes 0. To restart reception, set the CRXDEN bit to 0 (reception disabled), and then set the CRXDEN bit to 1 (reception enabled) after waiting for one or more cycles of the count source.

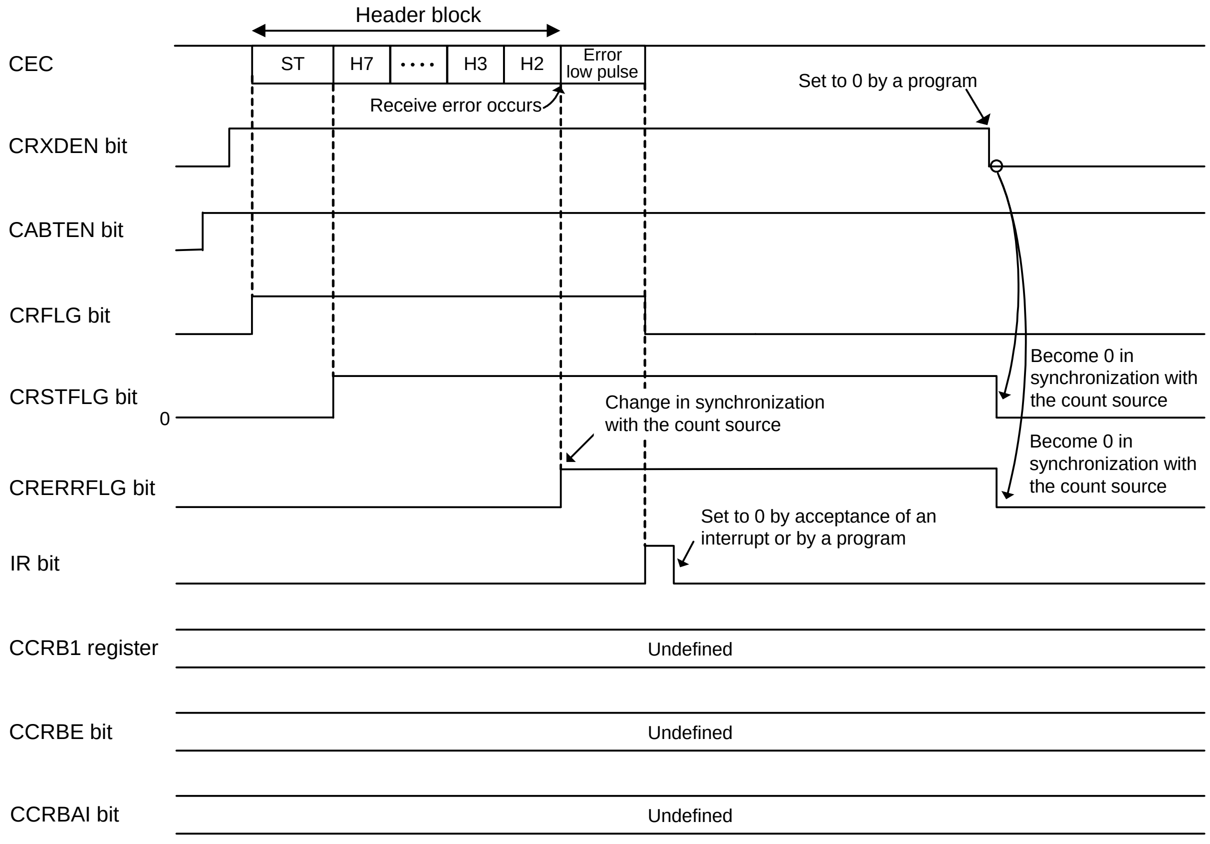


CRXDEN bit: Bit in the CECC3 register
Bits CRFLG, CRD8FLG, and CRSTFLG: Bits in the CECFLG register
IR bit: Bit in the CEC2IC register
Bits CCRBE and CCRBAI: Bits in the CCRB2 register

The above diagram applies under the following conditions.

- The CFIL bit in the CICC2 register is set to 0 (filter disabled).
- The CRISEL0 bit in the CISEL register is set to 0 (8th bit receive interrupt disabled).
- The CRISEL1 bit in the CISEL register is set to 1 (10th bit receive interrupt enabled).
- The CRISELS bit in the CISEL register is set to 1 (reception start bit interrupt enabled).

Figure 26.10 Reception Example



CRXDEN bit: Bit in the CECC3 register
CABTEN bit: Bit in the CECC4 register
Bits CRFLG, CRERRFLG, and CRSTFLG: Bits in the CECFLG register
IR bit: Bit in the CEC2IC register
Bits CCRBE and CCRBAI: Bits in the CCRB2 register

The above diagram applies under the following conditions.

- The CFIL bit in the CECC2 register is 0 (filter disabled)
- The CRISEL2 bit in the CISEL register is 1 (receive error interrupt enabled)
- The CRISELS bit in the CISEL register is 0 (reception start bit interrupt disabled)

Figure 26.11 Reception Example (Change from Error Low Pulse Output Disabled to Enabled When an Error Occurs)

26.3.6 Transmission

26.3.6.1 Transmit Signal Timing Select

Rising or falling timing of the transmit signal can be selected.
The rising timing of the transmit signal is selected by bits CRISE2 to CRISE0 in the CECC4 register.
Figure 26.12 shows Rising Timing of Transmit Signal.

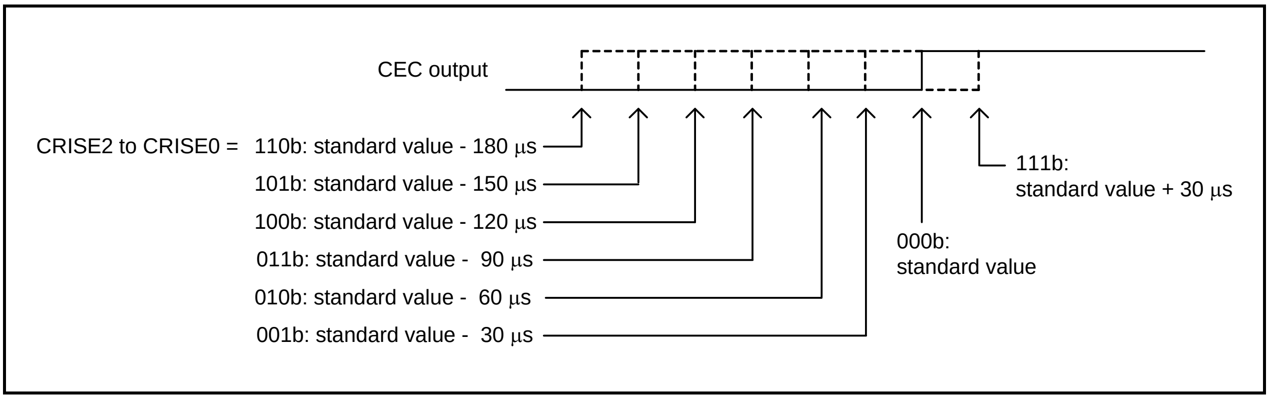

CEC output
CRISE2 to CRISE0 =
110b: standard value - 180 µs
101b: standard value - 150 µs
100b: standard value - 120 µs
011b: standard value - 90 µs
010b: standard value - 60 µs
001b: standard value - 30 µs
000b:
standard value
111b:
standard value + 30 µs

Figure 26.12 Rising Timing of Transmit Signal

The falling timing of the transmit signal is selected by bits CFALL1 to CFALL0 in the CECC4 register.
Figure 26.13 shows Falling Timing of Transmit Signal.

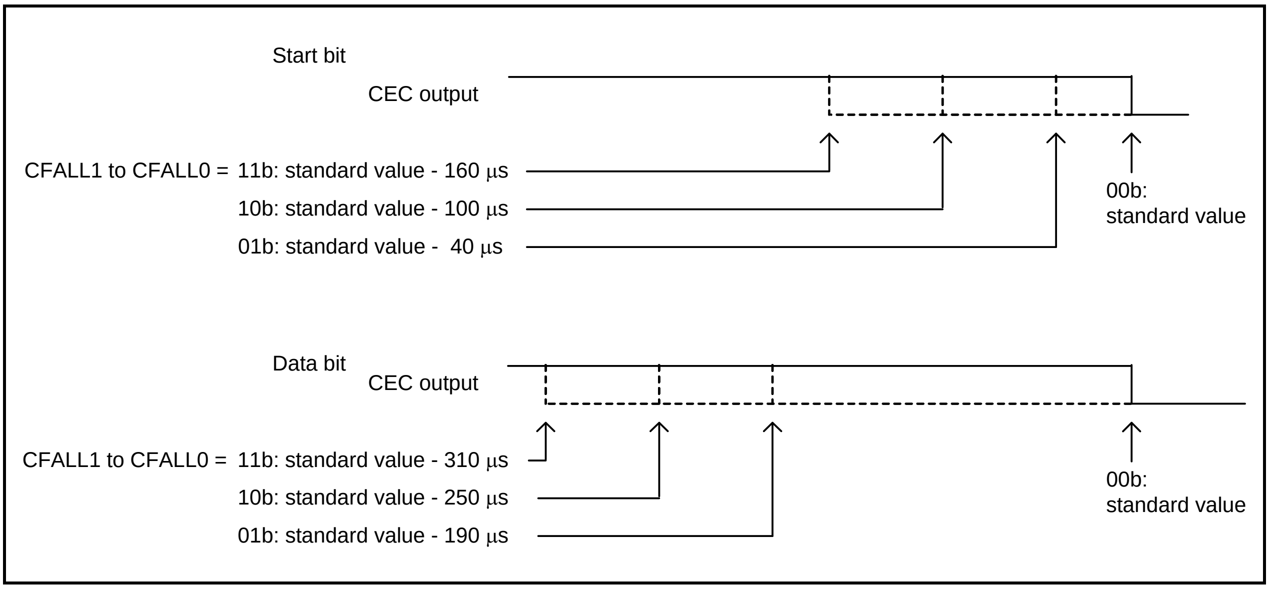

Start bit
CEC output
CFALL1 to CFALL0 =
11b: standard value - 160 µs
10b: standard value - 100 µs
01b: standard value - 40 µs
00b:
standard value
Data bit
CEC output
CFALL1 to CFALL0 =
11b: standard value - 310 µs
10b: standard value - 250 µs
01b: standard value - 190 µs
00b:
standard value

Figure 26.13 Falling Timing of Transmit Signal

26.3.6.2 Arbitration Lost Detection

When data is transmitted, an arbitration lost is detected in the following cases:

- The CEC output changes from Hi-Z to low by the external source.
- When changing the CEC pin from low output to Hi-Z, the pin level remains low even though it is outside the tolerated range.

A range for detecting the arbitration lost is selected by the CTABTS bit in the CECC2 register. Figure 26.14 shows Arbitration Lost Detectable Range.

When the arbitration lost is detected, the CTABTFLG bit in the CECFLG register becomes 1 (arbitration lost detected).

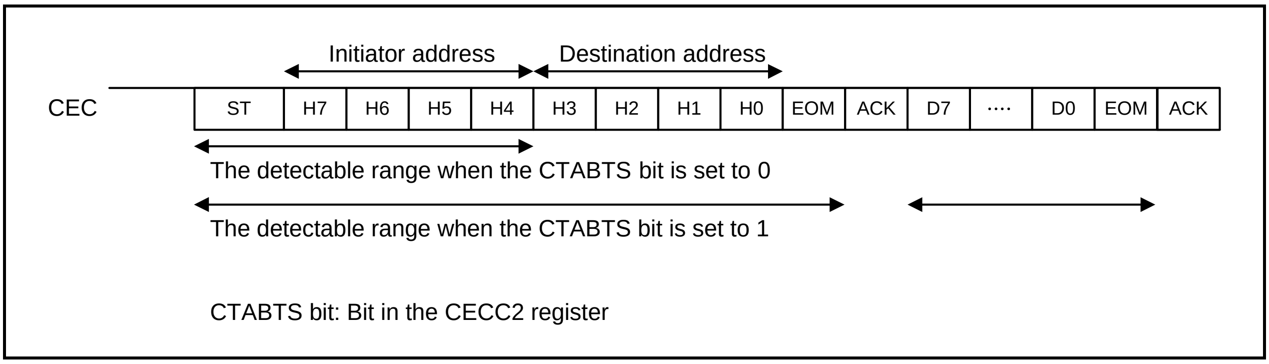
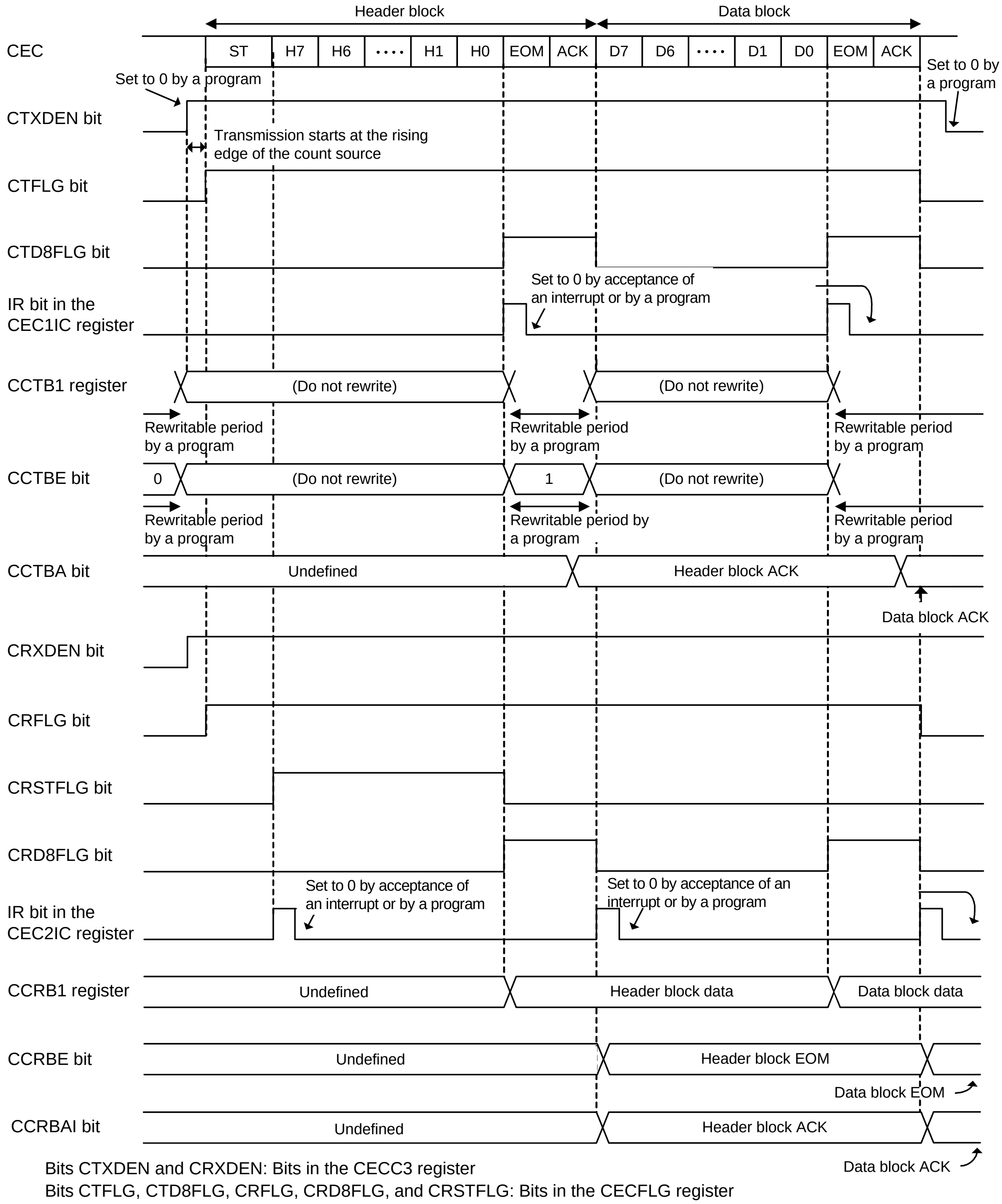

Initiator address
Destination address
CEC
ST
H7
H6
H5
H4
H3
H2
H1
H0
EOM
ACK
D7
····
D0
EOM
ACK
The detectable range when the CTABTS bit is set to 0
The detectable range when the CTABTS bit is set to 1
CTABTS bit: Bit in the CECC2 register

Figure 26.14 Arbitration Lost Detectable Range

26.3.6.3 Transmission Example

Figure 26.15 shows a Transmission Example, Figure 26.16 shows a Transmission Example (When NACK Received) and Figure 26.17 shows a Transmission Example (When an Arbitration Lost Detected).

Set the CTXDEN bit in the CECC3 register to 0 (transmit disabled) after the transmission. To continue the transmission, set the CTXDEN bit to 0 (transmit disabled) after sending one frame (one header block and one or more data blocks), and wait for one or more cycles of the count source before setting the CTXDEN bit to 1 (transmit enabled).

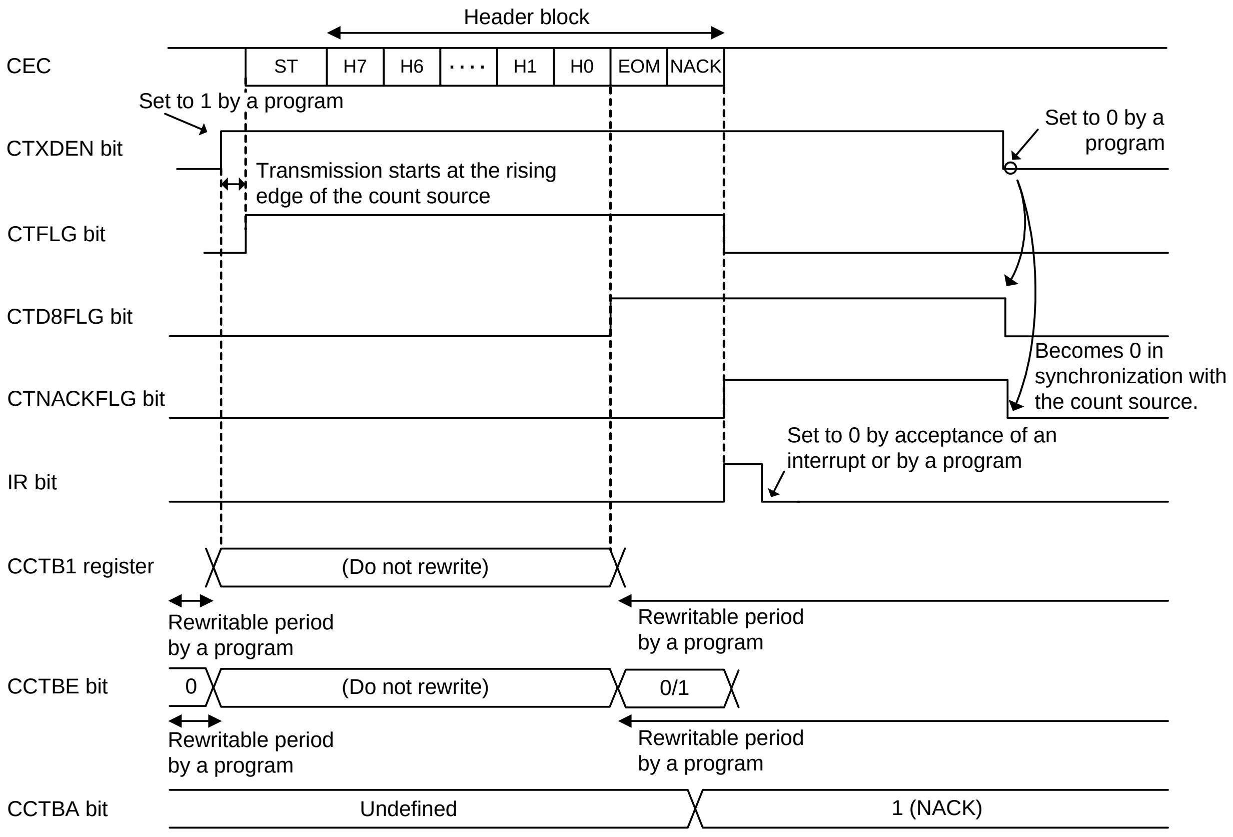


Bits CTXDEN and CRXDEN: Bits in the CECC3 register
Bits CTFLG, CTD8FLG, CRFLG, CRD8FLG, and CRSTFLG: Bits in the CECFLG register
Bits CCTBE and CCTBA: Bits in the CCTB2 register
Bits CCRBE and CCRBAI: Bits in the CCRB2 register

The above diagram applies under the following conditions:

- The CTISEL0 bit in the CISEL register is set to 1 (8th bit transmit interrupt enabled).
- The CTISEL1 bit in the CISEL register is set to 0 (10th bit transmit interrupt disabled).
- The CEOMI bit in the CECC3 register is set to 0 (EOM enabled).
- The CFIL bit in the CECC2 register is set to 0 (filter disabled).
- The CRISEL0 bit in the CISEL register is set to 0 (8th bit receive interrupt disabled).
- The CRISEL1 bit in the CISEL register is set to 1 (10th bit receive interrupt enabled).
- The CRISELS bit in the CISEL register is set to 1 (reception start bit interrupt enabled).

Figure 26.15 Transmission Example

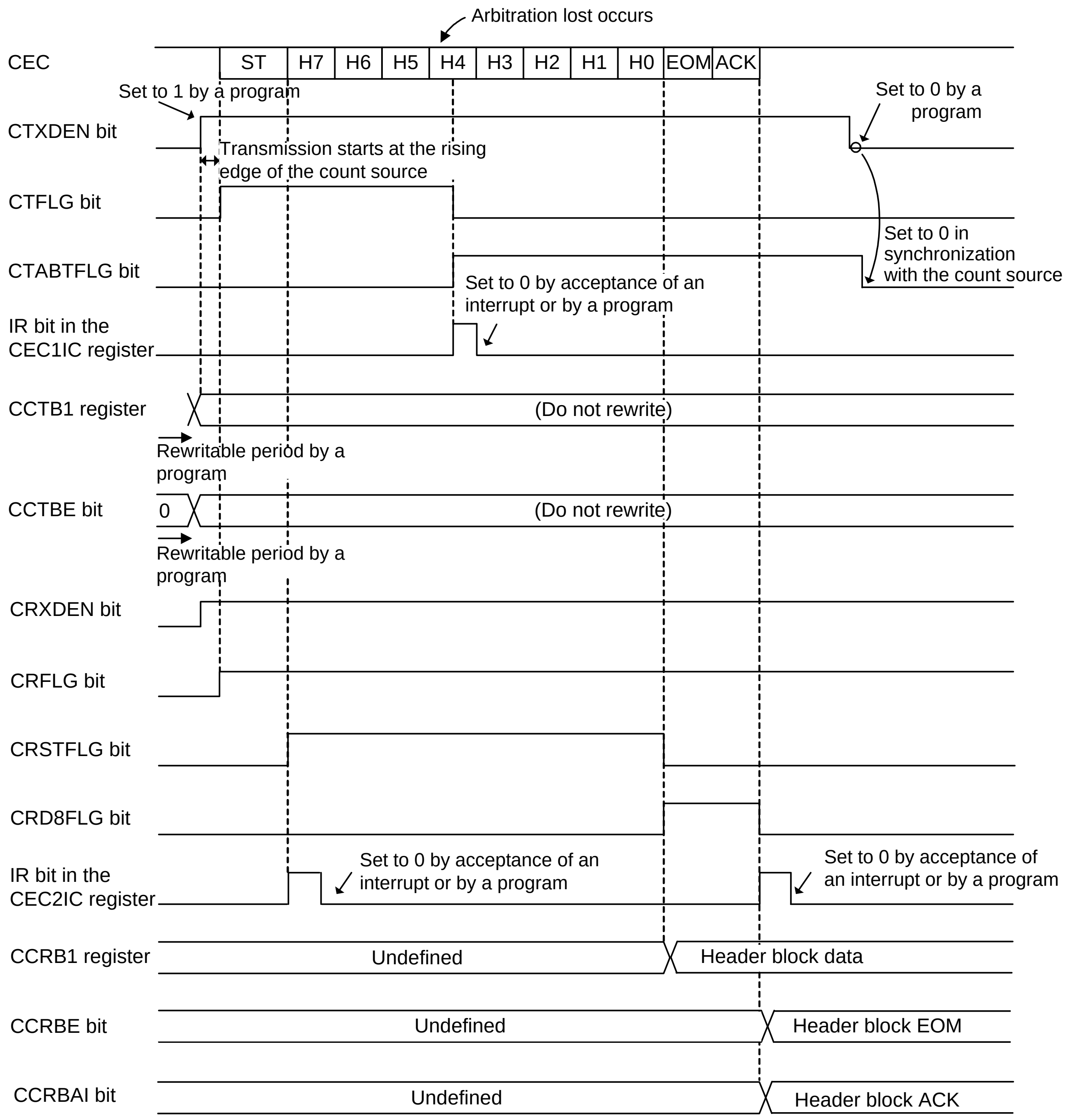

Header block
CEC
ST
H7
H6
····
H1
H0
EOM
NACK
Set to 1 by a program
CTXDEN bit
Transmission starts at the rising edge of the count source
Set to 0 by a program
CTFLG bit
CTD8FLG bit
Becomes 0 in synchronization with the count source.
CTNACKFLG bit
Set to 0 by acceptance of an interrupt or by a program
IR bit
CCTB1 register
(Do not rewrite)
Rewritable period by a program
Rewritable period by a program
CCTBE bit
0
(Do not rewrite)
0/1
Rewritable period by a program
Rewritable period by a program
CCTBA bit
Undefined
1 (NACK)

CTXDEN bit: Bit in the CECC3 register
Bits CTFLG, CTD8FLG, and CTNACKFLG: Bits in the CECFLG register
IR bit: Bit in the CEC1IC register
Bits CCTBE and CCTBA: Bits in the CCTB2 register

The above diagram applies under the following conditions.

- The CTISEL2 bit in the CISEL register is set to 1 (transmit error interrupt enabled).
- The CTNACK bit in the CECC2 register is set to 1, and the CTACKEN bit is 1 (transmission stops with NACK).

Figure 26.16 Transmission Example (When NACK Received)


Arbitration lost occurs
CEC
ST H7 H6 H5 H4 H3 H2 H1 H0 EOM ACK
Set to 1 by a program
CTXDEN bit
Set to 0 by a program
Transmission starts at the rising edge of the count source
CTFLG bit
CTABTFLG bit
Set to 0 in synchronization with the count source
Set to 0 by acceptance of an interrupt or by a program
IR bit in the CEC1IC register
CCTB1 register
(Do not rewrite)
Rewritable period by a program
CCTBE bit
0
(Do not rewrite)
Rewritable period by a program
CRXDEN bit
CRFLG bit
CRSTFLG bit
CRD8FLG bit
IR bit in the CEC2IC register
Set to 0 by acceptance of an interrupt or by a program
Set to 0 by acceptance of an interrupt or by a program
CCRB1 register
Undefined
Header block data
CCRBE bit
Undefined
Header block EOM
CCRBAI bit
Undefined
Header block ACK

Bits CTXDEN and CRXDEN: Bits in the CECC3 register
Bits CTFLG, CTABTFLG, CRFLG, CRD8FLG, and CRSTFLG: Bits in the CECFLG register
Bits CCRBE and CCRBAI: Bits in the CCRB2 register
CCTBE bit: Bit in the CCTB2 register

The above diagram applies under the following conditions:

- The CTISEL2 bit in the CISEL register is set to 1 (transmit error interrupt enabled).
- The CFIL bit in the CECC2 register is set to 0 (filter enabled).
- The CRISEL0 bit in the CISEL register is set to 0 (8th bit receive interrupt disabled).
- The CRISEL1 bit in the CISEL register is set to 1 (10th bit receive interrupt enabled).
- The CRISELS bit in the CISEL register is set to 1 (reception start bit interrupt enabled).

Figure 26.17 Transmission Example (When an Arbitration Lost Detected)

26.4 Interrupts

The CEC function has CEC1 interrupt and CEC2 interrupt. Table 26.9 and Table 26.10 list CEC Interrupt Sources. These sources generate a CEC1 interrupt or CEC2 interrupt request. When the CRISELM bit in the CISEL register is 1, the eighth/tenth bit receive interrupt request is generated if the received Destination address is either one of the following case:

- Matches the address selected by the CRADRI1 or CRADRI2 register.
- Broadcast (1111b)

Figure 26.18 shows CEC Function Interrupt.

Table 26.9 CEC1 Interrupt Sources

Type	Source	Interrupt Request Timing	Interrupt Enable Bit
Transmit interrupt	Eighth bit transmitted	When the CTD8FLG bit changes from 0 to 1	CTISEL0
	Tenth bit transmitted	When the CTD8FLG bit changes from 1 to 0	CTISEL1
Transmit error interrupt	Arbitration lost	When the CTABTFLG bit changes from 0 to 1	CTISEL2
	NACK received (Direct) ACK received (Broadcast)	When the CTNACKFLG bit changes from 0 to 1	

CTD8FLG, CTABTFLG, CTNACKFLG: Bits in the CECFLG register
CTISEL0, CTISEL1, CTISEL2: Bits in the CISEL register

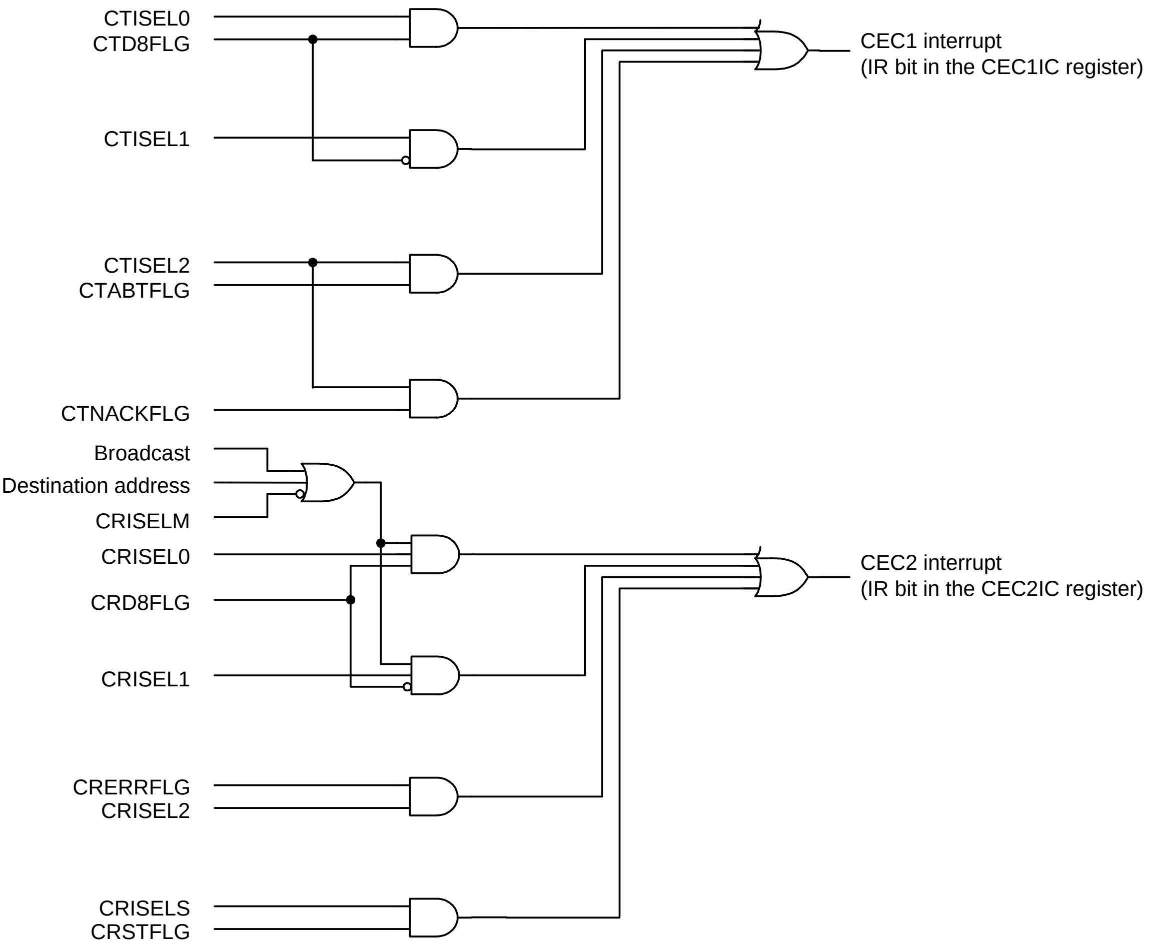
Table 26.10 CEC2 Interrupt Sources

Type	Source	Interrupt Request Timing	Interrupt Enable Bit
Receive interrupt	Eighth bit received	When the CRD8FLG bit changes from 0 to 1 (1)	CRISEL0
	Tenth bit received	When the CRD8FLG bit changes from 1 to 0 (1)	CRISEL1
	Start bit detected	When the CRSTFLG bit changes from 0 to 1	CRISELS
Receive error interrupt	Nonstandard signal received	When the CRERRFLG bit changes from 0 to 1	CRISEL2

CRD8FLG, CRSTFLG, CRERRFLG: Bits in the CECFLG register
CRISEL0, CRISEL1, CRISELS, CRISEL2: Bits in the CISEL register

Note:

1. The CRISELM bit in the CISEL register affects the interrupt.



CRISELS, CTISEL2, CTISEL1, CTISEL0, CRISELM, CRISEL2, CRISEL1, CRISEL0: Bits in the CISEL register
CRSTFLG, CTD8FLG, CRD8FLG, CTNACKFLG, CTABTFLG, CRERRFLG: Bits in the CECFLG register

Figure 26.18 CEC Function Interrupt

For the interrupt request timing, refer to the operation examples.
For interrupt control, refer to 14.7 “Interrupt Control”. Table 26.11 lists the CEC Function Interrupt-Associated Registers.

Table 26.11 CEC Function Interrupt-Associated Registers

Address	Register	Symbol	Reset Value
006Bh	CEC1 Interrupt Control Register	CEC1IC	XXXX X000b
006Ch	CEC2 Interrupt Control Register	CEC2IC	XXXX X000b
0205h	Interrupt Source Select Register 3	IFSR3A	00h

The CEC function shares the interrupt vectors and the interrupt control registers with other peripheral functions. To use CEC1 interrupt, set the IFSR33 bit in the IFSR3A register to 1 (CEC1). To use CEC2 interrupt, set the IFSR34 bit in the IFSR3A register to 1 (CEC2).

26.5 Notes on CEC

26.5.1 Registers and Bit Operation

The registers and bits of the CEC function are synchronized with the count source. Therefore, the internal circuit starts to operate from the next count source timing, while the values of the register are changed immediately after rewriting the register.
When rewriting the same bit successively or reading the bit changed under the influence of another bit, wait for one or more cycles of the count source.

Example: when rewriting the same bit successively
(1) Change the bit to 0.
(2) Wait for one or more cycles of the count source.
(3) Change the same bit to 1.

Example: when reading the bit rewritten under the influence of another bit
(after reception is disabled, to ensure that the CRERRFLG bit in the CECFLG register becomes 0 (no reception error detected)).
(1) Set the CRXDEN bit in the CECC3 register to 0 (reception disabled)
(2) Wait for one or more cycles of the count source.
(3) Read the CRERRFLG bit in the CECFLG register.

26.5.2 VIH of the CEC pin

VIH of the CEC pin does not meet the CEC standard value. Apply VIH to the CEC pin or use the CEC external circuit shown in Figure 26.19 “CEC External Circuit” to change the CEC pin input voltage to VIH of the CEC pin or above.

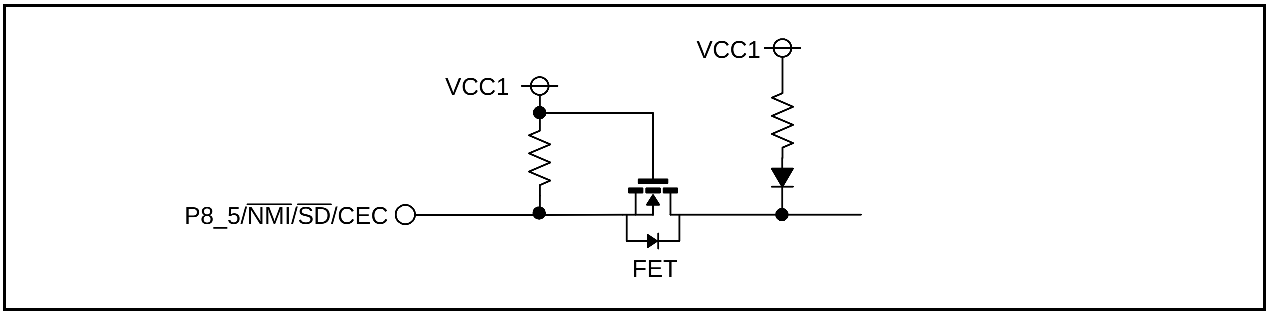


Figure 26.19 CEC External Circuit

27. A/D Converter

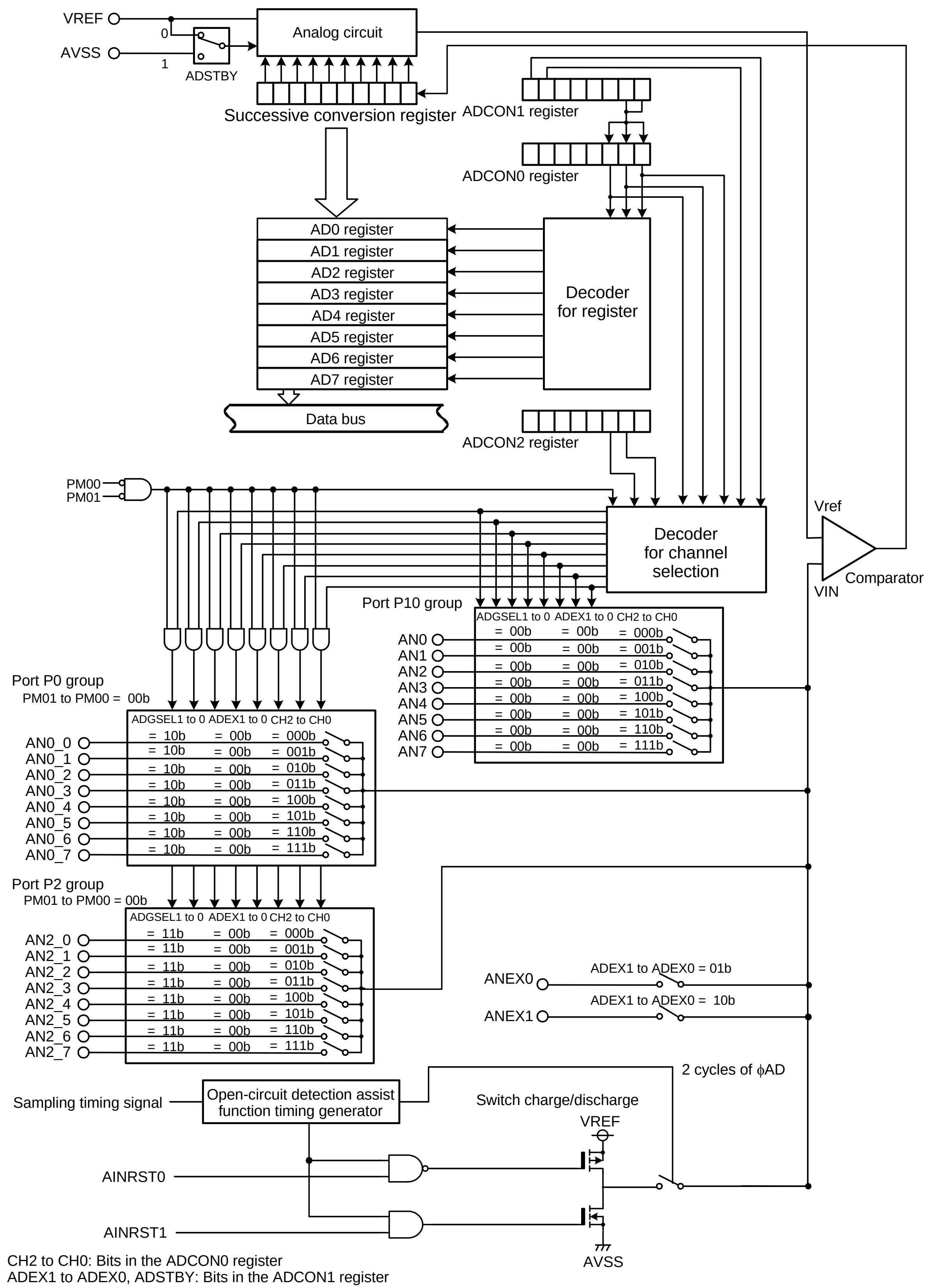
27.1 Introduction

The A/D converter consists of one 10-bit successive approximation A/D converter.

Table 27.1 lists the A/D Converter Specifications and Figure 27.1 shows an A/D Converter Block Diagram.

Table 27.1 A/D Converter Specifications

Item	Specification
A/D conversion method	Successive approximation
Analog input voltage	0 V to AVCC (VCC1)
Operating clock ϕAD	f1, f1 divided by 2, f1 divided by 3, f1 divided by 4, f1 divided by 6, f1 divided by 12, fOCO40M divided by 2, fOCO40M divided by 3, fOCO40M divided by 4, fOCO40M divided by 6, or fOCO40M divided by 12
Resolution	10 bits
Integral nonlinearity error	AVCC = VREF = 5 V AN0 to AN7, AN0_0 to AN0_7, or AN2_0 to AN2_7 input: ±3 LSB ANEX0 or ANEX1 input: ±3 LSB AVCC = VREF = 3.0 V AN0 to AN7, AN0_0 to AN0_7, or AN2_0 to AN2_7 input: ±3 LSB ANEX0 or ANEX1 input: ±3 LSB
Operation modes	One-shot mode, repeat mode, single sweep mode, repeat sweep mode 0, repeat sweep mode 1
Analog input pins	8 pins (AN0 to AN7) + 2 pins (ANEX0 and ANEX1) + 8 pins (AN0_0 to AN0_7) + 8 pins (AN2_0 to AN2_7)
A/D conversion start conditions	• Software trigger The ADST bit in the ADCON0 register is set to 1 (A/D conversion start). • External trigger (retrigger is enabled) Input to the $\overline{\text{ADTRG}}$ pin changes from high to low after the ADST bit is set to 1 (A/D conversion start).
Conversion rate per pin	Minimum 43 ϕAD cycles



CH2 to CH0: Bits in the ADCON0 register
ADEX1 to ADEX0, ADSTBY: Bits in the ADCON1 register
ADGSEL1 to ADGSEL0: Bits in the ADCON2 register
PM01 to PM00: Bits in the PM0 register

Figure 27.1 A/D Converter Block Diagram

Table 27.2 I/O Ports

Pin Name	I/O	Function
AN0 to AN7	Input	Analog input
ANEX0, ANEX1	Input	Analog input
AN0_0 to AN0_7	Input	Analog input
AN2_0 to AN2_7	Input	Analog input
$\overline{\text{ADTRG}}$	Input	Trigger input

Note:

1. Set the direction bit of the ports sharing a port to 0 (input mode).

27.2 Registers

Table 27.3 lists registers associated with A/D converter. Refer to 8.2.6 “Peripheral Clock Stop Register 1 (PCLKSTP1)” for the explanation of the PCLKSTP1 register. Set the CKS3 bit in the ADCON2 register before setting other registers associated with A/D converter excluding the PCR register. However, bits in the ADCON2 register and the CKS3 bit can be set simultaneously. After changing the CKS3 bit, set the registers in the same way again.

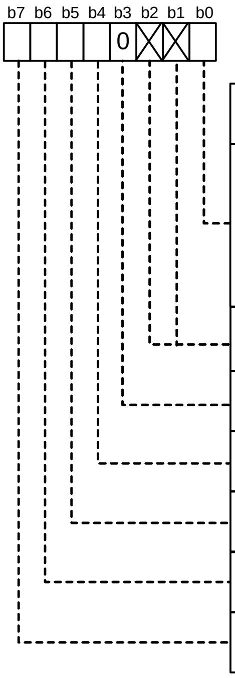
The PCR register can be set before setting the CKS3 bit. After changing the CKS3 bit, the PCR register does not need to be set again.

Table 27.3 Registers

Address	Register	Symbol	Reset Value
0016h	Peripheral Clock Stop Register 1	PCLKSTP1	0XXX XX00b
0366h	Port Control Register	PCR	0000 0XX0b
03A2h	Open-Circuit Detection Assist Function Register	AINRST	XX00 XXXXb
03C0h	A/D Register 0	AD0	XXXX XXXXb
03C1h			0000 00XXb
03C2h	A/D Register 1	AD1	XXXX XXXXb
03C3h			0000 00XXb
03C4h	A/D Register 2	AD2	XXXX XXXXb
03C5h			0000 00XXb
03C6h	A/D Register 3	AD3	XXXX XXXXb
03C7h			0000 00XXb
03C8h	A/D Register 4	AD4	XXXX XXXXb
03C9h			0000 00XXb
03CAh	A/D Register 5	AD5	XXXX XXXXb
03CBh			0000 00XXb
03CCh	A/D Register 6	AD6	XXXX XXXXb
03CDh			0000 00XXb
03CEh	A/D Register 7	AD7	XXXX XXXXb
03CFh			0000 00XXb
03D4h	A/D Control Register 2	ADCON2	0000 X00Xb
03D6h	A/D Control Register 0	ADCON0	0000 0XXXb
03D7h	A/D Control Register 1	ADCON1	0000 X000b

27.2.1 Port Control Register (PCR)

Port Control Register



Symbol	Address	Reset Value
PCR	0366h	0000 0XX0b

Bit Symbol	Bit Name	Function	RW
PCR0	Port P1 control bit	Operation performed when the P1 register is read 0 : When the port is set to input, the input levels of pins P1_0 to P1_7 are read. When set to output, the port latch is read. 1 : The port latch is read regardless of whether the port is set to input or output.	RW
— (b2-b1)	No register bits. If necessary, set to 0. The read value is undefined.		—
— (b3)	Reserved bit	Set to 0.	RW
PCR4	CEC output enable bit	0 : CEC output disabled 1 : CEC output enabled	RW
PCR5	$\overline{\text{INT6}}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR6	$\overline{\text{INT7}}$ input enable bit	0 : Enabled 1 : Disabled	RW
PCR7	Key input enable bit	0 : Enabled 1 : Disabled	RW

PCR5 ($\overline{\text{INT6}}$ input enable bit) (b5)

Set the PCR5 bit to 1 ($\overline{\text{INT6}}$ input disabled) when using the AN2_4 pin for analog input.

PCR6 ($\overline{\text{INT7}}$ input enable bit) (b6)

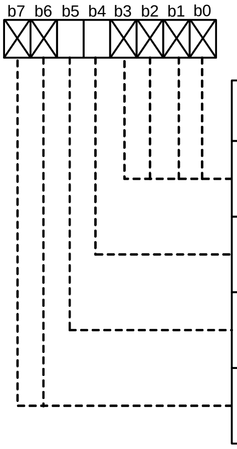
Set the PCR6 bit to 1 ($\overline{\text{INT7}}$ input disabled) when using AN2_5 pin for analog input.

PCR7 (Key input enable bit) (b7)

Set the PCR7 bit to 1 (key input disabled) when using pins AN4 to AN7 for analog input.

27.2.2 Open-Circuit Detection Assist Function Register (AINRST)

Open-Circuit Detection Assist Function Register



Symbol	Address	Reset Value
AINRST	03A2h	XX00 XXXXb

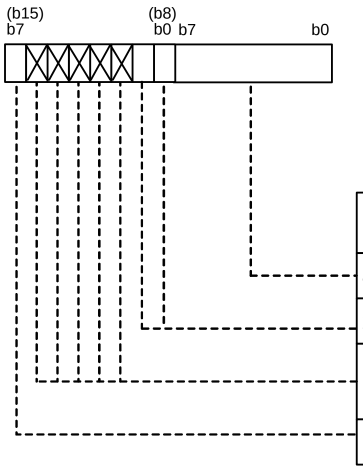
Bit Symbol	Bit Name	Function	RW
— (b3-b0)	No register bits. If necessary, set to 0. The read value is undefined.		—
AINRST0	Open-circuit detection assist function enable bit	b5 b4 0 0 : Open-circuit detection disabled 0 1 : Charge before conversion 1 0 : Discharge before conversion 1 1 : Do not set	RW
AINRST1			RW
— (b7-b6)	No register bits. If necessary, set to 0. The read value is undefined.		—

AINRST1-AINRST0 (Open-circuit detection assist function enable bit) (b5-b4)

To enable the A/D open-circuit detection assist function, set the AINRST0 bit or AINRST1 bit to 1, and then set the ADST bit in the ADCON0 register to 1 (A/D conversion) after waiting for one cycle of ϕAD.

27.2.3 A/D Register i (ADi) (i = 0 to 7)

A/D Register i (i = 0 to 7)



Symbol	Address	Reset Value
AD0	03C1h to 03C0h	0000 00XX XXXX XXXXb
AD1	03C3h to 03C2h	0000 00XX XXXX XXXXb
AD2	03C5h to 03C4h	0000 00XX XXXX XXXXb
AD3	03C7h to 03C6h	0000 00XX XXXX XXXXb
AD4	03C9h to 03C8h	0000 00XX XXXX XXXXb
AD5	03CBh to 03CAh	0000 00XX XXXX XXXXb
AD6	03CDh to 03CCh	0000 00XX XXXX XXXXb
AD7	03CFh to 03CEh	0000 00XX XXXX XXXXb

Function		RW
8 lower bits of A/D conversion result		RO
2 upper bits of A/D conversion result		RO
No register bits. If necessary, set to 0. The read value is 0.		—
Reserved bit	The read value is 0.	RO

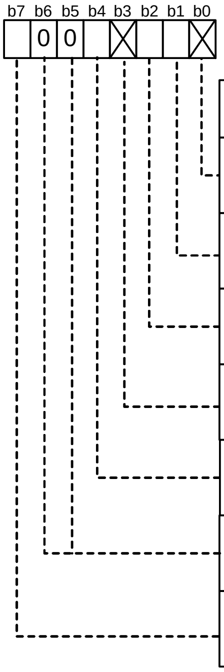
The A/D conversion result is stored in the ADi register corresponding to pins ANi, ANEXi, AN0_i, and AN2_i. Read the ADi register in 16-bit units. Table 27.4 lists Analog Pin and A/D Conversion Result Storing Register.

Table 27.4 Analog Pin and A/D Conversion Result Storing Register

Analog Pin				A/D Conversion Result Storing Register
AN0	ANEX0	AN0_0	AN2_0	AD0 register
AN1	ANEX1	AN0_1	AN2_1	AD1 register
AN2	–	AN0_2	AN2_2	AD2 register
AN3	–	AN0_3	AN2_3	AD3 register
AN4	–	AN0_4	AN2_4	AD4 register
AN5	–	AN0_5	AN2_5	AD5 register
AN6	–	AN0_6	AN2_6	AD6 register
AN7	–	AN0_7	AN2_7	AD7 register

27.2.4 A/D Control Register 2 (ADCON2)

A/D Control Register 2



Symbol	Address	Reset Value
ADCON2	03D4h	0000 X00Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	No register bit. If necessary, set to 0. The read value is undefined.		—
ADGSEL0	A/D input group select bit	b2 b1 0 0 : AN0 to AN7 0 1 : Do not set 1 0 : AN0_0 to AN0_7 1 1 : AN2_0 to AN2_7	RW
ADGSEL1			RW
— (b3)	No register bit. If necessary, set to 0. The read value is undefined.		—
CKS2	Frequency select bit 2	Refer to the CKS0 bit in the ADCON0 register.	RW
— (b6-b5)	Reserved bits	Set to 0	RW
CKS3	fAD select bit	0: f1 1: fOCO40M	RW

If the ADCON2 register is rewritten during A/D conversion, the conversion result is undefined.

ADGSEL1-ADGSEL0 (A/D input group select bit) (b2-b1)

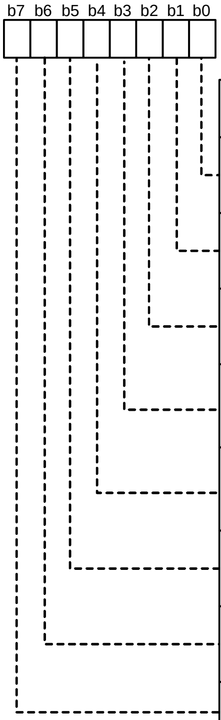
Pins AN0_0 to AN0_7 are used as analog input pins even if bits PM01 to PM00 in the PM0 register are set to 01b (memory expansion mode) and bits PM05 to PM04 are 11b (multiplexed bus is allocated to the entire $\overline{CS}$ space).

CKS3 (fAD select bit) (b7)

Set the CKS3 bit while A/D conversion is stopped.
Set the CKS3 bit, and then set other A/D converter related registers. Also, after changing the CKS3 bit, set the A/D converter related registers again. Note that bits in the ADCON2 register and the CKS3 bit can be set simultaneously.

27.2.5 A/D Control Register 0 (ADCON0)

A/D Control Register 0



Symbol	Address	Reset Value
ADCON0	03D6h	0000 0XXXb

Bit Symbol	Bit Name	Function	RW
CH0	Analog input pin select bit	In one-shot mode or repeat mode b2 b1 b0 0 0 0 : AN0 0 0 1 : AN1 0 1 0 : AN2 0 1 1 : AN3 1 0 0 : AN4 1 0 1 : AN5 1 1 0 : AN6 1 1 1 : AN7	RW
CH1			RW
CH2			RW
MD0	A/D operation mode select bit 0	b4 b3 0 0 : One-shot mode 0 1 : Repeat mode 1 0 : Single sweep mode 1 1 : Repeat sweep mode 0 or repeat sweep mode 1	RW
MD1			RW
TRG	Trigger select bit	0 : Software trigger 1 : ADTRG trigger	RW
ADST	A/D conversion start flag	0 : A/D conversion stop 1 : A/D conversion start	RW
CKS0	Frequency select bit 0	Refer to the description of the CKS0 bit.	RW

If the ADCON0 register is rewritten during A/D conversion, the conversion result is undefined.

CH2-CH0 (Analog input pin select bit) (b2-b0)

In one-shot and repeat modes, pins AN0_0 to AN0_7 and AN2_0 to AN2_7 can be used in the same way as pins AN0 to AN7. Use bits ADGSEL1 to ADGSEL0 in the ADCON2 register to select the desired group. These bits are disabled in single sweep mode, repeat sweep mode 0, and repeat sweep mode 1.

MD1-MD0 (A/D operation mode select bit 0) (b4-b3)

A/D operation mode is selected by a combination of bits MD1 to MD0 and the MD2 bit in the ADCON1 register. Table 27.5 lists A/D Operation Mode.

Table 27.5 A/D Operation Mode

Bit Setting			A/D Operation Mode
ADCON1 register	ADCON0 register		
MD2	MD1	MD0	
0	0	0	One-shot mode
0	0	1	Repeat mode
0	1	0	Single sweep mode
0	1	1	Repeat sweep mode 0
1	1	1	Repeat sweep mode 1

Only set the combinations listed above.

CKS0 (Frequency select bit 0) (b7)

φAD frequency is selected by a combination of the CKS0 bit in the ADCON0 register, the CKS1 bit in the ADCON1 register, and bits CKS3 and CKS2 in the ADCON2 register. Select bits CKS2 to CKS0 after setting the CKS3 bit in the ADCON2 register. Note that bits CKS3 and CKS2 can be set simultaneously. Table 27.6 lists φAD Frequency.

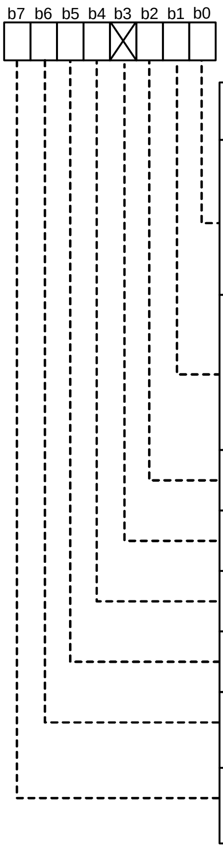
Table 27.6 φAD Frequency

CKS3	CKS2	CKS1	CKS0	φAD
0	0	0	0	fAD(f1) divided by 4
	0	0	1	fAD(f1) divided by 2
	0	1	0	fAD(f1)
	0	1	1	
	1	0	0	fAD(f1) divided by 12
	1	0	1	fAD(f1) divided by 6
	1	1	0	fAD(f1) divided by 3
	1	1	1	
1	0	0	0	fAD(fOCO40M) divided by 4
	0	0	1	fAD(fOCO40M) divided by 2
	1	0	0	fAD(fOCO40M) divided by 12
	1	0	1	fAD(fOCO40M) divided by 6
	1	1	0	fAD(fOCO40M) divided by 3
	1	1	1	

Only set the values listed above.

27.2.6 A/D Control Register 1 (ADCON1)

A/D Control Register 1



Symbol	Address	After Reset
ADCON1	03D7h	0000 X000b

Bit Symbol	Bit Name	Function	RW
SCAN0	A/D sweep pin select bit	In single sweep mode or repeat sweep mode 0 b1 b0 0 0: AN0 to AN1 (2 pins) 0 1: AN0 to AN3 (4 pins) 1 0: AN0 to AN5 (6 pins) 1 1: AN0 to AN7 (8 pins) In repeat sweep mode 1 b1 b0 0 0: AN0 (1 pin) 0 1: AN0 to AN1 (2 pins) 1 0: AN0 to AN2 (3 pins) 1 1: AN0 to AN3 (4 pins)	RW
SCAN1			RW
MD2	A/D operation mode select bit 1	0 : Any mode other than repeat sweep mode 1 1 : Repeat sweep mode 1	RW
— (b3)	No register bit. If necessary, set to 0. Read as undefined value		—
CKS1	Frequency select bit 1	Refer to the CKS0 bit in the ADCON0 register.	RW
ADSTBY	A/D standby bit	0 : A/D operation stopped (standby) 1 : A/D operation enabled	RW
ADEX0	Extended pin select bit	In one-shot mode or repeat mode b7 b6 0 0: ANEX0 to ANEX1 are not used 0 1: ANEX0 input is A/D converted 1 0: ANEX1 input is A/D converted 1 1: Do not set this value	RW
ADEX1			RW

If the ADCON1 register is rewritten during A/D conversion, the conversion result is undefined.

SCAN1-SCAN0 (A/D sweep pin select bit) (b1-b0)

These bits are disabled in one-shot and repeat modes. In single sweep mode, repeat sweep mode 0, and repeat sweep mode 1, pins AN0_0 to AN0_7 and AN2_0 to AN2_7 can be used in the same way as pins AN0 to AN7. Use bits ADGSEL1 to ADGSEL0 in the ADCON2 register to select the desired group.

MD2 (A/D operation mode select bit 1) (b2)

A/D operation mode is selected by a combination of bits MD1 to MD0 in the ADCON0 register and the MD2 bit. See Table 27.5 “A/D Operation Mode”.

ADSTBY (A/D standby bit) (b5)

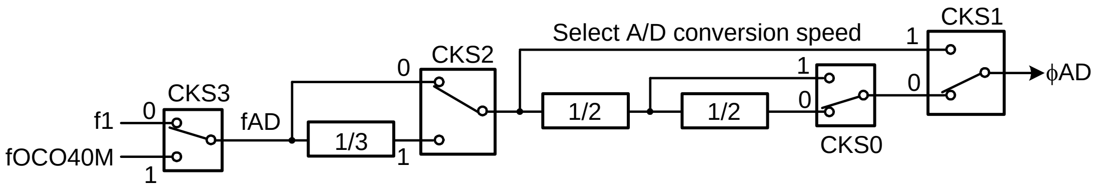
If the ADSTBY bit is changed from 0 (A/D operation stopped) to 1 (A/D operation enabled), wait for one ϕAD cycle or more before starting A/D conversion.
When the A/D converter is not used, no current flows in the A/D converter by setting the ADSTBY bit to 0 (A/D operation stopped: standby). This helps reduce power consumption.

27.3 Operations

27.3.1 A/D Conversion Cycle

A/D conversion cycle is based on fAD and ϕAD. Divide fAD so ϕAD conforms the standard frequency. Figure 27.2 shows fAD and ϕAD.

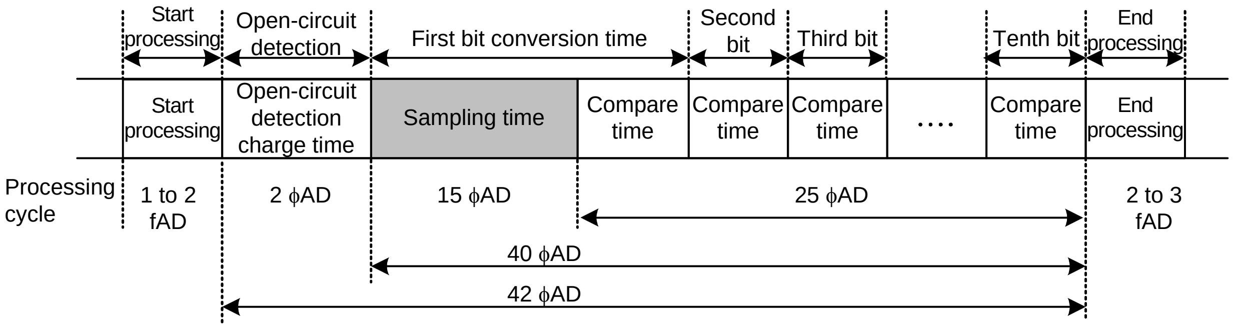
Set the PCKSTP1A bit in the PCLKSTP1 register to 0 (f1 provide enabled) when using f1 as the clock source of fAD.



CKS0: Bit in the ADCON0 register
CKS1: Bit in the ADCON1 register
CKS2, CKS3: Bits in the ADCON2 register

Figure 27.2 fAD and ϕAD

Figure 27.3 shows A/D Conversion Timing.



The above figure applies under the following conditions:

- One-shot mode
- ϕAD = fAD

Figure 27.3 A/D Conversion Timing

Table 27.7 lists Cycles of A/D Conversion Item. A/D conversion time is described below.
Start processing time depends on which ϕAD is selected.
A/D conversion starts after the start processing time elapses by setting the ADST bit in the ADCON0 register to 1 (A/D conversion start). When reading the ADST bit before starting A/D conversion, 0 (A/D conversion stop) is read.
When selecting multiple pins, or in a mode which performs A/D conversion multiple times, inter-execution processing time is inserted between A/D conversions.
In one-shot mode and single sweep mode, the ADST bit becomes 0 at the end processing time and the last A/D conversion result is stored in the ADi register.

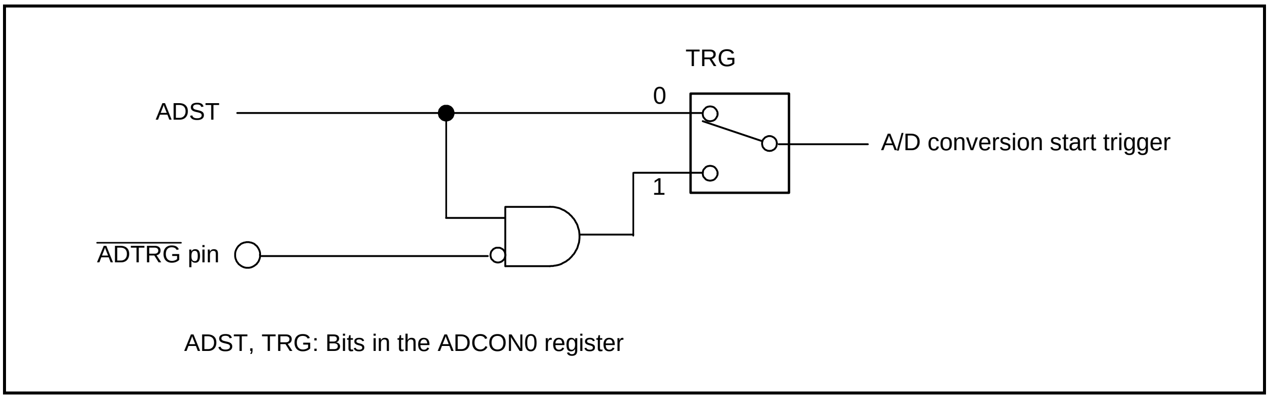
One-shot mode:
  Start processing time + A/D conversion execution time + end processing time
Two pins are selected in single sweep mode:
  Start processing time + (A/D conversion execution time + inter-execution processing time + A/D conversion execution time) + end processing time

Table 27.7 Cycles of A/D Conversion Item

A/D Conversion Item		Number of Cycles
Start processing time	ϕAD = fAD	1 to 2 cycles of fAD
	ϕAD = fAD divided by 2	2 to 3 cycles of fAD
	ϕAD = fAD divided by 3	3 to 4 cycles of fAD
	ϕAD = fAD divided by 4	3 to 4 cycles of fAD
	ϕAD = fAD divided by 6	4 to 5 cycles of fAD
	ϕAD = fAD divided by 12	7 to 8 cycles of fAD
A/D conversion execution time	Open-circuit detection disabled	40 cycles of ϕAD
	Open-circuit detection enabled	42 cycles of ϕAD
Inter-execution processing time		1 cycle of ϕAD
End processing time		2 to 3 cycles of fAD

27.3.2 A/D Conversion Start Conditions

An A/D conversion start trigger has a software trigger and an external trigger. Figure 27.4 shows A/D Conversion Start Trigger.



ADST, TRG: Bits in the ADCON0 register

Figure 27.4 A/D Conversion Start Trigger

27.3.2.1 Software Trigger

The software trigger is enabled when the TRG bit in the ADCON0 register is 0 (software trigger). A/D conversion starts by setting the ADST bit in the ADCON0 register to 1 (A/D conversion start).

27.3.2.2 External Trigger

The external trigger is enabled when the TRG bit in the ADCON0 register is 1 ($\overline{\text{ADTRG}}$ trigger). To use this trigger, set the following:

- The direction bit of the port which shares a pin with $\overline{\text{ADTRG}}$ is 0 (input mode).
- The TRG bit in the ADCON0 register is 1 ($\overline{\text{ADTRG}}$ trigger).
- The ADST bit in the ADCON0 register is 1 (A/D conversion start).

Under the above conditions, when input to the $\overline{\text{ADTRG}}$ pin is changed from high to low, A/D conversion starts.

Set the high- and low-level durations of the pulse input to the $\overline{\text{ADTRG}}$ pin to two or more cycles of fAD.

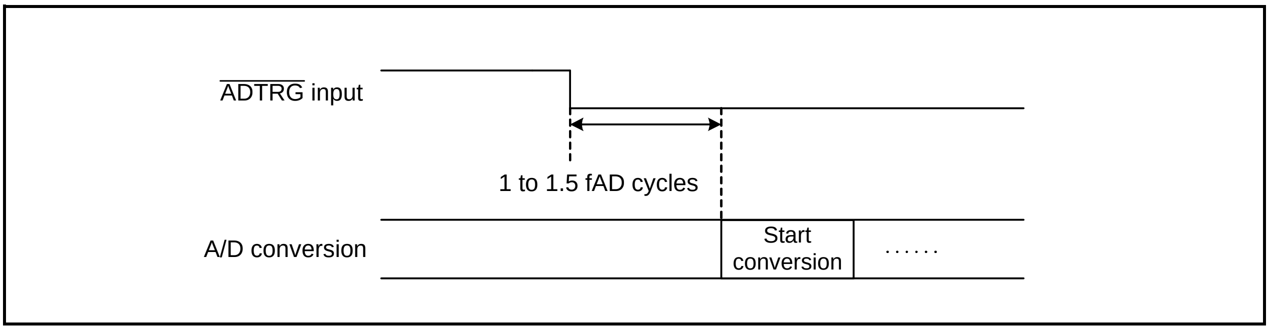


Figure 27.5 A/D Conversion Start Timing When External Trigger Input

27.3.3 A/D Conversion Result

When reading the ADi register before A/D conversion is completed, the undefined value is read. Read the ADi register after completing A/D conversion. Use the following procedure to detect the completion of A/D conversion.

- In one-shot mode and single sweep mode:
  The IR bit in the ADIC register becomes 1 (interrupt requested) at a completion of A/D conversion. Ensure that the IR bit becomes 1 to read the ADi register.
  When not using an A/D interrupt, set the IR bit to 0 (interrupt not requested) by a program after reading the ADi register.

- In repeat mode, repeat sweep mode 0, and repeat sweep mode 1:
  The IR bit remains unchanged (no interrupt request is generated). At first, read the ADi register after one A/D conversion time elapses (refer to 27.3.1 “A/D Conversion Cycle”). After that, whenever the ADi register is read, the conversion result which has been obtained before reading is read.
  The ADi register is overwritten after every A/D conversion. Read the value before the ADi register is overwritten.

27.3.4 Extended Analog Input Pins

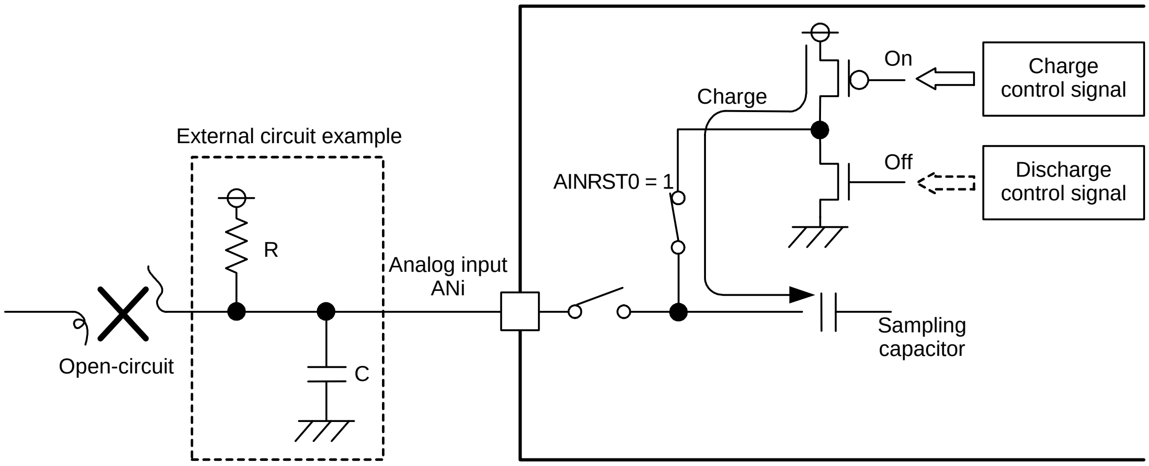
In one-shot mode and repeat modes, pins ANEX0 and ANEX1 can be used as analog input pins by setting bits ADEX1 to ADEX0 in the ADCON1 register.
The A/D conversion result of pins ANEX0 and ANEX1 are stored in registers AD0 and AD1, respectively.

27.3.5 Current Consumption Reduce Function

When the A/D converter is not in use, power consumption can be reduced by setting the ADSTBY bit in the ADCON1 register to 0 (A/D operation stopped: standby) to shut off any analog circuit current flow.
To use the A/D converter, set the ADSTBY bit to 1 (A/D operation enabled) and wait for one ϕAD cycle or more before setting the ADST bit in the ADCON0 register to 1 (A/D conversion start). Do not set bits ADST and ADSTBY to 1 at the same time.
Also, do not set the ADSTBY bit to 0 (A/D operation stopped: standby) during A/D conversion.

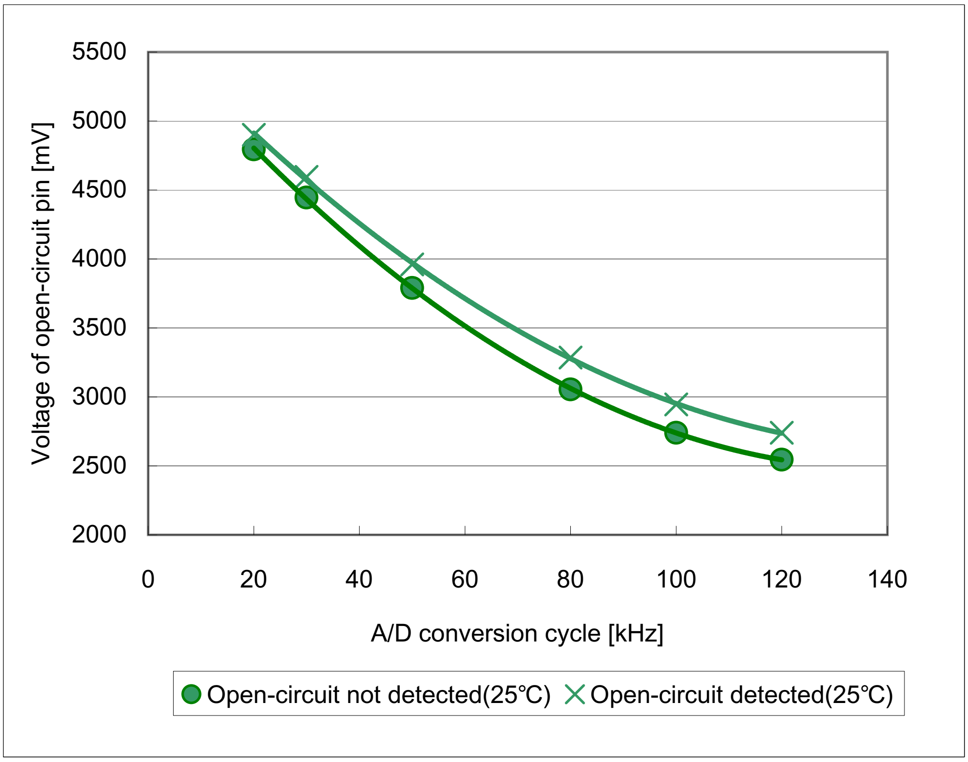
27.3.6 Open-Circuit Detection Assist Function

The A/D converter has a function to set the charge of the sampling capacitor to a predefined state (AVCC or AVSS) before A/D conversion starts. This helps prevent the influence of analog input voltage from the previous conversion and more reliably detect an open-circuit of a trace connected to an analog input pin.
Figure 27.6 shows A/D Open-Circuit Detection Example on AVCC (Preconversion Charge) and Figure 27.8 shows A/D Open-Circuit Detection Example on AVSS (Preconversion discharge).
The conversion result in open-circuit depends on the external circuit. Use this function only after careful evaluation of the system.



ANi: ANi (i = 0 to 7), ANEXi, AN0-i, AN2-i
AINRST0: Bit in the AINRST register

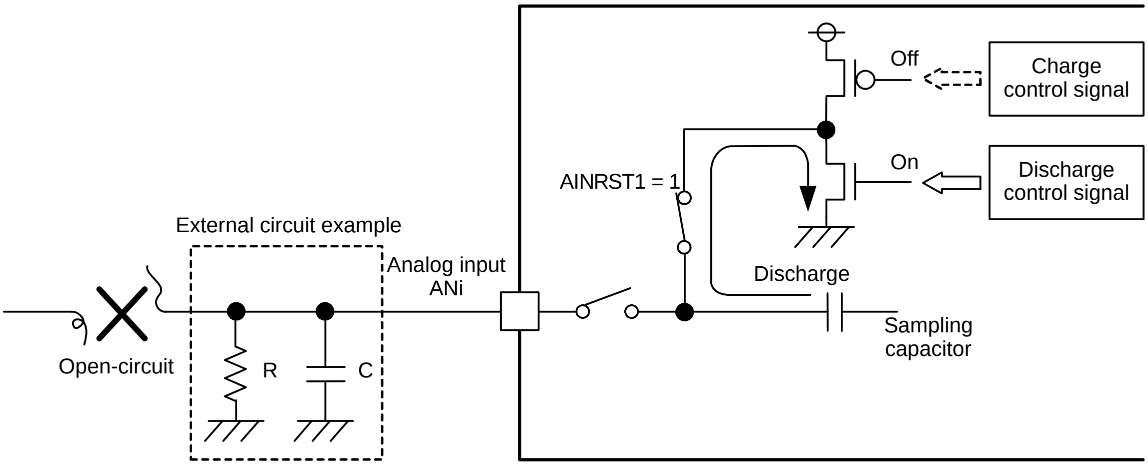
Figure 27.6 A/D Open-Circuit Detection Example on AVCC (Preconversion Charge)



Measuring Condition (common)
VCC1 = 5.12 V
Analog input pin is AN0
R = 100 kΩ
C = 100 pF between AN0 and GND
XIN = 10 MHz

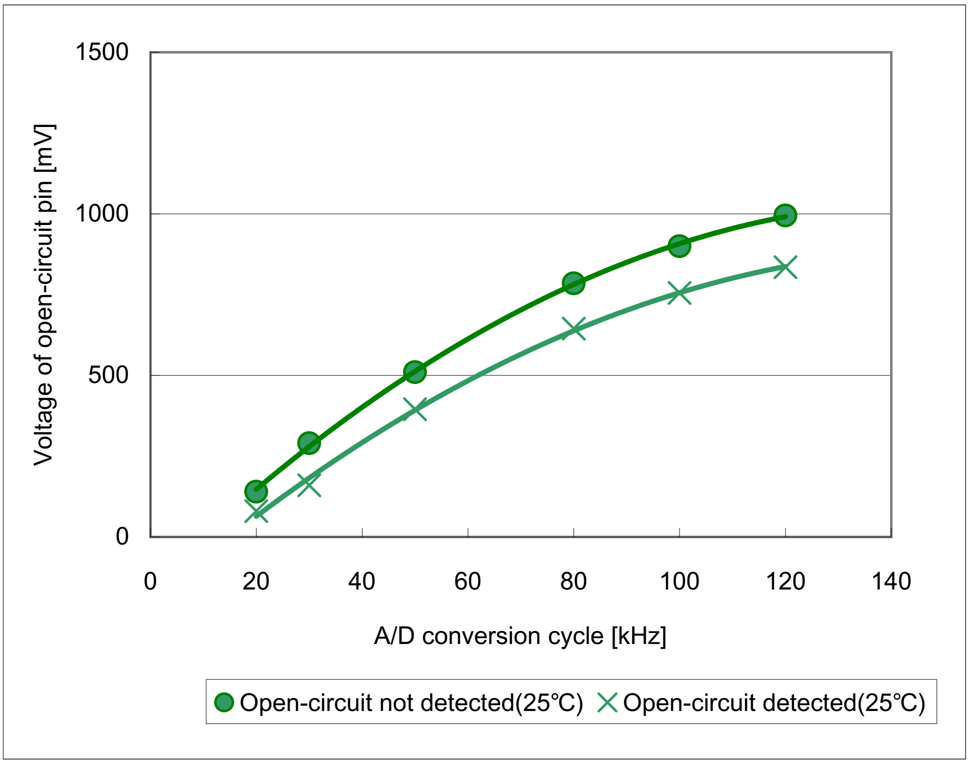
The horizontal axis shows how many times A/D conversion is performed per ms.
For example, 20 kHz indicates A/D conversion is performed every 50 µs.

Figure 27.7 A/D Open-Circuit Detection (Charge) Characteristics (Standard Characteristics)



ANi: ANi (i = 0 to 7), ANEXi, AN0-i, AN2-i
AINRST1: Bit in the AINRST register

Figure 27.8 A/D Open-Circuit Detection Example on AVSS (Preconversion discharge)



Measuring Condition (common)
VCC1 = 5.12 V
Analog input pin is AN0
R = 100 kΩ
C = 100 pF between AN0 and GND
XIN = 10 MHz

The horizontal axis shows how many times A/D conversion is performed per ms.
For example, 20 kHz indicates A/D conversion is performed every 50 µs.

Figure 27.9 A/D Open-Circuit Detection (Discharge) Characteristics (Standard Characteristics)

27.4 Operational Modes

27.4.1 One-Shot Mode

In one-shot mode, the analog voltage applied to a selected pin is converted to a digital code once. Table 27.8 lists One-Shot Mode Specifications.

Table 27.8 One-Shot Mode Specifications

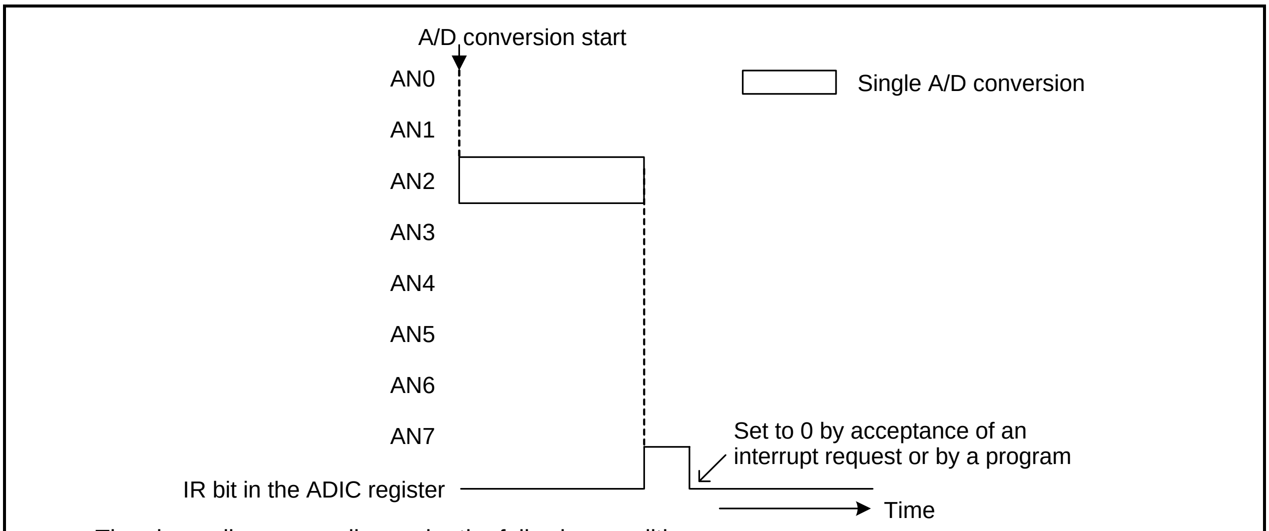
Item	Specification
Function	Bits CH2 to CH0 in the ADCON0 register and bits ADGSEL1 to ADGSEL0 in the ADCON2 register, or bits ADEX1 to ADEX0 in the ADCON1 register are used to select a pin. The analog voltage applied to the pin is converted to a digital code once.
A/D conversion start conditions	• When the TRG bit in the ADCON0 register is 0 (software trigger) the ADST bit in the ADCON0 register is set to 1 (A/D conversion starts). • When the TRG bit is 1 ($\overline{\text{ADTRG}}$ trigger) the input level at the $\overline{\text{ADTRG}}$ pin changes from high to low after the ADST bit is set to 1 (A/D conversion start).
A/D conversion stop conditions	• Completion of A/D conversion (if a software trigger is selected, the ADST bit becomes 0 (A/D conversion stop)). • Set the ADST bit to 0.
Interrupt request generation timing	Completion of A/D conversion.
Analog input pin	Select one pin from AN0 to AN7, AN0_0 to AN0_7, AN2_0 to AN2_7, ANEX0, or ANEX1.
Reading of A/D conversion result	Read the register among AD0 to AD7 that corresponds to the selected pin.

Table 27.9 Registers and Settings in One-Shot Mode [1]

Register	Bit	Setting
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.
PCR	PCR5	Set to 1 ($\overline{\text{INT6}}$ input disabled) when using the AN2_4 pin for analog input.
	PCR6	Set to 1 ($\overline{\text{INT7}}$ input disabled) when using the AN2_5 pin for analog input.
	PCR7	Set to 1 (key input disabled) when using pins AN4 to AN7 for analog input.
AINRST	AINRST1, AINRST0	Select whether open-circuit detection assist function is used or not.
AD0 to AD7	b9 to b0	A/D conversion result can be read.
ADCON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕAD frequency.
	CKS3	Select fAD.
ADCON0	CH2 to CH0	Select analog input pin.
	MD1 to MD0	Set to 00b.
	TRG	Select a trigger.
	ADST	Set to 1 to start A/D conversion and set to 0 to stop it.
	CKS0	Select ϕAD frequency.
ADCON1	SCAN1, SCAN0	Disabled
	MD2	Set to 0.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when performing A/D conversion.
	ADEX1, ADEX0	Select whether ANEX0 and ANEX1 are used or not

Note:

1. This table does not describe a procedure.


A/D conversion start
AN0
AN1
AN2
AN3
AN4
AN5
AN6
AN7
Single A/D conversion
Set to 0 by acceptance of an interrupt request or by a program
IR bit in the ADIC register
Time

The above diagram applies under the following conditions:

- Bits CH2 to CH0 in the ADCON0 register are 010b (AN2).
- Bits ADGSEL1 to ADGSEL0 in the ADCON2 register are 00b (AN0 to AN7).

Figure 27.10 Operation Example in One-Shot Mode

27.4.2 Repeat Mode

In repeat mode, the analog voltage applied to a selected pin is repeatedly converted to a digital code. Table 27.10 lists Repeat Mode Specifications.

Table 27.10 Repeat Mode Specifications

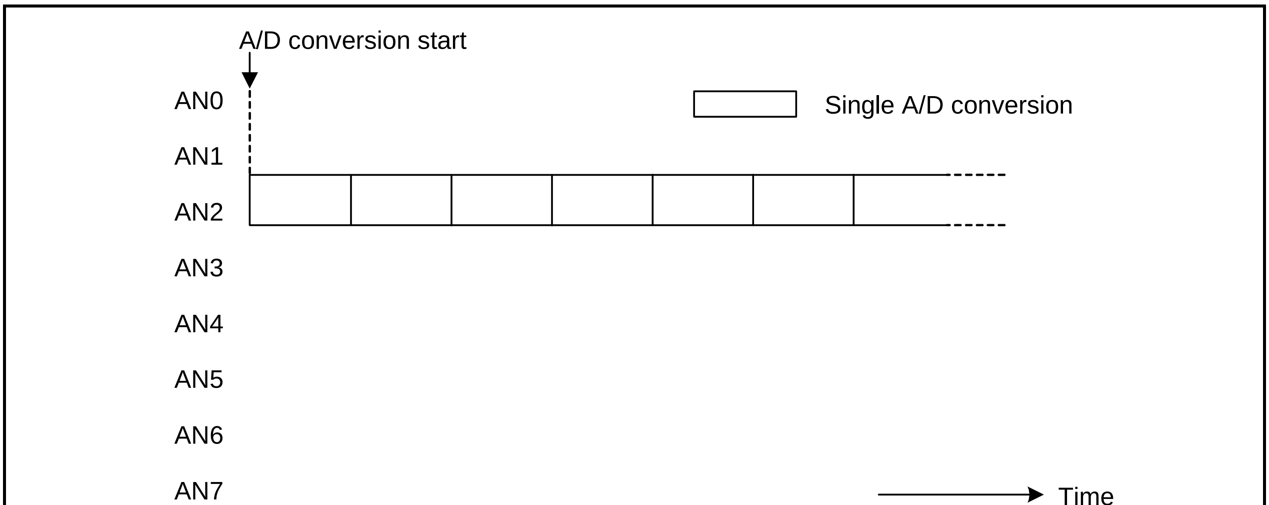
Item	Specification
Function	Bits CH2 to CH0 in the ADCON0 register and bits ADGSEL1 to ADGSEL0 in the ADCON2 register, or bits ADEX1 to ADEX0 in the ADCON1 register are used to select a pin. The analog voltage applied to the pin is repeatedly converted to a digital code.
A/D conversion start conditions	• When the TRG bit in the ADCON0 register is 0 (software trigger) the ADST bit in the ADCON0 register is set to 1 (A/D conversion start). • When the TRG bit is 1 ($\overline{\mathrm{ADTRG}}$ trigger) the input level at the $\overline{\mathrm{ADTRG}}$ pin changes from high to low after the ADST bit is set to 1 (A/D conversion start).
A/D conversion stop condition	Set the ADST bit to 0 (A/D conversion stop).
Interrupt request generation timing	No interrupt requests generated
Analog input pin	Select one pin from among AN0 to AN7, AN0_0 to AN0_7, AN2_0 to AN2_7, ANEX0, or ANEX1.
Reading of A/D conversion result	Read the register among AD0 to AD7 that corresponds to the selected pin.

Table 27.11 Registers and Settings in Repeat Mode [1]

Register	Bit	Setting
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.
PCR	PCR5	Set to 1 ($\overline{\text{INT6}}$ input disabled) when using the AN2_4 pin for analog input.
	PCR6	Set to 1 ($\overline{\text{INT7}}$ input disabled) when using the AN2_5 pin for analog input.
	PCR7	Set to 1 (key input disabled) when using pins AN4 to AN7 for analog input.
AINRST	AINRST1, AINRST0	Select whether open-circuit detection assist function is used or not.
AD0 to AD7	b9 to b0	A/D conversion result can be read.
ADCON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕAD frequency.
	CKS3	Select fAD.
ADCON0	CH2 to CH0	Select analog input pin.
	MD1 to MD0	Set to 01b.
	TRG	Select a trigger.
	ADST	Set to 1 to start A/D conversion and set to 0 to stop it.
	CKS0	Select ϕAD frequency.
ADCON1	SCAN1, SCAN0	Disabled
	MD2	Set to 0.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when performing A/D conversion.
	ADEX1, ADEX0	Select whether ANEX0 and ANEX1 are used or not

Note:

1. This table does not describe a procedure.



The above diagram applies under the following conditions:

- Bits CH2 to CH0 in the ADCON0 register are 010b (AN2).
- Bits ADGSEL1 to ADGSEL0 in the ADCON2 register are 00b (AN0 to AN7).

Figure 27.11 Operation Example in Repeat Mode

27.4.3 Single Sweep Mode

In single sweep mode, the analog voltage applied to selected pins is converted one-by-one to a digital code. Table 27.12 lists the Single Sweep Mode Specifications.

Table 27.12 Single Sweep Mode Specifications

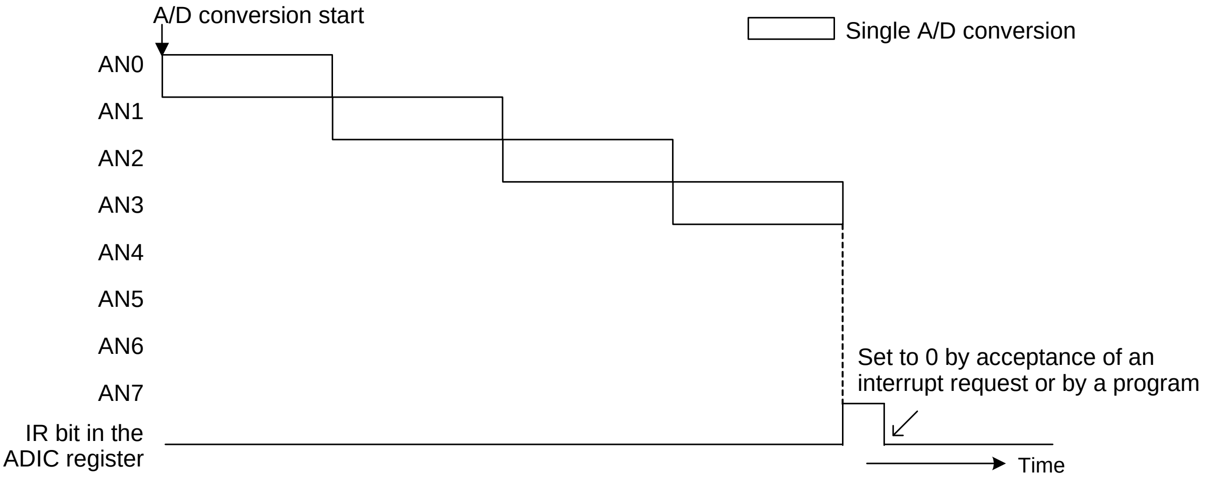
Item	Specification
Function	Bits SCAN1 to SCAN0 in the ADCON1 register and bits ADGSEL1 to ADGSEL0 in the ADCON2 register are used to select pins. The analog voltage applied to the pins is converted one-by-one to a digital code.
A/D conversion start conditions	• When the TRG bit in the ADCON0 register is 0 (software trigger) the ADST bit in the ADCON0 register is set to 1 (A/D conversion start). • When the TRG bit is 1 ($\overline{\text{ADTRG}}$ trigger) the input level at the $\overline{\text{ADTRG}}$ pin changes from high to low after the ADST bit is set to 1 (A/D conversion start).
A/D conversion stop conditions	• Completion of A/D conversion (if a software trigger is selected, the ADST bit is set to 0 (A/D conversion stop)). • Set the ADST bit to 0.
Interrupt request generation timing	Completion of A/D conversion
Analog input pin	Select one of the following groupings from AN0 to AN7: 2 pins: AN0 and AN1 4 pins: AN0 to AN3 6 pins: AN0 to AN5 8 pins: AN0 to AN7 AN0_0 to AN0_7 and AN2_0 to AN2_7 can also be selected in the same way.
Reading of A/D conversion result	Read the registers among AD0 to AD7 that corresponds to the selected pin.

Table 27.13 Registers and Settings in Single Sweep Mode [1]

Register	Bit	Setting
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.
PCR	PCR5	Set to 1 ($\overline{\text{INT6}}$ input disabled) when using the AN2_4 pin for analog input.
	PCR6	Set to 1 ($\overline{\text{INT7}}$ input disabled) when using the AN2_5 pin for analog input.
	PCR7	Set to 1 (key input disabled) when using pins AN4 to AN7 for analog input.
AINRST	AINRST1, AINRST0	Select whether open-circuit detection assist function is used or not.
AD0 to AD7	b9 to b0	A/D conversion result can be read.
ADCON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕAD frequency.
	CKS3	Select fAD.
ADCON0	CH2 to CH0	Disabled
	MD1 to MD0	Set to 10b.
	TRG	Select a trigger.
	ADST	Set to 1 to start A/D conversion and set to 0 to stop it.
	CKS0	Select ϕAD frequency.
ADCON1	SCAN1, SCAN0	Select analog input pin.
	MD2	Set to 0.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when performing A/D conversion.
	ADEX1, ADEX0	Set to 00b.

Note:

1. This table does not describe a procedure.


A/D conversion start
Single A/D conversion
AN0
AN1
AN2
AN3
AN4
AN5
AN6
AN7
Set to 0 by acceptance of an interrupt request or by a program
IR bit in the ADIC register
Time

The above diagram applies under the following conditions:

- Bits SCAN1 to SCAN0 in the ADCON1 register are 01b (AN0 to AN3 (4 pins)).
- Bits ADGSEL1 to ADGSEL0 in the ADCON2 register are 00b (AN0 to AN7).

Figure 27.12 Operation Example in Single Sweep Mode

27.4.4 Repeat Sweep Mode 0

In repeat sweep mode 0, the analog voltage applied to selected pins is repeatedly converted to a digital code. Table 27.14 lists the Repeat Sweep Mode 0 Specifications.

Table 27.14 Repeat Sweep Mode 0 Specifications

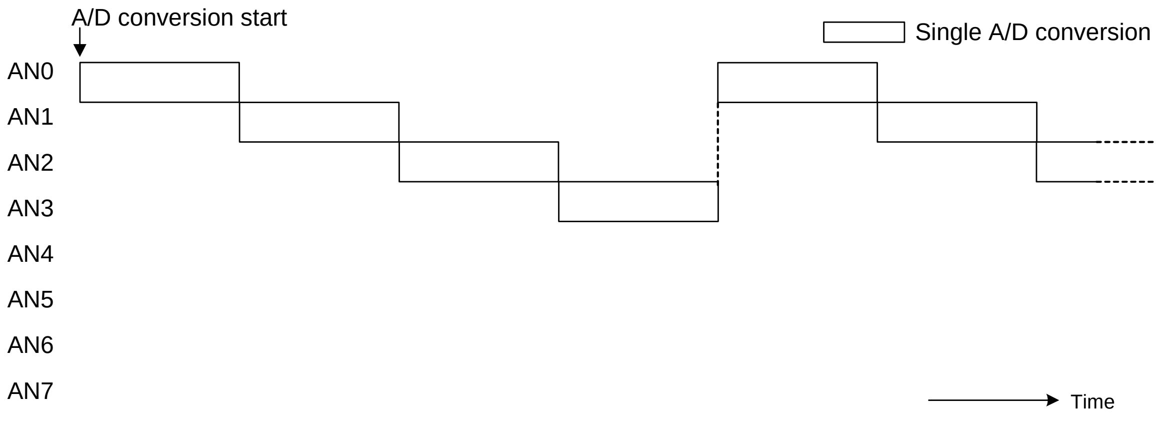
Item	Specification
Function	Bits SCAN1 to SCAN0 in the ADCON1 register and bits ADGSEL1 to ADGSEL0 in the ADCON2 register are used to select pins. Analog voltage applied to the pins is repeatedly converted to a digital code.
A/D conversion start conditions	• When the TRG bit in the ADCON0 register is 0 (software trigger) the ADST bit in the ADCON0 register is set to 1 (A/D conversion start). • When the TRG bit is 1 ($\overline{\text{ADTRG}}$ trigger) the input level at the $\overline{\text{ADTRG}}$ pin changes from high to low after the ADST bit is set to 1 (A/D conversion start).
A/D conversion stop condition	Set the ADST bit to 0 (A/D conversion stop).
Interrupt request generation timing	No interrupt requests generated
Analog input pin	Select one of the following groupings from AN0 to AN7: 2 pins: AN0 and AN1 4 pins: AN0 to AN3 6 pins: AN0 to AN5 8 pins: AN0 to AN7 AN0_0 to AN0_7 and AN2_0 to AN2_7 can also be selected in the same way.
Reading of A/D conversion result	Read the registers among AD0 to AD7 that correspond to the selected pins.

Table 27.15 Registers and Settings in Repeat Sweep Mode 0 [1]

Register	Bit	Setting
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.
PCR	PCR5	Set to 1 ($\overline{\text{INT6}}$ input disabled) when using the AN2_4 pin for analog input.
	PCR6	Set to 1 ($\overline{\text{INT7}}$ input disabled) when using the AN2_5 pin for analog input.
	PCR7	Set to 1 (key input disabled) when using pins AN4 to AN7 for analog input.
AINRST	AINRST1, AINRST0	Select whether open-circuit detection assist function is used or not.
AD0 to AD7	b9 to b0	A/D conversion result can be read.
ADCON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕAD frequency.
	CKS3	Select fAD.
ADCON0	CH2 to CH0	Disabled
	MD1 to MD0	Set to 11b.
	TRG	Select a trigger.
	ADST	Set to 1 to start A/D conversion and set to 0 to stop it.
	CKS0	Select ϕAD frequency.
ADCON1	SCAN1, SCAN0	Select analog input pin.
	MD2	Set to 0.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when performing A/D conversion.
	ADEX1, ADEX0	Set to 00b.

Note:

[1] This table does not describe a procedure.



The above diagram applies under the following conditions:

- Bits SCAN1 to SCAN0 in the ADCON1 are 01b (AN0 to AN3 (4 pins)).
- Bits ADGSEL1 to ADGSEL0 in the ADCON2 are 00b (AN0 to AN7).

Figure 27.13 Operation Example in Repeat Sweep Mode 0

27.4.5 Repeat Sweep Mode 1

In repeat sweep mode 1, the analog voltage applied to eight selected pins, including some prioritized pins, is repeatedly converted to a digital code. Table 27.16 lists the Repeat Sweep Mode 1 Specifications.

Table 27.16 Repeat Sweep Mode 1 Specifications

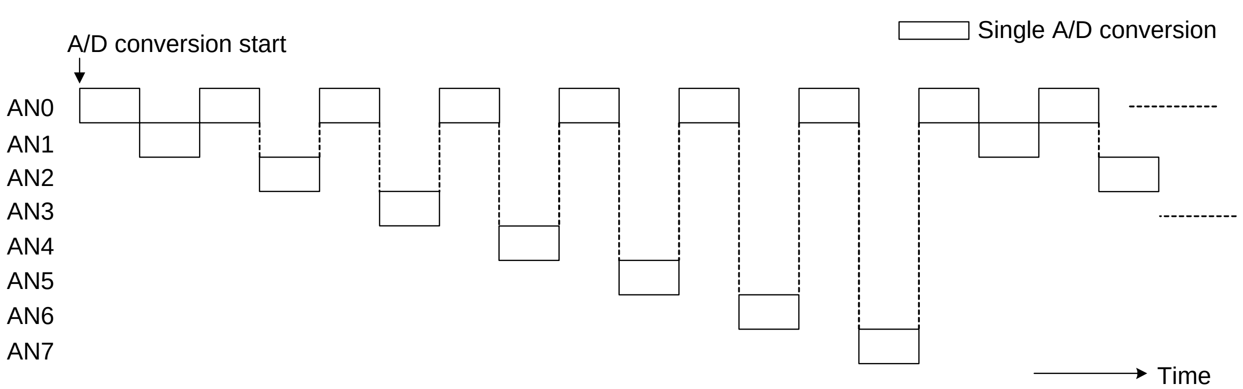
Item	Specification
Function	The input voltage of all eight pins selected by setting bits ADGSEL1 to ADGSEL0 in the ADCON2 register is repeatedly converted to a digital code. One to four pins selected by SCAN1 to SCAN0 in the ADCON1 register is/are converted by priority. Example: If AN0 is prioritized, input voltage is converted to a digital code in the following order: AN0→AN1→AN0→AN2→AN0→AN3 •••
A/D conversion start conditions	• When the TRG bit in the ADCON0 register is 0 (software trigger), the ADST bit in the ADCON0 register is set to 1 (A/D conversion start). • When the TRG bit is 1 ($\overline{\text{ADTRG}}$ trigger), the input level at the $\overline{\text{ADTRG}}$ pin changes from high to low after the ADST bit is set to 1 (A/D conversion start).
A/D conversion stop condition	Set the ADST bit to 0 (A/D conversion stop).
Interrupt request generation timing	No interrupt requests generated
Analog input pins to be given priority when A/D converted	Select one of the following groupings from AN0 to AN3: 1 pin: AN0 2 pins: AN0 and AN1 3 pins: AN0 to AN2 4 pins: AN0 to AN3 AN0_0 to AN0_3 and AN2_0 to AN2_3 can be selected in the same way.
Reading of A/D conversion result	Read the registers among AD0 to AD7 that correspond to the selected pins.

Table 27.17 Registers and Settings in Repeat Sweep Mode 1 (1)

Register	Bit	Setting
PCLKSTP1	PCKSTP1A	Set to 0 when using f1.
PCR	PCR5	Set to 1 ($\overline{\text{INT6}}$ input disabled) when using the AN2_4 pin for analog input.
	PCR6	Set to 1 ($\overline{\text{INT7}}$ input disabled) when using the AN2_5 pin for analog input.
	PCR7	Set to 1 (key input disabled) when using pins AN4 to AN7 for analog input.
AINRST	AINRST1, AINRST0	Select whether open-circuit detection assist function is used or not.
AD0 to AD7	b9 to b0	A/D conversion result can be read.
ADCON2	ADGSEL1, ADGSEL0	Select analog input pin group.
	CKS2	Select ϕAD frequency.
	CKS3	Select fAD.
ADCON0	CH2 to CH0	Disabled
	MD1 to MD0	Set to 11b.
	TRG	Select a trigger.
	ADST	Set to 1 to start A/D conversion and set to 0 to stop it.
	CKS0	Select ϕAD frequency.
ADCON1	SCAN1, SCAN0	Select a pin to be given priority when A/D converted
	MD2	Set to 1.
	CKS1	Select ϕAD frequency.
	ADSTBY	Set to 1 when performing A/D conversion.
	ADEX1, ADEX0	Set to 00b.

Note:

1. This table does not describe a procedure.



The above diagram applies under the following conditions.
- Bits SCAN1 to SCAN0 in the ADCON1 register are 00b (AN0 (1 pin)).
- Bits ADGSEL1 to ADGSEL0 in the ADCON2 register are 00b (A0 to AN7).

Figure 27.14 Operation Example in Repeat Sweep Mode 1

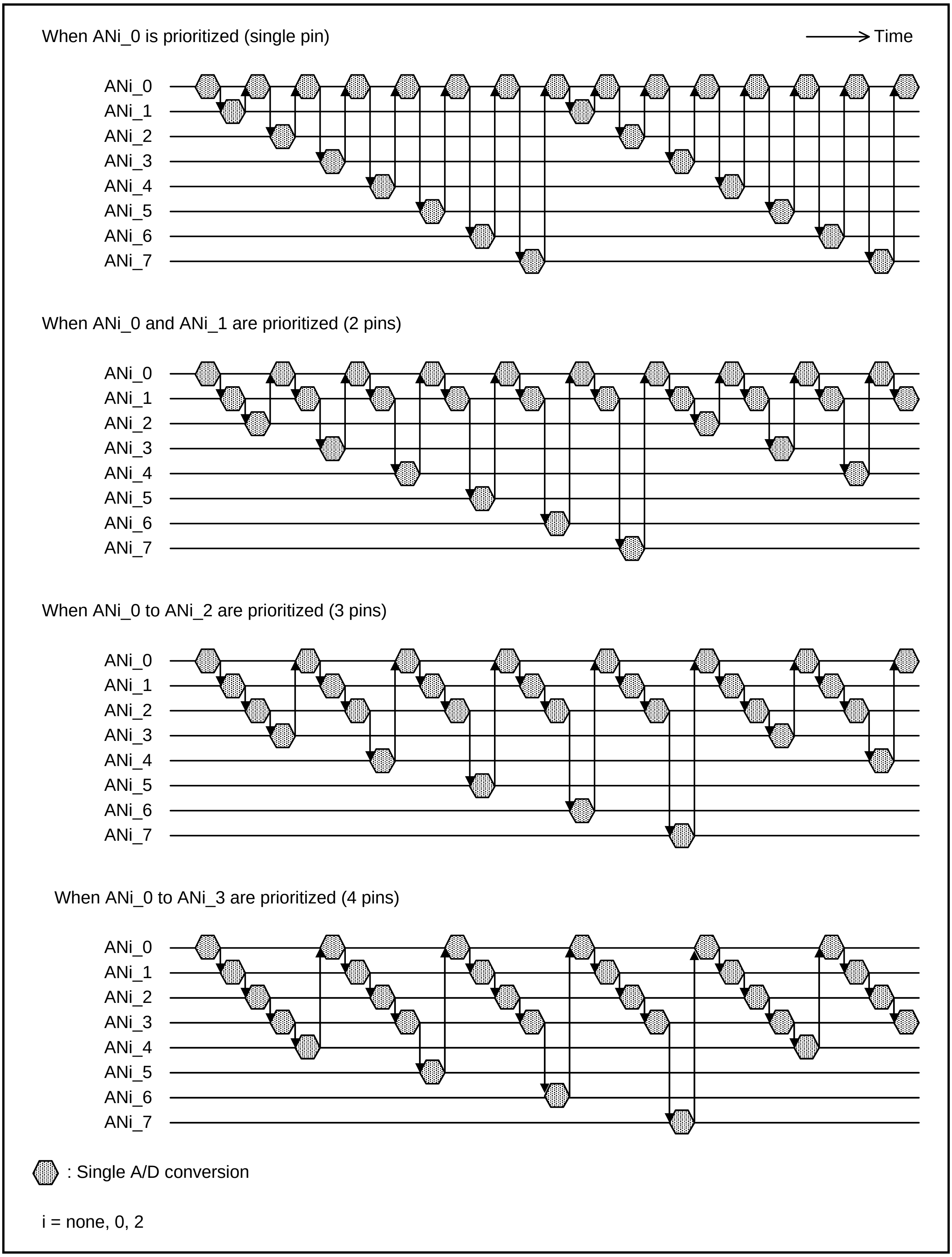

When ANi_0 is prioritized (single pin)
Time
ANi_0
ANi_1
ANi_2
ANi_3
ANi_4
ANi_5
ANi_6
ANi_7
When ANi_0 and ANi_1 are prioritized (2 pins)
When ANi_0 to ANi_2 are prioritized (3 pins)
When ANi_0 to ANi_3 are prioritized (4 pins)
: Single A/D conversion
i = none, 0, 2

Figure 27.15 Transition Diagram of Pins Used during A/D Conversion in Repeat Sweep Mode 1

27.5 External Sensor

To perform A/D conversion accurately, charging the internal capacitor C shown in Figure 27.16 must be completed within a specified period of time.

T: Specified period of time (sampling time)
R0: Output impedance of sensor equivalent circuit
R: Internal resistance of the MCU
X: Precision (error) of the A/D converter
Y: Resolution of the A/D converter be Y (Y is 1024)

Generally, $VC = VIN\left\{1 - e^{-\frac{1}{C(R0+R)}t}\right\}$

When t = T, $VC = VIN - \frac{X}{Y}VIN = VIN\left(1 - \frac{X}{Y}\right)$

$$e^{-\frac{1}{C(R0+R)}T} = \frac{X}{Y}$$

$$-\frac{1}{C(R0+R)}T = \ln\frac{X}{Y}$$

Therefore, $R0 = -\dfrac{T}{C \bullet \ln\frac{X}{Y}} - R$

Figure 27.16 shows Analog Input Pin and External Sensor Equivalent Circuit. Impedance R0 by which voltage VC between pins of the capacitor C changes from 0 to VIN - (0.1/1024)VIN in time T when the difference between VIN and VC is 0.1LSB is obtained. (0.1/1024) means that A/D precision drop due to insufficient capacitor charge is kept to 0.1LSB in A/D conversion. However, the actual error is the value of absolute accuracy added to 0.1LSB.
When ϕAD is 20 MHz, T is 0.75 µs. Output impedance R0 for charging capacitor C sufficiently within time T is obtained as follows.

T = 0.75 µs, R = 10 kΩ, C = 6.0 pF, X = 0.1, and Y = 1024. Therefore,

$$R0 = -\frac{0.75 \times 10^{-6}}{6.0 \times 10^{-12} \bullet \ln\frac{0.1}{1024}} - 10 \times 10^{3} \approx 3.5 \times 10^{3}$$

Thus, the output impedance R0 of the sensor equivalent circuit, making the A/D converter precision (error) 0.1LSB or less, is up to 3.5 kΩ.

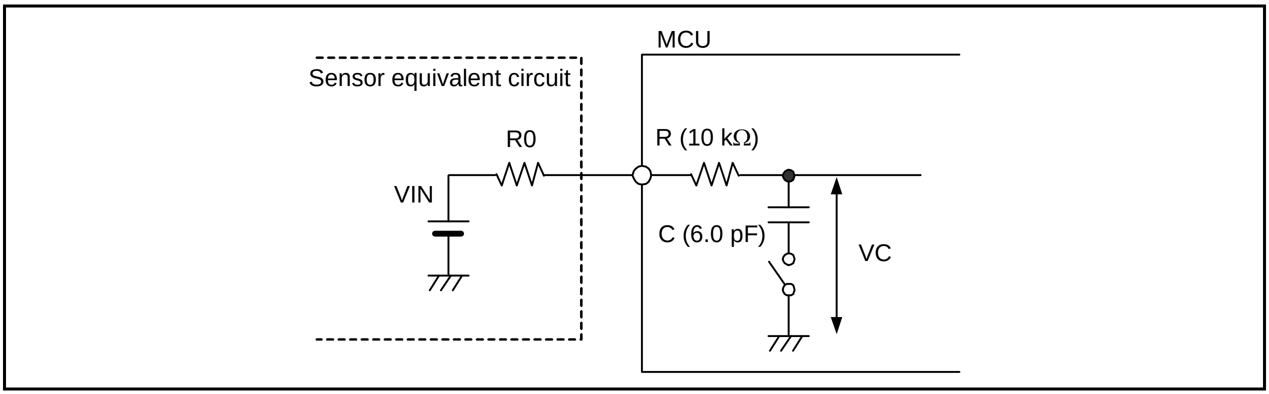


Figure 27.16 Analog Input Pin and External Sensor Equivalent Circuit

27.6 Interrupt

Refer to the operation examples for timing of generating interrupt requests.

Also, refer to 14.7 “Interrupt Control” for details. Table 27.18 lists Registers Associated with A/D Converter Interrupt.

Table 27.18 Registers Associated with A/D Converter Interrupt

Address	Register	Symbol	Reset Value
004Eh	A/D Conversion Interrupt Control Register	ADIC	XXXX X000b

27.7 Notes on A/D Converter

27.7.1 Analog Input Voltage

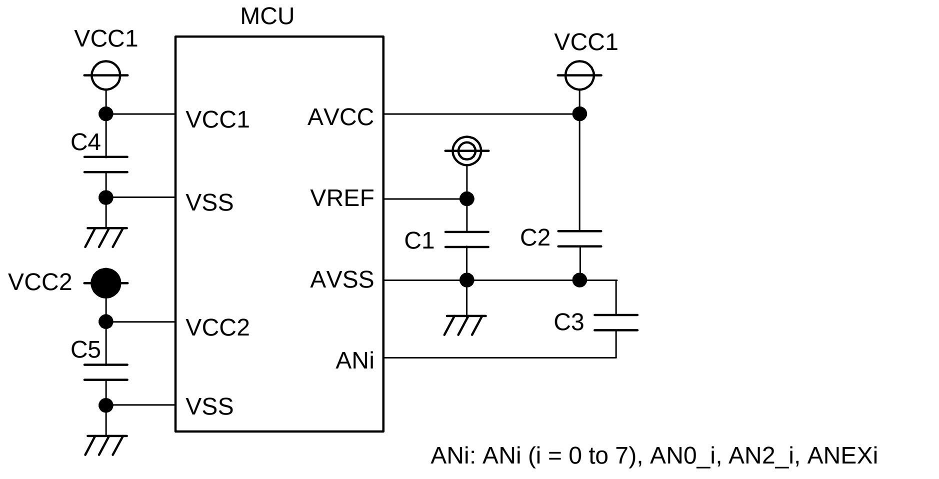
Set the analog input voltage as follows:
analog input voltage (AN_0 to AN_7, ANEX0, and ANEX1) ≤ VCC1
analog input voltage (AN0_0 to AN0_7 and AN2_7 to AN2_7) ≤ VCC2

27.7.2 Analog Input Pin

Do not use any pin from AN4 to AN7 as analog input pin if any pin from $\overline{\text{KI0}}$ to $\overline{\text{KI3}}$ is used as a key input interrupt.

27.7.3 Pin Configuration

To prevent operation errors due to noise or latchup, and to reduce conversion errors, place capacitors between the AVSS pin and the AVCC pin, the VREF pin, and analog inputs (ANi (i = 0 to 7), ANEXi, AN0_i, and AN2_i). Also, place a capacitor between the VCC1 pin and VSS pin.



ANi: ANi (i = 0 to 7), AN0_i, AN2_i, ANEXi

Notes:
1. Reference values: C1 ≥ 0.1 μF, C2 ≥ 0.1 μF, C3 ≥ 100 pF, C4 ≥ 0.1 μF, C5 ≥ 0.1 μF.
2. The traces for the capacitor and MCU should be short and wide as much as physically possible.

Figure 27.17 Example of Pin Configuration

27.7.4 Register Access

Set registers associated with A/D converter after setting the CKS3 bit in the ADCON2 register. However the other bits in the ADCON2 register and the CKS3 bit can be set at the same time. After changing the CKS3 bit, set the others in the same way.
Write registers ADCON0 (excluding the ADST bit), ADCON1, and ADCON2 when A/D conversion stops (before a trigger is generated).
After A/D conversion stops, set the ADSTBY bit in the ADCON1 register from 1 to 0.

27.7.5 A/D Conversion Start

When rewriting the ADSTBY bit in the ADCON1 register from 0 (A/D operation stopped) to 1 (A/D operation enabled), wait for one ϕAD cycle or more before starting A/D conversion.

27.7.6 A/D Operation Mode Change

When the A/D operation mode has been changed, reselect analog input pins by using bits CH2 to CH0 in the ADCON0 register or bits SCAN1 to SCAN0 in the ADCON1 register.

27.7.7 State When Forcibly Terminated

If A/D conversion in progress is halted by setting the ADST bit in the ADCON0 register to 0 (A/D conversion stopped), the conversion result is undefined. In addition, the unconverted ADi register (i = 0 to 7) may also become undefined. Do not use any value in ADi registers when setting the ADST bit to 0 by a program during A/D conversion.

27.7.8 A/D Open-Circuit Detection Assist Function

The conversion result in open-circuit depends on the external circuit. Use this function only after careful evaluation of the system. Do not use this function when VCC1 > VCC2.

When A/D conversion starts after changing the AINRST register, follow these steps:

(1) Change bits AINRST1 to AINRST0 in the AINRST register.

(2) Wait for one cycle of ϕAD.

(3) Set the ADST bit in the ADCON0 register to 1 (A/D conversion started).

27.7.9 Detecting Completion of A/D Conversion

In one-shot mode and single sweep mode, use the IR bit in the ADIC register to detect completion of A/D conversion. When not using an interrupt, set the IR bit to 0 by a program after detection.

When 1 is written to the ADST bit in the ADCON0 register, the ADST bit becomes 1 (A/D conversion start) after start processing time elapses (see Table 27.7 “Cycles of A/D Conversion Item”). Therefore when reading the ADST bit immediately after writing 1, 0 (A/D conversion stop) may be read.

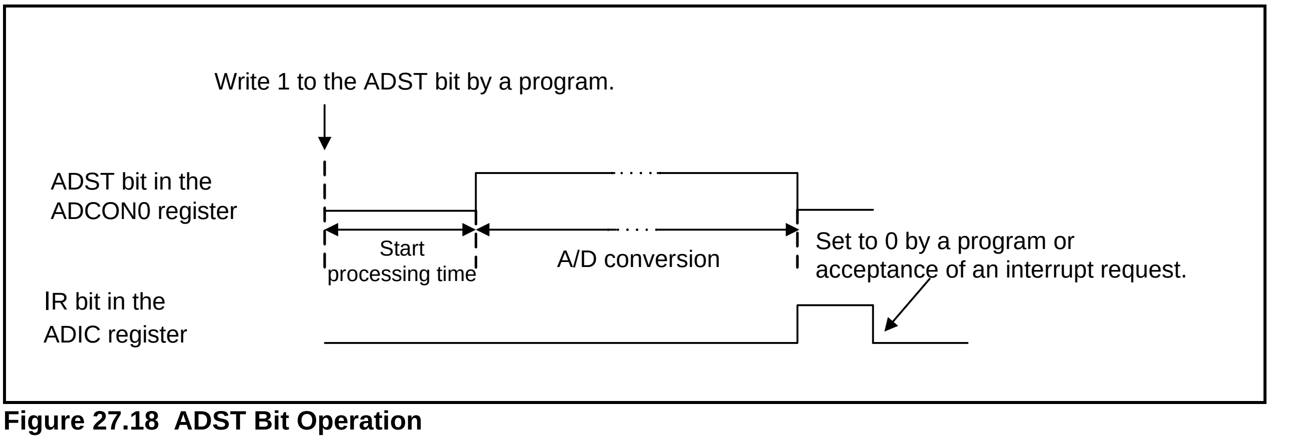

Write 1 to the ADST bit by a program.
ADST bit in the ADCON0 register
Start processing time
A/D conversion
Set to 0 by a program or acceptance of an interrupt request.
IR bit in the ADIC register

Figure 27.18 ADST Bit Operation

27.7.10 ϕAD

Divide fAD so ϕAD conforms to the standard frequency.

In particular, consider the maximum and minimum values of fOCO40M when the CKS3 bit in the ADCON2 register is 1 (fOCO40M is fAD).

28. D/A Converter

28.1 Introduction

The D/A converter is an 8-bit, R-2R type converter. There are two independent D/A converters.
Table 28.1 lists the D/A Converter Specifications and Figure 28.1 shows the D/A Converter Block Diagram.

Table 28.1 D/A Converter Specifications

Item	Specification
D/A conversion method	R-2R
Resolution	8 bits

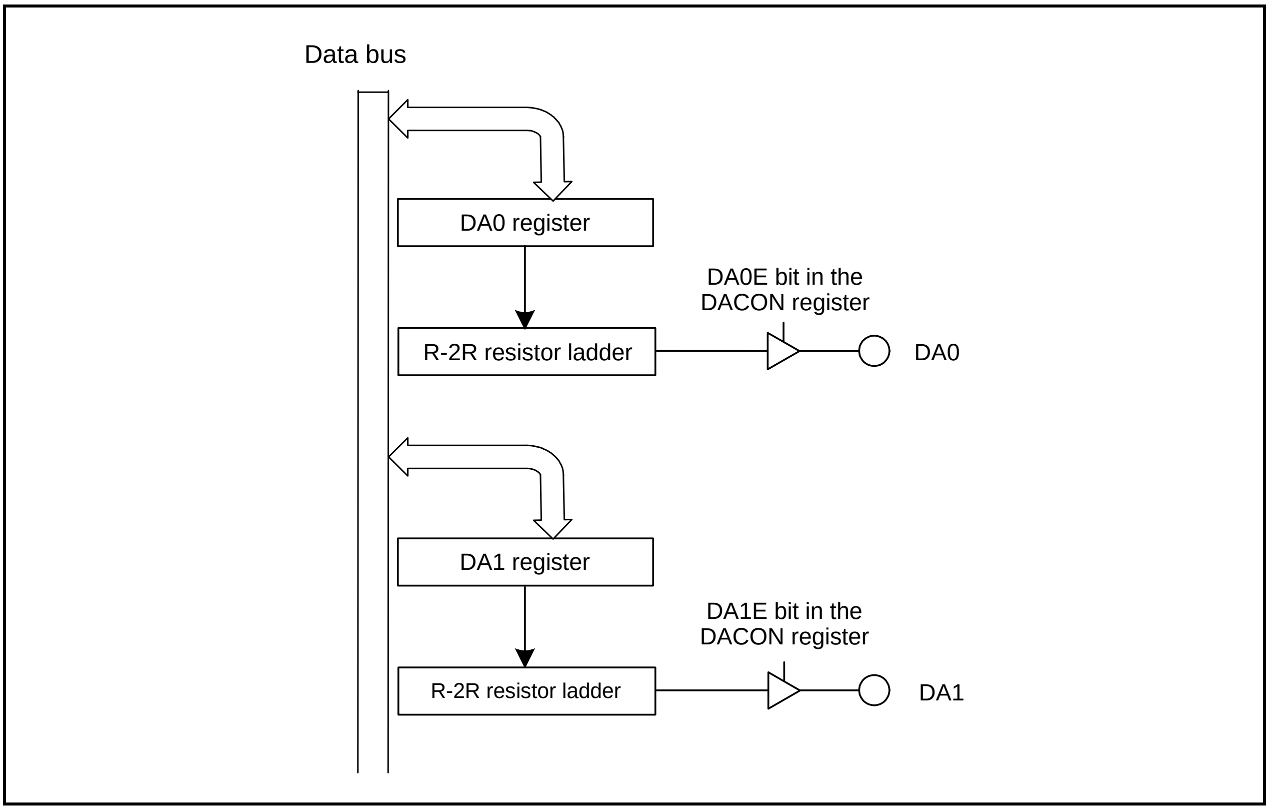


Figure 28.1 D/A Converter Block Diagram

Table 28.2 I/O Ports

Pin Name	I/O	Function
DA0	Output [1]	D/A comparator output
DA1		

Note:

1. Set the direction bit of the ports sharing a pin to 0 (input mode). When the DAiE bit (i = 0, 1) in the DACON register is set to 1 (output enabled), the corresponding port cannot be pulled up.

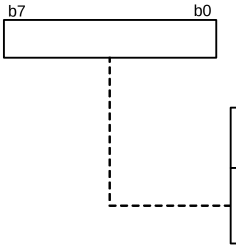
28.2 Registers

Table 28.3 Registers

Address	Register	Symbol	Reset Value
03D8h	D/A0 Register	DA0	00h
03DAh	D/A1 Register	DA1	00h
03DCh	D/A Control Register	DACON	00h

28.2.1 D/Ai Register (DAi) (i = 0, 1)

D/Ai Register (i = 0, 1)

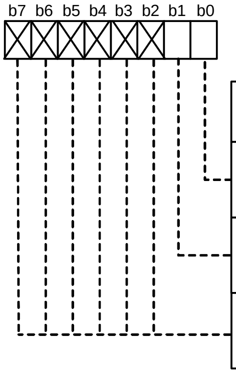


Symbol	Address	Reset Value
DA0	03D8h	00h
DA1	03DAh	00h

Function	Setting Range	RW
Output value of D/A conversion	00h to FFh	RW

28.2.2 D/A Control Register (DACON)

D/A Control Register



Symbol	Address	Reset Value
DACON	03DCh	00h

Bit Symbol	Bit Name	Function	RW
DA0E	D/A0 output enable bit	0 : Output disabled 1 : Output enabled	RW
DA1E	D/A1 output enable bit	0 : Output disabled 1 : Output enabled	RW
— (b7-b2)	No register bits. If necessary, set to 0. The read values are undefined.		—

28.3 Operations

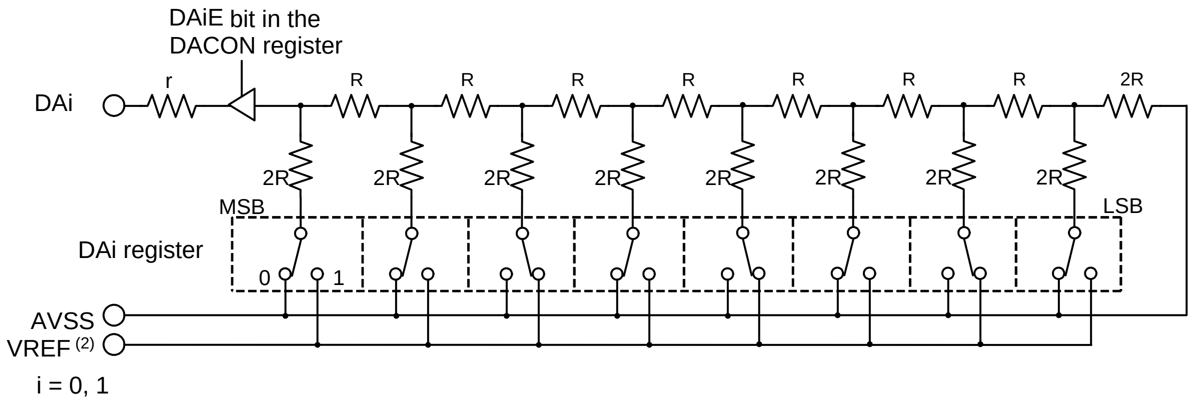
D/A conversion is performed by writing a value to the DAi register (i = 0, 1).

Output analog voltage (V) is determined by the value n (n = decimal) set in the DAi register.

$$V = VREF \times \frac{n}{256} \quad (n = 0 \text{ to } 255)$$

VREF: Reference voltage

Figure 28.2 shows the D/A Converter Equivalent Circuit.



Notes:

1. The above diagram assumes the DAi register is 2Ah.
2. VREF is not related to the ADSTBY bit in the ADCON1 register.

Figure 28.2 D/A Converter Equivalent Circuit

28.4 Notes on D/A Converter

28.4.1 When Not Using the D/A Converter

When not using the D/A converter, set the DAiE bit (i = 0, 1) in the DACON register to 0 (output disabled) and the DAi register to 00h in order to minimize unnecessary current consumption and prevent current flow to the R-2R resistor.

29. CRC Calculator

29.1 Introduction

The cyclic redundancy check (CRC) calculator detects errors in data blocks. This CRC calculator is enhanced by an additional feature, the CRC snoop, in order to monitor reads from and writes to a certain SFR address, and perform CRC calculations automatically on the data read from and data written to the aforementioned SFR address.

Table 29.1 CRC Calculator Specifications

Item	Specification
Generator polynomial	CRC-CCITT ($X^{16} + X^{12} + X^5 + 1$) or CRC-16 ($X^{16} + X^{15} + X^2 + 1$)
Selectable functions	• MSB/LSB selectable • CRC snoop

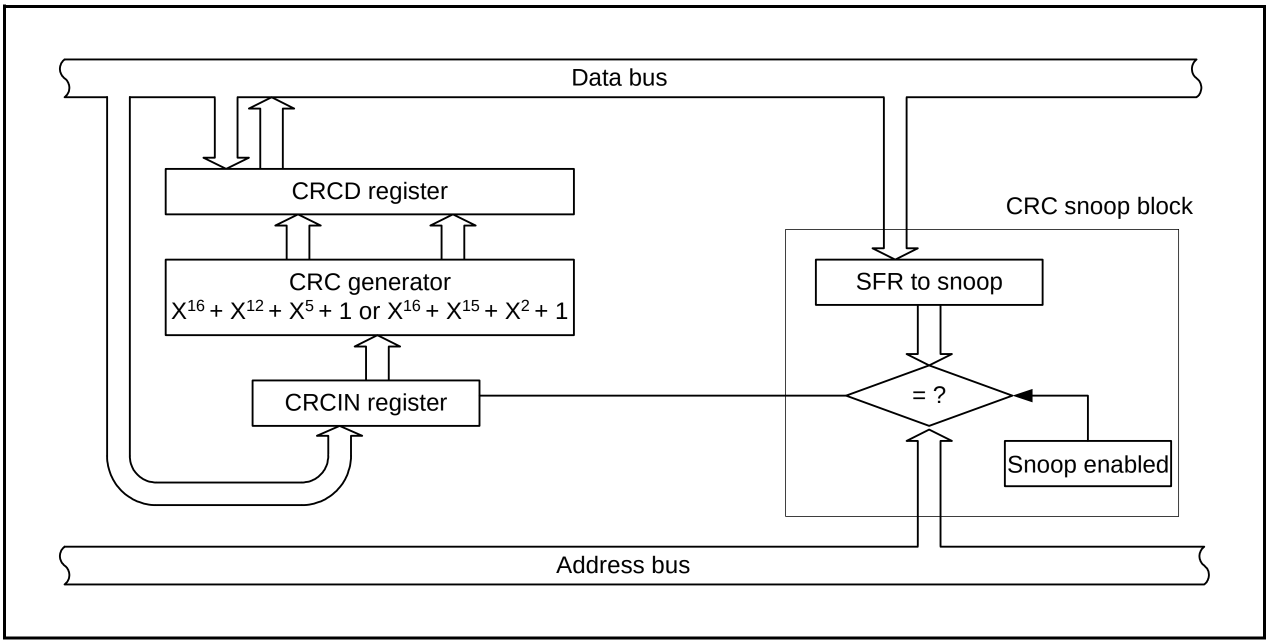


Figure 29.1 CRC Calculator Block Diagram

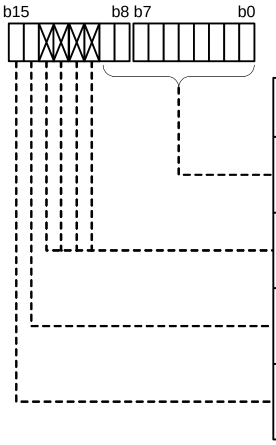
29.2 Registers

Table 29.2 Registers

Address	Register	Symbol	Reset Value
03B4h	SFR Snoop Address Register	CRCSAR	XXXX XXXXb
03B5h			00XX XXXXb
03B6h	CRC Mode Register	CRCMR	0XXX XXX0b
03BCh	CRC Data Register	CRCD	XXh
03BDh			XXh
03BEh	CRC Input Register	CRCIN	XXh

29.2.1 SFR Snoop Address Register (CRCSAR)

SFR Snoop Address Register



Symbol	Address	Reset Value
CRCSAR	03B5h to 03B4h	00XX XXXX XXXX XXXXb

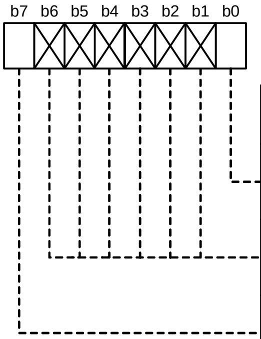
Bit Symbol	Bit Name	Function	RW
CRCSAR9 to CRCSAR0	SFR snoop address bit	Set the SFR address to snoop	RW
— (b13-b10)	No register bits. If necessary, set to 0. The read value is undefined.		—
CRCSR	Snoop-on-read enable bit	0: Disabled 1: Enabled	RW
CRCSW	Snoop-on-write enable bit	0: Disabled 1: Enabled	RW

CRCSR (Snoop-on-read enable bit) (b14)
CRCSW (Snoop-on-write enable bit) (b15)

Do not set bits CRCSR and CRCSW to 1 at the same time. Set the CRCSR bit to 0 when the CRCSW bit is 1. Set the CRCSW bit to 0 when the CRCSR bit is 1.

29.2.2 CRC Mode Register (CRCMR)

CRC Mode Register

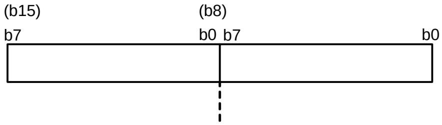


Symbol	Address	Reset Value
CRCMR	03B6h	0XXX XXX0b

Bit Symbol	Bit Name	Function	RW
CRCPS	CRC polynomial select bit	0: $X^{16} + X^{12} + X^5 + 1$ (CRC-CCITT) 1: $X^{16} + X^{15} + X^2 + 1$ (CRC-16)	RW
— (b6-b1)	No register bits. If necessary, set to 0. The read value is undefined.		—
CRCMS	CRC mode select bit	0: LSB first 1: MSB first	RW

29.2.3 CRC Data Register (CRCD)

CRC Data Register



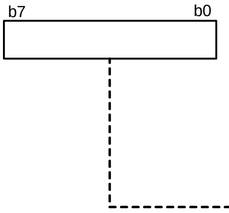
Symbol	Address	Reset Value
CRCD	03BDh to 03BCh	Undefined

Function	Setting Range	RW
When data is written to the CRCIN register after setting the initial value in the CRCD register, the CRC code can be read from this register.	0000h to FFFFh	RW

Write 0000h to the CRCD register and then write the first data to the CRCIN register. Execute this operation every time CRC calculation is performed. Refer to the setting procedures described in Figure 29.2 “CRC Calculation When Using CRC-CCITT” and Figure 29.3 “CRC Calculation When Using CRC-16”.

29.2.4 CRC Input Register (CRCIN)

CRC Input Register



Symbol	Address	Reset Value
CRCIN	03BEh	Undefined

Function	Setting Range	RW
Data input	00h to FFh	RW

29.3 Operations

29.3.1 Basic Operation

The CRC (Cyclic Redundancy Check) calculator detects errors in data blocks. The MCU uses two generator polynomials to generate CRC: CRC-CCITT ($X^{16} + X^{12} + X^5 + 1$) and CRC-16 ($X^{16} + X^{15} + X^2 + 1$).

The CRC code is 16-bit code generated for a given length of a data block in 8-bit units. After setting the default value in the CRCD register, the CRC code is stored in the CRCD register every time 1-byte of data is written to the CRCIN register. CRC code generation for 1-byte data is completed in two CPU clock cycles.

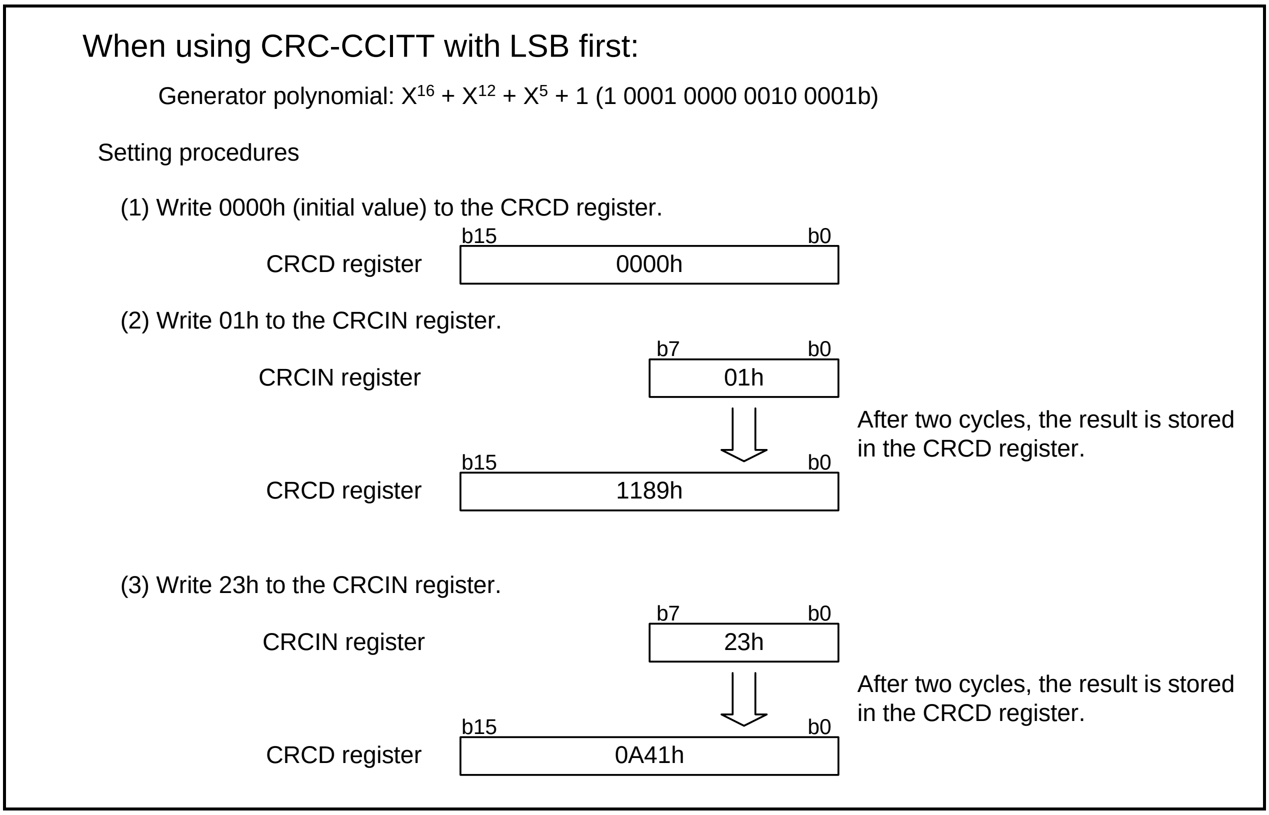
29.3.2 CRC Snoop

The CRC snoop monitors reads from and writes to a certain SFR address and performs CRC calculation on the data read from and written to the aforementioned SFR address automatically. Because the CRC snoop recognizes writes to and reads from a certain SFR address as a trigger to automatically perform CRC calculation, there is no need to write data to the CRCIN register. All SFR addresses from 0020h to 03FFh are subject to the CRC snoop. The CRC snoop is useful in monitoring writes to the UART transmit buffer, and reads from the UART receive buffer.

To use this function, write a target SFR address to bits CRCSAR9 to CRCSAR0 in the CRCSAR register. Then, set the CRCSW bit in the CRCSAR register to 1 to enable snooping on writes to the target, or set the CRCSR bit in the CRCSAR register to 1 to enable snooping on reads from the target.

When setting the CRCSW bit to 1 and writing data to a target SFR address by CPU or DMA, the CRC calculator stores the data in the CRCIN register and performs CRC calculation. Similarly, when setting the CRCSR bit to 1 and reading data in a target SFR address by CPU or DMA, the CRC calculator stores the data in the CRCIN register and performs CRC calculation.

CRC calculation is performed 1-byte at a time. When the target SFR address is accessed in words (16 bits), CRC code is generated on the lower byte (1 byte) of data.



When using CRC-CCITT with LSB first:

Generator polynomial: $X^{16} + X^{12} + X^{5} + 1$ (1 0001 0000 0010 0001b)

Setting procedures

(1) Write 0000h (initial value) to the CRCD register.

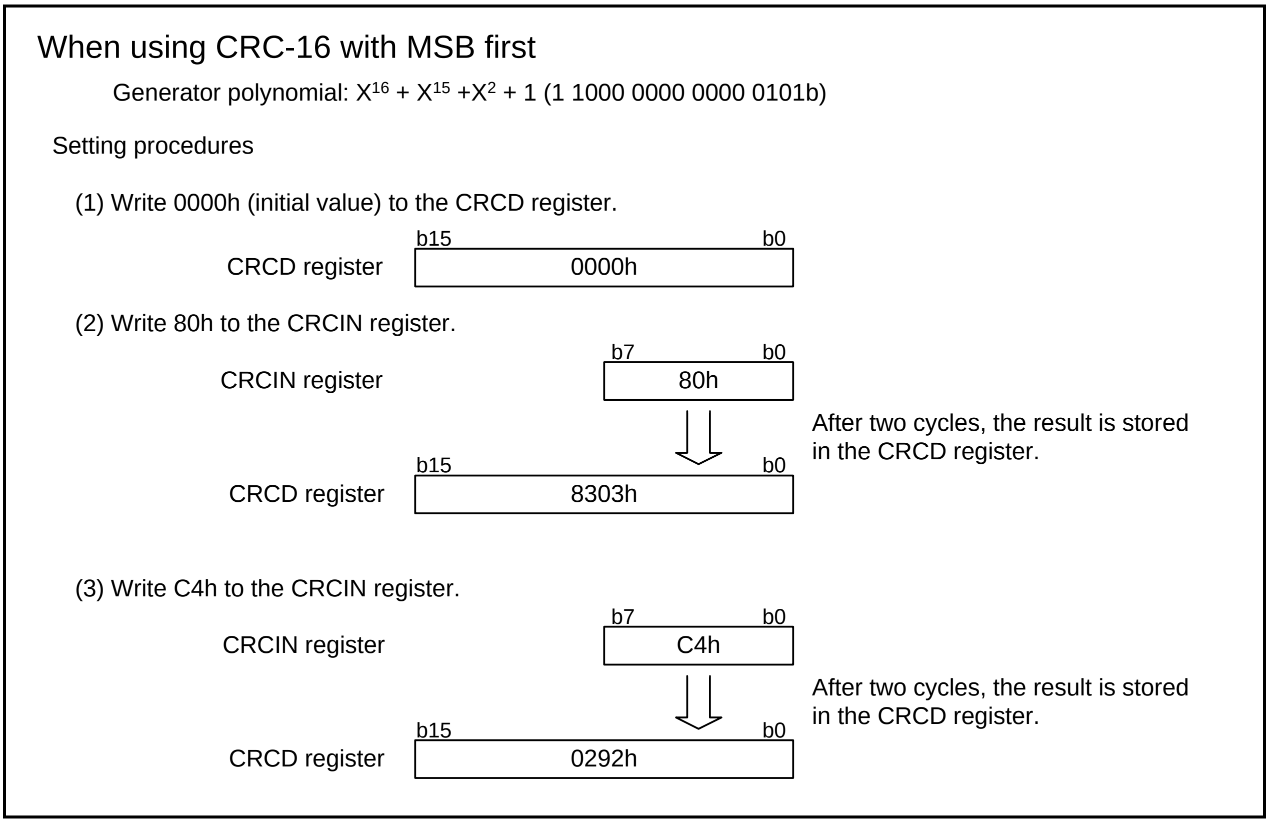
(2) Write 01h to the CRCIN register.

After two cycles, the result is stored in the CRCD register.

(3) Write 23h to the CRCIN register.

After two cycles, the result is stored in the CRCD register.

Figure 29.2 CRC Calculation When Using CRC-CCITT



When using CRC-16 with MSB first

Generator polynomial: $X^{16} + X^{15} + X^{2} + 1$ (1 1000 0000 0000 0101b)

Setting procedures

(1) Write 0000h (initial value) to the CRCD register.

(2) Write 80h to the CRCIN register.

After two cycles, the result is stored in the CRCD register.

(3) Write C4h to the CRCIN register.

After two cycles, the result is stored in the CRCD register.

Figure 29.3 CRC Calculation When Using CRC-16

30. Flash Memory

Note

There are no P11 to P14 in the 100-pin package. For the 100-pin package, do not use these pins for the entry of user boot function.

30.1 Introduction

This product uses flash memory as ROM. In this chapter, flash memory refers to the flash memory inside the MCU.

In this product, the flash memory can perform in three rewrite modes: CPU rewrite mode, standard serial I/O mode, and parallel I/O mode.

Table 30.1 lists Flash Memory Specifications (see Table 1.1 to Table 1.4 “Specifications” for the items not listed in Table 30.1).

Table 30.1 Flash Memory Specifications

Item		Specification
Flash memory rewrite modes		3 modes (CPU rewrite, standard serial I/O, and parallel I/O)
Erase block	Program ROM 1	See Figure 30.1 “Flash Memory Block Diagram”.
	Program ROM 2	1 block (16 KB)
	Data flash	2 blocks (4 KB each)
Program method		In 2-word (4-byte) units
Erase method		Block erase
Program and erase control method		Program and erase controlled by software commands
Suspend function		Program suspend and erase suspend
Protect method		A lock bit protects each block.
Number of commands		8
Program and erase cycles	Program ROM 1 and program ROM 2	1,000 times (1)
	Data flash	10,000 times (1)
Data retention		20 years
Flash memory rewrite disable function		Parallel I/O mode ROM code protect function Standard serial I/O mode ID code check function, forced erase function, and standard serial I/O mode disable function
User boot function		User boot mode

Note:

1. Definition of program and erase cycles:
   The program and erase cycles is the number of erase operations performed on a per-block basis. For example, assume that a 4 KB block is programmed in 1,024 operations, writing 2 words at a time, and erased thereafter. In this case, the block is considered to have been programmed and erased once.
   If the program and erase cycles are 1,000 times, each block can be erased up to 1,000 times.

Table 30.2 Flash Memory Rewrite Modes Overview

Flash Memory Rewrite Mode	CPU Rewrite Mode	Standard Serial I/O Mode	Parallel I/O Mode
Function	The flash memory is rewritten when the CPU executes software commands. EW0 mode: Rewritable in areas other than the flash memory EW1 mode: Rewritable in the flash memory	The flash memory is rewritten using a dedicated serial programmer. Standard serial I/O mode 1: Clock synchronous serial I/O Standard serial I/O mode 2: 2-wire clock asynchronous serial I/O	The flash memory is rewritten using a dedicated parallel programmer.
Areas which can be rewritten	Program ROM 1, program ROM 2, and data flash	Program ROM 1, program ROM 2, and data flash	Program ROM 1, program ROM 2, and data flash
CPU operating mode	Single-chip mode Memory expansion mode (EW0 mode)	Boot mode	Parallel I/O mode
ROM programmer	None	Serial programmer	Parallel programmer
On-board rewrite	Available	Available	Unavailable

30.2 Memory Map

The flash memory is used as ROM in this product. The flash memory is comprised of program ROM 1, program ROM 2, and data flash. Figure 30.1 shows the Flash Memory Block Diagram.

The flash memory is divided into several blocks, each of which can be protected (locked) from being programmed or erased. The flash memory can be rewritten in CPU rewrite, standard serial I/O, and parallel I/O modes.

Program ROM 2 can be used when the PRG2C0 bit in the PRG2C register is 0 (program ROM 2 enabled).

Data flash can be used when the PM10 bit in the PM1 register is set to 1 (0E000h to 0FFFFh: data flash). Data flash is divided into block A and block B.

Table 30.3 lists the differences among program ROM 1, program ROM 2, and data flash.

In single-chip mode or memory expansion mode, program can be allocated in either program ROM 1, program ROM 2, or data flash.

Table 30.3 Program ROM 1, Program ROM 2, and Data Flash

Item	Flash Memory		
	Program ROM 1	Program ROM 2	Data flash
Program and erase cycles	1,000 times		10,000 times
Forced erase function	Enabled		Disabled
Frequency limit when reading	No		Yes
User boot program	Do not allocate	Allocatable	Do not allocate

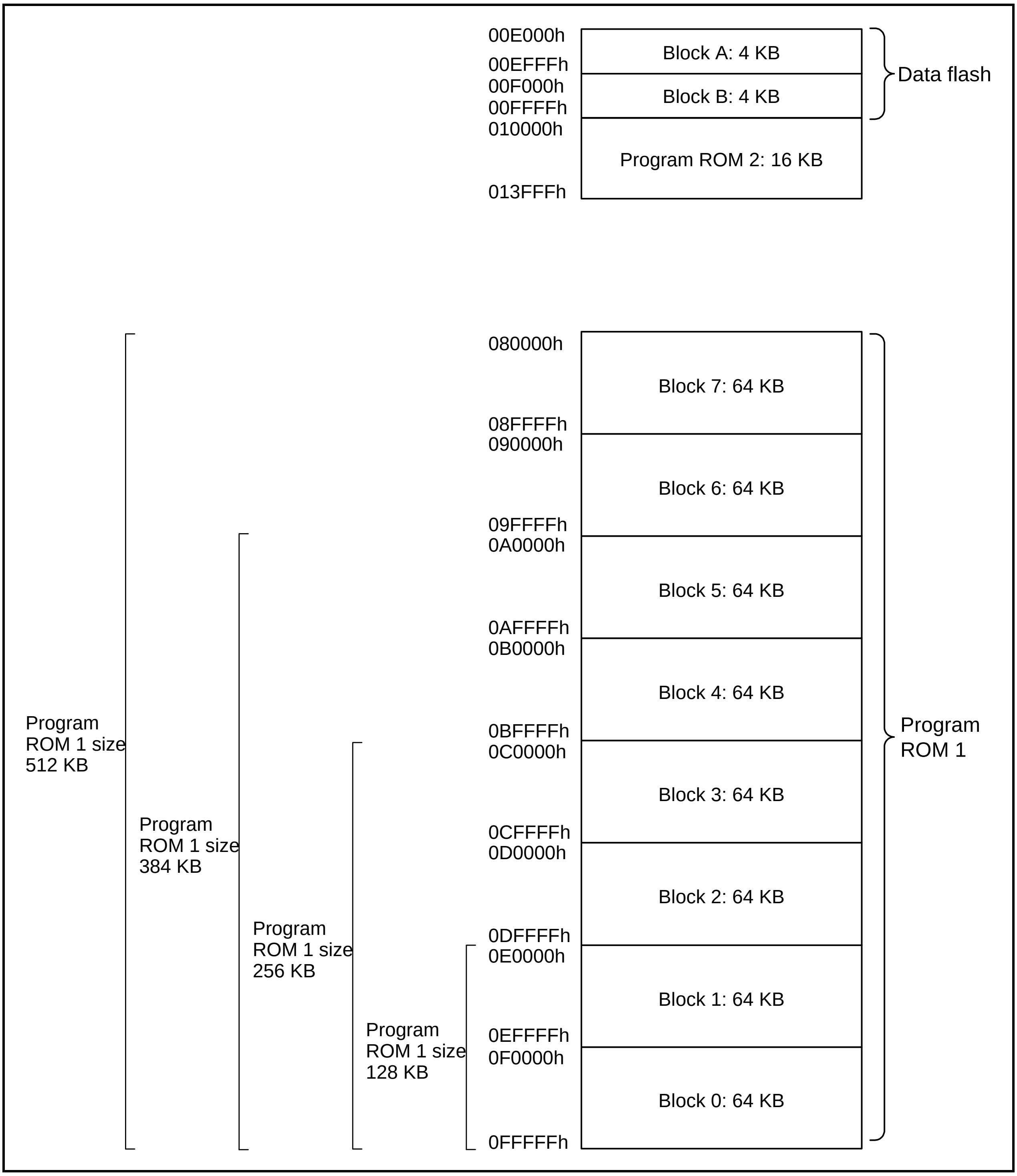


Figure 30.1 Flash Memory Block Diagram

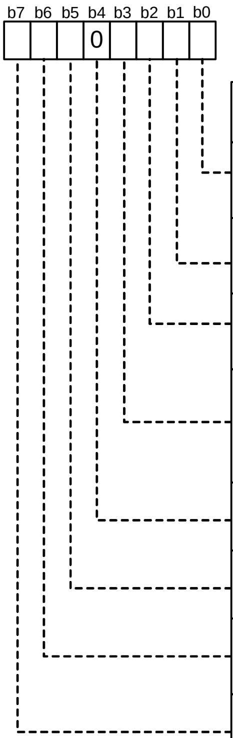
30.3 Registers

Table 30.4 Registers

Address	Register	Symbol	Reset Value
0220h	Flash Memory Control Register 0	FMR0	0000 0001b (Other than user boot mode) 0010 0001b (User boot mode)
0221h	Flash Memory Control Register 1	FMR1	00X0 XX0Xb
0222h	Flash Memory Control Register 2	FMR2	XXXX 0000b
0223h	Flash Memory Control Register 3	FMR3	XXXX 0000b
0230h	Flash Memory Control Register 6	FMR6	XX0X XX00b

30.3.1 Flash Memory Control Register 0 (FMR0)

Flash Memory Control Register 0



Symbol FMR0

Address 0220h

Reset Value
0000 0001b (other than user boot mode)
0010 0001b (user boot mode)

Bit Symbol	Bit Name	Function	RW
FMR00	RY/$\overline{\text{BY}}$ status flag	0 : Busy (being written or erased) 1 : Ready	RO
FMR01	CPU rewrite mode select bit	0 : CPU rewrite mode disabled 1 : CPU rewrite mode enabled	RW
FMR02	Lock bit disable select bit	0 : Lock bit enabled 1 : Lock bit disabled	RW
FMSTP	Flash memory stop bit	0 : Flash memory operation enabled 1 : Flash memory operation stopped (low power-mode, flash memory initialized)	RW
— (b4)	Reserved bit	Set to 0	RW
— (b5)	Reserved bit	Set to 0 in other than user boot mode Set to 1 in user boot mode	RW
FMR06	Program status flag	0 : Completed as expected 1 : Completed in error	RO
FMR07	Erase status flag	0 : Completed as expected 1 : Completed in error	RO

FMR00 (RY/$\overline{\text{BY}}$ status flag) (b0)

This bit indicates the flash memory operating state.

Conditions to become 0:

- When executing the following commands:
  Program, block erase, lock bit program, read lock bit status, and block blank check
- When the flash memory stops (the FMSTP bit is 1)
- During the wake up operation when the FMSTP bit is changed from 1 to 0

Condition to become 1:

- Other than those above.

FMR01 (CPU rewrite mode select bit) (b1)

Commands can be accepted by setting the FMR01 bit to 1 (CPU rewrite mode enabled).
To set the FMR01 bit to 1, write 0 and then 1 in succession. Do not generate any interrupts or DMA transfers between setting 0 and 1.
Change the FMR01 bit when the PM24 bit in the PM2 register is 0 ($\overline{\text{NMI}}$ interrupt disabled) or high is input to the $\overline{\text{NMI}}$ pin.
While in EW0 mode, write to this bit from a program in an area other than flash memory.
Enter read array mode, and then set this bit to 0.

FMR02 (Lock bit disable select bit) (b2)

The lock bit is disabled by setting the FMR02 bit to 1 (lock bit disabled) (Refer to 30.8.4 “Data Protect Function”).
The FMR02 bit does not change the lock bit data, but disables the lock bit function. If an erase command is executed when the FMR02 bit is set to 1, the lock bit data status changes from 0 (locked) to 1 (unlocked) after command execution is completed.
To set the FMR02 bit to 1, write 0 and then 1 to the FMR02 bit in succession when the FMR01 bit is 1. Make sure no interrupts or DMA transfers will occur before writing 1 after writing 0.
Do not change the FMR02 bit while programming, erasing or suspending.

FMSTP (Flash memory stop bit) (b3)

The FMSTP bit resets the flash memory control circuits and minimizes current consumption in the flash memory. Access to the internal flash memory is disabled when the FMSTP bit is set to 1 (flash memory operation stopped). Set the FMSTP bit by a program located in an area other than the flash memory.
Set the FMSTP bit to 1 under the following condition:

- A flash memory access error occurs while erasing or programming in EW0 mode (the FMR00 bit does not revert to 1 (ready)).

After the FMSTP bit is set to 0 (Flash memory operation enabled), wait until the flash memory circuit stabilizes (tps), then perform the next operation.
Also when the FMSTP bit is set to 0 immediately after this bit is set to 1, wait for tps after the bit is set to 1. The procedure for this case is described below.

(1) Set the FMSTP bit to 1.
(2) Wait until the flash memory circuit stabilizes (tps).
(3) Set the FMSTP bit to 0.
(4) Wait for tps.

The FMSTP bit is enabled when the FMR01 bit is 1 (CPU rewrite mode). When the FMR01 bit is 0, although the FMSTP bit can be set to 1 by writing 1, the flash memory is neither placed in low-power mode nor initialized.
When the FMR22 bit is 1 (slow read mode enabled) or the FMR23 bit is 1 (low-current consumption read mode enabled), do not set the FMSTP bit in the FMR0 register to 1 (flash memory operation stopped). Also, when the FMSTP bit is 1, do not set the FMR22 or FMR23 bit to 1.

FMR06 (Program status flag) (b6)

This bit indicates the auto-program operation state.
Condition to become 0:

- Execute the clear status command.

Condition to become 1:

- Refer to 30.8.7.1 “Full Status Check”.

Do not execute the following commands when the FMR06 bit is 1:
Program, block erase, lock bit program, and block blank check.

FMR07 (Erase status flag) (b7)

This bit indicates the auto-erase operation state.
Condition to become 0:

- Execute the clear status command

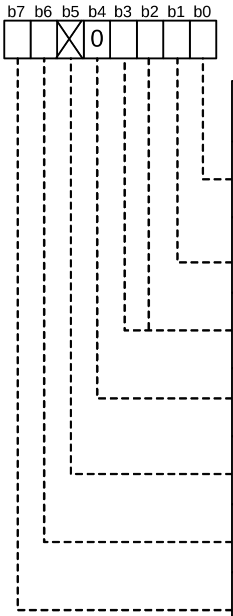
Condition to become 1:

- Refer to 30.8.7.1 “Full Status Check”.

Do not execute the following commands when the FMR07 bit is 1:
Program, block erase, lock bit program, and block blank check.

30.3.2 Flash Memory Control Register 1 (FMR1)

Flash Memory Control Register 1



Symbol	Address	Reset Value
FMR1	0221h	00X0 XX0Xb

Bit Symbol	Bit Name	Function	RW
— (b0)	Reserved bit	The read value is undefined.	RO
FMR11	Write to FMR6 register enable bit	0 : Disabled 1 : Enabled	RW
— (b3-b2)	Reserved bits	The read value is undefined.	RO
— (b4)	Reserved bit	Set to 0	RW
— (b5)	No register bit. If necessary, set to 0. The read value is undefined.		—
FMR16	Lock bit status flag	0 : Lock 1 : Unlock	RO
FMR17	Data flash wait bit	0 : 1 wait 1 : Follow the setting of the PM17 bit in the PM1 register	RW

FMR11 (Write to FMR6 register enable bit) (b1)

Change FMR11 bit when the PM24 bit in the PM2 register is 0 ($\overline{\text{NMI}}$ interrupt disabled) or high is input to the $\overline{\text{NMI}}$ pin.

FMR16 (Lock bit status flag) (b6)

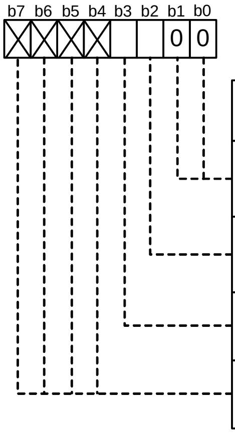
This bit indicates the execution result of the read lock bit status command.

FMR17 (Data flash wait bit) (b7)

This bit is used to select the number of waits for data flash.
When setting this bit to 0, one wait is inserted to the read cycle of the data flash. The write cycle is not affected.

30.3.3 Flash Memory Control Register 2 (FMR2)

Flash Memory Control Register 2



Symbol	Address	Reset Value
FMR2	0222h	XXXX 0000b

Bit Symbol	Bit Name	Function	RW
— (b1-b0)	Reserved bits	Set to 0	RW
FMR22	Slow read mode enable bit	0 : Disabled 1 : Enabled	RW
FMR23	Low current consumption read mode enable bit	0 : Disabled 1 : Enabled	RW
— (b7-b4)	No register bits. If necessary, set to 0. The read value is undefined.		—

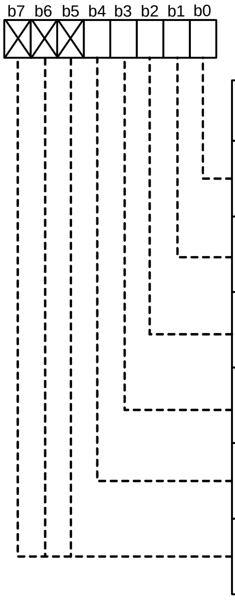
FMR22 (Slow read mode enable bit) (b2)

FMR23 (Low-current consumption read mode enable bit) (b3)

Refer to 9.4 “Power Control in Flash Memory”.

30.3.4 Flash Memory Control Register 3 (FMR3)

Flash Memory Control Register 3



Symbol	Address	Reset Value
FMR3	0223h	XXXX 0000b

Bit Symbol	Bit Name	Function	RW
FMR30	Suspend function enable bit	0 : Disabled 1 : Enabled	RW
FMR31	Suspend request bit	0 : Command restart 1 : Suspend request	RW
FMR32	Erase suspend status flag	0 : Erase suspend not accepted 1 : Erase suspend accepted	RO
FMR33	Program suspend status flag	0 : Program suspend not accepted 1 : Program suspend accepted	RO
— (b4)	Reserved bit	The read value is undefined.	RO
— (b7-b5)	No register bits. If necessary, set to 0. The read value is undefined.		—

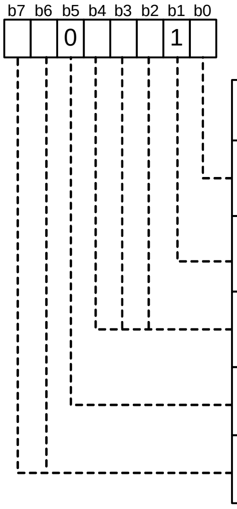
FMR30 (Suspend function enable bit) (b0)

To set the FMR30 bit to 1, write 0 and then 1 in succession. Make sure no interrupts or DMA transfers will occur before writing 1 after writing 0.

30.3.5 Flash Memory Control Register 6 (FMR6)

Flash Memory Control Register 6

Symbol	Address	Reset Value
FMR6	0230h	XX0X XX00b



Bit Symbol	Bit Name	Function	RW
FMR60	EW1 mode select bit	0 : EW0 mode 1 : EW1 mode	RW
FMR61	Reserved bit	Set to 1	RW
— (b4-b2)	Reserved bits	The read value is undefined.	RO
— (b5)	Reserved bit	Set to 0	RW
— (b7-b6)	Reserved bits	The read value is undefined.	RO

When accessing the FMR6 register, select a CPU clock frequency of 10 MHz or less by setting the CM06 bit in the CM0 register and bits CM17 and CM16 in the CM1 register. Also, set the PM17 bit in the PM1 register to 1 (wait state).

FMR60 (EW1 mode select bit) (b0)

To set the FMR60 bit to 1, write 1 when both FMR01 bit in the FMR0 register and FMR11 bit in the FMR1 register are 1.

Change the FMR60 bit when the PM24 bit in the PM2 register is 0 ($\overline{\text{NMI}}$ interrupt disabled) or high is input to the $\overline{\text{NMI}}$ pin. Also, change this bit when the FMR00 bit in the FMR0 register is 1 (ready).

FMR61 (b1)

Set the FMR61 bit to 1 when using CPU rewrite mode.

30.4 Optional Function Select Area

In an option function select area, the MCU state after reset and the function to prevent rewrite in parallel I/O mode are selected.

The option function select area is not an SFR, and therefore cannot be rewritten by a program. Set an appropriate value when writing a program to the flash memory. The entire option function select area becomes FFh when the block including the option function select area is erased.

In blank products, the OFS1 address value is FFh when shipped. After a value is written by the user, this address takes on the written value. In programmed products, the OFS1 address is the value set in the user program prior to shipping.

Selection using the optional function select area can be used in single-chip mode or memory expansion mode. The option function select area cannot be used in microprocessor mode. When using the MCU in microprocessor mode, clear the internal ROM.

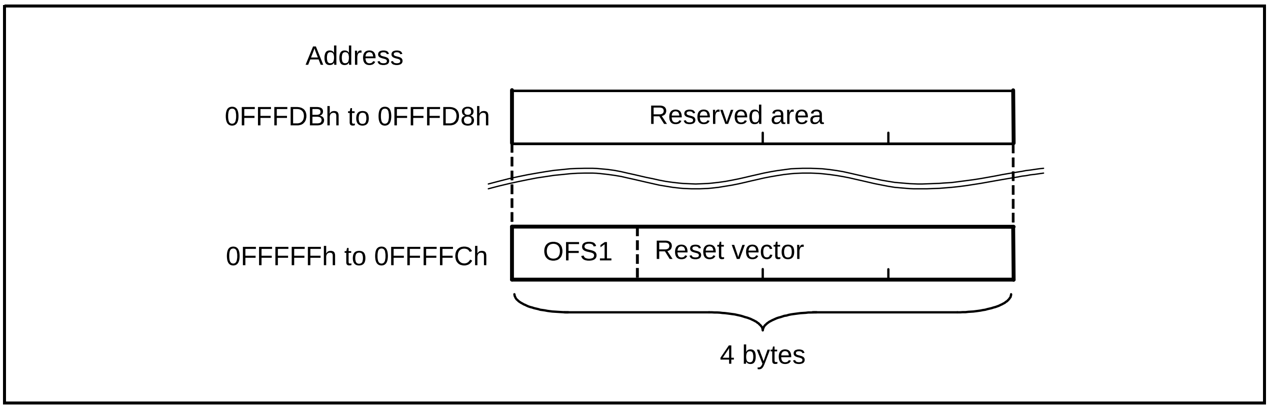


Figure 30.2 Option Function Select Area

30.4.1 Optional Function Select Address 1 (OFS1)

Optional Function Select Address 1

b7	b6	b5	b4	b3	b2	b1	b0
			1			1	

Symbol OFS1

Address FFFFFh

Bit Symbol	Bit Name	Function
WDTON	Watchdog timer start select bit	0 : Watchdog timer starts automatically after reset 1 : Watchdog timer is stopped after reset
— (b1)	Reserved bit	Set to 1.
ROMCR	ROM code protect cancel bit	0 : ROM code protection cancelled 1 : ROMCP1 bit enabled
ROMCP1	ROM code protect bit	0 : ROM code protection enabled 1 : ROM code protection disabled
— (b4)	Reserved bit	Set to 1.
VDSEL1	Vdet0 select bit 1	0 : Vdet0_2 1 : Vdet0_0
LVDAS	Voltage detector 0 start bit	0 : Voltage monitor 0 reset enabled after hardware reset 1 : Voltage monitor 0 reset disabled after hardware reset
CSPROINI	After-reset count source protection mode select bit	0 : Count source protection mode enabled after reset 1 : Count source protection mode disabled after reset

ROMCR (ROM code protect disable bit) (b2)
ROMCP1 (ROM code protect bit) (b3)

These bits are used to disable the flash memory from being read or rewritten in parallel I/O mode.

Table 30.5 ROM Code Protect

Bit Setting		ROM Code Protect
ROMCR bit	ROMCP1 bit	
0	0	Disabled
0	1	
1	0	Enabled
1	1	Disabled

30.5 Flash Memory Rewrite Disable Function

This function disables the flash memory from being read, written, and erased. The following are details for each mode:

Parallel I/O mode

ROM code protect function

Standard serial I/O mode

ID code check function, forced erase function, and standard serial I/O mode disable function

30.6 Boot Mode

A hardware reset occurs while a low-level signal is applied to the P5_5 pin and a high-level signal is applied to pins CNVSS and P5_0. After reset, the MCU enters boot mode. In boot mode, user boot mode or standard serial I/O mode is selected in accordance with the content of the user boot code area. Refer to 30.9 “Standard Serial I/O Mode” for details.

The MCU does not enter boot mode in power-on reset and voltage monitor 0 reset.

30.7 User Boot Mode

This mode is used for starting the flash memory rewrite program programmed by a user.

Allocate the flash memory rewrite program to program ROM 2. In user boot mode, the program is executed from address 10000h (starting address of program ROM 2). After starting the program, the flash memory is rewritten according to the program in EW0 or EW1 mode.

30.7.1 User Boot Function

User boot mode can be selected by the status of a port when the MCU starts in boot mode. Table 30.6 lists the User Boot Function Specifications.

Table 30.6 User Boot Function Specifications

Item	Specification
Entry pin	None or select a port from P0 to P14
User boot start level	Select high or low
User boot start address	Address 10000h (program ROM 2 start address)

Set “UserBoot” in ASCII code to addresses 13FF0h to 13FF7h in the user boot code area, select a port for entry from addresses 13FF8h to 13FF9h and 13FFAh, and select the start level with address 13FFBh. After starting boot mode, user boot mode or standard serial I/O mode is selected in accordance with the input level of the selected port.

In addition, if addresses 13FF0h to 13FF7h are set to “UserBoot” in ASCII code and addresses 13FF8h to 13FFBh are set to 00h, user boot mode is selected.

In user boot mode, the program of address 10000h (program ROM 2 start address) is executed.

Figure 30.3 shows the User Boot Code Area, Table 30.7 lists Start Mode (When Port Pi_j is Selected for Entry), Table 30.8 lists “UserBoot” in ASCII Code, and Table 30.9 lists Addresses of Selectable Ports for Entry.

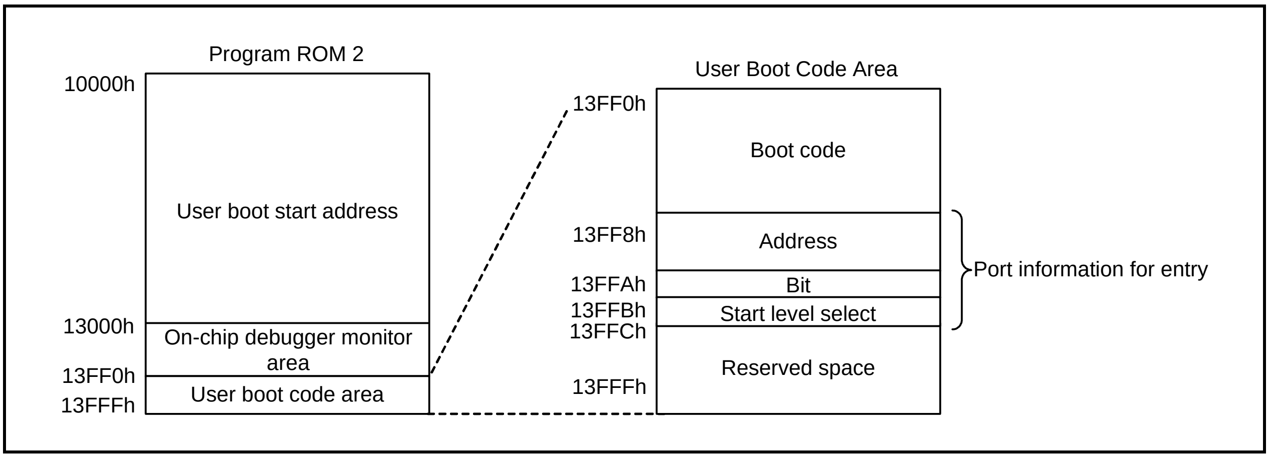


Figure 30.3 User Boot Code Area

Table 30.7 Start Mode (When Port Pi_j is Selected for Entry) (1)

Boot Code (13FF0h to 13FF7h)	Port Information for Entry			Port Pi_j Input Level	Start Mode
	Address (13FF8h to 13FF9h)	Bit (13FFAh)	Start level select (13FFBh)		
"UserBoot" in ASCII code (2)	0000h	00h	00h	–	User boot mode
	Pi register address (3)	00h to 07h (value of j)	00h	High	Standard serial I/O mode
				Low	User boot mode
	Pi register address (3)	00h to 07h (value of j)	01h	High	User boot mode
				Low	Standard serial I/O mode
Other than "UserBoot" in ASCII code	–	–	–	–	Standard serial I/O mode

i = 0 to 14; j = 0 to 7 (when i = 14; j = 0, 1)

Notes:

1. Only use the values listed in Table 30.7.
2. See Table 30.8 "UserBoot" in ASCII Code.
3. See Table 30.9 "Addresses of Selectable Ports for Entry".

Table 30.8 "UserBoot" in ASCII Code

Address	ASCII Code
13FF0h	55h (upper-case U)
13FF1h	73h (lower-case s)
13FF2h	65h (lower-case e)
13FF3h	72h (lower-case r)
13FF4h	42h (upper-case B)
13FF5h	6Fh (lower-case o)
13FF6h	6Fh (lower-case o)
13FF7h	74h (lower-case t)

Table 30.9 Addresses of Selectable Ports for Entry

Port	Address		Port	Address		Port	Address	
	13FF9h	13FF8h		13FF9h	13FF8h		13FF9h	13FF8h
P0	03h	E0h	P6	03h	ECh	P12	03h	F8h
P1	03h	E1h	P7	03h	EDh	P13	03h	F9h
P2	03h	E4h	P8	03h	F0h	P14	03h	FCh
P3	03h	E5h	P9	03h	F1h	—	—	
P4	03h	E8h	P10	03h	F4h			
P5	03h	E9h	P11	03h	F5h			

Table 30.10 Example Settings of User Boot Code Area

When starting up in user boot mode while input level of the port P1_5 is low:

Address	Setting Value	Meaning
13FF0h	55h	Upper-case U
13FF1h	73h	Lower-case s
13FF2h	65h	Lower-case e
13FF3h	72h	Lower-case r
13FF4h	42h	Upper-case B
13FF5h	6Fh	Lower-case o
13FF6h	6Fh	Lower-case o
13FF7h	74h	Lower-case t
13FF8h	E1h	Port P1_5
13FF9h	03h	
13FFAh	05h	
13FFBh	00h	Low level

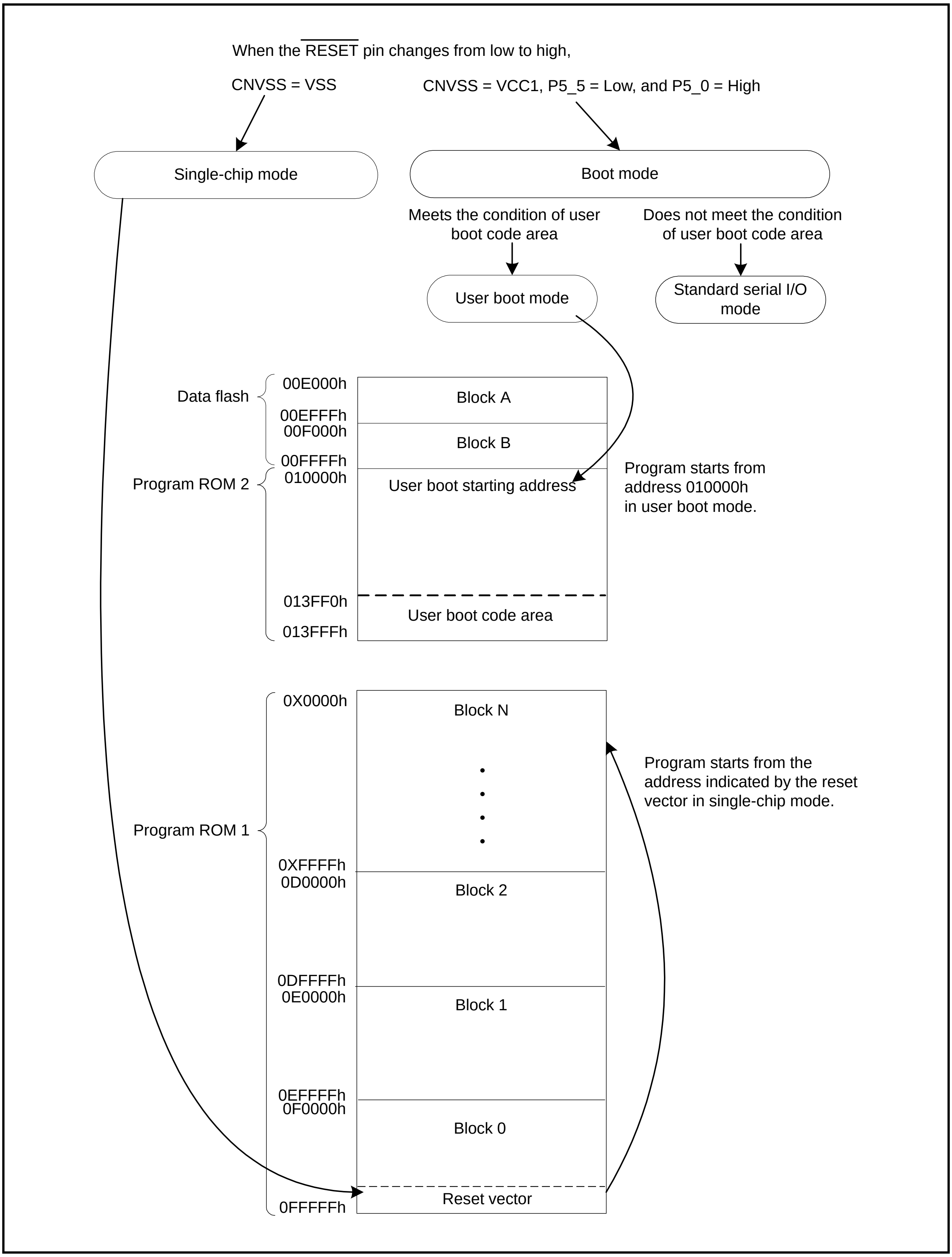

When the RESET pin changes from low to high,
CNVSS = VSS
CNVSS = VCC1, P5_5 = Low, and P5_0 = High
Single-chip mode
Boot mode
Meets the condition of user boot code area
Does not meet the condition of user boot code area
User boot mode
Standard serial I/O mode
Data flash
Program ROM 2
00E000h
00EFFFh
00F000h
00FFFFh
010000h
013FF0h
013FFFh
Block A
Block B
User boot starting address
User boot code area
Program starts from address 010000h in user boot mode.
Program ROM 1
0X0000h
0XFFFFh
0D0000h
0DFFFFh
0E0000h
0EFFFFh
0F0000h
0FFFFFh
Block N
Block 2
Block 1
Block 0
Reset vector
Program starts from the address indicated by the reset vector in single-chip mode.

Figure 30.4 Program Starting Address in User Boot Mode

30.8 CPU Rewrite Mode

In CPU rewrite mode, the flash memory can be rewritten when the CPU executes software commands. Program ROM 1, program ROM 2, and data flash can be rewritten with the MCU mounted on the board and without using a ROM programmer.

The program and block erase commands are executed only in individual block areas of program ROM 1, program ROM 2, and data flash.

The flash memory has a suspend function to temporarily suspend operation when erasing or programming in CPU rewrite mode. Refer to 30.8.5 “Suspend Function” for details of the suspend function.

EW0 mode and EW1 mode are available in CPU rewrite mode. Table 30.11 lists the differences between EW0 mode and EW1 mode.

Refer to 30.8.1 “EW0 Mode” and 30.8.2 “EW1 Mode” for details.

Table 30.11 EW0 Mode and EW1 Mode

Item	EW0 Mode	EW1 Mode
Operating mode	• Single-chip mode • Memory expansion mode	Single-chip mode
Rewrite control program allocatable area	• Program ROM 1 • Program ROM 2 • External area	• Program ROM 1 • Program ROM 2
Rewrite control program executable area	The rewrite control program must be transferred to an area other than the flash memory (e.g., RAM) before being executed.	The rewrite control program can be executed in program ROM 1 and program ROM 2.
Rewritable area	• Program ROM 1 • Program ROM 2 • Data flash	• Program ROM 1 • Program ROM 2 • Data flash Excluding blocks with the rewrite control program
Software command restriction	None	• Do not execute program and block erase commands in a block with the rewrite control program. • Read status register command Do not execute.
Mode after program/erase, or during program/erase suspend	Read status register mode	Read array mode
State during auto write and auto erase	Bus is not in a hold state.	Bus is in a hold state. (1)
Flash memory status detection	• Read bits FMR00, FMR06, and FMR07 in the FMR0 register, and bits FMR32 and FMR33 in the FMR3 register by a program. • Execute the read status register command, and then read bits SR7, SR5 and SR4 in the status register.	Read bits FMR00, FMR06, and FMR07 in the FMR0 register, and bits FMR32 and FMR33 in the FMR3 register by a program.

Note:

1. Refer to 11.3.1.2 “Bus Hold” for detail about the bus hold.

30.8.1 EW0 Mode

The MCU enters CPU rewrite mode when the FMR01 bit in the FMR0 register is set to 1 (CPU rewrite mode enabled) and is ready to accept commands. EW0 mode is selected by setting the FMR60 bit in the FMR6 register to 0. Figure 30.5 shows Setting and Resetting of EW0 Mode

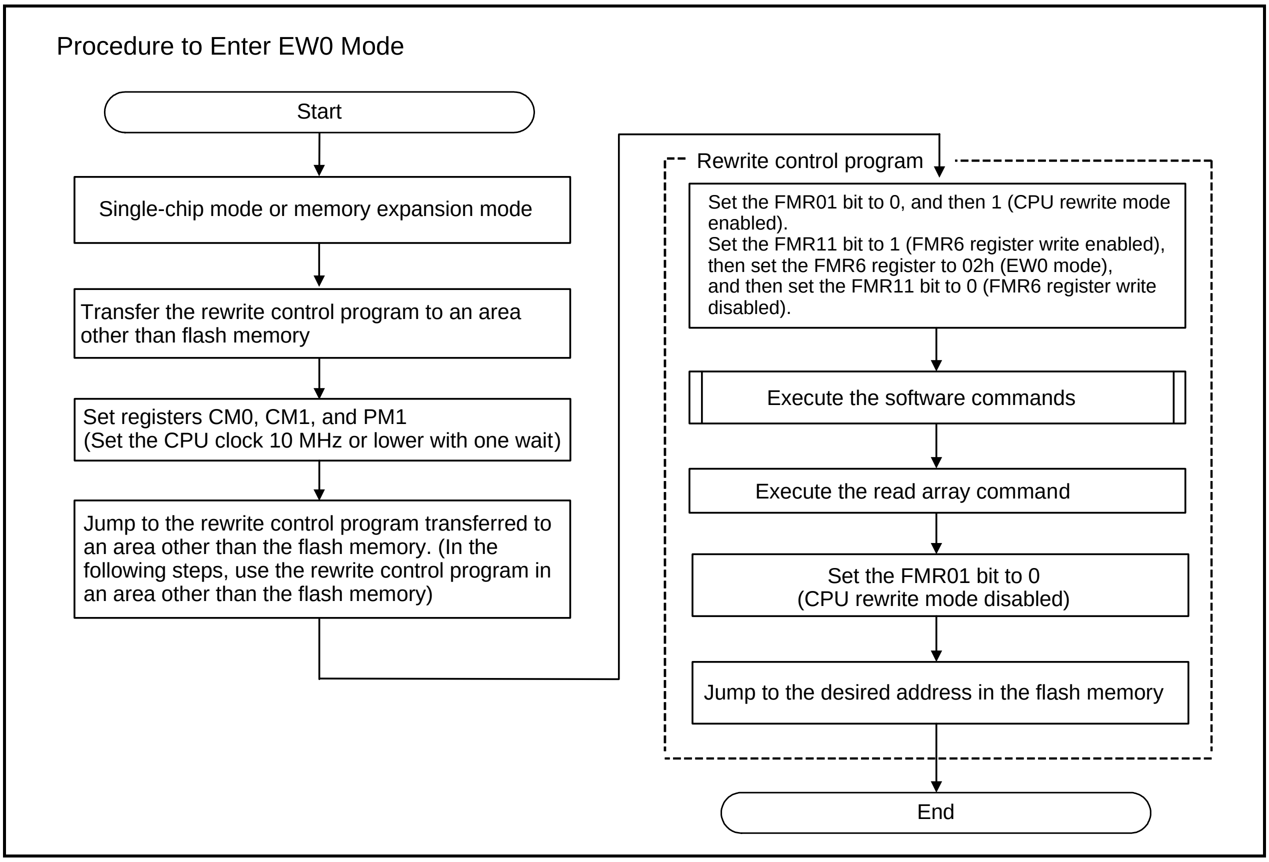

Procedure to Enter EW0 Mode
Start
Single-chip mode or memory expansion mode
Transfer the rewrite control program to an area other than flash memory
Set registers CM0, CM1, and PM1 (Set the CPU clock 10 MHz or lower with one wait)
Jump to the rewrite control program transferred to an area other than the flash memory. (In the following steps, use the rewrite control program in an area other than the flash memory)
Rewrite control program
Set the FMR01 bit to 0, and then 1 (CPU rewrite mode enabled). Set the FMR11 bit to 1 (FMR6 register write enabled), then set the FMR6 register to 02h (EW0 mode), and then set the FMR11 bit to 0 (FMR6 register write disabled).
Execute the software commands
Execute the read array command
Set the FMR01 bit to 0 (CPU rewrite mode disabled)
Jump to the desired address in the flash memory
End

Figure 30.5 Setting and Resetting of EW0 Mode

Do not execute the following instructions in EW0 mode:
UND instruction, INTO instruction, JMPS instruction, JSRS instruction, and BRK instruction.

The following are interrupts which can be used in EW0 mode and operations when the interrupts occur during auto-erase operation or auto-program operation:

- Maskable interrupt (suspend disabled)
  To use the interrupt, allocate a variable vector table in an area other than the flash memory.
- Maskable interrupt (suspend enabled)
  To use the interrupt, allocate a variable vector table in an areas other than the flash memory.
  When the FMR00 bit in the FMR0 register is checked in the interrupt routine and the result is 0 (being written or erased), auto-erase operation or auto-program operation suspends after td(SR-SUS) elapses by setting the FMR31 bit in the FMR3 register to 1 (suspend request). Auto-erase operation or auto-program operation restarts by setting the FMR31 bit to 0 (command restart) at the completion of the interrupt.
- $\overline{\text{NMI}}$, watchdog timer, oscillator stop/restart detect, voltage detect 1, and voltage detect 2 interrupts
  Auto-erase operation or auto-program operation is forcibly stopped as soon as the interrupt occurs, and then the interrupt process starts.
  After the flash memory restart, execute auto-erase operation again and confirm that it is completed as expected in order to read the correct value.

The watchdog timer operates even in auto erasing or auto programming operation. Refresh the watchdog timer regularly.

Table 30.12 Modes after Executing Commands (in EW0 Mode)

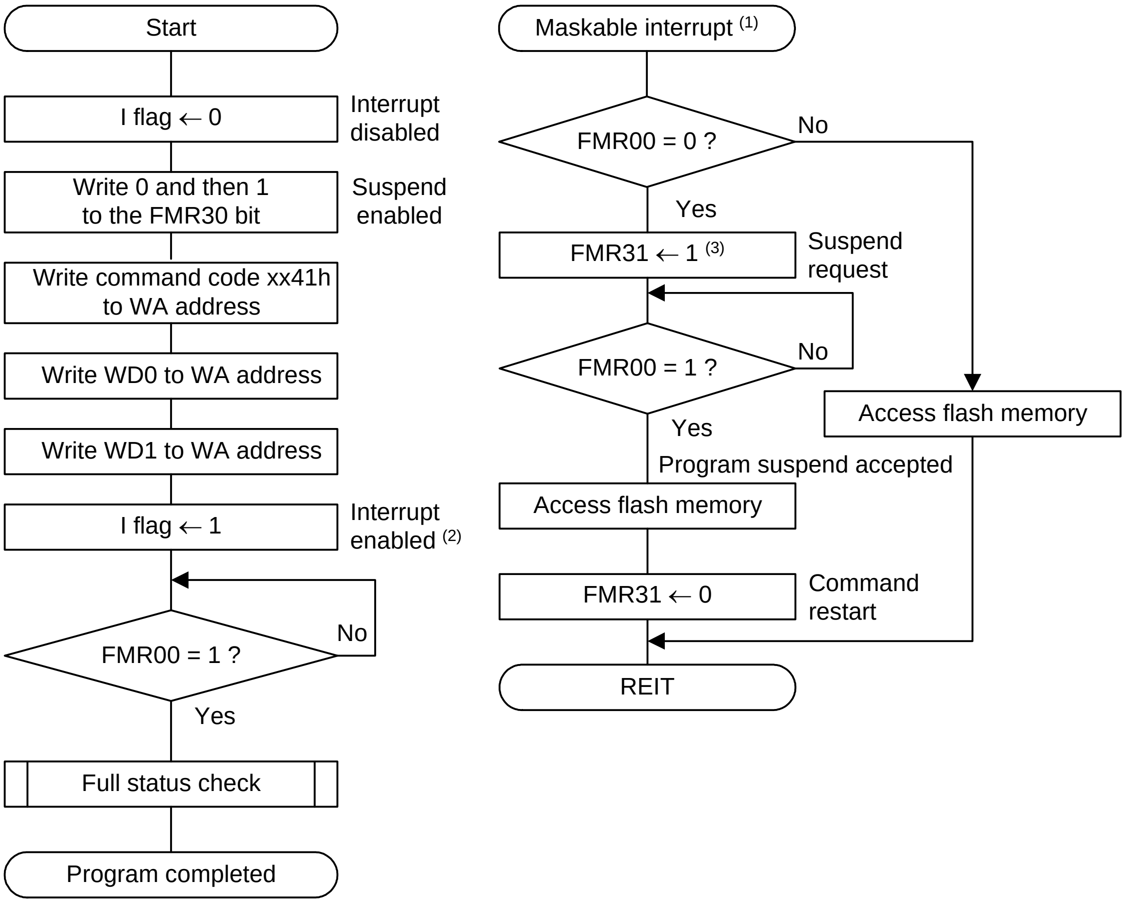
Command	Mode after Executing Command
Read array	Read array mode
Clear status register	Read array mode
Program	Read status register mode [1]
Block erase	
Lock bit program	
Read lock bit status	Read lock bit status mode [1]
Block blank check	Read status register mode [1]

Note:

1. Flash memory can be read only in read array mode.

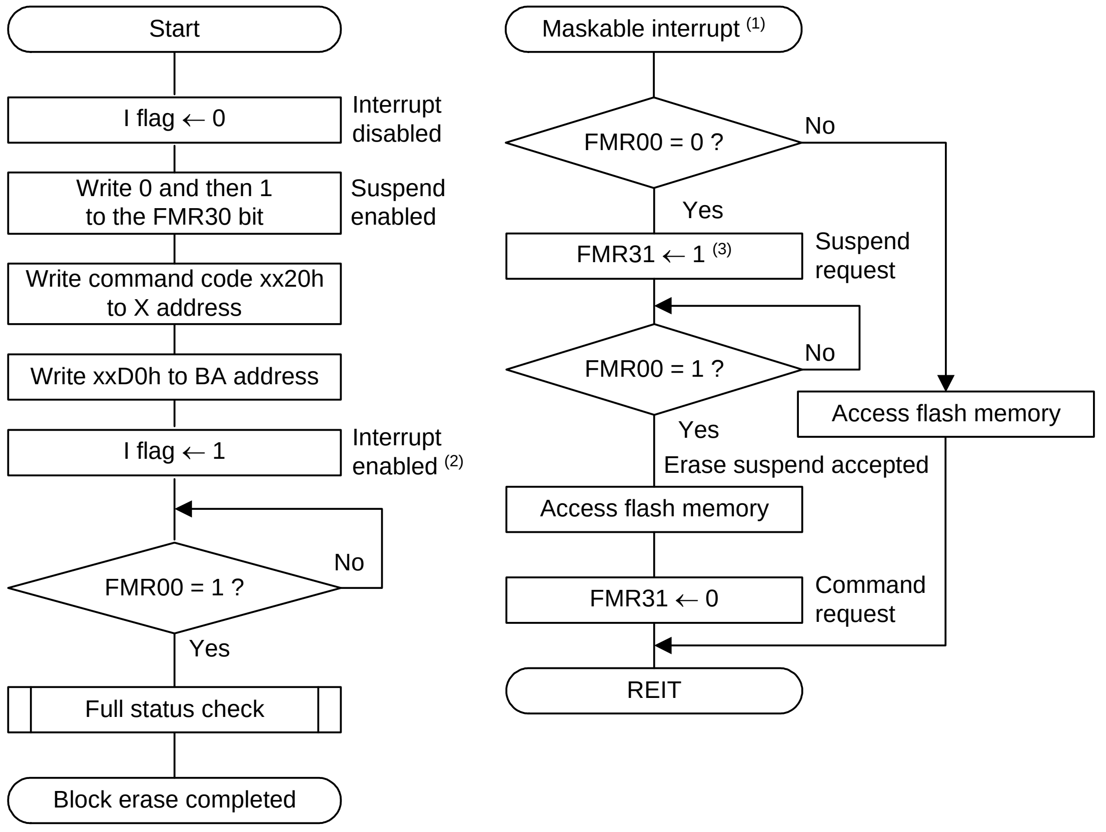
30.8.1.1 Suspend Function (EW0 Mode)

When using suspend function in EW0 mode, check the status of the flash memory in the interrupt routine and enter suspend mode. Program suspend or erase suspend is not accepted until td(SR-SUS) elapses after the FMR31 bit is set to 1. Access to the flash memory after confirming the acceptance of program suspend or erase suspend by the FMR33 or FMR32 bit. Set the FMR31 bit to 0 (command restart) to restart auto-program and auto-erase operations at the completion of the access to the flash memory. Figure 30.6 to Figure 30.8 show a flowchart in EW0 mode when the suspend function is enabled, and Figure 30.9 shows Suspend Operation Example in EW0 Mode.



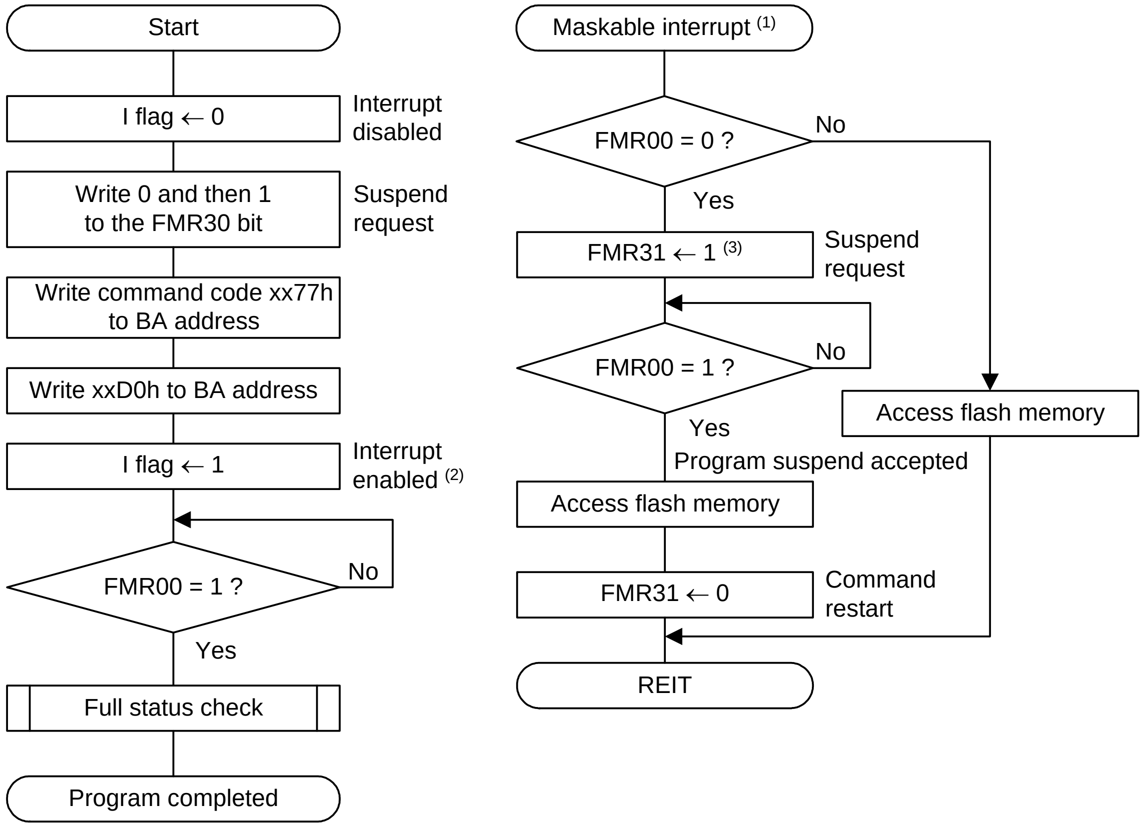
Notes:
1. In EW0 mode, set the interrupt vector table for interrupts to be used and the interrupt routine in areas other than flash memory.
2. When interrupts are not used, an instruction to enable interrupts is not necessary.
3. Program is not suspended until td(SR-SUS) elapses after the FMR31 bit is set to 1.

Figure 30.6 Program Flowchart in EW0 Mode (Suspend Function Enabled)



Notes:
1. In EW0 mode, set the interrupt vector table for interrupts to be used and the interrupt routine in areas other than flash memory.
2. When interrupts are not used, an instruction to enable interrupts is not necessary.
3. Erase is not suspended until td(SR-SUS) elapses after the FMR31 bit is set to 1.

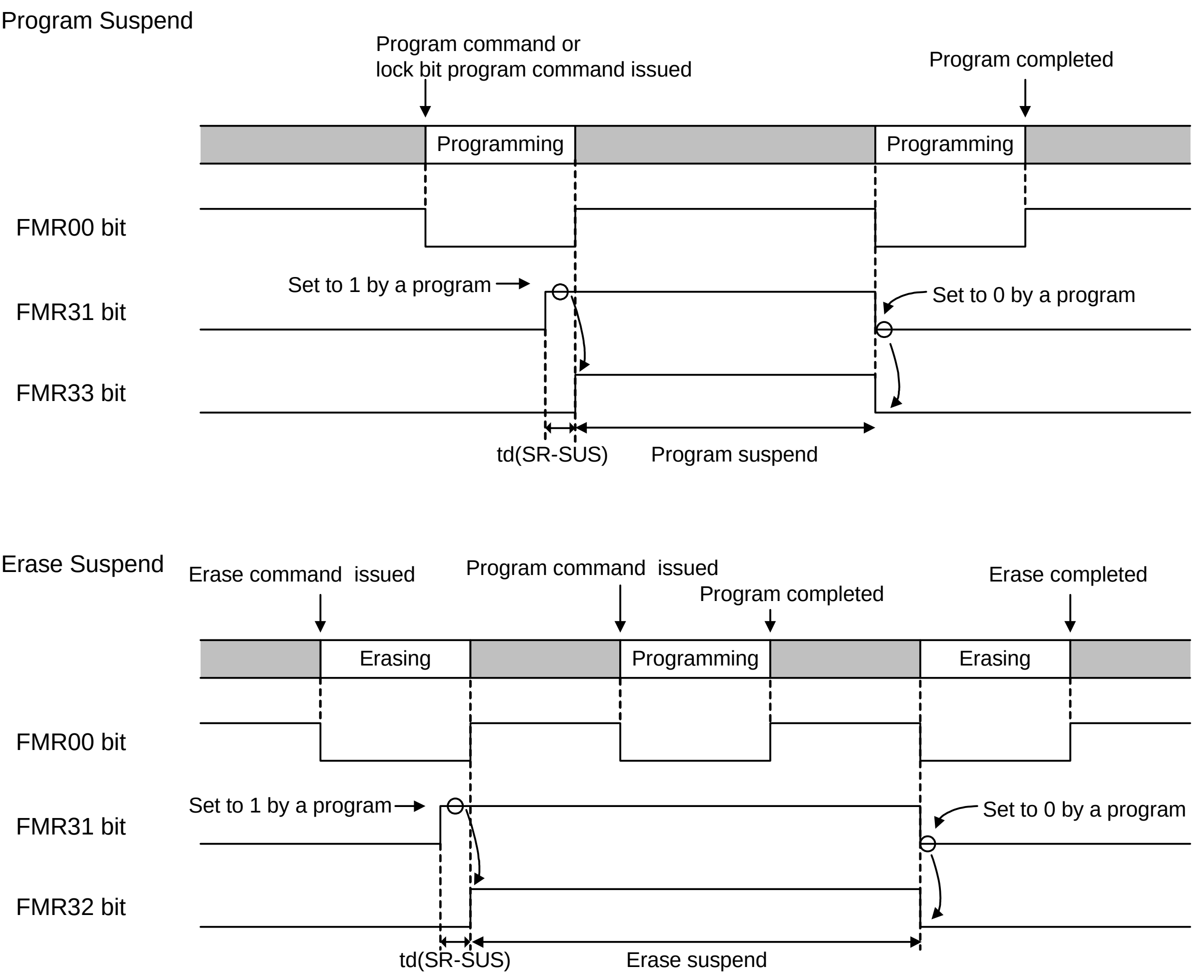
Figure 30.7 Block Erase Flowchart in EW0 Mode (Suspend Function Enabled)



Notes:

1. In EW0 mode, set the interrupt vector table for interrupts to be used and the interrupt routine in areas other than flash memory.
2. When interrupts are not used, an instruction to enable interrupts is not necessary.
3. Program is not suspended until td(SR-SUS) elapses after the FMR31 bit is set to 1.

Figure 30.8 Lock Bit Program Flowchart in EW0 Mode (Suspend Function Enabled)



FMR00: Bit in the FMR0 register
FMR33, FMR32, FMR31: Bits in the FMR3 register

The above assumes the following:

- The FMR30 bit in the FMR3 register is 1 (suspend enabled).

Figure 30.9 Suspend Operation Example in EW0 Mode

30.8.2 EW1 Mode

EW1 mode is selected by setting the FMR60 bit in the FMR6 register to 1 after setting the FMR01 bit in the FMR0 register to 1. Figure 30.10 shows Setting and Resetting of EW1 Mode.
When a program or erase operation is initiated, the CPU halts all program execution until the operation is completed.

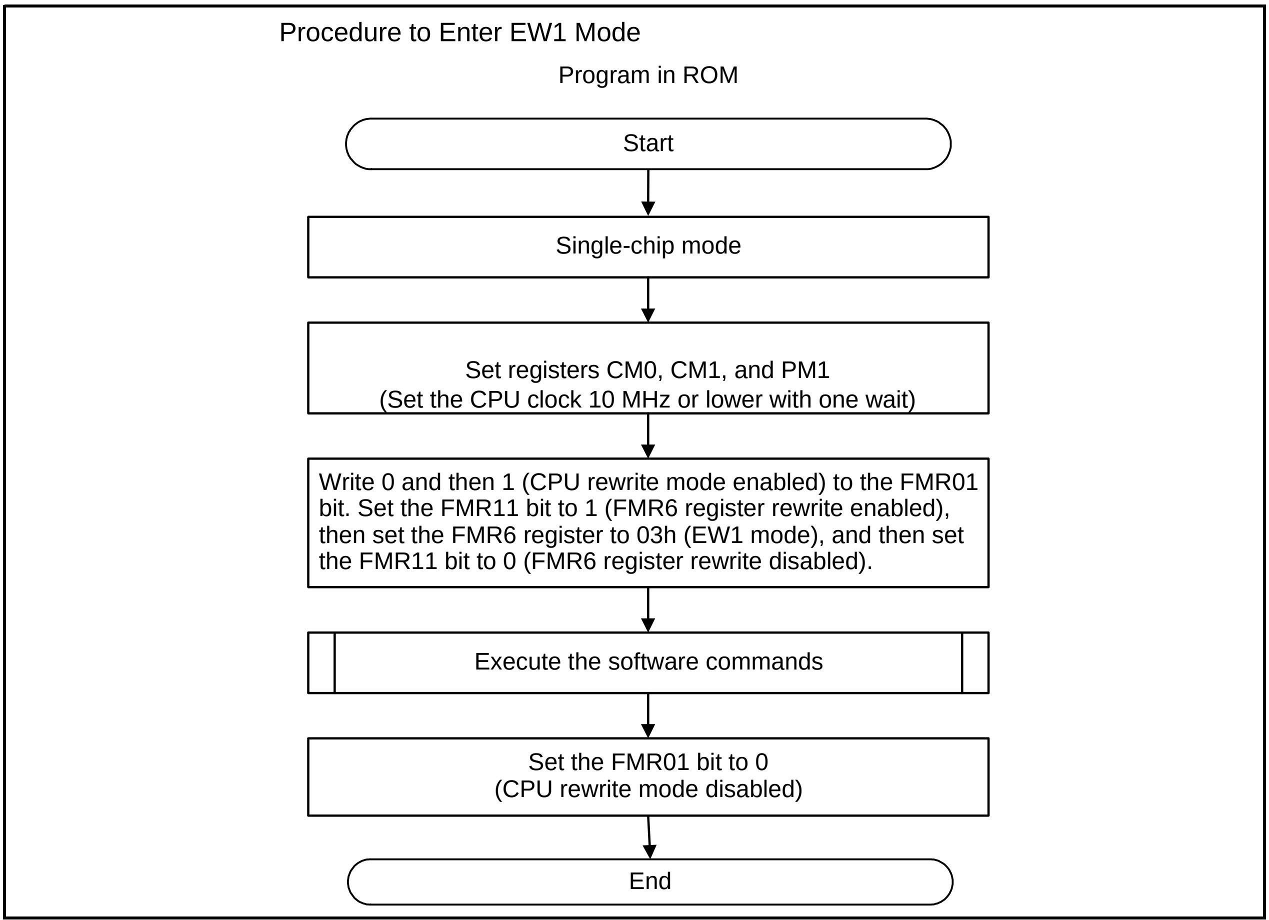

Procedure to Enter EW1 Mode
Program in ROM
Start
Single-chip mode
Set registers CM0, CM1, and PM1
(Set the CPU clock 10 MHz or lower with one wait)
Write 0 and then 1 (CPU rewrite mode enabled) to the FMR01 bit. Set the FMR11 bit to 1 (FMR6 register rewrite enabled), then set the FMR6 register to 03h (EW1 mode), and then set the FMR11 bit to 0 (FMR6 register rewrite disabled).
Execute the software commands
Set the FMR01 bit to 0
(CPU rewrite mode disabled)
End

Figure 30.10 Setting and Resetting of EW1 Mode

The following are interrupts which can be used in EW1 mode and operations when the interrupts occur during auto-erase operation or auto-program operation:

- Maskable interrupt (suspend function enabled)
  Auto-erase operation or auto-program operation suspends after td(SR-SUS) elapses and the interrupt process is executed. Auto-erase operation or auto-program operation restarts by setting the FMR31 bit in the FMR3 register to 0 (command restart) after the interrupt process is completed.
- Maskable interrupt (suspend function disabled)
  Auto-erase operation or auto-program operation has a higher priority level and the interrupt request has to wait. The interrupt process is executed after auto-erase operation or auto-program operation is completed.
- $\overline{\text{NMI}}$, watchdog timer, oscillator stop/restart detect, voltage detect 1, and voltage detect 2 interrupts
  Auto-erase operation or auto-program operation forcibly stops as soon as the interrupt occurs, and then the interrupt process starts.
  After the flash memory restart, execute auto-erase operation again and confirm that it is completed as expected in order to read the correct value.

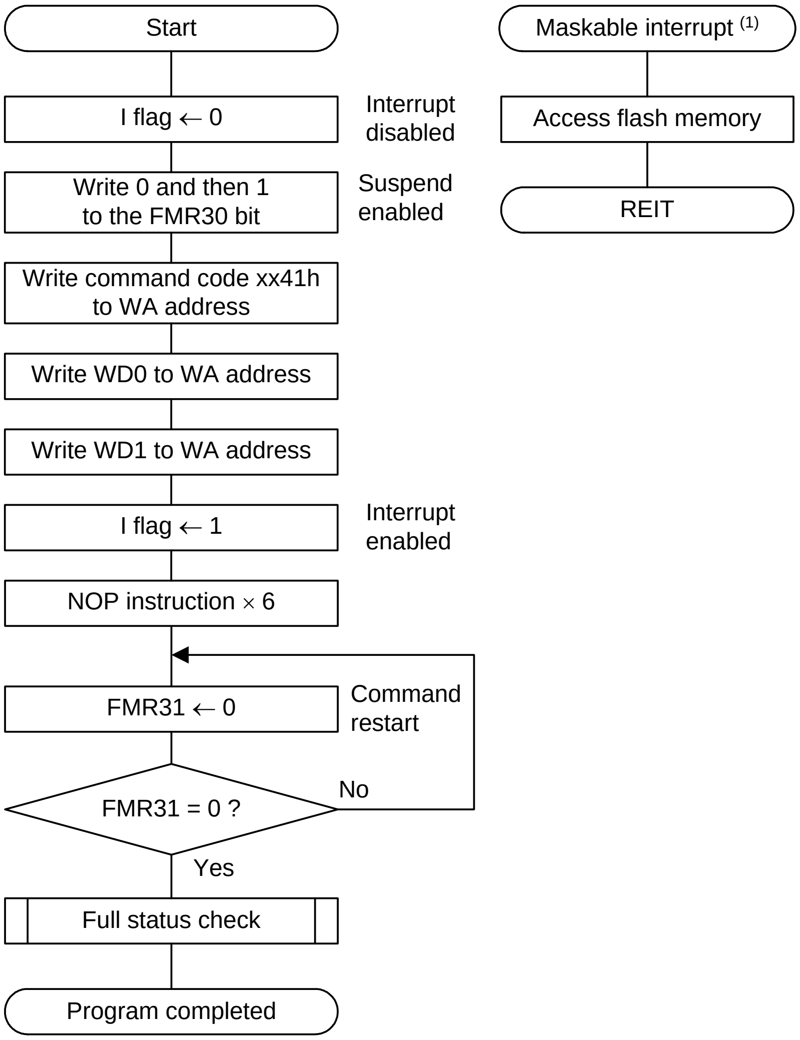
The watchdog timer stops its counting during auto-erase or auto-programming. Do not use EW1 mode while the CSPRO bit in the CSPR register is 1 (count source protection mode enabled). Use EW0 mode. However, counts does not stop during erase suspend or program suspend. As the interrupt request may be generated, initialize the watchdog timer regularly using the suspend function.

Table 30.13 Modes after Executing Commands (in EW1 Mode)

Command	Mode after Executing Command
Read array	Read array mode
Clear status register	
Program	
Block erase	
Lock bit program	
Read lock bit status	
Block blank check	

30.8.2.1 Suspend Function (EW1 Mode)

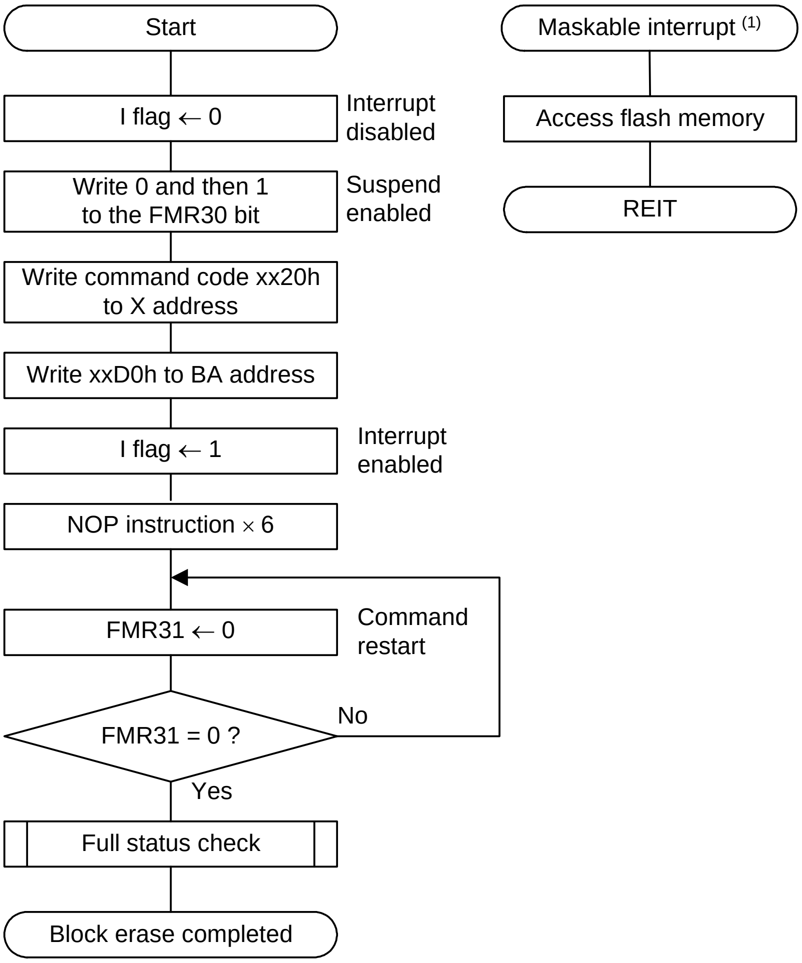
When using suspend function in EW1 mode, an interrupt request is not accepted until td(SR-SUS) elapses after the interrupt request is generated. When the interrupt request is accepted, the flash memory enters erase suspend or program suspend. Set the FMR31 bit to 0 (command restart) to restart automatic program and erase operations at the completion of the interrupt. Figure 30.11 to Figure 30.13 show a flowchart in EW1 mode when the suspend function is enabled, and Figure 30.14 shows Suspend Operation Example in EW1 Mode.



Note:

1. An interrupt request is not accepted until td(SR-SUS) elapses after the interrupt request is generated. Enable interrupts used to enter suspend mode beforehand.

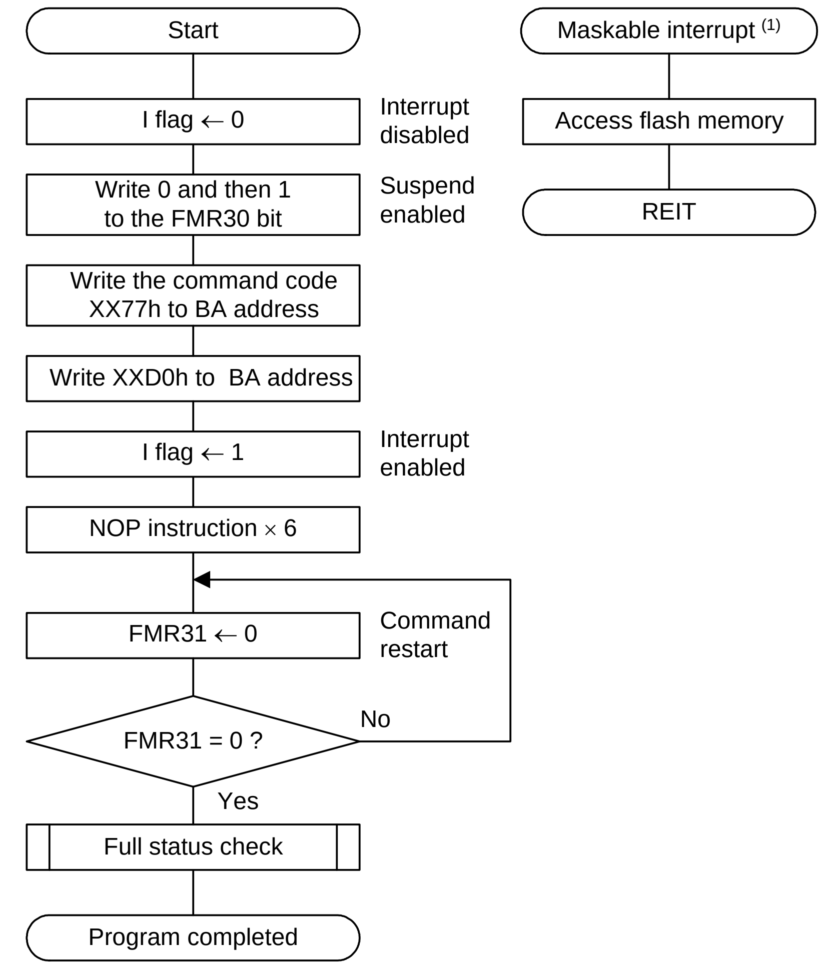
Figure 30.11 Program Flowchart in EW1 Mode (Suspend Function Enabled)



Note:

1. An interrupt request is not accepted until td(SR-SUS) elapses after the interrupt request is generated. Enable interrupts used to enter suspend mode beforehand.

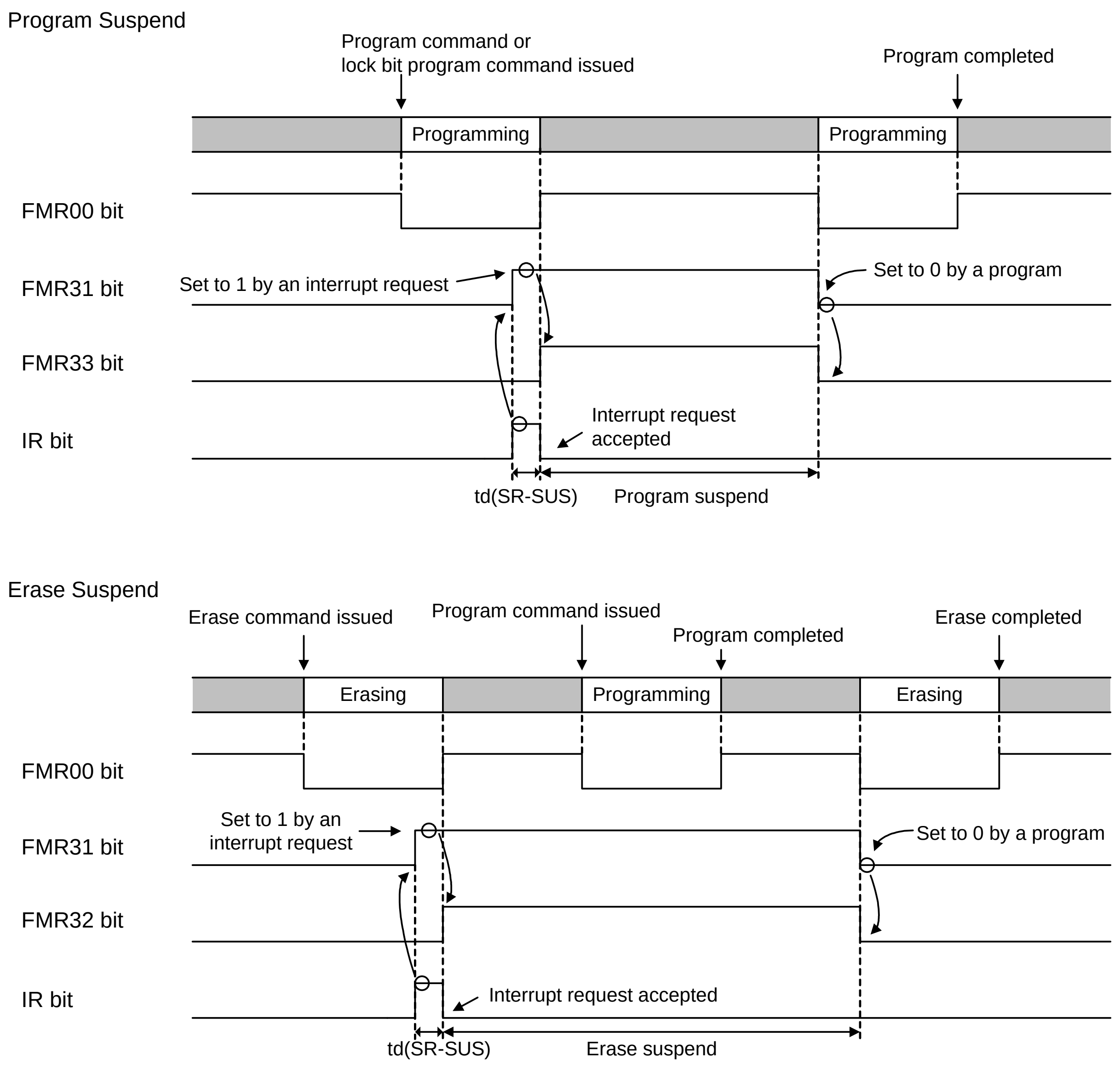
Figure 30.12 Block Erase Flowchart in EW1 Mode (Suspend Function Enabled)



Note:

1. An interrupt request is not accepted until td(SR-SUS) elapses after the interrupt request is generated. Enable interrupts used to enter suspend mode beforehand.

Figure 30.13 Lock Bit Program Flowchart in EW1 Mode (Suspend Function Enabled)



FMR00: Bit in the FMR0 register
FMR33, FMR32, FMR31: Bits in the FMR3 register
IR: Interrupt control register to enter suspend mode

The above assumes the following:

- The FMR30 bit in the FMR3 register is 1 (suspend enabled).

Figure 30.14 Suspend Operation Example in EW1 Mode

30.8.3 Operating Speed

Select a CPU clock frequency of 10 MHz or less by setting the CM06 bit in the CM0 register and bits CM17 and CM16 in the CM1 register before entering CPU rewrite mode (EW0 or EW1 mode). Also, set the PM17 bit in the PM1 register to 1 (wait state).

30.8.4 Data Protect Function

Each block in the flash memory has a nonvolatile lock bit. The lock bit is enabled by setting the FMR02 bit to 0 (lock bit enabled). The lock bit allows blocks to be individually protected (locked) against being programmed and erased. This prevents data from being inadvertently written to or erased from the flash memory. Table 30.14 lists Lock Bit and Block State.

Table 30.14 Lock Bit and Block State

FMR02 Bit in the FMR0 Register	Lock Bit	Block State
0 (enabled)	0 (locked)	Protected against being programmed and erased
	1 (unlocked)	Can be programmed or erased
1 (disabled)	0 (locked)	Can be programmed or erased
	1 (unlocked)	

Condition to become 0:

- Execute the lock bit program command

Condition to become 1:

- Execute the block erase command while the FMR02 bit in the FMR0 register is set to 1 (lock bit disabled).

If the block erase command is executed while the FMR02 bit is set to 1, the target block is erased regardless of lock bit status. The lock bit data can be read by the read lock bit status command.
Refer to 30.8.6 “Software Commands”, for details on each command.

30.8.5 Suspend Function

The suspend function suspends automatic programming and erasure. It can be used for an interrupt operation because program ROM 1, program ROM 2, and data flash can be read while automatic programming or erasure is suspended. Enable the interrupts used to enter suspend mode beforehand.

The program command, erase command, and lock bit program command are subjects for suspend. Suspend operation is the same for the program command and lock bit program command, so both commands are described together as program suspend.

Do not suspend again in suspend mode. Table 30.15 lists Operation after Command is Issued during Suspend.

Table 30.15 Operation after Command is Issued during Suspend

Suspend	Command	Operation	
		Blocks erased or programmed before suspend	Other blocks
Erase suspend (Suspend while executing erase command)	Block erase	The command is not executed. A command sequence error occurs.	
	Program	The command is not executed. A command sequence error occurs.	The command can be executed. Program suspend does not start or an error does not occur even when setting the FMR31 bit to 1 (suspend request).
	Lock bit program	The command is not executed. A command sequence error occurs.	The command can be executed.
	Read array	The command can be executed.	
	Read status register		
	Clear status register		
	Read lock bit status	The command is not executed. A command sequence error occurs.	The command can be executed.
	Block blank check	Do not execute the command.	
Program suspend (Suspend while executing program or lock bit program command)	Block erase	The command is not executed. A command sequence error occurs. [1]	
	Program		
	Lock bit program		
	Read array	The command can be executed.	
	Read status register		
	Clear status register	Do not execute the command. [1]	
	Read lock bit status	Do not execute the command.	
	Block blank check		

Note:

1. If the command sequence error occurs after executing block erase, program, or lock bit program commands mistakenly during program suspend. Execute the clear status register command, then restart suspend.

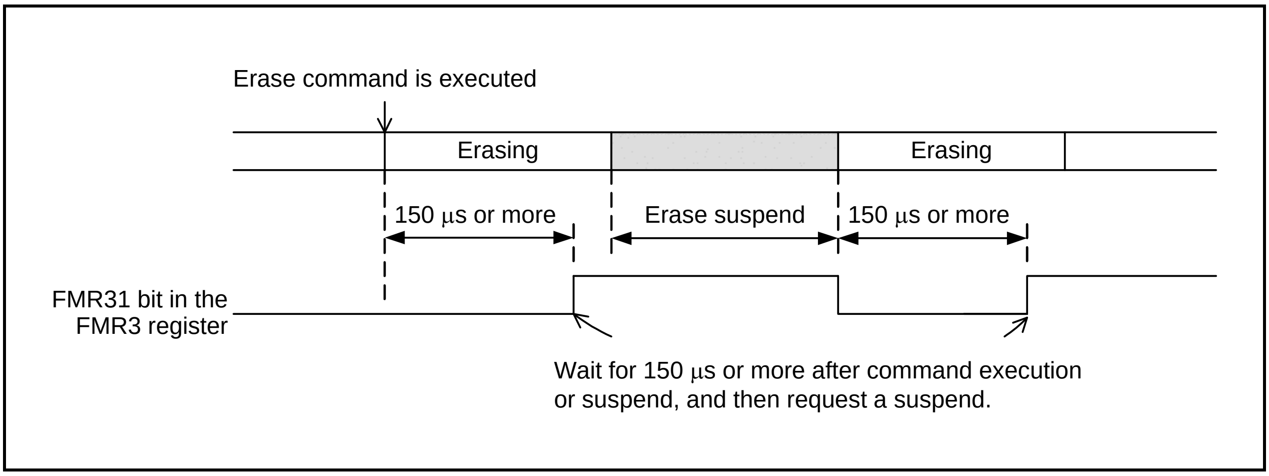

Erase command is executed
Erasing
Erasing
150 µs or more
Erase suspend
150 µs or more
FMR31 bit in the FMR3 register
Wait for 150 µs or more after command execution or suspend, and then request a suspend.

Figure 30.15 Suspend Request

30.8.6 Software Commands

Table 30.16 list Software Commands. Read or write commands and data in 16-bit units. When command code is written, the upper 8 bits (D15 to D8) are ignored.

Table 30.16 Software Commands

Command	First Bus Cycle			Second Bus Cycle			Third Bus Cycle		
	Mode	Address	Data (D15 to D0)	Mode	Address	Data (D15 to D0)	Mode	Address	Data (D15 to D0)
Read array	Write	x	xxFFh	–	–	–	–	–	–
Read status register	Write	x	xx70h	Read	x	SRD	–	–	–
Clear status register	Write	x	xx50h	–	–	–	–	–	–
Program	Write	WA	xx41h	Write	WA	WD0	Write	WA	WD1
Block erase	Write	x	xx20h	Write	BA	xxD0h	–	–	–
Lock bit program	Write	BA	xx77h	Write	BA	xxD0h	–	–	–
Read lock bit status	Write	x	xx71h	Write	BA	xxD0h	–	–	–
Block blank check (1)	Write	x	xx25h	Write	BA	xxD0h	–	–	–

SRD	: Data in the status register (D7 to D0)
WA	: Write address (set the end of the address to 0h, 4h, 8h, or Ch)
WD0	: Write data lower word (16 bits)
WD1	: Write data upper word (16 bits)
BA	: Highest block address (even address)
x	: Any even address in program ROM 1, program ROM 2, or data flash
xx	: 8 upper bits of command code (ignored)

Note:

1. Block blank check command is designed for programmer manufacturer. Not for customers in general.

Software commands are described below.
For symbols shown in the flowcharts, refer to those in Table 30.16.
Refer to 30.8.5 “Suspend Function” for program, block erase, and lock bit program commands when using suspend function.

30.8.6.1 Read Array Command

The read array command is used to read the flash memory.
By writing the command code xxFFh in the first bus cycle, the flash memory enters read array mode. The value of the specified address can be read in 16-bit units by entering the address to be read after the next bus cycle.
The flash memory remains in read array mode until another command is written. Therefore, the values of multiple addresses can be read consecutively.

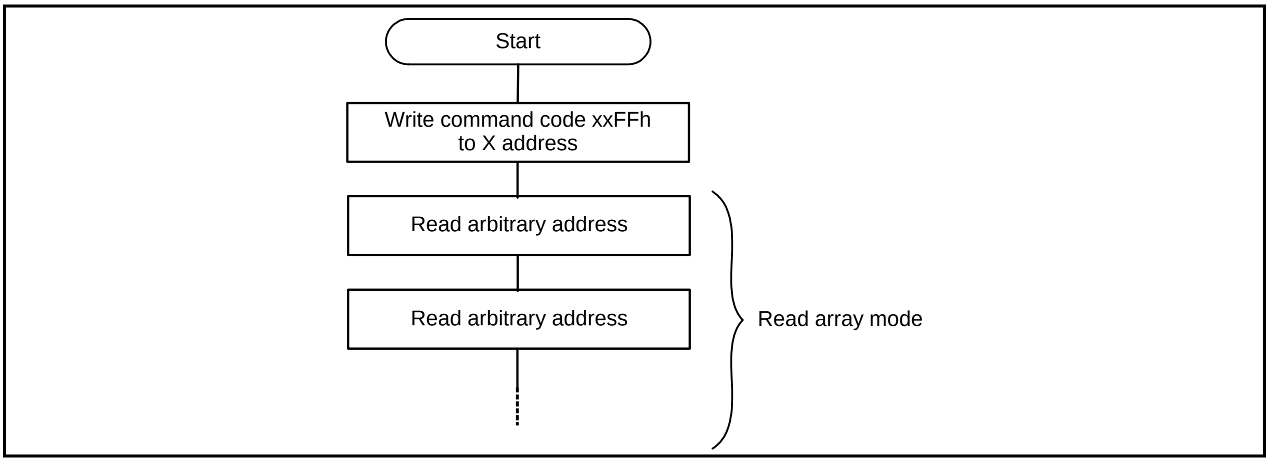


Figure 30.16 Read Array Command

30.8.6.2 Read Status Register Command

The read status register command is used to read the status register.

By writing the command code xx70h in the first bus cycle, the status register can be read in the second bus cycle. (Refer to 30.8.7 “Status Register”). To read the status register, read an even address in program ROM 1, program ROM 2, or the data flash.

Do not execute this command in EW1 mode.

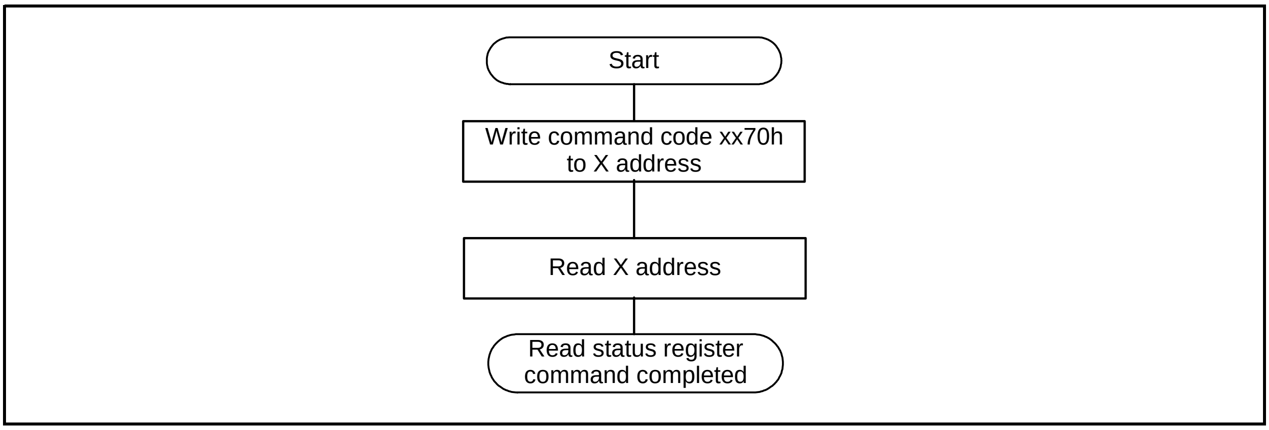

Start
Write command code xx70h to X address
Read X address
Read status register command completed

Figure 30.17 Read Status Register Command

30.8.6.3 Clear Status Register Command

The clear status register command is used to clear the status register.

By writing the command code xx50h, bits FMR07 and FMR06 in the FMR0 register (SR5 and SR4 in the status register) become 00b.

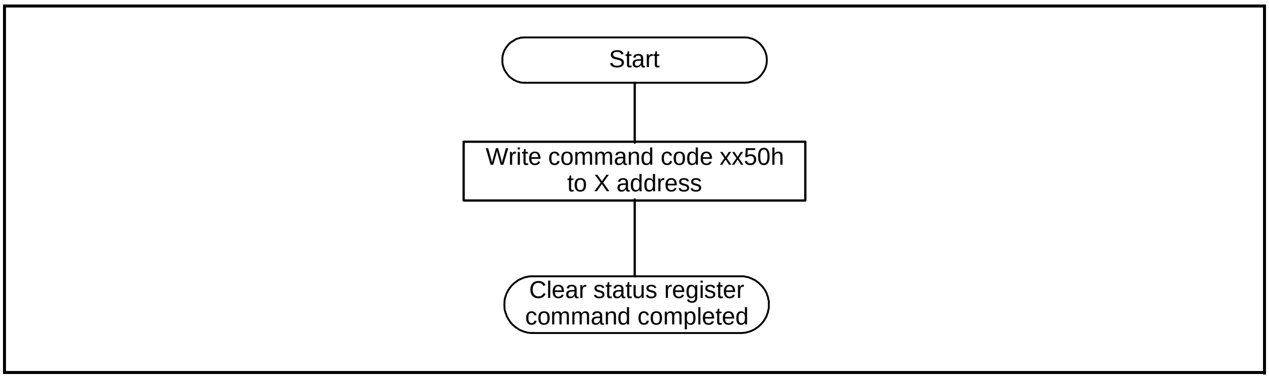

Start
Write command code xx50h to X address
Clear status register command completed

Figure 30.18 Clear Status Register Command

30.8.6.4 Program Command

The program command is used to write 2 words (4 bytes) of data to the flash memory.

By writing xx41h in the first bus cycle and data to the write address in the second and third bus cycles, an auto-program operation (data program and verify) is started. Set the end of the write address to 0h, 4h, 8h, or Ch.

The FMR00 bit in the FMR0 register indicates whether the auto-program operation has been completed. The FMR00 bit is 0 (busy) during the auto-program operation, and becomes 1 (ready) after the auto-program operation is completed. Do not execute other commands while the FMR00 bit is 0.

After the auto-program operation is completed, the FMR06 bit in the FMR0 register indicates whether or not the auto-program operation has been completed as expected. (Refer to 30.8.7.1 “Full Status Check”).

Do not rewrite the addresses already programmed. Figure 30.19 shows a flowchart of the Program Command (Suspend Function Disabled).

The lock bit protects individual blocks from being programmed inadvertently. (Refer to 30.8.4 “Data Protect Function”.)

In EW1 mode, do not execute this command on a block to which the rewrite control program is allocated.

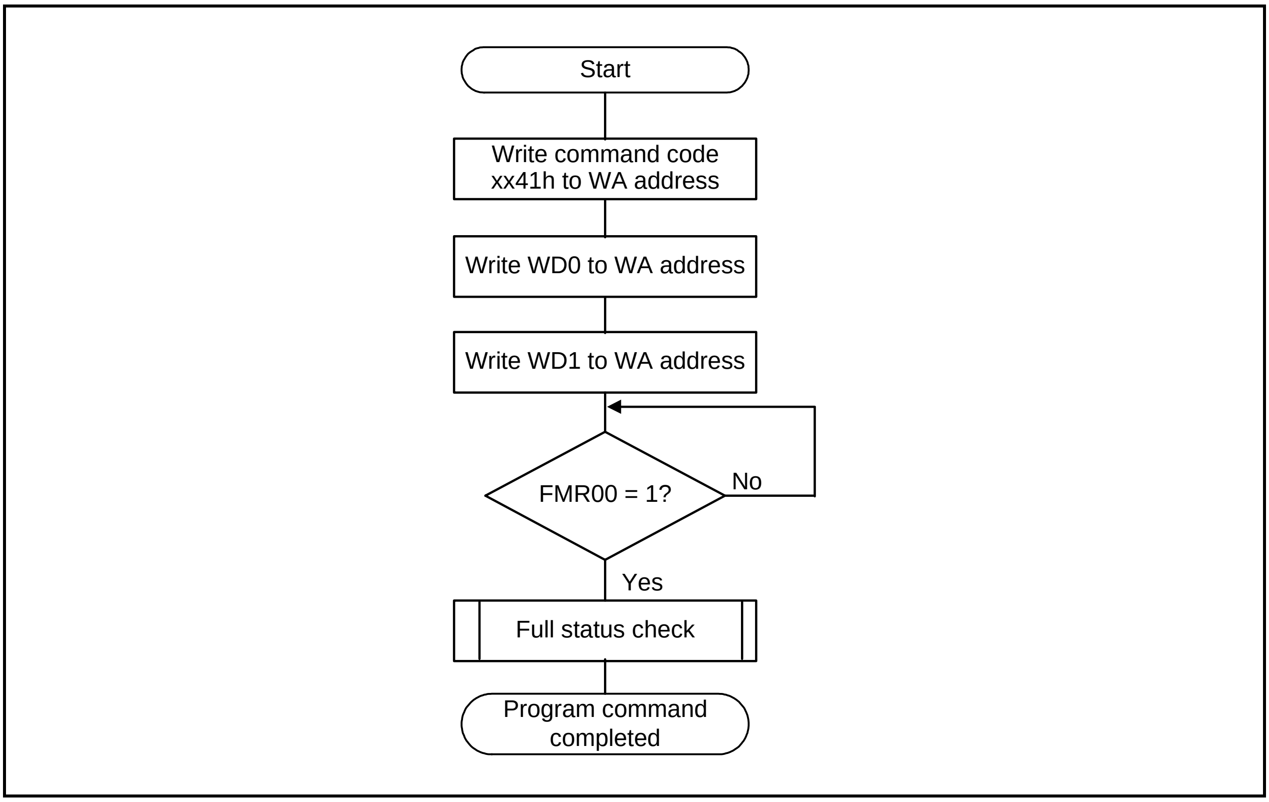


Figure 30.19 Program Command (Suspend Function Disabled)

30.8.6.5 Block Erase Command

By writing xx20h in the first bus cycle and xxD0h to the highest even address of a block in the second bus cycle, an auto-erase operation (erase and verify) is started on the specified block.

The FMR00 bit in the FMR0 register indicates whether the auto-erase operation has been completed. The FMR00 bit is 0 (busy) during the auto-erase operation, and becomes 1 (ready) when the auto-erase operation is completed. Do not execute other commands while the FMR00 bit is 0.

After the auto erase operation is completed, the FMR07 bit in the FMR0 register indicates whether or not the auto erase operation has been completed as expected. (Refer to 30.8.7.1 “Full Status Check”).

Figure 30.20 shows a flowchart of the Block Erase Command (Suspend Function Disabled).

The lock bit protects individual blocks from being erased inadvertently. (Refer to 30.8.4 “Data Protect Function”.)

In EW1 mode, do not execute this command on the block to which the rewrite control program is allocated.

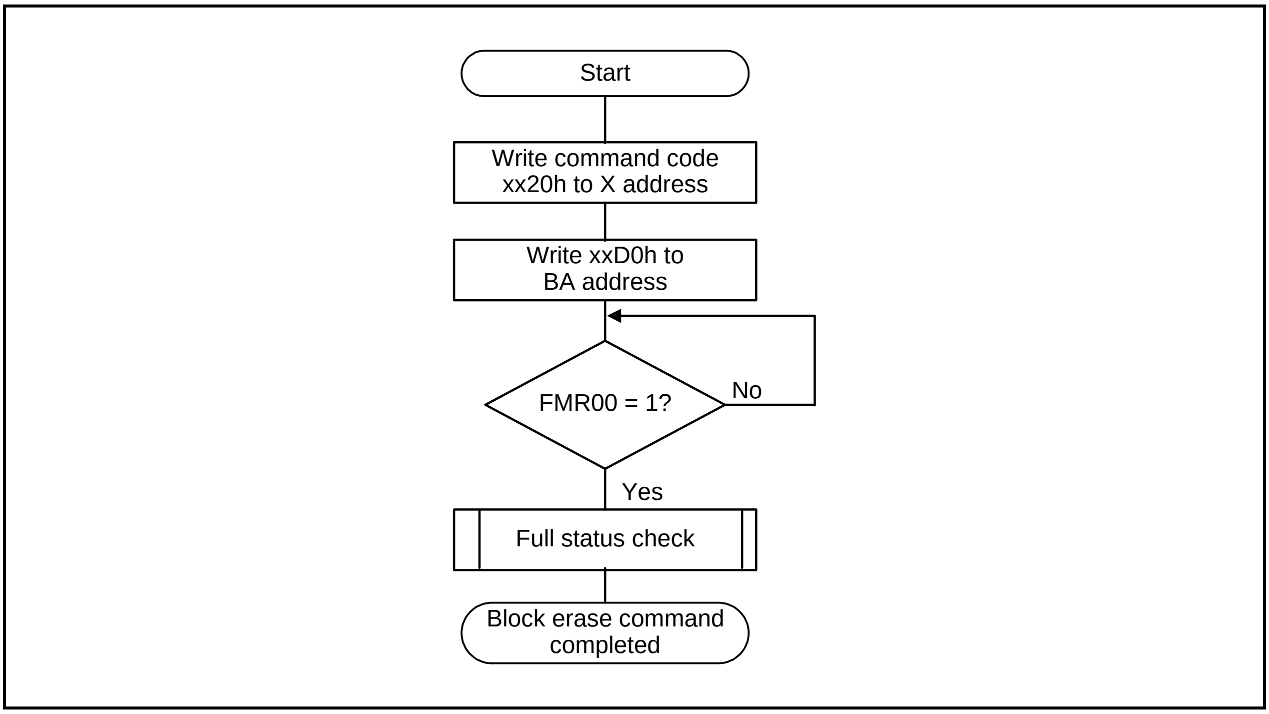

Start
Write command code xx20h to X address
Write xxD0h to BA address
FMR00 = 1?
No
Yes
Full status check
Block erase command completed

Figure 30.20 Block Erase Command (Suspend Function Disabled)

30.8.6.6 Lock Bit Program Command

The lock bit program command is used to set the lock bit for a specified block to 0 (locked).

By writing xx77h in the first bus cycle and xxD0h to the highest even address of a block in the second bus cycle, the lock bit for the specified block is set to 0. The address value specified in the first bus cycle must be the same highest address of a block specified in the second bus cycle.

Figure 30.21 shows a flowchart of the Lock Bit Program Command (Suspend Function Disabled).

Execute the read lock bit status command to read the lock bit state (lock bit data).

The FMR00 bit in the FMR0 register indicates whether a lock bit program operation has been completed. Do not execute other commands while the FMR00 bit is 0.

Refer to 30.8.4 “Data Protect Function”, for details on lock bit functions and how to set it to 1 (unlocked).

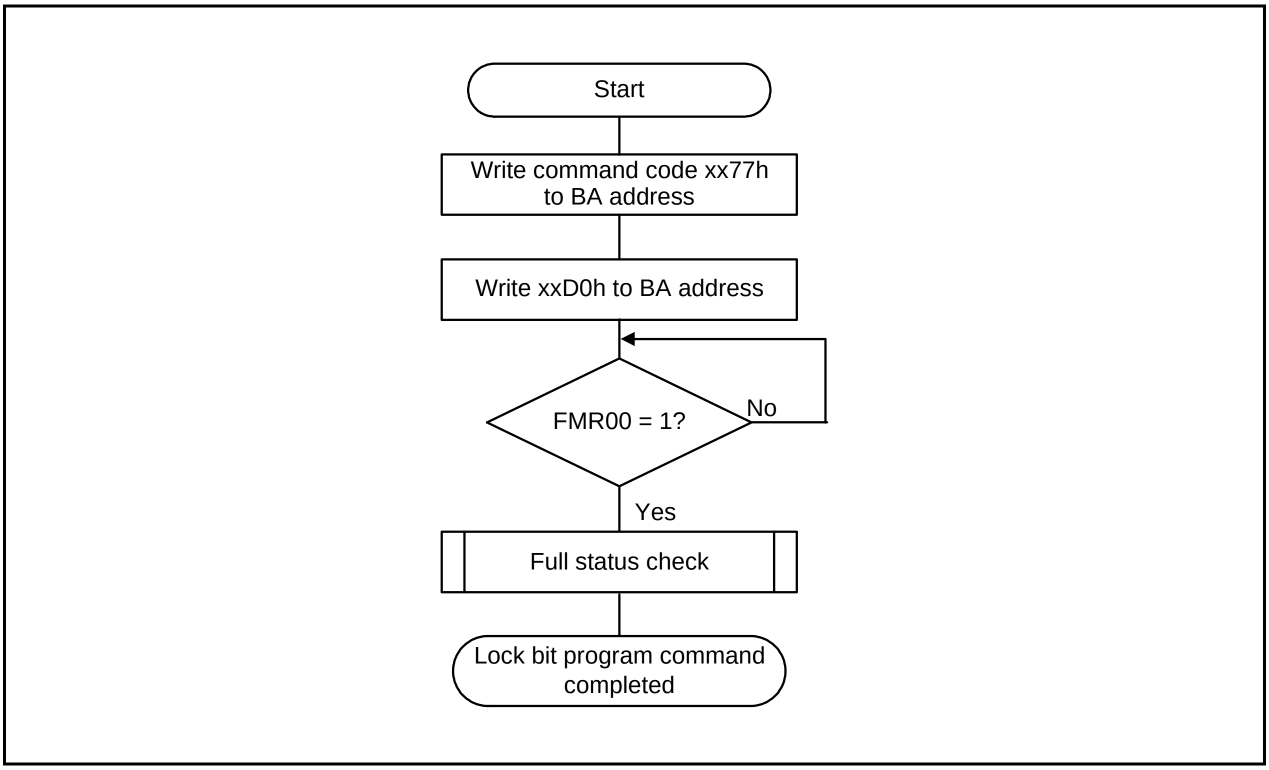

Start
Write command code xx77h to BA address
Write xxD0h to BA address
FMR00 = 1?
No
Yes
Full status check
Lock bit program command completed

Figure 30.21 Lock Bit Program Command (Suspend Function Disabled)

30.8.6.7 Read Lock Bit Status

The read lock bit status command is used to read the lock bit state of a specified block.

By writing xx71h in the first bus cycle and xxD0h to the highest even address of a block in the second bus cycle, the FMR16 bit in the FMR1 register stores information on the lock bit status of a specified block. Read the FMR16 bit after the FMR00 bit in the FMR0 register becomes 1 (ready). Do not execute other commands while the FMR00 bit is 0.

Figure 30.22 shows a flowchart of the Read Lock Bit Status Command.

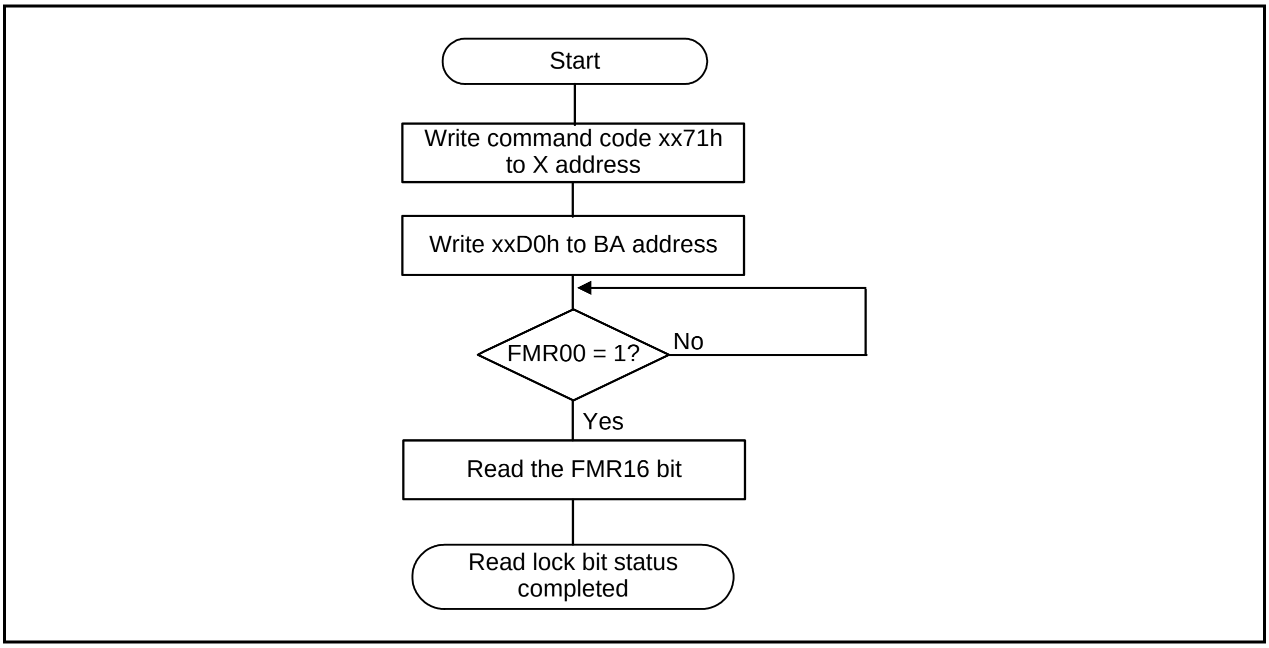

Start
Write command code xx71h to X address
Write xxD0h to BA address
FMR00 = 1?
No
Yes
Read the FMR16 bit
Read lock bit status completed

Figure 30.22 Read Lock Bit Status Command

30.8.6.8 Block Blank Check Command

The block blank check command is used to check whether or not a specified block is blank (state after erase).

By writing xx25h in the first bus cycle and xxD0h in the second bus cycle to the highest even address of a block, the check result is stored in the FMR07 bit in the FMR0 register. Read the FMR07 bit after the FMR00 bit in the FMR0 register is set to 1 (ready). Do not execute other commands while the FMR00 bit is 0.

The block blank check command is valid for unlocked blocks.

If the block blank check command is executed on a block whose lock bit is 0 (locked), the FMR07 bit (SR5) is set to 1 (not blank) regardless of the FMR02 bit state.

Figure 30.23 shows a flowchart of the Block Blank Check Command.

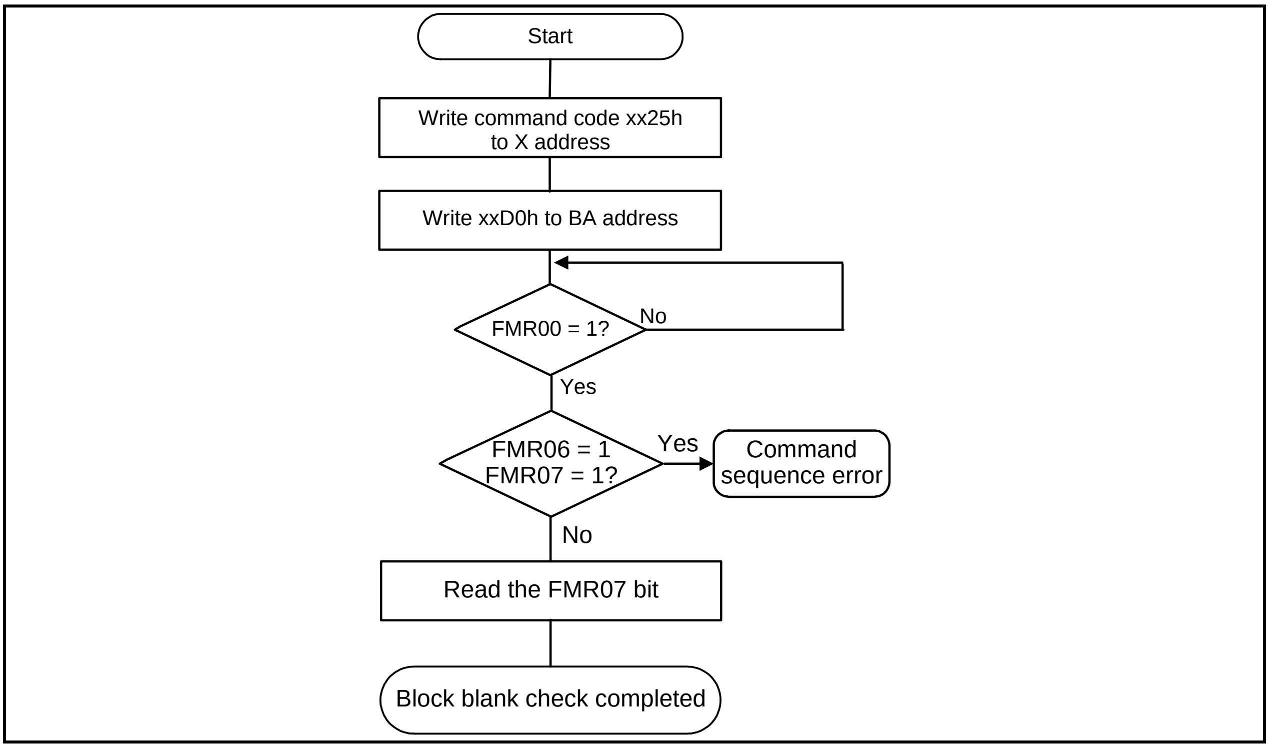

Start
Write command code xx25h to X address
Write xxD0h to BA address
FMR00 = 1?
No
Yes
FMR06 = 1 FMR07 = 1?
Yes
Command sequence error
No
Read the FMR07 bit
Block blank check completed

Figure 30.23 Block Blank Check Command

As a result of block blank check, when the block is not blank, execute the clear status register command before executing other software commands.

The block blank check command is designated for use with a programmer. Use this command where instantaneous power failures do not occur. When an instantaneous power failure occurs while the block erase command is executed, execute the block erase command again. The block blank check command cannot be used to check whether the erase operation is successfully completed or not.

Do not execute the block blank check command during suspend.

30.8.7 Status Register

The status register indicates flash memory operating state and whether or not an erase or program operation has been completed as expected.

Bits FMR00, FMR06, and FMR07 in the FMR0 register indicate status register states. Refer to 30.3.1 “Flash Memory Control Register 0 (FMR0)” for a description of each bit.

Table 30.17 Difference in Reading of Status Register

Item	FMR0 register	Command
Condition	No limit	
Reading procedure	Read bits FMR00, FMR06, and FMR07 in the FMR0 register	• Read any even address in program ROM 1, program ROM 2, or data flash after writing the read status register command. • Read any even address in program ROM 1, program ROM 2, or data flash after executing the program command, block erase command, lock bit program command, or block blank check command before executing the read array command.

Table 30.18 Status Register

Bits in Status Register	Bit in FMR0 Register	Status	Status		Reset Value
			0	1	
SR0 (D0)	-	Reserved	-	-	-
SR1 (D1)	-	Reserved	-	-	-
SR2 (D2)	-	Reserved	-	-	-
SR3 (D3)	-	Reserved	-	-	-
SR4 (D4)	FMR06	Program status	Completed as expected	Completed in error	0
SR5 (D5)	FMR07	Erase status	Completed as expected	Completed in error	0
SR6 (D6)	-	Reserved	-	-	-
SR7 (D7)	FMR00	Sequencer status	Busy	Ready	1

D0 to D7: The data buses read when the read status register command is executed.

30.8.7.1 Full Status Check

If an error occurs, bits FMR06 and FMR07 in the FMR0 register become 1, indicating the occurrence of an error. Therefore, the execution results can be confirmed by checking these status bits (full status check).

Table 30.19 Errors and FMR0 Register States

FMR00 Register		Error	Error Occurrence Conditions
FMR07 bit	FMR06 bit		
1	1	Command sequence error	• Command is written incorrectly. • Data other than xxD0h and xxFFh is written in the second bus cycle of the lock bit program, block erase, block blank check, or read lock bit status command. [1]
1	0	Erase error	• The block erase command is executed on a locked block. [2] • The block erase command is executed on an unlocked block, but the auto-erase operation is not completed as expected. • The block blank check command is executed, and the check result is not blank.
0	1	Program error	• The program command is executed on a locked block. [2] • The program command is executed on an unlocked block, but the auto-program operation is not completed as expected. • The lock bit program command is executed, but the lock bit is not written as expected.

Notes:

1. When writing xxFFh in the second bus cycle of the command, the flash memory becomes the state before executing the command, and the command code written in the first bus cycle is cancelled.
2. When the FMR02 bit is 1 (lock bit disabled), no error occurs even under the conditions above.

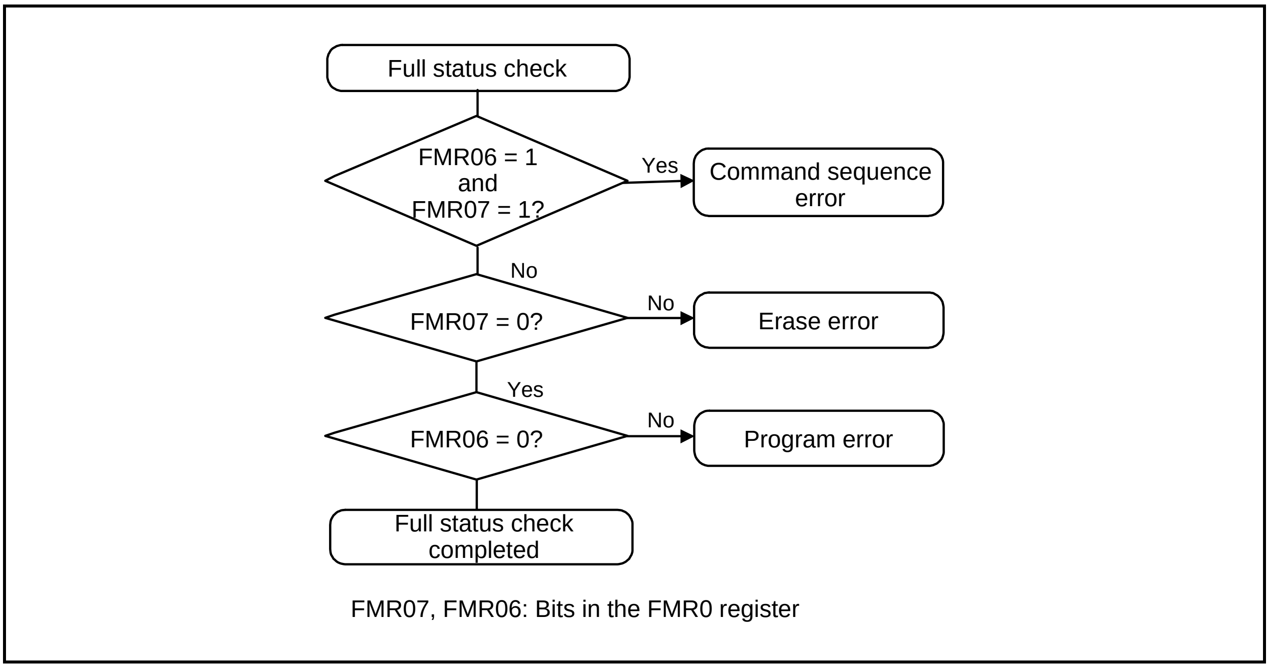


Figure 30.24 Full Status Check

30.8.7.2 Handling Procedure for Errors

When errors occur, follow the procedures below.

Do not execute the program, block erase, lock bit program, and block blank check commands when either FMR06 or FMR07 bit is 1 (completed in error). Execute each command after executing the clear status register command.

Command sequence error

(1) Execute the clear status register command and set bits FMR06 and FMR07 to 0 (completed as expected).

(2) Check if the command is written correctly and execute the correct command.

Erase error

(1) Execute the clear status register command and set the FMR07 bit to 0 (completed as expected).

(2) Execute the read lock bit status command. If the lock bit in the block where the error occurred is set to 0 (locked), set the FMR02 bit in the FMR register to 1 (lock bit disabled).

(3) Execute the block erase command again.

(4) Repeat (1) to (3) until an erase error is not generated.

If an error still occurs even after repeating three times, do not use that block.

When handling an erase error of the block blank check command and erasing is not necessary, execute (1) only.

Program error

[When a program operation is executed]

(1) Execute the clear status register command and set the FMR06 bit to 0 (completed as expected).

(2) Execute the read lock bit status command. If the lock bit in the block where the error occurred is set to 0, set the FMR02 bit in the FMR0 register to 1.

(3) Execute the program command again.

If the lock bit is set to 1 (unlocked), do not use the address in which error has occurred as it is. Execute the block erase command to erase the block, in which the error has occurred, before executing the program command to write to the same address again.

If an error still occurs, do not use that block.

[When a lock bit program operation is executed]

(1) Execute the clear status register command and set the FMR06 bit to 0.

(2) Set the FMR02 bit in the FMR0 register to 1.

(3) Execute the block erase command to erase the block where the error occurred.

(4) Execute the lock bit program command again after writing the data as needed.

If an error still occurs, do not use that block.

30.9 Standard Serial I/O Mode

In standard serial I/O mode, a serial programmer supporting the M16C/65C Group can be used to rewrite program ROM 1, program ROM 2, and data flash while the MCU is mounted on a board.

Standard serial I/O mode has following modes:

- Standard serial I/O mode 1: The MCU is connected to the serial programmer by using clock synchronous serial I/O
- Standard serial I/O mode 2: The MCU is connected to the serial programmer by using 2-wire clock asynchronous serial I/O

For more information about the serial programmer, contact the serial programmer manufacturer. Refer to the user’s manual included with your serial programmer for instructions.

30.9.1 ID Code Check Function

Use the ID code check function in standard serial I/O mode. This function determines whether the ID codes sent from the serial programmer match those written in the flash memory. If the ID codes do not match, commands sent from the serial programmer are not accepted. However, if the 4 bytes of the reset vector are FFFFFFFFh, ID codes are not compared, allowing all commands to be accepted.

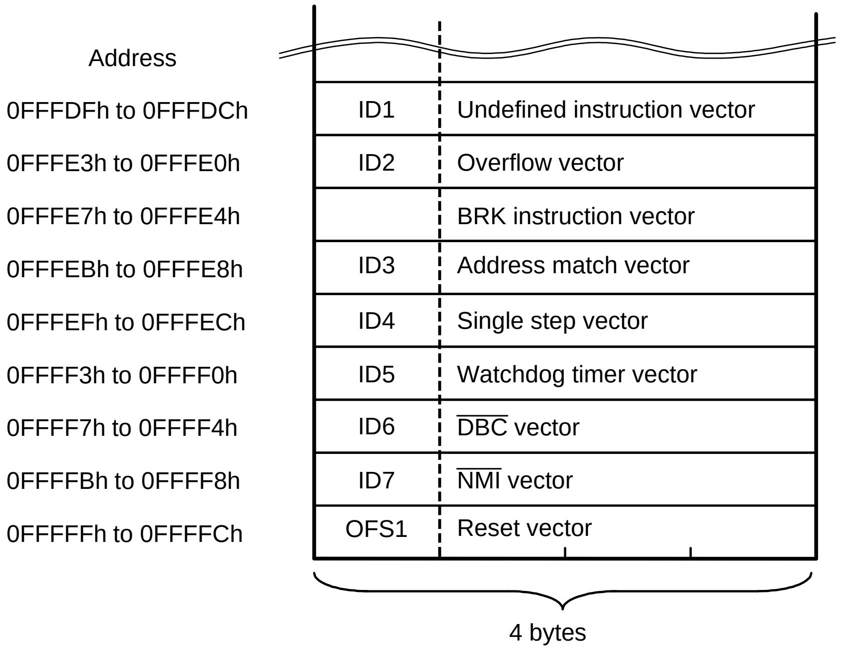
The ID codes are 7-byte data stored consecutively, starting with the first byte, at addresses 0FFFDFh, 0FFFE3h, 0FFFEBh, 0FFFEFh, 0FFFF3h, 0FFFF7h, and 0FFFFBh. The flash memory must have a program with the ID codes set in these addresses. Figure 30.25 shows ID Code Storage Addresses.

The ID code of “ALeRASE” in ASCII code is used for forced erase function. The ID code “Protect” in ASCII code is used for standard serial I/O mode disable function. Table 30.20 lists Reserved Word of ID Code. All ID code storage addresses and data must match the combinations listed in Table 30.20. When the forced erase function or standard serial I/O mode disable function is not used, use another combination of ID codes.

Table 30.20 Reserved Word of ID Code

ID Code Storage Address		Reserved Word of ID Code (ASCII)	
		ALeRASE	Protect
FFFDFh	ID1	41h (upper-case A)	50h (upper-case P)
FFFE3h	ID2	4Ch (upper-case L)	72h (lower-case r)
FFFEBh	ID3	65h (lower-case e)	6Fh (lower-case o)
FFFEFh	ID4	52h (upper-case R)	74h (lower-case t)
FFFF3h	ID5	41h (upper-case A)	65h (lower-case e)
FFFF7h	ID6	53h (upper-case S)	63h (lower-case c)
FFFFBh	ID7	45h (upper-case E)	74h (lower-case t)

All ID code storage addresses and data must match the combinations listed in Table 30.20.



Address		
0FFFDFh to 0FFFDCh	ID1	Undefined instruction vector
0FFFE3h to 0FFFE0h	ID2	Overflow vector
0FFFE7h to 0FFFE4h		BRK instruction vector
0FFFEBh to 0FFFE8h	ID3	Address match vector
0FFFEFh to 0FFFECh	ID4	Single step vector
0FFFF3h to 0FFFF0h	ID5	Watchdog timer vector
0FFFF7h to 0FFFF4h	ID6	$\overline{\text{DBC}}$ vector
0FFFFBh to 0FFFF8h	ID7	$\overline{\text{NMI}}$ vector
0FFFFFh to 0FFFFCh	OFS1	Reset vector

Figure 30.25 ID Code Storage Addresses

30.9.2 Forced Erase Function

Use the forced erase function in standard serial I/O mode. When the reserved word, “ALeRASE” in ASCII code, is sent from the serial programmer as an ID code, the contents of program ROM 1 and program ROM 2 will all be erased. However, if the ID codes stored in the ID code storage addresses are set to a reserved word other than “ALeRASE” (other than the combination table listed in Table 30.20), the ROMCR bit in the OFS1 address is 1 (ROMCP1 bit enabled), and the ROMCP1 bit in the OFS1 address is 0 (ROM code protect enabled), the forced erase function is ignored and ID code check is executed by the ID code check function. Table 30.21 lists conditions and functions for forced erase function.

When both the ID codes sent from the serial programmer and the ID codes stored in the ID code storage addresses correspond to the reserved word “ALeRASE”, program ROM 1 and program ROM 2 will be erased. However, when the serial programmer sends other than “ALeRASE”, even if the ID codes stored in the ID code storage addresses are “ALeRASE”, there is no ID match and no command is accepted. The flash memory cannot be operated.

Table 30.21 Forced Erase Function

Condition			Function
ID code from serial programmer	Code in ID code storage address	ROMCP1 bit in the OFS1 address	
ALeRASE	ALeRASE	–	Program ROM 1 and program ROM 2 all erase (forced erase function)
	Other than ALeRASE (1)	1 (ROM code protect disabled)	
		0 (ROM code protect enabled)	ID code check (ID code check function)
Other than ALeRASE	ALeRASE	–	ID code check (ID code check function. No ID match)
	Other than ALeRASE (1)	–	ID code check (ID code check function)

Note:

1. When the combination of the stored addresses is “Protect”, refer to 30.9.3 “Standard Serial I/O Mode Disable Function”.

30.9.3 Standard Serial I/O Mode Disable Function

Use the standard serial I/O mode disable function in standard serial I/O mode. When the ID codes in the ID code stored addresses are set to “Protect” in ASCII code (see Table 30.20 “Reserved Word of ID Code”), the MCU does not communicate with the serial programmer. Therefore, the flash memory cannot be read, written or erased by the serial programmer. User boot mode can be selected even when the ID codes are set to “Protect”.

When the ID codes are set to “Protect”, the ROMCR bit in the OFS1 address is 1 (ROMCP1 bit enabled), and the ROMCP1 bit in the OFS1 address is set to 0 (ROM code protect enabled), ROM code protection cannot be disabled by the serial programmer. Therefore, the flash memory cannot be read, written, or erased by the serial or parallel programmer.

30.9.4 Standard Serial I/O Mode 1

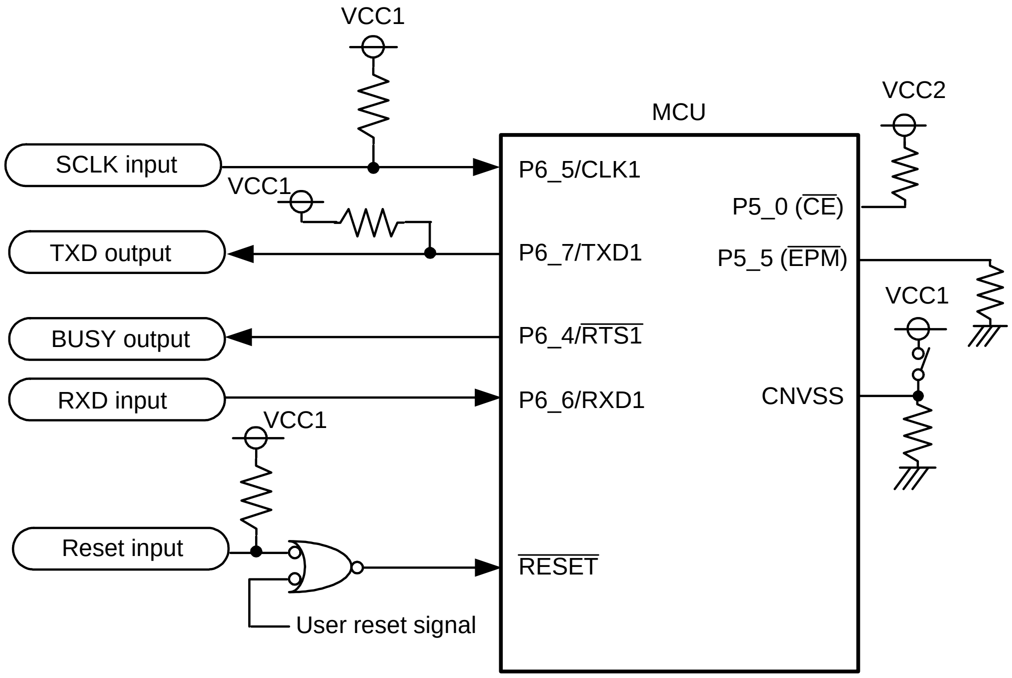
In standard serial I/O mode 1, a serial programmer is connected to the MCU using clock synchronous serial I/O.

Table 30.22 Pin Functions (Flash Memory Standard Serial I/O Mode 1)

Pin	Name	I/O	Power Supply	Description
VCC1, VCC2, VSS	Power input		-	Apply the flash memory program and erase voltage to the VCC1 pin, and VCC2 to the VCC2 pin. The VCC application condition is that VCC2 ≤ VCC1. Apply 0 V to the VSS pin.
CNVSS	CNVSS	I	VCC1	Connect to the VCC1 pin.
$\overline{\text{RESET}}$	Reset input	I	VCC1	Reset input pin.
XIN	Clock input	I	VCC1	Input a high-level signal to the XIN pin and open the XOUT pin when the main clock is not used. Connect a ceramic resonator or crystal between pins XIN and XOUT when the main clock is used. To input an externally generated clock, input it to the XIN pin and open the XOUT pin.
XOUT	Clock output	O		
BYTE	BYTE input	I	VCC1	Connect this pin to VSS or VCC1.
AVCC, AVSS	Analog power supply input			Connect the AVCC pin to VCC1 and the AVSS pin to VSS, respectively.
VREF	Reference voltage input	I		Reference voltage input pin for A/D converter. When using standard serial I/O mode 1, and power supply to VREF is not supplied, connect with VSS.
P0_0 to P0_7	Input port P0	I	VCC2	Input a high- or low-level signal or leave open.
P1_0 to P1_7	Input port P1	I	VCC2	Input a high- or low-level signal or leave open.
P2_0 to P2_7	Input port P2	I	VCC2	Input a high- or low-level signal or leave open.
P3_0 to P3_7	Input port P3	I	VCC2	Input a high- or low-level signal or leave open.
P4_0 to P4_7	Input port P4	I	VCC2	Input a high- or low-level signal or leave open.
P5_1 to P5_4, P5_6, P5_7	Input port P5	I	VCC2	Input a high- or low-level signal or leave open.
P5_0	$\overline{\text{CE}}$ input	I	VCC2	Input a high-level signal.
P5_5	$\overline{\text{EPM}}$ input	I	VCC2	Input a low-level signal.
P6_0 to P6_3	Input port P6	I	VCC1	Input a high- or low-level signal or leave open.
P6_4 / $\overline{\text{RTS1}}$	BUSY output	O	VCC1	BUSY signal output pin
P6_5/CLK1	SCLK input	I	VCC1	Serial clock input pin
P6_6 / RXD1	RXD input	I	VCC1	Serial data input pin.
P6_7 / TXD1	TXD output	O	VCC1	Serial data output pin.
P7_0 to P7_7	Input port P7	I	VCC1	Input a high- or low-level signal or leave open.
P8_0 to P8_7	Input port P8	I	VCC1	Input a high- or low-level signal or leave open.
P9_0 to P9_7	Input port P9	I	VCC1	Input a high- or low-level signal or leave open.
P10_0 to P10_7	Input port P10	I	VCC1	Input a high- or low-level signal or leave open.
P11_0 to P11_7	Input port P11	I	VCC1	Input a high- or low-level signal or leave open.
P12_0 to P12_7	Input port P12	I	VCC2	Input a high- or low-level signal or leave open.
P13_0 to P13_7	Input port P13	I	VCC2	Input a high- or low-level signal or leave open.
P14_0 to P14_1	Input port P14	I	VCC1	Input a high- or low-level signal or leave open.

Table 30.23 Setting of Standard Serial I/O Mode 1

Signal	Input Level
CNVSS	VCC1
$\overline{\text{EPM}}$	VSS
$\overline{\text{RESET}}$	VSS → VCC1
$\overline{\text{CE}}$	VCC2
SCLK	VCC1



Notes:

1. Control pins and external circuitry will vary depending on the programmer. For more information, refer to the programmer manual.
2. In this example, modes are switched between single-chip mode and standard serial I/O mode by controlling the CNVSS pin input with a switch.
3. If in standard serial I/O mode 1, there is a possibility that the user reset signal will go low during serial I/O mode, break the connection between the user reset signal and $\overline{\text{RESET}}$ pin by using, for example, a jumper switch.

Figure 30.26 Circuit Application in Standard Serial I/O Mode 1

30.9.5 Standard Serial I/O Mode 2

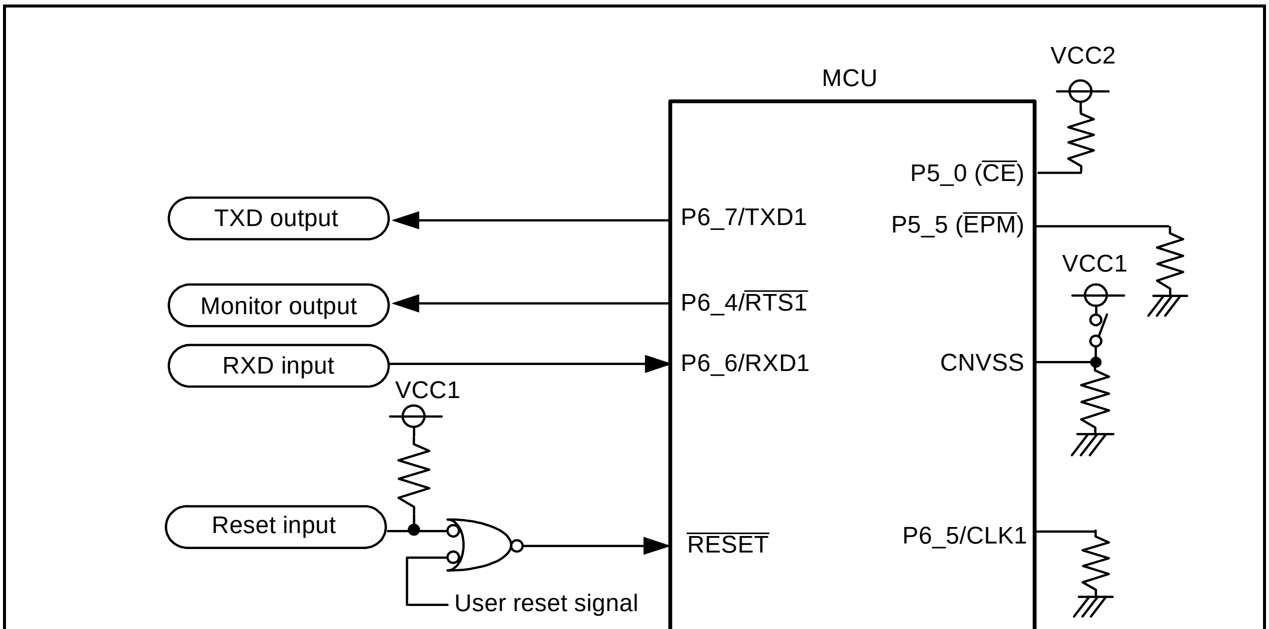
In standard serial I/O mode 2, a serial programmer is connected to the MCU by using 2-wire clock asynchronous serial I/O. The main clock is used.

Table 30.24 Pin Functions (Flash Memory Standard Serial I/O Mode 2)

Pin	Name	I/O	Power Supply	Description
VCC1, VCC2, VSS	Power input		-	Apply the flash memory program and erase voltage to the VCC1 pin, and VCC2 to the VCC2 pin. The VCC application condition is that VCC2 ≤ VCC1. Apply 0 V to the VSS pin.
CNVSS	CNVSS	I	VCC1	Connect to the VCC1 pin.
$\overline{\text{RESET}}$	Reset input	I	VCC1	Reset input pin.
XIN	Clock input	I	VCC1	Connect a ceramic resonator or crystal between pins XIN and XOUT. To input an externally generated clock, input it to the XIN pin and open the XOUT pin.
XOUT	Clock output	O	VCC1	
BYTE	BYTE input	I	VCC1	Connect this pin to VSS or VCC1.
AVCC, AVSS	Analog power supply input			Connect the AVCC pin to VCC1 and the AVSS pin to VSS.
VREF	Reference voltage input	I		Reference voltage input pin for A/D converter. When using standard serial I/O mode 2, and power supply to VREF is not supplied, connect with VSS.
P0_0 to P0_7	Input port P0	I	VCC2	Input a high- or low-level signal or leave open.
P1_0 to P1_7	Input port P1	I	VCC2	Input a high- or low-level signal or leave open.
P2_0 to P2_7	Input port P2	I	VCC2	Input a high- or low-level signal or leave open.
P3_0 to P3_7	Input port P3	I	VCC2	Input a high- or low-level signal or leave open.
P4_0 to P4_7	Input port P4	I	VCC2	Input a high- or low-level signal or leave open.
P5_1 to P5_4, P5_6, P5_7	Input port P5	I	VCC2	Input a high- or low-level signal or leave open.
P5_0	$\overline{\text{CE}}$ input	I	VCC2	Input a high-level signal.
P5_5	$\overline{\text{EPM}}$ input	I	VCC2	Input a low-level signal.
P6_0 to P6_3	Input port P6	I	VCC1	Input a high- or low-level signal or leave open.
P6_4 / $\overline{\text{RTS1}}$	BUSY output	O	VCC1	Monitor signal output pin for checking the boot program operation.
P6_5/CLK1	SCLK input	I	VCC1	Input a low-level signal
P6_6 / RXD1	RXD input	I	VCC1	Serial data input pin.
P6_7 / TXD1	TXD output	O	VCC1	Serial data output pin.
P7_0 to P7_7	Input port P7	I	VCC1	Input a high- or low-level signal or leave open.
P8_0 to P8_7	Input port P8	I	VCC1	Input a high- or low-level signal or leave open.
P9_0 to P9_7	Input port P9	I	VCC1	Input a high- or low-level signal or leave open.
P10_0 to P10_7	Input port P10	I	VCC1	Input a high- or low-level signal or leave open.
P11_0 to P11_7	Input port P11	I	VCC1	Input a high- or low-level signal or leave open.
P12_0 to P12_7	Input port P12	I	VCC2	Input a high- or low-level signal or leave open.
P13_0 to P13_7	Input port P13	I	VCC2	Input a high- or low-level signal or leave open.
P14_0 to P14_1	Input port P14	I	VCC1	Input a high- or low-level signal or leave open.

Table 30.25 Setting of Standard Serial I/O Mode 2

Signal	Input Level
CNVSS	VCC1
$\overline{\text{EPM}}$	VSS
$\overline{\text{RESET}}$	VSS → VCC1
$\overline{\text{CE}}$	VCC2
P6_5/CLK1	VSS



Notes:
1. Control pins vary by programmer. For more information, refer to the programmer manual.
2. In this example, modes are switched between single-chip mode and standard serial I/O mode by controlling the CNVSS pin input with a switch.

Figure 30.27 Circuit Application in Standard Serial I/O Mode 2

30.10 Parallel I/O Mode

In parallel I/O mode, program ROM 1, program ROM 2, and data flash can be rewritten using a parallel programmer supporting the M16C/65C Group. Contact the parallel programmer manufacturer for more information. Refer to the user's manual included with your parallel programmer for instructions.

30.10.1 ROM Code Protect Function

The ROM code protect function disables the flash memory from being read or rewritten during parallel I/O mode. Refer to 30.4.1 "Optional Function Select Address 1 (OFS1)". The OFS1 address is located in block 0 of program ROM 1.

When the ROMCR bit in the OFS1 address is 1 (ROMCP1 bit enabled) and the ROMCP1 bit is set to 0, the ROM code protect function is enabled.

To cancel ROM code protect, erase block 0 including the OFS1 address using standard serial I/O mode or CPU rewrite mode.

30.11 Notes on Flash Memory

30.11.1 OFS1 Address and ID Code Storage Address

The OFS1 address and ID code storage address are part of flash memory. When writing a program to flash memory, write an appropriate value to those addresses simultaneously.

In the OFS1 address, the MCU state after reset and the function to prevent rewrite in parallel I/O mode are selected. The OFS1 address is 0FFFFFh. This is the most significant address of block 0 in program ROM 1 and upper address of reset vector. Also, the ID code storage address is in block 0 and upper address of the interrupt vector.

The ID code check function cannot be disabled. Even if the protect using the ID code check function is unnecessary, input the appropriate ID code when using a serial programmer or debugger. Without the appropriate ID code, the serial programmer or debugger cannot be used.

ex) Set FEh to the OFS1 address

When using an address control instruction and logical addition:

```
  .org 0FFFFCh
RESET:
  .lword start | 0FE000000h
```

When using an address control instruction:

```
  .org 0FFFFCh
RESET:
  .addr start
  .byte 0FEh
```

(Program format varies depending on the compiler. Refer to the compiler manual.)

30.11.2 Reading Data Flash

When $2.7\text{ V} \le \text{VCC1} \le 3.0\text{ V}$ and $f(\text{BCLK}) \ge 16\text{ MHz}$, or $3.0\text{ V} < \text{VCC1} \le 5.5\text{ V}$ and $f(\text{BCLK}) \ge 20\text{ MHz}$, one wait must be inserted to execute the program on the data flash and read the data. Set the PM17 in the PM1 register or FMR17 bit in the FMR1 register to insert one wait.

30.11.3 CPU Rewrite Mode

30.11.3.1 Operating Speed

Select a CPU clock frequency of 10 MHz or less by setting the CM06 bit in the CM0 register and bits CM17 and CM16 in the CM1 register before entering CPU rewrite mode (EW0 or EW1 mode). Also, set the PM17 bit in the PM1 register to 1 (wait state).

30.11.3.2 CPU Rewrite Mode Select

Change FMR01 bit in the FMR0 register, FMR11 bit in the FMR1 register, and FMR60 bit in the FMR6 register while in the following state:

- The PM24 bit in the PM2 register is 0 ($\overline{\text{NMI}}$ interrupt disabled).
- High is input to the $\overline{\text{NMI}}$ pin.

Change the FMR60 bit while the FMR00 bit in the FMR0 register is 1 (ready).

30.11.3.3 Prohibited Instructions

Do not use the following instructions in EW0 mode:
UND instruction, INTO instruction, JMPS instruction, JSRS instruction, and BRK instruction.

30.11.3.4 Interrupts (EW0 Mode and EW1 Mode)

- Do not use an address match interrupt during command execution because the address match interrupt vector is located in ROM.
- Do not use a non-maskable interrupt during block 0 erase because fixed vector is located in block 0.

30.11.3.5 Rewrite (EW0 Mode)

If the power supply voltage drops while rewriting the block where the rewrite control program is stored, the rewrite control program is not correctly rewritten. This may prevent the flash memory from being rewritten. If this error occurs, use standard serial I/O mode or parallel I/O mode for rewriting.

30.11.3.6 Rewrite (EW1 Mode)

Do not rewrite any blocks in which the rewrite control program is stored.

30.11.3.7 DMA transfer

In EW0 mode, do not use flash memory as a source of the DMA transfer.
In EW1 mode, do not generate a DMA transfer while the FMR00 bit in the FMR0 register is 0 (auto programming or auto erasing).

30.11.3.8 Wait Mode

To enter wait mode, set the FMR01 bit in the FMR0 register to 0 (CPU rewrite mode disabled) before executing the WAIT instruction.

30.11.3.9 Stop Mode

To enter stop mode, set the FMR01 bit to 0 (CPU rewrite mode disabled), and then disable DMA transfer before setting the CM10 bit in the CM 1 register to 1 (stop mode).

30.11.3.10 Software Command

Observe the notes below when using the following commands.

- Program
- Block erase
- Lock bit program
- Read lock bit status
- Block blank check

(a) The FMR00 bit in the FMR0 register indicates the status while executing these commands. Do not execute other commands while the FMR00 bit is 0 (busy).

(b) Use these commands in 40 MHz on-chip oscillator mode, high-speed mode, medium-speed mode, and PLL operating mode. Do not change clock modes while the FMR00 bit in the FMR0 register is 0 (busy).

(c) After executing the program, block erase, or lock bit program command, perform a full status check per command (Do not execute multiple commands or same command more than once before performing a full status check).

(d) Do not execute the program, block erase, lock bit program, or block blank check command when either or both bits FMR06 and FMR07 in the FMR0 register are 1 (error).

(e) Do not use these commands in slow read mode (when the FMR22 bit is 1) or low current consumption read mode (when both bits FMR22 and FMR23 are 1).

30.11.3.11 PM13 Bit

The PM13 bit in the PM1 register becomes 1 while the FMR01 bit in the FMR0 register is 1 (CPU rewrite mode enabled). The PM13 bit returns to the former value by setting the FMR01 bit to 0 (CPU rewrite mode disabled). When the PM13 bit is changed during CPU rewrite mode, the value of the PM13 bit after being changed is not reflected until the FMR01 bit is set to 0.

30.11.3.12 Area Where the Rewrite Control Program is Executed

Bits PM10 and PM13 in the PM1 register become 1 in CPU rewrite mode. Execute the rewrite program in internal RAM or an external area which can be used when both bits PM10 and PM13 are 1. Do not use the area (40000h to BFFFFh) where accessible space is expanded when the PM13 bit is 0 and 4-MB mode is set.

30.11.3.13 Program and Erase Cycles and Execution Time

Execution time of the program, block erase, and lock bit program commands becomes longer as the number of programming and erasing increases.

30.11.3.14 Suspending the Auto-Erase and Auto-Program Operations

When the program, block erase, and lock bit program commands are suspended, the blocks for those commands must be erased. Execute the program and lock bit program commands again after erasing.

Those commands are suspended by the following reset or interrupts:

- Hardware, power-on, voltage monitor 0, voltage monitor 1, voltage monitor 2, oscillator stop detect, watchdog timer, software resets.
- $\overline{\text{NMI}}$, watchdog timer, oscillator stop/restart detect, voltage monitor 1, and voltage monitor 2 interrupts.

30.11.4 User Boot

30.11.4.1 User Boot Mode Program

Note the following when using user boot mode:

- When using user boot mode, make sure to allocate the program to be executed to program ROM 2.
- Bits VDSEL1 and LVDAS in the OFS1 address are disabled in boot mode.
- When restarting the MCU in user boot mode after starting it in user boot mode, RAM becomes undefined.
- If addresses 13FF8h to 13FFBh are all 00h, the MCU does not enter standard serial I/O mode. Therefore, the programmer or on-chip debugger cannot be connected.
- As the reset sequence differs, the time necessary for starting the program is longer than in single-chip mode.
- Functions in user boot mode cannot be debugged by the on-chip debugging emulator or full spec emulator.
- While using user boot mode, do not change the input level of the pin used for user boot entry. However, if there is a possibility that the input level may change, perform the necessary processes in user boot mode, then restart the MCU in single-chip mode before the input level changes.
- To use user boot mode after standard serial I/O mode, turn off the power when exiting standard serial I/O mode, and then turn on the power again (cold start). The MCU enters user boot mode under the right conditions.

31. Electrical Characteristics

31.1 Electrical Characteristics (Common to 3 V and 5 V)

31.1.1 Absolute Maximum Rating

Table 31.1 Absolute Maximum Ratings

Symbol	Parameter		Condition	Rated Value	Unit
V_{CC1}	Supply voltage		$V_{CC1} = AV_{CC}$	–0.3 to 6.5	V
V_{CC2}	Supply voltage		$V_{CC1} = AV_{CC}$	–0.3 to V_{CC1} + 0.1 [1]	V
AV_{CC}	Analog supply voltage		$V_{CC1} = AV_{CC}$	–0.3 to 6.5	V
V_{REF}	Analog reference voltage		$V_{CC1} = AV_{CC}$	–0.3 to V_{CC1} + 0.1 [1]	V
V_I	Input voltage	$\overline{\text{RESET}}$, CNVSS, BYTE, P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1 XIN		–0.3 to V_{CC1} + 0.3 [1]	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7		–0.3 to V_{CC2} + 0.3 [1]	V
		P7_0, P7_1, P8_5		–0.3 to 6.5	V
V_O	Output voltage	P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1 XOUT		–0.3 to V_{CC1} + 0.3 [1]	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7		–0.3 to V_{CC2} + 0.3 [1]	V
		P7_0, P7_1, P8_5		–0.3 to 6.5	V
P_d	Power consumption		–40°C < $T_{opr} \leq$ 85°C	300	mW
T_{opr}	Operating temperature	When the MCU is operating		–20 to 85/–40 to 85	°C
		Flash program erase	Program area	0 to 60	
			Data area	–20 to 85/–40 to 85	
T_{stg}	Storage temperature			–65 to 150	°C

Note:

1. Maximum value is 6.5 V.

31.1.2 Recommended Operating Conditions

Table 31.2 Recommended Operating Conditions (1/3)

V_{CC1} = V_{CC2} = 2.7 to 5.5 V at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified.

Symbol	Parameter		Standard			Unit
			Min.	Typ.	Max.	
V_{CC1}, V_{CC2}	Supply voltage ($V_{CC1} \geq V_{CC2}$)	CEC function is not used	2.7	5.0	5.5	V
		CEC function is used	2.7		3.63	V
AV_{CC}	Analog supply voltage			V_{CC1}		V
V_{SS}	Supply voltage			0		V
AV_{SS}	Analog supply voltage			0		V
V_{IH}	High input voltage	P3_1 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7	0.8V_{CC2}		V_{CC2}	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 (in single-chip mode)	0.8V_{CC2}		V_{CC2}	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 (data input in memory expansion and microprocessor modes)	0.5V_{CC2}		V_{CC2}	V
		P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1 XIN, $\overline{\text{RESET}}$, CNVSS, BYTE	0.8V_{CC1}		V_{CC1}	V
		P7_0, P7_1, P8_5	0.8V_{CC1}		6.5	V
		CEC	0.7V_{CC1}			V
V_{IL}	Low input voltage	P3_1 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7	0		0.2V_{CC2}	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 (in single-chip mode)	0		0.2V_{CC2}	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 (data input in memory expansion and microprocessor mode)	0		0.16V_{CC2}	V
		P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7,P11_0 to P11_7, P14_0, P14_1 XIN, $\overline{\text{RESET}}$, CNVSS, BYTE	0		0.2V_{CC1}	V
		CEC			0.26V_{CC1}	V
$I_{OH(sum)}$	High peak output current	Sum of $I_{OH(peak)}$ at P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7			-40.0	mA
		Sum of $I_{OH(peak)}$ at P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, and P13_0 to P13_7			-40.0	mA
		Sum of $I_{OH(peak)}$ at P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4			-40.0	mA
		Sum of $I_{OH(peak)}$ at P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0 to P14_1			-40.0	mA
$I_{OH(peak)}$	High peak output current	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1			–10.0	mA
$I_{OH(avg)}$	High average output current [1]	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1			–5.0	mA

Note:

1. The average output current is the mean value within 100 ms.

Table 31.3 Recommended Operating Conditions (2/3)

V_{CC1} = V_{CC2} = 2.7 to 5.5 V at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified.

Symbol	Parameter		Standard			Unit
			Min.	Typ.	Max.	
$I_{OL(sum)}$	Low peak output current	Sum of $I_{OL(peak)}$ at P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0 to P14_1			80.0	mA
		Sum of $I_{OL(peak)}$ at P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_5, P12_0 to P12_7, P13_0 to P13_7			80.0	mA
$I_{OL(peak)}$	Low peak output current	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1			10.0	mA
$I_{OL(avg)}$	Low average output current [1]	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1			5.0	mA
$f_{(XIN)}$	Main clock input oscillation frequency	V_{CC1} = 2.7 V to 5.5 V	2		20	MHz
$f_{(XCIN)}$	Sub clock oscillation frequency			32.768	50	kHz
$f_{(PLL)}$	PLL clock oscillation frequency	V_{CC1} = 2.7 V to 5.5 V	10		32	MHz
$f_{(BCLK)}$	CPU operation clock		2		32	MHz
$t_{SU(PLL)}$	PLL frequency synthesizer stabilization wait time	V_{CC1} = 5.0 V			2	ms
		V_{CC1} = 3.0 V			3	ms

Note:

1. The average output current is the mean value within 100 ms.

Table 31.4 Recommended Operating Conditions (3/3) [1]

V_{CC1} = 2.7 to 5.5 V, V_{SS} = 0 V, and T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified.
The ripple voltage must not exceed $V_{r(VCC1)}$ and/or $dV_{r(VCC1)}/dt$.

Symbol	Parameter		Standard			Unit
			Min.	Typ.	Max.	
$V_{r(VCC1)}$	Allowable ripple voltage	V_{CC1} = 5.0 V			0.5	Vp-p
		V_{CC1} = 3.0 V			0.3	Vp-p
$dV_{r(VCC1)}/dt$	Ripple voltage falling gradient	V_{CC1} = 5.0 V			0.3	V/ms
		V_{CC1} = 3.0 V			0.3	V/ms

Note:

1. The device is operationally guaranteed under these operating conditions.

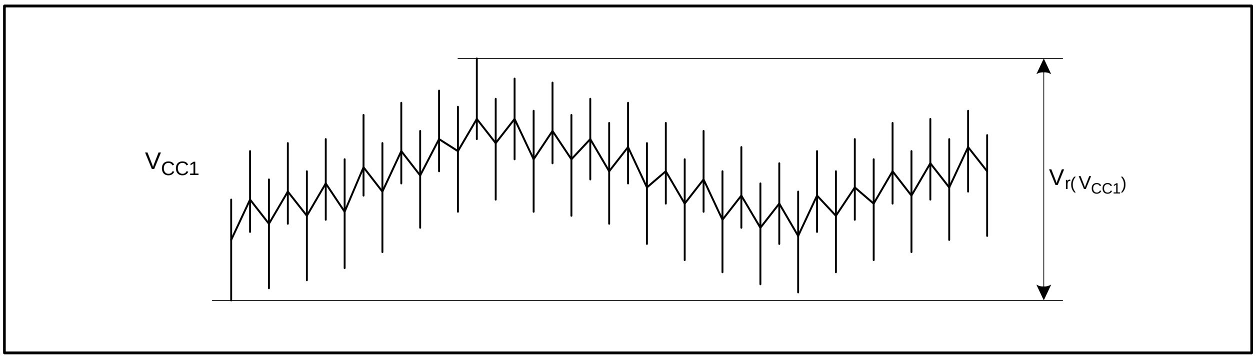


Figure 31.1 Ripple Waveform

31.1.3 A/D Conversion Characteristics

Table 31.5 A/D Conversion Characteristics (1/2) (1)

V_{CC1} = AV_{CC} = 3.0 to 5.5 V ≥ V_{CC2} ≥ V_{REF}, V_{SS} = AV_{SS} = 0 V at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified.

Symbol	Parameter		Measuring Condition		Standard			Unit
					Min.	Typ.	Max.	
-	Resolution		AV_{CC} = V_{CC1} ≥ V_{CC2} ≥ V_{REF}				10	Bits
I_{NL}	Integral non-linearity error	10 bits	V_{CC1} = 5.0 V	AN0 to AN7 input, AN0_0 to AN0_7 input, AN2_0 to AN2_7 input, ANEX0, ANEX1 input (Note 2)			±3	LSB
			V_{CC1} = 3.3 V	AN0 to AN7 input, AN0_0 to AN0_7 input, AN2_0 to AN2_7 input, ANEX0, ANEX1 input (Note 2)			±3	LSB
			V_{CC1} = 3.0 V	AN0 to AN7 input, AN0_0 to AN0_7 input, AN2_0 to AN2_7 input, ANEX0, ANEX1 input (Note 2)			±3	LSB
-	Absolute accuracy	10 bits	V_{CC1} = 5.0 V	AN0 to AN7 input, AN0_0 to AN0_7 input, AN2_0 to AN2_7 input, ANEX0, ANEX1 input (Note 2)			±3	LSB
			V_{CC1} = 3.3 V	AN0 to AN7 input, AN0_0 to AN0_7 input, AN2_0 to AN2_7 input, ANEX0, ANEX1 input (Note 2)			±3	LSB
			V_{CC1} = 3.0 V	AN0 to AN7 input, AN0_0 to AN0_7 input, AN2_0 to AN2_7 input, ANEX0, ANEX1 input (Note 2)			±3	LSB

Notes:

1. Use when AV_{CC} = V_{CC1}.
2. Flash memory rewrite disabled. Except for the analog input pin, set the pins to be measured as input ports and connect them to V_{SS}. See Figure 31.2 “A/D Accuracy Measure Circuit”.

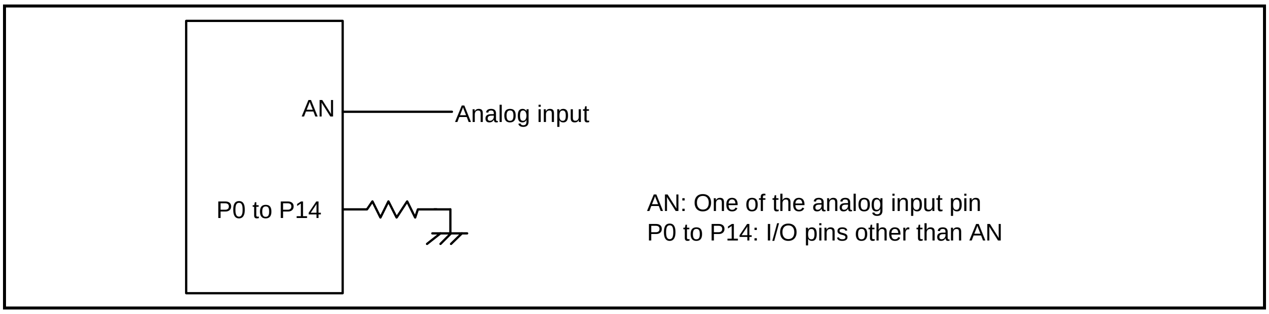

AN
Analog input
P0 to P14
AN: One of the analog input pin
P0 to P14: I/O pins other than AN

Figure 31.2 A/D Accuracy Measure Circuit

Table 31.6 A/D Conversion Characteristics (2/2) (1)

$V_{CC1} = AV_{CC} = 3.0$ to $5.5\ V \geq V_{CC2} \geq V_{REF}$, $V_{SS} = AV_{SS} = 0\ V$ at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified.

Symbol	Parameter		Measuring Condition	Standard			Unit
				Min.	Typ.	Max.	
ϕAD	A/D operating clock frequency	AN0 to AN7 input, ANEX0 to ANEX1 input	$4.0\ V \leq V_{CC1} \leq 5.5\ V$	2		25	MHz
			$3.2\ V \leq V_{CC1} \leq 4.0\ V$	2		16	MHz
			$3.0\ V \leq V_{CC1} \leq 3.2\ V$	2		10	MHz
		AN0_0 to AN0_7 input, AN2_0 to AN2_7 input	$4.0\ V \leq V_{CC2} \leq 5.5\ V$	2		25	MHz
			$3.2\ V \leq V_{CC2} \leq 4.0\ V$	2		16	MHz
			$3.0\ V \leq V_{CC2} \leq 3.2\ V$	2		10	MHz
-	Tolerance level impedance				3		kΩ
D_{NL}	Differential non-linearity error		(4)			±1	LSB
-	Offset error		(4)			±3	LSB
-	Gain error		(4)			±3	LSB
t_{CONV}	10-bit conversion time		V_{CC1} = 5 V, ϕAD = 25 MHz	1.60			μs
t_{SAMP}	Sampling time			0.60			μs
V_{REF}	Reference voltage			3.0		V_{CC1}	V
V_{IA}	Analog input voltage (2), (3)			0		V_{REF}	V

Notes:
1. Use when $AV_{CC} = V_{CC1}$.
2. When $V_{CC1} \geq V_{CC2}$, set as below:
   Analog input voltage (AN0 to AN7, ANEX0, and ANEX1) $\leq V_{CC1}$
   Analog input voltage (AN0_0 to AN0_7 and AN2_0 to AN2_7) $\leq V_{CC2}$.
3. When analog input voltage is over reference voltage, the result of A/D conversion is 3FFh.
4. Flash memory rewrite disabled. Except for the analog input pin, set the pins to be measured as input ports and connect them to V_{SS}. See Figure 31.2 “A/D Accuracy Measure Circuit”.

31.1.4 D/A Conversion Characteristics

Table 31.7 D/A Conversion Characteristics

$V_{CC1} = AV_{CC} = V_{REF} = 3.0$ to $5.5\ V$, $V_{SS} = AV_{SS} = 0\ V$ at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified.

Symbol	Parameter	Measuring Condition	Standard			Unit
			Min.	Typ.	Max.	
-	Resolution				8	Bits
-	Absolute Accuracy				2.5	LSB
t_{SU}	Setup Time				3	μs
R_O	Output Resistance		5	6	8.2	kΩ
I_{VREF}	Reference Power Supply Input Current	See Notes 1 and 2			1.5	mA

Notes:
1. This applies when using one D/A converter, with the D/A register for the unused D/A converter set to 00h.
2. The current consumption of the A/D converter is not included. Also, the I_{VREF} of the D/A converter will flow even if the ADSTBY bit in the ADCON1 register is 0 (A/D operation stopped (standby)).

31.1.5 Flash Memory Electrical Characteristics

Table 31.8 CPU Clock When Operating Flash Memory ($f_{(BCLK)}$)

V_{CC1} = 2.7 to 5.5 V, T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified.

Symbol	Parameter	Conditions	Standard			Unit
			Min.	Typ.	Max.	
-	CPU rewrite mode				10 [1]	MHz
f(SLOW_R)	Slow read mode				5 [3]	MHz
-	Low current consumption read mode			fC(32.768)	35	kHz
-	Data flash read	2.7 V ≤ V_{CC1} ≤ 3.0 V			16 [2]	MHz
		3.0 V < V_{CC1} ≤ 5.5 V			20 [2]	MHz

Notes:
1. Set the PM17 bit in the PM1 register to 1 (one wait).
2. When the frequency is over this value, set the FMR17 bit in the FMR1 register to 0 (one wait) or the PM17 bit in the PM1 register to 1 (one wait)
3. Set the PM17 bit in the PM1 register to 1 (one wait). When using 125 kHz on-chip oscillator clock or sub clock as the CPU clock source, a wait is not necessary.

Table 31.9 Flash Memory (Program ROM 1, 2) Electrical Characteristics

V_{CC1} = 2.7 to 5.5 V at T_{opr} = 0°C to 60°C (option: -40°C to 85°C), unless otherwise specified.

Symbol	Parameter	Conditions	Standard			Unit
			Min.	Typ.	Max.	
-	Program and erase cycles [1], [3], [4]	V_{CC1} = 3.3 V, T_{opr} = 25°C	1,000 [2]			times
-	2 word program time	V_{CC1} = 3.3 V, T_{opr} = 25°C		150	4000	µs
-	Lock bit program time	V_{CC1} = 3.3 V, T_{opr} = 25°C		70	3000	µs
-	Block erase time	V_{CC1} = 3.3 V, T_{opr} = 25°C		0.2	3.0	s
$t_{d(SR-SUS)}$	Time delay from suspend request until suspend				$5 + \frac{3}{f(BCLK)}$	ms
-	Interval from erase start/restart until following suspend request		0			µs
-	Suspend interval necessary for auto-erasure to complete [7]		20			ms
-	Time from suspend until erase restart				$30 + \frac{1}{f(BCLK)}$	µs
-	Program, erase voltage		2.7		5.5	V
-	Read voltage	T_{opr}= -20°C to 85°C/-40°C to 85°C	2.7		5.5	V
-	Program, erase temperature		0		60	°C
t_{PS}	Flash memory circuit stabilization wait time				50	µs
-	Data hold time [6]	Ambient temperature = 55°C	20			year

Notes:
1. Definition of program and erase cycles:
The program and erase cycles refer to the number of per-block erasures. If the program and erase cycles are n (n = 1,000), each block can be erased n times. For example, if a block is erased after writing 2 word data 16,384 times, each to a different address, this counts as one program and erase cycles. Data cannot be written to the same address more than once without erasing the block (rewrite prohibited).
2. Cycles to guarantee all electrical characteristics after program and erase. (1 to Min. value can be guaranteed).
3. In a system that executes multiple programming operations, the actual erasure count can be reduced by writing to sequential addresses in turn so that as much of the block as possible is used up before performing an erase operation. It is advisable to retain data on the erasure cycles of each block and limit the number of erase operations to a certain number.
4. If an error occurs during block erase, attempt to execute the clear status register command, then execute the block erase command at least three times until the erase error does not occur.
5. Customers desiring program/erase failure rate information should contact a Renesas Electronics sales office.
6. The data hold time includes time that the power supply is off or the clock is not supplied.
7. After an erase start or erase restart, if an interval of at least 20 ms is not set before the next suspend request, the erase sequence cannot be completed.

Table 31.10 Flash Memory (Data Flash) Electrical Characteristics

V_{CC1} = 2.7 to 5.5 V at T_{opr} = -20 to 85°C/-40 to 85°C, unless otherwise specified.

Symbol	Parameter	Conditions	Standard			Unit
			Min.	Typ.	Max.	
-	Program and erase cycles [1], [3], [4]	V_{CC1} = 3.3 V, T_{opr} = 25°C	10,000 [2]			times
-	2 word program time	V_{CC1} = 3.3 V, T_{opr} = 25°C		300	4000	μs
-	Lock bit program time	V_{CC1} = 3.3 V, T_{opr} = 25°C		140	3000	μs
-	Block erase time	V_{CC1} = 3.3 V, T_{opr} = 25°C		0.2	3.0	s
$t_{d(SR-SUS)}$	Time delay from suspend request until suspend				$5 + \frac{3}{f(BCLK)}$	ms
-	Interval from erase start/restart until following suspend request		0			μs
-	Suspend interval necessary for auto-erasure to complete [7]		20			ms
-	Time from suspend until erase restart				$30 + \frac{1}{f(BCLK)}$	μs
-	Program, erase voltage		2.7		5.5	V
-	Read voltage		2.7		5.5	V
-	Program, erase temperature		–20/–40		85	°C
t_{PS}	Flash memory circuit stabilization wait time				50	μs
-	Data hold time [6]	Ambient temperature = 55°C	20			year

Notes:

1. Definition of program and erase cycles
   The program and erase cycles refer to the number of per-block erasures.
   If the program and erase cycles are n (n = 10,000), each block can be erased n times.
   For example, if a 4 KB block is erased after writing 2 word data 1,024 times, each to a different address, this counts as one program and erase cycles. Data cannot be written to the same address more than once without erasing the block (rewrite prohibited).
2. Cycles to guarantee all electrical characteristics after program and erase. (1 to Min. value can be guaranteed).
3. In a system that executes multiple programming operations, the actual erasure count can be reduced by writing to sequential addresses in turn so that as much of the block as possible is used up before performing an erase operation. For example, when programming groups of 16 bytes, the effective number of rewrites can be minimized by programming up to 256 groups before erasing them all in one operation. In addition, averaging the erasure cycles between blocks A and B can further reduce the actual erasure cycles. It is also advisable to retain data on the erasure cycles of each block and limit the number of erase operations to a certain number.
4. If an error occurs during block erase, attempt to execute the clear status register command, then execute the block erase command at least three times until the erase error does not occur.
5. Customers desiring program/erase failure rate information should contact a Renesas Electronics sales office.
6. The data hold time includes time that the power supply is off or the clock is not supplied.
7. After an erase start or erase restart, if an interval of at least 20 ms is not set before the next suspend request, the erase sequence cannot be completed.

31.1.6 Voltage Detector and Power Supply Circuit Electrical Characteristics

Table 31.11 Voltage Detector 0 Electrical Characteristics

The measurement condition is V_{CC1} = 2.7 to 5.5 V, T_{opr} = -20°C to 85°C/-40°C to 85°C, unless otherwise specified.

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
V_{det0}	Voltage detection level Vdet0_0 (1)	When V_{CC1} is falling.	1.80	1.90	2.10	V
	Voltage detection level Vdet0_2 (1)	When V_{CC1} is falling.	2.70	2.85	3.00	V
-	Voltage detector 0 response time (3)	When V_{CC1} falls from 5 V to (Vdet0_0 - 0.1) V			200	µs
-	Voltage detector self power consumption	VC25 = 1, V_{CC1} = 5.0 V		1.5		µA
$t_{d(E-A)}$	Waiting time until voltage detector operation starts (2)				100	µs

Notes:
1. Select the voltage detection level with the VDSEL1 bit in the OFS1 address.
2. Necessary time until the voltage detector operates when setting to 1 again after setting the VC25 bit in the VCR2 register to 0.
3. Time from when passing the V_{det0} until when a voltage monitor 0 reset is generated.

Table 31.12 Voltage Detector 1 Electrical Characteristics

The measurement condition is V_{CC1} = 2.7 to 5.5 V, T_{opr} = -20°C to 85°C/-40°C to 85°C, unless otherwise specified.

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
V_{det1}	Voltage detection level Vdet1_6 (1)	When V_{CC1} is falling.	2.80	3.10	3.40	V
	Voltage detection level Vdet1_B (1)	When V_{CC1} is falling.	3.55	3.85	4.15	V
	Voltage detection level Vdet1_F (1)	When V_{CC1} is falling.	4.15	4.45	4.75	V
-	Hysteresis width when V_{CC1} of voltage detector 1 is rising			0.15		V
-	Voltage detector 1 response time (3)	When V_{CC1} falls from 5 V to (Vdet1_0 - 0.1) V			200	µs
-	Voltage detector self power consumption	VC26 = 1, V_{CC1} = 5.0 V		1.7		µA
$t_{d(E-A)}$	Waiting time until voltage detector operation starts (2)				100	µs

Notes:
1. Select the voltage detection level with bits VD1S0 to VD1S3 in the VD1LS register.
2. Necessary time until the voltage detector operates when setting to 1 again after setting the VC26 bit in the VCR2 register to 0.
3. Time from when passing the V_{det1} until when a voltage monitor 1 reset is generated.

Table 31.13 Voltage Detector 2 Electrical Characteristics

The measurement condition is V_{CC1} = 2.7 to 5.5 V, T_{opr} = -20°C to 85°C/-40°C to 85°C, unless otherwise specified.

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
V_{det2}	Voltage detection level Vdet2_0	When V_{CC1} is falling	3.70	4.00	4.30	V
-	Hysteresis width at the rising of V_{CC1} in voltage detector 2			0.15		V
-	Voltage detector 2 response time (2)	When V_{CC1} falls from 5 V to (Vdet2_0 - 0.1) V			200	µs
-	Voltage detector self power consumption	VC27 = 1, V_{CC1} = 5.0 V		1.7		µA
$t_{d(E-A)}$	Waiting time until voltage detector operation starts (1)				100	µs

Notes:

1. Necessary time until the voltage detector operates after setting to 1 again after setting the VC27 bit in the VCR2 register to 0.
2. Time from when passing the V_{det2} until when a voltage monitor 2 reset is generated.

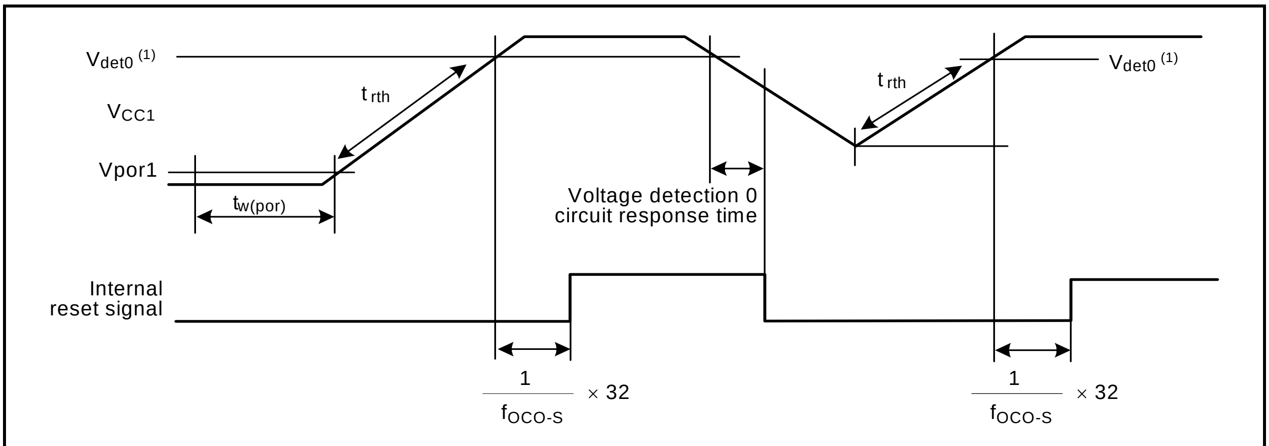
Table 31.14 Power-On Reset Circuit

The measurement condition is V_{CC1} = 2.0 to 5.5 V, T_{opr} = -20°C to 85°C/ -40°C to 85°C, unless otherwise specified.

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
V_{por1}	Voltage at which power-on reset enabled (1)				0.5	V
t_{rth}	External power V_{CC1} rise gradient		2.0		50000	mV/ms
$t_{w(por)}$	Time necessary to enable power-on reset		300			ms

Note:

1. To use the power-on reset function, enable voltage monitor 0 reset by setting the LVDAS bit in the OFS1 address to 0. Also, set the VDSEL1 bit to 0 (Vdet0_2).



Note:

1. V_{det0} indicates the voltage detection level of the voltage detection 0 circuit.

Figure 31.3 Power-On Reset Circuit Electrical Characteristics

Table 31.15 Power Supply Circuit Timing Characteristics

The measurement condition is V_{CC1} = 2.7 to 5.5 V and T_{opr} = 25°C, unless otherwise specified.

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
$t_{d(P-R)}$	Internal power supply stability time when power is on [1]				5	ms
$t_{d(R-S)}$	STOP release time				150	µs
$t_{d(W-S)}$	Low power mode wait mode release time				150	µs

Note:

1. Waiting time until the internal power supply generator stabilizes when power is on.

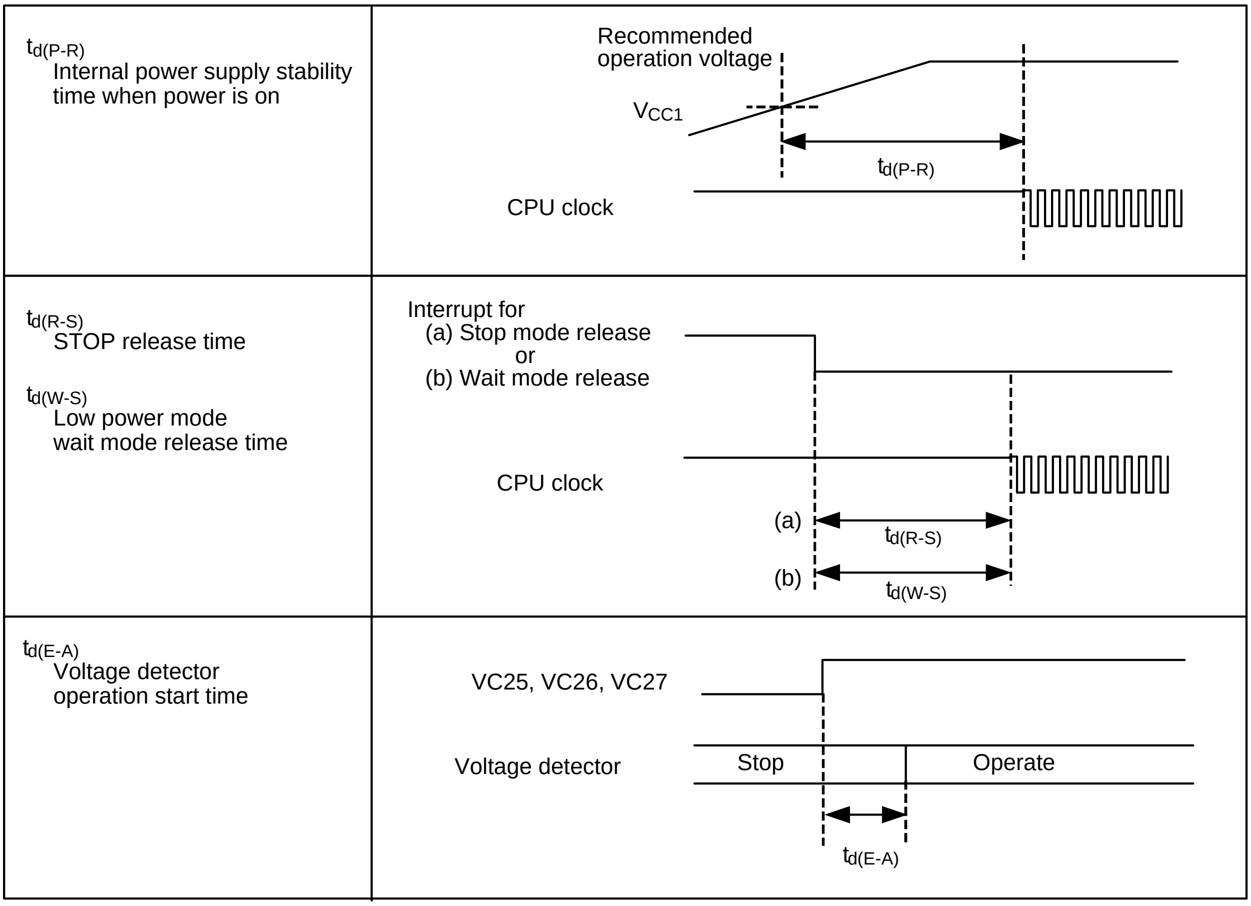


Figure 31.4 Power Supply Circuit Timing Diagram

31.1.7 Oscillator Electrical Characteristics

Table 31.16 40 MHz On-Chip Oscillator Electrical Characteristics (1/2)

V_{CC1} = 2.7 to 5.5 V, T_{opr} = -20°C to 85°C/-40°C to 85°C, unless otherwise specified.

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
f_{OCO40M}	40 MHz on-chip oscillator frequency	Average frequency in a 10 ms period	38	40	42	MHz
tsu(f_{OCO40M})	Wait time until 40 MHz on-chip oscillator stabilizes				2	ms

Table 31.17 125 kHz On-Chip Oscillator Electrical Characteristics

V_{CC1} = 2.7 to 5.5 V, T_{opr} = –20°C to 85°C/–40°C to 85°C, unless otherwise specified.

Symbol	Parameter	Condition	Standard			Unit
			Min.	Typ.	Max.	
f_{OCO-S}	125 kHz on-chip oscillator frequency	Average frequency in a 10 ms period	100	125	150	kHz
tsu(f_{OCO-S})	Wait time until 125 kHz on-chip oscillator stabilizes				20	µs

31.2 Electrical Characteristics (V_{CC1} = V_{CC2} = 5 V)

31.2.1 Electrical Characteristics

V_{CC1} = V_{CC2} = 5 V

Table 31.18 Electrical Characteristics (1) [1]

V_{CC1} = V_{CC2} = 4.2 to 5.5 V, V_{SS} = 0 V at T_{opr} = –20°C to 85°C/–40°C to 85°C, $f_{(BCLK)}$ = 32 MHz unless otherwise specified.

Symbol	Parameter		Measuring Condition	Standard			Unit
				Min.	Typ.	Max.	
V_{OH}	High output voltage	P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1	I_{OH} = –5 mA	V_{CC1} – 2.0		V_{CC1}	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7	I_{OH} = –5 mA	V_{CC2} – 2.0		V_{CC2}	
V_{OH}	High output voltage	P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1	I_{OH} = –200 μA	V_{CC1} – 0.3		V_{CC1}	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7	I_{OH} = –200 μA	V_{CC2} – 0.3		V_{CC2}	
V_{OH}	High output voltage XOUT	HIGH POWER	I_{OH} = –1 mA	V_{CC1} – 2.0		V_{CC1}	V
		LOW POWER	I_{OH} = –0.5 mA	V_{CC1} – 2.0		V_{CC1}	
	High output voltage XCOUT	HIGH POWER	With no load applied		2.6		V
		LOW POWER	With no load applied		2.2		
V_{OL}	Low output voltage	P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1	I_{OL} = 5 mA			2.0	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7	I_{OL} = 5 mA			2.0	
V_{OL}	Low output voltage	P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1	I_{OL} = 200 μA			0.45	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7	I_{OL} = 200 μA			0.45	
V_{OL}	Low output voltage XOUT	HIGH POWER	I_{OL} = 1 mA			2.0	V
		LOW POWER	I_{OL} = 0.5 mA			2.0	
	Low output voltage XCOUT	HIGH POWER	With no load applied		0		V
		LOW POWER	With no load applied		0		

Note:

1. When $V_{CC1} \neq V_{CC2}$, refer to 5 V or 3 V standard depending on the voltage.

$V_{CC1} = V_{CC2} = 5$ V

Table 31.19 Electrical Characteristics (2) (1)

$V_{CC1} = V_{CC2} = 4.2$ to 5.5 V, $V_{SS} = 0$ V at $T_{opr} = -20$°C to 85°C/–40°C to 85°C, $f_{(BCLK)} = 32$ MHz unless otherwise specified.

Symbol	Parameter		Measuring Condition	Standard			Unit
				Min.	Typ.	Max.	
$V_{T+} - V_{T-}$	Hysteresis	$\overline{\text{HOLD}}$, $\overline{\text{RDY}}$, TA0IN to TA4IN, TB0IN to TB5IN, $\overline{\text{INT0}}$ to $\overline{\text{INT7}}$, $\overline{\text{NMI}}$, $\overline{\text{ADTRG}}$, $\overline{\text{CTS0}}$ to $\overline{\text{CTS2}}$, $\overline{\text{CTS5}}$ to $\overline{\text{CTS7}}$, SCL0 to SCL2, SCL5 to SCL7, SDA0 to SDA2, SDA5 to SDA7, CLK0 to CLK7, TA0OUT to TA4OUT, $\overline{\text{KI0}}$ to $\overline{\text{KI3}}$, RXD0 to RXD2, RXD5 to RXD7, SIN3, SIN4, $\overline{\text{SD}}$, PMC0, PMC1, SCLMM, SDAMM, CEC, ZP, IDU, IDV, IDW		0.5		2.0	V
$V_{T+} - V_{T-}$	Hysteresis	$\overline{\text{RESET}}$		0.5		2.5	V
I_{IH}	High input current	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1 XIN, $\overline{\text{RESET}}$, CNVSS, BYTE	$V_I = 5$ V			5.0	µA
I_{IL}	Low input current	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1 XIN, $\overline{\text{RESET}}$, CNVSS, BYTE	$V_I = 0$ V			–5.0	µA
R_{PULLUP}	Pull-up resistance	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1	$V_I = 0$ V	30	50	100	kΩ
R_{fXIN}	Feedback resistance	XIN			1.5		MΩ
V_{RAM}	RAM retention voltage		In stop mode	1.8			V

Note:

1. When $V_{CC1} \neq V_{CC2}$, refer to 5 V or 3 V standard depending on the voltage.

$V_{CC1} = V_{CC2} = 5$ V

Table 31.20 Electrical Characteristics (3)

R5F36506CNFA, R5F36506CNFB, R5F3650ECNFA, R5F3650ECNFB, R5F36506CDFA, R5F36506CDFB, R5F3650ECDFA, R5F3650ECDFB

$V_{CC1} = V_{CC2} = 4.2$ to 5.5 V, $V_{SS} = 0$ V at $T_{opr} = -20$°C to 85°C/–40°C to 85°C, $f_{(BCLK)} = 32$ MHz unless otherwise specified.

Symbol	Parameter	Measuring Condition		Standard			Unit
				Min.	Typ.	Max.	
R_{fXCIN}	Feedback resistance XCIN				8		MΩ
I_{CC}	Power supply current In single-chip, mode, the output pin are open and other pins are V_{SS}	High-speed mode	$f_{(BCLK)} = 32$ MHz XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		24.0		mA
			$f_{(BCLK)} =32$ MHz, A/D conversion XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		24.7		mA
			$f_{(BCLK)} = 20$ MHz XIN = 20 MHz (square wave) 125 kHz on-chip oscillator stopped		16.0		mA
		40 MHz on-chip oscillator mode	Main clock stopped 40 MHz on-chip oscillator on, divide-by-4 ($f_{(BCLK)} = 10$ MHz) 125 kHz on-chip oscillator stopped		17.0		mA
		125 kHz on-chip oscillator mode	Main clock stopped 40 MHz on-chip oscillator stopped, 125 kHz on-chip oscillator on, no division FMR22 = 1 (slow read mode)		500.0		µA
		Low-power mode	$f_{(BCLK)} = 32$ kHz In low-power mode FMR22 = FMR23 = 1 On flash memory [1]		160.0		µA
			$f_{(BCLK)} = 32$ kHz In low-power mode On RAM [1]		45.0		µA
		Wait mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator on Peripheral clock operating $T_{opr} = 25$°C		20.0		µA
			$f_{(BCLK)} = 32$ kHz (oscillation capacity High) 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock operating $T_{opr} = 25$°C		11.0		µA
			$f_{(BCLK)} = 32$ kHz (oscillation capacity Low) 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock operating $T_{opr} = 25$°C		6.0		µA
			XIN = 6 MHz 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock f1 provision disabled except timers (PCKSTP1A = 1) Main clock as a timer clock source (PCKSTP11 = 0, PCKSTP17 = 1) A given timer operating		1.2		mA
		Stop mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock stopped $T_{opr} = 25$°C		1.7		µA
		During flash memory program	$f_{(BCLK)} = 10$ MHz, PM17 = 1 (one wait) $V_{CC1} = 5.0$ V		20.0		mA
		During flash memory erase	$f_{(BCLK)} = 10$ MHz, PM17 = 1 (one wait) $V_{CC1} = 5.0$ V		30.0		mA

Note:

1. This indicates the memory in which the program to be executed exists.

$V_{CC1} = V_{CC2} = 5$ V

Table 31.21 Electrical Characteristics (4)

R5F3651ECNFC, R5F3651KCNFC, R5F3650KCNFA, R5F3650KCNFB, R5F3651MCNFC, R5F3650MCNFA, R5F3650MCNFB, R5F3651NCNFC, R5F3650NCNFA, R5F3650NCNFB, R5F3651ECDFC, R5F3651KCDFC, R5F3650KCDFA, R5F3650KCDFB, R5F3651MCDFC, R5F3650MCDFA, R5F3650MCDFB, R5F3651NCDFC, R5F3650NCDFA, R5F3650NCDFB

$V_{CC1} = V_{CC2} = 4.2$ to 5.5 V, $V_{SS} = 0$ V at $T_{opr} = -20$°C to 85°C/–40°C to 85°C, $f_{(BCLK)} = 32$ MHz unless otherwise specified.

Symbol	Parameter	Measuring Condition		Standard			Unit
				Min.	Typ.	Max.	
R_{fXCIN}	Feedback resistance XCIN				8		MΩ
I_{CC}	Power supply current In single-chip, mode, the output pin are open and other pins are V_{SS}	High-speed mode	$f_{(BCLK)} = 32$ MHz XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		26.0		mA
			$f_{(BCLK)} = 32$ MHz, A/D conversion XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		27.0		mA
			$f_{(BCLK)} = 20$ MHz XIN = 20 MHz (square wave) 125 kHz on-chip oscillator stopped		17.0		mA
		40 MHz on-chip oscillator mode	Main clock stopped 40 MHz on-chip oscillator on, divide-by-4 (f(BCLK) = 10 MHz) 125 kHz on-chip oscillator stopped		18.0		mA
		125 kHz on-chip oscillator mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator on, no division FMR22 = 1 (slow read mode)		550.0		µA
		Low-power mode	$f_{(BCLK)} = 32$ kHz In low-power mode FMR22 = FMR23 = 1 on flash memory (1)		170.0		µA
			$f_{(BCLK)} = 32$ kHz In low-power mode on RAM (1)		45.0		µA
		Wait mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator on Peripheral clock operating $T_{opr} = 25$°C		20.5		µA
			$f_{(BCLK)} = 32$ kHz (oscillation capacity High) 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock operating $T_{opr} = 25$°C		11.0		µA
			$f_{(BCLK)} = 32$ kHz (oscillation capacity low) 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock operating $T_{opr} = 25$°C		6.0		µA
			XIN = 6 MHz 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock f1 provision disabled except timers (PCKSTP1A = 1) Main clock as a timer clock source (PCKSTP11 = 0, PCKSTP17 = 1) A given timer operating		1.2		mA
		Stop mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock stopped $T_{opr} = 25$°C		1.7		µA
		During flash memory program	$f_{(BCLK)} = 10$ MHz, PM17 = 1 (one wait) $V_{CC1} = 5.0$ V		20.0		mA
		During flash memory erase	$f_{(BCLK)} = 10$ MHz, PM17 = 1 (one wait) $V_{CC1} = 5.0$ V		30.0		mA

Note:

1. This indicates the memory in which the program to be executed exists.

$V_{CC1} = V_{CC2} = 5$ V

31.2.2 Timing Requirements (Peripheral Functions and Others)

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at $T_{opr} = -20$°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.2.1 Reset Input ($\overline{\text{RESET}}$ Input)

Table 31.22 Reset Input ($\overline{\text{RESET}}$ Input)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(RSTL)}$	$\overline{\text{RESET}}$ input low pulse width	10		µs

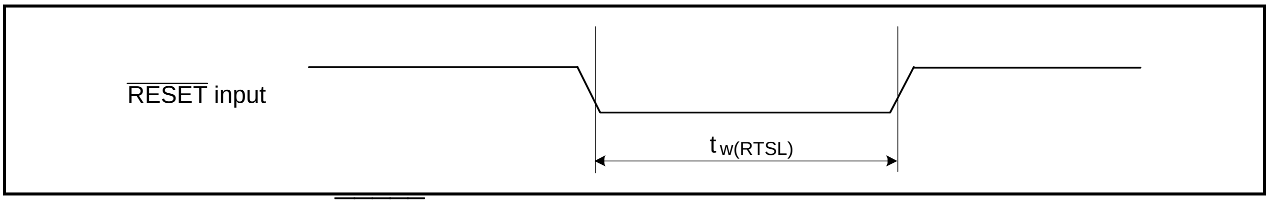


Figure 31.5 Reset Input ($\overline{\text{RESET}}$ Input)

31.2.2.2 External Clock Input

Table 31.23 External Clock Input (XIN Input) (1)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t_c	External clock input cycle time	50		ns
$t_{w(H)}$	External clock input high pulse width	20		ns
$t_{w(L)}$	External clock input low pulse width	20		ns
t_r	External clock rise time		9	ns
t_f	External clock fall time		9	ns

Note:

1. The condition is $V_{CC1} = V_{CC2} = 3.0$ to 5.0 V.

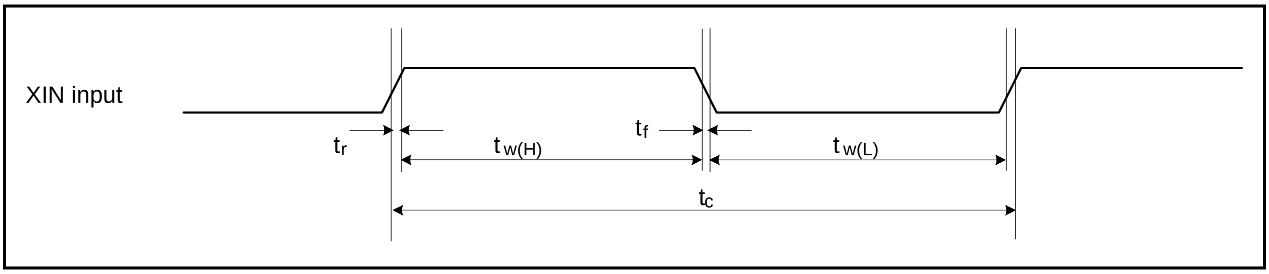


Figure 31.6 External Clock Input (XIN Input)

$V_{CC1} = V_{CC2} = 5$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.2.3 Timer A Input

Table 31.24 Timer A Input (Counter Input in Event Counter Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	100		ns
$t_{w(TAH)}$	TAiIN input high pulse width	40		ns
$t_{w(TAL)}$	TAiIN input low pulse width	40		ns

Table 31.25 Timer A Input (Gating Input in Timer Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	400		ns
$t_{w(TAH)}$	TAiIN input high pulse width	200		ns
$t_{w(TAL)}$	TAiIN input low pulse width	200		ns

Table 31.26 Timer A Input (External Trigger Input in One-Shot Timer Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	200		ns
$t_{w(TAH)}$	TAiIN input high pulse width	100		ns
$t_{w(TAL)}$	TAiIN input low pulse width	100		ns

Table 31.27 Timer A Input (External Trigger Input in Pulse Width Modulation Mode and Programmable Output Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(TAH)}$	TAiIN input high pulse width	100		ns
$t_{w(TAL)}$	TAiIN input low pulse width	100		ns

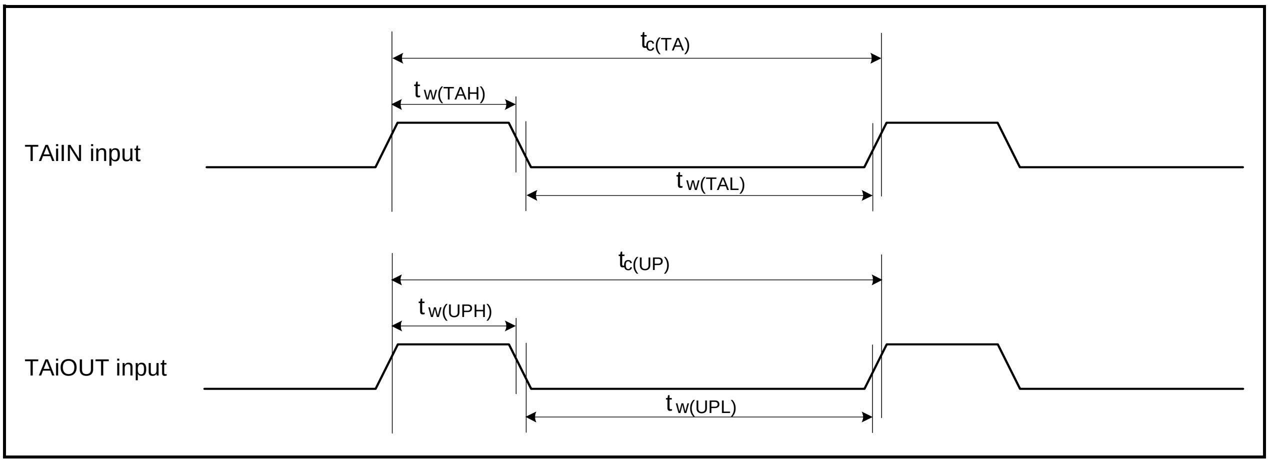


Figure 31.7 Timer A Input

$V_{CC1} = V_{CC2} = 5$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

Table 31.28 Timer A Input (Two-Phase Pulse Input in Event Counter Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	800		ns
$t_{su(TAIN-TAOUT)}$	TAiOUT input setup time	200		ns
$t_{su(TAOUT-TAIN)}$	TAiIN input setup time	200		ns

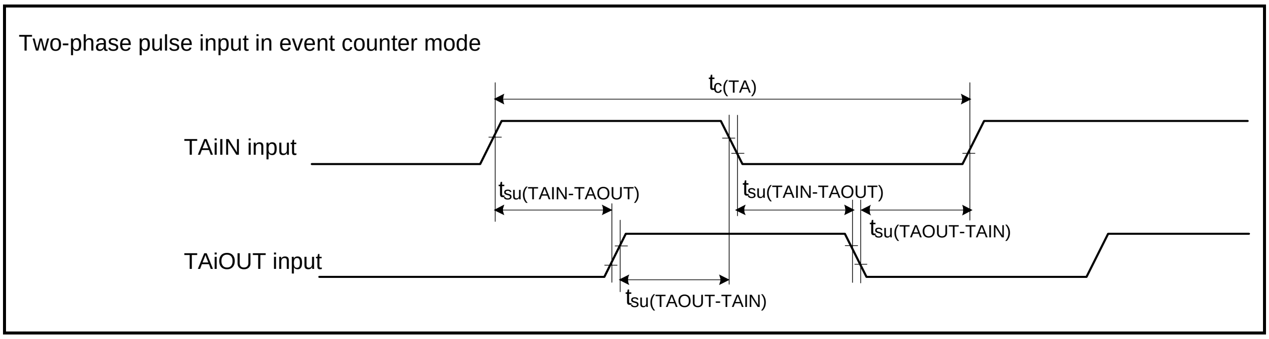


Figure 31.8 Timer A Input (Two-Phase Pulse Input in Event Counter Mode)

$V_{CC1} = V_{CC2} = 5$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at $T_{opr} = -20$°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.2.4 Timer B Input

Table 31.29 Timer B Input (Counter Input in Event Counter Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiIN input cycle time (counted on one edge)	100		ns
$t_{w(TBH)}$	TBiIN input high pulse width (counted on one edge)	40		ns
$t_{w(TBL)}$	TBiIN input low pulse width (counted on one edge)	40		ns
$t_{c(TB)}$	TBiIN input cycle time (counted on both edges)	200		ns
$t_{w(TBH)}$	TBiIN input high pulse width (counted on both edges)	80		ns
$t_{w(TBL)}$	TBiIN input low pulse width (counted on both edges)	80		ns

Table 31.30 Timer B Input (Pulse Period Measurement Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiIN input cycle time	400		ns
$t_{w(TBH)}$	TBiIN input high pulse width	200		ns
$t_{w(TBL)}$	TBiIN input low pulse width	200		ns

Table 31.31 Timer B Input (Pulse Width Measurement Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiIN input cycle time	400		ns
$t_{w(TBH)}$	TBiIN input high pulse width	200		ns
$t_{w(TBL)}$	TBiIN input low pulse width	200		ns

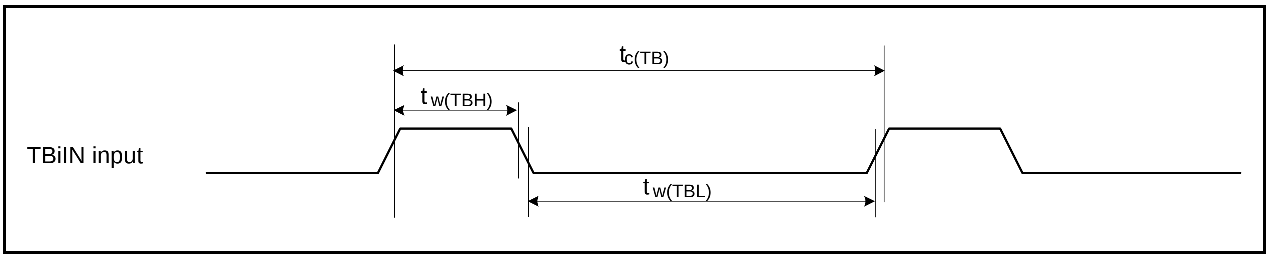


Figure 31.9 Timer B Input

$V_{CC1} = V_{CC2} = 5$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.2.5 Serial Interface

Table 31.32 Serial Interface

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(CK)}$	CLKi input cycle time	200		ns
$t_{w(CKH)}$	CLKi input high pulse width	100		ns
$t_{w(CKL)}$	CLKi input low pulse width	100		ns
$t_{d(C-Q)}$	TXDi output delay time		80	ns
$t_{h(C-Q)}$	TXDi hold time	0		ns
$t_{su(D-C)}$	RXDi input setup time	70		ns
$t_{h(C-D)}$	RXDi input hold time	90		ns

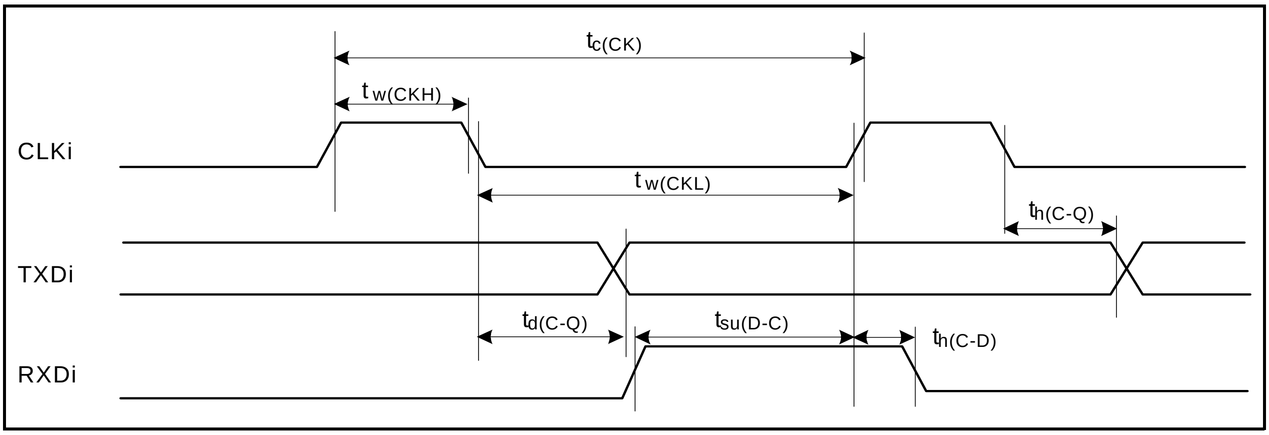


Figure 31.10 Serial Interface

31.2.2.6 External Interrupt $\overline{\text{INTi}}$ Input

Table 31.33 External Interrupt $\overline{\text{INTi}}$ Input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(INH)}$	$\overline{\text{INTi}}$ input high pulse width	250		ns
$t_{w(INL)}$	$\overline{\text{INTi}}$ input low pulse width	250		ns

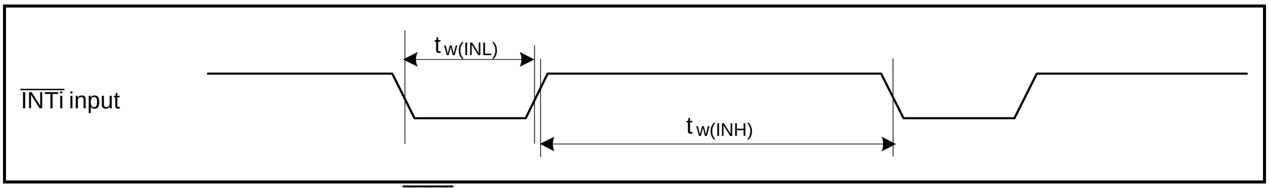


Figure 31.11 External Interrupt $\overline{\text{INTi}}$ Input

$V_{CC1} = V_{CC2} = 5$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.2.7 Multi-master I^{2}C-bus

Table 31.34 Multi-master I^{2}C-bus

Symbol	Parameter	Standard Clock Mode		Fast-mode		Unit
		Min.	Max.	Min.	Max.	
t_{BUF}	Bus free time	4.7		1.3		µs
$t_{HD;STA}$	Hold time in start condition	4.0		0.6		µs
t_{LOW}	Hold time in SCL clock 0 status	4.7		1.3		µs
t_R	SCL, SDA signals' rising time		1000	20 + 0.1 Cb	300	ns
$t_{HD;DAT}$	Data hold time	0		0	0.9	µs
t_{HIGH}	Hold time in SCL clock 1 status	4.0		0.6		µs
f_F	SCL, SDA signals' falling time		300	20 + 0.1 Cb	300	ns
$t_{su;DAT}$	Data setup time	250		100		ns
$t_{su;STA}$	Setup time in restart condition	4.7		0.6		µs
$t_{su;STO}$	Stop condition setup time	4.0		0.6		µs

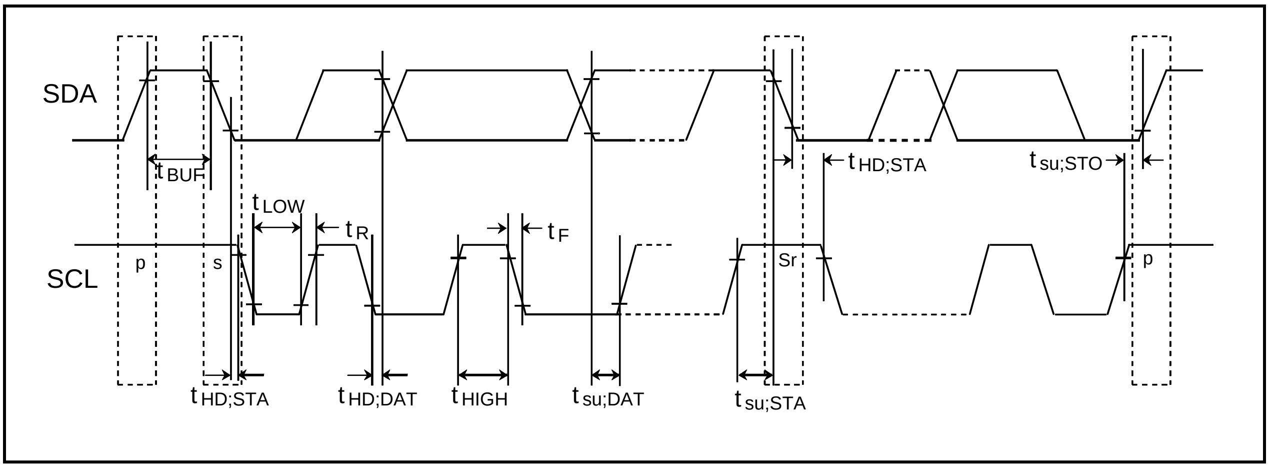


Figure 31.12 Multi-master I^{2}C-bus

$V_{CC1} = V_{CC2} = 5$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.3 Timing Requirements (Memory Expansion Mode and Microprocessor Mode)

Table 31.35 Memory Expansion Mode and Microprocessor Mode

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{ac1(RD-DB)}$	Data input access time (for setting with no wait)		(Note 1)	ns
$t_{ac2(RD-DB)}$	Data input access time (for setting with 1 to 3 waits)		(Note 2)	ns
$t_{ac3(RD-DB)}$	Data input access time (when accessing multiplex bus area)		(Note 3)	ns
$t_{ac4(RD-DB)}$	Data input access time (for setting with 2ϕ + 3ϕ or more)		(Note 4)	ns
$t_{su(DB-RD)}$	Data input setup time	50		ns
$t_{su(RDY-BCLK)}$	$\overline{\text{RDY}}$ input setup time	80		ns
$t_{h(RD-DB)}$	Data input hold time	0		ns
$t_{h(BCLK-RDY)}$	$\overline{\text{RDY}}$ input hold time	0		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 45[ns]$$

2. Calculated according to the BCLK frequency as follows:

$$\frac{(n + 0.5) \times 10^9}{f_{(BCLK)}} - 45[ns]$$ n is 1 for 1 wait setting, 2 for 2 waits setting and 3 for 3 waits setting.

3. Calculated according to the BCLK frequency as follows:

$$\frac{(n - 0.5) \times 10^9}{f_{(BCLK)}} - 45[ns]$$ n is 2 for 2 waits setting, and 3 for 3 waits setting.

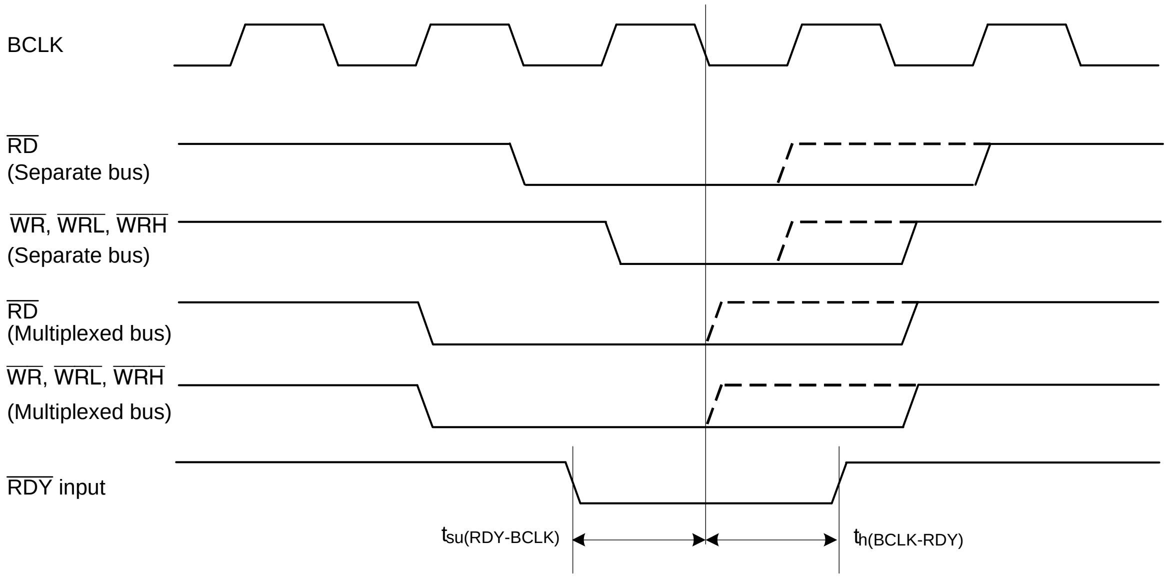
4. Calculated according to the BCLK frequency as follows:

$$\frac{n \times 10^9}{f_{(BCLK)}} - 45[ns]$$ n is 3 for 2ϕ + 3ϕ, 4 for 2ϕ + 4ϕ, 4 for 3ϕ + 4ϕ, and 5 for 4ϕ + 5ϕ.

Memory Expansion Mode and Microprocessor Mode

$V_{CC1} = V_{CC2} = 5$ V

(Effective in wait state setting**)**


BCLK
$\overline{\text{RD}}$
(Separate bus)
$\overline{\text{WR}}$, $\overline{\text{WRL}}$, $\overline{\text{WRH}}$
(Separate bus)
$\overline{\text{RD}}$
(Multiplexed bus)
$\overline{\text{WR}}$, $\overline{\text{WRL}}$, $\overline{\text{WRH}}$
(Multiplexed bus)
$\overline{\text{RDY}}$ input
$t_{su(RDY-BCLK)}$
$t_{h(BCLK-RDY)}$

Measuring conditions

- $V_{CC1} = V_{CC2} = 5$ V
- Input timing voltage: $V_{IL} = 1.0$ V, $V_{IH} = 4.0$ V
- Output timing voltage: $V_{OL} = 2.5$ V, $V_{OH} = 2.5$ V

Figure 31.13 Timing Diagram

$V_{CC1} = V_{CC2} = 5$ V

31.2.4 Switching Characteristics (Memory Expansion Mode and Microprocessor Mode)

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.4.1 In No Wait State Setting

Table 31.36 Memory Expansion Mode and Microprocessor Mode (in No Wait State Setting)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.14		25	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		0		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 2)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			25	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			15	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		–4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			25	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			25	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 1)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR) (3)		(Note 4)		ns

Notes:

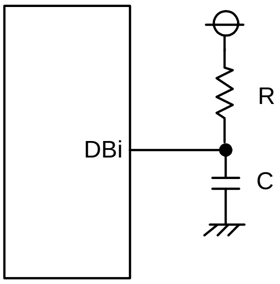
1. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 40[ns]$$ $f_{(BCLK)}$ is 12.5 MHz or less.

2. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 10[ns]$$

3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1 - V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30\ \text{pF} \times 1\ \text{k}\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
$= 6.7$ ns.



4. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 20[ns]$$

Hold time is equal to or less than 0 ns when the BCLK frequency exceeds 25 MHz.

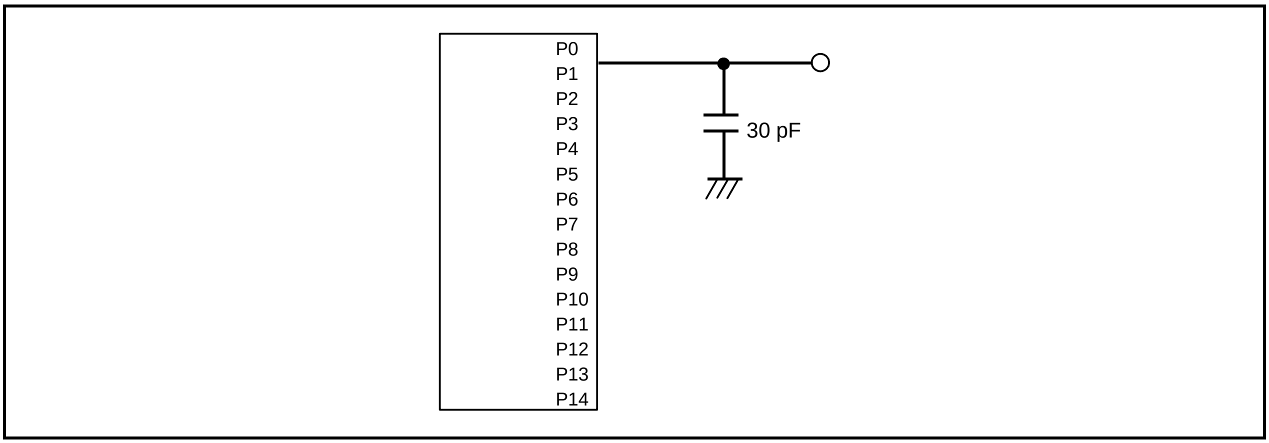
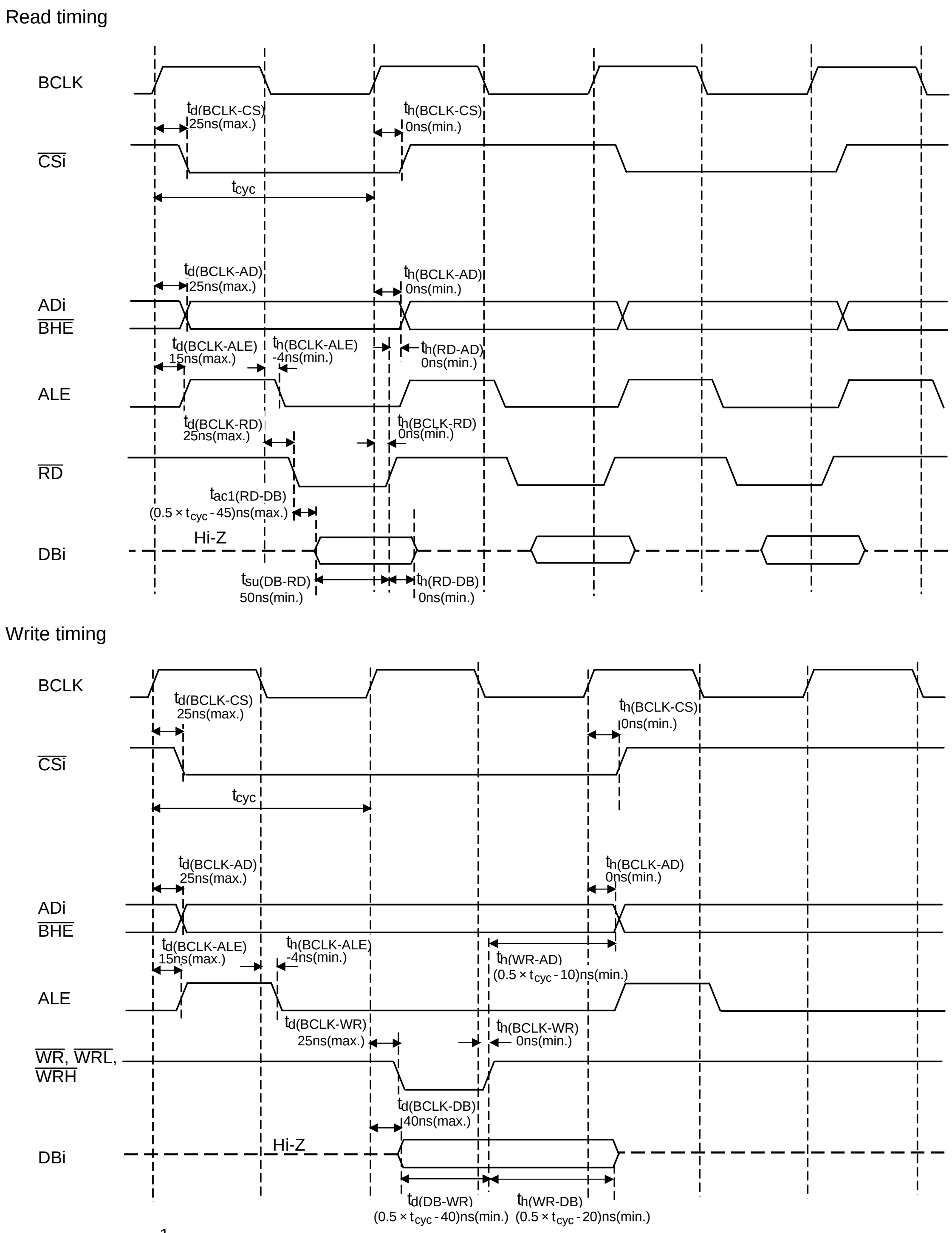


Figure 31.14 Ports P0 to P14 Measurement Circuit

Memory Expansion Mode and Microprocessor Mode
(in no wait state setting)

$V_{CC1} = V_{CC2} = 5V$



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

Measuring conditions

- $V_{CC1} = V_{CC2} = 5V$
- Input timing voltage: $V_{IL} = 0.8$ V, $V_{IH} = 2.0$ V
- Output timing voltage: $V_{OL} = 0.4$ V, $V_{OH} = 2.4$ V

Figure 31.15 Timing Diagram

$V_{CC1} = V_{CC2} = 5$ V

Switching Characteristics

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.4.2 In 1 to 3 Waits Setting and When Accessing External Area

Table 31.37 Memory Expansion Mode and Microprocessor Mode (in 1 to 3 Waits Setting and When Accessing External Area)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.14		25	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		0		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 2)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			25	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			15	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		-4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			25	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			25	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 1)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR)(3)		(Note 4)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

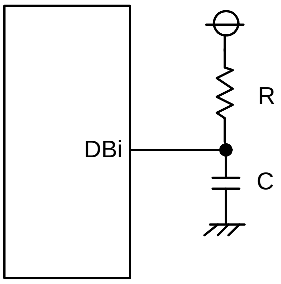
$$\frac{(n-0.5)\times 10^9}{f_{(BCLK)}} - 40[ns]$$

n is 1 for 1 wait setting, 2 for 2 waits setting and 3 for 3 waits setting.
When n = 1, $f_{(BCLK)}$ is 12.5 MHz or less.

2. Calculated according to the BCLK frequency as follows:

$$\frac{0.5\times 10^9}{f_{(BCLK)}} - 10[ns]$$

3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1 - V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30\text{ pF} \times 1\text{ k}\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
$= 6.7$ ns.



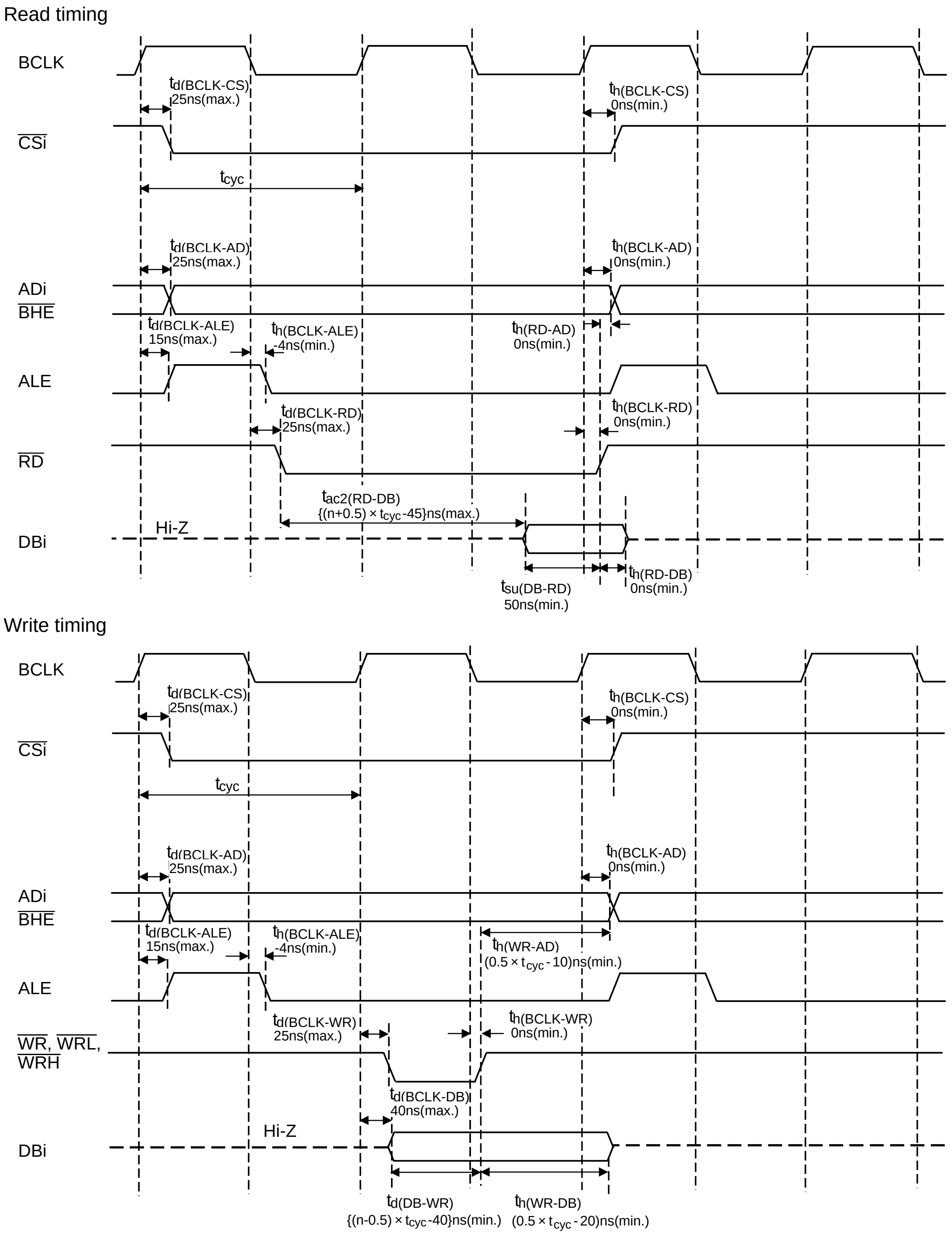
4. Calculated according to the BCLK frequency as follows:

$$\frac{0.5\times 10^9}{f_{(BCLK)}} - 20[ns]$$

Hold time is equal to or less than 0 ns when the BCLK frequency exceeds 25 MHz.

Memory Expansion Mode and Microprocessor Mode
(in 1 to 3 waits setting and when accessing external area)

$V_{CC1} = V_{CC2} = 5V$



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

Measuring conditions

- $V_{CC1} = V_{CC2} = 5V$
- Input timing voltage: $V_{IL} = 0.8$ V, $V_{IH} = 2.0$ V
- Output timing voltage: $V_{OL} = 0.4$ V, $V_{OH} = 2.4$ V

n: 1 (when 1 wait)
2 (when 2 waits)
3 (when 3 waits)

Figure 31.16 Timing Diagram

$V_{CC1} = V_{CC2} = 5$ V

Switching Characteristics

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.4.3 In 2 or 3 Waits Setting, and When Accessing External Area and Using Multiplexed Bus

Table 31.38 Memory Expansion Mode and Microprocessor Mode (in 2 or 3 Waits Setting, and When Accessing External Area and Using Multiplexed Bus) (5)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.14		25	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		(Note 1)		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 1)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			25	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{h(RD-CS)}$	Chip select output hold time (in relation to RD)		(Note 1)		ns
$t_{h(WR-CS)}$	Chip select output hold time (in relation to WR)		(Note 1)		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			25	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			25	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 2)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR)		(Note 6)		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time (in relation to BCLK)			15	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time (in relation to BCLK)		–4		ns
$t_{d(AD-ALE)}$	ALE signal output delay time (in relation to Address)		(Note 3)		ns
$t_{h(AD-ALE)}$	ALE signal output hold time (in relation to Address)		(Note 4)		ns
$t_{d(AD-RD)}$	RD signal output delay from the end of address		0		ns
$t_{d(AD-WR)}$	WR signal output delay from the end of address		0		ns
$t_{dz(RD-AD)}$	Address output floating start time			8	ns

Notes:

1. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 10[ns]$$

2. Calculated according to the BCLK frequency as follows:

$$\frac{(n - 0.5) \times 10^9}{f_{(BCLK)}} - 40[ns]$$ n is 2 for 2-wait setting, 3 for 3-wait setting.

3. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 25[ns]$$

4. Calculated according to the BCLK frequency as follows:

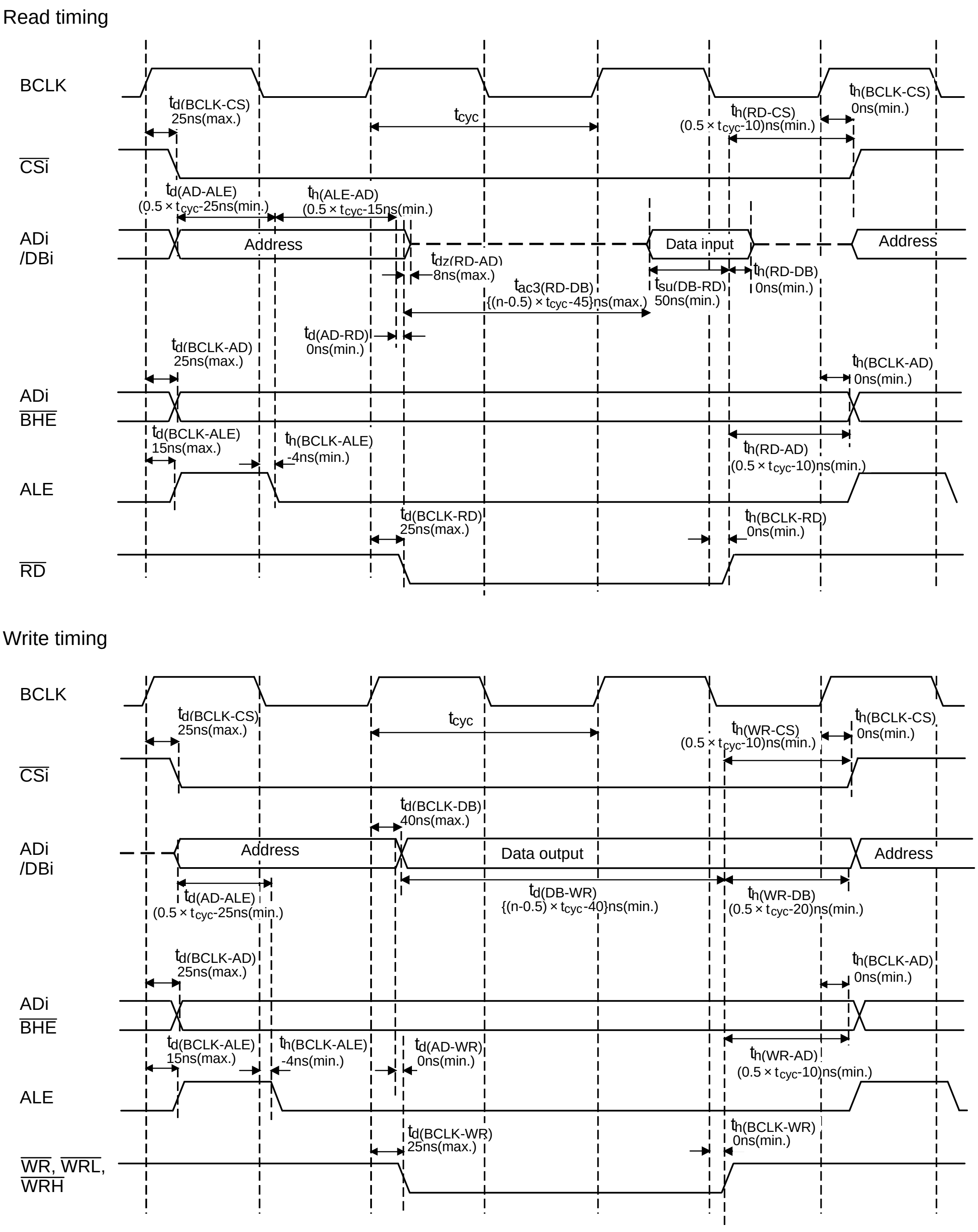
$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 15[ns]$$

5. When using multiplex bus, set $f_{(BCLK)}$ 12.5 MHz or less.

6. Calculated according to the BCLK frequency as follows: $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 20[ns]$

Memory Expansion Mode and Microprocessor Mode
(in 2 or 3 waits setting, and when accessing external area and using multiplexed bus)

$V_{CC1} = V_{CC2} = 5V$



Measuring conditions

- $V_{CC1} = V_{CC2} = 5V$
- Input timing voltage: $V_{IL} = 0.8$ V, $V_{IH} = 2.0$ V
- Output timing voltage: $V_{OL} = 0.4$ V, $V_{OH} = 2.4$ V

n: 2 (when 2 waits)
3 (when 3 waits)

Figure 31.17 Timing Diagram

$V_{CC1} = V_{CC2} = 5$ V

Switching Characteristics

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.4.4 In Wait State Setting 2ϕ + 3ϕ, 2ϕ + 4ϕ, 3ϕ + 4ϕ, and 4ϕ + 5ϕ, and When Accessing External Area

Table 31.39 Memory Expansion Mode and Microprocessor Mode (in Wait State Setting 2 ϕ + 3 ϕ, 2 ϕ + 4ϕ, 3ϕ + 4ϕ, and 4ϕ + 5ϕ, and When Accessing External Area)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.14		25	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		0		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 2)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			25	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			15	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		-4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			25	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			25	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 1)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR) (3)		(Note 4)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

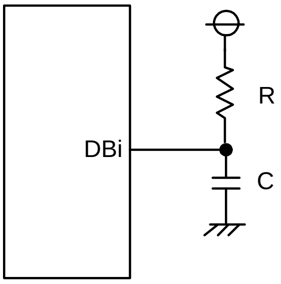
$$\frac{(n-0.5)\times 10^9}{f_{(BCLK)}} - 40[ns]$$

n is 3 for 2ϕ + 3ϕ, 4 for 2ϕ + 4ϕ, 4 for 3ϕ + 4ϕ, and 5 for 4ϕ + 5ϕ.

2. Calculated according to the BCLK frequency as follows:

$$\frac{0.5\times 10^9}{f_{(BCLK)}} - 10[ns]$$

3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1 - V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30\text{ pF} \times 1\text{ k}\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
= 6.7 ns.

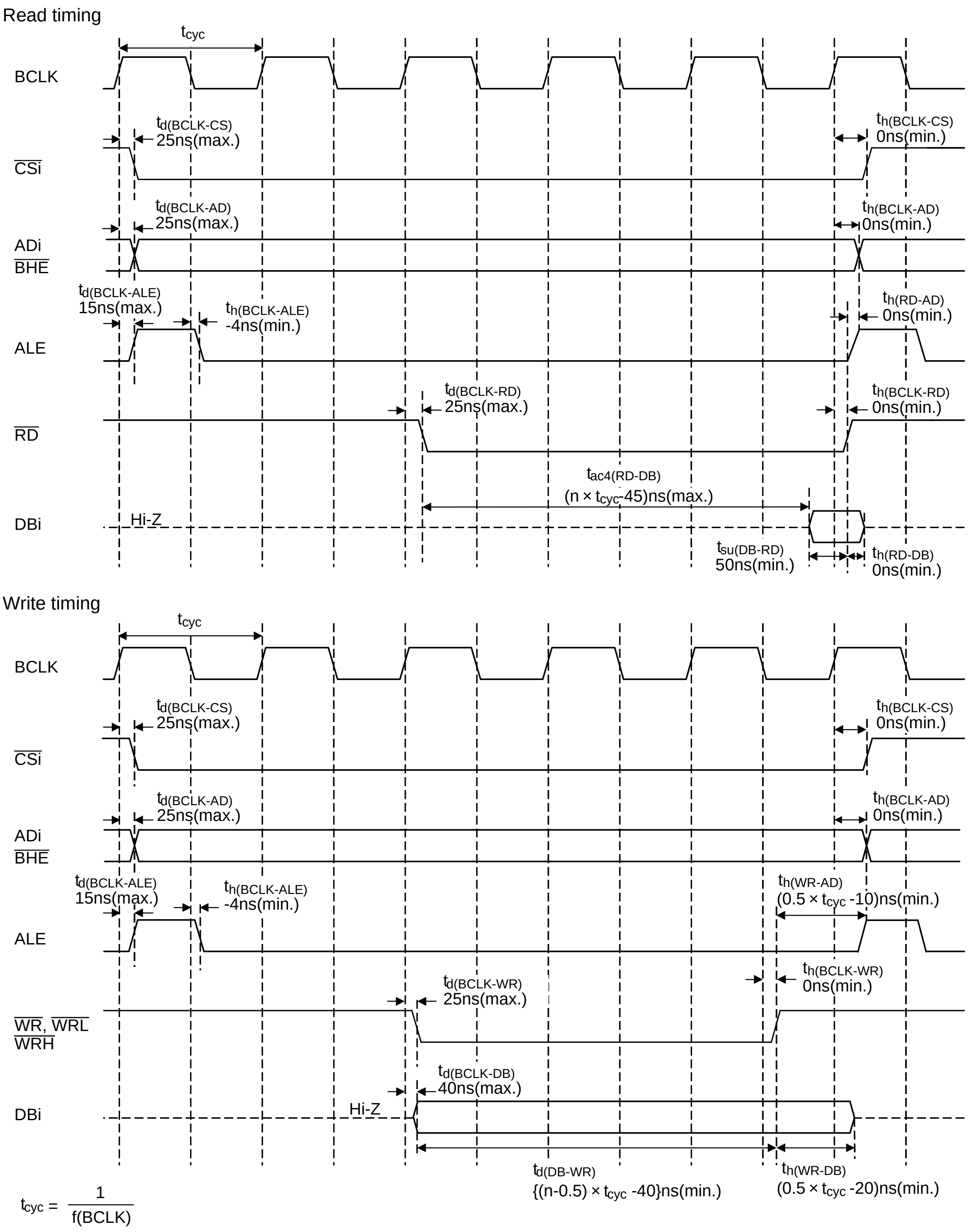


4. Calculated according to the BCLK frequency as follows: $\frac{0.5\times 10^9}{f_{(BCLK)}} - 20[ns]$

Hold time is equal to or less than 0 ns when the BCLK frequency exceeds 25 MHz.

Memory Expansion Mode and Microprocessor Mode
(in wait state setting 2 ϕ + 3 ϕ, 2 ϕ + 4 ϕ, 3ϕ + 4 ϕ, and 4 ϕ + 5 ϕ, and
when accessing external area)

$V_{CC1} = V_{CC2} = 5V$



$$t_{cyc} = \frac{1}{f(BCLK)}$$

Measuring conditions

- $V_{CC1} = V_{CC2} = 5V$
- Input timing voltage: V_{IL} = 0.8 V, V_{IH} = 2.0 V
- Output timing voltage: V_{OL} = 0.4 V, V_{OH} = 2.4 V

n: 3 (when 2 ϕ + 3 ϕ)
4 (when 2 ϕ + 4 ϕ or 3 ϕ + 4 ϕ)
5 (when 4 ϕ + 5 ϕ)

Figure 31.18 Timing Diagram

$V_{CC1} = V_{CC2} = 5$ V

Switching Characteristics

($V_{CC1} = V_{CC2} = 5$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.2.4.5 In Wait State Setting 2ϕ + 3ϕ, 2ϕ + 4ϕ, 3ϕ + 4ϕ, and 4ϕ + 5ϕ, and When Inserting 1 to 3 Recovery Cycles and Accessing External Area

Table 31.40 Memory Expansion and Microprocessor Modes (in Wait State Setting 2ϕ + 3ϕ, 2ϕ + 4ϕ, 3ϕ + 4ϕ, and 4ϕ + 5ϕ, and When Inserting 1 to 3 Recovery Cycles and Accessing External Area)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.14		25	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		(Note 4)		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 2)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			25	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			15	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		-4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			25	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			25	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 1)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR) (3)		(Note 5)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

$$\frac{n \times 10^9}{f_{(BCLK)}} - 40[ns]$$

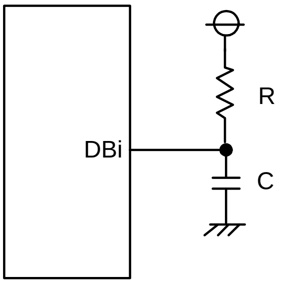
n is 3 for 2ϕ + 3ϕ, 4 for 2ϕ + 4ϕ, 4 for 3ϕ + 4ϕ, and 5 for 4ϕ + 5ϕ.

2. Calculated according to the BCLK frequency as follows:

$$\frac{m \times 10^9}{f_{(BCLK)}} - 10[ns]$$

m is 1 when 1 recovery cycle is inserted, 2 when 2 recovery cycles are inserted, and 3 when 3 recovery cycles are inserted.

3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1 - V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30\text{ pF} \times 1\text{ k}\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
$= 6.7$ ns.



4. Calculated according to the BCLK frequency as follows:

$$\frac{m \times 10^9}{f_{(BCLK)}} + 0[ns]$$

m is 1 when 1 recovery cycle is inserted, 2 when 2 recovery cycles are inserted, and 3 when 3 recovery cycles are inserted.

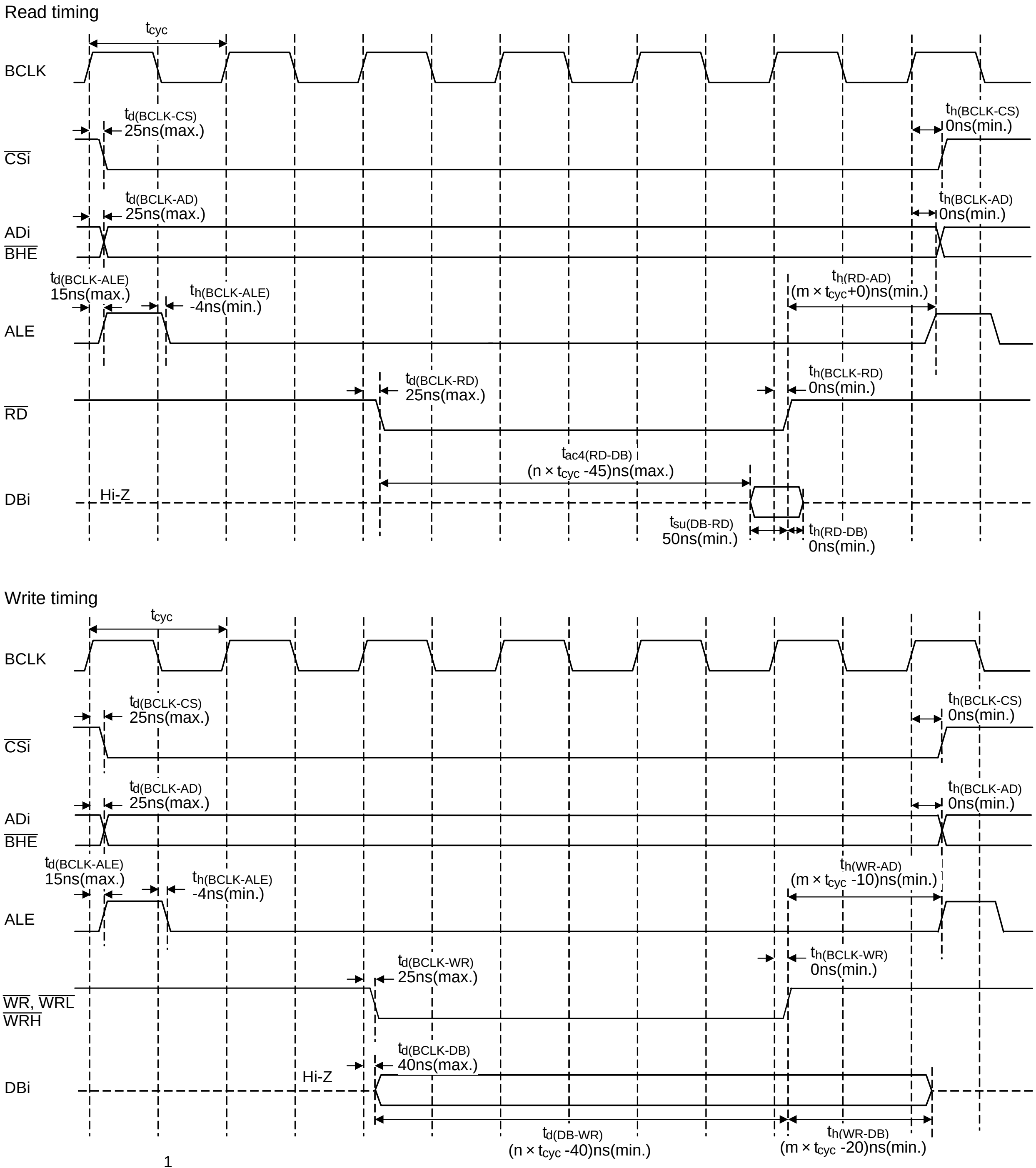
5. Calculated according to the BCLK frequency as follows:

$$\frac{m \times 10^9}{f_{(BCLK)}} - 20[ns]$$

m is 1 when 1 recovery cycle is inserted, 2 when 2 recovery cycles are inserted, and 3 when 3 recovery cycles are inserted.

Memory Expansion Mode and Microprocessor Mode
(in wait state setting 2 ϕ + 3 ϕ, 2 ϕ + 4 ϕ, 3ϕ + 4 ϕ, and 4 ϕ + 5 ϕ, and
when inserting 1 to 3 recovery cycles and accessing external area)

$V_{CC1} = V_{CC2} = 5V$



$$t_{cyc} = \frac{1}{f(BCLK)}$$

Measuring conditions

- $V_{CC1} = V_{CC2} = 5V$
- Input timing voltage: $V_{IL} = 0.8$ V, $V_{IH} = 2.0$ V
- Output timing voltage: $V_{OL} = 0.4$ V, $V_{OH} = 2.4$ V

n: 3 (when 2 ϕ + 3 ϕ)
4 (when 2 ϕ + 4 ϕ or 3 ϕ + 4 ϕ)
5 (when 4 ϕ + 5 ϕ)

m: 1 (when 1 recovery cycle inserted)
2 (when 2 recovery cycles inserted)
3 (when 3 recovery cycles inserted)

Figure 31.19 Timing Diagram

31.3 Electrical Characteristics (V_{CC1} = V_{CC2} = 3 V)

31.3.1 Electrical Characteristics

VCC1 = VCC2 = 3 V

Table 31.41 Electrical Characteristics (1) [1]

V_{CC1} = V_{CC2} = 2.7 to 3.3 V, V_{SS} = 0 V at T_{opr} = -20°C to 85°C/-40°C to 85°C, $f_{(BCLK)}$ = 32 MHz unless otherwise specified.

Symbol	Parameter			Measuring Condition	Standard			Unit
					Min.	Typ.	Max.	
V_{OH}	High output voltage	P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1		I_{OH} = –1 mA	V_{CC1} – 0.5		V_{CC1}	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7		I_{OH} = –1 mA	V_{CC2} – 0.5		V_{CC2}	
V_{OH}	High output voltage XOUT		HIGH POWER	I_{OH} = –0.1 mA	V_{CC1} – 0.5		V_{CC1}	V
			LOW POWER	I_{OH} = –50 µA	V_{CC1} – 0.5		V_{CC1}	
	High output voltage XCOUT		HIGH POWER	With no load applied		2.6		V
			LOW POWER	With no load applied		2.2		
V_{OL}	Low output voltage	P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P14_0, P14_1		I_{OL} = 1 mA			0.5	V
		P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P12_0 to P12_7, P13_0 to P13_7		I_{OL} = 1 mA			0.5	
		CEC		I_{OL} = 1 mA		0	0.5	V
V_{OL}	Low output voltage XOUT		HIGH POWER	I_{OL} = 0.1 mA			0.5	V
			LOW POWER	I_{OL} = 50 µA			0.5	
	Low output voltage XCOUT		HIGH POWER	With no load applied		0		V
			LOW POWER	With no load applied		0		
V_{T+}-V_{T-}	Hysteresis	$\overline{\text{HOLD}}$, $\overline{\text{RDY}}$, TA0IN to TA4IN, TB0IN to TB5IN, $\overline{\text{INT0}}$ to $\overline{\text{INT7}}$, $\overline{\text{NMI}}$, $\overline{\text{ADTRG}}$, $\overline{\text{CTS0}}$ to $\overline{\text{CTS2}}$, $\overline{\text{CTS5}}$ to $\overline{\text{CTS7}}$, SCL0 to SCL2, SCL5 to SCL7, SDA0 to SDA2, SDA5 to SDA7, CLK0 to CLK7, TA0OUT to TA4OUT, $\overline{\text{KI0}}$ to $\overline{\text{KI3}}$, RXD0 to RXD2, RXD5 to RXD7, SIN3, SIN4, $\overline{\text{SD}}$, PMC0, PMC1, SCLMM, SDAMM, ZP, IDU, IDV, IDW			0.2		1.0	V
		CEC			0.2	0.5	1.0	V
		$\overline{\text{RESET}}$			0.2		1.8	V
I_{IH}	High input current	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1 XIN, $\overline{\text{RESET}}$, CNVSS, BYTE		V_I = 3 V			4.0	µA
–	Leakage current in powered-off state		CEC	V_{CC1} = 0 V			1.8	µA
I_{IL}	Low input current	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_0 to P7_7, P8_0 to P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1 XIN, $\overline{\text{RESET}}$, CNVSS, BYTE		V_I = 0 V			–4.0	µA
R_{PULLUP}	Pull-up resistance	P0_0 to P0_7, P1_0 to P1_7, P2_0 to P2_7, P3_0 to P3_7, P4_0 to P4_7, P5_0 to P5_7, P6_0 to P6_7, P7_2 to P7_7, P8_0 to P8_4, P8_6, P8_7, P9_0 to P9_7, P10_0 to P10_7, P11_0 to P11_7, P12_0 to P12_7, P13_0 to P13_7, P14_0, P14_1		V_I = 0 V	50	80	150	kΩ
R_{fXIN}	Feedback resistance XIN					3.0		MΩ
V_{RAM}	RAM retention voltage			In stop mode	1.8			V

Note:

1. When V_{CC1} ≠ V_{CC2}, refer to 5 V or 3 V standard depending on the voltage.

$V_{CC1} = V_{CC2} = 3$ V

Table 31.42 Electrical Characteristics (2)

R5F36506CNFA, R5F36506CNFB, R5F36506CDFA, R5F36506CDFB, R5F3650ECNFA, R5F3650ECNFB, R5F3650ECDFA, R5F3650ECDFB

$V_{CC1} = V_{CC2} = 2.7$ to 3.3 V, $V_{SS} = 0$ V at $T_{opr} = –20°C$ to 85°C/–40°C to 85°C, $f_{(BCLK)} = 32$ MHz unless otherwise specified.

Symbol	Parameter	Measuring Condition		Standard			Unit
				Min.	Typ.	Max.	
R_{fXCIN}	Feedback resistance XCIN				16		MΩ
I_{CC}	Power supply current In single-chip, mode, the output pin are open and other pins are V_{SS}	High-speed mode	$f_{(BCLK)} = 32$ MHz XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		24.0		mA
			$f_{(BCLK)} = 32$ MHz, A/D conversion XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		24.7		mA
			$f_{(BCLK)} = 20$ MHz XIN = 20 MHz (square wave) 125 kHz on-chip oscillator stopped		16.0		mA
		40 MHz on-chip oscillator mode	Main clock stopped 40 MHz on-chip oscillator on, divide-by-4 ($f_{(BCLK)} = 10$ MHz) 125 kHz on-chip oscillator stopped		17.0		mA
		125 kHz on-chip oscillator mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator on, no division FMR22 = 1 (slow read mode)		450.0		μA
		Low-power mode	$f_{(BCLK)} = 32$ MHz In low-power mode FMR 22 = FMR23 = 1 On flash memory [1]		160.0		μA
			$f_{(BCLK)} = 32$ MHz In low-power mode On RAM [1]		40.0		μA
		Wait mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator on Peripheral clock operating $T_{opr} = 25°C$		20.0		μA
			$f_{(BCLK)} = 32$ MHz (oscillation capacity High) 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock operating $T_{opr} = 25°C$		8.0		μA
			$f_{(BCLK)} = 32$ kHz (oscillation capacity Low) 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock operating $T_{opr} = 25°C$		4.0		μA
			XIN = 6 MHz 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock f1 provision disabled except timers (PCKSTP1A = 1) Main clock as a timer clock source (PCKSTP11 = 0, PCKSTP17 = 1) A given timer operating		0.5		mA
		Stop mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock stopped $T_{opr} = 25°C$		1.6		μA
		During flash memory program	$f_{(BCLK)} = 10$ MHz, PM17 = 1 (one wait) $V_{CC1} = 3.0$ V		20.0		mA
		During flash memory erase	$f_{(BCLK)} = 10$ MHz, PM17 = 1 (one wait) $V_{CC1} = 3.0$ V		30.0		mA

Note:

[1] This indicates the memory in which the program to be executed exists.

$V_{CC1} = V_{CC2} = 3$ V

Table 31.43 Electrical Characteristics (3) (1/2)

R5F3651ECNFC, R5F3651KCNFC, R5F3650KCNFA, R5F3650KCNFB, R5F3651MCNFC, R5F3650MCNFA, R5F3650MCNFB, R5F3651NCNFC, R5F3650NCNFA, R5F3650NCNFB,
R5F3651ECDFC, R5F3651KCDFC, R5F3650KCDFA, R5F3650KCDFB, R5F3651MCDFC, R5F3650MCDFA, R5F3650MCDFB, R5F3651NCDFC, R5F3650NCDFA, R5F3650NCDFB
$V_{CC1} = V_{CC2} = 2.7$ to 3.3 V, $V_{SS} = 0$ V at $T_{opr} = -20$°C to 85°C/–40°C to 85°C, $f_{(BCLK)} = 32$ MHz unless otherwise specified.

Symbol	Parameter	Measuring Condition		Standard			Unit
				Min.	Typ.	Max.	
R_{fXCIN}	Feedback resistance XCIN				16		MΩ
I_{CC}	Power supply current In single-chip, mode, the output pin are open and other pins are V_{SS}	High-speed mode	$f_{(BCLK)} = 32$ MHz XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		26.0		mA
			$f_{(BCLK)} = 32$ MHz, A/D conversion XIN = 4 MHz (square wave), PLL multiplied by 8 125 kHz on-chip oscillator stopped		27.0		mA
			$f_{(BCLK)} = 20$ MHz XIN = 20 MHz (square wave) 125 kHz on-chip oscillator stopped		17.0		mA
		40 MHz on-chip oscillator mode	Main clock stopped 40 MHz on-chip oscillator on, divide-by-4 (f(BCLK) = 10 MHz) 125 kHz on-chip oscillator stopped		18.0		mA
		125 kHz on-chip oscillator mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator on, no division FMR22 = 1 (slow read mode)		500.0		µA
		Low-power mode	$f_{(BCLK)} = 32$ MHz In low-power mode, FMR 22 = FMR23 = 1 on flash memory (1)		170.0		µA
			$f_{(BCLK)} = 32$ MHz In low-power mode, on RAM (1)		40.0		µA
		Wait mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator on Peripheral clock operating $T_{opr} = 25$°C		20.0		µA
			$f_{(BCLK)} = 32$ MHz (oscillation capacity High) 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock operating $T_{opr} = 25$°C		8.0		µA
			$f_{(BCLK)} = 32$ kHz (oscillation capacity Low) 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock operating $T_{opr} = 25$°C		4.0		µA
			XIN = 6 MHz 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock f1 provision disabled except timers (PCKSTP1A = 1) Main clock as a timer clock source (PCKSTP11 = 0, PCKSTP17 = 1) A given timer operating		0.5		mA

Note:
1. This indicates the memory in which the program to be executed exists.

$V_{CC1} = V_{CC2} = 3$ V

Table 31.44 Electrical Characteristics (3) (2/2)

R5F3651ECNFC, R5F3651KCNFC, R5F3650KCNFA, R5F3650KCNFB, R5F3651MCNFC, R5F3650MCNFA, R5F3650MCNFB, R5F3651NCNFC, R5F3650NCNFA, R5F3650NCNFB,
R5F3651ECDFC, R5F3651KCDFC, R5F3650KCDFA, R5F3650KCDFB, R5F3651MCDFC, R5F3650MCDFA, R5F3650MCDFB, R5F3651NCDFC, R5F3650NCDFA, R5F3650NCDFB
$V_{CC1} = V_{CC2} = 2.7$ to 3.3 V, $V_{SS} = 0$ V at $T_{opr} = –20°C$ to 85°C/–40°C to 85°C, $f_{(BCLK)} = 32$ MHz unless otherwise specified.

Symbol	Parameter	Measuring Condition		Standard			Unit
				Min.	Typ.	Max.	
I_{CC}	Power supply current In single-chip, mode, the output pin are open and other pins are V_{SS}	Stop mode	Main clock stopped 40 MHz on-chip oscillator stopped 125 kHz on-chip oscillator stopped Peripheral clock stopped $T_{opr} = 25°C$		1.6		µA
		During flash memory program	$f_{(BCLK)} = 10$ MHz, PM17 = 1 (one wait) $V_{CC1} = 3.0$ V		20.0		mA
		During flash memory erase	$f_{(BCLK)} = 10$ MHz, PM17 = 1 (one wait) $V_{CC1} = 3.0$ V		30.0		mA

$V_{CC1} = V_{CC2} = 3$ V

31.3.2 Timing Requirements (Peripheral Functions and Others)

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.2.1 Reset Input ($\overline{\text{RESET}}$ Input)

Table 31.45 Reset Input ($\overline{\text{RESET}}$ Input)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(RSTL)}$	$\overline{\text{RESET}}$ input low pulse width	10		µs

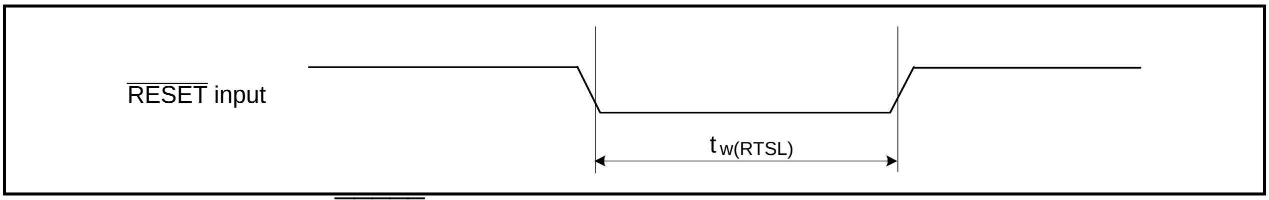


Figure 31.20 Reset Input ($\overline{\text{RESET}}$ Input)

31.3.2.2 External Clock Input

Table 31.46 External Clock Input (XIN Input) (1)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
t_c	External clock input cycle time	50		ns
$t_{w(H)}$	External clock input high pulse width	20		ns
$t_{w(L)}$	External clock input low pulse width	20		ns
t_r	External clock rise time		9	ns
t_f	External clock fall time		9	ns

Note:
1. The condition is $V_{CC1} = V_{CC2}$ = 2.7 to 3.0 V.

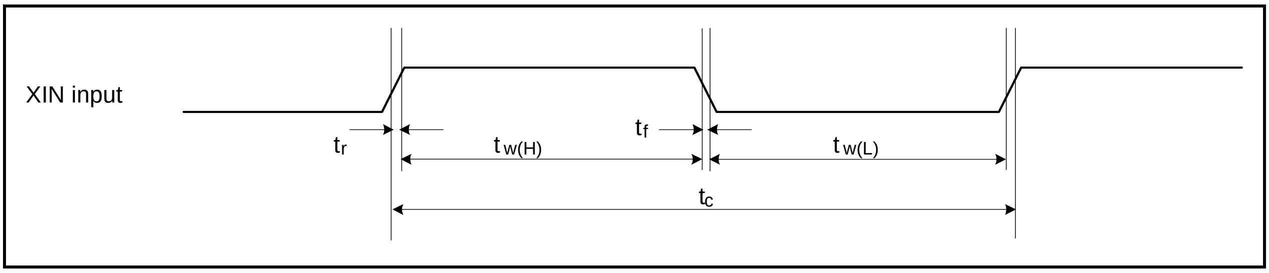


Figure 31.21 External Clock Input (XIN Input)

$V_{CC1} = V_{CC2} = 3$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at $T_{opr} = -20$°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.2.3 Timer A Input

Table 31.47 Timer A Input (Counter Input in Event Counter Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	150		ns
$t_{w(TAH)}$	TAiIN input high pulse width	60		ns
$t_{w(TAL)}$	TAiIN input low pulse width	60		ns

Table 31.48 Timer A Input (Gating Input in Timer Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	600		ns
$t_{w(TAH)}$	TAiIN input high pulse width	300		ns
$t_{w(TAL)}$	TAiIN input low pulse width	300		ns

Table 31.49 Timer A Input (External Trigger Input in One-Shot Timer Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	300		ns
$t_{w(TAH)}$	TAiIN input high pulse width	150		ns
$t_{w(TAL)}$	TAiIN input low pulse width	150		ns

Table 31.50 Timer A Input (External Trigger Input in Pulse Width Modulation Mode and Programmable Output Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(TAH)}$	TAiIN input high pulse width	150		ns
$t_{w(TAL)}$	TAiIN input low pulse width	150		ns

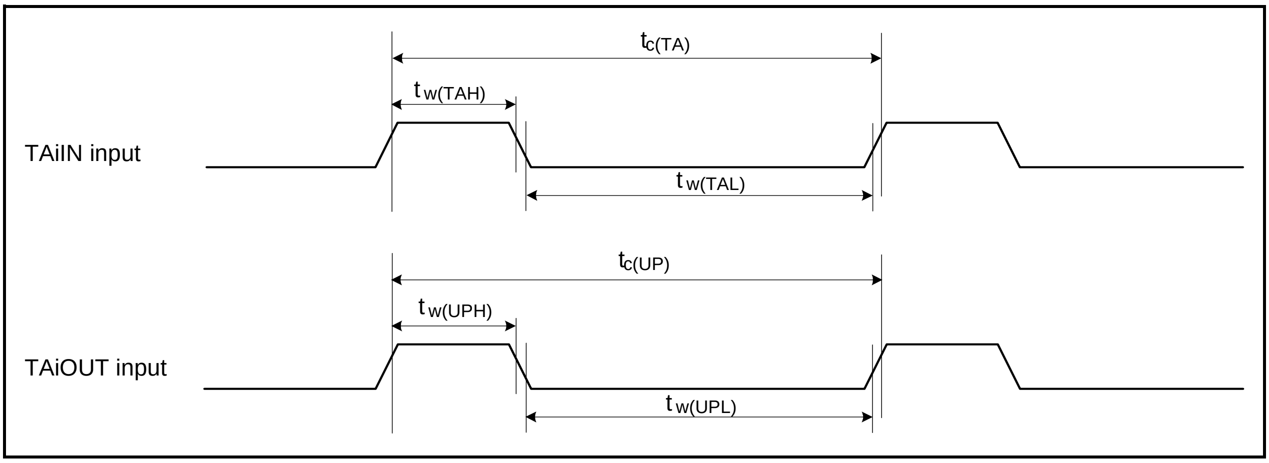


Figure 31.22 Timer A Input

$V_{CC1} = V_{CC2} = 3$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

Table 31.51 Timer A Input (Two-Phase Pulse Input in Event Counter Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TA)}$	TAiIN input cycle time	2		µs
$t_{su(TAIN-TAOUT)}$	TAiOUT input setup time	500		ns
$t_{su(TAOUT-TAIN)}$	TAiIN input setup time	500		ns

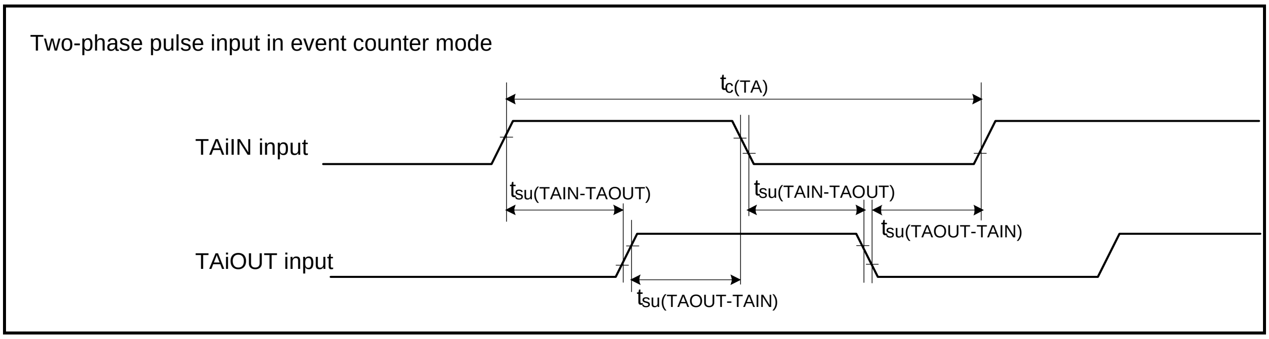


Figure 31.23 Timer A Input (Two-Phase Pulse Input in Event Counter Mode)

$V_{CC1} = V_{CC2} = 3$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.2.4 Timer B Input

Table 31.52 Timer B Input (Counter Input in Event Counter Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiIN input cycle time (counted on one edge)	150		ns
$t_{w(TBH)}$	TBiIN input high pulse width (counted on one edge)	60		ns
$t_{w(TBL)}$	TBiIN input low pulse width (counted on one edge)	60		ns
$t_{c(TB)}$	TBiIN input cycle time (counted on both edges)	300		ns
$t_{w(TBH)}$	TBiIN input high pulse width (counted on both edges)	120		ns
$t_{w(TBL)}$	TBiIN input low pulse width (counted on both edges)	120		ns

Table 31.53 Timer B Input (Pulse Period Measurement Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiIN input cycle time	600		ns
$t_{w(TBH)}$	TBiIN input high pulse width	300		ns
$t_{w(TBL)}$	TBiIN input low pulse width	300		ns

Table 31.54 Timer B Input (Pulse Width Measurement Mode)

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(TB)}$	TBiIN input cycle time	600		ns
$t_{w(TBH)}$	TBiIN input high pulse width	300		ns
$t^{w(TBL)}$	TBiIN input low pulse width	300		ns

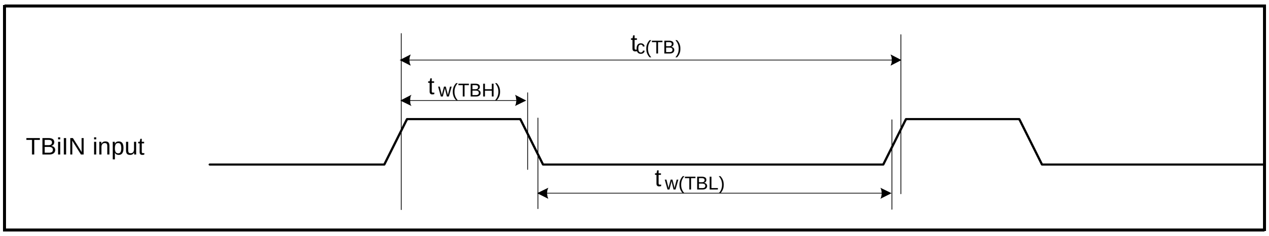


Figure 31.24 Timer B Input

$V_{CC1} = V_{CC2} = 3$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.2.5 Serial Interface

Table 31.55 Serial Interface

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{c(CK)}$	CLKi input cycle time	300		ns
$t_{w(CKH)}$	CLKi input high pulse width	150		ns
$t_{w(CKL)}$	CLKi input low pulse width	150		ns
$t_{d(C-Q)}$	TXDi output delay time		160	ns
$t_{h(C-Q)}$	TXDi hold time	0		ns
$t_{su(D-C)}$	RXDi input setup time	100		ns
$t_{h(C-D)}$	RXDi input hold time	90		ns

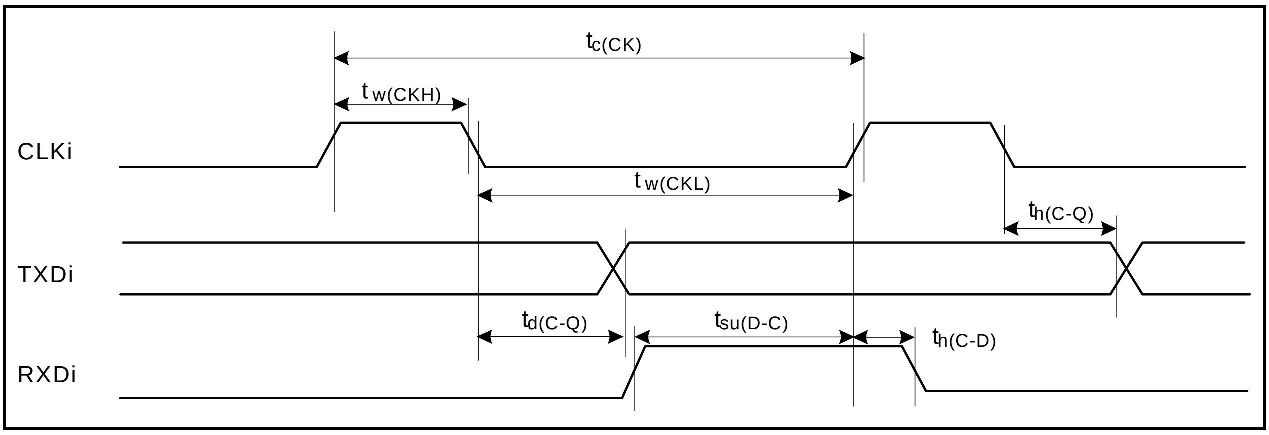


Figure 31.25 Serial Interface

31.3.2.6 External Interrupt $\overline{\text{INTi}}$ Input

Table 31.56 External Interrupt $\overline{\text{INTi}}$ Input

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{w(INH)}$	$\overline{\text{INTi}}$ input high pulse width	380		ns
$t_{w(INL)}$	$\overline{\text{INTi}}$ input low pulse width	380		ns

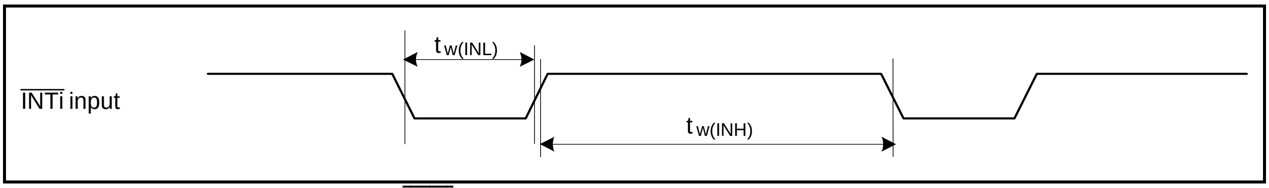


Figure 31.26 External Interrupt $\overline{\text{INTi}}$ Input

$V_{CC1} = V_{CC2} = 3$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at $T_{opr} = -20°C$ to 85°C/-40°C to 85°C unless otherwise specified)

31.3.2.7 Multi-master I²C-bus

Table 31.57 Multi-master I²C-bus

Symbol	Parameter	Standard Clock Mode		Fast-mode		Unit
		Min.	Max.	Min.	Max.	
t_{BUF}	Bus free time	4.7		1.3		µs
$t_{HD;STA}$	Hold time in start condition	4.0		0.6		µs
t_{LOW}	Hold time in SCL clock 0 status	4.7		1.3		µs
t_R	SCL, SDA signals' rising time		1000	20 + 0.1 Cb	300	ns
$t_{HD;DAT}$	Data hold time	0		0	0.9	µs
t_{HIGH}	Hold time in SCL clock 1 status	4.0		0.6		µs
f_F	SCL, SDA signals' falling time		300	20 + 0.1 Cb	300	ns
$t_{su;DAT}$	Data setup time	250		100		ns
$t_{su;STA}$	Setup time in restart condition	4.7		0.6		µs
$t_{su;STO}$	Stop condition setup time	4.0		0.6		µs

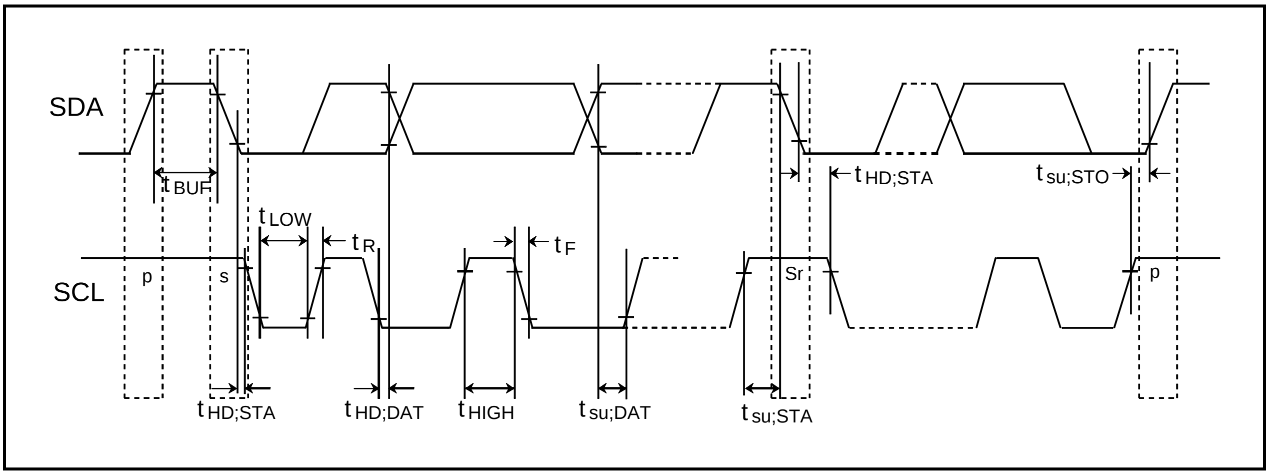


Figure 31.27 Multi-master I²C-bus

$V_{CC1} = V_{CC2} = 3$ V

Timing Requirements

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at $T_{opr} = -20$°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.3 Timing Requirements (Memory Expansion Mode and Microprocessor Mode)

Table 31.58 Memory Expansion Mode and Microprocessor Mode

Symbol	Parameter	Standard		Unit
		Min.	Max.	
$t_{ac1(RD-DB)}$	Data input access time (for setting with no wait)		(Note 1)	ns
$t_{ac2(RD-DB)}$	Data input access time (for setting with wait)		(Note 2)	ns
$t_{ac3(RD-DB)}$	Data input access time (when accessing multiplex bus area)		(Note 3)	ns
$t_{ac4(RD-DB)}$	Data input access time (for setting with 2 ϕ + 3 ϕ or more)		(Note 4)	ns
$t_{su(DB-RD)}$	Data input setup time	60		ns
$t_{su(RDY-BCLK)}$	$\overline{\text{RDY}}$ input setup time	85		ns
$t_{h(RD-DB)}$	Data input hold time	0		ns
$t_{h(BCLK-RDY)}$	$\overline{\text{RDY}}$ input hold time	0		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 60[ns]$$

2. Calculated according to the BCLK frequency as follows:

$$\frac{(n + 0.5) \times 10^9}{f_{(BCLK)}} - 60[ns]$$ n is 1 for 1 wait setting, 2 for 2 waits setting and 3 for 3 waits setting.

3. Calculated according to the BCLK frequency as follows:

$$\frac{(n - 0.5) \times 10^9}{f_{(BCLK)}} - 60[ns]$$ n is 2 for 2 waits setting, 3 for 3 waits setting.

4. Calculated according to the BCLK frequency as follows:

$$\frac{n \times 10^9}{f_{(BCLK)}} - 60[ns]$$ n is 3 for 2 ϕ + 3 ϕ, 4 for 2 ϕ + 4 ϕ, 4 for 3 ϕ + 4 ϕ, 5 for 4 ϕ + 5 ϕ,.

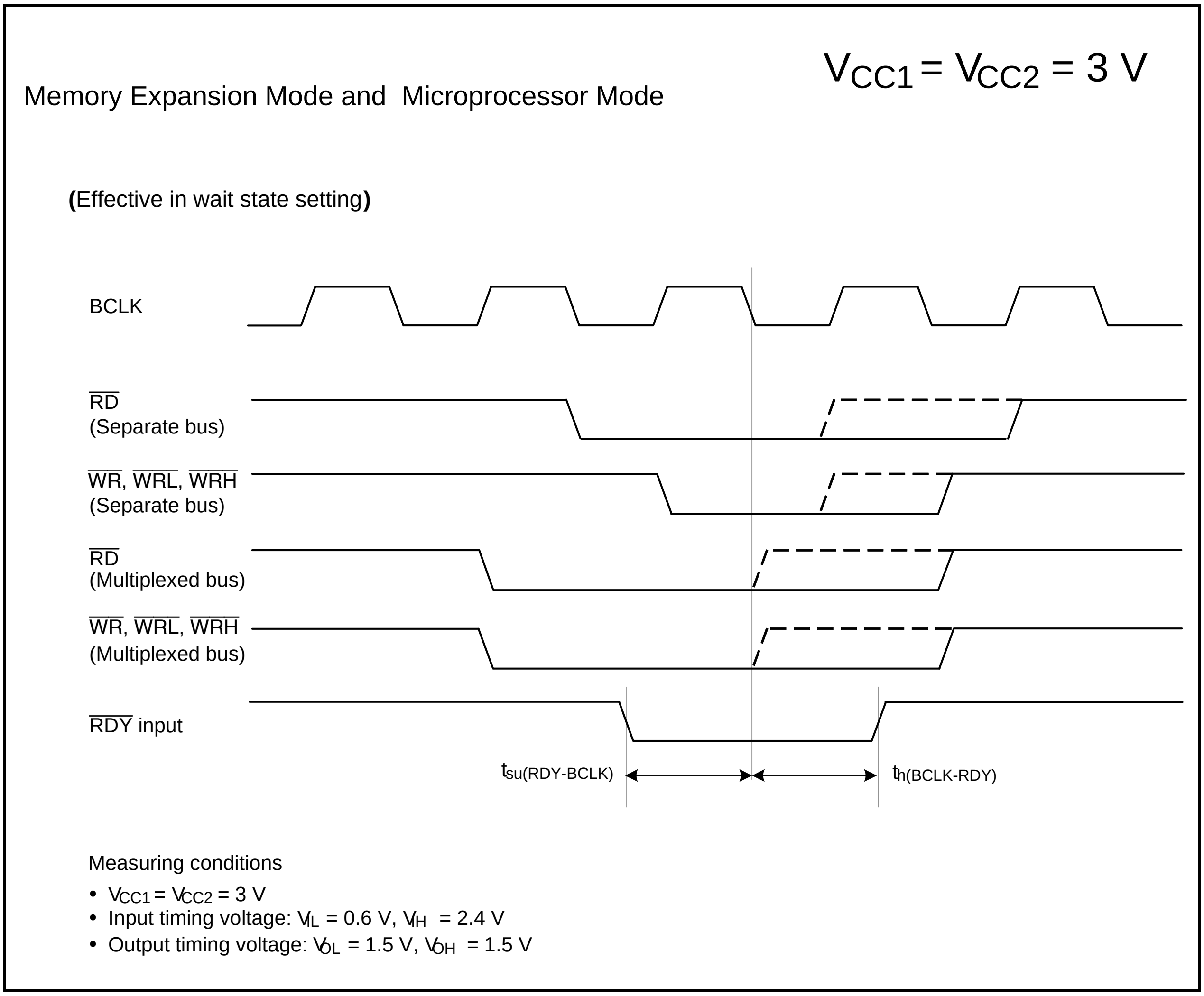

Memory Expansion Mode and Microprocessor Mode
$V_{CC1} = V_{CC2} = 3$ V
(Effective in wait state setting)
BCLK
$\overline{RD}$ (Separate bus)
$\overline{WR}$, $\overline{WRL}$, $\overline{WRH}$ (Separate bus)
$\overline{RD}$ (Multiplexed bus)
$\overline{WR}$, $\overline{WRL}$, $\overline{WRH}$ (Multiplexed bus)
$\overline{RDY}$ input
$t_{su(RDY-BCLK)}$
$t_{h(BCLK-RDY)}$
Measuring conditions
• $V_{CC1} = V_{CC2} = 3$ V
• Input timing voltage: $V_{IL} = 0.6$ V, $V_{IH} = 2.4$ V
• Output timing voltage: $V_{OL} = 1.5$ V, $V_{OH} = 1.5$ V

Figure 31.28 Timing Diagram

$V_{CC1} = V_{CC2} = 3$ V

31.3.4 Switching Characteristics (Memory Expansion Mode and Microprocessor Mode)

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.4.1 In No Wait State Setting

Table 31.59 Memory Expansion and Microprocessor Modes (in No Wait State Setting)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.29		30	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		0		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 2)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			30	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			25	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		–4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			30	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			30	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 1)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR) (3)		(Note 4)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

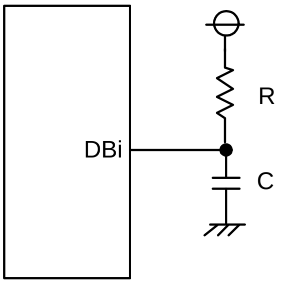
$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 40[ns]$$

$f_{(BCLK)}$ is 12.5 MHz or less.

2. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 15[ns]$$

3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = –CR \times \ln(1 – V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ,
hold time of output low level is
$t = –30 \text{ pF} \times 1 \text{ k}\Omega \times \ln(1 – 0.2V_{CC2}/V_{CC2})$
= 6.7 ns.



4. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 25[ns]$$

Hold time is equal to or less than 0 ns when the BCLK frequency exceeds 20 MHz.

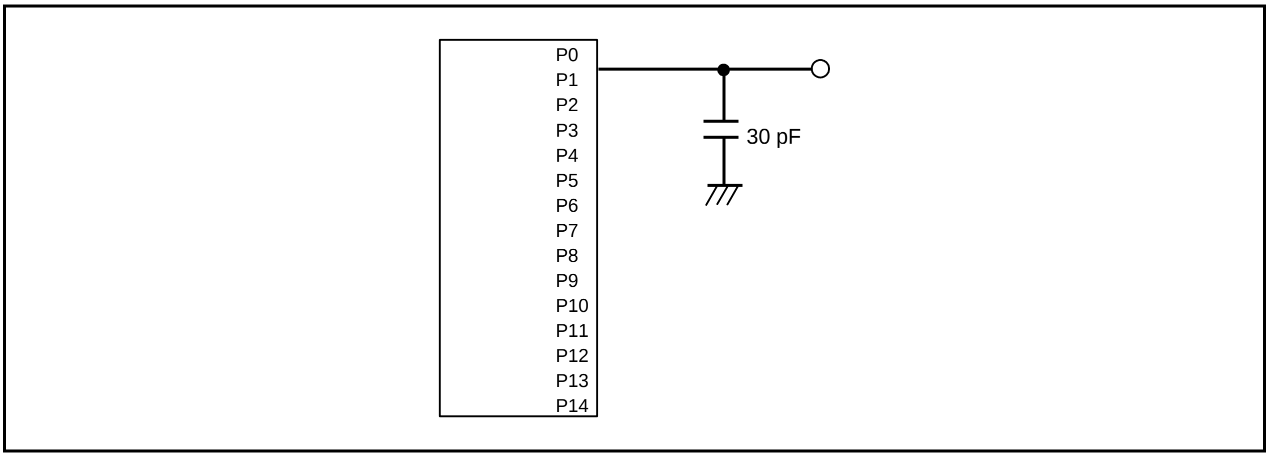
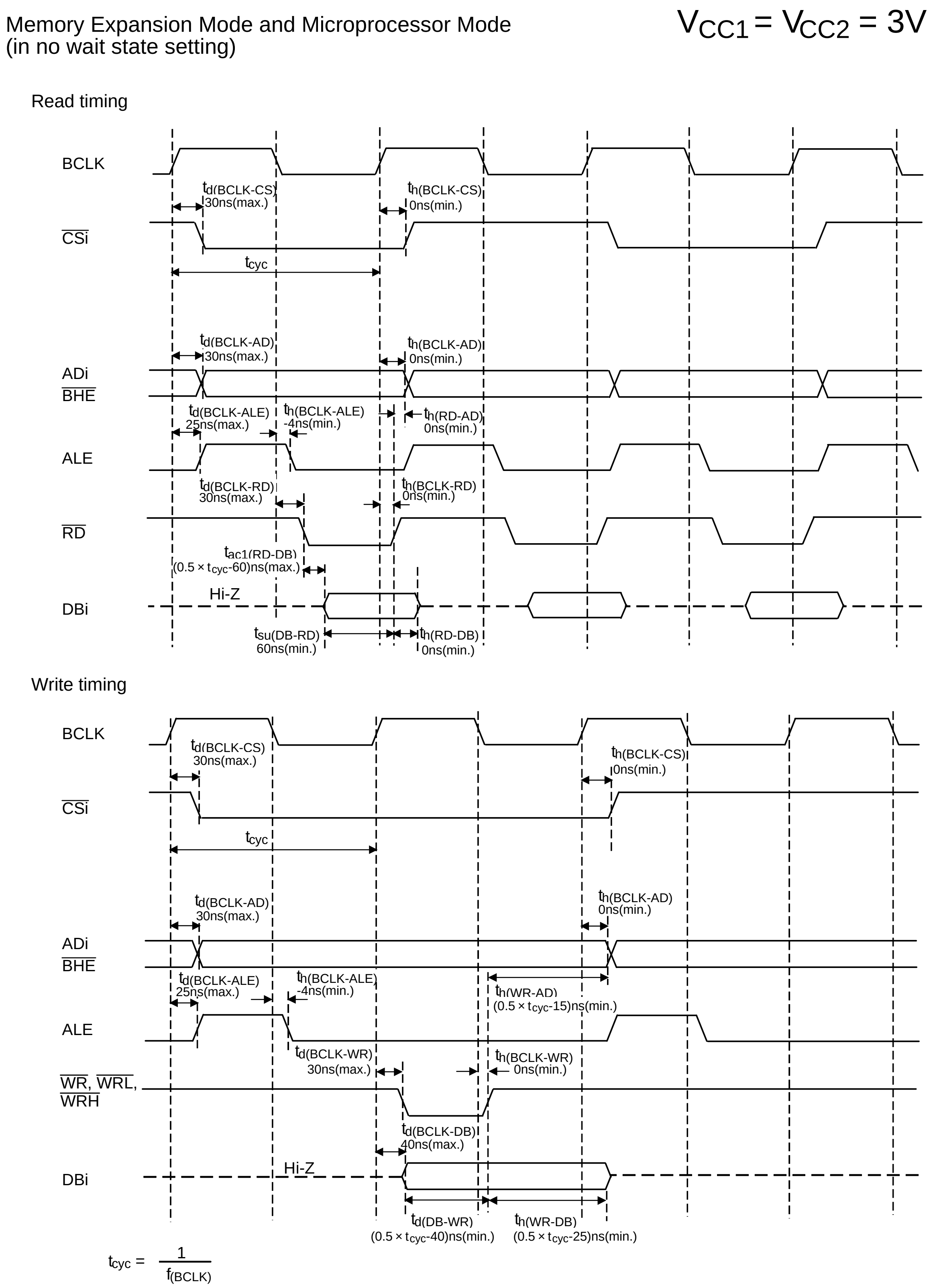


Figure 31.29 Ports P0 to P14 Measurement Circuit


Memory Expansion Mode and Microprocessor Mode
(in no wait state setting)
$V_{CC1} = V_{CC2} = 3V$
Read timing
BCLK
$t_{d(BCLK-CS)}$ 30ns(max.)
$t_{h(BCLK-CS)}$ 0ns(min.)
CSi
t_{cyc}
$t_{d(BCLK-AD)}$ 30ns(max.)
$t_{h(BCLK-AD)}$ 0ns(min.)
ADi
BHE
$t_{d(BCLK-ALE)}$ 25ns(max.)
$t_{h(BCLK-ALE)}$ -4ns(min.)
$t_{h(RD-AD)}$ 0ns(min.)
ALE
$t_{d(BCLK-RD)}$ 30ns(max.)
$t_{h(BCLK-RD)}$ 0ns(min.)
RD
$t_{ac1(RD-DB)}$ (0.5 × t_{cyc}-60)ns(max.)
Hi-Z
DBi
$t_{su(DB-RD)}$ 60ns(min.)
$t_{h(RD-DB)}$ 0ns(min.)
Write timing
BCLK
$t_{d(BCLK-CS)}$ 30ns(max.)
$t_{h(BCLK-CS)}$ 0ns(min.)
CSi
t_{cyc}
$t_{d(BCLK-AD)}$ 30ns(max.)
$t_{h(BCLK-AD)}$ 0ns(min.)
ADi
BHE
$t_{d(BCLK-ALE)}$ 25ns(max.)
$t_{h(BCLK-ALE)}$ -4ns(min.)
$t_{h(WR-AD)}$ (0.5 × t_{cyc}-15)ns(min.)
ALE
$t_{d(BCLK-WR)}$ 30ns(max.)
$t_{h(BCLK-WR)}$ 0ns(min.)
WR, WRL, WRH
$t_{d(BCLK-DB)}$ 40ns(max.)
Hi-Z
DBi
$t_{d(DB-WR)}$ (0.5 × t_{cyc}-40)ns(min.)
$t_{h(WR-DB)}$ (0.5 × t_{cyc}-25)ns(min.)
$t_{cyc} = \frac{1}{f_{(BCLK)}}$

Measuring conditions

- $V_{CC1} = V_{CC2} = 3V$
- Input timing voltage: $V_{IL} = 0.6$ V, $V_{IH} = 2.4$ V
- Output timing voltage: $V_{OL} = 1.5$ V, $V_{OH} = 1.5$ V

Figure 31.30 Timing Diagram

$V_{CC1} = V_{CC2} = 3$ V

Switching Characteristics

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.4.2 In 1 to 3 Waits Setting and When Accessing External Area

Table 31.60 Memory Expansion Mode and Microprocessor Mode (in 1 to 3 Waits Setting and When Accessing External Area)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.29		30	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		0		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 2)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			30	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			25	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		-4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			30	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			30	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 1)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR) [3]		(Note 4)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

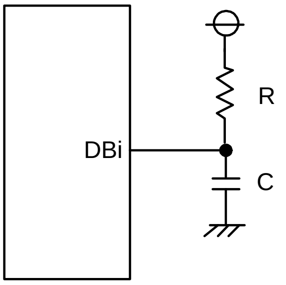
$$\frac{(n-0.5)\times 10^9}{f_{(BCLK)}} - 40[ns]$$

n is 1 for 1 wait setting, 2 for 2 waits setting and 3 for 3 waits setting.
When n = 1, $f_{(BCLK)}$ is 12.5 MHz or less.

2. Calculated according to the BCLK frequency as follows:

$$\frac{0.5\times 10^9}{f_{(BCLK)}} - 15[ns]$$

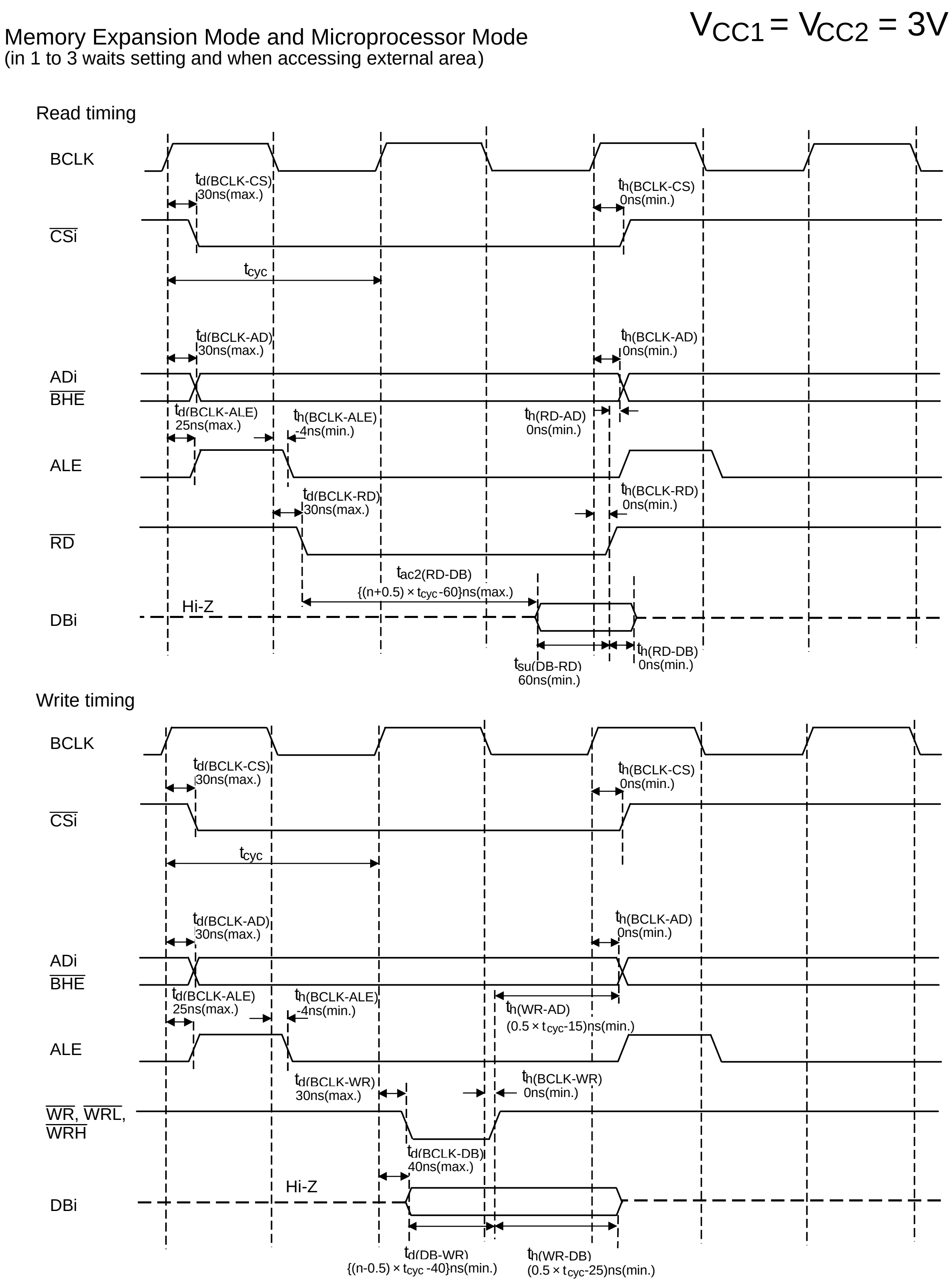
3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1-V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30\text{ pF} \times 1\text{ k}\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
= 6.7 ns.



4. Calculated according to the BCLK frequency as follows:

$$\frac{0.5\times 10^9}{f_{(BCLK)}} - 25[ns]$$

Hold time is equal to or less than 0 ns when the BCLK frequency exceeds 20 MHz.



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

Measuring conditions

- $V_{CC1} = V_{CC2} = 3V$
- Input timing voltage: V_{IL} = 0.6 V, V_{IH} = 2.4 V
- Output timing voltage: V_{OL} = 1.5 V, V_{OH} = 1.5 V

n: 1 (when 1 wait)
2 (when 2 waits)
3 (when 3 waits)

Figure 31.31 Timing Diagram

$V_{CC1} = V_{CC2} = 3$ V

Switching Characteristics

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.4.3 In 2 or 3 Waits Setting, and When Accessing External Area and Using Multiplexed Bus

Table 31.61 Memory Expansion Mode and Microprocessor Mode (in 2 or 3 Waits Setting, and When Accessing External Area and Using Multiplexed Bus) (5)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.29		50	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		(Note 1)		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 6)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			50	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{h(RD-CS)}$	Chip select output hold time (in relation to RD)		(Note 1)		ns
$t_{h(WR-CS)}$	Chip select output hold time (in relation to WR)		(Note 1)		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			40	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			40	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			50	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 2)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR)		(Note 7)		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time (in relation to BCLK)			25	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time (in relation to BCLK)		−4		ns
$t_{d(AD-ALE)}$	ALE signal output delay time (in relation to Address)		(Note 3)		ns
$t_{h(AD-ALE)}$	ALE signal output hold time (in relation to Address)		(Note 4)		ns
$t_{d(AD-RD)}$	RD signal output delay from the end of address		0		ns
$t_{d(AD-WR)}$	WR signal output delay from the end of address		0		ns
$t_{dz(RD-AD)}$	Address output floating start time			8	ns

Notes:

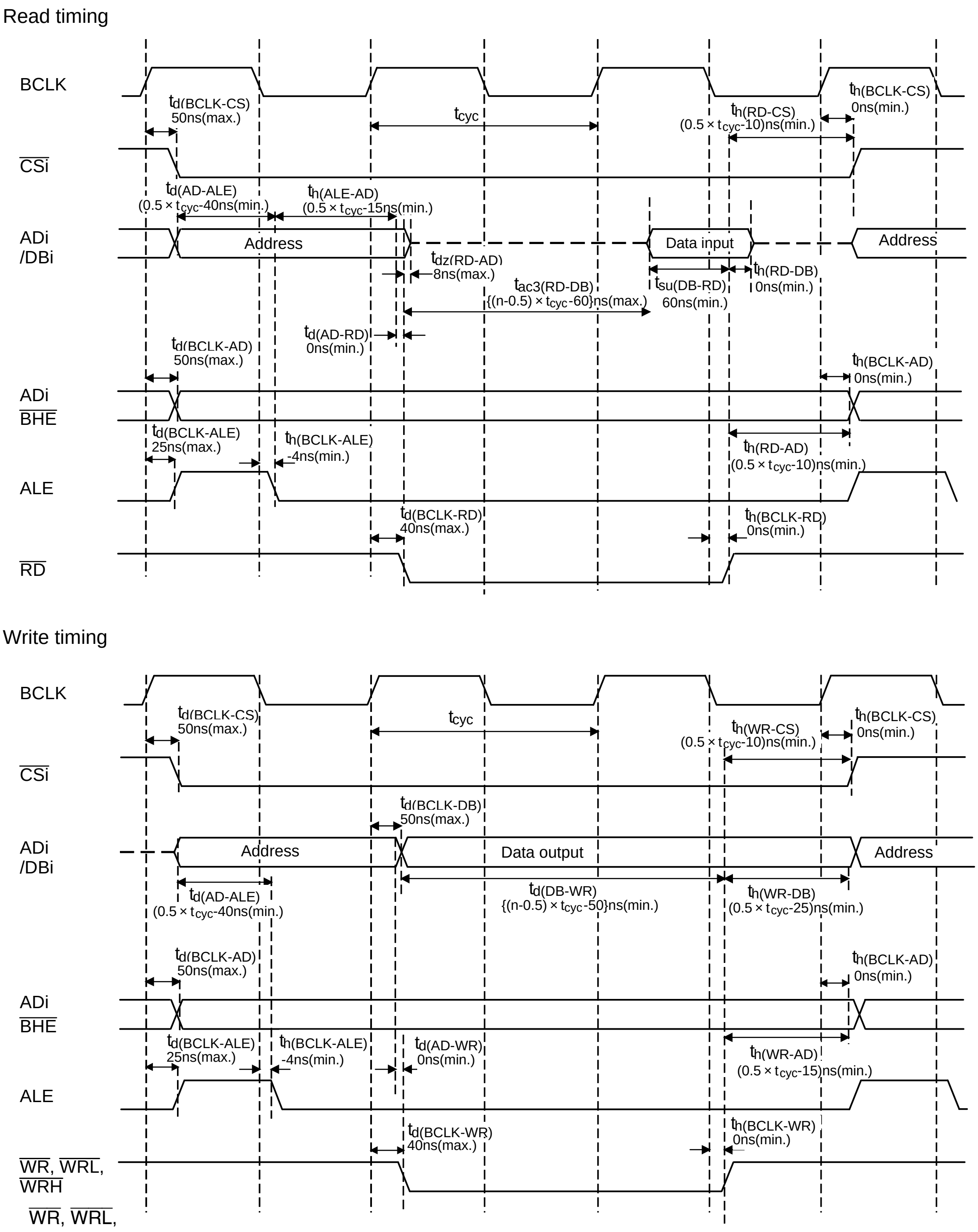
1. Calculated according to the BCLK frequency as follows: $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 10[ns]$
2. Calculated according to the BCLK frequency as follows:

   $\frac{(n - 0.5) \times 10^9}{f_{(BCLK)}} - 50[ns]$ n is 2 for 2 waits setting, 3 for 3 waits setting.
3. Calculated according to the BCLK frequency as follows: $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 40[ns]$
4. Calculated according to the BCLK frequency as follows: $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 15[ns]$
5. When using multiplexed bus, set $f_{(BCLK)}$ 12.5 MHz or less.
6. Calculated according to the BCLK frequency as follows: $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 15[ns]$
7. Calculated according to the BCLK frequency as follows: $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 25[ns]$

Memory Expansion Mode and Microprocessor Mode

(in 2 or 3 waits setting, and when accessing external area and using multiplexed bus)

$V_{CC1} = V_{CC2} = 3V$



$$t_{cyc} = \frac{1}{f_{(BCLK)}}$$

Measuring conditions

- $V_{CC1} = V_{CC2} = 3V$
- Input timing voltage: V_{IL} = 0.6 V, V_{IH} = 2.4 V
- Output timing voltage: V_{OL} = 1.5 V, V_{OH} = 1.5 V

n: 2 (when 2 waits)
3 (when 3 waits)

Figure 31.32 Timing Diagram

$V_{CC1} = V_{CC2} = 3$ V

Switching Characteristics

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.4.4 In Wait State Setting 2ϕ + 3ϕ, 2ϕ + 4ϕ, 3ϕ + 4ϕ, and 4ϕ + 5ϕ, and When Accessing External Area

Table 31.62 Memory Expansion and Microprocessor Modes (in Wait State Setting 2ϕ + 3ϕ, 2ϕ + 4ϕ, 3ϕ + 4ϕ, and 4ϕ + 5ϕ, and When Accessing External Area)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.29		30	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		0		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 2)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			30	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			25	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		-4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			30	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			30	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 1)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR) (3)		(Note 4)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

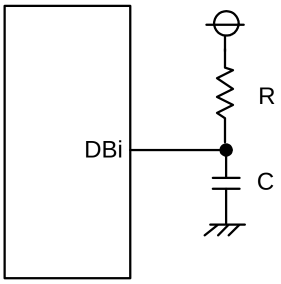
$$\frac{(n - 0.5) \times 10^9}{f_{(BCLK)}} - 40[ns]$$

n is 3 for 2ϕ + 3ϕ, 4 for 2ϕ + 4ϕ, 4 for 3ϕ + 4ϕ, and 5 for 4ϕ + 5ϕ.

2. Calculated according to the BCLK frequency as follows:

$$\frac{0.5 \times 10^9}{f_{(BCLK)}} - 15[ns]$$

3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1 - V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30 \text{ pF} \times 1 \text{ k}\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
= 6.7 ns.

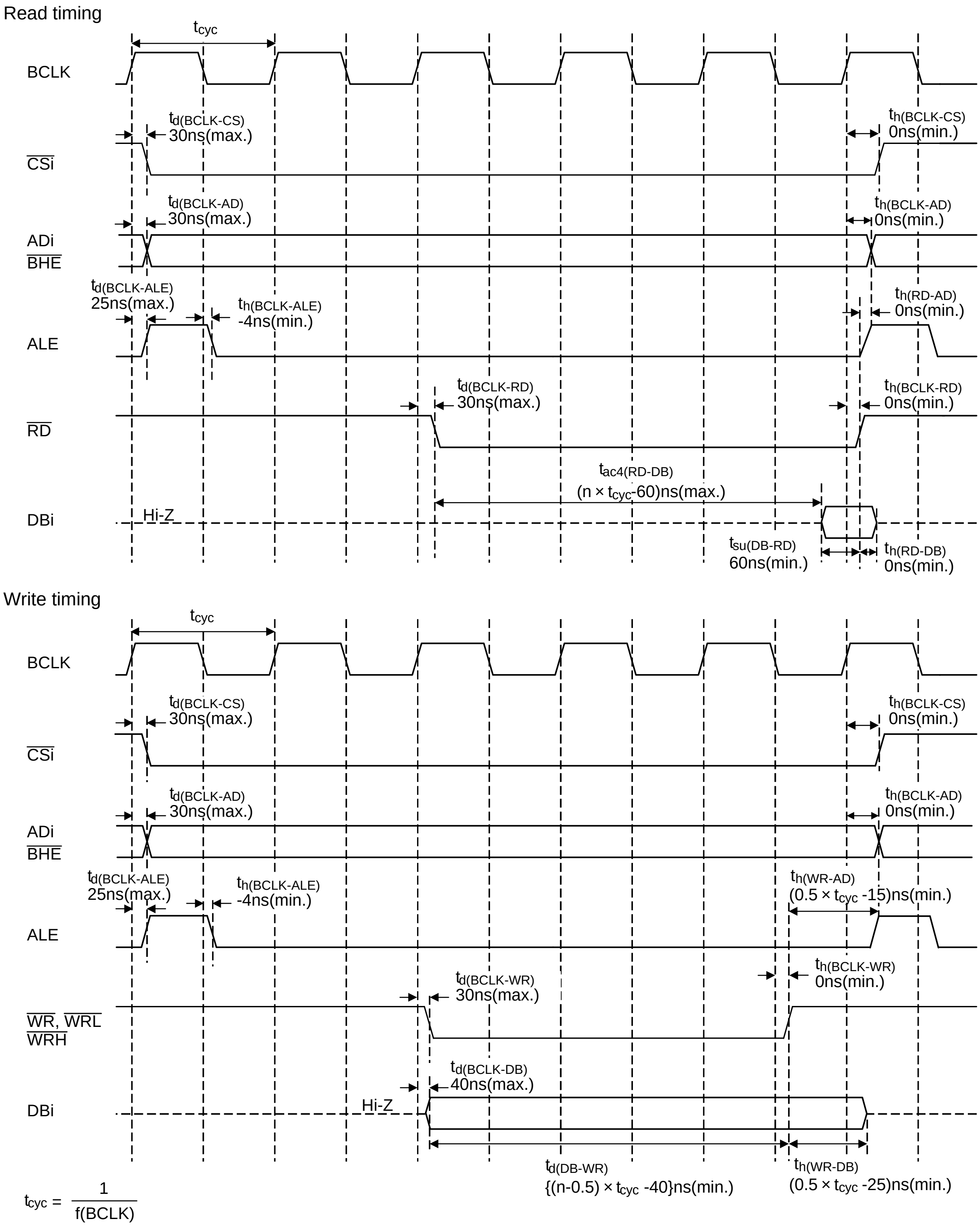


4. Calculated according to the BCLK frequency as follows: $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 25[ns]$

Hold time is equal to or less than 0 ns when the BCLK frequency exceeds 20 MHz.

Memory Expansion Mode, Microprocessor Mode
(in wait state setting 2 ϕ + 3 ϕ, 2 ϕ + 4 ϕ, 3ϕ + 4 ϕ, and 4 ϕ + 5 ϕ, and when accessing external area)

$V_{CC1} = V_{CC2} = 3V$



Measuring conditions

- $V_{CC1} = V_{CC2} = 3V$
- Input timing voltage: $V_{IL} = 0.6$ V, $V_{IH} = 2.4$ V
- Output timing voltage: $V_{OL} = 1.5$ V, $V_{OH} = 1.5$ V

n: 3 (when 2 ϕ + 3 ϕ)
4 (when 2 ϕ + 4 ϕ or 3 ϕ + 4 ϕ)
5 (when 4 ϕ + 5 ϕ)

Figure 31.33 Timing Diagram

$V_{CC1} = V_{CC2} = 3$ V

Switching Characteristics

($V_{CC1} = V_{CC2} = 3$ V, $V_{SS} = 0$ V, at T_{opr} = -20°C to 85°C/-40°C to 85°C unless otherwise specified)

31.3.4.5 In Wait State Setting 2ϕ + 3ϕ, 2ϕ + 4ϕ, 3ϕ + 4ϕ, and 4ϕ + 5ϕ, and Inserting 1 to 3 Recovery Cycles and Accessing External Area

Table 31.63 Memory Expansion Mode and Microprocessor Mode (in Wait State Setting 2ϕ + 3ϕ, 2ϕ + 4ϕ, 3ϕ + 4ϕ, and 4ϕ + 5ϕ, and Inserting 1 to 3 Recovery Cycles and Accessing External Area)

Symbol	Parameter	Measuring Condition	Standard		Unit
			Min.	Max.	
$t_{d(BCLK-AD)}$	Address output delay time	See Figure 31.29		30	ns
$t_{h(BCLK-AD)}$	Address output hold time (in relation to BCLK)		0		ns
$t_{h(RD-AD)}$	Address output hold time (in relation to RD)		(Note 4)		ns
$t_{h(WR-AD)}$	Address output hold time (in relation to WR)		(Note 2)		ns
$t_{d(BCLK-CS)}$	Chip select output delay time			30	ns
$t_{h(BCLK-CS)}$	Chip select output hold time (in relation to BCLK)		0		ns
$t_{d(BCLK-ALE)}$	ALE signal output delay time			25	ns
$t_{h(BCLK-ALE)}$	ALE signal output hold time		-4		ns
$t_{d(BCLK-RD)}$	RD signal output delay time			30	ns
$t_{h(BCLK-RD)}$	RD signal output hold time		0		ns
$t_{d(BCLK-WR)}$	WR signal output delay time			30	ns
$t_{h(BCLK-WR)}$	WR signal output hold time		0		ns
$t_{d(BCLK-DB)}$	Data output delay time (in relation to BCLK)			40	ns
$t_{d(DB-WR)}$	Data output delay time (in relation to WR)		(Note 1)		ns
$t_{h(WR-DB)}$	Data output hold time (in relation to WR) (3)		(Note 5)		ns

Notes:

1. Calculated according to the BCLK frequency as follows:

$$\frac{n \times 10^9}{f_{(BCLK)}} - 40[ns]$$

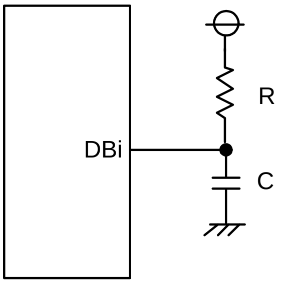
n is 3 for 2ϕ + 3ϕ, 4 for 2ϕ + 4ϕ, 4 for 3ϕ + 4ϕ, and 5 for 4ϕ + 5ϕ.

2. Calculated according to the BCLK frequency as follows:

$$\frac{m \times 10^9}{f_{(BCLK)}} - 15[ns]$$

m is 1 when 1 recovery cycle is inserted, 2 when 2 recovery cycles are inserted, and 3 when 3 recovery cycles are inserted.

3. This standard value shows the timing when the output is off, and does not show hold time of data bus.
Hold time of data bus varies with capacitor volume and pull-up (pull-down) resistance value.
Hold time of data bus is expressed in
$t = -CR \times \ln(1 - V_{OL}/V_{CC2})$
by a circuit of the right figure.
For example, when $V_{OL} = 0.2V_{CC2}$, C = 30 pF, R = 1 kΩ, hold time of output low level is
$t = -30 \text{ pF} \times 1 \text{ k}\Omega \times \ln(1 - 0.2V_{CC2}/V_{CC2})$
= 6.7 ns.



4. Calculated according to the BCLK frequency as follows:

$$\frac{m \times 10^9}{f_{(BCLK)}} + 0[ns]$$

m is 1 when 1 recovery cycle is inserted, 2 when 2 recovery cycles are inserted, and 3 when 3 recovery cycles are inserted.

5. Calculated according to the BCLK frequency as follows:

$$\frac{m \times 10^9}{f_{(BCLK)}} - 25[ns]$$

m is 1 when 1 recovery cycle is inserted, 2 when 2 recovery cycles are inserted, and 3 when 3 recovery cycles are inserted.

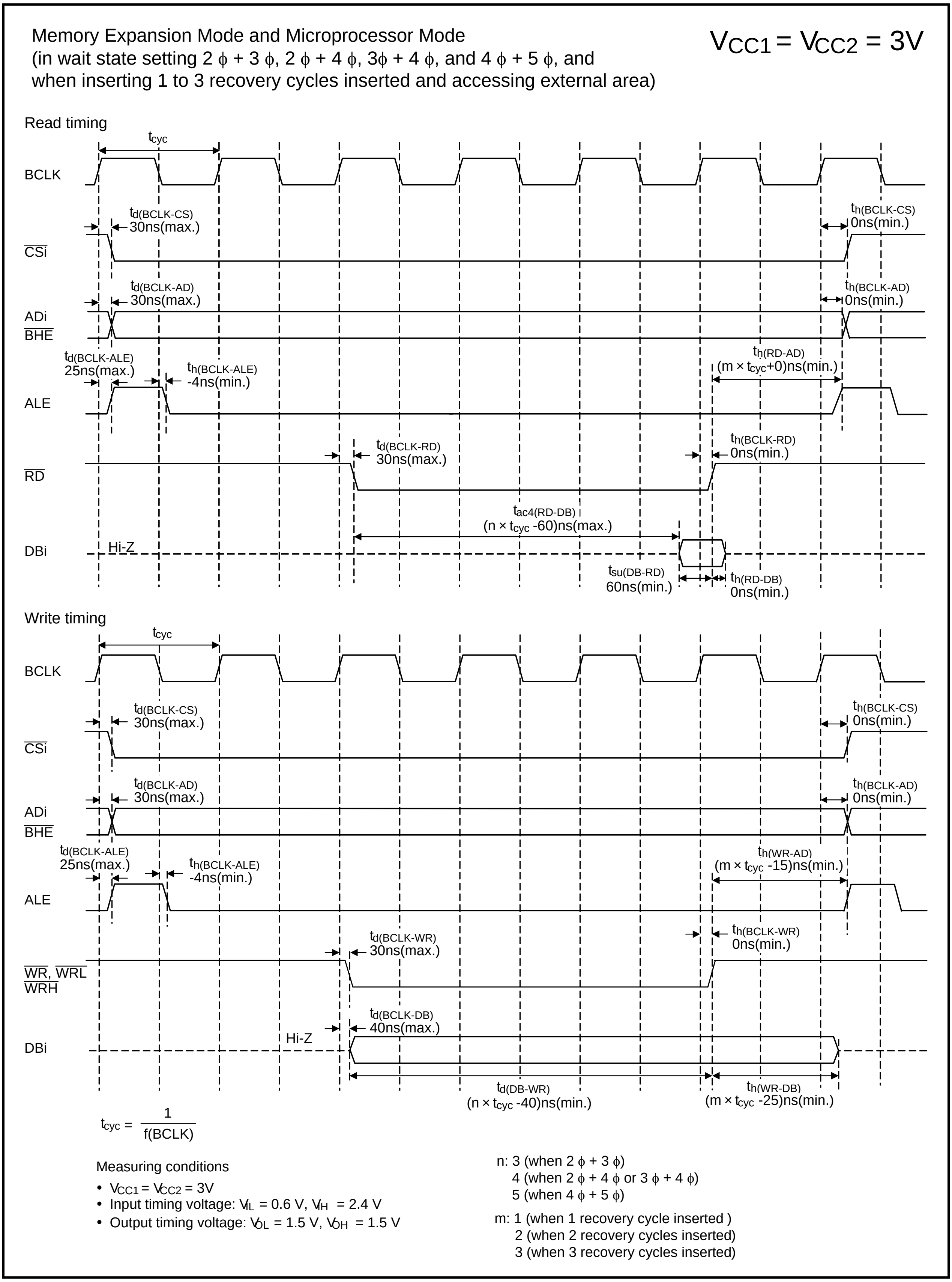


Figure 31.34 Timing Diagram

32. Usage Notes

32.1 Notes on Noise

Connect a bypass capacitor (approximately 0.1 µF) across pins VCC1 and VSS, and pins VCC2 and VSS using the shortest and thickest possible wiring. Figure 32.1 shows the Bypass Capacitor Connection.

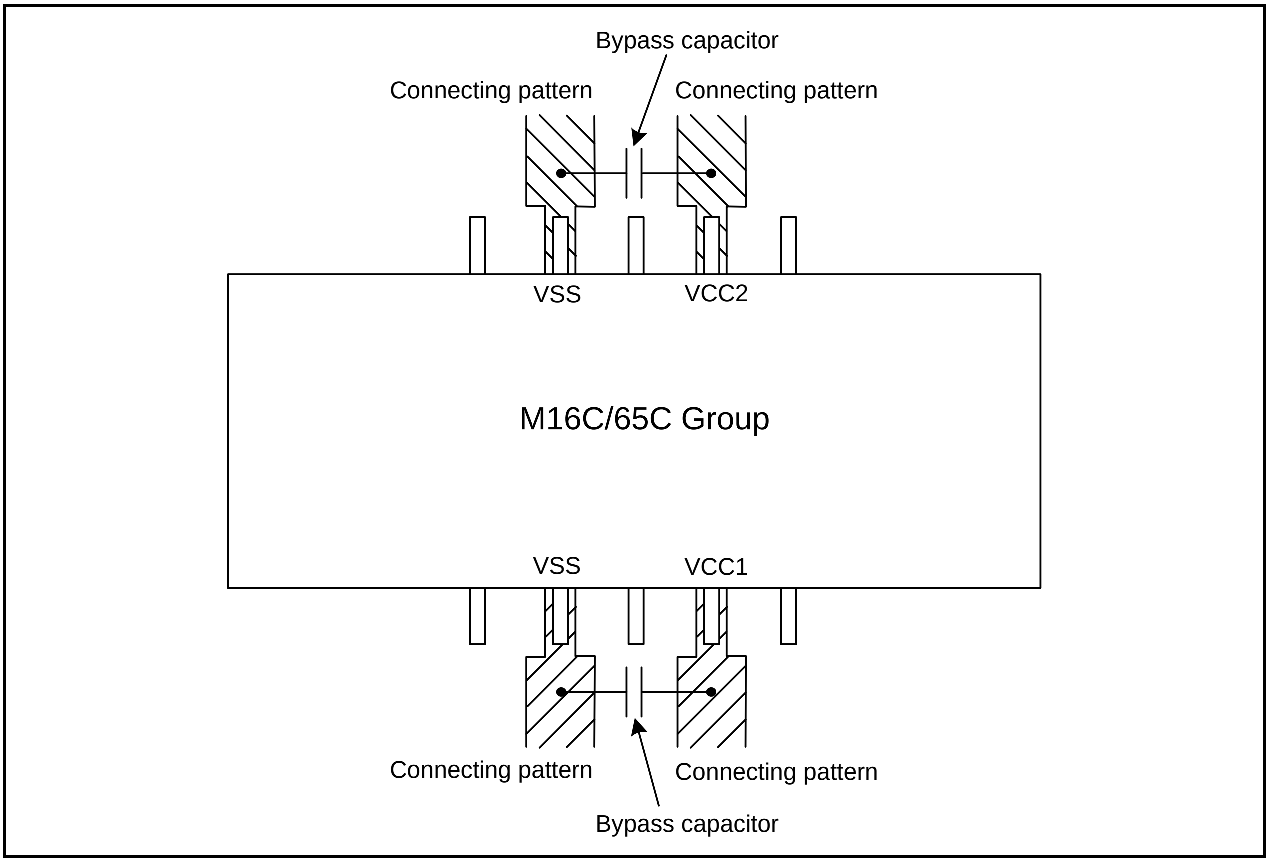


Figure 32.1 Bypass Capacitor Connection

32.2 Notes on SFRs

32.2.1 Register Settings

Table 32.1 lists Registers with Write-Only Bits and registers whose function differs between reading and writing. Set these registers with immediate values. Do not use read-modify-write instructions. When establishing the next value by altering the existing value, write the existing value to the RAM as well as to the register. Transfer the next value to the register after making changes in the RAM.
Read-modify-write instructions can be used when writing to the no register bits.

Table 32.1 Registers with Write-Only Bits

Address	Register	Symbol
0249h	UART0 Bit Rate Register	U0BRG
024Bh to 024Ah	UART0 Transmit Buffer Register	U0TB
0259h	UART1 Bit Rate Register	U1BRG
025Bh to 025Ah	UART1 Transmit Buffer Register	U1TB
0269h	UART2 Bit Rate Register	U2BRG
026Bh to 026Ah	UART2 Transmit Buffer Register	U2TB
0273h	SI/O3 Bit Rate Register	S3BRG
0277h	SI/O4 Bit Rate Register	S4BRG
0289h	UART5 Bit Rate Register	U5BRG
028Bh to 028Ah	UART5 Transmit Buffer Register	U5TB
0299h	UART6 Bit Rate Register	U6BRG
029Bh to 029Ah	UART6 Transmit Buffer Register	U6TB
02A9h	UART7 Bit Rate Register	U7BRG
02ABh to 02AAh	UART7 Transmit Buffer Register	U7TB
02B6h	I2C0 Control Register 1	S3D0
02B8h	I2C0 Status Register 0	S10
0303h to 0302h	Timer A1-1 Register	TA11
0305h to 0304h	Timer A2-1 Register	TA21
0307h to 0306h	Timer A4-1 Register	TA41
030Ah	Three-Phase Output Buffer Register 0	IDB0
030Bh	Three-Phase Output Buffer Register 1	IDB1
030Ch	Dead Time Timer	DTT
030Dh	Timer B2 Interrupt Generation Frequency Set Counter	ICTB2
0327h to 0326h	Timer A0 Register	TA0
0329h to 0328h	Timer A1 Register	TA1
032Bh to 032Ah	Timer A2 Register	TA2
032Dh to 032Ch	Timer A3 Register	TA3
032Fh to 032Eh	Timer A4 Register	TA4
037Dh	Watchdog Timer Refresh Register	WDTR
037Eh	Watchdog Timer Start Register	WDTS

Table 32.2 Read-Modify-Write Instructions

Function	Mnemonic
Transfer	MOV*Dir*
Bit processing	BCLR, BM*Cnd*, BNOT, BSET, BTSTC, and BTSTS
Shifting	ROLC, RORC, ROT, SHA, and SHL
Arithmetic operation	ABS, ADC, ADCF, ADD, DEC, DIV, DIVU, DIVX, EXTS, INC, MUL, MULU, NEG, SBB, and SUB
Decimal operation	DADC, DADD, DSBB, and DSUB
Logical operation	AND, NOT, OR, and XOR
Jump	ADJNZ, SBJNZ

32.3 Notes on Protection

After setting the PRC2 bit to 1 (write enabled), by writing to a given SFR, the PRC2 bit becomes 0 (write disabled). Change the registers protected by the PRC2 bit in the next instruction after setting the PRC2 bit to 1. Make sure there are no interrupts or DMA transfers between the instruction that sets the PRC2 bit to 1 and the next instruction.

32.4 Notes on Resets

32.4.1 Power Supply Rising Gradient

When supplying power to the MCU, make sure that the power supply voltage applied to the VCC1 pin meets the SVCC conditions.

Symbol	Parameter		Standard			Unit
			Min.	Typ.	Max.	
SVCC	Power supply VCC1 rising gradient (Voltage range: 0 to 2.0 V)		0.05			V/ms
	Power supply VCC1 rising gradient (Voltage range: 2.0 V to VCC1)	3.6 V < VCC1 ≤ 5.5 V			5.5	V/ms

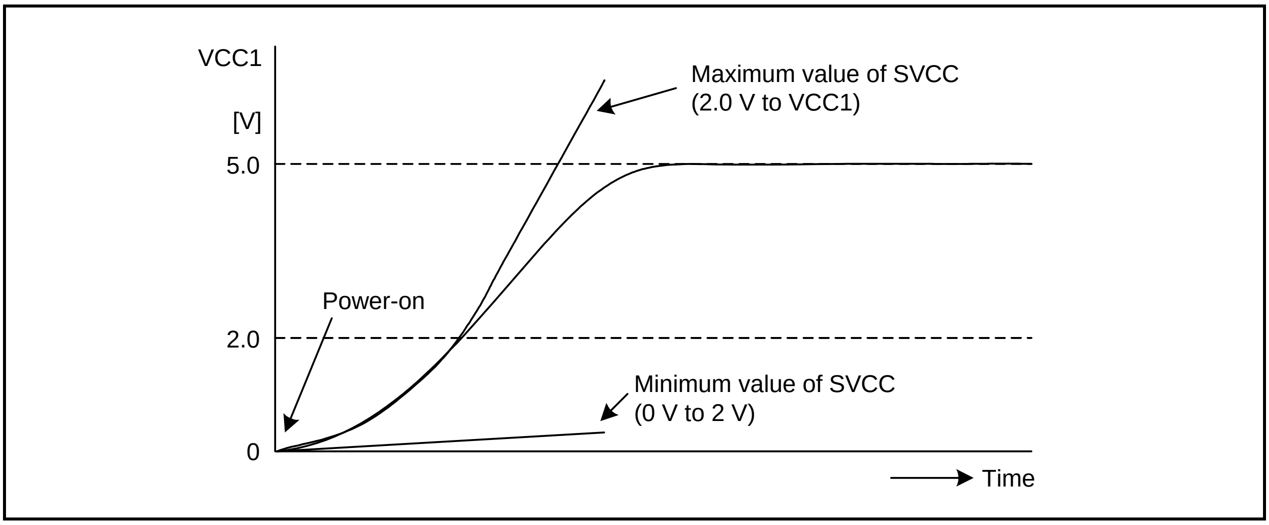


Figure 32.2 SVCC Timing (3.6 V < VCC1)

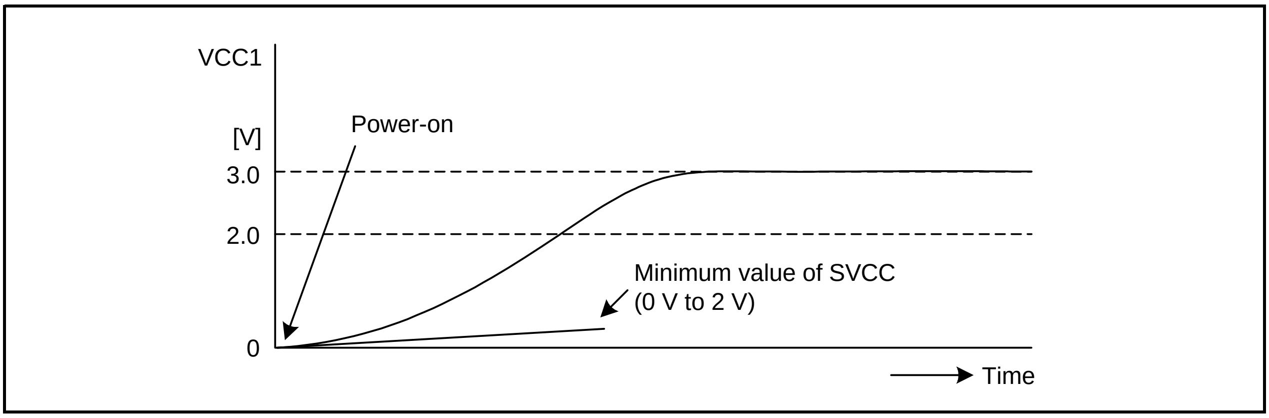


Figure 32.3 SVCC Timing (VCC1 ≤ 3.6 V)

32.4.2 Power-On Reset

Use the voltage monitor 0 reset together with the power-on reset. To use the power-on reset, set the LVDAS bit in the OFS1 address to 0 (voltage monitor 0 reset enabled after hardware reset) and the VDSEL1 bit to 0 (Vdet0_2). In this case, the voltage monitor 0 reset is enabled (the VW0C0 bit and bit 6 in the VW0C register are 1, and the VC25 bit in the VCR2 register is 1) after power-on reset. Do not disable these bits by a program.

32.4.3 OSDR Bit (Oscillation Stop Detect Reset Detect Flag)

When an oscillator stop detect reset is generated, the MCU is reset and then stopped. This state is canceled by hardware reset or voltage monitor 0 reset.
Note that the OSDR bit in the RSTFR register is not affected by a hardware reset, but becomes 0 (not detected) from a voltage monitor 0 reset.

32.5 Notes on Clock Generator

32.5.1 Oscillator Using a Crystal or a Ceramic Resonator

To connect a crystal/ceramic resonator follow the instructions below:

- The oscillation characteristics are tied closely to the user's board design. Perform a careful evaluation of the board before connecting an oscillator.
- Oscillator structure depends on a crystal/ceramic resonator. The M16C/65C Group MCU contains a feedback resistor, but an additional external feedback resistor may be required. Contact the manufacturer of crystal/ceramic resonator regarding circuit constants, as they are dependent on the a crystal/ceramic resonator or stray capacitance of the mounted circuit.
- Check output from the CLKOUT pin to confirm that the clock generated by the oscillator is properly transmitted to the MCU.

The procedure for outputting a clock from the CLKOUT pin is listed below. Set the clock output from the CLKOUT pin to 25 MHz or lower.

Outputting the main clock

(1) Set the PRC0 bit in the PRCR register to 1 (write enabled).
(2) Set the CM11 bit in the CM1 register, the CM07 bit in the CM0 register, and the CM21 bit in the CM2 register all to 0 (main clock selected).
(3) Select the clock output from the CLKOUT pin (see the table below).
(4) Set the PRC0 bit in the PRCR register to 0 (write disabled).

Table 32.3 Output from CLKOUT Pin When Selecting Main Clock

Bit Setting		Output from the CLKOUT Pin
PCLKR register	CM0 register	
PCLK5 bit	Bits CM01 to CM00	
1	00b	Clock with the same frequency as the main clock
0	10b	Main clock divided by 8
0	11b	Main clock divided by 32

Outputting the sub clock

(1) Set the PRC0 bit in the PRCR register to 1 (write enabled).
(2) Set the CM07 bit in the CM0 register to 1 (sub clock selected).
(3) Set the PCLK5 bit in the PCLKR register to 0, and bits CM01 to CM00 in the CM0 register to 01b (fC output from CLKOUT pin).
(4) Set the PRC0 bit in the PRCR register to 0 (write disabled).

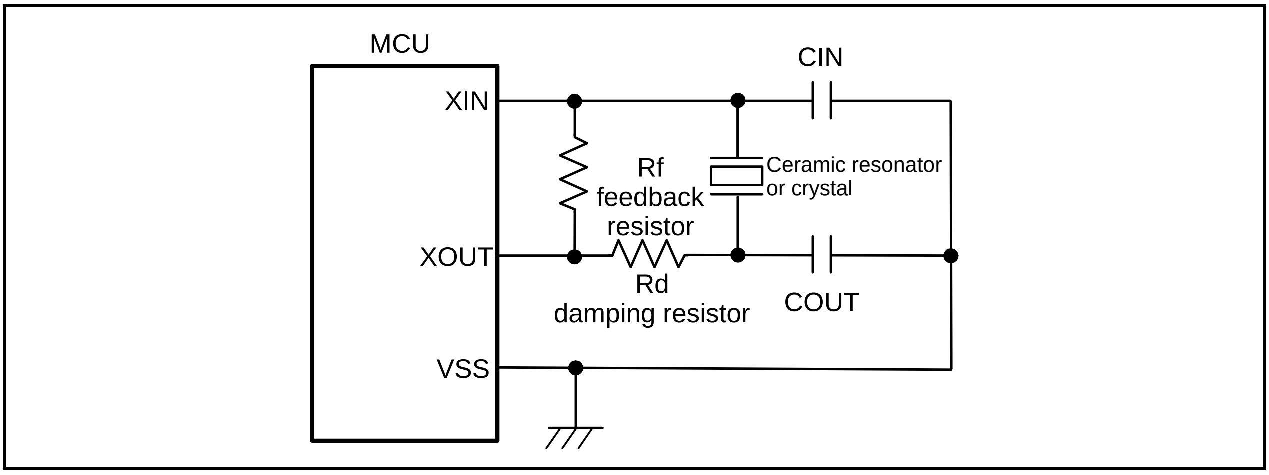


Figure 32.4 Oscillator Example

32.5.2 Noise Countermeasure

32.5.2.1 Clock I/O Pin Wiring

- Connect the shortest possible wiring to the clock I/O pin.
- Connect (a) the capacitor's ground lead connected to the crystal/ceramic resonator, and (b) the MCU's VSS pin, with the shortest possible wiring (maximum 20 mm).

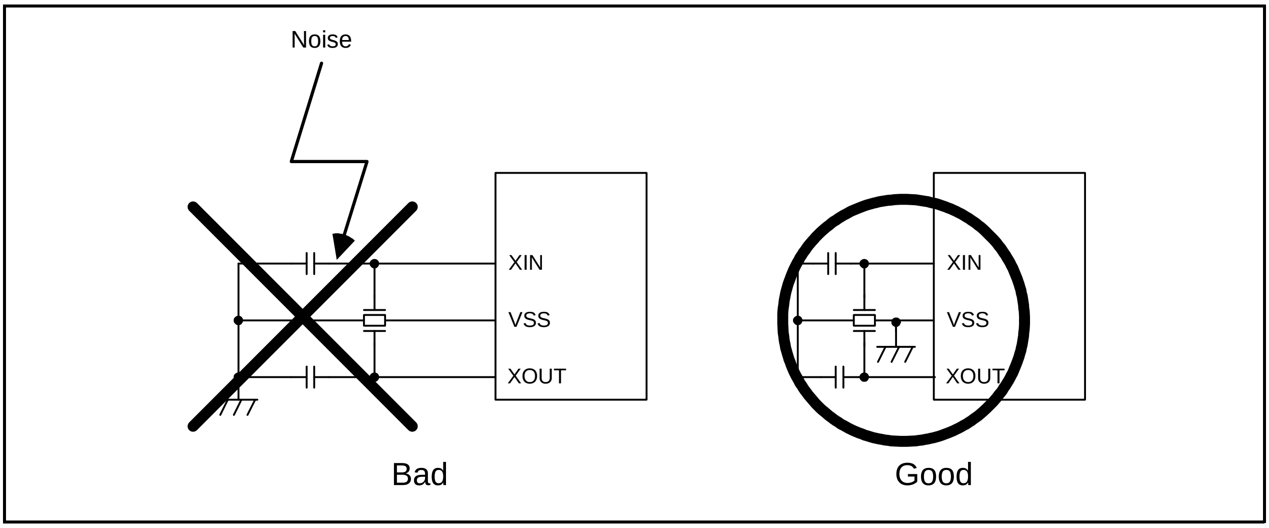


Figure 32.5 Clock I/O Pin Wiring

Reason:
When noise enters the clock I/O pin, the clock waveform becomes unstable, which causes an error in operation or a program runaway. Also, if a potential difference attributed to the noise occurs between the VSS level of the MCU and the VSS level of the crystal/ceramic resonator, an accurate clock is not input to the MCU.

32.5.2.2 Large Current Signal Line

For large currents that exceed the MCU's current range, wire the signal lines as far away from the MCU as possible (especially the crystal/ceramic resonator).

Reason:
In the system using the MCU, there are signal lines for controlling motors, LEDs, and thermal heads. When a large current flows through these signal lines, noise is generated due to mutual inductance.

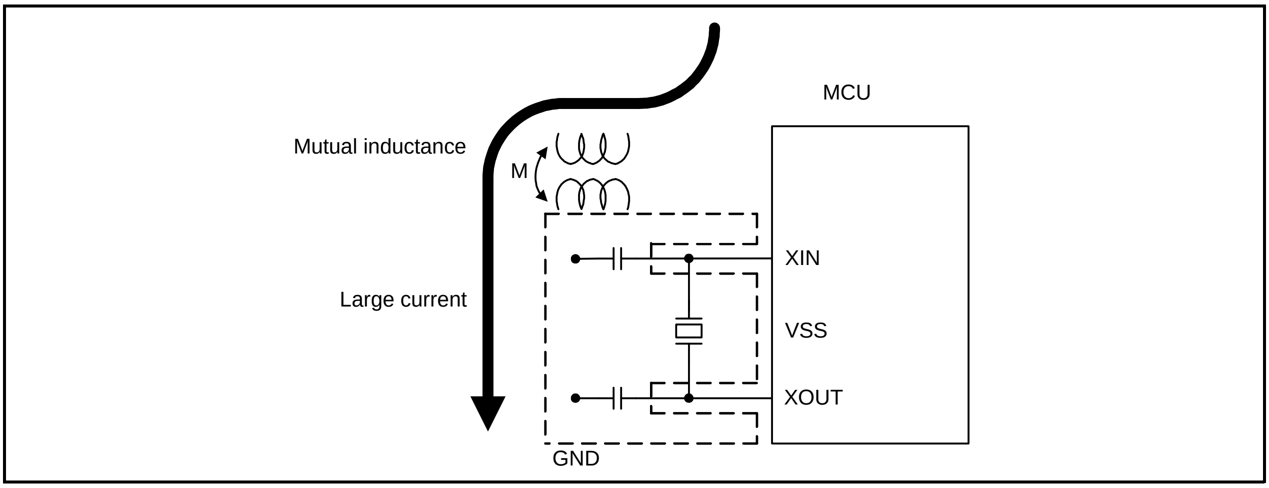


Figure 32.6 Large Current Signal Line Wiring

32.5.2.3 Signal Line Whose Level Changes at a High-Speed

For a signal line whose level changes at a high-speed, wire it as far away from the crystal/ceramic resonator and its wiring pattern as possible. Do not wire it across or extend it parallel to a clock-related signal line or other signal lines which are sensitive to noise.

Reason:
A signal whose level changes at a high-speed (such as the signal from the TAiOUT pin) affects other signal lines due to the level change at rising or falling edges. Specifically, when the signal line crosses the clock-related signal line, the clock waveform becomes unstable, which causes an error in operation or a program runaway.

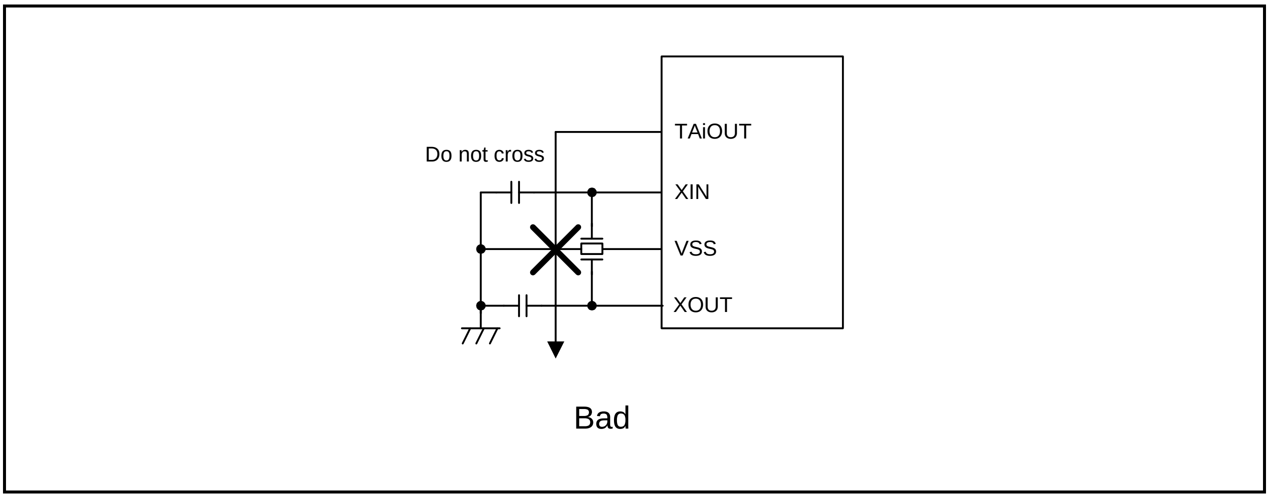


Figure 32.7 Wiring of Signal Line Whose Level Changes at High-Speed

32.5.3 CPU Clock

(Technical update number: TN-M16C-109-0309)
When an external clock is input from the XIN pin and the main clock is used as the CPU clock, do not stop the external clock.

32.5.4 Oscillator Stop/Restart Detect Function

- In the following cases, set the CM20 bit to 0 (oscillator stop/restart detect function disabled), and then change the setting of each bit.
    - When the CM05 bit is set to 1 (main clock stopped)
    - When the CM10 bit is set to 1 (stop mode)
- To enter wait mode while using the oscillator stop/restart detect function, set the CM02 bit to 0 (peripheral function clock f1 not turned off during wait mode).
- This function cannot be used if the main clock frequency is 2 MHz or lower. In that case, set the CM20 bit to 0 (oscillator stop/restart detect function disabled).
- While the CM27 bit is 1 (oscillation stop/restart detect interrupt), when the FRA01 bit is 1 (40 MHz on-chip oscillator selected), set the FRA00 bit to 1 (40 MHz on-chip oscillator on). (Do not set the FRA00 bit to 0 while FRA01 bit is 1, and vice versa.)

32.5.5 PLL Frequency Synthesizer

To use the PLL frequency synthesizer, stabilize the supply voltage within the acceptable range of power supply ripple.

Table 32.4 Acceptable Range of Power Supply Ripple

Symbol	Parameter		Standard			Unit
			Min.	Typ.	Max.	
$f_{(ripple)}$	Power supply ripple allowable frequency (VCC1)				10	kHz
$V_{P-P(ripple)}$	Power supply ripple allowable amplitude voltage	(VCC1 = 5 V)			0.5	V
		(VCC1 = 3 V)			0.3	V
$V_{CC(\|\Delta V/\Delta T\|)}$	Power supply ripple rising/falling gradient	(VCC1 = 5 V)			0.3	V/ms
		(VCC1 = 3 V)			0.3	V/ms

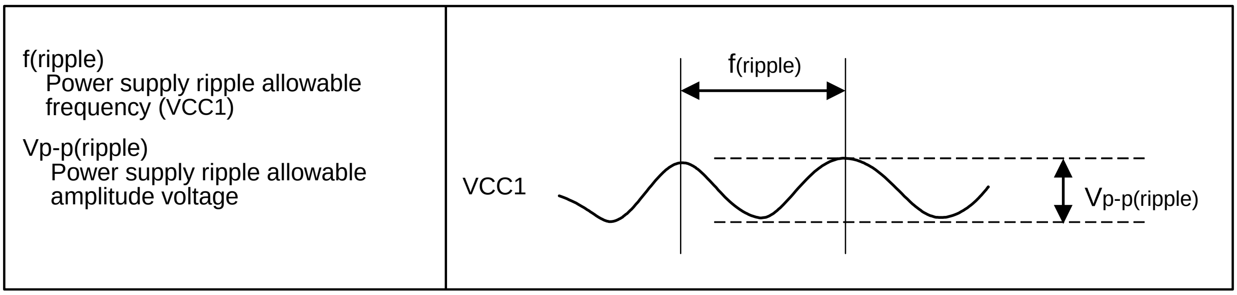

f(ripple)
Power supply ripple allowable frequency (VCC1)
Vp-p(ripple)
Power supply ripple allowable amplitude voltage
f(ripple)
VCC1
Vp-p(ripple)

Figure 32.8 Voltage Fluctuation Timing

32.6 Notes on Power Control

32.6.1 CPU Clock

When switching the CPU clock source, wait until oscillation of the switched clock source is stable. After exiting stop mode, wait until oscillation stabilizes before changing the division.

32.6.2 Wait Mode

- Insert four or more NOP instructions following the WAIT instruction. When entering wait mode, because the instruction queue prefetches instructions that follow the WAIT instruction, prefetched instructions are sometimes executed prior to the interrupt routine used to exit wait mode. As shown below, when the instruction to set the I flag to 1 is allocated just before the WAIT instruction, interrupt requests are not accepted before the WAIT instruction is executed.

  The following is an example program for entering wait mode:

```
Program Example:  FSET   I        ;
                  WAIT            ; Enter wait mode
                  NOP             ; Insert at least four NOP instructions
                  NOP
                  NOP
                  NOP
```

- Do not enter wait mode from PLL operating mode. To enter wait mode from PLL operating mode, first enter medium-speed mode, then set the PLC07 bit to 0 (PLL off).
- Do not enter wait mode from low current consumption read mode. To enter wait mode from low current consumption read mode, set the FMR23 bit in the FMR2 register to 0 (low current consumption read mode disabled).
- Do not enter wait mode from CPU rewrite mode. To enter wait mode from CPU rewrite mode, first set the FMR01 bit in the FMR0 register to 0 (CPU rewrite mode disabled), then disable the DMA transfer.
- Set the PLC07 bit in the PLC0 register to 0 (PLL off). When the PLC07 bit is 1 (PLL on), current consumption cannot be reduced even in wait mode.

32.6.3 Stop Mode

- When exiting stop mode by a hardware reset, drive the $\overline{\text{RESET}}$ pin low for 20 fOCO-S cycles or more.
- Set the MR0 bit in the TAiMR register (i = 0 to 4) to 0 (pulse not output) when using timer A to exit stop mode.
- When entering stop mode, insert a JMP.B instruction immediately after executing an instruction that sets the CM10 bit in the CM1 register to 1 (stop mode), and then insert at least four NOP instructions. When entering stop mode, the instruction queue reads ahead the instructions following the instruction which sets the CM10 bit to 1. Thus, some of the instructions may be executed before the MCU enters stop mode or before the interrupt routine for returning from stop mode. As shown below, when the instruction to set the I flag to 1 is allocated just before the instruction to set the CM10 bit to 1, interrupt requests are not accepted before entering stop mode.

The following is an example program for entering stop mode:

```
Program Example:   FSET     I
                   BSET     0, CM1   ;  Enter stop mode
                   JMP.B    L2       ;  Insert a JMP.B instruction
          L2:
                   NOP               ;  At least four NOP instructions
                   NOP
                   NOP
                   NOP
```

- Do not enter stop mode from PLL operating mode. To enter stop mode from PLL operating mode, first enter medium-speed mode, then set the PLC07 bit to 0 (PLL off).
- Do not enter stop mode from low current consumption read mode. To enter stop mode from low current consumption read mode, set the FMR23 bit in the FMR2 register to 0 (low current consumption read mode disabled).
- Do not enter stop mode from CPU rewrite mode. To enter stop mode from CPU rewrite mode, first set the FMR01 bit in the FMR0 register to 0 (CPU rewrite mode disabled), then disable the DMA transfer.
- Do not enter stop mode when the oscillator stop/restart detect function is enabled. To enter stop mode, set the CM20 bit in the CM2 register to 0 (oscillator stop/restart detect function disabled).
- Do not enter stop mode when the FMR01 bit is 1 (CPU rewrite mode enabled), and do not enter stop mode when the flash memory is stopped (bits FMR01 and FMSTP are 1).

32.6.4 Low Current Consumption Read Mode

- Enter low current consumption read mode through slow read mode (see Figure 9.5 “Setting and Canceling Low Current Consumption Read Mode” for details).
- When the FMR23 bit in the FMR2 register is 1 (low current consumption read mode enabled), do not set the FMSTP bit to 1 (flash memory stopped). Also, when the FMSTP bit is 1, do not set the FMR23 bit to 1.
- When the FMR01 bit in the FMR0 register to 1 (CPU rewrite mode enabled), do not set the FMR23 bit in the FMR2 register to 1 (low current consumption read mode enable).

32.6.5 Slow Read Mode

- When the FMR01 bit in the FMR0 register to 1 (CPU rewrite mode enabled), do not set the FMR22 bit in the FMR2 register to 1 (slow read mode enabled).

32.7 Notes on Bus

32.7.1 Reading Data Flash

When 2.7 V ≤ VCC1 ≤ 3.0 V and f(BCLK) ≥ 16 MHz, or when 3.0 V < VCC1 ≤ 5.5 V and f(BCLK) ≥ 20 MHz, one wait must be inserted to read the data flash. Use the PM17 bit or the FMR17 bit to insert one wait.

32.7.2 External Bus

When a hardware reset, power-on reset, or voltage monitor 0 reset is performed with a high-level input on the CNVSS pin, the internal ROM cannot be read.

32.7.3 External Access Immediately after Writing to the SFRs

When accessing an external device after writing to the SFRs, the write signal and $\overline{\text{CSi}}$ signal switch simultaneously. Thus, adjust the capacity of each signal so as not to delay the write signal.

32.7.4 Wait and $\overline{\text{RDY}}$

Do not use the $\overline{\text{RDY}}$ function when bits CSEi1W to CSEi0W in the CSE register are 11b.

32.7.5 $\overline{\text{HOLD}}$

$\overline{\text{HOLD}}$ input is unavailable. Connect the $\overline{\text{HOLD}}$ pin to VCC2 via a resistor (pull-up).

32.8 Notes on Programmable I/O Ports

Note

For the 100-pin package, do not access the addresses of registers P11 to P14, PD11 to PD14, or PUR3.

32.8.1 Influence of $\overline{\text{SD}}$

When a low-level signal is applied to the $\overline{\text{SD}}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{\text{SD}}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$/TA1IN/$\overline{\text{V}}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{\text{W}}$, P8_0/TA4OUT/RXD5/SCL5/U, P8_1/TA4IN/$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$/$\overline{\text{U}}$

32.8.2 Influence of SI/O3 and SI/O4

When the SMi2 bit in the SiC register is set to 1 (SOUTi output disabled), the target pin becomes high-impedance regardless of which pin function being used.

32.8.3 100-Pin Package

Do not access the addresses assigned to registers P11 to P14, PD11 to PD14, and the PUR3 register.

32.9 Notes on Interrupts

32.9.1 Reading Address 00000h

Do not read address 00000h by a program. When a maskable interrupt request is accepted, the CPU reads interrupt information (interrupt number and interrupt request priority level) from address 00000h during the interrupt sequence. At this time, the IR bit of the accepted interrupt is cleared to 0 (interrupt not requested).
If address 00000h is read by a program, the IR bit for the interrupt which has the highest priority among the enabled interrupts becomes 0. This may cause problems such as interrupts being canceled or an unexpected interrupt request being generated.

32.9.2 SP Setting

Set a value in the SP (USP, ISP) before accepting an interrupt. The SP (USP, ISP) is set to 0000h after reset. Therefore, if an interrupt is accepted before setting a value in the SP (USP, ISP), the program may go out of control.
Set a value in the ISP at the beginning of the program. For the first instruction after reset only, all interrupts are disabled.

32.9.3 $\overline{\text{NMI}}$ Interrupt

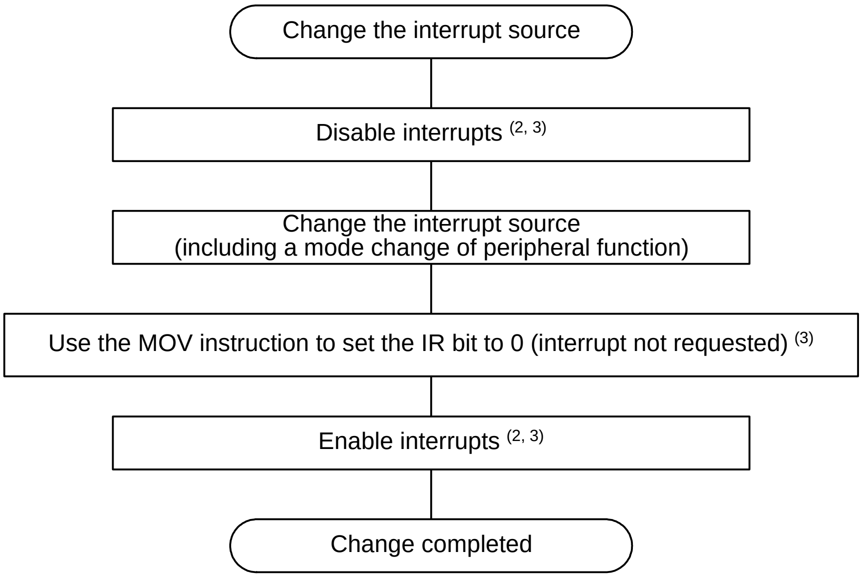
- When not using the $\overline{\text{NMI}}$ interrupt, set the PM24 bit in the PM2 register to 0 ($\overline{\text{NMI}}$ interrupt disabled).
- The $\overline{\text{NMI}}$ interrupt is disabled after reset. The $\overline{\text{NMI}}$ interrupt is enabled by setting the PM24 bit in the PM2 register to 1. Set the PM24 bit to 1 when a high-level signal is applied to the $\overline{\text{NMI}}$ pin. When the PM24 bit is set to 1 while a low-level signal is applied, an $\overline{\text{NMI}}$ interrupt is generated. Once the $\overline{\text{NMI}}$ interrupt is enabled, it cannot be disabled until the MCU is reset.
- The MCU cannot enter stop mode while the PM24 bit is 1 ($\overline{\text{NMI}}$ interrupt enabled) and input on the $\overline{\text{NMI}}$ pin is low. When input on the $\overline{\text{NMI}}$ pin is low, the CM10 bit in the CM1 register is fixed to 0.
- Do not enter wait mode while the PM24 bit is 1 ($\overline{\text{NMI}}$ interrupt enabled) and a low signal is input to the $\overline{\text{NMI}}$ pin. When the $\overline{\text{NMI}}$ pin is driven low, the CPU clock remains active even though the CPU stops, and therefore, the current consumption of the chip does not drop. In this case, the normal condition is restored by the next interrupt generation.
- Set the low- and high-level durations of the input signal to the $\overline{\text{NMI}}$ pin to 2 CPU clock cycles + 300 ns or more.

32.9.4 Changing an Interrupt Source

When the interrupt source is changed, the IR bit in the interrupt control register may become 1 (interrupt requested). To use an interrupt, change the interrupt source, and then set the IR bit to 0 (interrupt not requested).

In this section, the changing of an interrupt source refers to all elements used in changing the interrupt source, polarity, and timing assigned to each software interrupt number. Therefore, if a mode change of any peripheral function involves changing the source, polarity or timing of an interrupt, be sure to clear the IR bit for that interrupt to 0 (interrupt not requested) after making such changes. Refer to the descriptions of the individual peripheral functions for details of the interrupts.

Figure 32.9 shows the Procedure for Changing the Interrupt Generate Source.


Change the interrupt source
Disable interrupts (2, 3)
Change the interrupt source (including a mode change of peripheral function)
Use the MOV instruction to set the IR bit to 0 (interrupt not requested) (3)
Enable interrupts (2, 3)
Change completed

IR bit: A bit in the interrupt control register

Notes:

1. Execute the above settings individually. Do not use one instruction to execute two or more settings simultaneously.
2. Use the I flag for the $\overline{\text{INTi}}$ interrupt (i = 0 to 7).
   For the interrupts from peripheral functions other than the $\overline{\text{INTi}}$ interrupt, disable the peripheral function that is the source of the interrupt so as not to generate an interrupt request before changing the interrupt source. In this case, if the maskable interrupts can all be disabled without causing a problem, use the I flag. Otherwise, use corresponding bits ILVL2 to ILVL0 in the interrupt control register whose interrupt source is to be changed.
3. Refer to 32.9.5 “Rewriting the Interrupt Control Register” for details about the instructions to be used and the notes to be taken for instruction execution.

Figure 32.9 Procedure for Changing the Interrupt Generate Source

32.9.5 Rewriting the Interrupt Control Register

To modify the interrupt control register, follow either of the procedures below:

- Modify in places where no interrupt requests corresponding to the interrupt control register may occur.
- If an interrupt request can be generated, disable that interrupt and then rewrite the interrupt control register.

When using the I flag to disable an interrupt, set the I flag as shown in the sample program code below. (Refer to 32.9.6 “Instruction to Rewrite the Interrupt Control Register” for rewriting the interrupt control registers using the sample program code.)

Examples 1 through 3 show how to prevent the I flag from becoming 1 (interrupt enabled) before the contents of the interrupt control register is rewritten, owing to the effects of the internal bus and the instruction queue buffer.

Example 1: Using the NOP instruction to pause the program until the interrupt control register is modified

```
INT_SWITCH1:
    FCLR      I                 ; Disable interrupts.
    AND.B     #00H, 0055H       ; Set the TA0IC register to 00h.
    NOP                         ;
    NOP
    FSET      I                 ; Enable interrupts.
```

Example 2: Using a dummy read to delay the FSET instruction

```
INT_SWITCH2:
    FCLR      I                 ; Disable interrupts.
    AND.B     #00H, 0055H       ; Set the TA0IC register to 00h.
    MOV.W     MEM, R0           ; Dummy read.
    FSET      I                 ; Enable interrupts.
```

Example 3: Using the POPC instruction to change the I flag

```
INT_SWITCH3:
    PUSHC     FLG
    FCLR      I                 ; Disable interrupts.
    AND.B     #00H, 0055H       ; Set the TA0IC register to 00h.
    POPC      FLG               ; Enable interrupts.
```

32.9.6 Instruction to Rewrite the Interrupt Control Register

- Do not use the BTSTC and BTSTS instructions to rewrite the interrupt control registers.
- Use the AND, OR, BCLR, BSET, or MOV instruction to rewrite interrupt control registers.
  When an interrupt request is generated for the register being rewritten while executing an AND, OR, BCLR, or BSET instruction, the IR bit becomes 1 (interrupt requested) and remains 1.

32.9.7 $\overline{\text{INT}}$ Interrupt

- Either a low level of at least tw(INL) width or a high level of at least tw(INH) width is necessary for the signal input to pins $\overline{\text{INT0}}$ through $\overline{\text{INT7}}$, regardless of the CPU operation clock.
- If the POL bit in registers INT0IC to INT7IC, bits IFSR7 to IFSR0 in the IFSR register, or bits IFSR31 to IFSR30 in the IFSR3A register are changed, the IR bit may inadvertently become 1 (interrupt requested). Be sure to set the IR bit to 0 (interrupt not requested) after changing any of these register bits.

32.10 Notes on the Watchdog Timer

After the watchdog timer interrupt is generated, use the WDTR register to refresh the watchdog timer counter.

32.11 Notes on DMAC

32.11.1 Write to the DMAE Bit in the DMiCON Register (i = 0 to 3)

(Technical update number: TN-M16C-92-0306)
When both of the following conditions are met, follow steps (1) and (2) below.

Conditions

- Write 1 (DMAi is in active state) to the DMAE bit when it is 1.
- A DMA request may be generated simultaneously when writing to the DMAE bit.

Steps

(1) Set bits DMAE and DMAS in the DMiCON register to 1 simultaneously. (1)

(2) Make sure the DMAi circuit is in an initialized state (2) by a program.
If DMAi is not in an initialized state, repeat these two steps.

Notes:

1.The DMAS bit does not change even if set to 1. However, it becomes 0 when set to 0 (DMA not requested). Therefore, when writing to the DMiCON register to set the DMAE bit to 1, set the value to be written to the DMAS bit to 1 to retain its state immediately before writing.
Similarly, when writing to the DMAE bit with a read-modify-write instruction, set the DMAS bit to 1 to retain the DMA request that was generated while executing the instruction.

2.Read the TCRi register to verify whether DMAi is in an initialized state.
If the read value is equal to the value that was written to the TCRi register before the DMA transfer started, DMAi is in an initialized state. When a DMA request is generated after writing to the DMAE bit, the read value is a value written to the TCRi register minus 1. If the read value is a value in the middle of a transfer, DMAi is not in an initialized state.

32.11.2 Changing the DMA Request Source

When the DMS bit or any of bits from DSEL4 to DSEL0 in the DMiSL register is changed, the DMAS bit in the DMiCON sometimes becomes 1 (DMA requested). Set the DMAS bit to 0 (DMA not requested) after changing the DMS bit or bits DSEL4 to DSEL0 in the DMiSL register.

32.12 Notes on Timer A

32.12.1 Common Notes on Multiple Modes

32.12.1.1 Register Setting

The timer stops after reset. Set the mode, count source, counter value, etc., using registers TAiMR, TAi, TAi1, UDF, TRGSR, PWMFS, TACS0 to TACS2, TAPOFS, TCKDIVC0, PCLKR, and bits TAZIE, TA0TGL, and TA0TGH in the ONSF register before setting the TAiS bit in the TABSR register to 1 (count started) (i = 0 to 4).

Set the TCDIV00 bit in the TCKDIVC0 register before setting other registers associated with timer A. After changing the TCDIV00 bit, set other registers associated with timer A again.

Always make sure registers TAiMR, UDF, TRGSR, PWMFS, TACS0 to TACS2, TAPOFS, TCKDIVC0, PCLKR, and bits TAZIE, TA0TGL, TA0TGH in the ONSF register are modified while the TAiS bit is 0 (count stopped), regardless of whether after reset or not.

32.12.1.2 Event or Trigger

When bits TAiTGH to TAiTGL in the registers ONSF or TRGSR are 01b, 10b, or 11b, an event or a trigger occurs when an interrupt request of the selected timer is generated. An event or trigger occurs while an interrupt is disabled because an interrupt request signal is generated regardless of the I flag, IPL, or interrupt control registers.

For some modes of the timers selected using bits TAiTGH to TAiTGL, an interrupt request is generated by a source other than overflow or underflow.

For example, when using pulse-period measurement mode or pulse-width measurement mode in timer B2, an interrupt request is generated at an active edge of the measurement pulse. For details, refer to the “Interrupt request generation timing” in each mode’s specification table.

32.12.1.3 Influence of $\overline{\text{SD}}$

When a low-level signal is applied to the $\overline{\text{SD}}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{\text{SD}}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$/TA1IN/$\overline{\text{V}}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{\text{W}}$, P8_0/TA4OUT/RXD5/SCL5/U, P8_1/TA4IN/$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$/$\overline{\text{U}}$

32.12.1.4 Main Clock

When using the main clock for the timer A and timer B count source (PCKSTP17 bit in the PCLKSTP1 register is 1), adhere the following:

- Set the PCKSTP11 bit in the PCLKSTP1 register to 0 (f1 supply enabled).
- The main clock can be used in PLL operating mode, high-speed mode, medium-speed mode, or wait mode. Do not use the main clock for the timer A and timer B count source in other modes.
- When the PCKSTP17 bit is set to 1 and timer A or timer B operates in wait mode, set the CM02 bit to 0 (peripheral function clock f1 does not stop in wait mode).

32.12.2 Timer A (Timer Mode)

32.12.2.1 Reading the Timer

The counter value can be read from the TAi register at any time while counting. However, if the counter is read at the same time as it is reloaded, the read value is FFFFh. Also, if the counter is read before it starts counting, or after a value is set in the TAi register while not counting, the set value is read.

32.12.3 Timer A (Event Counter Mode)

32.12.3.1 Reading the Timer

While counting, the counter value can be read at any time by reading the TAi register. However, while reloading, FFFFh can be read in underflow, and 0000h in overflow. When the counter is read before it starts counting and after a value is set in the TAi register while not counting, the set value is read.

32.12.4 Timer A (One-Shot Timer Mode)

32.12.4.1 Stop While Counting

When setting the TAiS bit to 0 (count stopped), the following occurs:

- The counter stops counting and reload register values are reloaded.
- The TAiOUT pin outputs a low-level signal when the POFSi bit in the TAPOFS register is 0, and outputs a high-level signal when it is 1.
- After one cycle of the CPU clock, the IR bit in the TAiIC register becomes 1 (interrupt requested).

32.12.4.2 Delay between the Trigger Input and Timer Output

As the one-shot timer output is synchronized with an internally generated count source, when an external trigger is selected, a maximum 1.5 cycle delay of the count source occurs between the trigger input to the TAiIN pin and timer output.

32.12.4.3 Changing Operating Modes

The IR bit becomes 1 when the timer operating mode is set by any of the following:

- Selecting one-shot timer mode after reset
- Changing the operating mode from timer mode to one-shot timer mode
- Changing the operating mode from event counter mode to one-shot timer mode

To use the timer Ai interrupt (IR bit), set the IR bit to 0 after the changes listed above are made.

32.12.4.4 Retrigger

When a trigger occurs while counting, the counter reloads the reload register to continue counting after generating a retrigger and decrementing once. To generate a trigger while counting, generate a retrigger after at least one cycle of the timer count source has elapsed following the previous trigger.

When an external trigger is generated, do not generate a retrigger for 300 ns before the count value becomes 0000h. The one-shot timer may stop counting.

32.12.5 Timer A (Pulse Width Modulation Mode)

32.12.5.1 Changing Operating Modes

The IR bit becomes 1 when setting a timer operating mode with any of the following:

- Selecting PWM mode or programmable output mode after reset
- Changing the operating mode from timer mode to PWM mode or programmable output mode
- Changing the operating mode from event counter mode to PWM mode or programmable output mode

To use the timer Ai interrupt (IR bit), set the IR bit to 0 by a program after the changes listed above are made.

32.12.5.2 Stop While Counting

When setting the TAiS bit to 0 (count stopped) during PWM pulse output, the following occur:
When the POFSi bit in the TAPOFS register is 0:

- Counting stops
- When the TAiOUT pin is high, the output level goes low and the IR bit becomes 1.
- When the TAiOUT pin is low, both the output level and the IR bit remain unchanged.

When the POFSi bit in the TAPOFS register is 1:

- Counting stops.
- When the TAiOUT pin output is low, the output level goes high and the IR bit is set to 1.
- When the TAiOUT pin output is high, both the output level and the IR bit remain unchanged.

32.12.6 Timer A (Programmable Output Mode)

32.12.6.1 Changing the Operating Mode

The IR bit becomes 1 when setting a timer operating mode with any of the following:

- Selecting PWM mode or programmable output mode after reset
- Changing the operating mode from timer mode to PWM mode or programmable output mode
- Changing the operating mode from event counter mode to PWM mode or programmable output mode

To use the timer Ai interrupt (IR bit), set the IR bit to 0 by a program after the changes listed above are made.

32.12.6.2 Stop While Counting

When setting the TAiS bit to 0 (count stopped) during pulse output, the following occur:
When the POFSi bit in the TAPOFS register is 0:

- Counting stops.
- When the TAiOUT pin is high, the output level goes low.
- When the TAiOUT pin is low, the output level remains unchanged.
- The IR bit remains unchanged.

When the POFSi bit in the TAPOFS register is 1:

- Counting stops
- When the TAiOUT pin output is low, the output level goes high.
- When the TAiOUT pin output is high, the output level remains unchanged.
- The IR bit remains unchanged.

32.13 Notes on Timer B

32.13.1 Common Notes on Multiple Modes

32.13.1.1 Register Setting

The timer is stopped after reset. Set the mode, count source, etc., using registers TBiMR, TBCS0 to TBCS3, TBi, TCKDIVC0, PCLKR, PPWFS1, and PPWFS2 before setting the TBiS bit in the TABSR or TBSR register to 1 (count started) (i = 0 to 5).

Rewrite registers TBiMR, TBCS0 to TBCS3, TCKDIVC0, PCLKR, PPWFS1, and PPWFS2 while the TBiS bit is 0 (count stopped), regardless of whether after reset or not.

32.13.1.2 Main Clock

When using the main clock for the timer A and timer B count source (PCKSTP17 bit in the PCLKSTP1 register is 1), adhere the following:

- Set the PCKSTP11 bit in the PCLKSTP1 register to 0 (f1 supply enabled).
- The main clock can be used in PLL operating mode, high-speed mode, medium-speed mode, or wait mode. Do not use the main clock for the timer A and timer B count source in other modes.
- When the PCKSTP17 bit is set to 1 and timer A or timer B operates in wait mode, set the CM02 bit to 0 (peripheral function clock f1 does not stop in wait mode).

32.13.2 Timer B (Timer Mode)

32.13.2.1 Reading the Timer

While counting, the counter value can be read at any time by reading the TBi register. However, FFFFh is read while reloading. When the counter is read before it starts counting and after a value is set in the TBi register while not counting, the set value is read.

32.13.3 Timer B (Event Counter Mode)

32.13.3.1 Reading the Timer

While counting, the counter value can be read at any time by reading the TBi register. However, FFFFh is read while reloading. When the counter is read before it starts counting and after a value is set in the TBi register while not counting, the set value is read.

32.13.3.2 Event

When the TCK1 bit in the TBiMR register is 1, an event occurs when an interrupt request of the selected timer is generated. An event or trigger occurs while an interrupt is disabled because an interrupt request signal is generated regardless of the I flag, IPL, or interrupt control registers.

When the timer selected by the TCK1 bit uses pulse-period measurement mode or pulse-width measurement mode, an interrupt request is generated at an active edge of the measurement pulse.

32.13.4 Timer B (Pulse Period/Pulse Width Measurement Modes)

32.13.4.1 MR3 Bit in the TBiMR Register

To clear the MR3 bit to 0 by writing to the TBiMR register while the TBiS bit is 1 (count started), be sure to set the same value as previously set to bits TMOD0, TMOD1, MR0, MR1, TCK0, and TCK1, and set bit 4 to 0.

32.13.4.2 Interrupts

The IR bit in the TBiIC register becomes 1 (interrupt requested) when an active edge of a measurement pulse is input, or timer Bi overflows (i = 0 to 5). The source of an interrupt request can be determined by setting the MR3 bit in the TBiMR register within the interrupt routine.
Use the IR bit in the TBiIC register to detect overflows only. Use the MR3 bit only to determine the interrupt source.

32.13.4.3 Event or Trigger

When timer Bi in pulse-period measurement mode or pulse-width measurement mode is used as an event or trigger for timer A or timer B other than timer Bi, an event or trigger occurs at both the overflow and active edge of the measurement pulse.

32.13.4.4 Operations between Count Start and the First Measurement

When a count is started and the first active edge is input, an undefined value is transferred to the reload register. At this time, a timer Bi interrupt request is not generated.

The value of the counter is undefined after reset. If the count is started in this state, the MR3 bit may become 1 and a timer Bi interrupt request may be generated after the count starts before an active edge is input. When a value is set in the TBi register while the TBiS bit is 0 (count stopped), the same value is written to the counter.

32.13.4.5 Pulse Period Measurement Mode

When an active edge and overflow are generated simultaneously, input is not recognized at the active edge because an interrupt request is generated only once. Use this mode so an overflow is not generated, or use pulse width measurement mode.

32.13.4.6 Pulse Width Measurement Mode

In pulse width measurement, pulse widths are measured successively. Check whether the measurement result is a high-level width or a low-level width in the user program.
When an interrupt request is generated, read the TBiIN pin level in the interrupt routine, and check whether it is the edge of an input pulse or overflow. The TBiIN pin level can be read from bits in the register of ports sharing a pin.

32.14 Notes on Three-Phase Motor Control Timer Function

32.14.1 Timer A and Timer B

Refer to 17.5 “Notes on Timer A” and 18.5 “Notes on Timer B”.

32.14.2 Influence of $\overline{\text{SD}}$

When a low-level signal is applied to the $\overline{\text{SD}}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{\text{SD}}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$/TA1IN/$\overline{\text{V}}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{\text{W}}$, P8_0/TA4OUT/RXD5/SCL5/U, P8_1/TA4IN/$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$/$\overline{\text{U}}$

32.15 Notes on Real-Time Clock

32.15.1 Starting and Stopping the Count

The real-time clock uses the TSTART bit for instructing the count to start or stop, and the TCSTF bit which indicates count started or stopped. Bits TSTART and TCSTF are in the RTCCR1 register.

The real-time clock starts counting and the TCSTF bit becomes 1 (count started) when the TSTART bit is set to 1 (count started). It takes up to two cycles of the count source until the TCSTF bit becomes 1 after setting the TSTART bit to 1. During this time, do not access registers associated with the real-time clock (1) other than the TCSTF bit.

Similarly, when setting the TSTART bit to 0 (count stopped), the real-time clock stops counting and the TCSTF bit becomes 0 (count stopped). It takes up to three cycles of the count source until the TCSTF bit becomes 0 after setting the TSTART bit to 0. During this time, do not access registers associated with the real-time clock other than the TCSTF bit.

Note:

1. Registers associated with the real-time clock: RTCSEC, RTCMIN, RTCHR, RTCWK, RTCCR1, RTCCR2, RTCCSR, RTCCSEC, RTCCMIN, and RTCCHR.

32.15.2 Register Settings (Time Data, etc.)

Write to the following registers/bits when the real-time clock is stopped:

- Registers RTCSEC, RTCMIN, RTCHR, RTCWK, and RTCCR2
- Bits H12H24 and RTCPM in the RTCCR1 register
- Bits RCS0 to RCS4 in the RTCCSR register

The real-time clock is stopped when bits TSTART and TCSTF in the RTCCR1 register are 0 (real-time clock stopped).

Set the RTCCR2 register after setting the registers and bits mentioned above (immediately before the real-time clock count starts).

Figure 20.4 shows Time and Day Change Procedure (No Compare Mode or Compare Mode 1), and Figure 20.5 shows Time and Day Change Procedure (Compare Mode 2 or Compare Mode 3).

32.15.3 Register Settings (Compare Data)

Write to the following registers when the BSY bit in the RTCSEC register is 0 (not while data is updated).

- Registers RTCCSEC, RTCCMIN, and RTCCHR

32.15.4 Time Reading Procedure in Real-Time Clock Mode

In real-time clock mode, read time data bits [1] when the BSY bit in the RTCSEC register is 0 (not while data is updated).

When reading multiple registers, if data is rewritten between reading registers, an errant time will be read. To prevent this, use one of the following steps when reading:

- Using an interrupt
  In the real-time clock periodic interrupt routine, read the values necessary from the appropriate time data bits.
- Monitoring by a program 1
  Monitor the IR bit in the RTCTIC register by a program and read necessary values of time data bits after the IR bit becomes 1 (periodic interrupt requested).
- Monitoring by a program 2
  Read the time data according to Figure 32.10 “Time Data Reading”.

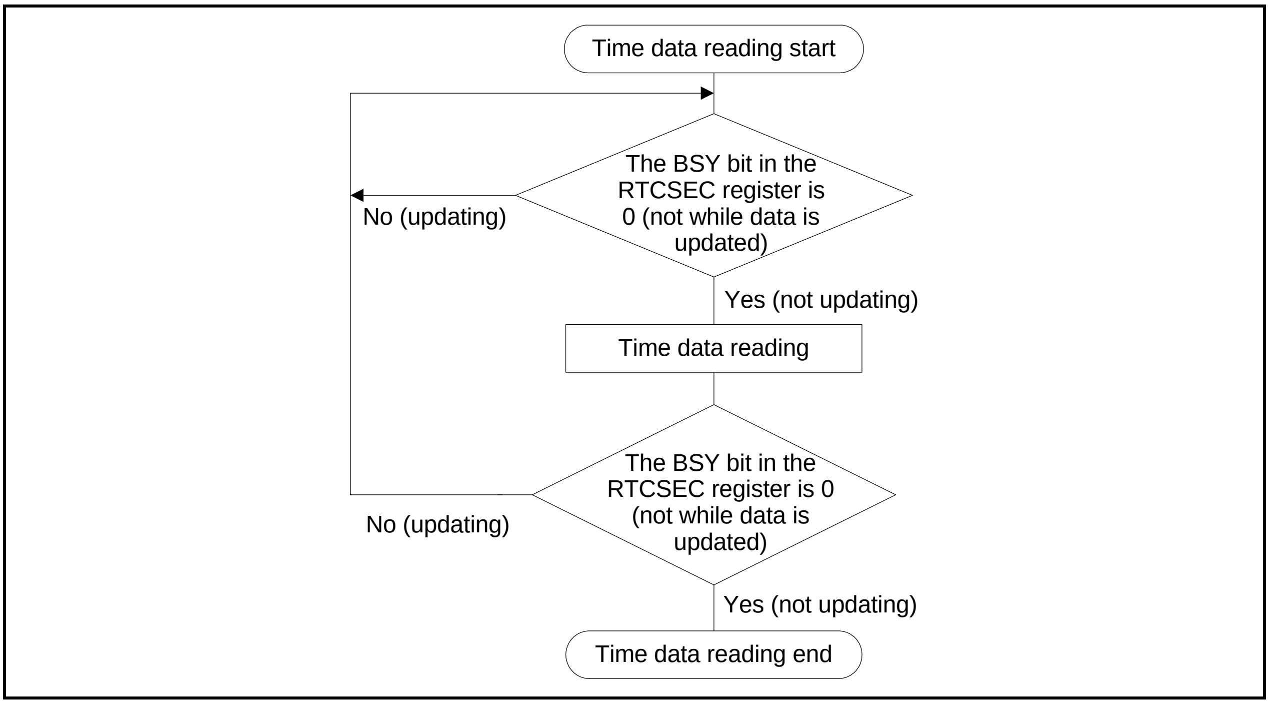

Time data reading start
The BSY bit in the RTCSEC register is 0 (not while data is updated)
No (updating)
Yes (not updating)
Time data reading
The BSY bit in the RTCSEC register is 0 (not while data is updated)
No (updating)
Yes (not updating)
Time data reading end

Figure 32.10 Time Data Reading

- Using read results if they are the same value twice
  (1) Read the values necessary from time data bits.
  (2) Read the same bit as (1) and compare the contents.
  (3) If the contents match, adopt that value as the correct value. If the contents do not match, repeat until the read contents match with the previous contents.

Also, when reading multiple registers, read them as continuously as possible.

Note:

1. Time data bits are as follows:
   Bits SC12 to SC10 and SC03 to SC00 in the RTCSEC register
   Bits MN12 to MN10 and MN03 to MN00 in the RTCMIN register
   Bits HR11 to HR10 and HR03 to HR00 in the RTCHR register
   Bits WK2 to WK0 in the RTCWK register
   The RTCPM bit in the RTCCR1 register

32.16 Notes on Remote Control Signal Receiver

32.16.1 Starting/Stopping PMCi

The EN bit in the PMCiCON0 register controls the start/stop of PMCi. The ENFLG bit in the PMCiCON2 register indicates that operation started/stopped.

The PMCi circuit starts operating by setting the EN bit to 1 (operation enabled) and the ENFLG bit becomes 1 (operating). After setting the EN bit to 1, it takes up to two cycles of the count source before the ENFLG bit becomes 1.

When the EN bit is set to 0 (operation disabled), the PMCi circuit stops operating and the ENFLG bit becomes 0 (operation stopped). After setting the EN bit to 0, it takes up to one cycle of the count source before the ENFLG bit becomes 0.

Between setting the EN bit to 1 and the ENFLG bit becoming 1, and while the ENFLG bit is 1, do not access bits in the PMCi associated registers (registers listed in Table 22.4 and Table 22.5 "Registers") except for the ENFLG bit.

32.16.2 Reading the Register

When the following registers are read while data changes, an undefined value may be read.

Flags in registers PMCiCON2 and PMCiSTS

Registers PMCiTIM, PMC0DAT0 to PMC0DAT5, and PMC0RBIT

Follow the procedures below to avoid reading an undefined value.

<u>In pattern match mode</u>

- Using an interrupt
  Set the DRINT bit in the PMCiINT register to 1 (data reception complete interrupt enabled) and read the registers within the PMCi interrupt routine.
- Monitoring by a program 1
  Set the DRINT bit in the PMCiINT register to 1 (data reception complete interrupt enabled) and monitor the IR bit in the PMCiIC register by a program. Read the registers when the IR bit becomes 1 (interrupt request is generated).
- Monitoring by a program 2
  (1) Monitor the DRFLG bit in the PMCiSTS register.
  (2) When the DRFLG bit becomes 1, monitor the DRFLG bit until it becomes 0.
  (3) Read the necessary content of the registers when the DRFLG bit becomes 0.

<u>In input capture mode</u>

- Using an interrupt
  Set the TIMINT bit in the PMCiINT register to 1 (timer measure interrupt enabled) and read the registers within the PMCi interrupt routine.
- Monitoring by a program 1
  Set the TIMINT bit in the PMCiINT register to 1 (timer measure interrupt enabled) and monitor the IR bit in the PMCiIC register by a program. Read the registers when the IR bit becomes 1 (interrupt request is generated).

If the register data may change at the same time as the register is read even with above countermeasures, read the register more than once to determine whether the read value is correct.

32.16.3 Rewriting the Register

Rewrite the registers and bits related to PMC excluding the EN bit in the PMCiCON0 register when both of the EN bit in the PMCiCON0 register and the ENFLG bit in the PMCiCON2 register are 0 (PMCi stops).

32.16.4 Combined Operation

When using combined operation, set same value to bits TYP1 to TYP0 in the PMC0CON1 register and bits TYP1 to TYP0 in the PMC1CON1 register.

32.17 Notes on Serial Interface UARTi (i = 0 to 2, 5 to 7)

32.17.1 Common Notes on Multiple Modes

32.17.1.1 Influence of $\overline{\text{SD}}$

When a low-level signal is applied to the $\overline{\text{SD}}$ pin while the IVPCR1 bit in the TB2SC register is 1 (three-phase output forcible cutoff by input on $\overline{\text{SD}}$ pin enabled), the following pins become high-impedance:
P7_2/CLK2/TA1OUT/V, P7_3/$\overline{\text{CTS2}}$/$\overline{\text{RTS2}}$/TA1IN/$\overline{\text{V}}$, P7_4/TA2OUT/W,
P7_5/TA2IN/$\overline{\text{W}}$, P8_0/TA4OUT/RXD5/SCL5/U, P8_1/TA4IN/$\overline{\text{CTS5}}$/$\overline{\text{RTS5}}$/$\overline{\text{U}}$

32.17.1.2 Register Setting

Set the OCOSEL0 or OCOSEL1 bit in the UCLKSEL0 register before setting other registers associated with UART0 to UART2 or UART5 to UART7. After changing the OCOSEL0 or OCOSEL1 bit, set other registers associated with UART0 to UART2 or UART5 to UART7 again.

32.17.1.3 CLKi Output

(Technical update number: TN-16C-A178A/E)

When using the N-channel open drain output as an output mode of the CLKi pin, use following procedure to change the pin function:

When changing the pin function from the port to CLKi.
(1) Set bits SMD2 to SMD0 in the UiMR register to a value other than 000b to select serial interface mode.
(2) Set the NODC bit in the UiSMR3 register to 1.
When changing the pin function from CLKi to the port.
(1) Set the NODC bit to 0.
(2) Set bits SMD2 to SMD0 to 000b to disable the serial interface.

32.17.2 Clock Synchronous Serial I/O Mode

32.17.2.1 Transmission/Reception

When the $\overline{\text{RTS}}$ function is used with an external clock, the $\overline{\text{RTSi}}$ pin (i = 0 to 2, 5 to 7) outputs a low-level signal, which informs the transmitting side that the MCU is ready for a receive operation. The $\overline{\text{RTSi}}$ pin outputs a high-level signal when a receive operation starts. Therefore, transmit timing and receive timing can be synchronized by connecting the $\overline{\text{RTSi}}$ pin to the $\overline{\text{CTSi}}$ pin on the transmitting side. The $\overline{\text{RTS}}$ function is disabled when an internal clock is selected.

32.17.2.2 Transmission

If the transmission is started while an external clock is selected and the TXEPT bit in the UiC0 register (i = 0 to 2, 5 to 7) is 1 (no data present in transmit register), meet the last requirement at either of the following timings:

External clock level:
- The CKPOL bit in the UiC0 register is 0 (transmit data is output at the falling edge of transmit/receive clock and receive data is input at the rising edge) and the external clock is high.
- The CKPOL bit is 1 (transmit data is output at the rising edge of transmit/receive clock and receive data is input at the falling edge) and the external clock is low.

Requirements to start transmission (in no particular order):
- The TE bit in the UiC1 register is 1 (transmission enabled).
- The TI bit in the UiC1 register is 0 (data present in the UiTB register).
- When the $\overline{\text{CTS}}$ function is selected, input on the $\overline{\text{CTSi}}$ pin is low.

32.17.2.3 Reception

In clock synchronous serial I/O mode, a shift clock is generated by activating a transmitter. Set the UARTi-associated registers for a transmit operation even if the MCU is used for a receive operations only. Dummy data is output from the TXDi pin (i = 0 to 2, 5 to 7) while receiving.

When an internal clock is selected, a shift clock is generated by setting the TE bit in the UiC1 register to 1 (transmission enabled) and placing dummy data in the UiTB register. When an external clock is selected, set the TE bit to 1 (transmission enabled), set dummy data in the UiTB register, and input an external clock to the CLKi pin to generate a shift clock.

If data is received consecutively, an overrun error occurs when the RI bit in the UiC1 register is 1 (data present in the UiRB register) and the next receive data is received in the UARTi receive register. Then, the OER bit in the UiRB register becomes 1 (overrun error occurred). At this time, the UiRB register is undefined. When an overrun error occurs, program the transmitting and receiving sides to retransmit the previous data. If an overrun error occurs again, the IR bit in the SiRIC register remains unchanged.

To receive data consecutively, set dummy data in the low-order byte in the UiTB register for each receive operation.

If the reception is started while an external clock is selected and the TXEPT bit in the UiC0 register is 1 (no data present in transmit register), meet the last requirement at either of the timings below.

External clock level:

- The CKPOL bit in the UiC0 register is 0 (transmit data is output at the falling edge of transmit/receive clock and receive data is input at the rising edge) and the external clock is high.
- The CKPOL bit is 1 (transmit data is output at the rising edge of transmit/receive clock and receive data is input at the falling edge) and the external clock is low.

Requirements to start reception (in no particular order):

- The RE bit in the UiC1 register is 1 (reception enabled).
- The TE bit in the UiC1 register is 1 (transmission enabled).
- The TI bit in the UiC1 register is 0 (data present in the UiTB register).

32.17.3 Special Mode 1 (I^{2}C Mode)

32.17.3.1 Generating Start and Stop Conditions

(Technical update number: TN-16C-130A/EA)
When generating start, stop, and restart conditions, set the STSPSEL bit in the UiSMR4 register (i = 0 to 2, 5 to 7) to 0 and wait for more than a half cycle of the transmit/receive clock. Then set each condition generation bit (STAREQ, RSTAREQ, and STPREQ) from 0 to 1.

32.17.3.2 IR Bit

Set the following bits first, and then set the IR bit in each UARTi interrupt control register to 0 (interrupt not requested).

Bits SMD2 to SMD0 in the UiMR register, the IICM bit in the UiSMR register,
the IICM2 bit in the UiSMR2 register, the CKPH bit in the UiSMR3 register

32.17.3.3 Low/High-level Input Voltage and Low-level Output Voltage

The low-level input voltage, high-level input voltage, and low-level output voltage differ from the I^{2}C-bus specification.

Refer to the recommended operating conditions for I/O ports which share the pins with SCL and SDA.

I^{2}C-bus specification
High level input voltage (V_{IH}) = min. 0.7 V_{CC}
Low level input voltage (V_{IL}) = max. 0.3 V_{CC}

32.17.3.4 Setup and Hold Times When Generating a Start/Stop Condition

When generating a start condition, the hold time (t_{HD}:STA) is a half cycle of the SCL clock. When generating a stop condition, the setup time (t_{SU}:STO) is a half cycle of the SCL clock.

When the SDA digital delay function is enabled, take delay time into consideration (see 23.3.3.7 “SDA Digital Delay”).

The following shows a calculation example of hold and setup times when generating a start/stop condition.

Calculation example when setting 100 kbps

- UiBRG count source: f1 = 20 MHz
- UiBRG register setting value: n = 100 - 1
- SDA digital delay setting value: DL2 to DL0 are 101b (5 or 6 cycles of UiBRG count source)

f_{SCL} (theoretical value) = f1 / (2(n+1)) = 20 MHz / (2 × (99 + 1)) = 100 kbps
t_{DL} = delay cycle count / f1 = 6 / 20 MHz = 0.3 μs
$t_{HD:STA}$ (theoretical value) = 1 / (2f_{SCL} (theoretical value)) = 1 / (2 × 100 kbps) = 5 μs
$t_{SU:STO}$ (theoretical value) = 1 / (2f_{SCL} (theoretical value)) = 1 / (2 × 100 kbps) = 5 μs
$f_{HD:STA}$ (actual value) = $t_{HD:STA}$ (theoretical value) - t_{DL} = 5 μs - 0.3 μs = 4.7 μs
$f_{SU:STO}$ (actual value) = $t_{SU:STO}$ (theoretical value) + t_{DL} = 5 μs + 0.3 μs = 5.3 μs

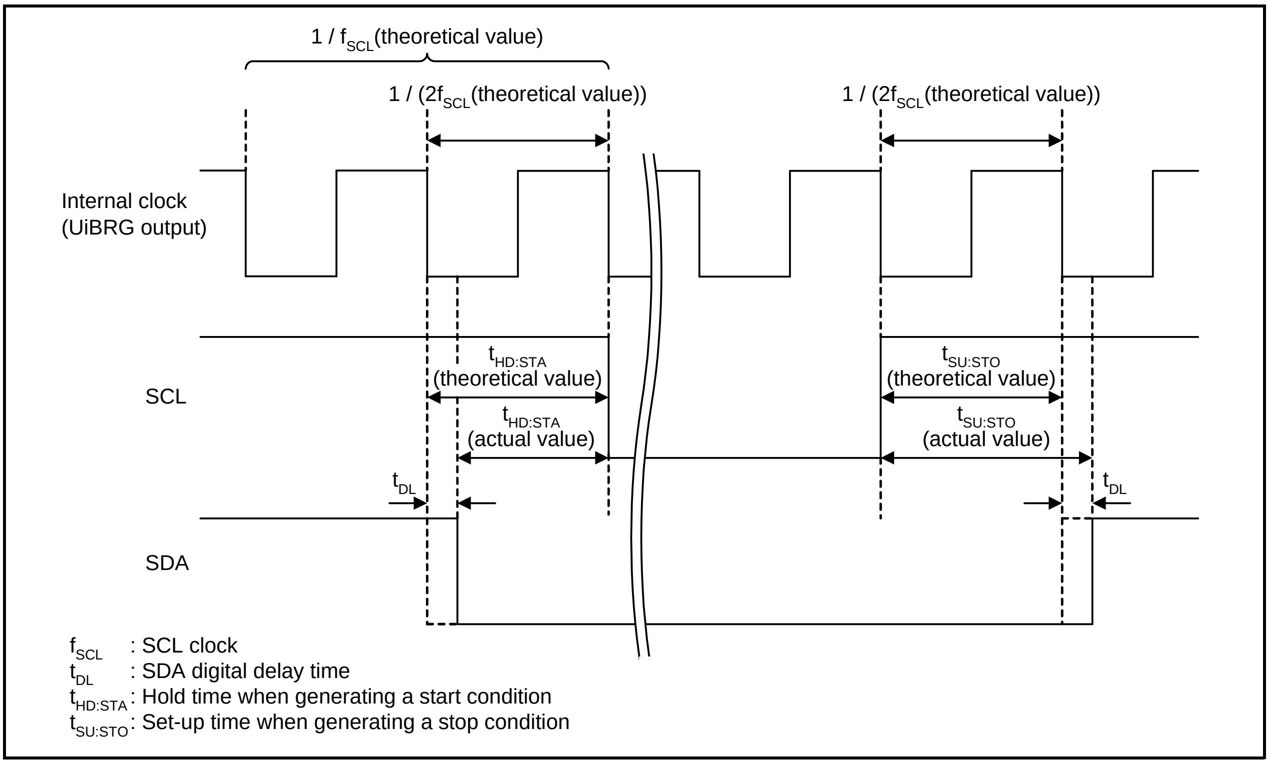

1 / fSCL(theoretical value)
1 / (2fSCL(theoretical value))
1 / (2fSCL(theoretical value))
Internal clock
(UiBRG output)
SCL
tHD:STA
(theoretical value)
tHD:STA
(actual value)
tSU:STO
(theoretical value)
tSU:STO
(actual value)
tDL
tDL
SDA
fSCL : SCL clock
tDL : SDA digital delay time
tHD:STA : Hold time when generating a start condition
tSU:STO : Set-up time when generating a stop condition

Figure 32.11 Setup and Hold Times When Generating Start and Stop Conditions

32.17.3.5 Restrictions on the Bit Rate When Using the UiBRG Count Source

In I^2C mode, set the UiBRG register to a value of 03h or greater.
A maximum of three UiBRG count source cycles are necessary until the internal circuit acknowledges the SCL clock level. The connectable I^2C-bus bit rate is one-third or less than the UiBRG count source speed. If a value between 00h to 02h is set to the UiBRG register, bit slippage may occur.

32.17.3.6 Restart Condition in Slave Mode

When a restart condition is detected in slave mode, the successive processes may not be executed correctly. In slave mode, do not use a restart condition.

32.17.3.7 Requirements to Start Transmission/Reception in Slave Mode

When transmission/reception is started in slave mode and the TXEPT bit in the UiC0 register is 1 (no data present in transmit register), meet the last requirement when the external clock is high.
Requirements to start transmission (in no particular order):

- The TE bit in the UiC1 register is 1 (transmission enabled).
- The TI bit in the UiC1 register is 0 (data present in the UiTB register).

Requirements to start reception (in no particular order):

- The RE bit in the UiC1 register is 1 (reception enabled).
- The TE bit in the UiC1 register is 1 (transmission enabled).
- The TI bit in the UiC1 register is 0 (data present in the UiTB register).

32.17.4 Special Mode 4 (SIM Mode)

(Technical update number: TN-M16C-101-0309)
After reset, a transmit interrupt request is generated by setting bits U2IRS and U2ERE in the U2C1 register to 1 (transmission completed, error signal output), then setting the TE bit to 1 (transmission enabled) and the transmission data to the U2TB register. Therefore, when using SIM mode, make sure to set the IR bit to 0 (interrupt not requested) after setting these bits.

32.18 Notes on SI/O3 and SI/O4

32.18.1 SOUTi Pin Level When SOUTi Output Is Disabled

When the SMi2 bit in the SiC register is set to 1 (SOUTi output disabled), the target pin becomes high-impedance regardless of which pin function being used.

32.18.2 External Clock Control

The data written to the SiTRR register shifts each time the external clock is input. When completing data transmission/reception of the eighth bit, read or write to the SiTRR register before inputting the clock for the next data transmission/reception.

32.18.3 Register Access

Set the SM22 bit in the S34C2 register before setting other registers associated with SI/O3 and SI/O4. After changing the SM22 bit, set other registers associated with SI/O3 and SI/O4 again.

32.18.4 Register Access When Using the External Clock

When the SMi6 bit in the SiC register is 0 (external clock), write to the SMi7 bit in the SiC register and SiTRR register under the following conditions:

- When the SMi4 bit in the SiC register is 0 (transmit data is output at the falling edge of transmit/receive clock and receive data is input at the rising edge): CLKi input is high.
- When the SMi4 bit in the SiC register is 1 (transmit data is output at the rising edge of transmit/receive clock and receive data is input at the falling edge): CLKi input is low.

32.18.5 SiTRR Register Access

Write transmit data to the SiTRR register while transmission/reception is stopped. Read receive data from the SiTRR register while transmission/reception is stopped.

The IR bit in the SiIC register becomes 1 (interrupt requested) during output of the eighth bit.

When the SM26 bit (SOUT3) or SM27 bit (SOUT4) in the S34C2 register is 0 (high-impedance after transmission), the SOUTi pin becomes high-impedance when the transmit data is written to the SiTRR register immediately after an interrupt request is generated, and the hold time of the transmit data becomes shorter.

32.18.6 Pin Function Switch When Using the Internal Clock

(Technical update number: TN-16C-121A/EA)

If the SMi3 bit in the SiC register (i = 3, 4) changes from 0 (I/O port) to 1 (SOUTi output, CLKi function) when setting the SMi2 bit to 0 (SOUTi output) and the SMi6 bit to 1 (internal clock), the SOUTi initial value set to the SOUTi pin by the SMi7 bit may be output for about 10 ns. Then, the SOUTi pin becomes high-impedance.

If the output level from the SOUTi pin when the SMi3 bit changes from 0 to 1 becomes a problem, set the SOUTi initial value by the SMi7 bit.

32.18.7 Operation after Reset When Selecting the External Clock

When the SMi6 bit in the SiC register is 0 (external clock) after reset, the IR bit in the SiIC register becomes 1 (interrupt requested) by inputting an external clock for 8 bits to the CLKi pin. This will also occur even when the SMi3 bit in the SiC register is 0 (serial interface disabled) or before a value is written to the SiTRR register.

32.19 Notes on Multi-master I^2C-bus Interface

32.19.1 Limitation on CPU Clock

When the CM07 bit in the CM0 register is 1 (CPU clock is a sub clock), do not access the registers listed in Table 25.4 “Registers”. Set the CM07 bit to 0 (main clock, PLL clock, or on-chip oscillator clock) to access these registers.

32.19.2 Register Access

Refer to the notes below when accessing the I^2C interface control registers. The period from the rising edge of the first clock of the slave address or 1-byte data transmission/reception to the falling edge of an ACK clock is considered to be the transmission/reception period. When the ACKCLK bit is 0 (no ACK clock), the transmission/reception period is from the rising edge of the first clock of the slave address or 1-byte data transmission/reception to the falling edge of the eighth clock.

32.19.2.1 S00 Register

Do not write to the S00 register during transmission/reception.

32.19.2.2 S1D0 Register

Do not change bits other than the IHR bit in the S1D0 register during transmission/reception.

32.19.2.3 S20 Register

Do not change bits other than the ACKBIT bit in the S20 register during transmission/reception.

32.19.2.4 S3D0 Register

- Do not use the bit managing instruction (read-modify-write instruction) to access the S3D0 register. Use the MOV instruction to write to this register.
- Rewrite bits ICK1 and ICK0 when the ES0 bit in the S1D0 register is 0 (I^2C interface disabled).

32.19.2.5 S4D0 Register

Rewrite bits ICK4 to ICK2 when the ES0 bit in the S1D0 register is 0 (I^2C interface disabled).

32.19.2.6 S10 Register

- Do not use the bit managing instruction (read-modify-write instruction) to access the S10 register. Use the MOV instruction to write to this register.
- Do not write to the S10 register when bits MST and TRX change their values.

Refer to operation examples in 25.3 “Operations” for bits MST and TRX change.

32.19.3 Low/High-level Input Voltage and Low-level Output Voltage

The low-level input voltage, high-level input voltage, and low-level output voltage differ from the I^2C-bus specification.
Refer to the recommended operating conditions for I/O ports which share the pins with SCL and SDA.

I^2C-bus specification
High level input voltage (V_{IH}) = min. 0.7 V_{CC}
Low level input voltage (V_{IL}) = max. 0.3 V_{CC}

32.20 Notes on CEC

32.20.1 Registers and Bit Operation

The registers and bits of the CEC function are synchronized with the count source. Therefore, the internal circuit starts to operate from the next count source timing, while the values of the register are changed immediately after rewriting the register.
When rewriting the same bit successively or reading the bit changed under the influence of another bit, wait for one or more cycles of the count source.

Example: when rewriting the same bit successively
(1) Change the bit to 0.
(2) Wait for one or more cycles of the count source.
(3) Change the same bit to 1.

Example: when reading the bit rewritten under the influence of another bit
(after reception is disabled, to ensure that the CRERRFLG bit in the CECFLG register becomes 0 (no reception error detected)).
(1) Set the CRXDEN bit in the CECC3 register to 0 (reception disabled)
(2) Wait for one or more cycles of the count source.
(3) Read the CRERRFLG bit in the CECFLG register.

32.20.2 VIH of the CEC pin

VIH of the CEC pin does not meet the CEC standard value. Apply VIH to the CEC pin or use the CEC external circuit shown in Figure 32.12 “CEC External Circuit” to change the CEC pin input voltage to VIH of the CEC pin or above.

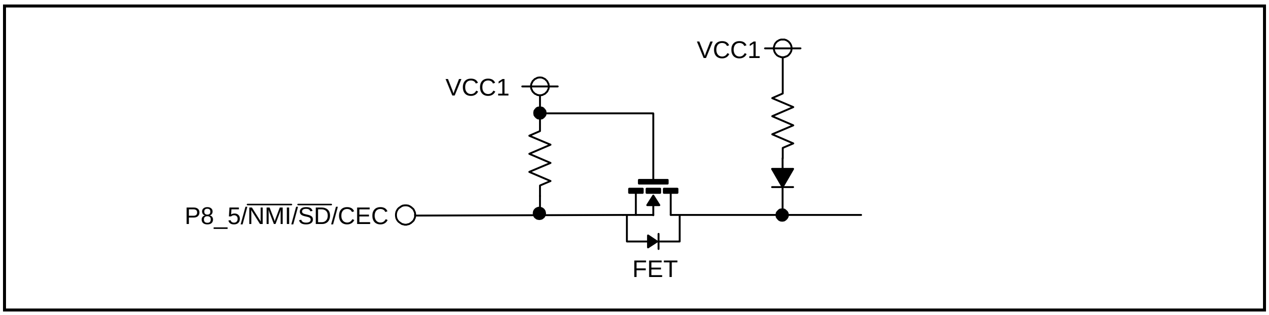


Figure 32.12 CEC External Circuit

32.21 Notes on A/D Converter

32.21.1 Analog Input Voltage

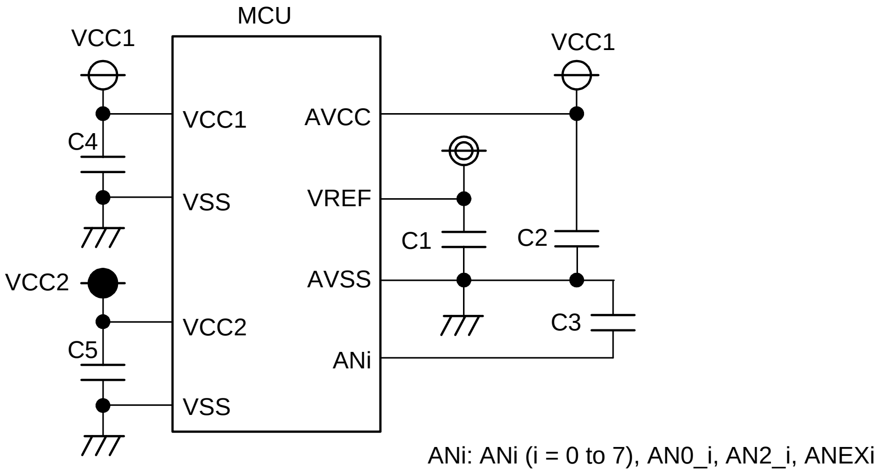
Set the analog input voltage as follows:
analog input voltage (AN_0 to AN_7, ANEX0, and ANEX1) ≤ VCC1
analog input voltage (AN0_0 to AN0_7 and AN2_7 to AN2_7) ≤ VCC2

32.21.2 Analog Input Pin

Do not use any pin from AN4 to AN7 as analog input pin if any pin from $\overline{\text{KI0}}$ to $\overline{\text{KI3}}$ is used as a key input interrupt.

32.21.3 Pin Configuration

To prevent operation errors due to noise or latchup, and to reduce conversion errors, place capacitors between the AVSS pin and the AVCC pin, the VREF pin, and analog inputs (ANi (i = 0 to 7), ANEXi, AN0_i, and AN2_i). Also, place a capacitor between the VCC1 pin and VSS pin.



Notes:
1. Reference values: C1 ≥ 0.1 µF, C2 ≥ 0.1 µF, C3 ≥ 100 pF, C4 ≥ 0.1 µF, C5 ≥ 0.1 µF.
2. The traces for the capacitor and MCU should be short and wide as much as physically possible.

Figure 32.13 Example of Pin Configuration

32.21.4 Register Access

Set registers associated with A/D converter after setting the CKS3 bit in the ADCON2 register. However the other bits in the ADCON2 register and the CKS3 bit can be set at the same time. After changing the CKS3 bit, set the others in the same way.
Write registers ADCON0 (excluding the ADST bit), ADCON1, and ADCON2 when A/D conversion stops (before a trigger is generated).
After A/D conversion stops, set the ADSTBY bit in the ADCON1 register from 1 to 0.

32.21.5 A/D Conversion Start

When rewriting the ADSTBY bit in the ADCON1 register from 0 (A/D operation stopped) to 1 (A/D operation enabled), wait for one ϕAD cycle or more before starting A/D conversion.

32.21.6 A/D Operation Mode Change

When the A/D operation mode has been changed, reselect analog input pins by using bits CH2 to CH0 in the ADCON0 register or bits SCAN1 to SCAN0 in the ADCON1 register.

32.21.7 State When Forcibly Terminated

If A/D conversion in progress is halted by setting the ADST bit in the ADCON0 register to 0 (A/D conversion stopped), the conversion result is undefined. In addition, the unconverted ADi register (i = 0 to 7) may also become undefined. Do not use any value in ADi registers when setting the ADST bit to 0 by a program during A/D conversion.

32.21.8 A/D Open-Circuit Detection Assist Function

The conversion result in open-circuit depends on the external circuit. Use this function only after careful evaluation of the system. Do not use this function when VCC1 > VCC2.

When A/D conversion starts after changing the AINRST register, follow these steps:

(1) Change bits AINRST1 to AINRST0 in the AINRST register.
(2) Wait for one cycle of ϕAD.
(3) Set the ADST bit in the ADCON0 register to 1 (A/D conversion started).

32.21.9 Detecting Completion of A/D Conversion

In one-shot mode and single sweep mode, use the IR bit in the ADIC register to detect completion of A/D conversion. When not using an interrupt, set the IR bit to 0 by a program after detection.

When 1 is written to the ADST bit in the ADCON0 register, the ADST bit becomes 1 (A/D conversion start) after start processing time elapses (see Table 27.7 “Cycles of A/D Conversion Item”). Therefore when reading the ADST bit immediately after writing 1, 0 (A/D conversion stop) may be read.

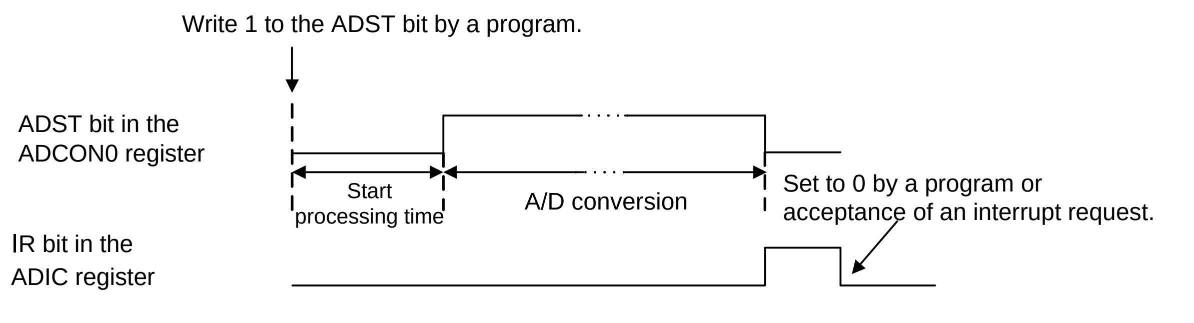

Write 1 to the ADST bit by a program.
ADST bit in the ADCON0 register
Start processing time
A/D conversion
Set to 0 by a program or acceptance of an interrupt request.
IR bit in the ADIC register

Figure 32.14 ADST Bit Operation

32.21.10 ϕAD

Divide fAD so ϕAD conforms to the standard frequency.

In particular, consider the maximum and minimum values of fOCO40M when the CKS3 bit in the ADCON2 register is 1 (fOCO40M is fAD).

32.22 Notes on D/A Converter

32.22.1 When Not Using the D/A Converter

When not using the D/A converter, set the DAiE bit (i = 0, 1) in the DACON register to 0 (output disabled) and the DAi register to 00h in order to minimize unnecessary current consumption and prevent current flow to the R-2R resistor.

32.23 Notes on Flash Memory

Note

There are no P11 to P14 in the 100-pin package. For the 100-pin package, do not use these pins for the entry of user boot function.

32.23.1 OFS1 Address and ID Code Storage Address

The OFS1 address and ID code storage address are part of flash memory. When writing a program to flash memory, write an appropriate value to those addresses simultaneously.

In the OFS1 address, the MCU state after reset and the function to prevent rewrite in parallel I/O mode are selected. The OFS1 address is 0FFFFFh. This is the most significant address of block 0 in program ROM 1 and upper address of reset vector. Also, the ID code storage address is in block 0 and upper address of the interrupt vector.

The ID code check function cannot be disabled. Even if the protect using the ID code check function is unnecessary, input the appropriate ID code when using a serial programmer or debugger. Without the appropriate ID code, the serial programmer or debugger cannot be used.

ex) Set FEh to the OFS1 address

When using an address control instruction and logical addition:

```
  .org 0FFFFCh
RESET:
  .lword start | 0FE000000h
```

When using an address control instruction:

```
  .org 0FFFFCh
RESET:
  .addr start
  .byte 0FEh
```

(Program format varies depending on the compiler. Refer to the compiler manual.)

32.23.2 Reading Data Flash

When $2.7 \text{ V} \leq \text{VCC1} \leq 3.0 \text{ V}$ and $f(\text{BCLK}) \geq 16$ MHz, or $3.0 \text{ V} < \text{VCC1} \leq 5.5 \text{ V}$ and $f(\text{BCLK}) \geq 20$ MHz, one wait must be inserted to execute the program on the data flash and read the data. Set the PM17 in the PM1 register or FMR17 bit in the FMR1 register to insert one wait.

32.23.3 CPU Rewrite Mode

32.23.3.1 Operating Speed

Select a CPU clock frequency of 10 MHz or less by setting the CM06 bit in the CM0 register and bits CM17 and CM16 in the CM1 register before entering CPU rewrite mode (EW0 or EW1 mode). Also, set the PM17 bit in the PM1 register to 1 (wait state).

32.23.3.2 CPU Rewrite Mode Select

Change FMR01 bit in the FMR0 register, FMR11 bit in the FMR1 register, and FMR60 bit in the FMR6 register while in the following state:

- The PM24 bit in the PM2 register is 0 ($\overline{\text{NMI}}$ interrupt disabled).
- High is input to the $\overline{\text{NMI}}$ pin.

Change the FMR60 bit while the FMR00 bit in the FMR0 register is 1 (ready).

32.23.3.3 Prohibited Instructions

Do not use the following instructions in EW0 mode:
UND instruction, INTO instruction, JMPS instruction, JSRS instruction, and BRK instruction.

32.23.3.4 Interrupts (EW0 Mode and EW1 Mode)

- Do not use an address match interrupt during command execution because the address match interrupt vector is located in ROM.
- Do not use a non-maskable interrupt during block 0 erase because fixed vector is located in block 0.

32.23.3.5 Rewrite (EW0 Mode)

If the power supply voltage drops while rewriting the block where the rewrite control program is stored, the rewrite control program is not correctly rewritten. This may prevent the flash memory from being rewritten. If this error occurs, use standard serial I/O mode or parallel I/O mode for rewriting.

32.23.3.6 Rewrite (EW1 Mode)

Do not rewrite any blocks in which the rewrite control program is stored.

32.23.3.7 DMA transfer

In EW0 mode, do not use flash memory as a source of the DMA transfer.
In EW1 mode, do not generate a DMA transfer while the FMR00 bit in the FMR0 register is 0 (auto programming or auto erasing).

32.23.3.8 Wait Mode

To enter wait mode, set the FMR01 bit in the FMR0 register to 0 (CPU rewrite mode disabled) before executing the WAIT instruction.

32.23.3.9 Stop Mode

To enter stop mode, set the FMR01 bit to 0 (CPU rewrite mode disabled), and then disable DMA transfer before setting the CM10 bit in the CM 1 register to 1 (stop mode).

32.23.3.10 Software Command

Observe the notes below when using the following commands.

- Program
- Block erase
- Lock bit program
- Read lock bit status
- Block blank check

(a) The FMR00 bit in the FMR0 register indicates the status while executing these commands. Do not execute other commands while the FMR00 bit is 0 (busy).

(b) Use these commands in 40 MHz on-chip oscillator mode, high-speed mode, medium-speed mode, and PLL operating mode. Do not change clock modes while the FMR00 bit in the FMR0 register is 0 (busy).

(c) After executing the program, block erase, or lock bit program command, perform a full status check per command (Do not execute multiple commands or same command more than once before performing a full status check).

(d) Do not execute the program, block erase, lock bit program, or block blank check command when either or both bits FMR06 and FMR07 in the FMR0 register are 1 (error).

(e) Do not use these commands in slow read mode (when the FMR22 bit is 1) or low current consumption read mode (when both bits FMR22 and FMR23 are 1).

32.23.3.11 PM13 Bit

The PM13 bit in the PM1 register becomes 1 while the FMR01 bit in the FMR0 register is 1 (CPU rewrite mode enabled). The PM13 bit returns to the former value by setting the FMR01 bit to 0 (CPU rewrite mode disabled). When the PM13 bit is changed during CPU rewrite mode, the value of the PM13 bit after being changed is not reflected until the FMR01 bit is set to 0.

32.23.3.12 Area Where the Rewrite Control Program is Executed

Bits PM10 and PM13 in the PM1 register become 1 in CPU rewrite mode. Execute the rewrite program in internal RAM or an external area which can be used when both bits PM10 and PM13 are 1. Do not use the area (40000h to BFFFFh) where accessible space is expanded when the PM13 bit is 0 and 4-MB mode is set.

32.23.3.13 Program and Erase Cycles and Execution Time

Execution time of the program, block erase, and lock bit program commands becomes longer as the number of programming and erasing increases.

32.23.3.14 Suspending the Auto-Erase and Auto-Program Operations

When the program, block erase, and lock bit program commands are suspended, the blocks for those commands must be erased. Execute the program and lock bit program commands again after erasing.

Those commands are suspended by the following reset or interrupts:

- Hardware, power-on, voltage monitor 0, voltage monitor 1, voltage monitor 2, oscillator stop detect, watchdog timer, software resets.
- $\overline{\text{NMI}}$, watchdog timer, oscillator stop/restart detect, voltage monitor 1, and voltage monitor 2 interrupts.

32.23.4 User Boot

32.23.4.1 User Boot Mode Program

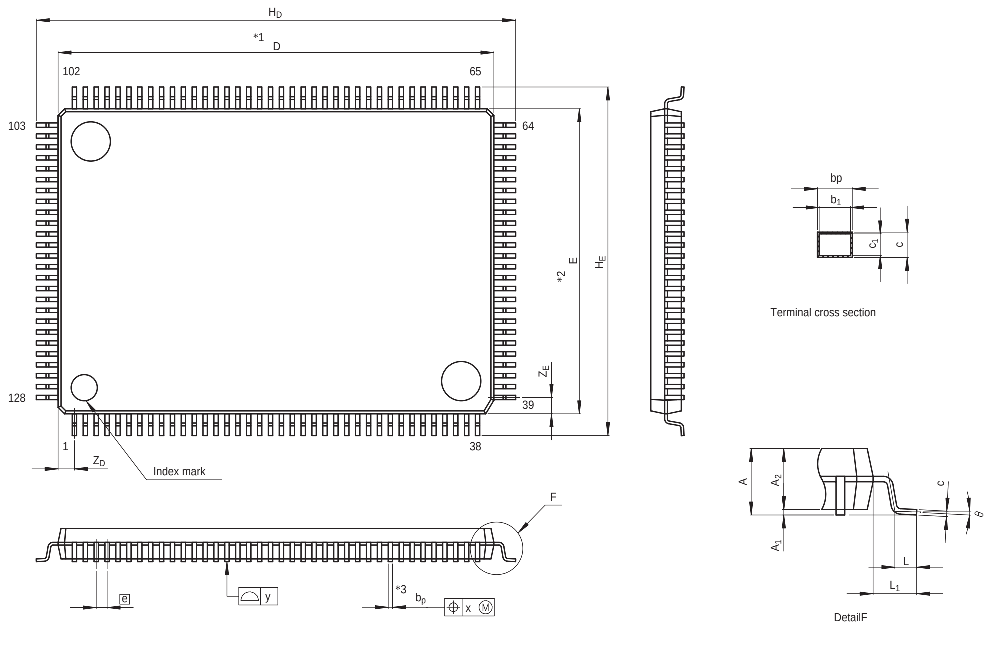
Note the following when using user boot mode:

- When using user boot mode, make sure to allocate the program to be executed to program ROM 2.
- Bits VDSEL1 and LVDAS in the OFS1 address are disabled in boot mode.
- When restarting the MCU in user boot mode after starting it in user boot mode, RAM becomes undefined.
- If addresses 13FF8h to 13FFBh are all 00h, the MCU does not enter standard serial I/O mode. Therefore, the programmer or on-chip debugger cannot be connected.
- As the reset sequence differs, the time necessary for starting the program is longer than in single-chip mode.
- Functions in user boot mode cannot be debugged by the on-chip debugging emulator or full spec emulator.
- While using user boot mode, do not change the input level of the pin used for user boot entry. However, if there is a possibility that the input level may change, perform the necessary processes in user boot mode, then restart the MCU in single-chip mode before the input level changes.
- To use user boot mode after standard serial I/O mode, turn off the power when exiting standard serial I/O mode, and then turn on the power again (cold start). The MCU enters user boot mode under the right conditions.

Appendix 1. Package Dimensions

The information on the latest package dimensions or packaging may be obtained from “Packages“ on the Renesas Electronics website.

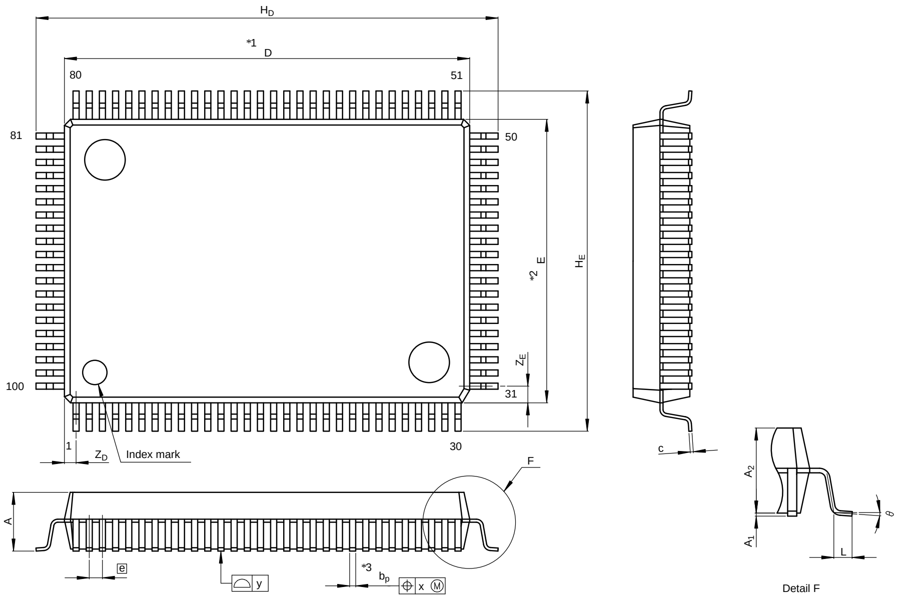
JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP128-14x20-0.50	PLQP0128KB-A	128P6Q-A	0.9g



NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	19.9	20.0	20.1
E	13.9	14.0	14.1
A_2	—	1.4	—
H_D	21.8	22.0	22.2
H_E	15.8	16.0	16.2
A	—	—	1.7
A_1	0.05	0.125	0.2
b_p	0.17	0.22	0.27
b_1	—	0.20	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
$\boxed{e}$	—	0.5	—
x	—	—	0.10
y	—	—	0.10
Z_D	—	0.75	—
Z_E	—	0.75	—
L	0.35	0.5	0.65
L_1	—	1.0	—

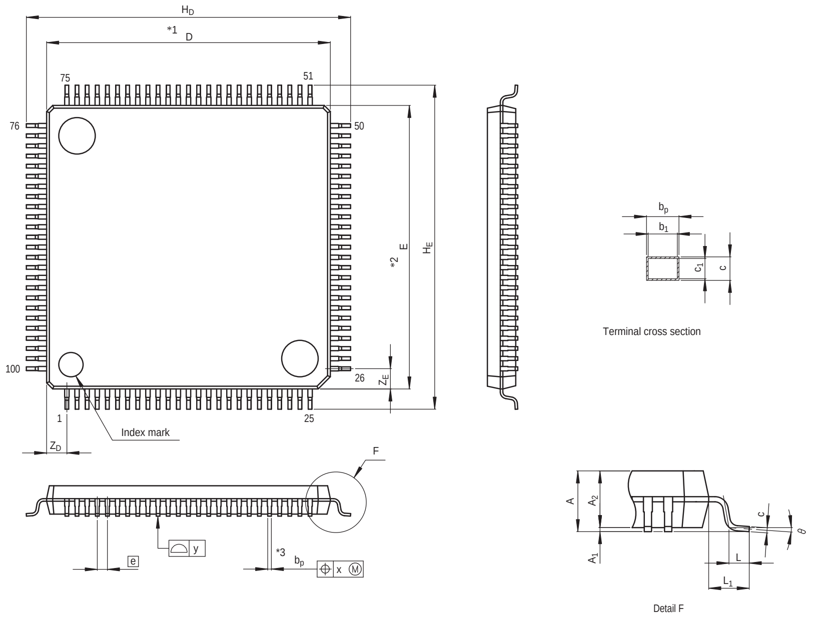
JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-QFP100-14x20-0.65	PRQP0100JD-B	100P6F-A	1.8g



NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	19.8	20.0	20.2
E	13.8	14.0	14.2
A_2	—	2.8	—
H_D	22.5	22.8	23.1
H_E	16.5	16.8	17.1
A	—	—	3.05
A_1	0	0.1	0.2
b_p	0.25	0.3	0.4
c	0.13	0.15	0.2
θ	0°	—	10°
$\boxed{e}$	—	0.65	—
x	—	—	0.13
y	—	—	0.10
Z_D	—	0.575	—
Z_E	—	0.825	—
L	0.4	0.6	0.8

JEITA Package Code	RENESAS Code	Previous Code	MASS[Typ.]
P-LQFP100-14x14-0.50	PLQP0100KB-A	100P6Q-A / FP-100U / FP-100UV	0.6g



NOTE)
1. DIMENSIONS "*1" AND "*2" DO NOT INCLUDE MOLD FLASH.
2. DIMENSION "*3" DOES NOT INCLUDE TRIM OFFSET.

Reference Symbol	Dimension in Millimeters		
	Min	Nom	Max
D	13.9	14.0	14.1
E	13.9	14.0	14.1
A_2	—	1.4	—
H_D	15.8	16.0	16.2
H_E	15.8	16.0	16.2
A	—	—	1.7
A_1	0.05	0.1	0.15
b_p	0.15	0.20	0.25
b_1	—	0.18	—
c	0.09	0.145	0.20
c_1	—	0.125	—
θ	0°	—	8°
e	—	0.5	—
x	—	—	0.08
y	—	—	0.08
Z_D	—	1.0	—
Z_E	—	1.0	—
L	0.35	0.5	0.65
L_1	—	1.0	—

Appendix 2. Differences between M16C/65 and M16C/65C

Appendix Table 2.1 Differences between M16C/65 and M16C/65C (Specifications)

Item	M16C/65	M16C/65C
Enable/disable peripheral clock provision	N/A	Available (bits PCKSTP1A and PCKSTP11 in the PCLKSTP1 register)
Timer A/timer B clock source selection	f1 only	f1 or main clock (the PCKSTP17 bit in the PCLKSTP1 register)
Flash memory, suspend function	N/A	Available
Usable area of program ROM 1	Whole area is usable when the PM13 bit is 1, and the IRON bit is 1.	Conditional: PM13 bit = 0: max. D0000h to FFFFFh PM13 bit = 1: max. 80000h to FFFFFh
Electrical characteristics	—	Characteristics of voltage detector, power-on reset circuit, and oscillator improved.

Refer to the User’s Manual: Hardware for details.

Appendix Table 2.2 Differences between M16C/65 and M16C/65C (Bus Timing)

Item		M16C/65	M16C/65C
Timing requirement VCC1 = VCC2 = 5 V	tsu(DB-RD)	Min. 40[ns]	Min. 50[ns]
Timing requirement VCC1 = VCC2 = 3 V	tsu(DB-RD)	Min. 50[ns]	Min. 60[ns]
Switching characteristics VCC1 = VCC2 = 5 V	th(WR-DB) Minimum value	No recovery cycle $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 10[ns]$ Recovery cycle inserted $\frac{m \times 10^9}{f_{(BCLK)}} - 10[ns]$	No recovery cycle $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 20[ns]$ Recovery cycle inserted $\frac{m \times 10^9}{f_{(BCLK)}} - 20[ns]$
Switching characteristics VCC1 = VCC2 = 3 V	th(WR-AD) Minimum value	No recovery cycle $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 10[ns]$ Recovery cycle inserted $\frac{m \times 10^9}{f_{(BCLK)}} - 10[ns]$	No recovery cycle $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 15[ns]$ Recovery cycle inserted $\frac{m \times 10^9}{f_{(BCLK)}} - 15[ns]$
	th(WR-DB) Minimum value	No recovery cycle $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 10[ns]$ Recovery cycle inserted $\frac{m \times 10^9}{f_{(BCLK)}} - 10[ns]$	No recovery cycle $\frac{0.5 \times 10^9}{f_{(BCLK)}} - 25[ns]$ Recovery cycle inserted $\frac{m \times 10^9}{f_{(BCLK)}} - 25[ns]$
Switching characteristic	th(BCLK-DB)	Min. 0[ns]	(Standard not available)

m: Inserted recovery cycle numbers

Refer to the User’s Manual: Hardware for details.

REGISTER INDEX

1. Items revised or added in this version

REVISION HISTORY	M16C/65C Group User's Manual: Hardware

Rev.	Date	Description	
		Page	Summary
1.10	Jul 31, 2012	**Overview**	
		6	Table 1.5 Product List (N-Version), Table 1.6 Product List (D-Version): Changed development statuses.
		Resets	
		56	6.2.1 Processor Mode Register 0 (PM0): Added the description regarding PM02, PM04 to PM07 to the register explanation.
		64	6.4.3 Power-On Reset Function: Changed “the rise gradient is trth or more” to “the rise gradient is trth” in the second line of the first paragraph.
		64	Figure 6.5 Power-On Reset Circuit and Operation Example: Changed tw(por1) to tw(por).
		Clock Generator	
		94	Figure 8.1 System Clock Generator: Changed a part of the configuration in the PLL frequency synthesizer.
		96	8.2.1 Processor Mode Register 0 (PM0): Added the description regarding PM02, PM04 to PM07 to the register explanation.
		111	8.3.6 Sub Clock (fC): Deleted P8_5 in the parenthesis in step (1).
		Processor Mode	
		145	10.2.1 Processor Mode Register 0 (PM0): Added the description regarding PM02, PM04 to PM07 to the register explanation.
		146	10.2.2 Processor Mode Register 1 (PM1): Added the description regarding PM11, PM14 and PM15 to the register explanation.
		Bus	
		163	Table 11.8 Pin Functions for Each Processor Mode: • Added note 7. • Changed the Memory Expansion Mode column for P3_0.
		Programmable I/O Ports	
		191, 192	Figure 13.8 I/O Ports (N-channel Open Drain Output), Figure 13.9 I/O Ports ($\overline{\text{NMI}}$): Partially modified.
		Three-Phase Motor Control Timer Function	
		350, 370, 375	Table 19.2 Three-Phase Motor Control Timer Function Specifications (2/2), Table 19.9 Three-Phase Mode 0 Specifications, and Table 19.12 Three-Phase Mode 1 Specifications: Modified the Specification column of the Three-phase PWM output width.
		Remote Control Signal Receiver	
		440	Figure 22.4 Setting Values of the Header Pattern and Data Patterns: Added the explanation.
		455	Table 22.13 Registers and Setting Values in Pattern Match Mode (Combined Operation) (1/2): Changed the PMC1 column of the PMCiCON1 register for bits TYP0 and TYP1.
		470	22.5.4 Combined Operation: Added.
		Serial Interface UARTi (i = 0 to 2, 5 to 7)	
		479	23.2.3 UARTi Transmit/Receive Mode Register (UiMR) (i = 0 to 2, 5 to 7): Added the description regarding I^{2}C mode.
		480, 484	23.2.5 UARTi Transmit Buffer Register (UiTB) (i = 0 to 2, 5 to 7), 23.2.8 UARTi Receive Buffer Register (UiRB) (i = 0 to 2, 5 to 7): Modified the Reset Value.
		510	Table 23.15 I/O Pin Functions in I^{2}C Mode: Added note 1.
		Multi-master I^{2}C-bus Interface	
		602	25.5.3 Low/High-level Input Voltage and Low-level Output Voltage: Added.
		CRC Calculator	
		674	29.2.3 CRC Data Register (CRCD): Added the explanation.
		676	Figure 29.2 CRC Calculation When Using CRC-CCITT and Figure 29.3 CRC Calculation When Using CRC-16: Changed.
		Flash Memory	
		681	30.3.1 Flash Memory Control Register 0 (FMR0): Changed the description of steps in the FMSTP bit explanation.
		Electrical Characteristics	
		Vcc = 5 V	
		745, 746	Table 31.20 Electrical Characteristics (3) and Table 31.21 Electrical Characteristics (4): Changed the Measuring Condition column of 40 MHz on-chip oscillator for the 40 MHz on-chip oscillator mode in the I$_{CC}$.

Rev.	Date	Description	
		Page	Summary
1.10	Jul 31, 2012	**Vcc = 3 V**	
		767, 768	Table 31.42 Electrical Characteristics (2) and Table 31.43 Electrical Characteristics (3) (1/2): Changed the Measuring Condition column of 40 MHz on-chip oscillator for the 40 MHz on-chip oscillator mode in the I_{CC}.
		Usage Notes	
		819	32.16.4 Combined Operation: Added.
		825	32.19.3 Low/High-level Input Voltage and Low-level Output Voltage: Added

Refer to 2. “Items revised or added in previous versions” for the items revised or added in previous versions.

2. Items revised or added in previous versions

REVISION HISTORY	M16C/65C Group User’s Manual: Hardware

Rev.	Date	Description	
		Page	Summary
0.10	Oct 29, 2010	-	First Edition issued.
1.00	Feb 07, 2011	Overall	Changed terminologies are as follows: • “oscillation/oscillator circuit” to “oscillator” • “oscillator” to “a crystal/ceramic resonator” • “oscillator manufacturer” to “manufacturer of crystal/ceramic resonator” • “on-chip oscillator oscillation circuit” to “on-chip oscillator”
		Overview	
		3, 5	Table 1.2 Specifications for the 128-Pin Package (2/2), Table 1.4 Specifications for the 100-Pin Package (2/2): Changed the Description column of the Current Consumption row.
		6	Table 1.5 Product List (N-Version), Table 1.6 Product List (D-Version): Changed the development status.
		Clock Generator	
		108	8.3.2 PLL Clock: Modified the explanation of how to generate PLL clock from the main clock.
		Power Control	
		141	9.6.3 Stop Mode: Changed “before the WAIT instruction is executed” to “before entering stop mode” in the last sentence of the third bullet.
		Interrupt	
		235	14.10 Key Input Interrupt: Modified the explanation of the condition for the IR bit in the KUPIC register to become 1.
		Timer B	
		326, 327	18.2.4 Timer Bi Register (TBi) (i = 0 to 5), 18.2.5 Timer Bi-1 Register (TBi1) (i = 0 to 5): Modified the Reset Value.
		Serial Interface UARTi	
		502	Figure 23.13 Receive Timing in UART Mode: Modified “UiBRG count source” to “Clock divided by UiBRG”.
		Multi-Master I^2C-bus Interface	
		590	Figure 25.15 Operation When Transmitted/Received a Slave Address or Data: Changed the description of bits TRX, ADR0, and AAS in parenthesis for when a slave address is received.
		Flash Memory	
		695	Table 30.12 Modes after Executing Commands (in EW0 Mode): Changed the Mode after Executing Command of the Clear status register.
		Electrical Characteristics	
		VCC = 5 V	
		744, 745	Table 31.20 Electrical Characteristics (3), Table 31.21 Electrical Characteristics (4): Added conditions when XIN is 6MHz to the Wait mode measuring condition.
		754, 757, 759, 761, 763	In Switching Characteristics (Memory Expansion Mode and Microprocessor Mode), Table 31.36, Table 31.37, Table 31.38, Table 31.39, Table 31.40: • Deleted the th(BCLK-DB) row. • Changed the formula of th(WR-DB) for minimum standard.
		756, 758, 760, 762, 764	Figure 31.15, Figure 31.16, Figure 31.17, Figure 31.18, Figure 31.19: Deleted the description of th(BCLK-DB), and changed the formula of th(WR-DB) in the Write timing.
		VCC = 3 V	
		766, 767	Table 31.42 Electrical Characteristics (2), Table 31.43 Electrical Characteristics (3) (1/2): Added conditions when XIN is 6MHz to the Wait mode measuring condition.
		775, 777, 780, 782, 784	In Switching Characteristics (Memory Expansion Mode and Microprocessor Mode), Table 31.58, Table 31.59, Table 31.60, Table 31.61, Table 31.62: • Deleted the th(BCLK-DB) row. • Changed the formula of th(WR-AD) for minimum standard. • Changed the formula of th(WR-DB) for minimum standard.
		779, 781, 783, 785, 787	Figure 31.30, Figure 31.31, Figure 31.32, Figure 31.33, Figure 31.34: • Deleted the description of th(BCLK-DB), and changed the formulas of th(WR-AD) and th(WR-DB) in the Write timing.

Rev.	Date	Description	
		Page	Summary
1.00	Feb 07, 2011	**Usage Notes**	
		798	32.6.3 Stop Mode: Changed “before the WAIT instruction is executed” to “before entering stop mode” in the last sentence of the third bullet.
		Appendix 2. Differences between M16C/65 and M16C/65C	
		834	Appendix 2. Differences between M16C/65 and M16C/65C: Added

M16C/65C Group User’s Manual: Hardware

Publication Date:	Rev.0.10	Oct 29, 2010
	Rev.1.10	Jul 31, 2012

Published by: Renesas Electronics Corporation

RENESAS

SALES OFFICES

Renesas Electronics Corporation

http://www.renesas.com

Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics America Inc.
2880 Scott Boulevard Santa Clara, CA 95050-2554, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited
1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada
Tel: +1-905-898-5441, Fax: +1-905-898-3220

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-585-100, Fax: +44-1628-585-900

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-65030, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
7th Floor, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100083, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 204, 205, AZIA Center, No.1233 Lujiazui Ring Rd., Pudong District, Shanghai 200120, China
Tel: +86-21-5877-1818, Fax: +86-21-6887-7858 / -7898

Renesas Electronics Hong Kong Limited
Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2886-9318, Fax: +852 2886-9022/9044

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
1 harbourFront Avenue, #06-10, keppel Bay Tower, Singapore 098632
Tel: +65-6213-0200, Fax: +65-6278-8001

Renesas Electronics Malaysia Sdn.Bhd.
Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics Korea Co., Ltd.
11F., Samik Lavied' or Bldg., 720-2 Yeoksam-Dong, Kangnam-Ku, Seoul 135-080, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141

Colophon 1.1

M16C/65C Group

Renesas Electronics Corporation